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Microstructural changes, steady-state deformation and strain localisation during large strain deformation of rocks

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Ductile deformation in the Earth's crust and mantle is often concentrated in narrow shear zones. These shear zones play a fundamental role in the deformation dynamics of the earth's lithosphere during mountain building, subduction and continental break-up. Shear zones exhibit large amounts of strain with an increase in strain from the edge to the center of the shear zone. Those large strains are often accompanied with large changes in microstructure due to processes such as dynamic recrystallization, grain size refinement, development of strong foliations, development of crystallographic preferred orientations, weakening of the rock as well as progressive localisation of the deformation into more and more concentrated zones. The interplay between all those different processes produce the various microstructures that are often studied in natural shear zones to assess the deformation conditions and history of plate tectonic processes. Experimental deformation studies under controlled conditions are used to produce relationships between the different processes active in shear zones (rheology, microstructural changes, and CPO development) in order to make those quantitative inferences on natural shear zones,

Here I will present the outcomes from large strain torsion experiments at elevated temperatures and pressures on monophase calcitic rocks showing that very large strains are needed before true steady-state conditions in rocks are attained. Continuous changes in crystallographic preferred orientations and continuous dynamic recrystallization by grain boundary migration and subgrain rotation recrystallization occur up to the largest shear strains achieved in the study (shear strain of 50). Dynamic recrystallization from an undeformed coarse-grained calcite rock types towards a fine-grained ultramylonite is accompanied by a modest (∼20%) weakening of the rock. However, this modest weakening never caused strain localisation in the samples. In contrast to the homogeneous deformation in these monophase calcitic material, two-phase calcite-anhydrite aggregates always resulted in strain localisation and the formation of sample scale shear zones. The formation of those experimental shear zones were the first experimentally produced large-scale strain localisation structures in rocks. It is inferred that deformation of multiphase rock types quickly form a heterogeneous distribution of the different phases, thereby causing heterogeneity in the strength across the sample that facilitates strain localisation. In contrast to experiments on monophase rock types, the heterogeneity in strength cannot be annihilated in multiphase rocks that easily (diffusional processes are hampered by phase boundaries). In the monophase calcite experiments, heterogeneities in strength due to e.g. grain size differences or orientation differences do occur, but grain boundary diffusional processes destroy those heterogeneities relatively quickly preventing strain localisation on a large sample scale to occur (equivalent to shear zone scale in nature).