The In Situ Stress Field of the West Tuna Area, Gippsland Basin: Implications for Natural Fracture-Enhanced Permeability and Wellbore Stability

Gippsland Location Map

- Oil field
- Gas field

Longford Gas Plant

Map showing locations of various fields and gas plants in the Gippsland region.
Objectives

The Problem: The R- and S-reservoirs have low permeability. Drilling has been associated with stuck pipe and fluid loss.

Aims: • Determine the in situ stress tensor
    • Determine the extent and nature of natural fracturing
    • Probability of fracture enhanced permeability
    • Finite element modelling to assess wellbore stability
Presentation Outline

• In Situ Stress in West Tuna
• Fracture characterisation and fracture enhanced permeability
• Wellbore stability and finite element modelling of near wellbore stress
• Conclusions
Reservoir Stresses

- $S_{Hmax}$ Orientation
- $S_V$ Magnitude
- $S_{hmin}$ Magnitude
- $S_{Hmax}$ Magnitude
$S_v \text{ Magnitude}$

\[ S_v = \int_0^z \rho(z)g \, dz \]

\( \rho_{av} \) from checkshot velocity
Leak Off Tests

$S_{hmin}$ Magnitude

Pressure (MPa) vs. Depth (m)

LOP

$P_c$
Kirsch Equations

\[ \sigma_{\theta \theta} = (\sigma_{H_{\text{max}}} + \sigma_{h_{\text{min}}}) - 2(\sigma_{H_{\text{max}}} - \sigma_{h_{\text{min}}}) \cos 2\theta - \Delta P \]
$S_{Hmax}$ Orientation

Circumferential Stress (MPa)

Azimuth with Respect to Maximum Horizontal Stress

Breakout
Compressive rock strength
DITF
Tensile rock strength
$S_{Hmax}$ Magnitude

$S_{Hmax\text{ Ori}} = 138^\circ \text{ N}$

$S_v = 21 \text{ MPa}$

$P_P = 9.8 \text{ MPa}$

$S_{hmin} = 21 \text{ MPa}$

$S_{Hmax} = 38 \text{ MPa}$

Depth = 1000 m

$S_{Hmax} > S_{hmin} \sim S_v$
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Natural Fractures

Electrically conductive fractures in cemented sandstones
Conductive fractures are optimally oriented to be hydraulically conductive in the far-field.

Conductive fractures are restricted to cemented sandstones with low matrix permeability.

Conductive fractures may be important to reservoir connectivity.
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3D Homogenous Block Model Results

Verification using Kirsch equations

\[ \sigma_{\theta\theta} = (\sigma_{H\max} + \sigma_{h\min}) - 2(\sigma_{H\max} - \sigma_{h\min}) \cos^2 \theta - \Delta P \]

\[ \sigma_{\theta\theta \max} = 3\sigma_H - \sigma_h - P_w - P_o = 100 \text{ MPa} \]

\[ \sigma_{\theta\theta \min} = 3\sigma_h - \sigma_H - P_w - P_o = 20 \text{ MPa} \]
3D Layered Model

Material Properties

- **Sandstone**
  - $E = 40 \text{ GPa}$
  - $\nu = 0.25$

- **Shale**
  - $E = 8.5 \text{ GPa}$
  - $\nu = 0.35$

Circumferential Stress

**Sandstone**

- Azimuth with Respect to Maximum Horizontal Stress
- Circumferential Stress (MPa)
- Compressive strength
- 133 MPa
- 21.1 MPa

**Shale**

- Azimuth with Respect to Maximum Horizontal Stress
- Circumferential Stress (MPa)
- Compressive strength
- 40.7 MPa
- 17.1 MPa
Conclusions

1. The in situ stress field in West Tuna is on the boundary of strike-slip and compression.

2. Fractures are optimally oriented to be hydraulically conductive in the far-field.

3. Breakouts and DITFs only occur in cemented sandstones. This can be explained by stress partitioning.
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