A natural analogue study of CO2 migration in faults using Matsushiro Earthquake Swarm data

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Because the dynamics and long-term behavior of faults are difficult to characterize by laboratory tests, studies of natural analogues provide valuable knowledge about potential fault behavior during deep injection of CO_2.

A swarm of earthquakes began in the Matsushiro area of Nagano city, Central Japan in 1965. The most active period lasted until 1967, followed by a five-year period of lower activity. During the earthquake swarm, a large volume of CO_2-saturated water discharged at the ground surface through surface ruptures in the epicenter region. The earthquake swarm was well observed and documented, and many scientists investigated the mechanism behind the tremors.

The earthquake swarm is a promising natural analogue to study the interaction of CO_2 bearing fluid flow and solid deformations. Thus, we started a study using coupled processes modelling and geochemical monitoring in the region.

In this region, approximately 60,000 earthquakes were felt while an additional ten times, i.e. about 600,000, unfelt tremors were recorded (JMA, 1968) during five-year-term (1965-1970). The total energy released was M6.4. During the swarm, ten million tons of CO_2 bearing water discharged at the surface through newly created surface ruptures. Beneath the ruptured zone, there was an active fault. The distribution of the surface ruptures and horizontal displacements of the ground surface showed movements along a left lateral, NW-SE oriented, strike slip fault, which is centered near the swarm epicenter. Also, up to 90 cm of uplift was measured. Those facts suggest that one probable cause of the swarm is water intrusion from great depth and associated dilatancy reactivated the fault system. Nakamura (1971) defined this mechanism as a water eruption.

Adding the mechanism of the water eruption, we hypothesize that chemical and mechanical interactions of CO_2 with the formations played key roles controlling the eruption of water and CO_2 at the surface.

Hence, we are studying how CO_2 migration depends on the dynamic behavior within the deep formations. The dynamic fault behavior affecting the trapping mechanisms for CO_2, and how potential breaching of cap formations along faults and the overlying fault system are the most interesting part of the study. To investigate the hypothesized mechanism for CO_2 release, and to investigate at what conditions such phenomena could occur, we plan to 1) synthesize existing data for the Matsushiro site, 2) conduct new CO_2 flux measurements at the site, and 3) perform coupled processes modelling, including both geomechanics and geochemistry.

Geochemical modeling with the TOUGH-REACT reactive transport simulator (Xu et al., 2004) is used to analyze fluid flow, including phase transition of CO_2 and chemical reaction of carbonic acid and rocks. The coupled CO_2 fluid flow and mechanical processes, including fault motion and associated permeability changes, are modelled using the TOUGH-FLAC coupled reservoir-geomechanical simulator (Rutqvist et al., 2002).

Using the Matsushiro as a natural analogue for studies of fault, the behavior of faulted and CO_2 injected region will be investigated. The outcomes of the study will be valuable for establishing risk assessment for CO_2 seepage through faults.

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