Geophysical Research Abstracts
Vol. 18, EGU2016-1869-2, 2016
EGU General Assembly 2016

The relationship between strain geometry and geometrically necessary dislocations

Lars Hansen (1) and David Wallis (2)

(1) Department of Earth Sciences, University of Oxford, Oxford, UK (David.Wallis@earth.ox.ac.uk), (2) Department of Earth Sciences, University of Oxford, Oxford, UK (lars.hansen@earth.ox.ac.uk)

The kinematics of past deformations are often a primary goal in structural analyses of strained rocks. Details of the strain geometry, in particular, can help distinguish hypotheses about large-scale tectonic phenomena. Microstructural indicators of strain geometry have been heavily utilized to investigate large-scale kinematics. However, many of the existing techniques require structures for which the initial morphology is known, and those structures must undergo the same deformation as imposed macroscopically. Many deformed rocks do not exhibit such convenient features, and therefore the strain geometry is often difficult (if not impossible) to ascertain. Alternatively, crystallographic textures contain information about the strain geometry, but the influence of strain geometry can be difficult to separate from other environmental factors that might affect slip system activity and therefore the textural evolution.

Here we explore the ability for geometrically necessary dislocations to record information about the deformation geometry. It is well known that crystallographic slip due to the motion of dislocations yields macroscopic plastic strain, and the mathematics are established to relate dislocation glide on multiple slip systems to the strain tensor of a crystal. This theoretical description generally assumes that dislocations propagate across the entire crystal. However, at any point during the deformation, dislocations are present that have not fully transected the crystal, existing either as free dislocations or as dislocations organized into substructures like subgrain boundaries. These dislocations can remain in the lattice after deformation if the crystal is quenched sufficiently fast, and we hypothesize that this residual dislocation population can be linked to the plastic strain geometry in a quantitative manner.

To test this hypothesis, we use high-resolution electron backscatter diffraction to measure lattice curvatures in experimentally deformed single crystals and aggregates of olivine for which the strain geometry is known. Tested geometries include constrictional strain, flattening strain, and plane strain. We use measured lattice curvatures to calculate the densities and spatial distributions of geometrically necessary dislocations. Dislocation densities are calculated for each of the major dislocation types in olivine. These densities are then used to estimate the plastic strain geometry under the assumption that the population of geometrically necessary dislocations accurately represents the relative activity of different dislocations during deformation. Our initial results demonstrate compelling relationships between the imposed strain geometry and the calculated plastic strain geometry. In addition, the calculated plastic strain geometry is linked to the distribution of crystallographic orientations, giving insight into the nature of plastic anisotropy in textured olivine aggregates. We present this technique as a new microstructural tool for assessing the kinematic history of deformed rocks.