

Lithology Prediction Using Rock Physics Analysis and Seismic Inversion within Miocene Fluvial Reservoir Interval in the Songkhla Basin, Gulf of Thailand

Bagus Priyanto

Petroleum Geoscience Program, Department of Geology, Faculty of Science,
Chulalongkorn University, Bangkok 10330, Thailand

*Corresponding author email: bagus.priyanto@yahoo.com

Abstract

The study area is located within the Songkhla Basin and lies in southern area of western part of the Gulf of Thailand. The reservoirs in the Songkhla Basin are fluvial sands. These reservoir sands are compartmentalized and show rapid lateral stratigraphic changes due to their fluvial nature and it is not easy to map reservoir sands by using conventional seismic data. Rock physics analysis and seismic inversion techniques were applied to map the distribution of reservoir sands within the Miocene interval. Rock physics analysis shows that P-impedance can only differentiate porous sands (total porosity > 22-24%) from shales, while low porosity sands have same P-impedance as of shales. Porous sands have low P-impedance (less than 7000 g/cc*m/s). Moreover, relatively low porosity (total porosity up to 18-22%) sands can be detected by using P-impedance and Vp/Vs information in combination. P-impedance volume was computed through post-stack seismic inversion and the results are in reasonable match with the P-impedance logs at three well locations. Similarly, simultaneous inversion was performed to compute P-impedance and Vp/Vs. The results were checked by different QC parameters. Sand bodies were captured by using computed thresholds of P-impedance and Vp/Vs volumes. Most of the sand distribution is restricted within the faulted zone and it appears that sedimentation was controlled by structural configuration of the basin. Present study reveals that post-stack and simultaneous inversion can successfully map the lithology heterogeneity within the Miocene reservoir interval in the Songkhla Basin.

Keywords: Rock Physics, Seismic Inversion, Lithology Prediction, Sand Distribution, Songkhla Basin

1. Introduction

One of the fundamental aspects in the prospect evaluation or development of hydrocarbon discovery is to predict the reservoir distribution and its quality. The issue is more challenging where the reservoirs are restricted in lateral distribution.

Seismic inversion is one of the techniques that can be used to predict the reservoir distribution and reservoir quality. Seismic inversion is a method, which recovers earth rock properties from seismic

data. In other words, inversion is a technique for creating a model of the earth using the seismic data as input (Russell, 1988).

The derived parameters through inversion such as P-impedance, S-impedance and density are directly related to rock properties such as lithology, porosity, fluid content, etc. Therefore, interpretation can be made on lithological units rather than on seismic wavelet response. The rock property sections such as impedance (P and S) and density derived through seismic inversion can improve layer visualization and vertical

resolution and can serve as lithology indicator (Pendrel and van Riel, 1997).

This paper presents results of seismic inversion study over an oil-producing field of the Songkhla Basin, Gulf of Thailand (Figure 1) and seismic inversion has not been done before in the study area

The objectives of this study are to:

- Conduct rock physics analysis focusing on Miocene interval to determine lithology sensitive rock physics parameters.
- Conduct seismic inversion within the Miocene reservoir intervals.
- Map the distribution of reservoir sands in the Miocene interval.

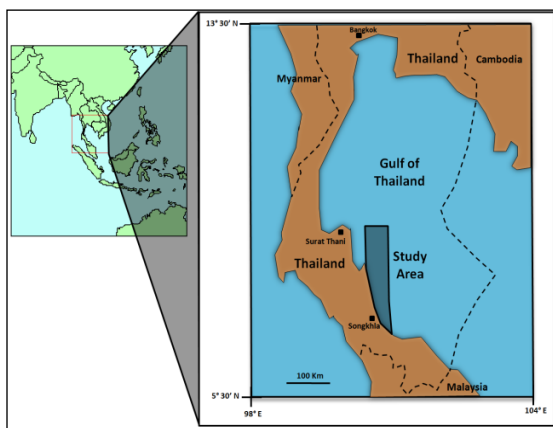


Figure 1. Map of Southeast Asia region and map showing study area (dark blue polygon) in the Gulf of Thailand.

2. Methodology

Various methodologies were used in order to detect and map of sand distribution. Two main methods are rock physics analysis and seismic inversion. The rock physics is the link between the log data and the seismic data. The purpose of rock physics in this study is to decide which rock physics parameter can differentiate between sand and shale. Rock physics analysis also helps to choose the appropriate inversion technique for lithology discrimination e.g. if P-impedance can differentiate between sands and shales on cross plots of well log data then

the post-stack seismic inversion process can help in differentiating these lithologies. Otherwise, pre-stack seismic inversion may be helpful. Then, The rock properties volumes were created using constrained sparse spike seismic inversion (CSSI) which is a trace based iterative algorithm that narrows down the range probable solutions within user defined constraints (Pendrel and van Riel, 1997).

3. Results

Rock Physics Analysis

Rock physic analysis was conducted using combination of cross plots P-impedance, clay volume (VCLA), Vp/Vs, Density, and saturation water (SW) logs.

According to the rock physics analysis, P-impedance inversion can only detect the higher porosity sands (PHIT > 0.22-0.24) (Figure 2), while simultaneous inversion solving for P-impedance and Vp/Vs would be more appropriate for lithology discrimination. This may useful for identification of the sands with lower porosity (PHIT in the range up to 0.18-0.22).

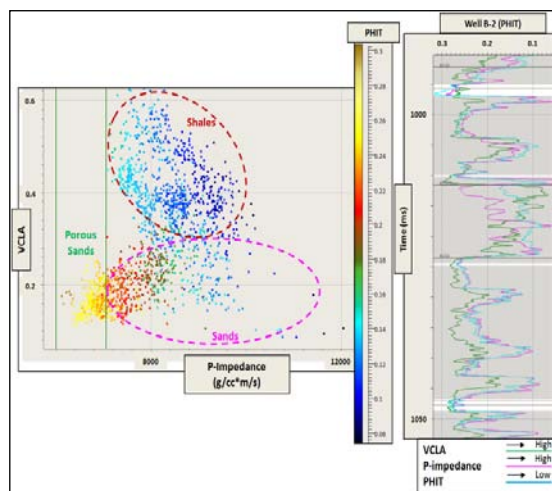


Figure 2. Cross plot of VCLA and P-impedance from Miocene interval. The green line in the cross plot is range of porous sands and associated with low P-impedance. Low P-impedance is highlighted by white zone on displayed log. Cross plot is colored by PHIT.

Seismic Inversion Result

When the inversion process finished, It is important to check the result, especially at well location, does it match or not.

In this paper, I described only one example of QC inversion result which is comparison of inverted sections to original logs. Figure 3 shows impedance features of the wireline logs and the adjacent derived impedance traces at B-3 well location showing good agreement between the inversion result compare to original log. Based on in the quality control parameters, the inversion results are reliable and can be used for lithology prediction.

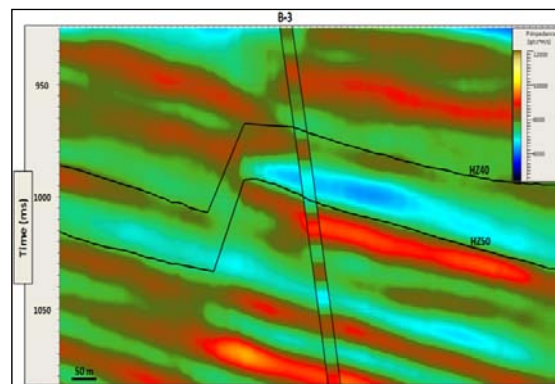


Figure 3. Comparison of acoustic impedance inversion section along well B-3. P-impedance log displayed in high cut filter (70 Hz).

4. DISCUSSIONS

Interpretation of Sand Distribution

Low values of inverted acoustic impedance volume from post stack inversion ($P\text{-impedance} < 7000 \text{ g/cc}\cdot\text{m/s}$) were extracted from horizon slice to image the lateral distributions of high porosity sands ($PHIT > 0.22\text{-}0.24$). Figure 4 present the representative map of acoustic impedance images along with line-drawing interpretations of recognizable patterns of porous sand distribution at from horizon slice HZ40 (+28ms). The figure reveals that the porous sands are majority located in the central area along the fault boundary in the down thrown part of the major fault.

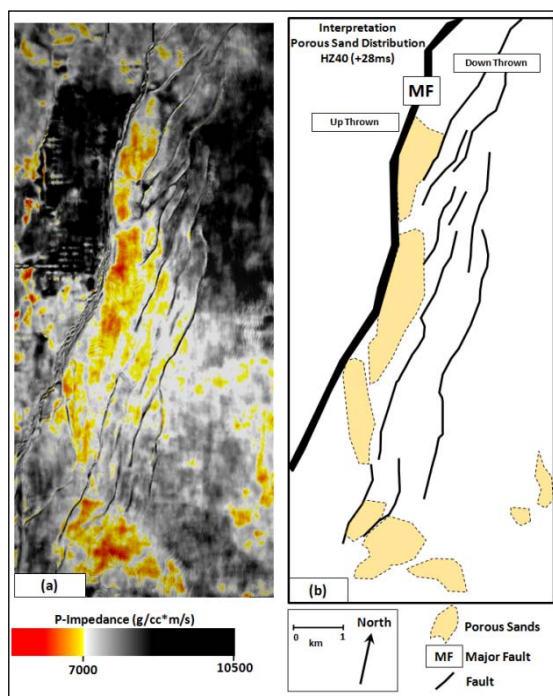


Figure 4. (a) Map view image of low value acoustic impedance (post-stack inversion) extracted at HZ40 (+28ms) horizon slice, (b) Possible line drawing patterns of porous sands.

Tectonic Control on Sedimentation and Deposition Environment

According to Kartikasari (2011), initial rifting occurred in Eocene (?) or in Early Oligocene along a series of north-south trending faults within the Songkhla basin. The rifting phase was followed by inversion in Lower Early Miocene. In Early Miocene, there was second phase of rifting followed by thermal subsidence in Lower Middle Miocene. The study area has major north-south fault that has larger throw in the south as compared to the north. Moreover, the graben block has thicker sediments as compared to up-thrown fault (Figure 5).

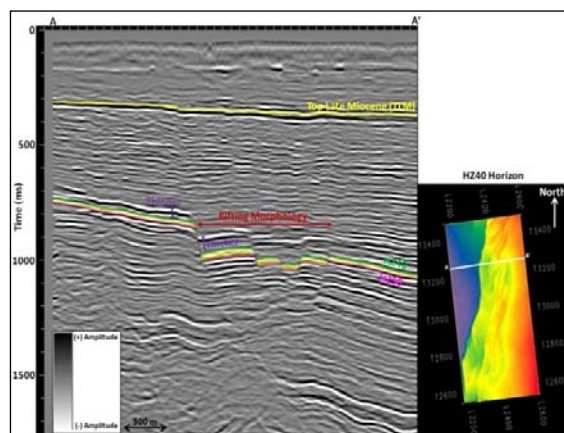


Figure 5. Seismic interpretation along the rifting morphology. The sediment package is thicker in the graben blocks.

Core and gamma ray logs were used to identify the depositional environments. The core data reveals that reservoir interval is composed of coarse grain sandstone with claystone deposition in its lower part and upper part. The coarse grain sandstones reservoir interval has cross bedding and bioturbation. This interval was interpreted as fluvial channel sandstone with some marine influence. This sandstone reservoir interval has blocky shape pattern in gamma ray log (Figure 6). The bottom part (below the reservoir) of core consists of abundant root structure claystone and interpreted as fluvial floodplain. The upper parts (above the reservoir) of core interval also consist of abundant of siderite nodule claystone and interpreted as fluvial floodplain to levee deposits. Based on core interval, overall the sediments were deposited in fluvial systems dominated.

A vertical section and map view section of acoustic impedance volume and intersecting B-1 well location is displayed in Figure 7. This figure reveals that the porous sands have good agreement with low impedance and high porosity sands at well locations. The porous sands in vertical section show lens shape geometry and distributed in the central area along the major fault. Rift and

boundary-fault might govern a considerable influence on the style of sand deposition. Ronghe and Surarat (2002) in Suphan Buri basin of Thailand have reported similar sand distribution dictated by the structure configuration of the basin.

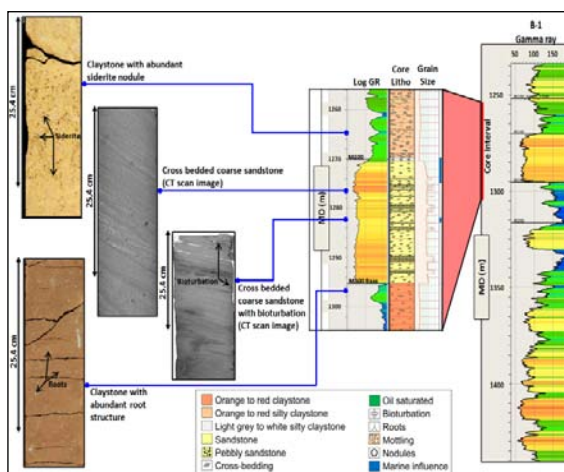


Figure 6. Characteristic of lithology, grain size, and sedimentary structure from core interval of B-1 well. The reservoir interval interpreted as fluvial channel sandstone. The gamma ray log has typically blocky shape pattern and has a good agreement with core data.

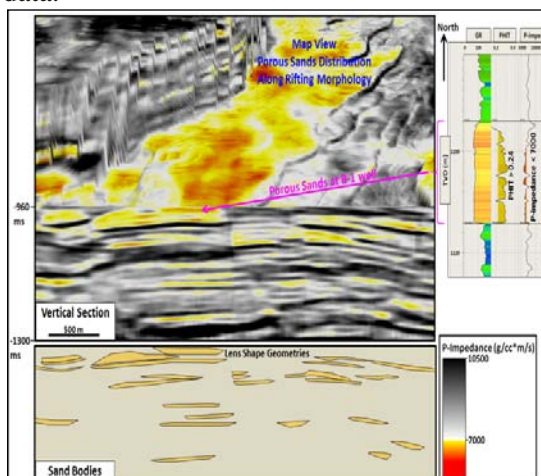


Figure 7. Acoustic impedance volume. A vertical section (in time, ms) and map view section intersecting B-1 well location.

Implication for Future Potential Reservoir Targets

As both post-stack and pre-stack inversion successfully isolated sands, the sand maps derived from these inversion techniques can be used for future exploration in the area.

This study provides maps of high porosity sands within the reservoir interval by using acoustic impedance volumes derived from post-stack inversion. The map results are in match with the well data at drilled locations. As the three drilled well indicates that these sands are oil-bearing, the sands located in other high structures within/near the fault blocks are promising for future exploration and development (Figure 8).

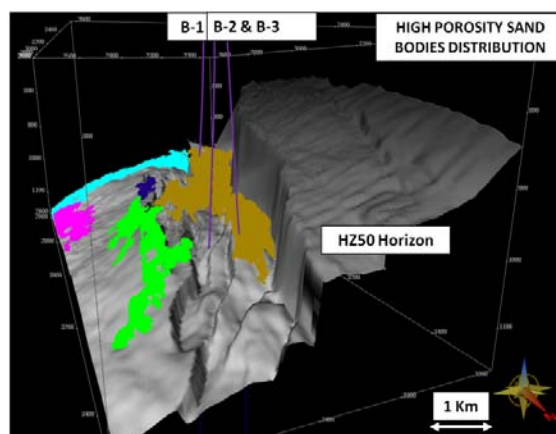


Figure 8. 3-D display of high porosity captured sand bodies by using acoustic impedance volume underlain by HZ50 horizon. A single sand body represents in single color.

5. Conclusions

Rock physics analysis and seismic inversion techniques were applied to map the Miocene reservoirs of the Songkhla Basin of the Gulf of Thailand. The main findings and conclusions are summarized below:

- Based on rock physics analysis, acoustic impedance can only differentiate higher porosity sands (PHIT >22-24%) from

- shales and these sands associated with low P-impedance values (P-impedance < 7000 g/cc*m/s).
- If P-impedance and Vp/Vs volumes are used in combination, they can differentiate even lower porosity sands (in the range up to 18-22%).
 - Inverted P-impedance volume computed through post-stacked inversion provides reasonable prediction for higher porosity sands.
 - Combination of P-impedance and Vp/Vs from simultaneous inversion successfully isolated relatively lower porosity sands.
 - The seismic inversion techniques successfully map the sand distribution between H40 and H50 horizons.
- Pendrel, J.V., and P. van Riel, 1997, Methodology for seismic inversion and modeling- a western Canadian reef example: Canadian Society of Exploration Geophysicists Recorder, v.22, no. 5.
- Pendrel, J.V., 2001, Seismic inversion-the best tool for reservoir characterization: Canadian Society of Exploration Geophysicists Recorder, v. 26, p. 16-23.
- Ronghe, S., and K. Surarat, 2002, Acoustic impedance interpretation for sand distribution adjacent to a rift boundary fault, Suphan Buri basin, Thailand: AAPG Bulletin, v. 86, no. 10, P. 1753-1771.

6. Acknowledgements

I am thankful to Dr. Mirza Naseer Ahmad for final research project supervision and manuscript revision, and to Prof. Phillip Rowell for the discussion during final research and study. I thank Mr. Andrew Laird for the discussion. I thank Petroleum Geoscience Program, Chulalongkorn University for the scholarship to pursue the master degree. I thank Fugro-Jason Geoscience and Landmark Graphic Corporation for the donation of the software for this research project.

7. References

- Kartikasari, H.A., 2011, Structural style of Songkhla basin, Gulf of Thailand: M.Sc. thesis, Chulalongkorn University, 63 p.
- Oldenburg, D.W., T. Scheuer, and S., 1983, Recovery of the acoustic impedance from reflection seismograms: Geophysics, v. 48, no.10, p. 1318-1337.

- Russell, B.H, 1988, Introduction to seismic inversion methods: SEG Course Notes Series, no.2, 90 p.