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

Rutchaneeporn Thongmueen

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

*Corresponding author email: A_silvi@hotmail.com

Abstract

The study area encompasses two new development platforms, PKWA and PKWB in the Pakarang Field, Pattani Basin, Gulf of Thailand where the main reservoirs are fluvial sands. These reservoirs have complex stratigraphic architectures in terms of geometries and continuity which results in high uncertainties in reserve estimation in this field as well as elsewhere in this basin. This study attempts to predict their distribution, geometry and identify depositional environments based on an integrated investigation of wireline log data and seismic data. The 47 study wells were used to determine depositional environment, characterize reservoir architectures and investigate sand distributions. Based on wireline logs, depositional facies were interpreted as channel fills and overbank/floodplain deposits. The I to M interval shows a northeast-southwest orientation of sand channel distribution with clear sand body definition whereas the channel systems are much more variable of distribution of sands in other intervals. Seismic attribute analysis was used to predict sand body orientations, geometries and their areal distributions. The results of seismic based analysis shows a good relationship between high amplitude anomalies and sand distribution interpreted from the well logs, especially in the I to M interval. This study shows the main reasons for reserve estimation downgrading in this field is, (1) there is complex and variable fluvial sand systems and (2) complex structural style in this area. Also the sands are thin and discontinuous even though they are widely extensive at some levels. There are some good areas however, and this study could be used for future well planning in order to increase the production in this area such as by infill drilling in selected locations.

Keywords: Pakarang Field, Sand Distribution, Depositional Environments

1. Introduction

The Pakarang Field is located in the central part of the Pattani Basin, Gulf of Thailand (Figure 1). In the Pattani Basin, the main reservoirs are fluvial sands which have complex stratigraphic architectures in terms of geometries and continuity of reservoirs. This results in high uncertainties in reserve estimation in this basin. This study focuses on an area encompassing two new development platforms, PKWA and PKWB which encountered problems of this kind, with significant downgrading of initial reserve estimations and significant variations of pay, even though some wells are located along similar trends to the exploration wells. In order to understand these uncertainties in the Pakarang field, and integrated study using well log data in combination with seismic data was carried out. Depositional environment analysis was also included in this study.

The main purposes of this study are:

1.) To understand the reservoir architecture of the main intervals of interest in terms of sand body distributions by defining their depositional orientation and geometries.

2.) To determine the various depositional environments of the reservoirs in these intervals of interest.

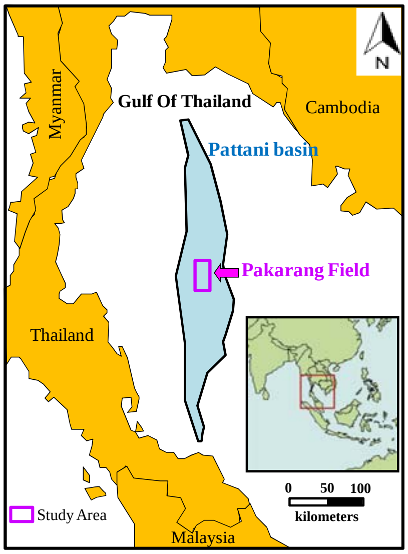

Figure 1. The study area is located within the Pattani Basin, Gulf of Thailand.

2. Methods

An integration well log data and seismic based analysis was used to investigate sand distributions and determine depositional environments within the three intervals of interest. The gamma ray - acoustic impedance crossplots were generated in order to determine the relationship between rock properties and acoustic impedances, and these results can be used to predict the actual seismic response for sands versus shale in the study area. The depositional environment was interpreted based on gamma ray log analysis and the regional stratigraphic setting in the absence of core data. Marker identification and well-to-well correlation were used to construct sand distribution maps that were then used to give preliminary information about the reservoir geometries. Moreover, the combination of gross sand and net pay maps were constructed to study the relationship between sand and hydrocarbon accumulation.

To compare well log data to the seismic, synthetic seismograms were generated. The F, I, M and O markers were interpreted as key horizons and 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 in each interval. The best results were windows ranging from 20 to 50 ms tied to the key horizons.

3. Results

3.1. Well log analysis

Gamma Ray - Acoustic Impedance Crossplots

The lower acoustic impedance intervals match with the low gamma ray as sands between F to I interval. The acoustic impedance curve shows good correlation with gamma ray log response. Good AI separation between sands and shale were observed on the crossplots. This analysis explains that sands should be able to be differentiated from shales on the seismic data in this interval. However, the deeper intervals (I to O) shows lower impedance contrast between sands and shale.

Depositional Environment Analysis

The PK08 well in the northern part and the PK11 well in the southern part were analyzed and show common characteristics such as blocky to bell-shaped low gamma ray curves that were interpreted as channel fill facies and serrated high gamma ray curves that could be interpreted floodplain or overbank deposits. Figure 2 is representative of the depositional environments see in the study area.

The F to I interval showed less channel-sand rich environments in the north than in the southern area. This could be due to the fact that the southern wells were drilled more in the middle of the sand fairway. In the I to M interval, blocky channel sands are interpreted inter-bedded with finer sand-shale intervals which are interpreted as overbank or floodplain deposits. This suggests a fluvial meander belt depositional environment. In the M to O interval sands are generally thinner and floodplain environments are more dominant. This suggests a lack of major fluvial channels in this interval. The regional setting of Sequence 2 and Sequence 3 comprises channel fills and overbank facies.

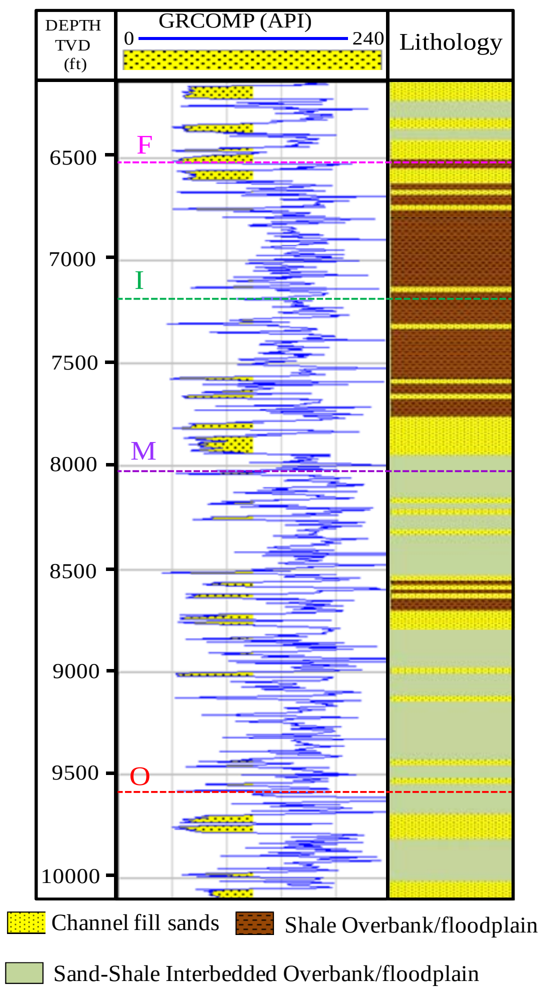

Figure 2. The general interpretation in PK08 well in the northern area shows mainly sand and shale in this area.

Well to Well Correlation and Sand distribution maps

The general observations are explained as below.

Markers: The F and I stratigraphic markers were easy to correlate in both along and across fault blocks, whereas the M and O markers are hard to correlate due to the log curve showing not clear characteristics. Based on observations on the map, the gross thickness isopach map is consistent thickness from the northeast to southwest direction, whereas the interval thickens from northwest to southeast in the direction of basin center that might imply the basinward towards the southeast and the edge of the basin towards the northwest during deposition.

Sands: The sand distribution was investigated using two correlation panels within each interval. The F to I and I to M interval maps are shown here as they have the most net pay in this area.

The F to I interval gross sand map shows two northeast-southwest trending channel belts, with thickest development to southwest (Figure 3a). Net to gross reaches maximum of 30% in this interval (Figure 3b). Well correlation B-B’ (Figure 4) in the south shows thick stacked channel sands in narrow meander belt in the southwest area. Net to gross is highest in this area also. In contrast, the northern area has more discontinuous and thinner sands.

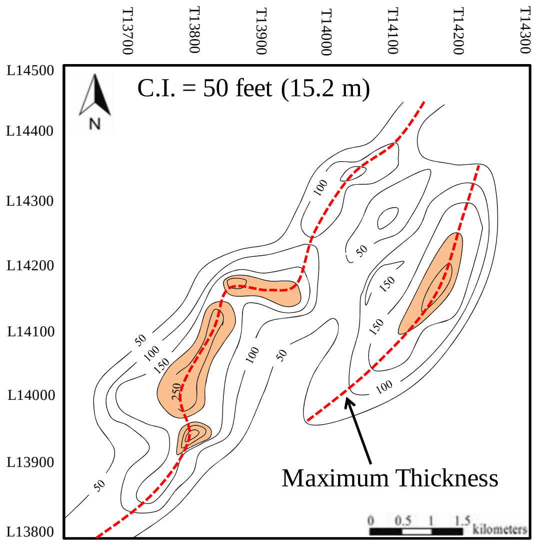

Figure 3a. The gross sand map in F to I interval shows two northeast-southwest trending channel belts.

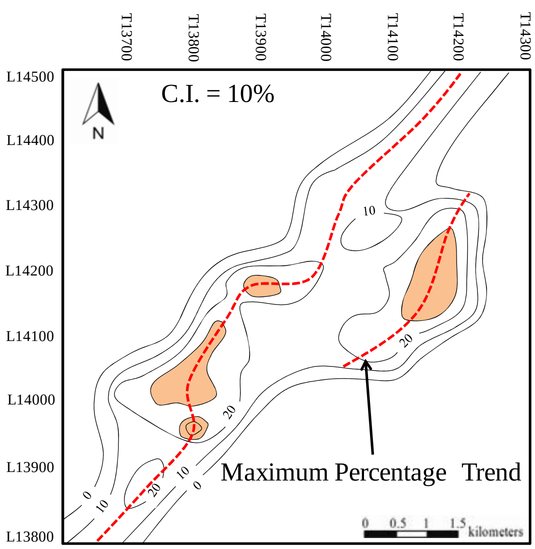

Figure 3b. The net to gross map in F to I interval shows a maximum percentage of 30% trending from northeast-southwest.

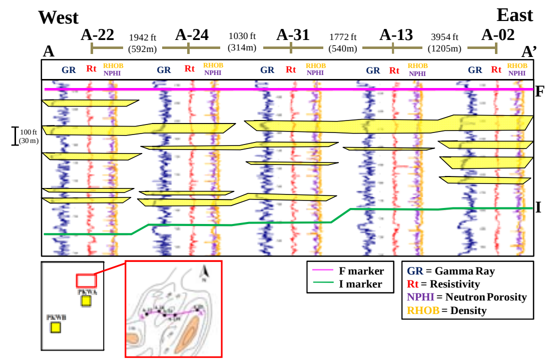

Figure 4. The well to well correlation panel B-B' across fault blocks between F and I interval in the southern area shows thick stacked channel sands in narrow meandering belt.

For the I to M interval, the gross sand map (Figure 5a) shows two northeast-southwest trending channel belts with thickest development to the southwest but more wide spread than the F to I interval. The net to gross sand map (Figure 5b) in this interval reaches maximum of 30% and is more wide spread. The well correlation A-A' (Figure 6) in the northern area shows thin discontinuous sands to east and thicker stacked channel sand to west. Similar variations are seen in the south.

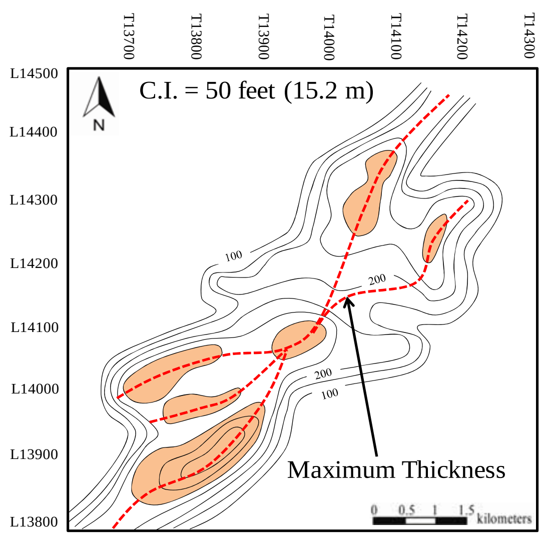

Figure 5a. The gross sand map shows northeast-southwest trending channel belts with thickest development to southwest.

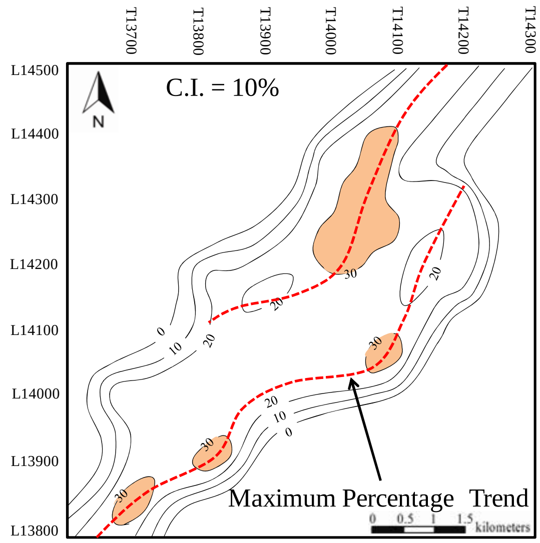

Figure 5b. The net to gross map shows reaches maximum of 30% and is more wide spread.

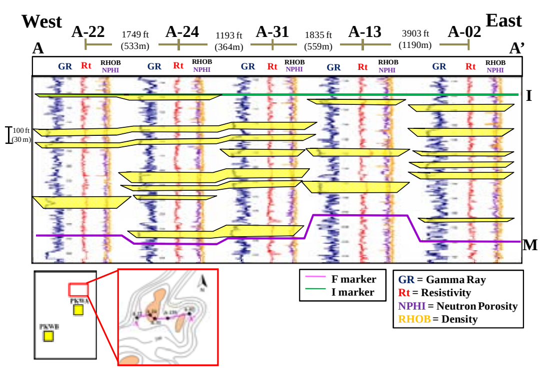

Figure 6. The well to well correlation panel A-A' across fault blocks between I and M interval in the northern area shows thin discontinuous sands to east and thicker stacked channel sand to west.

In the M to O interval the gross sand shows two northeast-southwest trending channel belts but net to gross is overall lower and reaches maximum of 20%. This interval is dominantly discontinuous thin sands compared with other intervals.

In summary, sand systems are quite variable with narrow belts of thick stacked channel sands in some areas and in other areas thin discontinuous sands are more common.

3.2 Seismic interpretation

One synthetic seismogram was generated using the PK02 well in the northern area and has a good correlation between the rock property changes observed in well logs with changes in the seismic response, especially at the key markers. The seismic data has normal polarity and troughs can be mapped as sand bodies.

The four key horizons were mapped and structural style was interpreted to consist of an elongate north to south symmetrical full graben between two less faulted platforms. This structural style is seen at the F marker level (Figure 7) which is representative of the structure at all marker levels. The normal fault systems have tilted fault blocks with gently-dipping strata resulting in three-way dip closures at the upthrown side of both east-dipping and west-dipping faults. Consequently, in this area, the dominant trap style is structurally fault-bound dip closures with shales that act as top seals.

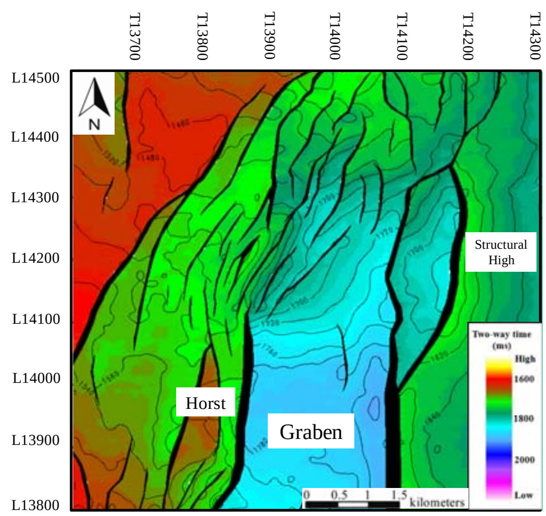

Figure 7. The two-way time structural map of the F horizon shows a dominant north-south trending normal fault system with structural highs to the west, a horst the south-east and graben down the middle in the study area.

The structural high to the east and the horst block in the southeast are the two largest traps in this area. Elsewhere complex faulting creates a lot of smaller traps.

The results of the crossplot analysis and the synthetic seismogram tie show that sands have low impedance in the study area. These sands are troughs on the seismic whereas shale or low-energy environments are represented by the background low amplitudes. The thicker sandstones are represented by higher amplitudes. Three RMS attribute maps using a +20 ms window tied to F, I and M horizons were generated to show sand distribution patterns in each interval.

4. Discussion

The interpretation of depositional environments should be carefully done in the absence of core data. The well log data does not provide a unique interpretation of depositional environment in this sand or shale succession but can be used to determine facies associations in a broader scale which gives better results that interpreting from individual facies only. Also the seismic amplitude extractions do not provide direct information of depositional environments but the observed patterns in the relative acoustic impedance contrasts do show the sand-rich or mud-rich distribution trends. A combined interpretation of both data sets is useful.

Using a combination of overlays of gross sand distribution maps, RMS attribute maps, structural maps and net pay maps, several observations can be explained.

The gross sand map/RMS attribute map overlays show good correlation in each interval. The F to I interval has areas of thick stacked channel sand with low sinuosity but thin unconnected sands covering the rest of the area. As a consequence, this interval is highly variable in distribution of sands (Figure 8).

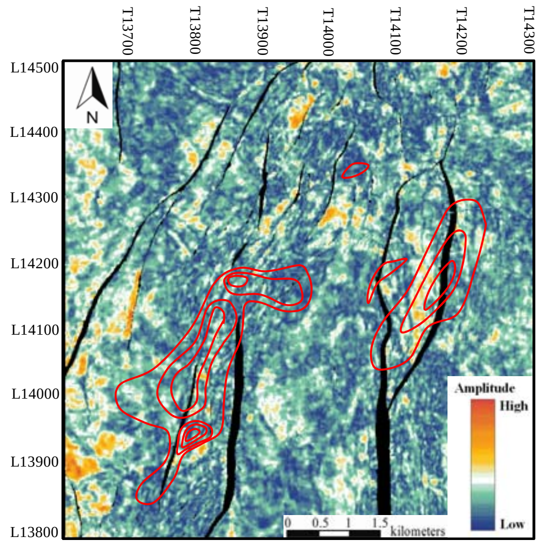

Figure 8. The overlay of the gross sand from well with the +20 ms RMS amplitude map from F horizon shows the concurrence between thick sands and high amplitudes.

The I to M interval map also shows a good match between well and seismic data (Figure 9) and shows a northeast to southwest trending sand distribution because of thicker channel sand deposits than other intervals and good correlation between well to well across fault blocks. The stacked channel belt is quite broad with low sinuosity. The M to O interval shows a poorer correlation due to discontinuous thin sands widespread throughout the area.

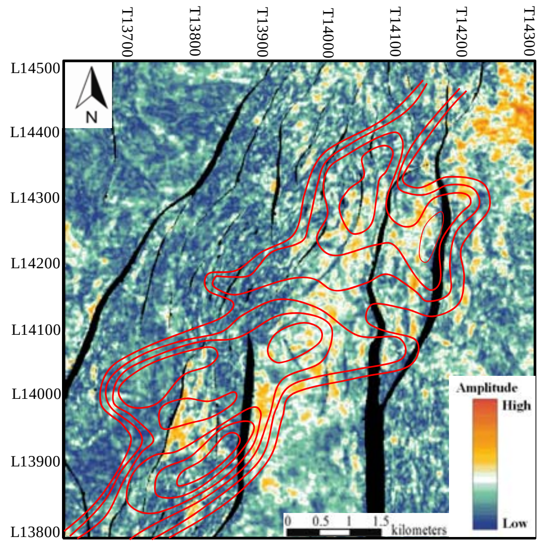

Figure 9. The overlay of the gross sand from well with the +20 ms RMS amplitude map from I horizon shows the concurrence between thick sands and high amplitudes.

In summary sand distribution is highly variable, from narrow stacked channel systems to broad floodplains with thin discontinuous sands. This complexity makes it difficult to estimated reserves in this area.

The gross sand /structural map overlays in the three intervals of interest all show the complex structural styles such as gently dipping tilted strata and many faults in relation to sand distribution. The structural maps generally show limited structural closures. Furthermore, the thickest sands in these intervals are not widespread and often the sand trend cuts across faults leading to smaller space for the hydrocarbon accumulation. This can also cause hydrocarbons to leak across faults and migrate to other areas. These are factors along with the very complexly faulted structural style which downgrade reserve estimations.

The gross sand/net pay map overlays show an obvious mismatch between the net pay maps and the gross sand maps. The I to M interval has high net pay whereas both the F to I and M to O intervals have less net pay. Some well have sands but they have little or no pay. This suggests that net pay distribution is not related to thickness of sands. Consequently, sand distribution is not a significant factor in downgrading reserve estimations in this area which is more related to structural style. The overlay map of the I to M interval (Figure 10) is shown as an example.

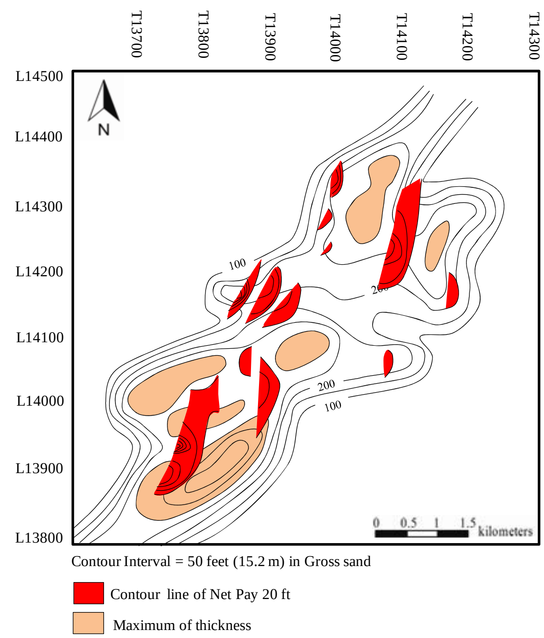

Figure 10. The overlays of the gross sand from well with net pay map for I to M interval shows the gross sand not matching with net pay. Some wells have high thickness of sand with little or no pay.

In summary, the best reservoir targets within the study area are the sands between I to M interval. This is because in this interval the sands are deposited in a broad meander belt right across the area and provide good reservoir qualities such as high porosity (12 to 20 percent from neutron porosity logs) due to well-sorted channel fill sediments and considerable thickness of sand. However, the complex structure still makes it hard predicting reserves and planning development.

5. Conclusions

Using an integration of well log and seismic data, sand distributions and depositional environment analysis the following conclusions can be made;

- The three intervals of interest were dominated by fluvial deposition which consists of channel fill sandstones and extensive fine-grained floodplain/overbank deposits.
- The sand distribution maps shows a broad meander channel with low to high sinuosity oriented in the northeast-southwest in I to M interval whereas the channel systems are much more variable of distribution in the other intervals.
- The amplitude extractions from seismic data show the northeast-southwest trend of distribution of sands in the I to M interval whereas the F to I and the M to O intervals have quite scattered amplitude extractions.
- The I to M interval has the best reservoir potential due to considerable sand thickness and good reservoir quality represented by the blocky channel restricted sands.
- The combination of gross sand map and structural map shows complex structure is the one factor of downgrading reserve estimations in this study.
- The correlation between gross sand distribution and net pay is not good in each interval of interest. Some wells have high gross sand but they have less pay or no pay.

In summary, the problems related to downgrading reserve estimations is due to (1) complex and variable fluvial sand systems and (2) complex structural style in this area.

6. Acknowledgements

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