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Scales of microstructure during dislocation creep in minerals

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To predict the natural deformation of rocks by creep requires an accurate constitutive law governing the mechanisms of production, motion, and annihilation of defects under geologic conditions. Comparison of natural microstructures with those produced during deformation in the laboratory suggests that several creep regimes are likely to exist, each regime being determined by the relative kinetics of various hardening and recovery mechanisms. At higher homologous temperatures, defect distributions are relatively homogenous, and deformation rate can be described by a single internal variable, e.g. dislocation density, or sub-grain spacing. An example of such a constitutive law is the commonly used power-law creep equation. For mantle peridotites, this equation provides a useful and accurate framework to understand mantle flow. However, for crustal rocks at lower temperatures, the defect microstructure may develop two or more characteristic length scales. In these cases, an accurate description of the deformation kinetics will likely require the identification of additional internal state variables. One example of coarser-grained scaling of dislocations can be observed in the Verrucano quartzite, just overlying the Lochseitenkalk formation along the Glaurus thrust. A second example can be seen in samples of Carrara marble experimentally deformed at temperatures less than 700 K. Current constitutive laws, at least as developed for geologic materials, do not accurately describe deformations that are controlled by such internal state variables. Although such microstructures pose a problem for accurate mechanical predictions, they may also represent an additional opportunity to gauge the conditions under which rocks are deformed naturally.