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Depositional System and Facies Analysis in the Central Pattani Basin, Gulf Of Thailand

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Abstract

Fluvial sands comprise the main reservoirs in the Central Pattani Basin, Gulf of Thailand and they exhibit complex stratigraphic architectures which results in high uncertainties in reserve estimation and development strategies. To better understand these uncertainties this study analyzes the distribution and depositional environments of sand reservoirs within a producing field of the Central Pattani Basin to characterize reservoir architecture and analyze sand distribution using the wireline log data from 47 development wells. Based on wireline analysis, three depositional facies were interpreted within the Early to Middle Miocene interval of interest. These were fluvial dominant, estuarine to fluvial and coastal plain environments. Sand distribution maps and well log correlations indicate the orientation of sand bodies with lateral continuity of sands in the changing depositional environments. To further delineate sand body geometries seismic RMS attribute analyses were used and these show a good relationship between high amplitude anomalies and well log derived sand interpretations. Due to an overall regression from Early to Middle Miocene the depositional environments shifted from marginal marine dominant to fluvial dominant within the interval of interest. The variation in sediment supply to the fluvial systems affected potential reservoir geometries significantly. The Early Middle Miocene C to F interval shows well developed wide meander channel belts in an estuarine to fluvial environment and is the main hydrocarbon bearing stratigraphic unit in the area of interest.

Keywords: Pattani Basin, Fluvial, Estuarine, Coastal plain, RMS attribute analysis

1. Introduction

The Pattani Basin in the Gulf of Thailand is an important hydrocarbon producing basin with up to 10km of thick non-marine to marginal marine clastic strata of Cenozoic age (Lian and Bradley.,1986; Chinbunchorn et al.,1989). Fluvial sands comprise the main reservoirs in the basin and they exhibit complex stratigraphic architectures in terms of geometries and continuity of reservoirs. This results in high uncertainties in reserve estimation in the basin.

To better understand these uncertainties a producing field was chosen as the study area located in the central part of the Pattani Basin which has both gas and condensate production (Figure 1). The study area comprises about 505 km^2 and focuses on a well log data set which has full log suites from 47 wells covering seven platforms and 3D seismic interpretation to study the distribution and depositional environment of sand reservoirs within the area of interest. The main objectives of the study are:

- To understand the reservoir architecture of the main intervals of

interest in terms of sand body distributions by defining their depositional orientation and geometries.
- To determine the various depositional environments of the reservoirs in these intervals of interest.

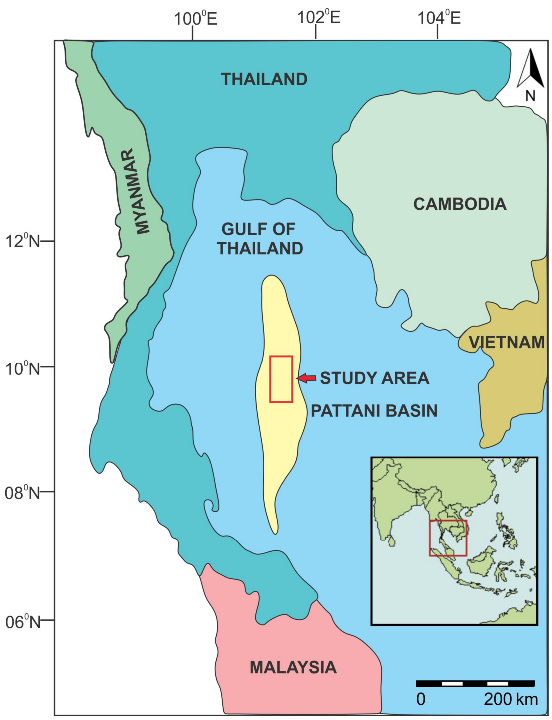

Figure 1: Location of the study area in the Central Pattani Basin, Gulf of Thailand.

2. Methodology

To analyze the sand body distribution and to determine the depositional environment an integration of well log analysis and seismic interpretation were used. The depositional environment was interpreted based on well log analysis and regional stratigraphic setting due to absence of core data. Marker identification and well to well correlation were used to construct a series of sand distribution maps from the net to gross calculation to understand the reservoir geometries. The initial correlation framework used two key markers the Mid-Miocene unconformity (MMU) and an intra-mid Miocene marker (D). The key horizons MMU and D were also used to create two way time structure maps which were used to generate seismic attribute maps by using the RMS (root mean square) amplitude attribute within various time windows in each interval. The net to gross sand distribution maps were compared with the RMS amplitude maps and adjusted to show the changes of sand thickness through the study area consistent with the different depositional environments interpreted.

3. Results

3.1 Well Log Analysis

Depositional Environment Analysis

Based on the regional stratigraphic succession of the Pattani Basin, the zone of interest in this study lies within the depositional units comprising coastal plain to fluvial. It is interpreted as marginal marine to fluvial deposition. The general interpretation of well, PJ-13, located in the central part of the study area was analyzed and interpreted to identify depositional environments in the intervals of interest (Figure 2).

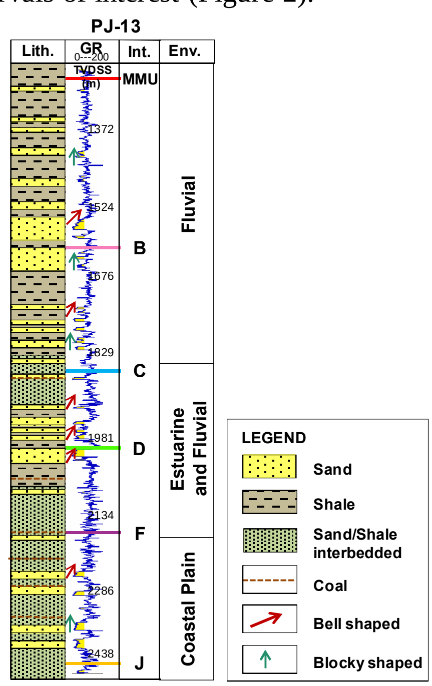

Figure 2: The general interpretation of depositional environments from well PJ 13 based on gamma ray curve.

Common characteristics of channel fill and overbank floodplain deposits were identified. The interval from MMU to C is interpreted as fluvial dominant, the interval from C to F is estuarine to fluvial dominant and the interval from F to J is coastal plain to floodplain dominant.

Well to Well Correlation

In the well log analysis five intervals of interest were correlated. Between the MMU and D picks two other markers, B and C, were interpreted and below the D marker, another two markers, F and J, were interpreted which covers the whole interval of interest. Within these intervals, the total thickness and sand net to gross characteristics were generated and analyzed using the full suites of logs from 47 wells.

Sand distribution maps

The upper two intervals are between the MMU to B and B to C markers. The total thickness map of these two intervals show the significant thickening trend towards the southeast. The net to gross map shows a prominent meander belt in the western part with a maximum 40% of sand in MMU-B interval whereas in the B to C interval three dominant wide channel belts with a maximum 30% of sand are observed (Figure 3a). The well correlation panel D-D' (Figure 3b) in the B-C interval shows discontinuous and stacked channel sands. The sand bodies are not laterally extensive but can be correlated locally.

For the C to D and D to F intervals the total thickness map shows a broad thickening trend toward the central to southern part of the area. The C to D interval is the sandiest of these two intervals and the net to gross sand map of this interval shows two broad meander channel belts which run through the thick in the central part (Figure 4a). Narrower channel belts are observed in the lower D to F interval with a maximum of 30% in this area. The well correlation panels in these two intervals show the presence of some continuous sand deposits. The thick continuous sand deposition in the C to D interval indicates broad meander belts (Figure 4b) and variable thick and thin stacked channel sands and thin continuous sand deposits indicates both small and broad meander channel belt systems in the D to F interval. The cross-sections also indicate deposition of interbedded minor coal seams in a lower energy estuarine environment at this time.

In the F to J interval, the total thickness map shows a thickening trend towards the central part and the net to gross

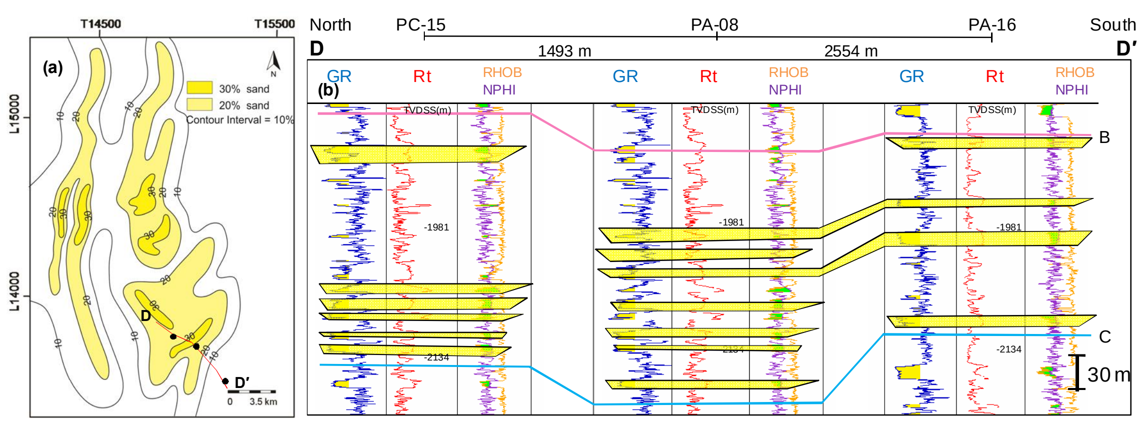

Figure 3: (a) The net to gross sand map shows the maximum percentage of 30% in the centre of the channel belts in B to C interval. (b) The well to well correlation panel D-D′ for the B to C interval shows both stacked and discontinuous channel sands.

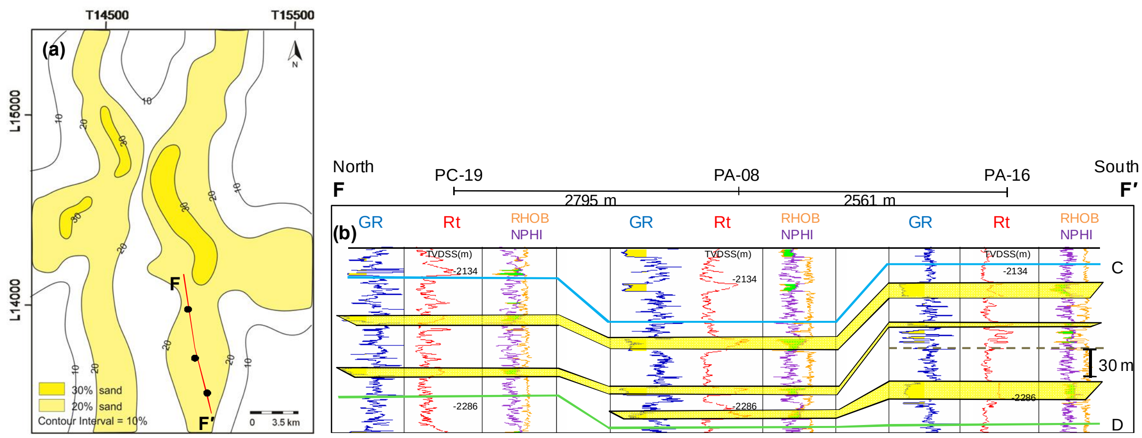

Figure 4: (a) The net to gross sand map shows the maximum percentage of 30% in the centre of two broad meander channel belts in C to D interval. (b) The well to well correlation panel F-FNj for the C to D interval shows some continuous channel sands.

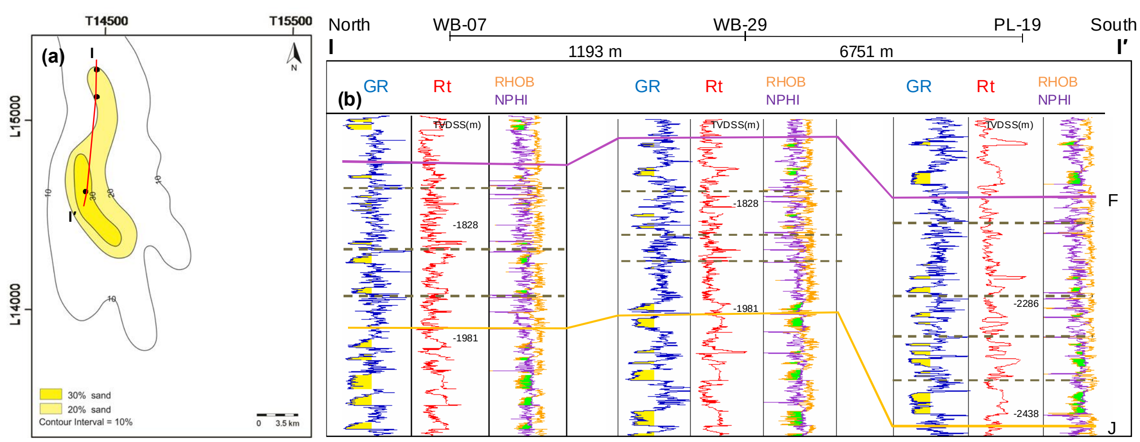

Figure 5: (a) The net to gross sand map shows the maximum percentage of 30% in the north western channel belt in F to J interval. (b) The well to well correlation panel I-INj in the F to J interval shows interbedded sand shale and numerous coal deposition.

map shows a broad sandy area to the northwest where the net to gross reaches a maximum of 30% in the western area (Figure 5a). Sand deposition is limited and localized during this interval. The correlation panel I-INj (Figure 5b) indicates interbedded sand-shale deposition with numerous coal deposits which could indicate a floodplain to coastal plain depositional environment.

3.2 Seismic Interpretation

Horizon Interpretation and Structural Mapping

MMU and D are the two key horizons which were used as guides to define the other intermediate markers both between these two horizons and in the deeper section below the D marker horizon in the well log analysis. The MMU horizon is a relatively high amplitude peak through the study area and is laterally extensive throughout the whole area. Consistent characteristic were observed along this horizon. The D horizon was also interpreted as a relatively strong continuous peak which was extensive throughout the study area. A simplified cross-section (Figure 6) based on the seismic interpretation shows the increasing thickness of the MMU to C interval to the SE whereas below C the thickness trends are relatively parallel.

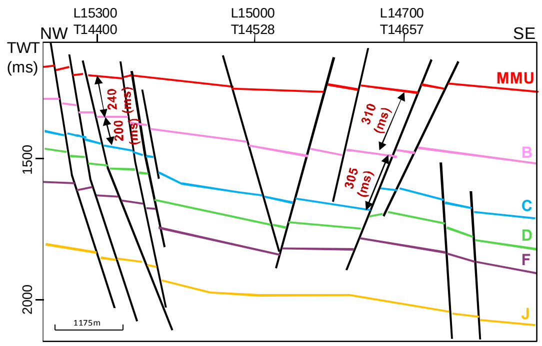

Figure 6: A simplified cross-section based on seismic showing the increasing thickness of the intervals above C marker towards the southeast and with a more consistent thickness of the intervals below the C marker.

From the TWT structural maps of MMU (Figure 7) and D horizon it can be interpreted that the study area is dominated by north-south trending normal faults which create tilted fault blocks with gently dipping strata. The study area is characterized by a north-south trending symmetrical full-graben fault system which is the typical characteristic of the Pattani basin. Structural highs and three way dip closures are created at the up-thrown side of both east and west dipping faults.

RMS Attribute Analysis

From the well to seismic tie and previous studies in the area it is assumed that the seismic section has a normal polarity. The troughs are the indicator of sand reflections and high energy condition on the seismic section whereas shale or low energy environments are represented by the peaks or

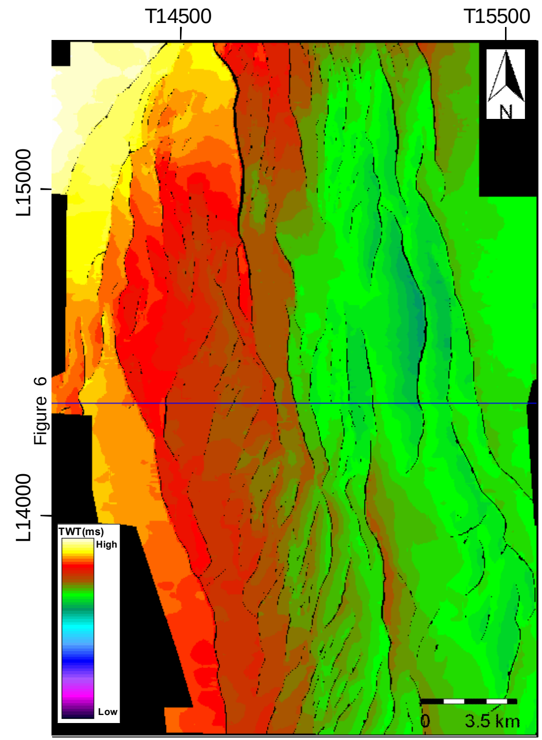

Figure 7: TWT structure map of MMU horizon showing north-south trending normal fault system with structural high to the northwest.

low amplitudes. Thicker sand bodies are clearly indicated by strong amplitude trough-peak reflections. Five RMS attribute maps in the five intervals of interest (MMU to B, B to C, C to D, D to F and F to J) using 100ms windows tied to the MMU, B and D horizons were generated to show possible sand distribution patterns in each interval. These amplitude patterns were used in conjunction with the well log data to develop depositional trends and interpretations for each interval.

The RMS attribute map of a +100ms window in the B to C interval shows areas of relatively high amplitude in the north central and western areas suggesting these are areas of significant meander belt development with numerous highly sinuous but narrow channel geometries in the other areas (Figure 8a). The RMS attribute map of a -100ms window in the C to D interval shows well imaged high

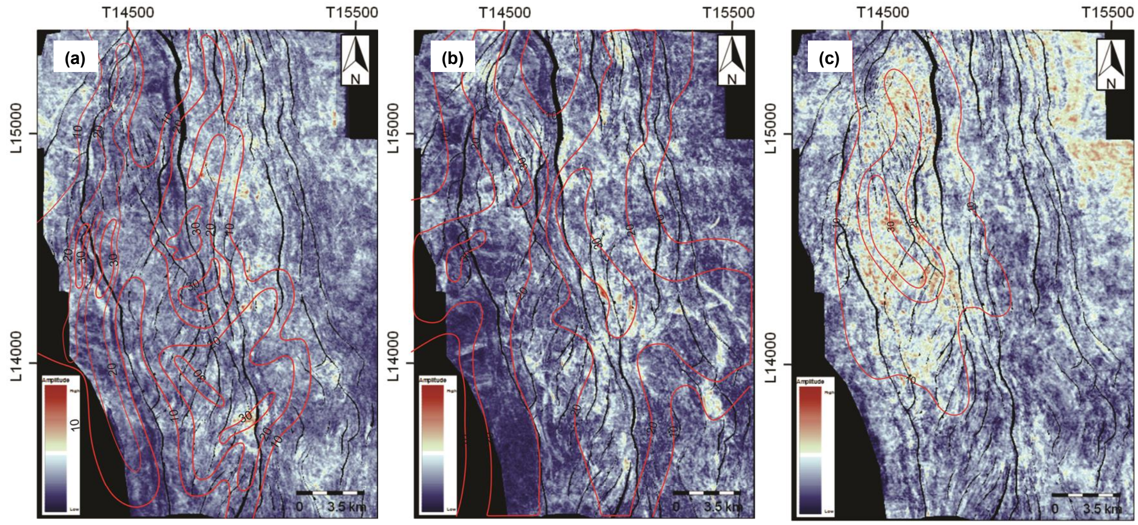

Figure 8: Net to gross sand overlay on RMS attribute map (50 ms window) shows a good correlation in (a) the B to C interval (b) the C to D interval and (c) the F to J interval.

amplitude sinuous meander belts with clear north-south orientation (Figure 8b). The RMS attribute map of a +100 ms window in the F to J interval shows a high amplitude area in the north western area which indicates a very broad and diffuse meander belt system whereas the low amplitude areas in the south and east indicate lower energy depositional environments (Figure 8c).

4. Discussion

Due to the absence of core data the interpretation of the depositional environment was done in a broader scale from the facies associations using the well log data. The channel geometry and patterns were analyzed using the RMS attribute maps and combining the seismic and wire line datasets, the depositional environments were interpreted. The study area covers the late syn-rift stages from Early to Middle Miocene. Three distinct depositional environments characterize the five intervals in the study area.

Coastal plain environment

The first interval which was identified between the F to J markers at the base of the interval of interest was interpreted as the coastal plain to floodplain deposits. The well log correlation panel (Figure 5b) shows discontinuous thin sands and interbedded sand-shale sequences with abundant coal seams which are widespread throughout the area. The net to gross map overlain on the RMS attribute map shows a relatively diffuse amplitude pattern in the western area (Figure 8c). The variable high and low energy depositional conditions in this interval could be summarized as a coastal plain or floodplain deposit. Due to the absence of biostratigraphy and core data the accurate interpretation of coastal or floodplain deposition was not possible.

Estuarine to fluvial environment

Above the coastal plain deposits the next two intervals which were identified as D to F and C to D show a significantly different depositional system which were interpreted as an estuarine to fluvial dominant environment. The C to D interval exemplifies this depositional environment. Two broad north-south oriented high amplitude meander belts characterizes the C to D interval (Figure 8b). A 50 ms window of RMS extraction shows the high sinuous channel geometry with a broad channel belt width about 1500-2100m. Generally the high sinuous channels have width about 130-200m. The well log correlation panel (Figure 4b) shows laterally continuous sand distribution which also confirms good continuity of the channel belts. The presence of a few coal seams indicates the influence of estuarine environments which was confirmed from the RMS attribute patterns. In summary, the presence of coal, estuarine channel geometries , broad and narrow meander belts and lateral continuity of sand in this interval characterizes it to an estuarine to fluvial dominant depositional environment.

Fluvial environment

Overlying the estuarine deposits are two thick intervals which were identified as the MMU to B and B to C intervals. They show characteristics of fluvial deposits and the B to C interval exemplifies this depositional environment. The sand distribution map overlain on the a 50ms window of RMS attribute map in the B to C interval (Figure 8a) shows a significant development of high sinuous meander belts with a broad channel belt width which are about 1000-1500m in the north, central and western part of the study area. Generally the high sinuous channels have width about 100-130m. The well correlation panel (Figure 3b) shows blocky patterns in the discontinuous and stacked sand deposits. The uppermost interval in the area of interest lies between the MMU to B markers and shows high amplitude sandy meander belts which tend to be relatively narrow and with low sinuous scattered small channels have width of 50-80m. In summary, the channel geometry coupled with the discontinuous and stacked sand distribution in these two upper intervals characterizes them as deposited in a fluvial dominant environment.

From early Miocene to the MMU the area was in an overall regression as depositional environments shifted from marginal marine dominant to fluvial dominant. At the same time variations in sediment supply to the fluvial systems affected potential reservoir geometries significantly. For example, compare the D-F to the C-D interval and the B-C to the MMU-B. The best reservoir targets within the study area are the sands between C to D and D to F. In these two intervals the net to gross estimation shows a high percentage of sand. The continuity of sand deposition in broad meander belts provides good reservoirs with high porosity (12 to 20 % from Neutron-porosity log) due to well sorted channel fill sediments and a thick and broad extended sand distribution.

6. Conclusions

The five intervals of interest were dominated by fluvial deposition which consist of channel fill sandstones, fine grained floodplain/overbank deposits, estuarine and coal deposits. The sand distribution maps show dominant north-south oriented meander channel belts systems with low to high sinuosity in fluvial dominated and estuarine environments in the C to F interval. In comparison the intervals between MMU to C show a more scattered distribution of sands with high to low sinuosity in fluvial dominant depositional environments. The bell to blocky shaped continuous thick sands in the C to F interval have the best reservoir potential and quality due to their depositional style and geometry. In summary, the integration of well logs and seismic studies can be used to predict the fluvial reservoir architecture and lead to a better understanding of reservoirs in terms of sand distribution, reservoir quality and channel geometries.

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8. References

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