What do we know about the gas isotopic composition from British Columbia's and Alberta's Montney Fm.?

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Summary

Over the last fourteen years, there have been increasing interest in understanding the fate and mechanisms controlling the generation and distribution of formational wet and dry gases. The Montney Formation is a remarkable unconventional western Canadian natural gas reservoir, and one of the largest in the world, with reserves estimated in approximately 121,080 billion m^3 of natural gas in-place. To place this figure in context, it has been projected that natural gas reserves of the Montney Formation can cover Canada's demand for the next 136 years (Energy Briefing Note, 2013). The competitiveness of natural gas has steadily increased since 2008, surpassing the growth rate of other non-renewable energies (Chen et al., 2018). Therefore, there have been major research efforts to spatially constrain important reservoir parameters, such as temperature, pressure, pressure gradient, mineralogy, maturity and, importantly, gas compositional variability (e.g., Oil, B. C., BC oil and Gas Commission, 2012) the Montney Fm. dry gas isotopic composition and variability (i.e., Desrocher, 1997; Tilley and Muehlenbachs, 2006). Here we compiled the published dataset and complement it with unpublished stable C isotopic composition measurements on production dry and carbon dioxide gases from boreholes located in British Columbia (BC) and Alberta (AB). The aim is to produce spatial isotopic maps which can be correlated with other published reservoir data (work in progress). Traditional cross-plots $\delta^{13}C_2$ versus $\delta^{13}C_3$, indicate early produced Kerogen type II gases, which are preferentially distributed near the shallow part of the reservoir, particularly in the western AB's (W5), whereas more mature gas is been produced from the basin depocentre in eastern BC. Ubiquitous mature gas, and isotopic gas reversals were identified by using a Chung plot (Chung et al., 1988). These roll-over isotope reversals, however, seem to be limited to the deeper basin. Cross-plots $\delta^{13}CH_4$ *vs.* $\delta^{13}CO_2$ indicate a narrow maturity trend, with increasing biodegradation toward the shallower reservoir (NW Alberta), and also unravel biogenic and thermal admixture, with significant abiotic over biotic gas generation processes.

Methods

The data re-evaluated here correspond to production gas from the Montney Fm. compiled over the last sixteen years. Gas samples isotopic composition come from a published MSc. thesis (Desrocher, 1997) and unpublished in-lab analyzed samples. Dry gas carbon isotope ratios (methane, ethane, propane and iso-butane and *n*-butane) analysis were performed at the University of Alberta by using a Finnigan MAT 252 GC-C CF-IRMS system. Two injections were done for each gas sample. The first 5 μL injection provide isotopic ratios on abundant methane. A second larger volume injected (up to 30 mL of gas) provide isotopic information on the low concentrated ethane, propane and butane gases. Carbon isotope compositions are reported as $\delta^{13}C$ values in ‰ (per mil) with respect to the V-PDB standard. Reproducibility of $\delta^{13}C$ values for methane was ± 0.5‰ and ± 0.2‰ for the C_2+ alkanes (ethane, propane and butane). The database includes samples from AB and BC, where the Montney Fm. is geographically represented in the subsurface (Fig. 1a, b). Not all of the samples have detailed associated geological and geochemical information available. However, approximate facies and depths have been retrieved from AccuMap software© and compared with previous lithofacies maps (Edwards et al., 1990).

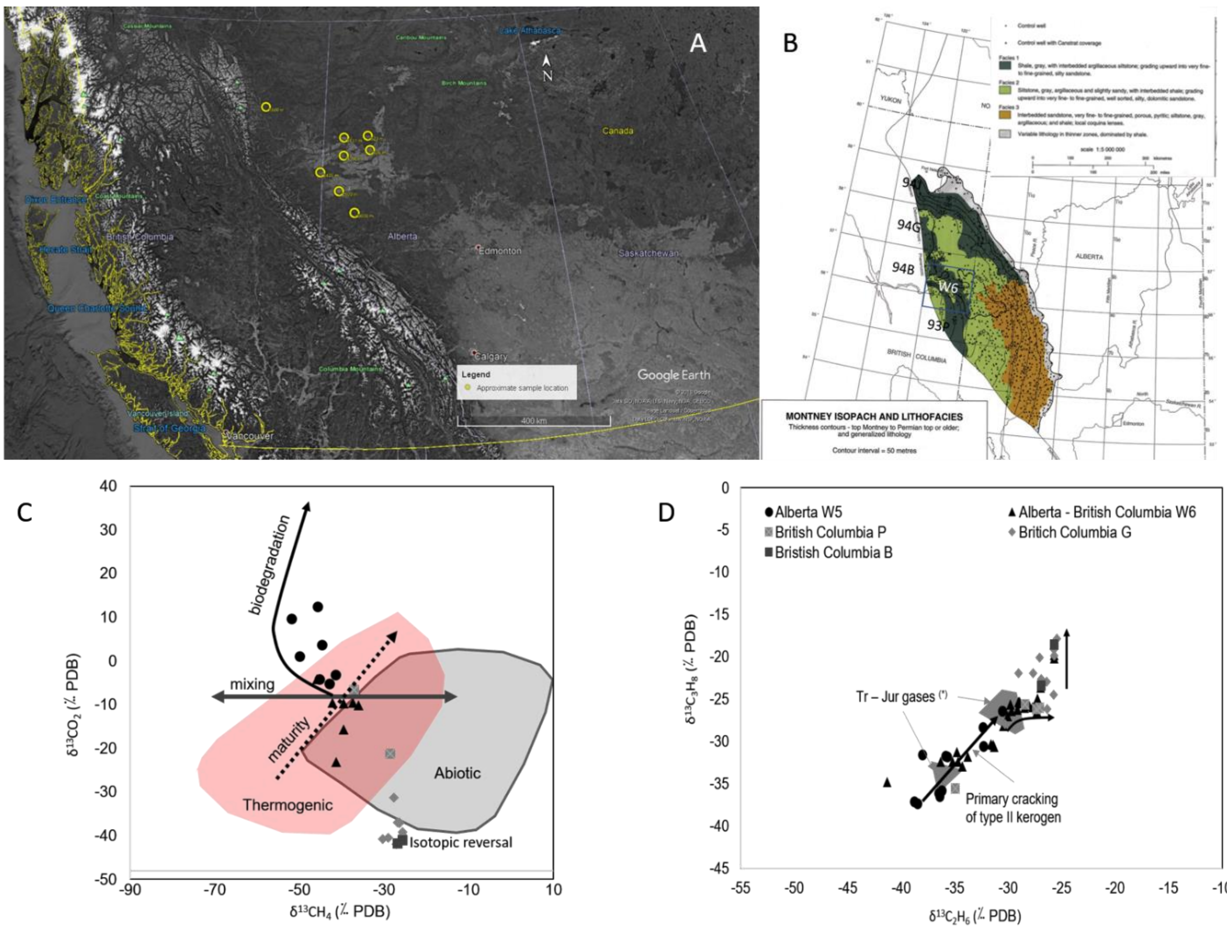

Figure 1. The Montney Formation dry gases sampling location (A); lithofacies distribution (modified from Edwards, et al. 1990)(B); corresponding carbon stable isotopic composition cross-plots (C); and $\delta^{13}CH_4$ versus $\delta^{13}CO_2$ plot shows isotopic fingerprinting related to processes that let to gas formation; while (D) $\delta^{13}C_2H_6$ versus $\delta^{13}C_3H_8$ shows the genetic source and maturation processes trend, shaded field represent Triassic Jurassic isotopic data from Ojay and Belloy fields as identified by Tilley and Muehlenbachs (2006).

Results and observations

Montney Fm. is a Triassic sedimentary succession located in the subsurface between northeastern British Columbia and western Alberta. Figure 1a shows representative sampling areas and their location. The Montney' lithofacies represent passive margin deposition in marine shelf and slope environments (*e.g.* Podruski et al., 1988; Rivard et al., 2014). As shown in Figure 1b, the lithofacies distribution is not geographically uniform and varies from the distal areas, where they consist on shale and siltstone-dominated succession, with variable degrees of post-depositional dolomitization, to the proximal areas of the basin, where fine grained sandstone underlies coquina facies (see Gibson and Barclay, 1989 and Edwards et al., 1990 for further details).

The Montney gas isotope signatures indicate that formational gas distribution vary according the variation of facies described above, which represent most of the reservoir source rock heterogeneity. The $\delta^{13}CH_4$ values range between -51.9 and -28.6 ‰, while $\delta^{13}C_2H_6$ isotopic composition range between -41.3 and -25.5 ‰. These isotopic values point to the evaluated dry gases being mature and largely thermogenic in origin. Two shale gas samples exhibit isotopically reversed gas signatures developed toward British Columbia that correspond to the deeper part of the basin, whereas, toward the shallow part, in western Alberta, the isotopic signature is lighter and characteristic of early generation and entrapment.

A $\delta^{13}CH_4$ *vs.* $\delta^{13}CO_2$ cross-plot display a trend pointing to some degree of gas source variability. According to a recent reassessment of the significance of such trend (Milkov et al. 2018), it can be concluded that ~70% of the isotopic data reflects thermogenic generation and associated abiotic processes. Such estimation agrees with Tilley and Muehlenbachs (2006). Several samples collected in boreholes located in the shallower basin follow a trend indicative of biodegradation. Since carbon decomposition may lead to inorganic and organic CO_2 gas mixtures, a mode detail investigation is required. On the other hand, a $\delta^{13}C_2H_6$ *vs.* $\delta^{13}C_3H_8$ cross-plot shows genetic correlation, and most of the gas samples fall within a trend indicative of early gas generation, which is in turn typical of kerogen Type II/III (Ibrahimbas and Riediger, 2005; Slatt and Rodriguez, 2012; Rivards et al., 2014). These samples, also, plot near and within the Jurassic-Triassic isotopic boundaries established by Tilley and Muehlenbachs, (2006). However, most of the samples located at eastern British Columbia from south to north P, B and G show isotopic values that, as proposed by Tilley and Muehlenbachs (2006), maybe related to a terrestrial organic matter source (Fig. 1d). Such samples are also characteristically enriched in propane. Some produced gases showed partial and complete isotope reversal among gas (i.e. $\delta^{13}C_{methane}>\delta^{13}C_{ethane}>\delta^{13}C_{propane}$), particularly toward the SE of BC-93P (Fig. 1b). Chung plots demonstrated that such isotopic trend is a typical feature in this area, and is also present in BC, western Alberta (W6).

Conclusions

The spatial variability of the stable C isotope composition of dry alkanes within the Triassic Montney Fm. in BC and AB seems to be given not only by source rock lithofacies, but also by basin evolution, thermal temperature and pressure. Ubiquitous dry gasses changes should be taken into consideration during interpretation of isotope data obtained from unconventional shale gas reservoirs to provide further understanding basin-scale generation and migration mechanisms.

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