# Flow in polycrystalline ice

**C. Wilson**

**B. Marmo**

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e ice can accommodate large amounts of intracrystalline plastic ing develops specific flow characteristics and crystallographic preferred orientations. Ice flow at the scale of an ice crystal is dominated by the anisotropic nature of the crystal, with its dominant slip system in the basal plane. Polar ice tends to develop a preferred bulk fabric in response to its stress, strain rate and temperature history as it ages in cold ice sheets. Deformation is localised at the base of ice sheets, so the crystallographic fabric becomes progressively more pervasive with depth, with preferred vertical c-axis fabrics. This means that the anisotropic behaviour during flow is also manifested at scales larger than the ice grains as ice becomes progressively harder to compress vertically, and easier to shear horizontally with the development of contrasting brittle-ductile regimes.

Time-lapse images photographed through an optical microscope are presented which demonstrate intracrystalline processes associated with the deformation of granular ice aggregates in either a pure shear or simple shear. Sequences show that contemporaneous with these processes are dynamic recrystallisation, which involves nucleation of equiaxed grains, the motion of grain boundaries and the development of a preferred dimensional orientation. Underlying this deformation is the movement of dislocations and the generation of defect structures that contribute to the creep behaviour in polycrystalline ice. However, single crystals of ice have a very strong plastic anisotropy, as glide is several orders of magnitude easier on basal systems than on non-basal systems. An analogy is made to other hexagonal minerals such as quartz where the most commonly reported slip system is in the basal plane.

When polycrystalline ice is subjected to stress the deformation of individual grains is blocked by neighbouring grains and this builds up internal stresses both in the deforming grains and those around them. These stresses can be relieved in a variety of ways, all of which play some part in the deformation, namely:

1. Non-uniform deformation within a single grain can produce bending and the formation of undulose extinction or kinking.

2. Grains may slide over one another and microcracks may be nucleated.

3. Grain boundary migration will occur, causing some grains to grow at the expense of others. This process requires diffusion-controlled recovery, and may accompany the intracrystalline glide.

4. In regions which are highly deformed recrystallisation occurs, with the nucleation and subsequent growth of new grains, often more favourably oriented for basal slip. This can occur repeatedly during deformation, and is known as dynamic recrystallisation; this is accelerated by a decrease in grain size and where the initial orientation of grains are at a maximum critical resolved shear stress.

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