

RM10

Impact on Gross-Rock Volume Distributions from Uncertainties in Surfaces and Hydrocarbon Contacts

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SUMMARY

The gross-rock volume often accounts for the largest uncertainty in reserves. It is therefore important to obtain a correct gross-rock volume distribution and to reduce the uncertainty by using all available data. We demonstrate a way of obtaining accurate volume estimates by imposing realistic and consistent physical and stochastic relationships between the surfaces and hydrocarbon contacts that define the reservoir rock volume. The uncertainty is reduced by using all relevant information collected in wells; well markers, zone logs in horizontal sections, and gas/fluid content along wells. Uncertainties in all these data types are handled. The impact on volume distributions from different assumptions and data types are demonstrated by several examples. We will in particular demonstrate how restrictions on the possible spill point depth have impact on the potential trap size and the trapped volume. Some of the results are obtained using standard stochastic simulation (Monte Carlo) techniques but in particular the highly non-linear relationship between a surface and its spill point requires rejection sampling techniques. Rejection sampling is simple but very inefficient so a fast approximate approach to simulating surfaces is investigated. The conclusion is that the approximation works for calculating volumes but individual surface realizations have unacceptable artefacts.

Introduction

Calculating gross-rock volume of a petroleum reservoir is done by calculating the volume between the cap-rock, a possible base surface, the hydrocarbon/water contact and a possible gas/oil contact. This gives a maximum of two geological surfaces and two hydrocarbon contacts. The simplest example only involves a cap-rock and a hydrocarbon contact but most realistic examples involves more than these two surfaces. Hydrocarbon contacts are usually assumed to be near horizontal prior to production but can differ in separate fault blocks. The standard approach to obtain a volume distribution is to generate a large set of stochastic realizations of surfaces and contacts and calculate the volume for each realization. The volume distribution is simply represented by the large set of randomly distributed volumes obtained from all the realizations. Expectations, P10, P90, or other statistics are easily extracted from this set of volumes. This approach is simple and accurate provided the number of stochastic realizations is sufficiently large, the assumptions made when generating the surfaces are realistic, and the stochastic simulation algorithm is correct. An accurate probability distribution for the volumes is important. Equally important is the width of the probability distribution, which is the uncertainty in the volume. The width can only be reduced by introducing more data or information. In this talk we will show how to obtain accurate probability distributions by using realistic assumptions and how to obtain less uncertainty by including more data.

Method

The standard way of generating surfaces is to use stochastic simulation of Gaussian random fields. Various simulation techniques are available. We argue that a combination of unconditional simulations and kriging with trends for the conditioning provides a flexible and efficient approach. Moreover, this approach is consistent with using kriging to obtain predictions and prediction error (kriging error). This method can be adapted to handle multiple correlated surfaces and horizontal wells (Abrahamsen and Benth 2001, Abrahamsen et.al. 2012). Highly non-linear information such as spill point depth, trap size or minimum column thickness cannot be handled by kriging techniques so we have to resort to rejection sampling. Rejection sampling simply means to generate a realization and check if some criteria are met. If not, new realizations must be generated until the criteria are met. So rejection sampling is a simple but potentially extremely inefficient conditioning method. We have tested rejection sampling on a few cases conditioning on spill point depth (Abrahamsen et.al. 2000). The efficiency of rejection sampling depends heavily on the acceptance rates. To handle low acceptance rates we have tested an approximate conditional simulation algorithm that is 5 – 10 times faster. The approximate simulation algorithm uses a pre-calculated prediction and prediction error to obtain correct expectations and point-wise standard deviations. The spatial correlations however, are incorrect close to well observations. Several tests show that this has minor implications for the volume distributions so this is an acceptable approximation when time becomes important.

Example of volume distributions obtained when adding more well data

The model consists of the top and bottom surfaces of the reservoir and a horizontal oil water contact (OWC). The reservoir is assumed to be a filled structure so that the OWC is at the depth of the spill point of top reservoir. The gross-rock volume above the OWC is calculated. Three wells are included sequentially to mimic an early appraisal situation. The spill point is only accepted if it is consistent with well observations. Figure 1 shows a fence diagram through the three wells. The acceptance rates for the three examples are 98 %, 46 % and 5 %. Figure 2 shows that the volume distributions narrow as more data becomes available. The uncertainty in the cap-rock is reduced in certain areas by the restriction on the spill point depth.

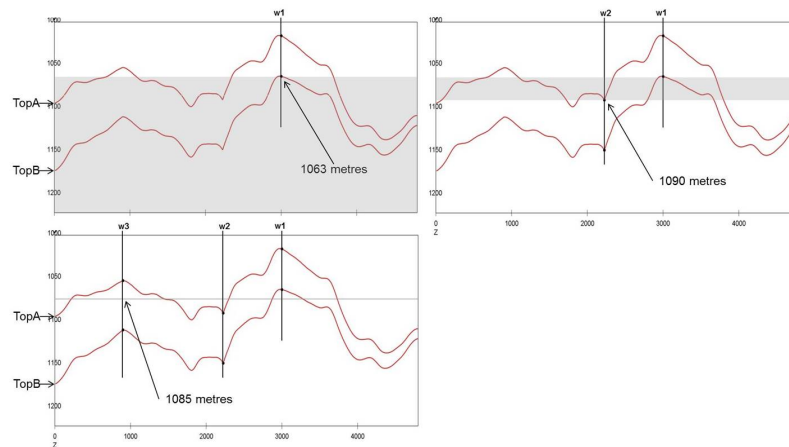


Figure 1 Fence diagram through the three wells. The grey areas indicate the acceptable depths for the spill points for the three cases.

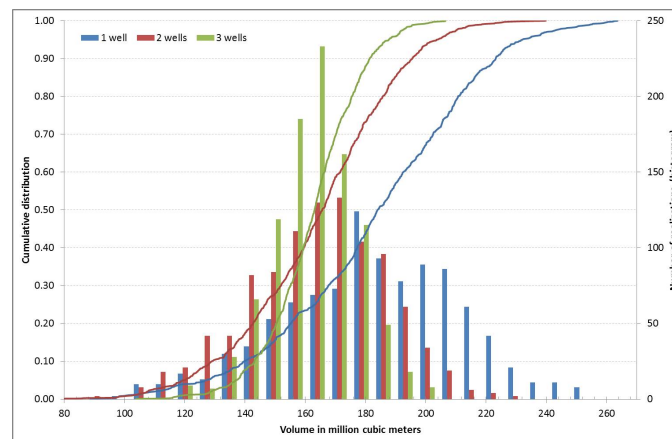


Figure 2 Histogram and cumulative distribution of calculated volumes from 1000 realizations with 1, 2 and 3 wells.

Conclusion

Using stochastic simulation provides a correct and reproducible method for obtaining volume distributions. These distributions are sensitive to geological assumptions and on the available data. It is impossible to obtain realistic volume distributions without using stochastic models. In most cases we are forced to calculate volumes from stochastic realizations.

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