Molecular Composition and Isotope Mapping of Natural Gas in NEBC

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Summary

The British Columbia (BC) Natural Gas Atlas (BC-NGA; http://bc-nga.ca) is a 3 year project to obtain samples and data on molecular composition (MC) and stable isotope ratio (ISO) geochemistry of natural gas in North Eastern British Columbia (NEBC, Evans and Whiticar, 2017). The primary objective of the collection of the data is to release the material to a public web-site with maps of MC and ISO data from a variety of gas sources, including mudgas collected during drilling, downhole flow tests, production gas, and gas collected from surface casing vent flow emissions. The geochemical interpretation of some of these samples is being released as a M.Sc. thesis (Evans, in press).

The petroleum system active in one area may not have been active in other areas, or they have been overprinted by localized geological processes in specific plays. The addition of new data plus compilation of existing data to a regional baseline dataset support interpretive diagrams to determine gas sources and migration. One of the primary geochemical findings is that methane is a less reliable indicator of primary gas, due to mixing and alteration, but that the more conservative ethane and propane offer more robust interpretations.

Background and Method

In the last ten years, commercial natural gas production in NEBC has shifted to unconventional reservoirs (Hayes, 2018). Identification of gas sources using geochemical techniques in concert with the geologic settings are critical to improve exploration strategies and outcomes.

The study area in NEBC is part of the Western Canadian Sedimentary Basin (Mossop and Shetsen, 1994). The stratigraphic column includes Paleozoic, Mesozoic, and Cenozoic age strata of thousands of meters thickness with numerous depositional hiatus and regional aquitards. Within this stratigraphic column are hydrocarbon reservoirs that have been developed for oil and gas production. A previous geological framework for NEBC, already published as the Conventional Natural Gas Play Atlas (BC Ministry of Energy, and Mines and Petroleum Resources, 2006a,b,c) did not include any geochemistry data, but it formed the foundation upon which the geochemistry compilation was correlated (Evans and Hayes, 2018). New unconventional hydrocarbon targets have been identified: a) Horn River sub-basin (BC Ministry of Energy, and Mines and Petroleum Resources, 2011), b) Montney play (BC Oil and Gas Commission, 2012; BCMEM, 2013), c) Cordova Embayment (BC Ministry of Forests, Lands, Natural Resource Operations and Rural Development, 2015), and d) Liard sub-basin (Ferri et al., 2017). The BC Oil and Gas Commission (OGC) requires geochemistry data from natural gas wells in BC to be publicly available and there are hundreds of reports available via downloads from the OGC website.

Natural gas is comprised of predominantly methane (CH_4 labeled C1) with smaller amounts of ethane (C_2H_6 labeled C2), propane (C_3H_8 labeled C3), butane (C_4H_{10} labeled nC4), iso-butane (C_4H_{10} branching and labeled iC4), some heavier hydrocarbons, and occasional sour gas (hydrogen sulphide or H_2S). The stable isotope ratios of carbon ($\delta^{13}C$) and of hydrogen ($\delta^{2}H$) together with the relative molecular abundances provide geochemical indicators of petroleum source and migration (Schoell, 1980; Whiticar 1990, 1994, 1996, 1999). The combination of gas geochemical parameters are often able to delineate the character of natural gas. These include the Bernard diagram (C1/(C2+C3) vs. $\delta^{13}C1$; Whiticar 1994), CD diagram ($\delta^{13}C1$ vs. $\delta^{2}H$; Schoell, 1980; Whiticar, 1994), Berner-Faber plots ($\delta^{13}C1$ vs. $\delta^{13}C2$; $\delta^{13}C2$ vs. $\delta^{13}C3$; Berner and Faber 1996), and Lorant-Prinzhofer diagrams ($\delta^{13}C2$- $\delta^{13}C3$ vs. C2/C3, C2/C3 vs. C2/iC4; Prinzhofer and Battani, 2003).

Previous studies of the geochemistry of NEBC presented findings primarily in the form of Bernard and CD diagrams, however the data is not available from the OGC and thus is not mappable or used in interpretations in this study (e.g. Tilley and Muehlenbachs, 2013; Norville, 2014).

Results, Observations, Conclusions

Gas samples from wells were collected by the operating company and sent to SEOS, University of Victoria for MC and ISO analysis. The results were reported to the OGC and are available from that web-site. Other geochemical data was downloaded from the OGC and incorporated into a database and maps hosted on the Geoscience BC web-site. Some of the recent isotopic data is from well profiles at locations across NEBC (Figure 1). Cross-plots were generated from the compiled data.

The Bernard diagram generally produces a single overlapping data cluster, which is largely insufficient to differentiate the different gas occurrences. Only the formations known to have high thermal maturity are clearly distinguished (Figure 2). The CD diagram is also not always used to separate gases in the basin (Figure 3), an outcome that is further hampered by the frequent lack of $\delta^{2}H$ data. The Prinzhofer diagram (Figure 4) and the Lorant diagram (Figure 5) are sometimes more indicative of the sources. However, the Berner-Faber parameters $\delta^{13}C1$- $\delta^{13}C2$ (Figure 6) and $\delta^{13}C2$-$\delta^{13}C3$ (Figure 7) that are more informative.

Novel/Additive Information

Results from this study suggest that methane is isotopically depleted relative to other gases present in the petroleum system and thus the methane is mobile and possibly migrated from other sources or highly reactive. The ethane and propane appear to be geochemically conservative. The Prinzhofer diagram is functional without ISO data, but also misses much of the subtlety. The Lorant diagram shows better distinction between geochemical populations, but reviewing the data in isotopic crossplots like the Berner-Faber diagrams is more diagnostic. Geochemistry analysis based solely on methane (e.g., Bernard and CD diagrams) will be misleading and molecular and isotopic analyses should be completed on the higher hydrocarbons in the petroleum system for determination of sources of potential natural gas emissions.

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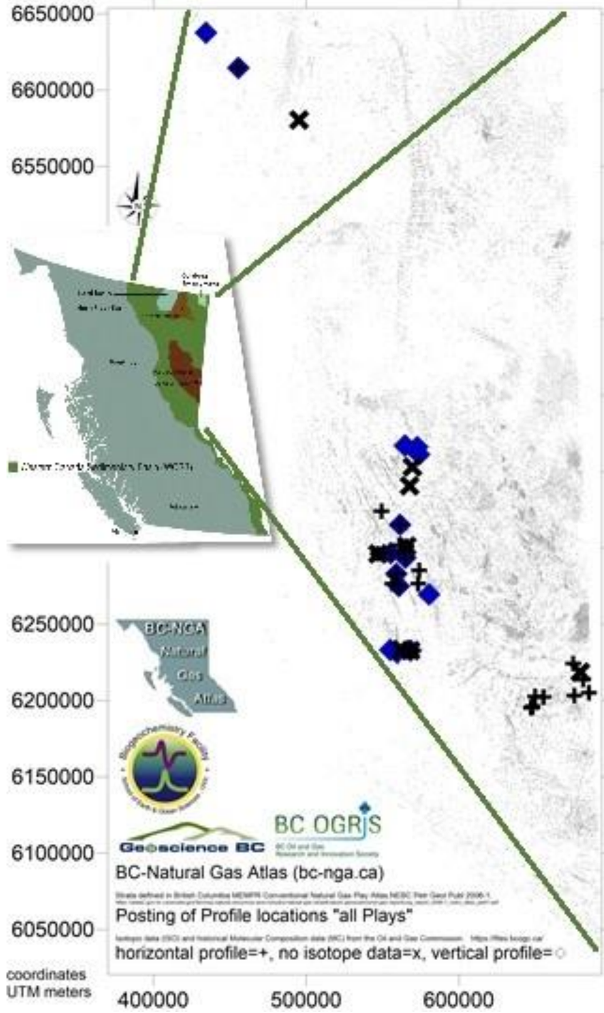

Figure 1. Location map of NEBC isotopic data from well profiles (posting locations per OGC surface hole locations).

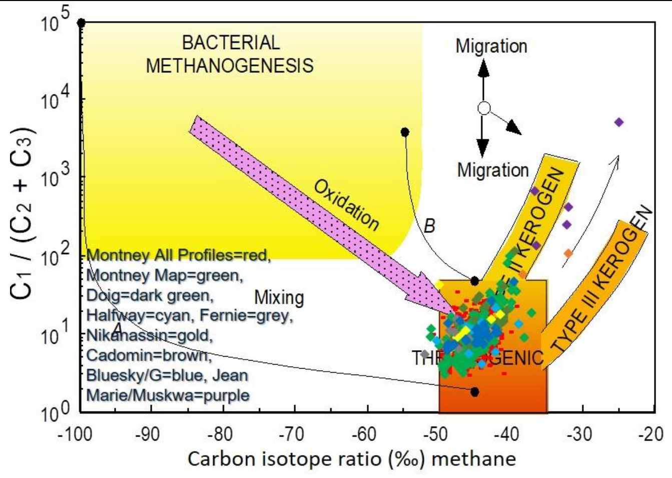

Figure 2. Bernard diagram for selected plays in NEBC – data is from the OGC public record.

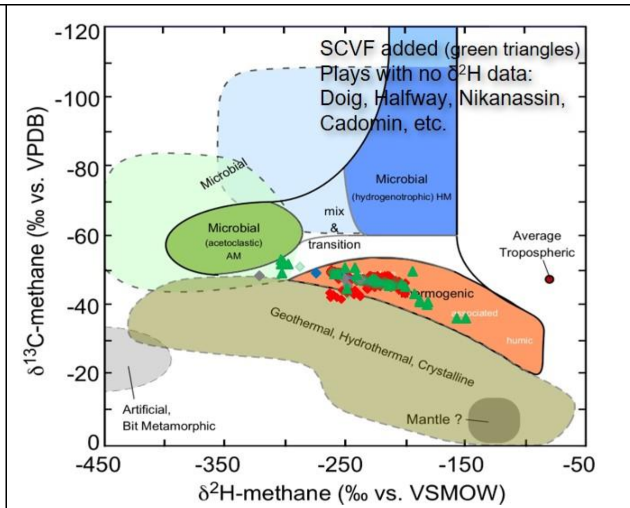

Figure 3. CD diagram for selected plays in NEBC – data is from the OGC public record.

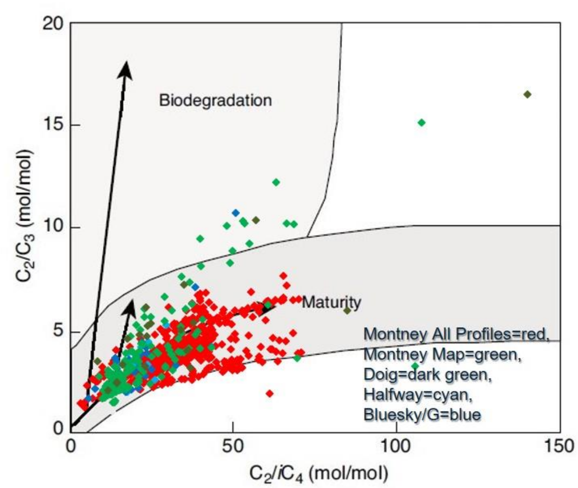

Figure 4. Prinzhofer diagram for selected plays in NEBC – data is from the OGC public record.

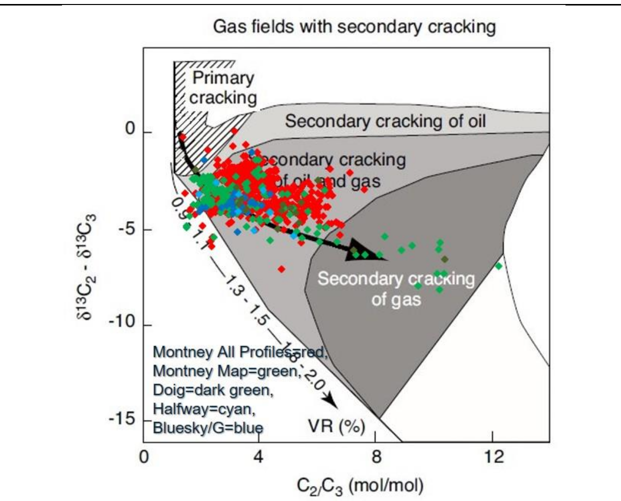

Figure 5. Lorant diagram for selected plays in NEBC – data is from the OGC public record.

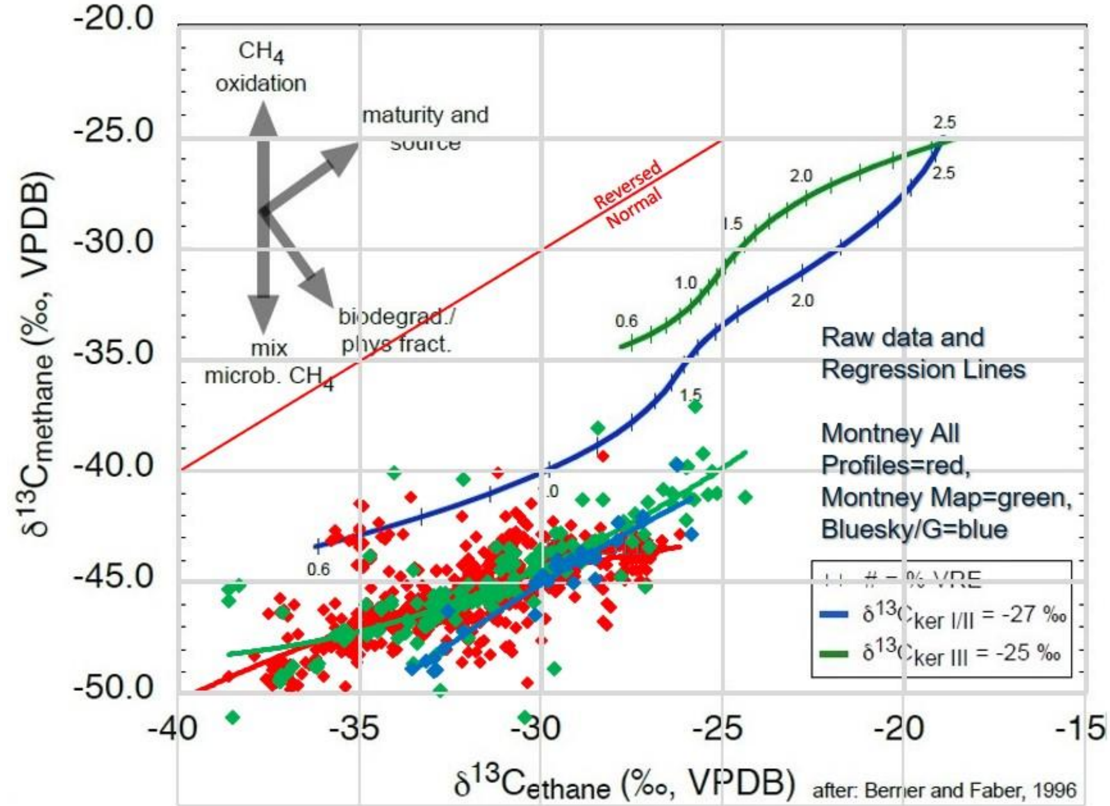

Figure 6. Isotope δ13C1 versus δ13C2 crossplots for selected plays in NEBC – data is from the OGC public record.

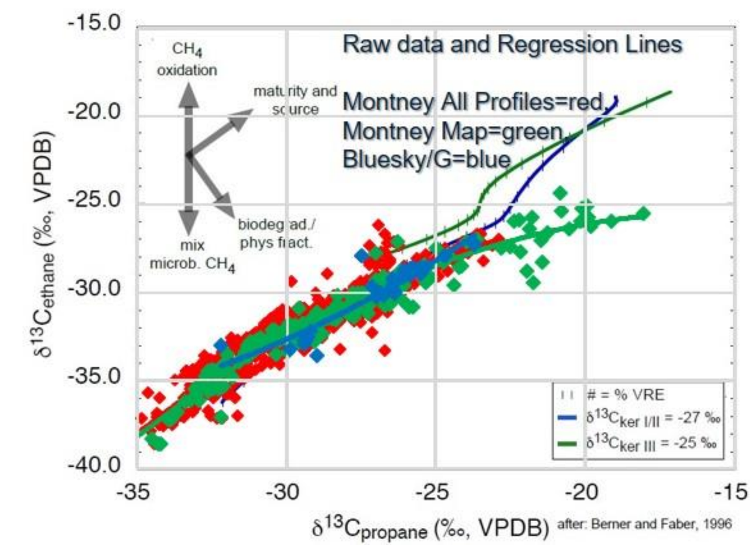

Figure 7. Isotope δ13C2 versus δ13C3 crossplots for selected plays in NEBC – data is from the OGC public record.

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