Geophysical Research Abstracts,
Vol. 11, EGU2009-12466, 2009
EGU General Assembly 2009

Time-dependent brittle deformation in Darley Dale sandstone

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The characterization of time-dependent brittle rock deformation is fundamental to understanding the long-term evolution and dynamics of the Earth's upper crust. The chemical influence of water promotes time-dependent deformation through stress corrosion cracking that allows rocks to deform at stresses far below their short-term failure strength. Here we report results from a study of time-dependent brittle creep in water-saturated samples of Darley Dale sandstone (initial porosity of 13%).

Conventional creep experiments (or 'static fatigue' tests) show that time to failure decreases dramatically with the imposed deviatoric stress. They also suggest the existence of a critical level of damage beyond which localized failure develops. Sample variability results however in significant scattering in the experimental data and numerous tests are needed to clearly define a relation between the strain rate and the applied stress. We show here that stress-stepping experiments provide a means to overcome this problem and that it is possible this way to obtain the strain rate dependence on applied stress with a single test. This allows to study in details the impact of various thermodynamical conditions on brittle creep.

The influence of effective stress was investigated in stress-stepping experiments with effective confining pressures of 10, 30 and 50 MPa (whilst maintaining a constant pore fluid pressure of 20 MPa). In addition to the expected purely mechanical influence of an elevated effective stress our results also demonstrate that stress corrosion appears to be inhibited at higher effective stresses. The influence of doubling the pore fluid pressure however, whilst maintaining a constant effective stress, is shown to have no effect on the rate of stress corrosion. We then discuss the results in light of acoustic emission hypocentre location data and optical microscope analysis and use our experimental data to validate proposed macroscopic creep laws.