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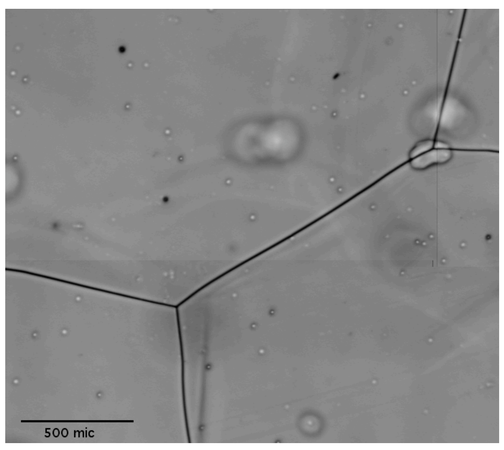
Microstructure investigations on grain scale of ice from Antarctica (EDML) to establish deformation and its mechanisms

Method

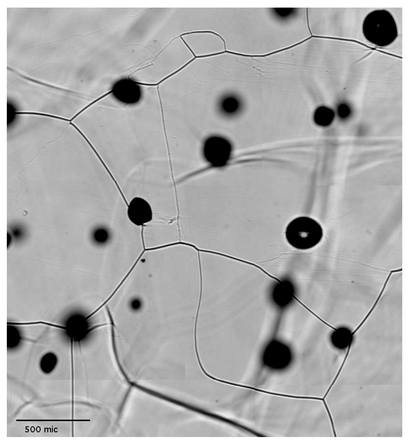
Thick sections (50 mm x 100 mm x 5 mm) parallel to the axis of the ice core are mapped with a microscope after microtoming and sublimation. Each scan contains approximately 1500 pictures (2.5 mm x 1.4 mm).

Which microstructure features are visible? What do they look like? Grain boundary hierarchy

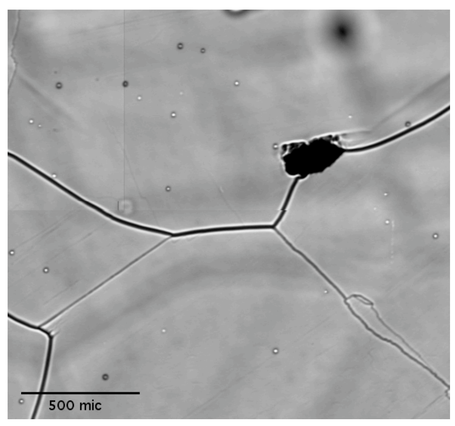
(Sub-)Grain boundaries are the most common features. Their Shapes, intensity and orientation with respect to other microstructural elements (e. g. slip lines) vary with microstructural processes.



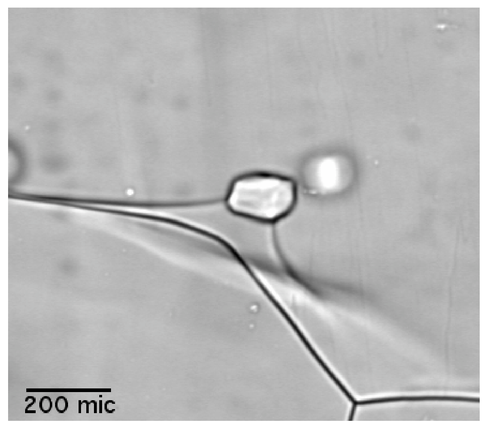
Straight grain boundaries (1374 m depth)



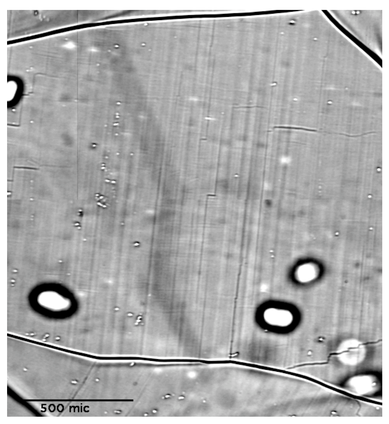
Bulged grain boundaries (655 m depth)



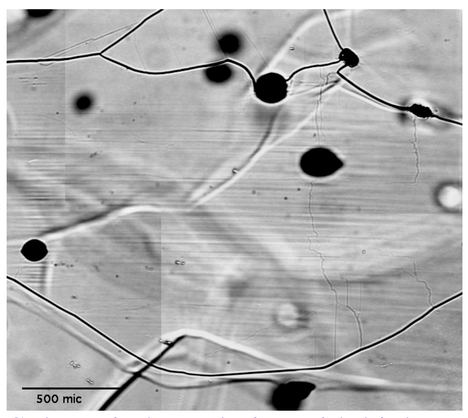
Pinned grain boundaries by air bubble and sub-grain boundary (1494 m depth)



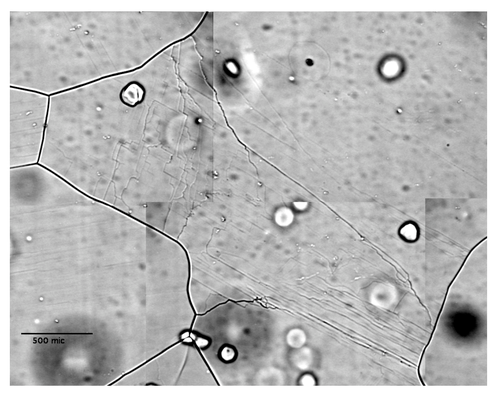
Pinned grain boundaries by air hydrate (1605 m depth)



Sub-grain boundaries parallel to slip lines (1885 m depth)



Sub-grain boundaries with high angles to slip lines (1053 m depth)



Sub-grain boundaries forming networks (1605 m depth)

Recrystallisation regimes

Three dominant recrystallisation regimes are described in the literature (Alley 1992 , Montagnat & Duval 2000):

1. Normal grain growth (upper several hundreds of meters): Average grain size increases.
2. Polygonisation/Sub-grain rotation recrystallisation (between 1. and 3.): Sub-grain boundaries perpendicular to slip lines occur.
3. Migration recrystallisation (deepest hundreds of meters at critical T close to -10°C): Rapid grain boundary migration occurs between dislocation-free nuclei and deformed grains. Interlocking grains occur.

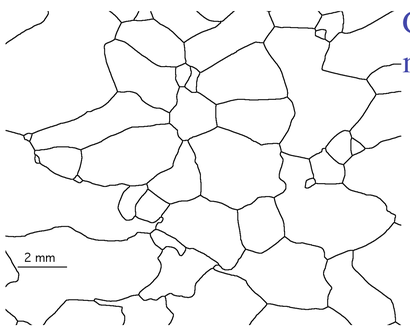
Observations and Data

About 50 samples from maximum 100 m depth difference have been qualitatively tested.
In some (10) samples statistical investigations have been done.

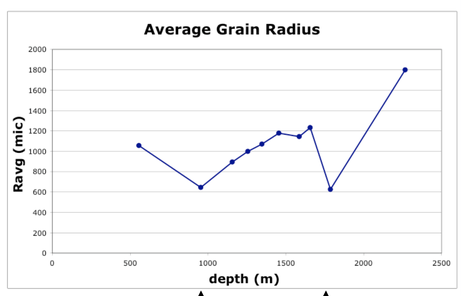
1. Straight grain boundaries are rare. Bulging of grains is observed already in 100 m depth. Foam texture, as expected, is not observed. First data show, that average grain size between 550 and 2260 m is modulated by changing climate variations (last glacial period).

2. Sub-grain boundaries are observed from 100 m depth. At 230 m depth already 58% of all grains contain sub-grain boundaries.

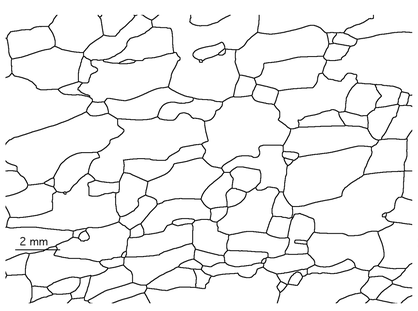
3. Deepest hundreds of meters are not yet drilled (whole length of core 2800 m). Grains in deepest available samples are not interlocking more intense than in shallower depths.



Grain boundary network (555 m depth)



Glacial maxima of last glacial period



Grain boundary network (2395 m depth)

Preliminary results indicate that the recrystallisation regimes described in the ice core literature are not easy to apply to the EDML ice core.

References

Alley, R. B. 1992. Flow-law hypotheses for ice-sheet modelling. Journal of Glaciology 38, 245-256.

Montagnat, M., Duval, 2000. Rate controlling processes in the creep of polar ice, influence of grain boundary migration associated with recrystallisation. Earth and Planetary Science Letters 183, 179-186.