

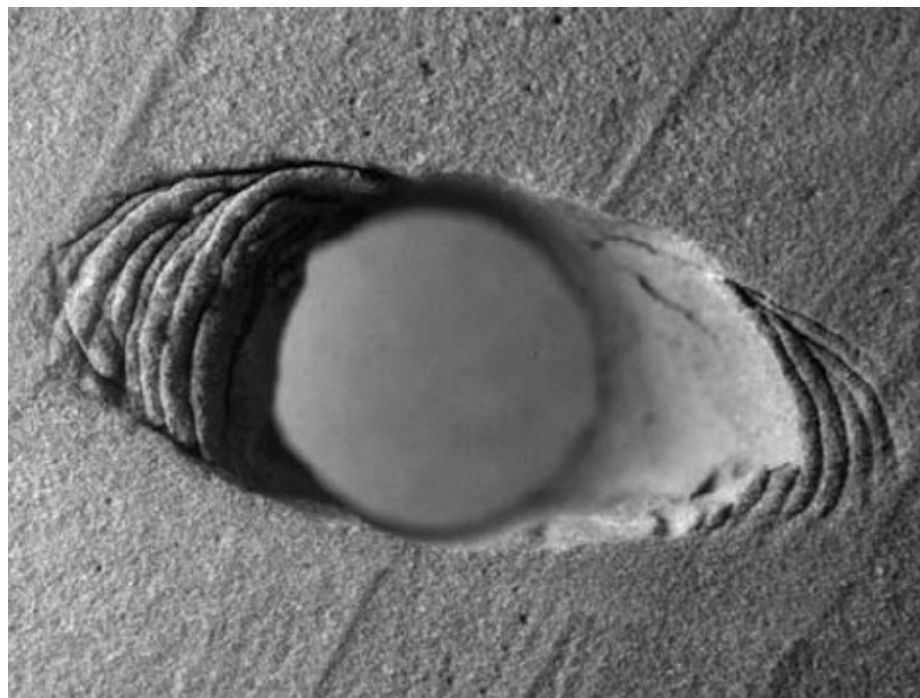
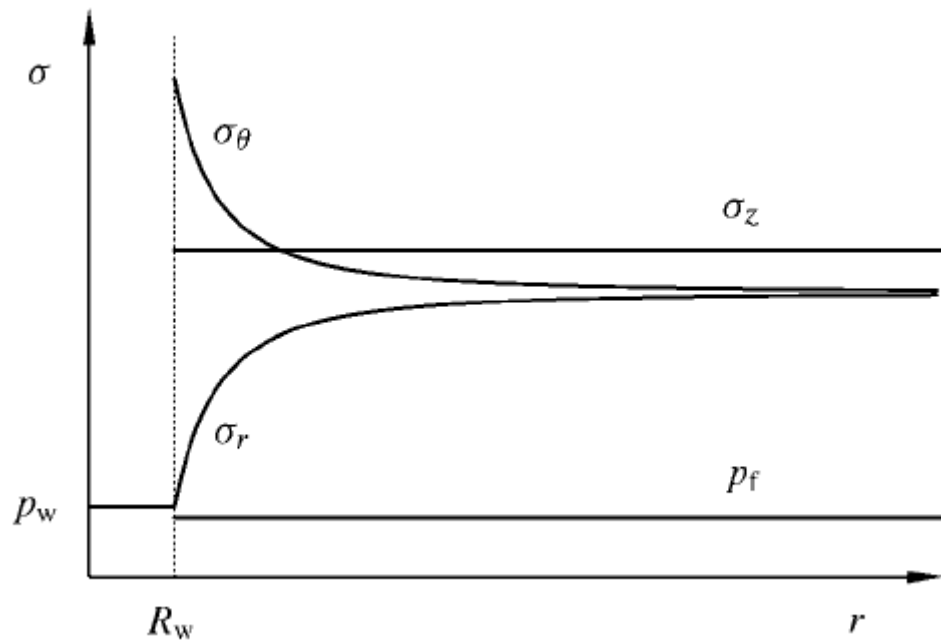
The transition from elastic to non-elastic rock behaviour

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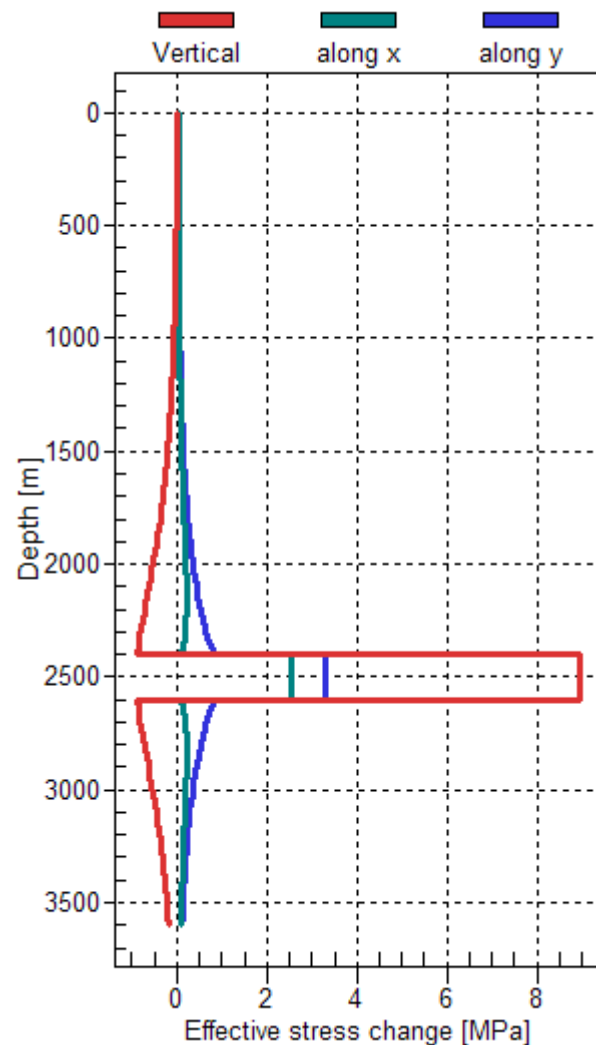
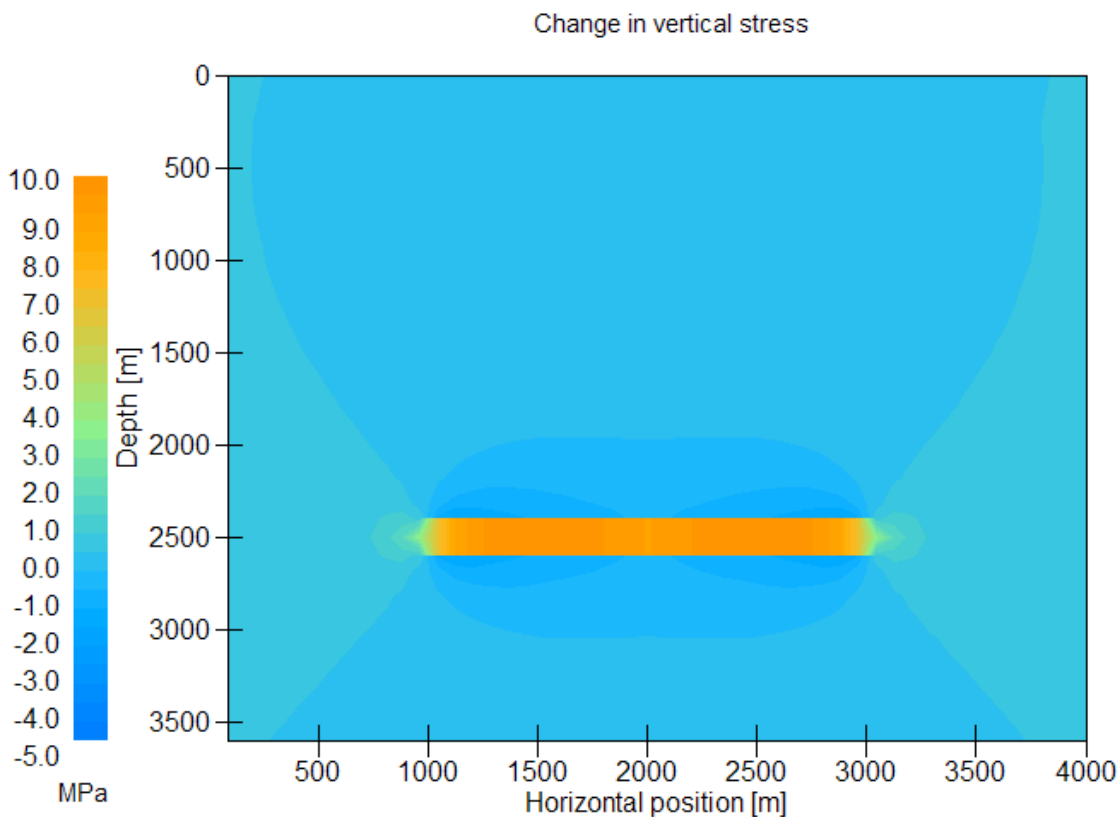
ROSE Seminar, April 19, 2010, Trondheim

In field situations,
we expose rocks to stress changes
varying from zero to failure stress



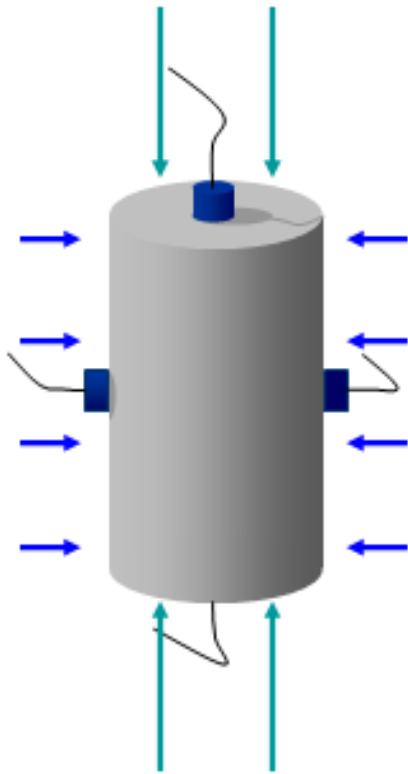
At which level do we start
to inflict damage on the rock?

In field situations,
we expose rocks to stress changes
varying from zero to failure stress



At which level do we start
to inflict damage on the rock?

Can we learn something from laboratory tests?



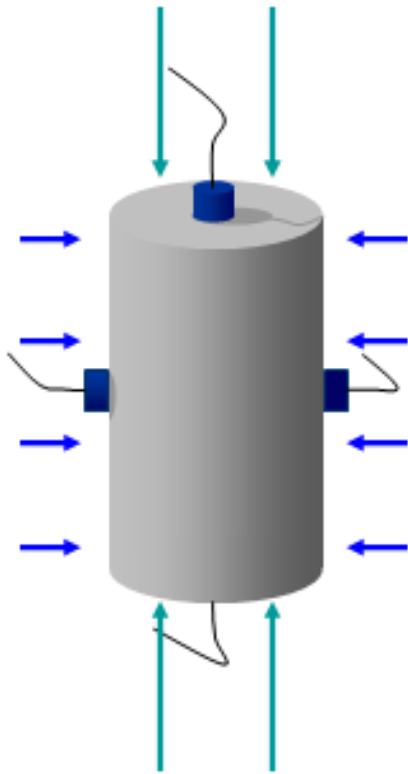
Simultaneous measurements of

static moduli $H = \frac{\Delta\sigma_z}{\Delta\varepsilon_z}$

and dynamic moduli $H_e = \rho V_{P,z}^2$

We consider the non-elastic compliance $\frac{1}{H} - \frac{1}{H_e}$
as a measure of damage

Can we learn something from laboratory tests?



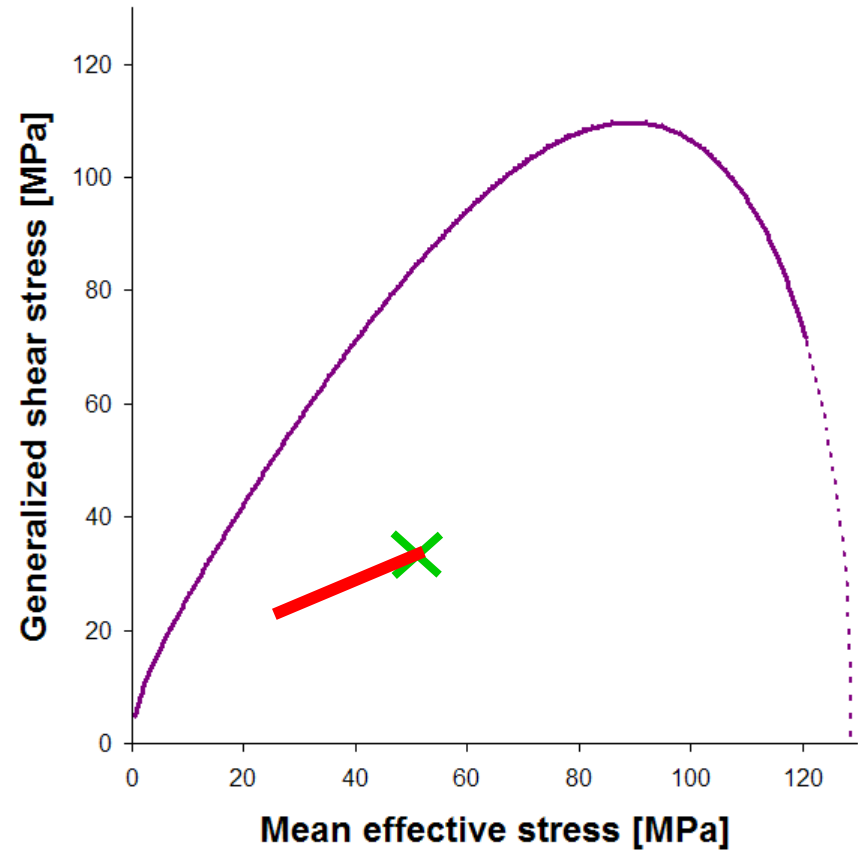
Test material: Dry Castlegate sandstone

29% porosity - 70% quartz, 30% feldspar, no clay

Stress paths

In the field:

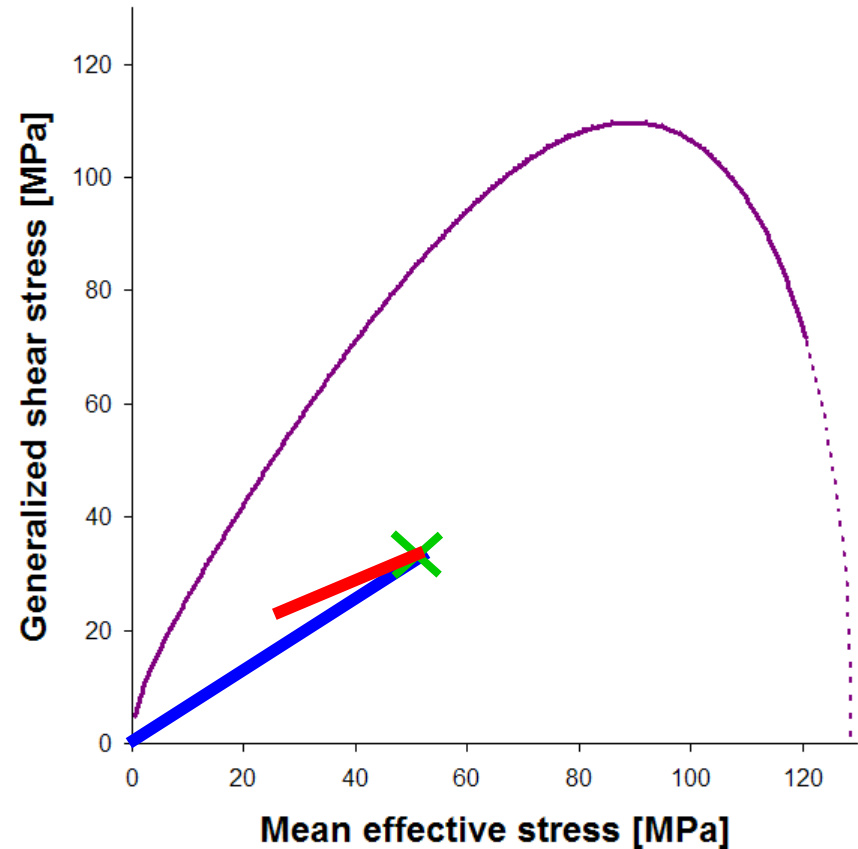
Stress changing
from its in situ state



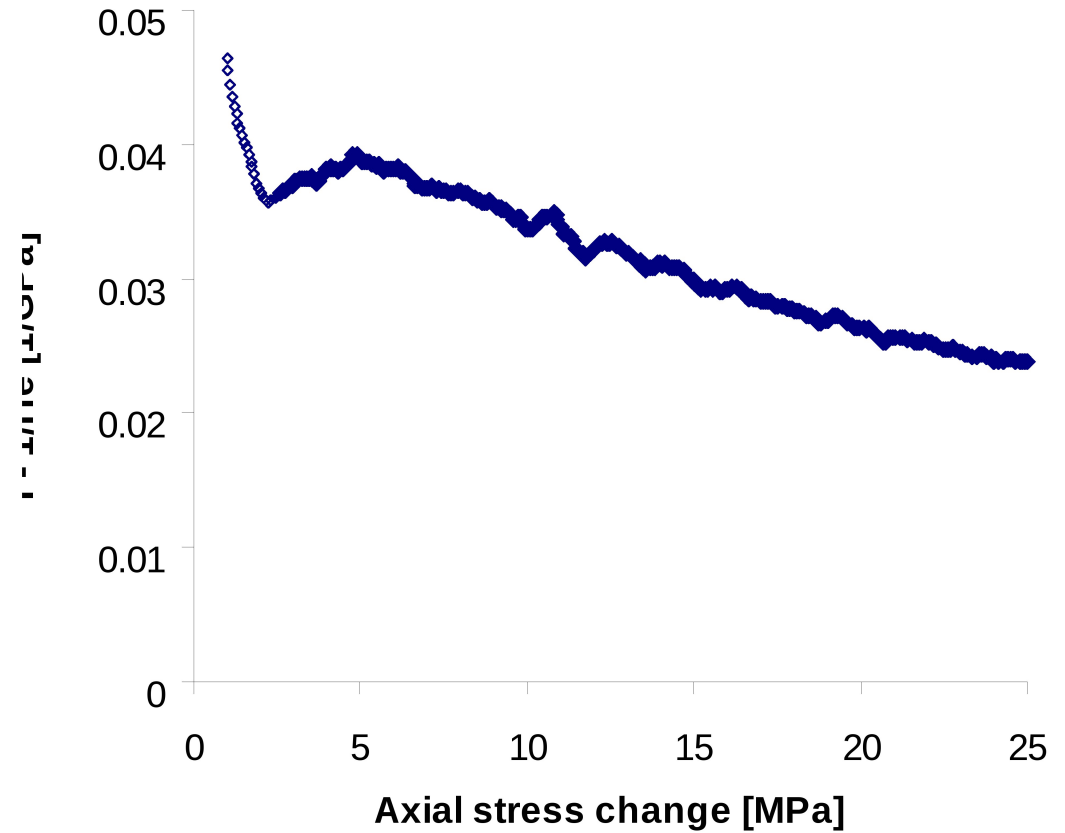
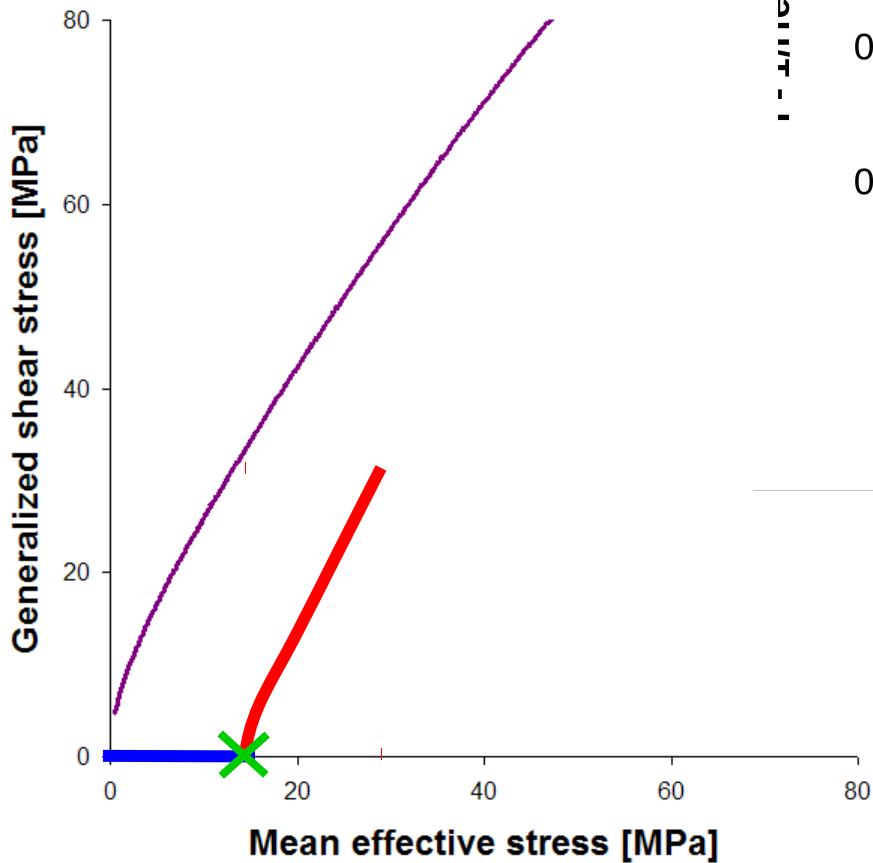
Stress paths

In the lab:

We consider what happens when the stress path makes a turn

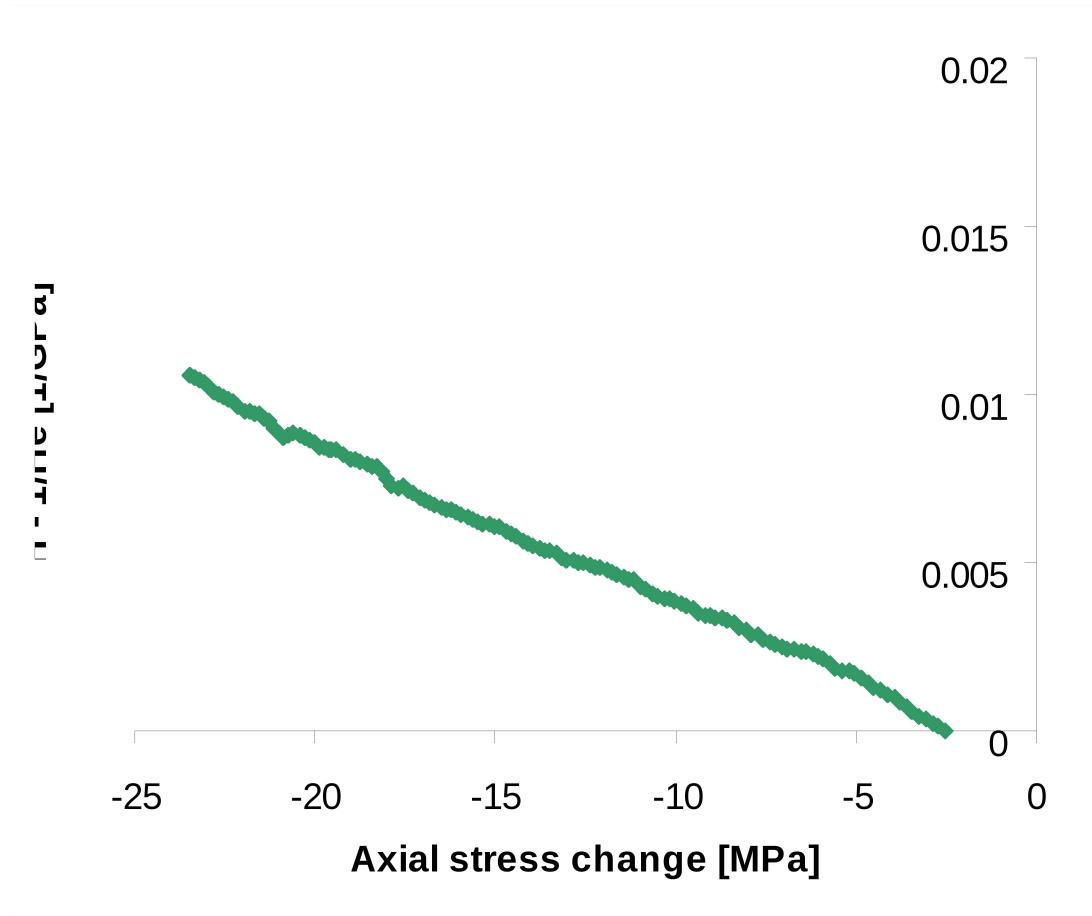
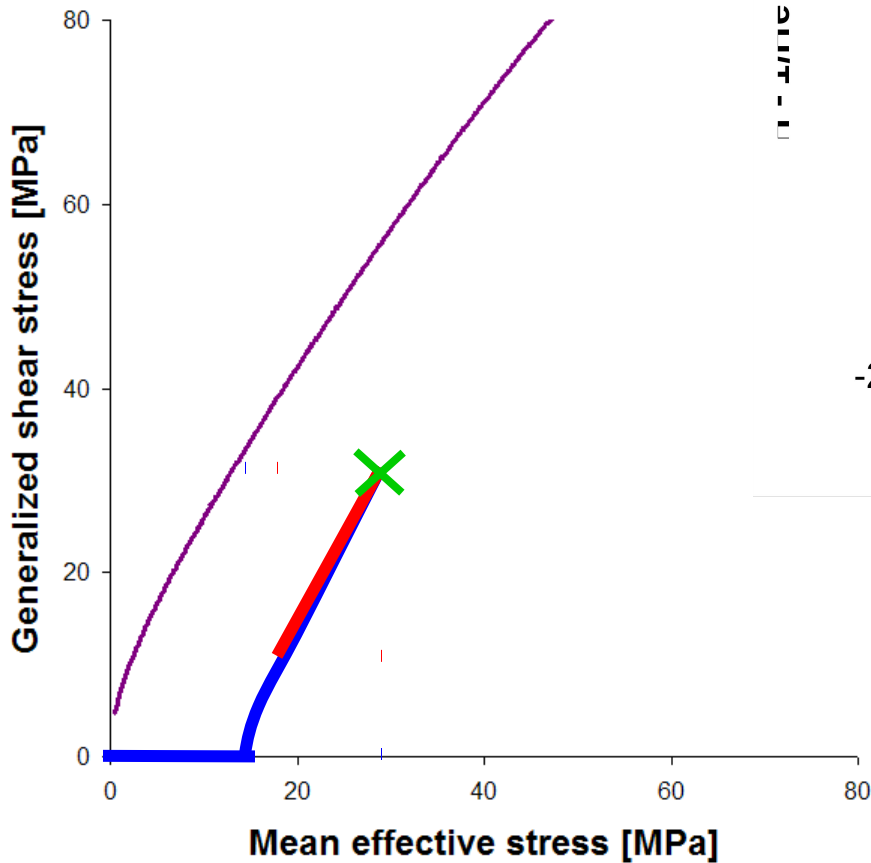


From hydrostatic loading to uniaxial compaction (K_0)



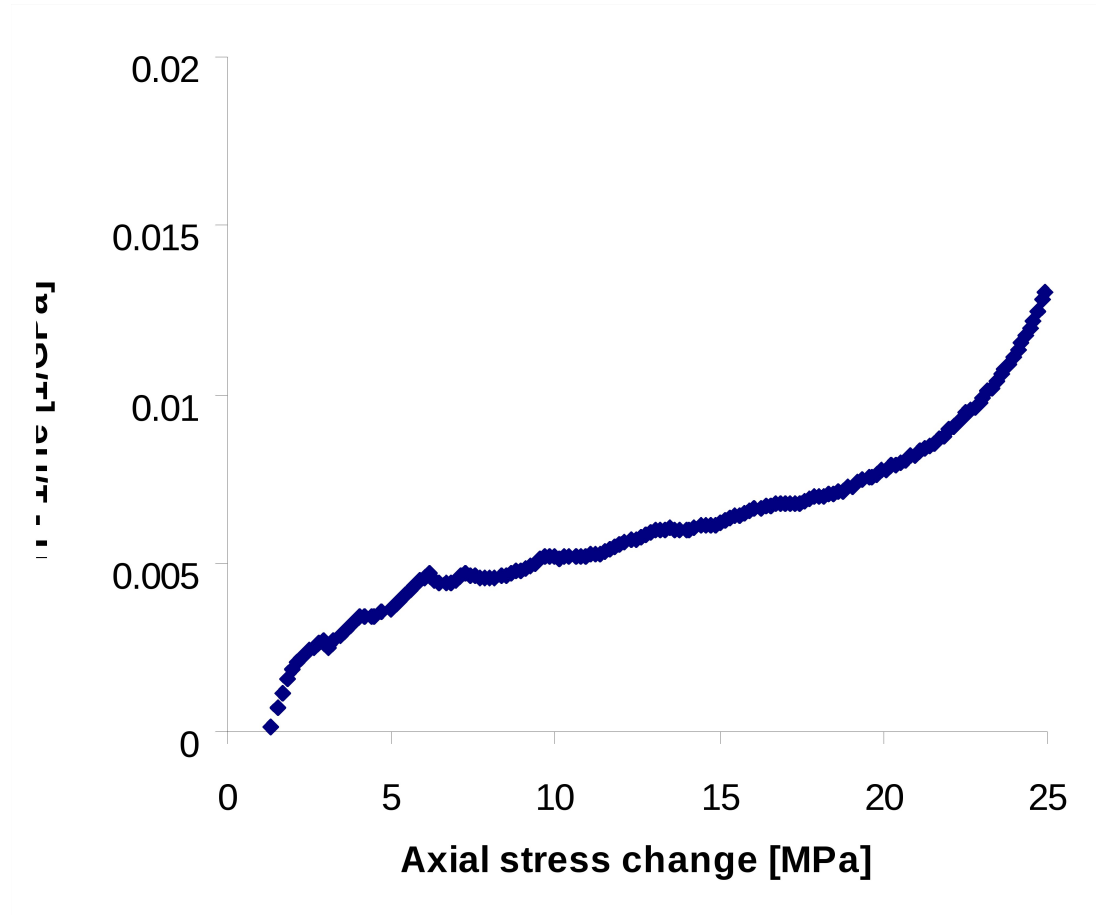
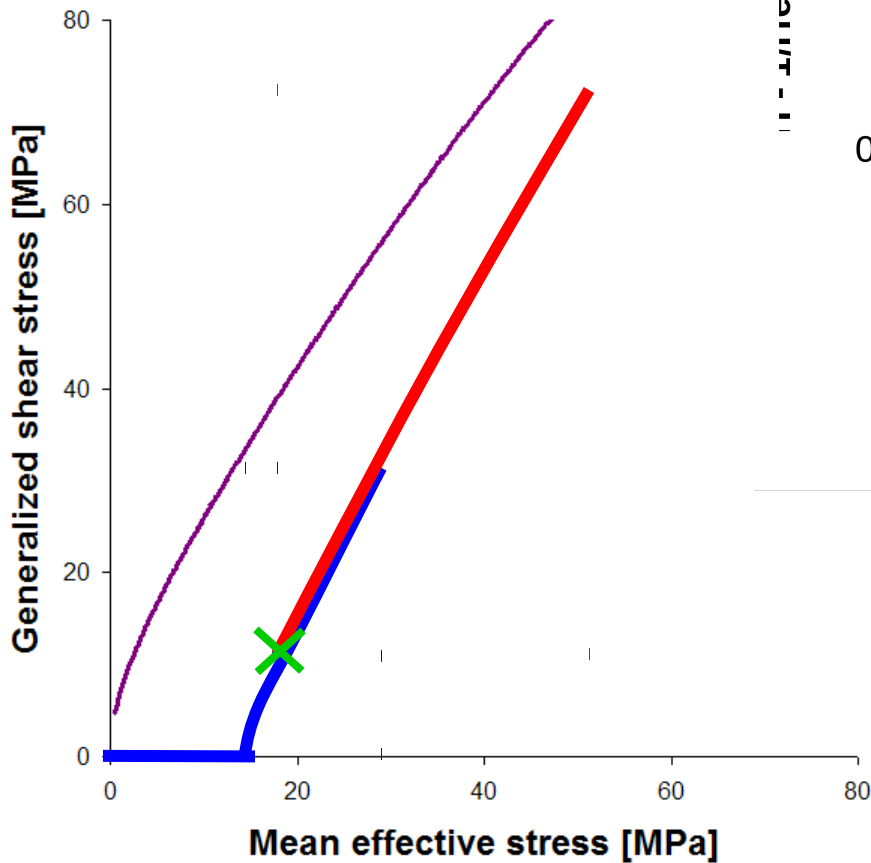
Non-elastic compliance reaches full size (almost) immediately

From K_0 loading
to K_0 unloading



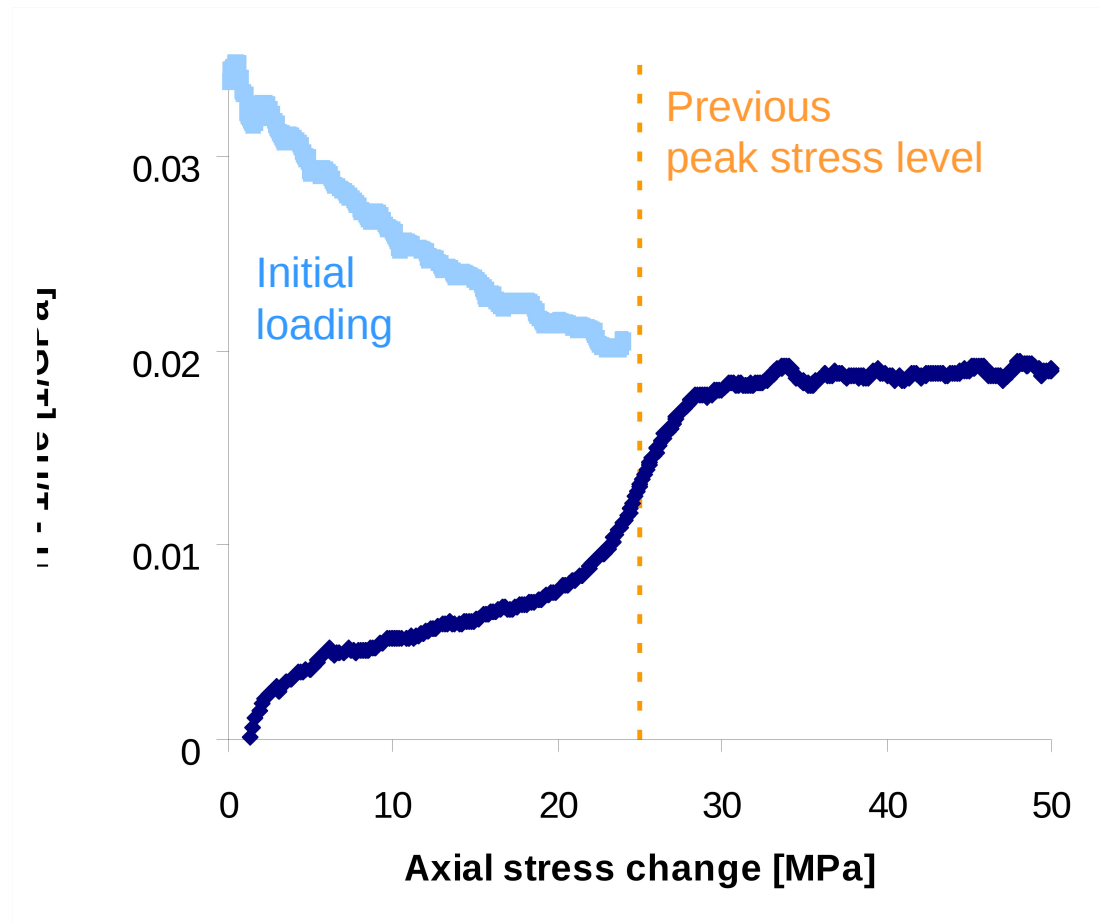
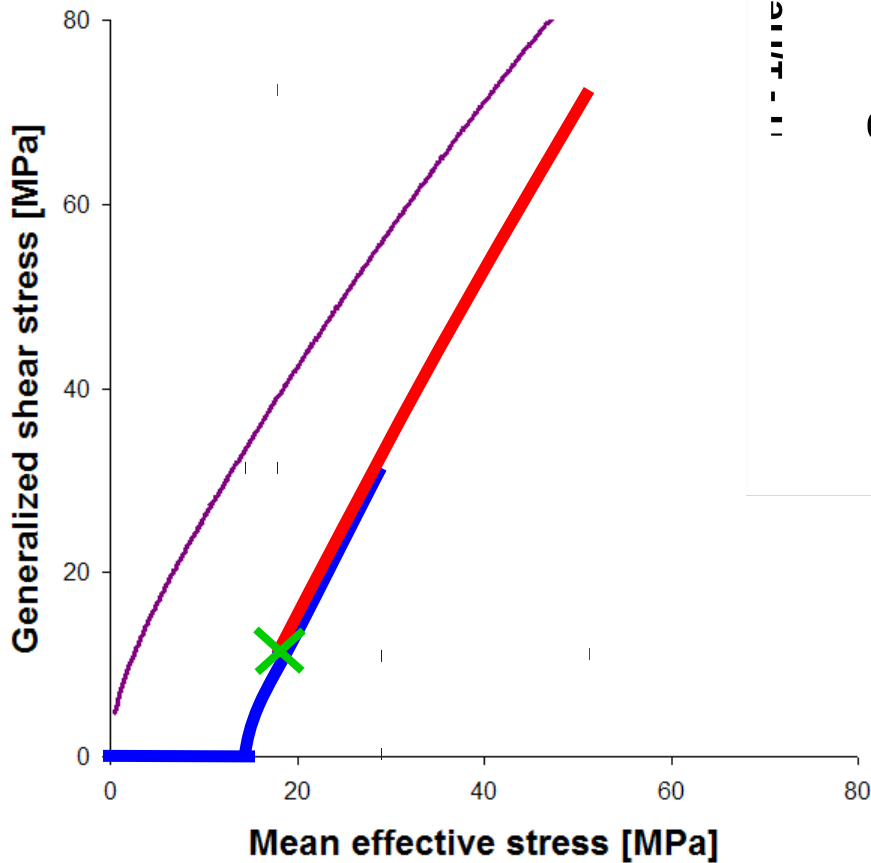
Non-elastic compliance increases linearly with stress change

From K_0 unloading
to K_0 reloading



Non-elastic compliance increases slowly (starting at a finite value?)

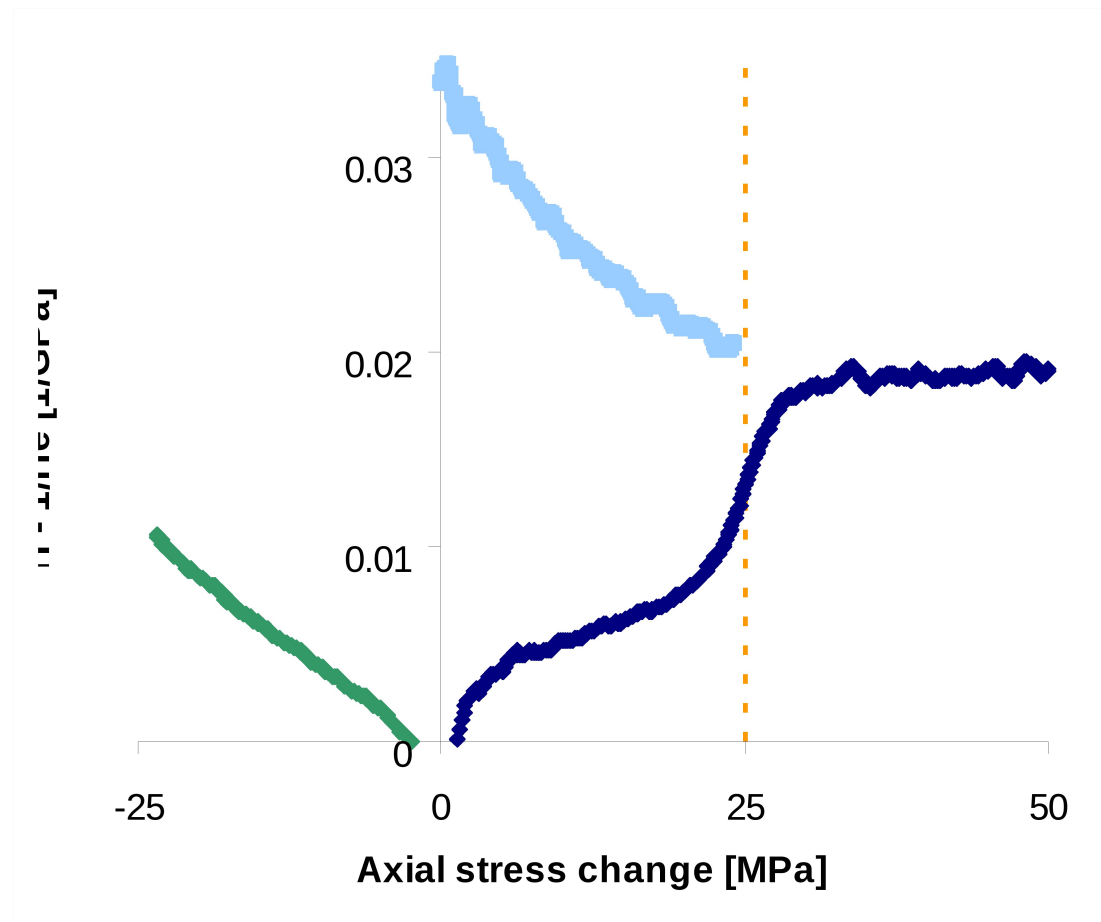
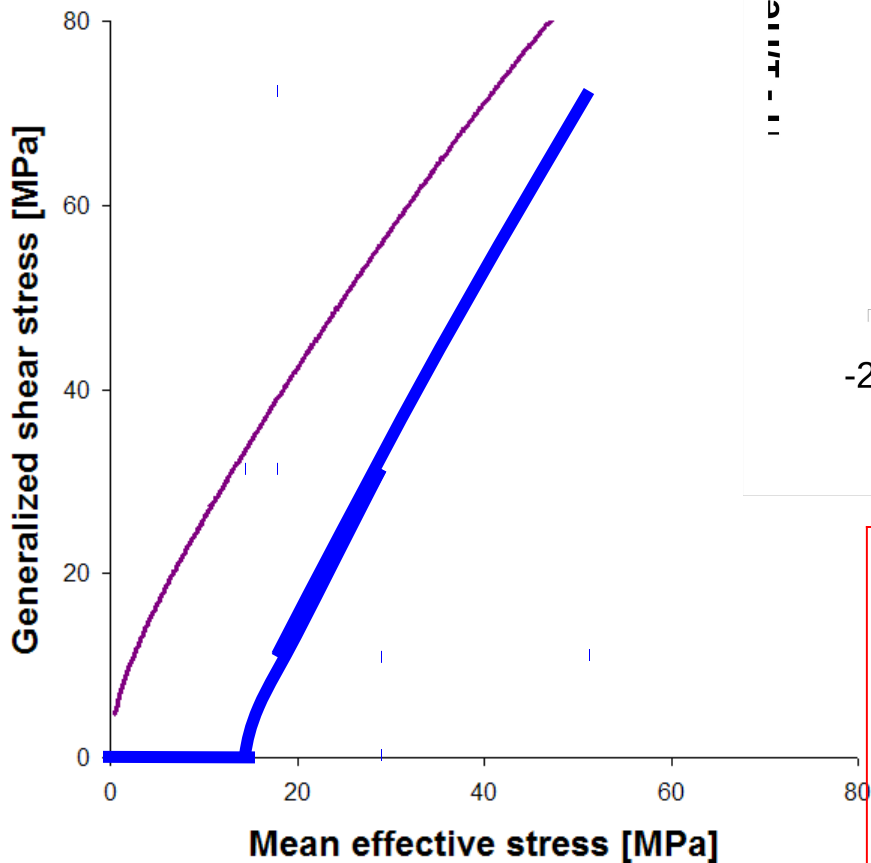
From K_0 unloading
to K_0 reloading



Non-elastic compliance reaches
initial level above previous
peak stress

Stress memory effect!

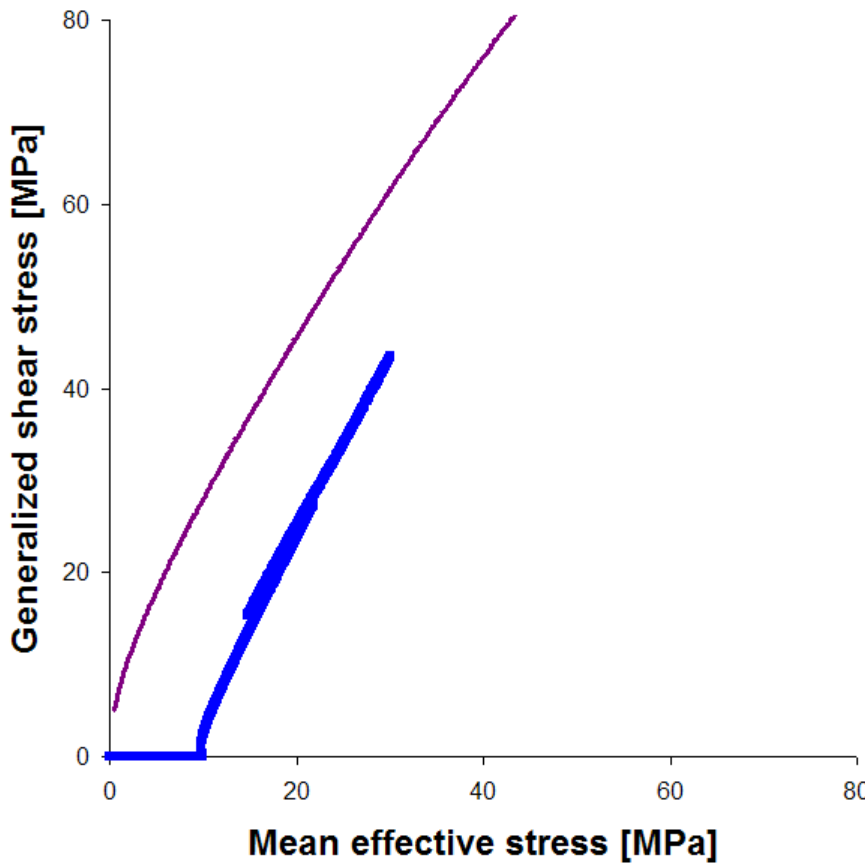
Summarizing K_0 loading/unloading/reloading



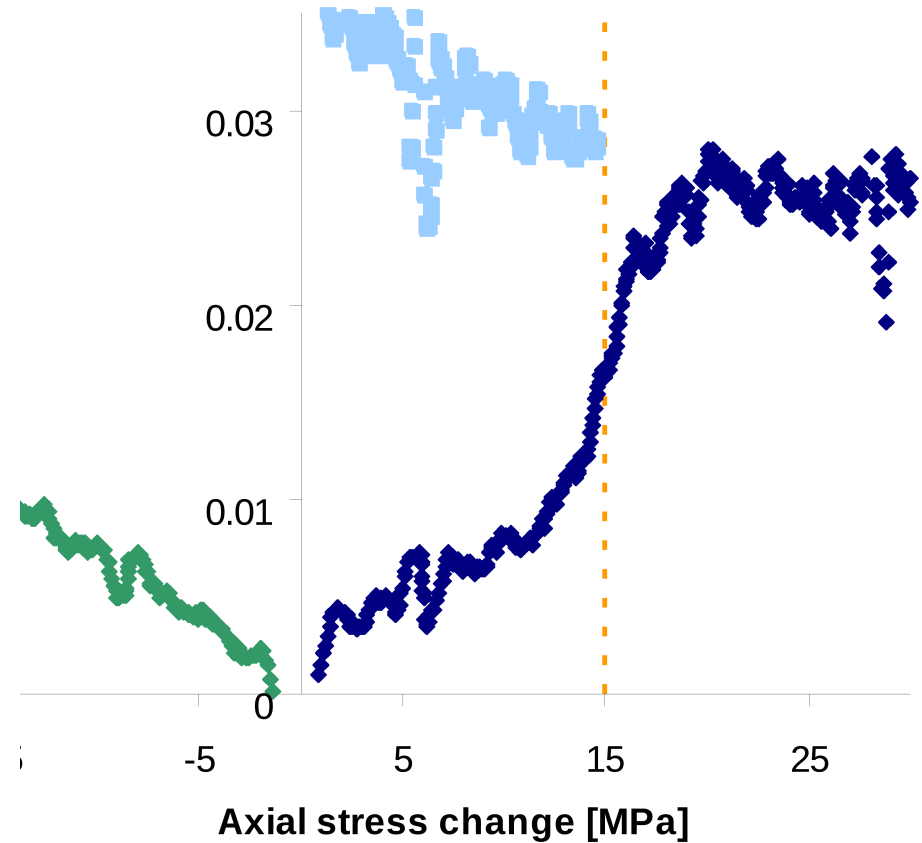
Initial loading: High level
Unloading: Low level, linear increase
Reloading: Low – but finite – level below previous peak stress

Summarizing K_0
loading/unloading/reloading

Different test – same picture

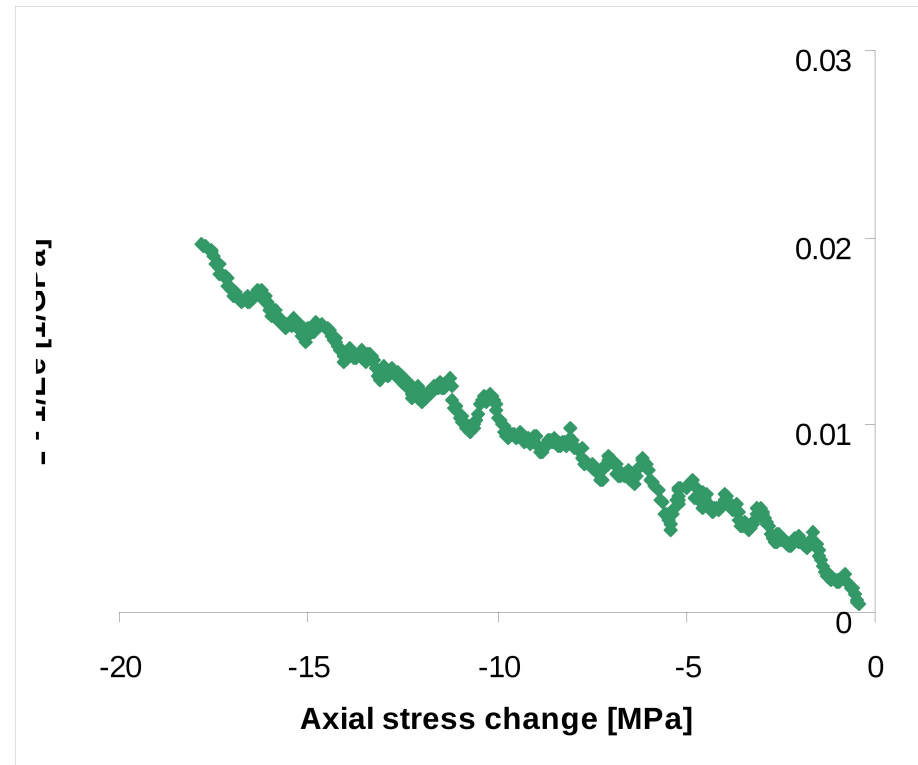
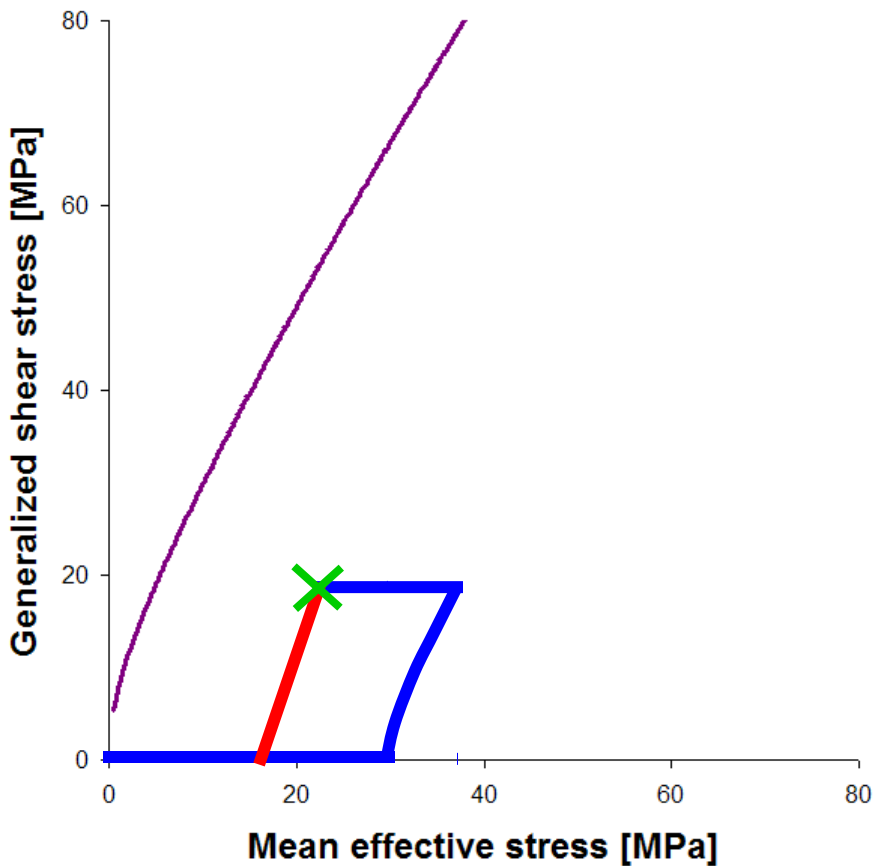


Vertical axis label: τ/σ



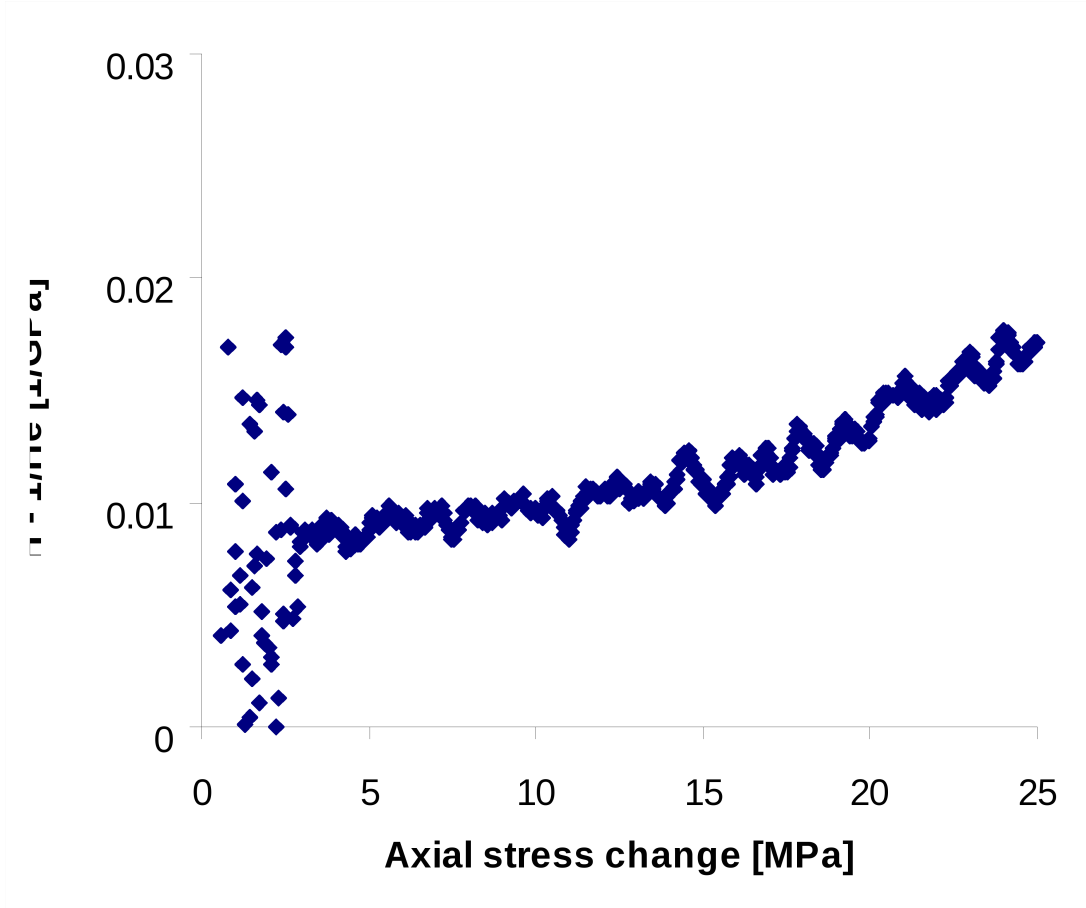
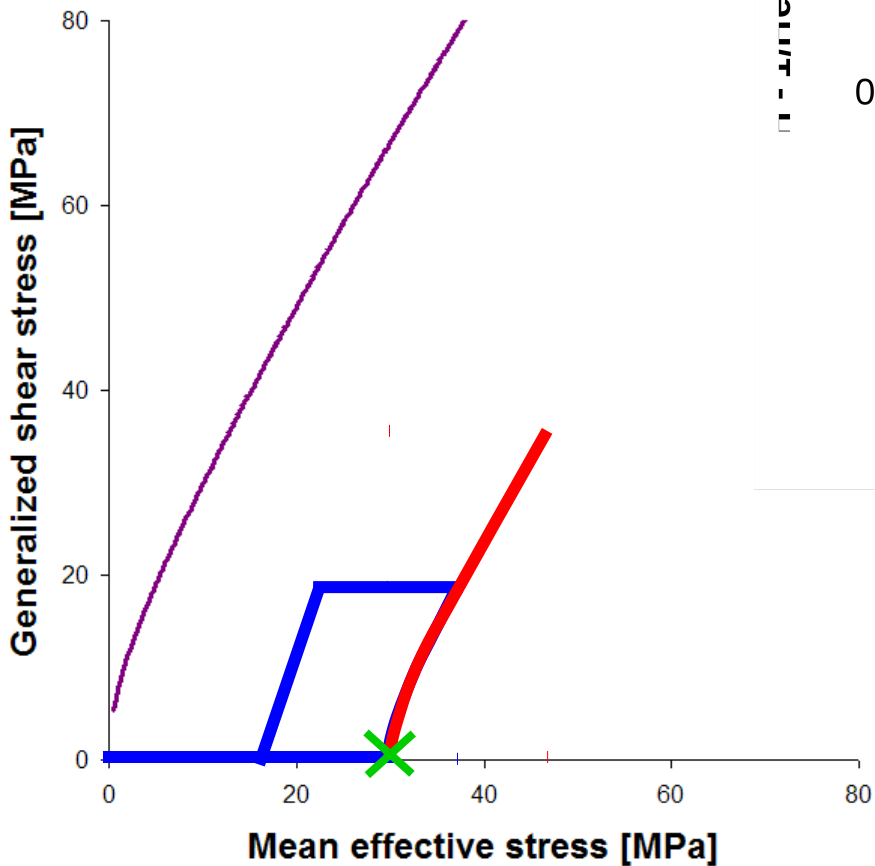
Initial loading: High level
Unloading: Low level, linear increase
Reloading: Low – but finite – level below previous peak stress

Uniaxial unloading along new path



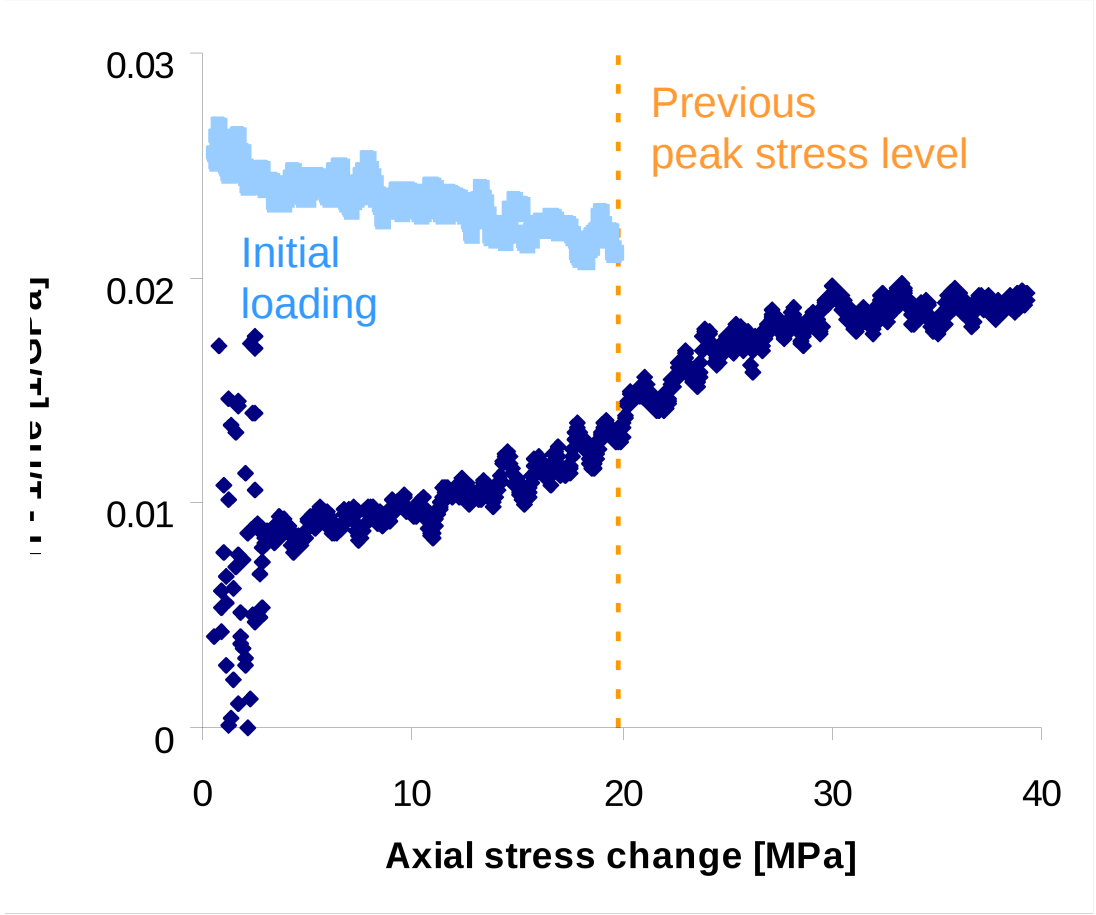
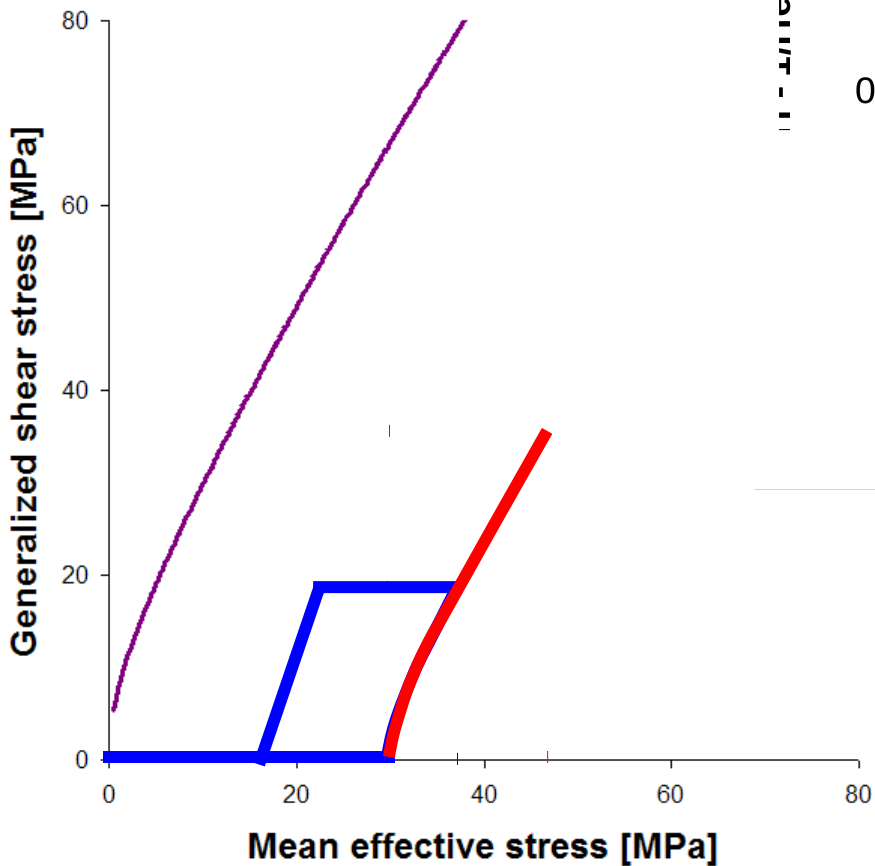
Non-elastic compliance increases linearly with stress change

Retracing an old path after a roundtrip

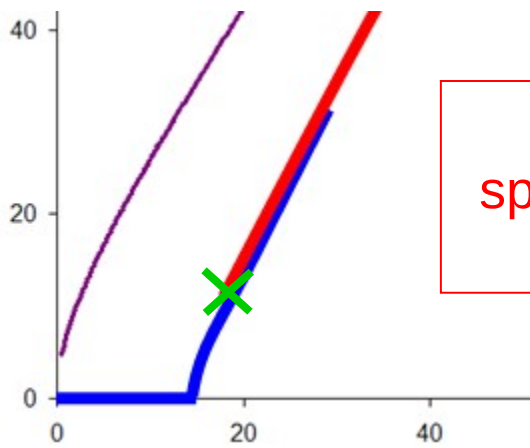
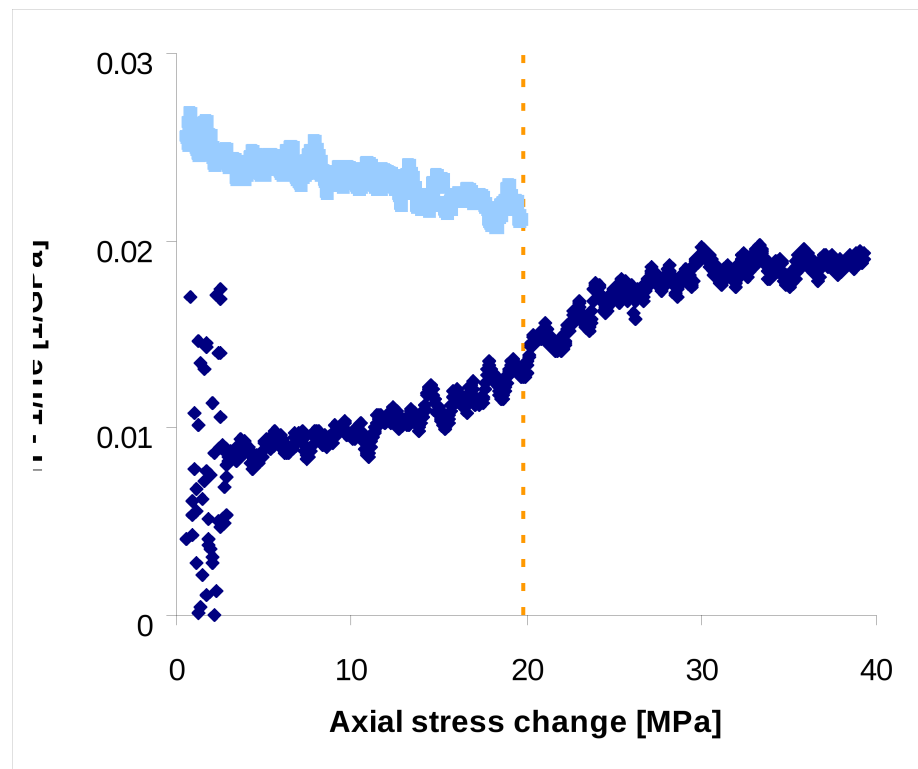
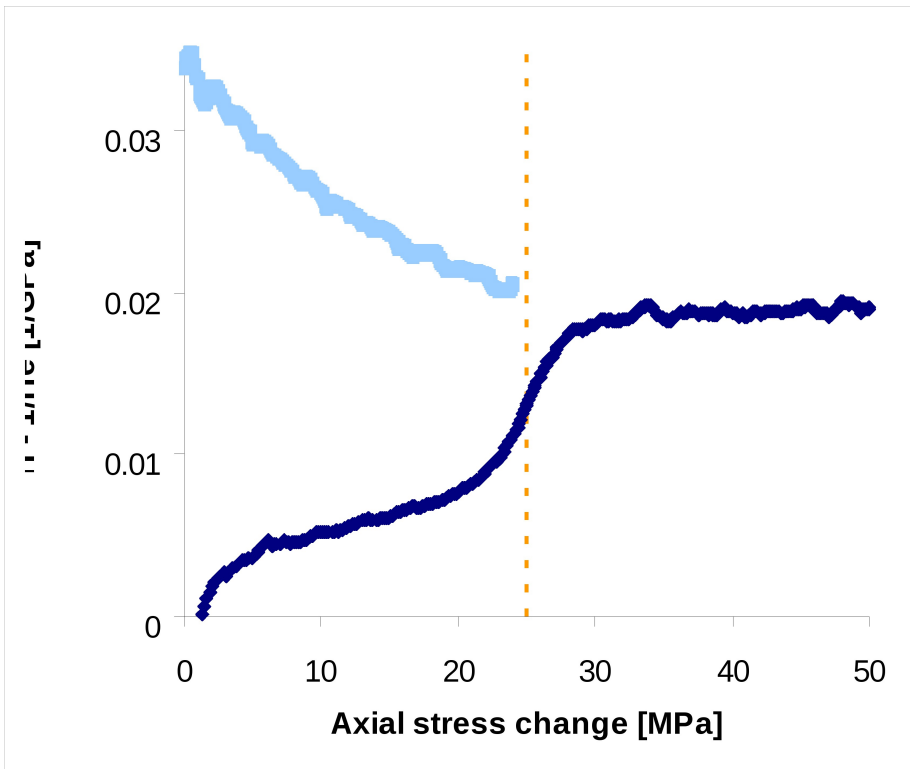


Non-elastic compliance increases slowly, starting at a finite (?) value

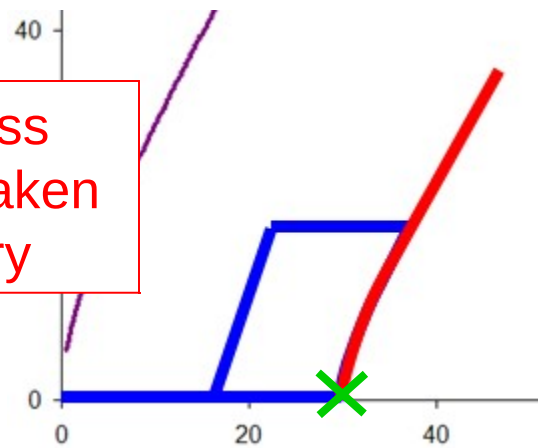
Retracing an old path after a roundtrip



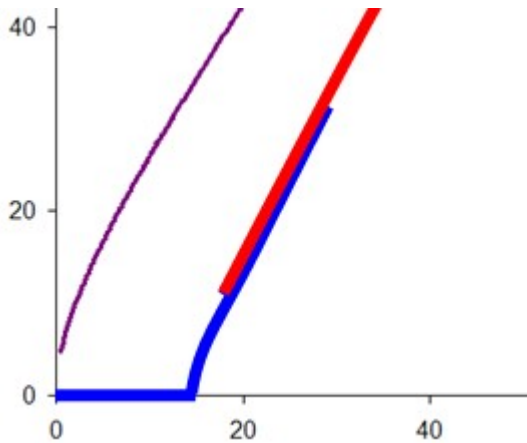
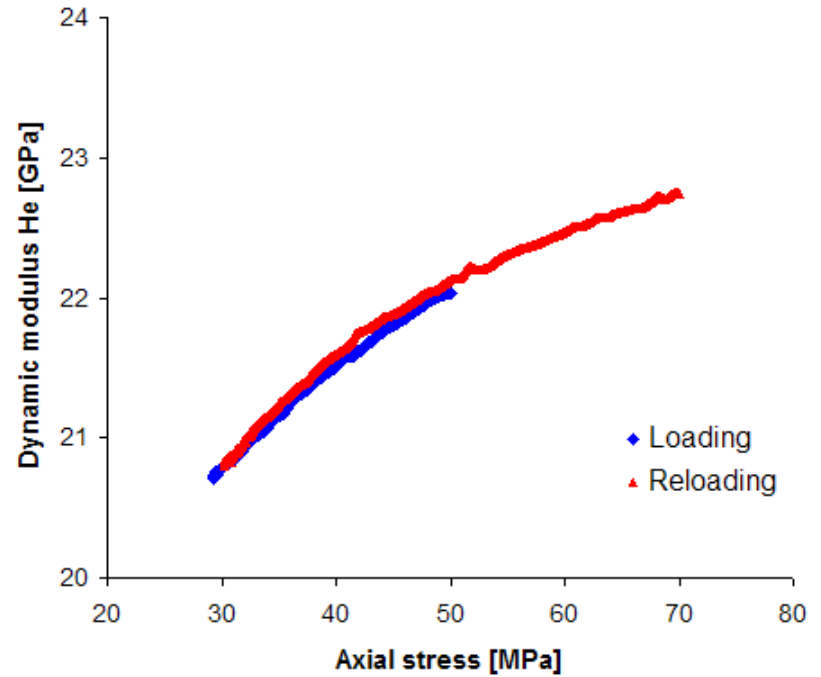
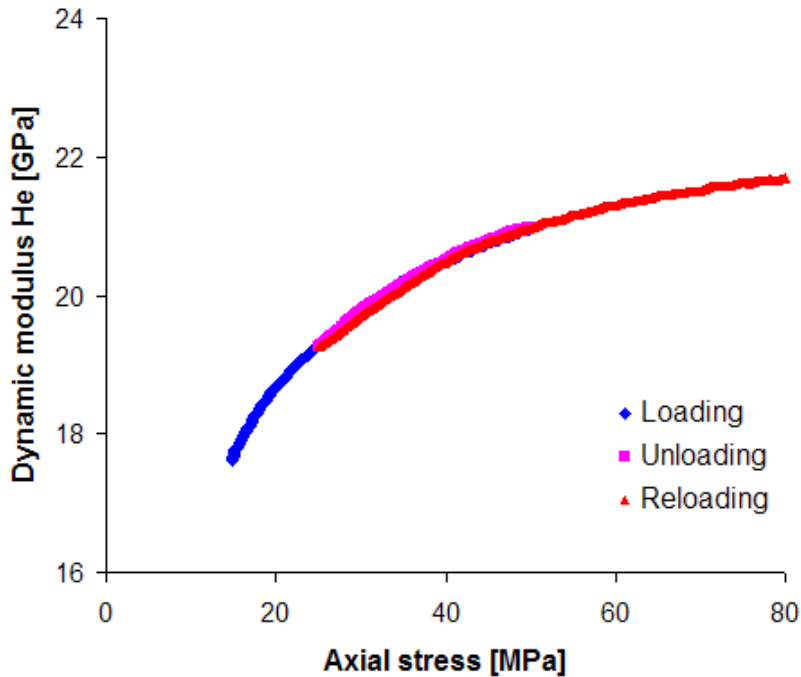
Non-elastic compliance reaches initial level above previous peak stress



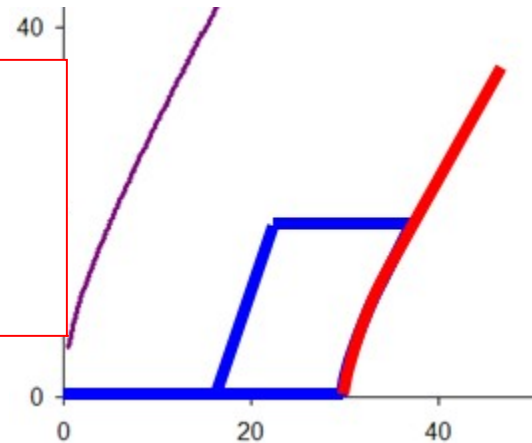
A roundtrip in stress space seems to weaken the rock's memory



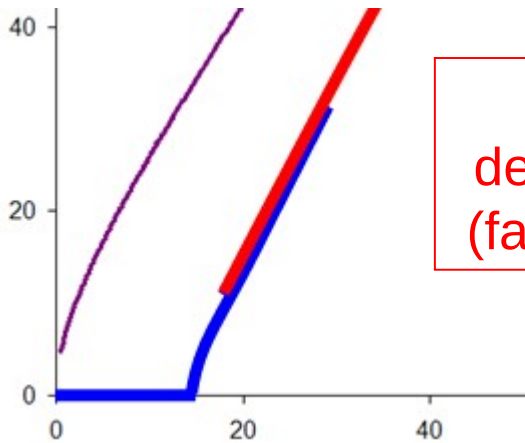
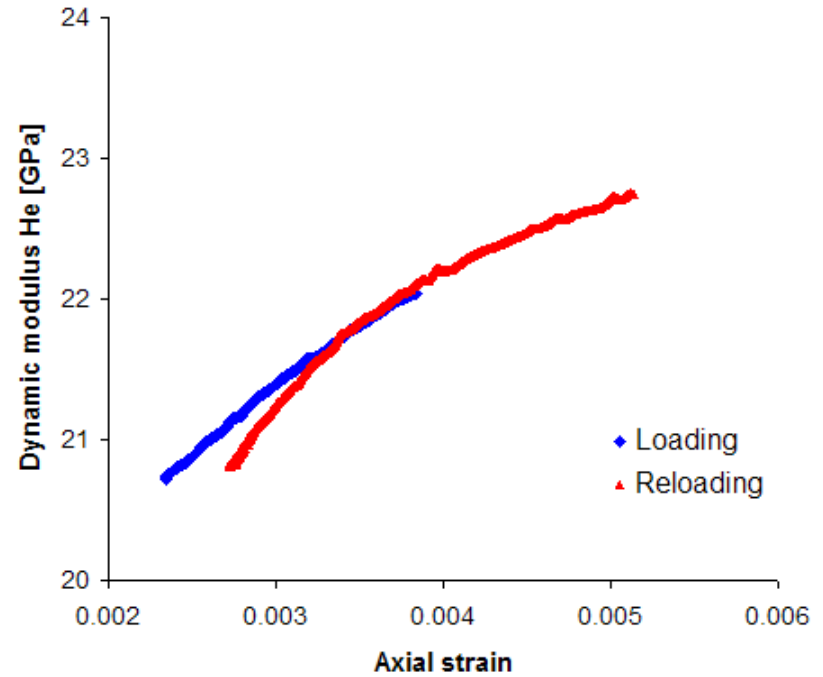
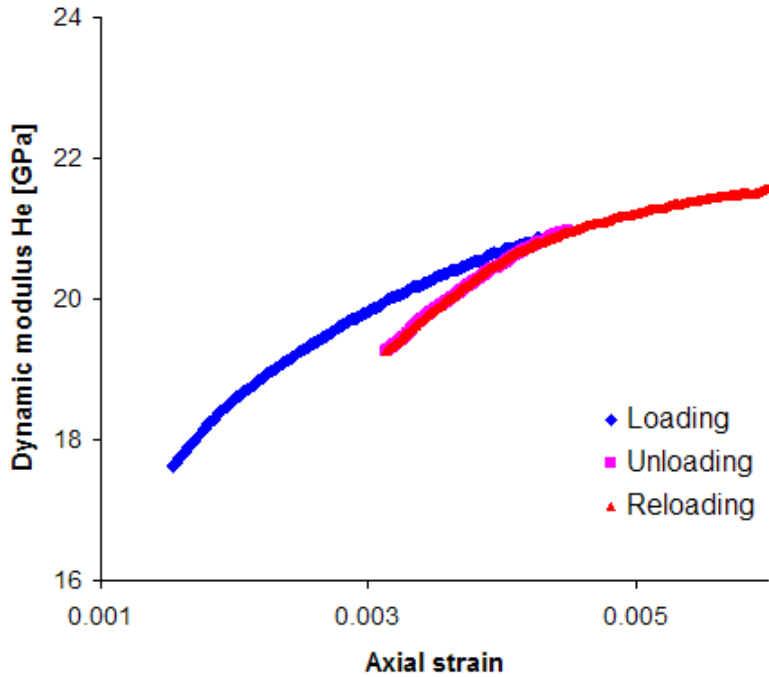
What about the elastic modulus $H_e = \rho V_{P,z}^2$?



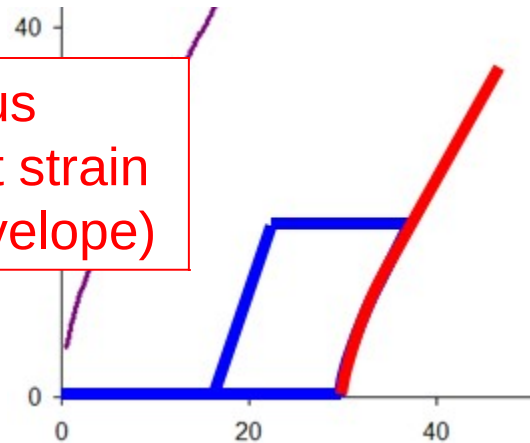
1:1 relationship
between
elastic modulus
and stress



What about the elastic modulus $H_e = \rho V_{P,z}^2$?



The elastic modulus depends on stress, not strain (far from the failure envelope)



Summary