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Development of risk assessment methods in the implementation of exploration projects

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Abstract

The peculiarity of oil and gas projects is their long implementation period, during which they are subject to the influence of a large number of different risk factors that complicate project implementation and result in failure to achieve the planned economic indicators set by investors. The effective operation of companies therefore depends on how reliably investors can predict the prospects for project development. The success of the subsequent functioning of the investment project depends to a large extent on the reliability of the assessment of the effectiveness of the investment project, based on the optimally chosen strategy of its development, and, above all, on the anticipation of possible risk factors and tools for their prevention. Therefore, at present, the competitive struggle in the oil and gas production industry is currently shifting to the area of pre-project preparation of investment projects and increasing the reliability (quality) of their economic efficiency assessment at the stage of making a decision to start their implementation.
Geological risks become important in the implementation of exploration projects, the first stage in the overall process of developing the Company's assets. It is necessary to find a balance between the cost of project implementation and the amount of accumulated hydrocarbons for the forecast period, which will ensure maximum profitability of the project. The challenge to optimize the financial outlay on the implementation of geological exploration works by focusing on the most promising and important projects for companies becomes relevant. In this regard, the article considers the methodological approaches proposed by the author to assess the risks of exploration with the aim of improving the efficiency of the planning process and reducing inefficient financial costs.

Keywords: risks, projects, financial efficiency, exploration works, dynamic risk assessment, statistical risk assessment, toolkit.

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实施地质勘探项目时评估风险的方法发展

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简介

石油天然气项目的一个显著特点是它们具有漫长的实施期，在此期间受到大量不同风险因素的影响，这些因素使项目实施变得复杂，并成为投资者未能达到其规划经济指标的原因。因此，企业的有效运作取决于投资者对项目发展前景的预见能力。基于选择的最佳发展策略以及尤为重要的是预见可能的风险因素和防范工具，对投资项目的效益进行可靠评估，在很大程度上决定了投资项目后续运作的成功。因此，当前石油天然气开采行业的竞争转移到了投资项目的前期准备和在投资决策阶段提高评估其经济效益可靠性（质量）的领域。
在地质勘探项目实施过程中，地质风险变得至关重要。需要在项目实施成本和预测期内累积的碳氢化合物数量之间寻求平衡，以确保项目的最大盈利能力。优化地质勘探工作的财务支出成为一项重要任务，通过将精力集中在对公司最具前景和重要的项目进行研究来实现。因此，本文讨论了评估地质勘探项目风险的方法论方法，以提高规划过程的效率并降低无效的财务支出。

关键词： 风险、项目、财务效益、地质勘探工作、动态风险评估、统计风险评估、工具。

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Introduction

A characteristic feature of oil and gas projects is the long implementation period, during which they are exposed to a large number of different risk factors: geological, production, financial and others, which complicate their implementation and cause the failure to achieve the planned economic indicators set by investors. Another important feature is that the volume of required investments is significant [Zubareva et al., 2005]. At the same time, the effective operation of companies depends not only on the size of the investment, but also on how reliable the investors themselves believe the project's development prospects to be. The success of the investment project's subsequent operation depends to a large extent on the reliability of the assessment of its effectiveness based on a correctly chosen strategy for its future development (planned volumes of hydrocarbon production, development technologies, etc.) and, above all, on the anticipation of possible negative (risk) factors and tools for their prevention. Therefore, competition in the oil industry is moving into the area of pre-project preparation of investment projects and increasing the reliability (quality) of assessing their economic efficiency at the stage of making a decision to start implementation.

When implementing geological exploration projects - at the initial stage of the overall process of developing the company's assets - geological risks become important [Imamov, 2014a]. Also at this stage it is necessary to find a balance (optimal strategy) between the costs of project implementation and the amount of accumulated hydrocarbons over the forecast period (planning horizon), which will ensure the maximum value of the financial indicator NPV (Net Present Value, net discounted flow). The task of optimising the financial costs of carrying out geological exploration works by concentrating efforts on studying the most promising and important projects for the companies becomes important.

There is no generally accepted methodology for the assessment and consideration of risk factors during the implementation of geological exploration projects that is accepted and shared by the majority of participants in the process (market) [Imamov, Yolokhova, 2015]. Oil and gas companies use their own corporate approaches and tools in their activities[1]. In this regard, the article discusses the proposed methodological approaches to quantitative risk assessment of geological exploration projects in order to improve the efficiency of the planning process and reduce ineffective financial costs.

1. Research methodology

Currently, oil and gas producing companies are paying increasing attention to assessing the economic risks associated with geological, technological and other uncertainties that may limit project realisation when making investment decisions in geological exploration (hereafter referred to as GE). At the same time, geological risks (hereinafter referred to as GR) play an important role in this process, as most exploration projects are implemented in an environment of geological uncertainty [Imamov, 2014a; 2014b].

Geological uncertainty affects the volumes of cumulative hydrocarbon production and therefore the value of the discounted net present value flow. Therefore, the expected monetary value (EMV) indicator is used to account for geological risks in investment planning [Bush, Johnston, 2003]. The expected monetary value of the project is calculated using the following formula:

$$EMV = NPV \times Rusp - Zrisk \times (1 - Rusp),$$

where EMV is the expected monetary value of the project (roubles), NPV is the net present value flow (roubles), $Rusp$ is the probability of geological success of the exploration (units), $Zrisk$ is the risky capital cost of the project (roubles).

The key indicator in the calculation of the EMV indicator, as follows from the formula, is the probability or chance of geological success. In international practice, the term 'chance of geological success' - gCoS (Geological Chance of Success). has become widely used. This indicator reflects the probability that the predicted reservoir or deposit will be discovered [Rose, 2001; Zagranovskaya, 2023].

Geological success is the main prerequisite for the financial success of geological exploration, and the success of the entire project ultimately depends on how accurately it is calculated. In this respect, methods for calculating the probability of geological success are becoming increasingly important in modern conditions. One of the ways to improve the accuracy of the calculation can be to use the results of conceptual geological modelling carried out in the region (district) of interest to the companies. The proposed methodological approach is described below.

In the practice of risk analysis of geological exploration (geological risk analysis), two approaches to the interpretation of geological data on an object (asset) have been formed - static and dynamic. In the first case, the information is analysed at a certain point in time (i.e. modern data). In this case, certain assumptions are taken into account to assess the sequence of geological processes over time. However, the static approach will not be able to take into account, in the formation and development of an oil and gas basin (its part), changes in various geological processes and parameters during its history from the perspective of a single hydrocarbon system. The use of a dynamic approach based on basin modelling tools provides a more reliable assessment of the geological risks associated with the implementation of exploration projects. In this case, a reconstruction of the geological history of the basin (its part) is carried out - from the moment of formation of the crystalline basement to the present stage - with modelling of all geological processes influencing the formation of its oil and gas potential [Tissot, Welte, 1981; Vassoevich, 1986].

Obviously, the dynamic approach is more accurate for assessing GR. However, the static approach also has a place: after all, when companies enter new areas, initial geological and geophysical information is not always available in sufficient quantity and quality to fully apply basin modelling technologies.

[1] See, for example: Methodology for evaluating new hydrocarbon exploration and production assets. St. Petersburg, Gazpromneft STC LLC, 2015.

2. Results from the analysis of evaluation methods

Static geological risk assessment. When conducting a static assessment of geological prospects, it is suggested that a risk matrix be constructed to calculate the ultimate probability of success of geological exploration. This is a quadratic diagram with the risk of the hydrocarbon system on the horizontal axis (from left to right, from larger to smaller) and the risk of finding oil and gas on the vertical axis (from bottom to top, from larger to smaller).

Hydrocarbon system risk assesses the likelihood that the processes necessary to form hydrocarbon reservoirs have occurred in the geological history of the region (basin or part of it) being assessed. The higher the hydrocarbon system risk, the lower the probability of deposit formation.

The risk of finding hydrocarbons in a prospective area evaluates the quality of predicting the results of the analysis of geological processes of formation of hydrocarbon deposits. The higher the risk, the lower the probability of finding a deposit (Fig. 1).

If all the points (system parameters) that characterise the main geological parameters are grouped in a triangular sector above the diagonal joining the upper left and lower right corners, the risk can be considered acceptable and the values along the axes allow the geologist to quantify the probability of a positive outcome for each system parameter. If at least one point is outside this zone, the risk is considered unacceptable.

The results of a risk assessment are highly dependent on the quality of the input data used in the analysis and the quality of the description and prediction of geological processes. At the same time, predicting the combination of various elements (parameters) of hydrocarbon systems and the geological processes that influence them is a very important step in improving the quality of the gCoS prediction.

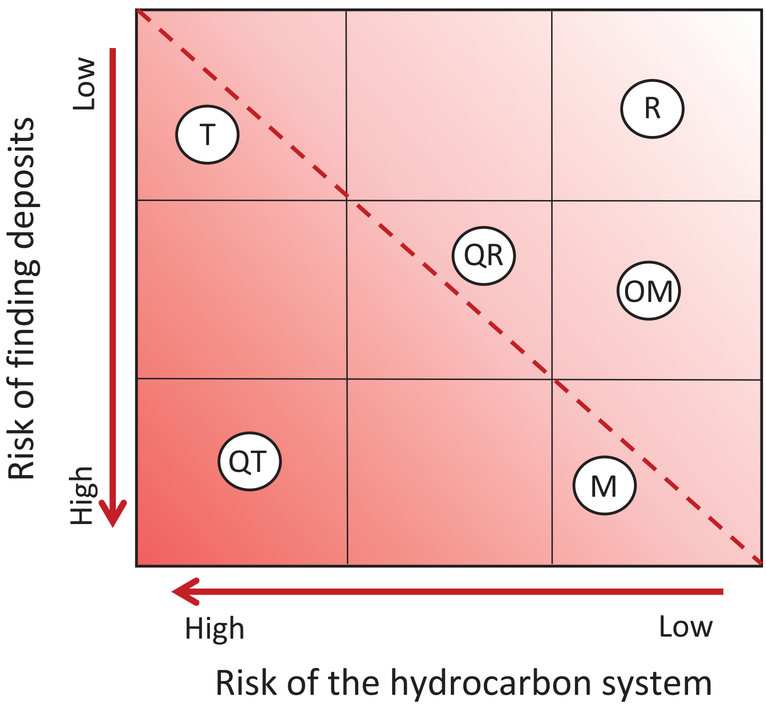
It should be noted that the static method of assessing geological risks using a matrix is limited in situations where a number of important factors related to the history of the oil and gas formation need to be taken into account for the GCoS analysis. In this respect, it is advisable to apply this approach to new (to the company) exploration prospects (exploration assets) where there is insufficient geological and geophysical data to allow the application of dynamic analysis of hydrocarbon systems. As geological exploration is carried out and geological, geophysical, geochemical and other data are accumulated, companies have the opportunity to assess the geological risks of exploration in the analysed region (area) on the basis of a dynamic approach, if the spatiotemporal processes of hydrocarbon generation and formation of their accumulations are predicted.

Dynamic geological risk assessment. A dynamic approach to assessing the chances of geological success, as already mentioned, consists in the spatio-temporal modelling of the processes of changes in the main parameters of the hydrocarbon system. The system model is a dynamic model that allows us to reconstruct the processes of formation, migration, accumulation and loss of oil and gas in the hydrocarbon system during the geological history of the development of the sedimentary basin. During the modelling process, geological indicators can be presented in one-, two- or three-dimensional form for the studied zone (area). In addition, they can represent a model of both a single reservoir and an entire oil and gas basin (hereafter referred to as OGB).

The gCoS assessment process breaks down geological success as a complex concept into its component factors (dynamics), the implementation of which leads to the formation of hydrocarbon reservoirs. At the same time, the following key factors necessary for the formation of their deposits are examined (Fig. 2):

- the presence in the section of the sedimentary cover of the areas (zones) under consideration of oil and gas source strata (hereinafter referred to as OGSS), which,

Fig. 1. Geologic risk matrix



OM – oil matrix risk

QT – risk of having a quality tire (fluid seal)

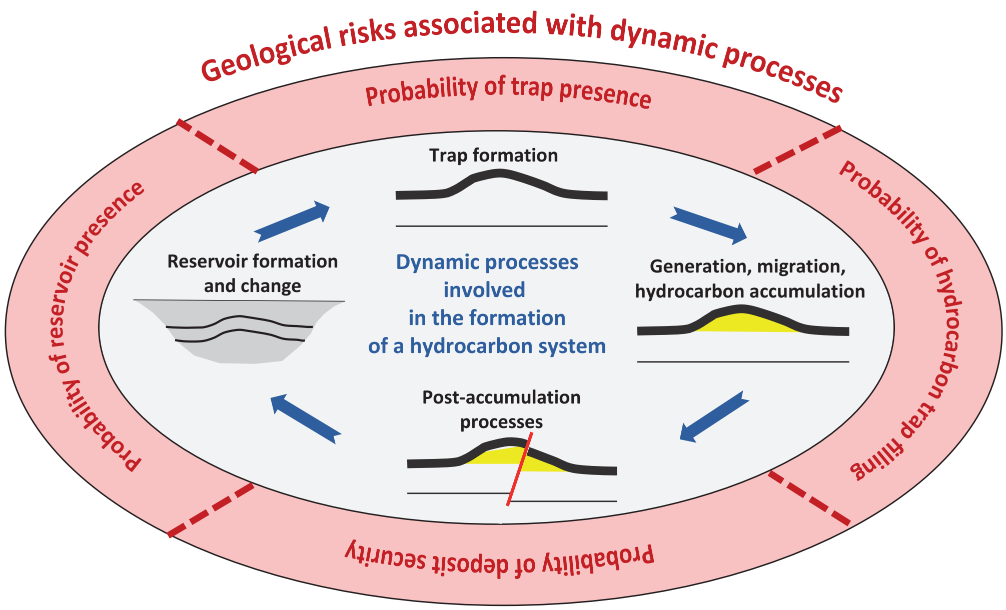
R – reservoir risk

M – risk of hydrocarbon migration

T – risk of a trap

QR – risk of having quality reservoirs

Fig. 2. Geological risks associated with the formation and maintenance of hydrocarbon reservoirs



depending on their composition and conditions of occurrence, may produce hydrocarbons;

- favourable migration-accumulation processes from the OGSS development zone (generation centre) to reservoir layers (reservoirs) in hydrocarbon accumulation zones;
- preservation of hydrocarbon reservoirs (deposits) formed during geological history.

In the process of analysing the dynamic factors obtained by modelling the hydrocarbon system, the probability of the existence of a reservoir, the existence of a hydrocarbon trap, the filling of the trap with hydrocarbons and the safety of the deposit after its formation are assessed. The final overall indicator of the predicted reservoir is calculated by multiplying the independent geological factors (Table 1). In addition, some factors have their own independent sub-factors, which are also multiplied to obtain a common value characterising the main factor. The proposed formula for calculating the final indicator is shown in the table.

Some of the dynamic success factors describe features that are characteristic of the entire oil and gas reservoir under consideration, while others may only characterise a local geological object within its boundaries. For example, the factor of the presence of oil and gas source strata is a regional feature, and the factor of the presence of a trap is a predominantly local feature. It should be noted that in recent years (for objective historical reasons) increasingly complex geological systems have been studied, which cannot always be integrated into simplified models. Almost all geological risk (success) factors, with the exception of OGSS, can be both regional and local. For example, when assessing the likelihood of the existence of hydrocarbon migration pathways, it is often necessary to consider not only regional conditions (the presence of persistent reservoir strata, tectonic faults, the distance from the source of hydrocarbon generation to the accumulation zone), but also the possibility of the existence of local barriers to a particular trap in its immediate vicinity.

The proposed dynamic risk assessment tools largely cover the process of formation of a hydrocarbon resrvoir (field). However, it does not include some external conditions and risks of a larger order that can affect the effectiveness of the implementation of an exploration asset (geological object/objects), for example, the likelihood of the implementation of the geological concept proposed by experts for the assessment of a poorly explored territory (zone, area, etc.). Often, without the necessary factual geological and geophysical information, geologists evaluate prospect areas on the basis of hypotheses about the structure of the area under consideration, the sedimentation conditions, the time of formation and migration of hydrocarbons, and so on. However, if the assumed hypothesis turns out to be incorrect, the geological risks may be significantly higher. This effect can be reduced by having companies' strategic exploration assets studied by separate expert groups and by organising their consideration by related specialist departments within companies.

Conclusion

Thus, as shown above, in the implementation of geological exploration projects, geological success is one of the main conditions for financial success, and the success of the whole project ultimately depends on how accurately it is calculated. In the practice of risk analysis in geological exploration, two approaches to the interpretation of geological data can be distinguished - static and dynamic. At the same time, the use of a dynamic approach based on catchment modelling tools allows for a more reliable assessment of the gCoS indicator.

Based on the results of consideration of the above-mentioned methodology for assessing risks during the

Table
Dynamic factors and conditions for geological exploration success

Dynamic success factor in geological exploration	Environment	Probability indicator	Calculation of the final indicator
Security of the deposit after its formation	Absence of deposit destruction processes caused by mechanical, physical, chemical or biochemical influences on the formed resrvoir (field)	*Pс*	
Existence of reservoir	Presence of reservoir strata in the section. Favourable areal distribution, effective thickness, filtration and capacity properties, facies variability, diagenetic processes	*Pпр*	*Pпр = Pф × Pи*
	Presence of facies with favourable reservoir characteristics	*Pф*	
	Favourable post-depositional changes in reservoir rocks	*Pи*	
Presence of a hydrocarbon trap	The presence of a geological body capable of trapping hydrocarbons. Reliable mapping of the trap based on actual data, accuracy of depth and area constructions, tightness and integrity of the seal and screens (tectonic, lithological) at the time of initial saturation and thereafter	*Pл*	*Pл = Pк × Pп*
	Presence of a closed circuit	*Pк*	
	Presence of fluid seal (tyre)	*Pп*	
Filling the trap with hydrocarbons	The existence of a source that ensures the supply of a promising area of hydrocarbons, depending on: the strength and areal distribution of the source rock; the content, type of organic matter and the degree of its catagenetic transformation. Filling of the hydrocarbon trap, taking into account its location in relation to the migration paths, the time of trap formation and migration time, the possibility of undersaturation (incomplete filling).	*Pз*	*Pз = PТ × Pм*
	Existence of oil and gas resources (sequences)	*PТ*	
	Time to realise oil and gas potential and hydrocarbon migration	*Pм*	
gCoS = *Pс × Pпр (Pф × Pи) × Pл (Pк × Pп) × Pз (PТ × Pм)*			

implementation of exploration projects, it can be argued that it is a serious tool for calculating the success rate of work. Confidence in this is based on the ability to reconstruct the main geological processes that determine the presence of hydrocarbon deposits within the area of the project being evaluated. The resulting gCoS indicator can have a significant impact on the financial efficiency of developing an exploration asset.

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