Quantification and sensitivity of fault seal parameters demonstrated in an integrated reservoir modelling work flow. A case study on the Njord Field, Halten Terrace, Norway *Vortrag*

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The primary objective of this paper is to present a fault seal case study from the Njord Field, offshore Norway. The study utilised analogue field studies as well as core descriptions and petrophysical well data in order to evaluate the sealing potential of large to medium scale faults that segment the reservoir. Dynamic data and 4D seismic information was used to calibrate the results

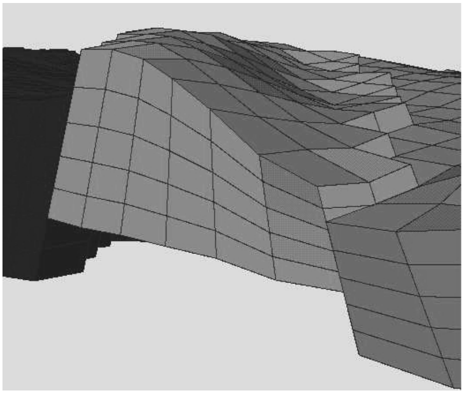

Figure 1: Reservoir simulator grid. Fault zones will be represented as grid cell boundaries with no volume.

through multiple fault seal scenarios.

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The study was performed using the FaultSeal module of Irap RMS.

Intensive faulting has in nearly all cases a strong influence on fluid flow in reservoirs. As methods to investigate fault seal have evolved and the tools are becoming integrated in the reservoir modelling work flows, the effect of faults now have an increased influence in numerical models of reservoir communication. Also, several recent articles have increased our understanding of faults and their effect on fluid flow in different types of lithology and reservoirs (e.g. Yielding et al. 1997, Manzocchi et al. 1999, Sperrevik et al. 2002). In reservoirs where faults form complex fault patterns and comprise effective seals, a good representation of the faults requires the three-dimensional geometry, displacement pattern, fault zone thickness variation and deformation characteristics. In current reservoir simulator grids, such properties must be captured in a regularised coarse grid on the grid cell boundaries (Fig. 1).

The Njord Field is one of the most challenging oil fields offshore Norway, particularly in terms of prediction of structural deformation and flow communication (Dart et al. 2004, Rivenæs et al. 2005). The field is located on the Halten Terrace, ca. 130 km NW of Kristiansund, Norway. The reservoir sequence of the Lower Jurassic Tilje Formation is approximately 120 m thick, and comprises alternating sandstones and shales, which were deposited in a tidal to estuarine paleoenvironment (Dalland et al. 1988). The structural development of the field is defined by several rifting phases throughout the Triassic, Jurassic and Early Cretaceous (Blystad et al. 1995, Ehrlich & Gabrielsen 2003). The field is structurally deformed by a com-

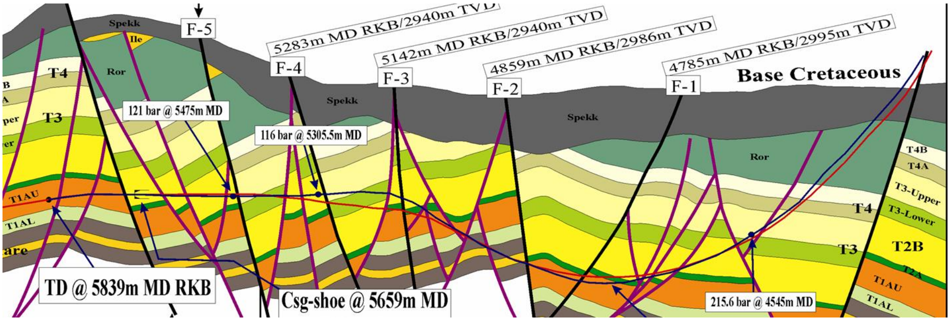

Figure 2: Cross section through a part of the Njord field showing intensive faulting and reservoir segmentation

plex pattern of segmented and linked extensional faults, which have led to a high degree of compartmentalization in the reservoir zone (Fig. 2).

Since production start-up in 1997, dynamic well data, 4D seismic surveys, and tracer data have shown that faults have a significant effect on fluid flow and communication patterns within the Njord field. Faults with displacement in excess of 25 meters are commonly regarded as sealing in relation to production timescales (Dart et al. 2004). The sealing mechanism on these faults has been assumed to be caused by shale/clay smearing. Previous unpublished studies have shown that the most important factors in fault seal assessments of the Njord field are the stratigraphy involved in faulting as well as the fault throw. Analogue field studies have therefore focussed on the mechanisms of incorporating incompetent lithology from the host rock into fault zones, and to quantify the sealing capacity of such faults (Fig. 3). Dynamic well data from the Njord field, however, show that the pressure differences across the faults are higher than those predicted from analyses of clay/shale smear. Based on core observations and measurements, it is concluded that cementation processes have been active along the faults and have increased the fault seal capacity for the faults in the Njord Field (Fig. 4). In cases where cementation processes act along faults, fault seal analysis evaluating smear effects only become ambiguous.

Figure 3: Fault core (ca. 1 m thick) consisting of sand lenses, fault gouge, and smeared coal and shale. The fault throw is approximately 15 m. Locality: Hartley Steps, Northumberland, England

This study focussed on integrating the fault seal calculations in a common reservoir modelling workflow in order to quickly investigate the effects of changing fault seal parameters and algorithms with respect to reservoir performance (Figure 5). The fault seal module of

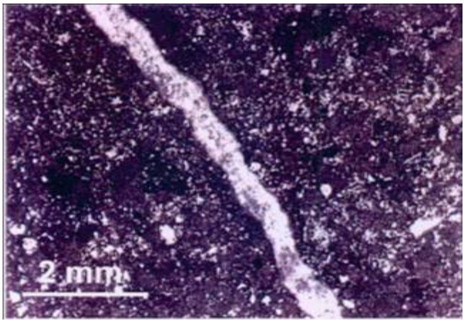

Figure 4: Micro-fault cemented by calcite

RMS has the ability to create and organize a large number of fault rock property predictions, and to export final results for reservoir simulation. The algorithms include Shale Gouge Ratio (SGR), Shale Smear Factor (SSF), Clay Smear Potential (CSP), and user-defined SGR curves, as well as the published algorithms of Manzocchi et al. (1999) and Sperrevik et al. (2002). The module supports stair-step implementation of faults, and include numerous and advanced cell face visualization that allow answers to be viewed and checked. The results from this study demonstrate the importance of evaluating the deformation mechanisms of fault prior to fault seal analyses, and the effect of a geological fault seal tuning process. The study further shows the value of integrating fault seal as one work task in a reservoir modelling work flow, enabling multiple sensitivity runs and rapid assessment of the fault seal results. The integrated workflow will certainly encourage an even tighter communication between geologists and reservoir engineers.

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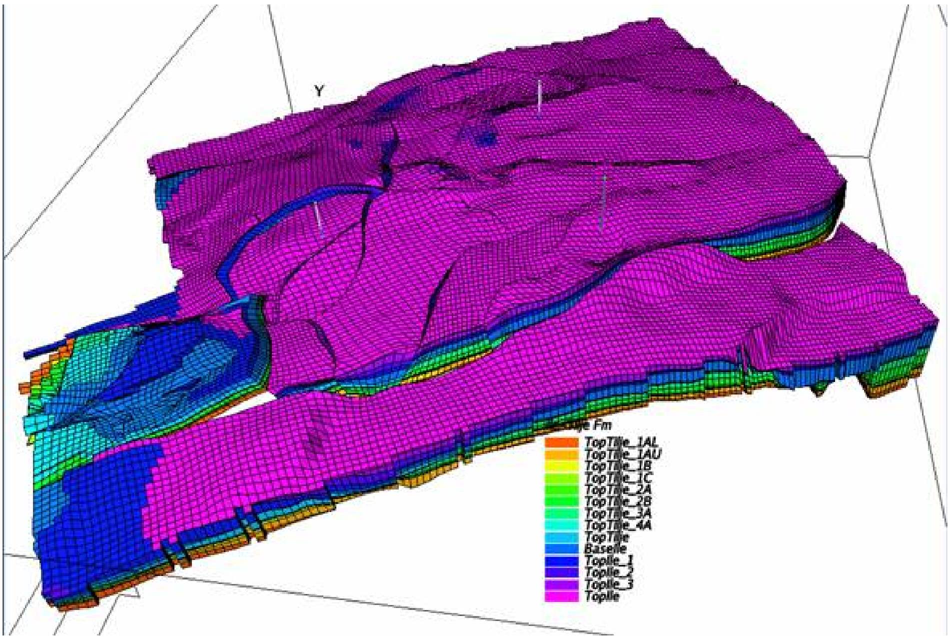

Figure 5: 3D grid of the east flank, Njord Field