Assessment of Methane Occurences and Sources in Groundwater in Alberta: A Progress Report

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Summary

With the rapid expansion of natural gas exploitation from unconventional reservoirs including coalbed methane and shale gas plays, there is some public concern about potential future contamination of shallow potable groundwater. In order to enable a scientifically sound assessment of potential future deterioration of freshwater resources in shallow aquifers, it is essential to first establish and understand the current baseline of groundwater quality including dissolved or free gases. In collaboration with Alberta Environment and Sustainable Resource Development (AESRD), we have been provided with groundwater and free gas samples from the Alberta groundwater observation well network (GOWN) and provide here a preliminary assessment of methane occurrences and methane sources emerging from this ongoing program. Such baseline groundwater charcaterization efforts are of great value for assessing potential future impacts on shallow groundwater or for demonstrating the lack thereof.

Introduction

Some public concern has been raised regarding potential future contamination of Alberta's groundwater as a result of shale gas development either by intrusion of formation water, flow-back water or stray gas leakage. A major challenge for environmental impact assessment in the context of unconventional hydrocarbon exploitation is the definition of the non-impacted baseline conditions. Groundwater resources overlying low-permeability hydrocarbon host rocks may be impacted to different extents by naturally occurring deep saline fluids and by natural gas emanations and/or by previous human activities (e.g. conventional hydrocarbon production). Once unconventional gas exploitation has started to a large extent, the establishment of baseline groundwater compositions is difficult giving rise to highly controversial debates about the occurrence and potential extent of environmental impacts of unconventional gas production.

In order to enable a scientifically sound assessment of potential future deterioration of freshwater resources in Alberta's aquifers, it is essential to first establish and understand the current baseline of groundwater quality. Therefore, we have commenced with a systematic assessment of the geochemical and isotopic compositions of water and gases obtained from Alberta's groundwater observation well network (GOWN) with special emphasis on the sources and processes controlling methane in Alberta's aquifers. The objective of this contribution is to provide preliminary results from this ongoing groundwater baseline monitoring program.

Methods

Over the last 4 years, AESRD has collected water and free gas samples from more than 190 GOWN wells in the province of Alberta and submitted these samples to the University of Calgary for isotopic fingerprinting of groundwater, its dissolved constituents, and of free gases occurring in some aquifers in Alberta. We have determined the isotopic compositions of water, selected dissolved constituents, and of free gases including methane obtained from shallow groundwater by isotope ratio mass spectrometry. The $\delta^{13}C$ and $\delta^{2}H$ values of methane are a useful tracer for identifying the sources and the formation pathways of methane (e.g. Whiticar, 1999).

Results & Discussion

Since 2008, 408 groundwater samples have been collected from the GOWN network with some repeat samples being derived from the same wells. Of the 408 groundwater samples, 158 were associated with a free gas phase. In the free gas samples, methane concentrations varied widely from less than 0.05ppmv to a maximum value of 998000ppmv. 78 samples contained more than 1% methane. A total of 112 free gas samples also contained ethane with concentrations ranging from less than 0.05ppmv to 3000ppmv. Only 5 samples contained propane with concentrations exceeding 1 ppmv.

Figure 1 shows a cross-plot of $\delta^{13}C$ values and concentrations of methane. The majority of the samples (n = 44) are characterized by $\delta^{13}C_{CH4}$ values lower than -60 ‰ while only 4 samples had $\delta^{13}C$ values slightly higher than -60 ‰.

Biogenic methane is produced by bacteria that preferentially metabolize ^{12}C (Clark & Fritz, 1997) resulting in large carbon isotope fractionation yielding $\delta^{13}C$ values of methane typically between -60 ‰ and -110 ‰. Highly depleted ^{13}C and ^{2}H distinguishes biogenic methane from thermogenic methane (Whiticar,1999). Figure 2 shows that the majority of the obtained samples have $\delta^{13}C$ values below -60 ‰ and all $\delta^{2}H$ values were below -200 ‰. This is consistent with a biogenic origin of the methane in free gas from the investigated groundwater samples. The wetness parameter was also used to potentially differentiate thermogenic from biogenic gas:

Wetness parameter = (concentration of CH_4) / (concentration of C_2H_6 + C_3H_8 + etc.)

Wetness values >1000 with $\delta^{13}C$ values of methane <-60 ‰ are characteristic for biogenic gas. Figure 3 reveals that most samples had low $\delta^{13}C$ values of methane and high wetness parameters consistent with a biogenic methane source.

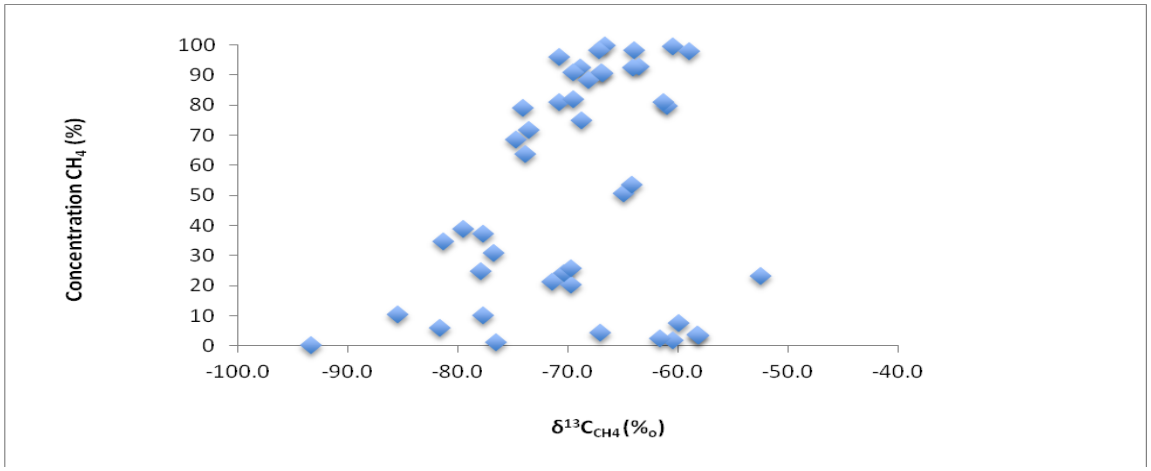

Figure 1: Methane concentration versus $\delta^{13}C_{CH4}$.

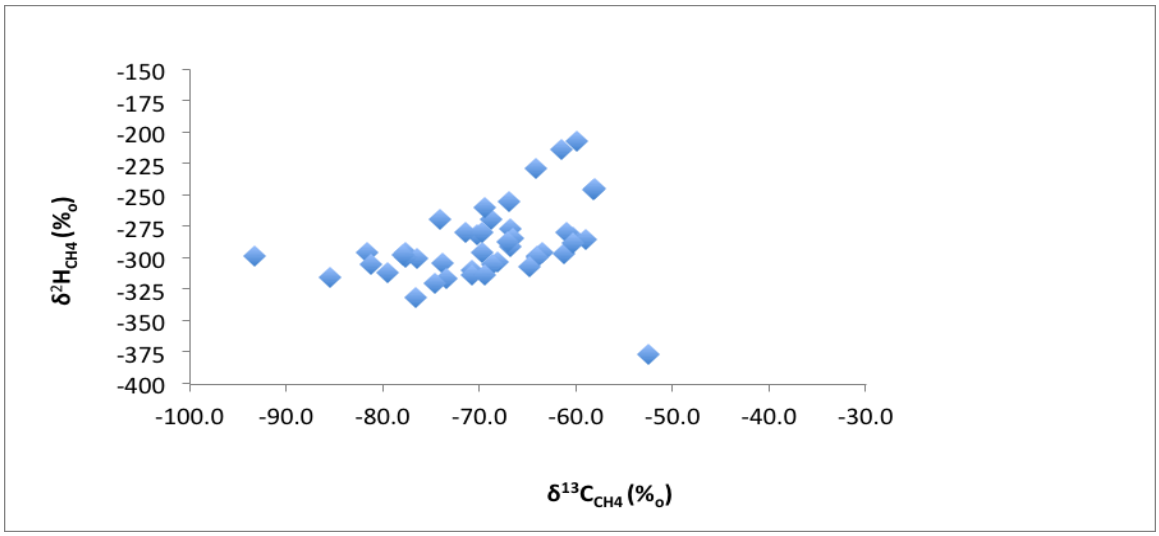

Figure 2: $\boldsymbol{\delta}^{13}C$ versus $\delta^{2}H$ values of methane in free gas samples.

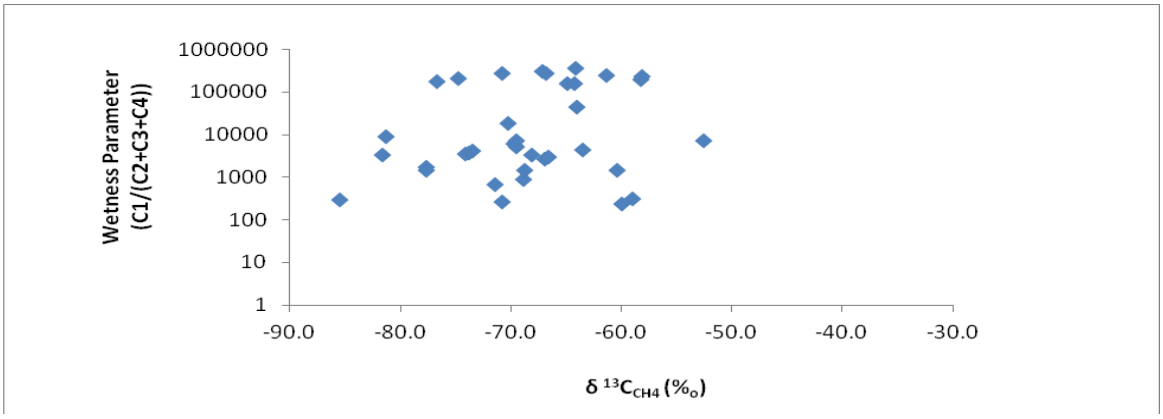

Figure 3: Wetness parameter versus $\boldsymbol{\delta}^{13}C$ values of methane.

Conclusions

The free gas samples obtained from groundwater samples from aquifers in Alberta appear to contain methane of biogenic origin. The next step in this study is to complete chemical and isotopic analyses for all samples and correlate gas occurrences with hydrogeological conditions and geological formations. When completed, this work will contribute to a better understanding of the quality of groundwater and its gases in Alberta, and may serve as an important baseline against which potential future impacts can be compared.

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