



Australian School of Petroleum

**Natural CO₂ Accumulations as Analogues for CO₂
Geological Storage and CO₂-Induced Diagenesis in the
Otway Basin, Australia**

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Geological storage of CO₂ 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 CO₂ accumulations reservoired in the Otway Basin, southeast Australia, provided the means to analogously demonstrate the long-term interaction between CO₂, formation fluids and lithologies within a CO₂ storage system. CO₂-specific diagenetic events are proposed to increase the long-term integrity of the storage system through CO₂-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 CO₂ entered the system. Elemental and isotopic analyses related the magmatically-sourced CO₂ to petrologically identified late-stage carbon-bearing minerals. Where key petrological differences corresponded to the late-stage carbonate products, CO₂-induced diagenesis was confirmed as the cause, supported by specific equations. Each lithology's diagenetic history was developed, showing the onset of CO₂-induced diagenesis and alteration stages.

CO₂-induced reactions buffered H⁺, released during CO₂ 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 Fe²⁺, Mg²⁺ and Ca²⁺ cation release. A series for CO₂-carbonate mineral trapping was interpreted, from siderite through to ferroan dolomite precipitation, controlled by Fe²⁺, Mg²⁺ and Ca²⁺ cation availability.

CO₂-induced alteration also occurred in the Belfast Mudstone seal lithology, where CO₂ was reservoired within fractured shale and interbedded siltstone/sandstone. CO₂-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 pCO₂ 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 CO₂-rich Pretty Hill Formation. CO₂ mineral trapping from model predictions were 12 kg/m³ (after 20 years) and 100 kg/m³ (after 1,000 years). Net CO₂ stored from petrological analyses were negative for Waarre C (-12 kg/m³), moderately positive for the Pretty Hill Formation (36 kg/m³) and very high for the greensands in the Flaxmans Formation (335 kg/m³).

Local intensive CO₂-induced diagenesis has modified reservoir and seal petrology within the Otway Basin. Storage site selection and operations could optimise CO₂ storage by exploiting these diagenetic processes. For example, Boggy Creek's natural CO₂ 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 CO₂ geological storage projects.

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution to Maxwell Noel Watson and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text.

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