Experimental investigation on fault reactivation by water injection and the relationship between slip characteristics and injection rate

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In-situ water injection tests have been conducted in the geothermal field reveal that changes in the water injection rate may induce earthquakes (Okamoto et al., 2018). It has also been confirmed in laboratory experiments that stick-slip is induced by the rapid water injection rate, and fault creep is caused by the slow water injection rate (Wang et al., 2020). This result indicates the injection rate is important in considering the mechanism of induced seismicity while the injected volume is thought to play a key parameter for the induced seismicity (McGarr, 2014). However, the relationship between the water injection rate and the magnitude of induced seismicity, which is an indicator of safety in resource development, remains unclear. To investigate the contribution of the injection rate to the mechanism and magnitude of fault slip caused by injection, we conducted water injection tests on thermally cracked Inada granites with 1) only pre-cut fault and 2) with borehole that reaches from the bottom of the sample to the pre-cut fault surface. From the results of elastic wave velocity tomography, estimated water pressure along the fault, and fault failure analysis based on the Mohr-Coulomb law, it is clear that stick-slip occurs when the increase rate of water pressure in the fault (pressurization rate) exceeds a certain threshold, which is ~1.2×10^{-2} MPa/sec for this series of experiments. Since the rate of water supply to the fault is governed by the hydraulic diffusivity of the rock near the fault, sudden stress drop could occur repeatedly even after the onset of slip if pore pressure in the rock surrounding the fault is higher than the pore pressure within the fault zone. This indicates that even if the water injection is stopped in a resource development site, induced seismicity may occur depending on the residual pore pressure and its diffusion rate.

Keywords: injection rate, induced seismicity, Inada granite

