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Deformation initiation and localization around inclusions

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Deformation localization along narrow zones of variable scales is a common feature in orogenic belts. Although there are a number of studies that focus on the evolution of brittle fault zones, little is known about the initiation and localization of ductile shear zones. To study the nucleation and evolution of high temperature shear zones, we performed shear experiments in marbles containing structural heterogeneities and analyzed the deformation microstructures and the resulting crystallographic orientation. Cylindrical samples of coarse-grained Carrara marble containing one or two 1 mm thin artificially prepared sheets of fine-grained Solnhofen limestone 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 strains, intense twinning of calcite is observed in the calcite grains of Carrara marble near the inclusion. The distance from the tip of the inclusion in which twinning is observed increases with increasing strain. Orientation of the twin planes may vary from parallel to normal to the tip of the inclusion, and with increasing strain there is a tendency of development of "twin conjugates". Together with twinning, subgrain boundaries are observed in this region, possibly followed by initial grain size reduction. In these experiments, strain is localized into narrow bands, as revealed by misorientation maps showing the degree of internal lattice distortion of individual calcite crystals around the tip of the inclusion, reaching values from 3 to 10˚, depending on the strain. Internal misorientation of grains increases with decreasing distance to the inclusion. Strain is localized into narrow, long bands extending several mm into the matrix. The degree of localization decays exponentially with increasing distance from the tip of the inclusion. A weak initial development of crystallographic orientation along this process zones is evident starting at very low strains, increasing in strength with increasing strain. The microstructural modifications observed at the tip of the inclusions are possibly caused by the stress concentration in this region. Towards higher strains, deformation of calcite grains progressively affects the surrounding of the inclusions. Our results demonstrate the importance of structural and stress heterogeneities for the nucleation and formation of localized shear bands at elevated temperatures.