

Intraformational migration of oil, gas-condensate and methane-rich gas in the Montney unconventional petroleum fairway

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Summary

The Early Triassic Montney Formation of the Western Canada Sedimentary Basin had a complex history of petroleum charging from both external and internal source rocks. Recent geochemical studies across the Montney unconventional petroleum fairway recognize three main widespread episodes of internal (intraformational) migration of hydrocarbons (Figures 1, 2). The first episode was oil migration from distal Montney organic-rich source rocks during rapid burial (Euzen et al., 2018; Laycock et al., 2021; Watt et al., 2022). The second episode was gas-condensate migration during overpressuring close to the time of maximum burial (Wood et al., 2022). The final episode was methane-rich gas migration mainly during basin uplift and depressurization (Wood and Sanei, 2016, 2017; Sereda and Fur, 2017; Euzen et al., 2018, 2019, 2020, 2021; Wood et al., 2021; Chalmers et al., 2022). This presentation will review the geological and geochemical evidence for these three main episodes of intraformational hydrocarbon migration and discuss their temporal and spatial context within the Montney unconventional petroleum play.

Present-day oil, condensate, wet gas and dry gas reservoir-fluid windows in the Montney Formation generally align with depth and thermal maturity trends increasing to the southwest (Figure 1). However, the composition and distribution of Montney hydrocarbon fluids determined by thermal maturity were significantly modified by gas-condensate migration during deep burial (Kuppe et al., 2012; Wood et al., 2022) and later by migration of methane-rich gas (Wood and Sanei, 2016; Euzen et al., 2018; Wood et al., 2022) during uplift (Figures 1, 2). Regional mapping of Montney produced gas composition shows that the late-stage migration of methane-rich gas was enhanced along intricate, stratigraphically and structurally controlled pathways (red arrows, Figure 1). These dry gas migration pathways have direct economic impacts on well performance such as higher gas-oil ratios and lower hydrocarbon liquid contents than expected from routine thermal maturity proxies (Wood and Sanei, 2017; Wood et al., 2021).

Although our knowledge of intraformational hydrocarbon migration in the Montney unconventional petroleum play has advanced in recent years, there is still much to unravel. A key aspect that is currently not well understood is how the intimate co-existence of unconfined macropores and confined nanopores differentially controlled the migration and partitioning of hydrocarbon fluids (e.g., Alharthy et al., 2016). Improved understanding of micro-scale heterogeneity in hydrocarbon

fluid distribution, particularly in the context of dynamic (non-equilibrium) PVT conditions through burial and uplift, will help to clarify the range and complexity of phase behaviour and production characteristics observed in this world-class unconventional petroleum play.

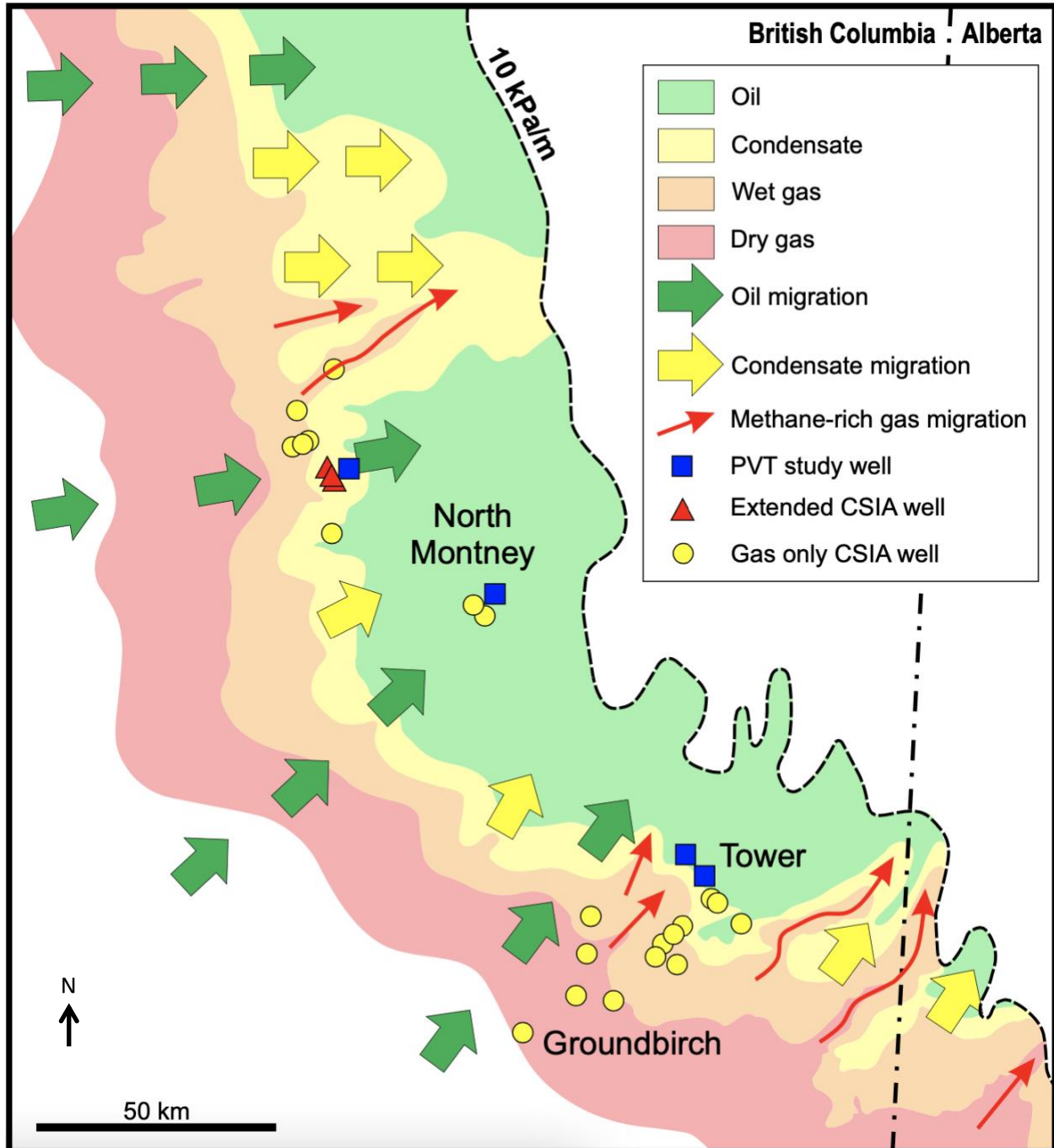


Figure 1. Map schematically showing three main episodes of intraformational hydrocarbon migration in the Montney unconventional petroleum play of northeast British Columbia and northwest Alberta. Green arrows show early lateral

migration of oil from distal Montney organic-rich source rocks (Euzen et al., 2018; Laycock et al., 2021; Watt et al., 2022). Yellow arrows show migration of gas-condensate (Wood et al., 2022). Red arrows show major pathways of late-stage methane-rich gas migration (Wood and Sanei, 2016, 2017; Sereda and Fur, 2017; Euzen et al., 2018, 2019, 2020, 2021; Wood et al., 2021; Chalmers et al., 2022). Colour-shaded areas represent present-day hydrocarbon fluid windows in the Upper Montney. Symbols indicate key data wells from the study by Wood et al. (2022); PVT - recombination PVT compositional data, CSIA - compound-specific isotope analysis. Modified from Euzen et al. (2020) and Wood et al. (2022).

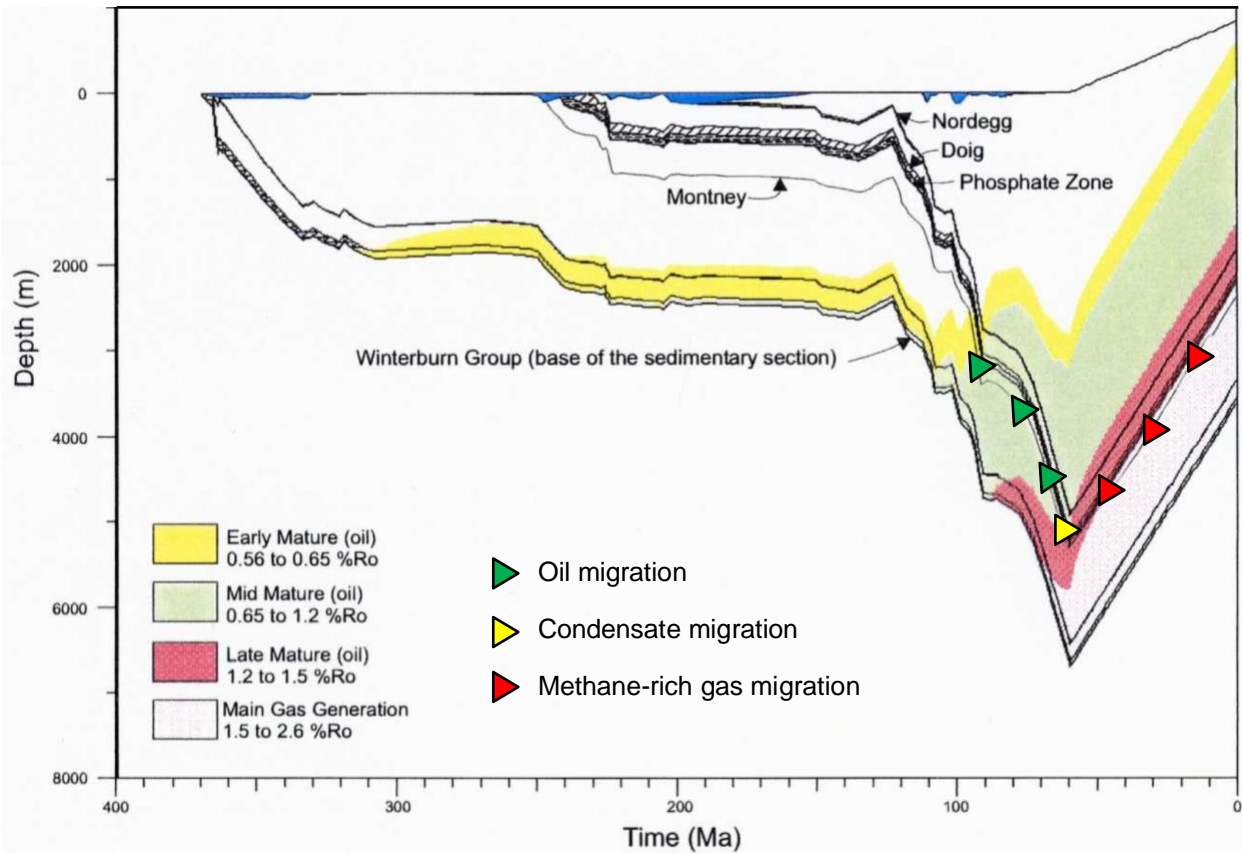


Figure 2. Burial-uplift history for well 10-35-71-13W6, showing maturity windows of Montney, Doig and Nordegg source rocks. Modified from Ness (2001). Coloured triangles indicate the generalized timing of the three main episodes of intraformational hydrocarbon migration in the Montney unconventional petroleum play; green - early lateral migration of oil from distal Montney organic-rich source rocks during rapid burial; yellow - migration of gas-condensate close to the time of maximum burial; red - migration of methane-rich gas during uplift.

References

- Alharthy, N.S., Teklu, T.W., Nguyen, T.N., Kazemi, H. and Graves, R.M., 2016. Nanopore compositional modeling in unconventional shale reservoirs. *SPE Reservoir Evaluation & Engineering*, 19(03), 415-428.
- Chalmers, G.R., Lacerda Silva, P., Bustin, A.A., Sanlorenzo, A. and Bustin, R.M., 2022. Geology and Geochemistry of the Hydrocarbon Compositional Changes in the Triassic Montney Formation, Western Canada. *Energies*, 15, 8677.

- Euzen, T., Chatellier, J.Y., and Mort, A., 2018. Geological controls on fluid compositional variations in unconventional hybrid plays: Insight from gas geochemistry (Montney Play, Western Canada). Unconventional Resources Technology Conference, 23-25 July, 2018, Houston, Texas, USA.
- Euzen, T., Watson, N., Chatellier, J-Y., Mort, A., and Magenot, X., 2019. Petroleum System Analysis Using Unconventional Gas Geochemistry: Examples from the Montney Play of Western Canada. Unconventional Resources Technology Conference, 22-24 July 2019, Denver, Colorado, USA.
- Euzen, T., Watson, N., Cui, A., Wilson, J., and Cronkwright, D., 2020. Mapping Liquid Recovery Potential in an Unconventional Play: A Practical Approach Integrating Geology, Geochemistry and PVT Properties (Montney Fm., Canada). Unconventional Resources Technology Conference, 20-22 July, 2020, Virtual.
- Euzen, T., Watson, N., Fowler, M., Mort, A., and Moslow, T.F., 2021. Petroleum distribution in the Montney hybrid play: Source, carrier bed, and structural controls. AAPG Bulletin 20, 201-222.
- Kuppe, F.C., Nevoikshonoff, G. and Haysom, S., 2012. Liquids rich unconventional Montney: The geology and the forecast. SPE Canadian Unconventional Resources Conference, 30 October–1 November, 2012, Calgary, Alberta, Canada.
- Laycock, D., Watt, E., Tobin, R., Kelly, S., Johnston, M. and Michael, E., 2021. Examining the origins and yield impact of a stratified oil column in the Montney Formation, NE BC. Unconventional Resources Technology Conference, 26-28 July, 2021, Houston, Texas, USA.
- Ness, S.M., 2001. The Application of Basin Analysis to the Triassic Succession, Alberta Basin: An Investigation of Burial and Thermal History and Evolution of Hydrocarbons in Triassic Rocks. Unpublished M.Sc. Thesis. University of Calgary, Calgary, Alberta, Canada.
- Sereda, R. and Fur, J., 2017. The Lower Montney Turbidite Complex of Northwest Alberta and Northeast British Columbia: Evolution of an Oil and Gas Play from Conventional to Unconventional. Unconventional Resources Technology Conference, Austin, Texas, USA, 24-26 July 2017. URTeC: 2674327.
- Watt, E.A., Laycock, D.P., Michael, E., Tobin, R.C., Kelly, S., and Johnston, M.N., 2022. Hydrocarbon charge and petroleum system evolution of the Montney Formation: A multidisciplinary case study of the Blueberry sub-play in Northeast British Columbia, Canada. Bulletin of Canadian Energy Geoscience, 69, 21–50.
- Wood, J.M., and Sanei, H., 2016. Secondary migration and leakage of methane from a major tight-gas system. Nature Communications 7, 13614; 10.1038/ncomms13614.
- Wood, J.M., and Sanei, H., 2017. Secondary migration of methane as a modifier of hydrocarbon fluid distribution in the Montney tight-gas fairway. GeoConvention, Calgary, Alberta, Canada, 15-19 May 2017.
- Wood, J.M., Euzen, T., Sharp, L. and Leroux, S., 2021. Phase separation and secondary migration of methane-rich gas accompanying uplift of an unconventional tight-hydrocarbon system, Montney Formation, western Canada. Marine and Petroleum Geology, 124, 104808.
- Wood, J.M., Cesar, J., Ardakani, O.H., Rudra, A., and Sanei, H., 2022. Geochemical evidence for the internal migration of gas condensate in a major unconventional tight petroleum system. Scientific Reports, 12(1), 1-15.