TRONDHEIM CCS CONFERENCE

CO_2 CAPTURE, TRANSPORT AND STORAGE

Can low permeable rocks be used for storing CO_2? The potential Longyearbyen CO_2 reservoir

By
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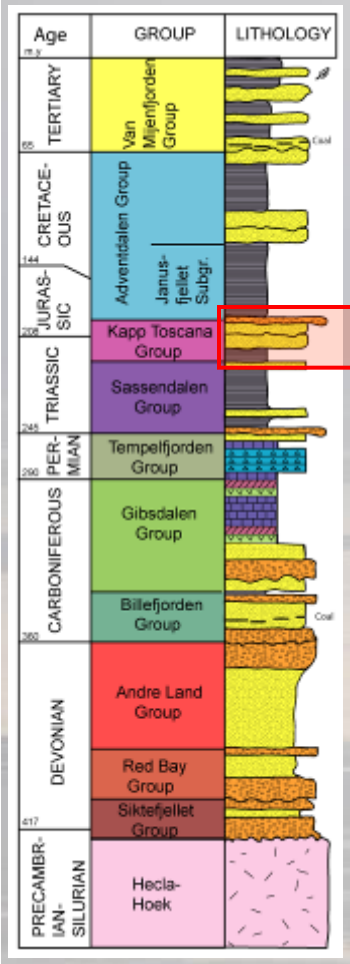
Trondheim, June 15, 2011

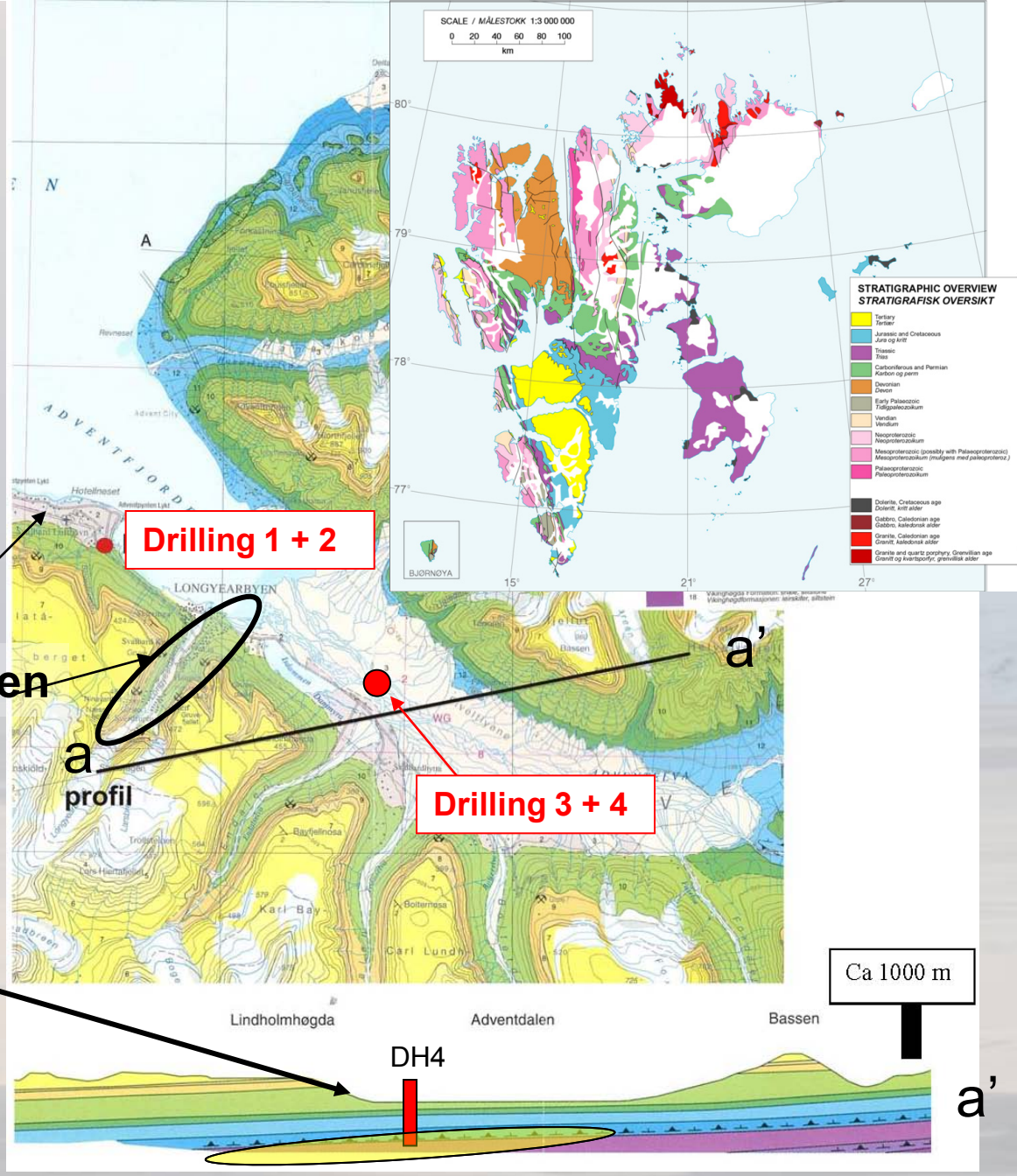
SINTEF NTNU CIPR UNIS

Longyearbyen CO2-lab - an unique test site "everything" within a radius of 7 km

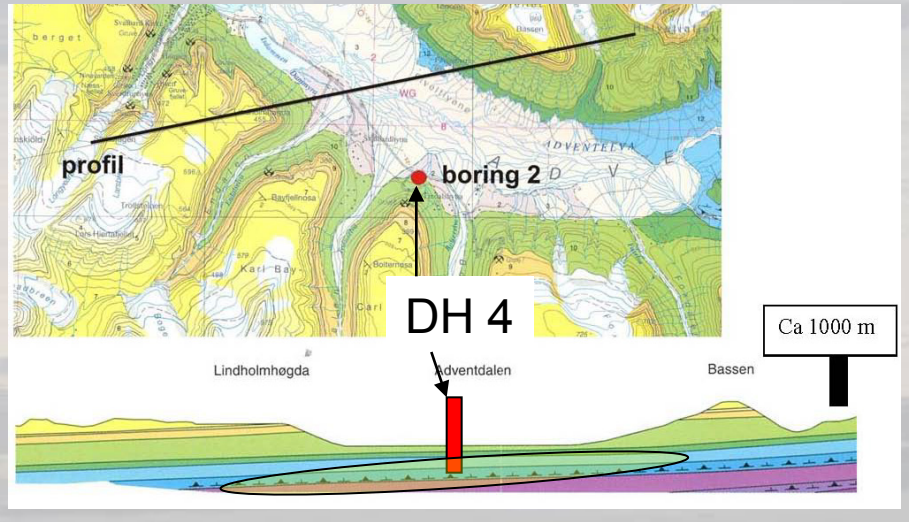
An integrated research and education laboratory at UNIS,
With wide contributions

CO2-storage near Longyearbyen

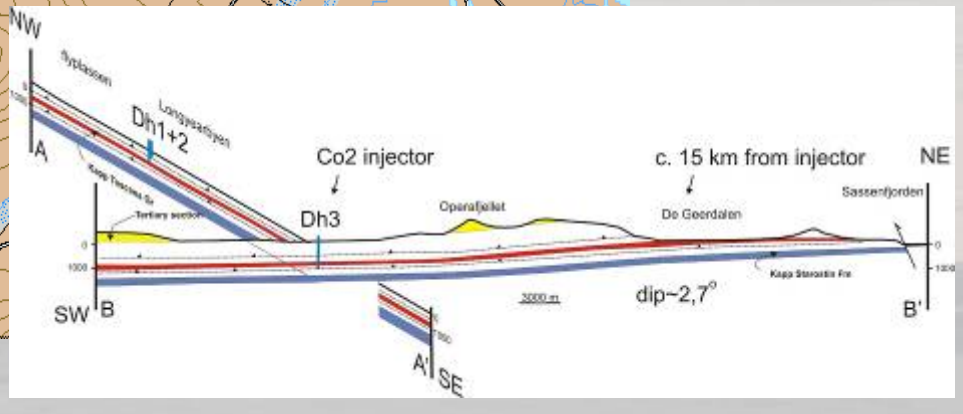


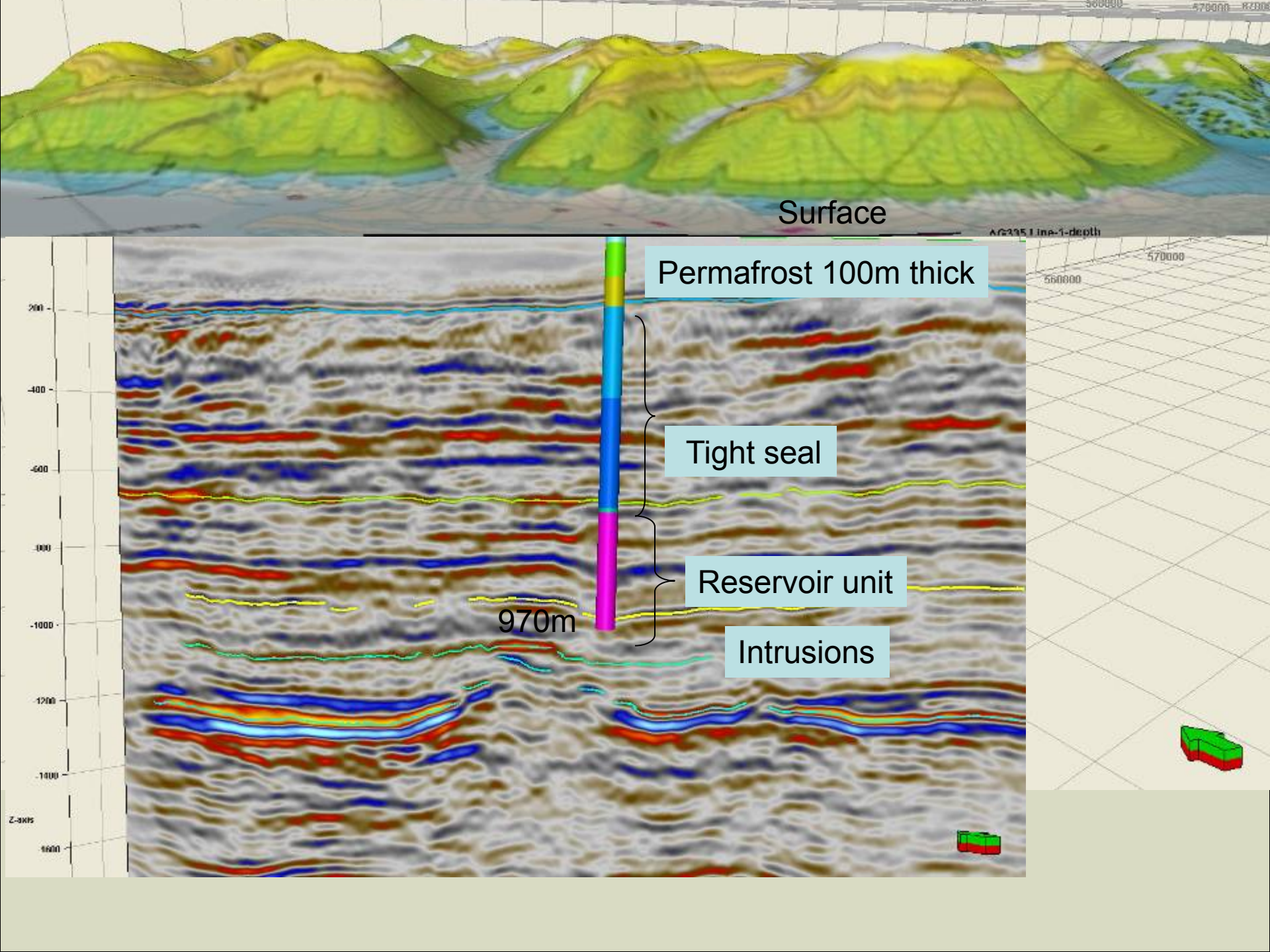


No trap but a monocline outcropping to the north east



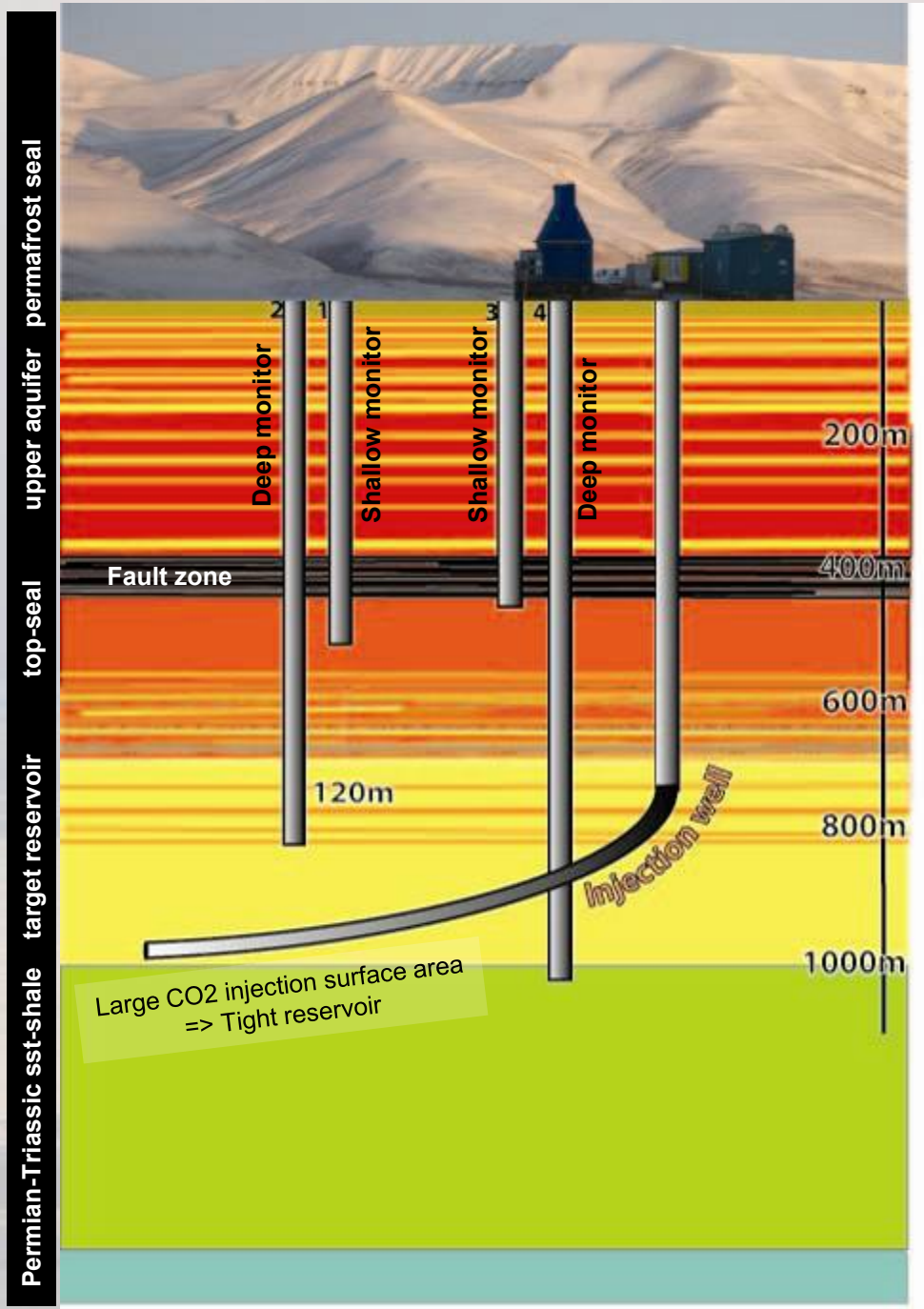
Seismic monitoring: Establishing seismic base line during winter time (Explosives as source - minor harm on nature)
Purpose; "Listen" to fracturing during test and for later monitoring



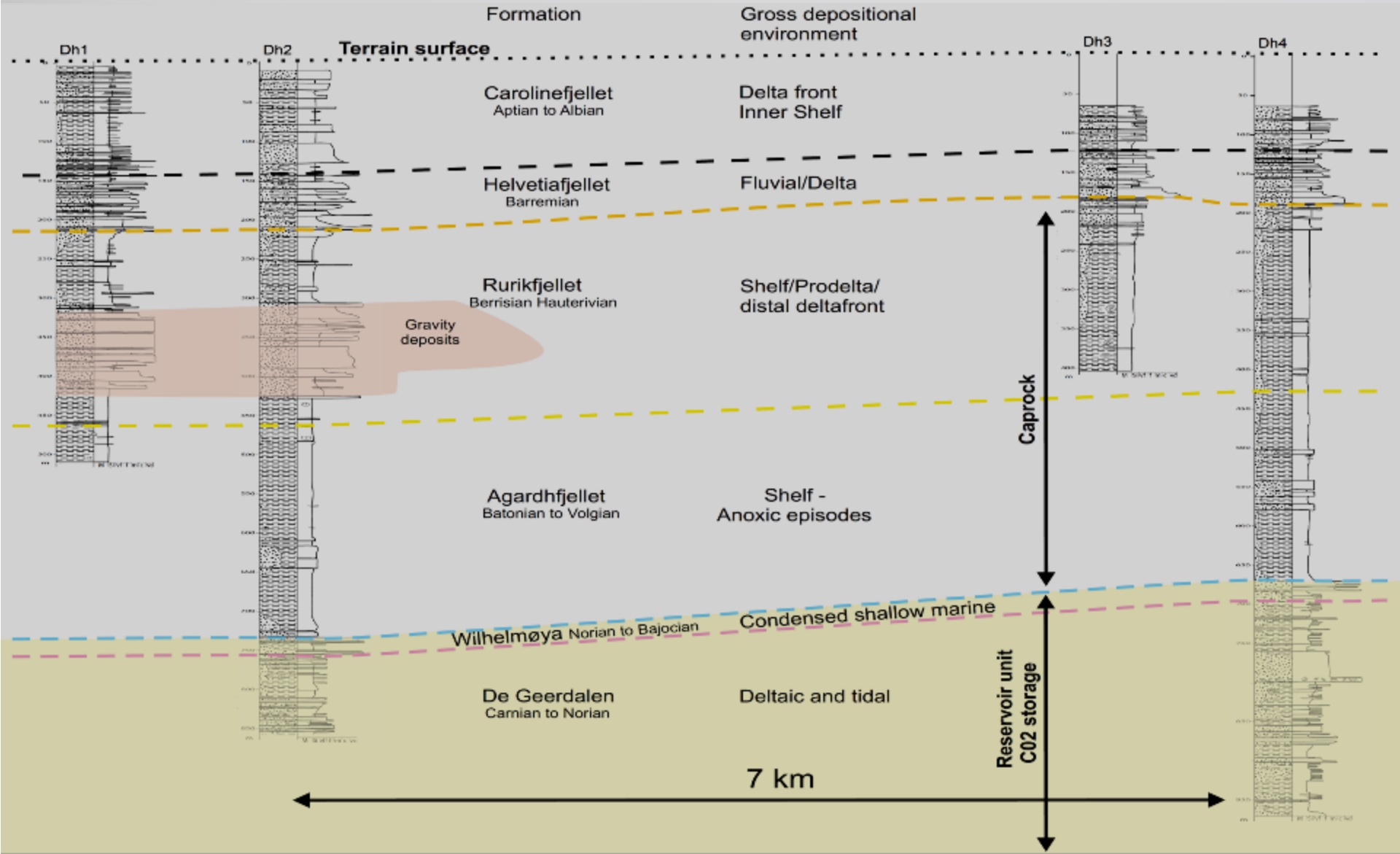

Surface
Permafrost 100m thick
Tight seal
Reservoir unit
970m
Intrusions

Drilled four wells
first three failure

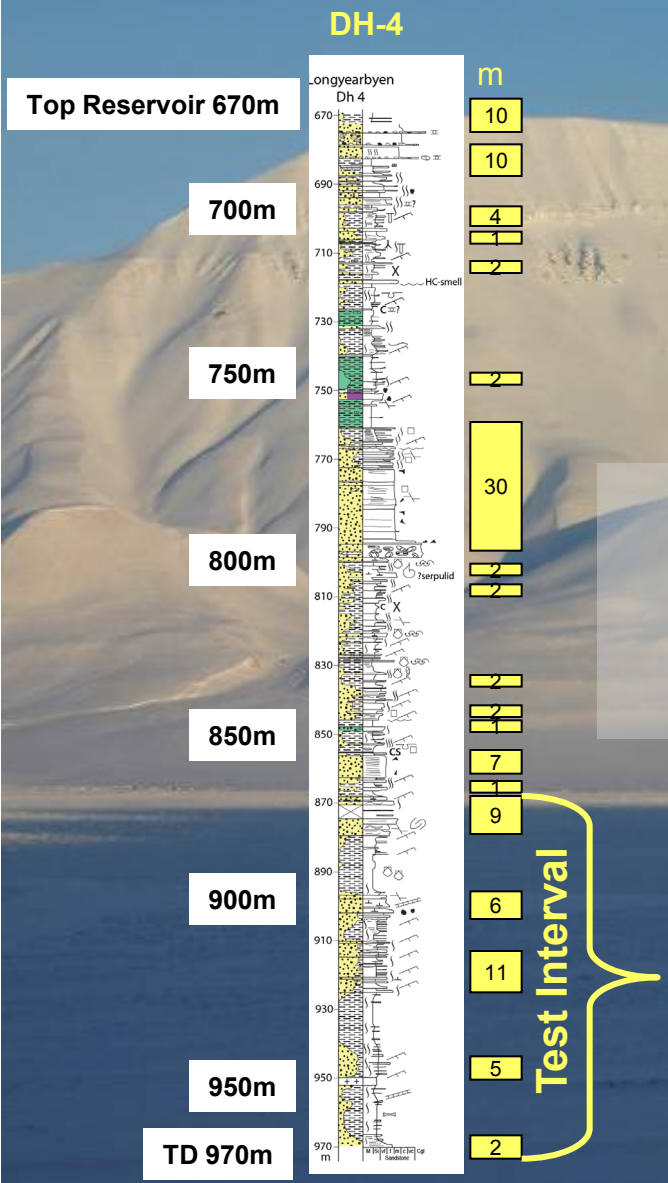
Drill hole 4 finished 27/11-09
- Total depth 970 m
- Cored reservoir unit i.e. Lower 300 m
- Cored ~500 m cap rock shales



The Longyearbyen wells



The Reservoir



Log from A. Mørk, Sintef

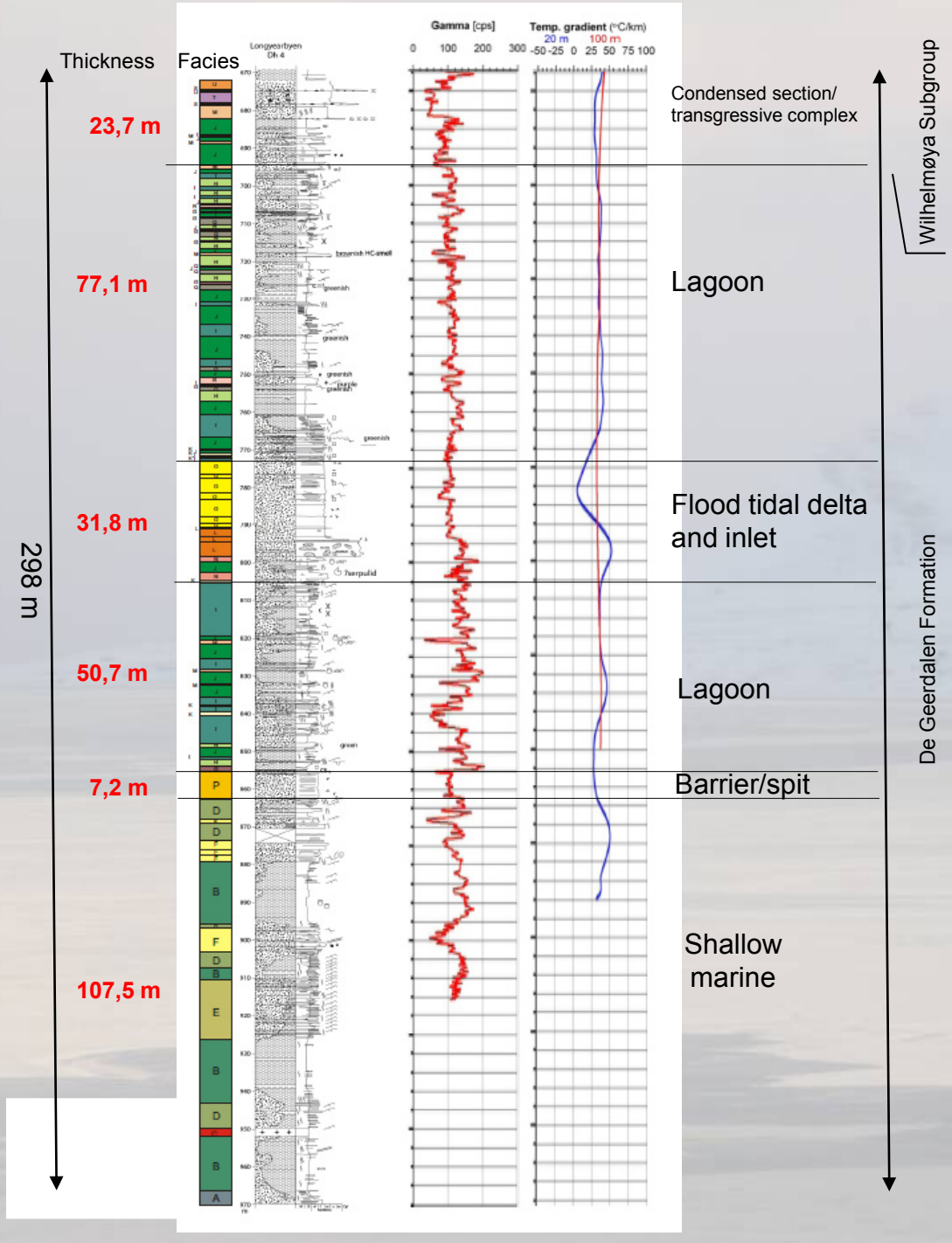
Gross Reservoir Unit 300m
Net drilled sandstone of the reservoir unit => 93m
Porosity varies from 2 to 18%
Permeability varies from 0,1 to 2 mD
Highly fractured rock

First gross test interval (870m-970m) => 100m
Net sandstone of the first test interval => 33m
Net sand/gross first test interval= 0,33 (e.g. possible N/G 0,2-0,3)

300m Cored section of the potential reservoir unit (CO_2 - storage unit); Upper Triassic to Middle Jurassic Shallow marine sandstones and shales

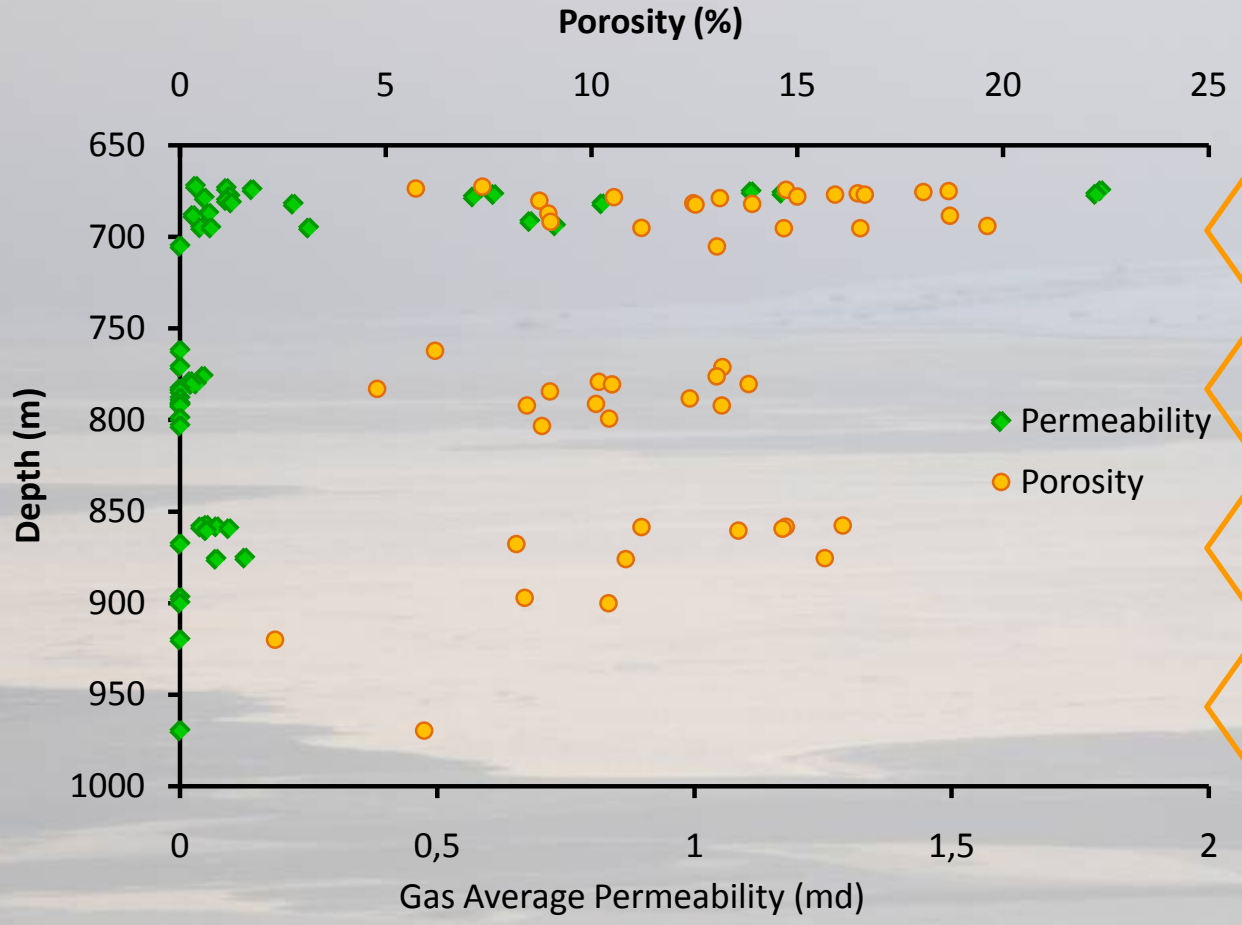
DH4 -depositional environment

- De Geer Fm. capped by Wilhelmøya Subgrp. and Janusfjellet Subgrp.
- Reservoir interval shows a shallowing upwards lagoonal/deltaic environment with high percentage of muddy facies
- No clear evidence of fluvial influence or extensive wave reworking
- Main sand units are interpreted as barrier/channel complexes in a relatively sheltered, dominantly tidal environment
- No evidence for substantial changes in relative sea level in De Geer Fm. – sedimentation keeping pace with subsidence.



Porosity & Permeability

- 51 samples from well Dh4



Highest porosity and permeability

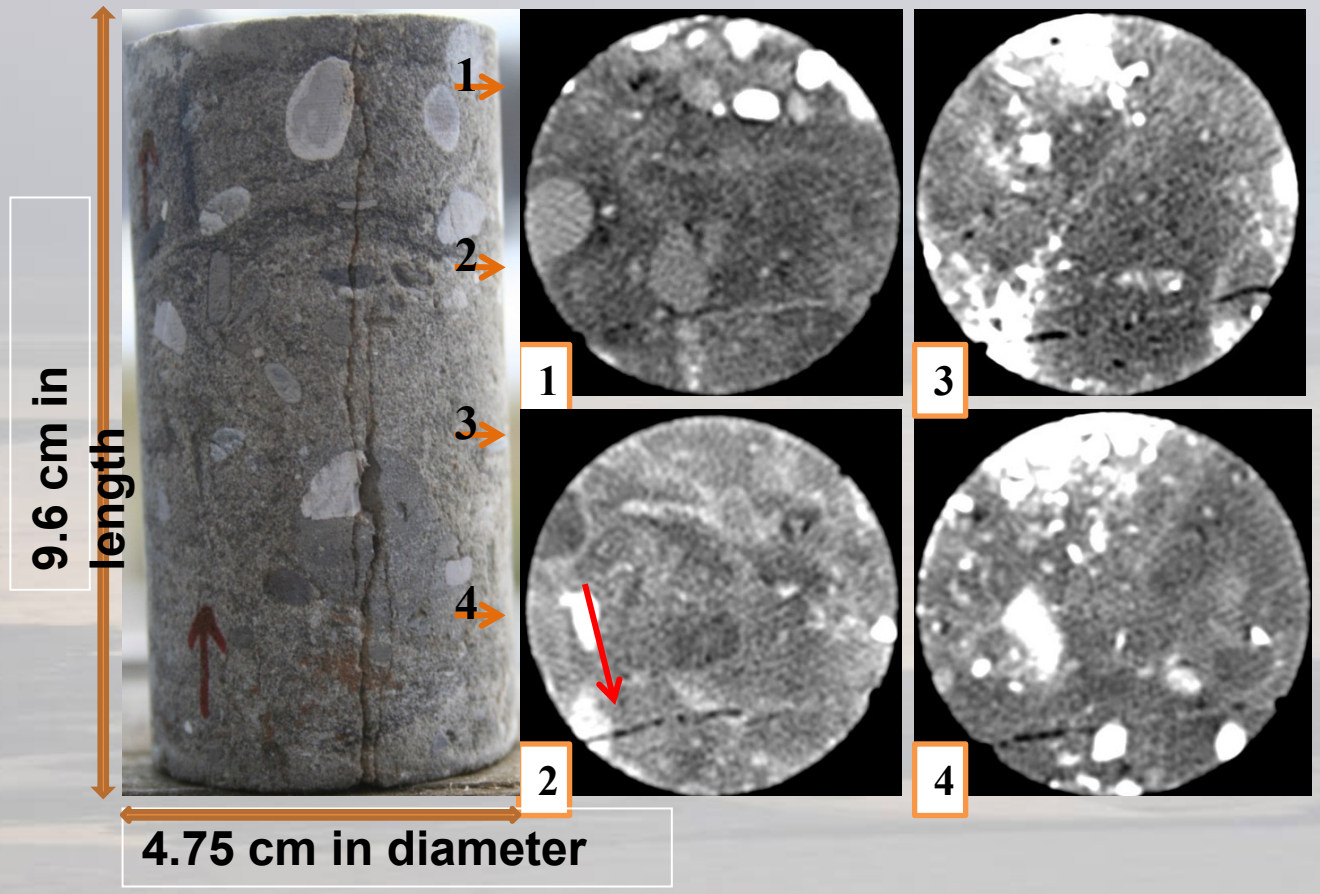
Microdarcies permeability

Moderate porosity and permeability

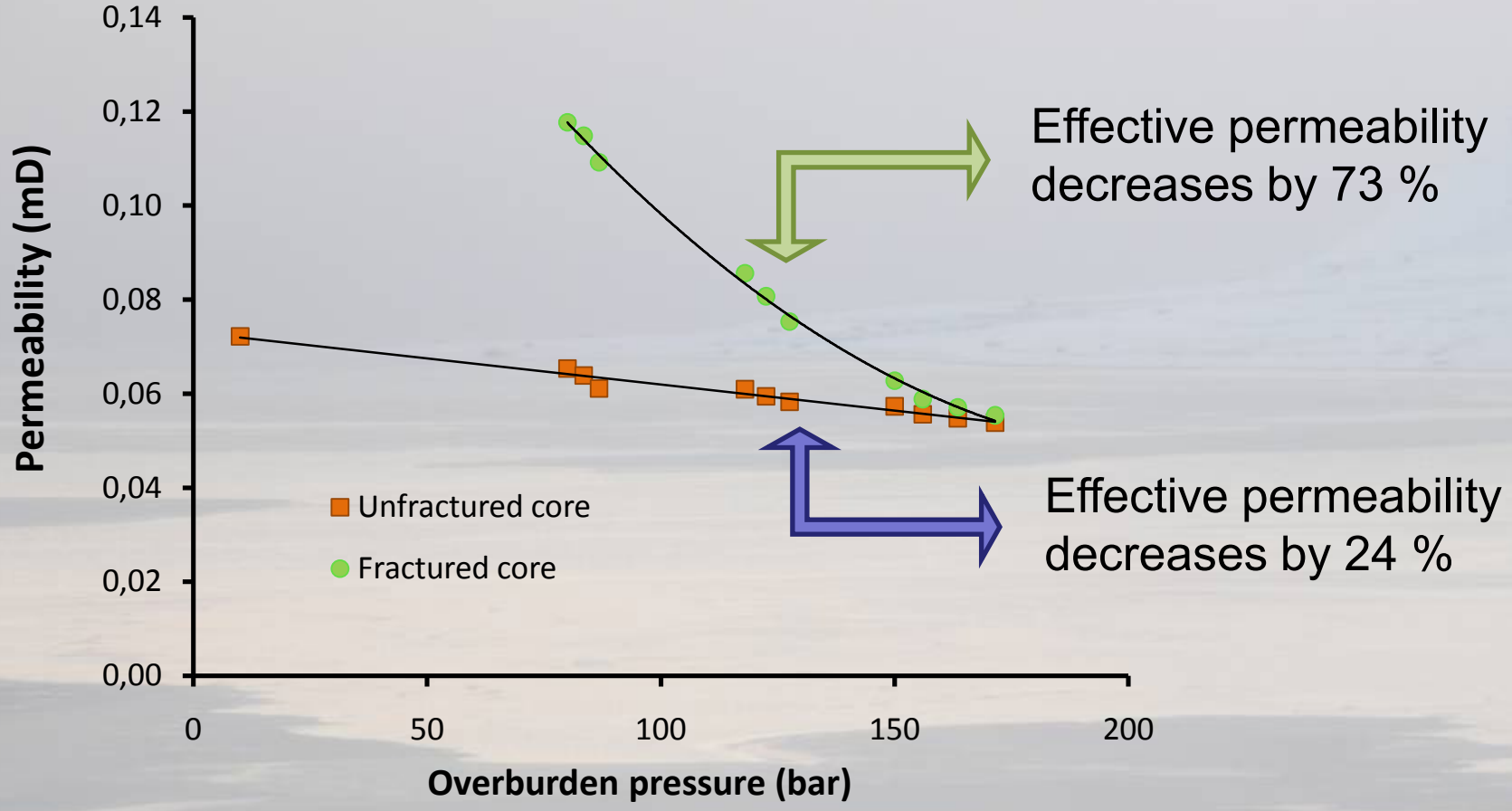
Lowest porosity and permeability

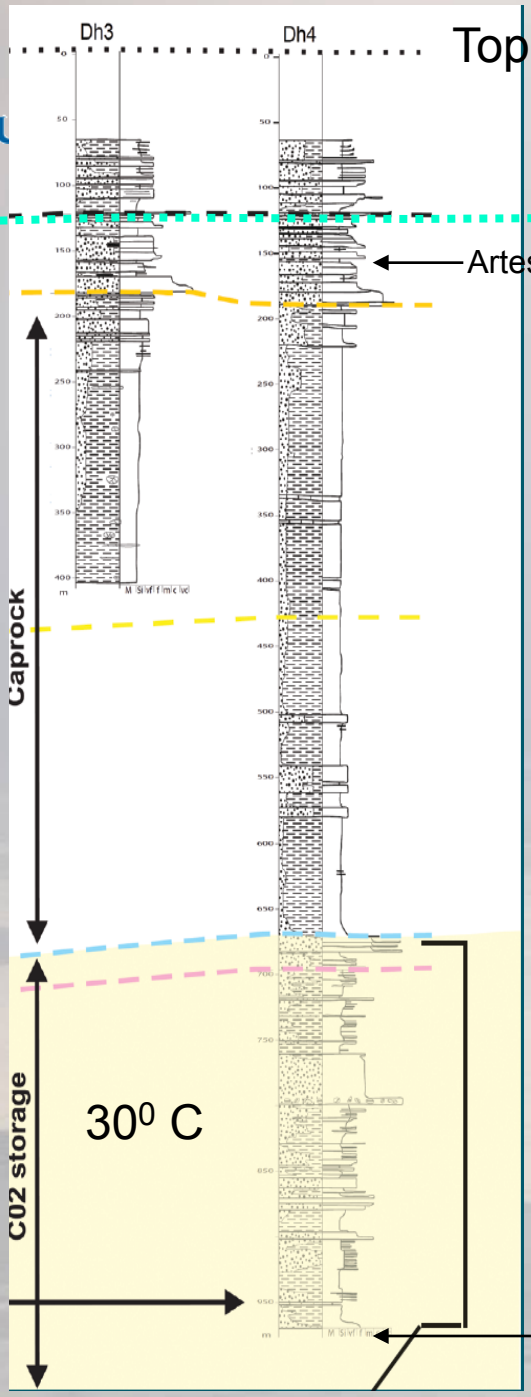
CT-scan results for for fractured sample

A short injection tests showed that the rock has fairly good injectivity



Permeability variations versus overburden pressure





Top Surface +17m msl

PERMAFOST LINE (Down to)

Artesian water - slight over pressure

Slight
over pressured
Sandstone unit

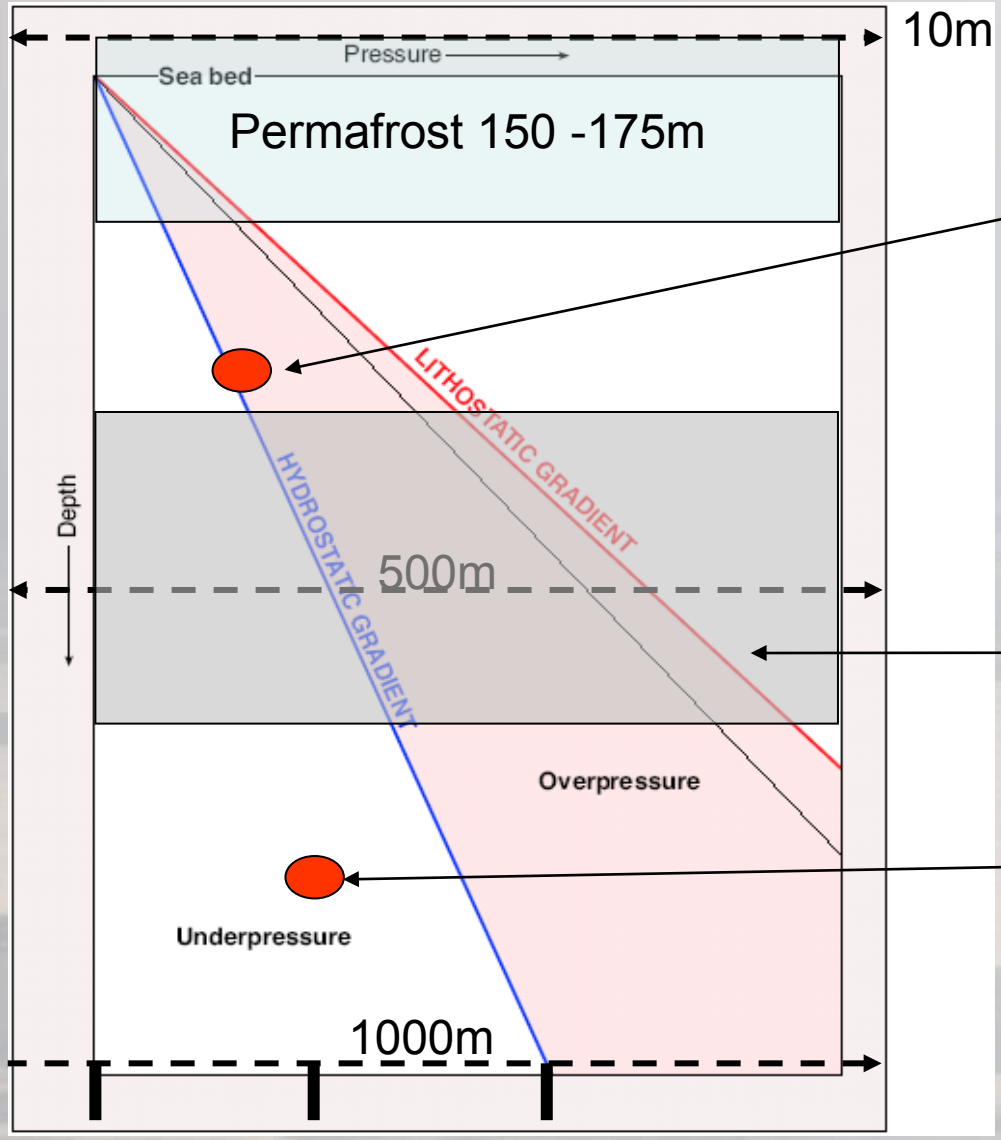
A current efficient seal

Under pressured
Sandstone unit

50bar under pressure
Highly fractured section
Triassic/Middle Jurassic unconventional reservoir low perm 0,1 -1mD
Test permeability 45-50md – fractures

970mTVD

Pressure plot from Dh4



34 -35 bar at 340 (330msl) Festningen Sandstone

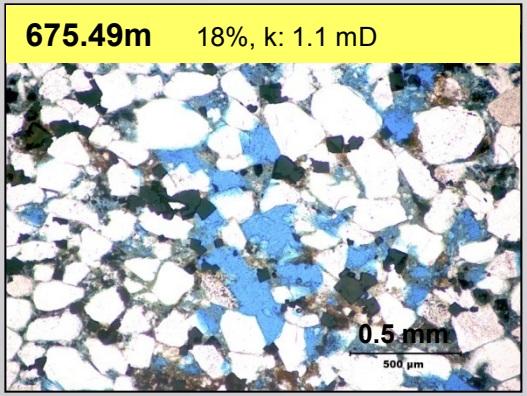
400m Upper Jurassic – Lower Cretaceous shale

37 bar at 870m (860msl)

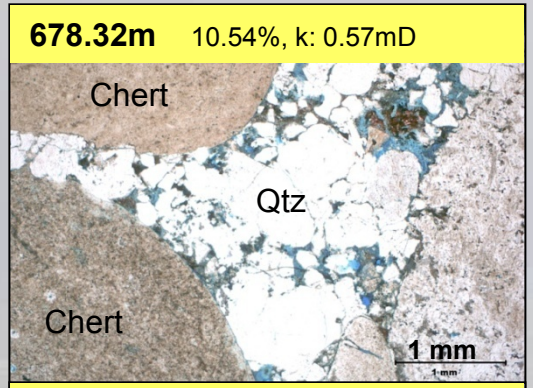
DH 4

Core Dh4, Wilhelmøya SubGp. (670-695m)

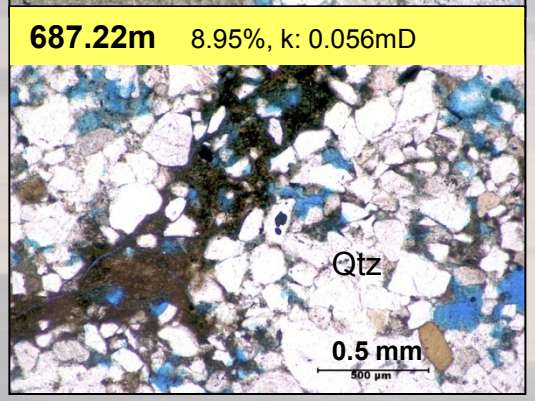
Porosity is shown by blue colour



Sandstone:
- isolated porosity, clay minerals, pyrite cement

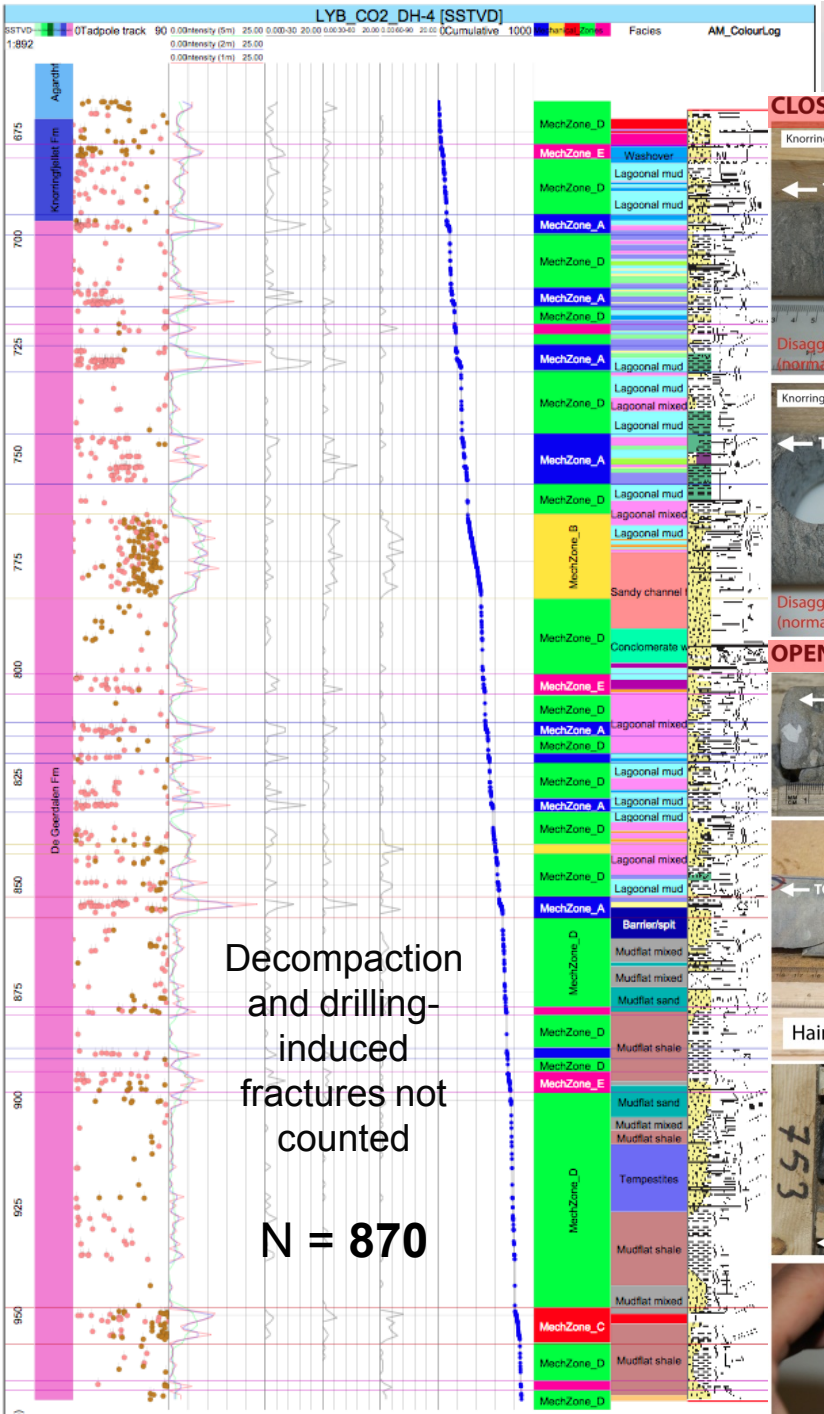


Conglomerate:
-sandstone-supported,
coarser fragments: chert, quartz, phosphorite etc.



Sandstone:
- patchy distribution of clay with carbonate cement vs. quartz-cemented domains

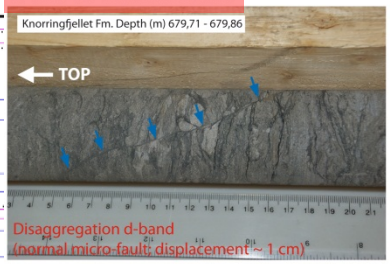
Core fracture count and characterization

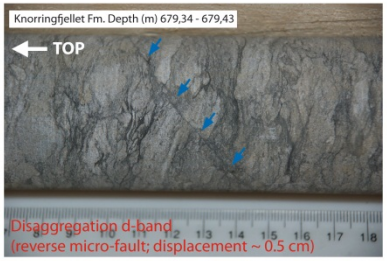


Decompaction and drilling-induced fractures not counted

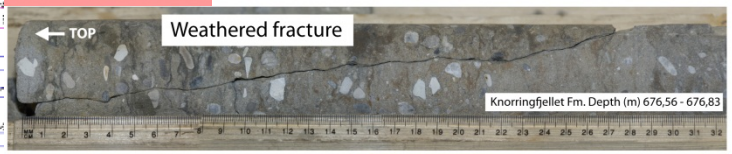
N = **870**

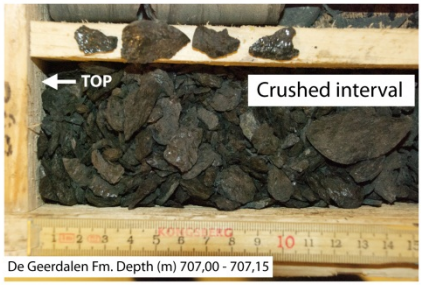
CLOSED FRACTURES

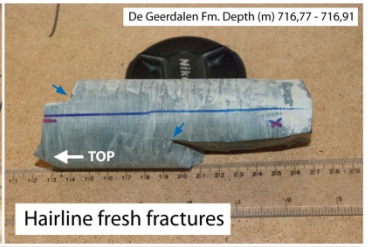


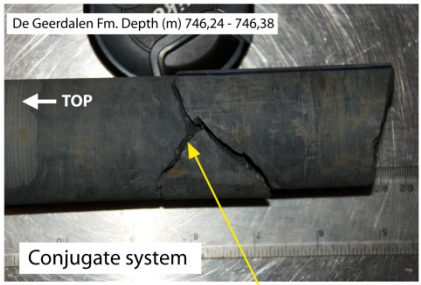


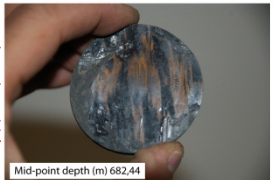
OPEN FRACTURES

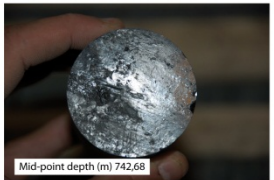




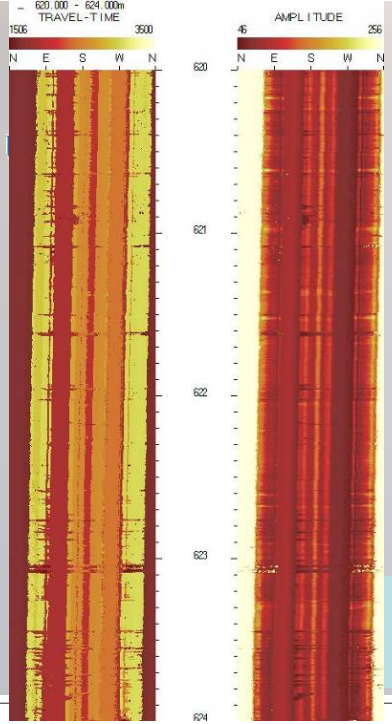








Televiewer



Televiewer fracture orientations
Stereogram of mapped fractures in Dh4 (440-700 m), N= **284**

NB! Log covered only the uppermost 30 m of the reservoir

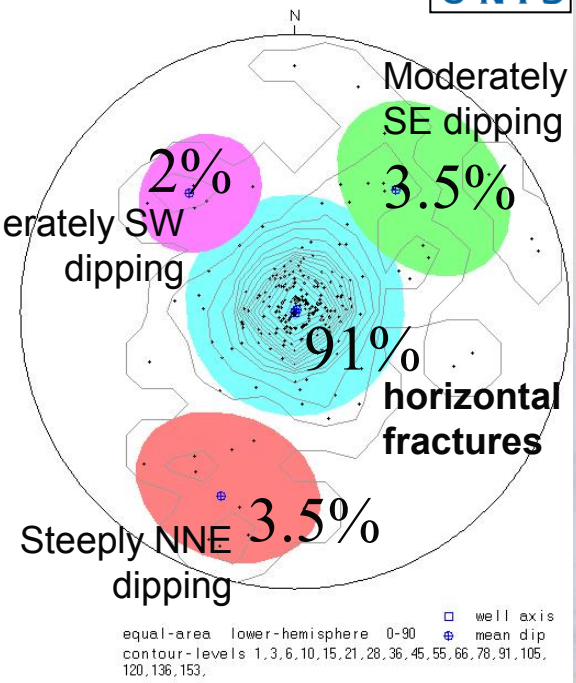
Zone 0, 441.861 - 707.014m
Deviation 0.6 N207.4
Mean dip format: strike and dip
dip data sets .....
BHTV dips

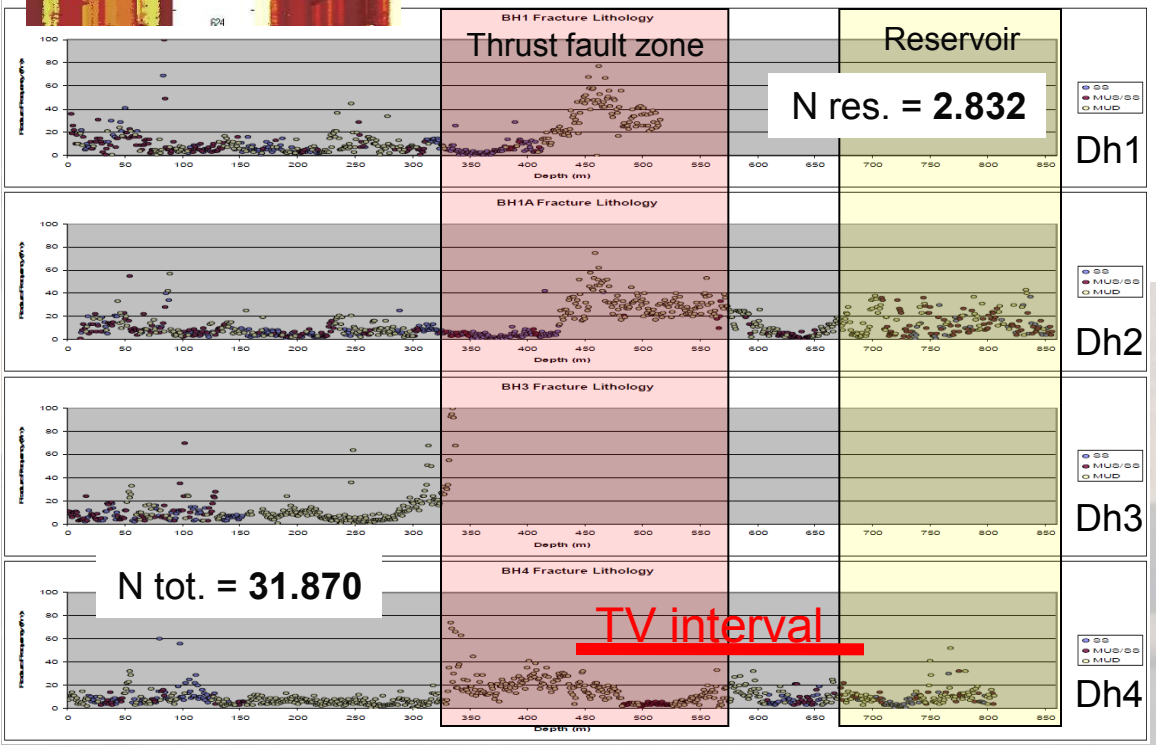
	mean dip	n	f
N128 1	N128 1	258	0.97
N292 61	N292 61	10	(0.08)
N130 48	N130 48	10	(0.06)
N048 48	N048 48	6	(0.03)

intersections

	N128 1	N292 61	N130 48	N048 48
N128 1		0 N292	0 N130	1 N227
N292 61	0 N292		12 N299	36 N088
N130 48	0 N130	12 N299		40 N179
N048 48	1 N227	36 N088	40 N179	

Dominance of horizontal fractures in statistics due to low-angle thrust fault zones bounding the reservoir





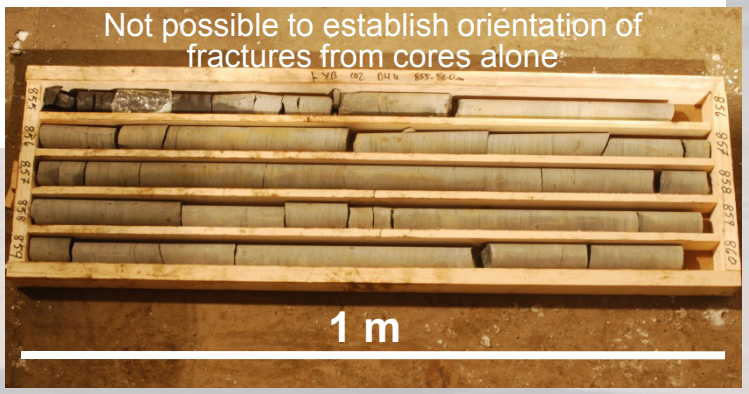
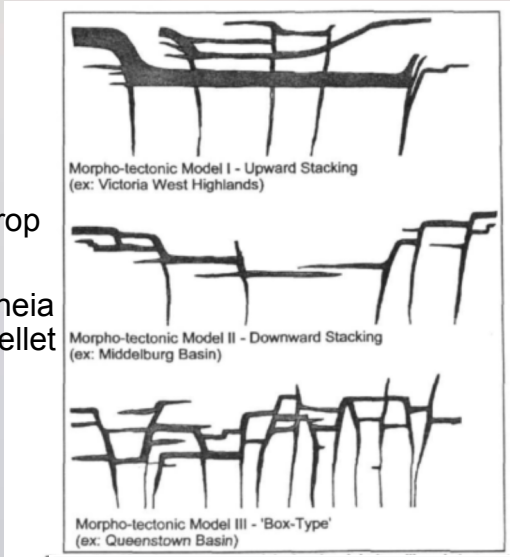


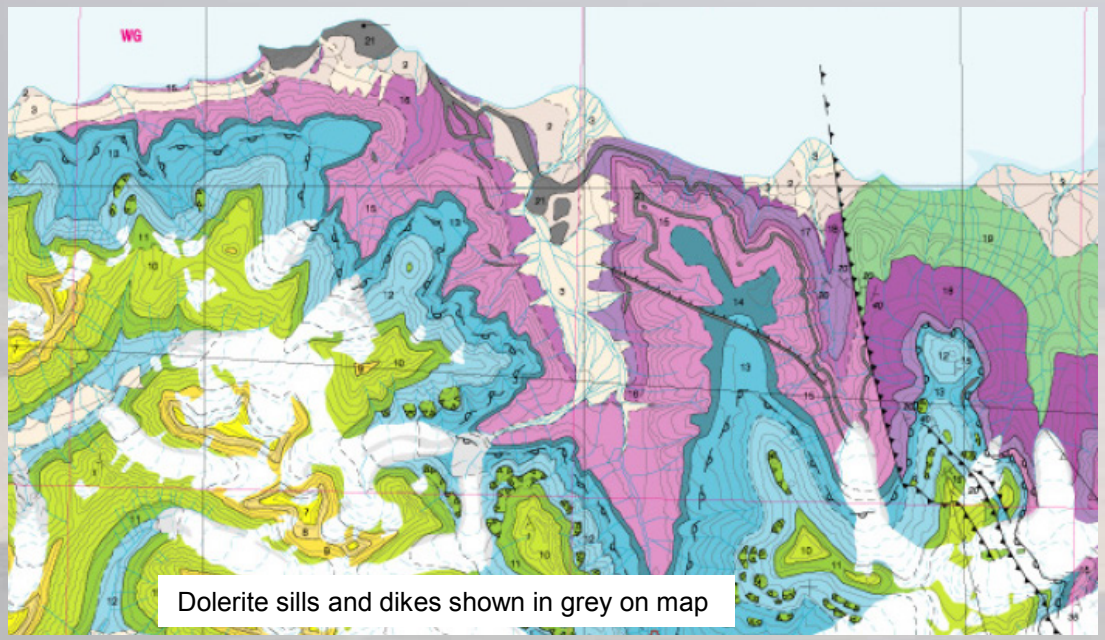
Photo-based fracture counts from cores depth/lithology *vs* dip angle,
NB! Decompaction and drilling-induced fractures underestimated

Doleritic intrusions

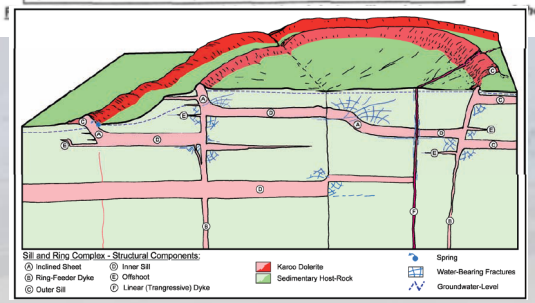
Observed in outcrops and seismics

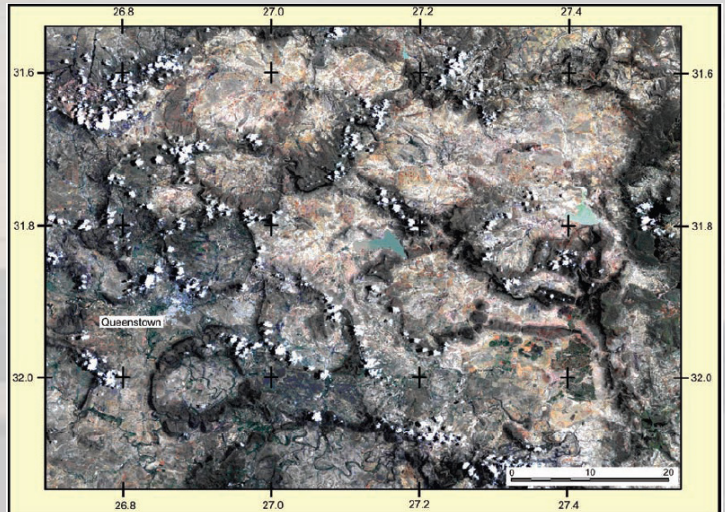
- Parallel or sub-parallel to bedding + inclided sills and dikes
- Typically few m to 50 m thick
- Two intervals with intrusions mapped on seismic in Adventdalen and outcrop
- 2,3 m thick dolerite dike close to TD of DH-4
- Occur mainly in in lower part of De Geer formation or upper part of Botneheia Fm. but some vertical dikes penetrate all the way up through the Agardhfjellet Fm.
- Distribution of dikes uncertain – some are too small to see on seismic
- Dikes may act as barriers to fluid flow
- Datings suggest early Cretacous age





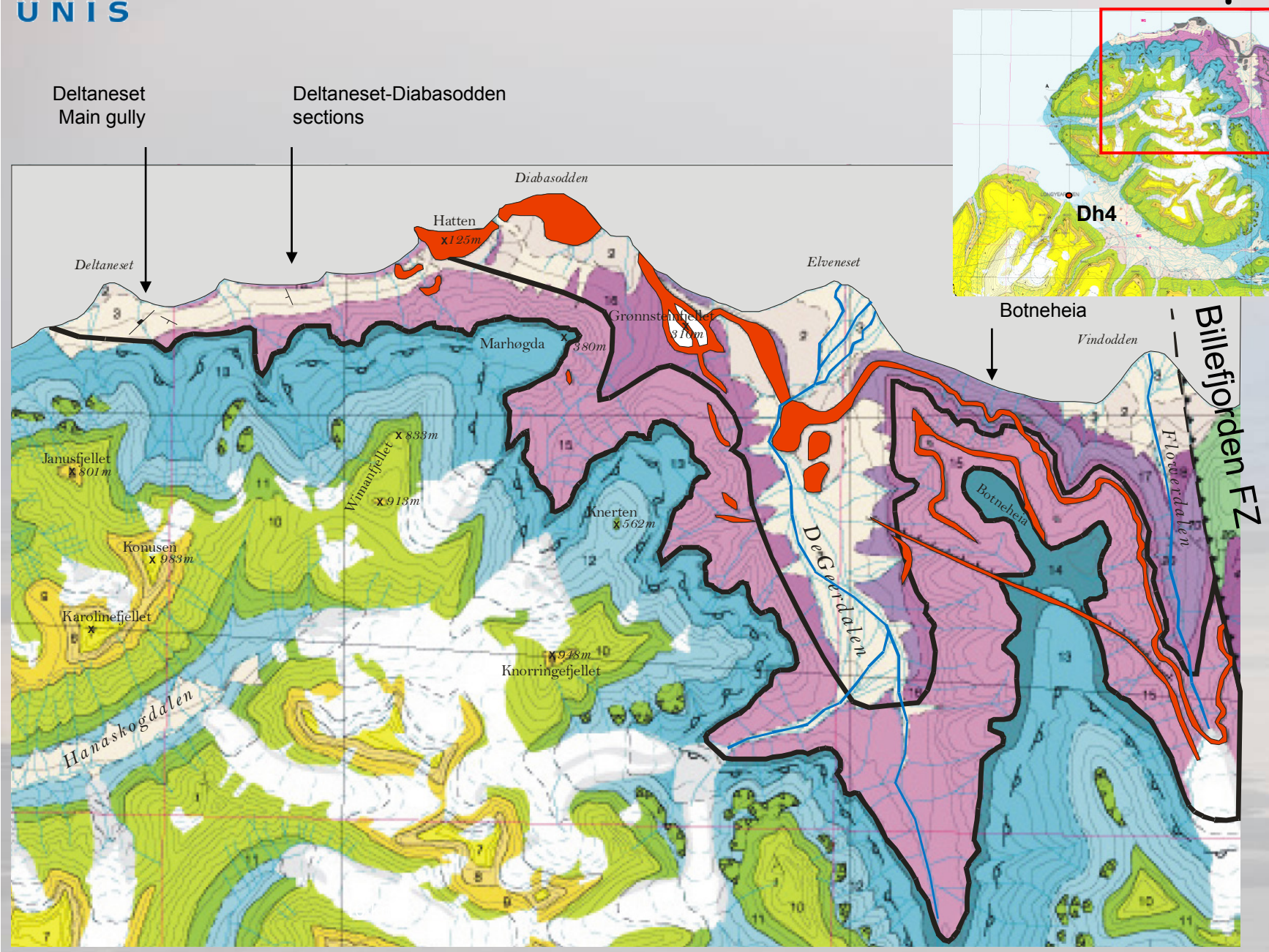
Dolerite sills and dikes shown in grey on map



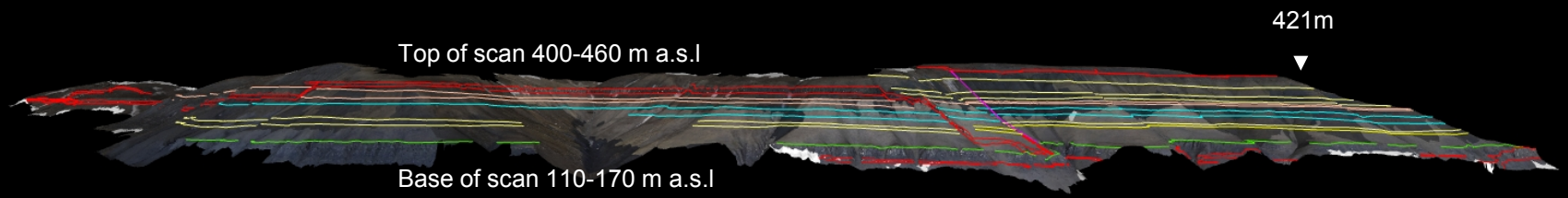


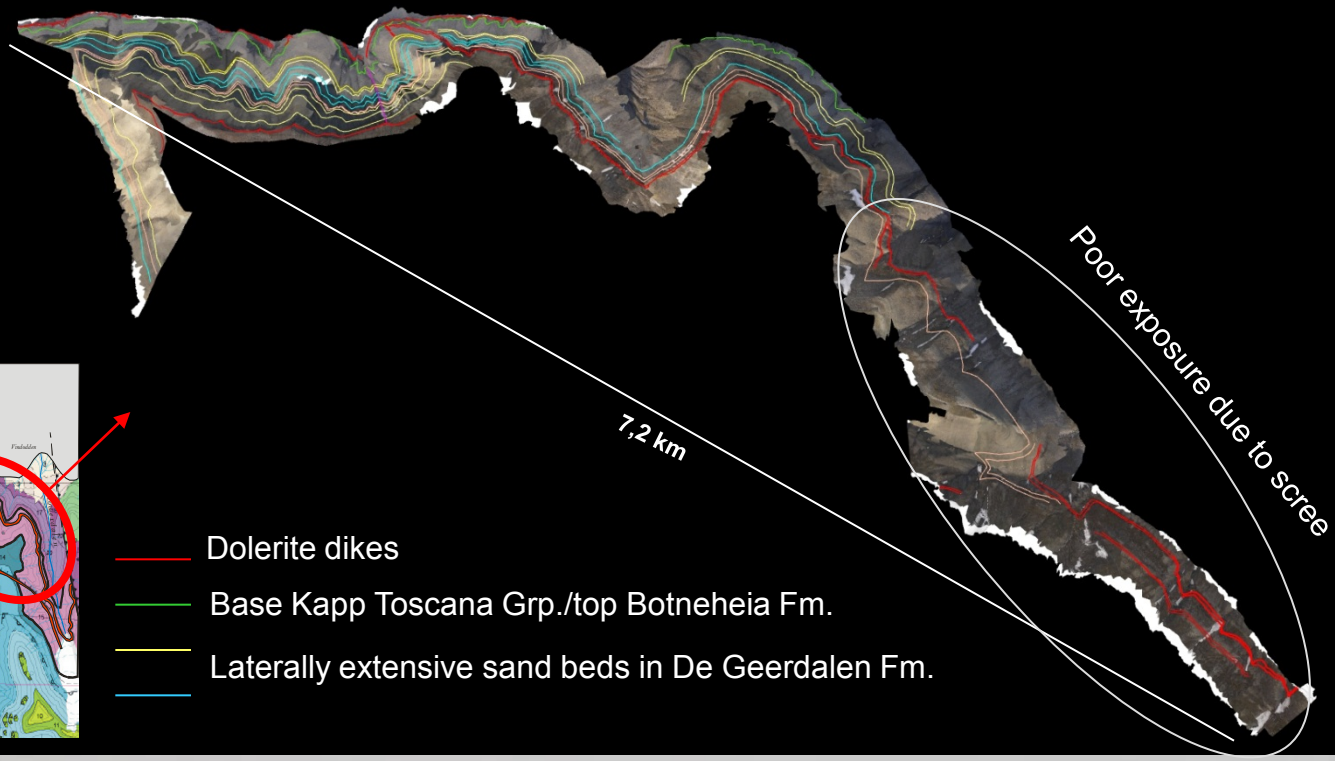
Karoo basin intrusions may be an appropriate Analogue. Figures from Murray et al. 2006

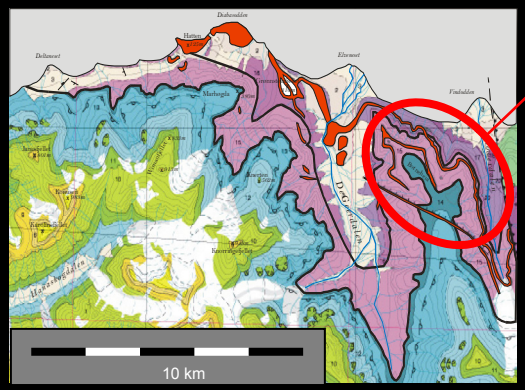
Structural observations from outcrops



Botneheia area: Lidar-scan of lower 170-190 m of the Kapp Toscana reservoir



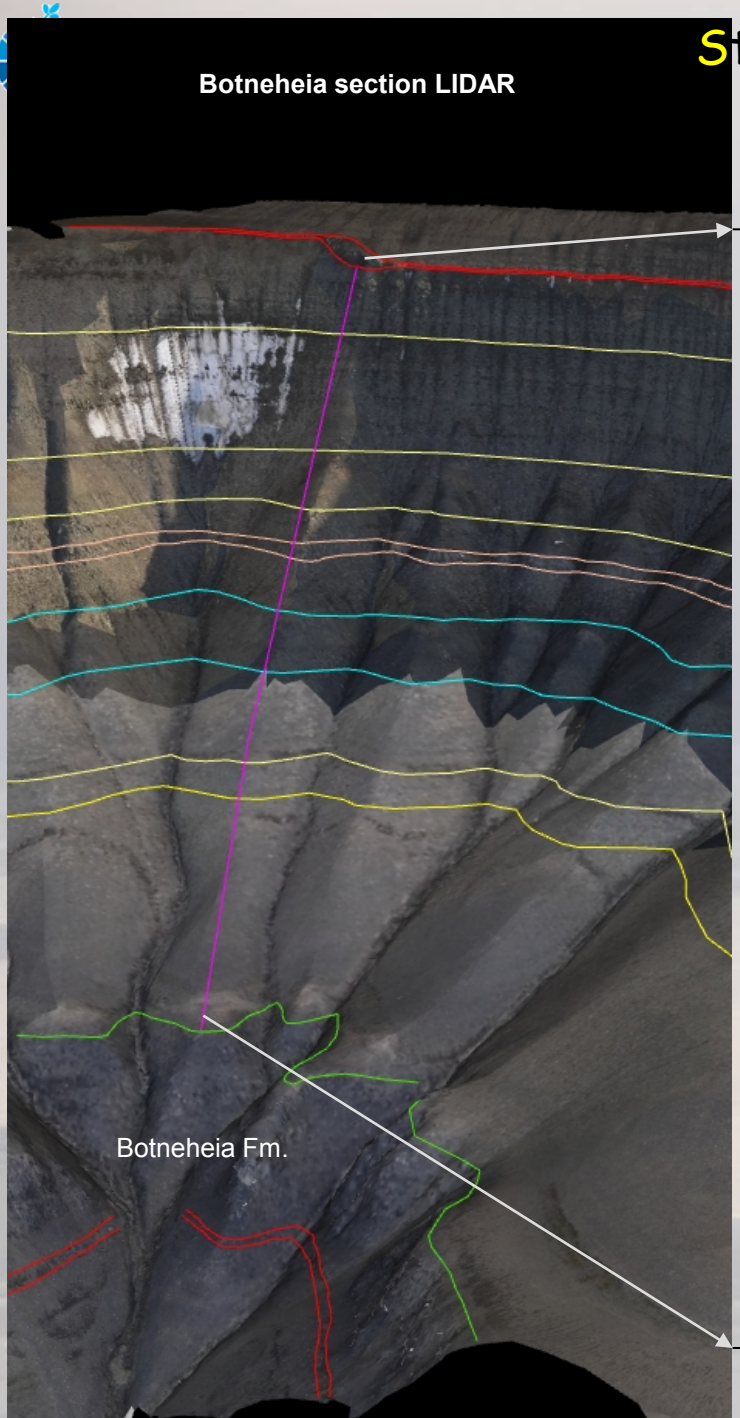




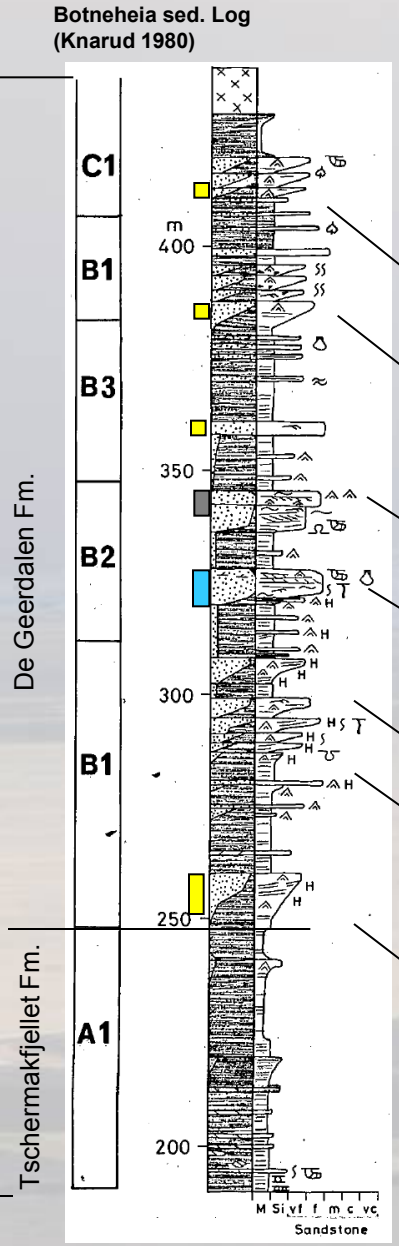
Dolerite dikes

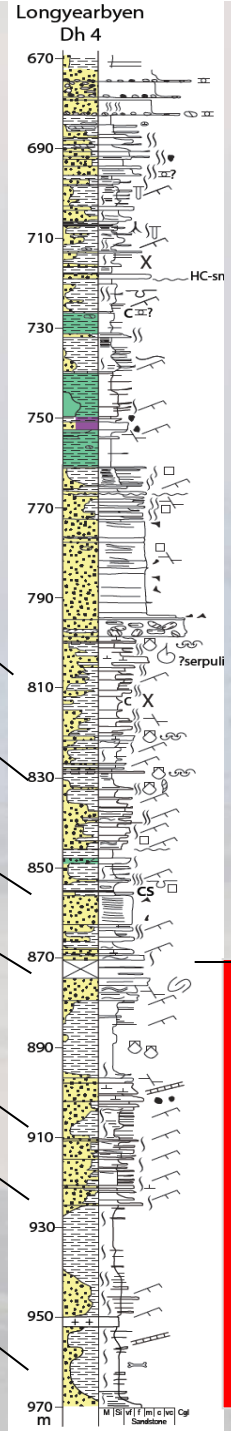
Base Kapp Toscana Grp./top Botneheia Fm.

Laterally extensive sand beds in De Geerdalen Fm.

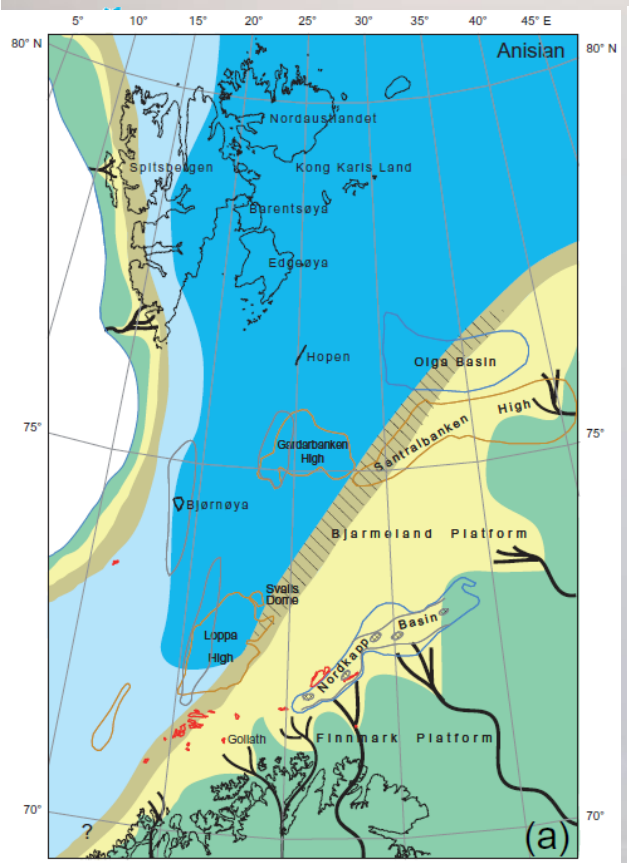


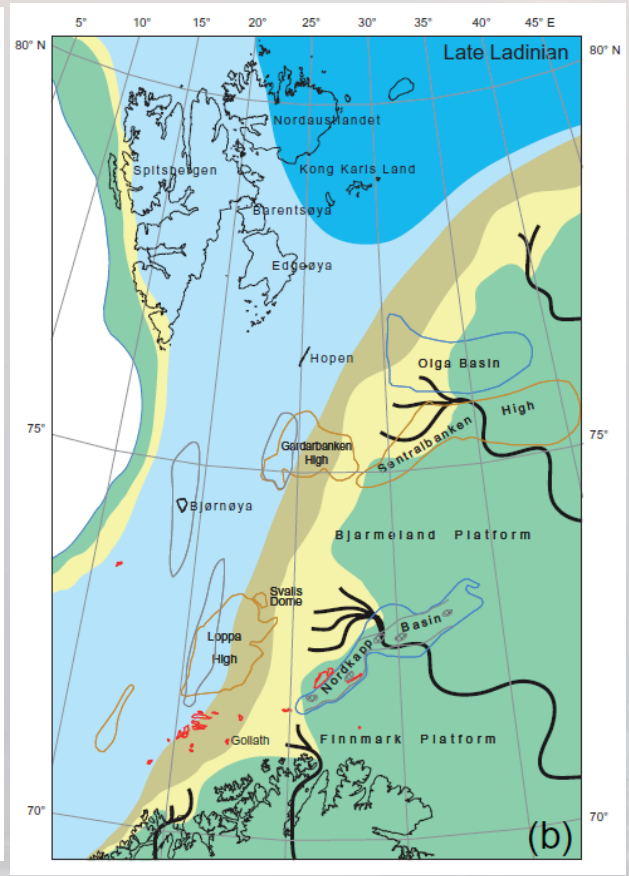
Stratigraphy can be correlated to the lower part of the reservoirinterval in DH4

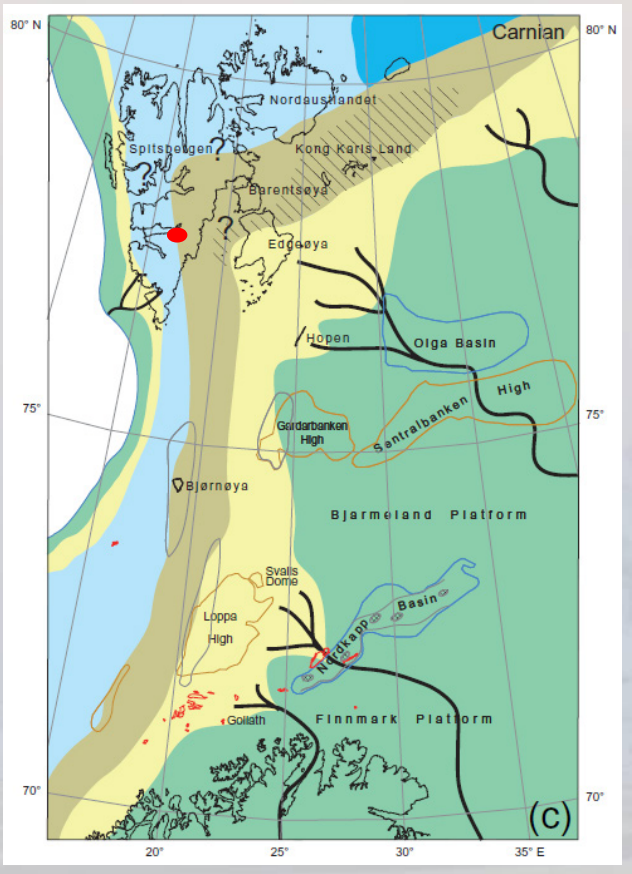




Injection interval







Depositional environments

- Delta plain
- Deltaic / Fluvial
- Prodelta
- Shallow shelf
- Deep shelf
- Salt diapir

Structural elements

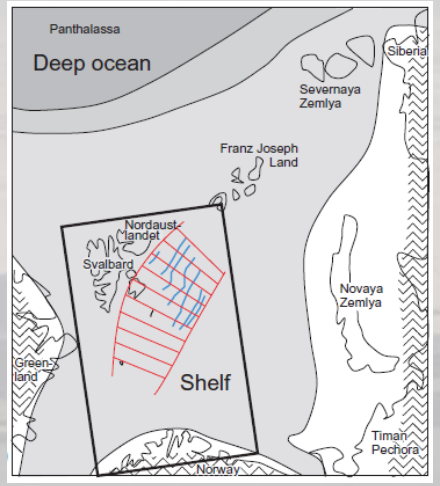
- Clinoforms
- High (recent)
- Basin (recent)
- Palaeohigh
- Field / discovery

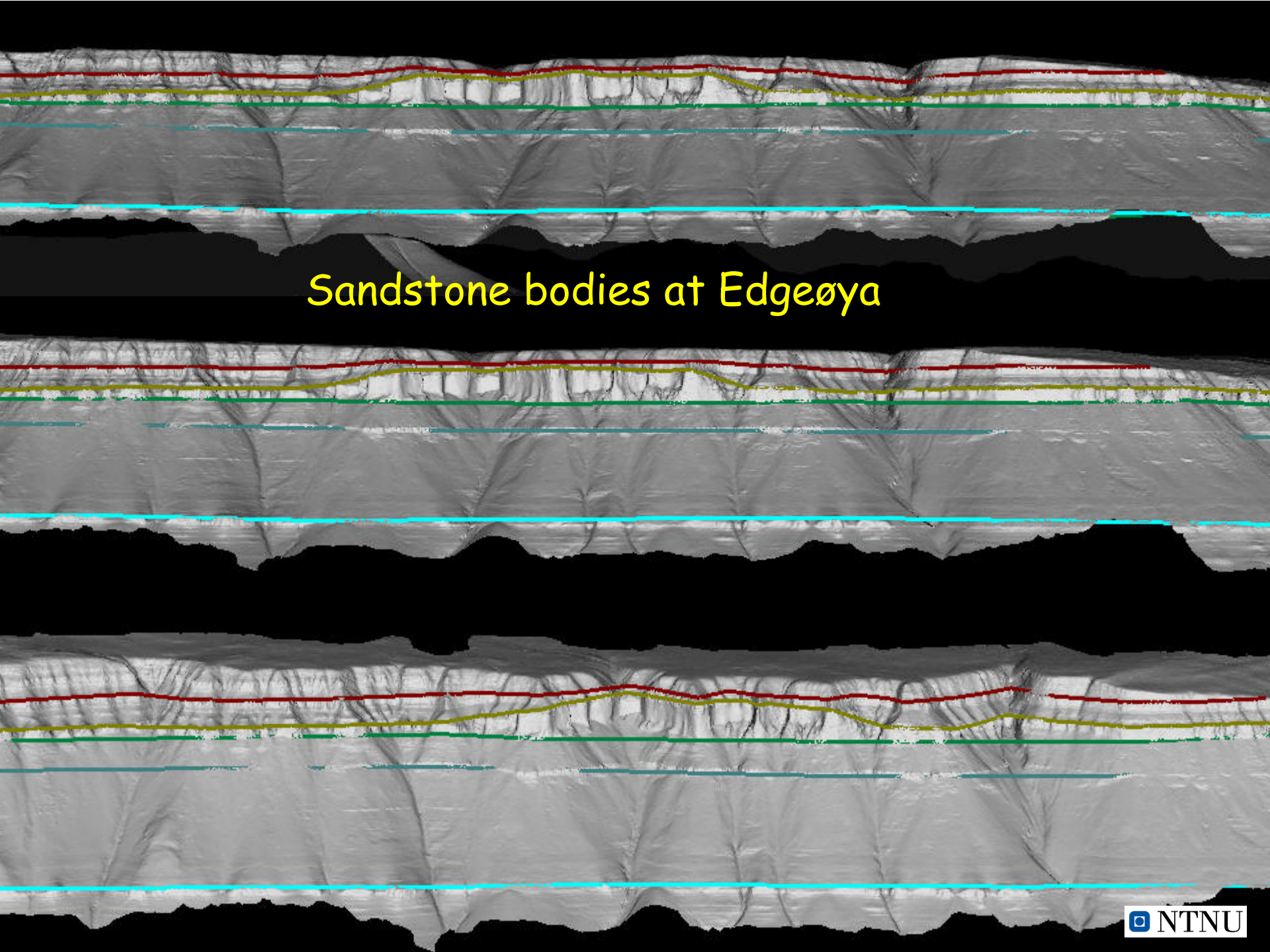
Figures from Riis et al. 2008

Regional paleogeography

-Coastal progradation across shallow shelf from the SE during Triassic

-Longyearbyen area I situated at the outer margin of this system, close to a gradually narrowing seaway stretching south




Sandstone bodies at Edgeøya

The project has identified important issues to be addressed for further work next years

- **Can this low permeable reservoir store the amount of CO_2 produced by the Longyearbyen coal power plant? 1 as test site, 2 for years**
- Are fractures gradually expanding (not stepwise) and how do we further test this hypothesis, could more geophones record this?
- Are permeable fractures penetrating the cap rocks?
  If so - what is the limit of the fracture pressure
- Is the entire reservoir section injective? The injection tests this far only on the lower 100 m ("worst" part) out of the 300 m section
- Are shales of the reservoir section fractured and contributing to injectivity?
- Confirm the under pressured reservoir and its generation

AG-341. Geological constraints of CO2 sequestration
10 ECTS (The new value chain of coal)
Ongoing university course

- Safety -/HSE in Arctic areas
- Global political challenges and agendas. Energy and technologies
- Subsurface challenges of storage. G&G *(upstream)*
- Coal - from generation, accumulation to production and energy supplier *(upstream and downstream))*
- CO2 storage strategies *(upstream)*
- Case Studies of CO2 storage *(upstream and downstream))*
- Field work/ Excursions *(upstream and downstream))*

Thank you for your attention

Visit our web site:
http://co2-ccs.unis.no/