Fracturing Using Supercritical CO_2 and Water – Application to Carbon Sequestration

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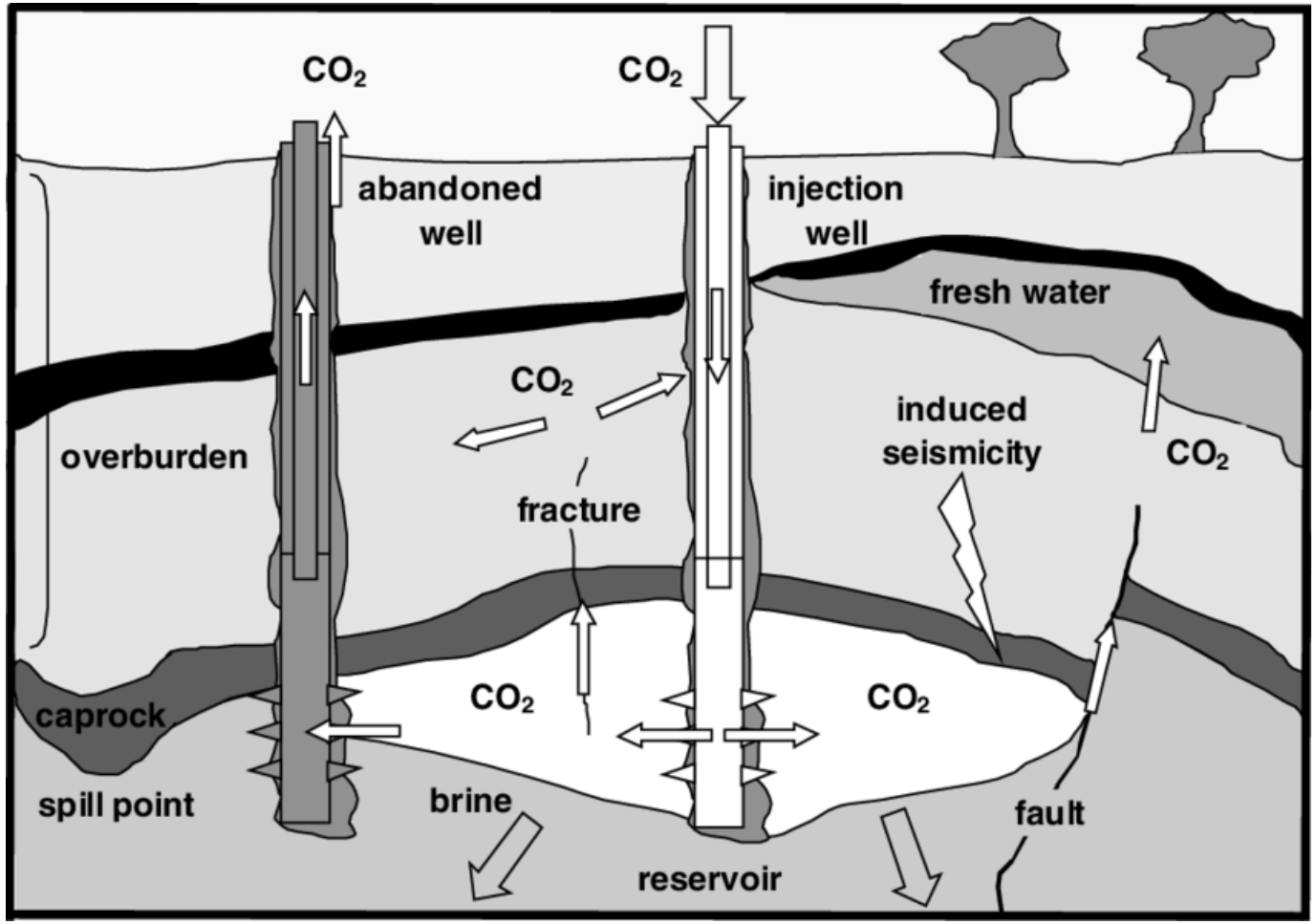
Outline

- Motivation
- Experimental procedure
- Results and discussion
  - Breakdown pressure and acoustic emissions
  - Hypocenter location of acoustic emissions
  - Fracture dimensions
  - Permeability of fracture
  - Fracture morphology
- Conclusions
- Summary
- Recommendation

Motivation

High injection pressure of CO_2 :

- Increase the storage capacity of CO_2
- Injection – induced fractures pose risk to CO_2 containment
  - Breakdown pressure is typically determined in a leak-off test (uses a water-based fluid)

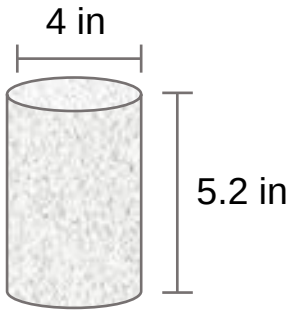


Damen et al. 2006

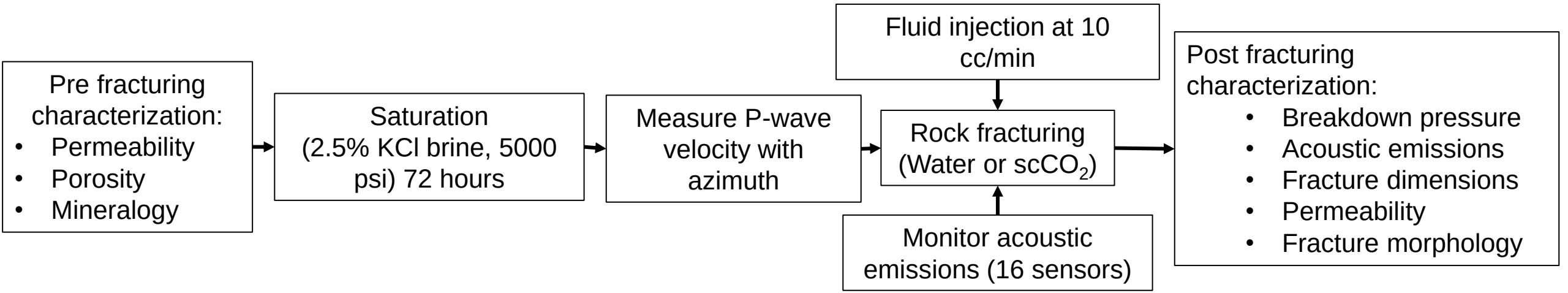
Objective

Investigate induced fractures risk during supercritical CO_2 injection

Experimental procedure



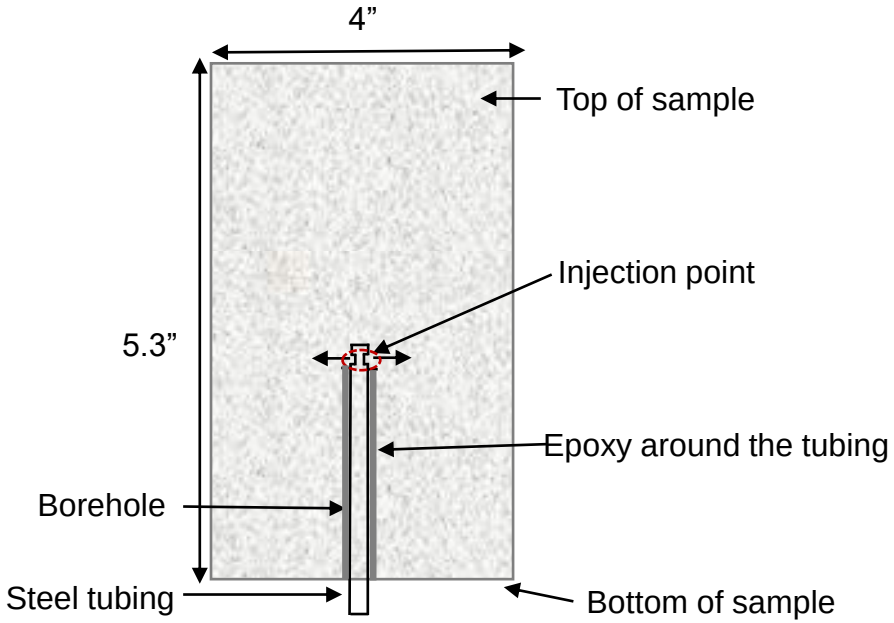
Sample	Gas filled porosity (%)	Permeability (md)	Mineralogy (wt%)		
			Quartz	Clay	Others
Tennessee sandstone (six cylindrical samples)	6.5	0.015	84	11	5



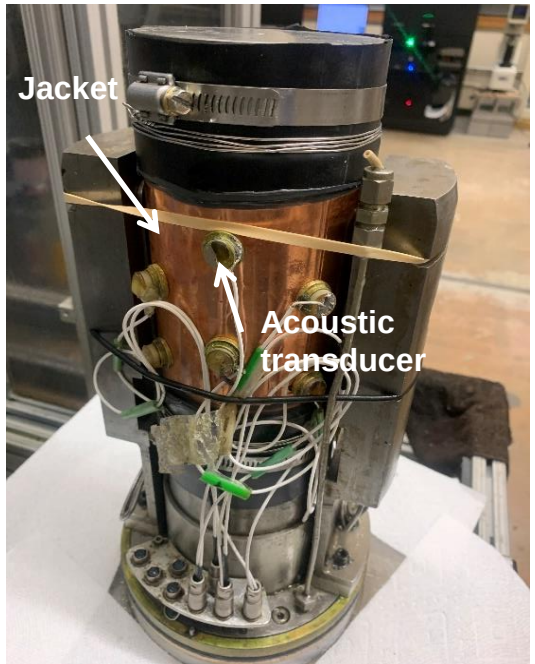
Stresses (psi): σ_V= 1500, σ_h = 500, σ_H= 3000

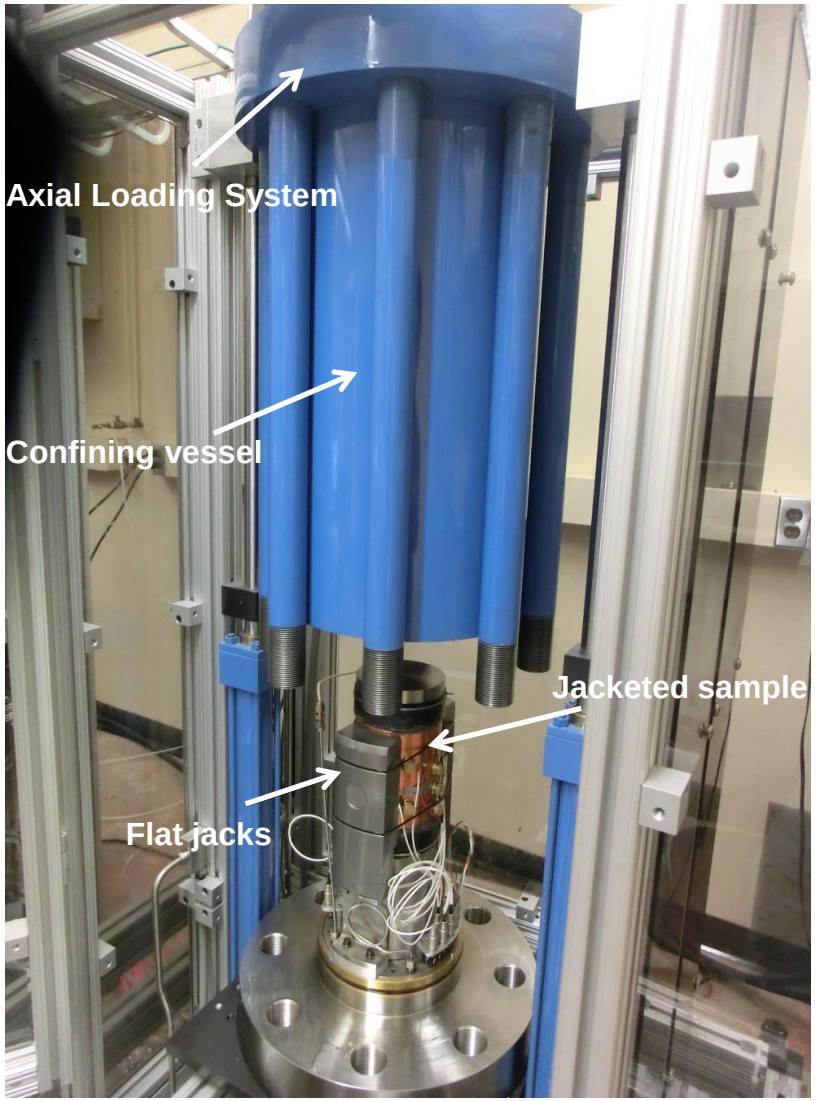
Experimental procedure

Unjacketed sample



Jacketed sample

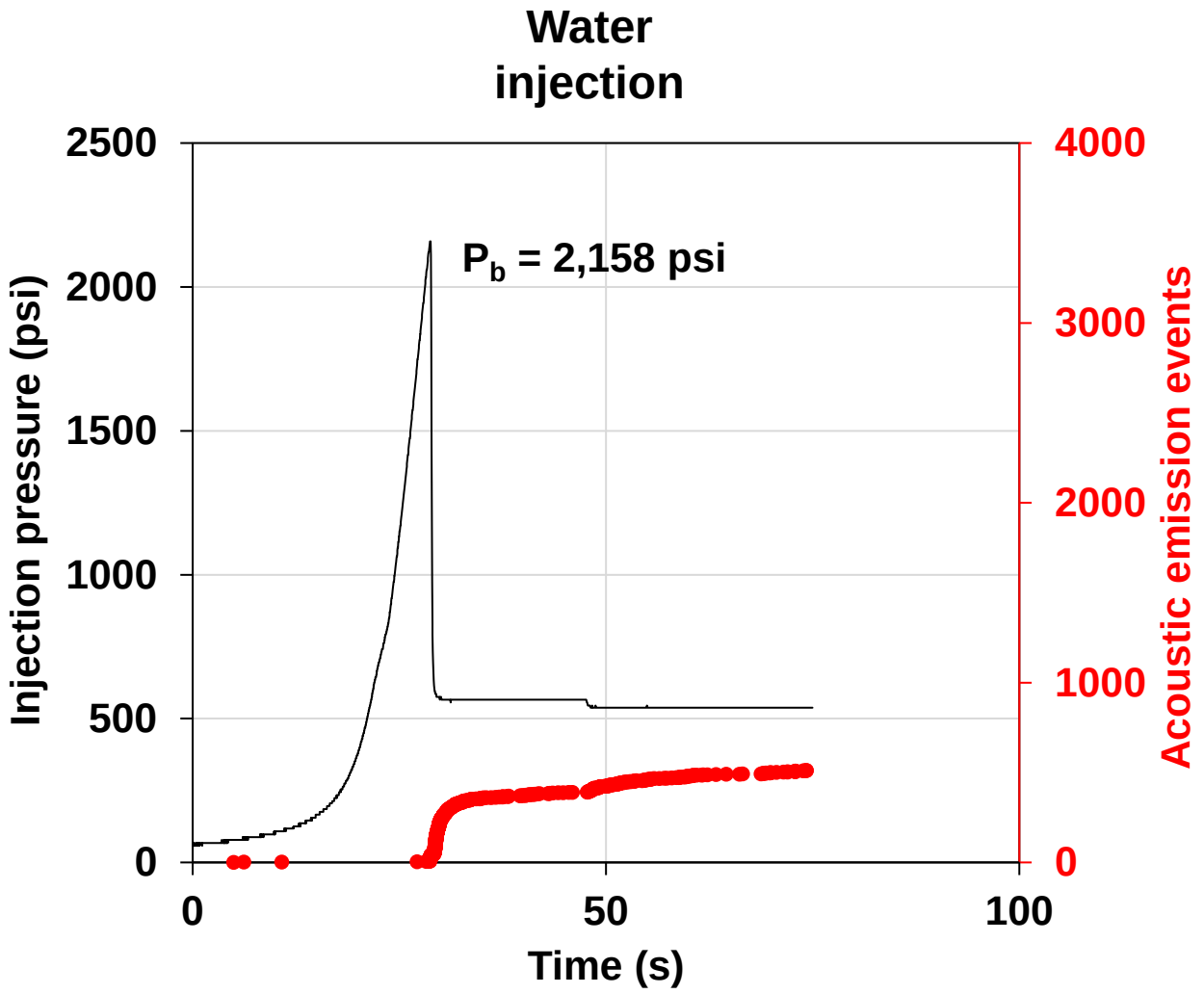


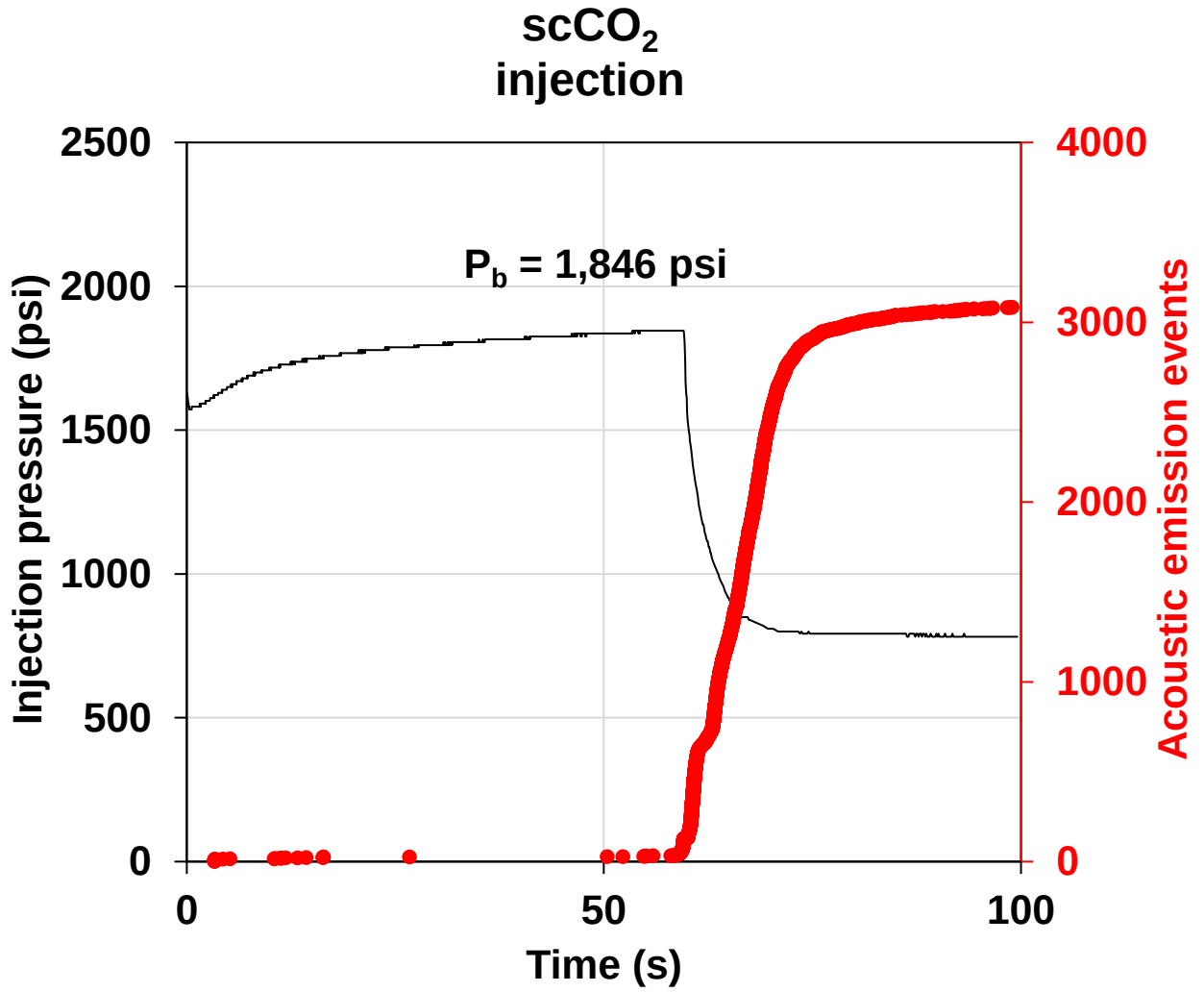


Triaxial Cell

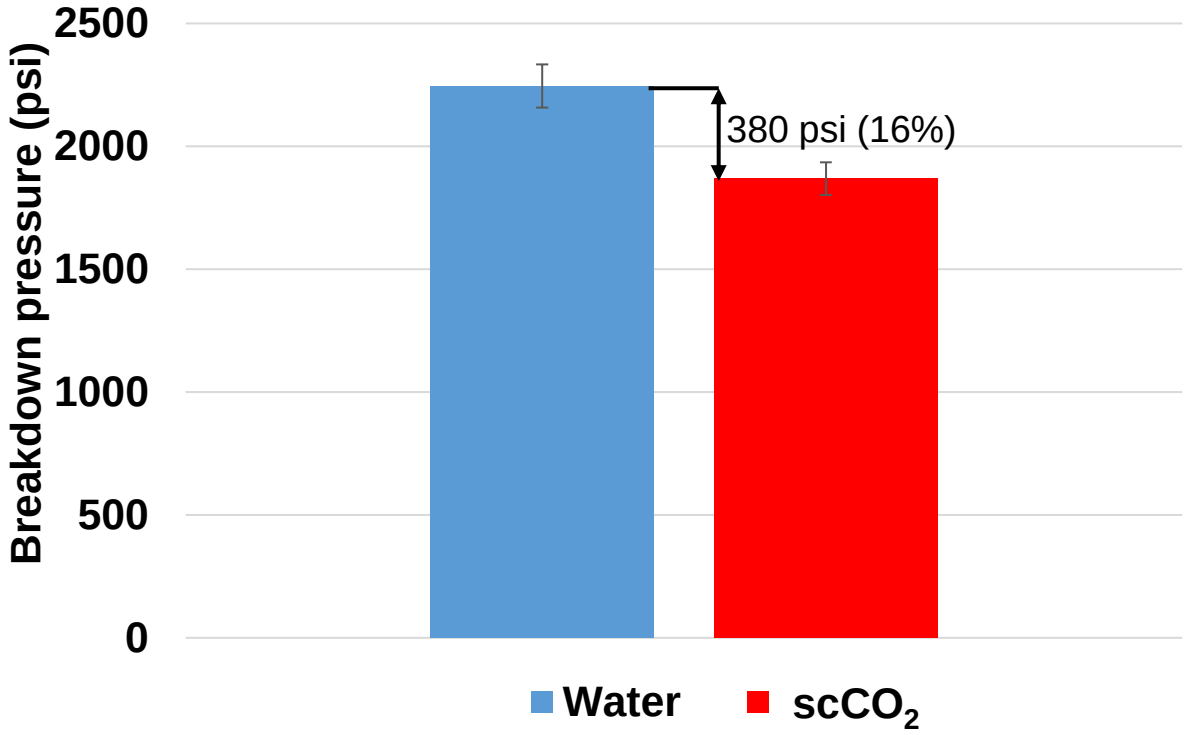
Results and discussion

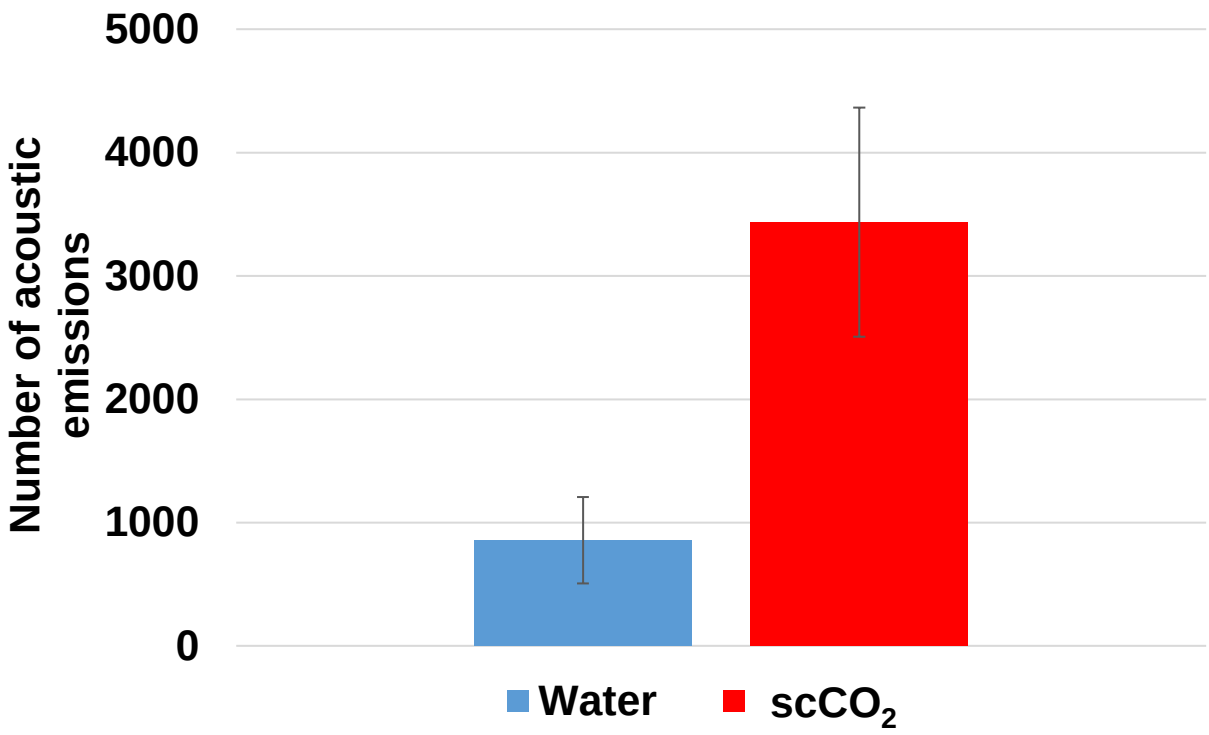
Breakdown pressure and acoustic emissions





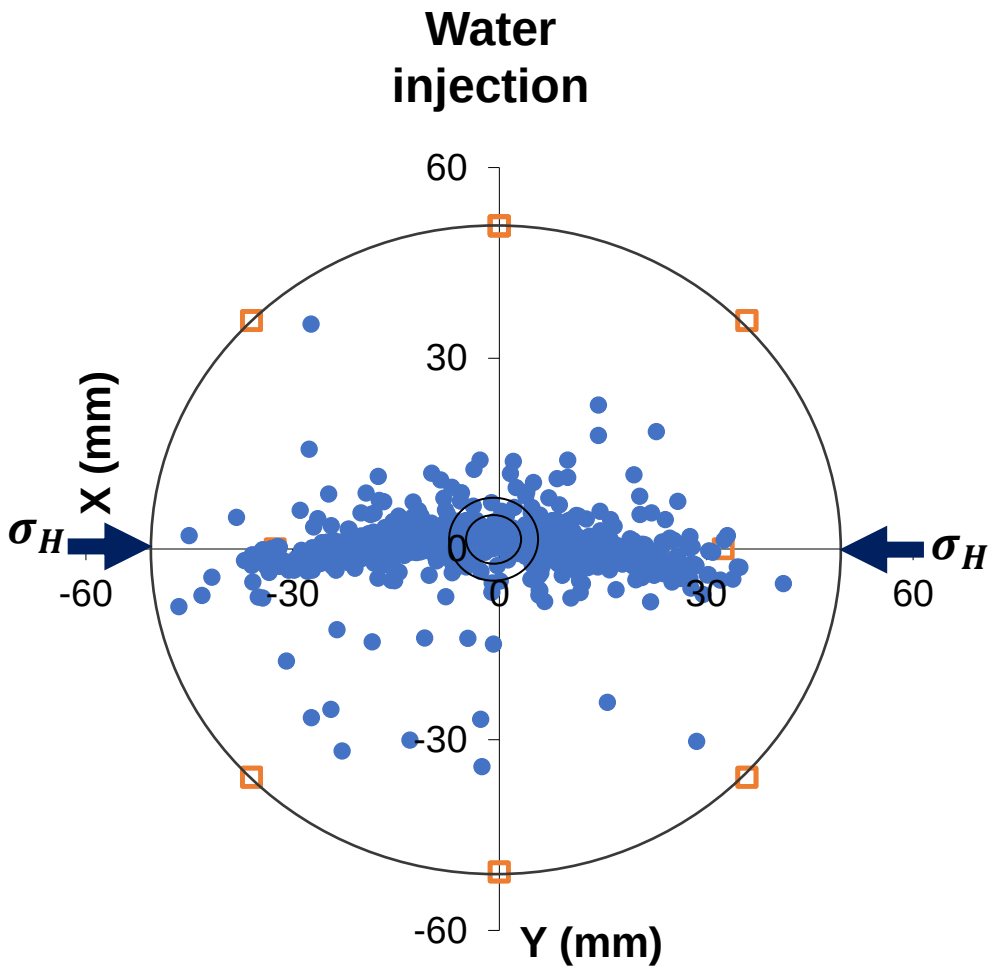
Breakdown pressure and acoustic emissions

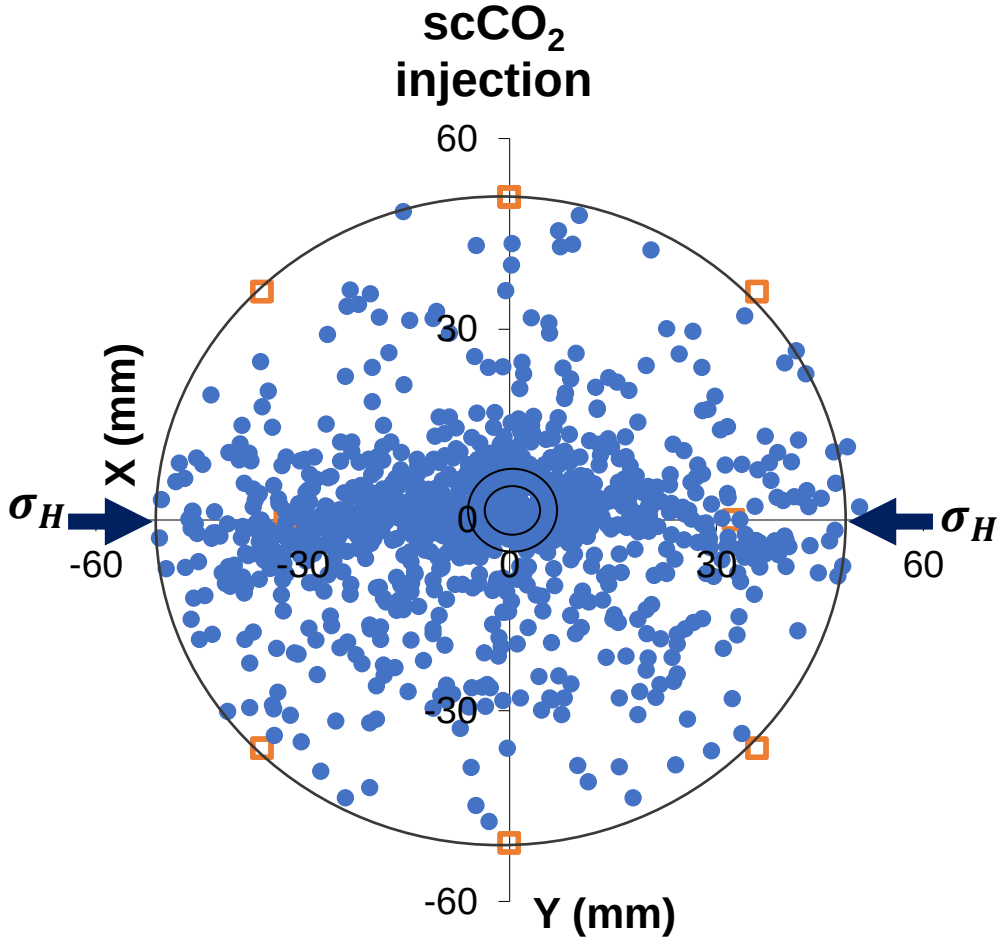




Acoustic emissions increased by a factor 4 using $ScCO_2$.

Hypocenter location: plan view





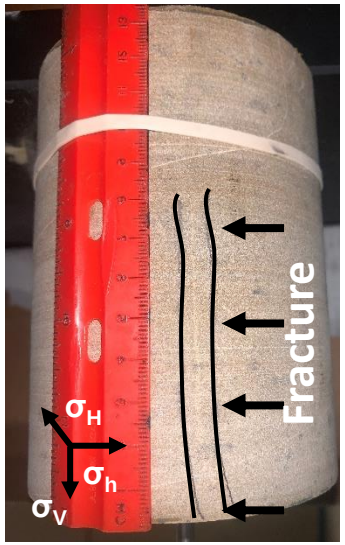
Located event Sensor

Fracture dimensions

Water injection

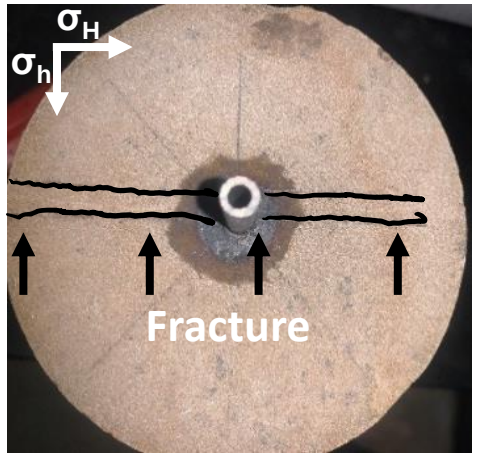
Top view

Left side view



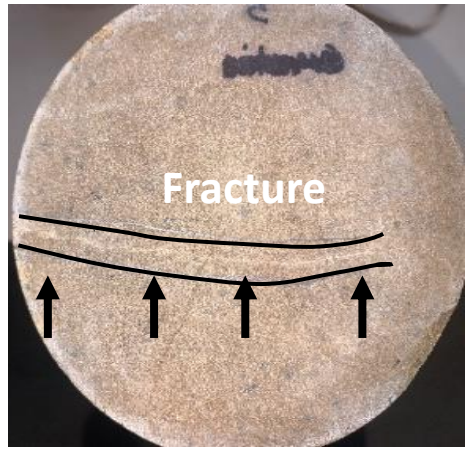
Right side view

Bottom view

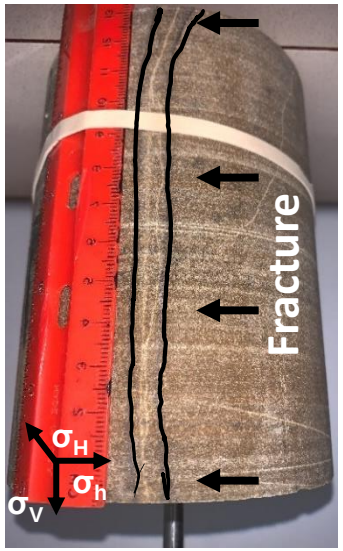


$scCO_2$ injection

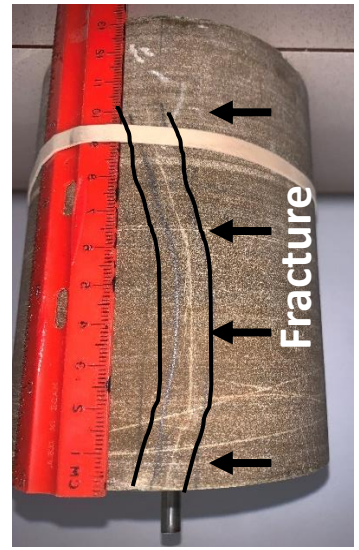
Top view



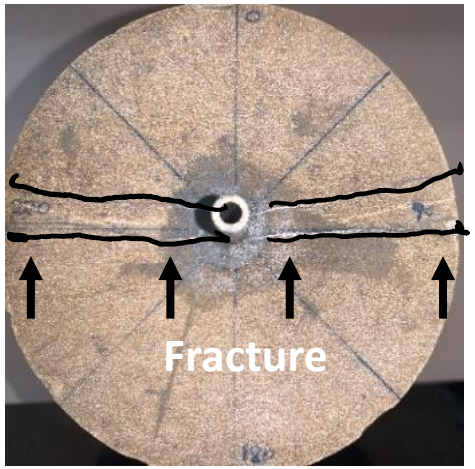
Left side view



Right side view

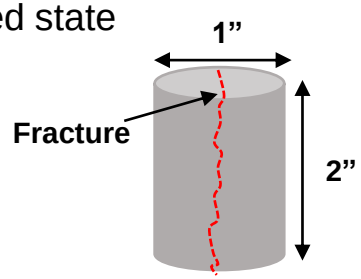


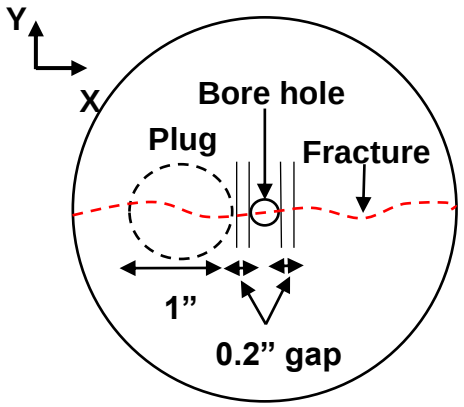
Bottom view

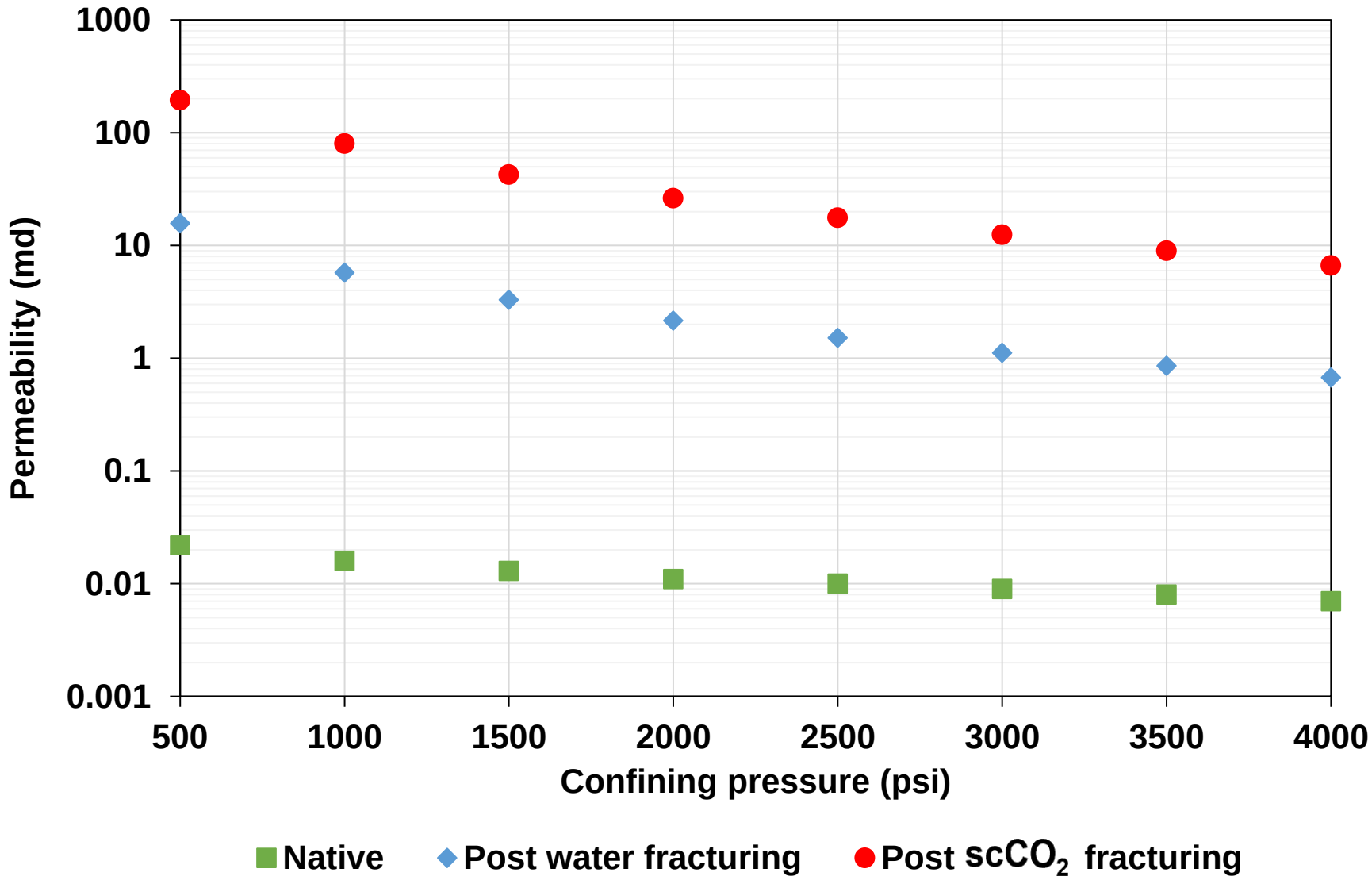


Gas permeability of fractured plugs

Helium gas
Dried state



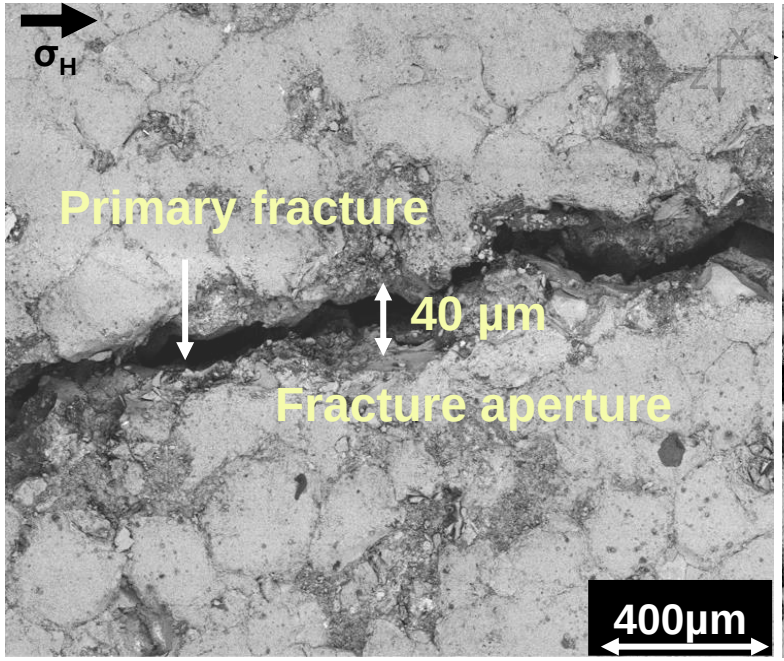


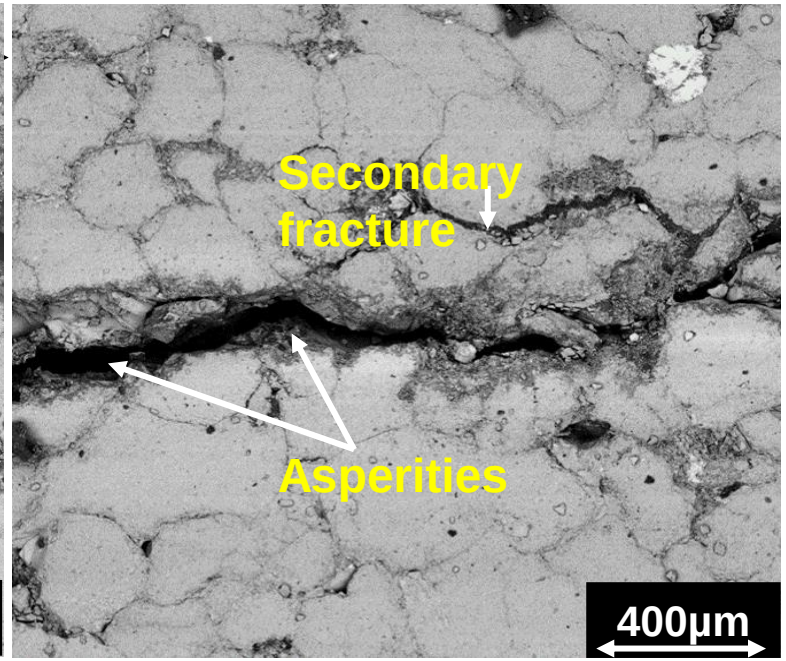


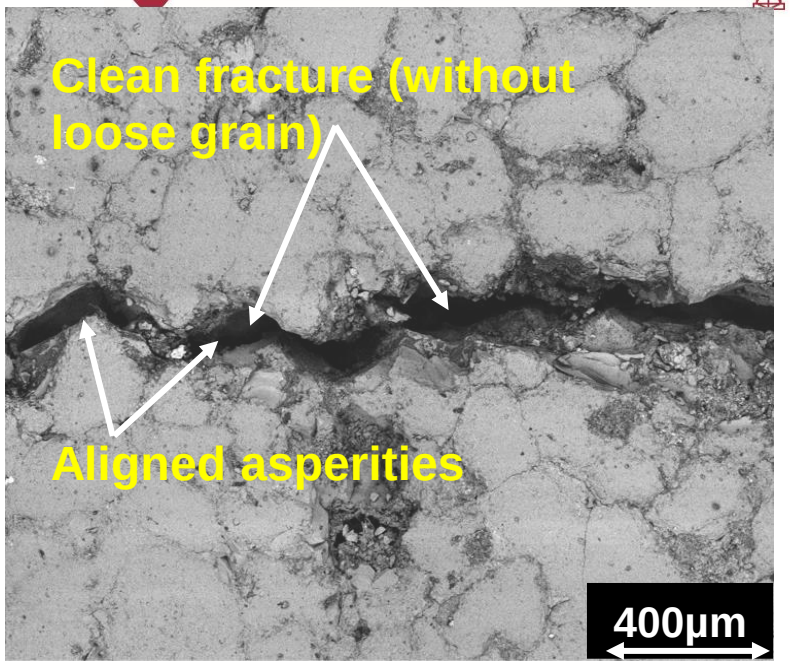
Fracture morphology

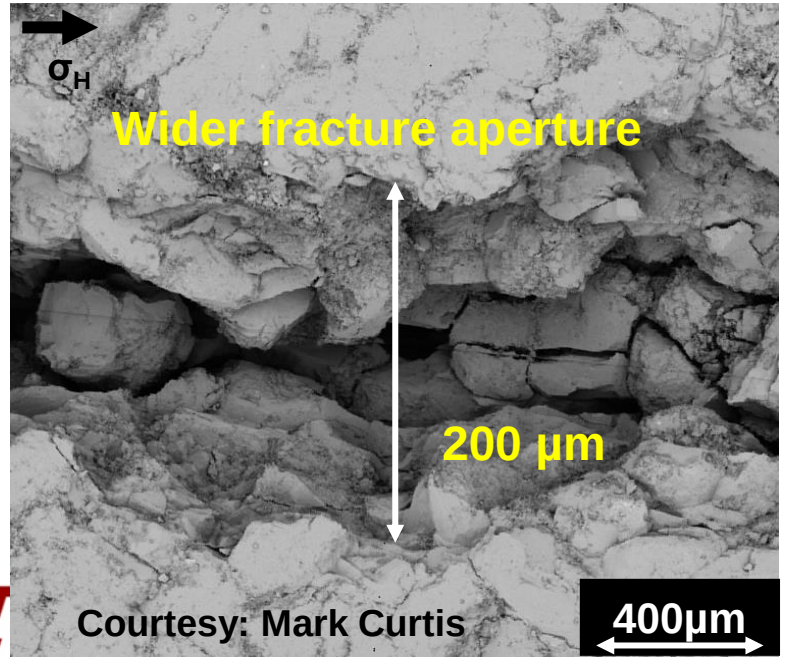
Water injection

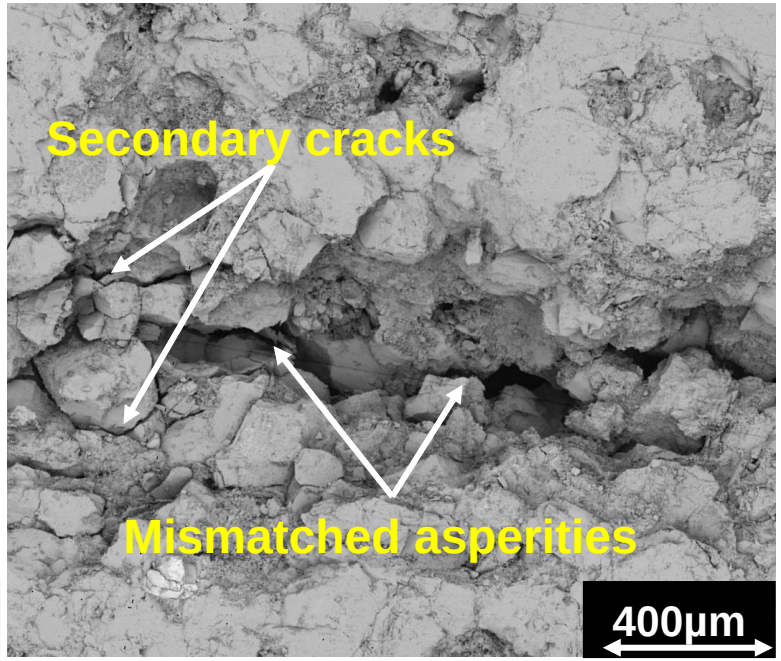
scCO$_2$ injection

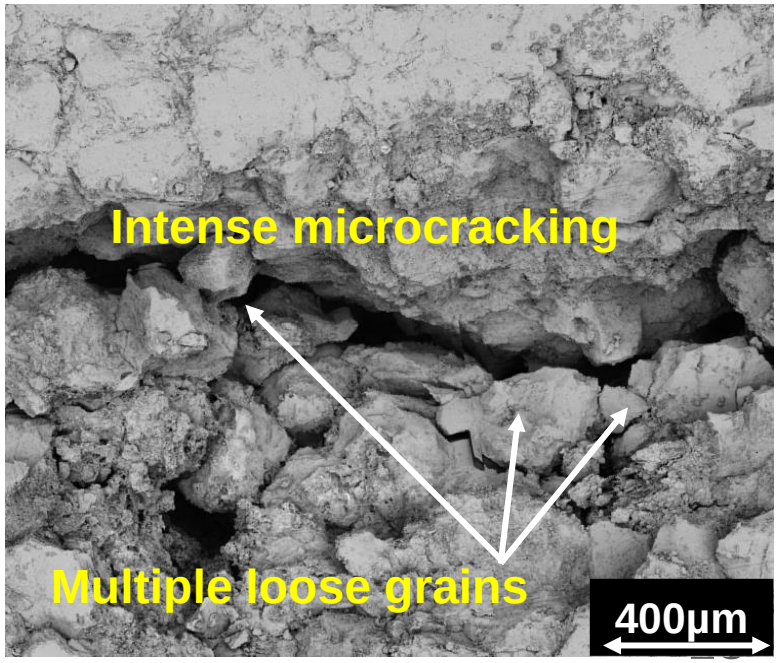












Conclusions

Our experiments with $scCO_2$ and water in Tennessee sandstone shows:

- The average breakdown pressure with $scCO_2$ is about 380 psi (16%) lower than with water.
- $ScCO_2$ fracturing shows an increase by a factor of 4 in acoustic emissions
- Fractures created by $scCO_2$ are more complex (longer length, wider aperture, mismatched asperities and loose grains). Consequently, this leads to an increase in permeability of fractures by one order of magnitude.

Summary

Formation breakdown will occur at a lower pressure with $scCO_2$ injection than the estimated breakdown pressure from leak-off test. Generated fractures can propagate long distances into the formation and can be more transmissive. Thus, these fractures can easily facilitate the migration of CO_2 from the sequestration zone.

Recommendation

Laboratory fracturing studies with CO_2 on core samples should be done to determine the exact breakdown pressure.

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Thank you

Acknowledgement

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IC³ Technical Assistants

Micaela Langevin

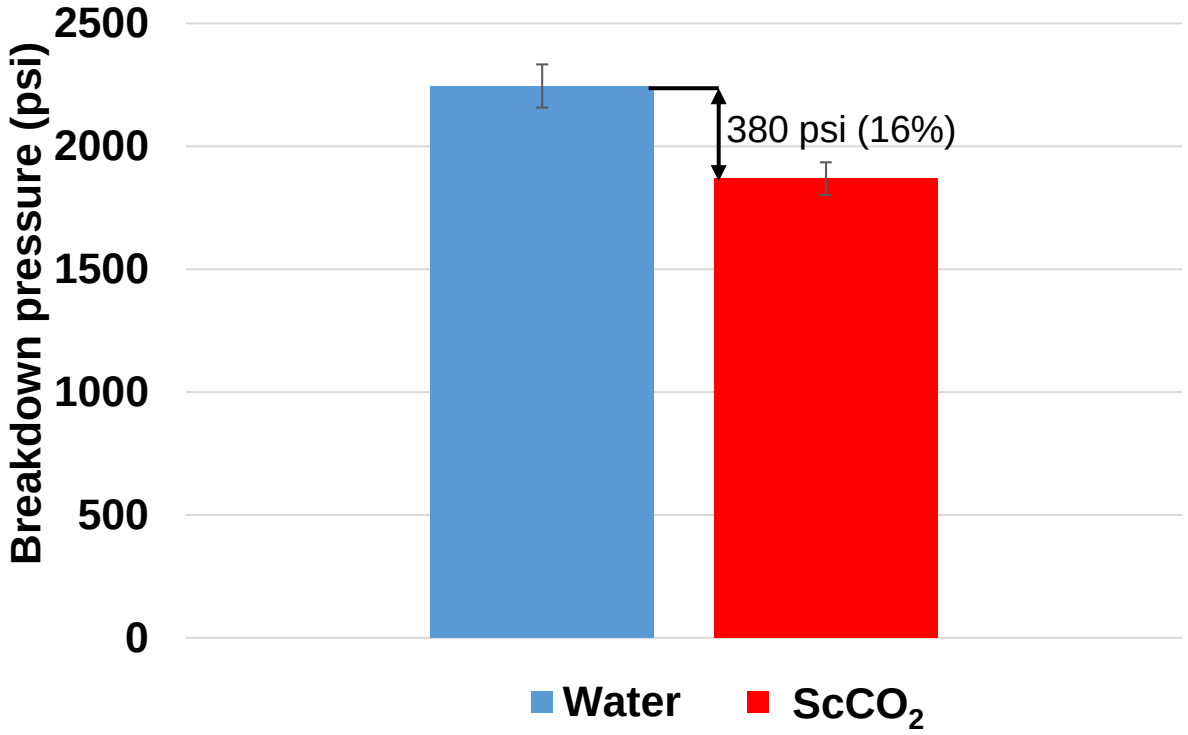
Gary Stowe

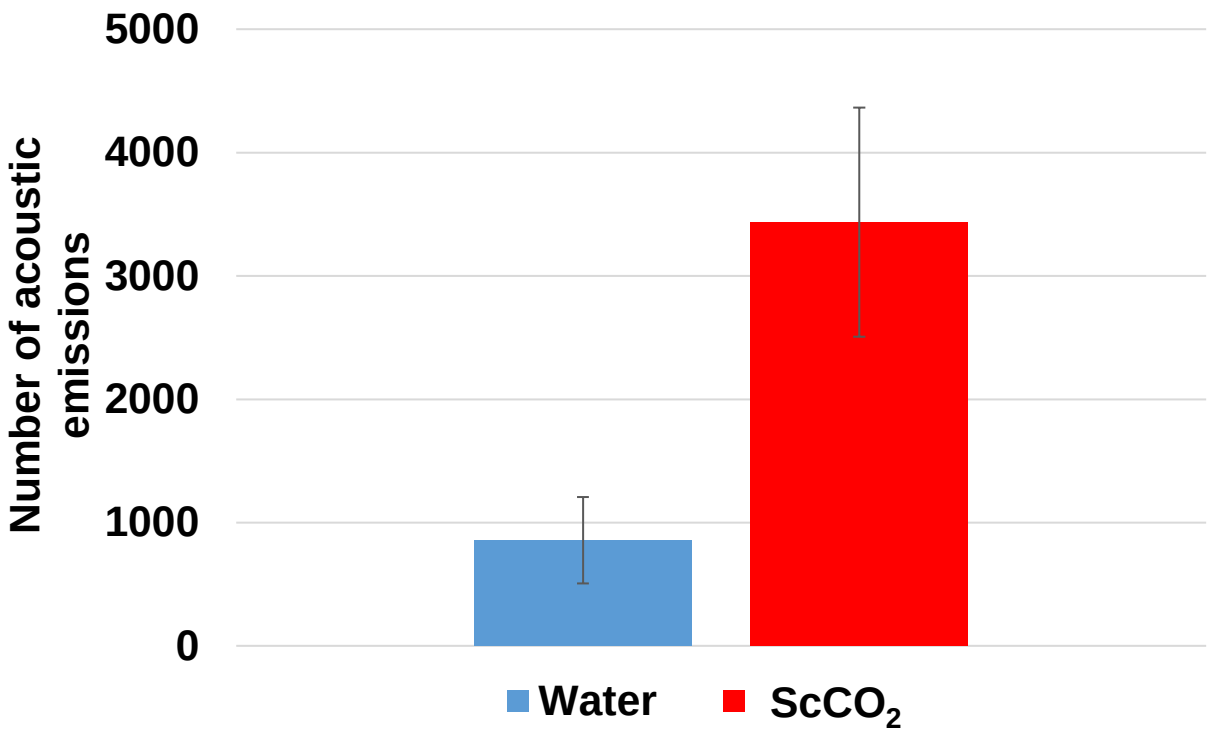
References

1. Damen, K., Faaij, A.P.C., and Turkenburg, W.C. 2006. Health, Safety and Environmental Risks of Underground Co2 Storage-Overview of Mechanisms and Current Knowledge. Climatic Change.

Back-up slides

Breakdown pressure and acoustic emissions

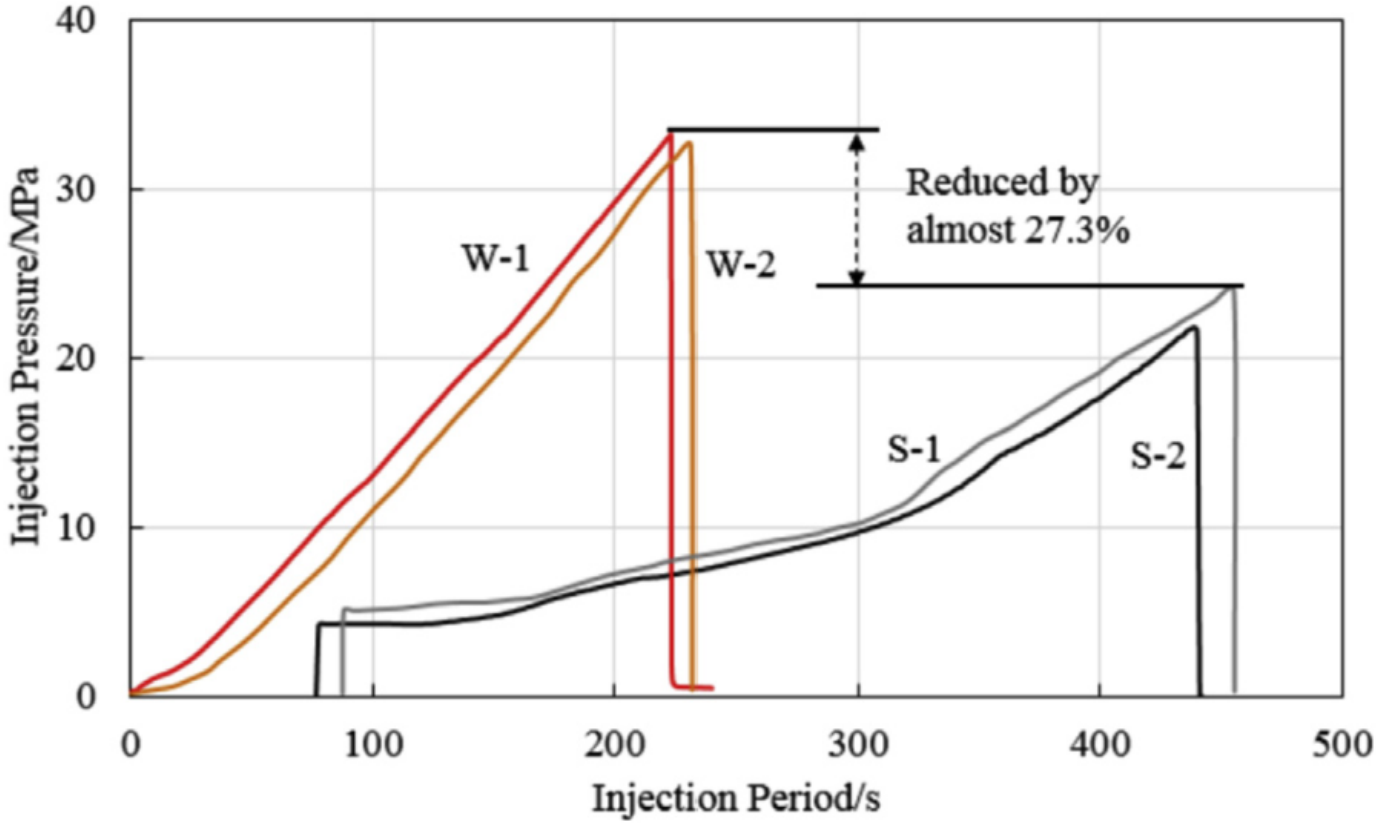




Acoustic emissions increased by a factor 4 using $ScCO_2$.

$$P_b^H = 3\sigma_V - \sigma_H - P_p + T_o, if\ \sigma_{V<}\sigma_H$$

$ScCO_2$ viscosity: 15 times lower than water viscosity (Deng. et al. 2021)


40
30
20
10
0
Injection Pressure/MPa
0
100
200
300
400
500
Injection Period/s
W-1
W-2
Reduced by
almost 27.3%
S-1
S-2

Viscosity and diffusion coefficient of $ScCO_2$

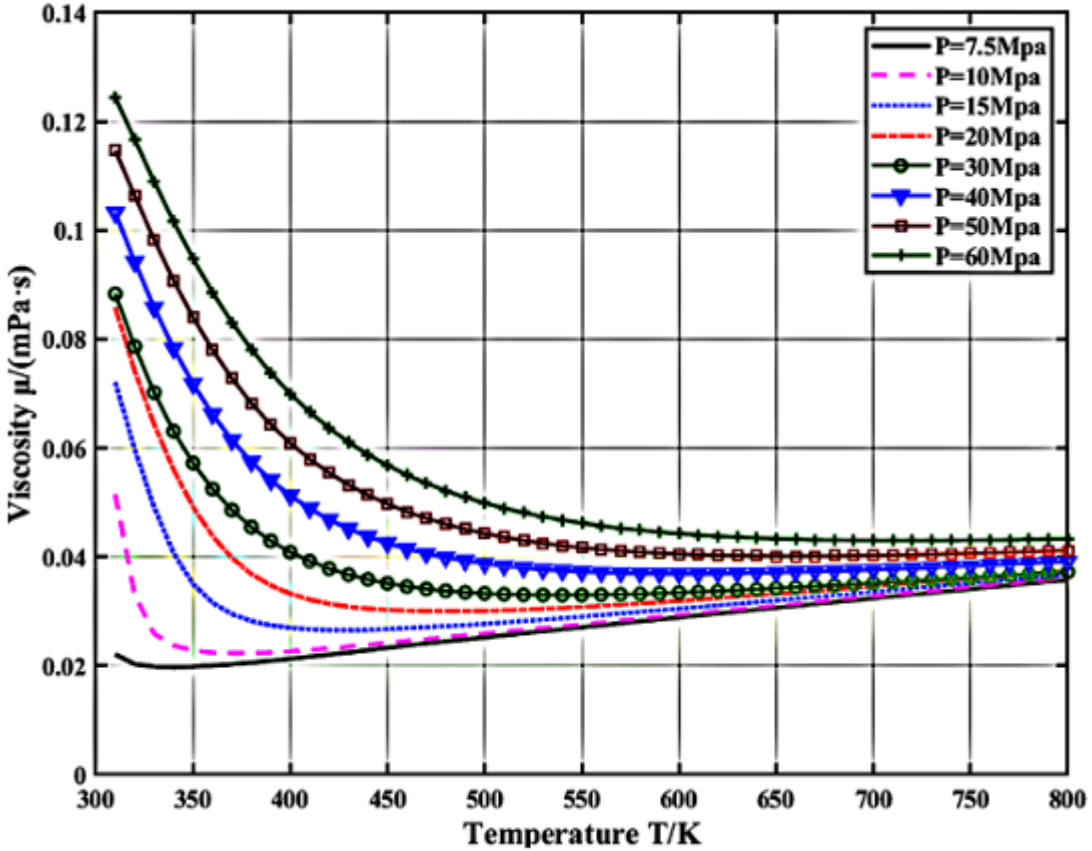


Figure 4. Viscosity calculation data plate.

Deng et al., 2021

- Viscosity: 0.05 – 0.07 cp @ 310K and 11.8 MPa
- Viscosity: 20 – 15 times lower than that of water
- Diffusion/leak off rate of CO2 @ 333.15 – 373.15 K, 10-25 MPa, 50 mD = 0.9 – 18.5 * 10^{-4} cm^3/s (Lv et al., 2019)
- Injection/pressure build up rate: 10 cm^3/s
- Compressibility of CO_2 = 10^{-9} – 10^{-8} Pa^{-1} which is 1 – 2 order of magnitude greater than that of water