

Mobile geophysics for searching and exploration of Domanic hydrocarbon deposits

M Ya Borovsky¹, B V Uspensky², S E Valeeva², A S Borisov²

¹LTD "Geofizservis", Kazan, Russia

²Institute of Geology and Petroleum Technologies, Kazan Federal University, Kazan, Russia

Abstract. There are noted features of shale hydrocarbons occurrence. It is shown the role of geophysical prospecting in the geological prospecting process for non-traditional sources of hydrocarbon. There are considered the possibilities of non-seismic methods for forecasting, prospecting, exploration and preparation of Domanikovan hydrocarbons accumulations for exploration. It is emphasized the need for geophysical studies of tectonic disturbances. Modern aerogeophysical instrumentation and methodological support allows to combine high-precision magneto-prospecting with gravimetric and gamma spectrometry. This combination of geophysical methods contributes to the diagnosis of active and latent faults.

1. Introduction

In the Volga-Urals oil and gas basin, Zaidelson et al [1] distinguish "domanikites", representing bituminous clayey-siliceous carbonates of Upper Devonian-Tournaisian deposits. In the Russian Federation, these rocks, along with the Bazhenov Formation and the Hadum Formation of the Ciscaucasia, are attributed to the shale sequences [2].

There are the features of the hydrocarbons accumulations in shale [3, 4]:

- shales - the source rocks and the reservoir at the same time;
- low porosity and permeability of the enclosing strata;
- diffuse state of hydrocarbons in the stratum;
- continuity of clusters;
- lack of traditional systems for monitoring deposits (oil-water contact, structural, lithological).

2. Methodology

A decisive role at different stages of geological exploration for non-traditional sources of hydrocarbons, including shale oil and gas, belongs to geophysical exploration. The extraction process requires modern technologies for both prospecting and exploration of deposits, and for the implementation of the developing the desired objects process. This necessitates a high-level real-time visualization of processes in the shale reservoir, including changes in the physical and mechanical characteristics and parameters of the reservoir rock, the state of the deposit during production. A geophysical observation, in which seismic prospecting plays an important role [5] serves as a tool for technical vision in solving the problem of prospecting, exploration, development and production of shale hydrocarbons.

The efficiency of the geological exploration process depends to the choice of research directions resulting from the study of each particular facility. Separate stages and stages of exploration work have as their goal the study of specific large-scale objects.



At the initial stage of sedimentary basins or their separate parts research, regional work is conducted to study the inherent common features of the geological structure and oil and gas. In the future, at different stages of the basins study, regional problems are posed with specific problems, determined by the degree of prior study, by the technical and methodological capabilities of geological and geophysical studies.

Addressing issues at the regional level, as a tectonic zoning, is of the utmost importance for the search for minerals. It allows [6]:

- 1) to establish general prospects for the search minerals in the region;
- 2) identify areas that require more detailed search operations.

Khain stresses "... knowledge of the regional structure of an area is no less (if not more) important for assessing the prospects of oil than the significance of the local structure of its individual sections."

This provision is relevant for the general system of geological exploration for shale hydrocarbons.

Expressness and the current availability of a large number of maps and geophysical parameters graphs necessitate the use of aerogeophysical reconnaissance in information support of geological exploration for shale hydrocarbons. Essential as a choice of the most promising directions of "Exploration play" [7] and certain preparation of areas for detailed works.

The regional direction assumes [8, 9] the most complete use of geophysical surveys performed earlier in significant areas, which is due to the large area of shale gas and oil plays.

It is necessary to obtain information about the internal structure of the folded base to identify areas with specific sedimentation conditions against the background of surrounding areas,

3. Results and Discussions

By the present time, certain experience and ideas on the geophysical study of the crystalline basement have been accumulated [1, 2, 3]. Most researchers note that the structure and composition of the basement rocks is the main geological factor determining the nature of gravitational and, in particular, magnetic anomalies. An obligatory element of the method is the compilation of physical fields zoning maps or schemes.

Analysis of geological and geophysical materials indicates the possibility of isolating regional tectonic disturbances by the geophysical complex (gravimetry and magneto-prospecting) and remote (space survey) methods with data on the landscape indication. These regional tectonic disturbances are the boundaries on which the facies and thicknesses of various intervals of the sedimentary cover deposits.

For the most part the criteria for detecting and tracing faults from the results of geophysical observations are generally accepted [1-5]: the boundaries of sections with specific morphology of the geomagnetic field and the gravity field; zones of high horizontal gradients (magnetic and gravitational steps); steep and sharp limitation of magnetic anomalies. The peculiarity of the regional disruptive disturbances manifestation is the presence of secondary deformations of the gravitational (in zones of intense

horizontal gradients) and magnetic fields. The study of the geophysical fields structure makes it possible in many cases to determine the character of the tectonic movements along the fault zones.

When preparing prospective areas for detailed geological prospecting for hydrocarbons of shale, attention should be paid to the compilation of a structural skeleton of fault tectonics. Analysis of faults, in particular their stresses and orientations, is necessary [5] for both regional and detailed scale of reservoir interpretation: faults and discontinuities can dynamically affect. It should be noted [7] that clarifying the position of the faults and assessing their effect on the conditions for the formation of hydrocarbon traps is one of the main tasks of aerogeophysical exploration.

It is advisable to use high-precision gravimetric prospecting at the stages of local forecasting, which makes it possible to determine the distribution in the cross-section and lateral, such a parameter as density, and, consequently, porosity. New principles of interpretation based on gravity modeling [10] and tomographic processing and visualization [11] give (Fig. 1) extensive information on decompressed and compacted (low-porous, low-permeability) zones and areas.

By Slepak [10] "... In studying the geological structure of oil fields, gravity prospecting should be aimed at identifying and interpreting the anomalies created by the lateral variability of densities in the sedimentary cover and in the crystalline basement." As a result of these studies, is developed a technique for solving inverse problems aimed at detecting anomalous changes in the gravitational field caused by lateral variability in densities. The fundamental point of the developed methods is the consideration of the earth crust as a two-layer model, consisting of a sedimentary cover and a crystalline base. Interpretation of the first upper layer makes it possible to study the features of the geological structure of oil deposits at sites of local structural forms and carry out their prediction, the second layer - to identify the block structure of the crystalline basement, the zone of faults and decompression of rocks.

To obtain reliable materials, according to Mikhailov [1-5] the following requirements must be met:

- straightness and parallelism of profiles;
- orthogonal network of profiles;
- the scale of the survey corresponds to the size of the search objects;
- the output of the gravimetric profile into the normal field of gravity (that is, beyond the limits of the anomalies-forming object).

Carrying out high-precision gravimetric works in combination with 3D seismic acquisition allows creating seismic-gravimetric models [10], which significantly improves seismic performance in forecasting and prospecting for oil deposits.

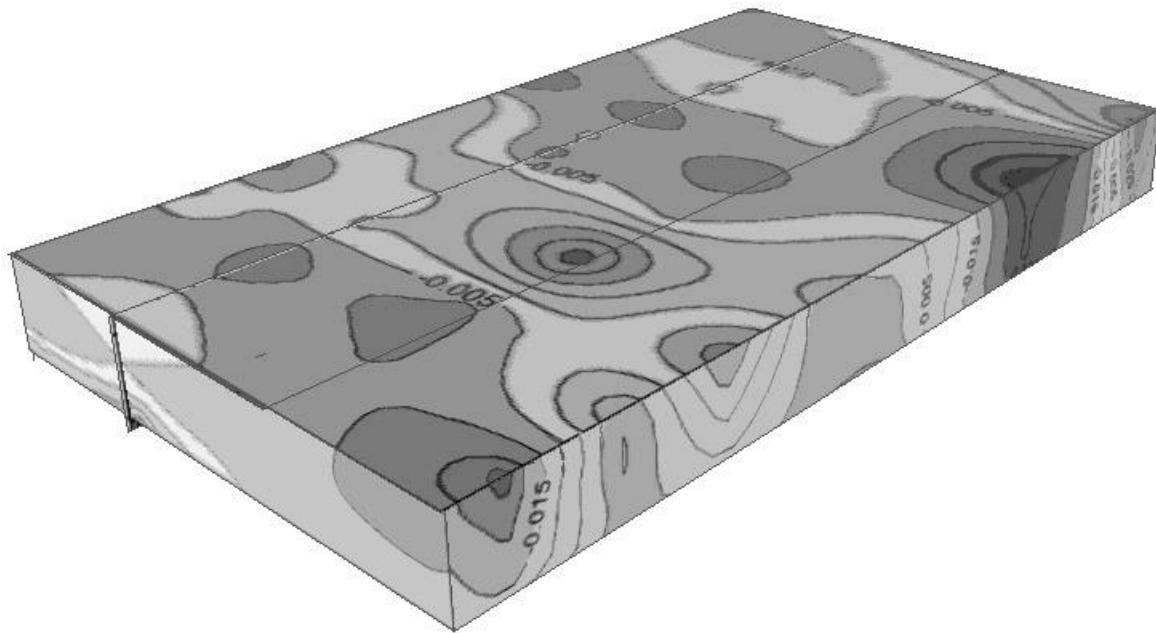


Figure 1. A volumetric model of the lateral variability of the densities in the section Yamashinskaya structure (according to Slepak, 2012)

The use of high-precision gravimetric prospecting will likely contribute to increasing the efficiency of prospecting for plots that are promising for shale hydrocarbons, at the stage of exploration and preparation for development – for optimal placement of horizontal wells.

There are only single descriptions of the results of the electrical exploration application for prospecting and exploration of shale hydrocarbons deposits. It is conducted [12] experiments on the feasibility of application non-traditional geoelectric methods for the formation of a short-pulse electromagnetic field (SPEF) and vertical electroresonance sounding (VERS) and a new method for processing remote sensing data (RS) to search for free gas accumulations (methane) within the coal-bearing rocks. By an area survey using the SPEF method, anomalies such as a "free gas (methane) deposit" or an oil deposit can be detected and mapped (Fig. 2). Depths of the anomalously polarized formations (APF) location of the "gas" type are determined by the VERS probing. The method of processing remote sensing data also allows the rapid identification and mapping of anomalies such as "free gas deposits". The results of the experiments, in the opinion of the authors [12] show that the SPEF-VERZ technology, together with the remote sensing data processing method, can be successfully used in the search and exploration of free gas accumulations (methane) within the distribution of coal-bearing formations.

Shell's experience shows [12] that only 5% of shale spreading areas are suitable for economically acceptable gas production. The use of the proposed express technology of "direct" searches for hydrocarbon accumulations shows [12] that the identified anomalies of "hydrocarbon reservoir type" occupy about 6% of the area searches. As a result, it is concluded that mobile technologies allow the prompt discovery and mapping of the "Sweet Spots" zones within which industrial development of shale hydrocarbons can be organized.

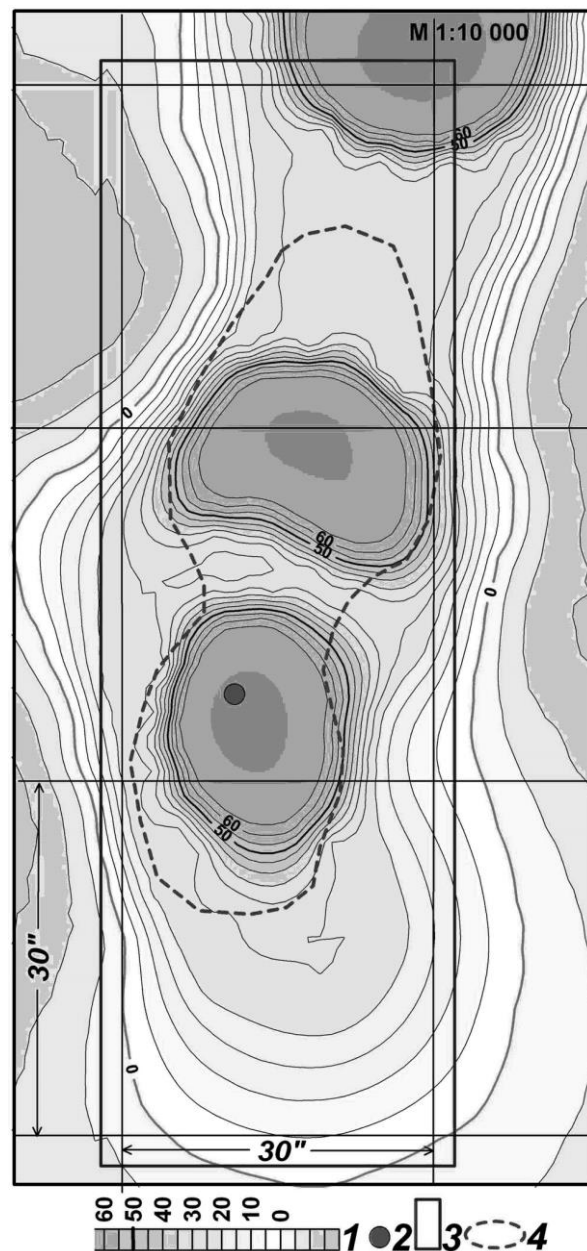


Figure 2. The "hydrocarbon reservoir type" map of the "oil" type

1 - scale of intensity of response in pressure values (MPa); 2 - drilled well, 3 - contour of the site; 4 - contour of "hydrocarbon reservoir type" type "oil" (according to SP Levashov et al., 2013)

There are proposals to use the biogeophysical method (BGF-method) for the search and exploration of shale hydrocarbons, the bases of which were developed by the Russian geophysicist N.M. Andreev. The technology for prospecting and exploration of hydrocarbon deposits based on the BGF method was described by the author at the All-Russian Conference on Deep Genesis of Oil "1st Kudryavtsev Readings" (Moscow, CGE, October 22-25, 2012).

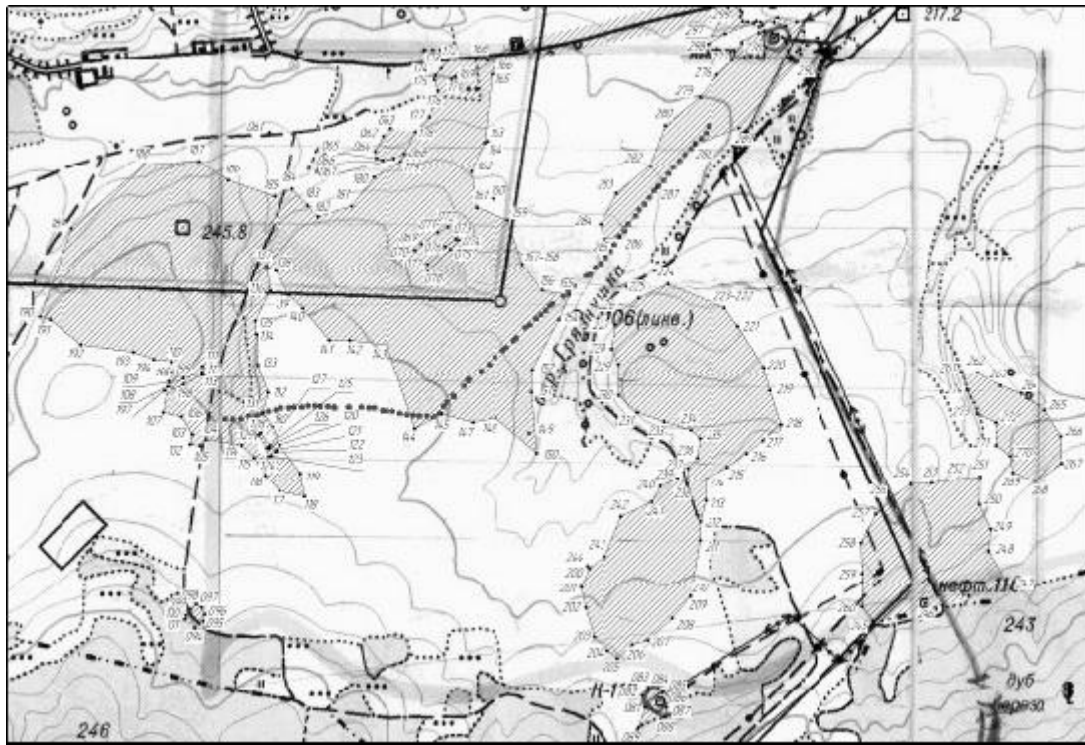


Figure 3. The results of a detailed mapping of extensive PGF anomalies - oil deposits (according to NM Andreev, 2012)

At the base of the phenomenon is the interaction effect of a certain field of the Earth with a highly sensitive biological sensor, which is the organism of the human operator. The effect of this field on such a sensor, apparently, changes the vector of the lines of force of the so-called "human biofield", which leads to rotation of the frames in his hands, giving them certain positions. At the same time, the force acting on the frame and the position it takes have its own characteristic features when the operator crosses various manifestations of the given field-global grid structures that are his background or boundaries of anomalies that in some places disturb the harmonious picture of the grid structures. This allows (according to NM Andreev) to isolate and map (Fig. 3) such anomalies on the surface of the Earth, which is the main task of the BGF method, in contrast to dowsing, radio-eesia, etc.), whose adherents claim the possibility "Dialogue" with a certain "information field" of the Earth with the help of frames (vines), receiving very different information about the objects of the search.

The use of direct searches for hydrocarbons in the enclosing strata is complicated [1, 3], apparently, by the scattered nature of the hydrocarbons occurrence in shales. Probably, concentrated accumulations ("deposits") of shale oil and gas are formed as a result of a fracturing operation, when hydrocarbons are drained along the cracks to a horizontal well. In other words, the formation of separate deposits of shale hydrocarbons is technogenic in our opinion.

The process of crack formation after hydraulic fracturing of the productive formation is fixed [5] with microseismic observations. There are [13, 14, 15] very favorable physico-geological prerequisites for the use of high-resolution electrical prospecting. The development of shale oil and gas necessitates the

prediction of [1-5] migration routes of concentrated fluid streams formed as a result of a fracturing operation of a productive formation in a horizontal well and entering the upper layers of the sedimentary cover. The presence of weakened zones affects the efficiency of hydraulic fracturing and creates the danger of negative impact on the environment.

4. Conclusions

Modern aerogeophysical instrumentation and methodological support allows [7] to integrate high-precision magneto-prospecting with gravimetric and gamma spectrometry. This combination of geophysical methods contributes to the diagnosis of faults to active and latent ("dead").

The development of new technologies for locating zones of high fracturing and continuity, identifying zones of oil, gas and water saturation, tracking the dynamics of fluid flows cause [16] the use of monitoring methods that provide information about the changed properties, geometry and structure of productive horizons.

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