Controls on Reservoir Geometry and Distribution, Tantawan Field, Gulf of Thailand

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Abstract

Integration of well log and seismic analysis in a study area in the Tantawan field, Gulf of Thailand shows that sand architecture, connectivity and distribution can be influenced by local structural setting. The depositional systems in the study area were discriminated into two main types based on their different sand geometries, and distributions resulting from changes in local fault movement during deposition. Sands in the upper sand system were interpreted as a vertically stacked shoestring sand complex deposited by a laterally constrained river system whereas in the lower sand system two broad sands were interpreted to be complex stacked meander belt sands in a low gradient drainage system. Partial fault activity was recognized only during deposition of the upper sand system with thickened section between interpreted Markers 2 and 5 on the down-thrown side of faults and in the central graben. Fault movement increased accommodation space and sands stacked vertically inter-bedded with sealing shales. Net to gross is lower and fault seal potential enhanced providing traps for hydrocarbon accumulations. In comparison, accommodation space was limited during deposition of the lower sand system. Stacked sand bodies are thicker and fault seal potential is decreased. Water-bearing sands are more common in this interval. Based on this analysis, local fault activity provides a potential environment for fining upward depositional systems which provide zones of enhanced hydrocarbon trapping potential in the complexly faulted structures within the Pattani Basin.

Keywords: Tantawan Field, Controls on sand geometry and distribution, Fault growth, Accommodation space

1. Introduction

The area of interest is located mostly in Tantawan Field in the eastern flank of the Pattani Basin, Gulf of Thailand covering approximately 197 square kilometers. The purpose of this study is to document detailed reservoir architecture and distribution of sand geometries using well log data and 3D seismic data in the shallow Middle Miocene section of the Tantawan field located in the north central part of the Pattani Basin (Figure 1). The goal is to be able to confidently predict reservoir distribution using well log and visualization techniques of 3D seismic data in the different types of predominately non-marine to fluvial deltaic depositional environments interpreted in this area and more importantly, to understand what controls the changes in fluvial architecture that is observed. This knowledge should help in documenting the detailed reservoir complexity which is critical for better petroleum reservoir development and management.

2. Methodology

Lithologies and chronostratigraphic makers were interpreted using significant well log characteristics and wire-line cross-plots in 42 wells.

The synthetic seismogram of WELL-02 in the central part of the area was generated to integrate rock properties from well log and seismic data. Major markers identified in well logs were tied to seismic reflectors using this synthetic seismogram. Markers 2 and 5 were identified to be key markers based on seismic continuity across the structure of the area. Both of these markers in seismic interpretation were matched with marker picking in well logs of all studied wells. Two way time structural maps for the two key markers were constructed from interpolation of interpreted horizons in the study area. Markers 2 and 5 were chosen to represent structure at the top and base of the reservoir zones of interest across faults.

Moreover, an isochron map of the interval was constructed to define the overall trend of thickness in the interested reservoir zone. This map was combined with structural maps for interpretation of reservoir distribution.

Root mean square (RMS) attribute maps using many different windows were created using seismic amplitude values to define the orientation of reservoirs. The appropriate amplitude extraction windows were based on

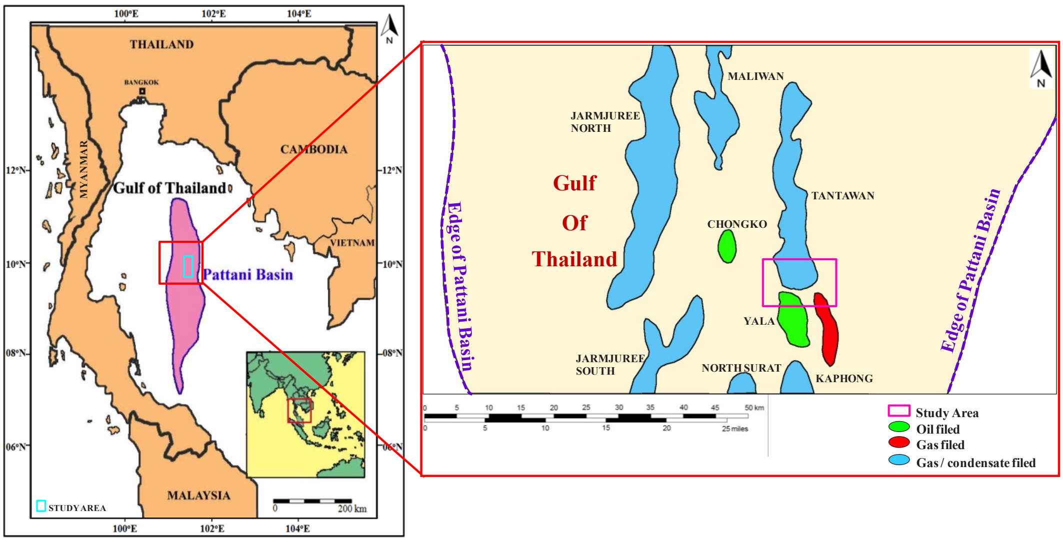

Figure 1. The study area situated in the north central portion of the Pattani Basin, Gulf of Thailand (modified from Jardine, 1997) and hydrocarbon accumulations in the Tantawan area

sand thickness, sand chronostratigraphy and resolution of the seismic.

The combination of all results could be used to analyze reservoir architecture, connectivity, and distribution. Thickness of individual sands was plotted but there are many way to draw maps using only these thickness values. The supporting data from results of seismic interpretation helped control the distributed reservoir orientations and TWT structural and isochron maps support reservoir depositional data throughout the structure of the area. The RMS attribute maps highlighted anomalous amplitudes which indicated reservoir extension.

3. Well log Characterization

Lithological determination within the interested interval was based on wireline log characteristics and can be separated into 3 main lithologies which are sandstone, shale, and coal. However, the chronostratigraphic markers were based on the well log characters and their lateral extensive correlation which normally represent coals and shales (Figure 2).

The Mid-Miocene Unconformity (MMU) is one of the regional markers in the Gulf of Thailand (Crossley, 1990) and it is relevant to this study as the depositional systems of interest lie immediately below it. More importantly, there is a change of lithology succession from fining upward to coarsening upward at the interpreted MMU boundary which ndicates a changing depositional environment from fluvial deposition to delta plain deposition (Figure 3).

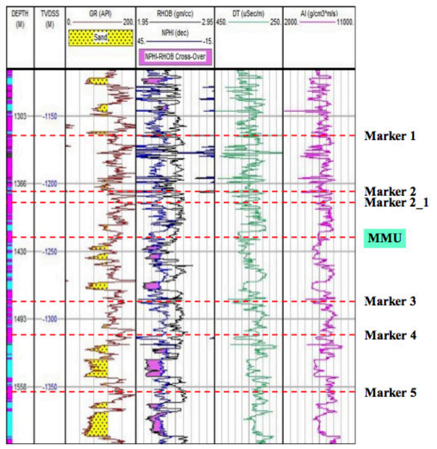

Figure 2. Lithological separations from the neutron - density versus gamma ray cross-plot of WELL-33 between Marker 1 to Marker 6 indicate similar lithologies defined by wireline log characteristics.

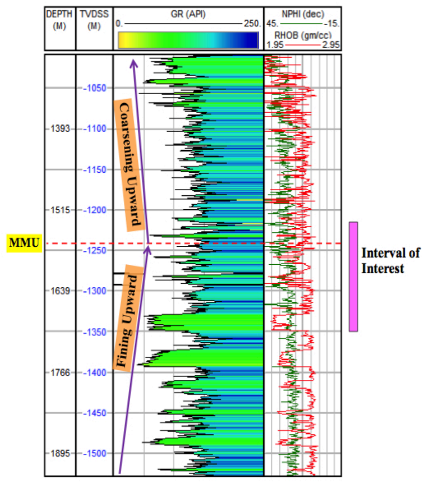

Figure 3. Changing gamma ray values from WELL-33 shows 2 stratigraphic successions with different depositional environment to identify Mid-Miocene Unconformity (MMU) marker.

Well to well correlation of sand in this study was based on chronostratigraphic markers and characteristics of sands through vertical and lateral extension. Marker 3 was interpreted to separate two sand systems based on the different of sand architectures

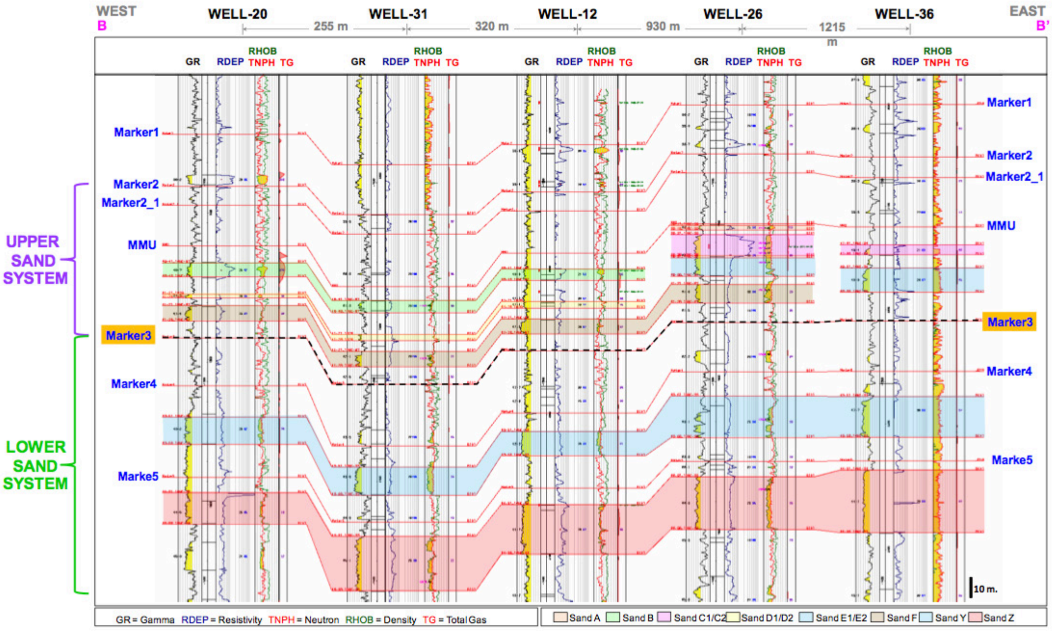

Figure 4. The well to well correlation panel across structure between Marker 1 to Marker 6 in the southern part of the study area showing the separation into upper and lower sand systems.

above and below it. These are defined as the upper and lower sand systems (Figure 4). Sands in the upper sand system were confidently divided into six individual sands whereas sands in the lower sand system were separated into only two sands. Sands in the lower sand system were much thicker and wider in distribution than sands in the upper sand system.

4. Seismic Characterization and Interpretation

Markers 2 and 5 from well log analysis were tied to seismic reflectors using synthetic seismogram of WELL-02. Marker 2 was identified to be a coal which correlated to a reflection peak and Marker 5 was interpreted to be shale that also correlated to a peak.

Marker 2 two-way structural map shows the structural style of the area (Figure 5). The area is characterized by a predominantly elongate north-south trending graben with a distinct offset in a northwest-southeast direction of the graben trend. The shallowest portions are located on the western flank and the deepest portion located in the middle of the graben.

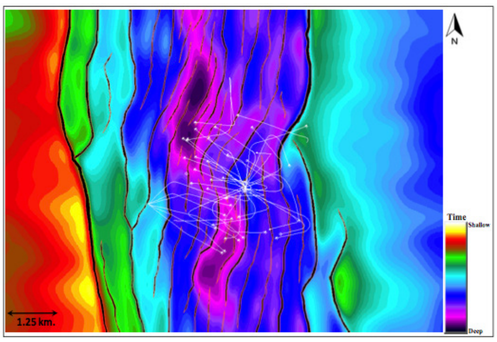

Figure 5. The two-way time structural map of Marker 2 illustrates north-south trending normal fault system with deep graben in the middle and shallow flanks east and west of the study area.

An isochron map was constructed for the interval between Markers 2 and 5 to identify thickness trends of sediments (Figure 6). The overall interval thickens into the central of the graben and thins on the margins to the east and west of the area. The thickening of sediment downward into the graben is the result of slight fault movement during deposition (Figure 7). This is a very important observation and can be seen in the zoomed in part of the isochron map. The thicker section seen on the downthrown side of the faults suggests growth of the fault during deposition and this movement could significantly influence depositional style, reservoir thickness, continuity and distribution.

Three Root Mean Square (RMS) attribute maps were constructed to represent upper and lower sand systems. Only one representative map was used covering all six sands in the upper sand system which shows scattered and restricted high amplitude in the central

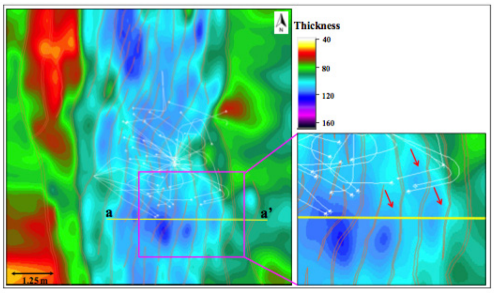

Figure 6. The isochron map between Markers 2 and 5 shows thickening section to the central graben of the study area. Red arrows demonstrate thick sections occurring locally on the downthrown side of the normal faults.

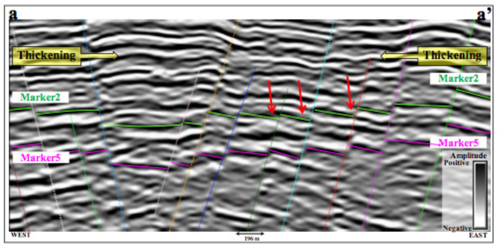

Figure 7. The seismic cross section a-a' shows thickening section between Markers 2 and 5 from margins into the graben and also minor growth across some faults in interval (red arrows). Figure 6 for location.

graben that indicates the meandering channel orientation.

The overall trend of this map can be separated into two north-south trending groups. Another two RMS attribute maps covering the lower sand system demonstrate obvious broad high amplitude groups which indicate meander belt features with high sinuosity (Figure 8).

5. Reservoir Distribution Analysis

Sands in the upper sand system based on well log data were predominantly thin and closely stacked vertically, so RMS attribute map analysis might not be the best methodology to indicate individual sand distribution. Hence, sand isopach maps were generated for each of the sands based on the tight well control and adjusted to match the RMS attribute map. Figure 9 summarizes the nomenclature used to define the sand systems from a well correlation in the central part of the study area

The six sands in the upper sand system can be separated into two distinct geographical groups based on

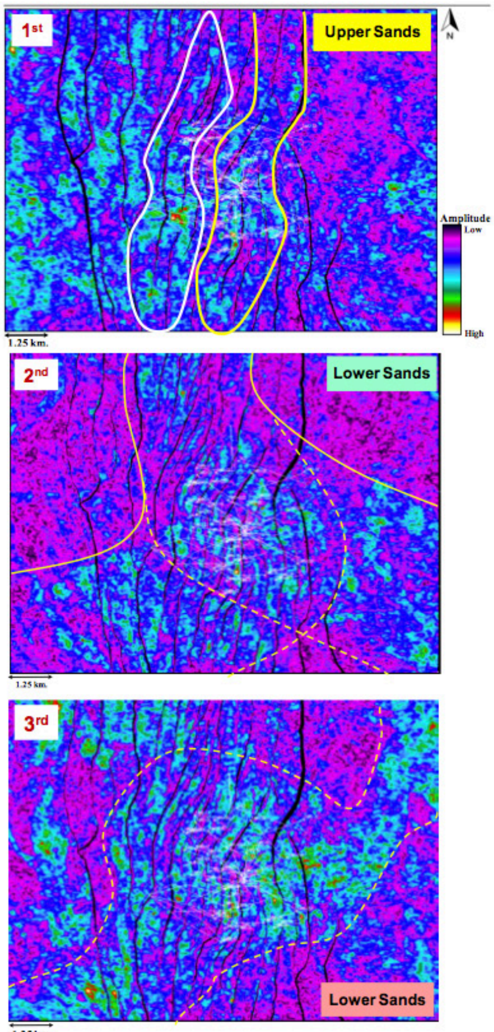

Figure 8. Three RMS amplitude map covering upper and lower sand systems which indicate meandering features and orientation. Yellow and white lines represent interpreted meander belt features and orientations.

well control and the RMS attribute map analysis (Figure 10). The deposition of many thin elongate sand bodies in a short period of time occurred and they moved laterally, indicating avulsion of the channel systems. The lateral constraint of the system suggests that fault activity may have partially controlled deposition during this time. In

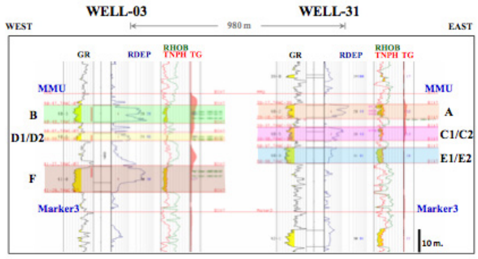

Figure 9. A summary cross-section of the upper sand system in the central part of the study area.

comparison, sands in the lower sand system based on well log data and RMS map were predominantly thick and laterally extensive cutting across the N-S fault system in places (Figure 11).

6. Discussion

The depositional systems in the study area can be separated into the upper and lower sand systems based on depositional architectures and distributions of the sands using an integration of well log and seismic data. Both sand systems are dominantly fluvial successions which ties to the regional correlation of the depositional sequence immediately below the Mid-Miocene Unconformity. The major factor which differentiates these two systems in the study area is a variation in accommodation space created by partial normal fault movement in a north-south orientation

The upper sand system contains six relatively thick and narrow sand bodies which have low to medium sinuosity. The individual sands were well imaged in well logs with bell and blocky gamma-ray shapes whereas their seismic response was more indistinctive. However, a general sense of orientation in a north-south direction, bound by faults, is interpreted. Additionally, the interpretation of this interval shows slight thickening downward into the graben and on the downthrown side of faults (Figure 7). Hence, this sand system is interpreted as an isolated shoestring fluvial sand complex deposited by a laterally constrained river system. Sands deposited in this low gradient system were controlled by local normal faults which were partially re-activated during deposition resulting in an increase in accommodation space which led to vertical rather than lateral accretion of these deposits in a north-south direction.

The lower sand system comprises two broad sands with relatively high sinuosity located above and below the interpreted Marker 5. The characteristic of both sands is blocky and bell gamma-ray shapes of inseparable individual sands in the well log, and on the seismic, a high amplitude cluster with high sinuosity on the RMS attribute map (Figure 11). The high amplitude cluster cuts across the north-south trending structures of the area, so both sands in the lower sand system are interpreted to be deposited in the absence of fault movement without any evidence of sediment thickening across the faults. These sands are interpreted to be complex stacked meander belt sands in a low gradient drainage system dominated by lateral accretion rather than vertical accretion due to a lack of accommodation space.

The meander belt sands of the lower system contain higher volumes of sand than the shoestring sands above them. However, according to well log interpretation, most reservoirs in the lower sand system are water-bearing sands whereas there are many hydrocarbon bearing sands in the upper sand system (Figure 12). Two main factors which affect this hydrocarbon distribution in the study area are reservoir thickness and seal. Sands are thinner in the upper sand system and net to gross is less than in the lower sand system which makes the possibility of hydrocarbon leakage through normal faults or sand juxtaposition in the lower sand system much more likely than in the upper sand system. This might be the reason why predominantly water-bearing sands are encountered in the lower sand system relatively to the upper sand systems. The upper sand system consists of many thin, narrow and isolated sand bodies with vertical accretion controlling their deposition and with impermeable sediments surrounding them. They are prime targets as hydrocarbon bearing reservoirs in terms of appropriate seal. Moreover, these isolated sands in the upper sand system can be vertically stacked due to the fault movement controlling them which enhances potential pay count.

Fault growth has a major influence on sand body orientation as well. The thickening sections in the downthrown side of faults affect sand distribution in some parts of the upper sand system as with the bottom most hydrocarbon bearing sand in WELL-09 but their lateral extent may be more north-south, parallel to the faults, rather than across the faults. Water-bearing sands in the lower sand system as in
WELL-31 (Figure 12) demonstrate great thickness but with only thin impermeable sediments between them.

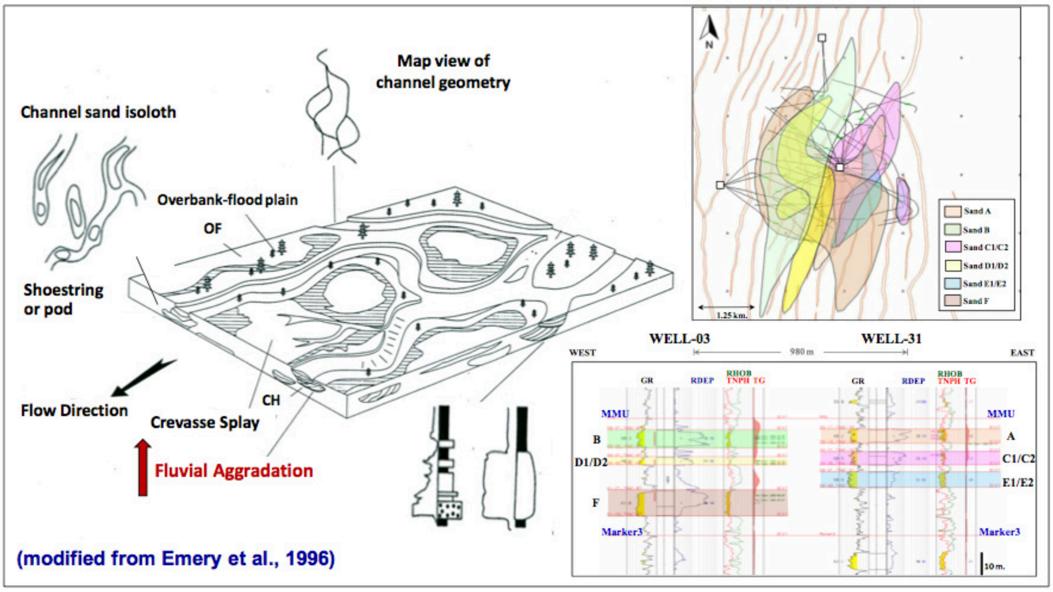

Figure 10. The representative block diagram and sand architecture model of shoestring sands (modified from Emery et al., 2006) with interpreted sand geometry of upper sand system. Characteristics of sands on well logs show isolated stack sands in vertical rather than lateral accretion.

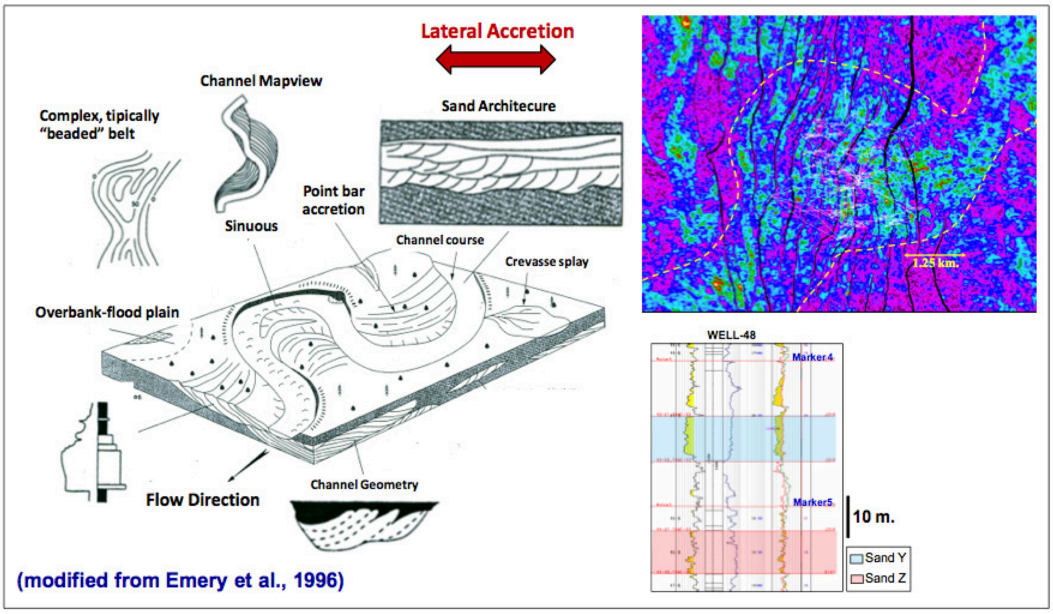

Figure 11. The representative block diagram and sand architecture model of complex stacked meander belt sands (modified from Emery et al., 1996) corresponding to the interpreted sand geometry of the lower sand system

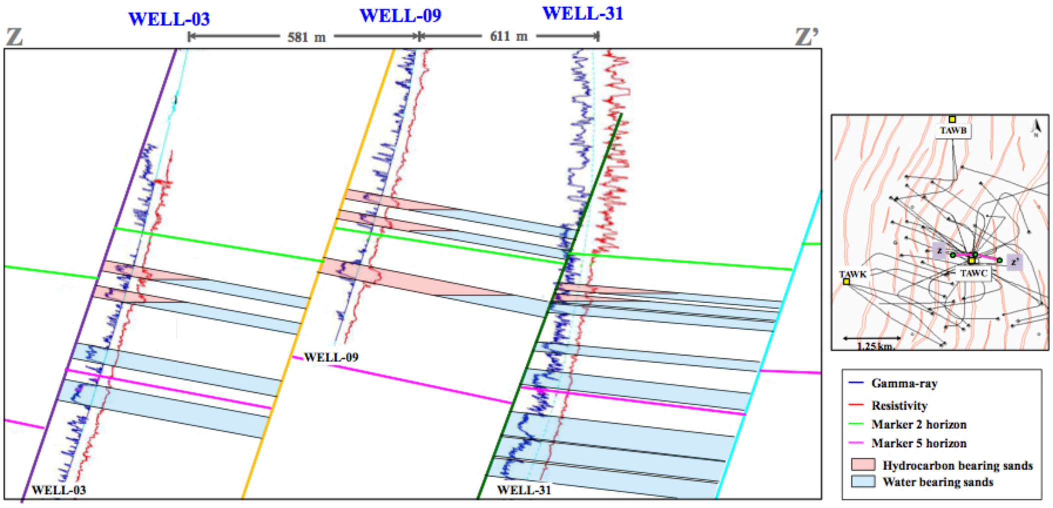

Figure 12. Representative E-W cross-section showing the hydrocarbon distribution in the study area. Hydrocarbons are concentrated in the upper sand system close to Marker 2 where sands are thinner and net to gross is lower.

With no fault activity to enhance accommodation space, sands are deposited laterally rather than vertically and fault leakage is more likely.

In summary, this study shows that understanding fault growth is extremely important in understanding controls on the depositional systems in this basin, and in turn, the hydrocarbon distribution. Fault growth creates local accommodation space which enhances vertical stacking of reservoir / seal pairs. According to the regional tectonic setting of the Gulf of Thailand the zone of interest in this study area was deposited in the post-rift phase of basin development and yet the interpretation of 3D seismic data in this study indicates local fault movement during sedimentary deposition of the upper sand system which affects sand distribution in some part of the area. Thus, the interpretation of sand architecture, connectivity and distribution in any area of evaluation within the Pattani Basin should take local fault activity into account.

7. Conclusion

1. Depositional environment of reservoirs are dominantly fluvial floodplain deposition.

2. Sands in the study area can be separated into two systems based on their depositional architectures and distribution. The upper sand system is interpreted to be vertically stacked shoestring fluvial sand complex in a laterally constrained river system. The lower sand system is identified to be complex stacked meander belt sands in a low gradient drainage system.

3. Fault growth controlled sand distribution in the upper sand system which was thicker in the down-thrown side of normal faults and downward into the central graben. This fault movement created increased accommodation space which allowed isolated sands to be vertically stacked inter-bedded with shales. Net to gross is lower and fault seal potential is enhanced providing traps for hydrocarbon accumulations.

4. In contrast, accommodation space was limited during deposition of the lower sand system. Stacked sand bodies are thicker and fault seal potential is decreased. Water-bearing sands are more common in this interval.

5. Based on this analysis, local fault activity provides a potential environment for fining upward depositional systems which provide zones of enhanced hydrocarbon trapping potential in the complexly faulted structures within the Pattani Basin

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9. References

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