Hydraulic monitoring results during SIMFIP injection experiments through Shionohira fault zones in Fukushima Prefecture, Japan

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The Shionohira fault caused the April 11, 2011 Fukushima ken Hamadori Earthquake of Mw 6.7 which occurred one month after the Tohoku-Oki earthquake of Mw 9.0. Co-seismic surface ruptures trending NNW-SSE allowed to estimate a normal slip faulting with a 2 m maximum displacement. The authors have been conducting a series of studies at the Shionohira fault and its southern extensions in order to develop a fault activity evaluation method.
The fault slip injection tests using a SIMFIP (Step-Rate Injection Method for Fracture In-situ Properties) probe have been performed at the Shionohira and Minakamikita sites (Aoki, et al., 2019 and Watanabe, et al., 2019). This report gives the hydraulic monitoring results obtained from a borehole located about 3m distance from the injection hole during the injection tests conducted at both sites.

In the fault slip injection tests, double packers were placed above and below the underground fracture and high pressure water was injected from the surface to artificially trigger a slip in the fracture in order to measure the three dimensional deformation in micrometer to millimeter units (Guglielmi et al., 2013). Pore pressure was monitored in a monitoring hole located about 3 meters from the injection hole in order to check the continuation of a fracture zone and to obtain hydro-mechanical data.

Significant increase in pore pressure was measured in the intervals of fault fracture zone corresponding to the increase of water inflow at both Shionohira and Minakamikita sites, suggesting that water flow pass had been created from the injection interval to the monitoring boreholes through fracture plane. Backflow of the injected water from the open fracture back into the interval was also observed. Permeability in fault plane will be discussed at the conference.

At Shionohira site, a vertical injection borehole of 30m length was drilled at 7.3m from the top of the fault escarpment (S70W) perpendicular to the strike of Shionohira fault (N20W). A vertical monitoring borehole of 30m length was drilled in the direction of S70W at 7.3m from the top of the fault escarpment perpendicular to the strike of the fault. The distance between the two boreholes was 3.3m running nearly parallel to the fault at N8W. Pore pressure was monitored with a single packer set at depths of GL.-12.20m to GL.-13.20m in the monitoring borehole. Test 1 was conducted between depths 7.0m and 11.5m isolated with upper and lower packers and pressurized above the recently activated fault zone in the unfaulted sandstone layers. Test 2 was conducted between depths 12.8m and 17.3m across the recently activated fault zone. Test 3 was held at depths between 17.0m and 21.4m to assess the ancient fault activation zones in the metamorphic green schist. A significant increase in pore pressure was measured in Test 2.

At Minakamikita site, the target fault has an N-S strike with a dip of 80 degrees to the west. Because of the limitation in study area, injection and monitoring boreholes were drilled at 50 degrees to the east from the surface, of 30m lengths each. The distance between the two boreholes was 3.5m. Pore pressure was monitored with double packers set at depths of GL.-17.0m to GL.-18.0m and GL.-25.0m to GL.-25.9m in the monitoring borehole.

Injection tests were performed at the following four intervals: (1) fracture zone 1 (G.L.-19.75 to -21.70m); (2) fracture zone 2(G.L.-21/65 to -23.60m); (3) sandstone layer G.L.-17.85 to -19.80m); and (4) greenschist (G.L.-23.29 to -25.24m). A significant increase in pore pressure was measured at interval (2).

Keywords: Shionohira fault, SIMFIP experiment, Hydraulic monitoring, Injection experiment

