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Grain boundary hierarchy in the EPICA-DML deep ice core, Antarctica

Introduction

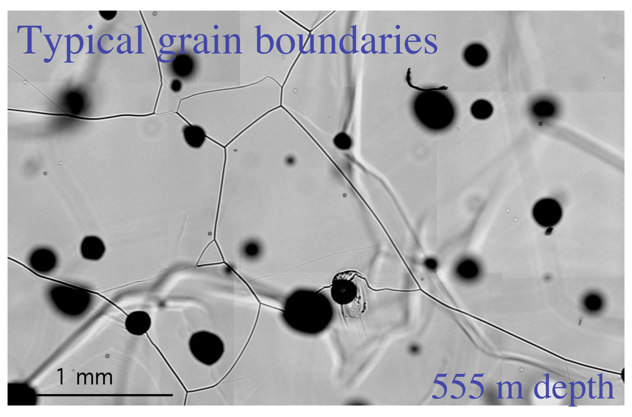
Macroscopic flow of ice can result from a number of different mechanisms, each of which dominate the rheology of the ice at a particular range of physical conditions (temperature, pressure, differential stress). The polycrystalline ice of ice sheets consits of grains, which are discontinuous at the boundaries and deform by the migration of crystal defects on the atomic scale. Microstructural processes like polygonization, grain growth and recrystallisation are directly affected by the (sub-) grain boundary arrangement and hierarchy. Optically visible traces of these processes were recorded along the EPICA-DML ice core. Preliminary results of this study are presented in this poster.

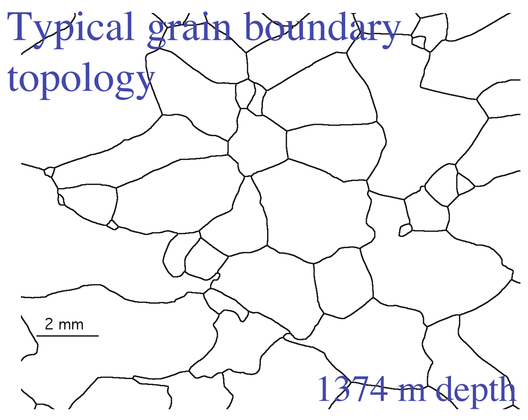
Method

Thick sections (50 mm x 100 mm x 5 mm) were cut parallel to the vertical axis of the EPICA Dronning Maudland (EDML) ice core, currently drilled in Antarctica and were mapped under a microscope. A digital image of an entire section in microscopic resolution was reconstructed and used to extract information about the (sub-) grain boundary topology and the occurrence of bulging and pinning.

Grain boundaries

• They appear as strong black lines.
• Grain boundaries are connected to each other (grains are closed).

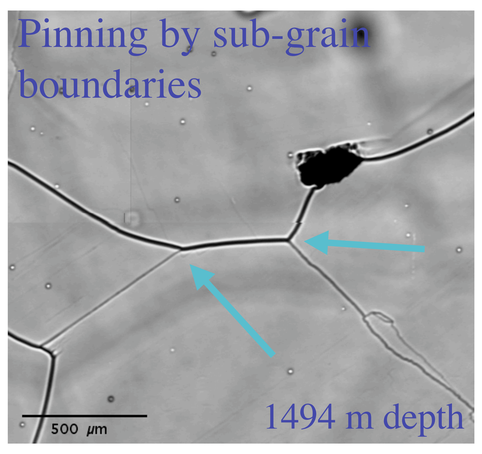


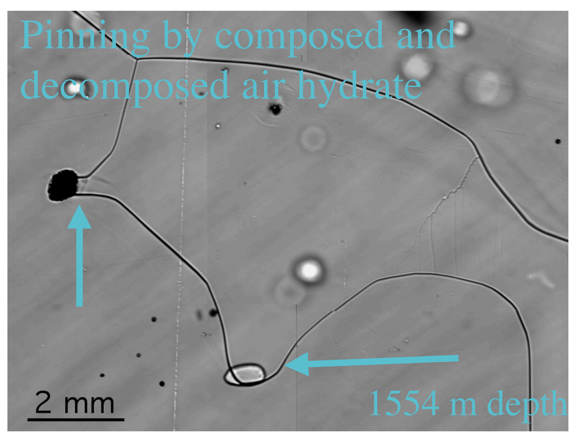


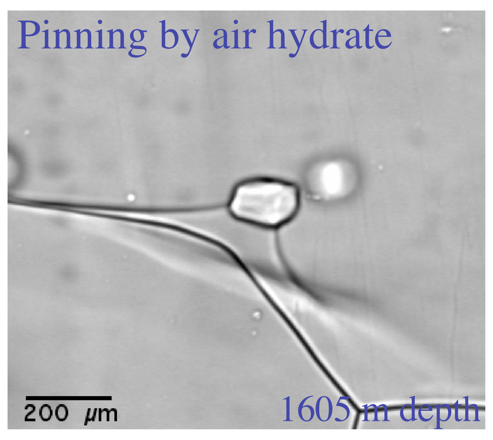
• Foam textures characteristic for normal grain growth expected within the upper hundreds of meters (~500 m) is not observed. Qualitatively, the appearance of the grain boundary topology does not change with depth.

Grain boundary pinning

• Moving grain boundaries can become pinned by inclusions (air bubble or hydrate clathrate) and sub-grain boundaries.
•10-20% of all grains show pinning.

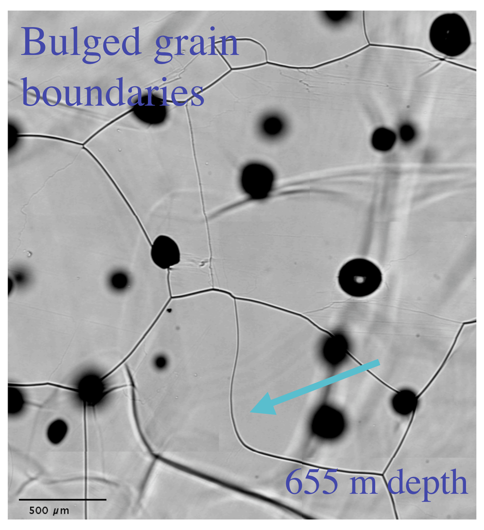




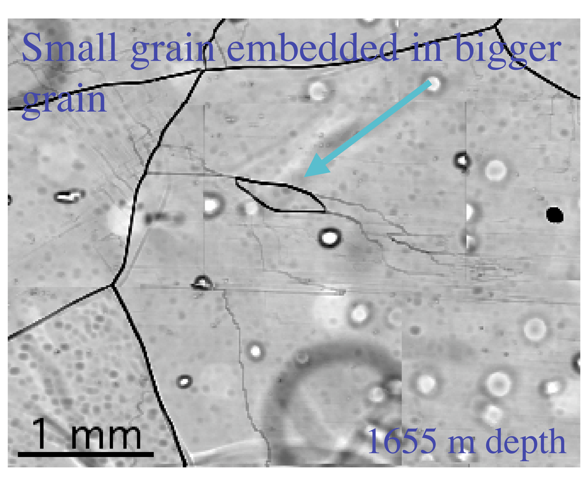


Grain boundary bulging

• Bulging of grain boundaries indicates strain induced grain boundary migration.
• 70-80% of all grains show bulged grain boundaries.



(Sub-)Grain boundary loops - “Island grains”



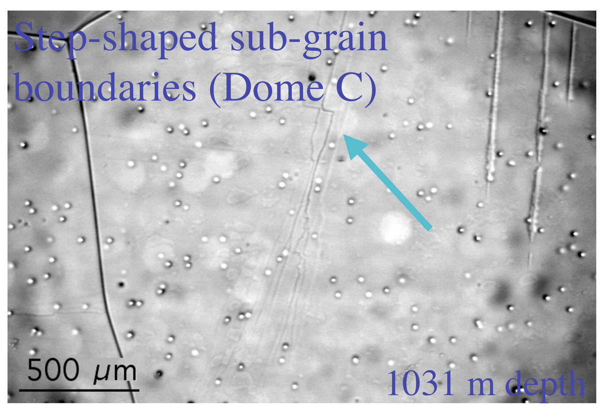
• Small isolated grains embedded in larger grains, often in sub-grain bearing parts of a grain
• Two possibilities of formation:
1) 3D-effect (loops as section of out-bulging part of a grain)
2) loop as new nucleated grain in deformed part of the host grain
• 1-2% of all grains show embedded island grains.

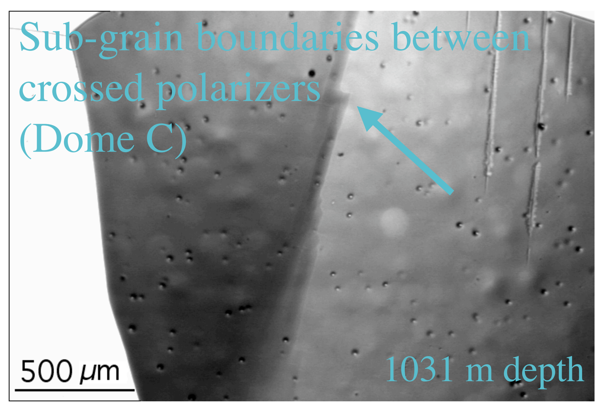
Conclusions

In the upper 2500 m of the EDML ice core we cannot recognize qualitative differences or trends in the appearance of the grain boundary topology, in bulging and pinning. Furthermore occur sub-grain boundaries in all depths without differences in arrangement. This may indicate that the competing processes deformation, grain growth and recrystallisation equally contribute to the observed microstructure and work largely independent on depth and age. This is surprising as normal grain growth is assumed to dominate in the upper hundreds of meters of the ice sheet, migration recrystallisation in the lowest and polygonisation in between.

Sub-grain boundaries

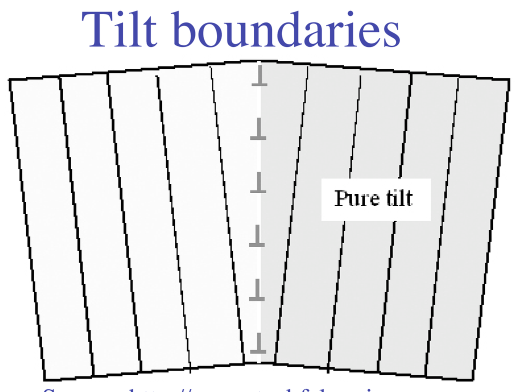
• They appear as thinner, fainter lines.
• Between crossed polarizers a sample shows misorientation at sub-grain boundaries.
• Sub-grain boundaries can fade out (sub-grains seem open).
• > 50% of all grains contain sub-grain boundaries independent on depth.



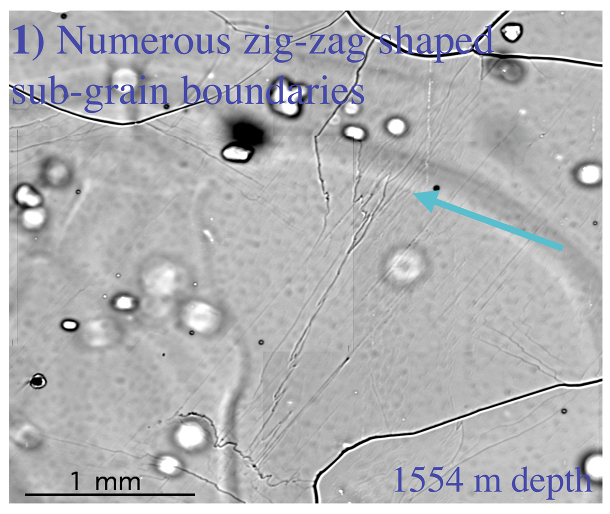


Sub-grain boundaries perpendicular to basal plane

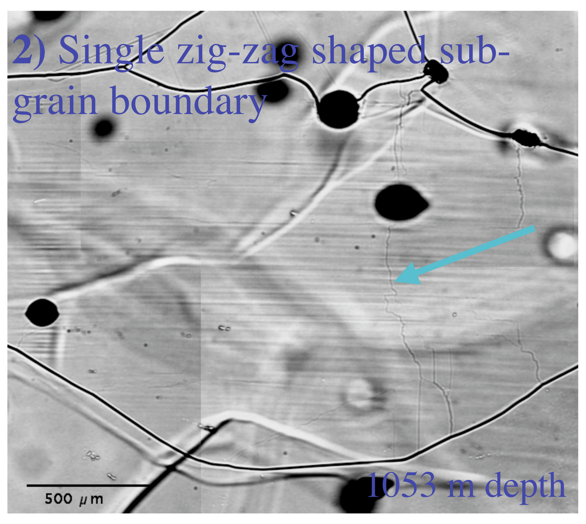
Tilt boundaries



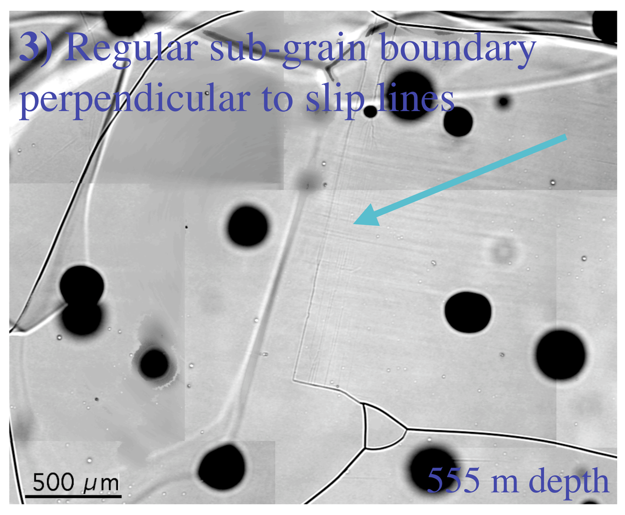
Source: http://www.techfak.uni-kiel.de/matwis/amat/def_en/index.html



1) irregular, zig-zag shaped, numerous in one part of a grain
• Interpretation: beginning stage of sub-grain boundary formation during polygonisation. Edge dislocations induced by deformation start to arrange during recovery and form arrays of edge dislocations (tilt boundaries).



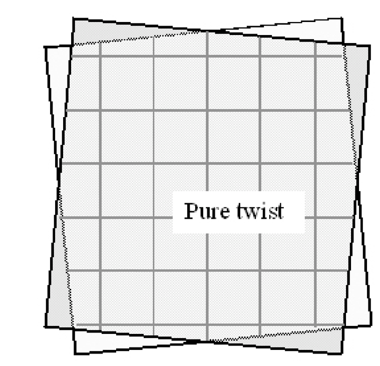
2) Arrangement and accumulation of dislocations and tilt boundaries leads to ordering. Number decreases and sub-grain boundaries become more smooth.



3) In the late stage of development one single sub-grain boundary divides the grain (polygonisation) perpendicular to slip lines.

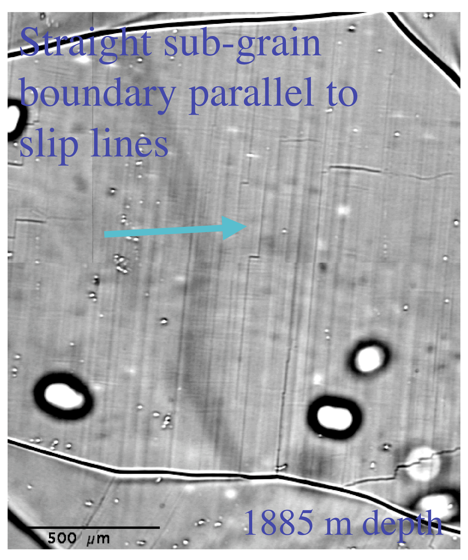
Sub-grain boundaries parallel to basal plane

Twist boundaries



Source: http://www.techfak.uni-kiel.de/matwis/amat/def_en/index.html

• Straight sub-grain boundaries, parallel to slip lines
• Interpretation: they develop when part of a grain is twisted (rotation axis parallel to c-axis). Arrays of screw dislocations accumulate and form sub-grain boundaries.



Dependence on geometry

• The occurrence of sub-grain boundaries at necks of bulged or severely exposed parts of a grain, shows that interaction with grain boundaries is related to geometry of grains.