THE BEETALOO JV: EXPLORING AND APPRAISING A VERY LARGE FRONTIER SHALE BASIN

SPE - Brisbane

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Unconventional exploration in Australia

EIA estimates of technically recoverable resources (2013)

<table>
<thead>
<tr>
<th>Country</th>
<th>TCF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 China</td>
<td>1,115</td>
</tr>
<tr>
<td>2 Argentina</td>
<td>802</td>
</tr>
<tr>
<td>3 Algeria</td>
<td>707</td>
</tr>
<tr>
<td>4 U.S.</td>
<td>665</td>
</tr>
<tr>
<td>5 Canada</td>
<td>573</td>
</tr>
<tr>
<td>6 Mexico</td>
<td>545</td>
</tr>
<tr>
<td>7 Australia</td>
<td>437</td>
</tr>
<tr>
<td>8 South Africa</td>
<td>390</td>
</tr>
<tr>
<td>9 Russia</td>
<td>285</td>
</tr>
<tr>
<td>10 Brazil</td>
<td>245</td>
</tr>
<tr>
<td>Total</td>
<td>7,299</td>
</tr>
</tbody>
</table>

Farm-in activity: 2010-14
Shale Exploration Rule 1: Choosing the correct basin is the most important decision you make

Is sweet spot hunting worthwhile?
Shale Exploration Rule 1: Choosing the correct basin is the most important decision you make
Shale Exploration Rule 2: Keep it qualitative when comparing and ranking basins or plays

- Sediment origins (intra-basinal vs. extra-basinal)
- Dominant hydrocarbon system (self sourcing vs. migrated)
- Continuity of targets
- Target depth
- Stacked targets
- Stress regime
- Maturity and liquids potential
- Surface access/utilization
- Play diversity
Origin and the Beetaloo Joint Venture Background

Timeline

✓ Origin Energy and Sasol farm-in to the permits held by Falcon Oil & Gas in May 2014.

✓ Exploration Campaign Phase 1 begins (2015/2016)

✓ NT Fracking Moratorium Sep 2016

✓ Sasol farms-out 2017 with Origin retaining 70% interest
Where and what do we explore for?

✓ 530 km southeast of Darwin
✓ 3 Exploration Permits covering ~18,500 km² Acreage (Core Area)
✓ 2 primary targets – Velkerri and Kyalla formation
✓ 1 secondary target – Chambers River formation
How big is 18,500 km²?

~ size of Wales
Where to begin?

What we knew at time of entry

- Excellent quality oil prone marine (algal) source rock
- Intra-basinal sediment origin
- Self sourcing
- Basin shape and extent
- Kyalla upside – the only permits with material exposure to the liquids rich Kyalla
- Structurally passive
- Good surface access

Key technical unknowns

- Continuity
- Gas saturation and mobility
- Pore pressure
- Reservoir quality
- Completion quality
- Stress regime
- Maturity
Initial objectives

- Confirm the presence and continuity of thick, high quality, and gas saturated source rock intervals in the Velkerri
- Confirm that the Velkerri is not in a reverse stress regime
- Test and refine the basin/maturity model
- Build up play concepts (collect data on secondary targets opportunistically)

Accelerate to a horizontal
Origin have drilled three vertical exploration wells: confirming the continuity of gas saturated source rock intervals.
Velkerri Play Fairway Map

• The Permits provide access to most completely preserved Roper Group depocentre

• Three organic rich intervals with excellent reservoir quality in the Velkerri Formation: A Shale, B Shale and C Shale from oldest to youngest
  - B Shale and C Shale have thicknesses >40m

• Over 90% of the Middle Velkerri area in the Permits is viewed as geologically prospective

• Exposure to extensive dry and wet gas fairways in the Middle Velkerri

• No pervasive geohazards within the Permits that could impact horizontal well development unlike in the Gorrie Sub-Basin
Play concepts

- **Velkerri**
  - Stacked targets (A,B,C)
  - Diverse maturity range
    - Liquids rich gas play fairway along the northern and eastern flank (untested)
    - Dry gas play fairway (tested)
- **Kyalla** (untested)
  - Multiple targets
  - Liquids rich gas fairway in the core
  - Liquids rich gas / volatile oil towards the flanks
- **Chambers River** (untested)
  - Strat trap play
  - Shallow
  - Liquids rich gas / volatile oil
Shale Exploration Rule 3: Don’t over capitalize on vertical wells

Vertical well are only useful to assess systematic risks that can kill a play, to collect static data that help to inform a decision with respect to a horizontal, or to provide depth control

Sweetspot hunting vs. concept testing

Design the vertical pilot with an option to sidetrack and drill a horizontal lateral

Fracking and flow testing a vertical well is a poor use of resources

Invest in DFITs instead
Why are DFITs useful when accelerating towards a horizontal multi-frac well?

Horizontal Multi-Frac Well

- Where to land the horizontal?
- How to stimulate?
- What stage spacing?
- How many stages?
- Where to drill?
What Engineers Spend Their Days Worrying About

Horizontal Multi-Frac Well

Where to land the horizontal?

Where to drill?

How to stimulate?

How many stages?

What stage spacing?

What is the stress regime?

Tectonic stress coupling?

Minimum horizontal stress?

Pore pressure?

Permeability?

Net horizontal stress?

Net fracture pressure complexity?

Is there stress anisotropy?

Near wellbore tortuosity?

Rock fabric?

Natural fractures?

Do we expect simple or complex fractures?

Proppant Concentrations?

Volume?

Fluid efficiency?

Pump rates?

What frac fluid to use?

How should we design the perforations?

Perforation pressure losses?

Is there stress anisotropy?

Pump rates?

Volume?
What is the reservoir quality?

Permeability?

Pore pressure?

Minimum horizontal stress?

What is the stress regime?

Tectonic stress coupling?

Net horizontal stress?

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Pump rates?

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Pump rates?

What to land the horizontal?

How should we design the perforations?

Perforation pressure losses?

Fluid efficiency?

Net horizontal stress?

Net fracture pressure complexity?

How to stimulate?

Horizontal Multi-Frac Well

Where to drill?

Where to land the horizontal?
Where to land the horizontal?  How to stimulate?  How many stages?  What stage spacing?  Where to drill?
Positioning yourself to execute a horizontal multifrac well

The choice is yours…
Amungee: To drill a lateral or not is not the only question...

<table>
<thead>
<tr>
<th>Tier 1 (RQ&amp;CQ)</th>
<th>B Shale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thickness (m)</td>
<td>29.5</td>
</tr>
<tr>
<td>TOC (%)</td>
<td>4.1</td>
</tr>
<tr>
<td>Phi Gas (%)</td>
<td>4-4.5</td>
</tr>
<tr>
<td>Poisson’s ratio</td>
<td>0.2</td>
</tr>
<tr>
<td>Young Modulus (GPA)</td>
<td>32.8</td>
</tr>
</tbody>
</table>
How to know which way to drill the lateral

- Drill in the minimum horizontal stress direction
  - Why? – transverse fractures

- Wouldn’t rely on the world stress map given the data density
How to know which way to drill the lateral

Ran and interpreted FMIs for both Kalala S-1 and Amungee NW-1 for breakouts and DITFs.

Conducted and imaged an open-hole XLOT at Amungee to confirm fracture orientation.

Aligned with world stress map.

Now we are ready to drill ....
Shale Exploration Rule 4: Drill the well to be frac friendly

Adopt a drilling and geo steering philosophy to minimize wellbore tortuosity (undulations)
  - Costs saved in drilling can easily be lost in completions

Completions is the new big ticket item…sorry drillers
Shale Exploration Rule 5: The MEM is really important

\[ \text{Shmax} - \text{Shmin} \]

After Macneil et al, Warpinski et al and Fisher et al

Cote SPE Brisbane 2017
Australia’s longest ‘plug n perf’ fracture stimulation – 11 stages across 1000 metres in 12 days
Shale Exploration Rule 6: Know your key risks and be prepared to adjust

Base fluid design: slick water
- Why? – Surface area creation more important than fracture conductivity

Contingent fluid design: hybrid
- Why? – Pump rate limitations through 4.5” casing

Deployment: Plug and perf
- Why? – Provides the greatest amount of flexibility for on the fly adjustments and screen out recover

Plugs: Flow through frac plugs
- Why? – Risk of casing deformation

Toe sleeve
- Why? – Pump toe stage DFIT to calibrate HFS model
- Key risk: Toe sleeve does not shift
- Contingency: Coil tubing
Why being prepared paid off at Amungee

- Toe sleeve did not shift – jetted with coil
- Difficulty placing with slick water – swapped over to hybrid after stage 2
- Casing deformation event occurred – none of the plugs were milled out past the point of deformation
- Where there is change there is opportunity
  - Proved a tighter more aggressive stage can be executed
Amungee NW-1H stimulation achievements

11 stages completed
87% of design proppant placed
  - 100% in hybrid treatments
2.5M lb of proppant placed in 67,000 bbl of fluid
2 frac stages completed in 1 day
400,000 lbs placed in biggest stage
15 minutes NPT (0.1%)
Zero spills
Zero safety incidents

But it gets better…
Extended production test results

Billion year old gas!
Extended production test results

Limiting factors

i. ~65% lateral utilisation
ii. Plugs 1 to 6 not milled out
iii. 4.5” casing
Amungee NW-1H discovery is specific to the B Shale only over 2C area – lots of running room

### 2C Contingent Resource estimates (gross)

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>km²</td>
<td>1,968</td>
</tr>
<tr>
<td>Original Gas In Place (OGIP)</td>
<td>TCF</td>
<td>61</td>
</tr>
<tr>
<td>Contingent Resource</td>
<td>TCF</td>
<td>6.6</td>
</tr>
</tbody>
</table>

### Original Gas in Place Best Estimate (gross)  

<table>
<thead>
<tr>
<th>Description</th>
<th>Unit</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Area</td>
<td>km²</td>
<td>16,145</td>
</tr>
<tr>
<td>Original Gas In Place (OGIP)</td>
<td>TCF</td>
<td>496</td>
</tr>
<tr>
<td>OGIP/Area</td>
<td>BCF/km²</td>
<td>31</td>
</tr>
</tbody>
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1. P50 area from the Contingent Resource area distribution
2. OGIP presented is the product of the P50 Area by the P50 OGIP per km²
3. Estimated Gas Contingent Resource category of 2C
4. Falcon, 2017
Appraisal next steps – improve performance AND decrease costs

- Rates $\uparrow$ + Costs $\downarrow$: a firmly established paradigm in US shale plays and QLD CSG
- Through well design and pad-operation efficiencies
  - Longer laterals – 2.5-3 km
  - Increase frac stage density and lateral utilisation
  - Pilots to demonstrate feasibility

Source: https://www.otmconsulting.com/insight/repeating-the-us-shale-revolution/
Efficiency of horizontal development demonstrated
Analogues in North America prove it is technically possible…

Antero has reduced well costs while increasing EURs

### Capital Efficiency – Longer Laterals Improve ROR

<table>
<thead>
<tr>
<th></th>
<th>2014</th>
<th>2016</th>
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<tbody>
<tr>
<td>Well cost ($m)</td>
<td>12.3</td>
<td>7.6</td>
</tr>
<tr>
<td>Lateral length (ft)</td>
<td>8,052</td>
<td>8,903</td>
</tr>
<tr>
<td>Drilling days</td>
<td>29</td>
<td>12</td>
</tr>
<tr>
<td>EUR per well (Bcfe)</td>
<td>14.5</td>
<td>22.3</td>
</tr>
<tr>
<td>F&amp;D ($/mcf)</td>
<td>0.88</td>
<td>0.40</td>
</tr>
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</table>
Summary of a world class unconventional resource in the making

• The Beetaloo has the potential to be a world class unconventional resource

• The Beetaloo has the potential to become Australia’s largest gas resource

• Key challenges/risk
  - Overcome the moratorium
  - Uncertain regulatory regime
  - Improve well performance
  - Repeatability
  - Drive costs down
THANK YOU

• Beetaloo Team:
  - Lisa Baruch
  - Carl Altman
  - Brenton Richards
  - Ed Wong
  - Dylan Stringer
  - George Nairn
  - David Close
  - Faiz Mohinudeen
  - Rachael Illet