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Simulation of Fluid Pressure and Fracturing in CO_2 Sequestration

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Abstract

CO_2 sequestration in underground aquifers has the potential to reduce atmospheric CO_2 emissions on the order of hundreds of gigatons. However, rock fractures, formed during injection, may release toxic species into the water table and release CO_2 into the atmosphere. A model to compute the internal rock stresses induced by the injection of CO_2-rich water is developed to simulate the initiation and propagation of rock fractures. A mixed finite element-finite volume model is used to calculate the fluid pressure, stresses, and strains induced by injection of CO_2 into a geologic saline aquifer-caprock formation. The Terzaghi effective stress is determined from the calculated overburden pressure and fluid pressure. When the Terzaghi effective stress exceeds the rock tensile stress at a given depth, simulated fractures are induced. The effect of the simulated fractures is upscaled to the reservoir scale by estimating an incremental permeability by means of Oda's permeability tensor. The effect of fractures on the mineralization of CO_2 is simulated by estimating the impact of fractures on the free surface area of the solid, rock phase. The free surface area impacts the dissolution and precipitation of carbonate minerals. We examine the optimal rate of fracturing to maximize the amount of CO_2 sequestered while minimizing the risk of damaging caprock integrity, and minimizing transport of CO_2 through the caprock layer. This poroelastic pressure and fracture module is used to approximate formation pressure during injection of CO_2 rich water into the Oligocene Frio Formation along the Texas Gulf Coast, with simulation parameters derived from the Frio Test Pilot Experiment. Simulation results are compared to bottom-hole pressure data obtained from an observation well 30 meters away from the injection well, during a 35-day monitoring phase beginning with four days of CO_2 injection.