UNIS CO_2 Lab of Arctic Norway

- Coal power with CO_2 storage?

- What about the natural gas?

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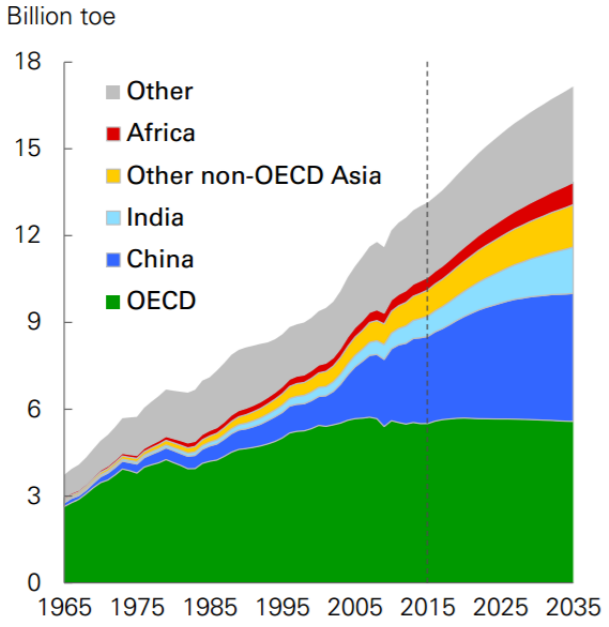
and the large
project team and partners

Hosted by … UNIS

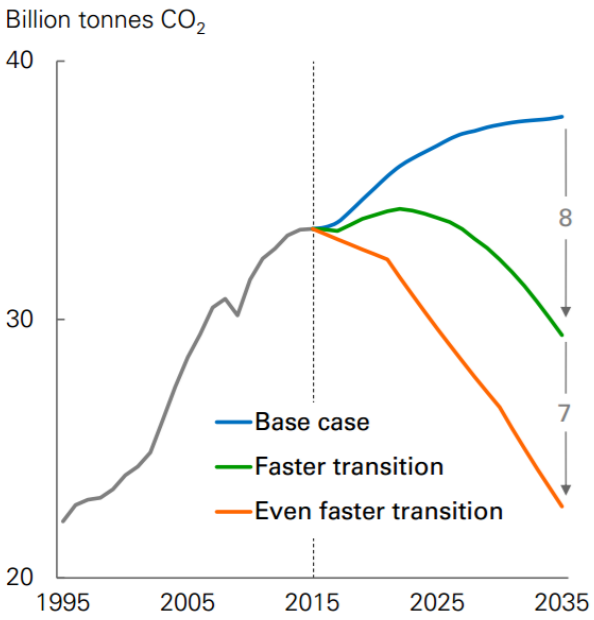
Growth requires energy and produces CO_2 emissions

- CCUS is expected to contribute to reducing global CO_2 emissions on the order of 1-2 billion tonnes by 2035 in order to reach Paris-treaty targets
- We cannot do this in Longyearbyen alone – but the onshore site can help industrial projects elsewhere, particularly to test **injection** strategies and **monitoring** techniques

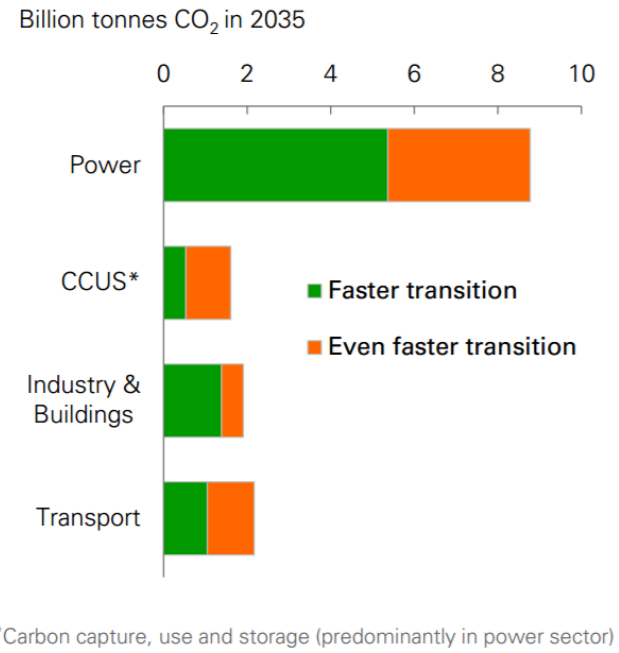
Energy consumption by region



Carbon emissions



Reductions in emissions versus base case



*Carbon capture, use and storage (predominantly in power sector)

https://www.bp.com/content/dam/bp/pdf/energy-economics/energy-outlook-2017/bp-energy-outlook-2017.pdf Also available on AppStore and Google Play

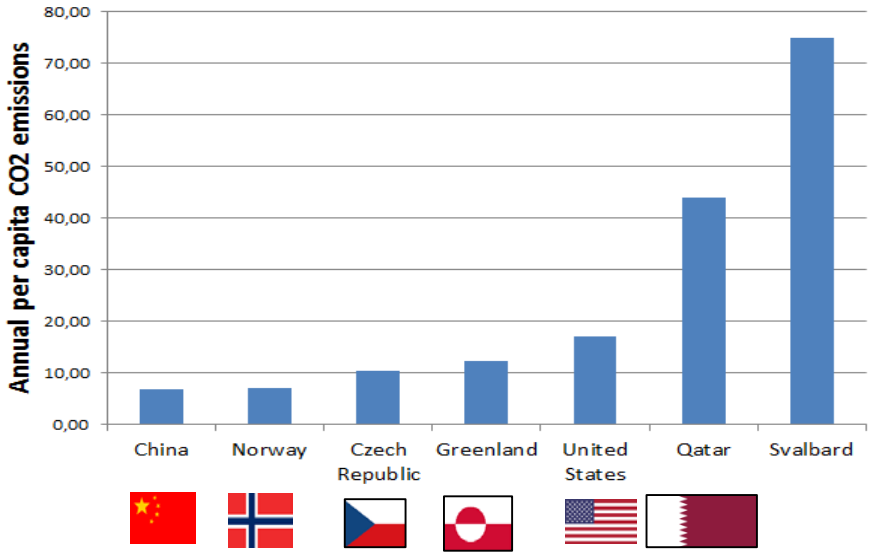
CO_2 emissions on Svalbard

Svalbard vs Norway:
- Svalbard has 10* larger CO_2 per capita footprint than mainland Norway
- Svalbard emits 0.4% of Norwegian emissions
- More than 50% of CO_2 emissions are from point sources (i.e. coal fuelled power plants)

Some CO_2 figures to ponder:

1 tur-retur flight Oslo-Longyearbyen (per pers.):
Average annual car use, ca 18 000 km:
Annual LYR power plant emissions, 2014:
Annual CO_2 injection at Sleipner:
Global CO_2 emissions, 2014:

Source: World Bank/SSB, year 2011-2015



What do we have on Svalbard (for energy)?

- Coal – a threat or opportunity?

Longyearbyen CO_2 lab project

UNIS

Coal mines

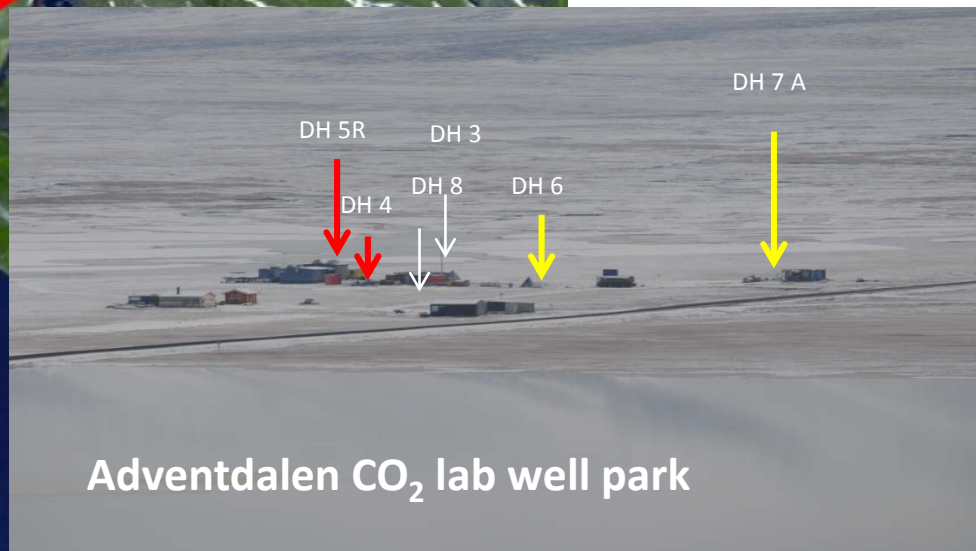
CO2 sequestration site

Longyearbyen

Power plant

DH 1,2

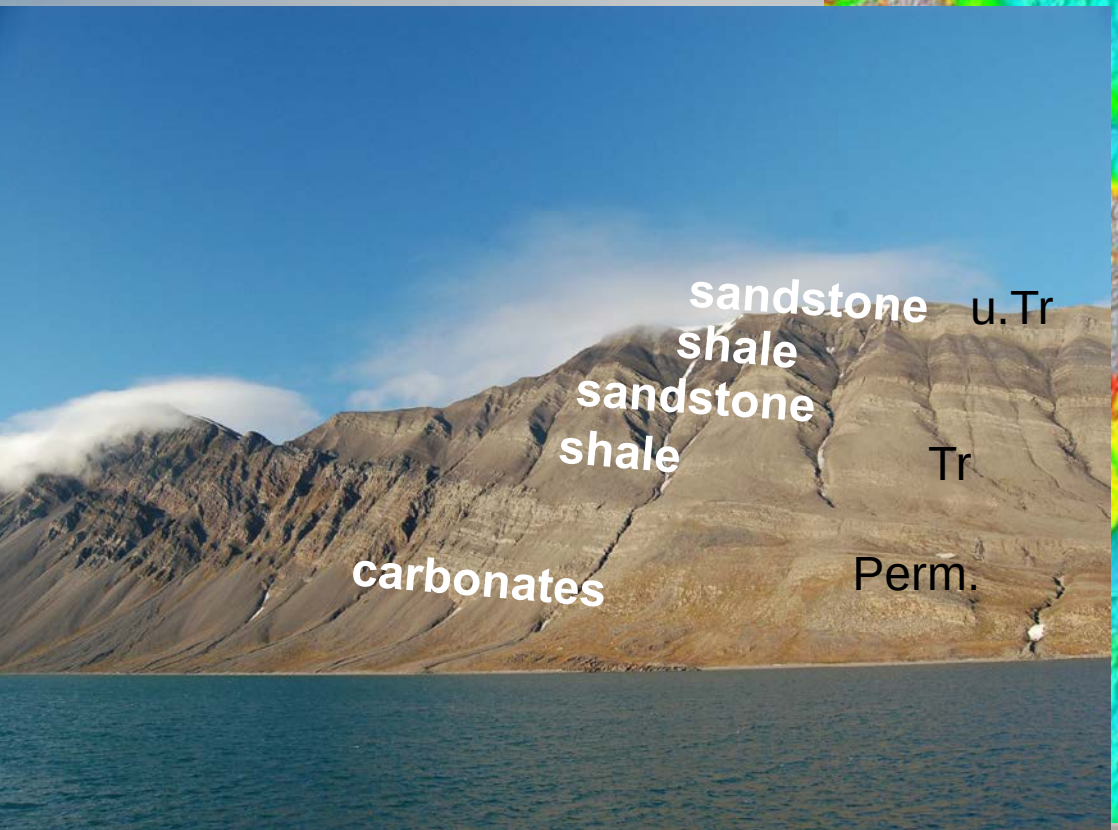
- Initiated in 2007, Phase II completed in 2015 (report at co2-ccs.unis.no)
- Coal source, Power plant, CO2 storage site all within a 7 km radius
- No land use conflict or NIMBY

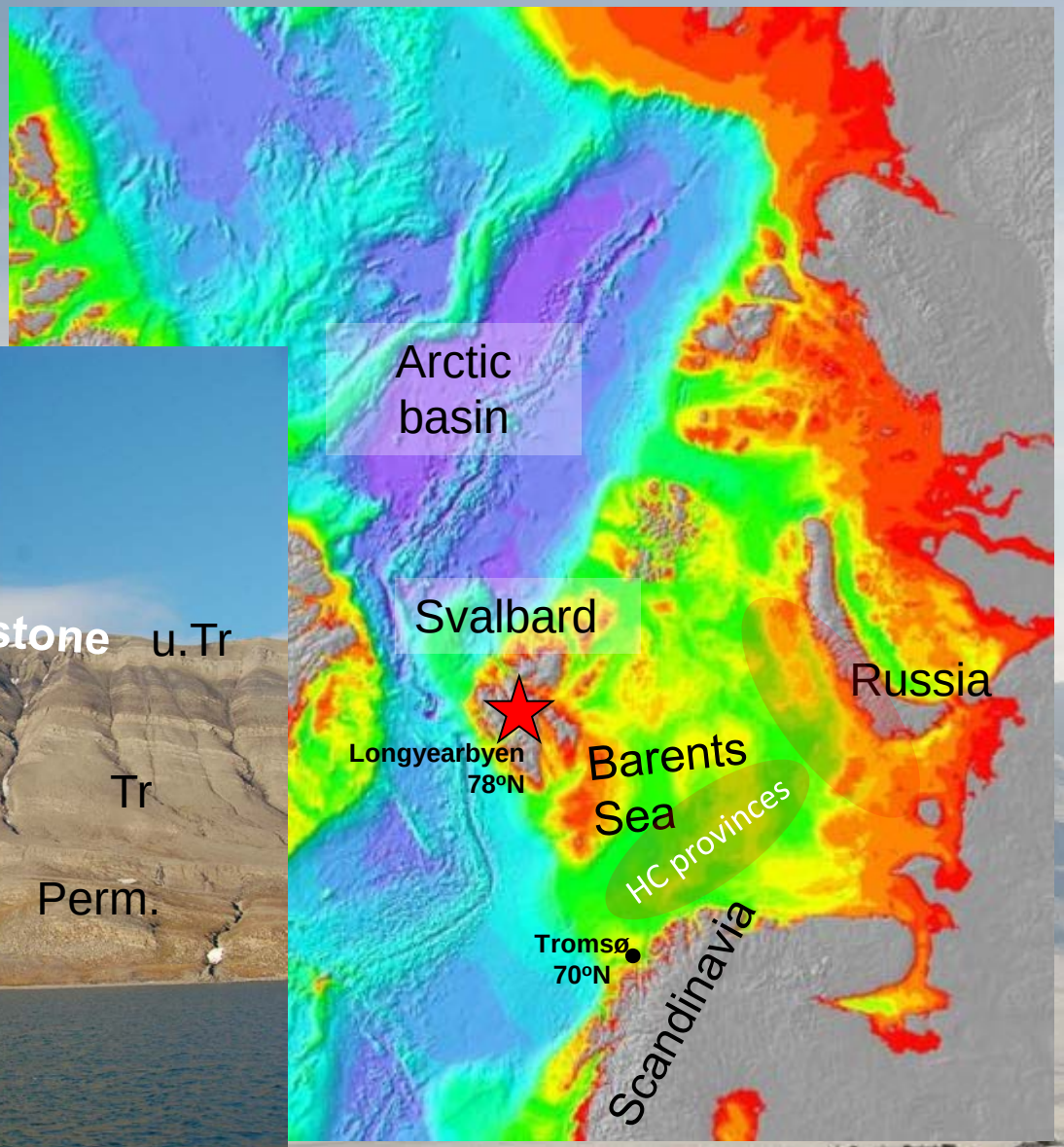


What do we need for CO_2 storage?

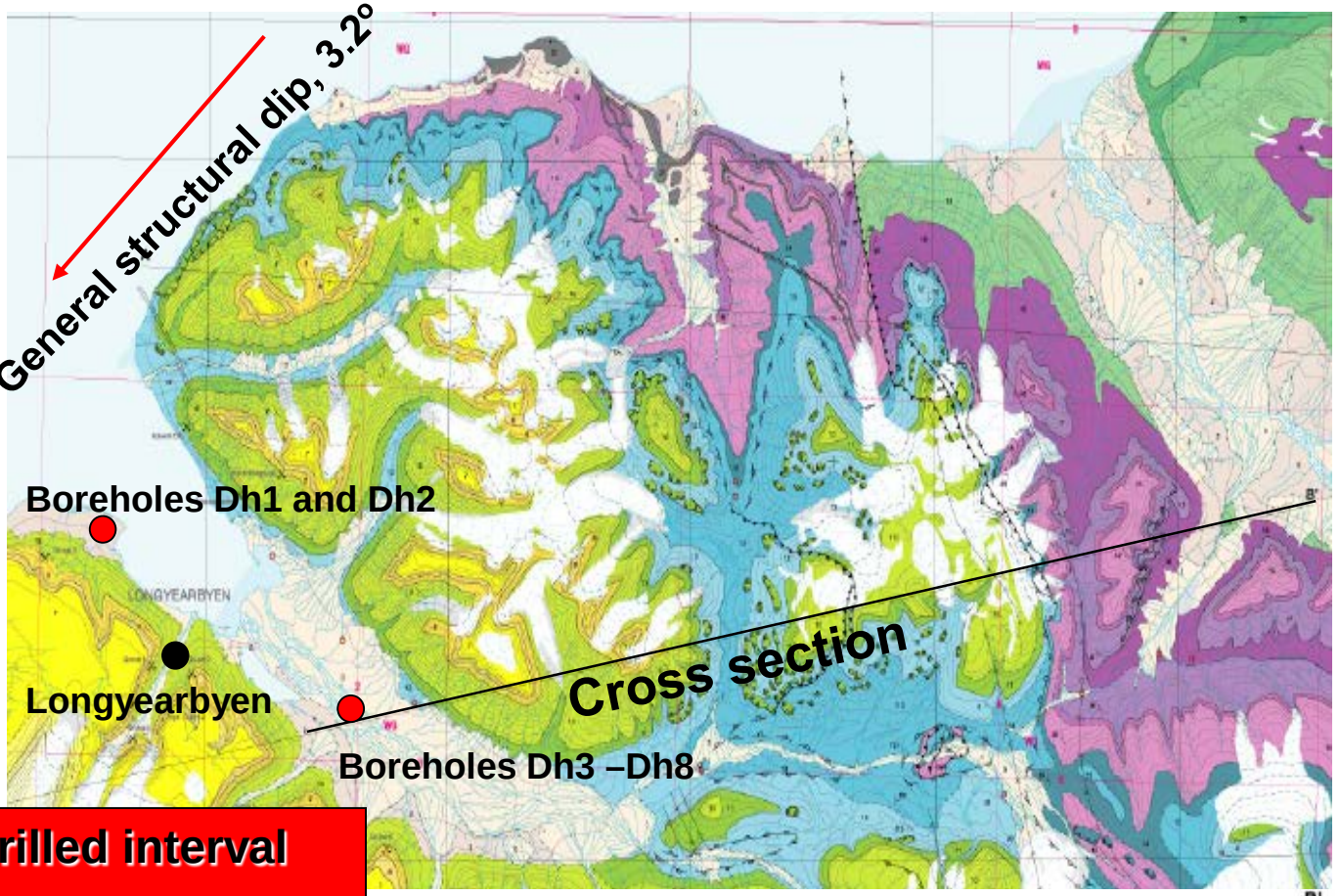
Reservoir rock
- sandstone or carbonates

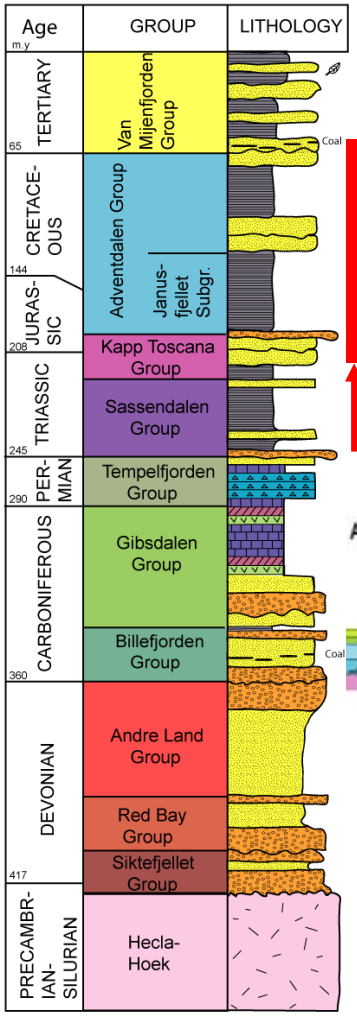
Cap rock
- Shales or evaporites





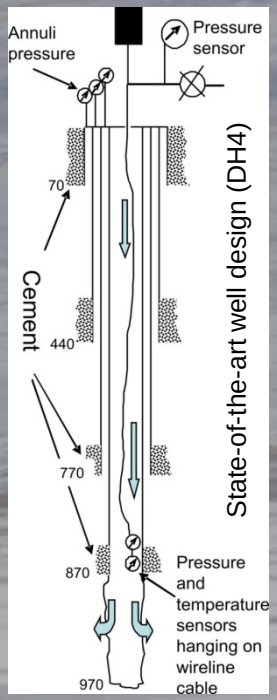
Geological overview





- Reservoir mainly shallow marine sandstones and shales capped by coarse-grained conglomerates
- Regional dip towards SW - reservoir section exposed ca.15km NE of the drilling site, but lateral seals => UNDERPRESSURED !!!

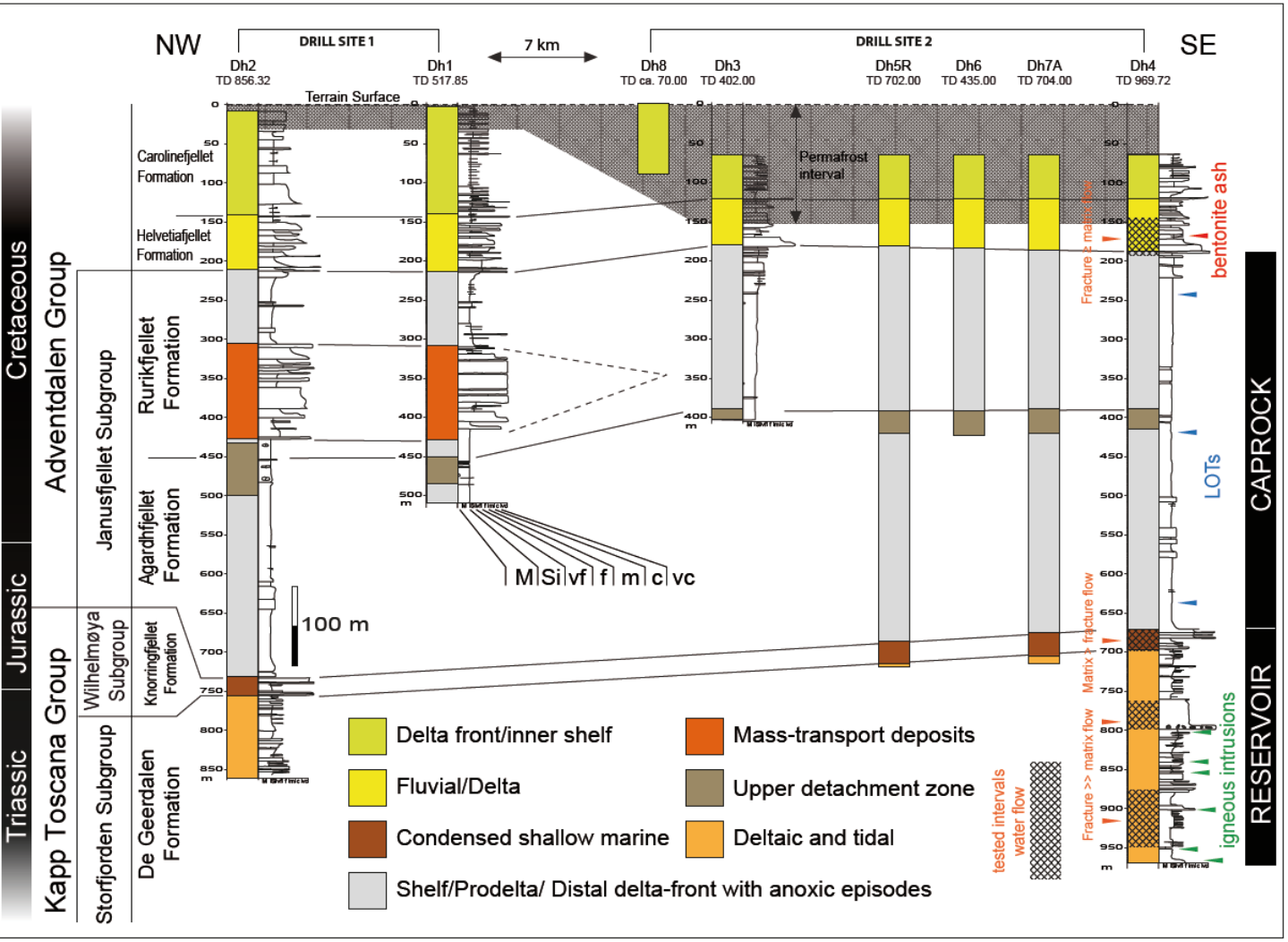
CO_2 lab well park

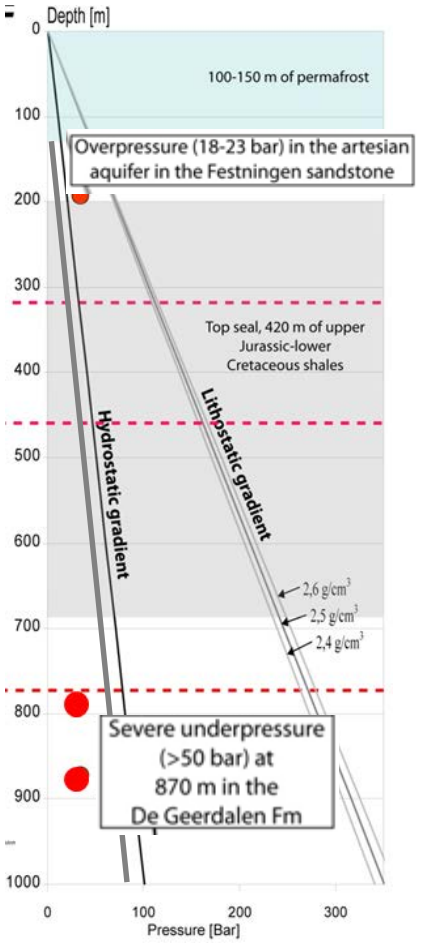


- 8 cored slim holes wells (Description and interpretation of 4,5 km cored section-one well TD 970m i.e. 960MSL)
- 4 units tested and analyzed with high pressured water injection (including two units with cross well flows)
- 3 leak-off-tests (LOT) tests for sealing properties
- 2D Seismics and micro seismic acquisition and monitoring
- Petrophysics, petrology, diagenesis
- Subsurface/outcrop link studies (tectonics, sedimentology, mapping of fractures)
- Reservoir modeling focused on dual porosity/permeability; matrix and fractures
- > 40 fully peer-reviewed journal articles, 17 affiliated PhD students, 3 affiliated Post-Docs, 21 MSc students, MSc/PhD level course on CO_2 sequestration
- Plugging & abandonment of wells following discovery of natural gas

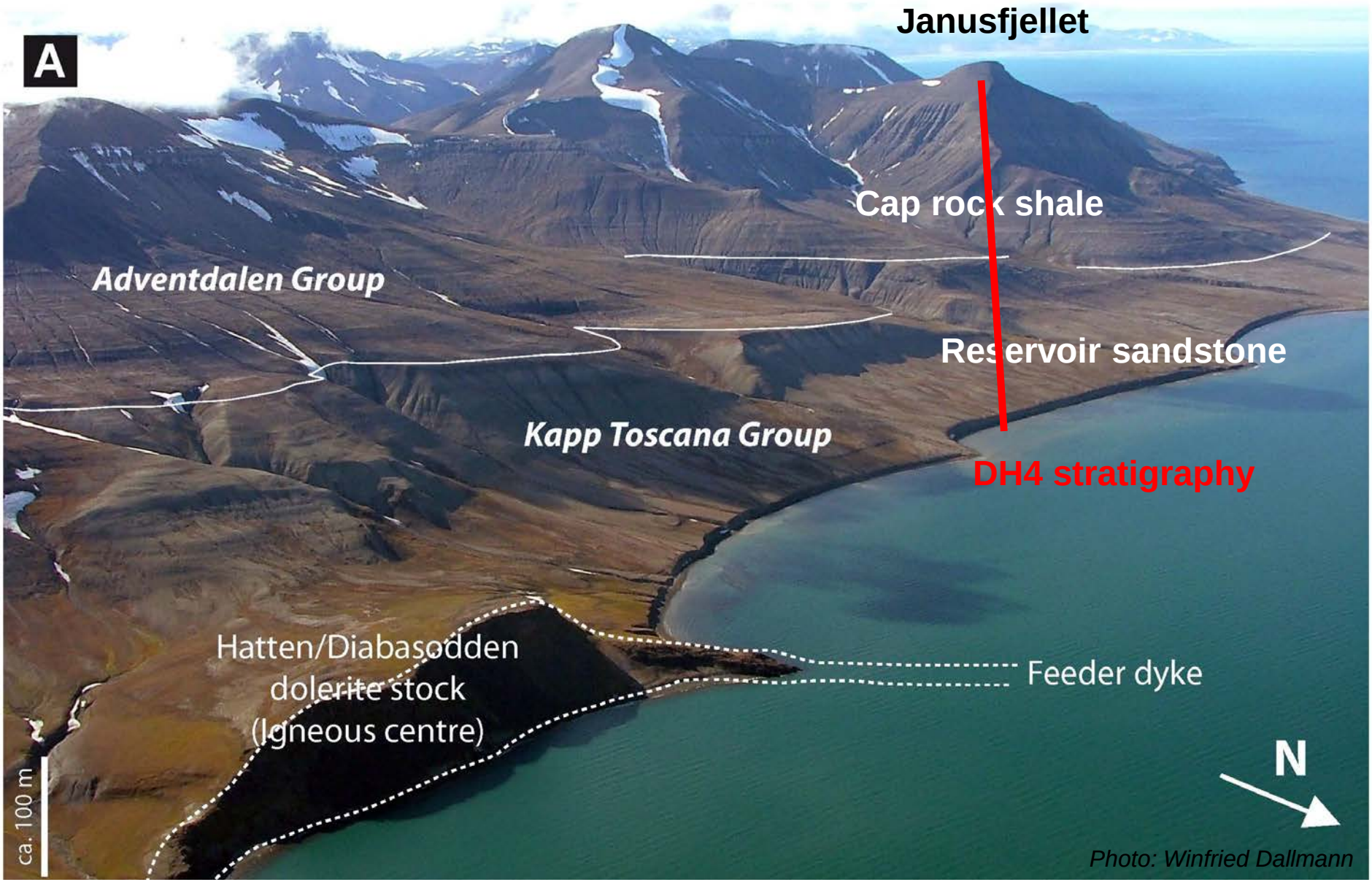
Sedimentary system from drill cores

- Siliciclastic succession, with a naturally fractured reservoir at 670-970m
- Caprock, including detachment in Agardhfjellet Fm, is a robust top seal
- Early Cretaceous igneous intrusion locally present



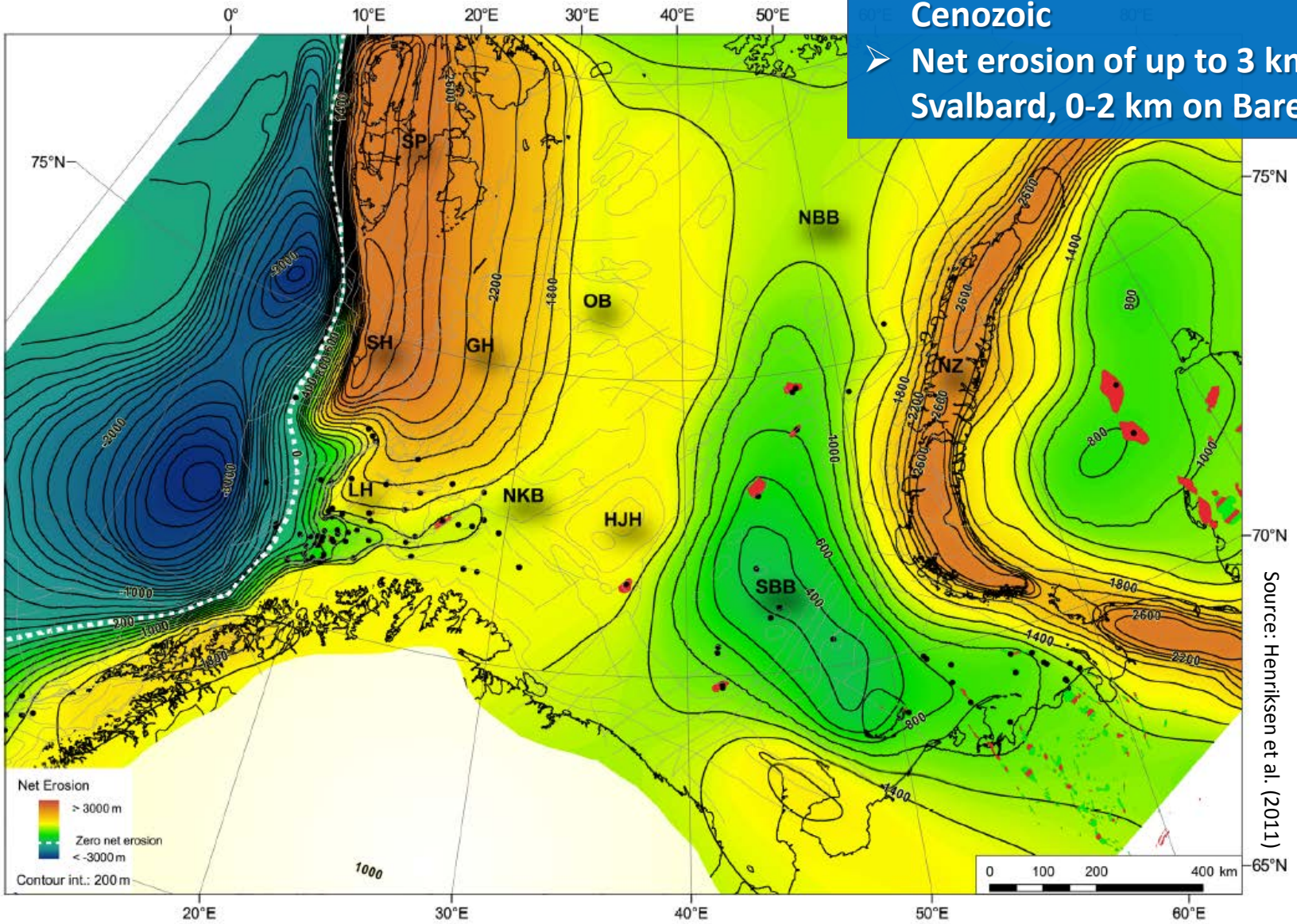


Reservoir-cap rock succession at Deltaneset-Hatten



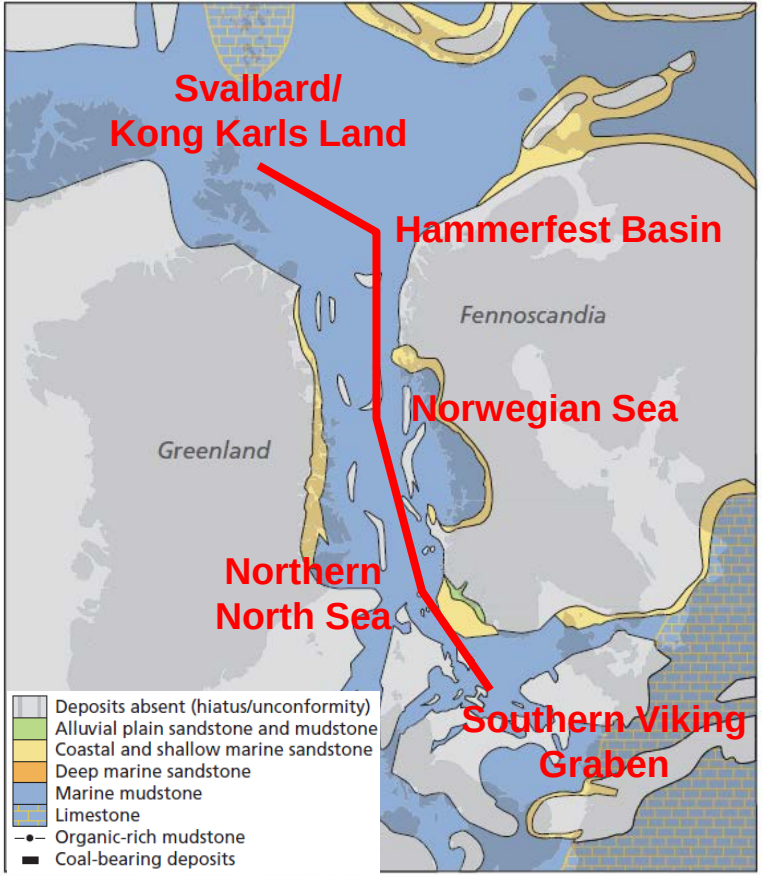
Net erosion of Barents shelf

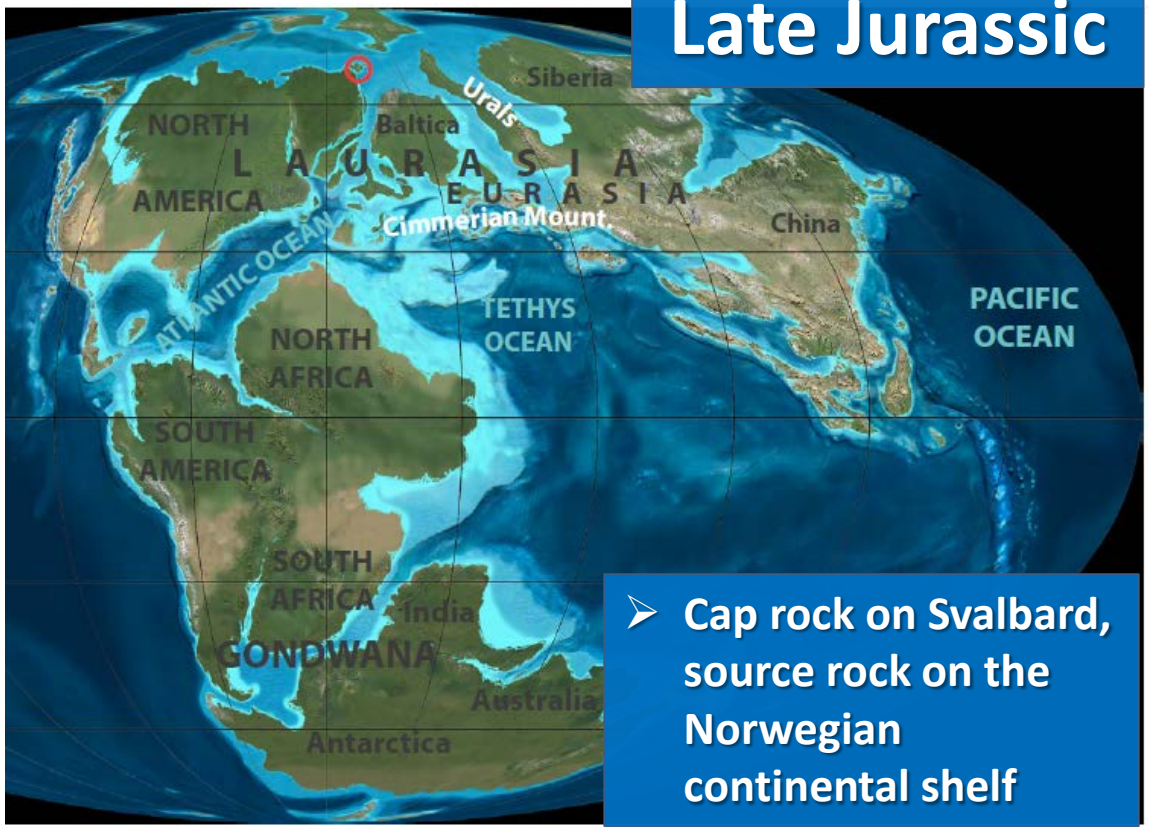
- Extensive tectonic and glacial-related uplift and net erosion in Cenozoic
- Net erosion of up to 3 km on Svalbard, 0-2 km on Barents shelf

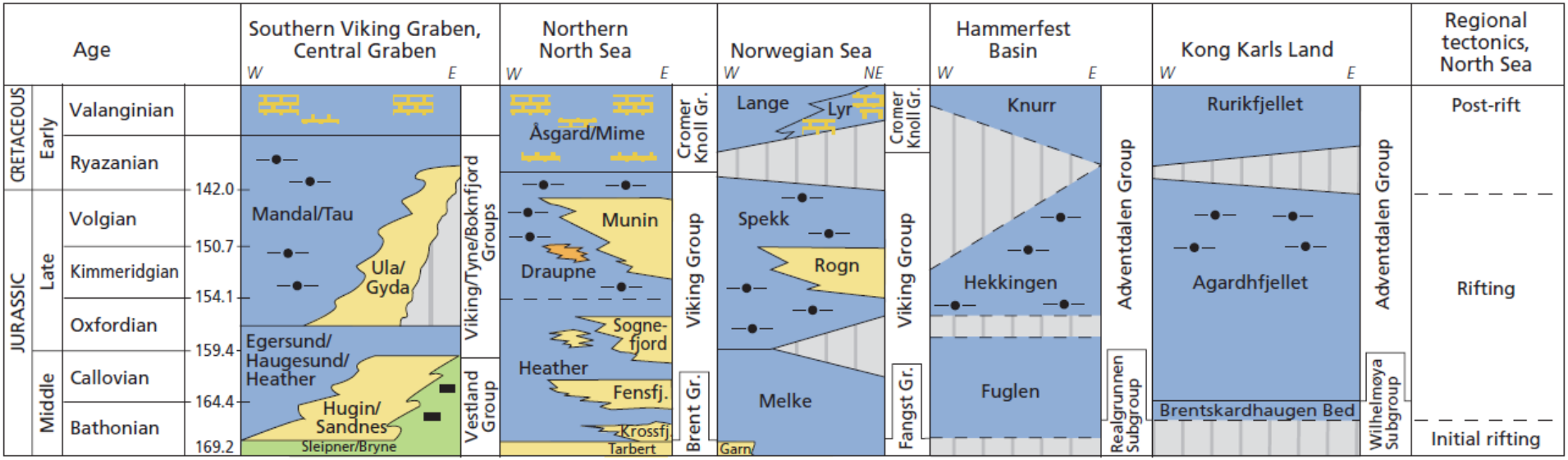


Source: Henriksen et al. (2011)

NZ - Novaya Zemlia
SBB - South Barents Basin
NBB - North Barents Basin
HJH - Hjalmar Johansen Hight
NKB - Nordkapp Basin
LH - Loppa High
OB - Olga Basin
SP - Spitsbergen
SH - Stappen High
GH - Gardarbanken High
Gas discovery
Oil/gas discovery
800 Net erosion contour
-1000 Net deposition contour
Wells


Svalbard/
Kong Karls Land
Hammerfest Basin
Fennoscandia
Norwegian Sea
Greenland
Northern
North Sea
Southern Viking
Graben
Deposits absent (hiatus/unconformity)
Alluvial plain sandstone and mudstone
Coastal and shallow marine sandstone
Deep marine sandstone
Marine mudstone
Limestone
Organic-rich mudstone
Coal-bearing deposits


Late Jurassic
Siberia
Urals
NORTH
AMERICA
Baltica
L A U R A S I A
E U R A S I A
Cimmerian Mount.
China
ATLANTIC OCEAN
TETHYS
OCEAN
PACIFIC
OCEAN
NORTH
AFRICA
SOUTH
AMERICA
SOUTH
AFRICA
India
GONDWANA
Australia
Antarctica
Cap rock on Svalbard, source rock on the Norwegian continental shelf


Age
Southern Viking Graben, Central Graben
Northern North Sea
Norwegian Sea
Hammerfest Basin
Kong Karls Land
Regional tectonics, North Sea
W
E
NE
CRETACEOUS
JURASSIC
Early
Late
Middle
Valanginian
Ryazanian
Volgian
Kimmeridgian
Oxfordian
Callovian
Bathonian
142.0
150.7
154.1
159.4
164.4
169.2
Mandal/Tau
Ula/
Gyda
Egersund/
Haugesund/
Heather
Hugin/
Sandnes
Sleipner/Bryne
Viking/Tyne/Boknfjord Groups
Vestland Group
Åsgard/Mime
Munin
Draupne
Sogne-
fjord
Heather
Fensfj.
Krossfj
Tarbert
Cromer
Knoll Gr.
Viking Group
Brent Gr.
Lange
Lyr
Spekk
Rogn
Melke
Garn
Cromer
Knoll Gr.
Viking Group
Fangst Gr.
Knurr
Hekkingen
Fuglen
Adventdalen Group
Realgrunnen
Subgroup
Rurikfjellet
Agardhfjellet
Brentskardhaugen Bed
Adventdalen Group
Wilhelmøya
Subgroup
Post-rift
Rifting
Initial rifting

Learnings from well test programme

Fracture pressure, aquifer ~42 bar

Fracture ≥ matrix flow reservoir

Fracture pressure, shale ~65 bar

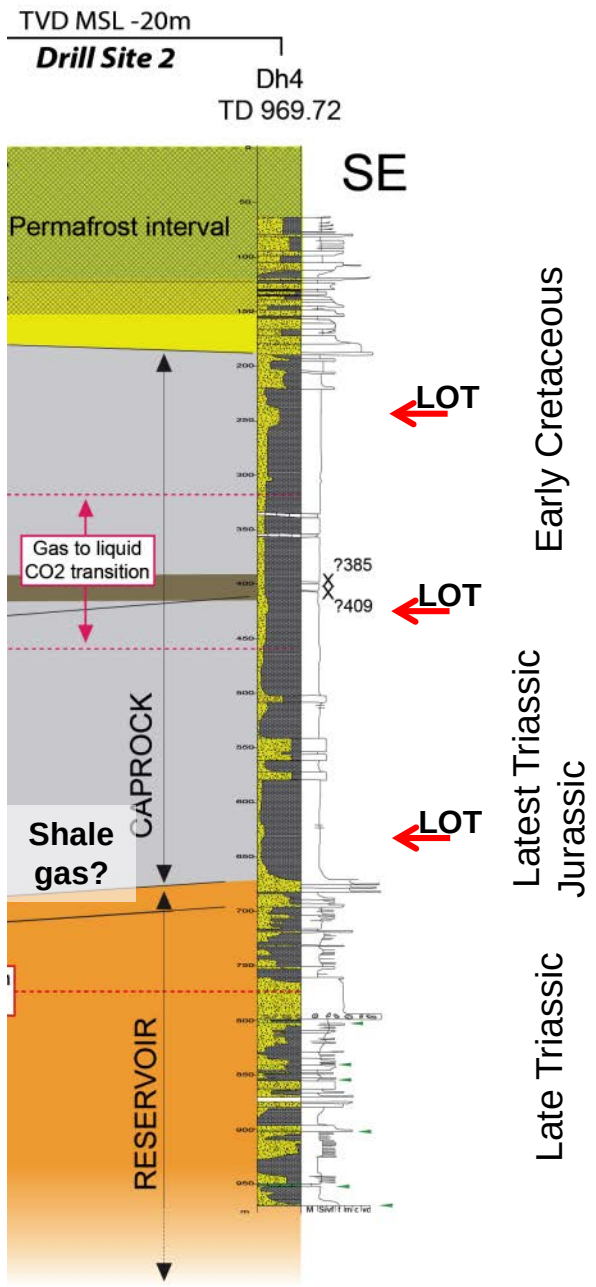
Fracture pressure, shale ~118 bar

Fracture pressure,
self-sealing shale ~124 bar

Fracture pressure, reservoir ~124 bar

Matrix > fracture flow reservoir

Fracture >> matrix flow reservoir



Conclusions of CO_2 Pilot project

(for more see co2-ccs.unis.no Phase II report)

- An efficient **seal** for buoyant fluid (i.e. until 125 Bar) is confirmed
- **Low pressure** reservoir (might change phase of CO_2)- Depleted reservoir as produced field in North Sea
- **Storage capacity** and **injectivity** is confirmed – though CO_2 injection is needed to reduce risk related to CO_2 behaviour in subsurface
- **Fractures** are the main fluid flow conduits, very low matrix permeability
- Unconventional segmented reservoir
- **Natural gas** is present in the subsurface

Siliciclastic succession, with a naturally fractured reservoir at 670-970m

Caprock, including detachment fault in Agardhfjellet Fm, is a robust top seal

The road ahead – visions of an Arctic Energy lab

- **Research themes building on Phase II results**
  - Focussed fieldwork on structural mapping of fracture and fault systems within the cap rock shale
  - Detailed mapping of the structural heterogeneities within the lower part of the cap rock, notably sand injectites
  - Hyperspectral imaging of core material to determine clay mineralogy and its lateral and vertical variation
  - Geophysical characterization (2D seismic, TEM/MT/CSMT etc.) of shale
  - Rock physical characterization of shales and comparison to less severely buried equivalent units in the Barents Sea
- **Long-term visions requiring longer-term financing. Ambitions to become:**
  - an international test site for onshore CO_2 storage in conventional and unconventional reservoirs
  - a test site for testing CO_2 monitoring and injection techniques on the field-scale
  - a unique laboratory of the entire CCS value chain – from coal to the storage unit(s)
  - UNIS CO_2 lab becomes the place where young people go to experience field based studies on carbon capture and storage
  - An onshore shale-laboratory

Thank you for your attention!

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Photo: Anja Fleig

Local learning – global applications

Project	Operator	Date started	CO_2 injected (Mtpa)	Main challenge	Role of UNIS CO_2 lab Storage Pilot
UNIS CO_2 Lab	UNIS	???	Max 0.085	Access to CO_2	N/A
Industrial-scale CCS projects (http://www.globalccsinstitute.com/projects/large-scale-ccs-projects#map)					
Sleipner	Statoil	1996	0.9	No monitoring well	Monitoring focus.
Weyburn, CA	Canovus/ Apache	2000	3.0	Public opinion	Learnings from monitoring
In Salah	Sonatrach/BP/Statoil	2004	0	Political situation	?
Snøhvit	Statoil	2008	0.7	No monitoring well. Injectivity issues.	Monitoring, storage, injectivity.
Lula, Brazil	Petrobras	2013	0.7	?	Monitoring, storage, injectivity.
Boundary Dam	Saskpower	2014	1.0	?	Storage pilot using coal.
Uthmaniyah, Saudi Arabia	Saudi Aramco	2015	0.8	?	Monitoring, storage, injectivity.
Gorgon, Aus	Chevron	2017?	3.4-4.0	?	Monitoring, storage, injectivity.