Are Present-Day Stresses Inferred from Petroleum Exploration Data Consistent with Neotectonic Structures in Australia?

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AAPG International, November 2006, Perth
Introduction

- breakouts, DITF and LOT-type data used to address wellbore stability and fracture stimulation
- predict fault reactivation particularly for prediction of seal integrity
Conclusions

• rich record of Neogene deformation which has created, amplified and/or breached hydrocarbon traps
• orientation of Neogene structures varies around continent but is everywhere consistent with present-day $\sigma_H$ orientation
• in several Australian basins neotectonic structures and FMS suggest reverse fault regimes ($\sigma_h > \sigma_v$) whereas wellbore data suggest $\sigma_h < \sigma_v$ or $\sigma_h \sim \sigma_v$
• caution in using wellbore data to predict fault reactivation
• horizontal stress magnitudes vary temporally and spatially
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- SE Australian passive margin
- NW Australian passive margin
- conclusions

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Pecten-Minerva Line

Top Narrawaturk ~ Top Oligocene

Yallourn Monocline, Latrobe Valley

Haunted Hill Formation: Pliocene
Yallourn Formation: Middle-Upper Miocene

Dickinson et al. (2002)
SE Australia Topography & Stress
Otway and Gippsland Basin Neogene Faults

Dickinson et al. (2002)
Earthquake Focal Mechanism Solutions

Allen et al. (2005)
Hydrocarbon Exploration
Well-Based Stress Magnitude Data

- vertical stress ~20 MPa @ 1km and 63-69 MPa @ 3km depth
- minimum horizontal stress varies from west to east

<table>
<thead>
<tr>
<th>Location</th>
<th>Stress Rate (MPa/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SA Otway</td>
<td>15.5</td>
</tr>
<tr>
<td>Vic Otway</td>
<td>18.5</td>
</tr>
<tr>
<td>Gippsland</td>
<td>20.0</td>
</tr>
</tbody>
</table>

\[ \sigma_h < \sigma_v \quad \text{to} \quad \sigma_h \sim \sigma_v \]
Conclusions: SE Australian Margin

- rich record of Neogene compressional deformation in eastern Otway, Torquay and Gippsland Basins consistent with NW-SE $\sigma_{H\text{max}}$ from wellbore data
- neotectonics and focal mechanism solutions suggest reverse fault regime ($\sigma_v < \sigma_h < \sigma_H$)
- hydrocarbon exploration well data suggest $\sigma_h < \sigma_v$ to $\sigma_h \approx \sigma_v$

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Barrow Sub-Basin A-A’

Williams and Poynton (1985)
Barrow Sub-Basin C-C’

Green: Late Miocene
Purple: Middle Miocene
Blue: Early Oligocene
Reflectors Above Base Tertiary

Hearty et al. (2002)
Dampier Sub-Basin Line M85-2953

Barber (1994)
Exmouth & Barrow Sub-Basins

Barber (1988)
Hydrocarbon Exploration
Well-Based Stress Magnitude Data
Conclusions: NW Australian Margin

- rich record of Neogene compressional deformation in Carnarvon Basin consistent with ~$100^\circ$N $\sigma_{Hmax}$ from wellbore data
- neotectonics suggest reverse fault regime ($\sigma_v<\sigma_h<\sigma_H$)
- hydrocarbon exploration well data suggest $\sigma_h<\sigma_v$

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Perth Basin

- E-W $\sigma_H$ (overcoring, breakouts, DITF & FMS)
- orthogonal, N-S striking Quaternary reverse faults
- reverse fault FMS
- Perth Basin leak-off tests: $\sigma_h < \sigma_v$
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Conclusions

- rich record of Neogene deformation which has created, amplified (Scarborough, Rough Range and Minerva) and/or breached (Timor Sea) hydrocarbon traps belies widely held notion of a stable continent
- orientation of Neogene structures varies around continent but is everywhere consistent with present-day $\sigma_{H\text{max}}$ orientation
- in several Australian basins neotectonic structures and FMS suggest reverse fault regimes ($\sigma_h > \sigma_v$) whereas wellbore geomechanical data suggest $\sigma_h < \sigma_v$ or $\sigma_h \sim \sigma_v$
- caution in using wellbore data to predict fault reactivation (calibrate against neotectonic record)

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Conclusions

- Leak-off tests do not reliably yield $\sigma_h$? ($\sigma_h \sim \sigma_v$ vs. $\sigma_h < \sigma_v$)
- Neotectonic structures misinterpreted?
- Temporal variation in horizontal stress magnitude (horizontal stresses relax after faulting, then build up due to far-field stresses)?
- Variation in stress magnitudes with depth: leak-off tests vs. focal mechanism solutions?
- Stress partitioning onto major faults?

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