Transport properties and its implication of pore pressure change due to frictional heating during 1999 Taiwan Chi-Chi earthquake

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"Thermal Pressurization", which is one of the possible dynamic fault weakening mechanisms during slip is conceptually well known for several ten years. Sudden fluid pressure generation due to frictional heating reduces the vertical effective pressure and results in the fault weakening. According to this mechanism, transport properties of fault zones, such as permeability and storage capacity, are critical for the fault slip behavior.

The Chelugnpu fault was activated during the 1999 Chi-Chi earthquake. The northern part of the fault motion is characterized by fast velocity, large displacement (10 m), and low frequency ground motion. In contrast, the southern part had much smaller displacements, but the levels of accelerations were higher. Taiwan Chelungpu-fault Drilling Project (TCDP) started from 2002 and succeeded in penetrating the Chelungpu fault and recovered core samples from two holes, Hole A (total depth, 2003.00 m) and Hole B (1352.60 m). Textual observation and rock magnetic analyses of fault rocks in Hole B implied the evidence of heat generation, though the temperature did not rise up to the melting point (Hirono et al. 2006). Borehole temperature measurement in Hole A observed the very low temperature anomaly around the fault zone (Kano et al. 2006). These results indicate the low degree of the frictional heating due to very low friction during the slip, and it also implies thermal pressurization was occurred effectively during the earthquake. To demonstrate the assumption, the transport and frictional properties of the fault rocks are measured by laboratory experiments, and pore pressure and temperature rise histories during the earthquake are evaluated using experimental data. Shallow borehole core samples for the northern and the southern sites, TCDP borehole samples, and outcrop samples for the three main thrusts (Chelungpu, Shuangtung and Shuichangliu Faults) are selected for the study to investigate the variation of fault properties between north and south and the depth variation of fault zones.

Permeability of fault rocks showed large variation among faults zone, and permeability for the northern site showed 10^{-16} to 10^{-18} m^2 at the depth of 1 to 3 km, and for the south, permeability showed 10^{-15} to 10^{-17} m^2, which is one order larger than that for the south. For surface outcrop of Chelungpu Fault, permeability is large ranging from 10^{-15} to 10^{-16} m^2, and 10^{-16} ~ 10^{-17} m^2 for Shuichangliu Fault, and smallest for Shangtung Fault ranging from 10^{-17} to 10^{-19} m^2. On the other hand there are small differences in specific storage among faults, and values are from 10^{-9} to 10^{-10} Pa^{-1}. High frictional gouge experiments were conducted at dry condition with 1.03 m/s in speed and 0.6 to 0.9 MPa in normal stress. There are small differences in high velocity frictional behaviors among faults. Frictional coefficient suddenly increases up to 0.67 to 1.08, and gradually decreases down to 0.15 to 0.22 with slip. Numerical analyses indicated that thermal pressurization is ineffective for the south of Chelungpu Fault, on the contrary weakening is relatively enhanced by thermal pressurization for the north, which were consistent with seismic behavior of the Chi-Chi earthquake. Thermal pressurization is most effective for Shuangtung Fault and less effective for Shuichangliu Fault. If Shuangtung fault represents deeper part of Chelungpu fault, one may argue that thermal pressurization would be effective at depths of Chelungpu fault.