The Study of Reservoir Distribution Within the Stratigraphic Traps Using Seismic Attributes, Central Pattani Basin, Gulf of Thailand

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Abstract

The study of reservoir distribution within stratigraphic traps is necessary to open up hydrocarbon resources and add more opportunity in hydrocarbon discovery. The study area is a mature exploration and development area where most of the structural traps have been tested and relevant hydrocarbon resources have been developed. In addition, the reservoir are dominantly thin-bed sands which are mainly undetectable using the original seismic volume. Therefore, this study integrates 3D seismic volumes, well log data, rock physics analysis, horizons interpretation and seismic attributes analysis to identify potential stratigraphic traps and improve the visualization of reservoir distribution. Crossplots analysis using ten well log data reveals that density, P-wave velocity and P-impedance can be used for lithology discrimination where sand has lower density and P-impedance as well as higher P-wave velocity compare to shale. Several seismic attributes including amplitude enhancement, edges detection and thin-bed detection were applied to the full-stacked and partial angle-stacked seismic volumes. The RMS amplitude extraction clearly imaged channelized features oriented in N-S direction and parallel to basement. The drilled well data proved that these chan-nelized features are associated with sands and hydrocarbons. Thus, the results indicate that the channel orientations and hydrocarbon traps are not influenced by basement and the seismic onlap onto basement does not always imply shoreline deposit. Moreover, the integration of imaged channels with known hydrocarbons at well locations and structural mapping can be used to identify reservoir distribution for predicting well locations. The high amplitude channelized features located within structural closures can identify stratigraphic traps forming lower risk exploration and development targets

Keywords: Stratigraphic traps, Thin-bed sands, Seismic onlap, Seismic attributes

1. Introduction

The study area is located in the central part of Pattani basin, Gulf of Thailand (Figure 1). It is a mature exploration and development area where most of the structural traps have been tested and relevant hydrocarbon resources have been developed. Thus, the identification and testing of stratigraphic traps could help to open up hydrocarbon resources and add to the opportunity for exploration of hydrocarbon. Moreover, drilling in development phase of the field encountered hydrocarbons within the onlapping stratigraphic wedge onto basement which could be imaged seismically and be potential stratigraphic traps.

Moreover, there are no previous studies have been done in this onlapping trap section before. However, the thin-bed sands within the study interval are undetectable using original seismic amplitudes. Therefore, the additional subsurface characterization techniques for imaging and mapping reservoirs are needed.

The main objectives of the study consist of;

1) To document the occurrence of stratigraphic traps
2) To identify the reservoir distribution within the onlap stratigraphic section

2. Methodology

The study was done by integrating 3D seismic volumes, well log data and three main approaches including rock physics analysis, horizons interpretation and seismic attributes analysis using different parameters (Figure 2).

The 3D seismic data compose of full-stacked and three partial angle-stacked seismic volumes. The seismic data are zero phase data with increasing in acoustic impedance as a peak. The frequency bandwidths vary from 10 Hz to 45 Hz and dominant frequency is 20 Hz. There are 82 wells which compose of gamma ray, resistivity, density, neutron porosity and compres-sional sonic logs that were used in the study.

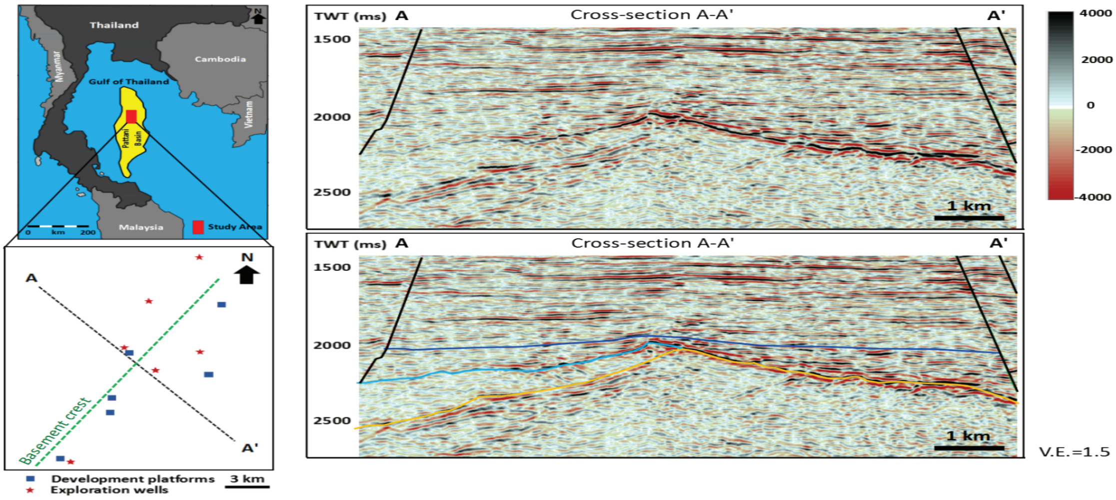


Figure 1 Map shows location of the study area in central part of Pattani basin. The seismic cross-section A-A' shows seismic onlap onto basement section with bounding faults.

The first step of the study is to identify potential stratigraphic traps. The onlapping sands onto basement and pinch-out of channel sands into impermeable shale are potential stratigraphic traps in the study interval. Then, determine the difference in rock properties to discriminate sand and shale using crossplots of density, P-wave velocity, P-impedance and S-wave velocity versus depth and separated by shale volumes. The horizons representing the top of basement, top of seismic anomaly, top of seismic onlap and middle part of onlapping wedge have been interpreted in the next step.

After that, the seismic attributes including amplitude enhancement, thin-bed detection and edges detection were applied to the seismic data within the onlap section. And finally, the results of seismic anomaly were compared with available well data to identify the relation of amplitude responses with reservoir sands and fluid contents.

3. Results

3.1. Rock physics analysis

Crossplots of rock physics parameters The crossplots of density, P-impedance, P-wave velocity and S-wave velocity versus depth have been generated to separate sand from shale trends. Shale was determined by shale volume ≥ 0.7 and sand was determined by shale volume ≤ 0.3.

The crossplot of density versus depth (Figure 3A) resulted as an increasing in density

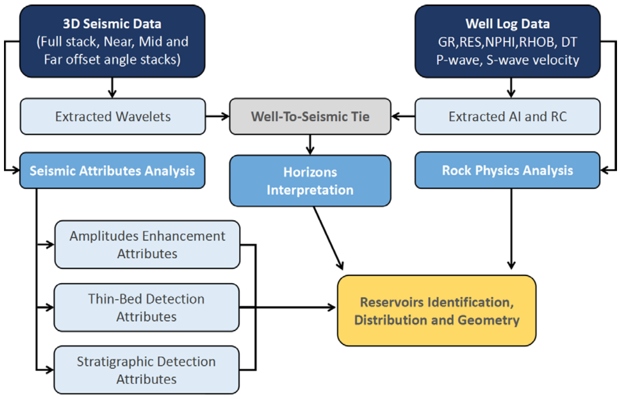


Figure 2 Schematic diagram showing data and main approaches that were used for the study

with depth where sand has lower density than shale in the entire section. The density contrast decrease with depth because sand has higher compaction trend and is more compressibility compare to shale as increasing depth.

The crossplot of P-wave velocity versus depth (Figure 3B) shown as an increase in P-wave velocity with depth where sand slightly has higher P-wave velocity than shale. When rocks become denser and pore spaces become reduced, the compressional wave travels faster through solid components than fluids therefore the velocity increase. The difference between P-wave velocity of sand and shale increases with depth and follows the compaction trend.

The crossplot of P-impedance versus depth (Figure 3C) resulted as a minor increase in P-impedance with depth. Sand has slightly lower

P-impedance compared to shale due to the lower density. The contrast of P-impedance of sand and shale decrease with depth which follows the compaction trend of density and velocity.

The crossplot of S-wave velocity versus depth (Figure 3D) is shown as a slight increase in S-wave velocity with depth. There is no obvious difference between S-wave velocity of sand and shale. Shear waves cannot travel through fluids and caused sand and shale which consist of similar solid components to respond as an equivalent S-wave velocity.

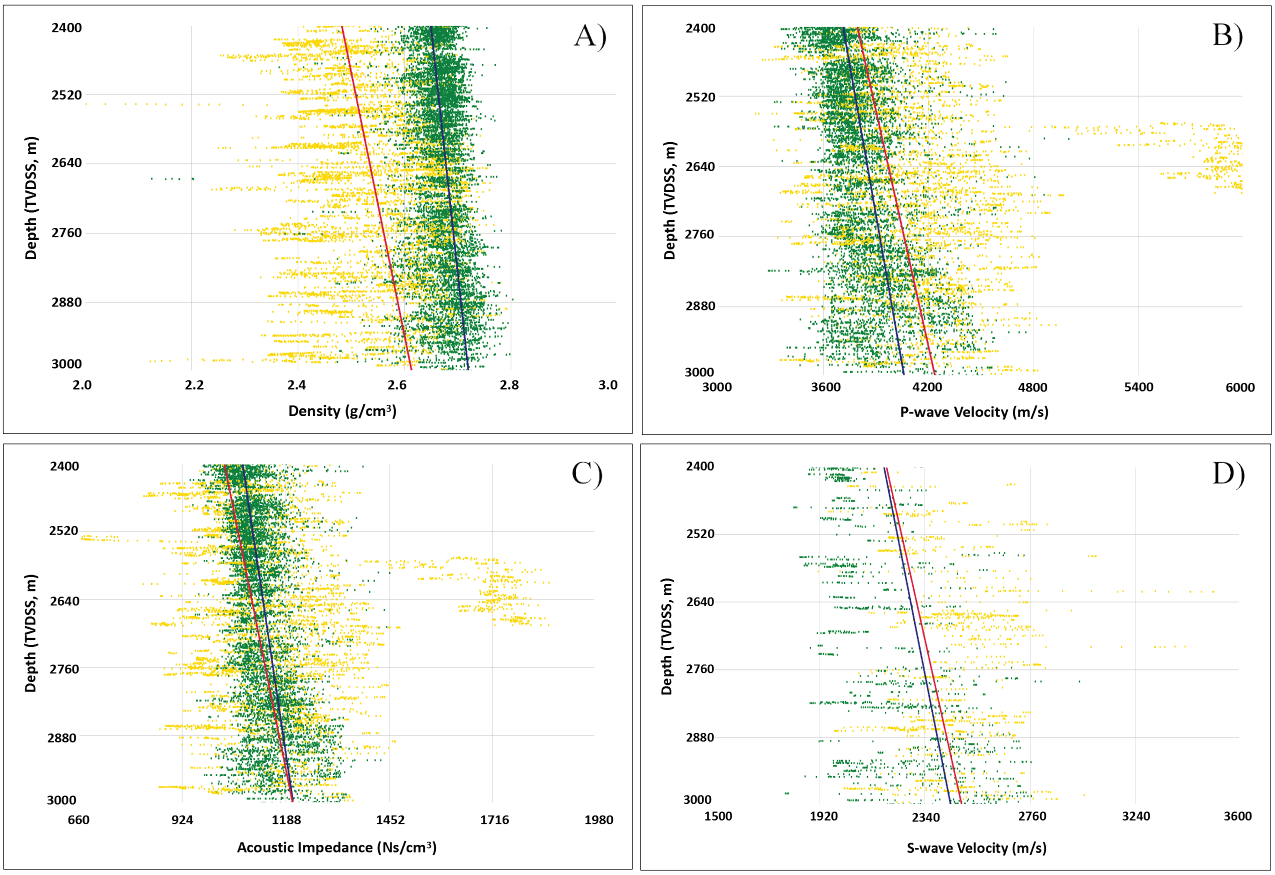


Figure 3 Results from crossplots of rock physics parameters versus depth and separated by shale volumes including A) Density, B) P-wave velocity, C) P-impedance and D) S-wave velocity

3.2. Horizons interpretation

Four main horizons were interpreted to identify the structural trending of the onlap section and were used for the seismic attributes analysis including top of basement, top of seismic anomaly, top of seismic onlap and middle part of onlapping wedge (Figure 4A)

Horizons representing top of basement and seismic anomaly were identified as strong positive amplitude reflectors (Figures 4B and 4C). These are related with a strong contrast in acoustic impedance as a result of a significant increase in density and velocity. The log responses of well B-01 and SU-II that were drilled into theses features were used to support the identification. The seismic anomaly A was interpreted as part of basement based on the primary mud log data with the results of XRD (X-Ray Diffractometer) and Carbon-Oxygen isotope analysis (Chaikajornwat, 2017). Moreover, horizon A (top of onlap section) and horizon B (middle part of onlap section) show depositional patterns as consistent thickness and orientation.

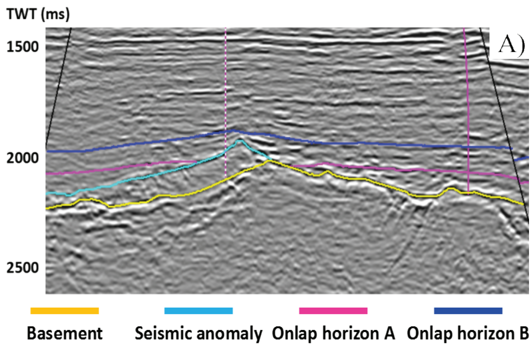


Figure 4A Result from horizons interpretation

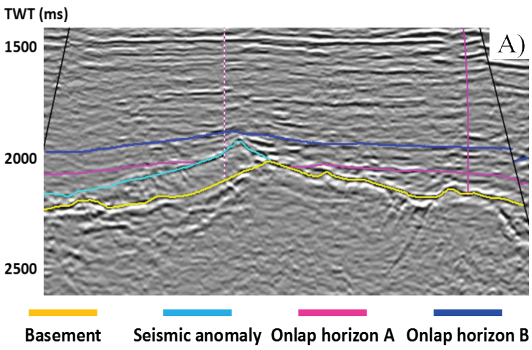


Figure 4B Reflector represents basement

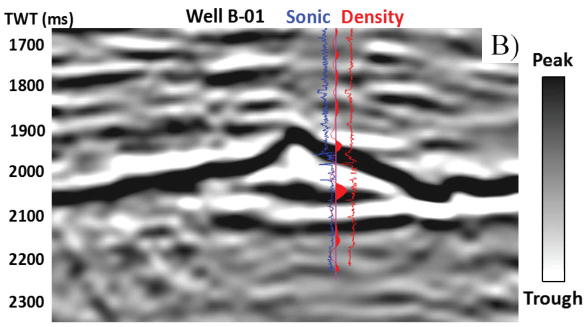


Figure 4C Reflector represents top of seismic anomaly A overlying basement

3.3. Seismic attributes analysis

Amplitude enhancement attributes The RMS amplitude extraction attribute was applied to the seismic data within the onlapping stratigraphic wedge section. There is an obvious narrow (400 m) and high amplitude channelized feature oriented in N-S direction has been imaged using the attribute volume within horizon A and A-20 ms (Figure 5A). The horizon A-20 ms was generated by shifting horizon A up 20 ms (35 m) to cover the reflection peak and trough. All full-stacked and partial angle-stacked seismic volumes could detect the same channel with no significant amplitude difference between near- and mid- offset volumes. Well F-03 penetrated the channelized feature and encountered 24 meters-thick wet sand which is thicker than the calculated tuning thickness (21 meters) (Figure 5B). Although the water-bearing sand could not prove the occurrence of stratigraphic trap, the amplitude anomaly could help to map the reservoir sands distribution.

Another RMS amplitude attribute was applied within horizon A-60 ms and A-80 ms and image obvious high amplitude channelized feature oriented in N-S direction (Figure 6A). There is no significant amplitude difference between near- and mid-offset volumes. Well SU-VI penetrated the feature and found a 12 meters-thick wet sand (Figure 6B). This water-bearing sand is associated with an amplitude anomaly that helps in mapping the reservoir sands. Another well SU-V found a 12 meters-thick gas sand where top of sand match well with reflection trough on seismic section (Figure 6C). The association between amplitude anomaly and gas sand found in this well prove the occurrence of stratigraphic traps.

Moreover, according to the result of wet sand and gas sand found within the same imaged channelized feature, this could indicate that the amplitude anomaly helps in mapping reservoir sands but not in mapping the fluids-bearing sands.

There are undiscovered areas including channelized features that are located at higher structural locations compared to the locations of wells SU-VI and SU-V that form potential structural-stratigraphic traps (Figure 6D). There are no faults in the study interval and the channel location is clearly independent from the basement location. The reservoir sands could be sealed by impermeable shale as a result of facies change.

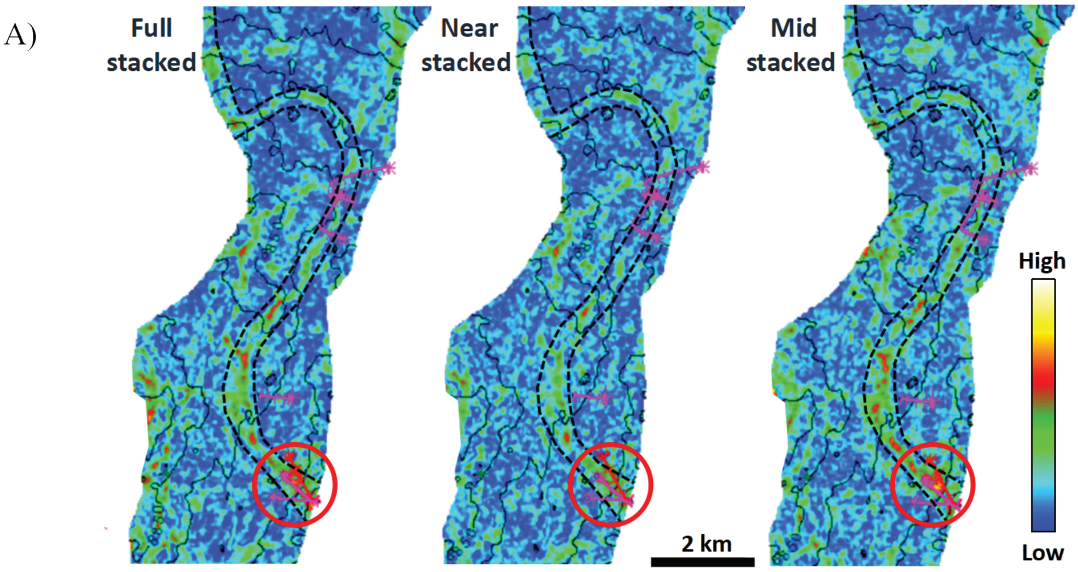


Figure 5A Detection of N-S oriented high amplitude channelized feature. Well F-03 (red circles) was drilled into channelized feature

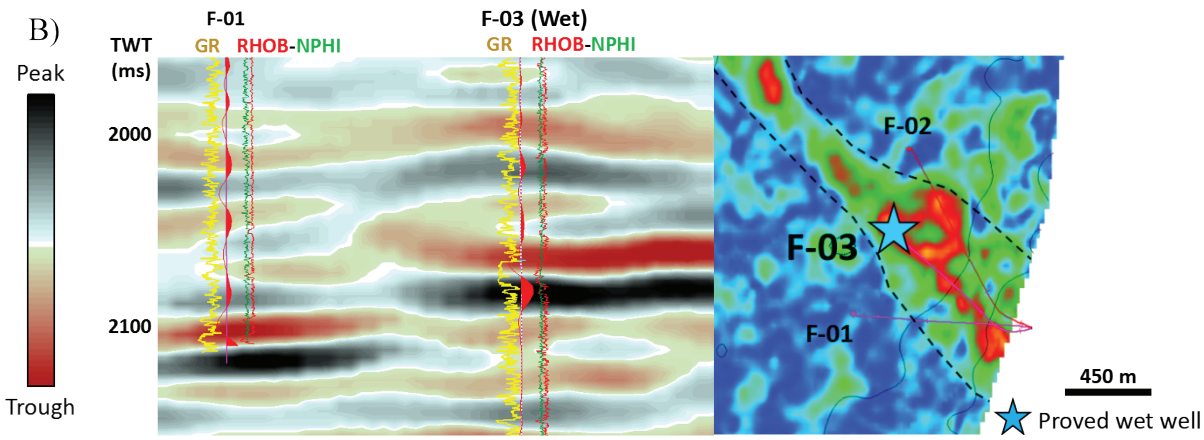
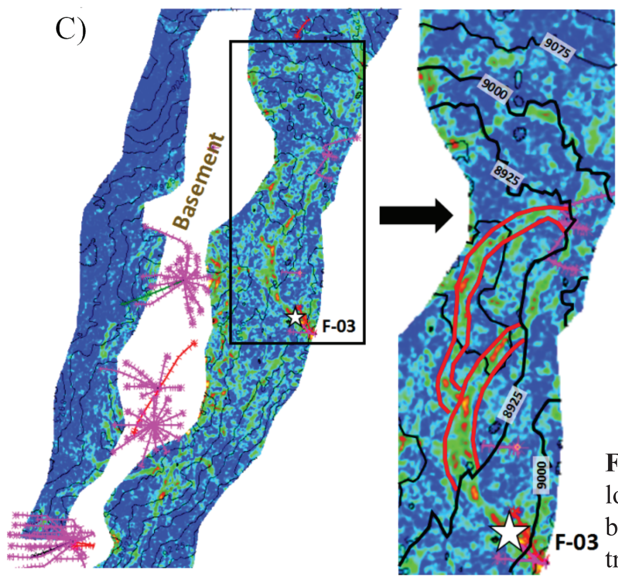


Figure 5B Well F-03 found as wet sand where top of sand match with reflection trough



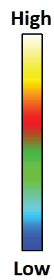


Figure 5C Channelized features located at higher locations compare to well F-03 and independent from basement location are potential structural-stratigraphic trap areas

A)

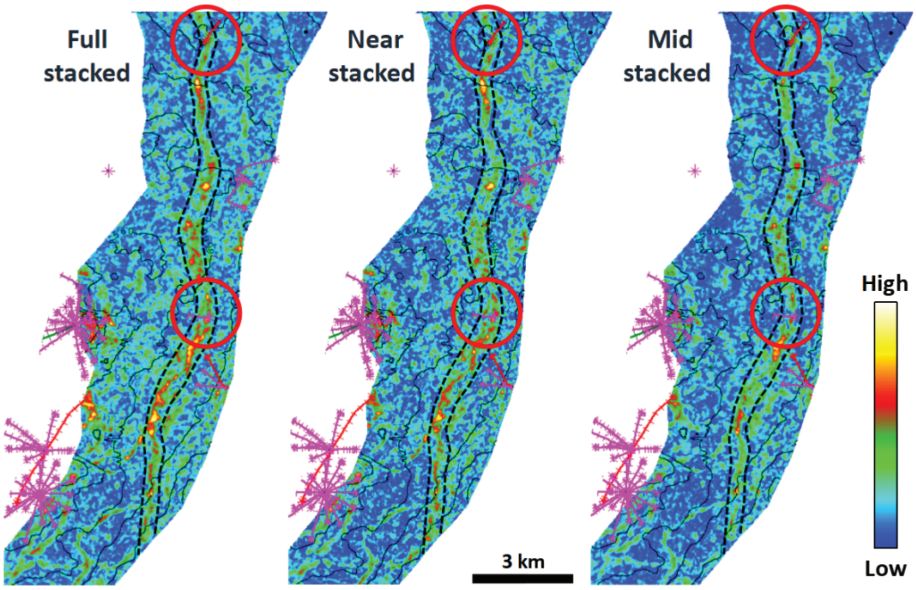


Figure 6A Detection of N-S oriented high amplitude channelized feature. Wells SU-VI and SU-V (red circles) were drilled into channelized feature

B)

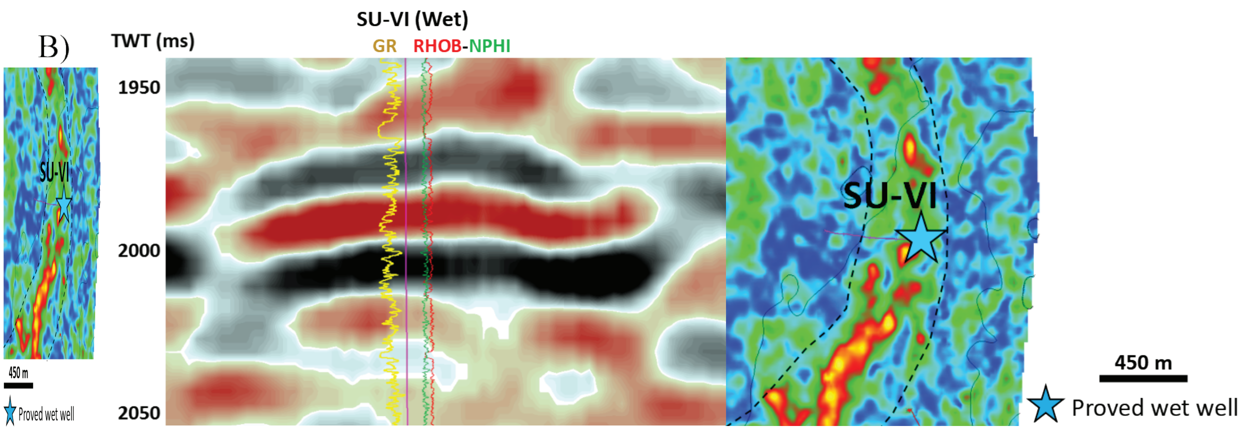


Figure 6B Well SU-VI found as wet sand where top of sand match with reflection trough

The RMS amplitude extraction attribute was applied to the seismic data at shallower (1250 ms) and higher frequency data (30-50 Hz) to image the reservoir distribution and identify the association between amplitude anomaly, offset (stacking angles of seismic data) and fluids contents. This resulted in detecting high amplitude channelized features in NW-SE to N-S direction. Three wells, A-16, A-17 and A-26, penetrated the channelized feature and found 8-9 meters-thick wet sands (Figure 7A). The far offset angle-stacked seismic volume could image brighter amplitudes compare to the near and mid offset angle-stacked seismic volumes (Figure 7B).

Thin-bed detection attributes

The spectral decomposition has been applied to the seismic data. The results from attribute volume within horizons A and A-20 ms clearly detected channelized features and reservoir sands with the spectral frequencies ranging from 15 Hz to 35 Hz (Figure 8).The calculated sand tuning thickness from these frequencies are about 12-28 meters. This thickness matched with thickness of sand that was found in well F-03.

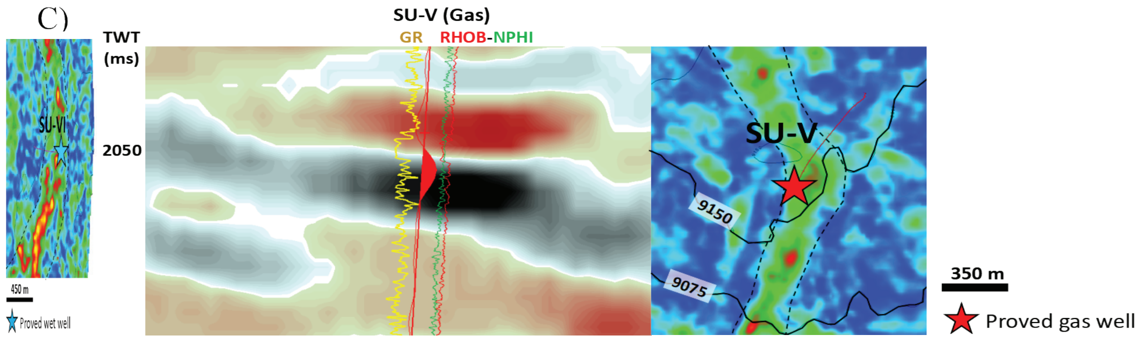


Figure 6C Well SU-V found as gas sand where top of sand match with reflection trough

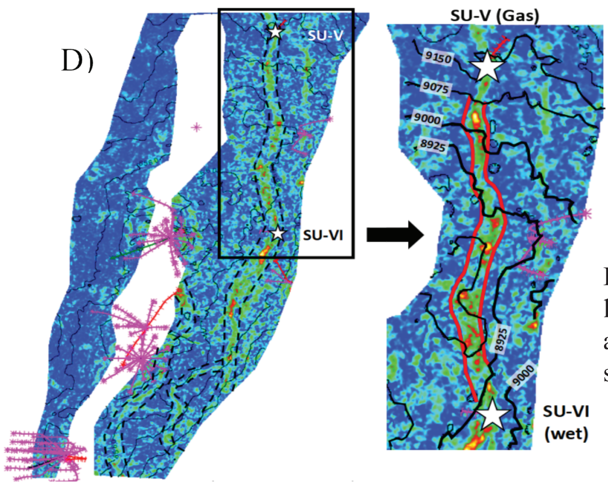
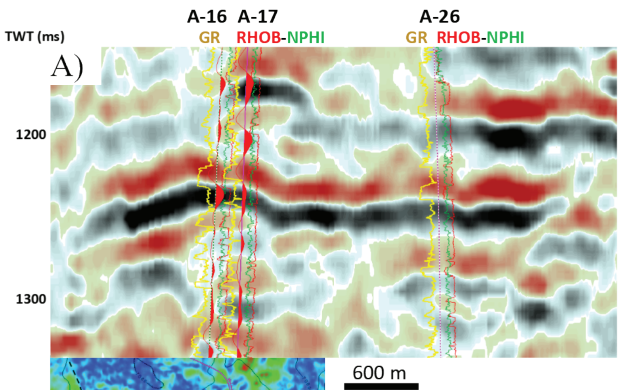


Figure 6D Channelized features located at higher locations compare to wells SU-VI and SU-V which are independent from basement location are potential structural-stratigraphic trap areas



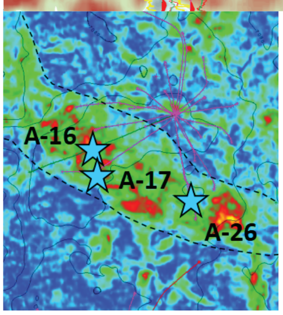


Figure 7A Wells A-16, A-17 and A-26 found as wet sands

4. Discussions

The details of the main advantages in each approach for the study of stratigraphic traps and reservoir distribution consist of;

4.1) The rock physics crossplots can distinguish between sand and shale (Figure 3). The dominant parameter for discrimination is density. The density and compressional wave are influenced by both rock matrix and pore fluids while the shear wave mainly interacts with rock framework. The different in rock properties are important in imaging reservoir using seismic data. According to lower P-impedance of sand compared to shale, the top of sand that was overlain by shale is probably a reflection trough on seismic data.

4.2) The seismic attributes can provide a better imaging of stratigraphic features, identify stratigraphic traps and reservoir tuning thickness and predict the potential reservoir locations (Figure 5-8). The RMS amplitude extraction clearly image high amplitude channelized features where amplitude anomaly help in mapping reservoir sands. Moreover, the integration of seismic attributes with know hydrocarbon at well locations are useful in predicting potential reservoir location and help to improve the

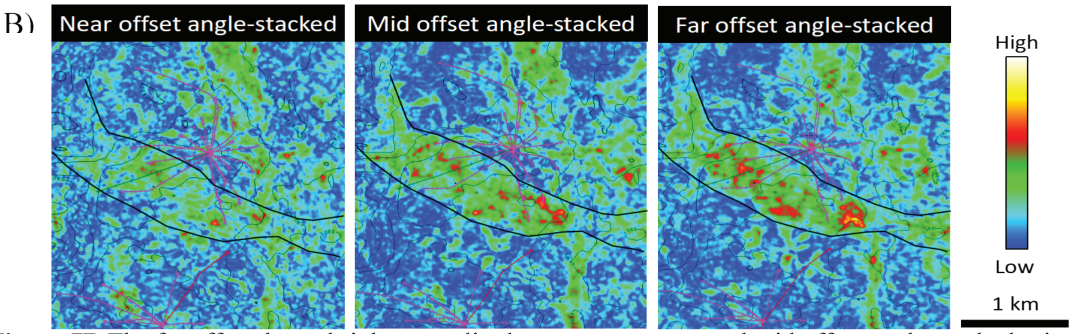
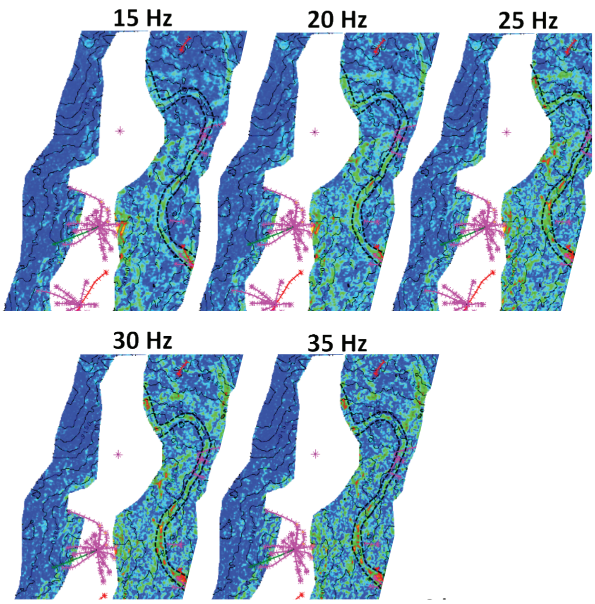


Figure 7B The far offset detect brighter amplitude compare to near and mid offset angle-stacked seismic volumes. This indicate a better reservoir sand imaging with increasing in offset



prediction of well locations as well as reducing risks in the future exploration and development.

5. Conclusions

The conclusions from the study are summarized as the following lists;

5.1) The seismic attributes analysis is a good technique to identify stratigraphic traps and reservoir distribution.

5.2) The seismic onlap observed at the basement contact does not always imply the transgression or depositional controlled by basement.

5.3) The channels and hydrocarbon traps are independent from basement location where sands could be sealed by the impermeable shale as a result of facies change.

5.4) There is no definitive hydrocarbon indicator that could be identified.

5.5) The spectral decomposition can help to identify reservoir sands thickness.

5.6) There are undiscovered areas which could be potential structural-stratigraphic traps including the channelized features located within the structural closure.

5.7) Recommended to apply additional inversion technique to differentiate fluids trapped in the reservoir.

6. Acknowledgments

I would like to express my very great appreciation to my supervisor Professor Angus John Ferguson for his excellent suggestion and encouragement throughout my research work. I also express my deeply gratitude to Professor John Warren, Professor Joseph Lambiase and all lecturers for their knowledge and advice throughout the program.

I would like to express my appreciation to Khun Oscar Yepes and all staffs at Chevron Thailand for enthusiastic advice and guidance. I also would like to express my gratitude to Chevron Thailand for the great opportunity and scholarship to study Master Degree and also their permission to use the data for this study.

I am particularity grateful to all staffs at the Petroleum Geoscience program. And I also would like to thank everyone in the Petroleum Geoscience class for their support, beautiful friendship and our precious moments.

My deeply appreciate is extended to my family members for their love and support.

7. References

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