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Micro-Scale Anatomy of the 1999 Chi-Chi Earthquake Fault Zone

A.-M. Boullier (1,2), E.-C. Yeh (3,2), S. Boutareaud (4), S.-R. Song (3,2), and C.-H. Tsai (5)

(1) - Laboratoire de Géophysique Interne et Tectonophysique, CNRS, Université Joseph Fourier, Grenoble, France , (2) International Laboratory (LIA) ADEPT, CNRS-NSC, France-Taiwan, (3) National Taiwan University, Department of Geosciences, Taipei, Taiwan, (4) Geologisches Institut, ETH-Zentrum, CH-8092 Zurich, Switzerland, (5) National Dong Hwa University, Institute of Earth Sciences, Hualien, Taiwan

Two TCDP bore-holes A and B were drilled in the northern part of the Chelungpu thrust fault where the Chi-Chi earthquake (September 21, 1999, Mw 7.6) showed large displacement, low ground acceleration and high slip velocity. In this paper, we describe the microstructures of the Chi-Chi Principal Slip Zone (PSZ) within black gouges localized at 1111m depth in Hole A and at 1136m depth in Hole B. In the FZA1111 the PSZ is a 2 cm-thick isotropic clay-rich gouge which contains aggregates formed by central clasts coated by clay cortex (Clay Clast Aggregates, CCAs), and fragments of older gouges segregated in the top third of the PSZ. In FZB1136 the PSZ is 3 mm-thick and is characterized by a foliated gouge displaying an alternation of clay-rich and clast-rich layers. The presence of CCAs, plucked underlying gouge fragments, gouge injections, and the occurrence of reverse grain size segregation of large clasts in the FZA1111 isotropic gouge suggest that the gouge was fluidized as a result of frictional heating and thermal pressurization. The foliated gouge in FZB1136 may be one locus of strain localization and related heat production. Small calcite veins present above the isotropic FZA1111 PSZ gouge, and characterized by an increasing strain with increasing distance away from the PSZ, are attributed to co-seismic fluid escape from the pressurized gouge. The observed microstructures are interpreted in view of their seismic implications for the Chi-Chi earthquake in terms of slip weakening mechanisms by thermal pressurization, gouge fluidization, co-seismic fluid distribution and post-seismic slip. Above the PSZ, several layers of compacted gouges containing deformed CCAs and gouge fragments correspond to several PSZ of past earthquakes similar to the Chi-Chi earthquake, and display a fault-parallel cleavage resulting from a low strain-rate pressure solution deformation mechanism that may be correlated to the inter-seismic periods.