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The influence of temperature on brittle creep in sandstones

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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 presence of water promotes time-dependent deformation through environment-dependent stress corrosion cracking that allows rocks to deform at stresses far below their short-term failure stress. Here we report results from an experimental study of the influence of an elevated temperature on time-dependent brittle creep in water-saturated samples of Darley Dale (initial porosity of 13%), Bentheim (23%) and Crab Orchard (4%) sandstones.

We present results from both conventional creep experiments (or 'static fatigue' tests) and stress-stepping creep experiments performed under 20°C and 75°C and an effective confining pressure of 30 MPa (50 MPa confining pressure and a 20 MPa pore fluid pressure). The evolution of crack damage was monitored throughout each experiment by measuring the three proxies for damage (1) axial strain (2) pore volume change and (3) the output of AE energy.

Conventional creep experiments have demonstrated that, for any given applied differential stress, the time-to-failure is dramatically reduced and the creep strain rate is significantly increased by application of an elevated temperature. Stress-stepping creep experiments have allowed us to investigate the influence of temperature in detail. Results from these experiments show that the creep strain rate for Darley Dale and Bentheim sandstones increases by approximately 3 orders of magnitude, and for Crab Orchard sandstone increases by approximately 2 orders of magnitude, as temperature is increased from 20°C to 75°C at a fixed effective differential stress. We discuss these results in the context of the different mineralogical and microstructural properties of the three rock types and the micro-mechanical and chemical processes operating on them.