THERMO-HYDRO-MECHANICAL MODELING OF GEOLOGIC CARBON STORAGE

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ABSTRACT

Carbon dioxide (CO_2) storage in deep geological formations is considered a promising solution for mitigating CO_2 emissions to the atmosphere. Currently, the emissions of this greenhouse gas as a result of hydrocarbon combustion for power generation exceed 30 Gt/yr. As a result of these emissions, the CO_2 concentration in the atmosphere has increased from the pre-industrial level of 280 parts per million in volume (ppmv) to the current 400 ppm. This increasing CO_2 concentration is affecting our climate and undesirable consequences are likely to occur. For instance, semiarid regions are experiencing a decrease of soil moisture that causes a sudden, irreversible shift towards desert conditions (Solé, 2007). If we want to keep the CO_2 concentration in the atmosphere below 450 ppmv to mitigate climate change, we should carry out several actions to significantly reduce our CO_2 emissions, including geologic carbon storage.

Pressure and temperature conditions of deep geological formations suitable for storing CO_2 are such that this greenhouse gas remains in a dense state, i.e., liquid or supercritical. Actually, in the conventional CO_2 storage it is usually assumed that CO_2 will reach the reservoir in supercritical conditions. However, CO_2 may not be in thermal equilibrium with the medium when it enters the aquifer because pressure and temperature injection conditions at the wellhead can be diverse and CO_2 will not equilibrate with the geothermal gradient if the flow rate is high (Paterson et al., 2008). Furthermore, injecting liquid (cold) CO_2 and maintaining liquid conditions along the wellbore is energetically efficient (and therefore, it is

likely to become a common practice) because it significantly reduces compression costs (Vilarrasa et al., 2013). Therefore, modeling of CO_2 injection and storage in deep saline formations should take into account non-isothermal two-phase flow processes in deformable porous media.

Thermo-hydro-mechanical modeling of CO_2 storage in deep saline formation is done using the finite element numerical code CODE_BRIGHT (Olivella *et al*., 1994, 1996) extended for CO_2 injection (Vilarrasa et al., 2013; 2014). We analyze the impacts of cold CO_2 injection on the rock mechanical stability, with a special focus on the caprock integrity.

We found that injection of cold CO_2 develops a cold region around the injection well that induces a thermal stress reduction in the reservoir due to its contraction. Stress redistribution, which occurs to satisfy stress equilibrium and displacement compatibility, causes the horizontal total stress to increase in the lower portion of the caprock. We show that it is important to properly consider thermo-hydro-mechanical processes in the reservoir and caprock, including complex interactions between the fluid and the porous media, especially in the low permeability caprock. In particular, we show that accounting for the thermal expansion of the grains is very important in low porosity formations to avoid simulating artificial porosity and total stress reductions in the cooled region of the caprock that yield unreal high mobilized friction angles in the lower part of the caprock in normal faulting stress regimes. Overall, injecting cold CO_2 should not be feared because of the thermal stresses reduction, though care should be taken to avoid excessive induced seismicity.

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