

Effects of water injection and groundwater outflow on the temperature profile in a borehole drilled into the Nojima fault zone

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We have been monitoring the temperature profile in a borehole drilled into the Nojima fault, which ruptured during the 1995 Hyogo-ken Nanbu (Kobe) earthquake. An optical fiber cable is used as a temperature sensor and the temperature distribution continuously along the cable is measured down to 1460 m depth with a resolution of about 0.1 K. We started temperature monitoring in July, 1997, 2.5 years after the earthquake. The overall temperature profile has been very stable, except for a local anomaly around 500 m that could be observed during the initial one month only. It indicates that effects of the earthquake on the thermal structure of the fault zone, if any, had become negligible in 2.5 years.

A series of water injection experiments was conducted in January to March, 2000. Water was injected into the borehole repeatedly with different pressures and flow rates. The injected water should lower the temperatures in the hole, but temperature decrease was observed only above about 550 m and no appreciable temperature change was detected below this depth. It suggests that the water leaked out of the hole near this point, though the hole was cased from the surface to the bottom with a perforated zone between 1596 m and 1671 m. After the cessation of injection, the temperature profile gradually returned to the original one but the recovery rate was much slower in some depth ranges. The recovery around 500 to 550 m was especially slow, probably because the water leaked out of the hole had cooled the surrounding formations extensively. It resulted in a local temperature anomaly, which was very similar to the one observed in July, 1997. The anomaly in 1997 is therefore thought to have been due to water leakage in a previous water injection experiment conducted in January to March, 1977. We will also report on results of another series of injection experiments scheduled for March to May, 2003.

The top of this borehole has been sealed since the optical fiber cable was installed, while natural outflow of groundwater had been observed before the installation. To investigate the nature of this groundwater flow, we monitored the temperature profile keeping the hole top open in two periods, October 31 to November 25, 2000 and January 7 to February 14, 2003. Outflow of groundwater containing some gas started right after the opening of the hole and continued throughout the two test periods. The upward water flow inside the hole caused a temperature rise above about 540 m in both cases. It means the groundwater flow came into the hole at this depth, which is the leaking point during the water injection experiment. The flow rate in the second test is about the same as that in the first test, indicating the outflow is driven by a natural overpressure at this depth, not a result of the water injection.