We CO2 P02

Feasibility Study Of Quantifying Porosity From Seismic Data In Smeaheia

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Summary

Equinor with Shell and Total, evaluate the feasibility for full-scale CO2 capture and storage project in Norwegian continental shelf. One of the challenges for CO2 storage sites is to assure containment and to assess possible leakage paths to the surface. Understanding the overburden's geological setting is crucial for this assessment. As part of the overburden risk assessment, we investigate the potential for quantifying porosity from seismic inversion data. Knowledge of the porosity distributions, may enable us to employ porosity-permeability models in the future to assess leakage pathways into the overburden.

Introduction

Equinor (formerly Statoil) has been operating the CO_2 storage projects (Sleipner and Snøhvit) for many years and is expanding this technology for future applications. Currently, Equinor in partnership with Shell and Total, is working on concept selection for a storage site offshore Norway as part of the Norwegian Full-Scale CCS project. The storage site is being designed to handle industrially produced CO_2 with injection rate of up to 1.5 MT/year over 25 years.

One of the challenges for CO_2 storage sites is to assure containment and to assess possible leakage paths to the surface. It is therefore, important to understand the formation geology and petrophysical properties. Understanding facies and property distributions both in the overburden and reservoir is crucial for assessing the storage capacity and sealing properties of the storage site. This work investigates the potential for an assessment from seismic data. An important parameter is permeability which is difficult to determine from seismic data. Instead, we use porosity. If we can determine reliable porosity distributions for a given lithology using seismic data, we can then utilize porosity-permeability models in a risk assessment for the CSS project. Our objective here is to perform a feasibility study for porosity quantification from seismic inversion data.

The saline aquifer of the Smeaheia fault block was the selected candidate for the Norwegian Full-Scale CCS project after a feasibility study conducted in 2016. Smeaheia is located 40 km offshore the western coast of Norway and is bounded by two main faults, the Øygarden fault in the East and the Vette fault in the West. The main host rocks targeted for storage are within the Sognefjord and Fensfjord formations (Jurassic, Viking group). There are two exploration wells in this area and the nearest producing field is Troll, which is located to the West of the Vette fault (Figure 1).

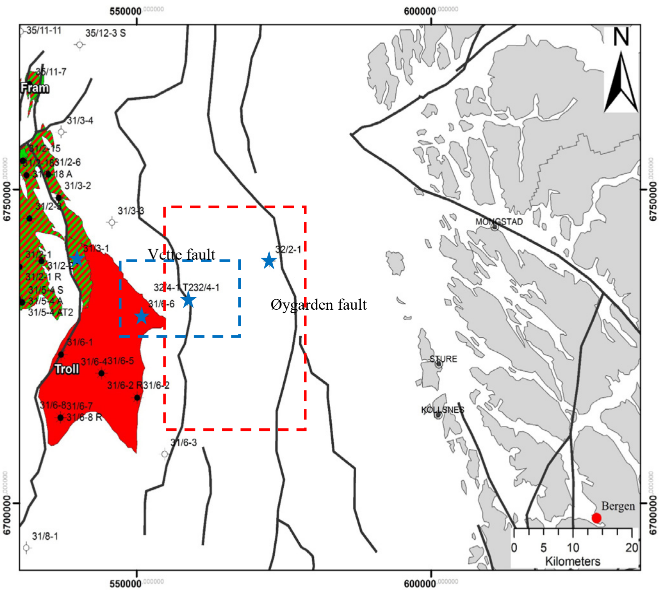

Figure 1 Map indicating the location of Smeaheia with red rectangle. Four wells identified with blue stars and the inversion area with blue rectangle.

Seismic and well data can be used to determine the subsurface properties. However, for economic reasons, the overburden usually does not have good well data coverage. For CO_2 storage projects this becomes even more challenging since CO_2 would preferably be stored in areas with a limited number of wells to reduce the risk of leakage. This decreases the amount of available data and raises the importance of using seismic data and its derivatives.

Data Analysis

Full stack seismic data over a limited area (10*15 km) from a CGG multiclient Broadseis survey were used for this study. The data were acquired in 2014/2015 and processed in 2017. The two legacy wells in Smeaheia and two extra wells from the Troll East field were included in the analysis.

In Smeaheia, the overburden consists of three main geological units of Jurassic and Cretaceous age. From shallowest to deepest, they are the Shetland group, the Cromer-Knoll group and the Draupne formation. The Shetland group is a well-known limestone unit with a distinct high acoustic contrast, whereas the Cromer-Knoll group mostly consists of marl. The deepest part of the overburden is the Draupne formation which is predominantly shaley and is lying on top of the storage unit, acting as the main seal for the storage unit (Figure 2). The Draupne formation is considered to be a good seal, however, due to the presence of carbonates in the Cromer-Knoll group, different possible escape routes through Vette fault appear possible. Therefore, the Cromer-Knoll group was chosen as our first candidate for our investigation. The storage unit contains a thick sand body from Top, Base-Draupne formation to Top-Brent formation (~1200 m to ~1600 m vertical depth) with intermittent streaks of cemented sandstone, characterized by high acoustic impedance. Data from the shallow section of the storage unit (from Top-Sognefjord formation to Base-Fensfjord formation) which contains a good sand quality were used for porosity estimation of the storage unit.

Well logs were analyzed to quality control the available data. From the four available well log suits, only one of them (well A) has measured shear sonic data in the storage complex, but most have P-sonic and density measurements in the majority of the inspected overburden. Logs processed with Lithology Fluid Prediction (LFP) (proprietary technology aimed at high quality control of the data and rejection of poor zones), were used for this study. These LFP logs have synthetic data for missing parts of the recorded data in the overburden.

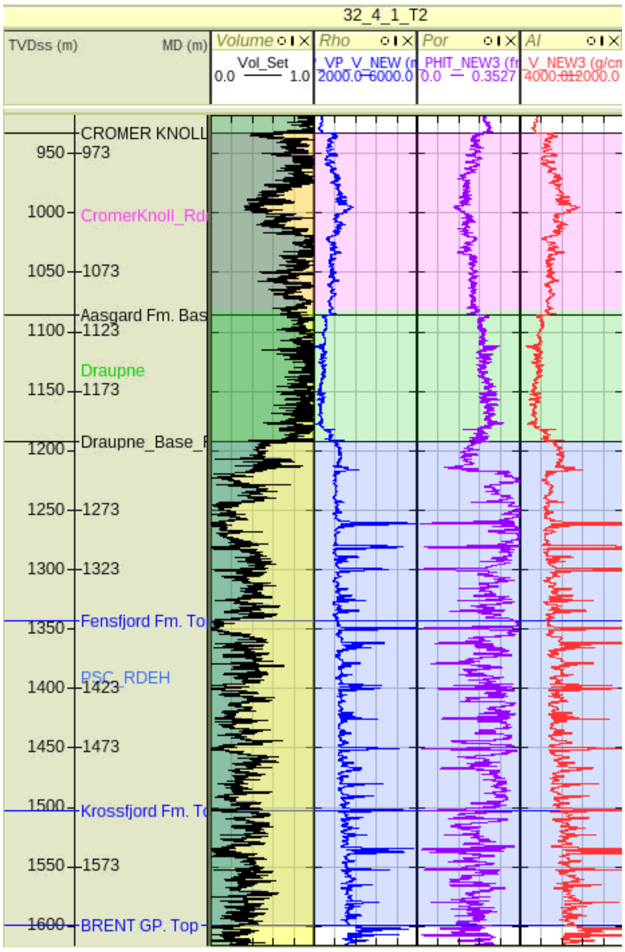

***Figure 2** Log data from well A (32/4-1-T2), the pinked area shows the Cromer-Knoll group, Green shows the Draupne formation and blue is the storage unit.*

The investigations suggest that seismic inversion can help to identify different seismic properties in Cromer-Knoll group. Acoustic impedance is the product of seismic inversion and is depending on several parameters, for example mineralogy and pore fluid content. However, there is also a good correlation between AI and porosity in the well data. This correlation is used to estimate porosity. This technique has been used in the past to estimate the porosity of reservoir sand stones [Cemen et. al 2014 and Dolberg et. al 2000]. Here, the absolute AI data used for porosity estimation.

Porosity Estimation

A preliminary relative seismic inversion was performed using an inhouse developed seismic inversion tool. The seismic data used in the preliminary inversion covers wells 32/4-1-T2 and 31/6-6, called well A and B in this study, respectively. A statistical wavelet was used in the inversion. Relative AI data from relative inversion were scaled up and merged to a low frequency model derived from well data to convert it to absolute AI values.

The seismic inversion data were used to estimate porosity distribution in the Cromer-Knoll group and the storage unit. The correlation between AI and porosity was used separately to estimate porosity for the Cromer-Knoll unit and the storage unit.

Figure 3a and 3b shows the comparison of porosity versus AI from log and porosity versus AI derived from seismic inversion in the well B location for the Cromer-Knoll. The porosity log was filtered corresponding to the seismic frequency spectrum. A comparison of best-fit-lines for these two cross plots show that they are roughly matching. There is considerable uncertainty around this best-fit-line which indicates heterogeneity in lithology within this interval. The best-fit-line equation from seismic inversion data was used to estimate a porosity volume from the AI volume obtained from seismic inversion.

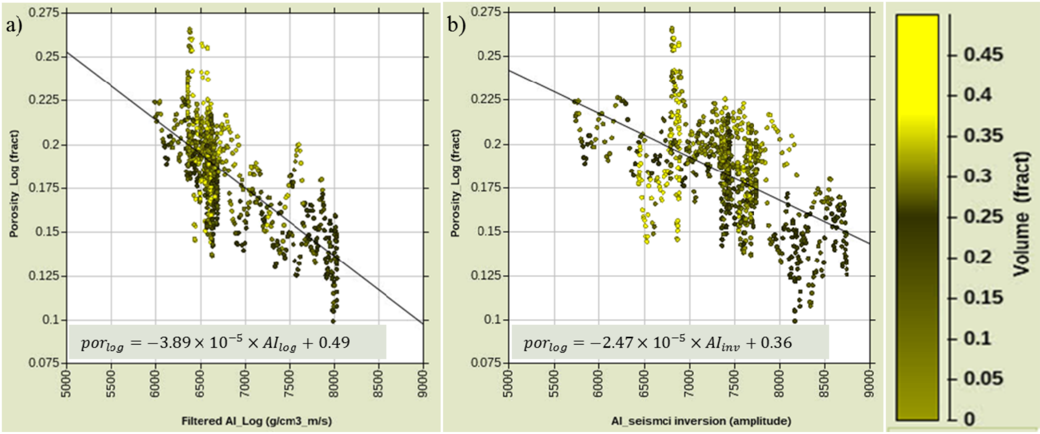

Figure 3 *Cross plot of a) Porosity versus filtered AI from log and b) porosity versus AI from seismic inversion for overburden in well B. Colour bar applied to both cross plots and colour coded with V-shale.*

The cross plot in Figure 4a shows the comparison of the estimated porosity and well log porosity for well B. The colour bar shows the percentage of difference between estimated porosity and log porosity. The best fit-line shows a reasonable correlation but errors in the porosity estimates are up to ±20%. The cross plot shows that the range of measured porosity in the well is from 0.1 to 0.26 while for the estimated porosity range in well location is from 0.15 to 0.22 which is a slightly smaller range.

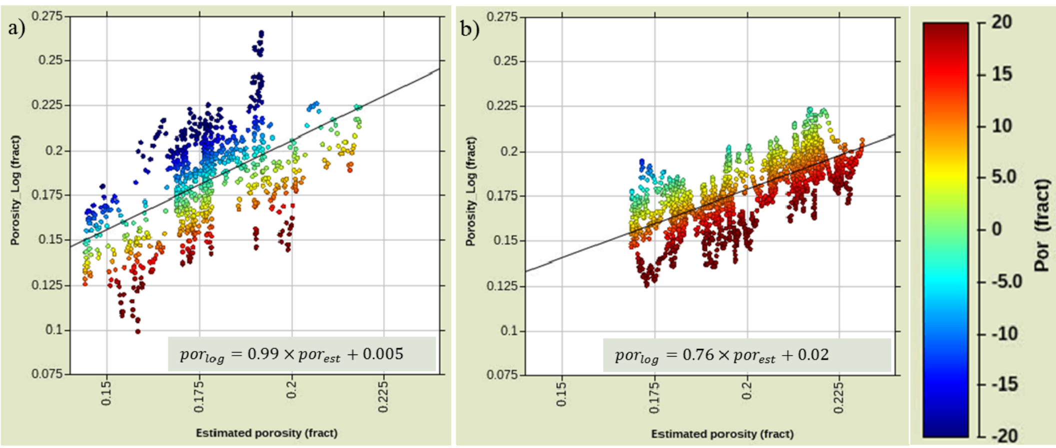

Figure 4 *Cross plot of estimated porosity from inversion versus porosity from log for a) well B and b) well A for Cromer-Knoll in overburden. The colour bar shows the percentage of difference between estimated porosity and log porosity.*

Well A was used to QC the estimated porosity. Figure 4b shows the cross plot of estimated porosity versus porosity log in this well. The slope of best-fit-line is 0.8 which is a reasonable estimation. The range of estimated porosity is smaller than the range of well porosity, which may be related to limited seismic resolution or to challenges in correctly quantifying the inversion wavelet.

Figure 5a shows a section from porosity volume estimated from seismic data for the Cromer-Knoll group in the overburden. Comparison between the estimated porosity and the measured porosity log, shows a reasonable match in the well location. Figure 5b shows a map of 100ms below the Cromer-Knoll horizon. The map shows that the estimated porosity for Smeaheia in this zone is in the range of 0.2 to 0.22. It is also showing that the area close to the Vette fault has higher porosity than the area around the well A in Smeaheia. Further investigation is needed to evaluate the impact of data quality on the higher porosity estimate along the fault. Nevertheless, the sealing capacity of the Vette fault needs to be assessed carefully in further work.

Conclusions

Porosity was estimated from the seismic inversion results for the overburden. We determined a porosity-acoustic impedance model for Cromer-Knoll from well log data. The range of estimated porosities are smaller than the log porosities. For Cromer-Knoll the inversion suggest that porosity is homogeneous and there is an indication of high porosity near the Vette fault, which, however, must be subjected to further investigations.

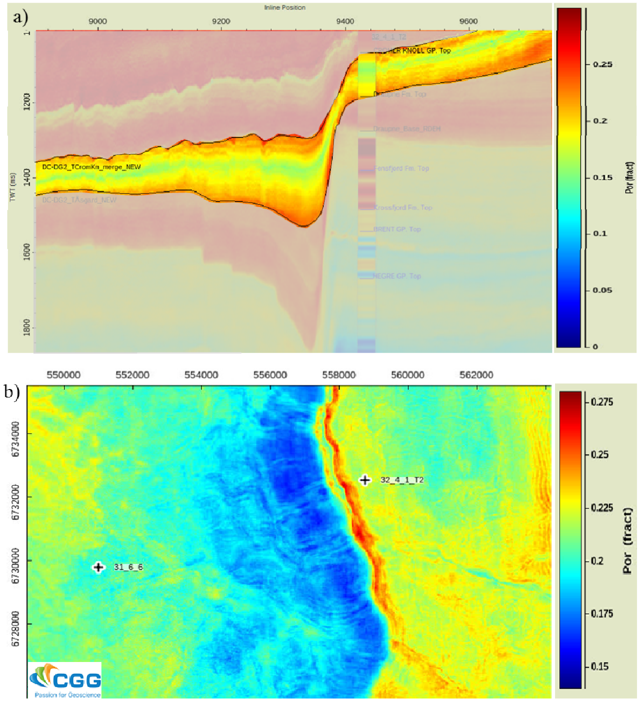

Figure 5a) *A section of porosity estimated from seismic inversion data for Cromer-Knoll. Zone of interest highlighted and below and above was oppected. Displayed log, is filtered porosity log. 5b) a porosity map of 100ms below Cromer-Knoll group which was estimated by using seismic inversion data.*

A porosity map derived from seismic data gives the benefit of lateral control, and it is useful for knowing the continuity of the overburden, especially in CO_2 storage fields. However, it should be noted that there is a high level of uncertainties involved in the estimation, which stem mainly from our model that assumes only a dependence of acoustic impedance on porosity. Further contributions to interpretation uncertainties maybe mineralogy and fluid content, which may explain the scatter presents in the cross plots (Figure 3). A further error source is that some of the well data that are used in the study are synthetic and therefore, inherently uncertain. Therefore, these results must be combined with other information before drawing final conclusions about potential leakage paths.

In following steps, we will evaluate the validity of the estimated porosities in our subsurface team. If these results are considered valuable, we will use different porosity-permeability models to evaluate the leakage potential of CO2 through Cromer-Knoll.

Acknowledgement

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References

Cemen, I., Fuchs, J., Coeffey, B., Gertson, R. and Hager, C., [2014] Correlating Porosity with Acoustic Impedance in Sandstone Gas Reservoirs: Examples from the Atokan Sandstones of the Arkoma Basin, Southeastern Oklahoma. *Search and Discovery Article*, #41255.

Dolberg, D. M., Helgesen, J., Hanssen, T. H., Magnus, I., Saigal G. and Pedersen, B. K., [2000], Porosity prediction from seismic inversion, Lavrans Field, Halten Terrace, Norway, *The Leading Edge*, April, 392-399.