Browse Basin 2014 Marine Survey - Investigating Containment for Potential Late Cretaceous CO_2 Storage Plays*

Chris Nicholson[1], Rowan Romeyn[1], Megan Lech[1], Steve T. Abbott[1], George Bernardel[1], Andrew Carroll[1], David Caust[1], Emmanuelle Grosjean[1], Ron Hackney[1], Floyd Howard[1], Rachel Melrose[1], Scott Nichol[1], Lynda Radke[1], Nadege Rollet[1], Justy Siwabessy[1], and Janice Trafford[1]

Search and Discovery Article #80511 (2016)**
Posted February 1, 2016

*Adapted from oral presentation given at AAPG/SEG International Conference & Exhibition, Melbourne, Australia, September 13-16, 2015

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Abstract

Geoscience Australia conducted a marine survey in the Caswell Sub-basin of the Browse Basin, offshore Western Australia, in late 2014 to investigate containment questions relating to the potential long-term geological storage of CO_2. The survey aimed to identify and characterise indicators of natural hydrocarbon or fluid seepage that may suggest the presence of deep plumbing systems which could compromise seal integrity. Prior to the survey, 2D and 3D seismic data were used to map fault networks connecting the Aptian regional seal to the sea floor and any associated amplitude anomalies. This mapping informed survey site selection aimed at testing seal integrity over Maastrichtian, Campanian, Valanginian and Barremian submarine fans in the Caswell Sub-basin, and up-dip migration and leakage of hydrocarbons, via channels and basin margin faults, such as the Heywood Fault, into shallow marine sands on the eastern shelf margin.

Vessel and Autonomous Underwater Vehicle (AUV) multibeam bathymetry and sub-bottom profiler systems confirmed the presence of recently active faults in the area, some with significant seafloor surface expression (up to 40 m offset). A subset of

these faults was visually inspected with a Remotely Operated Vehicle (ROV) which also confirmed the presence of diverse biological communities. Indications of shallow gas were observed on sub-bottom profiles, including amplitude anomalies, cross-cutting reflectors and zones of signal starvation. Water column observations including sidescan sonar, single-beam and multibeam echosounders, underwater video and photography did not conclusively identify hydrocarbon or other fluid seepage. Strong currents encountered during parts of the survey may have interfered with the direct detection of seeps in the water column. However, headspace gas and high-molecular weight hydrocarbon analysis from shallow cores also provided no evidence for migrated thermogenic gas or oil. While no active signs of seepage were observed, the geochemical and biological sampling undertaken will aid in baseline environmental investigations for this region.

References Cited

Abbott, Steve T., David Caust, Nadege Rollet, Megan E. Lech, Rowan Romeyn, Karen Romine, Kamal Khider, and Jane Blevin, 2015, Seven Cretaceous low-order depositional sequences from the Browse Basin, North West Shelf, Australia: A framework for CO_2 storage studies: AAPG/SEG International Conference & Exhibition, Melbourne, Australia, September 13-16, 2015, Abstract. http://www.searchanddiscovery.com/abstracts/html/2015/90217ice/abstracts/2210781.html

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Lech, Megan E., Nadege Rollet, David Caust, and Karen Romine, 2015, Paleogeographic evolution of Early Campanian to Maastrichtian supersequences in the Caswell Sub-Basin - Implications for CO_2 storage and hydrocarbon entrapment: AAPG/SEG International Conference & Exhibition, Melbourne, Australia, September 13-16, 2015, Abstract. http://www.searchanddiscovery.com/abstracts/html/2015/90217ice/abstracts/2210771.html

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Australian Government
Geoscience Australia

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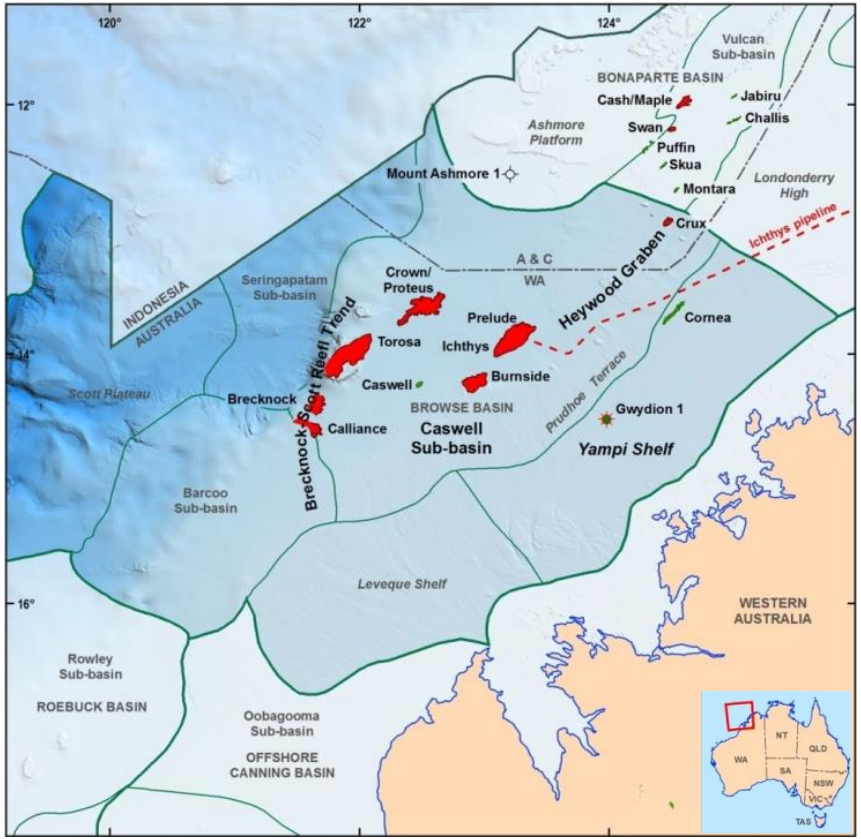
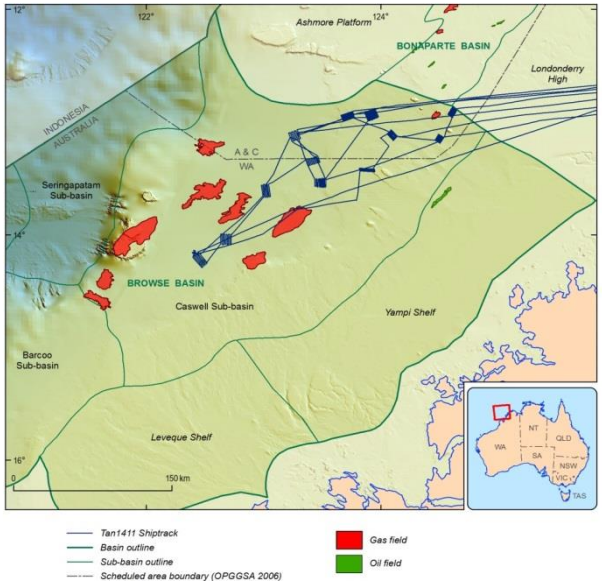
Browse Basin CO_2 Storage Prospectivity Study – Context



- Government funded NCIP program (2011/12-15) to investigate potentially suitable areas for CO_2 storage proximal to major emission sources



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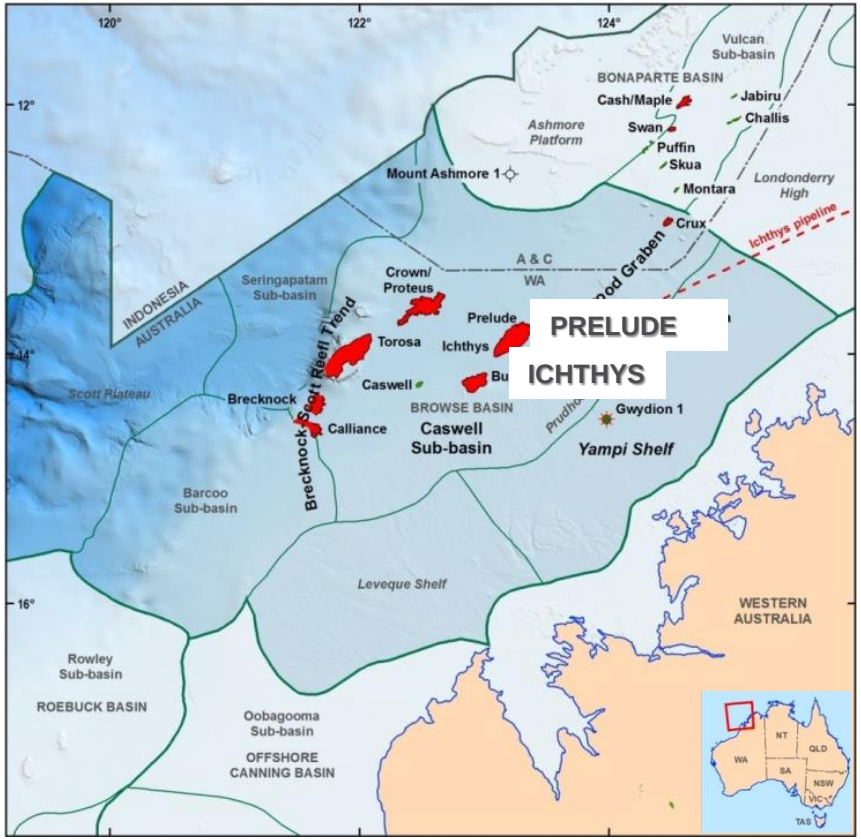

- Large undeveloped gas resources

  36 Tcf of gas and 1148 MMbbl of condensate

- Production infrastructure is in development for the Ichthys and Prelude fields
- Gas accumulations high in CO_2 (~ 8%)
- As production begins suitable sequestration options may be required
- Looking to build on past studies which identify potential options for geological storage of CO_2 (GEODISC, CO2CRC)

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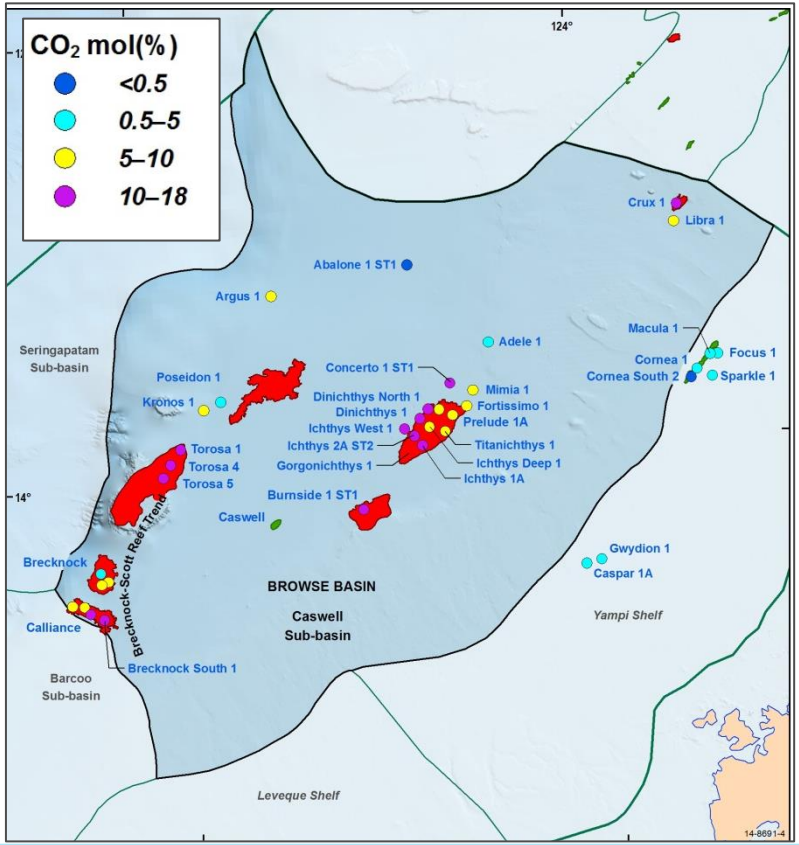

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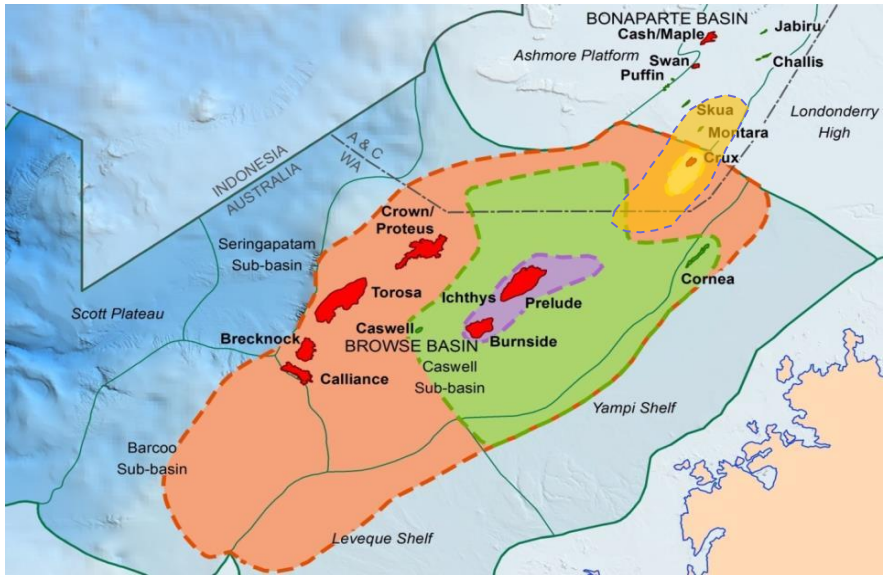
Browse Basin CO_2 Storage Prospectivity Study – Context

Browse Basin is prospective and relatively underexplored ⟶ many remaining questions!

- Understanding the source of natural gas and CO_2 in the Browse Basin is important
- Understanding which source rocks charged hydrocarbon accumulations is fundamental to future exploration success



Browse Basin Petroleum Systems

Westralian 3
Early Cretaceous
Echuca Shoals

Westralian 1 + 2
Jurassic – Early Cretaceous
Plover + Vulcan (thick)

Westralian 1 + 2
Jurassic
Plover + Lower Vulcan

Westralian 1
Early – Middle Jurassic
Plover

Le Poidevin, S.R., Kuske, T.J., Edwards, D.S. & Temple, P.R., 2015. Australian Petroleum Accumulations Report 7 Browse Basin: Western Australia and Territory of Ashmore and Cartier Islands adjacent area, 2nd edition. 2 ed. Record 2015/010. Geoscience Australia, Canberra. http://dx.doi.org/10.11636/Record.2015.010

Browse Basin CO_2 Storage Prospectivity Study – Context

An integrated study into CO_2 storage potential and hydrocarbon prospectivity

Basin analysis and sequence stratigraphic studies

- Reservoir seal plays suitable for CO_2 storage
- Factors impacting seal integrity
- Potential conflicts between CO_2 storage and petroleum resources

- ***Rollet et al.*** *– Cretaceous stratigraphic play fairway assessment in the Browse Basin: Implications for CO_2 storage.*
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- Factors impacting seal integrity
- Potential conflicts between CO_2 storage and petroleum resources

Geochemical studies

- Understand source rock distributions and their potential to generate hydrocarbons
- Define petroleum systems and their extent
- Origin of CO_2 in Plover/Brewster reservoirs?

- ***Grosjean et al.*** *– The Source of Oil and Gas Accumulations in the Browse Basin, North West Shelf of Australia: A Geochemical Assessment*

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An integrated study into CO_2 storage potential and hydrocarbon prospectivity

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2013 and 2014 Browse sampling surveys

- Investigate modern seepage that may compromise storage prospectivity
- Collect environmental baseline data before storage activities

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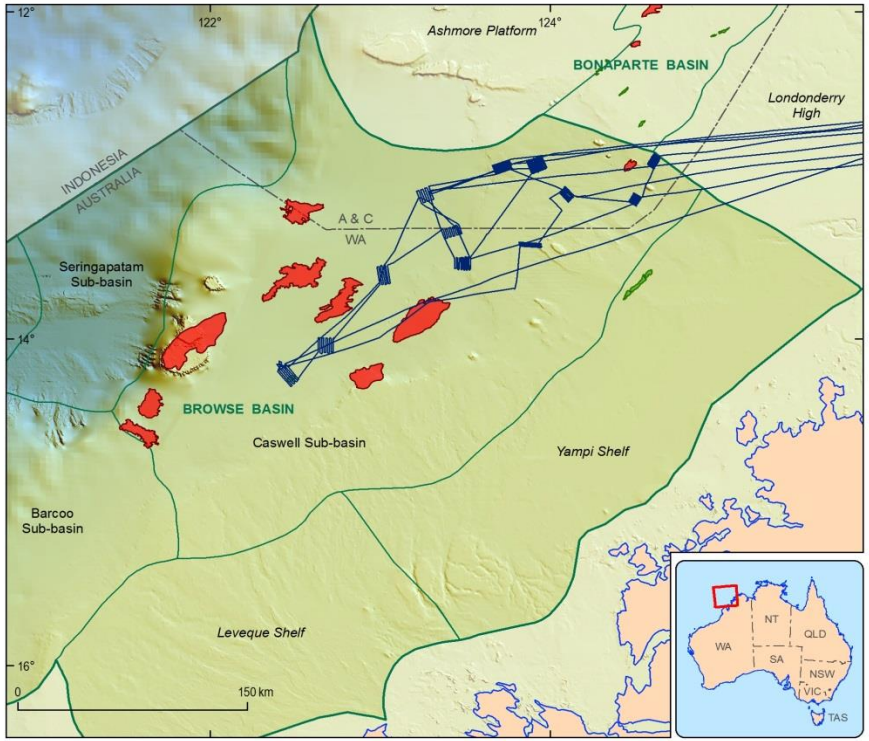


Browse Basin 2014 Marine Survey

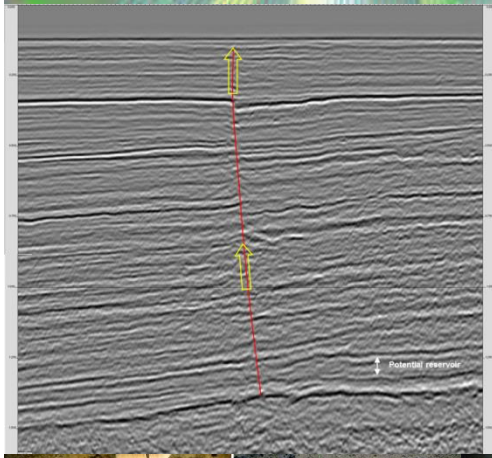
- Undertaken in three legs between October and November 2014
- Aboard RV Tangaroa (New Zealand National Institute of Water and Atmospheric Research - NIWA)
- Technical staff from Geoscience Australia, NIWA and Fugro Survey Pty Ltd.

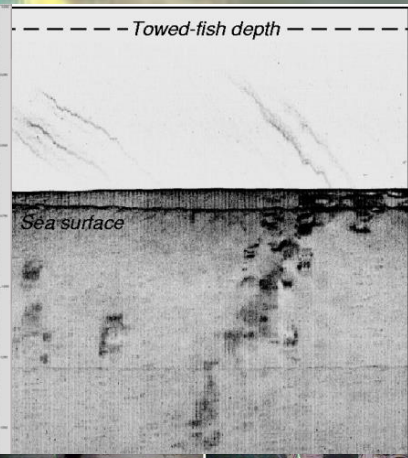
AUV – Detailed mapping

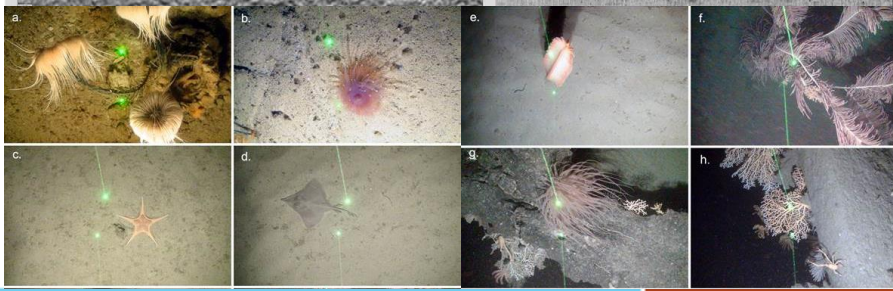
ROV – Physical Investigation

Survey Objectives

- To collect pre-competitive data to support a CO_2 storage assessment in the Browse basin
- Investigate modern seepage over CO_2 storage plays that may:
  - compromise storage prospectivity, or
  - help better understand petroleum systems
- Collect environmental baseline data before storage activities

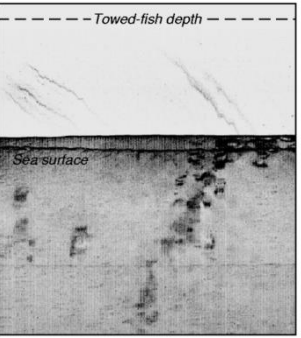






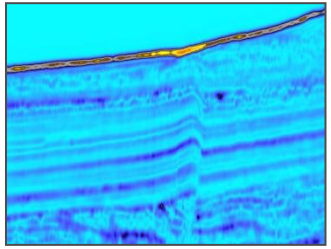
Features targeted during the survey

Direct seepage evidence



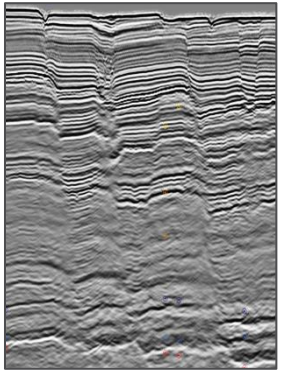
water column gas flares

Sub surface fluid indicators



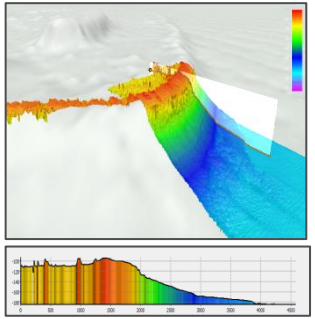
Amplitude anomalies above shallow faults

Deep plumbing faults

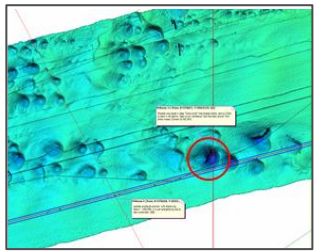


Seafloor – reservoir connectivity

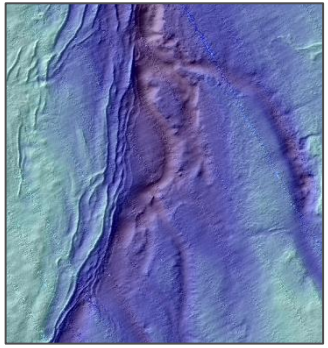
Potential seafloor seepage indicators



Drowned lowstand coral atoll

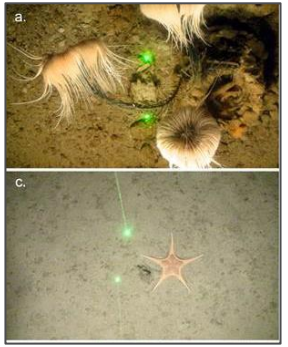


Pock marks



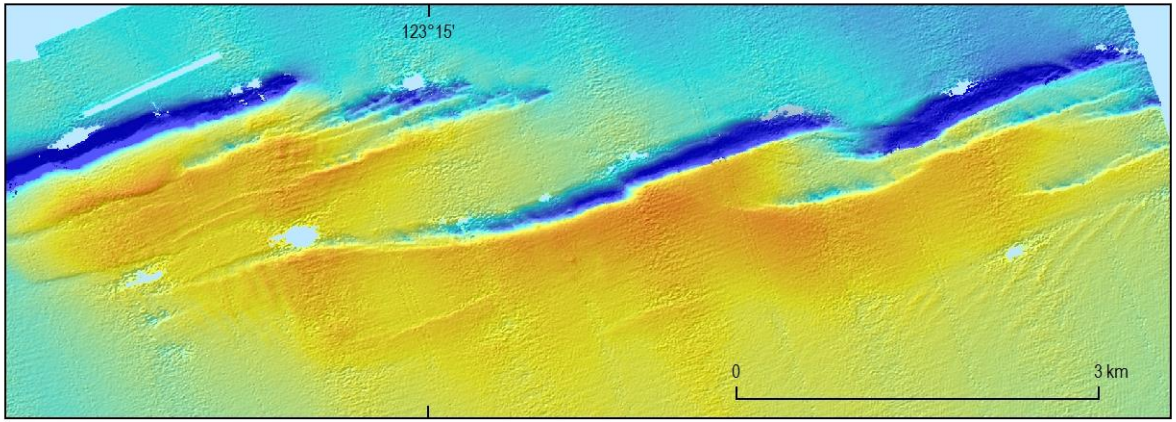
Fluid migration pathways associated with palaeo-channels

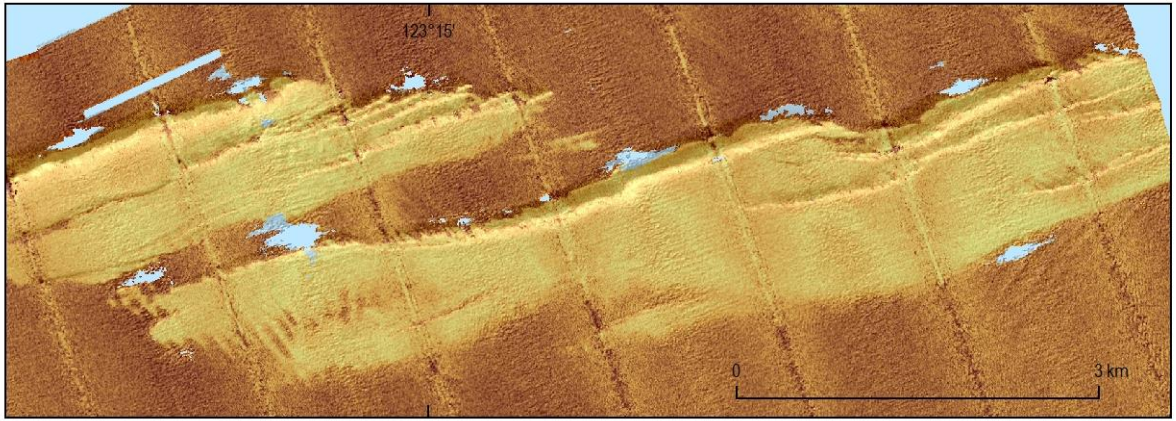
Baseline seabed environments



Biology, geomorphology, sedimentology & geochemistry

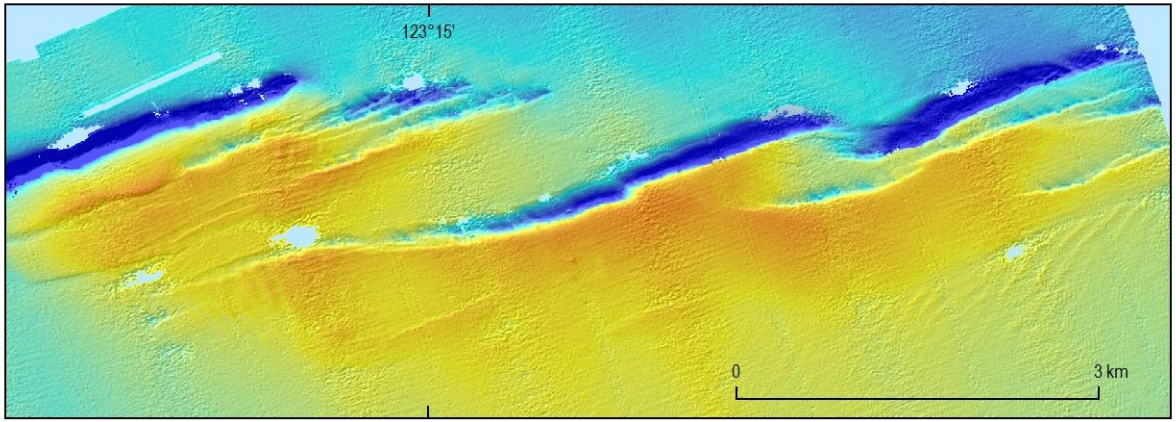
Data acquisition and survey workflow



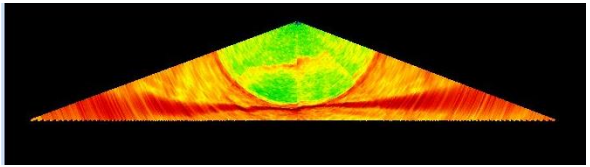


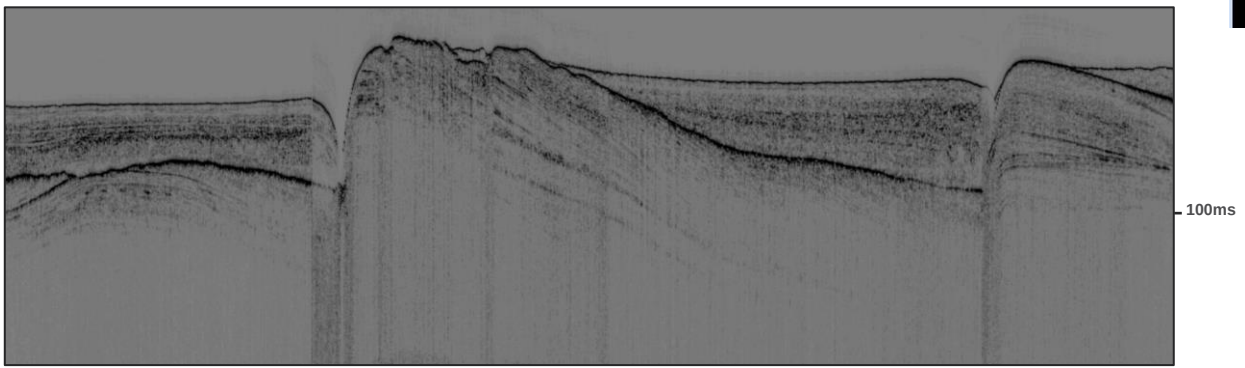
- Multibeam bathymetry
- backscatter/side scan sonar

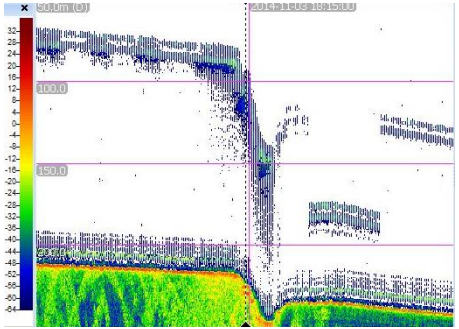
Data acquisition and survey workflow



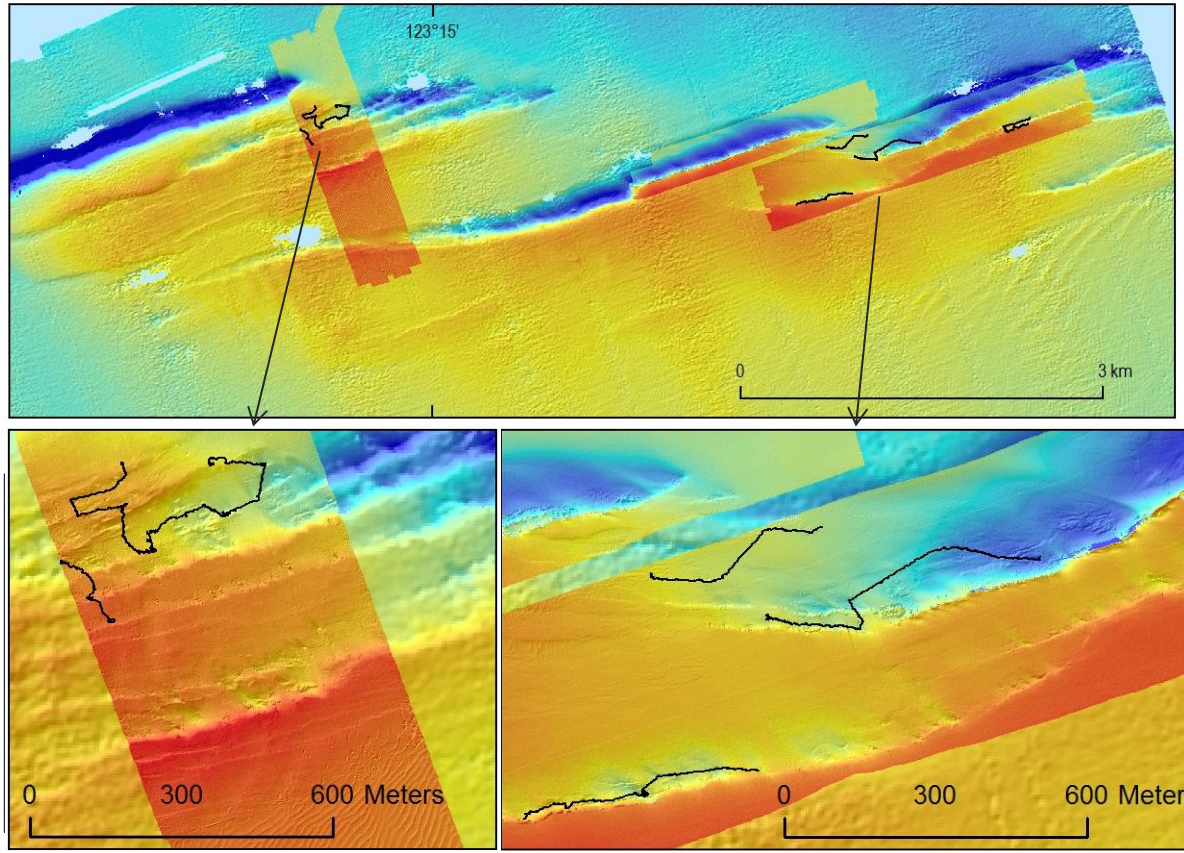
- Multibeam bathymetry
- backscatter/side scan sonar
- Sub bottom profiler
- Water column (Single + multi beam echo sounder)





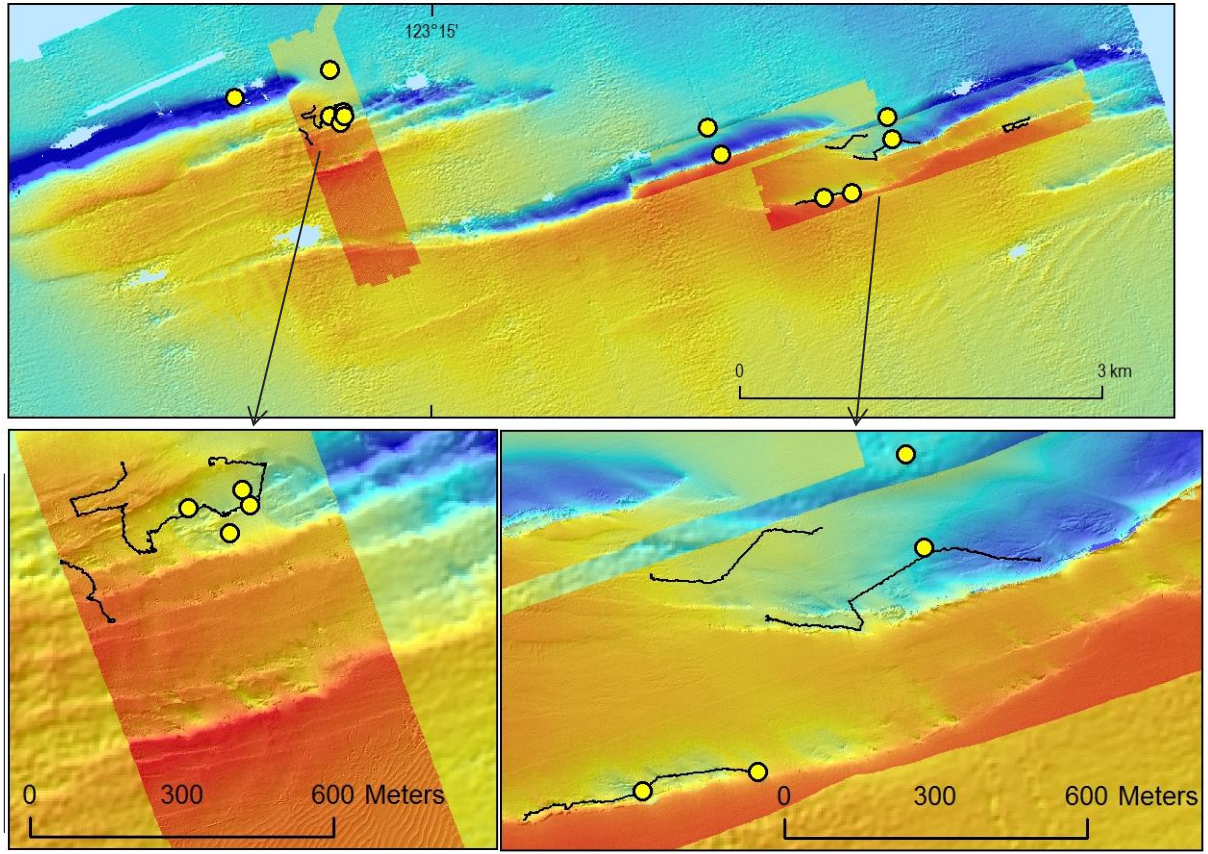


Data acquisition and survey workflow



- Multibeam bathymetry
- backscatter/side scan sonar
- Sub bottom profiler
- Water column (Single + multi beam echo sounder)
- AUV mapping
- ROV investigation

Data acquisition and survey workflow



- Multibeam bathymetry
- backscatter/side scan sonar
- Sub bottom profiler
- Water column (Single + multi beam echo sounder)
- AUV mapping
- ROV investigation
- Piston core and box core
- Geochemical sampling (headspace gas, GC, inorganic geochemistry, sedimentology, biology)
- ROV push cores
- ROV gas-tight fluid sampling
- Rock/sediment sampling

Survey site selection

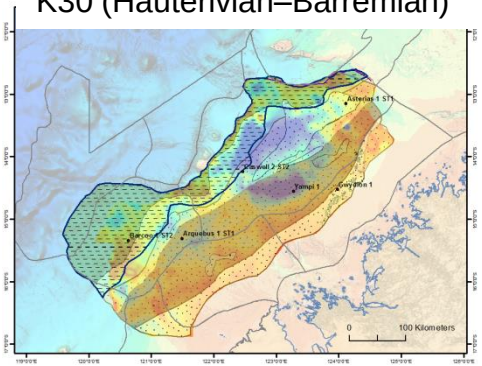
1. Reservoir seal pairs
2. Seal distribution
3. Optimum reservoir suitability

   (800–3000 m depth)
4. Seal integrity

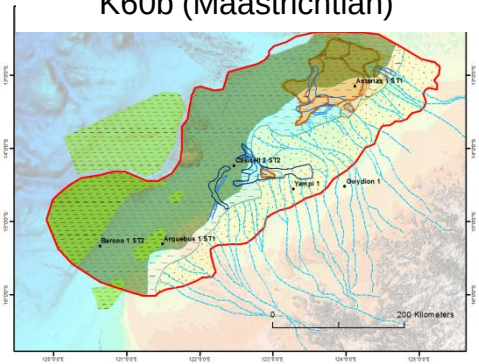
   (e.g., fault reactivation,

   sand connectivity)
5. Hydrocarbon conflicts

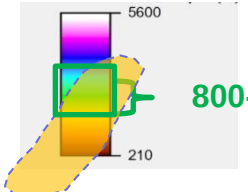
K30 (Hauterivian–Barremian)



K60b (Maastrichtian)

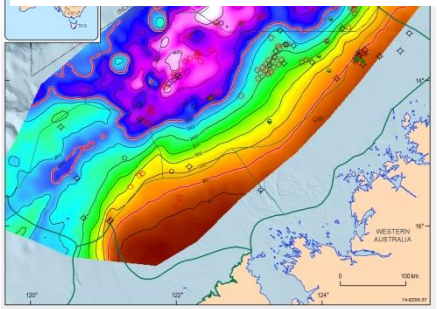


- Basin floor
- Coastal plain and shelf (mud prone)
- Coastal plain and shelf (sand prone)
- Slope



800-3000m depth

K30 (Hauterivian-Barremian)



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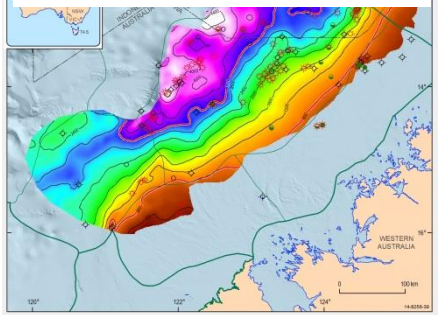

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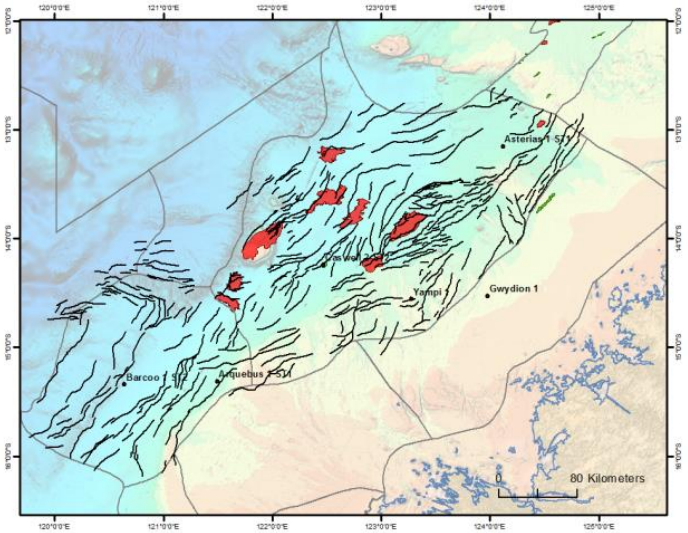

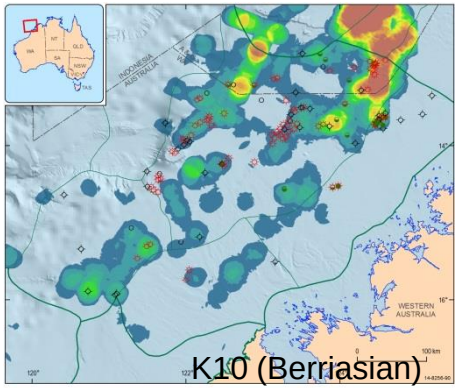

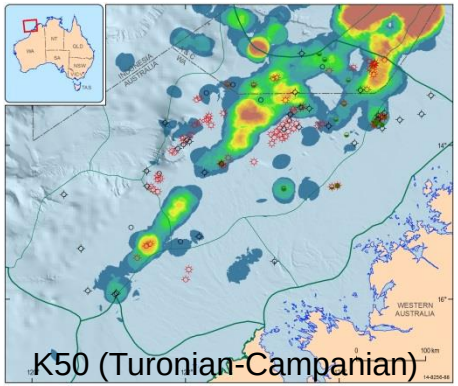

Lower Cretaceous

Upper Cretaceous

Survey site selection

1. Reservoir seal pairs
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   (e.g., fault reactivation,

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5. Hydrocarbon conflicts

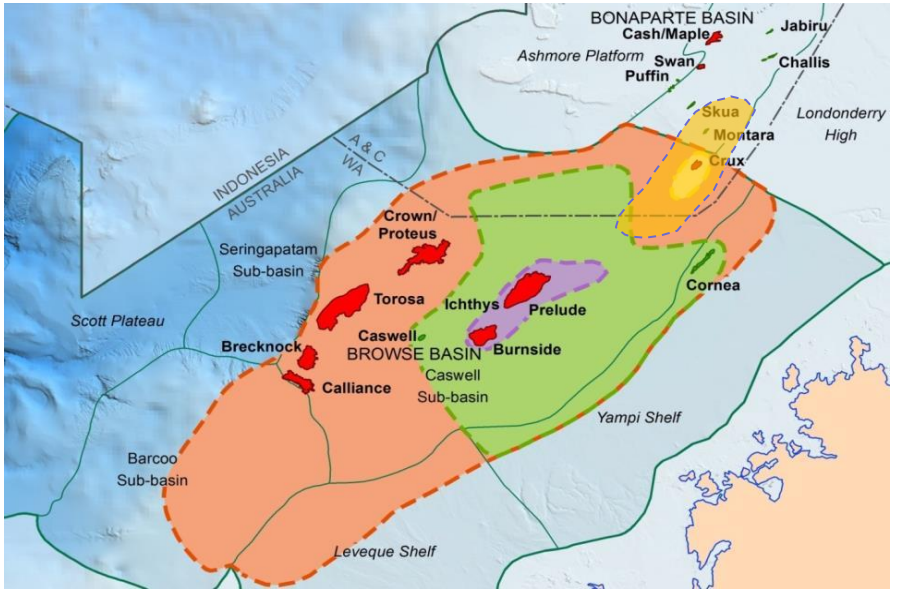
Browse Basin Petroleum Systems

Westralian 3
Early Cretaceous
Echuca Shoals

Westralian 1 + 2
Jurassic
Plover + Lower Vulcan

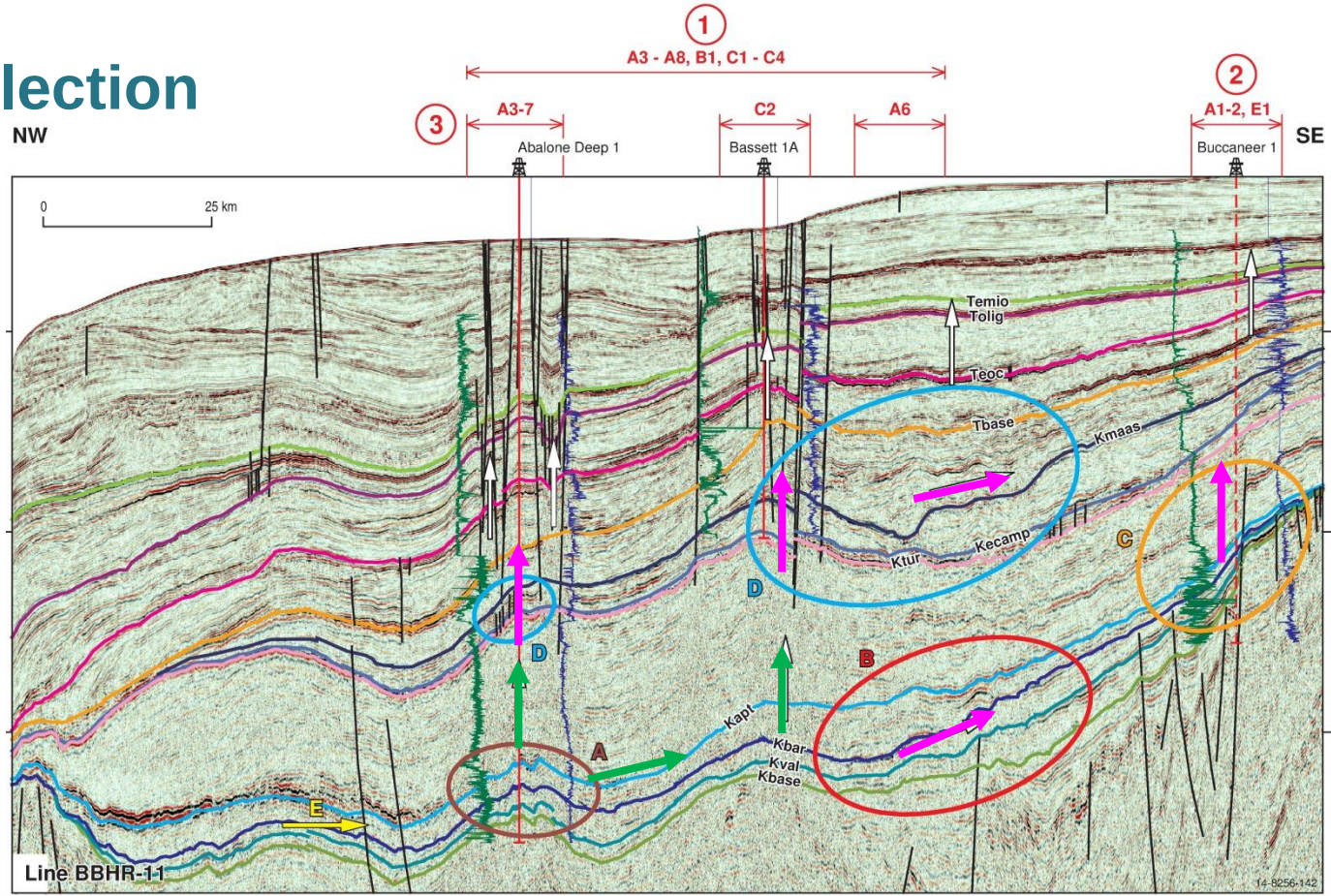
Westralian 1 + 2
Jurassic – Early Cretaceous
Plover + Vulcan (thick)

Westralian 1
Early – Middle Jurassic
Plover



Survey site selection

1. Impact of faulting on seal integrity above potential Maastrichtian and Campanian reservoirs
2. Up-dip migration along inboard reactivated faults from a variety of early and late Cretaceous plays
3. Seepage associated with the northern extent of Cretaceous hydrocarbon charge



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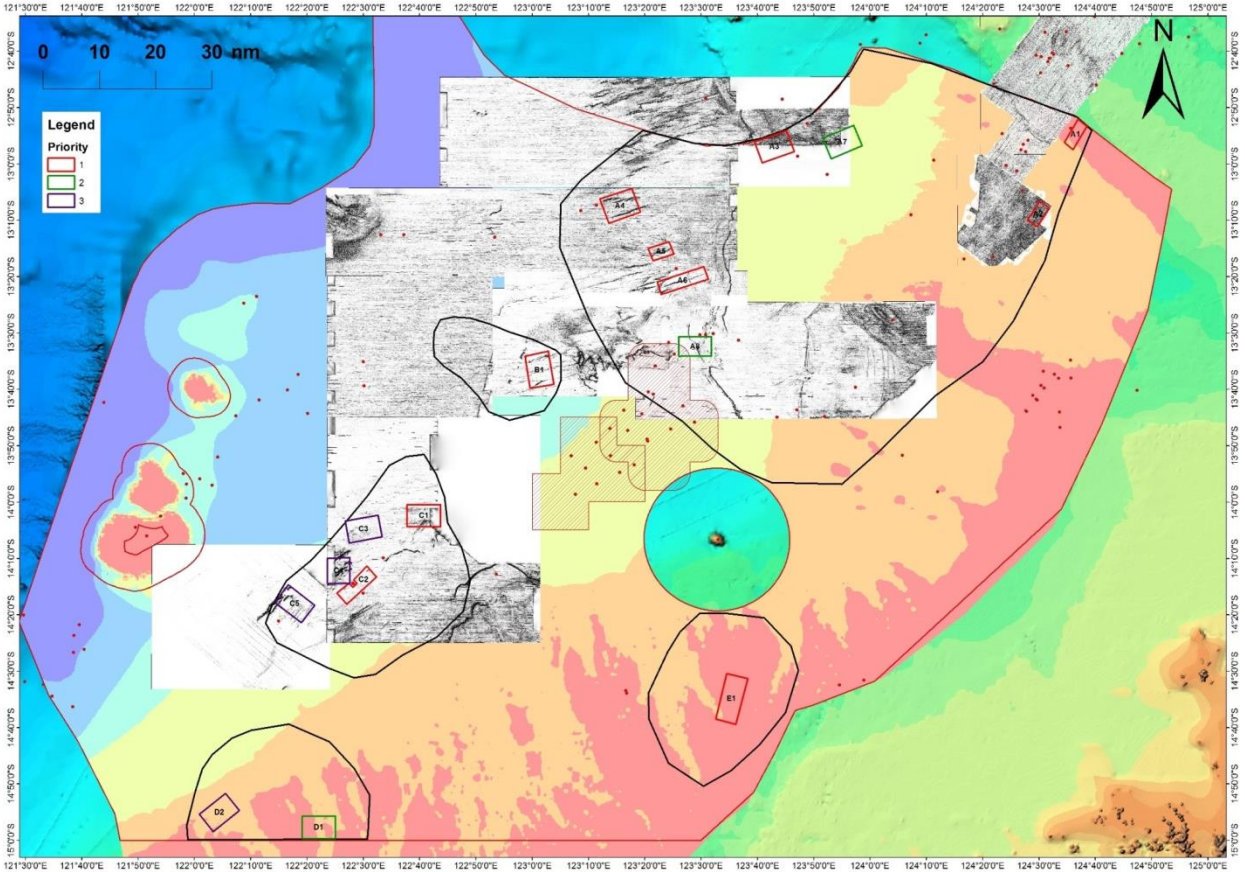
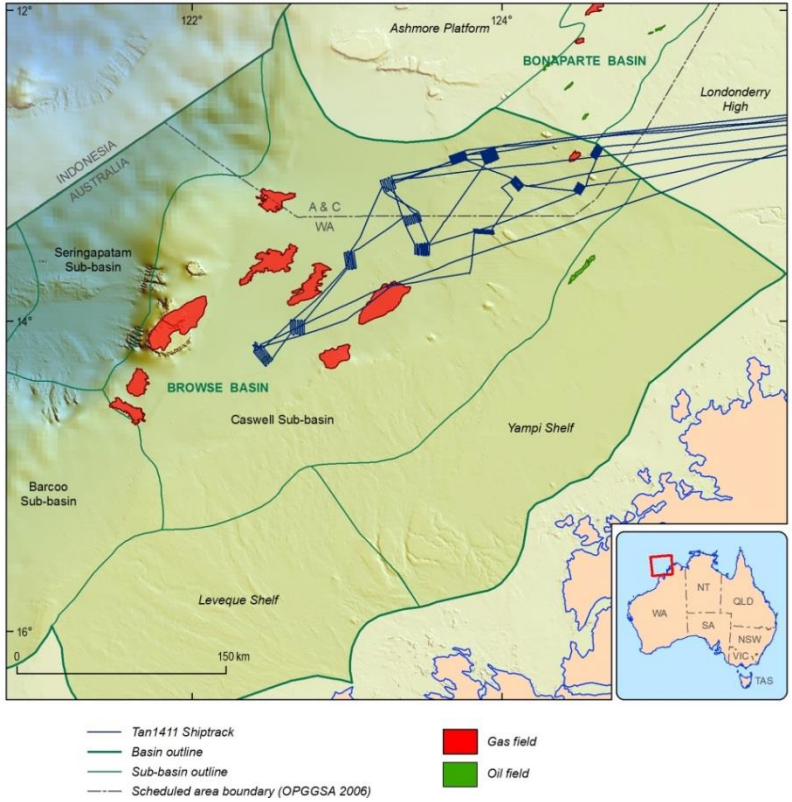


- 17 survey sites selected to test these scenarios
- 3 additional sites selected on survey
- Sites were selected based on faults observed on the seafloor and in seismic data that may:
  - form conduits between mapped reservoirs and seafloor
  - Access charge from source kitchen

Data collected

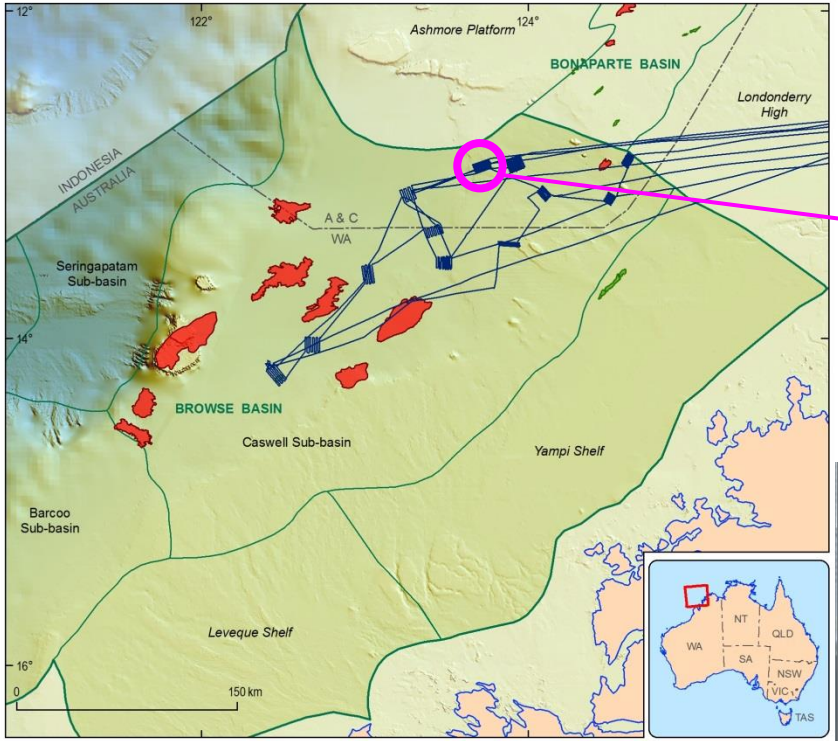
- Data was collected from 12 of the preselected sites and 3445 km^2 of seabed was mapped in water depths ranging from 90 to 490m
- 41 piston cores acquired

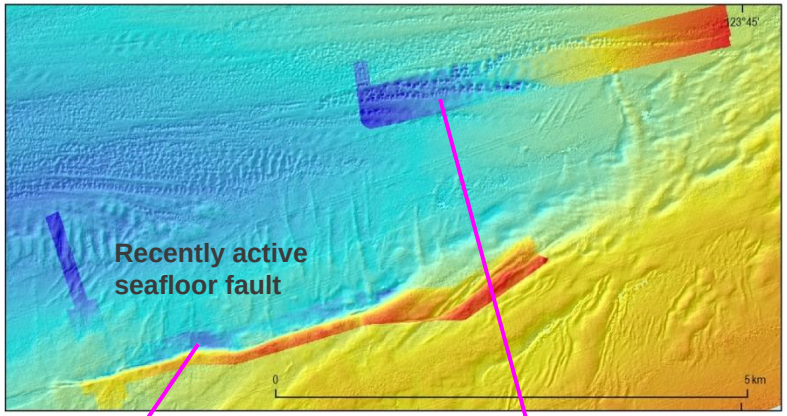
Data Type	Units	Total Amount
Multibeam (survey)	km^2	755
Multibeam (transit)	km^2	2990
Multibeam (total)	km^2	3445
Sub-bottom Profile (survey)	km	611
Sub-bottom Profile (transit)	km	5099
Sub-bottom Profile (total)	km	5711
Smith McIntyre Grab	No.	99
Piston Core	No.	41
AUV Multibeam	km^2	7.7
ROV Missions	No.	22
AUV Sub-bottom Profile	km	71
AUV Side-scan Sonar	km	71
AUV Camera	km	39
ROV Grab	No.	8
ROV Push-core	No.	1

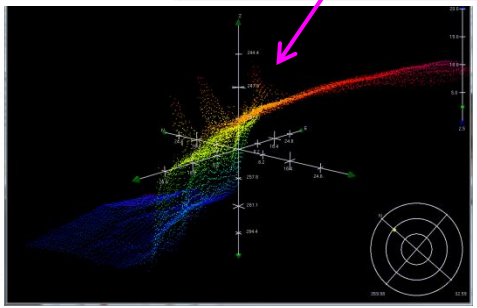


Results – coring

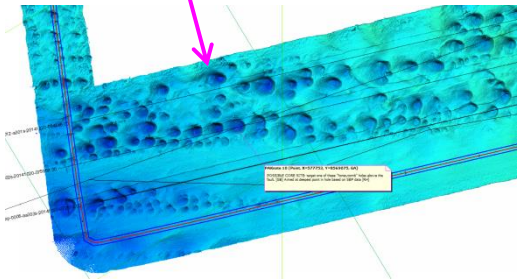
- Northern extent of Cretaceous charge
- Seal integrity for Maastrichtian sands







Water column flare above fault observed in MB data



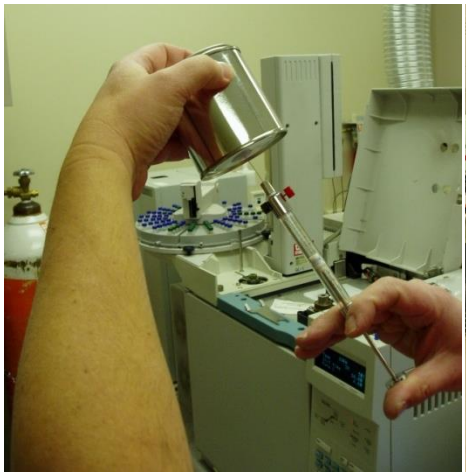
Honeycomb pock like features about shallow fault trace

Results – coring

- 41 cores recovered
- Cores collected using 6m long gravity core
- Cores cut into 1 m sections
- Lower 20 cm of each 1m core section samples for geochemical analysis

Results – Geochemical analyses for hydrocarbon seepage detection

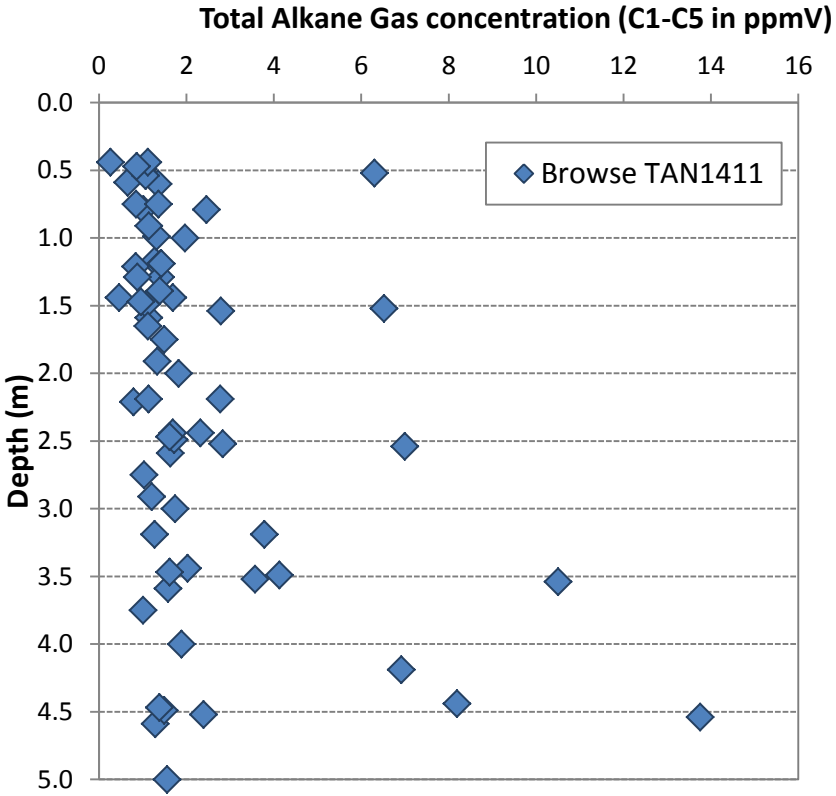
- Headspace gas analysis of core sediments: interstitial gases C_1-C_5



Techniques well established:

- best methods for seep sampling, detection and interpretation

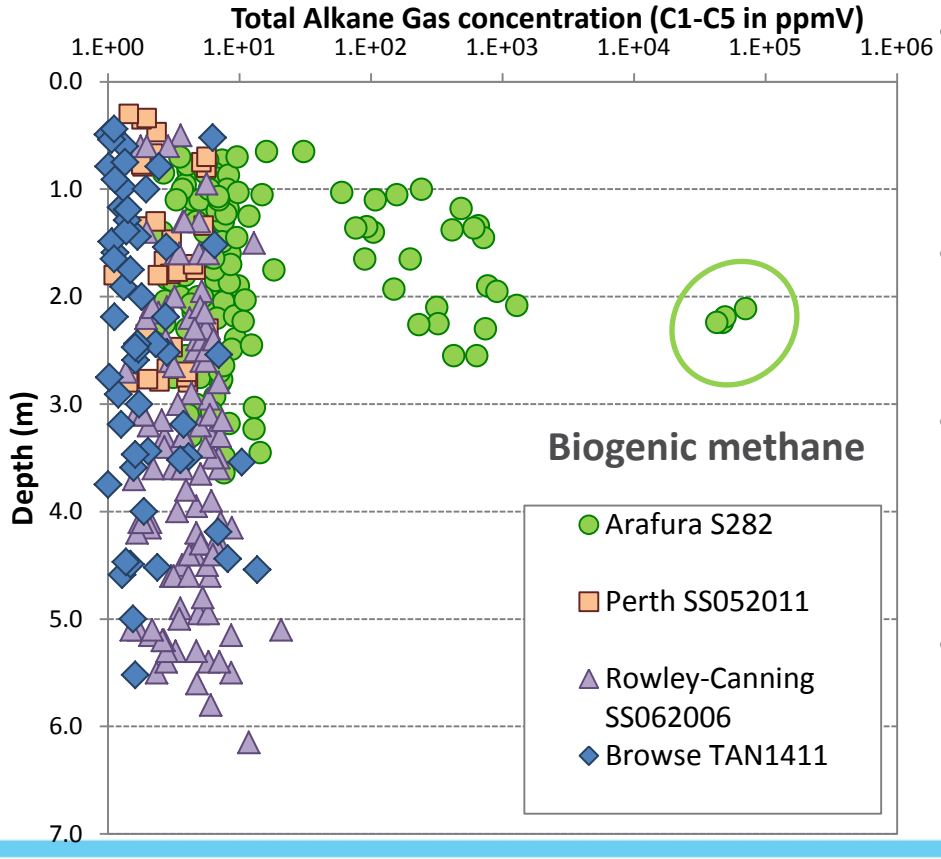
Results – Headspace gas data in cores



- Sampled C_1-C_5 concentrations up to 14 ppmV
- Background levels < 1000 ppmV (for GoM) (Abrams, 2005)
- All Browse sample concentrations are below background levels

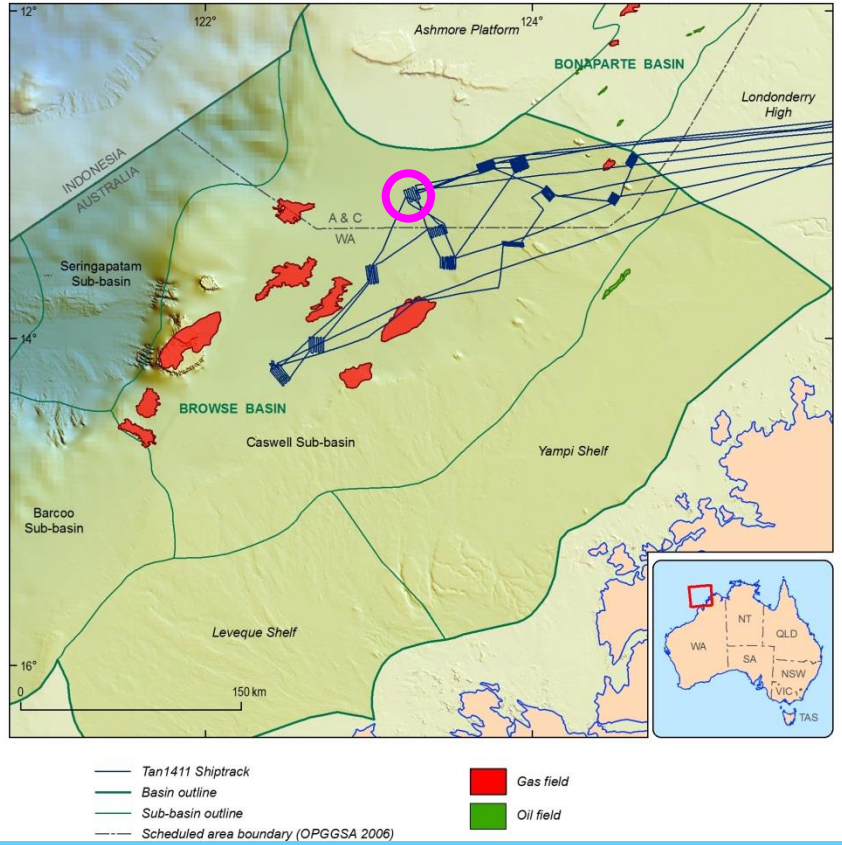
Abrams, M.A., 2005. Significance of hydrocarbon seepage relative to petroleum generation and entrapment. Marine and Petroleum Geology 22, 457-477.

Headspace gas: comparison with other surveys



- Comparison with Arafura survey S282 where CH_4 concentrations of up to 70,000 ppmV were found
- These elevated concentrations were found to be biogenic in origin
- Browse survey data showed no evidence for biogenic methane or migrated thermogenic gases
- Therefore there is no geochemical evidence for seepage associated with the northern extension of Cretaceous hydrocarbon charge

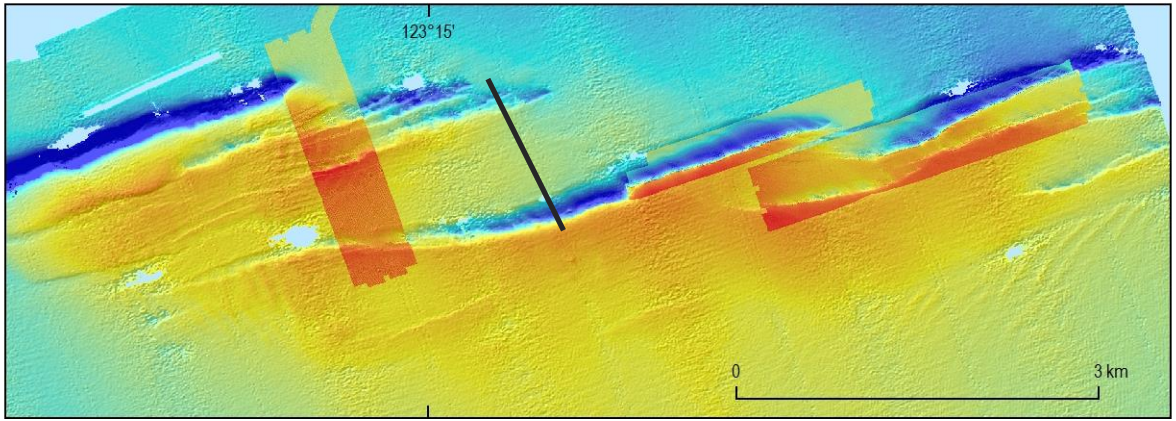
Fault seal risk for Maastrichtian and Campanian reservoirs

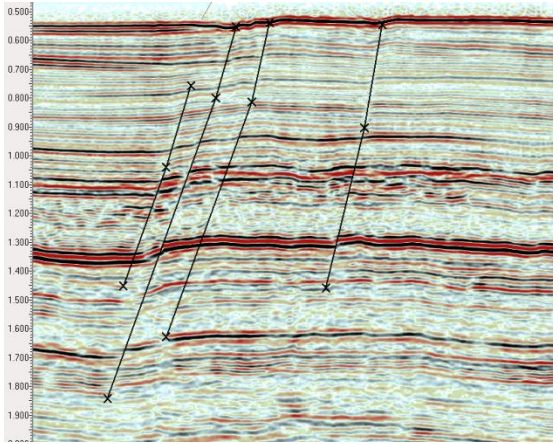


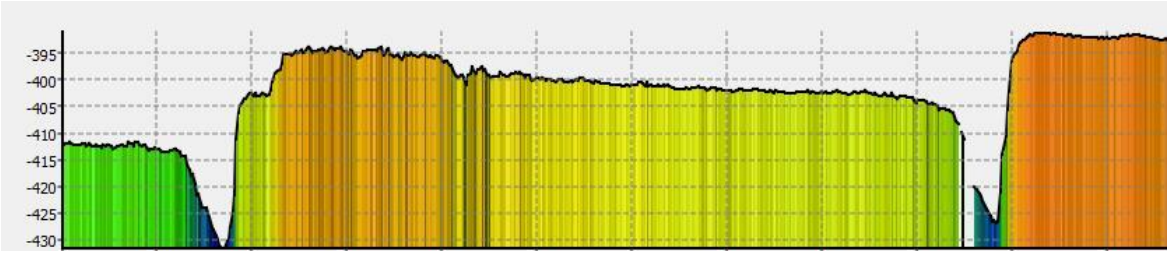
- Seafloor and subsurface data suggest recent faulting could impact seal integrity above potential Maastrichtian and Campanian reservoirs

Fault seal risk for Maastrichtian and Campanian reservoirs

Bathymetry confirms deep plumbing fault connectivity implied in seismic data and recent fault activity

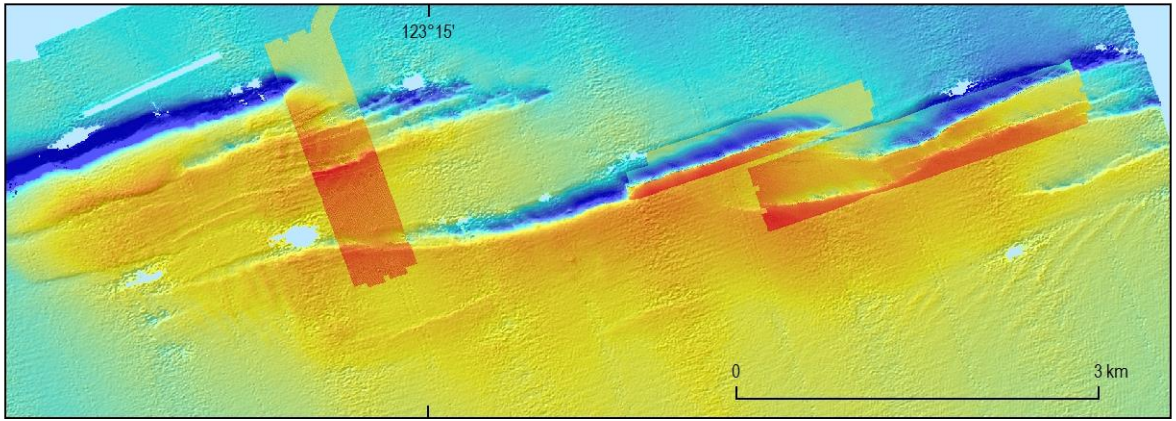




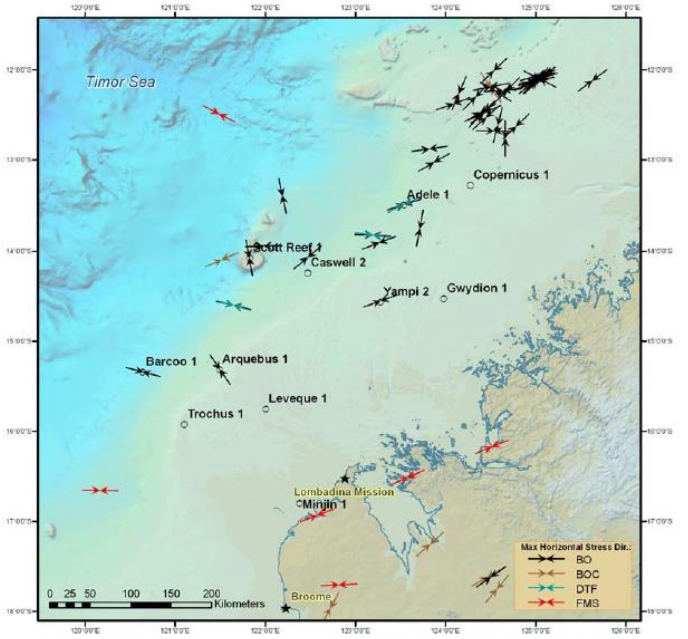


Faults observed are steep with up to 40 m offset at the sea floor

Fault seal risk for Maastrichtian and Campanian reservoirs



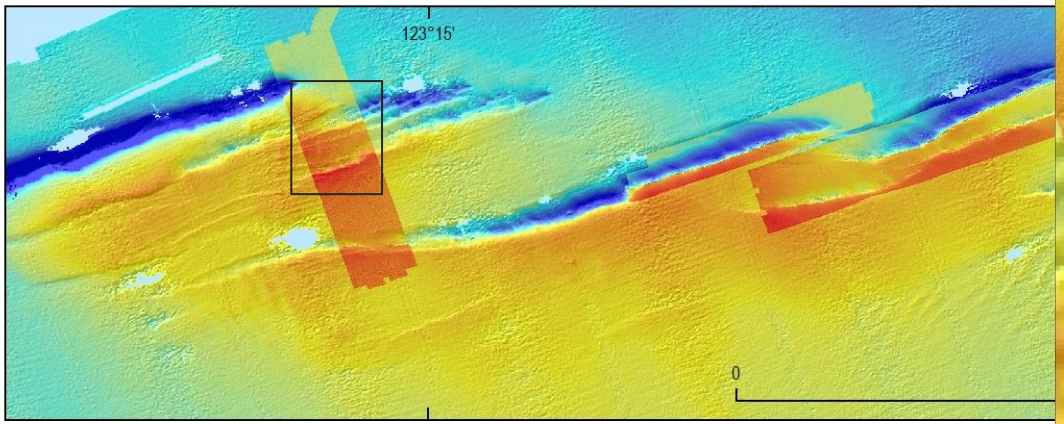
- Geomechanical analysis of wells reveals strike slip stress regime
- ESE-WNW and ENE-WSW faults have the highest reactivation risk

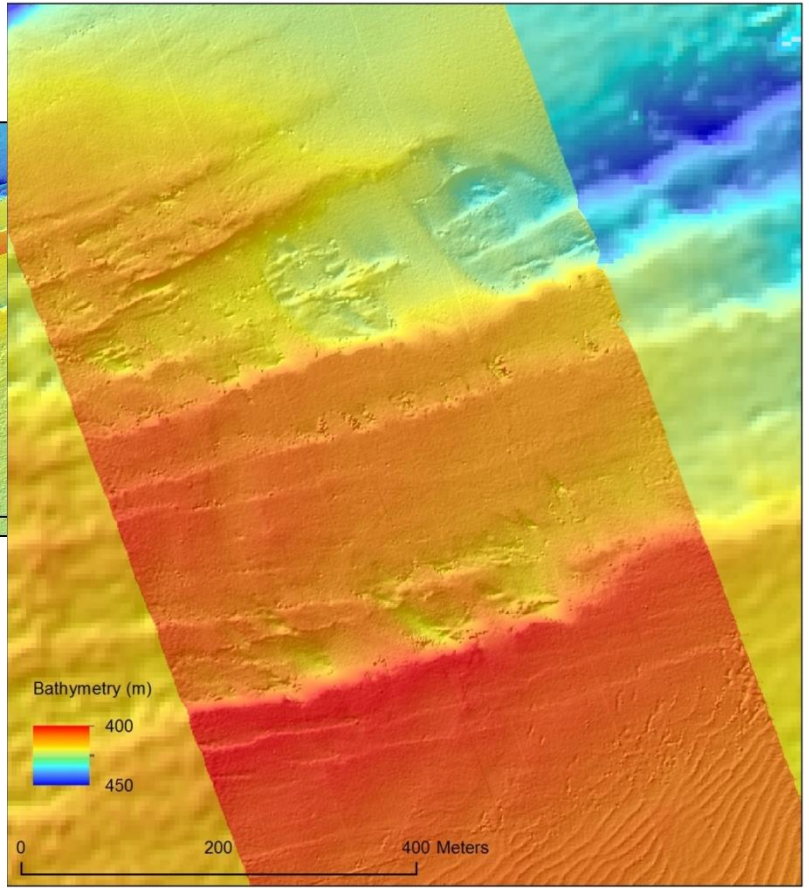


Geomechanical analysis – Current Stress Field - S_{Hmax} Orientation

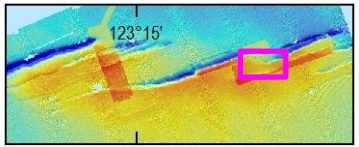
Fault seal risk for Maastrichtian and Campanian reservoirs

1m high resolution AUV bathymetry provides evidence of fault activity today!





Fault seal risk for Maastrichtian and Campanian reservoirs

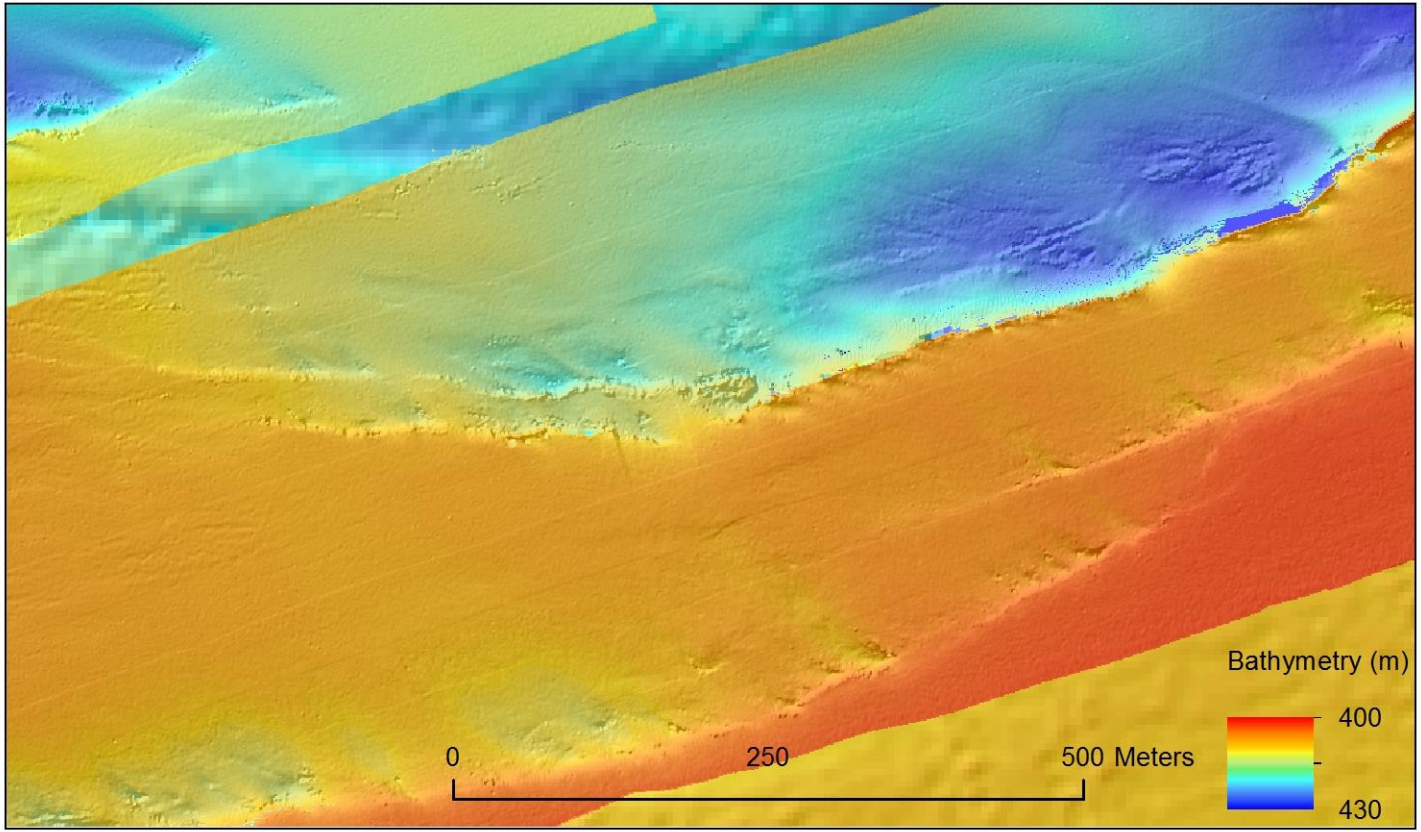


Synthetic faults divided by accommodation zones

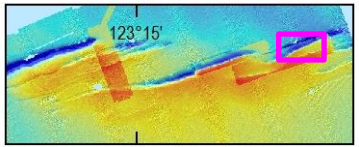
En echelon faulting

Relay ramps

Rider blocks

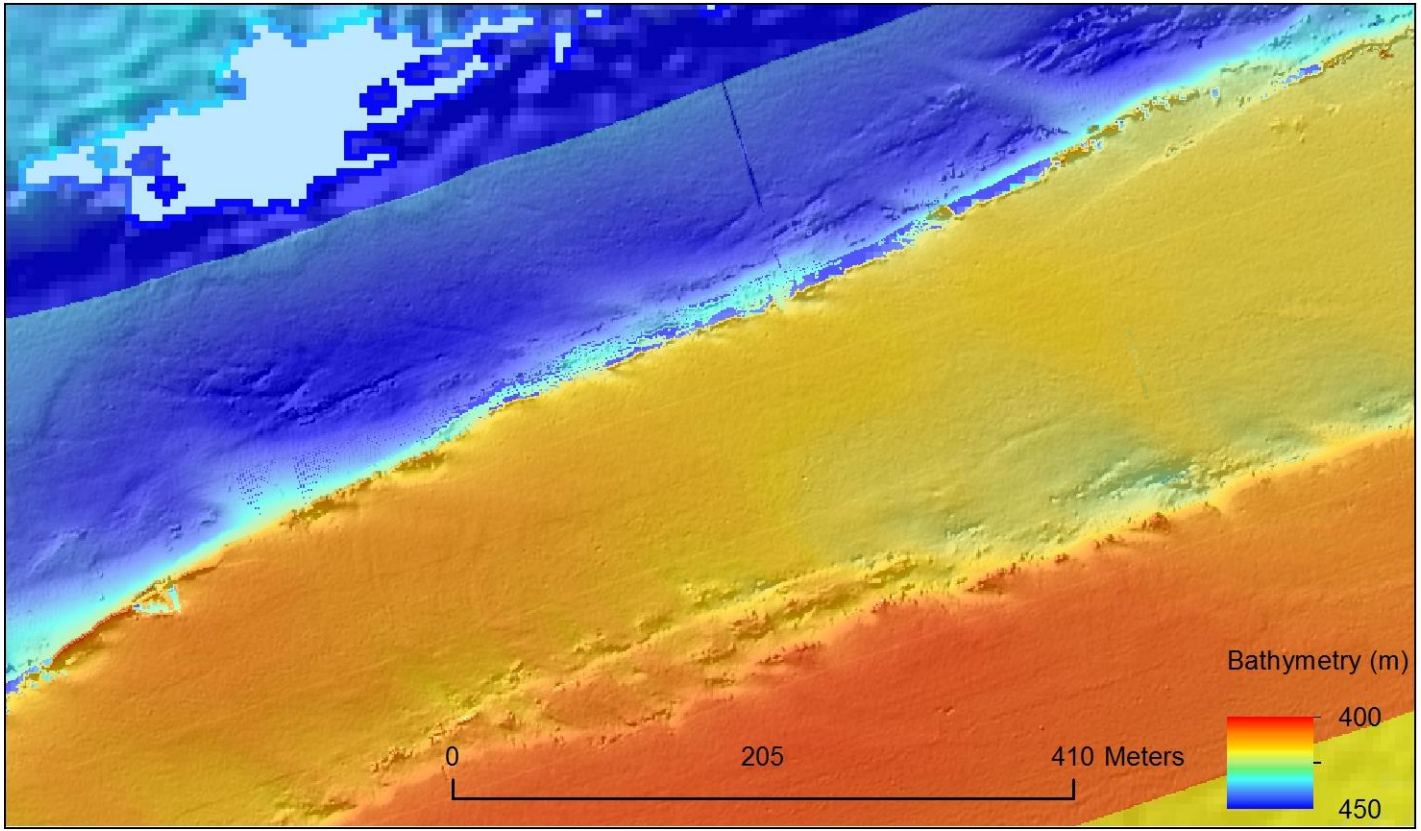


Fault seal risk for Maastrichtian and Campanian reservoirs

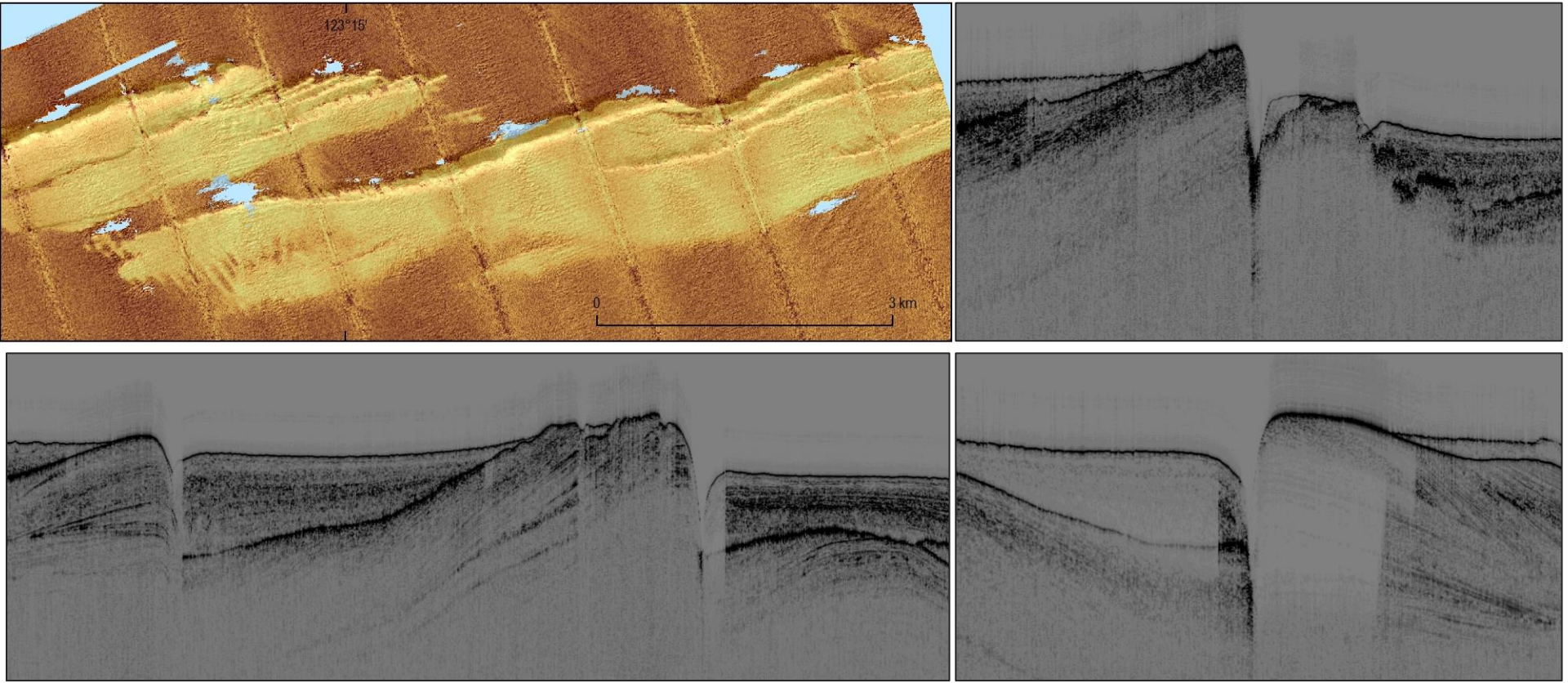


Steep offsets

Hanging wall fractures



Backscatter and support recent fault uplift



ROV footage of fault scarp in outcrop

Conclusions

- No geochemical evidence for seepage associated with the northern extent of Cretaceous hydrocarbon charge or up-dip migration to basin margins was detected

- However resource conflicts may still exist between hydrocarbons and potential Cretaceous storage reservoirs

- Recent deep plumbing fault activity is likely to impact seal integrity above potential Maastrichtian and Campanian storage reservoirs

Survey data and post survey report soon to be released by Geoscience Australia

A Marine Survey to Investigate Seal Integrity Between Reservoirs and Shallow Geology/Seafloor in the Caswell Sub-Basin, Browse Basin, Western Australia:

GA0345/GA0346/TAN1411 – Post-survey report

Telopathes sp. - new genus of Black Coral

Australian Government
Geoscience Australia

Acknowledgements

GA Team onboard: Ron Hackney, Lynda Radke, Scott Nichol, Janice Trafford, Megan Lech, Justy Siwabessy, Rachel Melrose, George Bernardel, Floyd Howard, Andrew Carroll, Rowan Romeyn

Ships crew: NIWA (NZ), AUV/ROV operators: Fugro

GA shore based staff: Matt Carey, Ian Atkinson, Craig Wintle, Jessica Gurney, John Pugh, Nadege Rollet, Steve Abbott, Dave Caust, Kim Picard, Tanya Whiteway, Melissa Fellows, Rachel Przeslawski, Anna Potter, Maggie Tran

Support from: IT, Finance, HR, GA Repository