CO2-driven Matsushiro swarm earthquakes: natural analogues of underground CO2 storage in Japan

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CO_2 and brine combined eruption triggered the Matsushiro swarm earthquakes at the Matsushiro in the Nagano City, central Japan since August 1965. The earthquake activity at the Matsushiro culminated in April 1966. Then, the earthquake activity quickly declined after CO_2 was released from newly formed surface cracks in the Matsushiro Earthquake Fault Zone. Large amount of CO_2 and brine fountained from cracks in and around the Earthquake Fault Zone. The mechanical and chemical analyses suggest that CO_2 bubbles induced the fluid pressure increase in shallower tips of cracks that eventually triggered swarm earthquakes. Big underground CO_2 bubbles of supercritical fluid and gas may induce fault instability and small earthquakes under critical tectonic stress states. Although CO_2 driven earthquakes are possibly very small, careful investigation of faults, in situ stresses, crustal deformation and seismicity are necessary to store large amount of CO_2 underground. Mechanical analyses indicate that CO_2 solution and CO_2 microbubbles do not induce large underground mechanical instability such as big bubbles of CO_2 supercritical fluid and CO_2 gas may induce.

Although possibly some 100 thousand tons of CO_2 were released with about 10 million tons of brine from cracks and fountains, the Matsushiro swarm earthquakes did not cause any casualties. The water-rich surface condition buffered the adverse effect of release of CO_2. About forty years later, shallow fresh groundwater almost completely cover up deep CO_2-rich brine except for a few spots of sporadic rise of few small bubbles in the area with thin shallow groundwater cover. Shallow groundwater covers deep CO_2-rich brine almost completely deep CO_2-rich brine in spite of the monoclinal geological structure of the Isobe natural carbon dioxide reservoir in the Annaka City, Gunma Prefecture, central Japan.

The CO_2-rich volcanic gas (72-95% CO_2) gushes from some 10 vents at the sea floor of the depth 78-200m in the northern Kagoshima bay, southwestern Japan. The volcanic Aira caldera formed the nearly closed sea basin of the northern Kagoshima bay. Total amount of CO_2 release is estimated about 20-100 tons- CO_2 per day. Most of CO_2 in gas bubbles are dissolved into the seawater within the several meters rise above the vents, while CO_2-free bubbles appear on the sea surface. The deep seawater is acidified in summer. However, the deep block of acidic sea water disappears in winter when the convection of seawater is active.

Water is important for the safety of underground CO_2 sequestration as a buffer against the adverse effects of CO_2.