Hard Breaks – Soft Ice ?

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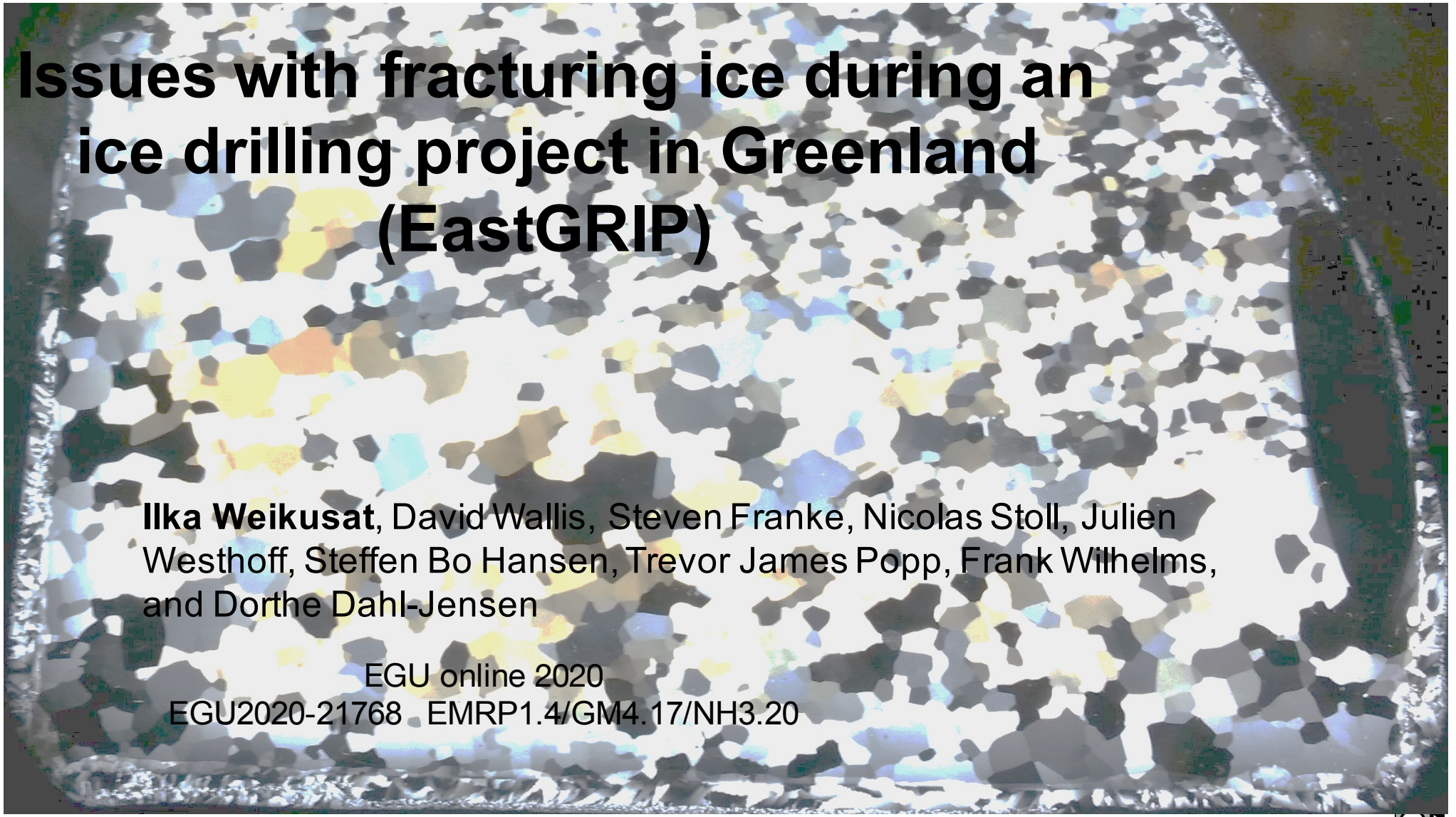

Issues with fracturing ice during an ice drilling project in Greenland (EastGRIP)

Ilka Weikusat, David Wallis, Steven Franke, Nicolas Stoll, Julien Westhoff, Steffen Bo Hansen, Trevor James Popp, Frank Wilhelms, and Dorthe Dahl-Jensen

EGU online 2020
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CENTRE FOR ICE AND CLIMATE
GEO Utrecht University
NiPR National Institute of Polar Research
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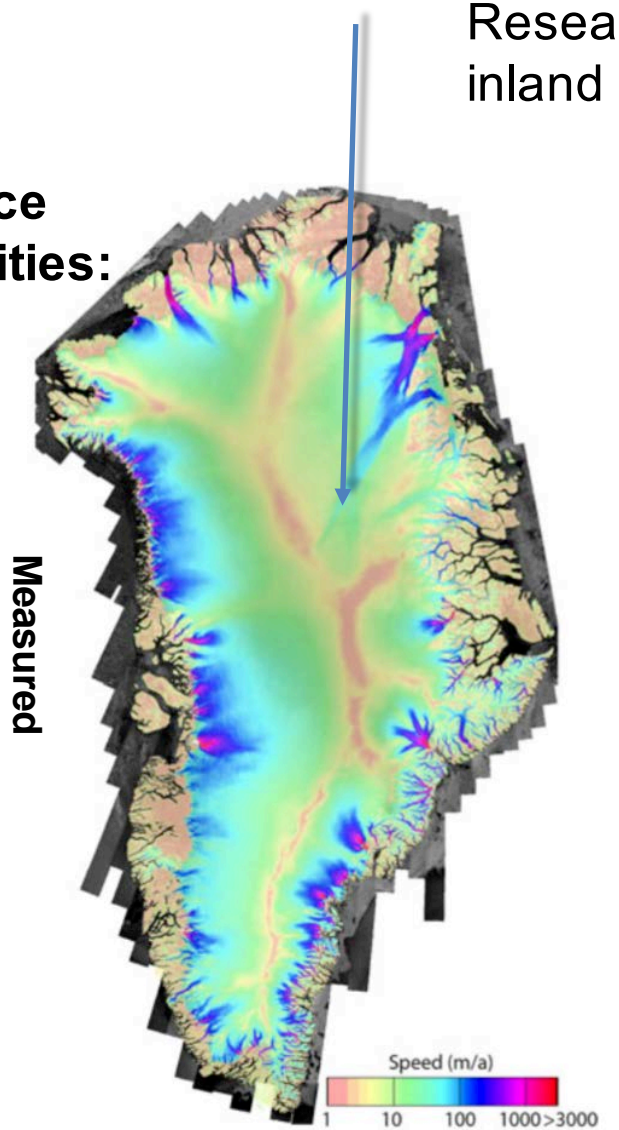
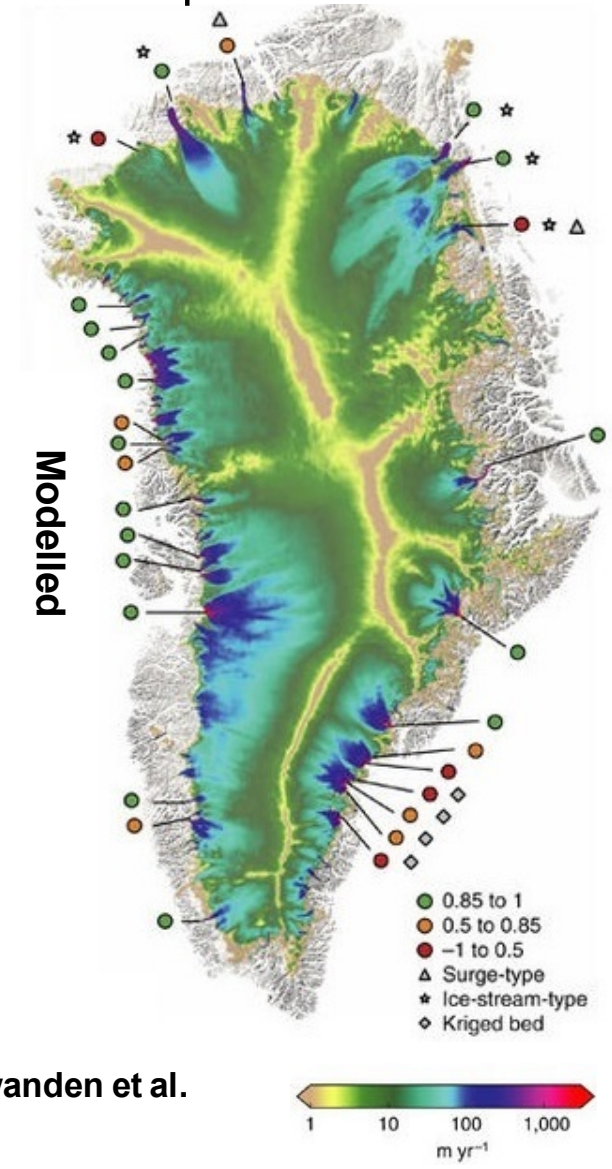
EastGRIP – East Greenland Ice Coring Project

Research aim: understanding ice streams as “highways” of inland ice transport towards the oceans (sea level relevance)

Surface Velocities:



Joughin et al. (2017)



Aschwanden et al. (2016)

IPCC 5 (2013)

- Models are still not able to predict **solid ice discharge** and **ice sheet contribution** well enough
- Significant uncertainties remain regarding the magnitude and rate of ice stream contribution towards sea-level rise
  ➔ **ice streams**

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EastGRIP - Work in the “lab”

- International project in NE-Greenland, aiming to retrieve an ice core from *NEGIS*
- Worldwide cooperation in the field and during the following analyses, managed by Centre for Ice and Climate (Denmark)
- Major partners: Germany, Japan, Norway, US, France

Greenland.net
(30.11.2017)

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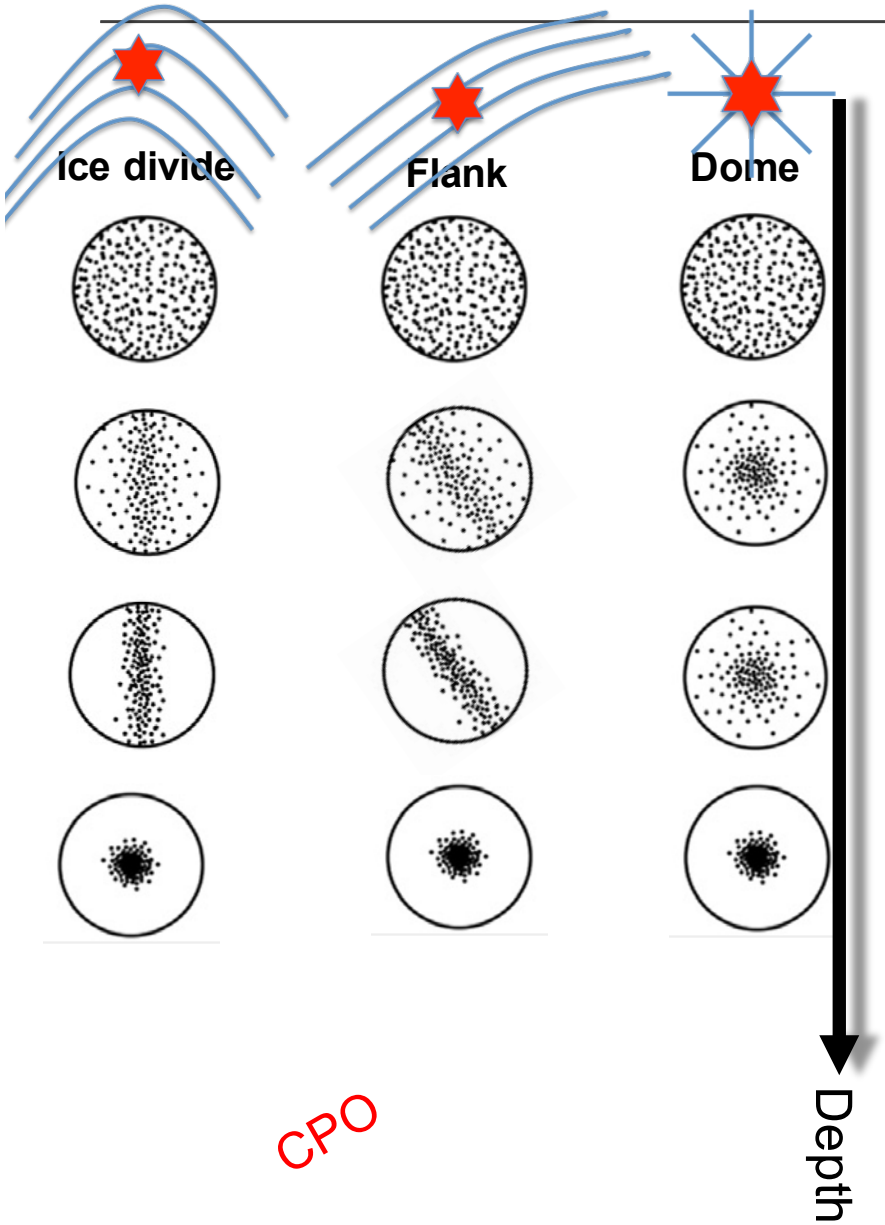
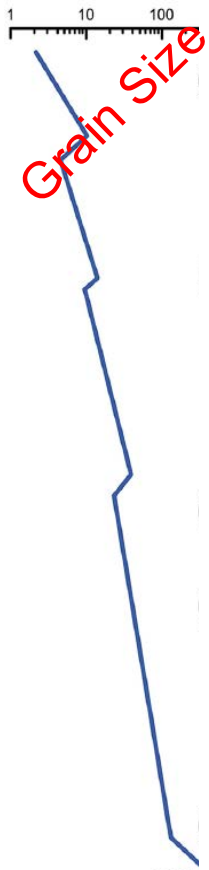
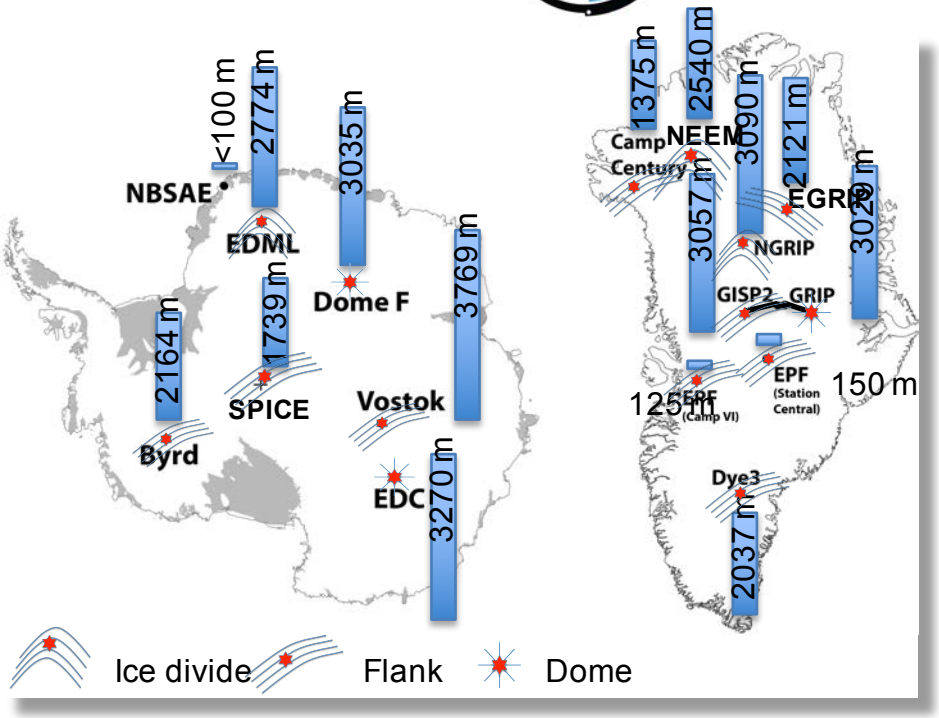
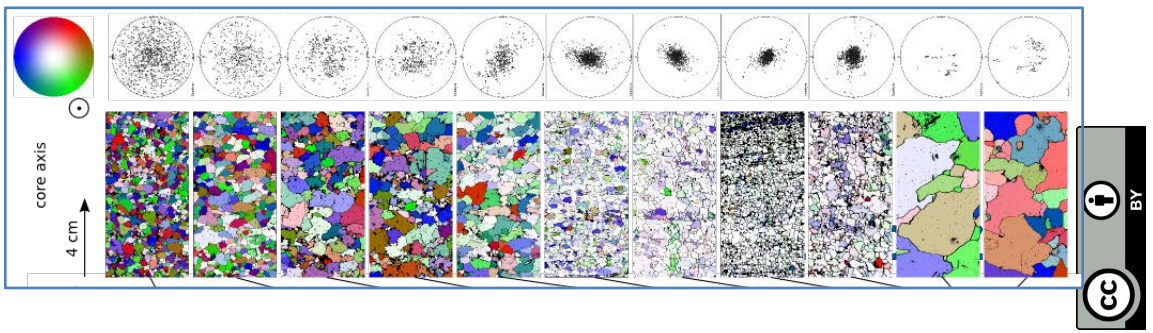
The rock “ice” in deep drill cores





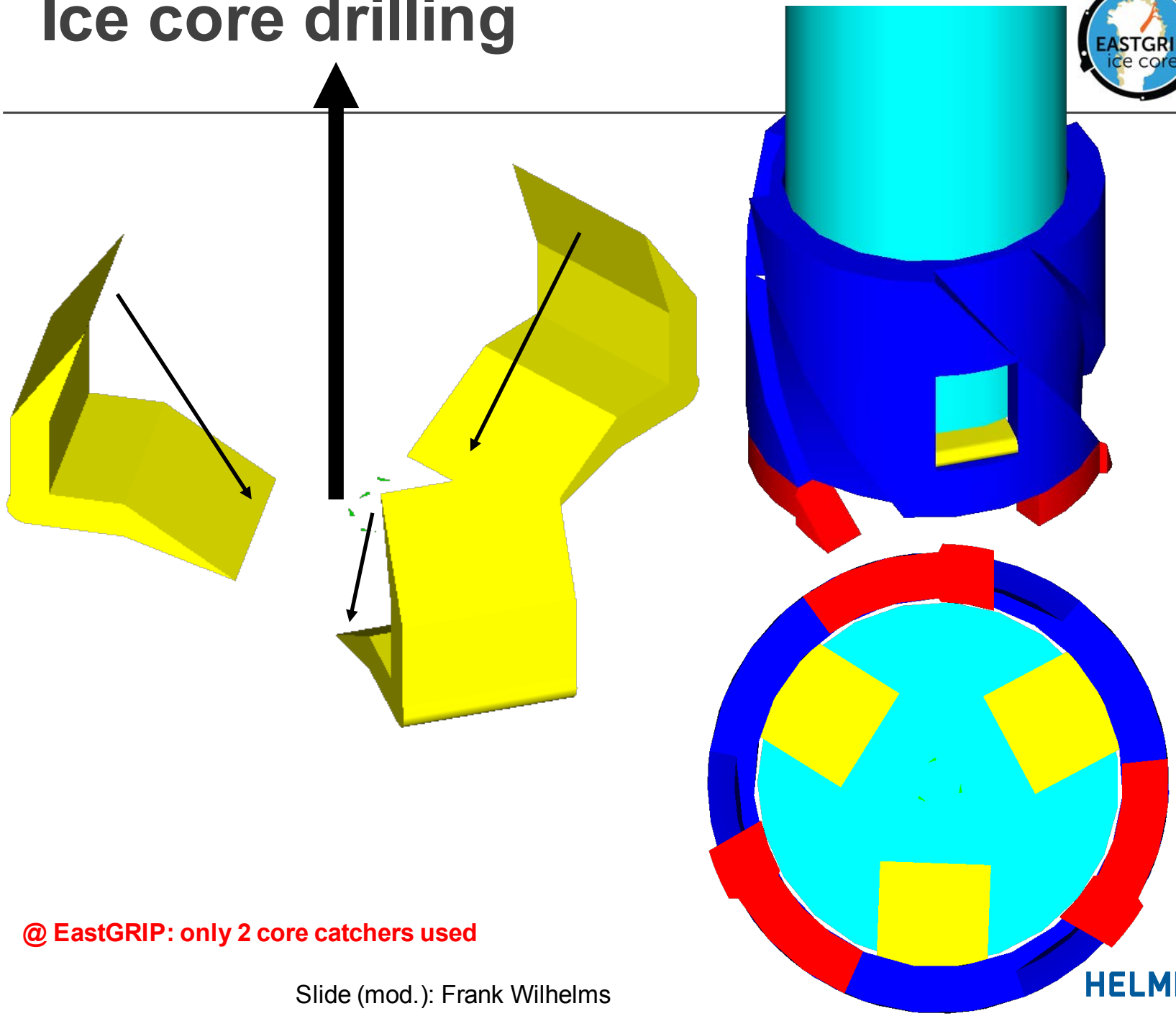


Example: NEEM



Convention: PolFigures projected into horizontal plain

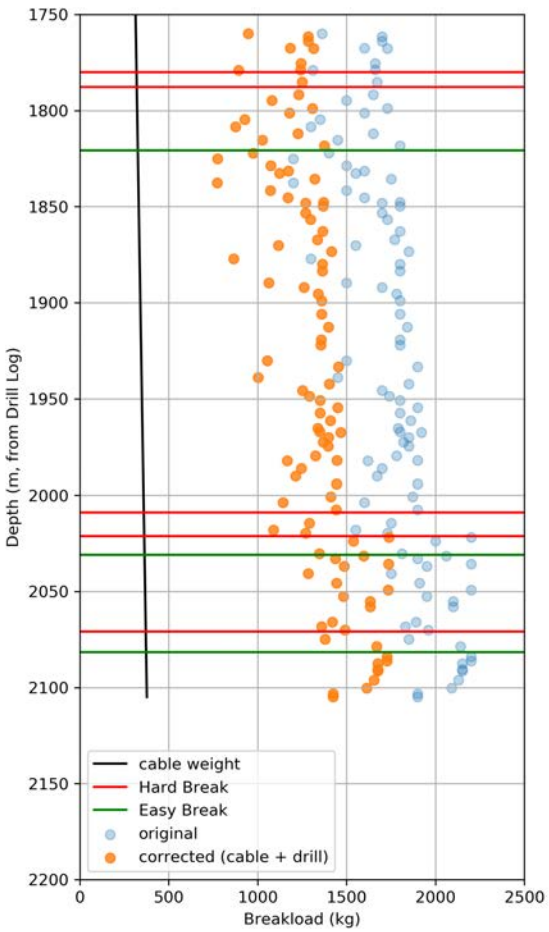
Ice core drilling



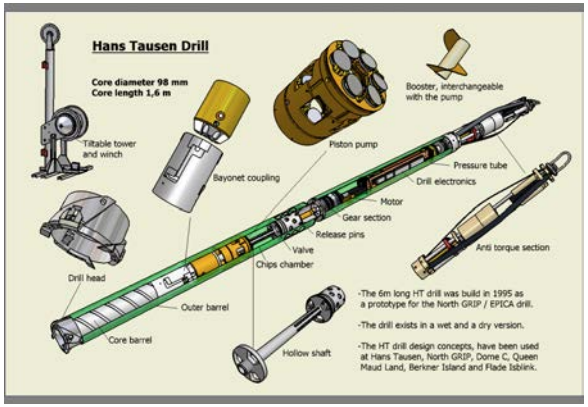
@ EastGRIP: only 2 core catchers used

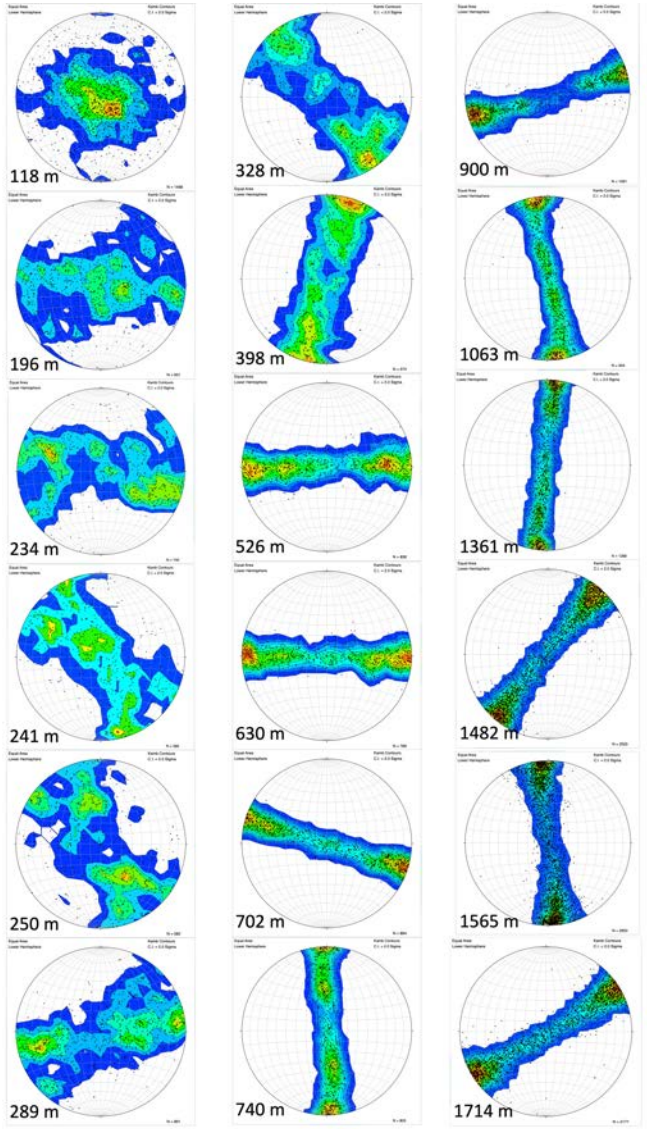
Slide (mod.): Frank Wilhelms

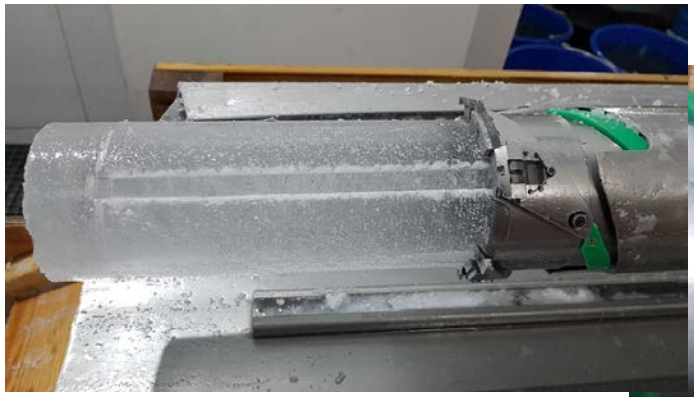
EGRIP



"super banger" needed to break the ice







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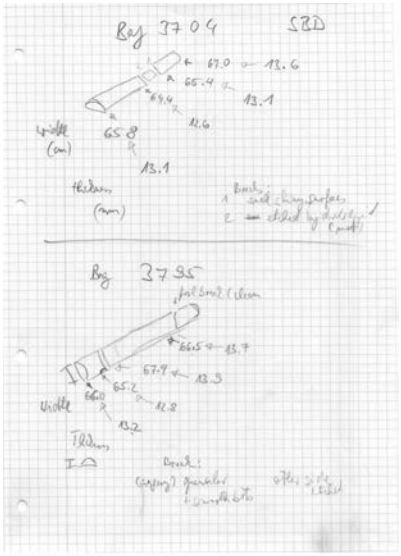
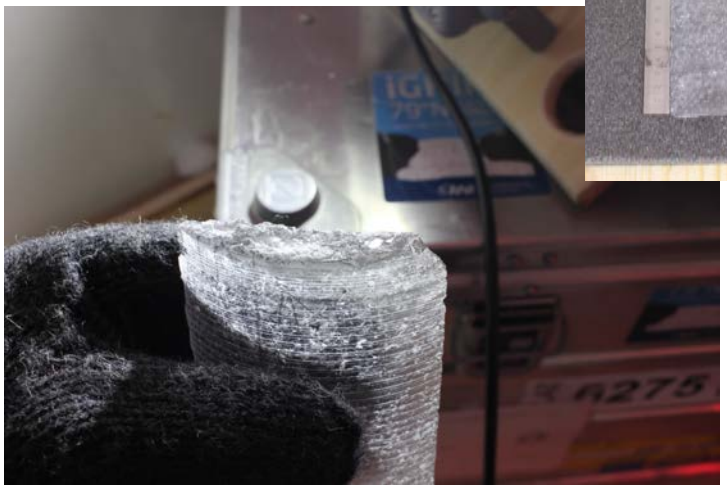
Core breaks - macroscopic



	Driller's depth (m)	Core bag
Super banger breaks:	1780.0	3260
	1787.8	3273
	2008.8	3681
	2021.1	3704
	2070.9	3795
"easy breaks"	1808.4	3311
	2077.9	3693
	2068.2	3785



- Macroscopic break structures do not indicate ductile failure → **brittle** failure

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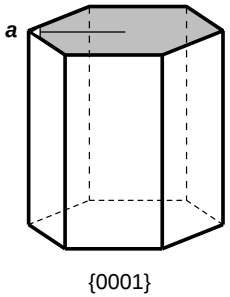
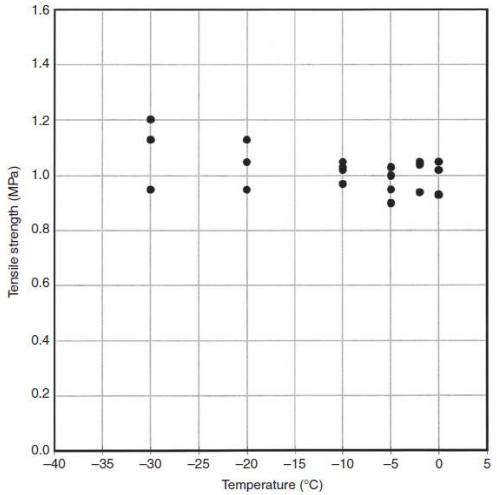
Fracturing of ice – tensile strength



Main cleavage plane = basal plane

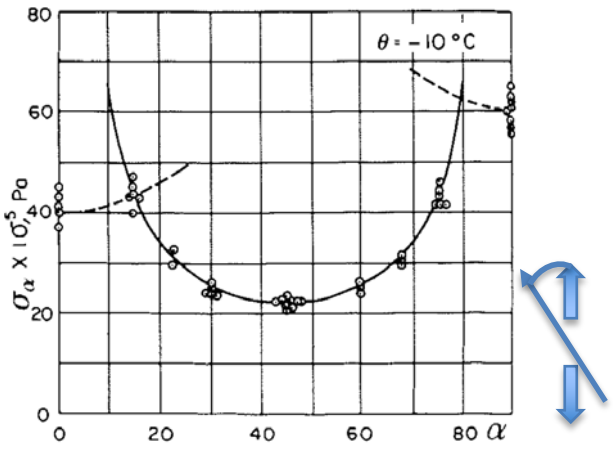
Two processes involved:
- Crack nucleation
- Crack propagation

negligible T dependence



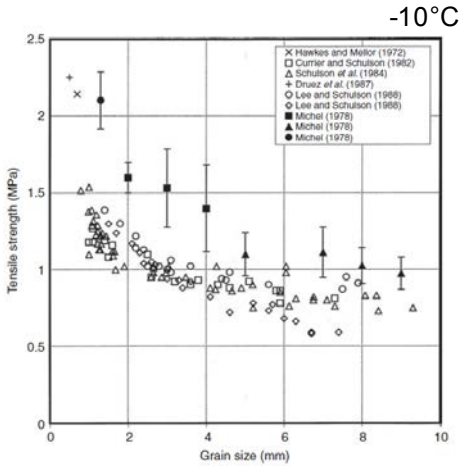
Schulson and Duval (2009) after Carter (1971)

dependence on CPO



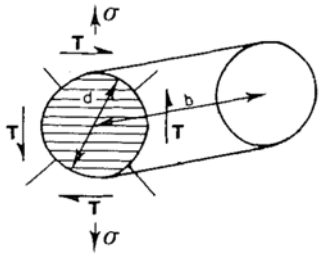
Carter and Michel (1971)

dependence on grain size



Schulson and Duval (2009)

Micromechanical model



Cracks will form when: $W_\tau + W_\sigma = W_{surface}$

$$\tau^2/2G_{66} + \sigma^2/2H_{33} = 3E_{surface}/d$$

For an optimally oriented grain:

$$\sigma = 7.94\times10^4\sqrt{1-0.9\times10^{-3}T/d}$$

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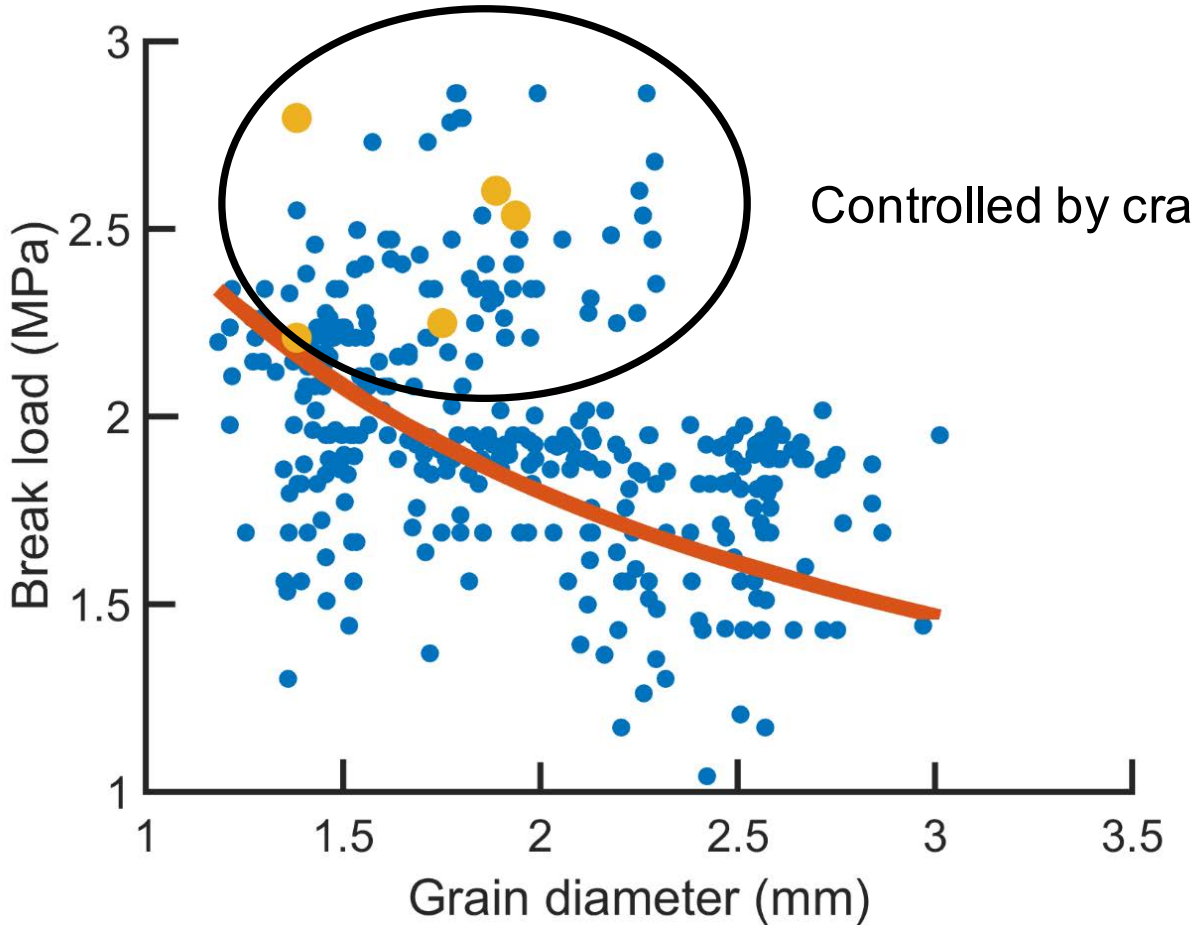
Superbangers (and others) stronger than crack nucleation model



Controlled by crack propagation?

Orange: super bangers

Michel`crack nucleation model (1978)

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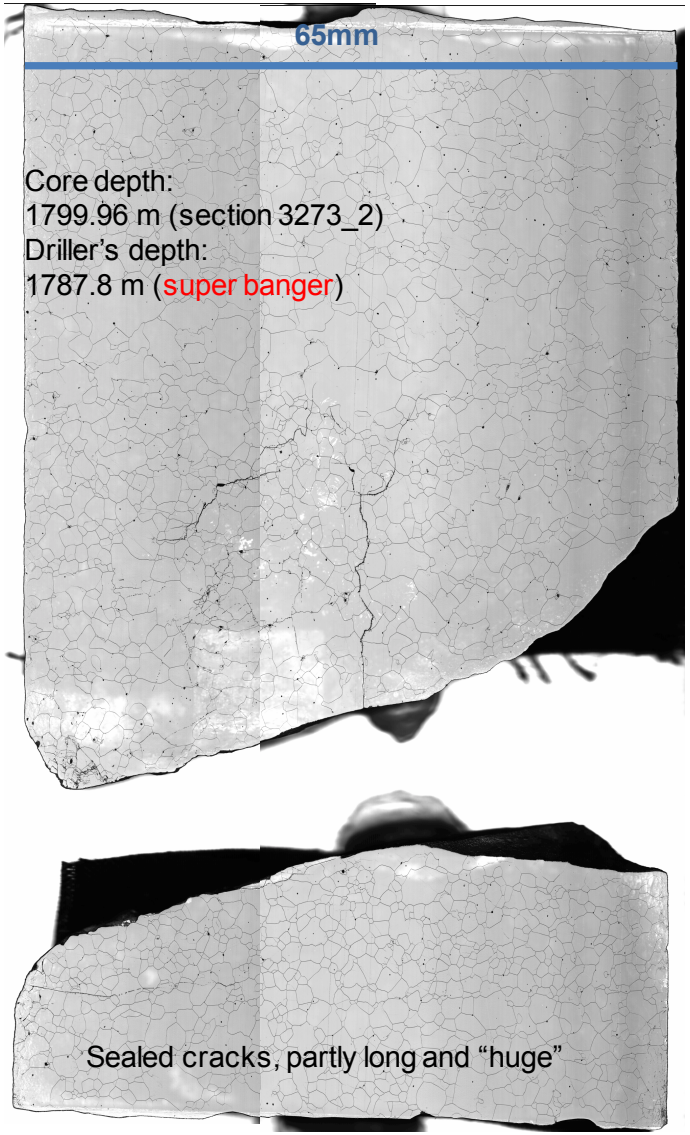
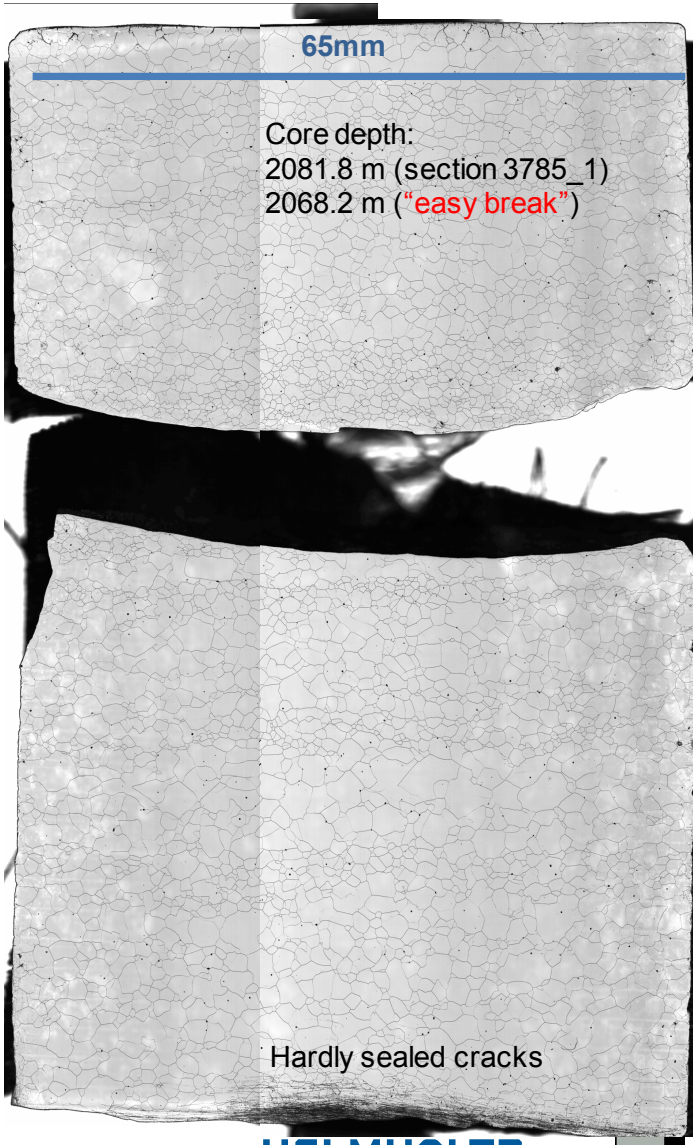
Evidences for crack propagation?





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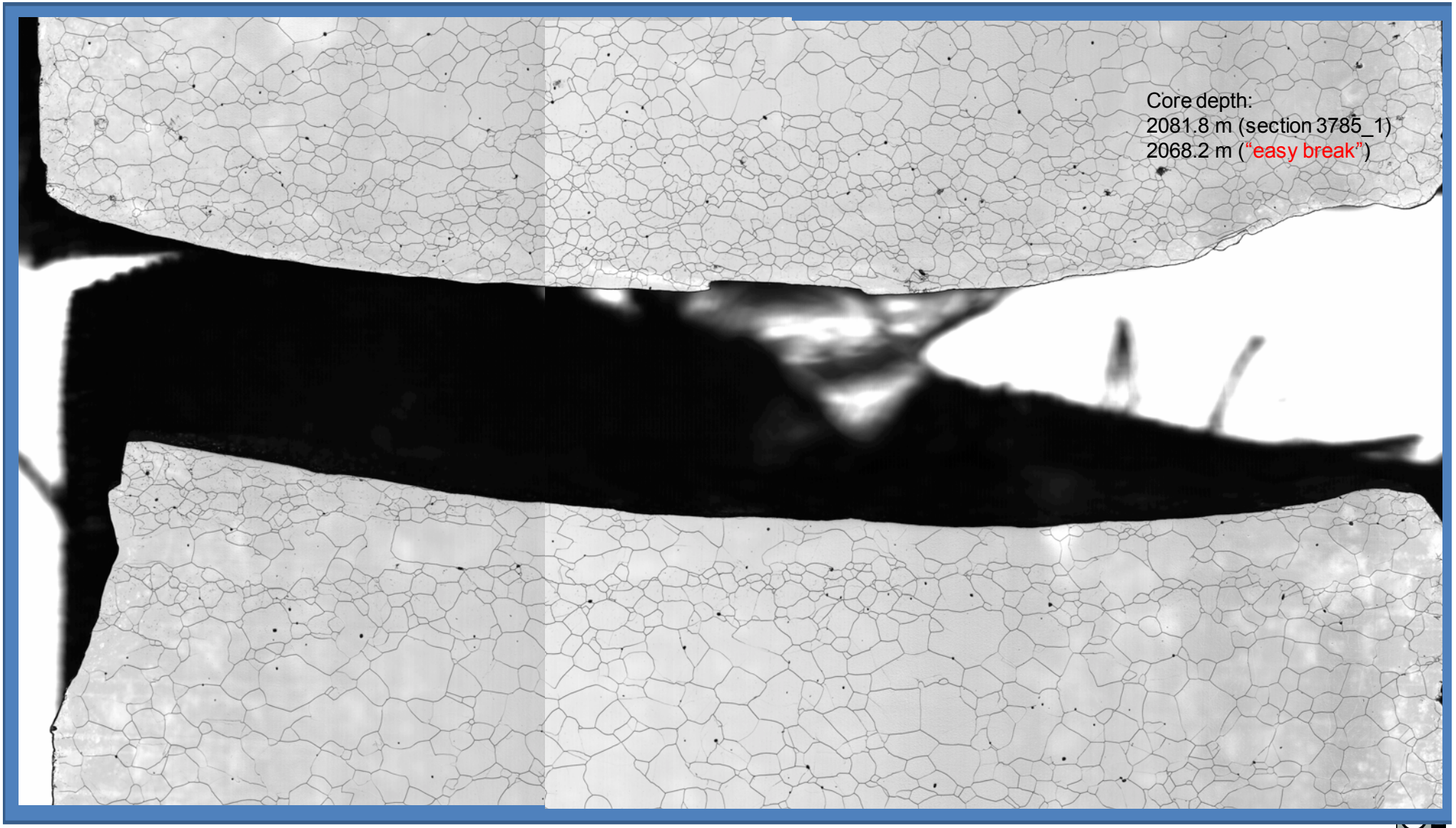
Evidences for crack propagation?



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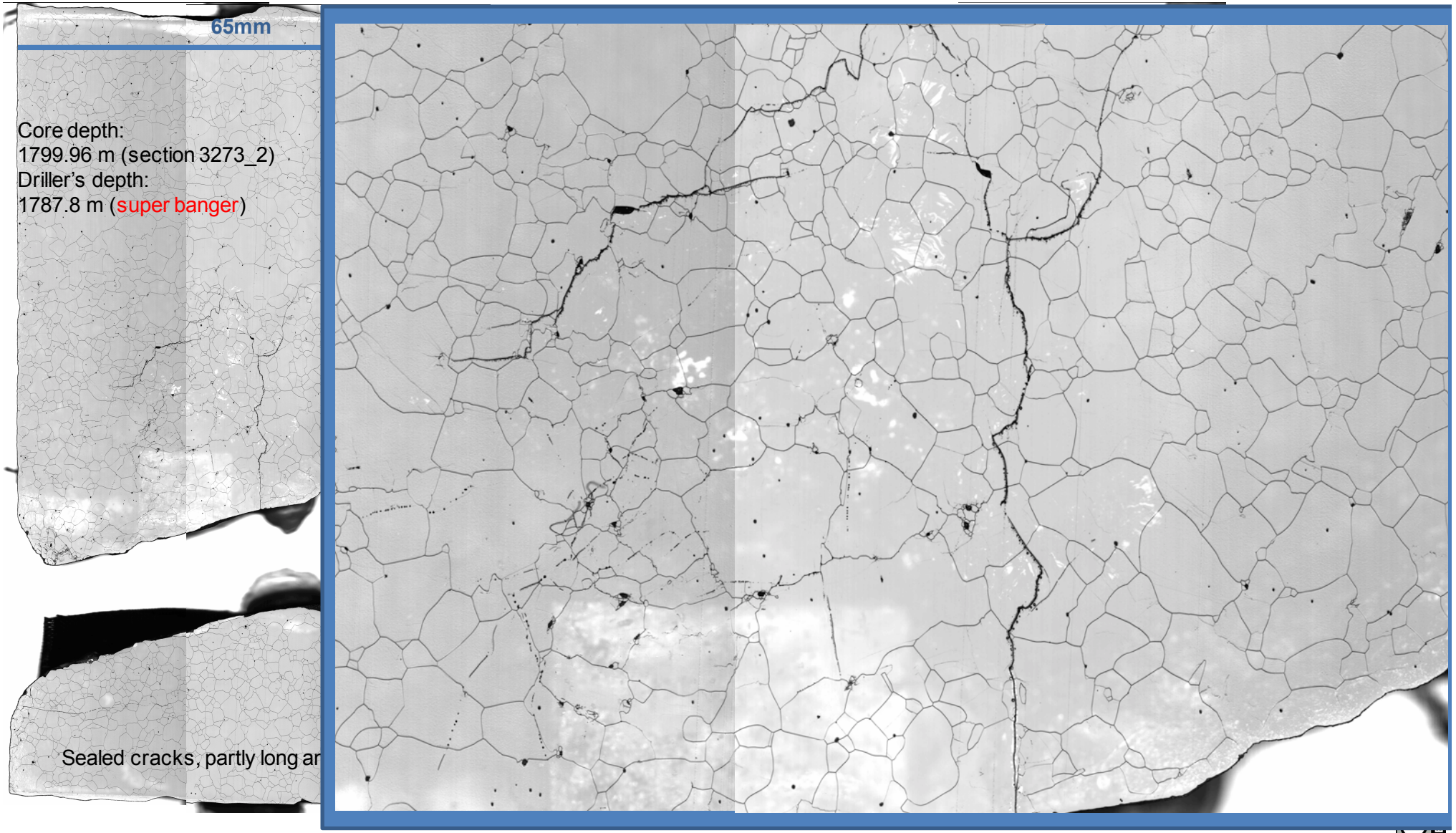
Evidences for crack propagation?



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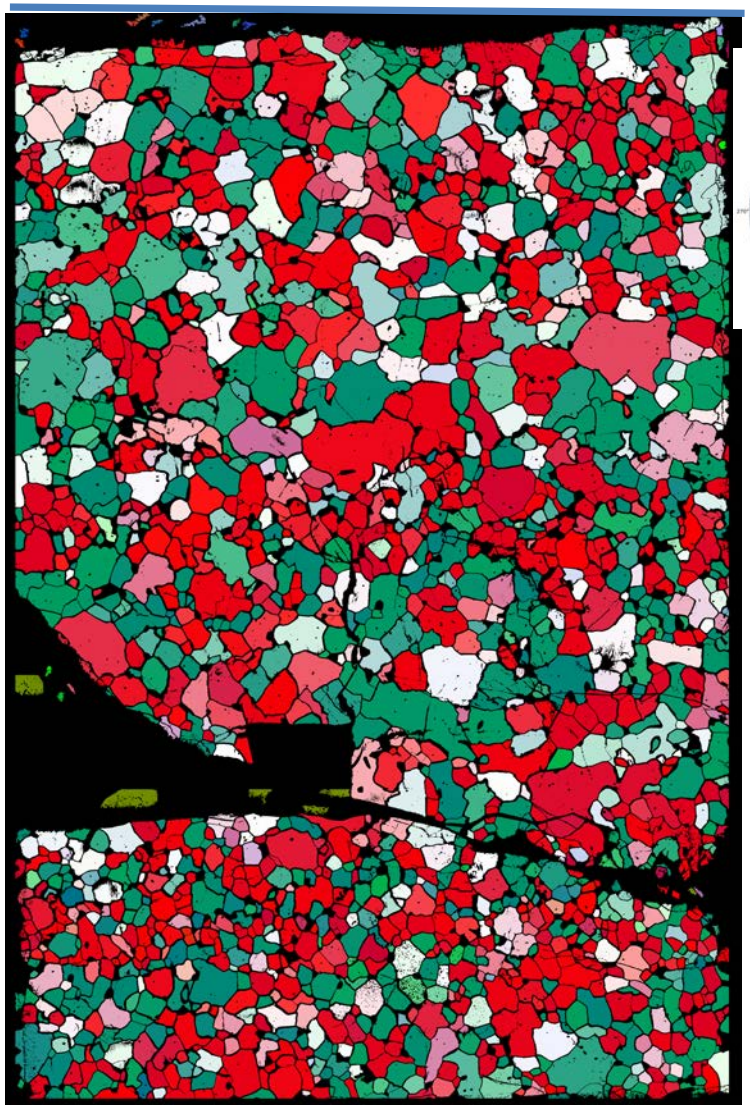
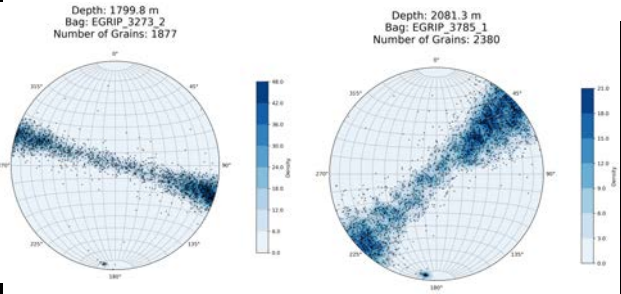
Evidences in the microstructure?

65mm





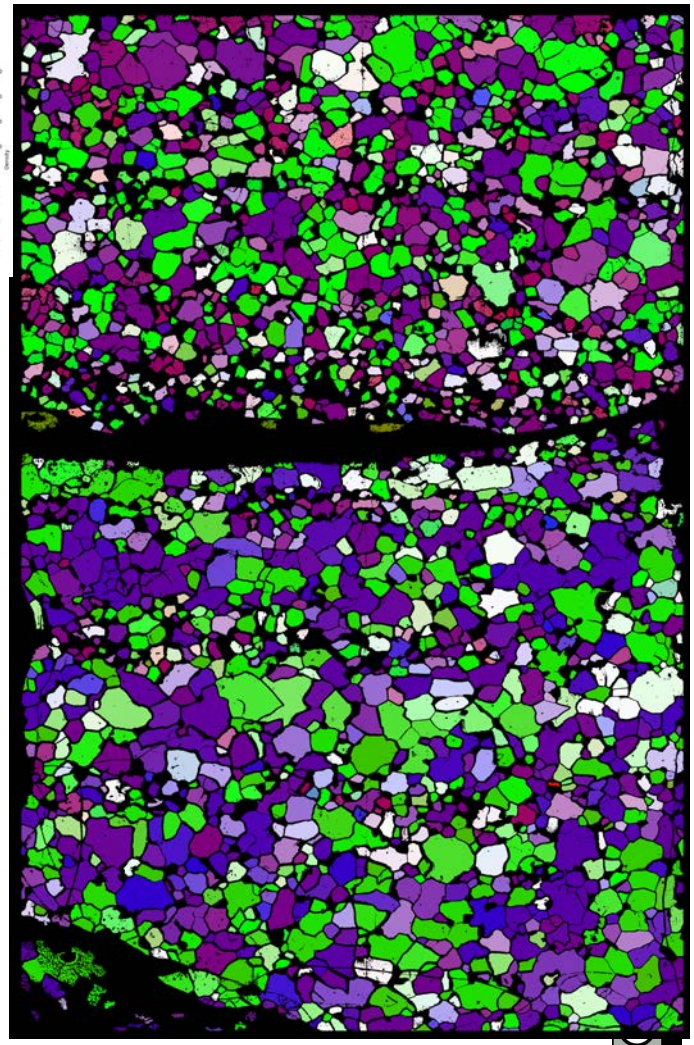
Core depth:
1799.96 m (section 3273_2)
Driller's depth:
1787.8 m (super banger)

Core depth:
2081.8 m (section 3785_1)
2068.2 m ("easy break")

False color images coding
c-axes orientation

Top

65mm



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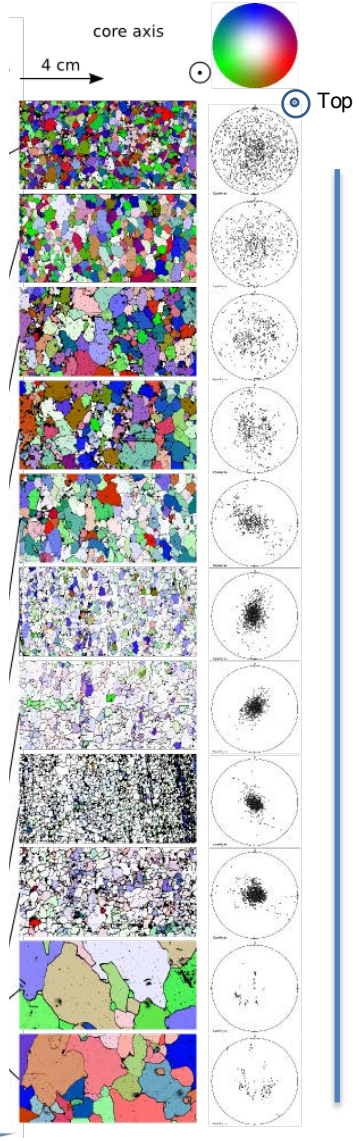
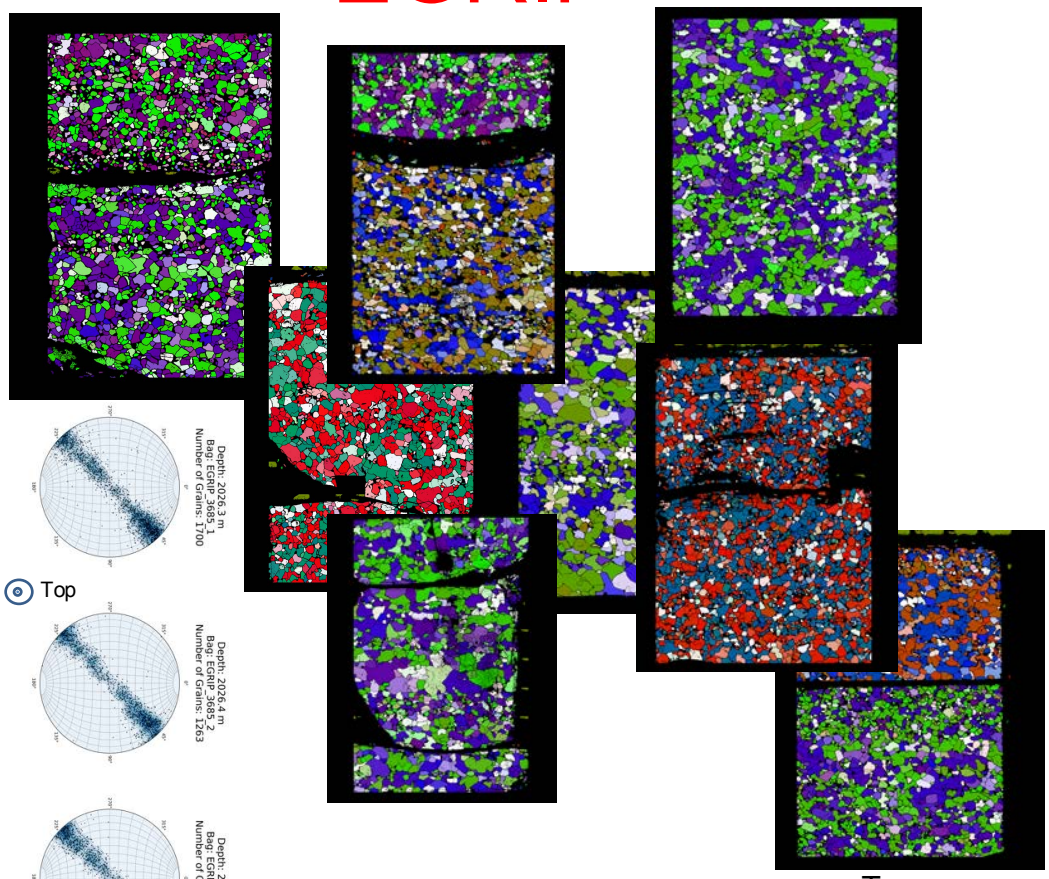
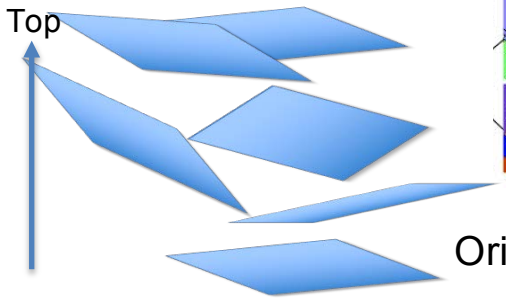
What is different in EGRIP?

NEEM

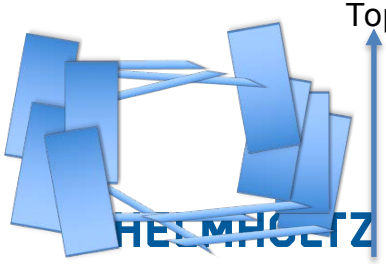


EGRIP





Orientation arrangement of basal planes = cleavage planes



PRELIMINARY Conclusions

- *Wanted : dissipation of mechanical energy into fast crack propagation*
- **brittle** failure → pulling harder can help (new cable, winch motor and winch driver)

- difficult CPO → in general breaks are harder ("easy breaks" still hard)
- additionally: grain size layering

- super banger breaks "tried hard" to break (micro cracks), but failed due to
  - small grain size → short tracks of easy cleavage + long tracks along grain boundaries
- "easy breaks" did break due to
  - larger grain size → long tracks of easy cleavage + short tracks along GB