UNCONVENTIONAL HYDROCARBON PLAYS IN THE PERMIAN SUCCESSION, SOUTH AUSTRALIA

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OUTLINE

• Permian basins in South Australia
• Gondwana glaciation
• Cooper Basin
  • Overview
  • Shale Gas
  • Tight Gas (Basin-centred gas)
  • Coal Seam Gas
• Arckaringa Basin
  • Sequence stratigraphic interpretation
  • Organic rich marine shales
  • Maglia 1 oil show
  • Coal gasification project
• Pedirka Basin
• Summary
PERMIAN BASINS IN SOUTH AUSTRALIA

Late Palaeozoic sedimentary basins on the Australian portion of Gondwana.
# Permian Basins in South Australia

## Cooper Basin

<table>
<thead>
<tr>
<th>System</th>
<th>Stage</th>
<th>Stratigraphy</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td>UEE Gunnedah</td>
<td>PP1</td>
<td>Patchawarra Formation</td>
<td>Merrimelia Formation</td>
</tr>
<tr>
<td></td>
<td>PP2</td>
<td></td>
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<tr>
<td></td>
<td>PP3</td>
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<td></td>
<td>PP4</td>
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## Pedirka Basin

<table>
<thead>
<tr>
<th>System</th>
<th>Stage</th>
<th>Stratigraphy</th>
<th>Lithology</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Purni Formation</td>
<td>Crown Point Formation</td>
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</tbody>
</table>

## Arckaringa Basin

<table>
<thead>
<tr>
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<th>Stratigraphy</th>
<th>Lithology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Mount Toondina Formation</td>
<td>Stuart Range Formation</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Boorthanna Formation</td>
</tr>
</tbody>
</table>
GONDWANA GLACIATION

Palaeogeographic reconstruction of the Australian Plate (after Veevers, 1984 and Baillie et al., 1994).
GONDWANA GLACIATION

Glacial sediments (Merrimelia and Tirrawarra formations) isopach.
GONDWANA GLACIATION

Arckaringa Basin Pre-Permian depth structure map.
GONDWANA GLACIATION

Main glacial valleys, southern Arckaringa Basin

Near top Lower Mount Toondina Fm SB?

Image captured from TrapTester – 5 x vertical exaggeration

3D PERSPECTIVE VIEW LOOKING WEST

Ice sheet, glaciers and fjords, SE coast of Greenland
SHALE GAS

• The US Energy Information Administration has estimated that the entire Cooper Basin (SA and QLD) has a risked recoverable shale gas resource of 85 Tcf
SHALE GAS

**ADSORPTION CAPACITY** is a function of a number of parameters including:

- Organic carbon content
- Organic maceral type and maturity (surface area)
- Temperature

Adsorption isotherm for Roseneath Shale core sample, Moomba 175

~ 24 scf/t at 3800 psi, T = 167.8°C
SHALE GAS

DIFFERENT TO TYPICAL NORTH AMERICAN SHALE GAS PLAYS

• Lower organic carbon contents, organic maceral type (Type III) and high temperatures mean that ADSORBED gas contents for Roseneath and Murteree shales will be significantly lower than for typical North American shale plays.

NOT TRUE SELF SOURCING SHALE RESERVOIRS?

• Some of the gas in the Roseneath and Murteree shales may have migrated from other source units

SILTSTONES

• A much higher percentage of gas stored as FREE gas in pore space.
High resistivities in the Permian succession of the Nappamerri Trough suggest gas saturation (from Hillis et al, 2001)
TIGHT GAS

Patchawarra Formation
Tmax vs HI cross plot

- Andree 2 (8)
- Gidgealpa 1 (3)
- Kurunda 1 (11)
- Murteree 2 (20)
- Pondirrie 2 (17)
- Snake Hole 1 (20)
- Sturt 3 (1), Sturt 4 (1), Sturt 6 (1), Sturt East 4 (1)
- Tibouchina 1 (3)
- Tirrawarra West 1 (22)
- Baraita 1 (4), Callabonna 1 (3), Cuttapinnie 1 (6), Dinkalal 1 (1), Fly Lake 3 (1), Gidgealpa 17 (1), Kanowana 1 (2), Kerinnia 1 (8), Kobarri 1 (6), Lake MacMillan 1 (3), Leelajyan 1 (10), Maraku 1 (4), Munkari 4 (7), Nulla 1 (7), Papyrus 1 (7), Spectre 1 (14), Tindilipie 2 (10), Tinga Tingana 1 (30), Tirrawarra 2 (2), Tirrawarra 16 (1), Tirrawarra North 1 (12), Toolachee East 2 (21), Toolmaroo 1 (1), Wancoco 1 (7)

- VR = 0.5 %

- VR = 1.35 %
TIGHT GAS

Merrimelia Ridge  Nappamarri Trough  Della - Nappacoongee Ridge

N Horizon  P Horizon  ROSENEATH SHALE

MURTEREE SHALE  Vc Horizon

20km
COAL SEAM GAS
COAL SEAM GAS

Wireline log correlation for the Patchawarra Formation highlighting the lateral continuity of the VC50 coal seam over 8 km at this location (sonic >115 microsecs/ft shaded black to highlight coals)

<table>
<thead>
<tr>
<th>Well name</th>
<th>VC50 seam thickness (m)</th>
<th>Total gas (units)</th>
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</thead>
<tbody>
<tr>
<td>Bindah-3</td>
<td>19</td>
<td>80-500</td>
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<tr>
<td>Meranji South-1</td>
<td>16</td>
<td>1,000</td>
</tr>
<tr>
<td>Cowralli-1</td>
<td>18</td>
<td>1,000-2,000</td>
</tr>
<tr>
<td>Cowralli-10</td>
<td>16</td>
<td>2,065-3,550</td>
</tr>
<tr>
<td>Kanowana-2</td>
<td>18</td>
<td>600-900</td>
</tr>
<tr>
<td>Tindilpie-7</td>
<td>16</td>
<td>1,000</td>
</tr>
<tr>
<td>Dorodillo-4</td>
<td>13</td>
<td>100-1,000</td>
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<tr>
<td>Battunga-1</td>
<td>23</td>
<td>1,835</td>
</tr>
<tr>
<td>Wimma-1</td>
<td>14</td>
<td>2,800</td>
</tr>
</tbody>
</table>
COAL SEAM GAS

Bindah 3 VC50 coal (8971' 5''), SEM micrograph showing microporosity (from Weatherford Laboratories petrology report in Bindah 3 Well Completion Report).

Bindah 3 VC50 coal (8977' 5''), SEM micrograph showing microporosity (from Weatherford Laboratories petrology report in Bindah 3 Well Completion Report).
ARCKARINGA BASIN

Arckaringa Basin Pre-Permian depth structure map.
Mount Toondina Formation delta progrades into basin from east

Pre-Permian basement

Base Permian Unconformity

HST

mfs

Line 84-XER_mig_08SX and 84-XES, looking SE, flattened on MFS (8 x vertical exaggeration)
SEQUENCE STRATIGRAPHIC INTERPRETATION

Line 84-XER_mig_08SX and 84-XES, looking SE, flattened on MFS (8 x vertical exaggeration)
SEQUENCE STRATIGRAPHIC INTERPRETATION

HANNS KNOB 1

Pre-Permian basement

85-YRK_mig_08SX (3 x vertical exaggeration) tied to Hanns Knob 1
ORIGINIC RICH MARINE SHALES

*Palynostratigraphy from Hanns Knob 1 WCR

- Samples with abundant alginite
- Samples with high TOC content
ARKEETA 1
Organic rich shales (TOC>2%, HI >400) are Type II source rocks at the threshold of oil generation.

ARCK 1
(Modified from Linc Energy ASX Announcement, 27 September 2011)
Mount Toondina Formation delta progrades into basin from east

Pre-Permian basement

ORGANIC RICH MARINE SHALES

Lines 84-XER_mig_08SX and 84-XES, looking SE, flattened on MFS
Approximate sub-crop edge of Neo-proterozoic basin - 6km east of Maglia 1

Lines 84-XFE and 85-YRK_mig_08SX, looking north
COAL GASIFICATION

ARCKARINGA CTL AND POWER PROJECT

Feedstock: Multi billion tonne coal resource
Mine/Process: Open cut mining, Gasification, Clean up SO2 and CO2 extraction
Conversion: Fischer-Tropsch, fuel production
Output: Refined Synfuels (86% diesel, 20% naphtha), Power 562 MW export capacity
Markets: South Australia, Exports to Asia, South Australian electricity consumers
PEDIRKA BASIN

Top Purni Depth Structure Map
SUMMARY

• Glacial topography created when Australia lay near the south pole is preserved in the subsurface.
• The Permian sediments infilling this topography offer a variety of hydrocarbon resource plays.
• Exploration for continuous gas plays in the Cooper Basin is progressing well with gas flows from fracture stimulated vertical wells exceeding 2 mmcf/d.
• Assessment of resource plays in the Arckaringa and Pedirka basins is less advanced at this stage, with play fairways yet to be identified.