Grain size is an important microstructural parameter affecting both brittle and plastic deformation processes. In the low temperature brittle regime, larger grain size materials typically have lower strength, whereas in the plastic flow regime smaller grain size materials tend to be weaker. It is not clear how grain size impacts at intermediate conditions where deformation of rock is accommodated by coupled brittle and plastic deformation processes.

To investigate the role of grain size in the semi brittle regime we deformed three calcite-rich rocks, spanning 3 orders of magnitude in grainsize (0.006-2 mm). A gas medium triaxial apparatus was used at a range of confining pressures (200-800 MPa) and temperatures (20-400°C), and samples were loaded at a constant axial strain rate (1×10⁻⁵ s⁻¹). Axial measurements of P-wave speed were performed during tests in order to infer the in-situ microstructural state of the sample.

Nearly all tests show strain hardening behaviour after yield, typical of semi-brittle deformation, which is quantified using the hardening modulus (h = ∂σ/∂ε). Grain size has a first order control on rock strength, with yield stress and h following a Hall-Petch type relationship at all P-T conditions. For a given temperature, h is low at low pressure (200 MPa) and accompanied by large decreases in wavespeed, and h increases at high pressure (>400 MPa) whereas velocity decreases by a smaller magnitude. This suggests that, at low temperature, strain hardening is relieved by microcracking. At constant pressure, wavespeed decreases significantly at 20°C with progressive deformation, but remains nearly constant at 400°C indicating a transition from dominantly brittle to fully plastic deformation with increasing temperature, in some cases with little change in the macroscopic strength.

Given that both strength and strain hardening behaviour depend on grain size, our data suggests that grain size dynamically impacts the long term rheology of the crust. Larger grain sizes will broaden the depth distribution of the brittle ductile transition and result in a weaker peak crustal strength.