Bulletin of Earth Sciences of Thailand

Sand Distribution and Depositional Environments East Yala Field, Pattani Basin, Gulf of Thailand

Thananya Rinsiri

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

*Corresponding author email: me_mymphmie@hotmail.com

Abstract

The E to F interval is the main hydrocarbon-bearing stratigraphic unit in the East Yala Field, Pattani Basin, Gulf of Thailand. The key reservoirs comprise mainly fluvial sands that have a stratigraphically complex architecture resulting in high uncertainties in reserve estimation. This study attempts to predict their distribution, geometry and identify depositional environments based on an integrated investigation of regional stratigraphy, wireline logs and seismic based analysis. The wireline log data from 72 study wells were used to determine depositional environments, characterize reservoir architectures and investigate sand distributions. Based on wireline log, depositional facies were interpreted as channel fills and overbank/floodplain deposits in an alluvial plain environment. The main north-south and northwest-southeast orientations of various sand bodies were observed in sand distribution maps. Seismic attribute analysis was used to delineate sand body orientations, geometries and their areal distributions. Results of the seismic based analysis show a good relationship between high amplitude anomalies and the presence of well log-derived sand interpretations. The evolution of the sand systems is from a restricted thick fluvial channel at base changing to broad bifurcated channels with a slight eastward shift in deposition in the middle. A broad lobe-shaped crevasse splay overlays this system, restricted to the north due to a transgression-caused backstepping. These findings can be used for well planning for future drilling projects and for generating reservoir simulation models for forecasting production profiles.

Keywords: Sand distribution, Depositional environment

1. Introduction

The Pattani Basin, located in the central Gulf of Thailand has a high hydrocarbon potential in terms of its large amount of remaining reserves. The key reservoirs in this basin are fluvial sands which have a stratigraphically complex architecture resulting in high uncertainties in reserve estimation. Therefore, this study is an attempt to reduce uncertainties in sand-body distributions in the East Yala Field, using a combination of wireline logs and seismic based analysis.

This study focuses on subsurface fluvial reservoirs observed in well logs to determine reservoir geometries, and as well uses 3D seismic data for identifying sand-body distributions in a field wide scale.

The main objectives of the study are :

1.) To improve the understanding of reservoir architecture in terms of the sand distributions in the East Yala field by defining the orientation and geometries of the main reservoirs.

2.) To determine the depositional environment of the reservoirs.

2. Methods

An integration well log data and seismic based analysis was used to investigate sand distributions and determine depositional environments. The gamma ray - acoustic impedance crossplots were done to determine the relationship between rock properties and acoustic impedances, the results can be then used to predict the actual seismic response in the study area. The depositional environment was interpreted based on gamma ray log analysis and the regional stratigraphic setting because of the core data absence. Marker identification and well-to-well correlation were used to construct a series of sand distribution maps that were then used to give preliminary information about the reservoir geometries and to determine an evolution of sand systems in the study area.

To compare well log data to the seismic, synthetic seismograms were generated. Two main E and F markers were interpreted as key horizons, then contoured to create two-way-time structural maps which were used to generate seismic attribute maps. Amplitude extraction maps were generated by using RMS (root mean square) amplitude attributes within various windows in order to define the sand distributions and outline the main paleo-orientation of the reservoirs in the study area. The best results were windows ranging from 20 to 30 ms tied to the key horizons.

3. Results

3.1. Well log analysis

Gamma Ray - Acoustic Impedance Crossplots

The low impedance intervals matched very well with the low gamma ray intervals that were interpreted as sands. The overall results indicate the lower acoustic impedance represents the lower density sandstone. Moreover, good separation between sands and the surrounding shale were observed. This suggests that sands should be distinguishable from the background shale on the seismic data. However, hydrocarbon-bearing sands and water-bearing sands cannot be distinguished using the crossplots. In this study, seismic reflectors associated with sands can be seen easier in the northern area than the southern part.

Depositional Environment Analysis

The results from well YAWG-30 and UNO-10A-3 located in the northern and southern areas show common characteristics include a blocky to bell-shaped low gamma ray curves that were interpreted as channel fills, and serrated high gamma ray curves were identified as floodplain or overbank deposits in an overall alluvial plain environment. These observations concur with the regional setting of Sequence 3, the zone of interest, that comprises channel fills and overbank facies which are dominant in an alluvial plain environment.

Well to Well Correlation

The general observations are explained as below;

Markers : The E and F markers are easy to correlate in both along and across fault blocks. The gross thickness was consistent along fault blocks in the north-south direction, whereas the interval thins toward the east that might infer a basinward facies towards the west, and the edge of the basin towards the east.

Sands : The distribution of sand-bodies within the interval of interest was investigated using five correlation panels The observations are summarized as follows;

Correlation panels along fault blocks and in the inferred depositional dip direction show quite consistent thickness of sediment successions between the E and F markers. The three sands of interest are correlated easily. The uppermost A sand is rapidly thinning to the south, and absent in the southern area. The middle B sand shows a regular thickness and good correlation. The bottommost C sand shows a consistent thickness in the northern area, whereas in the south it is much thicker but shows sharp thinning seen as pinchout.

Correlation panels across fault blocks and in the inferred depositional strike direction show the slightly thickening of sediment successions to the west. For the three sands of interest, the results show a gradual increase of sand thicknesses from east to west into basinward direction, and the southern area shows more restricted sand bodies (Figure 1) than in the northern area where they are more widespread in terms of lateral distributions across fault blocks (Figure 2).

Sand distribution maps

The overall results of the sand distribution maps show a similarity to each others with the typical distribution of sand-bodies characterized by a north-south orientation. Also the maximum thickness trend is aligned in the same direction. The sand-body thicknesses are quite consistent along the north-south trend, and significantly change laterally in the east- west direction (Figure 3). Consequently, the boundary of sand bodies can be easily mapped determined by the absence or presence of sands in penetrated wells.

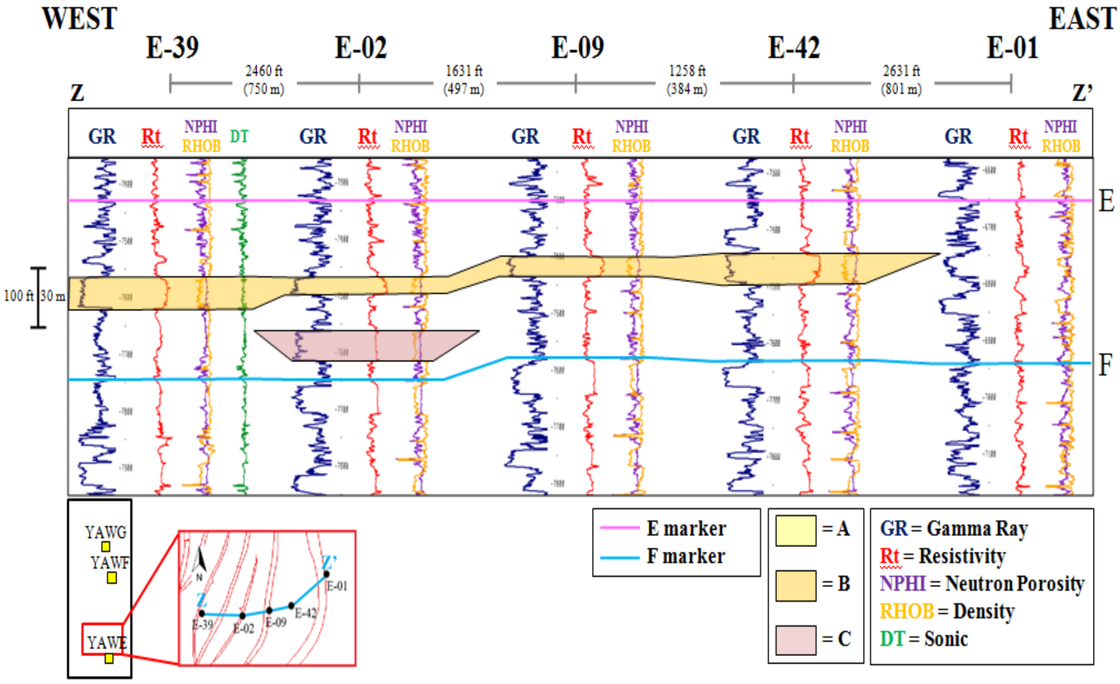

Figure 1. An example of a correlation panel across fault blocks in the southern area shows the consistent thickness between E and F markers; furthermore, the correlation of the lower two sands of interest shows the lateral limit of sand-bodies across fault blocks seen as pinchout of sands, especially the bottommost C sand.

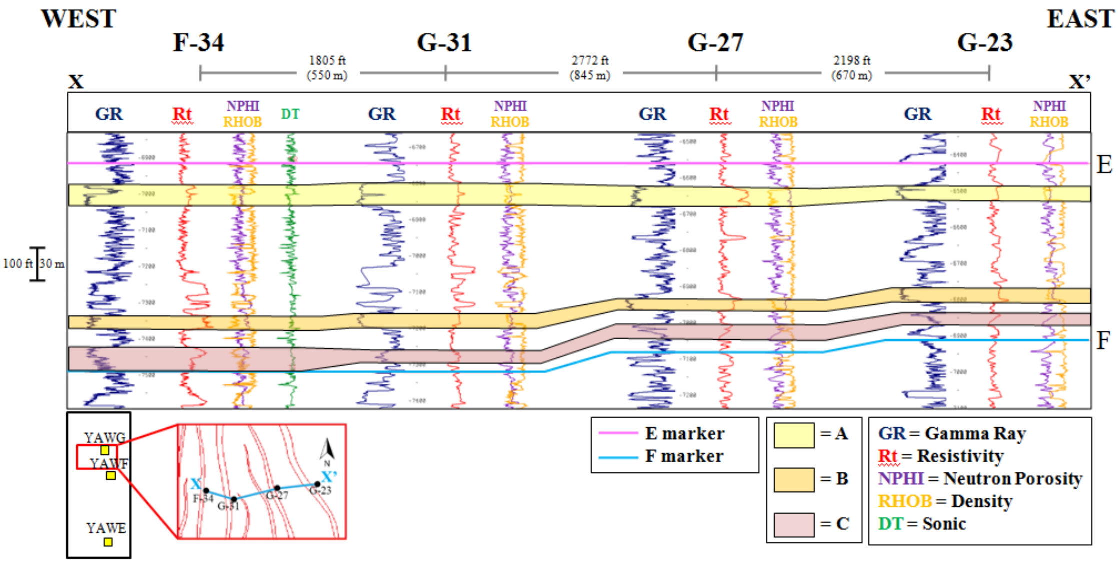

Figure 2. An example of a correlation panel across fault blocks in the northern area shows thinning between E and F markers to the east, and good correlation of three sands of interest that have a gradual increase of sand thicknesses to the west in basinward direction.

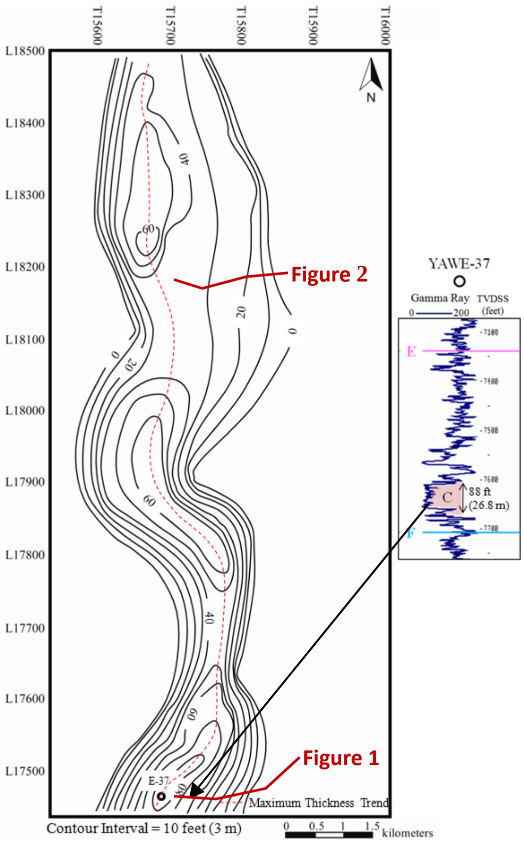

Figure 3. The C sand distribution map shows gentle sinuous belt-shaped character that has maximum thickness trend oriented in the north-south direction, and the sand is rapidly thinning in the east-west direction. The gamma ray curve shows the C sand characteristic.

3.2. Seismic interpretation

Well to Seismic Tie

Two synthetic seismograms were generated and have a good correlation between the rock property changes observed in well logs with changes in the seismic responses. The seismic data has normal polarity and troughs can be mapped with some confidence, indicative of sand bodies. In the north, the UNO-10A-2 tie gave better seismic reflectors corresponding to sand due to relatively lower impedance sands resulting in high impedance contrasts between the two different lithologies.

Horizon Interpretation and Structural Mapping

The two synthetic seismograms were used to provide ties to the two key E and F surfaces for initial horizon interpretations. Typical seismic sections show the consistent characteristics consist of strong amplitude relatively continuous peaks of the key E and F horizons. The interval in between shows strong troughs which have limited lateral extent, these are interpreted to represent sand bodies. Structural styles in this area comprise the full-graben faulted system, and gently dipping tilted strata high toward the upthrown side of faults, provided structural closures.

Two two-way-time structural maps of the key horizons were used to interpret the structural styles and were also used to determine the appropriate windows for the amplitude analysis. These maps show a dominant north-south trending normal fault system with structural highs to the east and west and a graben down the middle of the study area.

RMS Attribute Map Analysis

Sands in the study area are identified as low impedance sands from the result of crossplots. The synthetic ties also confirm that these sands are troughs on the seismic. Therefore, high amplitude troughs are an indicator of sands, while shale is represented by the background low amplitudes. The thicker sandstones are represented by higher amplitudes. These statements are supported by evidence of fluvial channel fills from penetrating wells that show generally fining-upward sandstone patterns (Figure 4).

The high amplitude corresponds to sands and the low amplitude corresponds to shale (Figure 5). This is an expected result based on the good correlation between sands observed in well logs and high amplitudes extracted from the seismic.

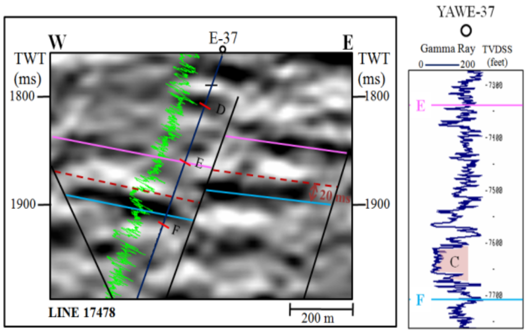

Figure 4. The seismic section shows a good relationship of high amplitude troughs compared to the C sand in a well log.

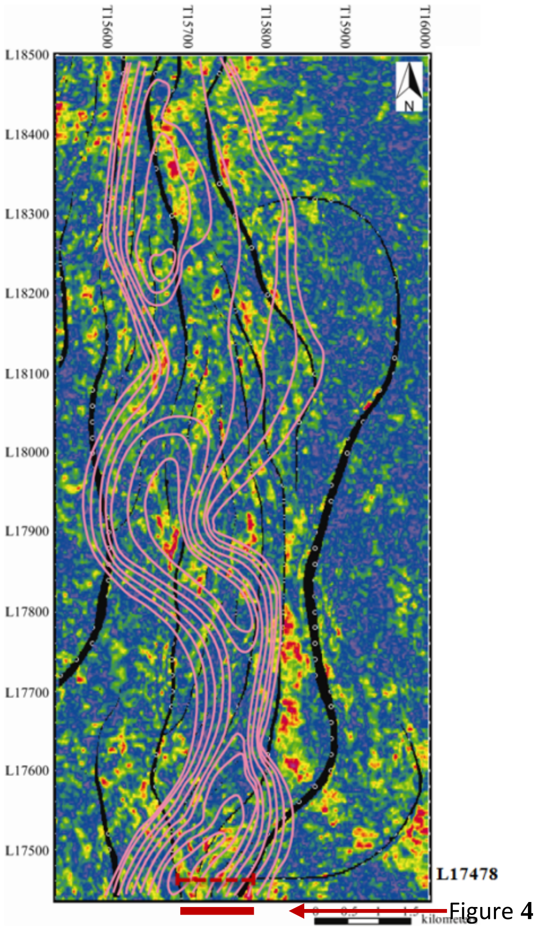

Figure 5. The overlay of the C sand isopach from wells with the -20ms RMS amplitude map from F horizon shows the concurrence between thick sands and high amplitudes.

4. Discussion

The evolution of the sand systems is from a restricted thick fluvial channel at base changing to broad bifurcated channels with a slight eastward shift in deposition in the middle and a broad lobe-shaped crevasse splay overlying this system, restricted to the north due to a transgression-caused backstepping. The sand net to gross map for interval E to F suggests a relatively confined fluvial system. However, the interpretation of depositional environment might not be unique due to the merits of well logs and seismic data, and the absence of core data. In addition, the results of amplitude extractions just indicate the sand-rich or mud-rich distribution trends only. For implications of reservoirs, the best reservoir target is the basal sand C because in the channel system, the restricted basal sand deposition provides the good reservoir qualities such as high porosity, considerable thickness and a broad extent of the sand body distribution.

5. Conclusions

The zone of interest was dominated by fluvial deposition which comprise channel fill sandstones and fine-grained floodplain /overbank deposits within an alluvial plain depositional environment. The meandering channel sand bodies are characterized by low to medium sinuous belt-shaped features oriented in the north-south direction except the crevasse-splay uppermost sand which has northwest-southeast splay-like feature. The amplitude extractions can be used to predict the sand-rich trend in the study area. In summary, the integration of well logs and seismic studies can be used to predict the fluvial reservoir architectures, and leads to a better understanding of reservoirs in terms of sand distributions, reservoir quality and general geometries.

6. Acknowledgements

I would like to express my sincere gratitude to my supervisor Dr. Philip Rowell, for his warm support and suggestions, and also Dr. Joseph Lambiase and Dr. John Warren for their knowledge through the Petroleum Geoscience Program. I would like to express my appreciation to Chevron Thailand and my supervisors; Mr. James Logan and Mr. Lance D. Brunsvold for offering me the opportunity to pursue this degree. Many thanks to all staff for precious support. Lastly, I am very thankful to my family, my colleagues and my friends for their encouragements and cheerfulness.

7. References

Bustin, R. M., & Chonchawalit, A., 1997. Petroleum Source Rock Potential and Evolution of Tertiary Strata, Pattani Basin, Gulf of Thailand, AAPG Bulletin, v. 81, no. 12, p. 2000-2023.

Jardine, E., 1997. Dual petroleum systems governing the prolific Pattani Basin, offshore Thailand. Petroleum systems of S.E. Asia and Australasia Conference, Jakarta, May 21-23, 1997, p. 351-363.

Watcharanantakul, R., & Morley, C. K., 2000. Syn-rift and post-rift modeling of the Pattani Basin, Thailand: evidence for a ramp-flat detachment. Marine and Petroleum Geology, v.17, p. 937-958.