CO_2 leakage potential as a result of induced seismicity

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The feasibility of permanently storing CO_2 has been debated due to the potential that fault reactivation leads to CO_2 leakage

PNAS

Earthquake triggering and large-scale geologic storage of carbon dioxide

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Despite its enormous cost, large-scale carbon capture and storage (CCS) is considered a viable strategy for significantly reducing CO_2 emissions associated with coal-based electrical power generation and other industrial sources of CO_2 [Intergovernmental Panel on Climate Change

PERSPECTIVE

PNAS

Geologic carbon storage is unlikely to trigger large earthquakes and reactivate faults through which CO_2 could leak

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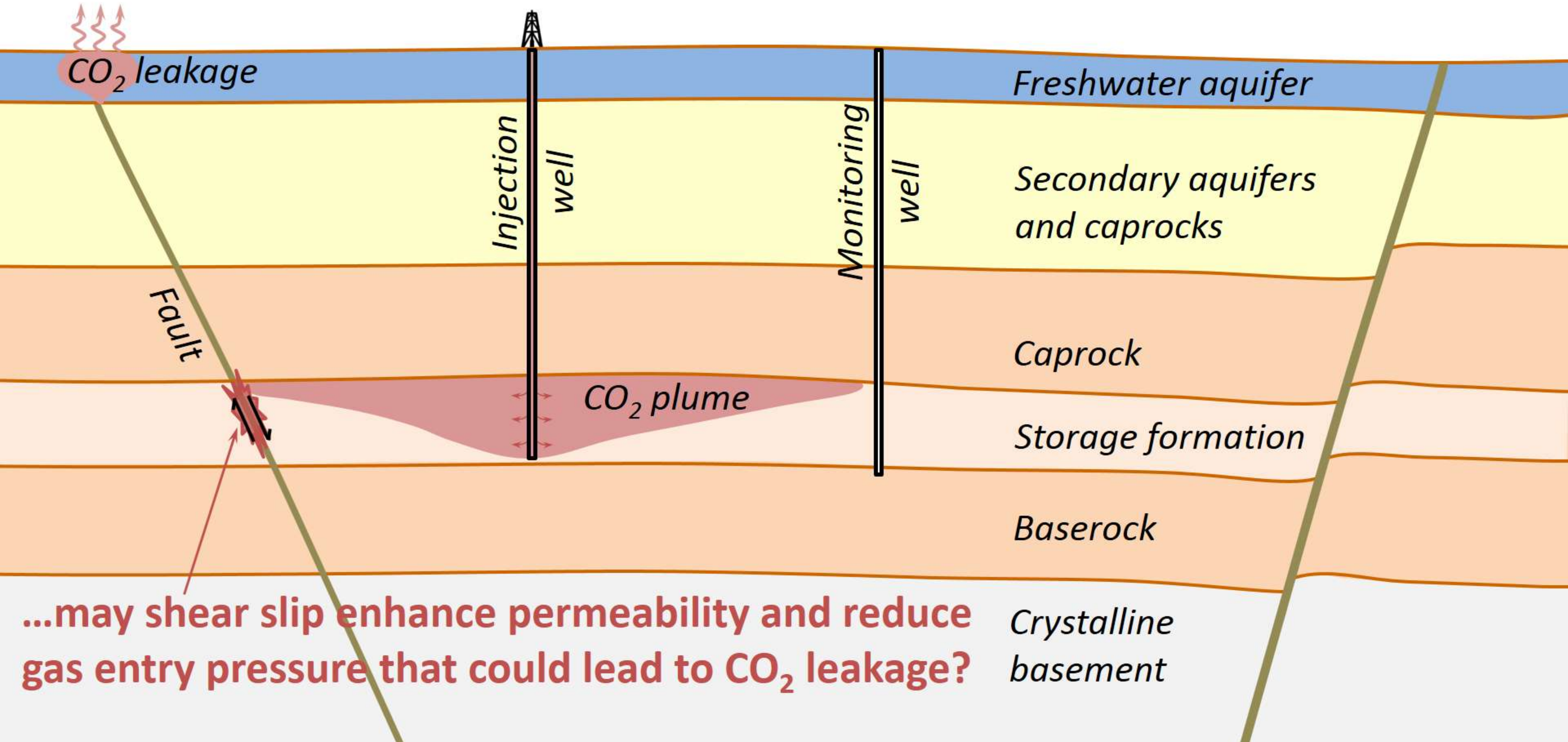
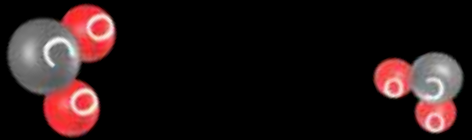
And letters by Juanes et al. (2012), Zoback and Gorelick (2012, 2015) and Vilarrasa and Carrera (2015)

It has been argued that induced seismicity will cause CO_2 leakage, but…

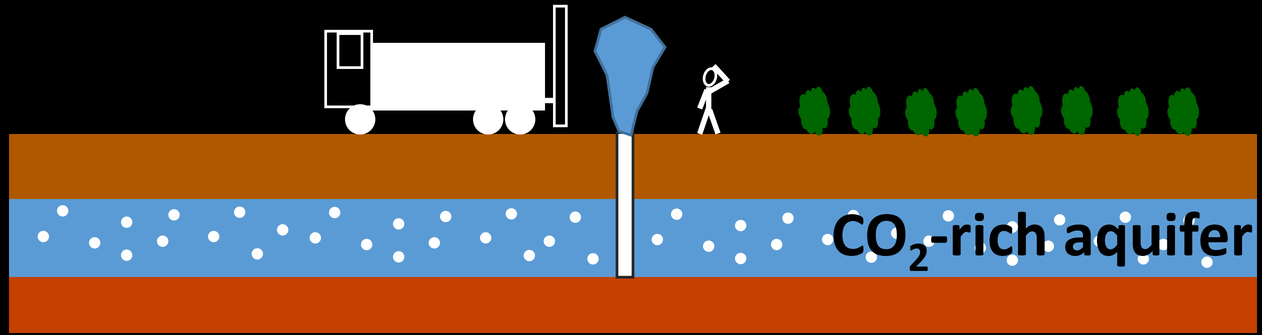


CO_2 leakage may pollute aquifers and form geysers



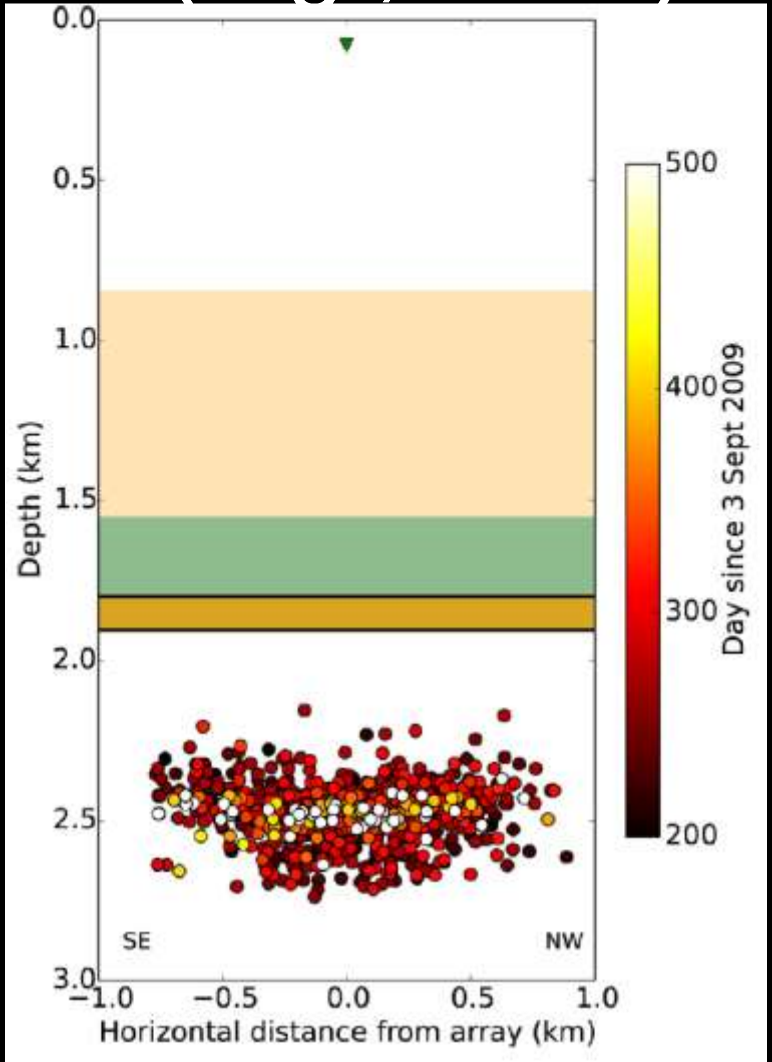
Touristic attractions!

Geysers are formed if a CO_2-rich aquifer is perforated



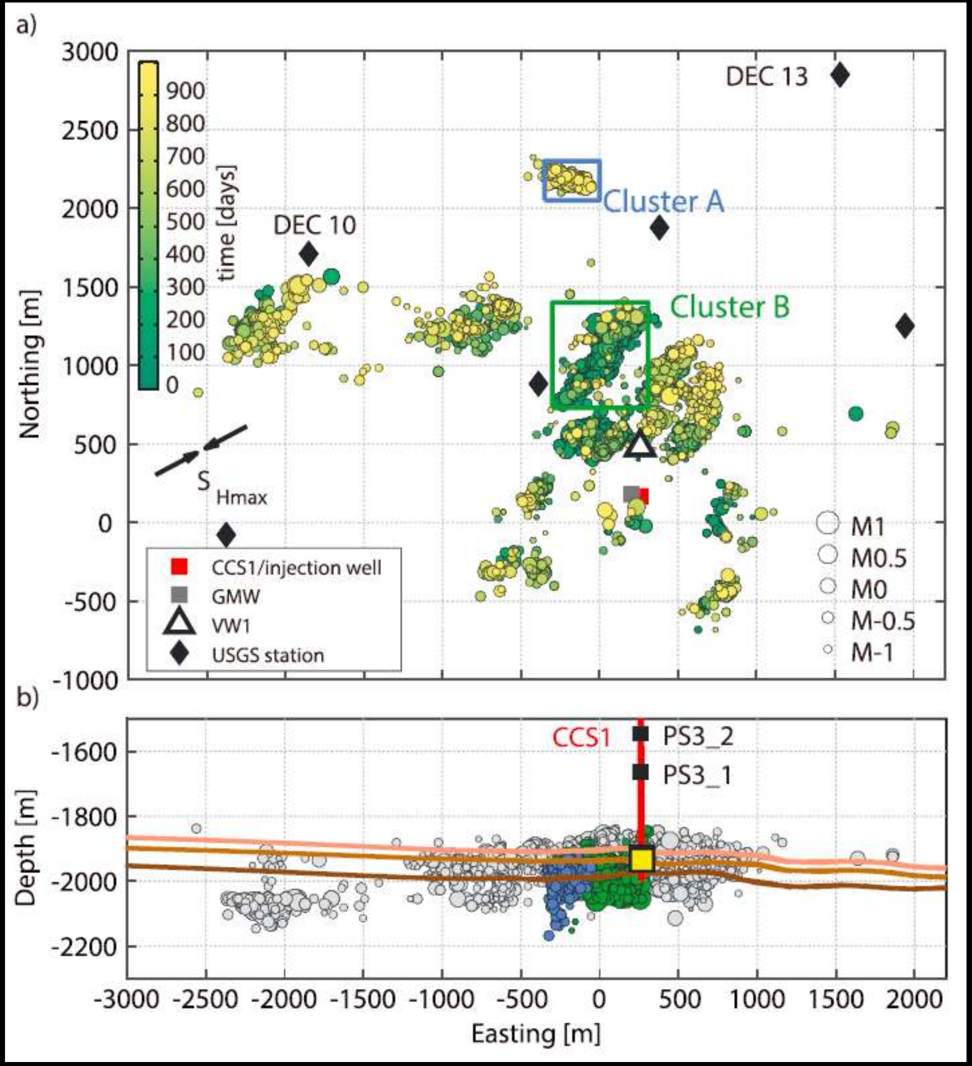
GCS has only induced microseismicity to date. Nonetheless, felt events have the potential to cancel projects (e.g., EGS)

In Salah (Algeria)



Stork *et al*. (2015) *IJGGC*

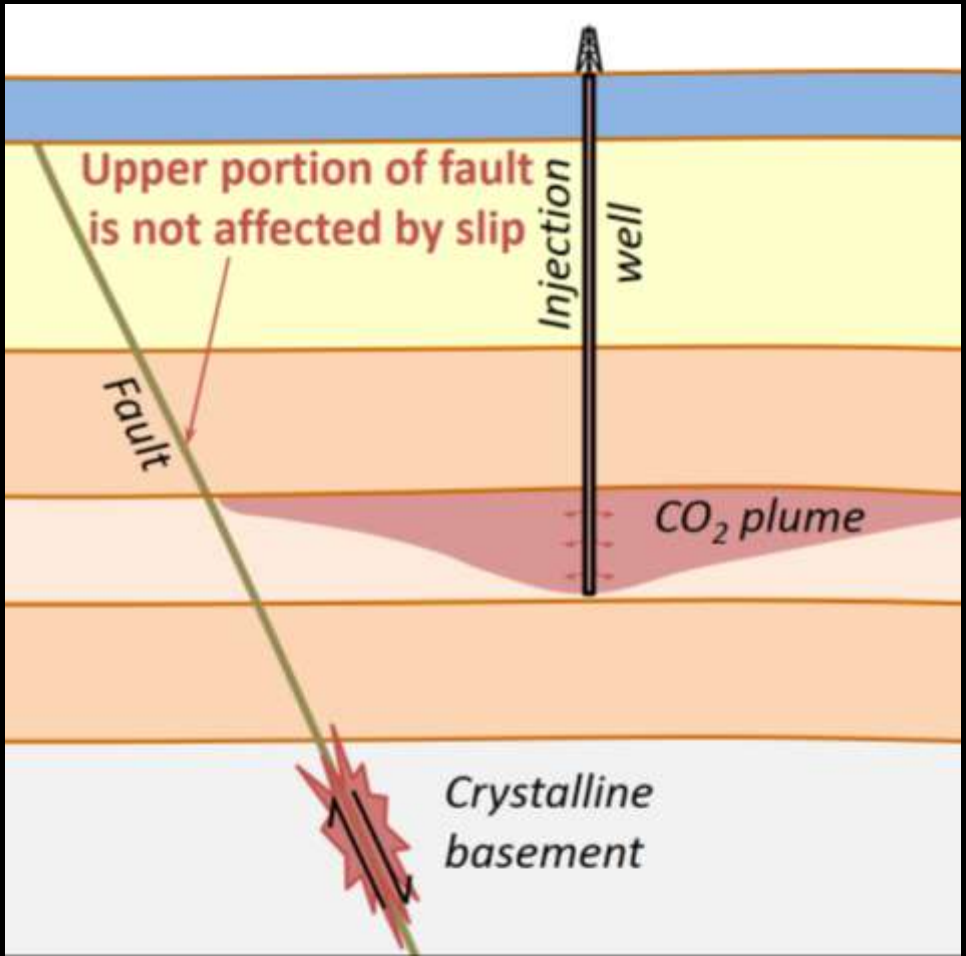
Decatur (Illinois, USA)

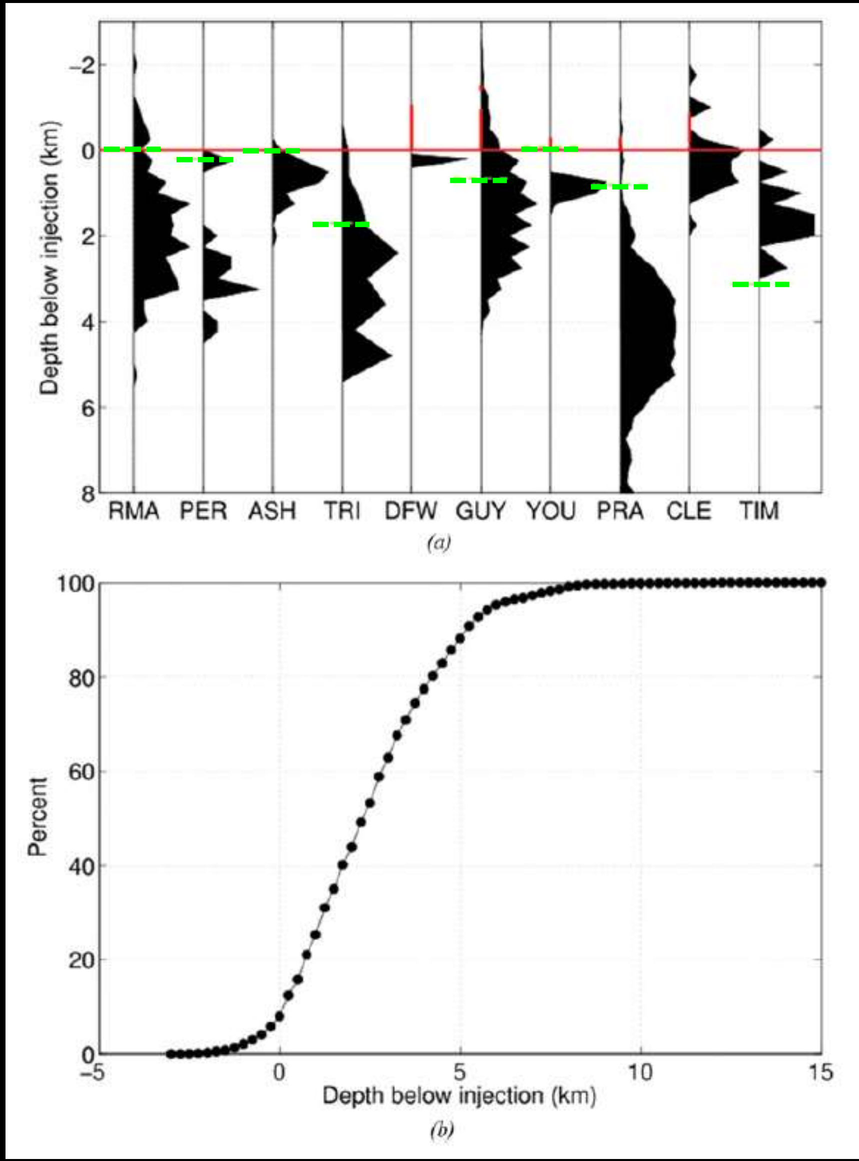


Goertz-Allmann *et al*. (2017) *IJGGC*

Most of the seismicity is induced in the crystalline basement, but CO_2 is injected in overlying sedimentary rocks

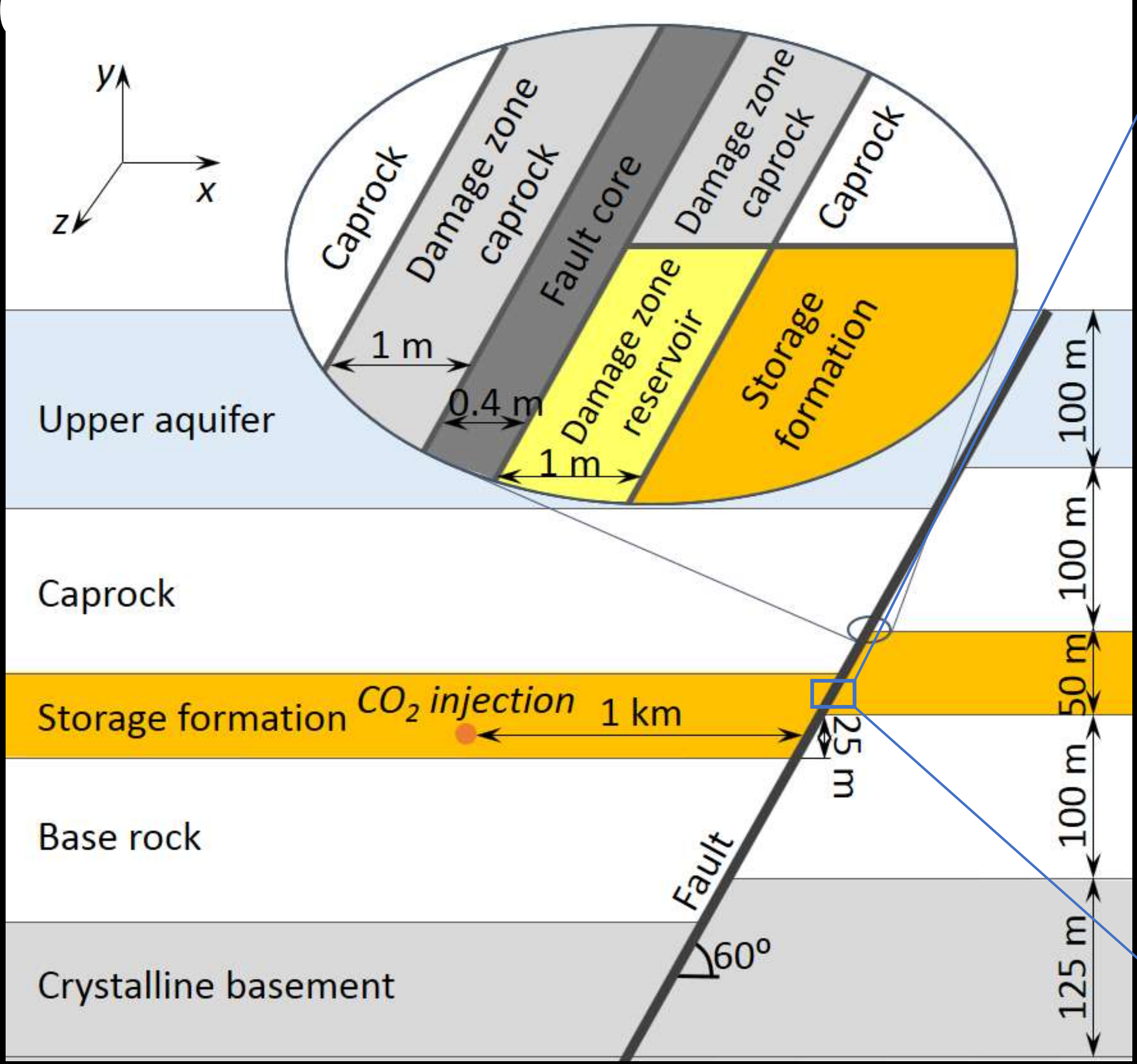
Wastewater disposal in the Central and Eastern US is a clear example



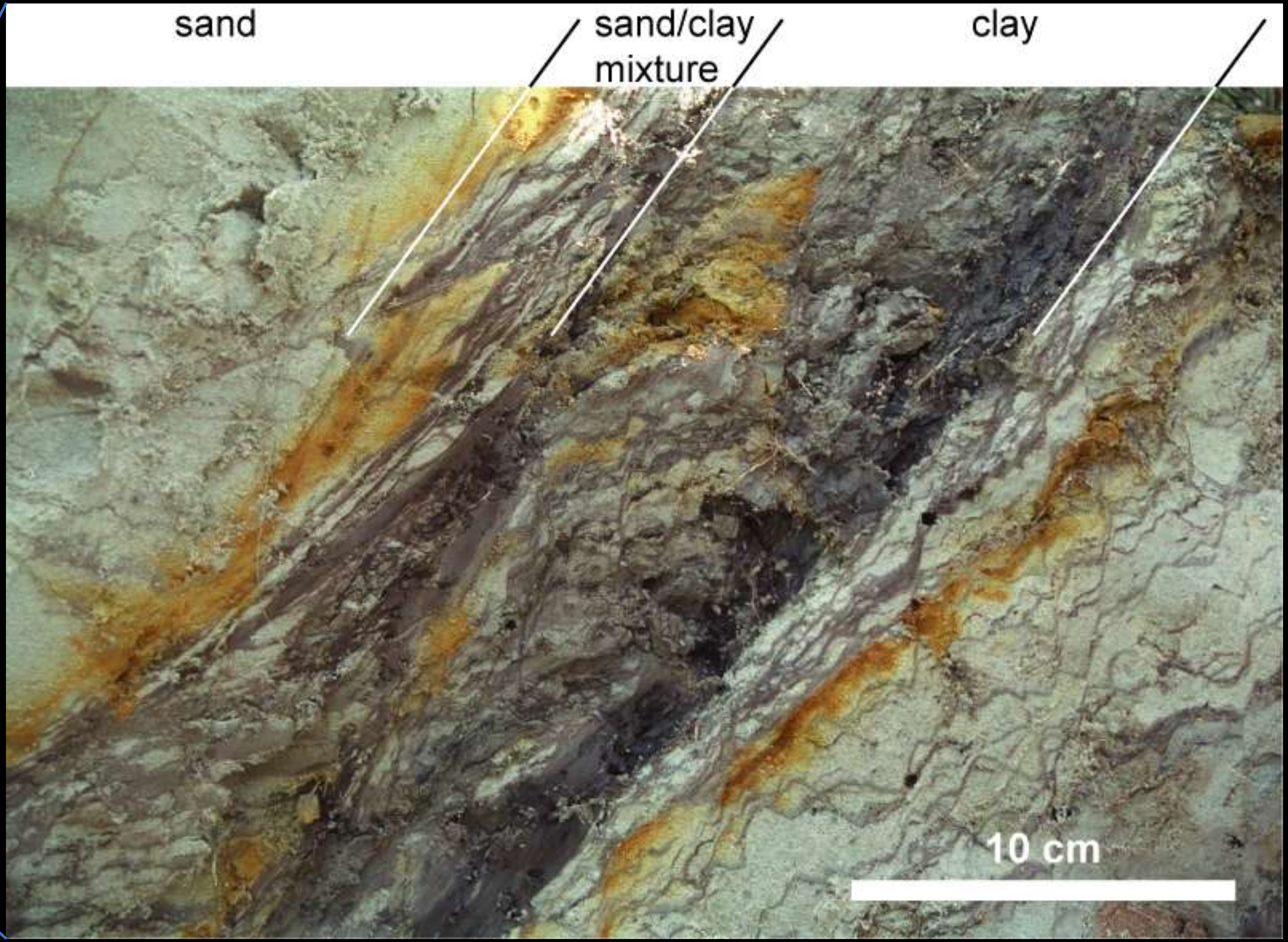


Verdon (2014) *ERL*

Faults incorporate clay as they accumulate slip, forming a low-permeable fault core surrounded by damage zone



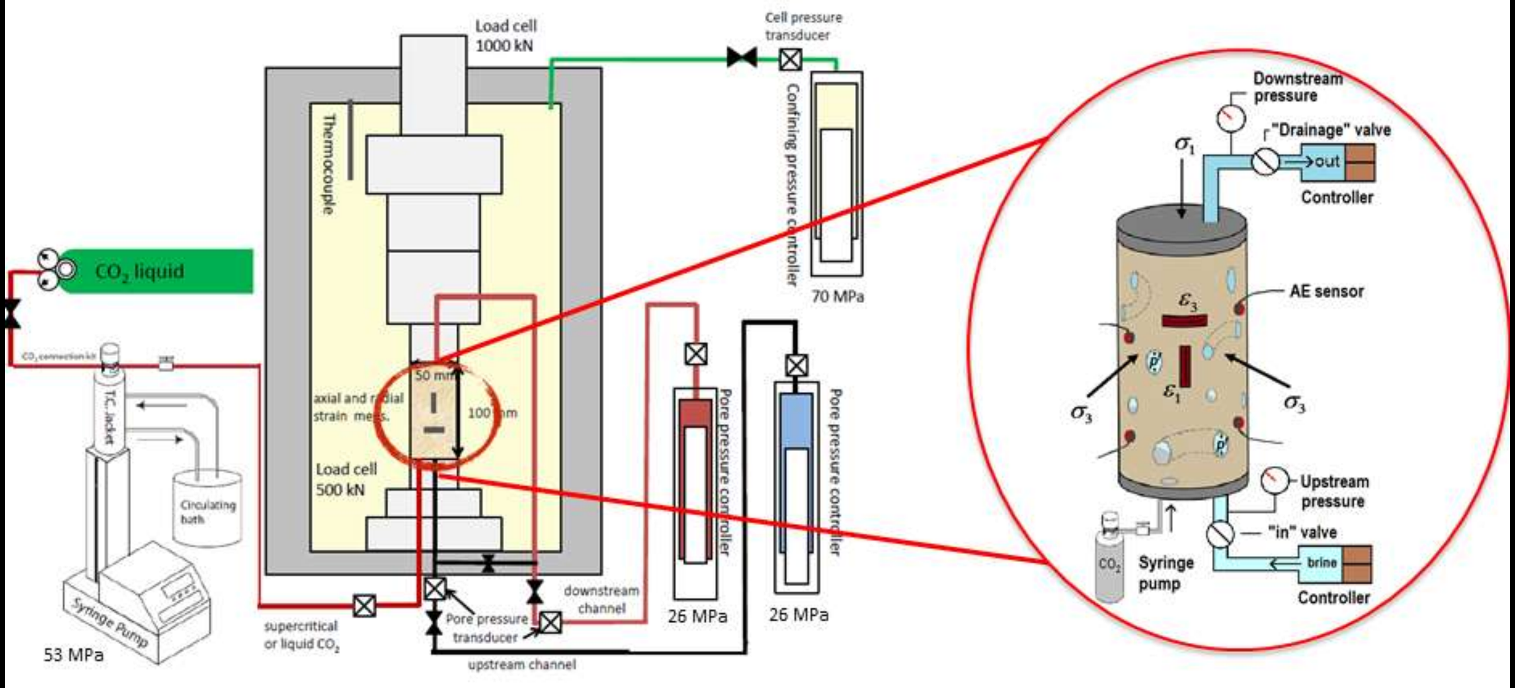
Vilarrasa *et al*. (2016) *JRMGE*



Van der Zee and Urai (2005) *J Struct. Geol.*

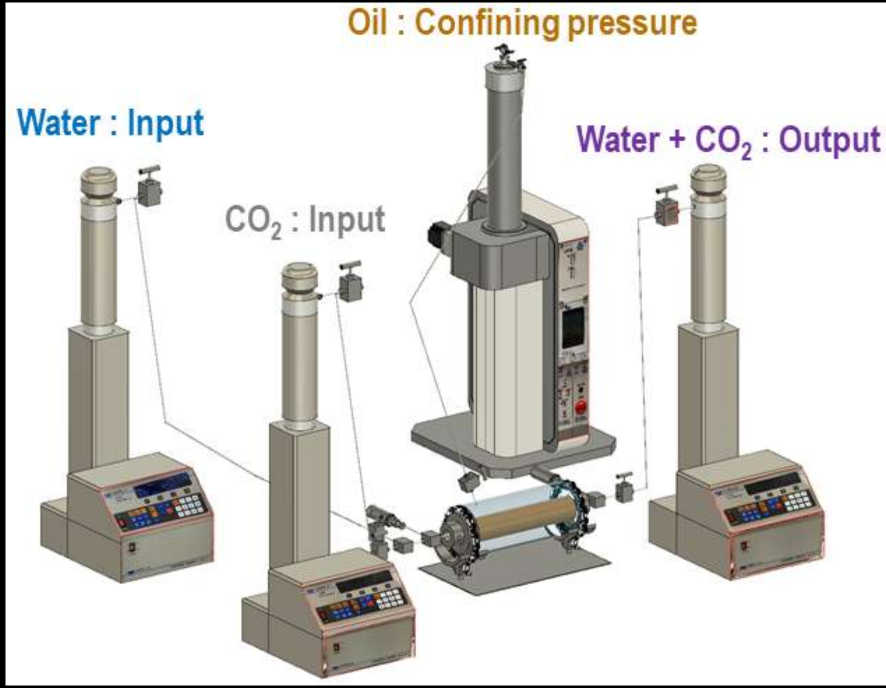
Rock properties are measured in the laboratory

Advanced Triaxial cell



CO_2 injection is performed under liquid (24 °C) and supercritical conditions (40 °C)

Core flooding device



Permits multiphase flow measurements

Storage formation: Berea sandstone (intact and failed)

Caprock/Base rock: Opalinus clay (intact and restructured)

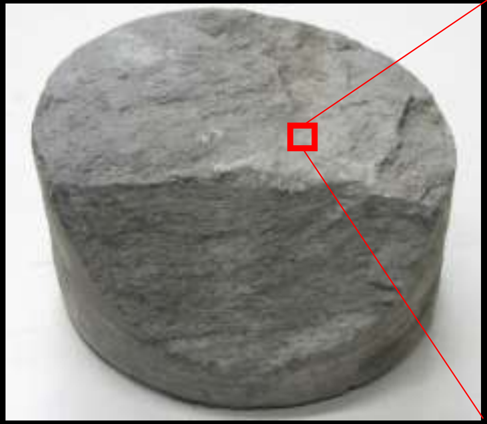
Basement: Charcoal granite

Makhnenko *et al*. (2017) *Energy Proc.*

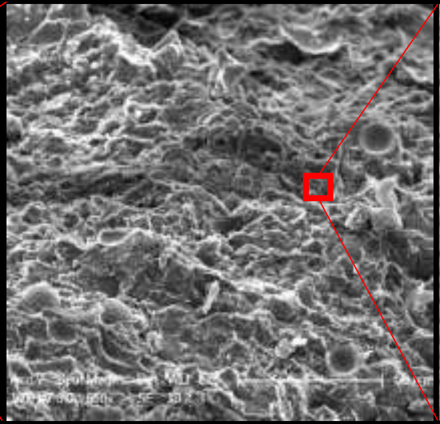
Kim *et al*. (2018) *Fluids*

Sheared Opalinus clay maintains a low permeability and high CO_2 entry pressure

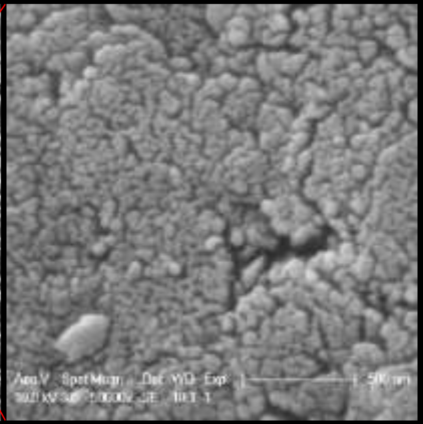
150 mm core



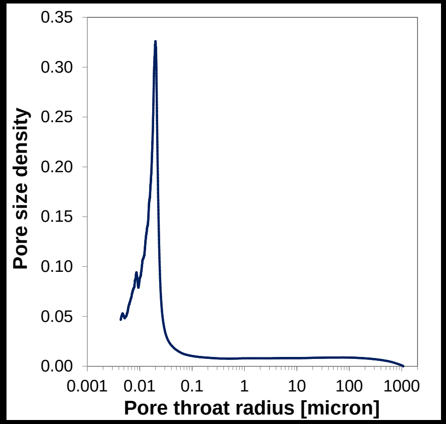
650x

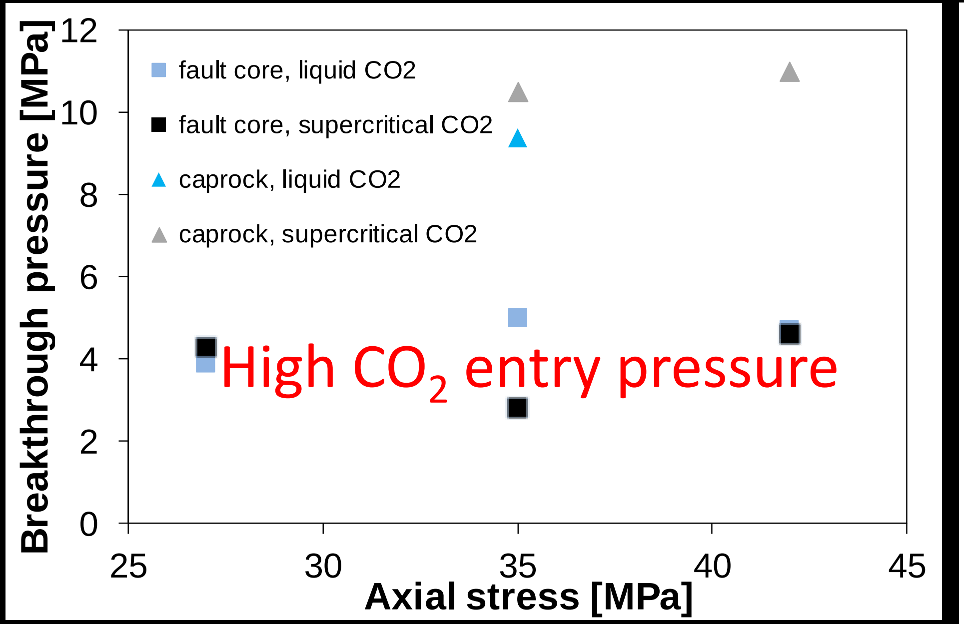


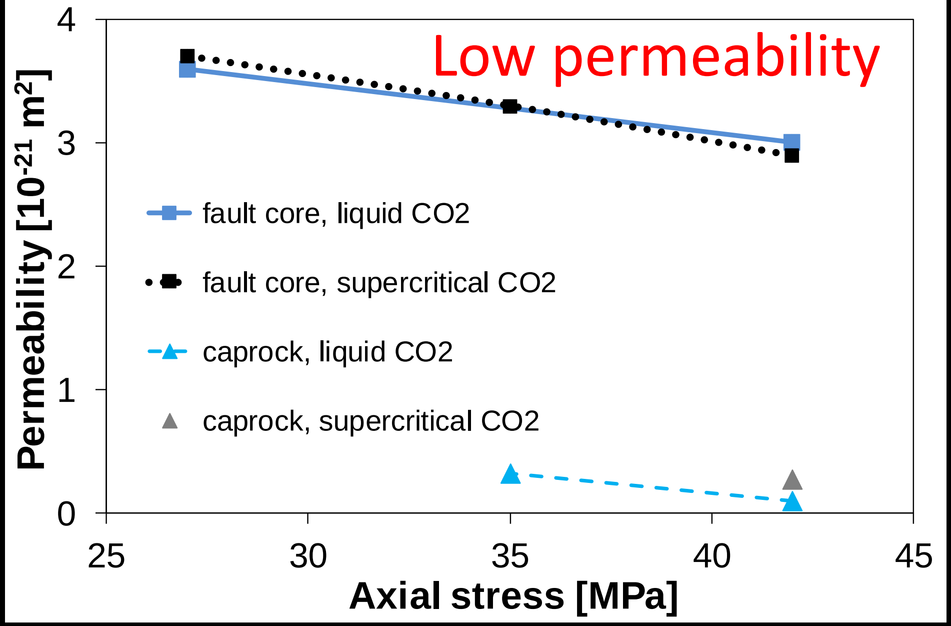
50000x



Pore size distribution

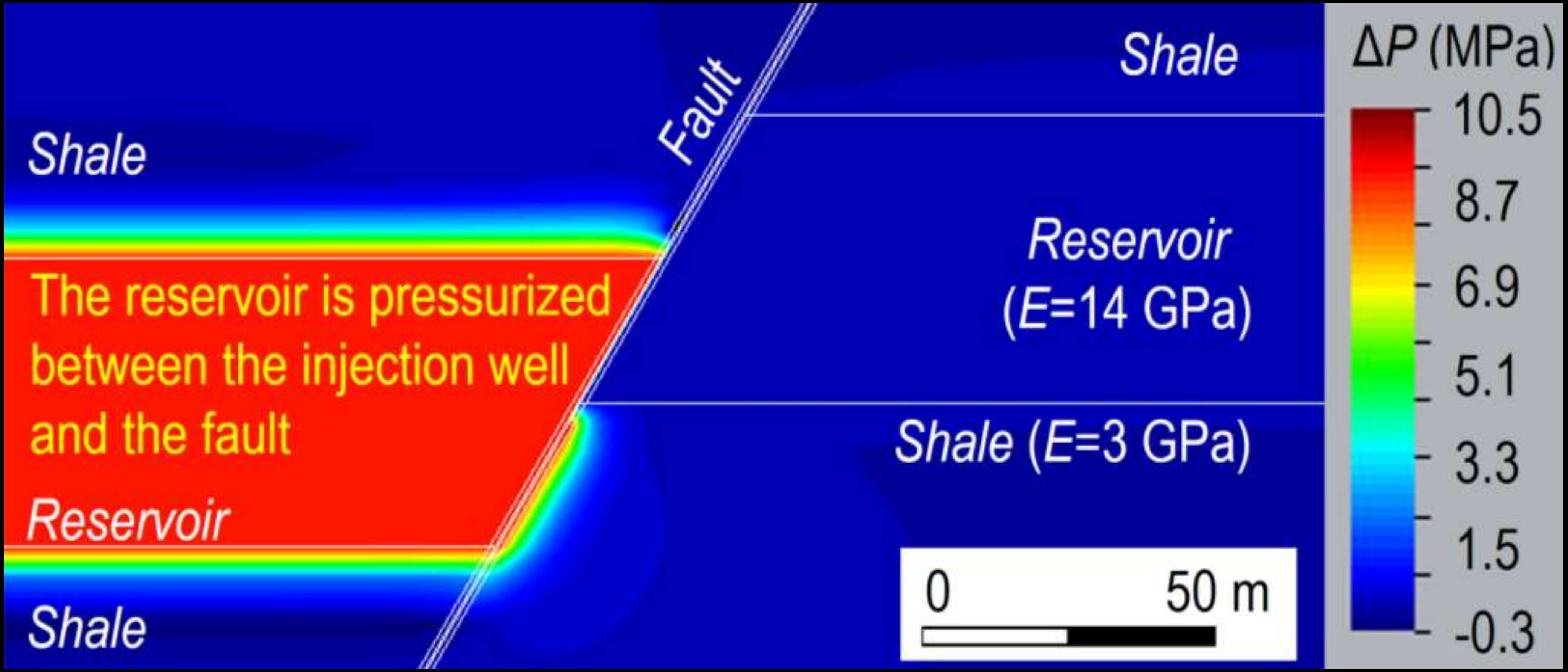






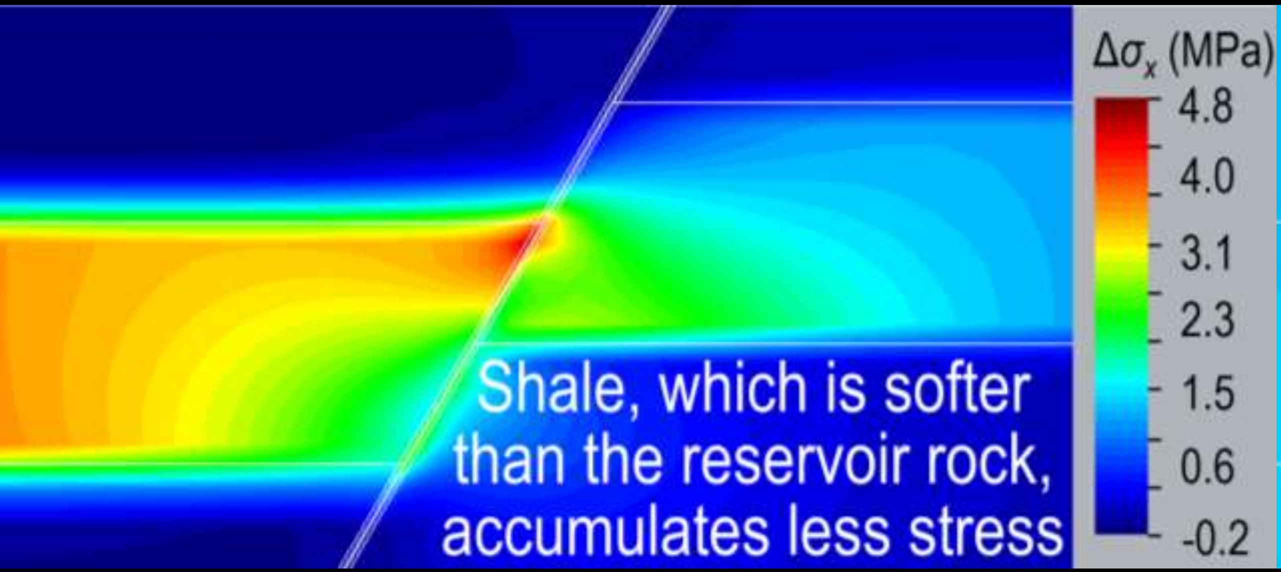
Vilarrasa and Makhnenko (2017) *Energy Proc.*

The low-permeability of the fault leads to a high pressure buildup if no pressure management is performed

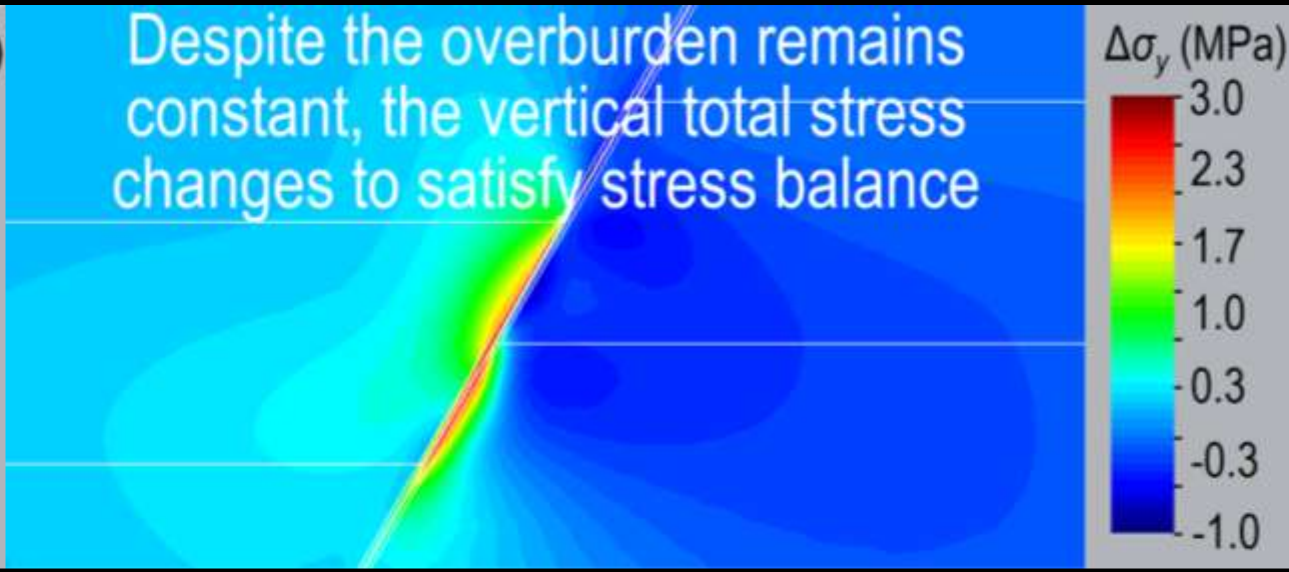


There is an inhomogeneous response of the stresses to reservoir pressurization due to the stiffness contrast

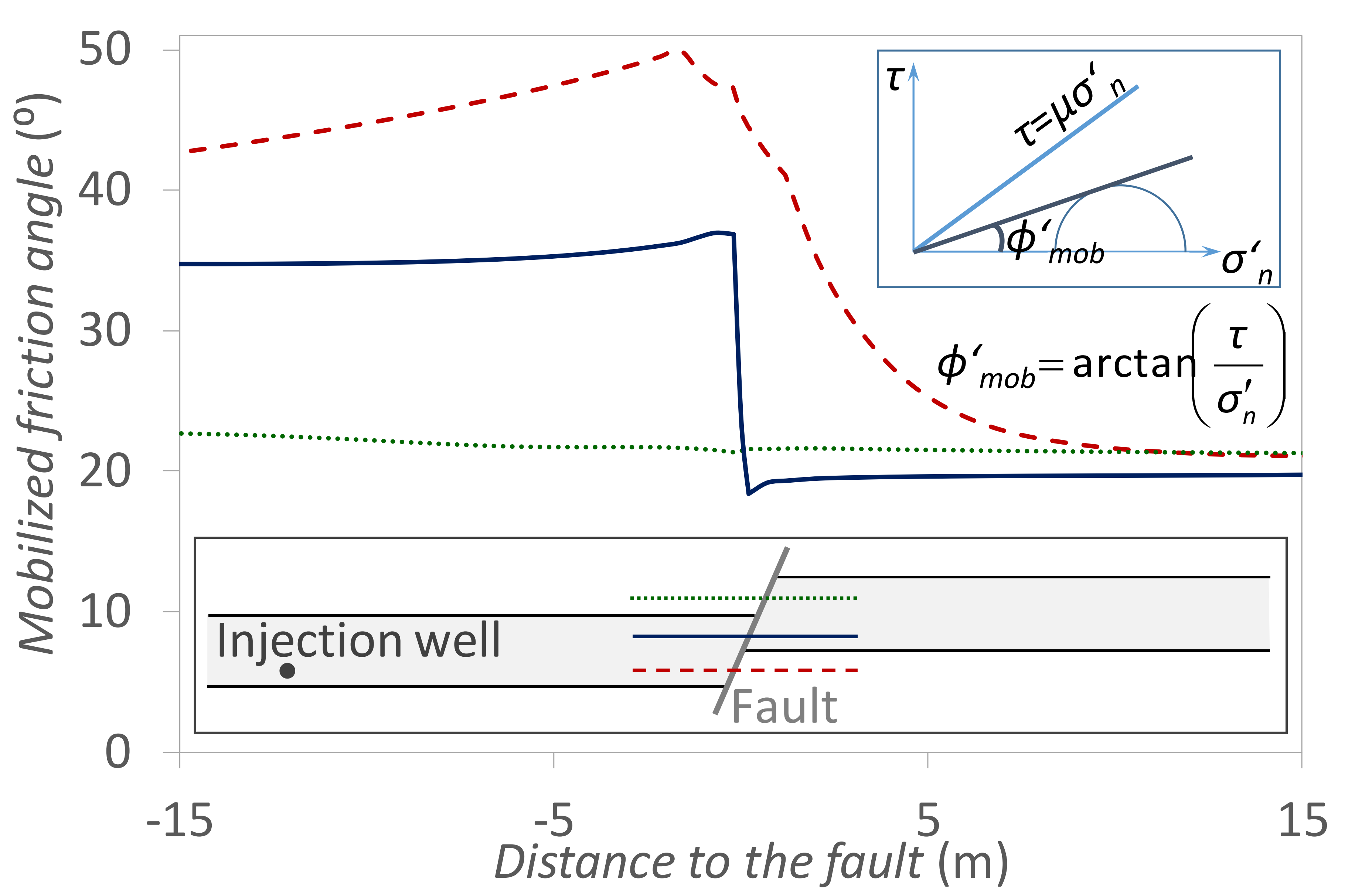
Horizontal total stress



Vertical total stress

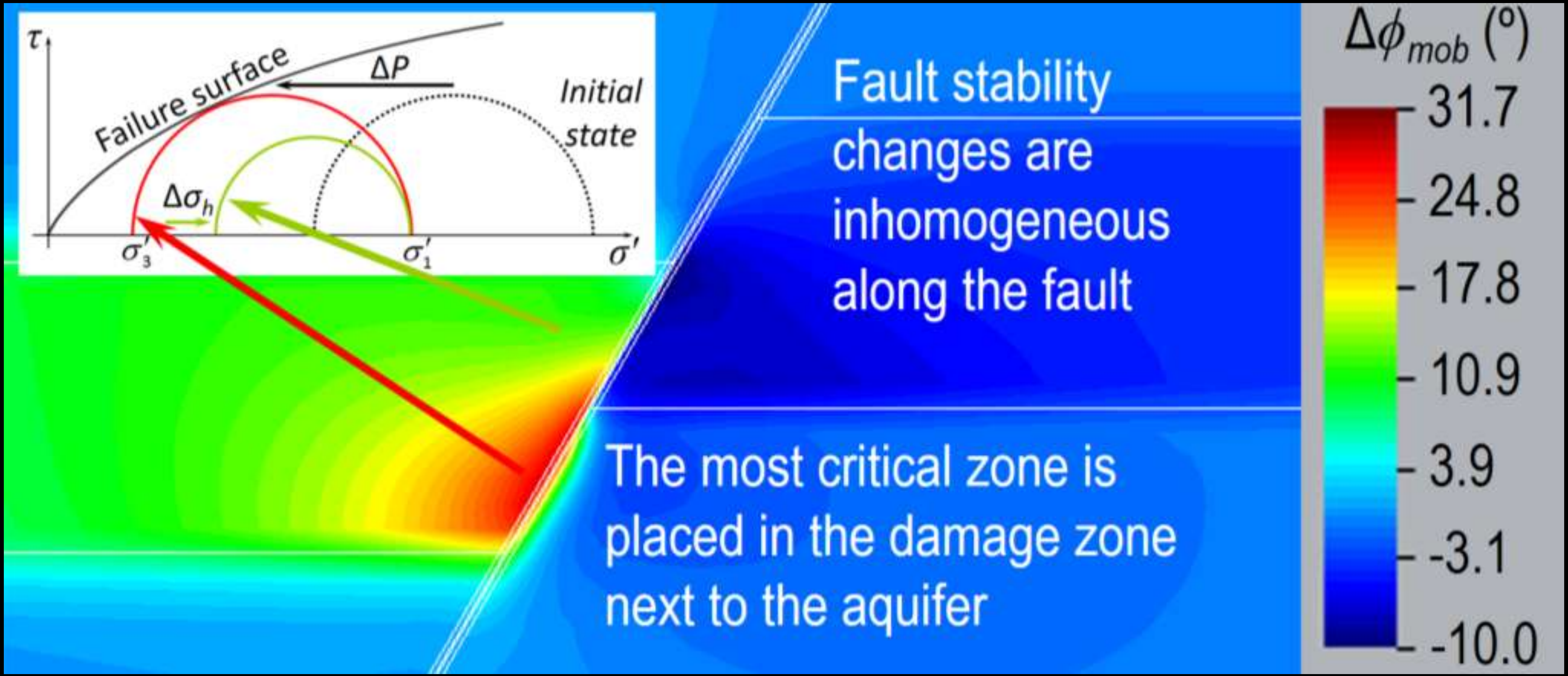


While caprock stability is maintained, preventing the risk of CO_2 leakage, fault stability within the reservoir decrea



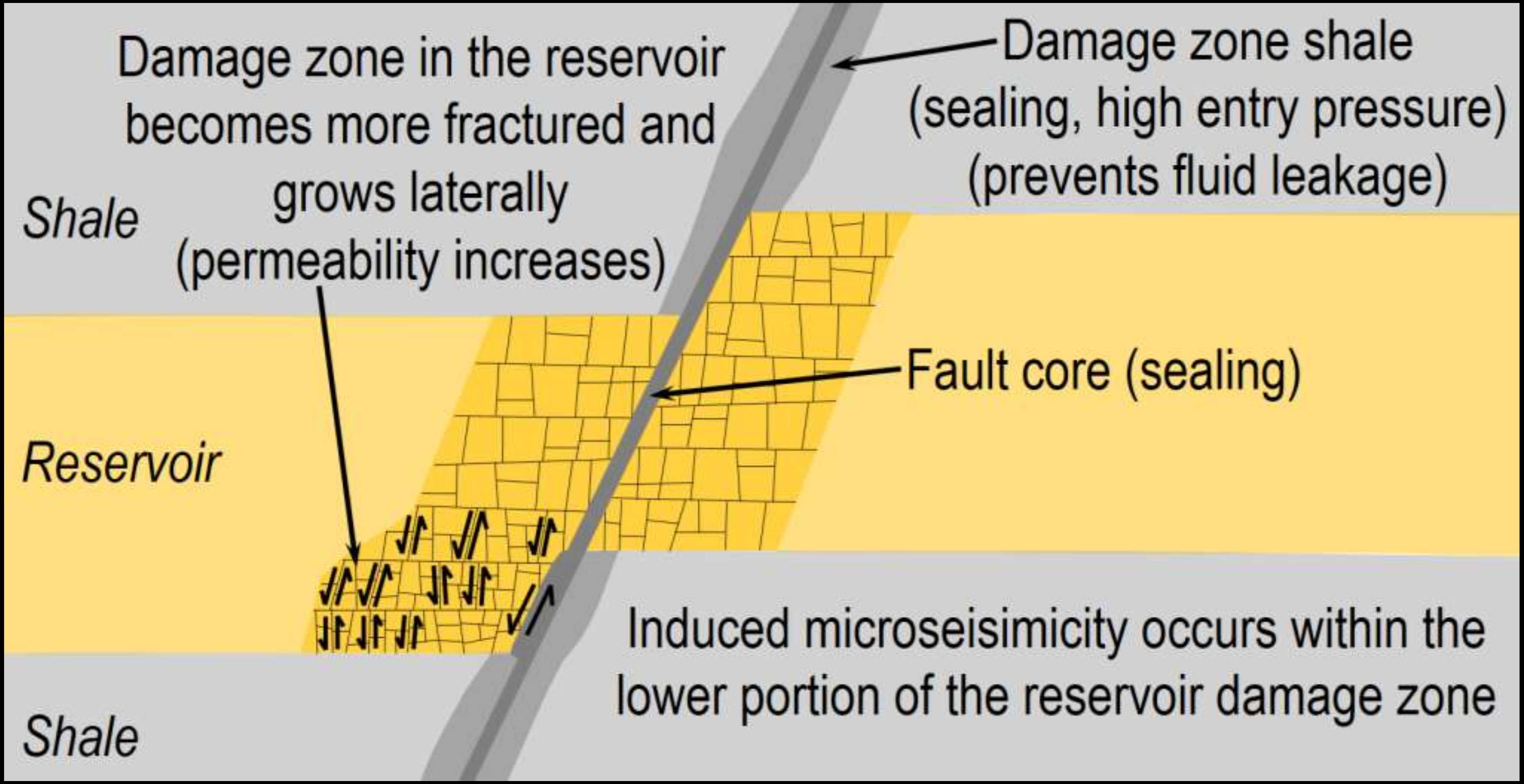
Fault instability is confined within the pressurized reservoir, so fault rupture will be arrested, limiting large events

Fault stability can be improved by performing pressure management (e.g., reducing pressure around fault by pumping water or with CO_2-geothermal)



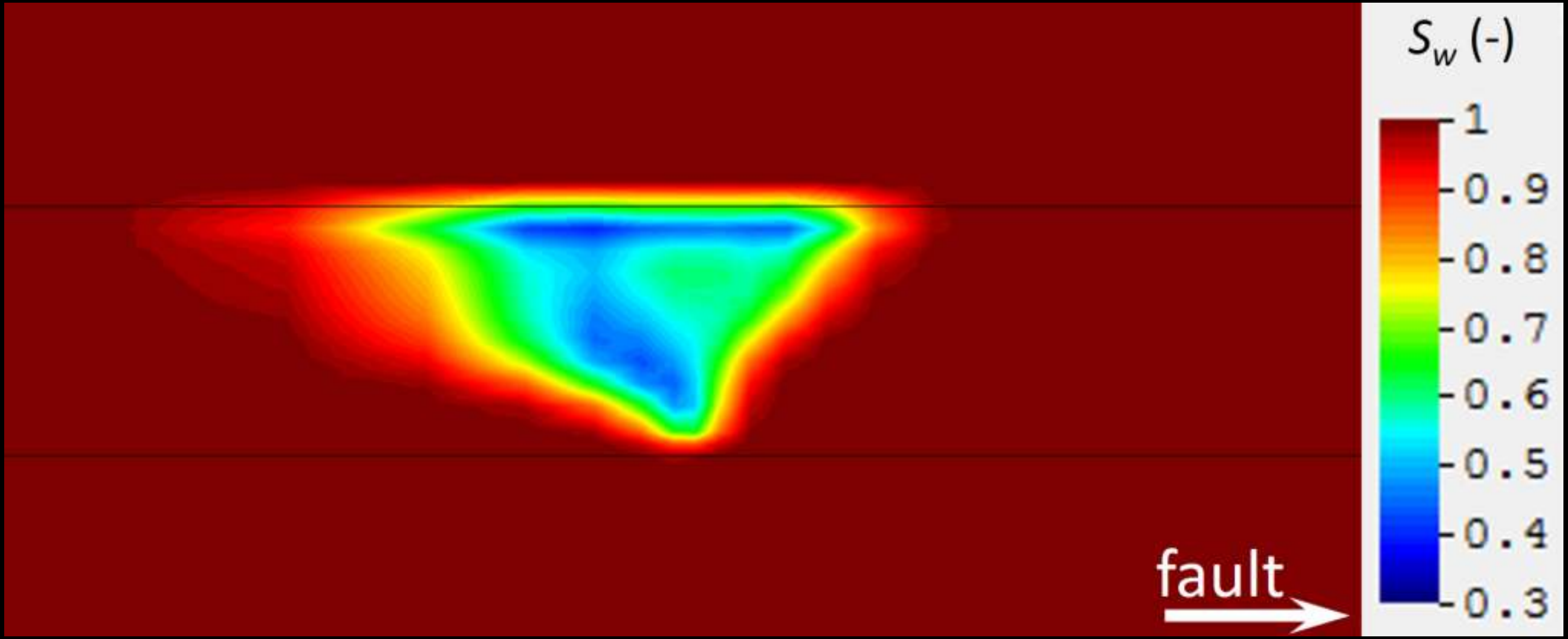
Induced microseismicity only causes local growth of the damage zone due to large stress inhomogeneity

Induced microseismicity



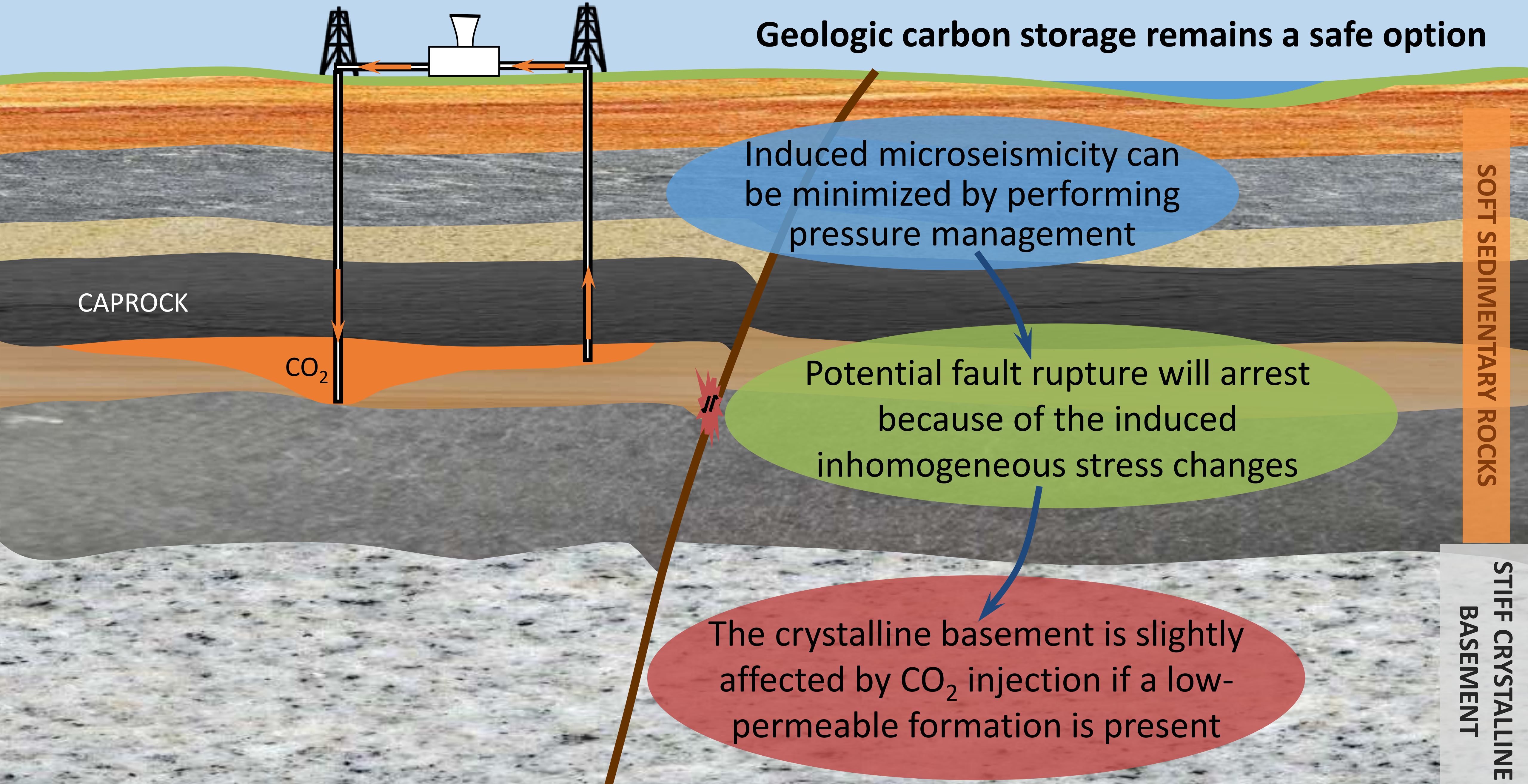
The CO_2 plume evolution is affected by the presence of the low-permeable fault, tending to migrate away from it

- CO_2 may reach faults at Gt-scale storage, but the high CO_2 entry pressure will prevent CO_2 leakage



Vilarrasa *et al*. (2019) *Solid Earth*

CO_2 leakage potential is low through clay-rich faults



Questions?

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