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Applicability of δ^{13}C analysis for the Quest CCS project's MMV plan

Luc Rock[1], Veith Becker[2], Chantsalmaa Dalkhaa[2], Pauline Humez[2], Michael Nightingale[2], Maurice Shevalier[2], Bernhard Mayer[2], Guoxiang Zhang[3]

[1]Shell Canada (Luc.Rock@shell.com); [2]Department of Geoscience, University of Calgary; [3]Shell International Exploration & Production

Summary

A key component of any CCS project is to demonstrate to stakeholders that the injected CO_2 is safely contained within a storage complex. Various techniques can be used for this purpose, such as geophysical, geochemical or isotope approaches. An assessment of the suitability of the natural abundance C isotopic composition of injected CO_2 as a tracer was done by conducting a number of studies (e.g. literature review, laboratory experiments) and collating information on the δ^{13}C values of background CO_2 sources (e.g. soil, groundwater, atmosphere) within the Quest Sequestration Lease Area (SLA) and the injection CO_2 gas. The findings from the literature review, laboratory experiments, and modeling work indicated that the inherent stable isotope composition of CO_2 can play a significant role in a Measurement, Monitoring and Verification (MMV) plan to demonstrate containment and conformance of the injected CO_2 at a CCS site dependent upon background conditions. At the Quest site, δ^{13}C of the injected CO_2 is sufficiently distinct from background values based on an extensive sampling and analysis program of various CO_2 sources. Hence, δ^{13}C analysis represents a promising tracer approach to be included within the MMV plan.

Introduction

In a recent report by the International Energy Agency (IEA), it was stated that *"…for the IEA all signs continue to point to the necessity and viability of CCS as a CO_2 abatement technology, within a portfolio of other low-carbon technologies*" and "*It is necessary to now concentrate on concrete action by both governments and industry to drive CCS forward*" (IEA, 2014). A number of small and large scale Carbon Capture and Storage (CCS) projects exist around the world. In Alberta, Shell, on behalf of the Athabasca Oil Sands Project venture (Shell Canada Energy, Chevron Canada Limited, Marathon Oil Canada Corporation), operates the Quest CCS project as part of the Scotford oil sands bitumen Upgrader. Quest will reduce direct CO_2 emissions from the Upgrader by up to 35%, which corresponds to taking 175000 cars off the road. First injection into the Basal Cambrian Sands (BCS) is planned for early 2015. A key component of any CCS project is to demonstrate to stakeholders that the injected CO_2 is safely contained within a storage complex. Various techniques can be used for this purpose, such as geophysical, geochemical or isotope approaches.

The aim of this paper is to present and to discuss the applicability of δ^{13}C analysis for monitroing purposes at the Quest site.

Methods & Materials

In order to assess the feasibility of $\delta^{13}C$ analysis for leakage monitoring at QUEST, a number of key tasks were undertaken. These included:

- A literature review on what is known and what is not known about stable isotope effects that are relevant for flow, transport and reactions of CO_2 injected into a geological storage reservoir and CO_2 potentially leaking from the reservoir towards the surface.
- Laboratory experiments to address the knowledge gaps with respect to C and O isotope fractionation affecting CO_2 under conditions (pressure, temperature, salinity) relevant to carbon storage projects.
- A modeling study to identify and test available geochemical modeling programs that are capable of predicting the extent of isotopic change of CO_2 as it leaks out of the injection reservoir towards the surface environment. This included a novel approach to couple TOUGHREACT and Geochemist's Workbench.
- Gathering of $\delta^{13}C$ of background CO_2 sources within the Quest Sequestration Lease Area (SLA) and the CO_2 injection gas.

Key Findings

The literature review (Mayer et al., under review) suggests that the stable carbon isotopic composition of injected CO_2 is a suitable tracer for assessing the movement and fate of injected CO_2 in the target reservoir and for leakage detection at CO_2 storage sites provided that the injected CO_2 is isotopically distinct from background CO_2 sources. A key advantage is that this tracer approach can be continuously used in large-scale commercial storage projects with CO_2 injection rates exceeding 1 million tons per year at reasonable cost.

The initial laboratory experiments conducted so far suggest that the $\delta^{13}C$ value of CO_2 hypothetically leaking from the reservoir is not expected to change significantly (e.g. by less than 2 ‰) from its original value under realistic leakage scenarios (Rock et al., 2014). This suggests that $\delta^{13}C$ appears to be a suitable tracer for CO_2 leaking from storage reservoirs, provided that the injected CO_2 is isotopically sufficiently distinct from background values.

Transport and reactions of injected CO_2 were modeled with ToughReact without isotopic information, while isotopic data were modeled in static batch mode using GWB (Shevalier et al., 2014). Isotopic changes during a continuous leakage of CO_2 into 5 overlying aquifers relative to the BCS were investigated using GWB. The results of the initial modeling attempts indicated that after 2 hours or less, depending on leakage rate, the remaining CO_2 leaking towards the surface will have the same $\delta^{13}C$ value as the injected CO_2. The modelling work conducted so far also demonstrated that coupling TOUGHREACT and Geochemist's Workbench (GWB) provides a feasible avenue to model the isotopic composition of CO_2 leaking from the storage reservoir towards the surface for a rapid first approximation.

At the Quest site, the isotopic composition of the injected CO_2 is sufficiently distinct from background values based on an extensive sampling and analysis of various CO_2 sources.

Conclusion

Hence, literature review, laboratory experiments, geochemical modeling work and field data collection indicate that $\delta^{13}C$ analyses on CO_2 and other carbon compounds is a valuable technique that can be considered for the Quest Measurement Monitoring and Verification (MMV) plan.

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