Helium, carbon and oxygen isotopes as natural tracers of CO_2 storage and migration in south east Australia

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Geochemical monitoring of CO_2 storage requires understanding of both innate and introduced fluids in the crust as well as the subsurface processes that can change the geochemical fingerprint of CO_2 during injection, storage and any subsequent migration. Here, we analyse a natural analogue of CO_2 storage, migration and leakage to the atmosphere using noble gas and stable isotopes to understand these processes.

The Otway Basin in SE Australia contains pure CO_2 and mixed CO_2-methane natural gas fields. CO_2-rich natural springs occur north of the basin, in Geelong and Daylesford. The relationship of the CO_2 migrating to the surface to the CO_2 retained in the reservoirs is currently uncertain.

Recent work has shown that stable isotope and noble gas fingerprinting can be used to determine the origin of reservoir fluids and CO_2 at the surface in natural springs [1]. Here we present new helium, carbon and oxygen isotope measurements of the CO_2 to determine the relationship between gases in the reservoirs and the springs.

Using $^3He/^4He$ ratios and helium and CO_2 abundance systematics we establish that well gases from Mount Gambier and Port Campbell regions of the Otway Basin are a mix of mantle and crustal components. We differentiate between the effects of radiogenic ^4He addition by interaction with the crustal fluids and dilution with shallow CO_2 to the initial gas composition and resolve that natural CO_2 springs are of the same magmatic origin as the CO_2 stored in the Otway Basin.

Dilution of the original helium composition correlates with a change in $\delta^{13}C$ values, indicating that wall-rock mineral dissolution and organic sources contribute additional carbon as the gas migrates through the shallow subsurface. Importantly, we show that the $^3He/^4He$ isotope signature is preserved and can be traced back to the original composition if the mixing end members are known, despite dilution with shallow CO_2. Extensive deep CO_2 migration through the shallow aquifer is also evident from the ^{18}O depletion in spring waters relative to the Local Meteoric Water Line.

[1]Gilfillan et al., 2008, GCA, 72. 1174-1198.