SELFRAC Project
Laboratory tests to characterize Sealing/Healing process

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Plan

- Overview of the experimental programm
- Experimental results
- Constitutive modelling

Overview of the experimental programm

- Characterization of Initial permeability (pulse tests)
- Tensile test (healing)
- Long-term permeability tests on hollow cylinders (in finalization)
- Mock-up test (hollow cylinder) (in progress)

Initial Permeability
Pulse tests

- Confinement 4.5MPa P_{inj} 2Mpa
- Mol k $=2x10^{-19}$ m^2
- Mont Terri

$4\text{-}6x10^{-20}$ m^2 ⊥ to the bedding plane

$1\text{-}5x10^{-19}$ m^2 // to the bedding plane

(anisotropy /material heterogeneity ?)

Tensile Test

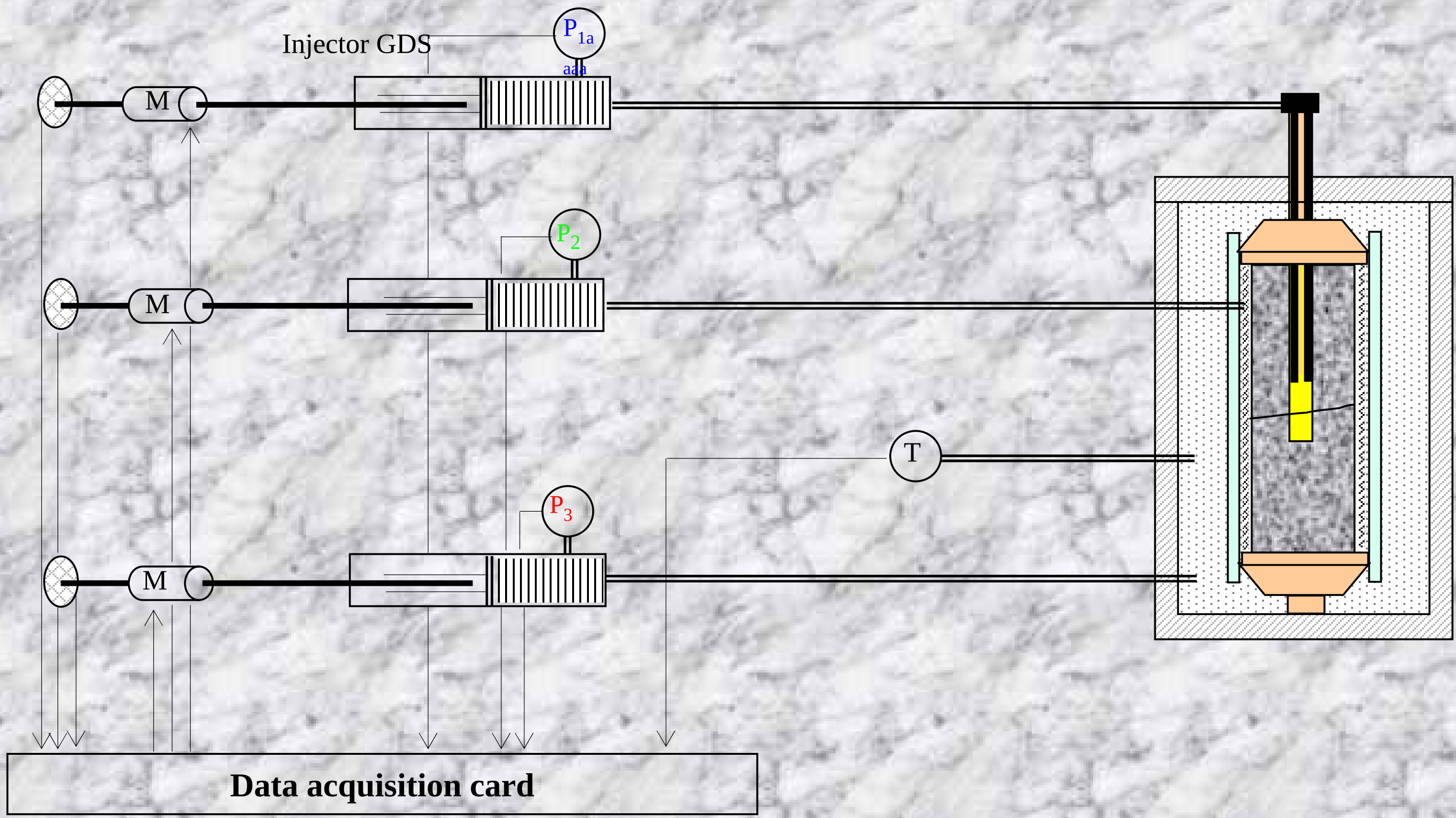
- Boom sample 60x120mm
- Tensile failure stress 0.2MPa
- a 0.5MPa normal stress appied during 10 days on the wetted fracture plane
- No cohesion recovery

Permeability test on hollow cylinder

- 50x100mm, cavity radius 2-4mm
- Steady state flow
- Longs duration (up to 9 months)
- Various hydromechanical paths (confinement pressure, inner and outer pore pressure, deviatoric stress)

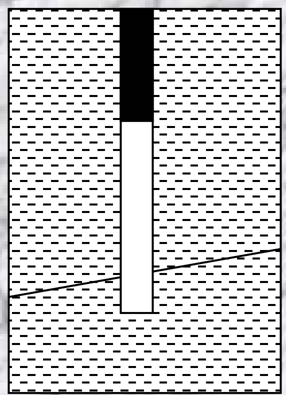
Permeability tests on hollow cylinders

Experimental set-up

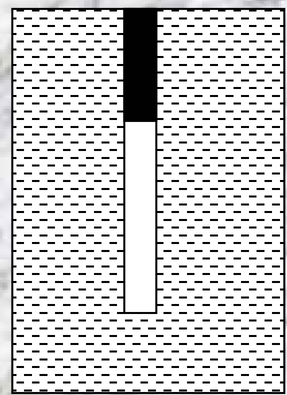


Permeability tests on hollow cylinders

2 types of tests in order to evaluate the effect of one discontinuity and the sealing/healing process

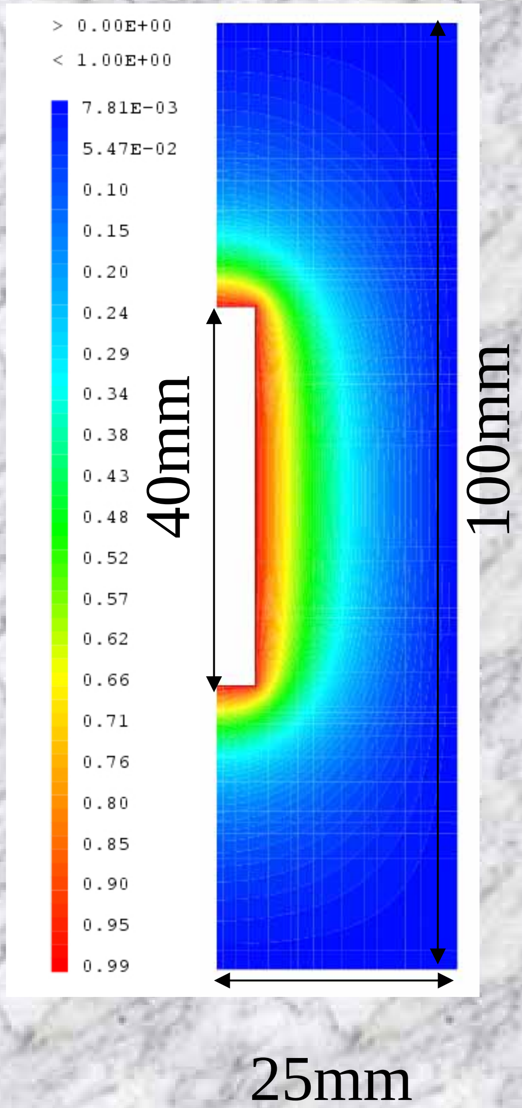


Sample with an initial radial fracture



Intact Sample

Permeability computation
Homogeneous sample



Steady state flow assumption

$$Q = k \frac{\Delta P}{\eta} L$$

Q : total flow rate

k : intrinsic permeability of an homogeneous rock

L : characteristic length numerically computed

ΔP : pore pressure difference

Permeability computation

Sample with a radial fracture

rock flow + fracture flow

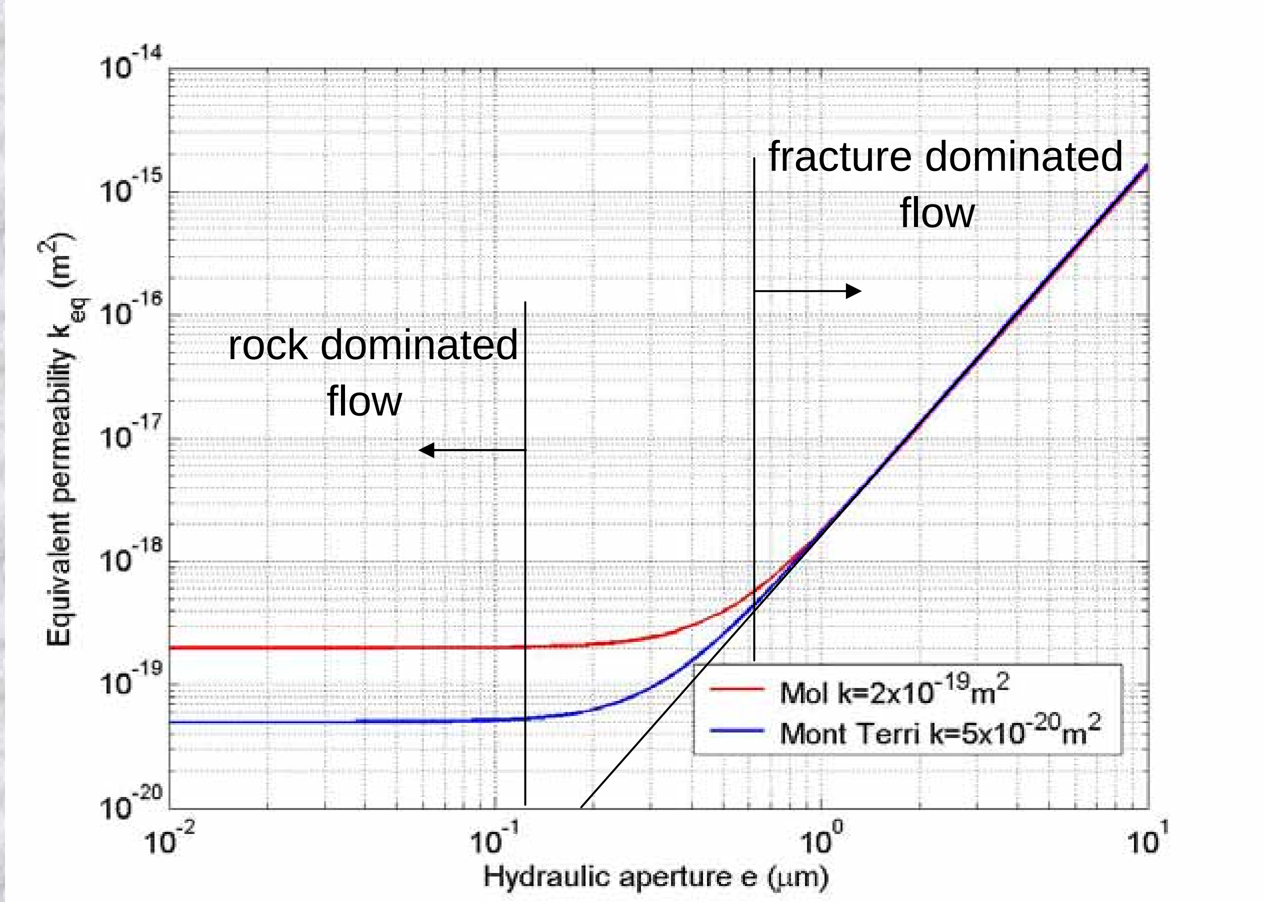
$$Q = Q_r + Q_f$$

$$= \frac{\Delta P}{\eta} k L + \frac{\Delta P}{\eta} \frac{\pi}{6 \log\left(\frac{r_e}{r_i}\right)} e^3$$

$$= \frac{\Delta P}{\eta} k_{eq} L$$ measured equivalent permeability

Permeability computation

sample with a radial fracture



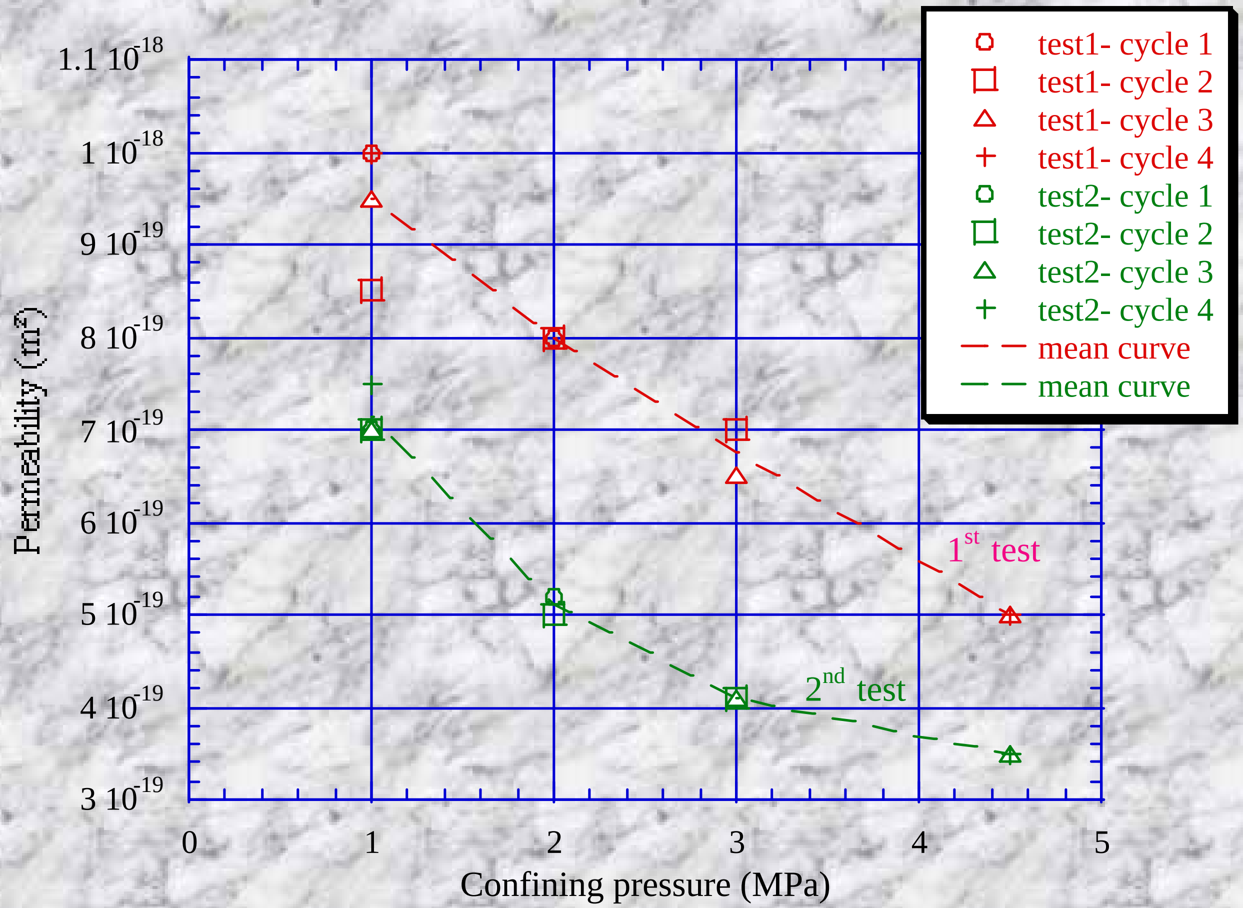
Permeability tests on hollow cylinders

Results - Mol clay

- reversible/irreversible (contractancy) effect of effective pressure on permeability
- no irreversible permeability increase after hydraulic fracturation : evidence of self-sealing. (see also MEGAS experiment Ortiz and al.1995)

Permeability tests on hollow cylinders

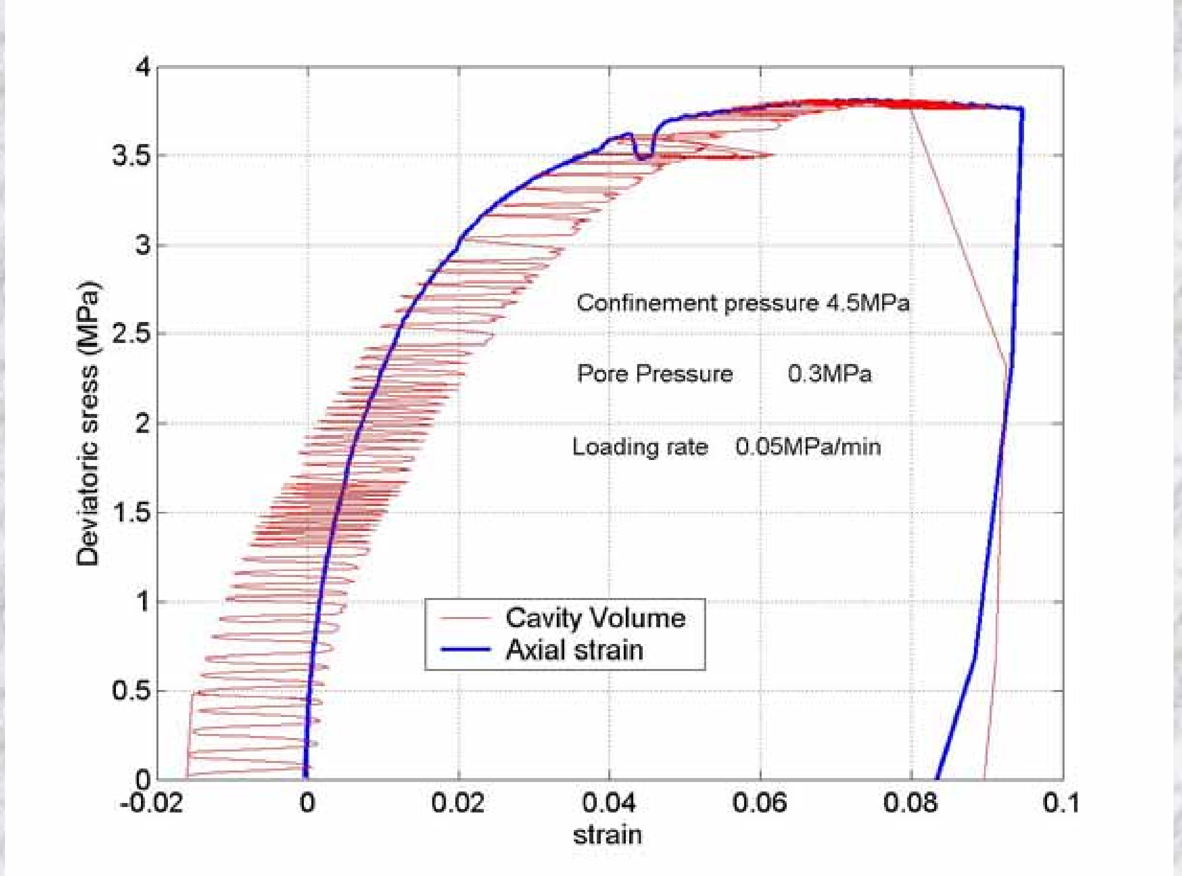
Mol



Reversible effect of confing pressure

Permeability tests on hollow cylinders

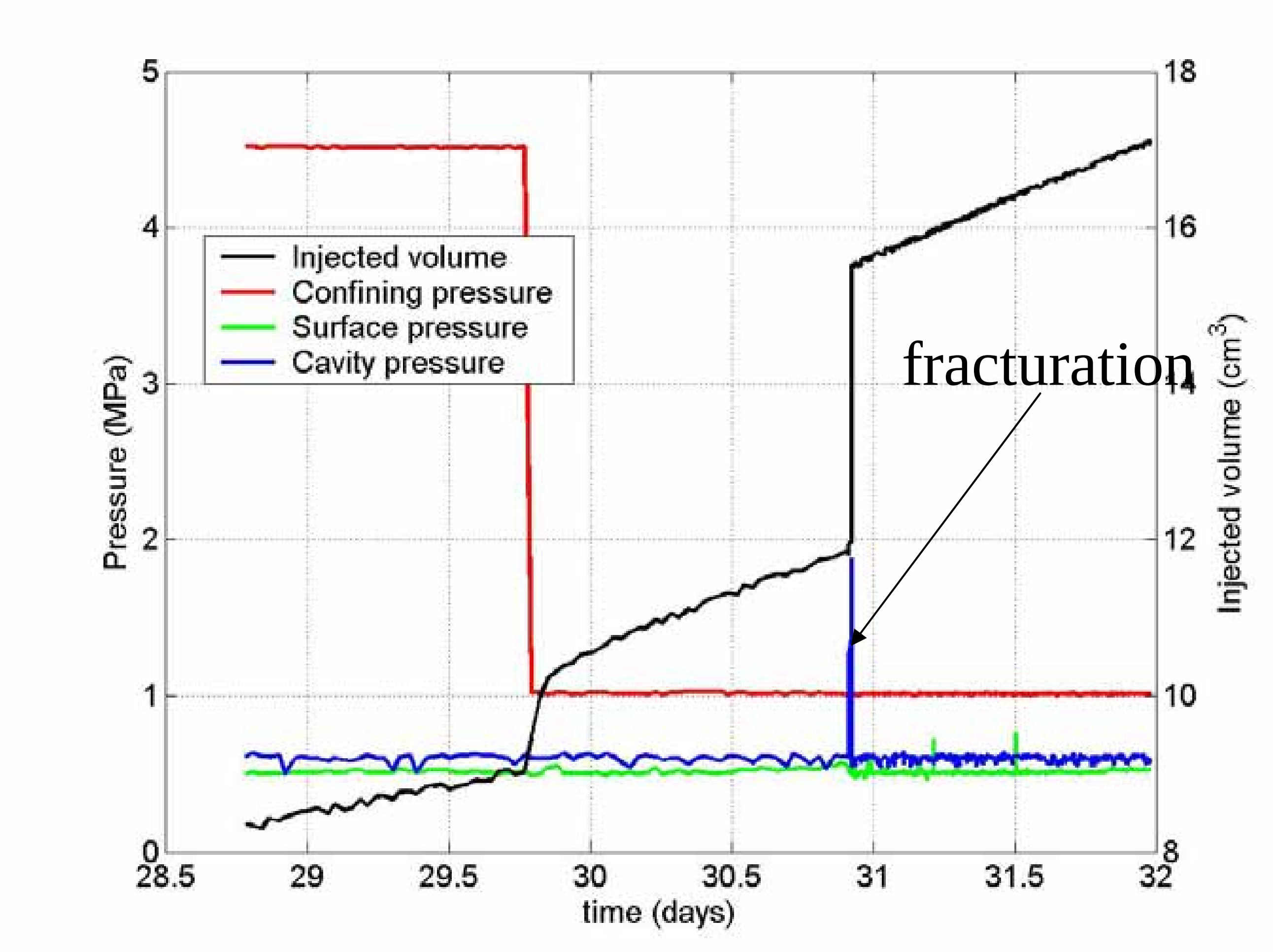
Mol – shearing stage (contractant behavior)



⇨ irreversible decrease of permeability ($k=2x10^{-19} m^2$ during 20 days)

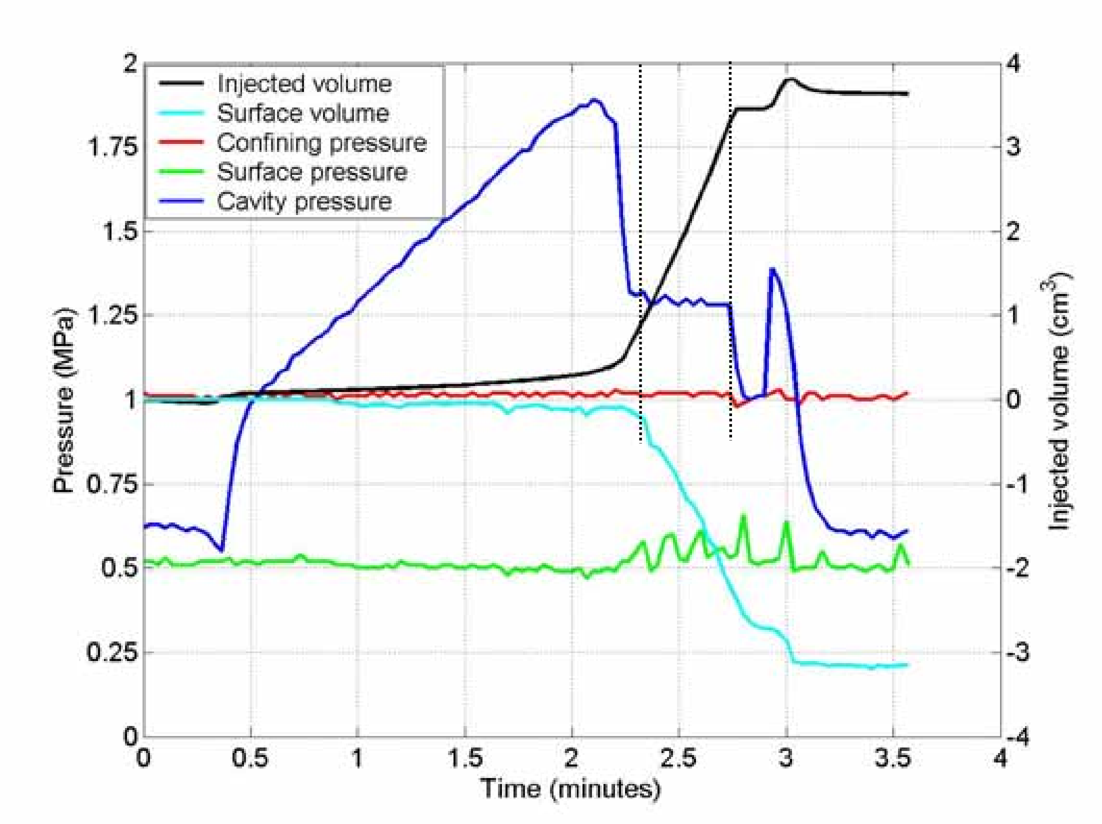
Permeability tests on hollow cylinders

Mol



Permeability tests on hollow cylinders

Mol – Hydraulic fracturation stage

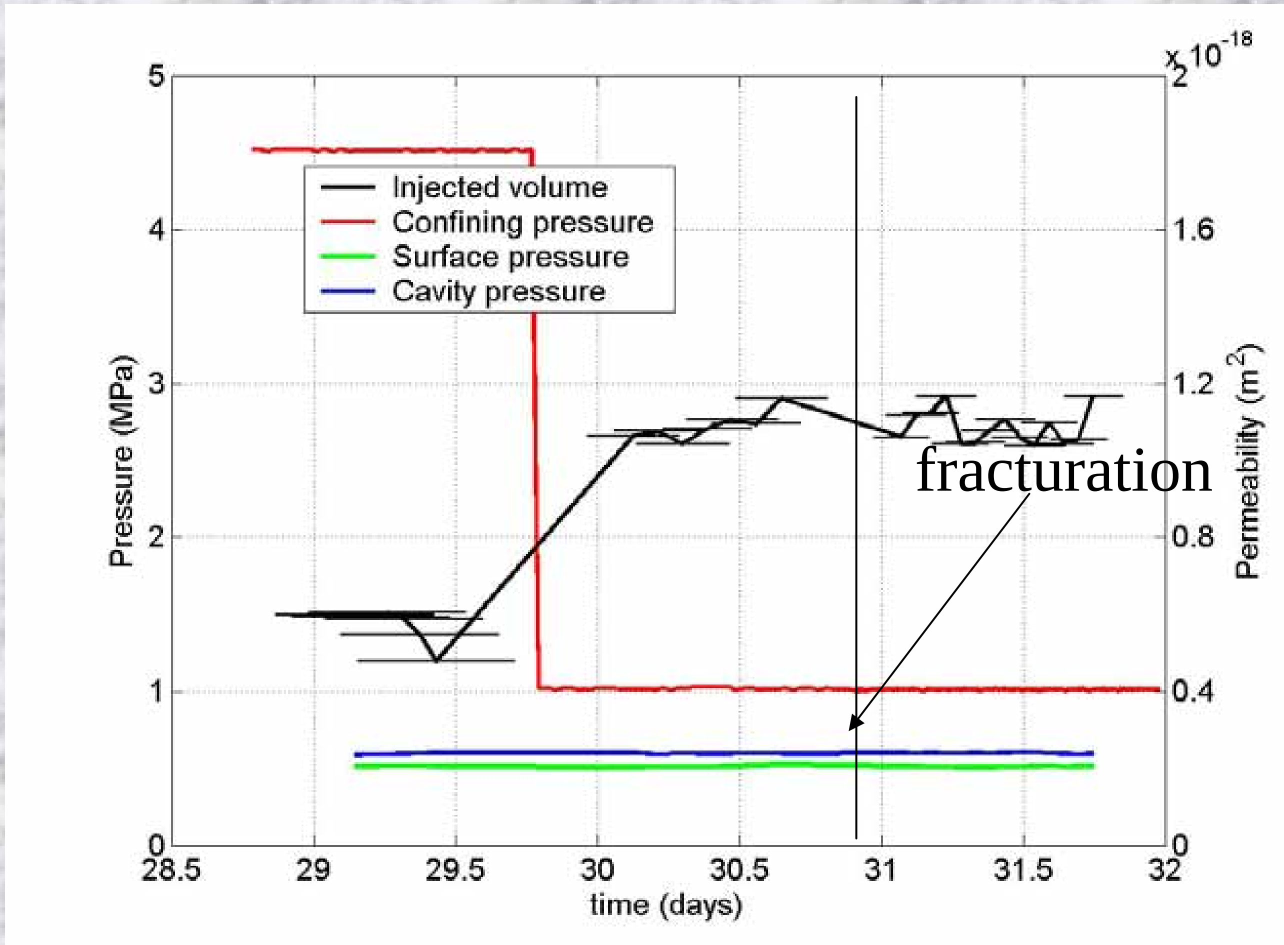


Steady state flow after fracturation

$k_{eq}=7x10^{-16}\ m^2$ $e = 8\mu m$

Permeability tests on hollow cylinders

Mol – Hydraulic fracturation stage



no irreversible effect of fracturation on permeability (self-sealing)

Permeability tests on hollow cylinders

Mol clay sample after dismantling

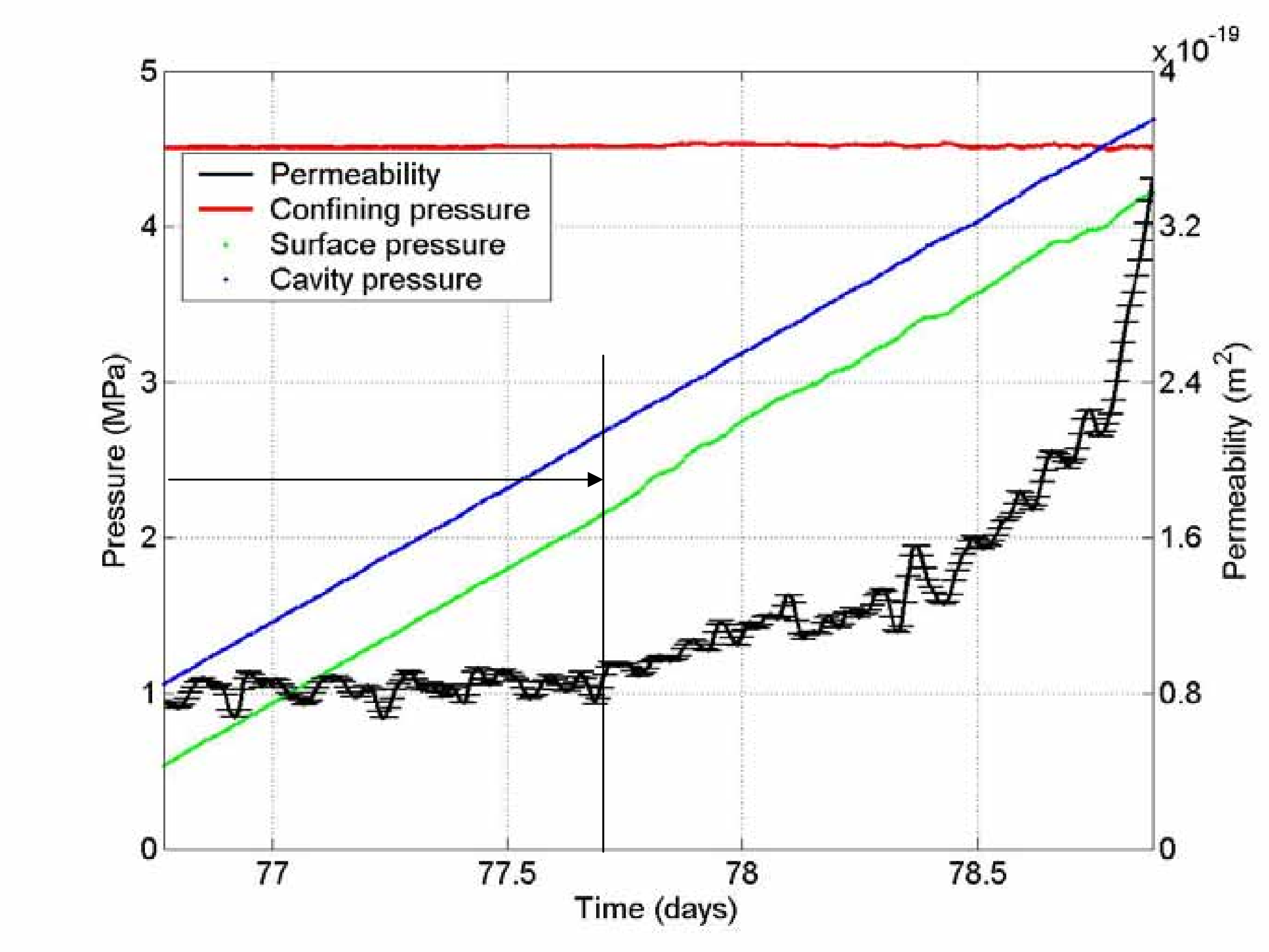
Permeability tests on hollow cylinders

Results – Mont Terri clay

- in finalization
- Tests performed on samples with a radial fracture
- $k_{eq}=5x10^{-20}$ m^2 $\rightarrow 5x10^{-19}$ m^2 ($e=0\rightarrow 0.7\mu m$ if $k=5x10^{-20}$ is assumed. transition from rock dominated flow to fracture dominated flow?)
- decrease of permeability according to time by a factor 5 in 95 days (fracture self-sealing?)
- Self-healing ? (to confirm after dismantling)
- A test on an intact sample is planned in order to confirm these results

Permeability tests on hollow cylinders

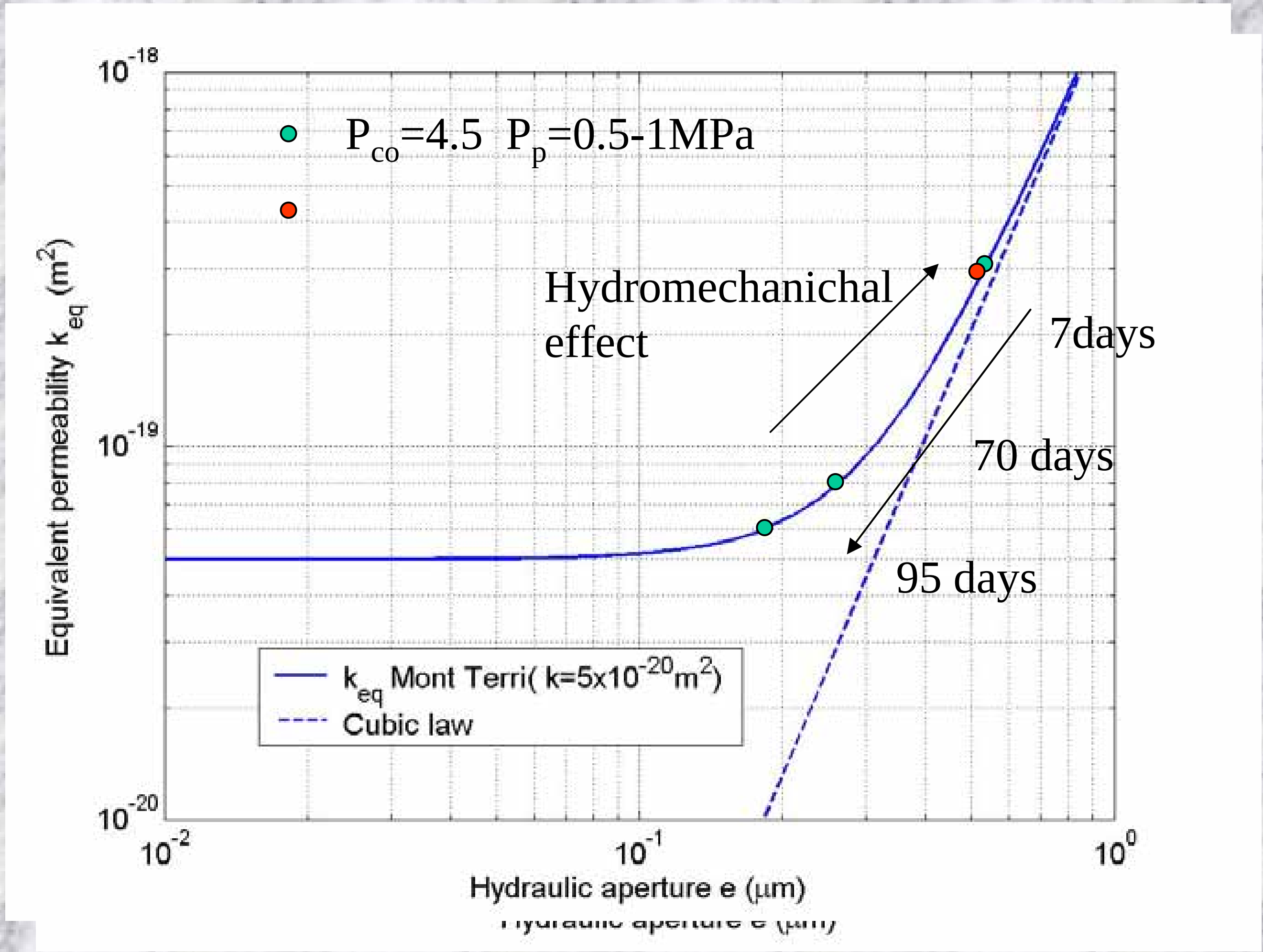
Results – Mont Terri clay



Hydromechanical effect

Permeability tests on hollow cylinders

Results – Mont Terri clay



Constitutive modelling

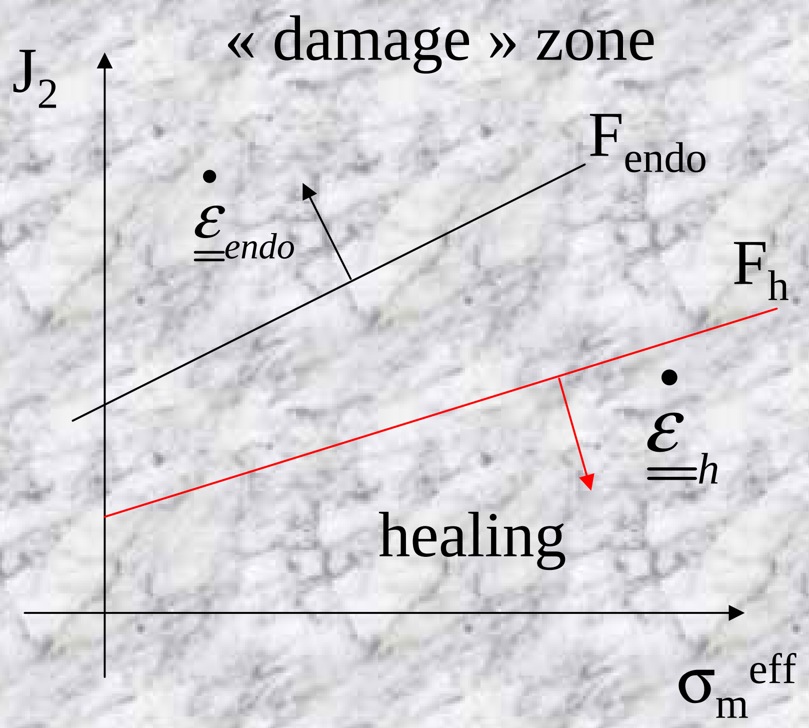
identified mechanism	model
• Consolidation	x
• time effect	x
• swelling	(x) indirect
• Dissolution/cristallization	

Constitutive modelling

modelling assumption

- Continuous porous medium
- Effective stress
- Introduction of a « healing strain »
- Strain/permeability coupling

Constitutive modelling



$$\underline{\underline{\varepsilon}}_{irr} = \underline{\underline{\varepsilon}}_{p} + \underline{\underline{\varepsilon}}_{vp} + \underline{\underline{\varepsilon}}_{h}$$

damage mechanisms

healing strain

$$\dot{\underline{\underline{\varepsilon}}}_h = \frac{1}{\eta}\left\langle -F_h \right\rangle^n \cdot \left|\varepsilon_{irr}\right|^p \cdot \frac{\partial F_h}{\partial \underline{\underline{\sigma}}^{eff}}$$

$$k\left(\underline{\underline{\varepsilon}}_{irr}, \underline{\underline{\varepsilon}}_{e}\right)$$