Heat Signature on the Chelungpu Fault Associated with the 1999 Chi-Chi, Taiwan Earthquake

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We observe a heat signature that may be associated with frictional heat generated at the time of faulting for a large earthquake, by precise temperature measurements. Following the September 21, 1999 Chi-Chi earthquake, the Taiwan Chelungpu-fault Drilling Project (TCDP) drilled two boreholes which penetrate the fault at depths of about 1100 m in the northern part of the rupture zone. During the earthquake, a fault displacement of about 6 m is estimated from seismic data in this area and a large surface rupture is observed. 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, six 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 thermometers) and a temperature measurement system (platinum thermometers). We installed both the quartz and platinum thermometers in the borehole at depths between 1090 - 1111 m and made long-term temperature measurements at 7 depth levels for 6 months. On September 2005, the quartz thermometers were 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. 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 earthquake. In order to improve the interpretation of the temperature signature, we modeled the temperature distribution across the fault, including (1) water flow and (2) spatial distribution of thermal conductivity. The modeling of water flow in the rock assuming one-dimensional flow and several values of flow velocity revealed that the temperature distribution is not disturbed by water flow. The different conductivity values caused by different rock types and water content can cause fluctuations in the observed temperature profile, which imply an upper bound of the estimated heat generated by the earthquake. The observed temperature signature means there is a very low level of friction at the time of the earthquake.