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Norway CCS Demonstration Project: Evaluation Of Jurassic Reservoirs For Safe CO2 Injection And Storage

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Summary

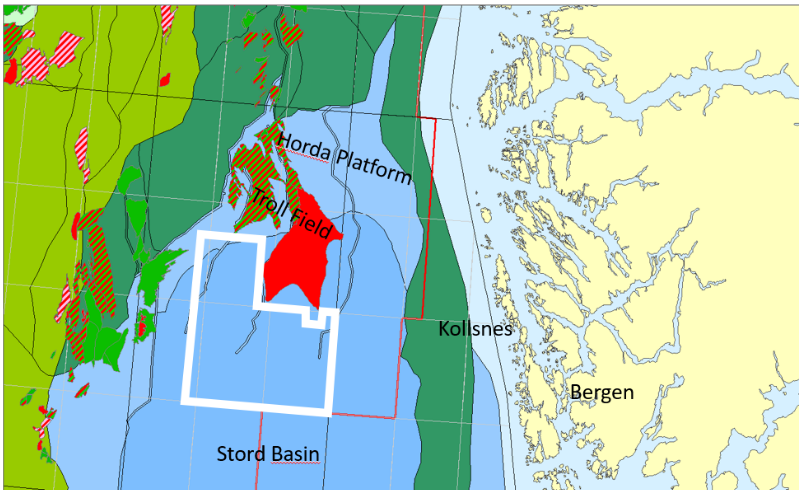
In July 2018, the Ministry of Petroleum and Energy (MPE) offered an area in the northern Stord Basin for applications to exploit a subsea reservoir for injection and storage of CO_2. This will be the first licence regulated by the Norwegian regulation for CO2 Storage (2014). By offering the area south of the Troll Field for an exploitation licence, it was decided to continue with the qualification of the Johansen-Cook aquifer for the Northern Light project.

In July 2018, the Ministry of Petroleum and Energy (MPE) offered an area in the northern Stord Basin for applications to exploit a subsea reservoir for injection and storage of CO_2. The deadline for application was September 7. According to Norwegian legislation, a licence for such exploitation can be granted to one company or a group of companies who are then given exclusive right to exploit the reservoirs in the licence area. This will be the first licence regulated by the Norwegian regulation for CO2 Storage (2014).

The utilization of these reservoirs is a part of the full scale CCS demonstration project which was launched by Norwegian Government. On behalf of the MPE, Gassnova follow up the financial and contractual part of the project. MPE and Norwegian Petroleum Directorate (NPD is the regulatory body. The transport and storage part of the project has been further developed by the Northern Lights project group where Equinor, Shell and Total cooperate. The plan is to capture CO2 in South-East Norway, transport it by ship to Kollsnes (fig. 1) and by pipeline to the storage location where it will be injected and stored. The volume of captured CO2 in the demonstration project is limited to 1.5 Mton annually for 25 years, but the selected storage location should have capacity to store CO2 from third party sources. The NPD will evaluate the applications including the capacity, risks and work program for the proposed site(s), and report to the MPE. In order to accomplish this, geological mapping and reservoir modelling has been undertaken for the aquifers in the region.

The Horda Platform and Stord Basin are located offshore west Norway (fig. 1). The crest of the Horda Platform is a structural closure, where oil and gas is trapped in the Upper Jurassic reservoirs of the giant Troll Field. This structure is also closed at the levels of the aquifers deeper down in the Jurassic section, making the area attractive for exploration of CO2 injection sites in the saline aquifers.

The area is covered by high quality 3D seismic data and the whole Jurassic section is penetrated by a number of exploration wells. Close to the coast and in the southernmost part of the study area only 2D seismic data exists. The NPD has access to all data, and older interpretation has been updated with the more recent seismic data sets. Pore pressure has been measured in most exploration wells.



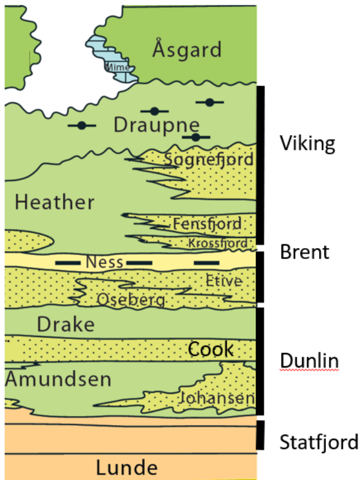


***Figure 1** Location of the announced area (white line).*
***Figure 2** Lithostratigraphy, formations and groups.*

The Jurassic stratigraphy in the study area is illustrated in fig. 2 and the cross-section (fig. 3). Throughout the Jurassic, the area was situated between a paleo-high in present day West Norway and basinal areas in the present day North Sea. Repeated faulting in the latest Triassic, Middle and late Jurassic can be correlated with pulses of sandy sediments derived from the east (Johansen, Oseberg, Krossfjord, Fensfjord and Sognefjord Formations). The relief increased due to increased tectonism in the late Jurassic. Late Jurassic erosional features and depositional systems can be correlated to paleovalleys and fjords in West Norway. These sandstones with a source from the east interfinger with marine shales and sandstones belonging to the larger Stord Basin and Viking Graben systems (Statfjord Group, Cook Formation and Brent Group).

The marine shales in the Amundsen, Drake and Heather Formations form seals between the sandstones formations. Four main aquifers can be defined, fig. 3.

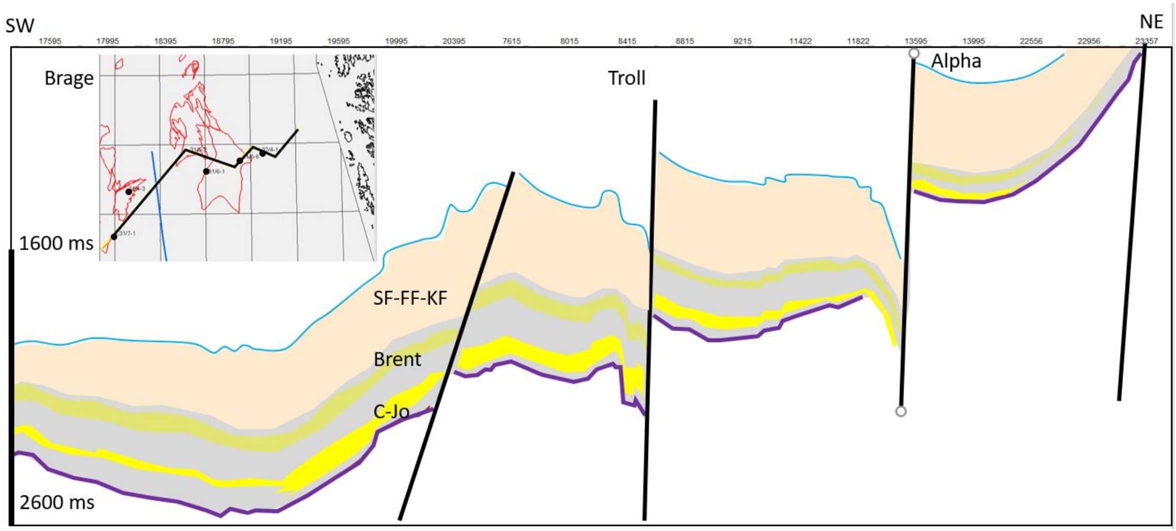


Figure 3 *Interpreted cross-section along seismic composite line. Tied to the wells 31/7-1, 31/4-3, 31/6-1, 31/6-6 and 32/4-1. SF-FF-KF: Heterolithic Sognefjord-Fensfjord-Krossfjord aquifer, Brent aquifer and Cook-Johansen aquifer. Sealing shales are colored light gray. Possible heterolithic aquifer below top Statfjord (purple line).*

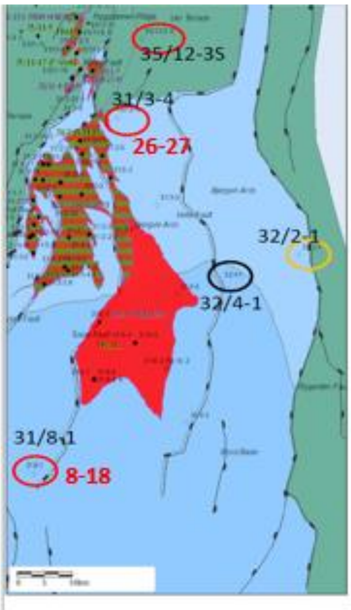
Fig 3 shows that major faults separate the structural closure of the Horda Platform from the eastern terrace and the Stord Basin south of Troll. There is a trend in depositional environment in the aquifers from a fluvial setting in the east to a shallow marine/deltaic environment in the Horda Platform. The Johansen Formation and the Viking Group sandstones shale out into a deeper shelf environment towards the west.

The Viking Group (Sognefjord) aquifer and the Johansen-Cook aquifer have the largest pore volumes and are most attractive for CO2 storage. These aquifers were characterized in the Norwegian CO2 Storage Atlas (NPD 2014) and have been the main candidates for the CCS full scale project.

Pressure management of aquifers is important both for CO2 storage and petroleum production in mature petroleum provinces. In a closed or half-open aquifer, pressure build-up will often be a limiting factor for the storage capacity of injected CO2. Aquifers surrounding producing gas fields have good storage capacity potential without need for production of formation water because of pressure depletion. The Jurassic aquifers in the study area were hydrostatically pressured before the main production started up in the Troll Field in 1996. Aquifer pressure is now depleted by more than 20 bar in the Sognefjord Formation (fig. 4), which is the main producing formation in the Troll Field. Due to internal layering, depletion in the other formations in the aquifer is less. Depletion has also been observed in the Brent Group aquifer, probably because of sand-sand juxtaposition at major faults.

In the Northern Lights project, the Alpha structure east of Troll (often referred to as Smeaheia structure) was selected for further qualification. An exploration well drilled prior to Troll production start-up found a thick water-bearing Sognefjord Formation at 1220 m depth, where more than 60 m had excellent quality. The cap rock was the sealing Draupne Formation.

Risks to be investigated for the Alpha structure were considered to be depth conversion, seal along boundary fault and pressure depletion. With hydrostatic conditions, the virgin aquifer pressure at the top of the structure was in the order of 120 bar. With future production and pressure depletion at the Troll Field, the pressure in the Alpha structure could drop to below the critical point of CO2, which is 72.7 bar. Below this pressure, CO2 will be in gas phase. In gas phase, CO2 will expand, and the corresponding storage capacity of the structure will be reduced. In order to investigate this risk, the NPD undertook a modelling study assisted by AGR.



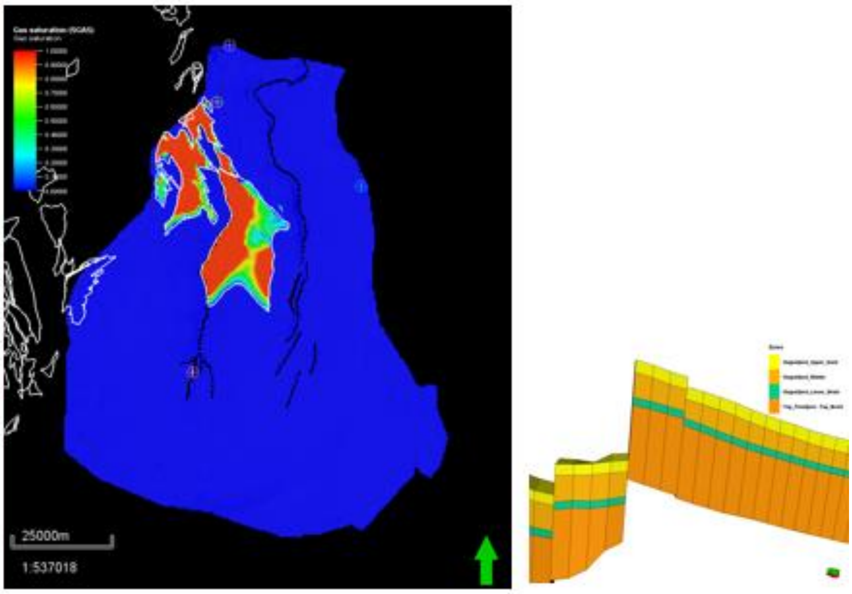


Figure 4 *Troll Field and exploration wells with pressure depletion in bar (red). Data from Fensfjord and Sognefjord Formations.*
Figure 5 *Four layer reservoir simulation model: Top layer coloured by water saturation, and E-W profile across the model.*

A simulation model was built, based on an updated geomodel (fig.5). The simulation model was history matched with production data from the Troll Field and pressure data from exploration wells. The main result was that there is a risk for a large pressure drop in the Sognefjord Formation aquifer in Smeaheia in the future. The most important factor was modelled to be the sealing capacity of the fault boundary between Troll and the Alpha structure. Except for a ramp structure, the fault offsets the whole Viking Group. However, if the ramp is completely open for flow, a large pressure drop was modelled already in 2040 (fig.6) If the ramp is totally closed, the pressure drop will be only a few bar in that time scale. Pressure drops were also modelled in a much longer time scale. These are more uncertain because the mapped aquifer is probably attached through faults and baffles to other aquifers and to the sea floor.

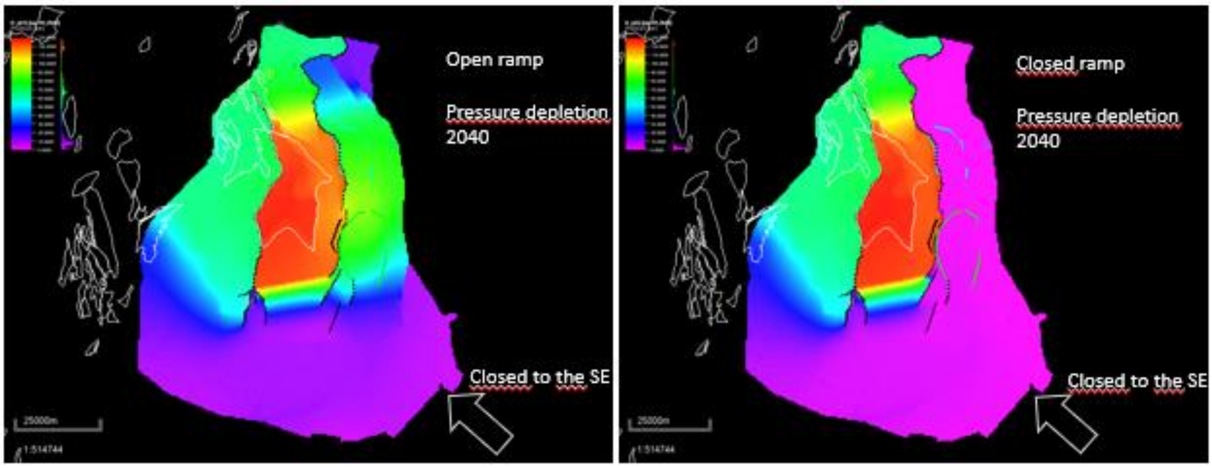


Figure 6 *Simulation results, showing pressure depletion in 2040. Warm colours – large depletion.*

An evaluation of the storage potential of the Johansen-Cook aquifer in the study area was presented by the NPD and SINTEF in 2009 (Bergmo et al. 2009). In order to improve the seismic data coverage of the area, Gassnova acquired 3D data in the area south-west of Troll and undertook a more detailed study of the potential in cooperation with Ross Offshore. Sundal et al. (2016) went further with the Gassnova data and interpretation and presented a detailed sedimentological model of the formation.

The Johansen - Cook aquifer defines a large structural trap at the Horda Platform, 600 m below the Troll Field. It is separated from the field by interbedded sealing shales and reservoir formations. The structure allows for CO2 injection in a downdip position relative to the Troll Field. Injected CO2 will migrate along a dipping slope for a long distance before it reaches the structural closure.

Risks which have been identified for CO2 injection in the Johansen-Cook aquifer are mainly related to reservoir quality and injectivity at the injection site. There are no wells close to the area in the south where injection has previously been proposed. Interpretation of seismic facies indicate sandy formations, but there is a change in seismic character between the injection area and the drilled wells, as discussed and interpreted by Sundal et al. (2016). Another risk is that in the case of large injection volumes, CO2 will eventually migrate into the structure below the Troll Field. There may be a risk of CO2 migration along faults up to the Troll reservoir. Previous modelling has shown that even migration of CO2 to below Troll will not happen before Troll production has ceased, but this combined risk should be considered for the qualification of the site. Leakage to the sea floor through geological formations will not happen for this injection alternative, because in the event of CO2 escape out of the storage complex it will be trapped in the depleted Sognefjord/Fensfjord Formations.

By offering the area south of the Troll Field for an exploitation licence, it was decided to continue with the qualification of the Johansen-Cook aquifer for the Northern Light project.

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