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Reservoir Characterization for CO_2 Storage and Monitoring Using Legacy Well Data and Seismic Data

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Summary

We are studying the Whale Basin and South Whale Sub-basin offshore Newfoundland to assess their potential for storing and monitoring CO_2. In this region, there are pre-existing well data and 2D seismic data that were acquired during previous exploration. This research is an effort to use these pre-existing data to learn as much as possible about this region to assess its potential for CO_2 storage. Multiple methods are used in this research. The first is interpreting the seismic data to map the important rock formations and the structures within this region. Following this, core samples from the wells were acquired and measurements were taken of their density, seismic velocity, porosity, and permeability. These measurements, along with data from the well logs, are used to build an understanding of the physical properties of the different rock formations. These structural and geophysical data are used to build reflectivity models of this region. There are multiple versions of these models, with changes made to the properties to reflect changes caused by CO_2 saturation, to assess if CO_2 could successfully be monitored seismically in this region.

Theory / Method / Workflow

2D seismic data over the northern part of the South Whale Basin and the southern part of the Whale Basin are used to map the important rock formations in this region, including multiple potential storage rocks and an impermeable caprock. This mapping is required to understand if CO_2 would remain in place within the storage rock, or if it would migrate away from the area of injection. Major structures within the study area are also mapped using the seismic data. The geologic interpretation is aided by the well log data. These data are used to build synthetic seismograms along the wells, which were used to build a velocity model of this region. This model is used to convert the seismic data from the time domain to the depth domain, allowing for rock volume calculation and building a connection between the seismic data and the well data and well tops.

The physical properties of the rock formations in the study area are studied using both the well log data and by measuring samples from the wells. Physical samples are acquired to measure their density, seismic velocity, porosity, and permeability. These measurements allow for a better understanding of the potential for storage and for trapping. The well logs are digitized, and attributes were built in Petrel to calculate the average density and seismic velocity of each formation along each well. The lithology logs are also used to assess the overall lithology, and lithology changes, of the main rock formations throughout the study area.

After collecting the structural and geophysical data from the previous methods, multiple reflectivity models are built. These models are simplified 3D estimations of smaller regions within the study area. The areas selected for modelling are those which are deemed most suitable for

CO_2 trapping and storage. These models are populated with density and velocity values based on the results from the physical rock analysis and well log data. There are two versions of each model; one containing the rock formations as interpreted in the seismic data, and a second which is the same, but includes a hypothetical CO_2 volume, with properties estimated from literature on how CO_2 saturation affects rock properties. These reflectivity models are each convolved with a wavelet extracted from the seismic data to produce pseudo seismic data. The difference between the CO_2 and non-CO_2-containing models is calculated to quantify the seismic response of the CO_2-plume. This process provides an estimate of the detectability of a CO_2 plume in a 4D seismic survey of these regions.

Results, Observations, Conclusions

Seismic interpretation has revealed the general structure of the rock formations in the study area. Throughout this region, there is a shale formation, the Dawson Canyon Fm, with an average thickness of 700 m. Within this formation there is a thin limestone unit, the Petrel Mbr, which has an average thickness of 65 m. Below the Dawson Canyon Fm, there is a formation composed of mainly sandstone, the Eider Fm, which has an average thickness of 210 m. The Petrel Mbr and Eider Fm are thought to be potential storage rocks for CO_2, with the Eider Fm being the most likely candidate. All the interpreted units dip gently towards the southwest, becoming shallower in the northeast. Structures including salt diapirs and extensional faults are seen regularly throughout the study area, being more common in the southern region. Salt diapirs deform the main rock units to various extents, where the Eider Fm often forms an anticlinal structure above the diapirs, or is truncated completely by taller diapirs. There is a wide range in the throw, size, and orientation of faults in this region. Some faults reach a few hundred metres beneath the seabed. However, there do not appear to be any large-scale trapping structures that would be suitable for laterally trapping CO_2. Without this type of structure, injected CO_2 would likely migrate upwards along the slope of the storage rock.

The measurements of the core samples provide estimates of the average properties of the different rock formations. These measurements indicate that the Eider Fm has an average porosity of 20%. The permeability could not be directly measured, but the friable nature of the samples indicates high permeability. These factors indicate that the Eider Fm would be a good candidate for CO_2 storage. The Petrel Mbr has an average porosity of 12% and low permeability, making it less viable as a storage rock. The Argo Fm, which forms the salt structures in this region, has near zero porosity and permeability, indicating that it could help to trap CO_2 where a storage rock truncates against a salt structure. Information from the well logs indicates that the Dawson Canyon Fm has low porosity and low permeability, which make it a potential caprock.

The reflectivity models indicate that injecting CO_2 into the Eider Fm would likely cause a large enough change to the acoustic impedance of the rock to be detectable on a 4D seismic survey. Pseudo seismic data made from convolving the reflectivity models with an extracted wavelet show that there is up to a 25% difference in seismic amplitude between the models containing CO_2 and the models without CO_2. A similar difference is seen in each of the models. Figure 1 shows some of the seismic interpretation and the resulting reflectivity models and data.

Overall, this study indicates that there are rock formations with properties suitable for storage, and there is an overlying thick shale formation which could function as a reliable caprock. The reflectivity modelling also indicates that any trapped CO_2 would be detectable in a 4D seismic

survey. However, successful CO_2 storage in this region may be compromised by the general structure of this region. We see that the formations within the study area rise gently towards the northeast, eventually rising to depths that are too shallow for supercritical storage. There are many potential small-scale trapping structures, such as small anticlines and truncations of storage formations, however these structures would not be able to successfully trap a large volume of CO_2, and would not prevent migration to shallower regions.

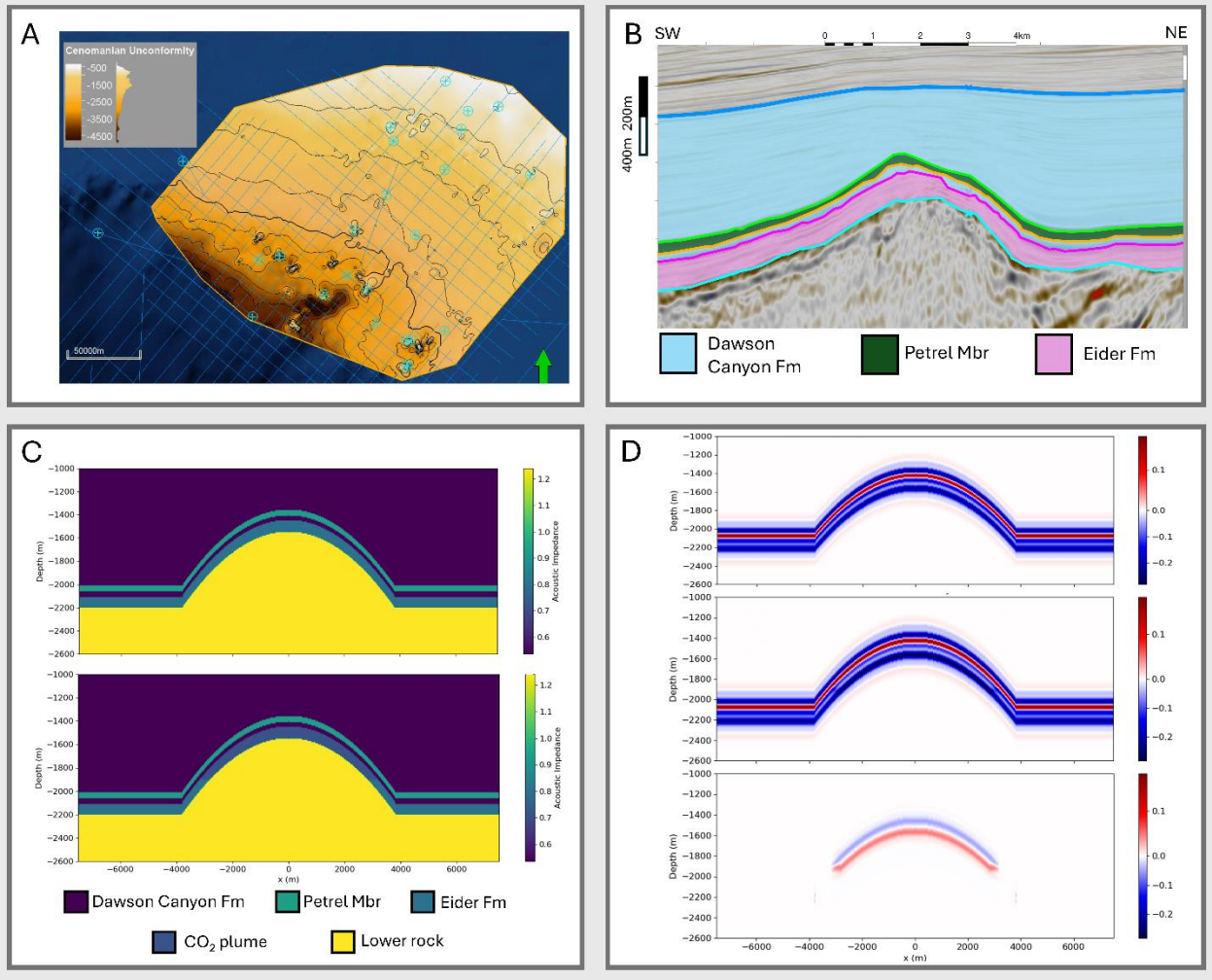


Figure 1: A) Map of Cenomanian unconformity, also the top of the Eider Fm, which is the main potential storage formation in this region. Seismic lines are displayed in blue, and well locations are displayed in light blue. B) Example of seismic interpretation, highlighting the main caprock, the Dawson Canyon Fm, and two potential storage rocks, the Petrel Mbr and the Eider Fm. In this image these formations are seen to form an anticline caused by development of a salt structure below. C) A slice of a reflectivity model based on the geometry seen in B), showing the acoustic impedance of each rock body. Top: Original reflectivity model. Bottom: CO_2-containing reflectivity model. D) Pseudo seismic data from the model shown in C). Top: Data from original model. Middle: Data from model containing CO_2. Bottom: Difference in data between the two models. Each of these images uses the same color scale for comparison.

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