

Organic matter composition in the Alberta Montney Formation

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Summary

Although the Montney Formation, part of the greater Triassic petroleum system in the Western Canadian Sedimentary Basin (WCSB), is one of the most prolific hydrocarbon resources in North America, the organic matter composition and source of hydrocarbons in the Montney Formation is not well understood. Previous studies have considered the organic-rich middle Triassic Doig Formation and lower Jurassic Gordondale member of Fernie Formation as major source rocks of the Triassic petroleum system (Allan and Creaney, 1991; Riediger et al., 1990; Ejezie, 2007). However, a regional organic petrography study in Alberta (Beaton et al., 2010; Reyes et al., 2010), as well as more recent regional sedimentology, sequence stratigraphy, and organic geochemistry studies (Crombez et al., 2017; Euzen et al., 2018; Romero-Sarmiento et al., 2016; Becerra et al., 2020), have reported primary organic matter in organic-rich intervals within the Montney Formation as possible internal source(s) of hydrocarbons. In contrast, other regional organic, transmitted light, and scanning electron microscopy (SEM) petrography studies of the Montney tight-gas and hydrocarbon liquids fairway in British Columbia and adjacent Alberta suggest the organic matter is dominantly secondary and derived from liquid oil or bitumen that migrated and was subsequently thermally cracked (Sanei et al., 2015; Wood et al., 2015, 2018a, b, 2020). In this study, we re-examined a sub-set of organic-rich interval samples from eleven cores across the Montney Formation in Alberta, part of the Beaton et al. (2010) data release, to investigate the origin and composition of the organic matter in the Montney Formation using legacy Rock-Eval6™ as well as collected new programmed pyrolysis, organic geochemistry, and petrography and fluorescence microscopy data at the Geological Survey of Canada.

The results of this study show that intermittent thin (2–10 cm thick) relatively organic-rich mudstone intervals (TOC \leq 1 wt. %) in the Montney Formation in central and western Alberta contain primary organic matter that can be considered as a local source of hydrocarbons in the Montney Formation in addition to other major adjacent organic-rich source rocks (i.e., Doig and Gordondale) within the Triassic petroleum system. These results are in agreement with Becerra et al. (2020) observation from elsewhere in Alberta. However, the thin, relatively organic-rich mudstone intervals in the Alberta Montney cannot be considered as the only source of the vast amount of petroleum (solid bitumen, oil, gas) in the formation. This new evidence suggests that the Montney Formation in Alberta can be considered as a hybrid unconventional hydrocarbon reservoir. A comprehensive regional organic petrography and geochemistry study throughout the basin will help to identify the major hydrocarbon families and their sources in the WCSB Triassic petroleum system.

Methods

The GSC Rock-Eval6™ legacy data (Beaton et al., 2010) for selected wells were used in this study. Additional samples from organic-rich intervals of the studied cores were analyzed by programmed pyrolysis (HAWK TOC analyzer) and organic petrography. A total of 7 rock extracts were fractionated into aliphatic and aromatic hydrocarbons using small-scale silica-liquid chromatography and were analyzed using standard methods for gas chromatography-mass spectrometry (GC-MS). The aliphatic fractions were also analyzed using gas chromatography – isotope ratio mass spectrometry (GC-irMS) for stable carbon compound-specific isotope analysis.

Results

The Alberta Montney samples generally have poor to good (*sensu* Peters and Cassa, 1994) total organic carbon (TOC) content, except four samples located in uppermost Montney immediately below the organic-rich Doig Formation, which have TOC content ranging from 13.8 to 19.1 wt. %. Excluding these samples, the rest of the Montney samples have TOC content that ranges from 0.2 to 3.6 wt. %, with a mean TOC content of 0.96 ± 0.5 wt. % ($n = 107$). The S1 value for all samples ranges from 0.05 to 6.2 (mg HC/g) with a mean value of 0.86 ± 0.87 (mg HC/g). The S2 value is highly variable and ranges from 0.08 to 116.2 (mg HC/g) with a mean value of 6.6 ± 18.1 (mg HC/g). The hydrogen index (HI) and oxygen index (OI) are highly variable and range from 12 to 659 (mg HC/g TOC) and 2 to 123 (mg CO₂/g TOC), respectively. The gradual decline in the HI values on the pseudo van Krevelen plot suggests an increase in thermal maturity and/or oxidation of organic matter after deposition. The Tmax of all samples ranges from 414 to 448°C with a mean value of 433 ± 18 °C ($n = 111$) suggesting the samples span a wide range of thermal maturity from immature to early oil window.

The studied mudstone samples can be divided into two major facies, (i) highly pyritic mudstone, and (ii) fine-grained siltstone facies. The dominant macerals in the samples are, (i) alginite (*Prasinophyte* such as *Leiosphaeridia* and *Tasmanites*), (ii) in-situ bituminite derived from algae, and pore-filling solid bitumen (iii) minor vitrinite, and (iv) trace amounts of inertinite. The fluorescence color of the alginite macerals ranges from bright green to dark yellow, indicates a gradual increase in thermal maturity from immature to early mature that is in agreement with the Tmax data. In some samples, the majority of the alginite macerals are pyritized and suggest a highly euxinic condition. In contrast to the mudstone intervals, the dominant maceral in fine-grained siltstone intervals is pore-filling solid bitumen with minor alginite. Pore-filling solid bitumen in siltstone intervals can have an adverse effect on Montney reservoir quality (e.g., Wood et al. 2015). Hydrocarbons generated in the mudstone facies likely migrated to adjacent thin fine-grained siltstone laminae, filled intergranular pore space which subsequently thermally cracked into other hydrocarbon fractions such as solid bitumen and gas (e.g., Becerra et al. 2020). These observations are consistent with mixed carbon isotope profiles (thermally altered and in-situ hydrocarbons), as well as variable redox conditions as indicated by aryl-isoprenoids distribution. Molecular indicators (e.g. alkylnaphthalene ratios) are also consistent with low-thermal maturity intervals. Polycyclic aromatic hydrocarbons do not correlate with each other, which indicates that their abundance is influenced by source effects rather than thermal alteration alone.

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References

- Allan, J., Creaney, S., 1991. Oil families of the Western Canada basin. *Bulletin of Canadian Petroleum Geology*, v. 39, 107-122.
- Becerra, D., Clarkson, C.R., Ghanizadeh, A., Ardakani O.H., 2020. First-Time Characterization of Black Shaly Facies along a Full Montney Core: Lithofacies Controls on the Distribution of Primary Organic Matter. *First-Time Characterization of Black Shaly Facies along a Full Montney Core: Lithofacies Controls on the Distribution of Primary Organic Matter*.
- Beaton, A.P., Pawlowicz, J.G., Anderson, S.D.A., Berhane, H., and Rokosh, C.D., 2010. Organic petrography of the Montney Formation in Alberta: shale gas data release. Energy Resources Conservation Board, ERCB/AGS Open File Report 7, p. 24.
- Crombez, V., Baudin, F., Rohais, S., Riquier, L., Euzen, T., Pauthier, S., Ducros, M., Caron, B. and Vaisblat, N., 2017. Basin scale distribution of organic matter in marine fine-grained sedimentary rocks: Insight from sequence stratigraphy and multi-proxies analysis in the Montney and Doig formations. *Marine and Petroleum Geology*, v. 83, 382-401.
- Ejezie, N., 2007. Triassic oil families and possible source rocks, Peace River embayment area, Alberta, Canada. Unpublished M.Sc. Thesis. University of Calgary, Calgary, Alberta, Canada.
- Euzen, T., Moslow, T. F., Crombez, V., Rohais, S., 2018. Regional stratigraphic architecture of the Spathian Deposits in Western Canada—Implications for the Montney resource play. *Bulletin of Canadian Petroleum Geology*, v. 66, 175-192.
- Peters, K.E., Cassa, M.R., 1994. *Applied Source Rock Geochemistry: Chapter 5: Part II. Essential Elements*. 93-120.
- Reyes, J., Beaton, A., Rokosh, C. D., Anderson, S. Organic facies in Early to Middle Triassic strata, Montney Formation of the Western Canadian Sedimentary Basin, Alberta Canada. 62nd International Committee for Coal and Organic Petrology Meeting. Belgrade, Serbia, September 26-October 2, 2010. Abstract, p 31.
- Riediger, C.L., Brooks, P.W., Fowler, M.G., Snowdon, L.R., 1990. Lower and Middle Triassic source rocks, thermal maturation, and oil-source rock correlations in the Peace River Embayment area, Alberta and British Columbia. *Bulletin of Canadian Petroleum Geology*, v. 38, 218-235.
- Romero-Sarmiento, M.F., Euzen, T., Rohais, S., Jiang, C. and Littke, R., 2016. Artificial thermal maturation of source rocks at different thermal maturity levels: Application to the Triassic Montney and Doig formations in the Western Canada Sedimentary Basin. *Organic geochemistry*, v. 97, 148-162.
- Sanei, H., Wood, J.M., Ardakani, O.H., Clarkson, C.R., Jiang, C., 2015. Characterization of organic matter fractions in an unconventional tight gas siltstone reservoir. *International Journal of Coal Geology*, v. 150, 296–305.
- Wood, J.M., Sanei, H., Curtis, M.E., Clarkson, C.R., 2015. Solid bitumen as a determinant of reservoir quality in an unconventional tight gas siltstone play. *International Journal of Coal Geology*, v. 150, 287–295.
- Wood, J.M., Sanei, H., Ardakani, O.H., Curtis, M.E. and Akai, T., 2018a. Organic petrography and scanning electron microscopy imaging of a thermal maturity series from the Montney tight-gas and hydrocarbon liquids fairway. *Bulletin of Canadian Petroleum Geology*, v. 66, p. 499–515.
- Wood, J.M., Sanei, H., Ardakani, O.H., Curtis, M.E., Akai, T., Currie, C., 2018b. Solid bitumen in the Montney Formation: Diagnostic petrographic characteristics and significance for hydrocarbon migration. *International Journal of Coal Geology*, v. 198, 48-62.
- Wood, J.M., Haeri-Ardakani, O., Sanei, H., Curtis, M.E., Royer, D., 2020. Application of paleoporosity and bitumen saturation concepts to tight-gas accumulations containing solid bitumen. *International Journal of Coal Geology*, v. 228, 103547.