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Strain localization in carbonate rocks experimentally deformed in the ductile field

E. Rybacki, L.F.G. Morales, and G. Dresen
GFZ German Research Centre For Geosciences, Potsdam, Germany

The deformation of rocks in the Earth's crust is often localized, varying from brittle fault gauges in shallow environments to mylonites in ductile shear zones at greater depth. A number of theoretical, experimental, and field studies focused on the evolution and extend of brittle fault zones, but little is known so far about initiation of ductile shear zones. Strain localization in rocks deforming at high temperature and pressure may be induced by several physical, chemical, or structurally-related mechanisms. We performed simple and pure shear deformation experiments on carbonate rocks containing structural inhomogenities in the ductile deformation regime. The results may help to gain insight into the evolution of high temperature shear zones.

As starting material we used cylindrical samples of coarse-grained Carrara marble containing one or two 1 mm thin artificially prepared sheets of fine-grained Solnhofen limestone, which act as soft inclusions under the applied experimental conditions. Length and diameter of the investigated solid and hollow cylinders were 10-20 mm and 10-15 mm, respectively. Samples were deformed in a Paterson-type gas deformation apparatus at 900˚C temperature and confining pressures of 300 and 400 MPa. Three samples were deformed in axial compression at a bulk strain rate of $8x10^{-5}$ $s^{-1}$to axial strains between 0.02 and 0.21 and 15 samples were twisted in torsion at a bulk shear strain rate of $2x10^{-4}$ s^{-1} to shear strains between 0.01 and 3.74.

At low strain, specimens deformed axially and in torsion show minor strain hardening that is replaced by strain weakening at shear strains in excess of about 0.2. Peak shear stress at the imposed condition is about 20 MPa. Strain localized strongly within the weak inclusions as indicated by inhomogeneous bending of initially straight strain markers on sample jackets. Maximum strain concentration within inclusions with respect to the adjacent matrix was between 4 and 40, depending on total strain and size of inclusions. The localization of strain extended into narrow, few mm long, bands in front of the inclusions, where the degree of localization decays exponentially with increasing distance from the tip of the inclusion. Preliminary microstructural analysis show pronounced recrystallization of the marble within this process zone, owing to stress concentration at the tip of the inclusion. The results demonstrate the importance of structural defects on localization in the ductile regime.