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The Green River natural analogue as a field laboratory to study the long-term fate of CO_2 in the subsurface

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Understanding the long-term response of CO_2 injected into porous reservoirs is one of the most important aspects to demonstrate safe and permanent storage. At the same time this is one of the least understood aspects of CCS in general. The reasons are that "long-term", in the sense of hundreds to thousands of years, is impractical from a laboratory and rather idealised from a reservoir modelling perspective. However understanding the coupled long-term hydro-chemical-mechanical response of a reservoir-seal pair following CO_2 injection is highly desirable to improve confidence and trust from a regulator and societal perspective, as well as to improve risk assessment and risk reduction.

In order to provide one building block to advance understanding of this subject, in July 2012 Shell recovered some 300m of core from a scientific drill hole through a natural CO_2 field near Green River, Utah. This core transected two sandstone formations (Entrada and Navajo) and one intervening seal layer, composed of interbedded marine clay-/silt and sandstones (Carmel Fm.). Fluid samples and core material were taken adjacent to the Little Grand Wash Fault (LGW), along which CO_2-charged fluids traverse from depth to the surface and which is believed to be the migration pathway for CO_2 inflow into the reservoirs. In-situ pH, CO_2 concentrations, and fluid element and isotope geochemistry were determined from wireline downhole sampling of pressurized fluids taken from the Navajo reservoirs. The fluid geochemistry provides important constraints on reservoir filling by flow of CO_2 –charged brines through the LGW fault damage zone, macro-scale fluid flow in the reservoirs and the state of fluid-mineral thermodynamic disequilibrium, from which the nature of the fluid-mineral reactions can be interpreted. In addition to core samples, we obtained control samples from stratigraphically equivalent outcrop locations and drill holes that were not subject to alterations by CO_2 -charged fluids and served as a direct comparison to the altered samples. We obtained geomechanical, mineralogical, geochemical and petrophysical laboratory data along the entire length of the core and from the control samples. Furthermore, we performed more detailed studies through portions of the caprock in direct contact with the CO_2-charged reservoirs. This was done to constrain the nature and penetration depths of the CO_2-promoted fluid-mineral reaction fronts. These reactions have taken place in the last $\sim$100,000 years, which has been set as an upper limit for the onset of CO_2 influx into the formations. This data has been used as input for reactive (transport) modeling. In addition, we compared geomechanical data from the CO_2 –exposed core and the unreacted control samples to assess the mechanical stability of reservoir and seal rocks in a CO_2 storage complex following mineral dissolution and precipitation for thousands of years.