Geologic Carbon Storage: Implications of Two-Phase Flow on Injection-Induced Stress on Faults

S. Prasun[1], S. Kim[2], S. A. Hosseini[3]

[1]Louisiana State University, Baton Rouge, LA, USA
[2]Department of Civil Engineering University of Nebraska - Lincoln, Omaha, NE, USA
[3]Bureau of Economic Geology, University of Texas - Austin, Austin, TX, USA

Abstract

Geologic carbon storage that involves injecting carbon dioxide (CO2) into a subsurface sequestration site provides the vital approach for reducing CO2 emissions into atmosphere and thus addressing climate change issue. One challenge associated with CO2 geologic storage is that pore-pressure buildup and subsequent poroelastic stress changes during CO2 injection may result in injection-induced seismicity on faults. Most of previous studies implemented numerical simulations based on a single-phase fluid flow condition during CO2 injection into a saline aquifer to investigate such a concern. This preposition neglects the effect of high compressibility of supercritical CO2, which may lead to an incorrect estimate of the poroelastic stress changes on faults. The objective of this study is to examine the effect of two-phase flow simulation and CO2 compressibility on the poroelastic stress changes for conductive faults connected to the target formation. This study compares results from the two-phase (CO2+water) flow condition with those from the single-phase flow condition to justify the adoption of two-phase numerical model.

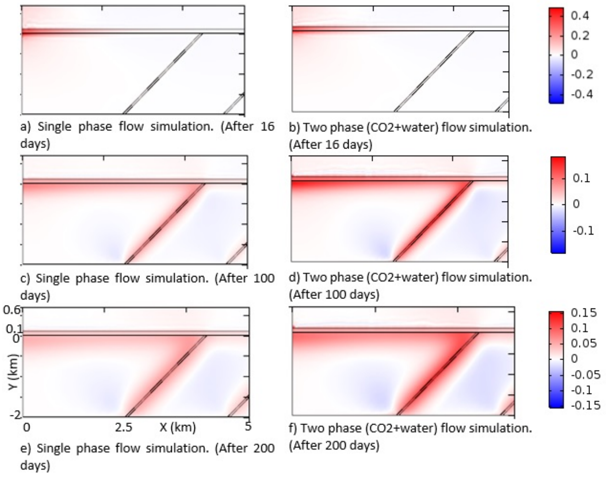
The simulation method in this study employs the Equation Based Modeling interface (i.e., coefficient form PDE module) in COMSOL to solve non-linear partial differential equations (PDE) with two dependent variables, 'saturation' and 'fluid-phase pressure' that define the two-phase CO2 and water immiscible flow. The equations include the gravity, capillary and fluid compressibility effects. The effect of solid deformation on pore pressure in the source term defines the solid-to-fluid coupling. The relative permeability interpolation table defines the mobility of each phase in a saline formation. The fluid-to-solid coupling is introduced by coupling PDE module with the COMSOL solid-mechanics interface that governs the change of stresses as a function of pressure. During the simulation, a constant injection rate of CO2 is imposed on the sandstone formation that is underlain by the basement rock with faults in it and overlain by an impermeable mudrock.

Inclusion of two-phase flow condition leads to a slower pore pressure diffusion into the basement layer due to the high compressibility of injected CO2, which results in a higher pore pressure concentration in the injection aquifer. Both single and multiphase fluid flow simulation demonstrated the larger change in the coulomb stress on faults where direct diffusion of pore pressure occurs, compared to the case where indirect poroelastic effect induces smaller changes in the coulomb stress on faults. However, the single-phase flow assumption significantly underestimates the coulomb stress changes in the target formation and faults in the basement where direct pore pressure changes occur. This implies that the single-phase flow assumption can substantially underestimate the

likelihood of injection-induced seismicity, particularly in conductive faults that are connected to the target formation.

This study using COMSOL Multiphysics provides a better fully-coupled poromechanical two-phase flow model that can improve an accurate estimate of stress field changes. Therefore, it may potentially be used for a better prediction of injection-induced seismicity on faults.

Figures used in the abstract



a) Single phase flow simulation. (After 16 days)

b) Two phase (CO2+water) flow simulation. (After 16 days)

c) Single phase flow simulation. (After 100 days)

d) Two phase (CO2+water) flow simulation. (After 100 days)

e) Single phase flow simulation. (After 200 days)

f) Two phase (CO2+water) flow simulation. (After 200 days)

Figure 1: Comparison of Change in coulomb stress between single phase fluid flow condition and two phase flow condition due to poroelastic stressing, Δτ (MPa) at t=16, 100 and 200 days for conductive faults