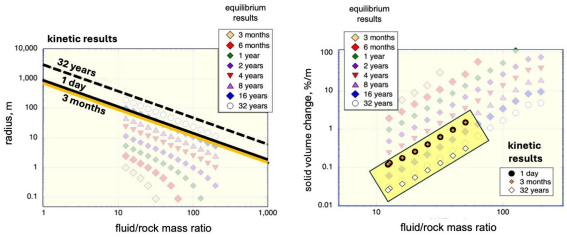
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Simple estimates of space & time variation of mineral dissolution & precipitation around boreholes injecting CO2-rich aqueous fluid for storage: Clogging, or not?

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A long-standing concern for subsurface CO_2 storage in reactive rock formations (ultramafic rocks including mantle peridotite, basaltic lavas) has been the potential for clogging of pore space with newly formed carbonate minerals. We have used EQ3/6 geochemical models and simple geometric parameterizations to explore length and time scales for precipitation and dissolution zones around boreholes used to inject CO_2-rich, aqueous fluids for geologic storage via carbon mineralization.

We first consider equilibrium reactions in uniform, cylindrical rings around a borehole. Initially, and far from the borehole, fluid-rock mass ratios are low, and fluid is close to equilibrium with the rock. As fluid-rock ratios reach intermediate values (5-10), precipitation of carbonate minerals, plus some hydration and oxidation, lead to increasing solid mass and volume, potentially filling pore space, even in basalt flow tops and other permeable horizons with initial porosity ~10 vol%. Where fluid-rock ratios rise to high values (>10), dissolution of carbonates and silicates in low pH CO_2-rich fluids moves the precipitation zone outward, and creates new pore space. For a given injection rate, we estimate the radii of precipitation and dissolution zones around the borehole as a function of time. Porosity changes are smaller when the initial rock is highly altered, minimizing solid volume increase due to hydration and oxidation, but mineralization still increases solid volume by > 10 vol%.

Using very simple parameterizations, we then show how kinetic inhibition - of mineral precipitation and/or the reactions changing pH - yields precipitation zones with larger volumes, extending farther from the borehole at any given time. Mineral formation in these wider precipitation zones is diffusely distributed, and may never fill pore space.

Moreover, the "reaction infiltration instability" can create porous dissolution channels with high fluid-rock ratios, focusing flow of acidic, CO_2-rich fluids farther from the borehole, penetrating cylindrical “precipitation fronts”. This could distribute precipitation over a larger rock volume and avoid clogging of pore space. Indeed, in this application, the reaction infiltration instability could be tuned, to form holes through precipitation fronts, accessing additional pore volumes, and optimizing carbon mineralization throughout a target aquifer, in both sedimentary and igneous rocks.