Stepping into the same river twice: field evidence for the repeatability of a CO_2 injection test

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Abstract

Almost all field tests of CO_2 injection are inherently one-off operations, and give little insight into the reproducibility of the results, yet are assumed to be representative of the reservoir unit in question. In 2011, the CO2CRC Residual Saturation and Dissolution Test, conducted at the onshore Otway site in Victoria, Australia, collected field data to characterize the residual CO_2 saturation in a thin low-salinity water-saturated reservoir unit within the Paaratte Formation at 1392-1398 m depth (total vertical depth sub-sea). The test compared the use of pressure and temperature measurements, pulsed neutron logging, noble gas tracers, reactive ester tracers, and a dissolution test. The data for each set of measurements have been separately analyzed, and provide a range of estimates of the near-well distribution of residual CO_2 saturation at different depths of investigation.

In late 2014, there was an opportunity to repeat some parts of the test in the same reservoir unit and using the same well, striving to keep the test sequence similar while improving some of the operational aspects and data collection procedures. The test design again required the injection of CO_2-saturated brine at some points, and although the procedure was improved from 2011, this requirement was still challenging to achieve under field conditions. Pressure and temperature measurements, pulsed neutron logs and noble gas tracers were again used, along with analysis of oxygen isotopes.

While the far-field permeability deduced from the 2014 pressure response agreed with the 2011 results, the near-well permeability was found to be reduced by nearly 60% in the repeat test. The 2014 noble gas tracer test achieved much higher tracer recovery than in 2011, due to better procedures. The interpretation of the 2011 tracer test used air/water tracer partition coefficients, since these were the best available data. Interpretation of the 2014 results is complicated by the recent publication of differing sets of tracer partition coefficients for CO_2/water at reservoir conditions, which give a wider range of uncertainty for inferred residual saturation achieved in the test. However, in all cases, the 2014 residual saturation deduced from the tracer test (which is a flow-weighted average over the near-well region, in which residual saturation varies both vertically and laterally) is significantly lower than in 2011. Operational changes, such as the procedure for injecting CO_2-saturated water, and the timing of injection events, account for at least some of this difference in the tracer test results.

There is strong evidence that the near-well reservoir response itself has also changed, and the reasons for this are explored. The geochemistry of the formation water samples altered significantly between 2011 and 2014, with a significant increase in total alkalinity and the concentration of major cations (e.g., K^+, Na^+, Ca^{2+}, Mg^{2+} and total Fe) and anions (e.g., SO_4^{2-}). These changes in the water chemistry are indicators of residual dissolved carbon dioxide and oxygen (from the Otway 2B project in 2011) reacting with minerals in the reservoir, leading to dissolution and possible precipitation of secondary minerals affecting near-well permeability. The inflow of sand into the well caused by water production activities in the 2011 and 2014 tests, which was confirmed during a well recompletion activity in 2015, could suggest that the injection and production cycles during the test itself have altered the near-well environment by migration of fines or sand. It is also possible that the final water disposal in 2011 might have allowed the growth of biofilms that could have reduced the near-well permeability. Implications for other CO_2 field injection tests are then discussed, in particular the sensitivity to certain details of the operational procedures in a single-well test, and the possibility of the test itself inducing near-well changes in the reservoir.