OIL AND GAS RESOURCE ASSESSMENT METHODOLOGIES: IMPLEMENTATION IN NATIONAL BALANCE ESTIMATION AND COMPANY'S EXPLORATION POLICY

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ABSTRACT. Resource assessment methodology has been discussed in many papers during the last 10-15 years and has been described as key issues in national balance estimation, as well as in national exploration and production policy making.
Geologic prospect and play assessment procedure involves two basic steps: play existence and delineation, in terms of number and size of prospects included; and second - if the constructed model is riskier than certain level.
The bases of the process lie on the concept of hydrocarbon systems, in conjunction with play concept as developed by number of authors (Dow, Perrodon, Demaison, Magoon). The main instrument to decide this problem is implementing the exploration probability analysis, which requires an evaluation of those geological factors that are critical to the discovery of recoverable quantities of hydrocarbons in traced prospects. Following factors are defined as critical and must be evaluated with respect to the resource assessment

- presence and quality of reservoir rocks;
- presence and quality of mature source rocks, as well as hydrocarbon expulsion, migration and charge processes;
- presence and trap mechanism;
- retention of hydrocarbons after accumulation;

Implementing a widely known probability techniques, many petroleum companies all over the work) registered remarkable growth ю their proved reserves. These results encourage authors to believe that this is the only way to reduce the geologic risk in Bulgarian exploration practice.

МЕТОДИЧЕН ПОДХОД ПРИ ОЦЕНКА НА РЕСУРСИТЕ ОТ НЕФТ И ГАЗ; ПРИЛОЖЕНИЕ ПРИ ИЗГОТВЯНЕ НА НАЦИОНАЛНИЯ БАЛАНС И ПРОУЧВАТЕЛНАТА СТРАТЕГИЯ НА КОМПАНИИТЕ

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РЕЗЮМЕ. Методичният подход при оценка на ресурсите от нефт и газ е обект на обсъждане в множество публикации, в които еднозначно се приема като ключов проблем при изготвяне на националните енергийни баланси, както и при изграждане на стратегия за концесионна политика. Обект е и на обсъждане и от компаниите за търсещи работи за нефт и газ.
В настоящата работа е описана процедура за оценка на ресурсите от нефт и газ на лицензионни блокове, зони и отделни площи, която включва два основни етапа: оценка на вероятността обектът да има характеристиката на нефтогазоносна зона (в смисъла на "petroleum play") и доколно представения модел за пресмятане на ресурсите е близък до реалността, с оглед пресмятане на риска.
Основата за оценката лежи върху принципите на петролно системния подход. Поради обстоятелството, че в аналитичния процес се оперира с показатели, които се съпровождат с неопределеност, тя е извършена в съчетание с вероятностния анализ, на основата на симулации с Монте Карло техники. Обект на конкретна оценка са онези показатели, които имат ключова роля в образуването на нефт и газ и формирането на техните находища:

- оценка за присъствието и ефективността на резервоарни фациеси;
- оценка за присъствието и качеството на генериращи скали, както и протичането на миграционни и акумулационни процеси;
- оценка на условията на капаниране на въглеводородните продукти;
- оценка на условията за тяхното съхраняване.

Описаният методичен подход е приложен върху зоната на развитие на Северобългарското издигане, както и на премера на конкретно находище – Долни луковит. Получените резултати ни дават основание да смятаме, че възможностите на петролно-системния подход предоставят възможност част от неизбежния геоложки риск да бъде редуциран.

Introduction

Hydrocarbon potentials of Bulgarian Phanerozoic section have been periodically assessed on the classical A, B, C, D approach (Georgiev, 1996; Вълчев, 1998; etc.) and the results have been good accepted. Now this approach is often omitted because of its predominantly qualitative outcomes. This paper presents an authors attempt to implement modern analytical techniques for prospect and play resource assessment, using the petroleum system concept. The purpose is not to create a completely new approach but to adapt existing techniques to the Bulgarian exploration practice using all available data.
Resource assessment methodology has been discussed in many papers during the last 10-15 years and has been described as key issues in national resources estimation, as

well as in national exploration and production policy making (White, 1993; Rose, 1987; MacKay, 1996; Meneley et al., 2003; Otis and Schneiderman, 1997 etc.). However, experience has also shown that geologists perform resources assessment in a very subjective manner, which should be avoid as much as possible, giving the priority to procedures, guarantee repeatable and reliable results.

Common Questions of companies and natural policy makers

Following the common petroleum exploration practice, three basic questions are to be answered:

- *What is the probability (chance) of at least one conventional oil and gas field to present within the assessing (licensed) area;*
- *How mach oil and gas present within the play outline, expressed as field-number and field size distribution (probability volumetric curve)?*
- *Haw much oil and gas present in individual prospect (prospect probability volumetric curve).*

There are number of papers discussing approaches (White & Gehman, 1978; Конторович et al., 1981, 1988; Шпильман, 1982 etc.) but currently the answers are being given depending on analyses and evaluation of those geological factors that are critical to oil and gas field formation and the exploration techniques used for discovery of recoverable hydrocarbons in traced prospects. This process is known as geological risk assessment, acting as a base for further engineering planning. The process is based mainly on the concepts of petroleum systems and their plays (Magoon and Dow, 1994). In Bulgarian practice this concept was highlighted by Йорданов (1996), Георгиев и Дабовски (1997), Georgiev (2002).

Petroleum system-play-prospect concept in resource assessment

Definitions

In order to avoid some misunderstanding, following definitions are accepted:

Petroleum system – includes all those geological elements and processes that are essential for an oil and gas deposit to exist in nature (after Magoon, 1988). A petroleum system encompasses a pod of active source rock and all genetically related oil and gas accumulations.

Play and prospect

A **play** is a group of prospects (potential field sites and any known related fields having common oil and gas sources, migration relationships, reservoir formation, seals and trap types (White, 1993 etc.).

A **prospect** is a potential trap that must be evaluated by drilling to determine whether it contains commercial quantities of petroleum. Once drilling is complete, the term "prospect" is dropped; the site becomes either a dry hole or a producing field. In Bulgarian, as well as in Russian papers “play” is close (but not completely equal) to “oil and gas zone” (нефтогазоносна зона) and prospect is almost equal to “structure” (перспективна структура, капан, ловушка).

Risk and uncertainty in exploration

In recent years National Geological Institutions have encouraged implementation of a petroleum system-play concept approach for resources assessment, involving the process of hydrocarbon origination and distribution. As we mentioned above, a play includes number of prospects of postulated distributions of hydrocarbon volumes. Their number and size distribution are important not only to predict the recoverable quantities but also for prospect economics.

As is well known, in exploration for oil and gas we are dealing with a great scale of uncertainty and risk that appears as inherent factors and requires a probabilistic treatment. Uncertainty is common used to characterize the fact that any outcome of a decision (process) is not precisely known, with the degree, described by probability that it will occur. Consequently, assessed probability refers to the adequacy of the geological model that will give the existence of at least one field, larger than a practical minimum size. This value ranges from 0 to 1.0 and define the success “chance” of discovery. As a rule this value is less than 1 and the rest part of probability value determines the geologic risk, i.e. “chance” of failure or not having a field, respectively discovery larger than a specified practical minimum size:

1 – Probability = Risk

Therefore uncertainty and risk assessment concept permit application of the traditional mathematical analyses, leading to more objective estimation of the petroleum resources, as well as more objective comparison between deferent plays and prospects, occurring in deferent areas. Below will be described approaches to resource assessment for prospect and plays separately, implementing the mentioned above probabilistic concept.

Prospect resource assessment procedure

The full process of prospect evaluation, based on petroleum system-play concept, incorporates number of investigation, focused on assessment of geological risk, estimation of hydrocarbon volumes, engineering, economics and postdrill review. In this work we discus only the part of it, encompasses the hydrocarbons-in-place estimation. Common approach to answer this topic requires the expectation curve to be obtained, using the probability distributions of the responsible factors, as well as geological risk assessment (Fig.1,2). Combining volumetric calculations with chance of success (“risk factor”) there could be construct the final probabilities curve (risked), giving the opportunity to extract the traditional probabilistic values (Pr.-90%; Pr.-50%, Pr.-10 % or others (Capen, 1996) for further prospect appraisal.

Volumetric estimation

The calculation of hydrocarbons-in-place can be applied to undrilled prospects implementing the classical volumetric equation, multiplying: (i) net pay volume; (ii) average porosity; (iii) average oil saturation; (iv) trap fill; (v) 1/formation volume factor; (vi) conversion factor (Fig.2).

Procedure for gas-in-place is similar.

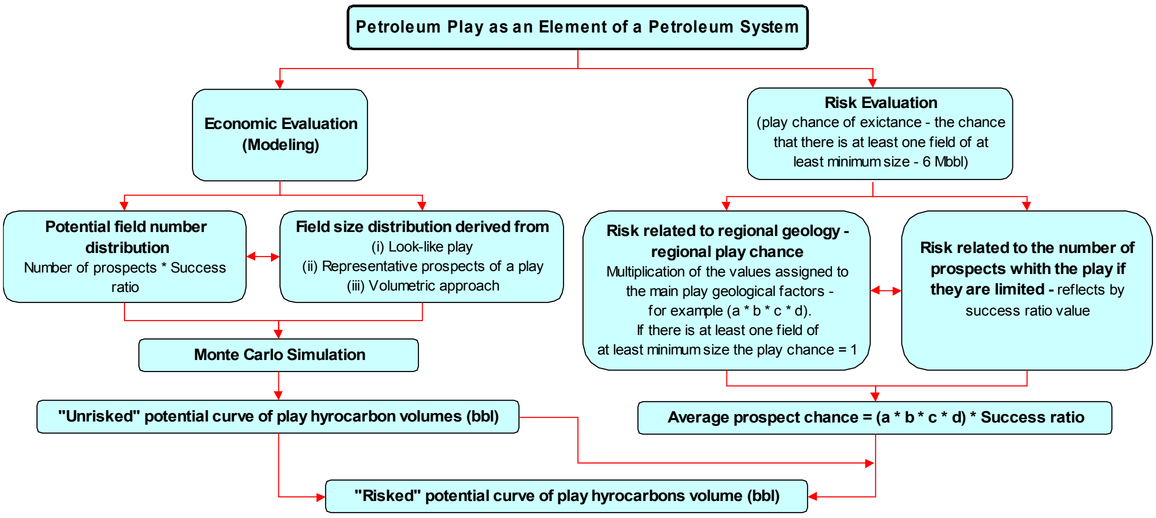

Fig. 1. Play resources assessment procedure

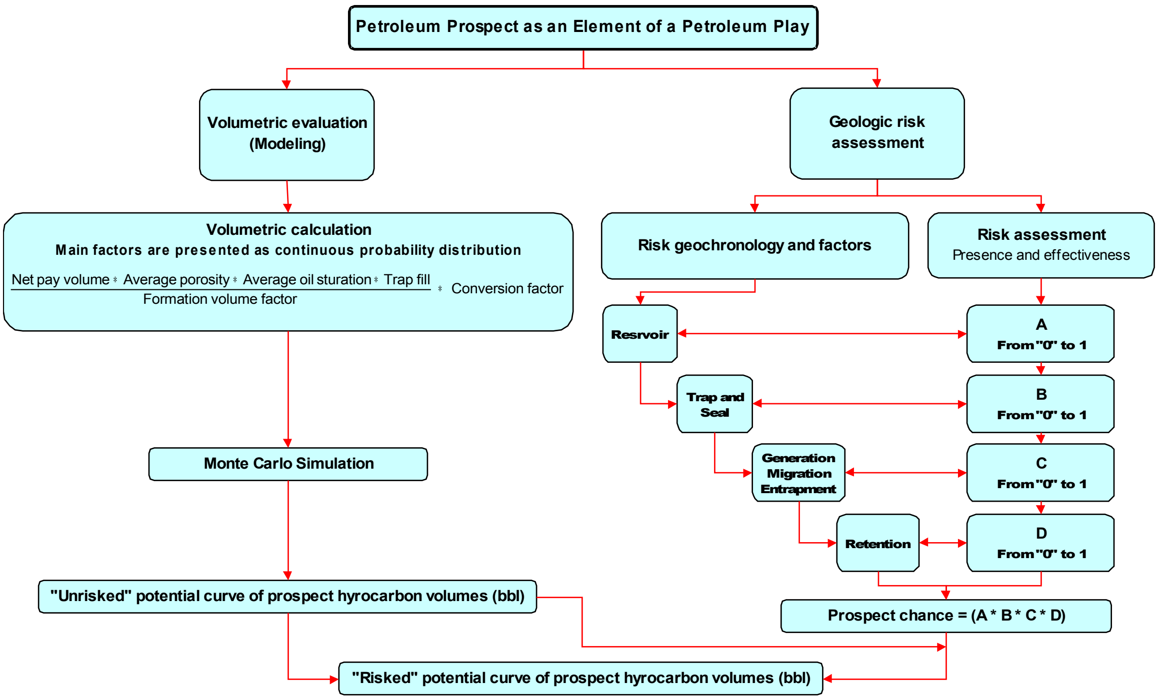

Fig. 2. Prospect resources assessment procedure

In practice, the potential volume distribution of hydrocarbons is made by multiplying the above parameters in a Monte Carlo simulation, running many trials (see appendix at the end). Each volume factor is entered into the simulation as a range of values, reflecting its uncertainties. As a final result assessor obtains the *unrisked* potential curve of hydrocarbon–in-place distribution.

Risk assessment

Risk factors definition

There are two approaches to determine the main risk factors, controlling the hydrocarbon occurrences: theoretical and practical. The first approach evolves from petroleum system-play concept, where four processes (generation, migration, entrapment and preservation or retention) are assumed to have taken basically position. These processes depend on group of main factors, which should be characterized by number of individual, independent parameters for personal judgment (assigned a value) of:

- ✓ Presence and quality of reservoirs (Probability of reservoir – **Pr**);
- ✓ Presence and quality of source rocks (Probability of source rock – **Psr**);
- ✓ Traps, seals and timing (sequence of time between generation, migration and trap formation (Probability of trap and seal – **Pt&s**);
- ✓ Preservation (Probability of preservation – **Ppr)**.

The second approach arises from company's exploration practice. Following the worldwide geologic experience as a systematic basis for prospect appraisal and negative results Rose (1987) and others have tried to answer the question: Which geological factors are responsible for most dry holes? Rose (1987) processing the data available, has concluded;

- ✓ The main cause is incorrect structural interpretations – 43% of dry holes;
- ✓ Incorrect reservoir prediction– 40% of dry holes;
- ✓ Incorrect prediction of trapping conditions – 13%;
- ✓ Wrong prediction of hydrocarbon charge – only 3%.

Discussion over these results leads to the following outcome: if the source rock exists, the chief cause for dry holes is incorrect structure interpretations and reservoir prediction – 83%. The same is in power for Bulgarian exploration practice. Considering geological risk factors, derived from the worldwide experience, one could determine the same group of factors which are responsible for negative results as listed above: structural interpretation, i.e. trap existence; reservoir prediction – presence of reservoir rocks; existence and quality of trapping and source rock characteristics. In this paper we are using the described above four main factors determining the geological risk of hydrocarbon discovery.

Risking prospect procedure

The probability of discovery is a value that is calculated on objective judgment of listed above group of main factor with respect to the presence and effectiveness, depending on case geological features. For examples the reservoir factors is assigned the value for existence of proper facies and value for effectiveness of porosity, permeability etc. It is clear that absent of one or more of these factors will result in a “dry hole”. In practice multiplying the group of main factors assessor obtains the value of adequacy – assessed risk. Hence, combined (weighted) probability (**Ps**) of occurrence (discovery, or commercial accumulation) is equal to:

Ps = Pr * Psr * Pt&s * Ppr

It is absolutely necessary these factors to be independent (correlation = zero). Otherwise another procedure should be implemented for probability calculation, described in many mathematical handbooks.

Risked expectation (potential) curve construction

The next step is risked potential curve construction, employing the calculated risk (chance of prospect to exist). In practice the unrisked curve should be discounted in order to reduce each potential by combined risk value. In our example each potential is reduced to 0.04.

Play resource assessment procedure

Given a licensed area that includes one or several postulated (conceptual) or frontier plays. Then the question how much hydrocarbons exist in-place in any conventional oil or gas field is answered implementing number of estimating techniques. These techniques depend on geological knowledge level and are described in many works (White and Gehnman, 1978; Baker et al., 1984, White, 1993; USGS, 2000; Meneley et al., 2003; Rostirolla et al., 2003; Shanley et al., 2004; Fugelli and Olsen, 2005 etc.). Russian papers are also published (Трофимук, 1989 and others). The ideal procedure is to aggregate all the individual prospect assessments. But very often the lack of data dictates another type of performance. Often the method of geochemical material balance is implemented covering all the key genetic factors. Because of difficulties to reconstruct all the elements of a system, it can not replace the more empirical approaches to assessment. Recently a straightforward way to assess undiscovered oil and gas resources is based on the estimation of the number and size distributions of potential fields in a play, using the modern Monte Carlo simulation. The procedure in its simplest form states that:

Play Hydrocarbon volume (in bbl) =
Numbers of prospects * Success ratios (potential fields from all the prospects) * Potential field size (in bbl)

The advantages of this approach are that it deals with prospect-play relation, as elements of a petroleum system (Fig.1). Additional requirement for accepted method, besides field number and size distribution is the estimate of chance that a play really exists (i.e. the chance of existence of at least one field of minimum size within the play outline). The steps and elements of the implemented procedure are shown in Fig.1, 2. They include two branches: volumetric part and risking evaluation. Implementing Monte Carlo simulation techniques, a “risked” potential curve of a play hydrocarbon volume is built.

Play fields-size and field- number distribution

Fields-size distribution

In practice there are three ways for building the field-size distribution:

- Using the geological analogy (look-alike approach) going from known to new area;
- The play already exist and plotting its representative prospects one can assessed the expected volumetric distribution;
- Monte Carlo simulation of the prospects volumetric factors to produce a distribution of possible field sizes.

In play assessment example we used data from Bulgarian exploration practice (historical reports) and Rumanian ones (Popesku, 1995) a proper distribution is built.

The assessor should take into account that hydrocarbon (HC) volume distribution curve must be constructed over principals of economically minimum size. HC economic volume is critical and determines the geological success (positive outcome or discovery). There are different approaches to determine the minimum prospect size. Otis and Scneidermann (1997) propose to be one capable of testing a stabilized flow; White (1993) - 50K to 50M bbl. In our consideration we choose 6M bbl, which is equal approximately to 0.9 million tone of oil, keeping in mind increasing prices of crude oil currently. It means that assigned values to the main parameters in whole assessment procedure, one should dealing with degree of adequacy according to the accepted minimum size – i.e. how close is the porosity for example to those values that are needed prospect to include at least 6M bbl.

Field-number distribution

The approach is similar to those techniques, described as apt to field-size. In completely postulated plays (virgin frontiers) it would be helpful to implement look-alike field density – for example number of field per unit area and others. In our case example we employ the distribution of the prospects in a play, times the future success ratio.

Success ratios definition

Special attention should be addressed to success ratio definition. It reflects an independent geologic risk among prospects and should be assess separately from the play chance attributes. It simply presents the number of prospects in a play which is expected to become fields. Generally it ranges from 0.3 to 0.9. Typically for a new play which is presented by positive marginal factors the success ratio equals 0.25-0.3. It means that if we have 4 prospects - one of them is expected to register discovery (be larger than the accepted minimum size of 6M bbl).

Play chance assessment procedure

The play chance means – the chance of occurrence of at least one field of minimum size. After Baker et al. (1984), White (1993) and others it must be calculated incorporating risks arising factors from regional geologic settings (regional play chance or marginal probability - **RPC**), as well as those related to the prospects if they are limited. These factors are independent and refer to the conditional probability. Inherent for a play factors are: reservoir facies, source rock, retention; inherent for each prospect – porosity, trap, seal, migration. Multiplying regional play chance (**RPC**) to play success ratio (**PSR**) equals the value of *average prospect chance* (**APC),** i.e. the chance of occurrence of at least one field of at least minimum size (potential volume of 6M bbl) within the play outline:

APC = RPC * PSR

Analyzing more then 80 basins White (1993) summarized that operating with the *average prospect chance* one could estimate the play resources, compatible with those, obtained by summing individual prospect assessment.

As the success outcome within a play requires all the regional factors to be adequate, *play chance* may easy to be understood asking: What is the chance that reservoir rock porosity is adequate to provide hydrocarbon saturation for of at least one field of at least minimum size. Proceeding in proper way with other common factors one could estimate the group chance of adequacy (see appendix at the end). In general sense, if the play chance is not zero and given unlimited number of prospects, then at least one of them is expected to cover requirements for success (discovery). Following White (1993) in productive plays “play chance” is equal to 1.00. For new areas it ranges from 0.3 -0.9, which means that lower cutoff hesitate near 0.3.

In practice the average prospect chance value reflects play risk estimate. For example if the unrisked mean of potential volume is 500M bbl, and *average prospect chance* is 0.5, then “risked mean” equals 250M bbl.

Conclusions

There is no methodology for resource assessment covering only advantages. The described above technique based on petroleum system-play concept is an attempt to reduce the risk of failure exploring a new area operating with probabilistic theory. Encouraged by the main petroleum companies as well as by governments implementing this approach the authors would like to be useful to those who are going to assess prospects and plays.

In order to improve the reliability of the mentioned method, efforts should be concentrated on key issues, and first of all on the personal judgment of the inherent uncertainties, concerning value assignment of those basic geologic factors, controlling generation, migration, trapping and retention of the petroleum, as well as the correct delineation of a play outline.

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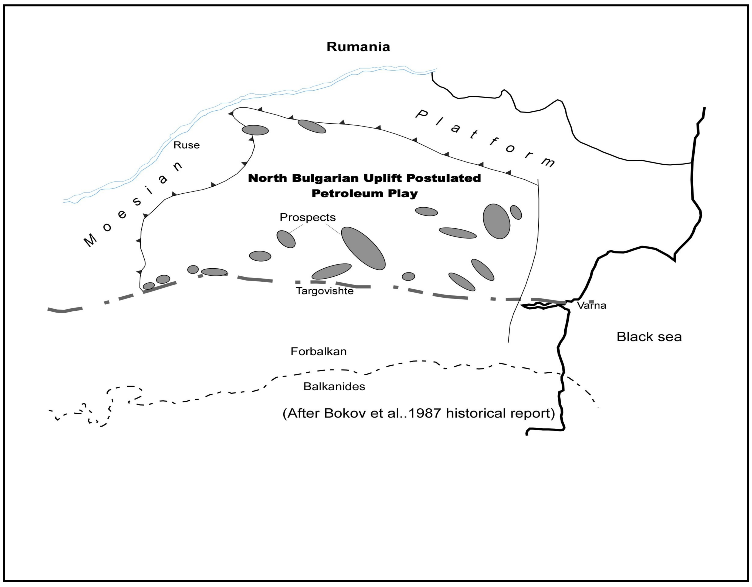
Appendix

Example of prospect and play resource assessment

Summary Sheet: NORTH BULGARIAN UPLIFT POSRULATED PETRLEUM PLAY AS A PART OF PALEOZOIC-CRATECEOUS PETROLEUM SYSTEM (After Popesku, 1995)

Total surface	7600 km^2
Prospect numbers: - structural type - stratigraphy type	 17 >10 (hypothetical) **Total - 27**
Possible source rock	Silurian black shale
Possible reservoir rock	Devonian carbonates Carboniferous clastic
Possible seals	Lower Paleozoic muds
Possible traps	Structural Stratigraphic, related to the major unconformities: C/P; P/T; T/J
Success ratio accepted	0.25

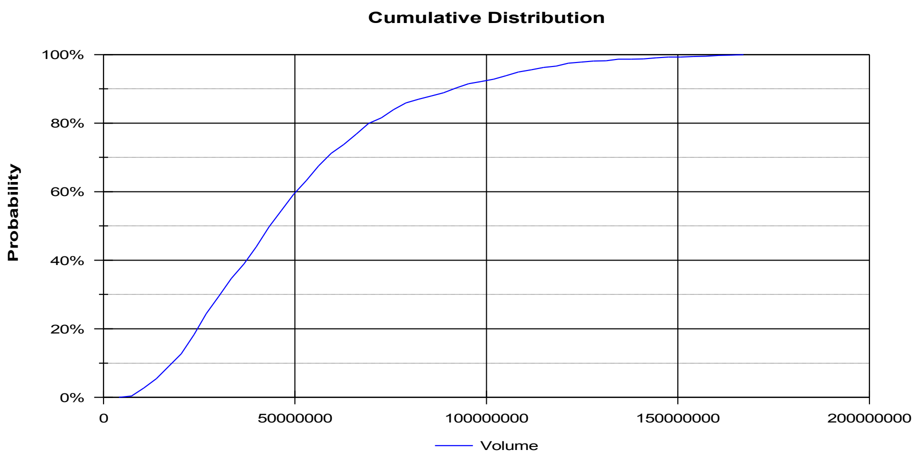


Volumetric evaluation

Number of prospects*success ratio*field size distribution, derived from Bulgarian exploration practice, multiplied in a Monte Carlo simulation (1000 trials, triangular distribution) equals the **“Unrisked” potential curve of a play hydrocarbon volume (in barrels o.e.) (see below graph of probability vs. volume)**	
Observations	1000
“Unrisked” Mean **“Risked” Mean**	**49.4M bbl o.e.** **49.4*.04= 1.976M bbl o.e.**
Minimum 5% 95%	4.04M bbl o.e. 13M bbl o.e. 108.5M o.e.

Risking evaluation

<u>A. Reservoir</u> *A.1 Existence of reservoir facies* *A.2 Effectiveness* *A.3 Thickness*	 0.8 0.7 1.0	0.56
<u>B. Trap and Seal</u> *B.1 Clouse reliability* *B.2 Effectiveness*	 0.7 0.9	0.63
<u>C. Source rock</u> *C.1 Existence* *C.2 Maturity* *C.3 Migration* *C.4 Time sequence*	 1.0 1.0 0.8 0.85	0.68
<u>D. Retention</u>	0.65	0.65
<u>Marginal probability</u> 0.56*0.63*0.68*0.65=0.16 <u>Success ratio – 0.25</u>		**0.16**
Average prospect chance - 0.25*.016 = 0.04 or 1: 25		**0.04**



Summary Sheet: NORTH BULGARIAN OIL FIELD IN THE CENTRAL PART OF THE MOESIN PLATFORM

EXPECTATION CALCULATIONS FOR HYDROCARBON IN-PLACE

Prospect Name - Alfa

Prospect area, m^2	**Mean**	**4350779**
	Minimum	3922658
	5 %	4060731
	95 %	4632378
	Maximum	4773417
Net Pay, m	**Mean**	**5.96**
	Minimum	2.85
	5 %	3.87
	95 %	7.83
	Maximum	8.73
Average Porosity	**Mean**	**0.12**
	Minimum	0.01
	5 %	0.05
	95 %	0.19
	Maximum	0.23
Average saturation	**Mean**	**0.58**
	Minimum	0.15
	5 %	0.29
	95 %	0.85
	Maximum	0.99
Trap Fill	**Mean**	**0.73**
	Minimum	0.50
	5 %	0.29
	95 %	0.85
	Maximum	0.89
Surface Hydrocarbon Volume Factor	**Mean**	**0.614**
	Minimum	0.606
	5 %	0.608
	95 %	0.621
	Maximum	0.625
Expected Hydrocarbon Volume in-place, m^3	**Mean**	**837971**
	Minimum	77803
	5 %	251061
	95 %	1747838
	Maximum	3379433

Postdrill Mean – ranges in 25 % according to predrill mean

Risk calculation of the Prospect Chance	Probability of Reservoir capable of producing hydrocarbon in the minimum trapping geometry	A	0.75
	Probability of adequacy of the data set (seismic, well and other source) outlining the trap	B	0.80
	Probability of significant mature source rock, as well as favorable pathway for migration and accumulation	C	0.85
	Probability of conservation (retention)	D	0.90
	PROSPECT CHANCE = A*B*C*D = 0.46 OR 1:2.17 (GOOD CHANCE)		0.46
	“Risked” mean = expected mean* prospect chance = 837971*0.46 = 385467		

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