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Grain Boundary Sliding : nomination for best supporting role in Rock Plasticity

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Localization of ductile strain in rocks results in development of mylonites/ultramylonites. Their microstructures indicate several concomitant deformation mechanisms. Along with crystal plasticity dominates, grain boundary sliding and diffusive/solution mass transport act along interfaces. The chronology of activation and the interactions between these mechanisms are unclear. Therefore, inference of the overall rheology of the mylonitic material seems illusory. In order to clarify these aspects we underwent a multi-scale investigation of the ductile deformation of synthetic rock salt. We combined mechanical testing with in situ optical microscopy (OM), scanning electron microscopy (SEM) and X-ray tomography (MCT). Digital image correlation (DIC) techniques allowed for measurements and characterization of the multiscale organization of 2D and 3D full strain fields. Macroscopic and mesoscopic shear bands appear at sample and microstructure scales, respectively. Discrete slip bands within individual grains allowed for identification of dominant crystal slip plasticity (CSP) and of the activated slip systems. However, we also clearly evidenced grain boundary sliding (GBS), contributing with < 5 % to the overall strain. Yet, GBS is continuously operating along with CSP, which indicates that in spite of being a secondary mechanism it is a necessary one. GBS and localized activity of secondary slip systems near interfaces appear to be necessary in order to accommodate for plastic strain incompatibilities between neighboring grains. More specifically, GBS accommodation mechanisms allow for relaxation of local stress enhancement and reduction of strain hardening. GBS appears to be directly involved in the formation of localized shear bands at the microstructural scale and to allow for the propagation of ductile strain throughout the whole specimen. Finite element (FE) modeling of the viscoplastic behavior of rock salt based on CSP alone is inadequate.
Our major conclusion is that during ductile deformation of rocks CSP and GBS act as co-operative mechanisms due to the pronounced plastic anisotropy of minerals. If at the beginning of ductile strain localization in rocks CSP appears as being the principal role, GBS happens to be best supporting one. We further suggest for mylonites that once grain size reduction and phase mixing had occurred, GBS may become the principal actor, allow for dominant Newtonian rheology and further localization.