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GEOLOGICAL RISK ASSESSMENT IN HYDROCARBON EXPLORATION

Bagirov E.

SOCAR, Baku, Azerbaijan: elchin.b.bagirov@socar.az

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Summary. The geological risk in hydrocarbon exploration is defined as the probability of the absence of a hydrocarbon accumulation in the study area. Exploration prospects can be characterized by three parameters that determine its value: expected gain (or volume of hydrocarbons), risks (or chance of success or failure) and cost of the project. Expected volumes are usually estimated in probabilistic terms, taking into account uncertainties. These uncertainties and risks often overlap and that leads to overestimation of geological risks. A methodology for estimating of potential reserves including geological risks is proposed in the paper. This distribution of hydrocarbon resource volumes indicates also both, the probability of the absence of hydrocarbons (geological risk) and the probability of volumes below a certain threshold (chance of commercial failure). The calculations are carried out by using the Monte Carlo method.

Introduction

Hydrocarbon prospect evaluation includes the potential reserve assessment of the area and geological risk assessment. The methodology for assessing resources and risks used by almost all companies is practically the same and differs only in details (Feller, 1968; Керимов и др., 2015; Rose, 2001). When assessing resources, a probabilistic approach is used, where all the geological input parameters are not accepted by one value, but are described by a probabilistic distribution. Then resources are calculated using the Monte Carlo stimulator and are presented in the form of a probability distribution. This way, the uncertainty of the input geological parameters of the model is taken into account when evaluating resources. The less reliable the parameters are, the greater their uncertainty, and the greater is the variance of the estimated resource. Then, companies, regardless of the previous process, evaluate the risks of individual parameters of hydrocarbon systems that may lead to failure, which is the absence of a hydrocarbon accumulation in the studied area. Unfortunately, there is no single methodology for risk evaluation, as well as there is no clear definition of risk. Many companies assess risks based on the degree of reliability of information and the scope of work by which geological parameters are estimated. This leads to the confusion of the concepts of "risk" and "uncertainty". Of course, more reliable data one has, the less the uncertainty of the parameters. However, reducing uncertainty does not necessarily reduce risks. It can lead to both: a reduction in risks or an increase in them. By calculating risks and volumetrics separately, the risk is double-dipped. It should be taken into account that estimated resources include the uncertainty of input parameters. And double-dipping may lead to an overestimation of risks.

There is no single approach to the number of risk parameters. In fact the greater the number of factors, the higher the estimated risk. Therefore, often the values of risks received by different companies can be significantly different, despite the fact that they work on the same data set.

Another point that leads to an overestimation of geological risk is the dependence of various parameters. When multiplying the risk values of different parameters, it is assumed that they are all independent. In reality, this condition is not fulfilled. For example, many parameters have a trend of change with depth. Therefore, they cannot be considered as independent random variables, but are correlative.

All of the above factors require a revision of the methodology for assessing geological risks.

Theoretical framework and method

Suppose that we are studying some geological parameter that can be described by various probability distributions $f_k(x)$. Moreover, each of the options can occur with a probability p_k, where $\sum_k p_k$=1. Then the final distribution of the parameter can be expressed as the mixture of the distributions (Feller, 1968, p.53).

$$w(x) = \sum_k f(x,\ \theta_k) p_k$$

Figure 1 shows an example of this procedure. A certain parameter can be described by a distribution density (in the left column) with probabilities of 0.3, 0.5, and 0.2, respectively. Then the density and distribution function of the mixture can be represented as graphs in the right column.

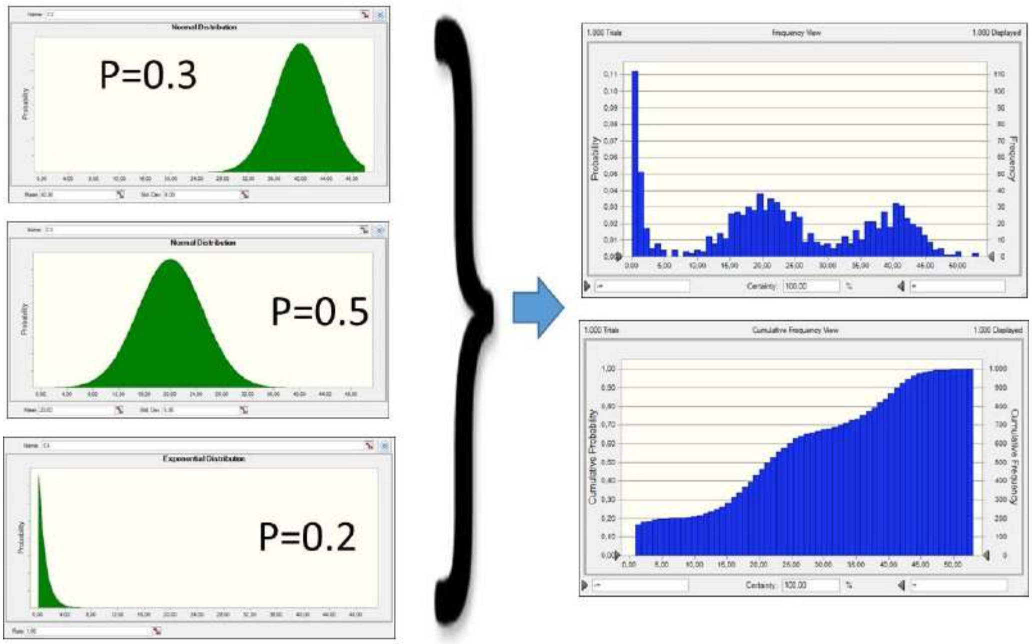

Fig. 1. Mixture of distributions (left column) with the probabilities of occurrence 0.3, 0.5 and 0.2 respectively with the resulting distribution (right column)

The methodology is the following – each of the geological parameters used in the assessment of potential reserves are described by a mixture of successful and unsuccessful case distribution. After that, using the Monte Carlo method, these parameters are simulated and the final distribution of potential reserves is calculated.

Figure 2 shows an example of risk-free (a) and risk-based (b) reserve distribution. Since by risk we mean the probability that the reserves will be close to zero, in this example, risk is approximately 0.4.

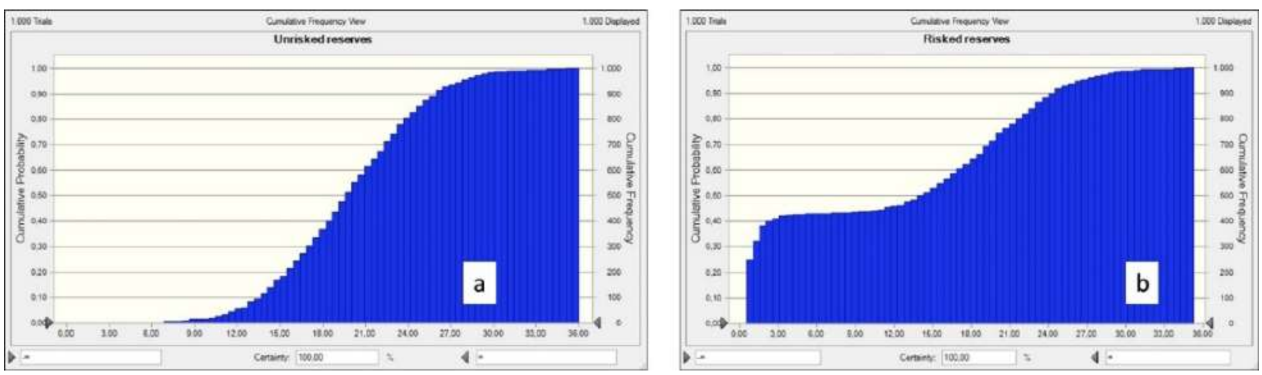

Fig. 2. Hypothetical reserve distribution function without (a) and with (b) accounted risk

Results and discussion

The risks, related with each element of hydrocarbon system should be estimated separately.

Source rocks. The source rock potential, UEP, is defined as the amount of hydrocarbons that these rocks can generate with the complete transformation of organic matter from one km^2 of the fetch area. This index mainly depends on the content of organic carbon (TOC), hydrogen index (HI) and the net thickness of the organically saturated range(s). The values of each of these parameters can be described by the corresponding distribution. Assuming, that the value of one of those the parameters (not necessarily all of them) is equal to zero, this means the absence of the parent rock. Let's define the source rock absence, as event {Net thickness=0}. In such case, by mixing the net thickness distribution and the "absence event" the final distribution of UEP can be obtained.

Migration losses. Migration losses can be estimated in the process of basin modeling. Probably, the most important factor that can lead to the absence of hydrocarbons is the position of the first carrier bed. The probability that the prospect is in the shadow of migration can be considered as one of the geological risk factors and should be quantitatively estimated.

Reservoirs. Here the approach can be similar to source presence risk. Under the volume of the container, we define the volume of void space that can contain hydrocarbons per unit area. This volume depends on porosity, hydrocarbon saturation, and net reservoir thickness. As a risk of the presence of reservoir rocks, one can define the event that net thickness is equal to zero. Using the mixture method, it is possible to obtain the risk-adjusted distribution of container volume per unit area.

Sealing capacity. This parameter determines the hydrocarbon column height that the caprock can contain. The risk of the seal can be related with the caprock leakage (hydrodynamic breakthrough, the presence of conductive faults, etc.). In this case, the height of the deposit can be equal to zero and the probability of such event can be defined as seal risk.

Oil-bearing area. This is the area of the site bounded by water-hydrocarbon contour and depends on sealing capacity. It can be calculated from the column height – area plot.

Trap risk usually is defined as the probability of the absence of a trap closure. This risk depends mainly on reliability of seismic data.

Taking into account all the risk factors, it is possible to estimate the resources, as shown in Figure 3.

Calculations have been conducted by using the Monte-Carlo method on Crystal Ball program.

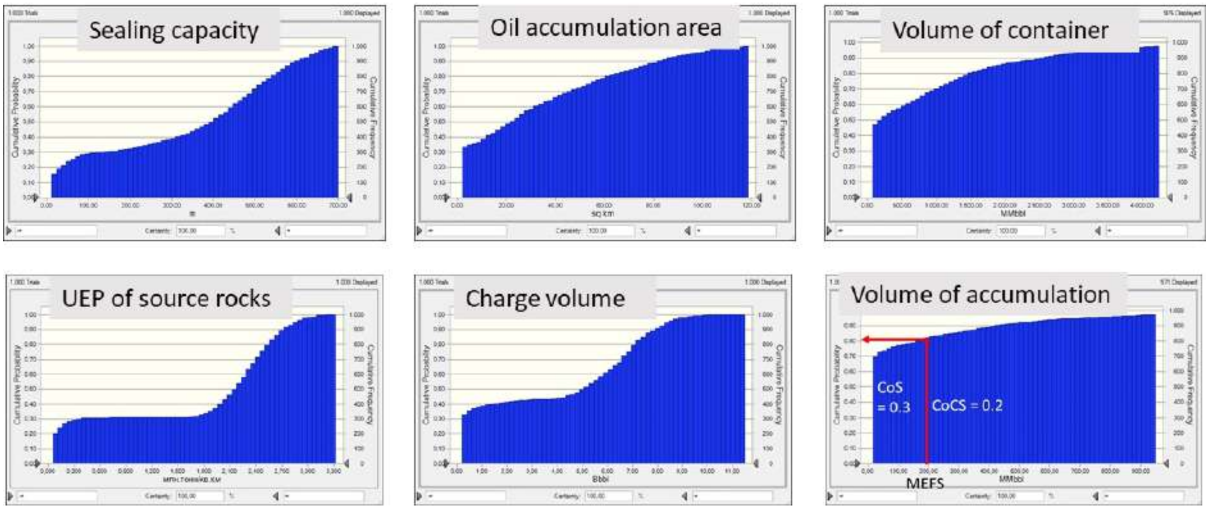

Fig. 3. Calculation of the volume of potential resources taking into account risks on a hypothetical structure

Conclusion

The proposed methodology allows to evaluate geological risk in exploration more objectively. Assessment of risks and volumes of expected reserves are carried out within the framework of a single procedure of probabilistic simulation using the Monte Carlo method. The risks related with different parameters of hydrocarbon systems are tied with geological framework. The problem of dependence of parameters, their number, as well as reassessment of risks is solved. Reserve distribution charts allow not only to estimate the range of expected reserves, but also allow to find the probability of the absence of accumulations (the chance of geological failure), and the probability that the expected reserves will be below some limit value (the chance of commercial failure).

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