

Peer Review Report

Review Report on Regional exploration and characterisation of CO₂ storage prospects in the Utsira-Skade Aquifer, North Viking Graben, North Sea

Original Research, Earth Sci. Syst. Soc.

Reviewer: Sian Evans

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EVALUATION

Q 1 Please summarize the main findings of the study.

The authors use a large 3D seismic dataset and selected well data to assess the reservoir quality distribution within the Utsira-Skade formations, building on a previous study by the same authors that assessed seal potential across the same region. The authors conclude by identifying the largest structural traps within their study area, and narrow this down to four traps which meet suitability requirements for CO₂ storage in terms of capacity, seal integrity and depth.

Q 2 Please highlight the limitations and strengths.

The paper is well written and logically structured, with appropriate methods used to perform the analysis. The authors make it clear that this study is intended for screening purposes, and therefore unknowns concerning dynamic pressure distribution during injection are left to future studies. This is a very relevant topic that will be of wide interest to readers of this special issue.

Q 3 Please comment on the methods, results and data interpretation. If there are any objective errors, or if the conclusions are not supported, you should detail your concerns.

On the whole the findings of the study are well supported. My main concern is with handling of uncertainty as detailed in the report below.

Q 4 Check List

Is the English language of sufficient quality?

Yes.

Is the quality of the figures and tables satisfactory?

Yes.

Does the reference list cover the relevant literature adequately and in an unbiased manner?

Yes.

Are the statistical methods valid and correctly applied? (e.g. sample size, choice of test)

Yes.

If relevant, are the methods sufficiently documented to allow replication studies?

Yes.

Are the data underlying the study available in either the article, supplement, or deposited in a repository? (Sequence/expression data, protein/molecule characterizations, annotations, and taxonomy data are required to be deposited in public repositories prior to publication)

No.

Does the study adhere to ethical standards including ethics committee approval and consent procedure?

Yes.

If relevant, have standard biosecurity and institutional safety procedures been adhered to?

Not Applicable.

Q 5 Please provide your detailed review report to the editor and authors (including any comments on the Q4 Check List):

The authors use a large 3D seismic dataset and selected well data to assess the reservoir quality distribution within the Utsira-Skade formations, building on a previous study by the same authors that assessed seal potential across the same region. The authors conclude by identifying the largest structural traps within their study area, and narrow this down to four traps which meet suitability requirements for CO₂ storage in terms of capacity, seal integrity and depth. The paper is well written and logically structured, with appropriate methods used to perform the analysis. The authors make it clear that this study is intended for screening purposes, and therefore unknowns concerning dynamic pressure distribution during injection are left to future studies. This is a very relevant topic that will be of wide interest to readers of this special issue. Below I include some recommendations to improve the quality of the manuscript for publication. Further minor comments are given in the attached annotated pdf.

Main comments

1. Porosity analysis

My principal recommendation is to address more fully the uncertainties inherent in the method used for porosity analysis. Firstly, were porosity logs acquired in any of the wells and how do they compare to the method of porosity estimation using the density logs?

Secondly, logs from only 17 wells were used to define the relationship between velocity and porosity and the plots show quite a lot of scatter, with a wide range of correlation coefficients and half of the wells showing weak to no correlation. What impact might this have on the results, in particular the quoted porosities? It may be pertinent to do some sensitivity analysis.

Finally, the equation is said to be calibrated to sandstones, with mudstones removed from the data before the poro-velocity relationship is derived, but this relationship is then applied across the dataset - including intervals with interbedded mudstones. Why then were the mudstones removed? Could this lead to an overestimation of porosity in some areas?

And as the authors mention in the text, porosity estimates will also be affected by velocity artefacts in the cube. Given all of this uncertainty, is the average porosity difference between the Skade and Utsira formations statistically significant (difference of 3%)? And can quoting porosity to 1 or 2 decimal places be justified (35.75% for prospects in the Skade fm vs. 34.3% for prospects in the Utsira)?

2. Storage capacity

In the calculation of effective storage capacity it is not clear where the net to gross value is taken from - is it from the nearest well to each prospective closure, or an average for the entire aquifer and thus the same value applied to every prospect? Also, since there is again uncertainty in the parameters used in the equation, it would be valuable to use upper and lower limits (e.g. for the porosity and N:G) and use this to give a range of estimates for the storage capacity. This would help get a handle on the precision of these calculations, since error may be introduced in multiple parameters and compounded.

3. Relationship to basal mounds

The authors observe that geometries and stratigraphic relationships within the units comprising the aquifer are related to mounds at the base of the aquifer. The downlapping and overlying depressions are attributed to late collapse and subsidence of the mounds, but an interesting relationship with the porosity trends is left unexplained. The Skade fm shows an increase in porosity above the mounds whereas the Utsira fm shows a decrease. The mounds have clearly influenced the depositional systems but what is the cause of this inverse relationship?

Additionally, it would be nice to include more contextual information about the genesis of the mounds if available - they are briefly linked to sandstone intrusions in the text but how deep are these intrusions relative to the mounds, what controls their spatial distribution and what is the internal composition of the mounds at the aquifer structural level?

4. Fault risk

To maximize security of potential prospects all faults are assumed to be leakage pathways in assessment of the containment confidence score. This eliminates large areas with potential prospects. If membrane seals are present in faults with small throws through clay rich units, would that open up many more of the prospects for evaluation? Worth mentioning the possibility as this is a significant unknown, and similar faults elsewhere in the region have proven membrane seals.

Figure comments

Figs 13 and 14 are wrong way round

Simplified inset maps would be helpful to aid spatial orientation for reader

Add approx. vertical exaggeration to figures with seismic sections

Add 'Depth (m)' axis label to Figs 7, 9 and 11

Fig 11 has depth markers within figure instead of external axis labels as in Figs 7 and 9 - somewhat confusing at a glance

Fig 11F has so many labels it is difficult to actually see what's going on in the seismic (similar issue to lesser extent in other figures)

Fig 15 - suggest highlighting the four closures with positive CC and appropriate depth

QUALITY ASSESSMENT

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|--|---|
| Q 6 ▶ Originality |  |
| Q 7 ▶ Rigor |  |
| Q 8 ▶ Significance to the field |  |

Q 9 Interest to a general audience

Q 10 Quality of the writing

Q 11 Overall quality of the study

REVISION LEVEL

Q 12 what is the level of revision required based on your comments:

Minor revisions.