CURISTEC
EXPERTISE PROVIDERS AND TRUST BUILDERS FOR OIL & GAS

TOTAL

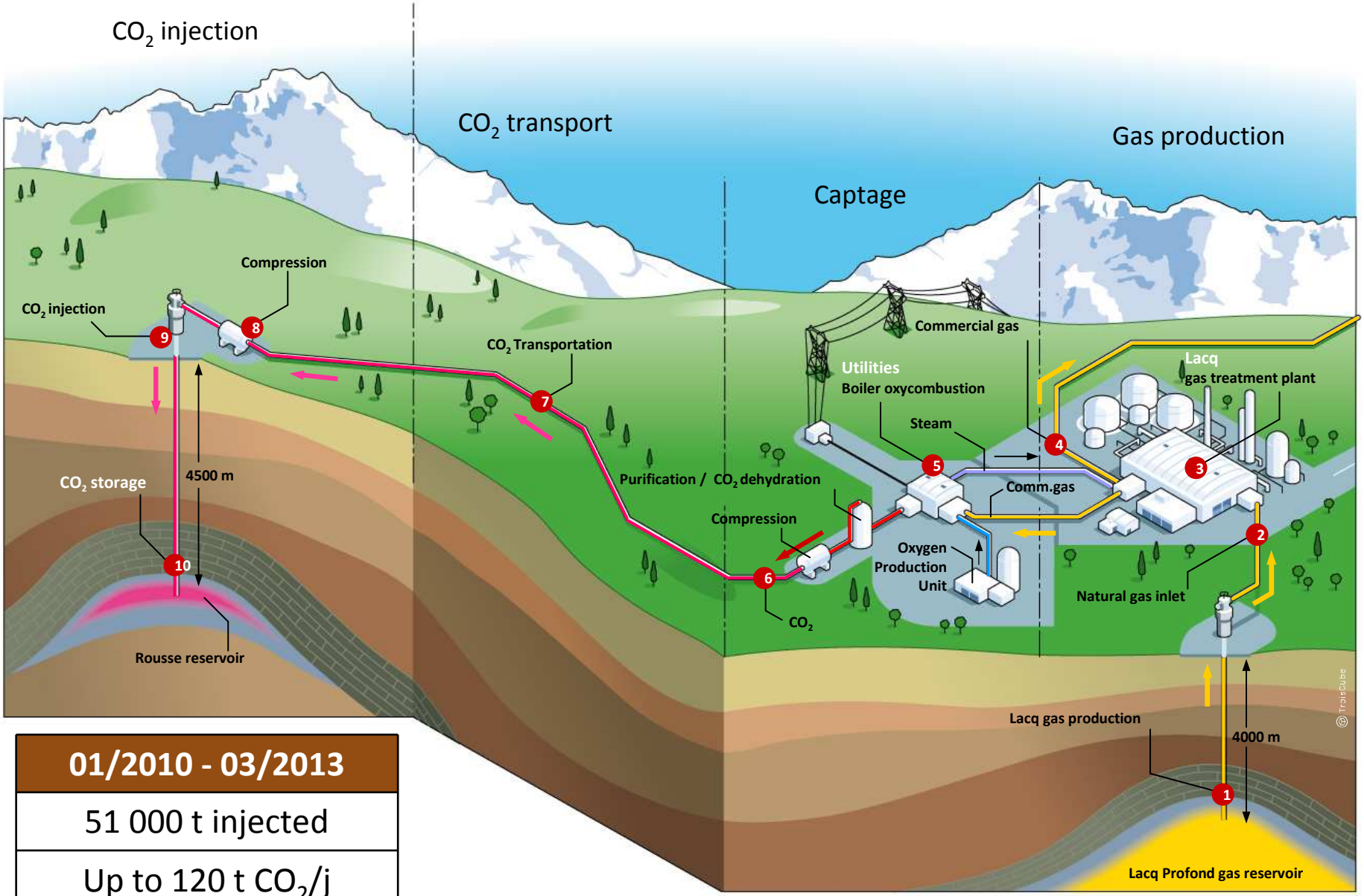
LACQ - ROUSSE CO_2 storage demonstration pilot

Axel-Pierre Bois – November, 25 2014

Agenda

- Rousse pilot
- Cement-sheath chemical integrity
- Cement-sheath mechanical integrity

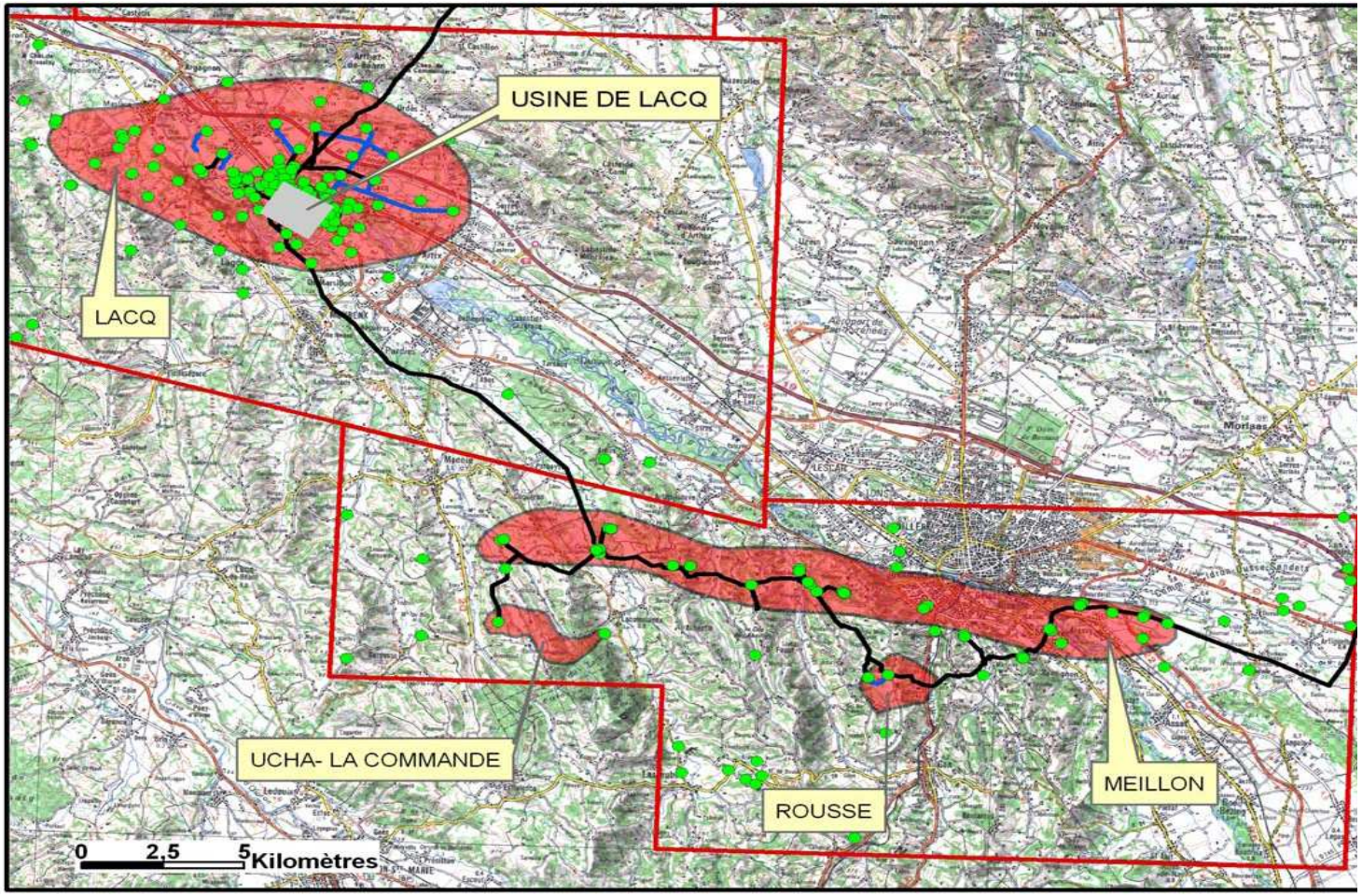
Lacq-Rousse demonstration pilot



01/2010 - 03/2013
51 000 t injected
Up to 120 t CO_2/j

Lacq-Rousse demonstration pilot

Selection among gas fields produced by TOTAL



Lacq-Rousse demonstration pilot

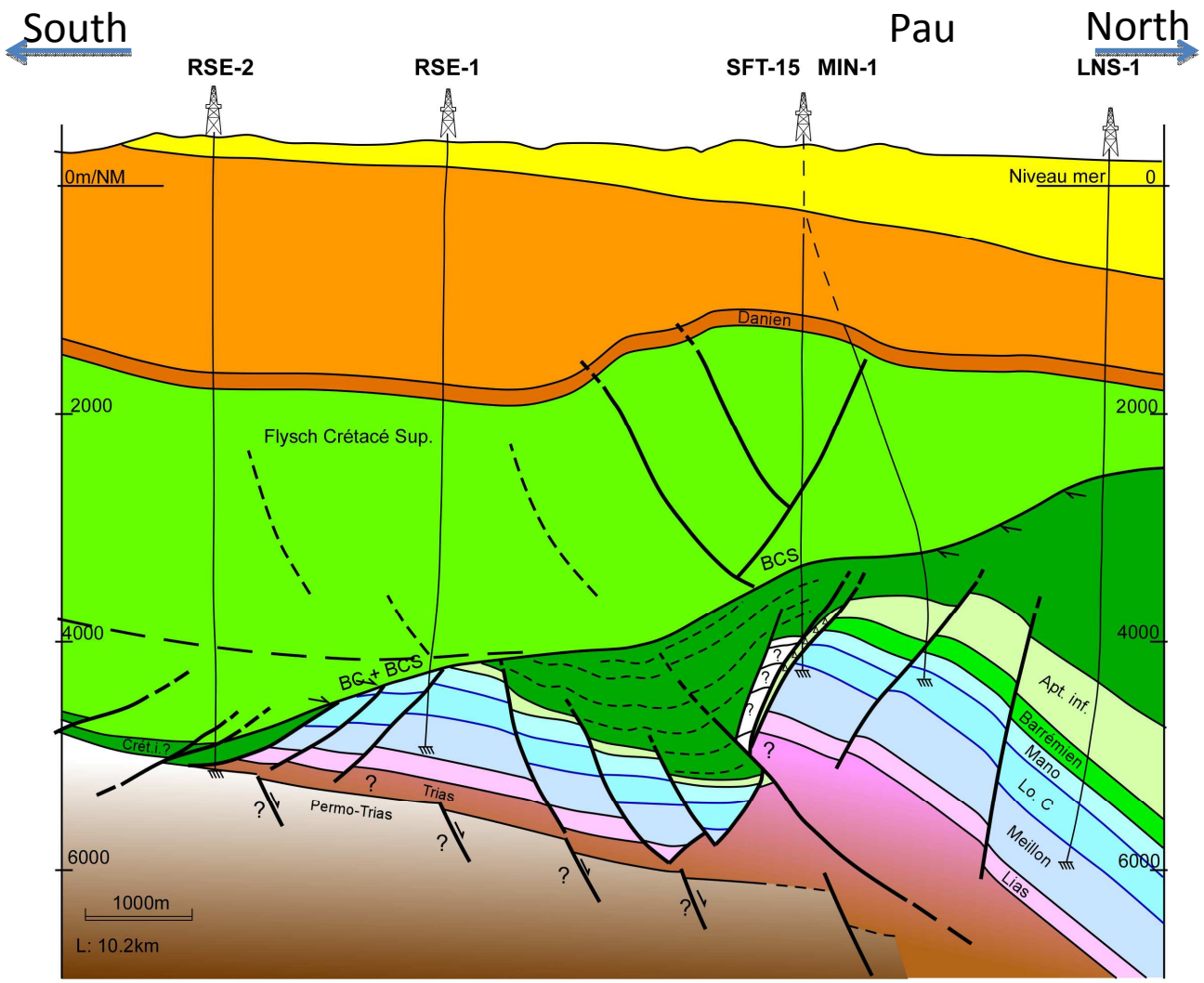
Reservoir comparison for site selection

	Max flow MSm^3/j	Cumul flow GSm^3	Pressure - MPa		Installations	Production
			Initial	Final		
Lacq	30	250	62	2	Oui	Oui
Meillon Saint Faust	10	58	48	10	Oui	Oui
Ucha-Lacommande	0.3	1.9	47	7	Non	Non
Rousse-Mano	0.3	0.9	48	3	Oui	Non
Rousse-Meillon	1.2	3.7	49	15	Oui	Oui

Pilot	0.06	0.06		10

- Rousse-Mano is an isolated low-pressure reservoir that is no longer produced and that is still completed
- It has been produced with on well : RSE-1

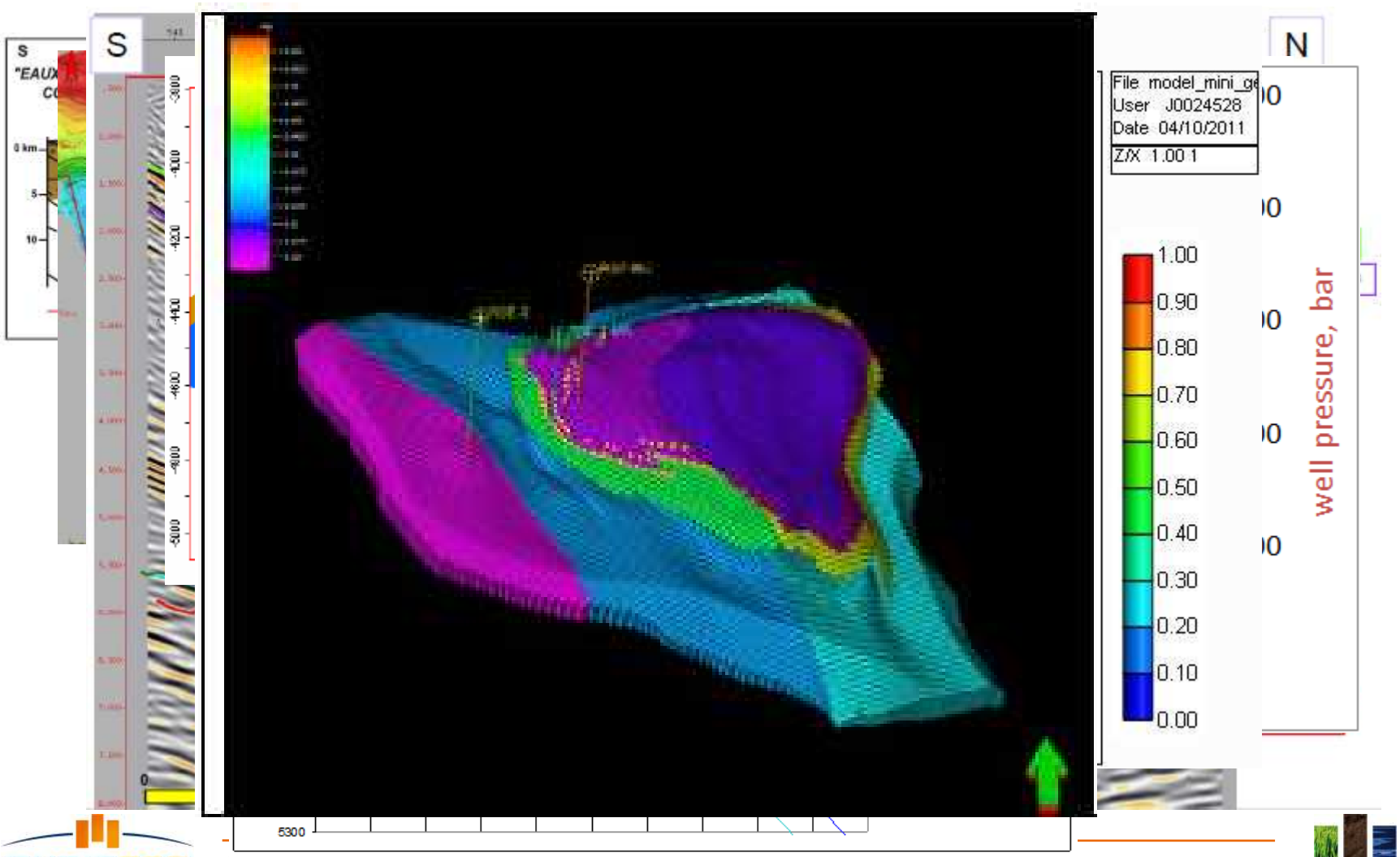
Lacq-Rousse demonstration pilot



Mano
Jurassic
Dolomitic
Fractured
4200 m (NM)
Φ ~3%
K_m < 1 mD K_f ~ 5 mD
150°C
48 ↘ 3 ↗ 8 MPa

Lacq-Rousse demonstration pilot

Geomechanical modeling



Lacq-Rousse demonstration pilot

- Under-pressurized reservoir
- Capillary entry pressure
  - Difficult to evaluate due to heterogeneity
- Geomechanics
  - No plasticity during production
  - Fault stability uncertainty at pressure larger than the initial pressure

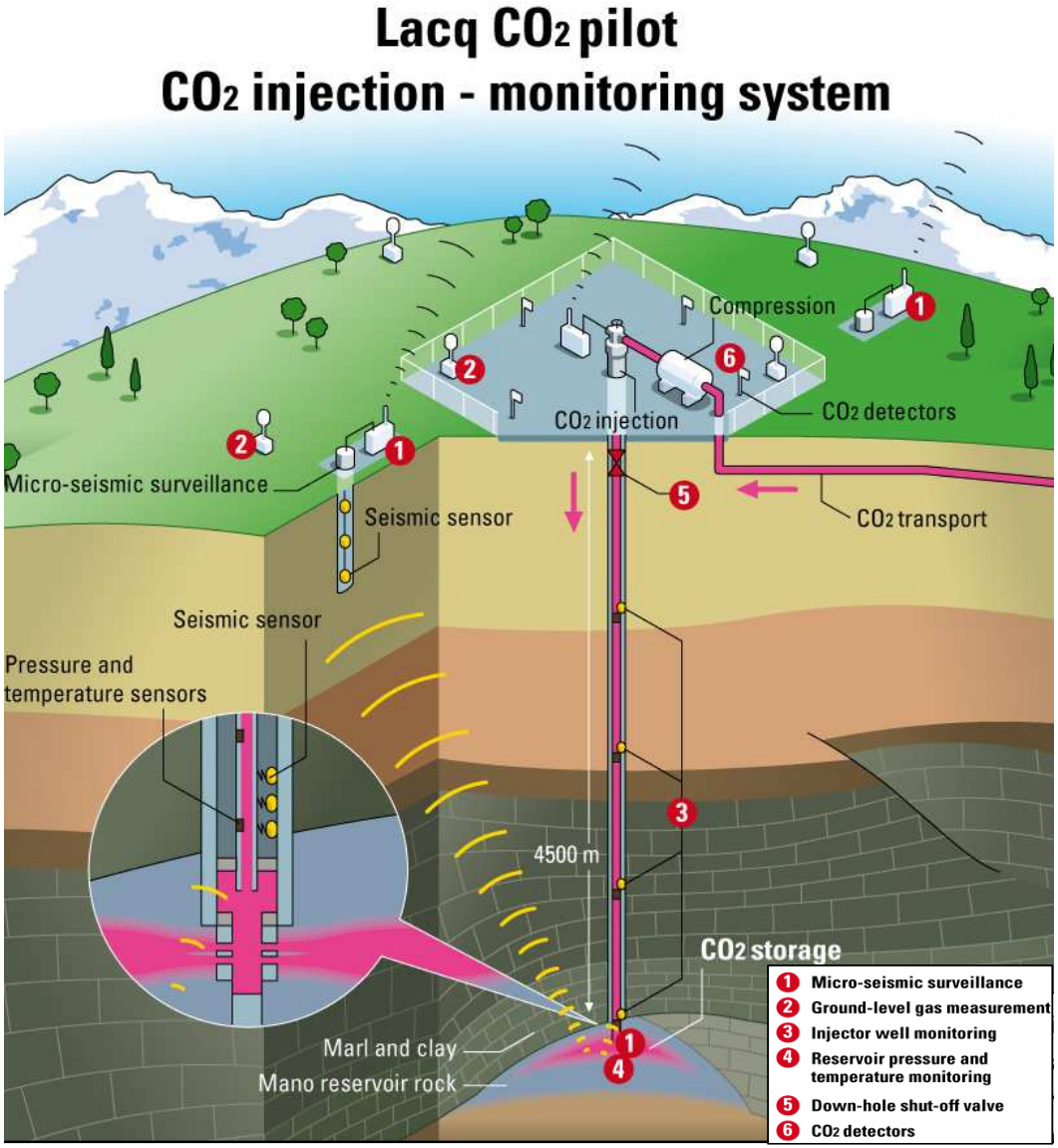
Lacq-Rousse demonstration pilot

- Geochemistry
  - Limited impact of CO_2 on the carbonated reservoir
  - Minor variations of mineralogy and porosity
  - Diffusion of CO_2 through the overburden slowed by geochemistry
- Deshydration in near wellbore area due to gas expansion

Lacq-Rousse demonstration pilot

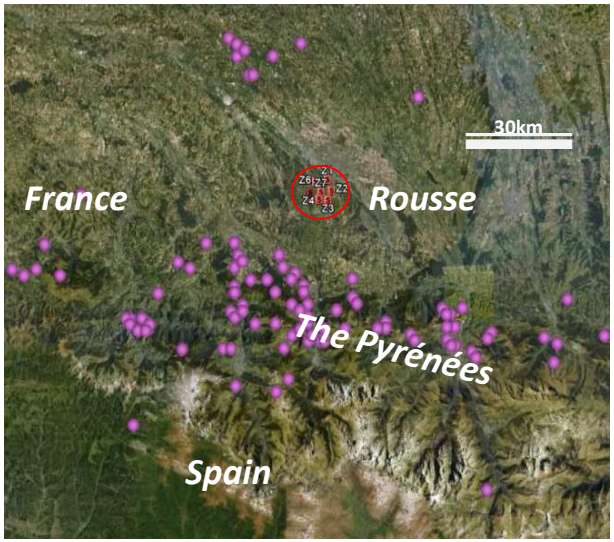
- CO_2 migrates downwards in the reservoir
  - No accumulation of CO_2 below the overburden
- **Wellbore integrity**
  - Cement sheath initially good
  - No risk due to mechanical damage
  - No risk due to chemical degradation

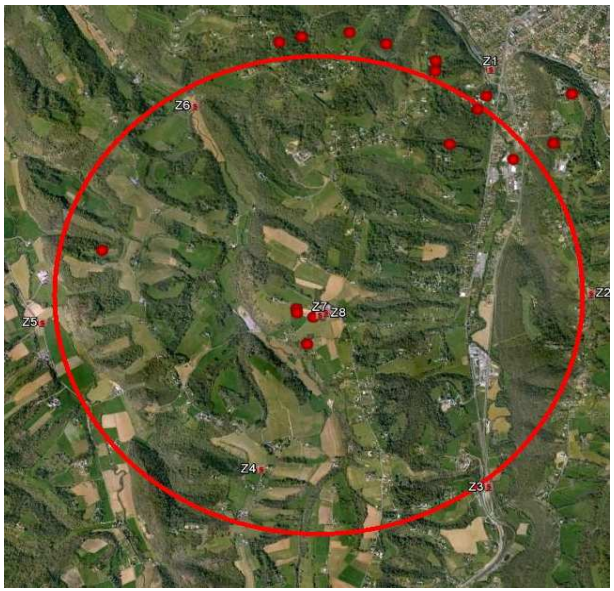
Lacq-Rousse demonstration pilot



- Injection monitoring
  - Flow, composition
- Surface seismicity monitoring
- Downhole reservoir monitoring
  - P, T @4335 m
  - Seismicity
- Environnemental monitoring

Lacq-Rousse demonstration pilot





- Regional seismicity related to Pyrenees and Lacq reservoir depletion
- Close to the site
  - Only 3 events detected by the surface network near Rousse with magnitude between -1 and -0.3
  - From March 2011, more than 2000 micro seisms detected by downhole sensors with magnitude between -2.4 and -0.8

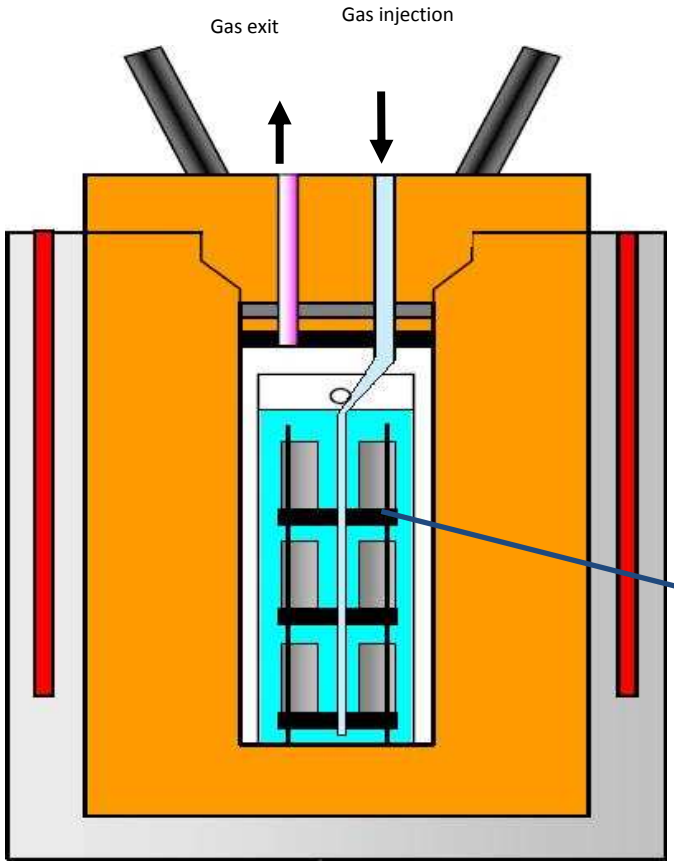
Cement / CO_2 : Uncoupled tests

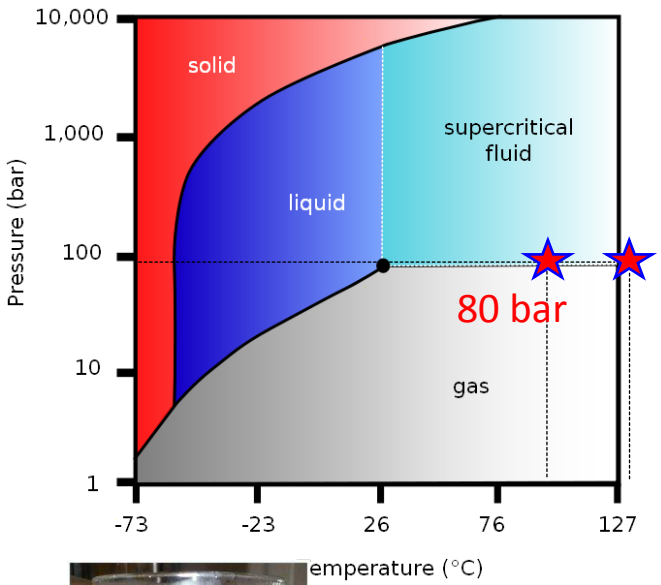
Cement is first in contact with $C0_2$ then mechanically tested

P_{CO2} = 8 MPa

T = 90°C
for neat class G

T = 140°C
for class G+35% silica BWOC



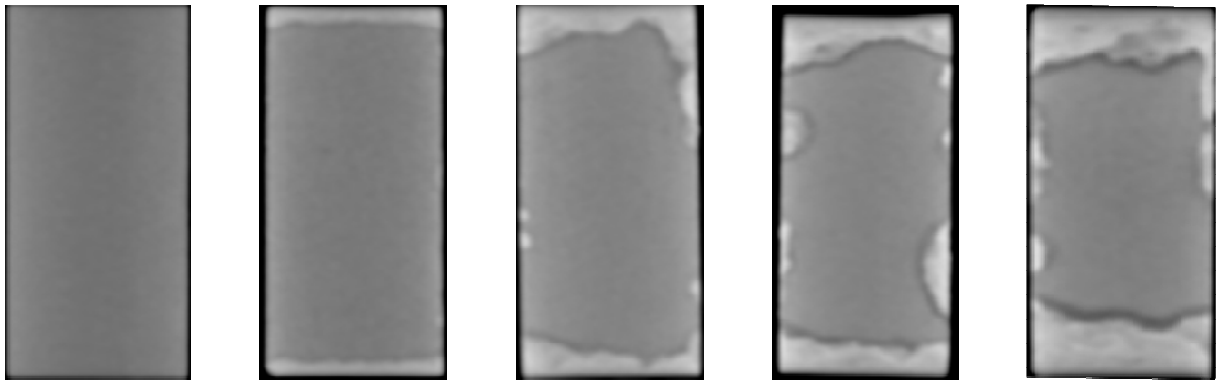


Cement/CO_2 : Uncoupled tests

X-Ray tomography: cement densification (carbonation) over time

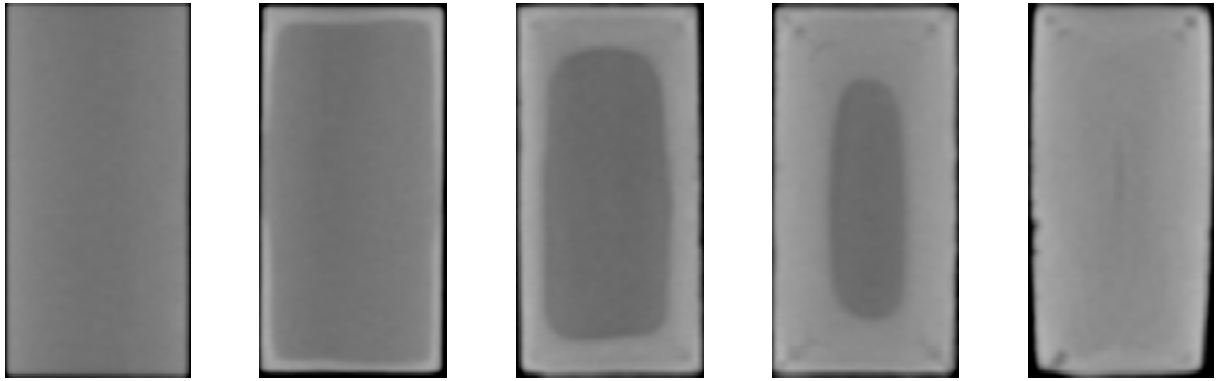
Hounsfield scale: 1100 — 2600

Neat Class G
90°C
8 MPa



Reference | 7 days | 36 days | 65 days | 90 days

Class G + Silica
140°C
8 MPa



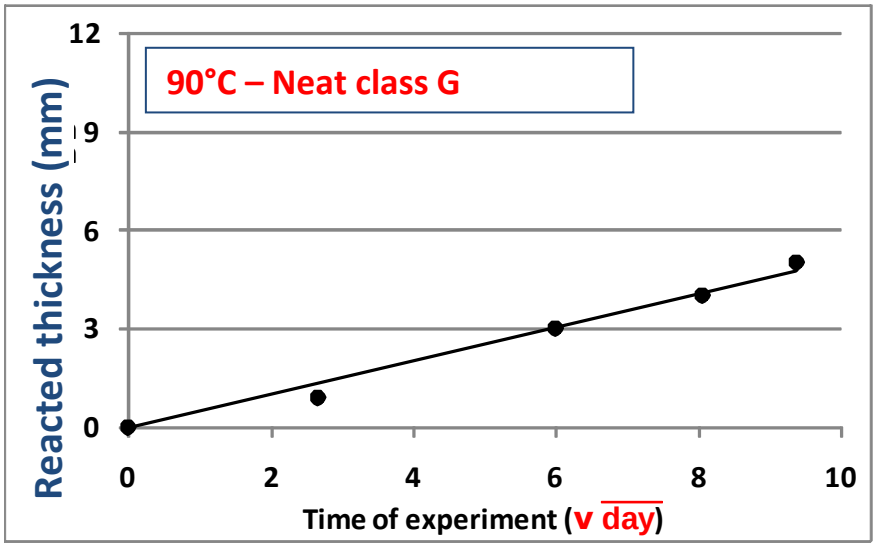
Reference | 4 days | 21 days | 31 days | 88 days

Cement/CO_2 : Uncoupled tests

Neat Class G @ 90°C & 8 MPa

Kinetics of the reaction:
Linear with respect to square root of time
9.6 mm/√yr

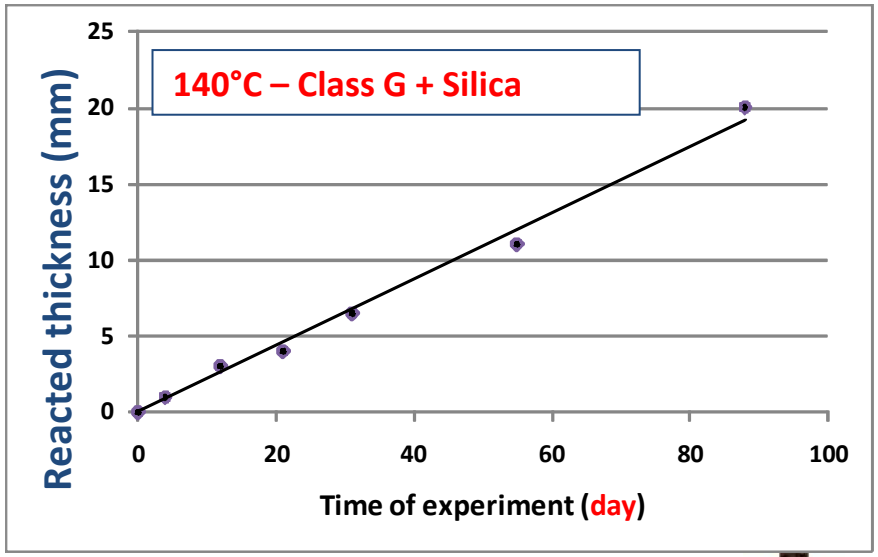
Porosity decreases from 30 to 22%



Class G + Silica @ 140°C & 8 MPa

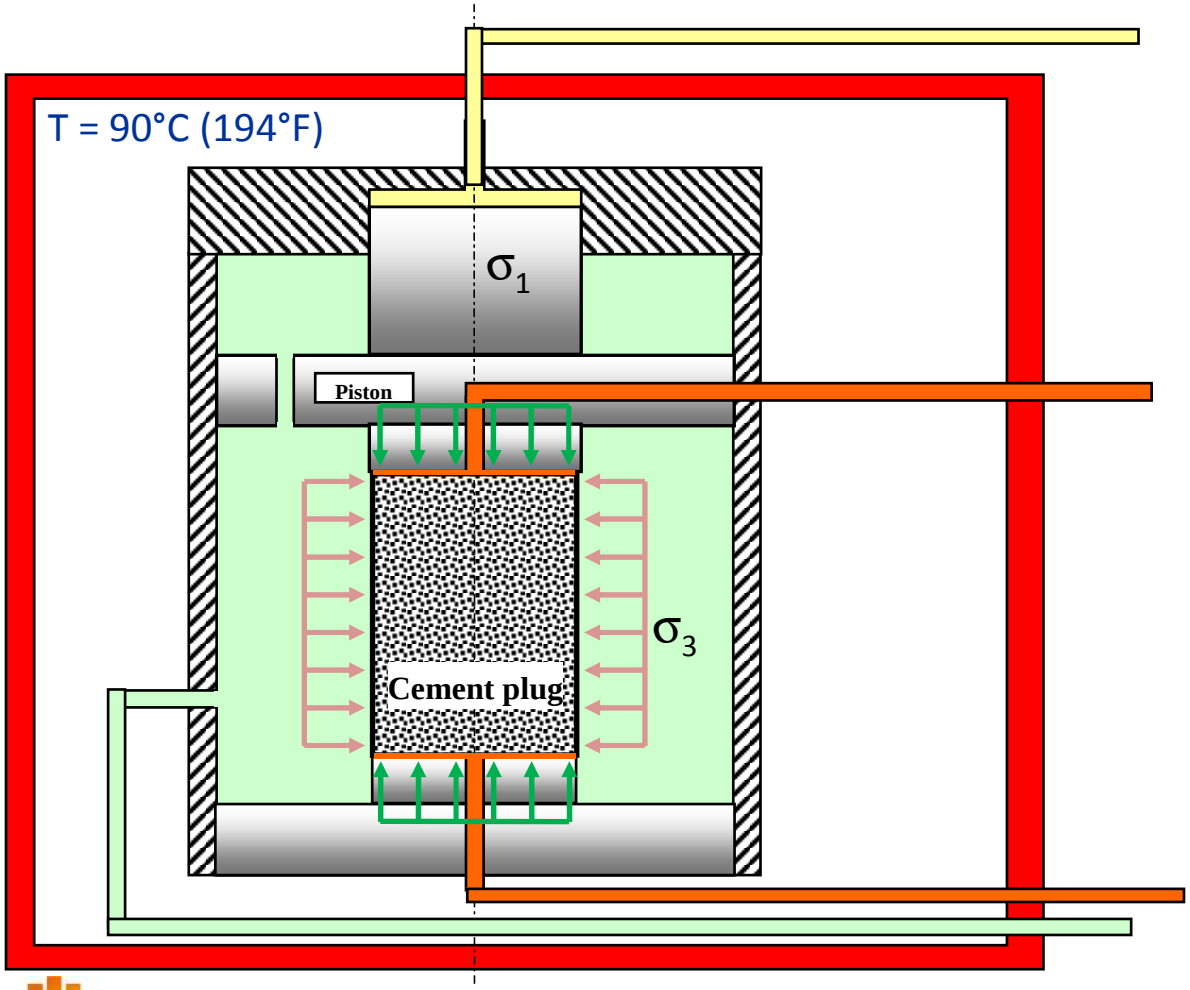
Kinetics of the reaction:
Linear with respect to time
73 mm/yr

Porosity is less affected (25-28%)



Cement / CO_2: Coupled tests

Cement is in contact with CO_2 under stress



Vertical stress

σ_1 = 6 MPa

Non reactive water

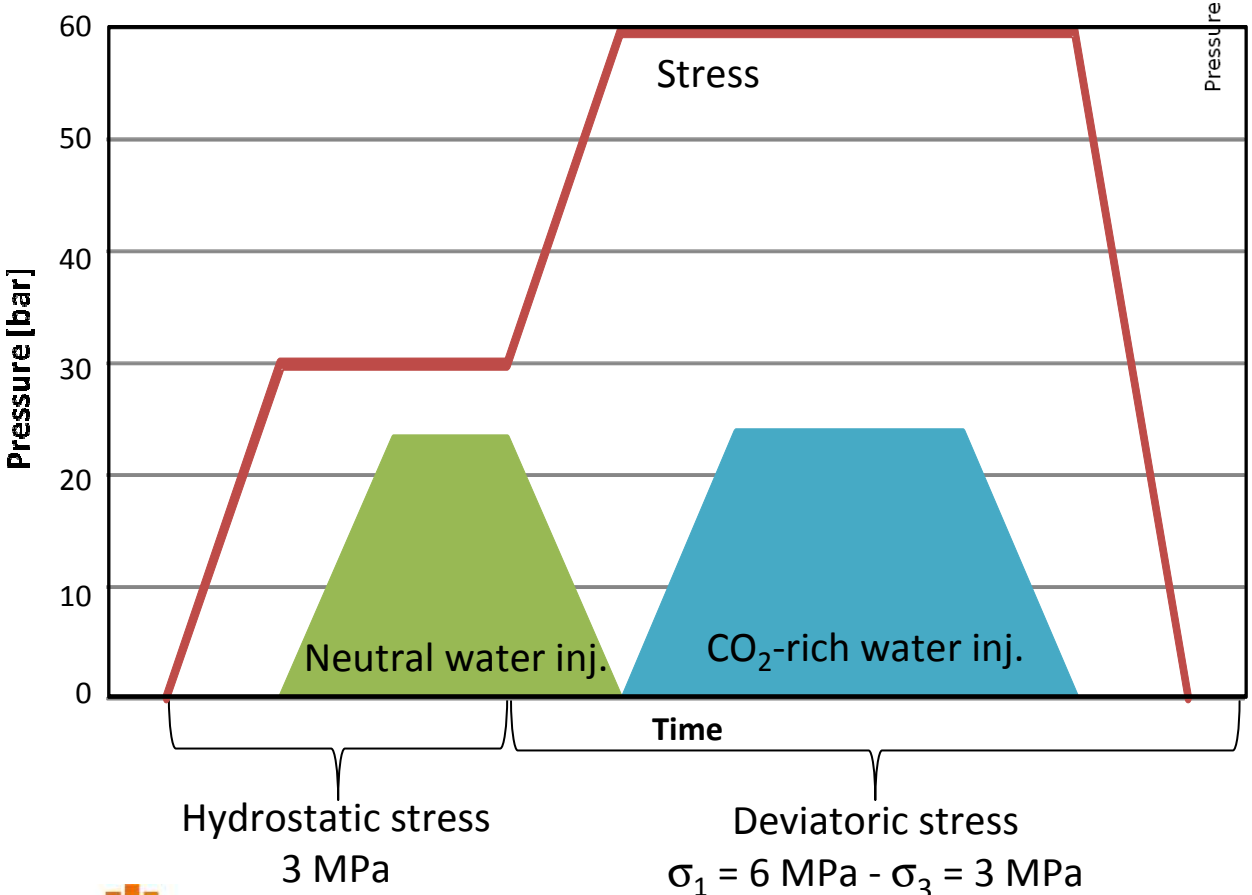
CO_2 rich fluid

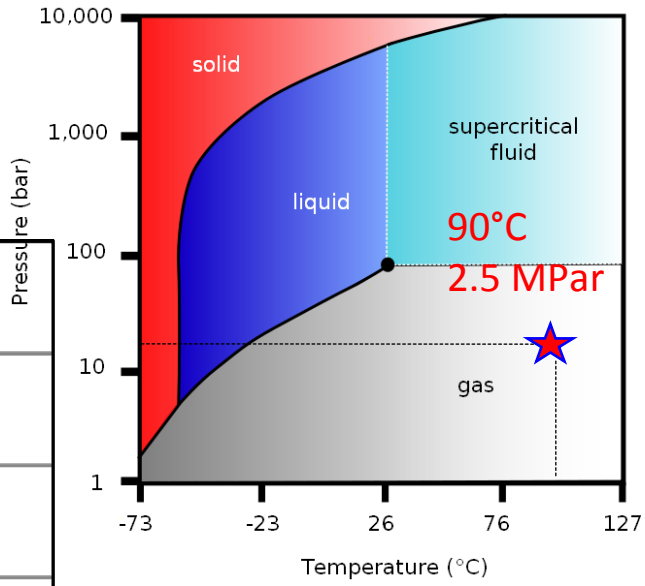
P_{CO2} = 2.5 MPa

Confining pressure

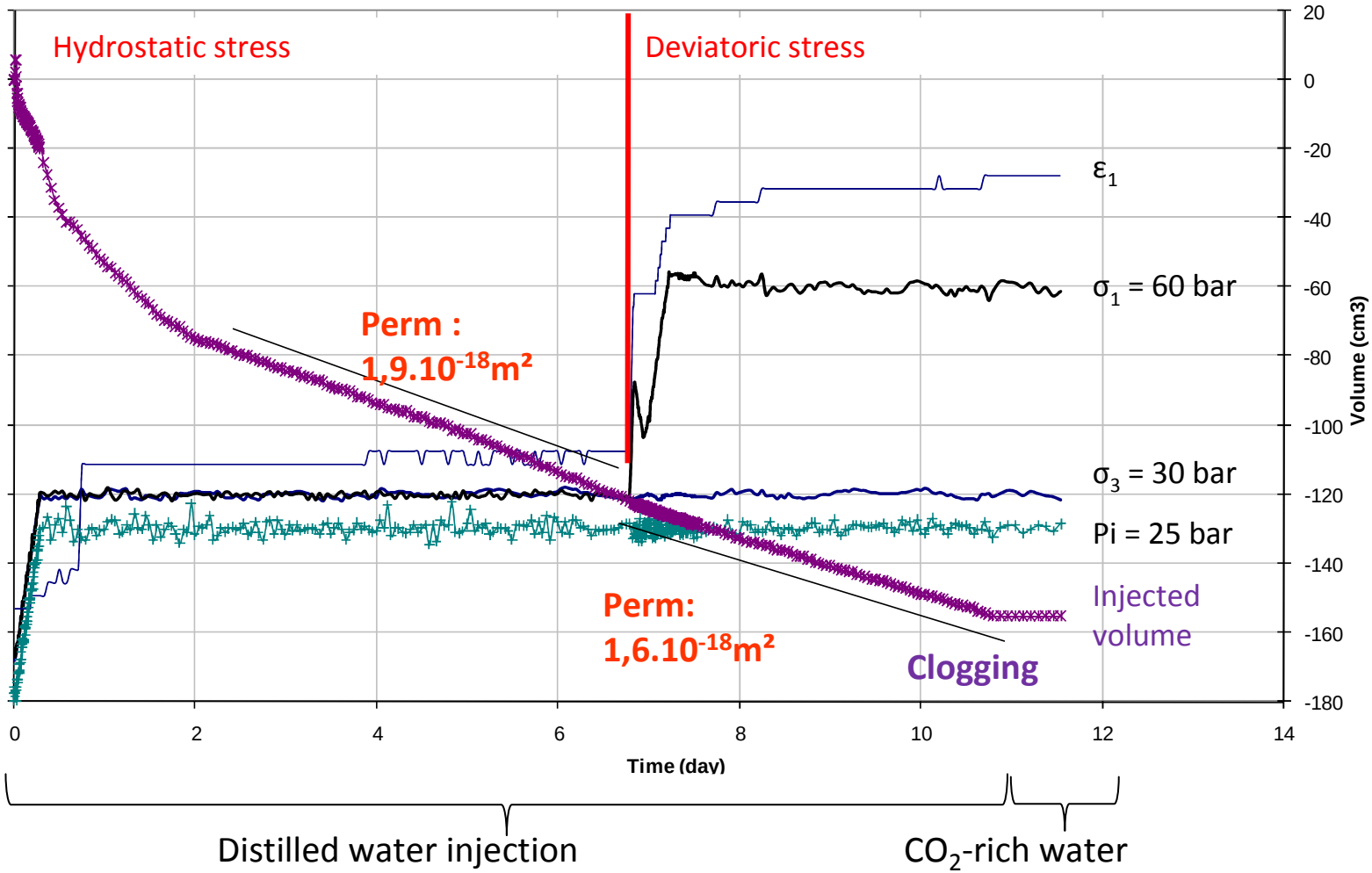
σ_3 = 3 MPa

Cement / CO_2: Coupled tests





Cement / CO_2: Coupled tests

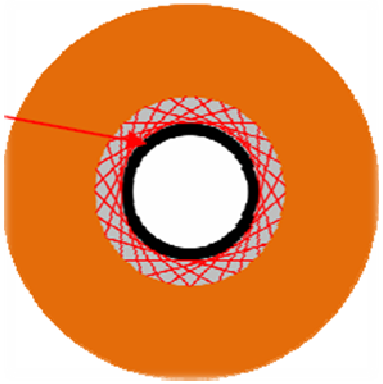


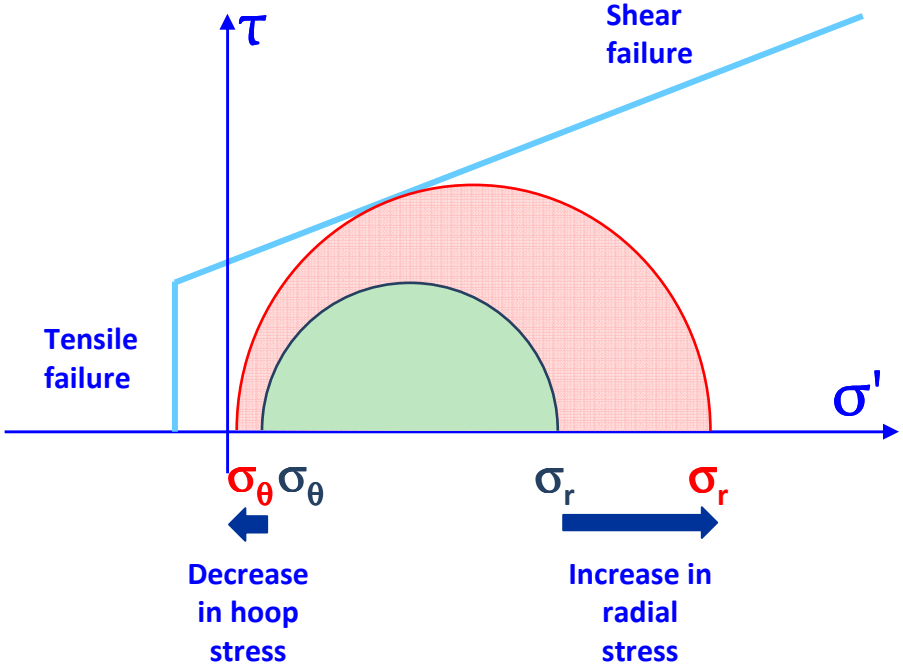
Cement-sheath mechanical integrity

Heating

Increase in mud pressure

Stiff formation



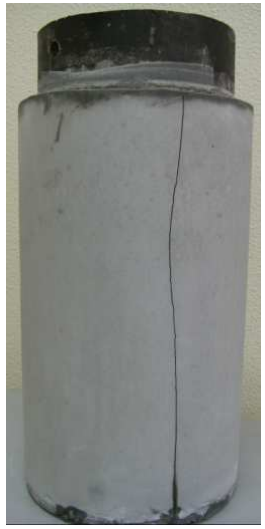


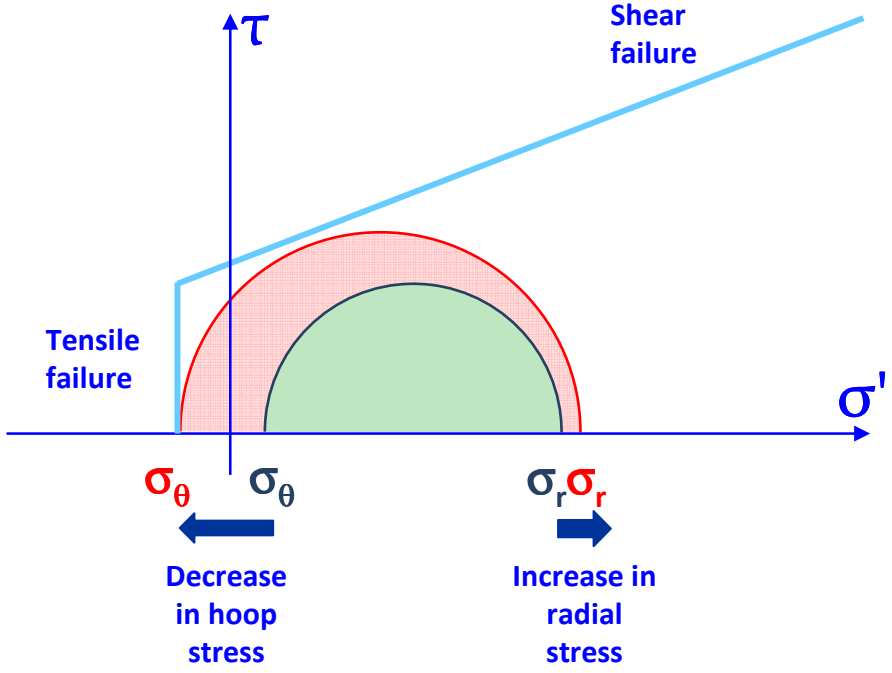
Cement-sheath mechanical integrity

Heating

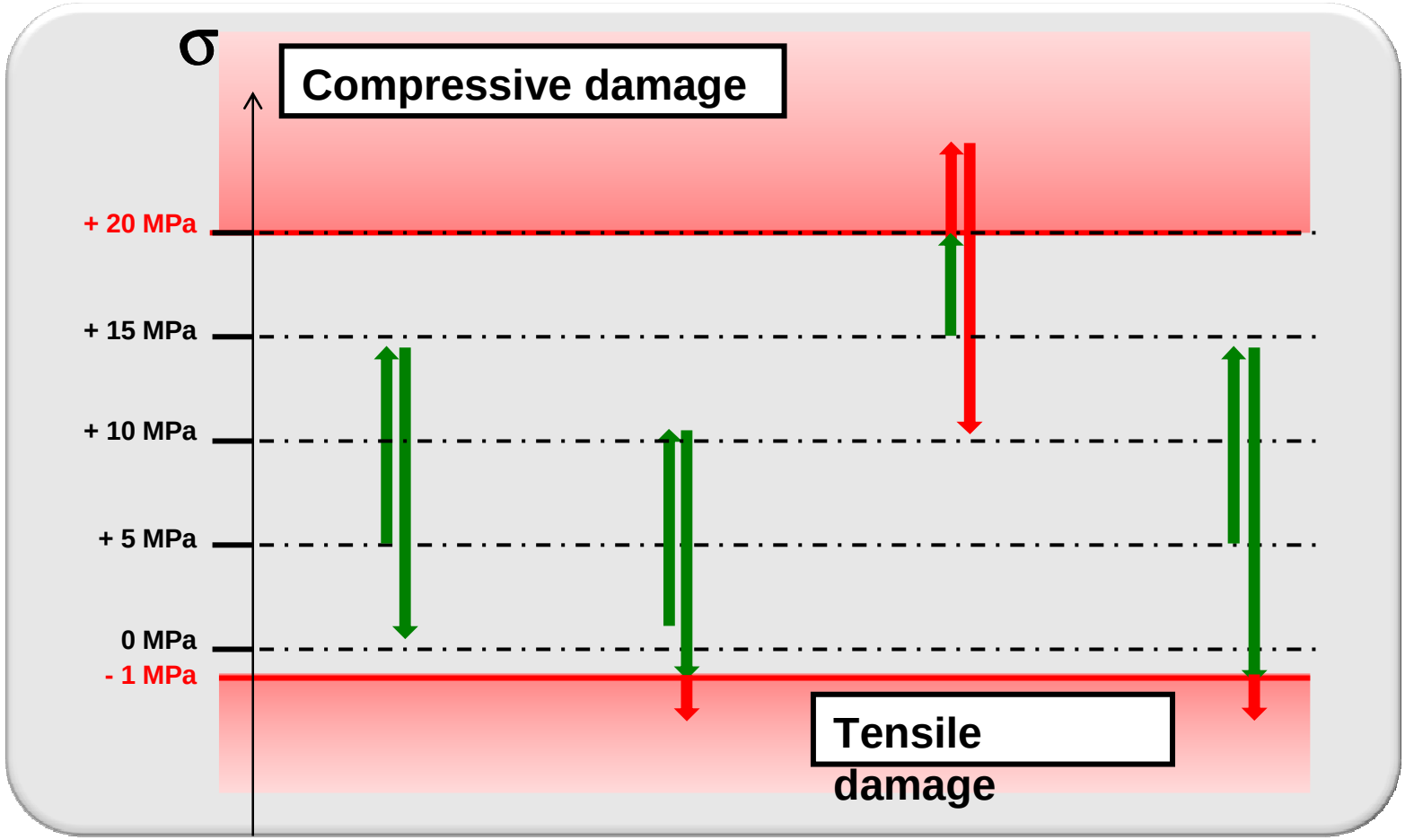
Increase in mud pressure

Soft formation

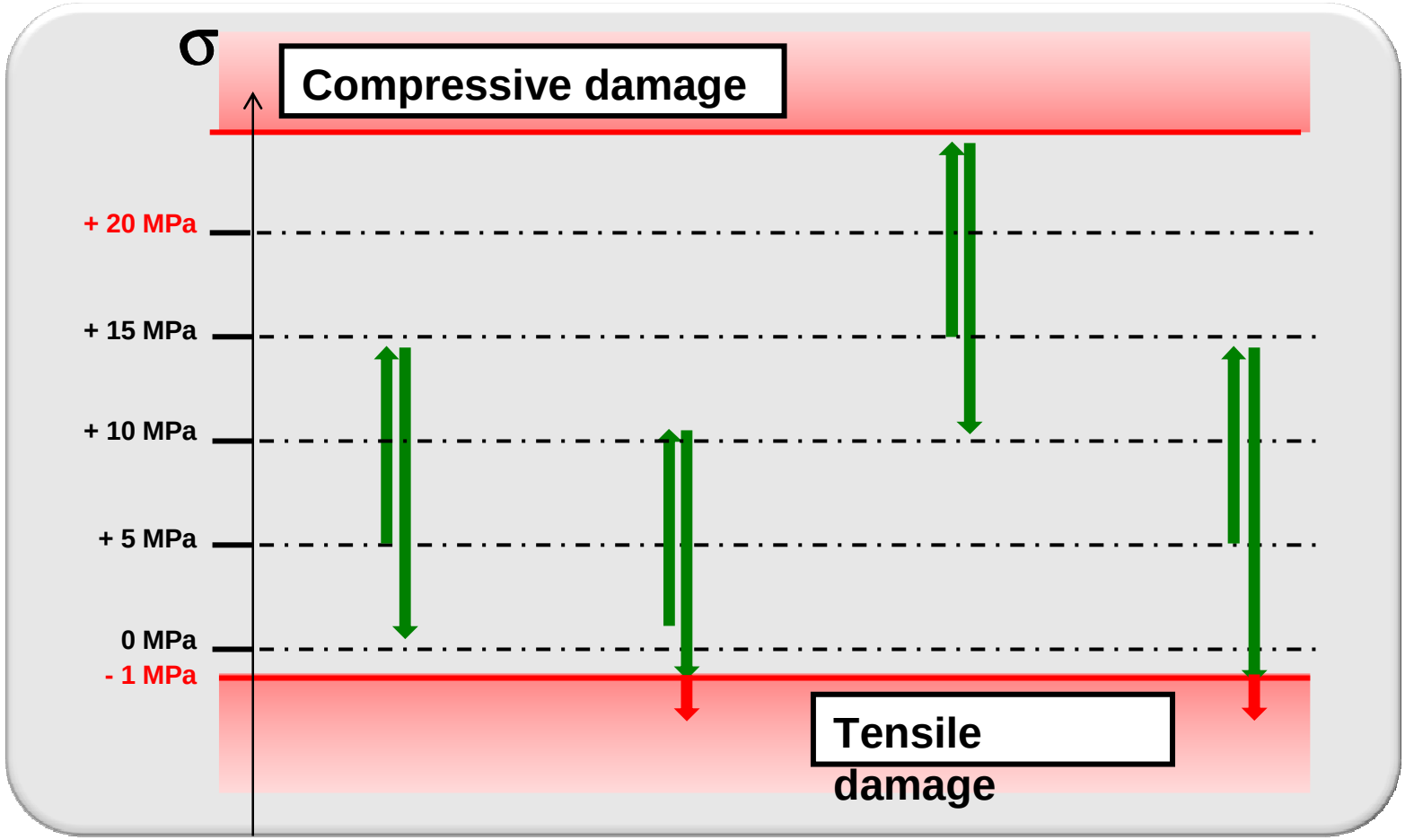




Cement-sheath mechanical integrity

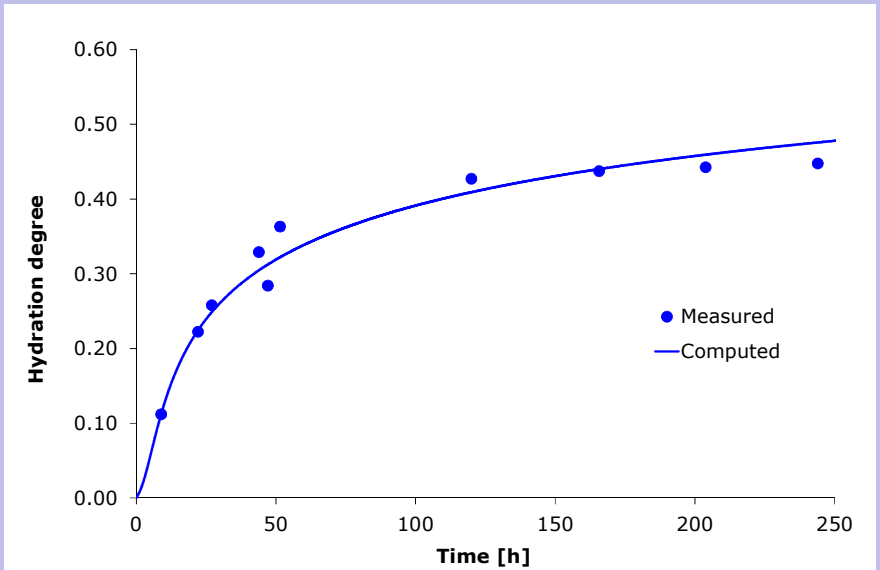


Cement-sheath mechanical integrity

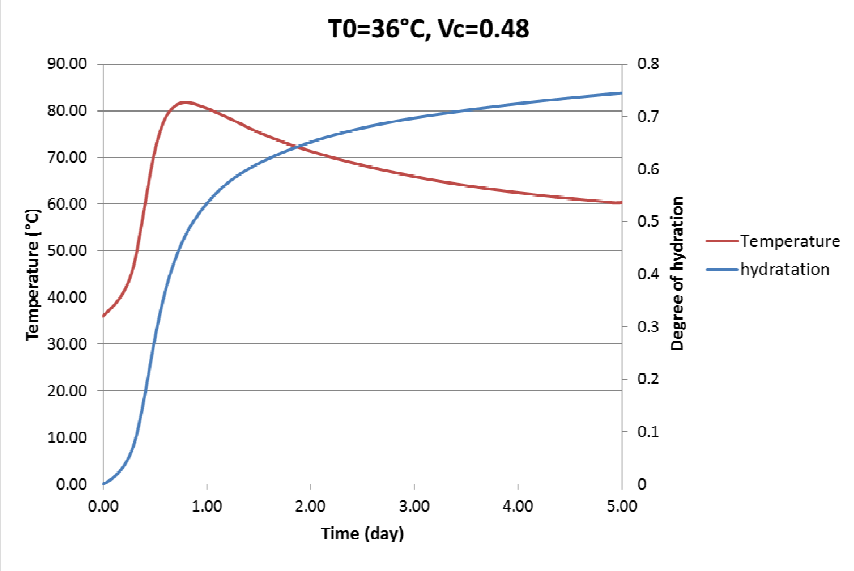


Cement-sheath mechanical integrity

In the Lab

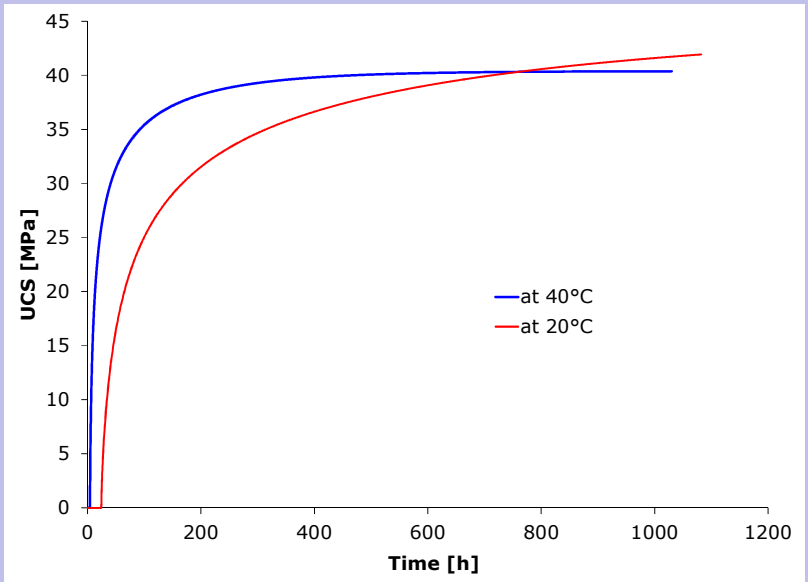


In the Hole

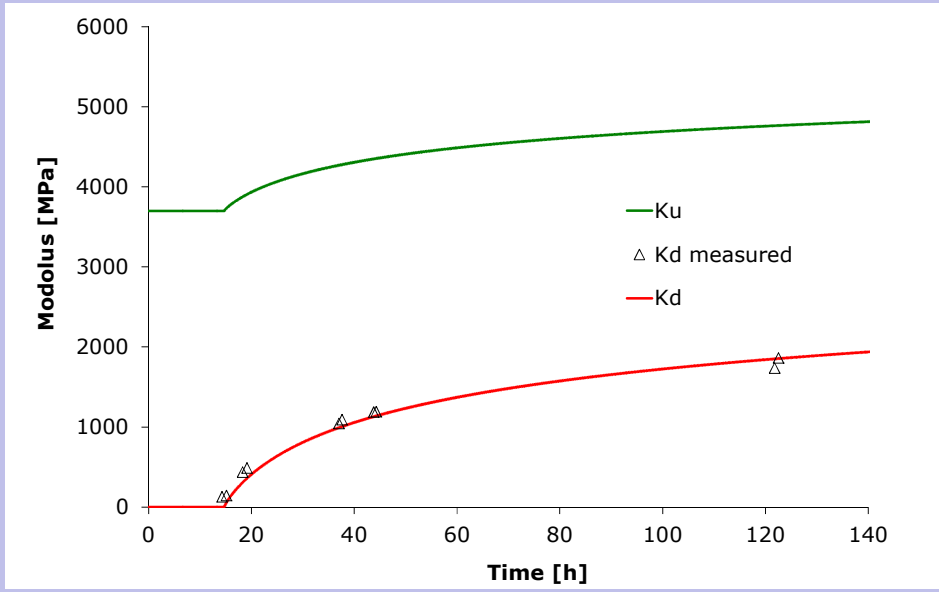


Cement-sheath mechanical integrity

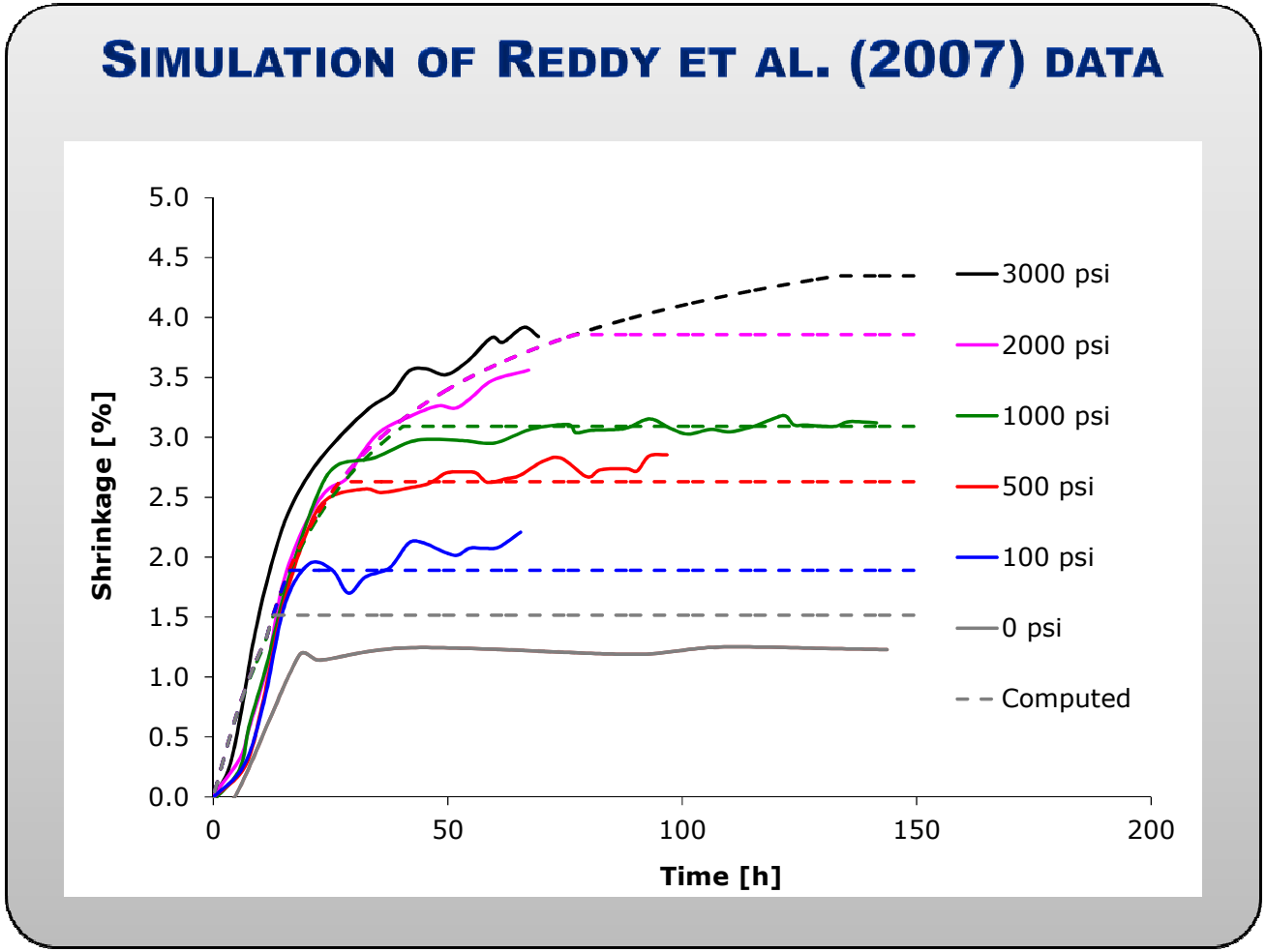
UCS



Bulk modulus

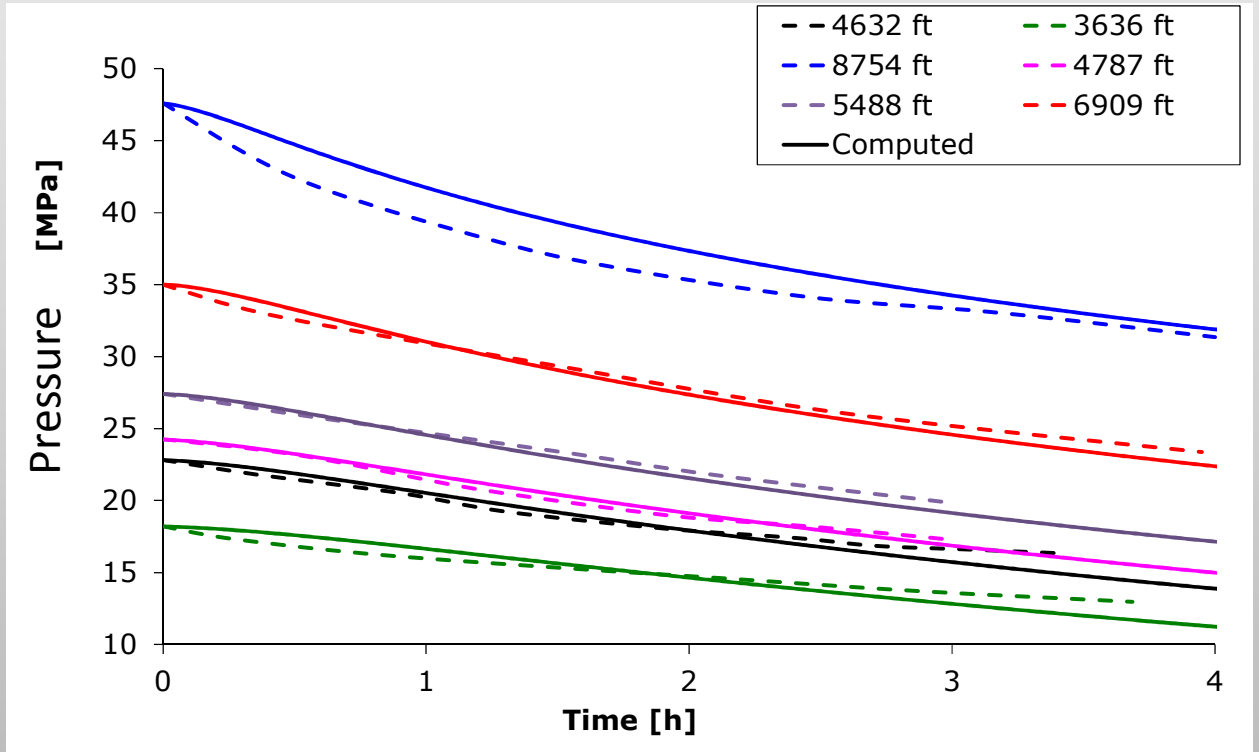


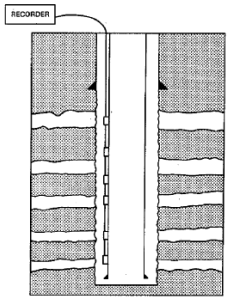
Cement-sheath mechanical integrity



Cement-sheath mechanical integrity

SIMULATION OF COOKE ET AL. (1983) DATA





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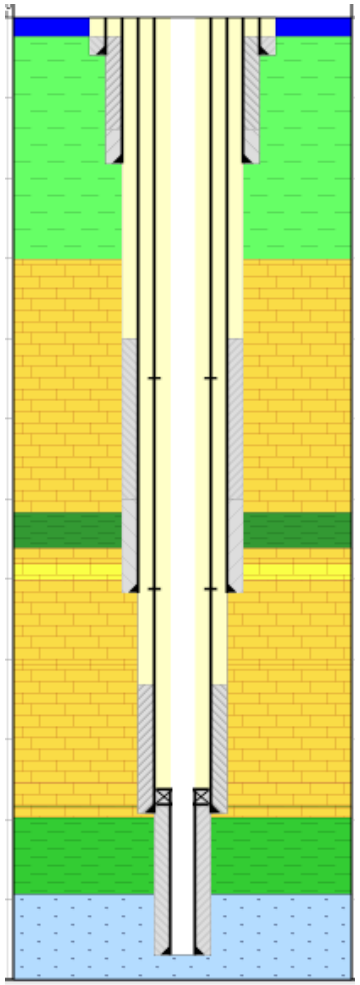
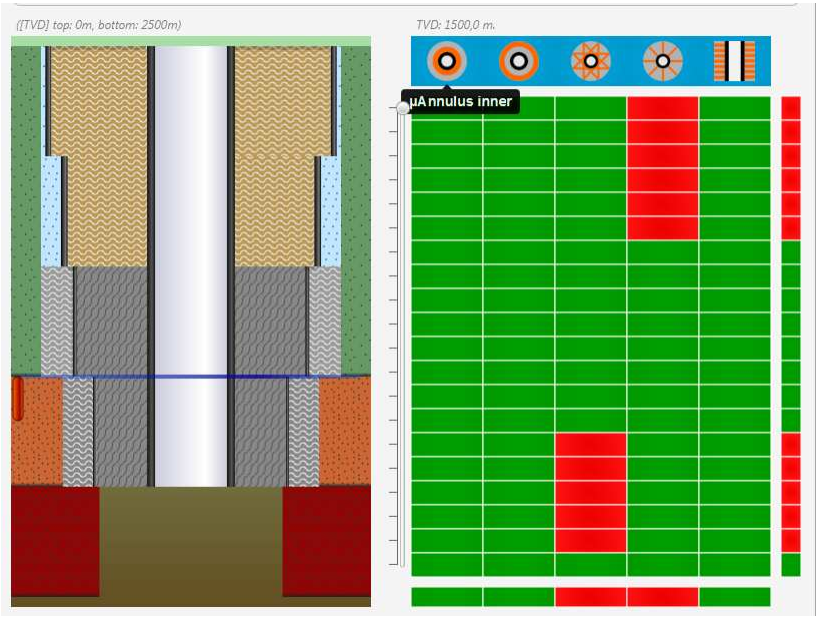
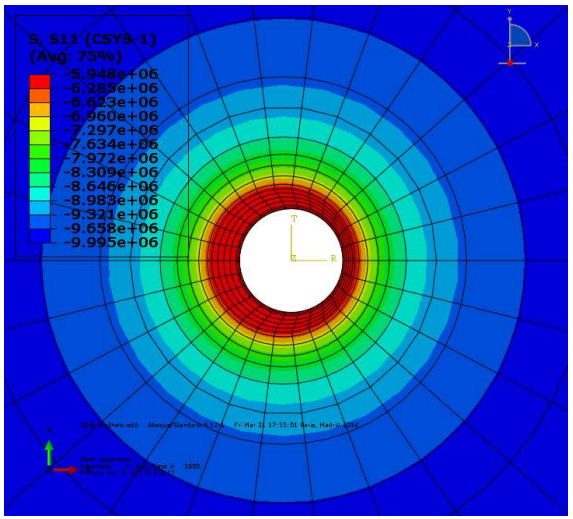
Cement-sheath mechanical integrity



Analytical



Numerical



Cement-sheath integrity

Loadings

- Cement hydration
- Mud pressure
- Temperature
- Pore-pressure
- Compaction
- Dynamic

Mechanisms

- Elasticity
- Shear failure
- Tensile failure
- Pore collapse
- Creep
- Fatigue
- Degradation

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Thank you

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