Geophysical Research Abstracts
Vol. 19, EGU2017-15277, 2017
EGU General Assembly 2017

Crack damage evolution in rocks deformed under true triaxial loading

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

(1) University College London, Earth Sciences, London, United Kingdom (browning.envhazards@gmail.com), (2) School of Geosciences, University of Aberdeen, Aberdeen AB24 3UE

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 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 formation of new, highly oriented, cracks by inelastic processes. By contrast, AE is associated only with the inelastic growth of new cracks. Crack growth is shown to be a function of differential stress regardless of the mean stress. New cracks 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 triaxial 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 were able to model comparative crack densities and orientations. When taken together the AE data, the velocities and the crack density data indicate that the intermediate principal stress plays a key role in suppressing the total amount of crack growth and concentrates it in a single plane, but the size of individual cracks remains constant. Hence, the differential stress at which rocks fail (strength) will be significantly increased under true triaxial stress conditions than under the much more commonly applied condition of conventional triaxial stress. Through a series of cyclic loading tests, we show that while individual stress states are important, the stress path by which this stress state is reached is equally important. Whether or not that stress state has been ‘visited’ before is also vitally important in determining and understanding damage states. Finally, we show that damage evolution can be anisotropic and must be considered as a three-dimensional problem. Such results are important for understanding three-dimensional crack damage evolution which is likely a key control on fluid migration in volcanoes and fault zones.