RISKING BRITTLE FAILURE OF CAPROCKS IN THE OTWAY BASIN, AUSTRALIA

S.D. Mildren[1] P.J. Boult[2] and B.A. Camac[3]

[1]Australian Petroleum Cooperative Research Centre,
National Centre for Petroleum Geology and Geophysics,
Adelaide University, Thebarton Campus, Adelaide, South Australia 5005.
smildren@ncpgg.adelaide.edu.au

[2]Office of Minerals and Energy Resources, South Australia
GPO Box 1671 Adelaide SA 5001
Boult.Peter@saugov.sa.gov.au

[3] Consultant, abc@granite.net.au

Many of the commercial hydrocarbon accumulations discovered within the Early Cretaceous Pretty Hill Formation in the onshore Otway Basin of southeastern Australia rely on a semi-brittle top seal (Laira Formation) and cross-fault seal. An integrated multi-disciplinary assessment of seal integrity in the Penola Trough identified fault reactivation as the controlling factor associated with seal breach (Jones et al, 2000). The risk of fault reactivation has since been calculated for various prospects across the Otway Basin using the FAST mapping technique (Mildren et al, 2002). However, in its original form, FAST failed to explain breached hydrocarbon accumulations associated with structurally bound traps with low risk of fault reactivation in the Penola Trough (Boult et al, 2002). Furthermore, these studies did not include a geomechanical analysis of the top seal to address the risk of brittle failure or the development of structural permeability networks.

Fault correlation and displacement mapping, using 3D seismic and variance data, was augmented with interpretation of dip-meter and high-resolution borehole images to reveal a complex fault history and contemporary stress distribution. Some Early Cretaceous, basement related, E-W faults have not been reactivated while Late Cretaceous to Tertiary NW-SE faults appear to have a shallow origin and have recently been reactivated. The maximum horizontal stress direction interpreted from borehole breakout and FMI images in Balnaves-1 indicate that the E-W Balnaves Fault influences stress trajectories by as much as 30° (Figure 1 and Figure 2). It is possible that fault related contemporary stress rotations on E-W faults are related to strength contrasts between fault rock and host rock.

Failure envelopes measured from cataclasites and host reservoir material at Banyula-1 indicate that the reservoir sandstone would fail in preference to the fault rock at high differential stresses (Dewhurst et al, 2002). In the scenario where the fault rock is stronger than the sealing unit, brittle failure of the seal would be a serious risk to trap integrity. It is possible that brittle failure of caprocks is a high risk in the Penola Trough. A new technique, based on the FAST methodology, is being developed to assess the risk of brittle failure of the caprock using the in situ stress field and rock strength as input parameters (Figure 3). Log derived strength estimates are used in conjunction with detailed observations of the in situ stress field to map risk across the Laira Formation. Fracture distribution through the seal is observed from image logs and used to calibrate risk calculated using the modified FAST methodology (Figure 4). The results from three separate traps in the Otway Basin are compared: Balnaves (partially breached), Zema (breached) and Redman (fill to spill).

BOULT, P.J., CAMAC, B.A. AND DAVIDS, A.W. 2002-3D Fault modelling and assessment of top seal structural permeability – Penola Trough, onshore Otway Basin. Australian Petroleum Production and Exploration Association Journal, 42 (1), 151- 166.

DEWHURST, D.N., JONES, R.M., HILLIS, R.R., AND MILDREN, S.D., 2002-Microstructural and geomechanical characterisation of fault rocks from the Carnarvon and Otway Basins. Australian Petroleum Production and Exploration Association Journal, 42 (1), 167-186.

JONES, R.M., BOULT, P., HILLIS, R.R., MILDREN, S.D. AND KALDI, J., 2000-Integrated hydrocarbon seal evaluation in the Penola Trough, Otway Basin. Australian Petroleum Production and Exploration Association Journal, 40(1), 194-211.

MILDREN, S.D., HILLIS, R.R. AND KALDI, J., 2002-Calibrating predictions of fault seal reactivation in the Timor Sea. Australian Petroleum Production and Exploration Association Journal, 42 (1), 187-202.

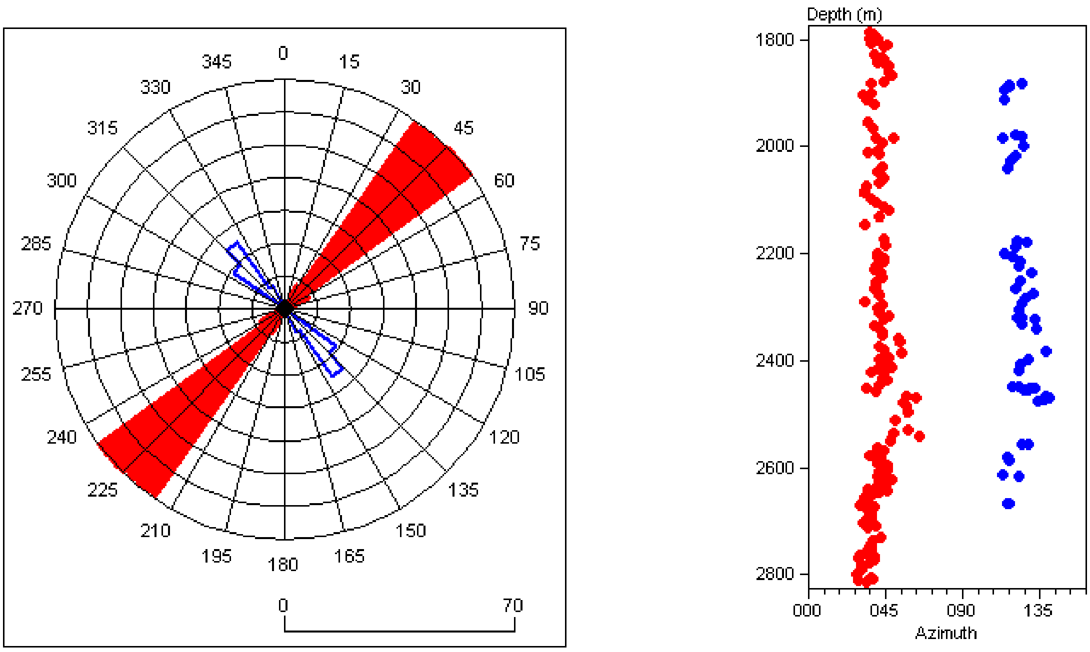

Figure 1 Breakout azimuth (red) and drilling induced tensile failure (DITF) azimuth (blue) from Balnaves-1. Note rotation of stress indicators at approximately 2500 m TVDSS.

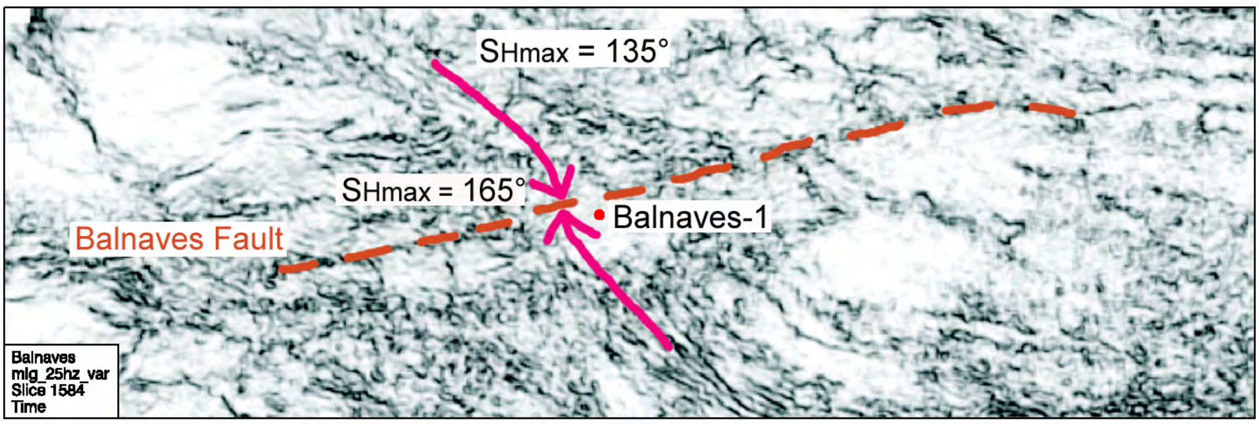

Figure 2 Illustration of σ_{Hmax} rotation adjacent to the Balnaves Fault as observed by breakouts and DITF.

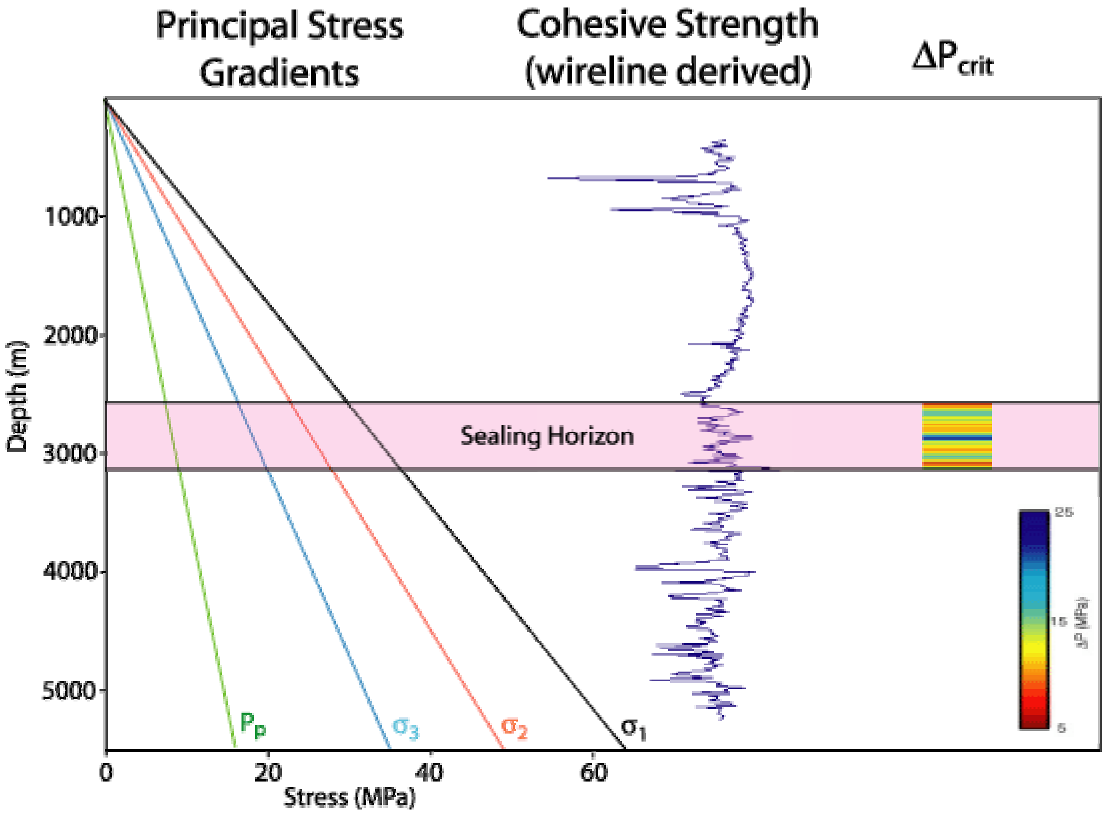

Figure 3 Graphical description of methodology used to risk brittle failure of caprock. Knowledge of the insitu stress tensor is combined with wireline derived mechanical rock properties to estimate the critical pressure change (ΔP_{crit}) required to induce brittle failure. ΔP_{crit} corresponds to the maximum buoyancy pressure the seal can hold which can be converted to an estimate of the maximum hydrocarbon column height or retention capacity.

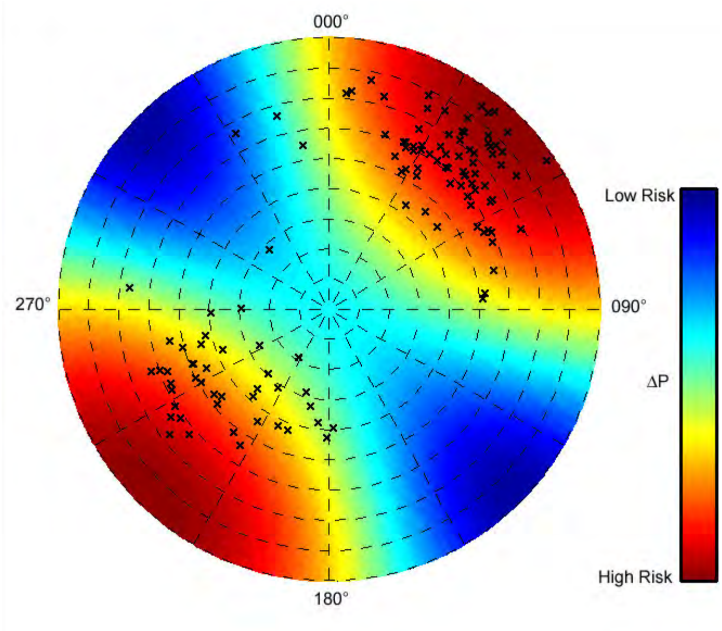

Figure 4 Fracture susceptibility stereonet for Laira Formation at Balnaves-1. ΔP is contoured with respect to all possible fracture orientations plotted as poles to planes on a southern hemisphere projection. Conductive natural fractures interpreted from the Balnaves-1 FMI image log through the Laira Formation are super imposed. Conductive natural fractures are assumed to be hydraulically conductive. Natural fractures plot in high risk zones corresponding with ΔP_{crit} for this particular stress environment and rock strength.