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Methods for analysis of high resolution temperature logs in deep boreholes

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We have made an effort to detect temperature signatures along faults that recently ruptured in large earthquakes. High-resolution temperature logs are essential not only for detecting the heat produced by fault rupture but also for the detailed study of thermal structures. We carried out temperature measurements in a borehole that penetrates the Chelungpu fault, Taiwan, using a high-resolution borehole temperature instrument. The instrument consists of quartz oscillator temperature detectors that can measure temperature with a resolution of 0.001 K. One problem with the instrument is the large response delay caused by the thermal inertia of the case of the instrument, which may make observed temperature logs different from the true temperature structure. For example, a sharp, or peaky, temperature anomaly becomes broad. We can avoid this instrument response by moving the instrument extremely slowly, however this is sometimes not practical because of the limitations of the winch speed. Alternatively, we need to develop methods to calibrate the measured high-resolution temperature logs. We examined two methods to calibrate the response of the instrument. One method is to fit the transient temperature response to a step temperature change by a model that characterizes the thermal time constant (Conaway, 1977). The other method is to calculate a transfer function, or impulse response function for the instrument, using a reference thermometer that measures the temperature without the effects of thermal inertia. To test the methods for calibration, we carried out temperature measurements in a 350-m-deep borehole in Atotsugawa drilled by NIED. We obtained high-resolution temperature logs using the quartz thermometer along with small-size reference thermometers whose instrument response is negligibly small. We assume that the temperature logs measured by small-size reference thermometers represent the true temperature structure. We imposed temperature changes by abruptly changing the depth of the instrument. The quartz thermometer recorded the temperature transients caused by the step-like temperature changes. A single time constant of 5 minutes basically fits the response of the instrument for the sudden temperature changes. Detailed examination revealed that the time constant at the time of the step-like-changes is smaller than 5 minutes. Also, there is a portion with a longer time constant. Multiple time constants are necessary to model the instrument response that consists of components with different thermal inertia. We also calculated the transfer function between the temperature logs obtained by the temperature instrument and by the small-size reference thermometers, using the same temperature transient used to obtain the time constant. The temperature logs modified by the calculated transfer function fit well to the logs obtained by the small-size reference thermometers. Acknowledgement: We thank K. Omura (NIED) for providing us an opportunity to use the borehole.