

Petroleum Prospectivity of the Houtman Sub-Basin, Offshore Perth Basin, Australia*

Lisa S. Hall¹, Irina Borissova², Emmanuelle Grosjean², Chris Southby², Ryan Owens², George Bernardel², and Cameron Mitchell²

Search and Discovery Article #11046 (2018)**

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¹Geoscience Australia, Symonston, ACT, Australia (lisa.hall@ga.gov.au)

²Geoscience Australia, Symonston, ACT, Australia

Abstract

The Houtman Sub-basin is an under-explored region of the northern Perth Basin, offshore Western Australia. Interpretation of Geoscience Australia's regional 2D seismic survey GA-349 reveals that this frontier depocentre contains up to 19 km of sediments. Regional correlation of the interpreted seismic stratigraphy across the offshore Perth Basin indicates that this includes up to 16 km of Permian–Early Cretaceous succession, with the potential to contain multiple source rocks equivalent to those identified in the adjacent producing depocentres, including the regionally extensive late Permian–Early Triassic Kockatea Shale. Multiple possible play types have been identified, including Permian– Early Triassic stratigraphic traps and Jurassic– Cretaceous tilted fault blocks. This study uses pseudo-3D petroleum systems modelling and a comprehensive review of the all offshore northern Perth source rocks to investigate the maturity and charge history of 10 potential Permian– Jurassic source rocks in the northern Houtman Sub-basin. A regional pseudo-3D petroleum systems model was constructed using the new seismic interpretation and sequence ages were assigned based on a newly developed regional tectonostratigraphic chart. The thermal history of the basin was modelled using lithospheric structure changes through time and was calibrated using corrected temperature and maturity data from 9 Perth Basin wells located along strike in equivalent tectonic settings. Source rock properties were assigned based on an extensive review of TOC, Rock Eval, and kinetic data from all offshore Perth Basin wells. Results predict that large cumulative hydrocarbon volumes have been generated from Permian–Triassic source rocks across the

study area, whilst Jurassic sources remain mostly immature. The spatial distribution of each potential source kitchen varies depending on burial depth, heat flow associated with rifting, and the amount of Valanginian erosion. Potential source rock yield is also highly dependent on source characteristics. The most promising potential source rock is the oil prone Hovea Member of the Kockatea Shale. If present, this has the potential to have generated large volumes of oil along the inboard margin of the subbasin. The majority of generation and expulsion occurred prior to Valanginian break-up. Therefore, the relative timing of expulsion and migration versus trap formation, along with trap preservation, remain key exploration risks.

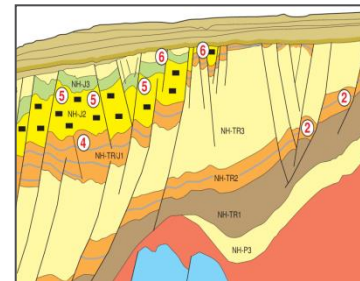
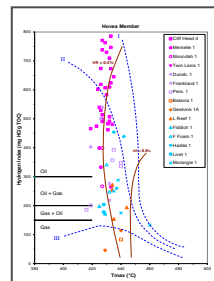
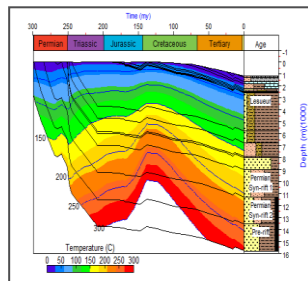
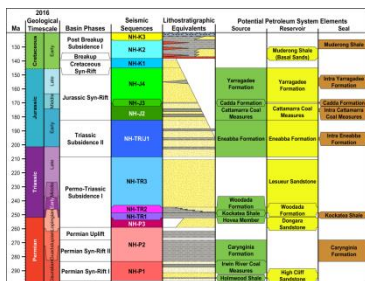
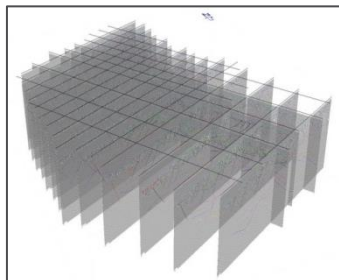
References Cited

- Hall, L.S., G. Sanchez, I. Borissova, L. Pryer, C. Southby, Z. Shi, and R. Hackney, 2017, Crustal Structure and Tectonic Evolution of the Northern Perth Basin, Australia: AAPG/SEG 2017 International Conference and Exhibition, London, England, October 15-18, 2017, [Search and Discovery Article #11027 \(2017\)](#). Website accessed January 2018.
- Grosjean, E., L.S. Hall, C.J. Boreham, and T. Buckler, 2017, Source Rock Geochemistry of the Offshore Northern Perth Basin: Regional Hydrocarbon Prospectivity of the Offshore Northern Perth Basin: Record 2017/18, Geoscience Australia, Canberra, 71 p. <http://dx.doi.org/10.11636/Record.2017.018>. Website accessed January 2018.
- Sanchez, G., L.S. Hall, Z. Shi, I. Borissova, L. Pryer, C. Southby, K. Romine, G. Westerman, C. Pietrucha, and A. Kroll, 2016, Houtman Sub-Basin Geophysical Modelling: FrogTech Pty Ltd, Canberra, Australia, 58 p.



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Acknowledgements

Seismic survey planning & acquisition

Irina Borissova, Jessica Gurney, Chris Southby, George Bernardel, Kathryn Owen, Anna Potter, Melissa Fellows, Rachel Przeslawski

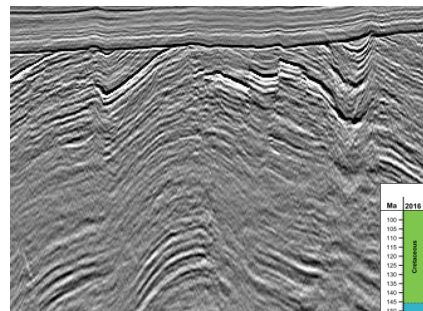


Data processing and QC

Merrie-Ellen Gunning, Tanya Fomin

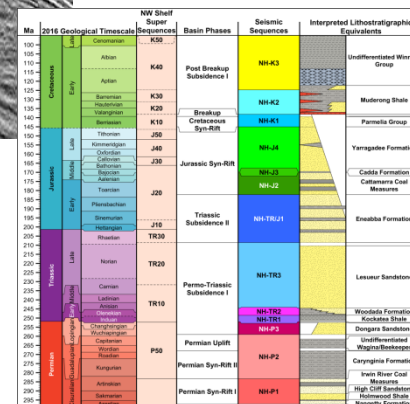
Initial seismic interpretation QC

Barry Bradshaw (Consultant)



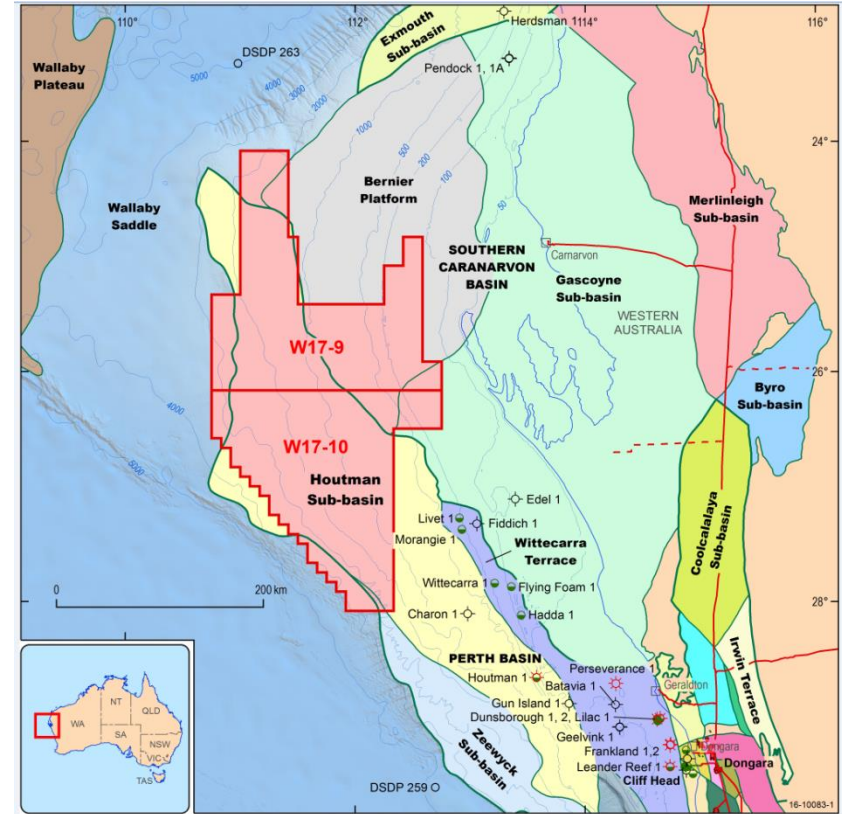
Geophysical modelling

Guillaume Sanchez, Lynn Pryer, Zhiqun Shi (FrogTech)



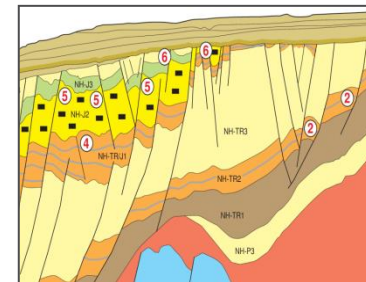
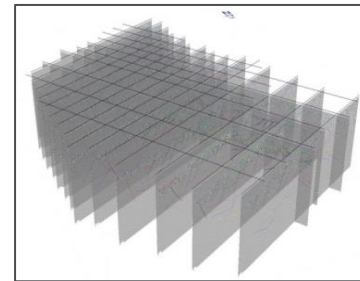
Northern Houtman Sub-basin

- Frontier province on Australia's western margin, located at the northern tip of the Perth Basin
- Prior to 2014, poor data distribution – widespread 2D seismic and no wells.
- Indications of a large depocentre (>12 km of sediment) but this was very poorly constrained.
- The offshore Perth basin hosts multiple proven petroleum systems, with current production (e.g. Cliff Head oil field).
- New data was required to better understand structural architecture and nature of basin fill to further assess the potential petroleum prospectivity of the region.

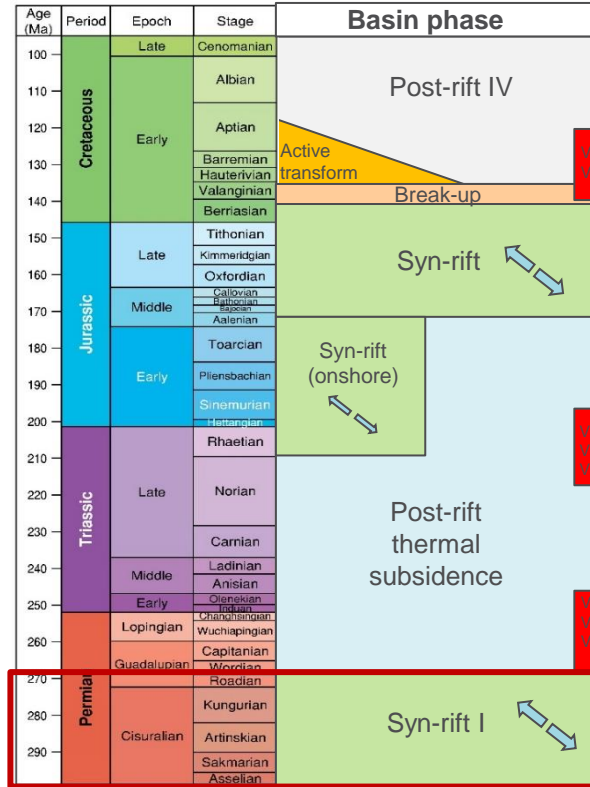


Project aims

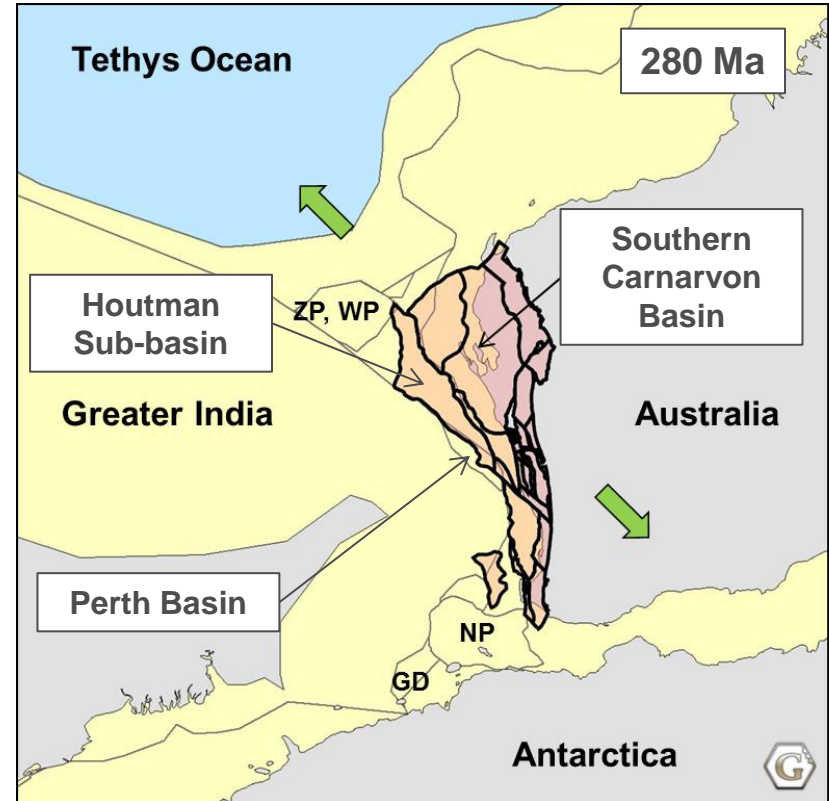
- Acquisition, interpretation and analysis of new seismic data to investigate the petroleum prospectivity of the northern Houtman Sub-basin.
 - Workflow:
 - Regional 2D precompetitive seismic data acquisition and processing
 - Seismic stratigraphic interpretation
 - New tectono-stratigraphic framework
 - Charge history scenario modelling
 - Identification of possible plays
-
- **Improve understanding of basin architecture and sediment fill**
 - **Initial assessment of regional scale hydrocarbon prospectivity**
 - **Supports Australia's current offshore petroleum acreage release**



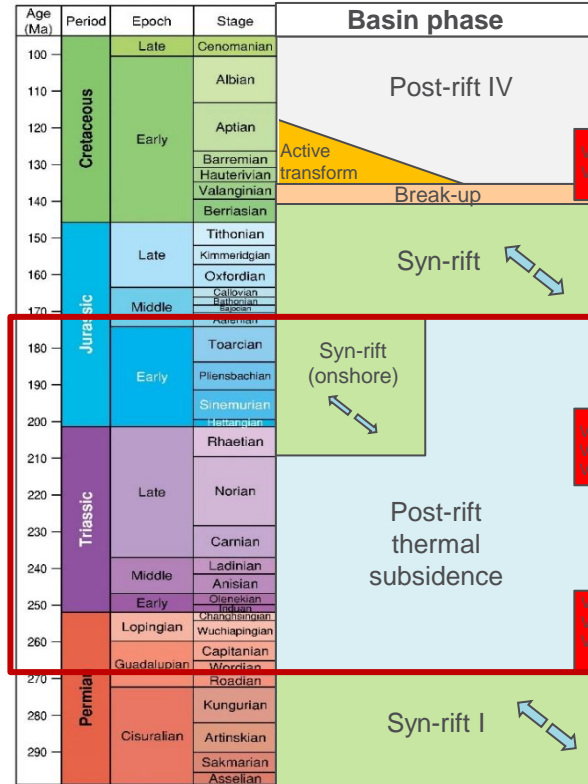
Regional tectonic evolution



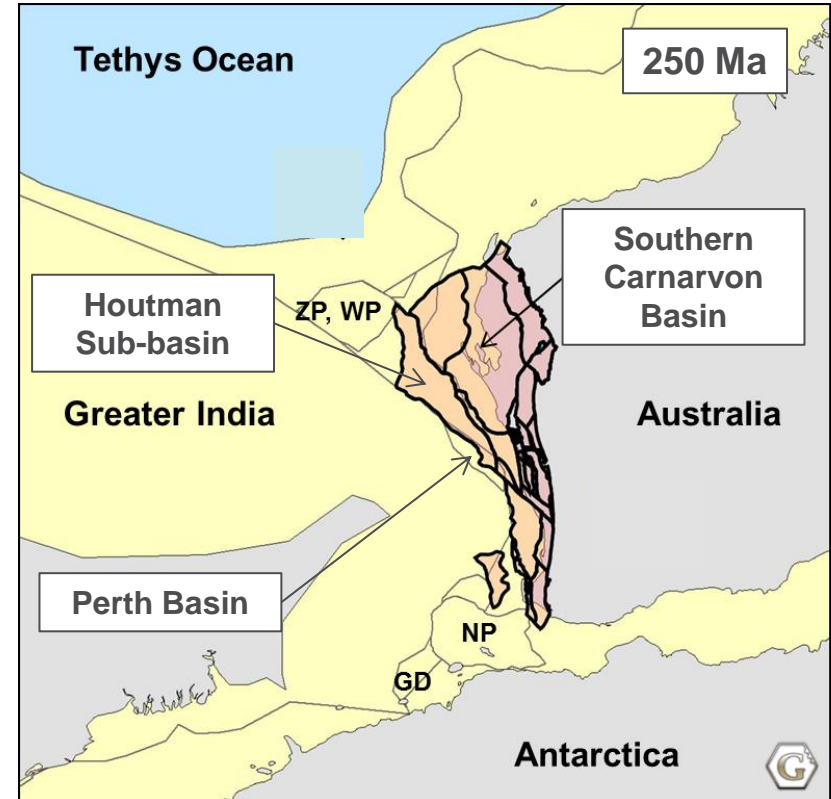
Permian syn-rift



Regional tectonic evolution



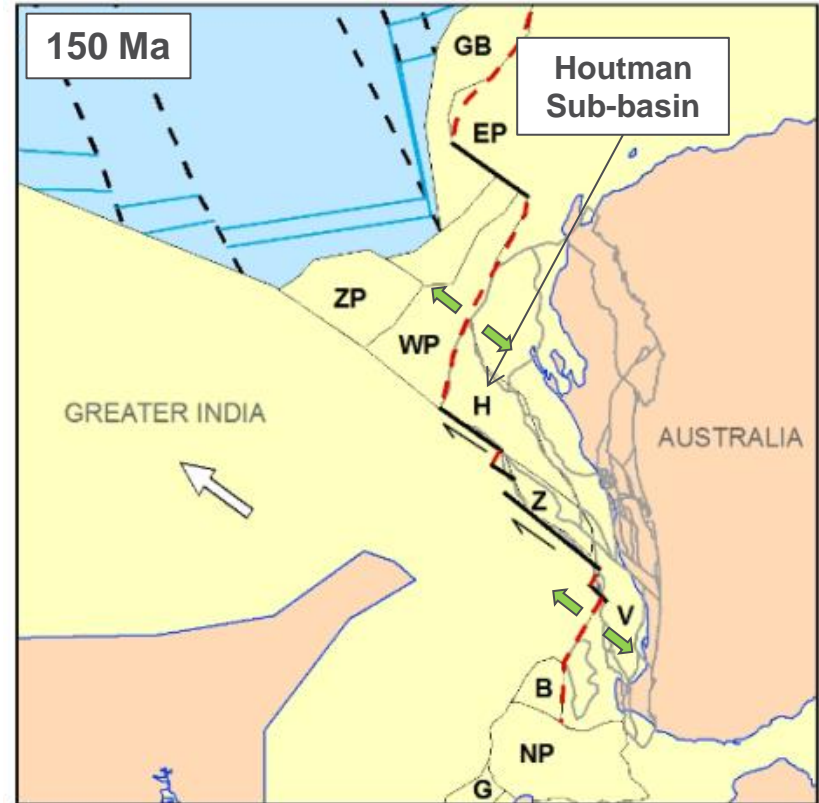
Late Permian – Early Jurassic



Regional tectonic evolution

Age (Ma)	Period	Epoch	Stage	Basin phase
100	Cretaceous	Late	Cenomanian	Post-rift IV
110			Albian	
120		Early	Aptian	
130			Barremian	
140			Hauterivian	
150			Valanginian	
160			Berriasian	Syn-rift
170	Jurassic	Late	Tithonian	
180			Kimmeridgian	
190			Oxfordian	
200			Gallian	
210		Middle	Callovian	
220			Volgian	
230			Aalenian	
240	Triassic	Early	Toarcian	Syn-rift (onshore)
250			Pliensbachian	
260			Sinemurian	
270		Late	Hettangian	Post-rift thermal subsidence
280			Rhaetian	
290			Norian	
300			Carnian	
310	Permian	Middle	Ladinian	
320			Anisian	
330			Olenekian	
340		Early	Induan	
350			Chinskian	
360		Lopingian	Wuchiapingian	
370			Capitanian	
380	Permian	Guadalupian	Wordian	Syn-rift I
390			Roadian	
400			Kungurian	
410		Cisuralian	Artinskian	
420			Sakmarian	
430			Asselian	

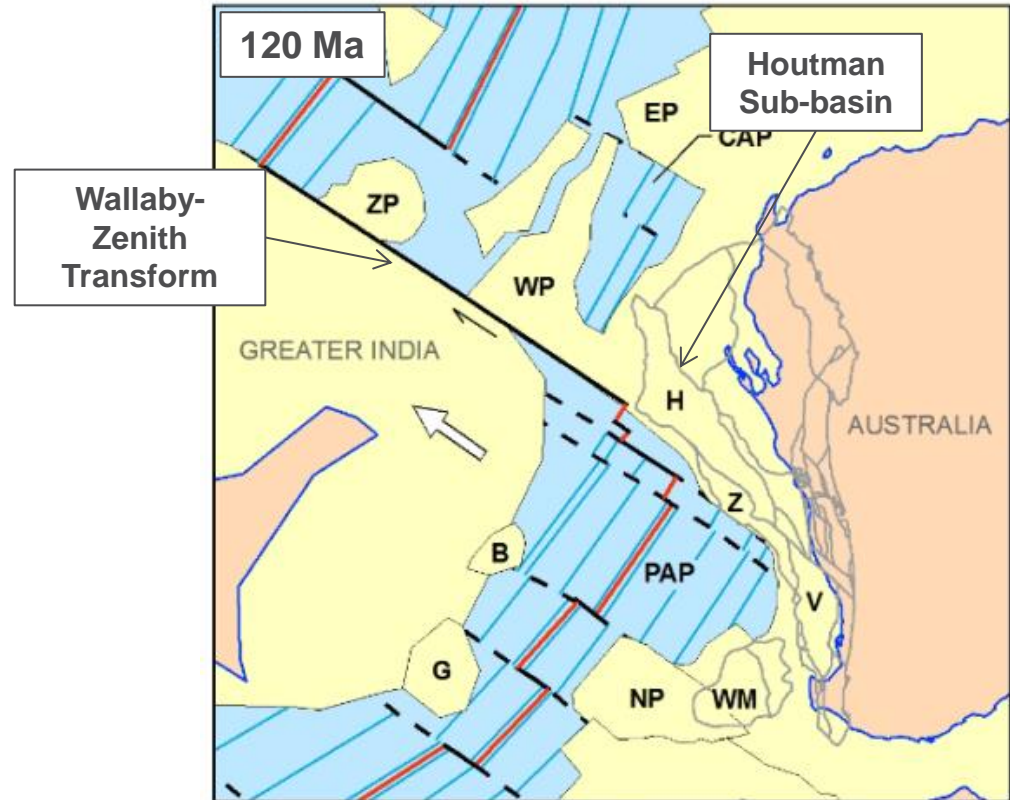
Jurassic syn-rift



Regional tectonic evolution

Age (Ma)	Period	Epoch	Stage	Basin phase
100	Cretaceous	Late	Cenomanian	Post-rift IV
110			Albian	
120		Early	Aptian	
130			Barremian	Active transform Break-up
140			Hauterivian	
150			Valanginian	
160	Jurassic	Late	Berriasian	Syn-rift
170			Tithonian	
180			Kimmeridgian	
190		Middle	Oxfordian	
200			Gallovian	
210			Rothliebian	
220			Aalenian	
230	Triassic	Late	Toarcian	Syn-rift (onshore)
240			Pliensbachian	
250			Sinemurian	
260		Early	Hettangian	
270			Rhaetian	
280			Norian	
290			Carnian	
300	Permian	Late	Ladinian	Post-rift thermal subsidence
310			Anisian	
320			Olenekian	
330		Middle	Induan	
340			Chinskian	
350			Wuchiapingian	
360			Capitanian	
370		Early	Wordian	
380			Roadian	
390			Kungurian	
400	Permian	Cisuralian	Artinskian	Syn-rift I
410			Sakmarian	
420			Asselian	
430				

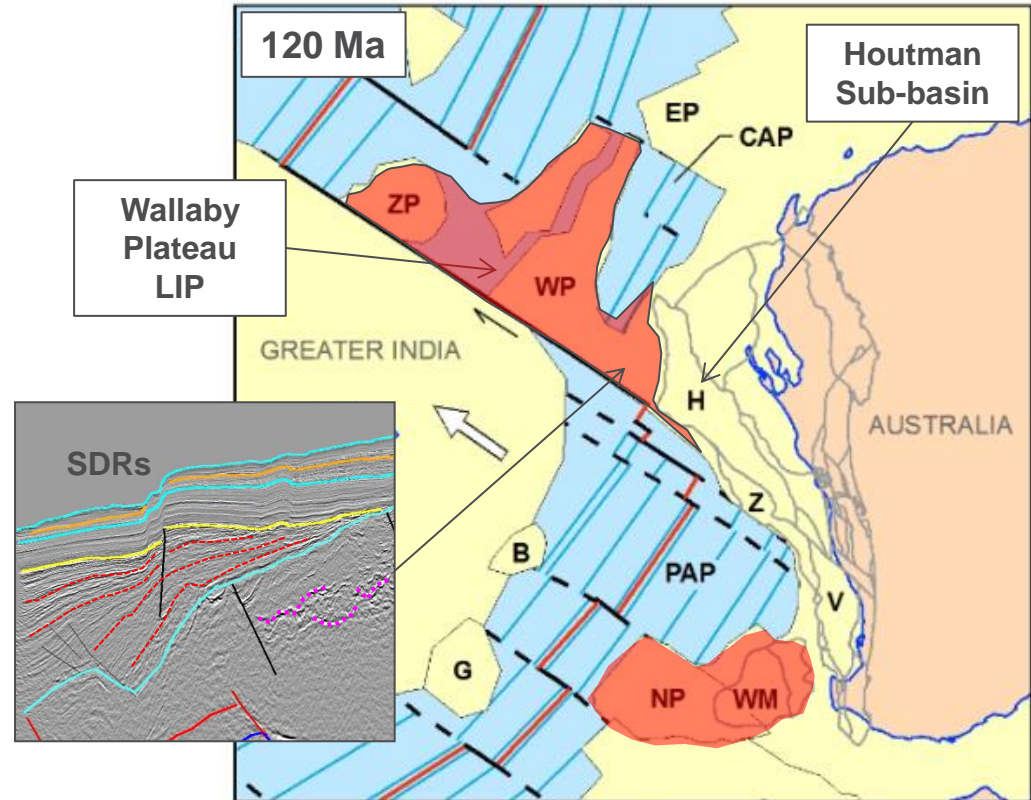
Early Cretaceous break-up



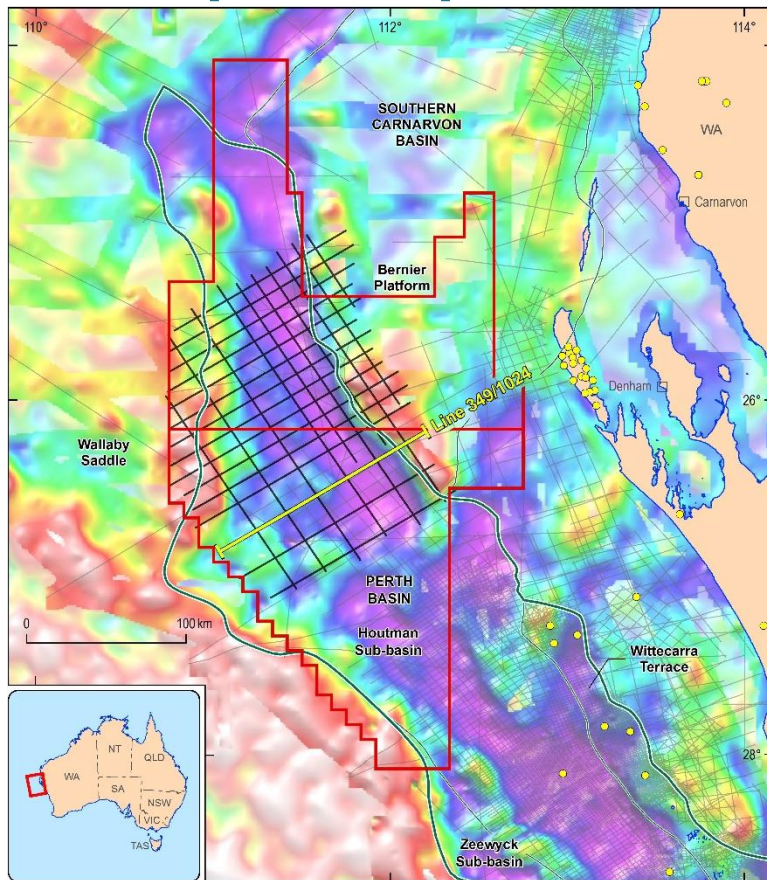
Regional tectonic evolution

Early Cretaceous break-up

Age (Ma)	Period	Epoch	Stage	Basin phase
100	Cretaceous	Late	Cenomanian	Post-rift IV
110			Albian	
120		Early	Aptian	
130			Barremian	Active transform
140			Hauterivian	
145			Valanginian	
150	Jurassic	Late	Berriasian	Break-up
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170			Kimmeridgian	
180			Oxfordian	
190			Gallian	
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210			Triassic	
220			Permian	
230			Carboniferous	
240			Devonian	
250	Triassic	Late	Artinskian	Syn-rift (onshore)
260			Sinemurian	
270			Hettangian	
280			Rhaetian	
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340			Chinskian	
350	Permian	Early	Wuchiapingian	Syn-rift I
360			Lopingian	
370			Capitanian	
380			Wordian	
390			Roadian	
400		Late	Kungurian	Syn-rift I
410			Cisuralian	
420			Artinskian	
430			Sakmarian	
440			Asselien	



New precompetitive data acquisition and processing



SURVEY:

15 November 2014 to 22 January 2015

3455 line km of 2D seismic data acquired

10-20 km line spacing

Deep Tow configuration (8 km streamer towed at 15.6m deep)

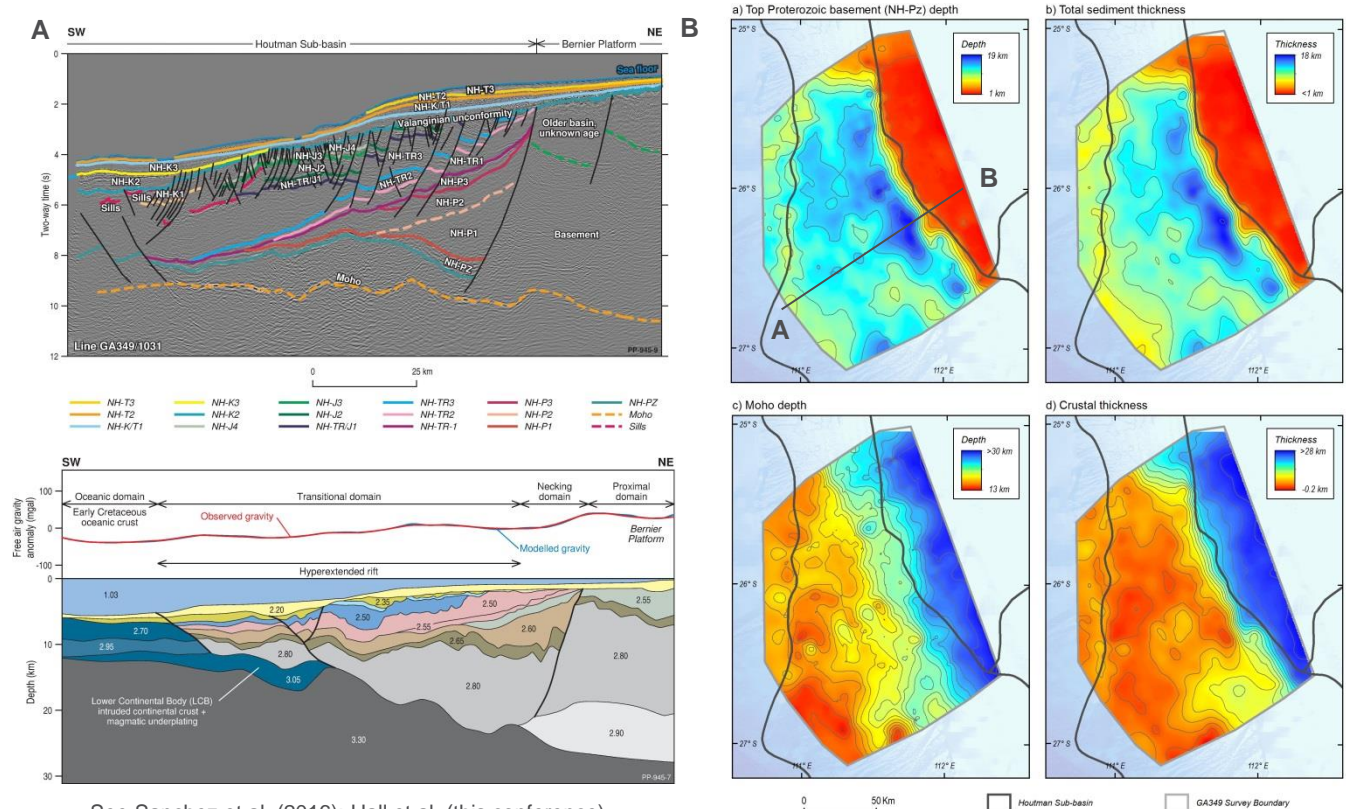
PROCESSED DATA:

Processed using broadband PreSTM/PreSDM.

Suite of products including velocity model and angle stacks released at the APPEA conference 2016

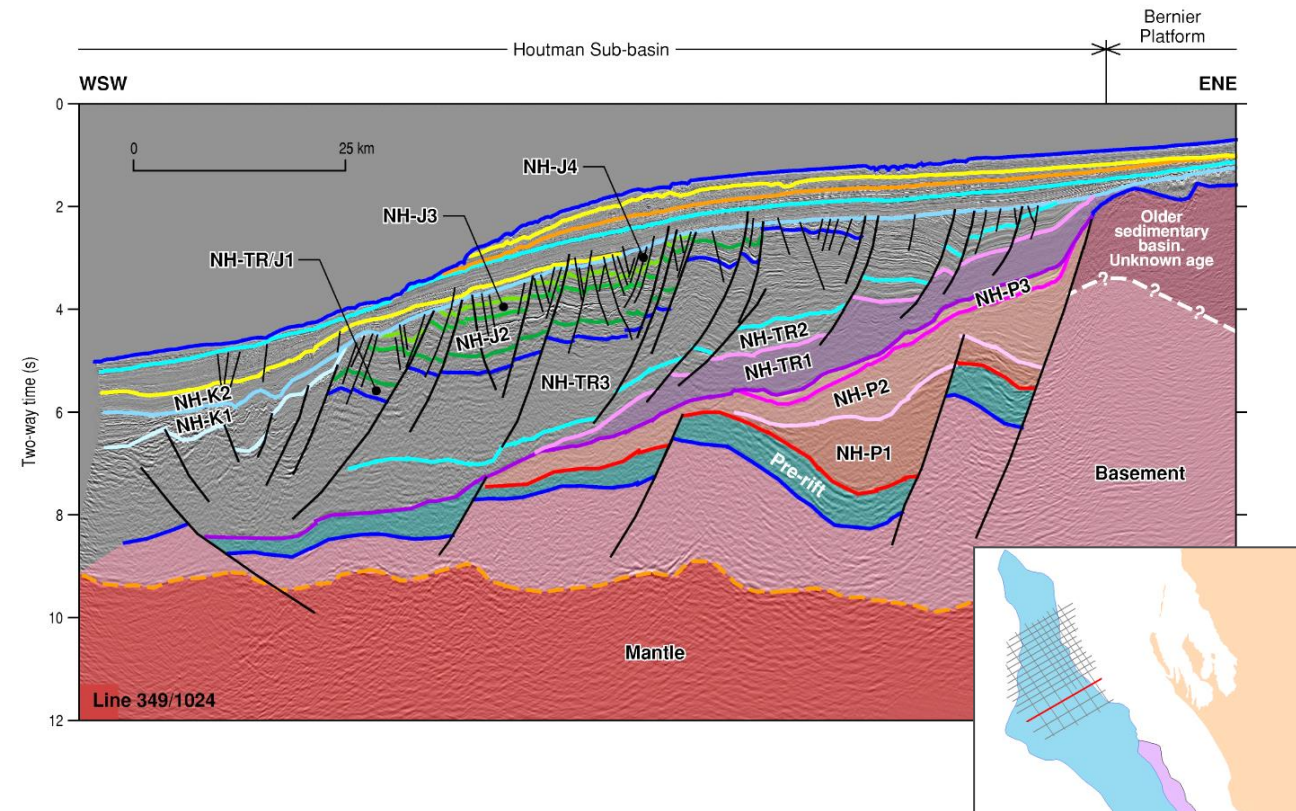
Seismic interpretation - crustal structure

- The whole crust is imaged
- Maximum 18 km sediment fill
- Hyper-extended crust (<5 km thick) beneath central sub-basin
- Extensive intrusive & extrusive magmatism outboard
- Confirmed by potential field modelling

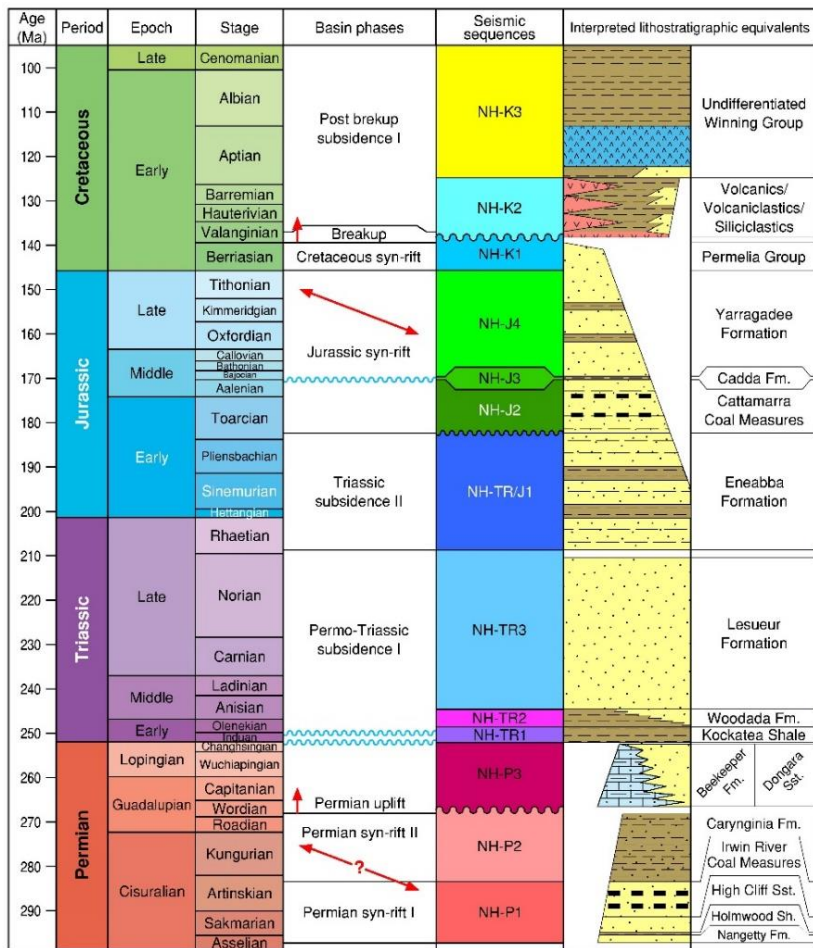


See Sanchez et al. (2016); Hall et al. (this conference)

Seismic interpretation – regional basin architecture



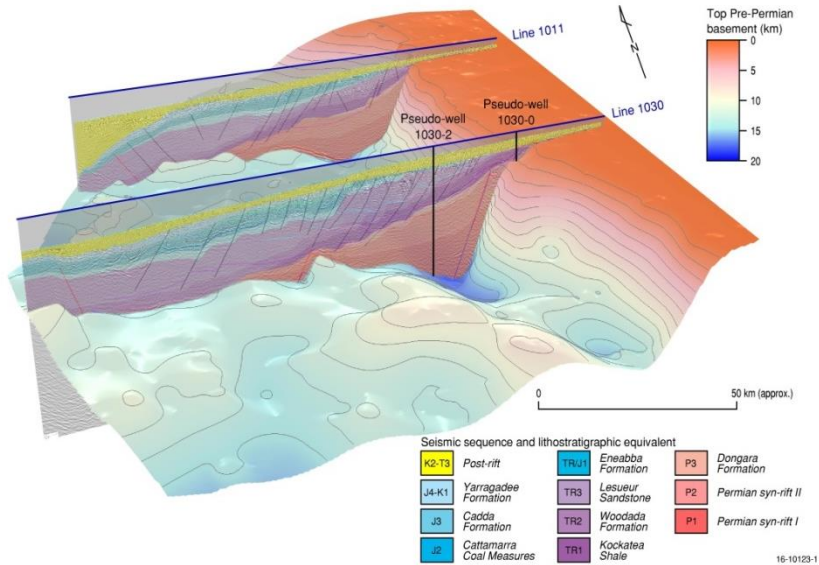
- 18 seismic sequences interpreted
- Basin phases
 - Pre-rift sequence – E. Paleozoic
 - Permian graben
 - Thick Triassic and early Jurassic
 - Late Jurassic rifting
 - Cretaceous break-up
- Similar to regional N Perth Basin



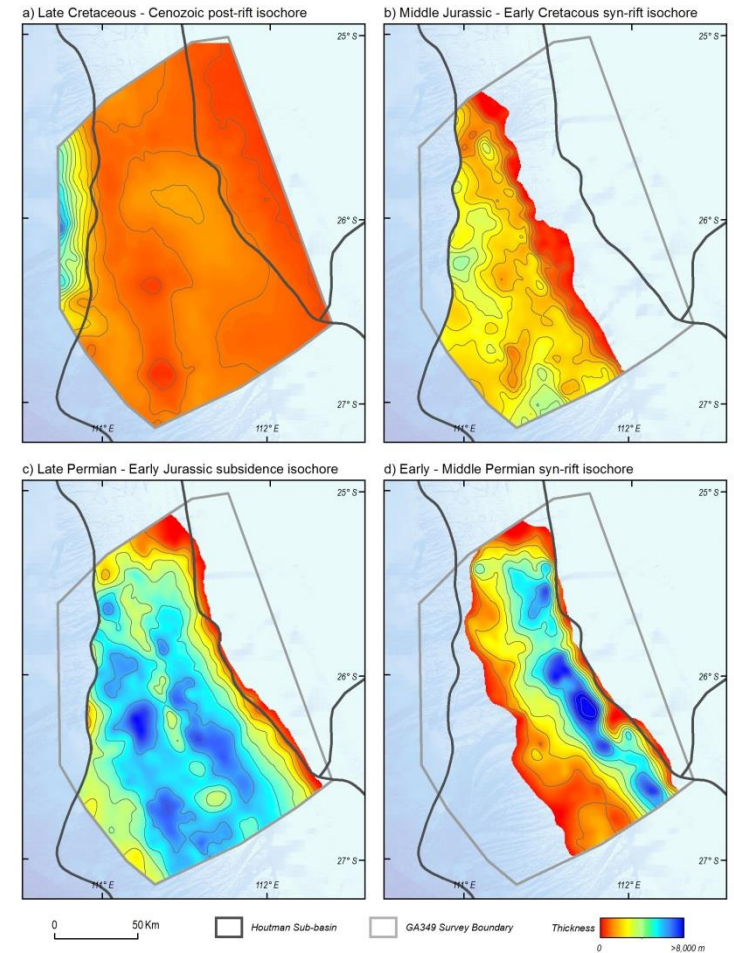
Northern Houtman Sub-basin tectono-stratigraphic framework

- Two syn-rift phases in the Permian
- Late Permian uplift and erosion followed by subsidence
- Marine transgression in the early Triassic
- Resumed rifting from mid-Jurassic
- Extensive magmatism since late Cretaceous in the outboard part of the basin
- Uplift and erosion preceding the breakup with non-deposition up to Aptian

Seismic interpretation – patterns of basin fill

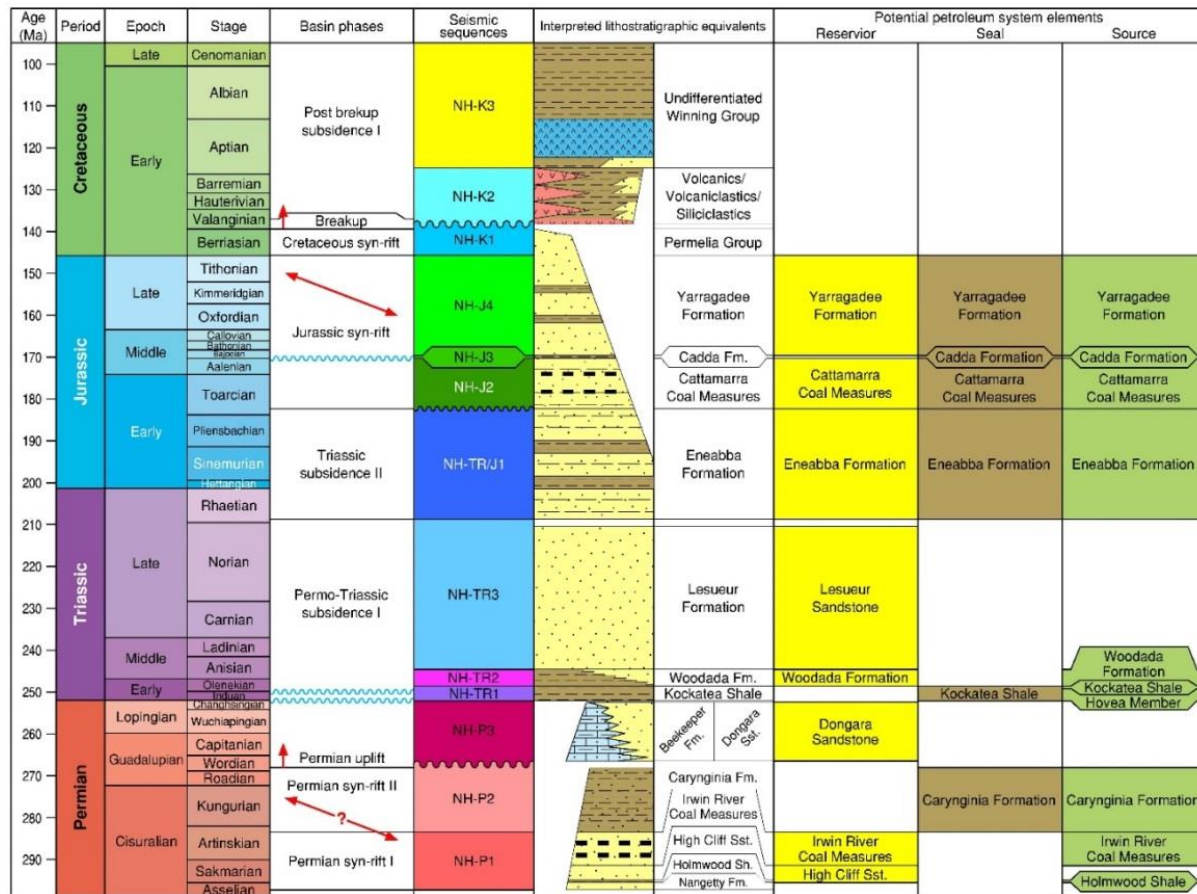


3D basin model from depth converted seismic interpretation

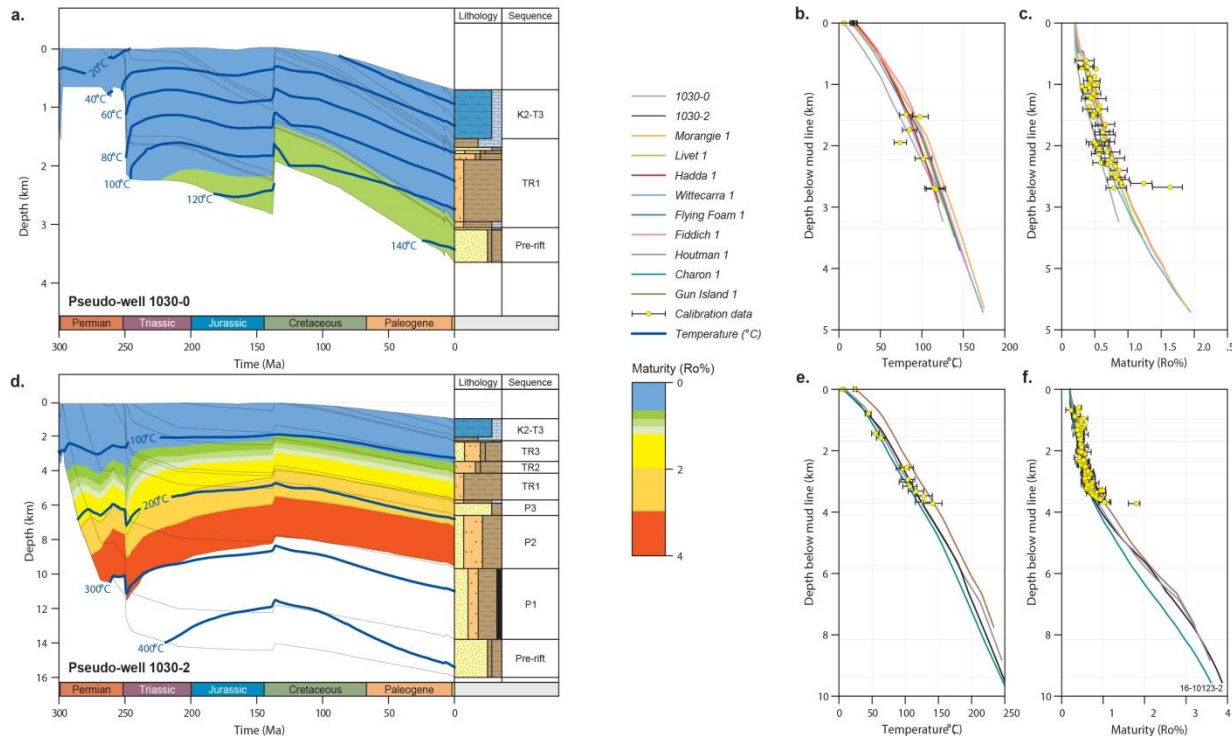


Petroleum systems elements

- Lithostratigraphy interpreted using sequence mapping, seismic facies and regional well correlation
- Suggests the potential presence of multiple potential source reservoir and seal intervals at a range of stratigraphic intervals

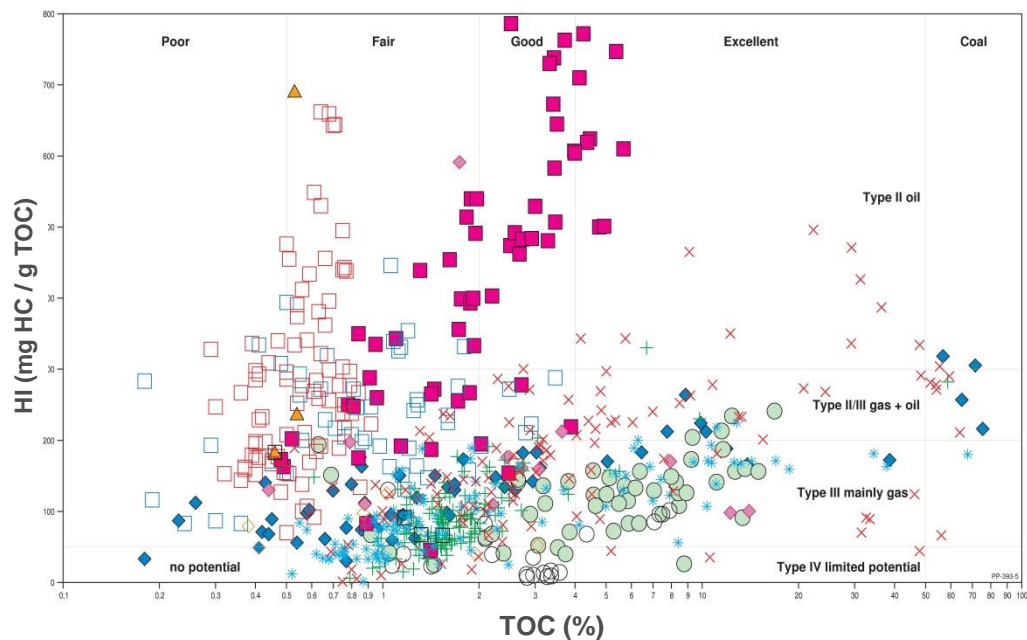


Burial and thermal history



- **Burial history:** 3D basin architecture, ages and lithologies, paleo-bathymetry, uplift and erosion
- **Thermal history:** temperature through time predicted from both burial history and tectonic history, taking into account lithospheric extension associated with both rifting events
- **Calibration:** correlation of temperature and maturity data from offshore Perth Basin wells, in equivalent tectonic settings

Source rock geochemistry



Geochemical characteristics of the SR are assigned from the Perth Basin wells (Grosjean et al., in press)

Major source rocks

Jurassic

- Yarragadee
- Cadda
- Cattamarra**
- Eneabba

Gas prone + some oil

Triassic

- Lesueur
- Woodada
- Kockatea
- Hovea Member**

Oil prone

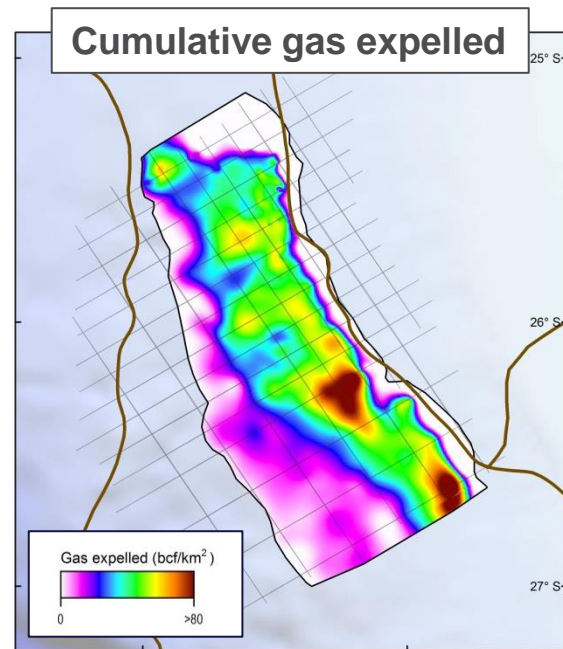
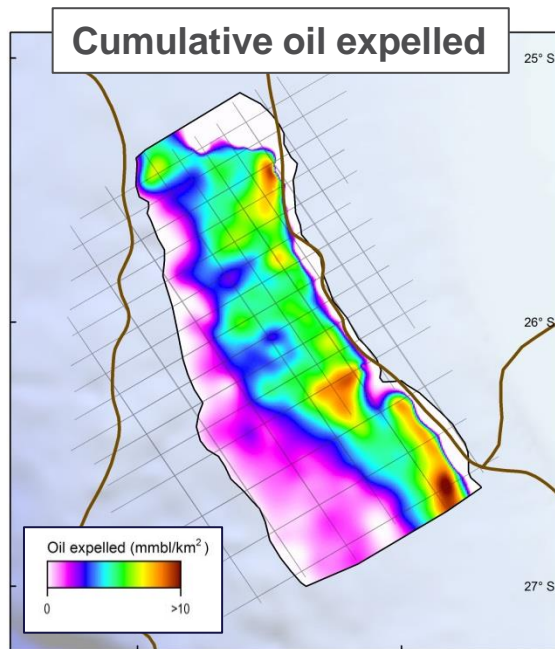
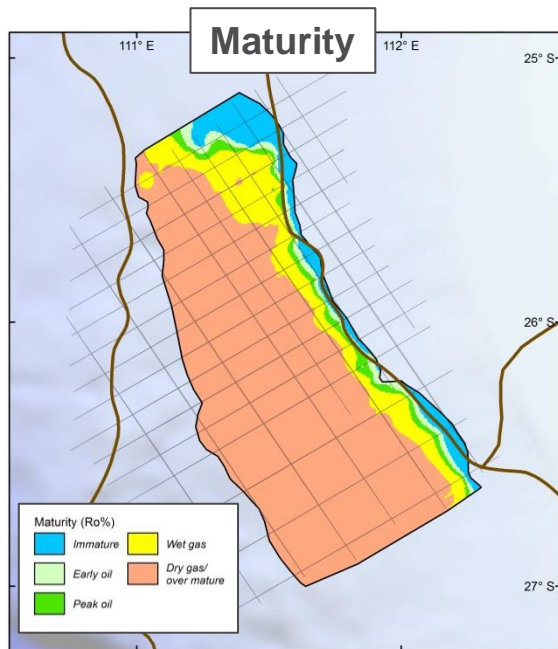
Permian

- Dongara
- Carynginia
- Irwin River**
- High Cliff
- Holmwood

Gas prone

Maturity & generation: Permian

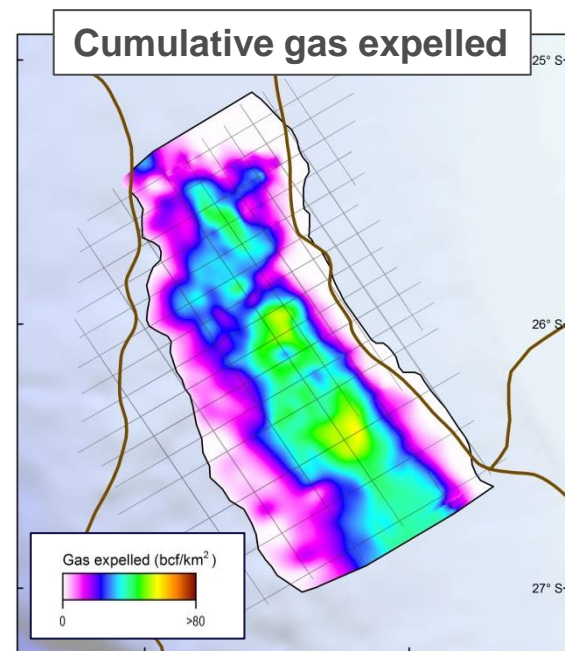
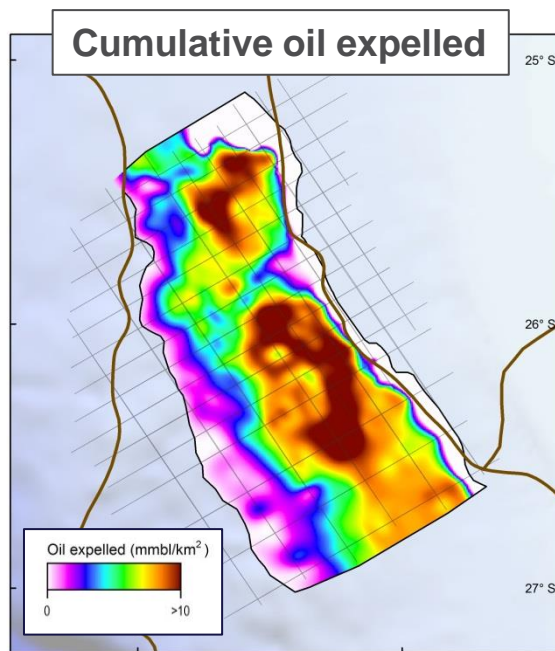
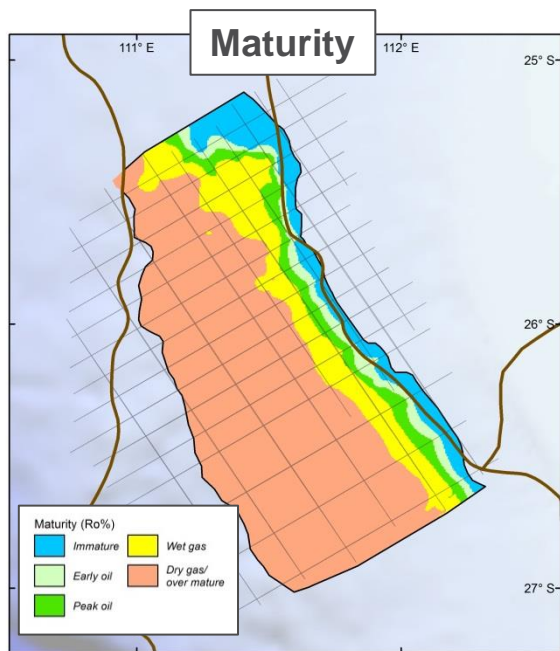
Scenario: *terrestrial gas prone source (type D/E) - Irwin River Coal Measures equivalent*



Large volumes of oil & gas but now over-mature

Maturity & generation: base Triassic

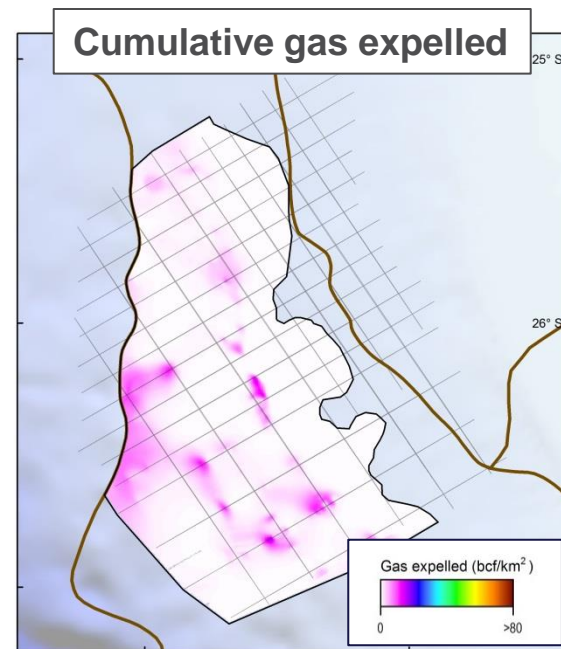
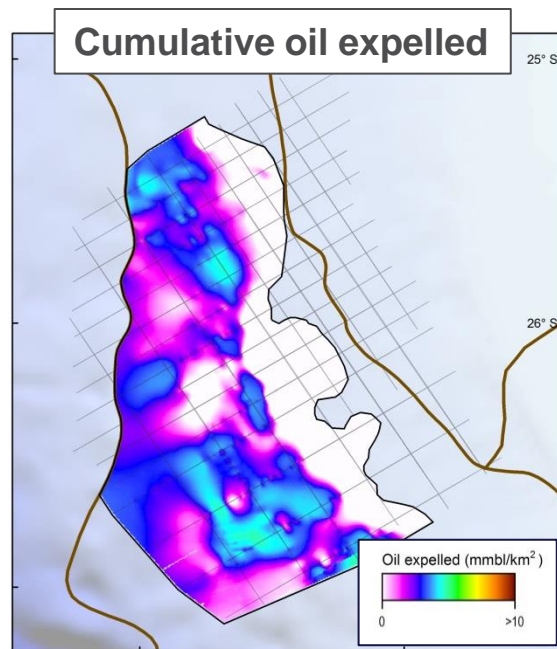
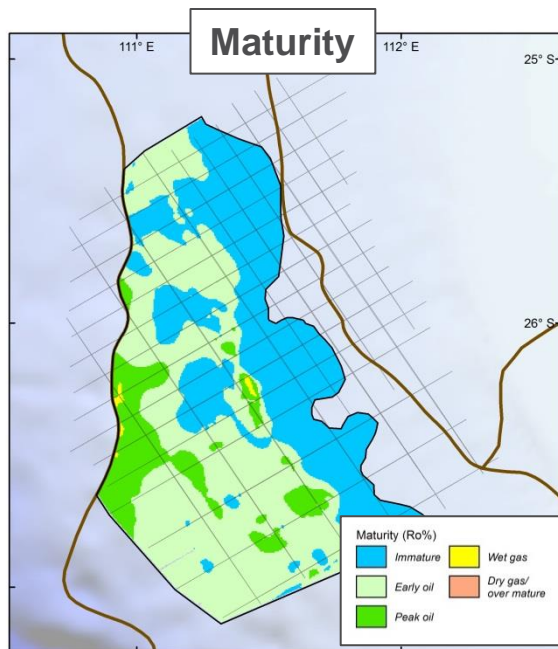
Scenario: *marine oil prone source (type B) - Hovea Mbr equivalent*



Large volumes of oil & some gas, but now over-mature, except along basin margin

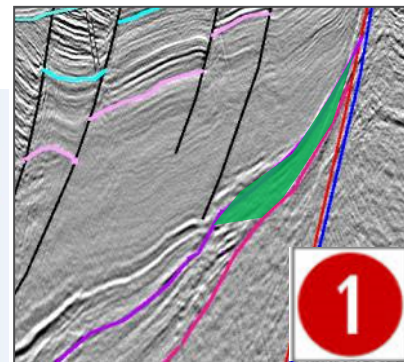
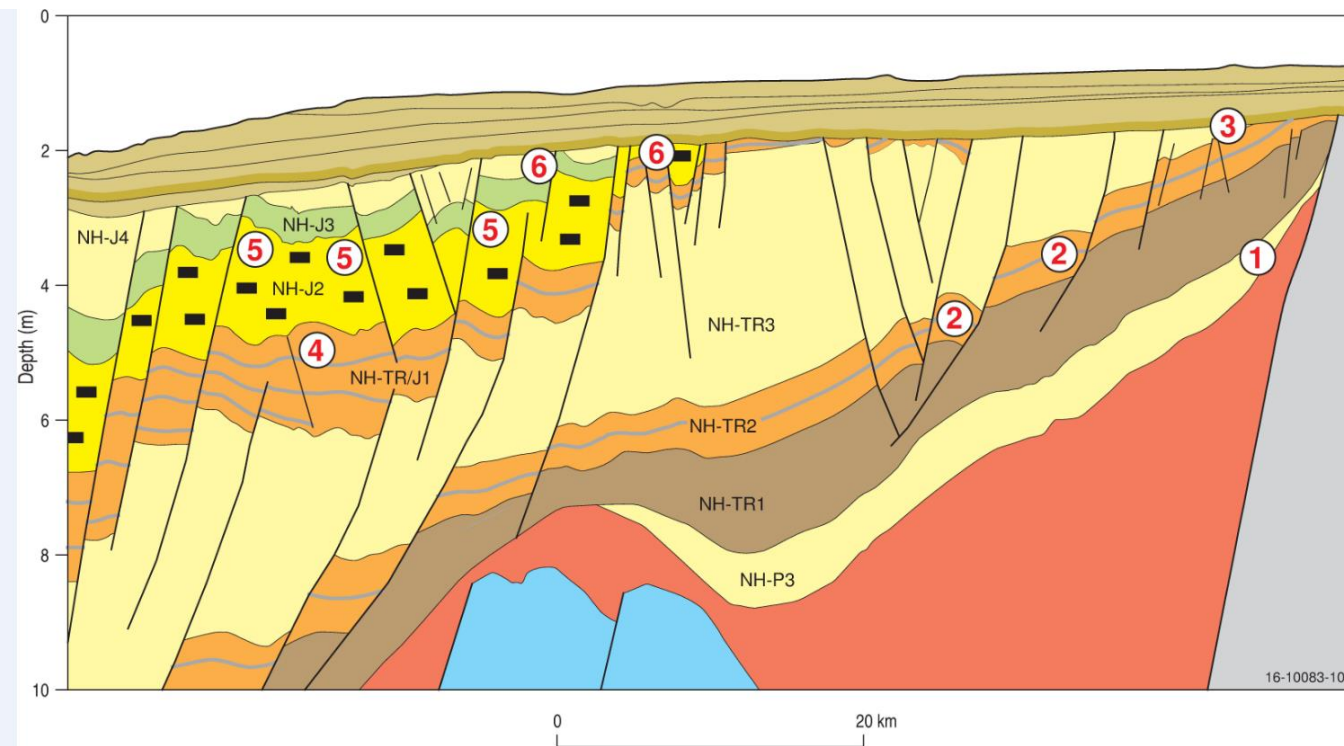
Maturity & generation: Jurassic

Scenario: mixed terrestrial and marine oil and gas prone source (types B and D/E) - Lower Cattamarra (Toarcian) equivalent

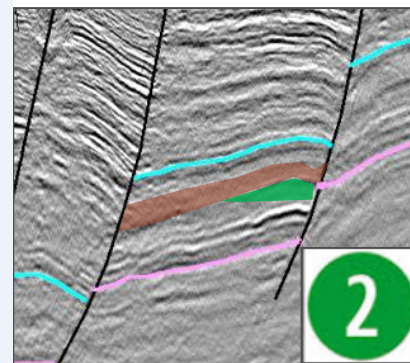


Oil generation in outer basin; impact of the Cretaceous magmatism?

Potential play types

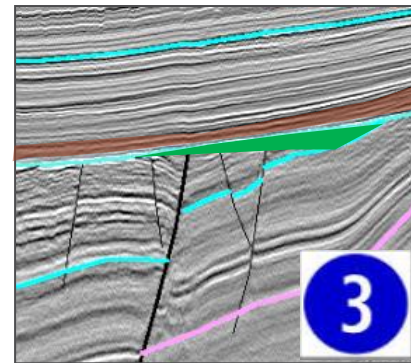
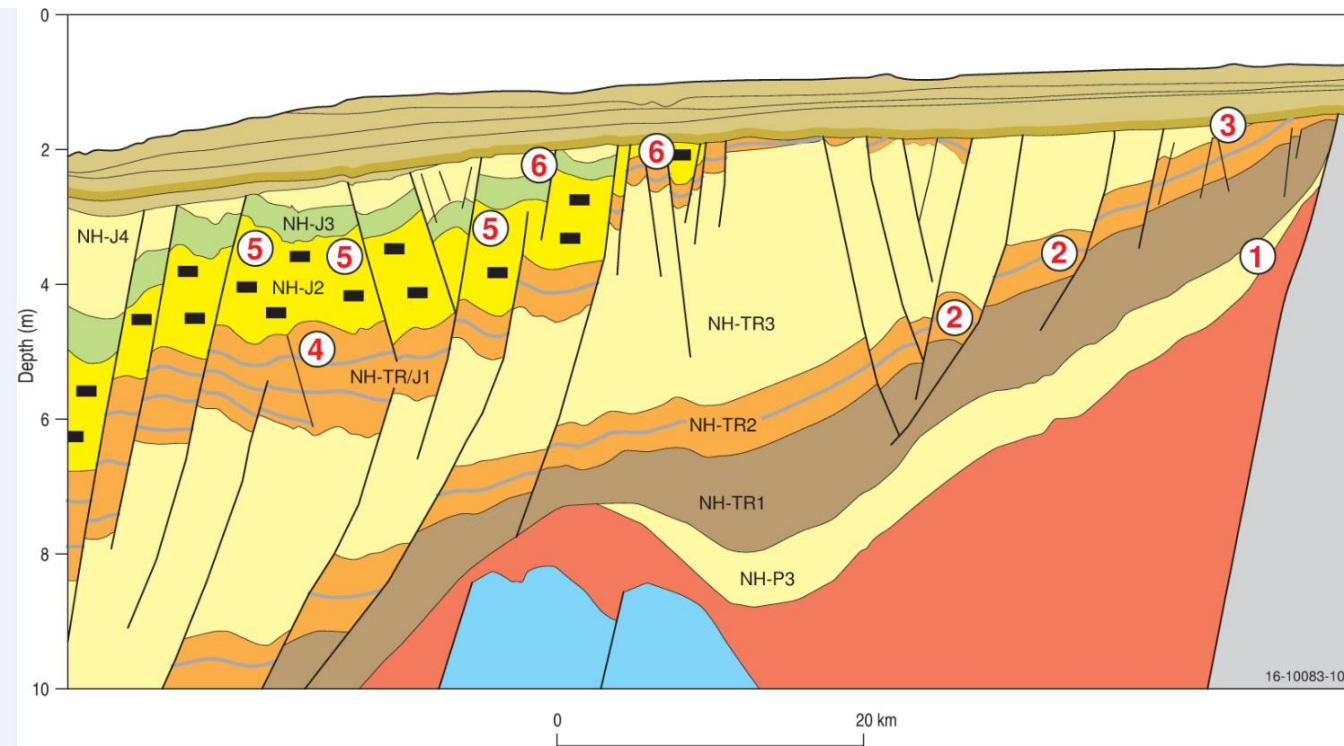


Kockatea /Dongara play

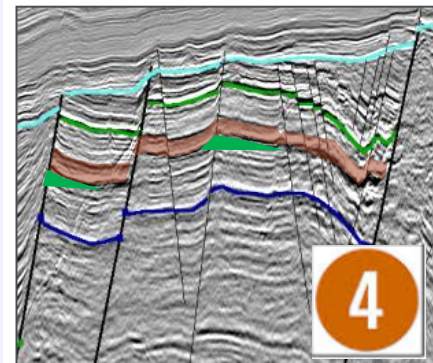


Roll-over anticline play

Potential play types

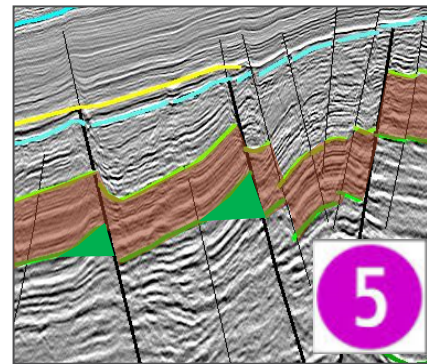
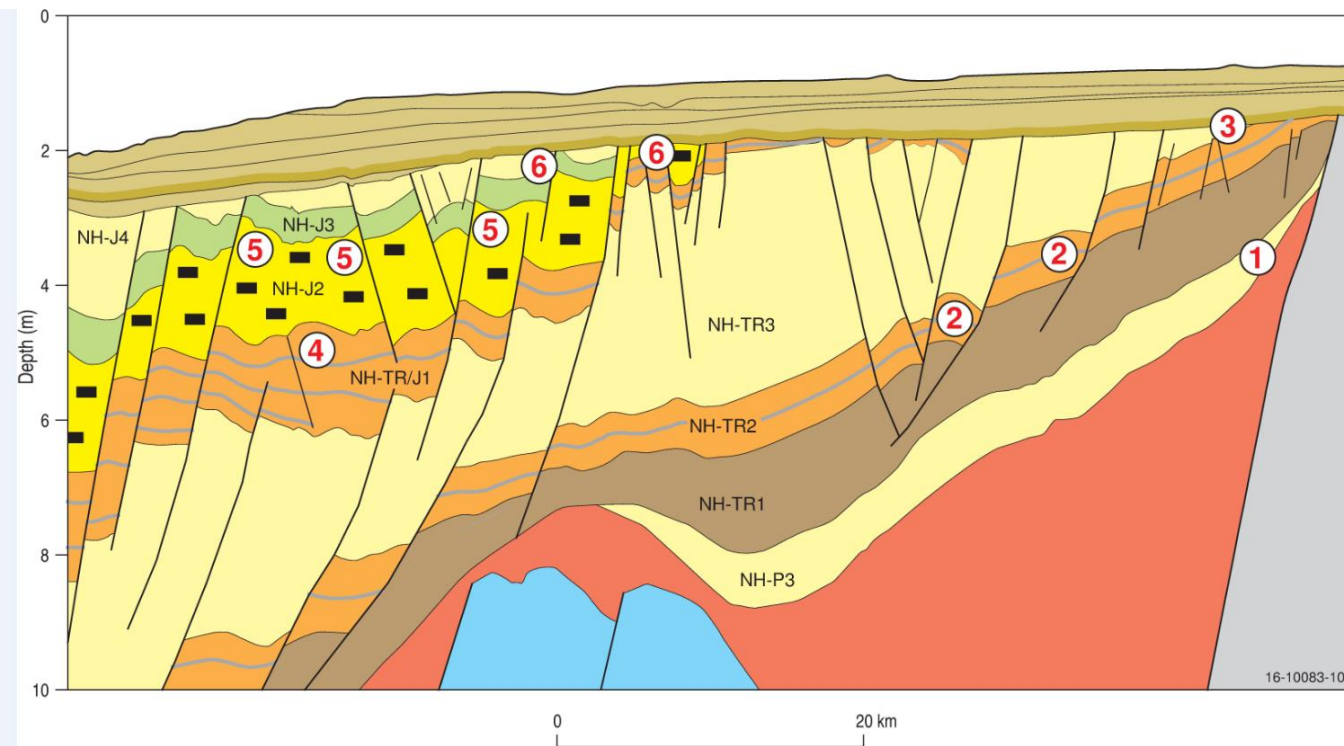


Sub-unconformity play
in Lesueur Sst

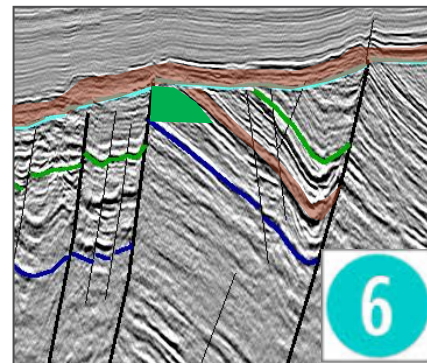


Fault-block plays in the
Eneabba Fm

Potential play types



Cadda Fm. fault block plays

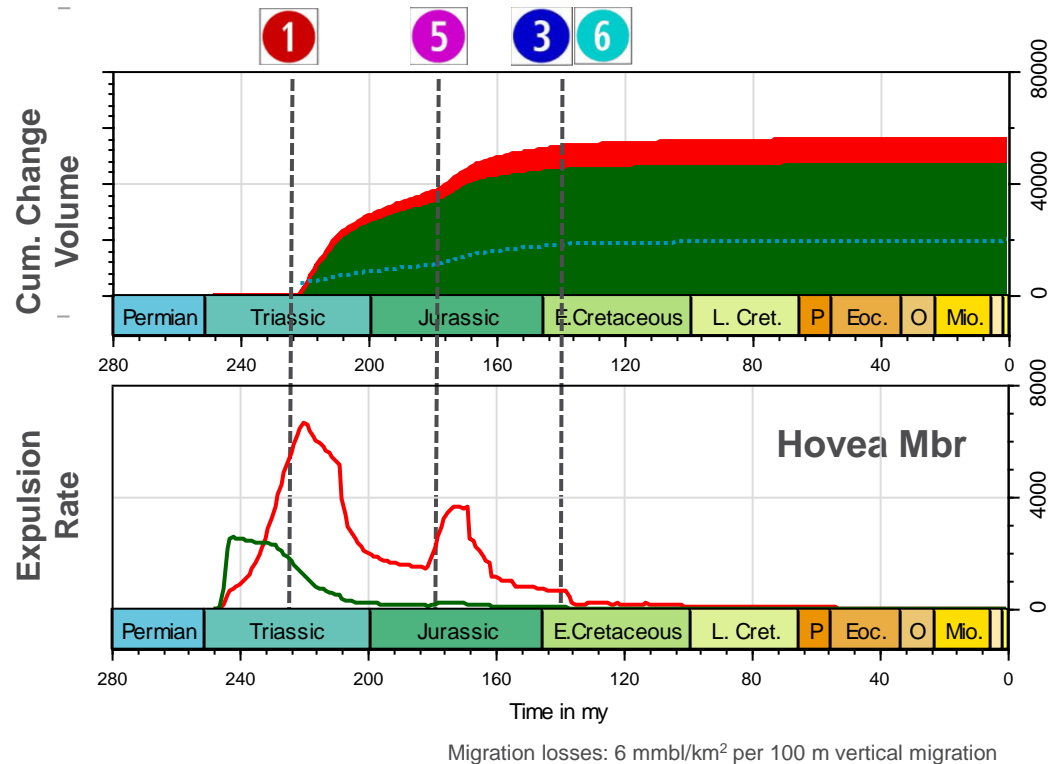


Jurassic – Lower Cretaceous sub-unconformity plays

Key risk charge timing

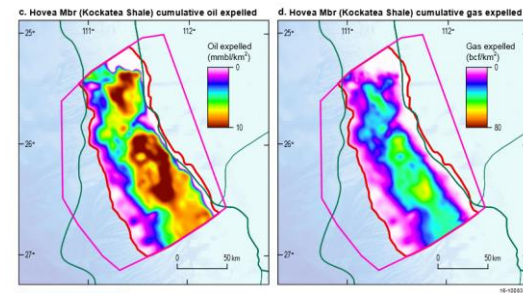
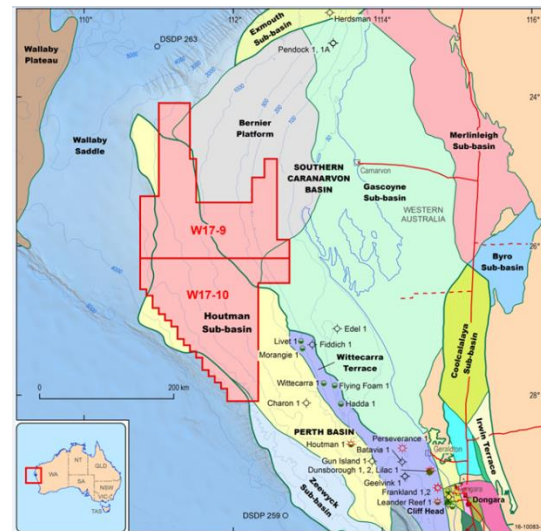
Example: Hovea Member

- Peak oil generation in the Triassic
 - Gas generation in the Triassic and Jurassic
 - Minor additional generation in the Cretaceous due to additional overburden
- **Timing of expulsion vs trap formation is a key risk in this basin**



Conclusions

- New seismic data imaged a large complex depocentre underpinned by hyperextended crust
- Correlation to southern Houtman and Abrolhos Sub-basins suggests the presence of Permian, Triassic and Jurassic oil- and gas-prone source rocks
- Lithospheric structure & volcanic margin evolution had significant impact on SR maturation.
- Modelling indicates that large volumes of hydrocarbons expelled since the Triassic
- Wide variety of potential traps at different stratigraphic levels indicate likely presence of the valid plays

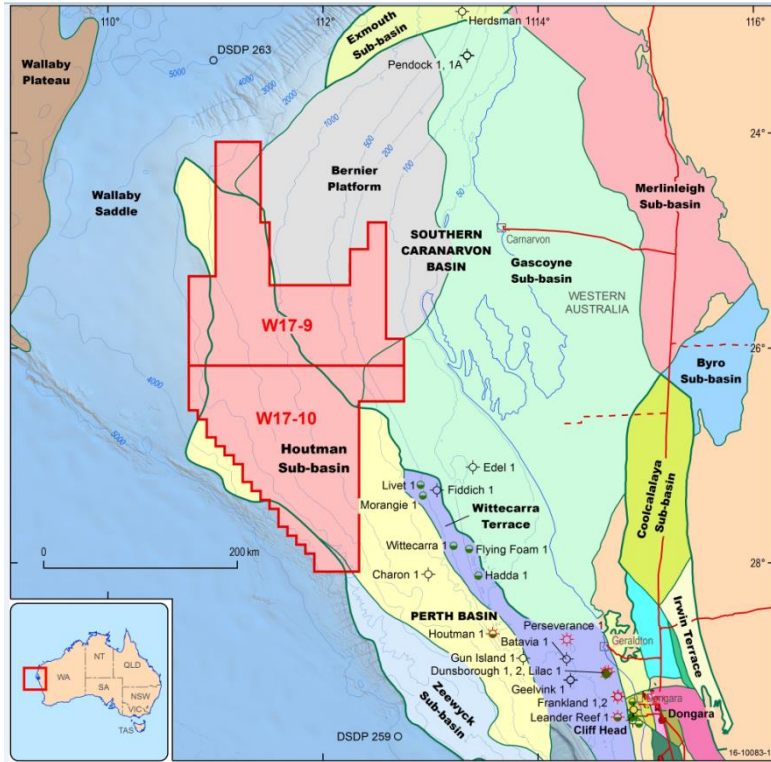


Australian acreage release

<http://www.petroleum-acreage.gov.au/>

Project webpage

<http://www.ga.gov.au/about/projects/resources/northern-houtman-sub-basin-project>



**Release Areas W17-9 and W17-10
Bids close on Thursday 22 March 2018**

Phone: +61 2 6249 9111

Web: www.ga.gov.au

Email: clientservices@ga.gov.au

Address: Cnr Jerrabomberra Avenue and Hindmarsh Drive, Symonston ACT 2609

Postal Address: GPO Box 378, Canberra ACT 2601