Low- and High-Resolution Fault Interpretations on Simulated Pressure Distributions: An Example from the North Sea

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Pressure modelling has been carried out in the Tune Field area, Viking Graben, offshore Norway (Figure 1). The pressures are considered to be controlled by compartments bounded by mapped faults. Two different interpreted fault maps at the top reservoir level (Brent Group) are used as input to the modelling. First, a low-resolution fault map is used, with only the large faults interpreted, and next, both large and small faults are included. The simulations show that higher fault map resolution used in the input increased the lateral pressure distribution accuracy.

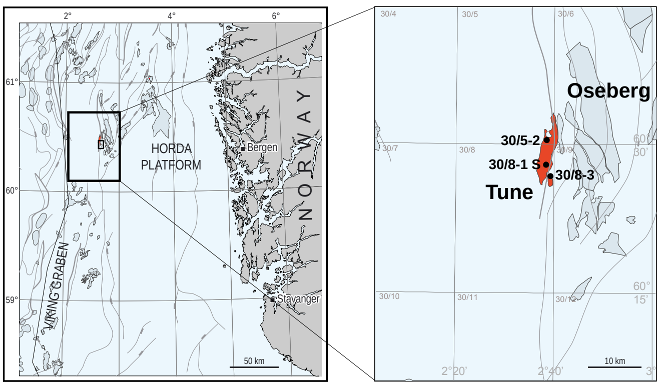

Figure 1 Overview map from the northern North Sea. Large frame marks the study area. Small frame marks study area in Childs et al. (2002)

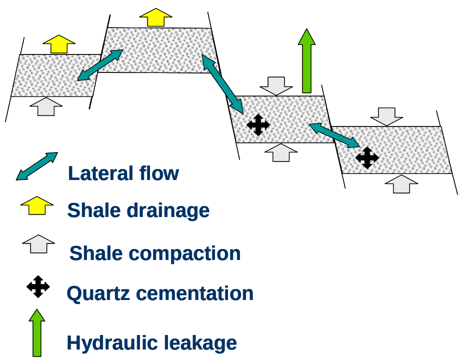

Figure 2 Different processes simulated in PRESSIM

Geological setting

The Tune Field consists of one north-south elongated structure approximately 2.5 km wide and 20 km long (Figure 1b). The field is located in a structurally complex area down-faulted to the west from the Oseberg South area. Towards west and east the field is delimited by large scale N-S striking normal faults dipping towards west.

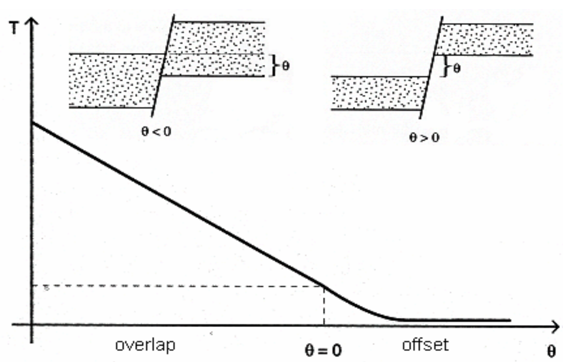

Figure 3 Juxtaposition faults have a linear relationship between throw and transmissibilites.

Method

The pressure simulator used (“PRESSIM”; Borge 2000, Lothe et al. 2004), was developed to simulate pressure dissipation and migration at basin scales (Figure 2, Table 1). The pressure compartments are defined by fault patterns interpreted at top reservoir level using reflection seismic data. The flux between the compartments and not the flow within the compartment itself was modelled. The most controlling factor for the transmissibility is the dip-slip displacement as illustrated in Figure 3.

Table 1 Geological processes modelled in PRESSIM

Processes	Comments
Lateral flow	Models lateral flow of formation water across low-permeable faults. Using the explicit forward Euler solution technique (Borge 2000).
Shale drainage	Divides the cap-rocks into a draining, accumulating and sealing zone (Borge 2000).
Compaction	Model mechanical compaction of shale (Baldwin & Butler 1995), mechanical compaction of sand and chemical compaction of sand (Walderhaug 1996).
Hydraulic leakage	Modelling hydraulic fracturing using Griffith and Mohr-Coulomb failure criterion for the first failure, and the sliding failure criterion for reactivation of the fault zone (Lothe et al. 2004).
Stresses	The minimum horizontal stress is determined using a empirical equation (Grauls 1996). The vertical stress is dependent on the overburden ($\sigma_v = \rho g z$) where ρ is density, g is gravity and z is depth.

Input data

Different input parameters are needed to build a pressure model: depth-converted horizons for different time steps, paleo-water depth maps, reservoir isopach map, measured pressure data from wells (Figure 4) and fault maps from top reservoir:

- Low-resolution fault map: 2D lines (Figures 5a & b).
- High-resolution fault map: from 2D lines and partly from 3D lines (Figures 5c & d).

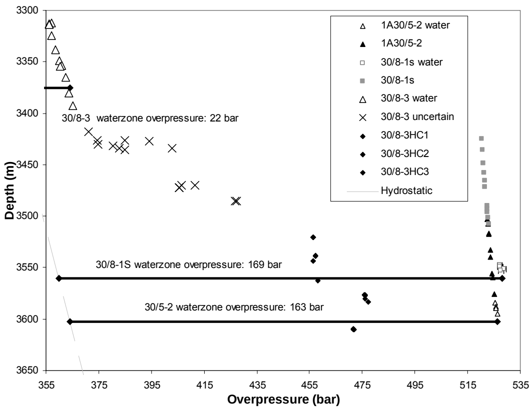

Figure 4 Overpressures measured in different wells in the Tune Field area (bar).

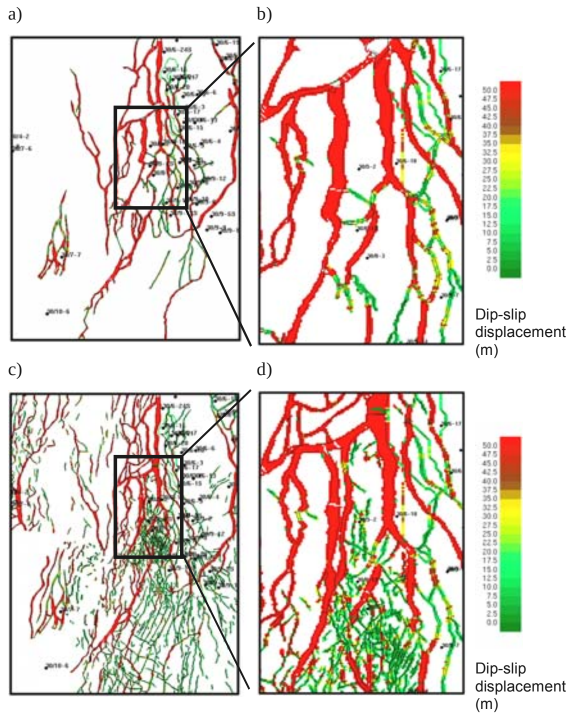

Figure 5 Low-resolution fault maps in a) All study area and b) Tune Field area. c) & d) High-resolution maps.

Results

The simulations show high overpressures generated in the deeper western parts of the Viking Graben, and hydrostatic in the eastern areas (Figure 6). A sharp pressure transition zone results from using the low-resolution fault map in the simulations (Figures 6a &b). Using high-resolution fault map results in a more transitional pressure distribution, since faults with less dip-slip displacement are interpreted (Figures 6c &d).

The transmissibilities across faults have to be lowered in order to match the observed pressured in the Tune field area (Figure 7).

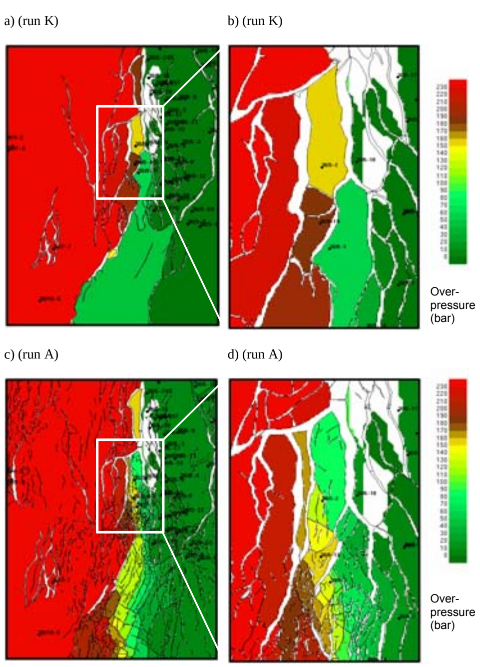

Figure 6 Simulated overpressure distribution today using a-b) low-resolution fault map and c-d) high-resolution fault map (coloured scale in bar). White areas are inside of faults, or eroded part of the reservoir.

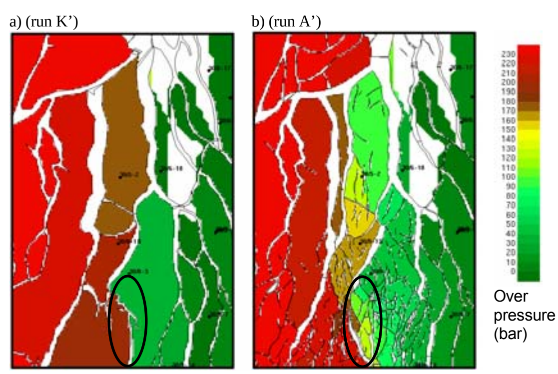

Figure 7 Simulated overpressure distribution today, using lowered transmissibilites across faults marked on the a) low-resolution and b) high-resolution fault maps.

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Figure 8 shows the difference between modelled and measured overpressure in the different compartments where wells exist. Too low overpressure (-240 bar) is generated in the deep western area when simulating the overpressure using both fault maps. This since too few faults are interpreted in the western area.

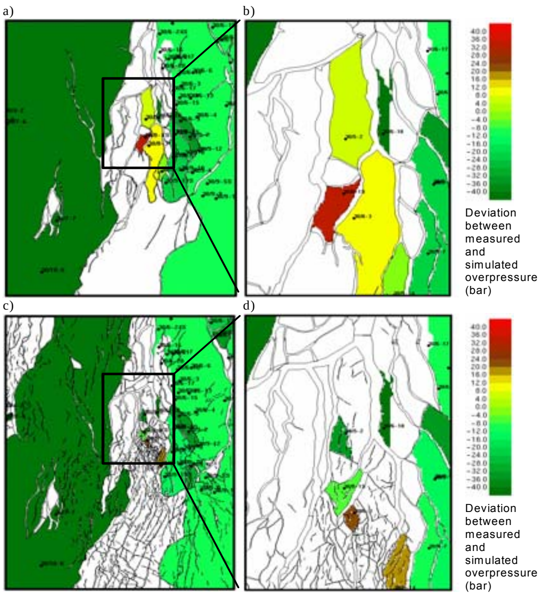

Figure 8 Deviation maps that show the compartment differences between simulated and measured overpressure in wells (coloured compartments), using low-resolution fault map with corrections a) and b), and high-resolution fault map with corrections c) and d).

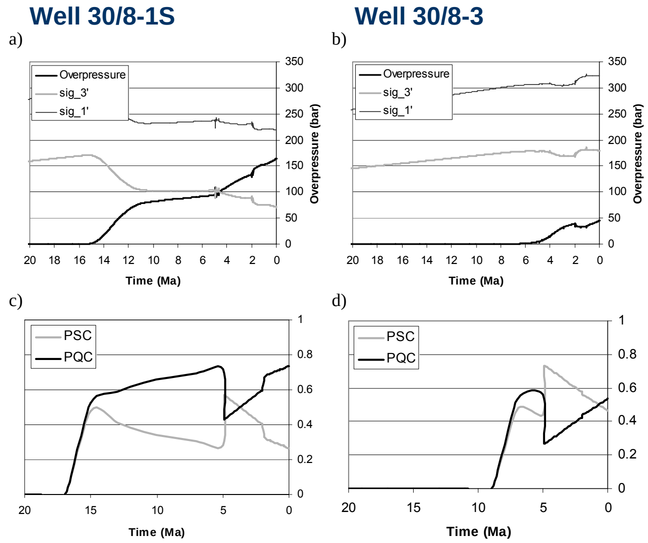

Figure 9 a & b) Pressure builds up in well 30/8-1S around 17 Ma, while in the well 30/8-3 the pressure build up started around 8 Ma. c-d) The simulations show that the pressure is controlled by quartz cementation and shale compaction.

Discussion

Childs et al. (2002) model the pressure difference between well 30/8-3 (~20 bar overpressure) and well 30/5-2 (~150 bar overpressure) using an Eclipse flow model. They find that the fault rock permeabilities are very low and/or the thickness of the fault zone is higher than what should be expected from published data.

When using the low-resolution fault map we obtain the same trend and to match the observed pressure data the transmissibility of one fault situated in the relay zone must be reduced. Using the high-resolution fault map the transmissibilities must be reduced across many of the small faults, to match the known pressure data. Even then, it is difficult to obtain the low pressure that is observed in well 30/8-3 (Figure 4), because too high pressures are simulated in the Tune in this case (Figure 9).

Conclusions

The key observations summarized as follows:

- Simulations using a low-resolution fault map give a large-scale understanding of the major trends in the pressure distribution throughout the sedimentary basin. Using high-resolution fault map give more detailed pressure modelling.
- To be able to match the overpressures measured in well 30/5-2 and 30/8-1S in the Tune Field, and well 30/8-3 east of Tune, small N-S striking faults need to have higher sealing capacity for fluids than expected.
- The intermediate pressures in the western area may be connected to pressures in the older units of the sedimentary column in the compartment of well 30/8-3.

References

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