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The Benefits and Limitations of Using Structural Models in Basin and Petroleum System Modeling: A Case Example from the East Coast Basin, New Zealand

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ABSTRACT

Basin and petroleum system modeling has become an integral part of the exploration process for many companies, causing modelers to develop streamlined workflows that often include simplification of basin structure and removal of faults. While this is typically sufficient in tectonically simple environments (i.e., passive margins), simplified models can have major limitations when applied in tectonically complex settings. Most basin and petroleum system models are developed as event-stepping models, where sediments undergo layer-by-layer backstripping to calculate their initial thickness and basin geometry for forward modeling. In structurally complex settings, the paleogeometries estimated through event-stepping are often incorrect and provide non-geologic solutions. Additionally, event-stepping models cannot handle thrust faults where a single horizon is duplicated on the z-axis. Therefore, paleo-stepping models provide a clear solution for structurally complex settings.

A paleo-stepping model was developed using 2D Petromod Teclink v2013.2® incorporating seventeen time steps and seventeen faults. Two end-member heat flow scenarios were tested based on calibration to vitrinite-inertinite reflectance and fluorescence analysis, T_{max}, the thermal alteration index, and present day temperatures. Custom bulk kinetics were used for both source rocks.

Results from this study show that structural events in the basin act as the main control on the timing and extent of source rock transformation. Transformation begins between early to late Miocene time for both the Waipawa Black Shale and Whangai Formation depending on the structural regime in the basin. In the Lachlan basin, the Waipawa Black Shale experiences a mid-to-late Miocene time step-wise increase in temperature associated with extensional faulting. Source rocks in the Lachlan footwall experience the earliest transformation due to early structural thickening from thrust faulting. It is worth noting that it is only possible to evaluate the Lachlan footwall region using the paleo-stepping model due to vertical duplication of horizons.

Results from this study also highlight that the pore pressure regime can be tightly controlled by the burial and uplift history within the distinct structural blocks. The faults are believed to compartmentalize the basin, such that the pressure of each structural regime evolves separately. Blocks that have been buried deeply with limited to no connectivity to the surface exhibit very high overpressure. However, blocks that have been hydraulically connected to the surface, either at present day or in the past, due to structural deformation exhibit moderate to no overpressure. These pressure histories impact both the anticipated present day pressure regime and the present day porosity.

In the East Coast Basin, the paleo-stepping model permits ready-assessment of the basin by structural sections, which have developed fairly independent of each other due to distinct tectono-histories. While paleo-stepping models add significant complexity and time to the modeling workflow, they provide more robust solutions in structurally complex environments.