Applications of Stress Testing and Micro-Proppants to Improve Frac Treatments in the Taroom Trough, Bowen Basin, Australia

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Background: The Taroom Trough, Bowen Basin, Queensland

- Cabawin 1 (1960) (A, Fig A) was the first well drilled into the deepest part of the Taroom Trough and proved the presence of a working petroleum system in the Permian Kianga Group (Fig B)
- In the period 2011-2015, seven QGC wells were drilled (See Fig A) to understand the tight gas sand prospectivity of Back Creek, Kianga, and Rewan Fms
- Daydream 2 was drilled downdip of QGC Daydream 1 (B, Fig A)

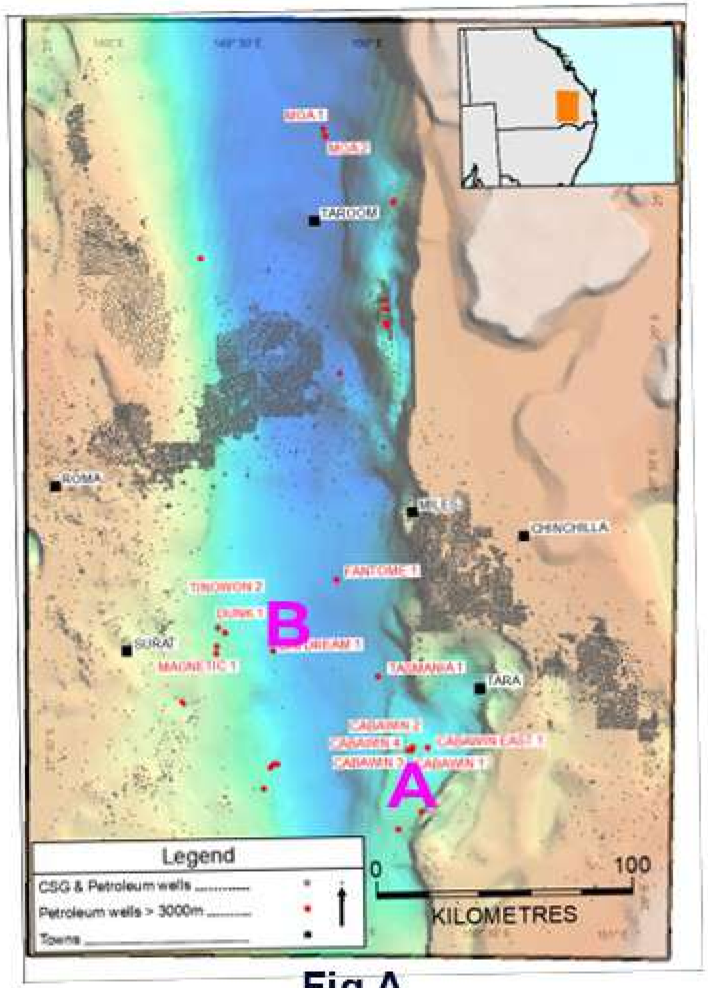


Fig A

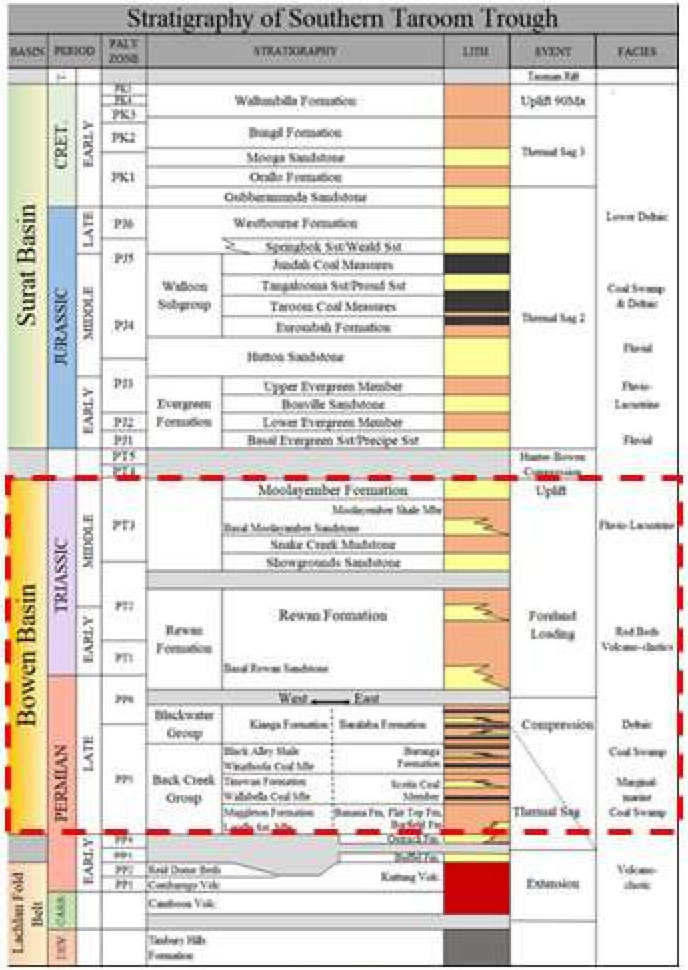
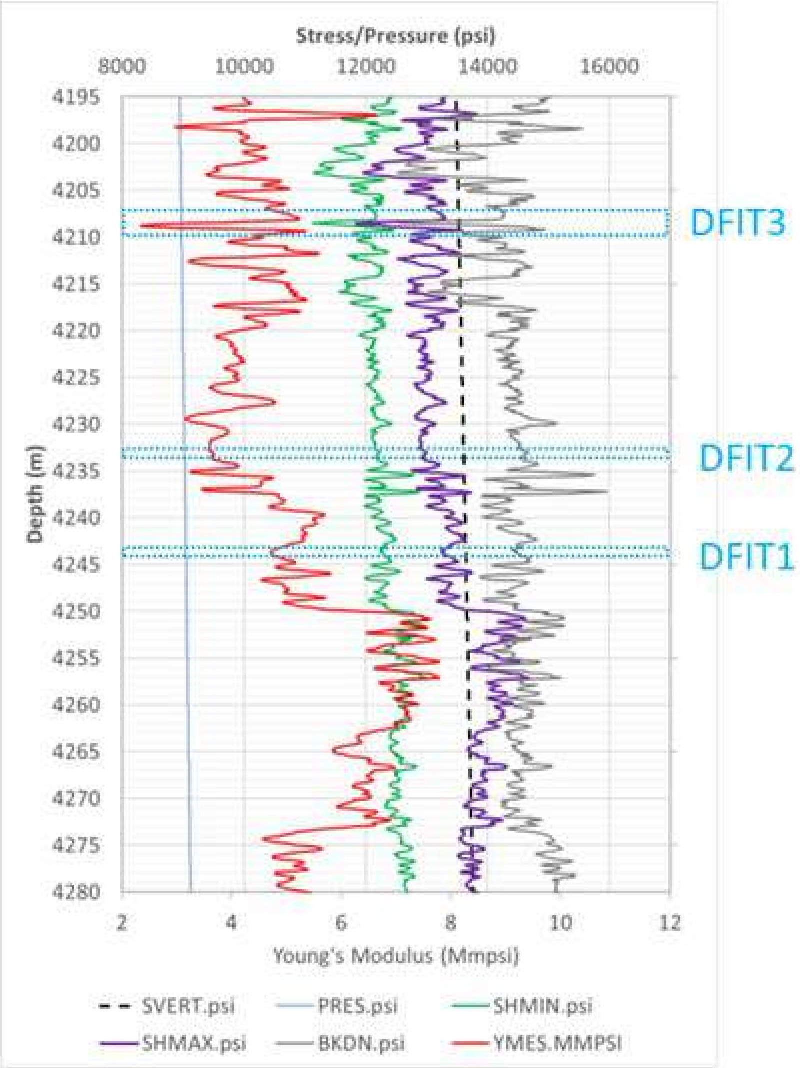


Fig B

Elixir Energy, Daydream 2 Back Creek Fm DFIT Strategy

- Three intervals were chosen for DFITs – 2 non-pay (rathole section) and 1 pay interval based on:
  - Varying modulus
  - Varying stress
  - Low breakdown pressures, bounding stresses
- Each interval acquired and confirmed the breakdown pressure and fracture closure
- On DFIT 3 (pay) ACA data was acquired to bracket the permeability (for later well testing) and confirm the overpressure derived from drilling estimates from gas "kick"



The Objective: Multiple DFITs in Varying Moduli

Data can be used to reach a singular solution for strains in a strike-slip stress regime by minimising an error function across the following 3-4 interrelated equations:

$$\sigma_{hmin} = \frac{\nu}{1-\nu}(\sigma_v - \alpha_v p_p) + \frac{E}{1-\nu^2}\varepsilon_h + \frac{E\nu}{1-\nu^2}\varepsilon_H + \alpha_h p_p$$

$$\sigma_{Hmax} = \frac{\nu}{1-\nu}(\sigma_v - \alpha_v p_p) + \frac{E}{1-\nu^2}\varepsilon_H + \frac{E\nu}{1-\nu^2}\varepsilon_h + \alpha_h p_p$$

$$P_{Breakdown} \text{ or } Pwb = 3\sigma_{hmin} - \sigma_{Hmax} - P_{Pore} + T_o$$

$$P_{FissureOpening} \text{ or } Pfo = 1/2\,(\sigma_{Hmax} + \sigma_{hmin}) + 1/2\,(\sigma_{Hmax} - \sigma_{hmin})\cos 2\theta$$

Blue items are observed

T_o = 0 for reopening fracture or relationship to Static Young's modulus, and a Biot's relationship of shaliness/porosity (note that shale gas studies confirm Biot's is variable)

Red Items are unknowns and fit by error minimisation (Johnson, 2016; Pokalai et al., 2016)

The Result: A Calibrated 1D Stress Profile

- Using the data from three locations with differing stress and moduli with the poro-elastic equations, a calibrated stress profile could be created for the Back Creek (Fig A) intervals that was corroborated to the top of the Kianga Fm generally indicating a mixed normal/strike-slip regime (Fig B)
- As aforementioned ACA was used to determine the permeability and confirm the pressure derived from drilling estimates and later confirmed by transient well testing of the uppermost interval

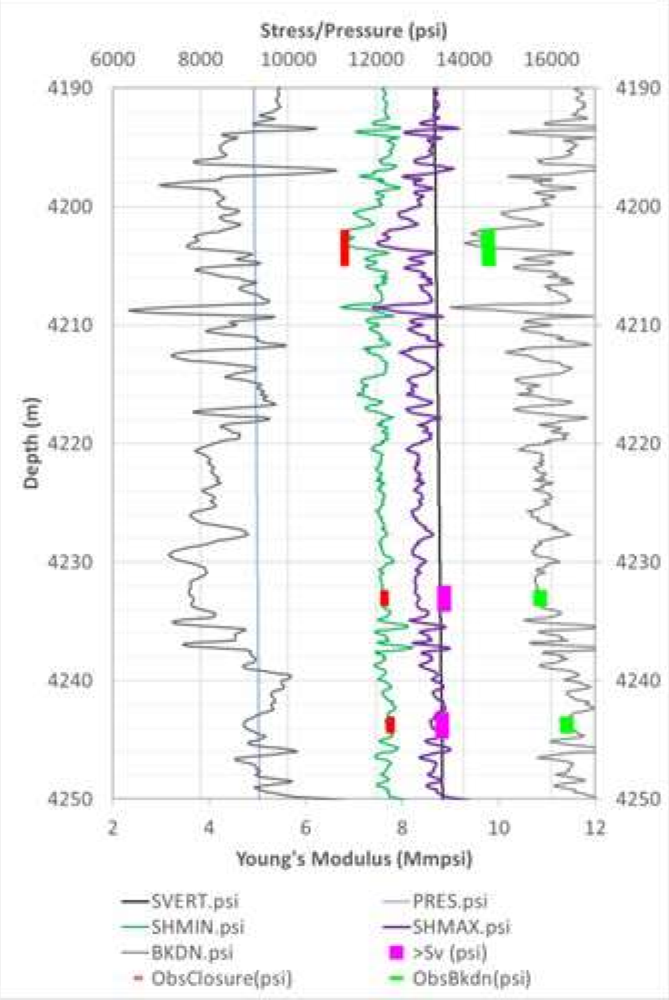


Fig A

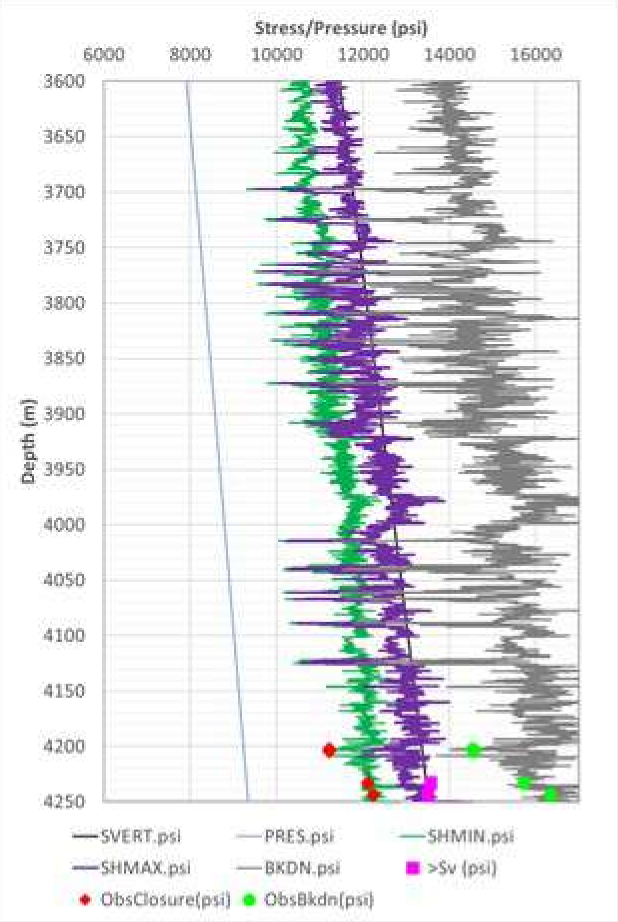
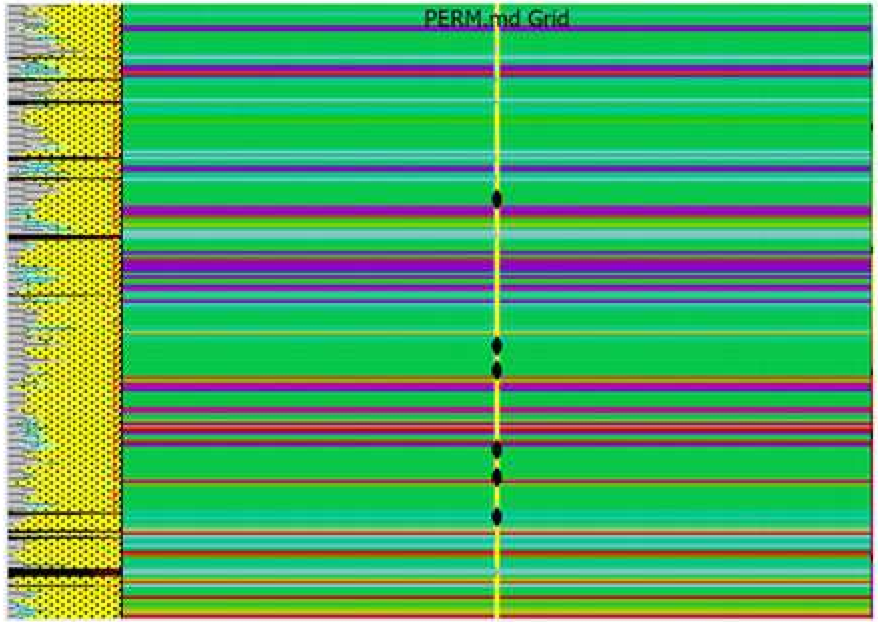
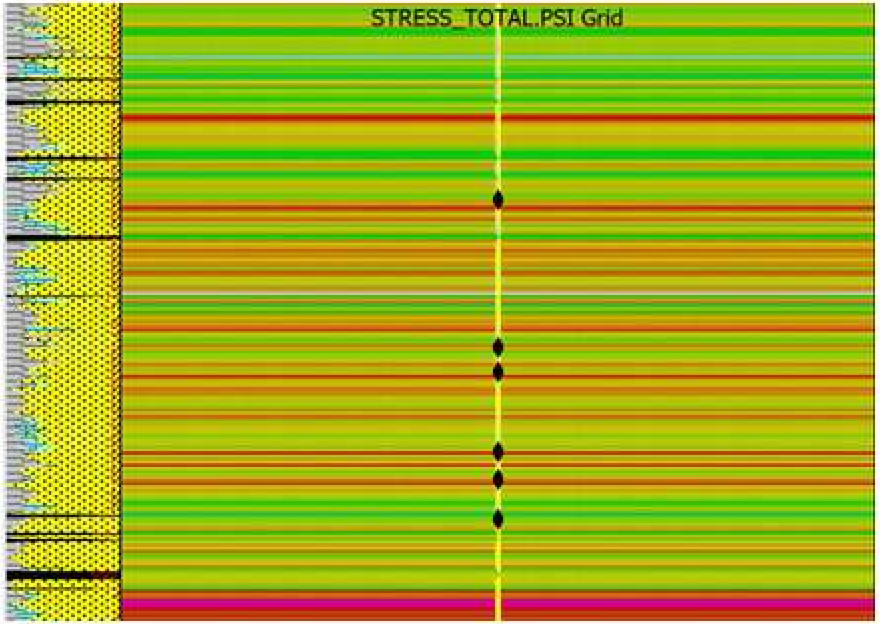


Fig B

The Reason: Improve Perforation Selection in Low-Permeability Sections in an Interbedded Strike-Slip Regime





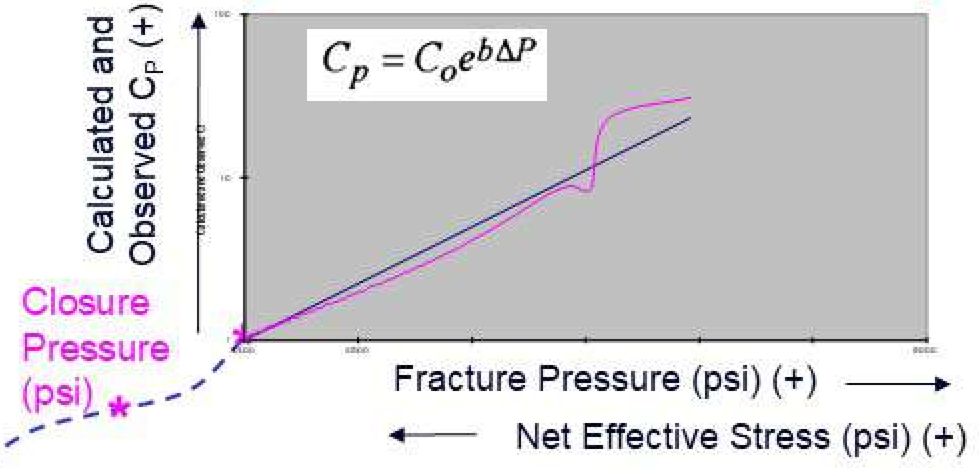
- Identifying low-stress initiation points adjoining higher permeability sections allowed standoff from lower-stressed interbedded coal intervals in Stages 2,4 & 5 that would "thief" the treatment
- Pre-frac modelling showed better results compared to earlier QGC perforation strategies in prior Taroom Trough wells (Johnson & Parker, 2023)

Goal 2: Improved Outcomes in Deep Coal Stimulations using Micro-Proppants

- Studies have shown that in high PDL environments with fracture complexity, have failed to deliver a SRV adequate to achieve commercial gas flows (Johnson, Scott, et al. 2010, Johnson, Glassborow, et al. 2010, Johnson et al. 2002, Flottmann et al. 2018, Flottman et al. 2013)
- Observed fracture complexity closes as a result of cleat/fracture scale and being unpropped (Johnson et al., 2010)
- Laboratory testing under low net-effective stress conditions indicates micro-proppant technology potentially benefits reservoirs with PDP and is designed to accelerate matrix shrinkage effects by keeping small fractures open (<50mm) (Keshavarz et al., various publications, 2014-2016)
- The 2022 UQ-NERA Project Final Report provides guidelines on design, execution, and evaluation of micro-proppant treatments as well as application guidance on execution (Johnson, Leonardi, You, Rabeiro, et al. 2022):
- **Field trials have been completed with two jobs successfully pumped in the Taroom Trough at ~3800 and ~4100 m intervals with gas noted from isolated, post-frac independent testing of coals at ~3800 m**

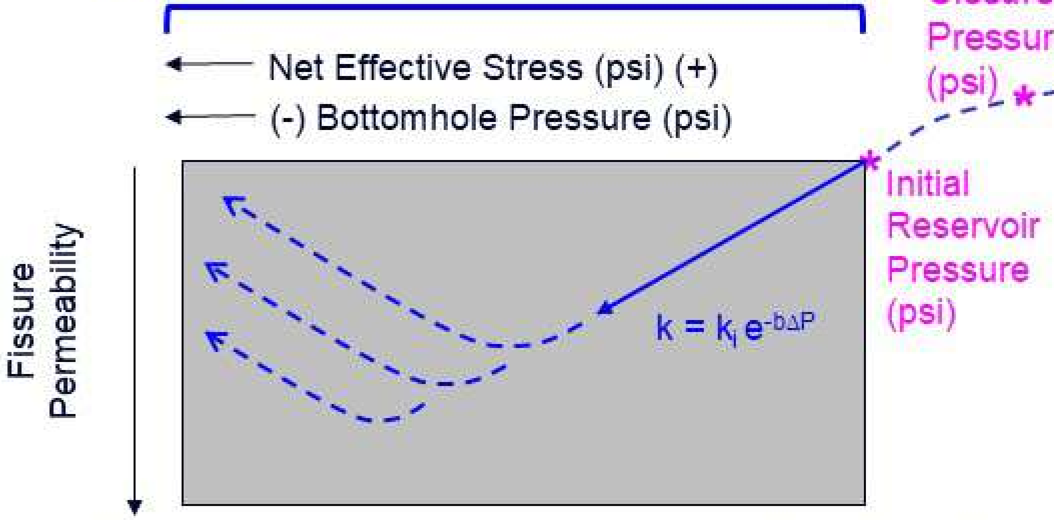
Why: Micro-Proppants In Coal Could Counter Negative PDP Effects During Production

(1) DFIT before closure analyses provide PDL coefficient 'b'



After Mukherjee & Barree (1996)

(3) Initial PDP parameters follow exponential decline, coefficient 'b'



(2) After closure analysis and 3D frac model can describe initial permeability and reservoir parameters

- Calculated C_p/C_o ratio is compared with the value obtained from the exponential relation, where b = slope (blue line)
- Carter leak off (C_L or C_o) equation is driven by permeability and delta pressure (Howard & Fast (1957)

$$C_{L_t} = 0.0374\left(P_f - P_o\right)\left(\frac{\phi k c_t}{\mu}\right)^{0.5}$$

Permeability change in coals are exponential functions of change in pressure/stress based on material properties and fracture compressibility (e.g., Palmer and Mansoori, 1998; Shi and Durucan, 2009; etc.)

Summary

- Elixir planned several R&D objectives to improve stimulation treatments in Daydream
  - Acquiring DFIT data to improve stimulation designs in mixed clastic intervals of Back Creek and Kianga Fms
  - Implementing a calibrated 1D stress profile to improve Back Creek and Kianga coal stimulation planning and post-frac evaluation
  - Applying micro-proppant technologies (<50μm) in both deep coal intervals to stimulate natural fractures and counter PDP effects
- DFITs in targeted pay and non-pay intervals did create a calibrated stress and permeability profile matching observations
- The calibrated stress profile allowed perforation placement to reduce fracture 'thieving' by small, lower-stressed interbedded coal intervals
- Evaluating and trialling MP coal treatments using DFITs and shut-in periods to evaluate low-permeability coals
- Daydream-2 achieved the first two microproppant coal stimulations flowing gas to surface from the six stimulated coal seams between 3,786 and 3,678 metres deep during flowback.