Petrophysical Analysis and Acoustic Impedance Inversion to Determine the Storage Target of Carbon Dioxide in Gundih Block, Central Java

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Abstract. A pilot project of Carbon Capture and Storage in Indonesia is being prepared in the Gundih field, Central Java. This project acquired Kujung formation as their target area. However, an alternative to that formation is being investigated with Kujung formation's data as a benchmark to determine the total capacity of storage in Gundih Block. To determine the other carbon dioxide storage target, several tests are needed, one of which is petrophysical analysis. The results of this analysis are porosity, permeability, and thickness of a reservoir. After determining the porosity cut off from the Well data, we use the acoustic impedance inversion approach to assess the spread of the reservoir laterally. In this paper, we estimated that the porosity ranges from 7-12% with an average permeability of 10 mD. After examining the lateral distribution of the reservoir through the inversion, we can roughly estimate the distribution of good porosity reservoir. With the same method and logs derived from Kujung formation, we estimate that the upside potential from Ngrayong formation has an average porosity of 30% and average permeability of 16 mD, which are good enough to become an area of interest. With these results, we conclude that determining the area of interest from other target formation through petrophysical analysis and acoustic impedance inversion is sufficient to determine reservoir areas in a formation, though further injection feasibility studies are needed to determine the feasibility of injection of CO2 in Ngrayong Formation.

1. Introduction

Gundih Block is a target for the pilot project of Carbon Capture and Storage (CCS) development in Indonesia. Since December 2013, Gundih block, owned by Pertamina EP actively produces gas as much as 70 mmscfd with a CO2 content of 20%. This field is projected to keep in production for 12 years. In this block, a central processing plant was established to separate 80% of methane gas which are sold to generate electricity in Tambak Lorok, Central Java and 20% of CO2 which are disposed to the air. The purpose of this pilot project is to utilize 20% of CO2 to reduce the effect of global warming [2].

To store CO2, there are certain criteria to find a feasible storage reservoir. A CO2 reservoir needs to have a caprock and a good porosity and permeability [4]. To find these characteristics, we use petrophysical analysis by looking into lithology, porosity, water saturation, and permeability. After determining the reservoir characteristics, we incorporate seismic data to find the continuation of the reservoir so we can roughly estimate the volume capacity of storage in that reservoir.
The target formation of this project is in Kujung Formation. However, an alternative to that formation is being investigated with Kujung formation's data as a benchmark to determine the total capacity of storage in Gundih Block. Even though the data in Kujung formation is enough to do petrophysical analysis, the data in the upside potential chosen, which is in Ngrayong Formation is insufficient for petrophysical analysis. To do so, some logs are needed to be generated with Kujung formation as a benchmark. This research studies if petrophysical analysis and acoustic impedance inversion are able to roughly estimate the reservoir characteristics in both Kujung formation and Ngrayong formation properly. The targeted output of the research is the estimated volume of the reservoir adequate to store CO2.

2. Methods

The data that were used in this research are well logs and seismic data. The wells that are being used are KTB-1 and RBT-2. 7 types of logs were used, such as GR, Caliper, RHOB, DT, RT, NPHI, PEF, and Check shot. However, there are only two logs that are available in Ngrayong formation, which are GR log and DT log. A density log is needed to make an Acoustic Impedance log, but since in Ngrayong formation that data is unavailable, therefore synthetic logs are generated to counter this setback. The synthetic logs are generated based on the same formation but in a different well nearby, which is JEPON-1 well. The seismic data that was used is 3D Post stack time migration data of the Gundih block.

In this research, two types of analyses were done: petrophysics analysis and Seismic inversion analysis. The inversion method that was used is model-based Acoustic Impedance Inversion. We start with finding out the porosity, permeability, and thickness of the reservoir based on the parameter of reservoir cutoff of porosity, permeability, thickness, water saturation, and volume of shale. After getting the porosity parameter, we determine the relationship between acoustic impedance and porosity on the well. After that, we did model-based acoustic impedance inversion to apply the relationship of acoustic impedance and porosity from well to the seismic [6]. After getting the rough estimate of the area of the reservoir. We estimate the volume of the reservoir by using a volumetric equation.

3. Results and discussion

Table 1 shows the porosity, permeability, Vclay and water saturation for well KTB-1 and RBT-2 in Kujung formation. In this table, we can infer that the clay content supports the report that Kujung formation consists of carbonate and shale. From these results, we can also infer that Kujung formation is mostly porous and are saturated by water.

| Well  | Vclay | Porosity | Permeability | Sw  |
|-------|-------|----------|--------------|-----|
|       | %     | %        | mD           | %   |
| KTB-1 | 9,0-80| 7,0-20   | 0.0006 – 96  | 20-100|
| RBT-2 | 0,5-35| 0,01-20  | 0.0001- 600  | 10-100|

With the reservoir cut off shown in Table 2, we can estimate the net pay or estimated thickness of the CO2 reservoir. The reservoir area for Kujung formation is shown in Table 3. Table 3 shows that the reservoir areas of Kujung formation have a thickness of 17.3 meters in KTB-1 and 17.9 in RBT-2. With that thickness, the reservoir in Kujung Formation is also thick enough to store CO2.
Table 2. Vclay, Porosity, Permeability and Thickness parameter for CO₂ Storage

| Parameter | Porosity | Permeability | Vcl | Thickness |
|-----------|----------|--------------|-----|-----------|
| Value     | >10%     | >10 mD       | 25% | >5 m      |

Table 3. Target zone for Kujung Formation

| Well | Top  | Bottom | Gross | Net | N/G | Av Phi | Av Sw | Av Vcl | Av Perm |
|------|------|--------|-------|-----|-----|--------|-------|--------|---------|
| KTB-1 | 2887.5 | 2921.8 | 34.3  | 17.3| 0.504| 0.135  | 0.404 | 0.198  | 10.68   |
| RBT-2 | 2992.5 | 3065.07| 72.54 | 17.98| 0.248| 0.165  | 0.058 | 0.085  | 8752.823|

With the target area of the reservoir estimated, the distribution of the reservoir can be estimated to figure out the location of the reservoir on seismic data. The seismic inversion utilizes 2 wells, KTB-1 and RBT-2. In Kujung formation we averaged the value of the log's Acoustic Impedance to minimize the error of the Inversion. The result of the inversion is shown in Figure 1.

![Figure 1](image1.png)

Figure 1. The acoustic impedance inversion result of Kujung formation

After acquiring the value of inverted Acoustic Impedance from the seismic data, we applied the relationship between Acoustic Impedance from well and porosity from well, demonstrated in Figure 2, to the seismic AI. With that relationship, we can make a porosity map displayed in Figure 3.
Figure 2. Relationship of acoustic impedance log and porosity log.

Figure 3. Porosity distribution in Kujung formation.

Figure 3 shows that the porosity that is considered good porosity ranges from 2700-2900 ms. This supports the result from the petrophysical analyses that show the reservoir is at 2887.70 m to 2921.40 m in KTB-1 and 2999.2 m – 3007 m in RBT-2. From the results taken, we made a porosity distribution map with time slice varied from 0, 30, 60 and 90 ms with a centered window of 30 ms to map how deep is the good porosity distribution. The time structure map is shown in Figure 4.
In Ngrayong formation, there is an additional step to do before the seismic inversion process, which is density modeling. The modeling of density was done by using Gardner's equation, which implies the relationship between Density and Velocity (VP). We used JEPON-1 well as a benchmark, which also has Ngrayong formation in-depth 1000-1500m. Since Ngrayong formation consists of sand and shale, two equations are needed to determine the density value of Ngrayong formation in KTB-1 and RBT-2. The types of lithologies are separated with GR index with the cut off of 50 API. The result of Gardner equation shown in Figure 5. After acquiring the synthetic density log, the same petrophysical analysis steps are done in Ngrayong formation also. The results of the target area of the reservoir are shown in Table 4.
With the target area of the reservoir estimated, the distribution of the reservoir can be estimated to figure out the location of the reservoir on seismic data. The seismic inversion utilizes 2 wells, KTB-1 and RBT-2. In Ngrayong formation we averaged the value of the log’s Acoustic Impedance to minimize the error of the Inversion. However, the relationship between porosity and AI is hard to distinguish, therefore we estimated the reservoir distribution by using the difference in lithologies. The lithology separation and reservoir distribution are displayed in Figure 6 and Figure 7.

**Table 4. Target zone for Ngrayong Formation**

| Well   | Top    | Bottom   | Gross | Net | N/G | Av Phi | Av Sw  | Av Vcl | Av Perm |
|--------|--------|----------|-------|-----|-----|--------|--------|--------|---------|
| KTB-1  | 1465.7 | 1560.1   | 94.4  | 8.5 | 0.09| 0.315  | 0.477  | 0.156  | 76.07   |
| RBT-2  | 879.96 | 925.53   | 45.57 | 26.75 | 0.587 | 0.39   | 0.456  | 0.121  | 23.979  |

Figure 6. Relationship of Gamma ray log and Acoustic Impedance from KTB-1(Blue) and RBT-1 (Red).

Figure 7. Sandstone thickness distribution in Ngrayong formation.
4. Conclusion
According to the analysis given. Petrophysical analysis and Acoustic Impedance inversion are enough to determine the target area of the reservoir in Kujung formation. Even though the petrophysical analysis in Ngrayong formation shows that Ngrayong formation is a good fit as an upside potential for CO2 Injections, the relationship between AI and porosity cannot be established due to factors such as inadequate log availability. Further data collection and coherent investigations are needed to establish a more accurate and complete knowledge of the potential in Ngrayong formation.

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