Using oxygen isotopes to quantitatively assess residual CO_2 saturation during the CO2CRC Otway Stage 2B Extension residual saturation test

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Abstract

Geological storage of CO_2 in rock formations, as part of Carbon Capture and Storage (CCS), is a promising means of directly lowering CO_2 emission from fossil fuel combustion (Baines and Worden, 2004). Residual trapping, the immobilization of CO_2 through trapping within individual and dead end spaces between rock grains, can play a major role for CO_2 plume migration, immobilization, storage security and reservoir management (Doughty and Pruess, 2004; Krevor et al., 2015). Despite the important role of residual trapping of CO_2 for commercial-scale CCS projects, there is a current lack of cost-effective and reliable methodologies to estimate the degree of residual trapping on a reservoir scale (Mayer et al., 2015).

Oxygen isotopes may be highly suitable for assessing the movement and fate of injected CO_2 in a formation. At CO_2 injection sites, due to the large quantities of CO_2 injected, CO_2 becomes a major oxygen source, and both CO_2 and water will change their oxygen isotope ratio ($\delta^{18}O$) due to isotopic equilibrium exchange reactions in a predictable way (Kharaka et al., 2006; Johnson et al., 2011; Mayer et al., 2015). It has been shown in CO_2-EOR (enhanced oil recovery) sites and in laboratory experiments that the change in reservoir water $\delta^{18}O$ due to isotopic exchange with CO_2 can be related to the volumetric reservoir saturation with CO_2 (Johnson and Mayer, 2011; Johnson et al., 2011).

However, oxygen isotopes have not been used in a single-well CO_2 storage experiment to quantitatively assess residual CO_2 saturation on reservoir scale.

Here, we present the first $\delta^{18}O$ measurements from a single-well experiment, the CO2CRC Otway Stage 2B Extension residual saturation test conducted in December 2014, used to estimate levels of residual trapping of CO_2. Following the initiation of the drive to residual saturation in the reservoir, reservoir water $\delta^{18}O$ decreased, as predicted from the baseline isotope ratios of water and CO_2, over a time span of only a few days. The isotope shift in the near-wellbore reservoir water is the result of isotope equilibrium exchange between residual CO_2 and formation water. For the region further away from the well, the isotopic shift in the reservoir water can also be explained by isotopic exchange with mobile CO_2 from ahead of the region driven to residual, or continuous isotopic exchange between water and residual CO_2 during its back-production, complicating the interpretation of the change in reservoir water $\delta^{18}O$ in terms of residual saturation. A small isotopic distinction of the baseline water and CO_2 $\delta^{18}O$, together with issues encountered during the field experiment procedure, further prevents the estimation of residual CO_2 saturation levels from oxygen isotope changes without significant uncertainty. The consistency of oxygen isotope-based near-wellbore saturation levels and independent estimates based on pulsed neutron logging (Ennis-King et al., this issue) indicates the potential of using oxygen isotope as an effective inherent tracer for determining residual saturation on a field scale within a few days.

In addition we will present results from laboratory experiments which will quantify the exact mechanism and timing of oxygen isotopic equilibrium exchange. The results from these tests are crucially needed to better understand the influence of oxygen isotope fractionation on the oxygen isotope shift in reservoir water during the CO2CRC Otway Stage 2B Extension residual saturation test, in particular further away from the well. Our combined results from the field and laboratory experiments will be beneficial to future field experiment setups. This will inform the use of oxygen isotopes as an inherent monitoring tracer of CO_2 migration and means to assess residual saturation on a reservoir scale prior to commercial CO_2 injection and storage.

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