CAPILLARY AND HYDRAULIC SEAL FAILURE IN THE TARANAKI AND EAST COAST BASINS, NEW ZEALAND

David Darby, Susan Ellis & Rob Funnell

Institute of Geological and Nuclear Sciences, PO Box 30368, Lower Hutt, New Zealand.
Email: david.darby@gns.cri.nz; Fax: +64 4 570 4603; Tel: +64 4 570 4894

Seals are often assumed to be a low-risk element of New Zealand's' petroleum systems, due to the abundance of mudstones in the Taranaki and East Coast basins. However, understanding seal behaviour is not straightforward in a dynamic plate boundary environment, with its attendant complex stress state and fluid flow regime. We suggest that seal effectiveness may form a major exploration risk for many overpressured prospects in NZ basins.

Oligocene-Eocene mudstones form regionally extensive caprocks in the Taranaki and East Coast Basins. Within this interval, late Eocene mudstones are mineralogically distinct, with high smectite contents causing low permeability and high ductility. This stratigraphic interval provides significant drilling problems in NZ basins and is critical for determining the development of overpressure. The regional hydrological importance of Eocene mudstones is identified using high-resolution forward basin modelling linked to a soil mechanics approach to seal characterisation. These techniques allow derivation of compaction parameters to quantify seal compaction under vertical loading, predict overpressure and accurately model hydrocarbon charge in three dimensions. Analysis of the capillary properties of seals in the region shows that (a) a soil mechanics-based model using a compression coefficient of 0.36 can predict the decrease in mudstone porosity with increasing stress, allowing recognition of a separate trend for Oligocene-Upper Eocene marls; (b) seals can retain a 12m - 700m gas column before capillary failure, with highest values in diagenetically-cemented Miocene mudstones and lowest values in Eocene siltstones; and (c) calculated permeability based on pore throat size and specific surface area ranges from 10^{-20} to 10^{-23} m^2, with lowest values in smectite-rich Oligocene mudstones.

Complex structural regimes such as the East Coast Basin provide additional challenges in understanding seal integrity. To address these challenges, a new quantitative technique for overpressure and stress assessment has been developed using a finite-element geomechanical model. This versatile modelling technique allows 3D simulation of the stress field of a prospect, and quantification of overpressure produced by both lateral and vertical loading (Figure 1). Models have been developed and benchmarked against East Coast examples to show (a) overpressuring due to rapid subsidence and late-stage tectonic shearing; (b) prediction of minimum stress magnitude with depth, and thus the maximum overpressure; and (c) overpressure resulting from inversion and deformation of depocentres. We show that hydraulic seal failure at structurally-controlled leak points regulates overpressure and fluid flow in the basin.

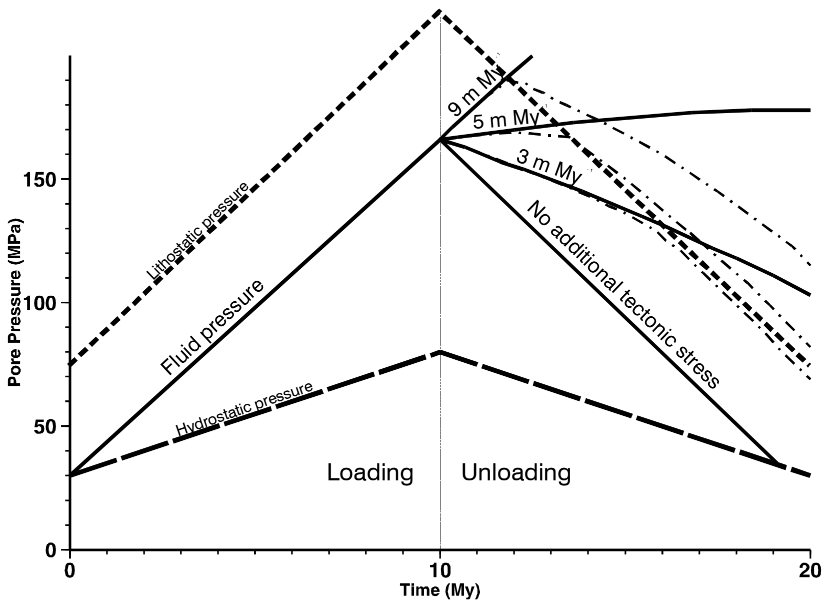

Figure 1. Modelled fluid pressure and seal integrity in the East Coast Basin, New Zealand. Overpressure is produced by disequilibrium compaction from 0-10 My. Erosion occurs from 10-20 My, and four evolutions in pore pressure related to varying deformation rates V′ are shown: V′ = 0 (no extra horizontal stress); V′ = 3 m My^{-1}; V′ = 5 m My^{-1}; and V′ = 9 m My^{-1}. Solid lines show results for no frictional yield, and dot-dashed lines show the equivalent results with frictional yield. Divergence between solid and dot-dashed lines occurs when the formation reaches yield stress. Note the existence of supra-lithostatic pore pressures at high deformation rates without seal failure.