Browse Basin 2014 Marine Survey - Investigating Containment for Potential Late Cretaceous CO₂ Storage Plays*

Chris Nicholson¹, Rowan Romeyn¹, Megan Lech¹, Steve T. Abbott¹, George Bernardel¹, Andrew Carroll¹, David Caust¹, Emmanuelle Grosjean¹, Ron Hackney¹, Floyd Howard¹, Rachel Melrose¹, Scott Nichol¹, Lynda Radke¹, Nadege Rollet¹, Justy Siwabessy¹, and Janice Trafford¹

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
**© Commonwealth of Australia (Geoscience Australia) 2016.
With the exception of the Commonwealth Coat of Arms and where otherwise noted, this product is provided under a Creative Commons Attribution 4.0 International Licence. http://creativecommons.org/licenses/by/4.0/legalcode

¹Geoscience Australia, Canberra, ACT, Australia (chris.nicholson@ga.gov.au)

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 CO₂. 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


Browse Basin 2014 Marine Survey – Investigating Containment for Potential Late Cretaceous CO₂ Storage Plays


Geoscience Australia, GPO Box 378, Canberra ACT 2601, AUSTRALIA, +61 (0)2 6249 9111, chris.nicholson@ga.gov.au
Government funded NCIP program (2011/12-15) to investigate potentially suitable areas for CO₂ storage proximal to major emission sources.
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)
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)
Browse Basin CO₂ Storage Prospectivity Study – Context

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

- Understanding the source of natural gas and CO₂ 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

Browse Basin CO₂ Storage Prospectivity Study – Context

An integrated study into CO₂ storage potential and hydrocarbon prospectivity

Basin analysis and sequence stratigraphic studies

• Reservoir seal plays suitable for CO₂ storage
• Factors impacting seal integrity
• Potential conflicts between CO₂ storage and petroleum resources

• Rollet et al. – Cretaceous stratigraphic play fairway assessment in the Browse Basin: Implications for CO₂ storage.

• Abbott et al. – Seven Cretaceous Low-Order Depositional Sequences From the Browse Basin, NWS, Australia: A Framework for CO₂ Storage Studies.

• Lech et al. – Palaeogeographic Evolution of Early Campanian to Maastrichtian Supersequences in the Caswell Sub-Basin – Implications for CO₂ Storage and Hydrocarbon Entrapment
Browse Basin CO\textsubscript{2} Storage Prospectivity Study – Context

An integrated study into CO\textsubscript{2} storage potential and hydrocarbon prospectivity

- Basin analysis and sequence stratigraphic studies
  - Reservoir seal plays suitable for CO\textsubscript{2} storage
  - Factors impacting seal integrity
  - Potential conflicts between CO\textsubscript{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\textsubscript{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*
Browse Basin CO₂ Storage Prospectivity Study – Context

An integrated study into CO₂ storage potential and hydrocarbon prospectivity

**Basin analysis and sequence stratigraphic studies**
- Reservoir seal plays suitable for CO₂ storage
- Factors impacting seal integrity
- Potential conflicts between CO₂ storage and petroleum resources

**Geochemical studies**
- Understand source rock distributions and their potential to generate hydrocarbons
- Define petroleum systems and their extent
- Origin of CO₂ in Plover/Brewster reservoirs?

**2013 and 2014 Browse sampling surveys**
- Investigate modern seepage that may compromise storage prospectivity
- Collect environmental baseline data before storage activities
Browse Basin 2014 Marine Survey – Investigating Containment for Potential Late Cretaceous CO₂ Storage Plays
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.

RV Tangaroa (NIWA, NZ)

AUV – Detailed mapping
ROV – Physical Investigation
Survey Objectives

- To collect pre-competitive data to support a CO₂ storage assessment in the Browse basin
- Investigate modern seepage over CO₂ 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**
- Towed fish depth
- Amplitude anomalies above shallow faults

**Sub surface fluid indicators**
- Seafloor – reservoir connectivity

**Deep plumbing faults**
- Drowned lowstand coral atoll

**Potential seafloor seepage indicators**
- Fluid migration pathways associated with palaeo-channels

**Baseline seabed environments**
- Biology, geomorphology, sedimentology & geochemistry

**Water column gas flares**

**Pock marks**
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)
- 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
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

2015 AAPG/SEG International Conference & Exhibition - 13 – 16 September 2015 Melbourne, Australia
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
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
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
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
eyear and late Cretaceous plays

3. Seepage associated with the northern extent of Cretaceous hydrocarbon charge
Survey site selection

- 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

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

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