

Probabilistic-statistical estimation of reserves and resources according to the international classification SPE-PRMS

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Abstract. Today in the oil and gas industry there is a large number of different classifications of hydrocarbon reserves and resources, each of which has advantages and disadvantages. This work includes analysis, comparison, as well as the possibility of comparing the results obtained at first glance, seemingly, from completely different methods of assessment of hydrocarbon reserves and resources.

The purpose of the paper is to consider the features of calculating hydrocarbon reserves by different methods and to study the feasibility and appropriateness of applying the probabilistic method for reserves audit. The oil reserves were calculated by volumetric method based on the geological model of the deposit, constructed using the IRAP RMS software package. The variability of the counting parameters was specified in the "Uncertainty" module, with the help of which it is possible to build a geological model with equiprobable realizations, having insufficient data on the main characteristics of the field.

When calculating the uncertainty, the variance by values was set for the following parameters: water-oil contact level, recalculation factor, porosity and water saturation coefficients. After computation and enumeration of possible implementations within the given parameters, the program generated the result in the form of three reserve values: P10 (probable), P50 (possible), P90 (proved). To compare the results of the reserves calculation, the resulting oil-saturated thickness maps were used to trace the distribution of geological reserves.

Based on the conducted research, it was revealed that input data and a different approach to the construction of the 3D geological model influence the final result in the distribution of the reservoir and the main parameters in the volume method formula. For a correct figure of hydrocarbon reserves (resources), it is necessary to use a multivariate distribution of counting parameters in the geological space of the considered object.

Key words: risk, probability-statistical estimation, Monte Carlo method, classification of reserves and resources of oil and combustible gases (RF Reserves Classification-2013), reserves and resources management system of liquid, gaseous and solid hydrocarbons (SPE-PRMS), comparison of domestic and international reserves assessment classifications

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A characteristic feature of the oil industry is an unforeseen change in oil prices. This is the basis of an uncertainty criterion that carries significant investment risk for oil companies (Knight, 2003). It is for this reason that such close attention is paid to risks. There are several categories of risk sources in the oil and gas sector in Russian science. Among them, it is customary to single out the following:

- geological risks;
- infrastructure risks;

- political risks;
- economic risks and others (Knight, 2003).

To date, there are two principal approaches to hydrocarbon resource estimation (oil and gas reserves estimation): deterministic and stochastic. Deterministic estimation is a selection of a single discrete scenario within the range of values that can be obtained as a result of probabilistic analysis. The second method implies the application of statistical distributions of parameters included in the formula of the volumetric method, where random realizations of each distribution of the counting parameter are multiplied in order to obtain a histogram of resources (reserves) for the evaluation object (Fig. 1) (Kelliher, Mahoney, 2000).

The generally accepted document in the field of probabilistic assessment of resources and reserves

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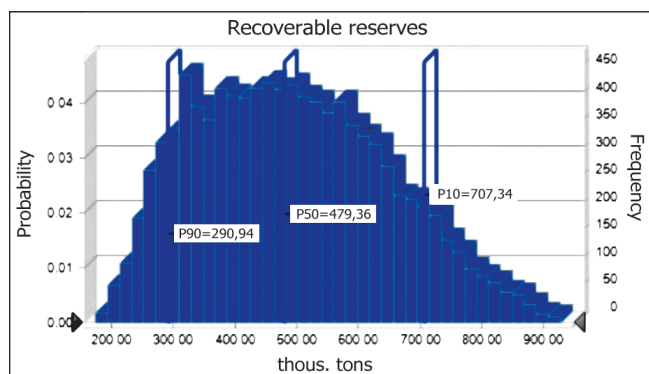


Fig. 1. An example of the histogram of the resources (reserves) distribution

calculation, including among Russian subsoil users, is the «Society of Petroleum Engineers – Petroleum Resources Management System» (SPE-PRMS). For the Russian Federation, a unified guideline regarding the principles of calculation and state accounting of reserves and resources is the methodical recommendation “Classification of reserves and resources of oil and combustible gases” (KZ RF-2013).

In these classifications, different methods of identifying a particular category of reserves (resources) are used. The difference between classifications is due to a number of reasons:

a) in estimation the proven reserves by PRMS, only existing (proven) at the time of the assessment of the field development technology reserves are taken into account. In practice of Russian companies, the orientation of both proven and promising technologies;

b) in estimation reserves according to international classifications, the average oil recovery factors are used, which are justified by analogous fields, while in the Russian classification they use final oil recovery factor values, including the use of secondary and tertiary methods for increasing oil recovery ;

c) in estimation reserves (resources), various methodical recommendations are used to single out one category or another, which leads to a difference in the value of reserves;

d) in practice of Russian companies, the assessment of resources and hydrocarbon reserves is usually made by deterministic methods, while probabilistic-statistical assessment methods are used abroad.

As practice work shows, for the Russian oil reserves classification, the basis of which is the volumetric method formula (deterministic method of reserves estimation), the overestimation of reserves (resources) without risk by categories of reserves (resources) is typical. This criterion is observed in the estimation of reserves (resources) by the Monte Carlo method, and in the case of multivariate geological modeling. Using the Monte Carlo method, it is difficult to take into account and reflect the internal connections between the parameters

of uncertainty. Firstly, the obtained distributions do not correspond to the existing knowledge about the object. They can be shifted in the direction of larger or smaller values, and also show more or less “variation”. Secondly, after assessing the reserves (resources) it is impossible to visualize the uncertainty in space, since the method does not take into account the physical volume of the object. As a result, it becomes necessary to apply the method of estimating uncertainty on models by key indicators. An advantage of the approach is that each implementation considers on an overall model that takes into account all available data and conceptual view of the estimation target. After estimating the uncertainty over a multitude of realizations, it is possible to visualize the results in the form of maps and geological profiles through the probability parameters.

Currently, there are many software tools that allow to carry out a probabilistic forecast with processing a large amount of information and perform a large number of iterations. A probabilistic assessment of the resource potential of promising objects was performed in the Resources Management System (RMS) “Uncertainty” software module, which allows identifying and evaluating the degree of uncertainty in the model and creating multivariate models taking into account the uncertainty.

In geological modeling, uncertainty is present at almost all stages: data import/export, correlation, structural modeling, averaging of well data, facies modeling, petrophysical modeling, reserves calculation, etc. (Sistema upravleniya resursami i zapasami... [Petroleum Resources Management System ...], 2007).

Using the various available properties of this module, it is possible to calculate many implementations of a particular model to substantiate decisions made at various stages of the geological substantiation of a field. Also, in addition to assessing the uncertainty of the model in which the same scenario is used, RMS “Uncertainty” allows creating many realizations, which makes it possible to evaluate the effect of each parameter on the simulation result.

Specifically, for the considered reservoir, the following ensemble of model implementations was selected:

- structural framework of the reservoir;
- wells with pointwise interpretation of porosity and oil saturation.

Let us consider the application of a multivariate (probabilistic) geological model at one of the reserve estimation target of the PJSC Tatneft field. The deposits of the Bobrikovskian horizon are composed of terrigenous rocks, the thickness of which varies from 1 to 13 m. In the sediments of the reservoir under study, two deposits of oil are found, which are associated with two different uplifts (Fig. 2).

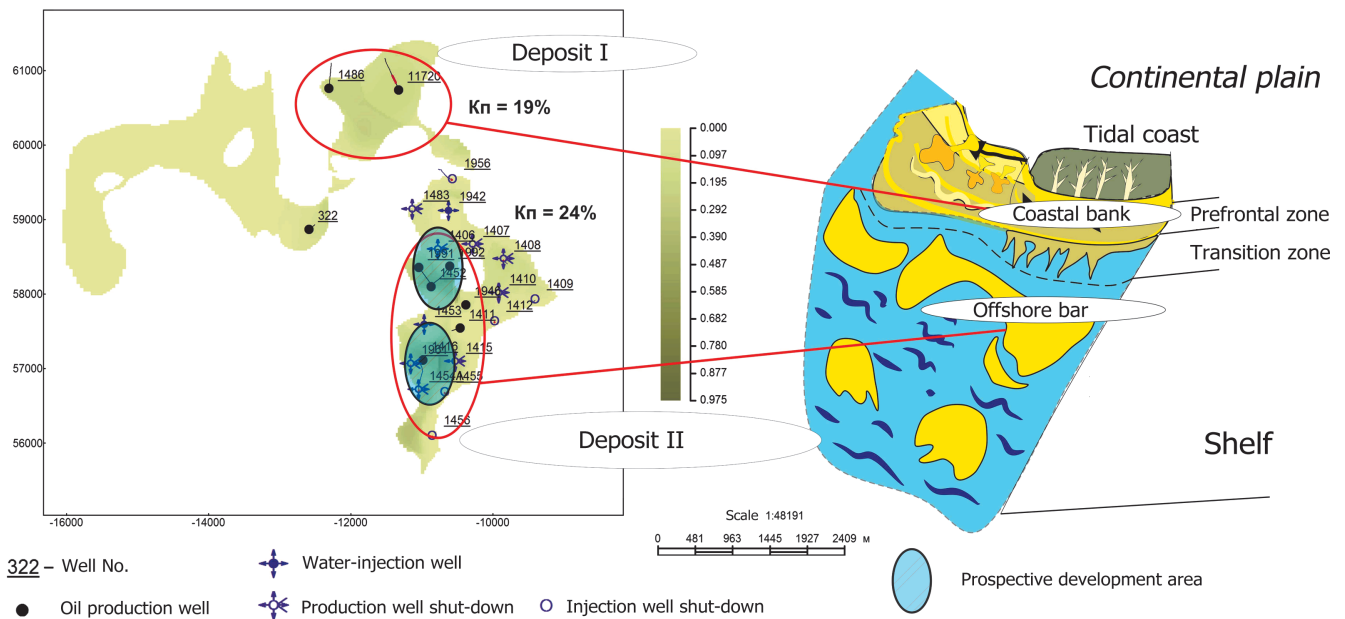


Fig. 2. Map of residual (mobile) oil reserves with the spatial distribution of sand bodies in the territory

According to the study conducted to recreate the conceptual model of the Sirenevsky field as a whole, the reservoir properties of rocks in the oil part of the field under consideration are different. The zone with a low value of the coefficient of porosity (19%) in the oil part is confined to the facies of a regressive longshore bar (deposit 1). The high value of the porosity coefficient (24%) is associated with the facies of the offshore bar (deposit 2). As a result, this heterogeneity is associated with the facial feature of the reservoir rocks of each of the deposits under consideration. Figure 2 shows a map of residual (mobile) oil reserves, on which the unevenness of sampling by area is well traced (Khisamov et al., 2017).

In accordance with the proposed formation concept of Bobrikovskian deposits on the territory of the field, the calculation of the probability-statistical model was carried out for each uplift separately.

Task definition

Let us consider the use of the probabilistic-statistical module RMS “Uncertainty” on the example of one of the uplifts of the field under consideration (deposit II).

When the values of the calculated parameters are scattered, a multivariate geological model was constructed in which the dispersion of the values was set for the following parameters:

- Oil/Water contact;
- Formation volume factor (B_o);
- Porosity coefficient (Porosity);
- Coefficient of water saturation (Water saturation zone) (Sistema upravleniya resursami i zapasami...

[Petroleum Resources Management System ...], 2007).

Changing the settings of the calculation algorithms when constructing the model and the subsequent cross-assessment of reliability, we obtain different basic

variants with different predictions of oil-saturated thickness ΔH_{oil} (Zakrevsky, 2009). Further, after setting the variables and scatter of variables, the number of realizations was set. Naturally, the larger the amount of the run that changes each coefficient, the longer and more accurate the calculation will be. In this case, the calculation was made for 200 implementations. The number of implementations depends on the power of the computer, but the final value of the implementations must ensure a lognormal distribution of reserves.

As a result of the generation of an ensemble of realizations, datasets are created: sets of 3D parameters, sets of net pay thicknesses maps and geological reserves obtained from them. Further, the probability of meeting of the reserves is calculated for each implementation separately.

According to the distribution in the diagram, the geological reserves of the multivariate model of the Bobrikovskian horizon of the considered deposit are as follows: P90 (proved) – 2.05 million m^3 ; P50 (probable) – 2.2 million m^3 ; P10 (possible) – 2.33 million m^3 (Fig. 3).

The geological reserves of oil in the considered reservoir, built in a deterministic method, amount to 2.76 million m^3 . In this method, volumetric parameters are given by static values. In other words, the geologist determined any parameter of the reservoir to within a tenth or hundredths of proportion. In this case, the calculated parameters of the deposit II have some variation in values with probability-statistical criteria according to the geological feature of the reservoir under consideration.

To compare the obtained geological reserves of the uplift, we used the values of the probabilistic-statistical assessment of reserves of the category P50 (as the most probable value) and the assessment of reserves

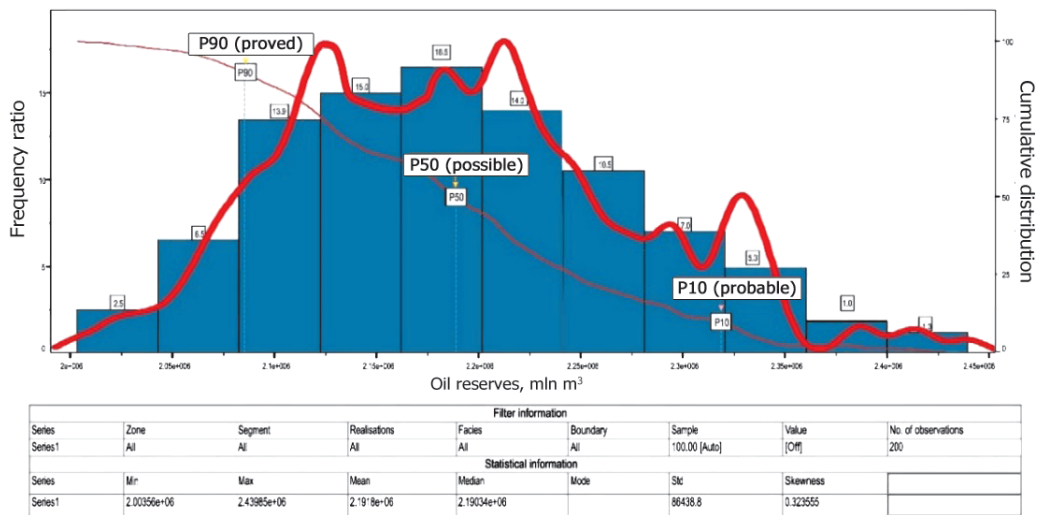


Fig. 3. Geological reserves by a multivariate (probabilistic) geological model of the deposit of the II East-Sirenevsky uplift of the Sirenevsky field

obtained from the deterministic model. According to the probabilistic-statistical assessment, the P50 reserves amount to 2.2 million m³ of oil.

According to the deterministic model, the initial oil in place of hydrocarbons amount to 2.7 million m³ of oil (which is 19% more than the probability-statistical model) (Fig. 4).

After estimating the uncertainty over a multitude of realizations, a map of net pay thickness was constructed for each of the realizations (P90, P50, P10). Also, a map of effective oil-saturated thickness for the implementation of P50 was implemented, generated after calculating parameters in the RMS “Uncertainty” module.

The areas of deposits, where oil-saturated rocks are widespread, were determined according to the calculation plan of the reservoir under consideration, which is limited by the external contour of oil-bearing capacity.

It is also necessary to take into account that the total volume of the initial oil in place in the probabilistic-statistical model is influenced by all the main volumetric parameters that are included in the implementation of a variety of realizations. Let us consider maps of net oil pay thickness constructed using various methods (Fig. 5).

In the end, when comparing the obtained data, several local zones were identified that contribute to the discrepancy in the statistics of geological reserves. For example, on both maps of net pay thickness, the limited elevation in the central part has different thickness lines (Fig. 5c). As a result, on the map constructed by the deterministic method, the value of the net-to-gross ratio is much higher than on the map of the probabilistic statistical 3D geological model.

This difference is due to the interpretation of drilling and geophysics data. In particular, in a deterministic assessment of reserves, the geophysicist determines the transition from the oil part of the reservoir to the water-saturated one with an accuracy of centimeters, on which the deposit area and the oil-saturated thickness of

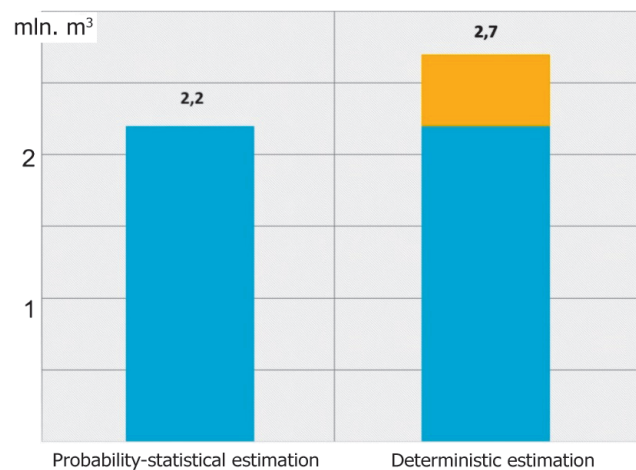


Fig. 4. Geological reserves of the Bobrikovskian horizon of a deposit 4 according to different methods of estimation, million m³

the reservoir depend. When determining the calculated parameters, due to the set of possible values, there is an error in the estimation. If we consider the assessment of reserves by the probabilistic-statistical method, then each element of the formula for calculating reserves under uncertainty conditions is given taking into account the variance, as described earlier. In this case, in the deterministic 3D geological model, the level of the oil-water contact of the considered uplift is taken according to the geophysical survey of wells and determined at an absolute elevation of minus 930 m out of 200 variations, which is 0.5 m less than in the deterministic 3D geological model (Table 1). This example is indicative of Fig. 5a, b and d.

Comparison of the results of the reserves assessment of the Russian classification and the classification of PRMS. Reserves division into categories

The allocation of categories of reserves by the considered area was carried out in accordance with the

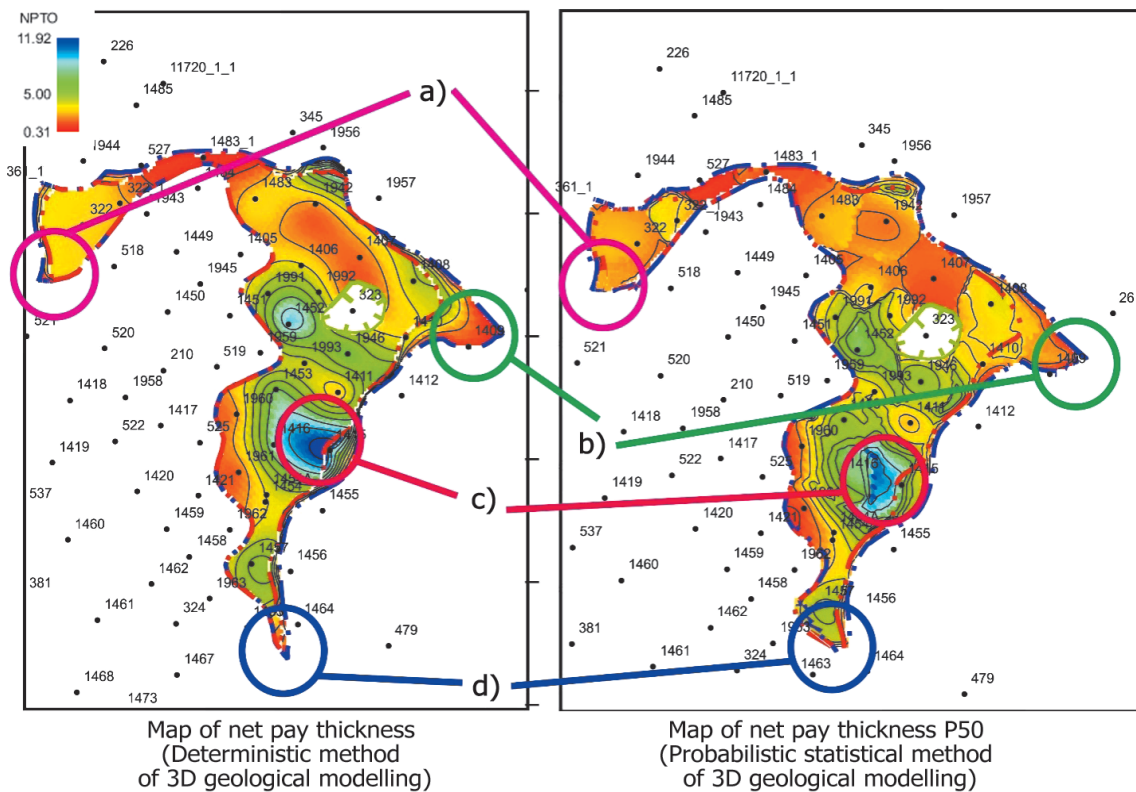


Fig. 5. Comparison of maps of net pay thickness of the Bobrikoskian horizon of the deposit 4

Method	OWC, m	Volume ratio	Porosity coefficient, un. fr.	Coefficient of water saturation, un. fr.	Initial geological reserves, mln m ³
Deterministic	930	1,059	0,24	0,3	2,76
Probabilistic-statistical (P50)	929,5	1,051	0,234	0,29	2,2

Table 1. Estimated parameters of oil deposit II of the considered field

methodological recommendations on the application of the PRMS classification.

According to the current classification of PRMS, oil reserves of the considered horizon are classified as PDP, PDNP and PUD.

The reserves of the Pletnevsky uplift 1 are attributed to the PDP and PUD categories. The sediment-bearing capacity was established according to the logging data and confirmed by the results of the formation test in all wells. Industrial oil production is carried out in two wells.

The reservoir reserves of the II East-Syrenevsky uplift are classified as PDP, PDNP and PUD. The sediment-bearing capacity was determined according to the logging data and was confirmed by the results of the formation test in 18 wells. Commercial oil production was carried out in 17 wells.

According to the methodological recommendations on the application of the PRMS classification, the boundaries of the categories are placed at a distance of 150 m from production wells (Fig. 6b).

A comparison of the substantiation of categories and

indicators of reserves according to the new classification and the PRMS system, carried out in accordance with a probabilistic-statistical assessment, shows a significant divergence of results and the procedure for identifying categories (Fig. 6). In general, a comparison of all deposits of the Bobrikovskian horizon of the Sirenevsky field showed that the total reserves of the considered measurement facility, compared with the PRMS, differ by + 24% (Table 2). Thus, geological reserves by category A in relation to adjacent reserves according to the international classification (PDP and PDNP) differ by + 17%. Reserves of category B1, calculated according to the national classification, are significantly larger than stocks of PUD by PRMS (+ 55%).

Ultimately, when calculating hydrocarbon reserves, using different methods, the ambiguity results in the final result of hydrocarbon reserves. In other words, if the reserves are estimated using various methods, the total amount of geological reserves according to the national classification, which is based on the deterministic method, will be overestimated, due to the conservative approach to identifying reserves categories and in an

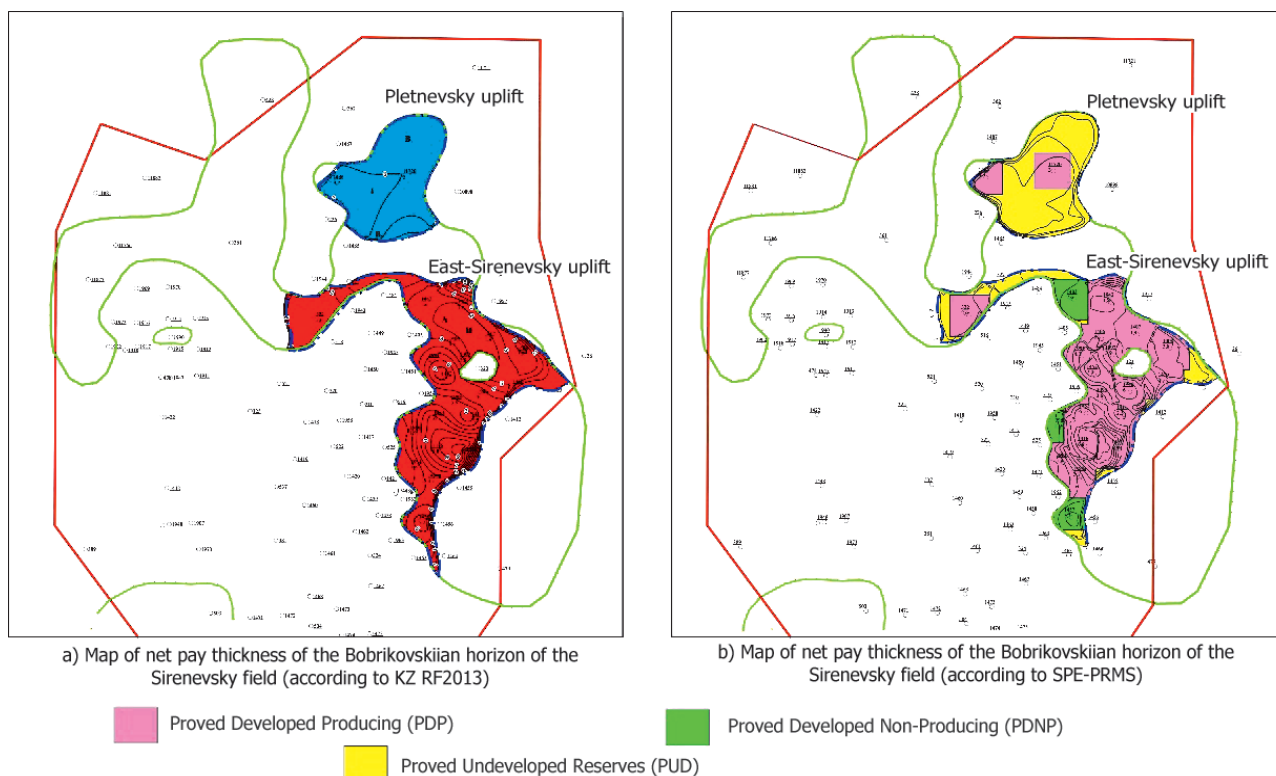


Fig. 6. Comparison of categorization of reserves according to the Russian classification (a) and according to PRMS (b)

Russian classification, 2013		Classification PRMS		Comparison of the KZ RF2013 reserves and PRMS reserves, %
Reserves category	Geological reserves, thous. tons	Reserves category	Geological reserves, thous. tons	
A	2766	PDP+PDNP	2282,4	+17%
B1	582	PUD	263,5	+55%
Total	3348		2545,9	+24%

Table 2. Comparison of the results of the estimation of oil reserves according to the Russian classification and the SPE-PRMS of the Bobrikovskian horizon of the Sirenevsky field

uncertain, ambiguous approach when averaging the calculated parameters bulk method.

Thus, a different approach in determining the accounting volumetric parameters influences the final result of the assessment of reserves, which causes a significant difference in the initial geological reserves of the considered calculation object. As the analysis has shown, for the selection of categories of reserves according to the Russian classification, the basis of which is the formula of the volumetric method, the overestimation of reserves (resources) relative to international classifications is characteristic. According to the results of the analysis performed in this work, the difference between the deterministic and probabilistic-statistical methods of the two deposits under consideration was 24%.

In order to rationally use the results of reserves calculation in the investment activities of the oil industry, it is necessary to standardize the approach in the formation of the government balance of reserves, which will contribute to the reduction of time and costs during the state examination of reserves.

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