From the back of the shed to the forefront of exploration: what the NTGS core store is revealing about the Roper Group shales of the greater McArthur Basin.

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Project context

• To acquire, compile and interpret key petroleum and metallogenic data for carbonaceous shale units in the greater McArthur Basin

• Staged approach starting with the youngest geology in the Roper Group

• Standardised assessment of all of the fine-grained units within the Roper Group
Old core with new stories to tell

NTGS core store - Darwin

Altree 2 – stored 27 years
Old core with new stories to tell

GA core store - Canberra

BMR Urapunga 3 – 31 years old
Roper Group stratigraphy

Adapted from Munson (2014).
Intermittent exploration for conventional petroleum since the 1960s, increased interest through the 1980-90s

Current focus is around the Beetaloo Sub-basin

Companies including Origin, Pangaea and Santos currently working in the area.
• 52 petroleum wells/ 550,000 km² basin, frontier basin status

• Interest renewed with advent of technology for tight gas recovery and favourable economic conditions

• All new wells targeting conventional and unconventional petroleum potential
Drilling history

- NTGS has contributed to a 40% increase in open file analytical data to the greater McArthur Basin.

- Pre-2007 petroleum and legacy mineral holes intersecting shale units sampled.

- NTGS has collected 1511 new samples from 80 drill cores.
Desirable characteristics of shale gas systems

- Marine shales with Type II kerogen (HIo: 250-800 mg HC/g rock)
- Organic rich source rock (>2 wt.% present-day TOC)
- Within the gas window (>1.4% Roe)
- Low oil saturations (<5% So)
- Significant silica content (>30%) with some carbonate presence
- Contains <30% clay mineralogy, non-swelling clay
- Low permeability (<1000-ηd), porosity (4-7%)
- Thickness of effective organic-rich mudstone ≥30 m
- Slightly to highly overpressured
- Continuous mappable systems
Original TOC values are up to 50% higher, varying as a function of thermal maturity.
TOC wt% for other Roper Group formations is low

- Poor to fair present-day TOC values
- Original values, even at a 50% increase, wouldn’t suffice
- Sample frequency is low

![Graph showing Total Organic Carbon content (wt%) for different formations with sample frequency on the y-axis and Total Organic Carbon content on the x-axis. The formations are: Chambers River Formation, Corcoran Formation, Crawford Formation, Hayfield mudstone, Jalboi Formation, and Mainoru Formation.]
Organic matter type and maturity

• Ideally marine shales with Type II kerogen ($H_{I_0}$: 250-800 mg/g)

Present-day ($H_{I_{pd}}$)

• Kyalla Fm $H_{I_{pd}}$: 53-777 mg hydrocarbon /g TOC
• Velkerri Fm $H_{I_{pd}}$: 51-730 mg hydrocarbon /g TOC

Original value ($H_{I_0}$)

300-900 mg hydrocarbon /g TOC
Type I/II oil-prone kerogen present.
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Mineralogy

- Significant silica content (>40%) with some carbonate presence
- Contains <30% non-swelling clay mineralogy
- Kyalla generally very clay rich (>30%)
- Velkerri Formation middle has low clay and high silica levels.

IDEAL MINERALOGY
Non-swelling clay component

- high proportions of non-swelling clay in Velkerri Fm
- Kyalla Fm clays dominantly non-swelling
Maturity 1.1% to 3.5%

data sourced from DIP014 (Revie, 2016)
Maturity 1.1% to 3.5%
Wet gas to dry gas maturity

Velkerri Fm primary target

Kyalla Fm secondary target

maturity windows sourced
from Hunt (1995) p.368

data sourced from DIP014 (Revie, 2016)
Wet gas to dry gas maturity

Beetaloo Sub-basin samples

maturity windows sourced from Hunt (1995) p.368

data sourced from DIP014 (Revie, 2016)
Complex thermal history

- Maceral reflectance values indicate current depths of $\approx 1100 - 1400$ m for wet gas window and $\approx >1500$ m depth to the dry gas window in the Beetaloo Sub-basin.

- Basin modelling indicates multiple burial and hydrocarbon generation events.

- High-heat flow present in the basin.

- Kyalla and Velkerri formations presently within oil to dry gas maturity depths in the depocentres.
Low permeability (<1000-ηd), porosity (4-7%)

- Roper Group shales have a favourable range of permeability for pressure retention:
  - Kyalla Fm (11 - 99.2 ηD)
  - Velkerri Fm (0.57 – 539 ηD)

- Roper Group shales have a favourable range of porosity:
  - Kyalla Fm: 3.5 – 7% (avg. 5%)
  - Velkerri Fm: 3.2 – 13.7% (avg. 8%)

adapted from O'Connor et al (2014)
Low permeability (<1000-\(\eta_d\)), porosity (4-7%)

Inclined dotted lines indicate time taken for all overpressure to dissipate.

- Roper Group shales will revert to hydrostatic pressure in 1 Ma unless gas generation and expansion occurs.
- It is essential for the Roper Group shales to be currently generating gas to retain overpressure

adapted from O'Connor et al (2014)
Thickness of effective organic-rich mudstone ≥30 m

- Kyalla Formation 800+ m (843 m in Shenandoah-1A)
- Velkerri Formation 750+ m (753 m in Sever-1)
- Thick endowments of low-clay/high brittle mineral content, high-TOC, low-permeability mudstone.

- Thicker than known world-class marine & lacustrine source rocks throughout the planet
Sub-surface mapping

- 2D subsurface mapping integrates 3D model of the base of the Roper Group and geochemistry.
- Sparse well and seismic control – contouring preferred method for TOC distribution.
- Flat and continuous stratigraphy through depocentres.
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Base of Roper Group greater McArthur Basin area (vertical exaggeration x5)

Adapted from Bruna & Dhu (2015)
2D TOC mapping

- 2D subsurface mapping integrates 3D model of the base of the Roper Group and geochemistry

- Sparse well and seismic control – contouring preferred method for TOC distribution

- Flat and continuous stratigraphy through depocentres

SEEBASE™ adapted from Pryer & Loutit (2005)
thermal maturity window mapping

- middle Velkerri Formation present within the dry gas window thermal maturity depths (approx. 1500 m, >1.4% R<sub>oe</sub>)

- Deepest regions also organically richest regions

SEEBASE™ adapted from Pryer & Loutit (2005)
Potential play fairway indicators

- middle Velkerri Formation

- Conservative estimation of play fairway indicators based on open file information of 3 basic criteria:
  1. TOC >2 wt.%
  2. Thickness >30 m
  3. Depth >1500 m

- Paucity of data controlling fairways.

SEEBASE™ adapted from Pryer & Loutit (2005)
Conclusions

- Legacy drill core from petroleum and mineral exploration has yielded previously overlooked information for the unconventional prospectivity of the McArthur Basin.

- The Kyalla and Velkerri formations contain favourable mineralogy, organic geochemistry, maturity, and physical properties for the generation of shale gas.

- Timing of generation imperative to pressure retention in the basin.

- Organic geochemistry, physical distribution and sedimentology suggest positive water balance enclosed marine basin depositional environment for Roper Group shales, building on previous interpretations of shallow marine depositional environment.
References


