Geophysical Research Abstracts, Vol. 9, 01458, 2007
SRef-ID: 1607-7962/gra/EGU2007-A-01458

Distinct modes of strain localization in “jacketed” and “unjacketed” siltstone just above the active Chelungpu fault, Taiwan

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We have conducted true triaxial compression tests to study the mechanical behavior leading to faulting in the siltstone from the depth of 890 m (Taiwan Chelungpu-fault Drilling Project, TCDP, hole A), just above the slip zone of the 1999 M7.3 Chi-Chi earthquake (1110 m). Rectangular prismatic specimens (19×19×38 mm) were subjected to two different lateral principal stresses (σ_2 and σ_3), and then loaded axially (σ_1) until brittle failure. Specimens were either ‘jacketed’ and maintained dry throughout, or ‘unjacketed’ so that a pair of opposite faces was exposed to the confining fluid applying σ_3. As expected, jacketed specimens developed localized shear zones steeply inclined in the direction of σ_3. SEM images show some axial microcracks within the shear zone, but considerably fewer than in previously tested crystalline rocks. We suspect that most microcracks are intergranular due to weak clay-rich cementation, and thus difficult to detect in this fine grained rock. Significantly, while the shear zones localize at decreasing dip angles as σ_3 rises, their dip increases steadily with rising σ_2 for unchanged σ_3, an observation consistent with the shear localization theory of Rudnicki and Rice (1975). The effect of σ_2 on strength can be best expressed by a Mogi-modified Nadai criterion: τ_{oct} = 2.32[$(\sigma_1 + \sigma_3)/2$]$^{0.75}$ (r = 0.995), where τ_{oct} is the octahedral shear stress at failure.

The unjacketed tests were designed to simulate the condition at a borehole wall, where rock is directly exposed to fluid pressure radially, but not in the tangential and vertical directions. Drilling mud was simulated by kerosene as the confining fluid of equivalent viscosity. True triaxial strength under identical σ_2 and σ_3 was significantly lower than that of jacketed specimens, and the difference increased as σ_3 was raised, reach-

ing 38 % at σ_3=60 MPa. Similar to previous unjacketed tests in crystalline rocks, the siltstone-fluid interaction generated extensile strain localization adjacent to the exposed faces, resulting in multiple through-going cracks parallel to the exposed faces resembling sheeting or exfoliation. This led to premature specimen failure. SEM imagery reveals microcracks advancing tortuously within the clay matrix along planes perpendicular to σ_3. Split grains indicate the lack of shear displacement along those fractures. We interpret this type of failure as resulting from the confining fluid infiltrating axial microcracks induced upon dilatancy onset. Internally pressurized cracks then extend unstably to specimen ends failing the rock. This type of extensile failure under compressive stresses is analogous to the borehole breakout phenomenon.