British Columbia Natural Gas Atlas Project: 2016 Project Update

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Introduction

Natural gas is associated with many sedimentary basins and marine depositional areas in British Columbia (BC). The BC Natural Gas Atlas (BC NGA) project (http://bc-NGA.ca/BC-NGA_Home.html) has just launched and proposes to map the major known gas occurrences throughout BC during the next few years, in a series of mapping phases. The initial phase of mapping has been focused on the areas of commercial natural gas production in northeastern BC (NEBC). The BC NGA project was initiated in response to regulatory changes, industry need and increased public recognition for geochemical data and basic interpretation. The industry uses gas geochemistry to understand hydrocarbon occurrences to aid in the identification and prioritization of areas of interest. Public interest stems from increased awareness of potential contamination issues, fugitive emissions, and supply and demand issues, such as the need for gas pipelines and LNG terminals.

The BC NGA project is using the concept of a 'gas fingerprint' based on molecular composition and analysis of stable isotopes of carbon and hydrogen to categorize and map gas sources, flow paths and destinations, both in geological/stratigraphic time and on a human timescale.

Background

Natural gas is a combination of naturally occurring hydrocarbons—primarily methane (CH_4), plus other non-hydrocarbon gases (in small amounts)—that can exist in a free or adsorbed phase in various types of reservoirs, frequently associated with possible hydrocarbon fluids. Economic production of natural gas as a fuel has a long history in BC, with most of the development in and production from NEBC. Environmental sensitivity of the public with regard to natural gas is increasing, with not only health effects from natural seeps and fugitive emissions being a significant concern (e.g., sour-gas effects on rural populations), but also the net effects of the same events on larger systems such as the economy (e.g., increased national gross domestic product from exporting to international markets), climate change (e.g., methane as a greenhouse gas more important than CO_2) and public safety (e.g., pipeline explosion and/or fire occurrences).

In 2006, the BC Ministry of Energy and Mines (MEM) published the first edition of the Conventional Natural Gas Play Atlas of Northeast British Columbia in three parts (BC Ministry of Energy and Mines, 2006a–c). This document was a series of synopses of each of the stratigraphic targets for natural gas development and commercial production. The focus of the Natural Gas Play Atlas was the overall description of each conventional gas play by its geological (depositional, sedimentological, diagenetic, structural) and reservoir characteristics. The BC NGA project is adding a geochemical section to many, but not all, of the intervals presented and is also adding strata that was previously considered unconventional.

The regulatory requirement for the isotopic portion of the geochemistry was initiated by the BC Oil and Gas Commission (BCOGC) in October 2015 with further clarification early in 2016 (BC Oil and Gas Commission, 2015, 2016). The requirements for operators to test and submit results of molecular composition of natural gas, including public release of data, have resulted in more data being available over a longer timeframe (BC Oil and Gas Commission, 2010, 2015b). In support of the requirements for the isotopic portion, Geoscience BC initiated this project, but with the intent to also include mapping of the natural gas molecular composition.

Area of Study

Location and Access

As noted above there are many regions within BC that have natural gas occurrences, but the BC NGA project is currently focusing on the NEBC portion of the Western Canadian Sedimentary Basin (WCSB) as phase 1 (Figure 1). Current natural gas exploration and development within the NEBC portion of the WCSB (highlighted in green) is more focused in the four areas marked within the WCSB on Figure 1: the Montney, Liard Basin, Horn River Basin and Cordova Embayment. There are other portions of the

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WCSB in BC, but the strata elsewhere are in the mountainous physiographic region with very little gas production and even less data available. Further review of other areas with gas occurrences are discussed as future phases of the project. The project area covers almost 120 000 km^2 of the province, with the eastern edge being more than 630 km long and the northern edge being more than 280 km long. Much of the area is boreal forest of the Interior Plains physiographic region.

Geology

Many of the natural gas occurrences in BC are in intermontane basins or in basins associated with accreted terranes. The NEBC region is unique in that it is a portion of the WCSB, which is a preserved foreland basin. Future publications on this project will present the geology in more detail once the strata for analysis have been determined.

Sampling

Field sampling of mud gas from chip samples and production gas from shut-in commercial wells was proposed for both industry and project staff, but field access has only been permitted for industry staff. The large volumes of archival chip samples required to generate the equivalent of mud gas analysis are generally not available in long term storage after drilling is completed. This difficulty has required adjustments to the project, as described below.

The number of mud gas samples was expected to be more than 500, but only 116 mud gas samples have been received to date from industry. Due to the otherwise low activity by industry in drilling the categories described in the legislation, the project allowed an additional 29 samples of production gas (16 originals plus duplicates) and completed the same analysis. More samples of production gas are being received by the project and samples of mud gas from all categories of drilling are expected in the future.

Further sampling is anticipated from industry sources once issues of safe collection, transport and analysis of samples containing sour gas (H_2S) are resolved.

Methods

The samples were received by the lab at the Biogeochemistry Facility at the University of Victoria School of Earth and Ocean Sciences (Victoria, BC).

The samples were stored in a secure location and isotope analysis was completed in summer 2016. First, the molecular composition of the gas was determined by gas chromatography (GC) with flame ionization detection for C1–C4 hydrocarbon gases and thermal conductivity detection for the nonionizable gas, CO_2. Molecular composition was not completed for all possible chemical components (for example, noble gases are not analyzed). Stable isotope ratios

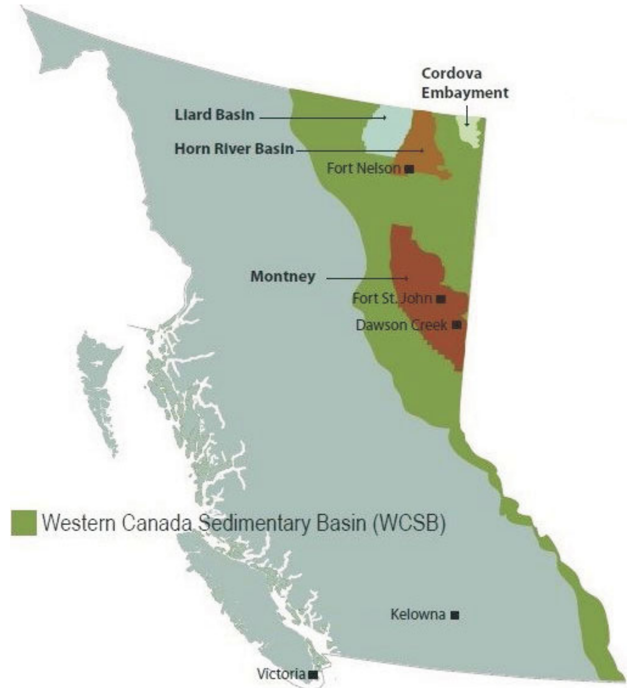

Figure 1. Location of the northeastern British Columbia portion of the Western Canadian Sedimentary Basin (in green), which is the project area for phase 1. The four sub-basins shown are current targets of natural gas exploration and development by industry (used with permission of the BC Oil and Gas Commission).

were measured by continuous flow–isotope ratio mass spectrometry (CF-IRMS), which is also referred to as GC-combustion-IRMS.

The carbon isotope ratio ($\delta^{13}C$) of the C1–C4 hydrocarbon gases are measured by online GC separation of the gas mixture (with He as carrier gas) followed by sequential oxidation of the individual species (CH_4, C_2H_6, C_3H_8, C_4H_{10}) to combustion CO_2 over a Cu-Pt wire microcombustion oven at approximately 1050°C. This combustion CO_2 is ported to an isotope ratio mass spectrometer (Finnigan™ MAT 252 or Delta+) to measure the isotopically different CO_2 molecules with atomic masses of 44, 45 and 46. These masses and their ratios are used to calculate the $^{13}C/^{12}C$ of the C1–C4 hydrocarbon gases, which is converted to conventional delta notation ($\delta^{13}C$) in ‰ (per mil) relative to the Vienna Pee Dee Belemnite (VPDB) standard. The accuracy and linearity of the measurements is determined by external calibration standards (Isometric Instruments standard gases). The external $\delta^{13}C$ accuracy and precision is ±0.2‰ for samples with >100 nmol hydrocarbon available.

Hydrogen isotope ratio (δ^2H) or (δD) of the C1–C4 hydrocarbon gases are similarly measured by online GC separation of the gas mixture (with He as carrier gas), but is instead followed by sequential reduction of the individual species (CH_4, C_2H_6, C_3H_8, C_4H_{10}) to reduction H_2 over a Ni microreduction oven at approximately 1400°C. This reduction H_2 is ported to an isotope ratio mass spectrometer (Finnigan MAT 252 or Delta+) to measure the isotopically different H_2 molecules with the atomic masses of 2, 3 and 4. These masses and their ratios are used to calculate the $^2H/^1H$ (also known as D/H) of the C1–C4 hydrocarbon gases, which is converted to conventional delta notation (δ^2H) or (δD) in per mil relative to the Vienna standard mean ocean water (VSMOW) standard. The same statement applies for the accuracy and linearity but the precision is ±0.3–0.4‰, depending on compound and amount.

Data

Molecular composition data were downloaded from the server at the BCOGC and subjected to rigorous data quality assurance–quality control (QA-QC). A substantial portion of the more recent data is from horizontal wells with numerous multilateral (HZML) legs tested in each well. This detailed analysis is especially valuable for local mapping and gas fingerprinting; however, the concentration of data points from a single area that HZML emulates can lead to data 'clusters'. This can lead to distortions when mapping at a regional scale and create geostatistical trends that 'plateau' the values. A consequence is that part of the data handling procedure is to manually decluster the data. The project method, which is undergoing constant refinement, will also elucidate any multimodal occurrences.

The addition of the new carbon and hydrogen stable isotope data into the integrated mapping results is expected to start in late 2016. The data will be eventually published as tables and associated maps on the Geoscience BC website (http://www.geosciencebc.com/s/BCNaturalGasAtlas.asp).

Analysis

Some of the early analyses were presented as a series of maps at the Unconventional Gas Technical Forum (UGTF) hosted by the BCOGC in April 2016 (Evans and Whiticar, 2016a, b). Those maps are not duplicated here because they are preliminary and subject to further QA-QC corrections as described above. The primary type of mapping algorithm is kriging using an unconstrained spherical variogram with octant search. Data will be presented on cross-sections through the strata in 2017. It is expected that the deliverables from the BC NGA project will include a full set of regional maps including contour plots and isopleths of gas compositions, and carbon plus hydrogen stable isotope ratios of methane and other light hydrocarbons. Where sufficient detailed depth data coverages allow, local cross-sections will be produced.

Future Work

The current discussion is somewhat restricted because the project is still in the start-up phase. As the project proceeds, web-based, analytical, database and visual products will be generated. It is anticipated that the results may initiate a review of the points mentioned in the conclusion of this paper.

The ongoing activities include the collection, submission and analyses of industry gas samples from NEBC. Future sampling is expected to include increasing numbers of sour gas samples. As a consequence, sampling, transport, handling and analytical SOPs must be adjusted. Map generation will continue to integrate both existing and additional incoming data.

Conclusions

This project is creating new regional geochemistry maps to

- assemble a catalogue of unique natural gas compositional IDs for active gas operations in NEBC,
- characterize and map the geochemical conditions of BC's major ongoing and future regions of petroleum exploration and production,
- contribute to understanding the geological framework of natural gas deposits at scales of fields to basins,
- assist petroleum system models to de-risk plays by understanding and predicting generation occurrences, histories and potential productivity of natural gas in BC,
- provide a robust baseline of gas signatures to identify and track fugitive emissions of natural gas (groundwater and atmosphere),
- offer a 'geochemical DNA' catalogue for different gas sources for provenance work in production, well completions, processing and transport and
- establish a database for fugitive emissions in surface waters and the atmosphere.

Most of the geochemistry is yet to be described and conclusions will be determined once the data review is completed.

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