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MODELING PECULIARITIES OF TWO BITUMEN DEPOSITS OF THE SHESHMIAN HORIZON OF THE UFIMIAN STAGE LOCATED IN THE REPUBLIC OF TATARSTAN

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Abstract. The aim of the work was to study the effectiveness and reliability of the interpolation methods of the Petrel 2013 software complex with different data density in the study of bitumen deposits on the territory of the Republic of Tatarstan. The article is based on data obtained from a comprehensive study of the Western (171 wells) and Eastern (61 wells) uplifts, including data from field geophysics and laboratory core research. Cross-validation was carried out using five interpolation methods from the standard Petrel 2013 set for reservoir thickness values. The following methods were used to build the models: Indicator kriging (IK), Sequential indicator simulation (SIS), Sequential indicator simulation (Gslib) (SIS (Gslib)), Truncated Gaussian simulation (TGS-GRFS), and Truncated Gaussian simulation (TGS-SGS). The results obtained made it possible to draw the following conclusion: the core selection methods and interpretation of the field geophysics data have a significant influence on the reliability of interpolation models.

Keywords: 3D modeling, interpolation, cross-validation, core, bitumen deposits
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Introduction

For geological structures, which are reservoirs for natural bitumen, there is often a high lithological and structural heterogeneity. In this regard, new problems arise in the modeling of similar deposits, considered in this article. Such tasks include:

A) choice of interpolation method, suitable for the structure under study;

B) choosing the optimal observation pattern arrangement to obtain the most reliable information about the geological structure.

The article is based on data obtained from a comprehensive study of the Western (171 wells) and Eastern (61 wells) uplifts (Fig. 1) located on the territory of the Republic of Tatarstan. Drilling of wells was carried out with chisels from 125.0 to 152.4 mm in diameter up to the productive interval; drilling was performed in the productive interval with core sampling by means of retrieving barrels KS-108 and UKS-U-109/67. After completion of drilling in the wells, a full range of geophysical studies was carried out. The core selected during the drilling process was sent to the laboratory to determine various petrophysical properties of the rocks.

Object of study

The objects of the study were deposits of bitumens in the Ufimian sediments in the Western (area of 15 km^2) and the Eastern (with an area of 4.0 km^2) uplifts (Fig. 1). The sediments of the Ufimian stage (P_1u) in the studied area are represented in the volume of the Sheshmian horizon (P_1ss), in which two packs are distinguished: the lower one is sandy-argillaceous (old-kuvakskian P_1ss_1) and the upper one is sandy (Ashalchinskian-P_1ss_2). On these uplifts, these packs are the base horizon for the heavy oil deposits of the Ufimian oil and gas bearing complex. The cover of the bituminous rocks of the Ufimian stage is the lower pack of the Baytuganian horizon (P_2bt_1) of the Kazanian stage.

The cover consists of clays gray, ash-gray, calcareous, strong, dense, marly, argillite-like, with siltstone interlayers, sometimes sandy, with crooked fractures,

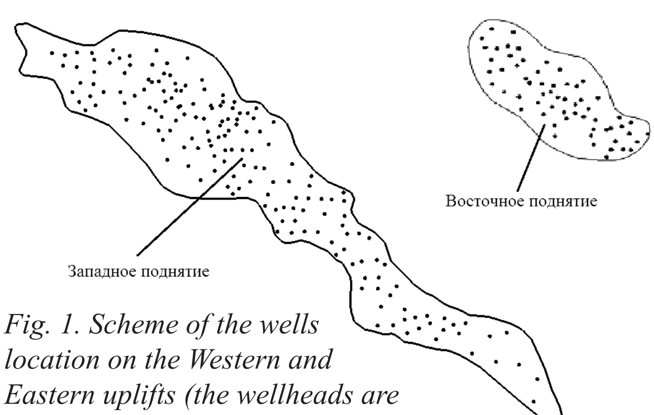

Fig. 1. Scheme of the wells location on the Western and Eastern uplifts (the wellheads are marked with dots).

layered along the stratification plane, with linguloid shells, pyrite crystals (“linguloid clay”) (Sukhov, 2014).

In tectonic terms, the area of occurrence of the Western uplift along the sedimentary stratum, including the Permian deposits, is located in the southern part of the structural zone of the II order, which complicates the western slope of the South Tatar arch. Along the Permian horizons, in turn, this terraced structural zone is complicated by a series of local uplifts of the III order, with which hydrocarbon deposits are closely connected. The Eastern uplift has a more complex structure and is a structural nose of the north-western strike, the arch of which is complicated by two shallow small domes. The structure of the Eastern uplift, identified by the roof of the Ufimian stage, has a zonal arrangement and is a structure of the III order, the roof of which along the top of the Sheshminian horizon corresponds to the maximum thickness of the sandstone pack.

Methodology and results of research

For cross-validation using the “folding knife” method, an irregular drill-out net consisting of 171 drilled wells in the Western uplift was transformed into a grid of 87 wells, by excluding wells in the staggered order on the uplift plane, thus evenly reducing the pattern of the observation arrangement by two times over the entire area of the uplift. By analogy with the Western uplift, on the Eastern uplift an irregular drill-out net consisting of 61 drilled wells was transformed into a net of 30 wells. Wells not included in the data set for constructing models became validated (test set) (Demyanov, Savelieva, 2010).

Interpolation technique	Western uplift		Eastern uplift	
	GIS data	Core data	GIS data	Core data
IK	0,733	0,745	0,625	0,490
SIS	0,721	0,721	0,730	0,470
SIS(Gslib)	0,741	0,725	0,664	0,470
TGS-GRFS	0,773	0,688	0,386	0,335
TGS-SGS	0,776	0,679	0,435	0,333

Table 1. Values of the correlation coefficient for each interpolation algorithm by geophysical and geological data from real data for the Western and Eastern uplifts

The following methods were used to interpolate the productive horizon thickness values: a) Indicator kriging (IK), b) Sequential indicator simulation (SIS) and Sequential indicator simulation (Gslib) (SIS (Gslib)), c) Truncated Gaussian simulation (TGS) using one of two modeling methods: TGS-GRFS using a random Gaussian simulation function and TGS-SGS using sequential Gaussian simulation.

To estimate the results of the work, a nonparametric Spearman correlation coefficient was used, which does not require a normal data distribution, which is not traced on the histogram for the Eastern uplift (Fig. 3b). The values of the Spearman correlation coefficient for each interpolation algorithm for geophysical and geological data are presented in Table 1. Analyzing these results, it can be noted that the best geophysical data on the

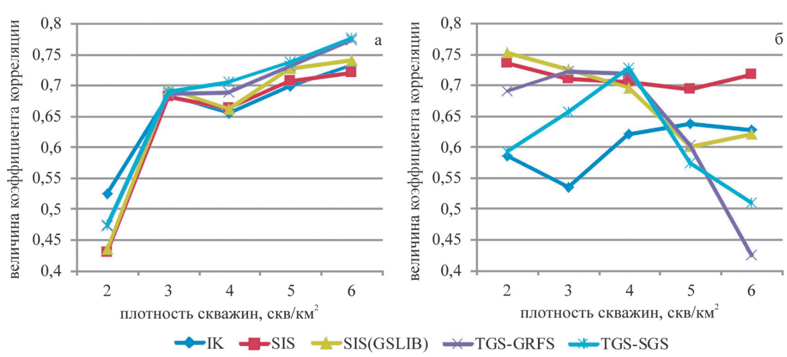

Fig. 2. The dependence graphs of the correlation coefficient on the data density from the results of geophysical studies of wells, a – for the Western uplift, b – for the Eastern uplift.

Interpolation technique	Western uplift		Eastern uplift	
	GIS data	Core data	GIS data	Core data
IK	0,733	0,745	0,625	0,490
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Fig. 3. The histogram of the frequency distribution of oil-saturated section of the productive horizon by geophysical data, a – for the Western uplift, b – for the Eastern uplift.

Western uplift showed the truncated Gaussian method (TGS-SGS), according to the core sampling -indicator Kriging (IK).

On the Eastern uplift, the best methods were the sequential indicator simulation (SIS) for geophysical data and indicator kriging (IK) for geological data.

The results of interpolation techniques for geophysical and geological data (Table 1) do not always coincide because of incomplete reliability of drilling results with core sampling.

This is due to the fact that during drilling, the clay inside the core shell is swollen and elongated under the action of the drilling mud, at the same time, the weakly cemented sandstone is washed away and remains fragmentarily in the core sampler in the process of drilling.

This problem was solved by introducing into the core drilling a small-sized core sampler UKS-U-109/67 in place of KS-108. After the introduction into the process of drilling with the selection of the core of the new core sampler, the minimum percentage of core removal by the wells increased to 95%, compared with 80% when using KS-108. On the Western uplift, the UKS-U-109/67 sampler drilled 166 wells out of 171, in the Eastern – 26 of 61 wells. Correspondingly, the values of the correlation coefficient (Table 1) in the Western uplift are higher than in the Eastern one, first of all, for the data on core sampling. Since in interpreting the field geophysical material, the geophysicist-interpreter relies, among other things, on the description of the core, especially when the geophysical curves are ambiguous in determining the water-bitumen contact, then the reliability of the results of geophysical studies on the Western uplift also increases.

At the next stage of the study, the influence of well arrangement pattern (number of wells per square kilometer) on the correlation coefficient was analyzed. As in the first case, wells were excluded from the set for construction in a staggered manner. On the Western uplift, data on 30; 45; 60; 75 and 90 wells were alternately remained in the well data set. On the Eastern uplift, data for 8; 12; 16; 20 and 24 wells were left in the well data set. The results are shown in Fig. 2a, b.

Analysis of the Western uplift from the graphs (Fig.2a) shows that the application of the interpolation technique on an irregular observation pattern leads to an increase in the correlation coefficient for all methods as the number of wells in the data set increases. The frequency distribution of productive capacities in the Western uplift corresponds to the normal distribution, which is confirmed by a monomodal histogram constructed according to the logging data for the given uplift (Fig. 3a).

According to the dependence graphs for the Eastern uplift (Fig. 2b), the correlation coefficient for the truncated Gaussian methods decreases sharply as the number of data in the construction set increases. The histogram for the Eastern uplift in Figure 3b has a bimodal view, accordingly, in this uplift, the law of normal data distribution does not hold. In this situation, the most reliable methods turned out to be based on indicator kriging (IK, SIS, SIS (Gslib)), which do not require normal data distribution. The reason for the lack of a normal distribution of data on the Eastern uplift is the complex geological structure of this uplift.

Conclusions

1. To construct the most accurate three-dimensional model of the uplift with an irregular observation pattern, it is not enough to apply one interpolation method. A complex application of the methods for each data set is required and the most appropriate one is selected after cross-validation.

2. It is necessary to take data on geophysical exploration of wells as the main and the most reliable information on the depth position and thickness of the Ufimian productive deposits of the Sheshmian horizon, and the geological description of the core – as additional information, due to the above problems arising during the core drilling process using a core sampler KS-108.

3. With a high qualitative level of fieldwork and a normal distribution of geological parameters, the quality of the interpolation model increases as the arrangement of the observation pattern increases. If the normal distribution in the data set and the irregular observation pattern are not adhered to, the best indicators are those based on indicator kriging, in particular, for the Eastern uplift, the method of sequential indicator simulation (SIS).

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