Creep in Thermally Cracked Granite: Physical, Mechanical and Damage Properties Evolution

X.Q.Wang[1,2], A.Schubnel[1], Y.Gueguen[1], J.Fortin[1], H.K.Ge[2]

1 Laboratoire de Geologie, Ecole Normale Superieure, CNRS,UMR 8538,24 Rue Lhomond,75005 Paris France
2 The Institute of Geophysics, China Earthquake Administration, 5 Minzu Road Haidian,10081 Beijing China

Introduction

- The understanding of the failure process and the characterization of time-dependent brittle deformation in brittle rock is very important to understand the long-term evolution and dynamics of the Earth's crust.

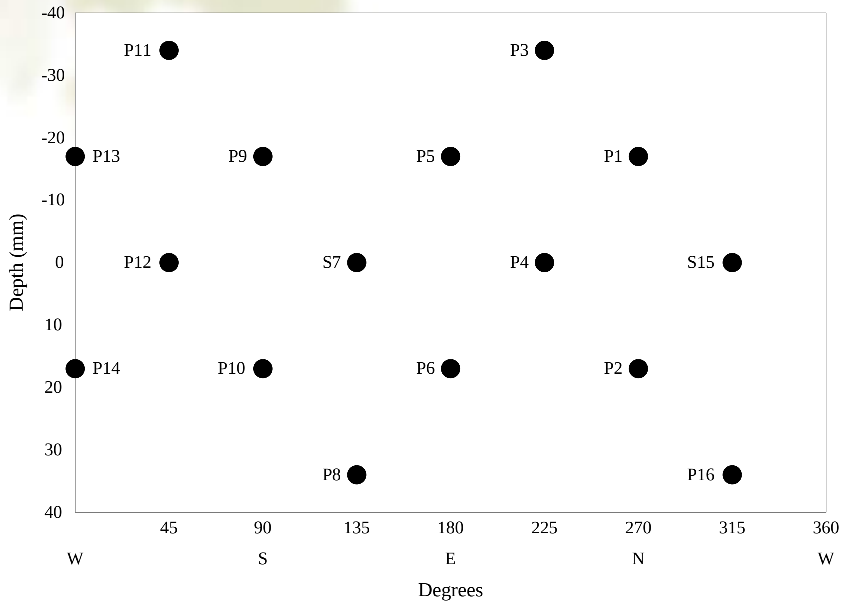
- The majority of rocks forming the crust contain lots of cracks and pores. Aqueous fluid are ubiquitous in the upper crust and the pores of most of the rocks are saturated.

- We investigate the effects of pervasive crack damage on the brittle rupture processes of a fine-grained granite, under triaxial stress (hydrostatic and deviatoric conditions), in wet (water) and dry (argon gas) saturated conditions

Contents

Experimental set-up and Methodology

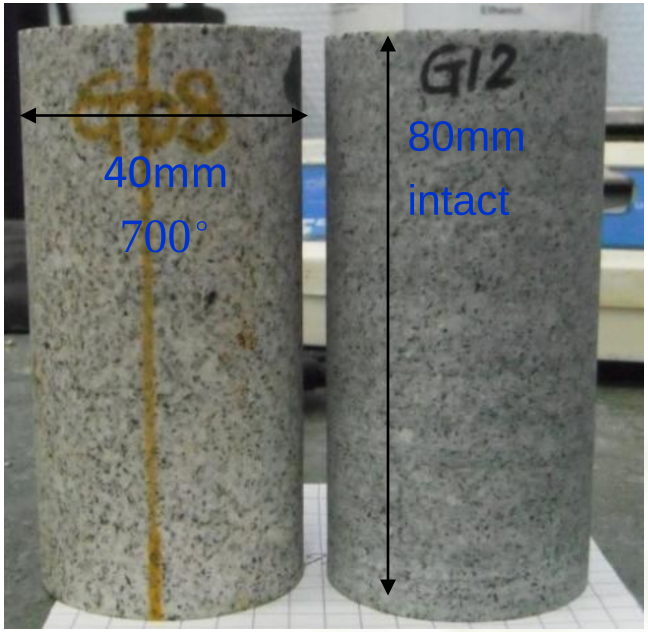
All experiments were conducted at 30 MPa effective confining pressure



Angular position of the 16 transducers

Hydrostatic experiments
Constant strain rate experiments
Stress-stepping experiments
strains, Vp, Vs and (AE).

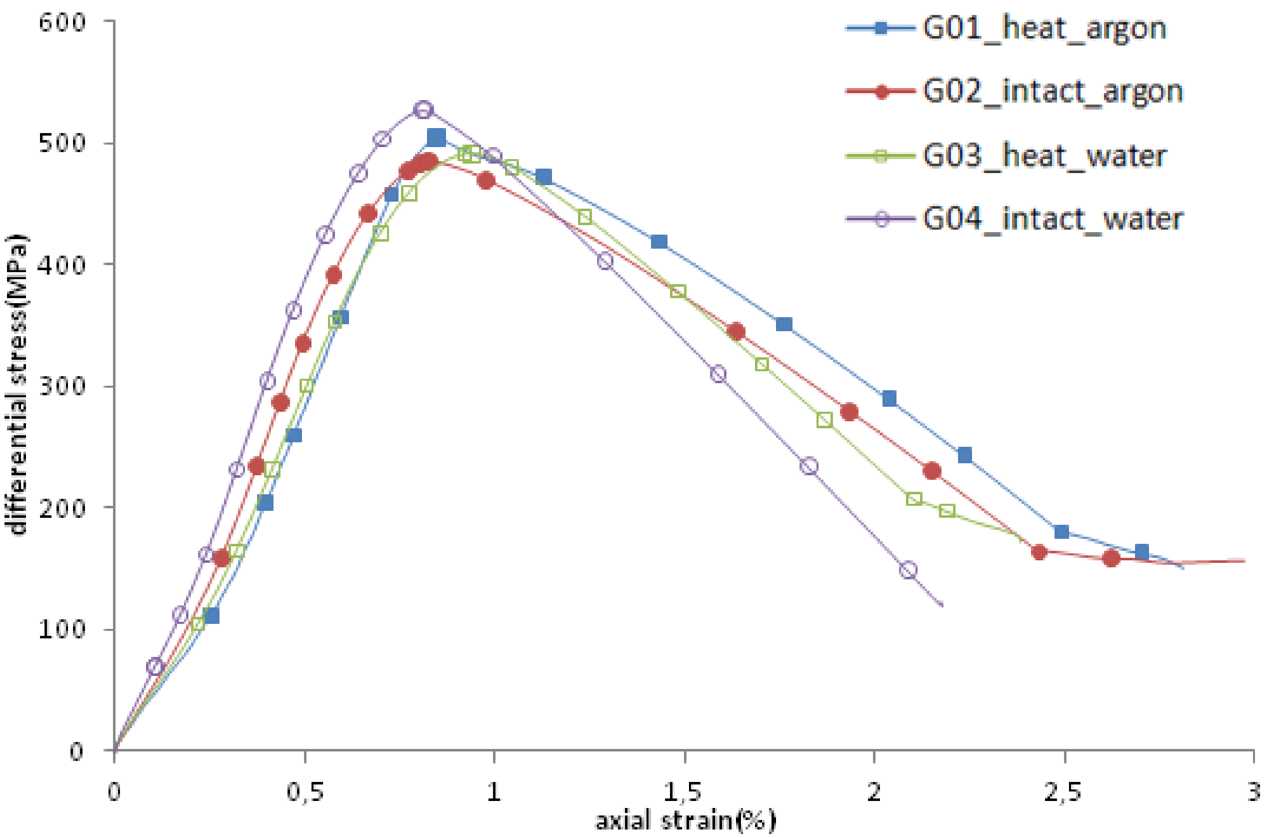
La Peyratte granite



Intact with an initial porosity ~1%
Heat-treated with porosity ~3%

Composition of La Peyratte granite	
Fine-grained(size)	800um
Plagioclase	40%
Kfeldspar	26%
Quartz	24%
Biotite	10%

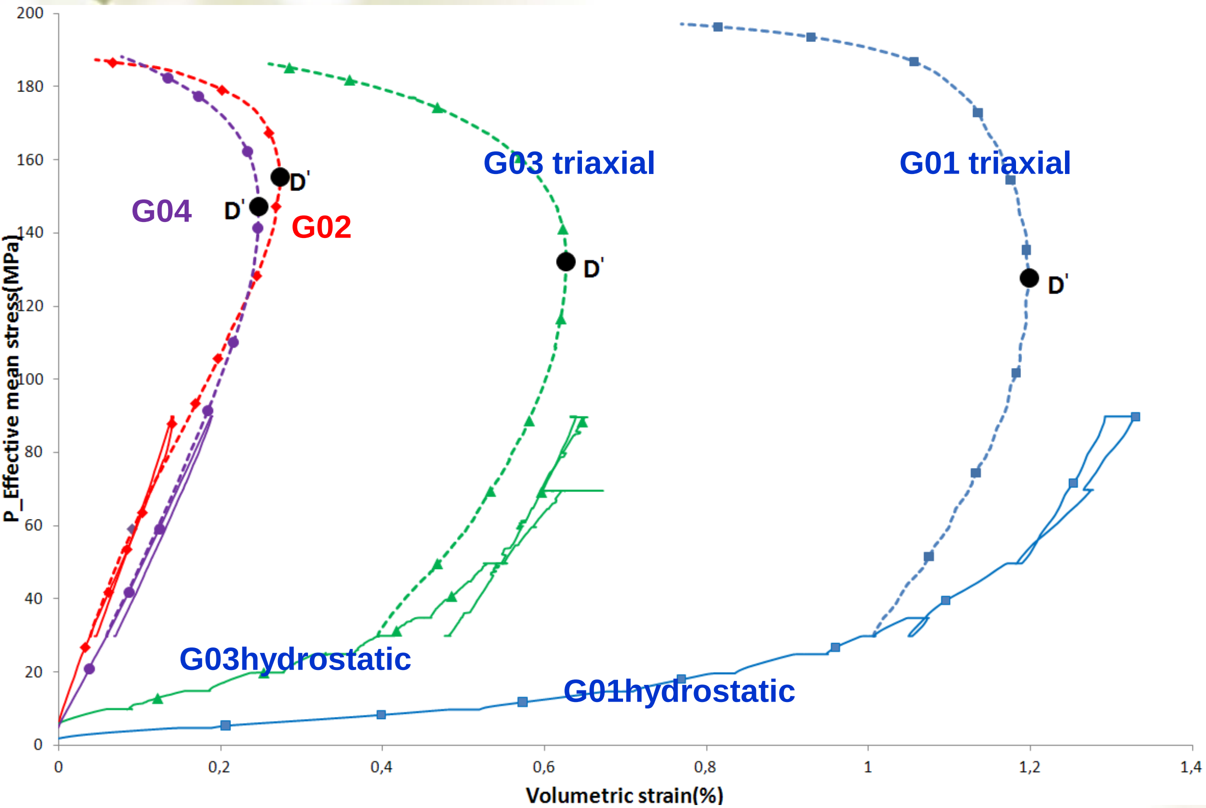
Constant strain experiments



Differential stress versus axial strain

Peak stress

Label	Differential stress Q @ peak stress (MPa)
G01_heat_argon	504
G02_intact_argon	485
G03_heat_water	491
G04_intact_water	527

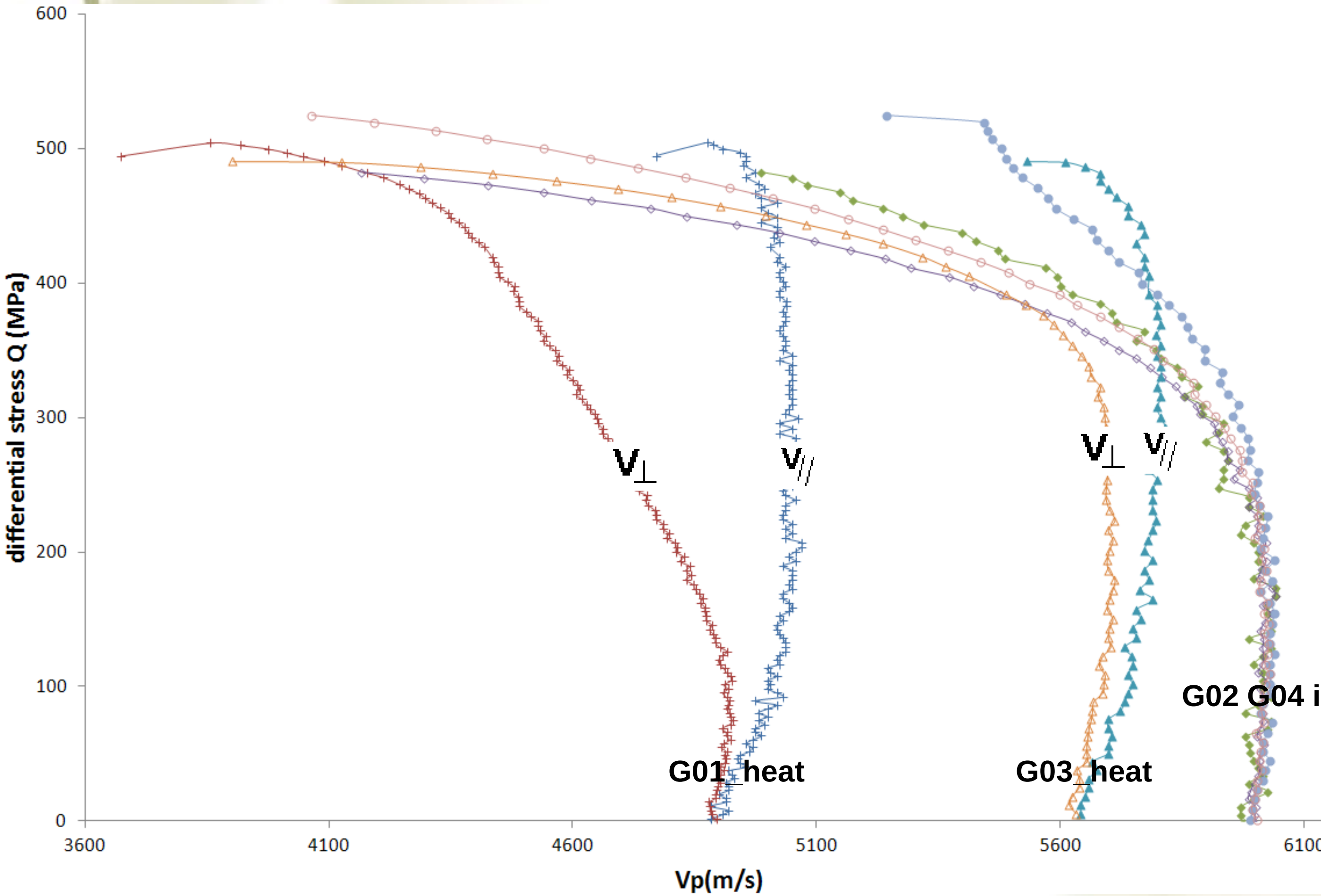


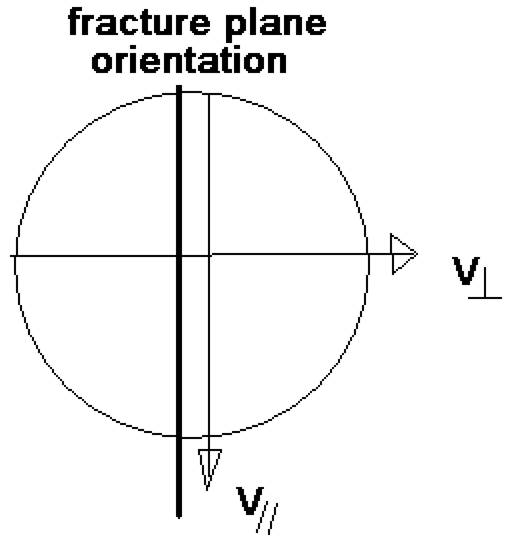
Effective mean stress versus volumetric strain

Onset of Dilatancy D′

Label	Differential stress Q at D′ (MPa)
G01_heat_argon	297.7
G02_intact_argon	400
G03_heat_water	333.1
G04_intact_water	374.8

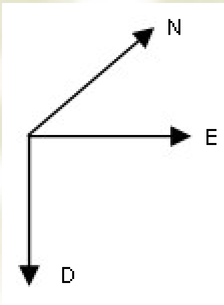
the velocity evolution during the triaxial process.



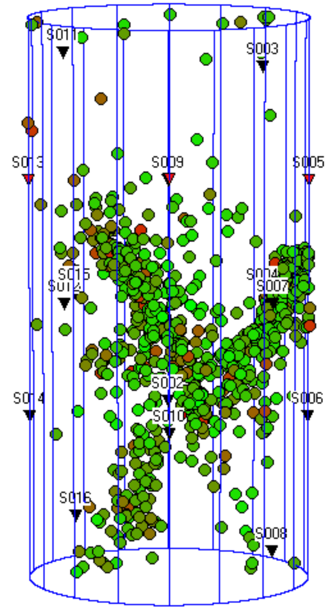


Differential stress Q versus P-wave velocity

Acoustic emission: hypocenter and focal mechanism(G01)

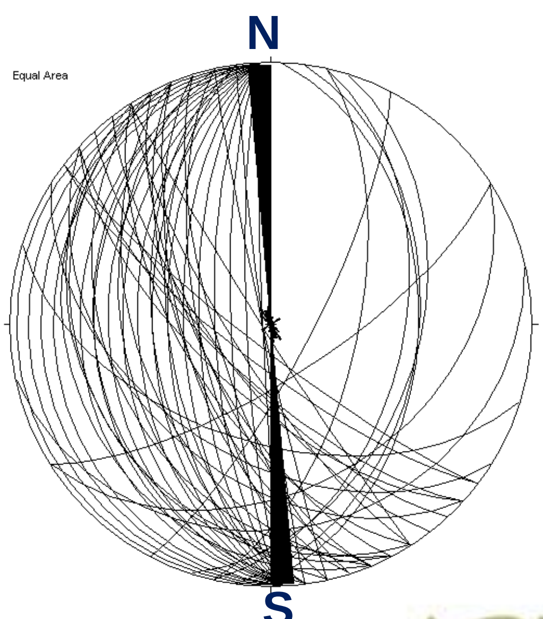


The coordinates



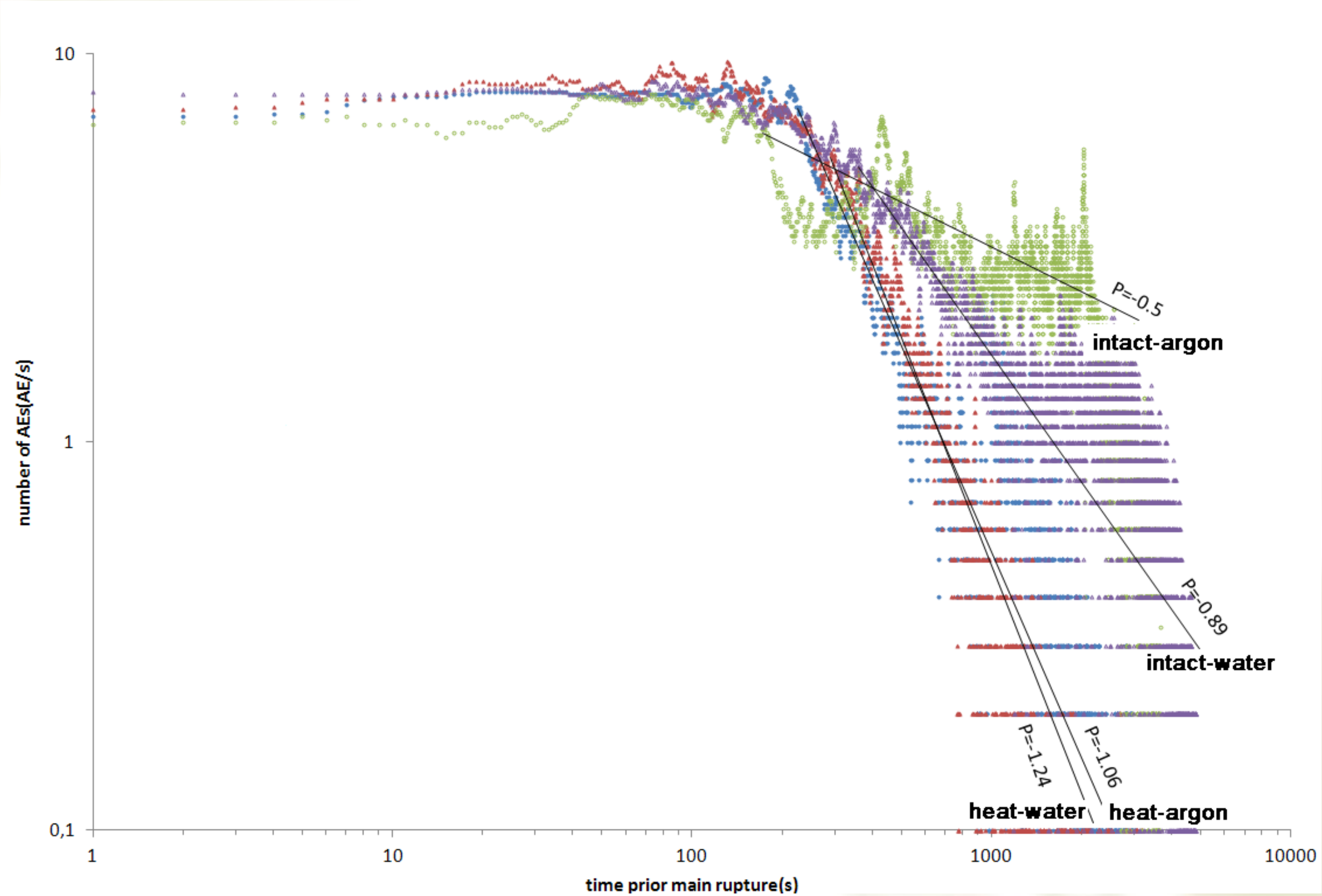
The location

G01 granite after failure



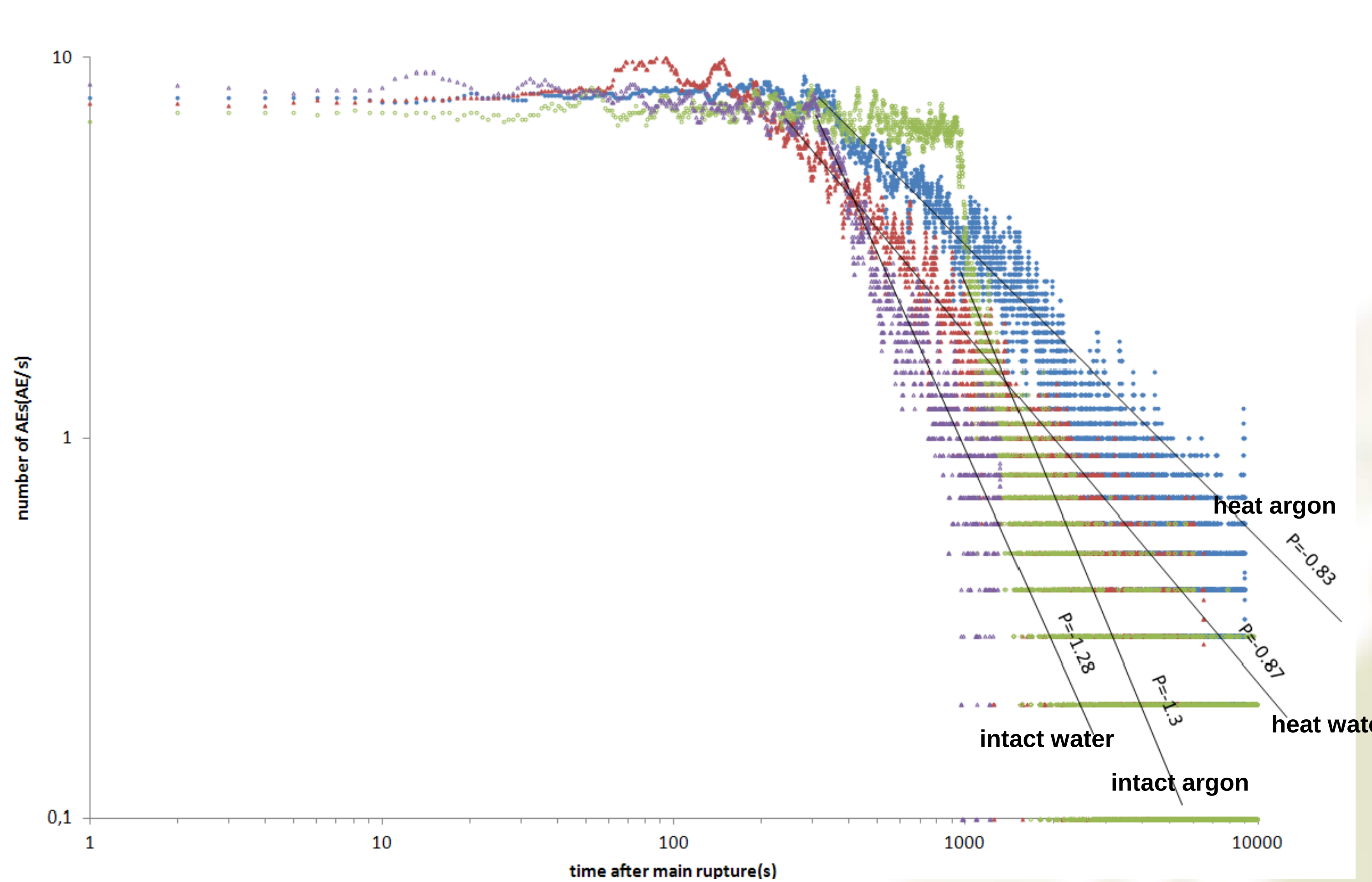
Equal angle stereonet of the focal mechanism

heat treated granite had less premonitory AE activity.
Why? Stress heterogeneity-intact rocks?
Anelastic attenuation_heat>Anelastic attenuation_intact?



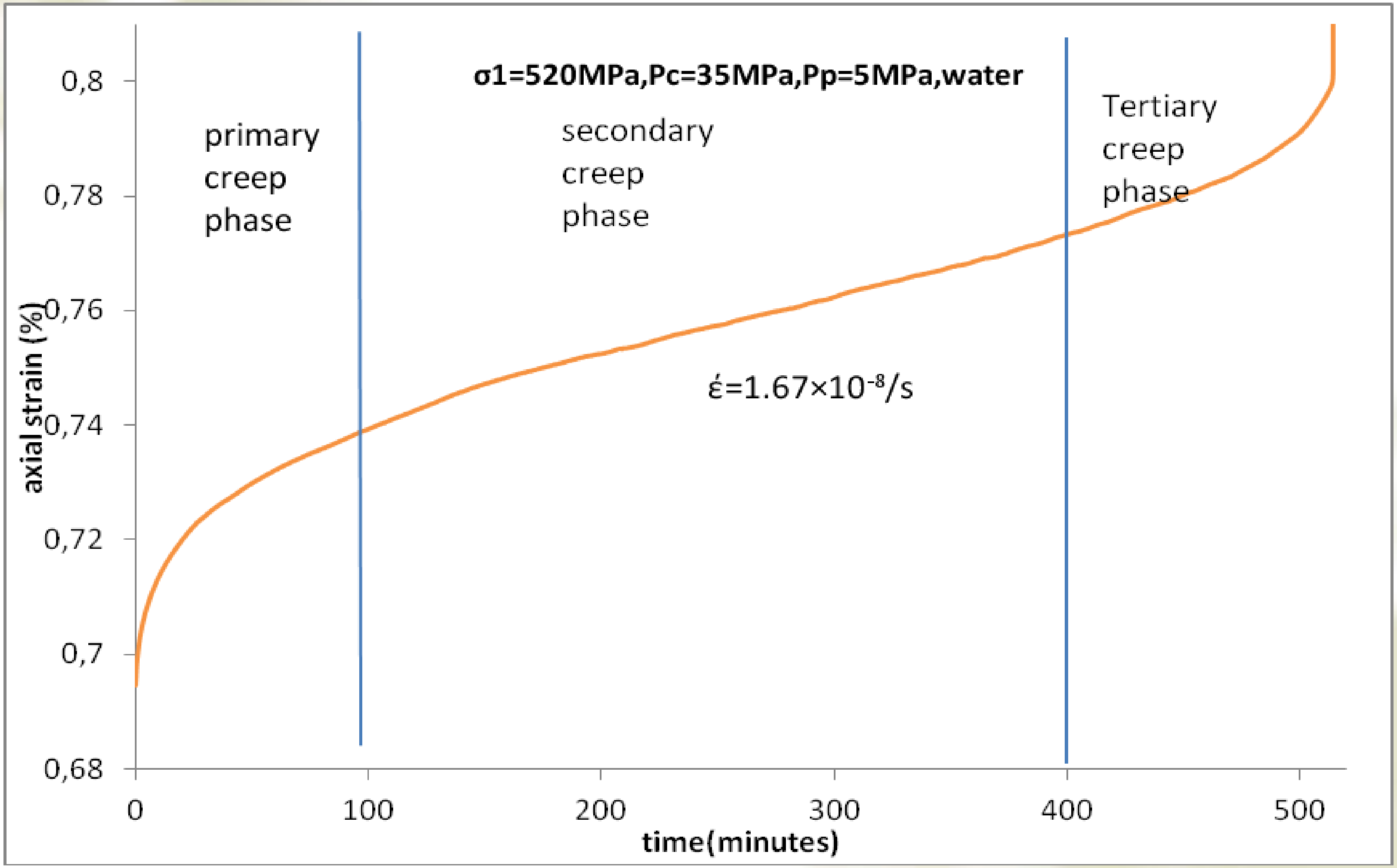
foreshocks

Anelastic attenuation_heat>Anelastic attenuation_intact ?
inconsistent with the aftershocks
heat treated granite had longer aftershocks activity
Why? Stress heterogeneity-heat treated rock



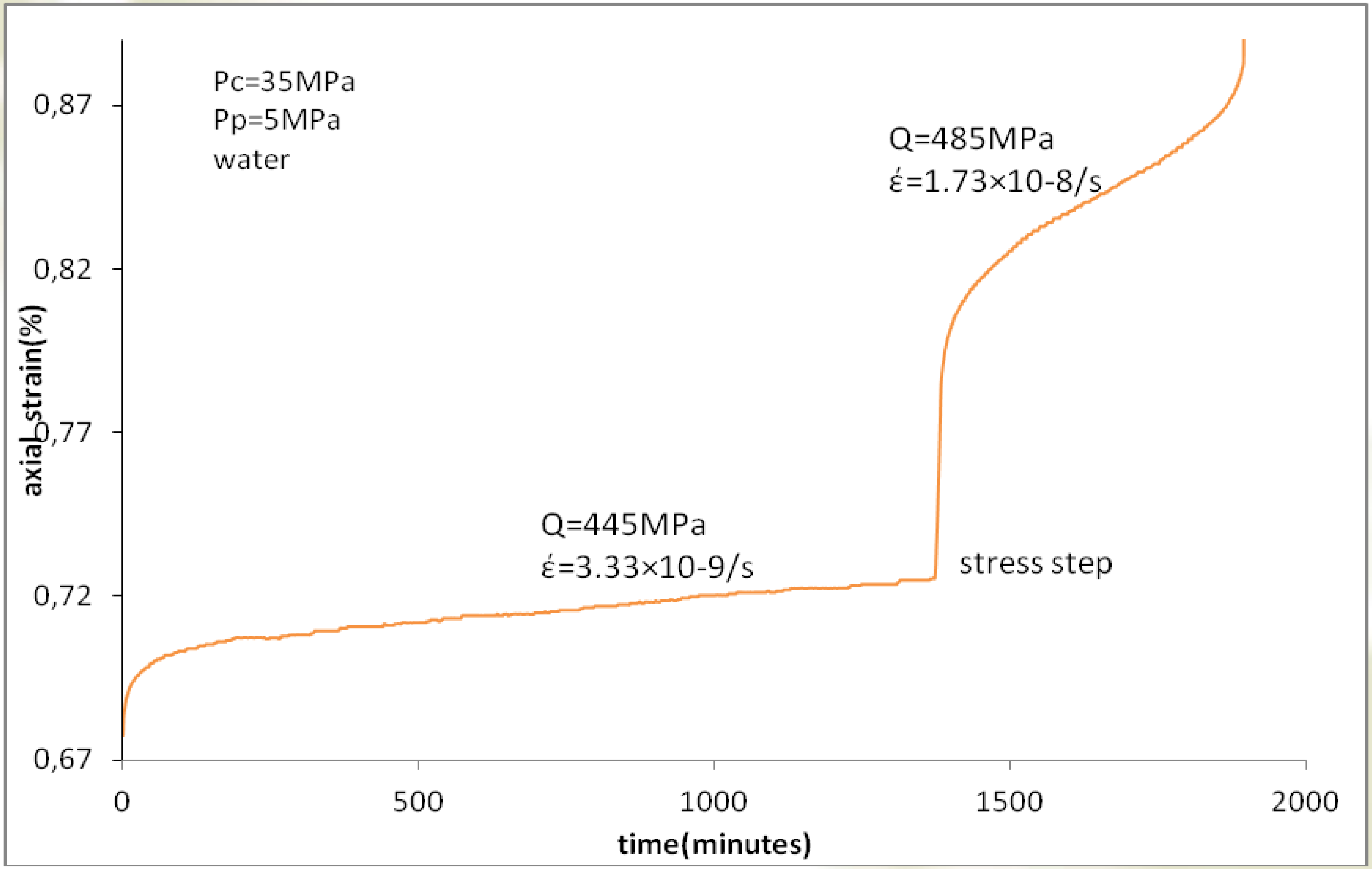
aftershocks

Stress-stepping creep experiments



The classic trimodal creep curve for brittle material

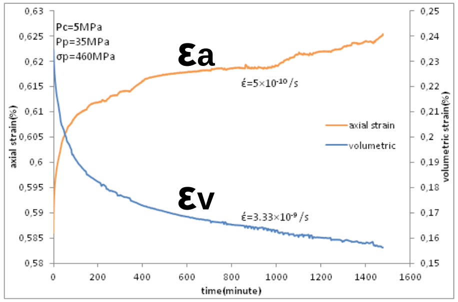
To overcome the natural rock sample variability

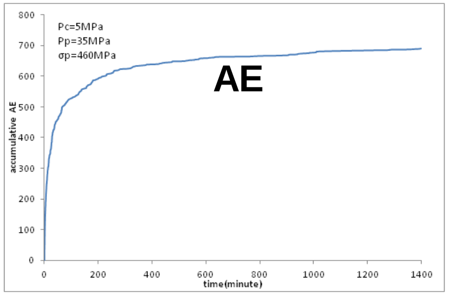


the methodology of the stress-stepping brittle creep experiments(Heap 2009 JGR)

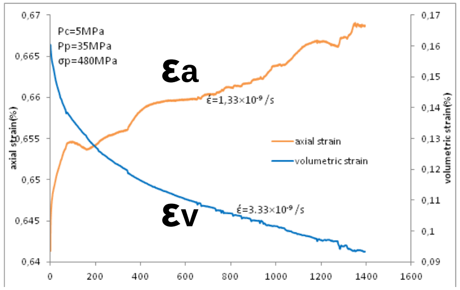
damage proxies (axial strain, volumetric strain, cumulative acoustic emission)

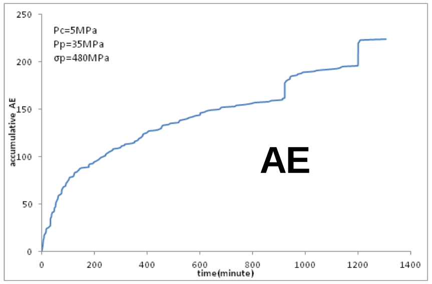
σ1=460MPa



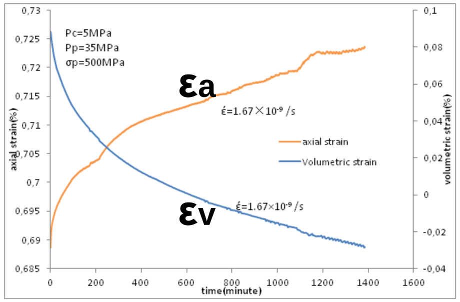


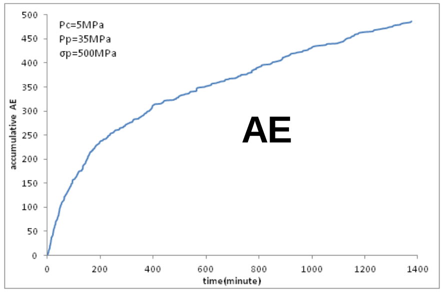
σ1=480MPa



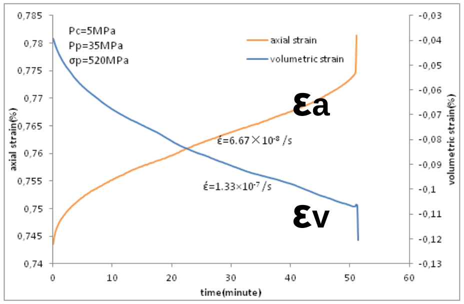


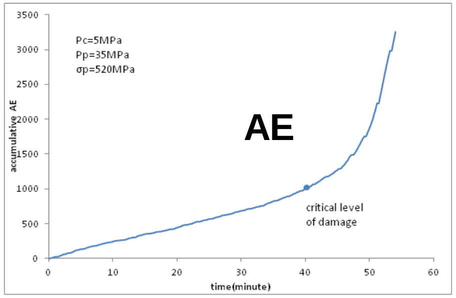
σ1=500MPa





σ1=520MPa





axial strain and volumetric strain

Cumulative AE

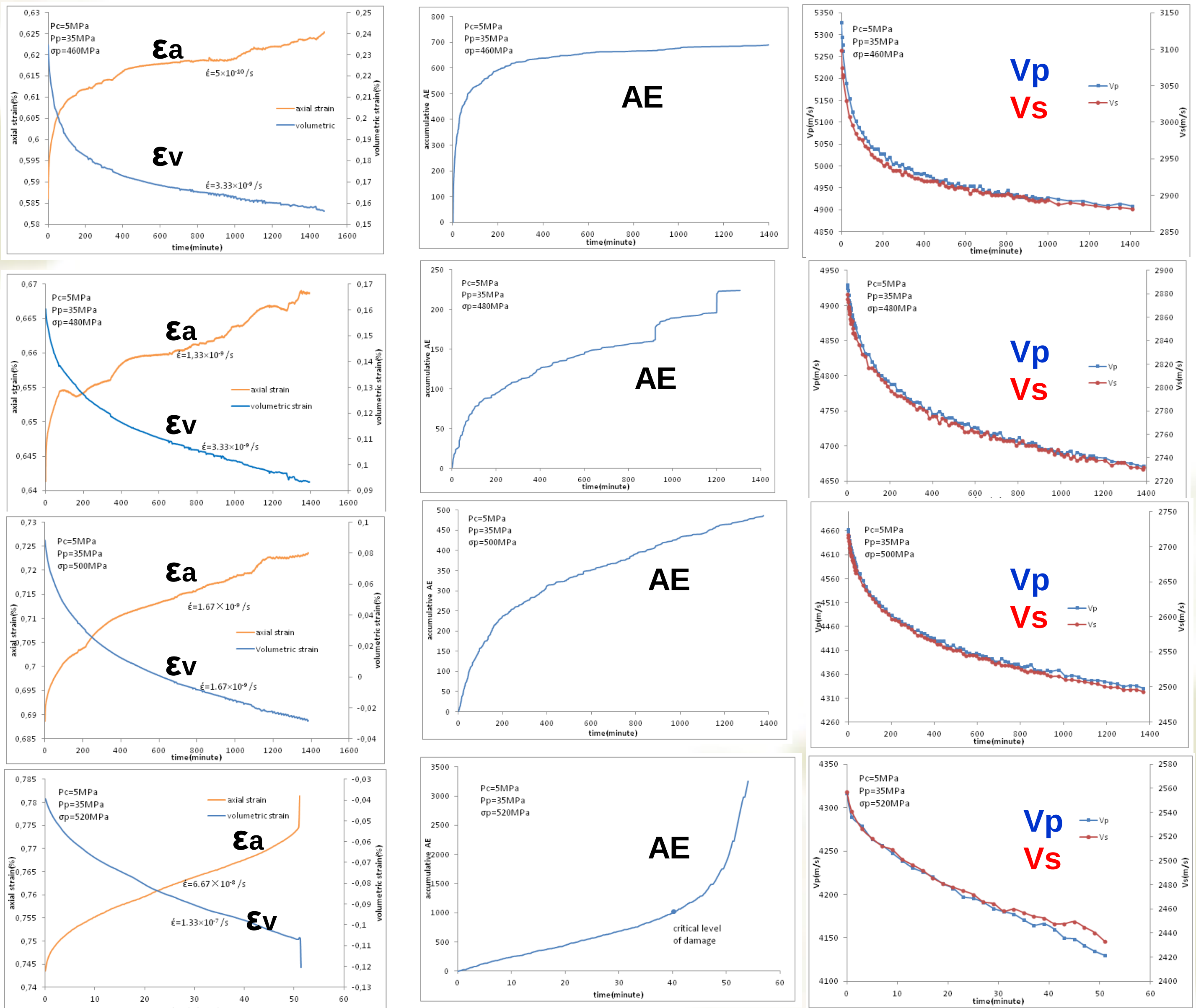
five damage proxies (axial strain, volumetric strain, cumulative acoustic emission, P wave and S wave)

σ1=460MPa

σ1=480MPa

σ1=500MPa

σ1=520MPa



axial strain and volumetric strain

Cumulative AE

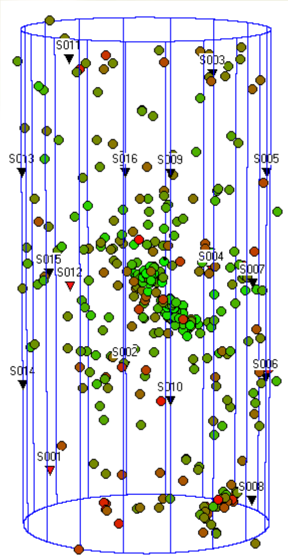
Vp Vs

Damage Levels: the localization during each creep phase

G10intact water

Early creep stage

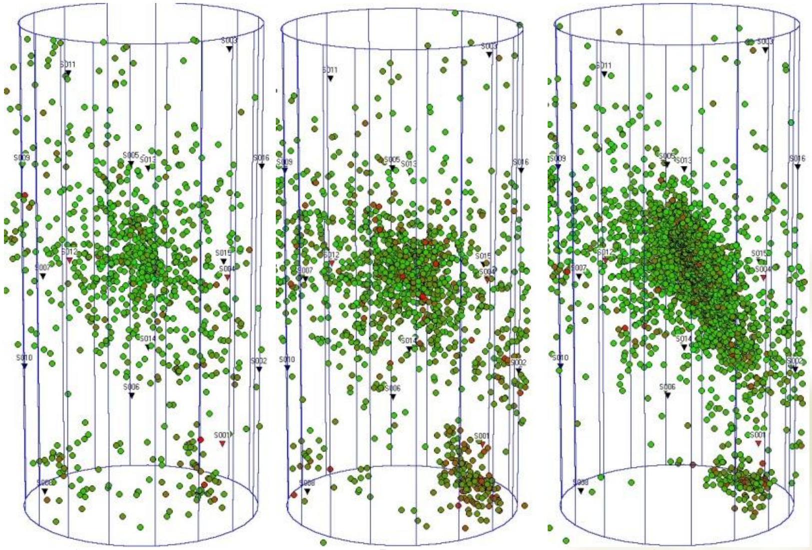
$\acute{\varepsilon}=3.33\times10^{-9}$ /s



σ1=480MPa

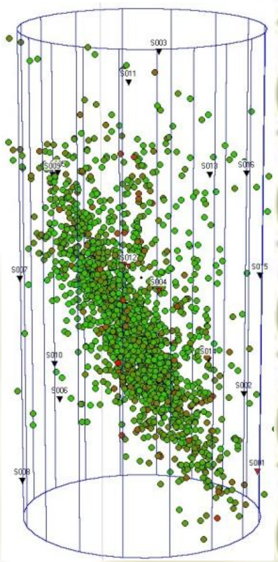
Terminal creep stage

$\acute{\varepsilon}=1.67\times10^{-8}$ /s



primary creep Secondary creep Tertiary creep

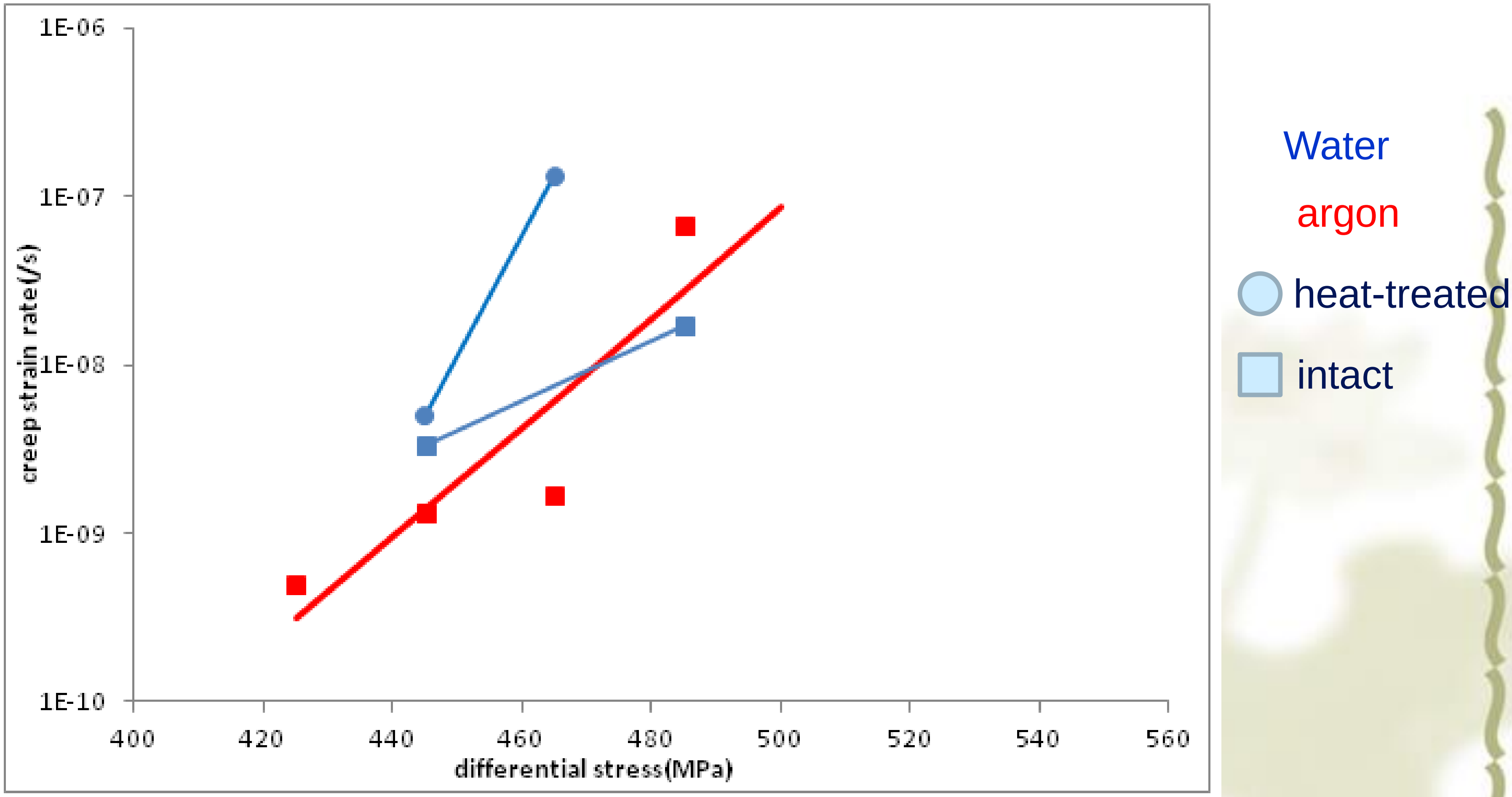
σ1=520MPa



The overall AE for G10

creep strain rate:

Heat-treated rock sample is more sensitive to the differential stress than the intact granites probably because of the initial damage level

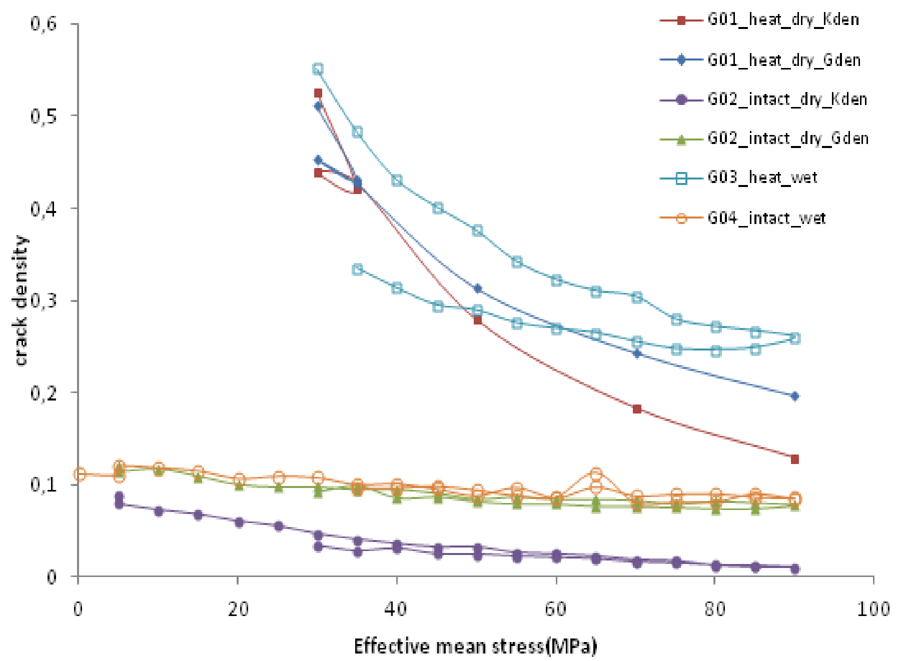


the creep strain rate versus the differential stress

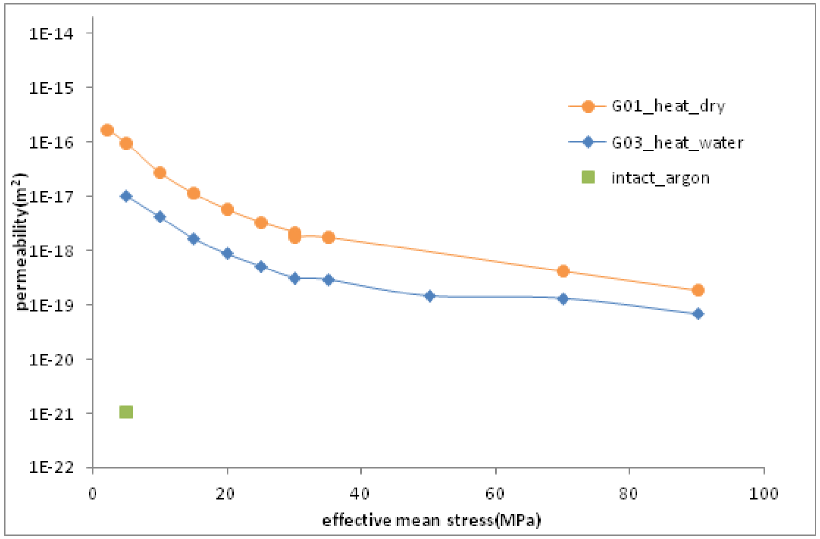
conclusions

- The brittle strength of the sample remained unchanged whether the sample was heat-treated or not, while the onset of dilatancy was observed at lower deviatoric stress in the heat-treated specimen.
- The P-velocity anistropy of heat-treated rock sample appeared very early while that of the intact rock sample appeared as early as 60% of the final rupture strength.
- In intact specimen, failure occurred after a larger premonitory AE activity, while heat-treated specimen had a longer aftershocks activity.
- In creep conditions, we show that extreme damage localization is already initiated during the early creep stages.
- the heat treated rock sample is more sensitive to differential stress than the intact rock samples probably because of initial damage.

Thanks for your attention



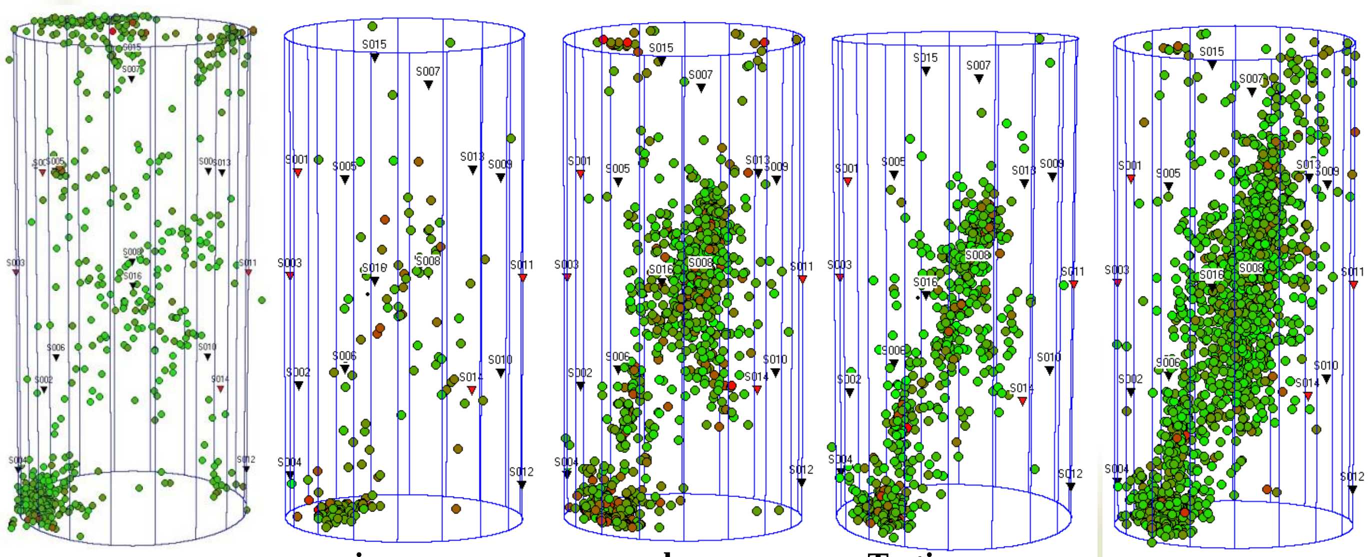
crack density



Permeability

Damage Levels:the localization during each creep phase

G09heat water



480MPa_656AE | primary creep | secondary creep | Tertiary creep | The overall AE

500MPa