

Sequestration of CO₂ in geothermal areas

Quintessa is providing numerical modelling support to a project investigating the feasibility of sequestering atmospheric CO₂ in geothermal areas. This sequestration strategy is one possible means for mitigating the effects of climate change caused by anthropogenic CO₂ emissions. The work is being done in collaboration with Mitsubishi Materials Corporation (MMC), the Research Institute of Innovative Technology for the Earth (RITE) and the Central Research Institute of Electric Power Industry (CRIEPI). Funding is being provided by Japan's New Energy Development Organisation (NEDO).

A potential advantage of sequestering CO₂ in geothermal areas, where high temperatures (to several hundred °C) occur, is that reactions between CO₂-charged water and rock will be more rapid than in rocks at lower temperatures. In turn these reactions could potentially favour the trapping of CO₂ in solid mineral phases such as calcite. However, to evaluate the feasibility of this sequestration option the coupled flow-reaction processes that would accompany CO₂ injection must be understood. If the reaction rates are too fast and the rocks' porosity and permeability decrease near to the CO₂ injection point, further CO₂ injection might be prevented. On the other hand, if reactions are too slow or porosity increases too much, then injected CO₂ might migrate too far and leak from the rock reservoir.

Quintessa has evaluated various aspects of this coupling, by theoretical modelling using a combination of widely used geochemical simulation codes (PHREEQC and Geochemist's Workbench) and Quintessa's own Raiden3 code. This latter code fully couples simulations of flow and reactions while taking into account reaction kinetics. One application of Raiden3 in the present project has been to develop an improved understanding of the processes that occur during the migration of CO₂-saturated water through granodiorite at 200°C and 100 bars (Figure 1).

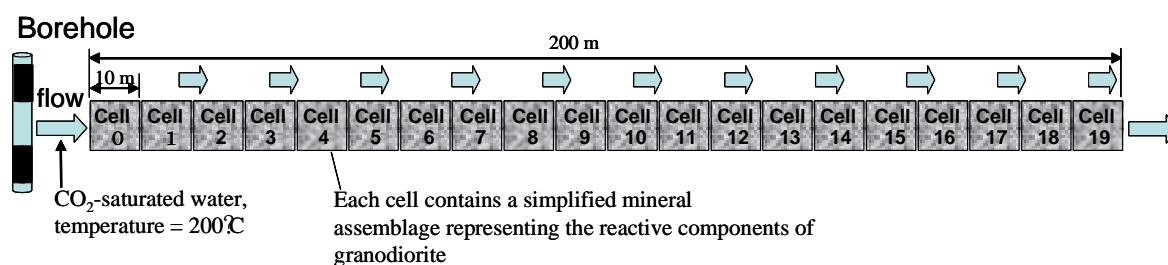


Figure 1. Schematic illustration of a 1D Raiden3 simulation of CO₂-saturated water migration through a granodiorite.

These Raiden3 simulations used kinetic data obtained from laboratory experiments and were run for periods of up to 100 years. The results indicate that CO₂ could be immobilized as solid calcite, which forms when the CO₂ combines with Ca²⁺ released by anorthite dissolution (Figure 2). The reactions are sufficiently fast that plausibly, dissolved CO₂ could be completely removed from the injected CO₂-saturated water over a length scale comparable to an actual reservoir (10² to 10³ metres). In the example illustrated, the maximum amount of calcite formed (275 mol m⁻³) would lock up all the CO₂ dissolved in water equivalent to about 5 rock pore volumes. A key finding is that after about 60 years the calcite precipitated initially near the injection point re-dissolves. It is predicted that this calcite could be re-precipitated further along the flow line. Variations in rock porosity are small and would not adversely affect the ability to inject CO₂ (Figure 3).

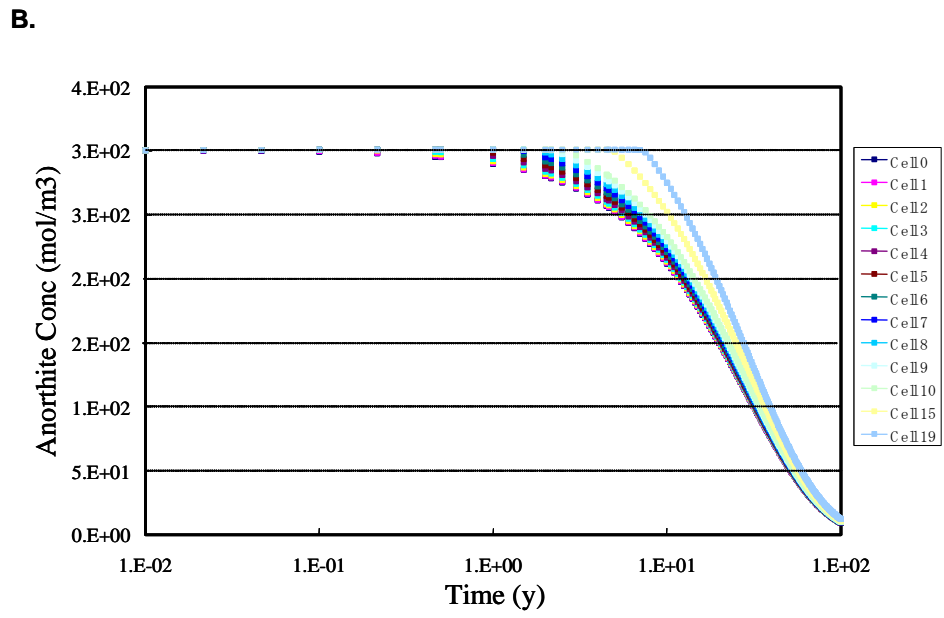
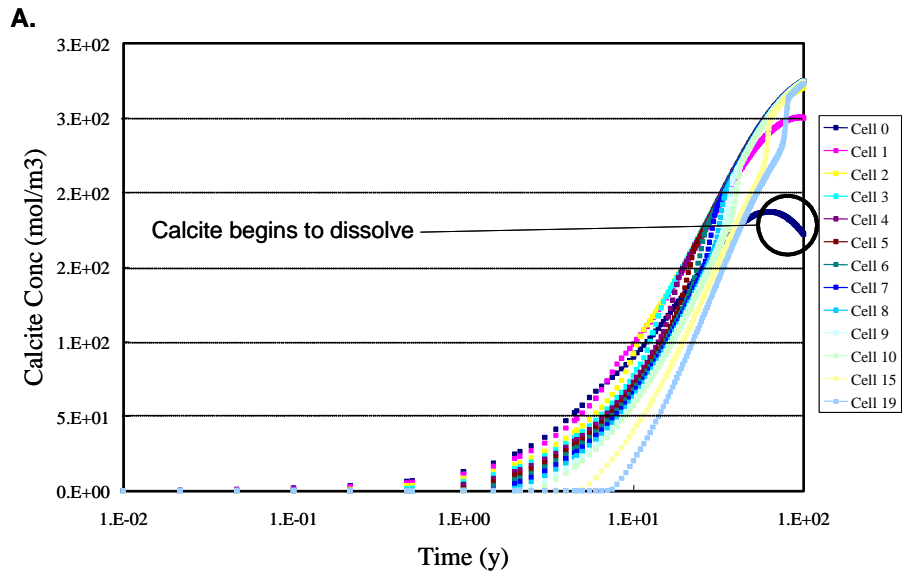


Figure 2. A. Variations in calcite concentrations along the 1D column as a function of time.
B. Corresponding variations in anorthite concentrations.

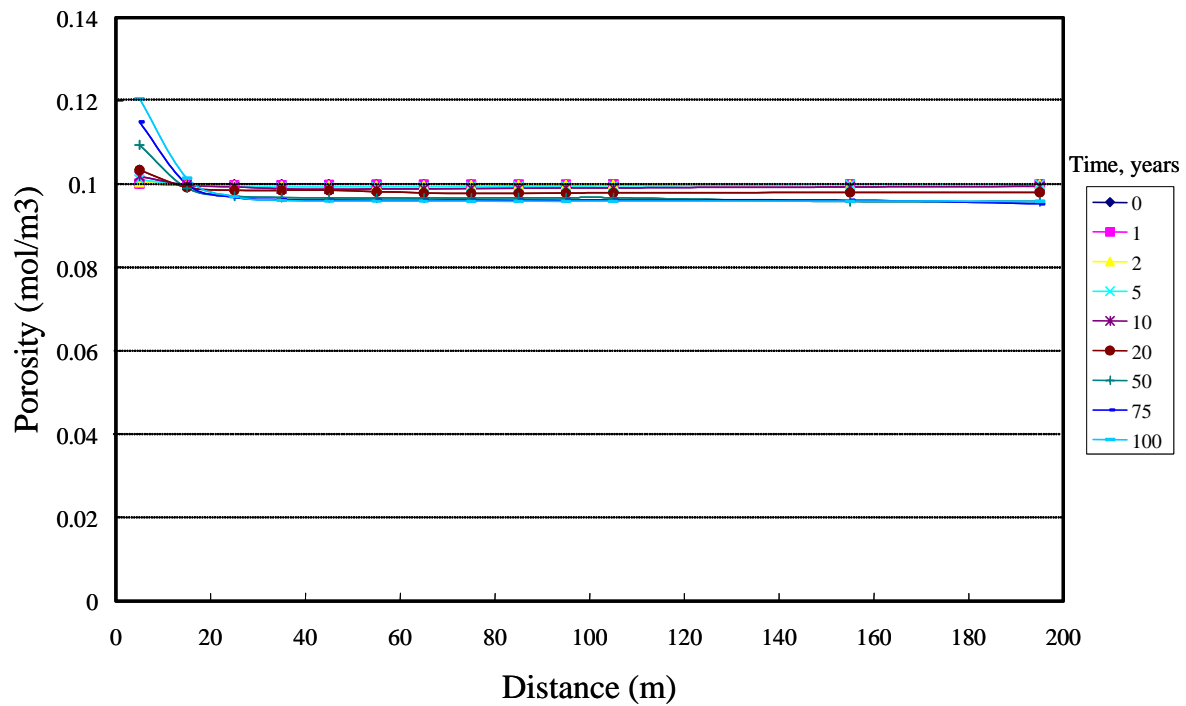


Figure 3. Variations in rock porosity during injection of CO₂-saturated water corresponding to the mineralogical changes illustrated in Figure 2.

These initial results indicate that, provided the injection rate is optimised for the prevailing temperature gradients, this sequestration option could be feasible and consequently merits further consideration. On-going work is investigating the sensitivity of these results to variations in chemical (especially kinetic) parameters and hydraulic parameters.