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Mineralogical and transport controls on the evolution of porous media texture

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Understanding the evolution of porous media is essential for many subsurface energy applications, including subsurface storage, shale gas production, fracking, CO2 sequestration, nuclear waste storage, and geothermal energy extraction. Both mineral composition and the intial pore structure of the medium play a significant role in this evolution. Conventional Darcy-scale models treat porous media as a continuum. This approach requires the assumption of well-mixed conditions inside the pore space as well as the use of mechnistic relationships between bulk parameters as the porous medium evolves (e.g. porosity-permeability, porosity-tortuosity). More recently, pore-scale models along with advanced characterization techniques have allowed for accurate simulations of flow and reactive transport within the pore space.

Here we use pore scale modeling to study the evolution of mineralogically and physically heterogeneous porous media as a result of mineral dissolution. We consider scenarios associated with CO2 sequestration focusing on the dissolution of carbonate minerals under a range of flow conditions in granular and fractured domains. For this purpose, a pore-scale flow and reactive transport model is developed that explicitly tracks mineral surfaces as they evolve using a direct numerical simulation approach.

Simulations of dissolution in single-mineral domains provide insights into the transport controls at the pore scale, while the simulation of a fracture surface composed of bands of faster-dissolving calcite and slower-dissolving dolomite provides insights into the mineralogical controls on evolution. Transport-limited conditions at the grain-pack scale may result in unstable evolution, a situation in which dissolution is focused in a fast-flowing, fast-dissolving path. Due to increasing velocities, the evolution in these regions is like that observed under conditions closer to strict surface control at the pore scale. That is, grains evolve to have oblong shapes with their long dimensions aligning with the local flow directions. Another example of an evolving reactive transport regime that affects local rates is seen in the evolution of the fracture surface. As calcite dissolves, the diffusive length between the fracture flow path and the receding calcite surfaces increases. Thus, the calcite dissolution reaction becomes increasingly limited by diffusion.

References

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