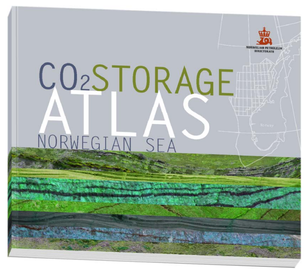

CO_2 STORAGE ATLAS NORWEGIAN SEA – A CASE STUDY FROM THE FROAN BASIN

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Conclusions

The Garn Formation has the best permeability and connectivity of the Jurassic sandstones in the Froan Basin (Norwegian Sea). All the aquifers are subcropping towards the Quaternary sediments along the coast. CO_2 injection projects should be planned to avoid long distance migration towards the subcrop and possible further seepage to the sea floor.

Modelling of injection in the aquifer indicates that it is possible to inject with a certain rate and volume where the CO_2 is trapped and/or dissolved before it reaches the subcrop area (8 Mt/year over 50 years). This will require 4 injection wells and give acceptable pressure increase (<20 bar). After 10.000 years most of the CO_2 will have gone into solution with the formation water or is residually trapped.

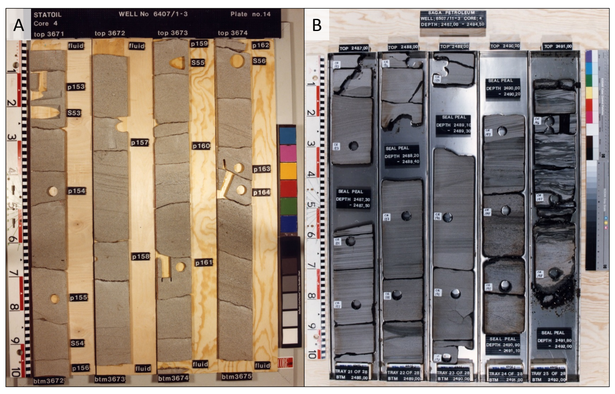
Based on simulation results the storage efficiency is low (0.2 %). Approximately 400 Mt of CO_2 can be safely stored in the Froan Basin Ile and Garn Formations.

Evaluation of the Froan Basin (Norwegian Sea) for CO_2 storage

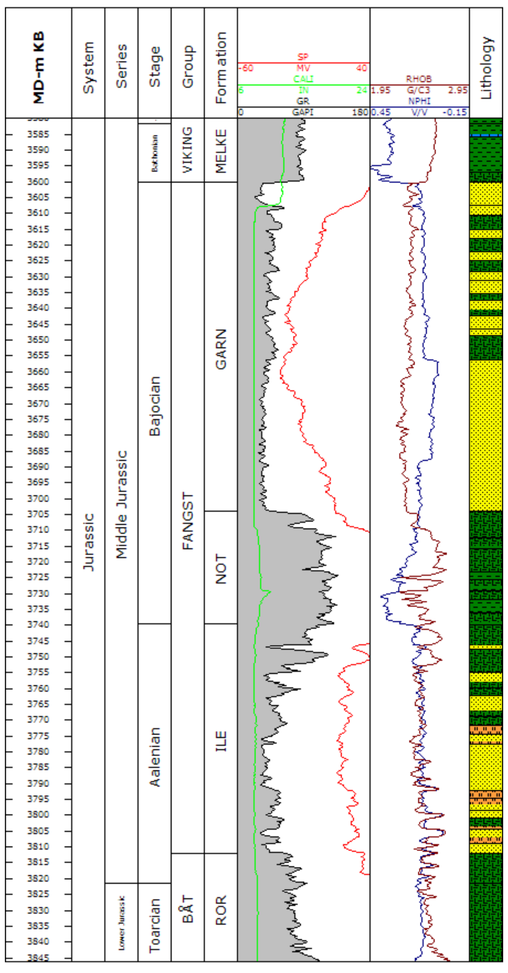
The aquifers in the Froan Basin have a consistent dip of 1-2 degrees from the Norwegian coast to the basinal areas. In the case of permeable beds occurring along the dip slope there is a risk that CO_2 injected down dip can migrate up to where the aquifer is truncated by the Quaternary glacial sediments. This setting is similar to several other aquifers in the Norwegian Continental Shelf.

The main objective of the study is to estimate the amount of CO_2 that can be safely stored, mainly based on reservoir simulation. Of particular interest is the understanding of the timing and extent of long distance CO_2 migration.

The aquifers which have been evaluated for CO_2storage are located at a depth between 600 and 3500 m and have a sufficiently high permeability, porosity and connectivity to enable injection and storage of CO_2.



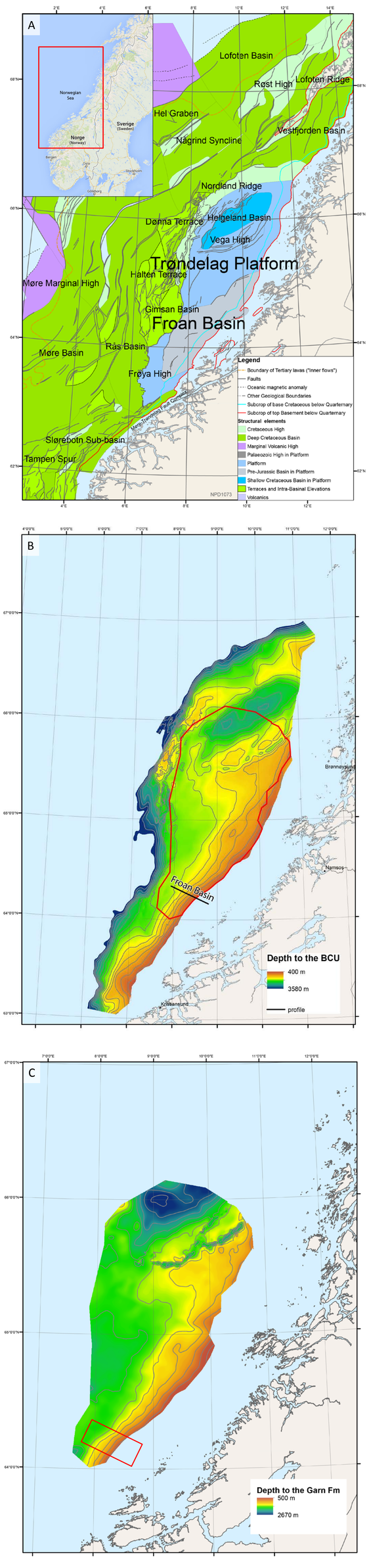
Core photos of (A) the Garn Formation and (B) the Ile Formation.



Well log from the well type section of the Garn Fm 6407/1-3.

The aquifers in the Froan Basin which is situated on the Trøndelag Platform have been studied by compilation of published maps, new seismic mapping, well studies and well correlation. Western areas have good data coverage with 3D seismic and several wells, while the remaining area has 2D seismic data and a few exploration wells.

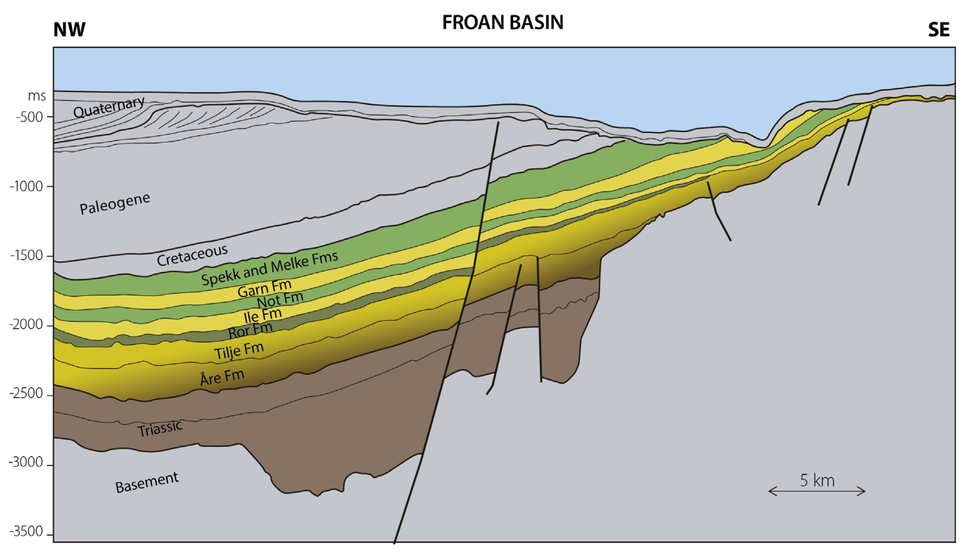
The main reservoir zones evaluated for CO_2 storage are the Ile and Garn Formations. They have very good reservoir properties at the shallow depths encountered in the Trøndelag Platform. The porosity and permeability used in the geomodel are based on the well log data and a few core measurements. The Garn Formation in the Froan Basin is dominated by shallow marine sediments where much better connectivity can be expected than in the tidal dominated Ile Formation. The Ile and Garn Formations shale out towards the north.



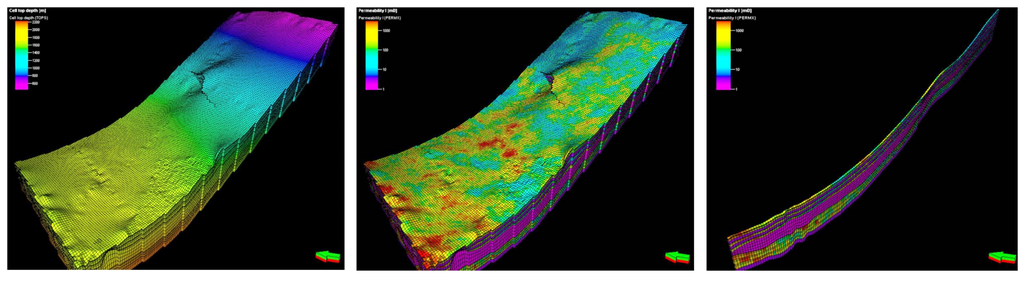
A: Structural elements of the Norwegian Sea.
B: Depth map of the BCU with the extent of the Garn aquifer and location of geosection indicated.
C: Depth map of the Garn Fm, with the sector model indicated.

Simulation sector model of the Froan Basin

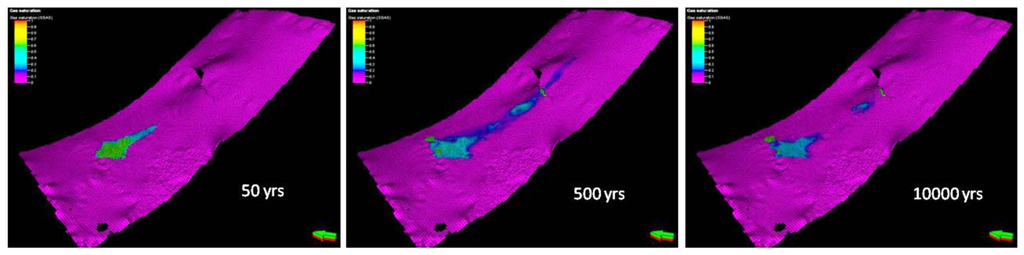
A simulation sector model of the Ile/Not/Garn Formations was build covering about 10 % of the total expected communicating aquifer volume. In the sector model one CO_2 injection well was located down dip, but alternative locations and injection zones have been simulated, with different injection rates. The injection period is 50 years, and the migration of the CO_2 plume was simulated and monitored for 10.000 years.



Geosection of the Froan Basin. The aquifers evaluated in this case study are the Ile and Garn Fm (yellow). The Not Fm (green) is a shaly unit interbedding the two aquifers zones; however the fault is juxtaposing Ile and Garn Fm and the two are therefore considered as one aquifer. The Spekk and Melke Fm (green) and the Cretaceous shales above the Garn Formation constitute an excellent top seal for the Jurassic aquifers.



Simulation sector model showing the depth (left), the permeability of top Garn (middle), and the permeability in cross section (right).



CO_2 plume in top Garn 3 mill Sm3/day , after 50 years (left), 500 years (middle), and 10 000 years (right).

Modelling results

Different injection rates and volumes have been simulated and upscaled to the estimated aquifer volume. The main upscaled scenario injects 8 MSm^3 CO_2/day for 50 years. The main criteria for evaluation of CO_2 storage volumes are acceptable pressure increase and confinement of CO_2 migration. CO_2 will continue to migrate upwards as long as it is in free and movable condition. Migration stops when CO_2 is permanently bounded or trapped, by going into solution with the formation water or by being residually trapped, or becoming structurally trapped (mineralogical trapping was not considered here).

After 10.000 years most of the CO_2 will have gone into solution with the formation water or is residually trapped. The results of the evaluation of the aquifer storage capacity are summarized in the table below.

The Garn/Ile aquifer		Summary	Summary
Storage system		half open	closed
Rock volume		4400 Gm^3	4400 Gm^3
Net volume		1100 Gm^3	1100 Gm^3
Pore volume		300 Gm^3	300 Gm^3
Average depth Garn Fm		1675 m	1675 m
Average depth Ile Fm		1825 m	1825 m
Average net/gross		0.25	0.25
Average porosity		0.27	0.27
Average permeability		580 mD	580 mD
Storage effieciency		4 %	0.2 %
Storage capacity aquifer		8 Gt	0.4 Gt
Reservoir quality			
	capacity	2	2
	injectivity	3	3
Seal quality			
	seal	3	3
	fractured seal	3	3
	wells	3	3
Data quality			
Maturation			

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