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An analytical approach of CO_2 injection induced caprock deflection

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CO_2 storage in geological formation, especially in deep aquifers, is becoming a compromising method to reduce the impact of CO_2 on the greenhouse effect. Practically, large-volume (>1Mt/year) of CO_2 could be injected into a deep aquifer. However, the response of such system is complex because of coupling between the flow and mechanical responses. High rate injection could result in an abrupt fluid pressures build-up, deforming the aquifer and result in surface uplifting, which highly affect public acceptation to the CO_2 storage projects.

The study focuses on a specific problem related to the surface uplift induced by the injection of CO_2 at depth. The methodology in this study includes the development of a mathematical model that incorporates elastic behaviour of storage mediums and two immiscible fluids (CO_2 and water) flow within the aquifers while surface rock layer is modelled as a thin plate. Governing equations are solved for the axisymmetric flexure deflection due to a constant rate injection of CO_2. Coupling between porosity and permeability is included via an iterative schema. Numerical integration stability has been improved as well.

Results show that this semi-analytical solution is capable to capture the pressure build-up during the very early stage of injection, resulting in a high rate surface uplift. With hydromechanical effects, pressure tends to stabilize and surface deformation rate decreases. Compared to FEM simulation, the calculation time carried out by the semi-analytical solution is very short. It can be employed as a preliminary design tool for risk assessment such as injection rate, porosity, rock properties and geological structures. This semi-analytical solution provides a convenient way to estimate the influence of high rate injection of CO_2 on the surface uplift. The methodology in this development can easily incorporate other pressure distributions. Thus one can benefit from the advances in hydrology researches as well.