Evolution process of ice fabrics in polar ice sheets inferred from anisotropic distribution of crystal orientation

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In order to better understand a detail paleoclimate from deep ice core study, the knowledge about the ice flow behavior is essential to us. We have to discuss how global change signals are formed and kept in the flowing ice sheet, and how the ice sheet changed in the past. We also need such information for the estimate dating of the ice cores. Many experiments indicate that the ice flow behavior is controlled by c-axis orientation distribution. Therefore, it is important that we understand how ice fabric development in polar ice sheets. In this study, we use X-ray Laue method to measure ice crystal orientations. An X-ray measurement apparatus, which can measure the orientation of c- and a-axis of each crystal with high measurement accuracy was developed. We present a-axes orientation distribution of the deep part of summit ice cores, the GRIP ice core, Greenland and the Dome Fuji ice core, Antarctica. The samples cut from a depth from 1932 m to 2647 m of the GRIP ice core and from 1679 m to 2450 m of the Dome Fuji ice core. Around these depths, the fabric pattern of c-axis orientation shows weak single maximum to strong single maximum. We expect that the azimuth of the a-axes is randomly distributed. However, an anisotropic distribution of a-axes occurred at some depths in the GRIP and Dome Fuji ice core. We suggest that this anisotropic distribution of a-axes is attributed to local simple shear parallel to the horizontal direction of the ice sheet in the deep part.

The simple shear deformation tests are performed on the GRIP ice core samples from a depth of 2427 m and 2593 m at –15 degree C. The objective of this test is to investigate the ice fabric development process under the simple shear stress field. After 30% shear strain of the both GRIP ice core sample, a weak concentration of a-axes is observed in direction to shear deformation. We now propose an explanation of these anisotropic distributions of a-axis orientations by using the anisotropy of crystallographic slip directions (e.g. parallel to [11-20] and [10-10]) of ice single crystal across the basal plane. The preferred glide direction is parallel to [11-20] in the basal plane, and then a-axis of each grain tends to align to the simple shear direction. However, the glide direction between parallel to [11-20] and parallel to [10-10] has no obvious anisotropy like the glide in basal plane and non-basal plane. Hence, slight anisotropic distribution of a-axes occurs at 30% shear strain. These results and considerations may help us to a better understanding of ice sheet structure and history of ice sheet deformation. Also it leads to improved ice sheet flow models that include finer details of ice fabric evolution process.