DYNAMIC SEAL FAILURE

Many exploration wells intersect traps from which hydrocarbons have leaked. The seals to these traps often fail despite being thick shales that should not be prone to capillary leakage. Leakage continues to the present day and structural permeability developed within the in situ stress field is likely to be a key cause. In situ stress data are used to avoid zones of enhanced structural permeability in seals.

Previously, such fractured seals have been classified as ‘hydraulic’ seals (with the concomitant assumption of extensional failure). Recognising the multiple components of structural permeability, we term such seals ‘dynamic’ seals, and infer:

• the limit on pore pressure may be less than sh;
• retention capacity may be less than (sh - Pp);
• ‘risking’ leaking fault orientations should recognise the potential of all components of structural permeability meshes.

DYNAMIC Fault-SEAL FAILURE

A FAST (Fault Analysis Seal Technology) map integrates structural geometry with in situ stress conditions to visualize relative probability of structural permeability. Structural geometry is best provided from seismic data. The quality of the data and the interpretation dictates the quality of the map. Faults are subdivided into fault segments at a frequency representative of the data resolution.

Fracture Susceptibility

The low porosity (<10%), low permeability (<1mD) Permian reservoirs of the Cooper Basin contain a vast tight gas resource. However, obtaining commercial flows is problematic. Induced hydraulic fracturing has met with limited success, and exploration is focusing on intersecting zones of enhanced natural structural permeability.

In this instance it is important to recognise that structural permeability developed within palaeostress fields may provide the key to unlock the tight gas resource. Ongoing analysis of the area is including:

• structural analysis of the tectonic history of the basin (3D restorations);
• assessment of the role and stress-sensitivity of pre-existing fractures, and;
• analysis of the contemporary stress field and its influence both on pre-existing fractures and in creating any ‘recent’ structural permeability.

Fracture populations can be observed on resistivity image logs (e.g. FMS, FMI and STAR). Conductive fractures are conventionally interpreted as open natural fractures and resistive fractures as closed. All fractures can be represented in terms of the shear and normal stress components on a 3D Mohr circle and can be compared to the predicted fracture susceptibility based on structural permeability theory.

There is a good correlation between the orientation of observed conductive fractures and predicted orientations of high fracture susceptibility and between the orientation of resistive fractures and predicted orientations of low fracture susceptibility. Conductive fractures that correspond to predicted orientations of low fracture susceptibility may be “open” due to the redistribution of stresses around the wellbore and may not necessarily be open in the far-field.

Compressive shear fractures that occur as part of breakout formation are observed as high angle, breakout parallel, conductive fractures on two opposing pads. These fractures are of drilling induced origin and are a response to the distribution of stresses at the borehole wall. The orientation of breakout related fractures corresponds to predicted orientations of low fracture susceptibility with respect to the far-field stresses. When these fractures are assessed in terms of the unique stress conditions at the borehole wall they correspond with considerably higher shear stress and fracture susceptibility prediction.

Structural permeability stereonets are used to determine relative probability for individual fault segments and each are designated a representative colour value. Each fault segment is plotted in its corresponding colour to produce a relative structural permeability map.

A FAST map allows rapid identification of fault segments that are more susceptible to failure through structural permeability networks. The impact of subtle changes in fault dip or orientation along strike and the effect on probability of fault seal breach can be evaluated rapidly and integrated with additional data.

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