ULTimateCO2 – Understanding the long-term fate of geologically stored CO2

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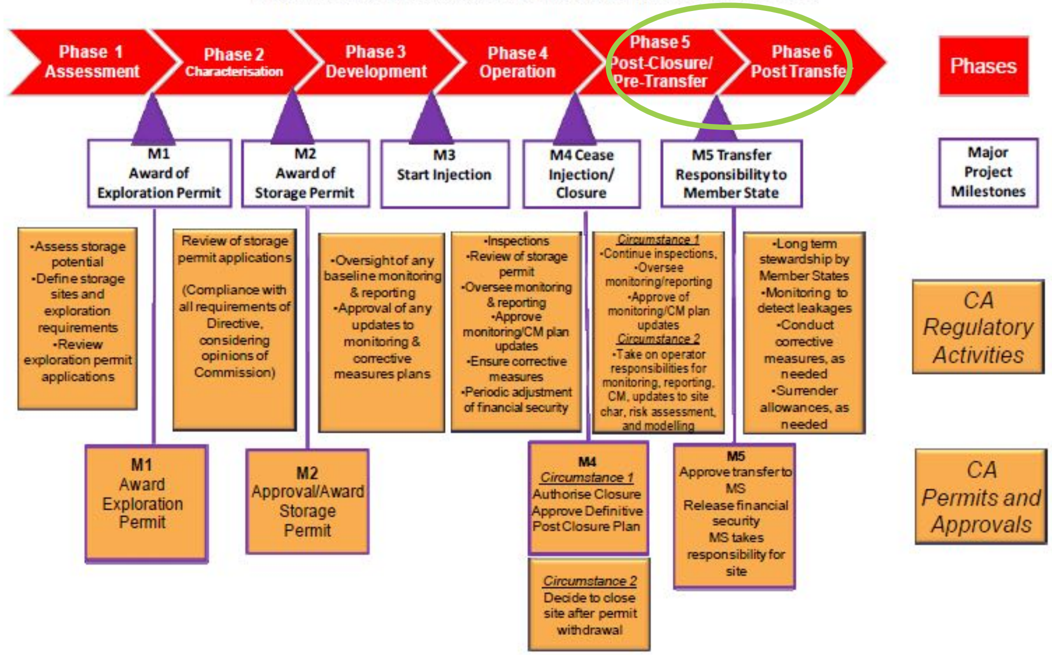
What is long term?

- **Regulation aspects**: from the CCS Directive. End of injection? end of monitoring? Site closure?

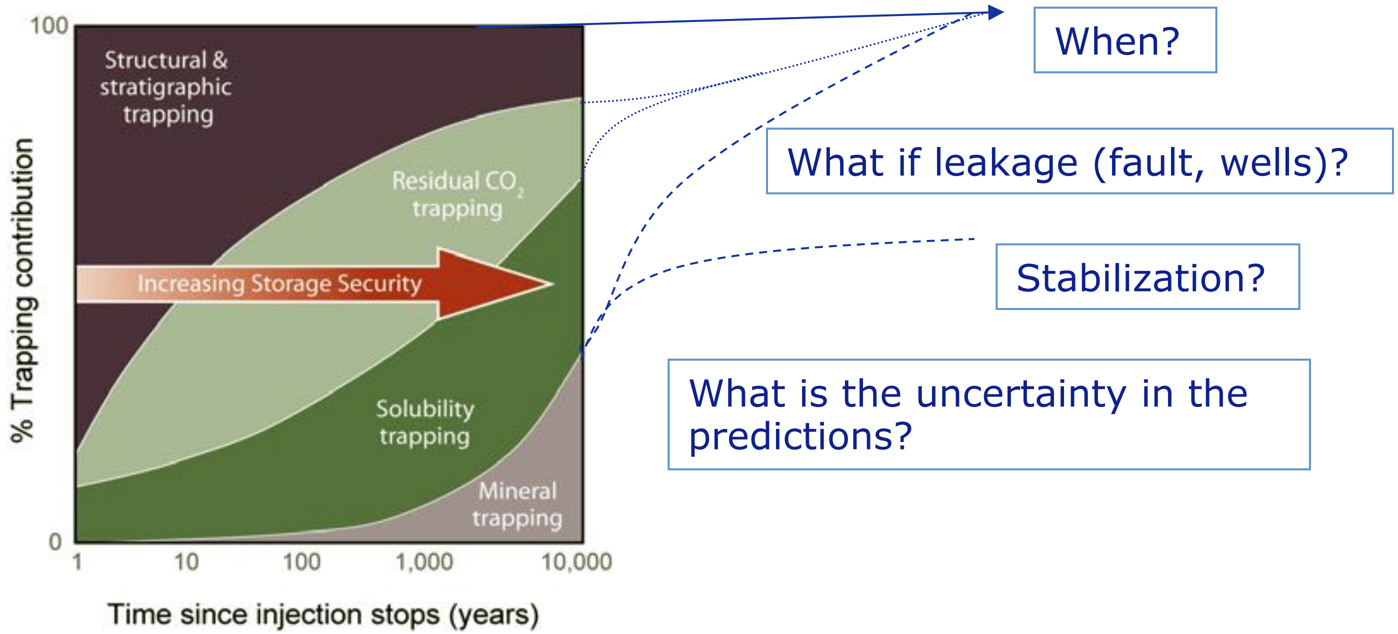
Figure 1: Summary of CO_2 Storage Life Cycle Phases and Milestones



ULTimateCO2 focused on the phase 5 and 6: transfer of responsibility between operators and competent authority

What is long term?

➔ **Physical processes aspects**: disappearance of free CO2? stability of the systems?



ULTimateCO2 aimed at addressing some of these aspects in a non exhaustive manner

Objectives (1/2)

- **Advance our knowledge** of specific processes that may affect the understanding of the long-term fate of CO2
- **Yield validated tools** for predicting long-term storage site performance
- **Laboratory, field and modelling** studies of**:**
  - **trapping mechanisms** in the reservoir (structural, residual dissolution and mineral [SRDM])
  - **fluid-rock interactions and effects on mechanical** integrity of the caprock
  - **leakage** associated with mechanical and chemical damage in the well vicinity
- **Integration of the results at regional scale**:
  - into assessing the overall long-term behaviour of storage sites at **basin scale** in terms of efficiency and security

Objectives (2/2)

- **Develop guidelines for operators and regulators to enable a robust demonstration of the assessment of long-term storage site performance:**
  - by drawing on the lessons learned within the project,
  - by relevant research internationally
  - through dialogue with targeted stakeholders

- **Help to raise confidence with key stakeholders**:
  - Dissemination of scientific knowledge on the long-term efficiency and safety widely to a broad audience, (Operators, investors, regulators, policy-makers, the research community, public NGOs and politicians)
  - To improve public perception

ULTimateCO2 consortium

Consortium

R&D Institute

NATURAL ENVIRONMENT RESEARCH COUNCIL

GEUS

TNO innovation for life

swisstopo

brgm Géosciences pour une Terre durable

BGR

IFP Energies nouvelles

EIFER European Institute for Energy Research

Industrial

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Ministère de l'Écologie, du Développement durable et de l'Énergie

Department of Energy & Climate Change

Private Consultant

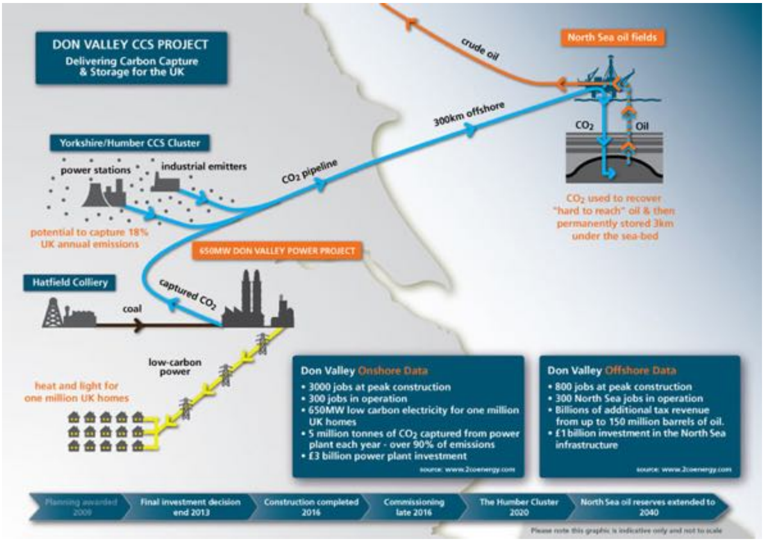
T. Torp

CO2 GeoNet

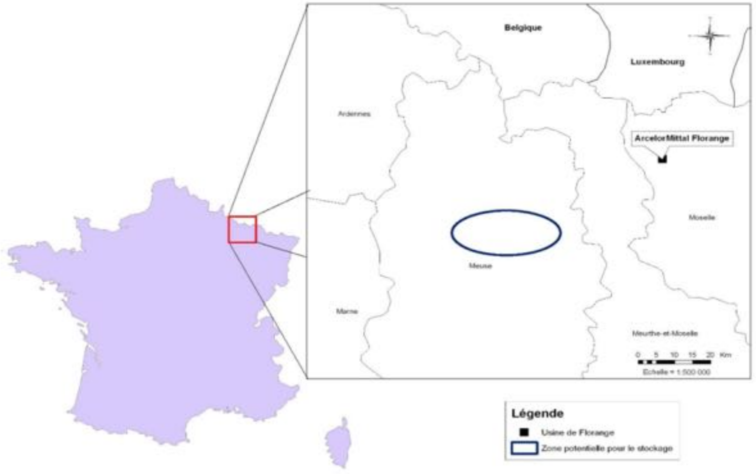
Long Term Reservoir trapping evolution

- **Realistic contexts and scales** ensured by using typical geological environments suitable for storage demonstration sites in deep saline sandstone formations: one **onshore in West Lorraine France** and the other **offshore in the North Sea, UK**

Off shore North Sea UK, Don Valley project, 2Co Operator combined with EOR

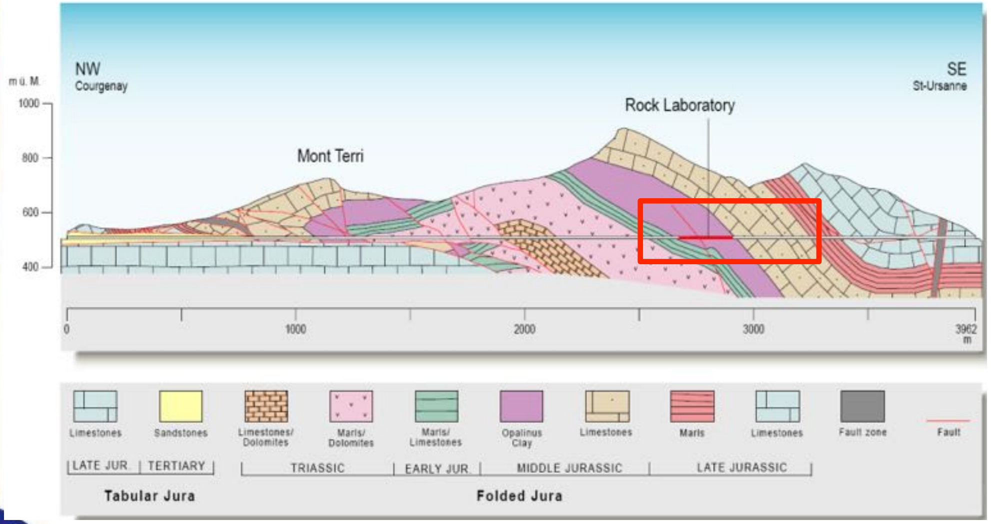


On Shore outcropping former ULCOS, NER300 candidate in Lorraine in France



Long term wellbore sealing integrity

Use of Underground Rock laboratory, Mont Terri in Switzerland



after Mont Terri project website, 2013

Directive Implementation

- The Operator shall prepare a report documenting that some required conditions have been met and shall submit a report to the Competent Authority for the latter to approve the transfer of responsibility.

- This report shall demonstrate, at least:
- ***the conformity of the actual behaviour of the injected CO2 with the modelled behaviour;***
- ***the absence of any detectable leakage;***
- ***that the storage site is evolving towards a situation of long-term stability.***

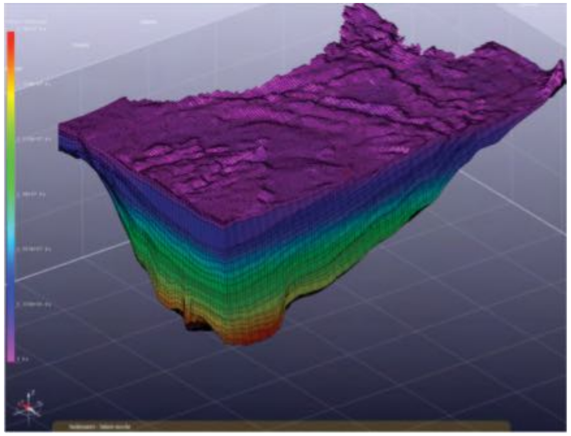
Guidelines structure

- Structure of the report based on these 3 criteria
  - ***(a) the conformity of the actual behaviour of the injected CO2 with the modelled behaviour***
  - ***(b) the absence of any detectable leakage***
  - ***(c) that the storage site is evolving towards a situation of long-term stability***

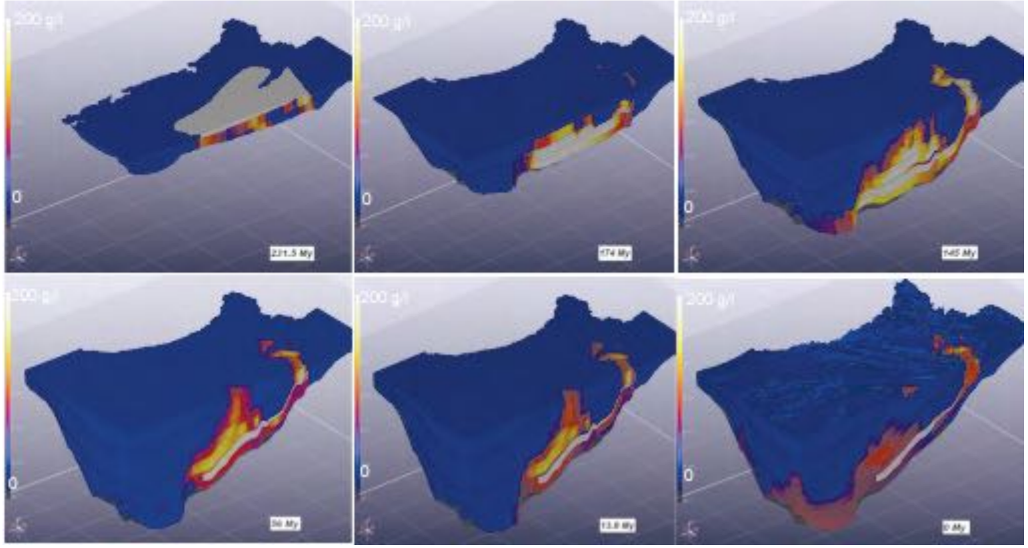
Contents

Combining basin and reservoir models

- Basin-reservoir coupling allows the initial hydro-dynamics and pressure singularities of a reservoir to be taken into account – leading to more accurate predictions for CO2 storage.
- *Improving the assessment of initial pressure conditions: initial pressure based on the basin model*
- *The Paris basin case*



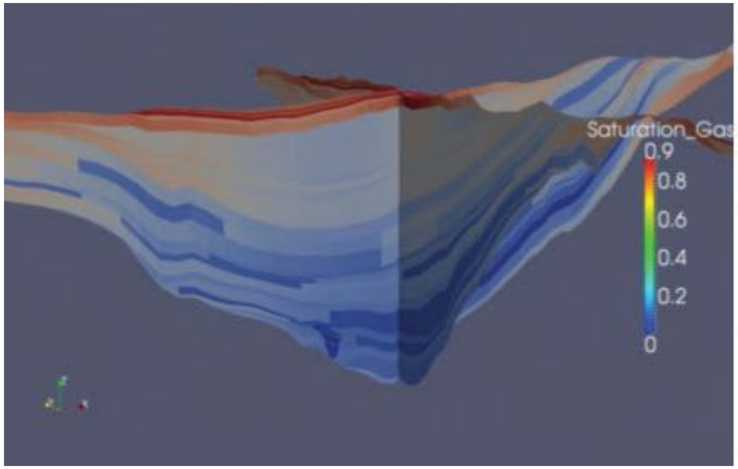
initial pressure
Calculated on the paris basin restiration model

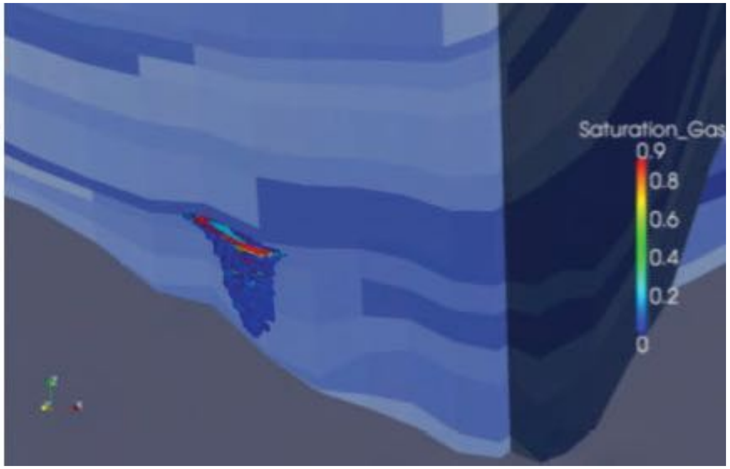


3D view of the simulated salinity field through time (231.5 My, 174 My, 143 My, 56 My, 12.8 My, today (0 My)). Color scales range from 0 g/l (deep blue) to 200 g/l (white).

Advanced modeling tools

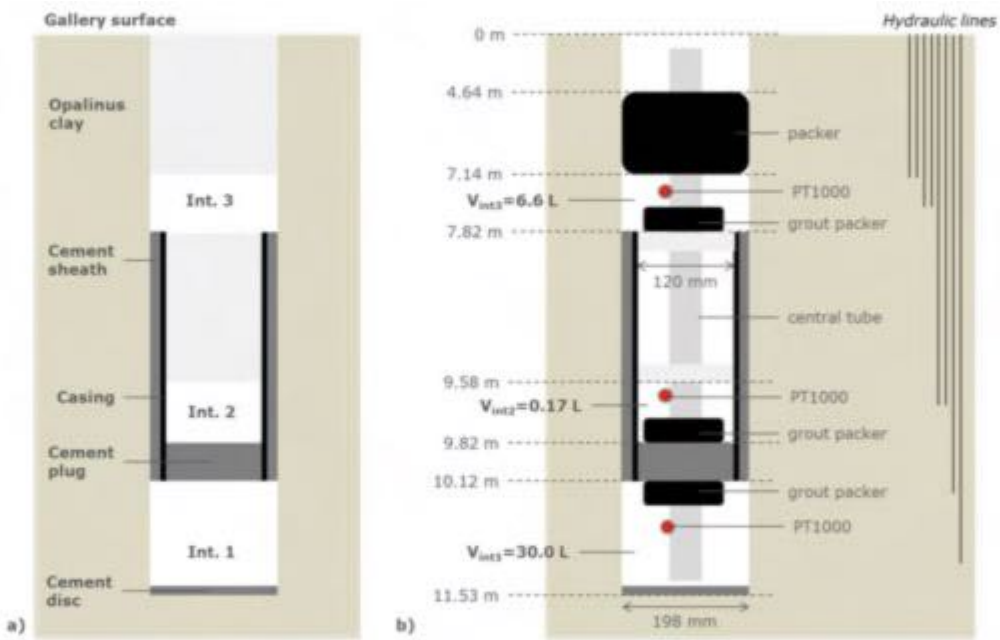
- **Adaptive Mesh Refinement** significantly improves modelling resolution
- *CO_2 gas saturation after 1,000 years by using an AMR technique (left – basin-scale view, right – reservoir-scale view)*

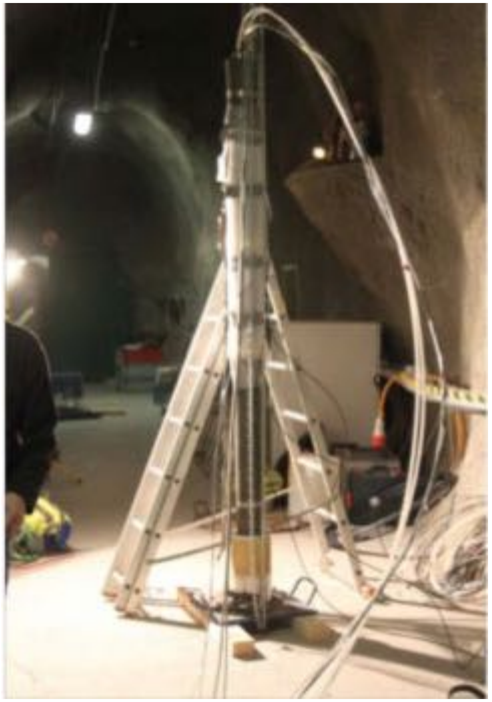




The Mont Terri well experiment

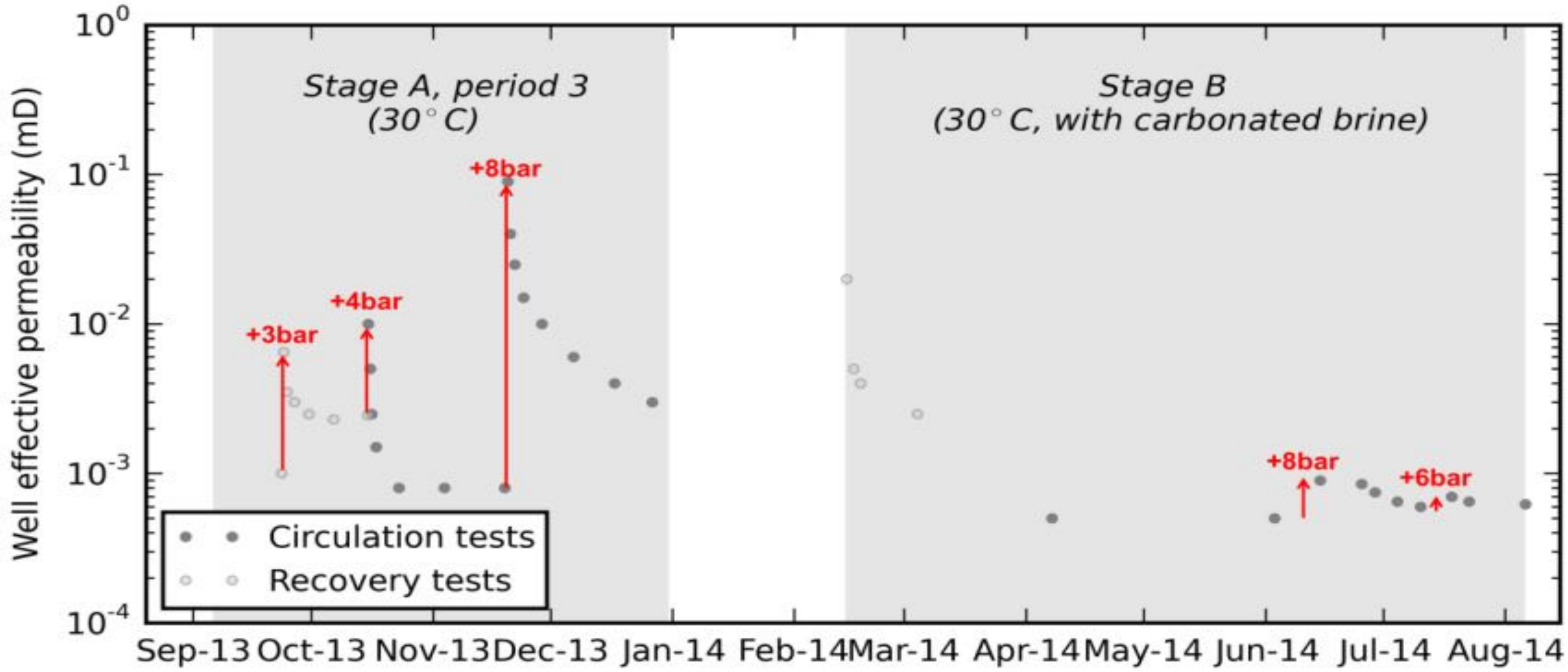
- A 1:1 scale experiment to evaluate the integrity of a pseudo well in contact with CO2-dissolved in water





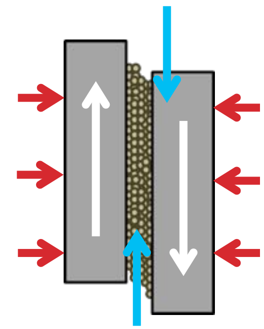
Well permeability

- Influence of Temperature and CO2

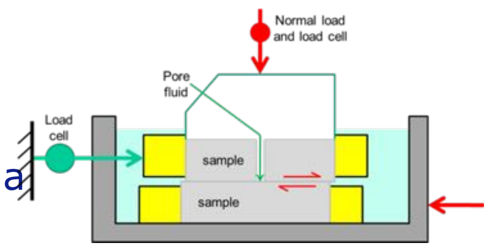


Long term fault sealing integrity

- **Three inter-related lines of laboratory experiments** investigate the long-term evolution of the mechanical properties and sealing integrity of fractured and faulted caprocks:
  - **Gouge shearing (UU):** Quantify effects of carbonate content and temperature on frictional & transport properties of simulated caprock fault-gouge by direct shear friction experiments on gouge at 20˚C -120˚C
  - **Fracture reactivation (BGS):** gas transport properties of a fracture. A cube of OPA loaded and sheared to create a "realistic" fracture, followed by a gas injection in the fracture plan to characterize the hydraulic fracture flow properties
  - **Chemical aging (IFPEN):** experiments evaluate the effects of a chemical attack (acid leaching) on the transport properties and mechanical integrity of pre-fractured (by freezing) Opalinus clay samples.

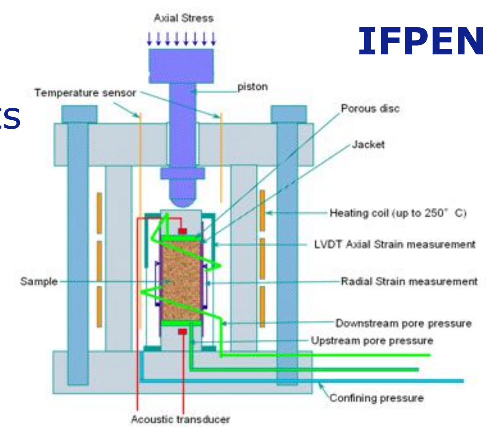


Utrecht Univ.



BGS

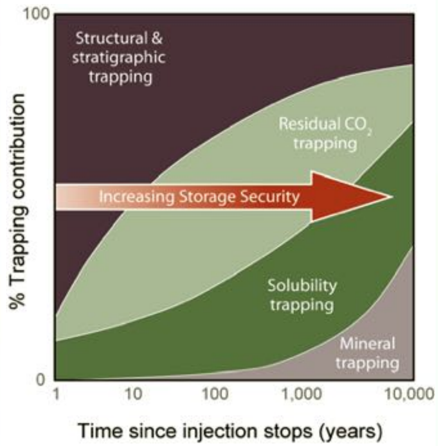
IFPEN

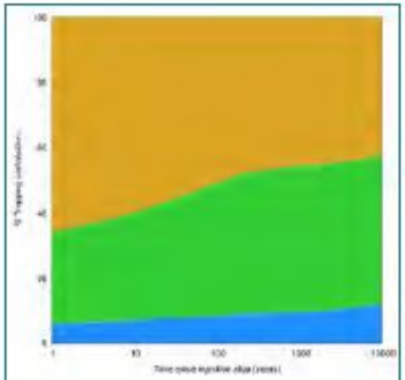


ALL MECHANICAL EXPERIMENTS CONDUCTED ON OPALINUS CLAY FROM MONT TERRI UNDERGROUND ROCK LABORATORY

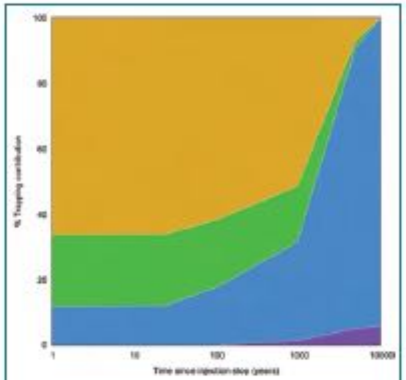
Trapping diagrams

- A large amount of free (mobile) gas remains after decades in the reservoir

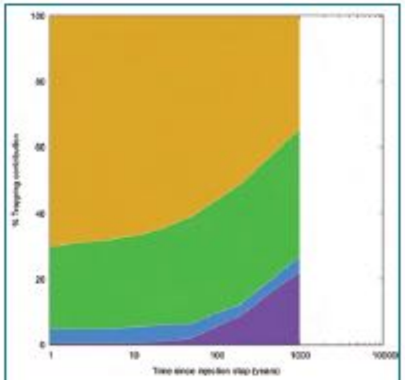




- North Sea Bunter case, without mineralization
- Closed domal structure
- A very large proportion of CO_2 remains in gaseous form, either structurally or residually trapped



- Sleipner storage site
- Flat aquifer
- Convection develops over the long term, giving rise to massive dissolution.
- Re-plot of the trapping diagram of Audigane et al., 2007[43]



- GeoLorraine case
- Tilted aquifer
- A large amount of CO_2 remains in supercritical form

Key messages (1/2)

- CO2 injected into a storage site can change its nature over time or reacting chemically with rocks to produce minerals
- **More than 50% of CO2 remains in a supercritical** for several decades after site closure (modeling work)
- Mineral trapping is limited in sandstone reservoirs
- Conformity between modelling and monitoring is more challenging for geochemical processes
- **Use of basin-scale models** to improving pressure impacts

Key messages (2/2)

- When testing Opalinus Clay resistance to various fault rupture mechanisms, **the caprock showed a low risk of failure.** These results are specific to experimental conditions and extrapolations to real-life situations should be taken with necessary caution.

- Well experience in Mont Terri reveals **a low impact of CO_2 on well integrity**. However, high sensitivity to pressure and temperature variations, meaning that the 'history' of the well will strongly influence its integrity.

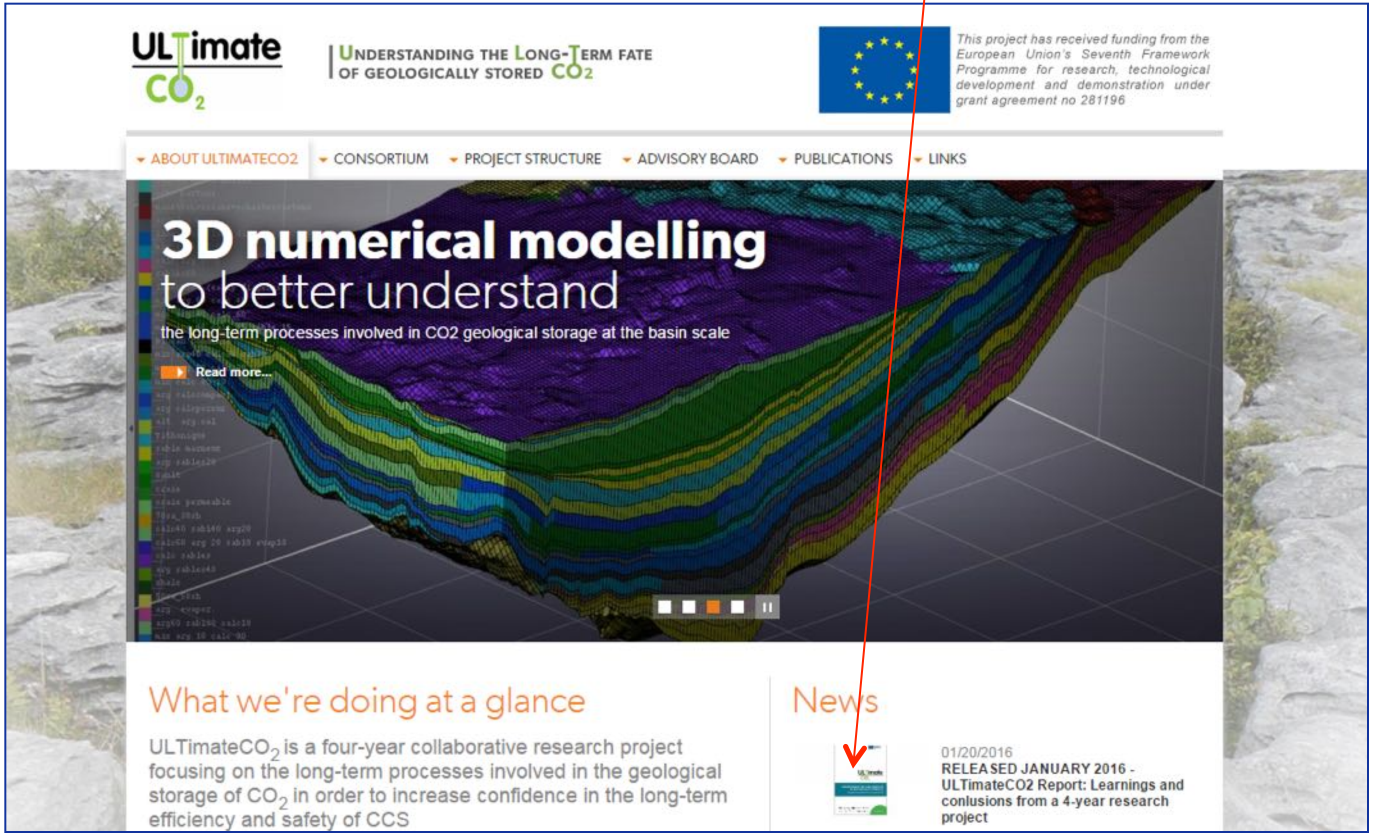
- In general, the integrity of **caprock and wells showed a tendency to self-heal** in the presence of CO_2.

Conclusion

In summary, ULTimateCO2 research confirmed that the impact of long-term CO2 storage is low – **no critical thresholds were reached in terms of pressure, fault reactivation** or the development of CO2 flux/flow. While uncertainty should be factored in when looking at long time scales, the migration of the CO2 plume was limited using the geological context of the project

Web site www.ultimateco2.eu

➔ **Download the guidelines report (public)!**



Thank you

Dissemination / events

- Press releases

- Publications / Congress
- COP21