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Uncertainty in Gross Rock Volume Analysis - A Stochastic or Deterministic Approach?

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SUMMARY

Quantifying the uncertainty in volumetrics is of paramount importance especially in mature basins such as the Southern North Sea. One of the key uncertainties is often the size of the gross rock volume (GRV), which is mostly dependent upon the seismic mapping of the reservoir and the time-depth conversion. This paper compares two methods to calculate the GRV uncertainty as a function of TWT uncertainty and velocity uncertainty. A stochastic time-depth conversion is used to estimate the depth uncertainty. Thereafter, the first method uses a stochastic approach creating multiple reservoir realisations using Sequential Gaussian Simulation. From this a GRV expectation curve is made, which gives a high case (P10) and low case (P90) volume. The outcome of the stochastic approach is compared to the outcome of the second method which is introduced in this paper; the plus-minus method. This method uses a simplified deterministic approach. A low case and high case depth map, corresponding to respectively a P90 and P10 GRV, are created by directly adding or subtracting a scaled depth uncertainty map from the base case depth map. Advantages and disadvantages of both methods are discussed. In addition recommendations are given on which method to use under what circumstances.

Introduction

In defining the size of hydrocarbon traps geoscientists have to deal with a large number of uncertainties. In the mature Southern North Sea (SNS) these uncertainties have become increasingly important when development decisions have to be taken [1]. One of the largest uncertainties is the size of the gross rock volume (GRV). Typically the GRV is based on seismic mapping and depends on seismic time maps and on the velocity model used for depth conversion. Both the uncertainties in the seismic time data and in the velocity model result in depth uncertainties. In the SNS velocity models are often layer based and used to conduct layercake time depth (TD) conversion [2]. This makes the GRV characterization more complex, and the uncertainty analysis more important.

The workflow that describes how we assess the impact of uncertainties in both velocity and two-way time (TWT) on the GRV is described in Figure 1. A proven method to translate the seismic and velocity uncertainty into a depth uncertainty is stochastic TD conversion. In this paper a Gaussian Monte Carlo algorithm is used to perform this conversion [3]. Once the depth uncertainty map is obtained we propose two methods to quantify the impact of this uncertainty on the GRV. The first method uses Sequential Gaussian Simulation (SGS) to generate a large number of possible surface realisations [4]. From these simulations a GRV expectation curve is derived. The second method, here referred to as the *plus-minus method*, uses a simplified, deterministic approach. A *low case* and *high case* map are created by directly adding or subtracting a scaled depth uncertainty map from the base case depth map. In this way, low and high case GRV's are derived. The advantages and disadvantages of both methods are investigated and compared, to finally give recommendations if a deterministic or stochastic approach to calculate the GRV is preferred.

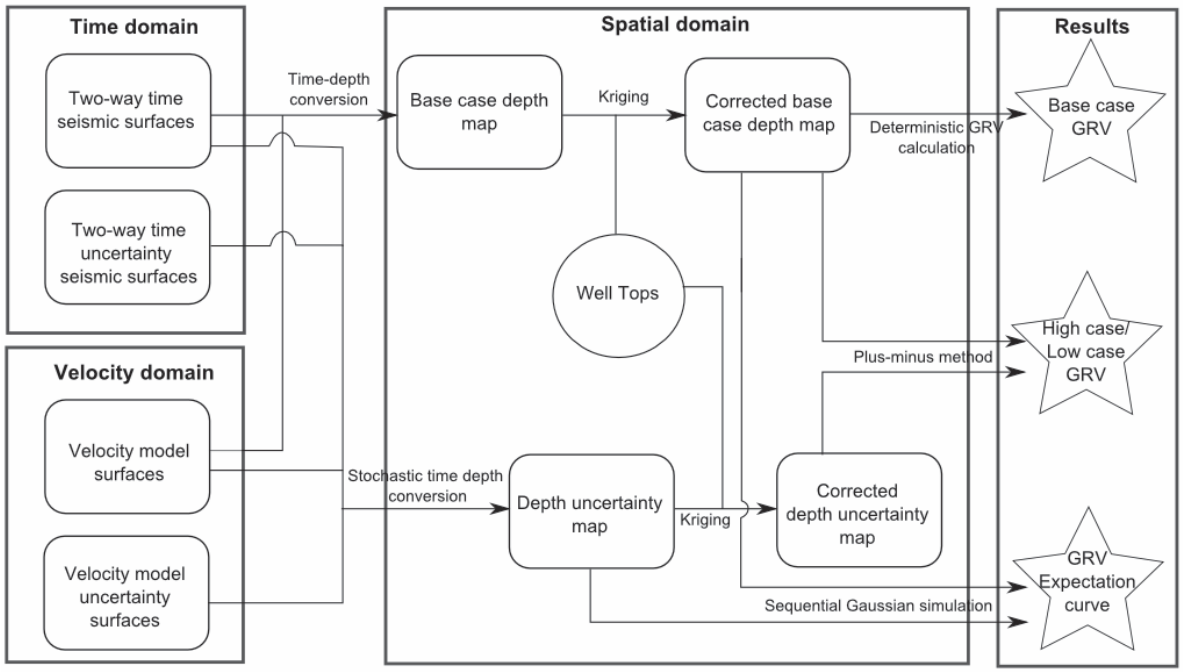

Figure 1. *Workflow to obtain a GRV uncertainty*

Stochastic time depth conversion

To convert the uncertainty in velocity and in seismic two-way time (TWT) to an uncertainty in depth, a stochastic TD conversion is performed. First a layer cake velocity model is made, which includes TWT grids of the different horizons and velocity functions for the different layers. A 'deterministic' TD conversion creates the most likely depth map, referred to as the base case depth map. Subsequently uncertainties in both TWT and velocity are assigned. These uncertainties can be either constant per layer, or spatially variable using grids.

To perform stochastic TD conversion a Gaussian Monte Carlo simulation is used. For this simulation it is assumed that both the velocity uncertainty and the TWT uncertainty have a Gaussian

distribution, with the standard deviation equal to the uncertainty. For each grid point in each layer a random TWT is taken from the Gaussian TWT probability density function (PDF) of that layer (Figure 2.1). Then for each grid point in each layer a random velocity is taken from the Gaussian velocity PDF (Figure 2.2). With this velocity the random grid point TWT of each layer is then converted to a depth (Figure 2.3). This process is repeated many times (e.g. 500x), after which the average and standard deviation of the outcome are calculated (Figure 2.4). The outcome is assumed to be Gaussian. The depth uncertainty map is then defined as two times the depth standard deviations (STD). Subsequently a Kriging algorithm is used to tie both the depth maps and the depth uncertainty maps to the wells.

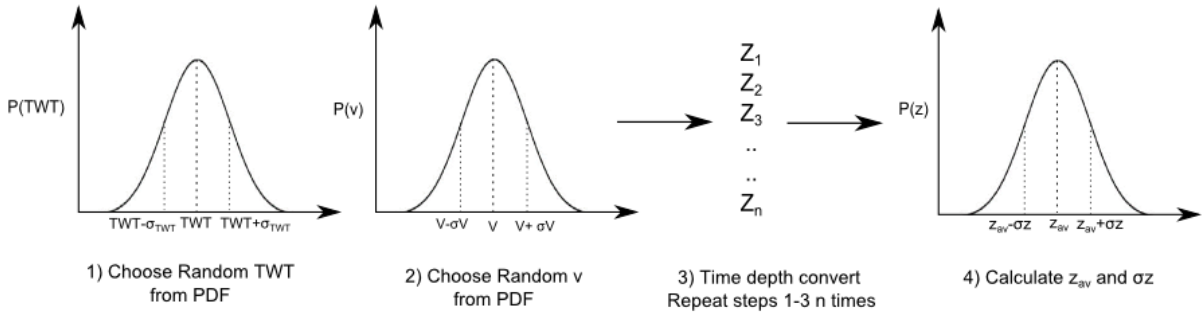

Figure 2. *Gaussian Monte Carlo simulation*

Method 1: Sequential Gaussian simulation

The first method to calculate the uncertainty in GRV uses the depth uncertainty map to make 250-500 possible top reservoir map realisations. From these multiple depth realisations a GRV expectation curve is made. To generate a possible surface realisation the following method is used. From the deterministic TD conversion a base case depth map z_{BC} is obtained. Each surface realisation can then be defined as $z_{rel,n} = z_{BC} + z_{err,n}$, with $z_{err,n} = \Delta z \cdot z_{ran,n}$ (Figure 3). Here Δz is the depth uncertainty map, and $z_{ran,n}$ is a randomly generated map constrained by a Sequential Gaussian Simulation (SGS) algorithm. This randomly generated map $z_{ran,n}$ is used to assign an error value to each grid point. Due to the nature of the SGS algorithm a smoothly correlated surface is created, described by the variogram with a range R. The range is chosen to be approximately equal to the wavelength of the depth error, in this case the dominant wavelength of the surface features. The distribution of each $z_{ran,n}$ map is Gaussian with an average of 0 and a standard deviation of 0.5 such that 95% of the drawn error values is between -1 and 1. This randomly generated map is tied to wells, as here the depth error is considered zero.

Once a top reservoir depth surface realisation $(z_{rel,n})$ is created, the GRV of the structure can be calculated. First a thickness is assigned to the reservoir layer. Then a fluid contact is implemented in the model. The contact can be taken constant, or can be varied per realisation, by a spill point detection algorithm. Thereafter the GRV is calculated for all surface realisations and plotted in an expectation curve. From the expectation curve a *high case* (P10), *low case* (P90) and *mid case* (P50) GRV can be derived.

Advantages: The method gives a realistic volumetric estimate, assuming all surface realisations are equally likely. It is also possible to implement a variable spill point detection if no wells with fluid contact information are available.

Disadvantages: The method creates many surface realisations, and is therefore fairly laborious. Furthermore the method requires extra input parameters such as the variogram range, which is often poorly constrained and has a large influence on the outcome of the simulation.

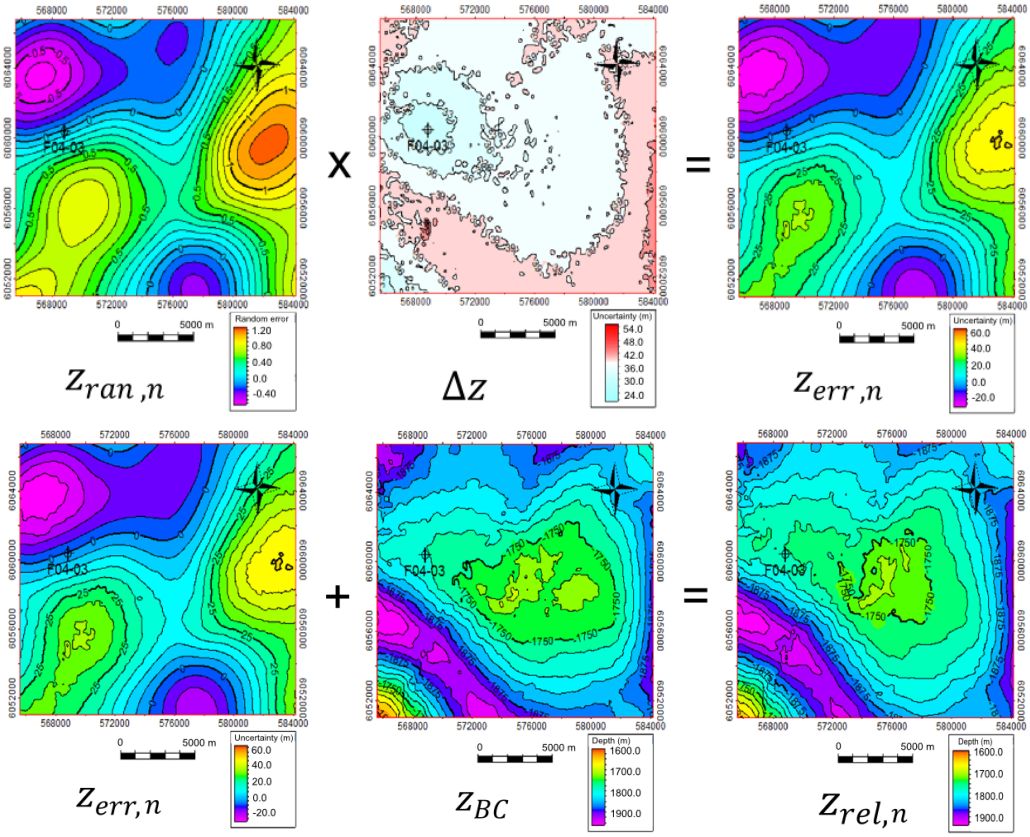

Figure 3. *Process to make a possible surface realisation*

Method 2: Plus-minus method

In case of the *plus-minus method* the fluid contact is assumed to be known. The high case depth map (corresponds to P10 volume) is defined as $z_{HC} = z_{BC} + \Delta z \cdot c$, while the Low case depth (P90 volume) is defined as $z_{LC} = z_{BC} - \Delta z \cdot c$ (See Figure 4). Here Δz is the depth uncertainty map, and c is a constant scaling factor. If $c = 0$ the base case GRV is obtained. The difficulty lies in establishing a c-value that defines the high and the low case maps (which contain P10, P90 GRV's). Several prospects in the SNS have been analysed with both methods to estimate c. Based on this empirical approach it appears that with a c-value of approximately 0.5, the *plus-minus method* gives an estimate of the GRV uncertainty comparable to the elaborate SGS methodology.

Advantages: The method is very simple to implement once the depth uncertainty map is available. Aside from the depth uncertainty map no extra input is needed to calculate the GRV uncertainty.
Disadvantages: An estimate must be made of the c-value that defines the upper and the lower case GRV. A precise estimate requires calibration using method 1. Another disadvantage of this method is that it can only be used when the water contact is known or assumed constant.

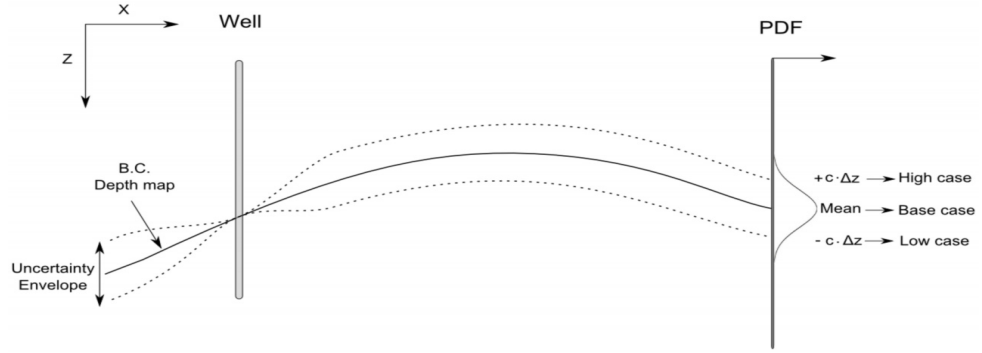

Figure 4. *Schematic representation of the plus minus method*

Case study: Updip potential in a Chalk prospect

To review both methods we present a simple case. The reservoir is a domal structure (Figure 3), and was TD converted using a 2-layer velocity model. The structure has been drilled on the flank without encountering hydrocarbons. However the structure still contains updip potential. With a deterministic TD conversion the GRV updip potential is estimated to be $1.91 \cdot 10^9$ m^3. A depth uncertainty map of the region was made by stochastic TD conversion. The fluid contact is assumed constant at the reservoir depth of the well. The thickness of the reservoir is larger than the potential hydrocarbon column. 250 SGS possible top reservoir realisations were made using a variogram range of 10 km. The GRV of all surface realisations were calculated and plotted in an expectation curve (Figure 5). This gives a P90 GRV of $0.82 \cdot 10^9$ m^3 and a P10 GRV of $3.58 \cdot 10^9$ m^3. With this information the c-value for the *plus-minus method* was established. The P10 volume and the P90 volume of the SGS method correspond respectively to a c of 0.5 and -0.48. This means that the P10 GRV is contained in a *high case* reservoir depth map which is created by adding the depth uncertainty map scaled by factor 0.5.

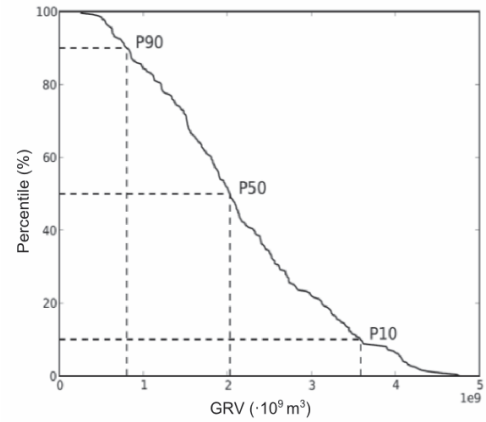

Figure 5. *GRV expectation curve from SGS*

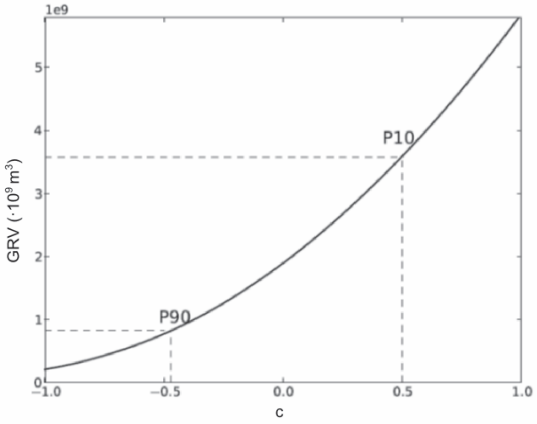

Figure 6. *GRV calculated with plus-minus method*

Conclusions

In this paper a Gaussian Monte Carlo TD conversion is used to create a depth uncertainty map. Two different approaches are proposed to use this map for calculating GRV uncertainty. For a more accurate calculation, sequential Gaussian simulation (SGS) can be used to obtain many different reservoir realisations. From this a GRV expectation curve can be made. This method is elaborate and needs extra input parameters such as the range of the variogram. Depending on the situation it might be more practical to use a simple approach. Therefore we propose the *plus-minus method*. By adding or subtracting a scaled version of the depth uncertainty map from the base case depth map, high and low cases GRV can be obtained. Several prospect were analysed with both methods and a c-value of approximately 0.5 gives a reasonably good estimate of the P90 and P10 GRV. In case the depth uncertainty is large compared to the potential hydrocarbon column it is strongly recommended to conduct a GRV uncertainty analysis. If the fluid contact is (approximately) known, the *plus-minus method* can be used. If the contact is unknown or depends on the spill point which varies per realisation, it is recommended to use SGS to estimate the GRV uncertainty.

References

[1] Hoetz, G. et al. 2012 Statistics on Wells in the Netherlands: What do we Learn? 74th EAGE Conference Copenhagen, Denmark, June 2012.
[2] Al-Chalabi, M., 1997b, Time-depth relationships for multilayer depth conversion, Geophysical Prospecting, 45, 715-720.
[3] Van Ravesteijn, M. 2014. Velsto, application for stochastic time depth conversion.
[4] Samson, P., Dubrule, O., Euler, N. 1996. Quantifying the Impact of Structural Uncertainties on Gross-Rock Volume Estimates. Society of Petroleum Engineers 35535.