Geophysical Research Abstracts
Vol. 17, EGU2015-6914-1, 2015
EGU General Assembly 2015

The Role of the Intermediate Principal Stress in the Brittle-Ductile Transition of Porous Sandstones

Xiaodong Ma (1) and Bezalel Haimson (2)

(1) Dept. of Geophysics, Stanford University, Stanford, CA, United States, (2) Dept.. of Materials Science and Engineering, Univ. of Wisconsin, Madison, WI, United States

Conventional triaxial experiments reveal that failure mode in some porous sandstones evolves from brittle, dilatant, localized high-angle shear band at low $\sigma_2 = \sigma_3$, to ductile localized failure in the form of compaction bands at high $\sigma_2 = \sigma_3$, to delocalized cataclastic flow at even higher $\sigma_2 = \sigma_3$ (*Wong and Baud*, 2012). Brittle ductile transition is characterized by multiple conjugate low-angle shear bands (*Paterson and Wong*, 2005).

True triaxial experiments ($\sigma_1 \geq \sigma_2 \geq \sigma_3$) enable the direct observation of the intermediate principal stress, σ_2, effect on rock mechanical behavior, including failure. We conducted a series of such tests on two quartz-rich porous sandstones, Coconino and Bentheim, and ascertained the effect of σ_2 on failure as σ_3 was gradually raised between tests from 0 to 150 MPa. In Coconino sandstone (17% porosity), the single, steeply inclined shear band developed at low σ_3 (= σ_2), turned into multiple conjugate, low angle, failure planes, signifying brittle-ductile transition, as σ_3 (= σ_2) reached about 100 MPa. However, by raising $\sigma_2$from test to test for the same σ_3 (= 100 MPa), the number of conjugate planes diminished and eventually reduced to one steeper shear band, failure stress rose, and the volumetric strain associated with failure changed from compactant at σ_2= σ_3 to dilatant at $\sigma_2 > \sigma_3$. These observations demonstrate that σ_2 embrittles Coconino sandstone and retards failure.

On the other hand, the brittle-ductile transition threshold in Bentheim sandstone (24% porosity), which occurs at about σ_3 (= σ_2) = 60 MPa, is characterized by increased compaction with the rise in σ_2, contrary to the Coconino sandstone behavior. A reasonable conjecture is that the apparent discrepancy in rock deformability as σ_2 rises above the constant $\sigma_3$is related to the difference in porosity (and hence stiffness) between the two rocks. As σ_2 is raised, the mean stress increases independently of rock type. In the higher porosity Bentheim sandstone, this brings about inelastic compaction sufficient to overwhelm the dilatant deformation due to the change in the deviatoric stress. In the Coconino, however, the lower porosity reduces compaction, so that dilatant deformation prevails.