Petroleum Potential of the Gage Submarine Fan, Offshore Perth Basin, Western Australia from Palaeogeographic Mapping and Geological Modelling*

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Abstract

The Vlaming Sub-basin is north-south trending Mesozoic depocentre in the Perth Basin, Western Australia that contains up to 14 km of sediment. Potential plays comprise the Early Cretaceous Gage Sandstone overlain by the South Perth Shale seal. Previous exploration primarily focused on structural traps in the syn-rift succession based on the assumption that all hydrocarbons were generated prior to or at the time of the breakup. Petroleum systems modelling undertaken by others in 2007 concluded that some source rocks in the sub-basin reached maturity after the deposition of the South Perth Shale seal, therefore making plays in the post-breakup Gage reservoir prospective. Deposited as a lowstand component of the deltaic South Perth Supersequence, the Gage Lowstand Fan (previously referred to as the Gage Sandstone) infilled palaeotopographic lows on the Valanginian breakup unconformity. Characteristics of the reservoir-seal pair were derived from sequence-stratigraphic analysis and seismic facies mapping that integrated 2D seismic interpretation, well log analysis and new biostratigraphic data. Palaeogeographic reconstructions for the South Perth Supersequence reveal a series of regressions and transgressions that infill palaeodepressions. The Gage reservoir is a sand-rich submarine fan system and ranges from canyon-confined inner fan deposits to middle fan deposits on a basin plain. Sand sheets in the distal middle fan and stacked channelised sands in the inner fan may provide an extensive reservoir of good to excellent quality. Seal quality of the South Perth Shale varies across the basin and may account for some dry wells. A re-evaluation of the regional seal determined the extent of the pro-delta shale facies within the South Perth Supersequence, which provides an effective seal for the underlying Gage reservoir. 3D geological modelling provided a better understanding of the reservoir heterogeneity by predicting changes to lithofacies and reservoir parameters away from the well. Flow path analysis identified multiple stratigraphic closures at the top of the Gage reservoir, with the most favourable located in the Rottnest Trough.

References Cited

Neumann, V., R. di Primio, and B. Horsfield, 2007, Burial history modelling and petroleum fluid bulk compositional predictions on the Vlaming and Mentelle Sub-basins, offshore southern Western Australia: GeoS4 Report 071001 for Geoscience Australia (unpublished).

Nicholson, C.J., I. Borissova, A.A. Krassay, C.J. Boreham, E. Monteil, V. Neumann, R. Di Primo, and B.E. Bradshaw, 2008, New exploration opportunities in the southern Vlaming Sub-basin: The APPEA Journal, v. 48, p. 371–379.

Richards, M., M. Bowman, and H. Reading, 1998, Submarine-fan systems I: characterization and stratigraphic prediction: Marine and Petroleum Geology, v. 15, p. 687-717.

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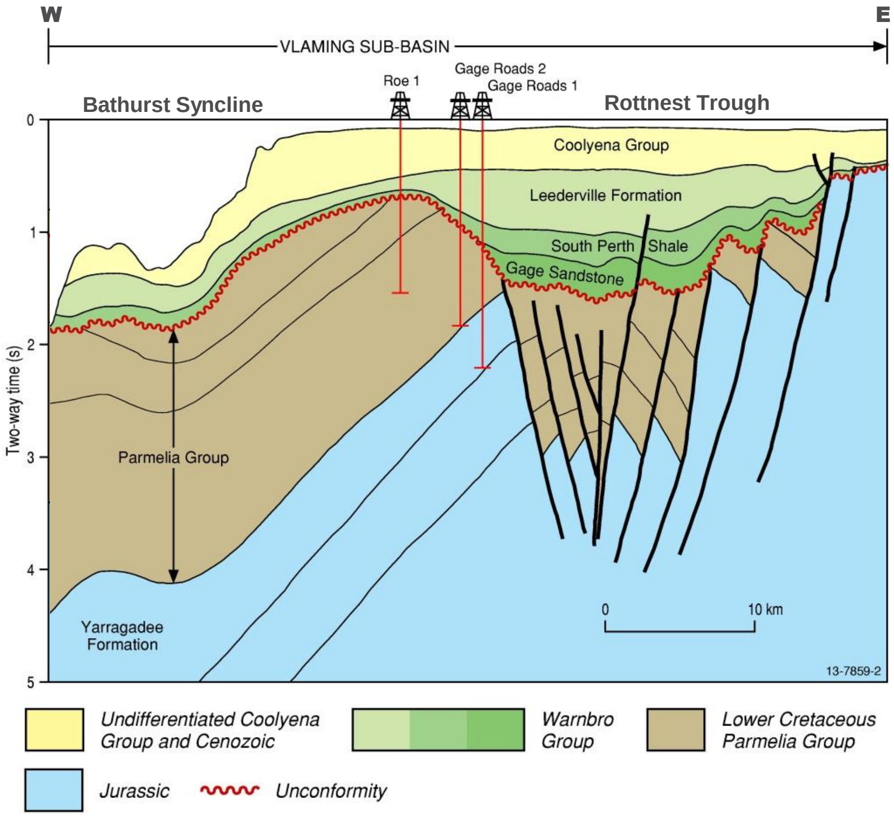
Aim

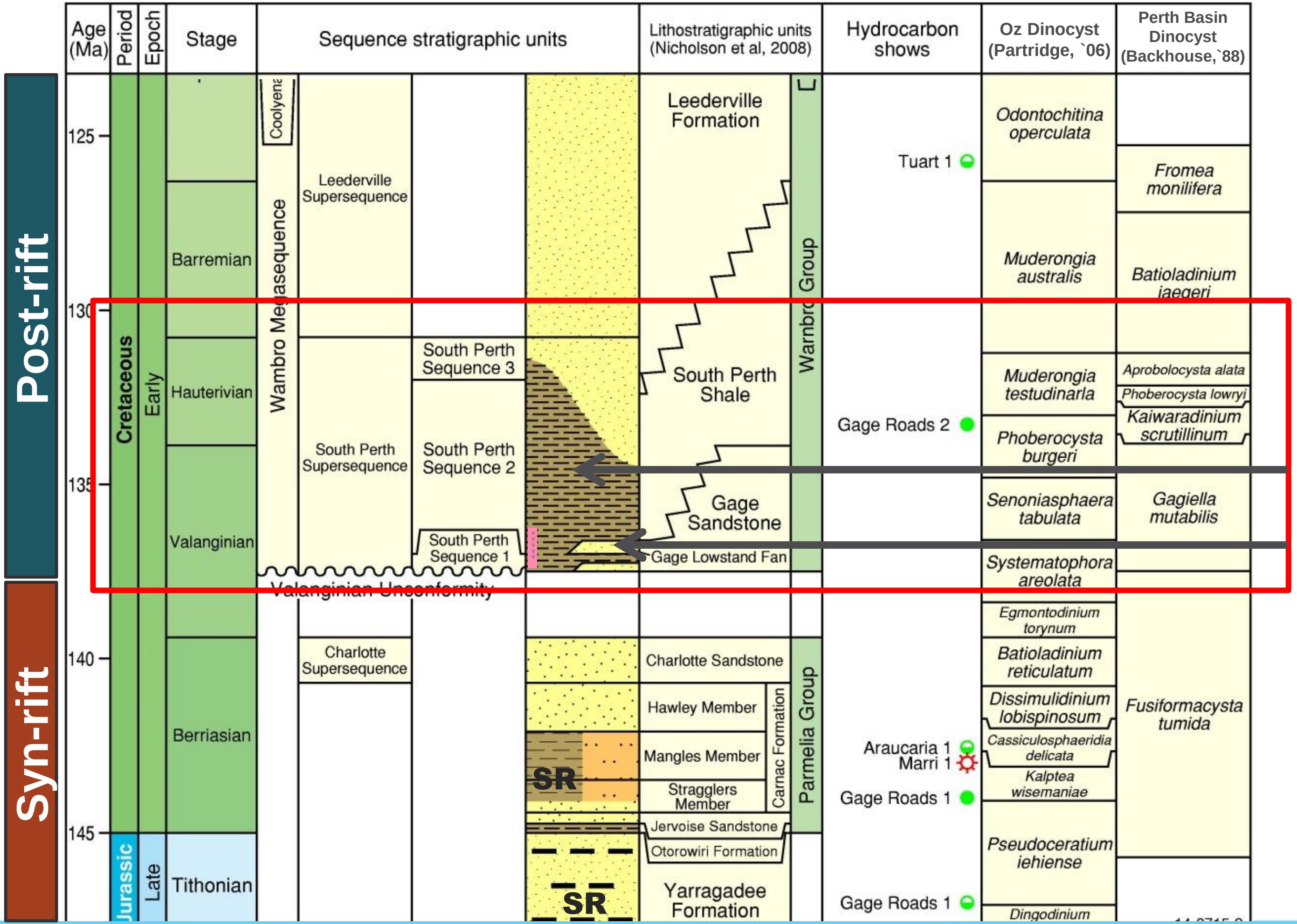
To provide a better understanding of the distribution of the quality reservoir and seal facies of the post-Valanginian breakup succession by:

1. Defining a new chronostratigraphic sequence framework for the post-rift Warnbro Group,
2. Better understanding the evolution of the South Perth Supersequence delta,
3. Identifying the location of the effective (good quality seal),
4. Mapping internal geometries of the Gage reservoir to identify the location of the enhanced reservoir properties, and
5. Identify location of potential exploration targets.

Geology



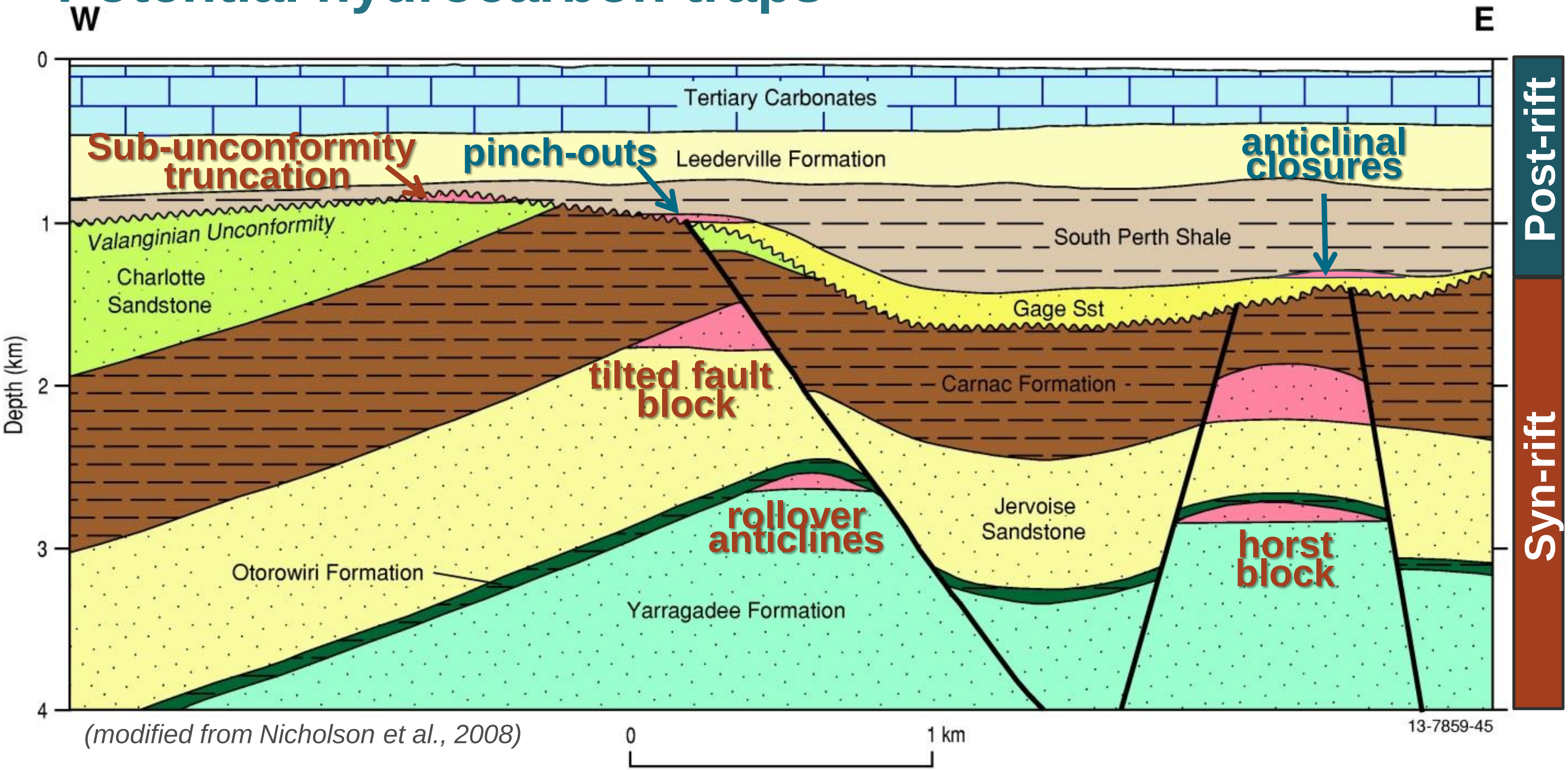
- Offshore/onshore Mesozoic depocentre
- Up to 15 km of Jurassic to E. Cretaceous sediments
- Several proven and potential source rocks
- Active petroleum system
- Gage Roads 1: sub-commercial oil accumulation, Marri 1: gas show
- Previous prospectivity assessments had syn-rift focus
- **Currently no exploration**



Effective seal

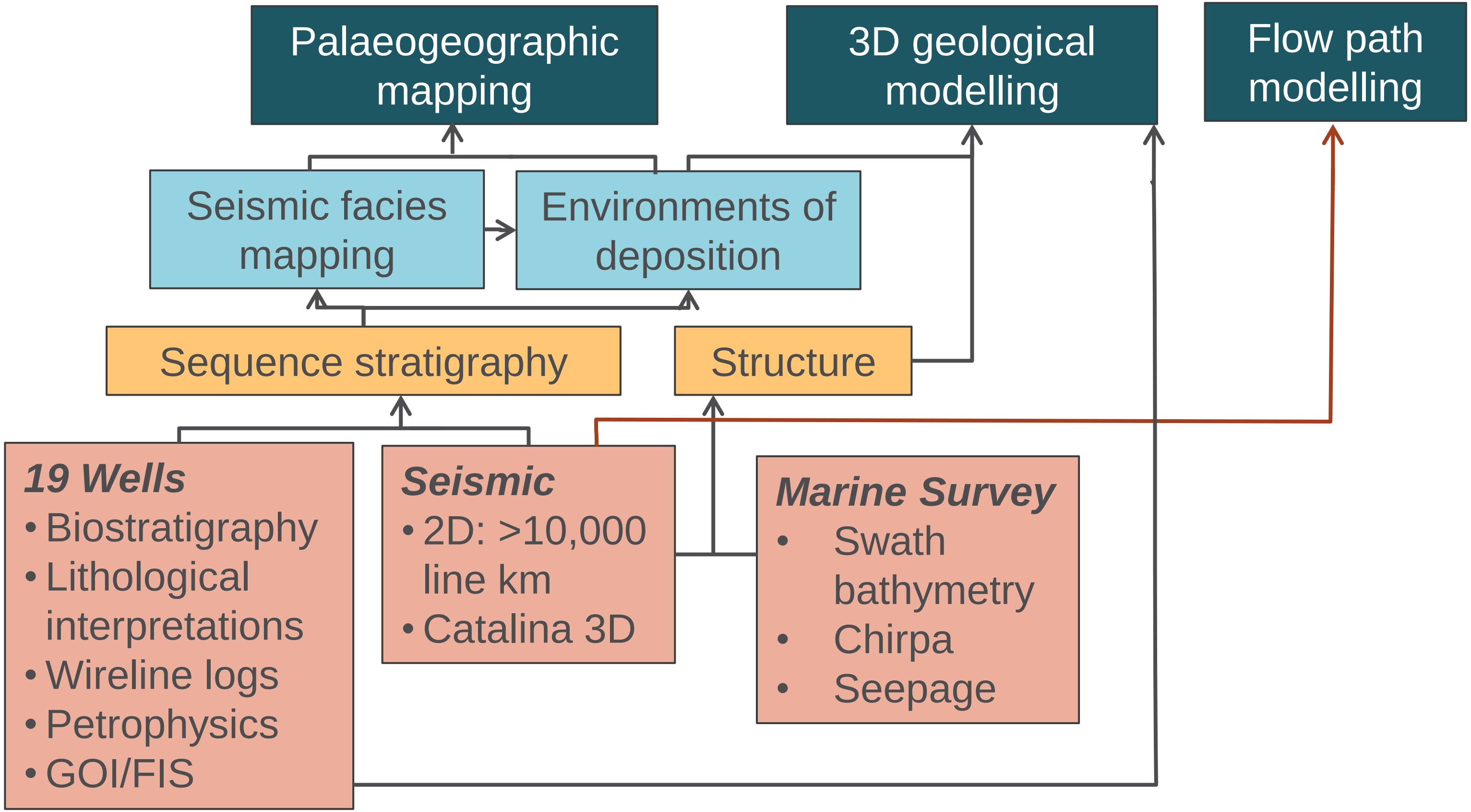
Gage reservoir

Potential hydrocarbon traps

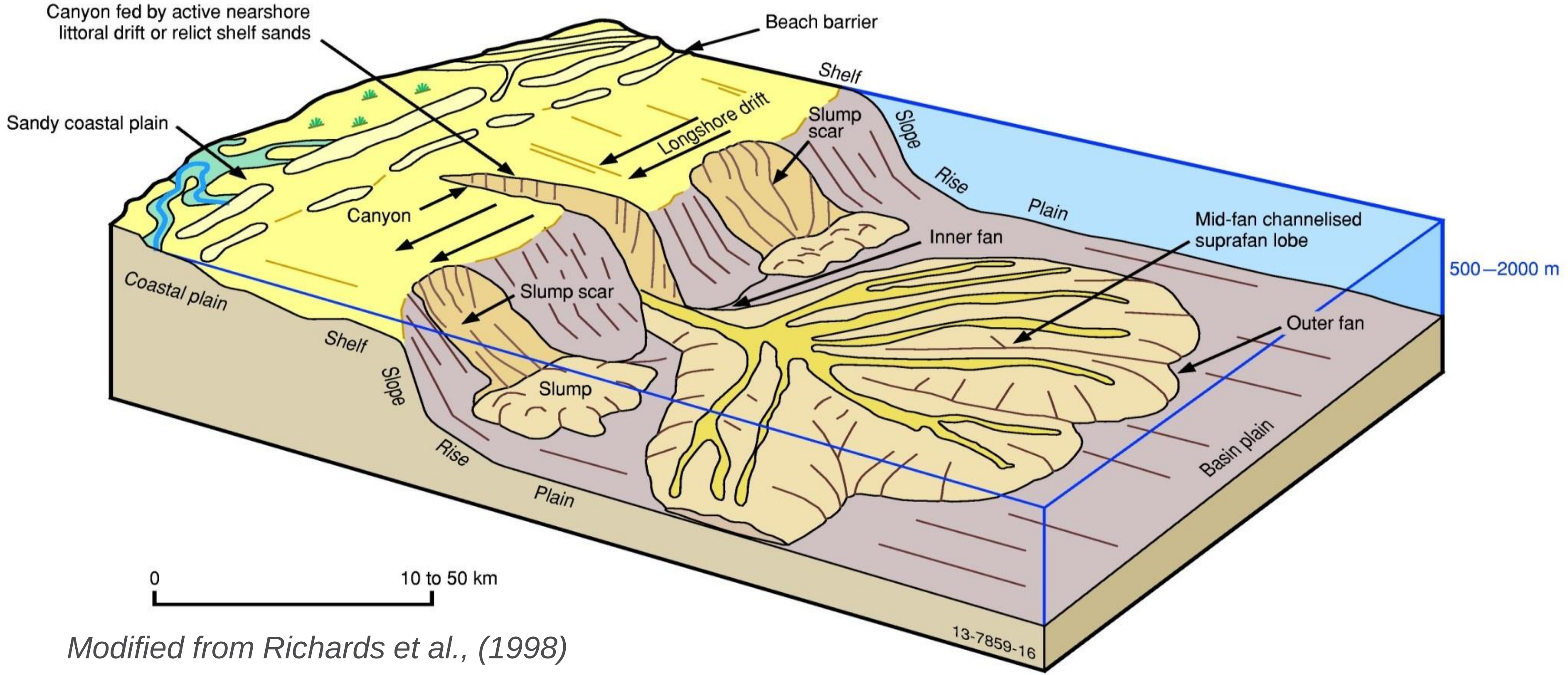


(modified from Nicholson et al., 2008)

Work flow


Palaeogeographic mapping
3D geological modelling
Flow path modelling
Seismic facies mapping
Environments of deposition
Sequence stratigraphy
Structure
19 Wells
• Biostratigraphy
• Lithological interpretations
• Wireline logs
• Petrophysics
• GOI/FIS
Seismic
• 2D: >10,000 line km
• Catalina 3D
Marine Survey
• Swath bathymetry
• Chirpa
• Seepage

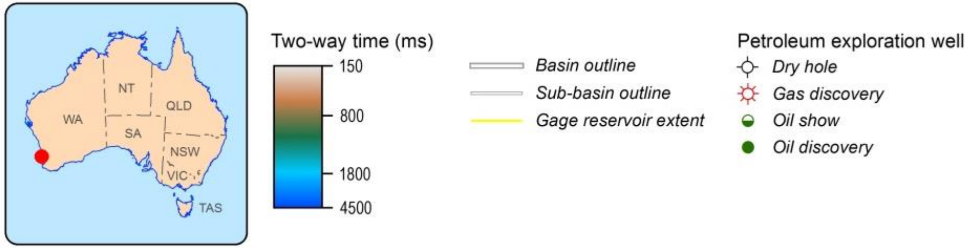
Gage reservoir model: deep-water submarine fan

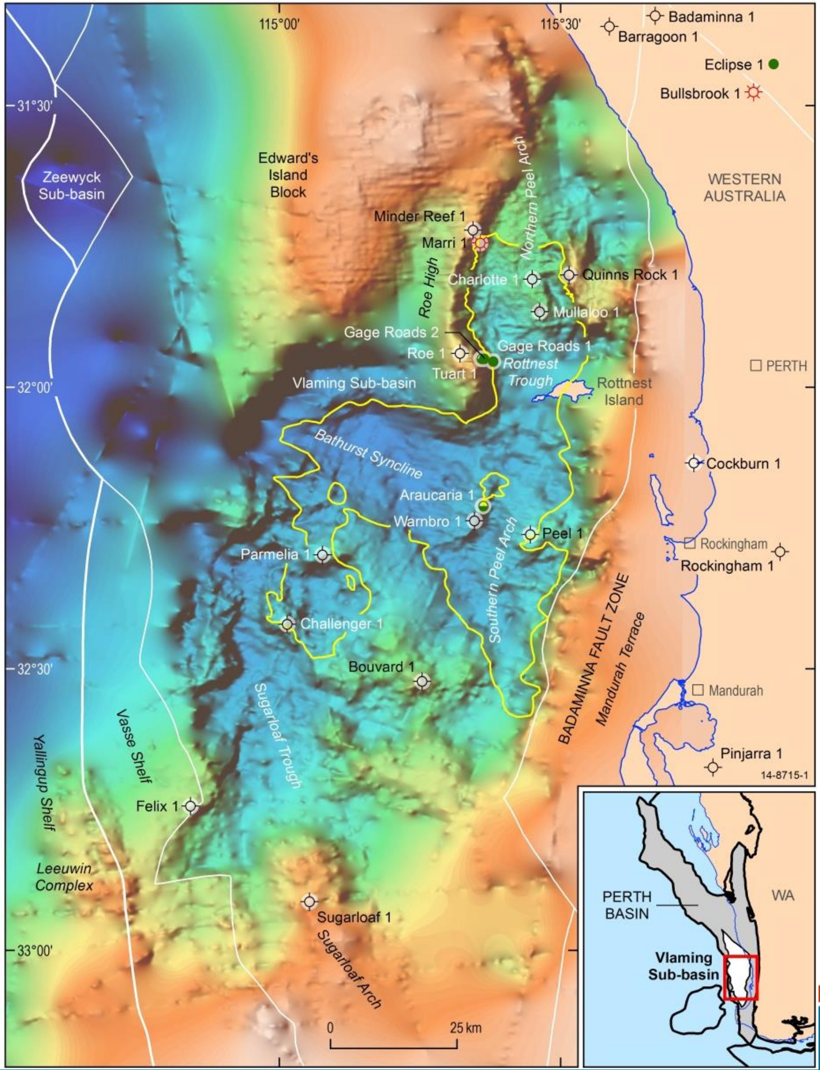


Modified from Richards et al., (1998)

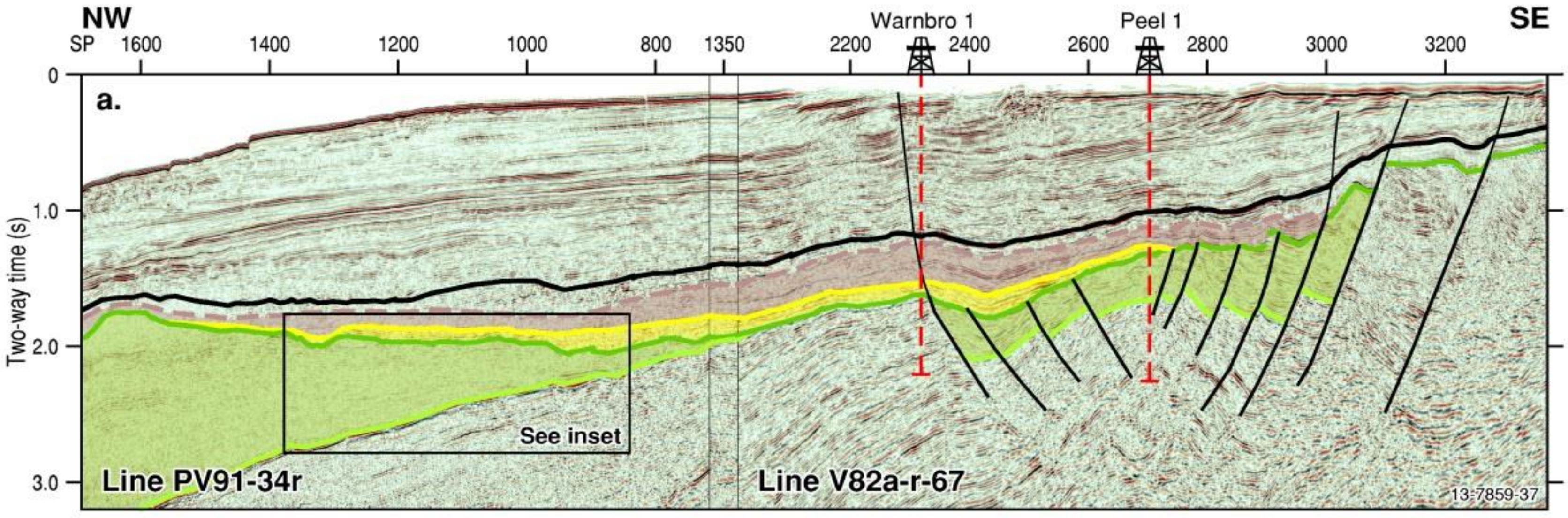
Break-up palaeotopography

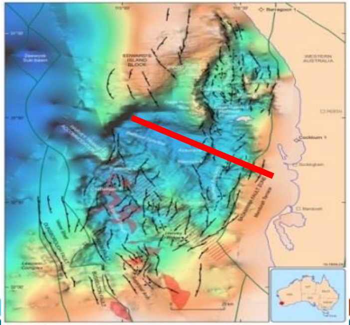
- Gage reservoir deposited directly on the Valanginian Unconformity
- Bounded by:
  - Badaminna Fault Zone,
  - shallow basement on Vasse & Yallingup shelves,
  - Edwards Island Block



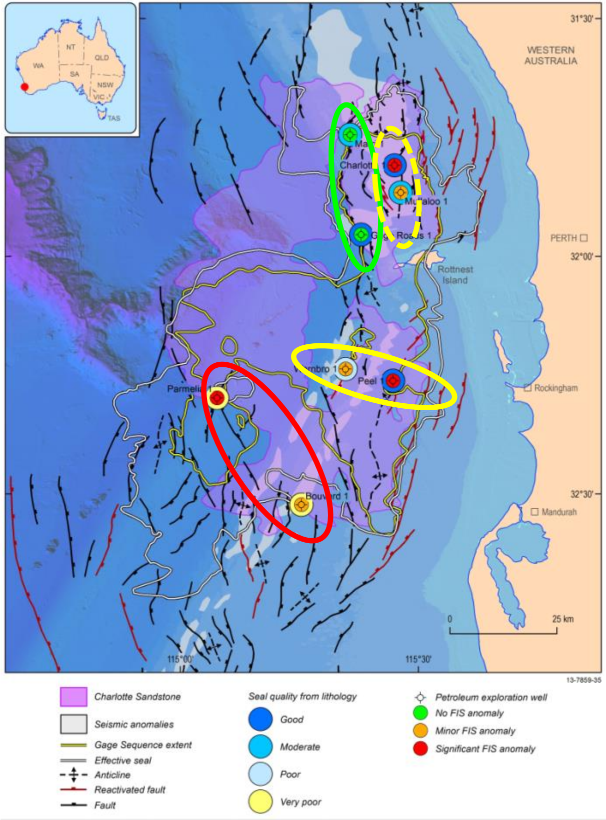


Relationship of reservoir and seal



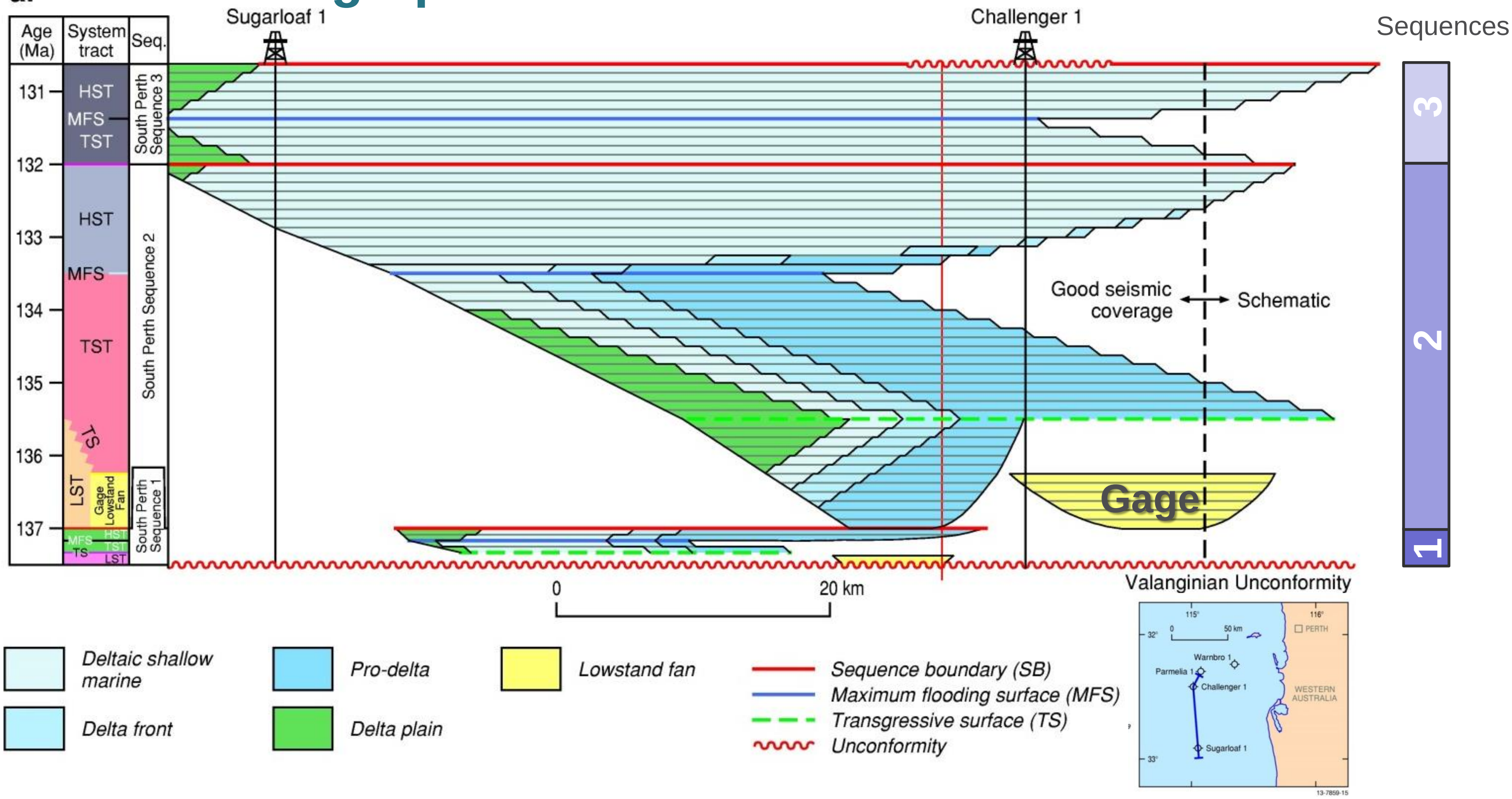


Fluid inclusion results – how good is the seal?

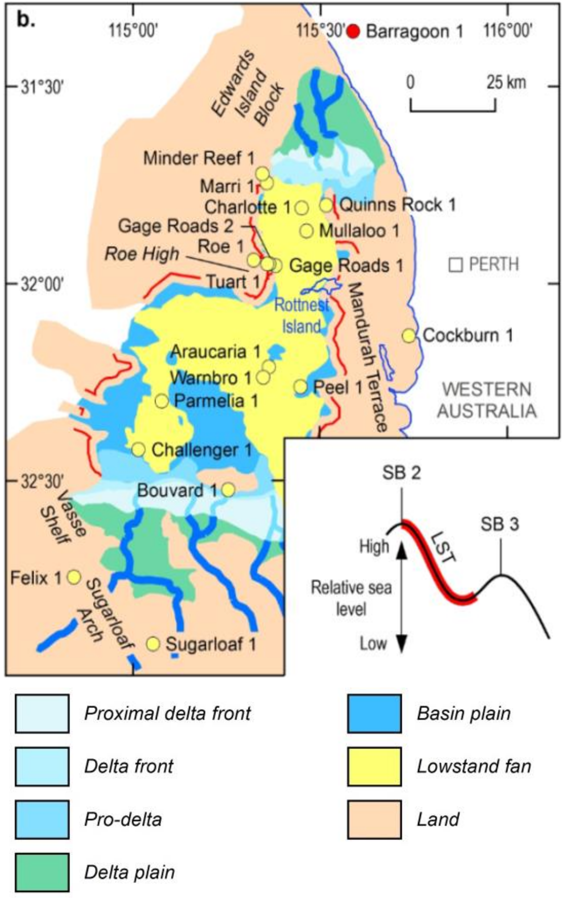


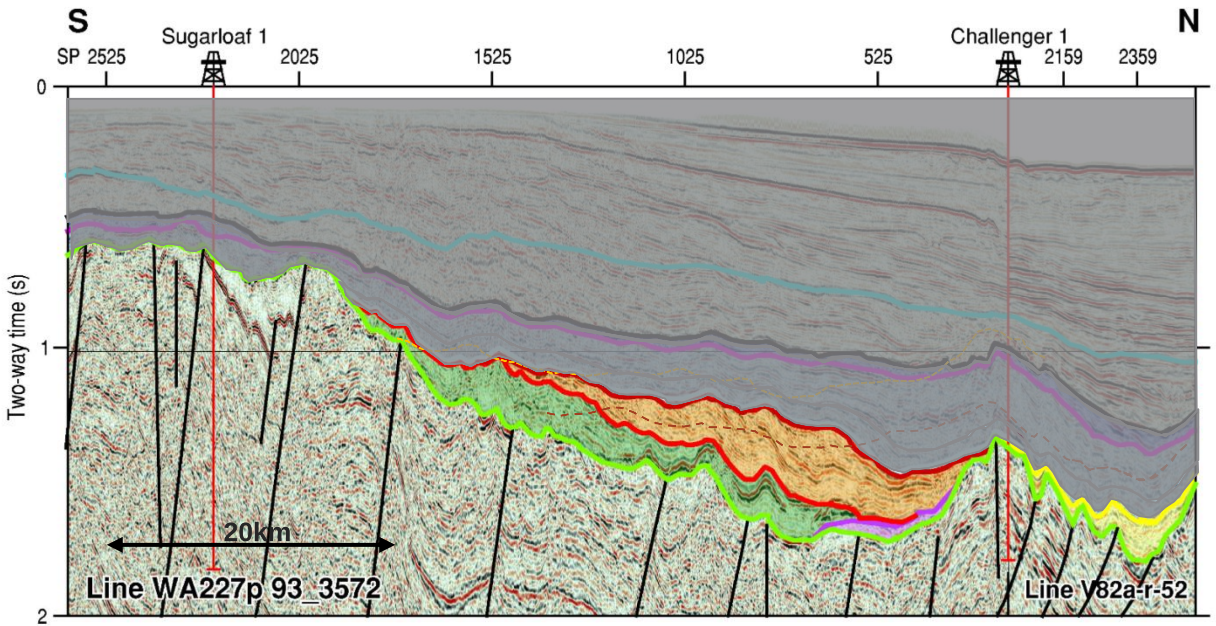
- FIS results indicate seal is major contributor to exploration failure:
  - Good seal at Gage Roads 1, 2 & Marri 1
  - No seal at Bouvard 1 and Parmelia 1
  - Possible seal breach by fault reactivation at Warnbro 1 & Peel 1
  - Suspected seal breach at Charlotte 1 & Mullaloo 1 – not possible to map reactivated faults due to seismic anomalies
- Better understanding of seal is critical

Chronostratigraphic chart



Evolution of the South Perth Supersequence delta





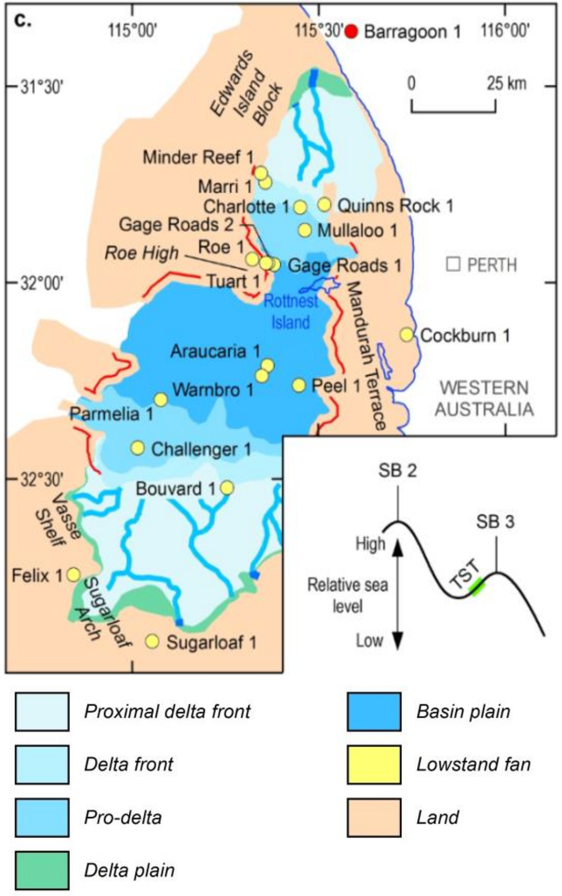
Sequence 1 / Sequence 2 LST

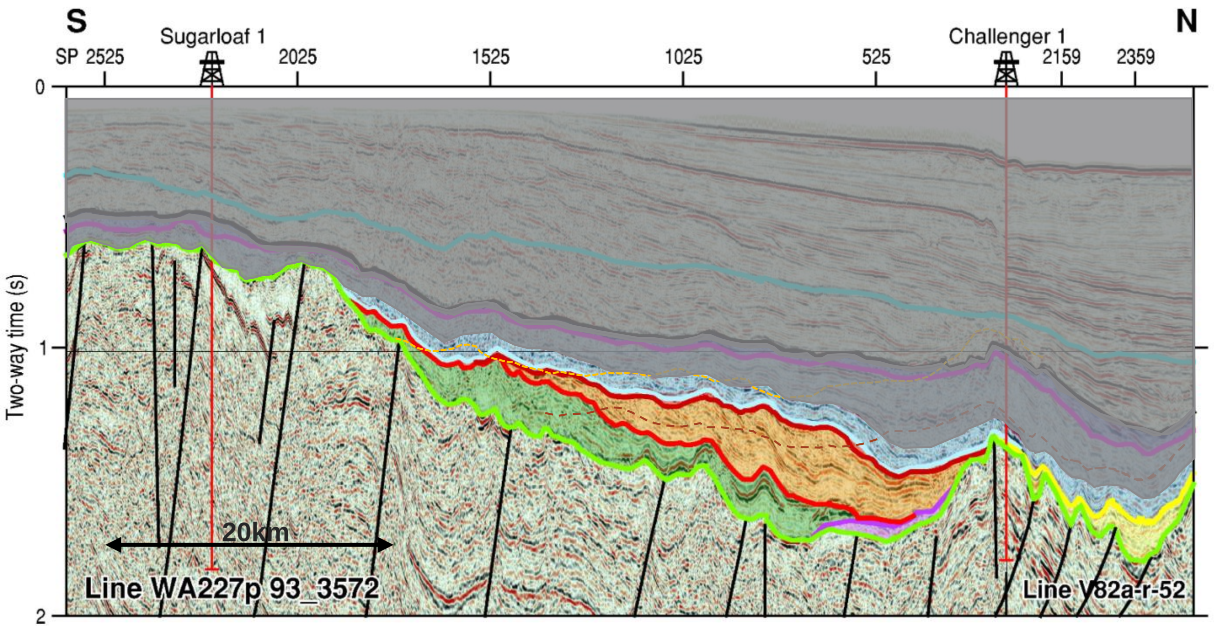
Gage Lowstand Fan

Effective Seal

Valanginian Unc

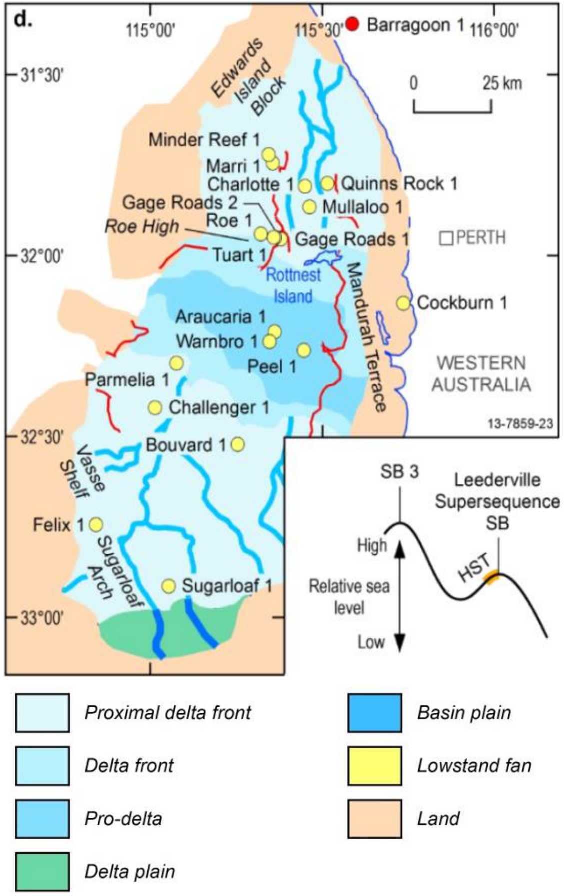
Evolution of the South Perth Supersequence delta

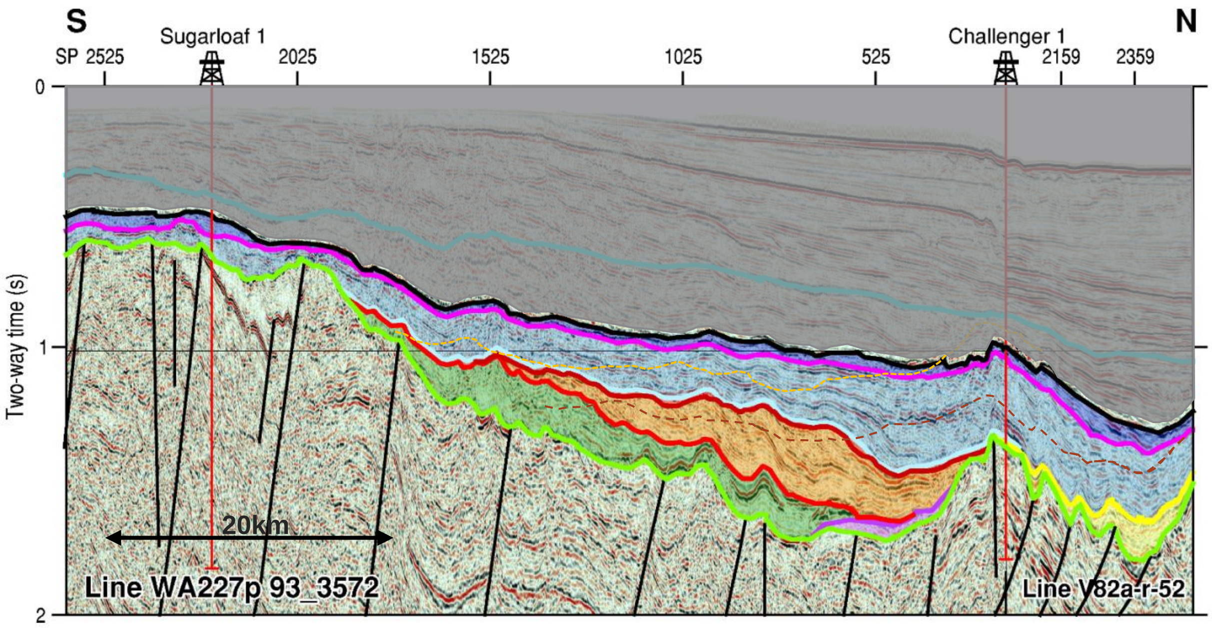




Sequence 2 TST

Evolution of the South Perth Supersequence delta





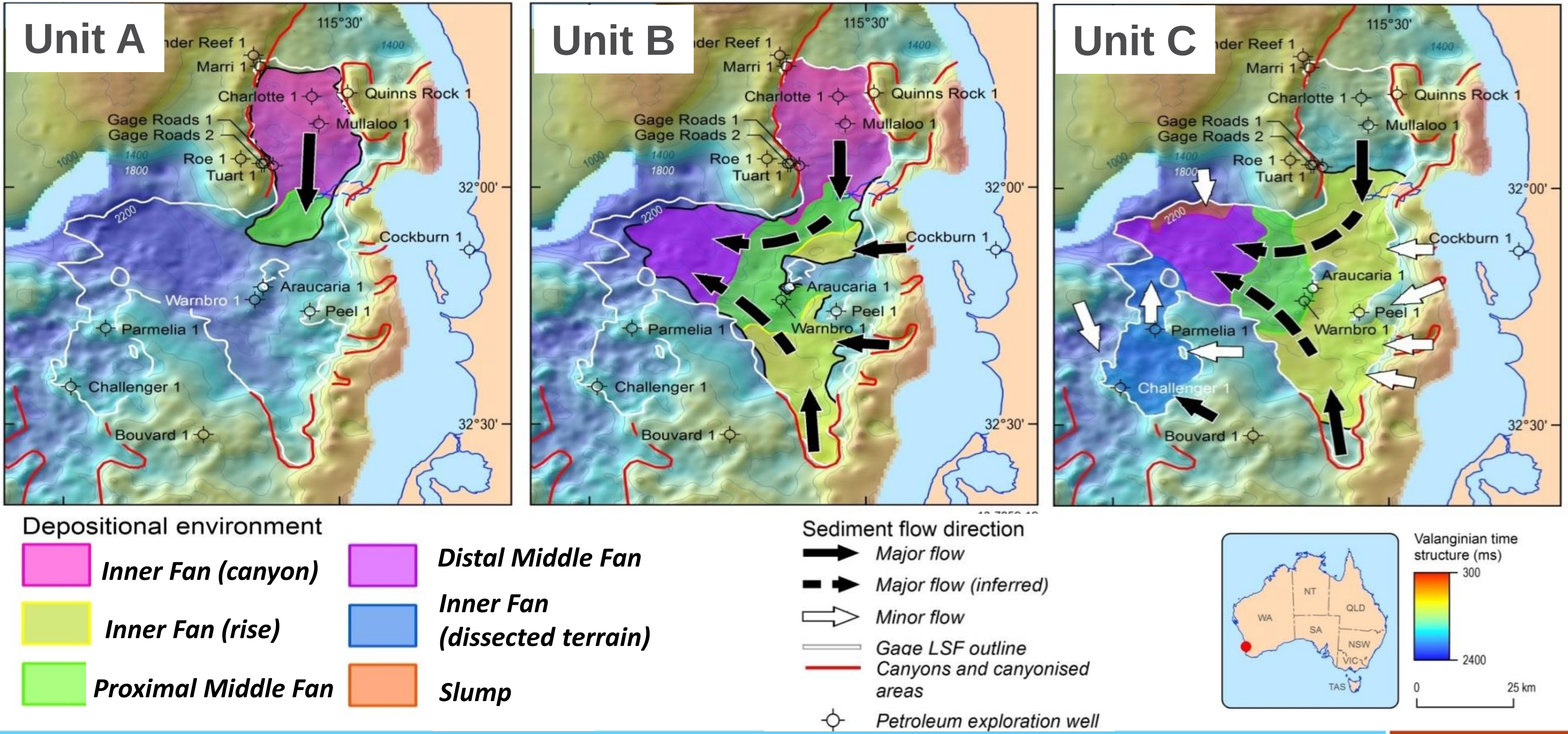
Sequence 3 HST

Gage Lowstand Fan

Effective Seal

Valanginian Unc

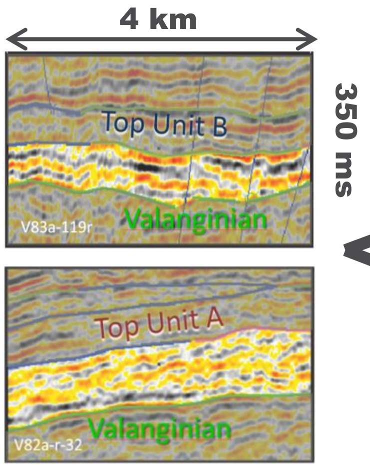
Depositional environments – Gage reservoir

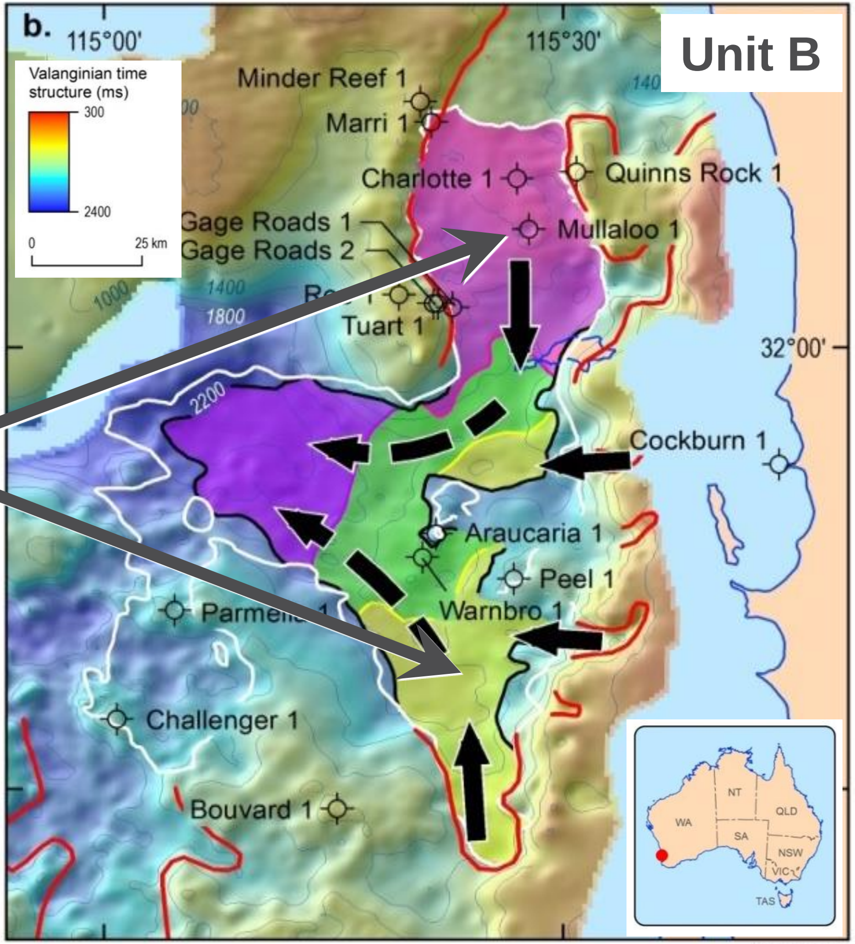


Gage depositional environment: seismic characteristics

INNER FAN

- Continuous, semi-continuous
- Variable amplitude
- Prograding
- Downlaps onto underlying unit





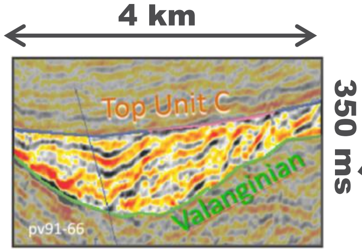
Depositional environment

- Inner fan (canyon) (Unit A and B)
- Inner fan (rise) (Unit B and C)
- Proximal middle fan (Unit A, B and C)
- Distal middle fan (Unit B and C)
- Inner fan (dissected terrain) (Unit C)
- Slump (Unit C)

Gage depositional environment: seismic characteristics

INNER FAN (DISSECTED)

- Dominantly continuous
- Med-high amplitude
- Prograding / lateral accretion
- Downlap onto underlying unit.



Depositional environment

- Inner fan (canyon) (Unit A and B)
- Inner fan (rise) (Unit B and C)
- Proximal middle fan (Unit A, B and C)
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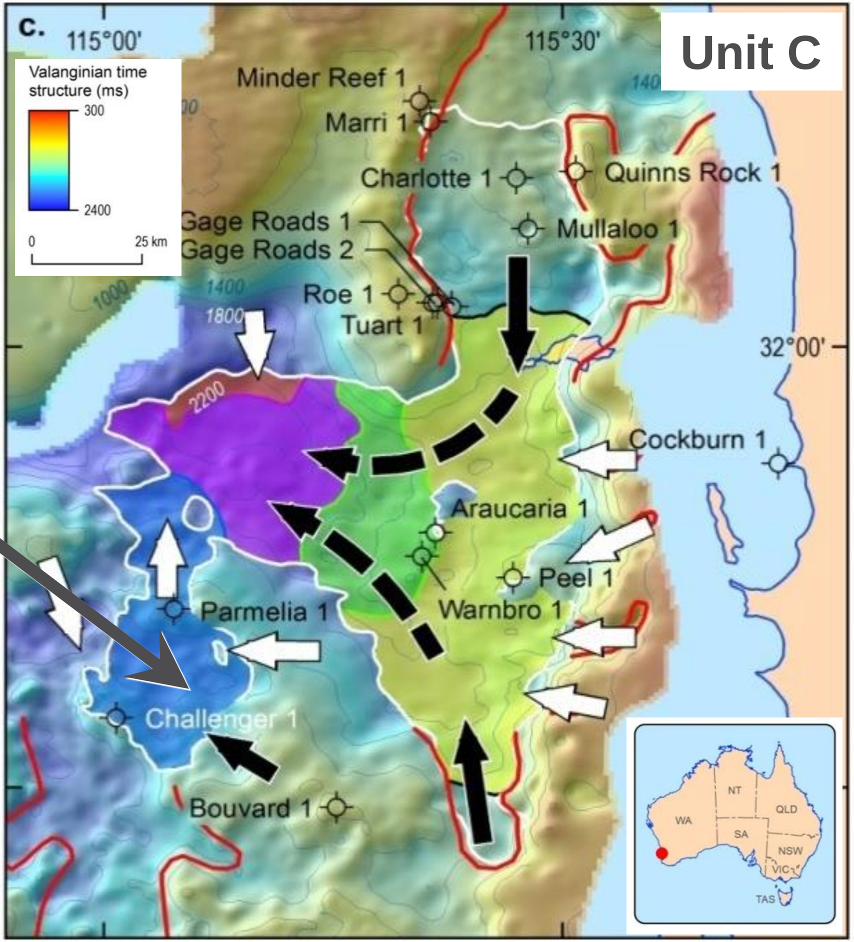
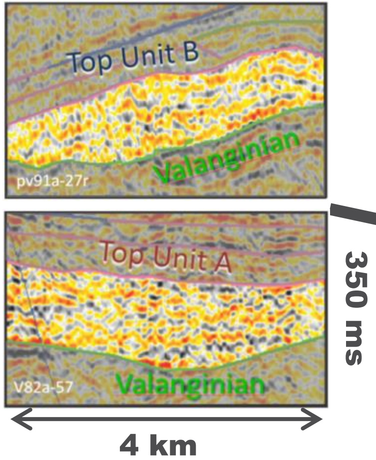
- Slump (Unit C)

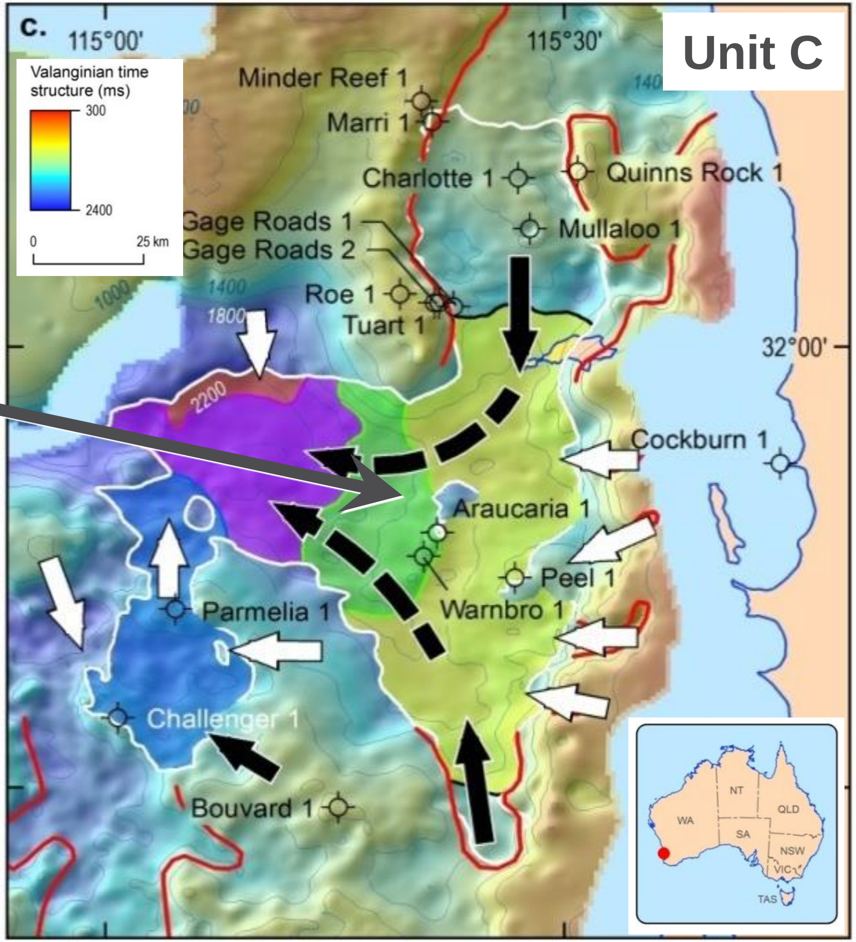


Gage depositional environment: seismic characteristics

PROXIMAL MIDDLE FAN

- Dominantly discontinuous
- Variable amplitude
- Prograding
- Downlap onto underlying unit





Depositional environment

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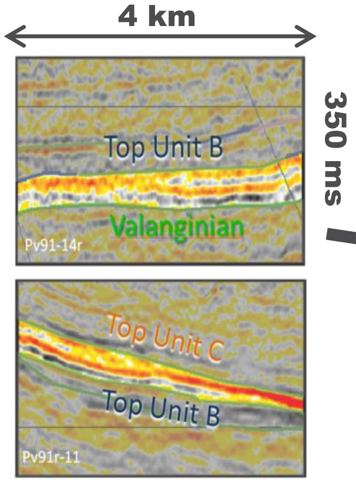
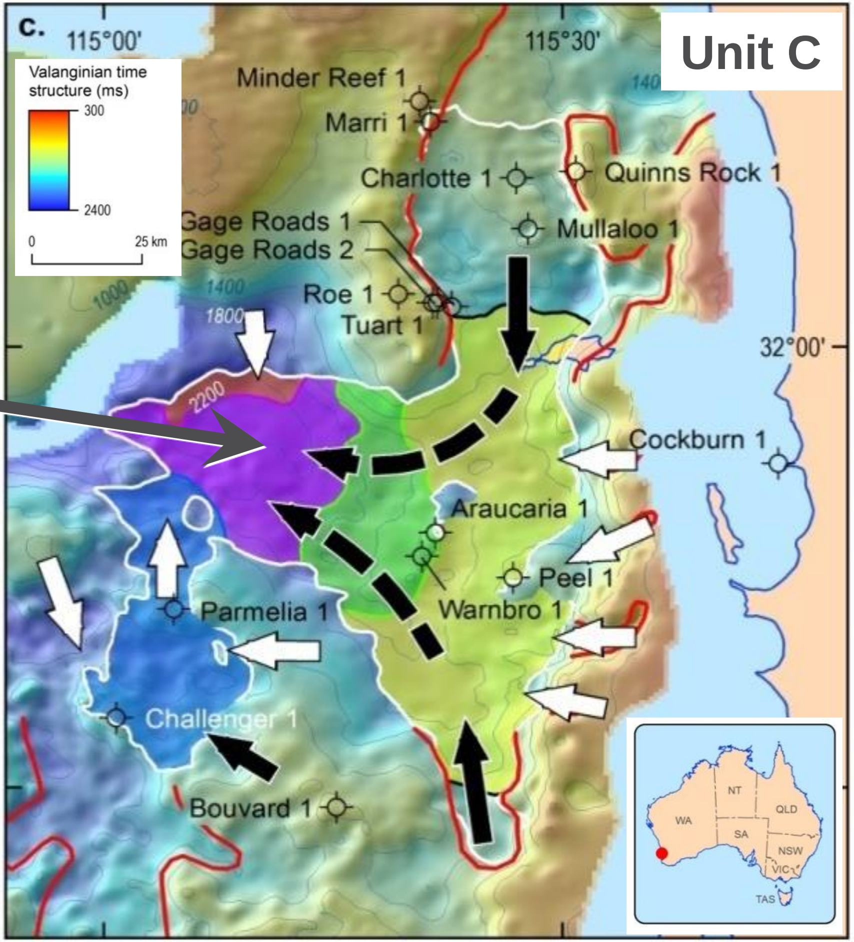
- Inner fan (rise) (Unit B and C)
- Proximal middle fan (Unit A, B and C)
- Distal middle fan (Unit B and C)
- Inner fan (dissected terrain) (Unit C)
- Slump (Unit C)

Gage depositional environment: seismic characteristics

DISTAL MIDDLE FAN

- Continuous reflectors
- Sheet-like
- Variable amplitude
- Prograding





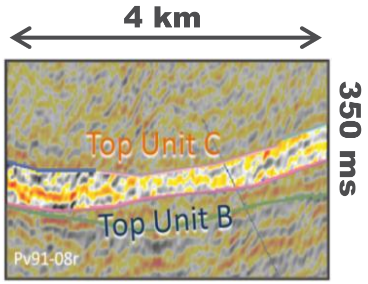
Depositional environment

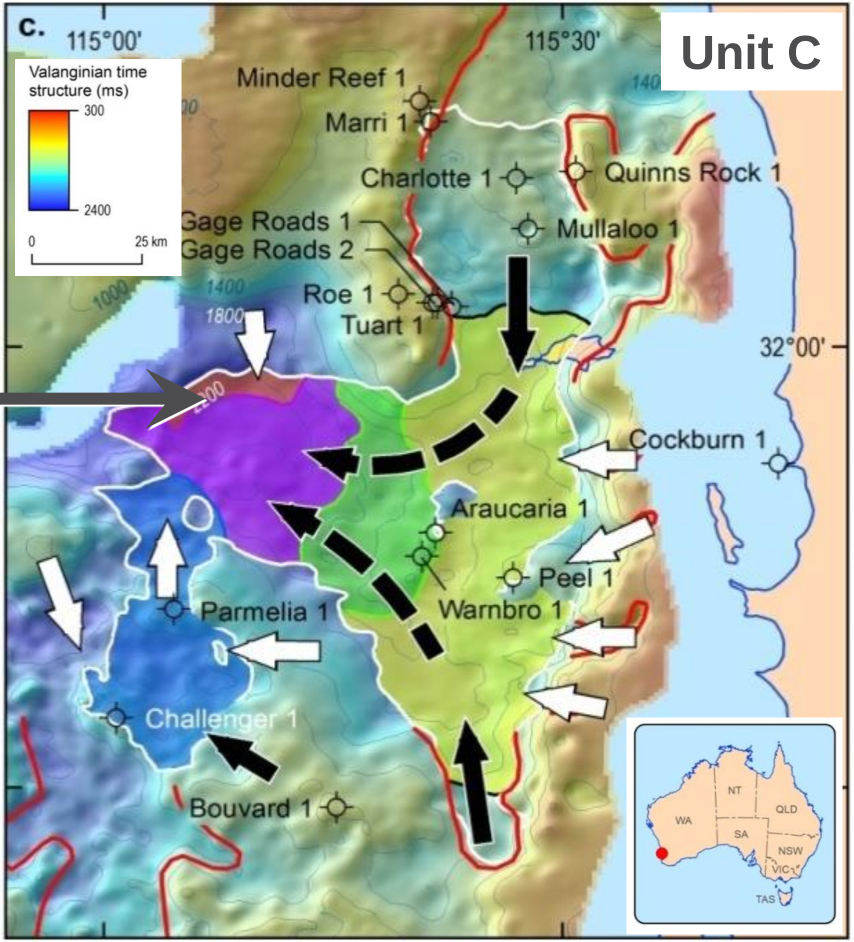
- Inner fan (canyon) (Unit A and B)
- Inner fan (rise) (Unit B and C)
- Proximal middle fan (Unit A, B and C)
- Distal middle fan (Unit B and C)
- Inner fan (dissected terrain) (Unit C)
- Slump (Unit C)

Gage depositional environment: seismic characteristics

SLUMP

- Discontinuous reflectors
- Low-mod amplitude
- Chaotic





Depositional environment

Inner fan (canyon) (Unit A and B)	*Distal middle fan (Unit B and C)*
Inner fan (rise) (Unit B and C)	*Inner fan (dissected terrain) (Unit C)*
Proximal middle fan (Unit A, B and C)	*Slump (Unit C)*

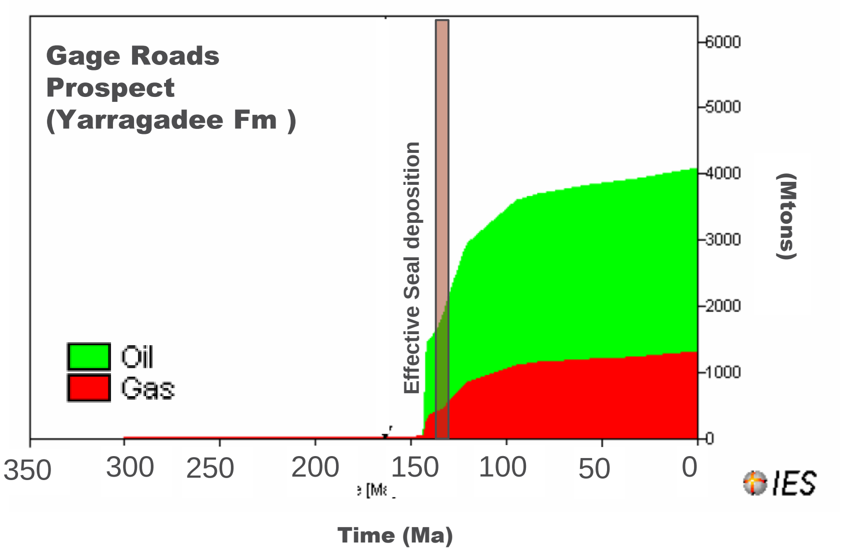
Depositional environments: reservoir characteristics

Slump	Distal middle fan	Proximal middle fan	Canyon-confined inner fan
Chaotic bedding, over compaction, lateral pinchouts	Non-channelised depositional lobe, sheet-like sand bodies, well sorted with high porosity	Transition zone with channels & suprafan lobe deposits	Stacked sand bodies in turbidity current & debris flow deposits
Highly variable, poor to fair sand body connectivity	good lateral & moderate vertical connectivity	good lateral & good-moderate vertical connectivity	excellent vertical communication; low lateral connectivity
poor reservoir properties	good reservoir properties	good to excellent reservoir properties	excellent reservoir properties

Increasing reservoir quality/certainty

Petroleum systems modelling

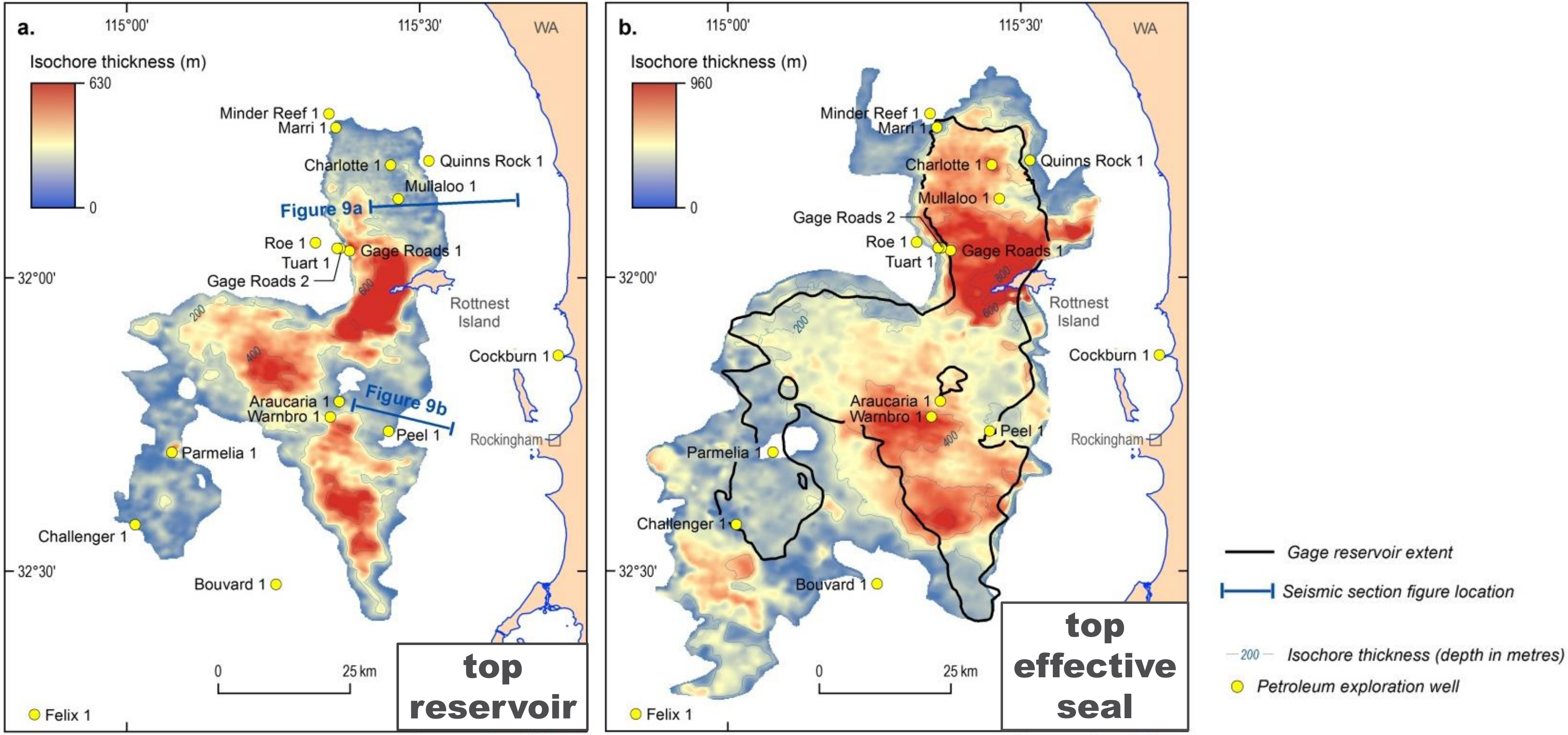
Cumulative expulsion



Neumann et al., 2007

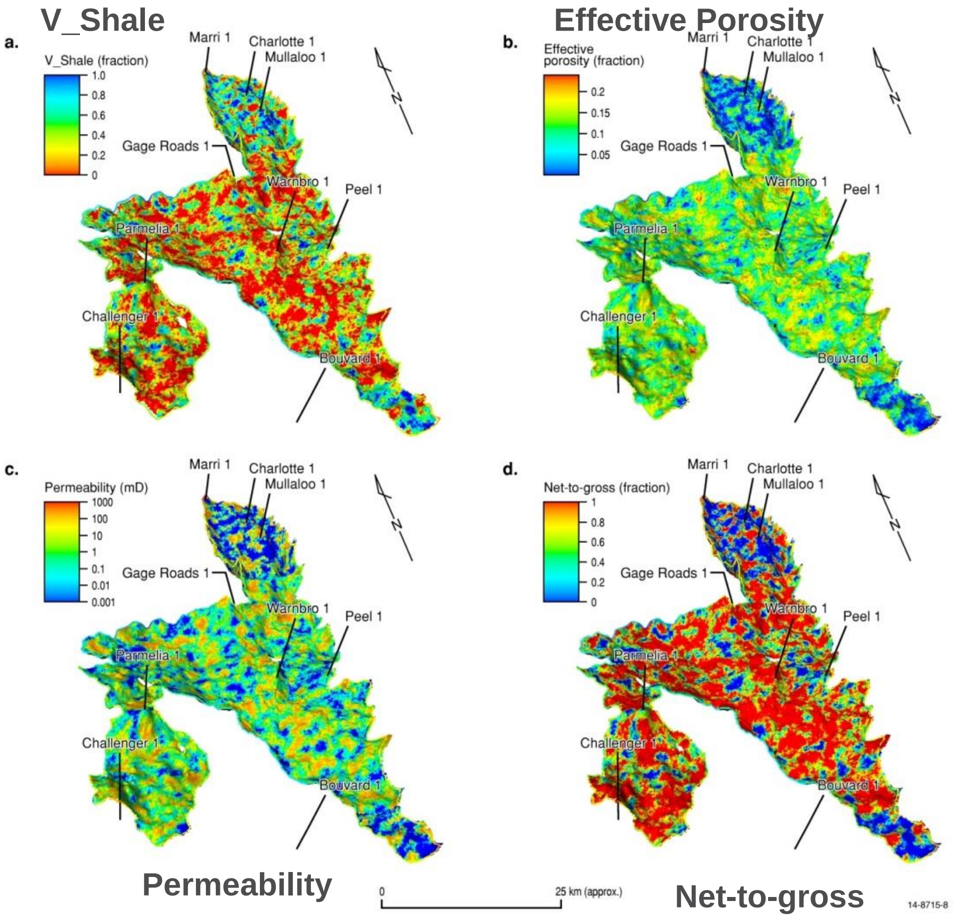
- Potential source rocks from Permian to E. Cretaceous
- Yarragadee Fm = best developed, most regionally extensive
- Hydrocarbon generation continued after deposition of effective seal
- Small amounts continued to generate throughout the Cenozoic
- Syn-rift faults active post breakup may create secondary accumulations in Gage reservoir
- Preservation of accumulations depends on the present-day seal integrity

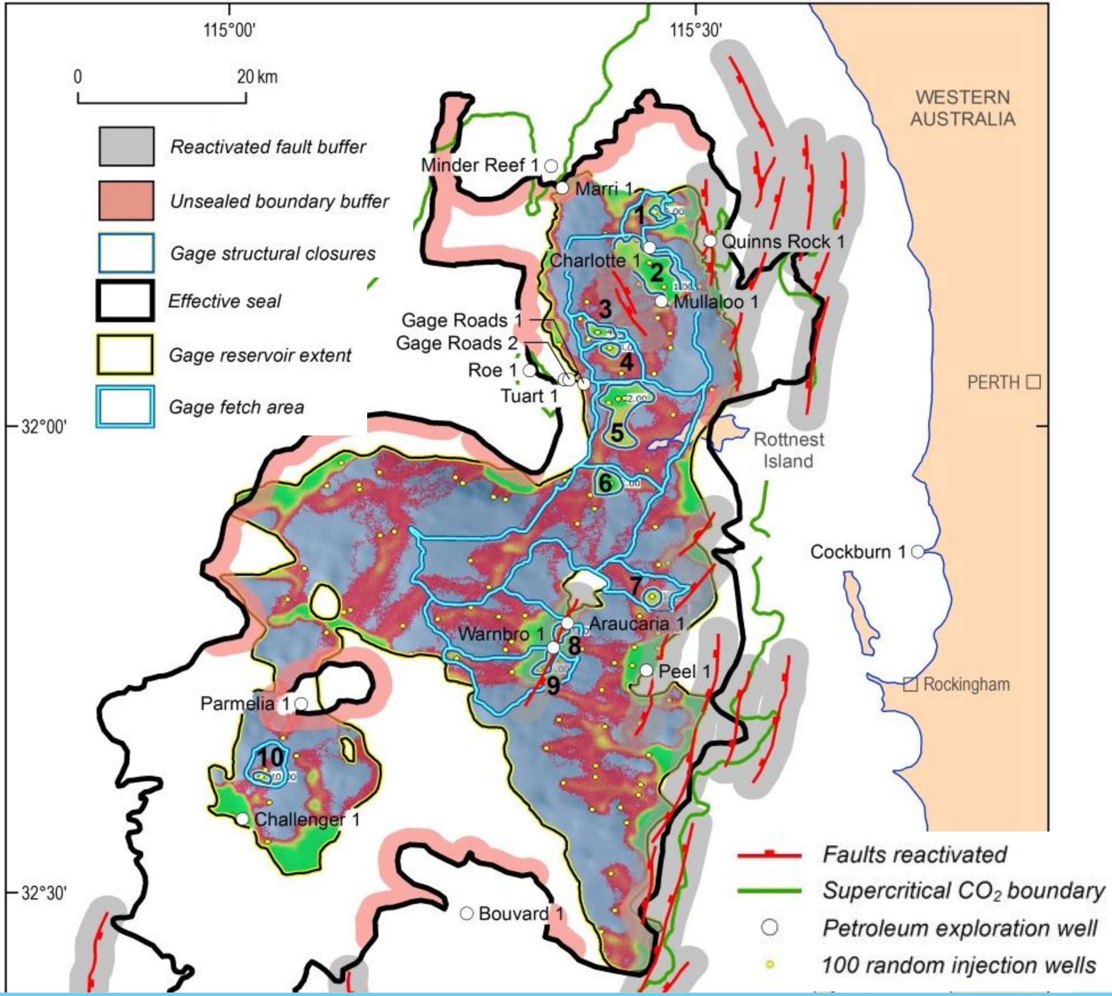
Isochore thickness of reservoir & effective seal



Reservoir modelling

- Core porosity = 9.5-23.9%, permeability from 0.124 to 1340 mD
- Mostly good to excellent reservoir properties
- Gage reservoir laterally heterogeneous
- Upper reaches of canyons:
  - least favourable reservoir qualities
  - correspond to thinner effective seal

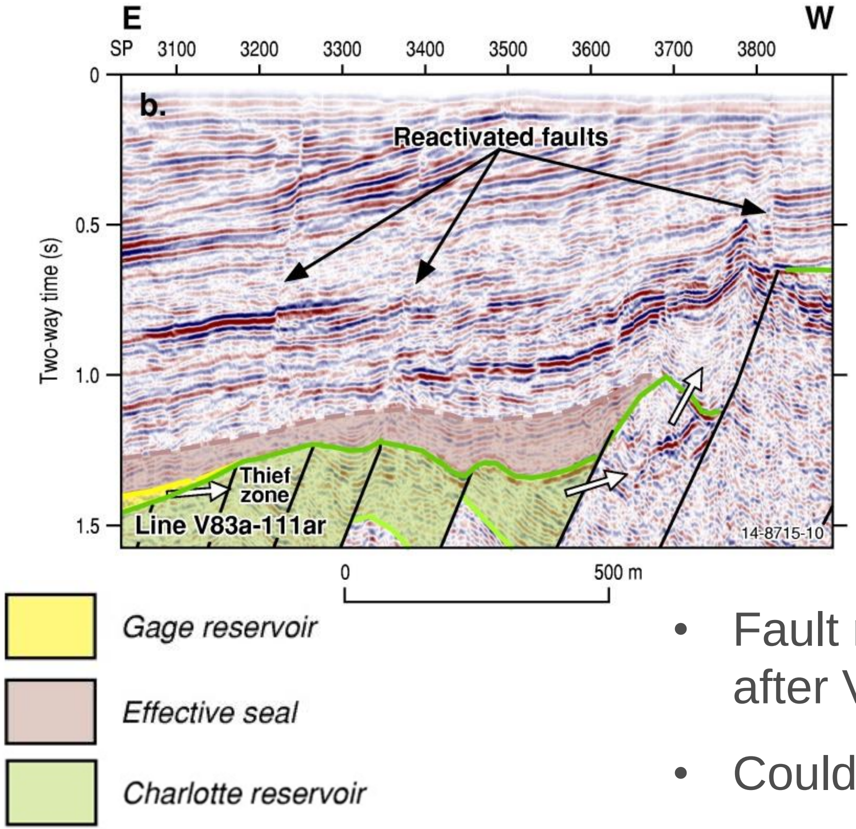


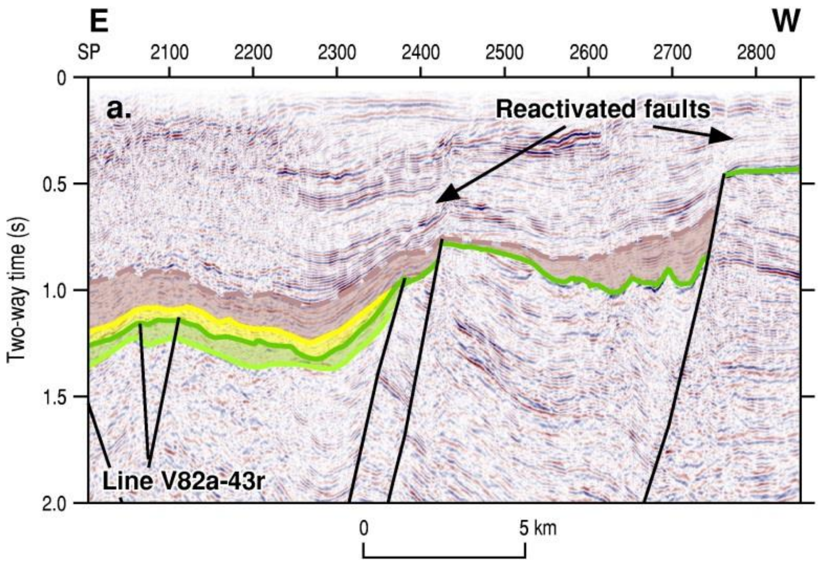


Flow path analysis

- Migration pathways (red) and structural closures (green)
- Multiple structural & stratigraphic closures at the top of Gage reservoir
- Most prospective structural closures in Rottnest Trough (large closures, away from faults)
- Stratigraphic pinch-outs onto Valanginian Unconformity (Roe High, Sugarloaf Trough, BFZ)

Risk - Reactivated faults & thief zones

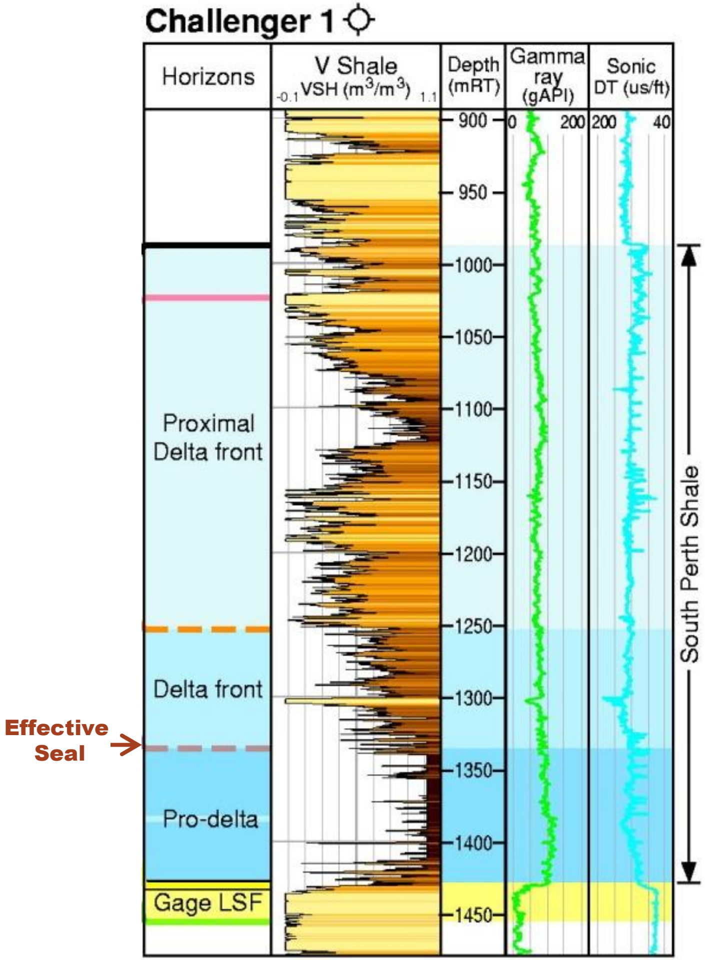




- Fault movement (and minor reactivation) continued after Valanginian. Do they jeopardise seal integrity?
- Could Charlotte reservoir act as thief zone?

Summary

- New understanding of the Vlaming Sub-basin post-rift succession (based on an integrated sequence stratigraphic analysis of well and seismic data)
- Better age control
- Better understanding of variations in depositional facies within main lithostratigraphic units
- Better understanding of spatial distribution of quality reservoir and seal



Conclusions

- Prospective reservoir-seal pair – not primary focus of previous exploration
- Plays: Post-breakup pinch-outs against the Valanginian Unconformity & anticlinal closures
- Regional seal re-evaluation indicate the pro-delta shale facies of South Perth Supersequence provides an effective seal for the underlying Gage reservoir
- Sand sheets in the distal middle fan and stacked channelised sands in the inner fan may provide an extensive reservoir
- Modelling predicts:
    - good-excellent reservoir properties suitable for hydrocarbon entrapment
    - multiple viable exploration targets, esp. in Rottnest Trough
- Deep-seated faults, penetrating the syn-rift section, are in direct contact with the Gage reservoir and it could be actively receiving hydrocarbon charge

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