AN INTEGRATED VELOCITY MODELING WORKFLOW TO PREDICT RELIABLE DEPTHS IN TRAT FIELD, GULF OF THAILAND

Sarayoot Geena

Petroleum Geoscience Program, Department of Geology, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand

*Corresponding author email: sarayootg@gmail.com

Abstract

Trat field is located within Pattani Basin of the Gulf of Thailand. The reservoirs in this field are predominantly Lower Middle Miocene fluvial sands. Traditionally, nearby check shot data have been used for depth prediction of proposed wells and it is common to observe significant difference between predicted and actual depths of key markers. In this study, different velocity sources have been used to build accurate velocity model for depth prediction. Accuracy of these models was tested by eliminating velocity information of some wells, through blind test analysis for both single wells and for whole platforms. Predicted depths from this blind test analysis were compared with their actual depths. This study shows that the most accurate depth prediction is obtained by integrating multiple velocity sources such as check shot data, T-D tables of synthetic seismograms, stacking velocities and pseudo velocities calculated from depths of picks and time of respective horizons. Moreover, these velocities were interpolated along the interpreted horizons to incorporate the structure constraints in the model. This new proposed workflow of velocity modeling significantly reduces the error in depth prediction.

Keywords : Pattani Basin, Velocity Model, Depth Prediction, Synthetic Seismograms.

1. Introduction

Currently simple average velocity function based on the velocity information from nearby exploration wells is used for prediction of depths of key horizons in proposed wells. Depth prediction using this velocity information is sometimes very erroneous and there is significant difference between predicted and actual depths. To improve on this, I applied various velocity modeling techniques and combined various velocity information such as stacking velocity, check shot information, and interpolation of velocities using structure interpretation, to propose a more appropriate and accurate depth prediction workflow

2. Database and methodology

Several input data were incorporate into velocity models The table below summarizes the datasets used.

Table 1. Detail of available data.

Data Type	Details
Seismic	3D PSTM seismic from line 1474 to 14994, trace from 15483 to 16918, 842.31 square kilometers
Velocity	RMS stacking velocity covered Trat field
T-D table	33 synthetic wells with T-D tables
Check shot	5 wells with check shot /VSP surveys
Horizons	5 horizons which are MMU, C, D, G and K horizons
Well data	102 well picks at MMU surface 93 well picks at C surface 85 well picks at D surface 22 well picks at G surface 1 well pick at K surface

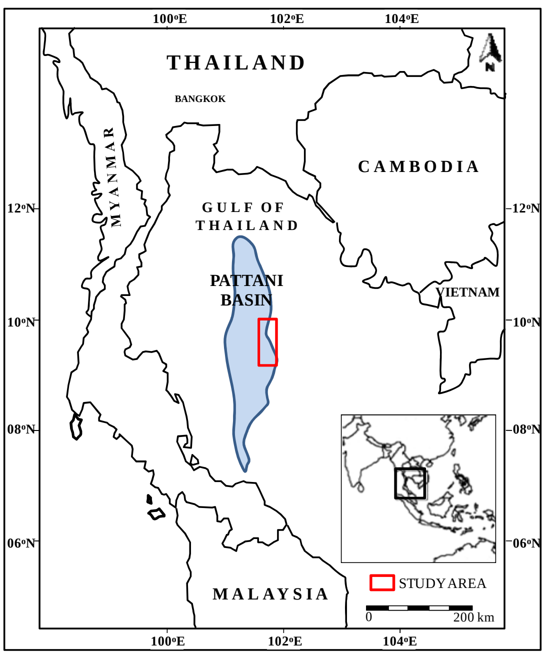

Figure 1. Location map of the Trat Field at the east of the Gulf of Thailand.

QC of check shot data

To ensure that check shot data is correctly acquired and input in the software database, QC was performed by examining the trends of interval and average velocities calculated from check shots' time depth relationships. Anomalous points were eliminated from the time depth functions.

Synthetic seismograms and Time-Depth tables

Synthetic seismograms were generated for 33 wells, which consist sonic and density log. Available check shot data was applied as reference curve to calibrate the T-D relationship obtained from sonic. Extracted wavelet within the zone of interest was used to convolve with the reflection coefficient series. Synthetics were matched with seismic data along the well bores by adjusting time-depth relationship through stretching and squeezing. These time depth relationships were used in velocity models.

Velocity modeling

Total six models were generated by using different types of velocity data along with structure interpretation. The detail of the each velocity model is mentioned in table 2. The horizontal and vertical spacing of each model is 50 m and 20ms.

Table 2. The velocity models used.

Model	Input velocity data types				
	5 Check shots	33 T-D Tables	5 Horizons	Pseudo velocity	RMS velocity
Model 1	X				
Model 2	X*				
Model 3		X			
Model 4		X	X		
Model 5		X	X	X	X
Model 6		X**	X	X	X

X* means using 5 edited check shot. X** using 33 T-D Tables with applied 4-separated zone of 5 edited check shot into it.

Validation of velocity models

Various statistical validation methods were applied to check the accuracy of each model. These methods are discussed below

Uncertainty analysis (drop-out analysis)

This analysis provides a measure for the uncertainty associated with a given velocity models. The procedure for this is as follow:

1. One well (pick and time/depth function data) is taken out at a time.
2. A new velocity volume is computed with the remaining data.
3. The depth at the different formation tops is computed using velocity volume.
4. The computed depth in step 3 is compared with the known well pick depth.

This difference in depths determines the confidence and accuracy of the velocity model. Report for each well is prepared to check the validity of models.

Blind test

To test the efficiency of the model, one selected platform was taken out of the model and then the depths of key markers of wells within blind zone were predicted. These predicted depths were compared with actual depths observed in the wells.

Velocity maps

After validation and QC process, one appropriate model was selected and velocity values were extracted along key horizons to see the velocity variation associated with geological features.

3. Discussion and results

QC of check shot data

Check shots of three wells (TR03, TR10 & TR15) show low velocity zones at different depth levels (Figure 2), while other two wells (11A-1, TR01) are showing general increase of velocities with depth.

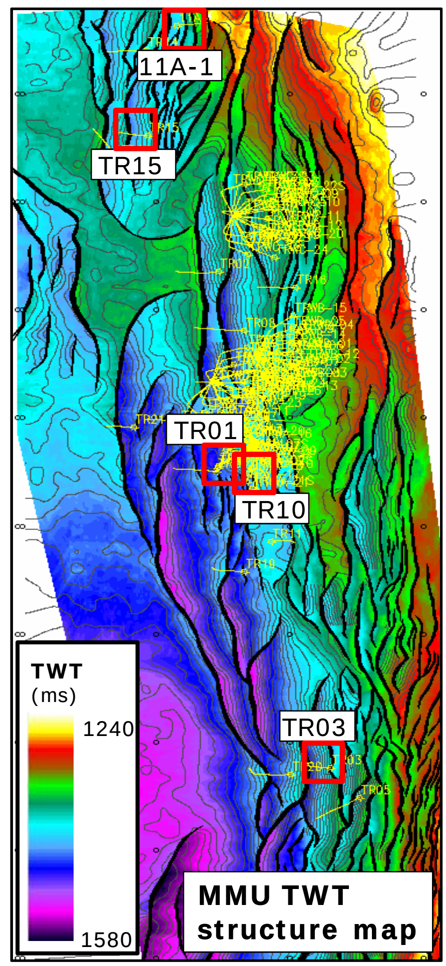

Figure 2. Two way time structural map of MMU highlighting locations of five check shots and check shots.

Three check shots that show low velocity zones were compared with respective sonic logs to check that either these low velocity zones exist on sonic logs. The low velocity zones observed on check shots are not observable on the sonic logs (Figure 3.).

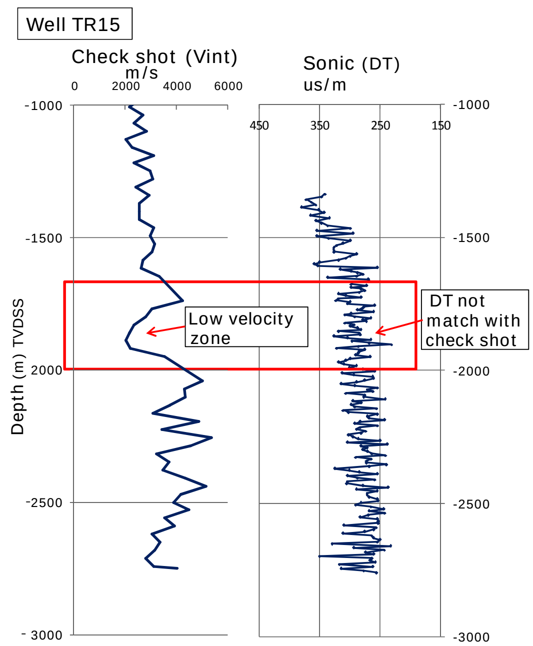

Figure 3. Comparison of check shot and sonic velocities of well TR15. Low velocity zone and check shot is not observed on sonic.

These values are assumed due to shallow low velocity zones or these are erroneous points. Therefore, these points were edited to remove these local effects. However, I prepared velocity models using both edited and non-edited check shots.

Validity of these models was tested by conducting different statistical tests.

Synthetic seismogram and well to seismic tie.

The correlation coefficients between synthetic and seismic section along well trajectory for 33 wells, ranges from 31 to 78, with average value of 58.84. The average time shift and phase rotation required to match synthetic and seismic is 0.67 ms and 3.97 degrees respectively.

Well log markers were picked based on sonic, gamma ray, resistivity, neutron and density logs characteristics. These markers mostly represent wide spread coals or shales. The synthetic seismogram response is not always the same because of the lateral lithological heterogeneity. The interpreted horizons are not necessarily following the well log markers. Mostly interpreted seismic reflections follow strong positive peaks near the well log picks (Figure 4.). Therefore, these interpreted seismic reflections are not exactly matching the well log markers

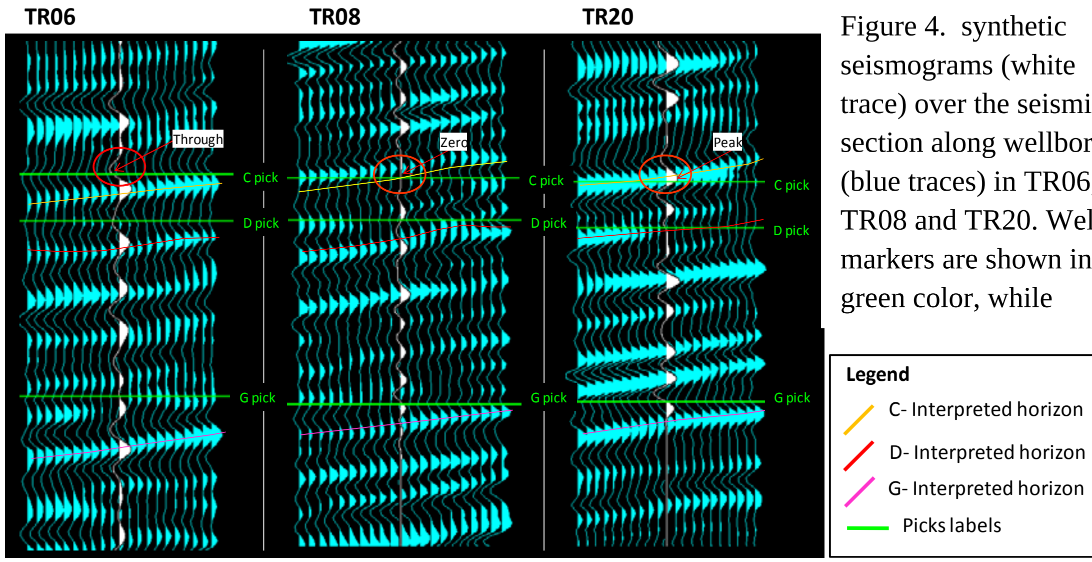

Figure 4. synthetic seismograms (white trace) over the seismic section along wellbore (blue traces) in TR06, TR08 and TR20. Well markers are shown in green color, while

Velocity models and depth prediction

This section describes statistical analysis of depth prediction by using different velocity models as discussed in methodology part. Moreover, velocity variations pattern for different models are discussed.

MODEL 1

This model uses velocity information of five unedited check shots. There is progressive increase in depth prediction error from MMU to G marker (Table 3). This increase of error with depth may be because of cumulative error at greater depths, but the error at G marker is very high (Table 3 & Figure 5).

MODEL2

This model uses five edited check shots. The error in depth prediction is reduced for this model as compared to Model 1(Figure 5 & Table 3). The error is significantly reduced for G marker. This improvement is caused by the removal of erroneous data points or low velocity anomalies.

MODEL3

This model uses T-D tables of 33 synthetic seismograms created by 5 non-edited check shots and older version of processed seismic data. The velocities in this model are also interpolated linearly without incorporating horizons. This model was used by Chevron for depth prediction. The average depth errors are mentioned in Table 3 & Figure 5.

MODEL 4

This model uses 33 synthetics generated by applying average polynomial fit of five edited check shots. Moreover, five interpreted horizons were also used to incorporate structure variations in velocity model. The average error for each pick is reduced for this model (Figure 5 and Table 3). The possible cause of improvement in depth prediction may be because of horizons and the use of average velocity T-D tables of five edited check shots. This provides reasonable velocity control above MMU T-D tables created from synthetic seismograms do not cover the section above the MMU

MODEL 5

This model uses T-D curves for 33 wells, 5 horizons, RMS velocities and pseudo velocities. The T-D curves of 33 wells were generated from synthetics by applying average polynomial T-D tables of five edited check shots. The significant reduction of average error in depth prediction was observed (Table 3 & Figure 5).

MODEL 6

This model uses the same velocity information as of MODEL 5 except it does not use average polynomial fit curve of 5 check shots. The area was divided into four zones and in each zone the nearest edited check shot was applied. This was done to check that either the depth prediction would improve after applying nearby check shots independently to accommodate local variations. The results are approximately the same for MMU, C and D marker, but for G marker it becomes worse as compared to MODEL 5 (Table 3).

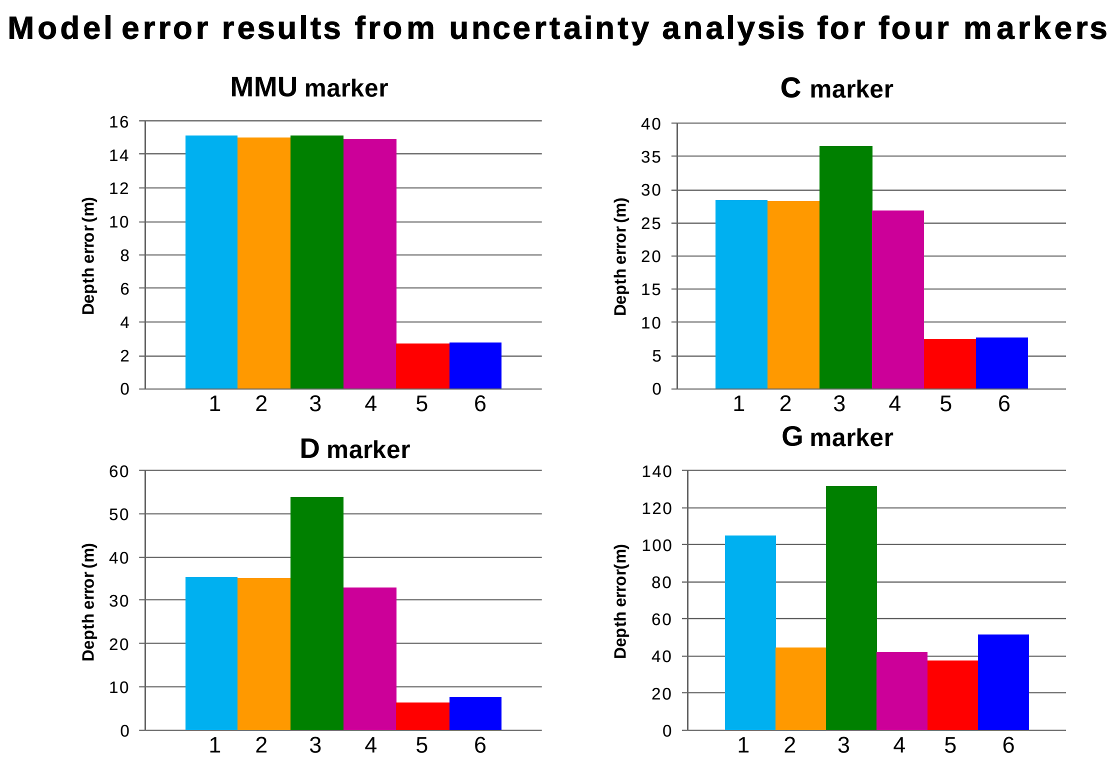

Figure 5. The average depth error for key markers by using different models, Model 5 was selected as velocity model represent.

	Average error in depth prediction (meters)			
	MMU (102 wells)	C (93 wells)	D (85 wells)	G (22 wells)
MODEL 1	15.18	28.43	35.57	105.16
MODEL 2	15.032	28.28	35.26	44.78
MODEL 3	15.18	36.61	53.9	131.72
MODEL 4	14.92	26.82	33.12	42.24
MODEL 5*	2.68	7.54	6.39	37.44
MODEL 6*	2.73	7.6	7.76	51.34

Table 3. Average depth prediction error for key markers by using different models. MODEL 5 and 6 are shown fewer error than the rest as highlight in red color box.

* These values are after uncertainty drop out analysis

Blind test

In order to test the validity of the model on larger scale, blind test was performed by dropping out the velocity information of one of the platforms and then the depths of the different markers were predicted. According to best statistical results, MODEL 5 was selected to perform the blind test. Forty wells from two selected platforms (TRWC and TRWD) were removed from the model in two iterations and the depths were predicted for different markers by using Model 5. The average errors in depth prediction are shown in Table 4.

I also compared the difference in depth prediction by using some of the individual wells of one platform (TRWD) by using MODEL 5 and the original model used by the Chevron. There is significant improvement in depth prediction and differences between predicted and actual depths are reduced (Figure 6).

Table 4. Average depth prediction error for blind test

Blind zone	Average depth (meters) error for			
	MMU	C	D	G
TRWC (20 wells)	2.16	6.20	7.45	12.2
TRWD (20 wells)	1.58	5.42	6.52	-

These same wells were shown in the introduction part. Therefore, Model 5 is more accurate model for depth prediction.

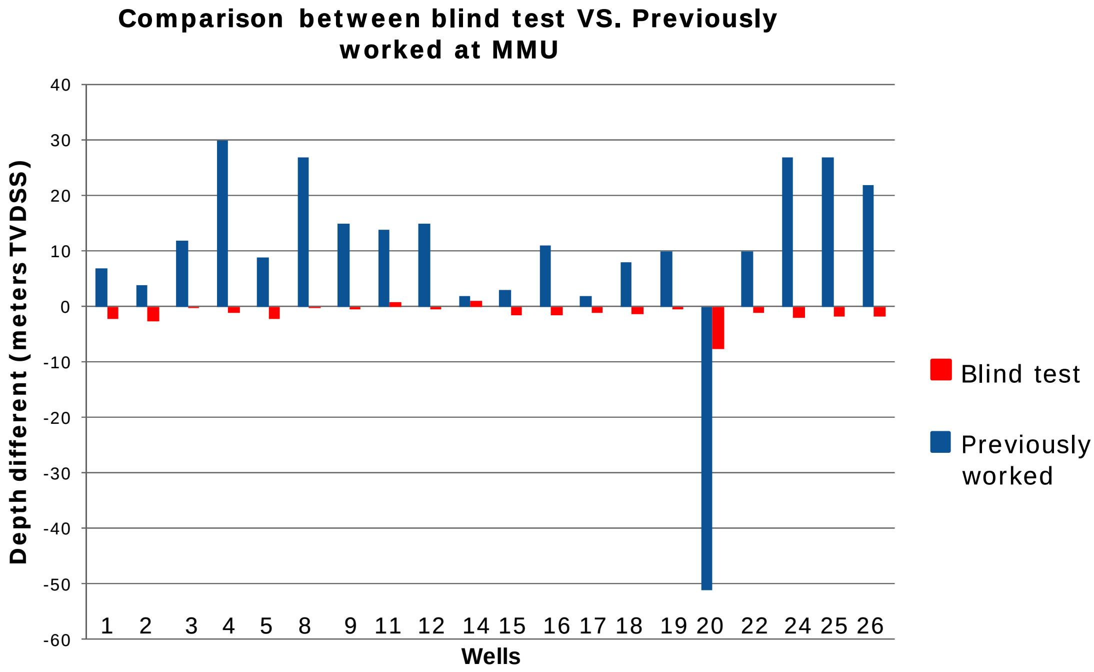

Figure 6. Comparison of predicted depths from MODEL 5 and predicted depths by applying check shot data to T-D function of synthetics without using structural trends.

Velocity maps

Velocity variation maps were extracted along four interpreted horizons (MMU, C, D and G) by using MODEL 5.

Velocity map of MMU shows maximum velocities within the deepest part of the basin along east dipping faults. The highest velocity values are observed in the middle and southern sub grabens and lowest velocities are in the north western part which is the highest part (Figure 7)

Similarly, velocity maps for other surfaces such as C, D, and G also show velocity variation along the structures. High velocities are observed in the deepest parts of the basin bounded by the faults and low velocities are observed in the north western part of the area.

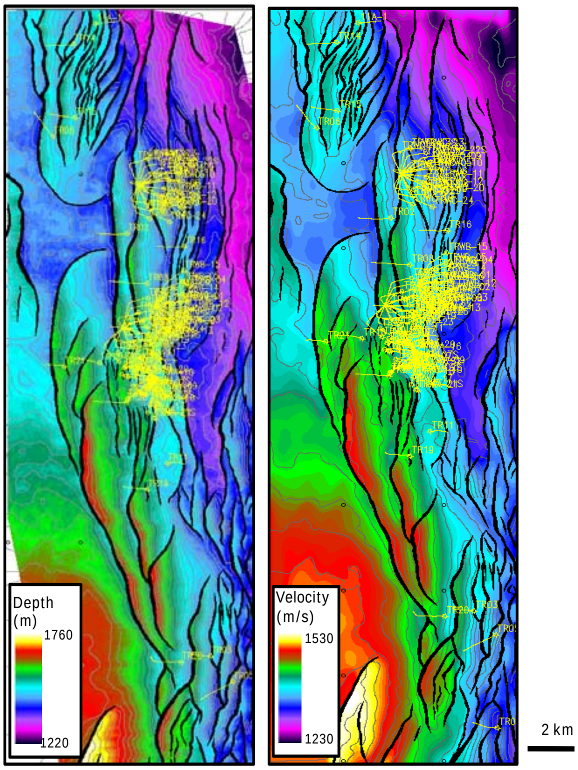

Figure 7. (left) Depth structure map and (right) Velocity map of MMU surface, high velocities are SW while low velocities are in NE part of the area.

4. Conclusions

This study evaluated different velocity sources for accurate depth prediction and suggested an integrated workflow of velocity modeling. The model, which predicted depths more accurately, uses check shot data, RMS velocities, and pseudo velocities. These velocities were interpolated along the interpreted horizons. The key findings and conclusions are summarized below

- Check shot data needs to be check carefully and local anomalies should be edited before using check shot data for velocity modeling. Check shot data show very low anomalous zones at different depth intervals. These anomalies may be due to low velocity shallow layers or localized variations.
- Velocity model using RMS velocities, Pseudo velocities and structural constraints along with check shot velocity information significantly improved the results. Therefore, it is recommended to create integrated velocity model by using these mentioned velocities for more reliable depth prediction.
- Time-depth functions generated from synthetics mostly cover portion below MMU. The missing velocities above MMU should be incorporated from average velocities obtained from check shot data.

5. Acknowledgements

I would like to thank my supervisor Dr. Mirza Naseer Ahmad, for his valuable comments, warm support and excellent suggestions throughout my research project, and also Prof. Phillip Rowell, Prof. Joseph Lambiase and Prof. John Warren for their knowledge through the Petroleum Geoscience Program. Chevron Thailand Exploration and Production, Ltd. is acknowledged for offering me the opportunity to use of their seismic, well log, check shots, and velocities data. Landmark is acknowledged for providing academic licenses of software. I am very appreciate to my company supervisors; Mr. Jim Logan, Mr. Lance D. Brunsvold , Mr. George Livesay and Miss korakot Surarat for giving me the chance to do this project and also Chevron Thailand and Petroleum Geoscience Program staffs for precious technical support throughout the year. My family, my colleagues and my friends are acknowledged for their cheerfulness during my research project.

6. References

Jardine, E., 1997, Dual Petroleum Systems Governing the Prolific Pattani Basin, offshore Thailand: Petroleum system of S.E. Asia and Australsia Conference: Jakarta, May 21-23, 1997, p. 351-363.

Turner, J., 2006, Pattani Basin stratigraphy: Bangkok, Chevron Thailand Exploration and Production Ltd.