Longyearbyen CO2 Lab pilot project of Arctic Norway

Researching CO2 sequestration in unconventional reservoir

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(scientific leader LYB CO2 and SUCCESS)

Snorre Olaussen (scientific leader)
Gunnar Sand (strategy, management)
Ragnhild Rønneberg (project director)
and the large
project team and partners

Hosted by UNIS …

Where?

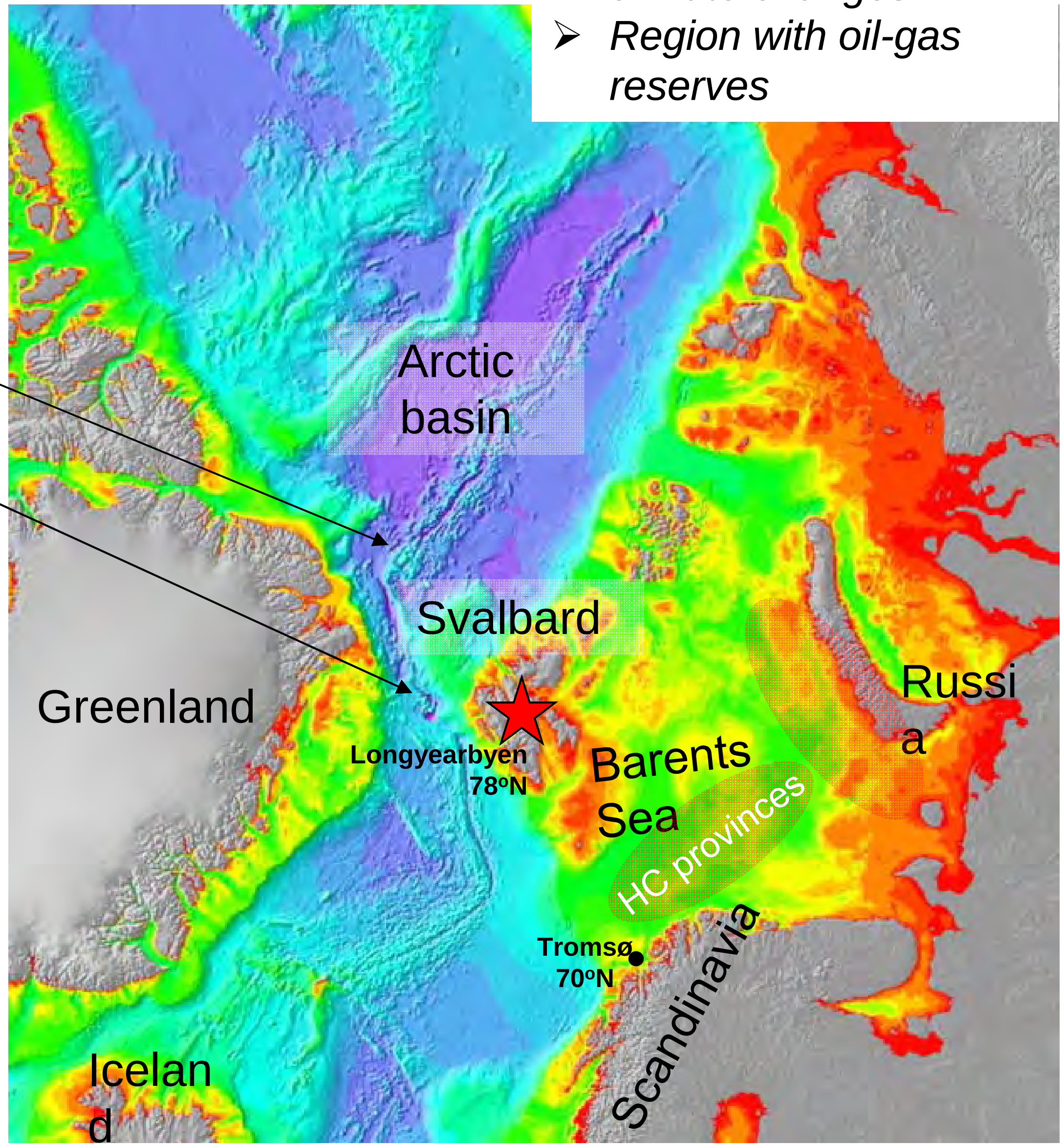
ON TOP OF THE WORLD, 78º North:

Regional setting of LYB CO2 Lab

- *High Arctic location, but global challenges*
- *Region sensitive to climate changes*
- *Region with oil-gas reserves*

Svalbard - an uplifted part of the Barents Shelf

- bordered to the N by a rifted margin
- bordered to the SW by a sheared or transtensional margin



Why?

Svalbard relies on black, dirty coal

... is that a threat
or an opportunity?

Why Longyearbyen?

Local advantages

- Local power plant is pilot size - ca. 60.000 tons CO_2/year.
- Distance between power plant and storage site is 5 km.
- Svalbard is a closed energy system – coal, power, CO_2 storage(?).
- Svalbard is considered an early warning region for climate change.
- Longyearbyen CO_2 lab fits in well with Svalbard's strict environmental laws
- Global attention with profiled visitors
- ✓ Outreach anno 2012: more than 170 newspaper and 25 TV coverage's in national + international media

General Secretary of UN with the UNIS student council

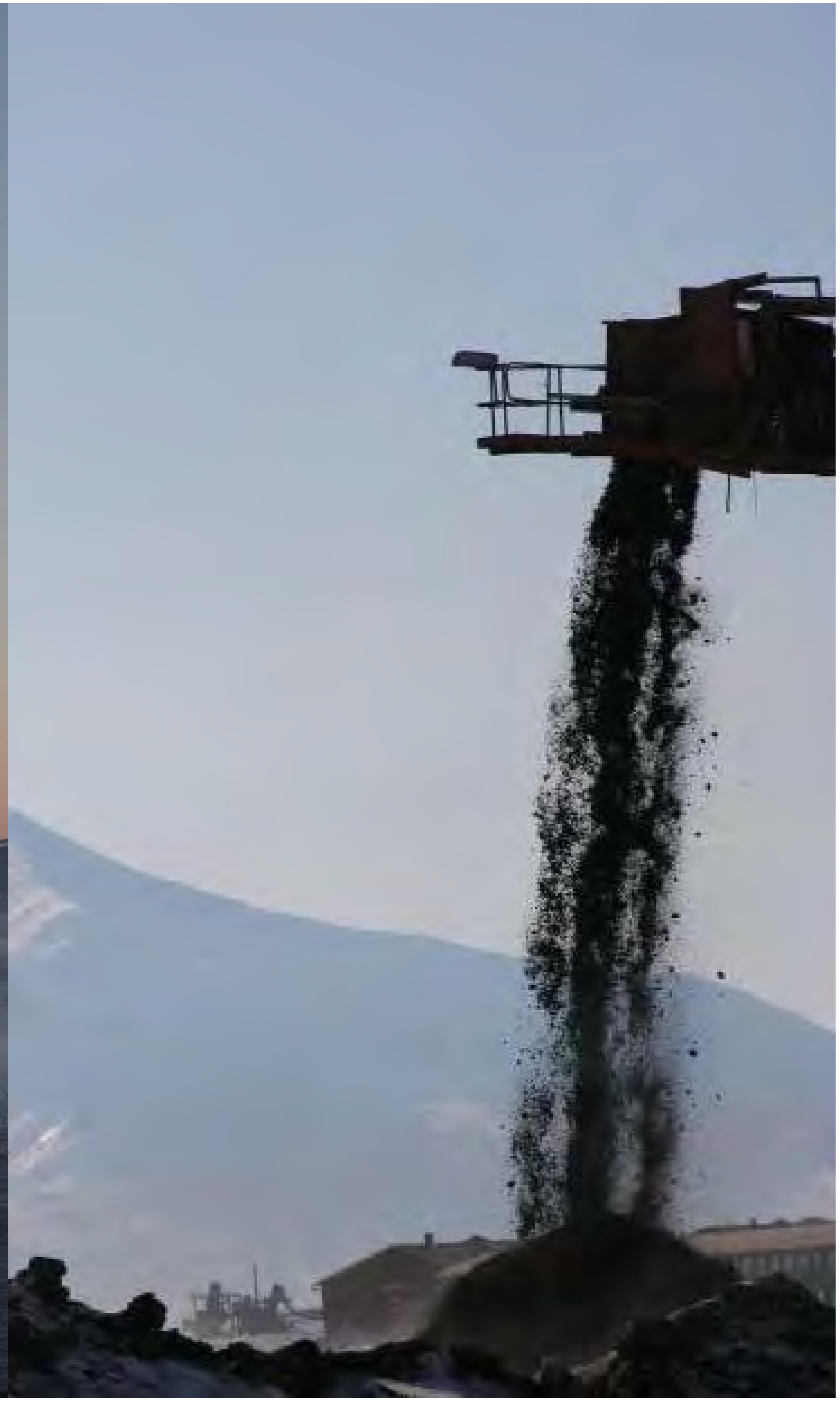
UN secretary Ban Ki-moon met with the members of the student council at UNIS. From left to right:Johannes Lose, Benedikte Jarstø, Mari Berg, Max Janson, Marie Føreid, Benjamin Merkel, Ban Ki-Moon, David Hammenstig, Matilda Hallerstig, Alexander Pilditch.

PROJECT VISIONS

Let’s follow the CO_2 from the source to the solution.

Let’s develop high level, field based, university studies along the CCS chain.

Let’s turn Longyearbyen into a high profile show case as a community that takes care of its emissions.



LYB CO2 Lab pilot

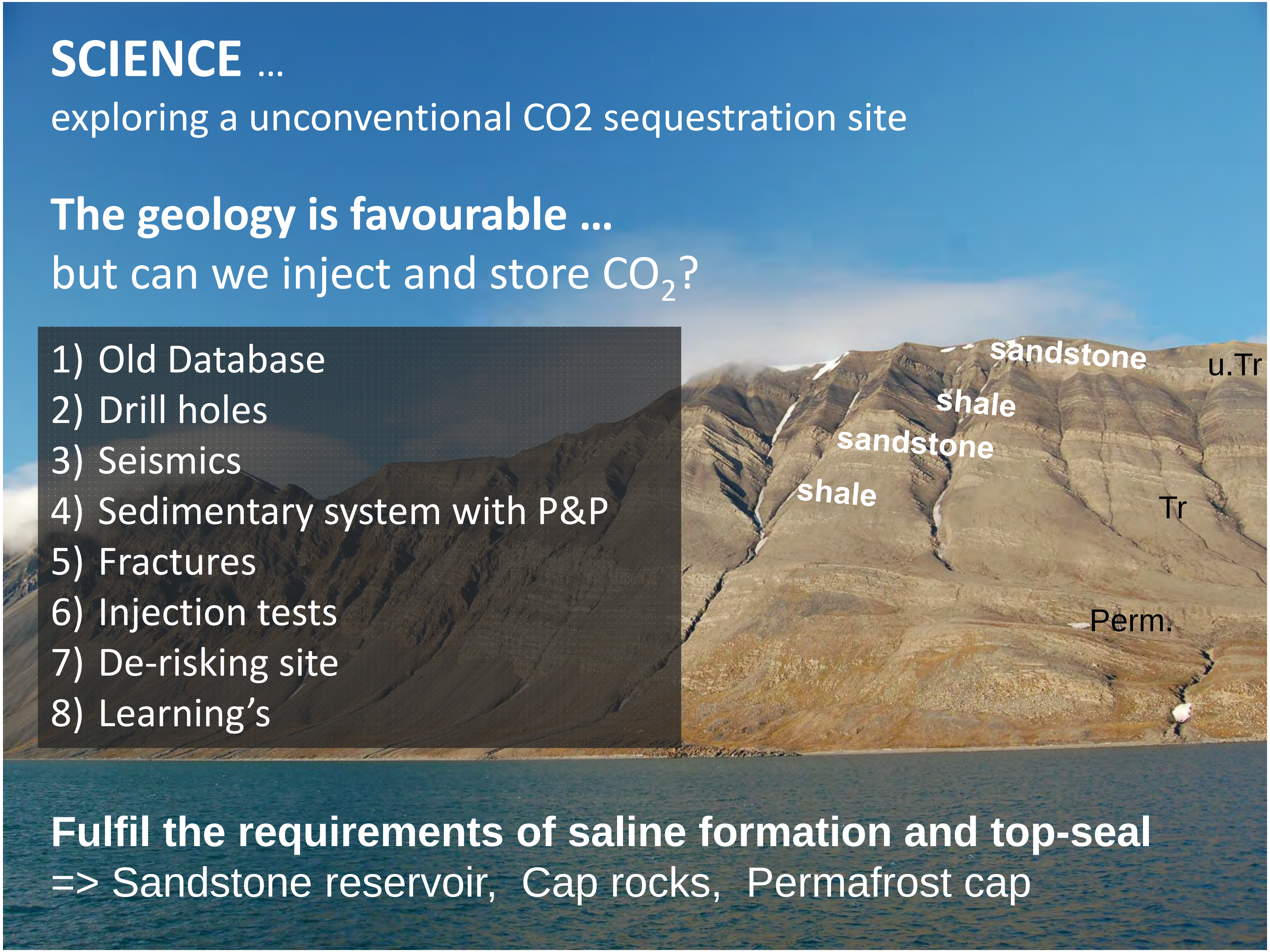
- **Project started in 2007, concluding pilot study in 2013**

- **Finances: 50% government funding, 50% private funding**
- **ca. M$ 20 when finalized in 2013**

- **100+ researchers involved,** including NRC-funded PhD-Postdoc's

- Research contributions by;
  - **All large Norwegian universities**
  - **SUCCESS** Center
  - **Research institutes**
  - **Contractors from oil-gas industry**
- Scientific inputs and funding by;
  - **ConocoPhillips, Statoil, Lundin Norway, Statkraft, Baker Hughes**
  - **SNSK, LNS, Gassnova**

- **International alliances**


SCIENCE …
exploring a unconventional CO2 sequestration site
The geology is favourable …
but can we inject and store CO_2?
1) Old Database
2) Drill holes
3) Seismics
4) Sedimentary system with P&P
5) Fractures
6) Injection tests
7) De-risking site
8) Learning’s
sandstone
u.Tr
shale
sandstone
shale
Tr
Perm.
Fulfil the requirements of saline formation and top-seal
=> Sandstone reservoir, Cap rocks, Permafrost cap

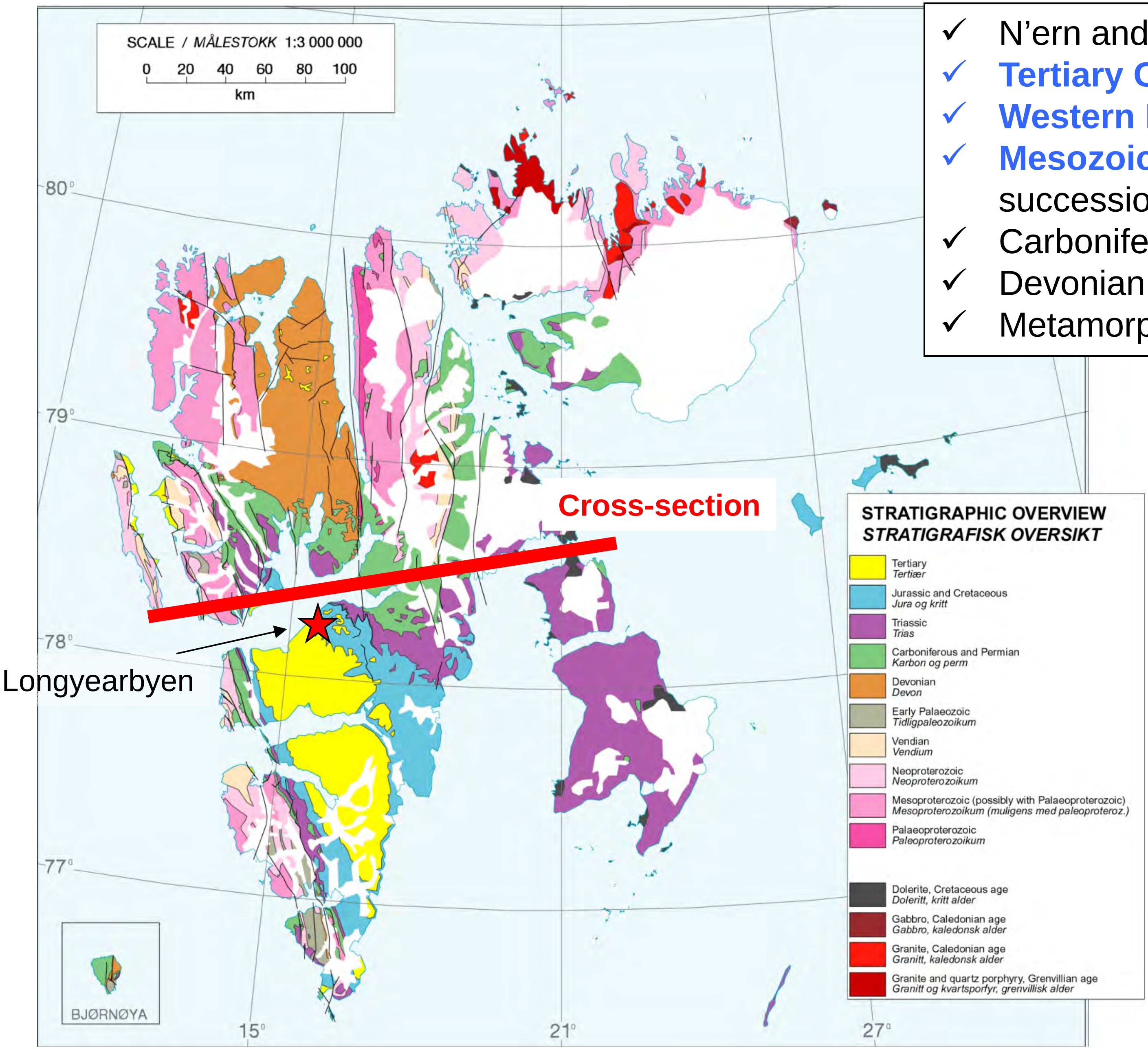
KEY CHALLENGES (verification roadmap)

1) **Succeed with technical operations in the High Arctic**
   - Slim-hole drilling with coring => datasets
   - Access to reservoir for injection testing
2) **Baseline data on rocks at 80-1000 m depth**
   - Seismic imaging
   - Drill core analysis of sedimentary succession (rocks, fractures, fluids, chemistry)
   - Drill core analysis of Poro-Perm.
   - Outcrop analysis (rocks and fractures)
3) **De-risking site – fracture flow systems and cap rock integrity**
   - Well-tests (LOT and injectivity) and Micro-seismicity
   - Specific Dh5 and Dh6 tests (LOT and well interference) of summer 2011
4) **Evaluate Injectivity and Storability**
   - Dh4 in 2009-10, Dh5R and Dh7A in 2012
   - **CO_2 capacity estimate: Probabilistic assessment volumetrix** (modified industry workflow)
5) **Conclusions (2013)**
6) **Education and Outreach** (undergraduate, Master, PhD students, Post Doc's, and public visibility)

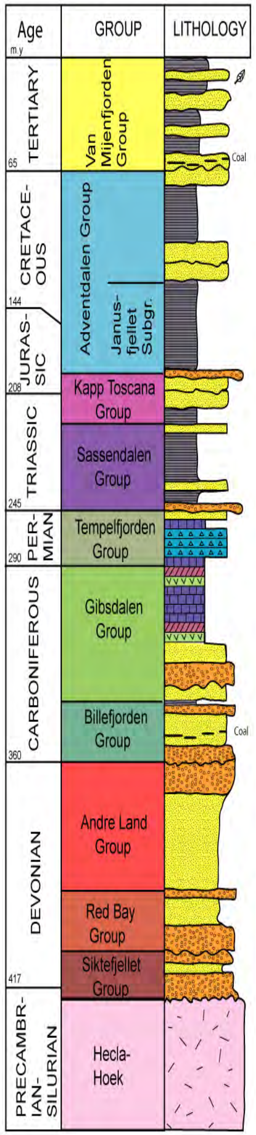
Next phase - Access to CO_2?

Database Spitsbergen's sedimentary basin

- ✓ N'ern and W'ern rifted margins
- ✓ **Tertiary Central basin**
- ✓ **Western Fold-thrust belt**
- ✓ **Mesozoic - Permian** platform succession
- ✓ Carboniferous basins
- ✓ Devonian basin
- ✓ Metamorphic basement

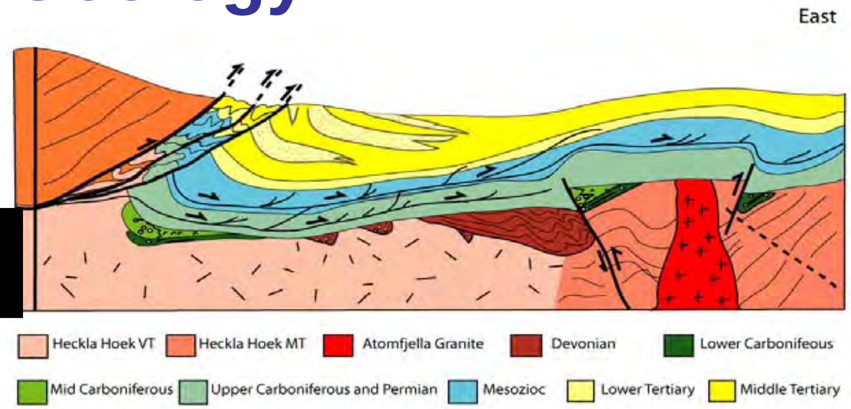


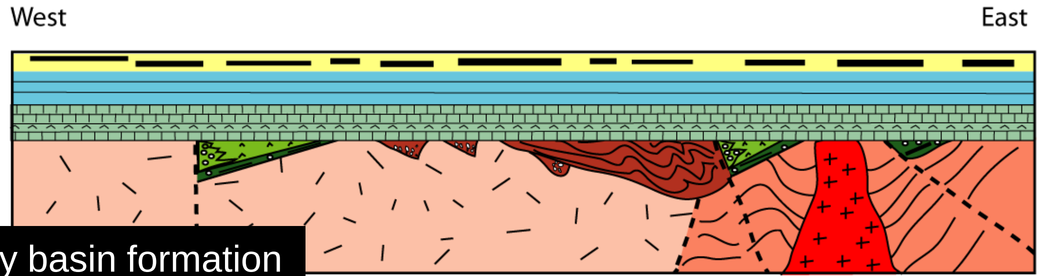
Evolution of Spitsbergen's Geology



Late Cretaceous erosion and subsequent clastic deposition in Tertiary foreland basin

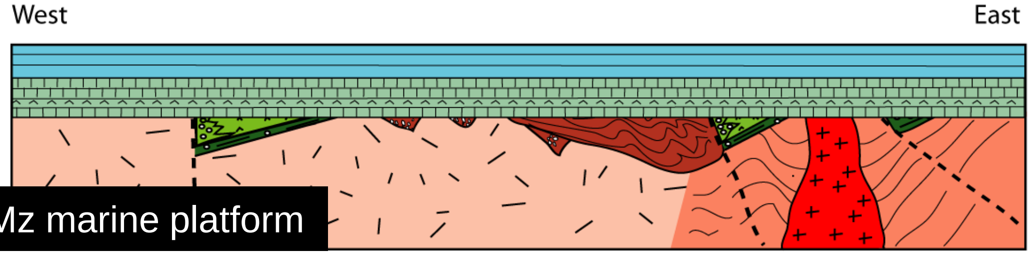
Paloc.-Eocene thrusting





Tertiary basin formation

Permian and Mesozoic platform deposits



Perm-Mz marine platform

Devonian and Carboniferous rift-basin fill

Old basement and rifting

Drilling and test site Adventdalen

- 7 cored slim holes wells (Description and interpretation of 4,5 km cored section-one well TD 970m i.e. 960MSL)
- 3 units tested and analysed with high pressured water injection (Including two units with cross well flows)
- 3 LOT tests for sealing properties
- 2D Seismic and micro seismic acquisition and monitoring
- Petrophysics, petrology, diagenesis
- Subsurface/outcrop link studies (tectonics, sedimentology, mapping of fractures)
- Reservoir modeling focused on dual porosity/permeabilty ; matrix and fractures

Drilling, well design (low-cost avenue)

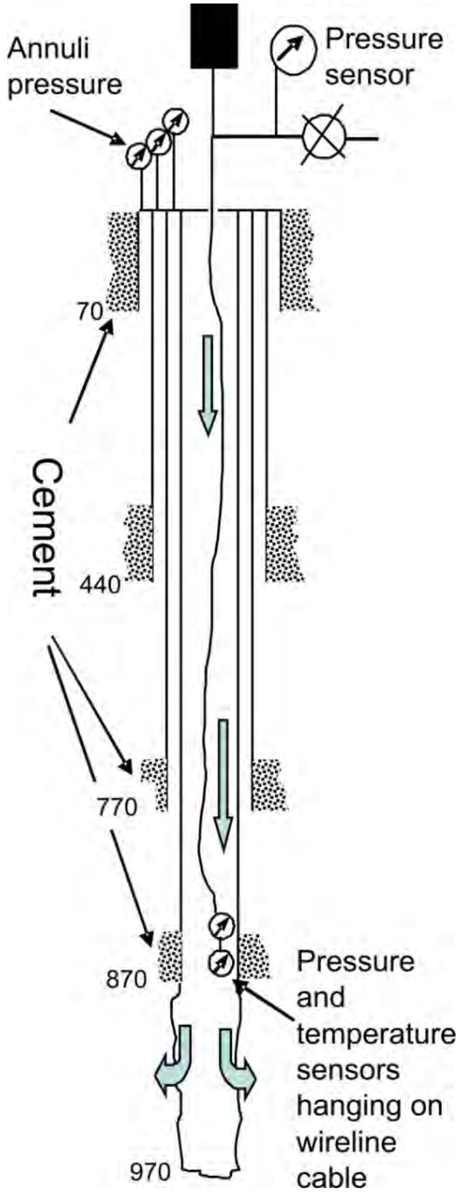
- Drill rig: ONRAM 1500
- Set up: **slim-hole**, wire-line full coring
- 1000-m deep hole of c. **M$ 1**

8 drill holes (anno August 2012)

- ➢ Drill holes to 516, 860, 403, 970, 701, 703 and 61 m
- ➢ Full coring; 4000 m core
- ➢ Slim-hole el-logging

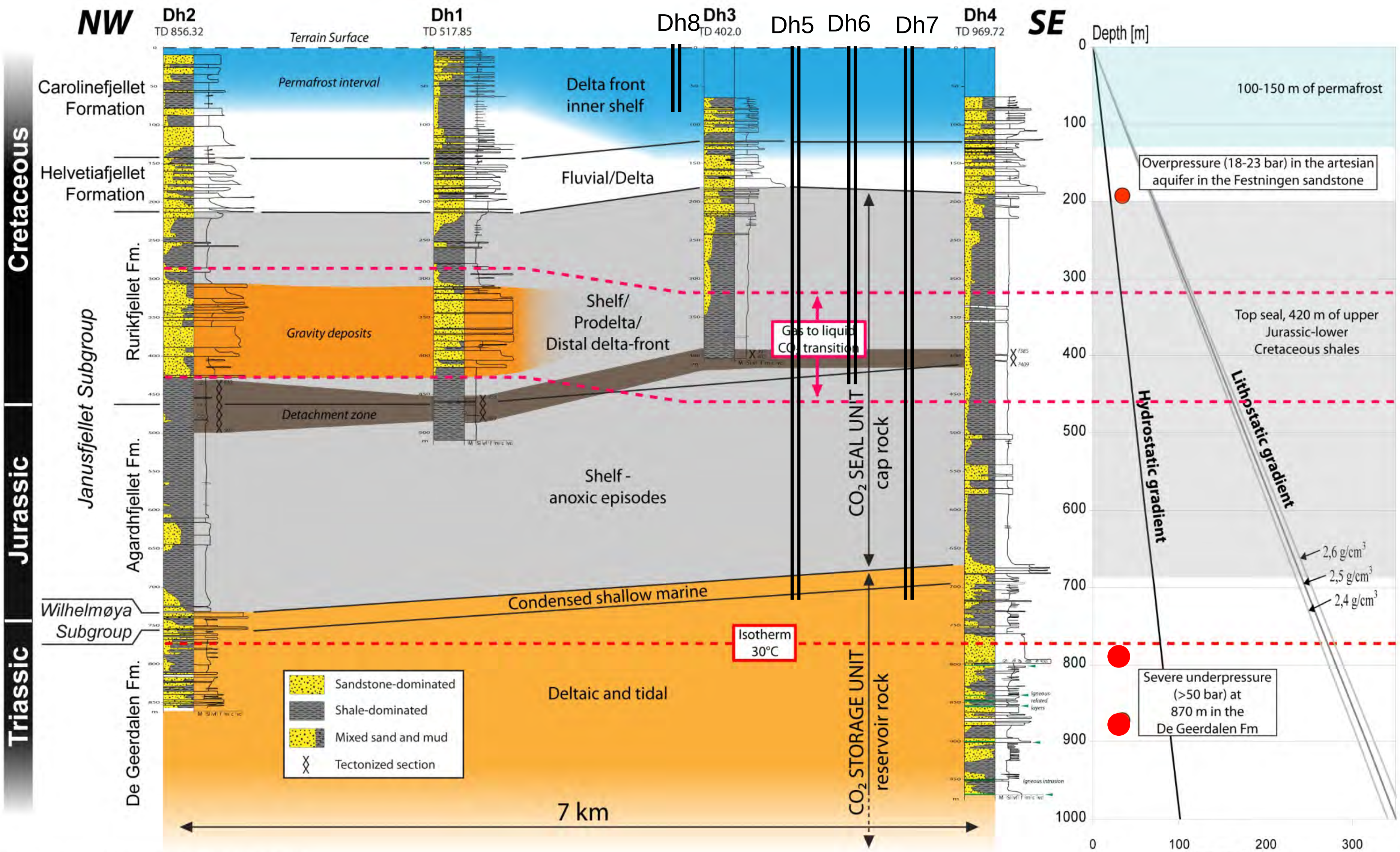
Problem: Well bore stability in fault zone (swelling clay)
Actions: 5 level telescope operation, KCl-mud, cement

State-of-the-art well design (DH4)



Sedimentary system, and the enigmatic pressure

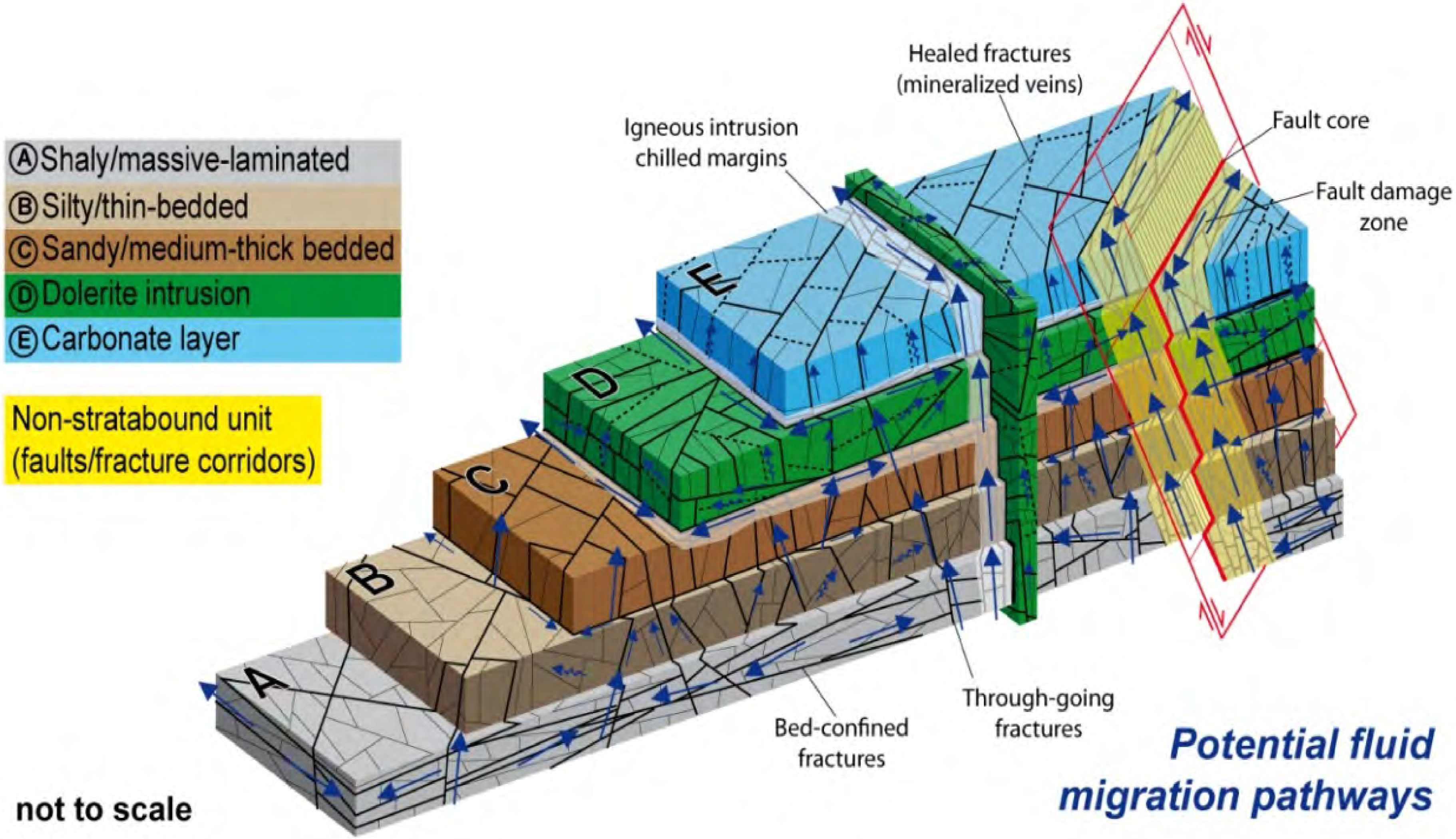
Subsurface geology from drill cores



Redrawn and modified from MØRK (2010) after OLAUSSEN et al. (2010)

Unconventional reservoir

- Tight sandstones; Poro 5-18%, Perm < 2 mD
- Fracture systems of the reservoir succession (670-970 m)



Learning's from well test program

⇒ injection campaigns vs. drill core data

Fracture pressure, aquifer ~42 bar

Fracture ≥ matrix flow reservoir

Fracture pressure, shale ~65 bar

Fracture pressure, shale ~118 bar

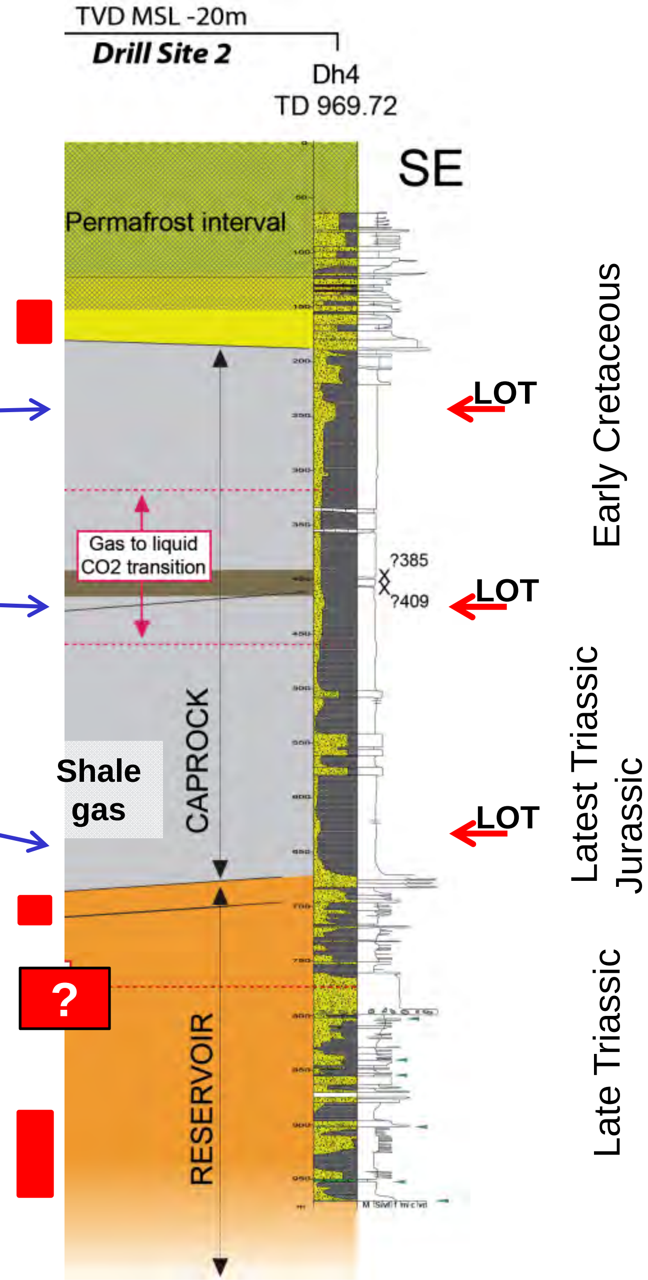
Fracture pressure,
self-sealing shale ~124 bar

Fracture pressure, reservoir ~124 bar

Matrix > fracture flow reservoir

Testing, summer 2013

Fracture >> matrix flow reservoir

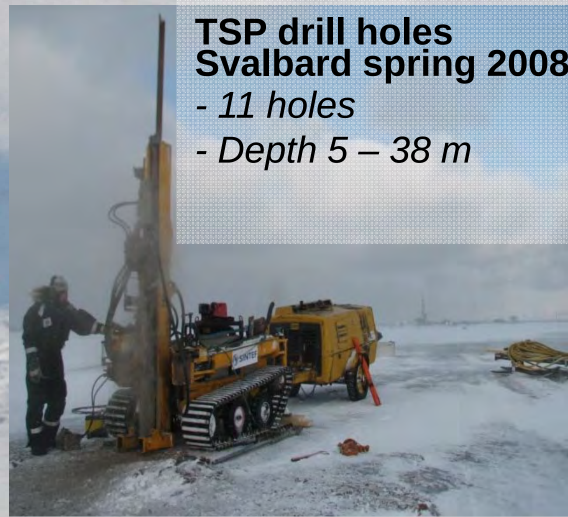


Permafrost as additional top seal

- Cored and tested permafrost section in Dh7

Hanne Christiansen

TSP drill holes
Svalbard spring 2008
- 11 holes
- Depth 5 – 38 m

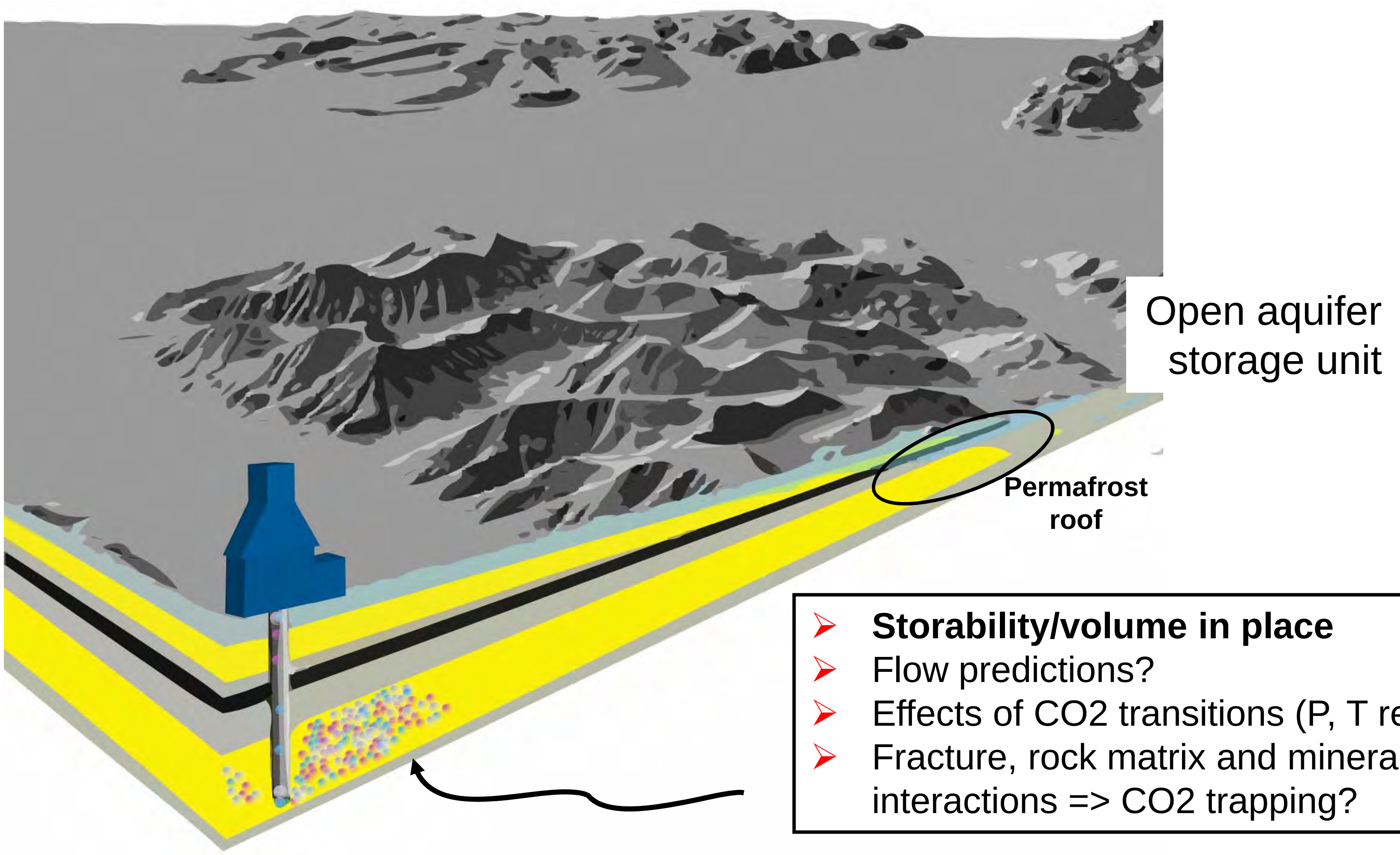


Geographic distribution of permafrost

Core with permafrost ice in otherwise un-consolidated mud

Towards conclusions (in November 2013)

- We have and efficient seal for a certain pressure
- There is storage capacity and injectivity in the main aquifer
- LOT's confirm considerable storage of buoyant fluid before reaching fracture pressure
- Surprising pressure regimes
- Although well known subsurface – surprises => "you learn as long as you drill"



- ➢ **Storability/volume in place**
- ➢ Flow predictions?
- ➢ Effects of CO_2 transitions (P, T related)?
- ➢ Fracture, rock matrix and mineral interactions => CO_2 trapping?

SITE VERIFICATION ROADMAP 2007-2013

Phase 1: **Succeed with technical operations in the High Arctic**
Baseline data acquisition and processing

Phase 2: **De-risking site – fracture flow systems and cap rock integrity**
Evaluate Injectivity and Storability;
the reservoir volume and cap-rock integrity verify possibility for CO_2 sequestr**ation**

Now: **Conclusions** (end of 2013)

- **Education** (undergraduate, Master, PhD students and Post Doc's)
- **Outreach** (establishing 'local' public acceptance)

WHAT COMES NEXT - Access to CO_2 (political aspects)

- **Ambition, Masterplan:** Full scale capture from coal-combusting power station, storing 60 ktons CO_2/y, cost < USD 180 mill.

- **Plan B:** Research capture and sequestration (campaigns of 6-10 ktons/y), cost < USD 15 mill., potentially ca. 50% reduction in CO_2 emission

How to approach the shale-gas?