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Coupled fluid flow and geomechanical modeling in geological CO2 storage: Application to Matsushiro phenomena

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The mechanical responses of CO2 reservoir and the caprock around the storage region become crucial for Japanese geological CO2 storage (GCS) after the M9.0 East Japan earthquake on March 11, 2011. The CCS Research Committee, METI (Ministry of Economy, Trade and Industry), recommended to screen out areas having a large-scale faults in the process of selection of storage site for 105t-scale demonstration (2009). Although the site for the planned demonstration adequately selected, we do not exclude fully at present the possibility of GCS reservoir failure and/or leakage of stored CO2 from GCS site(s) elsewhere in Japan caused by geomechanical motions.

The examples of such phenomena are the re-activation of pre-existing faults, induced seismicity, reservoir failure and unintended uplift and so on, some of which are observed in an actual demonstration site (Mathieson et al., 2009; Vasco et al., 2010; Onuma et al., 2011).

The unintended phenomena listed above are essentially connected with stress filed changes due to the increase in pore pressure, around the area of GCS, which is inevitable as GCS injects pressurized CO2 into an underground reservoir. The rise in pore pressure reduces an effective confining stress to modify the conditions toward the critical failure line of Mohr-Coulomb law. The change in pore pressure is most probably cause micro-scale (or, pore-scale) deformations within the rocks, which will give rise to the changes in rock permeability. The permeability change probably cause a change in fluid flow underground in the next step, which will promote further rock deformation and then change in fluid flow. The sequence of process can be analyzed by a coupled analysis using fluid flows simulator for rock media and that calculating the geomechanial process under the changing pore pressures. The TOUGH-FLAC code is a good and working example of this coupled simulator, being applied to follow the CO2 motion within faulted and tectonically active formations (Rudqvist et al., 2007, 2008) .

We consider that the coupled simulation of fluid flow and geomechanics, exemplified by TOUGH-FLAC simulation collaborating with LBNL, is the most important tool in developing the scheme to assess the fluid-mechanical conditions around the underground storage regions of CO2.

As not enough data such as rock deformation related to fluid flow is available from GCS site for evaluation of TOUGH-FLAC code applicability to Japanese geological condition, we investigate the Matsushiro field, Nagano, central Japan is selected for our natural analogue study. The Matsushiro field is famous for the earthquake swarm associated with the CO2-rich fluid upwelling during the period of 1965-1967. The Matsushiro phenomena was previously studied by using TOUGH-FLAC (Cappa et al., 2009), however, the geological model was simplified very much, so it is afraid that the possibly important geological features can be missed.

In this study, we modified their model based on the various filed and laboratory data and re-constructed the geological model with three layered strata according to P-wave velocity profile.

TOUGH-FLAC simulation has been conducted using updated geological model. The simulation results indicated the ground uplift due to fluid injection and the maginitude of the ground uplift is reasonably agree with actual observation in Matushiro field during the swarm.

Keywords: Coupled fuild flow geomechanical modelling, Geomechanics, Geological CO2 storage, Natural analogue, Matushiro phenomena