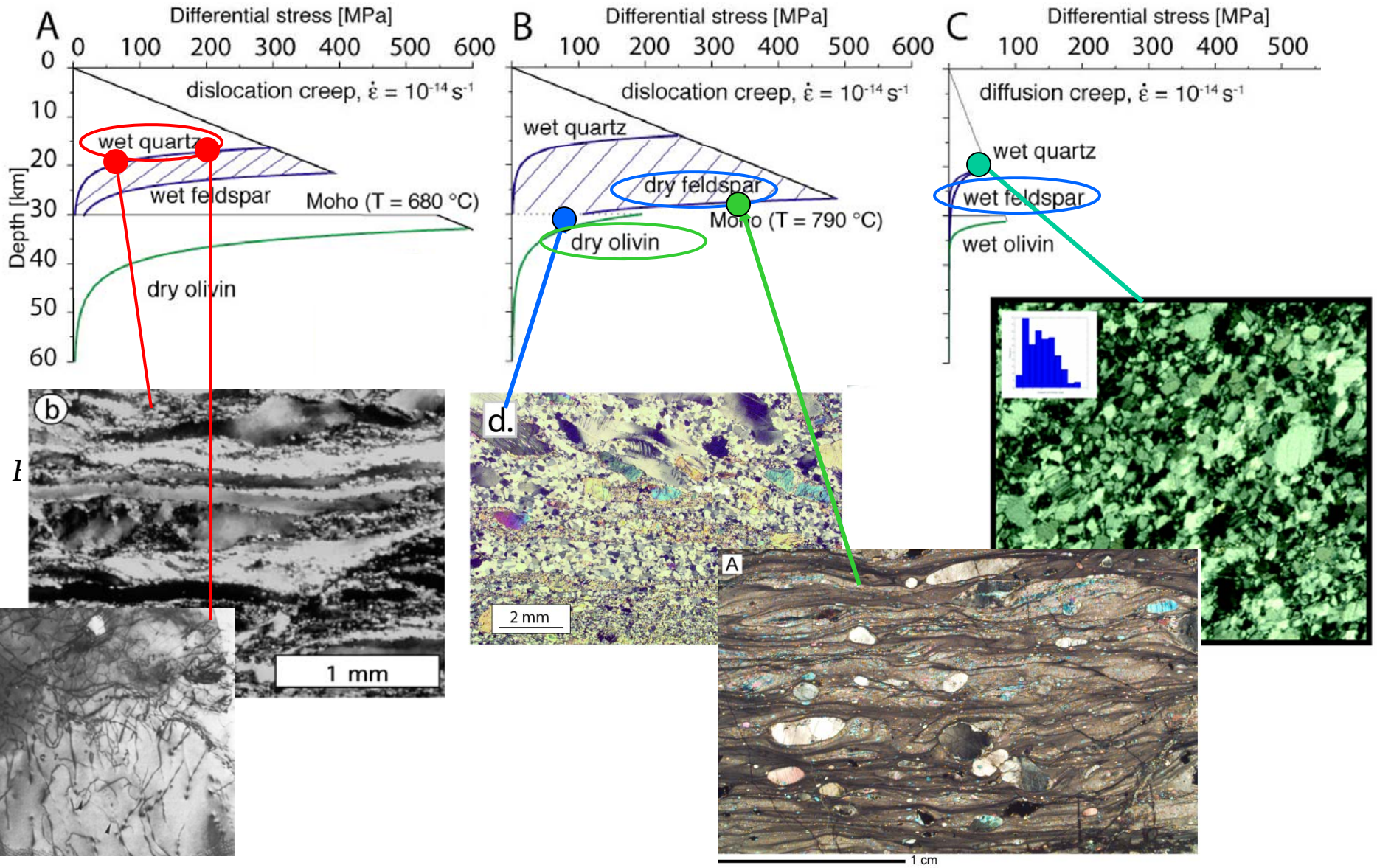
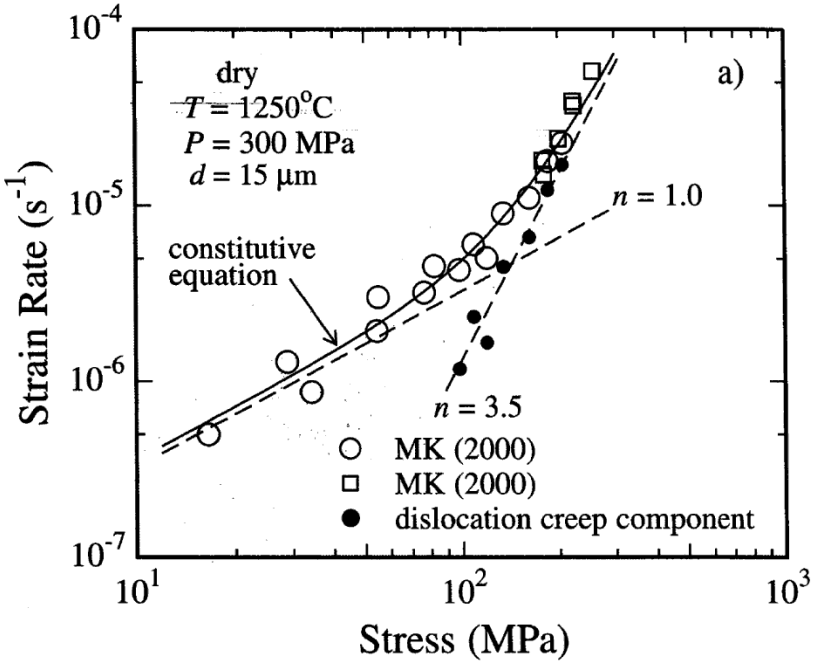
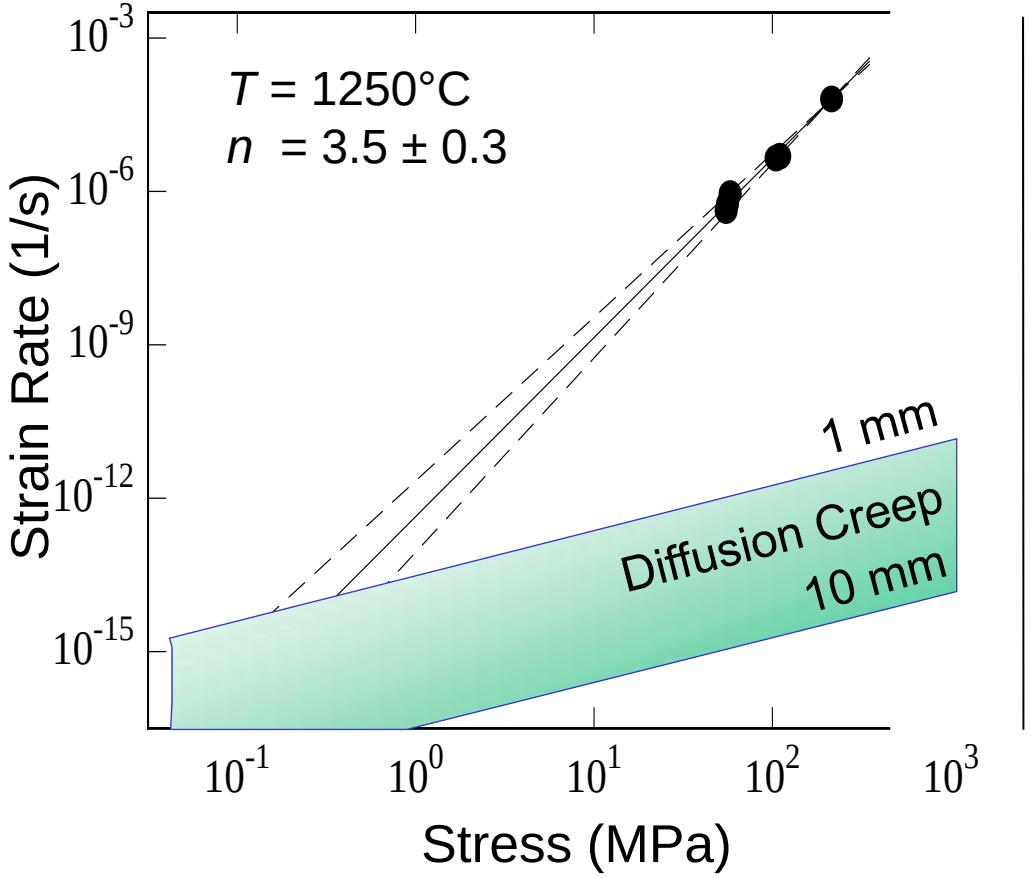
Rheology of the Crust and Mantle



CAN WE TRUST EXTRAPOLATION OF LAB DATA TO GEOLOGIC CONDITIONS????



Hirth & Kohlstedt, 2003



"Composite Rheology"

$\dot{\varepsilon} = \dot{\varepsilon}_{disl} + \dot{\varepsilon}_{diff}$

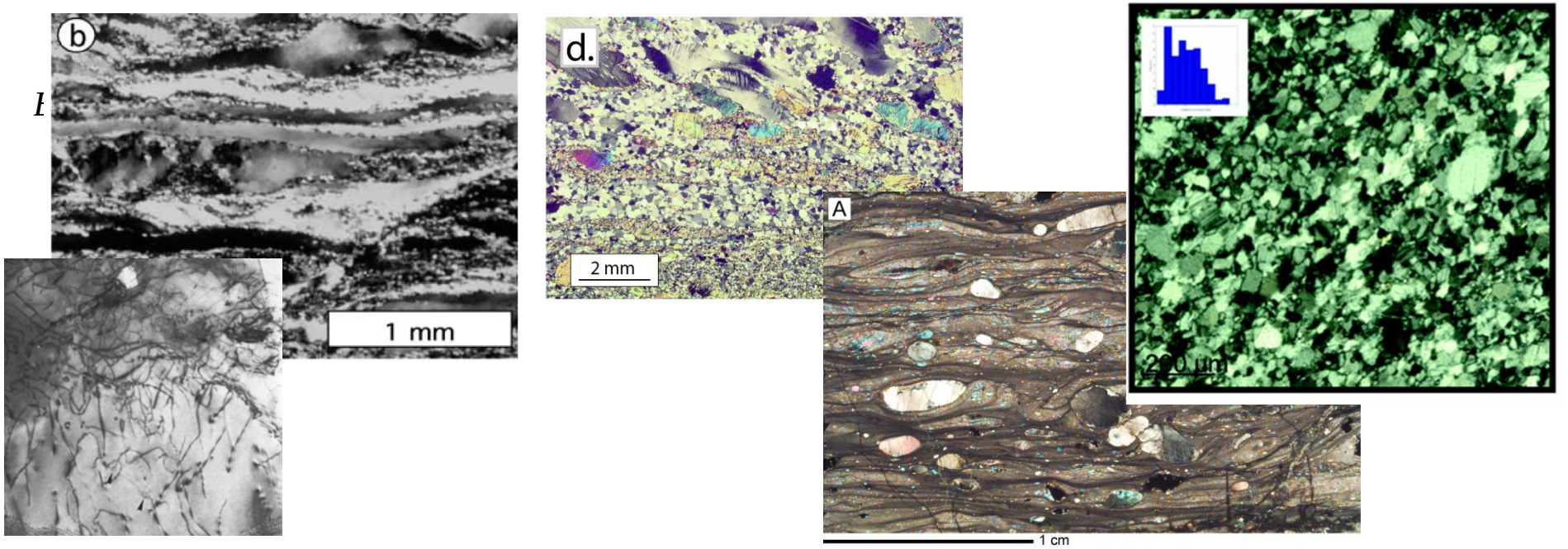
$$\dot{\varepsilon} = A\frac{\sigma^n}{d^m} f(\phi,\ C_{OH}) \exp\left(-\frac{Q + PV^*}{RT}\right)$$

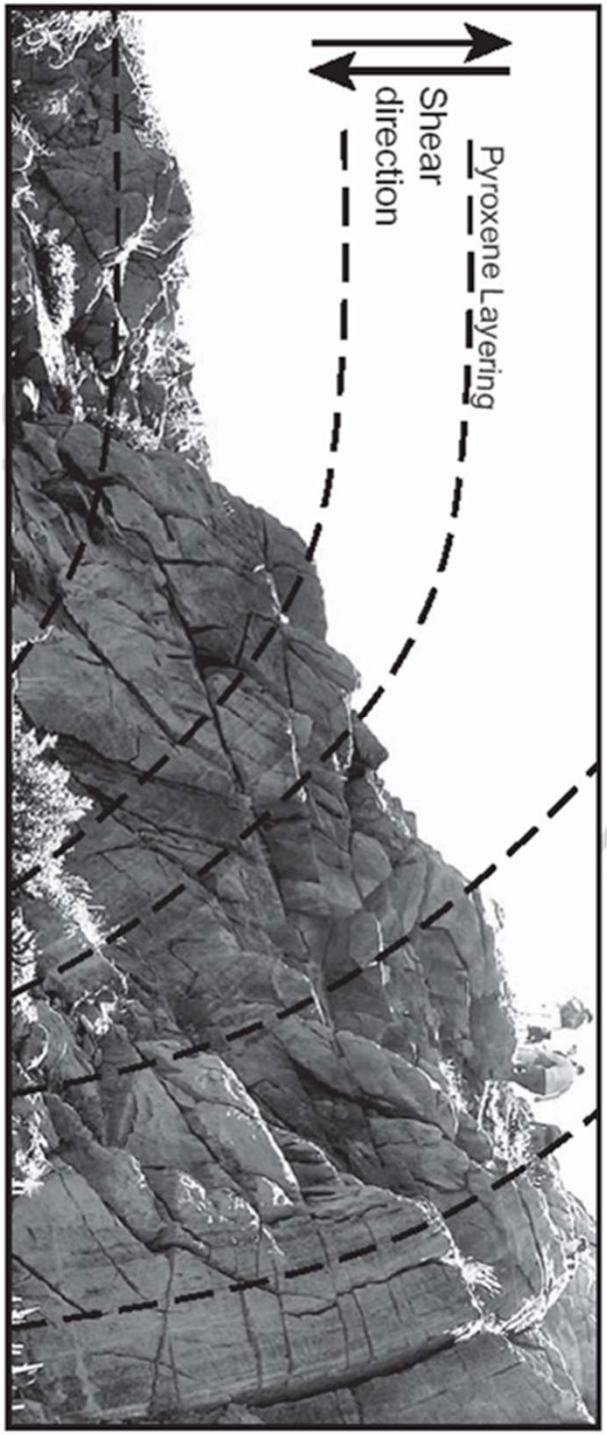
Microstructures provide evidence for operation of process

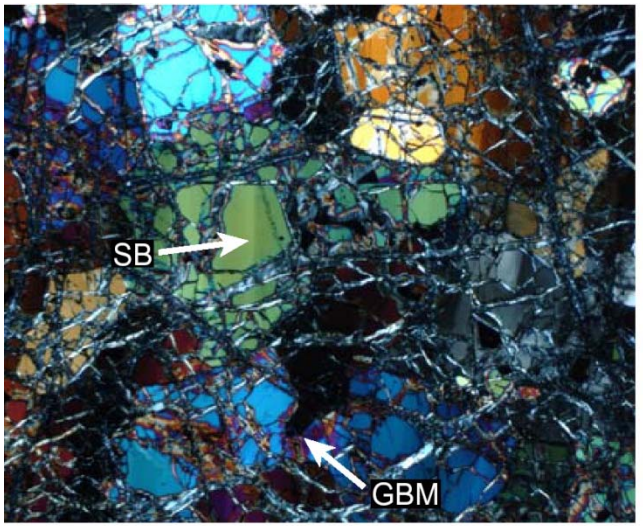
Need independent estimates for $\dot{\varepsilon}$ and T

Need estimate for σ

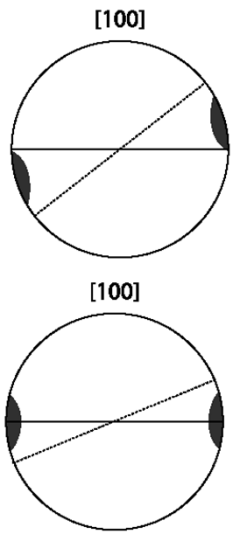
Theoretical bases for flow laws rely on diffusion kinetics and elasticity
NO SCALE DEPENDENCE FROM GRAIN SCALE TO PLATE SCALE



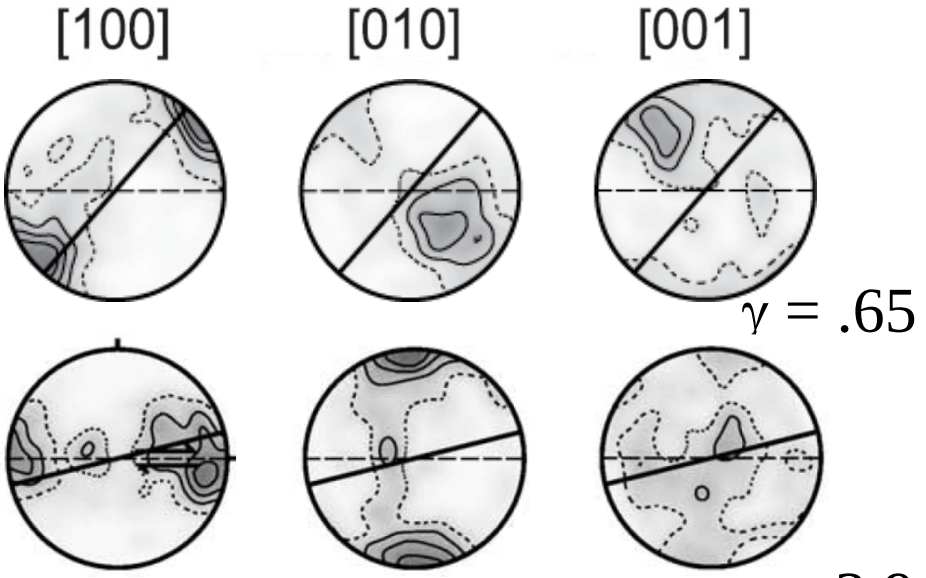




Lab



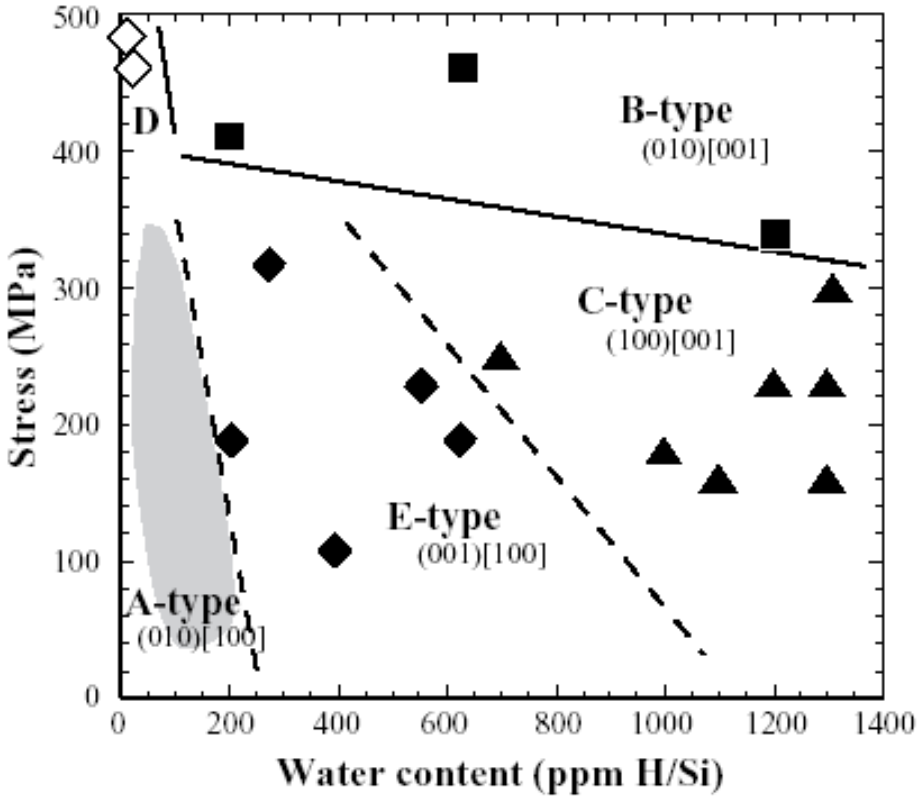
Type A

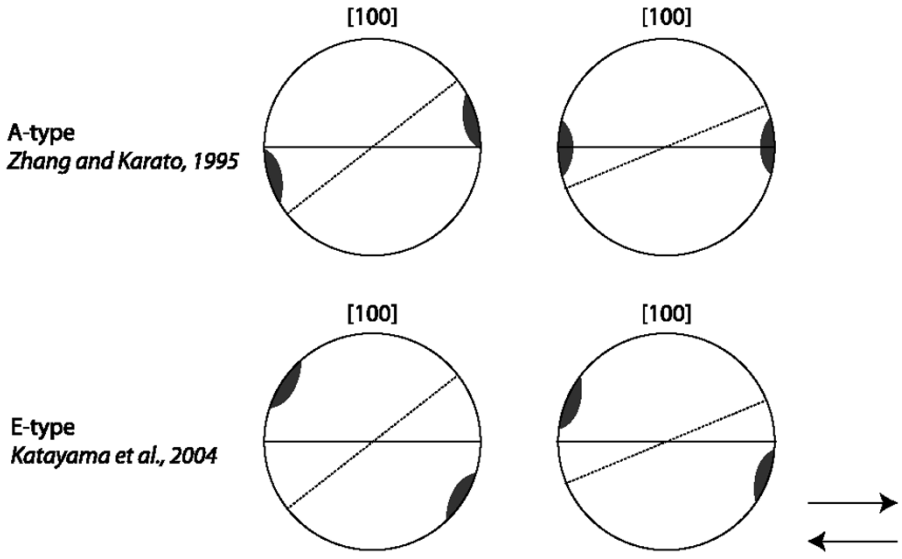


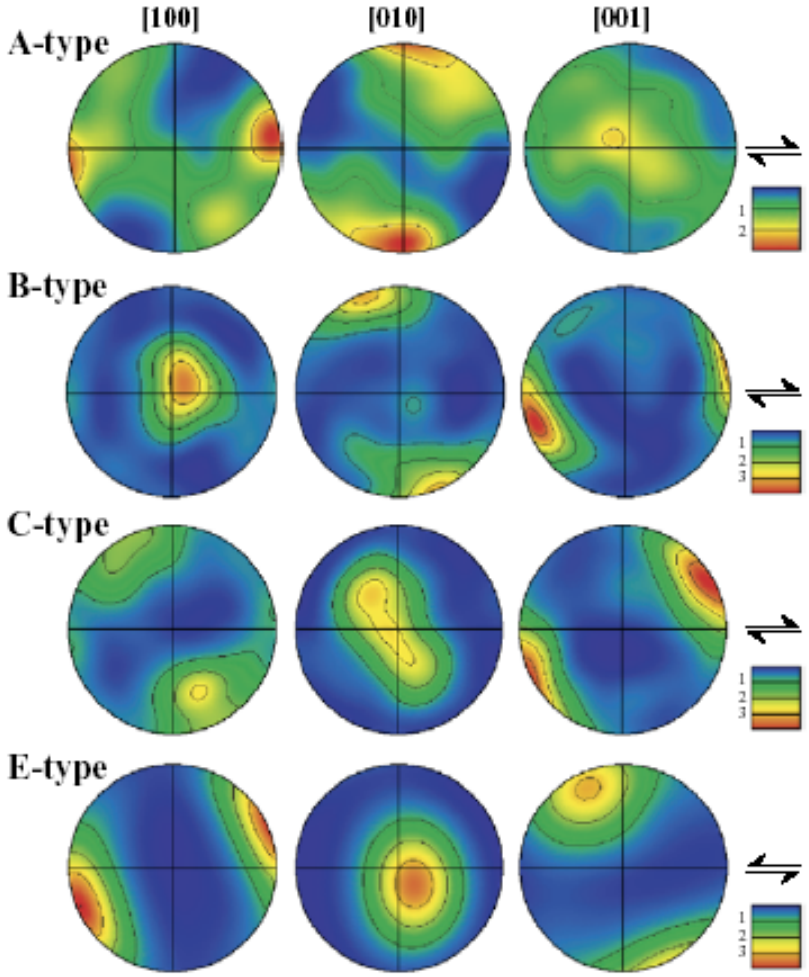
$\gamma = .65$

$\gamma = 3.9$

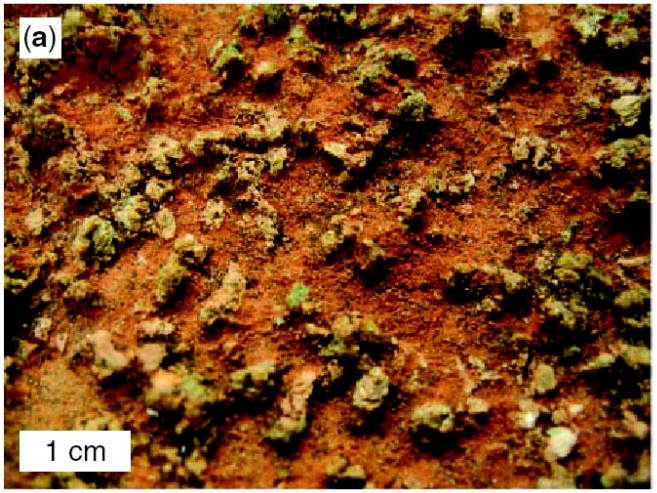
Warren et al., EPSL 2008

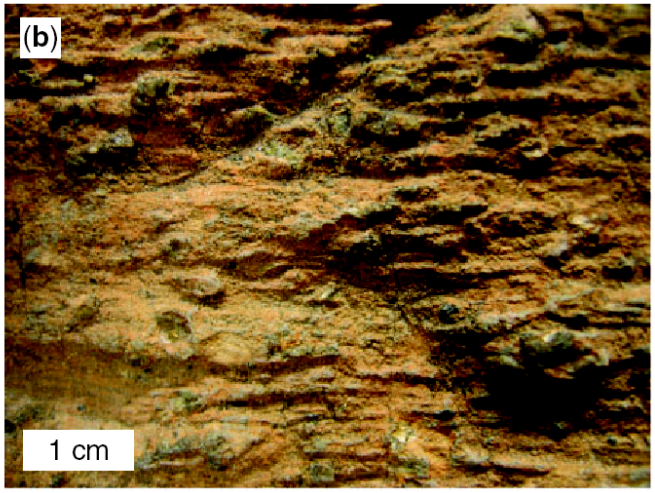




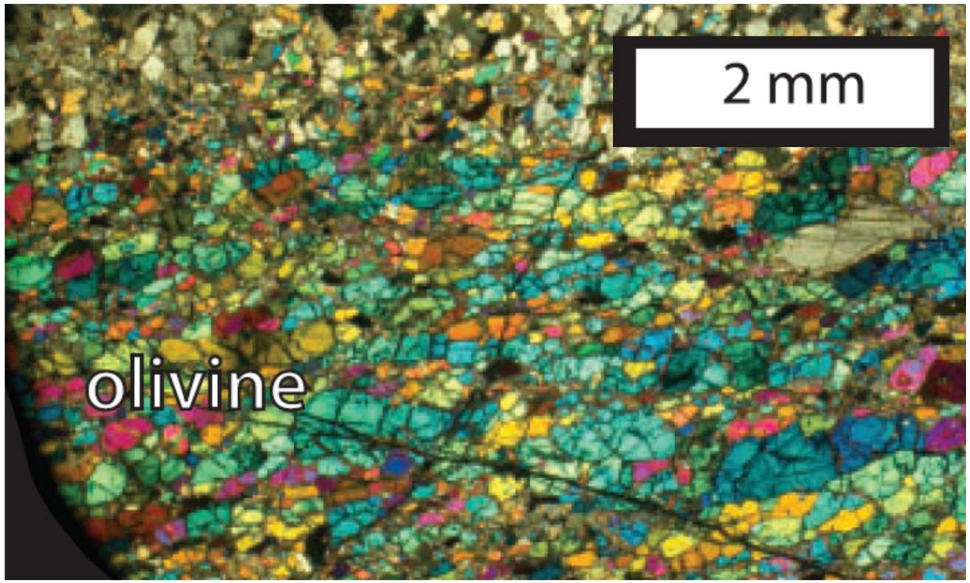


Katayama et al., 2004



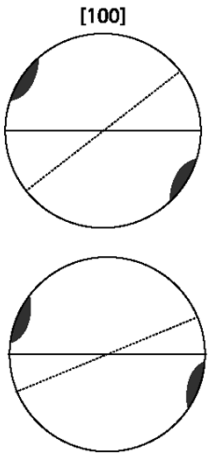


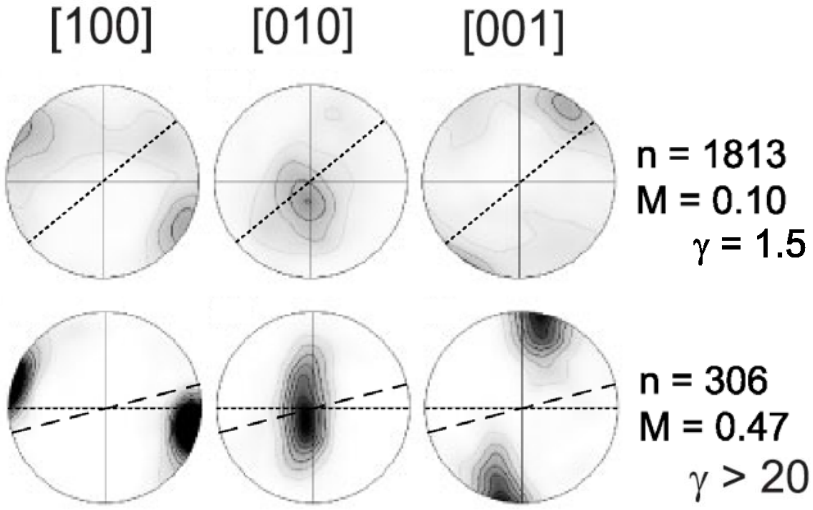
Skemer et al. JPET 2010



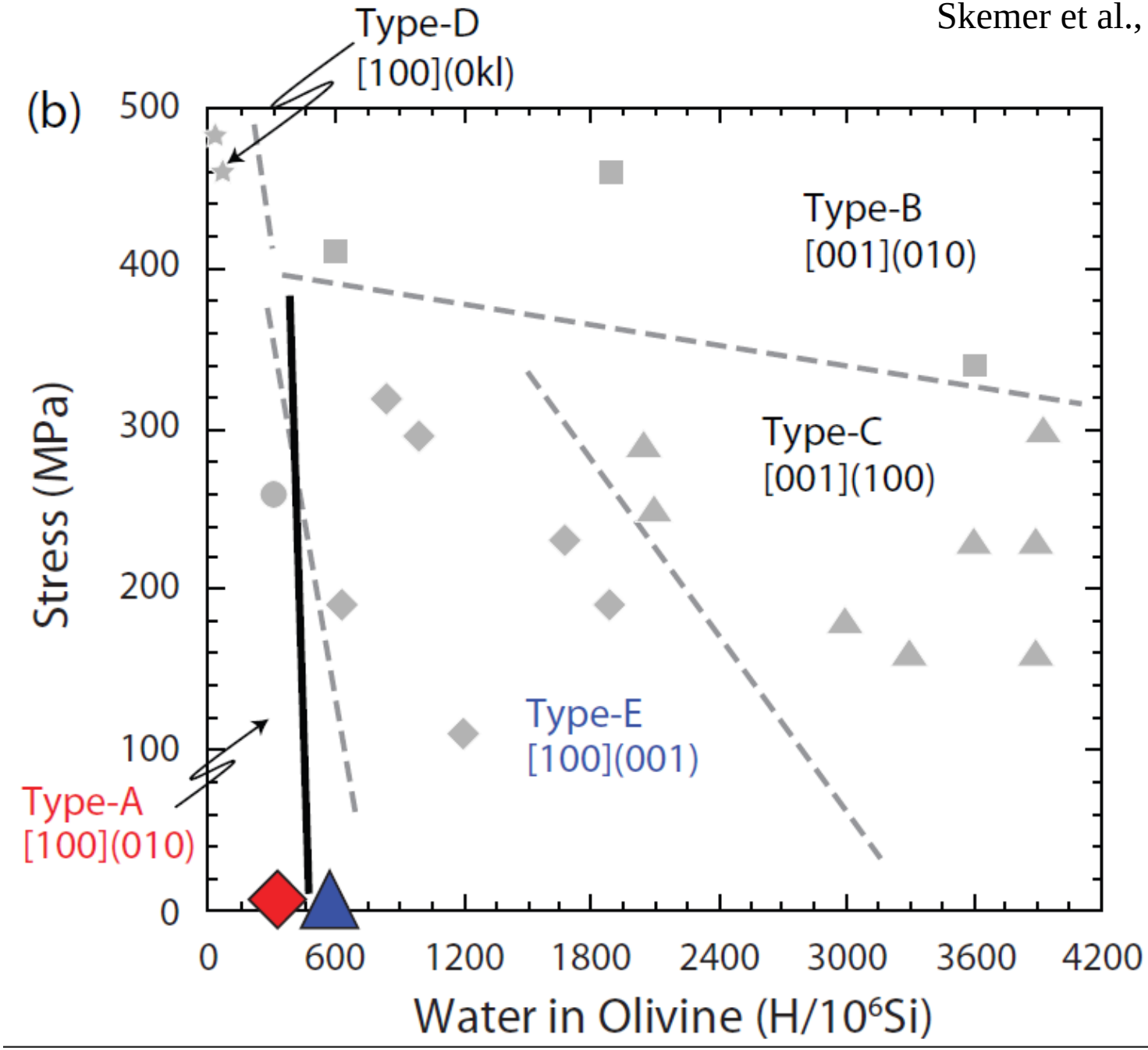
Type E

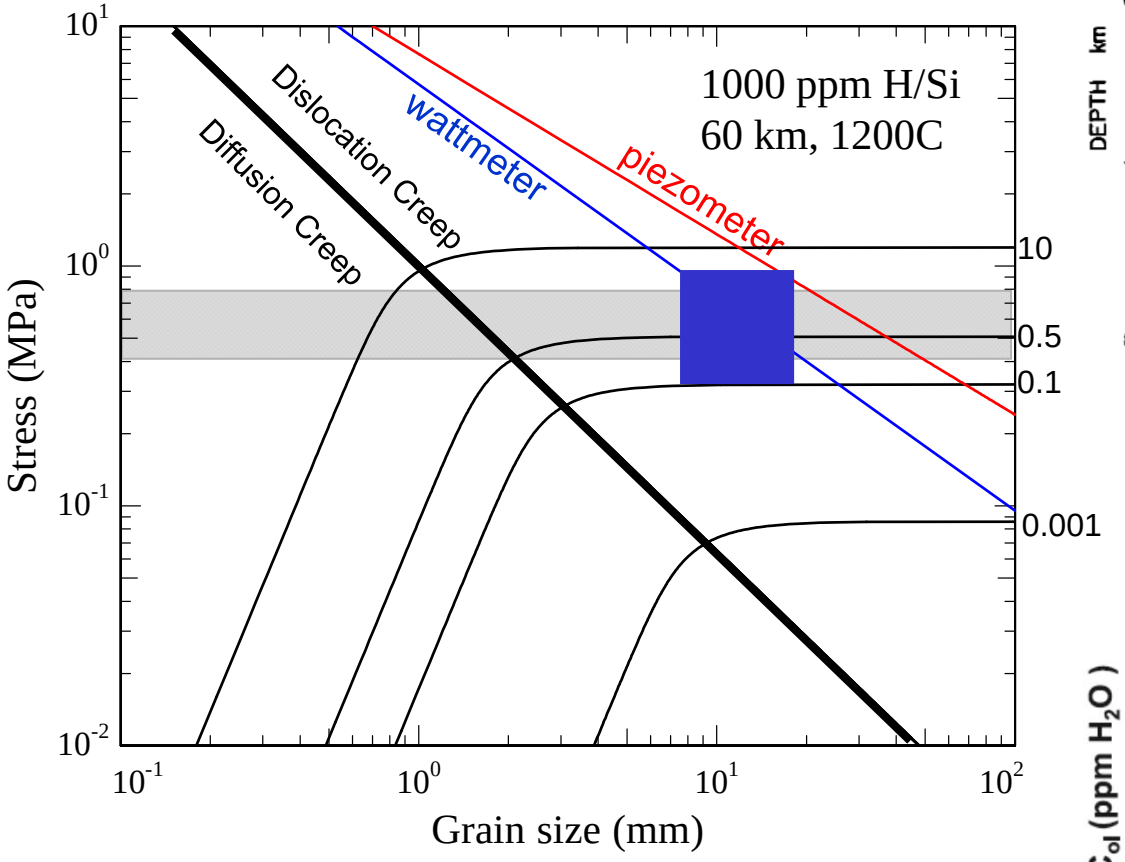
Lab





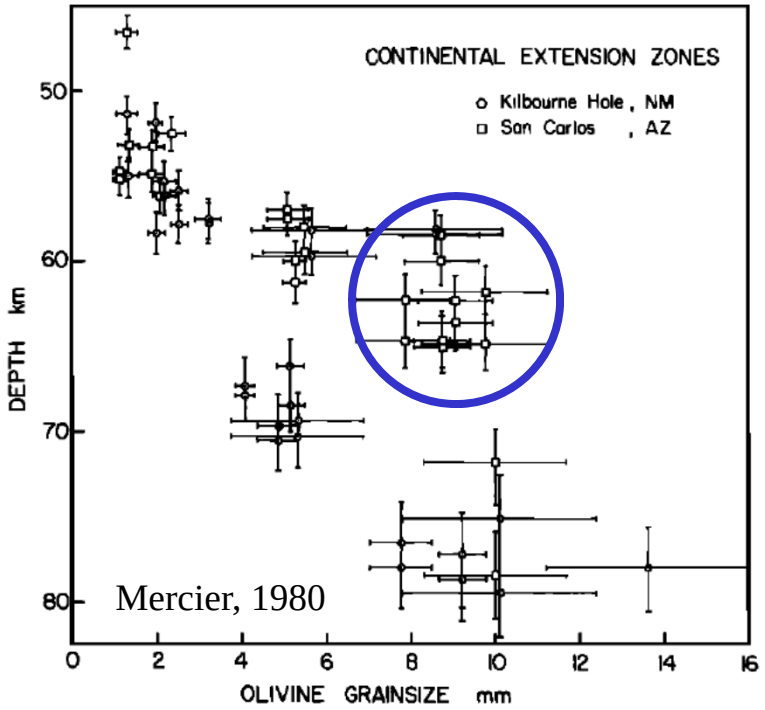
Skemer et al., in review

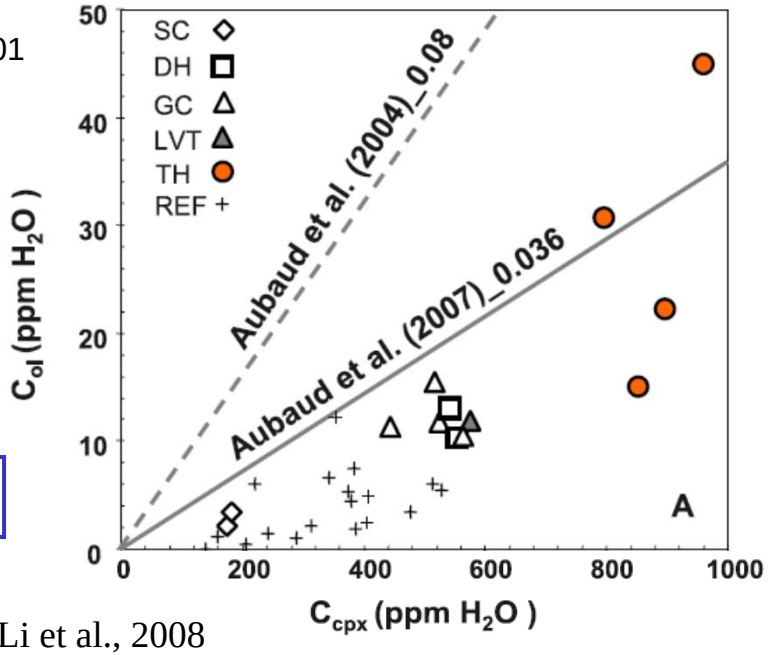




Freed et al., 2012

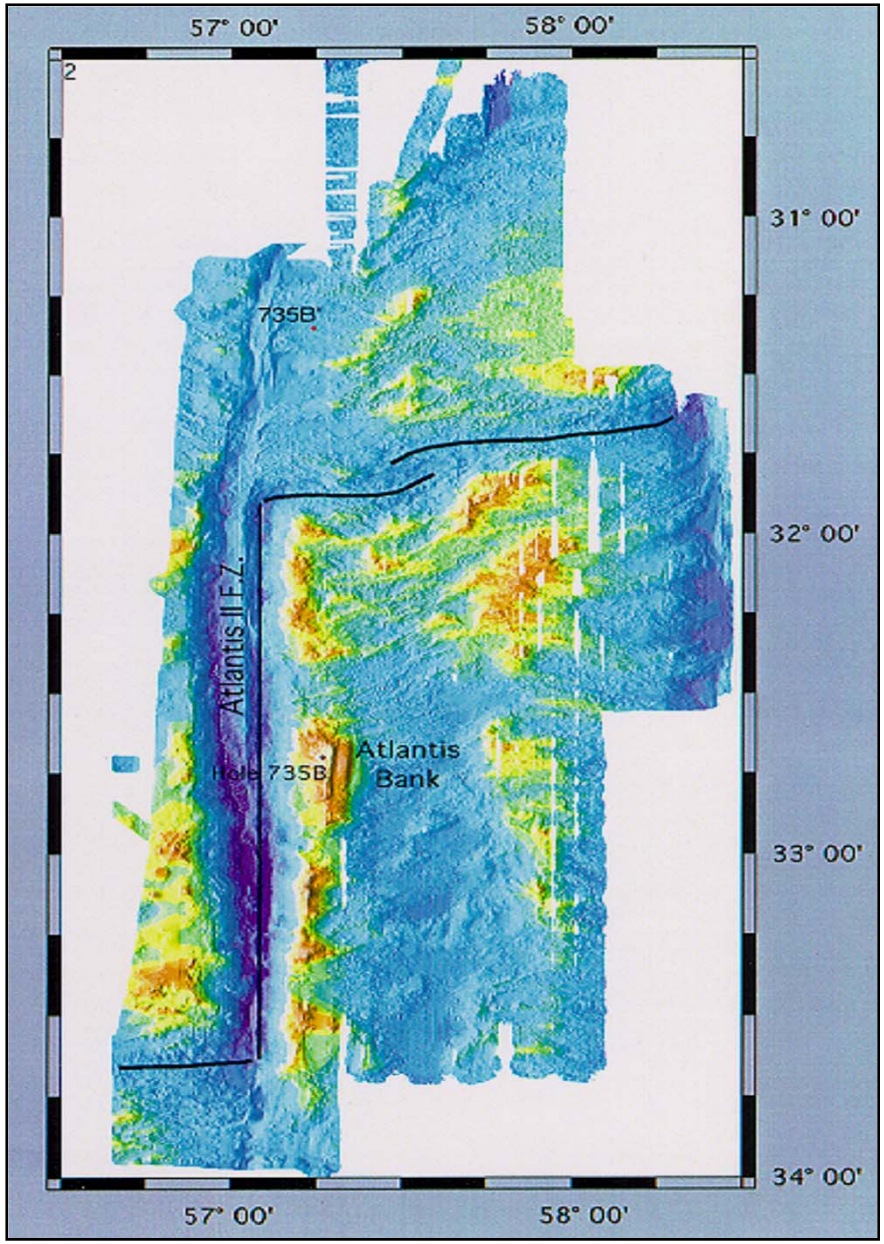
1000 ppm H/Si = 60 wt ppm

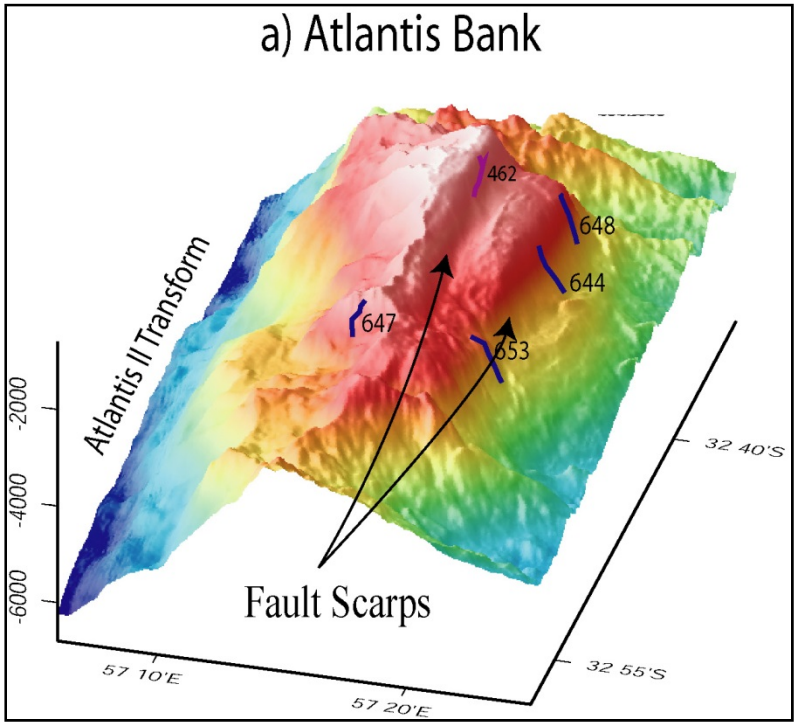


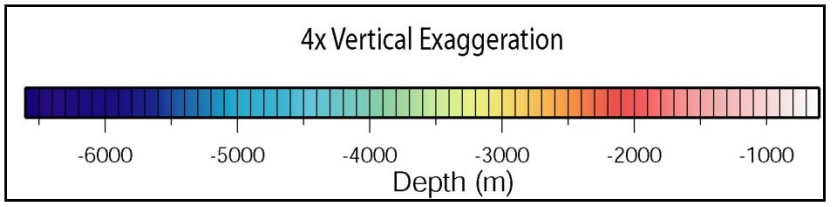


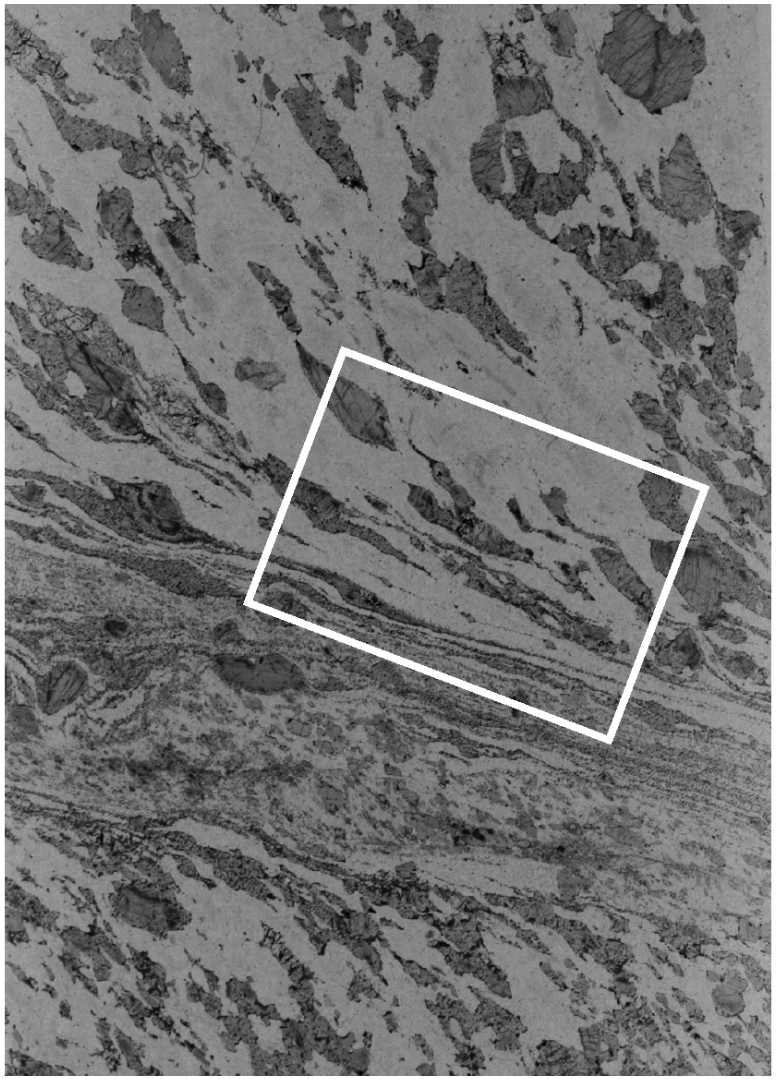
Li et al., 2008

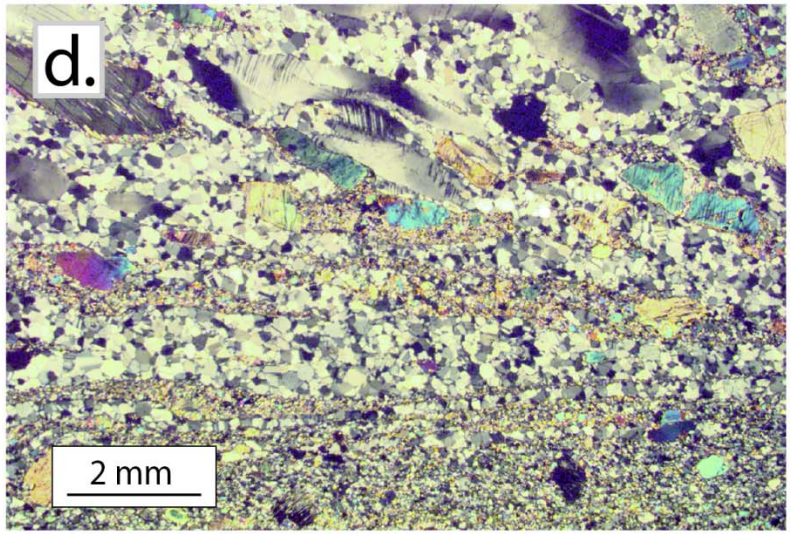
Atlantis Bank, SWIR

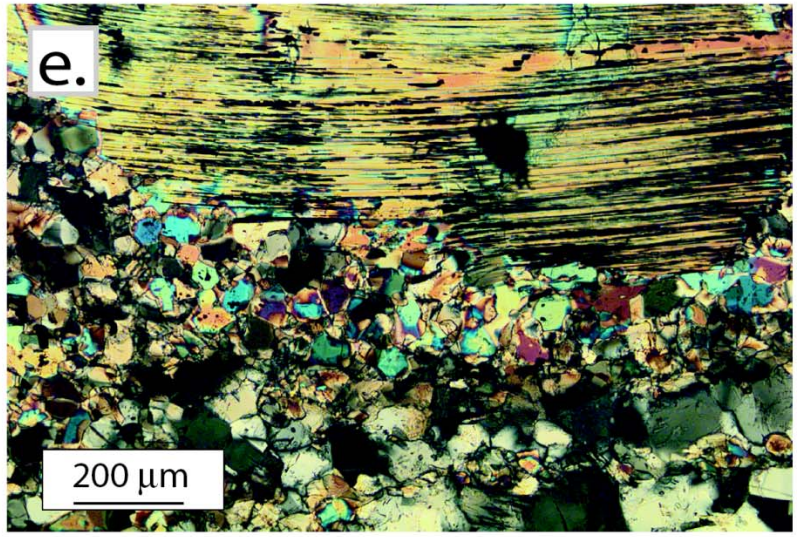




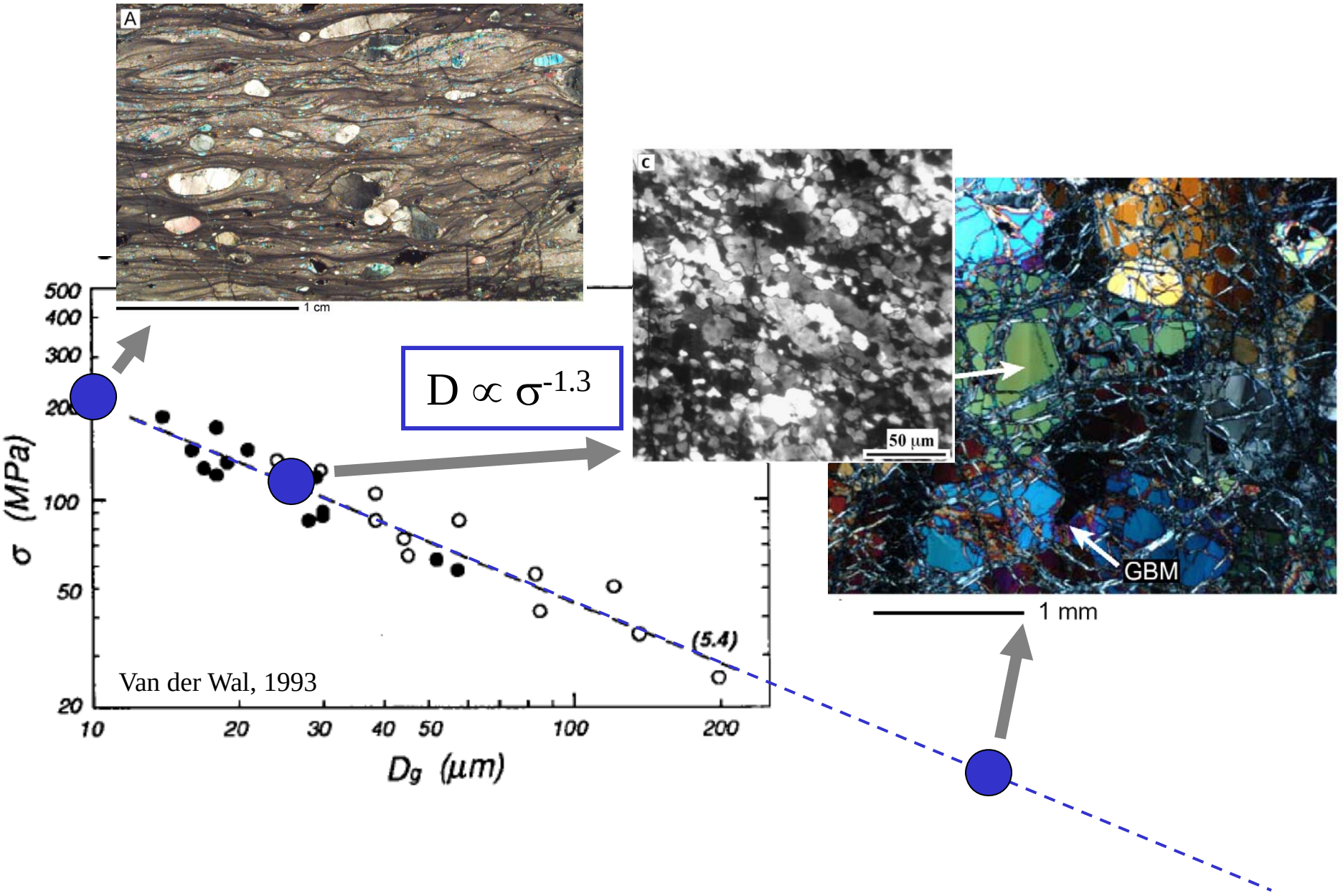


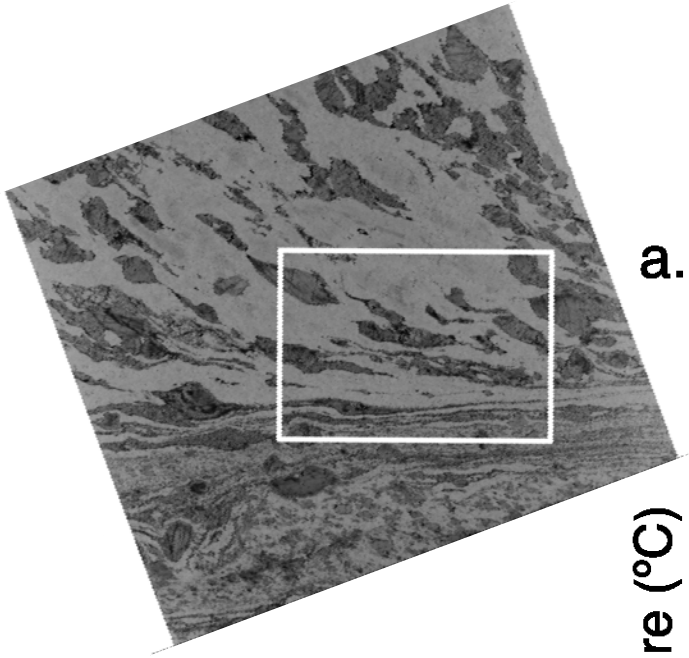




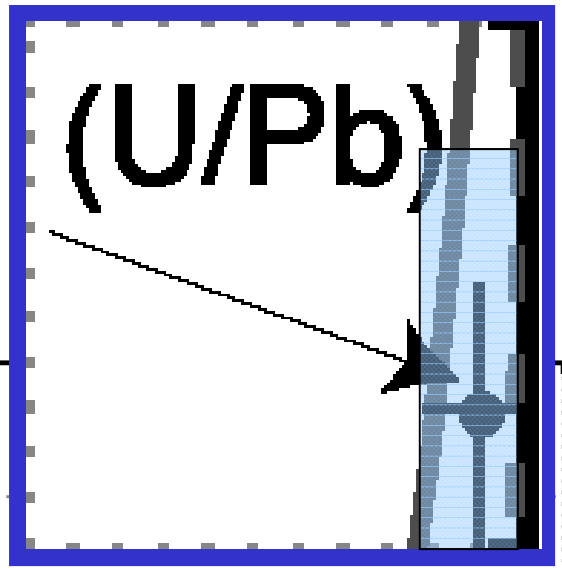


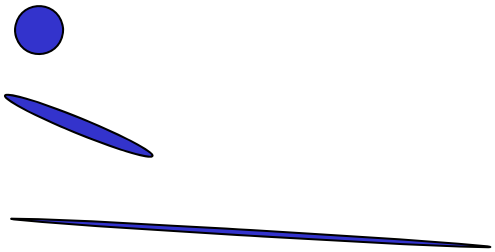
"Dry" Lower Crust (Oceanic Gabbro)

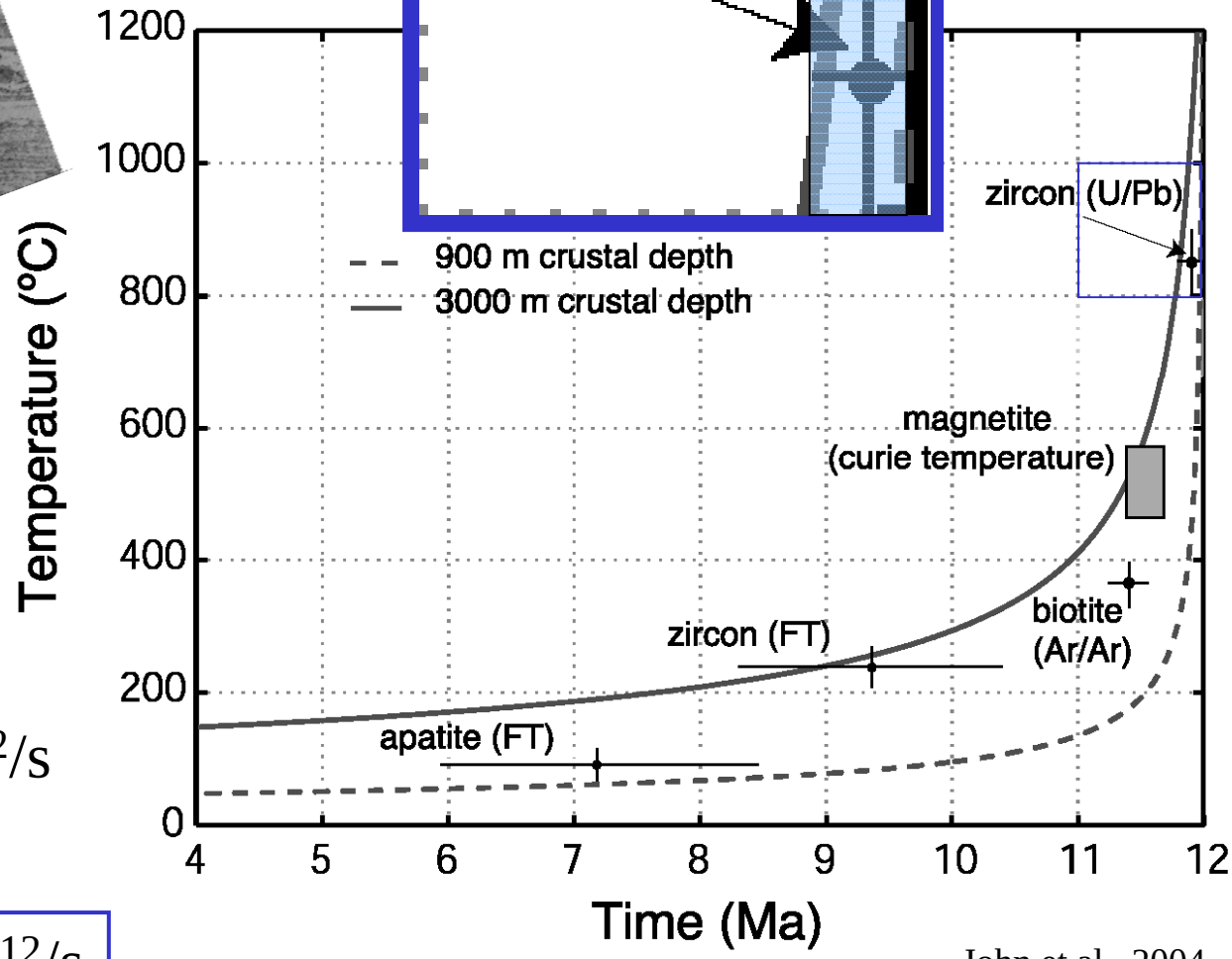

A
1 cm
C
50 µm
GBM
1 mm
D ∝ σ-1.3
σ (MPa)
500
400
300
200
100
50
20
10
20
30
40
50
100
200
Dg (µm)
(5.4)
Van der Wal, 1993



a.





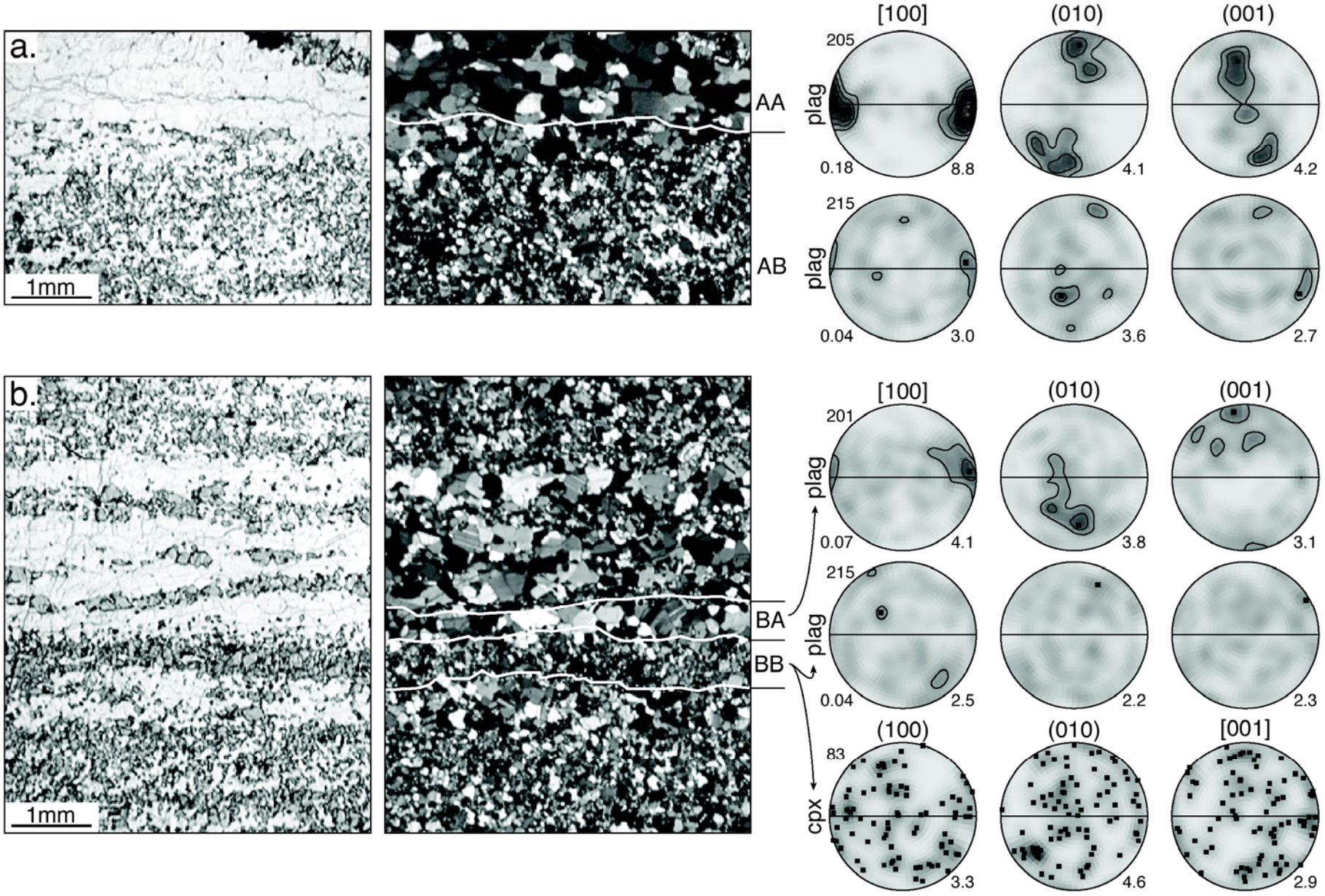


$10/200ky = 1.6\times10^{-12}/s$

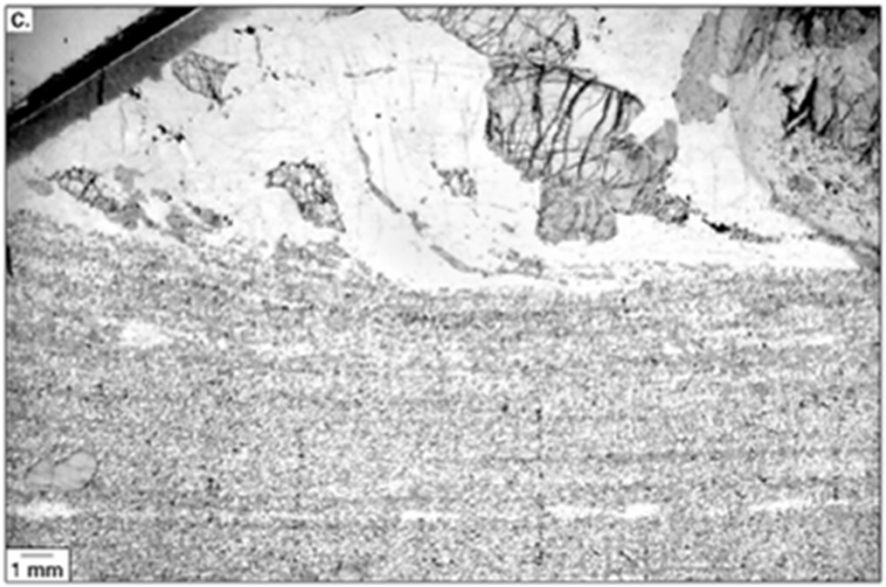
$3/1\ my = 10^{-13}/s$

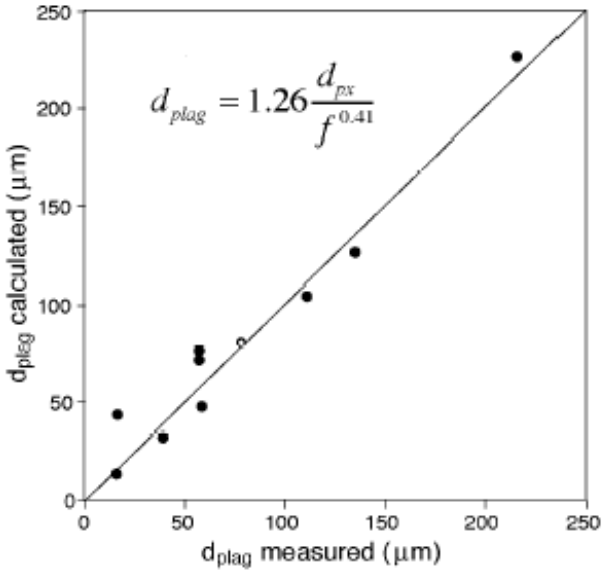
Strain Rate 10^{-11} to $10^{-12}/s$

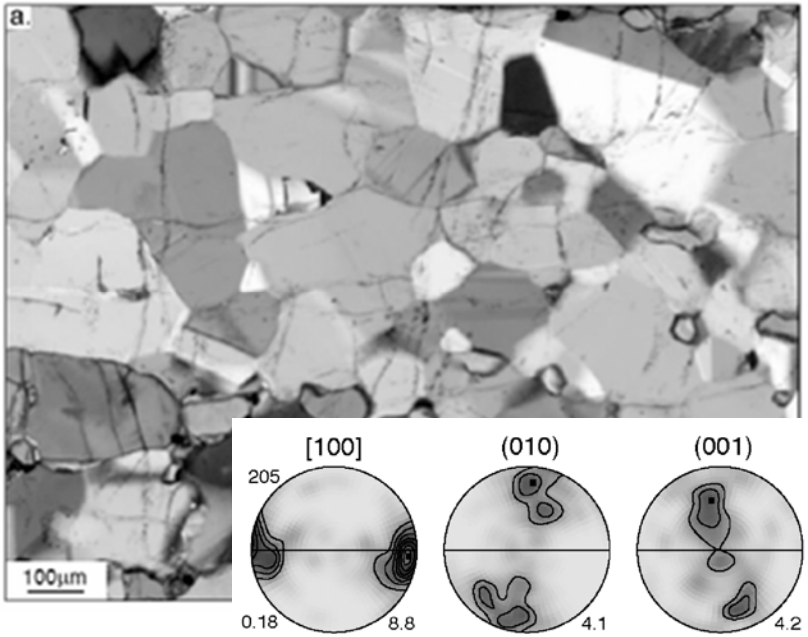
John et al., 2004

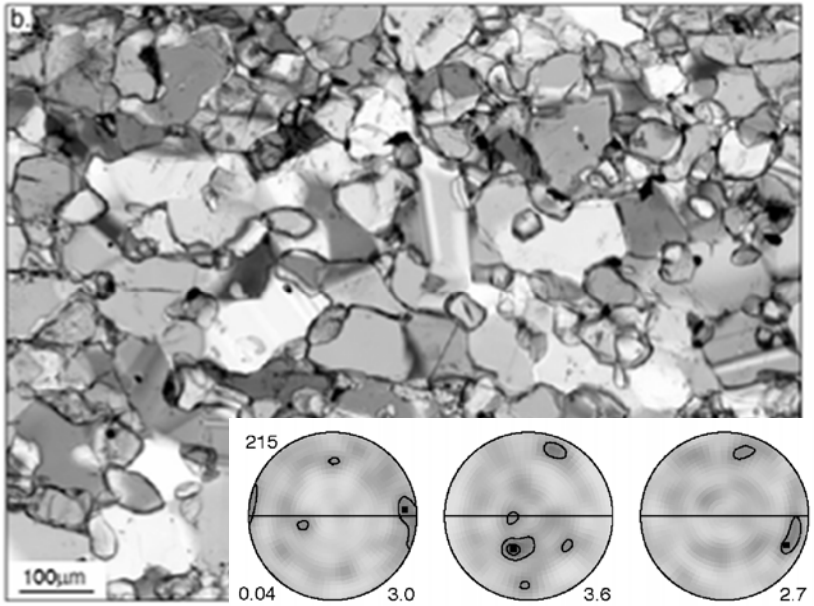


Mehl and Hirth, JGR 2008

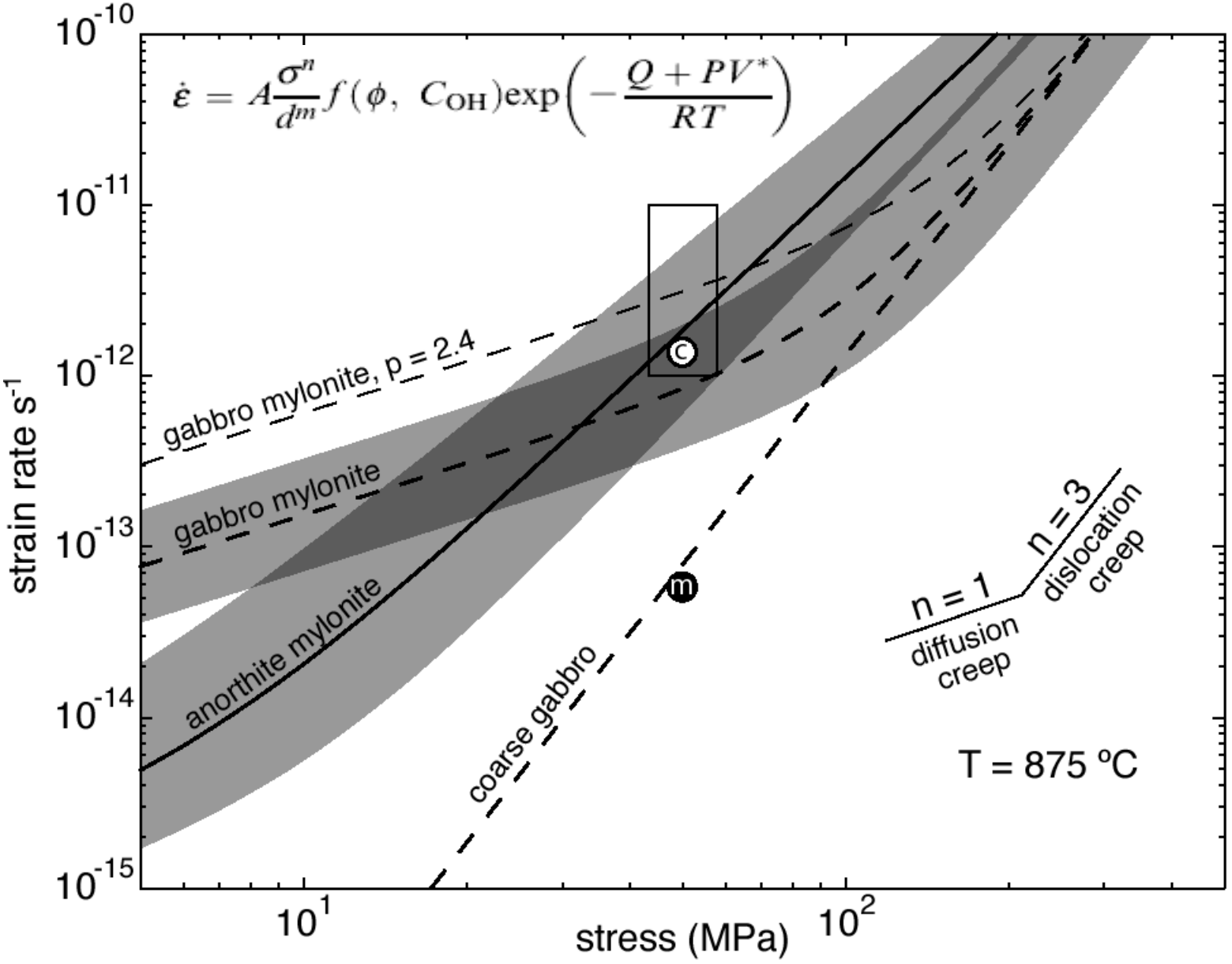






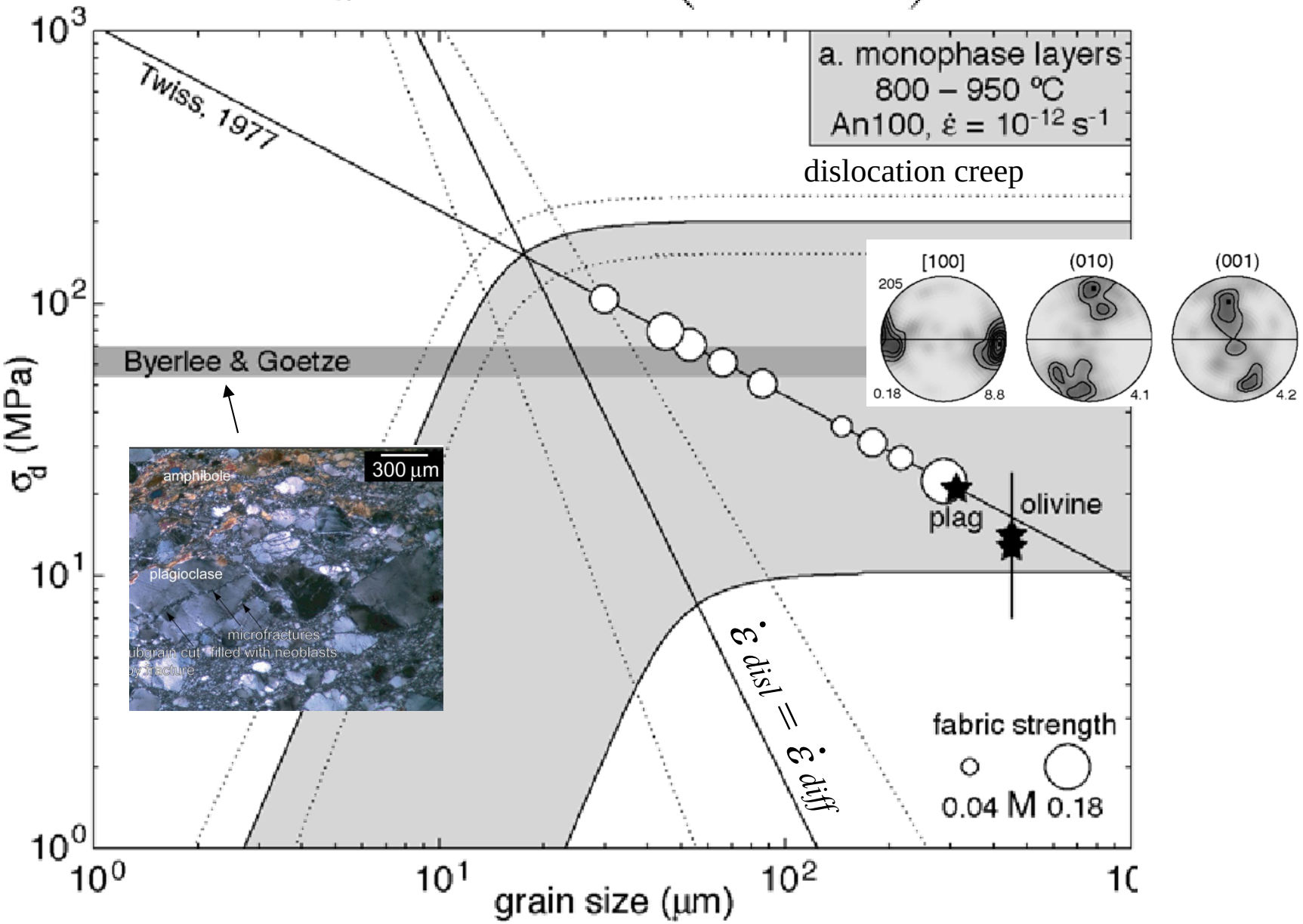


Mehl and Hirth, JGR 2008

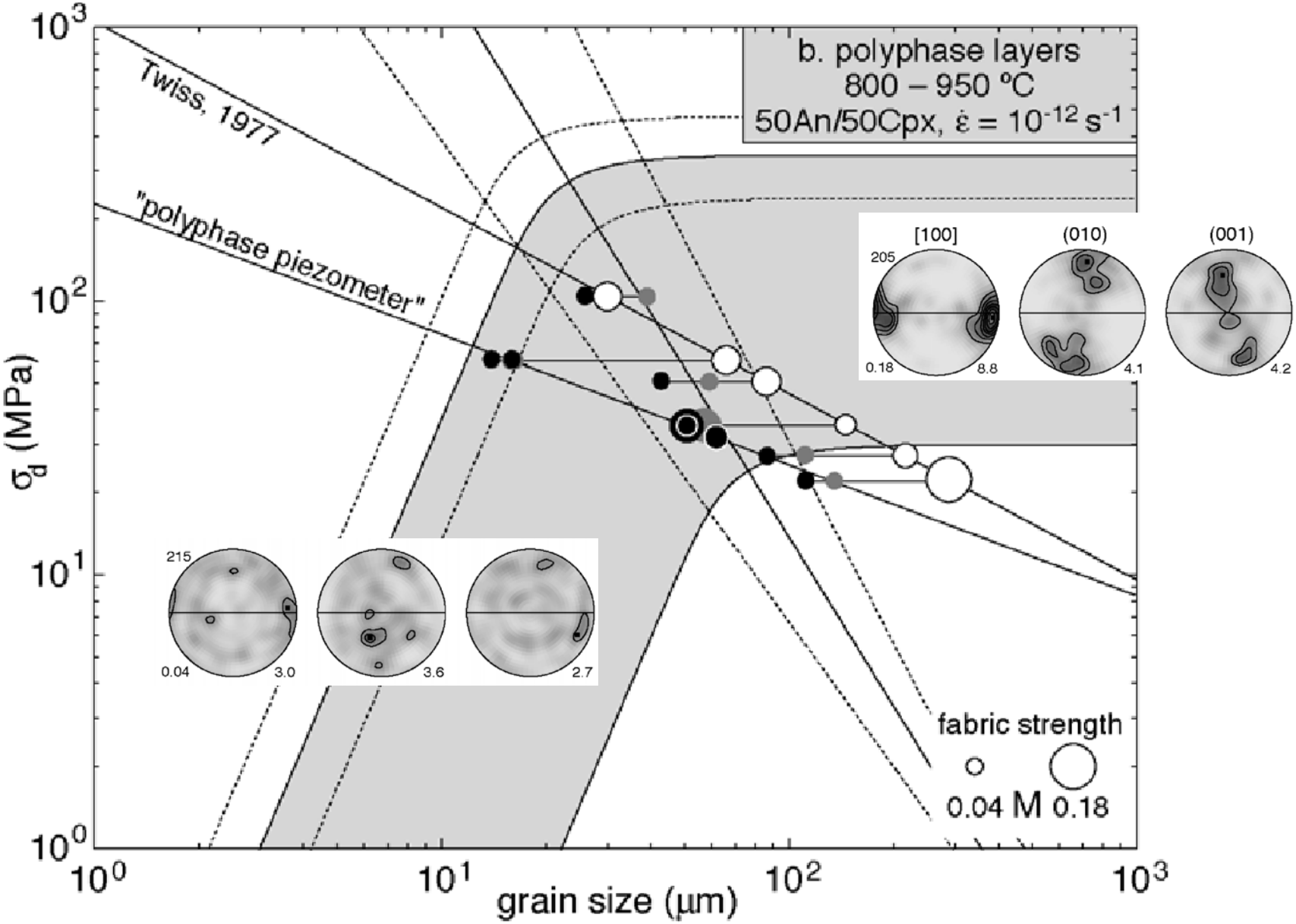


Mehl and Hirth, JGR 2008

$$\dot{\varepsilon} = A\frac{\sigma^n}{d^m} f(\phi,\ C_{OH}) \exp\left(-\frac{Q + PV^*}{RT}\right)$$

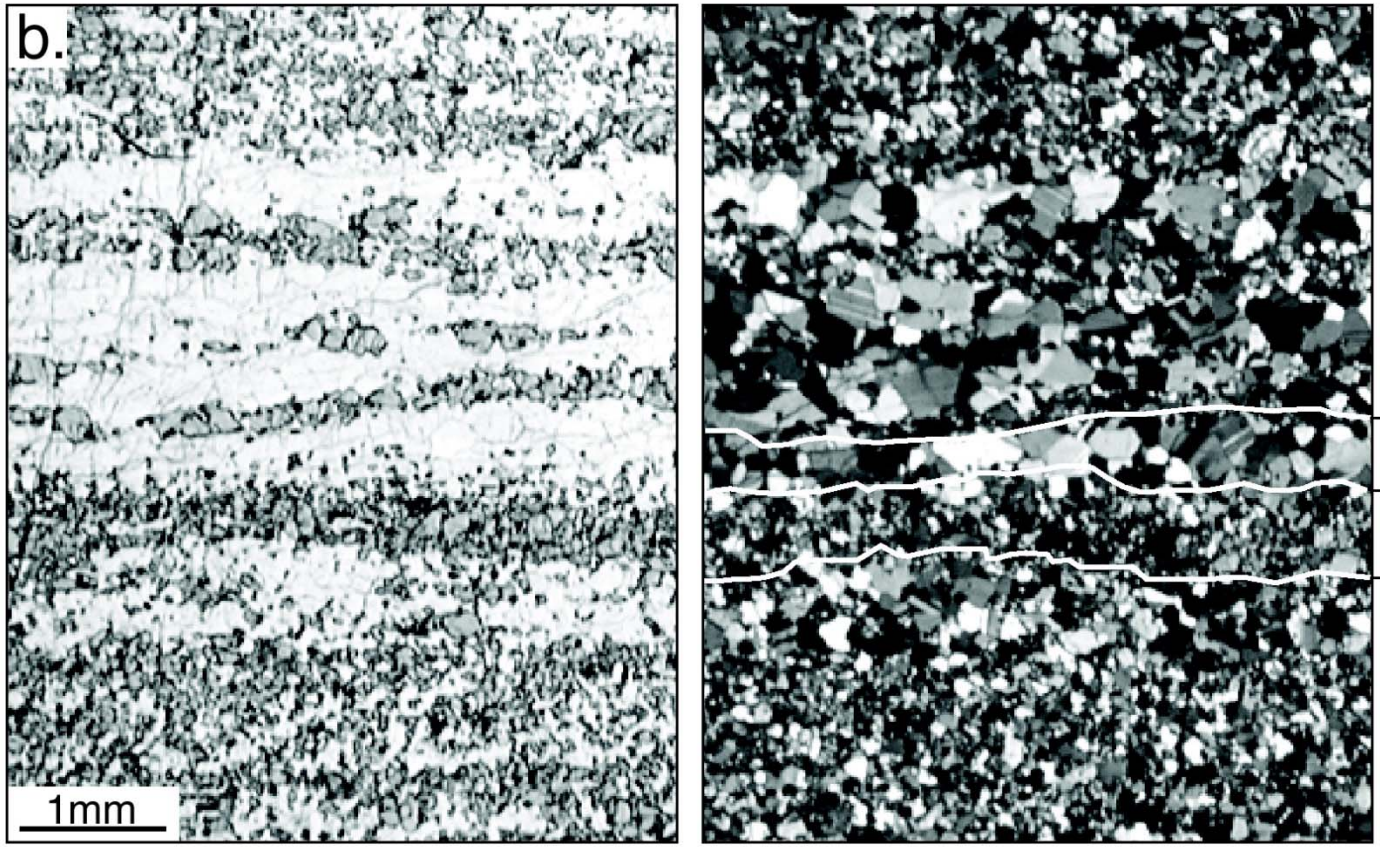


Mehl and Hirth, 2008



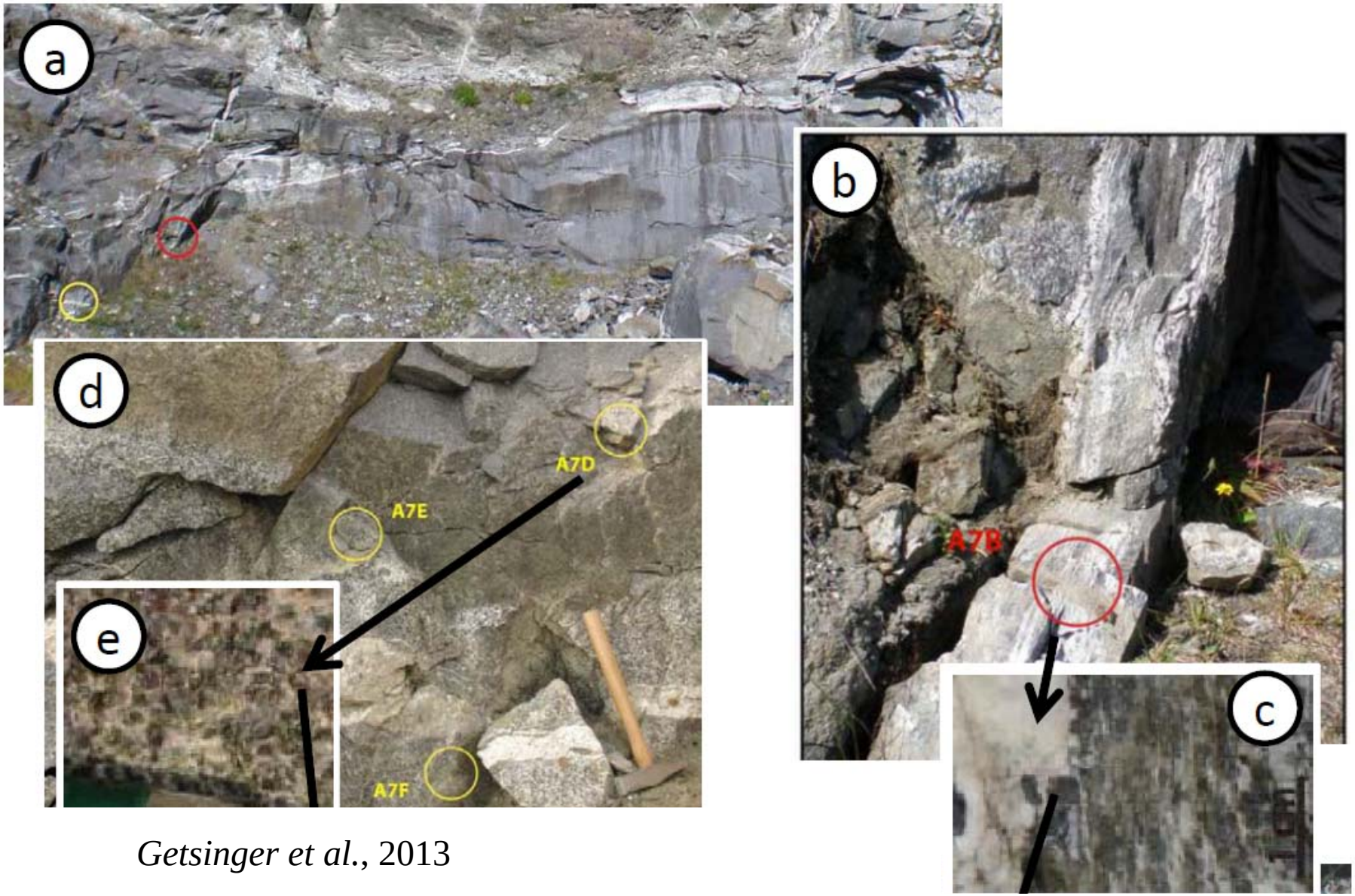
Mehl and Hirth, 2008

Use dislocation creep of plagioclase to model strength of lower crust

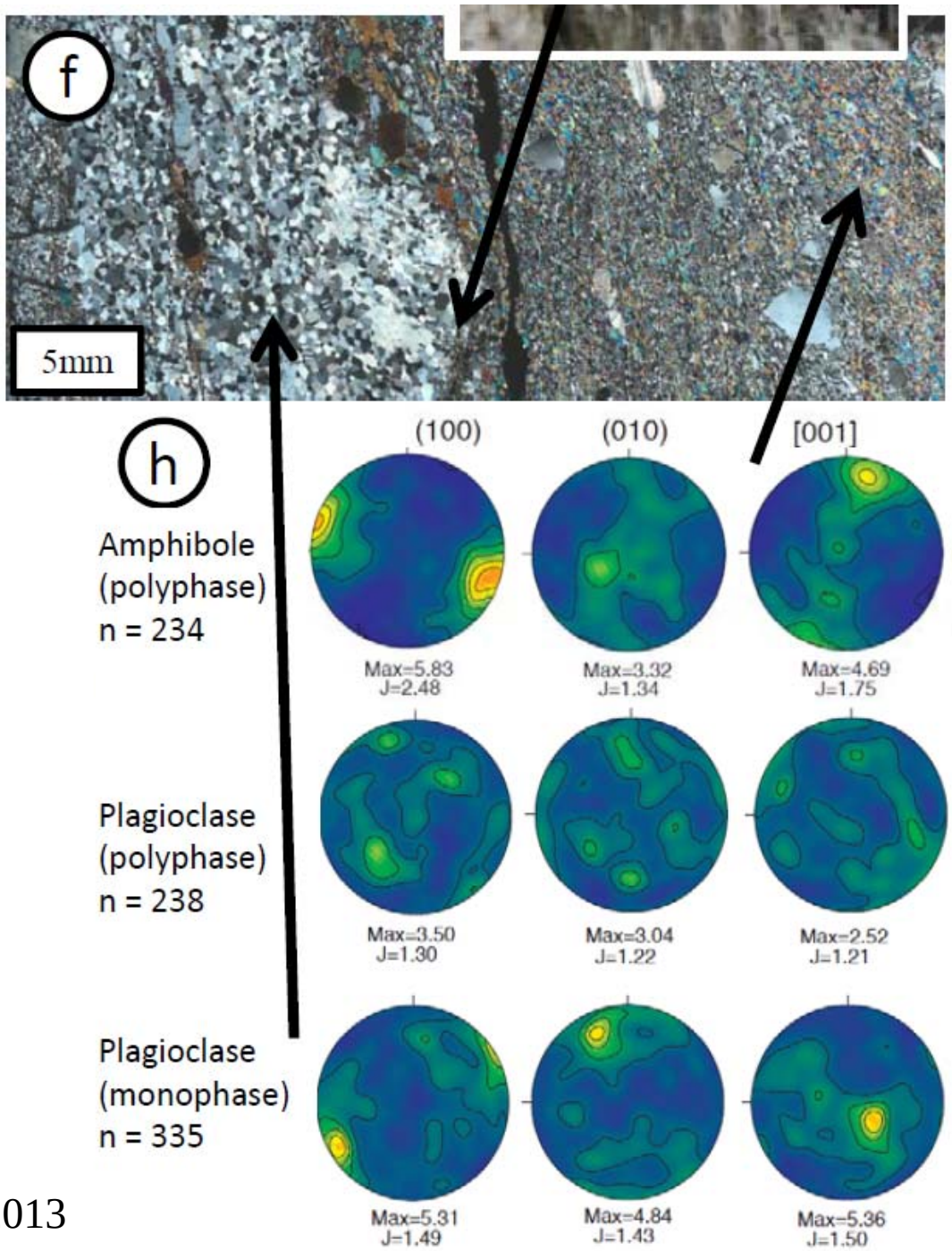


Mehl and Hirth, 2008

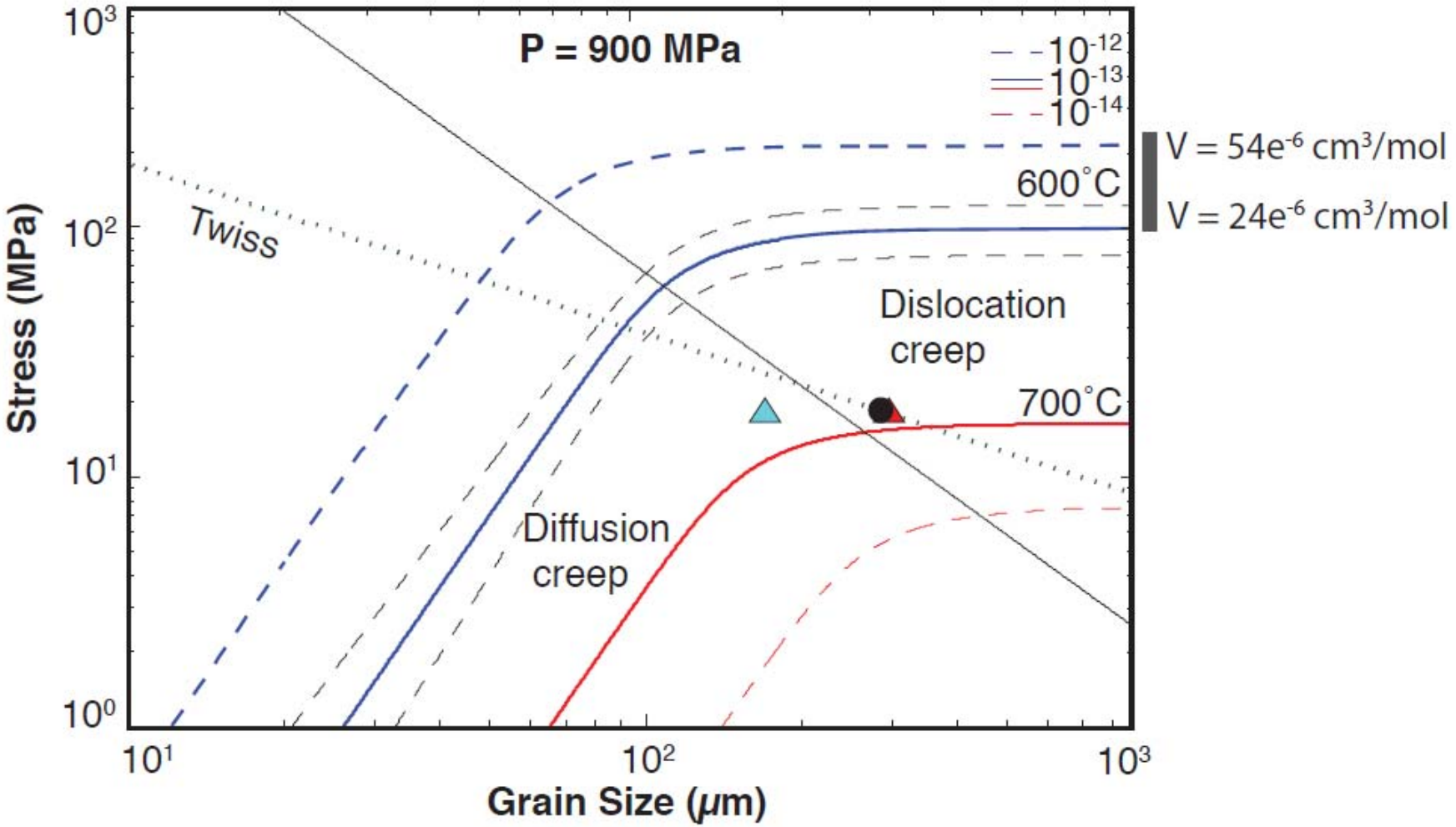
The effect of water content and metamorphism on the strength of lower crust



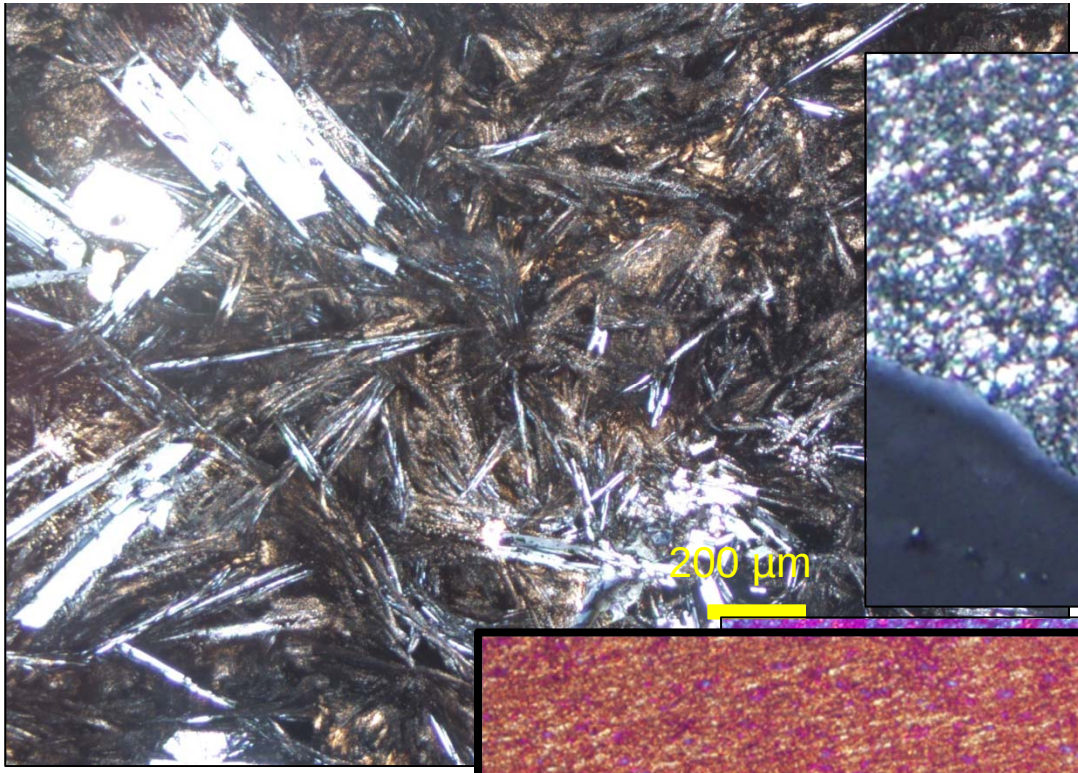
Getsinger et al., 2013

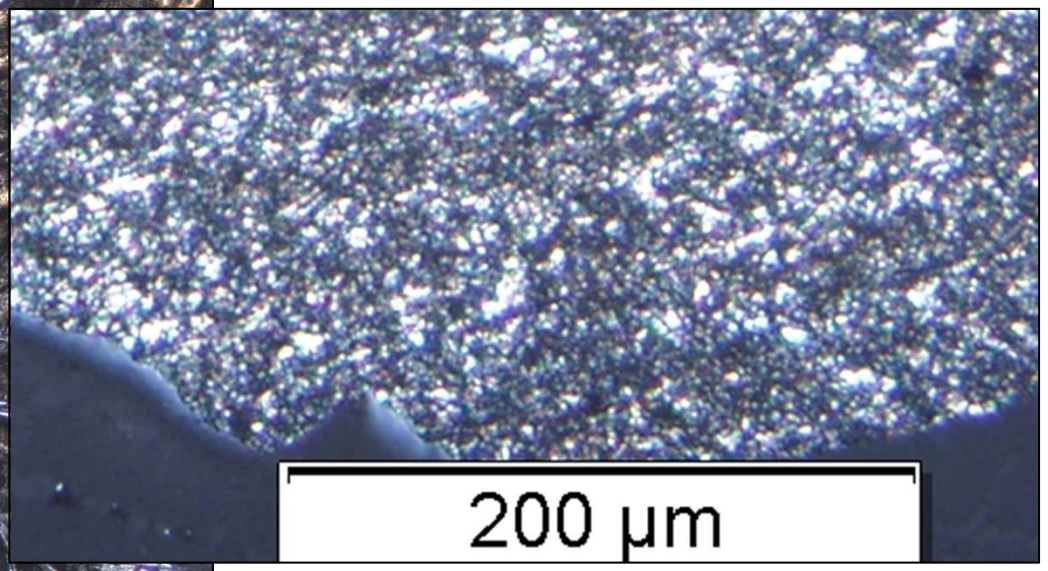


Getsinger et al., 2013



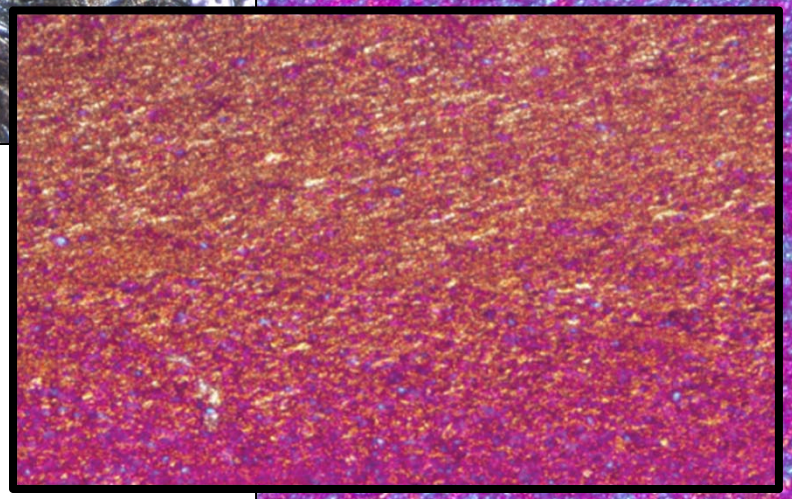
Getsinger et al., 2013



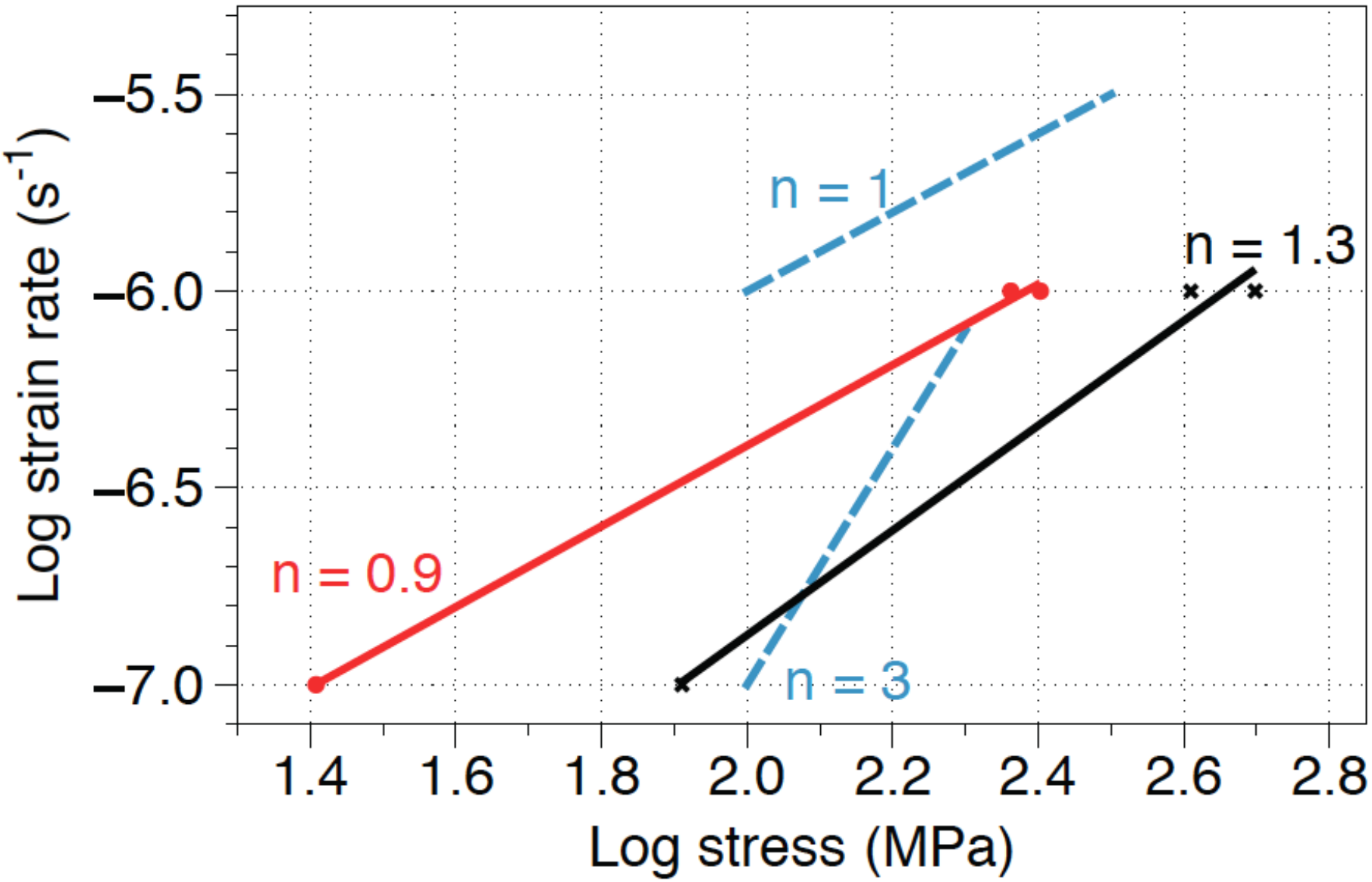


Basalt

Crossed polarized micrograph

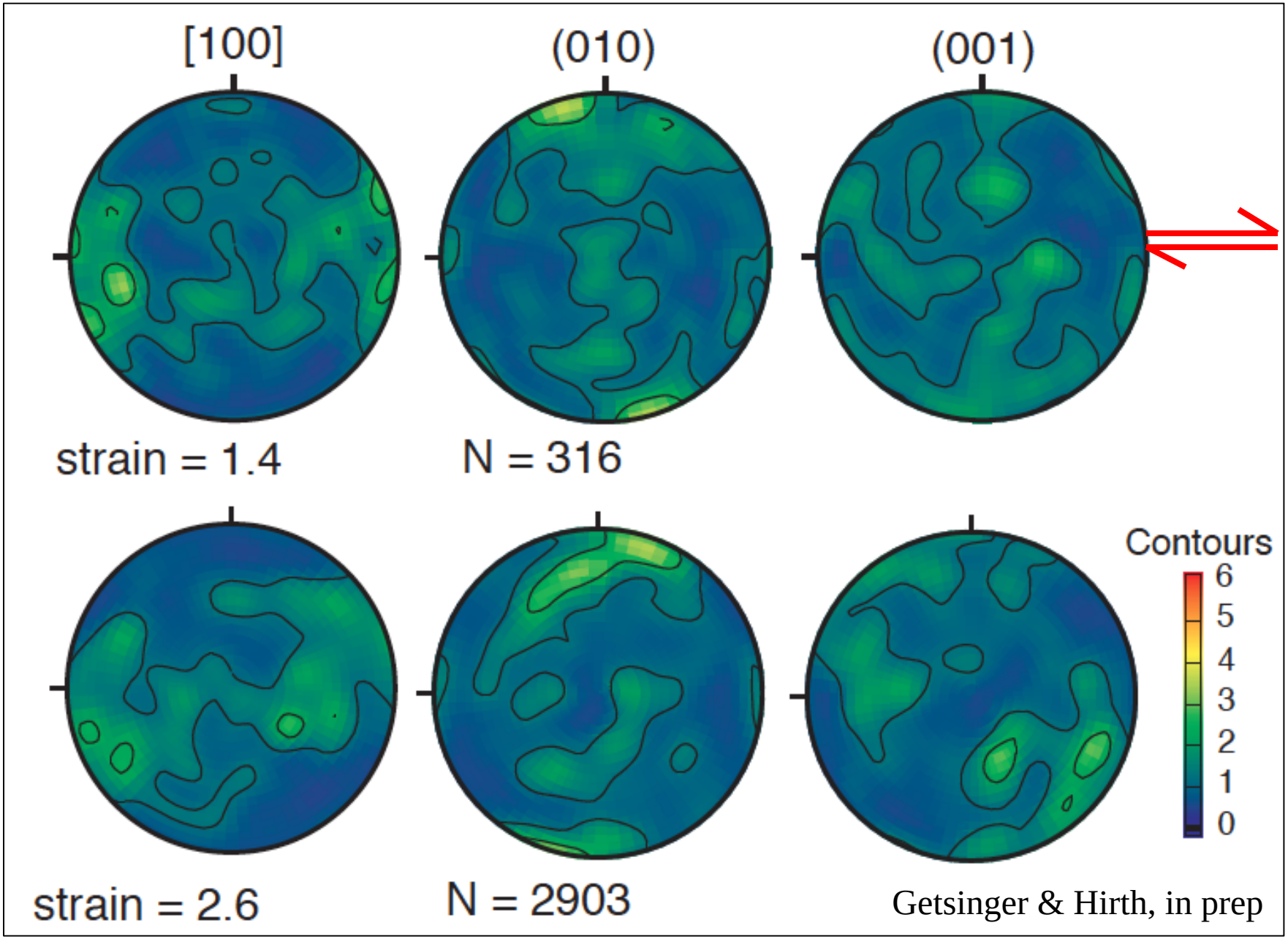


Synthetic Amphibolite

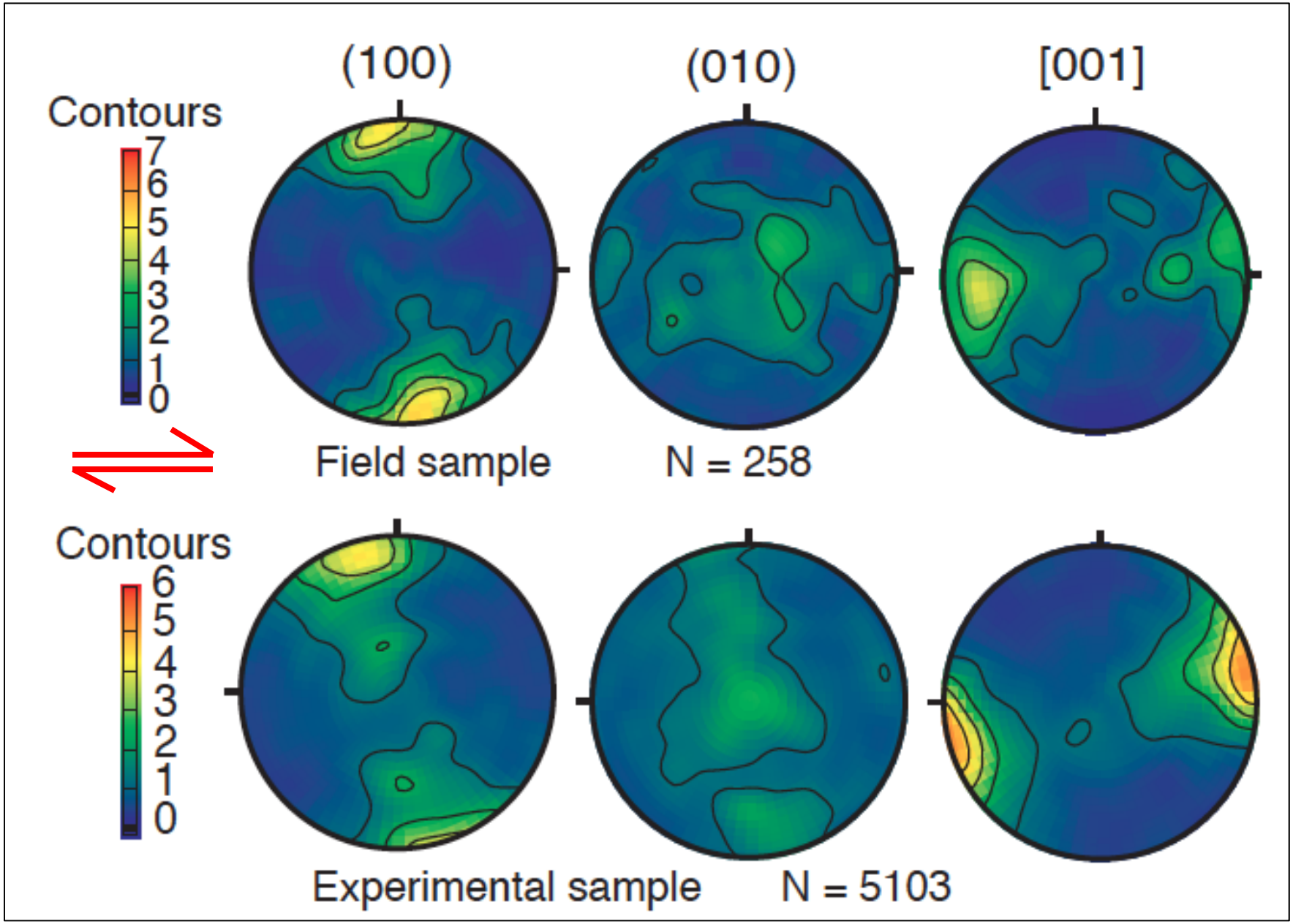


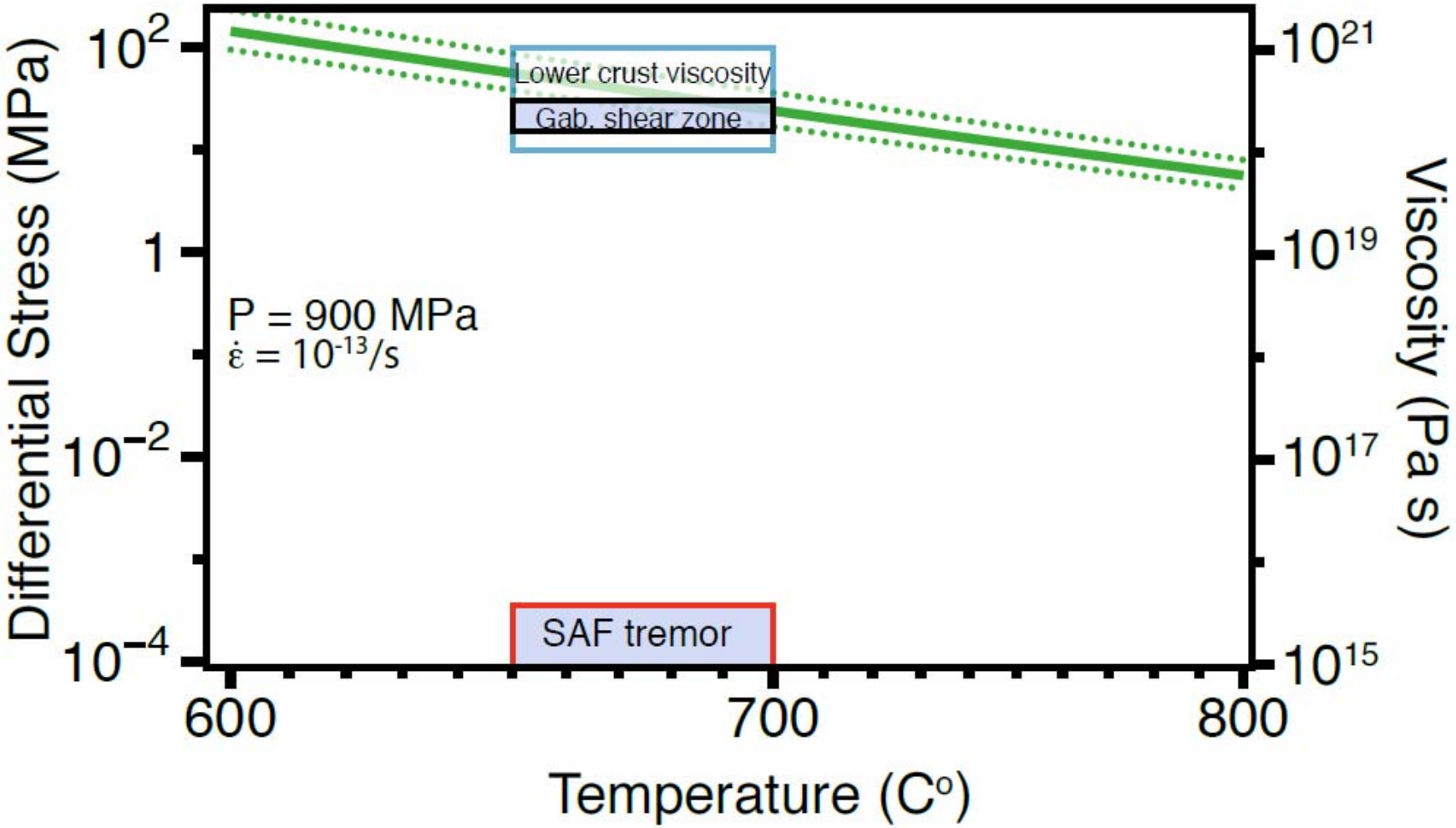
Getsinger & Hirth, in prep

Plagioclase LPO



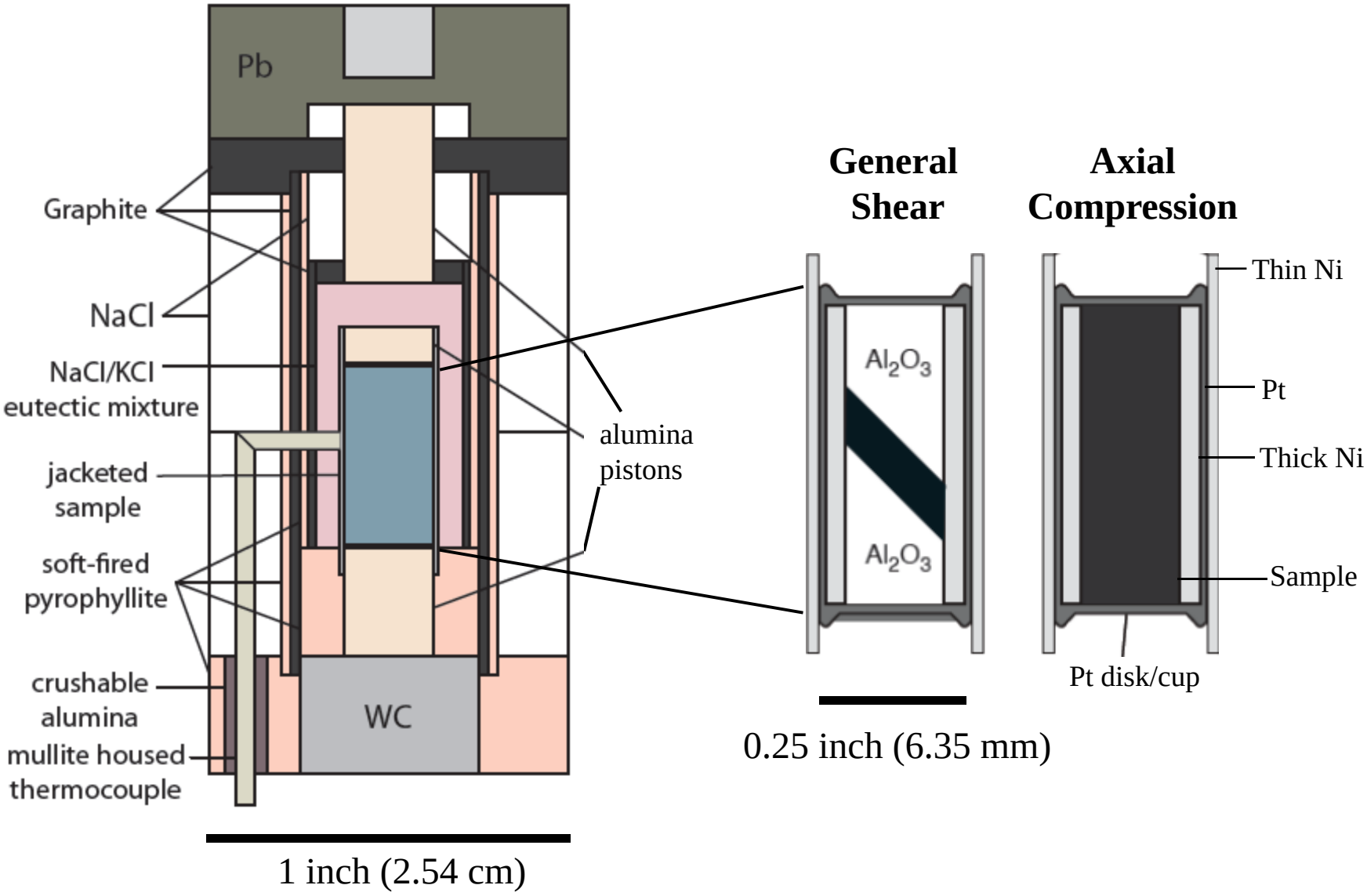
Amphibole fabric from field and laboratory





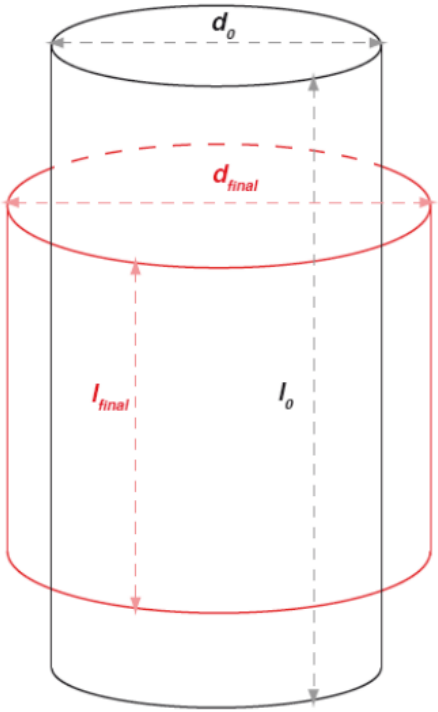
Getsinger et al., 2013

Experimental Design – Molten Salt Cell



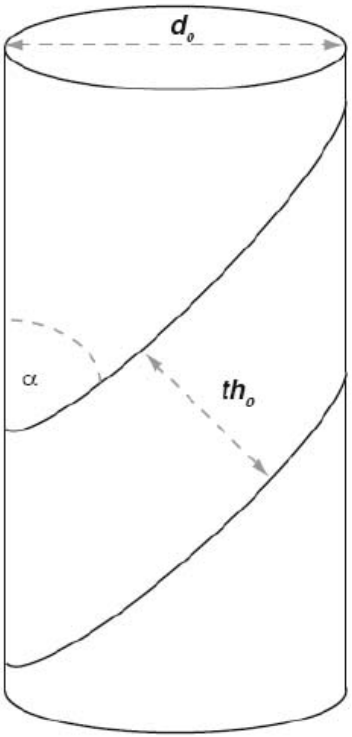
Geometrical Assumptions During Deformation

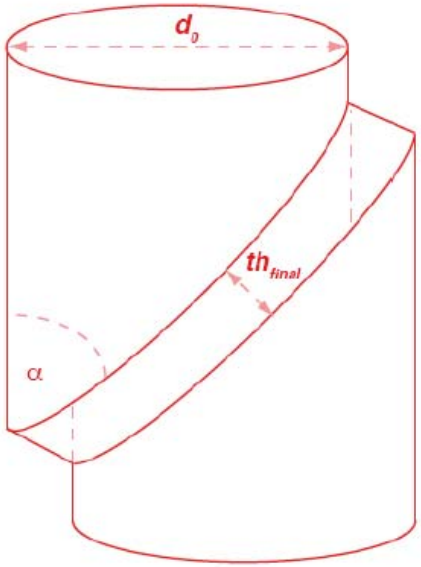
Axial Compression



Cross-sectional sample area
Grows as sample is shortened

General Shear

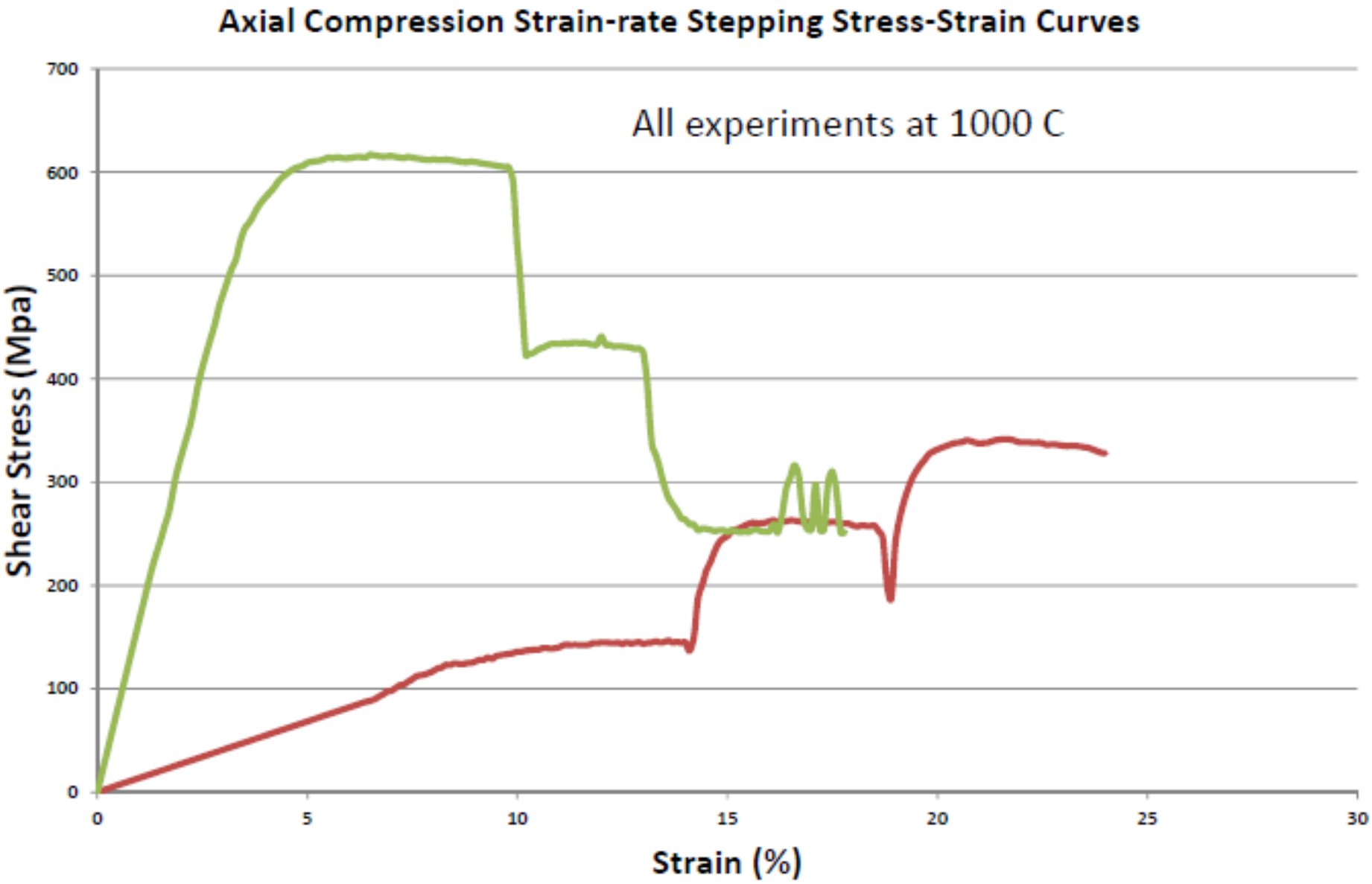




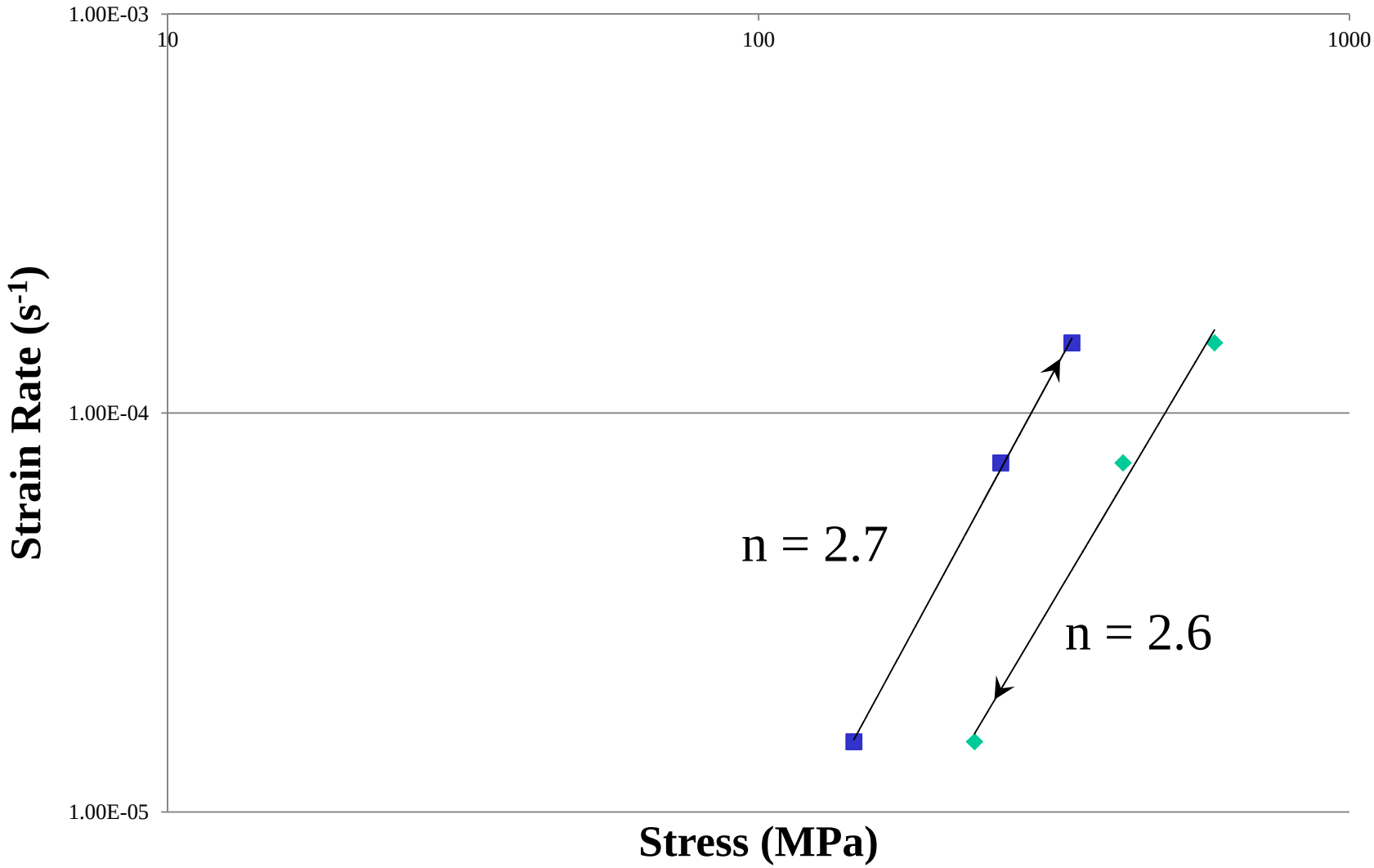
Cross-sectional area grows as sample is thinned,
Reduction is sample overlap reduces the portion of the sample that is feeling the differential stress

Diagrams courtesy of Matej Pec

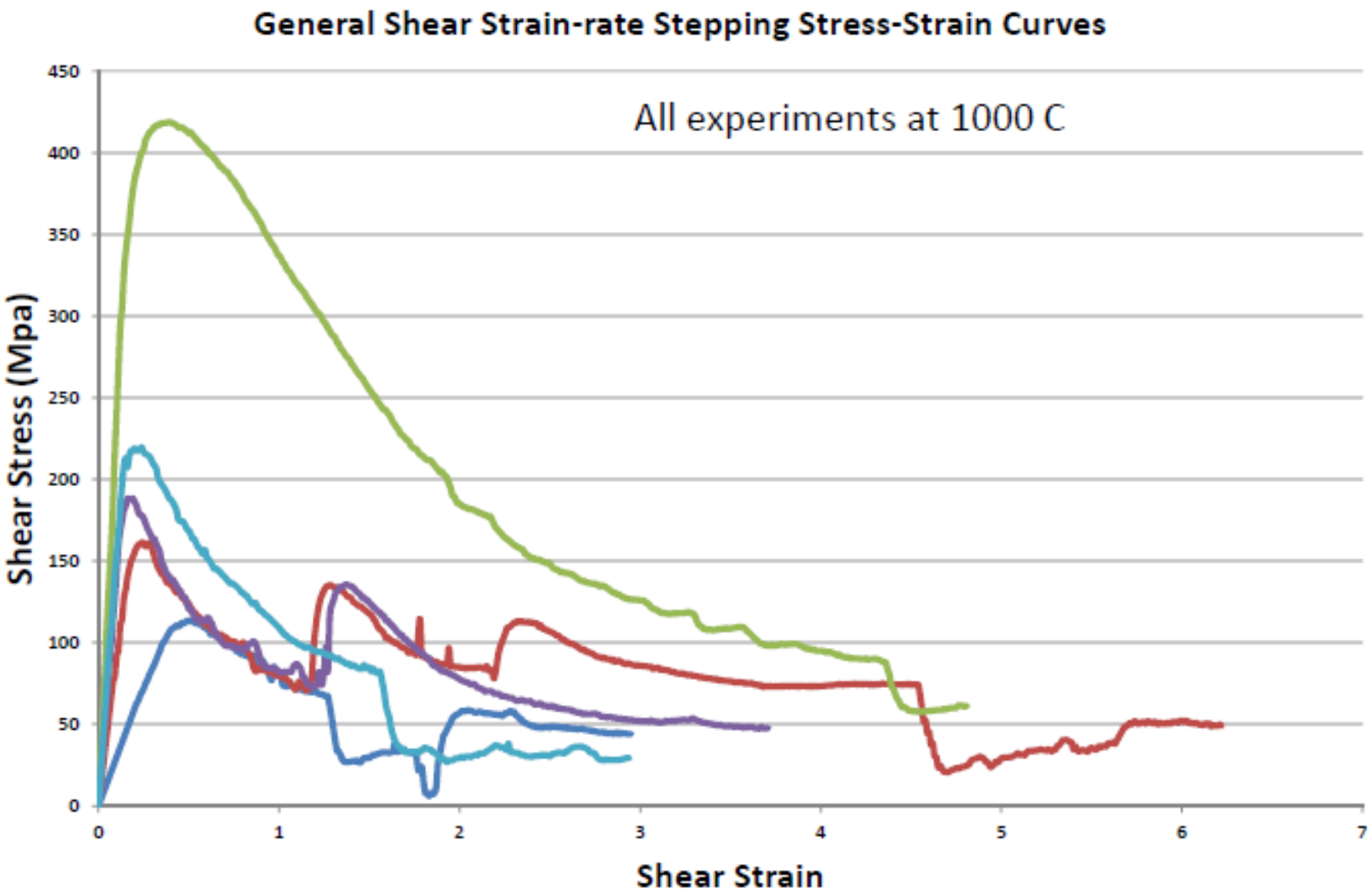
Strain-Rate Stepping Experiments



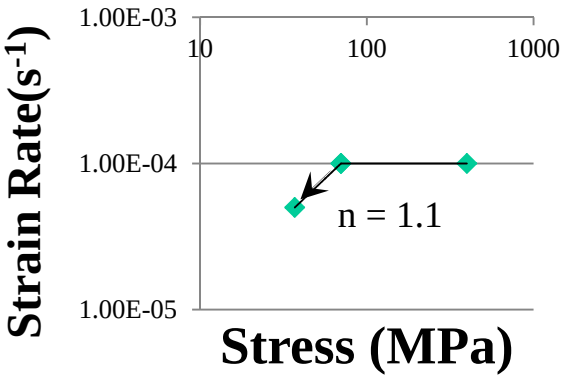
Log of Strain-rate vs. Log of Stress Plots for Axial Compression Experiments with Strain Rate Steps

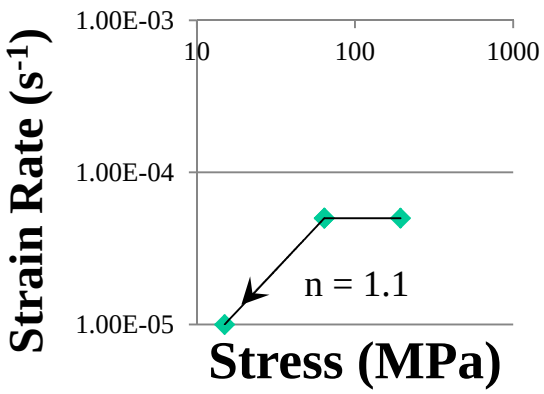


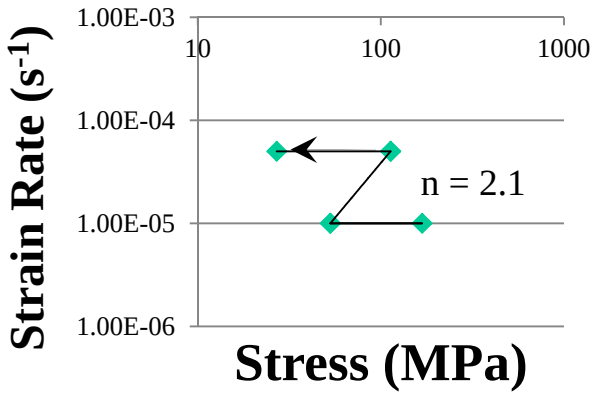
Strain-Rate Stepping Experiments

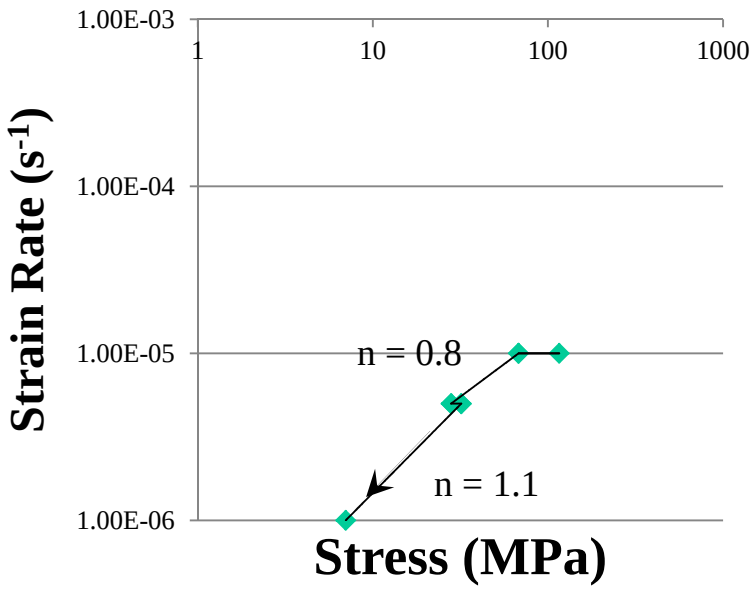


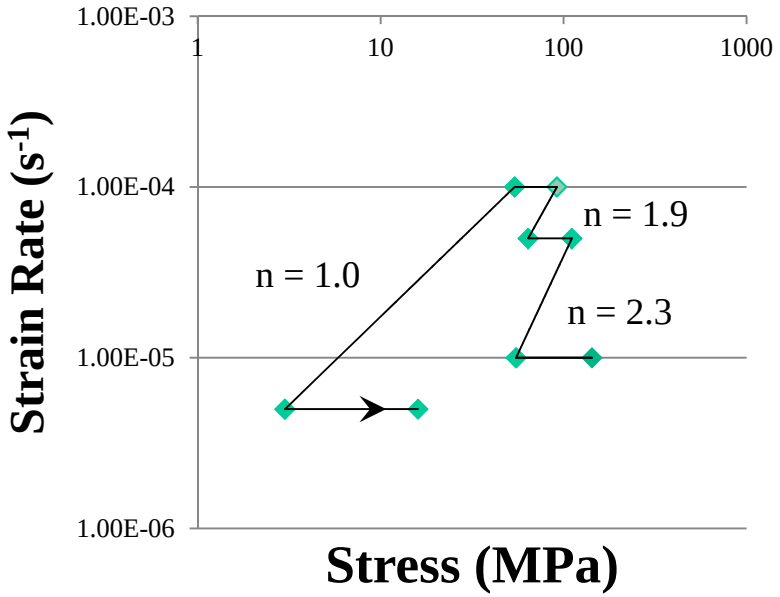
Log of Strain-rate vs. Log of Stress Plots for General Shear Experiments with Strain Rate Steps



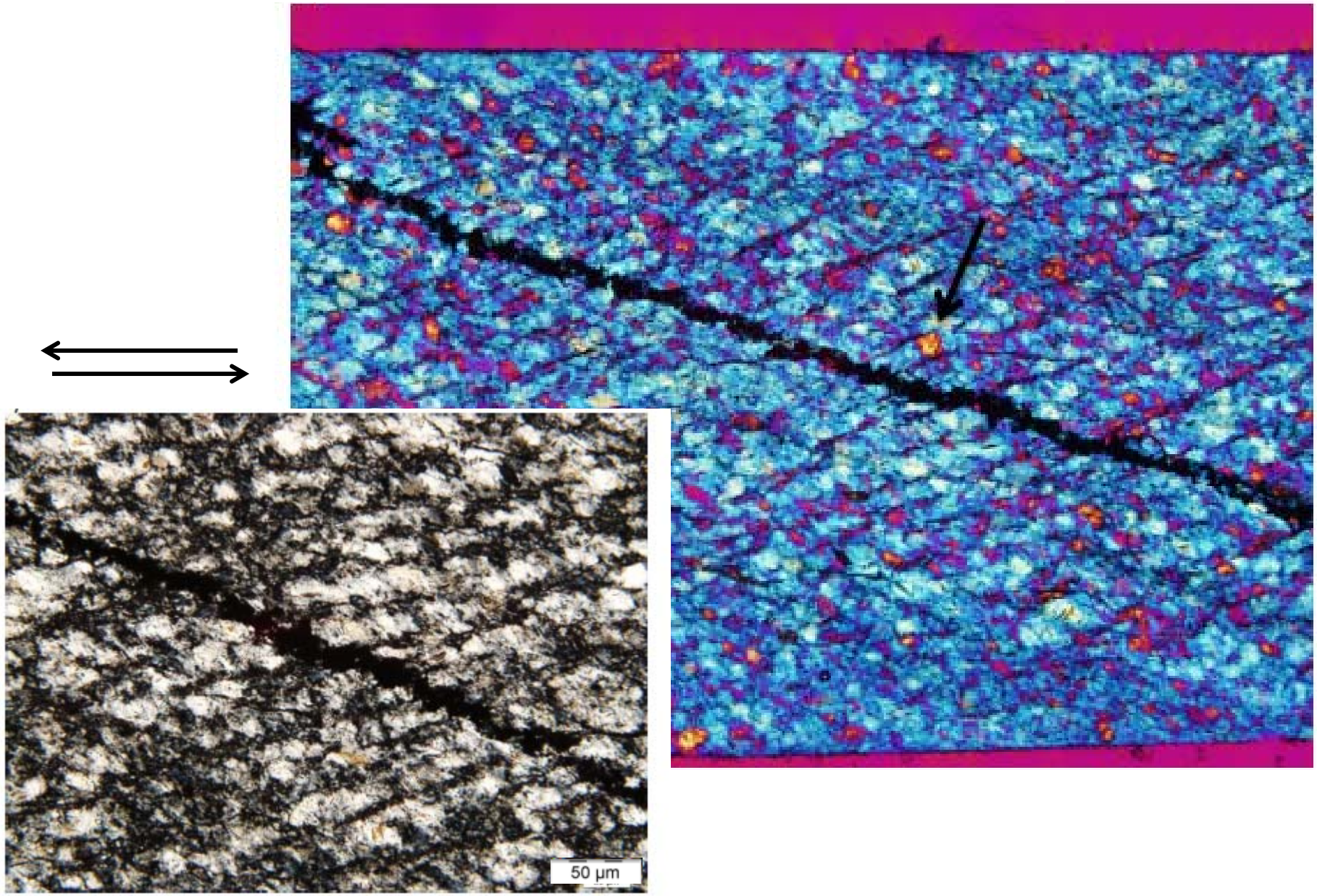






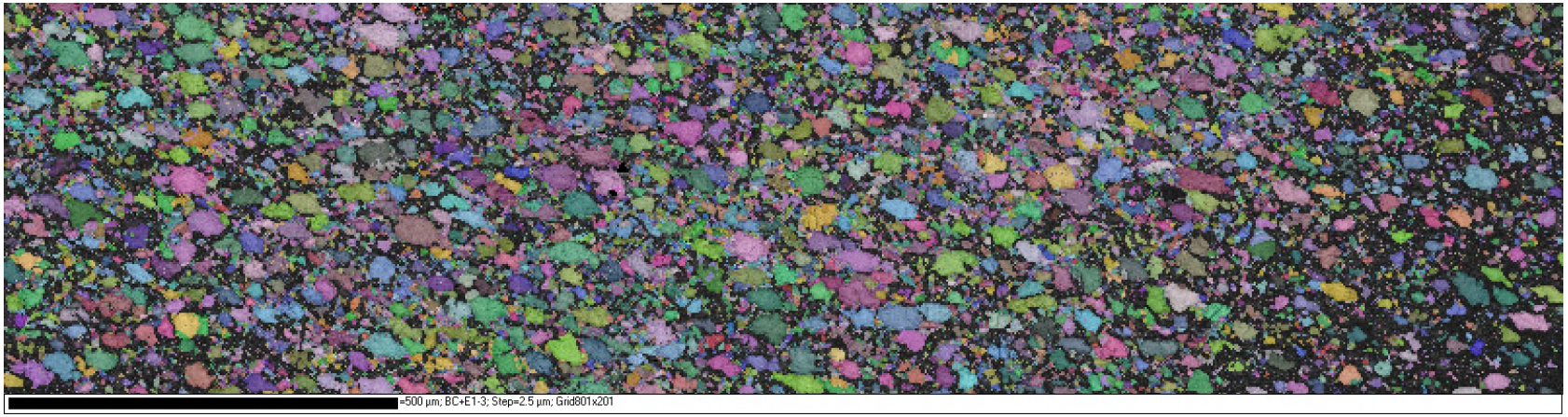


Optical Microstructures: 1000 C, 10^{-5} s^{-1}

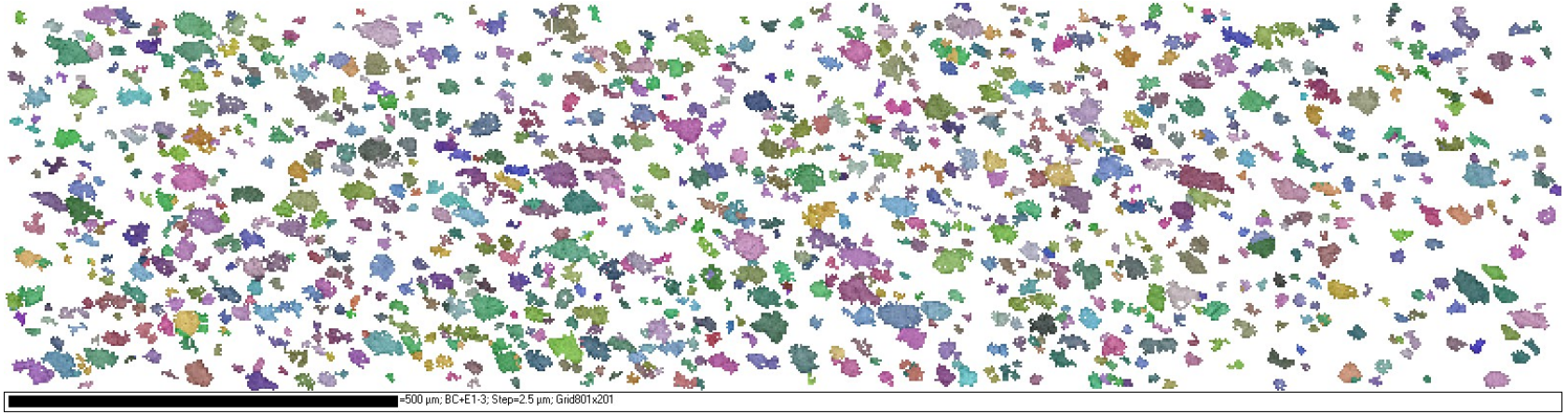


EBSD Data Acquired This Week At University of Otago

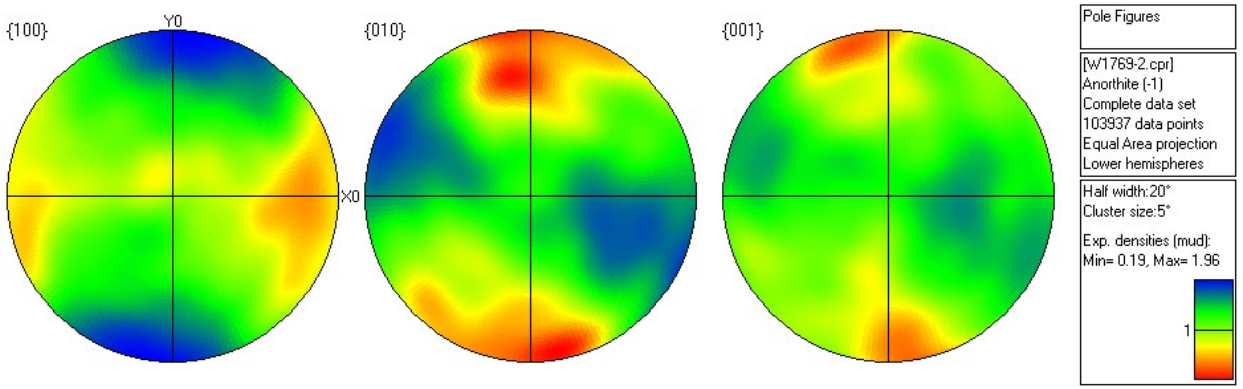
Low-Resolution Map at 2.5 micron step size



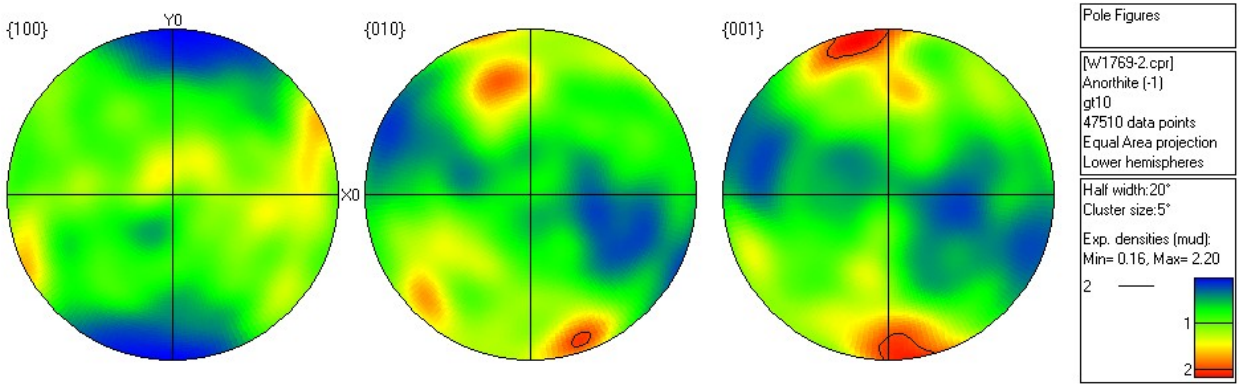
Grains larger than 10 micron extracted to differentiate LPO of relict vs. recrystallized grains



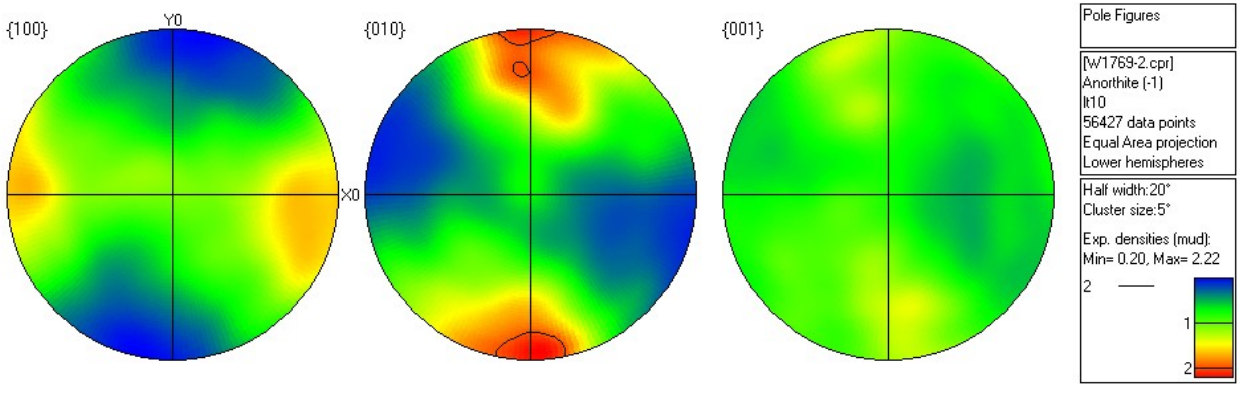
Full Sample

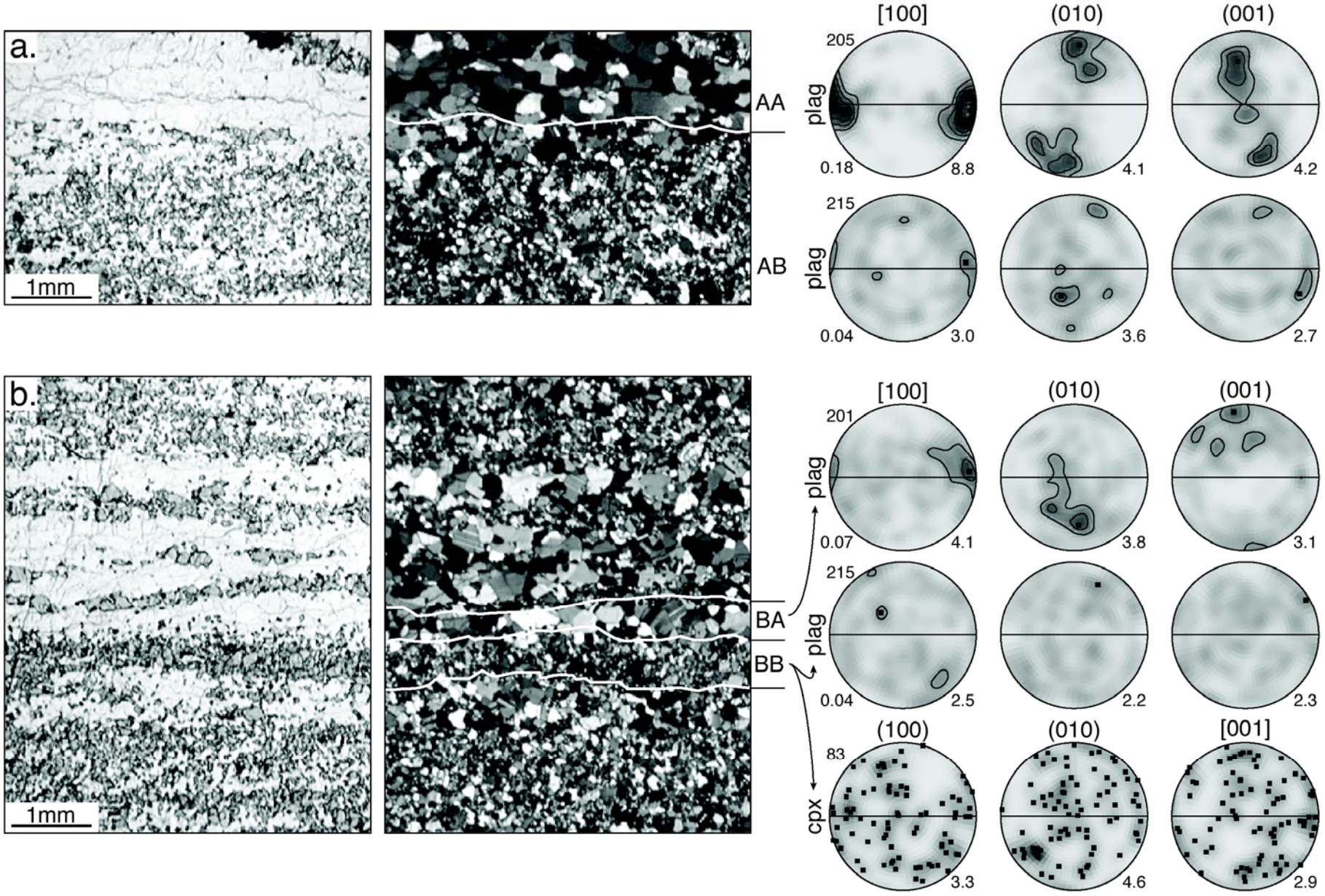


Relict Grains



Recrystallized Grains





Mehl and Hirth, JGR 2008