



geoconvention

Calgary • Canada • May 13-17 2019

Organic and Isotope Geochemistry of Hybrid Hydrocarbon Accumulations

Jaime Cesar, Michael Nightingale, Veith Becker, and Bernhard Mayer

Applied Geochemistry Group, Department of Geoscience, University of Calgary

Summary

Shales are the most common type of sedimentary rock in the Western Canadian Sedimentary Basin (WCSB). The development and production of shale gas in this region, however, do not have a long history. The Lower Triassic Montney Formation hosted the first application of horizontal drilling and multi-stage hydraulic fracturing only in 2004, and its hydrocarbon resources represent 145 years of Canada's 2012 natural gas consumption. The significance of this play relies not only on favorable reservoir properties but also on the high natural gas liquid (C₂-C₄) and condensate (C₅-C₁₂) content. The condensate contributes with a significant value to well production, which thus increases our interest in understanding its spatial distribution and abundance through the formation.

Lithofacies distribution in the Montney Formation is very complex, and often leads to the occurrence of closed and semi-closed systems where hydrocarbons have been generated or otherwise accommodated after migration, and thermally degraded. Such conditions resulted in isotope anomalies in C₁-C₃ alkanes after thermal cracking of heavier molecules. We have investigated these kinetic isotope effects (sometimes normal distribution, sometimes reversals) in order to define reservoir compartments, methane intraformational leakage, thermal maturation stage of the rock, and fluids mixing. We additionally present a preliminary interpretation on the molecular composition of liquid hydrocarbons from Montney reservoirs.

Methods

To attempt a regional survey, the carbon isotopic compositions of methane, ethane and propane in fluids from the Montney Formation, as reported in different sources (*e.g.* Desrocher, 1997; Tilley and Muehlenbachs, 2006; Sereda, 2017; this study), has been combined. The obtained $\delta^{13}\text{C}$ values usually correspond to produced gases from wells drilled in Alberta and British Columbia. When produced gas was not available, mud-gas data has been included.

In our investigation, 48 gas samples (IsoTubes) from a well drilled in Northeast British Columbia, were also analyzed and results were added to the database. For the molecular analysis, a 5mL aliquot of gas was removed from each IsoTube *via* a modified IsoTube septum valve and locking gas-tight syringe. Gas compositional analysis (H₂, He, N₂, O₂, Ar, CO₂ and alkanes C₁ to C₆) was completed by injecting the sample into a Scion 450/456 gas chromatograph (GC). The GC utilizes four separate analytical columns connected to three thermal conductivity detectors and a flame-ionization detector for gas separation and quantification. The lower detection limit for hydrocarbons is 1 ppm and for non-hydrocarbon gasses is 50 ppm. Certified gas standards were used to calibrate the GC immediately prior to the analysis. Analytical drift was monitored by injecting the appropriate gas standards after every ten samples analyzed. Analytical precision and accuracy for gas composition analysis is typically better than $\pm 2.5\%$ of the reported concentrations.



geoconvention

Calgary • Canada • May 13-17 2019

The C₁ to C₃ alkanes compound specific ¹³C/¹²C ratios of the gas samples were determined using continuous flow technology. The system is comprised of a Thermo Trace GC – GC-IsoLink system interfaced to a Thermo 253 mass spectrometer via a Thermo Conflo IV. Gas sampling was conducted as indicated above for GC compositional analysis. Aliquots of gas were injected into a helium carrier stream through the inlet of the GC using a gas tight syringe. Air, CO₂ and the hydrocarbon compounds of the gas are separated on a GC column before passing through a high temperature, combustion reactor (maintained at 1030 °C). All hydrocarbon gas species are quantitatively converted to CO₂ in passing through the combustion furnace. The separate CO₂ gas pulses are then swept sequentially, by the carrier gas, through a water trap (Nafion®) then into the open split interface which ‘leaks’ the gas into the mass spectrometer. The δ¹³C values of the unknown species were calculated by the instrument software (ISODAT 3.54). Results are expressed in the usual delta notation in per mil (‰) relative to the international V-PDB standard.

The same instrument was used for δ²H measurements but using a high temperature reactor (maintained at 1420 °C) instead of a combustion reactor. All hydrocarbon gas species are quantitatively converted to H₂ in passing through the high-temperature-conversion (HTC) furnace. The separate H₂ gas pulses are then swept sequentially, by the carrier gas, through a water trap (Nafion®) then into the open split interface which ‘leaks’ the gas into the mass spectrometer. The δ²H values of the unknown species were calculated by the instrument software (ISODAT 3.54), and the results are expressed in the usual delta notation in per mil (‰) relative to the international V-SMOW standard.

Results

The conducted survey revealed that the δ¹³C values of C₁-C₃ natural gas from the Montney Formation follow, in general, its thermal maturity trend (trend as established by BC Oil and Gas Commission, 2012; Rokosh *et al.*, 2012). This evidence is more effectively expressed in the δ¹³C of ethane (and also propane) compared to methane (Figure 1). A probable explanation for this scenario may rely on the possibility of methane migration into different reservoirs. An excess of methane had already been estimated by Woods and Sanei (2016) to explain anomalous wetness values and suggest migration pathways.

Our preliminary results from a well drilled in Northeast British Columbia, suggest a low maturity hybrid system where little methane migration is expected. Key compositional and isotopic proxies (*e.g.* *iso*-alkane ratios, gas wetness, δ¹³C and δ²H) are consistent with depth-increasing maturity.

The C₁-C₃ natural gas from the Montney Formation is isotopically normal although very low carbon isotope ratios for ethane (δ¹³C ≈ 42‰) have been detected in certain wells. The low δ¹³C values of ethane probably occur in localized closed systems caused by facies variations within lithologies.

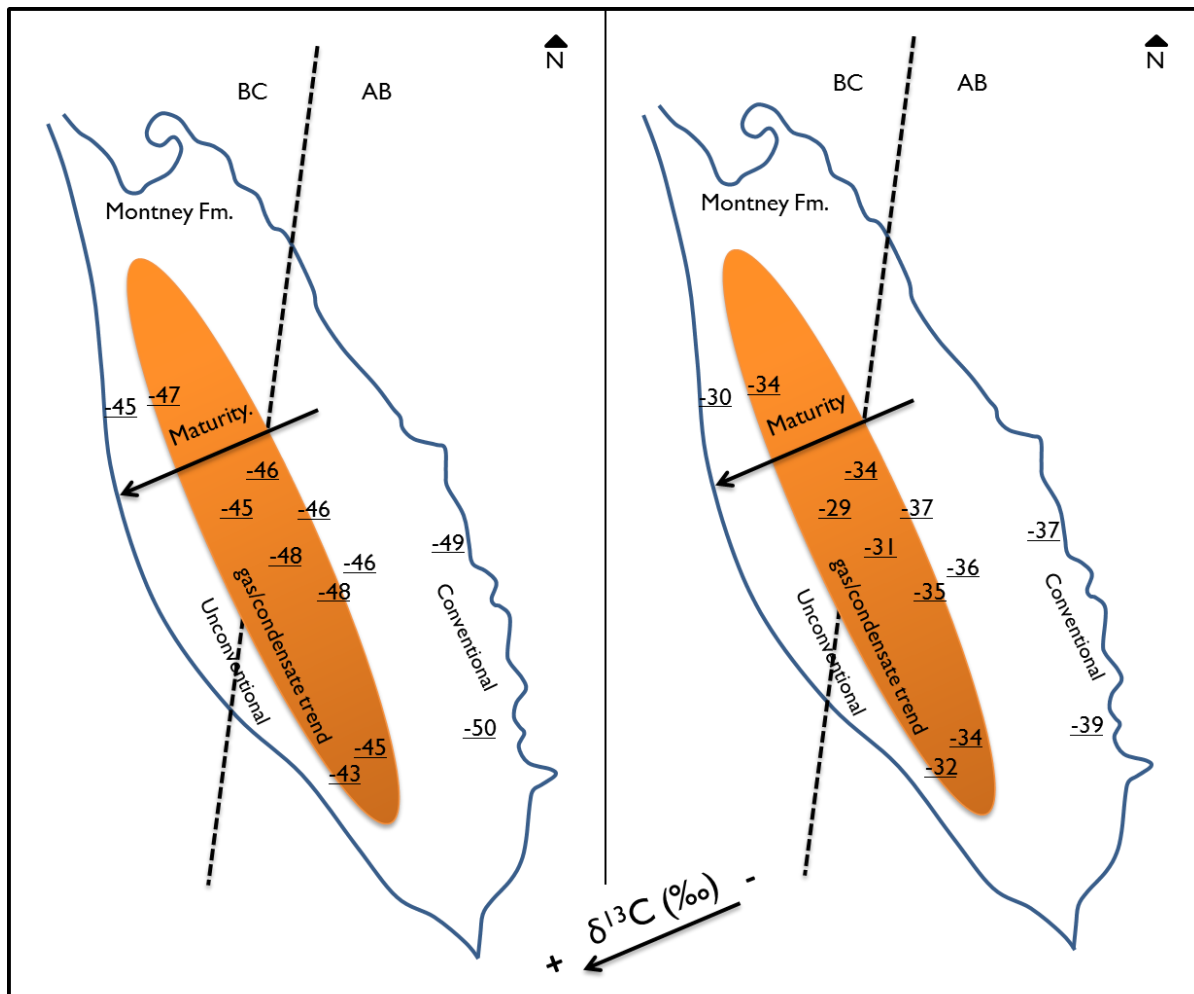


Figure 1. The $\delta^{13}\text{C}$ trend (in ‰) for methane (left) and ethane (right) gases from the Montney Formation (Desrocher, 1997; Tilley and Muehlenbachs, 2006; Sereda, 2017; this study)

Novel Information

For the first time, a preliminary organic geochemistry screening of liquid hydrocarbons (condensate) is reported. Produced condensate from the Montney formation in Northeast British Columbia shows a normal distribution with molar discontinuity at C_8 and C_{13} alkanes. We currently investigate the source and reservoir conditions for the formation of these fluids, which can potentially address condensate distribution and abundance in the Lower Triassic Montney reservoirs.

Conclusion

Our understanding of fluid dynamics in the Montney Formation is a fundamental tool for the evaluation of similar hybrid systems such as the Duvernay Formation, also in the WCSB. The isotopic evidence of closed systems in Upper Triassic and Jurassic strata also increases the

probability of fluids yet to be located within those sequences. Ultimately, characterizing the isotope fingerprint of hydrocarbons in hybrid plays from the WCSB is also an essential prerequisite to address environmental concerns about potential thermogenic gas migrating into the shallow hydrosphere.

References

BC Oil and Gas Commission (2012) Montney Formation Play Atlas NEBC. Government of British Columbia, 36 pp.

Desrocher, S. (1997) Isotopic and compositional characterization of natural gases in the lower and Middle Triassic Montney, Halfway, and Doig Formations, Alberta Basin. Unpublished Master's Thesis. University Of Calgary, 218 pp.

Rokosh, C., Lyster, S., Anderson, A., Berhane, H., Brazzoni, T. Chen, D., Cheng, Y., Mack, T, Pana, C., and Pawlowicz, J. (2012) Summary of Alberta's shale- and siltstone-hosted hydrocarbon resource potential. Energy Resources Conservation Board / Alberta Geological Survey, 339 pp.

Sereda, R. (2017). The lower Montney Turbidite Complex of Northwest Alberta and Northeast British Columbia: evolution of an oil and gas play from conventional to unconventional. *Search Discovery Article* **10987**, 1-39.

Tilley, B and Muehlenbachs, K. (2006) Gas maturity and alteration systematics across the Western Canada Sedimentary Basin from four mud gas isotope depth profiles. *Organic Geochemistry* **37**, 1856-1868.

Wood, J. and Sanei, H. (2016) Secondary migration and leakage of methane from a major tight-gas system. *Nature Communications* **7**(13614), 1-9.