Impact of CO_2 on mechanical properties of sandstone during sequestration for climate change mitigation

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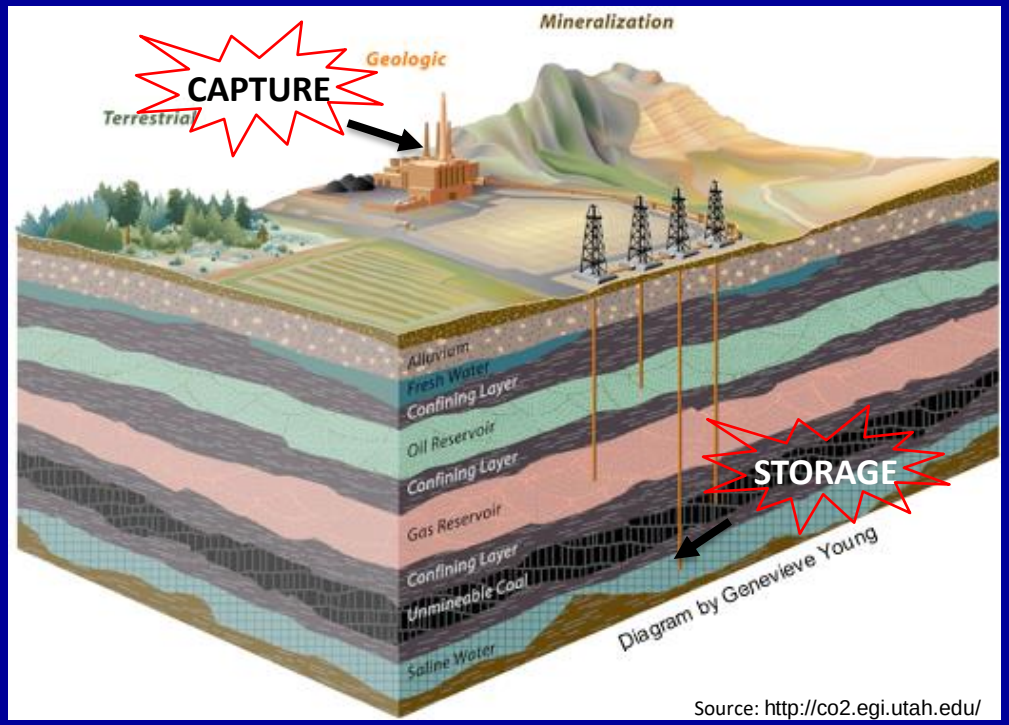
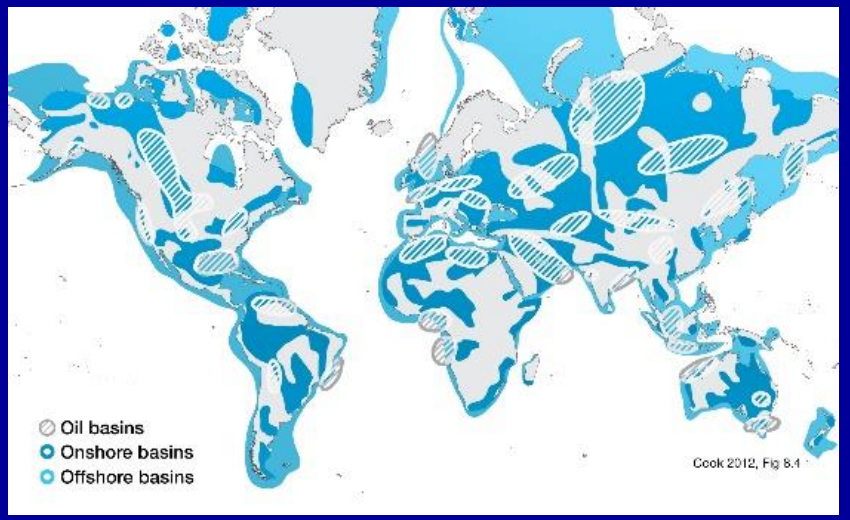
European Union
European Social Fund
OPERATIONAL PROGRAMME
EDUCATION AND LIFELONG LEARNING
investing in knowledge society
MINISTRY OF EDUCATION, LIFELONG LEARNING AND RELIGIOUS AFFAIRS
MANAGING AUTHORITY
NSRF 2007-2013
programme for development
EUROPEAN SOCIAL FUND
Co- financed by Greece and the European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

Geo-sequestration In deep saline aquifers

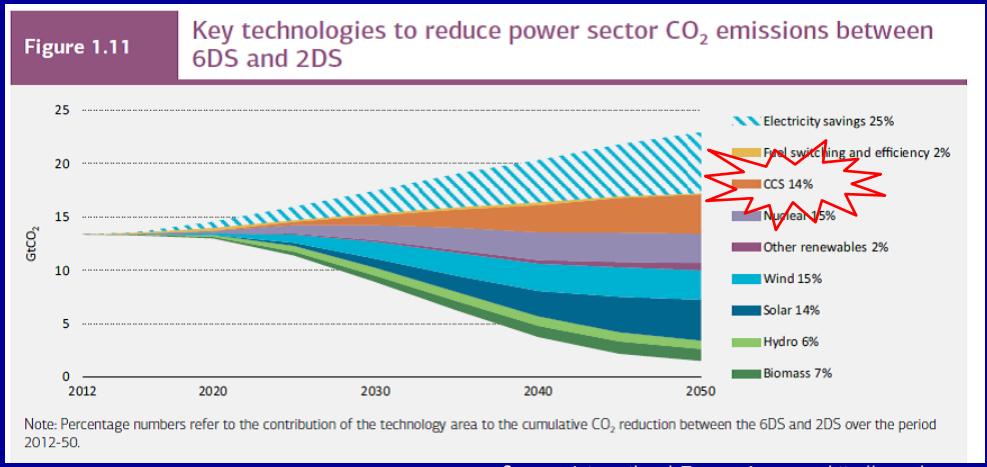


Source: http://co2.egi.utah.edu/

Spread of Sedimentary basins around the globe

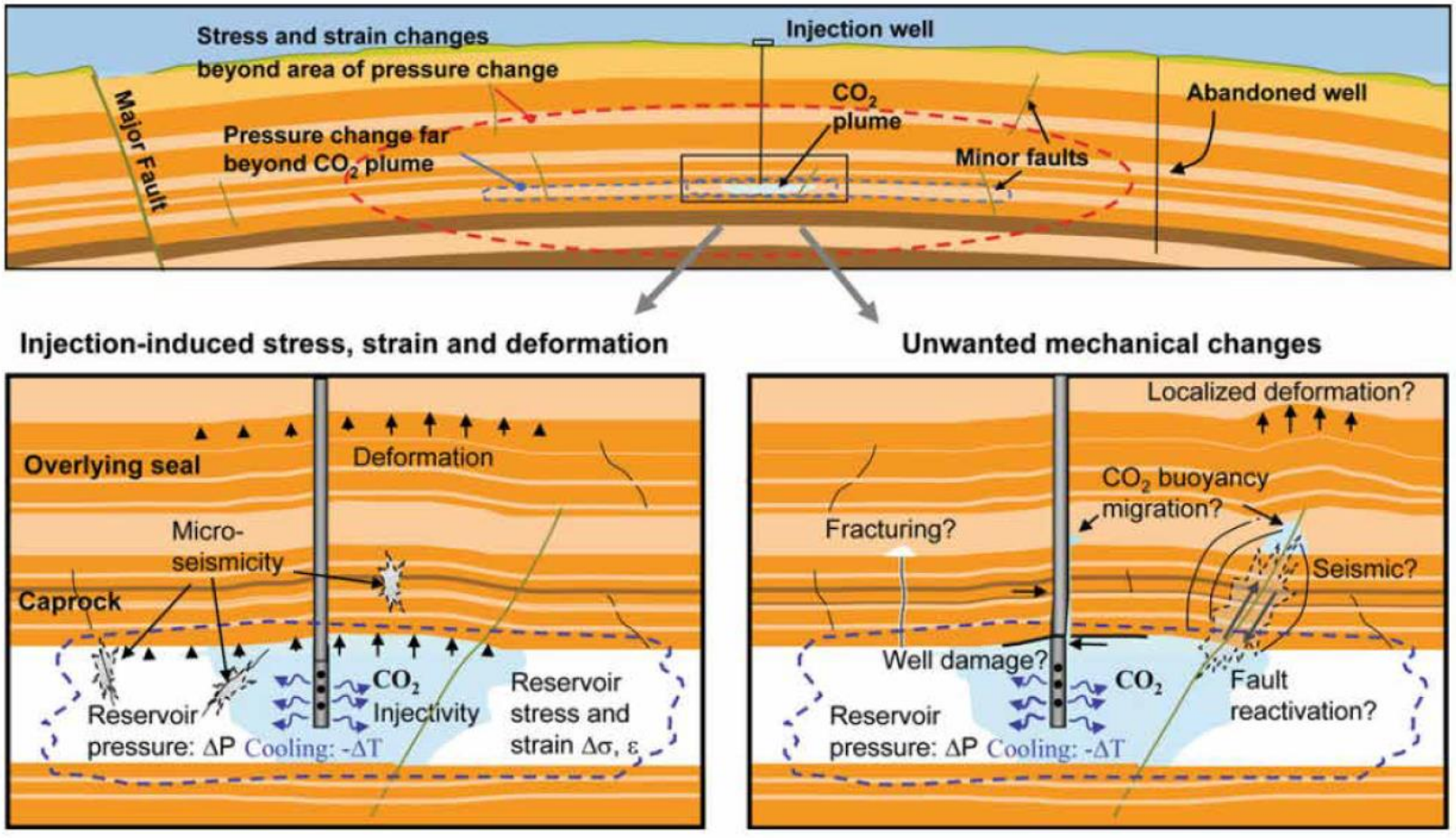


Source: International Energy Agency http://www.iea.org



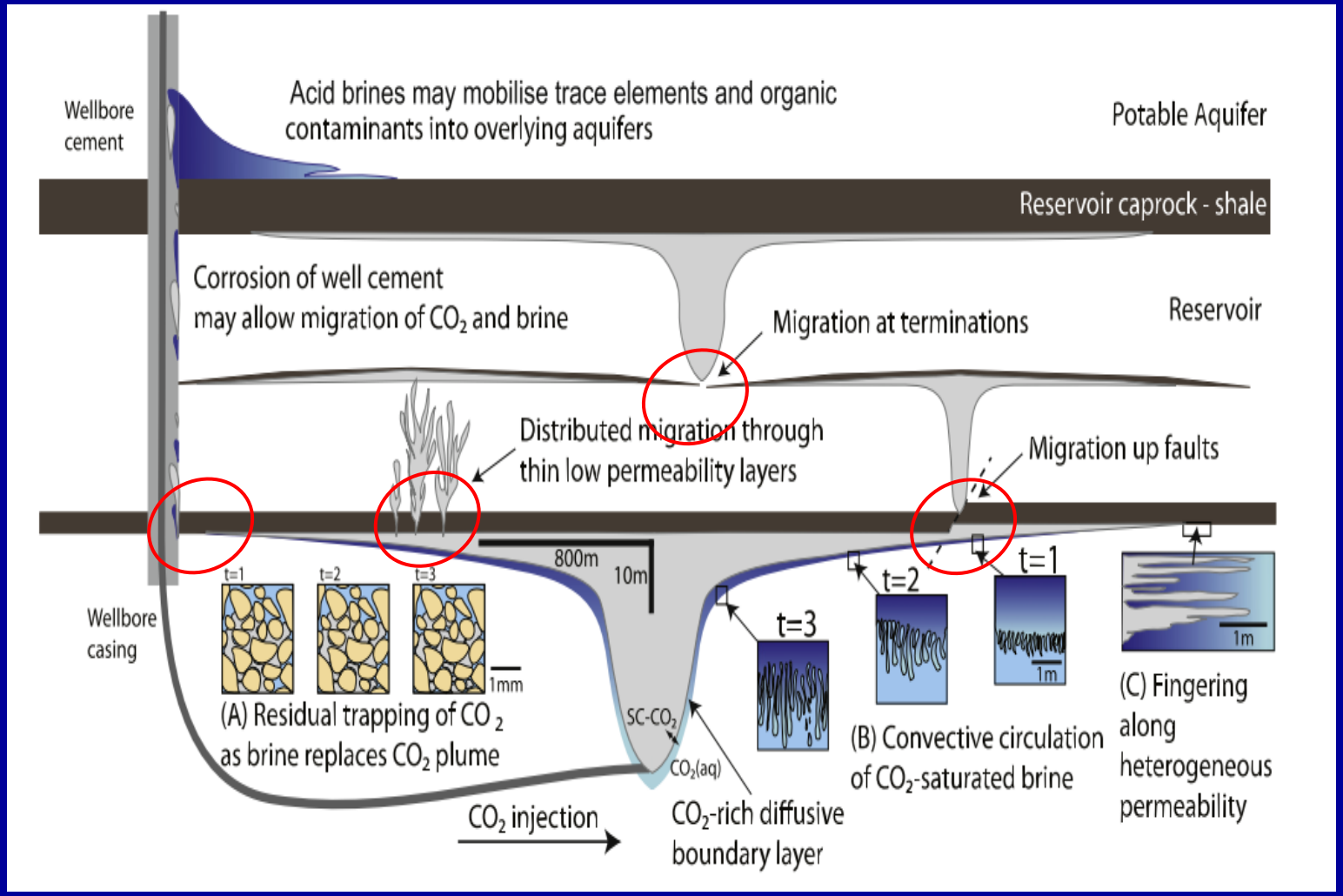
Source: International Energy Agency http://www.iea.org

Geo-mechanical Challenges while storing CO2



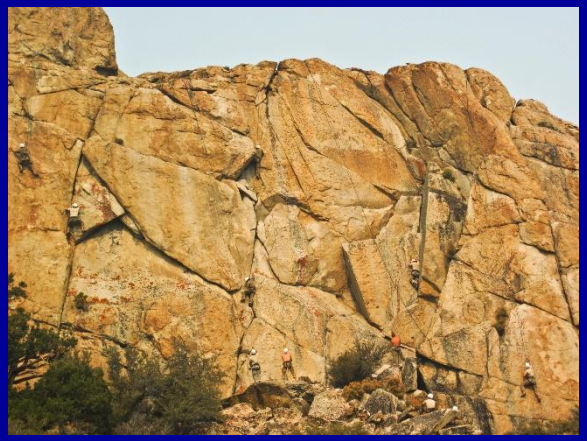
Geomechanical processes and key technical issues associated with geological storage of CO_2 in deep sedimentary formations (Rutqwist, J. 2012)

Potential Leakage pathways while storing CO2

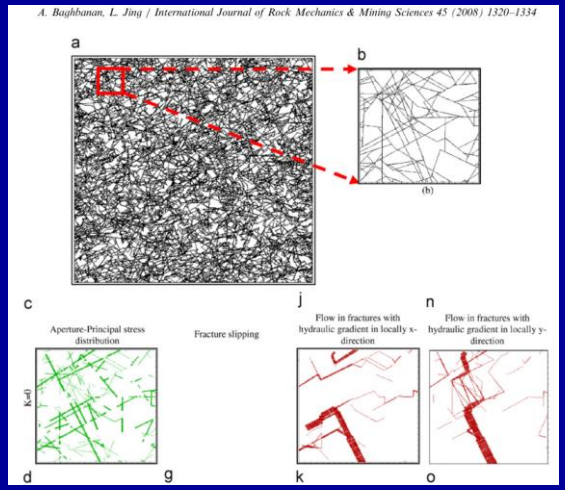


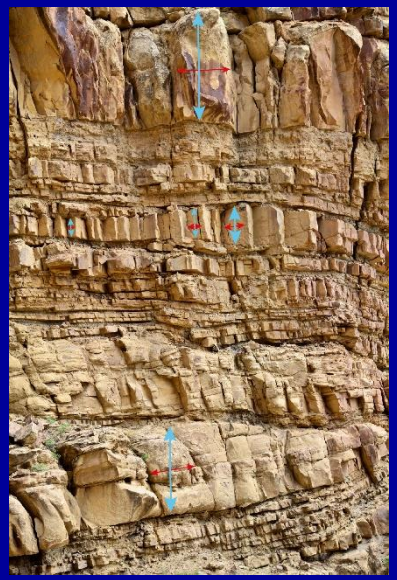
Source: Kampman et al (2014)

Rock mass: Jointed/Fractured/Faulted



Should be modeled as Discontinuous medium for fluid flow assessments for the most realistic approach





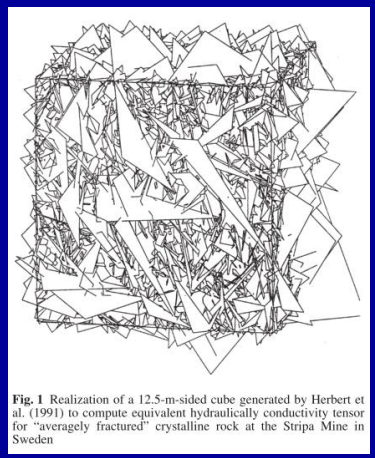
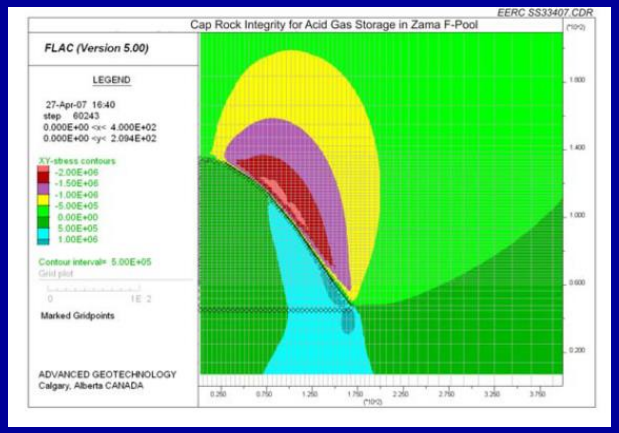


Fig. 1 Realization of a 12.5-m-sided cube generated by Herbert et al. (1991) to compute equivalent hydraulically conductivity tensor for "averagely fractured" crystalline rock at the Stripa Mine in Sweden

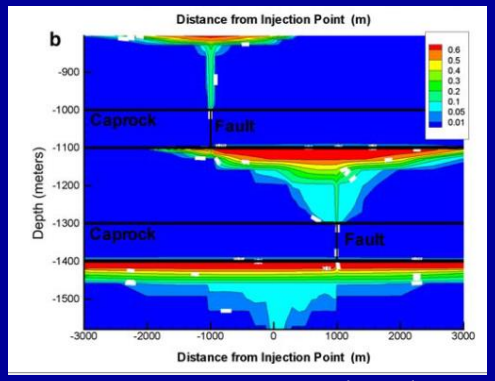
Rock mass modelled as equivalent continuous medium for CO2 storage (reactive flow/chemo-poro-mechanical problem)



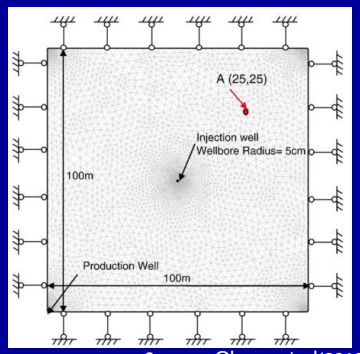
Source: Smith et al (2009)

-equivalent continuous m.
-Permeability Tensor

"Mushroom" shaped Co2 plume



Source: Rutqvist et al (2002)



Source: Chen et al(2010)

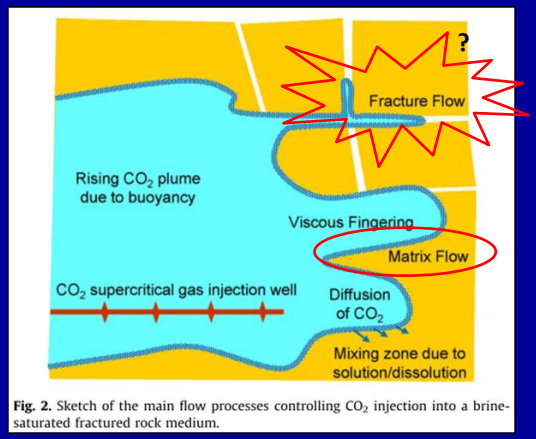


Fig. 2. Sketch of the main flow processes controlling CO_2 injection into a brine-saturated fractured rock medium.

Source: Iding and Ringrose (2010)

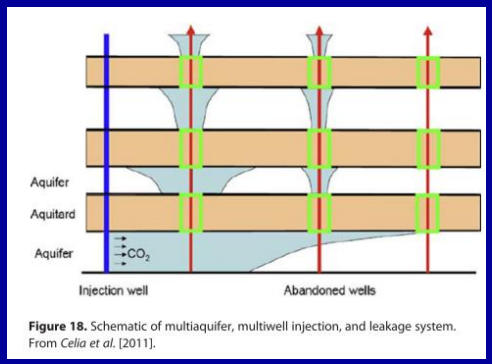
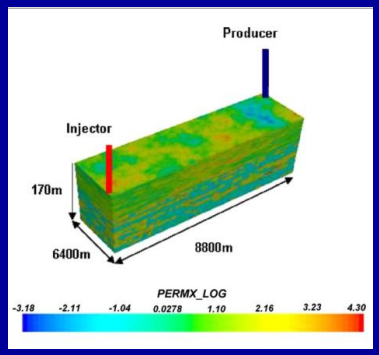


Figure 18. Schematic of multiaquifer, multiwell injection, and leakage system. From *Celia et al.* [2011].



Source: Qi et al (2009)

MAIN REASONS:

- Time consumption
- Software codes Available
- Resources Consumption

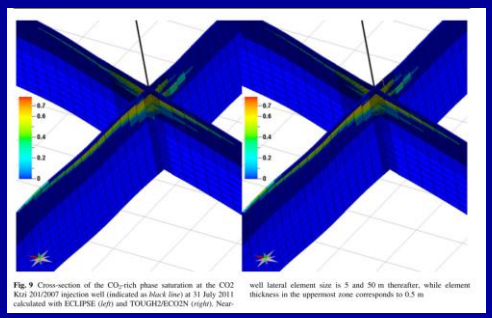
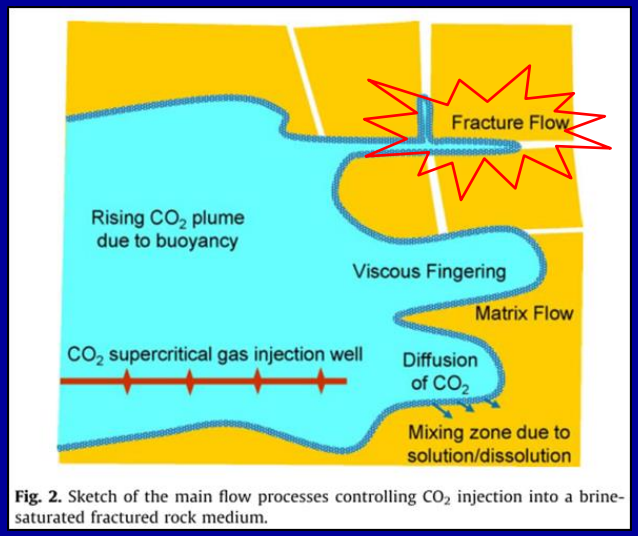


Fig. 9 Cross-section of the CO_2-rich phase saturation at the CO2 Ktzi 201/2007 injection well (indicated as *black line*) at 31 July 2011 calculated with ECLIPSE (*left*) and TOUGH2/ECO2N (*right*). Near-well lateral element size is 5 and 50 m thereafter, while element thickness in the uppermost zone corresponds to 0.5 m

Source: Kempka and Kühnet (2013)

Hydrological (fluid flow) behavior of fractures under stress/displacement



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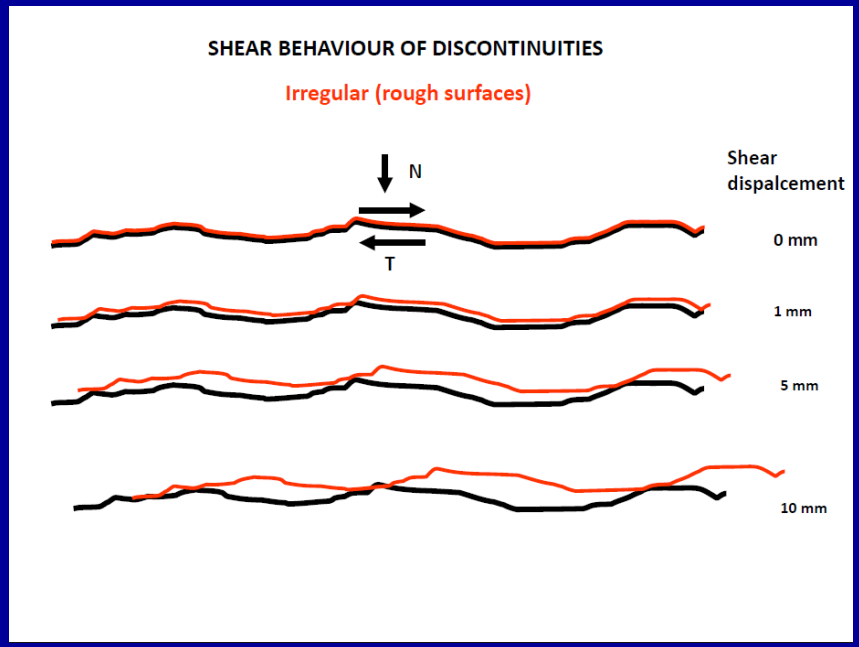
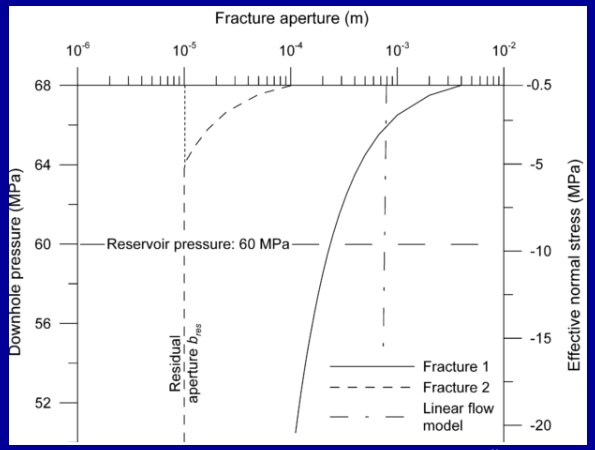


Source: prof Bandis w/sPresentation (2015)

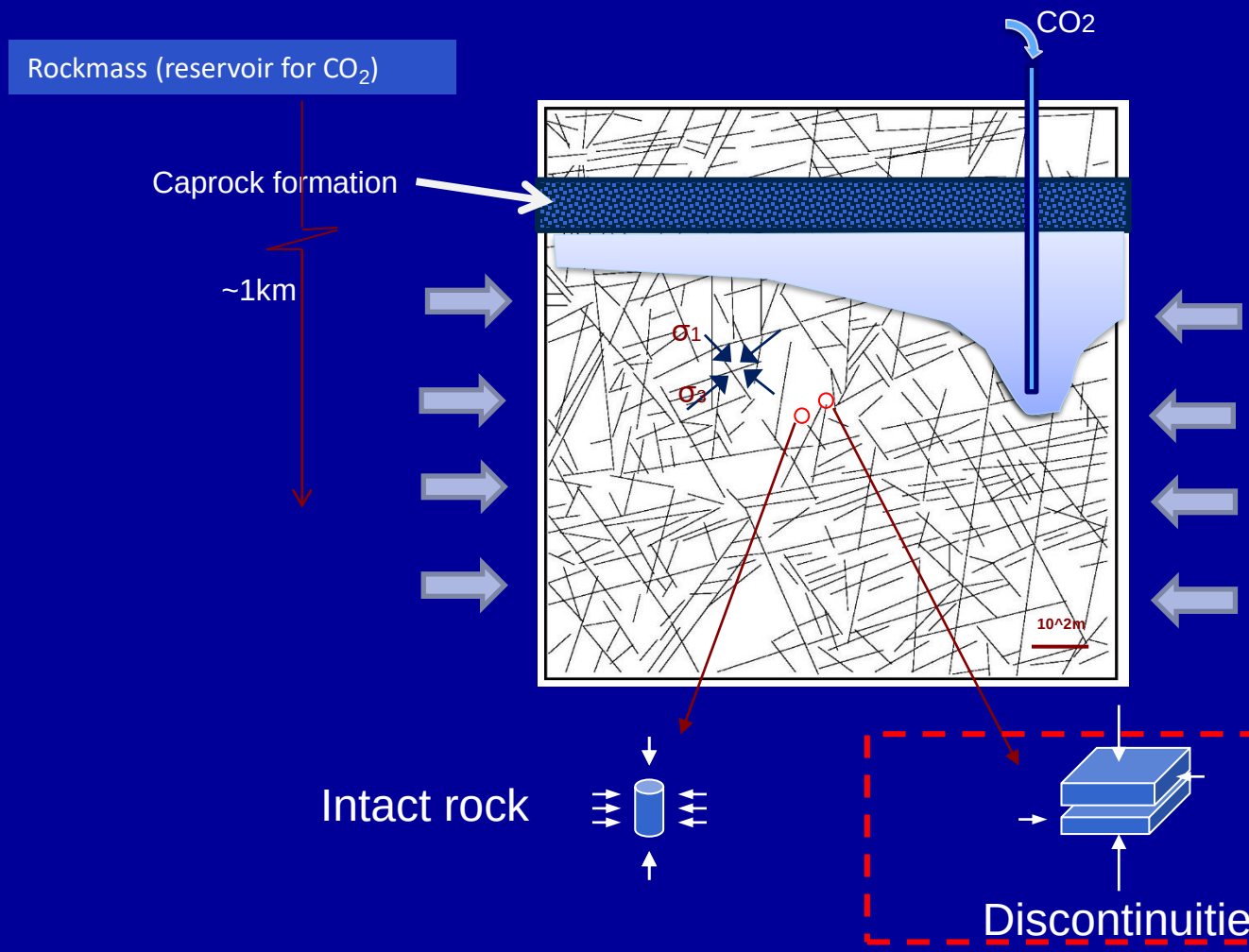


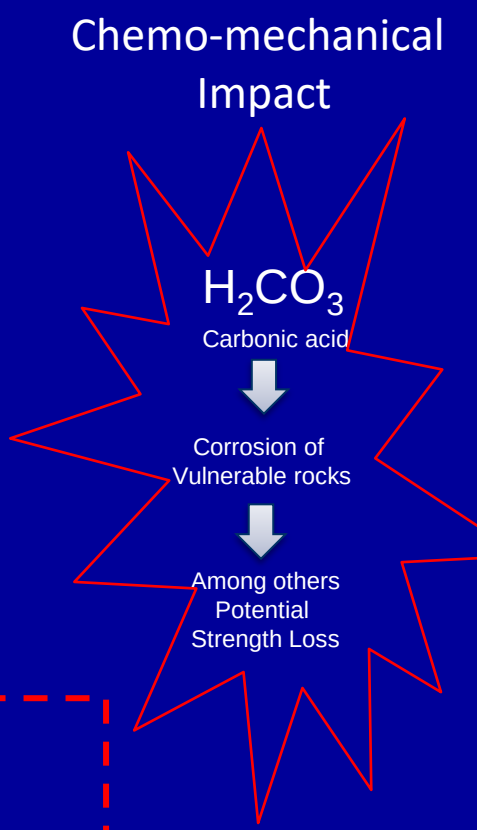
Source: Wessling(2009)

An interlocked 'closed' joint contrasted with its sheared and 'open' neighbour.

Coupled Geo-Chemo-mechanical challenges while storing CO_2

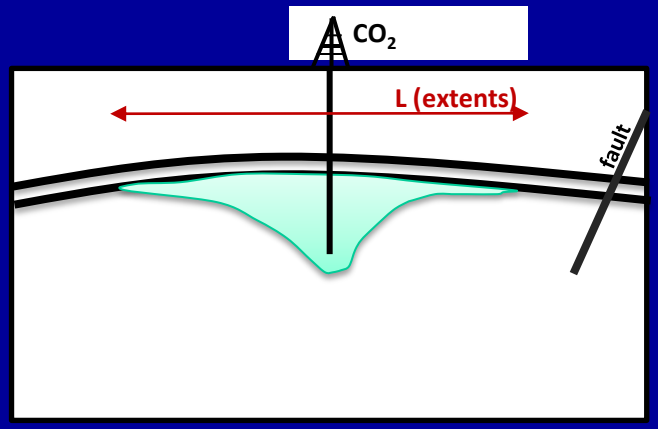
PhD Goals: Understanding the behavior of rockmass, and mainly fractures under exposure in CO_2, aiming to contribute scientifically in realistic Discrete Fracture Network models for CO2 underground sequestration assessments.



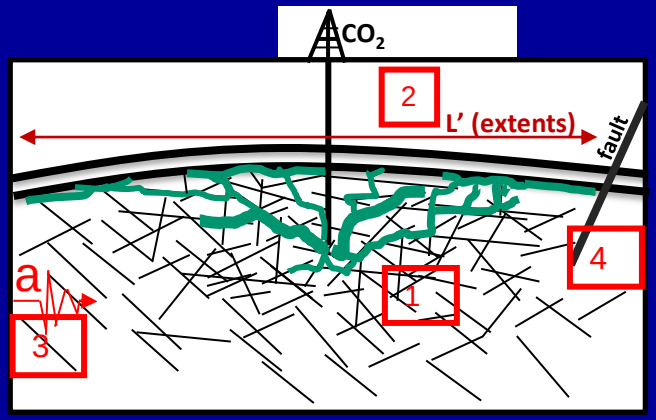


Research Questions

Equivalent continuous



Discontinuus continuous

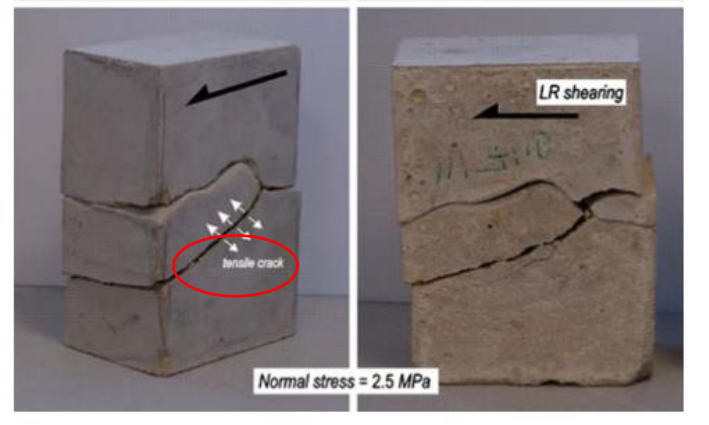


Questions:

1. **What might be the behavior of a reservoir, if we take into consideration that flow might be done mainly through fractures?**
2. **What may be the 'Liability zone' for the contractor, and for monitoring?**
3. **What might be the reaction of reservoir after an earthquake?**
4. **What if observed faults that neglected due to distance, are now accessible by CO_2 plume?**

How Fractures effect CO2 storage and reservoir behavior?

Tensile stress of fractures during Shear displacement



Source: Asadi et al (2013)

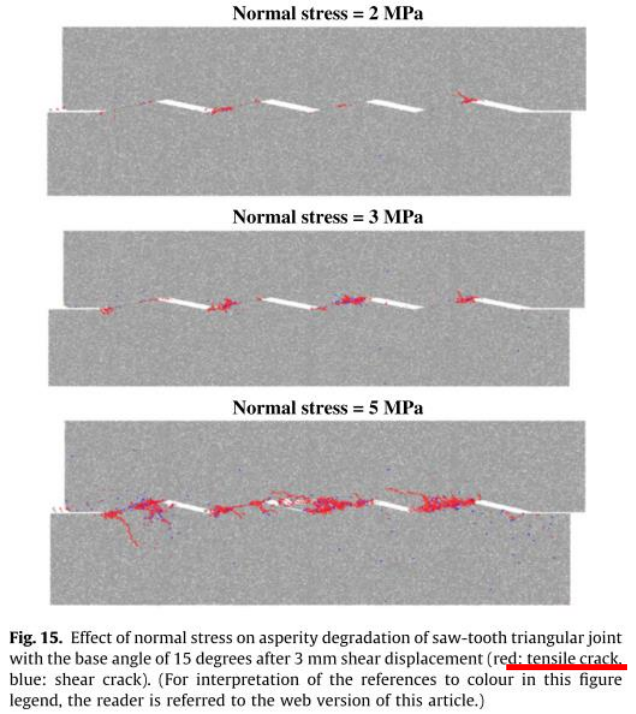


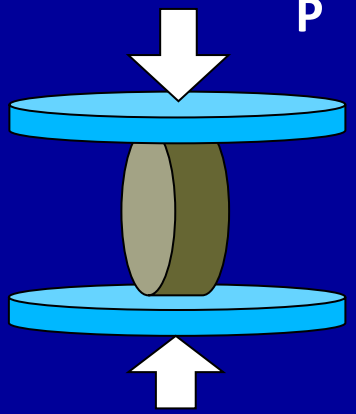
Fig. 15. Effect of normal stress on asperity degradation of saw-tooth triangular joint with the base angle of 15 degrees after 3 mm shear displacement (red: tensile crack, blue: shear crack). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Source: Bahaaddini et al (2013)

Indirect Tensile Strength test

Brazilian test

$$f_t = \frac{2P}{\pi DL}$$

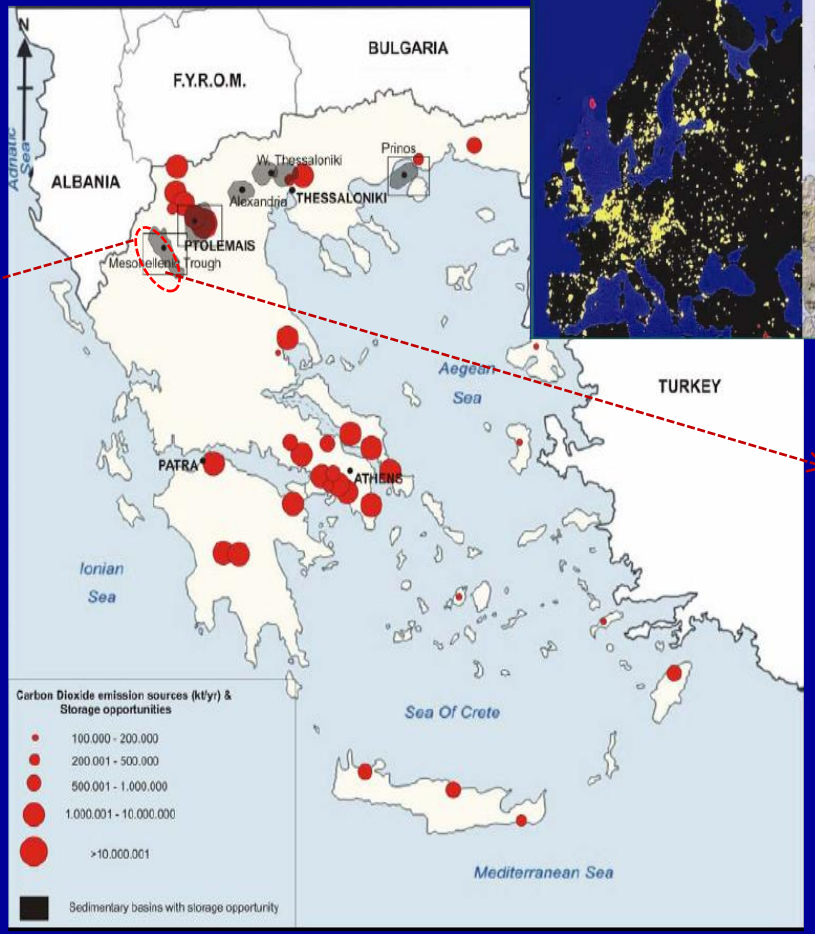


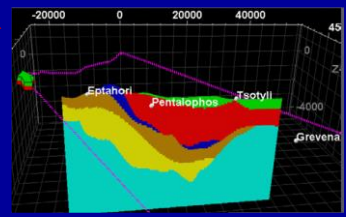
Sampling area/ Material for study

Sandstone (litharenite)

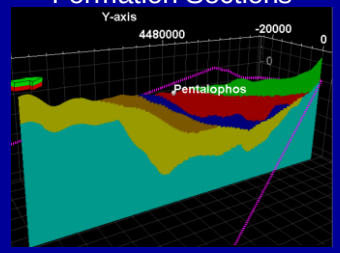
Sandstone (XRD analysis)	
Mineral	Percentage
Calcite	47%
Quartz	16%
Feldspar	14% (12% plagioclace, 2% K-feldspar)
Clay minerals	8%
Mica	7%
Clorite	5%
Dolomite	3%

Source: GESTCO project Summary Report 2004

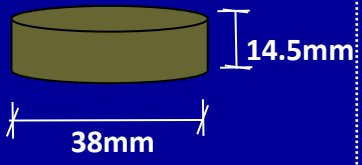




Formation Sections



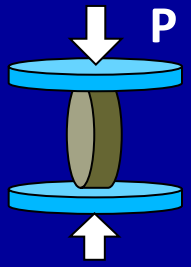
Procedure and Experimental setup



Specimen preparation

Brazilian test

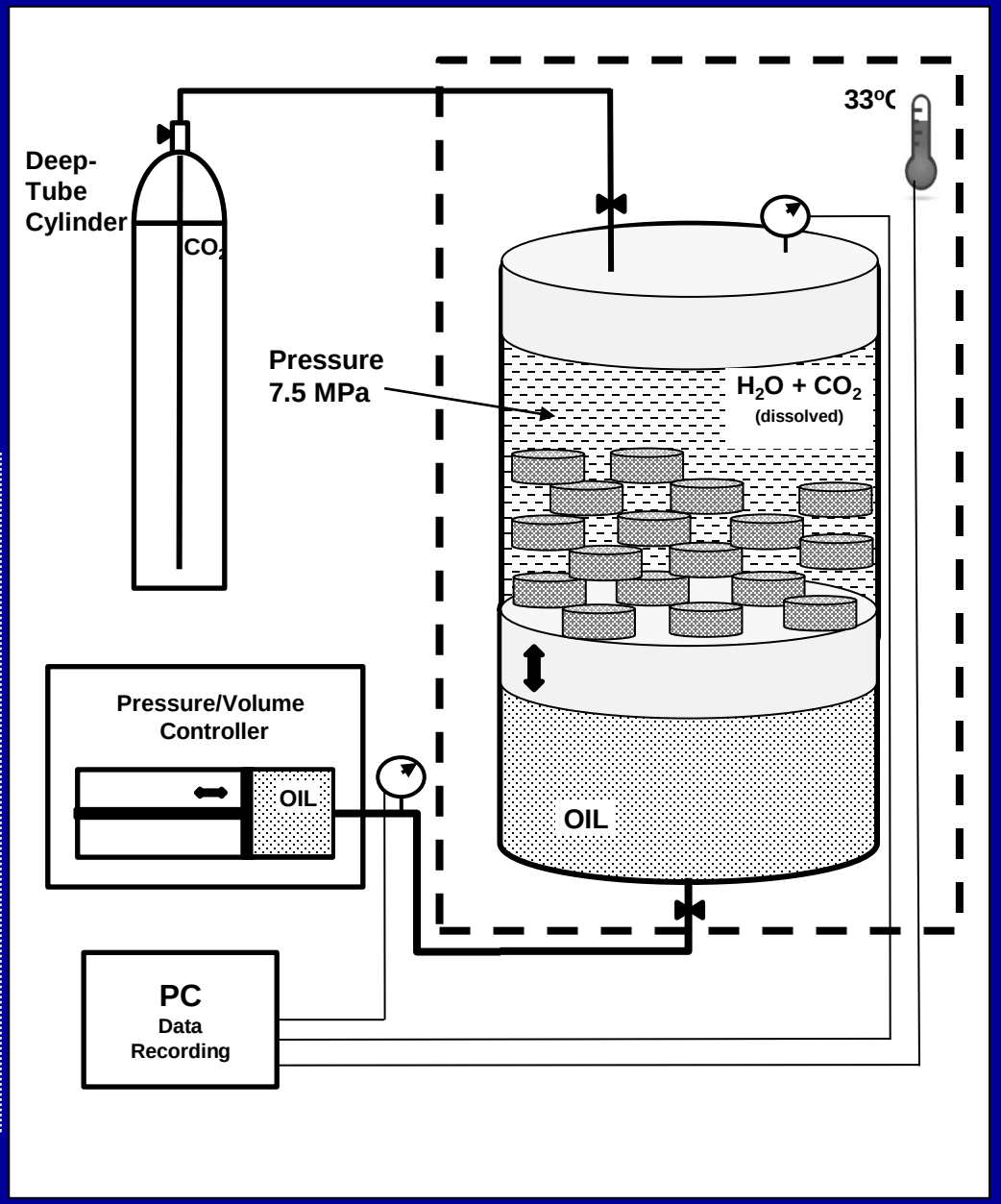
$$f_t = \frac{2P}{\pi DL}$$



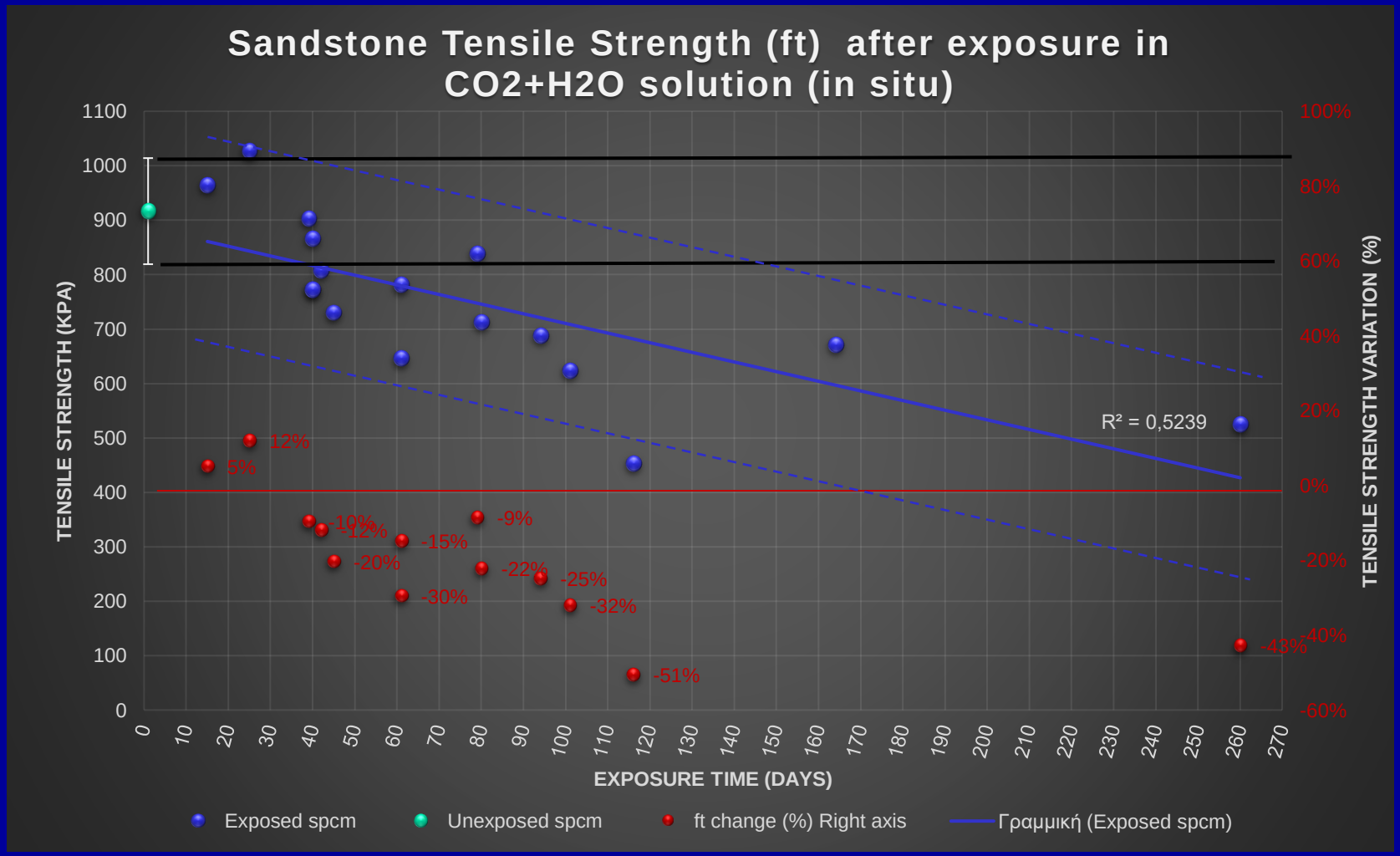
Periodically exposed specimens are tested for tensile strength (Brazilian test)

Exposure time (d)	
15	79
25	80
39	94
40	101
42	116
45	164
61	260

Testing procedure



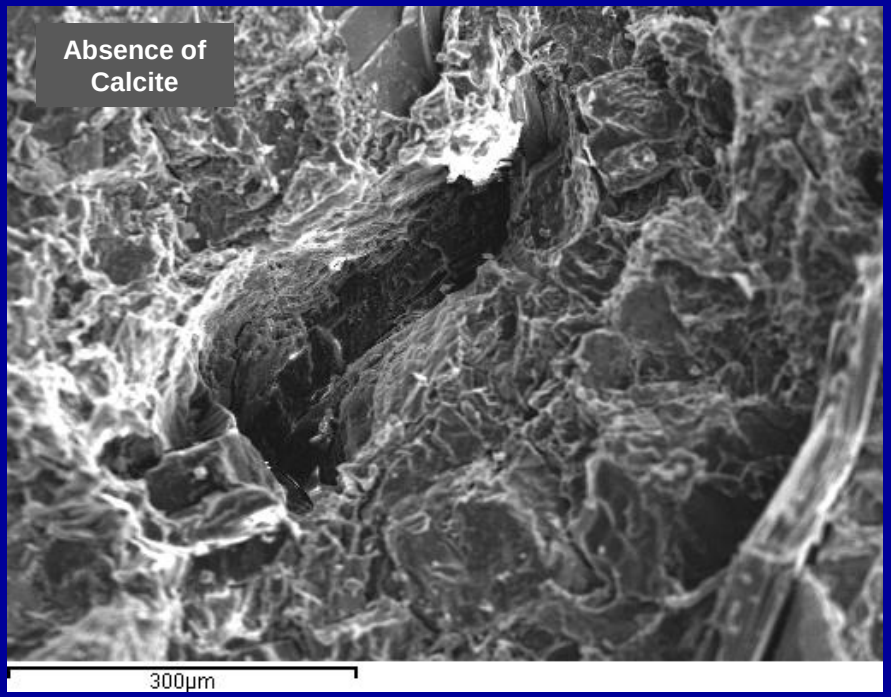
Impact on tensile strength – Results/Findings



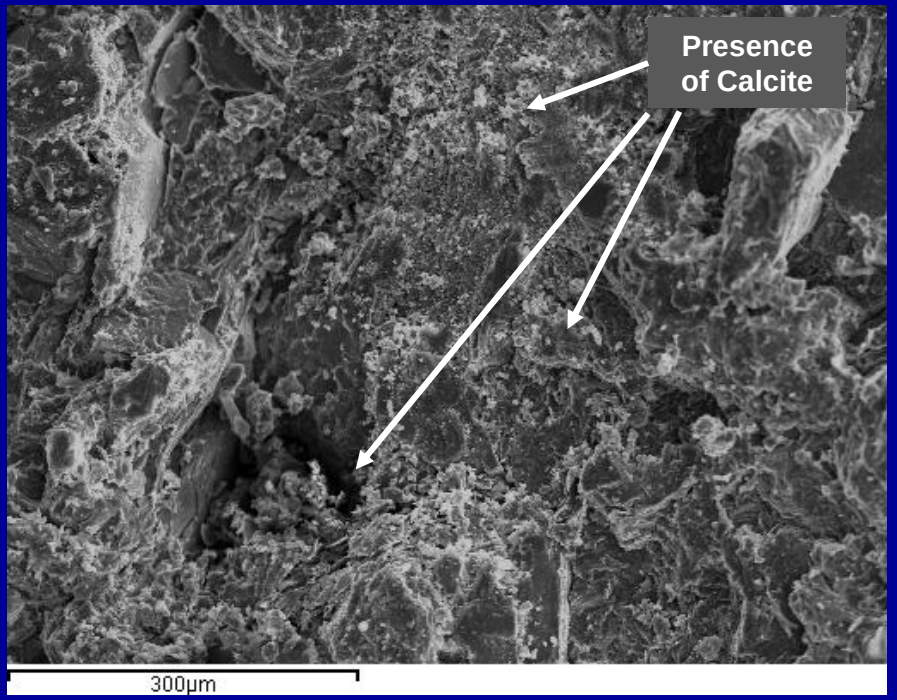
Analysis to reveal mechanical loss mechanism

SEM

Scanning electron microscope



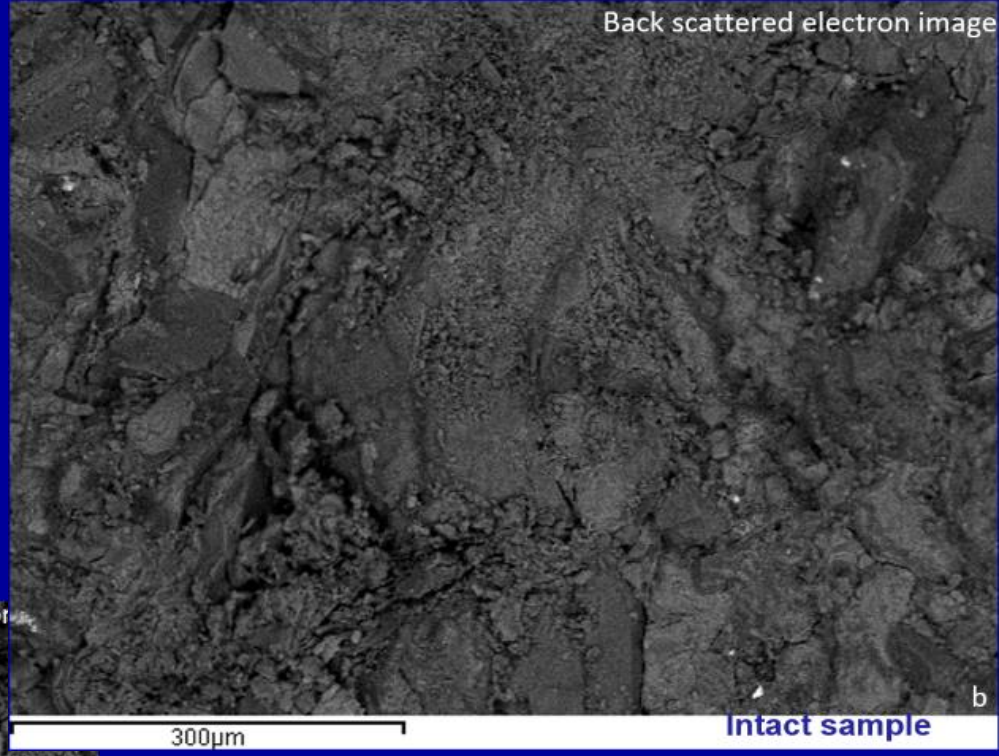
Exposed sample

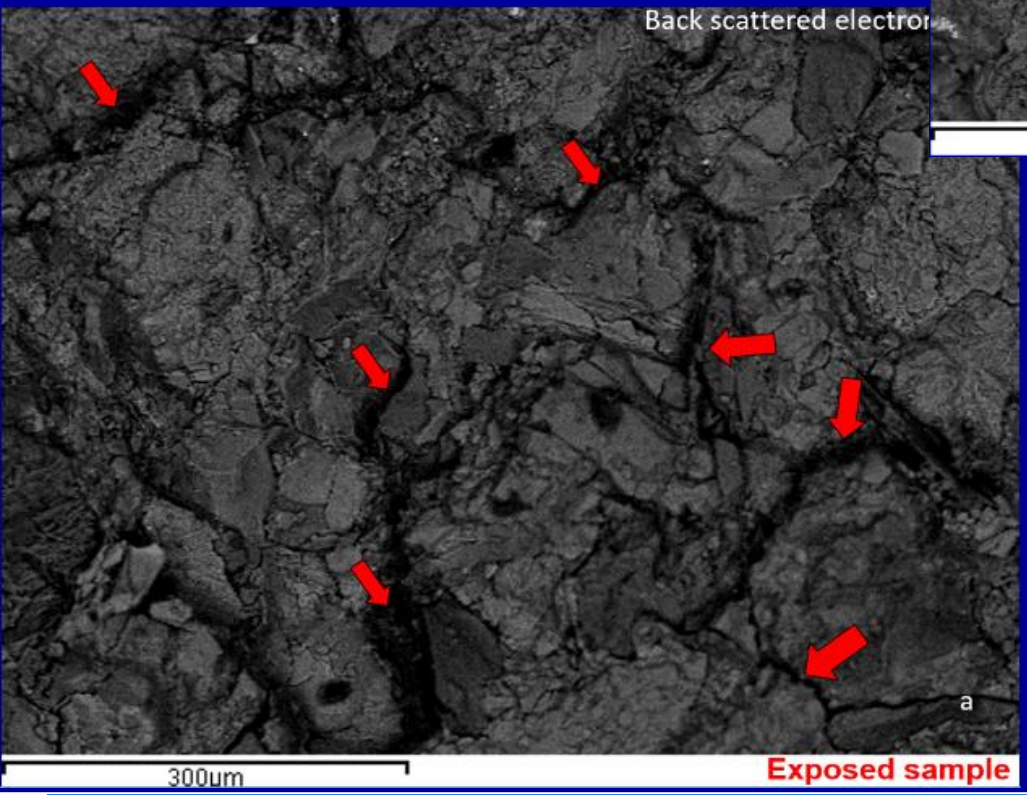


Intact sample

Note: Images **NOT** from the same sample (before/after)

Broadened Cracks





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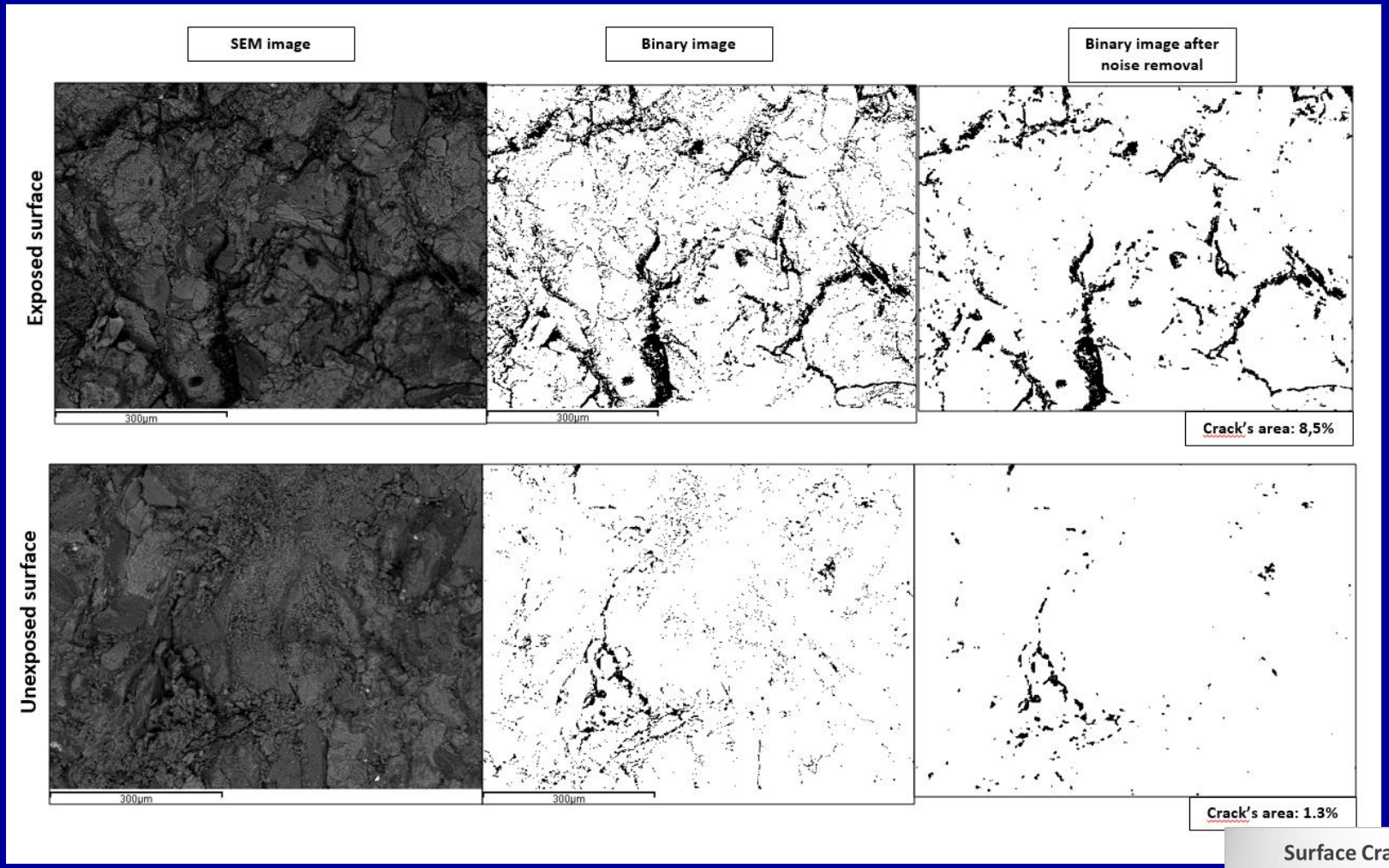
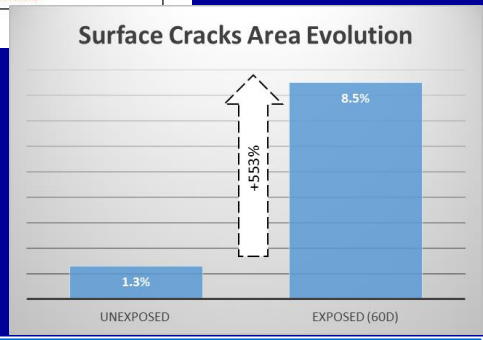
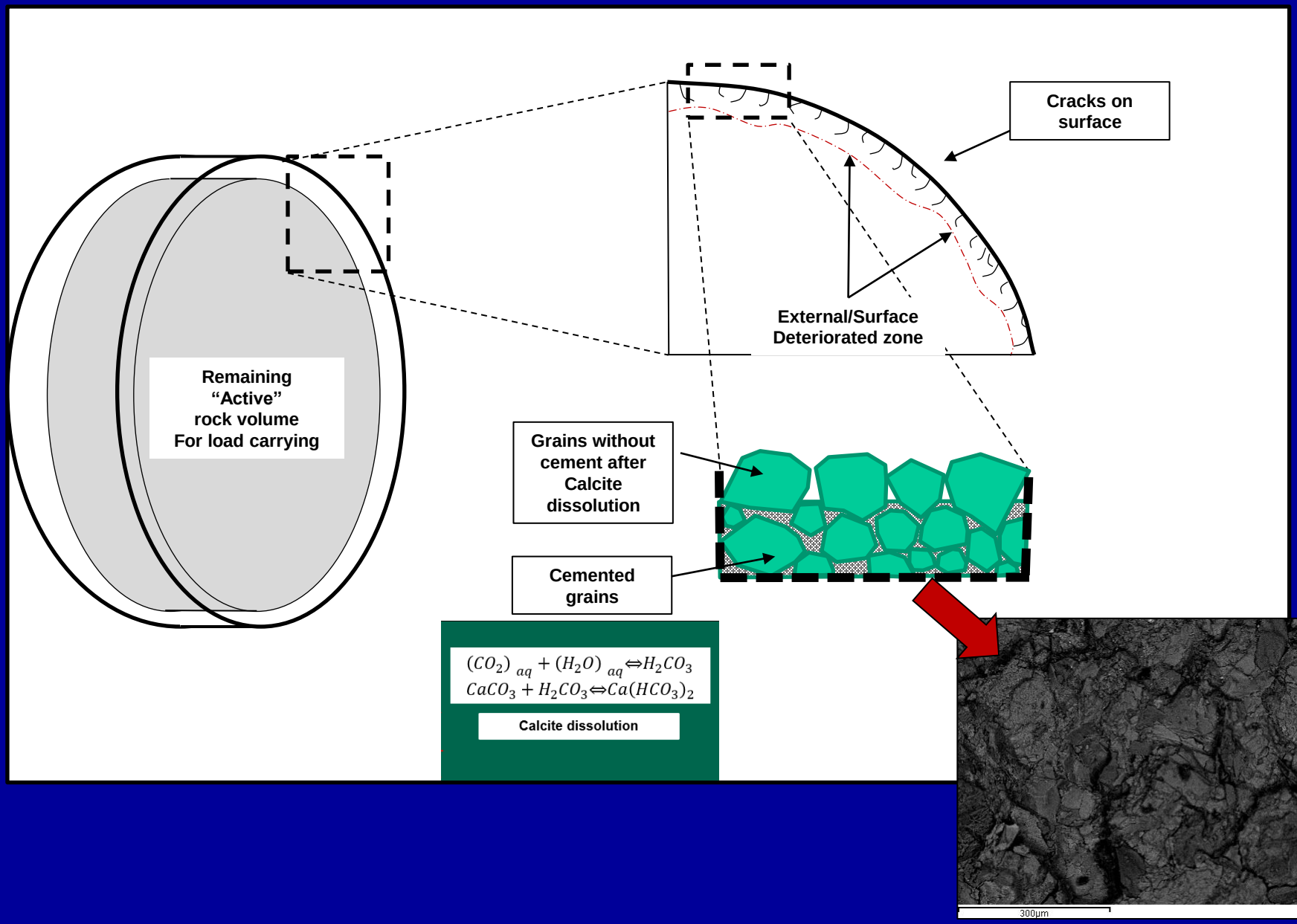
SEM image analysis





Mechanism responsible for Strength loss



Conclusions

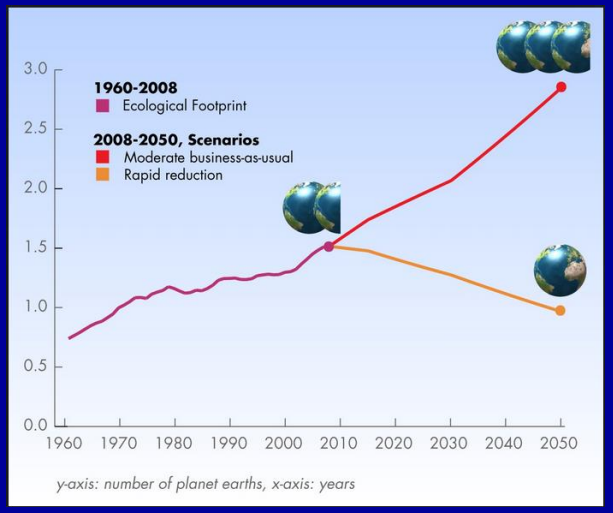
- Tensile strength of Sandstone reach in Ca reduces with time, after exposure in CO2-H2O solution (T:33oC, P:7.5 MPa)
- Surface cracks broaden under exposure, leading to surface deterioration.

Future work

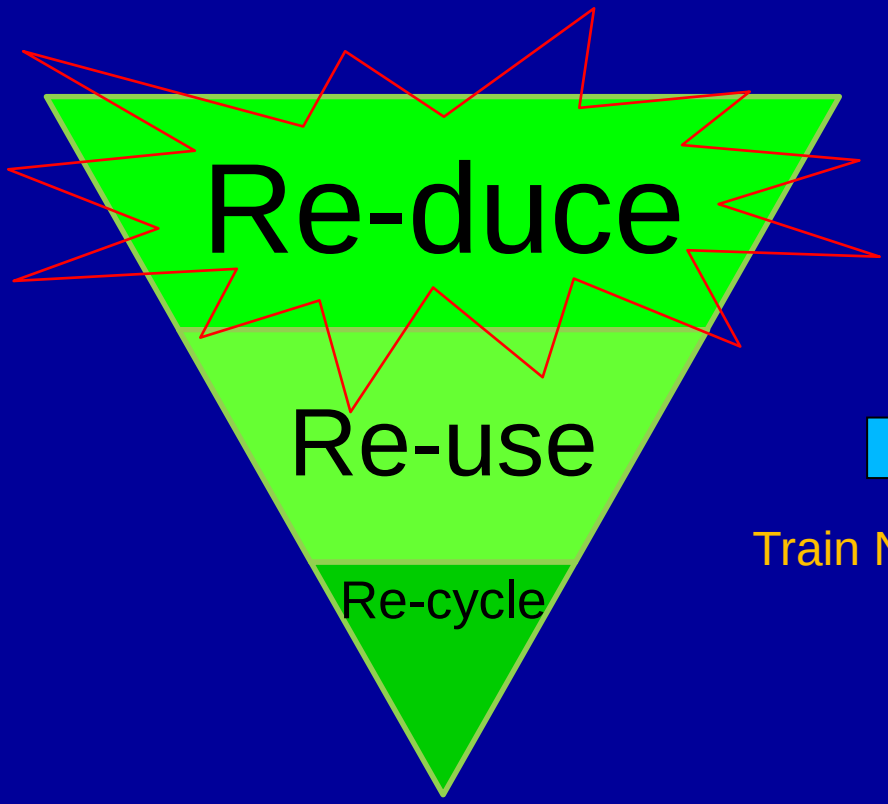
- We will study the effect of normal pressure on fracture's permeability, for the specific sandstone presented.
- We will use all the findings to simulate the behavior a fractured reservoir when injected with Co2, with emphasis on CO2 migration.

Opinion/Suggestion

Our Planet CANT
support our CURRENT resource demands



Source: http://www.footprintnetwork.org/



Train Next Generation
NOW

END

Thanks for your patience