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Fabrics and grain-shape orientations in EDML ice core, Antarctica

Introduction and Method

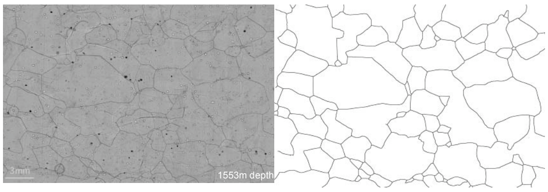
Interpretation of the palaeoclimatic information provided by a long ice core requires understanding on deformation and on evolution of stratigraphic layering present in the core. The aim of the presented study is to find evidences for deformation geometry regimes along the core. To obtain this understanding crystallographic and stratigraphic information available has been used. Combination of data from different methods gives insight into the deformation history.

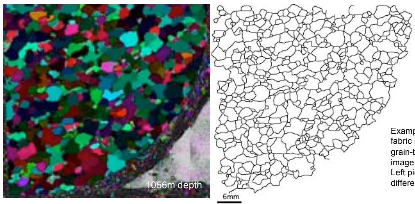
Vertical and horizontal thick and thin sections along the whole length of the ice core have been prepared (10m interval) and examined. Grain-shape data have been derived from microphotographs of sublimated surfaces of thick sections (grain boundaries as etch grooves, Kipfstuhl et al. submitted) for vertical sections and from photographs taken between crossed polarizers for horizontal sections. Grain boundary networks have been extracted by partly automated image analysis procedures (see examples) and grain elongation directions have been derived as the long axis direction of an approximated ellipse with same area on each grain.

Fabrics data are derived from thin sections measured with an automated fabric analyzer system (Wilson et al. 2003). Additionally to Schmidt-diagrams, we present eigenvalues of the orientation tensor derived by the c-axes distributions (Wallbrecher 1979), which describe the distribution as an ellipse with the eigenvalues being its three axes.

Also included to this analysis is the stratigraphic layering, which has been recorded as line scan documentation continuously along the the complete length of the core.

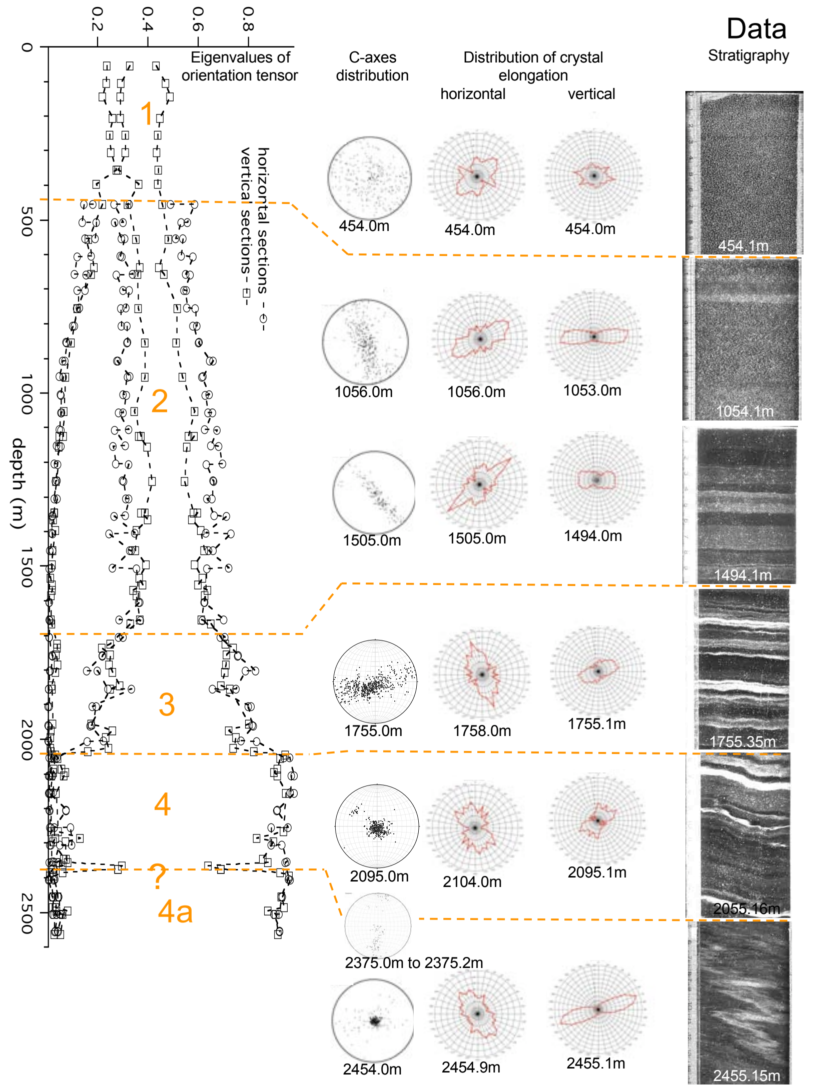
Example of microstructure mapping picture and resulting grain-boundary network obtained by image segmentation via threshold. Left pictures shows strong black lines which are grain boundaries revealed by sublimation.





Example of AVA-picture produced for fabric measurements and resulting grain-boundary network obtained by image segmentation via edge finding. Left pictures shows different grains in different colours.

Data



Interpretations and Conclusions

The data on c-axes distributions presented by eigenvalues of the orientation tensor (three axes of an ellipse describing the distribution) and by Schmidt-diagrams, data on grain elongation and stratigraphy show that five regions along the core length can be distinguished. Here the results are interpreted as effects of different deformation geometries.

Region **1**
(down to ~450 m depth)
- similar eigenvalues, due to random c-axes distributions
- no significant preferred crystal elongation direction
  - ➲deformation is not strong yet.

Region **2**
(~450 to 1700 m depth)
- eigenvalues start to separate into three levels ➔ evolution of girdle fabric (progressive narrowing of girdle)
- simultaneous strengthening of crystal elongation direction distribution
  - in vertical sections: parallel to the horizontal (although orientation of core lost in the brittle zone, random cutting) ➔true horizontal oblate-shaped elongation
  - in horizontal sections: perpendicular to the plane of c-axes
- horizontal stratigraphic layering becomes clearly visible
  - ➲increasing horizontal uni-axial extension deformation, as expected for ice-divide drilling sites (e.g. Lipenkov et al. 1989)

Region **3**
(~1700 to 2020 m depth)
- decrease of middle eigenvalue and increase of largest eigenvalue ➔slight tendency of concentration of c-axes inside girdle & slight rewidening of girdles in Schmidt-diagrams
- crystal elongations in vertical sections not horizontal any more
- slight buckling of stratigraphic layers starts
  - ➲destabilization of the horizontal uni-axial extension (local inclination of extension direction & changeover to the next deformation geometry)

Region **4**
(> ~2020 m depth)
- same level of lower eigenvalues & high level of largest eigenvalue ➔single maximum fabric along the vertical core axis)
- grain elongation direction histograms
  - in horizontal sections: preferred direction
  - in vertical sections: broad (45°), but distinct distribution with tendency of double/multiple maxima
- concurrently stronger folding & mean inclination of stratigraphic layers
  - ➲probably bed-parallel simple shear deformation (Wang et al. 2002)

Region **4a? or 5?**
(> ~2360 m depth)
- locally very restricted (~10 m @ 2375 m depth) backslide to girdle fabric ➔ three different eigenvalues
- single maximum fabric below that reoccurs, yet slightly inclined from the vertical
- crystal elongation direction distribution in vertical significantly narrows again
- Isoclinal z-folding observed in stratigraphy
  - ➲ ???

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References

Kipfstuhl, S. Hamann, I., Lambrecht, A., Freitag, J., Faria, S. H., Grigoriev, D., Azuma, N. 2005. Microstructure mapping – a new method for imaging deformation-induced microstructural features of ice on the grain scale. Submitted to Journal of Glaciology.

Lipenkov, V.Ya., Barkov,N.I., Duval, P., Pimienta, P. 1989. Crystalline texture of the 2083 m ice core at vostok station, Antarctica. Journal of Glaciology 35, (121), 392-398.

Wallbrecher,E. 1979. Methoden zum quantitativen Vergleich von Regelungsgraden und Formen strukturgeologischer Datenmengen mit Hilfe von Vektorstatistik und Eigenwertanalyse. Neues Jahrbuch Geol. Paläontol. Abh. 159,113-149.

Wang, Y., Thorsteinsson, T., Kipfstuhl, S., Miller, H., Dahl-Jensen, D., Shoji, H. 2002. A vertical girdle fabric in the NorthGRIP deep ice core, North Greenland. Annals of Glaciology 35, 515-520.

Wilson, J.L., Russell-Head, D.S., Sim, H.M. 2003. The application of an automated fabric analyzer system to the textural evolution of folded ice layers in shear zones. Annals of Glaciology 37, 7-12.