Windorah Gas Project

Developing a Significant Gas Field in the Cooper Basin

Real Energy Corporation Limited (ASX: RLE)
APPEA Conference : Extraction Technology for Basin Centred Gas
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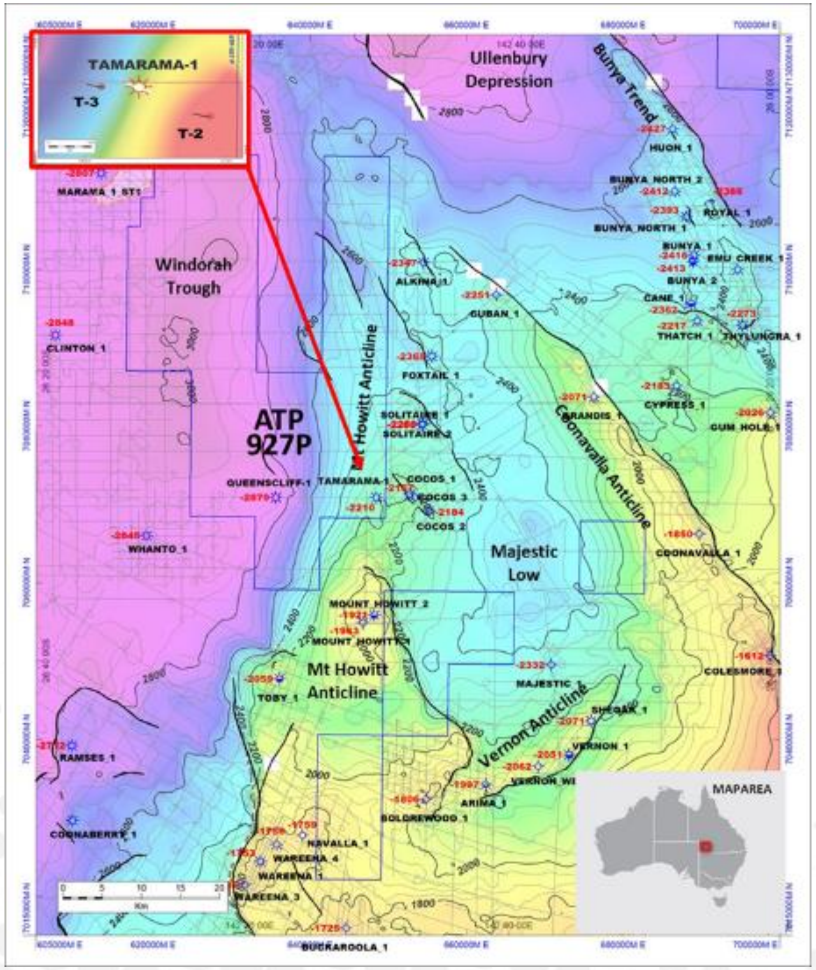
Geological Information
The geological information in this presentation relating to geological information and resources is based on information compiled by Mr Lan Nguyen, who is a Member of Petroleum Exploration Society of Australia, the American Association of Petroleum Geologist, and the Society of the Petroleum Engineers and has sufficient experience to qualify as a Competent Person. Mr Nguyen consents to the inclusion of the matters based on his information in the form and context in which they appear. The information related to the results of drilled petroleum wells has been sourced from the publicly available well completion reports.

Outline

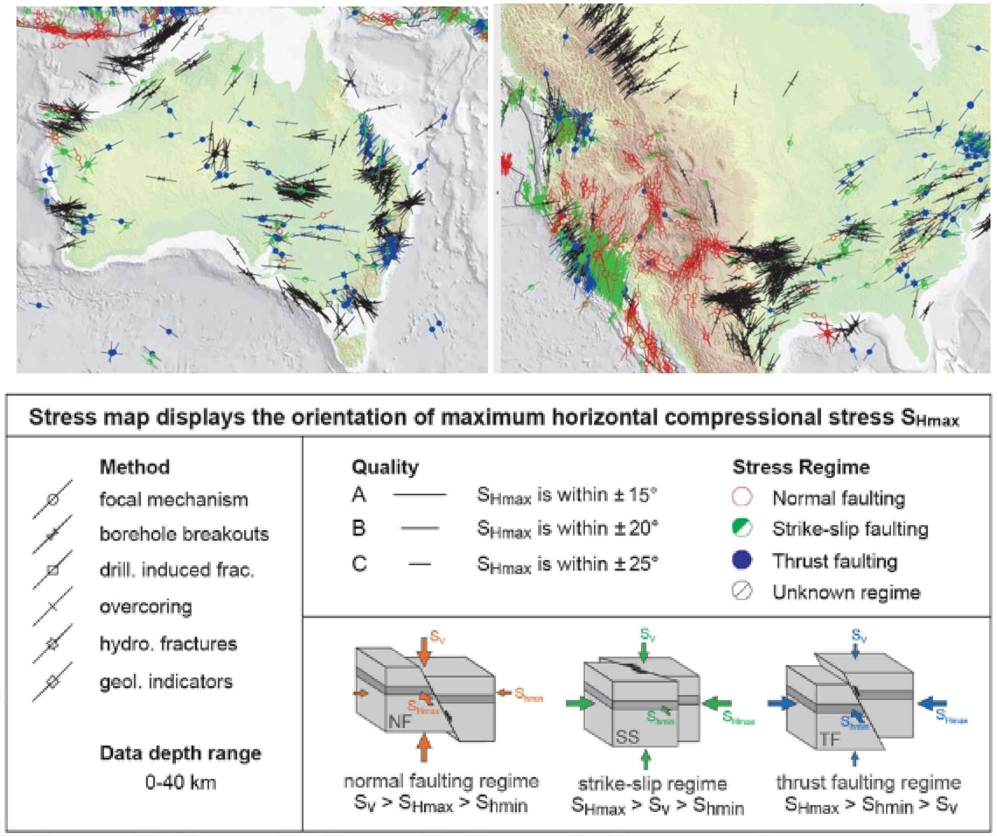
- Overview of the Cooper Basin and study area
- Tamarama 1 observations and results
- Tamarama 2 and 3 modifications
- Use of machine learning in Tamarama 2 log reconstruction
- Tamarama 2 and 3 observations
- Results to-date
- Conclusions
- Go-forward strategies

Cooper Basin and Study Area



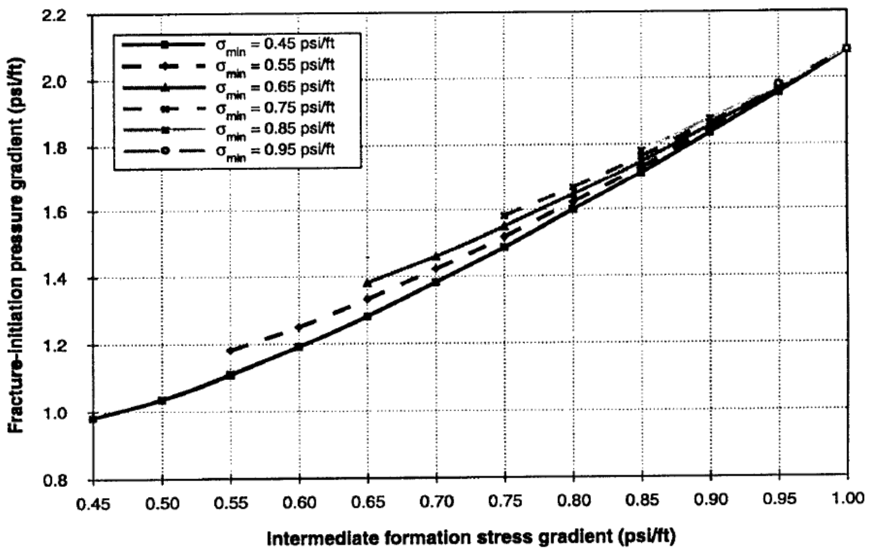
- Study area (ATP 927) is located in the Permo-Triassic Cooper Basin in SW
- Gas discoveries have been made on structural trends in adjacent areas
- Real Energy drilled, completed and tested Tamarama–1 and Queenscliff–1 with gas flow to surface from the Upper Patchawarra and Toolachee Fms after underbalanced perforating in 2014
- Both wells were drilled at locations independent of structural closure
- Tamarama 2 and 3 were drilled then stimulated in 2018

Cooper Basin Stress State



- Unlike North America problematic fracturing conditions result from high deviatory stress conditions in the Cooper Basin (Johnson & Greenstreet 2004)
- The Basin can be overpressured resulting in strike-slip with reverse stress states in the deeper portions (Reynolds et al, 2007)
- Diagnostic studies have shown problematic initiation likely propagates into far-field fracture complexity (Pitkin et al., 2012; Scott et al., 2013; Johnson et al., 2015)

Analytical Solutions for Fracture Initiation



After Deeg, SPE 47386, 1998

$$\sigma_r = \frac{\sigma_h + \sigma_H}{2}\left(1 - \frac{r_w^2}{r^2}\right) + \frac{\sigma_h - \sigma_H}{2}\left(1 - 4\frac{r_w^2}{r^2} + 3\frac{r_w^4}{r^4}\right)\cos 2\theta + \frac{r_w^2}{r^2}\left(P_w - \alpha P_o\right)$$

$$\sigma_t = \frac{\sigma_h + \sigma_H}{2}\left(1 + \frac{r_w^2}{r^2}\right) - \frac{\sigma_h - \sigma_H}{2}\left(1 + 3\frac{r_w^4}{r^4}\right)\cos 2\theta - \frac{r_w^2}{r^2}\left(P_w - \alpha P_o\right)$$

$$\sigma_v = P_{ob} - \alpha P_o$$

σ_r = radial stress
$\sigma_{t \text{ or } \theta}$ = tangential stress
σ_v = vertical stress

After Kirsch, 1889

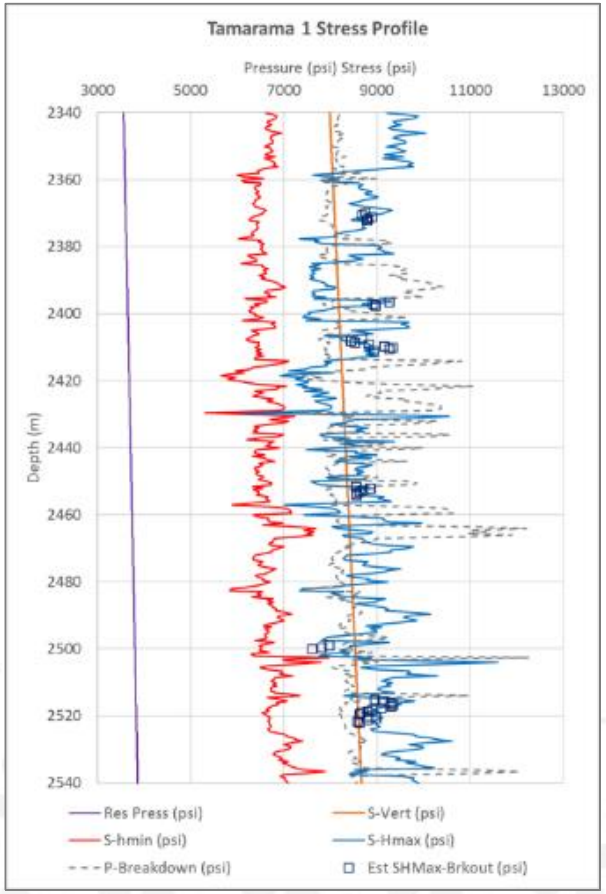
Johnson, AEGC, 2018

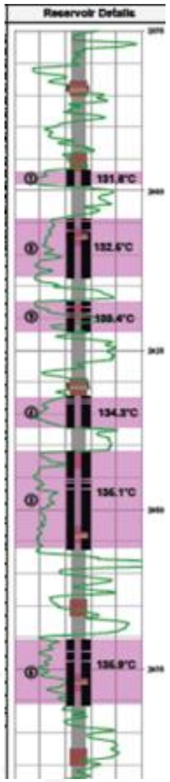
"I Have a Feeling We're Not in Kansas Anymore"– Dorothy, The Wizard of Oz

- Widespread belief: Vertical or horizontal wellbores drilled in the $\sigma_{h\text{-}min}$ direction will have improved low-permeability reservoir deliverability by creating simple vertical or transverse hydraulic fractures
  - These is likely in normally stressed environments where breakdown pressures are less than the vertical stress ($\sigma_{Vertical}$)
  - Believed that fractures oriented acutely to the plane normal to the $\sigma_{h\text{-}min}$ direction will naturally reorient themselves
  - **This works in North America where a normal stress regime prevails** $\sigma_{h\text{-}min} \leq \sigma_{H\text{-}Max} < \sigma_{Vertical}$ and natural fractures and joints are predominantly oriented in $\sigma_{H\text{-}Max}$ direction
- Reality: Australia is not so fortunate….we are strike-slip to reverse regime $\sigma_{h\text{-}min} \leq \sigma_{Vertical} << \sigma_{H\text{-}Max}$.
- Being in strike-slip is not so bad but breakouts and NWB flaws don't help our situation- see APPEA 2015 EA!

Johnson, AEGC, 2018

Tamarama 1 Observations and Results

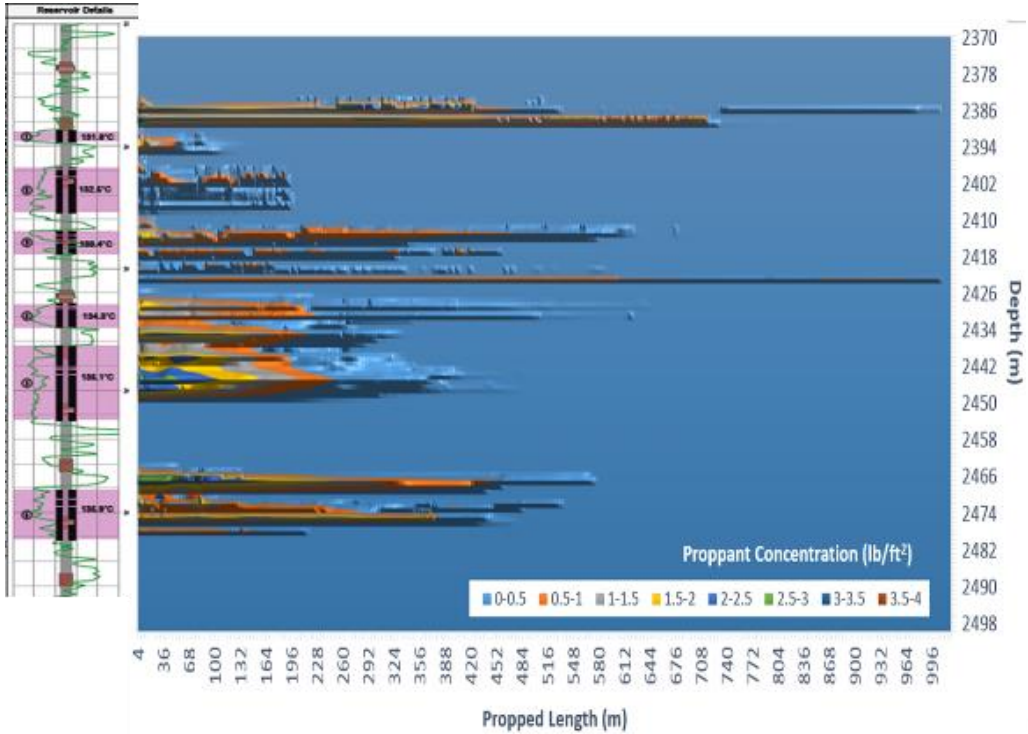




- Initial stress profile, petrophysics and rock-typing were used to develop completion strategy and determine intervals for DFITs
- DFIT data, borehole breakout and DITF indicated strike-slip stress state in sands/shales and normal and lowered stress state in coals
- Zones were isolated by an inside casing, tubing deployed, swell packer with frac sleeve, isolation system to achieve full coverage
- Five (5) frac stages were effectively targeted in the Patchawarra and Toolachee Fms

Tamarama 1 Observations and Results

- High tortuosity and screenout conditions were observed in all intervals except top interval stage, which indicated growth into the Toolachee coal
- Treatments totaled 342,000 gallons of gelled and crosslinked gelled water with 433,000 pounds of proppant, mostly 20/40 medium strength ceramic
- Well effectively flowed back load fluid then begin producing water after frac communication with the Toolachee coal



Post-Tamarama 1 Action Steps – Improve Well Orientation

- Question 1: could drilling inclined wells in the σ_{HMax} direction reduce wellbore defects by improved stability?
  - Recent experimentation with orienting wellbores in the σ_{HMax} direction reduced fracture complexities in another strike-slip Australian basin indicated that both 27° and 60° inclined wellbores resulted in significant improvements in fracture orientation based on surface tiltmeter and microseismic monitoring (Bentley et al., 2013)
  - Past studies of horizontal wells showed the benefit of alignment in the σ_{HMax} direction to create less complex, longitudinal fracturing aligned with the horizontal wellbore
- Action steps:
  - Tamarama 2 and 3 were in 31° and 25° final inclinations and azimuths of 279° and 271° WNW, respectively.
  - σ_{HMax} direction in the Windorah Trough was consistently observed from a study of surrounding wells as being 285° WNW, consistent with E-W trend of Cooper Basin

Post-Tamarama 1 Action Steps – NWBPL Reduction

- Question 2: could orienting perforation in the σ_{HMax} direction reduce NWBPL?
  - Past experimentation in the Cooper Basin of Southwest Queensland indicated that orienting perforations in the σ_{HMax} direction reduced NWBPL and improved well performance relative to offsetting well treatments without oriented perforations and the introduction of viscous gel slugs (Johnson, R. L., Jr. et al., 2002; Johnson, R. L., Jr. & Greenstreet, 2003).
- Action Step:
  - Perforations were aligned 4 jet shot per ft at 0° and 180° along the length of the wellbore for both DFIT and fracturing treatments.

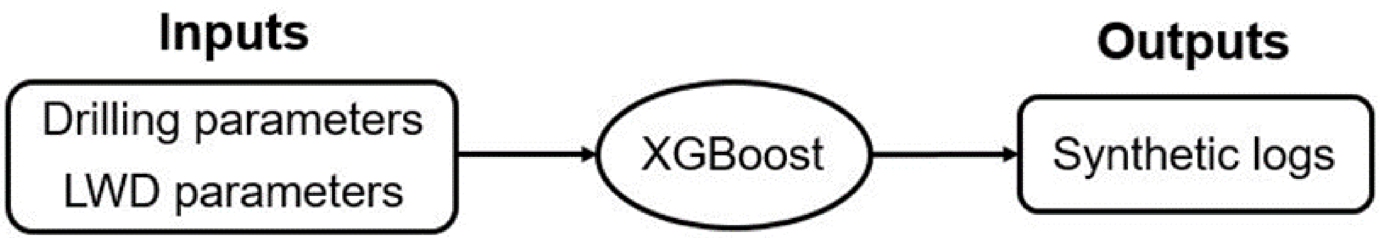
Post-Tamarama 1 Action Steps – Improved Frac Placement

- Question 3: could reductions in staging, better locating of perforations and reduced viscosity improve placement and reduce fracture heights?
  - Locating intervals further from lower stressed coals, reducing viscosity and managing proppant placement by using decreased size and increasing rate was hypothesized to increase fracture length and result in improved productivity
- Action Steps:
  - 4.5” Q-155 Casing and 15k wellheads were sourced to manage rates and 12,000 psi surface working pressures based on high NWBPL values observed in Tamarama 1.
  - Perforated intervals were based on pre-frac modelling using calibrated stress model from Tamarama 1 and DFIT data from Tamarama 3

Post-Tamarama 1 Action Steps – Improved Reservoir Characterisation

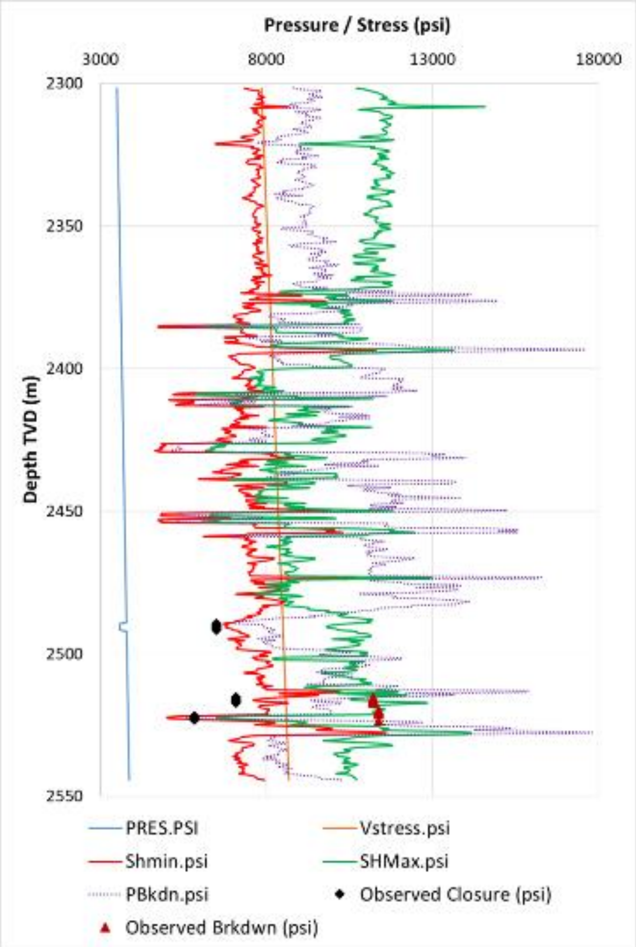
- Question 4, could machine learning better inform log-based stress modelling as a result of poor or missing log sections caused by high deviatory stresses?
  - Due to the high deviatory stresses and severe wellbore breakouts, many sections of logs are missing or of too poor quality to use directly for the hydraulic fracturing design.
  - Neural networks have been used in other cases to recreate pseudo sonic sections for hydraulic fracturing designs when sonic log data was unavailable (Mullen et al., 2007).
- Action steps: Apply machine learning on existing log and drilling data

Tamarama 2 and 3, Synthetic Log Construction



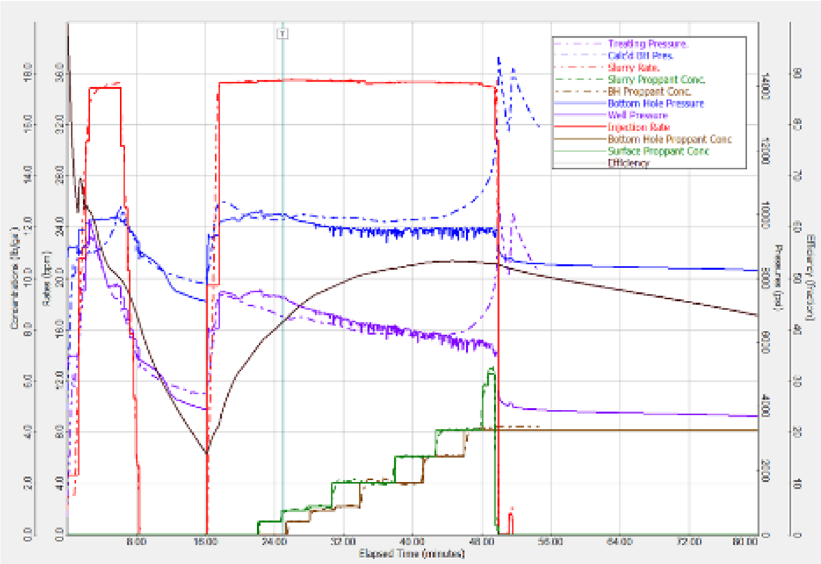
- Inputs include drilling parameters (e.g., rate of penetration (ROP), torque, weight on bit (WOB), etc.) and some LWD parameters (e.g., Gamma ray, hole diameter, etc.).
- Step 1: clean the data, extract and match time-based, real-time drilling and depth-based, LWD data,
- Step 2: feed the data into the XGBoost for computation.
- Output: synthetic logs including compressional and shear sonic velocity; bulk density, and neutron porosity.

Tamarama 3 DFITs Confirm Stress Profile

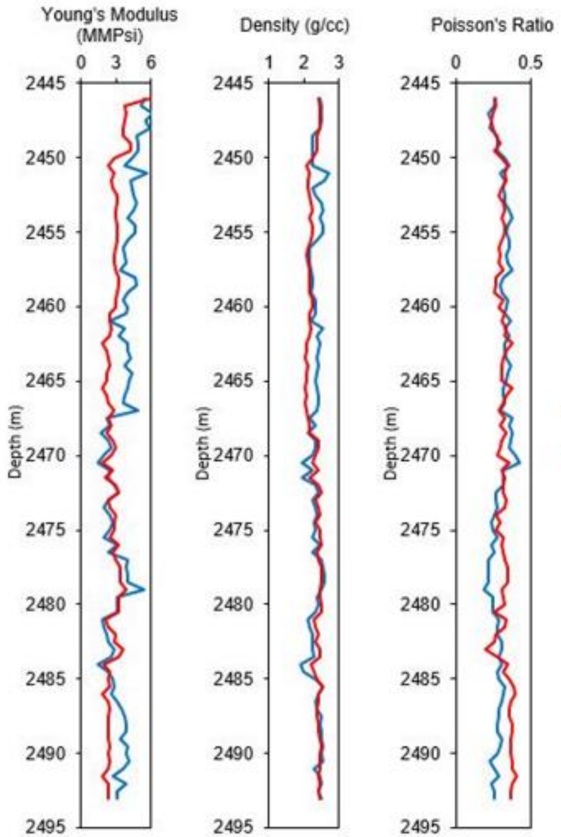


- Initial stress profile, petrophysics and rock-typing were used to develop completion strategy and determine intervals for DFITs based on Tamarama 1
- DFIT intervals chosen with varying modulus in rathole to history-match tectonic strains for stress profile
  - Clean breakdown and closure pressures collected
  - Tectonic strains (ε_{min}, ε_{max}) developed and proximate to Tamarama 1 values using using error minimization with poroelastic equations (Johnson, 2016; Pokalai et al., 2016)

Results Using Synthetic Logs- Tamarama 2

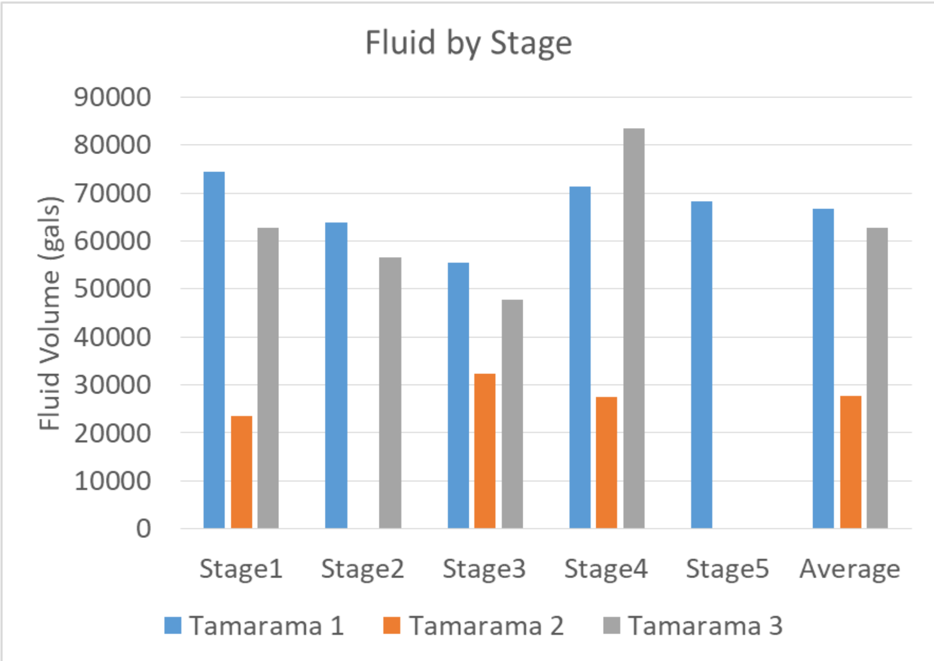


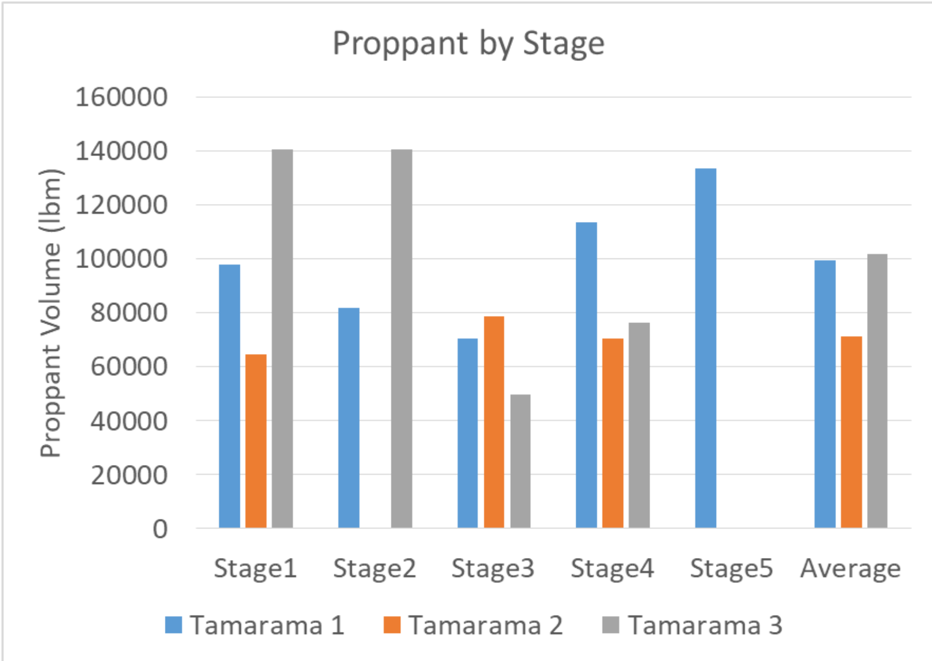
- Adjustments required to pre-frac estimates to match early job data
- Screenout not predicted by model



- Good correlation in early job data with region of good data control
- Fracture height growth into an area with low data was limitation

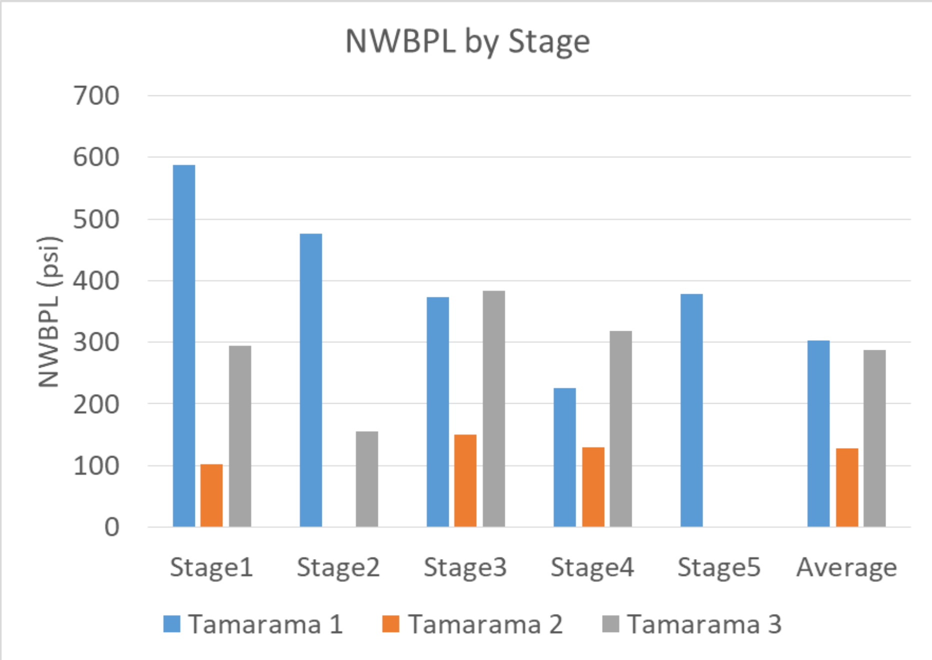
Tamarama 1, 2 and 3 BHTP Fluid and Proppant Volumes by Stage

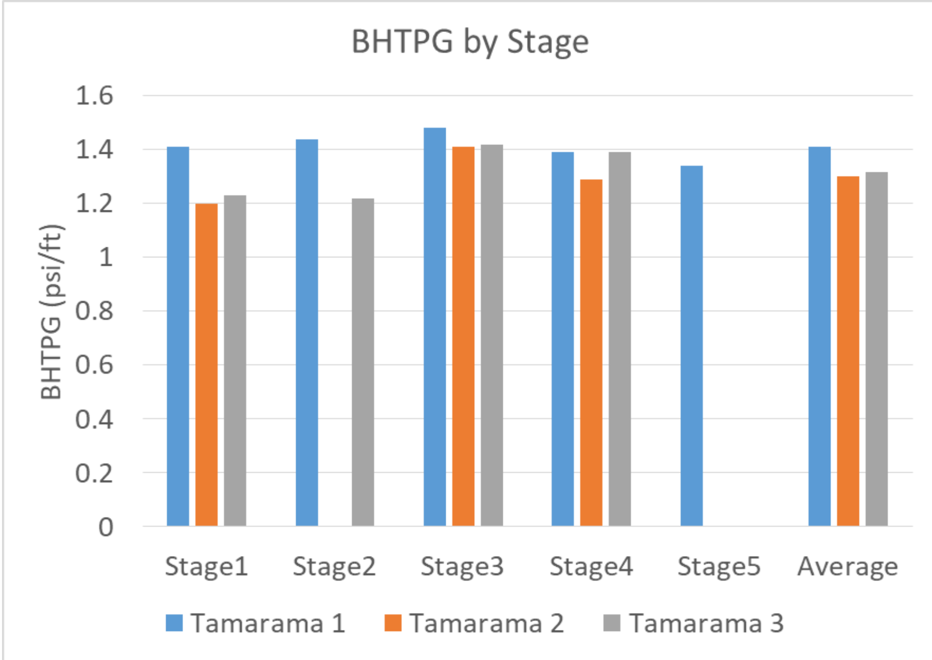




Note: Tamarama 2 materials limited by being last well in the two-well program and limited materials in country

Tamarama 1, 2 and 3 BHTP Versus Proppant Placed and Observed NWBPL

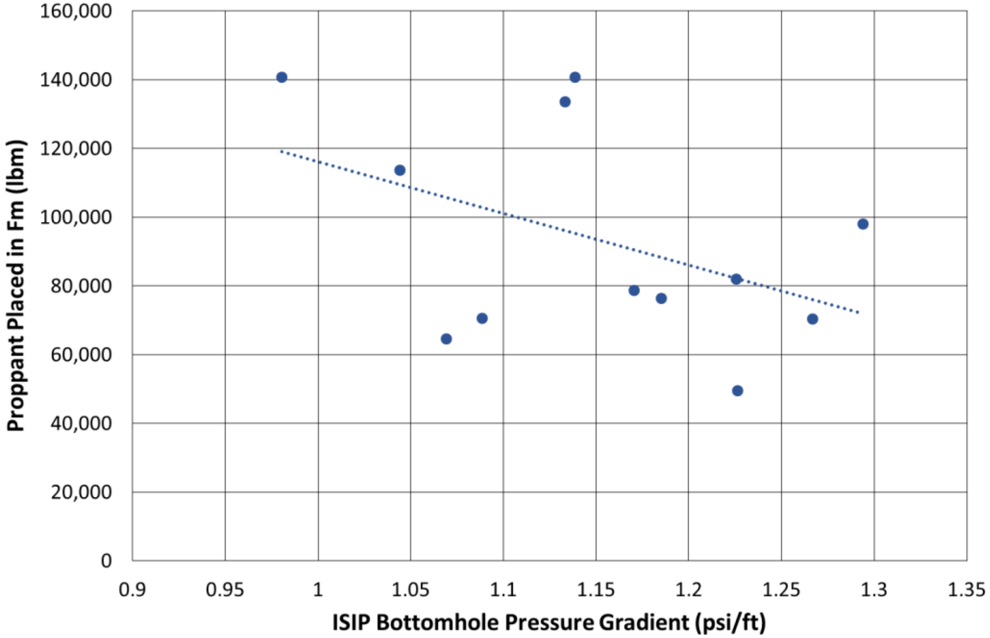




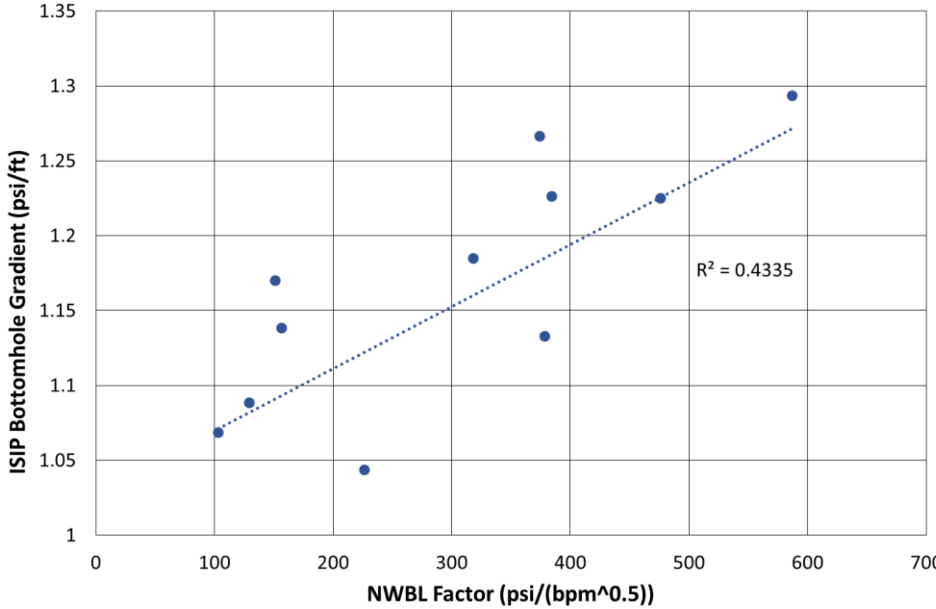
Note: Toolache stimulated in Tamarama 1 is believed to be source of water influx and not completed in Tamarama 2 and 3

High BHTPG evidencing complex fracturing

Tamarama 1, 2 and 3 BHTP Versus Proppant Placed and Observed NWBPL



Loose correlation confirms anecdotal evidence



Correlation confirmed by improved correlation with rank statistics

Results and Conclusions

- Up to 2.5-fold increase in observed test rates between Tamarama 1 and Tamarama 2 and 3
- 50% of the jobs on Tamarama 3 and all jobs on Tamarama 2 exhibited lower NWBPL than Tamarama 1
- There is a general trend across the three wells that NWBPL increases with higher stress values as demonstrated by ISIP gradients
- Almost all ISIP gradients exceeded 1 psi/ft, indicating fracture complexities
- Tamarama 2 was more difficult to place 20/40 proppant; operations were limited by materials/equipment to trial further remedies for NWBPL
- Confirms past observations regarding the significance of NWBPL in placement of Cooper Basin fracs
- improvements with fewer more focused fracs relative to Tamarama 1

Go-Forward Strategies

- One potential go-forward strategy is to align the wellbore within 30° to the σ_{HMax} direction and incline at a workable angle to the coals to allow more smoothly transitioning, acutely aligned fractures to the wellbore.
- Employ alternative open hole completion strategies that provide isolation but aid fracture initiation to counter difficulties experienced in other cases attempting multiple transverse fractures in cased and cemented horizontal wells in the deep Cooper Basin
- Continue vertical or deviated wells with increased, smaller, highly focused fractures
- **Overall goal is to increase overall fracture surface area**

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