UNIVERSITY OF LEEDS

Key issues related to underground geological CO_2 storage

Quentin Fisher

10th September 2021

Petriva Ltd., University of Leeds, Leeds, UK

E-mail: q.j.fisher@leeds.ac.uk

Outline

- Background to CO_2 storage
- Potential storage sites
- Key issues/unknowns
- Conclusions

CCS background

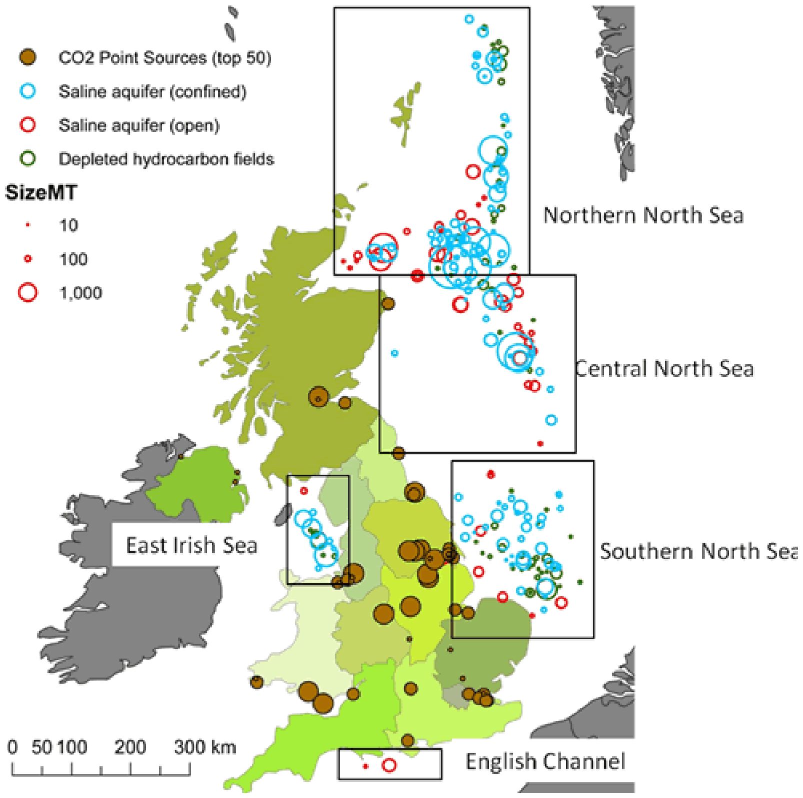
- CCS has been touted as a technology to reduce CO_2 emissions was first suggested in 1977 but has been slow to gain momentum
- Since 1972, CO_2 has been captured from the flue gas from gas plants in Texas and piped 220 miles before being injected into an oil field to enhance oil recovery
  - 175 million tonnes of CO_2 have now been injected into the reservoir
- Currently >100 active CO_2-EOR projects and 21 non-EOR projects capturing 30 Mt per year
- UK government planned a demonstration sites in 2015 but this was cancelled but now several projects seem to be going ahead offshore UK

Potential storage sites

- Storage sites can be broadly divided into three types
  - Disused gas fields
  - Disused oil fields
  - Deep saline aquifers
- Disused gas fields have an advantage that the pore space in the rock is filled with low pressure gas so large volumes of CO_2 can be injected before pressures become too high
- The pore space in saline aquifers and disused oil reservoirs are already filled with incompressible fluids so pressures will increase far more rapidly when injected with CO_2 unless the aquifers are very permeable and well connected

Storage capacity

- It has been estimated that UK continental shelf has enough storage capacity for 80 Gt of CO_2
- Enough to store CO_2 emitted by the UK for >250 years at current levels



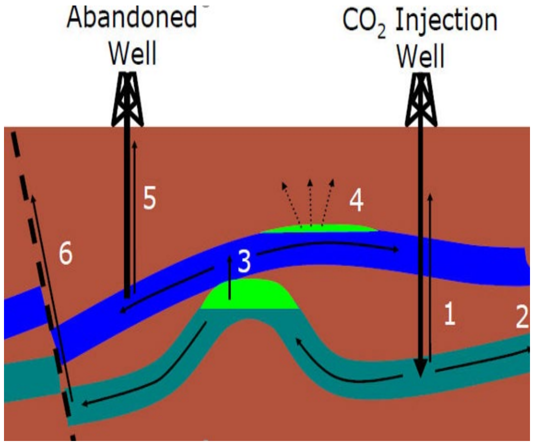
(from Energy Technologies Institute)

Technological readiness

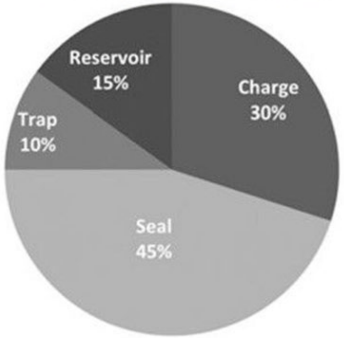
- Since 1972, CO_2 has been captured from the flue gas from for gas plants in Texas and piped 220 miles before being injected into an oil field to enhance oil recovery
  - 175 million tonnes of CO_2 have now been injected into the reservoir
- Currently >100 active CO_2-EOR project
- Currently 21 non-EOR projects capturing 30 Mt per year
- Natural gas has been stored in depleted gas reservoirs since 1915

Key issues: Leakage

- To be effective, leakage rates need to be <<1% per year so an effective seal to the storage sites is needed
- The seal to oil and gas reservoirs is proven as they have trapped petroleum for 10-300 million years
  - Question as to how much production impacts sealing capacity?
- Sealing capacity of caprocks to saline aquifers is often less certain and the petroleum industry has a poor record of estimating seal capacity

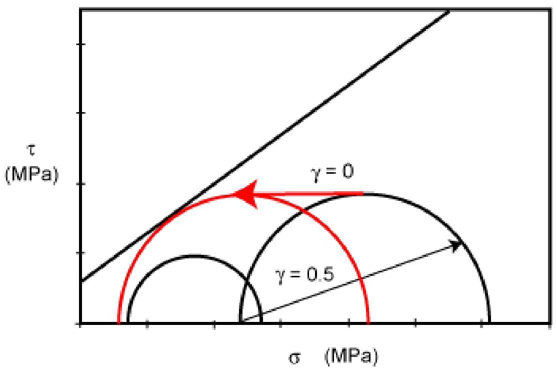


Reasons for failure of exploration wells (SLB study; Laver et al., 2012)

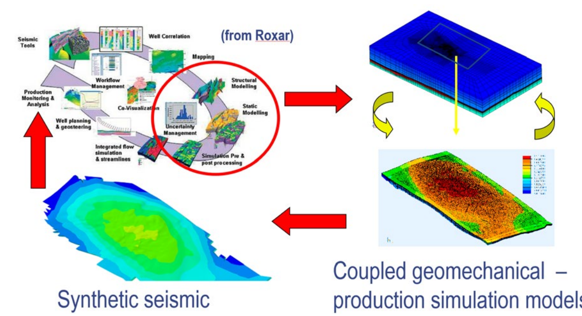


Key issues: Fault reactivation/leakage

- Poroelastic effects mean that subsurface stresses are coupled to pore pressures
- Failure to correctly predict stress path during CO_2 injection could lead to fault-reactivated causing seismicity and leakage
- Very few stress measurements have been made after start of reinjection
  - Evidence of hysteresis in stress path
- Significant advances made in coupled fluid flow - geomechanical modelling, which might help but constructing such models is highly complex and few are verified



based on Santarelli et al., (SPE, 47350)

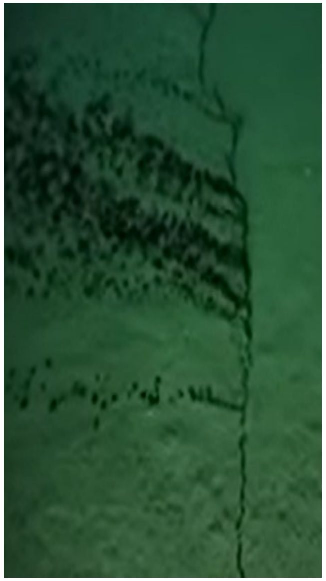


Key issues: Top seal leakage

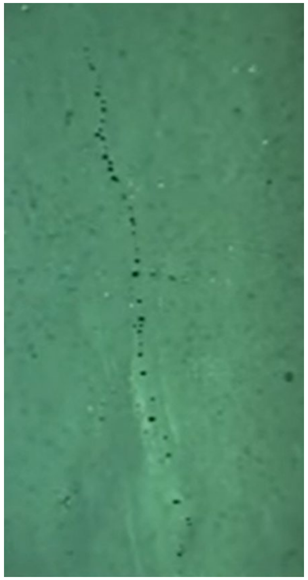
- The petroleum industry has a poor record in predicting top seal capacity
    - However, the fact that time-scales are different (>1000 years CCS, >10 Ma for petroleum) may mean this is not such an issue
- Worry that induced-fractures or reactivated faults may not close easily if gas is the leaking phase as oppose to brine or oil

Oil leakage from Frade Field, offshore Brazil

During injection



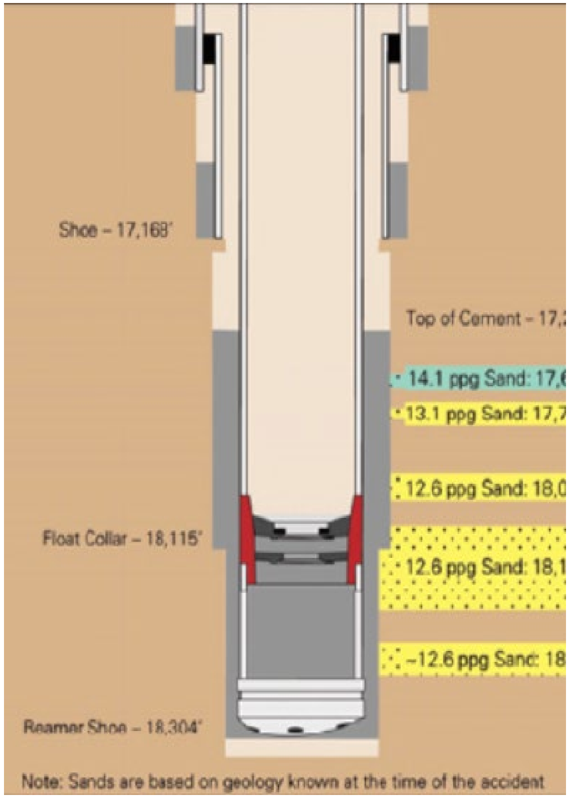
After injection



- https://www.youtube.com/watch?v=OtJTI4nv1QI

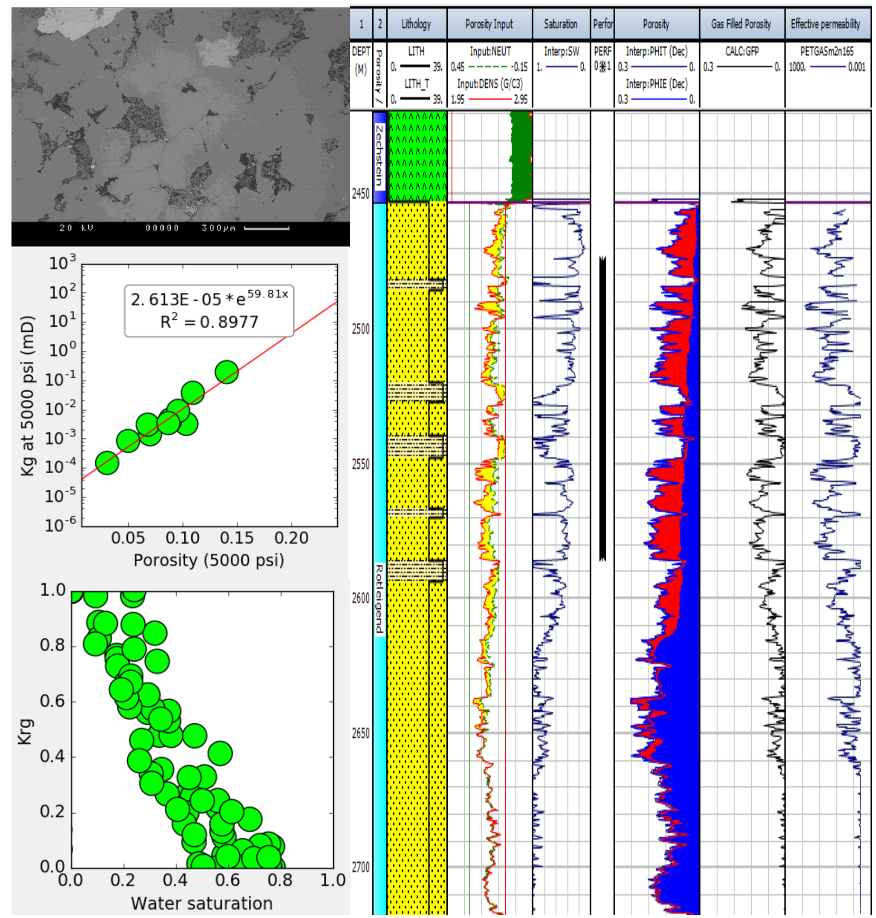
Key issues: Drilling into depleted reservoirs

- Not possible to reuse most existing wells for CO_2 storage in depleted reservoirs
- Horizontal stress in depleted reservoirs is often very low so weight of the cement column could create hydraulic fractures and prevent a good cement seal being formed around the casing
- Maybe licensing for new hydrocarbon reservoirs could involve making them compliant for CO_2 storage after abandon



Key issues: Reservoir quality

- Reservoir quality and connectivity of many saline aquifers is very poorly understood so expensive reservoir characterization my be necessary
- Costs could be cut by taking advantage of existing technology and databases e.g.:
  - Estimation of reservoir quality from cuttings
  - Fault rock properties and sedimentary architecture databases

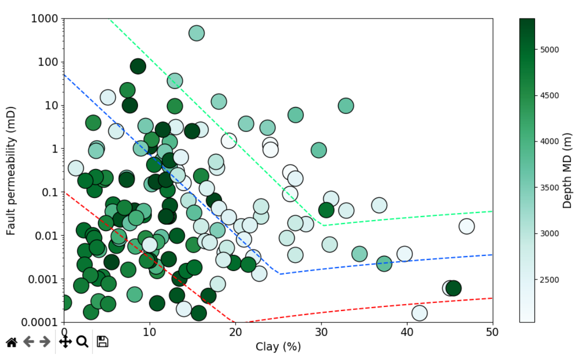


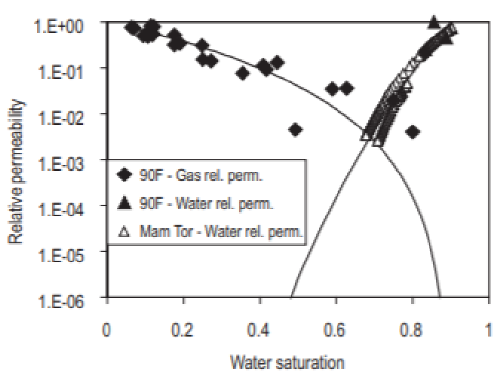
Key issues: Fault compartmentalization

- Fault compartmentalization could significantly impact CO2 injection into saline aquifers
- Already have large databases of the single and multiphase flow properties of fault rocks that can be used to reduce risk and plan injection strategies

Two-phase fluid flow properties of cataclastic fault rocks: Implications for CO_2 storage in saline aquifers

Christian Tueckmantel[1*], Quentin J. Fisher[1], Tom Manzocchi[2], Sergey Skachkov[1], and Carlos A. Grattoni[3]
[1]Centre for Integrated Petroleum Engineering and Geoscience, School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK
[2]Fault Analysis Group, School of Geological Sciences, University College Dublin, Dublin 4, Ireland
[3]Rock Deformation Research Limited, School of Earth and Environment, University of Leeds, Leeds LS2 9JT, UK





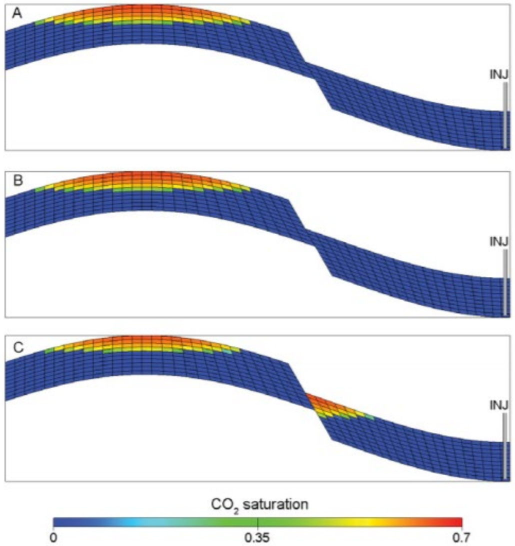


Figure 3. CO_2 saturation in central cross section of 3 models after 100 yr (40 yr of injecting and 60 yr of monitoring; INJ—position of injector well). CO_2 is injected into bottom right cell. The three cases differ only in the way the fault was incorporated into the model. A: Host case. B: Fault incorporated as transmissibility multipliers (single-phase case). C: Fault incorporated using dynamic upscaling based on laboratory data presented in Figure 1 (two-phase case).

Key issues: Cost/economic model

- CCS may cost >£50 per tonne of CO_2
- So >£200 extra per household per year
- Results from focus groups and opinion polls suggest general public support green policies such as reducing plastics but 80% objected to increasing energy bills by >5%

Conclusions

- CCS could potentially contribute significantly to achieving NetZero
- UK has storage capacity of >250 years at current emissions
- CCS can help with intermittency problems associated with wind and solar
- Technologies for underground CO_2 storage are quite well tested
- Might be worth insisting new petroleum fields are only developed with built-in infrastructure for CO_2 storage
- Technical issues do exist but do not prevent rapid expansion of CO2 storage (i.e. important not to let research questions hold back the technology)
- Key barrier to rapid deployment of CCS appears to be funding model