Numerical simulation of variational pore pressure response to ocean tidal loading during CO2 injection

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As a promising measure against global warming, CCS (Carbon dioxide capture and storage) has been extensively studied over recent decades and some large-scale projects are currently in operation worldwide. Carbon dioxide is captured from flue gases emitted from large sources such as coal-fired power plant, and injected and kept stored in a deep geologic formation for long-term. In the geologic CO2 storage, reliable and cost-effective monitoring techniques of the injected CO2 need to be established. It is well known that the pore-pressure of groundwater is affected by the earth and ocean tides. Recently, at a geologic CO2 storage project, it has been reported that the pore-pressure fluctuation at a monitoring well is explained by diurnal earth tides, and the amplitude of the pressure fluctuation significantly attenuated when the carbon dioxide arrived at the well due to the changes in compressibility of pore fluid around the well (i.e. the compressibility of CO2 is much smaller than that of water). This suggests a potential low-cost CO2 monitoring technique through monitoring and analyzing tidal responses of pore pressure during geologic CO2 storage. The tidal response of pressure is understood as a hydro-geomechanical coupled phenomena in deformable porous media containing water and CO2. Previous studies indicated that the changes in amplitude of pore-pressure before and after CO2 arrival at a monitoring well can be simply explained by poroelasticity theory. However, numerical simulations are required to further quantitatively investigate the tidal effects on pressure fluctuation at monitoring wells during CO2 injection. For example, the pressure response is possibly affected by many geometrical and geological settings in three-dimensional space, such as distance between the monitoring wells and CO2 plume, geometry of CO2 plume, and pressure dissipation induced by fluid flow. In this study, we developed a numerical simulator in the framework of poromechanics to simulate three-dimensional deformations and stress changes of geological formations under two-phase flow conditions of water-CO2, which was enhanced to be adoptive to cyclic loading by diurnal and semi-diurnal tide. Using this simulator, we investigate variation of responses of pore water pressure to the ocean tide loading during CO2 injection. Amplitude of the response at injection well decrease during CO2 injection, and somewhat recovered due to upward movement of CO2 plume after injection. The final amplitude in this simulation is smaller than initial amplitude under water saturated condition due to an effect of CO2 plume staying top of the reservoir.

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