Carbon Capture and Storage in Norway

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Norwegian Geotechnical Institute

https://sense-act.eu/

Presentation for Tallinn University of Technology
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Digital

Outline

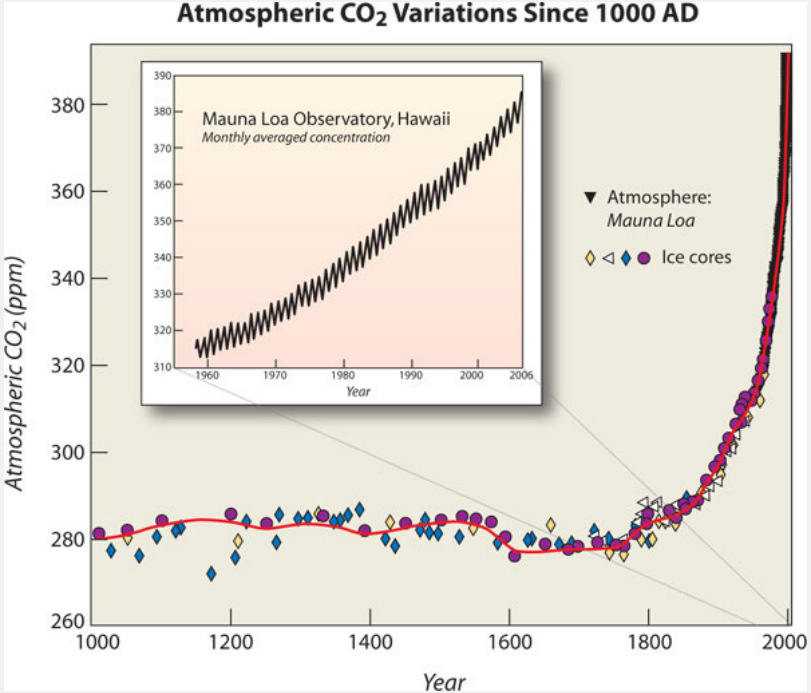
- Introduction
- CCS projects in Norway and beyond
- SENSE project
- Summary

This is NGI

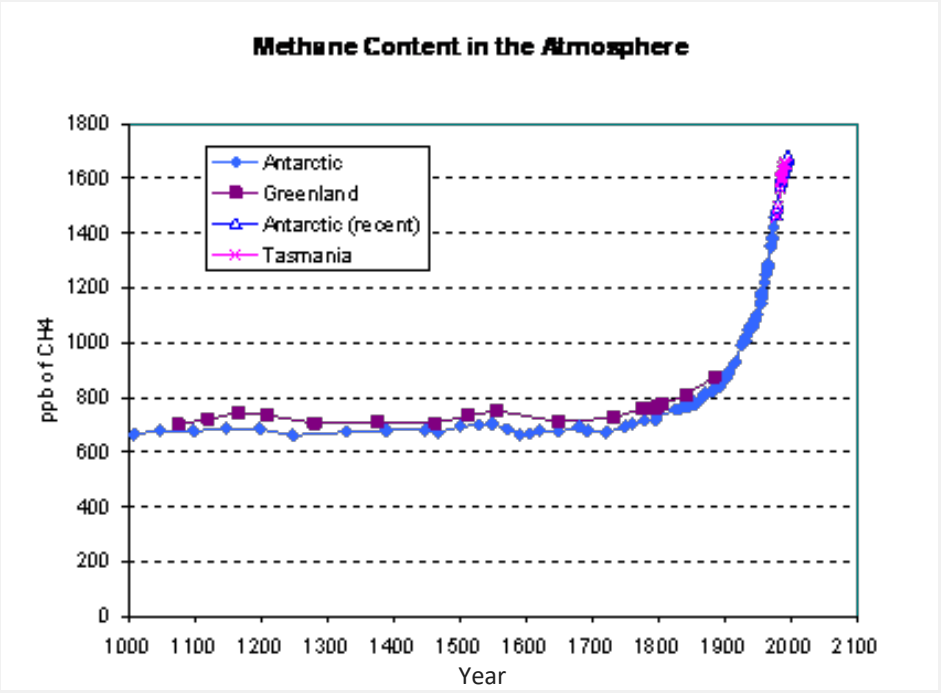
- NGI is Norway's **largest geotechnical specialist community** and a leading centre of research and consultancy in engineering-related geosciences.
- We are a **private commercial foundation** with head office and laboratories in Oslo.
- We work within the fields of **Offshore Energy**; **Building, Construction and Transportation**; **Natural Hazards**; and **Environmental Engineering**.
- Our social mandate dictates that we conduct **applied research**, **technological development and innovation**, and that we contribute to **development and education** within geotechnical and related geosciences.
- We research and develop **solutions** for industry and society, ensuring that we live and **build on safe ground**.




Intro: Greenhouse gases in the atmosphere



https://acidifyingoceans.weebly.com/

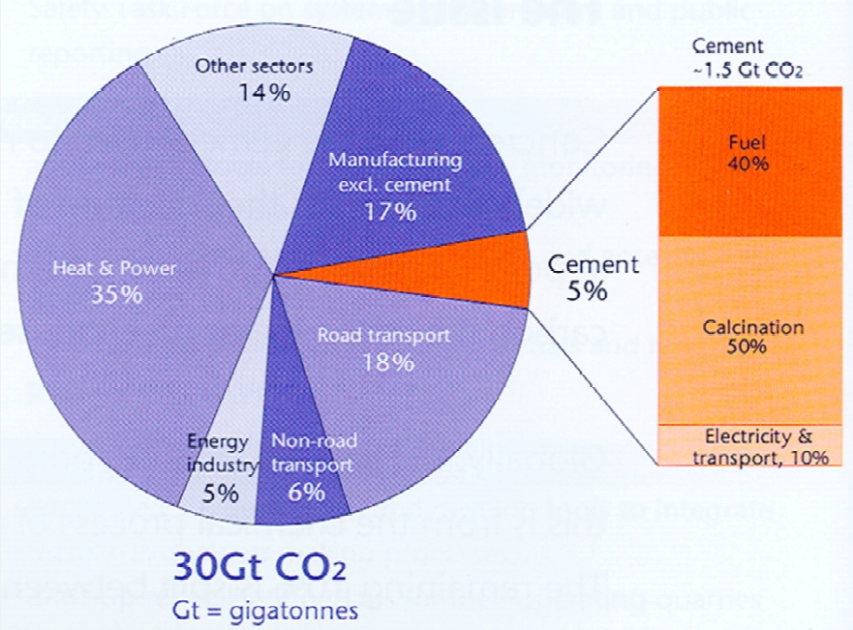


https://ecen.com/eee55/eee55e/growth_of%20methane_concentration_in_atmosphere.htm

CO_2 emission from industrial processes

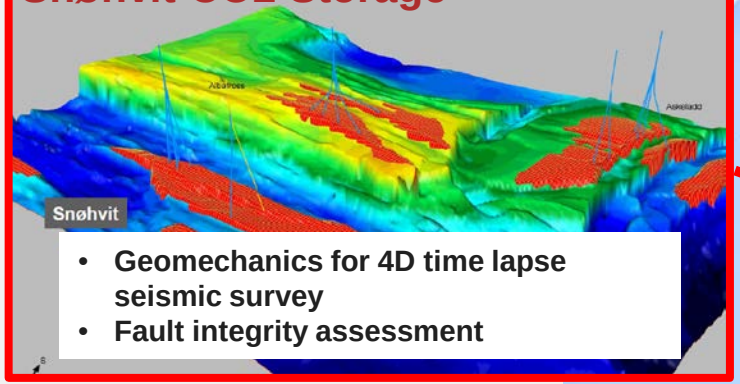
Cement production; double emissions, ca. 1500 Mt/y of CO2

- calcination of limestone: $CaCO_3$ → $CaO + CO_2$ (≈ 50%)
- Heat production from fossil fuel → CO_2 (≈ 40%)



CO_2 storage projects

Snøhvit CO2 Storage



- Geomechanics for 4D time lapse seismic survey
- Fault integrity assessment

Longyearbyen CO2 lab

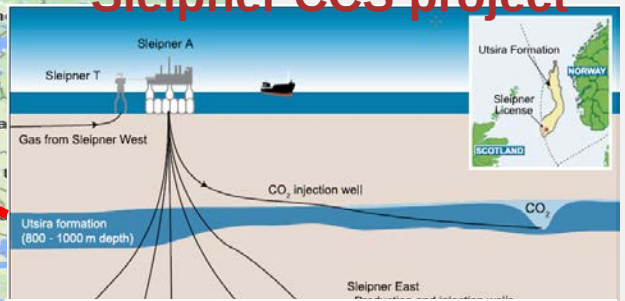
- Geomechanical interpretation of microseismicity
- Potential for aseismic events

- **Longship-Northern Lights Project**

In Salah CCS project

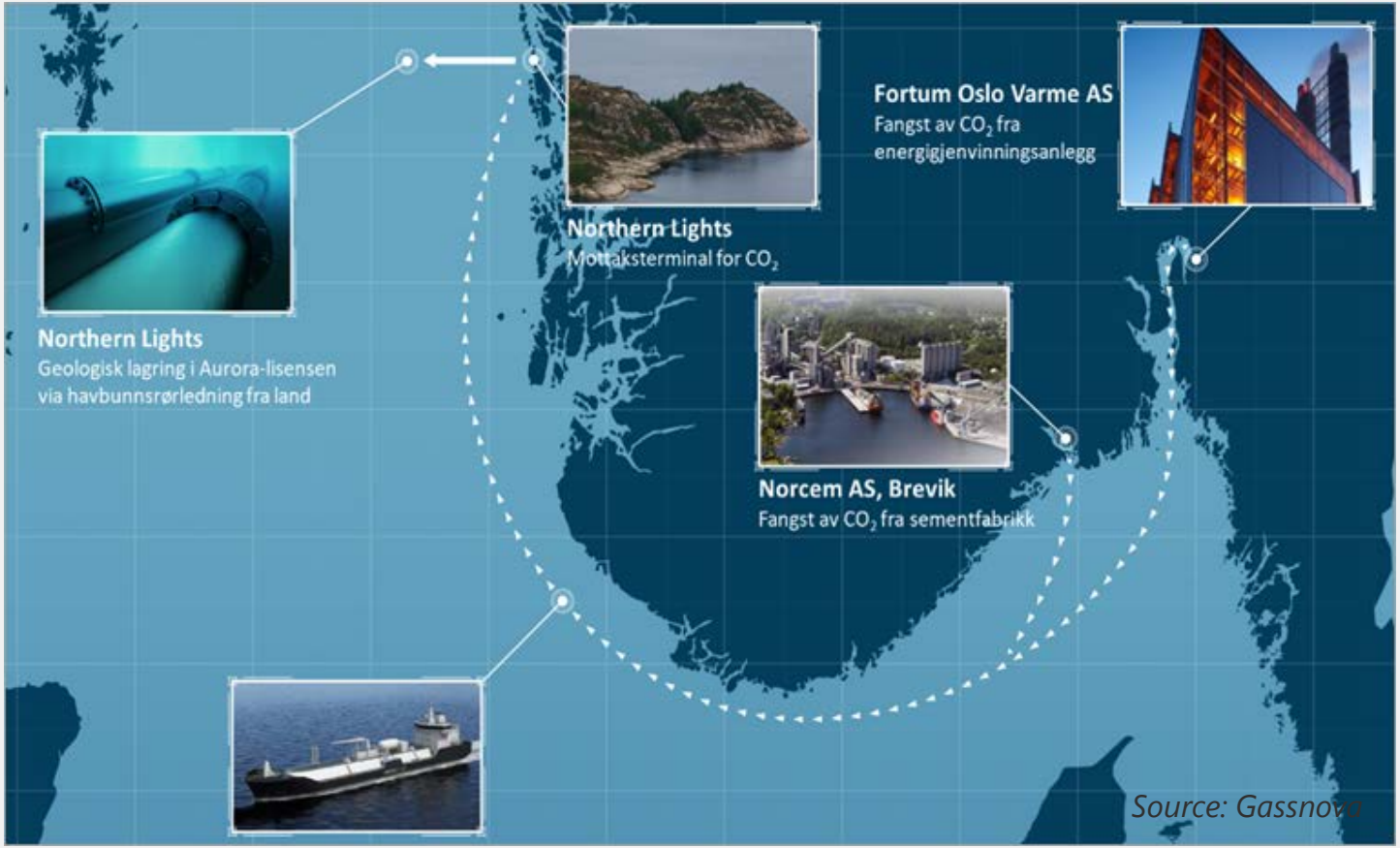
- Cap-rock integrity vs microsesimicity
- Geomechanical interpretation
- Injection history analysis
- InSAR data analysis

Sleipner CCS project



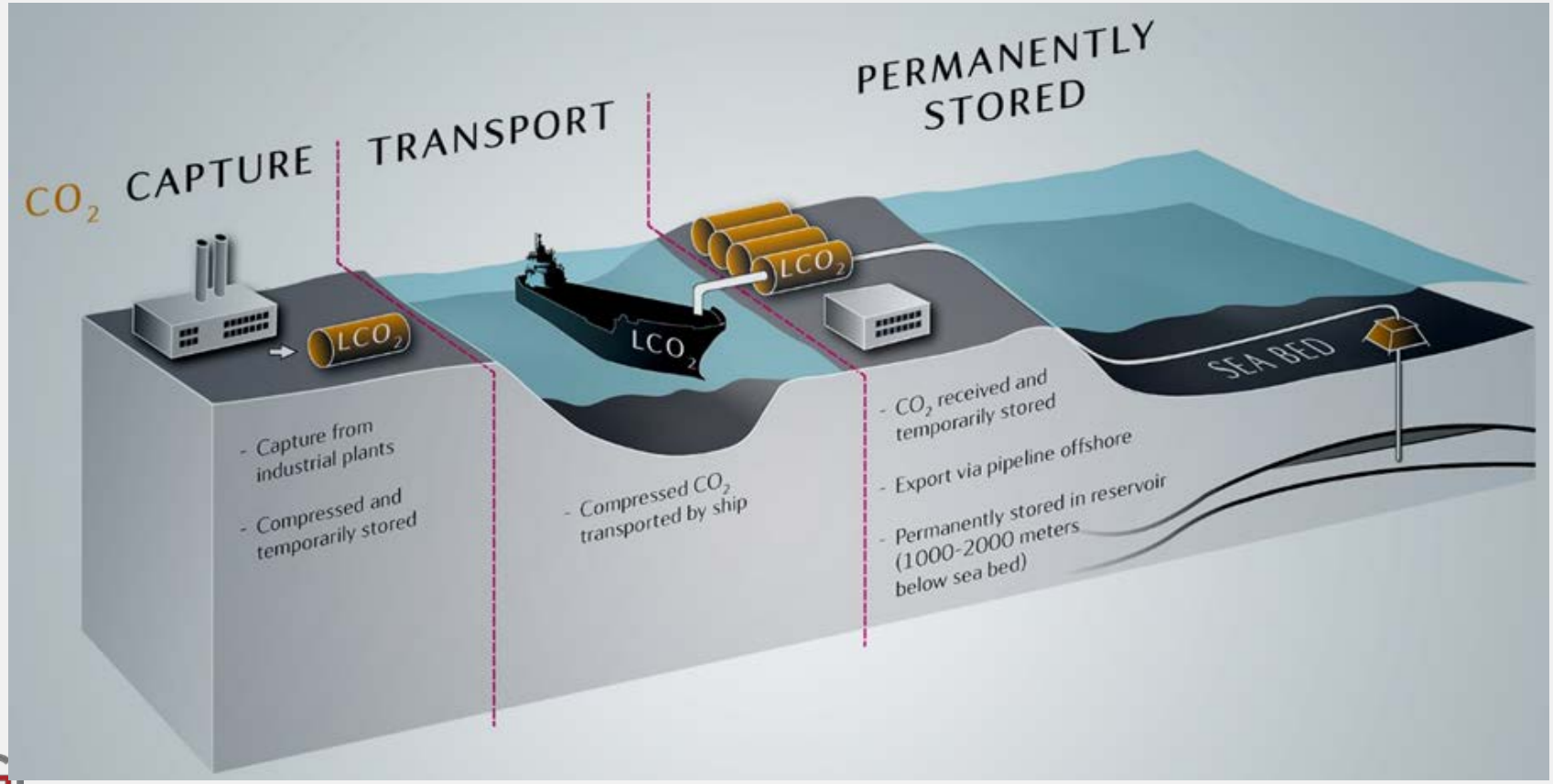
- History matching
- Seismic studies
- Gravity data

The Longship project: Full CCS chain



Source: Gassnova

The Longship project

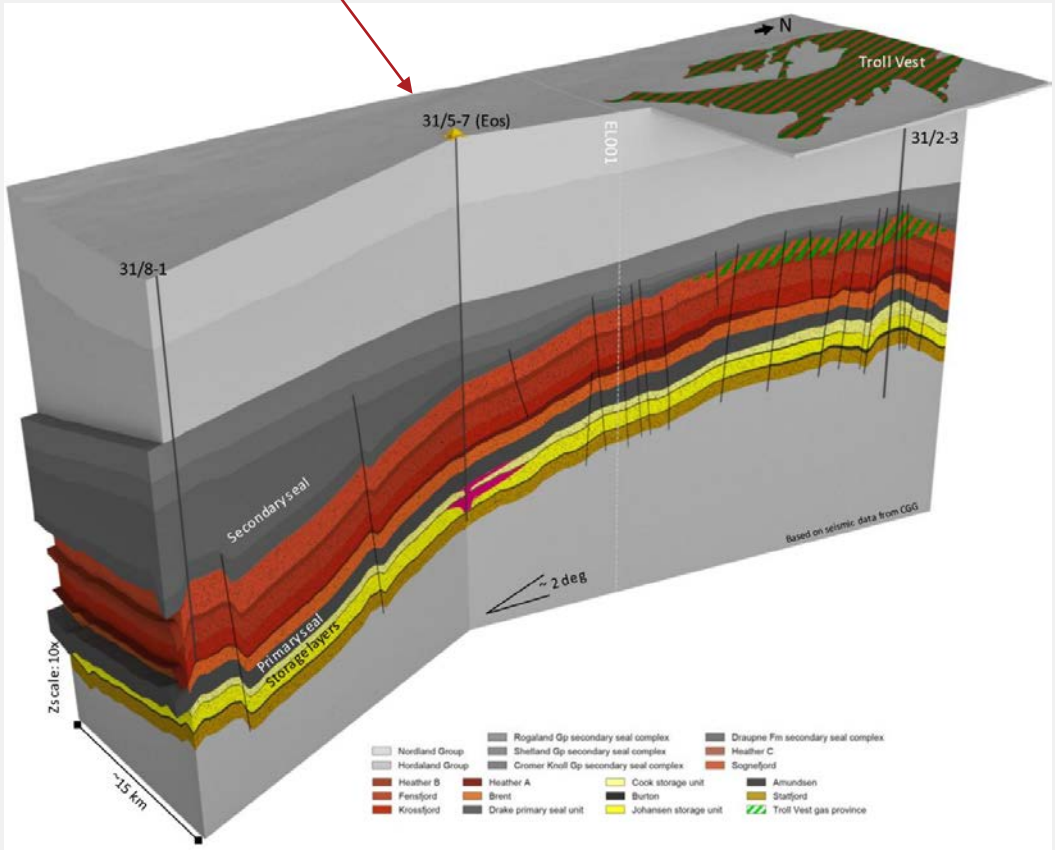


Aurora storage site and Eos well

- Well drilled January 2020, 2.6 km
- Confirms a good storage reservoir
- **The well logs and well tests are open access for research and further evaluations**

Ongoing work at NGI

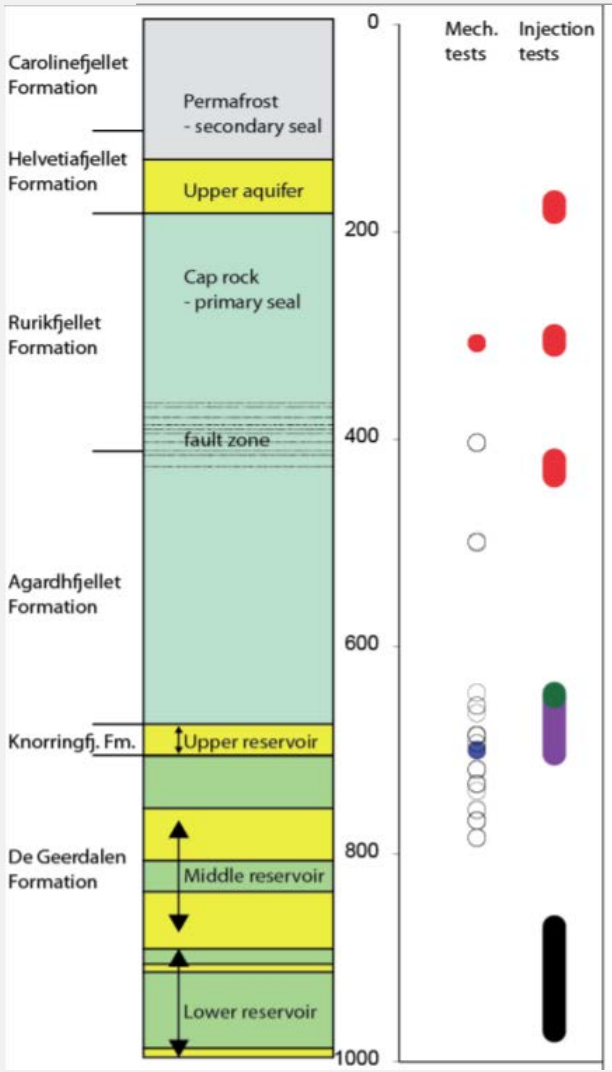
- **Core material** at NGI for rock mech testing
- NGI studies **thermo-mechanical** simulations of the well/reservoir

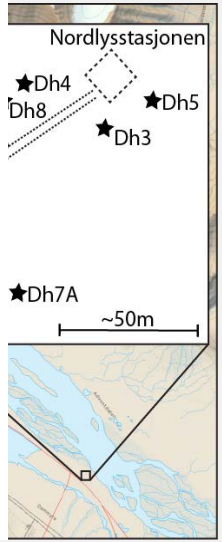


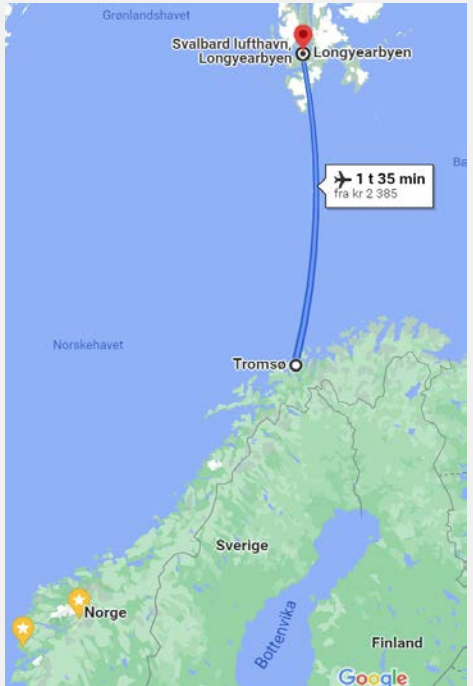
https://www.equinor.com/en/news/20201019-sharing-data-northern-lights.html

Longyearbyen CO2 lab pilot
Svalbard Arctic Norway

Geomechanical studies for Longyearbyen CO_2 Pilot



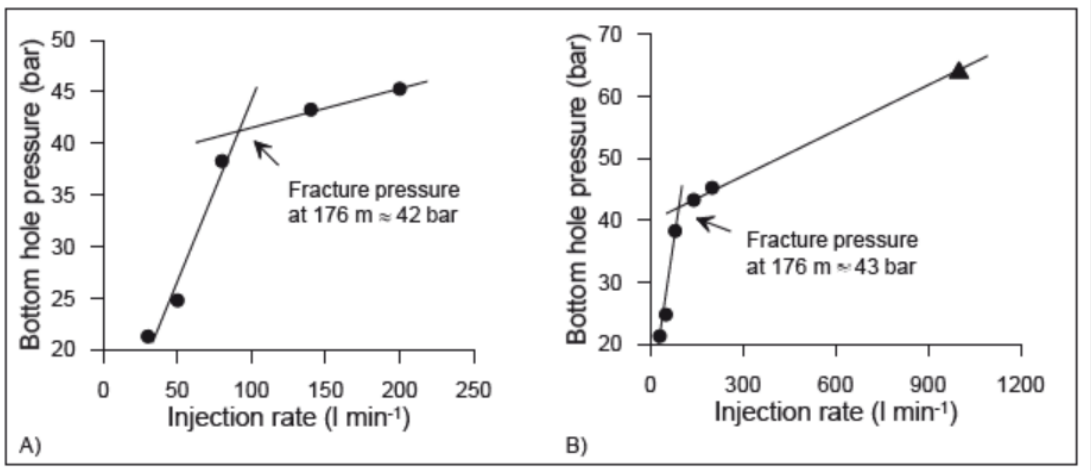




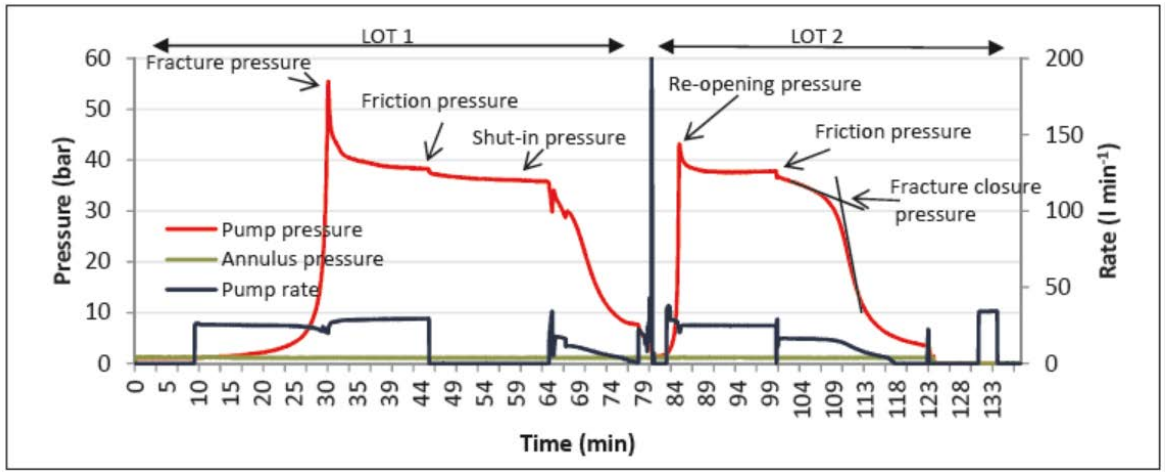
Geology profile

Q1: what is the max allowable pressure?

- Injection/leak-off tests



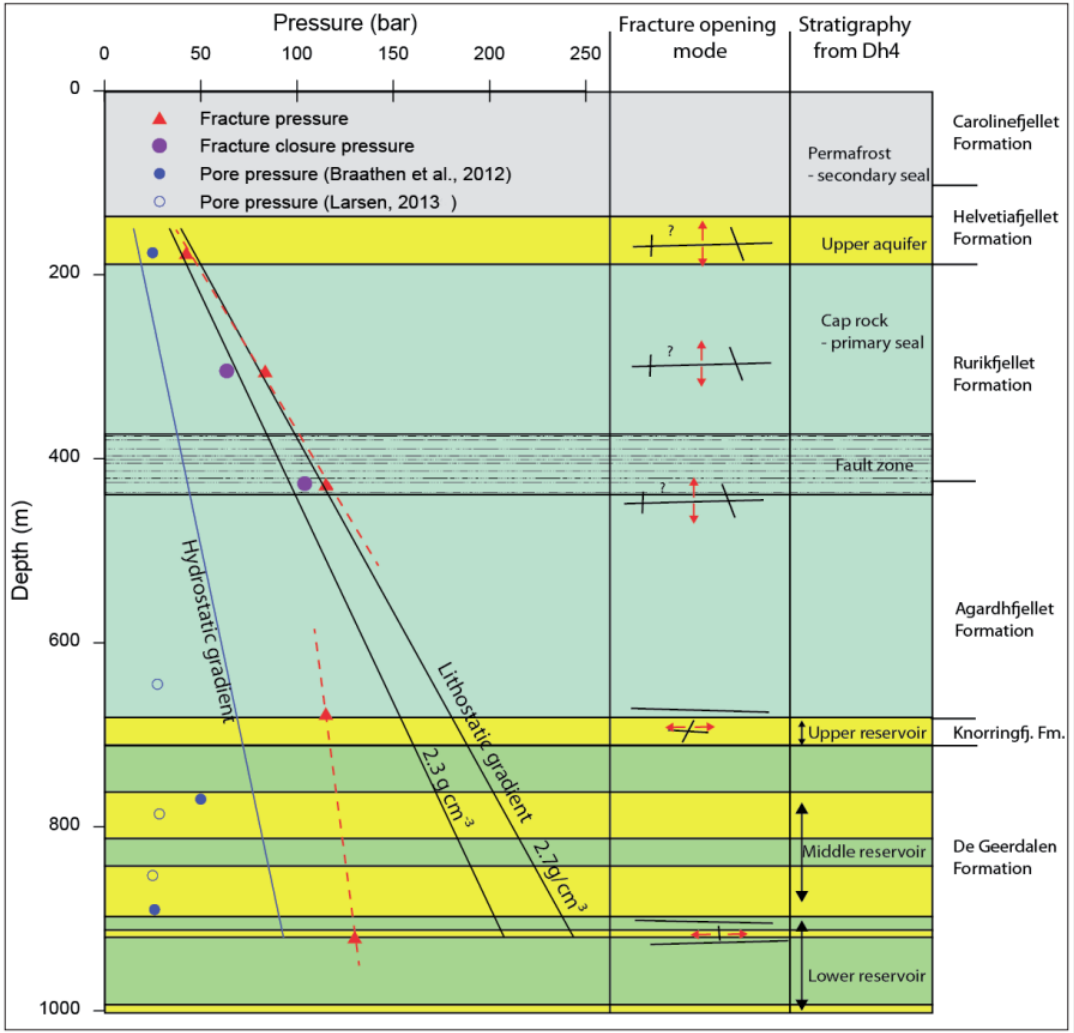
@171-181 m depth interval



@300-309 m depth interval

Q1: What is the max allowable pressure (Cont.)?

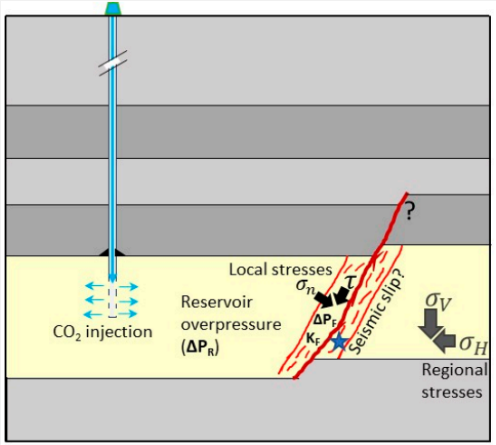
Section	Testing depth (m)/ Formation	Number and type of tests	Well No.
Overburden	171–181 Helvetia Fm.	Step rate test (SRT) Fracture test	Dh6
	300–309 Rurikfjellet Fm.	2 leak-off tests (LOT)	
	420–435 Agardhfjellet Fm.	2 leak-off tests (LOT)	
Reservoir	650–703 Lower Agardhfjellet Fm. Upper Knorringfjellet Fm.	2 step rate tests	Dh7A
	870–970 De Geerdalen Fm.	Step rate test	Dh4

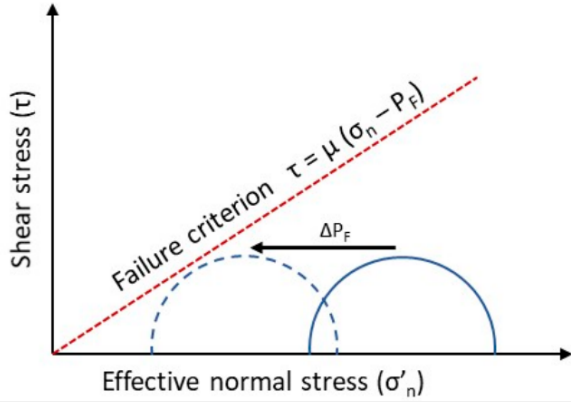


Q2. Does possible fracture/fault slip create any seismic event?

- Velocity step shear test- evolution of friction (μ):

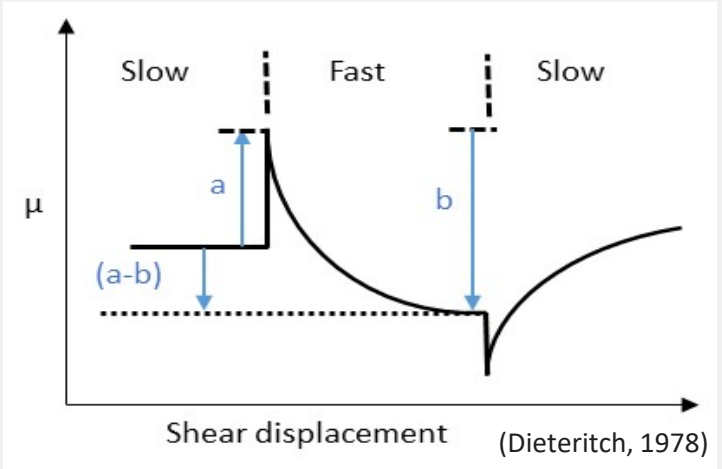
$$\mu = \mu_0 + a\ln\left({}^{V}/_{V_0}\right) + b\ln\left({}^{V_0\theta}/_{d_c}\right)$$





With state variable θ evolving according to:

$$d\theta/dt = 1 - \left({}^{V_0\theta}/_{d_c}\right) \qquad (a-b) = \frac{\mu_0 - \mu}{\ln\left({}^{V}/_{v_0}\right)}$$



(a-b) > 0 → Aseismic slip

(a-b) < 0 → Seismic slip

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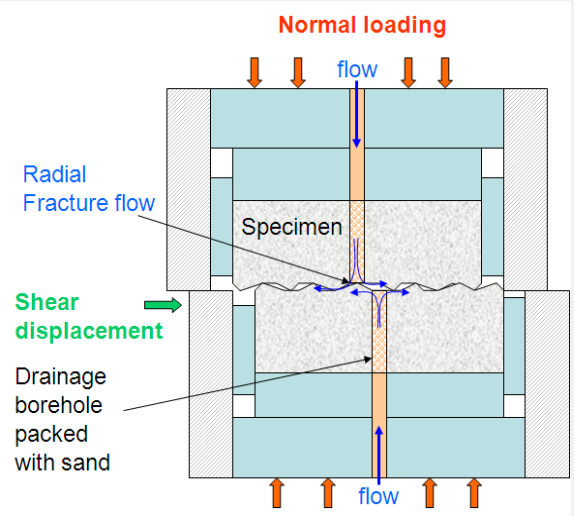
Direct shear test: a lab test used for evaluating seismic potential

- Direct shear test for determination of frictional properties and seismogenic potential

Rurikfjellet: Cretaceous shale from Svalbard, TOC = 1.5%,



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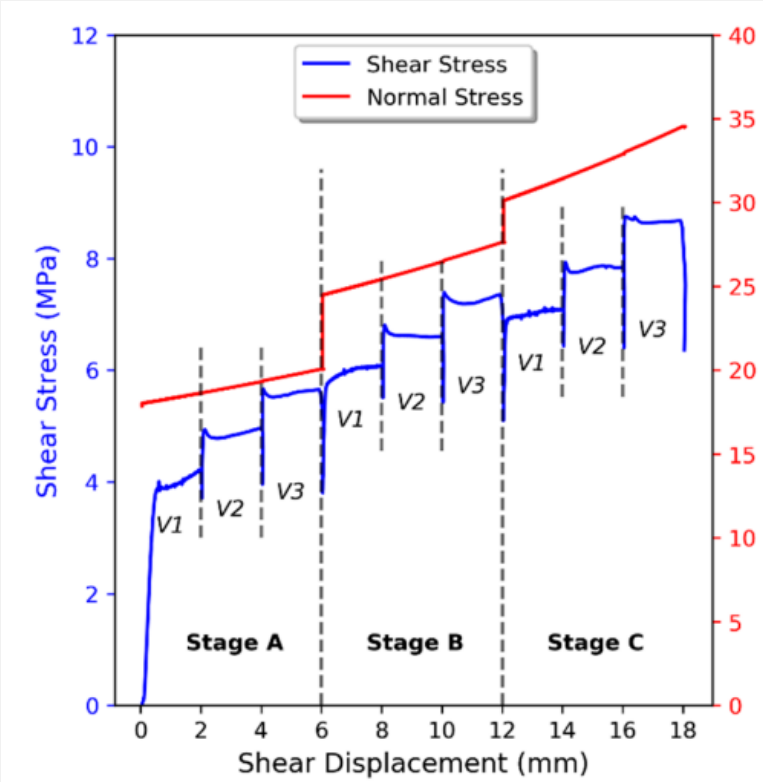
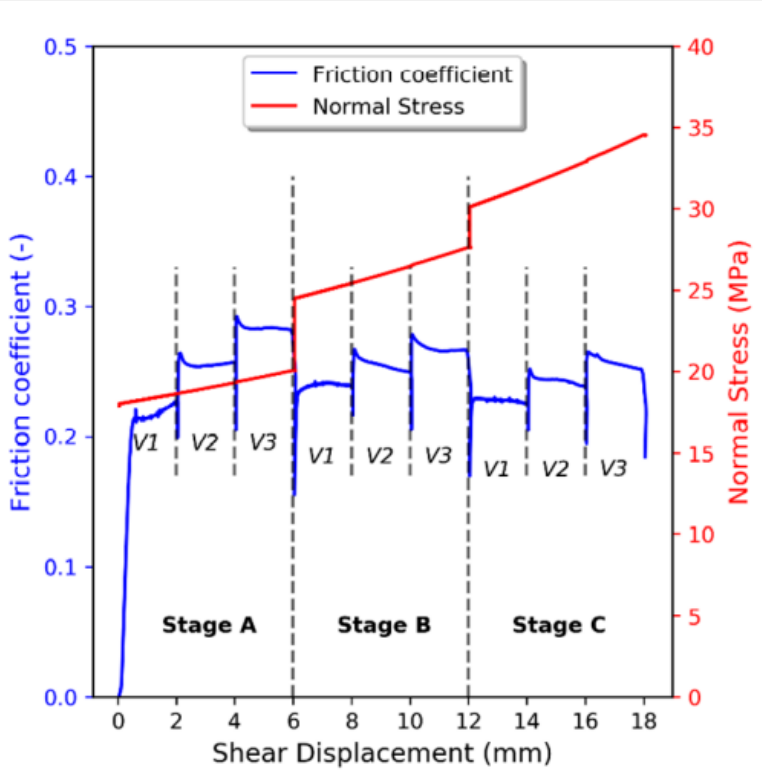
Seismogenic potential of Svalbard/Rurikfjellet shale

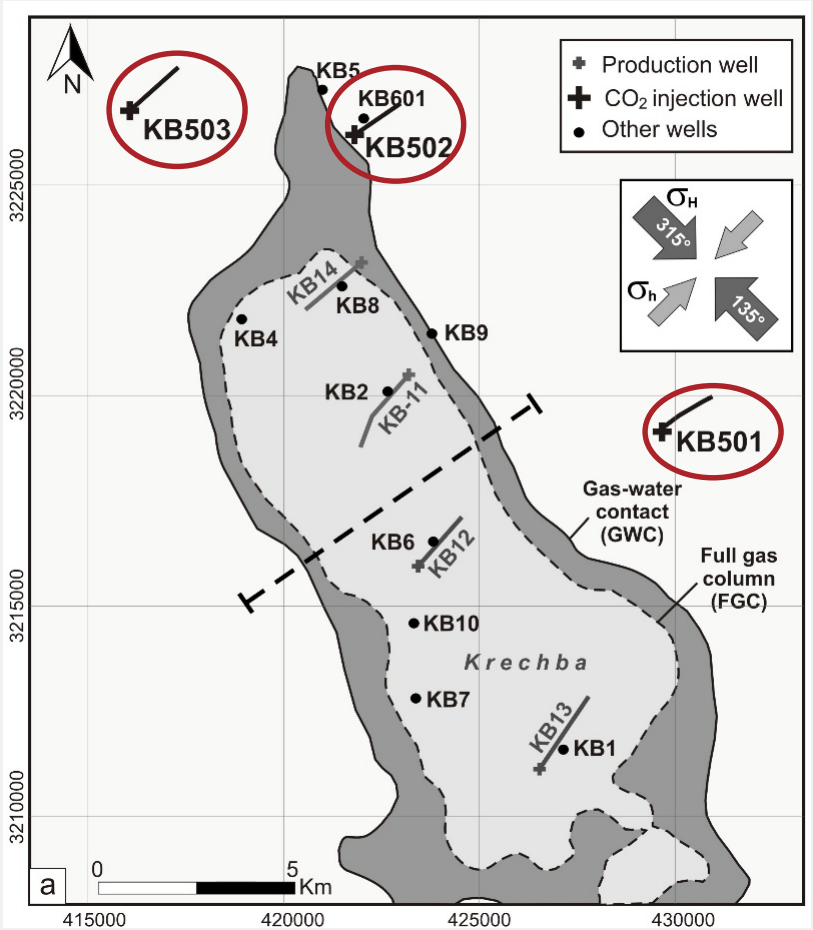


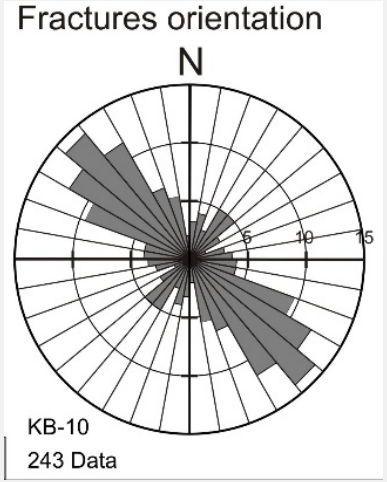


(a-b) > 0 → Aseismic slip

In Salah, Algeria

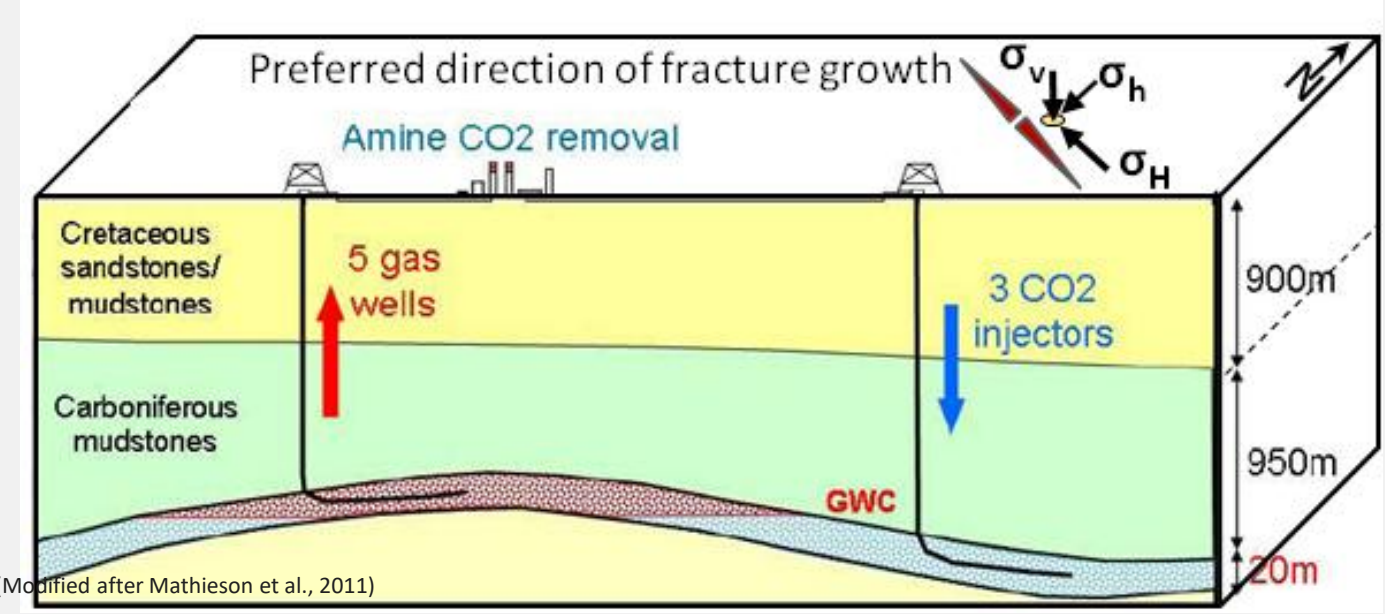
In Salah CO_2 storage site, Algeria





Ref.: Bjørnarå et al., 2018

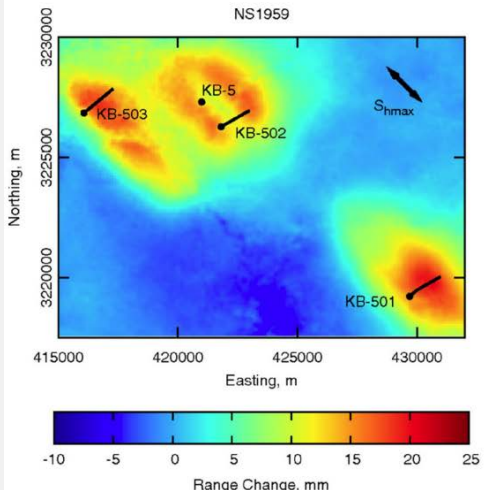
In Salah: Gas production, CO_2 separation-injection and ground surface response

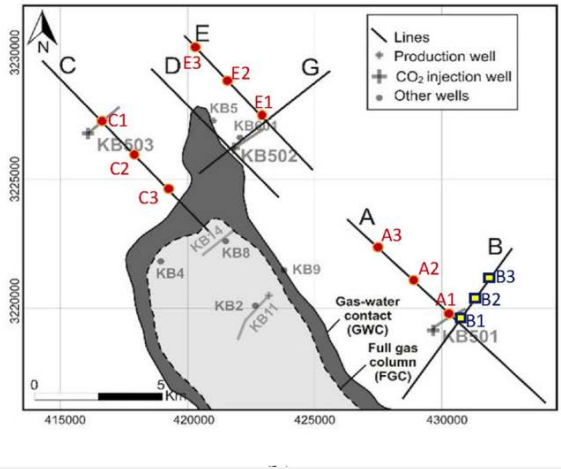


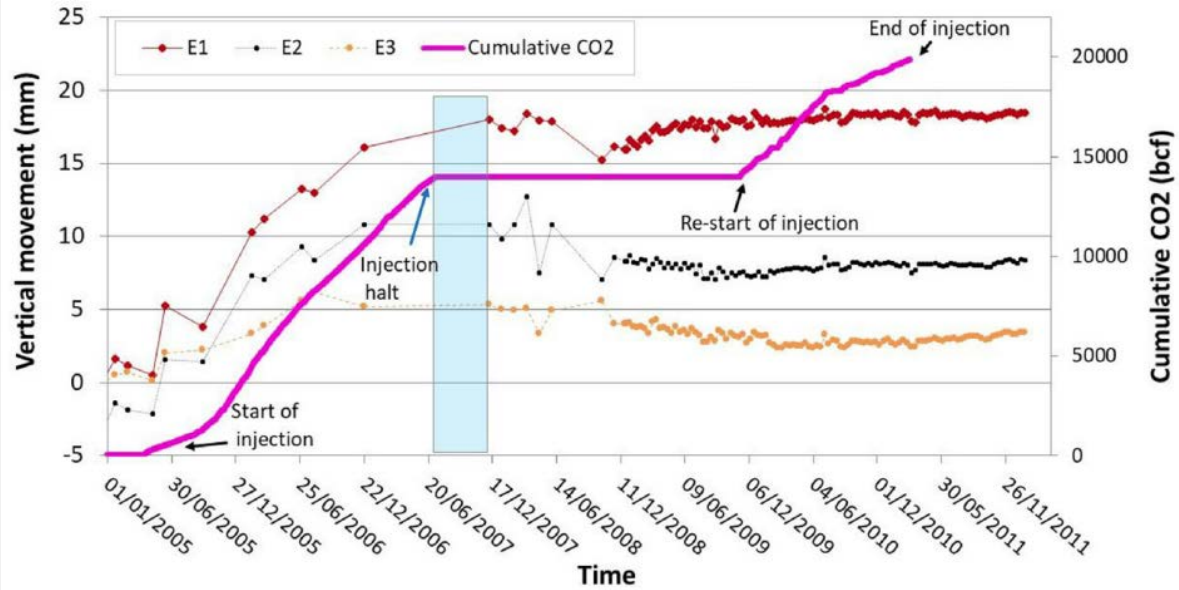
(Modified after Mathieson et al., 2011)

How is the performance of reservoir versus geomechanical constraints?

Ground surface monitoring- to detect reservoir behaviour







SENSE

Assuring integrity of CO2 storage sites through ground surface monitoring

https://sense-act.eu/

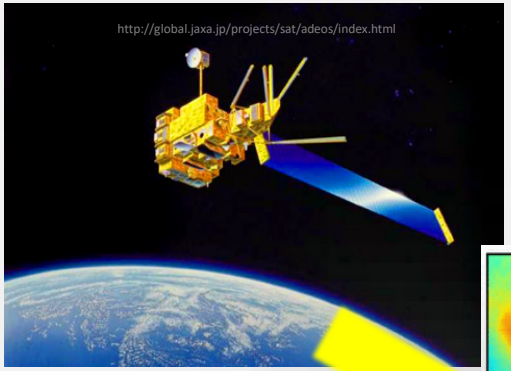
Ref.: Bohloli et al. 2018

https://sense-act.eu/

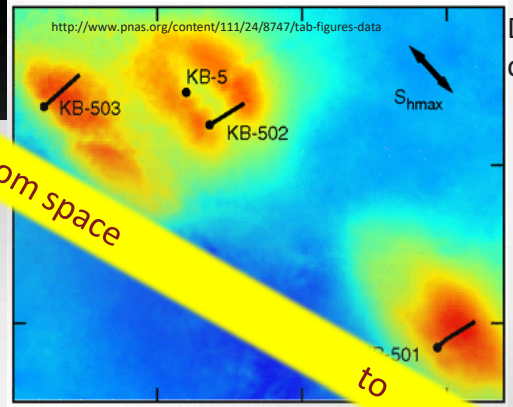
Assuring integrity of CO_2 storage sites through ground surface monitoring (SENSE)

Introduction: SENSE consortium

SENSE project concept



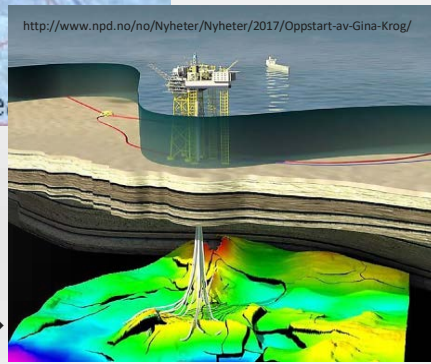
Satellite for monitoring ground motion onshore



Demonstration of concept onshore

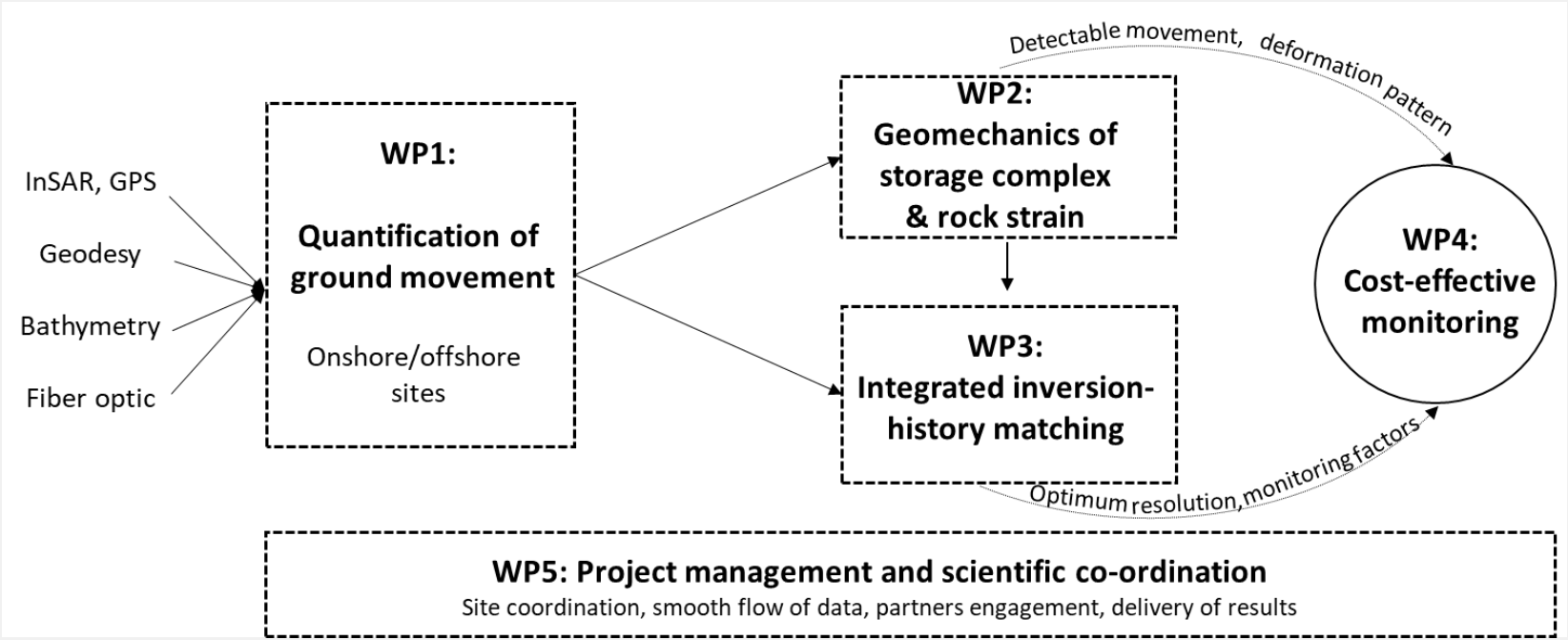
Demonstration offshore

From space to the subsurface



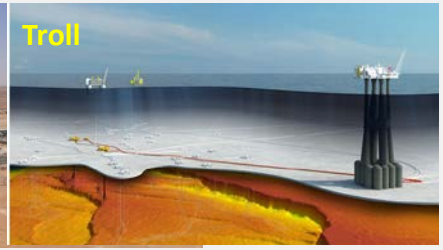
Geomechanical modelling, inversion- history matching → subsurface management & **containment assurance**

Project Structure



WP1: Measurement of ground deformation-case studies

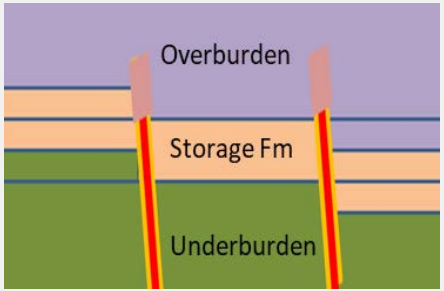
1. In Salah/Troll Subsidence data
2. Boknis Eck, Offshore Germany
3. Hatfield Moors, onshore UK
4. Gulf of Mexico



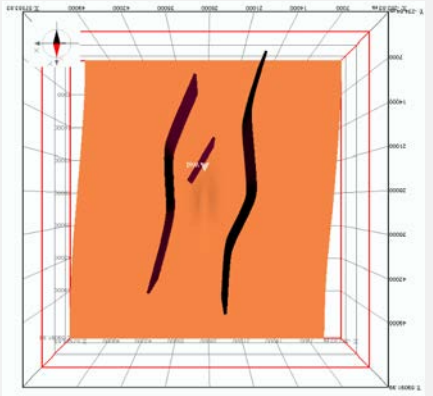
3. Hatfield Moors, natural gas storage, sandstone, 450 m deep

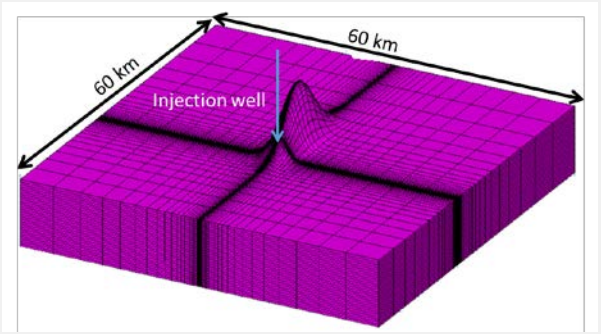
CONCEPTUAL MODELING- IMPACT OF FAULT PERMEABILITY ON GROUND DEFORMATION

- Reservoir at a 1600 m depth, 50 m thick
- 2800 t/d injection, 160 bar/40°C conditions, injection controlled by a 50 bar overpressure
- Injection well: 6 km from anticline summit
- Injection constrained by a max. overpressure [50 bar], max. inj. rate of **2800 t/d** (surface)
- Depth, thickness of storage formation and overburden are scenario-dependent.

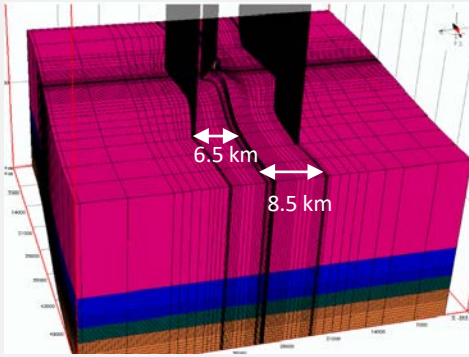


Faults (core and damage zones) with throw





Anticline trap

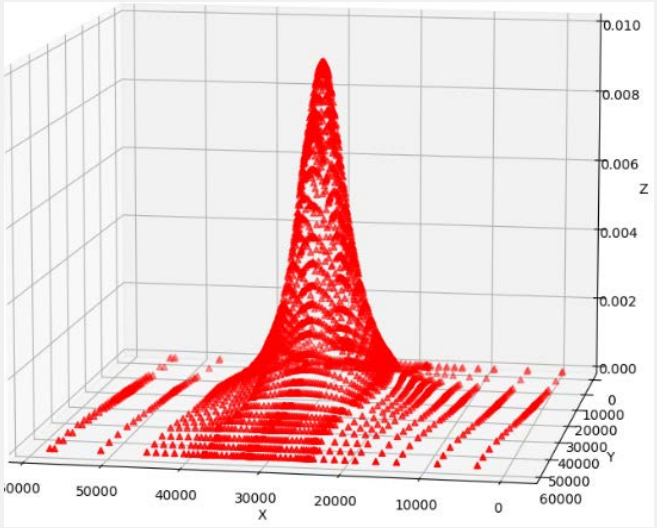


Anticline trap with sealing or draining faults

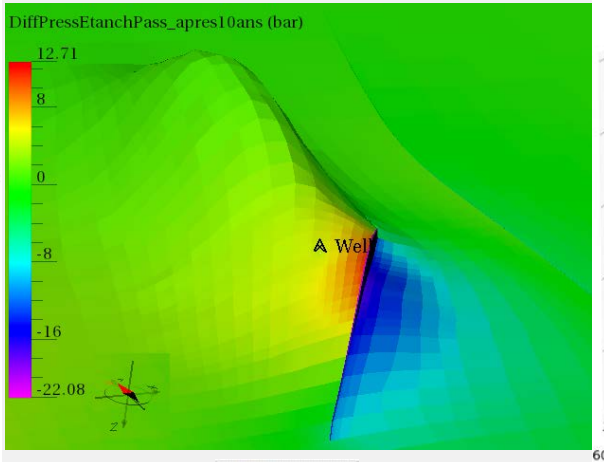
Impact of fault permeability of ground uplift

Anticline trap with sealing or draining faults

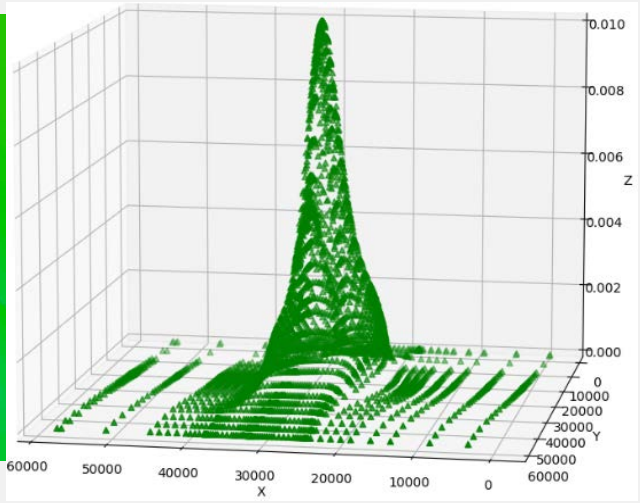
Draining fault



Pressure difference
Sealing – Draining Faults scenarii [bar]



Sealing fault

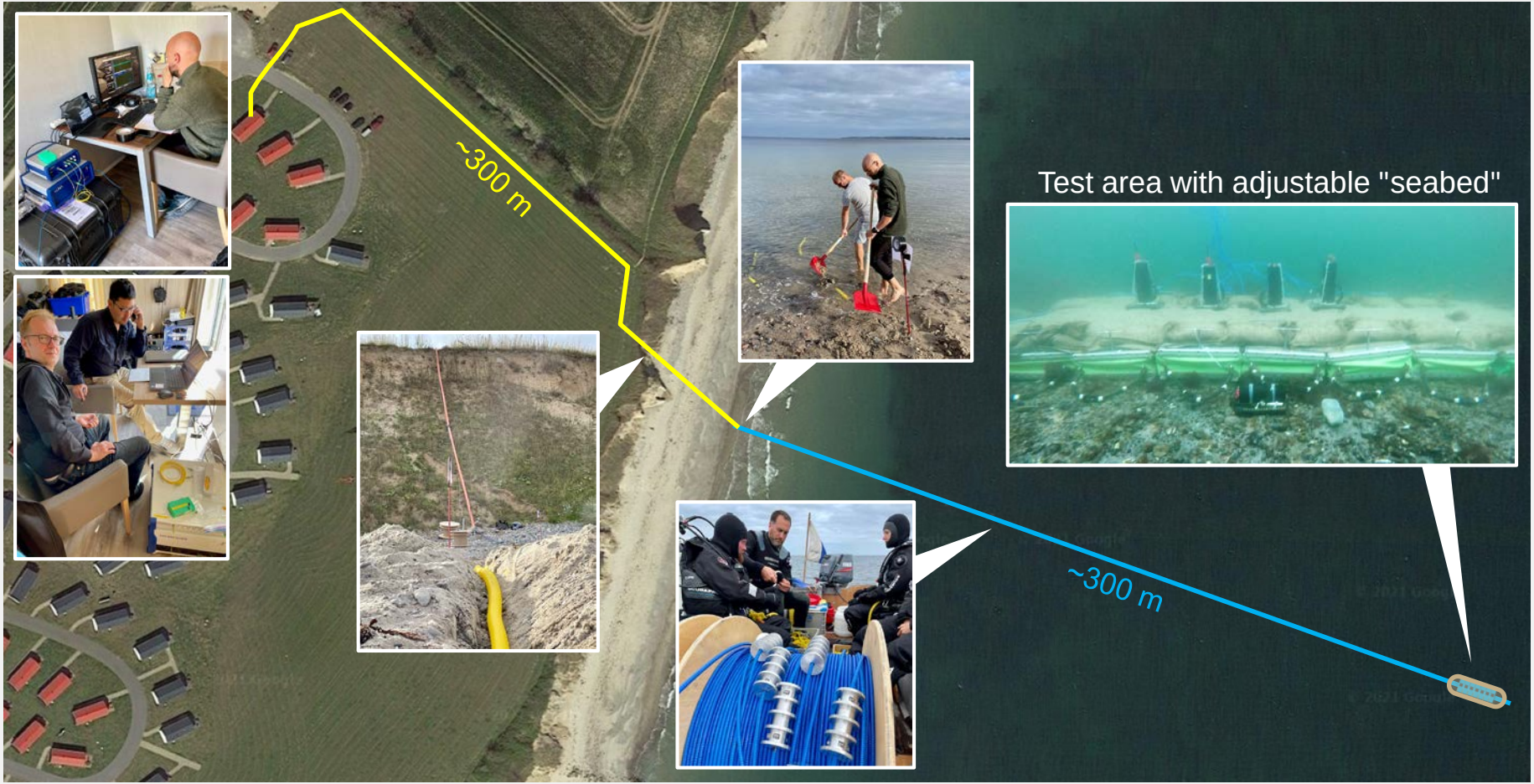


Hatfield Moors

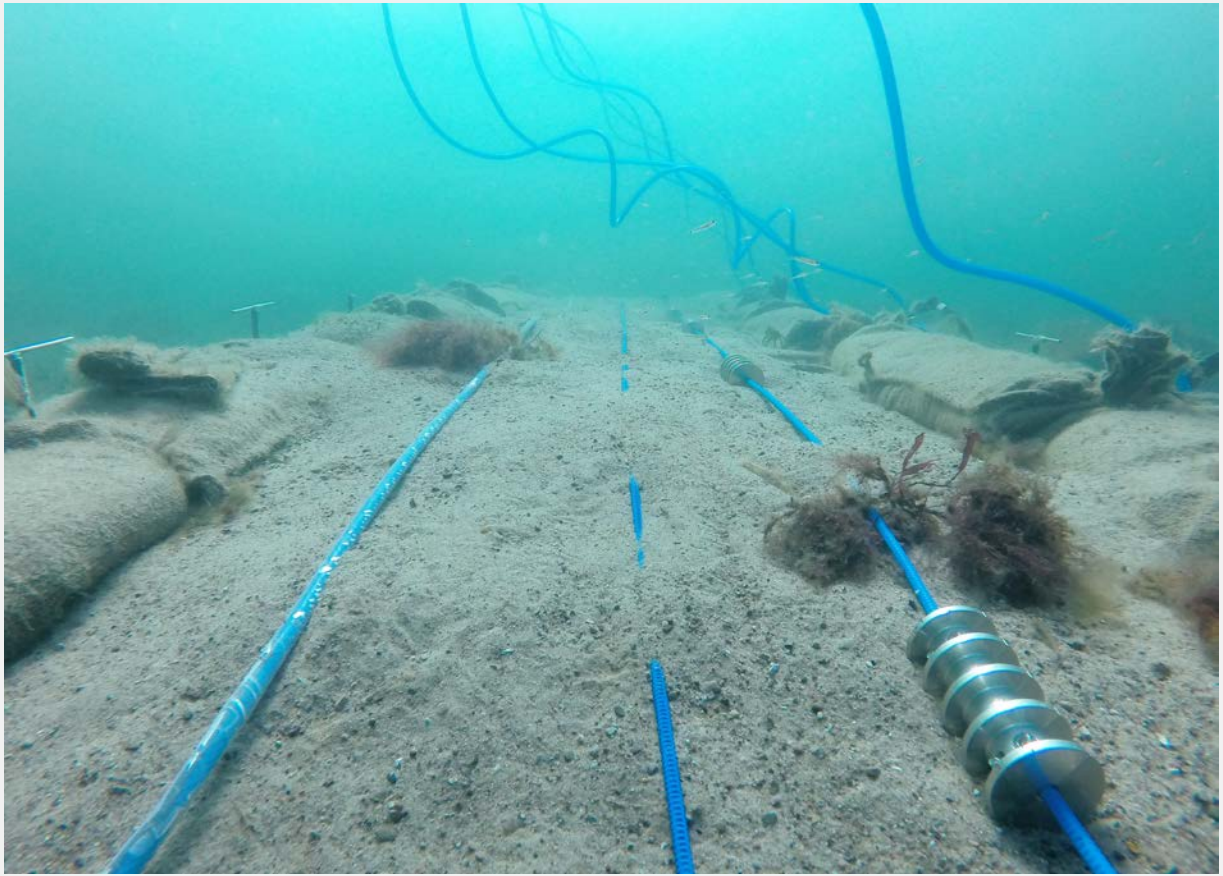
- Scottish power gas storage facility
- Analogous to CCS site
- Former peat ‘mine’
- Wetland nature reserve

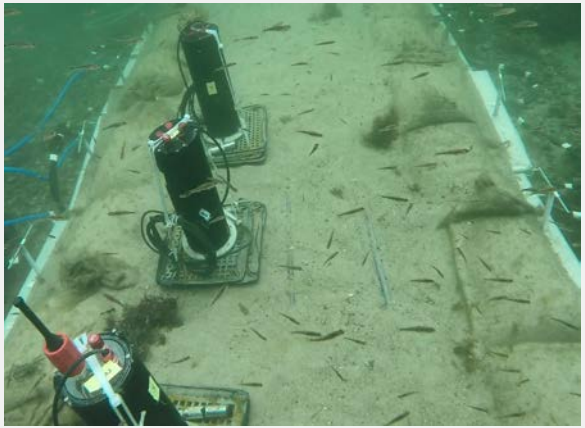
Hatfield Moors, UK

Fiber optics cable test at Boknis Eck



DSS Cable test at Boknis Eck

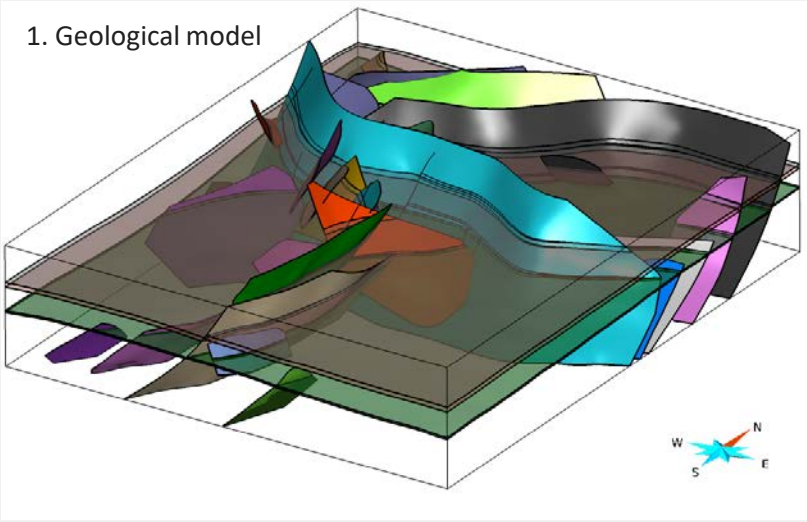




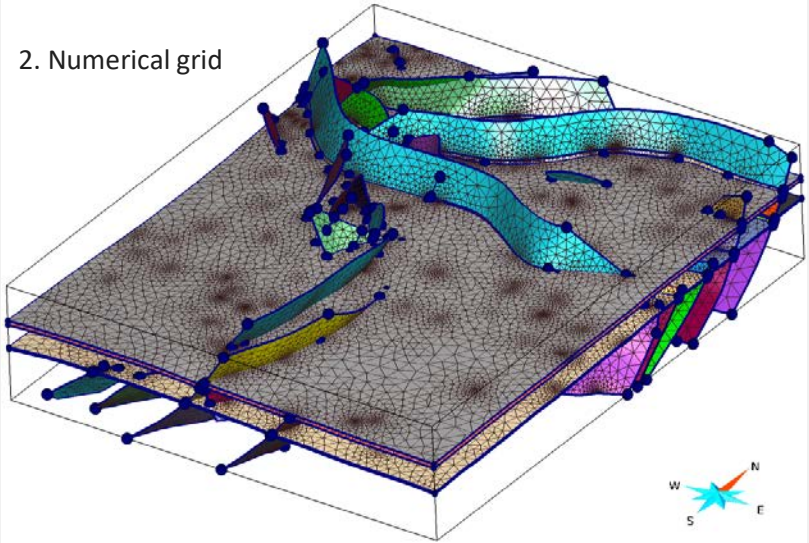
The nearshore tests were less controlled, but similar ground deformation sensitivity as in NGI's sandbox was demonstrated

Gulf-of-Mexico, USA

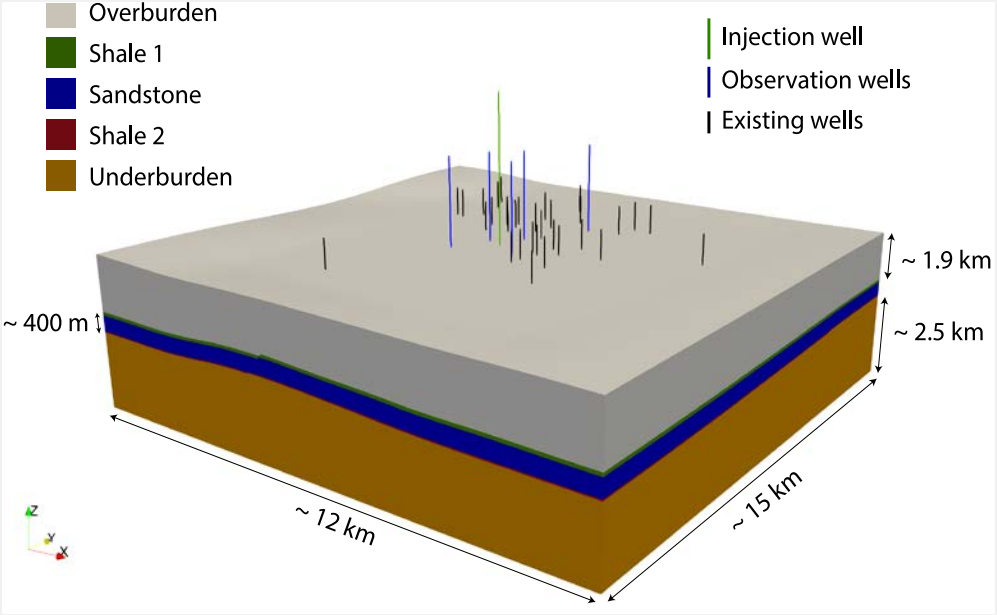
1. Geological model



2. Numerical grid



3. Geomechanical model



Lawrence Livermore National Laboratory

Summary

- CCS research community has gained lots of experience from early-running projects (In Salah, Sleipner, Snøhvit, Decatur, Quest, …) and pilots (Lacq Rose, Hontomin, Longyearbyen Lab, etc.) and can do assessment of CO2 storage sites with high confidence.

- Operators have very good experience with injecting CO2 into reservoirs in a safe way and have done so for > 25 years.

- The missing link is the business case; who should pay for CO2 sequestration? Emitters? The public?

  - What does the society with other types of waste/garbage? CO2 (that can not be reused) is a waste we produce!

NGI

Monitoring CO_2 Storage Sites
SENSE Webinar #2 - 25 January 2022

a) Ground deformation monitoring using fiber optics

By Dr Ziqiu Xue, Chief Researcher, Research Institute of Innovative Technology for the Earth (RITE-Japan); General Manager (Technical Division), Geological Carbon Dioxide Storage Technology Research Association

b) Ground deformation monitoring onshore and offshore

By Mr Per Sparrevik, Technical Expert (Norwegian Geotechnical Institute (NGI- Norway)
and Dr Jens Karstens, Postdoc Researcher, GEOMAR (Germany)

Event Information:

When: 25 January 2022 at 11:00-12:00 Central European Time (CET)
Where: Online via Teams
Registration via link: please see https://sense-act.eu/
Welcome to join us and hear about the latest advances on CO_2 storage site monitoring & SENSE project

Acknowledgement

https://sense-act.eu/

SENSE (Assuring integrity of CO_2 storage sites through ground surface monitoring) project No. 299664, has been subsidized through ACT (EC Project no. 691712) by Gassnova, Norway, United Kingdom Department for Business, Energy and Industrial Strategy, Forschungszentrum Jülich GMBH, Projektträger Jülich, Germany, The French Agency for the Environment and Energy Management, The United States Department of Energy, and State Research Agency, Spain. Additional support from Equinor and Quad Geometrics and permission to use data from the Krechba Field by In Salah Gas JV are appreciated.

@infoNGI

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