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CO2 Storage Potential Of The Neogene Stratigraphy In The North Viking Graben

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Summary

The main Neogene reservoirs for CO2 storage in the North Viking Graben are the Utsira and Skade Formations, collectively known as the Utsira- Skade Aquifer. This is one of ten aquifers in the North Sea that is deemed suitable for CO2 storage (Halland et al., 2011). Most studies have been either a large scale assessment of the entire aquifer or finer detailed studies in the southern area, as this is currently where injection of CO2 is currently taking place at the Sleipner storage facility. This study assesses the suitability of the aquifer and its surrounding stratigraphy in the North Viking Graben. Analysis showed that a lack of a thick depocentre at a suitable depth results in poorer potential in this region compared to its southern counterpart. Injection into the Utsira Formation would need to occur in the north-east section to be at a suitable depth, utilising mostly 20-100m thick sands with a maximum migration distance of 90 km. The Skade Formation benefits from 85m thick closed traps but a max migrati

Introduction

Since injection began in 1996, the Sleipner CO_2 storage site has demonstrated the capabilities of the late Neogene Utsira Formation to trap CO_2 on a commercial scale. This has since led to an array of studies on the Utsira Formation from reservoir characterisation through to CO_2 injection modelling and monitoring. Most of these studies have focused on either the Southern Utsira Member (subdivided by Eidvin et al., 2013) or the entire Utsira Formation, with little research dedicated to the Northern Utsira Member apart from localised well studies (e.g. Eidvin & Rundberg, 2001).

The Carbon Capture and Storage (CCS) industry will need to grow two orders of magnitude larger than its current size to become a viable option for mitigating greenhouse emissions (IEA, 2017). Although Sleipner has a capacity of 20 Mt CO_2, several studies have shown that the Utsira-Skade Aquifer is capable of trapping volumes of CO_2 on a giga-tonne scale (e.g. Halland et al., 2011), which is necessary to achieve this upscaling of the industry. The calculated volumes from these studies use large scale parameters such as reservoir geometry, depth and averaged porosity/permeability to provide a quick assessment of an aquifer. However, prior to actual injection, a more detailed assessment of the reservoir, seal and overburden is required. The objective of this study is a reservoir and seal characterisation of the Neogene deposits in the North Viking Graben (NVG), to assist in site selection if a more expansive area of the Utsira-Skade Aquifer is used for future CO_2 storage.

Methodology

Full 3D broadband seismic has been utilised and calibrated with 104 wells (Fig. 1). Top formation horizons were manually picked using published well formation tops from biostratigraphic and seismic studies. A horizon stack was automatically generated and matched with intra-formational shale barriers observed in wells. In areas of poor well coverage properties were simulated from geological modules and seismic attributes. A geomodel was created using all modelled and interpreted data which was then used to simulate CO_2 migration and risk of leakage from different injection sites.

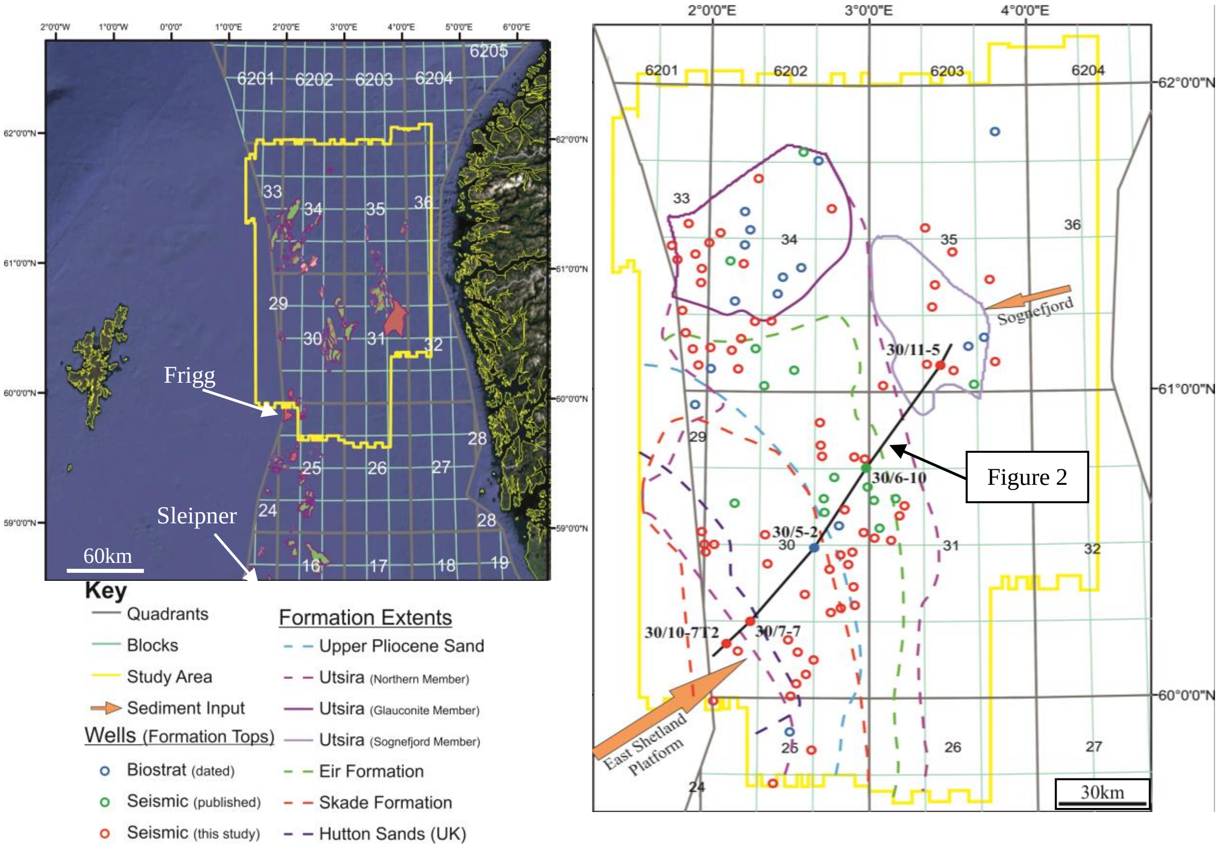

Figure 1 *Study area and data coverage. Utsira Glauconite Member extent from Rundberg & Eidvin, 2005. Hutton Sands extent from Gregersen & Johannessen, 2007.*

Reservoir and Seal Characterisation

The North Viking Graben Neogene sand deposits comprise the top Hordaland and full Nordland Groups. The main sand bodies are the Skade, Eir (name proposed in Eidvin et al., 2013), and Utsira Formations. The Eir Formation represents a 3 My unconformity within the lower section of the original Utsira Formation interpretation. As the formation is stratigraphically between the Utsira and Skade Formations and all three formations are in connection with each other in the west, this study refers to them as the Utsira-Eir-Skade Aquifer for the deposits north of the Frigg area (Fig. 1).

The Utsira-Eir-Skade Aquifer consists of sediments which infilled the Viking Strait; a narrow seaway that had formed during the Miocene. The majority of these sediments were sourced from the East Shetland Platform (ESP), with minor input from the Sognefjord area (Fig. 1 & 2). The ESP sediments represent a prograding deltaic sequence, with each formation down-lapping onto basin floor mudstones or on-lapping the top Oligocene unconformity at the Eastern Margin. Internally, the sand bodies range from thick blocky sands to cycles separated by 4–15 m shale layers. The thicker shale layers could be observed on the seismic and subsequently correlated and accounted for in the geomodel (Fig. 2). The top seal is mudstone clinoforms, which reach a maximum thickness of 330 m in the centre of the basin. To the East, younger sands sourced from the ESP result in a considerably thinner top seal (20 m), which the seismic shows to be locally breached by sediment remobilisation.

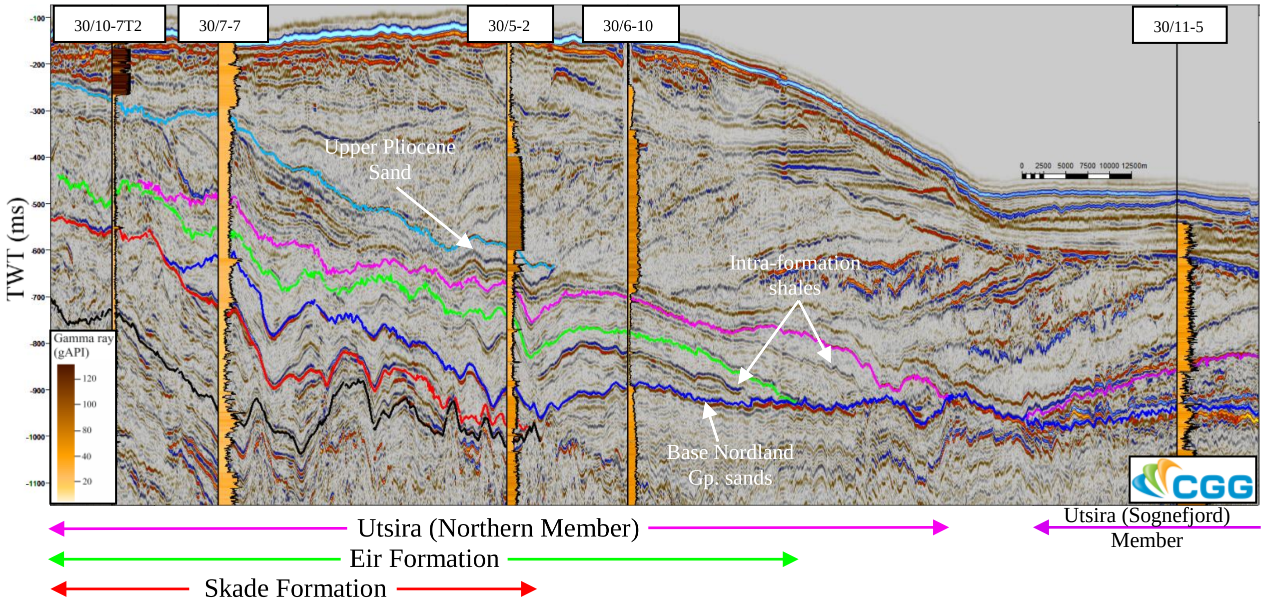

Figure 2 *Composite seismic line showing the extent and relationship of the Neogene Sands with gamma ray traces overlain. The position of the line and the formation extents are shown on figure 1.*

Storage Site Selection

The Skade Formation connects to the Utsira and Eir Formations in the West of the study area. The depth that these connect is <700 m and therefore a single injection site could only utilise the full aquifer at two separate injection depths due to the Skade Formation seal, although the displaced formation water is likely to be in communication. Therefore the formations were assessed separately.

The NPD checklist for CO_2 storage (Table 1) can be used for general capacity estimations. The cut-offs mainly apply to structural trapping, for residual trapping and dissolution (the highest potential trapping mechanisms in the area) other commercial projects have demonstrated lower valued parameters, e.g. The ‘In Salah’ project, Algeria, injects into 29m thick sandstone with 17% porosity. Porosity variations from well logs were input into the geomodel, however due to the high values they had little effect on altering CO_2 migration. The high values also meant fewer wells were needed to reach the required injection rate of CO_2, however the CO_2 migrated at a relatively faster rate.

Parameter	High Score	Low Score	Skade Fm.	Utsira/ Eir Fm.
Res Net thickness	>50m	<15m	Up to 450m	Up to 300m
Res Porosity	>25%	<15%	27%	32%
Res Top Depth	800 – 2500m	<800m or >2500m	310- 1340m	280- 1340m
Seal Thickness	>100m	<50m	0-95m	20-330m

***Table 1** Large scale assessment for the Utsira-Eir-Skade Aquifer. Analysis undertaken on 3D seismic and 104 wells (Skade Fm.= 42 wells, Eir Fm.= 63 wells, Utsira Fm.= 99 wells). Checklist (yellow) from Halland et al., 2011.*

The Utsira and Eir Formations combined contain a 290 m thick depocentre, the top of which is at an unsuitable depth for storage (Fig. 3a). The northern section offers the best opportunity for storage as it covers a large area below 700 m, although generally less than 50 m thick. A maximum distance of 90 km could be achieved if injecting at the furthest point downdip (Fig. 3a). The role of the intra-formational shale barriers depended on the injection locality, with a general trend of the shale layer influence becoming more important in redirecting the plume flow as one moves further south. Many small structural traps would be utilised as opposed to a few large ones (Fig. 3b).

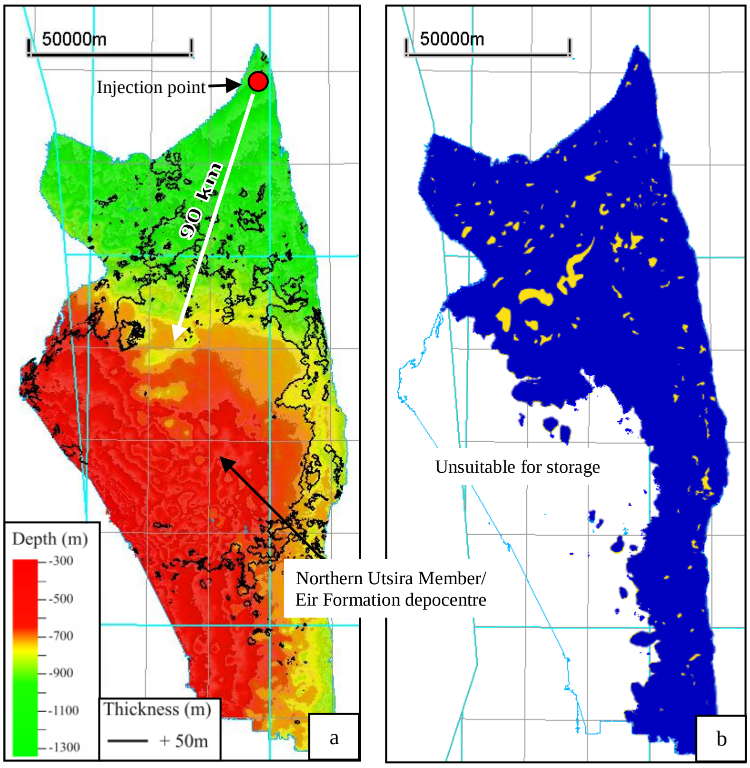

***Figure 3** CO_2 storage of the Northern Utsira Member and Eir Formation. a. Depth map highlighting suitable depth areas (green) and non- suitable areas (red), with 50+ m thickness contour. b. CO_2 accumulations at the top Utsira Formation.*

The Skade Formation is less extensive over the NVG compared to the Utsira and Eir Formations resulting in a maximum migration distance of 38 km. Remobilisation of older sediment below has resulted in a series of mounds that create suitable traps with a max fill to spill thickness of 85 m.

Conclusion

The Utsira-Eir-Skade Aquifer over the NVG lacks a thick large depocentre at the correct depth for storage like its southern counterpart, giving it a lower overall storage potential. The northern section of the Utsira and Eir Formations offers the best characteristics, with a maximum migration route of 90 km. However here the formations are generally less than 50 m thick, only increasing in thickness to above 50m in the final 25 km. The Skade Formation has a maximum migration route of 38 km, although it thickens rapidly to the east and has well defined structural traps for storage.

Acknowledgements

The authors would like to thank CGG for the access to the broadband seismic survey, TGS for providing the well data and the NERC for funding this study.

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