Precise temperature measurement in a deep borehole drilled in the Chelungpu fault, Taiwan

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We have made a precise temperature measurement to observe a heat signature that is associated with frictional heat generated at the time of faulting for a large earthquake. Following the September 21, 1999 Chi-Chi earthquake, the Taiwan Chelungpu-fault Drilling Project (TCDP) bored two holes which penetrate the fault at depths of about 1100 m near the town of Dakeng in the northern part of the rupture zone. During the earthquake, this area had large surface rupture, and a fault displacement of about 8 m is estimated from seismic data. The boreholes provided the rare opportunity to make temperature measurements in a fault zone with large slip from a recent earthquake. The precise temperature measurements were carried out in one of the boreholes from March to September 2005, 5.5-6 years following the earthquake. The borehole is cased with steel pipe so that there is no water flow between the borehole and surrounding rock, enabling much more stable temperature measurements. In order to obtain a high resolution temperature profile, we developed a borehole instrument (quartz thermometer) containing two quartz oscillator thermometers, separated by 3 m. We also developed a temperature measurement system (platinum thermometer) using 5 platinum resistance temperature detectors. We installed both quartz thermometers and platinum thermometers in the borehole at depths between 1090 - 1111 m and made a long-term temperature measurement at 7 depth levels for 6 months. On September 2005, the quartz thermometer was slowly lowered (about 1.0 m/minute) and raised (about 0.4 m/minute) in the borehole between the depths of 900 and 1250 m, producing four independent temperature profiles across the fault zone. The continuous recording of temperature at 10 s intervals produced 5 to 15 readings per meter. Temperature measurements in the borehole shows a small temperature increase (0.06 K) across the fault even 6 years after the earthquake, which is interpreted to be associated with the 1999 Chi-Chi, Taiwan earthquake. In order to improve the interpretation of the temperature signature, we modeled the a temperature distribution across the fault, including (1) spatial distribution of thermal conductivity and (2) water flow. The different conductivity values caused by different rock types and water content can cause fluctuations in the observed temperature profile. The water flow in the rock also can modify the temperature distribution. These modeling provide us an estimation of the upper bound of heat generated by earthquake, which leads to a very low level of friction at the time of the earthquake.