

MONTE CARLO SIMULATION FOR ESTIMATING GEOLOGIC OIL RESERVES. A CASE STUDY FROM KUÇOVA OILFIELD IN ALBANIA

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Abstract. Reserve Estimates of oil and gas is one of the most important and difficult tasks to accomplish in oil industry because of uncertainties and errors during all the process of Estimating Reserves. During all the processes, there will be errors and uncertainties that will impact in the result of reserves estimation. We may say that the Reserves Estimation is a function of time and data, which, at the end of the production, will be properly and finally defined. Reserves Estimation methods are classified as analogy, volumetric and of performance types. Volumetric and performance methods are the most used techniques; they differ from each other due to the type of used data. The choice of method depends on the phase of oilfield development and production maturity, degree of reservoir heterogeneity, quality and amount of data. The two established volumetric methods for Oil Reserves are deterministic and stochastic ones (DERMINEM, 2005). In case of deterministic method, mathematical formulas are used to estimate oil volumes in a reservoir. The stochastic method considers the fact that each parameter is not presented with a single value, but it is included in an interval of values and fits a probability distribution. The results from stochastic calculations are summarized generally by a descending (reverse) cumulative probability function commonly known as expectation curve (WADSLEY, 2011). We will use both methods in estimating reserves in case of Kuçova (KA-1 sector) Oilfield.

Keywords: Reserve, probability, oilfield, estimation, Monte Carlo.

Rezumat. Simularea Monte Carlo pentru estimarea rezervelor geologice de petrol. Studiu de caz câmpul petrolifer Kuçova din Albania. Estimarea rezervelor de petrol și gaz reprezintă unul dintre cele mai importante obiective pe care industria petrolieră trebuie să le îndeplinească datorită incertitudinilor și erorilor care se produc pe parcursul procesului de estimare a rezervelor. Pe parcursul tuturor proceselor se vor înregistra erori și incertitudini care vor avea impact asupra rezultatului estimărilor rezervelor. Putem spune că estimarea rezervelor este o funcție a timpului și datelor, care, la finalul producției, va fi probabil definită. Metodele de estimare a rezervelor sunt de mai multe tipuri: analogice, volumetrice și de randament. Metodele volumetrice și de randament sunt cele mai utilizate; acestea sunt diferite una de cealaltă prin datele utilizate. Alegerea metodei depinde de faza de dezvoltare a câmpului petrolifer și de maturitatea producției, gradul de heterogenitate a bazinului, calitatea și cantitatea datelor. Cele două metode volumetrice stabilite pentru estimarea rezervelor de petrol sunt deterministice și stocastice (DERMINEM, 2005). În cazul metodei deterministe, sunt utilizate formule matematice pentru estimarea volumului rezervelor de petrol. Metoda stocastică pleacă de la premiza că fiecare parametru are mai multe valori și, astfel, este inclus într-un interval de valori și prezintă o probabilitate de distribuție. Rezultatele calculelor stocastice sunt în general rezumate de o funcție de probabilitate cumulativă descendentă (inversă) cunoscută drept curbă de așteptare (WADSLEY, 2011). Vom utiliza metoda stocastică pentru estimarea rezervelor în cazul câmpului petrolifer Kuçova (sectorul KA-1).

Cuvinte cheie: rezerve, probabilitate, câmp petrolifer, estimare, Monte Carlo.

INTRODUCTION

The oil and gas reserves estimation methods can be grouped into the following categories (www.petrobject.com):

1. Analogy
2. Volumetric
3. Decline analysis
4. Material balance calculations for oil reservoirs
5. Material balance calculations for gas reservoirs
6. Reservoir simulation

The analogy method is applied by comparing factors for the *analogous* and *current* fields or wells. A *close-to-abandonment* analogous field is considered as an approximate to the field we are interested in. During the process, as production and pressure data from the field become more available, decline analysis and material balance calculations become the main methods of estimating reserves.

For the decline analysis, the most common decline curve relationship is the constant percentage decline exponential. With lower productivity of oil wells, some fit decline curve will be hyperbolic and harmonic. Material balance is mostly used for estimating gas reserves. By considering a reservoir as a closed system, the pressure in the reservoir will decline proportionately to the amount of gas produced. In any method of Reserves Estimation, two ways of calculation are used: deterministic or probabilistic. The deterministic procedure uses a single value for each parameter to input into an appropriate formula and, as result it produces a single value for the Reserves. The probabilistic method uses a fit distribution curve for each parameter and, through the use of Monte Carlo Simulation; a distribution curve for the result (Reserves) can be developed. Reserves can be calculated both ways and results are compared. If the two values agree, then we are more confident about the Reserves Estimation. If the two values are away different, we need to rerun the full procedure again (SMITH & BUCKEE, 1985). The magnitude of uncertainty, however, decreases with time (Fig.1).

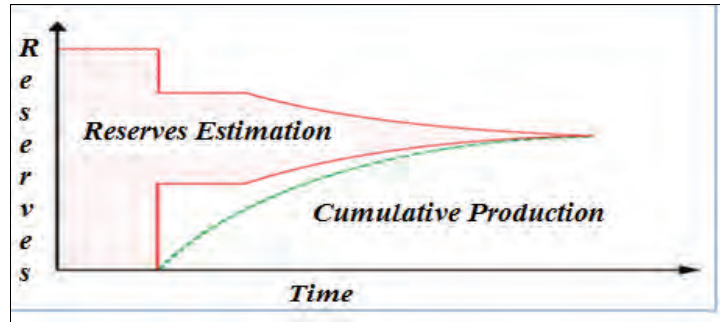


Figure 1. Magnitude of Reserves Estimation over time.

MATERIALS AND METHODS: CLASSIFICATION OF RESERVES: (SPE 2007, www.spe.org)

Resources are the total quantities of oil and gas and other related substances that are estimated, at a particular time, to be contained in, or that have been produced from known accumulations, plus those estimated quantities in accumulations are yet to be discovered.

Contingent Resources are those quantities of petroleum which are estimated, on a given date, to be potentially recoverable from known accumulations, but which are not currently considered to be commercially recoverable.

Prospective Resources are those quantities of petroleum which are estimated, on a given date, to be potentially recoverable from undiscovered accumulations.

Proven Reserves are those reserves claimed to have a reasonable certainty (at least 90% confidence) of being recoverable under existing economic and political conditions, with the present existing technology and state regulations. Oil industry specialists refer to this as P90 or 1P.

Proved plus Probable Reserves are those reserves claimed to have a reasonable certainty (at least 50% confidence) of being recoverable under existing economic and political conditions, with the present existing technology and state regulations. Oil industry specialists refer to this as P50 or 2P.

Proved plus Probable plus Possible Reserves are those reserves claimed to have a reasonable certainty (at least 10% confidence) of being recoverable under existing economic and political conditions, with present existing technology and state regulations. Oil industry specialists refer to this as P10 or 3P (Fig. 2).

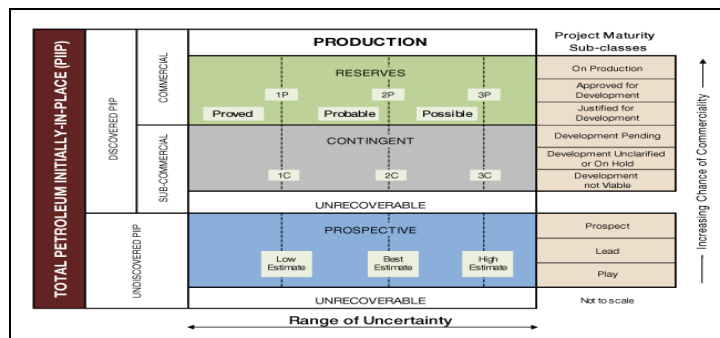


Figure 2. Reserves Classification.

ALBANIDES AND KUÇOVA OILFIELD: GEOLOGICAL SETTINGS

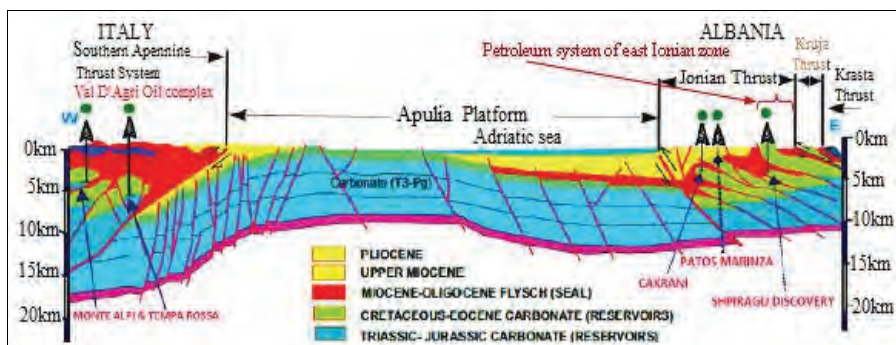


Figure 3. Southern Apennine & Ionian/ Kruja thrust systems (www.petromanias.com, modified by PRIFTI).

The Albanides represents the assemblage of the geological structures in the territory of Albania. Oil and gas fields are located in the area of the Ionian zone and Adriatic depression (Fig. 3). Oilfields are discovered in Kurveleshi belt, Berati belt and molasses section of Miocene extending over the eroded limestone (PRIFTI et al., 2014).

The north part of Berati anticline belt is constructed by three units: diapir of Dumre, the Tectonic blocks of Anticline belt of Berat and the Syncline of Ballagati. Berati anticline belt consists of two tectonic blocks called "thrust sheet Berat" and "thrust sheet Sqepuri". In the western and southern periphery of the diapir, there are located Kuçova oilfield and Rase- Pekisht oilfield (Fig. 4).

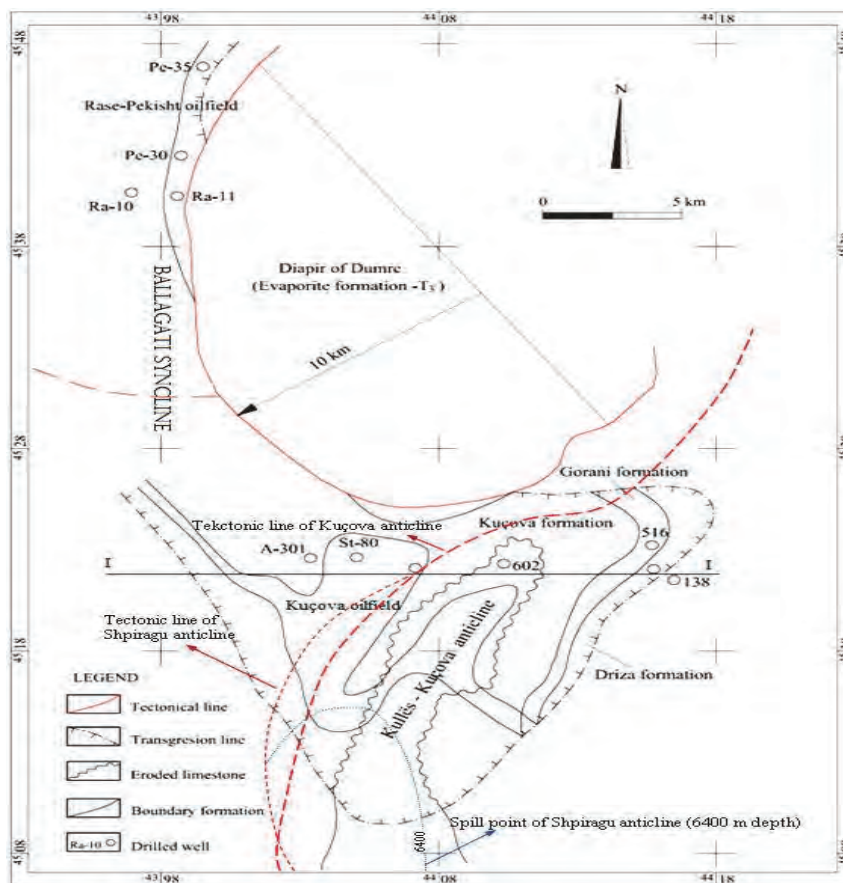


Figure 4. Kuçova, Rase - Pekisht and Dumre diapir (GJOKA et al., 2002, modified by Prifti).

KUÇOVA OILFIELD (KA-1 SECTOR)

Kuçova oilfield is located in the South Central region of Albania, approximately 40 km north east of Patos- Marinza oilfield. Kuçova oilfield was discovered in 1928 and was developed with the drilling of 1,722 wells in 5 major pools (Kozare, Gege, Ferme, Arreza and Kuçova- Sector 1), (www.bankers.com). Engineering evaluation of the oilfield indicates it is severely pressure depleted with an estimated recovery factor of 8.1% to date and an ultimate recovery forecast of 9.1% on primary recovery. Crude oil of Kuçova oilfield are aromatic- asphalt type (GJOKA et al., 2002), with 14 to 22 API range.

VOLUMETRIC METHOD: INPUT PARAMETERS

The volumetric method uses rock parameters values, the physical size of the reservoir, the pore volume within the rock matrix, the fluid content within the void space, the average depth of reservoir, etc. This provides an estimate of the hydrocarbons-in-place, from which ultimate recovery can be estimated by using an appropriate recovery factor (RF). For Oil Reserves, we have this formula:

$$OOIP = Q_{prov} = S * h * m * \mu * S_n * Y_n * 1 / b_n \tag{1}$$

$$UR = OOIP * RF \tag{2}$$

OOIP = Oil Originated in Place (Geological Reserves)

UR = Ultimate Recovery (Primary Recoverable Reserves)

Q = Oil Reserves (tons)

S = Oilfield area (m^2),

h_m = Average depth of reservoir (m)

m = Porosity ratio (%); it is the ratio of the volume of space to the total volume of a rock

S_m = Oil saturation (%); the relative amount of oil and gas in the pores of a rock, usually as a percentage of volume

γ_o = Density of oil ($\frac{kg}{m^3}$); mass per unit of oil volume

b_n = Formation Volume Factor; oil and dissolved gas volume at reservoir conditions divided by oil volume at standard conditions. Oil formation volume factor is almost always greater than 1

RF = Recovery Factor. For primary recovery (i.e., natural depletion of reservoir pressure), the RF does not exceed 20% in most cases. For secondary recovery, the incremental RF ranges from 15 to 25%.

THE DATA (RESERVOIR PARAMETERS): DETERMINISTIC METHOD

The simplest way to produce a number for Reserves is to use the average or mode of each reservoir parameter (Table 1). The number, produced by formula, is an approximate value of Reserves that may correspond to the average Reserves or P50. Besides the average value of Reserves, we may calculate the minimum and maximum values of Reserves or worst estimate and high estimate values. The values, giving some “probabilistic form” in our case, are: $Q_{min} = Q_w = 1.3M$ tons, $Q_{av} = Q_{best} = 4.4 M$ tons and $Q_{max} = Q_{high} = 17 M$ tons.

PROBABILISTIC METHOD AND MONTE CARLO SIMULATION

Monte Carlo technique consists in building a continuous probability density function (PDF) for each parameter and, after the formula, to generate a PDF for Reserves. The input PDFs (triangular, normal etc.) are combined either analytically (CAPEN, 1992) or by random sampling (Monte Carlo simulation).

By central-limit theorem, the resultant (Reserves) distribution approaches lognormal, regardless of the type of input variables. The area and the thickness of the reservoir are usually assigned the triangular distribution, the porosity is usually assigned a log normal distribution (CRONQUIST, 2001) following (ARPS & ROBERTS, 1958) and (KAUFMAN, 1963); in a given geologic setting, a log normal distribution is a reasonable fit to the frequency distribution of field size and other parameters like porosity, water saturation and net pay thickness.

In our case, following other similar cases and the distributions of data, it is used the triangular distribution (Table 1).

Table1. Partial Data of KA- 1 Sector, Kuçova Oilfield, parameters and their distributions.

Kuçova Oilfield Ka-1 sector data	Reservoir area m^2	Thickness M	Porosity %	Oil % saturation	Oil density	b_n
Average	2,500,000	15	22	75	0.85	
Intervals	1,5- 3,5 mil	8- 30	5-35	50-88	0.5-0.95	1.18- 1.22
Distributions	triangular	triangular	triangular	triangular	triangular	Uniform
Low	1,500,000	8	5	50	.5	1.18
Best	2,500,000	15	22	75	.85	1.2
High	3,500,000	30	35	88	.95	1.22
Distr. Values	(1.5; 2.5; 3.5)	(8; 15;30)	(.05; .22;.35)	(.5; .75;.88)	(.5; .85; .95)	1.188; 1.22

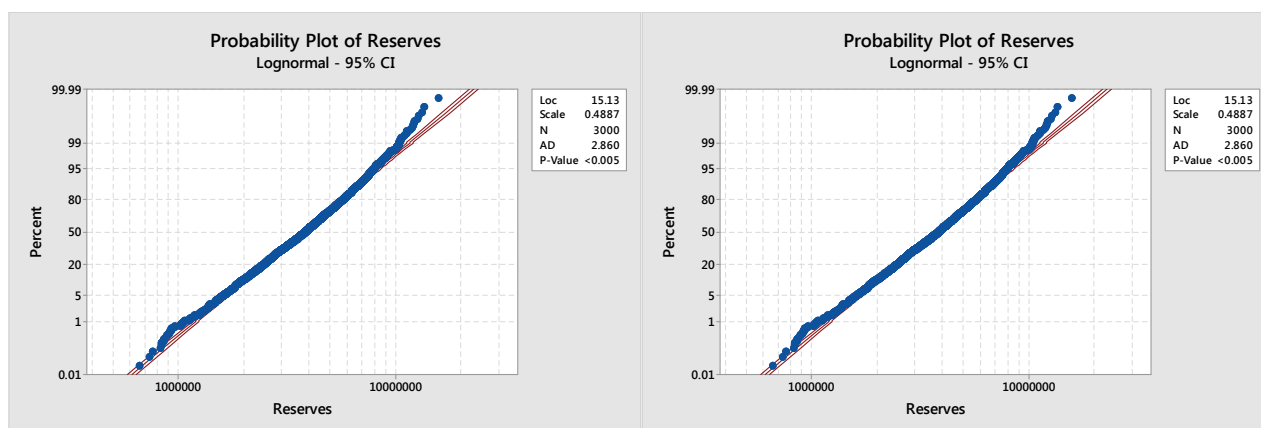


Figure 6. Reserves Lognormal Distribution.

The Monte Carlo simulation was run by using Minitab 17 software. With the reservoir parameters and their distributions, there are generated values for each of them (3,000 iterations) and, as result, the distributions for the Reserves was produced. As it is proved and tested, the Reserves fit the lognormal distribution (Fig. 6).

RESULTS

Cumulative Reserves gives us the Estimation for Proven Reserves (P10), Possible Reserves (P50) and Probable Reserves (P90), (Fig. 7).

Proven Reserve (P90) = 2 M tons. Reserves are equal or more than 2.0 M tons, with confidence 90%.

Proven and Possible Reserves (P50) = 3.7 M tons. Reserves are at least 3.7 M tons, with confidence 50%.

Proven, Possible and Probable Reserves (P10) = 7 M tons. Reserves are at least 7.0 M tons, with confidence 10%.

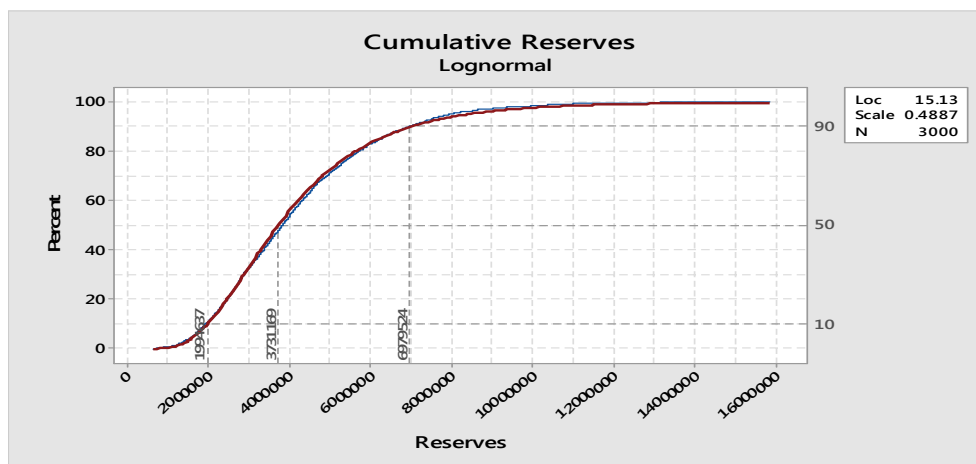


Figure 7. Cumulative Reserves and P10, P50, P90.

CONCLUSIONS

In this study, we re-evaluate oil Reserves of Kuçova oilfield; sector KA-1, by using the probabilistic method of Reserves Estimation.

Monte Carlo Simulation was successfully applied to the real oilfield to build the distribution of basic reservoir characteristics (net thickness of rock, porosity, oil saturation, etc).

For the purpose to have a fit distribution, there are some useful software like Cristal Ball, Cum Freq, Minitab, Stat Assist, Minitab, etc., which can find fit distribution, simulate random numbers, fill the missing data, etc.

When estimating low value or minimum value, it is not wise to produce all the minimum values of parameters, because this is not the case in real values. The minimum value of Reserves is bigger than produced; the maximum value is less than produced.

For a more “conservative” estimation, Reserves Distribution may have to be truncated to 10% or more. This is to avoid outliers that are produced by extreme values of parameters. As a result, we will have a more accurate estimation.

With more data, the accuracy and the fit distribution and, at the end, Reserves Estimation will be more precise, considering the level of confidence.

It is up to the company, after all the estimation process is done, to make the decision about projects, considering them and continuing or asking for other result from other methods.

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Received: March 23, 2015
Accepted: August 29, 2015