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How strong are crustal rocks when they start to melt? An experimental study of the flow of partially-molten synthetic ‘granite‘ under undrained conditions.

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Many orogenic belts (e.g. the Iberian Hercynides) show evidence of abstraction of large quantities of melt from the lower crust. As this occurs lower crustal rheology must be profoundly altered, yet little attention has been given to experimental studies of the flow of partially molten crustal rocks. Major problems in studies of the flow of such are (a) maintaining control of the grain size of the matrix of solid grains, (b) controlling the melt fraction, and (c) controlling the melt viscosity. The latter is closely linked to the water-content of the melt phase. These constraints require the use of synthetic test samples. In the present study we used a synthetic ‘granitoid‘ comprising a solid matrix of quartz grains (50 μm grain size) mixed with an albite-quartz melt prepared from oxides, with added water (2.5wt%) dissolved in the melt phase (viscosity 7 $\times$ 10^4 Pas). Experiments were performed undrained, with melt fractions of 10%, 20% and 30%. Constant strain rate, creep and stress relaxation experiments were carried out in a Paterson gas medium apparatus at 1273 and 1173K, mostly at 300 MPa confining pressure, up to 15% shortening strain. Strain rates *de/dt* ranged between 10^{-4} to less than 10^{-7}s^{-1}.

Fully ductile mechanical behaviour was observed, with a stress exponent of 1.8 at low strain rates, and tending towards linear viscous at the lowest stresses and strain rates. Melt fraction has a more profound effect on strength than water content, temperature or total confining pressure. Low strain rate data were fitted to a flow law of the form

de/dt = A exp($B\phi^m$) exp(-H/RT) σ^n

with the parameters log$A$ = -5.77, m = 2, n = 1.8, B = 57.1, H = 114 kJmol^{-1}. σ

is flow stress (MPa), ϕ is melt fraction and T is temperature (K). Extrapolation to geological strain rates using the above flow law shows that in nature migmatites bearing granitic melt will be extremely weak, much weaker than silicate rocks deforming by intracrystalline plasticity. Microstructural study shows grains remain equant at all strains, with no discernable formation of a flattening fabric nor substantial strain contribution from microfracturing. Thus intracrystalline plasticity is of minor importance and intergranular sliding is implied. The non-linear flow observed is tentatively attributed to a combination of sintering of grain contacts and failure and sliding of such contacts by fracturing or diffusive transfer.