How do rocks deform without opening up gaps? Implications for strength of the Earth

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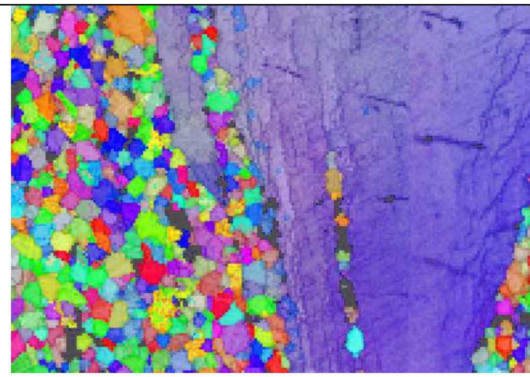
Introduction:

When rocks deep in the crust and mantle deform, the grains generally appear to have remained in contact. Dislocation creep (movement of linear intracrystalline defects so as to accomplish slip along atomic planes) is a key deformation mechanism in the Earth. Movement of dislocations is strongly controlled by crystallography – which means that when each grain has a different crystallographic orientation it should deform differently to its neighbours, opening up gaps. If we have *five* independent slip systems in a particular mineral then we can deform adjacent grains in harmony, but some important minerals such as plagioclase and olivine have fewer than five, as do other important crystalline materials such as ice (Chauve et al., 2017). So how do they deform? We need to know so that we can predict rock strength, because that is dependent on the ease of slip on the available slip systems *and* on how those slip systems interact. There are various opinions on how overall strength is controlled – some argue the strongest slip system will control it, others argue that the easier slip systems accommodate most of the deformation and the strongest one has a minor effect. Resolving this debate will assist in modelling large scale deformation in the Earth and will be addressed through a combination of field and microstructural studies and numerical modelling.

Project Summary:

Plagioclase is the most abundant mineral in the Earth's crust, and olivine in the upper mantle. Field studies on deformed anorthosite in Norway and peridotite in the Voltri area, Italy (Vissers et al., 1991) will set the scene for sample collection. In the laboratory, optical analysis will lead into mapping of crystallographic orientation using Electron Backscatter Diffraction, a technique Liverpool pioneered for Earth Science applications e.g. (Wheeler et al., 2001). This technique produces detailed microstructural maps automatically, from which lattice preferred orientations (which fingerprint dislocation creep) can be calculated. From the maps, the student will also deduce the presence of "stranded" dislocations which never slipped all the way through the lattice, and remain in distorted regions. These "geometrically necessary" dislocations will give clues as to which slip systems were active (Wheeler et al., 2009), and the local distortions will also be linked to the "accommodation problems" where neighbouring grains attempted to deform in different ways, building up local stress.

For a more complete understanding of how deformation has occurred, the student will use established numerical models for dislocation creep. One type, Visco-Plastic Self Consistent modelling, simplifies each grain to be an object deforming in an "averaged" surrounding of other grains (Lebensohn and Tome, 1993). Such models are widely used but do not have the capacity to simulate details of grain-grain interaction. Another model, based on a Fast Fourier Transform method, *does* address that e.g. (Castelnau et al., 2008). By comparing predictions of the two models with each other and with observed microstructures the student will provide a new picture of how dislocation creep is accommodated grain by grain and how that leads to the overall rock strength. The student will receive training in the EBSD, optical microscopy and mathematical techniques and will be part of a stimulating multidisciplinary environment within the Microstructure and Rock Deformation Research Group. The University of Liverpool provide a certified Postgraduate training programme for general research and other professional skills.

	
The Jotunheim, Norway	Deformed plagioclase, colour coded for crystal orientation. The colour variations in the large grain indicate lattice distortion

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