ARCHITECTURE AND DEPOSITIONAL ENVIRONMENT OF FLUVIAL SANDS IN MORAGOT FIELD OF PATTANI BASIN, GULF OF THAILAND

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Abstract

Pattani Basin is one of the most prolific hydrocarbon producing basins of the Gulf of Thailand. The reservoirs in the Pattani Basin are Early to Middle Miocene fluvial channel and overbank sands. Owing to the nature of fluvial deposits, reservoir sands are both laterally and vertically restricted, hence it is not always possible to predict the geometry and distribution of these sands based on the conventional seismic interpretation. This study aims to predict sand distribution by applying advanced imaging techniques such as RMS amplitude analysis, spectral decomposition, semblance and dip steered similarity. At shallow stratigraphic levels, RMS and semblance successfully identified sand bodies and mud filled channels associated with channel belts. On the other hand, deeper stratigraphic levels can be imaged more effectively by using spectral decomposition and dip steered similarity volumes. These images show the distribution of sands and mud filled channels at different stratigraphic level. The width of channel belts varies from 200 m to 3 km. These channel belts are N-S or NW-SE oriented. The depositional environment analysis in the zone of interest was carried out on the basis of seismic geomorphology assisted by the well log data. Broad channel belts in horizon slices and stacked channel sands in well log in the Early Miocene (O to K interval) are suggestive of the fluvial depositional environment. Whereas narrow channel belts with the widespread occurrence of coals in the early Middle Miocene (K to D interval) suggests that the deposition occurred in marginal marine setting. Very well developed meander belts in horizon slices and fining upward succession in well logs suggest depositional environment in the rest of the Middle Miocene (D to B interval) was predominantly fluvial. Mud filled channels identified in the horizon slices might act as a barrier and compartmentalize the reservoir. The proposed workflow of sand prediction in this study might help to reduce exploration risk.

Keywords: Spectral decomposition, RMS and Semblance.

1. Introduction

Pattani Basin is located at the centre of the Gulf of Thailand and consists of several structurally complex extensional basins. The study area Moragot field is located in the south of Pattani Basin. Major gas reservoirs are fluvial and deltaic sands. The fluvial depositional systems developed as an extensive fluvial/delta plain and rapidly avulsing meander belts. These sands are mostly thin and of small-scale lateral distribution, occasionally are in form of thick point-bar accretions. It is always not possible to predict the sand distribution based on conventional seismic data because of their rapid vertical and horizontal changes. The aim of this study is to image the sand distribution in the area. I applied attribute analysis and spectral decomposition techniques to detect the fluvial sand reservoirs within the study area.

This study utilizes the well logs and seismic geomorphology to examine the geometry and spatial distribution of sand bodies of Miocene fluvial system in the

Moragot field of the Pattani basin. Specific objectives of this research are following.

1) To evaluate the effectiveness of seismic attributes to delineate fluvial styles in the study area.

2) Defining sand bodies and observe changes in sand bodies and linking the variations in fluvial style with depositional environment

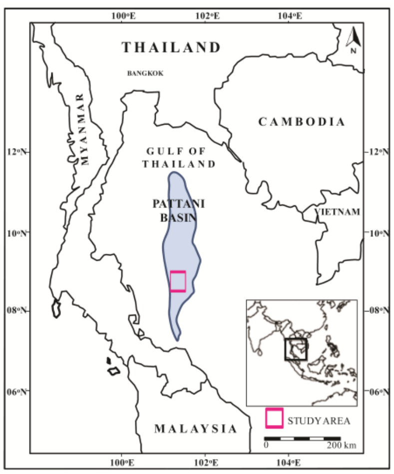

Figure 1. The location map of Moragot field, Gulf of Thailand.

2. Methods

Integration well logs data and seismic based analysis was used to compare well log data to the seismic, synthetic seismograms were generated. Three main B, D, K and O markers were interpreted as key horizons, and horizon slices within those intervals, which were used to generate seismic attribute, seismic coherence and CWT amplitude frequency for sand distribution. Semblance analysis was performed to identify channels. Finally sand distribution model were prepared in zone of interest with identification of depositional environment.

3. Results

3.1 Well log correlation and synthetic seismogram

Well log correlation shows that there are multiple sand bodies within the zone of the interest. The vertical and lateral distribution of these sands shows rapid variations. Some sands are only limited to narrow zones, while others are covering larger area.

The seismic data is of normal polarity as seabed (increase in acoustic impedance) is represented by peak. The synthetic seismograms of all four wells show reasonable cross correlation coefficients (greater than 60%) when compared with seismic data. Acoustic impedance of the sands is comparatively lower than shale. Consequently, the amplitudes are negative for sands on the synthetic and seismic data.

3.2 Seismic interpretation

The seismic character for B, D, K and O are mentioned markers represent low acoustic impedance and their synthetic response is trough, but on the seismic data, these markers were picked on nearby positive peak to perform the interpretation conveniently.

The two-way-time structural map is shown planar normal faults oriented north-south are common. The normal fault systems are defined as tilted fault blocks that cause gently dipping strata, which create dominant structural highs or three-way dip closures at the upthrown side of west-dipping fault.

3.3 Spectral decomposition analysis

A cross section of the amplitude-tuning cube with a short temporal window (24 ms) in the zone of interest shows that signals are in the range of 10~50 Hz. The spectral decomposition technique (CWT) reveals that amplitude is different for each frequency. The observations suggest lower frequencies (20-25 Hz) shows higher amplitude for thicker sands (>15m) and vice versa. RGB blending of different frequencies was particularly helpful in identification of channels.

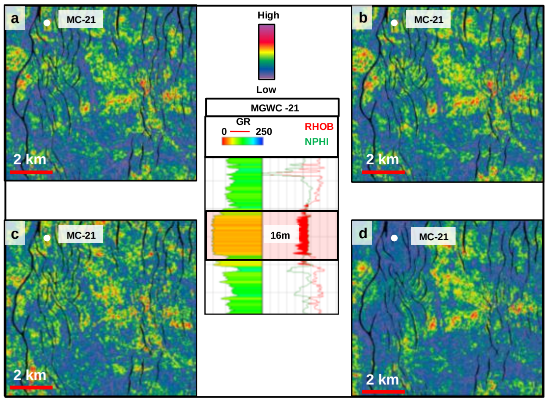

Figure 2. DFT 20 Hz (a) and 45 Hz (b) slices give identical response for 16m thick sand whereas CWT 20 Hz (c) and 45 Hz (d) give different response.

3.4 RMS attribute map analysis

Comparing between above and below K horizon. RMS amplitudes successfully identified thick sands (up to 10 meter), but it is not easy to detect thin sands (less than 10 meters) by using the RMS maps (**Fig.3**). The sands below K marker are mostly thick as compared to the sands below the K maker. On the other hand, sands between D and K marker are thin and narrow window extraction is required identify the sands.

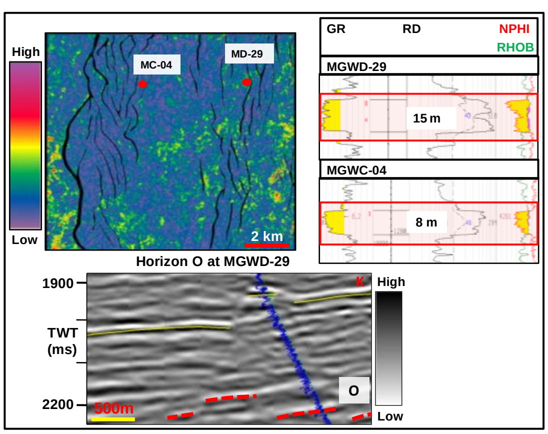

Figure 3: RMS shows high amplitude for 15m thick sand whereas no amplitude has been observed for 8m thick sand

3.5 Seismic coherence analysis

Coherency slices up to K-marker show good quality images and it is easy to interpret channels and sands, but the quality of coherency images below K-marker is not as good as of coherency slices above F-marker (**Fig.4**). Width of channels and channel belts can be measured by using coherency horizon slices and vertical sections. I measured width of channels and channel belts on various horizon slices, which are mentioned in the next section.

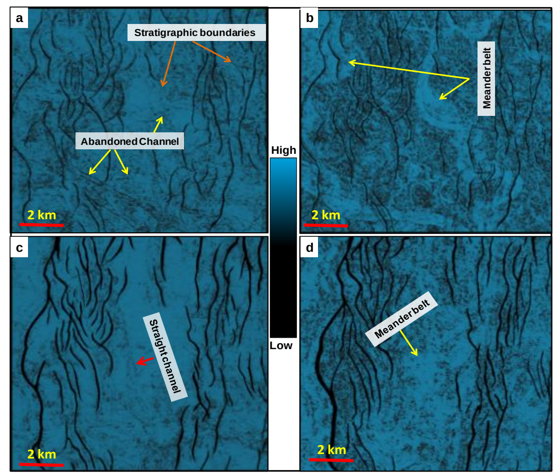

Figure 4: Semblance slices of Horizon B+80 (a), B+250 (b) (above K marker), K (c) and O (d) (below K-marker).

3.6 Mapping of sands

An examination of the illustrated nine horizon slices reveals a landscape of the different channel belts being closely spaced in vertical space. I tried to map the sands and associated channels by combining different techniques. Nine horizon slices were selected to coincide as close as possible with the sand bodies represented by bright negative amplitudes within the study interval.

In B to D interval

At the shallowest horizon slice shows most prominent and clear image of fluvial systems as compared to other horizon slices of deeper part. The horizon slice of RMS attribute shows well-developed NW-SE oriented fluvial system of high sinuosity (**Fig.5**). The paleoflow direction is towards the south-southeast. The channel belt width is very broad. This channel belt width is similar size in comparison with shallow seismic study of high-resolution seismic data that indicates the width of meander belts of Gulf Thailand (Posamentier & Kolla, 2003).

In D to K interval

Sands in this interval are thin hence CWT slice of 45 Hz has been utilized to map sands in this interval. Well log shows this interval contains abundant coal deposits. Some of the high amplitudes in horizon slices can be attributed to the presence of coal. Channel belts and associated channel width are narrow (**Fig. 6)**

In K to O interval

The horizon slices were analyzed between K & O marker by using lower frequency volumes as the sand thickness is higher. Spectral decomposition 20 Hz and dip steered similarity volume can adequately delineate the sands and associated mud filled channel. This interval shows broad channel belt. The width of the channel belt is in the range of 3 km and analogous to the ones found in the interval B to D. One noticeable feature in this interval is sand filled channel. This is indicative of back filling process due to marine transgression.

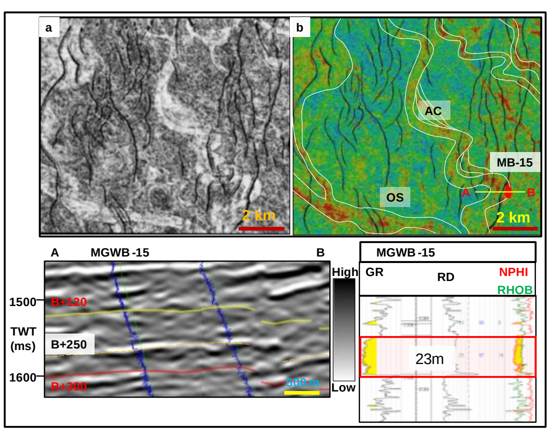

Figure 5: Dip steered similarity map (a) and RMS overlay on semblance (b) at horizon slice B+250. Well log shows sand at the location of high amplitude.

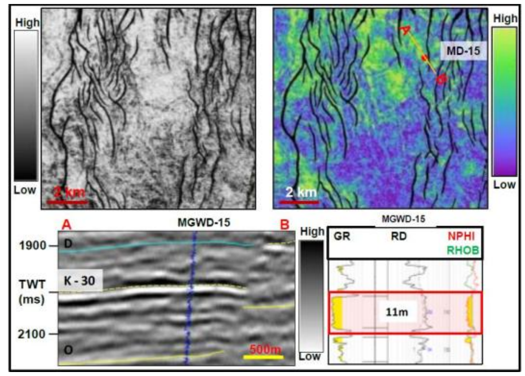

Figure 6: Dip steered similarity map (a) and RMS overlay on semblance (b) at horizon slice K-30. Well log shows sand at the location of high amplitude.

4. Discussion

4.1 Sand body Characteristics

The observed channel belt widths and channel widths are summarized in Table 1 for comparison. Channel belts widths below K marker and above D marker are larger as compared to channel belt width between D & K. Moreover, the channel widths above D marker and below K marker are in comparison with modern Chao Phraya River, while the meander belts between K & D have relatively small size (Table 1).

Age	Key Horizon	Horizon slices	Channel belt width	Channel width
Middle Miocene	B			
		B+80	1000- 2500 m	152 – 470 m
		B+180	300 – 500 m	50 – 60 m
		B+250	2000 – 3200 m	147 – 230 m
	D		200 – 800 m	60 – 100 m
		K- 150	200 - 400 m	90 – 200 m
		K-80	250 – 450 m	80 – 130 m
		K-30	230 – 420 m	60 – 170 m
	K		250 – 800 m	152 – 347 m
Early Miocene		O-100	500 – 2000 m	70 – 280 m
		O-50	500 - 2000 m	100 -250 m
	O		1000 – 3000 m	120 – 330 m

Table1: Summary of channel parameters observed at different stratigraphic level.

The fluvial system within K - O interval has multiple channel sands, which are mostly north-south trending. The sands are associated with broad N-S meander belts. Whereas D - K interval shows narrow meander belts, and there are also some high amplitude features in the selected horizon slices without any distinctive pattern. The high amplitude features are most likely because of the prevalence of coal.

The horizon slices B+80, B+180 and b+250 are characterized by paleoflow towards the south-southeast. B+80 and B+250 have sands associated with large single meander belts, while B+180 shows multiple narrow meander belts. The morphology of meander belts observed on B+250 is similar to the channel belts between K to O.

Fluvial system size and pattern change rapidly in the area over a short time window of 15 to 20 ms. An attempt at interpreting depositional environment has been undertaken to decipher the variability in channel systems and will be discussed in the next section.

4.2 Depositional Environment

Based on the variability of seismic geomorphology the zone of interest has been divided into three periods. Period 1 (**Horizon O to K**), Period 2 (**Horizon K to D**) and Period 3 (**Horizon D to B**). The depositional environment was carried out on the basis of seismic geomorphology with assistance of well logs.

The Early Miocene (O to K interval) shows well developed broad meander belts in the horizon slices and stacked channel sands in the well logs hence interpreted as fluvial environment. Whereas narrow meander belts with widespread occurrence of coals in the early Middle Miocene (K to D interval) suggests that the deposition occurred in the marginal marine setting. Very well developed meander belt and fining upward succession in the well log suggest depositional environment in the rest of the Middle Miocene (D to B interval) was predominantly Fluvial (**Fig.7**).

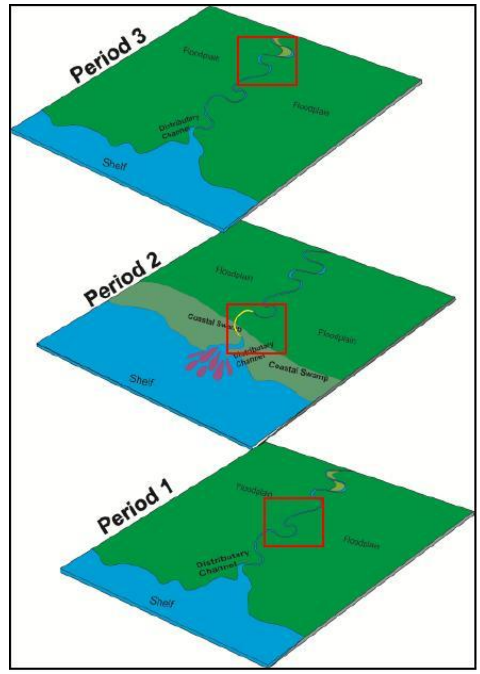

Figure 7: Paleogeography of depositional environments at different period.

4.3 Key findings and conclusions

Different geophysical techniques were applied to map the reservoir sands. Key findings and conclusions of the present study are summarized below.

1. Amplitude response of CWT spectral decomposition is different for different thickness of sands. Low frequencies (20-25 Hz) show high amplitudes for thick sands (>15m), while higher frequencies show bright amplitudes for relatively thinner sand beds.
2. Amplitude values of 20 Hz CWT spectral decomposition are directly proportional to hydrocarbon saturation. Amplitudes are higher for hydrocarbon bearing sands as compared to water-wet sands. Amplitude maps of low frequency can be used to detect prospect zones of hydrocarbon exploration.
3. RMS amplitude maps are useful to detect sand distribution associated with meander belts down to certain depth i.e. down to K marker.

4. 20 Hz CWT spectral decomposition along with coherency volume successfully mapped sands and mud filled channels. These mud-filled channels may act as barrier between two separate sand bodies. This may help to identify different reservoir compartments.
5. Meander belts above D and below K are broader compared to the meander belts in D to K interval.
6. The depositional environments in period 1, 2 and 3 are fluvial, marginal marine and fluvial respectively.

5. Acknowledgements

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