

## Rate dependent deformation of sandstone under hydrothermal conditions

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Porous sandstones transition from dilatant, brittle deformation at lower pressure, to compactant, ductile deformation at higher pressure. Both deformation modes are driven by microcracking, and are therefore expected to exhibit a time dependency due to chemical interactions between the pore fluid and the rock matrix. In the brittle regime, time-dependent failure and brittle creep are well documented, under a variety of hydrothermal conditions. However, much less is understood in the ductile regime.

We present results from a series of triaxial deformation experiments, performed under a range of conditions on fluid saturated Bleurswiller sandstone (initial porosity = 23%). With the aim of establishing what affect either elevated temperature (150°C) or pore fluid chemistry has on the rate of deformation under upper crustal pressures.

To test the influence of elevated temperature, water saturated samples were deformed at both room temperature and at 150°C to 4% axial strain, under either constant strain rate ( $10^{-5} \text{ s}^{-1}$ ) or constant stress (creep) conditions and at a range of effective pressures, focusing primarily on the ductile regime. Constant strain rate tests show that the increase in temperature reduces the differential stresses required for the onset of compaction in the ductile regime on the order of 15-20 MPa. The constant stress experiments highlighted that at 150°C the rock will undergo compactant creep at the same strain rate as its room temperature counterpart, but again requiring a differential stress reduction of 20 MPa.

We tested the sensitivity of fluid chemistry on the time dependency, through a series of experiments performed at 40 MPa effective pressure, again under either constant strain rate or constant stress (creep) conditions, with either water or chemically inert decane as the pore fluid. In addition to stress, axial strain and pore volume change, P wave velocities and acoustic emission were monitored throughout.

During constant stress tests, the strain rate initially decreased with increasing strain, before reaching a minimum and accelerating to a constant level beyond  $\sim 2\%$  axial strain. When plotted against axial strain, the strain rate evolution under constant stress conditions, mirrors the stress evolution during the constant strain rate tests; where strain hardening occurs prior to peak stress, which is followed by strain softening and an eventual plateau. In all our tests, the minimum strain rate during creep occurs at the same inelastic strain as the peak stress during constant strain tests, and strongly decreases with decreasing applied stress.

The microstructural state of the rock, as interpreted from similar volumetric strain curves, as well as the P-wave velocity evolution and AE production rate, appears to be solely a function of the total inelastic strain, and is independent of the length of time required to reach said strain. Under the same applied stress, decane saturated samples reached a minimum strain rate an order of magnitude lower than the water saturated samples. This is consistent with a mechanism of subcritical crack growth driven by chemical interactions between the pore fluid and the rock.