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Assessing CO₂ Storage Potential Within the Sunda Strait, Offshore Indonesia

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Abstract

Indonesia's Net Zero Emissions 2050 target urges the need for Carbon Capture, Utilization, and Storage (CCUS) activity. Saline aquifers offer one of the most promising yet underexplored storage options. This study will assess the Sunda Strait area in western Indonesia as a potential CO₂ storage in the Oligocene-Miocene Talang Akar Formation (TAF). The TAF consists of thick, porous, and laterally continuous sandstones interbedded with shales in a half-graben tectonic setting. According to Sukanto (1998), it is subdivided into the Zelda Group (Late Oligocene) and the overlying Gita Group (Early Miocene). The Middle-Upper Zelda interval is designated as the primary storage target and the overlying shale-prone Gumai Formation provides a regionally extensive seal. Fault-bounded compartments and stratigraphic variability provide the potential trapping mechanisms. Subsurface evaluation integrates geological and geophysical analyses. Five wells are examined to characterize lithology, porosity, and permeability. 2D and 3D seismic data, tied to wells, were used to map the Gumai seal, the Upper Zelda top, and the Middle Zelda base in order to define the structural configuration of the reservoir. RMS amplitude attributes are applied to delineate sand presence and distribution throughout the Area of Interest. Quantification of CO₂ storage capacity, using EASiTool (a public software developed at GCCC-BEG), will be performed in the future with consideration of geological factors (sand thickness, porosity, permeability, and pressure).

Well-log interpretation reveals sandstone-dominated sequences up to 1,000 m thick. Structural mapping identifies about 52 faults, including a major half-graben fault in the east and multiple growth faults in the west, which define a 38 × 51 km² focus area. These faults likely would not pose any risk of CO₂ leakage since they are distant from the storage target, which it is located within a structural syncline. RMS attribute analysis shows the highest sandstone concentration in a central depocenter, located within the

syncline. This would be the most favorable zone for CO₂ storage. Despite Indonesia's plan to initiate 15 CCS projects, CCS studies in Indonesia are still very limited despite its huge CO₂ storage potential. This study provides one of the first integrated geological evaluations offshore Indonesia and characterize the Sunda Strait as a potential CCS hub to support commercial-scale CO₂ storage operations in the country.

Introduction

Indonesia has set an ambitious target to produce 1 million barrels of oil per day (BOPD) and 12 billion standard cubic feet per day (BSCFD) of natural gas by 2030 (SKK Migas, 2021). However, achieving such a high level of energy production is expected to result in a huge number of emissions. Currently, Indonesia is embracing an energy transition to produce less carbon-intensive energy in the future with zero emissions called Net Zero Emissions (NZE). Carbon Capture and Storage, better known as CCS, is a key strategy Indonesian energy experts would perform to achieve the goal of increased hydrocarbon production. As Indonesia produces considerable amount of CO₂, Carbon Capture and Storage is important for meeting national goals. Indonesia has significant CO₂ storage capacity at competitive costs. With 15 planned projects across the nation (Indonesian Ministry of Energy and Mineral Resources, 2023), Indonesia already plans to implement CCS in at least 15 areas across the country and is predicted to commence the projects as soon as 2026.

CCS studies in Indonesia are still very limited despite its substantial storage potential across the country. The Sunda Strait Area is well known as a productive oil and gas production area but contains an overlooked region to the northeast that it is nonproductive. This study will assess the Sunda Strait Area's carbon storage capacity as a CCS/CCUS Hub. The CCS study of this research is not conducted in a depleted oil and gas field, which makes this area more challenging since saline aquifer storage is less understood in the country. This region to the northeast of the Sunda Strait Area contains significant potential for carbon storage. The prospective tor age interval is in the sandy Talang Akar Formation (TAF), which needs further characterization and evaluation before recommending any carbon sequestration projects. Therefore, it is expected that the northeast area will be one of the most pivotal areas for carbon storage in Indonesia. This thesis will provide a regional geologic characterization of the storage potential of the Sunda Asri Basin and will provide the Indonesia CCS community with a case study demonstrating the feasibility of developing a CCS industry in the country.

The TAF is a 1000-meter section of thick sandstones interbedded with fine-grained lithologies with overall good permeability (up to 1-3 Darcies). It is made of the Zelda (Oligocene) and Gita (Miocene) members (Figure 2). Sediments from the Zelda Member were deposited in fluvial depositional environments, while the Miocene Gita Member was deposited in mixed fluvial-marine environments within an overall transgression (Bishop, 2000).

Theory and/or Methods

The research will employ several methods in order to achieve the stated objectives.

1. The initial step involves picking the top and bottom seismic horizon of the targeted sections within the CO₂ storage window (Upper-Middle Zelda Member of the TAF). Petrel 2023 will be the main software utilized for this task.
2. Analyzing the well-log data from multiple wells in the research area to understand lithology distribution. The well-logs will be correlated for key stratigraphic horizons with Petrel 2023.
3. Picking all possible faults in the area of interest will help to identify structural compartments, structural trapping mechanism, and potential CO₂ leakage scenarios.
4. CCS prospect identification will be done based on the subsurface characterization (RMS amplitude, porosity, permeability, structural and stratigraphic trapping mechanism). Later beyond this paper, dynamic storage capacity of injected CO₂ will be conducted in EASiTool using geological factors (reservoir thickness, porosity, permeability, and pressure).

Results

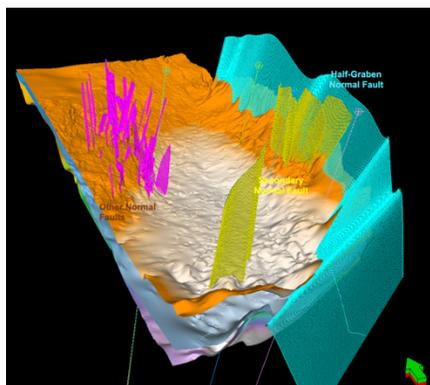


Figure 1. Structural Model of the Sunda Strait Area (The TAF is showcased on the top layer)

Structural model of the area (Figure 1) was constructed in Petrel 2023 using 2D and 3D seismic data. A major depositional axis of the half graben exists on the eastern side of the basin. This structural configuration influences both sediment deposition and the thickness variation observed within the Zelda Group of the TAF. Adjacent to the main eastern half-graben margin, several secondary normal faults are developed, forming a stepped structural geometry. Together, this network of main, secondary, and distributed faults defines the structural segmentation that influences reservoir thickness variability, lateral continuity, and potential compartmentalization relevant to CO₂ storage assessment. The model delineates major fault systems in the eastern sector interpreted as the half-graben structure, while smaller faults in the western sector are identified as growth faults. The structural model matches the regional cross section by Sukanto (1998).

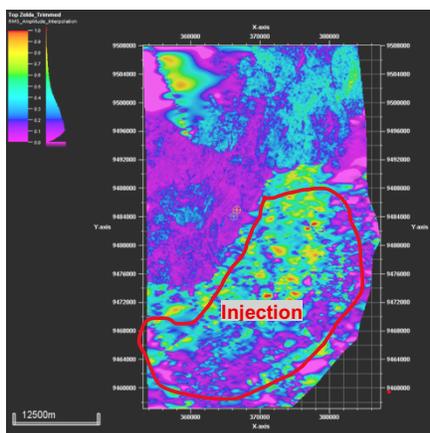


Figure 2. RMS Amplitude Map corresponding to Top Upper Zelda Group

The Top Upper Zelda marks the upper boundary of the primary storage interval which occur at depths of approximately 1,500–2,500 m across the study area. The normalized RMS amplitude map from Top Upper Zelda of the TAF horizon is shown in Figure 2, highlighting areas of relatively stronger reflectivity that corresponds to cleaner sand-prone. Root Mean Square (RMS) amplitude is a seismic attribute obtained from the square root of the average of the squared seismic trace amplitudes over a user-defined window. It is widely used to identify zones of high reflection energy that may correspond to reservoir-quality facies (Chopra & Marfurt, 2007).

The RMS amplitude map from Top Upper Zelda horizon is shown in Figure 2. Because the seismic dataset was compiled from multiple acquisition and processing packages, all the amplitude values were normalized to a 0–1 scale to keep the consistency. The normalized RMS amplitude values highlight areas of relatively stronger reflectivity, which commonly correspond to cleaner, sand-prone intervals within Upper-Middle Zelda Group of the TAF. The map shows a pronounced zone of higher RMS amplitude (blue-green-yellow color) in the central portion of the study area which means the depocenter area is reach of sand.

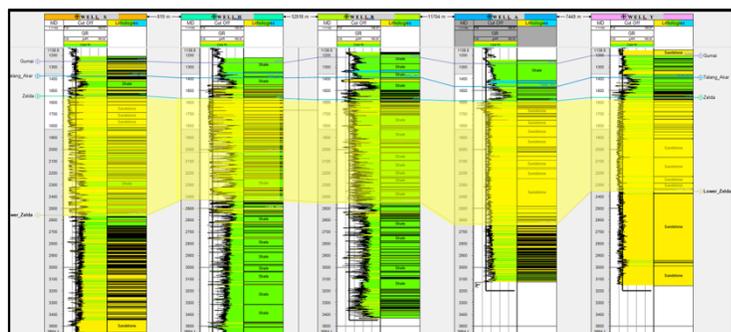


Figure 3. Well Log Correlation of Well S – Well H - Well B – Well A – Well Y, showing the Upper-Middle Zelda Group of the TAF (highlighted yellow) as the targeted zone for CO₂ injection.

Well-log correlation across the five wells allows investigation of the lateral and vertical continuity of the reservoir units that are relevant for CO₂ storage. The targeted interval (Upper-Middle Zelda Group of the TAF) is situated between around 1,500 and 2,600 m depth, consisting of sandstones interbedded with shale. The overall thickness of the Upper–Middle Zelda Group across the depocenter is approximately 1,000 m. The Lower Zelda Group lies beneath this interval and extends to approximately

3,200 m depth. Although it is part of the broader Talang Akar stratigraphy, this deeper unit is considered less favorable for storage as the group generally consists of reduced reservoir quality sandstone compared to the upper section.

Discussion

This whole formation is generally located in half-graben systems where syn-depositional faulting creates variable accommodation space and influences sediment distribution patterns (Pulunggono & Cameron, 1984), representing deposition in fluvial–deltaic to shallow-marine environments as it is characterized by heterogeneous but easy to correlate successions. Within this half-graben, the Zelda Group of the TAF tend to be thicker and more sand-rich as, reflecting repeated infilling by fluvial–deltaic systems deposited during the syn-rift period. The RMS amplitude aligns with the interpreted depocenter of the half-graben, suggesting greater sand development and more enhanced quality of sandstone reservoir within the syncline region that is consistent with the correlation and structural interpretation toward Upper-Middle Zelda Group.

In the correlation panel, Well B appears with noticeably thicker shale intervals because it is positioned in most eastward and toward the half-graben structural margin, where finer-grained deposition is more dominant. This result shows that there is a different facies change vertically within the TAF. Although the Gumai Fm above already serves as the regional seal, interbedded shale in the TAF will be a good local compartment to prevent CO₂ to leak further.

Conclusions

- The seismic-based model shows an eastern half-graben bounded fault system and western growth faults. It tells that this area is a large structural compartment with closing faults surrounding the area.
- The mapped Zelda Member spans 1500–2500 m, with the primary storage target located within the depocenter of the syncline where the sandstones would tend to accumulate, supported by the well log correlation with the overall thickness of 1000 m.
- RMS Attribute shows that the syncline or depocenter area is dominated by sandstone, defining a good area for CO₂ storage.
- Gamma-ray log analysis reveals that most wells penetrate sand-rich intervals, supporting favorable reservoir presence and quality; however, Well B indicates higher shale content, suggesting local heterogeneity in depositional facies because of the half-graben structural setting.
- The integration of seismic and well-log data demonstrates that the Zelda Member offers laterally continuous sandstone reservoirs bounded by regional seals. The structural compartmentalization and shale-rich zones in between the group may influence storage capacity and containment efficiency.
- Next approach will be determining how many injection zones between the targeted depth and doing EASiTool simulation (20 yrs): Run injection scenarios to forecast plume extent, pressure build-up, and containment under mapped boundaries.

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