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Author

Xu, Tianfu

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Analysis of Mineral Trapping for CO₂ Disposal in Deep Aquifers

Tianfu Xu, John A. Apps, and Karsten Pruess (Earth Sciences Division, Lawrence Berkeley National Laboratory, University of California, Berkeley, CA 94720; [510-486-7057](tel:510-486-7057); e-mail: Tianfu.Xu@lbl.gov)

CO₂ disposal into deep aquifers has been suggested as a potential means whereby atmospheric emissions of greenhouse gases may be reduced. However, our knowledge of the geohydrology, geochemistry, geophysics, and geomechanics of CO₂ disposal must be refined if this technology is to be implemented safely, efficiently, and predictably. As a prelude to a fully coupled treatment of physical and chemical effects of CO₂ injection, we have analyzed the impact of CO₂ immobilization through carbonate precipitation. A survey of all major classes of rock-forming minerals, whose alteration would lead to carbonate precipitation, indicated that very few minerals are present in sufficient quantities in aquifer host rocks to permit significant sequestration of CO₂. We performed batch reaction modeling of the geochemical evolution of three different aquifer mineralogies in the presence of CO₂ at high pressure. Our modeling considered (1) redox processes that could be important in deep subsurface environments, (2) the presence of organic matter, (3) the kinetics of chemical interactions between the host rock minerals and the aqueous phase, and (4) CO₂ solubility dependence on pressure, temperature and salinity of the system. The geochemical evolution under both natural background and CO₂ injection conditions was evaluated. In addition, changes in porosity were monitored during the simulations. Results indicate that CO₂ sequestration by matrix minerals varies considerably with rock type. Under favorable conditions the amount of CO₂ that may be sequestered by precipitation of secondary carbonates is comparable with and can be larger than the effect of CO₂ dissolution in pore waters. The precipitation of ankerite and siderite is sensitive to the rate of reduction of ferric mineral precursors such as glauconite, which in turn is dependent on the reactivity of associated organic material. The accumulation of carbonates in the rock matrix and induced rock mineral alteration due to the presence of dissolved CO₂ lead to a considerable decrease in porosity. The numerical experiments described here provide useful insight into sequestration mechanisms, and their controlling conditions and parameters.

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