Strength and stability of calcite gouge sheared at 20-600°C

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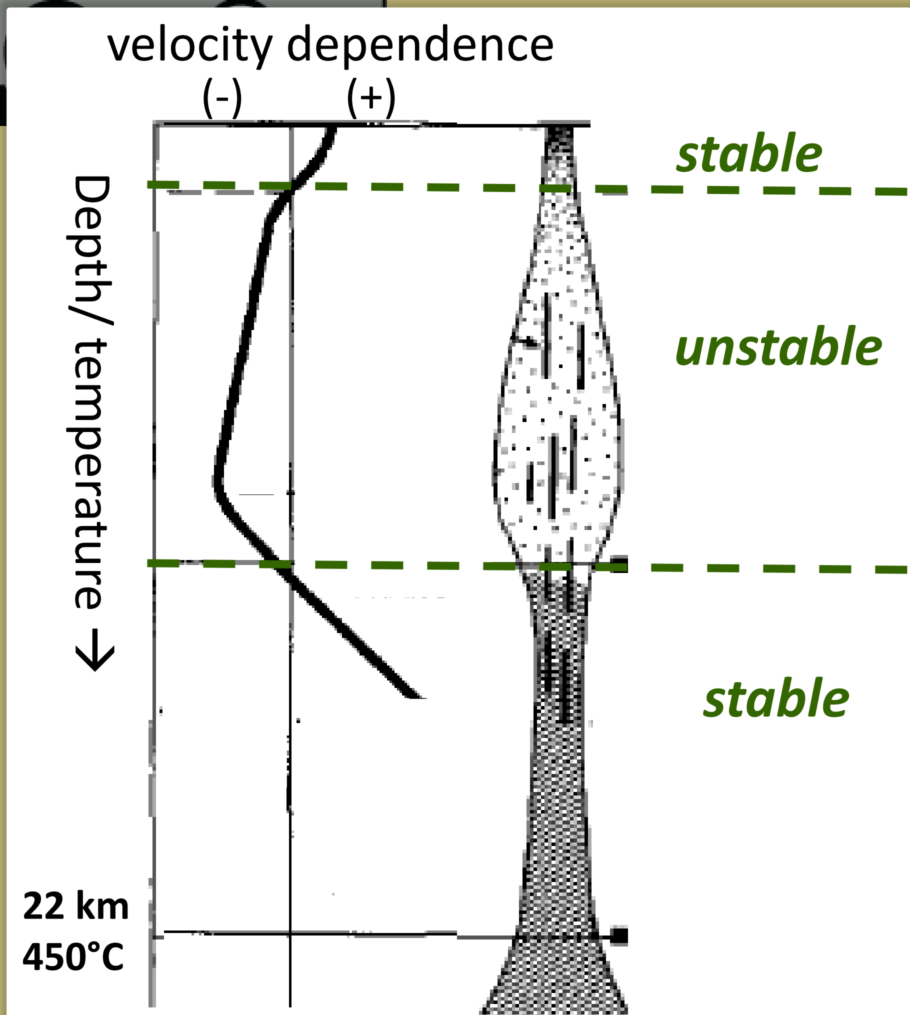
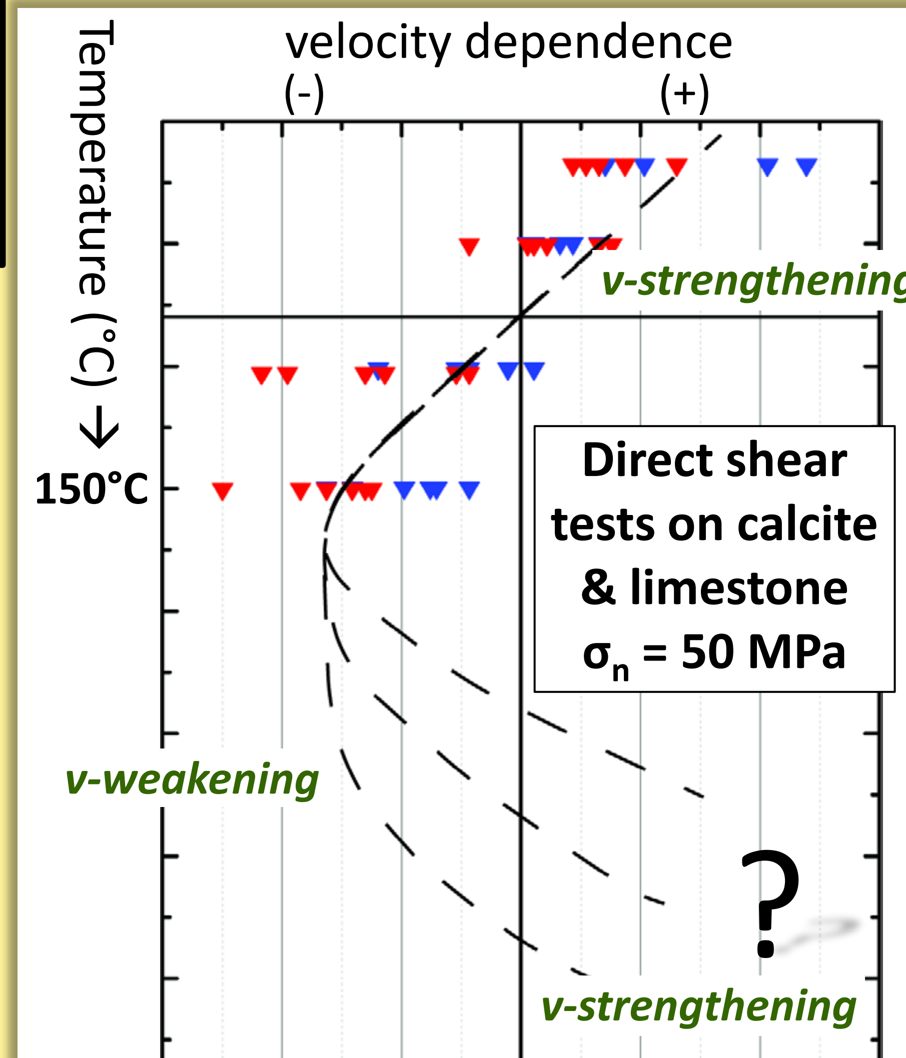
EGU General Assembly – Vienna – 30 April 2014

Introduction



Scholz, 1988 Geol. Rundsch.

seismogenic zone



Verberne et al., 2010 BSSA; Verberne et al., 2013 Geology

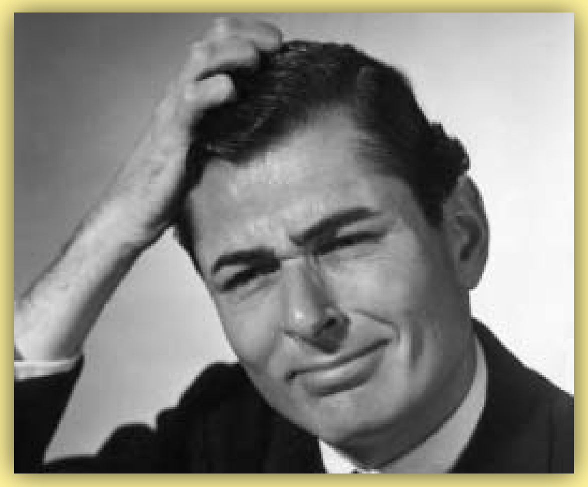
Calcite fault rock:

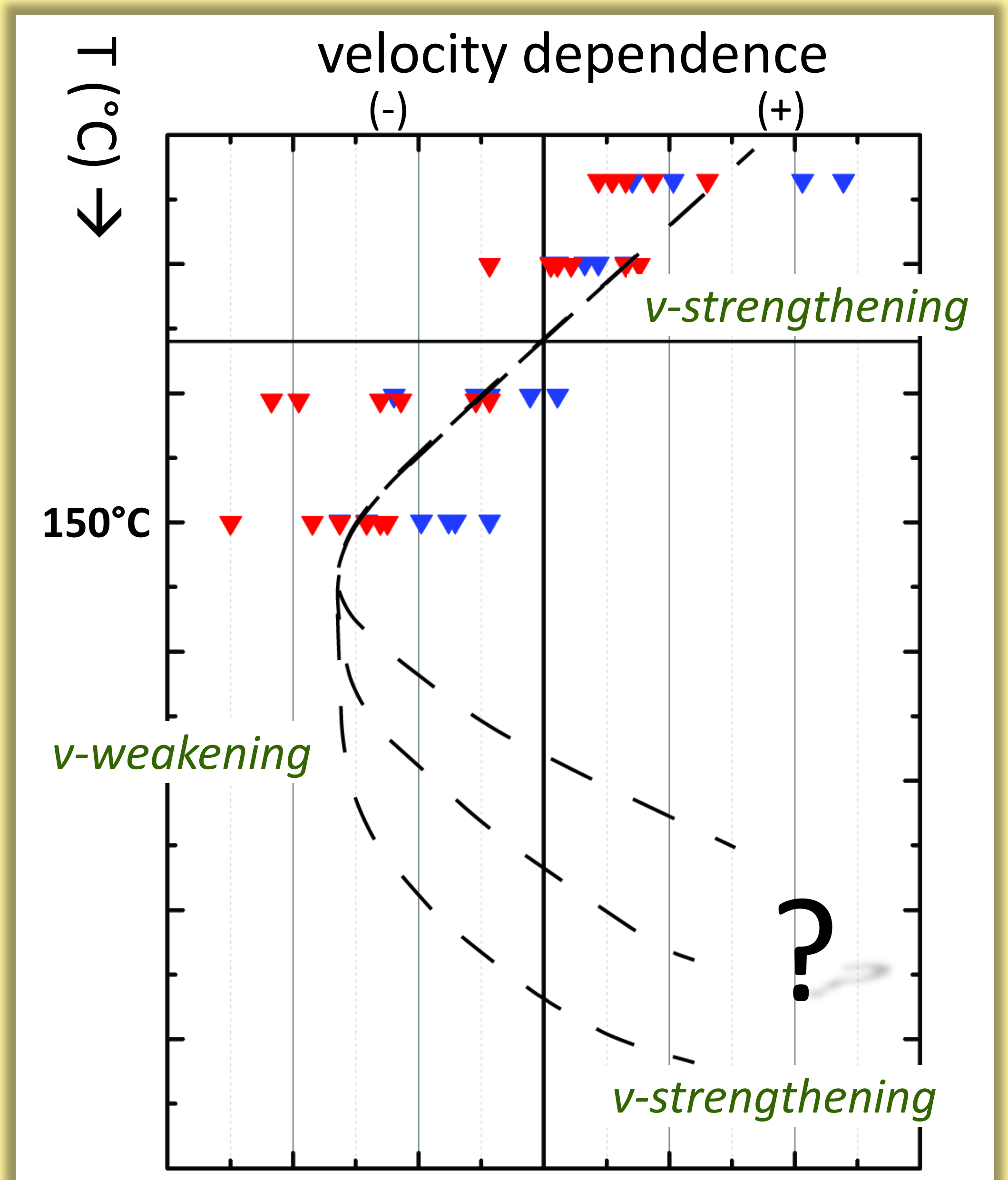
transition to **unstable** slip at

T ≈ 80-100°C...

Problem statement

At what temperature will calcite gouge transition back to stable sliding?





Materials & Methods

- Simulated gouge prepared from Iceland Spar $CaCO_3$
- Initial grain size ≈ 15-20 μm

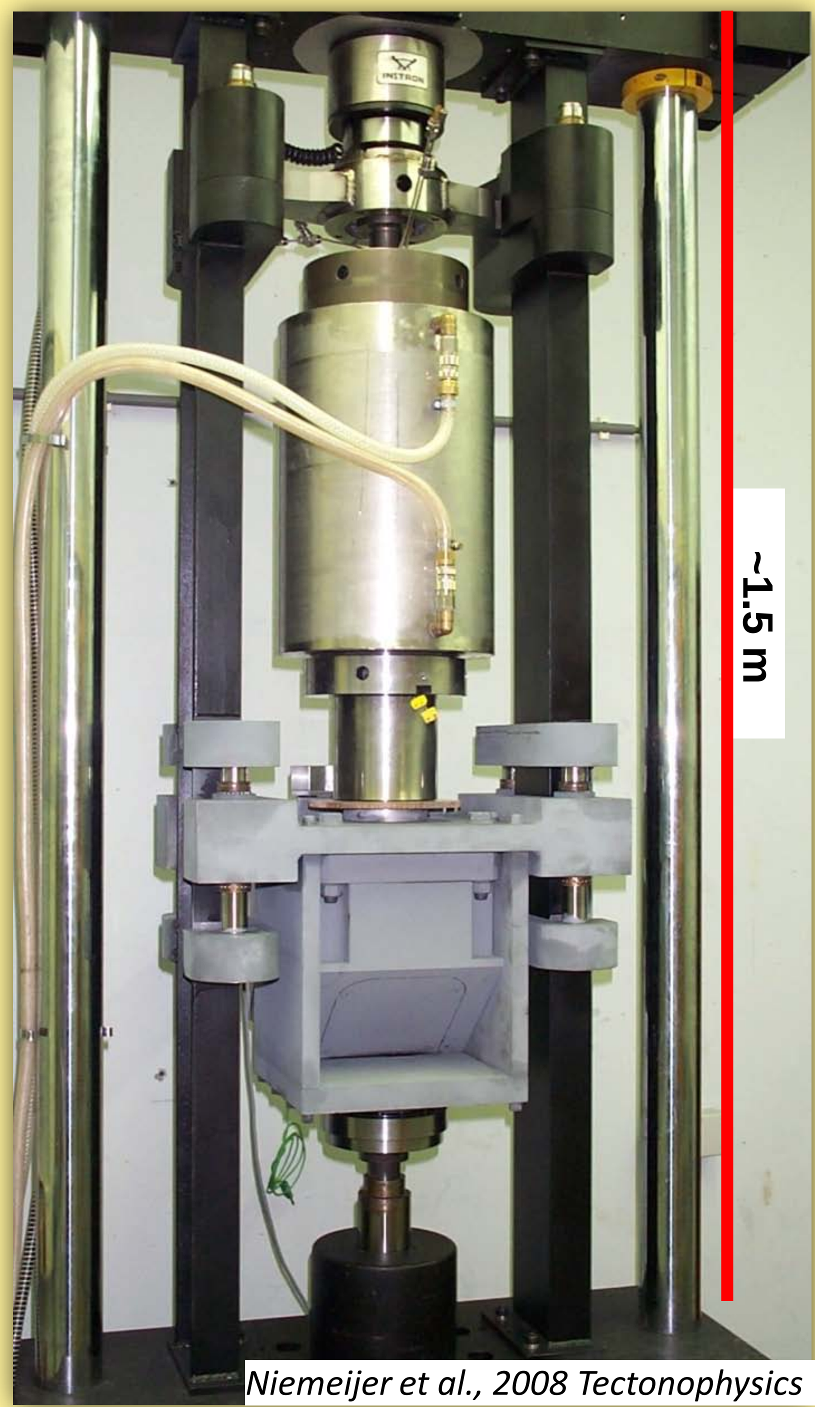
Ring shear experiments

- T = 20-600°C
- Eff. σ_n = 50 MPa
- P_f = 10-60 MPa
- v = 0.01 – 100 μm/s

v-steps: 0.01-0.03-0.1-0.3-1-....etc

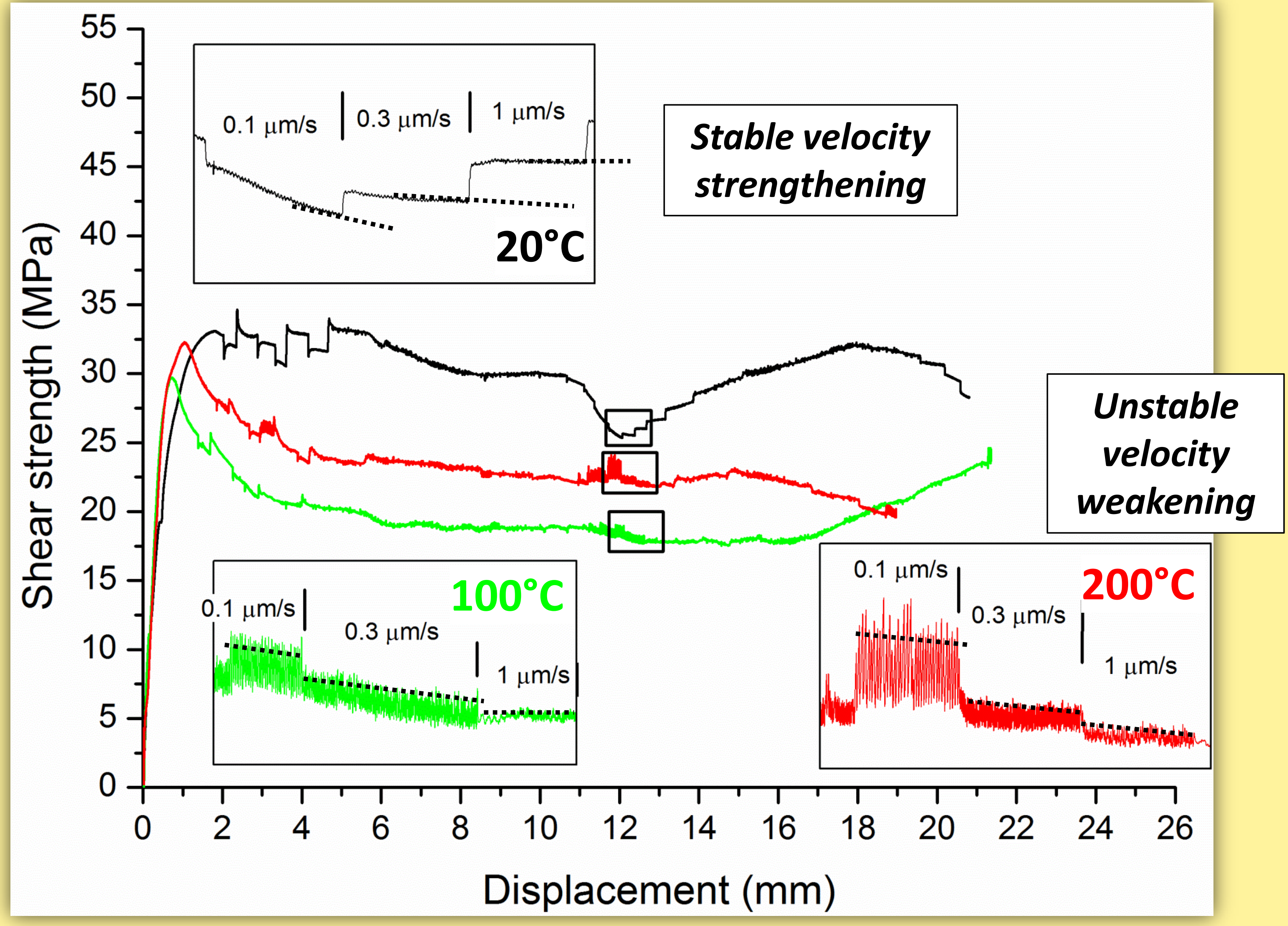
→ max. displ. = 20-23 mm

(γ ≈ 25-45)

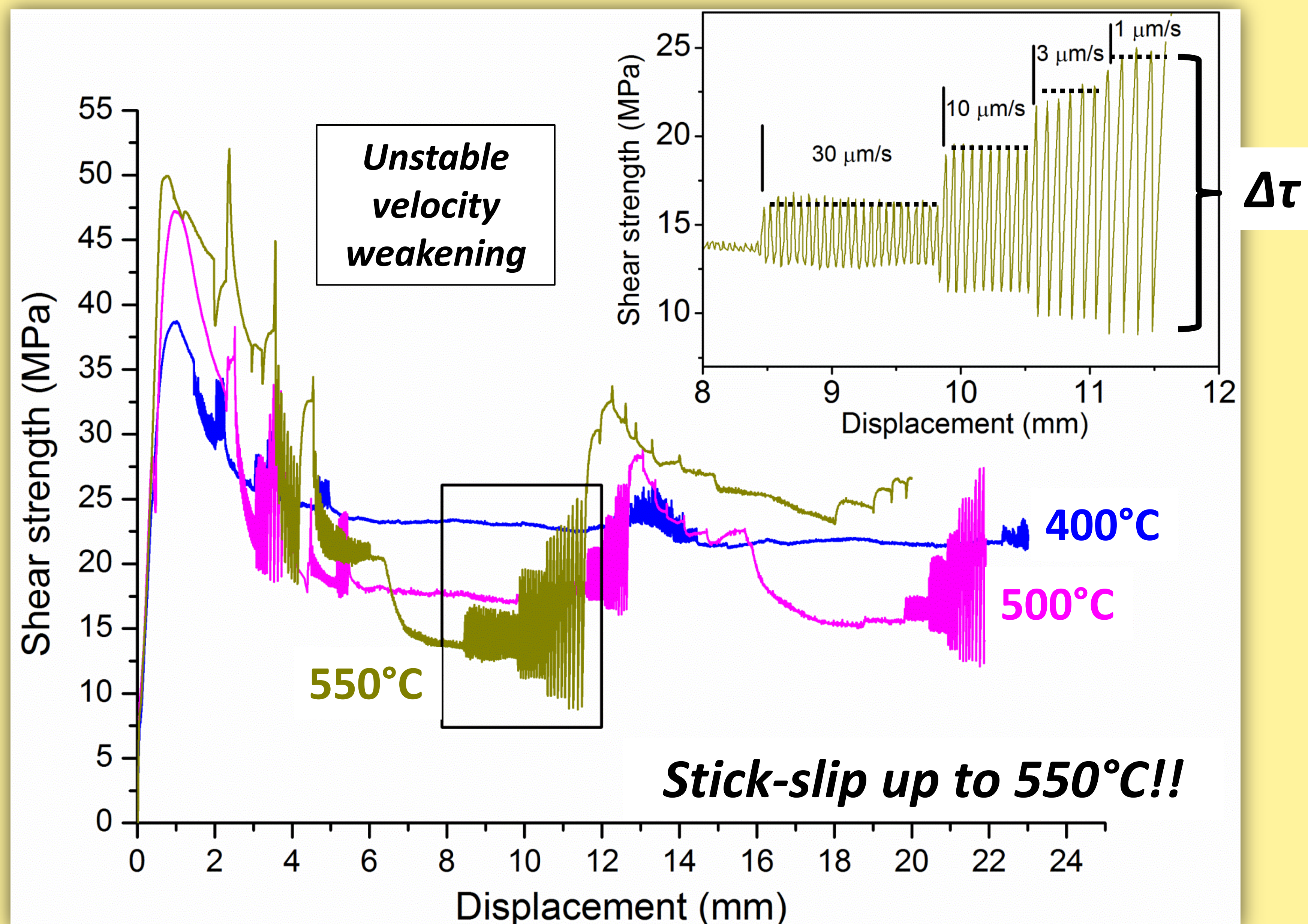


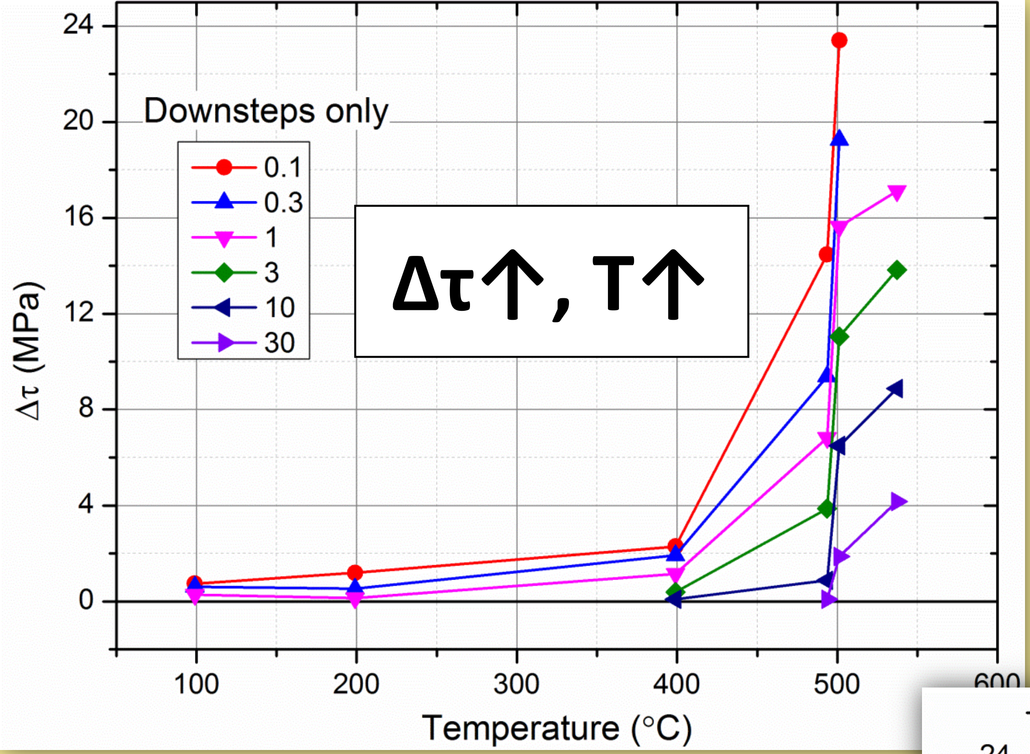
Niemeijer et al., 2008 Tectonophysics

Results: 20, 100, 200°C



400, 500, 550°C

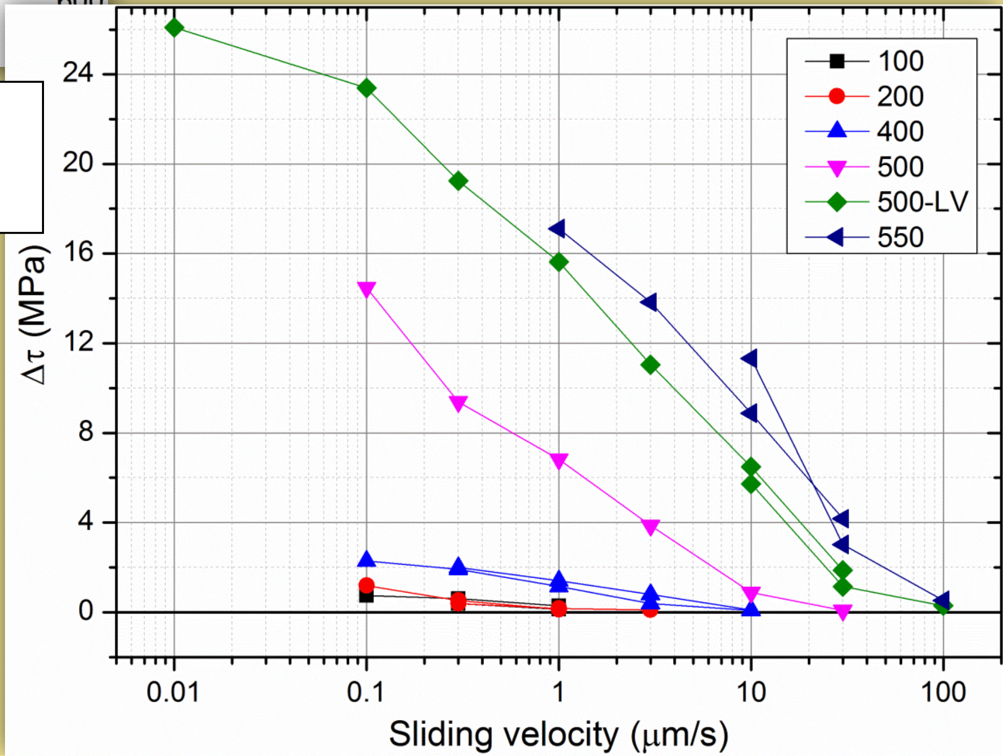

Unstable velocity weakening
Shear strength (MPa)
Displacement (mm)
30 μm/s
10 μm/s
3 μm/s
1 μm/s
Δτ
400°C
500°C
550°C
Stick-slip up to 550°C!!



Δτ↑, T↑

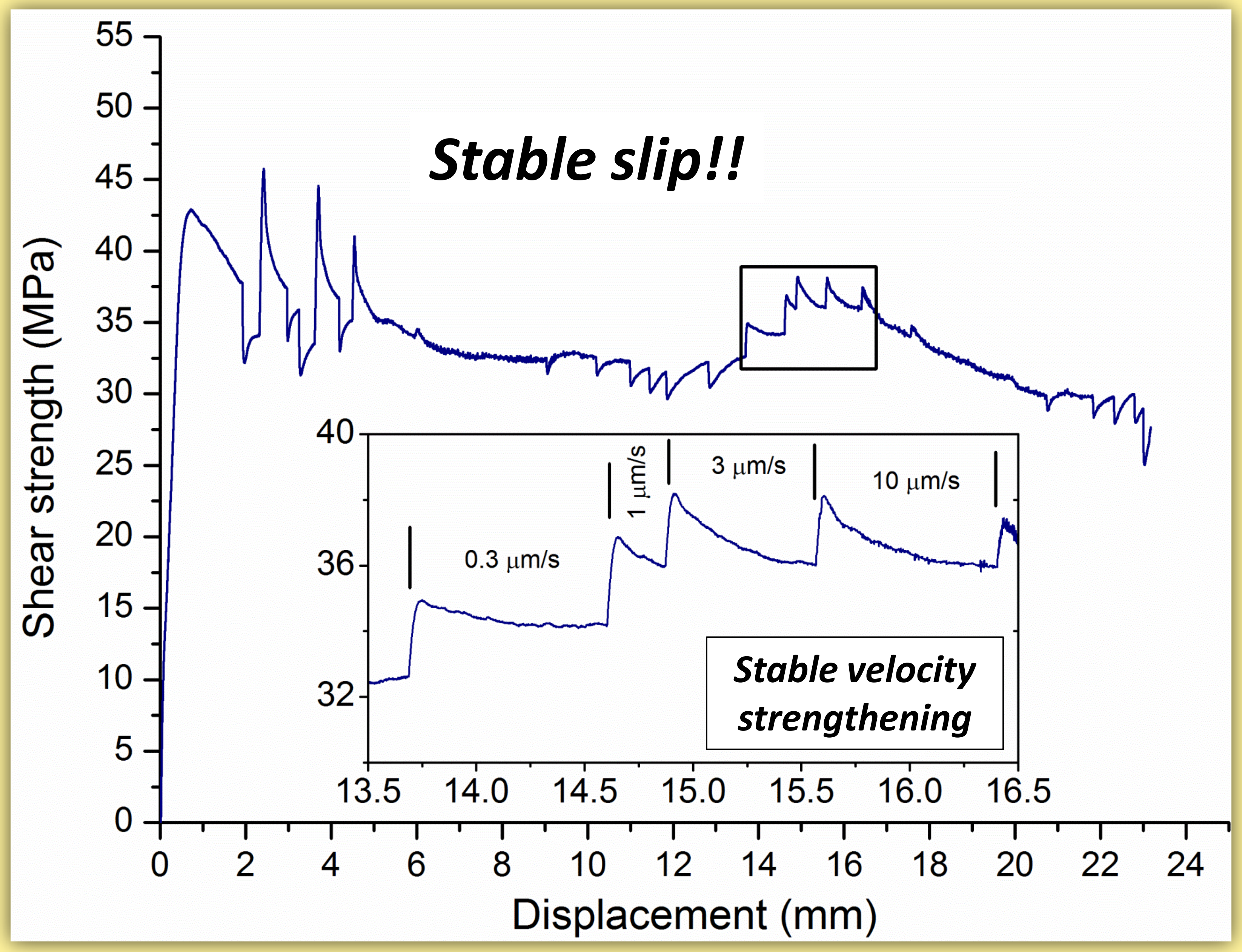
T = 100-550°C
Stress drops Δτ

Δτ↑, v↓



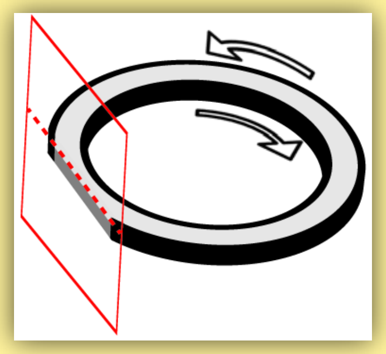
Stress drop increases with increasing T and decreasing v...

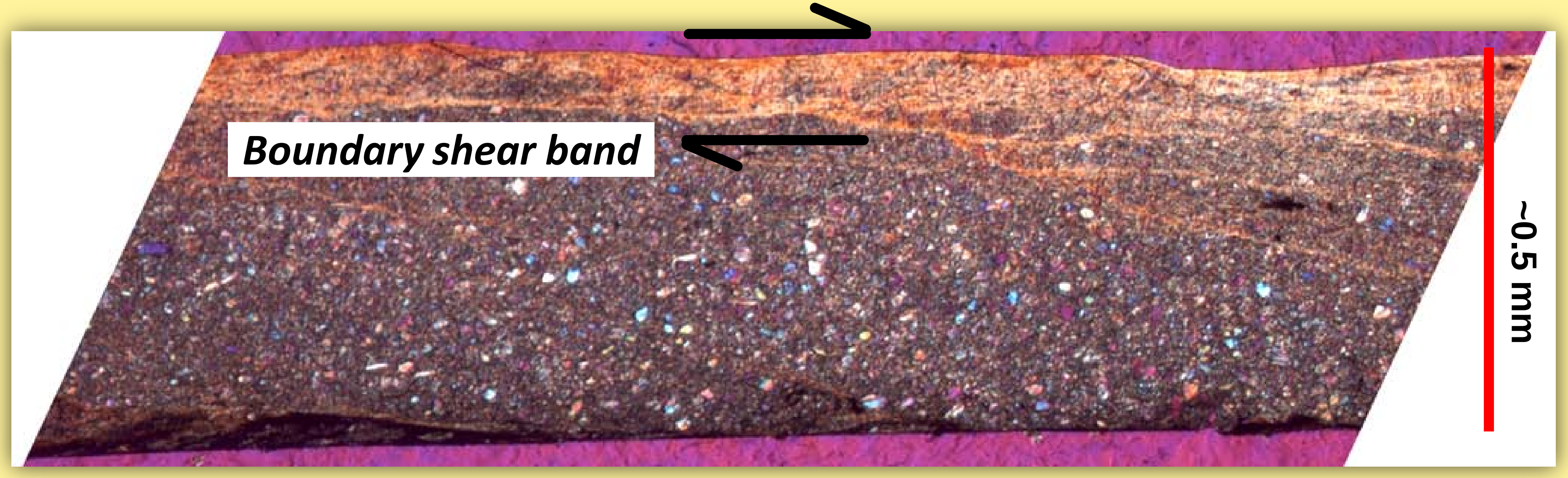
600°C



Stable slip!!
Shear strength (MPa)
Displacement (mm)
0.3 μm/s
1 μm/s
3 μm/s
10 μm/s
Stable velocity strengthening

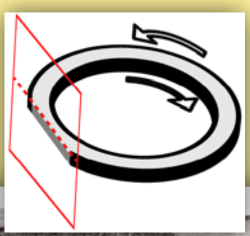
Microstructures: T ≤ 200°C

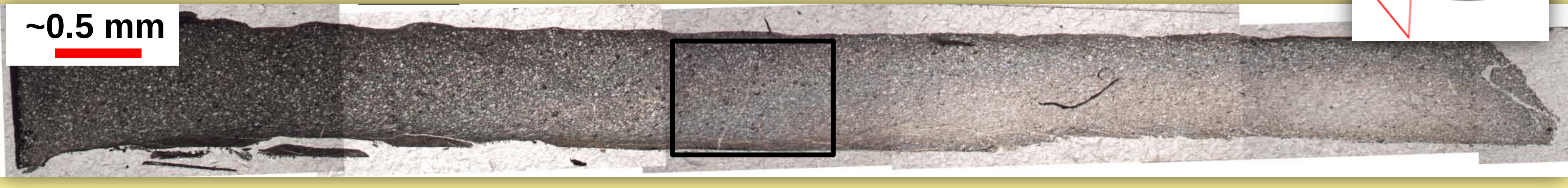




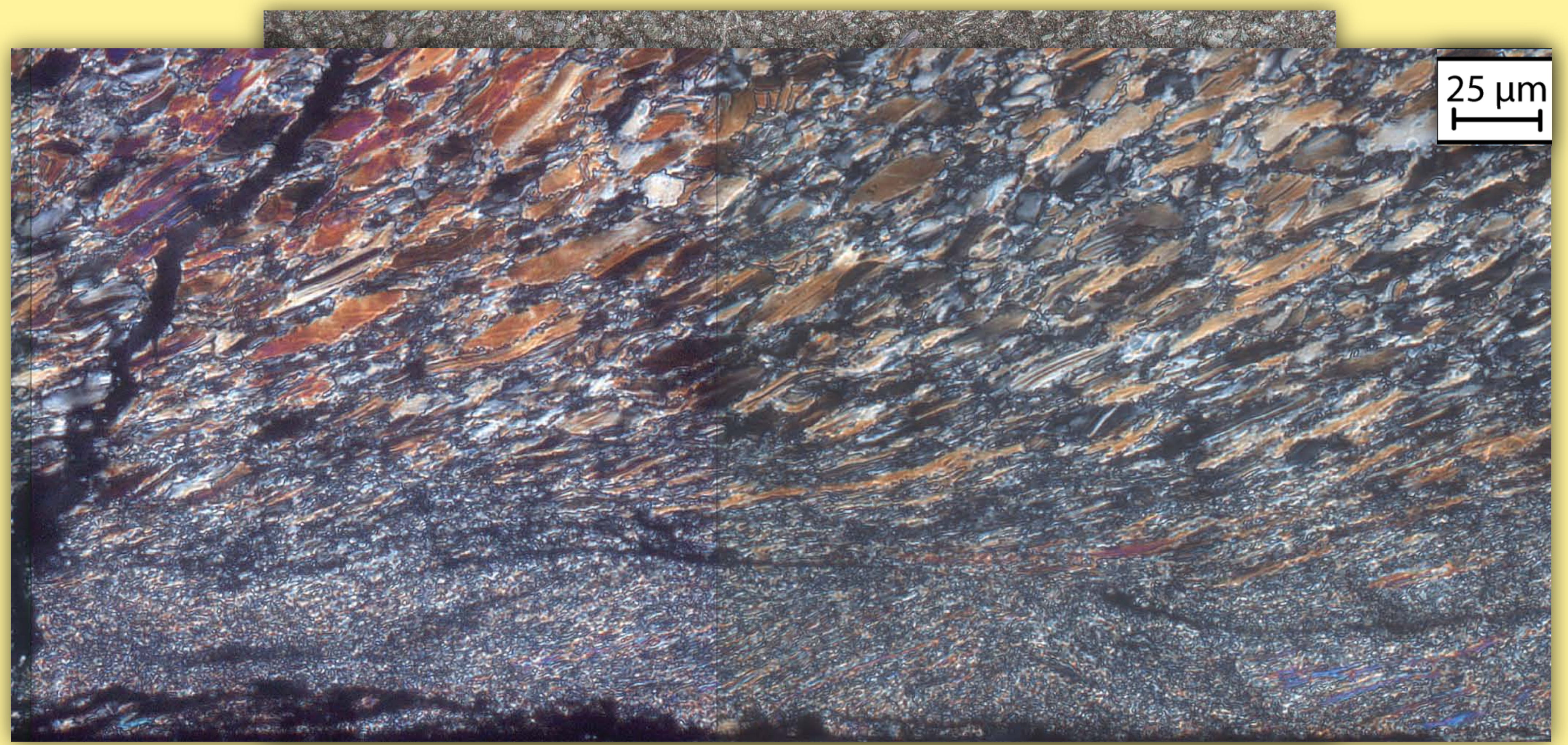
....Localized deformation....

400-550°C

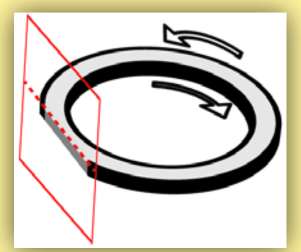


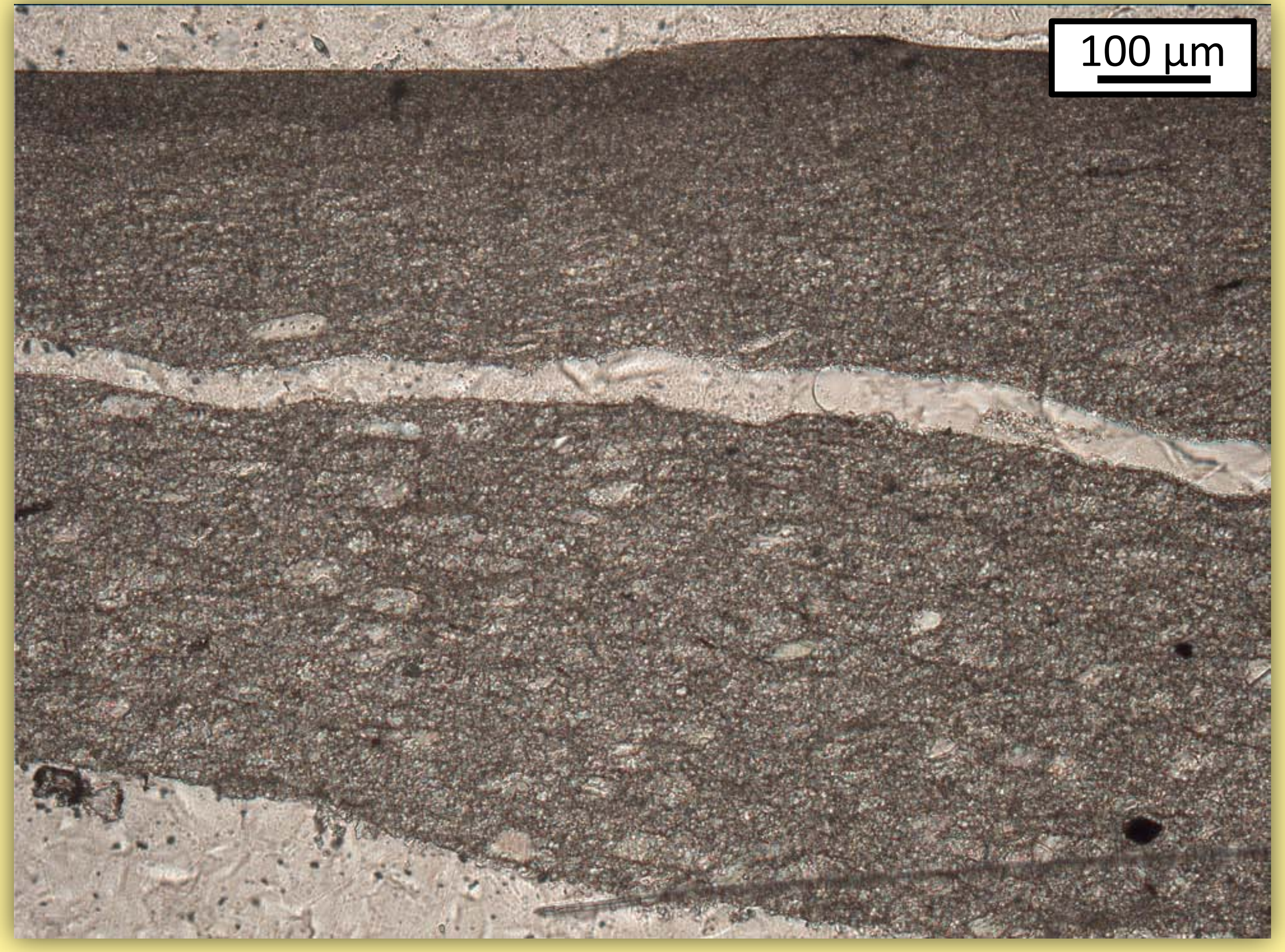


...plasticity of µm-sized matrix grains...



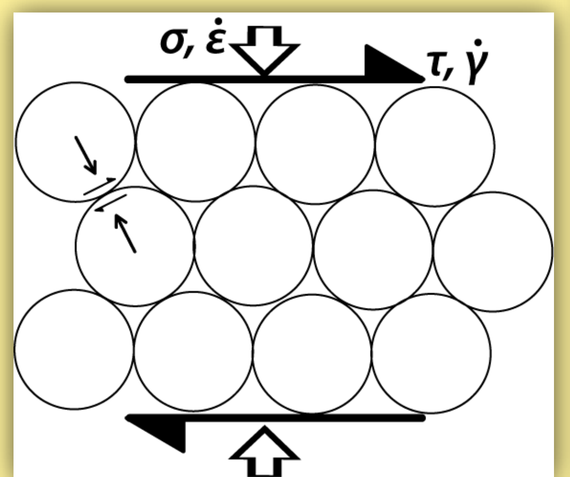
600°C (stable slip)

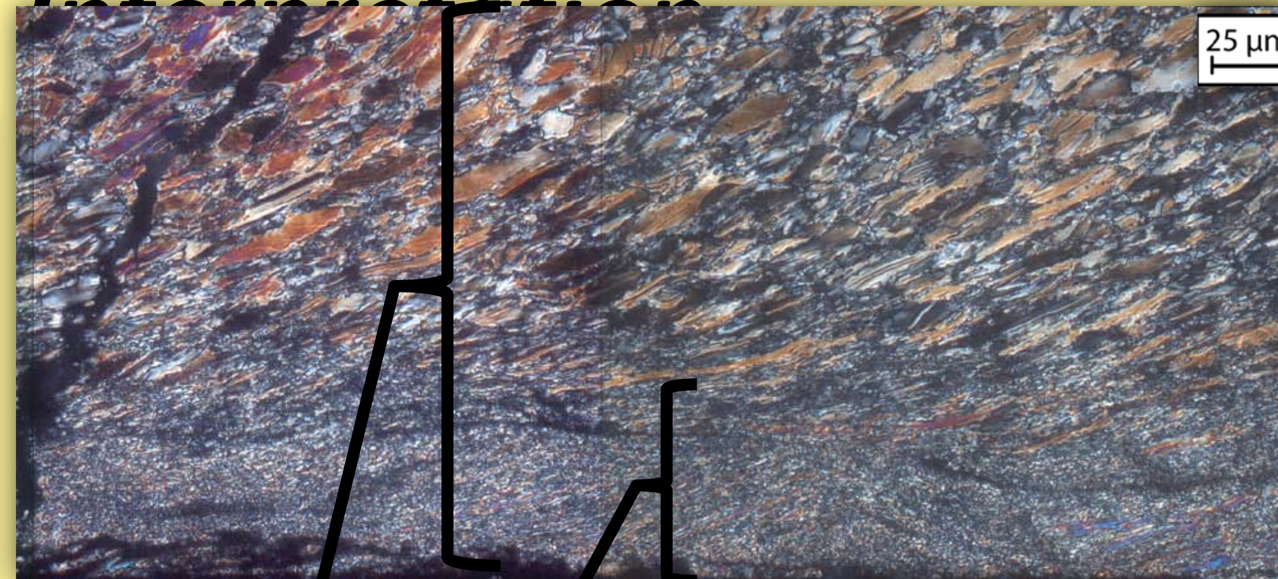


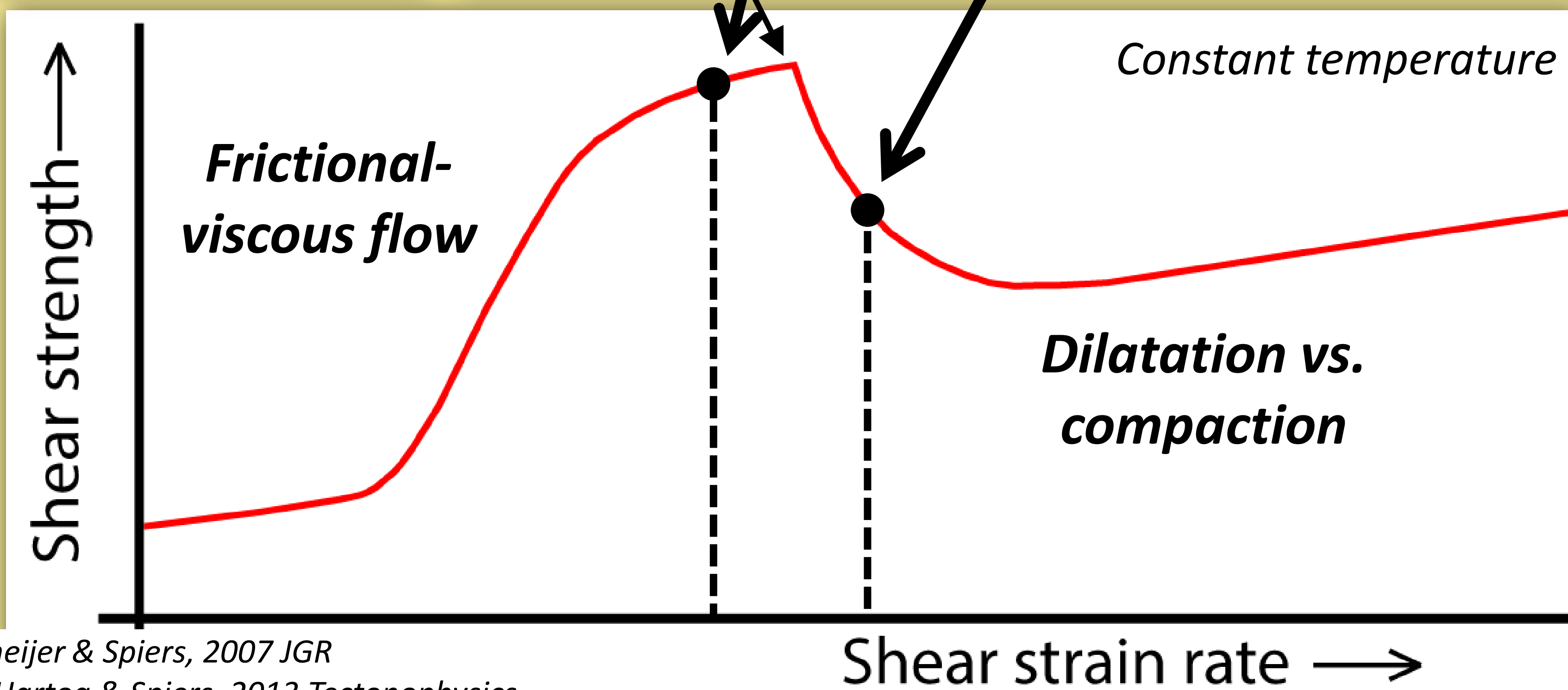


...distributed deformation...

Interpretation





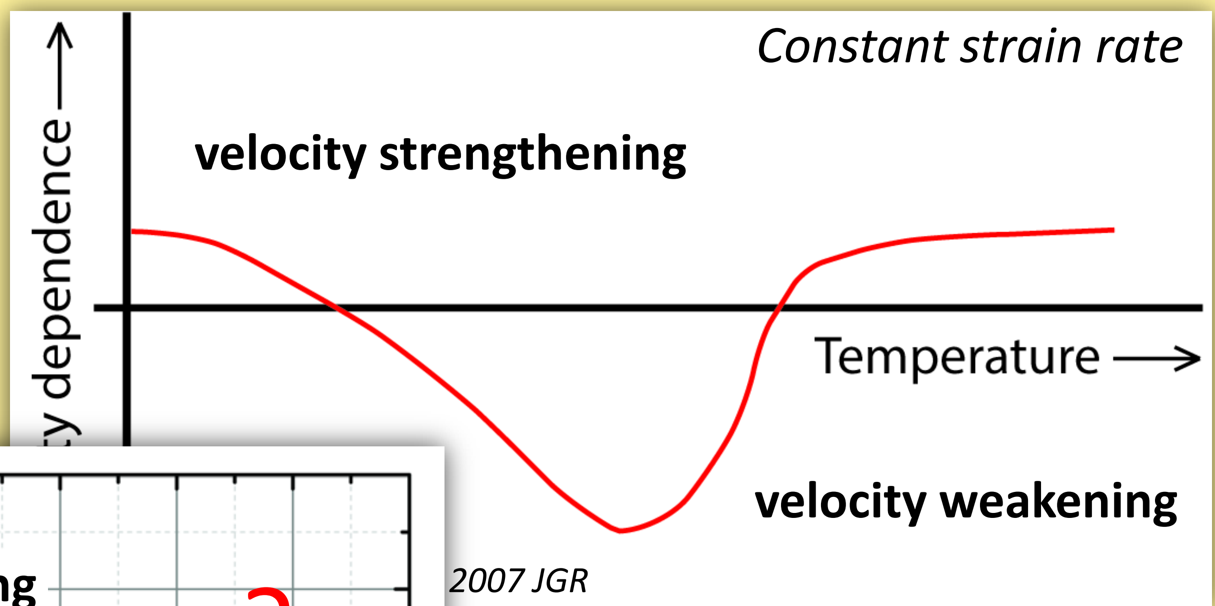


Niemeijer & Spiers, 2007 JGR
Den Hartog & Spiers, 2013 Tectonophysics

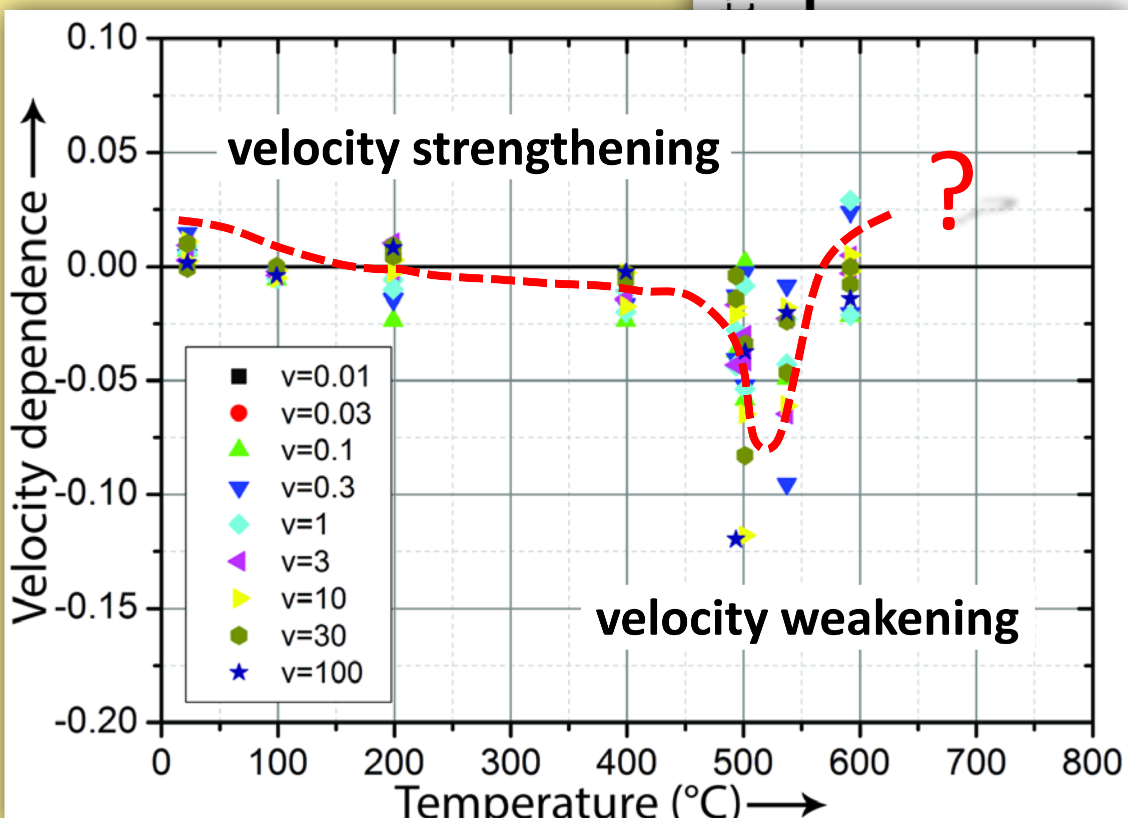
Interpretation

$$vel.dep. = \frac{\partial \mu}{\partial \ln(v)}$$

$$\approx \frac{\mu_2 - \mu_1}{\ln(v_2/v_1)}$$



2007 JGR
s, 2013 Tectonophysics



Our results are consistent with a model involving ***dilatation vs. compaction...***

Conclusions

- **Wet calcite fault gouge exhibits stable slip at 20°C, unstable slip at 100-550°C, and stable slip again at 590°C.**
- **The stress drop Δτ increases with increasing temperature and decreasing sliding rate.**
- **For T < 200°C, sheared gouge microstructures show localization. At 400-590°C, more distributed deformation (also) occurs.**
- **The results are consistent with a microphysical model involving a competition between dilatation vs. compaction.** *(cf. Niemeijer & Spiers, 2007 JGR)*

Thank you!