Geomechanics for reservoir and beyond

Examples of faults impact on fluid migration

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August 2014
Reservoir Geomechanics

It is critical to understand the mechanical behaviour of a reservoir to make optimal decision throughout the life of a field.

Stresses and deformations have potential to adversely impact exploration activities, field development, and production operations.

Development / production: reservoir response to production?

*Impact on fluid flow at production scale*

Exploration: reservoir containment and compartmentalisation?

*Impact on migration, trapping*
Hydrocarbon Reservoir

- Fault leakage
- Fault
- Top seal
- Reservoir
- Overburden

Breach trap
Reservoir Compaction / Overburden Movements

Modelling/monitoring of reservoir compaction caused by depletion allows assessing changes in reservoir performance and surface subsidence.

- 4D seismic – time shift > compaction > stress > poro-perm variation and fractures development
Fractured Reservoirs

Extent, orientation, hydraulic properties of fracture systems are essential for well planning and reservoir management

- Geomechanical fractures modelling
- DFN with estimate of properties for simulators
- Prediction of permeability
Fault Reactivation / Top Seal Integrity

Fault can be conduit or a barrier

• Stress state of fault
• Impact of pressure change

Top seal integrity is affected by pressure change

• Impact of pressure change
• Critical especially when injecting
Beyond Reservoir Geomechanics

Reservoir geomechanics to monitor and predict reservoir properties following production

- Impact of depletion and optimisation of recovery and safety
- Focused on production time scale and reservoir extent

Exploration geomechanics models rock behaviour at geological time scale

- Impact on migration, preservation, compartmentalisation
Timor Sea

- Success rate: ~10% (>20mmboe)
- ~694 mmbls oil ~643 mmbls condensate
  ~25 TCF gas

What causes underfilled and breached traps?
- Tertiary collision
- Trap-bounding faults reactivation
Timor Sea – Trap Integrity

- Plate flexure creates extensional regime
- Reactivation strain control trap breaching
- Reactivation strain is not homogeneous (partitioning)

Can we model strain partitioning and demonstrate link to trap breaching?
Reactivation strains are controlled by:
• fault size (strike length and height)
• tip location and overlap, jogs and relay zones
• pore pressure condition
Shear strain approximate structural permeability. High shear strains correlate locally with leaking fault planes.

Shear strain accumulation leads to fully connected fault zones and active pathway.
Timor Sea – Geomechanical Modelling

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Shear strain accumulation leads to fully connected fault zones and active pathway.

Validation of relationship between reactivation strain, hard-linkage and leakage (validation of empirical model).
Trap Integrity Algorithm
Thank you

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Summary / Conclusions

- Geomechanics is as important in Exploration than Development/Production
- Critical to understand migration of hydrocarbon to reservoir and trapping
- Need for calibration data
- Need for integrated workflow
- Critical to reduced exploration risks
South West Hub - CCS Demonstration Project

- Project feasibility stage
- Potential of CO$_2$ storage in the Lesueur sandstone
- Migration and leakage risk
Critically-stressed faults are likely to be conductive

- Shear stress vs sliding resistance (slip tendency)

Injection affects effective stress

- PP increase facilitate failure (fault stability)
- CO₂ column supported before failure

Fractures are not captured in geomodel

- Elastic Dislocation theory
- Large fault strain > perturbed stress tensor > Mohr-Coulomb failure > fractures
South West Hub – Geomechanics

Fault Slip Tendency

Fracture density and mode

Initial risk assessment
SW Hub – Impact of CO₂ Injection

3D mechanical-flow modelling to assess the stability of the reservoir seal couplet during CO₂ injection and surface effects

- 1 well injection rate 1 to 5 Mt/a (20 years period)
- Weak and strong fault scenarios

Elevation for weak fault 5Mt/a (20y)
Summary / Conclusions

1. Geomechanics can as important in Exploration than Development/Production

2. Critical to understand migration of fluids to reservoir and trapping/containment

3. Need for integrated workflow

4. Critical to reduced exploration risks
Northern Perth Basin - Trap Integrity

- Charge system below the Triassic Kockatea Shale
- Reactivation of Permian reservoir fault = trap breach
- Stress state on fault planes
- Simulation of Jurassic-Cretaceous reactivation
- Regional trap integrity framework

Lilac dry, 35 m POC

Dunsborough oil & gas, 30 m POC

Morangie dry, 50 m POC

Cliff Head, oil

NW (310)
Northern Perth Basin - Cliff Head

- *Main Horst* protected. Low shear strain > soft-linkage
- *East Ridge* with high shear strain > hard-linkage > breach
Northern Perth Basin – Risk Prediction

- Hard linkage through Kockatea shale = key risk
- Shear strain control linkage style (threshold=0.1 or c. 11° shear angle)
- Variations in strength and thickness of shale no primary risk factors
- Faults strike 340N to 100N likely to fail
- Size matters
- High incidence of breach trap due to tendency to drill larger NNW-oriented structures