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Deformation modes and geometries in the EPICA-DML ice core, Antarctica

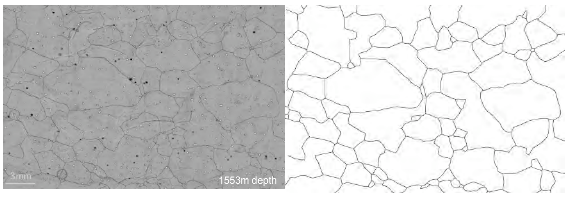
Introduction and Method

Interpretation and dating of the palaeo-climatic information provided by a long ice core requires knowledge and understanding of the post-depositional processes such as deformation and alteration of stratigraphic layerin in the core. Different deformation modes can affect the time sequences differently and thus the flow history for the whole length of the core must be known. Combination of crystallographic and stratigraphic data can reveal evidences for changing deformation modes along the core.

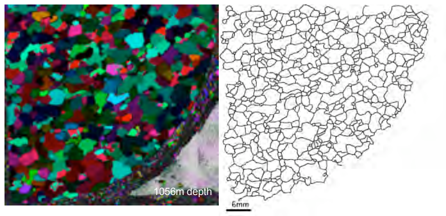
Vertical and horizontal thick and thin sections have been prepared (10m interval) and examined. Grain-shape data have been derived from microphotographs of sublimated surfaces of thick sections (grain boundaries as etch grooves, Kipfstuhl et al. 2006) for vertical sections and from photographs taken 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 measured 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 enveloping ellipse with the eigenvalues being its three axes.

Visual stratigraphic layering has been recorded continuously along the the complete length of the core with a line-scan camera (described by Svensson et al. 2005).

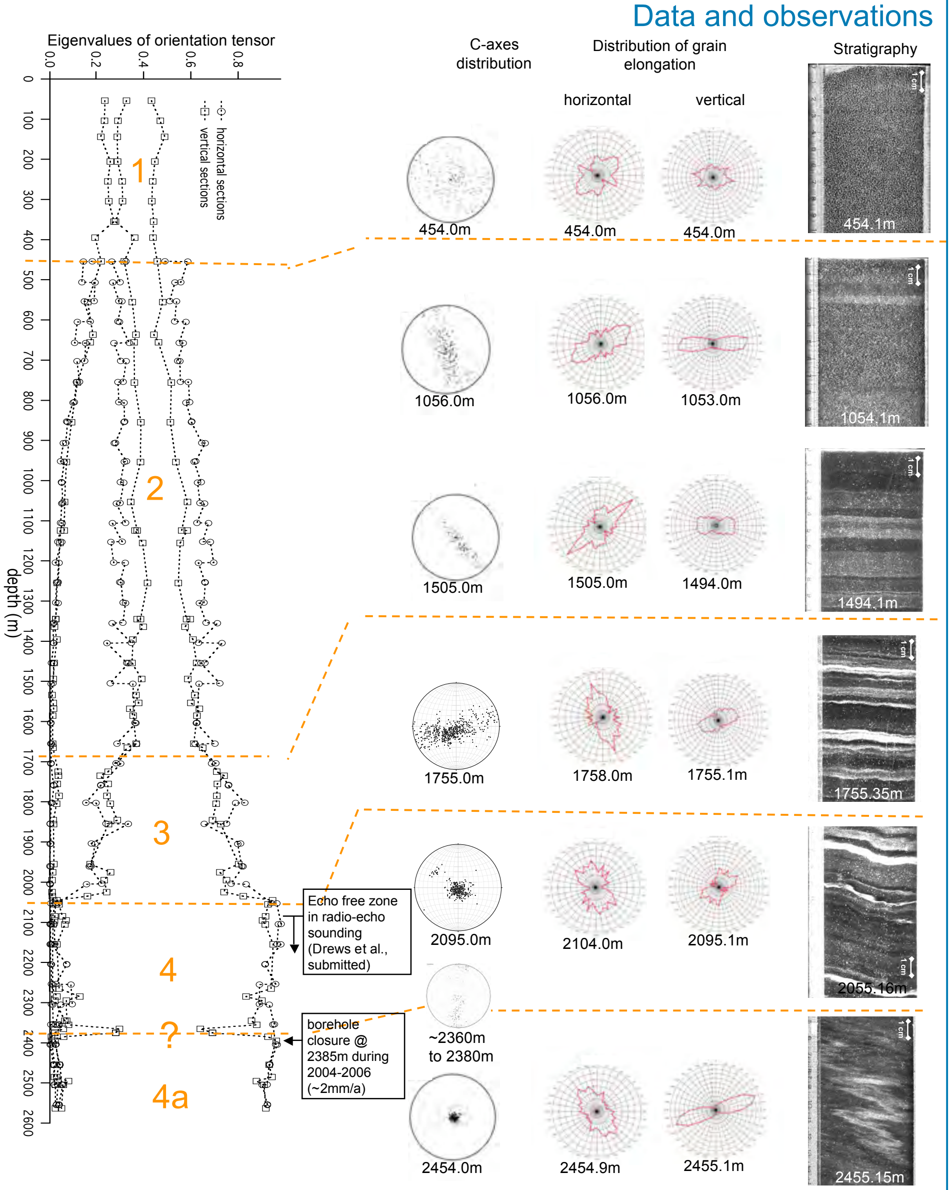


Example of microstructure mapping picture and resulting grain-boundary network obtained by image segmentation via threshold. Left picture shows strong black lines which are grain boundaries revealed by sublimation.



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 and observations



Interpretation and Conclusion

The crystal orientation fabric, grain elongation distributions and visual stratigraphy show that five regions along the core can be distinguished. Here the results are interpreted as effects of different deformation modes or flow 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 and 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 thus 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 2030 m depth)
•decrease of middle eigenvalue and increase of largest eigenvalue
➔slight tendency of concentration of c-axes inside girdle & slight re-widening of girdles in Schmidt-diagrams
•crystal elongations in vertical sections with angle to horizontal
•mm-scale undulations in visual stratigraphic layering
➲destabilization of the horizontal uni-axial extension (local inclination of extension direction & transition to the next deformation geometry)

Region 4
(> ~2050 m depth)
•two extreme levels of eigenvalues ➔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
•mm-scaled z-folding & inclination of stratigraphic layers (10°-15°)
•radio echos fade out due to loss of coherency of layers caused by intensely disturbing flow (Drews et al. submitted)
➲bed-parallel simple shear deformation (Wang et al. 2002)

Region 4a? or 5?
(> ~2360 m depth)
•locally very restricted (~20 to 30 m around 2375 m depth) backslide to girdle fabric ➔ three different eigenvalues
•below single maximum fabric reoccurs, yet slightly inclined from the vertical
•narrowing of grain elongation distribution in the vertical
•borehole closure coincides with micro-shear deformation microstructure (slanted brick wall pattern, Faria et al. 2006)
•strong isoclinal z-folding observed in stratigraphy
➲ bed-parallel simple shear with locally restricted high deformation shear zones ....???

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