Evidence of Petroleum System Evolution of the Southern Bredasdorp Basin, South Africa: A Multi-Dimensional Approach*

Lihle Madyibi1, Rolando di Primio2, George Smith1, Gesa Kuhlmann2, and Zahie Anka2

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1Geological Sciences, University of Cape Town, Cape Town, South Africa (lihle.madyibi@uct.ac.za)  
2Department 4 Chemistry of the Earth, GeoForschungsZentrum, Potsdam, Germany

Abstract

The southernmost Bredasdorp Basin, offshore South Africa, remains only partially understood with respect to petroleum systems evolution when compared to the northern and central flanks of the basin. The southern flank of the basin has been unsuccessful for hydrocarbons with most of the wells drilled to date yielding insignificant oil and gas shows. Incomplete integration of data in the southern area is a possible reason for the oil and gas search being hitherto unsuccessful. In this study, we apply a two-dimensional, later up-scaled to a three-dimensional, modeling approach in order to advance our understanding of the petroleum systems evolution in the southern flank of the Bredasdorp Basin.

The model is based on the interpretation of 64,490 m two-dimensional seismic-reflection profiles, as well as the analyses of well logs and cores that constrain the sedimentary facies distribution and the units’ age. Four main source rock intervals (Barremian, Aptian and Turonian) were modeled for maturity and hydrocarbon generation.

Different scenarios of erosion and heat flow histories were considered for model calibration. The best calibration with vitrinite reflectance data is achieved when an erosive event, removing up to ~ 800 m of Maastrichtian to early Paleogene sediments, is accounted for in the model. Maturity predictions suggest that the Barremian and Aptian source rocks are currently mature and started generating hydrocarbons at about 80 Ma, whereas the Turonian source rock is immature. Present-day modeled transformation ratios for both mature source rocks are higher than 50%. Nevertheless, petroleum generation seems to be halted at about 69 to 35 Ma and 12 to 0 Ma due to minimal burial depth of sediments.

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South Africa
Outline of the presentation

• Background and aims of the study

• Geological background
  – Sequence stratigraphy of the Bredasdorp sub-basin

• Methods used in the study
  – Seismic and well log data interpretation and integration
  – Depth conversion
  – 3D basin modelling

• Petroleum system evolution
  – Source rock maturity
  – Presence of reservoirs

• Concluding remarks
Notes by Presenter: The southernmost Bredasdorp Basin, offshore South Africa, remains only partially understood with respect to petroleum systems evolution when compared to the northern and central flanks of the basin.

The southern flank of the basin has been unsuccessful for hydrocarbons with most of the wells drilled to date yielding insignificant oil and gas shows.

Incomplete integration of data in the southern area is a possible reason for the oil and gas search being hitherto unsuccessful.

In this study, we apply a three-dimensional, modeling approach in order to advance our understanding of the petroleum systems evolution in the southern flank of the Bredasdorp Basin.
Geological Background

Sequence chronostratigraphic framework of the Bredasdorp Basin

<table>
<thead>
<tr>
<th>Time Period</th>
<th>Event Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Mesozoic</td>
<td>- Last major uplift</td>
</tr>
<tr>
<td></td>
<td>- Falkland plateau clears</td>
</tr>
<tr>
<td></td>
<td>- Agulhas Arch</td>
</tr>
<tr>
<td>Quarter-Jurassic</td>
<td>- Break-up unconformity</td>
</tr>
<tr>
<td></td>
<td>- Main flooding</td>
</tr>
<tr>
<td></td>
<td>- Major regional uplift</td>
</tr>
<tr>
<td></td>
<td>- 1st marine incursions</td>
</tr>
<tr>
<td>Lower Cretaceous</td>
<td>- Transform motion</td>
</tr>
<tr>
<td></td>
<td>- Prograding shelf deposition</td>
</tr>
<tr>
<td></td>
<td>- Thermal subsidence and sea level changes</td>
</tr>
<tr>
<td>Upper Cretaceous</td>
<td>- Thermal uplift</td>
</tr>
<tr>
<td></td>
<td>- Falkland plateau clears</td>
</tr>
<tr>
<td></td>
<td>- Agulhas Arch</td>
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<td></td>
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</tr>
</tbody>
</table>

Source: PASA Expl. brochure, 2007
NB: Faults might have been the conduits that allowed migration of oil.
Well to seismic tie

GR log tie – seismic section

E-F1

1. Lithologies

2. Facies

3. Time stratigraphy

- Deep water deposits
- Shallow marine sandstone
- Red beds
- Top basement
- Basement

- 13At1: Aptian source
- 1At1: Claystone, Shale, Siltstone, Sandstone
Depth Conversion performed using the Vo K method.

\[ Z_n = \frac{V_0}{k} \left( e^{\frac{k}{2}(t_n-t_{n-1})} - 1 \right) + (Z_{n-1} - Z_{\text{seafloor}}) e^{\frac{k}{2}(t_n-t_{n-1})} + Z_{\text{seafloor}} \]

\[ V_i = V_0 \phi^{+KZ} \]

Where

- \( t_{n-1}, t_n \) = two-way time (twt) to top and base of interval in seconds.
- \( Z_{n-1}, Z_n \) = depth to top and base of interval.
- \( Z_{\text{seafloor}} \) = depth to seafloor

Where

- \( V_i \) = Interval velocity
- \( V_0 \) = Surface velocity (at seafloor)
- \( K \) = Velocity gradient
- \( Z \) = Depth
Depth Conversion

13A source rock was deposited in the Aptian times

Structural highs formed during rifting phase are still prominent

Depth map to 13At1
3D Basin Modelling

Model building and calibration

<table>
<thead>
<tr>
<th>Source rock interval</th>
<th>TOC (wt. %)</th>
<th>HI (mg HC/g TOC)</th>
<th>Kerogen type</th>
<th>Source rock quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turonian</td>
<td>4.00</td>
<td>400.00</td>
<td>II</td>
<td>Very good</td>
</tr>
<tr>
<td>Aptian</td>
<td>2.00</td>
<td>250.00</td>
<td>II</td>
<td>Good</td>
</tr>
<tr>
<td>Barremian</td>
<td>2.00</td>
<td>250.00</td>
<td>II/III</td>
<td>Good</td>
</tr>
</tbody>
</table>

TOC, total organic carbon; HI, hydrogen index
Petroleum System Evolution

Source rock maturity

- Temperature
- Transformation of organic matter into kerogen component
- Expulsion of hydrocarbons

Aptian source rock (13At1)
Petroleum System Evolution

Source rock maturity

- Temperature
- Transformation of organic matter into kerogen component
- Expulsion of hydrocarbons

Aptian source rock (13At1)
**Petroleum System Evolution**

**Source rock maturity**

- Temperature
- Transformation of organic matter into kerogen component
- Expulsion of hydrocarbons

Aptian source rock (13At1)
Petroleum System Evolution

Source rock maturity
- Hydrocarbon generation potential

Aptian source rock (13At1)
Petroleum System Evolution

Reservoirs
- Accumulations
Concluding Remarks!!!

- The results of petroleum generation modelling show different maturity levels within the source rock interval 13A.
- The modelled burial history records major episodes of erosion that seems to have significantly affected the generation of petroleum during the Tertiary period.
- Oil and gas generated and accumulated before 67 ma is lost due to inversion and biodegradation.
Thank you for your attention