Geophysical Research Abstracts
Vol. 18, EGU2016-5575, 2016
EGU General Assembly 2016

The effects of heterogeneities and loading conditions in the development of shear zones

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Shear zones are regions of localized deformation and are frequently nucleated by material and/or structural heterogeneities and may develop under transient boundary conditions of strain rate and stress. Here we investigate shear zone nucleation and development due to mechanical heterogeneities. Experiments were performed in constant twist rate (CTR) and constant torque (CT) torsion tests to simulate the end member conditions of constant strain rate and constant stress. We have used hollow cylinders of Carrara marble samples containing weak inclusions of Solnhofen limestone. The experiments were conducted in a Paterson-type gas deformation apparatus at 900 °C temperature and 400 MPa confining pressure to maximum bulk shear strains of 3. Peak shear stress was about 20 MPa for all the samples, followed by smooth weakening and steady state behavior. The strain is predominantly localized in the host marble within the process zone in front of the inclusion, defined by a zone of intense grain size reduction due to dynamic recrystallization. Local shear strain values in the process zone are between 5 to 10 times higher than the bulk applied strain. In CT experiments, a narrow shear zone marked by intense grain size reduction is developed in front of the inclusion and the surrounding material remains relatively intact, whereas in CTR experiments the deformation is more widely distributed. The volume of recrystallized grains is nevertheless similar in the samples deformed at same bulk strains in both CT and CTR. At similar bulk strain, the crystallographic preferred orientation (CPO) in the process zone of CT experiments is stronger than in CTR experiments and CPO strength varies with grain size. Our observations suggest that the initial formation and transient deformation of shear zones is strongly affected by loading conditions.