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Physico-chemical processes during time dependent deformation in porous rocks

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The time, rate and environment dependence of the mechanical properties of rocks are usually assigned to chemical reactions between the fluid and the host rock that advance the growth of fractures in the medium. We have investigated the effect of pressure, temperature and chemically active fluid on the growth of a crack population by carrying out a series of cross-disciplinary rock deformation tests on porous sandstones. Rock strength decreases with strain rate and in the presence of a chemically active pore fluid. Microstructural analysis reveals a larger crack density in the slowly deformed samples. Time dependent growth of fractures precedes the macroscopic sample failure. In the weakly cemented sandstone damage proceeds in an exponential fashion as predicted by reaction rate theory. The well-cemented sandstone displays power law scaling that is consistent with the growth of multiple fractures in a stochastic granular medium. The microcrack growth is associated with a distinct geochemical signal due to dissolution from the newly created fracture surfaces. The precursory chemical signal follows the Arrhenius temperature dependence. It represents only small fraction of the estimated surface area of the rock sample, thus indicating that the reactive surface area is smaller than the geometric surface area. The chemical signal correlates with crack damage by a power law with an exponent of 0.37. This confirms that physico-chemical processes cause the rate and environment dependence of the mechanical, fluid flow and microseismic properties of these sandstones. However, the majority of the microseismic activity occurs only few minutes before the sample failure irrespective of the strain rate, hence suggesting the possibility that a single reaction rate may control the initiation of the chemically assisted crack growth in these rocks.