Studying the relationship of earthquakes and groundwater levels in Long Valley, California: Results from a 3-km deep borehole and high-temperature-capable monitoring tools

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Earthquakes generally nucleate at depths of several km or more below the earth's surface, and scientific drillholes are now planned to reach depths of 5 km. At these depths, temperatures are too high to utilize conventional pressure transducers. Similar temperatures may also be encountered in shallow boreholes in hydrothermal areas, and such boreholes have been hypothesized to be good sites for detecting fluid pressure changes of tectonic origin.

At Long Valley caldera, California, we have been experimenting with pressure-temperature measuring tools built to operate for extended periods at elevated temperatures. Long Valley caldera is an active volcanic location in eastern California, where both local and distant earthquakes have produced persistent water level drops in wells on and north of the caldera's resurgent dome, accompanied by earthquake-induced fluid level increases in the caldera's hydrothermally active south moat. It has been hypothesized that earthquake-induced water-level drops on and north of the resurgent dome may be caused by incremental dome inflation, while fluid level increases in the hydrothermal wells may be due to upward movement of hot material from depth. The water level changes are of special interest because Long Valley is a site where large distant earthquakes trigger microseismic activity.

We found that the high-temperature-capable tools are useful for learning about the behavior of the wells in Long Valley. A pumping test in the Long Valley Exploration Well (LVEW), a 3 km deep borehole penetrating the center of the resurgent dome, was carried out with such an instrument deployed at 2.6 km depth (temperature 102º C, pressure 22.3 MPa). Results from this test are consistent with a high-conductance planar fracture 10-100 m long in country rock with hydraulic diffusivity of 1-10 m2/s. Tidal amplitudes at the fracture zone depth are 1.93 kPa peak-to-peak, and the ratio of pressure change to strain based on the M2 earth tide constituent is 30.3 kPa/microstrain. In the LVEW, distant earthquakes produce water-level drops with shorter time constants than observed in shallower wells.

In summer, 2003, we deployed a high-temperature-capable sensor in a shallow thermal well in which fluid pressure increases are triggered by distant earthquakes. Previous monitoring in this well was done with a bubbler-type transducer incapable of responding to seismic waves. Continued fluid-pressure monitoring should yield more information about the time-space distribution of earthquake-induced fluid-pressure changes at Long Valley.