Building a Model of the Devonian Shale Basin, central NWT

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Summary

Building a hydrocarbon system model in the Northwest Territories presents many challenges. There are substantially fewer wells than in jurisdictions south of 60°N, with suitable well data being sparse and unevenly distributed. A second challenge is the sheer size of the area, which for this project encompasses the Mackenzie Plain region and portions of the Peel Plateau, Peel Plain, Franklin Mountains, and Mackenzie Mountains. This region contains the Devonian shale basin, a structurally complex stratigraphic package, which is the focus of this study. It includes the Horn River Group, which comprises the Hare Indian, Ramparts, and Canol Formations, and the Imperial Formation. This basin also hosts the Norman Wells oil field, and therefore has been studied by government agencies, industry, and academia for decades. The resulting datasets, including publicly available well files, survey reports, and outcrop and well sample data, were used in this study for the creation of local and regional geological models. The main objective of this project is to use these models to better understand the regional hydrocarbon system by attempting to predict known resource accumulations.

Theory / Method / Workflow

The study area includes the Mackenzie Plains region and adjacent portions of the Peel Plateau, Peel Plain, Franklin Mountains, and Mackenzie Mountains. Within the project's extents there are 584 wells and 30 outcrops. These were narrowed down to a subset based on the type of data available and data quality. Wells with a full slate of logs and lithological reports were prioritized, along with those that had been sampled for analyses. Data from the selected wells and outcrops were used to create point models, or models at the scale of a single well or outcrop. Each of these models comprises lithological data for each formation present, known unconformities with an estimate of missing stratigraphy, and maturity data from analyzed samples if available (vitrinite reflectance was prioritized). A regional heat flow estimate was also used for the point models, in this case 80 mW/m^2 (Majorwicz *et al.*, 1988). The point models were then used to generate local burial and exhumation histories, which could be compared to the available thermal maturity data. In addition, an estimate of the timing, quantity, and mixture of hydrocarbons generated and expulsed from the Canol Formation was created at each point model location (Figure 1).

A regional 3-D model was constructed using a surface layer based on a regional digital elevation model, accompanied by geological surfaces created from interpreted seismic lines. These surfaces include the tops of the Ramparts, Canol, Hare Indian, and Imperial Formations. The point models were subsequently added to help constrain some of the geological surfaces on a smaller scale. Other data used in the regional model included pressure and temperature values from borehole drill stem tests. These were verified to ensure that only values from successful tests were used. This dataset was used to generate and estimate the regional pressure-depth and temperature-depth curves.

Observations

Calibrating the resulting well and outcrop models using vitrinite reflectance data provides reasonable correlations between simulated depth vs. maturity curves and sample results. Similarly, the current iteration of the 3-D regional model appears to predict known maturity trends in a broad sense, based on the input data. This model makes several assumptions and has limitations due to data density and availability. The regional model assumes a degree of homogeneity in lithology, porosity, permeability, and distribution of organic matter in each rock layer. This is clearly not realistic but is a necessary simplification due to the modelling software's limitations. Currently, lack of continuity for some surfaces (partly due to the model's interpolation limits) impedes proper resource accumulation prediction even though interesting trends can be observed. Most of these issues are attributable to the relatively small and very sparse dataset and the sheer size of the geographical area being modelled. Additionally, the Gambill fault zone at the southern end of the study area can be considered a boundary for the basin. Data south of this fault is even more sparse and the heat regime appears to be very different from the rest of the modelled area.

Conclusions

In a general sense, the model has confirmed regional maturity trends that have been predicted in previous literature using data from chip samples. The KinEx graphs for the point models do potentially indicate more gas in the Devonian system than had been predicted prior to drilling in the 2010's. While the model has not yielded many novel predictions, the exercise was not without merit. The compilation of the regional model illustrated the challenges of attempting to simulate such a large area with limited data. Despite sparse data, the model pushed the limitations of both software and hardware. Therefore, any future work in this direction would likely benefit from a more limited scope, focusing on areas with full seismic coverage if possible. This would allow the surfaces to be more continuous without additional interpolation, and would limit any necessary sampling.

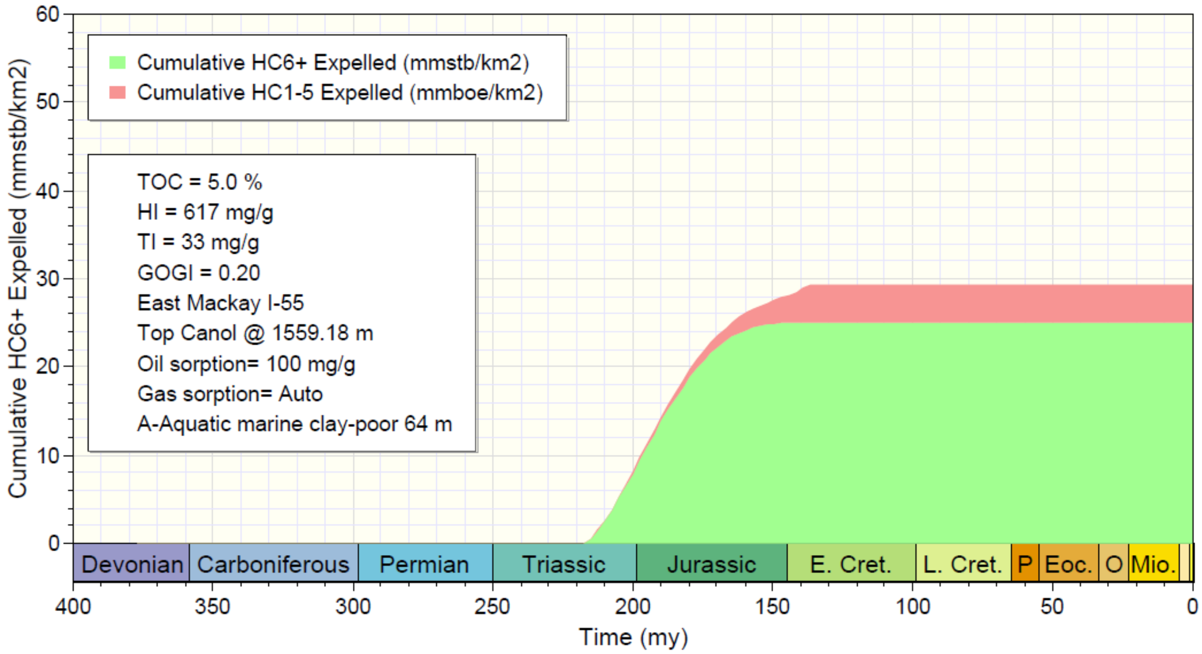

Figure 1: KinEx graph for the East Mackay I-55 well, estimating the amount of hydrocarbons generated from the Canol Formation to present.

References

Majorowicz, Jacek & Jones, F & Jessop, A.. (1988). Preliminary geothermics of the sedimentary basins in the Yukon and Northwest Territories (60°N-70°N) - estimates from petroleum bottom-hole temperature data. Bulletin of Canadian Petroleum Geology. 36. 39-51.