Contact: daniela.jansen@awi.de

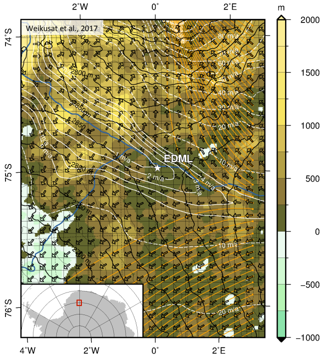
ALFRED-WEGENER-INSTITUT
HELMHOLTZ-ZENTRUM FÜR POLAR- UND MEERESFORSCHUNG

Daniela Jansen[1], I. Weikusat[1,2], T. Kleiner[1], F. Wilhelms[1,3], D. Dahl-Jensen[4], A. Frenzel[1], Nicolas Stoll[1], T. Binder[1], J. Eichler[1], S. H. Faria[5,6], S. Sheldon[4], C. Panton[4], S. Kipfstuhl[1], and H. Miller[1]

In situ-measurement of ice deformation from repeated borehole logging of the EPICA Dronning Maud Land (EDML) ice core, East Antarctica.

Introduction

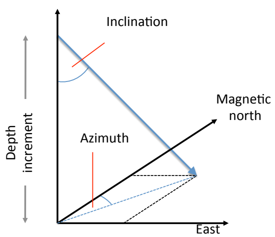
The EPICA Dronning Maud Land ice core was drilled between 2001 and 2006 at the Kohnen Station, Antarctica. During the drilling process the borehole was logged repeatedly, measuring temperature and pressure as well as azimuth and inclination (Wilhelms et al., 2015) Repeated logging of the borehole shape delivers an estimation of the in-situ deformation within the ice sheet, in particular shear strain rates for the lower part, which are essential for the effectiveness of ice transport from the inner continent towards the ocean.



As the ice flow velocity at the position of the EDML core is relatively slow (about 0.75 m a^{-1}), the changes of borehole shape between the logs during the drilling period were very small and thus difficult to interpret. Thus, the site has been revisited in the Antarctic summer season 2016/2017 and logged again using the same measurement system. Here we present the change of the borehole shape between November 2005 and December 2016, and correlate our findings with observed ice microstructure

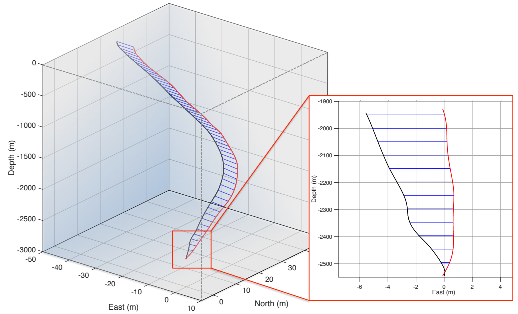
Instrumentation

The logging system developed by the University of Copenhagen (Gundestrup et al., 1994) recorded the tilt of the borehole with respect to the vertical (inclination) as well as the heading of the borehole with respect to magnetic north (azimuth) by means of two fluxgate magnetometers.



This dataset provides the basis for a 3-D reconstruction of the borehole shape by integrating over all depth increments. The data were processed with Matlab, with a script developed by C. Panton. Additional to the 3D borehole shape the vertical velocity gradient du/dz was calculated. In the top part of the borehole there are some undulations, but in the lower part where simple shear is the dominating deformation the shape appears to be more even.

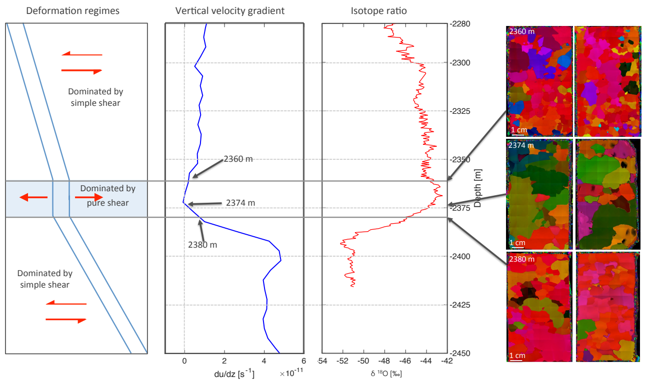
Borehole shape



The shape of the borehole describes a gentle curve, first pointing west north west and then at a depth of 1500 m turning towards south. The overall horizontal distance of 42 m from the top to the base of the borehole is small in comparison to the depth scale.

Deformation regimes

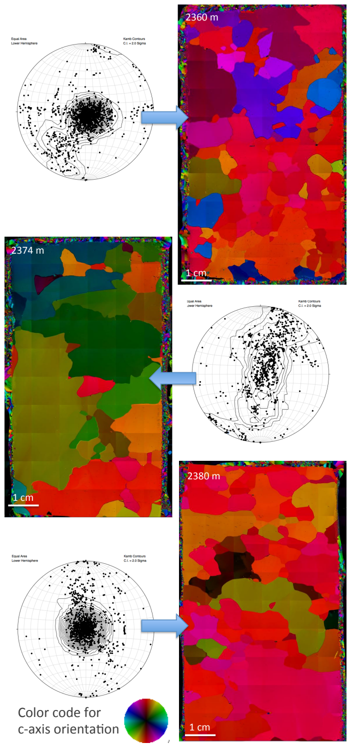
From the two borehole shape records we could derive a vertical profile of the velocity gradient. This can be used to estimate the local vertical shear strain rate. It appears that there is a transition from relatively high shear strain rate at the base, which reaches a minimum at 2372 m depth, where the vertical velocity gradient is as low as zero, indicating a pure shear environment.



Ice microstructure

Evaluation of ice thin section in the depth region around the shift in the velocity gradient showed, that the c-axes are distributed in a girdle, a fabric typical for the upper part of ice divides, and an indicator for pure shear. Weikusat et al. show that at EDML the girdle fabric is changing into a single maximum fabric at approx. 2000 m depth. Around a depth of 2370 m the girdle reappears for a narrow depth interval of about ten meters. At the same time the grain size is increasing significantly. Very large grains with an area of about 1000 mm^2 are found in all samples measured from this depth region. The grains are too large to estimate a mean grain size, as many of the large grains are cut at the sample edges. Above and below this area grain size is much smaller.

As an indicator for the impurity content the $\delta^{18}O$ ratio is plotted. From this and also from line scan images (not shown) we assume that the impurity content within the small grained samples shown here is not very different from the girdle region. The decrease of $\delta^{18}O$ below indicates the end of MIS 5.5.



Conclusions

- The girdle fabric indicates a layer of ice hardly affected by simple shear, which is sandwiched between a layer with strong shear below, and with moderate shear above.
- The larger grains are most likely due to less deformation, as the isotope curve show impurities content should be similar to finer grained layers above and directly below.
- Thus, it appears this layer might be a shadow zone due to the localized shear above and below.

References:

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Affiliations:
(1) Alfred-Wegener-Institut Helmholtz-Zentrum für Polar- und Meeresforschung, Bremerhaven, Germany (daniela.jansen@awi.de), (2) Department of Geosciences, Eberhard Karls University, Tübingen, Germany, (4) CIC, Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark, (3) Georg-August-Universität Göttingen, Göttingen, Germany, (5) Basque Centre for Climate Change (BC3), University of the Basque Country, Leioa, Spain, (6) IKERBASQUE, Basque Foundation for Science, Bilbao, Spain

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