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EBSD in Antarctic and Greenland Ice

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Ice, particularly the extensive amounts found in the polar ice sheets, impacts directly on the global climate by changing the albedo and indirectly by supplying an enormous water reservoir that affects sea level change. The discharge of material into the oceans is partly controlled by the melt excess over snow accumulation, partly by the dynamic flow of ice. In addition to sliding over bedrock, an ice body deforms gravitationally under its own weight. In order to improve our description of this flow, ice microstructure studies are needed that elucidate the dominant deformation and recrystallization mechanisms involved. Deformation of hexagonal ice is highly anisotropic: ice is easily sheared in the basal plane and is about two orders of magnitude harder parallel to the c-axis. As dislocation creep is the dominant deformation mechanism in polar ice this strong anisotropy needs to be understood in terms of dislocation activity. The high anisotropy of the ice crystal is usually ascribed to a particular behaviour of dislocations in ice, namely the extension of dislocations into partials on the basal plane. Analysis of EBSD data can help our understanding of dislocation activity by characterizing subgrain boundary types thus providing a tool for comprehensive dislocation characterization in polar ice.
Cryo-EBSD microstructure in combination with light microscopy measurements from ice core material from Antarctica (EPICA-DML deep ice core) and Greenland (NEEM deep ice core) are presented and interpreted regarding substructure identification and characterization. We examined one depth for each ice core (EDML: 656 m, NEEM: 719 m) to obtain the first comparison of slip system activity from the two ice sheets. The subgrain boundary to grain boundary threshold misorientation was taken to be 3-5° (Weikusat et al. 2011).
EBSD analyses suggest that a large portion of edge dislocations with slip systems basal <a> gliding on the basal plane were indeed involved in forming subgrain boundaries. However, an almost equal number of tilt subgrain boundaries were measured, involving dislocations gliding on non-basal planes (prism <c> or prism <c+a> slip). A few subgrain boundaries involving prism <a> edge dislocation glide, as well as boundaries involving basal <a> twist dislocation slip, were also identified. The finding that subgrain boundaries built up by dislocations gliding on non-basal planes are as frequent as those originating from basal plane slip is surprising and has impact on the discussion on rate-controlling processes for the ice flow descriptions of large ice masses with respect to sea-level evolution.

Weikusat, I.; Miyamoto, A.; Faria, S. H.; Kipfstuhl, S.; Azuma, N. & Hondoh, T.: Subgrain boundaries in Antarctic ice quantified by X-ray Laue diffraction J. Glaciol., 2011, 57, 85-94