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Compaction creep of granular calcite under upper crustal conditions: Effects of aqueous pore fluids and supercritical CO_2

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The compaction creep behaviour of granular calcite is directly relevant to the healing and slip behaviour of faults in carbonates terraines, to porosity and permeability evolution in carbonates, and to the response of depleted carbonate reservoirs to CO_2 storage. There is therefore much interest in quantifying the rates and mechanisms of compaction creep in carbonates. We have conducted one-dimensional compaction creep experiments on granular calcite (grain size 1-250 μm) at temperatures in the range 25-150 °C and effective axial stresses up to 50 MPa. Tests have been performed dry, using saturated $CaCO_3$ solution as pore fluid (wet tests), and using pore fluids consisting of saturated $CaCO_3$ solution in equilibrium with supercritical CO_2 at pressures up to 10 MPa (wet/CO_2 tests). Pore fluid salinity has also been varied. Dry experiments show negligible creep, whereas significant creep is obtained in wet and wet/CO_2 tests. Wet samples without CO_2show two main regimes of behaviour. At fine grain size ($<$100 μm), low effective stresses ($<$ 5 MPa) and/or high temperature ($>$ 100 °C), the mechanical behaviour and microstructures obtained resemble those expected for diffusion and/or precipitation controlled intergranular pressure solution. Samples deformed at higher stresses and lower temperatures, show a direct dependence of creep rate on stress and grain size, along with SEM evidence for grain scale cracking, indicating a switch to creep controlled by subcritical microcrack growth. Introduction of CO_2 into wet samples leads to an acceleration of creep by typically 1-2 orders of magnitude, with mechanical behaviour and microstructure suggesting that pressure solution dominates in fine grained material ($\leq$100 μm), giving way to subcritical crack growth and grain failure at coarser grain sizes. In the pressure solution regime, increasing CO_2 pressure causes an increase in creep rate that roughly corresponds to predictions assuming diffusion controlled pressure solution. Increasing temperature tends to decrease creep rates under all conditions investigated. Pore fluid salinity increases or decreases creep rate, depending on temperature and CO_2 pressure. The effects of the variables investigated are therefore complex and it remains difficult to arrive at simple compaction creep “laws”. On the other hand, using data from samples showing behaviour consistent with diffusion controlled pressure solution, the grain boundary diffusion product $D\delta$ for pressure solution is estimated to be around 10^{-19} m^3/s under *in situ* conditions.