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The intermediate principal stress effect on faulting and fault orientation

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We conducted true triaxial compression tests on rectangular prismatic specimens (19×19×38 mm) of siltstone core extracted from a depth of 1252 m, some 140 m below the borehole intersection with the Chelungpu Fault, Taiwan. Experiments consisted of four series of tests in each of which σ_3 was kept constant and σ_2 was varied from test to test. The major principal stress (σ_1), aligned with the long vertical side of the specimen, was raised at constant strain rate until a through-going, steeply dipping fault was initiated. As in igneous and metamorphic rocks previously tested, σ_1 required to bring about faulting rose as σ_2 was set at increasing levels above σ_3. This observation reflects the significant contribution of σ_2 to the compressive strength, and raises doubt about the suitability of the Mohr-Coulomb criterion. Rather, a strength criterion in terms of the invariants octahedral shear stress (τ_{oct}) as a function of mean stress (σ_{oct}) provides a good fit to the experimental data. In all tests fault strike was aligned with σ_2 direction. The angle (or dip) θ of the fault was also strongly affected by σ_2. For constant σ_3 the angle rose with σ_2, again departing from the Mohr-Coulomb criterion, which predicts a fault angle independent of the intermediate principal stress.

The experimental results, revealing the dependence of fault angle θ on σ_2, were compared with predictions based on shear localization theory incorporating a yield surface and plastic potential that depend on the following three stress invariants (rather than two, as in Rudnicki and Rice, 1975): τ_{oct}, σ_{oct}, and the Lode angle θ_L (=$\arctan\left\{[2\sigma_2 - \sigma_1 - \sigma_3] / \left[\sqrt{3}\,(\sigma_1 - \sigma_3)\right]\right\}$). Dependences of the yield surface and plastic potential on mean stress were inferred from the fault angles observed in axisymmetric compression and deviatoric pure shear. Using these relationships to predict fault angle θ for deviatoric stress states other than axisymmetric compression and pure shear, yields good agreement with the experimental observations. The results predict that for constant mean stress, the fault angle θ decreases as the deviatoric stress state varies from axisymmetric extension to axisymmetric compression. For fixed deviatoric stress states, θ decreases monotonically with increasing mean stress.