Introduction

A carbon dioxide (CO_2) sequestration project involves separating CO_2 from industrial sources or produced hydrocarbons from high contaminant gas fields, then transporting and injecting it into suitable deep geological formations for long-term storage. Carbon capture and storage (CCS) is particularly crucial for developing high CO_2 fields as it helps to avoid CO_2 emissions at the point source. It is considered one of the most efficient greenhouse gases (GHG) reduction processes, with a potential for near-zero failure Therefore, the development of CCS sites is essential to achieve future climate targets, including delivering negative emissions. Currently, CCUS activities reduce approximately 0.028 gigatons (GtC) of CO_2 annually. To meet the Paris Agreement target of reducing 2.8 GtC per year by 2050, the number of CCUS facilities worldwide must increase by a hundredfold compared to current levels (Baines & Lashko, 2020; Liu et al., 2017; Leung et al., 2014).

The efficacy of carbon capture and storage (CCS) projects hinges on three fundamental aspects: injectivity, storage capacity, and containment integrity. This study zeroes in on containment integrity, a crucial factor for successful in-situ CO_2 injection and geological storage. The research underscores the need for an in-depth analysis of overburden layers in hydrocarbon-bearing fields, areas often overlooked in comparison to hydrocarbon-rich zones. Our investigation aims to diminish uncertainties and assess potential risks to CO_2 containment, through a thorough investigation of seal and overburden layers in a layered clastic reservoir. This endeavor is critical for validating the underground sequestration of CO_2, ensuring environmental safety, and enhancing the effectiveness of CCS strategies.

Method and/or Theory

The study undertakes a meticulous investigation of a gas field estimated to contain approximately 12 trillion cubic feet of gas with an inherent CO_2 concentration of around 50%. A key strategy involves re-injecting produced CO_2 back into the aquifer portions of active reservoirs, integrating into the broader Storage Development Plan. A comprehensive seal and overburden integrity analysis was executed, involving advanced seismic and petrophysical studies, for evaluations of seal geometry, capacity, and integrity. This multi-faceted approach facilitated the aggregation of individual risk elements into a comprehensive risk assessment matrix, enhancing the geophysical and geological understanding of seal and overburden characteristics.

Evaluation of Seal geometry
Four elements i.e., Average Seal Thickness, Volume of Shale, Distribution/extent of mapped seals and seismic anomalies of features were analyzed for evaluation of seal geometry. The sequence above the Shallowest Hydrocarbon Bearing Zone in the field of interest and nearby fields was considered for the evaluation.

Evaluation of Seal Capacity
Six Mercury Injection Capillary Pressure (MICP) tests were conducted, and results were used to determine the CO_2 capillary pressure and CO_2 column height of the representative identified main seals. Based on the PT conditions of the sample depth, along with the estimated fluids density and calculated IFT data from established reference, gas columns heights of CO_2 and methane were established.

Evaluation of Seal Integrity
Gas While Drilling (GWD) analysis and Fault Integrity analysis were the two factors those were considered for the evaluation of Seal integrity. The GWD analysis comprised a semi-quantitative plot analysis method comprising generation and investigation of HC composition distribution plots, C1/C2 Pixler Ratio plots, C1/C3 and C2/C3 ratio plots, C1/C3 vs C2/C3 mixed ratio cross plots and Pixler line plots to predict seal efficiency and potential main leakage mechanism between the overburden units.
For fault integrity analysis, a detailed fault mapping exercise was conducted covering an area beyond the primary field of interest as it is planned to inject the CO_2 in the aquifer leg of the hydrocarbon bearing reservoirs. Mapped faults were analyzed for their location, vertical extension, and sealing nature to rank them from low to high-risk faults for containment integrity.

Conclusions

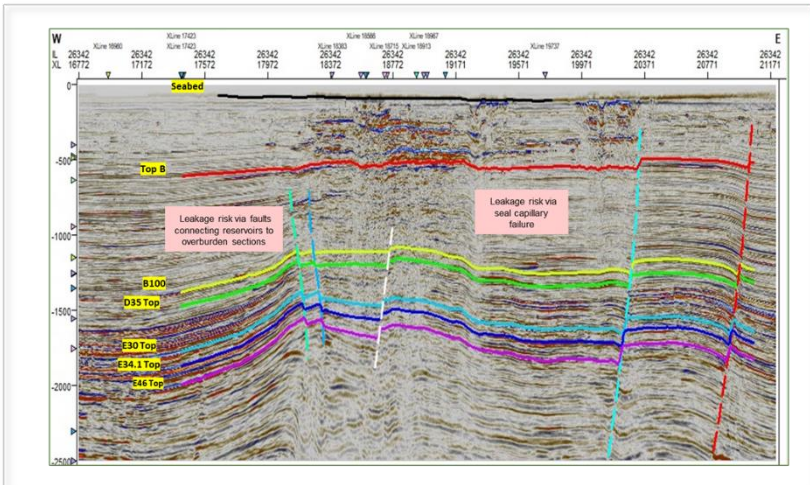
The study, "Pioneering CO_2 Capture and Geological Storage: Seal Integrity and Overburden Risk Assessment," elucidates critical findings and insights into CO_2 sequestration efficacy within a clastic reservoir system. Key takeaways include:

Seal and Overburden Analysis: Investigations revealed claystone layers exceeding 400 meters atop the Shallowest Hydrocarbon-Bearing Zone (SHBZ), potentially serving as effective seals. Nonetheless, interspersed sandy or silty strata may pose CO_2 leakage risks.

Seal Efficiency Variability: Microscopic Imbibition Capillary Pressure (MICP) tests indicated a predominantly microporous seal structure, while Gas-While-Drilling (GWD) data showed fluctuating hydrocarbon levels, pointing to inconsistent seal efficiency across the field.

Need for Comprehensive Studies: The findings advocate for extended isotopic and organic geochemistry analyses, alongside detailed capillary pressure assessments, to refine initial GWD insights and ascertain seal robustness.

Fault-Seal Risks: Mapped faults extending into the overburden underscore the necessity for advanced Fault-Seal Analysis to assess fault reactivation risks and guarantee CO_2 containment integrity.
This study emphasizes the importance of rigorous and expanded research to ensure the success of CO_2 geological storage initiatives.



Elements	Parameter	Risk
Seal Geometry	• Thickness	Low
	• Shale volume	Low
	• Distribution/extent	Low
	• Seismic feature	Med
Seal Capacity	• Capillary pressure & CO_2 column height	Low
Seal Integrity	• Pore pressure & GWD	Med
	• Fault Risk	High
	Overall	Med

***Figure 1** Integrated seal and overburden risk analysis*

References

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