Antigorite deformation and dehydration-induced compaction

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European Geosciences Union Annual Meeting, 07 May 2020

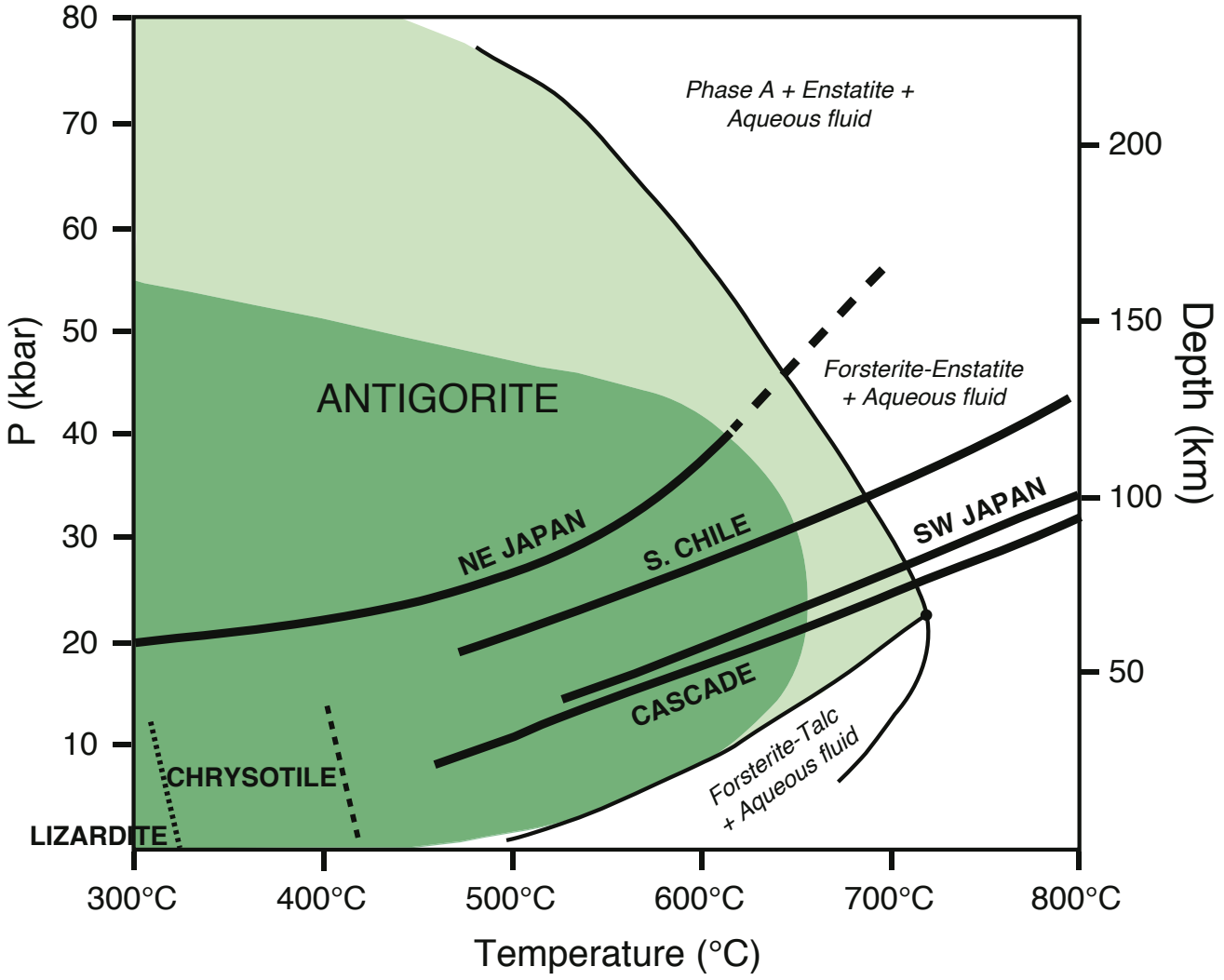
Funding

European Research Council

Established by the European Commission

Natural Environment Research Council

Antigorite in subduction zones



[Deschamps et al., 2013]

Key questions

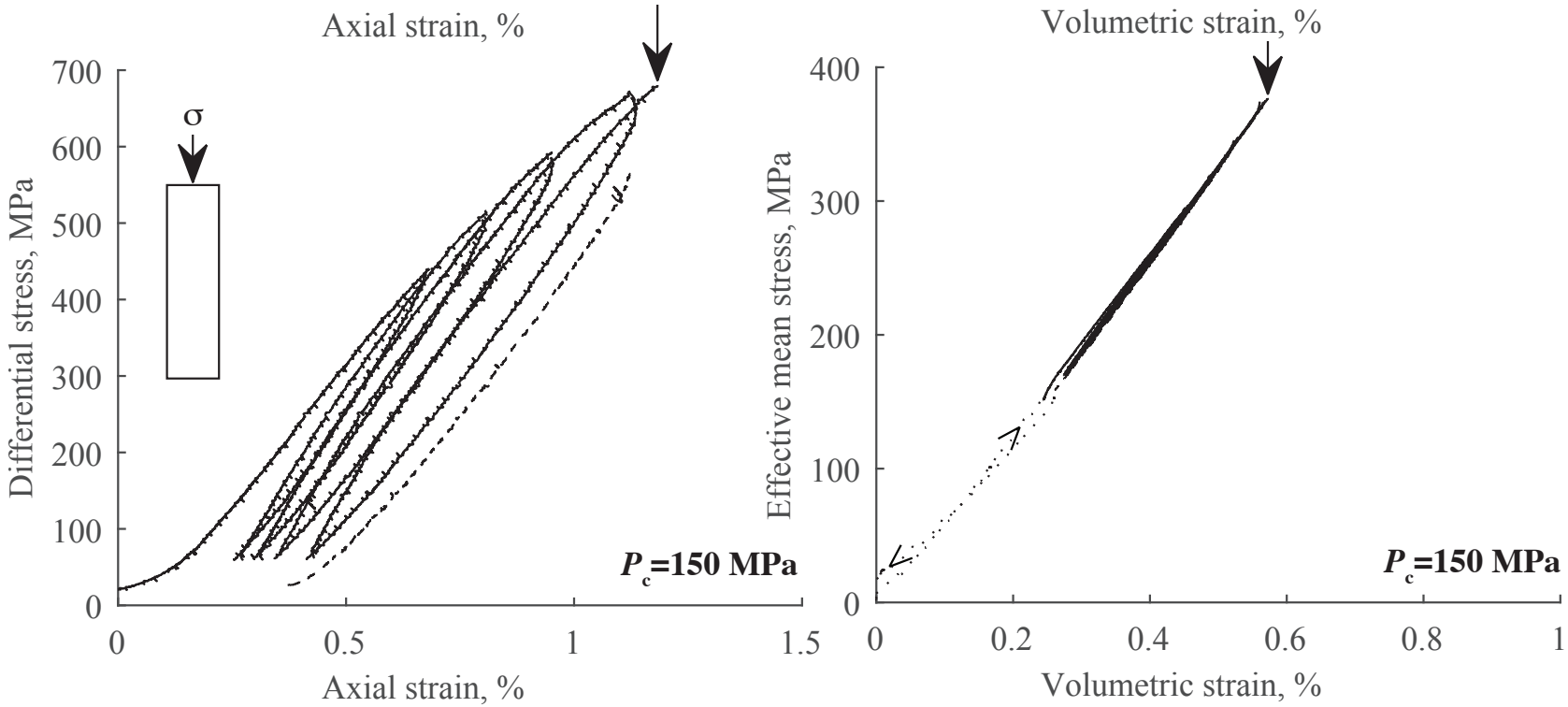
Deformation mechanisms and flow laws

- Major debate: **deformation mechanisms are poorly constrained** and extrapolations remain difficult (e.g., Hilairet et al., 2007; Jung et al., 2009; Chernak and Hirth, 2010; Amiguet et al., 2012).
- Antigorite is often referred to as **"semi-brittle"**.
- $\longrightarrow$ need to understand both the brittle and "ductile" regime.

Dehydration and earthquakes

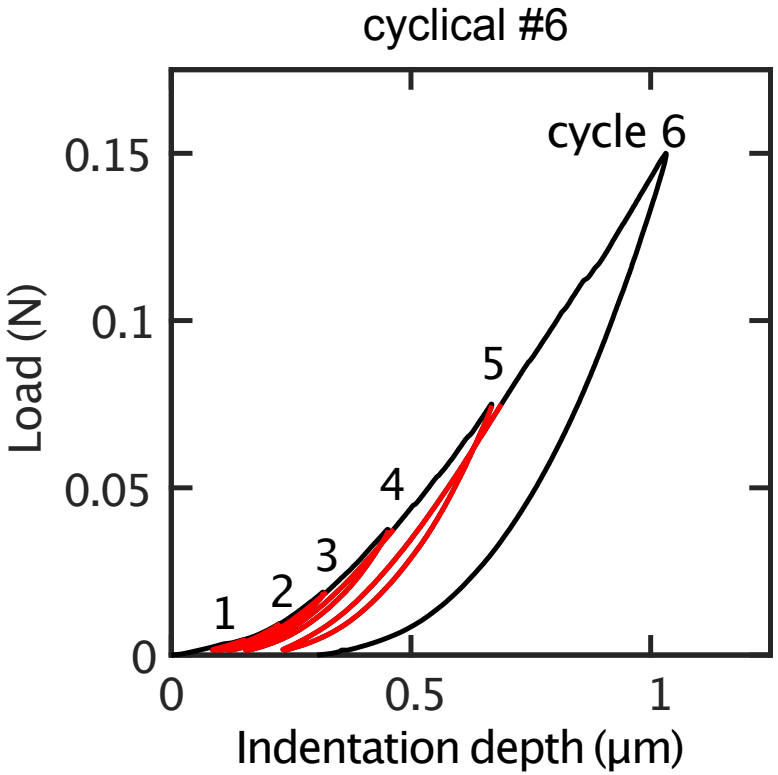
How is fluid pressure coupled to deformation when dehydration occurs at high pressure (when total volume change is < 0)?

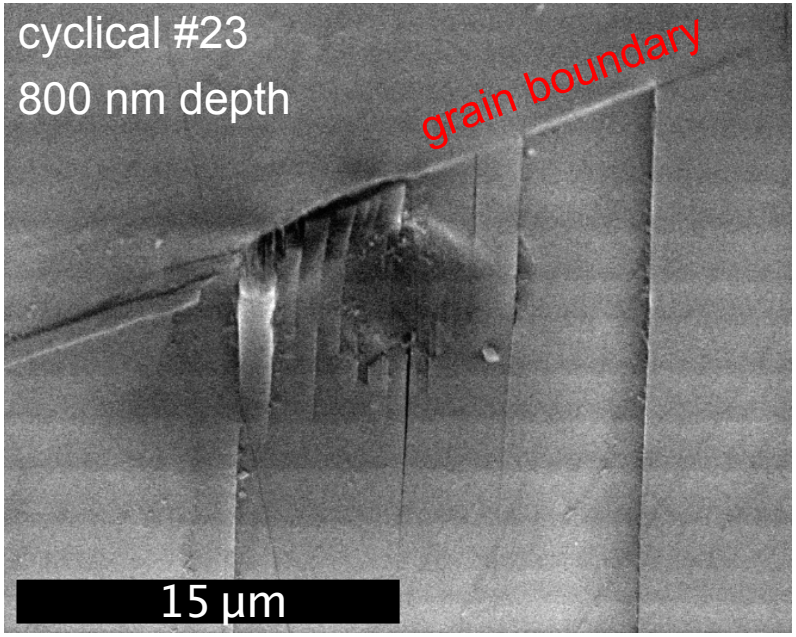
Brittle regime (low P, low T)



Shear dissipation but no volumetric dissipation. *Very different from other crystalline rocks.* [Escarìn et al., JGR 1997; David et al., JGR 2018]

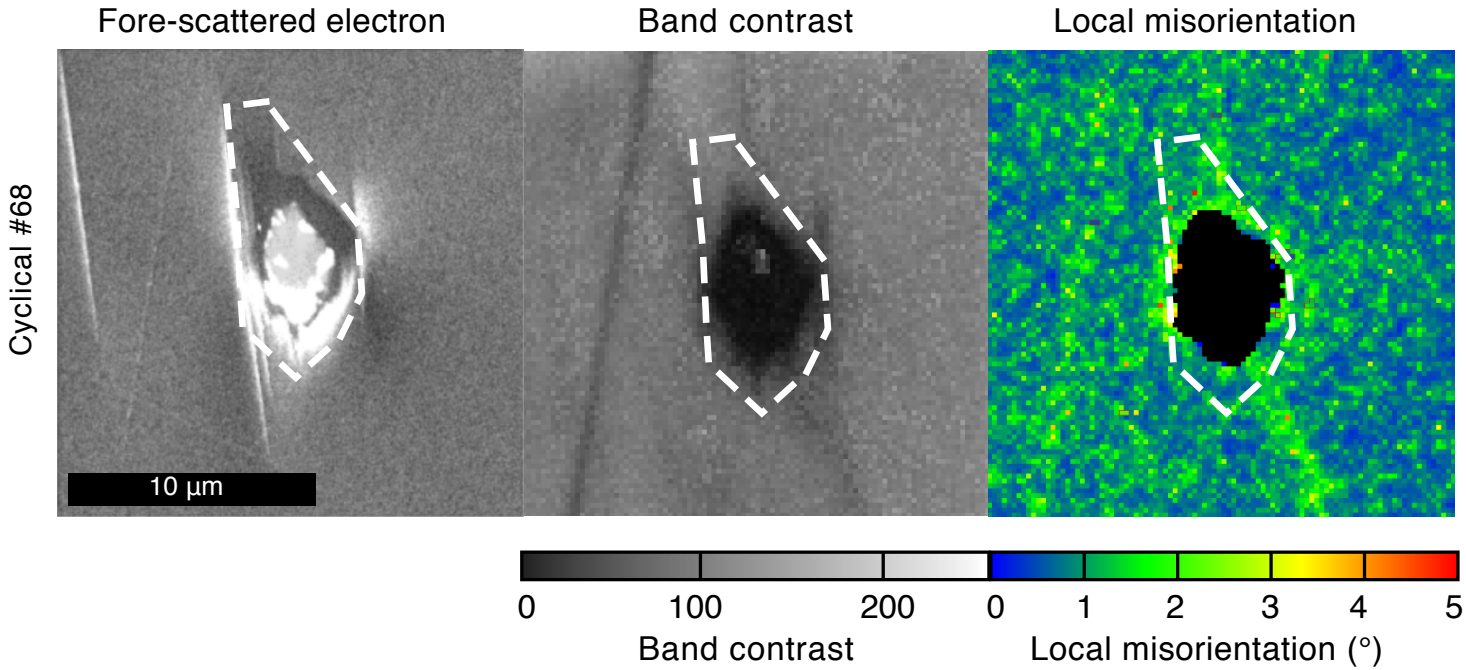
High pressure, low T (indentation)





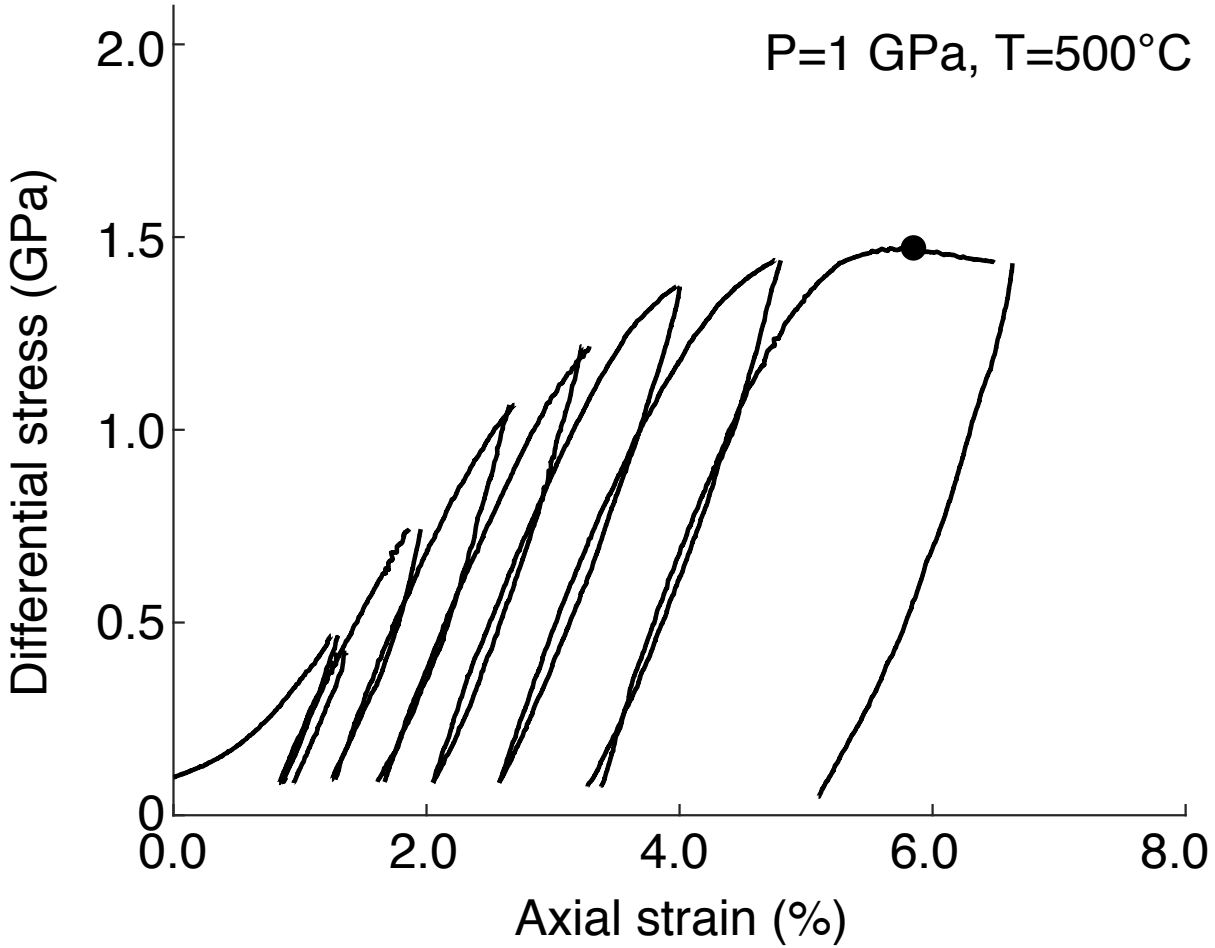
Shear dissipation also observed at grain scale. Delamination along basal planes. [Hansen et al., Proc. Roy. Soc. Lond. A 2020]

High pressure, low T (indentation)



Low apparent misorientation near indent → hard to see any dislocations. [Hansen et al., Proc. Roy. Soc. Lond. A 2020]

High pressure, high temperature



Shear dissipation and partial recovery of plastic strain, similar to low T regime. Compatible with internal sliding with T-dependent yield strength. [David, Brantut, Hirth, submitted]

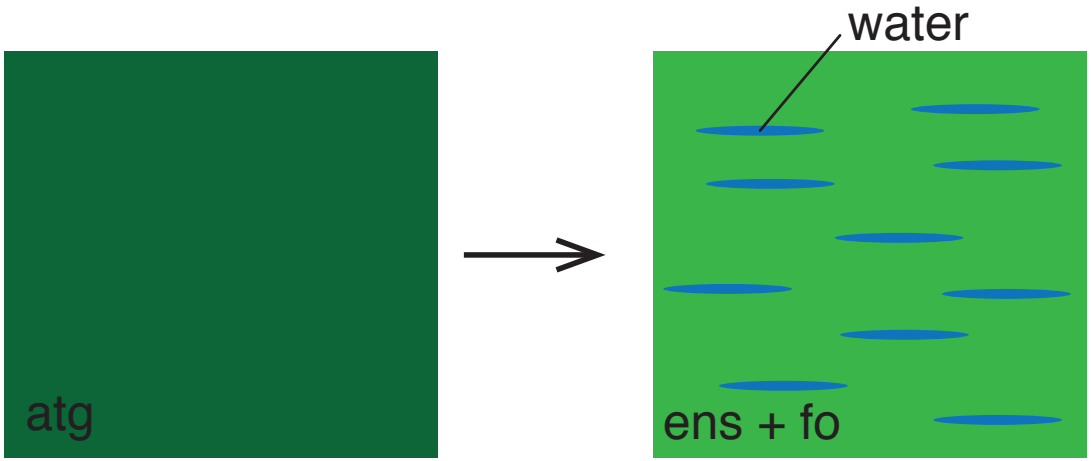
Deformation mechanism?

Key experimental observations:

- shear dissipation, little to no volume change,
- microstructures show intragranular delamination and kinking (+ see Amiguet et al., JGR 2014; Auzende et al., EPSL 2015),
- strain localisation at high T (+see Chernak and Hirth, EPSL 2010; Proctor and Hirth, JGR 2016),
- creep follows exponential laws (Burdette and Hirth, AGU 2019),
- no direct evidence for dislocation motion (+ see Idrissi et al., JGR 2020).

→ Compatible with intragranular sliding, limited by "friction" – perhaps no dislocations strictly speaking?. **semi-brittle flow**.
→ Flow law still uncertain. How to extrapolate?

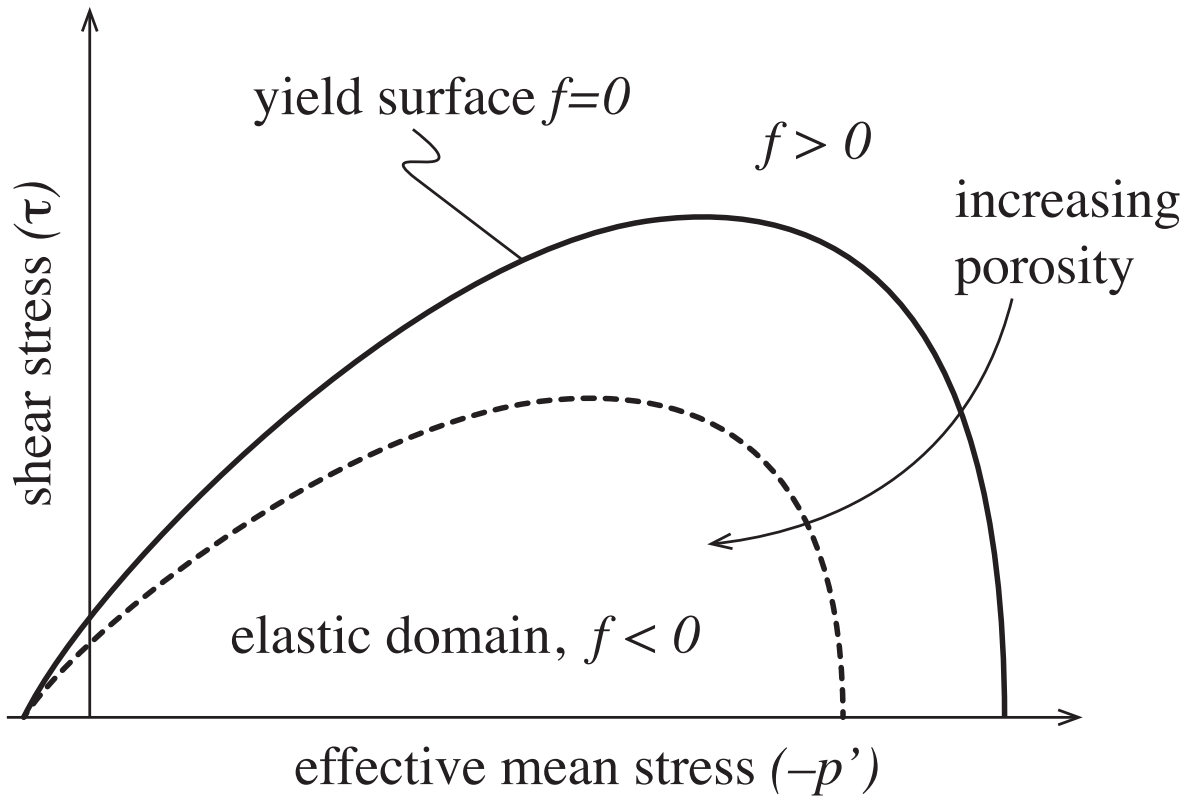
Dehydration and compaction: concept



At $P > 2$ GPa, generated pore volume $>$ generated fluid volume $\longrightarrow$ fluid pressure should decrease (if nothing else happens).

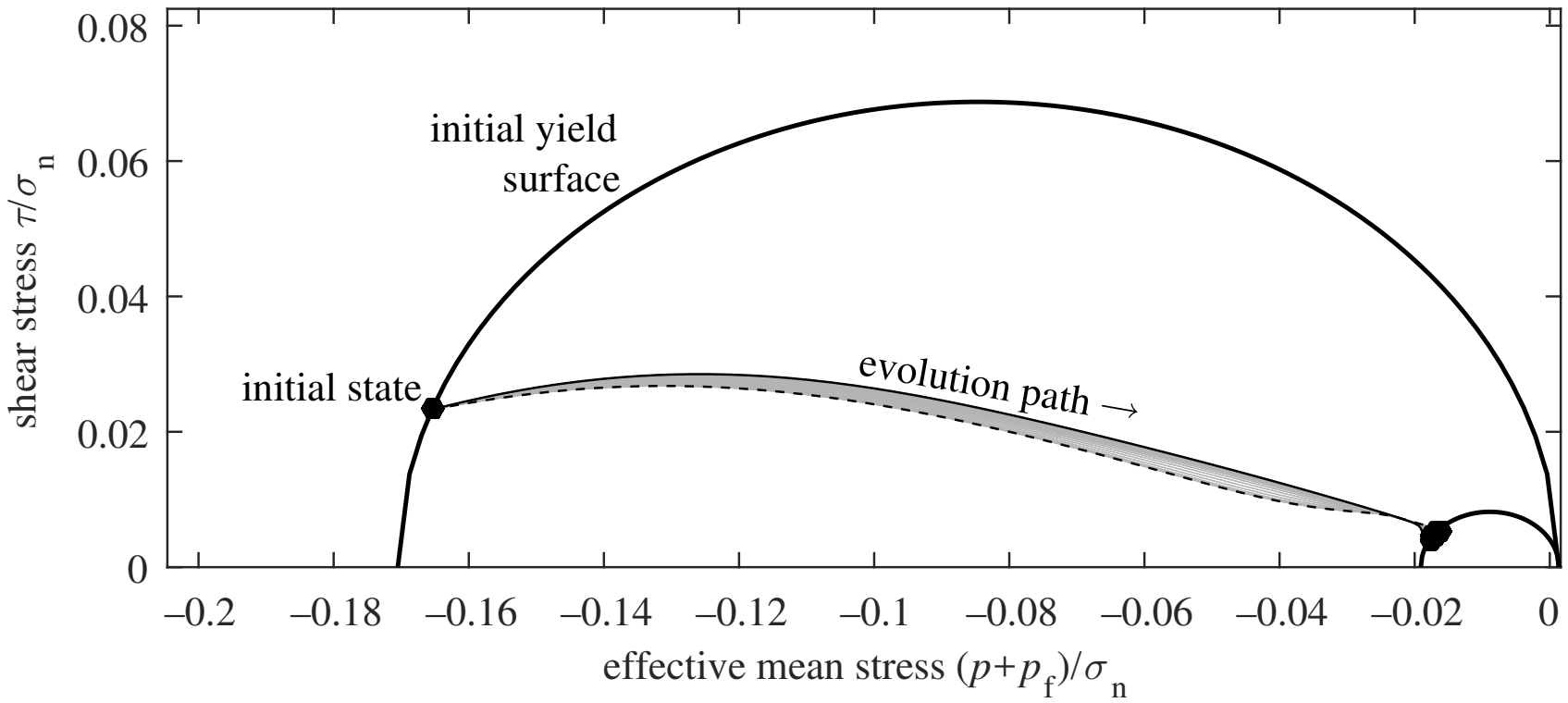
Dehydrated serpentinite as a porous aggregate

Antigorite is semi-brittle. When dehydration occurs, porosity is created and should compact (like in a sandstone).



Dehydration and compaction: instability

If aggregate strength degrades *enough* with increasing porosity, fluid pressure grows exponentially (analogue to porosity-wave mechanism, but time-independent rheology used).



Any sublithostatic fluid pressure (and elevated shear stress!) will quickly vanish. Strain rate scales with reaction rate. [Brantut, Stefanou, Sulem, JGR 2017]

Antigorite is unusual

Deformation

- Nondilatant in the brittle regime,
- Dominated by (intragranular?) sliding,
- Decrease in "internal friction" with increasing T: induces localisation?
- Lack of independent deformation mechanisms at crystal scale: mostly semi-brittle. Role of pressure solution in natural conditions?
- How to reconcile lab data with natural observations?

Dehydration

- At high pressure, fluid pressure rises rapidly (unstably) due to compaction,
- Dehydrated zones $\sim$ weak inclusions+sources of pore pressure $\rightarrow$ stress redistribution (Rutter et al., JSG 2007; Ferrand et al., 2017)

Perspectives

Rheology

We still do not have a rheology: is there a steady-state microstructure?
Effects of fluids: pressure solution might be critial, but hard to test in the lab.

Subduction zone dynamics

Brittle processes might dominate subduction interface, but not detectable by seismic methods (no dilation + no anomalous attenuation [not shown here])
Dehydration embrittlement might be triggered by unstable compaction.