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Dynamic recrystallization in rocks: mechanisms, microstructures and consequences

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Dynamic recrystallization and associated recovery processes that occur during dislocation creep of rocks are essential in maintaining steady-state flow in the Earth's middle and lower crust and in the mantle. Moreover, recrystallization and recovery exert significant influence on the development of rock microstructures and crystallographic preferred orientations (CPOs): these are prime factors in controlling rock physical properties and physical property anisotropies. A lack of detailed understanding of the physics of recrystallization remains a significant barrier to our ability to interpret geophysical remote sensing data of the Earth's subsurface.

Electron backscatter diffraction (EBSD) in the scanning electron microscope (SEM) enables us to measure the full crystallographic orientation of lattice volumes as small as 50nm in diameter. Existing recrystallization models have geometric consequences that are testable with EBSD: particularly in cases where 'parent' and 'daughter' grains can be identified. EBSD data from deformed rocks and from rock forming minerals deformed and recrystallized under laboratory conditions suggest that simple physical recrystallization models such as subgrain rotation recrystallization and grain boundary bulging cannot always account for all observed microstructures. Experiments with rock analogues (metals and NaCl) recrystallized in-situ in an SEM give further insights into recrystallization processes and illustrate the control of temperature history on the nature of resultant microstructures. In some cases we need to invoke extra processes, such as grain boundary sliding and consequent granular flow. In other cases data are inexplicable within our current physical understanding of grain-scale processes and we must explore the role of new grain nucleation mechanisms.