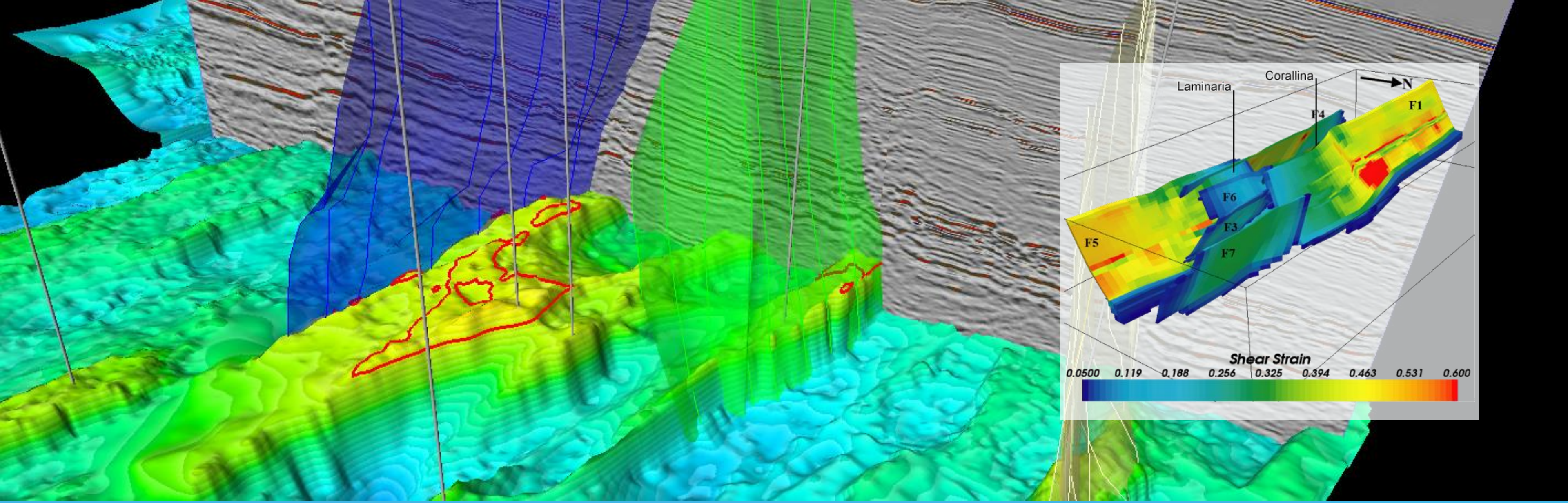


Geomechanics for reservoir and beyond

Examples of faults impact on fluid migration

Laurent Langhi | Team Leader
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.

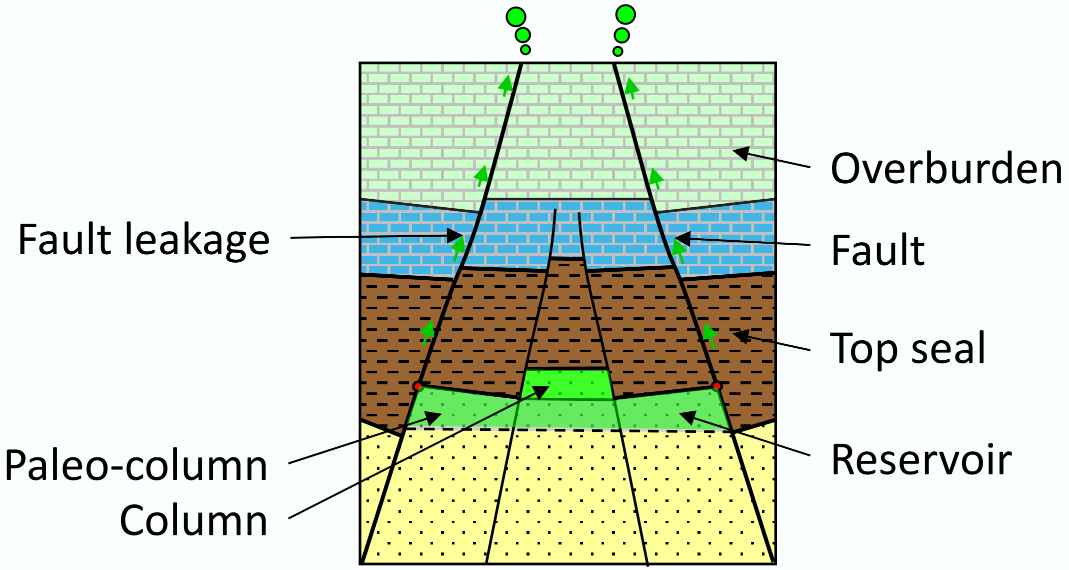
Development / production: reservoir response to production?

Impact on fluid flow at production scale

Exploration: reservoir containment and compartmentalisation?

Impact on migration, trapping

Hydrocarbon Reservoir

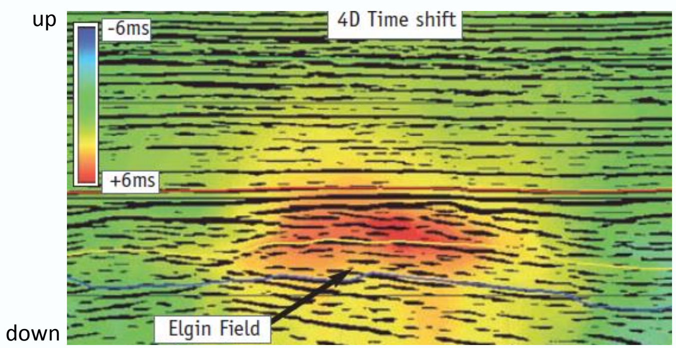


Breach trap
Intact trap

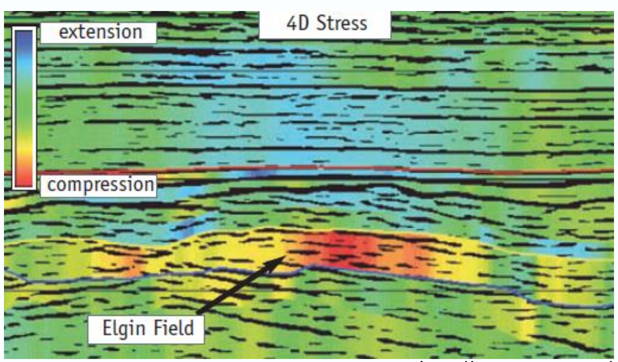
Reservoir Compaction / Overburden Movements

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



http://www.cgg.com/

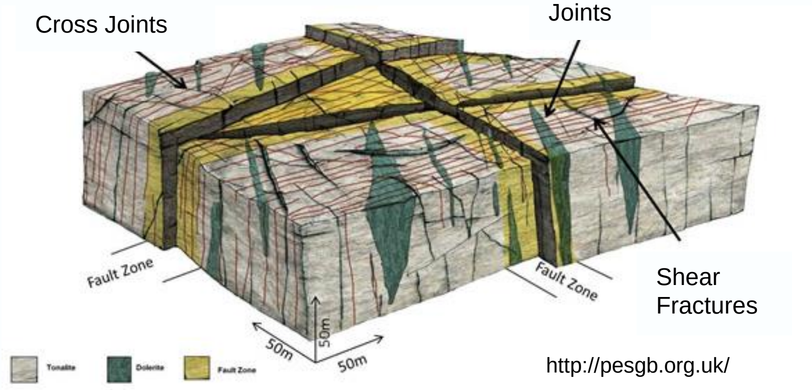


http://www.cgg.com/

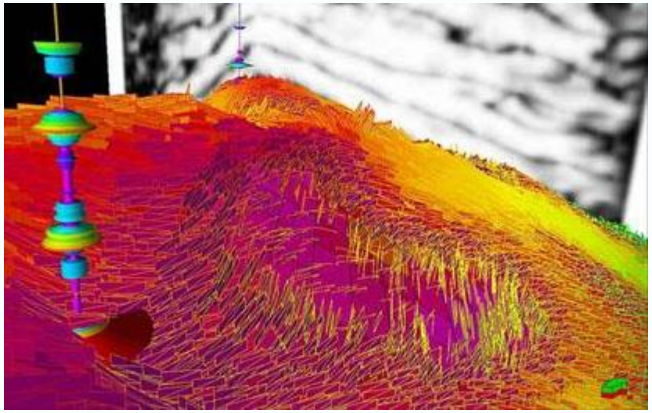
Fractured Reservoirs

http://www.ireservoir.com/

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



http://pesgb.org.uk/



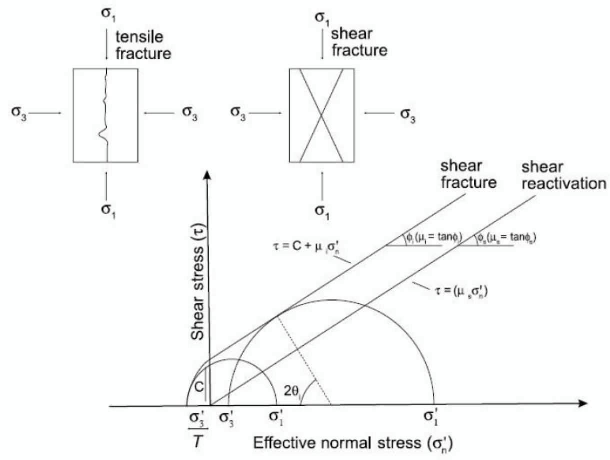
www.software.slb.com

- Geomechanical fractures modelling
- DFN with estimate of properties for simulators
- Prediction of permeability

Fault Reactivation / Top Seal Integrity

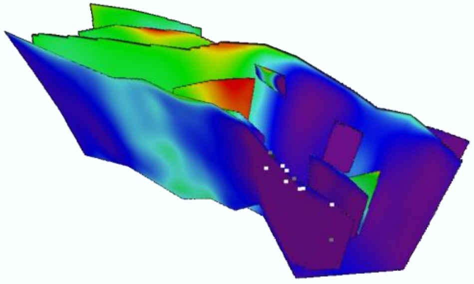
Fault can be conduit or a barrier

- Stress state of fault
- Impact of pressure change



Top seal integrity is affected by pressure change

- Impact of pressure change
- Critical especially when injecting



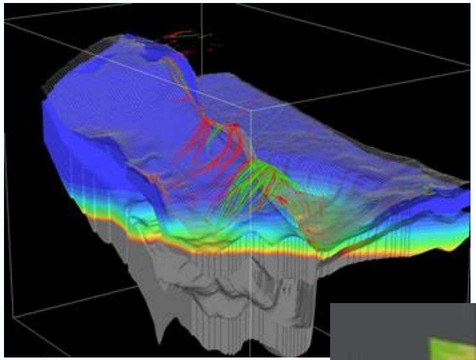
Beyond Reservoir Geomechanics

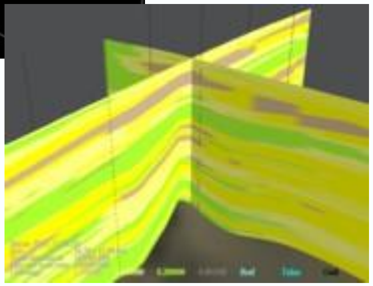
Reservoir geomechanics to monitor and predict reservoir properties following production

- 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

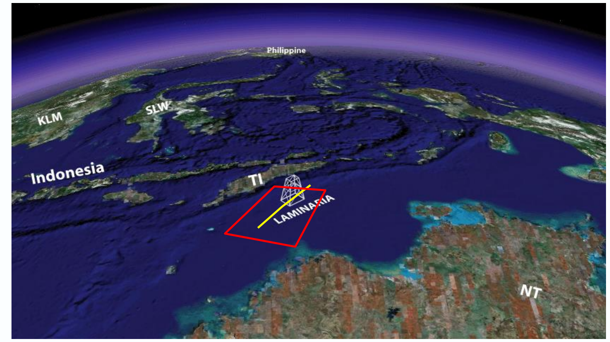
- Impact on migration, preservation, compartmentalisation

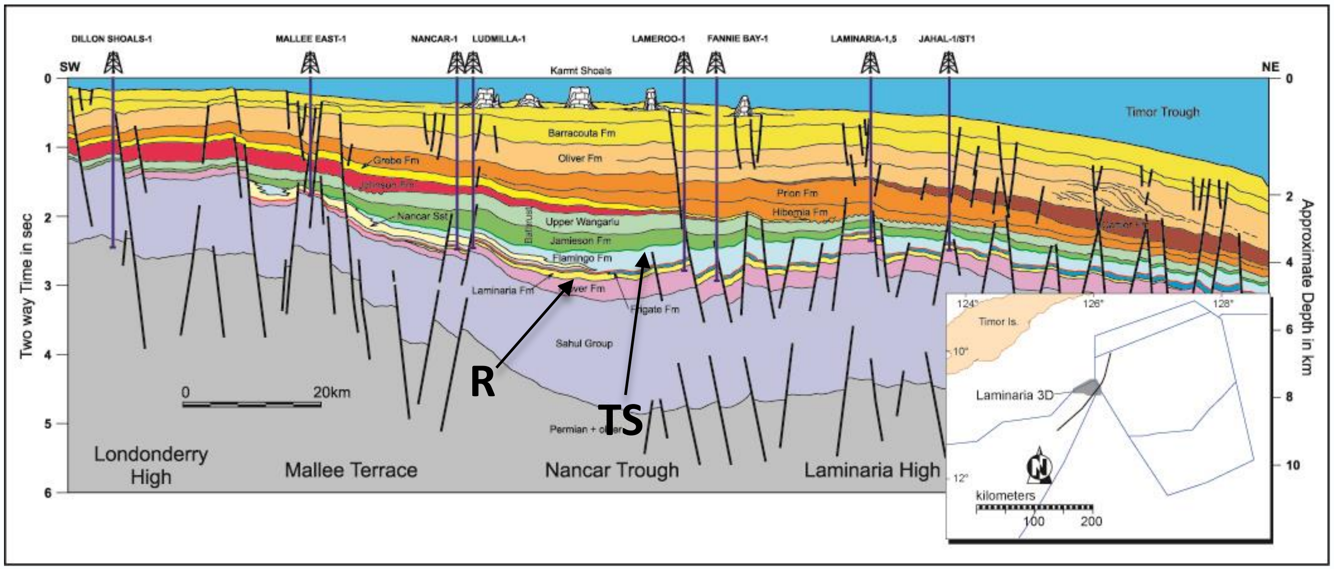


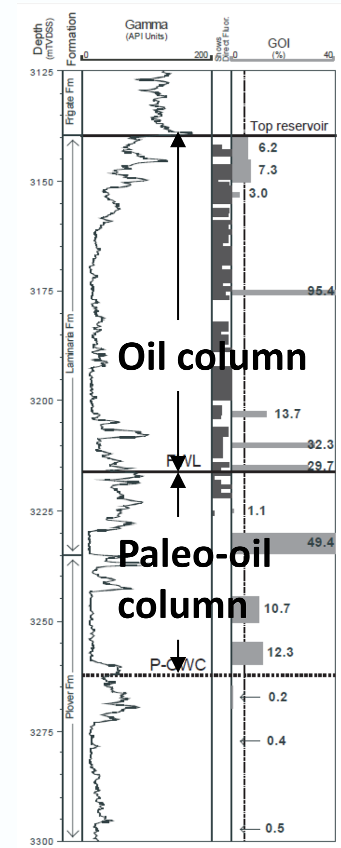


Timor Sea

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



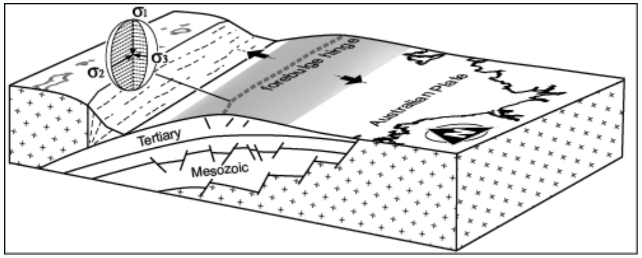




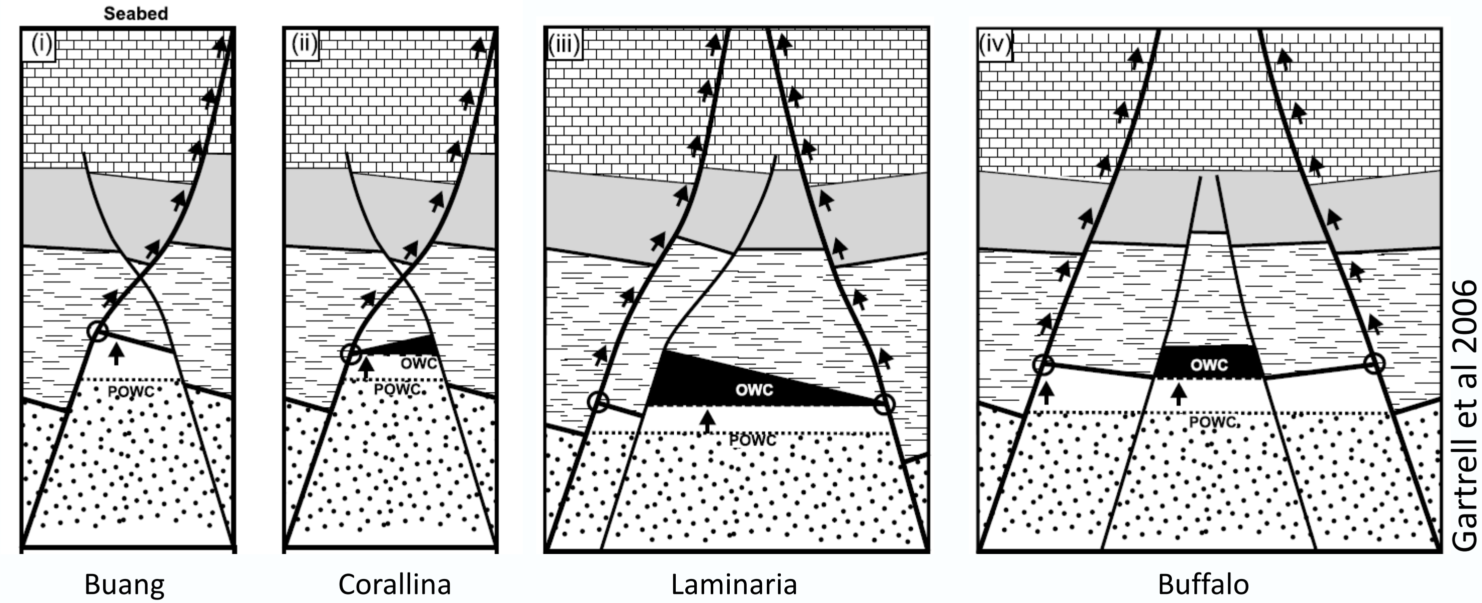
What causes underfilled and breached traps?

- 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)

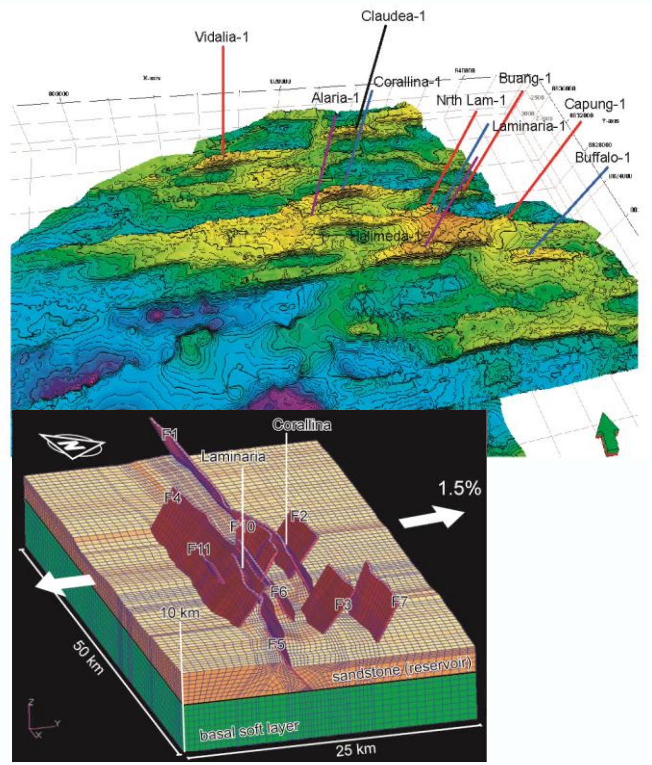


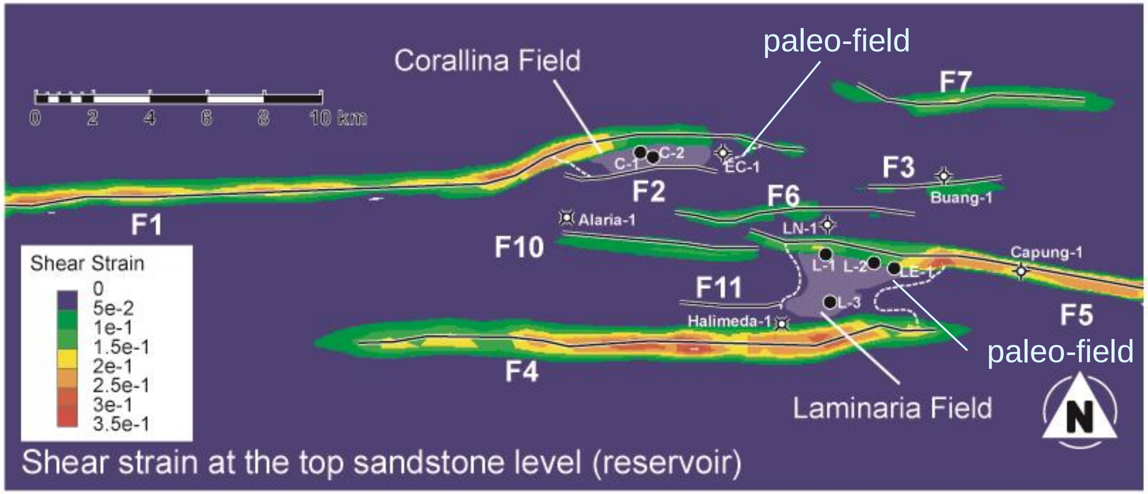
Can we model strain partitioning and demonstrate link to trap breaching?

Timor Sea – Geomechanical Modelling

3D finite difference code (FLAC3D)

- Deformation > Mohr-Coulomb isotropic elastic-plastic law
- Fluid flow > single phase; Darcy’s law for an isotropic porous medium



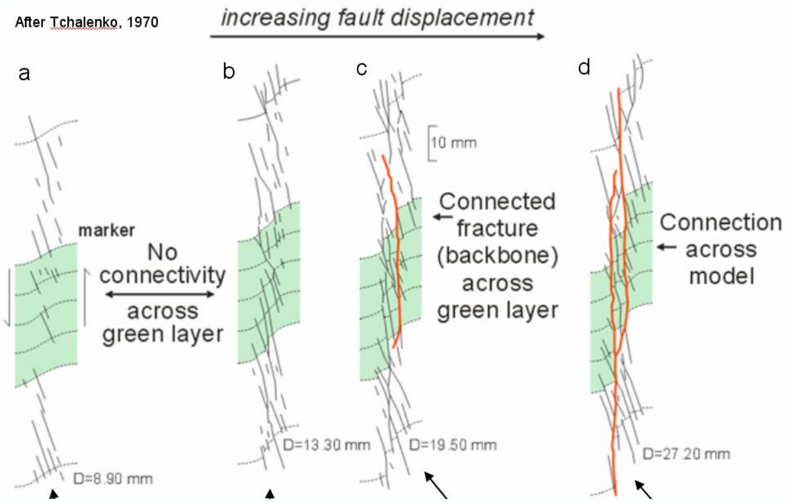


Reactivation strains are controlled by:

- fault size (strike length and height)
- tip location and overlap, jogs and relay zones
- pore pressure condition

Timor Sea – Geomechanical Modelling

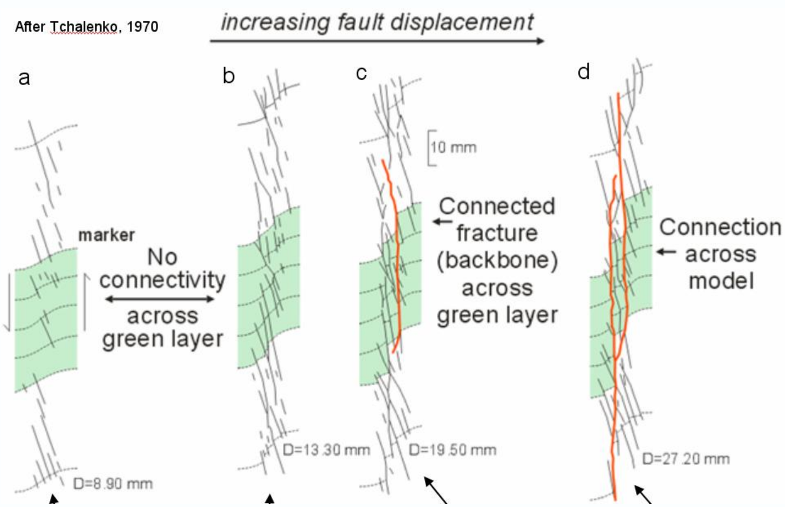
Shear strain approximate structural permeability. High shear strains correlate locally with leaking fault planes.



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

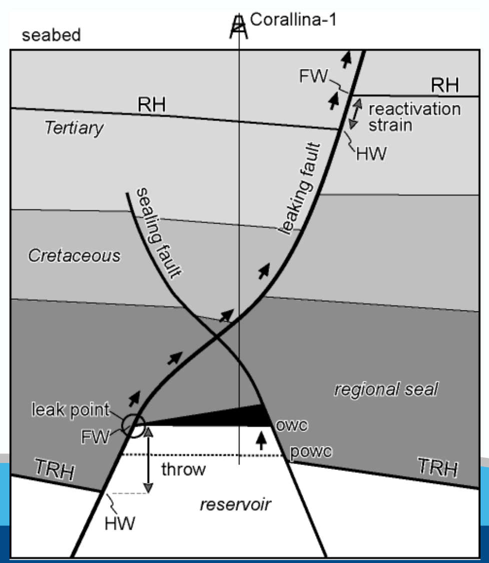
Timor Sea – Geomechanical Modelling

Shear strain approximate structural permeability. High shear strains correlate locally with leaking fault planes.

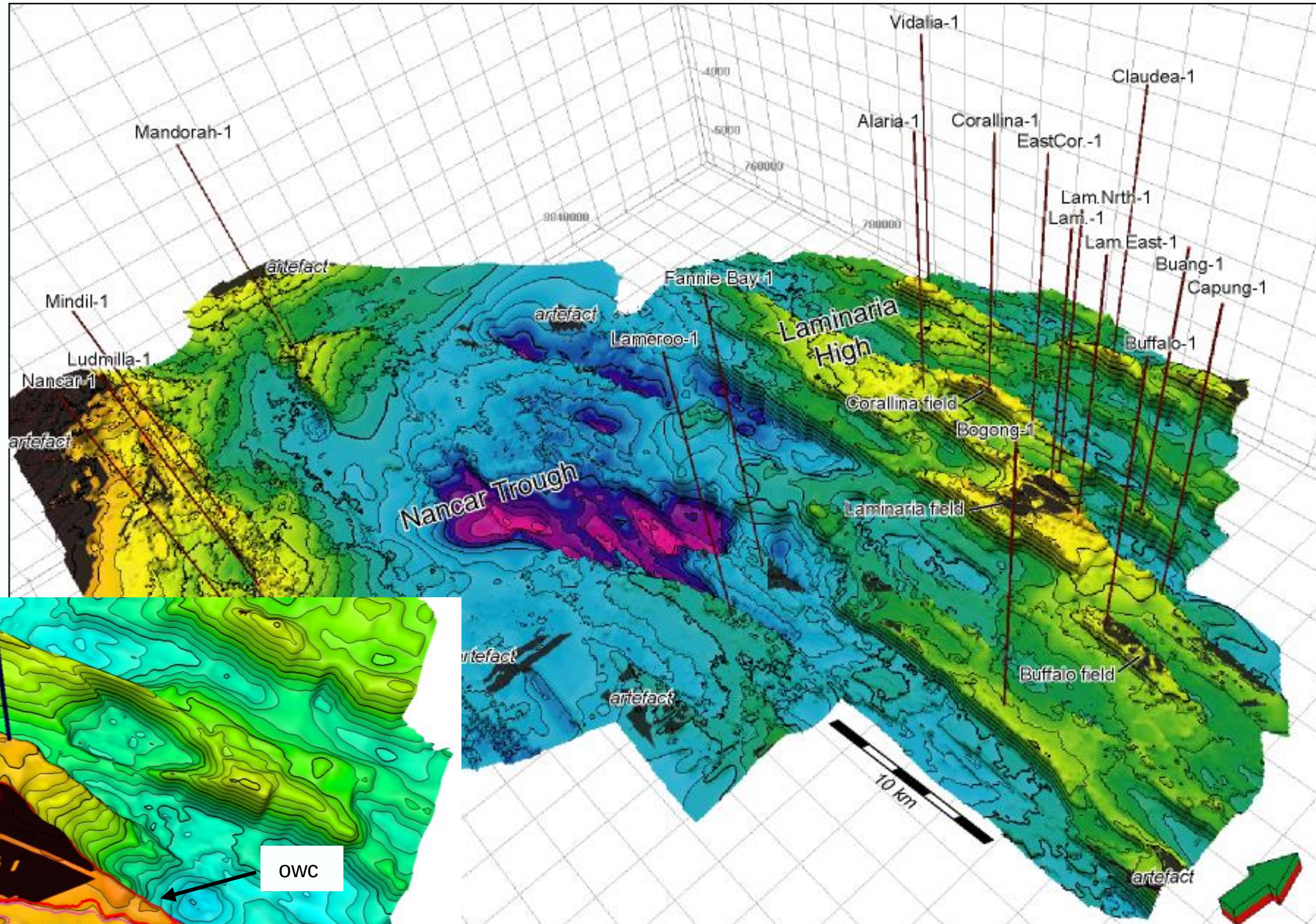


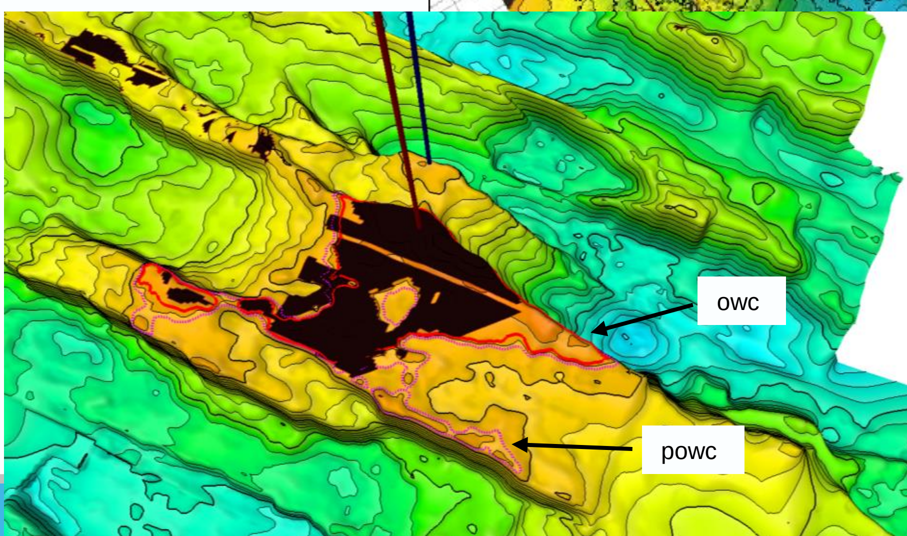
Shear strain accumulation leads to fully connected fault zones and active pathway.

Validation of relationship between reactivation strain, hard-linkage and leakage (validation of empirical model).



Trap Integrity Algorithm





Thank you

CESRE
Loz

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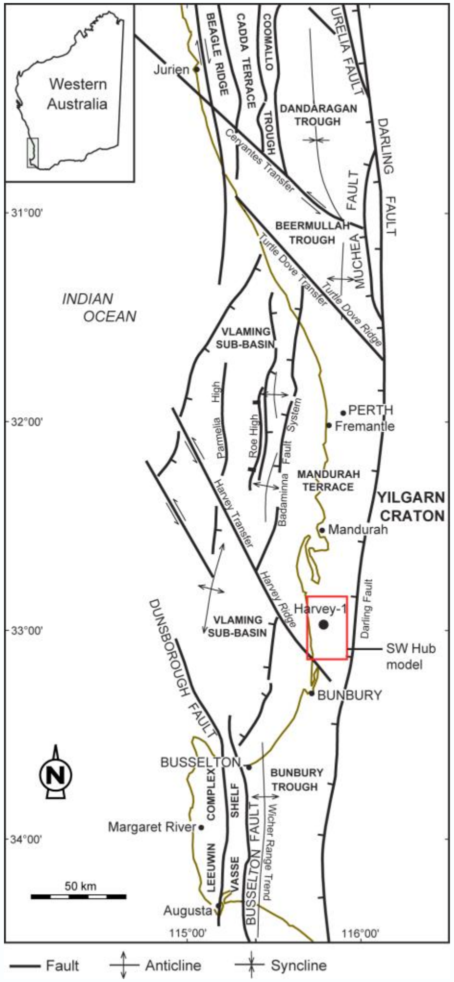
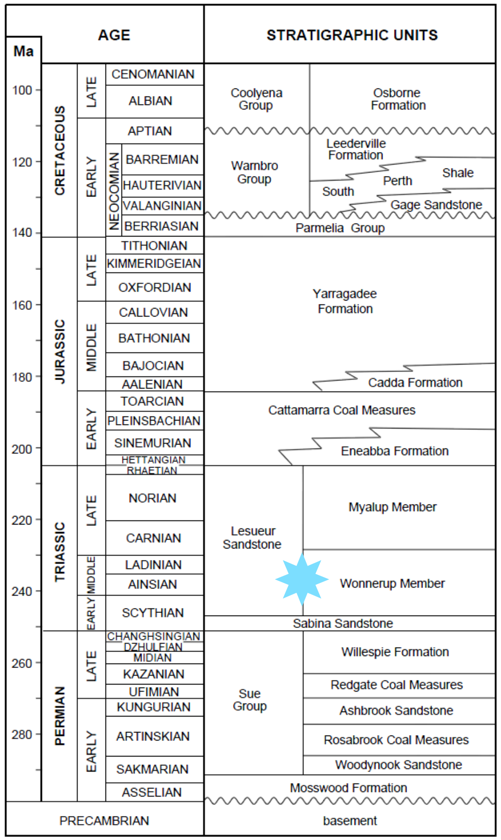
Summary / Conclusions

- 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

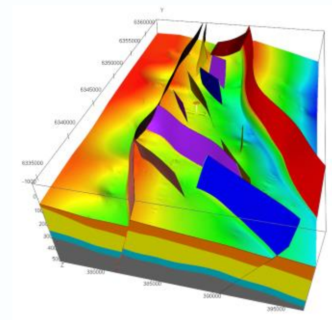
South West Hub - CCS Demonstration Project

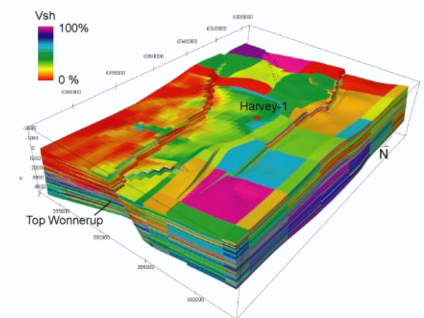


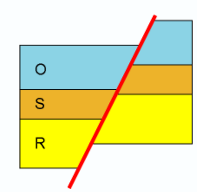


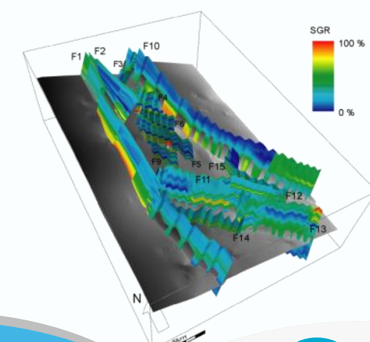
- Project feasibility stage
- Potential of CO_2 storage in the Lesueur sandstone

- *Migration and leakage risk*

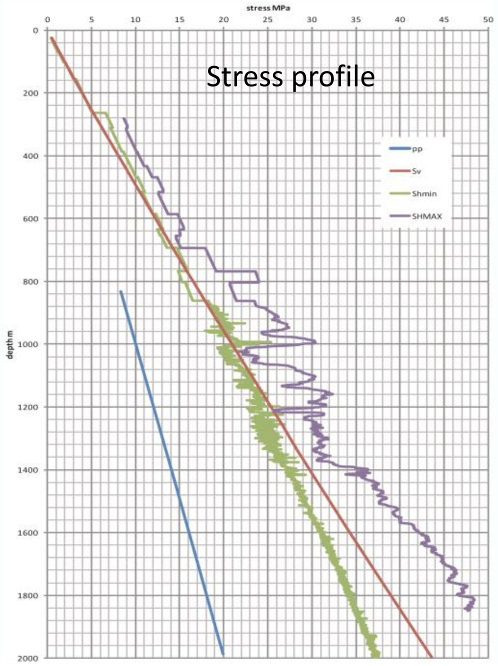








South West Hub – Geomechanics



Critically-stressed faults are likely to be conductive

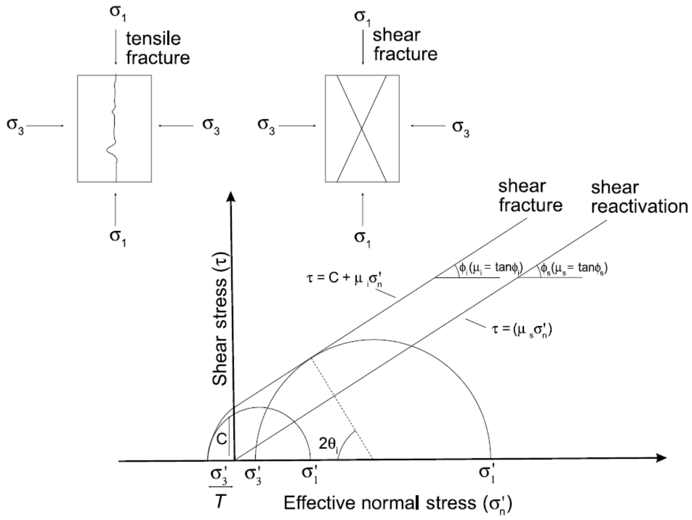
- Shear stress vs sliding resistance (slip tendency)

Injection affects effective stress

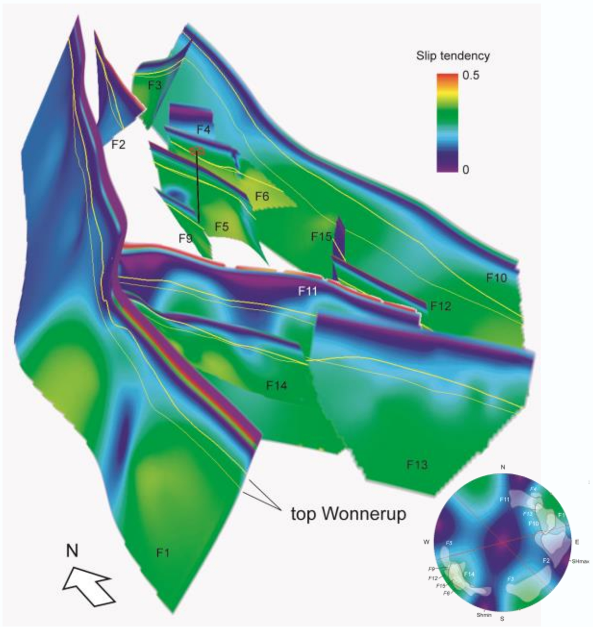
- PP increase facilitate failure (fault stability)
- CO_2 column supported before failure

Fractures are not captured in geomodel

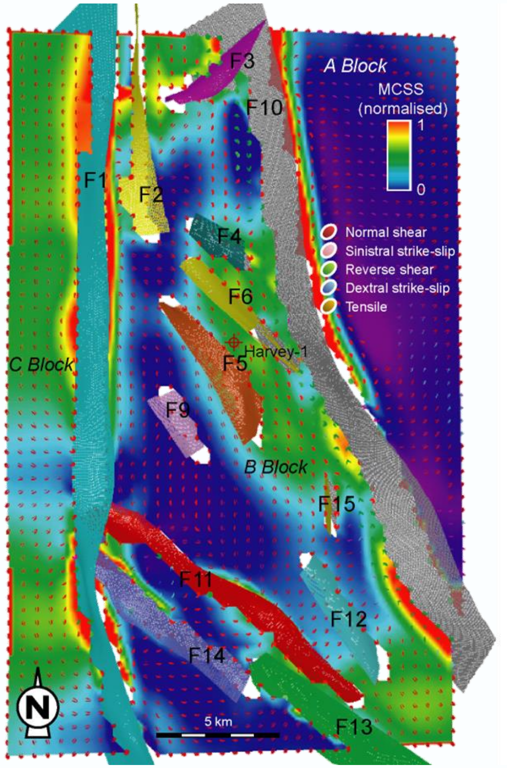
- Elastic Dislocation theory
- Large fault strain > perturbed stress tensor > Mohr-Coulomb failure > fractures



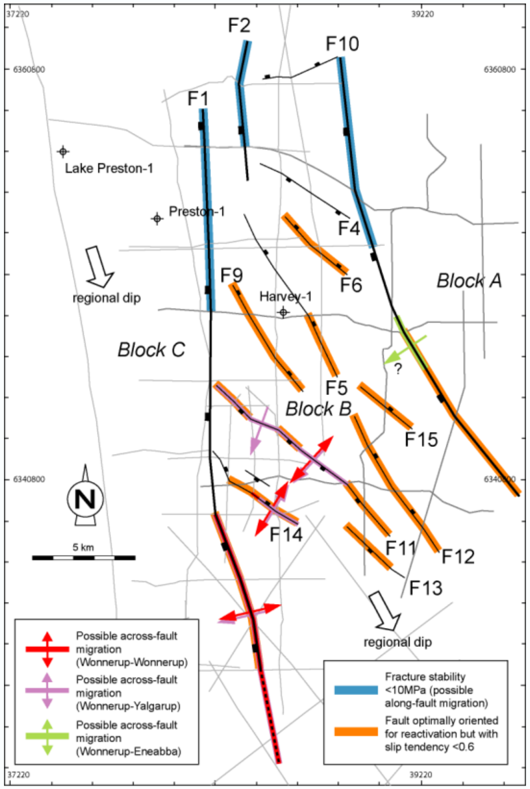
South West Hub – Geomechanics



Fault Slip Tendency

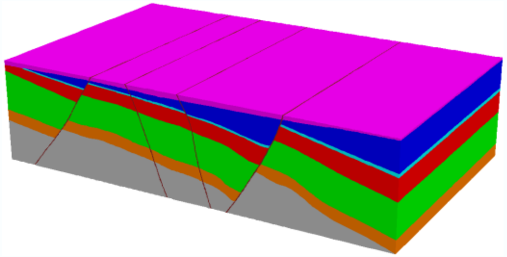


Fracture density and mode



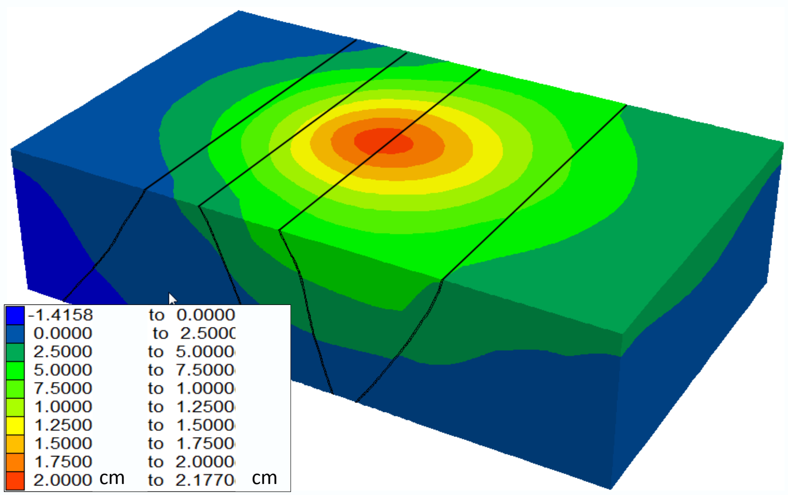
Initial risk assessment

SW Hub – Impact of CO_2 Injection

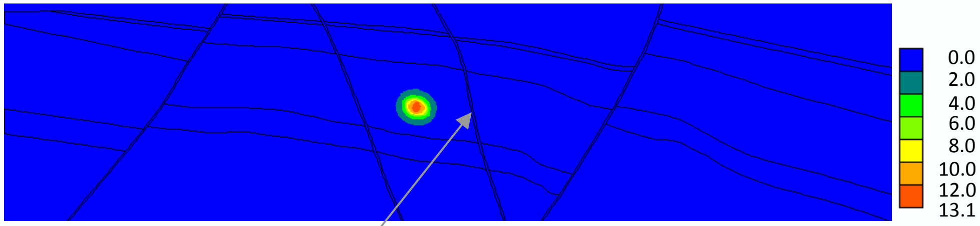


3D mechanical-flow modelling to assess the stability of the reservoir seal couplet during CO_2 injection and surface effects

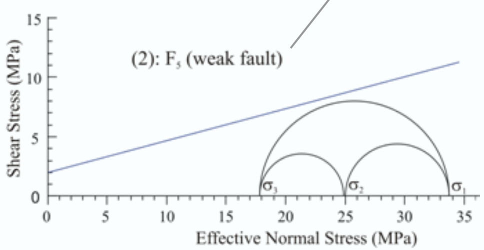
- 1 well injection rate 1 to 5 Mt/a (20 years period)
- Weak and strong fault scenarios

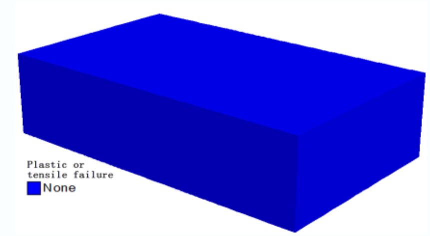


Elevation for weak fault 5Mt/a (20y)



Flow velocity (m/a) 5Mt/a (20y)

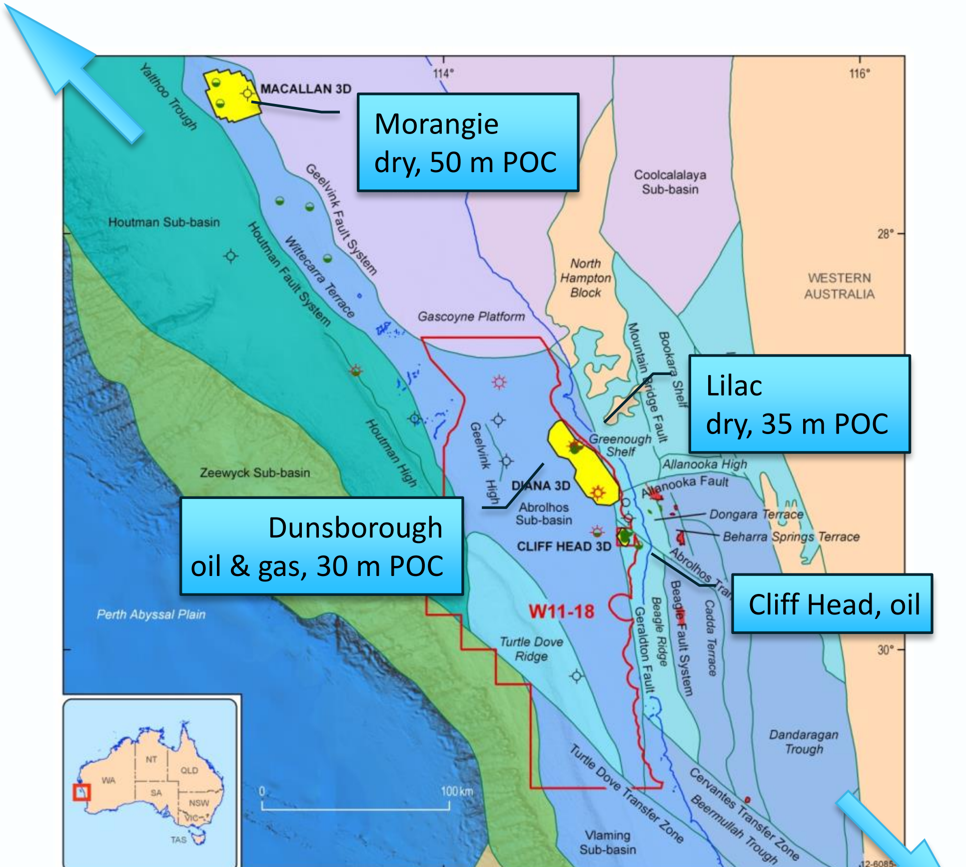




Summary / Conclusions

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

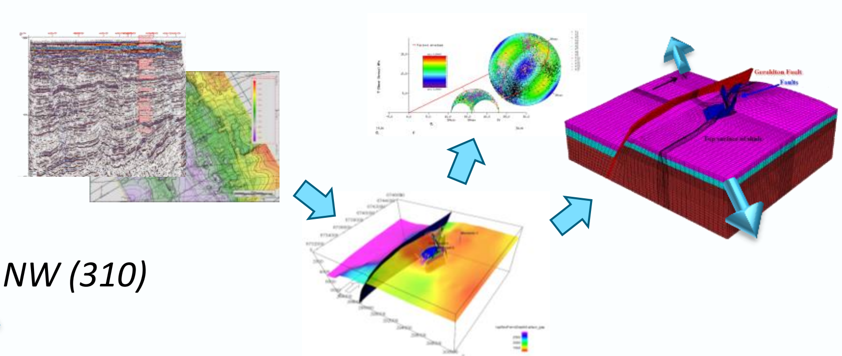
Northern Perth Basin - Trap Integrity



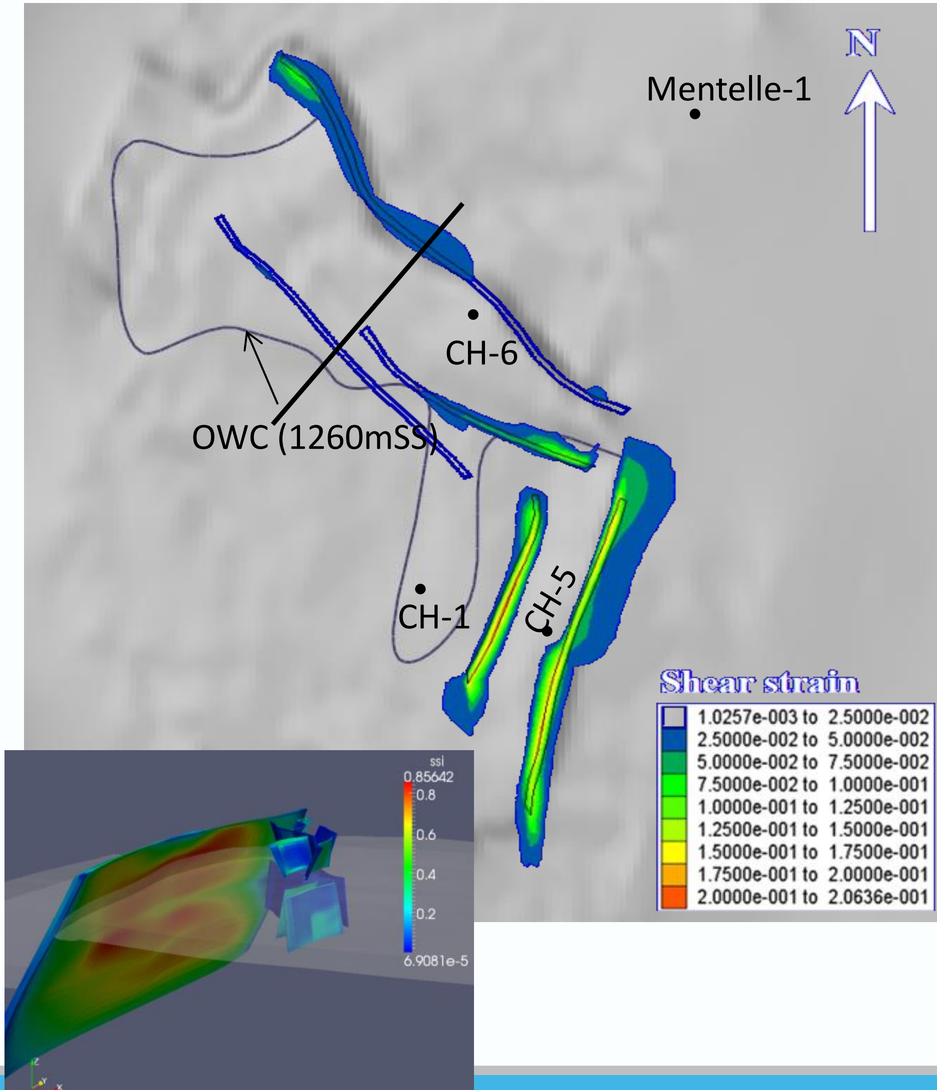
Well symbol information is sourced either from "open file" data from titleholders where this is publicly available as at 1 April 2011 or from other public sources. Field outlines are provided by Encom GPinfo, Pitney Bowes Software (PBS) Pty Ltd product. Whilst all care is taken in the compilation of the field outlines by PBS, no warranty is provided re the accuracy or completeness of the information, and it is the responsibility of the Customer to ensure, by independent means, that those parts of the information used by it are correct before any reliance is placed on them.

- 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

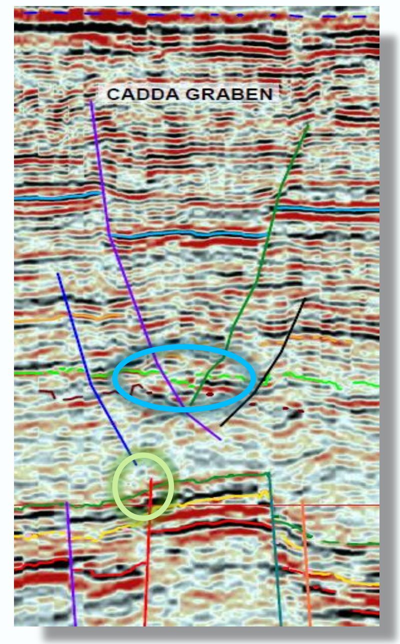
NW (310)



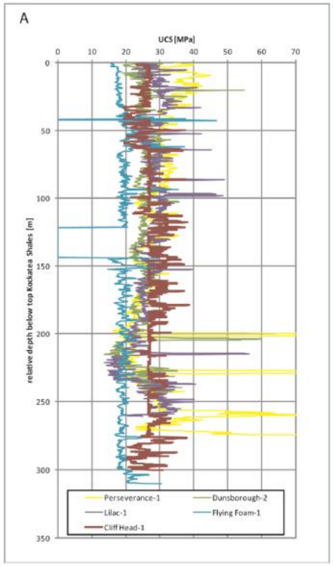
Northern Perth Basin - Cliff Head



- *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