APPLICATION OF SEISMIC ATTRIBUTES FOR RESERVOIR CHARACTERIZATION, SOUTH PATTANI BASIN, GULF OF THAILAND

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Abstract

Reservoirs of southern margin of Pattani Basin are mapped during company regular exploration evaluation but have not been looked into from a research oriented view. This study attempts to define the subsurface reservoir characters within Lower Miocene to Upper Miocene interval using 3D seismic attributes and well-log data. Reservoirs in this area are sometimes thin and have limited lateral extent which makes it difficult to predict the geometry and distribution of them. To predict sand character advanced imaging techniques such as : RMS (Root Mean Square) amplitudes, Spectral Decomposition and incoherency are used. At shallow stratigraphic levels, RMS volumes successfully resolved sand body geometries. But below 2000 meter due to a reduced acoustic impedance contrast between sand and shale RMS did not show distinctive images. On the other hand, using Spectral Decomposition CWT (Continuous Wavelet Transform) volumes can improve the image at deeper stratigraphic levels. It was also discovered that CWT outputs at 20 Hz can resolve thicker sands (>20m), while relatively thin beds and subtle features can be detected by higher frequencies. Therefore, these RMS and Spectral Decomposition imaging techniques were used jointly to examine the character of sands at different levels. Identified meander belts are N-S or NW-SE oriented and width of the belts vary from 200 m to 3 km. Based on the studied character of the sands they were divided into upper, middle and lower sand system. Upper sand system has well developed single meander belts in the above part and laterally migrated stacked sands at places in the lower part. Middle sand system shows more open marine influence as sands are distributed in a more scattered way with low sinuosity and as coal was observed in well logs. Lower sand system has thick stacked sands with moderate to low sinuosity and may have resulted from vertical aggregation of sands due to increased accommodation during syn-rifting.

1. Introduction

The G10/48 block is located on the southern part of the Pattani Basin within the Gulf of Thailand (Figure 1). The reservoirs in these basins are Lower to Middle Miocene fluvial channels and overbank sands and these reservoirs are dissected by the post-depositional faulting (Morley & Racey, 2011). The fluvial depositional systems developed as an extensive fluvial/delta plain with rapidly changing lithology. Therefore, because of these structural and stratigraphic complexities, it is important to suggest a workflow, which can reduce exploration risk.

The aim of this study is to image the sand reservoirs in the area of interest. Seismic attribute analysis techniques were applied to detect the Miocene fluvial sand reservoirs.

Specific objective of the current study are-

1.Utilize the applications of seismic attributes to map the reservoir sands by improving resolution

2. To characterize the geometry as well as spatial distribution of sand bodies of Miocene fluvial system

2. Methods

Integration well logs data and seismic based analysis was used to compare well log data to the seismic, synthetic seismograms were generated. Four main markers horizon marker 1, 2, 3 and 4 were interpreted as key horizons, and horizon slices within the reservoir interval, which were used to generate seismic attribute, seismic coherence and Continuous Wavelet Transform (CWT) amplitude for sand distribution.

3. RESULTS AND ANALYSIS

3.1 Well log analysis

The gamma ray-acoustic impedance versus depth cross-plot illustrates different acoustic impedance values of sands (colour coded by gamma-ray as light blue) and shales (colour coded by gamma-ray as pink, green and brown) in the zone of interest (Fig 2 & 3). In general shales have relatively higher acoustic impedance around 7000-12,000 g/cm^3*m/s, and sands have relatively lower acoustic impedance around 4000-7500 g/cm^3*m/s down to a certain level. After that level the acoustic impedance is quite mixed. Hence, the sands should be differentiated down to certain depth in seismic reflectors from background shale in this interval of interest in the study area. Another important character was observed in this study area is that the acoustic impedance contrast between sand and shale is solely due to density contrast. The depth versus density versus gamma-ray and depth versus sonic versus gamma-ray cross-plots reveal that it can separate sand and shale based on gamma-ray and density throughout the reservoir interval but the sonic value of sand and shale is quite mixed.

The Mid-Miocene Unconformity (MMU) and Top Oligocene are important regional markers and defines a distinct change in depositional environment. Cross-plots and depositional succession analysis (using gammaray pattern and change in seismic character) were used to identify this change using the Interactive Petrophysics program and seismic section. Cross-plots included were depth versus density.

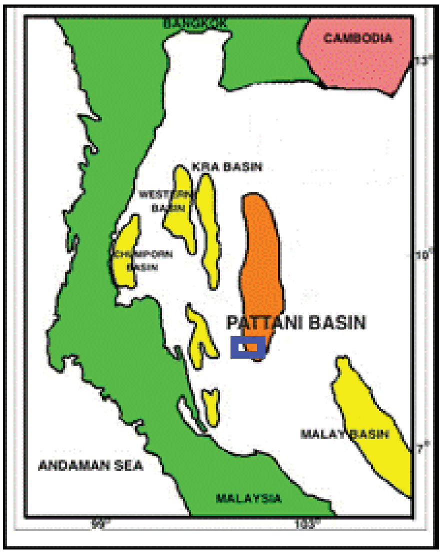


Figure 1. The location map of study area, Gulf of Thailand.

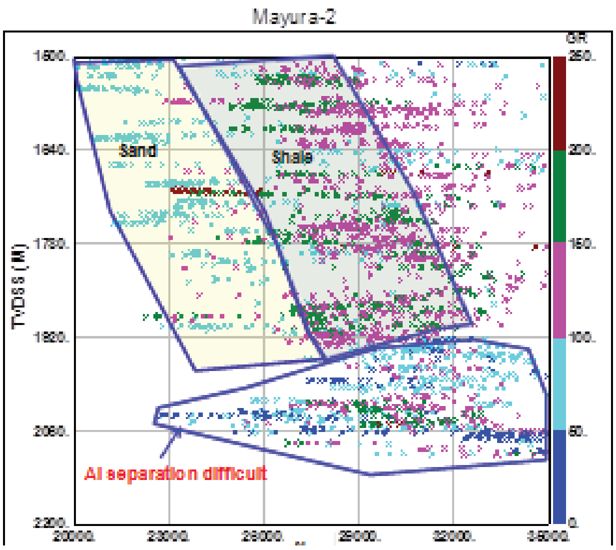


Figure 2. Cross plot representing depth versus AI response of Mayura-2 well color coded by gamma-ray.

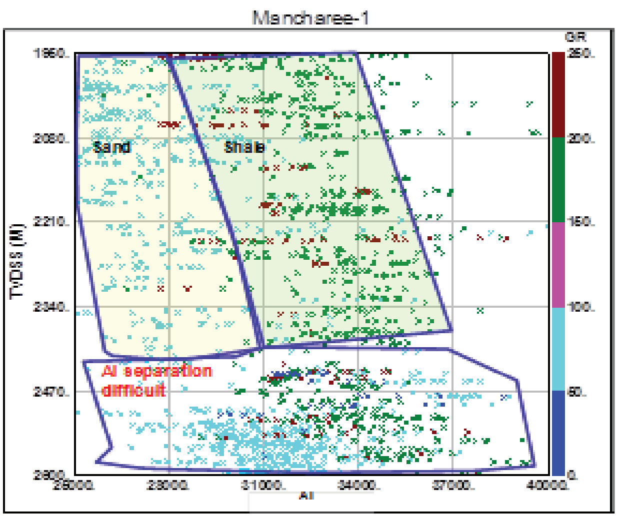


Figure 3. Cross plot showing depth versus AI response of Mancharee-1 well color coded by gamma-ray.

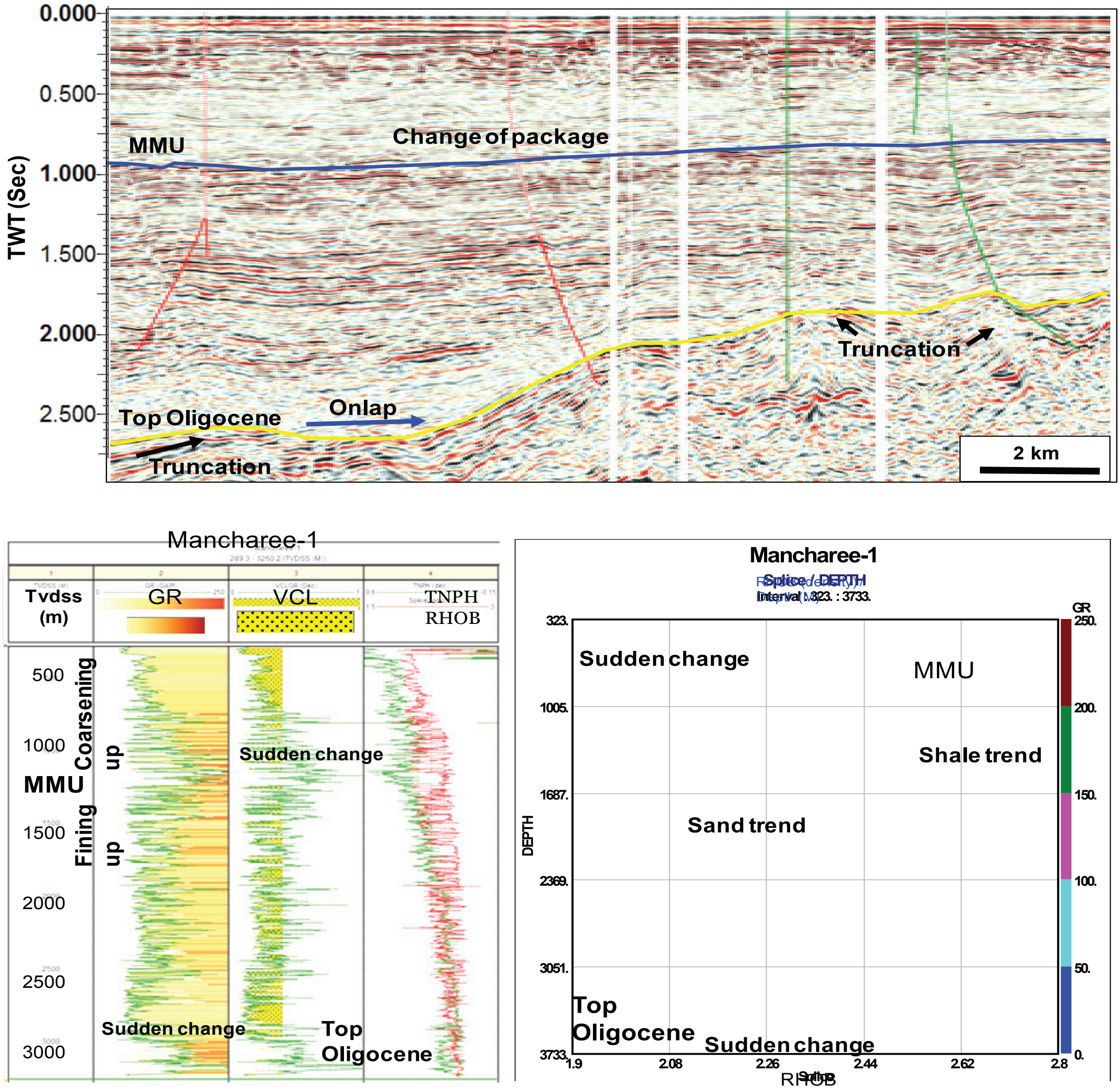


Figure 4. Figure showing the Middle Miocene marker and top Oligocene marker identification based on well log seismic character.

The MMU was difficult to identify based on only seismic character but top Oligocene marker was identifiable in both by seismic character and well log analysis . Therefore, changing of log values in cross-plots were useful in identifying the MMU marker (also change of succession in seismic was observed as an evidence). The Oligocene marker was identified using both cross-plots on well logs and mapped on seismic by truncation and onlap representing erosional features. These two markers were identified to delineate the reservoir interval (Figure 4).

3.2 Seismic Interpretation

3.2.1 Structural style of the study interval

Marker 2 time structural map was used to show 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 and eastern flank and the deepest portion located in the middle of the graben.

The isochron map was constructed for the interval between Marker 2 and Marker 4 to identify thickness trends of sediments (Figure 5). The overall interval thickens into the middle and thins to the margins to the east and west of the area. The thickening of sediment downward to the basin is the result of slight fault movement during syn-rift (Figure 5). The thicker section seen on the down-thrown side of the faults suggests growth of the fault during deposition and this movement could significantly influence depositional style, reservoir thickness, continuity and distribution.

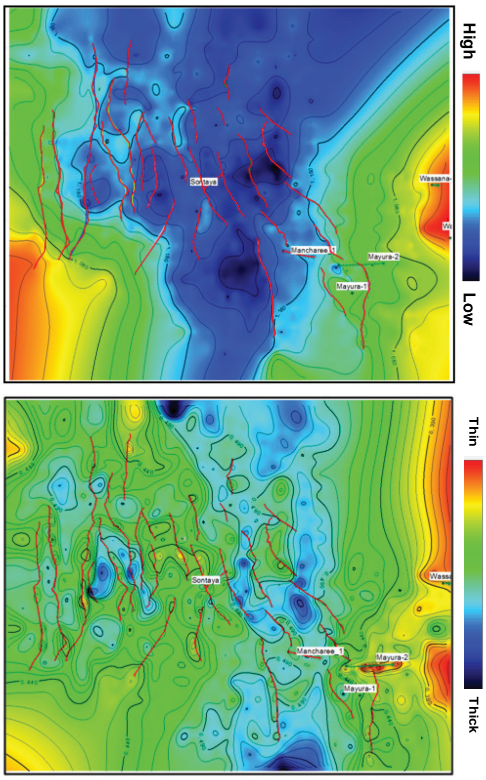


Figure 5. Structural contour map of Horizon marker 2 and Isochrone map between horizon marker 2 and horizon marker 4 to show the overall thickness trend of the study area.

3.2.2 Seismic attribute analysis to resolve reservoir sands

Low acoustic impedance sands were identified using cross-plot analysis and the top of the sand corresponds to a trough in seismic data (means positive polarity at reservoir level).

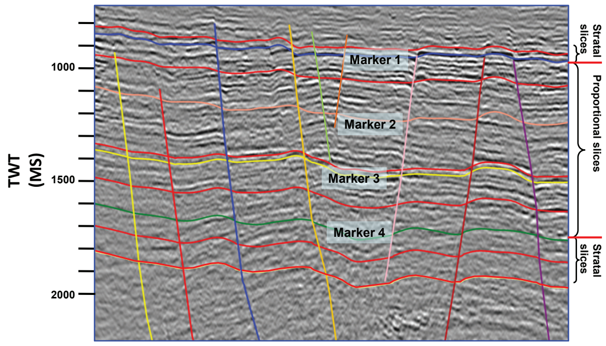


Figure 6. Showing the main four markers and calculated horizon slices used to run the seismic attribute analysis in reservoir interval.

Many root mean square (RMS) attribute maps and spectral decomposition maps were created to try and document geometry of these sand bodies.

RMS Analysis

The RMS amplitude values were calculated to recognize top and base of sands which correspond with troughs and peaks in the seismic reflectors due to the acoustic impedance contrasts.

Spectral Decomposition Analysis

In this study spectral decomposition technique (CWT) reveals that amplitude is different for each frequency (Ahmad et al. 2014). It was also observed that when the filter half window (Defines the time window to be used in computing the frequency content of the signal) length is low spectral decomposition worked better to identify more sands. It is observed that different thicknesses shows higher amplitude at different frequencies. It was observed that thinner sand bed (<15m) is associated with high amplitude at 35-40 Hz. On the other hand the thick sands yields strong amplitude anomalies at 20 Hz. So it can be assumed that the thin sand zones shows high amplitude at higher frequency of 35-40 Hz and thicker sand zones show higher amplitude at lower frequency of 20 Hz.

From the tuning thickness chart it was identified that tuning thickness is around 20 millisecond and also using average checkshot velocity of reservoir interval (around 2800 m/s) it was observed that tuning thickness is around 24 meters.

For this study 20 millisecond window (10 ms below and 10 ms above horizon and horizon slices) were used to calculate RMS outputs. It seems that RMS at that window successfully identified thick sands (up to 15 meter), but it is not easy to detect thin sands (less than 10 meters) by using the RMS maps. To identify the thinner sands spectral decomposition (CWT) technique was used and the filter half window which defines the time window to be used in computing the frequency content of the signal was reduced to 5 millisecond.

Within the study interval below horizon marker 1 (Near MMU) and above horizon marker 3, the sands are thick (from depth 900-1600 meter / 4000 ft to 5500 ft) as compared to the sands below horizon marker 3 (below 1600-1980 meter / 5600-6500 ft) and above the Horizon marker 4 (1751-2125 m / 5748-6975 ft). Also from horizon marker 4 down to deep slice 7 there is an interval (2100-2400 meter approx.) of very thick sand. Therefore, RMS amplitudes should efficiently detect the sands up to the deep slice 7 (2100-2400 meter/6900-7950 ft approx.) but it could not identify all the thick sands at deep slice 7.

On the other hand, based on cross plot analysis down to 2000 meter sand/shale acoustic impedance could be clearly differentiated and below that there is a zone where the acoustic impedance of sand and shale is quite mixed. In general, based on acoustic impedance cross plot sand can be identified using RMS amplitude attribute down to 2000 meter. But it was observed that spectral decomposition can observe more sands at specific frequency. Even in the deeper part where acoustic impedance contrast were mixed for sand and shale, at lower frequency spectral decomposition could identify thick sands. So, to identify more sands, spectral decomposition technique is useful in this case.

4. Discussion

Based on the interpreted horizon slices in between horizon marker 1 to horizon marker 4 and the stratal slices below horizon marker 4, three main types of sand characters are observed. They are referred as upper, middle and lower sand system. Upper sand system is located at depths from 900 to 1600 meter / 3000 to 5300 feet approximately. Middle sand system is situated at depth 1600 to 1980 meter / 5500 to 6500 feet where as the lower sand system extends from 2050 to 2425 meter / 6500 to 7950 feet roughly.

The upper sand system is characterized by thin to moderately thick sands in upper part (Figure 7) and more laterally and vertically extensive sands which are stacked at places in the lower part (Figure 8). Well developed closely spaced loop shaped sand body interpreted as meander bars with moderate to high sinuosity were observed in seismic which indicate strong fluvial influence at that level. The individual sands were well imaged in well logs with bell shaped and blocky gamma-ray shapes which may support strong continental influence.

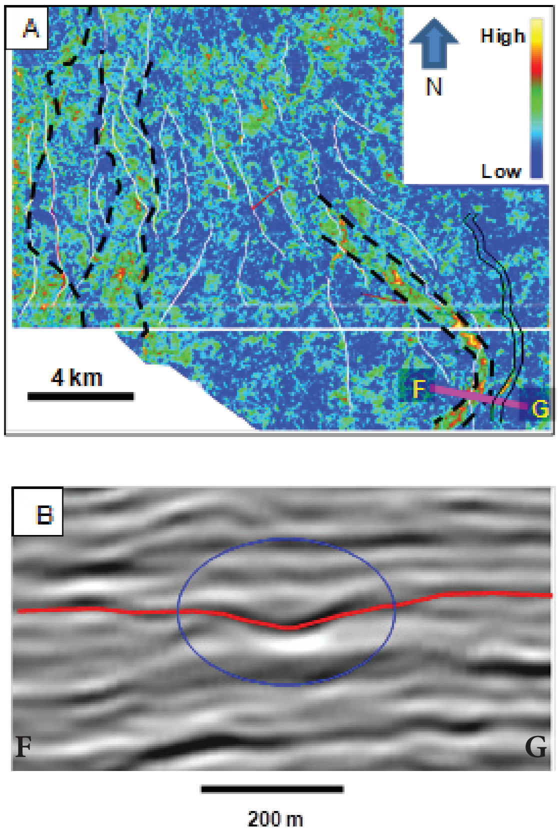


Figure 7. Upper sand system (top part) : A) Showing the interpreted meander belts (dashed), abandoned channel (black line) and the position of cross section is shown by pink line. B) Showing the F-G cross section and the meander belt associated with channel features are circled.

The middle sand system is characterized by thinner and less laterally extensive sands compared to sands in upper sand system. Well developed closely spaced meander bars are missing at this level and more shales are observed (Figure 9).

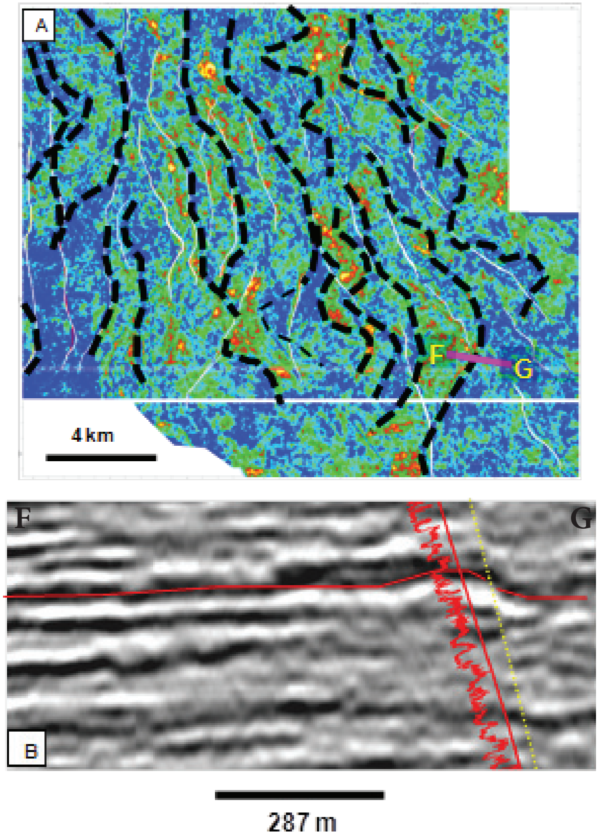


Figure 8. Upper sand system (bottom part) : A) Showing the meander belt interpretation (dashed). B) F-G seismic section along the well location shows continuity of the meander belt sand.

The average meander belt width of middle sand system ranges from 500-1000 meters. Deposition of sands seems to be more wide spread and scattered throughout the area with thin wedge shape. Well log shape was also found more serrated. and from Vclay cross plot higher clay percentages were observed. These may be indicative of more open marine influence at this level (Figure 9).

Sands in the lower sand system are represented by comparatively very thick sands at places (also confirmed by well log) but less laterally extensive compared to the upper sand system. Most of the thick sands are observed in the southern part of the area.

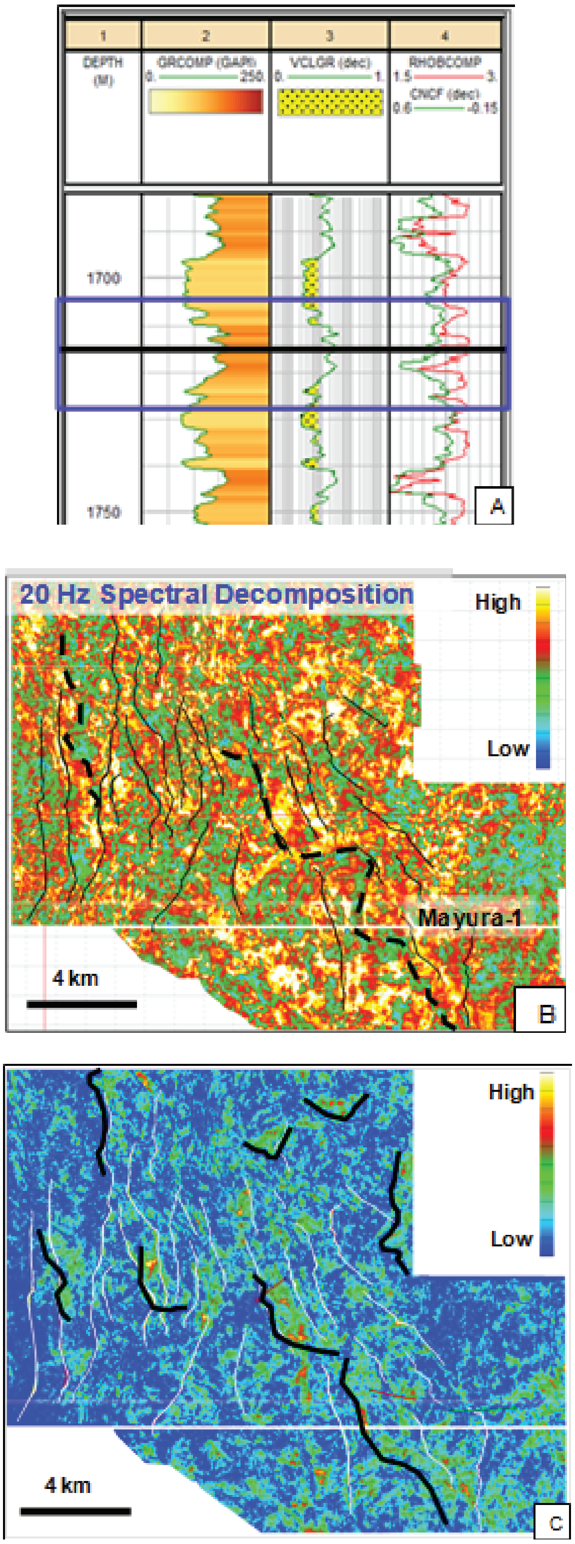
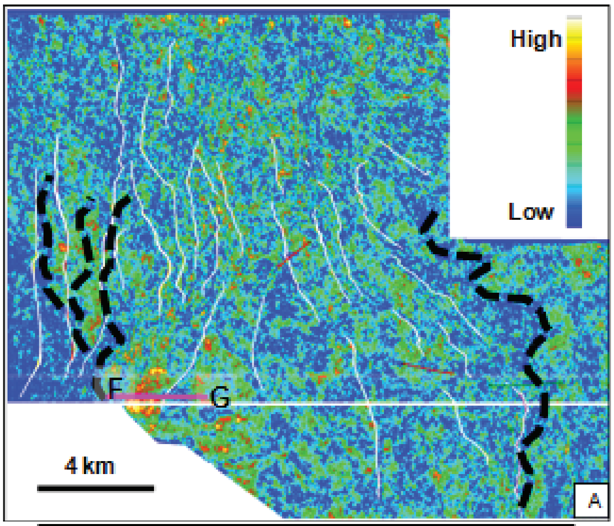
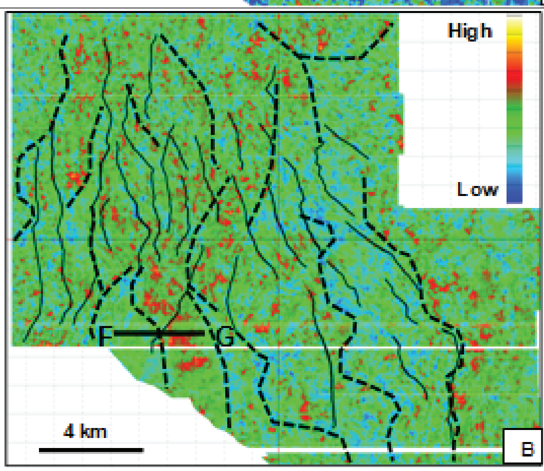


Figure 9. Middle sand system : A) well log showing serrated pattern in gamma-ray. B) Showing the meander belt interpretation (dashed) in 20 Hz spectral decomposition. Also showing it can detect more thick sand at places C) RMS, showing the observed scattered sand bodies throughout the area in black line.

Single meander belts are very difficult to identify at this level perhaps most of them are related to a stacked depositional environment (Figure 10). But in general width of the meander belts (stacked mostly) varies from 1000 to 3000 meters with moderate to low sinuosity. As this level is near syn-rift-post rift margin, sands are also affected by faults and the deposition seems to be more aligned with faults. Thickening of sands is also observed near faults (also showed in results section). Although at some places well logs showing thick sands in RMS map sands were not identifiable. The causes of not seeing sands in this part may be related to resolution problems or a problem related to acoustic impedance contrast between sand and shale as in the acoustic impedance crossplots it shows that below 2000 meter depth it was difficult to differentiate sand and shale. But CWT spectral decomposition at 20 hz can see those sands as it improved resolution (Figure 11).





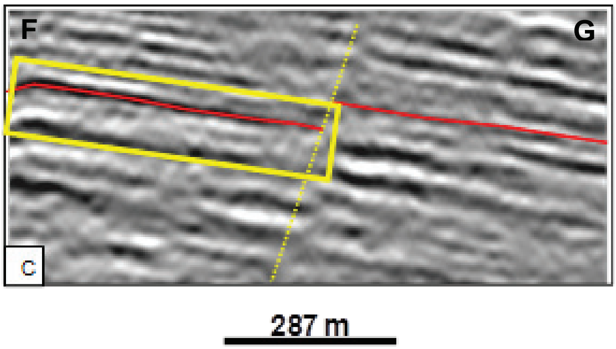
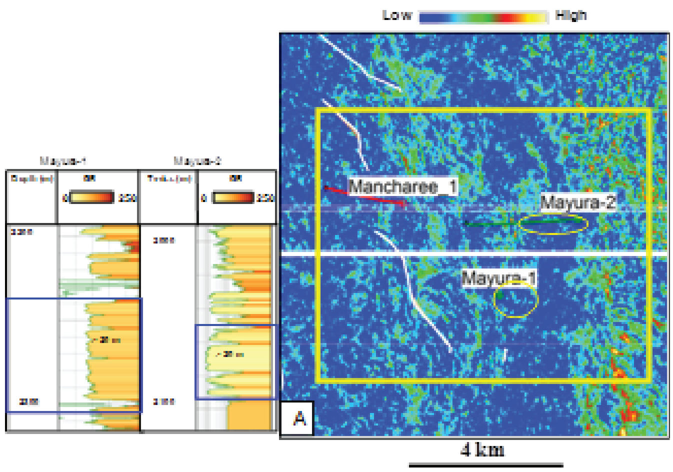


Figure 10. Lower sand system : A) Showing the meander belt interpretation (dashed) in RMS amplitude map although it was difficult to identify single meander belt. B) As from spectral decomp analysis it was observed at 40Hz CWT spectral decomposition can detect thinner sands and subtle features, an attempt was made to interpret multiple meander belts. C) Vertical seismic section F-G showing thick sand across the fault



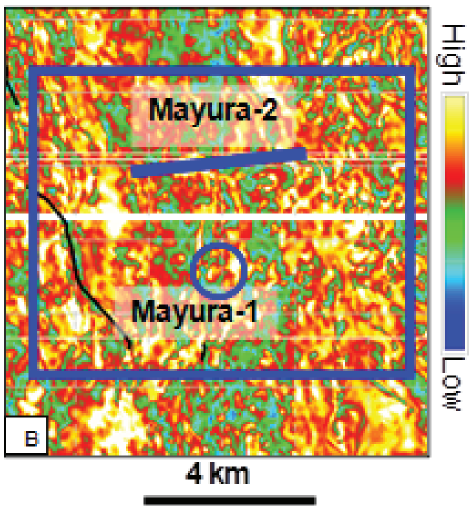


Figure 11. Below 2000 meter: A) RMS amplitude map could not detect thick sands at marked (yellow circled) well locations B) Showing 20 Hz spectral decomposition can observe more thick sands in well locations (Blue circled Mayura-1 and blue line represents Mayura-2 well).

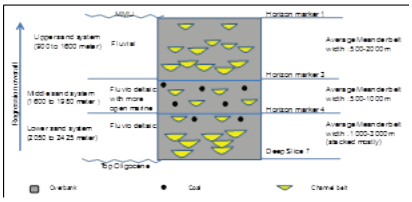


Figure 12. A simplified model showing the overall characteristics of reservoir sands at different level.

5. Conclusions

RMS volumes successfully resolved sand body geometries at shallow stratigraphic levels. Below 2000 meter due to AI problem RMS did not show distinctive images this can be solved using Spectral Decomposition CWT (Continuous Wavelet Transform) volumes and can improve the image at deeper levels. Therefore, RMS and Spectral Decomposition imaging techniques were used jointly at different levels.

6. Acknowledgements

I would like to thank my supervisor Mr. Angus John Ferguson, for his support and suggestions in this research project and also my professors: Dr. Joseph Lambiase, Dr. John Keith Warren and Dr. Mirza Naseer Ahmad. I would like to thank Kris Energy Thailand Exploration and Production, for providing me dataset.

7. Selected References

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