An aerial photograph of the Norwegian coastline, showing the sea and land. A cyan rectangular box is overlaid on the sea area, containing the title text.

**Storing of CO₂
offshore Norway,
Criteria for evaluation
of safe storage sites**

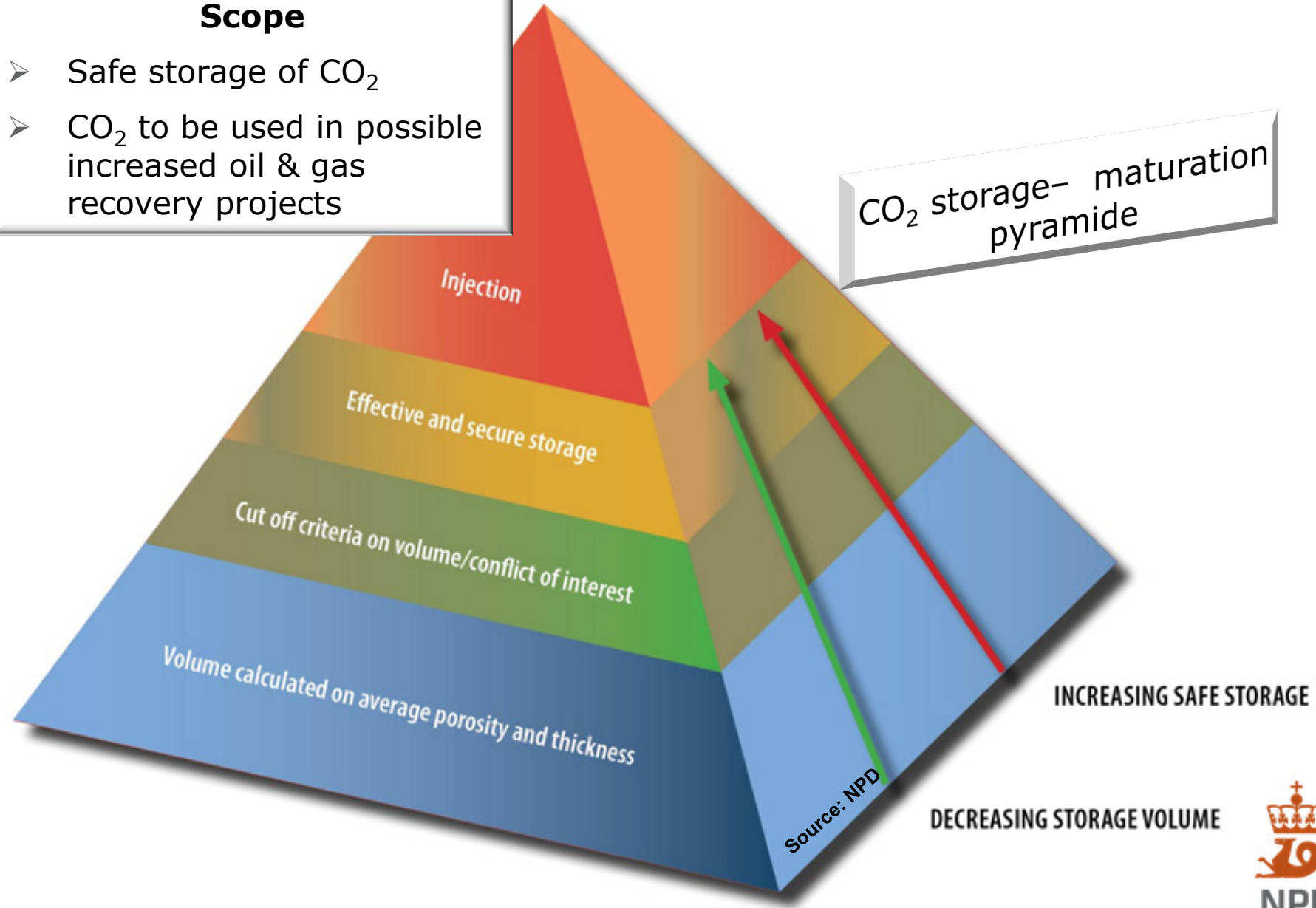
**Eva Halland
Norwegian Petroleum Directorate**

**Trondheim CCS Conference
June 14-16, 2011**

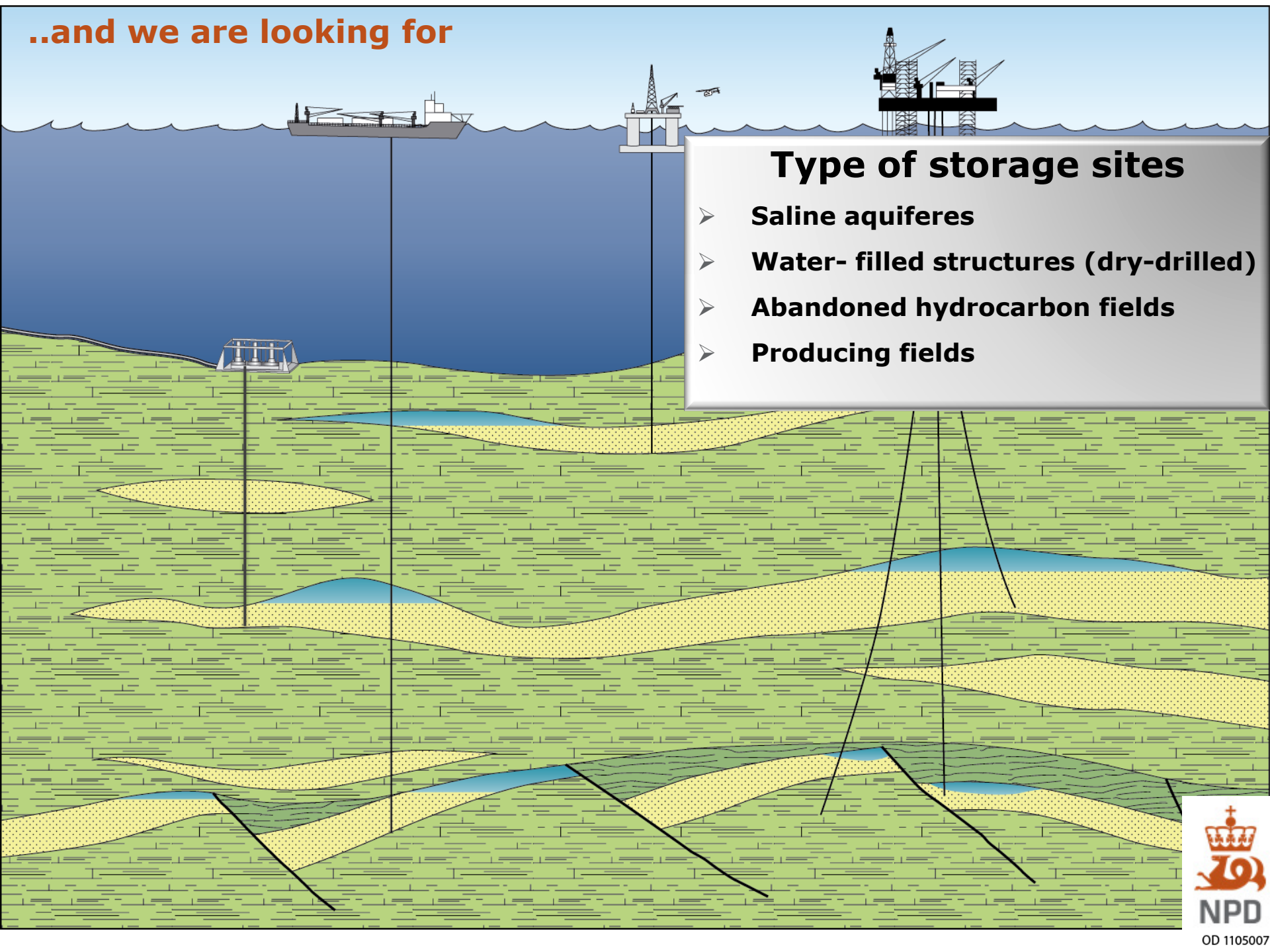
Storing of CO₂ offshore Norway

Scope

- Safe storage of CO₂
- CO₂ to be used in possible increased oil & gas recovery projects



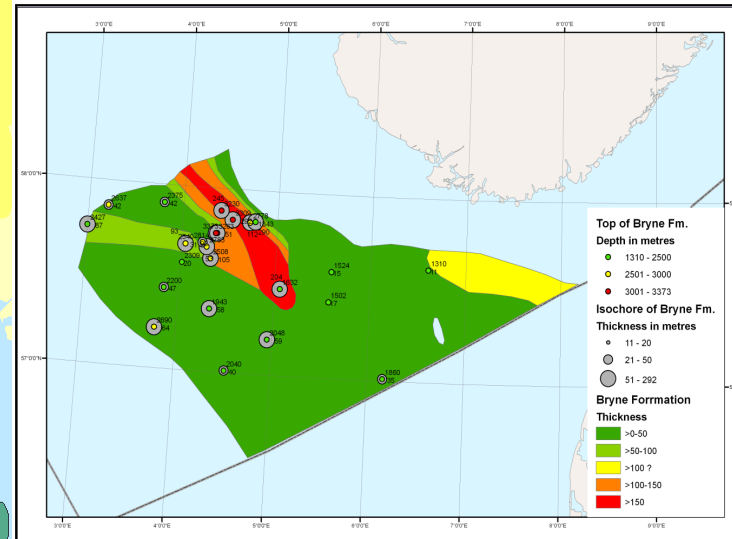
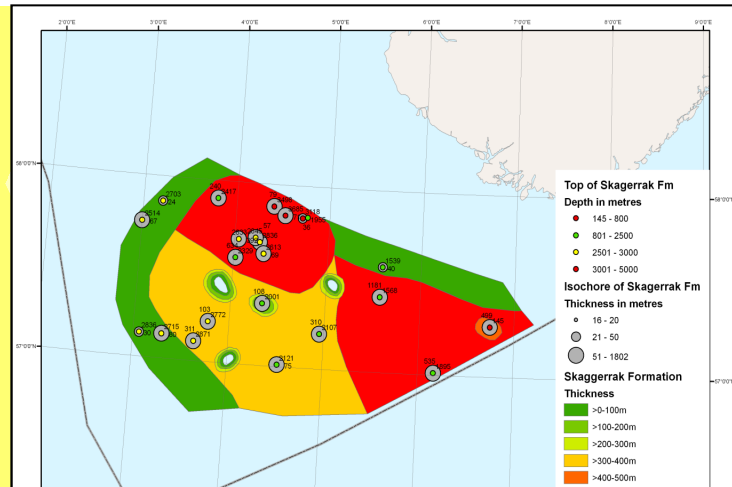
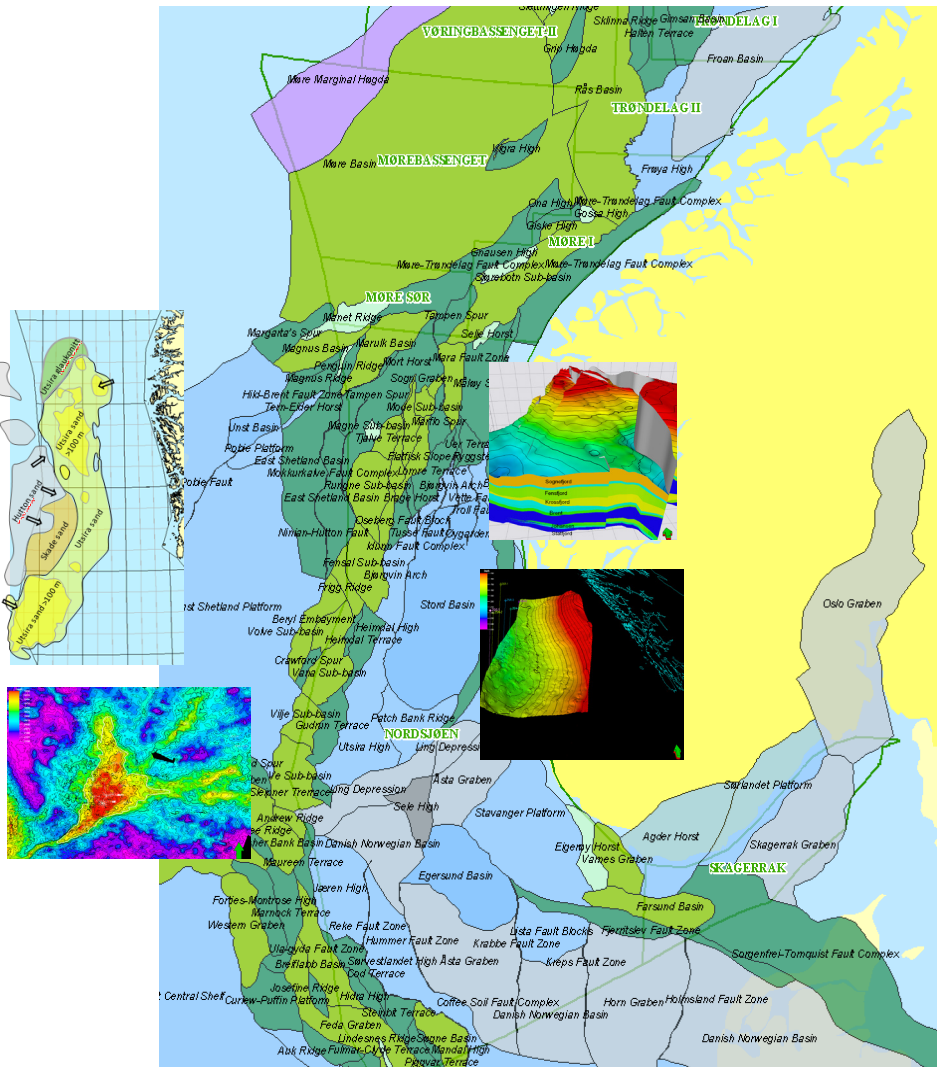
..and we are looking for



Type of storage sites

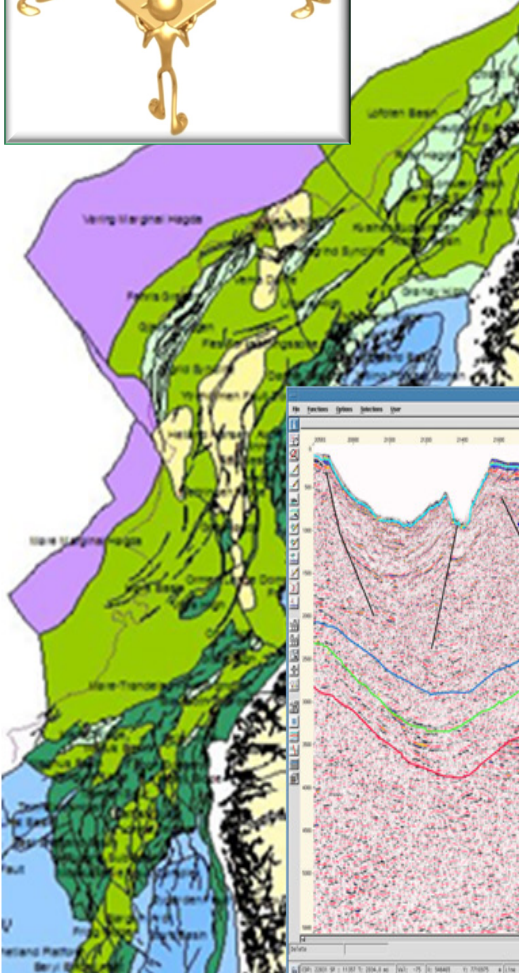
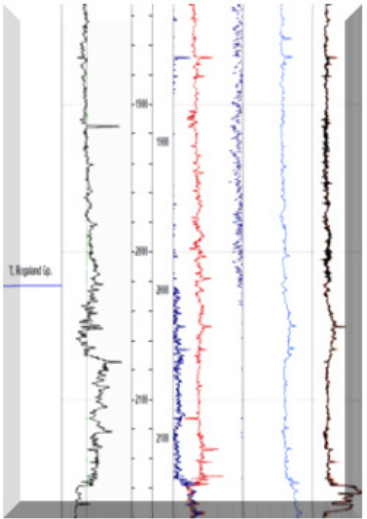
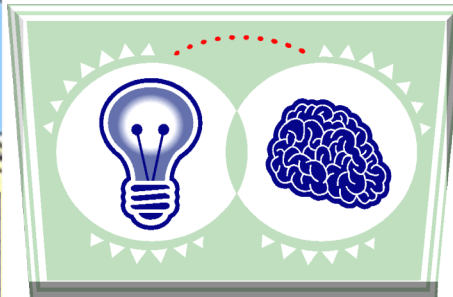
- Saline aquiferes
- Water- filled structures (dry-drilled)
- Abandoned hydrocarbon fields
- Producing fields

Norwegian shelf : Storage sites are present (some examples)

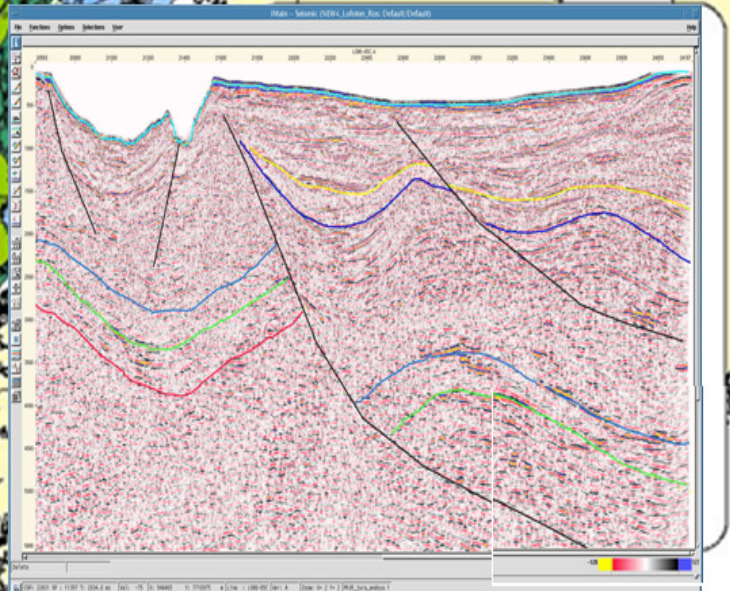


Our playground

NPD has access to all data on the Norwegian continental shelf that is collected by the petroleum industry



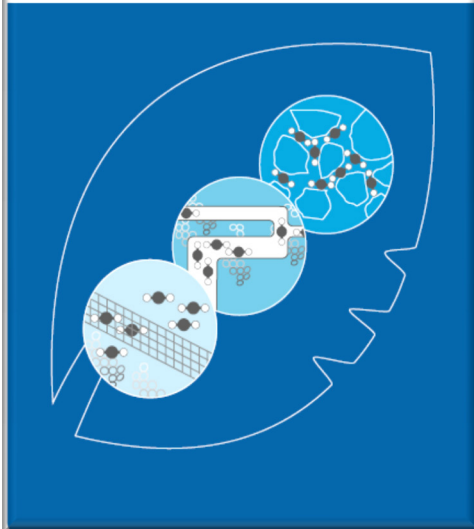
Depth in m (DIPG)	System	Series	Group	Formation	Core	Core	Core	Description
0 - 500	QUATERNARY							Recent 100 m in FUB 800 w. 1.5m Unconsolidated sandstones and claystones
500 - 1000	TERTIARY	Pliocene	Norstrand	Utra				Top Utra 100 m in FUB 800 w. 1.5m
1000 - 1600								Oligocene
	TERTIARY	Miocene	Norstrand	Stak				Top Stak 100 m in FUB 800 w. 1.5m
								Oligocene
	EGENE							Claystones with Limestone Sandstone streaks





**..based on knowledge
and cooperation with
the petroleum
industry**

CLIMIT
PROGRAMME PLAN 2010-2012



Two FME in CO₂ storage (Centre for Environment Friendly Energy research)

BIGCCS : 2009-2016, 22 partners

SUCCESS: 2009-2016, 8 partners

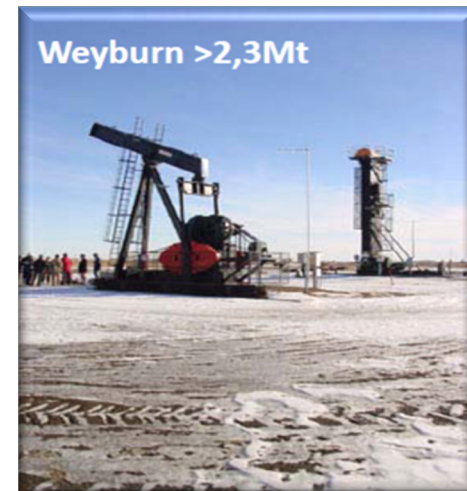
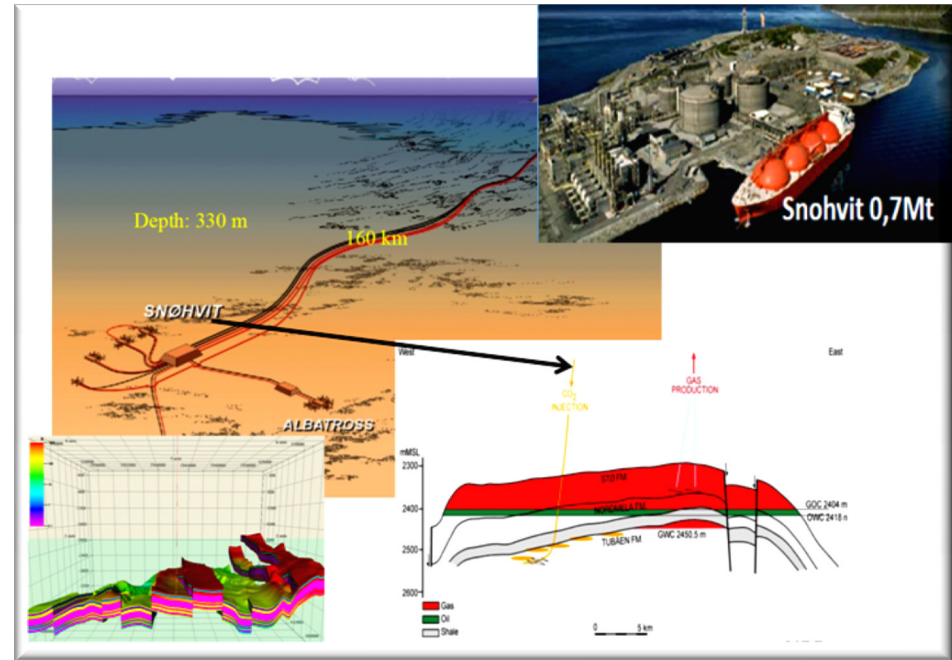
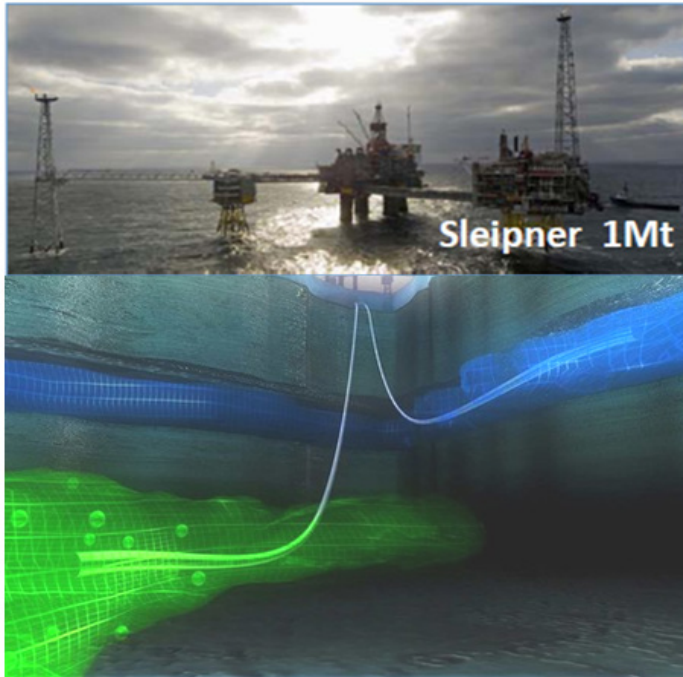
Longyearbyen CO₂Lab

Norwegian CO₂ Storage Forum,
chaired by NPD

NPD will give recommendations to MPE regarding where to store- and who will be allowed to store CO₂ offshore Norway.

**...in cooperation with
Universities,
Research Institutions**

...building on experience



Ranking Criteria for aquifers and structures

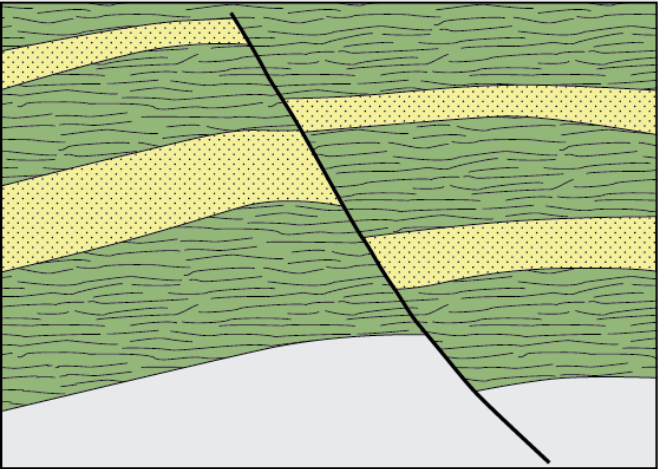
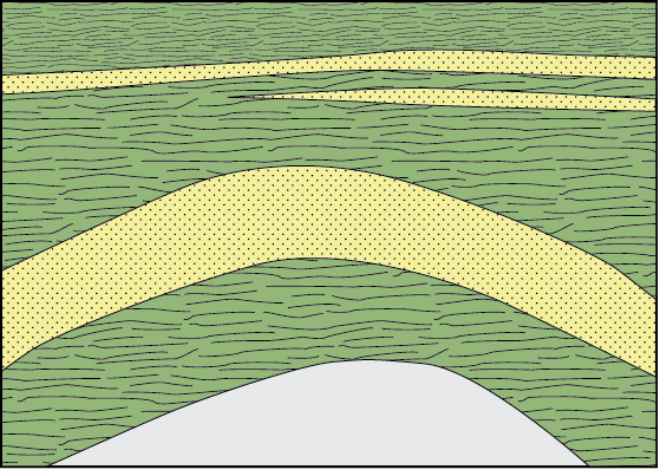
Ranking Criteria		Definitions, comments	
<u>Reservoir quality</u>	Capacity, communicating volumes	3	Large calculated volume, dominant high scores in checklist
		2	Medium / low estimated volume, or average score in the checklist
		1	Dominant low values , or at least one score close to unacceptable
	Injectivity	3	High value for permeability * thickness(k*h)
		2	Medium k*h
		1	Low k*h or at least one score close to unacceptable
<u>Sealing - quality</u>	Seal	3	Good sealing shale, dominant high scores in checklist
		2	At least one sealing layer with acceptable qualities
		1	Sealing layer can have poor qualities, low scores in checklist
	Fracture of seal	3	Insignificant break in the seal, dominant high scores in checklist
		2	Breaks in the seal (natural / wells), medium score in the checklist
		1	Low scores in checklist or a value close to unacceptable
Other leak risk	Wells	3	No previous drilling in the reservoir / safe plugging of wells
		2	Wells through the seal, status documented
		1	Status for the wells is unknown
<u>Data cover</u>	Good data cover	Limited data cover	Poor data cover

Other factors:
 How easy / difficult to prepare for monitoring and intervention.
 The need for pressure relief.
 Possible support for EOR projects.
 Potential for conflicts with future petroleum activity.

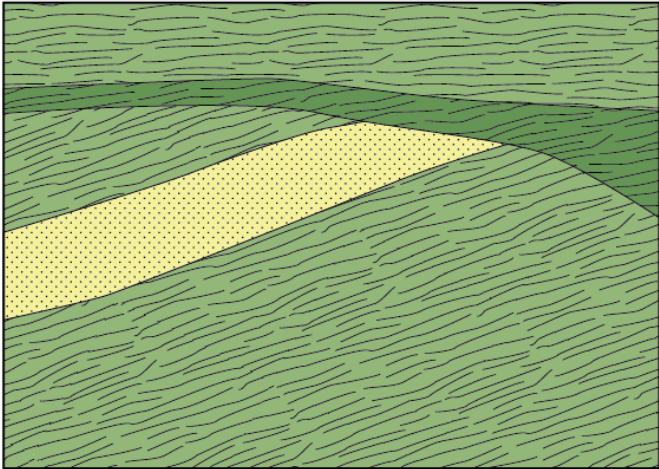
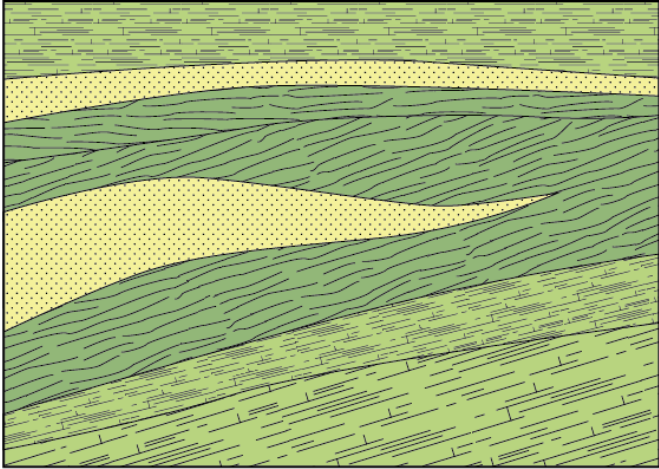
Checklist for Reservoir Properties

	Typical high and low scores		
Reservoir Properties	High	Low	Unacceptable values
Aquifer Structuring	Mapped or possible closures	Tilted, few /uncertain closures	
Traps	Defined sealed structures	Poor definition of traps	
Reservoir Type	Sandstone	Chalk	
Depth	800- 2500 m	< 800 m > 2500 m	< 500 m / > 4000 m
Layering	Homogeneous	Heterogeneous	
Reservoir Thickness	> 50 m	< 15 m	5 m (dependent of volum to be injected)
Average porosity in net reservoir	> 20 %	< 12 %	
Permeability	> 500 mD	< 10 mD	1 mD
Pore pressure	Hydrostatic or lower	Overpressure	Overpressure near fracturing pressure

Structural trapping

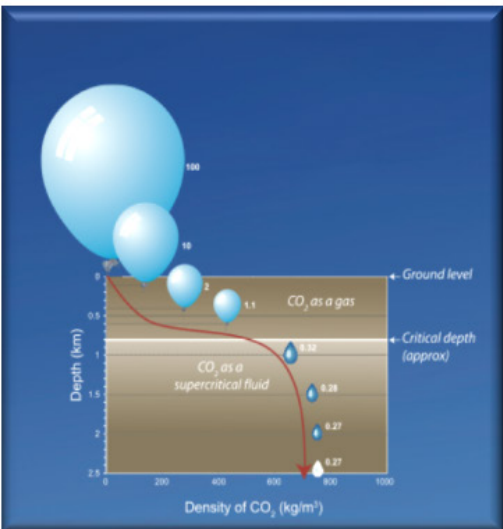


Stratigraphic trapping

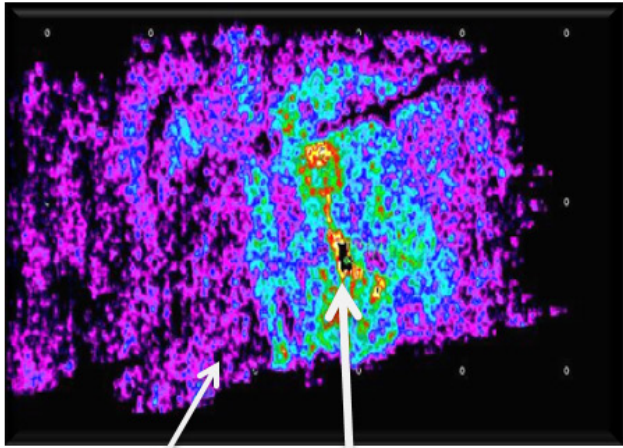
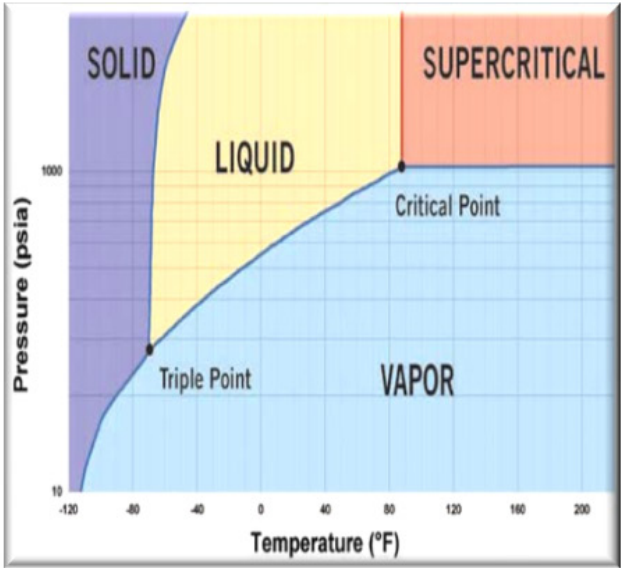
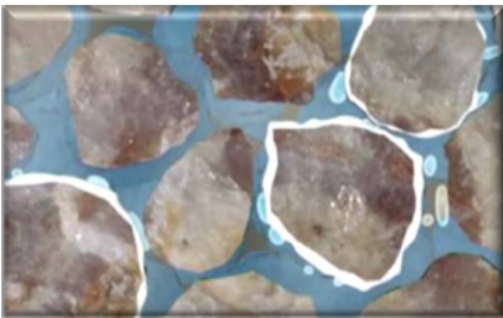
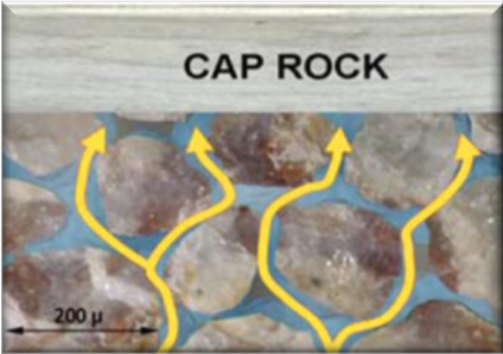
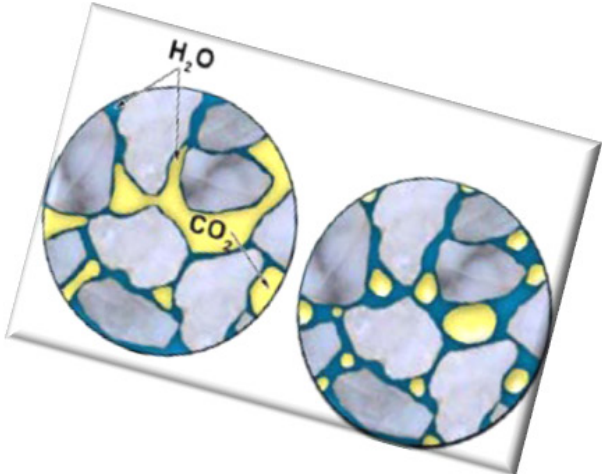


OD 1105005





- Storage depth
- Traps
- Seal
- Storage capacity
- Injectivity – pressure build up



CO₂ plume
Pressure affected area



Ranking Criteria for aquifers and structures

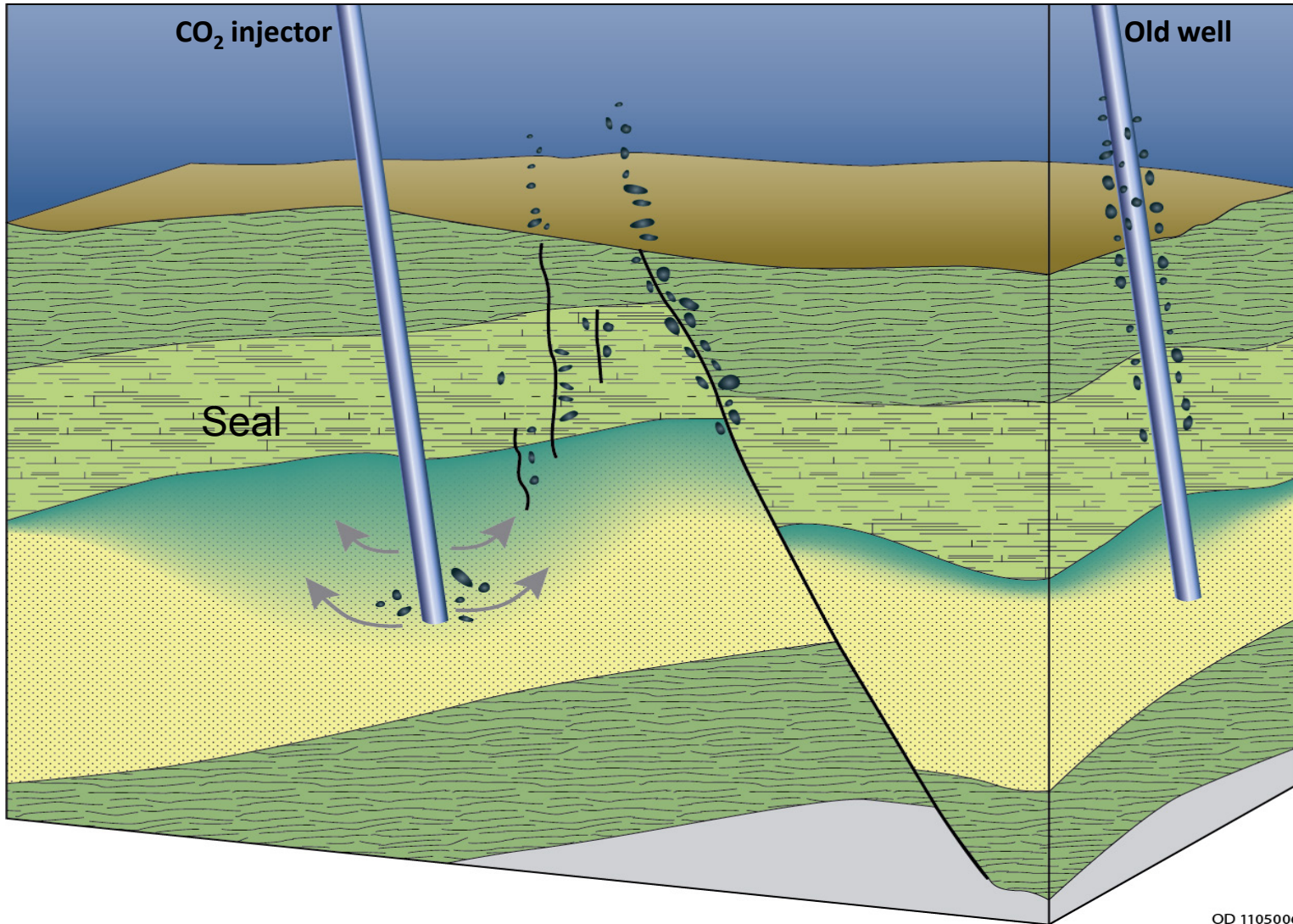
Ranking Criteria		Definitions, comments	
<u>Reservoir quality</u>	Capacity, communicating volumes	3	Large calculated volume, dominant high scores in checklist
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Other factors:
 How easy / difficult to prepare for monitoring and intervention.
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 Possible support for EOR projects.
 Potential for conflicts with future petroleum activity.

Checklist for Sealing Properties

	Typical high and low scores		
Sealing Properties	High	Low	Unacceptable values
Sealing layer	More than one seal	One seal	No known sealing layer over parts of the reservoir
Properties of seal	Proven pressure barrier/ >100 m	<50 m thickness	
Composition of seal	High clay content, homogeneous	Silty, or silt layers	
Faults	No faulting of the seal	Big throw through seal	Tectonically active faults
Other breaks through seal	No fracture	sand injections, slumps	Active chimneys with gas leakage
Wells (exploration/ production)	No drilling through seal	High number of wells	Consider the integrity of wells

Possible leakage points

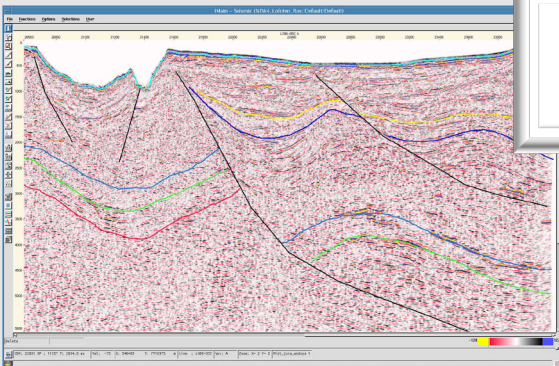


OD 1105006

Ranking Criteria for aquifers and structures

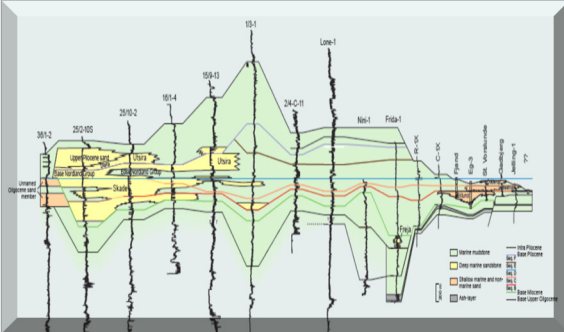
Ranking Criteria		Definitions, comments	
<u>Reservoir quality</u>	Capacity, communicating volumes	3	Large calculated volume, dominant high scores in checklist
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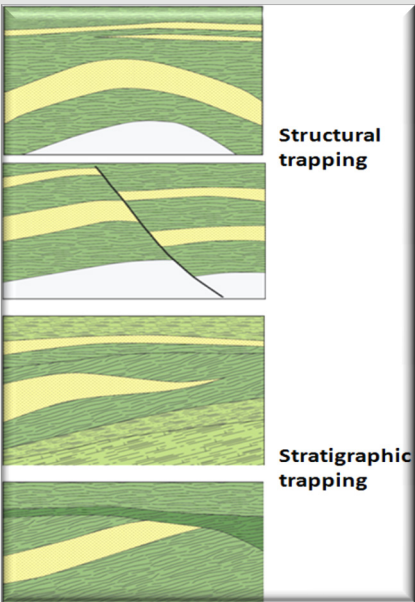


Evaluation process for safe CO₂ storage sites

Evaluation of data coverage and knowledge



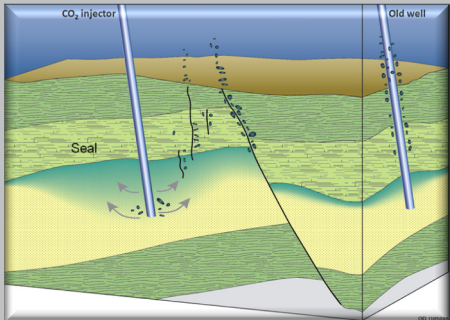
Stratigraphy (reservoir and seal)



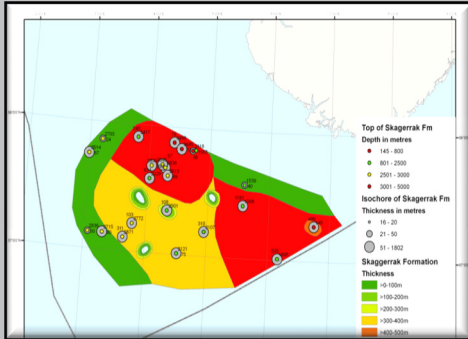
Trapping



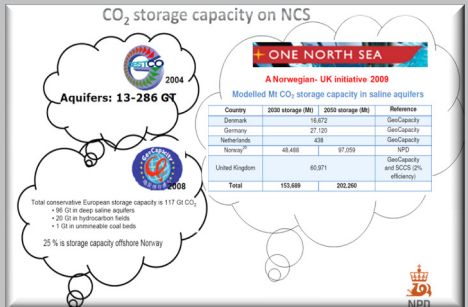
Ranking of reservoir/injectivity



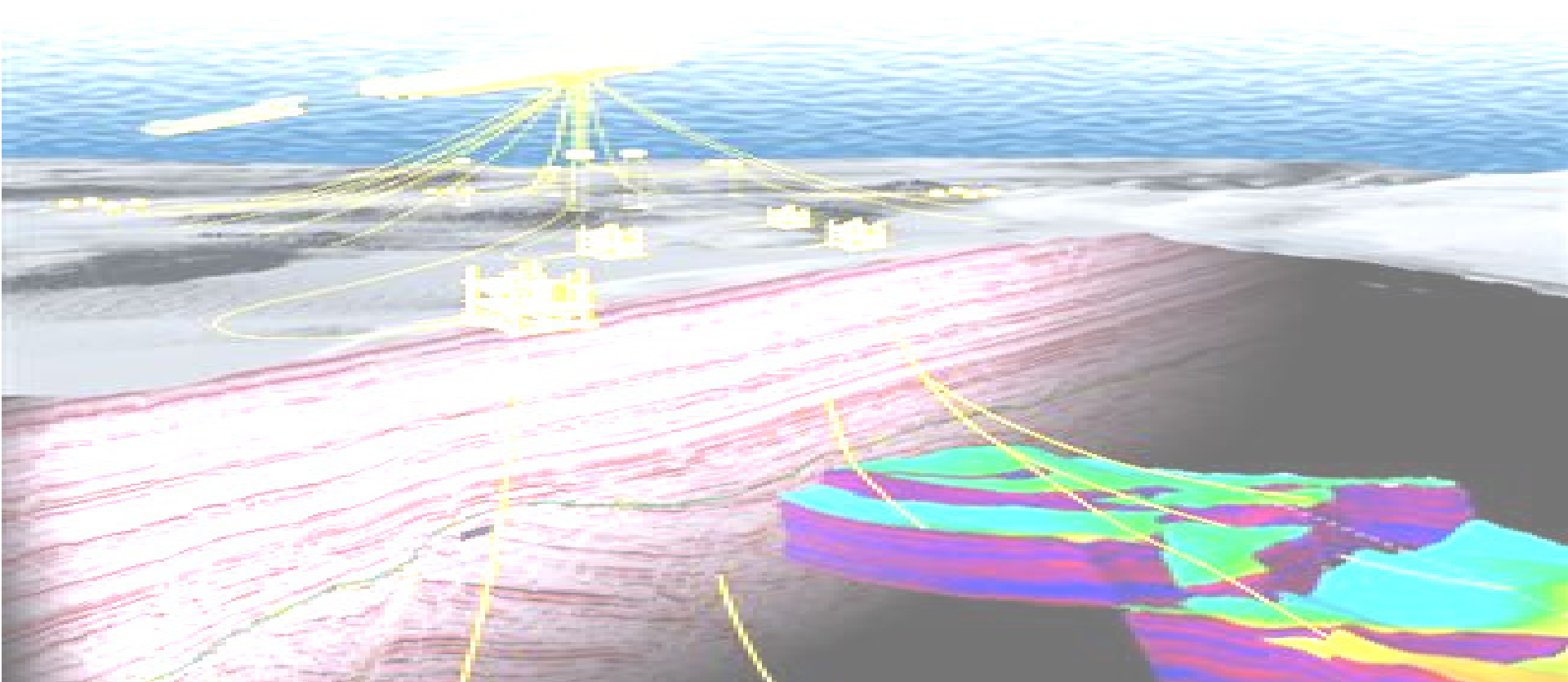
Ranking of seal efficiency



Map potential storage area



Estimate storage capacity



Thanks for your attention