Coupled thermo-hydro-mechanical modeling of geological CO_2 storage at In Salah, Algeria



Víctor Vilarrasa

(victor.vilarrasa@upc.edu)

Antonio P. Rinaldi and Jonny Rutqvist

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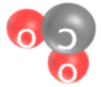
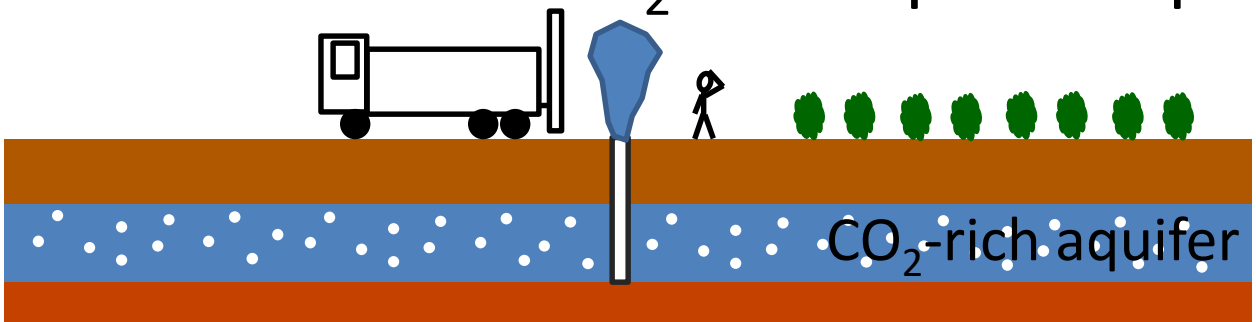
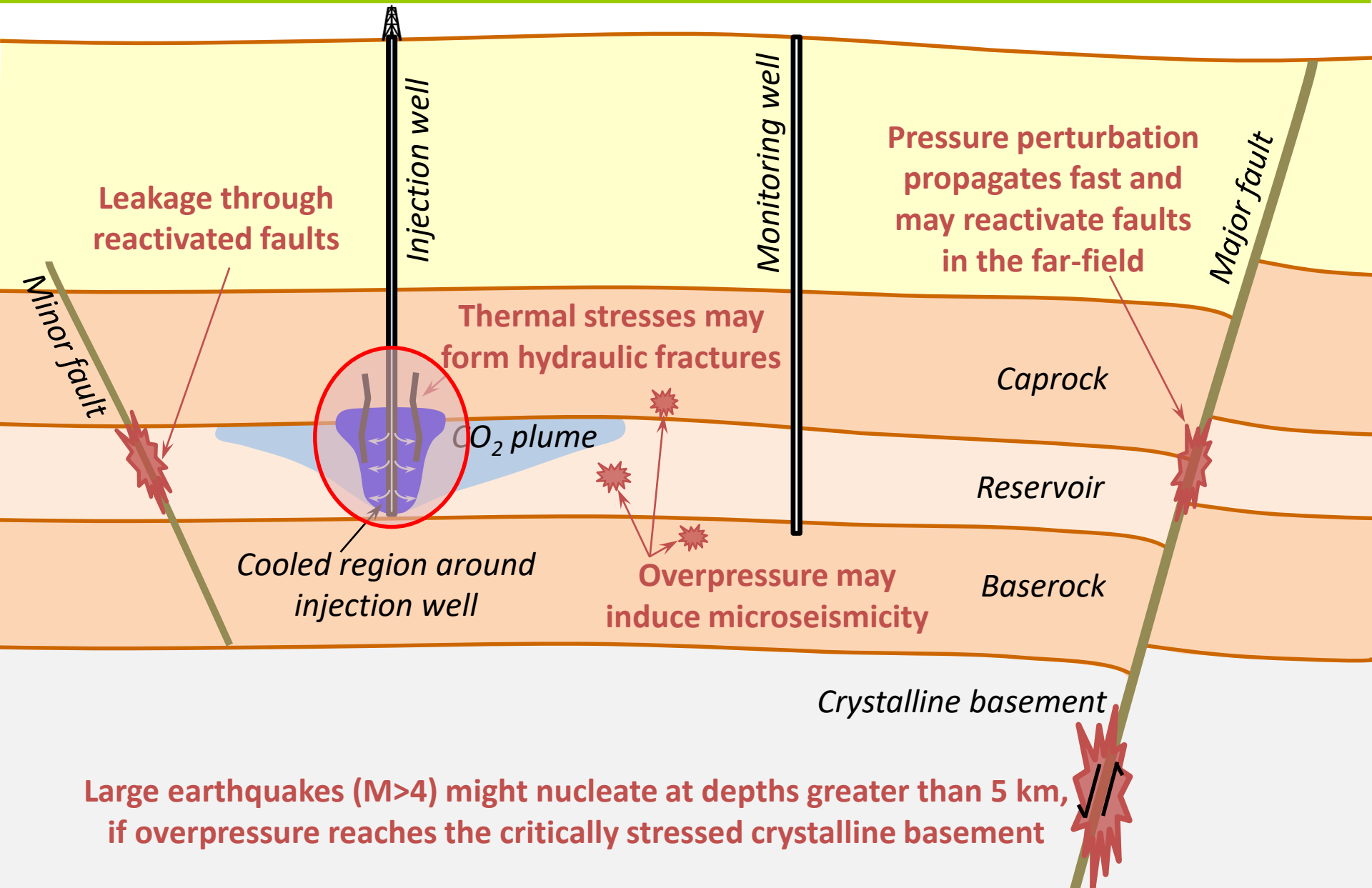
CO_2 LEAKAGE



Geysers are formed if a CO_2-rich aquifer is perforated

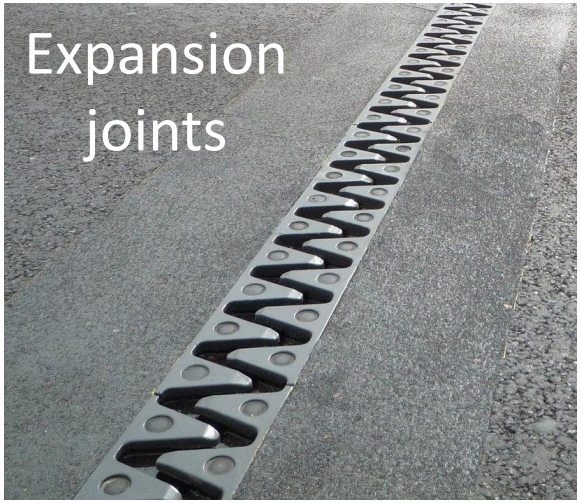


GEOMECHANICAL PROBLEMS



COOLING EFFECTS

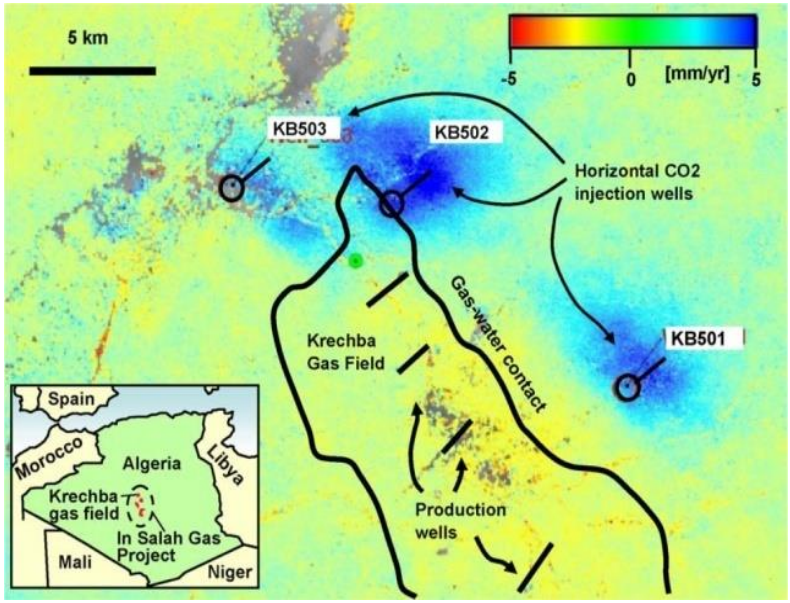
Thermal expansion-contraction processes



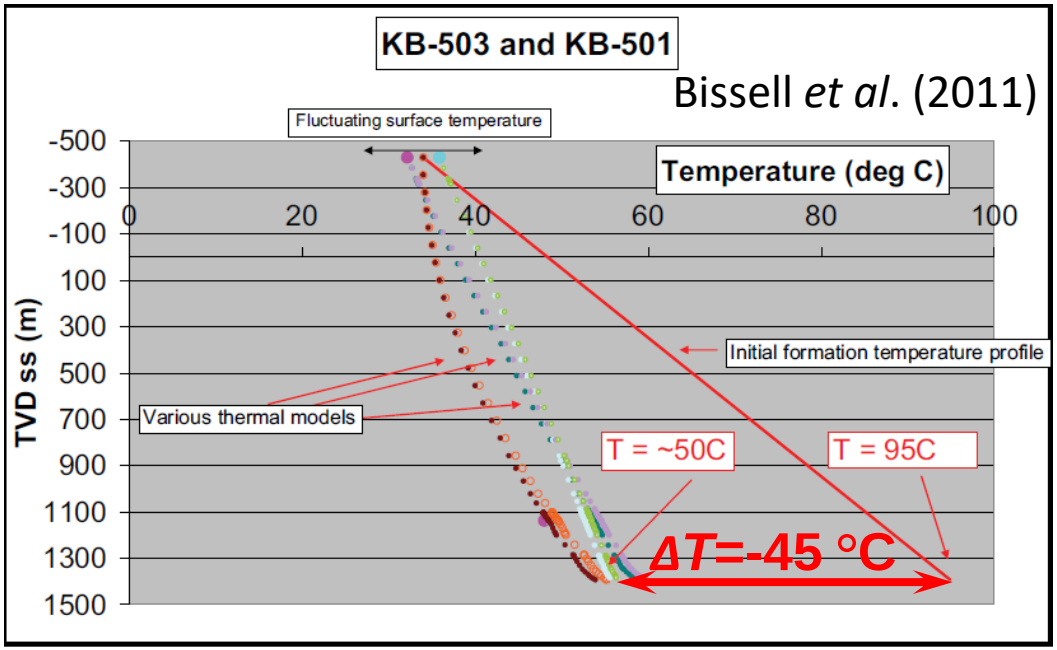
Thermal expansion-contraction processes are common in our daily life

Cooling of geomaterials may induce fractures (or open existing ones), like in lava flows

IN SALAH



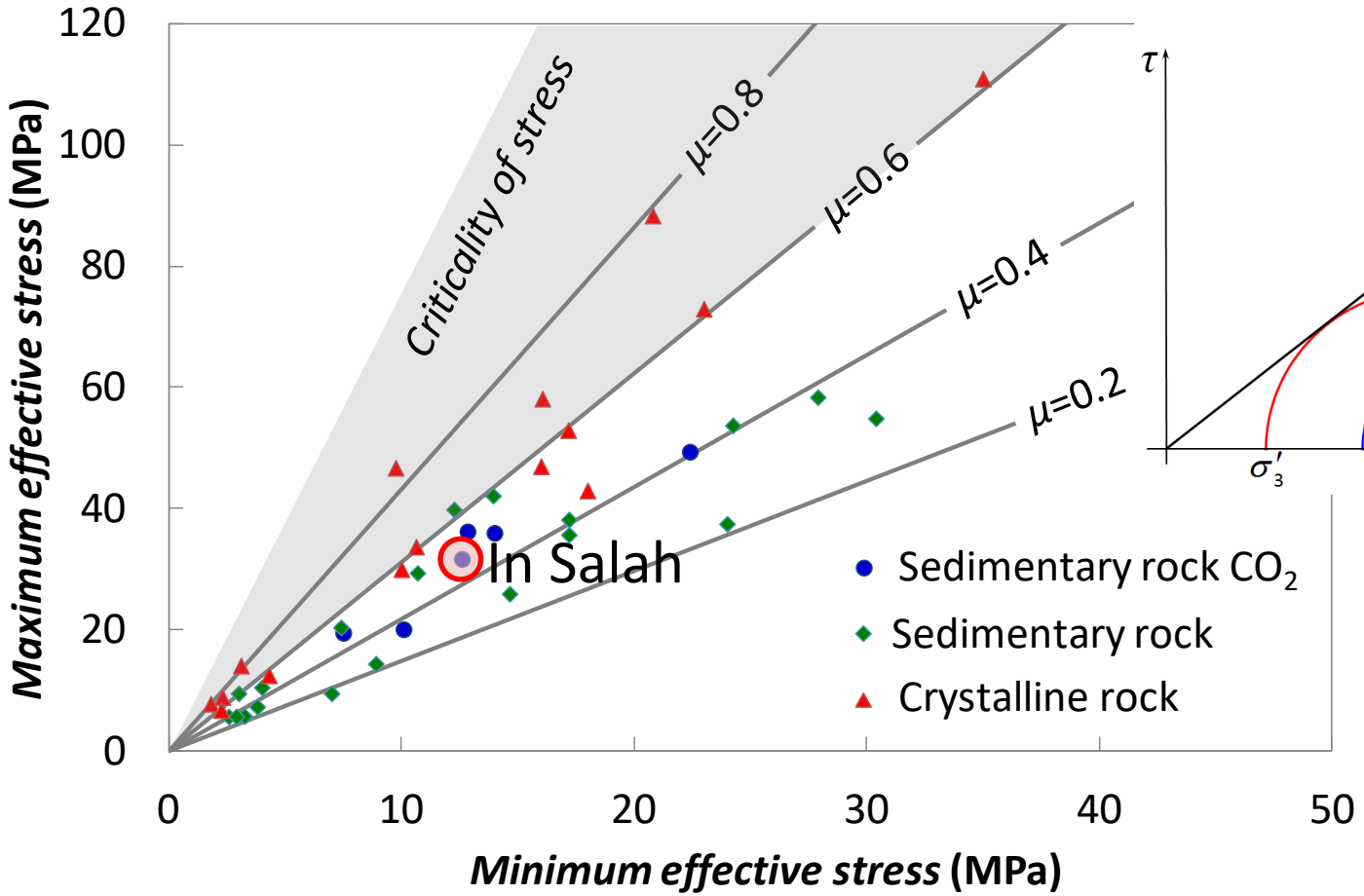
(Rutqvist *et al*., 2010)

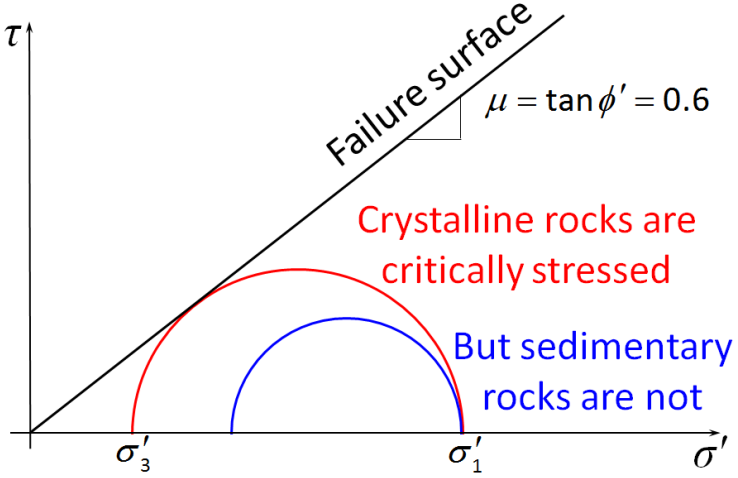


CO_2 was injected at the wellhead at surface temperature, but reached the storage formation 45 °C colder than the rock

STRESS STATE

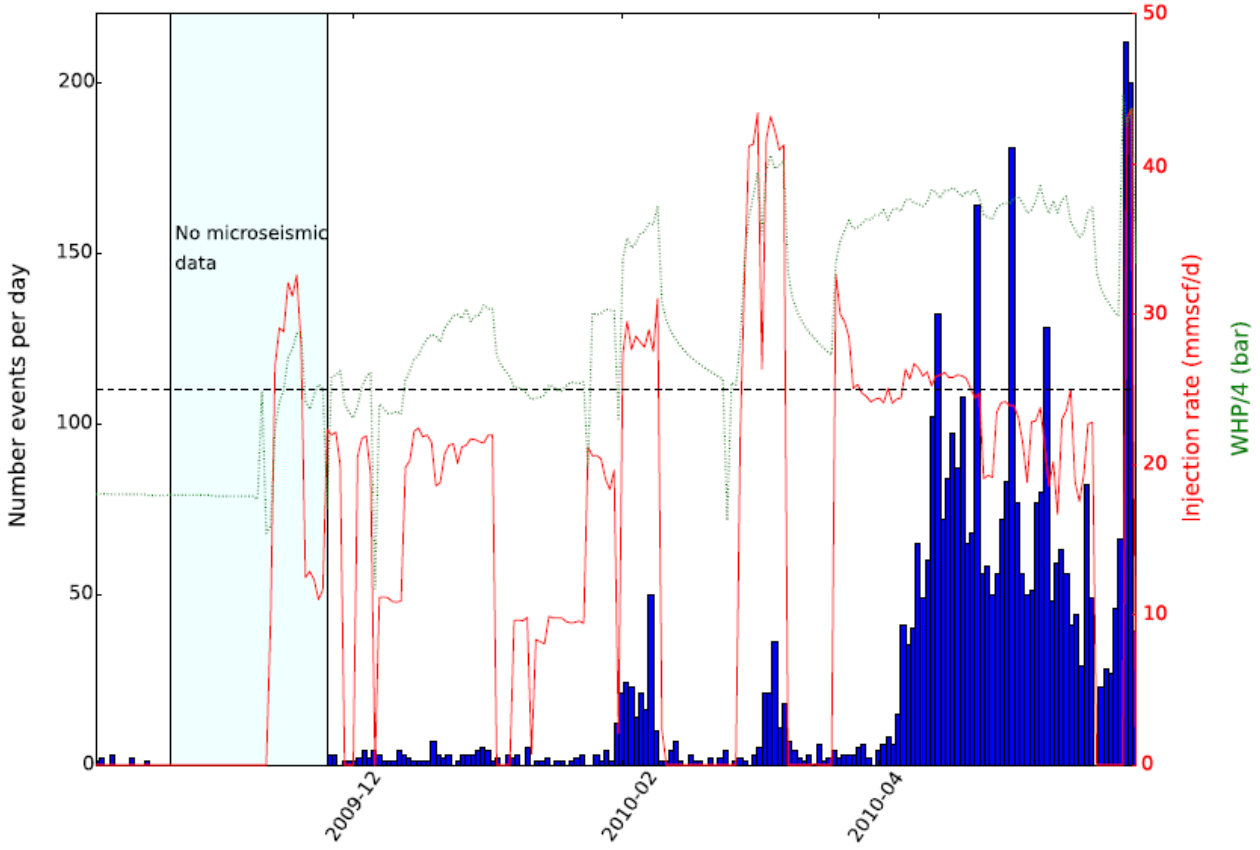
Geomechanical stability is highly dependent on the initial stress state. CO_2 will be stored in sedimentary formations, which are not critically stressed (Vilarrasa and Carrera, 2015, *PNAS*)

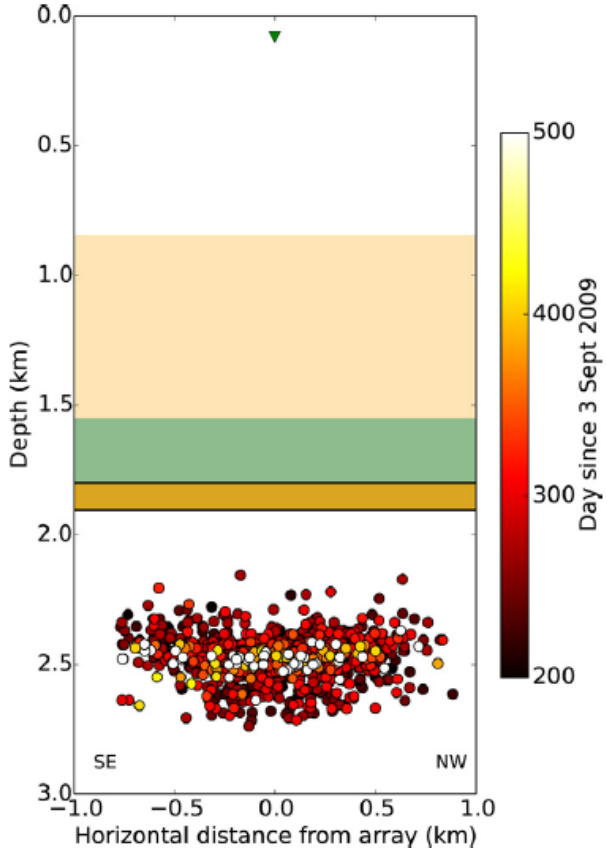




MICROSEISMICITY

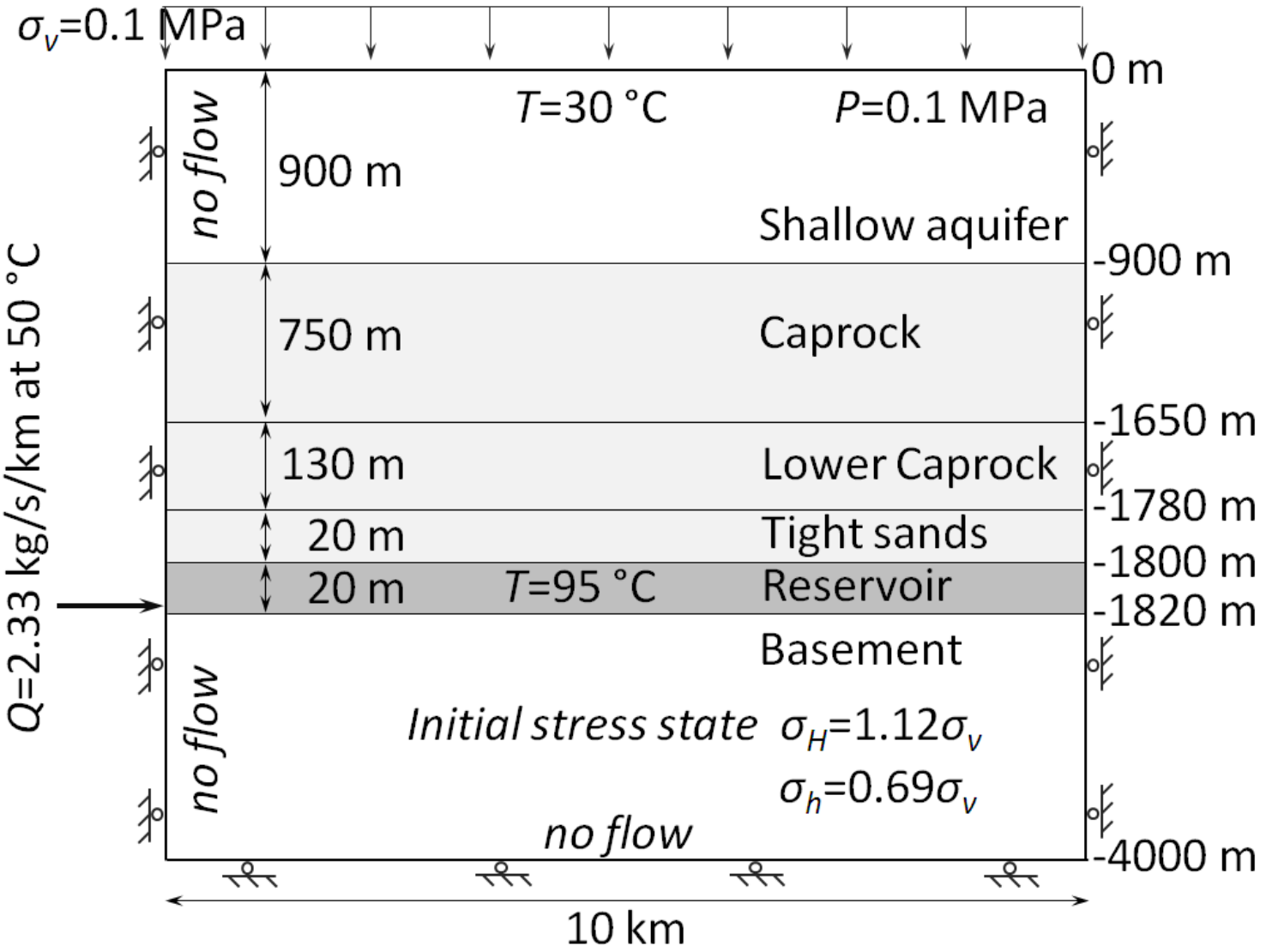
The higher the injection pressure, the larger the number of microseismicity events (Stork *et al*., 2015)





Microseismicity occurs below the storage formation

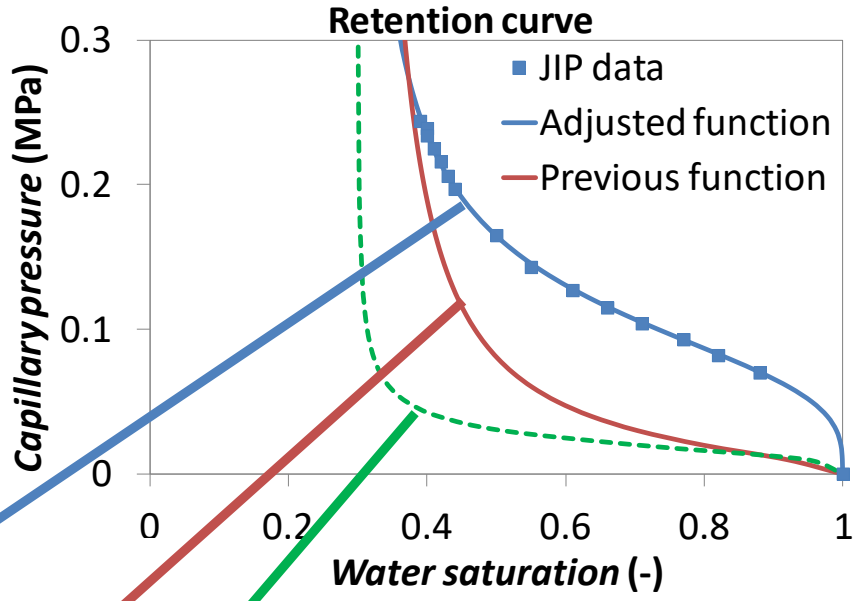
MODEL SETUP

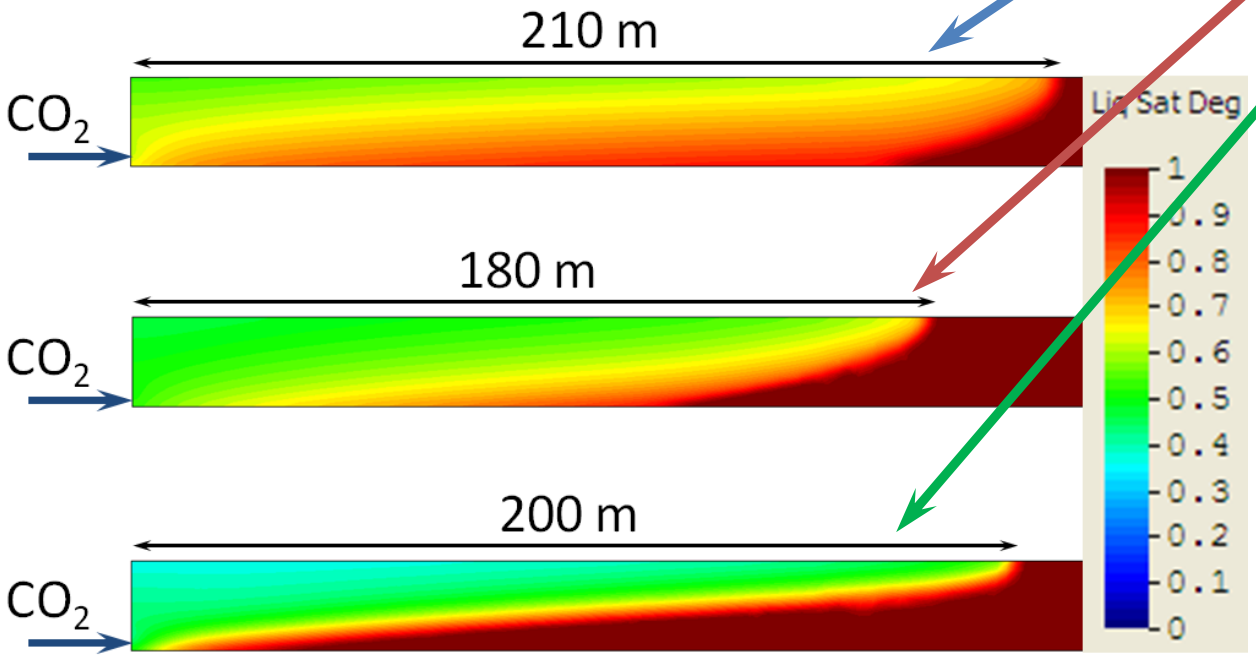


CODE_BRIGHT extended for CO_2 injection (Vilarrasa *et al.*, 2010)

CAPILLARY EFFECTS

The shape of the retention curve affects the CO_2 plume shape. However, the injection pressure is almost insensitive to the retention curve because the displaced volume is similar in all cases

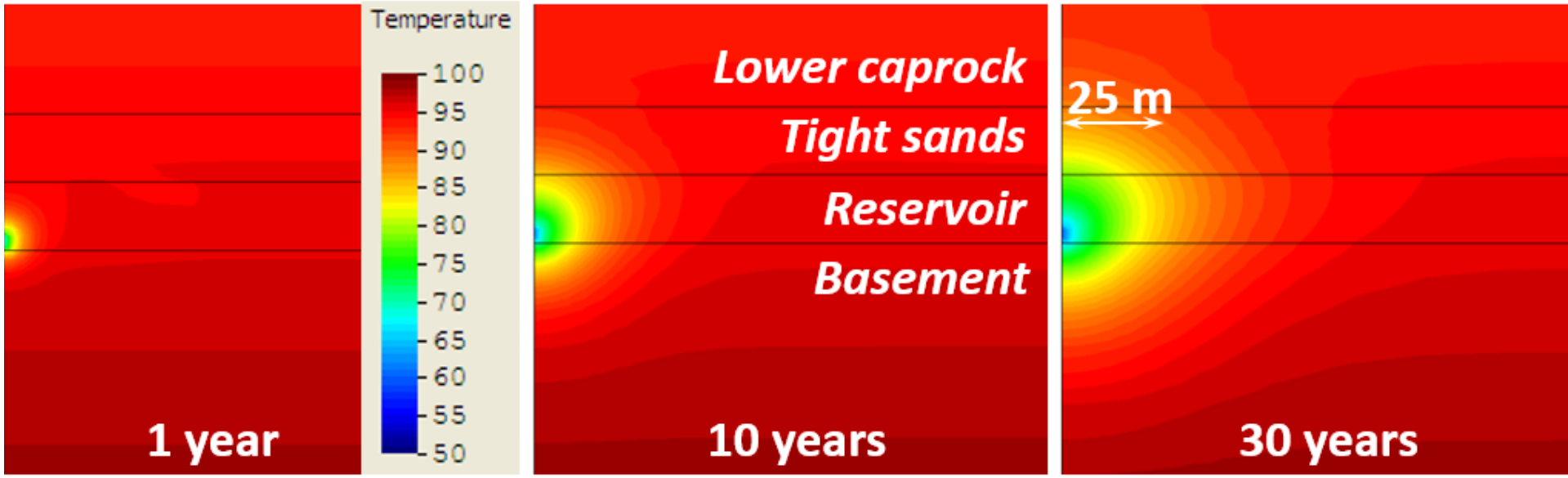




Vilarrasa *et al*. (2015)

COOLING

The cooling front advances slowly, affecting the near well zone. Heat transport occurs mainly by advection in the storage formation and by conduction in the caprock

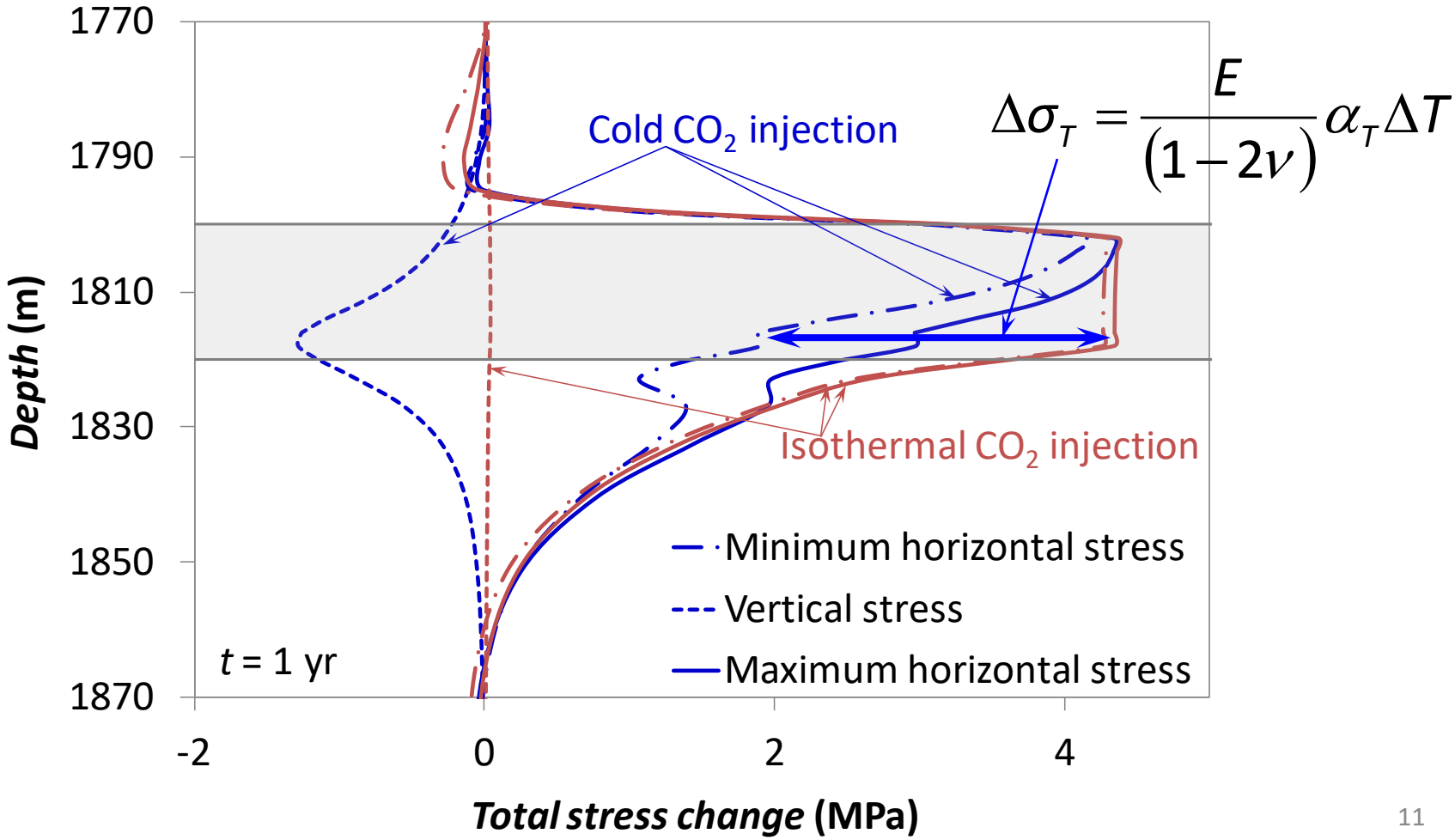


The large temperature decrease, combined with the hard rocks at In Salah ($E_{reservoir}$=10 GPa and $E_{tight\ sands}$=20 GPa) induces large thermal stress reduction

$$\Delta\sigma_T = \frac{E}{(1-2\nu)}\alpha_T \Delta T$$

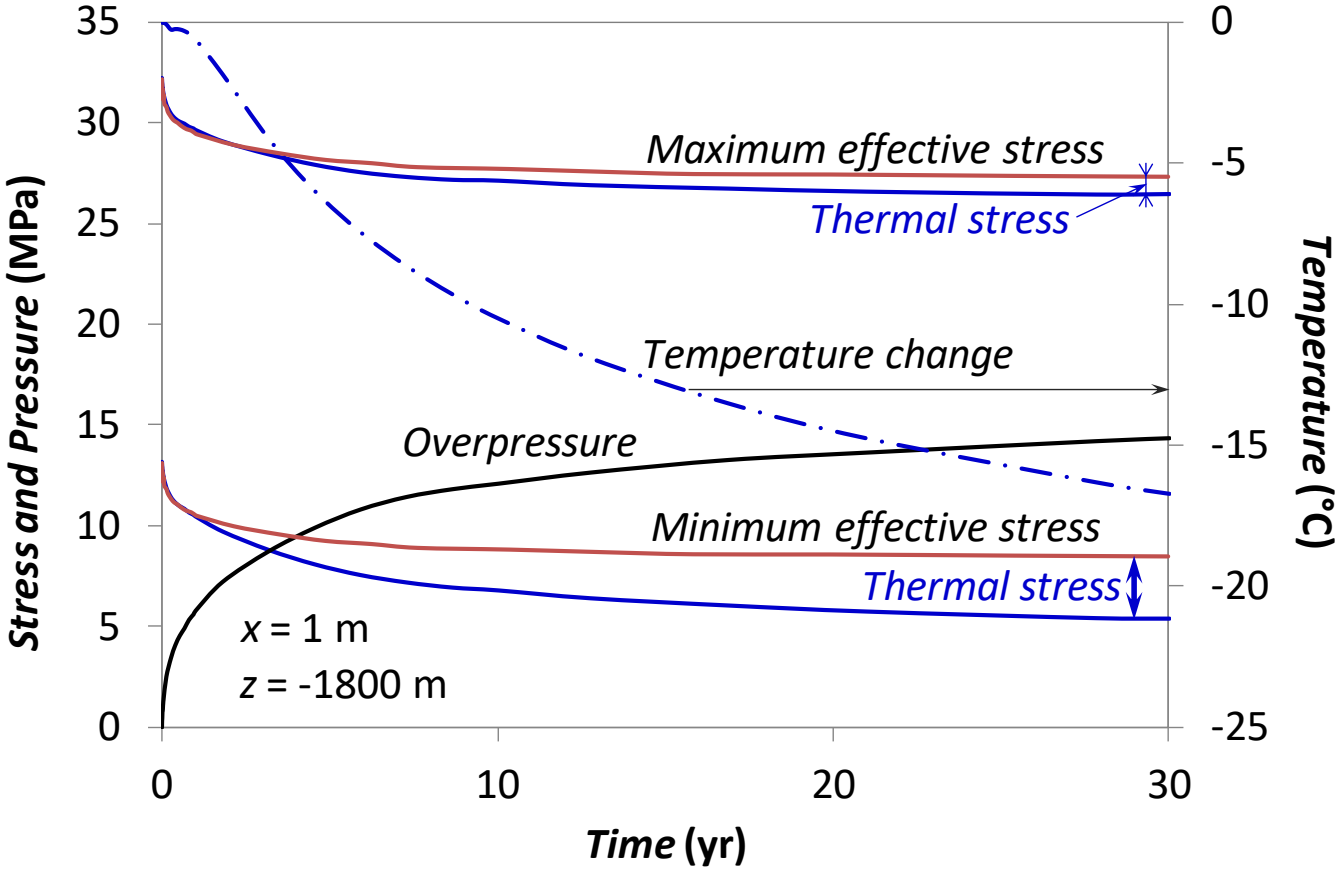
TOTAL STRESS CHANGES

The largest thermal stresses occur at the bottom of the reservoir, around the injection well



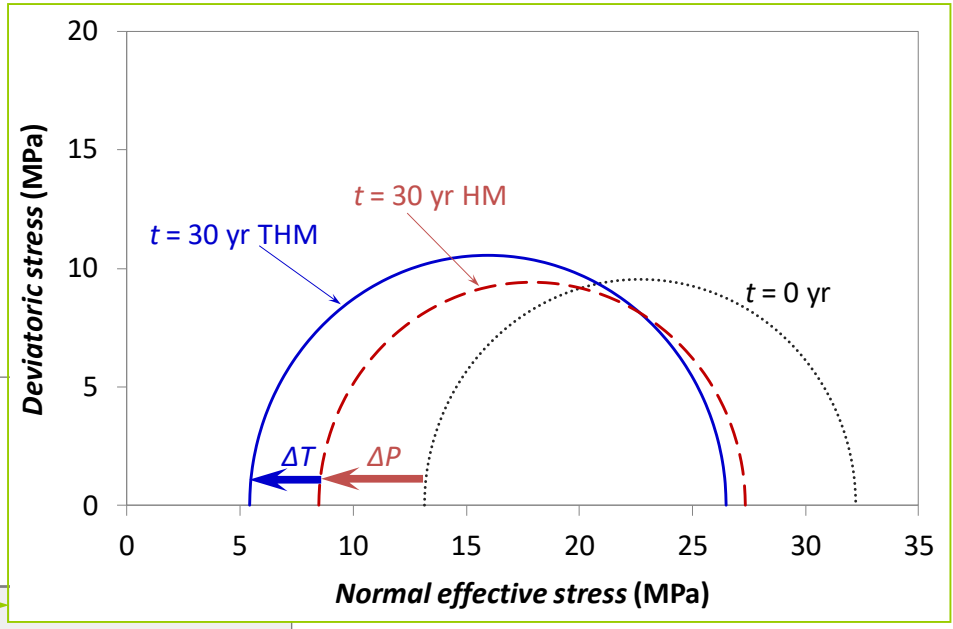
THERMAL STRESSES

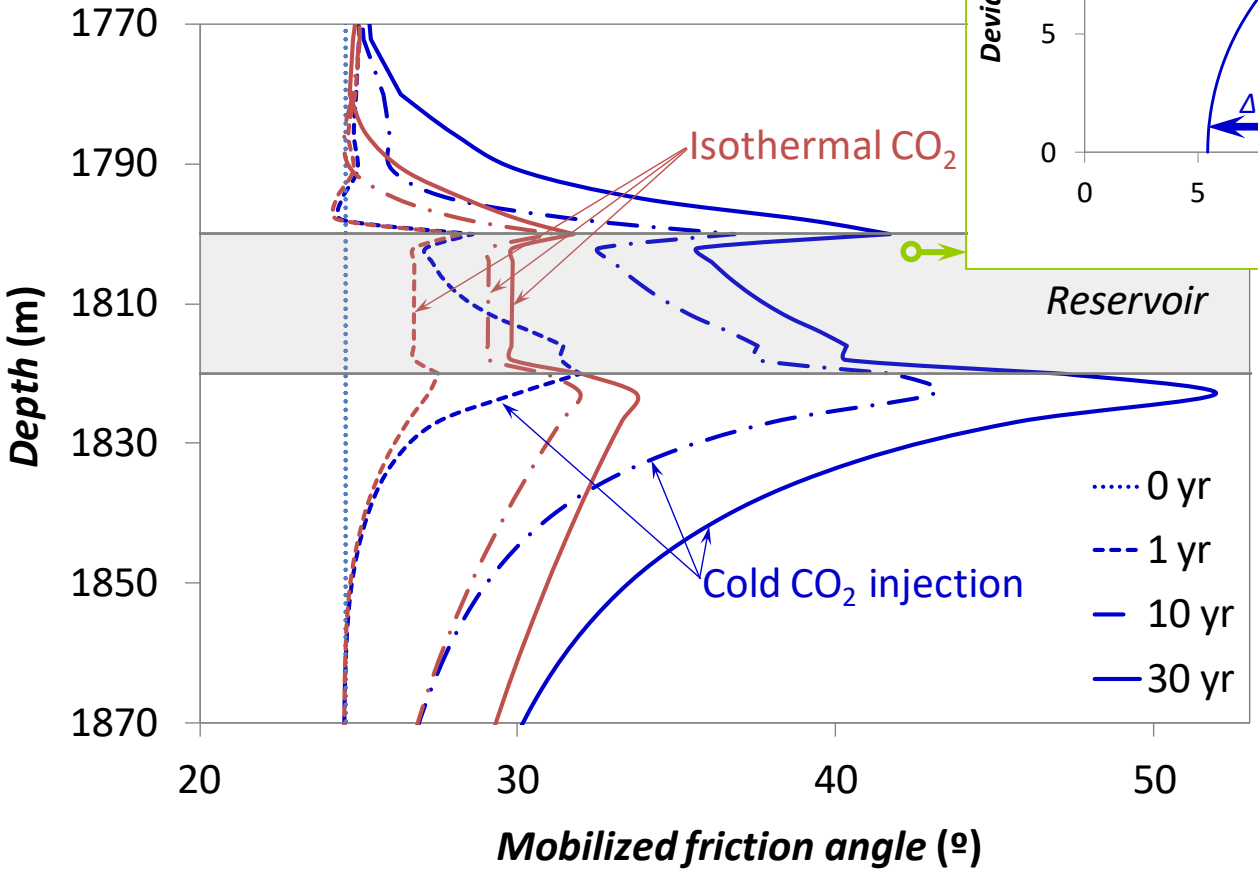
The minimum effective stress remains in compression at the bottom of the caprock over the 30 years injection period, but decreases as cooling becomes larger



ROCK STABILITY

The risk of shear failure of pre-existing fractures significantly increases inside the cooled region





A relatively permeable baserock may explain the microseismicity below the reservoir

CONCLUSIONS

- We investigate **thermal effects due to cooling on rock stability** at In Salah using a fully coupled THM code
- **Cooling propagates slowly**, so it only affects the region around injection wells
- **Tensile stresses are not predicted**, but **shear failure conditions occur**, which may induce microseismicity
- **Thermo-hydro-mechanical couplings** should be investigated case specifically to determine the **maximum sustainable injection pressure** and **temperature drop** to **achieve a safe injection**

ACKNOWLEGEMENTS

FRAC RISK

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U.S. DEPARTMENT OF ENERGY

THANK YOU FOR YOUR ATTENTION