The effect of dynamic recrystallization on rheology, microstructure and grain size distribution: Inferences from experiments on polycrystalline halite

Jan ter Heege, Hans de Bresser and Chris Spiers (poster presentation)

It is commonly observed that dynamic recrystallization can affect the rheology of rock materials by altering the microstructure during deformation. The rheology of dynamically recrystallizing materials can be affected by changes in the dislocation substructure or by changes in grain size distribution, leading to a different relative contribution of grain size sensitive and grain size insensitive creep. The grain size distribution can be altered by different processes associated with dynamic recrystallization, such as the consumption or coalescence of grains by migrating boundaries, leading to grain growth, or the formation of new high angle grain boundaries, leading to grain size reduction. This study focuses on two major issues related to the rheology of dynamically recrystallizing materials: (1) the development of a recrystallized grain size distribution and its dependence on the deformation conditions, and (2) assessment of rheological weakening due to dynamic recrystallization and its importance for strain localization in nature.

To investigate this, the effect of strain, temperature, stress and strain rate on rheology, microstructure and recrystallized grain size distribution was systematically explored using experiments on wet and dry polycrystalline halite. Samples of both wet and dry materials were deformed at 50 MPa confining pressure and strain rates of $5 \times 10^{-7}$ to $1 \times 10^{-4}$ s$^{-1}$, temperatures of 75-240°C and stresses of 7-22 MPa. The experiments stress the importance of water for deformation of rock materials as wet and dry polycrystalline halite show distinctly different flow behavior and strength at similar deformation conditions. Deformation of dry polycrystalline halite results in continuous work hardening and development of a clear subgrain structure under the investigated conditions. Deformation of wet polycrystalline halite results in oscillating flow stress accompanied by progressive subgrain rotation and massive fluid-assisted grain boundary migration, leading to a much lower flow stress than in the dry material. The observed flow behavior and strength can only be explained when composite dislocation and solution-precipitation creep in combination with grain boundary migration recrystallization are taken into account. Most of the resulting recrystallized grain size distributions of wet polycrystalline halite were found to be close to lognormal with a median grain size and standard deviation that decrease with increasing stress and temperature. The data allowed testing of available models for the development of steady state dynamic recrystallized grain size distributions. From the observed flow behavior, we infer that dynamic recrystallization does not lead to major rheological weakening in materials exhibiting relatively fast grain boundary migration. Therefore, it is unlikely that rheological weakening by grain boundary migration is sufficient to lead to strain localization in geological materials that in general exhibit lower migration rates than wet polycrystalline halite.