Faulting Dynamics on Frictional Heat and Thermal Pressurization of the 1999 Chi-Chi, Taiwan, Earthquake

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Abstract

We calculated the dynamic friction of the 1999 Chi-Chi earthquake from the estimation of the frictional energy from temperature logs and the energy estimated from the calculation of thermal pressurization during faulting. The strength drop during faulting was estimated by thermal pressurization modeling of the slip zone materials recovered from deep borehole. Most of the parameters for thermal pressurization (TP) calculations are obtained directory from recovered core and geophysical logging of Taiwan Chelungpu-fault Drilling Program (TCDP). New approach on TP calculation was proposed by incorporating the inelastic dilatancy and slip zone architecture in the model as we named it Geological Thermal Pressurization (GTP). From GTP, it shows that the temperature rise and the strength drop are strongly related to the value of inelastic dilatancy during faulting. From the neutron log of the shallow hole, the inelastic dilatancy estimated in the slip zone is about 10%. This value will yield the temperature rise of up to 1000 degree under thermal pressurization, and a complete strength drop of to the value of 10.5 MPa, which is equivalent to the value of 11 MPa obtained from seismic waveforms. For the frictional heat from temperature logs, two data sets of temperature loggings both from shallow borehole in 2000 [Tanaka et al., 2002, 2006] and deep borehole in 2005 [Kano et al., 2006] penetrating Chelung-pu fault zone show positive thermal anomaly right on the slip zones. Considering the thermal conductivity directly measured from the retrieved core of the TCDP, we suggest that the temperature anomaly observed in the deeper hole might be resulted from the thermal conductivity fluctuation [Tanaka et al.,2006b]. Thus, only the temperature logs from shallow hole were used to estimate dynamic friction during faulting. The frictional energy from the temperature measurement is about 26 MJ/m2, which is approximately close to the value obtained from the TP of the value of 19 MJ/m2. It suggests that the frictional heat obtained from the temperature residual might be resulted from the temperature rise during TP. The process of TP also yields the complete stress drop during faulting. The seismic

break down work(Wb) estimated by dynamic wave inversion at large slip region (10 m) of northern part of the fault [Ma et al., 2006] has a large value around 40 MJ/m^2. The surface fracture energy (1-4 MJ/m^2) estimated from fault gouge was estimated to be only 2-6% from the seismic breakdown work. The energy of TP contributes about 50% to the breakdown work. The calculation of GTP suggests the necessary of incorporating the inelastic dilatancy and slip zone structure for understanding of dynamic faulting of earthquake rupture.