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Monitoring of temperature profiles in boreholes with an optical fiber system

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We have been conducting temperature monitoring experiments in boreholes using an optical fiber temperature measurement system. This instrument sends a pulsed laser into an optical fiber and determines the temperature distribution continuously along the fiber based on the temperature dependence of the backscattered light spectrum. It is therefore possible to measure the temperature profile through a borehole at one moment with this system, though the temperature resolution is not very high, about 0.1 K.

We installed an optical fiber cable in a borehole drilled into the Nojima Fault down to a depth of 1460 m and started monitoring the temperature profile in July 1997. The temperature profile had been very stable for 2.5 years (July 1997 to January 2000) except for the shallowest part affected by the surface temperature variation and a small transient anomaly around 500 m, which resulted from a water injection experiment in February and March 1997. The second water injection experiment was then conducted and we could observe the thermal disturbance by injected water and the recovering process to the steady state very clearly (Yamano and Goto, 2000 Japan Earth and Planet. Sci. Joint Meeting).

We also examined the effect of water discharge from inside of the borehole on the temperature profile. We temporally opened the top of the borehole, which is usually sealed, and allowed groundwater to flow out of the hole for 25 days. Upward water flow inside the hole caused an increase in temperature of about 0.5 K. This temperature increase was observed only above 540 m and this depth was proved to be the point where groundwater discharge is occurring.

The variation of the ground surface temperature affects the temperature distribution near the surface. Diurnal temperature variation was observed in the uppermost part of the hole and the depth above which the variation is significant has changed with time. This depth is thought to indicate the water level in the hole and we could estimate the water level with a resolution of 1 to 2 m (the spatial resolution of the optical fiber system is 1 m). The estimated water level varied from 0 m to 10 m. The water level was probably controlled by the pressure of gas accumulated beneath the seal at the top.

Below the water level, the temperature observed in the hole should reflect the temperature of the surrounding formation. The annual variation of the ground surface temperature generally penetrates to a depth of 15 to 20 m depending on the thermal diffusivity of the formation. In the present case, the annual variation could be observed down to 17 - 18 m (the amplitude at 15 m is about 0.2 K). The temperature below 20 m was almost constant within the 0.1 K temperature resolution of the measurement system, which means we could not detect any longer-period component in the ground surface temperature variation in the 2.5-year record.

We then installed the optical fiber system in a shallow borehole drilled through the Chelungpu Fault, Taiwan. Monitoring of the temperature profile from the surface to 160 m was started in May 2001, but no significant temperature variation has been observed up to the present. The temperature decreases with depth down to about 120 m and increases with depth only below this depth. This anomalous temperature profile may result from groundwater flow around the borehole.