Electron optical studies of experimentally deformed Tennessee Sandstone and quartz + kaolinite gouge

R. H. Maddock, S. H. White and E. H. Rutter

Department of Geology, Imperial College, London SW7 2BP

Extended abstract

HVTEM and SEM (backscattered electron imagery) have been employed to examine the microstructures and determine the deformation mechanisms active in experimentally deformed Tennessee Sandstone and quartz + kaolinite gouge.

All experiments were performed at elevated temperature to 400 °C, confining pressures to 200 MPa and pore fluid pressures to 175 MPa. Pre-faulted Tennessee Sandstone samples were deformed by the stress relaxation method (Rutter *et al.*, 1978; Rutter and White, 1979) and in creep tests, achieving strain rates down to 10^{-10} s^{-1}. The quartz + kaolinite gouge, contained in a 35° sawcut in sintered alumina cylinders were deformed at constant strain rate ($\dot{e} = 10^{-4}$ s^{-1}).

Polished thin-sections of the constant strain rate deformed quartz + kaolinite gouge were examined in the SEM. A strong fabric, picked out in the SEM by orientated white mica platelets embedded in the clay, is developed in most samples. This comprises at least two planar elements: (i) a 'P' foliation at 135–180° to the shear direction; (ii) R_1 Riedel shears at 15–30° to the shearing direction. Quartz grains and heavy mineral impurities (e.g. rutile) are frequently streaked out—deformed by (ductile) cataclastic flow—into asymmetric trails parallel to either the 'P' or R_1 foliation. These features provide excellent kinematic indicators which are also found in natural gouges. The pervasive development of the fabrics complement the work-hardening behaviour seen on the stress–strain curves, in demonstrating that deformation is distributed throughout the gouge layer.

The Tennessee Sandstone samples were examined by HVTEM. The gouge zones in the pre-faulted specimens consisted of angular fragments (< 1 μm width) with angularity decreasing as the fragment size is reduced. Fractures which terminate in grains are marked by strained tips but no dislocation generation. Grains well removed from the gouge zone are characterized by interior dislocation structures consisting of coarse subgrains and unbound dislocations. Grains also displayed well-developed overgrowths marked by growth defects, growth layers, twins and dislocations. Corrosion microstructures, reduction in quartz grain angularity, euhedral overgrowths and finally cementation of void space with increasing experimental duration is interpreted in terms of water-assisted grain boundary diffusion or pressure solution deformation. This process has no effect on pre-existing dislocation structures even after 5 months at 400 °C. A transition in deformation mechanism from largely frictional cataclasis to water-assisted grain boundary diffusion is believed to account for the marked reduction in strength of the pre-faulted Tennessee Sandstone at strain rates below about 10^{-6} s^{-1}.

Knowledge of the microstructures and deformation mechanisms in both naturally- and experimentally-deformed fault-rocks is crucial to our understanding their rheological behaviour. Electron microscopy is essential to the acquisition of such knowledge. Future studies should include analytical electron microscopy to examine chemical–mineralogical changes occurring during deformation of fault-rocks.

References

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