Geophysical Research Abstracts,
Vol. 11, EGU2009-11886, 2009
EGU General Assembly 2009

Lessons Learned from Natural and Industrial Analogues for Storage of Carbon Dioxide

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The development of reliable monitoring tools to ensure the sustainability and the safety of geological storage is a prerequisite for the implementation of such sites.

In this framework, a geochemical method using noble gas and carbon isotopes geochemistry has been tested on natural and industrial analogues of CO_2 storage.

Our approach was to compare data obtained at different time scales, as natural analogues may be a proof that long term storage of CO_2 is feasible, whereas industrial analogues may demonstrate the ability to inject and monitor fluids at human time scales.

To this end, gases were sampled in different natural analogues (located in two CO_2 province, i.e. the Colorado Plateau and the French carbo-gaseous province) and in an industrial analogue (i.e. a natural gas storage located in the Paris Basin). Analyses of noble gas concentrations (He, Ne, Ar, Kr and Xe) and isotopic ratios ($^3He/^4He$, $^{20}Ne/^{22}Ne$, $^{21}Ne/^{22}Ne$, $^{38}Ar/^{36}Ar$, and $^{40}Ar/^{36}Ar$) were performed at IFP and IPGP Geochemistry laboratories. The concentrations and carbon isotopic ratios of associated major compounds (C_1-$C_5$and CO_2) were also determined.

First, the study of natural analogues showed systematic behaviours of the geochemical parameters, depending on the containment sites and the geological context.

The main common point of all the case studies is the omnipresence of a mantle-derived helium component, whatever the geological context (sedimentary basins or geothermal areas). This component seems to be a *sine qua non* condition of the existence of any natural CO_2 accumulation or leaks, and attests to a transfer between deep fluids and the sedimentary crust.

This study also yields geochemical criteria to evaluate the containment of a natural CO_2 analogue.

On the one hand, all the gases sampled in CO_2-leaking sites have CO_2/ ^3He ratios above the MORB (mid-ocean-ridge basalt) range of 1 x 10^9 to 1 x 10^{10}(Marty and Jambon, 1987), pointing to CO_2 predominantly derived from a crustal source. These samples paradoxically exhibit high R/Ra ratios (between 1,39 and 3,96Ra), attesting to a dominant mantle-derived helium component. Thus, in such CO_2-leaking sites, the origin of CO_2 seems to be related to the addition of crustal- CO_2, poor in helium, during gas migration.

On the other hand, gases sampled in good containment sites exhibit lower R/Ra ratio (0,36-1,07Ra), still indicating a present but smaller mantle-derived helium component, and associated to a typical MORB $CO_2/^3He$ ratio: these features highlight a dominant mantle source for the CO_2 in these gases.

Isotopic fractionation of noble gases appears also to be closely linked to the quality of the containment, since a mass-related isotopic fractionation of neon and argon has been observed in all the CO_2-leaking sites. This enrichment in the lightest noble gas isotope can be interpreted as a geochemical footprint of the rapid gas migration toward surface.

Second, a 2-years geochemical tracing experiment on a natural gas storage site exploited by the GDF SUEZ Company was performed. Gas sampling was done every month during both the injection (usually in summer) and withdrawal (usually in winter) periods.

This monitoring test demonstrates the possibility to identify physico-chemical processes taking place in the reservoir at a human time scale. More specifically, the gases sampled at the producing wells exhibit mixing trends between the different injected gas end-members, depending on the sampling date and the location of the wells. A significant partitioning between water and the gas phase has also been identified and is apparently related to changes of the gas to water volume ratio during gas withdrawal.

These two complementary studies proved the effectiveness of noble gases and carbon isotopes in terms of leak detection and as tracers of the CO_2 behaviour, thus increasing interest in the proposed method and providing general information on its use.

References:

Marty, B. and Jambon, A., 1987. C/^{3}He in volatile fluxes from the solid Earth: implications for carbon geodynamics. *Earth Planet. Sci. Lett.* **83**, pp. 16–26