Impact of CO2 saturated water solution on Grevena sandstone, a potential deep aquifer for carbon dioxide sequestration

Geomechanics of geological sequestration of CO2

Funded research Program "Thales"

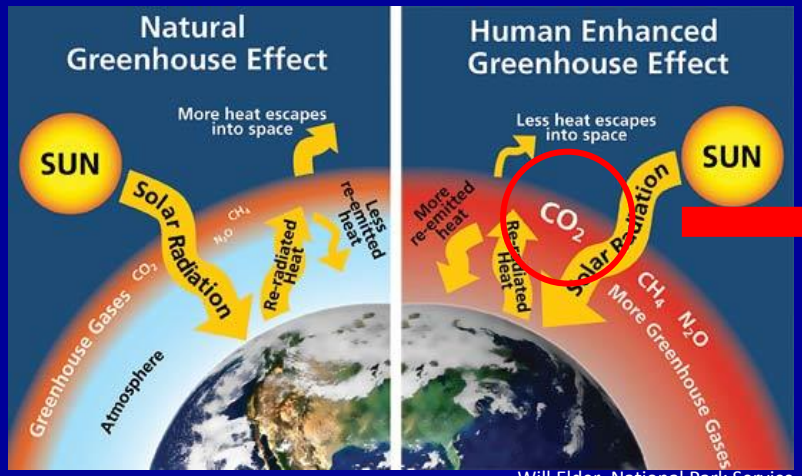
PhD Candidate
George Dimadis
Civil Engineer Msc

Alicante 2015-June

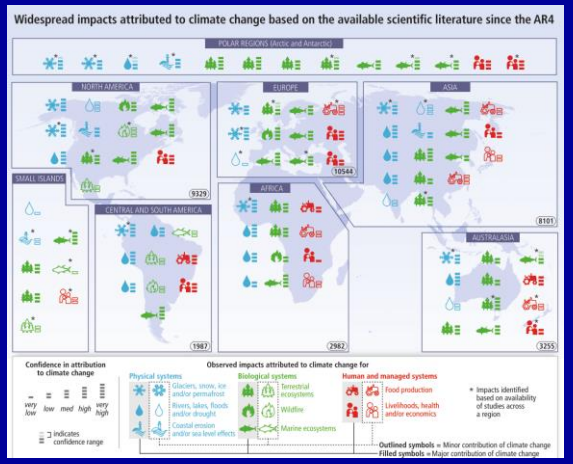
This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Thales. Investing in knowledge society through the European Social Fund.

European Union
European Social Fund
OPERATIONAL PROGRAMME
EDUCATION AND LIFELONG LEARNING
investing in knowledge society
MINISTRY OF EDUCATION, LIFELONG LEARNING AND RELIGIOUS AFFAIRS
MANAGING AUTHORITY
NSRF 2007-2013
programme for development
EUROPEAN SOCIAL FUND
Co- financed by Greece and the European Union

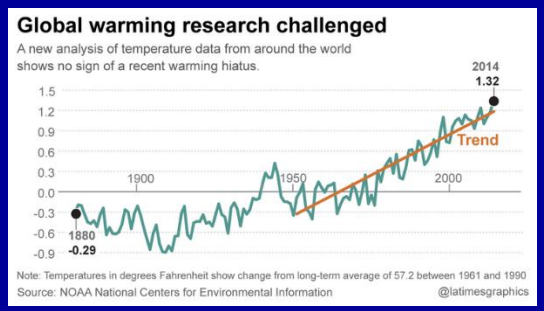
Problem : Greenhouse effect –Temperature Rise



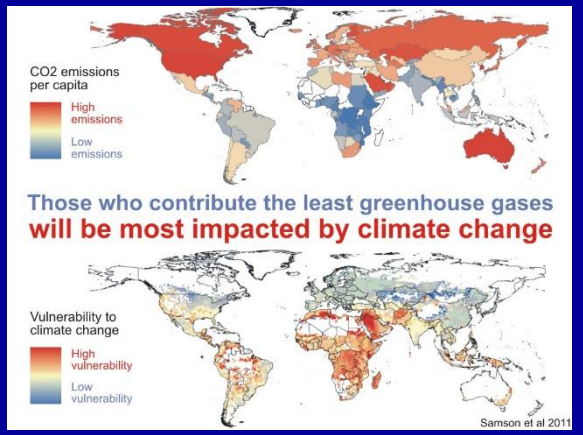
Will Elder, National Park Service



IPCC. (2014).



Karl, T. R et al. (2015). - National Oceanographic and Atmospheric Administration

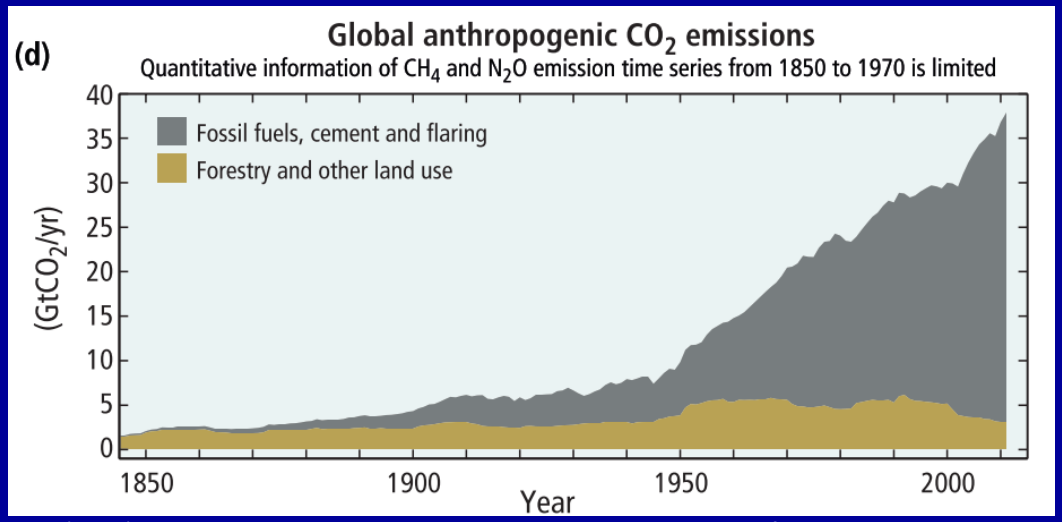


IMPACTS:

- Sea-level rise
- Desertification
- Bio systems instability

Main Cause of the Problem



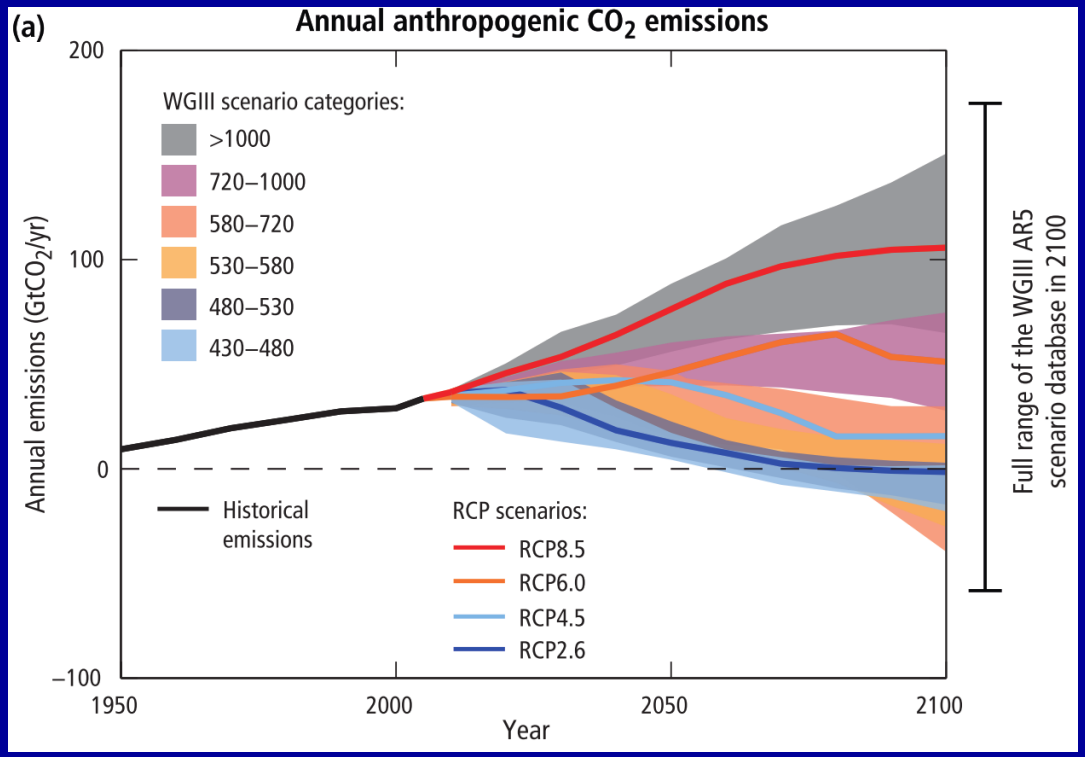


IPCC. (2014). *Climate Change 2014 Synthesis Report Summary Chapter for Policymakers*. *Ipcc*.



Source: http://www.globalcarbonatlas.org

Actions to solve/hault the problem



IPCC. (2014). *Climate Change 2014 Synthesis Report Summary Chapter for Policymakers. Ipcc.*

Ways for reduction:

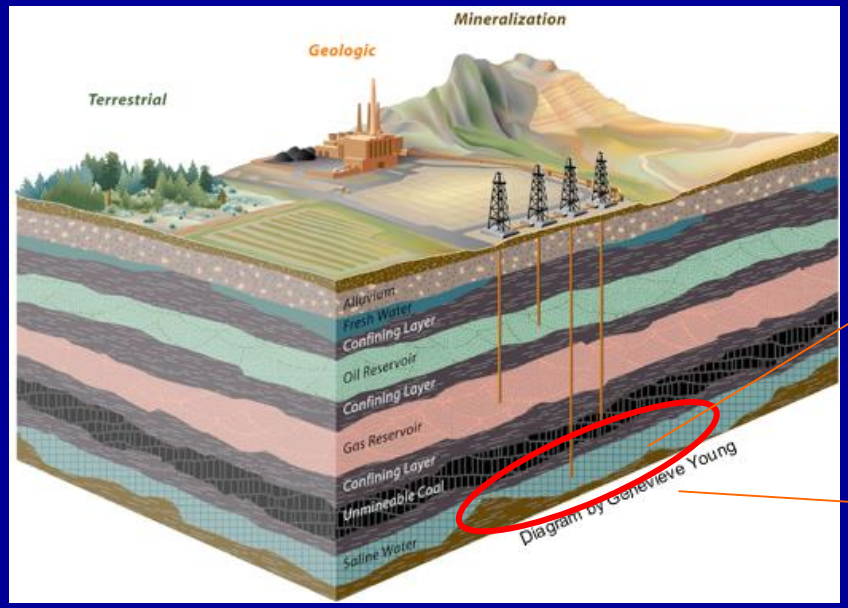
- Decarbonizing economies
- Stop of fossil fuel usage
- Renewable Energy sources
- Minimize GHG emissions

... G7 leaders meeting in Bavaria, Germany, said that in line with scientific findings, "deep cuts in global greenhouse gas emissions are required with a decarbonisation of the global economy ***over the course of this century****"...*

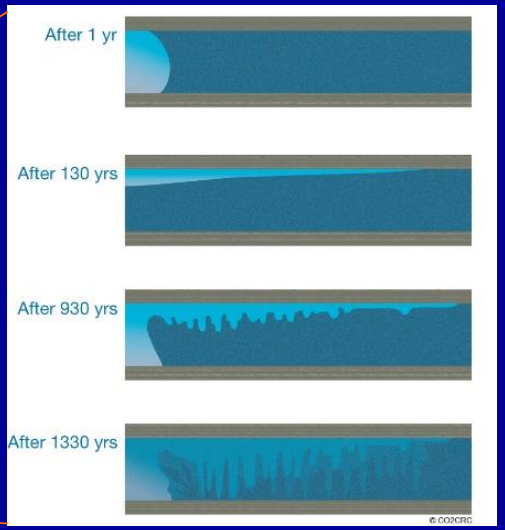
June 8, 2015 Financial Times

Potential SOLUTION : CCS - Carbon Capture & Storage

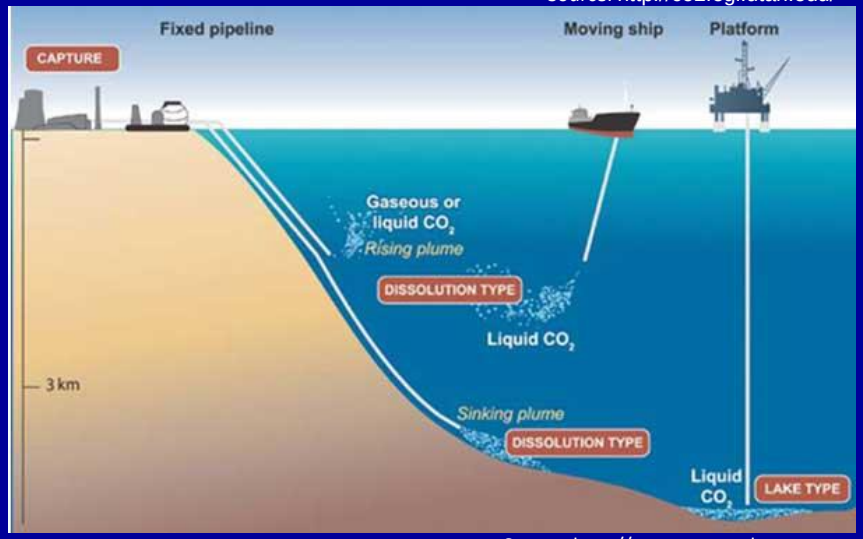
Promising Method to reduce CO2 emissions while still using fossil Fuels



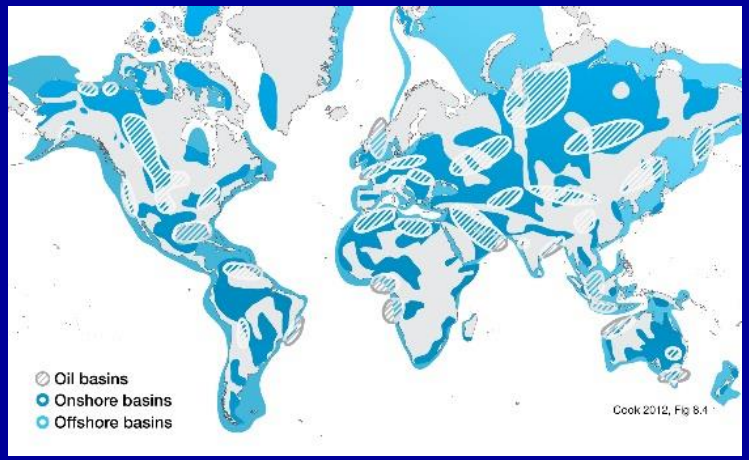
Source: http://co2.egi.utah.edu/



Source: CO2CRC Limited collaborative research organization
http://www.co2crc.com.au



Source: http://www.powerplantccs.com



Source: International Energy Agency http://www.iea.org

THALES Program
"Geomechanics of geological sequestration of CO2"
partners structure

NORWAY SINTEF
Petroleum Research
Department: Formation Physics

Faculty of engineering
University of Patras Research Team

Faculty of engineering
Aristotle University Research Team



FRANCE
Laboratory Navier
Ecole Des Ponts - ParisTech

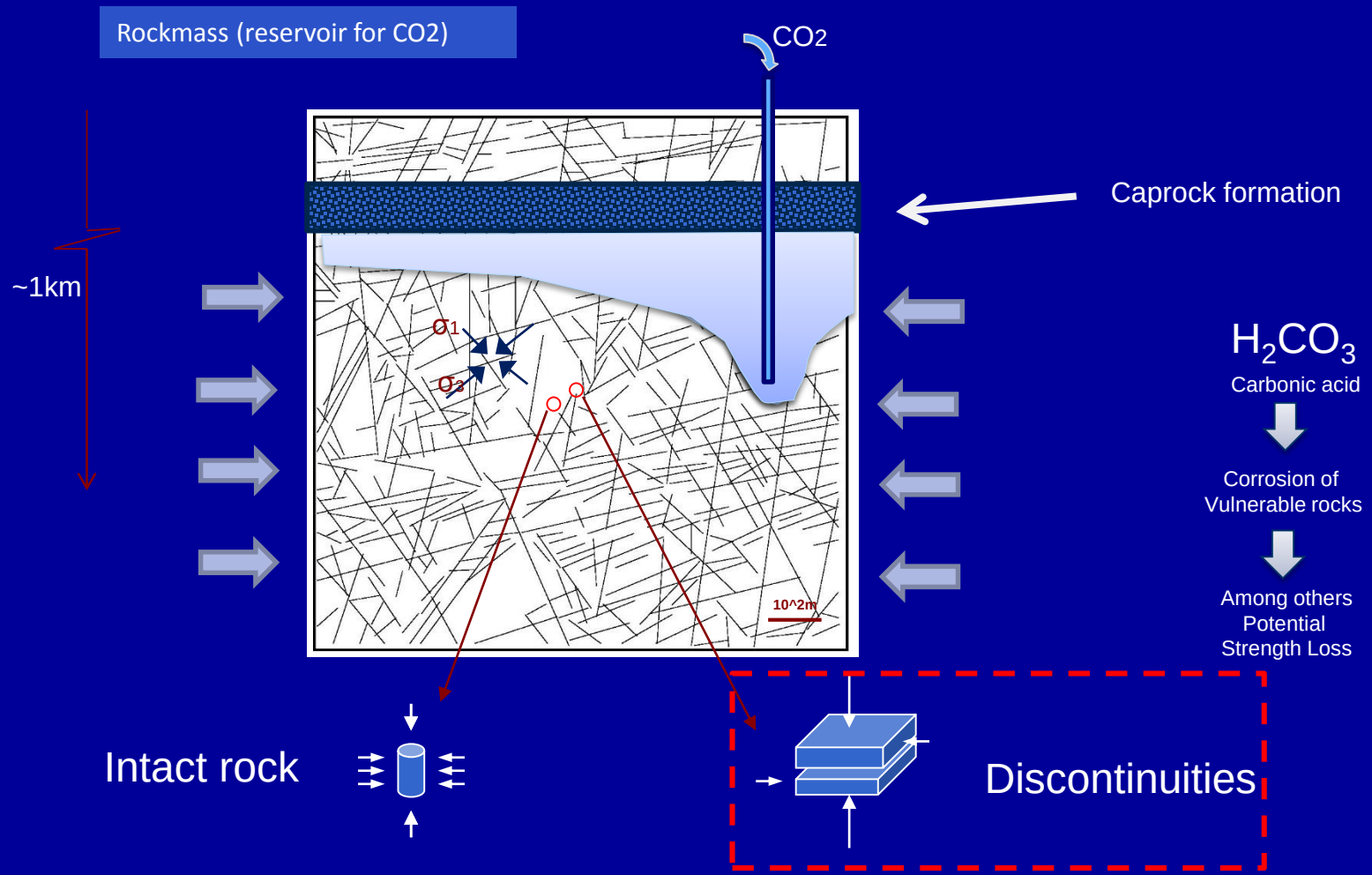
Department of Civil and Environmental Engineering
University of Cyprus

Faculty of Engineering
Cretan University Research Team

Centre for Research & Technology Hellas - CERTH
Research Team

Program's aims / Phd objectives

Understanding the behavior of rockmass,
when been used as CO2 underground reservoir



Sandstone Sampling site



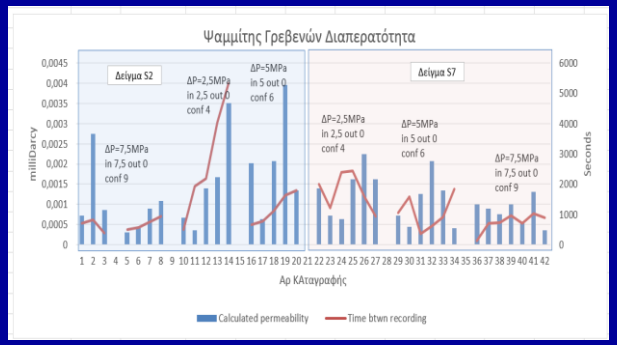
Basin of Eptachori formation (Anticline)







Sandstone characterization

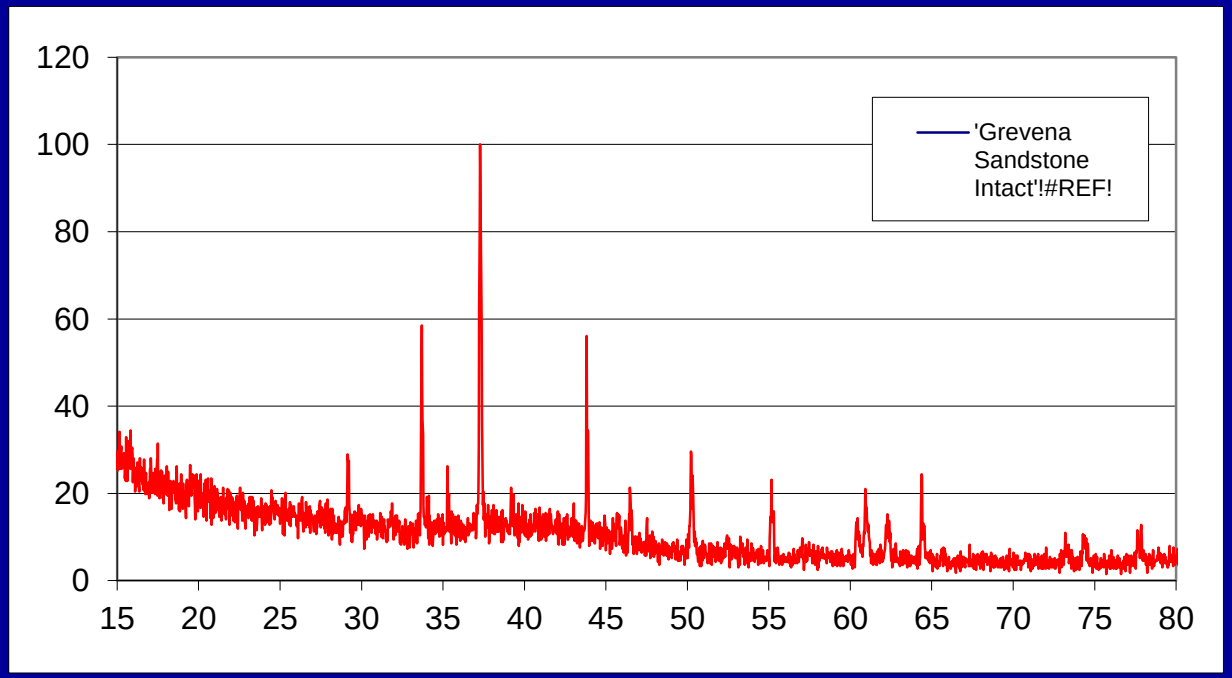




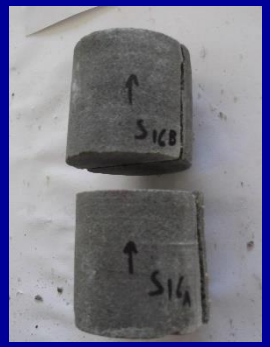
Saturated sandstone		
	Er (Gpa)	Peak load UcS (Mpa)
S6w	~~27,4~~	5,44
S11w	18,2	5,72
S15w	18,1	4,95
Mean	18,13	

Material	Permeability
Sandstone	~10^{-3}mD

X-ray Powder Diffraction Analysis	
Calcite	57%
Quartz	27%
Feldspar	7%
mica	9%



Sandstone sample, fracturing, exposure procedure

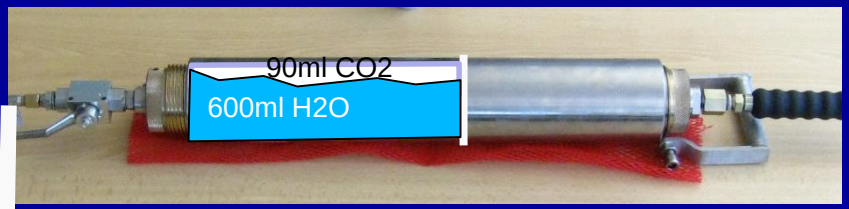


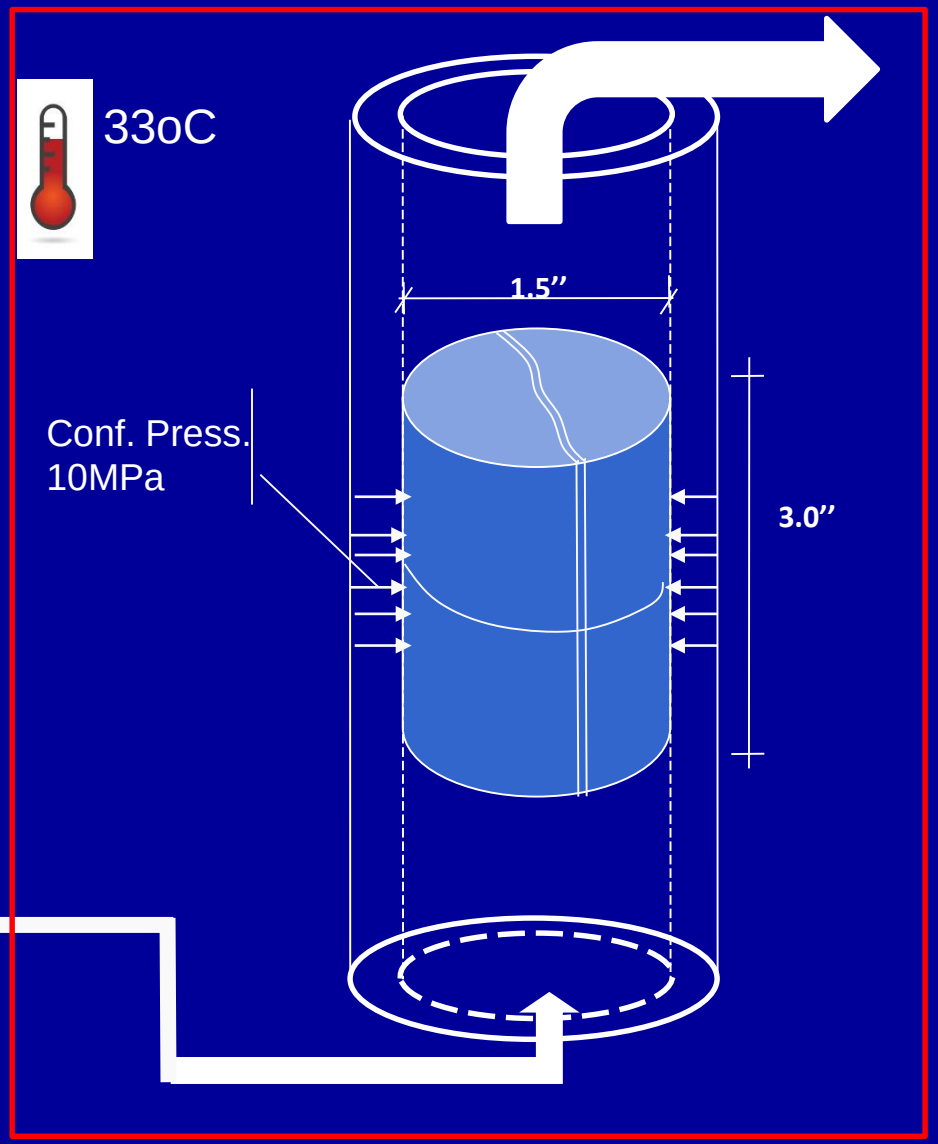




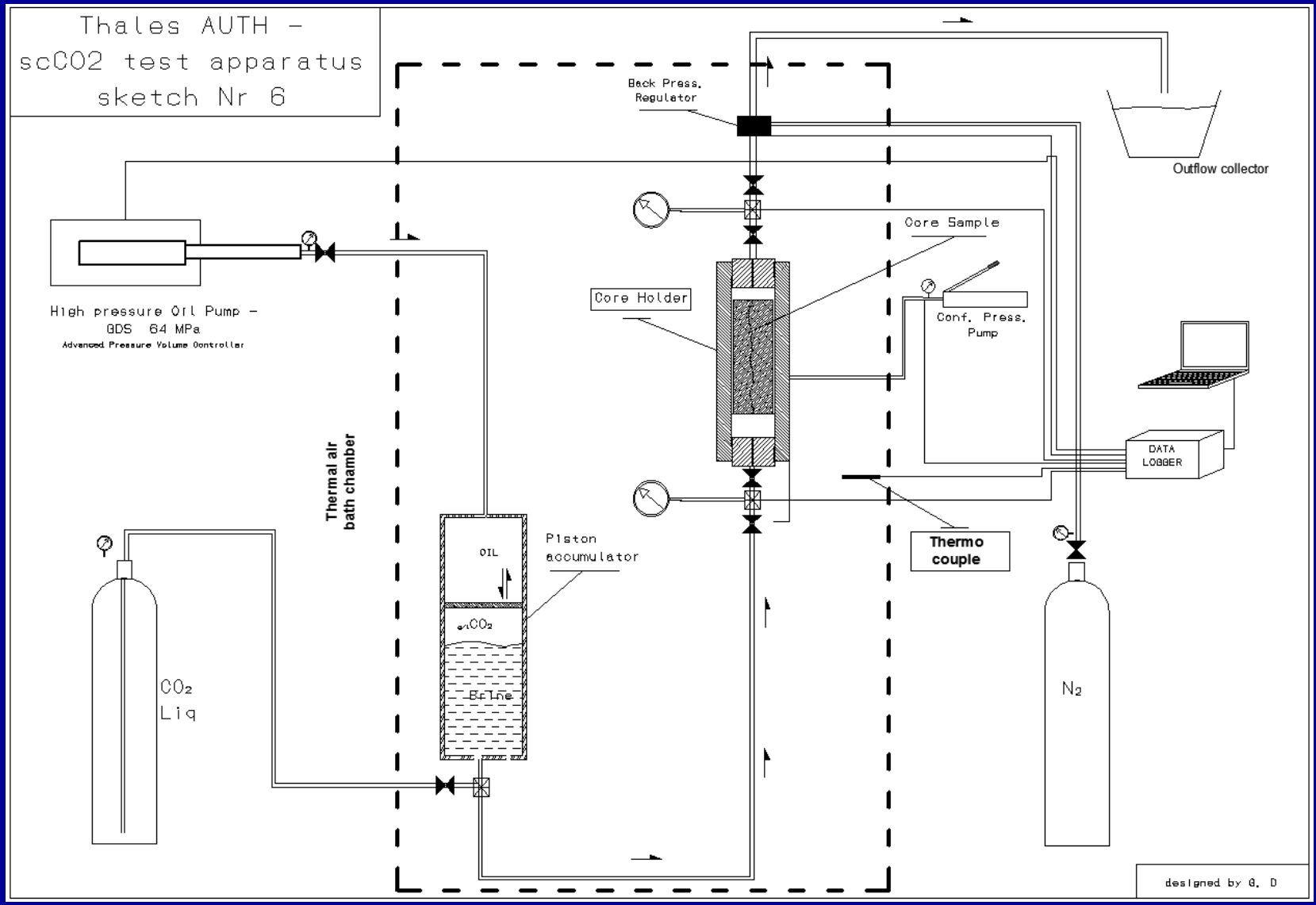






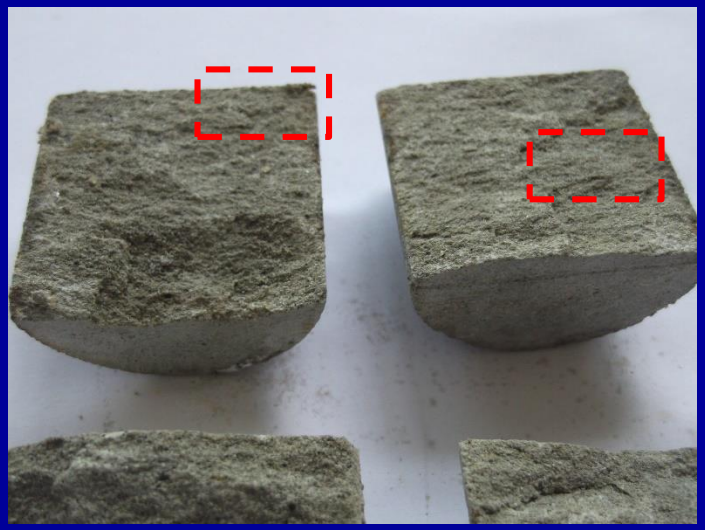


3 ml/hr H2O saturated with CO2
Conf. Press. 10MPa Temp 33oC
Total 700 ml solution (10days)
(21 x pore volume)

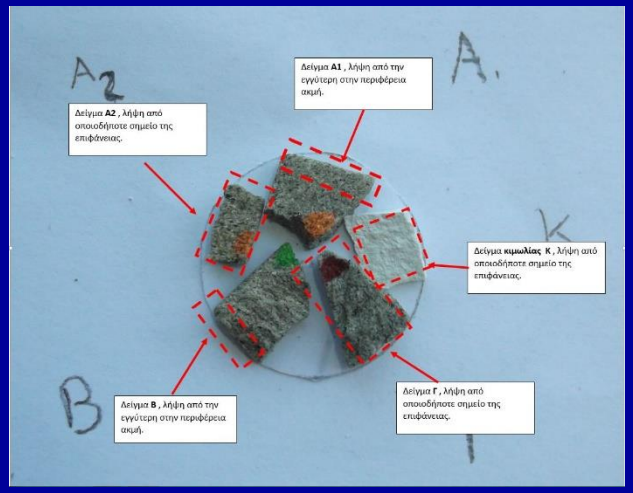


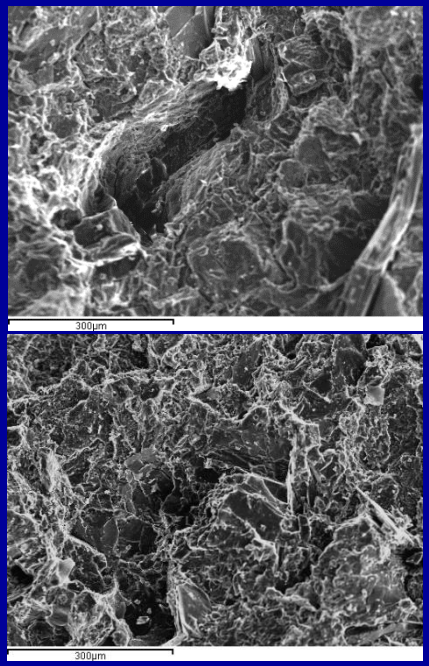
Test parameters

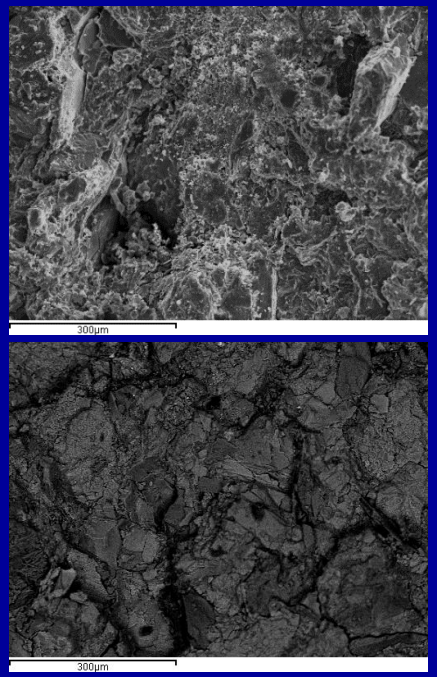
- 3 ml/hr H2O saturated with CO2
- Conf. Press. 10MPa
- Temp 33oC
- Total 700 ml solution (10days)(21 x pore volumes)



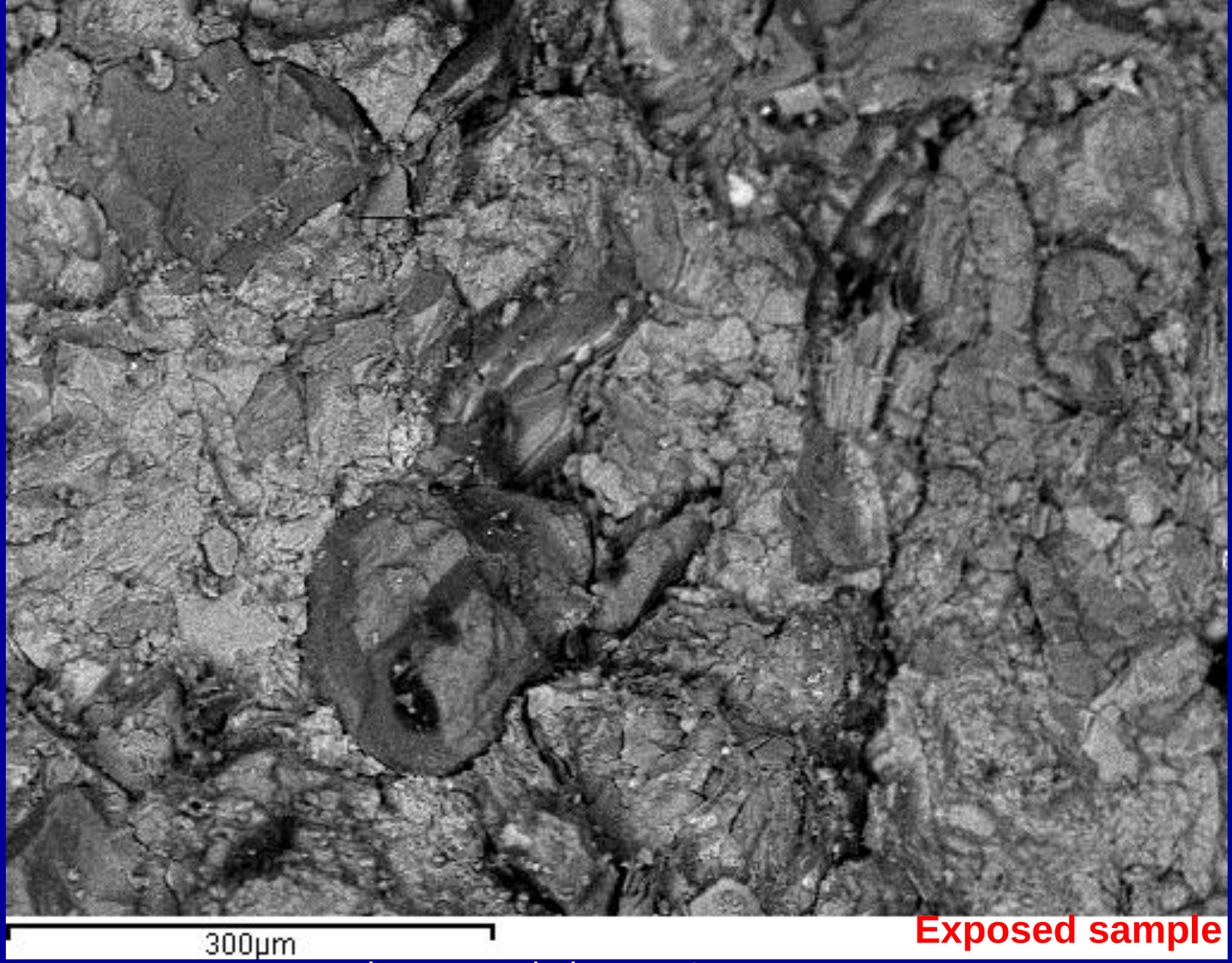

S16·A


A2
A1
Δείγμα **A2** , λήψη από οποιοδήποτε σημείο της επιφάνειας.
Δείγμα **A1** , λήψη από την εγγύτερη στην περιφέρεια ακμή.
K
Δείγμα **κυψελίας K** , λήψη από οποιοδήποτε σημείο της επιφάνειας.
B
Δείγμα **B** , λήψη από την εγγύτερη στην περιφέρεια ακμή.
Δείγμα **Γ** , λήψη από οποιοδήποτε σημείο της επιφάνειας.

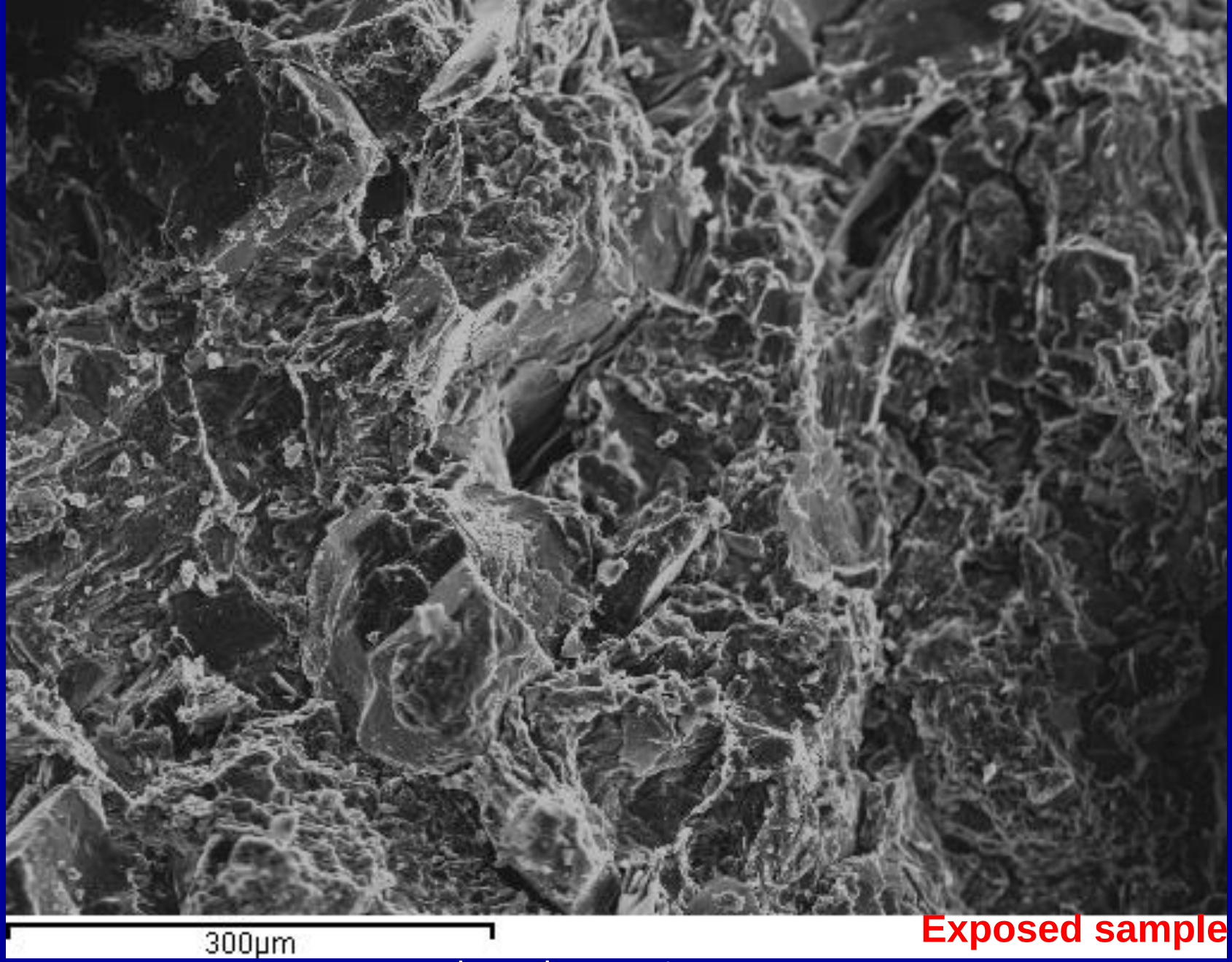

300μm
300μm


300μm
300μm

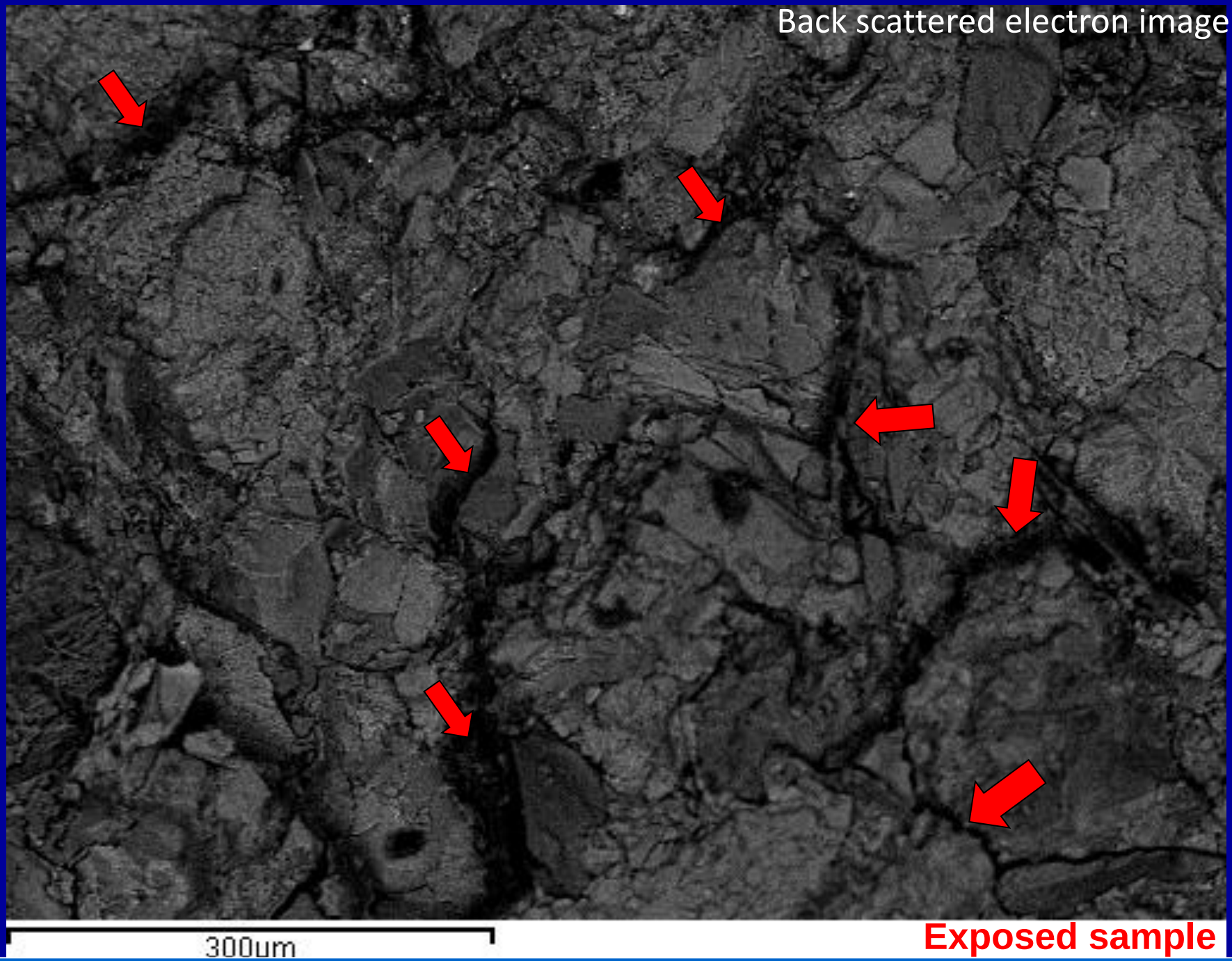
SEM

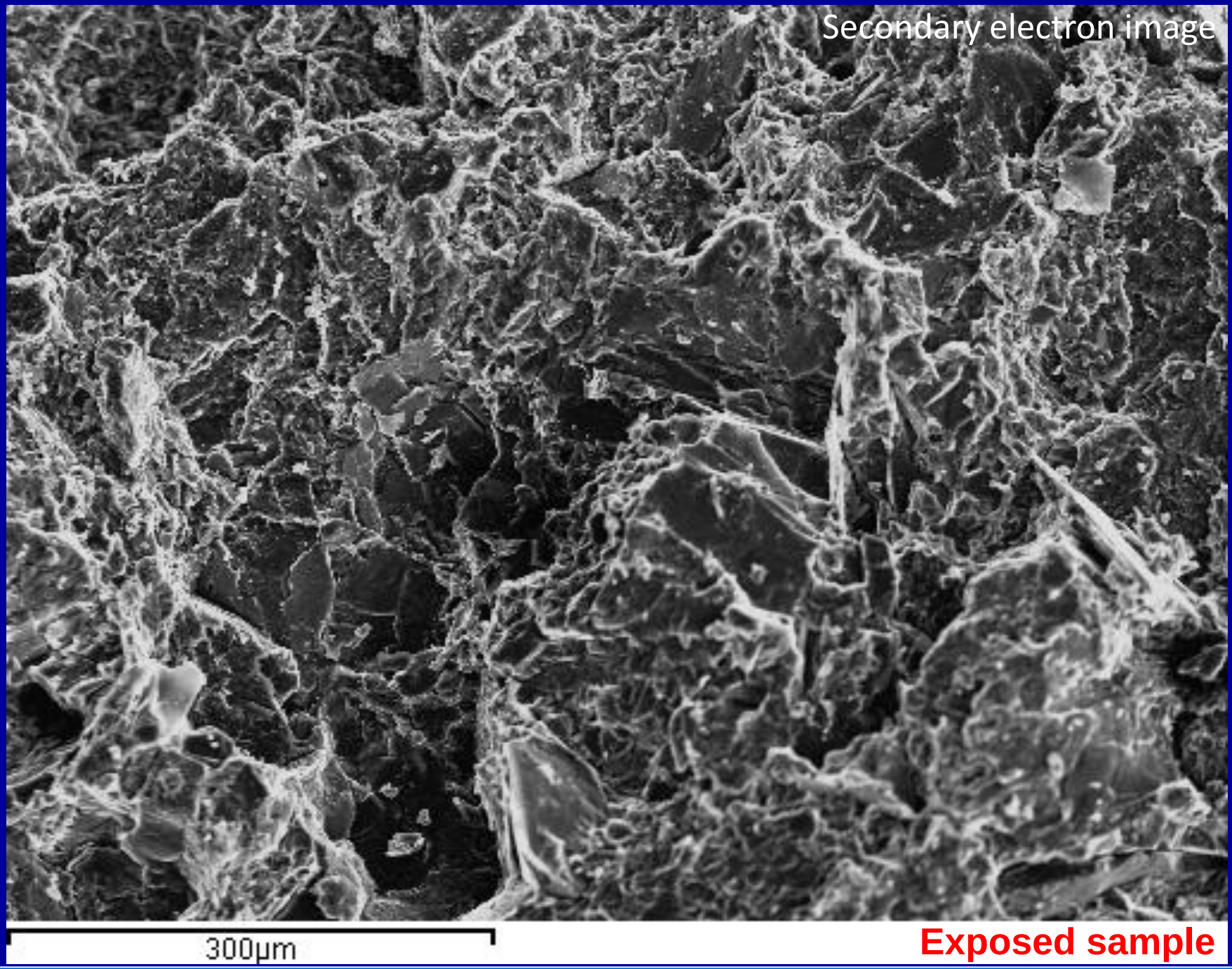


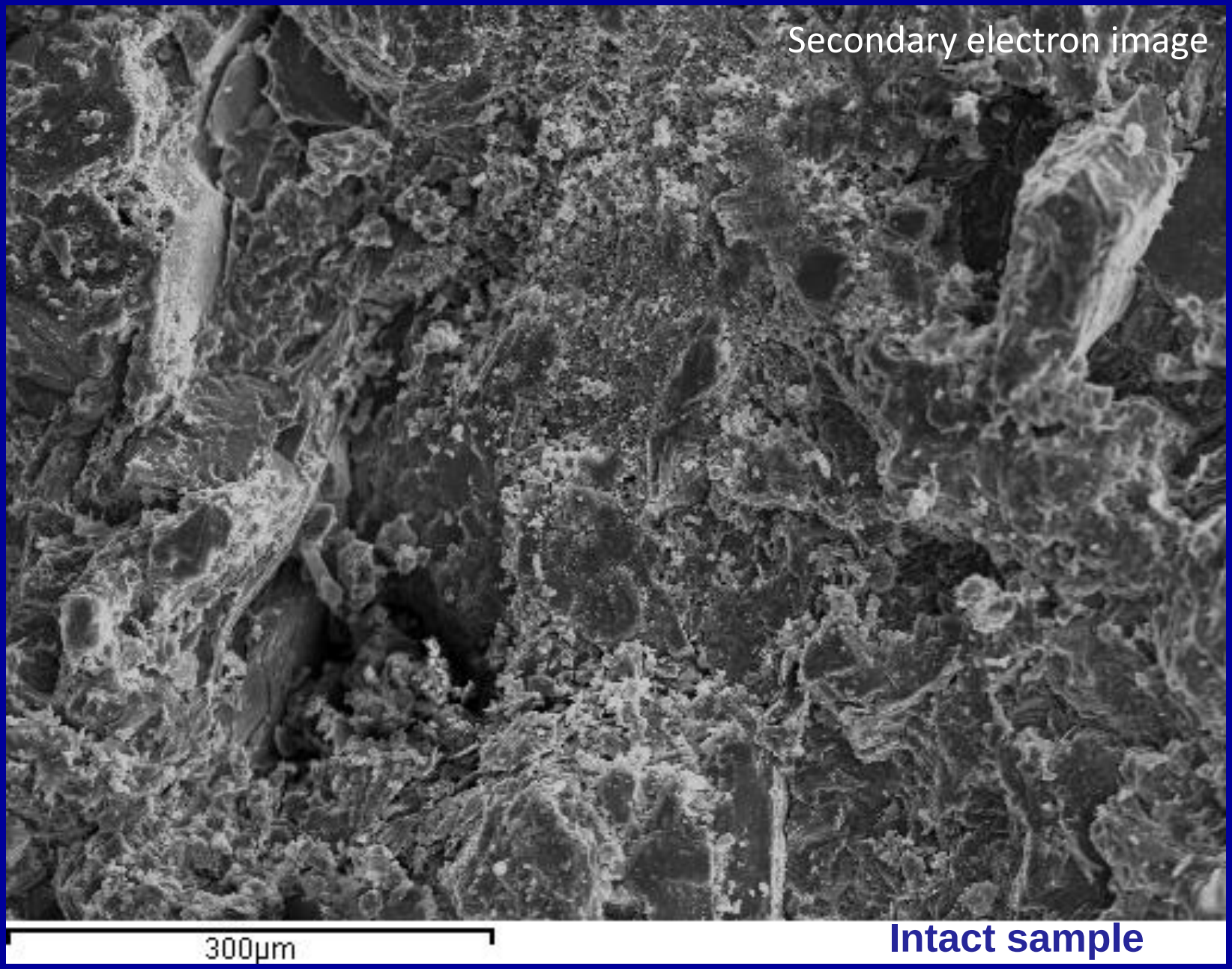
Back scattered electron image



Secondary electron image


Back scattered electron image
300um
Exposed sample

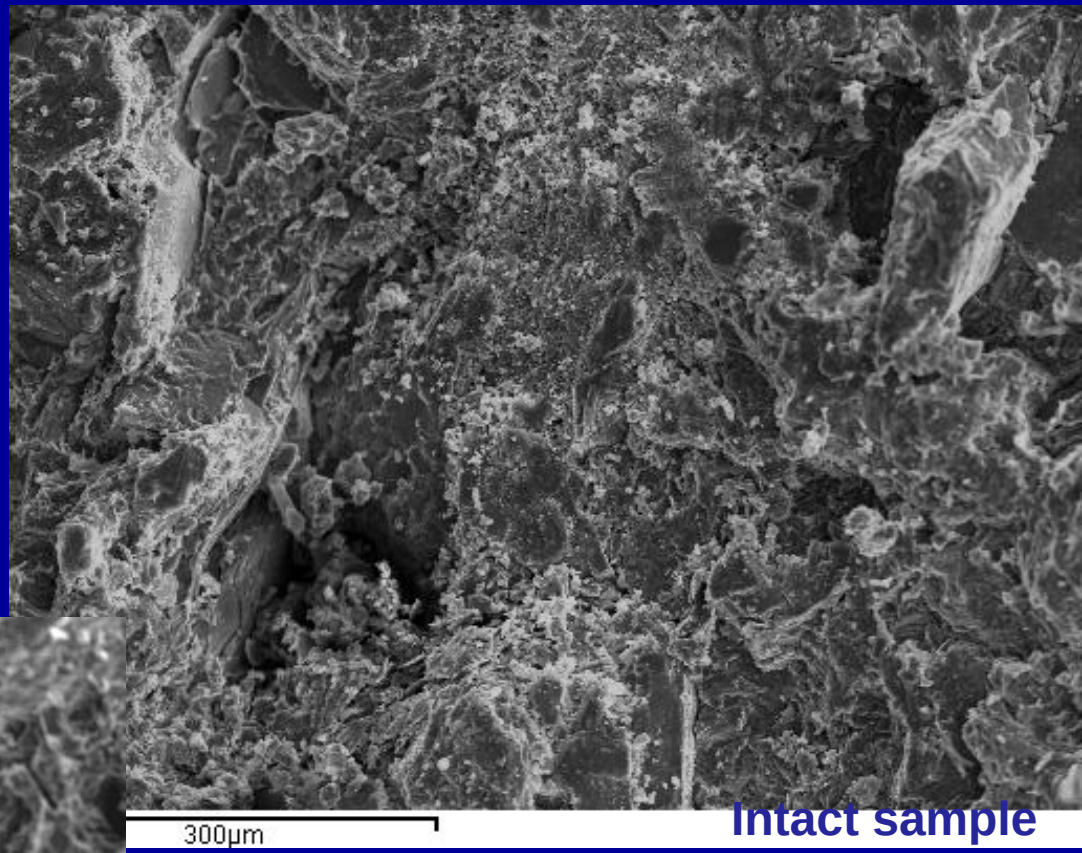

Secondary electron image
300μm
Exposed sample

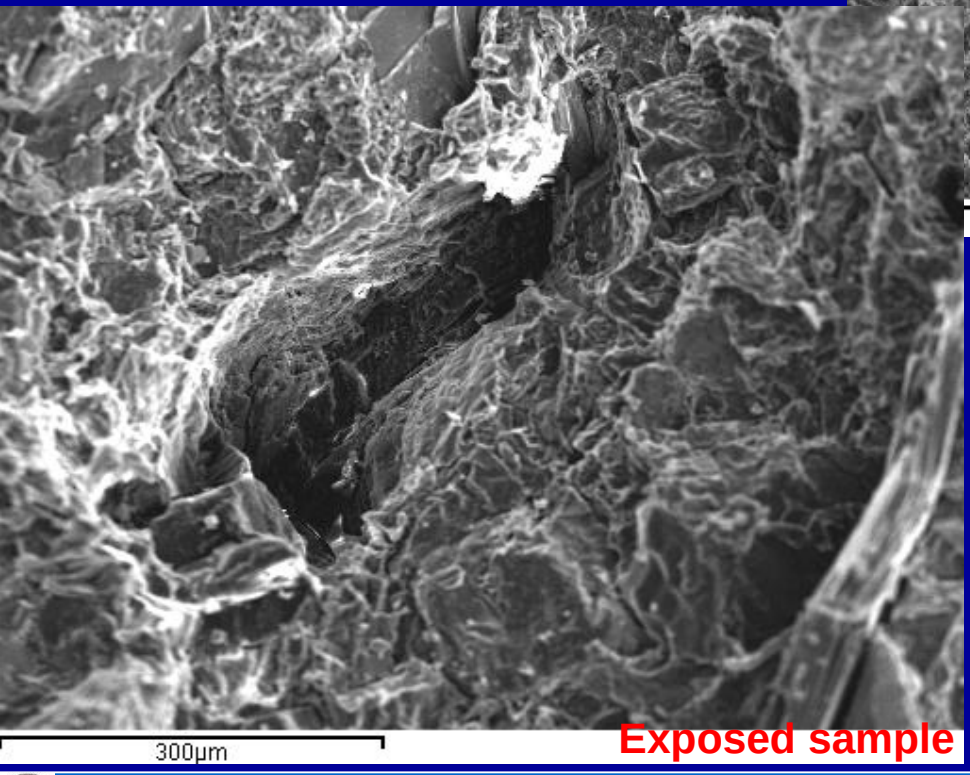

Secondary electron image
300μm
Intact sample


Back scattered electron image
300μm
Intact sample

Comparison

Secondary electron images

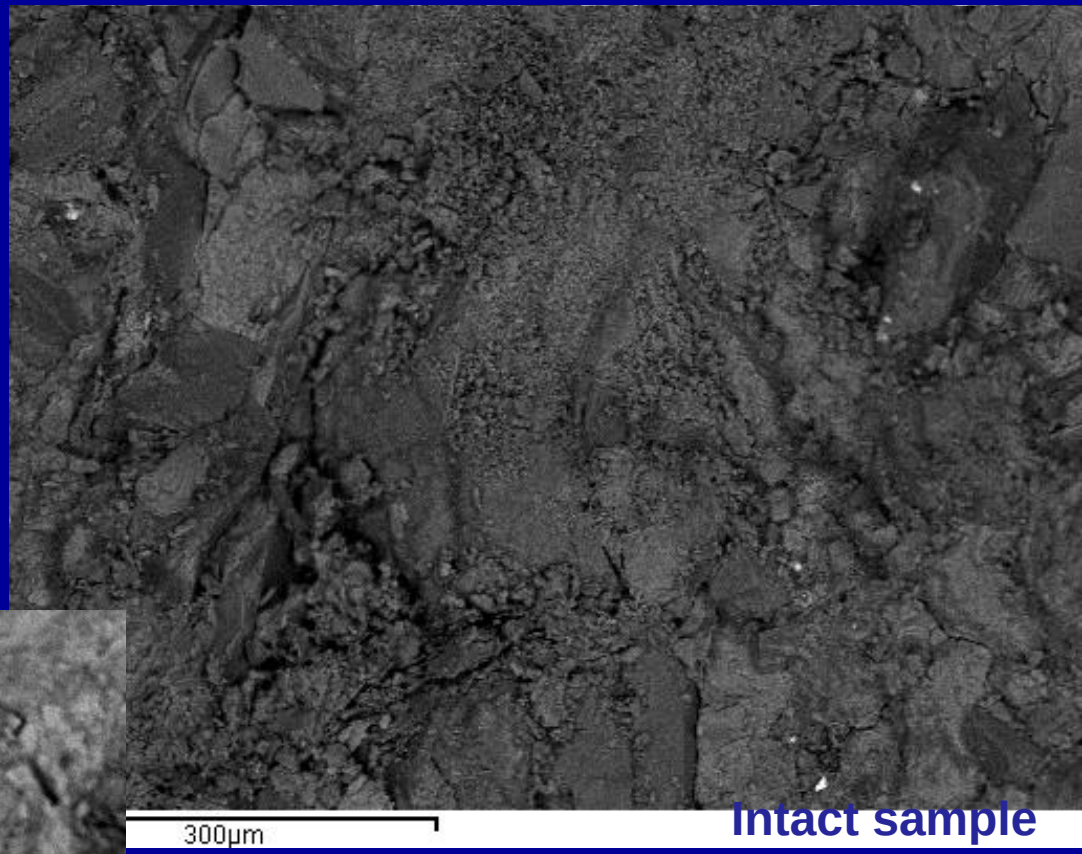




Absence of calcite particles after exposure

Comparison

Back scattered electron images





Absence of calcite particles after exposure



2 Samples Chalk

14 Samples Sandstone:

-2 exposed

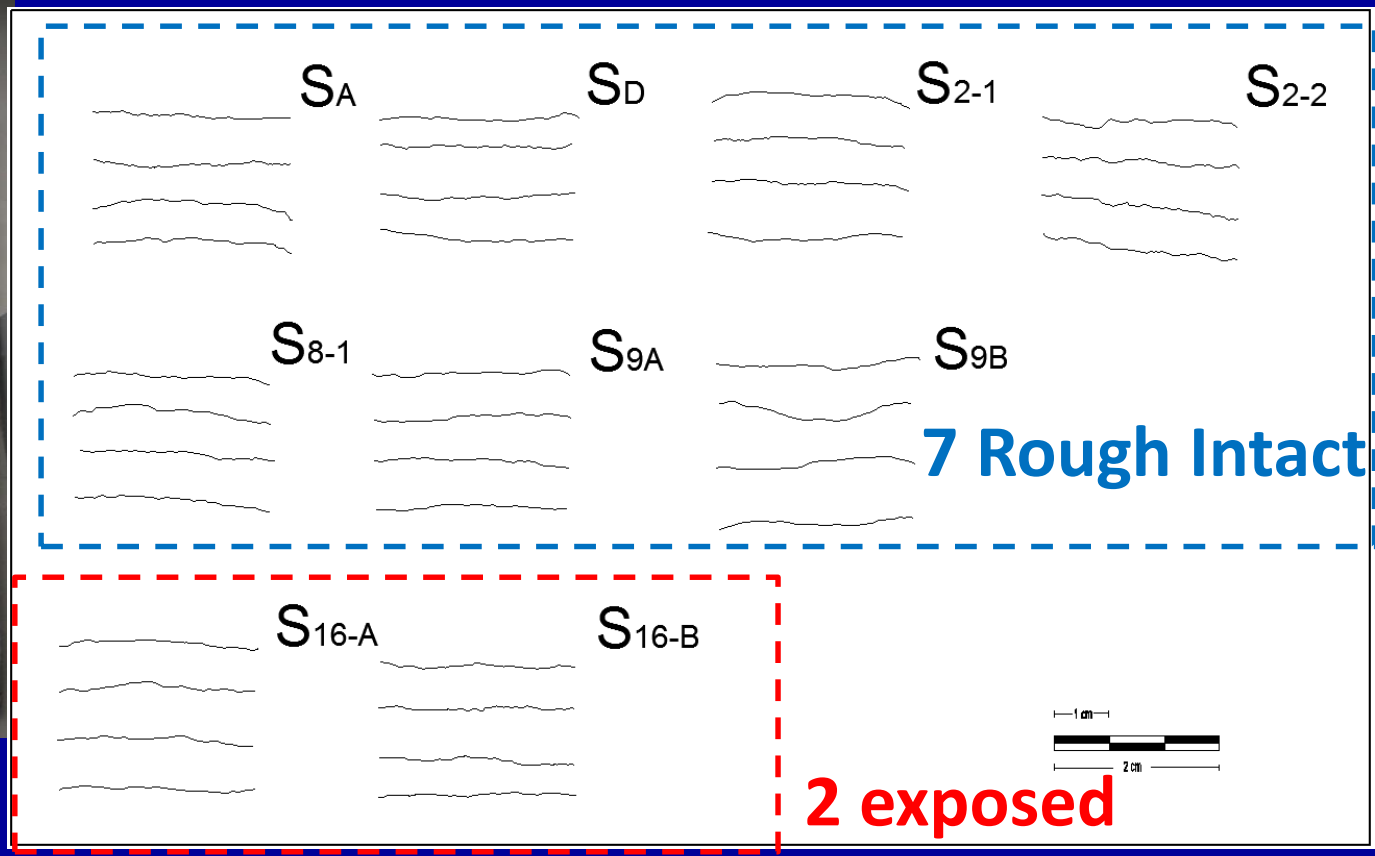
-5 Plain surface Intact

-7 Rough Intact



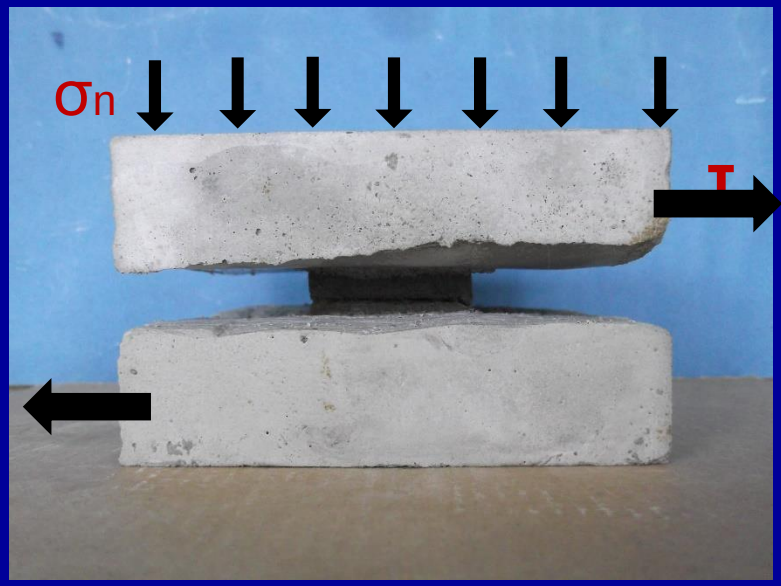
Fracture shear tests

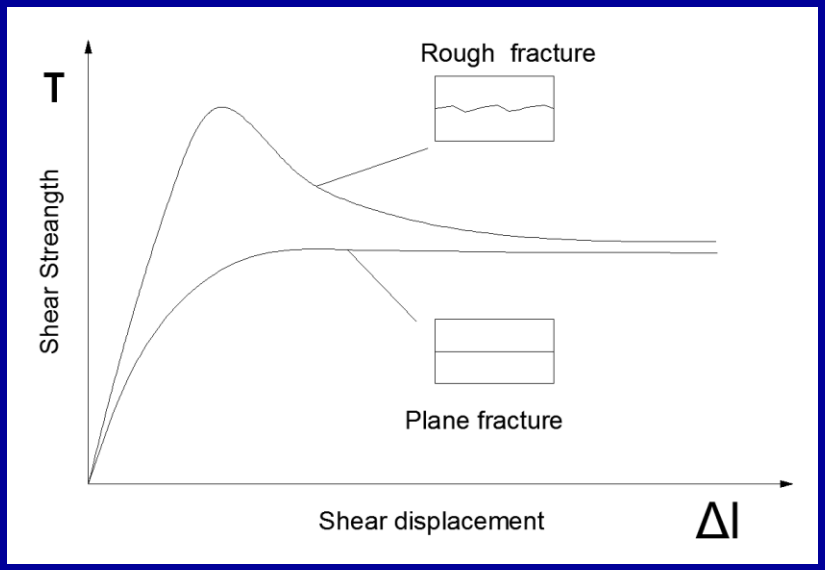






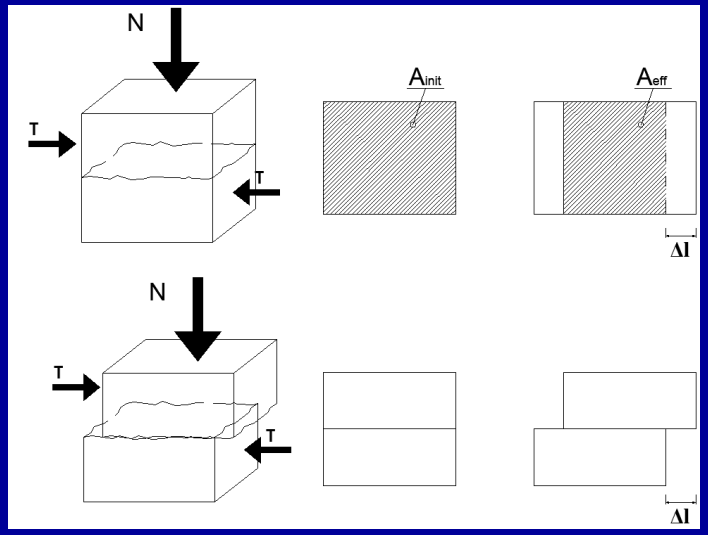
Fracture profiles of all samples



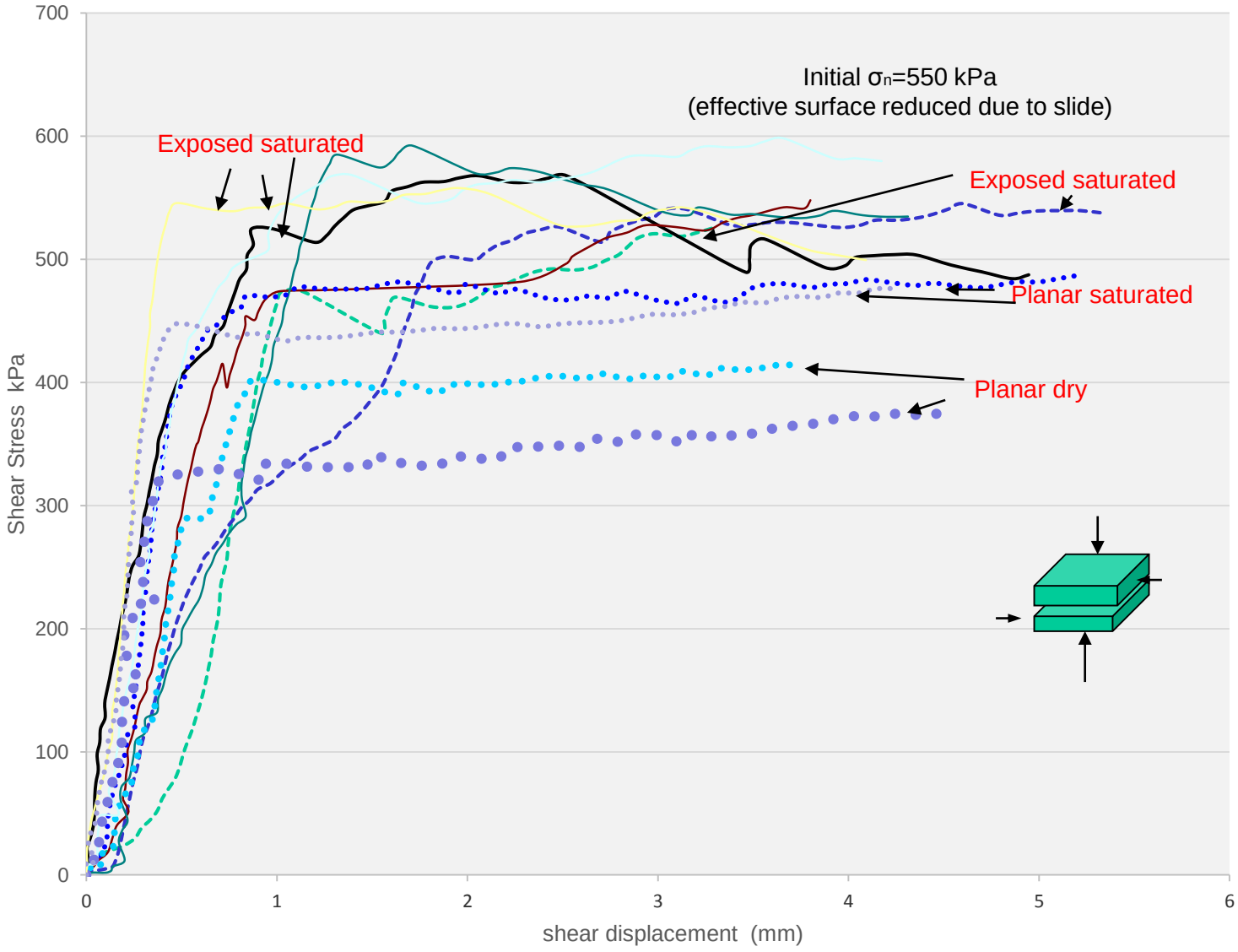


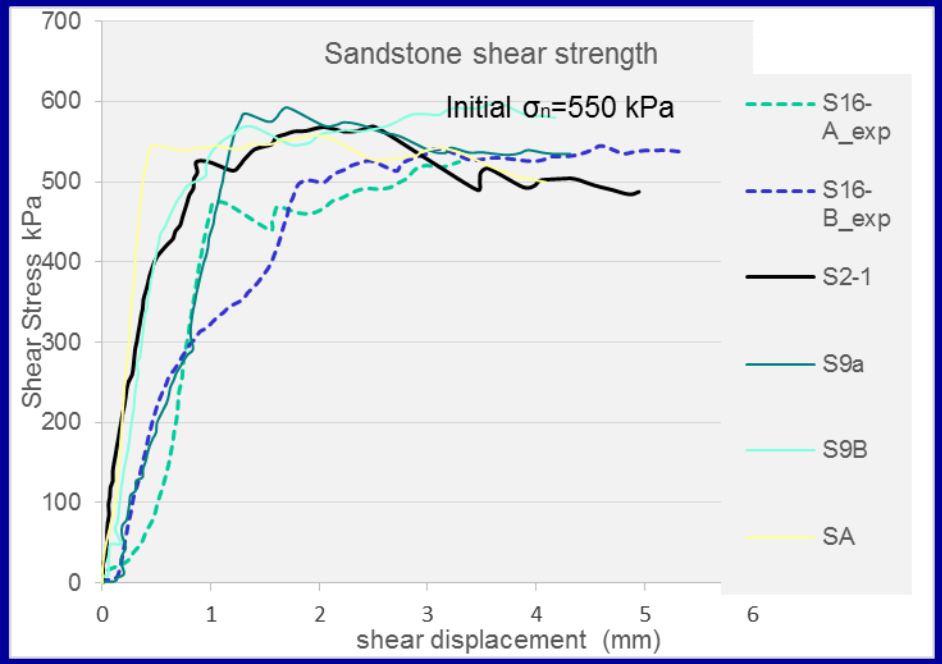
Shear Test

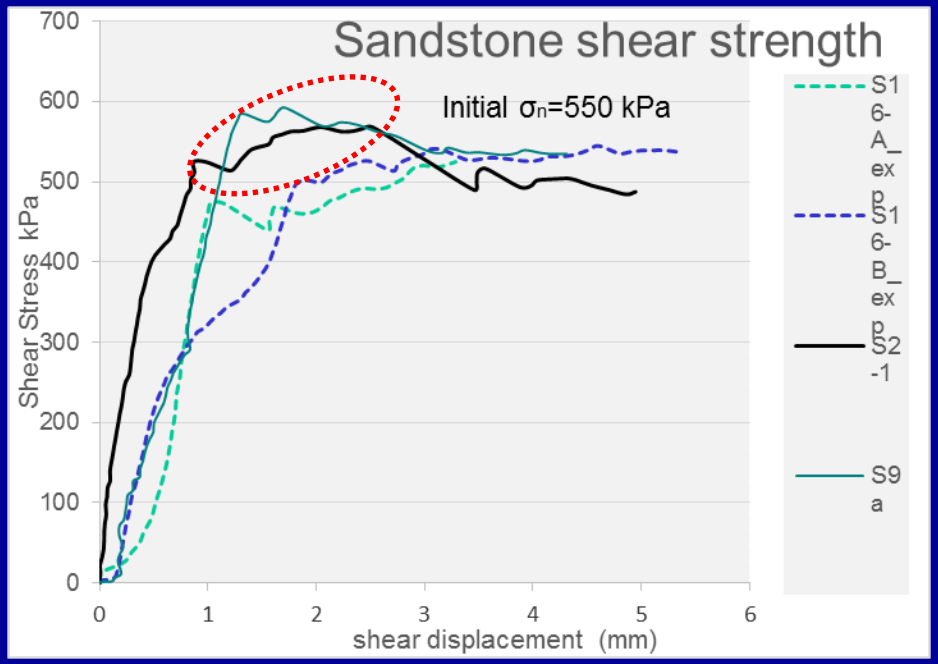
A_{eff}="Not constant"

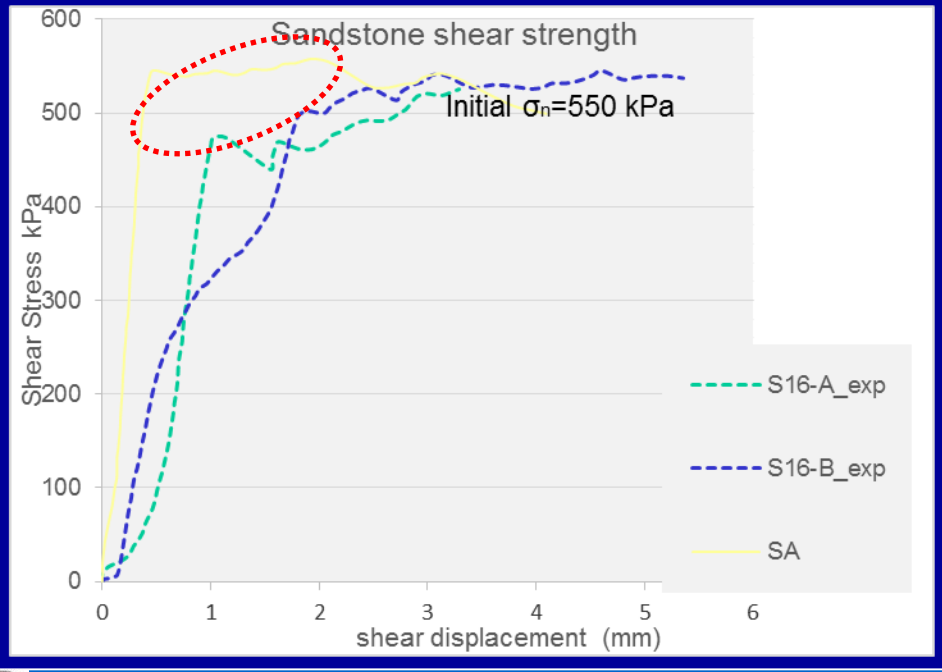


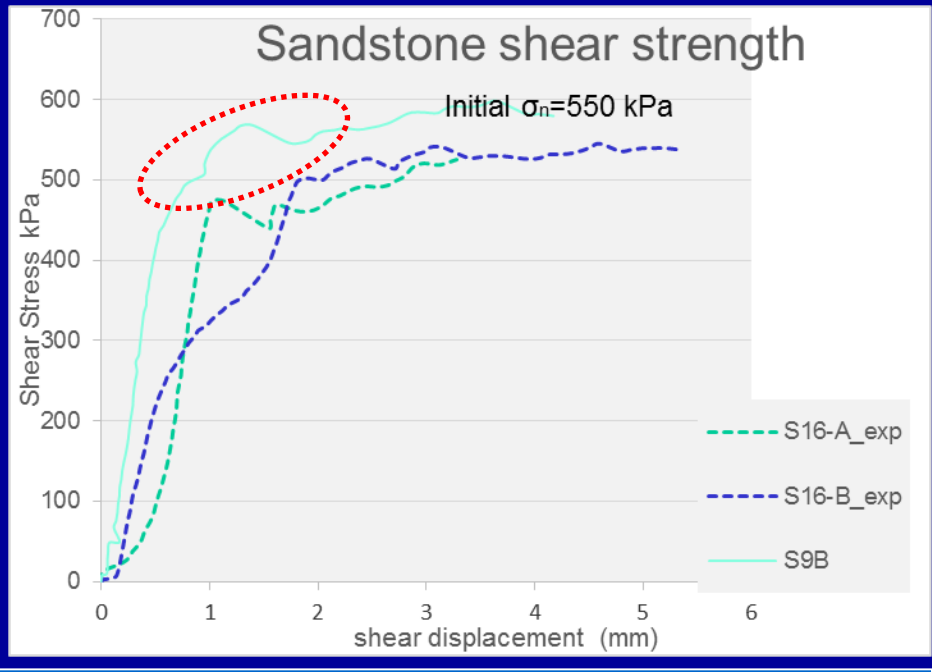
Sandstone shear strength

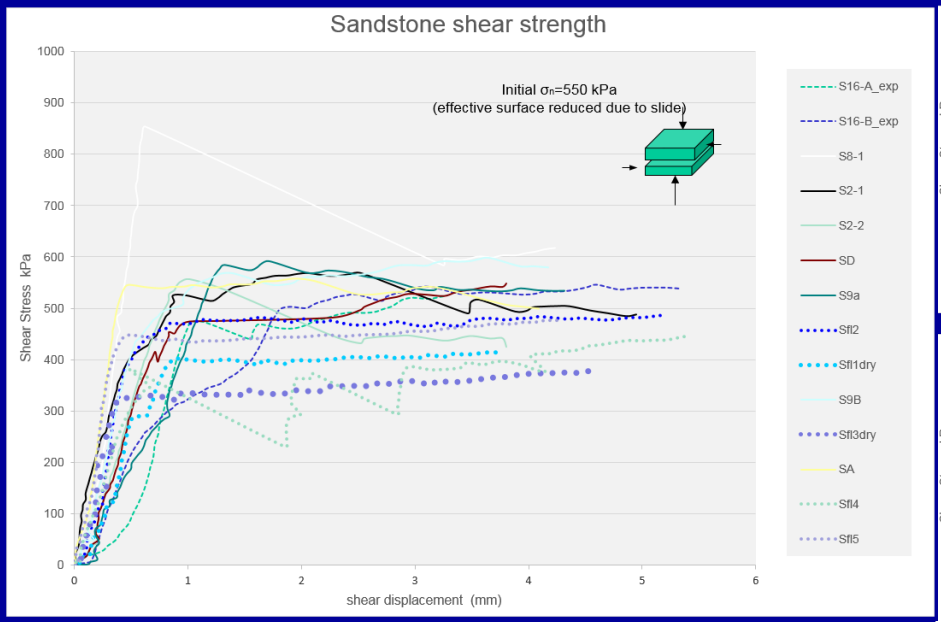


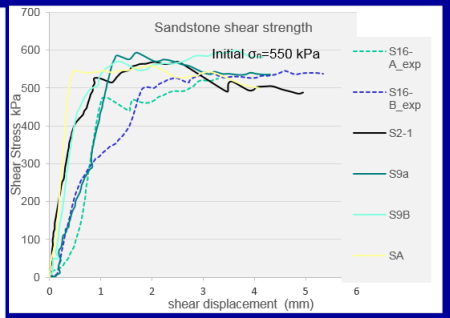

Sandstone shear strength
Initial σn=550 kPa
Shear Stress kPa
shear displacement (mm)
S16-A_exp
S16-B_exp
S2-1
S9a
S9B
SA

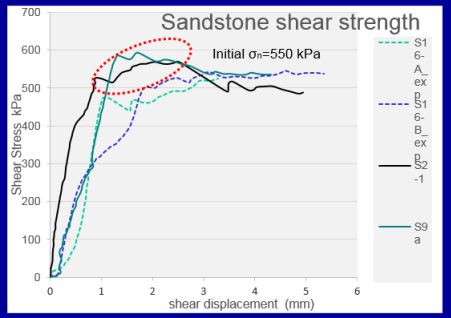

Sandstone shear strength
Initial σn=550 kPa
Shear Stress kPa
shear displacement (mm)
S16-A_exp
S16-B_exp
S2-1
S9a

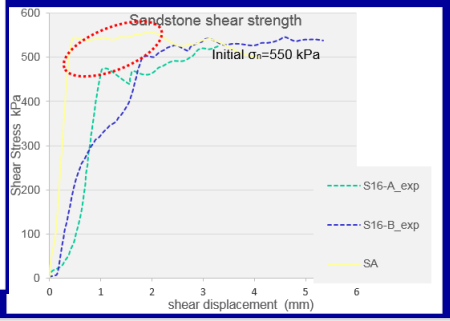

Sandstone shear strength
Initial σn=550 kPa
Shear Stress kPa
shear displacement (mm)
S16-A_exp
S16-B_exp
SA

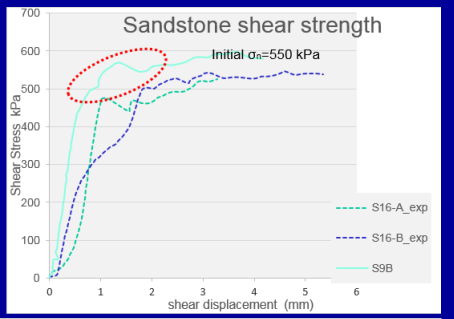

Sandstone shear strength
Initial σn=550 kPa
Shear Stress kPa
shear displacement (mm)
S16-A_exp
S16-B_exp
S9B



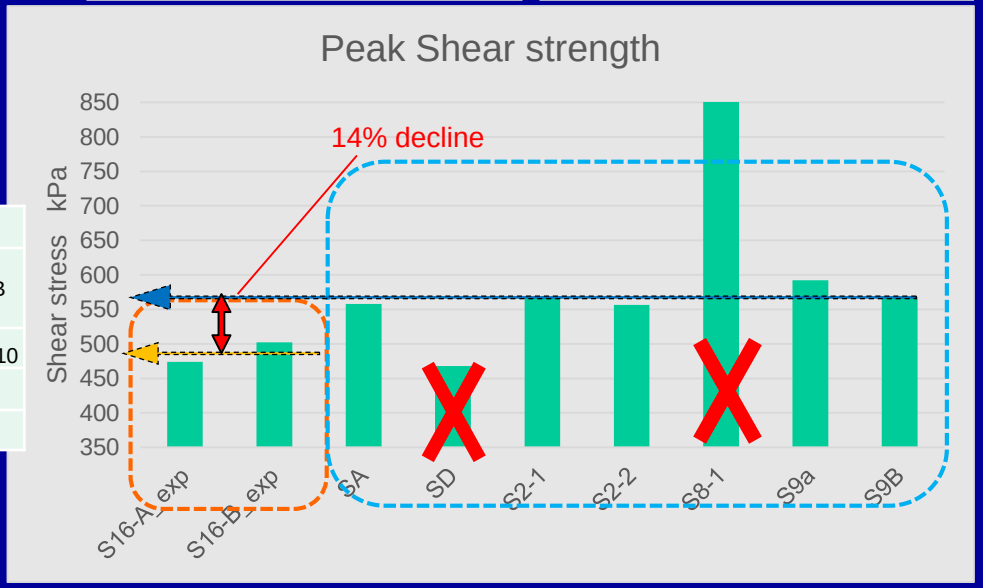


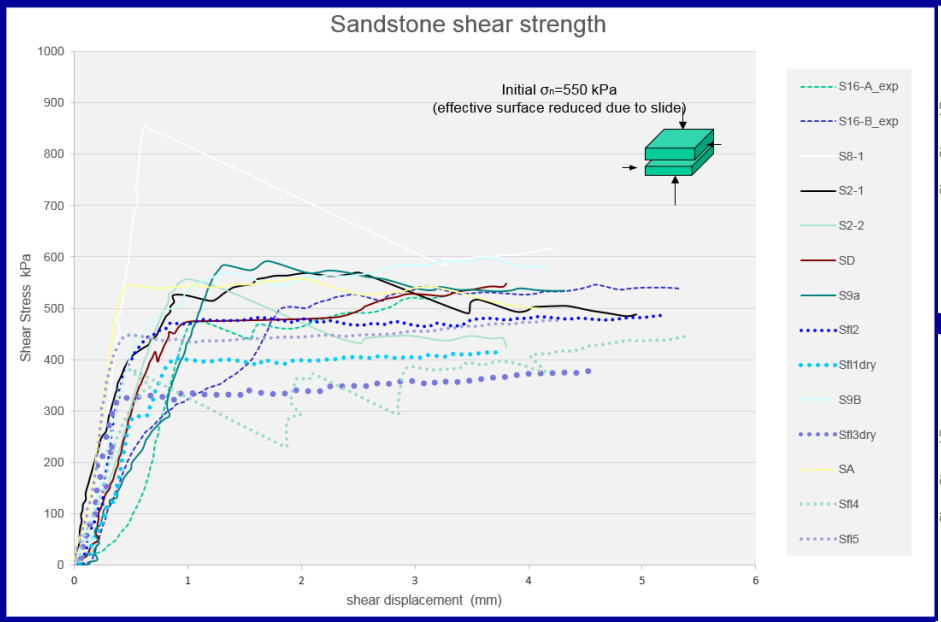


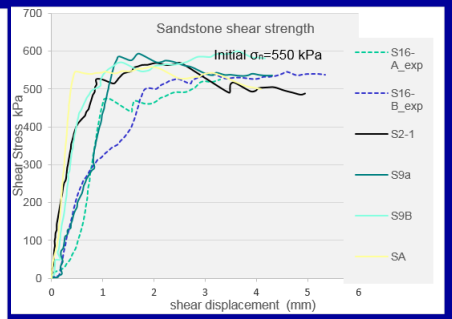


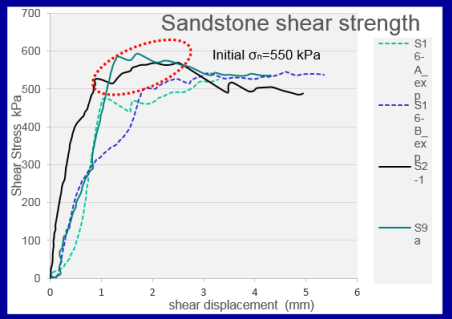


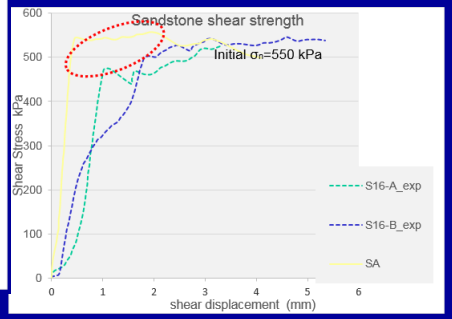
Peak Shear stress									
	S16-A_exp	S16-B_exp	SA	SD	S2-1	S2-2	S8-1	S9a	S9B
	473,92	502,30	557,90	467,95	567,89	556,64	853,25	592,34	568,10
average	488,11		568,58						
difference	**14,2%**								

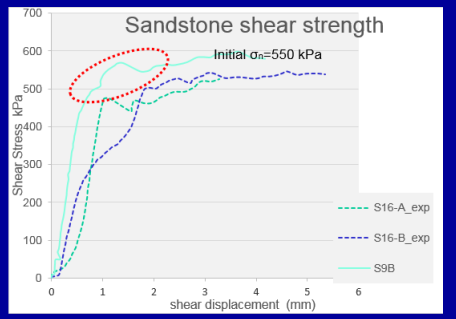






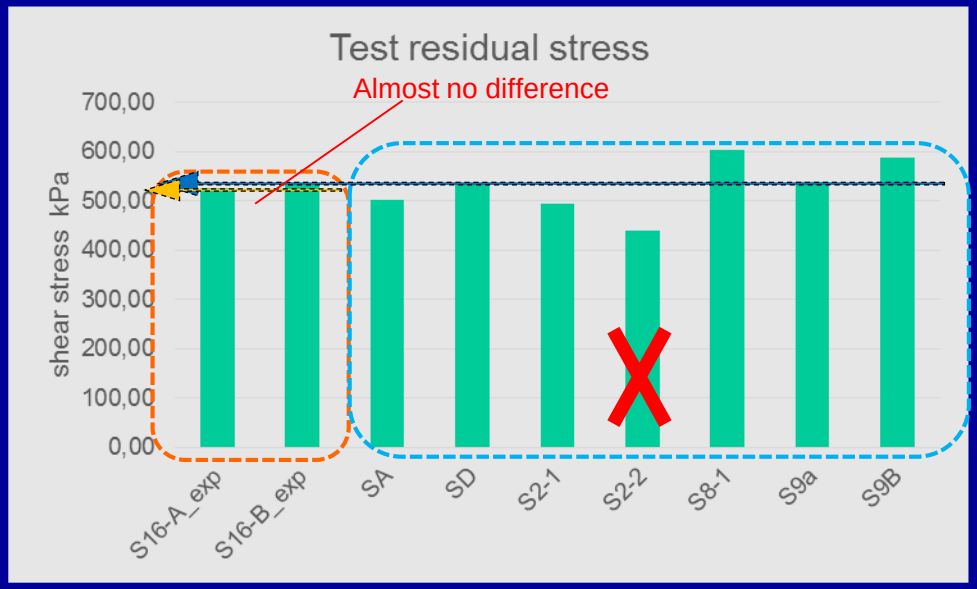




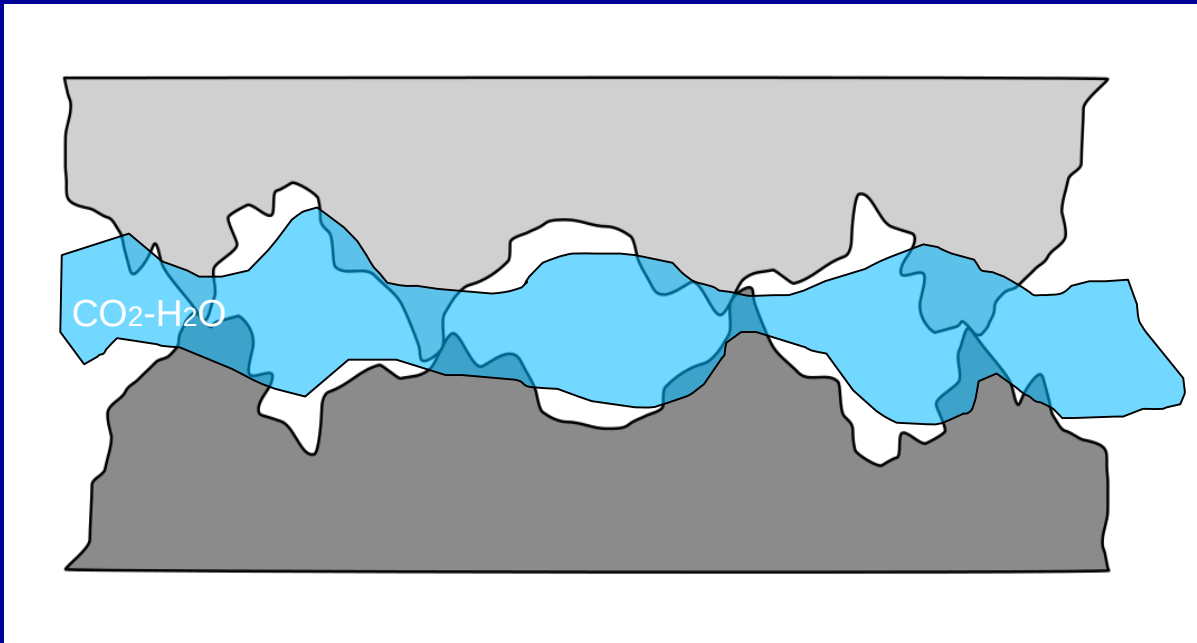


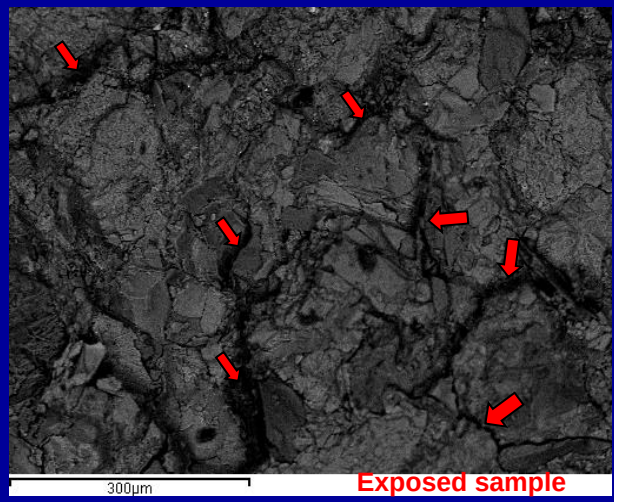
Residual Shear stress

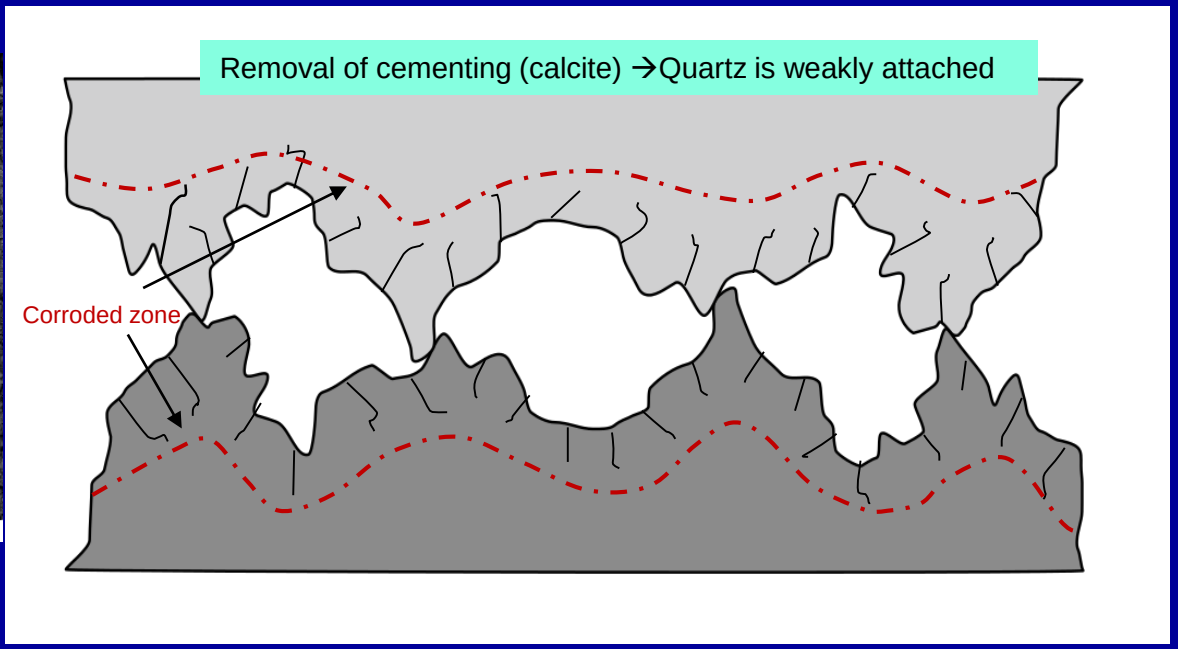
	S16-A_exp	S16-B_exp	SA	SD	S2-1	S2-2	S8-1	S9a	S9B
	525,74	534,57	503,43	536,50	495,35	439,19	602,96	538,10	588,40
average	530,16		544,12						
diference	2,6%								



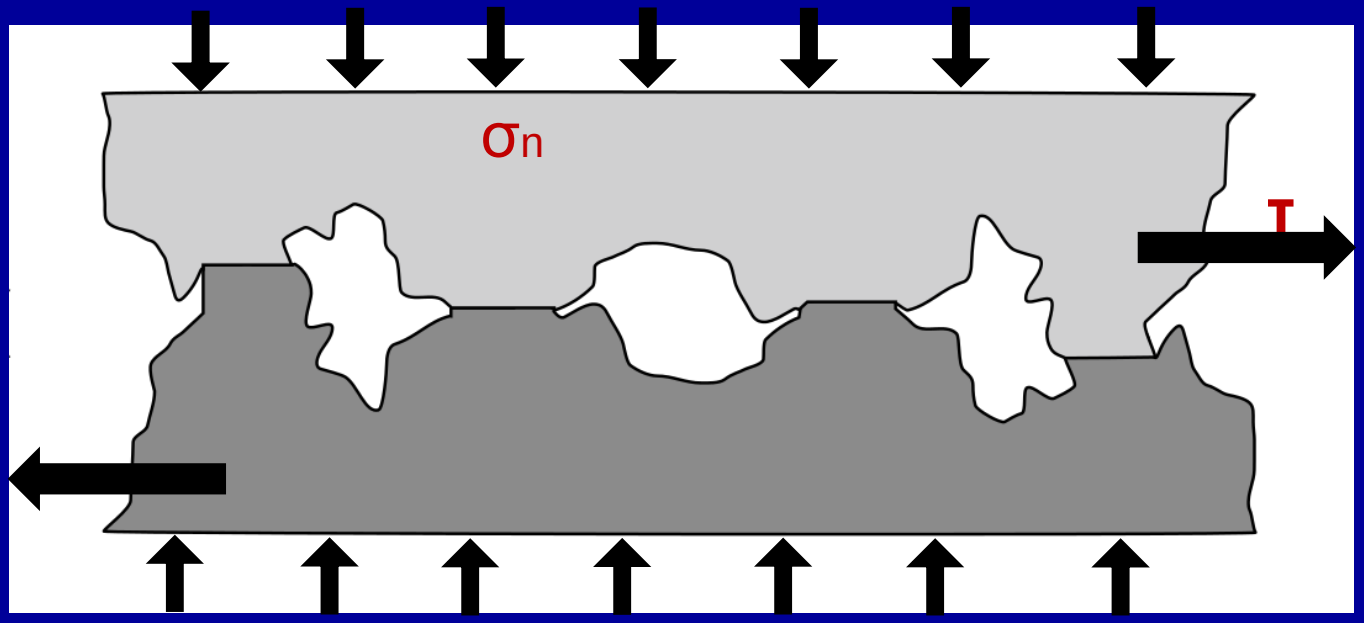
Possible Mechanism explaining loss on Peak Shear strength







Crack's surface becomes less rough



CONCLUSIONS

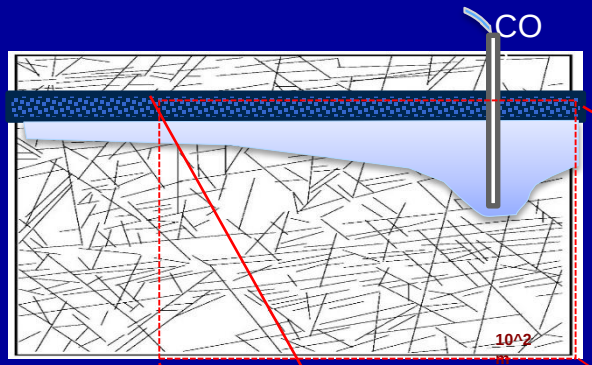
Mechanically induced fractures on sandstone samples (fracture area 36mm x36mm) were tested in shear strength tests.

- Fractures exposed in CO2-H20 solution (simulating underground CO2 storage (CCS)) appear a **peak-shear stress** loss of **14%** comparing to intact fractures.

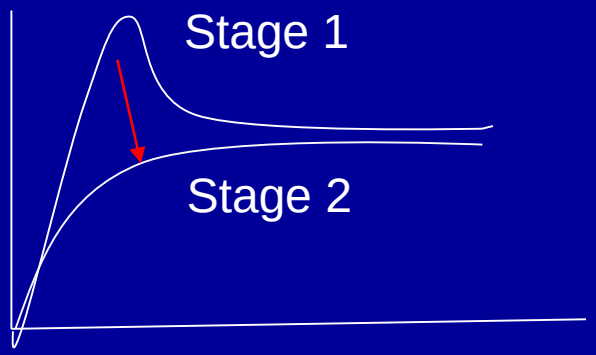
- **Residual-shear test** appear almost identical (**no loss**) in both sample categories (exposed and intact)

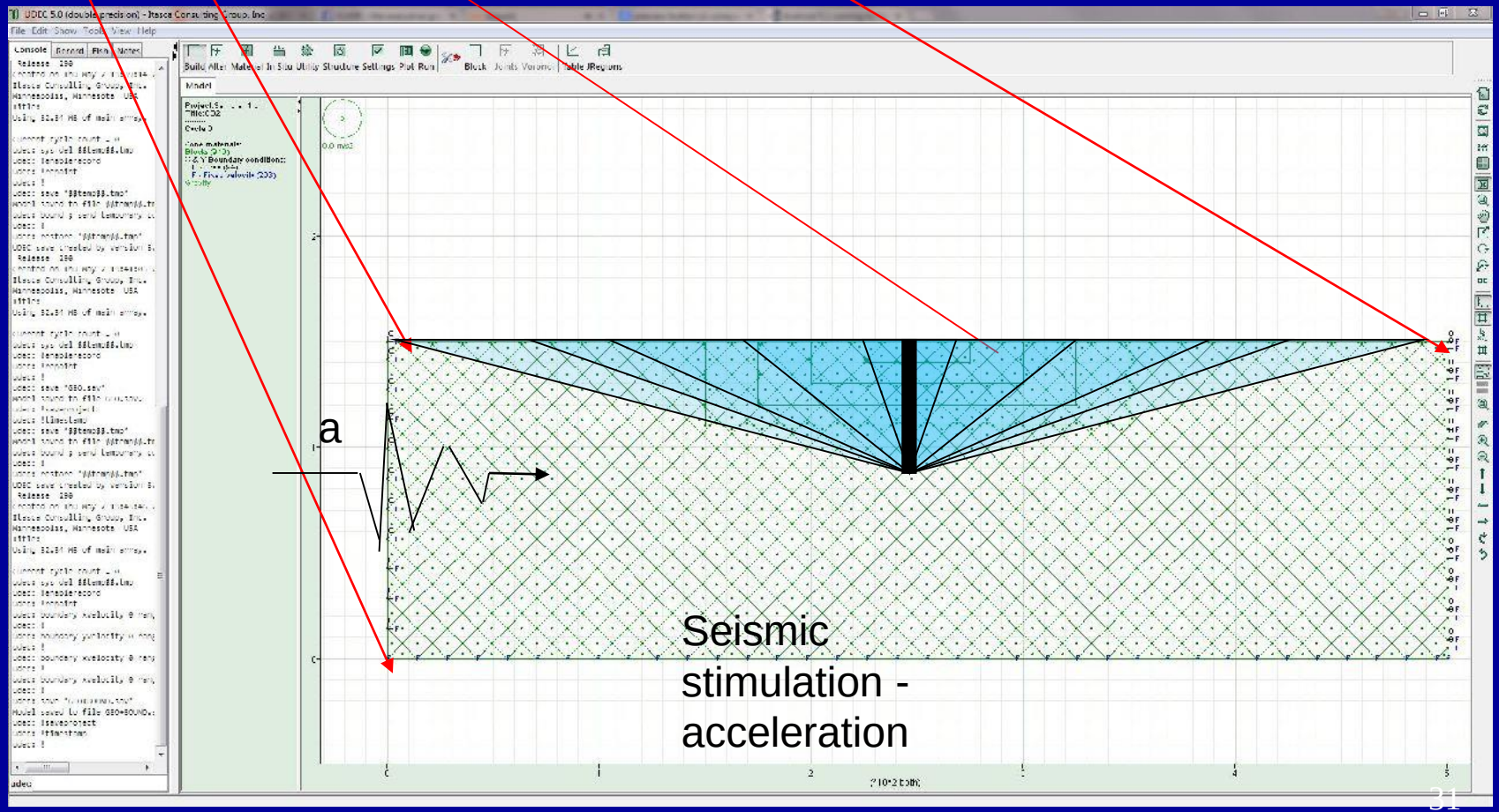
- Rock mass consisting of the above tested material (Grevena sandstone) under CO2 storage conditions, containing fractures might appear significant strength loss in shear movements. Shear movements might occur under dynamic enforcement (eg earthquake). Potentially such strength loss may result in differential displacement which may reactivate pre-existing faults resulting in affection of CO2 reservoir integrity (CO2 leakage back to atmosphere/biosphere).

Sheduled PC simulation



?





End of presentation

Thanks for your patience