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Geochemical reproduction of deep water related to Matsushiro earthquake swarm for TOUGH-FLAC simulation

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A technique of fluid flow ? rock mechanics couple simulation is attracting attentions in the research on CO2 geological storage (CGS) as a promising tool to assess stress conditions in reservoir and caprock associated with CO2 injection. The assessment is important in CGS to set conditions for sustainable injection that does not cause dynamic responses of underground rock mass such as plastic deformation, minor fracturing, re-activation of small faults and so on. AIST is conducting a study using TOUGH-FLAC simulator developed by LBNL, USA, to numerically simulate the 1965-1967 Matsushiro earthquake swarm as a natural analogue of dynamic leakage of stored CO2 associated with fault re-activation. The study using natural data was chosen as the basic data on ground motions and recognizable seismicity would never be obtained in actual CGS demonstration sites because the dynamic responses of rock mass must not occur in the demonstration. The objective of this natural analogue study is to customize the simulator applicable to Japanese CGS sites having bedrocks composed of so-called ”soft rock”.

It is necessary for fluid flow ? rock mechanics coupled simulation to give salinity of formation water in a geologic model as an initial condition. In the case of Matsushiro simulation, the salinity of injected water is also necessary since the Matsushiro earthquake swarm is considered to be caused by a forcible intrusion of saline water beneath the Marsushiro area. The salinity of initial formation water is determined from water geochemistry on several deep wells obtained in the survey during 2010-2011. The salinity of input water is newly estimated based on the similar dataset combined with hydrogen and oxygen isotopic ratios. The hydrogen and oxygen isotopic ratios of well water fall on a line having a gentle slope as compared to the meteoric water line (MWL), a similar relation reported by Yoshida et al. (2002). The extension of this line presents a field of ”andesitic water” by Guggenheim (1992). Assuming that the deep water caused the earthquake swarm has isotopic characteristics of the minimum of ”andesitic water”, the ratio of dilution of the deepest well water was determined from the isotopic ratios of the ”andesitic water” and of the shallow ground water on the MWL. The geochemistry of the deep water caused the earthquake swarm was then determined by using the dilution ratio and the compositions of the deepest well water. The salinity of the deep water caused the earthquake swarm is found to be comparable to present sea water. The salinity is about 7 times higher than that assumed in the previous study of TOUGH-FLAC modeling of the Mtaushiro earthquake swam (Cappa et al., 2009). Similarly, the concentration of HCO3 is estimated by using well water data. The estimated amount of CO2-related soluble species indicates that the initial deep water was oversaturated with respect to CO2 at the postulated temperatures and pressures of Matsushiro simulation.

Keywords: CO2 geological storage, Matsushiro earthquake swarm, natural analogue, dynamic leakage, TOUGH-FLAC, salinity