From Structure to Storage: Integrated Screening of a Complex Rollover Anticline for CO2 Containment

Introduction

Carbon Capture, Utilization and Storage (CCUS) projects require robust subsurface screening workflows to rapidly identify technically viable and low-risk storage sites prior to detailed appraisal and development. Effective screening must integrate various geoscience tools to evaluate containment, injectivity, and long-term storage performance under uncertainty.

This study presents an integrated subsurface screening workflow applied to a large (~300 km²) rollover anticline (Figure 1) located near a major industrial CO_2 emission source. The structure has been penetrated by multiple wells and formed in a syn-tectonic depositional environment (P. Vail, 1987 & Brown Jr et al., 2004), resulting in significant lateral variability in both aquifer and sealing facies. The workflow demonstrates how multiple geophysical and geological datasets can be combined to rapidly assess storage feasibility, quantify uncertainty, and support early-stage investment and development decisions.

A key screening risk identified at this site is the absence of a regionally continuous top seal. Instead, containment is expected to rely on a low net-to-gross interval interpreted as a confining complex. The primary objective of this study was to evaluate aquifer heterogeneity, seal effectiveness, and overall containment risk.

Geological Setting and Storage Challenges: The aquifer interval consists of thinly bedded heterogeneous sandstone (Figure 1) deposited in coastal to floodplain environments with limited lateral continuity. Sealing efficiency is controlled by shale interconnectivity rather than a single thick caprock. The structure formed under syn-tectonic conditions associated with a listric fault system (Brown Jr et al., 2004), driving rapid facies variability.

These characteristics poses a unique screening challenge, where containment depends on combined stratigraphic and structural trapping mechanisms rather than a single regional seal.

Method and/or Theory

An integrated geophysical and geological screening workflow was applied. Simultaneous seismic inversion (Hampson et al., 2005) generated Acoustic Impedance (AI) and Vp/Vs elastic property volumes. Rock physics analysis established relationships between elastic properties and lithology. AI versus Vp/Vs crossplots from well data show good separation and enabled probabilistic lithology discrimination away from wells (Avseth et al., 2010 & Mavko et al., 2009). These volumes were integrated into the static geomodel to constrain aquifer and sealing facies distribution.

The geomodel was then used for dynamic CO_2 plume simulation to evaluate plume migration pathways, pressure build-up and injectivity limits, and long-term containment performance. Screening sensitivity studies focused on permeability uncertainty and heterogeneity within the confining complex.

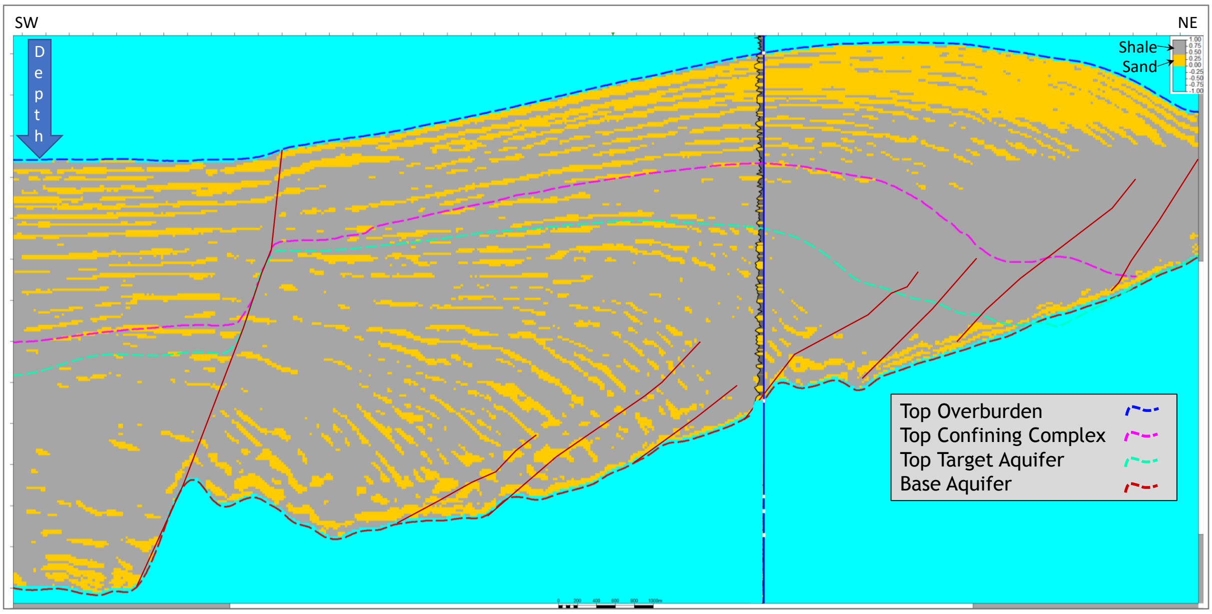

Figure 1 *A vertical section from lithology discrimination cube showing the target aquifer, overlying confining complex and rollover anticline. Shale is indicated with grey and sands are indicated with yellow color. Note the variations in the facies and low net-to-gross interval between pink to green surface. This low net-to-gross interval acted as a seal for upward migrating CO2 in the absence of a regional seal.*

Results

Integrated geophysical characterization indicates that a confining complex extends across the structural closure, with varying thickness. Although a thick regional seal is absent, laterally connected shale-rich intervals form a distributed sealing system.

The dominant sealing mechanism is interpreted to be flow tortuosity (Özdemir et al., 2006), which significantly restricts vertical CO_2 migration and is consistent with pressure compartmentalization observed in existing wells.

Dynamic simulations indicate permeability as the dominant control on plume migration. The confining complex behaves as a baffle system, with predicted leakage risk ranging between 1–5% of injected CO_2 for the base case scenario over a 250-year post-injection monitoring period.

Data Limitations:

Seismic data quality was poor near the base of the aquifer section, particularly reduced amplitudes associated with low-angle faulting in the up-dip side of the structure. However, the primary storage target is located downdip, reducing the impact of these uncertainties on overall storage screening outcomes.

Uncertainty in permeability distribution within the confining complex remains a key control on plume migration behavior. In addition, dirty aquifer facies were identified as having a strong influence on flow behavior and represent a key uncertainty requiring improved petrophysical calibration during later appraisal phases.

Overall, while these uncertainties influence screening confidence ranges, they do not preclude storage feasibility and instead define priorities for appraisal data acquisition and characterization.

Conclusions

The study demonstrates that integrated, screening-focused subsurface workflows can rapidly mature complex storage opportunities and support site ranking, appraisal prioritization, and investment decisions.

Results indicate that CO_2 storage in the studied rollover structure is technically feasible, with manageable leakage risk primarily controlled by the low net-to-gross confining complex. While seismic inversion provides valuable quantitative constraints, its main value in this context is reducing uncertainty within a broader screening workflow.

Integrated screening approaches such as this can accelerate deployment of secure geological storage capacity by enabling rapid technical evaluation and uncertainty quantification at early project stages.

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