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2-D basin modeling of the WCSB across the Montney-Doig system: implications for hydrocarbon migration pathways and unconventional resources potential

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Introduction

For now more than ten years, unconventional resources have taken a great importance in the petroleum production of many hydrocarbon fields of North America and in Western Canada. The deep part of the Western Canada Sedimentary Basin (WCSB), where conventional reservoirs are already produced, is one of the potentially promising areas for unconventional resources. In this basin, the Montney Formation is currently the most active liquid rich unconventional play. The present study aims at giving a first overview of the complete petroleum system with a special emphasis on the Triassic Montney and Doig formations, through the modeling of a representative section across the WCSB using a basin and petroleum modeling software.

Construction of the WCSB basin model

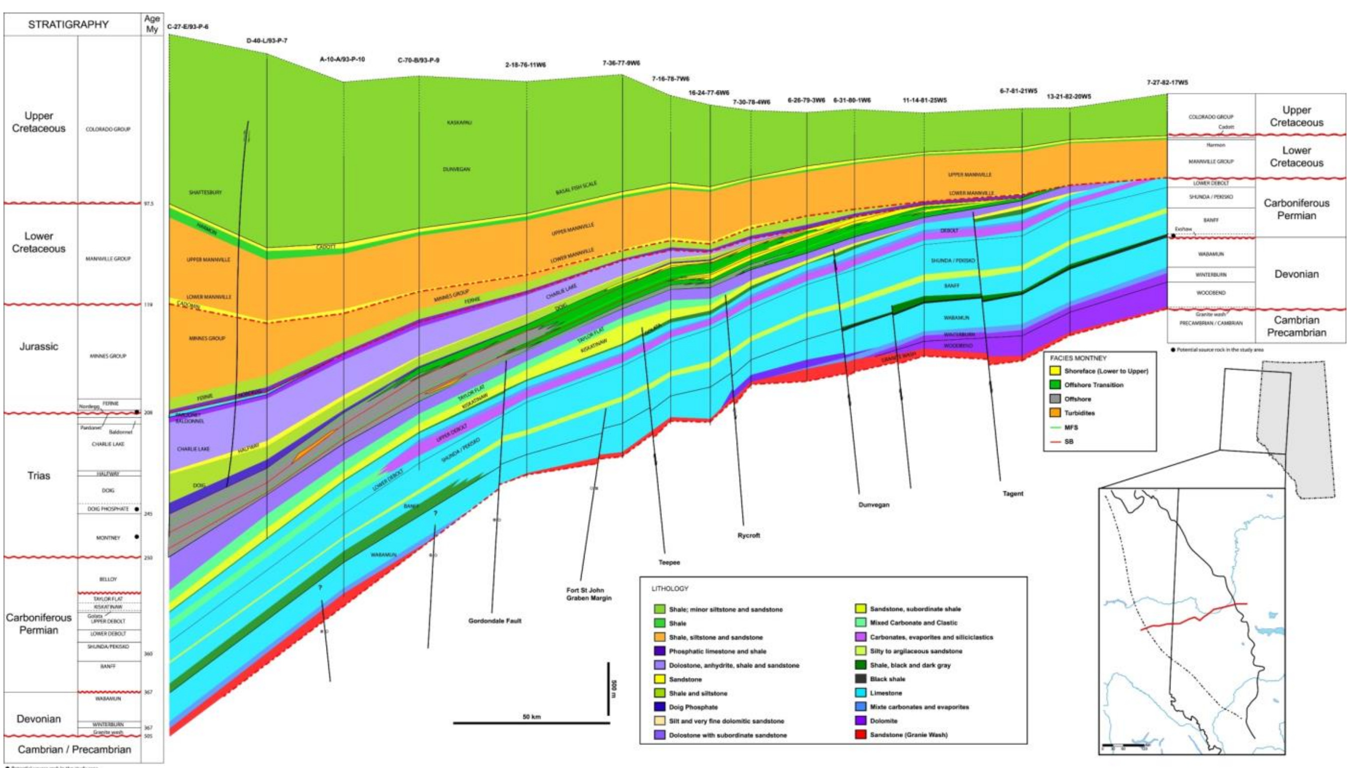

Figure 1: Stratigraphic cross section

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The 2-D model of the WCSB consists of 49 stratigraphic intervals that span from the Granite Wash basement that underlies the Devonian Woodbend group to Holocene sediments. Interval boundaries were chosen based on changes in the rock properties from the petroleum system point of view (seal, reservoir rock, source rock…) and on a modeling resolution aspect.

Three erosions were taken into account in the model. The second one corresponds to the sub-Mannville unconformity that we assumed to occur from 135Ma to 119Ma. Since this event occurred before the maximum burial depth was reached, limited effects are expected on thermal maturation. The Laramide Orogeny is the critical event that controls the petroleum system. Estimated thickness of eroded sediments associated with the Laramide Orogeny range from 2200 m close to the Rocky Mountains to 800 m near the Precambrian shield in Saskatchewan. Potential hydrocarbon sources are mainly the Devonian Duvernay Formation, the upper Devonian Exshaw Formation, the Triassic Montney and Doig Formations, the carbonates of the Nordegg Member (Gordondale source rock) and the coals of the Mannville Group (Creaney and Allan, 1990; Higley et al., 2005).

Source rocks can retain hydrocarbon generated in situ thanks to mechanisms occurring during the hydrocarbon generation. Indeed, during organic matter maturation porosity is created in the organic material (Romero-Sarmiento et al., 2013). Moreover mechanisms of gas adsorption also participates to hydrocarbon retention in source rocks. Thus it is important to estimate hydrocarbon quantity that could be adsorbed in WCSB source rocks.

Results and discussion

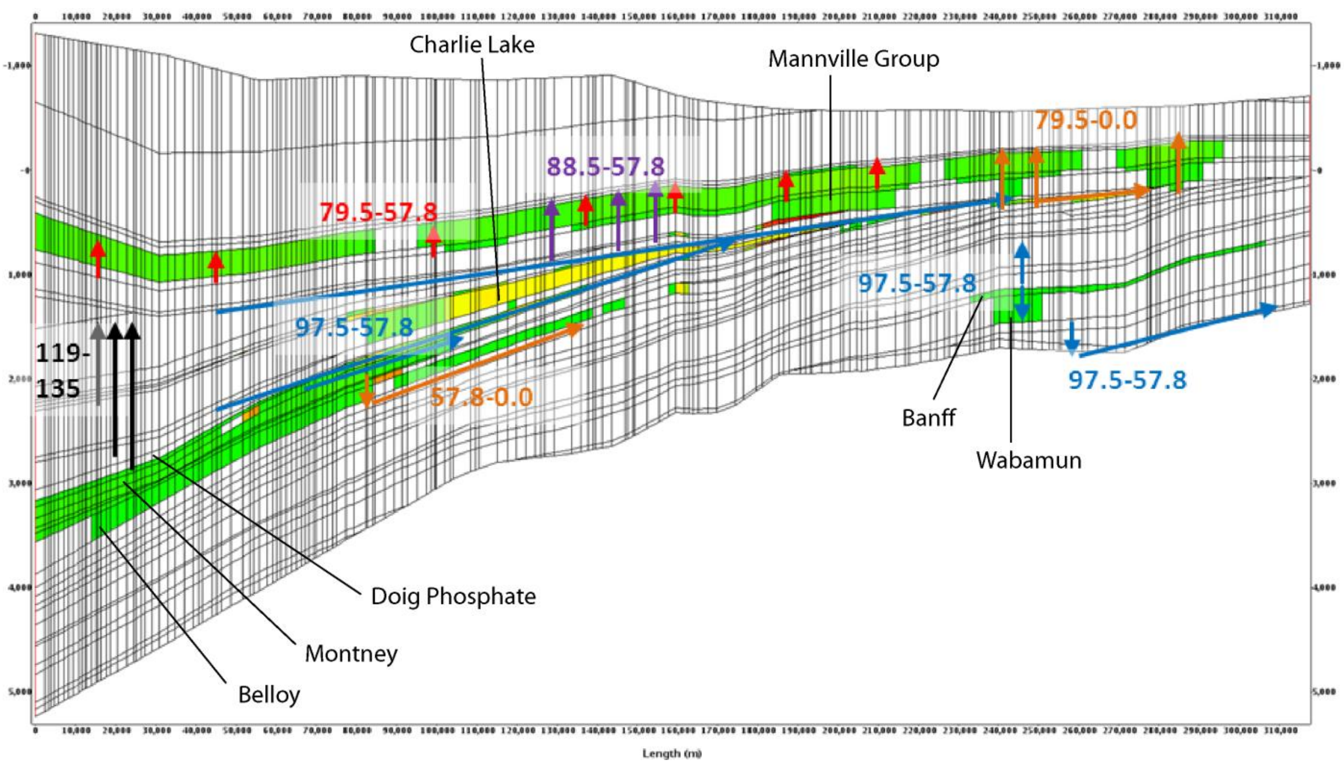

Figure 2: Migration pathways.
Arrows represent the direction of hydrocarbon migration with the corresponding ages of migration.
Hydrocarbons generated in the Montney formation mostly migrated laterally towards tight reservoirs of the Montney formation or in reservoirs of the underlying Belloy formation.
Hydrocarbons generated early in the Gordondale and Doig formations migrated vertically (-135Ma to -119Ma). Then migration was mostly lateral towards the eastern of the basin (-97.5Ma to -57.8Ma).
Vertical migration from Cadomin, Triassic reservoirs East of the Doig subcrop to Upper Mannville reservoirs occurs from -79.5Ma to present day.

Simulation results show hydrocarbon accumulations in tight reservoirs of the Montney formation. According to our model, hydrocarbons generated from the organic-rich part of the Montney Formation formed early in the basin history (between -88.5Ma and -57.8Ma) and did not migrate far up-dip in the basin, mostly accumulating in the tight reservoirs closely associated with these source rocks. This is consistent with observations and interpretation proposed by Law's (2002) and Ramirez et al.'s (2012) (

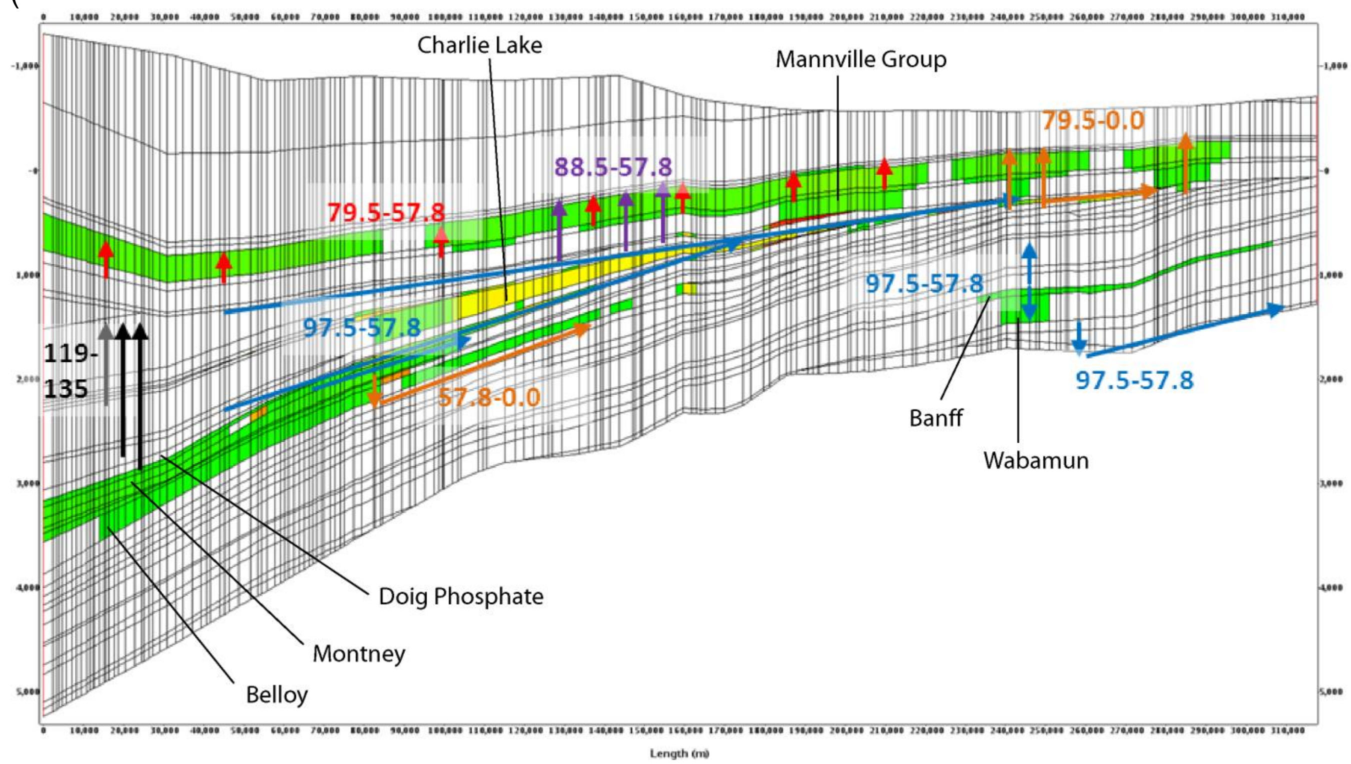

Figure 2).

Early generated oil from the Gordondale and Doig source rocks could have migrated more to the east in the Baldonnel and Cadomin formations towards the underlying Charlie Lake and Montney formations and filled reservoirs along their subcrop edges. Results (Figure 3) show a very high contribution from the Gordondale source rock in the stratigraphic traps along the Charlie Lake and Montney subcrop edges

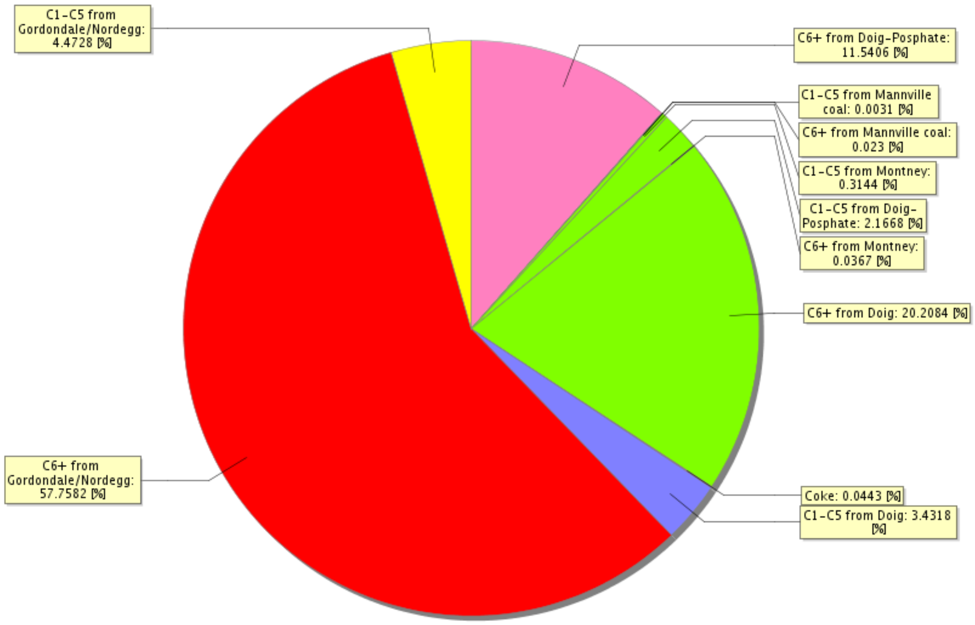

Figure 3: Origin of hydrocarbons of Charlie Lake and Montney formations along their subcrop edge according to the petroleum system model.

According to our simulation results, there could be as much expelled hydrocarbons as retained hydrocarbons in the sources rocks including adsorbed gas and free hydrocarbons in organic and matrix porosity). This could consequently represent huge amounts of oil and gas still in the source rocks. Most promising targets for such plays would be associated with Duvernay, Doig and Gordondale source rocks.

Conclusions

According to our model Montney and Doig source rocks could have started to generate hydrocarbons just before the erosion of the Minnes Group (Upper Jurassic). All source rocks reached their maximum transformation rate just before the last major erosion (early Palaeogene) which corresponds to their maximum burial. This period also corresponds to maximum overpressure in source rocks due to the peak of hydrocarbon generation. Analysis of both available pressure measurements and computed pressures suggest that present day overpressures are entirely due to hydrocarbon accumulation, not to compaction disequilibrium.

Our model was able to reproduce the large diversity of plays that are found in the WCSB: tight reservoirs, shale plays, conventional reservoirs with conventional and biodegraded oils. It strengthens the hypothesis of long-distance (>100km) migration of hydrocarbons from Gordondale and Doig source rocks to Lower Cretaceous Mannville and Triassic Charlie Lake and Montney reservoirs at their subcrop edges, as proposed by Higley et al. (2009) and supported by Berbesi et al. (2012). The study of source rocks contributions to the modelled oil accumulations are consistent with geochemical analysis performed by Adams et al. (2012). In spite of a simplified representation of source rocks distribution and richness, our results accredit the idea that Gordondale and Doig source rocks are major contributors to the main oil accumulations in the WSCB. Hydrocarbons generated by the Exshaw and Duvernay source rocks could have migrated further east in the basin. Hydrocarbons generated in Mannville source rocks have a much more limited distance of migration and have mostly accumulated within the Mannville Group itself. Montney sourced hydrocarbons did not really migrate from their source rock due to very low permeabilities. They can be found mostly in turbidite reservoirs (gas) and fine-grained distal deposits within the Montney formation and in the underlying Belloy formation (mostly gas). According to our results, there is a very high resource potential associated with hydrocarbons retained in the Duvernay, Doig and Gordondale source rocks.

References

Adams, J., Larter, S., Bennett, B. and Huang Haiping, 2012, Oil Charge Migration in the Peace River Oil Sands and Surrounding Region. GeoConvention 2012.

Berbesi, L. A., di Primio, R., Anka, Z., Horsfield, B. and Higley, D. K., 2012, Source rock contributions to the Lower Cretaceous oil accumulations in Alberta: A basin modeling study. AAPG Bulletin, 96, 7, 1211-1234.

Creaney, S. and Allan, J., 1990, Hydrocarbon generation and migration in the Western Canadian Sedimentary Basin, in J. Brooks, ed., Classic Petroleum Provinces, Geological Society Special Publication, 50, 189-202.

Higley, D. K., Mitchell, H., Roberts, L. N. R. and Steinshouer, D. W., 2005, 1-D/3-D Geological Model of the Western Canada Sedimentary Basin. The Rocky Mountain Association of Geologists, 42, 2, 1-13.

Higley, D. K., Lewan, M. D., Roberts, L. N. R. and Henry, M, 2009, Timing and petroleum sources for the Lower Cretaceous Mannville Group oil sands of northern Alberta based on 4D- modeling. AAPG Bulletin, 93, 203-213.

Law, B.E., 2002, Basin-centered gas systems. AAPG Bulletin, 86, 11, 1891-1919.

Ramirez, J. F. and Aguilera, R., 2012, Updip Water Blockage in the Nikanassin Basin Centered Gas Accumulation, Western Canada Sedimentary Basin. SPE 162774.

Romero-Sarmiento, M.F., Ducros, M., Carpentier, B., Lorant, F., Cacas, M.C., Pegaz-Fiornet, S., Wolf, S., Rohais, S. and Moretti, I., 2013, Quantitative evaluation of TOC, organic porosity and gas retention distribution in a gas shale play using petroleum system modelling: Application to the Missippian Barnett Shale. Marine and Petroleum Geology, 45, 315-330.