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SCCER SoE
SWISS COMPETENCE CENTER for ENERGY RESEARCH
SUPPLY of ELECTRICITY

Mechanical response of Opalinus Clay during CO_2 injection

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Carbon Capture Storage - CCS

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Capture process

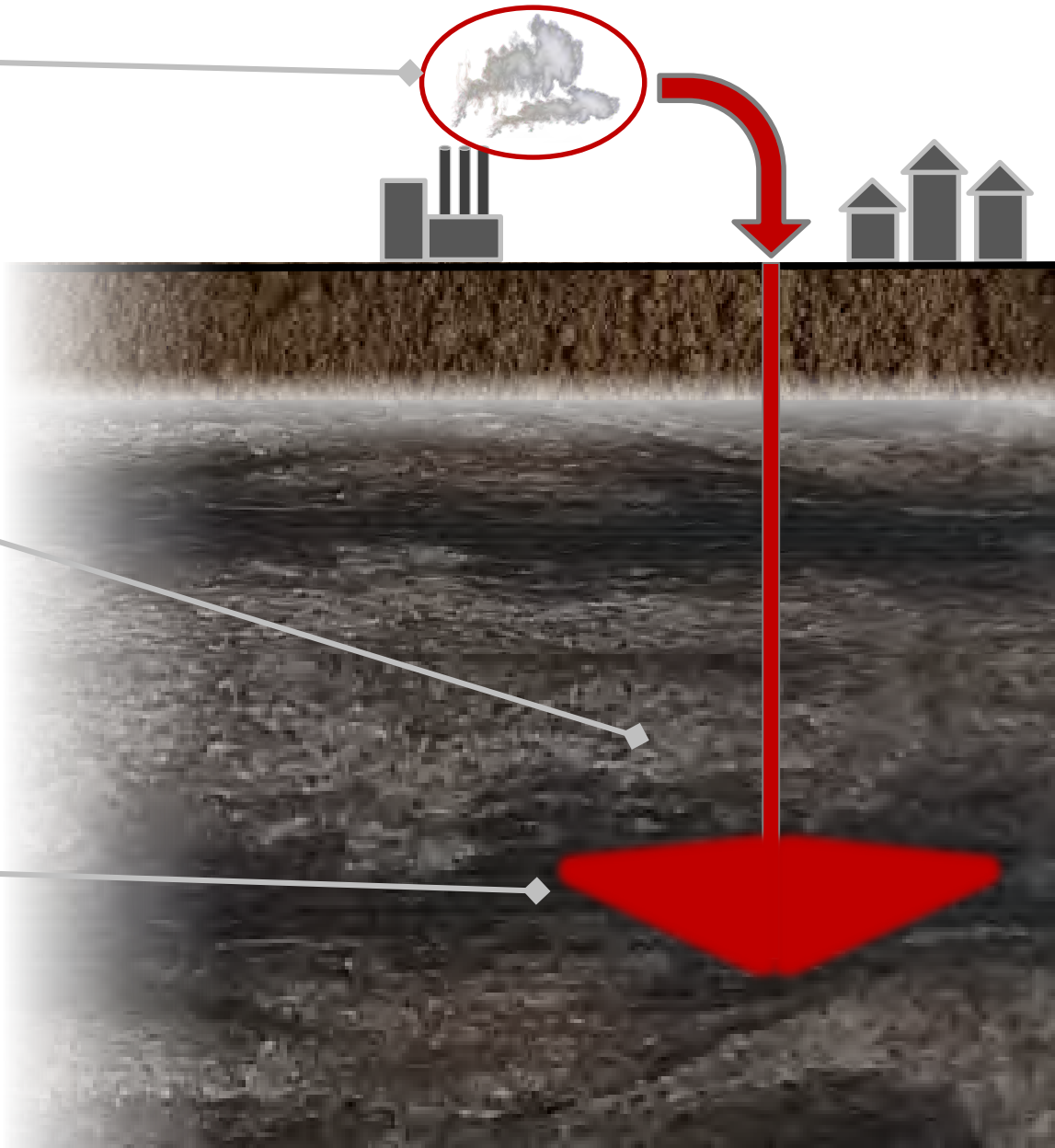
- CO_2 capture at the surface
- injection perfromed at the liquid state

Caprock formation

- barrier to prevent CO_2 migration to the surface
- low permeability (shales)

Reservoir formation

- high storage capacity
- depleted HC reservoirs
- saline aquifers



CCS – Caprock related challenges

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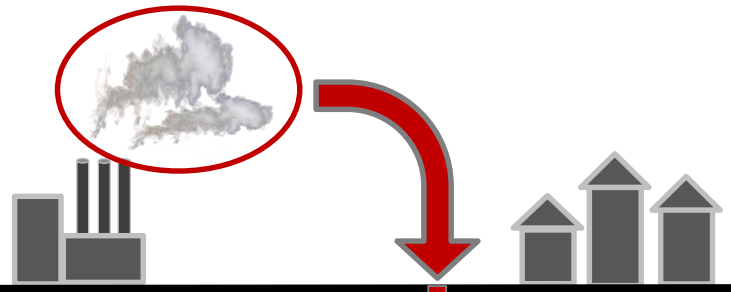
Definition of the injection pressure and flow rate



sealing capacity of the caprock

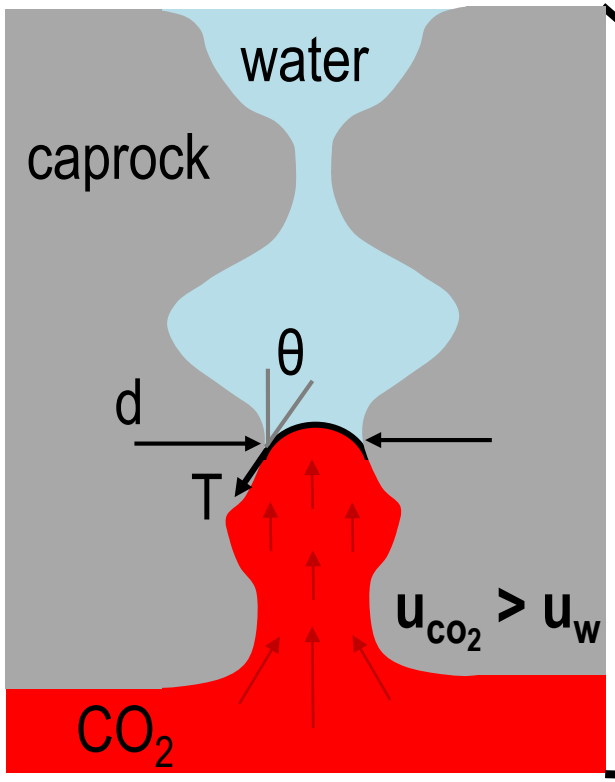
- assessment of the caprock capillary-entry pressure

integrity of the caprock

- fracture generation due to CO_2 overpressure
- failure due to thermal (cooling) effect

Caprock sealing capacity

Capillary Barrier Mechanisms



$$p_c = u_{CO_2} - u_w = \frac{4T\cos\theta}{d}$$

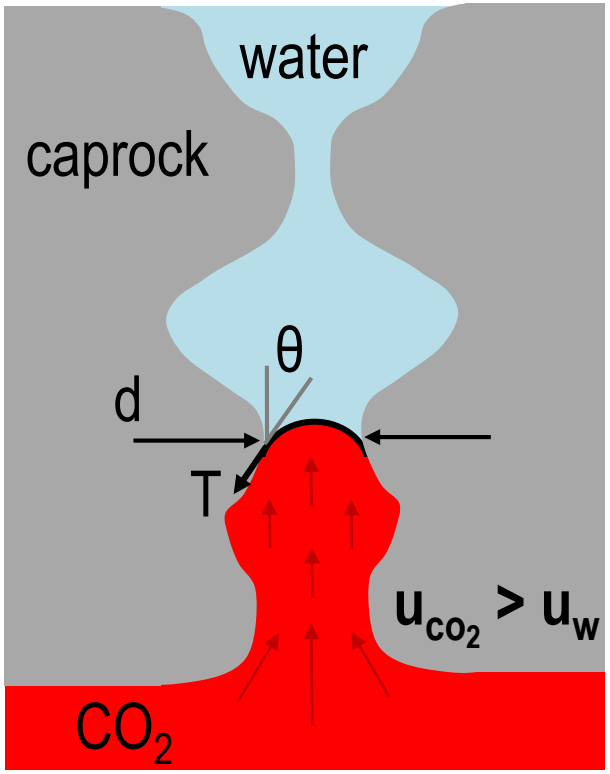
Capillary entry pressure (CO_2 overpressure)

T: surface tension

θ: contact angle

Caprock sealing capacity

Capillary Barrier Mechanisms



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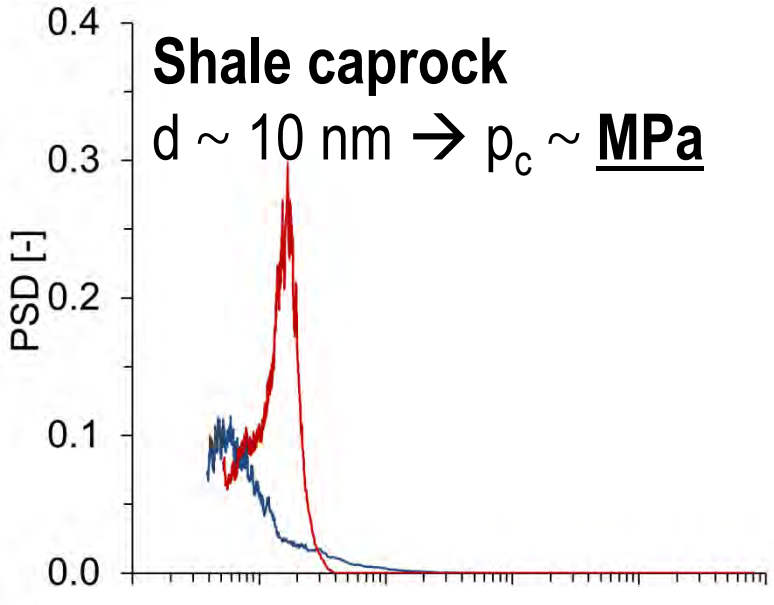
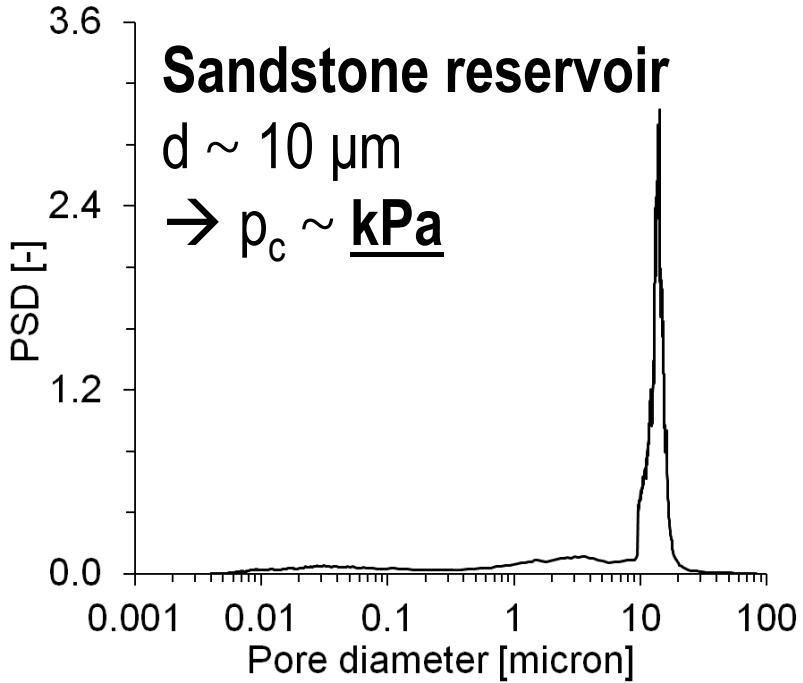
Capillary entry pressure (CO_2 overpressure)





CO_2 injection tests: objectives

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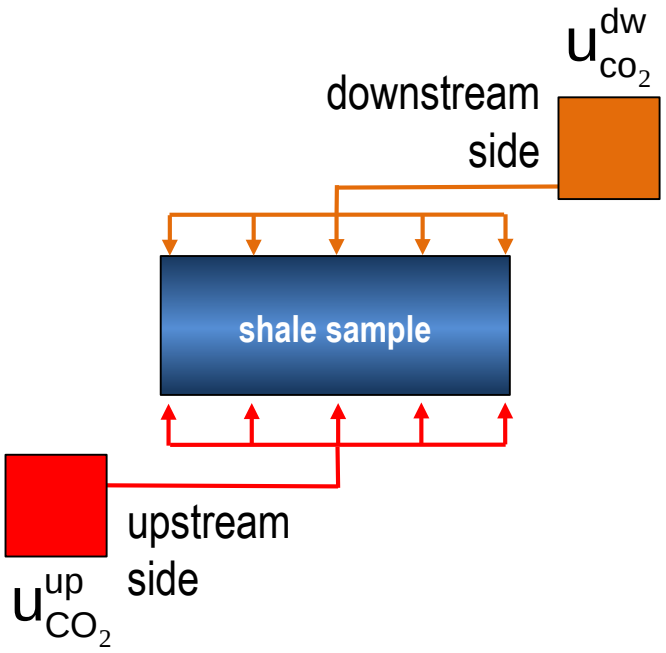
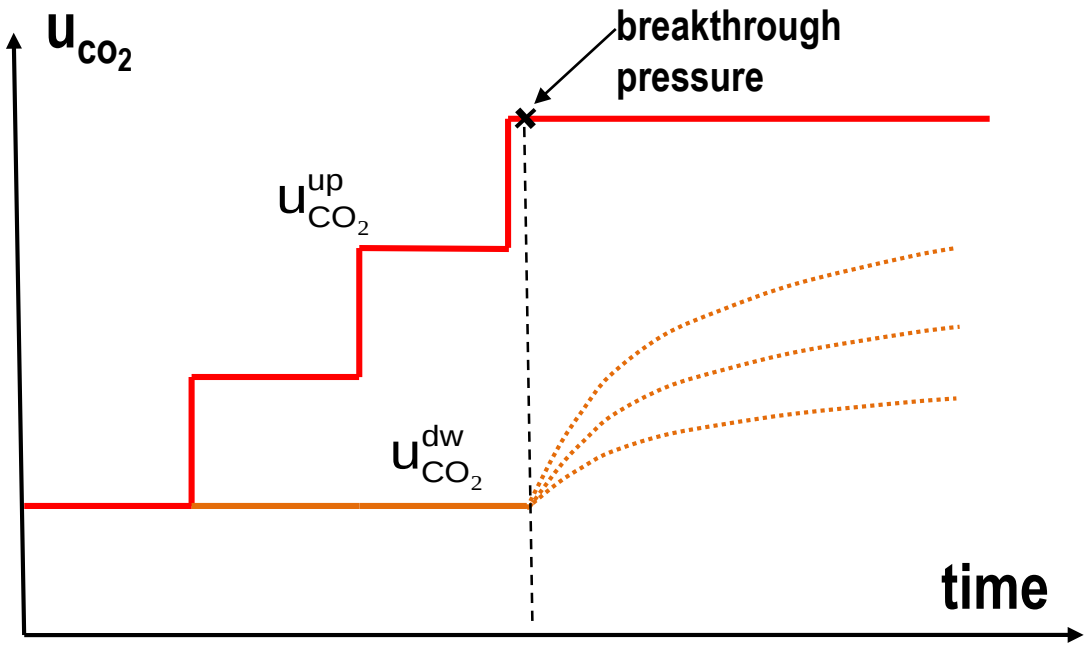
CO_2 injection experiments in water saturated samples





Challenges

- low permeability (nD range)
- entry vs breakthrough pressure
- CO_2 diffusion

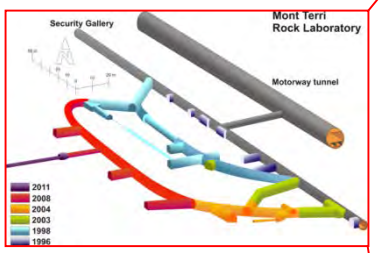
Aims of the study

- identify the capillary entry pressure
- CO_2 pressure analysis
- specimen deformation during injection
- hydro-mechanical coupling

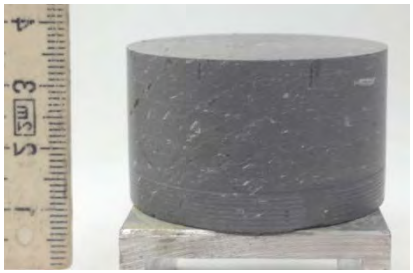
Tested material

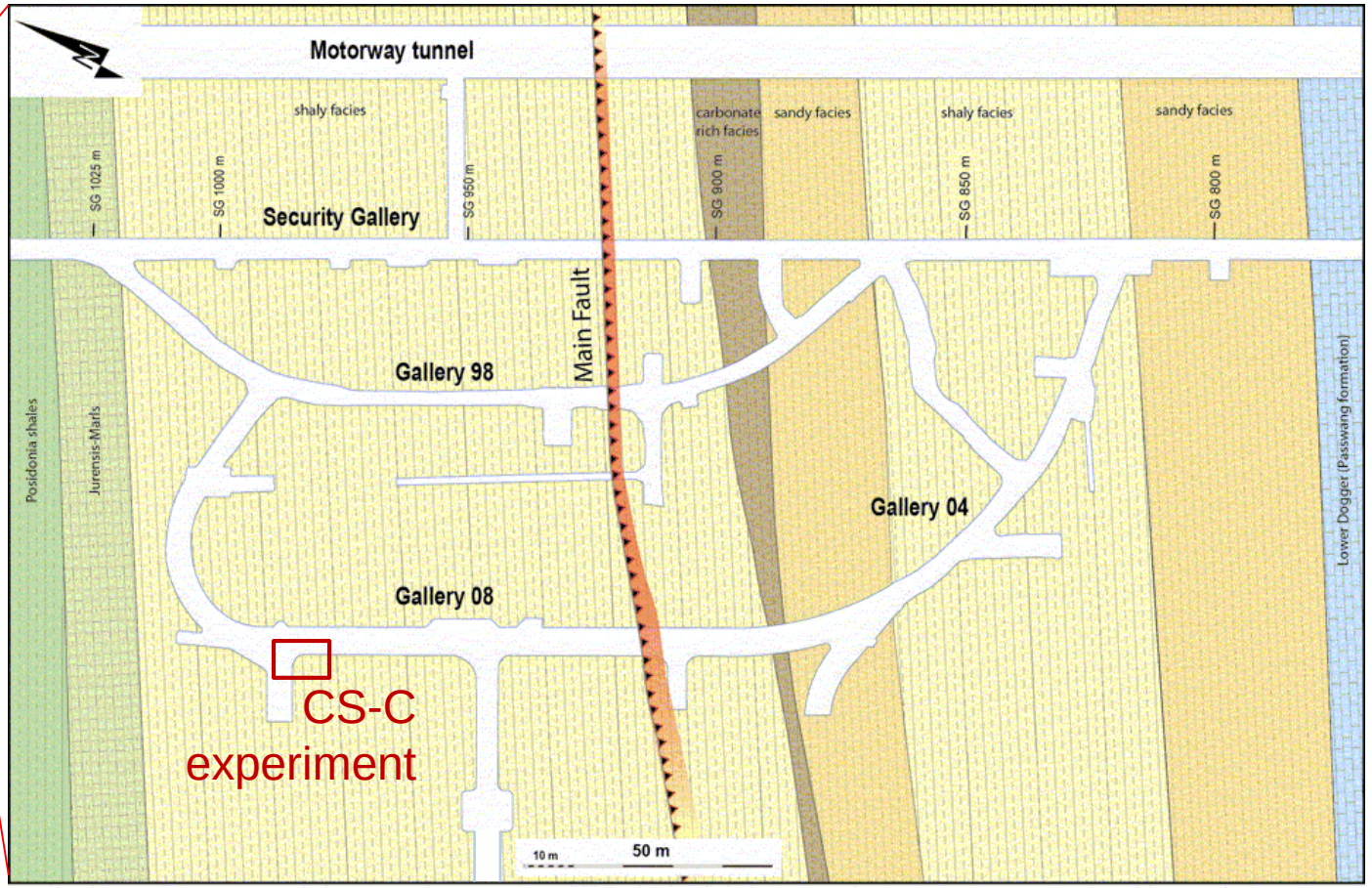
Shaly Opalinus Clay: intact sample

images from: mont-terri.ch



The Mont Terri URL





Opalinus Clay formation

Experimental set-up

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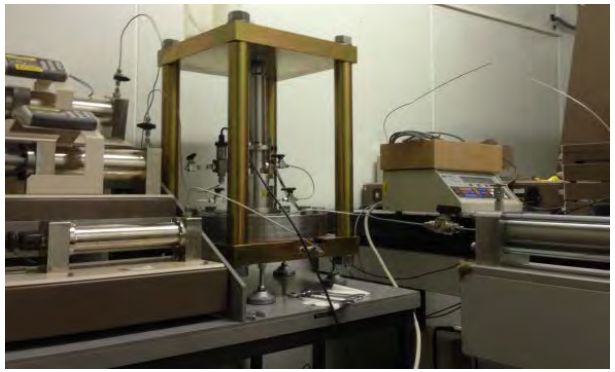

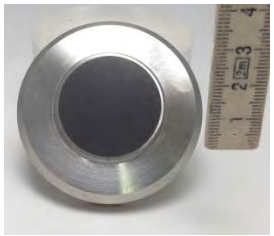

High pressure oedometric cell

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Testing procedure

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1. Saturation

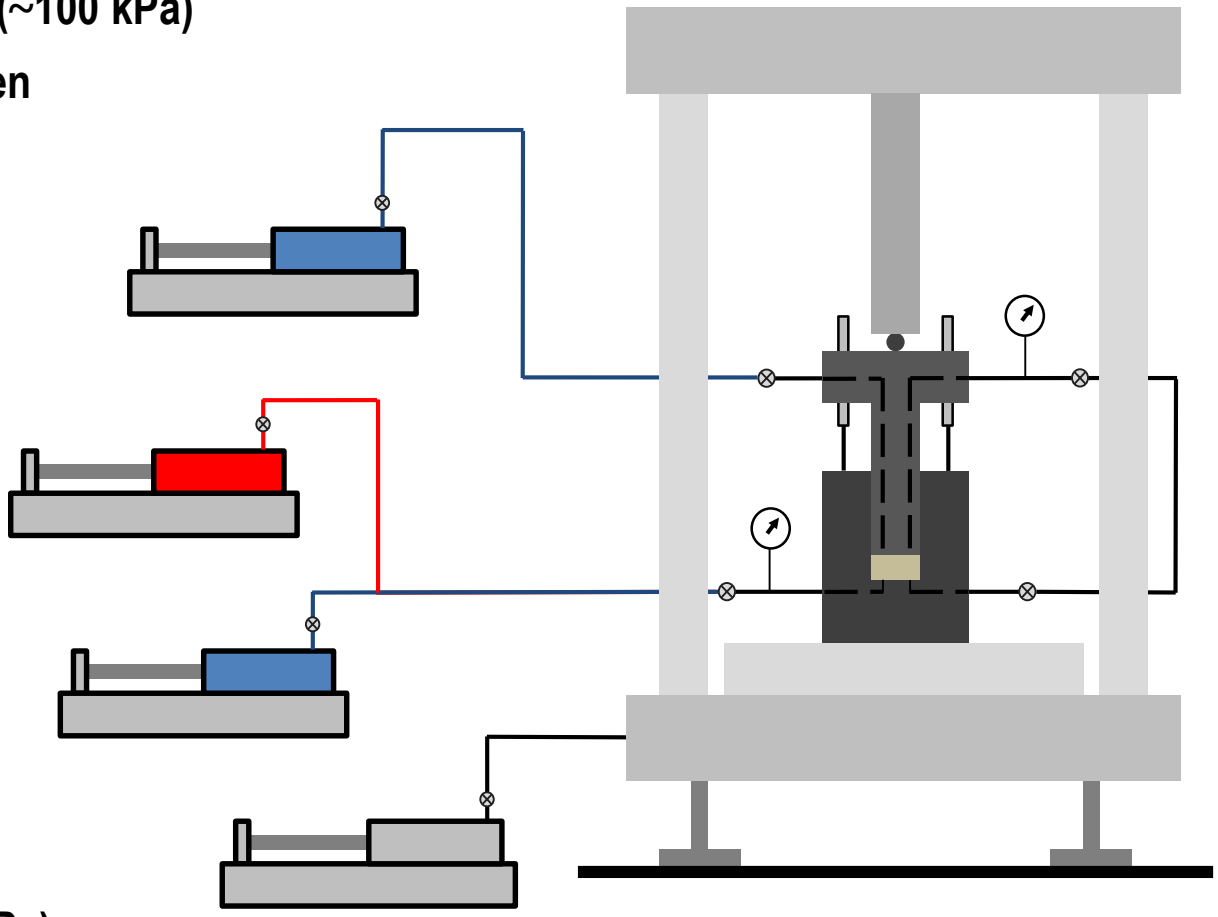
- water injection at low pressure (~100 kPa)
- constant volume of the specimen
- swelling pressure → 6 MPa

2. Permeability

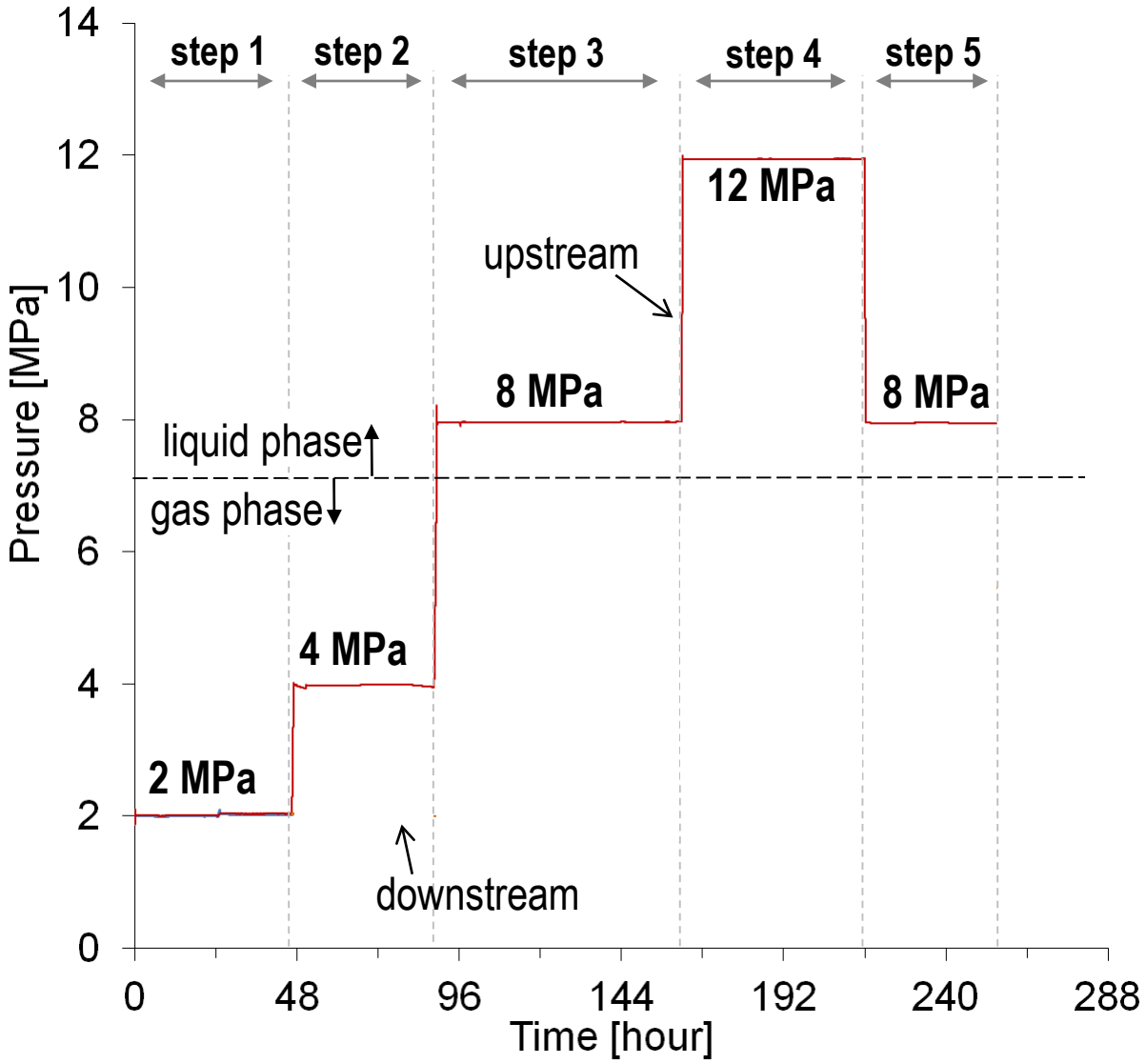
- steady state conditions (Darcy)
- $k = 1\text{-}2 \times 10^{-20}$ m^2 (~10 nD)
- pore water pressure u_w=2 MPa
- axial stress σ_a =24 MPa

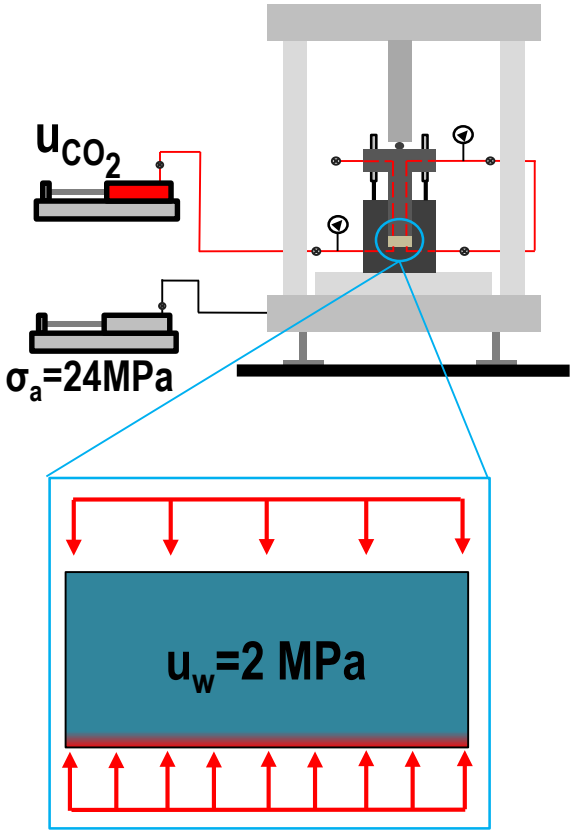
3. CO_2 injection

- stepwise injection
- gas CO_2 injection (u_{CO2} = 2, 4 MPa)
- liquid CO_2 injection (u_{CO2} = 8, 12 MPa)
- downstream pressure monitoring



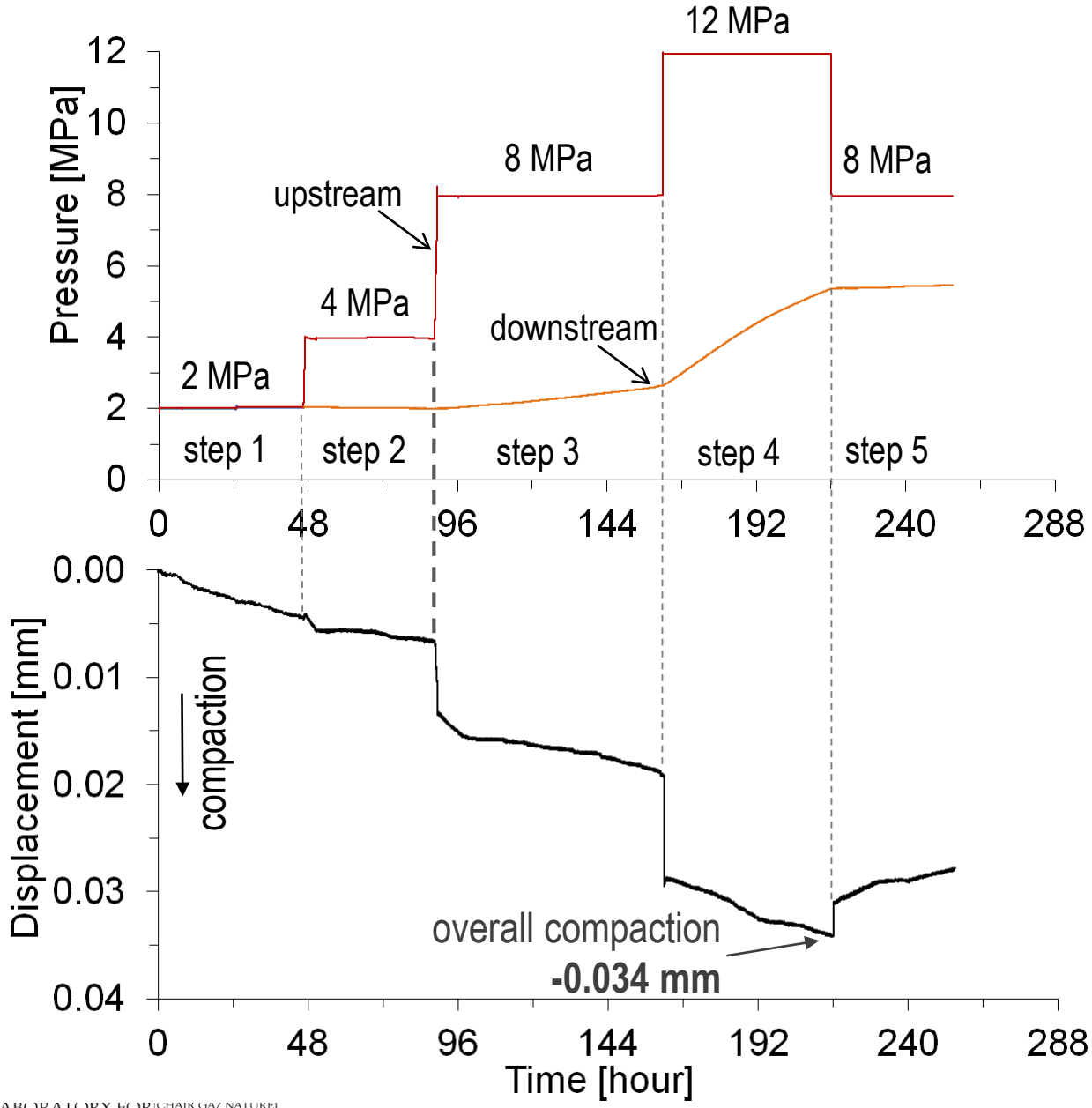
Results – CO_2 injection

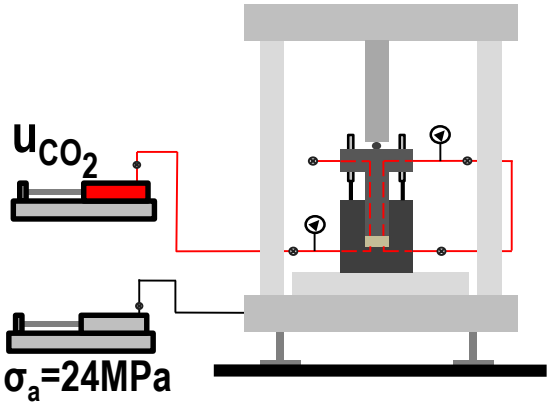




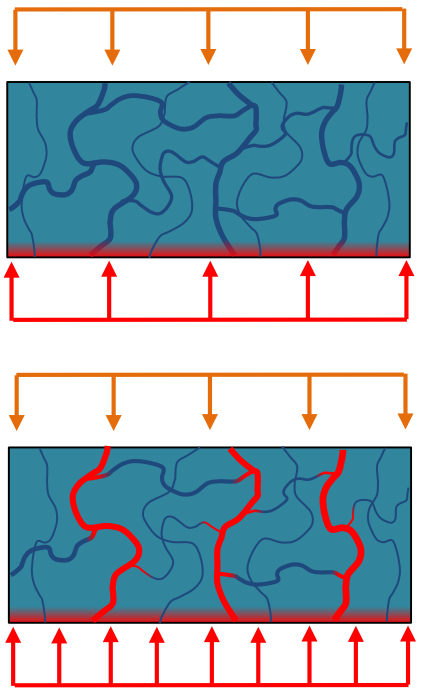
- Capillary entry pressure 2 - 6 MPa

Results – CO_2 injection

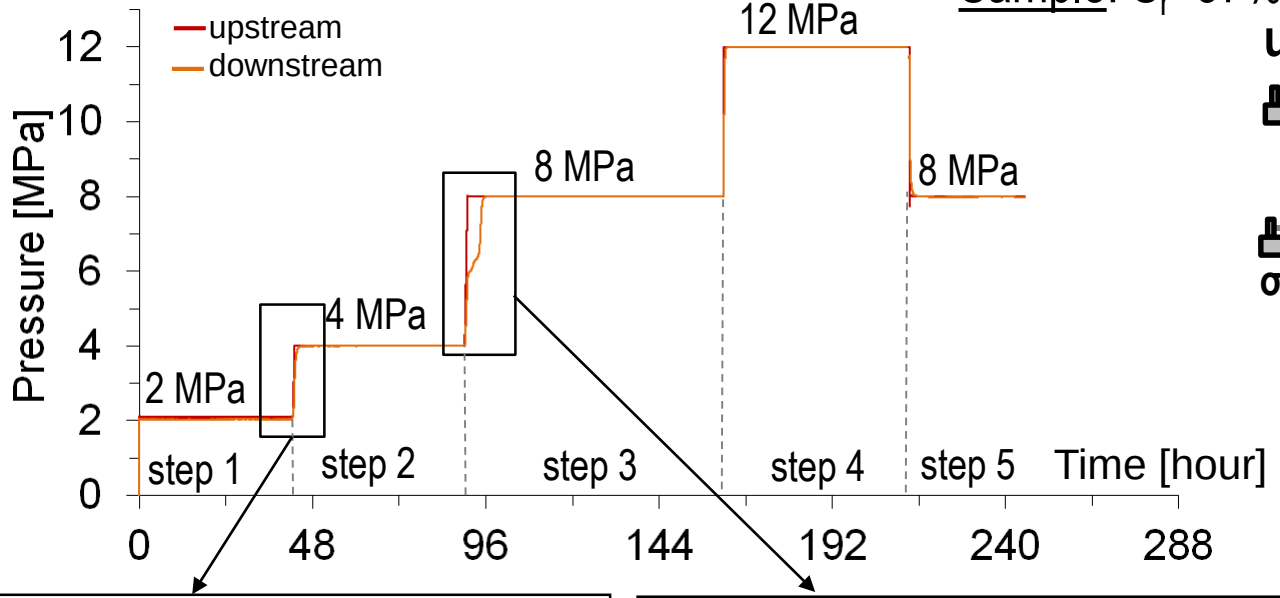




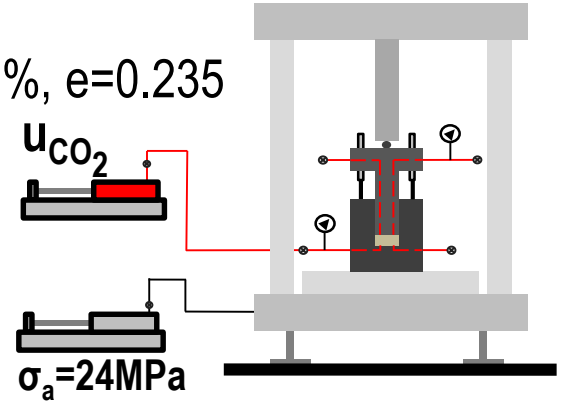
Saturated Sample

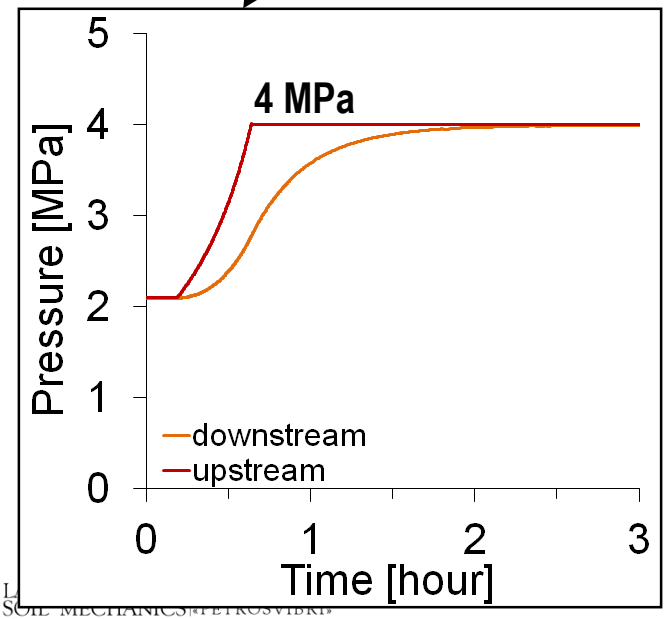


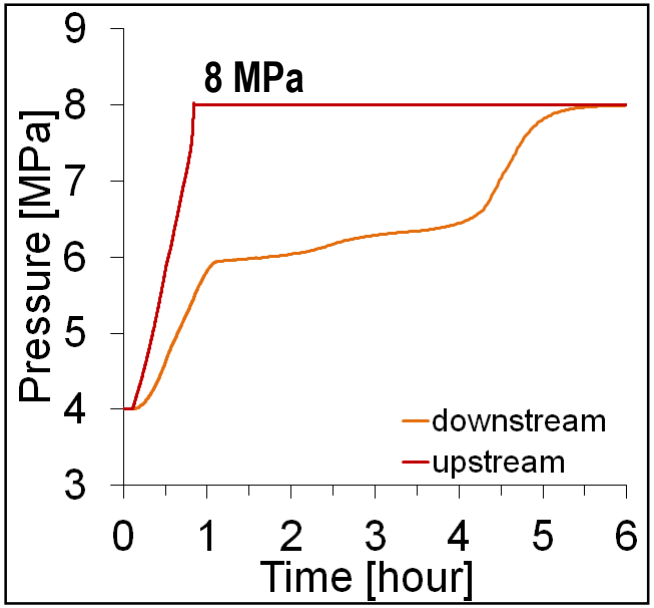
Results – CO_2 injection in unsaturated sample



Sample: S_r=37%, e=0.235







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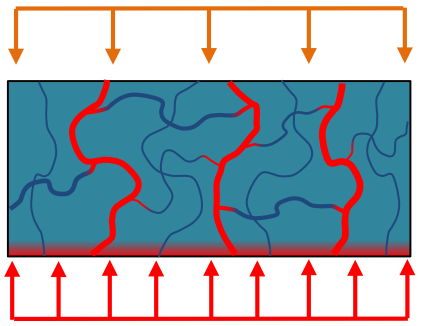

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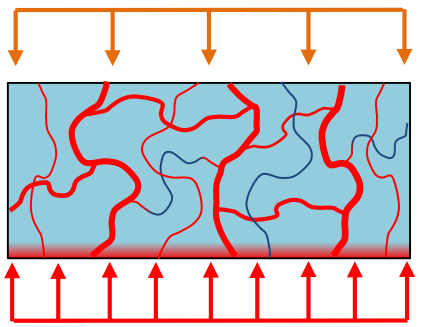

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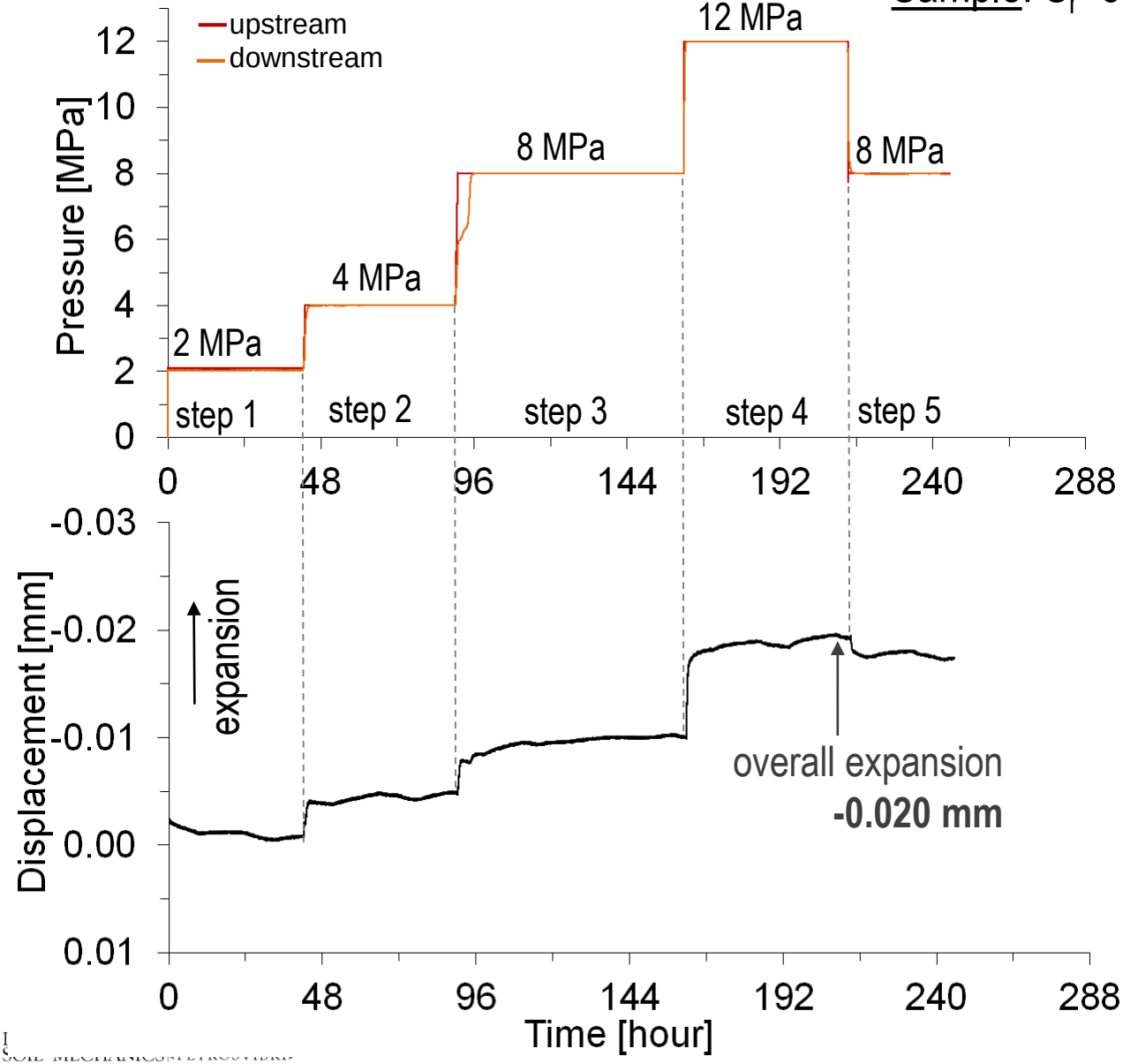

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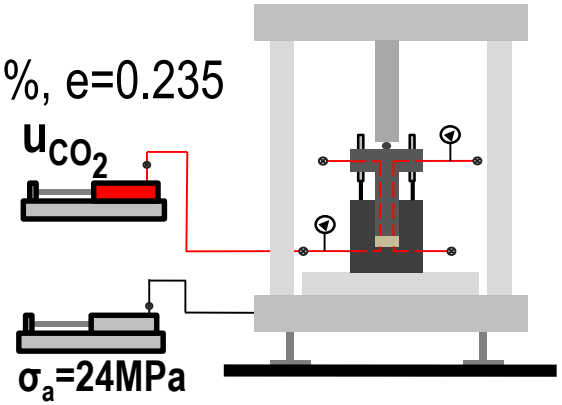

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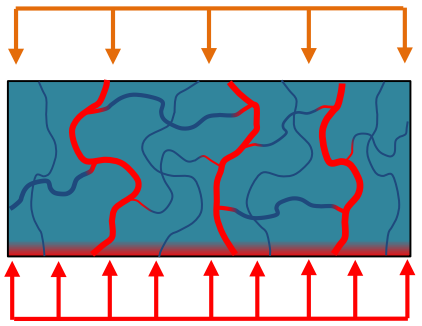

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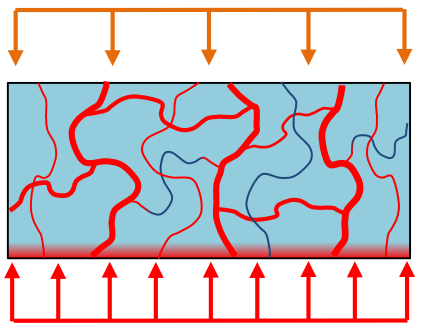

Summary

- experimental methodology to evaluate sealing capacity of shale
- intact Opalinus Clay:
  capillary entry pressure 2 - 6 MPa
- mechanical response dependent on water saturation
- compaction exhibited during injection in saturated sample