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Identification of a characteristic time and length for CO2 mineralization

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Owing to its ubiquity and the complexities arising from the coupling of flow with reaction, mineral precipitation in porous media remains a continued area of research in reactive transport. An area of current focus is the mineralization of CO2 in the subsurface. This is an attractive proposition because it allows for the secure and permanent sequestration of this greenhouse gas in subsurface reservoirs. In very general terms, this process involves the injection of a fluid charge, supersaturated in CO2, into the pores of a rock reservoir. Initial, in the vicinity of the entrance to the reservoir, the charge dissolves the rock and mixes with the existing pore water. However, at the point where sufficient cations have been taken up and the pH of the charge has increased, precipitation of calcite minerals occurs. Here, our focus will be on CO2 mineralization processes within rock masses that have relatively large values for the porosity and hydraulic conductivity. A particular target is basalts, with porosities in the range [0.05, 0.2] and hydraulic conductivities in the range [10-6, 10-5] m/s. Our expectancy is that CO2 mineralization in such systems is controlled by the clogging of the pore spaces with the mineral product. This clogging will restrict the ability to deliver the CO2 charge to the pore spaces at distances away from the reservoir entrance, eventually leading to complete clogging and shut-off termination of the operation. Within this scenario, our main aim is to arrive at a characteristic time and a characteristic length for the process, i.e., the time over which an effective operation can be sustained and the length (distance between input and output wells) that optimizes the storage potential of the reservoir. We achieve this by constructing a first order mineralization model that couples one-dimensional equations of porosity change, transport, and reaction. From this model we are readily able to identify a characteristic time scale for mineralization—essentially the earliest time for pore in the domain to clog. In addition, under the condition that flow through the domain is controlled by a fixed head drop, our model suggests the existence of a domain length that optimizes the storage, we propose that this an appropriate characteristic process length. A numerical analysis of the model identifies that a lower bound on this length can be obtained when the product of the hydraulic conductivity and head drop balances the mineralization reaction rate.

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References

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