The impact of structural deformation in a 2D basin and petroleum system model of the East Coast Basin, New Zealand

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The East Coast Basin is a petroliferous forearc basin located on the eastern margin of the North Island, NZ

- Subduction at Hikurangi Trench
- Subduction wedge & forearc basin (East Coast Basin)
- Frontal forearc high (Axial Ranges)
- Active arc (Taupo Volcanic Zone)

Bathymetry map from NIWA, 2008; rates of subduction and trench location from Barnes et al. 2010
The basin has numerous oil and gas seeps and shows:

- 5 oil seeps, but mostly gas seeps
- Most gas is pure methane although sometimes includes C2 to C5
- Isotopic data indicate gas is primarily thermogenic
- Oils have low sulfur content, non-waxy to medium waxy, and range API range of 27.8-34.5
- Over 40 wells drilled
- Several gas discoveries, but no commercial development
Research Objectives

1. Develop a structurally robust basin and petroleum system model that honors paleo-geometries (paleo-stepping model)

2. Assess the petroleum system development in the distinct structural regimes of the East Coast Basin

3. Determine key sensitivities for each structural regime
The focus of my study is in the Hawke Bay area along a 2D regional transect. Modified from Nicol and Uruski (2005)

- Subducting Hikurangi Plateau
- Basement comprised of meta-sedimentary greywacke
- Converging to passive margin sediments
- Neogene sediments deposit between imbricate thrusts
- Young subduction complex

Modified from Nicol and Uruski (2005)
The transect was structurally reconstructed to develop a structural framework for petroleum system development.
The transect was structurally reconstructed to develop a structural framework for petroleum system development.
Heat flow was calibrated using vitrinite-intertinite reflectance and fluorescence data from four wells:

- Hawke Bay-1
- Opoutama-1
- Hukarere-1
- Tawatawa-1
The base case heat flow scenario reflects three distinct thermal regimes related to changes in tectonic setting.
Four source rocks were modeled, although the two deepest are only hypothetical.
The Paleocene Waipawa Black Shale is the most prospective source rock in the region

• Environment of deposition most likely related to an oxygen minimum zone from the outer shelf to upper slope related to upwelling along the margin

• Biomarkers indicate that organic matter is primarily marine-derived from microalgae, although some terrestrial organic matter is also present

• Tied to oil seeps in the Wairarapa (southern) region of the basin
• Pepper and Corvi Organofacies B Type II kinetics

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<th>Low</th>
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(from GNS Science, 2005)
The Late Cretaceous Whangai Formation is a secondary source rock also considered in the model.

- Very siliceous formation; likely had limited terrigenous sediment supply

- Biomarkers indicate that organic matter is primarily marine-derived with a minor terrestrial component

- LOOSELY tied to seeps in the Raukumara (northern) region of the basin
- Pepper and Corvi Organofacies DE Type III kinetics

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(from GNS Science, 2005)

- Uncertainty of presence offshore
- Two older hypothetical source rocks are modeled for scenario testing
The model blocks were broken out into four main structural regimes for comparison.
The base case model shows that transformation has occurred in the deeper parts of the basin.
The base case model shows that transformation has occurred in the deeper parts of the basin.
The Waipawa Black Shale reaches 32% transformation in the Lachlan Footwall by 12 Ma
By 8.5 Ma, the Waipawa Black Shale has passed the critical moment in the Lachlan Footwall
The critical moment is slightly later for the Waipawa Black Shale in the Lachlan Basin.
The Whangai Formation reaches the critical moment close to present day
The Whangai Formation reaches the critical moment close to present day.
The timing of the critical moment varies by source rock and structural regime.
Uncertainties in the model were tested to determine their impact on timing and total generation.

Uncertainties tested include:

1. Timing of thrusting
2. Heat flow
   - No rifting event
   - Earlier cooling
3. Lithologies
4. Kinetics
The Waipawa Black Shale is most affected by an early heat flow cooling scenario.
The Whangai Formation is more sensitive to changes in the model than the Waipawa Black Shale.

<table>
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<tr>
<th>Scenario</th>
<th>Kinetics: Type I</th>
<th>Early Cooling</th>
<th>No Rifting</th>
<th>Muddy Neogene Lithofacies</th>
<th>Early Thrusting</th>
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The timing of initial thrusting is poorly constrained impacts critical moment timing in the Lachlan Footwall.
Conclusions

• It is best to integrate the structural framework in basin and petroleum system modeling in structurally complex basin settings

• Petroleum system assessment should be considered in terms of its structural regimes due to distinct timing of events, the total petroleum generated, and in addressing sensitivities
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Questions?

Cook’s Cove, East Coast Region, New Zealand