Deformation Features and Disturbances in the Stratigraphy of the EastGRIP Ice Core

Julien Westhoff (1), Ilka Weikusat (2,3), Sepp Kipfstuhl (2), Daniela Jansen (2), Anders Svensson (1), and Dorthe Dahl-Jensen (1,4)

(1) Physics of Ice, Climate, and Earth, Niels Bohr Institute, University of Copenhagen, Copenhagen, Denmark,
(2) Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany,
(3) Department of Geosciences, Eberhard Karls University Tübingen, Tübingen, Germany
(4) Centre for Earth Observation Science, University of Manitoba, Winnipeg, Canada

Photography encouraged

Data Used and Main Focus of Poster

Data used in this work is provided by the AWI-Linescanner during field work at EastGRIP and with this great thanks to Ilka Weikusat (AWI, Bremerhaven).
The main focus here is the Glacial Period of the EastGRIP core drilled so far: i.e. bag 2260 to 3199 (1243 m to 1760 m below surface).

EastGRIP

The EastGRIP (East GReenland Ice core Project) Ice Core is drilled in a highly dynamic area, the NEGIS (North East Greenland Ice Stream), with a surface velocity of 50 m/yr, representing high flow rates in this area. All previous deep ice cores in Greenland were mainly drilled to find undisturbed ice for climate reconstruction. In contrast, the main purpose of this ice core is to increase our understanding of ice flow and linking it to deformation features shown in the physical properties.

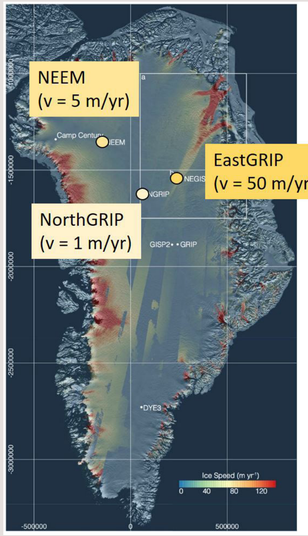


Fig. right: three drilling sites, with corresponding surface velocities (Vallelonga et al. 2014).

Line Scanner

Some of these deformation features can be made visible using the line scanner device. It scans a polished ice core slab illuminated by an indirect light source (similar to dark field microscopy) and thus makes internal features (e.g. impurities, bubbles, hydrates and partly grain boundaries) visible, creating a 10x165 cm image of the core.
Light traveling though the core is reflected and scattered at these features thus causing the camera to detect a bright section where the impurity content is high ("cloudy bands"), whereas ice with a low impurity concentration will not reflect light and contribute a dark layer in the image ("clear bands"). This is used to make layering, i.e. the stratigraphy, visible. Ice from the last glacial period has a well layered stratigraphy resulting from fairly regular annual dust storms in spring to summer. As deformation increases and deformation modes change towards the bottom of the core, these layers will show disturbances and folding.

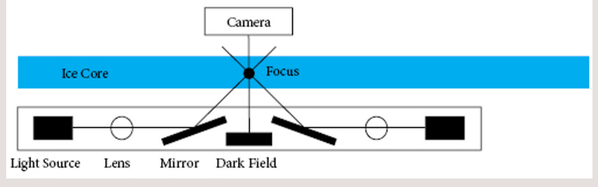


Fig above: sketched setup of the Line Scanner (modifyed from Svensson et al. 2005).

References

Svensson, A., Nielsen, S. W., Kipfstuhl, S., Johnsen, S. J., Steffensen, J. P., Bigler, M., Ruth, U., & Röthlisberger, R. (2005). Visual stratigraphy of the North Greenland Ice Core Project (NorthGRIP) ice core during the last glacial period. Journal of Geophysical Research: Atmospheres, 110(D2).

Vallelonga, P., Christianson, K., Alley, R. B., Anandakrishnan, S., Christian, J. E. M., Dahl-Jensen, D., ... & Winstrup, M. (2014). Initial results from geophysical surveys and shallow coring of the Northeast Greenland Ice Stream (NEGIS). The Cryosphere, 8(4), 1275-1287.

Deformation Features

Main deformation in the upper part of the ice sheet is pure shear (stretching along the horizontal and thinning in the vertical) and simple shear in the bottom parts. The gradual change from pure to simple shear is seen in the development of small scale disturbances in the layers, such as wavy patterns. The evolution of these features into z- and s-folds is expected in greater depth. Hereby the layer will deform into a z- or s-shape, overturning a section of the layer. Wavy features, such as the ones seen here, have not been observed in other cores and could be associated to the highly dynamic drill site in NEGIS.

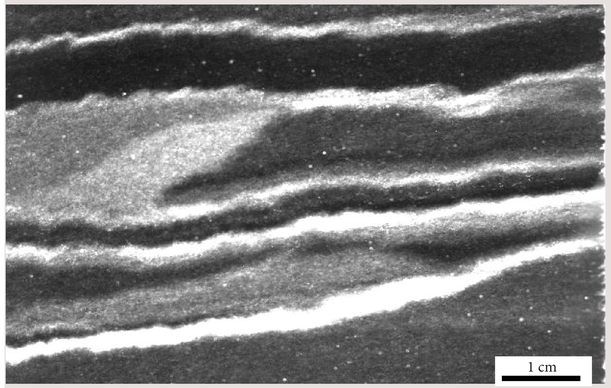


Fig. above: bag 3002 (1651.1 m) with strong disturbances in the stratigraphy of cloudy bands.

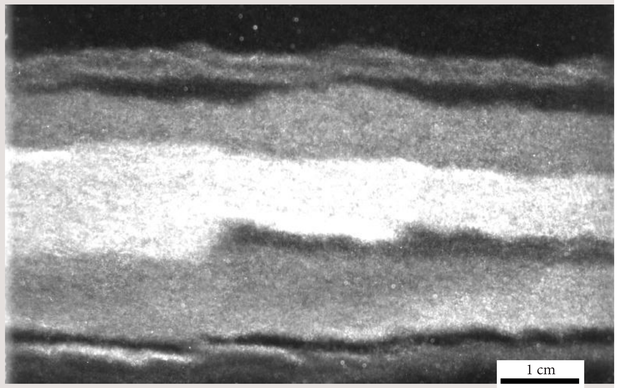


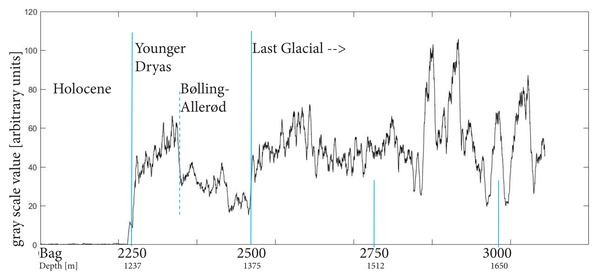
Fig. above: bag 3005 (1652.75 m) with sharp steps and a dark layer ending in the step.

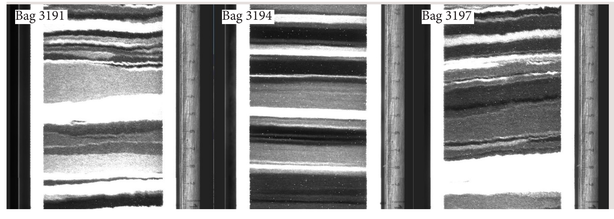
Grayscale and Age

The intensity (grayvalue) is derived from the visual intensity of different layers. There is a strong relationship between the grayscale values to the impurity concentration and ^{18}O of the water isotopes, which can be seen in the record of the NorthGRIP core (compare Svensson et al., 2005). As isotopes and impurities data is not available yet for EastGRIP, this figure shows a preliminary correlation of the gray value to the climate record.

The outer edge of this poster shows the transition from the Last Glacial into the Bølling-Allerød period; counter clockwise, starting in the bottom left corner.

Fig. right: preliminary results of gray values and age; using a 5 m running mean.





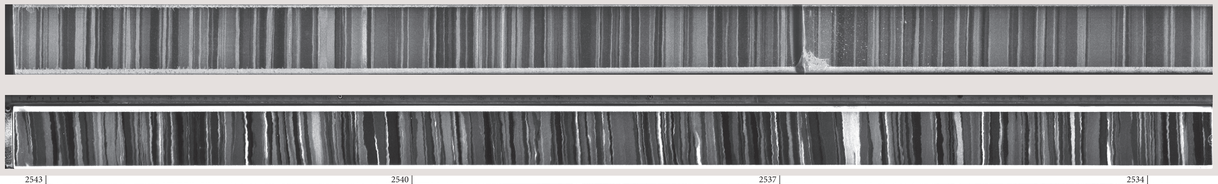
Dependancy on Core Orientation

Three consecutive core sections (left: bag 3191, middle: bag 3194, right: bag 3197) showing different features of disturbances, depending on viewing angle. Viewing angle is dependant on the vertical cut of the core during processing, which is chosen by core quality.
Since the disturbances are only seen at certain viewing angles, the features visible are strongly depend on the direction of ice flow.

Fig. left: difference in layer disturbances in three consecutive but rotated cores.

Comparing North- and EastGRIP

NorthGRIP core (top) is from a site with a surface velocity of 1 m/yr, resulting in lower strain rates and less deformation than at the EastGRIP site (bottom), which has a surface velocity of 55 m/yr. Both cores are from the same depth: bag 3196 (NorthGRIP) and bag 3197 (EastGRIP) - approx.: 1759 m depth.
NorthGRIP shows a well layered stratigraphy, while EastGRIP shows significant disturbances in the layers at this depth.



Evolution of Layer Deformation with Depth

The following images are from the Glacial Period, with cloudy bands that show an increase of deformation features with depth. All images are taken with the same camera settings.

Top image: bag 2297 (1263.35 m depth at bag bottom).
flat layers, with almost no folding
Middle image: bag 3008 (1654.40 m).
wavy layers, thickening and thinning of layers
Bottom image: bag 3110 (1710.50 m)
"fuzzy" layers with folding features with short wave lengths