# De-risking $CO_2$ injection and storage in Chalk

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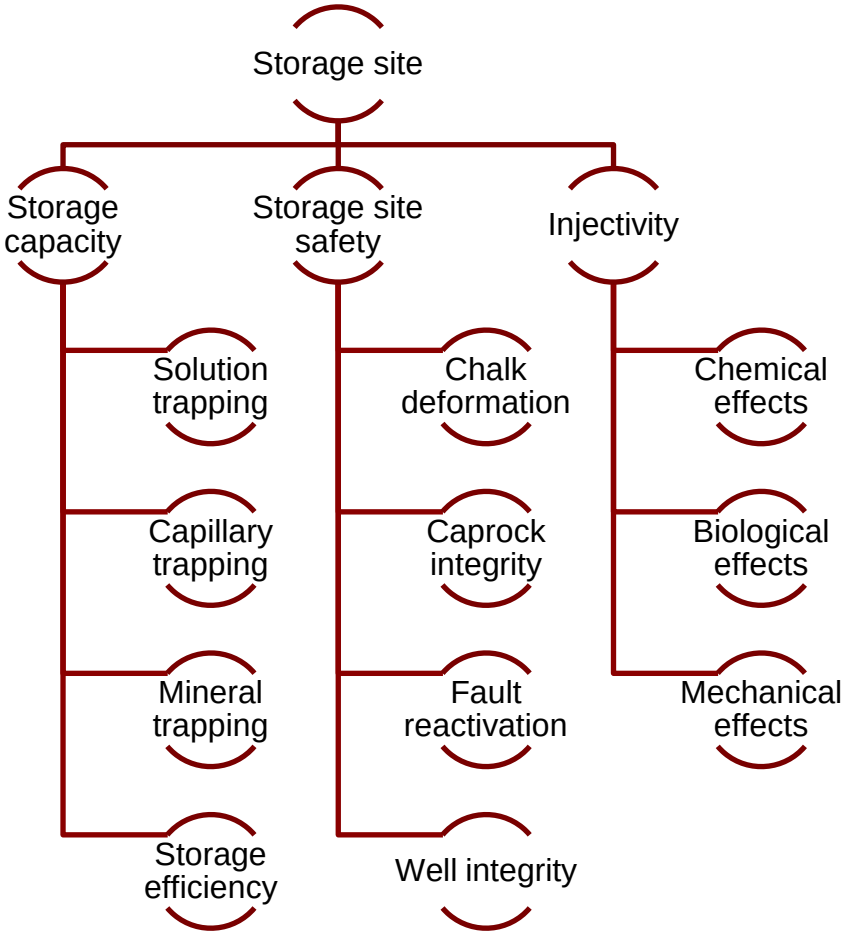
# $CO_2$ Storage – State of the Art Study

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## Challenges and enablers for large-scale $CO_2$ storage in chalk formations

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ABSTRACT

The past two decades of research on Carbon Capture and Storage (CCS) seem to have finally become fruitf
global leaders and energy-intensive industries are cooperating to materialize CCS projects and reach
promised reduction in $CO_2$ emissions. Traditionally, CCS projects targeted mostly high permeability sands
formations, despite the numerous carbonate fields undergoing $CO_2$ injection for Enhanced Oil Recovery (EOF
the United States or Canada. Because of the reactivity between calcite minerals and $CO_2$ saturated water, c
formations, characterized by high porosity and low permeability, have been previously portrayed as infeas
$CO_2$ storage sites. Although previous laboratory investigations were carried out to assess the performance of
EOR in North Sea chalk fields, these studies did not result in any field-scale demonstration projects; this may
change since a positive movement towards $CO_2$ storage in depleted oil fields has been recently initiated. In
work, we reviewed existing studies on $CO_2$ injection in chalk to address the suitability of this type of forma
for CCS. Although the evidence on the thermo-hydro-mechanical-chemical behaviour of chalk in the presen
$CO_2$-saturated aqueous solutions is mixed, the majority of flooding tests performed on reservoir core sample
not support further weakening relative to water injection conditions nor significant changes in the petrophy
properties. Along with the weakening effect and using the Danish North Sea chalk fields as a case study
addressed events that impact the storage site safety such as fault reactivation, and caprock and well integ
Furthermore, monitoring techniques relevant to offshore locations are also discussed. Based on studies on
types of carbonates, and considering the characteristics of chalk (e.g., permeability, wettability, and reacti
we analysed the relevance of different trapping mechanisms (i.e., solution, capillary, and mineral) but
several effects (i.e., chemical, biological, mechanical) that can lead to loss of injectivity. The main observa
and conclusions in this work can be easily extrapolated to other chalk formations worldwide.

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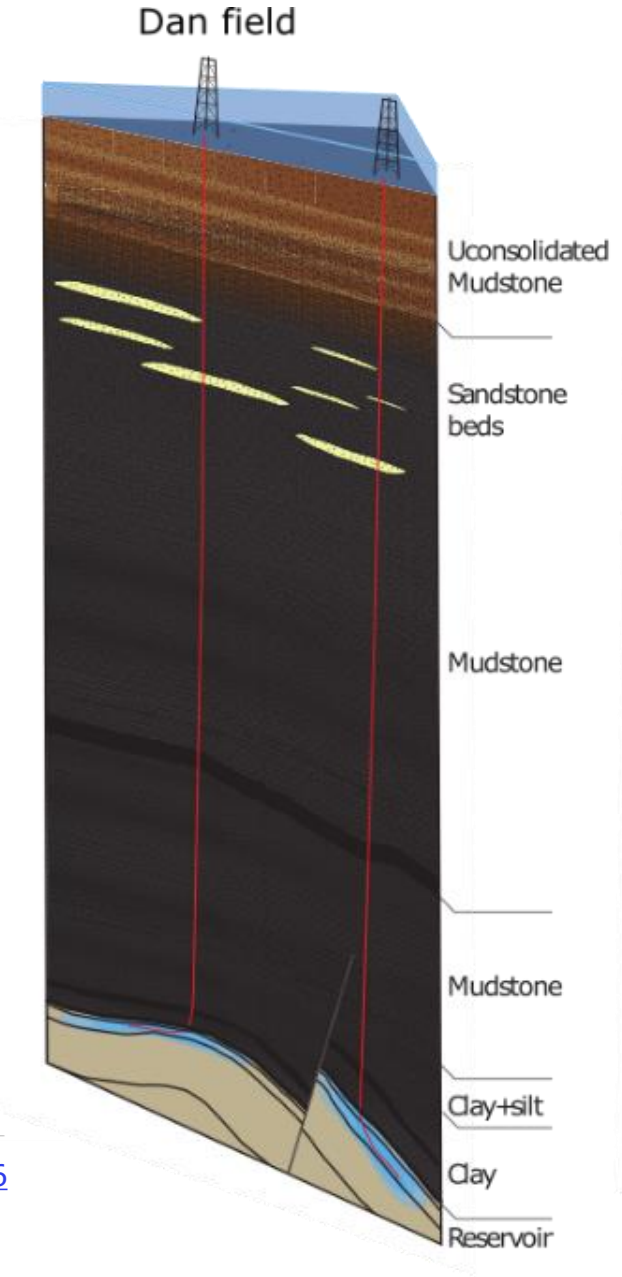


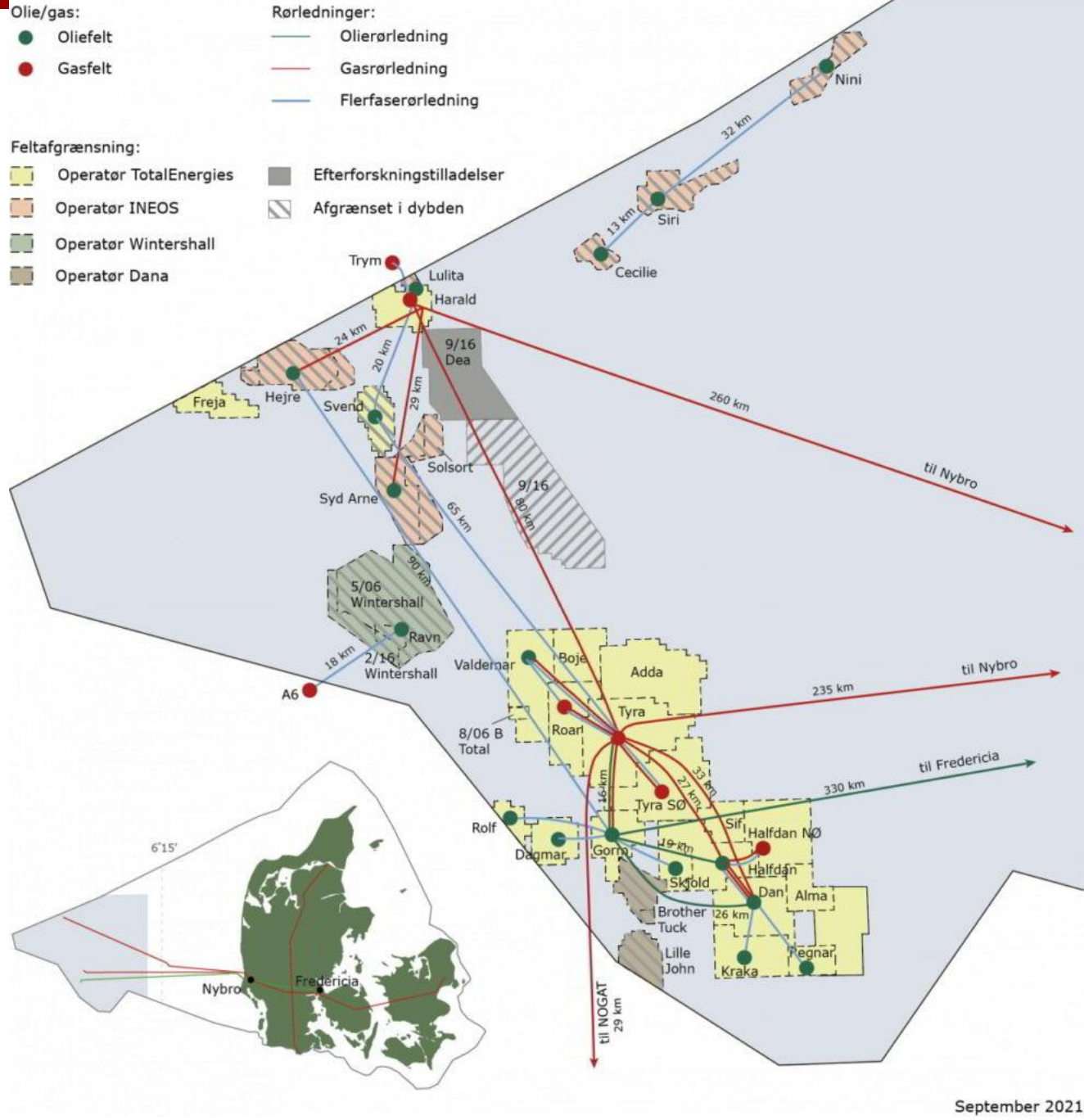
# $CO_2$ storage in depleted North sea hydrocarbon fields

## Benefits

- Available subsurface data and reservoirs models inherited from oil and gas operations
- Existing infrastructure
- Effective caprock
- Social acceptance of offshore sites compared to near shore ones

## Drawbacks

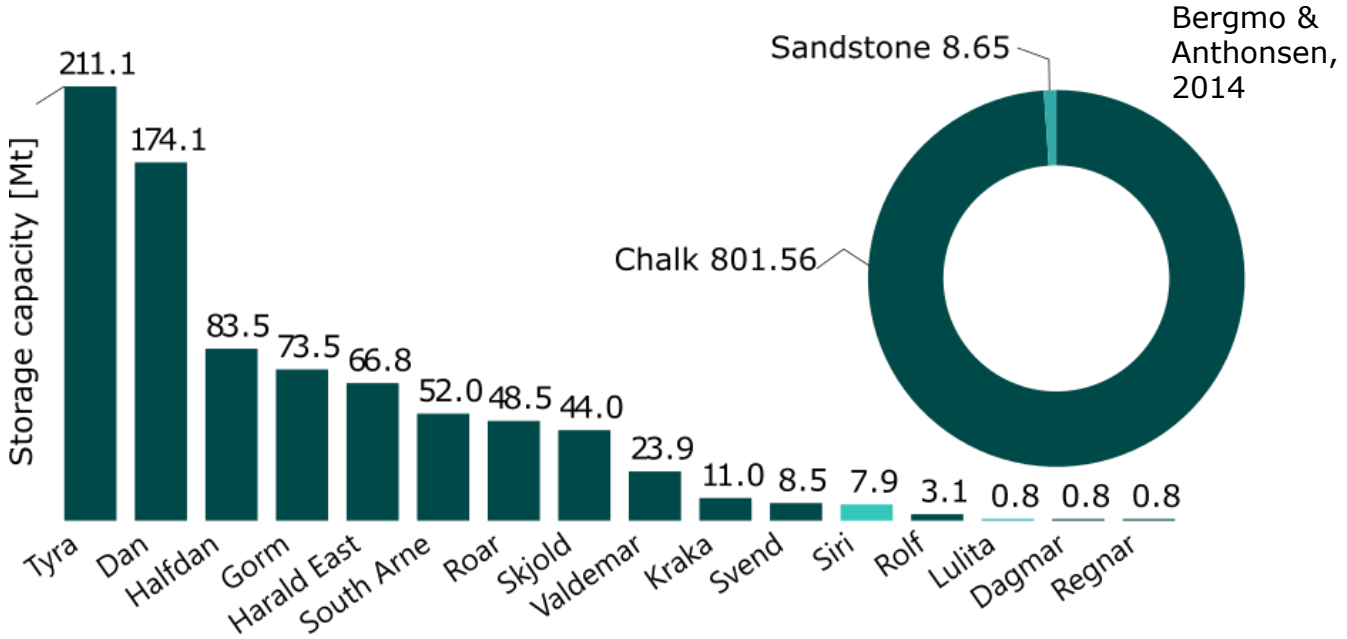
- Increased cost for $CO_2$ transportation offshore
- High number of wells may increase the probability for leaks



# Storage capacity

Estimates are highly uncertain and calculated using a static approach

Storage capacity for different fields in the Danish North Sea




Bergmo & Anthonsen, 2014

Overall capacity dependent on storage mechanisms

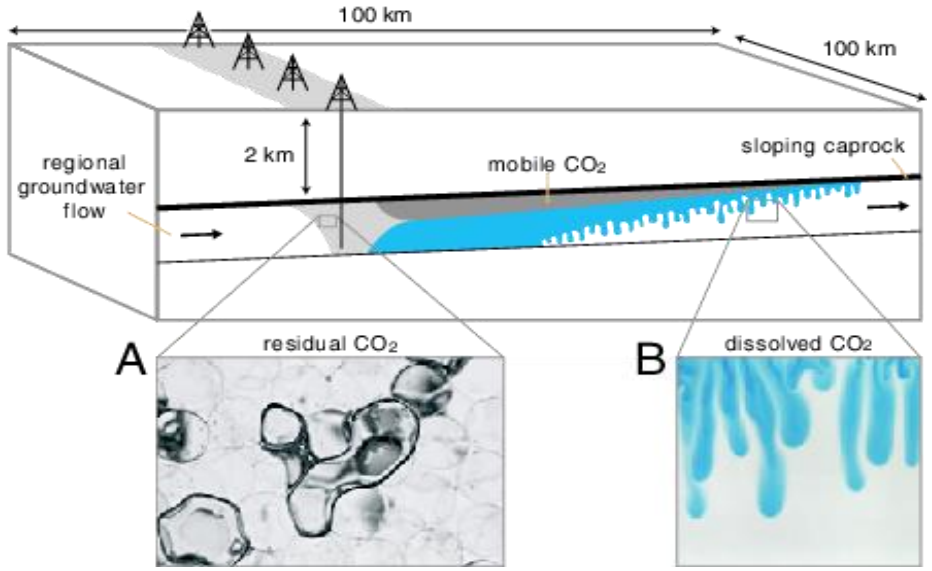
- Structural trapping
- Solution trapping
- Capillary trapping
- Mineral trapping

Storage mechanisms depend on:

- P, T, reservoir condition
- Chalk wettability and reactivity
- Saturations and compositions of brine and oil

# This project, focusing on chalk, will address:

- Injectivity
- Trapping efficiency
- Reservoir deformation
- Flow properties
- Upscaling
- Core to reservoir scale simulations
- Monitoring and acoustic responses




Szulczewski, M.L., et al. "Lifetime of carbon capture and storage as a climate-change mitigation technology." Proceedings of the National Academy of Sciences 109.14 (2012)

# Overview

**Data gathering**

**CO2 long term soaking experiments**

Challenges and enablers

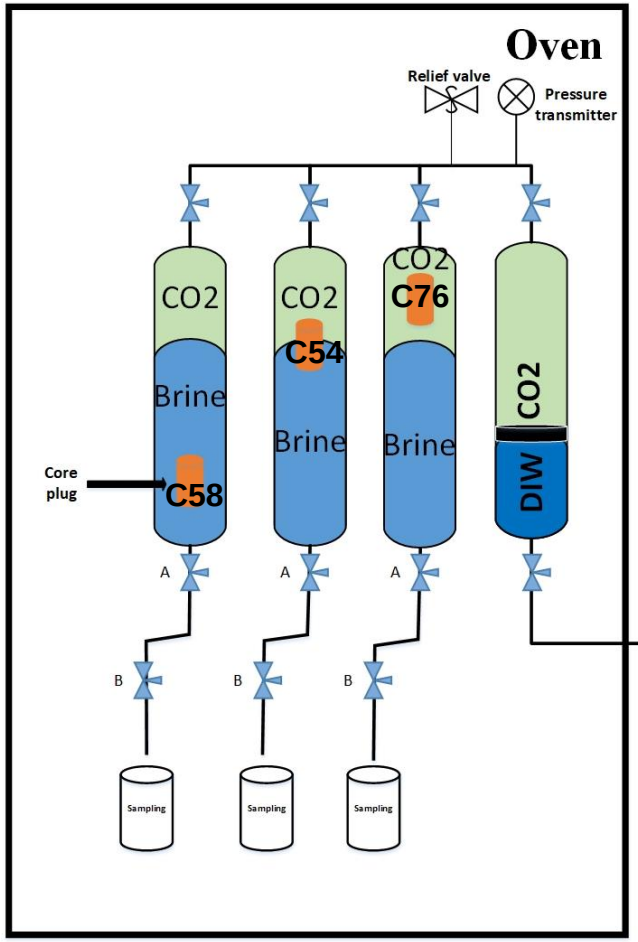
Test on 1-inch Gorm plugs to investigate effects longer term $CO_2$ exposure on the chalk in the presence of brine

**Completed**

**Paper published**

**Completed**

**Analysing results**




Aim:
Investigating long term $CO_2$-Brine-Rock interactions

**Core plugs**

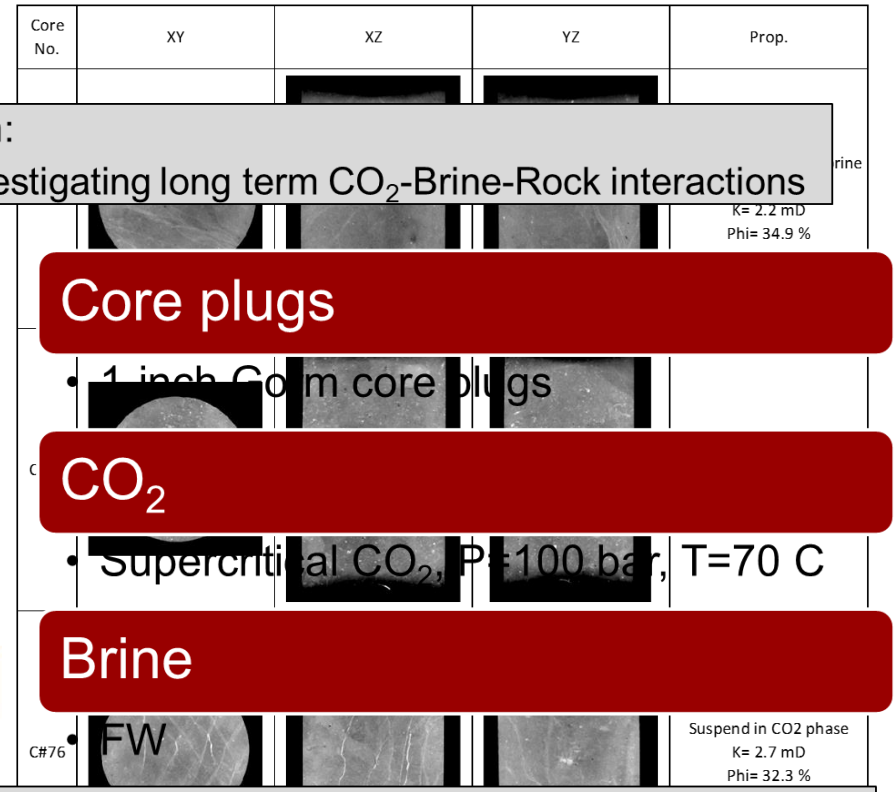
- 1-inch Gorm core plugs

**$CO_2$**

- Supercritical $CO_2$, P=100 bar, T=70 C

**Brine**

- FW




Analyses:

- Brine samples ion chromatography
- CT imaging before and after experiment
- Geomechanical tests after long term Soaking

# Overview

**Data gathering** → **CO2 long term soaking experiments** → **Core flooding in the CT scanner**

Challenges and enablers

Test on 1 inch Gorm plugs to investigate effects longer term $CO_2$ exposure on the chalk in the presence of brine

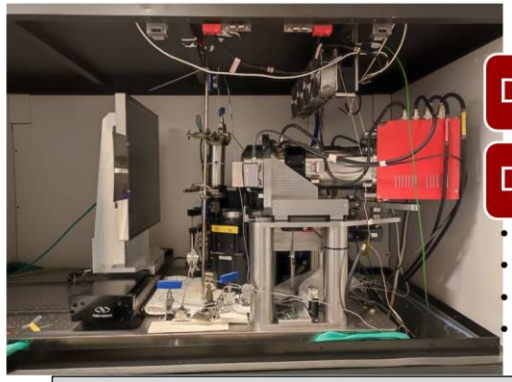
Test on 1.5 inch Gorm plugs to investigate effects of $CO_2$ injection in chalk under dynamic conditions

**Completed** → **Paper published**

**Completed** → **Analysing results**

**First test completed** → **Image processing**

**Aim:**
Investigating $CO_2$-Brine-Rock interactions in a dynamic condition



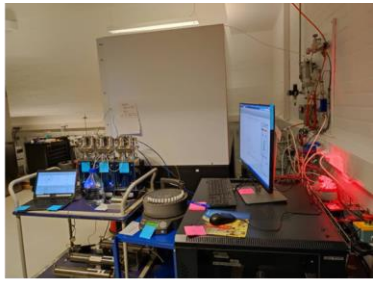
Different core plugs

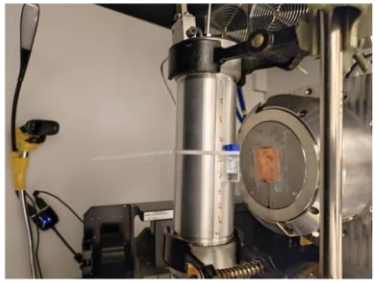
Different injection scenarios

- SC $CO_2$, Carbonated water,…
- Continuous injection, WAG,…
- Different injection rates
- …

**Analyses:**

- 3D CT imaging before and after experiment
- Imaging during the experiment (An image every 1 minute)
- Effluent samples ion chromatography
- Pressure-rate responses





**Current experiment**

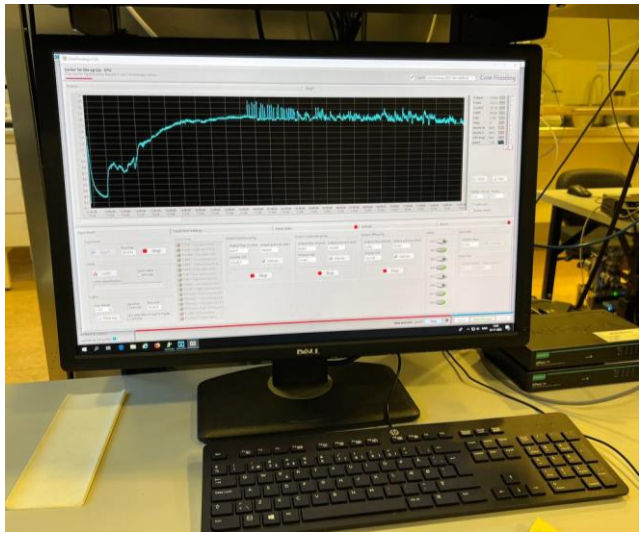
- Core plug: Stevns Klint
- Flooding scenario: Gorm FW → Carbonated FW
- Carbonated FW: 500 cc Gorm FW + 32gr $CO_2$
  pH~ 3.2
- Test conditions:
  Pressure = 100 bar
  Temperature = room

Liquid $CO_2$

# Overview

- ✓ Pressure-Production responses
- ✓ CT images
- ✓ Effluent analyses
- ✓ Geomechanical study

**Core flooding in CO2 flooding rigs**



Test on 1.5 inch Gorm plugs to investigate effects of $CO_2$ injection in

**flow behavior**

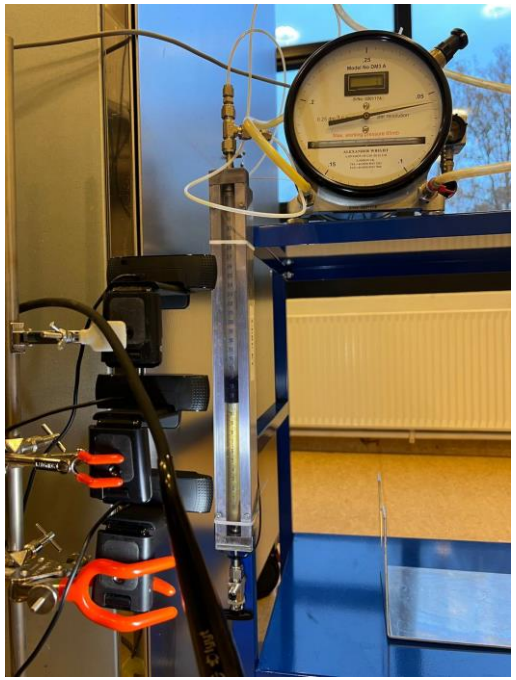
and

**geomechamical properties**

**Running**

↓

**Data acquisition**



# Overview

| Data gathering | CO2 long term soaking experiments | Core flooding in the CT scanner | Core flooding in CO2 flooding rigs | Core flooding by measuring acoustic signals |
|---|---|---|---|---|
| Challenges and enablers | Test on 1 inch Gorm plugs to investigate effects longer term $CO_2$ exposure on the chalk in the presence of brine | Test on 1.5 inch Gorm plugs to investigate effects of $CO_2$ injection in chalk under dynamic conditions | Test on 1.5 inch Gorm plugs to investigate effects of $CO_2$ injection in flow behavior and geomechamical properties | Test on 1.5 inch Gorm plugs to get more insights on $CO_2$ effect under dynamic conditions |
| **Completed** | **Completed** | **First test completed** | **Running** | **Preparation** |
| **Paper published** | **Analysing results** | **Image processing** | **Data acquisition** | **Modifying core holders** |

# Overview


| Challenges and enablers | Test on 1 inch Gorm plugs to investigate effects longer term $CO_2$ exposure on the chalk in the presence of brine | Test on 1.5 inch Gorm plugs to investigate effects of $CO_2$ injection in chalk under dynamic conditions | Test on 1.5 inch Gorm plugs to investigate effects of $CO_2$ injection in flow behavior and geomechamical properties | Test on 1.5 inch Gorm plugs to get more insights on $CO_2$ effect under dynamic conditions | Implementing the experimental results into the models to estimate the various trapping mechanisms and reducing the uncertaineties in the large scale modelling |
|---|---|---|---|---|---|
| **Completed** | **Completed** | **First test completed** | **Running** | **Preparation** | **Planned** |
| **Paper published** | **Analysing results** | **Image processing** | **Data acquisition** | **Modifying core holders** | **Planned** |

# Thanks for your attention

Any comments or questions?