Australian School of Petroleum

Natural CO_2 Accumulations as Analogues for CO_2 Geological Storage and CO_2-Induced Diagenesis in the Otway Basin, Australia

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Contents

Geological storage of CO_2 is a potential climate change abatement option, which must be validated as a long-term safe and economically viable technology before it can be implemented. Petrological examination of natural CO_2 accumulations reservoired in the Otway Basin, southeast Australia, provided the means to analogously demonstrate the long-term interaction between CO_2, formation fluids and lithologies within a CO_2 storage system. CO_2-specific diagenetic events are proposed to increase the long-term integrity of the storage system through CO_2-mineral trapping.

The petrological analyses allowed determination of the mineralogy in specific reservoir lithologies (e.g. Pretty Hill, Waarre C and Flaxmans formations) before and after late, externally-sourced CO_2 entered the system. Elemental and isotopic analyses related the magmatically-sourced CO_2 to petrologically identified late-stage carbon-bearing minerals. Where key petrological differences corresponded to the late-stage carbonate products, CO_2-induced diagenesis was confirmed as the cause, supported by specific equations. Each lithology's diagenetic history was developed, showing the onset of CO_2-induced diagenesis and alteration stages.

CO_2-induced reactions buffered H^+, released during CO_2 dissociation in formation water. Mineral alteration progression roughly matched the Goldich weathering series, with mineral surface area, water ion concentration and gas zone water saturation also controlling preferential alteration. Complex clays, Ca-carbonates, plagioclase and ferromagnesian silicates were mostly removed. Plagioclase showed strong etching to complete dissolution, and alkali-feldspar displayed minor etching to near-complete dissolution. Kaolinite and quartz were common reaction products, along with Fe^{2+}, Mg^{2+} and Ca^{2+} cation release. A series for CO_2-carbonate mineral trapping was interpreted, from siderite through to ferroan dolomite precipitation, controlled by Fe^{2+}, Mg^{2+} and Ca^{2+} cation availability.

CO_2-induced alteration also occurred in the Belfast Mudstone seal lithology, where CO_2 was reservoired within fractured shale and interbedded siltstone/sandstone. CO_2-related siderite precipitation correlated with seal capacity enhancement for these examples.

A P-T-X experimental procedure was applied to an unaltered Pretty Hill Formation sample at elevated ρCO_2 and temperature in artificial brine. The resultant sample mineralogy and water composition provided calibration for equilibrium and kinetic modelling. The resulting model predictions and experimental results are consistent with the interpreted diagenetic evolution in the CO_2-rich Pretty Hill Formation. CO_2 mineral trapping from model predictions were 12 kg/m^3 (after 20 years) and 100 kg/m^3 (after 1,000 years). Net CO_2 stored from petrological analyses were negative for Waarre C (-12 kg/m^3), moderately positive for the Pretty Hill Formation (36 kg/m^3) and very high for the greensands in the Flaxmans Formation (335 kg/m^3).

Local intensive CO_2-induced diagenesis has modified reservoir and seal petrology within the Otway Basin. Storage site selection and operations could optimise CO_2 storage by exploiting these diagenetic processes. For example, Boggy Creek's natural CO_2 accumulation (Waarre C sandstone overlain by Flaxmans Formation greensand and Belfast Mudstone seal) provide an excellent example of an ideal storage system; whereby injection into the Waarre C would be unhindered, yet high mineral trapping potential and slowed migration would occur in the overlying Flaxmans Formation. This ideal stratigraphic arrangement is common within passive margins successions, and hence are optimal targets for future CO_2 geological storage projects.

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Maxwell Noel Watson 10/08/2012.

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