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Strain localization in calcite-muscovite aggregates

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Natural deformation in calcite-mica rocks by plastic deformation is a commonly observed in the high-temperature deformation of carbonate mylonites. Studies of natural rocks attribute this to a complex interaction of granular flow and cycles of solution transfer, grain boundary diffusion, nucleation and grain growth. Here we present experimental evidence for strain localization and cavity nucleation that accompanies the ductile deformation. We performed high-temperature (600-727˚C) torsion experiments at 300 MPa confining pressure on fine-grained synthetic calcite-muscovite (50-50% by volume) aggregates with a constant angular displacement rate corresponding to a shear strain rate of $3x10^{-5}$ to $3x10^{-4}$ s^{-1}. The initial sample had a strong mica-foliation and the torsion experiments were conducted on cylindrical samples with the starting foliation parallel and perpendicular to the cylinder axis. In both the foliation parallel and the foliation perpendicular experiments there are similar stress strain patterns, with an initial hardening stage followed by a rather continuous and significant strain weakening ($>$ 60%) before a catastrophic rupture. The reproducibility of the torque for any experiment at the same conditions of temperature and pressure is within 3 Nm. Microstructural analysis shows that in low-strain experiments calcite grains show intense twinning while muscovite grains appear slightly bent and kinked. Higher strains promote a segregation of the two phases with calcite forming thin layers of fine, dynamically recrystallised grains, which act as localized shear bands; while muscovite grains keep their original size without showing any particular record of the imposed shear other than a strong shape preferred orientation. The localization produced catastrophic failure at moderate shear strains ($\gamma \sim 3$). Localization of the strain first involved ductile deformation to produce a new calcite layering with fine dynamically recrystallised grains along which cavities nucleated. The orientation

and kinematics of the cavities are comparable to R1 Riedel structures. In contrast to experiments on pure calcite that deformed homogeneously to large strains ($\gamma \sim 50$) all experiments on calcite-muscovite mixtures resulted in heterogeneous strain. It is concluded that deformation-induced heterogeneous phase distributions cause local strength differences initiating strain localization in the calcite-muscovite mixtures. In comparison to nature where lower strain rates are active our experiments clearly show that brittle fracturing may well occur in the high-temperature plastic regime below the brittle ductile transition zone.