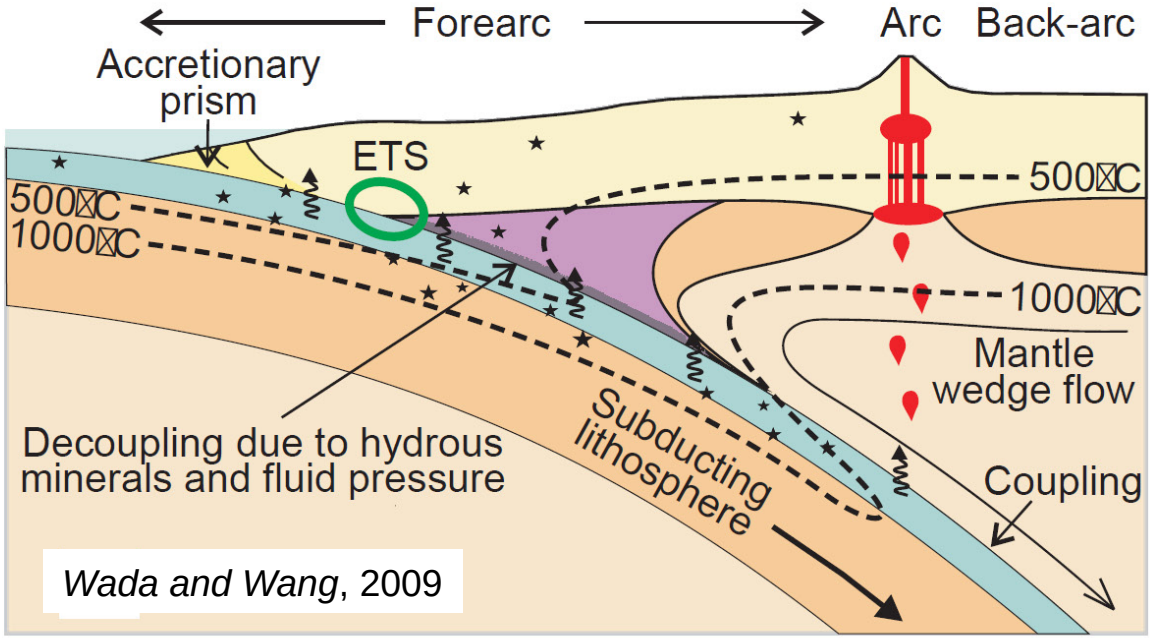
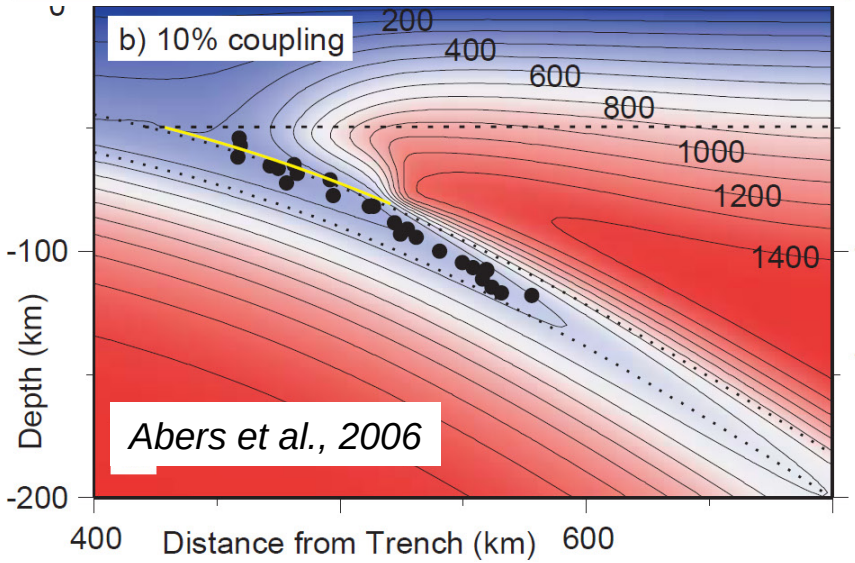
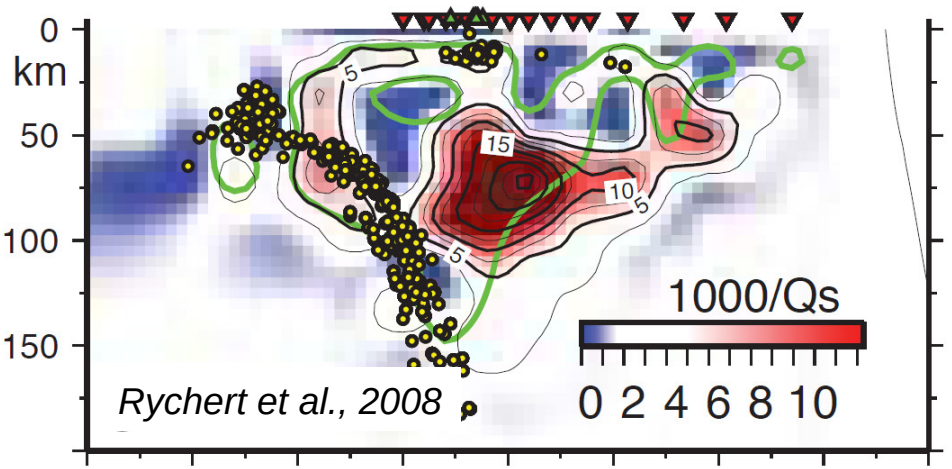
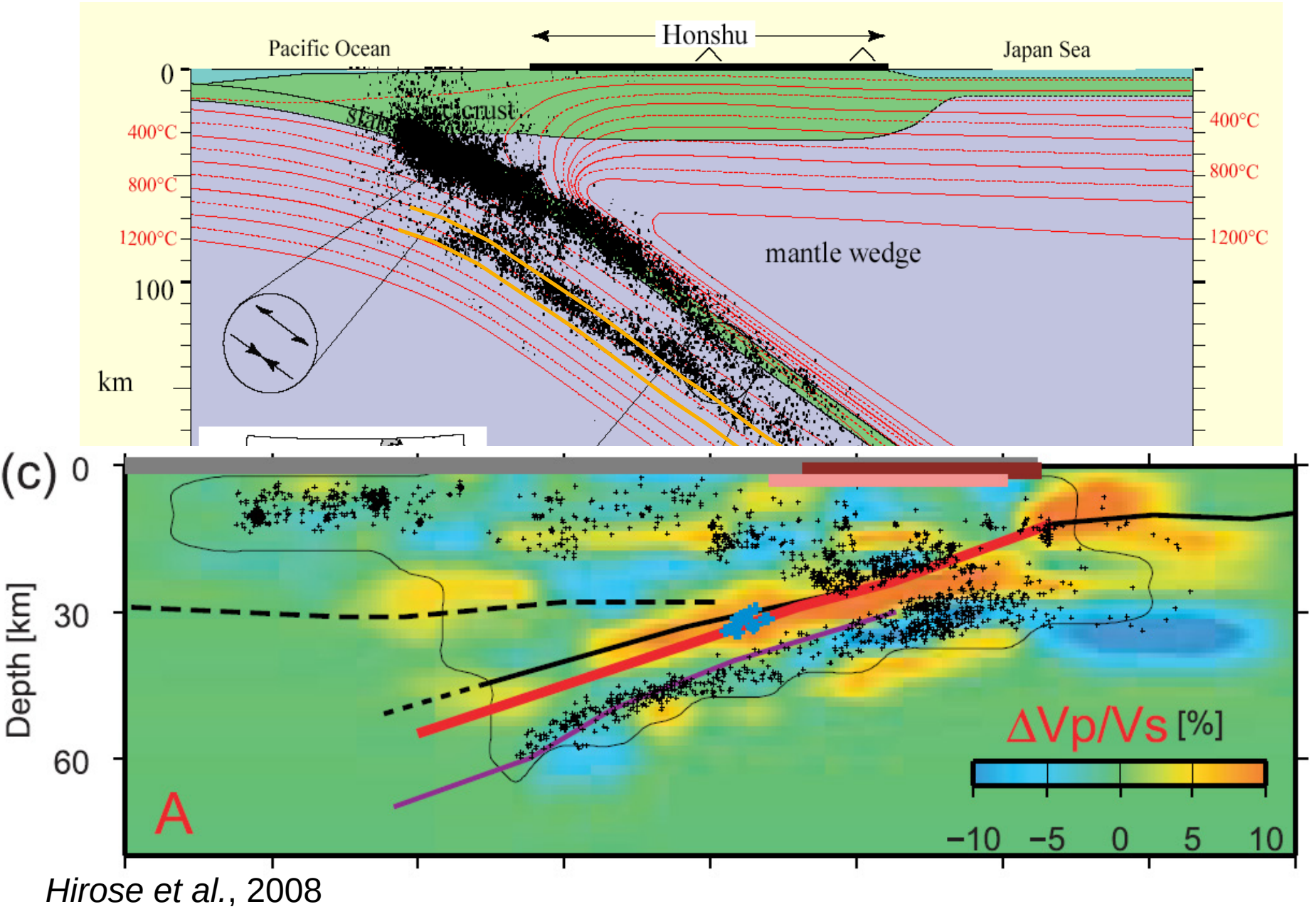
How do volatile release and transfer affect the rheology and dynamics of the plate interface



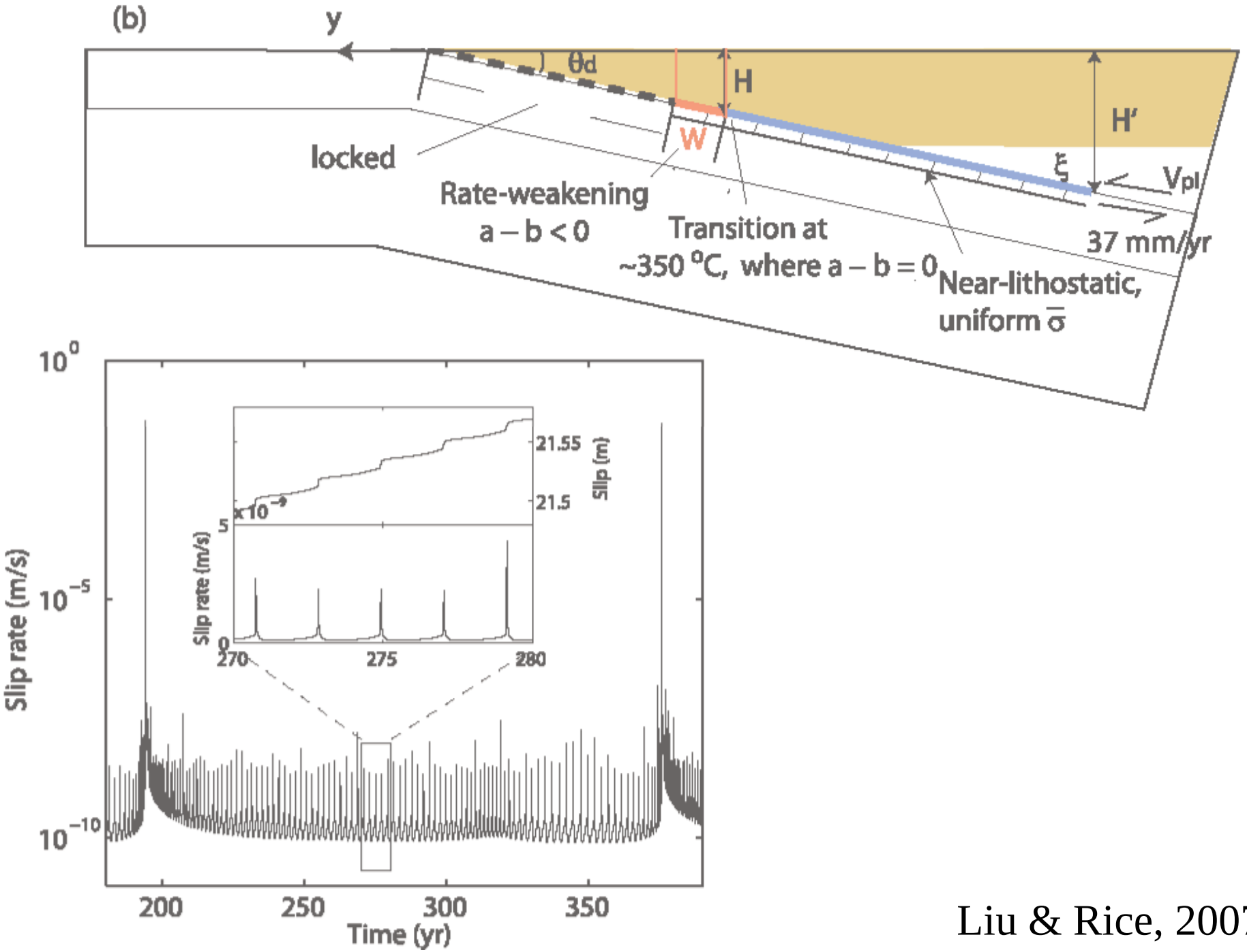
Slip behavior
Serpentinization
Dehydration



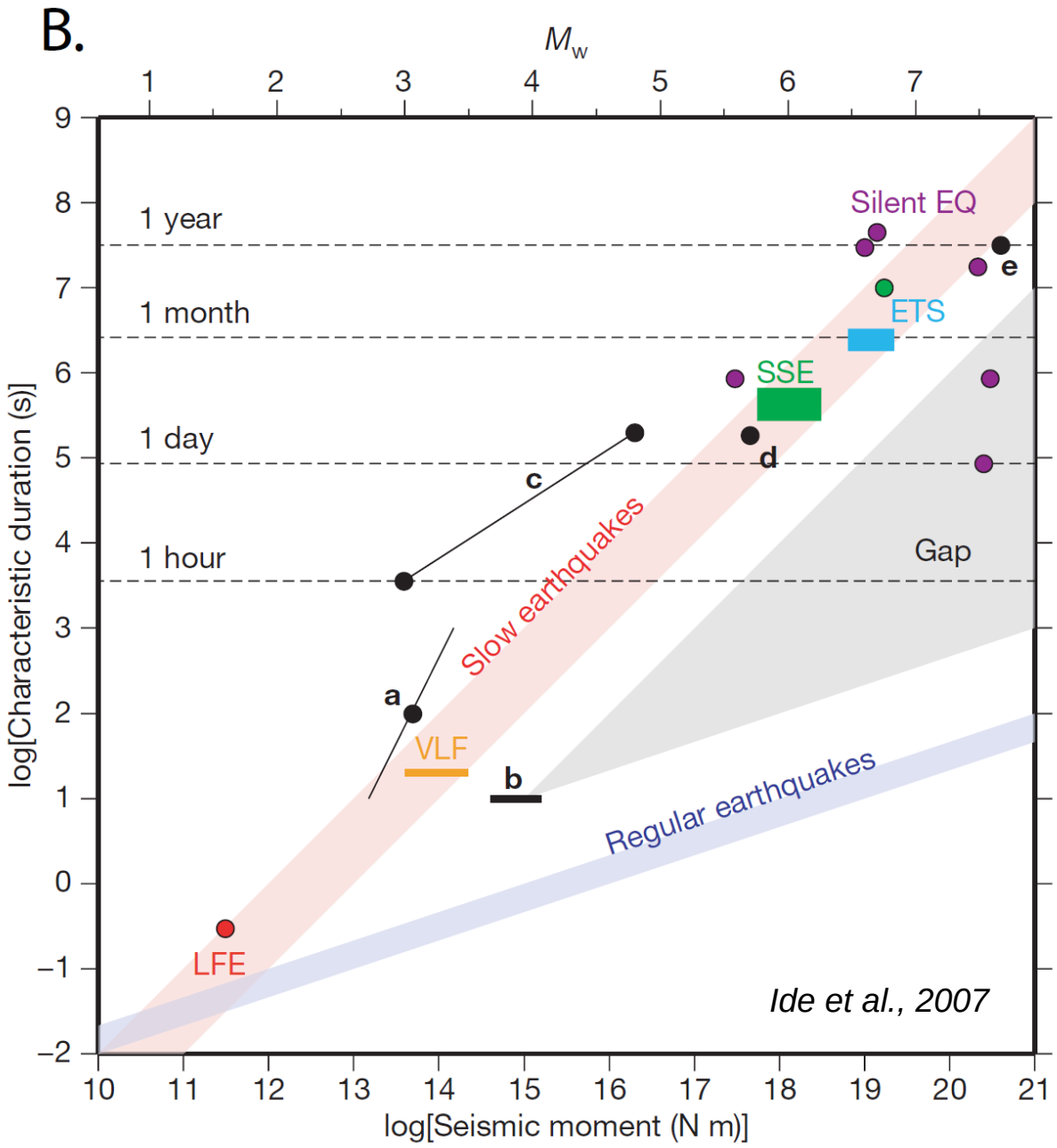


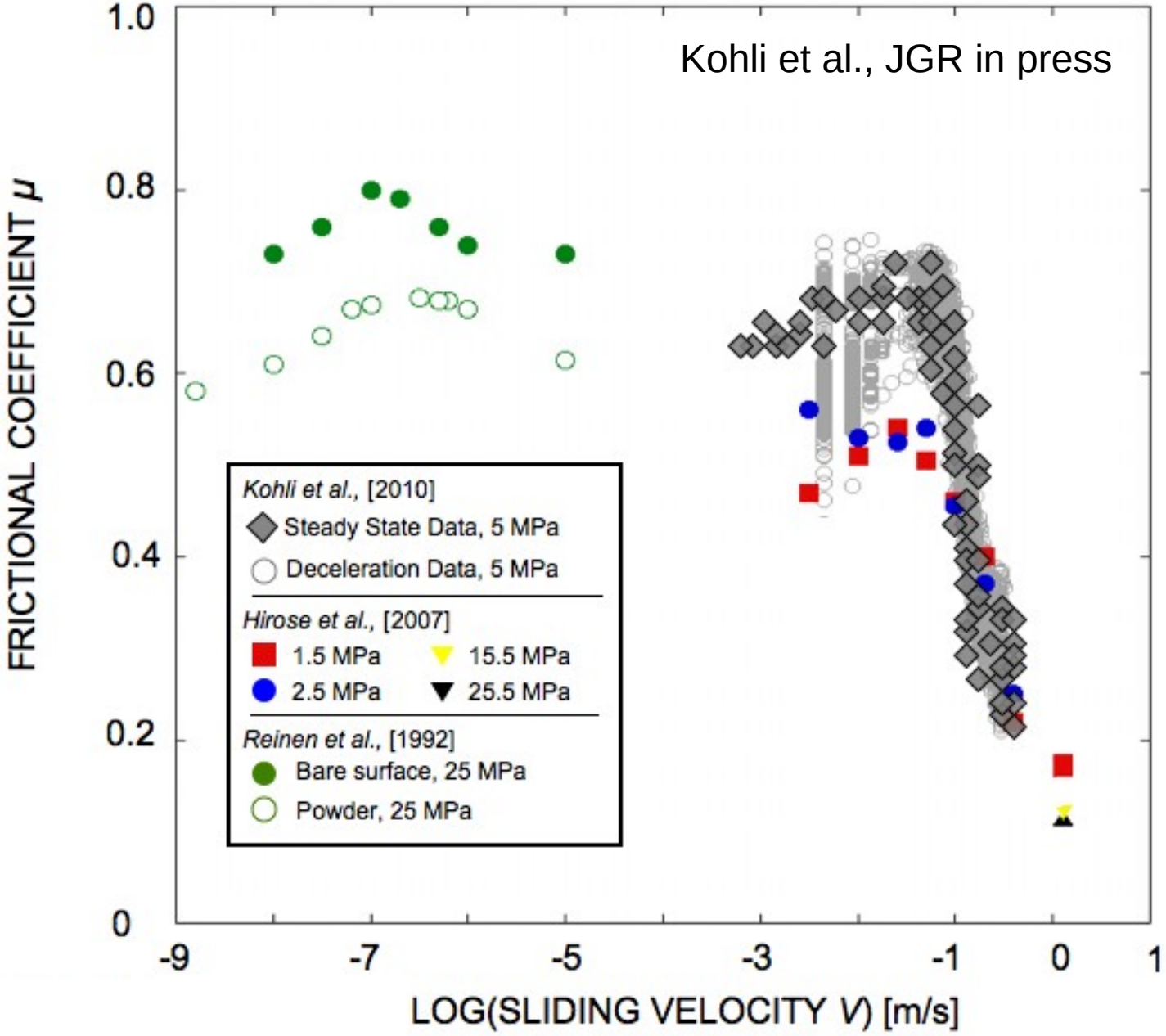


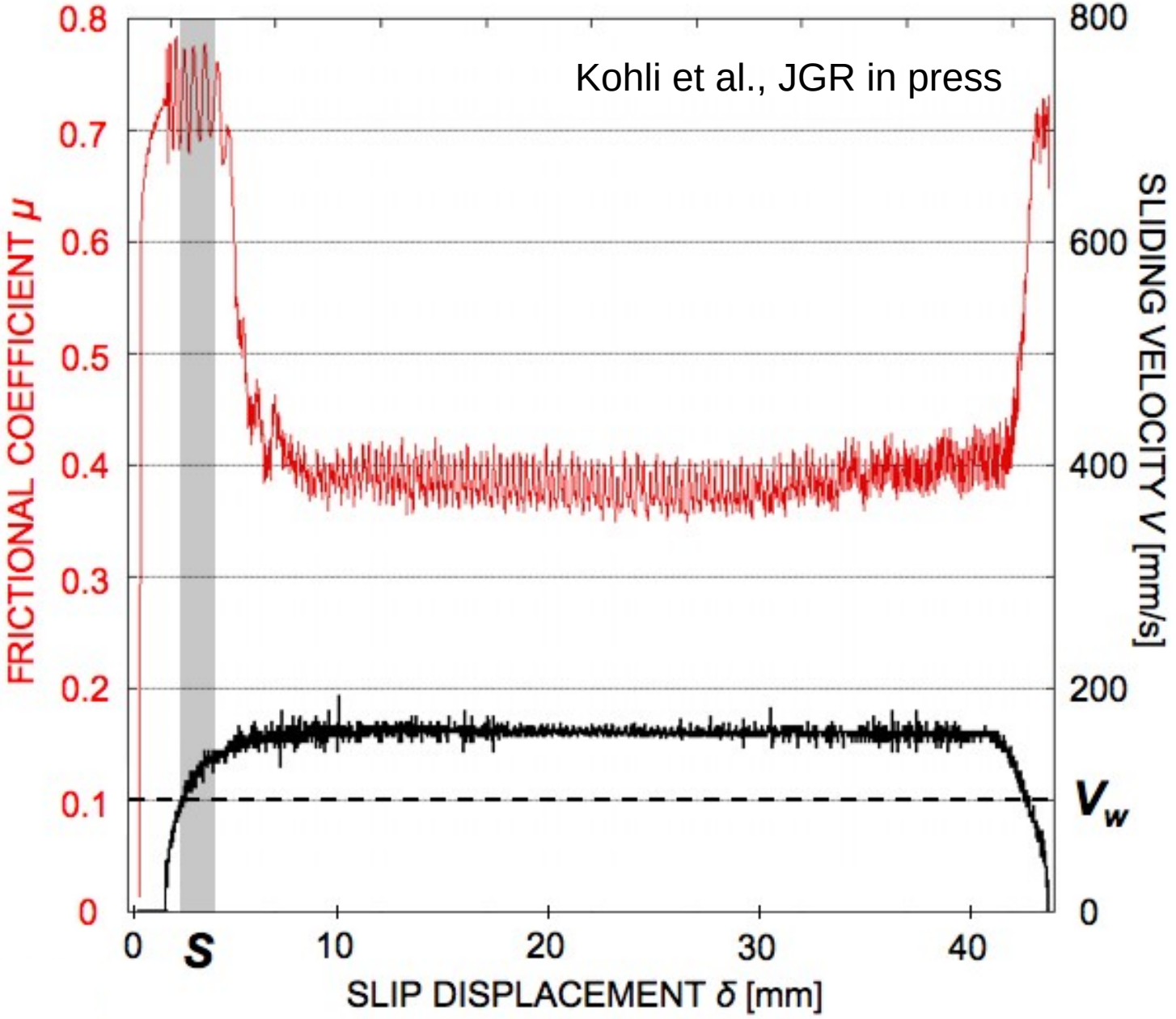
Hirose et al., 2008

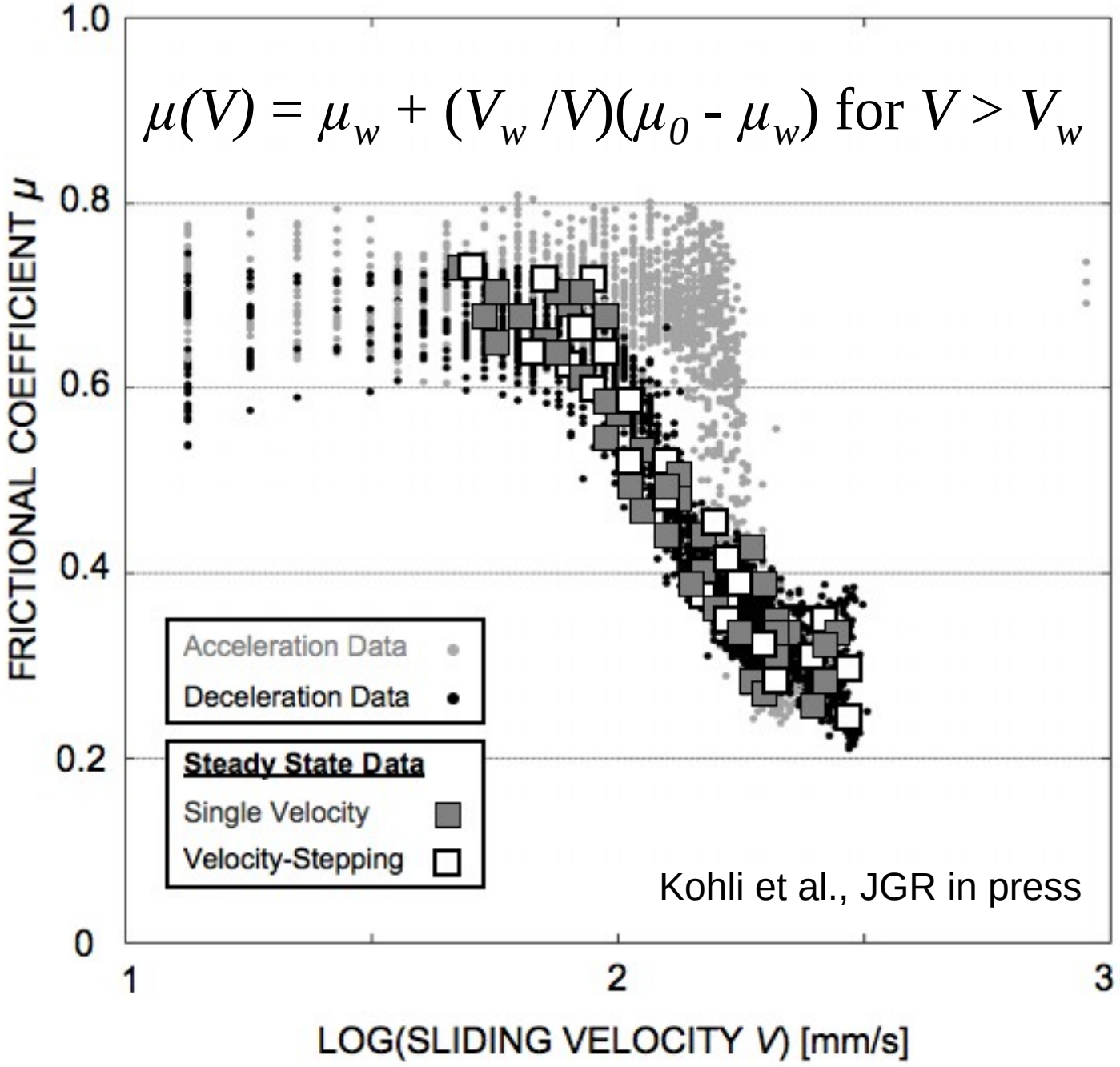


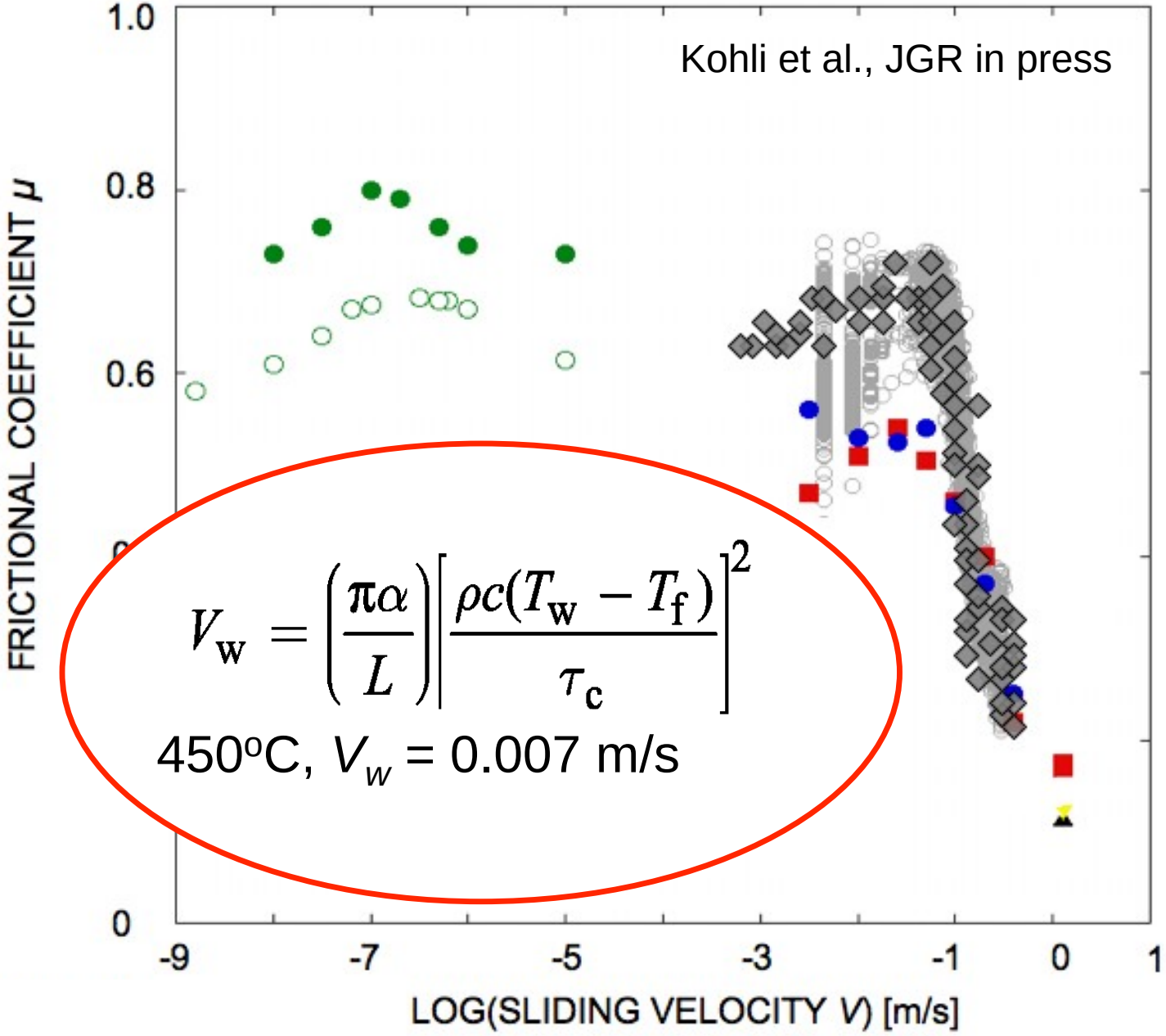
Liu & Rice, 2007

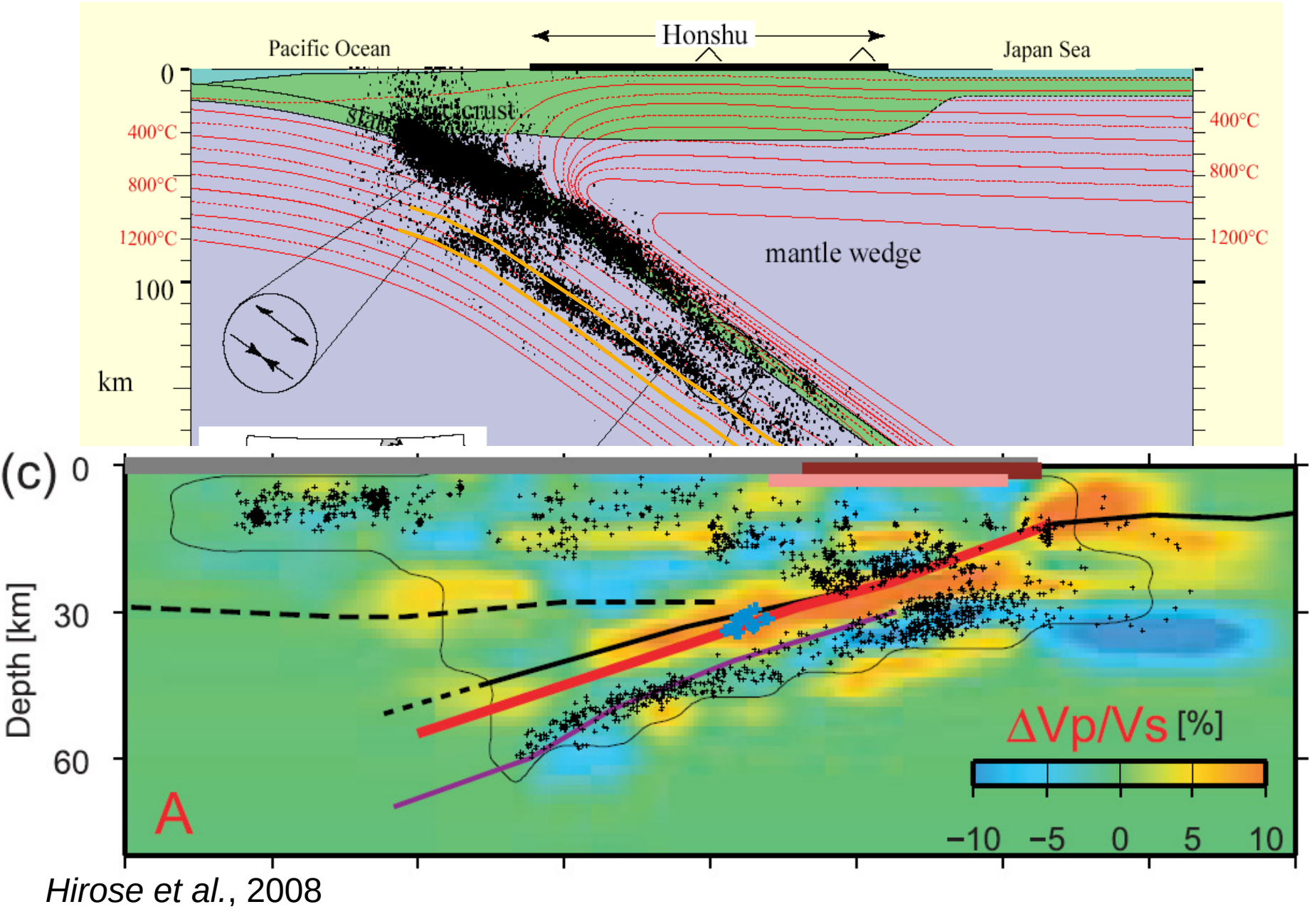

B.
M_w
1
2
3
4
5
6
7
9
8
7
6
5
4
3
2
1
0
−1
−2
1 year
1 month
1 day
1 hour
Silent EQ
ETS
SSE
Slow earthquakes
Gap
Regular earthquakes
VLF
LFE
a
b
c
d
e
Ide et al., 2007
log[Characteristic duration (s)]
10
11
12
13
14
15
16
17
18
19
20
21
log[Seismic moment (N m)]


Kohli et al., JGR in press
FRICTIONAL COEFFICIENT μ
1.0
0.8
0.6
0.4
0.2
0
-9
-7
-5
-3
-1
0
1
LOG(SLIDING VELOCITY V) [m/s]
Kohli et al., [2010]
Steady State Data, 5 MPa
Deceleration Data, 5 MPa
Hirose et al., [2007]
1.5 MPa
15.5 MPa
2.5 MPa
25.5 MPa
Reinen et al., [1992]
Bare surface, 25 MPa
Powder, 25 MPa

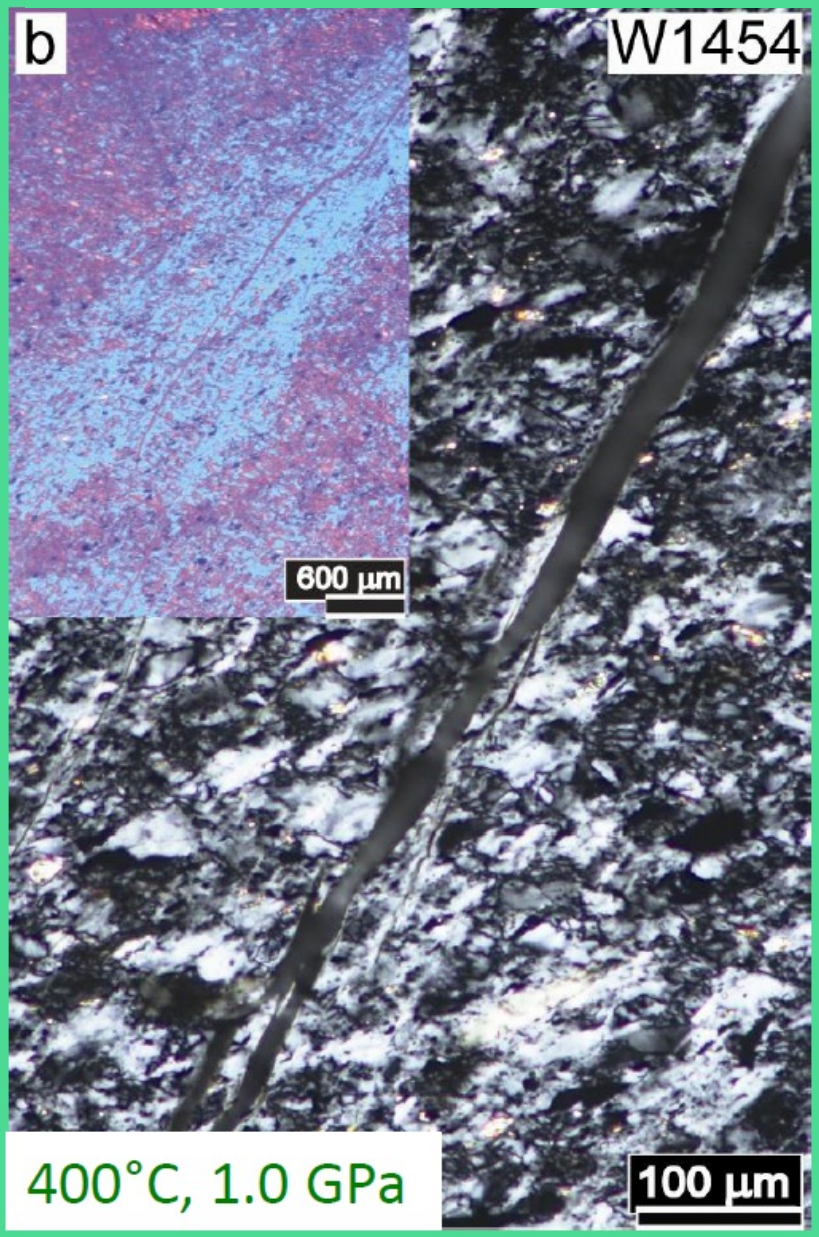

Kohli et al., JGR in press
FRICTIONAL COEFFICIENT μ
SLIDING VELOCITY V [mm/s]
SLIP DISPLACEMENT δ [mm]
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
800
600
400
200
0
V_w
0
S
10
20
30
40


$\mu(V) = \mu_w + (V_w/V)(\mu_0 - \mu_w)$ for $V > V_w$
FRICTIONAL COEFFICIENT μ
1.0
0.8
0.6
0.4
0.2
0
1
2
3
LOG(SLIDING VELOCITY V) [mm/s]
Acceleration Data
Deceleration Data
Steady State Data
Single Velocity
Velocity-Stepping
Kohli et al., JGR in press

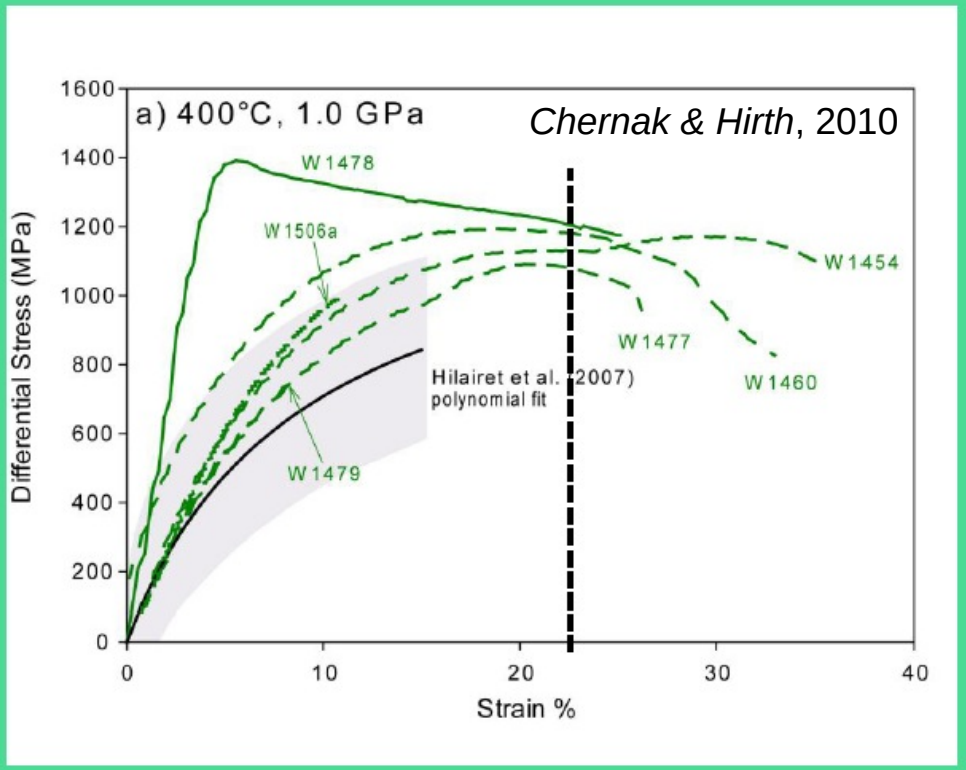

Kohli et al., JGR in press
FRICTIONAL COEFFICIENT μ
1.0
0.8
0.6
0
-9
-7
-5
-3
-1
0
1
LOG(SLIDING VELOCITY V) [m/s]
$V_w = \left(\frac{\pi\alpha}{L}\right)\left[\frac{\rho c(T_w - T_f)}{\tau_c}\right]^2$
450°C, V_w = 0.007 m/s

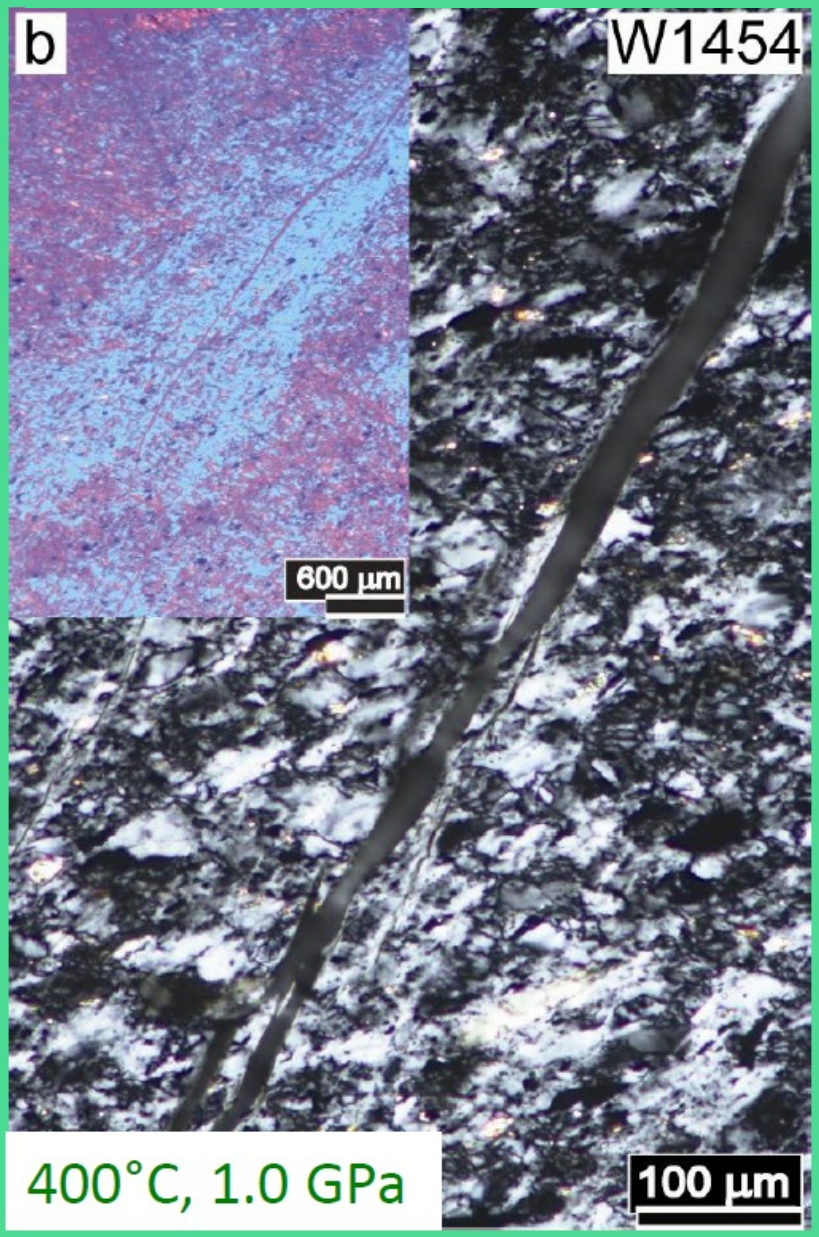


Hirose et al., 2008

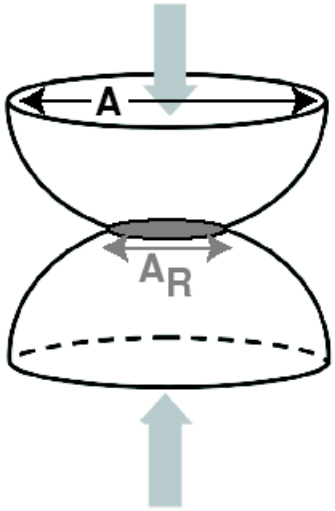


Antigorite, High T
Semi-brittle, localizes
at strain of 20-25%,
von-Mises criterion not satisfied





Antigorite
Semi-brittle, localizes
at strain of 20-25%,
von-Mises criterion not satisfied



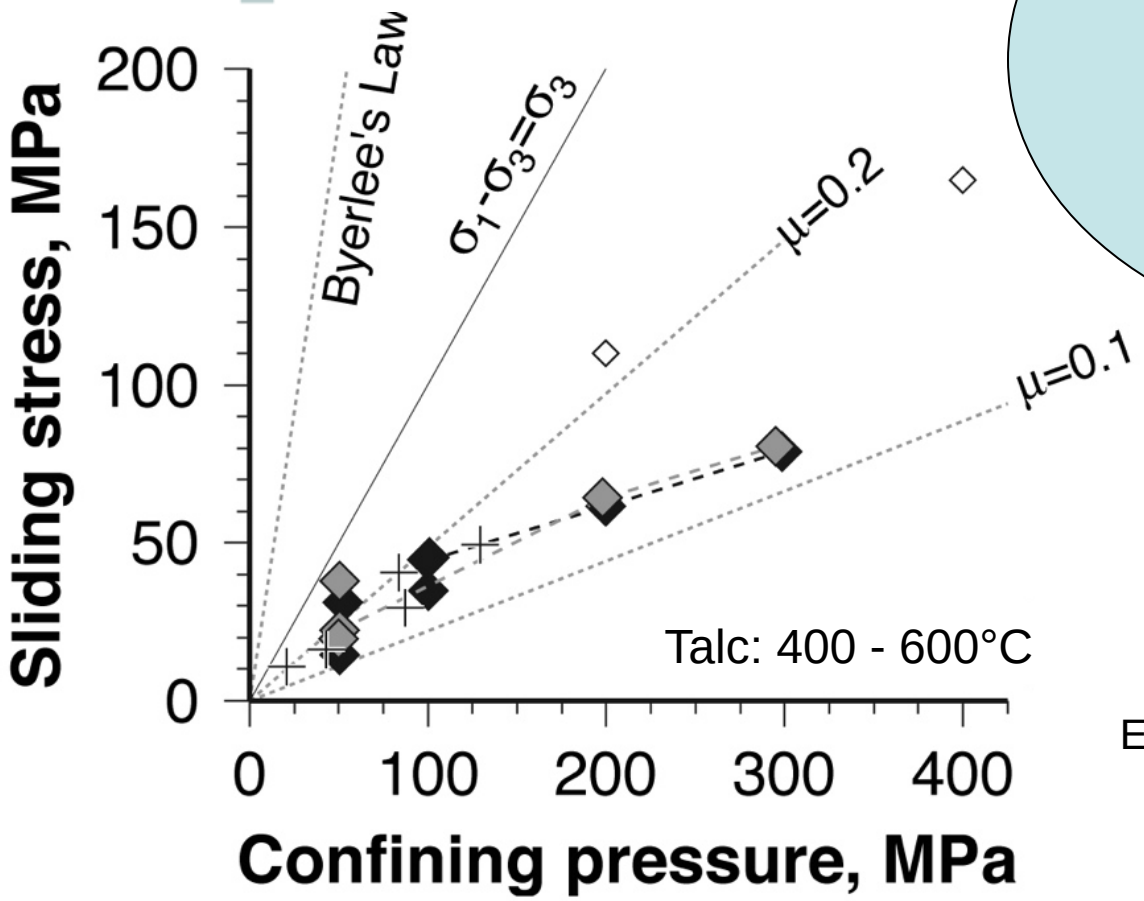
Adhesion Theory

$\mu \sim S/P$

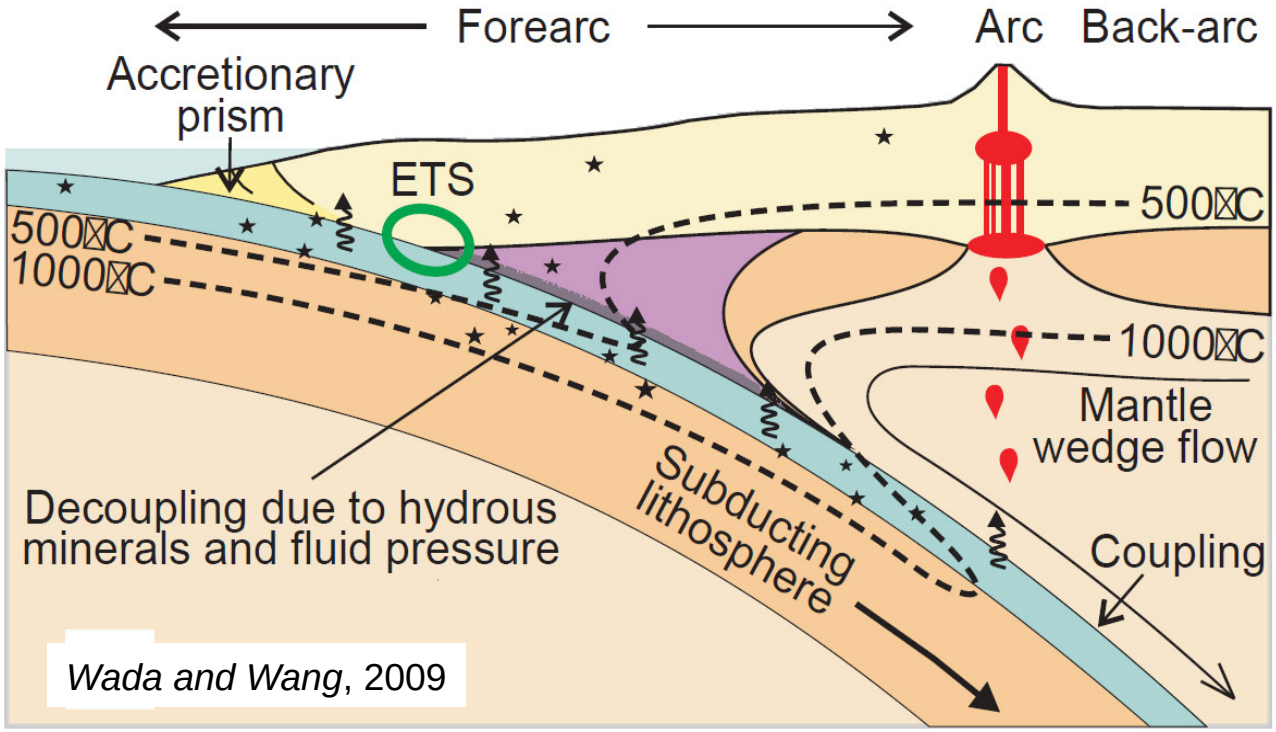
P = Penetration Hardness
S = Contact Shear Strength

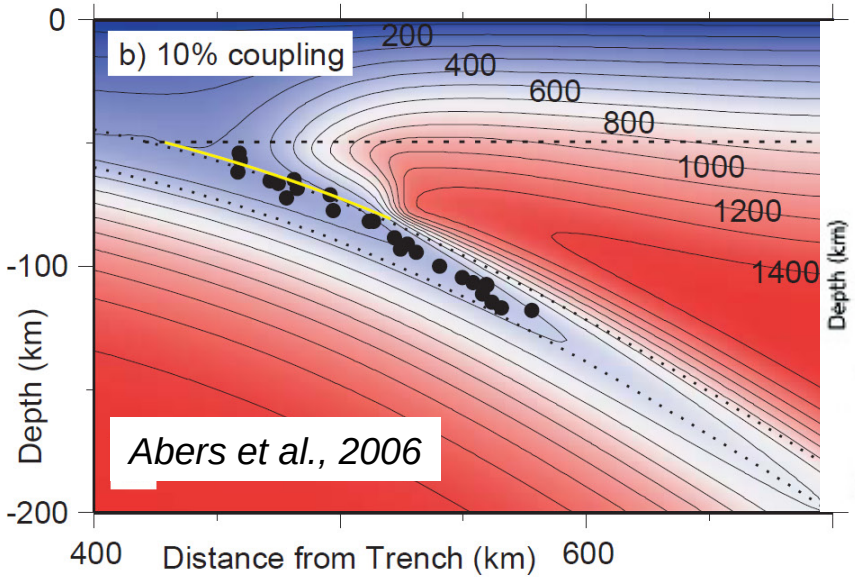
Most Rocks (i.e., Byerlee)
$S \approx P$

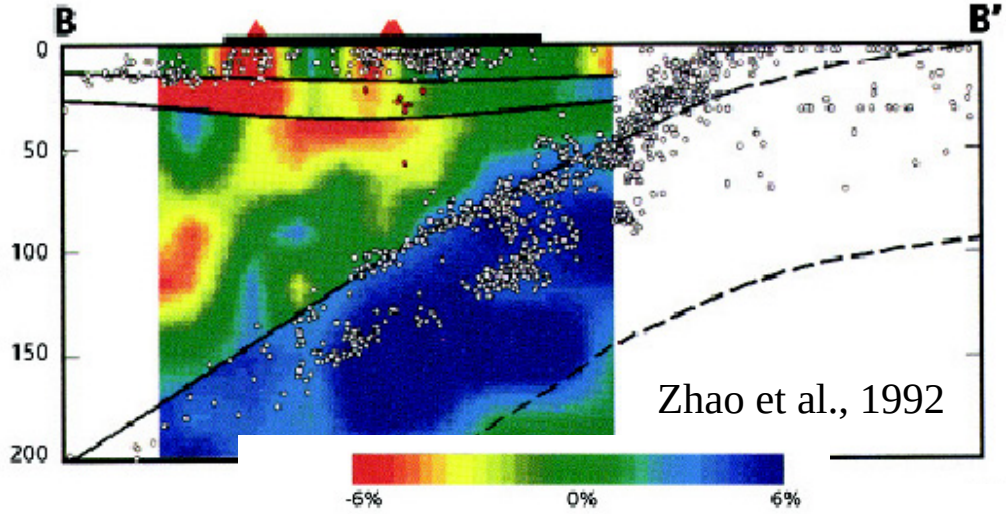
With large anisotropy
$S << P$

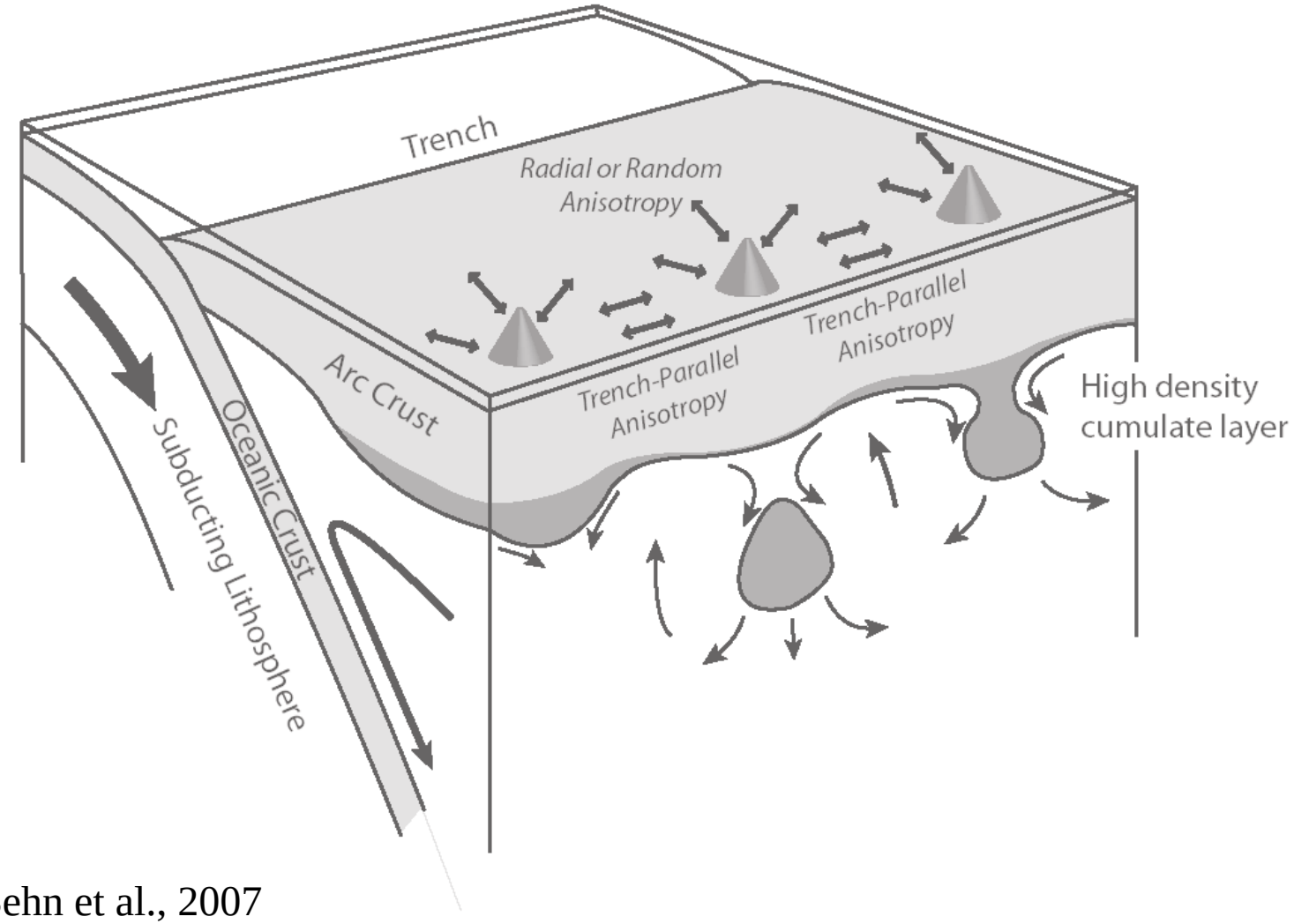


Escartin et al., 2008

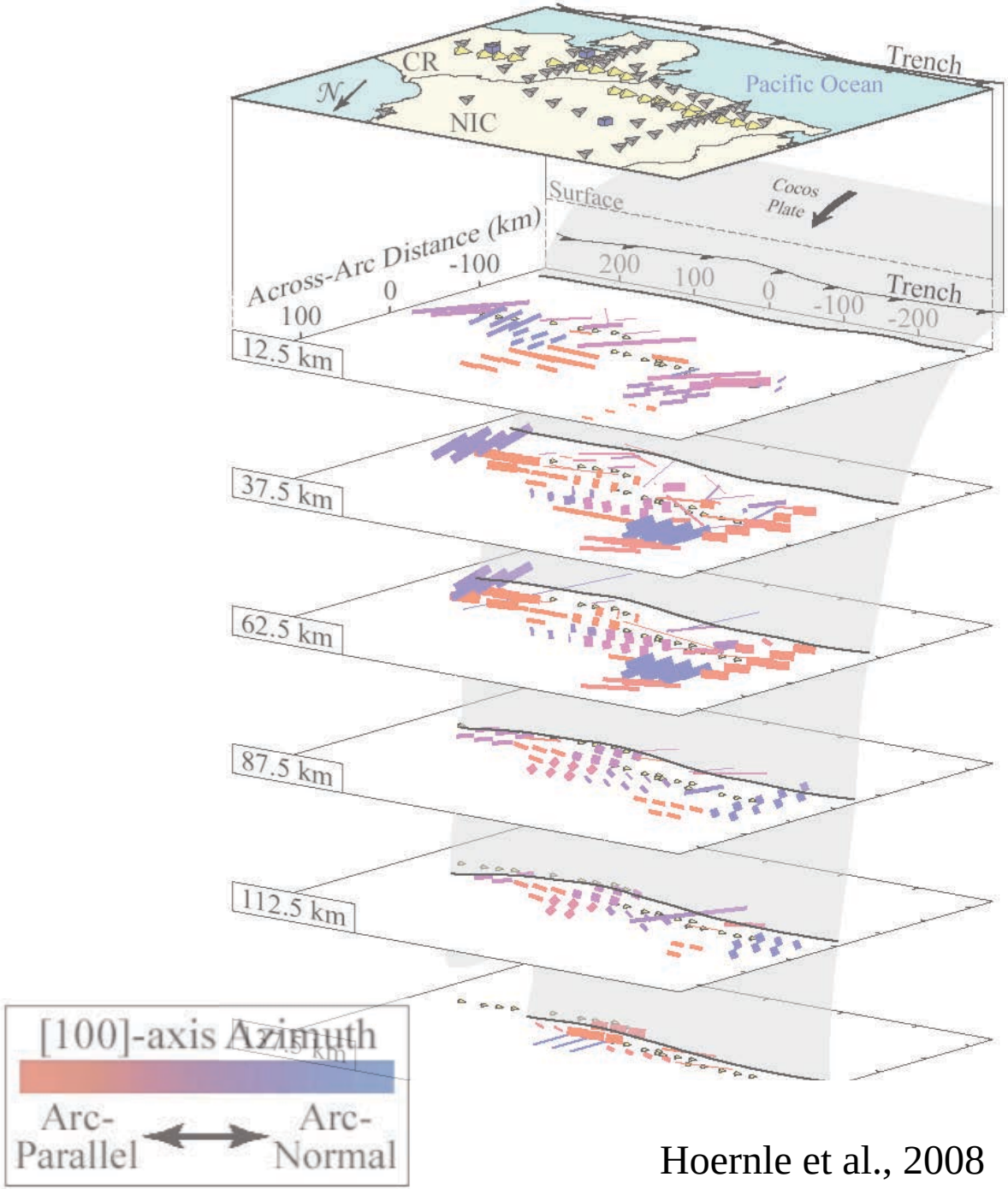

Forearc
Arc
Back-arc
Accretionary prism
ETS
500°C
1000°C
500°C
1000°C
Mantle wedge flow
Decoupling due to hydrous minerals and fluid pressure
Subducting lithosphere
Coupling
Wada and Wang, 2009


b) 10% coupling
200
400
600
800
1000
1200
1400
0
-100
-200
Depth (km)
400
Distance from Trench (km)
600
Abers et al., 2006


B
B'
0
50
100
150
200
Depth (km)
-6%
0%
6%
Zhao et al., 1992



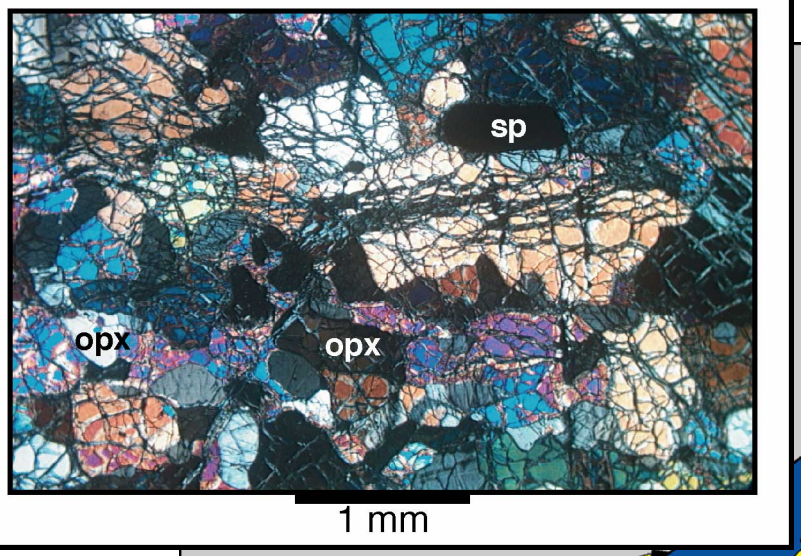
Behn et al., 2007

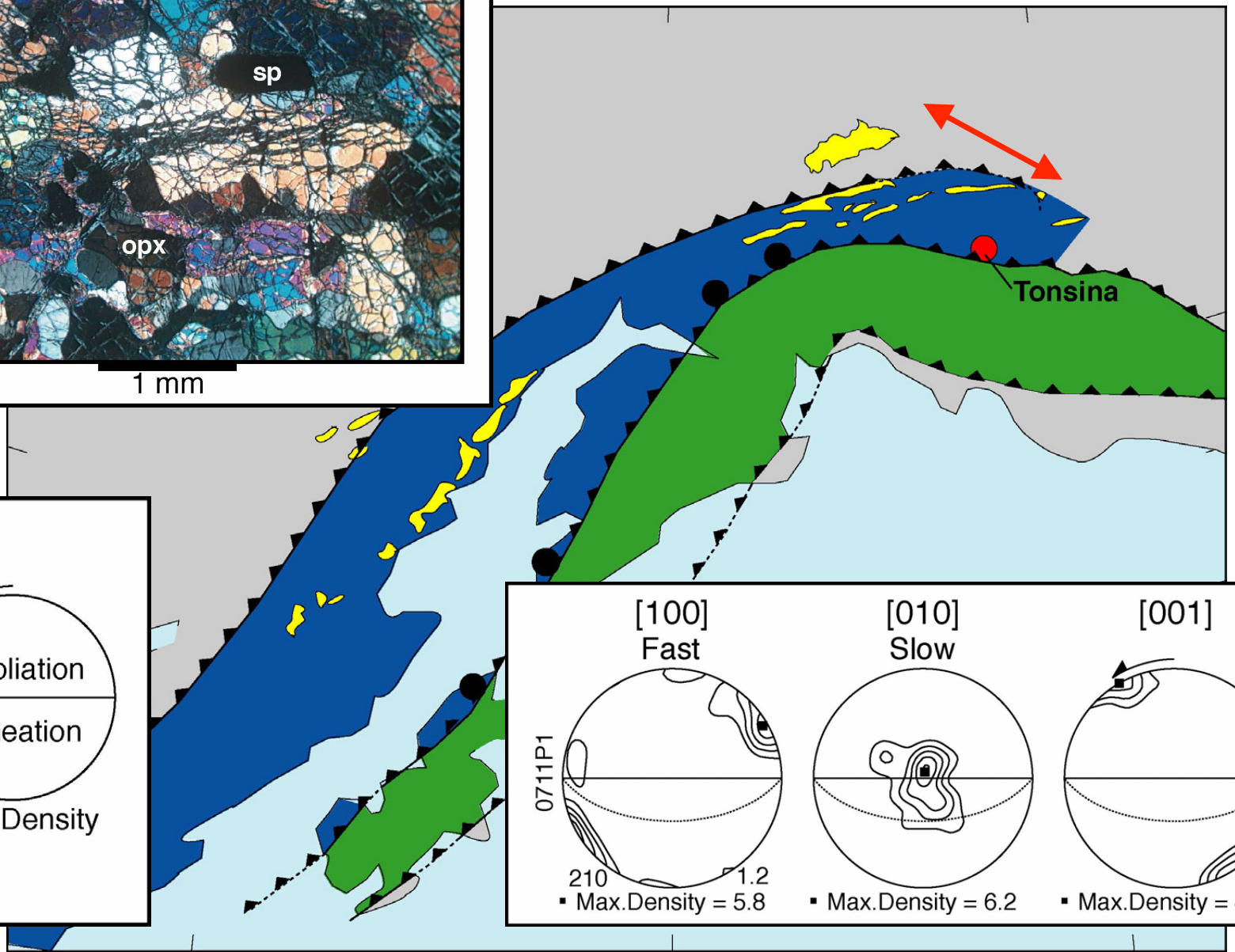


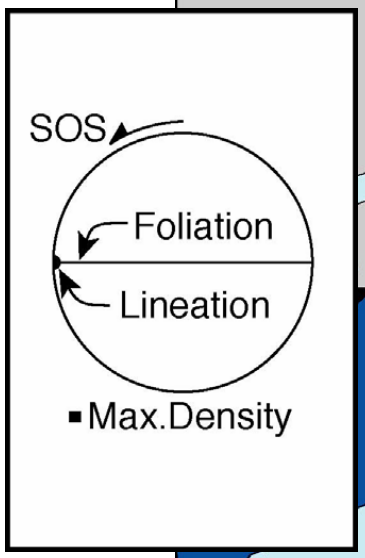
Hoernle et al., 2008

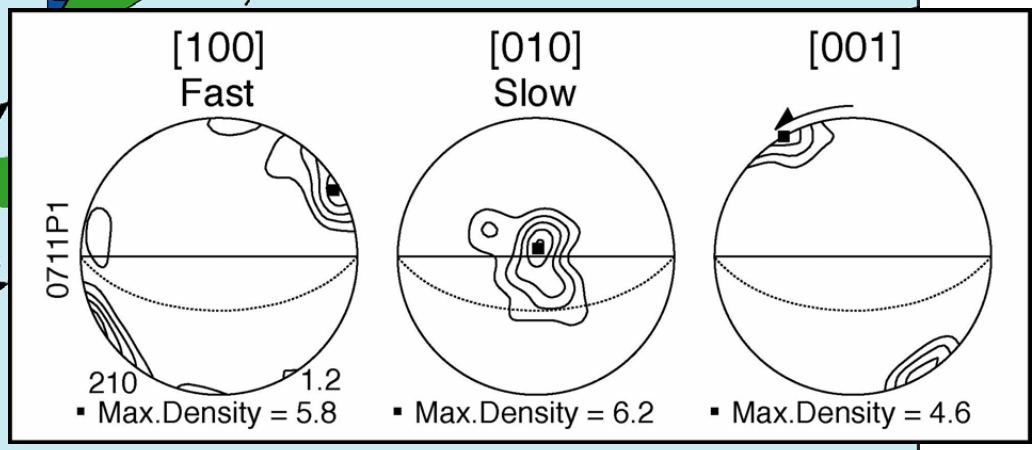
The Talkeetna Arc: Peridotite Microstructure

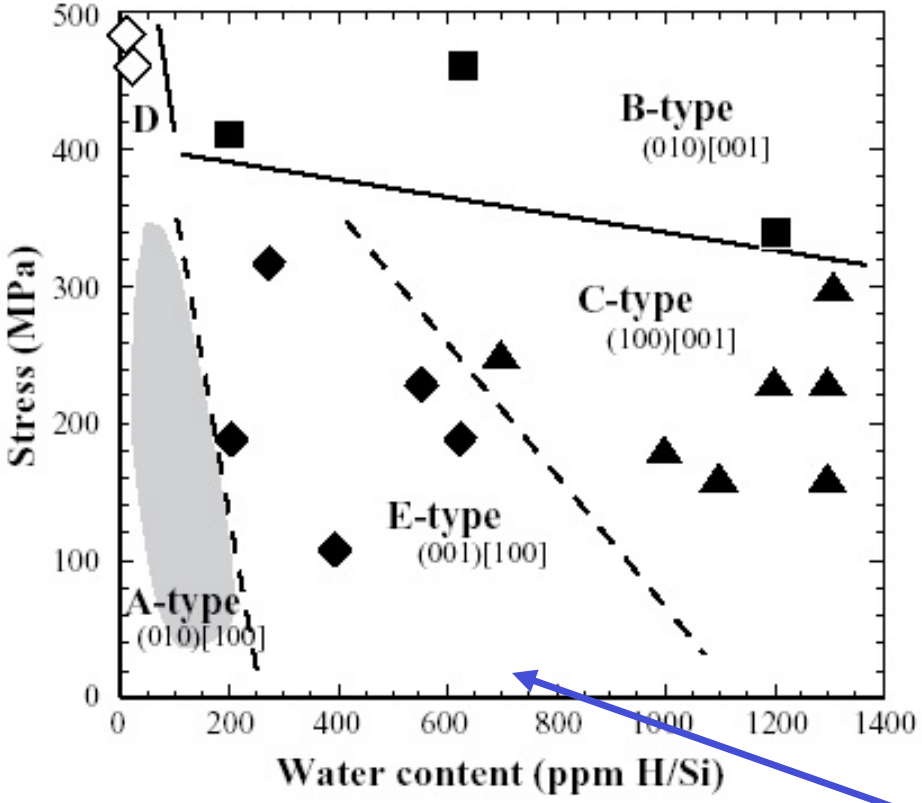
Mehl, Hacker, Hirth & Kelemen, 2003



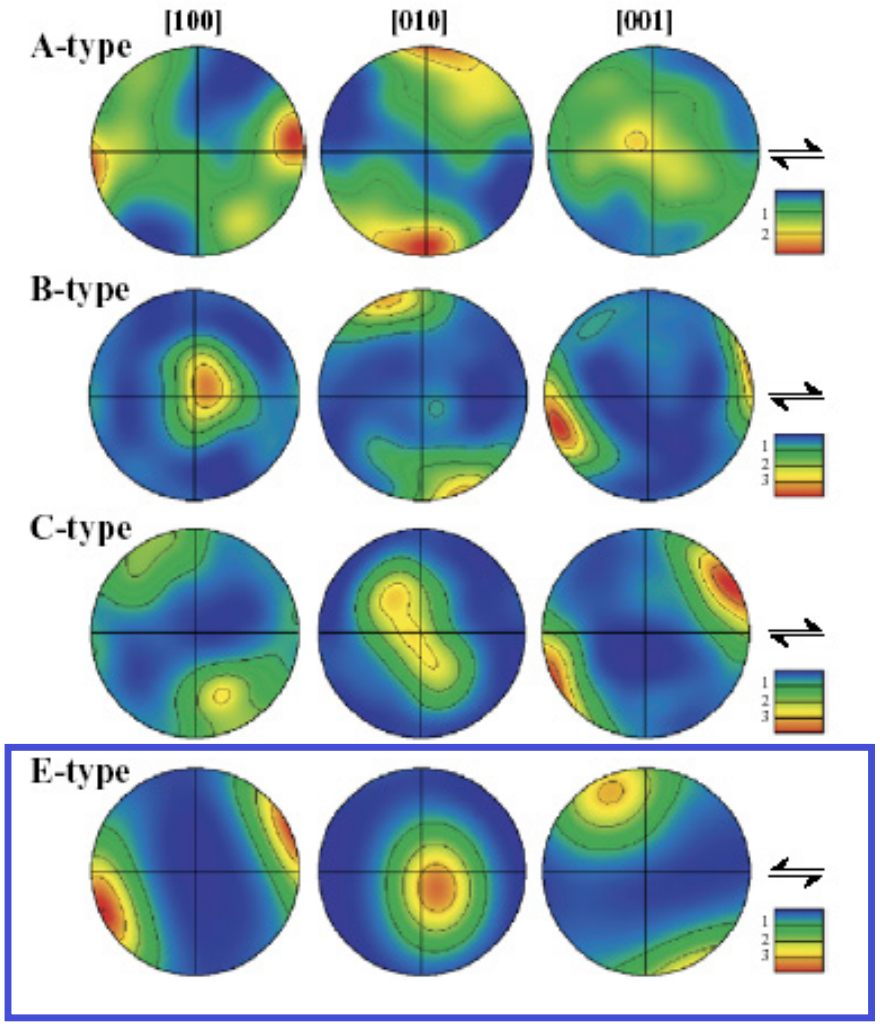








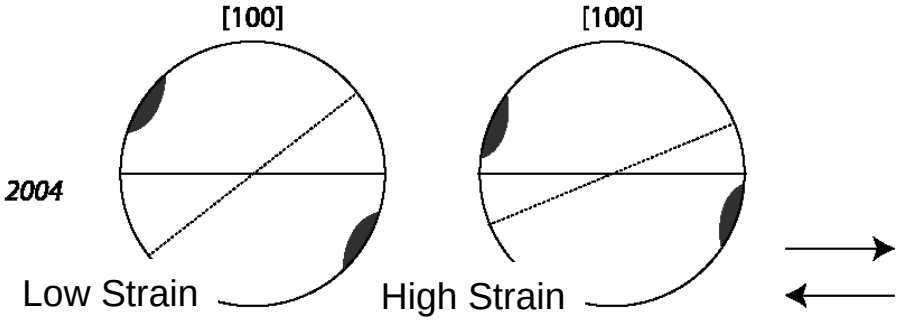
50 wt. ppm

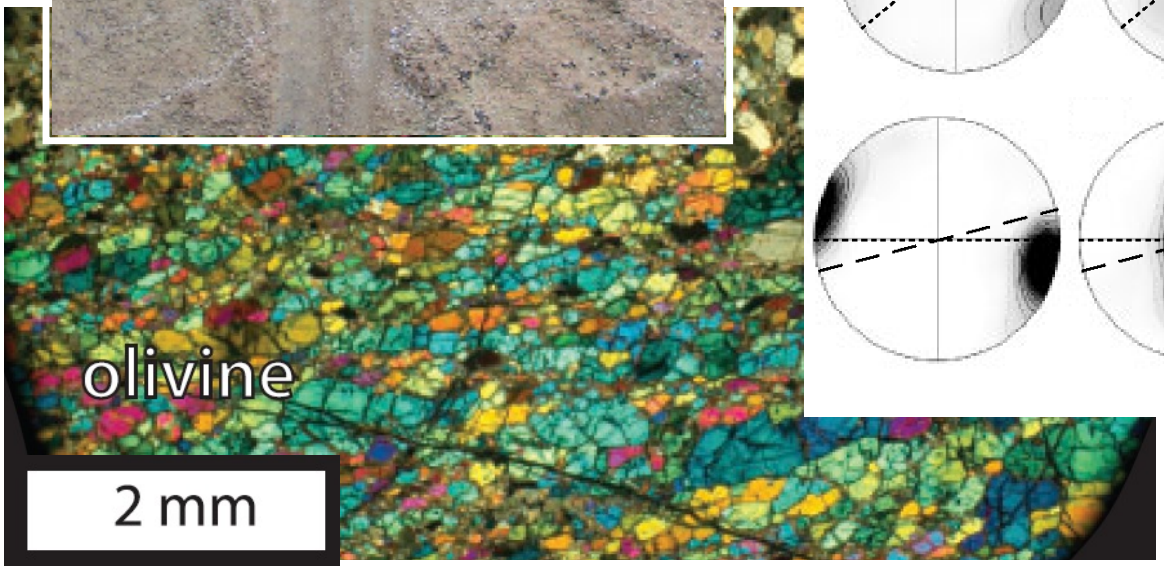


Katayama et al., 2004

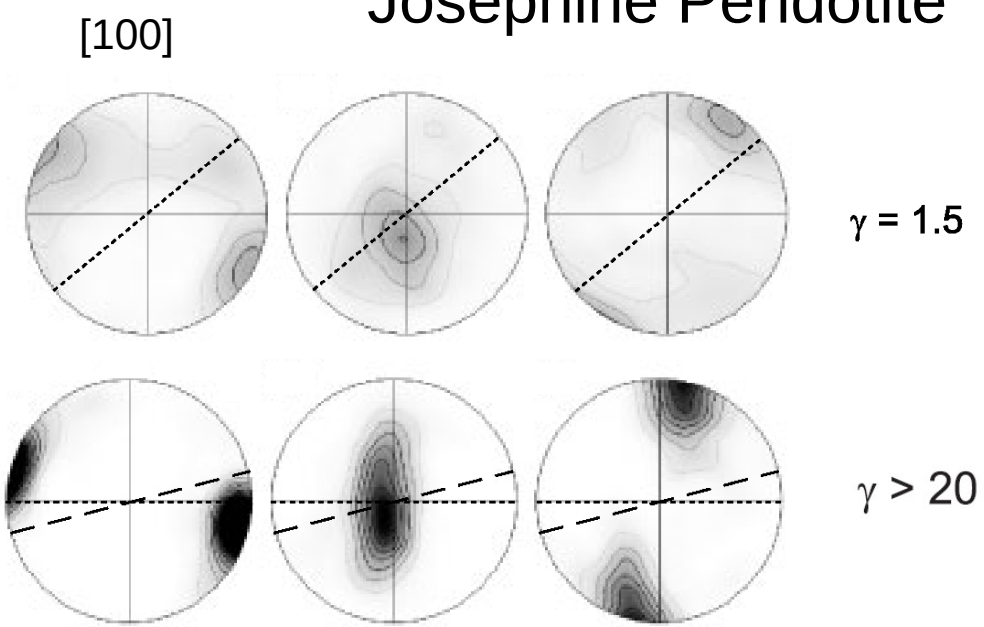
Lab

E-type
Katayama et al., 2004

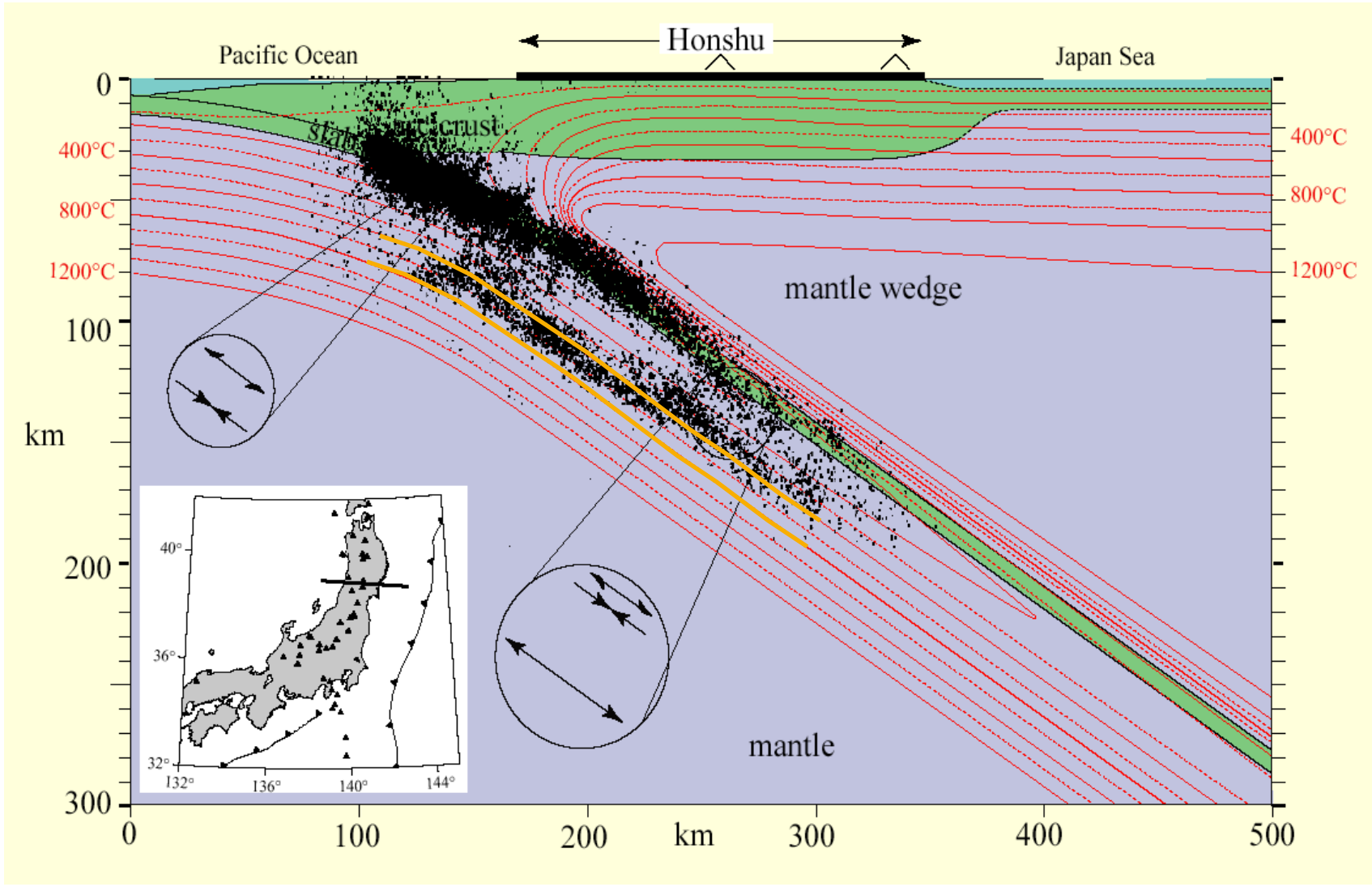


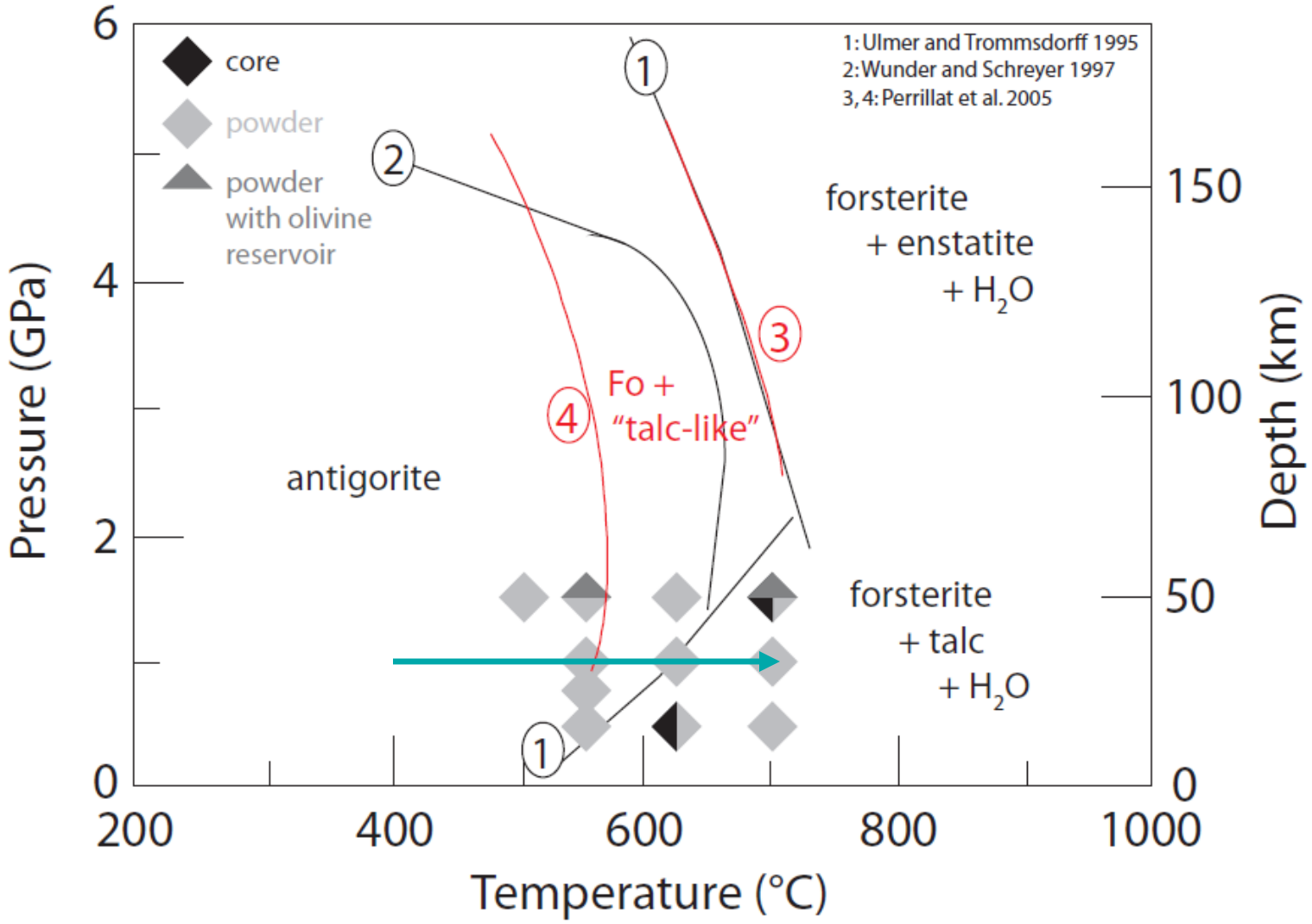


Josephine Peridotite

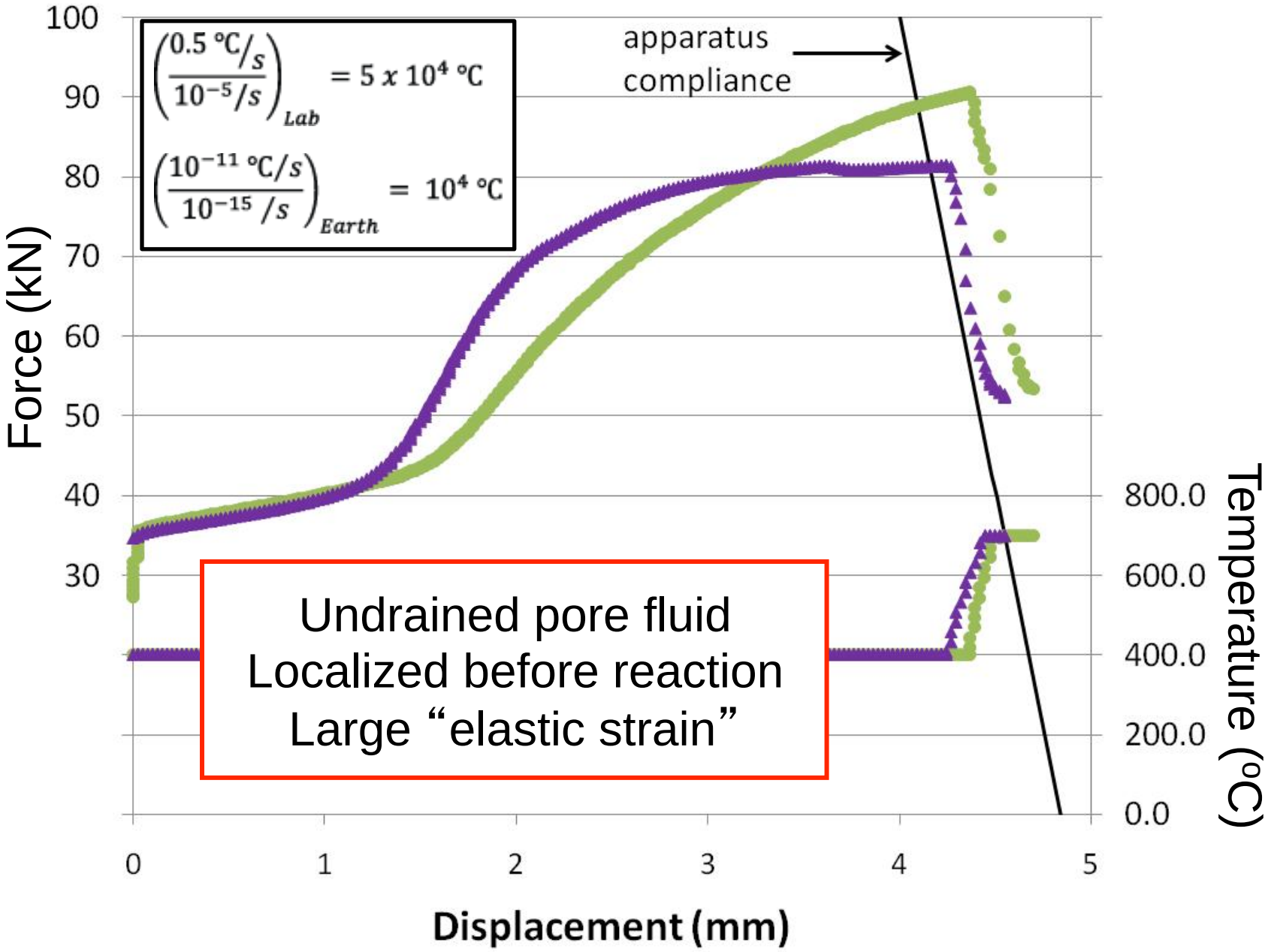


Skemer et al. JPET 2010

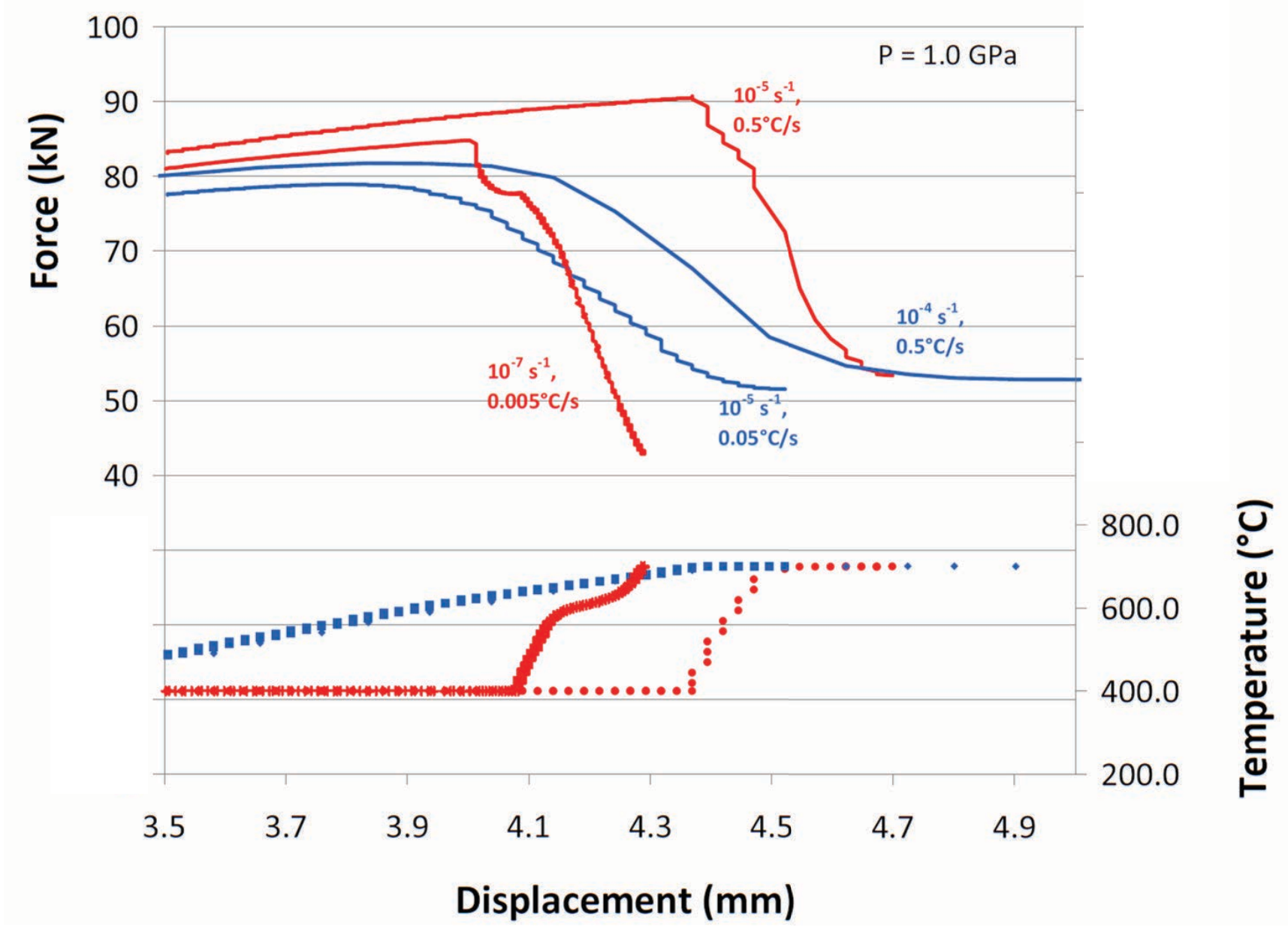

Honshu
Pacific Ocean
Japan Sea
0
400°C
800°C
1200°C
100
km
200
300
slab
crust
mantle wedge
mantle
400°C
800°C
1200°C
0
100
200
km
300
400
500
40°
36°
32°
132°
136°
140°
144°

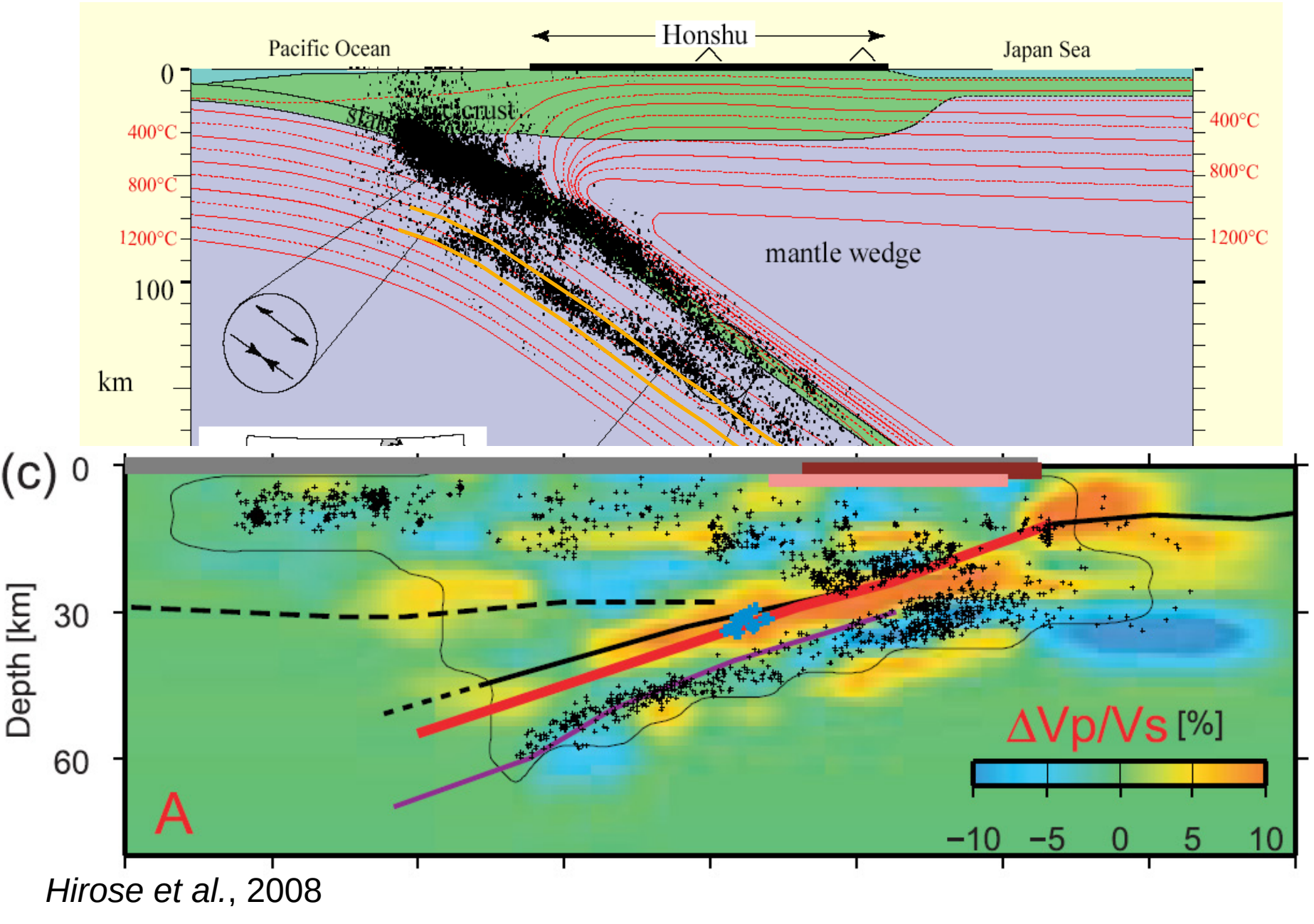


Chernak & Hirth, submitted

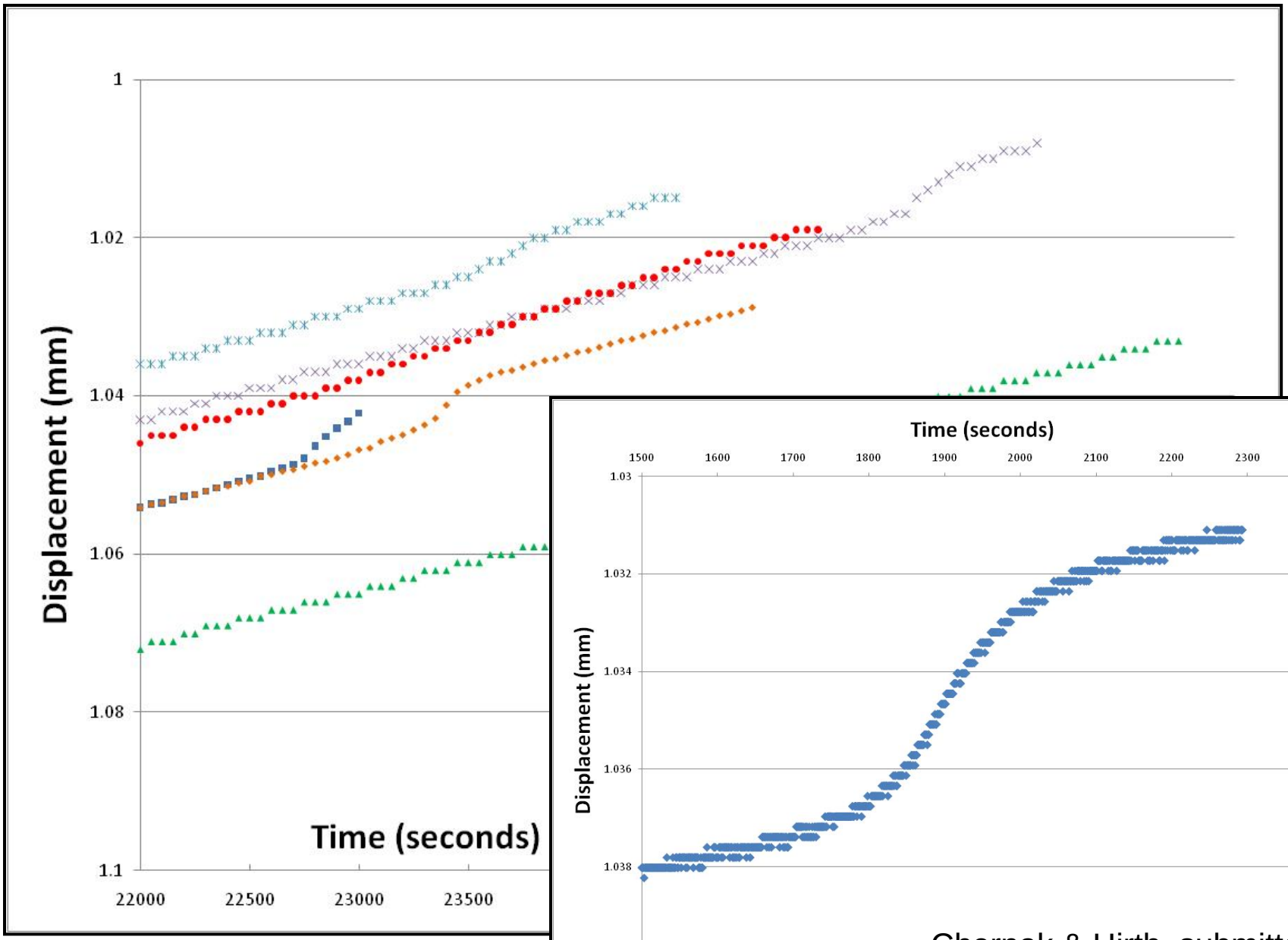


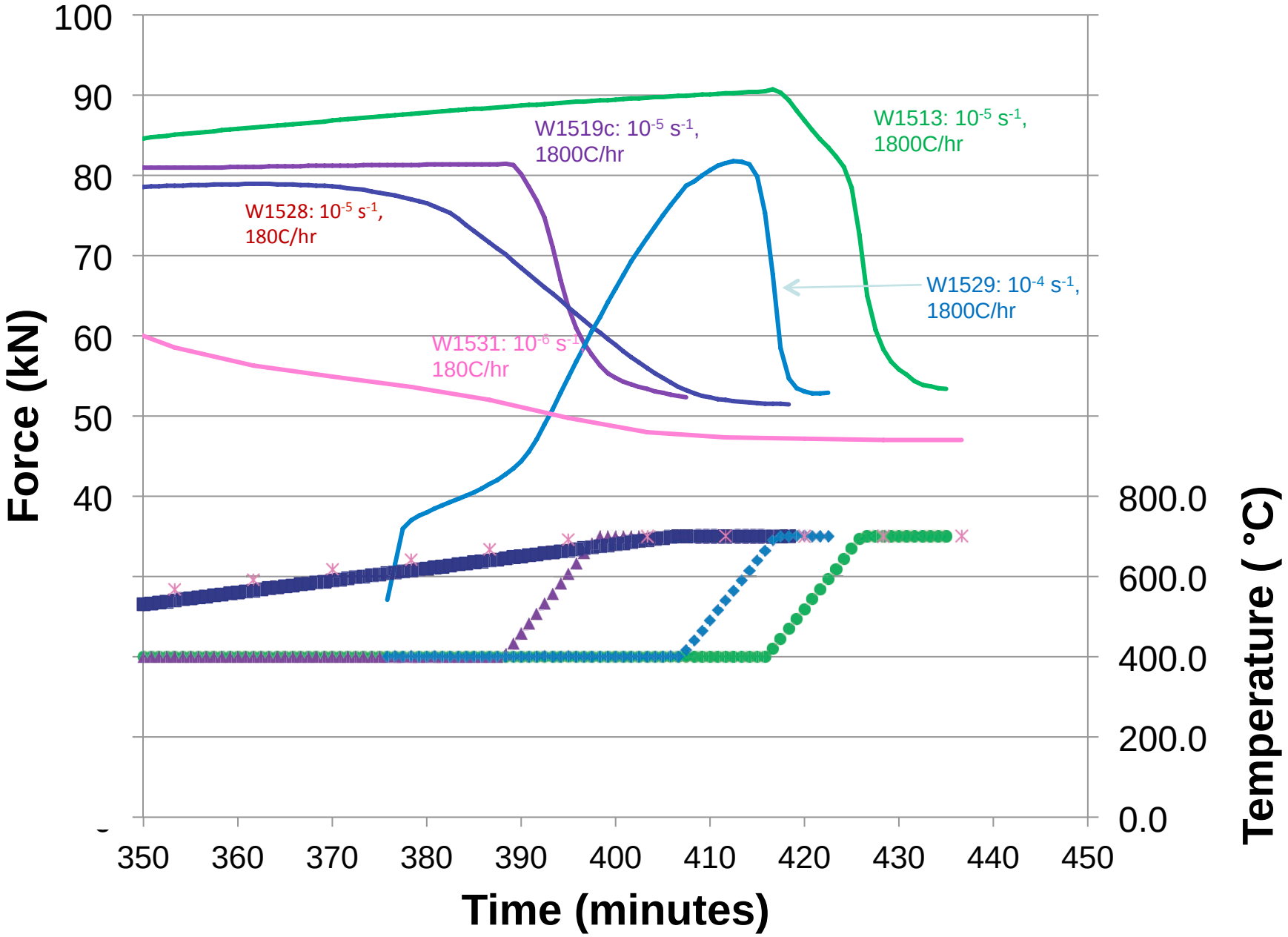
Chernak & Hirth, submitted


P = 1.0 GPa
10^{-5} s^{-1}, 0.5°C/s
10^{-4} s^{-1}, 0.5°C/s
10^{-7} s^{-1}, 0.005°C/s
10^{-5} s^{-1}, 0.05°C/s
Force (kN)
100
90
80
70
60
50
40
800.0
600.0
400.0
200.0
Temperature (°C)
3.5
3.7
3.9
4.1
4.3
4.5
4.7
4.9
Displacement (mm)

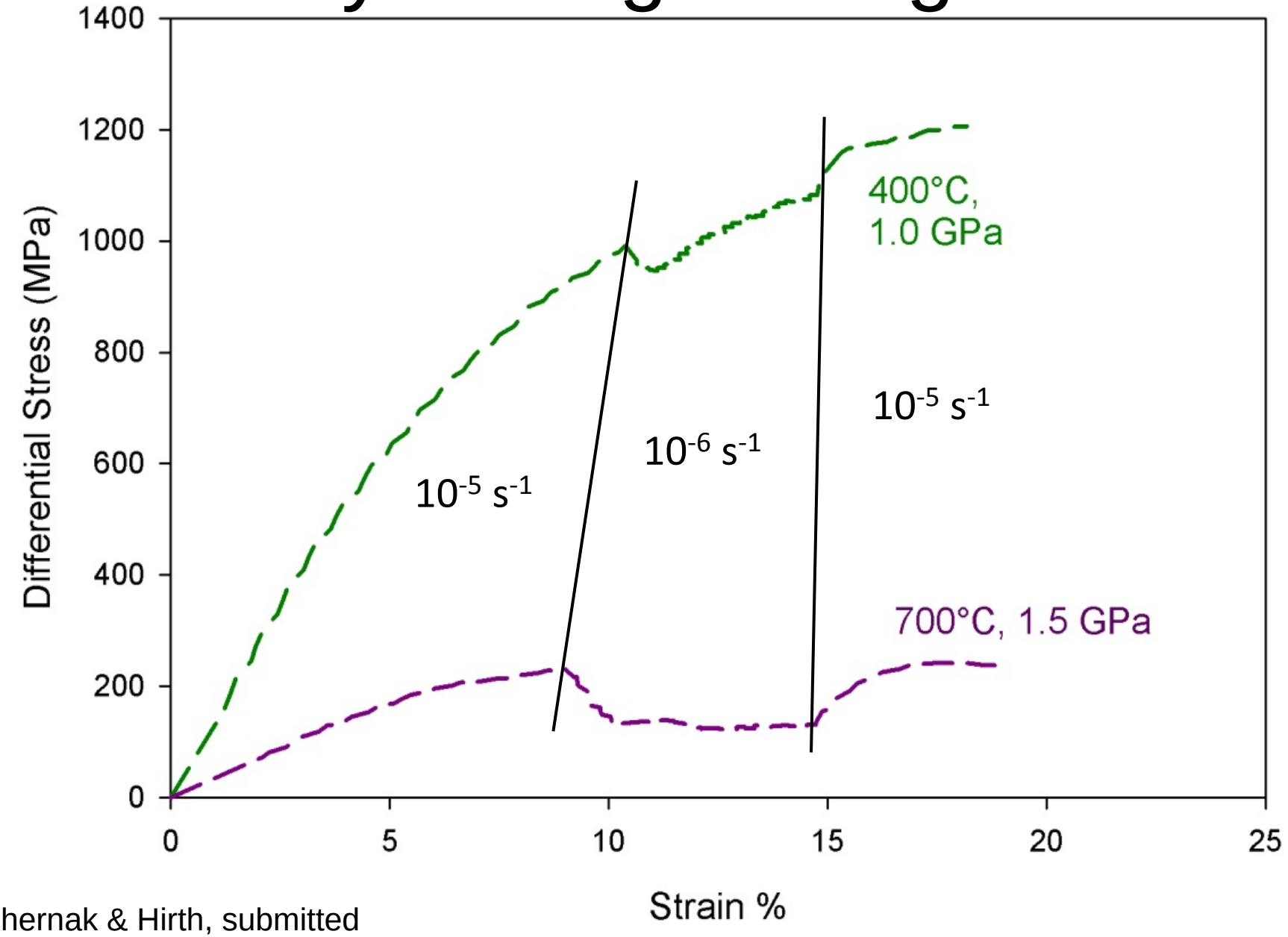


Hirose et al., 2008

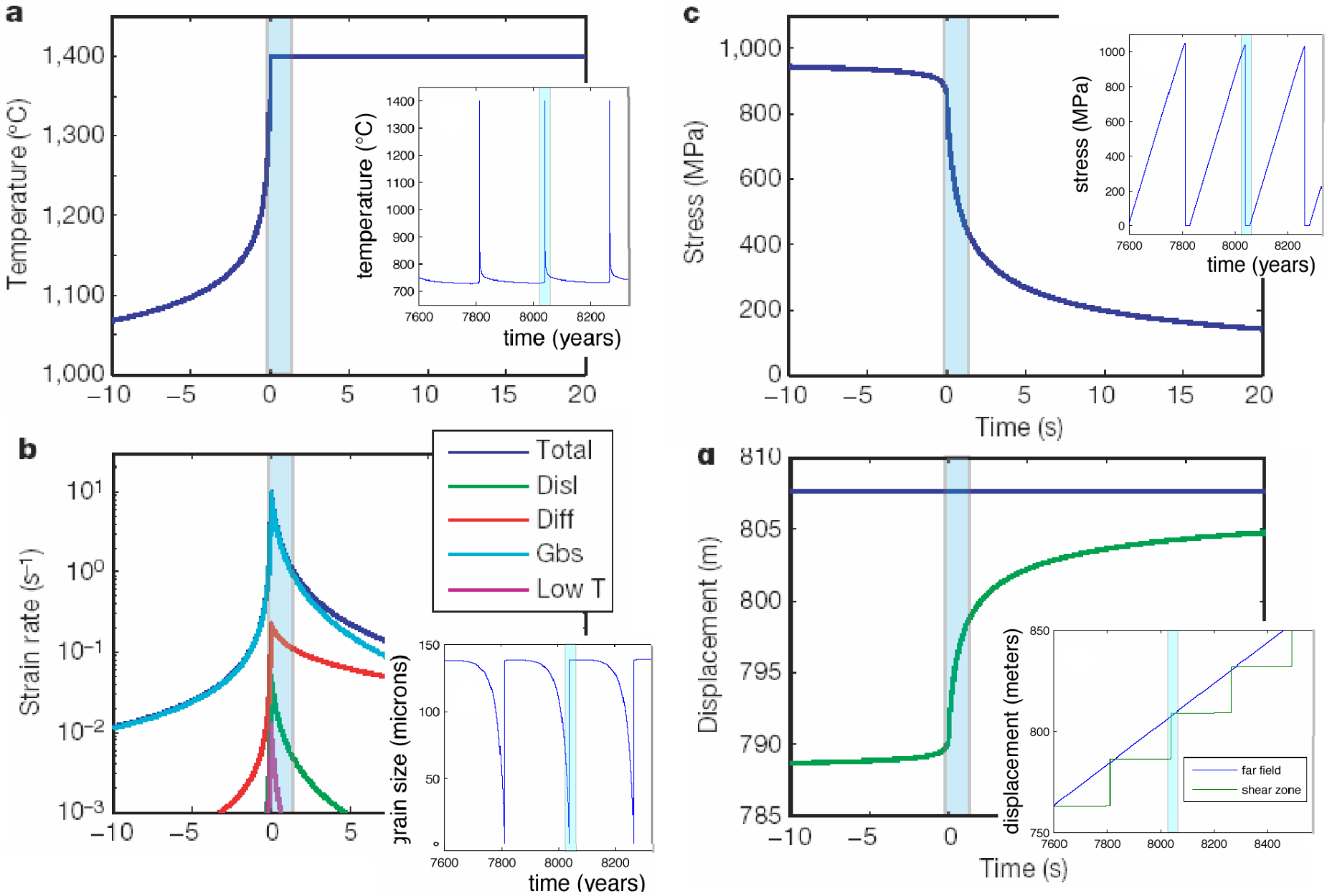

Displacement (mm)
1
1.02
1.04
1.06
1.08
1.1
22000
22500
23000
23500
Time (seconds)
Time (seconds)
1500
1600
1700
1800
1900
2000
2100
2200
2300
2400
Displacement (mm)
1.03
1.032
1.034
1.036
1.038
1.04
Chernak & Hirth, submitted


Force (kN)
100
90
80
70
60
50
40
W1513: 10-5 s-1, 1800C/hr
W1519c: 10-5 s-1, 1800C/hr
W1528: 10-5 s-1, 180C/hr
W1529: 10-4 s-1, 1800C/hr
W1531: 10-6 s-1, 180C/hr
800.0
600.0
400.0
200.0
0.0
Temperature (°C)
350
360
370
380
390
400
410
420
430
440
450
Time (minutes)

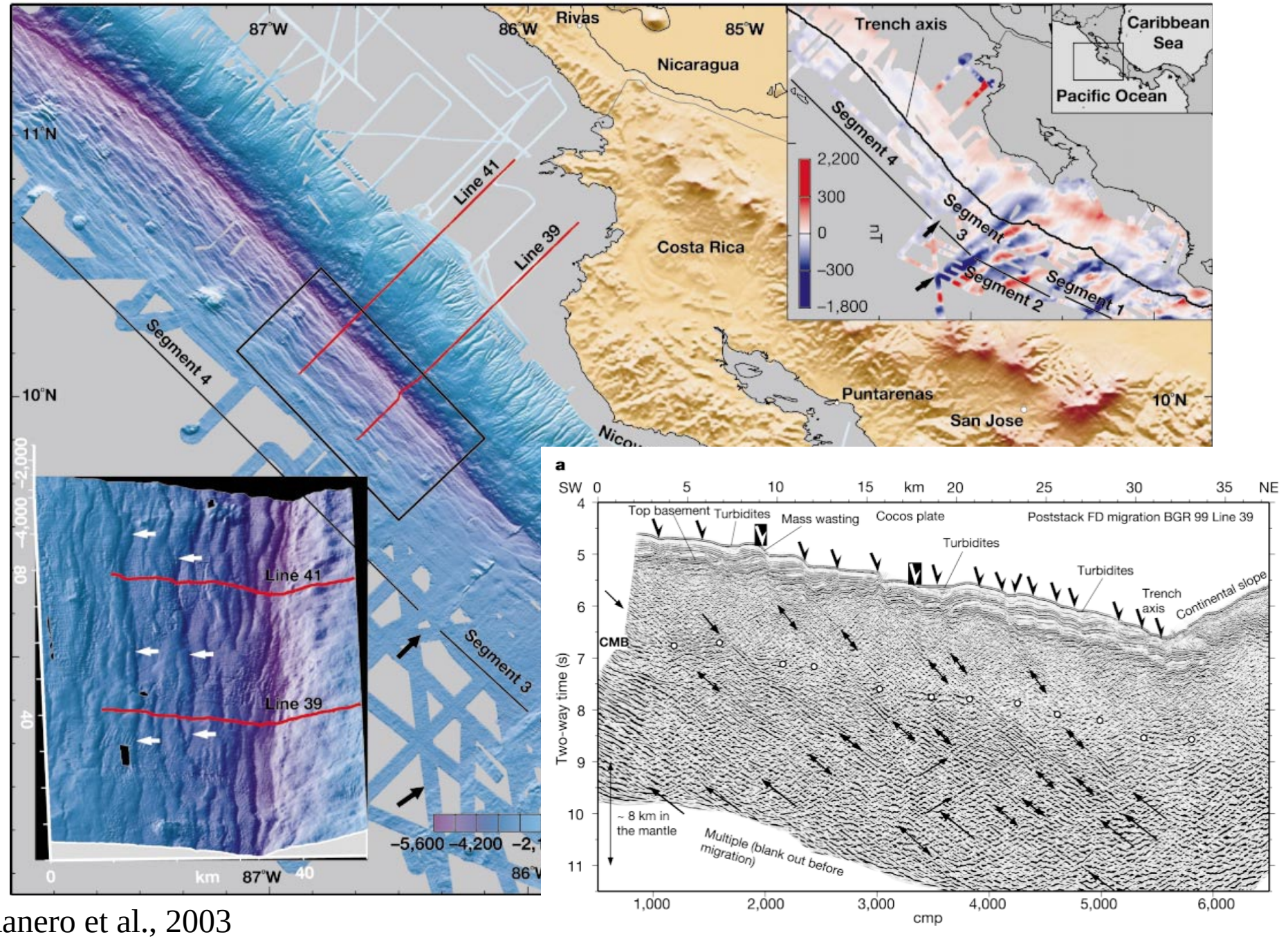
Velocity Strengthening Behavior



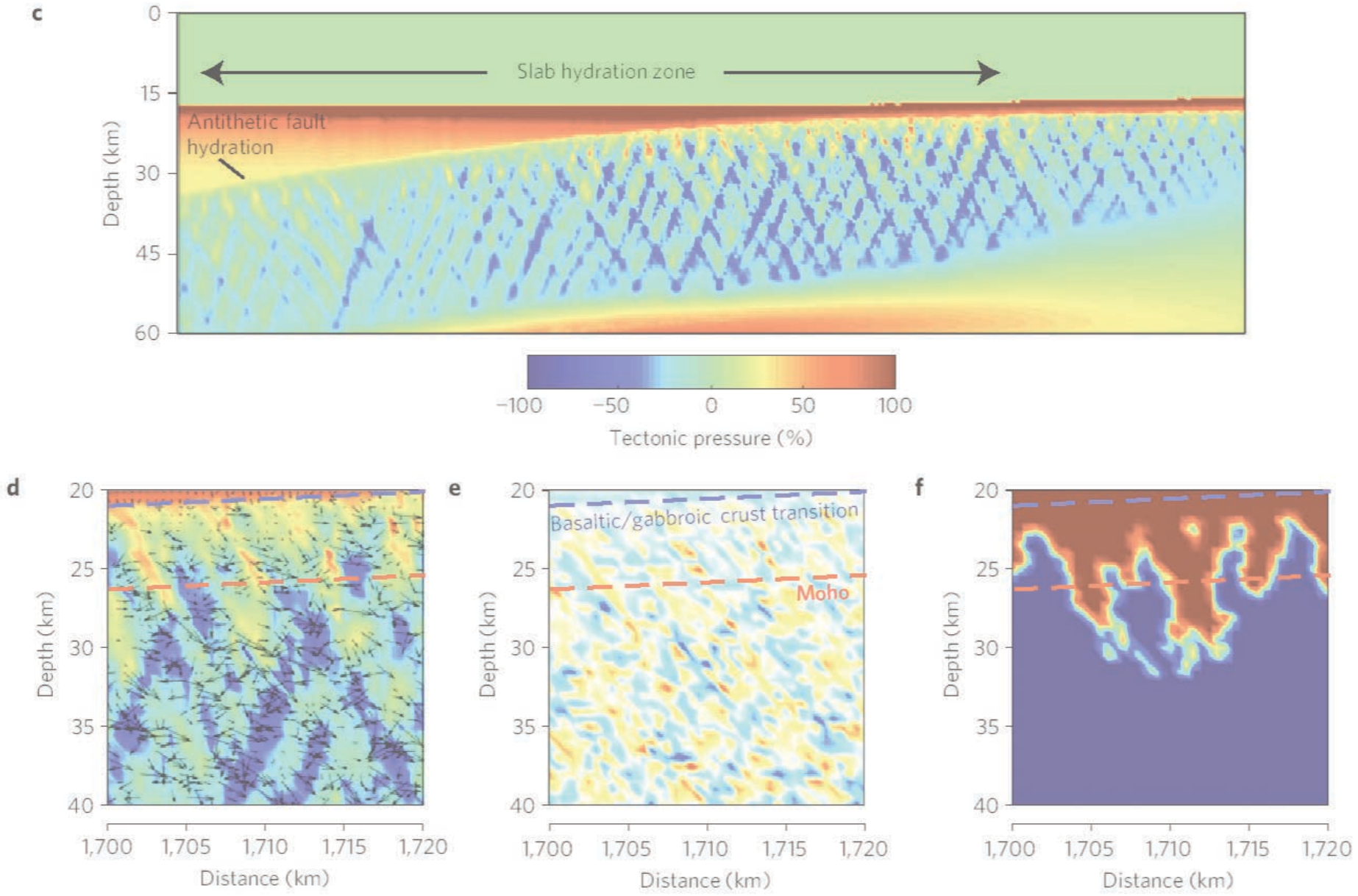
Chernak & Hirth, submitted



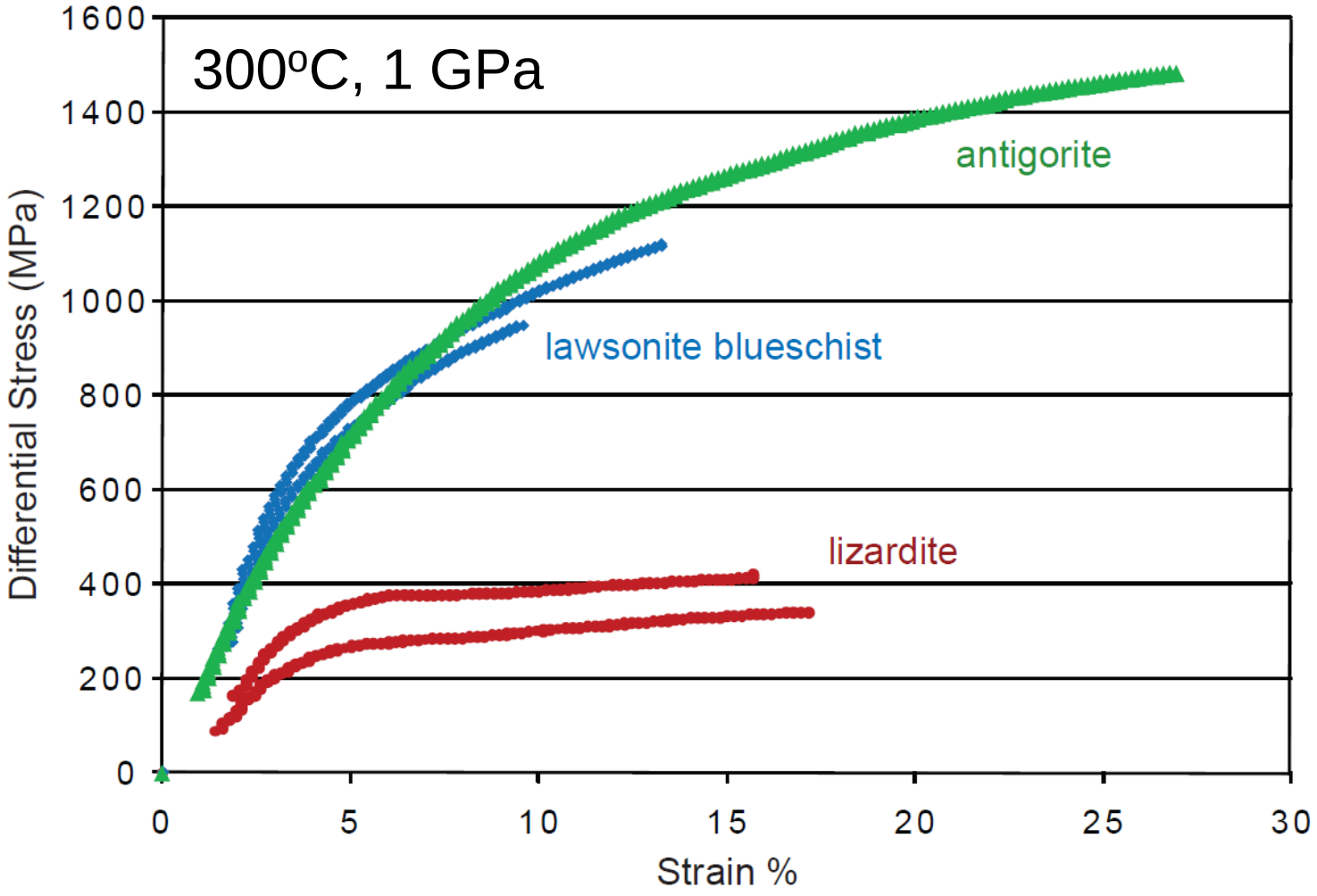
Kelemen & Hirth, 2007



Ranero et al., 2003

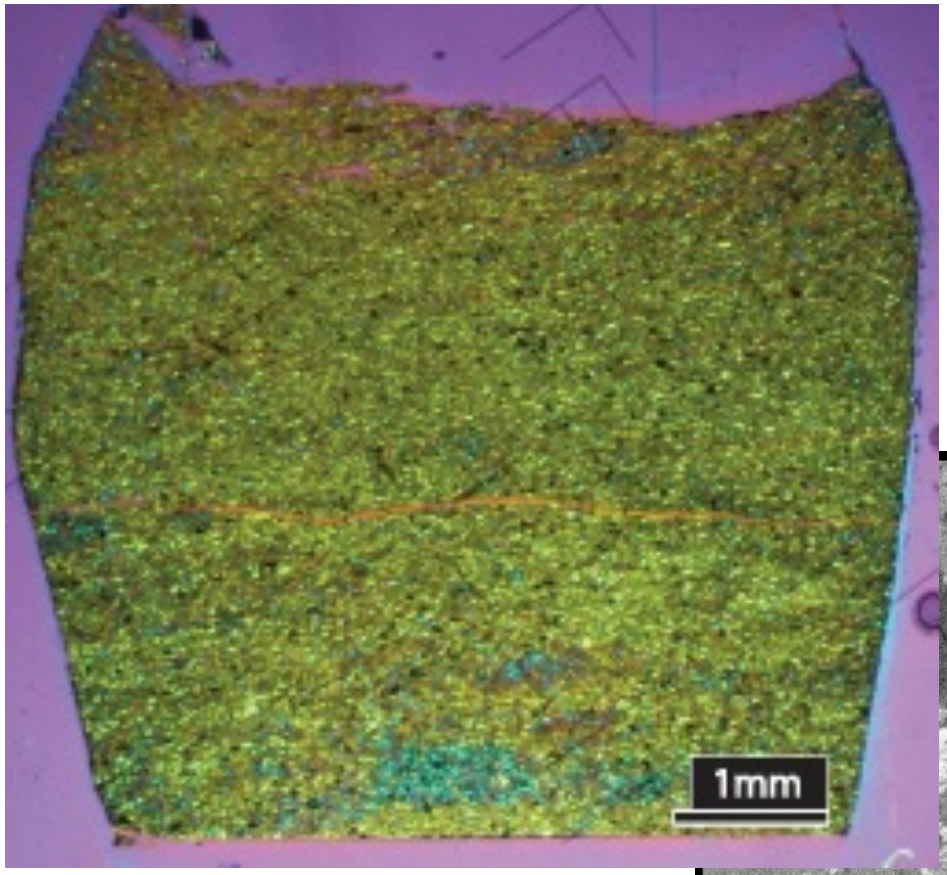


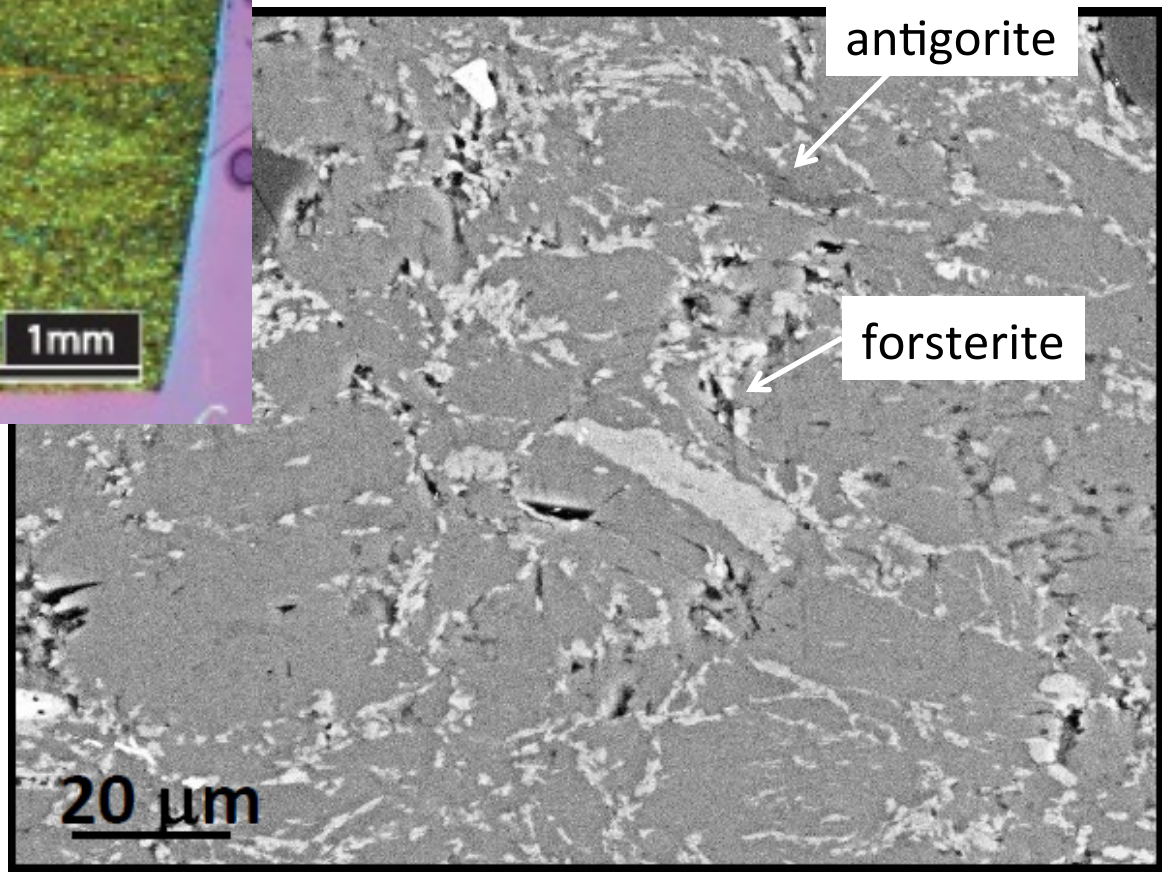
Faccenda et al., 2009



Doyle, Getsinger, Whitney & Hirth

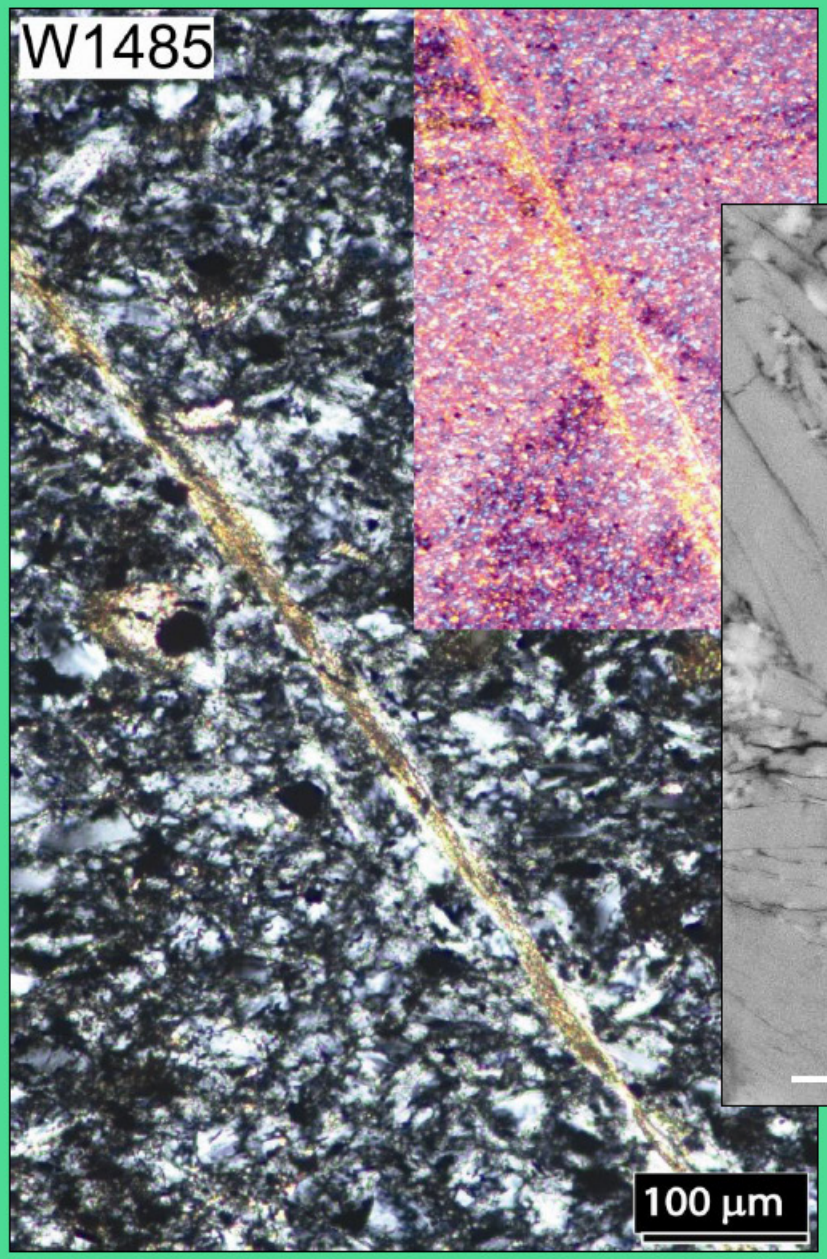
700°C, 1.5 GPa



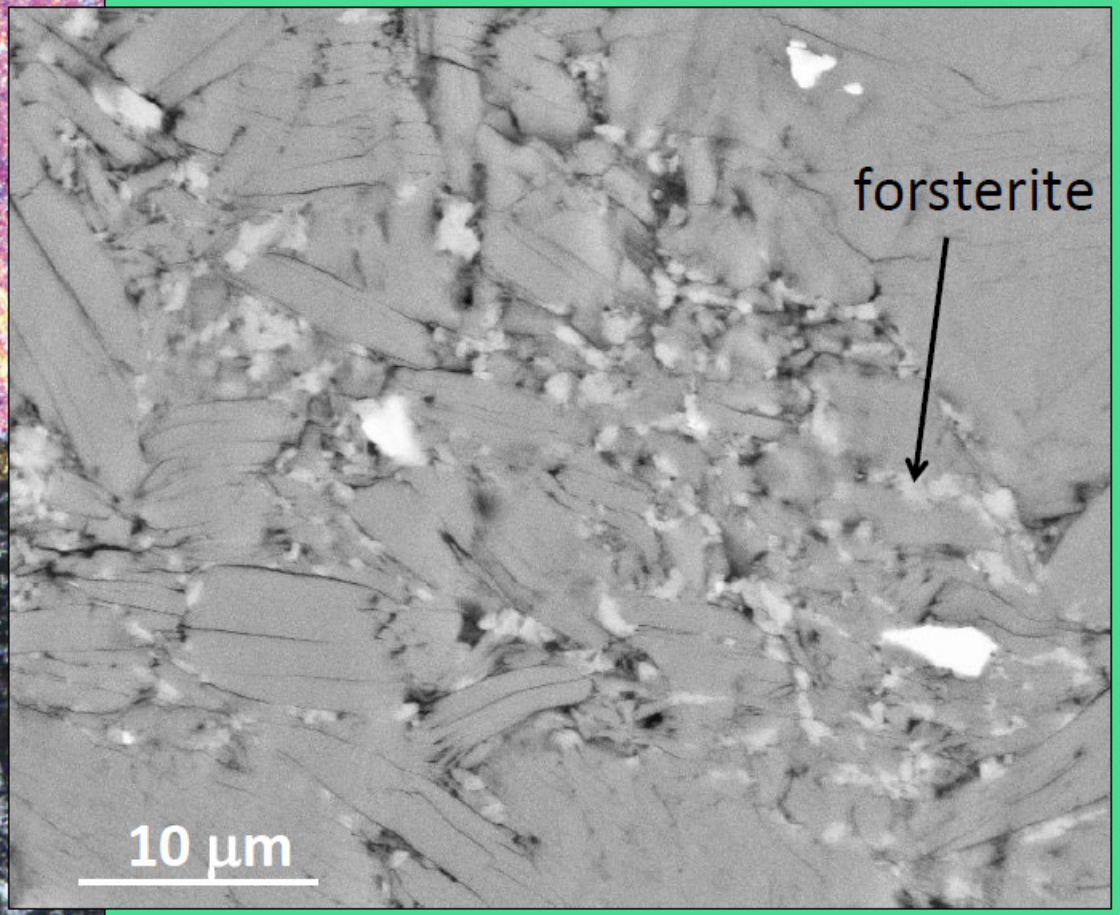


Chernak & Hirth, 2010

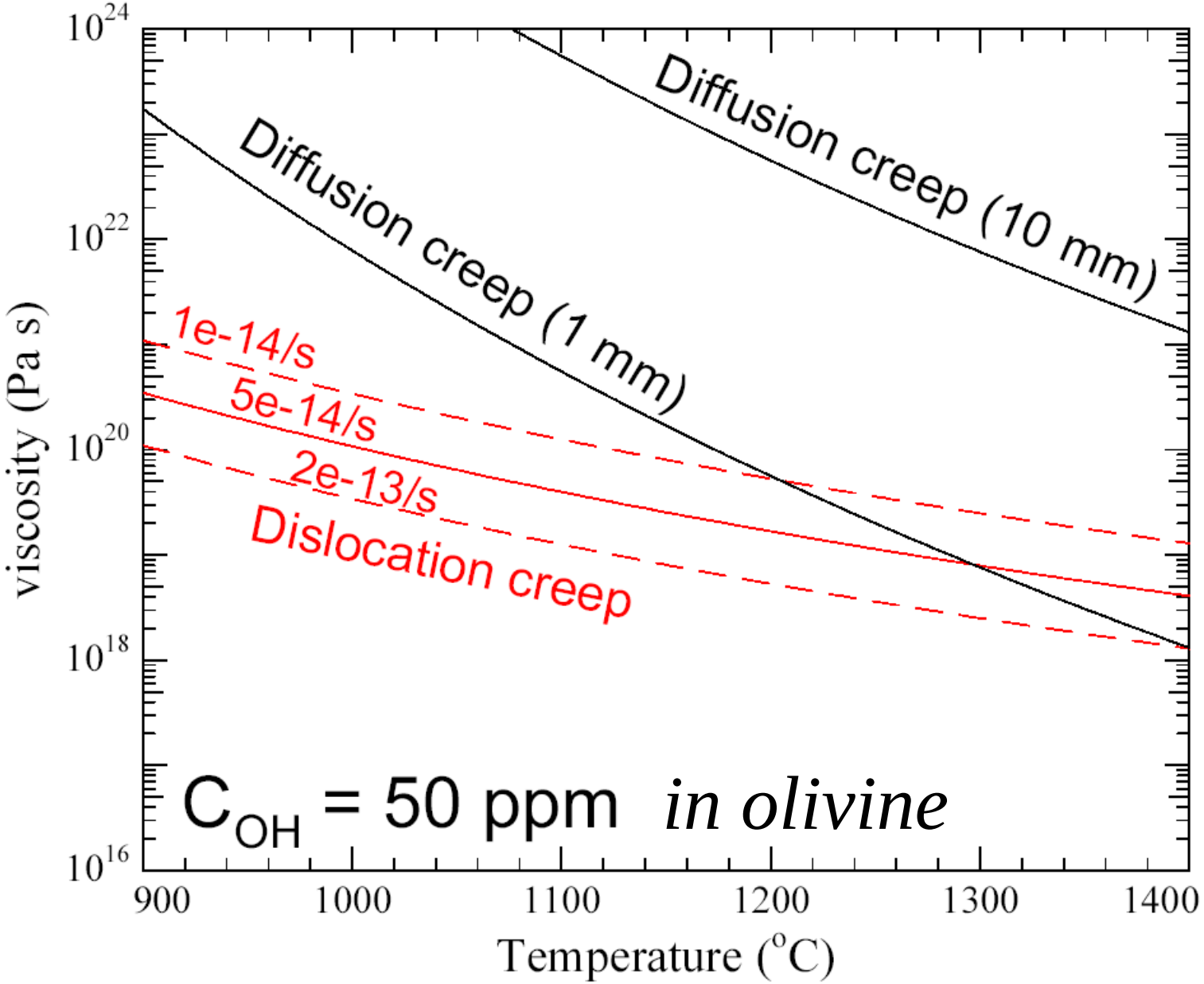
Where Dehydration is Expected: Low P

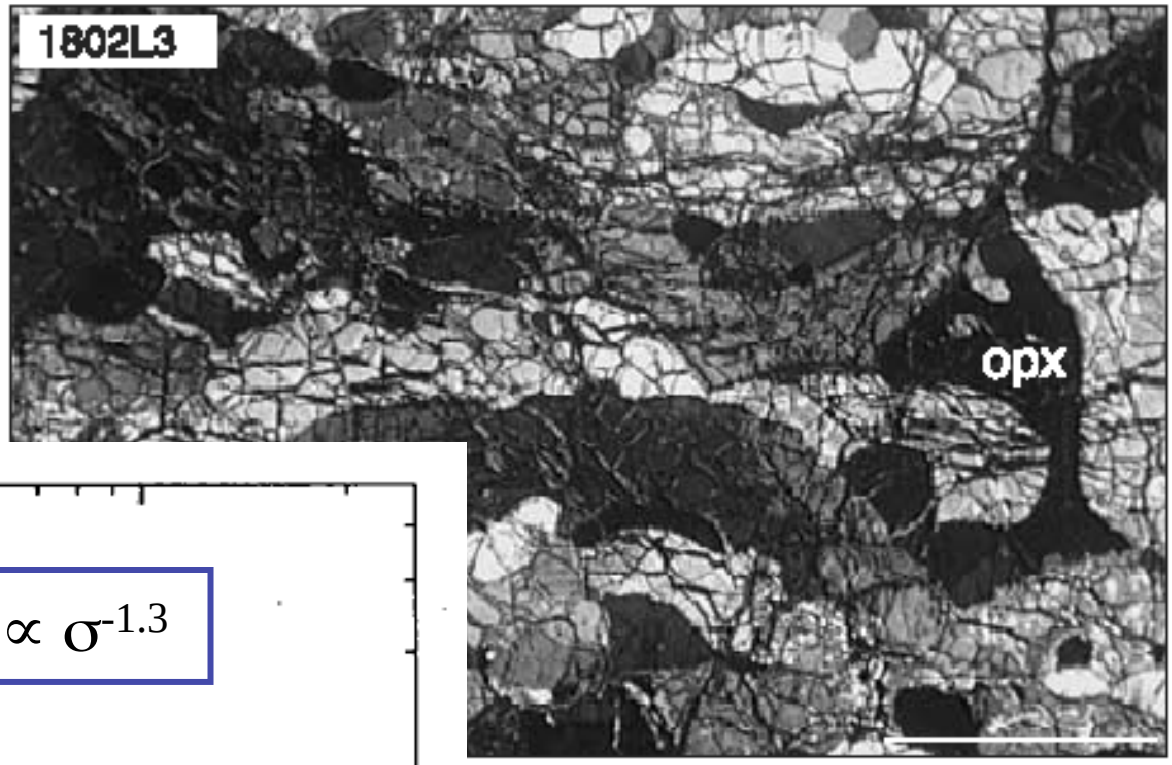


625°C, 0.5 GPa

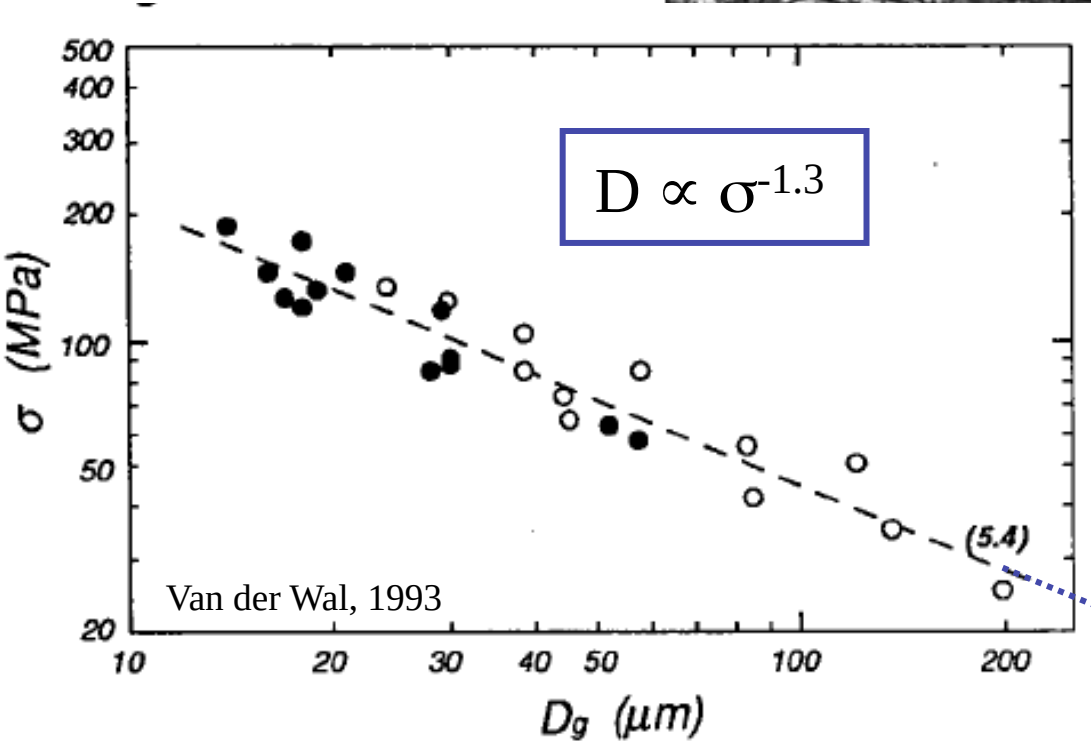


localized deformation

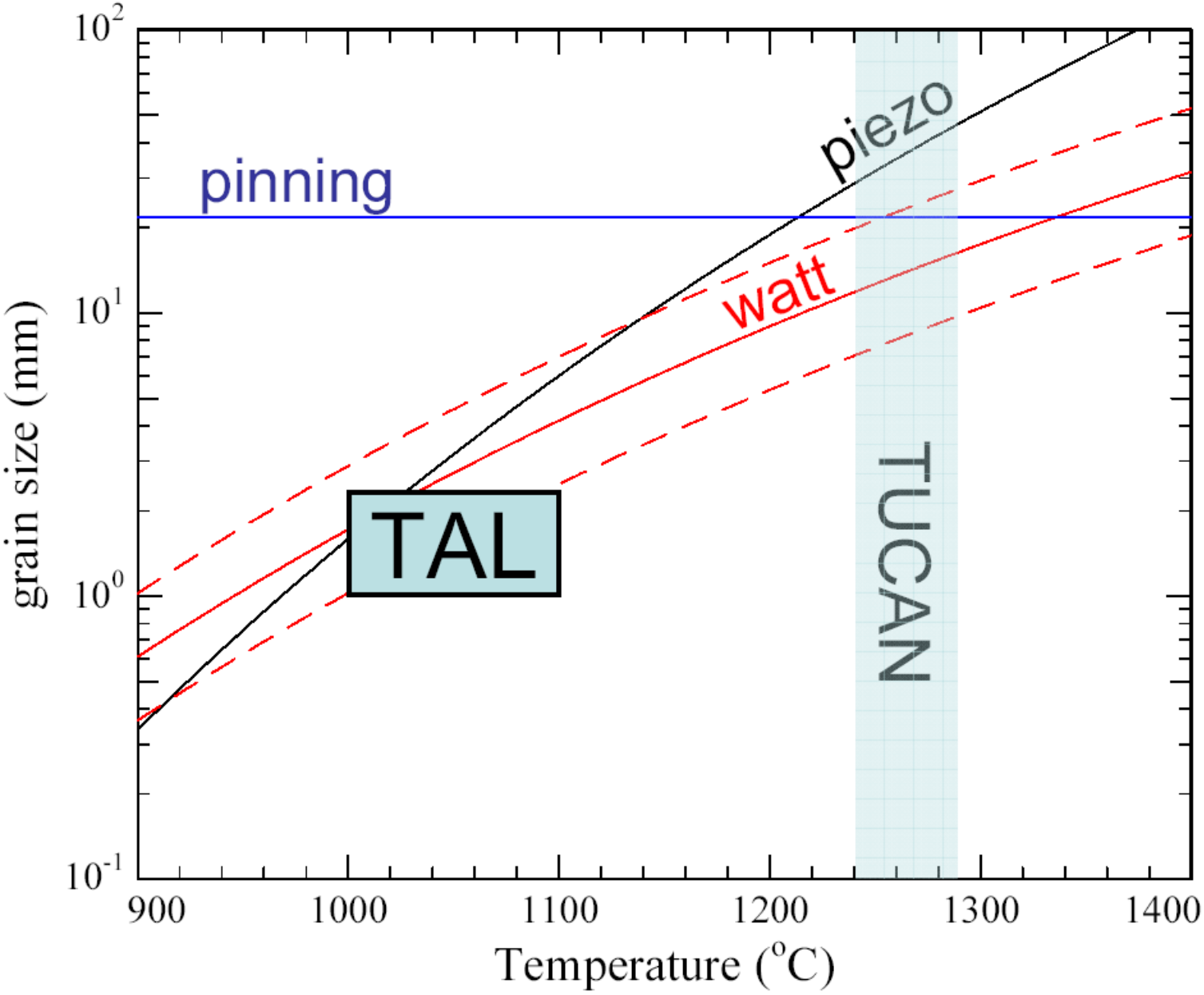

Diffusion creep (10 mm)
Diffusion creep (1 mm)
1e-14/s
5e-14/s
2e-13/s
Dislocation creep
C_{OH} = 50 ppm *in olivine*
viscosity (Pa s)
10^{24}
10^{22}
10^{20}
10^{18}
10^{16}
900
1000
1100
1200
1300
1400
Temperature (°C)

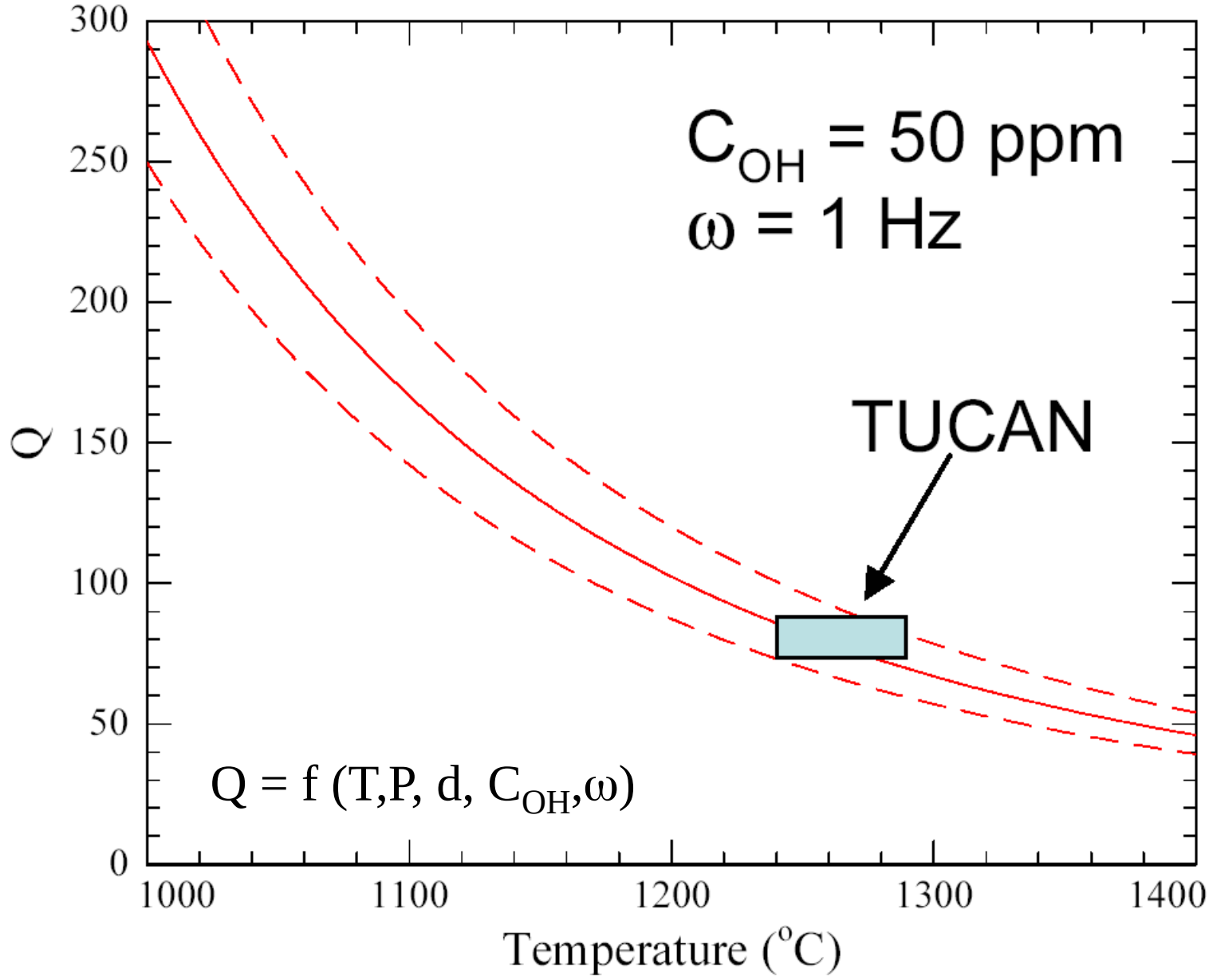


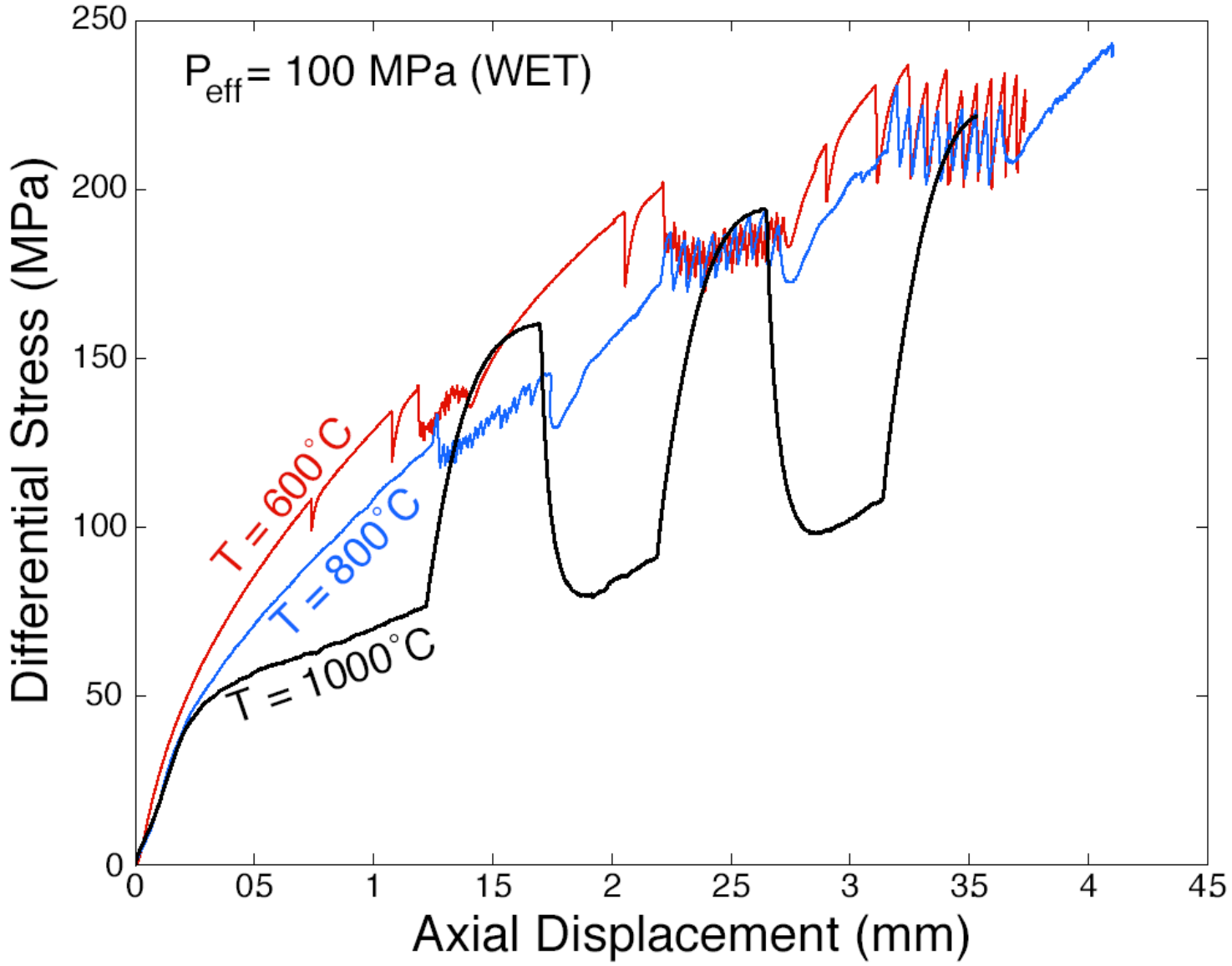
Mehl et al., 2003

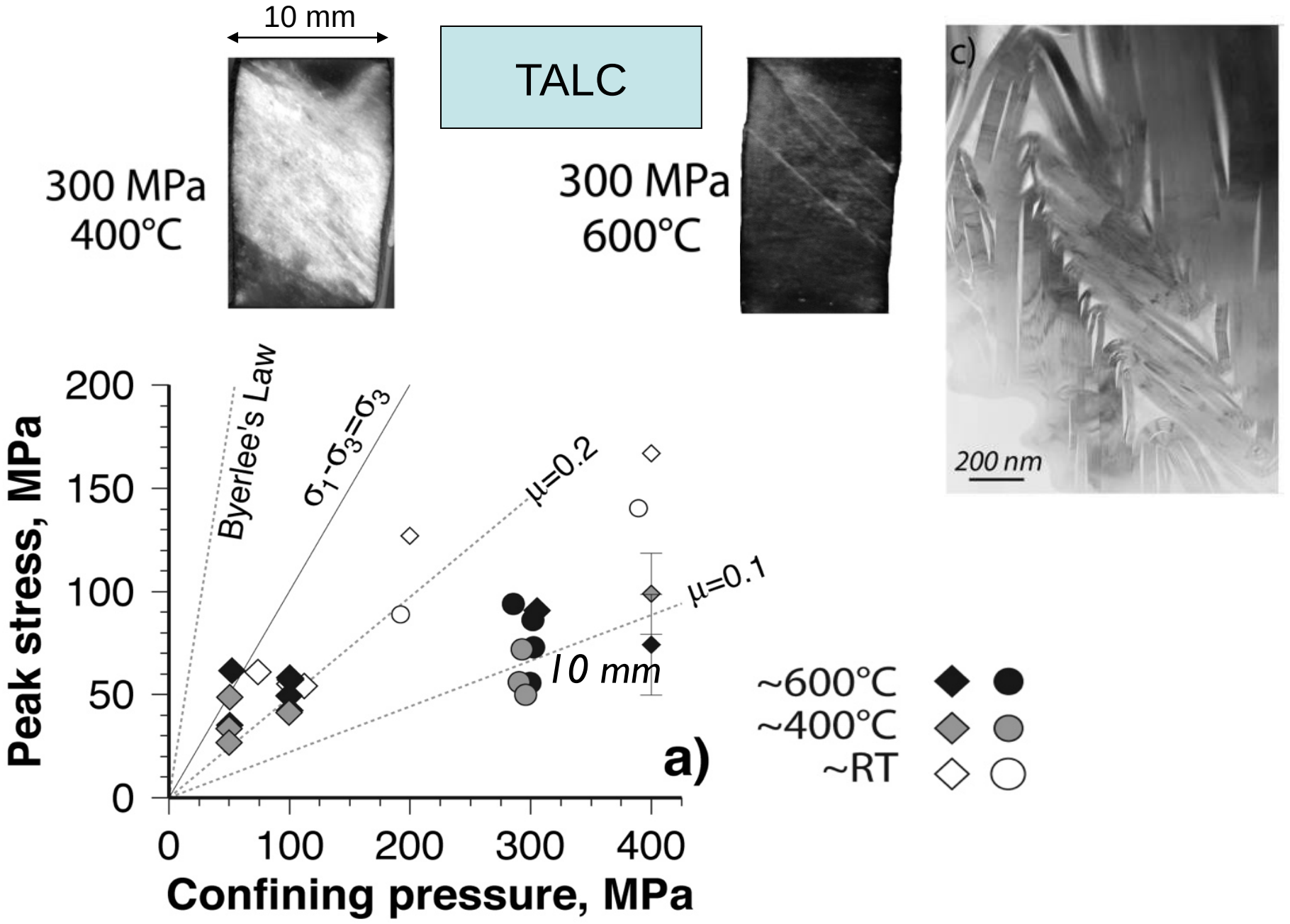


Tal

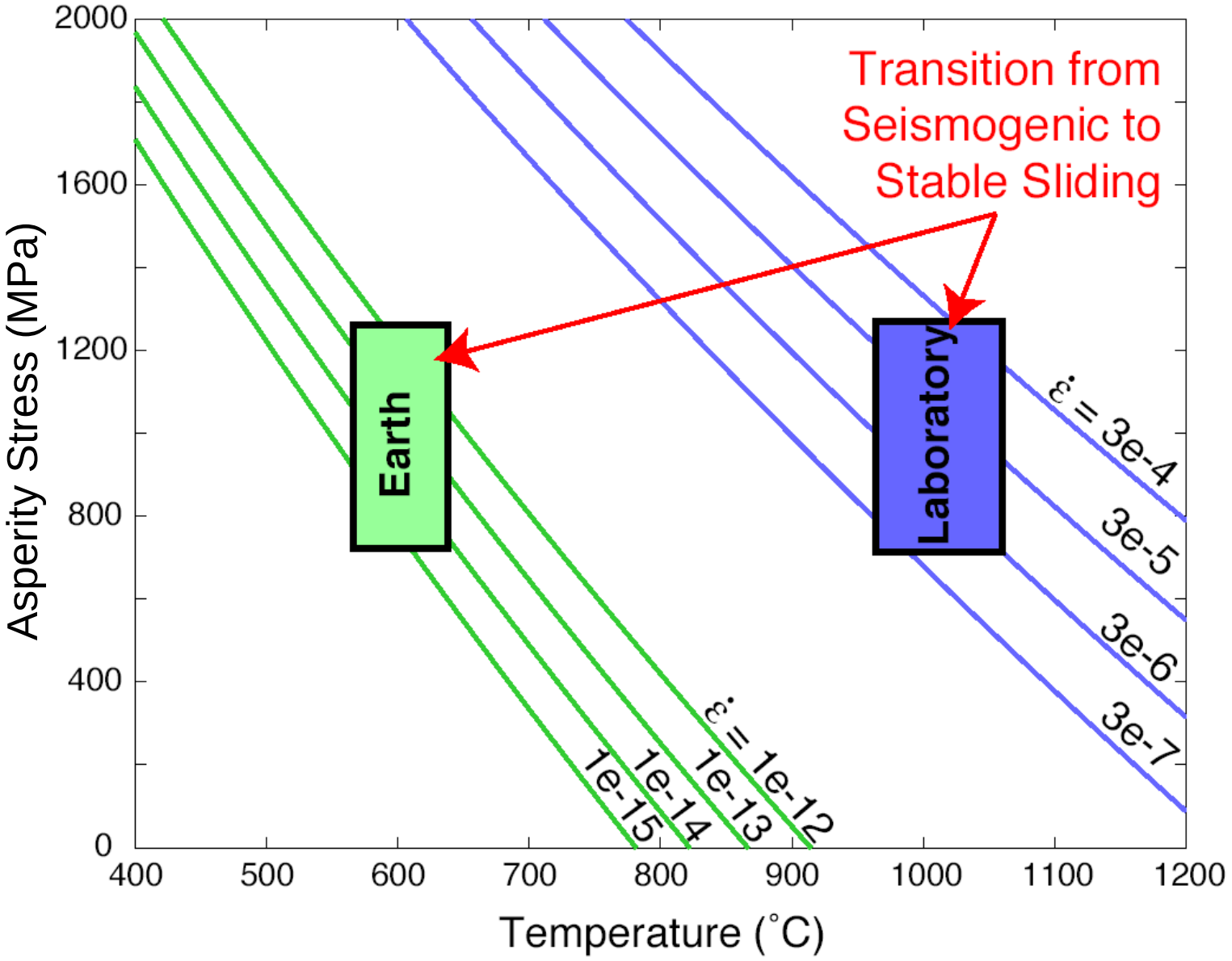

pinning
piezo
watt
TAL
TUCAN
grain size (mm)
Temperature (°C)
10^2
10^1
10^0
10^-1
900
1000
1100
1200
1300
1400


300
250
200
150
100
50
0
Q
1000
1100
1200
1300
1400
Temperature (°C)
C_OH = 50 ppm
ω = 1 Hz
TUCAN
Q = f (T,P, d, C_OH,ω)


P_eff = 100 MPa (WET)
T = 600°C
T = 800°C
T = 1000°C
Differential Stress (MPa)
Axial Displacement (mm)
250
200
150
100
50
0
0
05
1
15
2
25
3
35
4
45

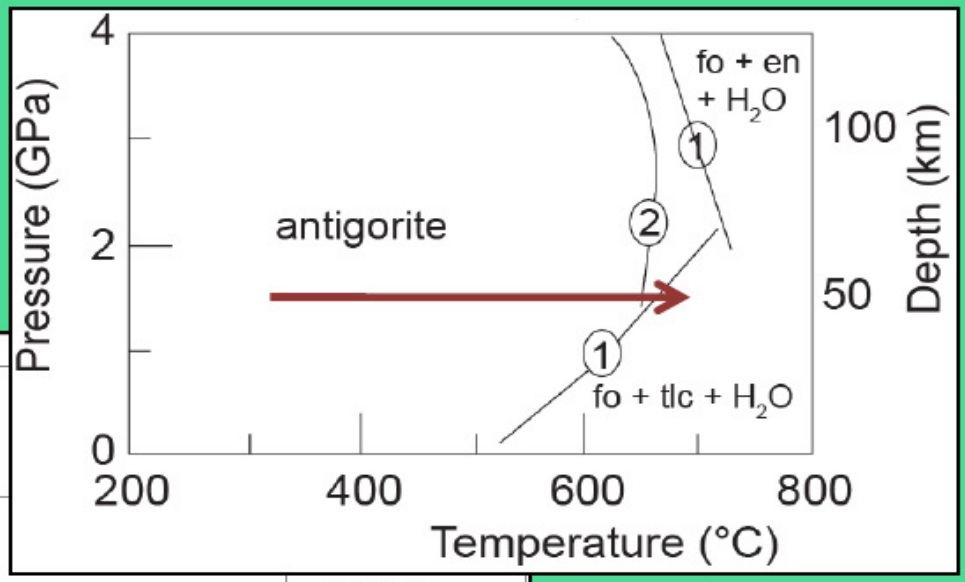


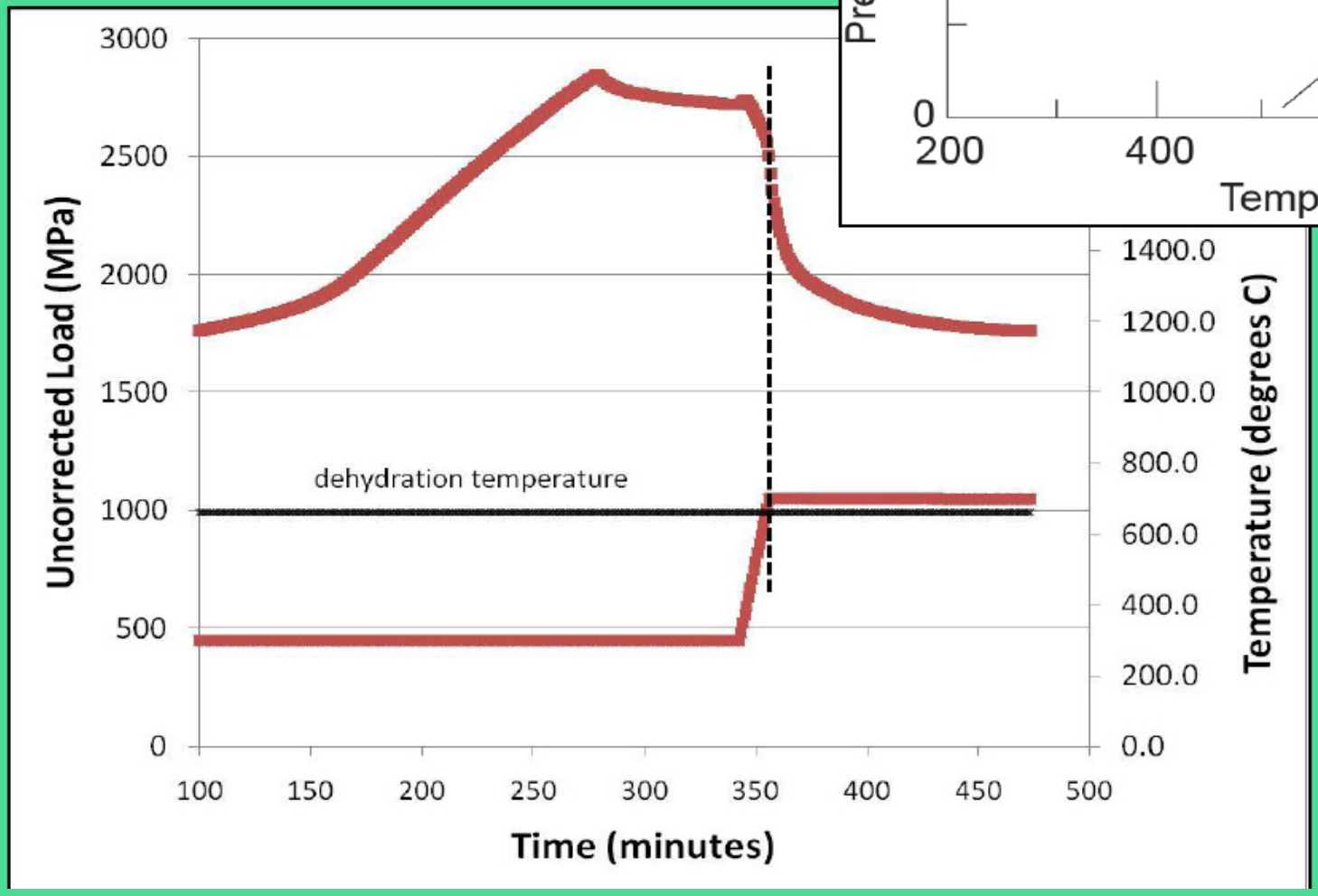
Escartin et al., 2008



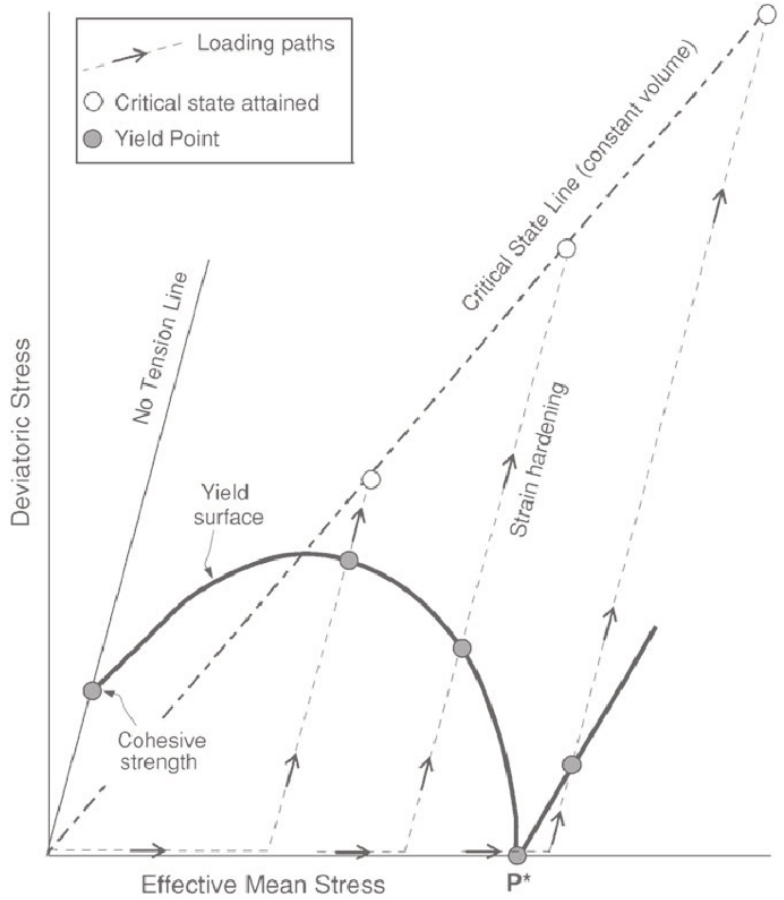
Boettcher, Hirth & Evans, 2007

Temperature Ramping





T increase:
1800°C/hr



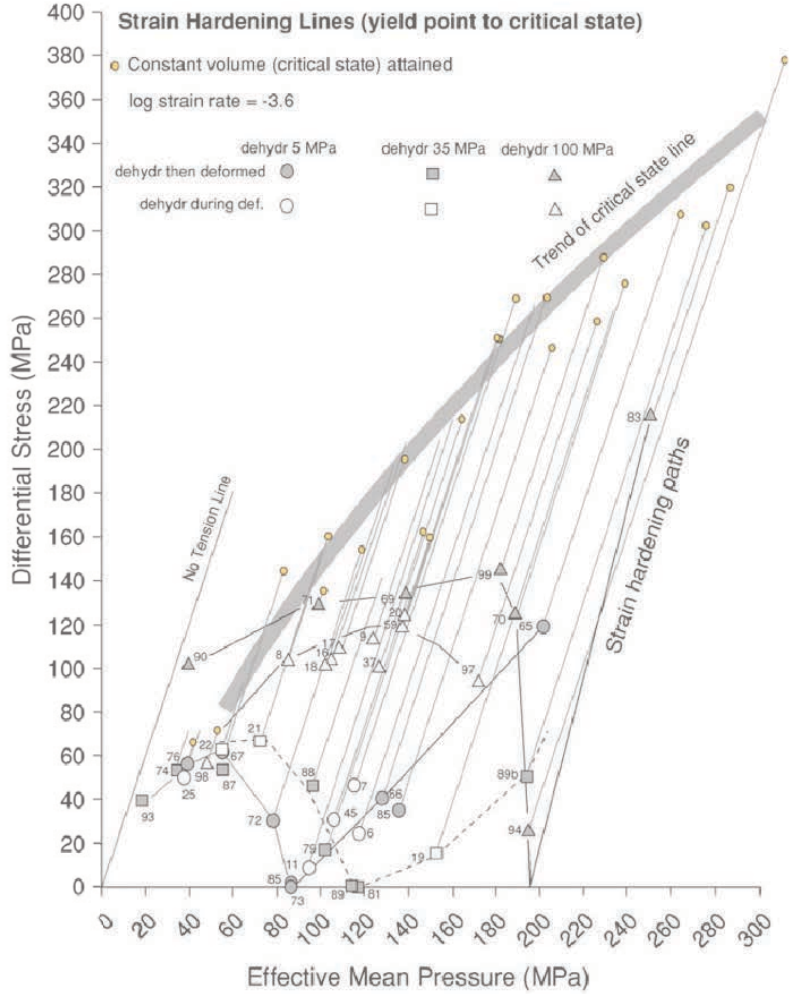


Fig. 5. Schematic illustration of expected mechanical behaviour of a porous material. The yield surface at low effective mean pressures represents dilatant deformation with brittle faulting and rises to a peak stress on the critical state line. Then it decreases in

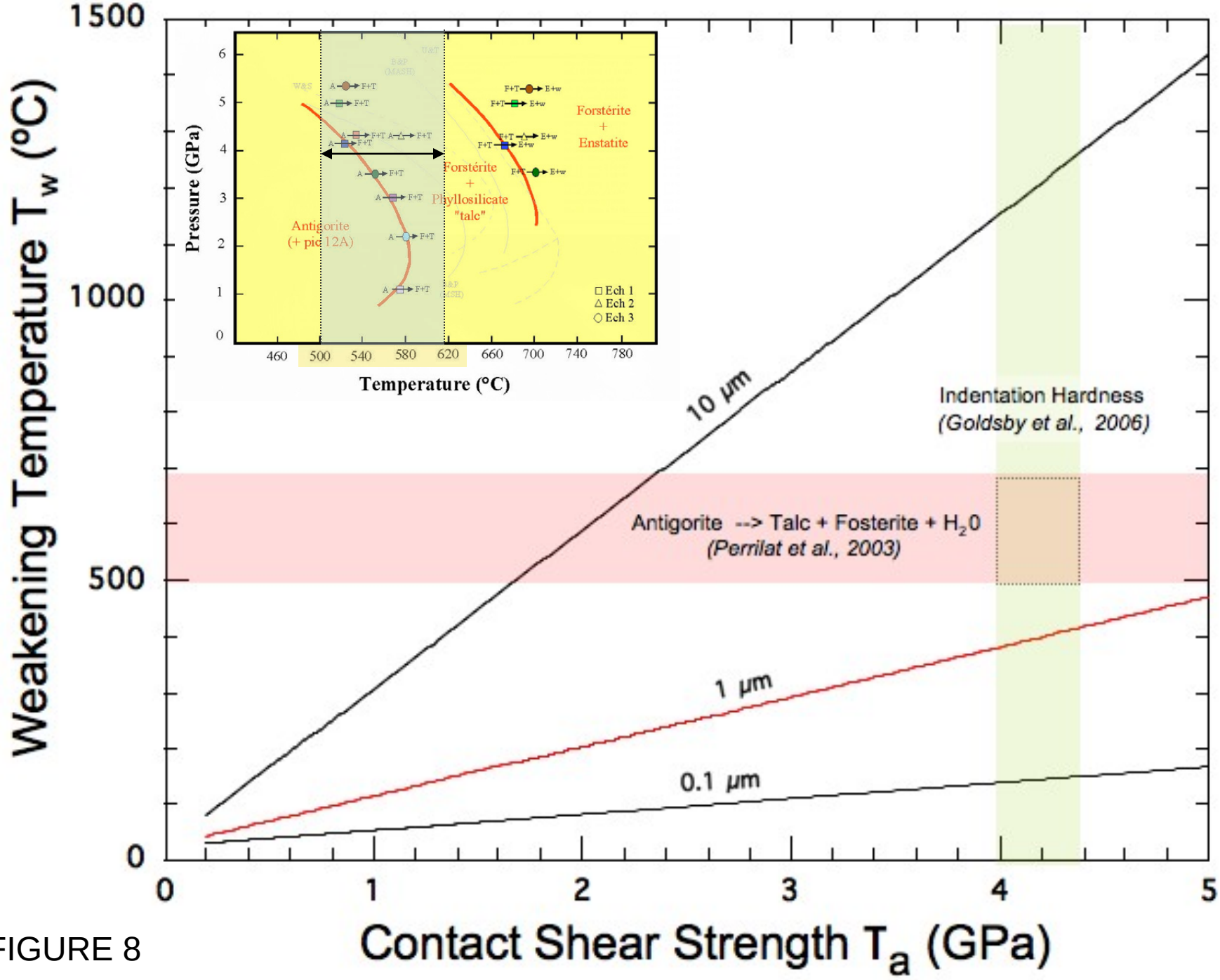
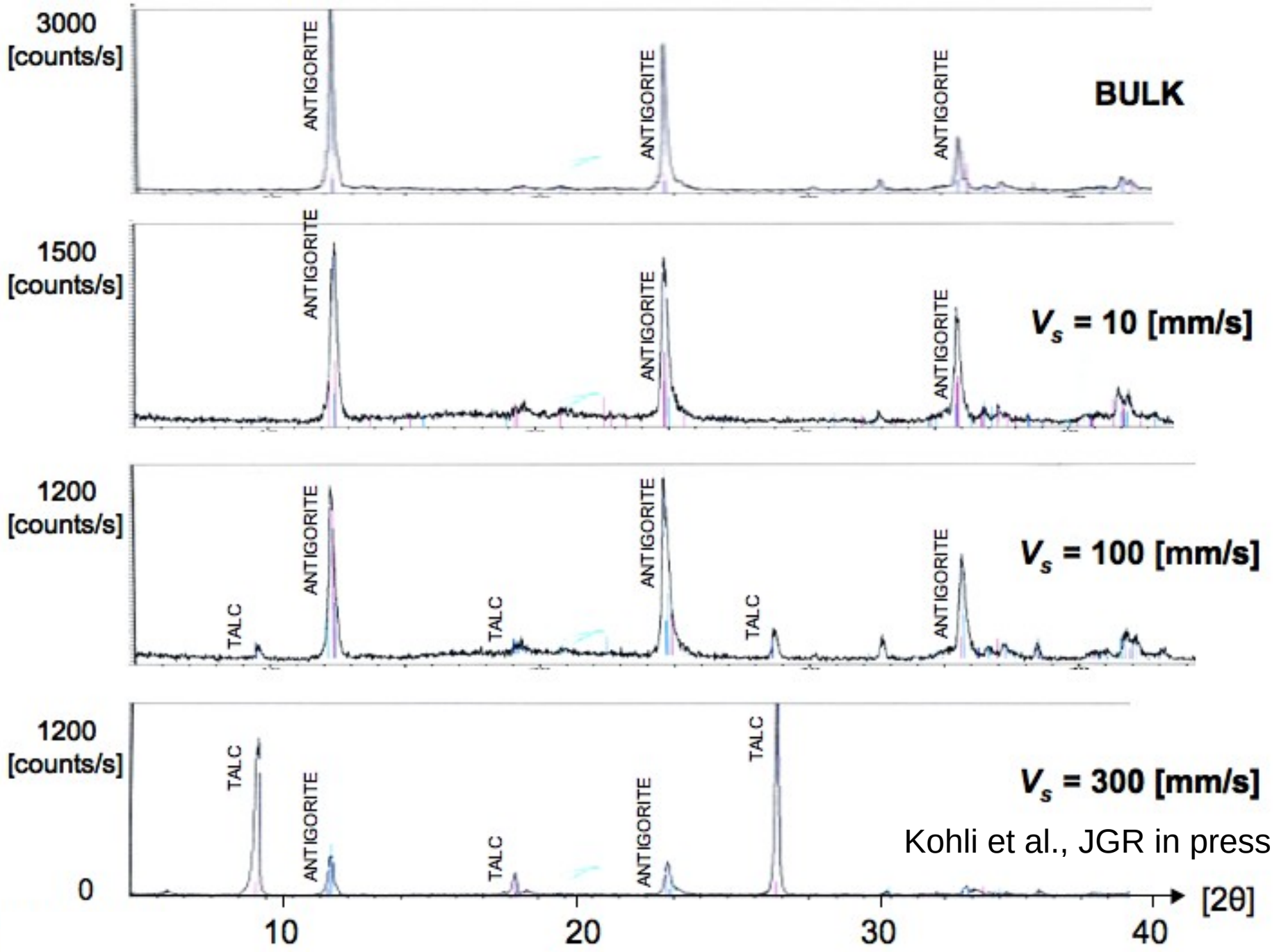

Weakening Temperature T_w (°C)
1500
1000
500
0
Contact Shear Strength T_a (GPa)
0
1
2
3
4
5
10 µm
1 µm
0.1 µm
Indentation Hardness
(Goldsby et al., 2006)
Antigorite --> Talc + Fosterite + H_2O
(Perrilat et al., 2003)
Pressure (GPa)
Temperature (°C)
Forstérite + Enstatite
Forstérite + Phyllosilicate "talc"
Antigorite (+ pic 12A)
Ech 1
Ech 2
Ech 3

FIGURE 8



Kohli et al., JGR in press