Triassic Fluvial Reservoir – Do You Know How to Find Your Sands?*

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Abstract

A successful appraisal program is the key for future field development hence having the 'right' well is the utmost priority and so is the data gathering. The prospect under investigation is part of a Triassic reservoir that is interpreted as a stacked channel system of about 500ft height. The channels are expected to show low sinuosity with N-S direction. Unfortunately, the seismic data does not allow guidance of channels or sand distribution in any way. The lateral overall sand fraction of the prospect was deducted from the vertical sand distribution at the two wells based on VSH cut-off. Using analogue data the channel geometry was estimated from the sand thickness and the depositional environment. Several methods and strategies were applied and compared for modelling the sand distribution and the bulk volume for the radius of influence of the appraisal well. The modelling showed that only a few parameters have a major influence on the sand volume calculated for the planned well: global sand fraction, channel width and channel thickness. From this work, a set of simple rules and guidelines can be derived that are applicable to many clastic reservoirs with limited well data and no additional seismic information for facies modelling: 1) Keep it simple. Often sophisticated models do not deliver added value in terms of sand distribution uncertainty and volumetric. 2) Work with different scenarios estimating the global sand fraction and eventually its distribution. 3) Use Gauss Indicator simulation for investigating the different scenarios: it is quick, simple and reliable. 4) Derive object (channel) thickness and width data range from analogue. These parameters are most influential on the spread of the sand volume distribution. 5) Use MPS for building a final model – it delivers more realistic results and is the preferred option for RE.

Introduction

This study is being focused at the Triassic reservoir of Central North Seas. The sedimentological analyses of the data of two exploration wells that have been drilled indicate a stacked channel system of circa 500 ft thickness. Furthermore, the petrophysical results combined with regional information let us assume channels of low sinuosity going in N-S direction. The 3D seismic delivers structural information but does not allow us to estimate the outlines of the channels nor channel belt.

Figure 1 shows the small prospect, which is confined by three faults. The two wells are about 2km away from each other. A new well shall be drilled at mid-distance between the existing wells. The challenge is to estimate the sand fraction at the new well and the reservoir volume within the area of influence, which for simplicity is assumed to be circular with a radius of 500m.

Estimation of Sand Fraction

A key model parameter is the global fraction of the different facies. In the case of Gauss facies simulation, it strongly influences the sand distribution away from the wells where the influence of the well data controlled by the variogram ranges is diminishing. In object modelling it defines the number of channels for a given set of channel parameters.

The sand fraction was derived from the VSH logs. After careful investigation of the data the cut-off for reservoir-sand – non-reservoir was set to 50%. Typically, the global fraction of the facies is deduced from the wells. It follows that you need many wells in order to get a reliable estimation of the facies fractions. Consequently, the facies fraction derived from two wells can be regarded as highly unreliable. However often it can be assumed that the vertical facies fraction over several zones of similar depositional environment is comparable to the lateral facies fraction given by any of the zones. Figure 2 shows two sand fractions for each of the wells as a function of the vertical reservoir range. For the low cut-off of 30% sand, the two wells show similar sand fraction for a zone thickness larger than 400ft. The functions of both cut-offs show sand fractions that vary strongly for small zone thickness and approach a threshold value with increasing zone thickness. In addition, the sand fraction for large cut-off (50%) is quite different between the two wells. This could mean that data of strong heterogeneity is included in the sand fraction estimation.

The conclusion is that much care should be taken in estimating the global facies fraction. In case of few wells and thin reservoirs, they can be completely unreliable. In such a case, one should consider deriving the facies fraction over a large depth range and assign the same fraction to all zones.

Influence of Model Parameters on Reservoir Volume Distribution

There are three common ways to model a stacked channel system: Gauss facies simulation, object (channel) modelling and facies modelling based on Multiple Point Statistics (MPS). Gauss facies simulation typically shows a very good performance and therefore can be used for getting a quick overview of the reservoir volume. MPS on the other hand is a very flexible tool that delivers results that are close to the ideas of the earth modeler. However, it may be time-consuming setting up the training image and getting a satisfactory model. Therefore, Gauss facies simulation and object modelling often are preferred to MPS for testing modelling parameters and analyzing their impact on the model and the volume.

In general, the volume distribution is described by its P50 value and its spread. In order to understand the influence of the different modelling parameters on the reservoir volume an idealized model of an extension of 10x10km and 200ft thickness was set up (Figure 3). The volumes were calculated for the circular area of interest with a radius of 500m as shown in the Figure 3. The volume spread was measured by

Spread = ((P10 – P90) / P50)*100 [%]

Figure 4 shows the result for Gauss facies simulation. The volume spread is plotted as a function of the major variogram range. The two graphs give the volume spread for two different normalized vertical variogram ranges which is defined as

Reservoir thickness / Vertical range

In case the vertical range is small compared to the zone thickness the horizontal range has no major influence on the volume spread. On the other hand, a large horizontal range combined with a small relative vertical range results in a significant volume spread. It is important to understand that this result is only valid for the selected circular area of interest with a radius of 500m. With increasing radius, the volume spread would decrease for a given horizontal range! The influence of the variogram range on the P50 volume is not significant.

The influence of the channel width and the channel thickness on the reservoir volume spread is similar to the variogram range discussed above. Figure 5 shows the volume spread as a function of the channel width for different relative channel depths. The relative channel depth is defined as

Reservoir thickness / Channel thickness

Again, this result is only valid for the used circular area of 500m radius. The channel model parameters wavelength and amplitude of the channel sinuosity do not influence the reservoir volume spread significantly. The influence of the model parameters on the P50 reservoir volume is small compared to the global sand fraction derived at the wells.

Finally, the influence of the MPS facies modelling on the reservoir volume distribution was analyzed. Based on the results discussed above it becomes clear that the properties of the training image will influence the reservoir volume distribution. The facies fraction of the training image has a strong influence on the P50 volume. The size of the individual geobodies defines the spread of the volume.

Facies Modelling of the Prospect

The work discussed above shows that for object modelling as well as for MPS facies modelling the key parameters are channel width and channel thickness together with the facies fraction. Using published analogue data (Fielding and Crane, 1987) the channel width was derived from the sand body thicknesses given by the two wells:

Cut-off	Sand fraction	Min thickness	Base case thickness	Max thickness	Min width	Base case width	Max width
50%	65%	10ft	50ft	80ft	100m	1000m	1500m

Three types of models were made and stochastically varied for the reservoir volume estimation:

- Object modelling. Several 100 models were calculated and the volume of the area of interest derived. The channel parameters were selected stochastically within the range given above.
- MPS facies simulation. The training image is based on object modelling with the channel parameters set for the base case. The only variable that changes from model to model is the random number that is used to derive the facies at each grid cell from the cumulated facies distribution function.
- Gauss facies simulation. The major horizontal variogram range was set to 3,000m. The minor horizontal range varies stochastically between 100m and 1,500 m. The vertical range varies within the value range of the channel thickness. In addition, the random number changes that are used by the algorithm to figure out the facies for each grid cell from the cumulated distribution function of the facies fractions.

Figure 6 shows the base case models for Gauss simulation, object modelling and MPS facies simulation. The models look very similar and in fact, at first sight it is difficult to assign the proper model to its algorithm used for modelling.

The volume distributions of the three modelling techniques are given in Figure 7. Unsurprisingly object modelling and Gauss simulation deliver very similar volume distributions. On the other hand, MPS facies modelling delivers a volume distribution with a similar P50 value but a much smaller spread. This is explained by the fact that the training image is based on the base case channel width and depth.

Recommendation and Conclusion

The method used in this study should be applicable to any stacked channel systems. The selected stochastic modelling methods (Gauss facies simulation, object modelling and MPS facies modelling) deliver reservoir volume distributions of similar P50 but possibly different spreads. Key parameter is the global facies fraction, which decides on the P50 volume. Variogram ranges, channel depth and channel widths control the volume spread.

Based on these results the recommendation is to focus on the discussed key parameters. A possible modelling strategy could be to use Gauss facies simulation for putting oneself quickly into the picture about the reservoir volume distribution. Object modelling should be used to understand the influence of the key channel parameters on the volume spread. Probably MPS facies modelling delivers the most realistic facies model. However, this modelling technique should not be used for estimating the reservoir volume uncertainty. Such an approach would include the setup of several training images based on different channel parameters. This would make the analysis very time consuming and cumbersome. Instead, MPS modelling should be used for setting up the base case model and eventual the low case and high case model.

Acknowledgements

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Reference Cited

Fielding, C.R., and R.C. Crane, 1987, An Application of Statistical Modelling to the Prediction of Hydrocarbon Recovery Factors in Fluvial Reservoir Sequences: in Recent Developments in Fluvial Sedimentology (SP39), p. 321-327.

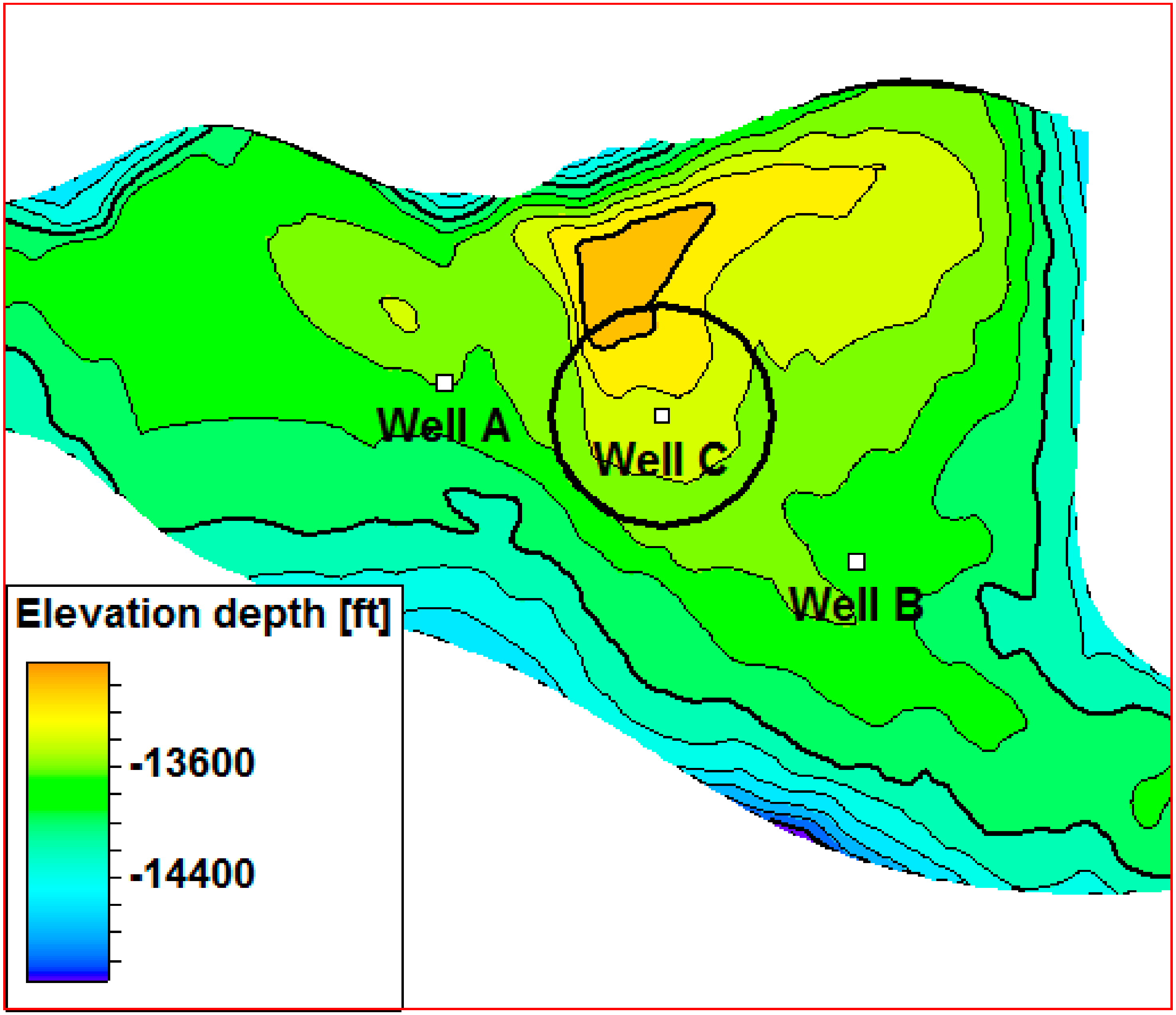

Figure 1. Outline of the prospect with drilled and planned wells.

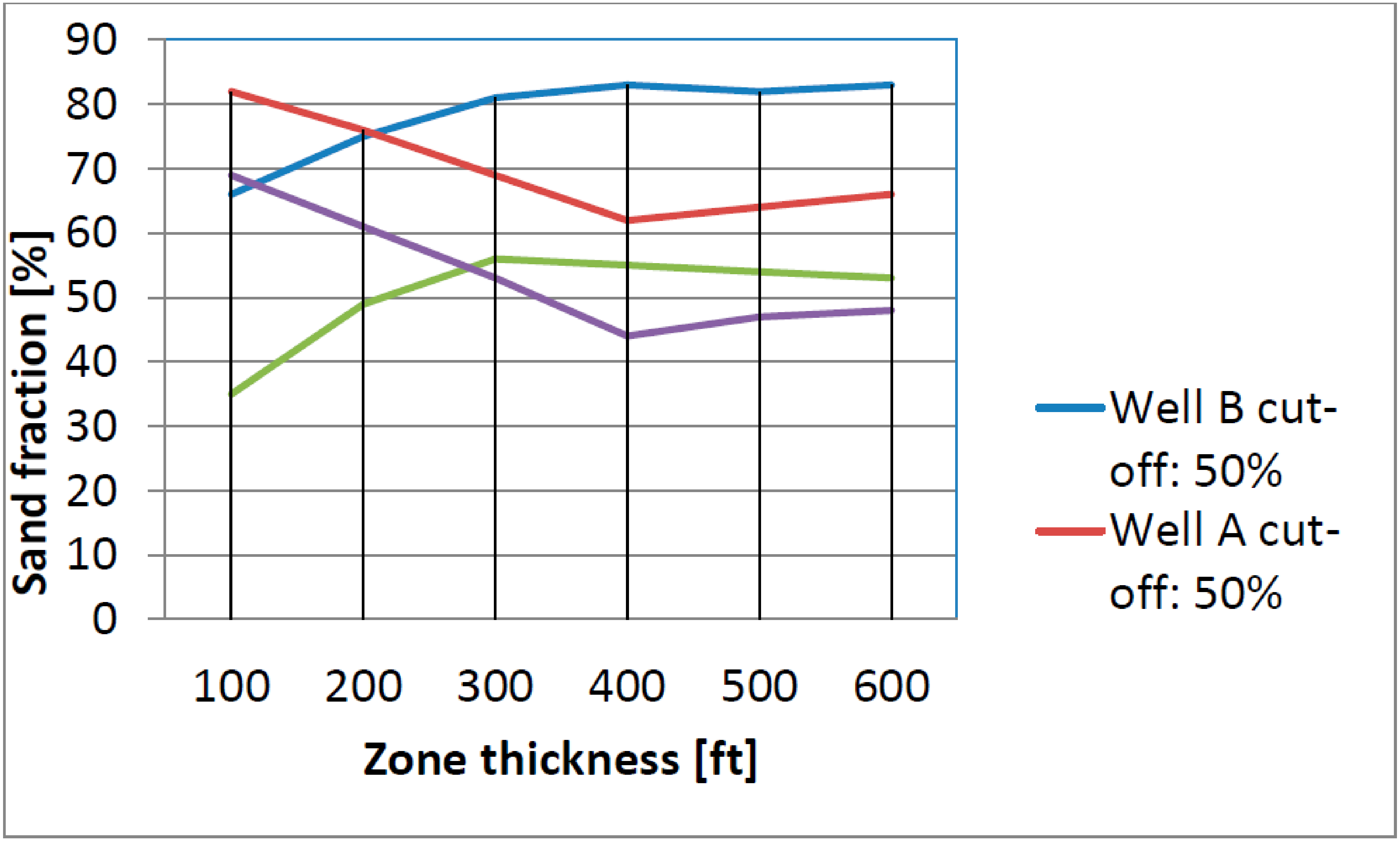

Figure 2. Variation of sand fraction at the two wells with increasing zone thickness.

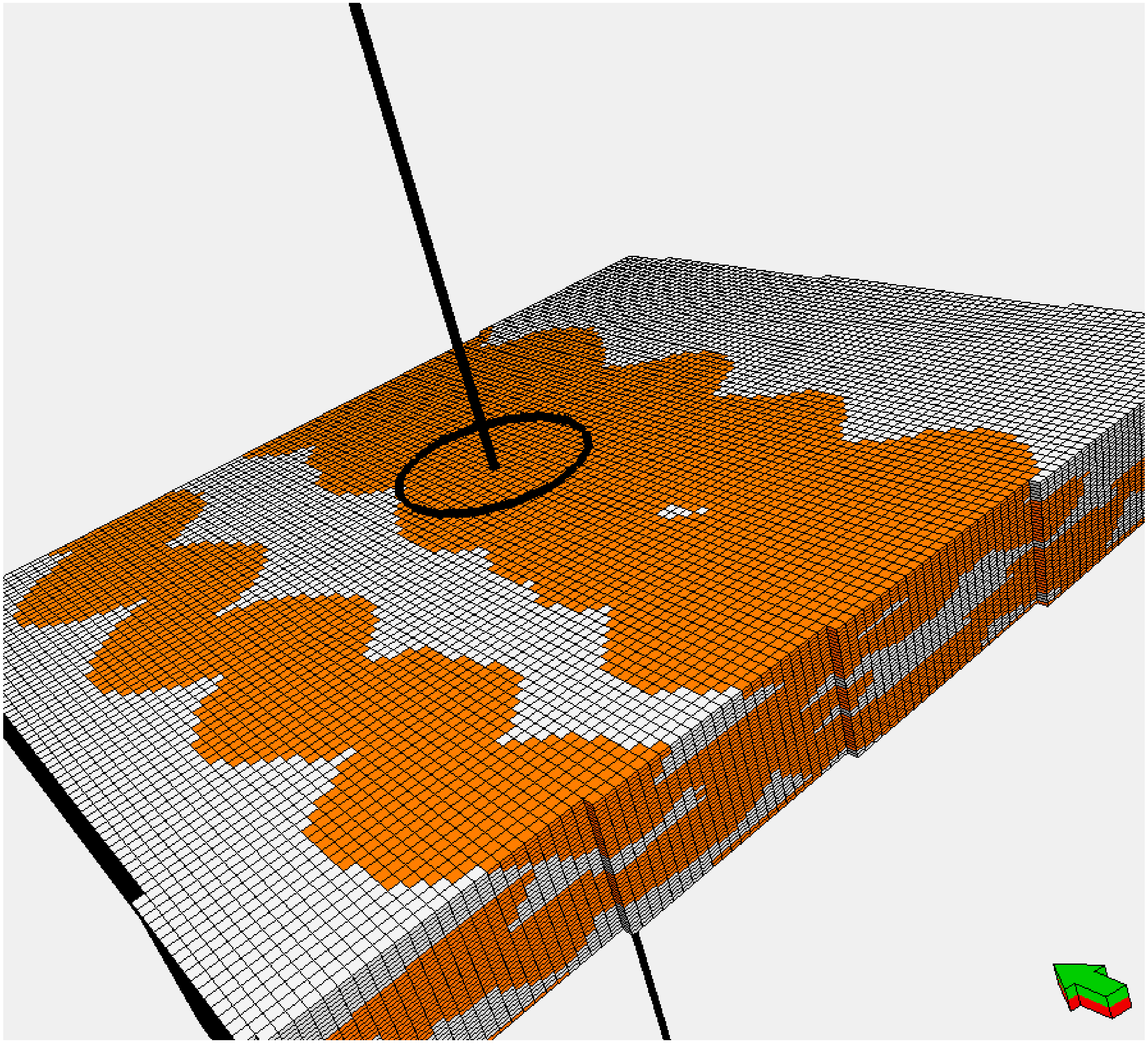

Figure 3. Idealised model for studying the influence of model parameters on the reservoir volume.

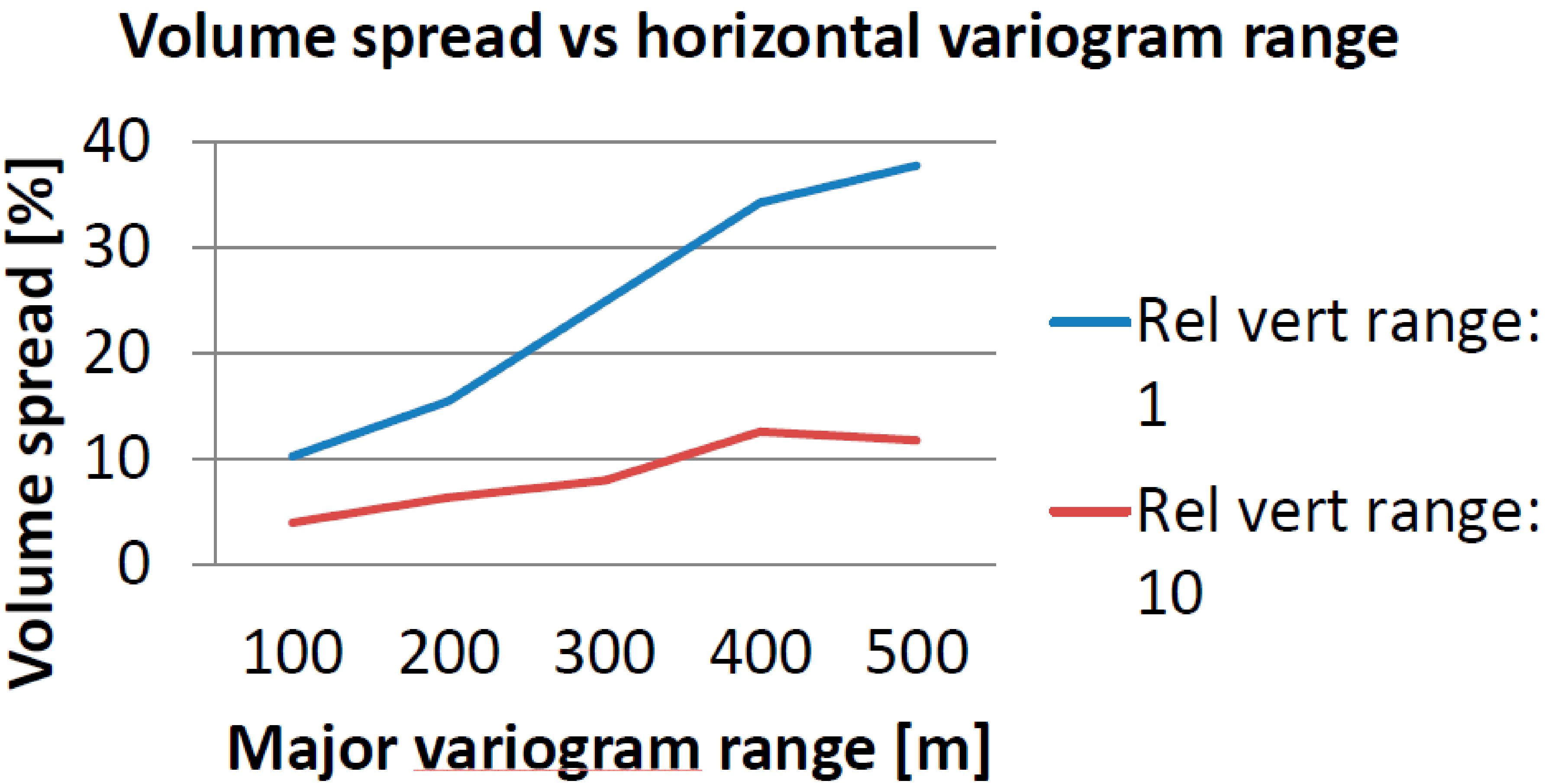

Figure 4. Influence of the variogram range on the reservoir volume distribution.

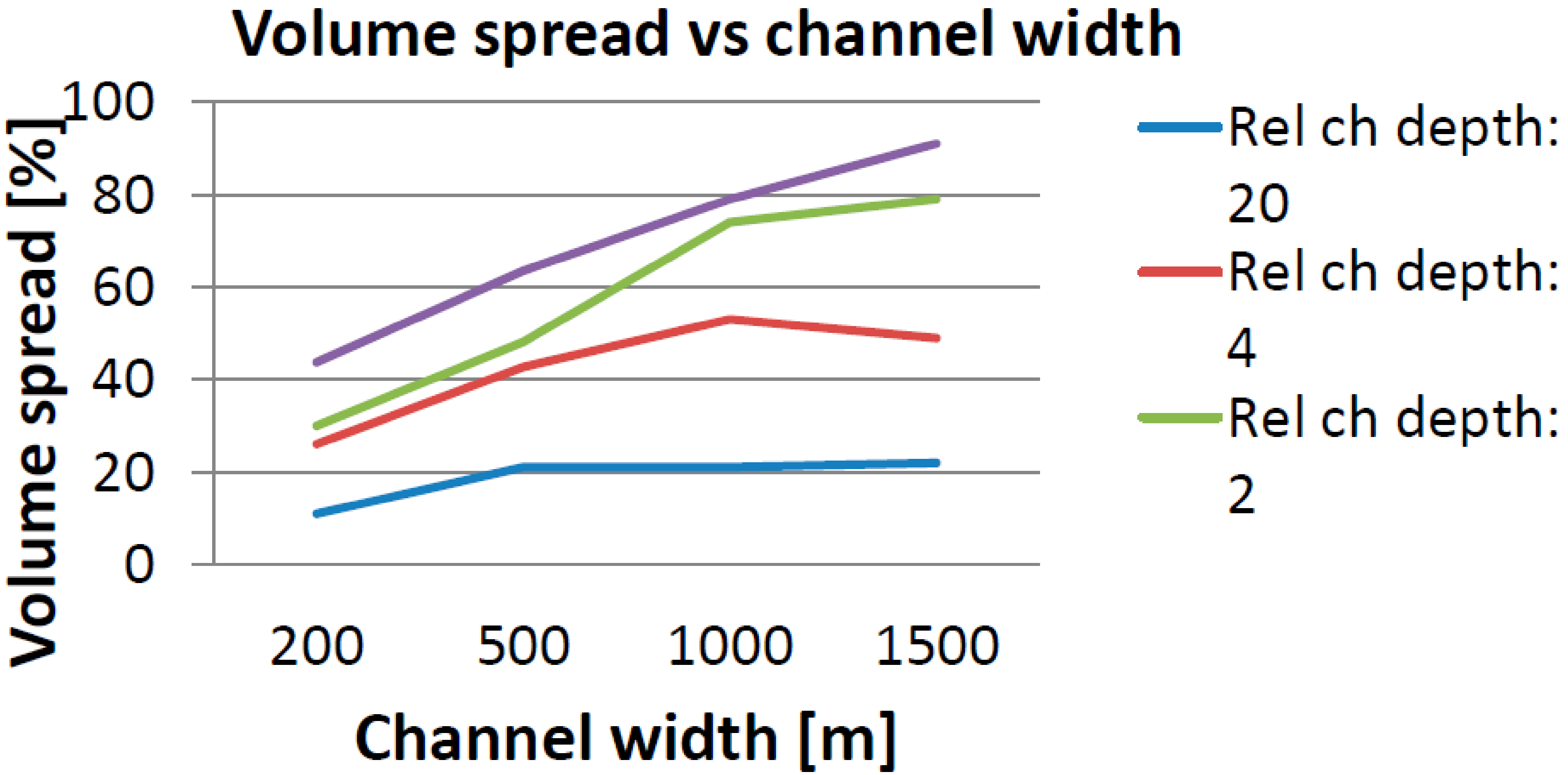

Figure 5. Influence of channel width and channel thickness (depth) on reservoir volume distribution.

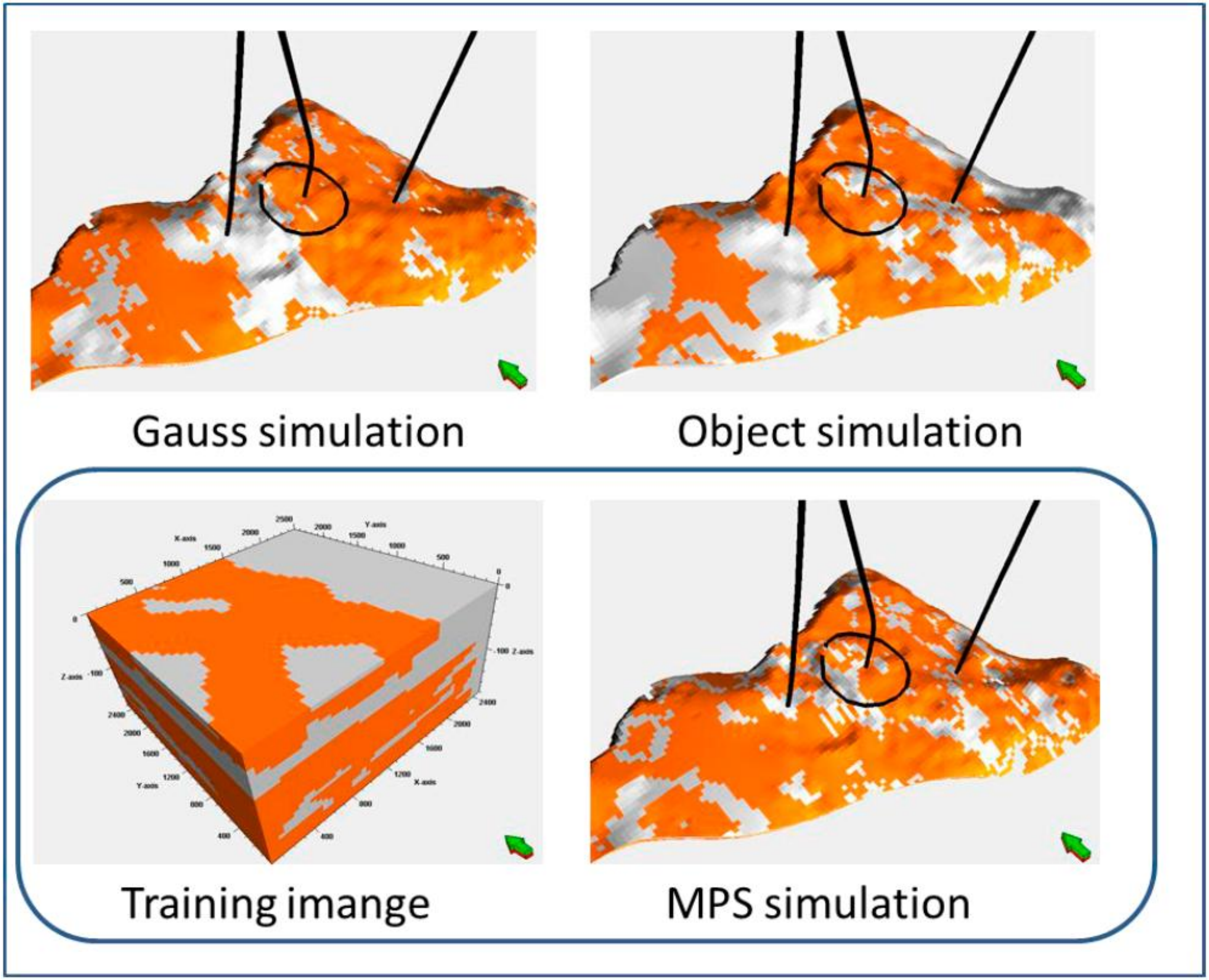

Figure 6. Base case models with wells and area of interest for volumetrics of three different modelling techniques.

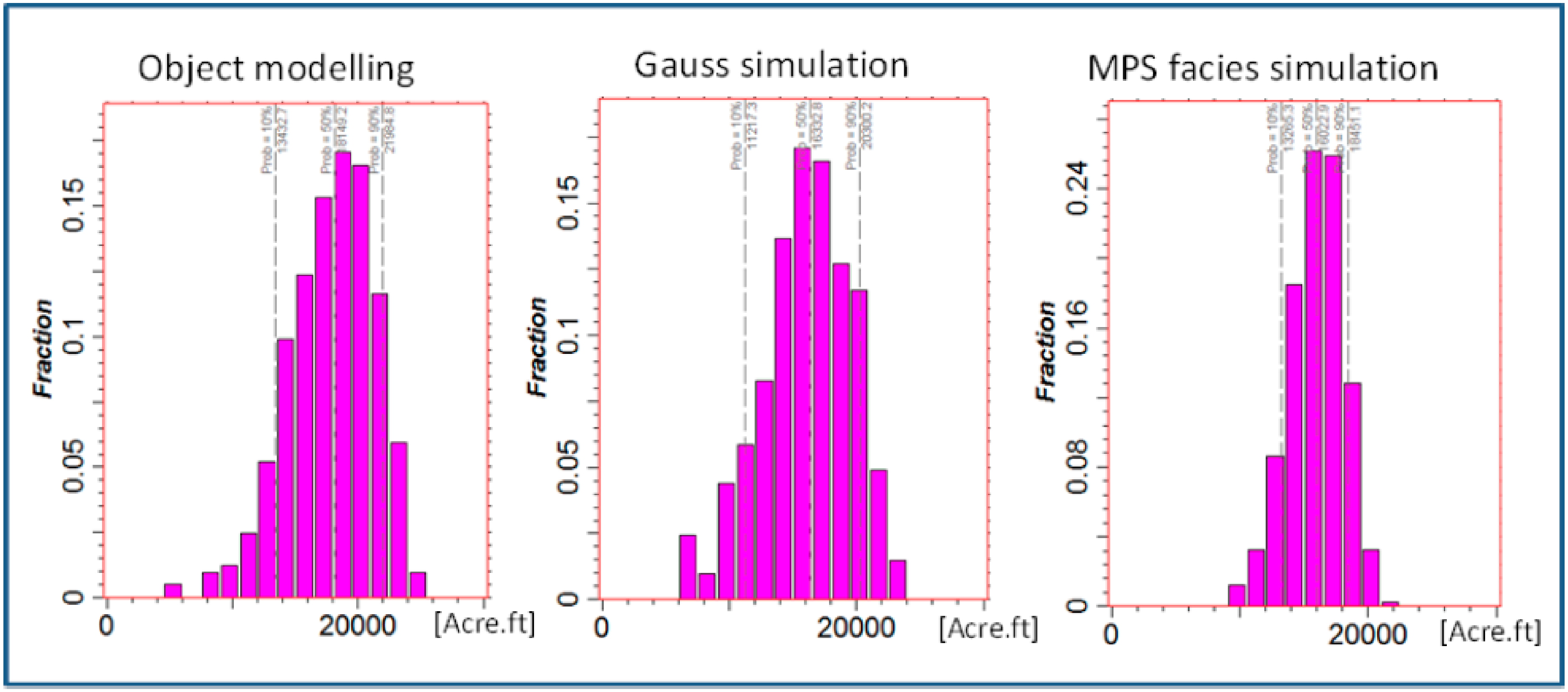

Figure 7. Reservoir volume distribution derived from several 100 models based on the three investigated modelling techniques.