geoconvention
Calgary • Canada • May 13-17 2019

# Basin Modelling and Thermal History of the Horn River and Liard Basins, Cordova Embayment, and Adjacent Parts of the Western Canadian Sedimentary Basin

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## Summary

The Devonian-aged organic rich formations in Northeastern British Columbia (NEBC), namely the Muskwa and Horn River Formations host immense volumes of hydrocarbons. Over the last decade these unconventional intervals have been the focus of many studies, including detailed sedimentology, source rock analysis, sequence stratigraphy, and shale rock property related research. Basin modelling is used in this study to further understand the basin evolution and determine the role of various geological properties in the burial and thermal history and subsequent present-day petroleum systems of northeastern BC.

## Introduction

In sedimentary basins, it is important to gain an understanding of basin evolution. Basin modelling through numerical simulations is a powerful tool in quantifying the burial and thermal history of a basin and hydrocarbon generation, migration and entrapment. Basin modelling requires the integration and knowledge of numerous variables, including regional geology, lithology, stratigraphy, tectonic history and heat flow. The northeastern British Columbia portion of the Western Canada Sedimentary Basin (WCSB) is relatively understudied and underexplored compared to most other areas in the basin. Hence, basin modelling can provide significant insights and constraints on the basin history and contribute to predicting the economic potential of this important area.

The objective of this study was to use basin modelling to understand the basin evolution and determine the role of various geological properties in the burial and thermal history and subsequent present-day petroleum systems of northeastern BC. One-dimensional (1-D) modeling and sensitivity analysis were performed at 24 well locations throughout the study area, leveraged by publicly available data and a multitude of prior research on the regional geology, lithology and stratigraphy. The models provide quantitative information on the basin, including the onset of hydrocarbon generation and subsequent thermal maturation, maximum burial depths and temperatures, and uplift and erosion rates. This study builds upon previous studies in NEBC, including an early basin modeling study by Morrow et al., (1993).

## Method

This study focused on reconstructing the basin through a series of 1-D basin models. The models were built using Schlumberger's PetroMod® 2015 software suite. In order for the models to be fully representative of the basin, all of the inputs must be defined according to the best available knowledge and data. Modelling inputs include lithology for the entire stratigraphic column, source-rock properties, boundary conditions (heat flow, surface-water interface temperature and paleo–water depths), and erosion and hiatus events. Each input has an effect on the model results and numerous iterations were needed to calibrate the models with measured maturity data points.

Included in the iterations, sensitivity analyses were completed for each well. Sensitivity analyses allow the variables (model inputs) to be determined more accurately and provide a quantitative understanding on the magnitude of impact these variables have on the overall petroleum systems. Many basin modeling studies use some form of sensitivity analysis (Bruns et al., 2013; Grobe et al., 2015; Bruns et al., 2016), often isolating heat flow and erosion. This study followed the same methodology, varying erosion and heat flow independently and systematically.

## Results

The models all experience similar basin histories throughout the Devonian and Mississippian Periods, and are all heavily influenced by foreland subsidence and subsequent erosion. The quantification of subsidence and erosion, however, differs greatly across the study area. The thickness of eroded overburden during the Eocene and, thus, maximum burial depths generally decrease towards the east. Based on the calculated burial depths and associated temperatures, the Devonian shales reached values greater than 4500 m and 220°C, respectively, in the Liard Basin. In western Alberta the values decrease to 1700 m and 92°C, respectively. In all cases, the increased burial depth during foreland subsidence allows the organic-rich intervals to rapidly mature, reaching maturities equivalent to present-day measured values by the Late Cretaceous.

Basin modelling results also provide insight into the timing of hydrocarbon generation across the study area. In the Liard Basin, the Devonian shale intervals begin generating hydrocarbons as early as 345 Ma due to increased burial depths from continued subsidence and deposition of the Besa River and Mattson Formations. Contrastingly, the western Alberta basin models calculate the onset of hydrocarbon generation to occur between 100 and 60 Ma; if generation occurs at all. The models within the Horn River Basin and adjacent areas begin generating hydrocarbons between 335 and 110 Ma. The models that experience generation later in the basin history can be connected to areas with larger volumes of producible condensate.

The sensitivity analyses help to constrain the calculated present-day maturity profiles and determine the most geologically accurate solution. The maturity profile is heavily influenced by erosion and heat flow, moving to higher reflectance values with increased values for either variable. By changing one variable at a time the models were able to calculate the relative change to the present-day maturity. Variation in present-day heat flow is the most dominant control, with a 10% change in heat flow causing a present-day maturity shift of ±0.4 %Ro. Changing erosion by the same relative amount shifts present-day maturity by ±0.2 %Ro. The results of sensitivity analyses allows for the most likely-solution to be determined with confidence while providing quantitative information on the importance of certain input variables.

## Conclusions

Basin modelling of the Liard and Horn River Basins, Cordova Embayment and western Alberta provides insight into burial history, thermal maturation and how the evolution of the basin has affected the present-day Devonian petroleum systems. Sensitivity analysis is important to ensure geologically accurate models, as each variable can significantly affect the basin evolution and present-day thermal maturity. Furthermore, the onset age of generation provides insight into the distribution and producibility of the present-day petroleum system.

## Acknowledgements

The authors would like to acknowledge financial support from Geoscience BC, EnCana Corporation, Devon Energy Corporation, Husky Energy Inc., Chevron Canada Limited, Canadian Natural Resources Limited and geoLOGIC Systems Limited.

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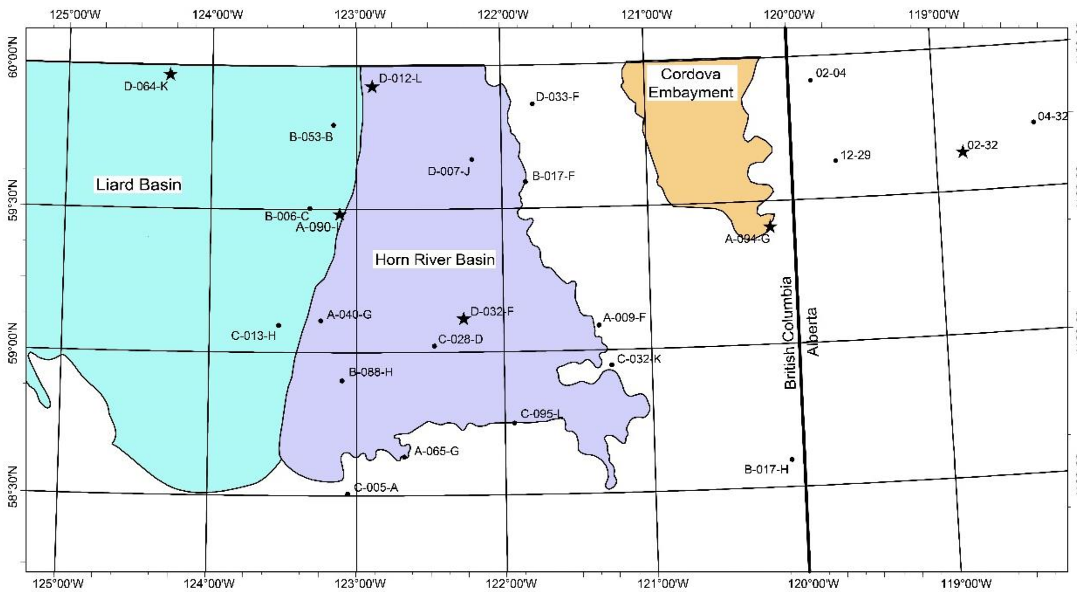


Figure 1. The location of 1D models within the study area in northeastern BC and adjacent areas. Model locations are represented by black dots, with black stars representing key models.

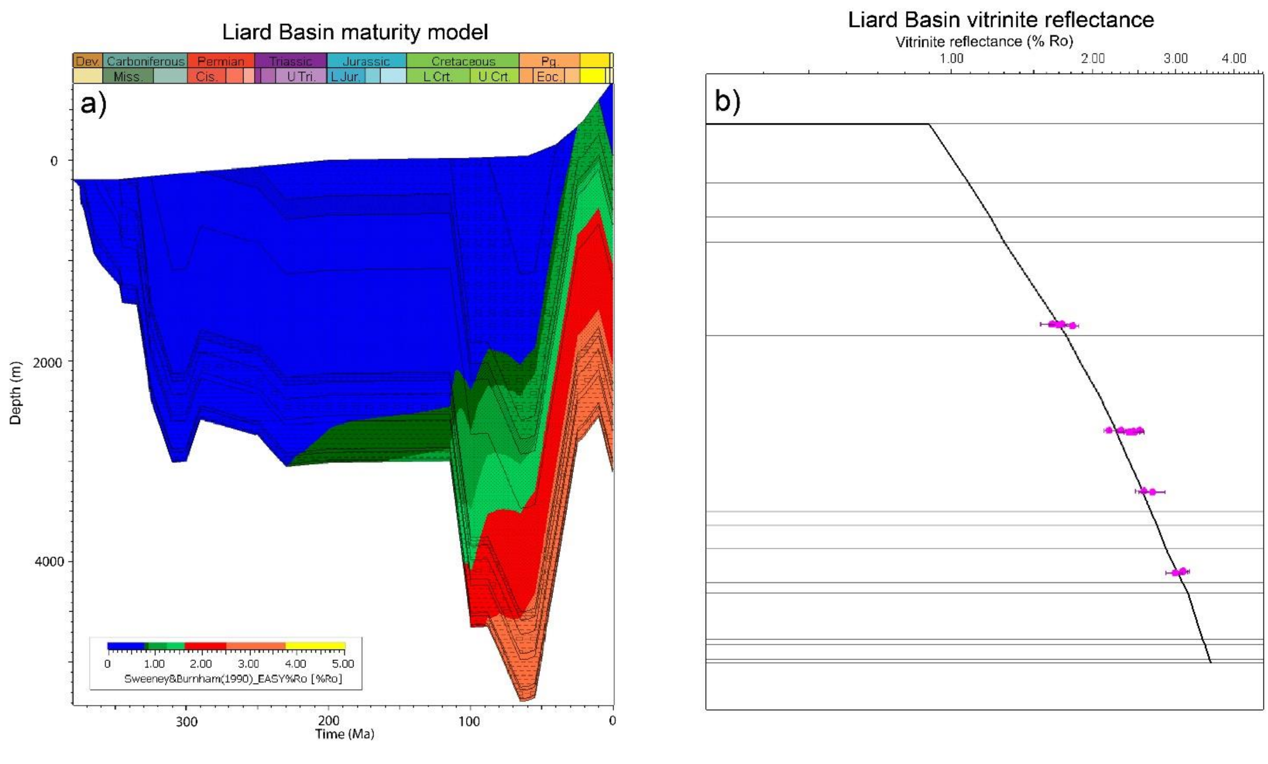


Figure 2. Burial history maturity models and present-day maturity profiles for a model from the Liard Basin. The burial history plots have a vitrinite reflectance overlay ranging from blue (immature) to green (oil to wet gas window) to red (dry gas) to orange (overmature). The calculated present-day maturity line is in black and matches well with the calibration data points (pink).