Geophysical Research Abstracts
Vol. 20, EGU2018-8144, 2018
EGU General Assembly 2018

Comparing crack damage evolution in rocks deformed under conventional and true triaxial loading

Philip Meredith (1), John Browning (1), Chris Stuart (1), Thomas Mitchell (1), Sophie Harland (2), and David Healy (2)

(1) University College London, Department of Earth Sciences, Earth Sciences, London, United Kingdom (p.meredith@ucl.ac.uk), (2) University of Aberdeen, School of Geosciences, Aberdeen, United Kingdom

Microcrack damage in rocks evolves in response to differential loading. However, the vast majority of experimental studies investigate damage evolution using conventional triaxial stress states ($\sigma 1 > \sigma 2 = \sigma 3$), whereas in nature the stress state is in general truly triaxial ($\sigma 1 > \sigma 2 > \sigma 3$). We present a comparative study of crack damage evolution during conventional triaxial vs. true triaxial stress conditions using results from measurements made on cubic samples of sandstone deformed in three orthogonal directions with independently controlled stress paths. We have measured, simultaneously with stress and strain, the changes in ultrasonic compressional and shear wave velocities in the three principal directions, together with the bulk acoustic emission (AE) output. Changes in acoustic wave velocities are associated with both elastic closure and opening of pre-existing cracks, and the inelastic formation of new cracks. By contrast, AE is associated only with the inelastic growth of new crack damage. The onset of new damage is shown to be a function of differential stress regardless of the level of mean stress. Hence, we show that damage can form due to a decrease in the minimum principal stress, which reduces mean stress but increases the differential stress. We measure the AE, in both conventional and true triaxial tests and find an approximately fivefold decrease in the number of events in the true triaxial case. In essence, we create two end-member crack distributions; one displaying cylindrical transverse isotropy (conventional triaxial) and the other planar transverse isotropy (true triaxial). By measuring the acoustic wave velocities throughout each test we are able to model comparative crack densities and orientations. Taken together, the AE data, the velocities and the crack densities indicate that the intermediate principal stress plays a key role in suppressing the total amount of crack growth and concentrating it in planes sub-parallel to the minimum stress. However, the size of individual cracks remains constant. Hence, the differential stress at which rocks fail (i.e. strength) will be significantly higher under true triaxial stress (where $\sigma 2 > \sigma 3$) than under conventional triaxial stress (where $\sigma 2 = \sigma 3$). Cyclic loading tests show that while individual stress states are important, the stress path by which these stress states are reached is equally important. Whether the stress state has been ‘visited’ before is key to determining and understanding damage states. The cyclic loading shows that further damage commences only when that previous maximum differential stress is exceeded, regardless whether this is achieved by increasing the maximum principal stress or by decreasing the minimum principal stress.