Rerum Naturalium Fragmenta

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User's Guide

by

T. Jasko

Chapter 4.
MONTE-CARLO CALCULATIONS

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Rerum Naturalium Fragmenta
Tamas Jasko editor
16 Melrose Place, Watford WD1 3LN, England

4. MONTE-CARLO CALCULATIONS

To see details of the computations select the Monte-Carlo option by pressing M in the Model menu. You can list the input data and the computed results by using the Display and Print options. The expectation curves can be displayed in graphic form by the STOIIP and Reserves options.

Model principles

The aim of the simulation model is to find the amount of hydrocarbons in place. This is calculated as the product of geological parameters. For oil prospects the factors multiplied together are usually gross rock volume, net/gross ratio, porosity, oil saturation and the reciprocal of formation volume factor.

For gas prospects the usual set of factors consists of gross rock volume, net/gross ratio, porosity, gas saturation and gas expansion.

If needed, other factors can be added to this list e.g. degree of trap fill. Together with the chance factor, the probability of finding at least some movable hydrocarbons, the factors determine the likely volume of hydrocarbons in place in the prospect.

Another variation expresses the gross rock volume as the product of two factors: area and formation thickness.

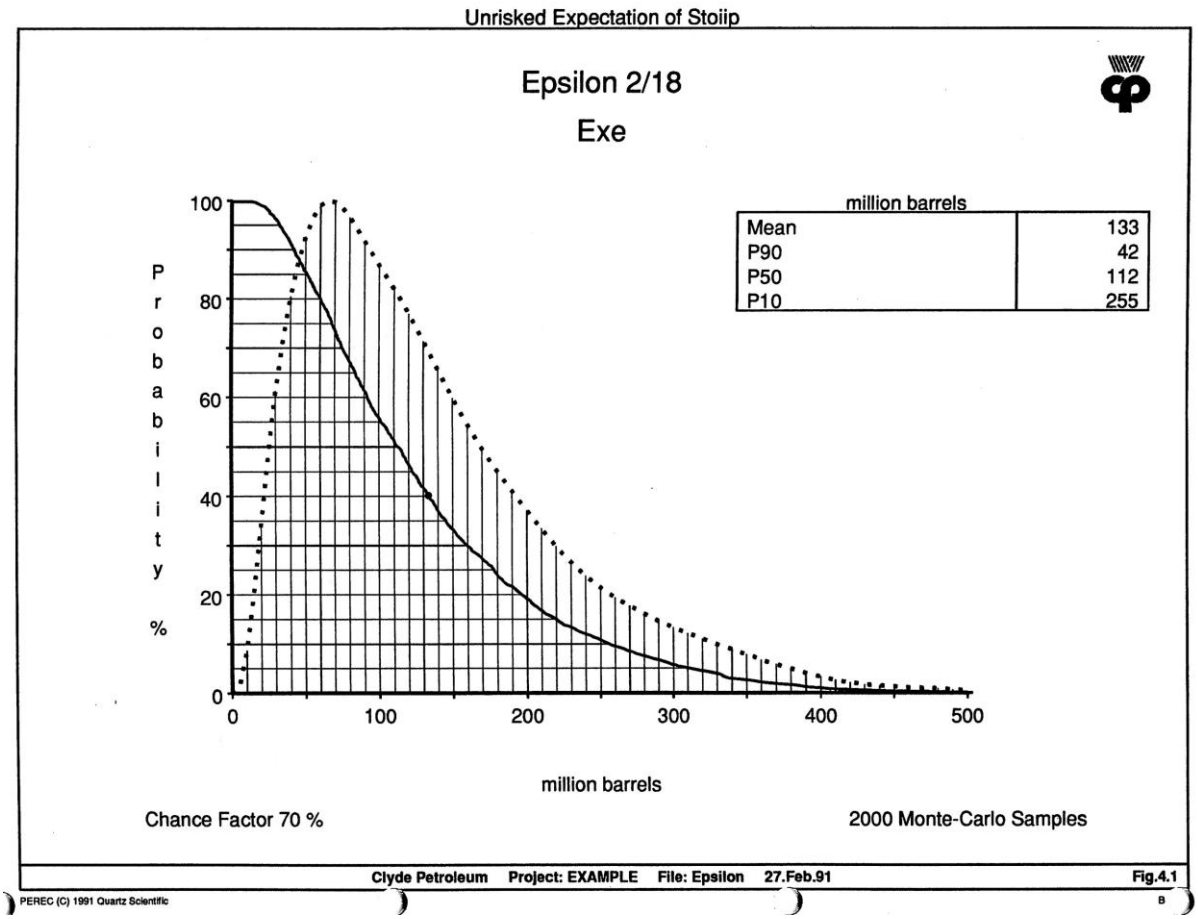
If all the factors are known exactly then the value of their product is easily obtained by a simple multiplication. As discussed in the chapter on factor distributions, the value of a factor is generally subject to uncertainty and the factor is thus defined as a random variable.

In this case the product can not be directly computed as a single figure. Rather, it will be another random variable, the distribution of which is obtained by the multiple integral of the product of the factors over the range of their distribution.

In certain cases the factor distributions may be given by analytical formulae and the solution of the integral may be attempted analytically. Such is the case if all the random variables are distributed according to the two-parameter log-normal law. In general, however, a stochastic approach is necessary, requiring extensive computations.

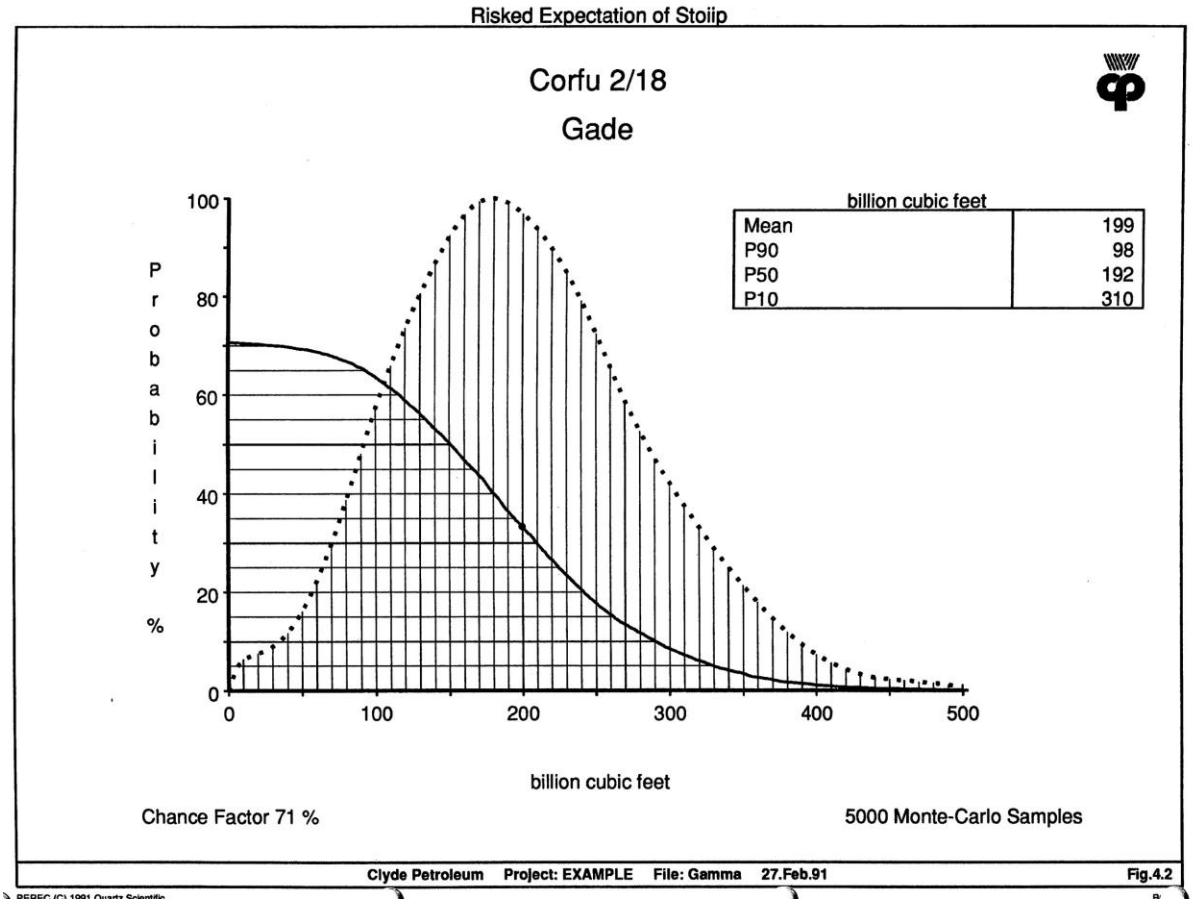
Monte-Carlo methods

The Monte-Carlo method takes a value at random from each of the distributions defined for the prospect parameters, multiplies these to give a single value of STOIIP (or reserves) and repeats the random selection until a large number of calculations are made. The distribution of the calculated values provides the distribution of hydrocarbons in place (or reserves).



The distribution of a geological parameter does not have to be known as a simple formula, it can be given as a curve or by other suitable definition. Random samples being obtained for each of the variables, these values are multiplied together and the product is kept as the first product sample.

This sequence of getting random values and storing their product is then repeated until the specified number of samples has been reached. The distribution of the target variable (oil or gas in place) is produced from these samples by sorting them in increasing order.

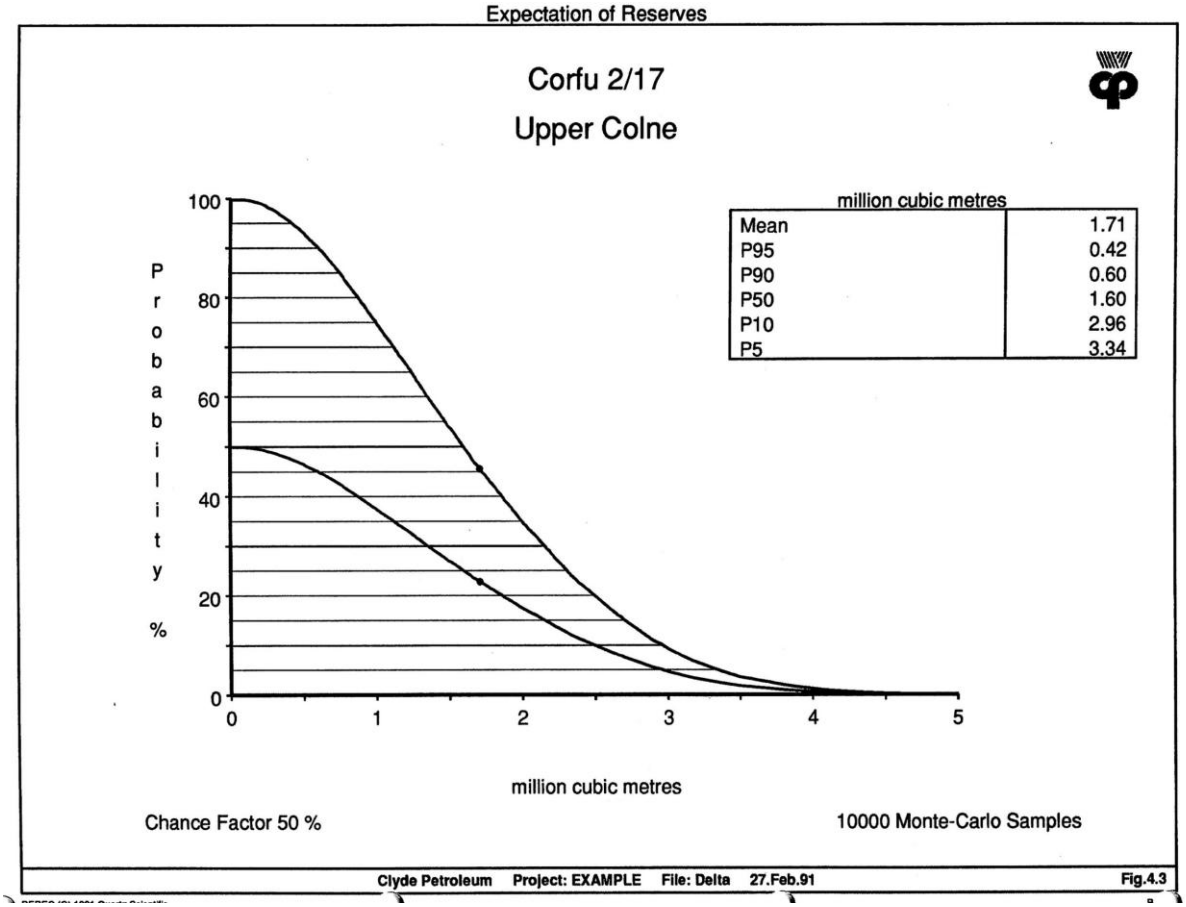


Calculation of results

After the necessary unit conversion, 500 values are selected in equal increments of probability i.e. 0.2 %. The usual number of Monte-Carlo samples is 2000, unless the user specifies a different number; but 500 values are adequate for displaying the distribution curve.

The results are usually expressed in cumulative percentages as P90, P50, P10. The expectation curves are plotted as curves of diminishing probability corresponding to the usual geological interpretation. In this sense P90 is the value expected to be found or exceeded with at least 90 % probability.

These figures are calculated by interpolating the ordered set of product samples. E.g. for 1000 samples, P10 will lie between the 100th and 101st sample value.



Random numbers and precision

The use of random numbers in Monte-Carlo methods affects the precision of computations. First of all, all the random number generators commonly used by computer programs produce pseudo-random numbers that are not really random.

In a sense, they are random enough – the series of numbers generated will satisfy statistical tests of randomness. But, given the initial seed, the sequence will be predictable. If the program is run again using the same seed, then it will produce exactly

the same numbers. This has the advantage that the results of simulation runs can be reproduced. They will be identical to many digits. This would not be possible if truly random numbers were used.

Of course, it is possible to use different seeds for different runs. The sensitivity of the method to fluctuations of random numbers can be studied by this approach.

Experiments show that in typical prospect calculations the error due to random numbers is about 0.5 % in the value of P50, while P10 and P90 have around 5 % relative error if 2000 samples are used. Using 10 000 samples will halve this error. Results of Monte-Carlo expectation estimates are therefore quoted to two significant digits on data sheets and expectation curves.

Running the simulation

When you select the Monte-Carlo option the program starts by asking for the name of the data file. The number of simulation samples can range from 500 to 10,000 as specified in the input file. The default is 5000 samples. The progress of computing the specified number of samples can be followed on the screen by the symbols displayed. One symbol is shown for every 250 samples.

At the end of the run a summary of results is printed on the screen. These include the average volume and the parameters requested by the user e.g. P50.

The program also shows the scatter of values as averages of 10 short runs and the variance of these numbers as a percentage indicating precision.

The 500 values describing the expectation curve are written to the data file for subsequent display and, possibly, for use by the prospect addition program.

Displaying expectation curves

If required, the computed expectation curve can be displayed on the screen in graphic form. There are two options to do this, one for hydrocarbons in place and the other for reserves. In either option you can choose between risked, or unrisked form of the curve or both.

Each of these options starts by asking for the model name, checks that computed results exist for the model and reads in the curve data.

Horizontal scale

The curve display program prompts for entering the horizontal scale range by displaying the range of computed values. The usual horizontal scale for expectancy curves allows for displaying data in the 0 to 1000 range. This can be changed by specifying the desired upper limit.

Unrisked expectation

unrisked expectation curves show the probability of finding a certain amount of oil or gas in place provided that there are some movable hydrocarbons present.

The expectation distribution is shown in cumulative and frequency curve form. The cumulative curve is shown by green or thin solid line. If you ask for a frequency curve it will be drawn using a red or thicker dotted line.

Because of the limitations of the Monte-Carlo method the cumulative curve usually has some random irregularities. These will be magnified in the 'raw' frequency curve obtained from the differences of the cumulative curve and for clear display the frequency curve has to be smoothed. The curve is smoothed by Bezier interpolation before display.

Risked expectation

Risked expectation curves show the unconditional probability distribution of oil or gas in place. This curve is based on the same data as the unrisked one but the cumulative probability of positive outcomes is scaled down to the level given by the chance factor. The risked curve may be used as input to net present value calculations of prospects.

When the program finished drawing, it pauses. Press a button to return to the menu, where you can use the Hardcopy option to obtain a plot of the curve just displayed.

Pi 2/18 - Humber

PROSPECT AND RESERVES PARAMETERS

PROSPECT PARAMETERS

	Minimum	Most likely	Maximum
Gross Rock Volume	150.0	550.0	1500.0
Net/Gross Ratio	66.0	77.0	88.0
Porosity	5.0	11.0	17.0
Gas Saturation	80.0	85.0	90.0
.s Expansion		280.0	
Recovery	20.0	26.0	30.0

	P90	Mean	P10
STOIIP Reserves (billion cu. ft)	235.0	512.9	843.1
Recoverable Reserves (billion cu. ft)	58.7	129.8	213.3

Clyde Petroleum Project: EXAMPLE Pi.Exp 27.Feb.91

Fig. 4.4

Summary of model results

To list a reservoir data file select the Display option. The program will prompt for a file name. The contents of the requested file will then be displayed on the screen. After displaying a page the program pauses. Press Return to display the next page.

Select the Print Results option of the Model menu to get a single page printed listing of the input data and the results computed by the Monte-Carlo program.

Both the screen display and the print option list the input data as entered, followed by the requested/computed results.
(Perec Version 2.5. User Guide, Quartz Scientific, Watford, 1991, p.13-16)