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Seismic Geomorphology and Depositional Environment from Upper Miocene to Recent in the Pattani Basin, Gulf of Thailand.

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Abstract

Integration of 3D seismic and well data reveals excellent fluvial geomorphology in the uppermost 900ms interval in the Pattani basin, Gulf of Thailand. Seismic attribute analysis technique was adopted to establish depositional environment from Upper Miocene to Recent succession. RMS, sweetness, semblance and spectral decomposition attributes are analyzed over forty key horizons. Spectral decomposition and sweetness exhibited better image as opposed to RMS image in all interval. Well log correlation of attributes and lithology show that sand gives high sweetness and high amplitude response, whereas, low sweetness and low amplitude is associated with shale. Based on fluvial styles the whole study interval is divided into five periods. Period 1 is characterized by moderate to high sinuous fluvial systems in the lower part. Backfilled sandy channels and low sinuosity systems are characterized in the upper part of the interval indicating a transgressive period. High to moderate sinuous systems with well developed meander belts are found in Period 2. Period 3 comprised of wide and low sinuosity channels associated with widespread coal deposition in an estuarine environment. Continuous, low amplitude and transparent reflection package exemplify Period 4 and indicate a marine deposition. Period 5 is dominated by broad, high sinuosity fluvial systems resting within incised valley with occasional unincised fluvial systems. Such wide variation in the fluvial styles serves as a warning towards a rather simplified assumption of fluvial styles and dimensions during reservoir modeling.

Keywords: Seismic Geomorphology, Seismic Attributes, Pattani Basin, Gulf of Thailand

1. Introduction

Seismic geomorphology has long been used as an essential tool for analyzing facies from different depositional settings (Davies et al., 2007). The complex architecture of fluvial systems has always been a problem in proper prediction of the reservoir sand. The study involves attribute analysis of 3D seismic volume and wireline log to document in detail the fluvial geomorphology and related facies in the uppermost 900ms interval in the central Pattani basin, Gulf of Thailand. RMS. sweetness, semblance and spectral decomposition attributes were used in the study. The main objective was to identify suitable seismic attributes for better imaging fluvial geomorphology and establishing the depositional environments for the upper Miocene to Recent succession in the Pattani Basin

2. Methods

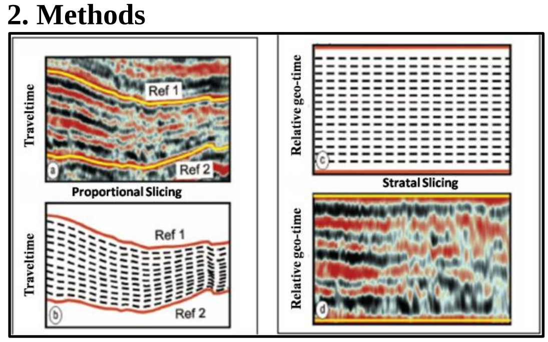

Figure 1 – Stratal and Proportional slicing method of horizon calculation (after Zeng, 2001).

The methodology involved analysis on both wireline and seismic data. Workflow started with interpreting key horizons in different stratigraphic interval. Later, intermediate intervals are divided into several slices by either stratal or proportional slicing method depending upon the nature of consistency of reflective packages (Figure 1).

The essential next step was to extract seismic attributes over the slices with equal analysis window. An analysis window of ±10ms, ± 20ms and +30ms was used in the study interval for all the four types of attributes. The attributes are compared with each-other to identify attributes that gave best image. Finally, the wireline trend and key lithological features are integrated with geologically significant geomorphic features to interpret the depositional environment of a particular interval.

3. Results

WIRELINE ANALYSIS

The available wells are analyzed for the dominant lithology in the study interval. From NPHI-RHOB cross plot in well 4, it was found that four types of lithology were present in the study interval (Figure 2a). Sand of the study area shows low density than shale and plot in the central part separated from the high GR shale in the lower part. Coal and coaly shale are other types of lithology found in the study interval. Wireline correlation across the study interval shows that the sand proportion gradually decreases upward and towards the south indicating the depositional system was shifting into more basinward towards south and in the upper part of the study area (Figure 2b).

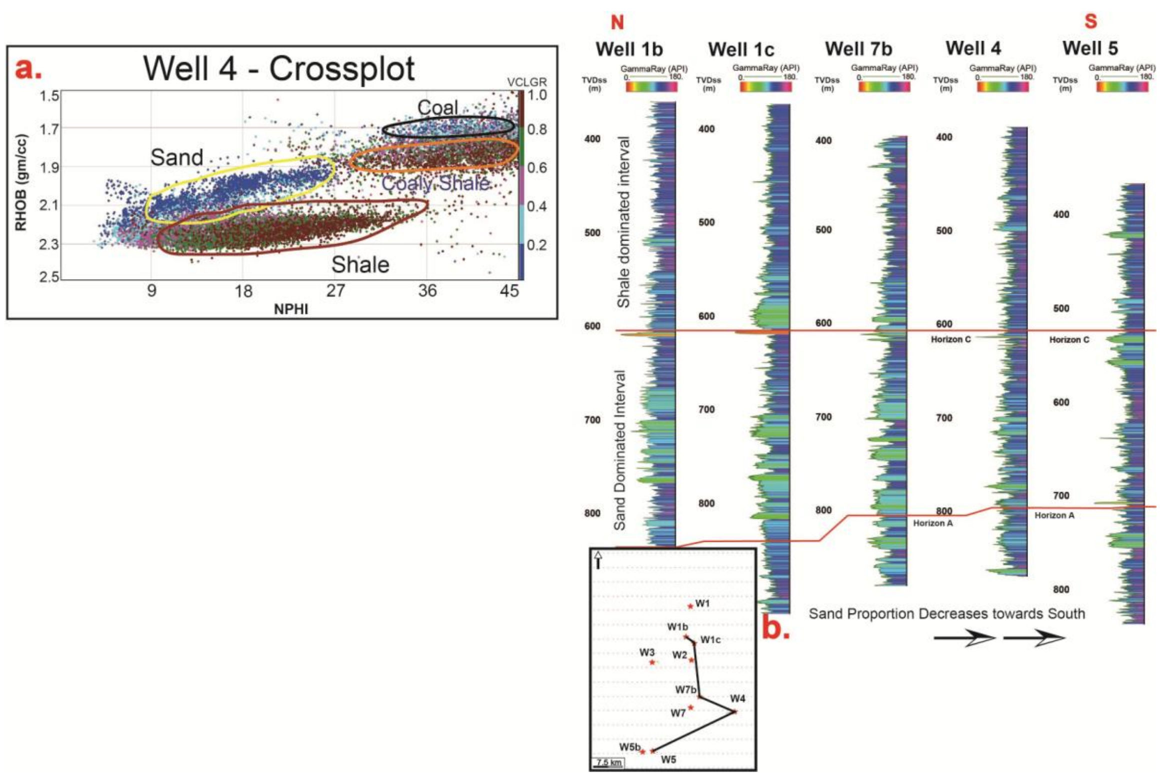

Figure 2 – Wireline analysis; 2a – NPHI-RHOB cross plot showing dominant lithology in the study interval; 2b – General GR trend in the study interval

SEISMIC ATTRIBUTE ANALYSIS

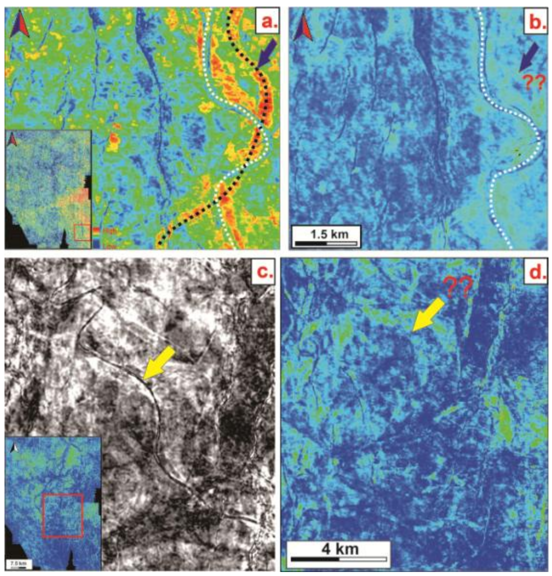

Figure 3 – Sweetness map (3a) showing clear fluvial geomorphology than RMS (3b); Spectral Decomposition 60Hz amplitude spectra clearly showing narrow features (3c) compared with RMS (3d);

Different seismic attributes were effective in different levels of the study interval. In the deeper section (500-900ms, below horizon C) spectral decomposition amplitude spectra and sweetness resulted better compared with RMS. Moreover, discrete frequency amplitude spectrum was often successful identifying subtle channelized features where other methods were not so effective. Conversely, in the intermediate interval (250-500ms) all the attributes gave similar result. The low reflective seismic packages are probably responsible for the poor image quality. In the lower interval (100-250ms) all the attributes gave better results. However, combination with semblance by opacity rendering is found to be more effective rather than single attributes.

SEISMIC GEOMORPHOLOGY

Slice A+80

Slice A+80 represents the deeper parts in the study interval. The seismic geomorphology as revealed from the sweetness map show moderate to high sinuous fluvial systems (Figure 4a). The high sweetness values are found to be associated with sand dominated interval while low sweetness represents shale prone interval in the well (Figure 5).

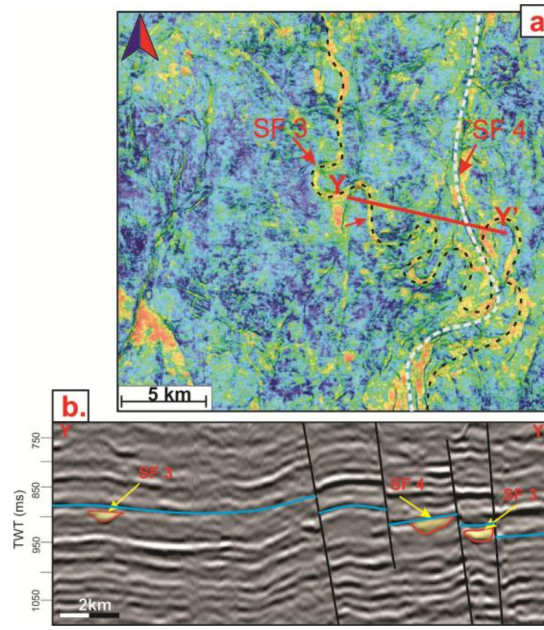

Figure 4 – Sweetness attribute map of slice A+80 showing two channelized system (4a); Trough over peak response on the channel fill indicating sand filled channel (4b);

A high sinuosity fluvial system observed in the slice showing high sweetness value in the channel suggesting a sandy back filled channel system of transgression (Figure 4b). Other channels found in this interval are characterized by low sweetness response indicating a mud filled channel.

Horizon A

The horizon is characterized by two broad and low sinuosity channelized system with no visible evidence of bar migration

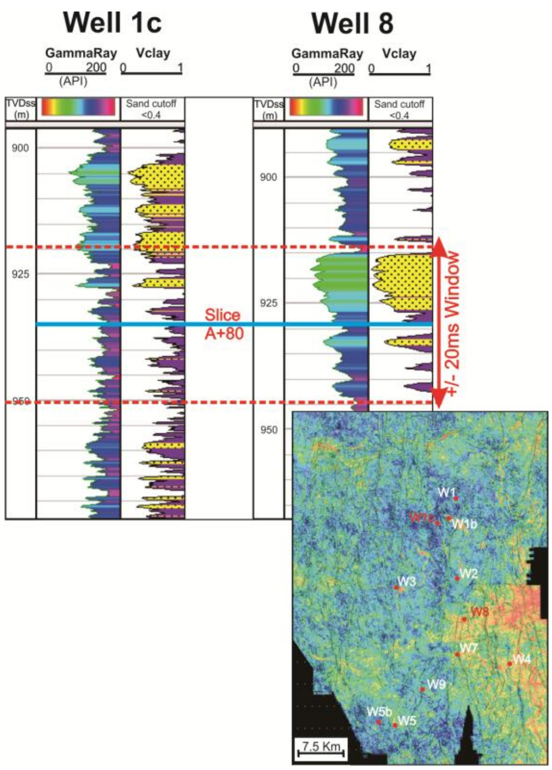

Figure 5 – GR log shows good correlation between sweetness and lithology in the slice A+80.

The channels are filled with low sweetness values indicating mud filled systems. There was extensive occurrence of coal in the NE-SW corner of the slice as indicated by very high sweetness and low GR wireline character.

Slice B2

The slice is characterized by broad sinuous fluvial systems as observed from sweetness attribute map in combination with semblance. Moderate to high sinuous channelized features are observed in different parts of the slice. Channels are found to be filled with low sweetness mud and associated point bars are related to high sweetness sand prone facies (Figure 6).

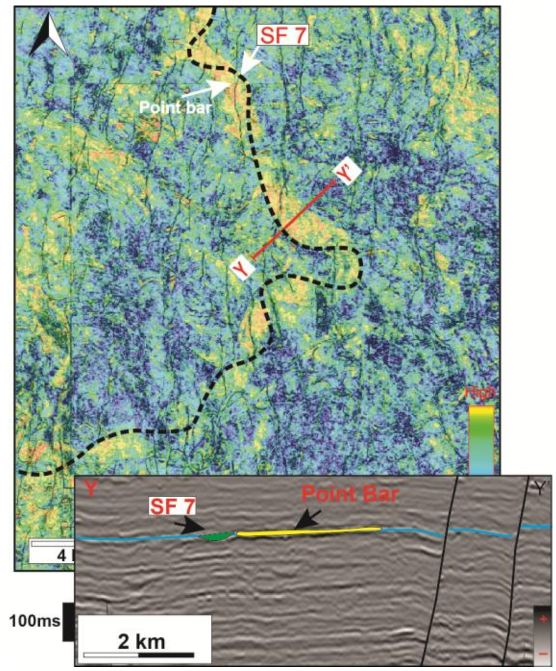

Figure 6 – Seismic attribute map and cross section showing meander belt with point bar and mud filled channel.

Horizon C

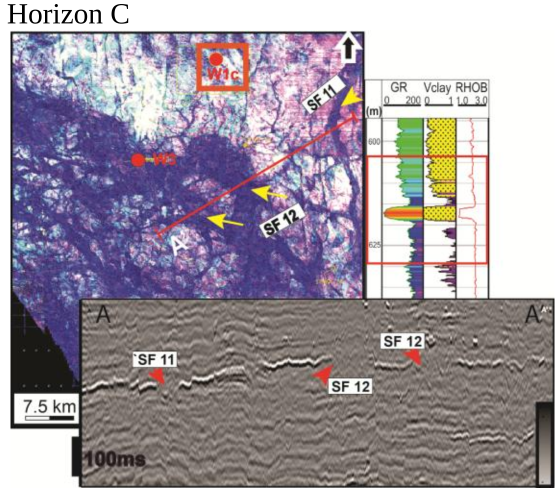

Figure 7 – Spectral decomposition amplitude spectra map of Horizon C, showing low sinuosity mud filled channel.

The spectral decomposition RGB blending of 40Hz, 50HZ and 70Hz frequency amplitude spectrum shows low sinuosity and low amplitude channelized features prevailing in the horizon. The broad mud filled channels often appear to be highly dissected (Figure 7). The high amplitude parts of the slice in the wireline log are found to be associated with thick (6m) coal layer.

Slice F

Slice F is represented by sweetness attribute map which shows scattered high sweetness response all over the slice.

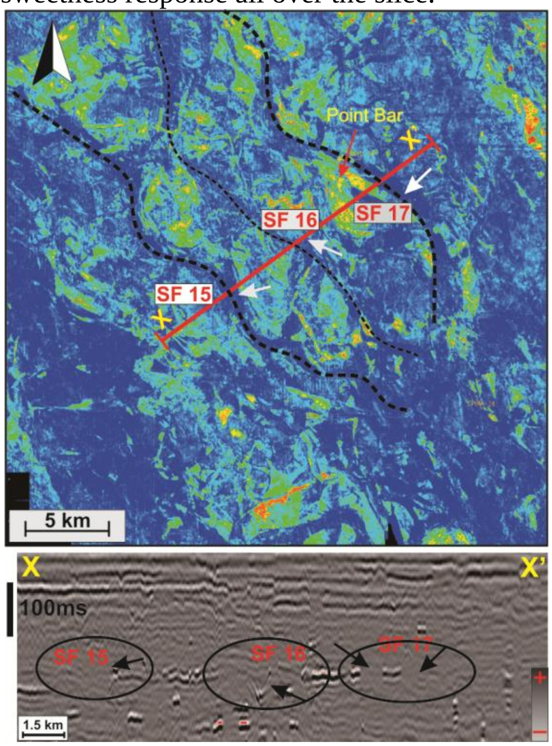

Figure 8 – Sweetness map showing channelized features of slice F

These high sweetness areas are crosscut by low sweetness sinuous channelized systems (Figure 8). These channels run in a low to moderate sinuosity course. The high sweetness response next to low sweetness channels is probably indicative of point par deposits.

Horizon G

Sweetness map of horizon G shows two channelized features of low to high sinuosity running from the NW-SE of the horizon. The channels are filled with low sweetness material indicating a mud filled system, while the meander loops are characterized by high sweetness response indicating a sand prone point bar. The horizon is characterized by increasingly higher numbers of channelized features.

Slice SF+70

The RMS attribute in combination with semblance shows broad, high sinuosity fluvial system with excellent lateral migration point bar geometry. Bar expansion and translation is clearly visible in the attribute map (Figure 9). Presence of tributary incised valley is noticed in different parts of the slice mainly in the interfluves of the major trunk valley. Channels are filled with low amplitude mud while point bars are possible sand prone area.

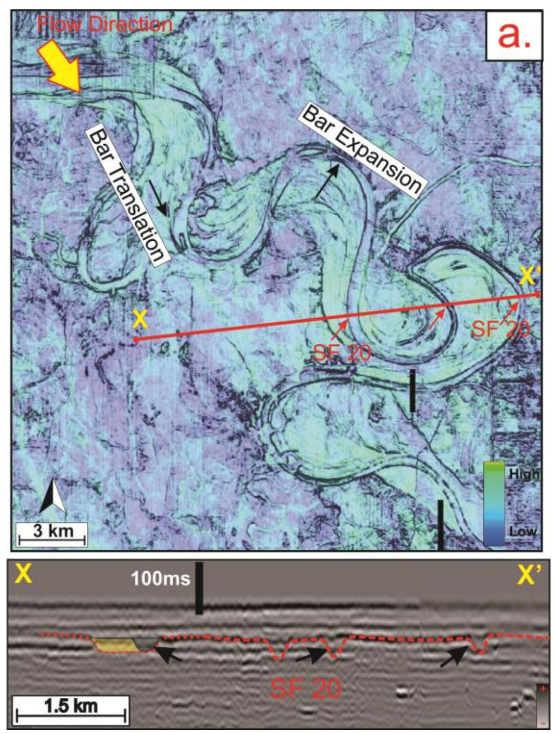

Figure 9 – RMS and semblance combination map showing geomorphologic features of incised fluvial system at slice SF+70.

4. Discussion

DEPOSITIONAL ENVIRONMENT

In this part, GR log trend and seismic geomorphological analysis was integrated to interpret depositional environment and channel evolution from Upper Miocene to Recent succession in the Pattani Basin, Gulf of Thailand. Based on the change in fluvial styles the whole interval is divided into five periods. The depositional environment interpretation is presented below -

Period 1 (900-700ms)

Seismic attribute maps of this interval show abundant moderate to high sinuosity channelized systems. The transgression period is marked by the presence of back filled sandy channel in the slice A+80. The upper part of this unit, the fluvial style changes to low sinuous system. Such low sinuous system with no evident bar migration indicates a low accommodation lower delta plain setting (Miall, 2002). The fining upward log response of this interval also indicates a fluvial dominance in this period. Therefore, Period 1 represents Fluvial dominated interval with estuarine influence in the top (Figure 10, Period 1).

Period 2 (700-600ms)

The period is characterized by high to moderate sinuosity fluvial system with well developed meander belt. Seismic attribute maps show abundant channelized features that are filled with mud. The wireline response show an overall high GR interval with occasional low GR fining upward interval interpreted as point bar deposit associated with the channelized features observed in the attribute maps. It is interpreted as a fluvial dominated interval (Figure 10, Period 2).

Period 3 (600-450ms)

The seismic attribute analysis of horizon C of this interval reveals a geomorphologic feature that closely resemblance to a lower part of an estuarine system with dissected distributary channel. The broad, low sinuosity channels are filled with low amplitude and transparent material indicating a mud filled system. The high amplitude areas are found to be associated with widespread and thick (~6m) coal layer. Such widespread coal deposition is more common of the infill of inter-distributary bay setting near coast (Fieldings, 1987). The low sinuosity mud filled channel and widespread coal occurrence indicate that the depositional environment represents an estuarine dominated interval (Figure 10, Period 3).

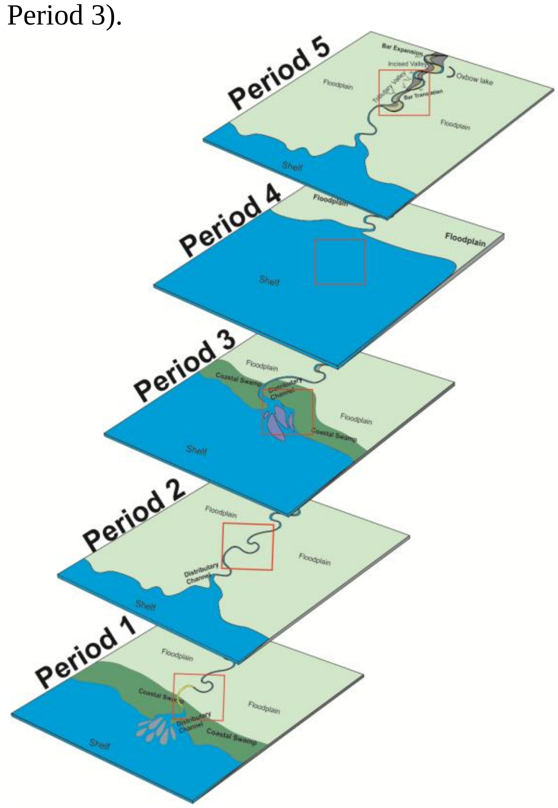

Figure 10 – Simplified depositional model of major periods in the study interval.

Period 4 (450-250ms)

The seismic attribute maps of this interval give very low RMS amplitude distribution and few slices with recognizable channelized features. Seismically, this interval is characterized by low amplitude, transparent reflection indicating a continuous low energy condition of deposition as of open marine setting (Reijenstein, 2011). The wireline response of this interval is characterized by very high GR interval with occasional low GR fining upward interval probably related with point bar deposits of the fluvial systems of this interval. Overall, the deposition of this period was probably taken place in a Marine influenced environment with occasional fluvial intervene (Figure 10, Period 4).

Period 5 (250-100ms)

Continuous and high reflective package characterizes the seismic section of this interval. High to moderate sinuous fluvial systems are frequently found in the attribute map. Most of these fluvial systems rest within incised trunk valley with occasional unincised fluvial system. The identification of incision is the presence of tributary incised valley in the inter-fluve area which feed the main trunk valley. The seismic geomorphologic features are closely resembles the modern day underfit incised fluvial systems as of Red Deer River, Central Canada. The sediments of period 5 is interpreted to be deposited in a fluvial dominated environment (Figure 10, Period 5)

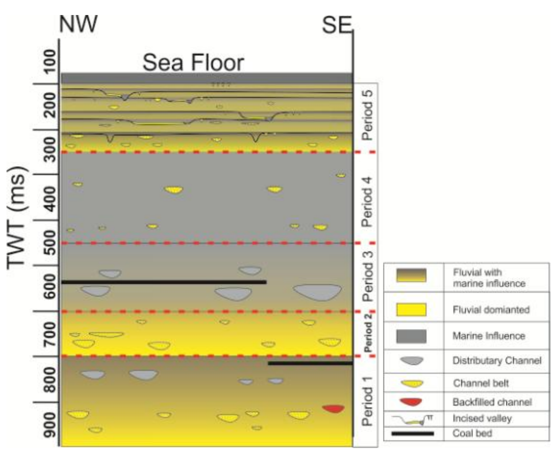

Figure 11 – Chronostratigraphic chart showing fluvial styles with the change in depositional environment.

A chronostratigraphic evolution of fluvial styles is shown in Figure 11. Low sinuosity, broad and wide mud filled channel and high amplitude sand filled channel represents period of low accommodation in a highstand/transgressive period. On the other hand, highly sinuous fluvial system with well developed meander belts represent period of modest accommodation system (Miall, 2002). Fluvial systems resting within incised systems indicate lowstand period (Posamentier, 2001).

FLUVIAL CONTROLLING FACTORS

The major control of fluvial system, as suggested by Miall (2002), is the change in the accommodation space by means of change in subsidence and/or change in eustatic sea level. However, the role of eustacy diminishes upstream while local factors (climate/subsidence) become dominant (Posamentier and Allen, 1999). The study interval as represent post-rift succession and tectonics has no significant influence on the fluvial styles. Therefore, the dominant control of the fluvial styles is more likely to be eustatic changes in sea level or pronounced climatic fluctuation. The evidence of sea level fluctuation in the Upper Miocene is evident by alternation of estuarine system and broad floodplain fluvial system. During Pleistocene, the marine influence was not observed in the seismic attribute map. This is not surprising, given the low range of tidal and wave action in the present day Gulf of Thailand area. Moreover, the underfit incised fluvial systems indicate a significant role of fluvial discharge as found in the modern day incised underfit fluvial systems. However, the role of sea level change could not be left alone, provided that the Pleistocene is characterized by large scale sea level change. It is only reasonable to assume that the fluvial styles of Pleistocene in dominated by both eustatic as well as climatic fluctuation.

5. Conclusions

This study confirms that sweetness and spectral decomposition has better ability to image fluvial geomorphology as compared with RMS attribute. The aforementioned attributes are effective predicting lithology where high sweetness and high amplitude indicate sand while low amplitude and low sweetness indicate shale. The post-rift succession of the study interval was not influenced by rifting. Basin formation was controlled by slow thermal subsidence. Change in the fluvial styles resulted as a response of change in depositional environment. Five depositional periods are identified within the study interval. Period 1 (900-700ms) begins with moderate to high sinuosity fluvial systems which gradually taken over by sand filled channel and low sinuosity mud filled channel of transgression period. Period 2 (700-600ms) represents fluvial dominance and moderate to high sinuosity fluvial systems. Period 3 (600-450ms) indicates low sinuosity and broad channel with widespread coal occurrence in an estuarine setting. Period 4 (450-250ms) is dominated by low reflective and transparent package of Marine deposition. Period 5 (250-100ms) is represented by high sinuosity fluvial system resting within incised valley. The seismic attribute map shows that the channels are mainly filled with mud, while point bar is the sand prone part of a fluvial system. The continuous mud filled channel is most likely to cut across the point bar and disturb the lateral connectedness of the sand deposits. Moreover, the wide variation in the fluvial styles should be taken as a warning against rather simplistic assumptions of fluvial styles and dimensions during reservoir modeling.

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