HYDRAULIC TOP SEAL FAILURE – THE RELATIONSHIP BETWEEN HIGH PORE PRESSURE AND HYDROCARBON PRESERVATION IN HP/HT REGIONS.

Richard E. Swarbrick\(^1\), Stephen A. O’Connor\(^1\), Richard W. Lahann\(^1,2\), Phillip Clegg\(^1\) and David T. Scott\(^1\).

\(^1\)GeoPressure Technology Ltd, Stockton Road, Durham, DH1 3UZ, England (s.a.oconnor@geopressure.co.uk).
\(^2\)Indiana University, Bloomington, Indiana, USA.

As drilling worldwide aims for deeper targets, particularly in High Pressure/High Temperature (HP/HT) conditions such as experienced in the Malay Basin, (e.g. Bergading Deep, Sepat Deep and Gulin and Deep-1 wells), top-seal failure represents a high risk due to reservoir pressures close to the fracture pressure. A new methodology has been developed to analyse hydraulic failure as part of the risking strategy for prospects in these HP/HT regions.

Part of the risking strategy for prospects is an assessment of seal breach risk at top reservoir, i.e. when the seal may be breached by high pore fluid pressures causing hydraulic fractures in the top-seal. Prediction of seal breach through hydraulic failure involves pore fluid pressures reaching or exceeding the minimum stress plus the tensile strength of the seal rock. In a water-wet reservoir, the buoyancy pressure in the hydrocarbon phase is considered to have a minor influence on rock behaviour and hydraulic failure is most closely linked to aquifer pressure. It is therefore necessary to study both the aquifer and hydrocarbon seal capacity in order to assess seal breach risk.

To assess seal integrity requires data to define pore fluid and fracture pressures. Fracture pressures and gradients can be derived from analysis of Leak-Off Test data (LOT), which can be compared with fluid pressures, derived from direct pressure measurements such as, RFT, FMT and MDT data, to analyse minimum effective stress and seal breach capacity (Figure 1). In some basins data show that the overburden can be the least stress, particularly where derivation of overburden from density data has been done. Accurate derivation of a predictive fracture pressure algorithm should include a pore pressure/stress coupling ratio term (which relates pore fluid pressure to horizontal stress magnitude through poroelastic fluid-stress interaction). Sense would dictate that the smaller the seal capacity at top reservoir, i.e. the closer the pore pressures are to the fracture strength of the rock, the greater likelihood of loss of hydrocarbons via fractures. This relationship observed from examination of high pressure wells from the Central North Sea. Using hydrocarbon seal capacity has minimal impact on the delineation of dry holes and discoveries (or certainly not with regard to the column lengths present in the studied wells). A similar relationship between pore pressure, least stress and preservation of hydrocarbons is observed in the Scotian Shelf, (Bell, 1999).
In the Central North Sea example, analysis of aquifer seal capacity has been conducted at top reservoir, and also at two stratigraphic horizons within the overlying top seal. The most convincing empirical relationship is within the top-seal where, using a cut-off of 50 MPa (750 psi), and a dataset of 66 wells, 88% discoveries of the wells are discoveries in excess of the cut-off. Below the cut-off are a series of dry holes and some discoveries which are non-commercial (Figure 2).

In other HP/HT basins such as Mid-Norway, Halten Terrace there is no clear relationship between seal capacity and hydrocarbon preservation, either at top reservoir or at shallower levels in the seal. The implication here are that in the Viking Graben and Mid-Norway regions, other (or additional to pressure) factors exist influencing top-seal failure. These controls are likely linked to difference crustal stresses, with the direction of maximum horizontal stress varying in relation to fault strike, for instance, in each of these areas. Crustal stresses are potentially a combination of ice-loading, isostatic rebound of the crust and rapid sediment loading in the Plio-Pleistocene. Other factors such as top-sea lithology and thickness are also considered, therefore, to have an impact in hydrocarbon preservation. Also that hydrocarbon pressures do not strongly influence hydraulic seal failure, rather, water pressure exerts the main control.

This paper will present the workflow which have been has been established in these studies, and how they can be applied to aid the de-risking of high pressure traps in areas such as the Malay and other SE Asia Basins.


Figure 2 Aquifer seal capacity (least stress minus aquifer pressure) calculated at Base Chalk for high pressures wells in the Central North Sea. A strong correlation is observed between aquifer seal capacities < 750 psi and dry holes.