# QUANTIFYING THE IMPACT OF THE FAULT MODELLING PARAMETERS ON PRODUCTION FORECASTING FROM CLASTIC RESERVOIRS.

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Over the past few years, there has been a strong focus on developing and using advanced methodologies for modelling faults and their impact in terms of flow in the reservoirs. So far, a lack of methods and tools, and probably the will not to increase the complexity of the simulation models had left behind this aspect of the reservoir, while methods for sedimentological modelling have been widely used for years.

Faults impact the reservoir behaviour both by affecting the connectivity, and by acting as permeability barriers. Except for small scale faults (near seismic resolution), the connectivity is quite well constrained by a combination of seismic and well data. But, due to the lack of controlling observations, the uncertainty attached to the fault sealing capacity is very high. Thus, reservoir models are still built with the assumption of an homogeneous fault permeability (when not simply open or sealed), and the sealing capacities of the faults *a posteriori* steered by history matching.

Predictive methods have been developed in order to link the geological surroundings to the sealing capacity of the fault (Yielding et al., 97, Manzocchi et al., 99). However, it is difficult to predict how influential would be the use of one seal modelling method or the other, and the handling of small scale faults, compare to the related uncertainties.

The aim of the study was to analyse the effect of different parameters which are required to realistically model both fault seal and geometry, using experimental design techniques. We first identified the main fault modelling factors, and defined two levels for each of them, according to our understanding and experience of the uncertainty range (see table below). We carried out a sensitivity analysis, using the same approach as Jones et al. (95), in order to evaluate the impact of each of these factors in flow simulation results. The input factors were assessed in three different synthetic reservoir models, each sequence representing different sedimentological environments, derived from North Sea fields (Jacobsen et al, 2000, Brandsæter et al, 2000). The reservoir models were based on a common horizon structure representing a tilted block (5 horizons). We chose to work on a geological model in order to preserve the scale of the heterogeneities. The fault population, geometry and sealing properties were directly updated into the 3D grid using Havana.

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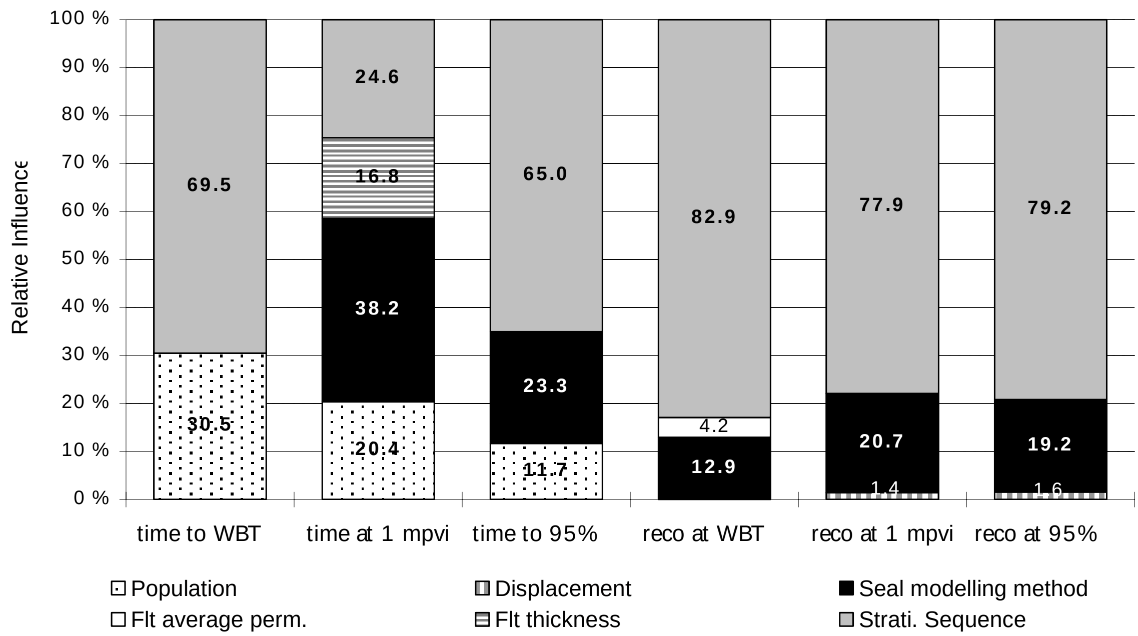
| Input Factors | Levels | | |
|---|---|---|---|
| Stratigraphic sequence | Seq_1<br>Heidrun Tilje and Åre<br>(0,0) | Seq_2<br>Gullfaks Ness<br>(0,1) | Seq_3<br>Gullfaks Tarbert<br>(1,0) |
| Fault Population (connectivity) | Low connectivity<br>17 faults<br>0 | High Connectivity<br>17 faults + 50 subseismic faults<br>1 | |
| Fault Displacement | Low displacement<br>= 85% of base displacement<br>& stochastic noise<br>0 | High displacement<br>=100% of base displacement<br>& stochastic noise<br>1 | |
| Fault seal modelling method | Homogeneous permeability<br>0 | Smear Gauge Ratio<br>& Shale Smear<br>1 | |
| Average Permeability | Low<br>0 | High<br>1 | |
| Fault Thickness | Low<br>0 | High<br>1 | |

Experiment 1

Experiment 2

The experimental design was reduced using standard optimisation methods, and replicates were run, in order to lower the noise brought by the stochastic realizations (sedimentological and petrophysical modelling). The different models were sent to a reservoir simulator (Eclipse). A few production measurements were selected, at water break through (10% water cut), at one moveable pore volume injected (1 mpvi), and at the end of production (95% water cut). For analysing the results, the weight of each input factor was computed as well as its significance. The results are shown in the illustration below:




Results of the sensitivity analysis. Only the significant factors are represented. They are drawn on a 100% scale bar (this does not represent 100% of variability explained, but 100% of variability due to these factors).

The main conclusion which can be drawn are:

- The stratigraphic sequence is a very significant factor. However, it might be a little bit overestimated here, due to the experiment settings.
- The reservoir model is strongly influenced by some of the fault parameters, especially *fault population* (⇔connectivity), and *seal modelling method*. *Fault population* has an impact only on the time measurements, not on recovery estimations. *Fault displacement* has almost no influence, as well as *fault average permeability*. *Fault thickness* is significant only in time to 1 mpvi.
- For each kind of measurement, we can rank the influential factors : for time measurements, *seal modelling method* and *pattern*; for recovery, *seal modelling method* only.

A second experiment was also run, in which the sequence factor disappeared; we only kept the multiple stochastic realizations. For each sedimentological environment, an independent experiment was designed (see table above). This experiment completed the first one by giving us a different point of view; we could, for each environment, rank the input factors, as well as compare the results between experiments. As expected, the results clearly highlight parallel behaviour of the fields, as well as differences. Predominant factors of the first experiment (seal modelling method and fault population), still are the most important, and quite steady between the models; Secondary factors, such as *fault average permeability* show different behaviour between the models.

Defining seal modelling method and fault population as most influential factors doesn't mean that other factors are not important, but that the uncertainty associated to them has lower consequences. The weight of those factors, as well as the variations we see between models highlight the need of assessing the uncertainties associated to all fields.

## References

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