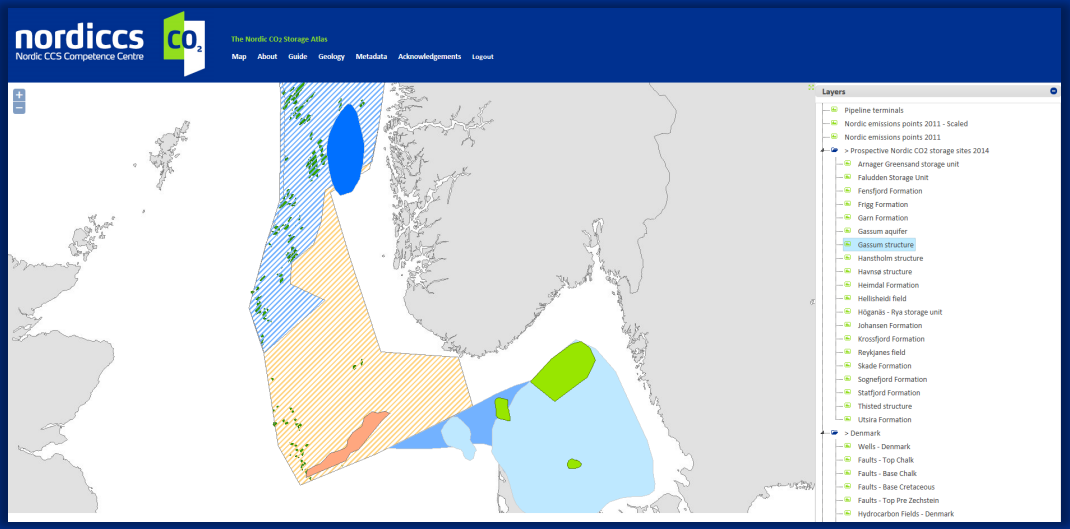
The Nordic Storage Atlas – an entrance to knowledge



Karen L. Anthonsen

GEUS – Geological Survey of Denmark and Greenland

norden
Top-level Research Initiative

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Nordic CO_2 storage options overview

Geology of the Nordic region. The Baltic shield, Caledonian, Cambrian basin, Mesozoic basins, basalts.

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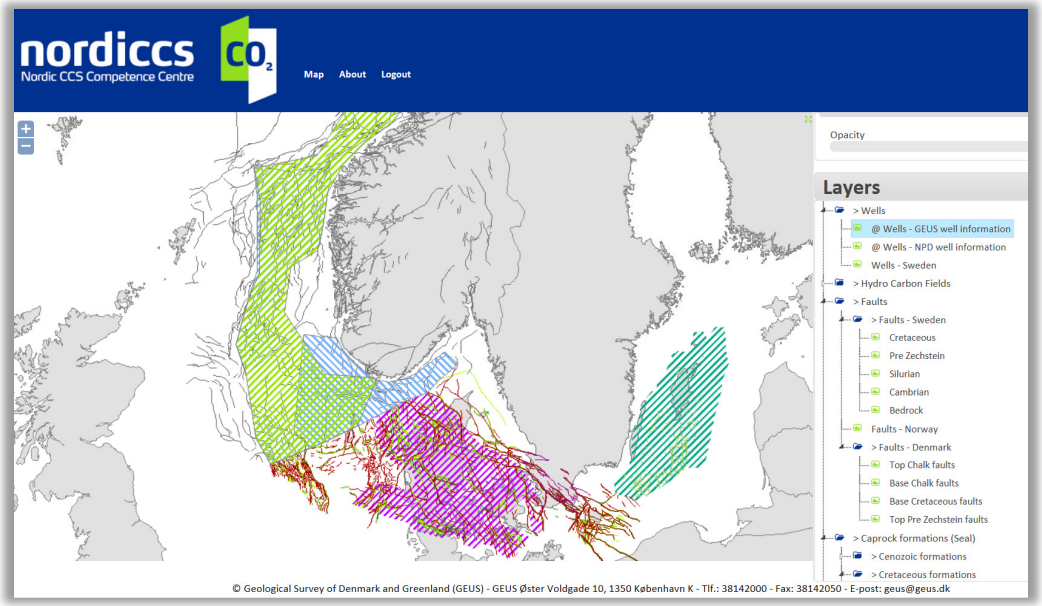
The Nordic CO_2 Storage Atlas – our goal

Review and update existing data bases and generate "The Nordic CO_2 Storage Atlas"



Make in public accessible as a webGIS

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The work process

1. Review of existing CO_2 databases
   - Norway – the Norwegian CO_2 storage atlas (2011-2014) by NDP
   - Denmark – results from GESTCO and GeoCapacity
   - Sweden – report on storage potential, but no digital data
   - Iceland – the CarbFix injection project, but no country evaluation
   - Finland – no storage option in sedimentary aquifers

2. Mapping and compilation of data for:
   - Aquifer formations
   - Storage units
   - Traps
   - Hydrocarbon fields
   - Permeable basalts
   - Caprocks (seal)
   - Faults
   - Exploration wells
   - Emission point sources
   - Pipeline terminals

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3. Capacity estimation for storage units, traps, hydrocarbon fields and permeable basalts

4. Screening and ranking of aquifer formations, storage units and traps. Point out the geological most attractive areas and sites for CO_2 storage based on our knowledge in 2014.

Reservoir properties	Optimal - 3 point	Questionable – 2 point	Caution – 1 point	Remarks
Depth	>800m-2500m	600-800m	<600m	Case specific depending on temperature gradient in the area
Porosity	>20%	10-20%	<10%	
Permeability	>100 mD	10-100 mD or extrapolated from closest well drilled through the reservoir	<10 mD or no data	Indicate gas or fluid measurements
Heterogeneity	Low N/G>0.4 Existents of uniform high porosity layers with thickness above 5 meter	Moderate N/G 0.1-0.4 Alternating high/low porosity layers. Layer thickness below 5 meter	High N/G<0.1 Highly alternating thin high/low porosity layers or channel sands with low connectivity. Diagenesis	Since heterogeneity is hard to quantify it advisable to give a remark about interpreted depositional environment and if the area has known diagenesis
Pore pressure	Hydrostatic or lower		Overpressure	
Thickness (Net sand)	>50m	15-50m	<15m	
Seal properties	Optimal	Questionable	Caution	
Thickness	>50m	20-50m	<20m	
Fault intensity	Low No mapped faults through reservoir or seal	Moderate Minor faults through reservoir or seal	High Large faults through reservoir and/or seal. Bounding faults	
Lateral extend	Continuous	Unsure about existence of a continuous seal. Seal locally thinner than 20 meter	Not continuous	
Multiple seals	More than one	Only one	Unsure if a seal exists	
Lithology of the primary seal	Homogeneous clay, mud or evaporites	Chalk	High content of silt or sand	
Safety/risk	Optimal	Questionable	Caution	
Seismicity	Low	Moderate	High	Both frequency and magnitude. Subjective, give argument for this category if moderate or high is chosen.
Risk of contamination of groundwater	No	Unsure	Yes	
Maturity/data coverage	Optimal	Questionable	Caution	
Wells	Well though the actual trap or storage unit	Well(s) though equivalent geological formations	No well data	
Seismic survey	3D seismic	2D seismic younger than 1970	2D seismic lines older than 1970 or sparse data	

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Publish the Nordic CO_2 storage Atlas on the web

data.geus.dk/nordiccs

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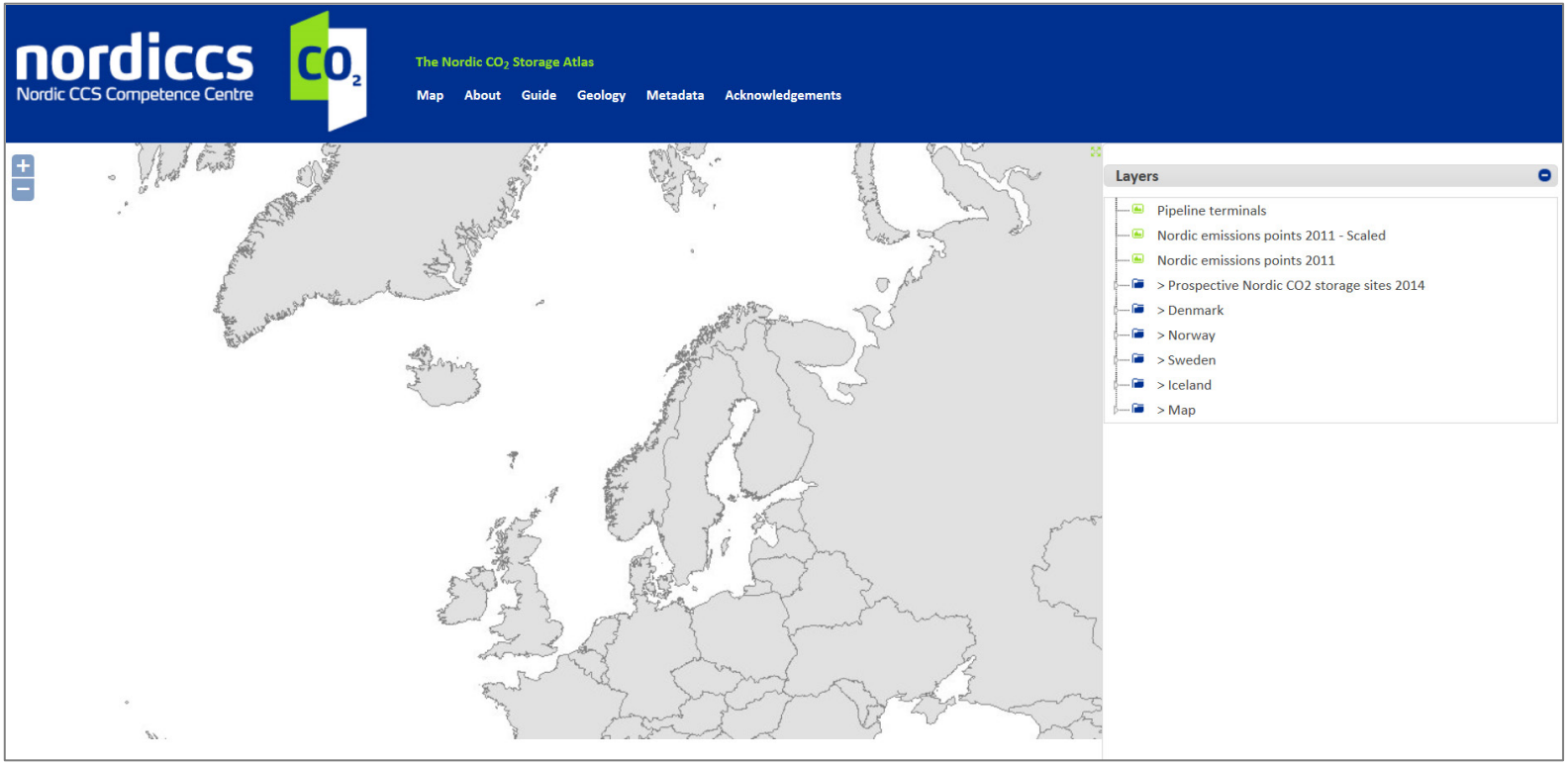

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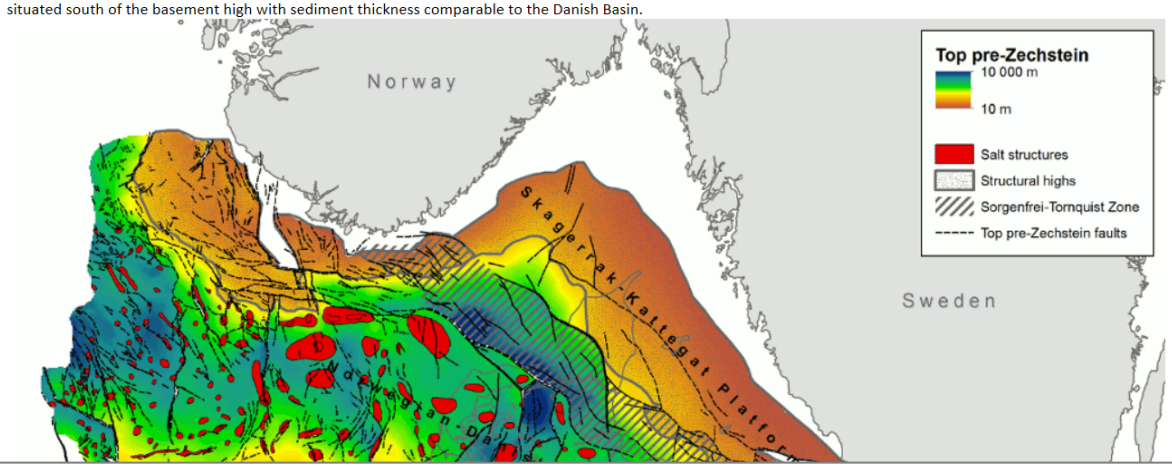
Geology and stratigraphy

Denmark

Geological framework

The geology of Denmark is characterised by a thick cover of sedimentary rocks of Late Palaeozoic – Cenozoic age. In the Danish Basin the sedimentary succession is up to 10 km thick (Fig. 1). The basin is bounded to the north and north east by the Fennoscandian Border Zone (Sorgenfrie-Tornquist zone and Skagerrak-Kattegat Platform) and to northwest–southeast by the basement high, the Ringkøbing-Fyn High. The sedimentary cover on this structural high is relatively thin (1–2 km). The North German Basin is situated south of the basement high with sediment thickness comparable to the Danish Basin.



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Metadata

Denmark

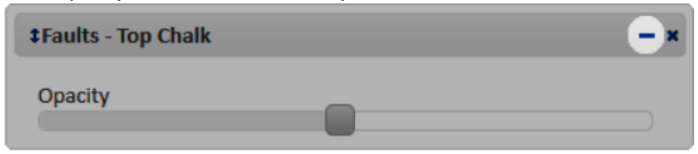
Wells - Denmark	
Scale	1:10 000
Created by	Geological Survey of Denmark and Greenland (GEUS)/Danish Energy Agency
Date of creation	March 2015
Updated by	
Date of update	
Description	Location of exploration wells in Denmark
Contact	Karen L. Anthonsen
Remarks	http://www.ens.dk/en/oil-gas/oil-gas-related-data/oil-gas-gis-service

Faults – Top Chalk, Base Chalk, Base Cretaceous, Top pre-Zechstein	
Scale	1:750 000 for Top Pre-Zechstein
	1:400 000 Top Chalk, Base Chalk and Base Cretaceous
Created by	Geological Survey of Denmark and Greenland (GEUS)
Date of creation	1999
Updated by	
Date of update	
Description	Location of faults in Denmark
Contact	Karen L. Anthonsen
Remarks	Based on: Japsen P & Langtofte C. 1991. “Base Chalk” and the Chalk Group. Geological Survey of Denmark. Map series No. 29. Japsen P & Langtofte C. 1991. “Top Triassic” and the Jurassic-Lower Cretaceous. Geological Survey of Denmark. Map series No. 30. Vejbæk OV & Britze P. 1994. Top Pre-Zechstein. Geological Survey of Denmark. Map series No. 45.

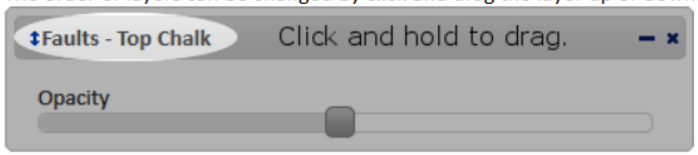
Guide to webGIS

- Blue folders are layer groups – click and open folder to expose the layers included.
- Green icons are separate layers – click and the layer will appear on the map.
- A layer can be more or less transparent by moving the "Opacity" slide.

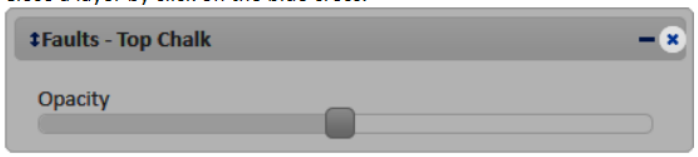
- The "Opacity" slide can be hidden by click on the blue dash.



- The order of layers can be changed by click and drag the layer up or down.



- Close a layer by click on the blue cross.



- Attributes are shown by click on the feature at the map. If more than one layer are open at the location all layers attributes will be shown.

Explanations to attribute data

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About NORDICCS

The Nordic CO_2 storage atlas is produced by NORDICCS – the Nordic CCS Competence Centre. The NORDICCS project is funded by user/industry partners and the Top-level Research Initiative (TRI).

TRI is a joint effort on the part of the Nordic countries to find solutions to global climate challenges - the largest-ever Nordic venture of its kind. The funding consists of finances from the Nordic Council of Ministers, the Nordic countries, and the Nordic institutions NordForsk, Nordic Innovation and Nordic Energy Research.

Project duration: from November 2011 to November 2015.

Link to NORDICCS website: http://www.sintef.no/Projectweb/NORDICCS/

Research Partners	
Chalmers University of Technology	Sweden
Geological Survey of Sweden (SGU)	Sweden
GEUS Geological Survey of Denmark and Greenland	Denmark
IVL Swedish Environmental Research Institute	Sweden
Norwegian University of Science and Technology (NTNU)	Norway
SINTEF Energy Research (host institution)	Norway
SINTEF Petroleum Research	Norway
Tel-Tek	Norway
University of Iceland	Iceland
University of Oslo	Norway
VTT Technical Research Centre of Finland	Finland

User/Industry Partners	
CO_2 Technology Centre Mongstad – TCM DA	Norway
Gassco	Norway
Norcem AS	Norway
Reykjavik Energy	Iceland

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Iceland Institute of Natural History

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The Nordic ranking of the 18 selected aquifer CO_2 storage areas and sites

Name	Ranking score	Storage Capacity in Mt	Country
Sognefjord Formation	45	11465	NO
Krossfjord Formation	45	3977	NO
Utsira Formation	44	21300	NO
Skade Formation	44	7560	NO
Heimdal Formation	44	5112	NO
Fensfjord Formation	44	4100	NO
Frigg Formation	44	1164	NO
Garn Formation	43	8003	NO
Gassum Aquifer (model area)	43	3700	DK
Havnsø (trap)	43	926	DK
Gassum (trap)	43	630	DK
Thisted (trap)	42	11039	DK
Hanstholm (trap)	42	2753	DK
Statfjord Formation	42	1850	NO
Johansen Formation	42	861	NO
Faludden (unit)	40	745	SE
Höganäs-Rya (unit)	39	543	SE
Arnager Greensand (unit)	39	521	SE
Total capacity		86249	

Norway	10
Denmark	5
Sweden	3
(Iceland	2)

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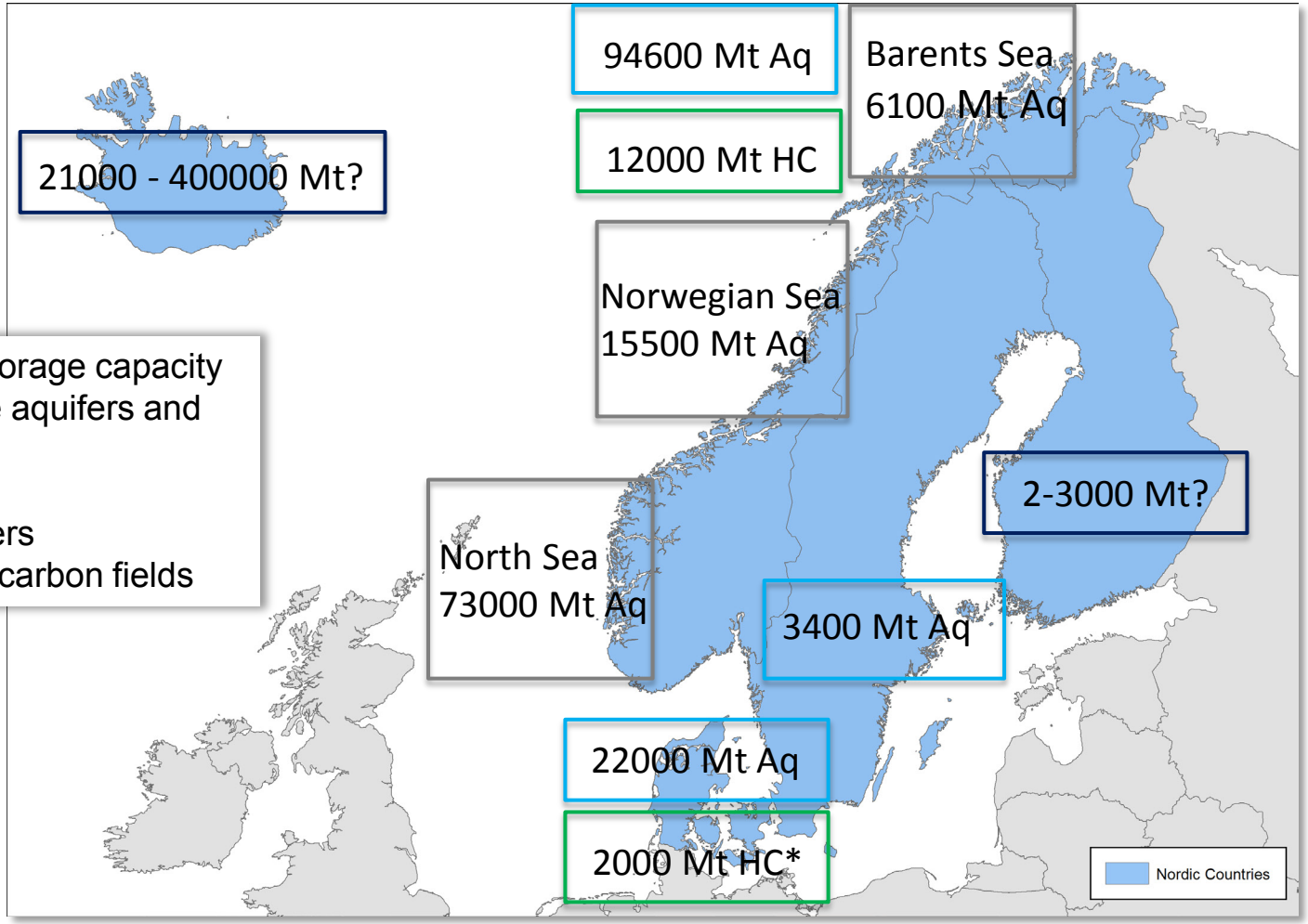
Total Nordic CO_2 storage capacity mapped until 2015



Total Nordic CO_2 storage capacity
134000 Mt in saline aquifers and hydrocarbon fields

120000 Mt in aquifers
14000 Mt in hydrocarbon fields

The storage capacities estimates are related to uncertainties and it requires further research to get better assessments. The storage capacity numbers changes, whenever new data are generated and better methods developed.

*Result from EU GeoCapacity

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Frants von Platen-Hallermund	GEUS (GIS databases)
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Per Aagaard	University of Oslo (Geology)
Yeufeng Gao	University of Oslo (GIS)
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Providing digital data to the Nordic CO_2 Storage Atlas

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NORWEGIAN PETROLEUM DIRECTORATE

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GEUS

SGU
Sveriges geologiska undersökning
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VATTENFALL

IVL Swedish Environmental Research Institute

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