Fault and Top Seals
Montpellier 2009

P47

Integrated Hydrodynamic Analysis of Fluid Pressure and Leak-off Pressure Distributions to Evaluate Seal Effectiveness

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SUMMARY

Hydrodynamic methods are used to analyse the present-day fluid overpressure and leak-off pressure distributions in offshore Netherlands in combination with recently completed stratigraphic and structural maps, and knowledge on distribution and characteristics of oil and gas accumulations. This paper presents an overview of the results, including an improved characterisation of the permeability framework of offshore Netherlands with focus on the seal effectiveness of the low permeable units and identification of locations of seal breach risk.

Research on fluid flow systems in sedimentary basins and the development and application of hydrodynamic analysis for oil and gas exploration purposes in the Netherlands started already in the late eighties. Continuation of such research was initially hampered by the lack of publicly available data on the deep subsurface of onshore and offshore Netherlands. This situation improved during the late nineties, and at present-day millions of data from oil and gas wells and groundwater wells are stored in a comprehensive quality controlled database at TNO, including fluid pressure and leak-off data (www.nlog.nl).

Hydrodynamic methods are used to analyse the present-day fluid overpressure and leak-off pressure distributions in offshore Netherlands in combination with recently completed stratigraphic and structural maps, and knowledge on distribution and characteristics of oil and gas accumulations. The hydrodynamic methods include the use and interpretation of fluid overpressure and hydraulic head maps for the main reservoir units in combination with different types of single well and multiwell cross-plots of fluid pressure and leak-off pressure. For example, we constructed multi-well plots that show the change in fluid pressure and leak-off pressure with depth for each of the main lithostratigraphic units, and for the main structural elements. These plots clearly demonstrate the regional difference in overpressured conditions and related risk of seal failure in the southern and northern part of offshore Netherlands (Figure 1).

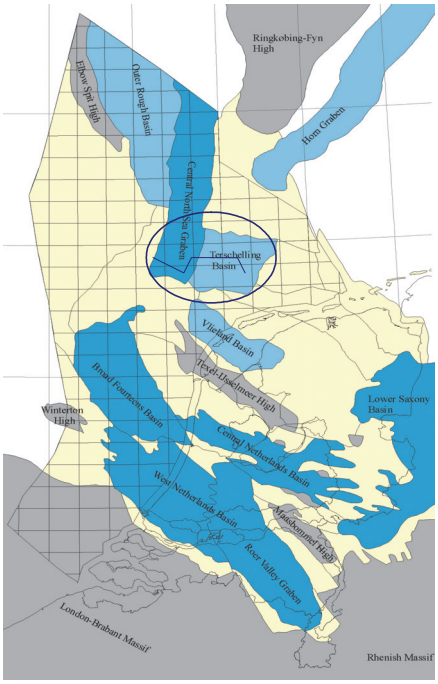

Figure 1 *The Netherlands onshore and offshore, the location of the main basins, and location of the EW cross-section of shown in Figure 3.*

In the southern area, close to normal fluid pressures are well below measured leak-off pressures. In the north, fluids are overpressured and may even approach the measured leak-off pressures in the Step Graben, Dutch Central Graben (Figure 2), Terschelling Basin , Schill Grund High, Friesland Platform and the Lauwerszee Trough. The pore pressures in these overpressured basins approach the leak-off pressures, especially at relatively shallow depths (in Chalk Group, Early Cretaceous Rijnland Group, and in Jurassic reservoir units) (Figure 2). The very high overpressures in the Terschelling Basin, Schill Grund High and Step Graben approach the realm of the leak-of pressures at greater depths.

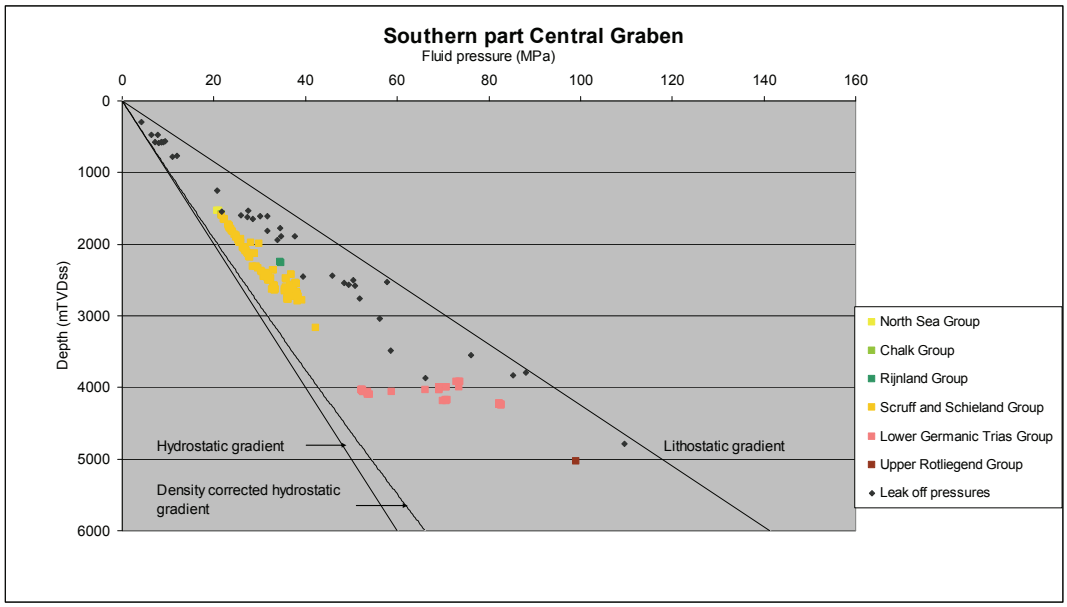

Figure 2 *Multi-well cross plot of fluid pressures and leak-off pressures in the southern part of the Dutch central Graben. Note the wide range of overpressures observed in the Lower Germanic Trias Group; the highest fluid pressures are in the realm of the measured leak-off pressures. At relatively shallow depths, the fluid pressures in the Vchalk and the Scruff and Schieland Group reach leak-off pressures as well.*

The general results of the integrated hydrodynamic analysis include the assessment of the 3D permeability framework and the related dewatering and seal breach risk conditions in offshore Netherlands (Figure 3).

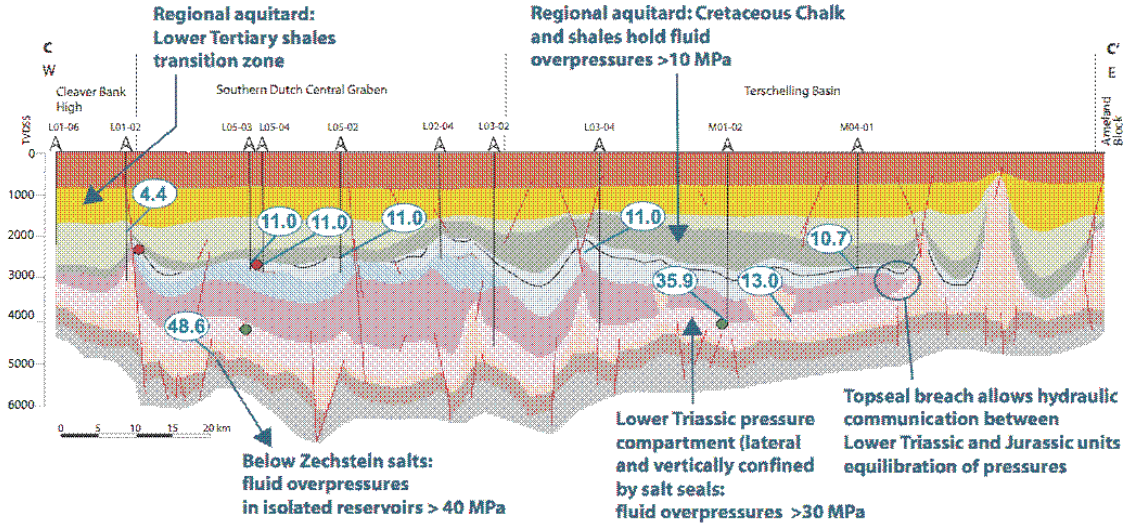

Figure 3 *WE cross section through the southern part of the Dutch Central Graben and the Terschelling Basin, including values of observed fluid overpressures (in MPa). See Figure 1 for location of the cross-section.*

This paper will present an overview of these results and provide more detailed information on selected topics, such as observed hydrodynamic phenomena in relation to occurrences of gas chimneys, shallow gas occurrences, leaky caprocks overlying hydrocarbon accumulations.