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Evaluating Oligocene Intra Platform Reef Carbonate Reservoir Potential Using Advance Model of Seismic Facies Analysis and Seismic Inversion – A Case Study Barito Basin Indonesia

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Abstract
Characterizing platform carbonate reservoir is a big challenge and requires more effort due to the lithology complexity. The Oligocene Middle Berai Platform Carbonate in the West of Barito Basin is an under-explored area, which is supported by the 2D seismic of 2015 vintage. The seismic data shows characteristics of mounded reflector configuration and lateral variation of seismic velocity as reef carbonate development indicators. The objective of this study is to evaluate the Intra Platform Reef Carbonate reservoir, where reservoir geometry is determined by facies seismic analysis and validated using Petrographic and Biostratigraphic reports. Thereafter rock properties are extracted using seismic inversion based on an advanced model. The acoustic impedance is expected to describe the development of reefal carbonate reservoirs in more detail, geologically make sense, and further predicting porosity. Validation result provides an overview of the estimated porosity range of reef facies 15-20%, reef debris 7-14%, and muddy facies 3-8%. These methods are effective in understanding the potential of Berai Carbonate Platform with reservoir properties and distribution. The results are successfully and significantly reduced exploration risk.

Introduction
The Berai Carbonate is one of the hydrocarbon reservoir targets deposited in the post-rift phase (Late Eocene – Early Oligocene) of the Barito Basin that has been explored through various studies and exploration drilling since the 1960s. Small amounts of hydrocarbons have been found in the Northern Basin with the structural play concept. In the Southern Basin with the stratigraphic play concept, all six wells were plugged and abandoned as dry holes. Although these attempts failed to find hydrocarbons, they did reveal particularly well-defined reef facies associations which may be useful in further exploration (P.J Pelton, 1974). Berai Carbonate potential reservoir study (Andromeda, 2013), based on Gross Depositional Environment Map shows patch reef and reef debris facies were well developed close to the edge of the basin (Western part of Barito).
In 2015 Pertamina EP acquired 2D regional seismic where covered the under-explored area in West Barito. Prospect evaluation conducted then concluded that Berai Carbonates play in this area was quite promising. Upper Berai Shale as a source rock has a good maturity level and the prospect area was relatively close to the kitchen. Seismic data on the carbonate platform shows some interesting features such as various reflector patterns and lateral interval velocity anomalies. However, the highest risk lies in the reservoir aspect due to the complexity of the carbonate rock and well data limitation for validating. We need a method that can identify and determine the reservoir geometry. Furthermore, the objective of this study is to evaluate the quality and distribution of the Berai Intra Platform Reef Carbonate reservoir.

Data and Method
We used well data consist of gamma ray, sonic, neutron porosity, and spontaneous potential log and 20 lines PSTM 2D seismic data with a density value of 2 km including interval velocity section. In addition, there are petrography and biostratigraphy study reports which relevant to Berai Carbonate. In understanding the reservoir potential, we use qualitative analysis with seismic facies and quantitative analysis with post-stack seismic inversion. The two results of the analysis were validated and then elaborated so that they were able to describe the reservoir in more detail.

2.1 Seismic Facies Analysis
The appearance of carbonate rocks in seismic data contains information about their original depositional environments, lithofacies, diagenesis, source rock, and reservoir potential (Figure 1). The identification of seismic facies is a study in pattern recognition. To characterize seismic facies, we need to describe four aspects or appearances such as the configuration or shape of reflections, the amplitude, the frequency, and the continuity (Macurda, 1997). The aspect that can be used as a reference for the type of facies is reflector configuration such as parallel or subparallel, divergent, progradational, mounded or draped, and onlap or onlap fill. Biostratigraphic information is needed to calibrate the interpretation result.

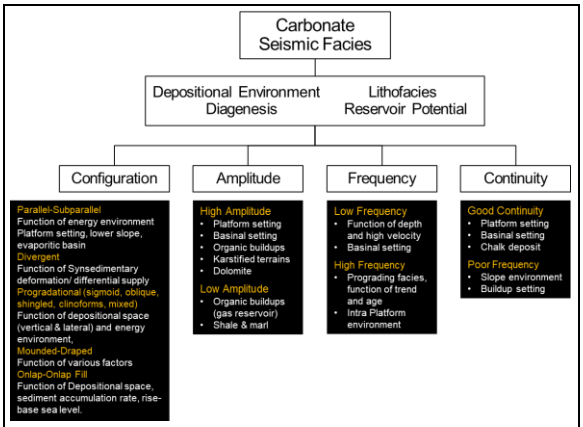

Figure 1. Carbonate Seismic Facies aspects and intepretation

There are eight pairs of well and seismic data that were analyzed for seismic facies and validated using petrographic and biostratigraphic information. The result is used for determining the vertical and lateral reservoir geometry. We use the satellite Bouguer Gravity Anomaly map to elaborate the interpretation of the prospect area to the regional scale.

2.2 Post Stack Inversion with Advance Model
Post stack inversion is a solution for reservoir characterization by integrating wells and seismic data, in the form of acoustic impedance as sensitive rock properties. In this study, we used model-based inversion with Advance Low Frequency Model (ALFM) which calculates well data and seismic interval velocity as external attributes (Figure 2). ALFM has a better geological trend because the lateral information is derived from seismic velocity. In the frontier exploration area where only a few wells are available, the utilization of seismic velocity in the ALFM plays important role in the quality of the results.

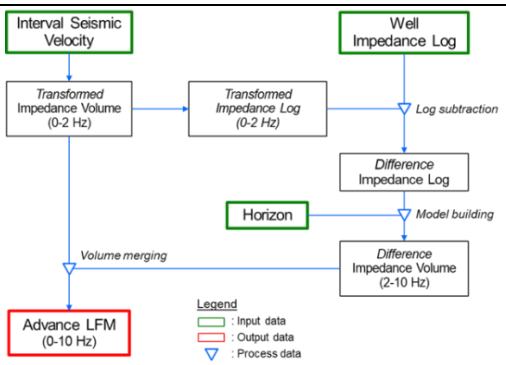

Figure 2. Post stack inversion with advance model workflow

Result and Discussion

Qualitative seismic observations on the Middle Berai Platform carbonate resulted in three types of configurations. There are parallel-subparallel, progradational, and mounded-draped which are all platform interior facies of Middle Berai. Based on the seismic facies' summary in Table 1, we conclude that mounded pattern was interpreted as a patch reef, validated to Barito-01 petrographic and biostratigraphic report. The porosity value range is taken from a study of Berai reservoir prospective which has been calculated from petrophysics analysis and validated by core data (Andromeda, 2013).

Table 1. Carbonate seismic facies summary in North & South Barito consists of depositional environment and porosity range estimation

Reflection Configurations	Depositional Environment	Porosity Range	Reference Well
Parallel Continuous - Sub Parallel Discontinuous	• Platform setting • Lagoonal facies (platform interior) • Shale dominated • Mudstone – Wackestone	3-8%	Titan-01, SJ-01, MRD-01, SMD-01, KK-01
Progradational (sigmoid, oblique, shingled)	• Platform setting • Shoal Facies (platform interior) • Related to Reef Debris, Carbonate Shedding • Wackestone – Packestone	10-15%	MRG-01, KTP-01
Mounded - Draped	• Platform setting • Patch Reef (Platform Interior) • Associate with Organic carbonate facies • Packestone - Grainstone	10-20%	BRT-01

Shale Dominated — Carbonate Dominated — Log Index = Gamma Ray; P-wave; Neutron Porosity; SP;

A seismic section on line 007 which is overlaid with seismic velocity intervals in Figure 3 shows a reflection configuration mounded pattern at the middle platform interval which correlates with high-velocity values (4000-5000 m/s). Mounded reflectors can easily be characterized by the appearance of a curve that has the opposite direction of the dipping pattern. Whereas the parallel and shingled patterns have lower velocity values (3200-4000 m/s). Meanwhile, a sub-parallel pattern on line 020 has a relatively high-velocity value (4200-4600 m/s) due to the effect of depth (depth burial). The vertical and lateral geometry of the reefal carbonate reservoir is determined from the reflection mounded pattern and high seismic velocity values.

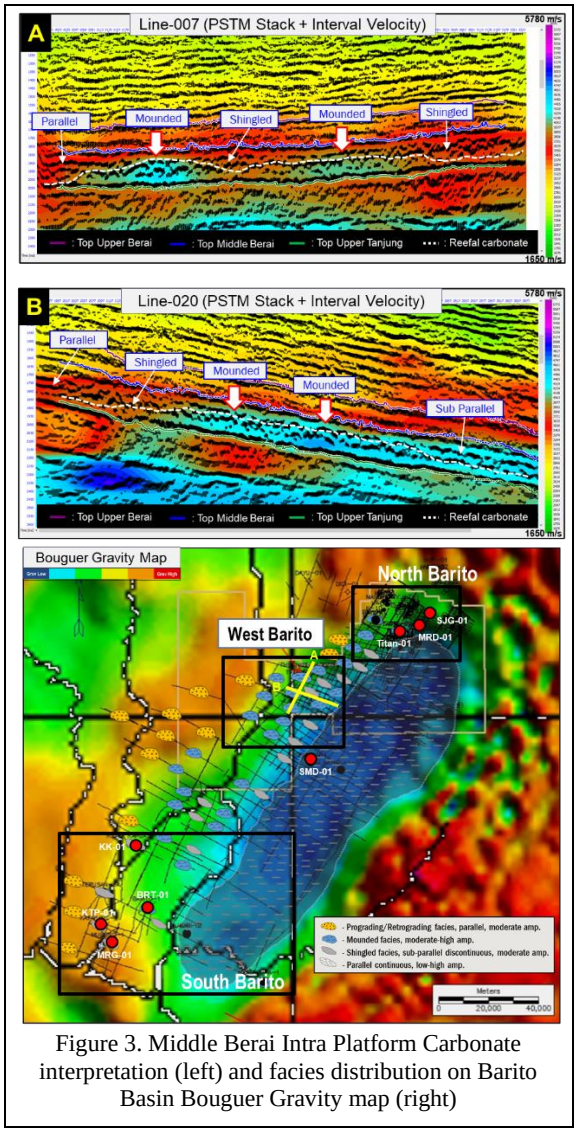

Figure 3. Middle Berai Intra Platform Carbonate interpretation (left) and facies distribution on Barito Basin Bouguer Gravity map (right)

Sensitivity analysis on Titan-01 well in Figure 4 shows that porous carbonate (NPHI 0.1-0.25) has a relatively lower impedance value (6000-9500 m/s.gr/cc) than tight carbonate. P-impedance is a sensitive parameter that can be used to map the distribution of high porosity carbonate reservoirs (10-25%).

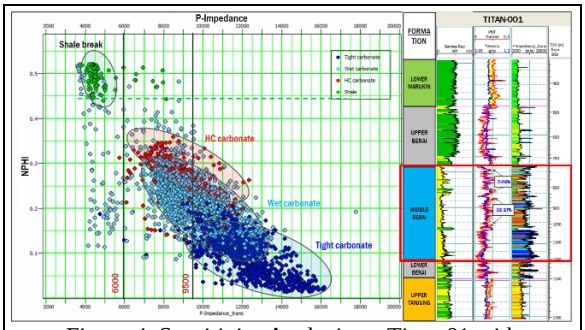

Figure 4. Sensitivity Analysis on Titan-01 with classification of lithofacies on Middle Berai Fm.

ALFM is calculated using seismic velocity interval and Titan-01 as the only reference well that is 40 km from the interest area. Acoustic Impedance section line 007 in Figure 5 shows a clear lateral trend of the P-impedance at 1900-2000 ms (purple-light blue), even though the position of Titan-01 is not in this line. Then we used a model-based inversion algorithm to calculate the PSTM stack preserve, ALFM and Titan-01 well data input with the lowest possible error to obtain optimal results. Porosity estimation is calculated based on the linear relationship between the P-impedance parameter and the NPHI on the sensitivity analysis performed on Titan-01.

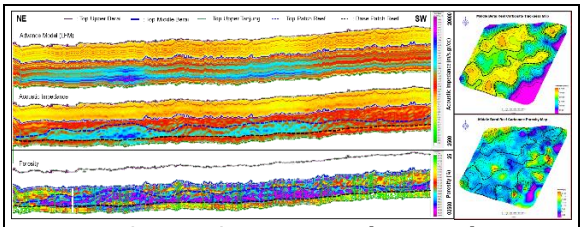

Figure 5. ALFM, Acoustic Impedance, and Porosity section of Line 007 (left). Isochrone Map and Porosity Map of Intra patch reef carbonate Middle Berai (right).

Seismic facies work effectively on good continuity and frequency quality seismic data because thickness and dipping layer are visible to determine patch reef geometry. Another indication of the patch reef is lateral velocity anomaly which has been successfully modeled in ALFM and supported the geological model information. Interpretation of 20 seismic lines resulted in many closures on the isochrone reef carbonate map (Figure 5). Estimated gross reservoir thickness can reach up 480 m with a distribution coverage of 33.000acres. The result of seismic inversion in the form of acoustic impedance is then converted into a porosity value. The value of the distribution of the reef facies porosity is quite valid in the range of 10-20%, reef debris 7-14%, and muddy facies 3-8% which is by following the recent study (Andromeda, 2013).

Conclusions

Based on the results of seismic facies and seismic inversion analysis validated with seismic velocity data and biostratigraphic reports, we have successfully mapped the development pattern of the intra patch reef carbonates reservoir in West Barito. Three closures are in line with the regional trend in the NE-SW trending lagoon zone. Reservoir modeling results indicate that the facies patch reef has the potential to become a good quality reservoir and has a wide coverage distribution. The validation result provides an overview of the estimated porosity range of reef facies 15-20%, reef debris 7-14%, and muddy facies 3-8%. The results of this evaluation are very positive and effective in reducing the risk of exploration in West Barito.

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