Structural Style and Tectonic Evolution of the Nakhon Basin, Gulf of Thailand

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Abstract

Nakhon Basin lies at the western margin of the Gulf of Thailand. Seismic interpretation study was carried out to identify structural features for better understanding of tectonic evolution of the Nakhon Basin. The main observed structure features of the area were growth faults, extension fault blocks, inversion and detached normal fault assemblages. The initial rifting created half grabens in Late Oligocene. Rifting phase was followed by inversion. Then in Early Miocene, re-activation of faults associated with initial rifting occurred due to the second phase of rifting and post rift thermal subsidence started during Middle Miocene, which continues until recent. The basin formed in response to oblique extension resulting from a component of right-lateral motion.

Keywords : Nakhon Basin, 2D Seismic, Structural style, Tectonics

1. Introduction

It is important to understand geological structures of a basin for petroleum exploration and improved knowledge of geological structures enhances the ability to construct more accurate basin models. The Northern Nakhon basin is located in the western portion of the Gulf of Thailand (Figure 1) and well known for oil and gas exploration. There is very few published material about the structure style of the basin therefore, this basin required a comprehensive study to understand its structure. This research attempted to analyze the structural style of the Nakhon basin by using 2D seismic data.

2. Methodology

Vertical seismic section interpretation was the most important component of this study to identify the structures in the area. In order to examine the lateral extend and variations in the thicknesses of different sedimentary sequences time structure maps and isopach maps were prepared. The amount of total extension was estimated by restoring the key interpreted seismic sections.

3. Results

A set of four horizons were interpreted over the 2D seismic data set by tying to available well log data and matching seismic signatures. The interpreted horizons are Middle Miocene, Early Miocene, Late Oligocene and Pre-Rift Basement (Figure 2).

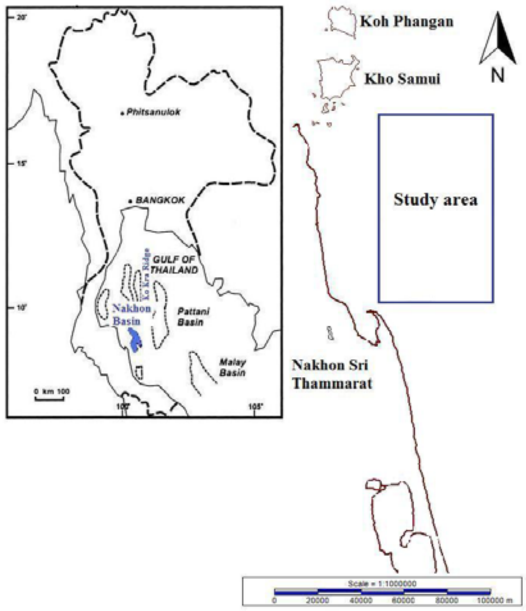

Figure 1. Location map of the Nakhon basin at the west of the Gulf of Thailand. Koh Samui and Koh Phangan are offshore islands north of Nakhon Sri Thammarat.

The main observed geological structures in seismic interpretation were growth faults, extension fault blocks, inversion structures and detached normal fault assemblages. The majority of faults dip eastward with north-south orientation. (See Figures 4 for plane view). The growth faults of the basin are also east-dipping faults with strike sub-parallel to north-south basement high (e.g. Ka Kra ridge) in the area. These faults were recognized by syntectonic strata thicken towards the fault. Reactivation of some growth faults occurred in Middle Miocene as a non-growth faults (Figure 2).

Vertical seismic sections of the centre part of the depocentre show inversion related structures and these inversion features are associated with high angle normal faults. This inversion is evidence of a switching in tectonic mode from extensional to compression or changing paleo-stress direction.

The fault block geometry is observed as a domino style and fault blocks appear as rotated slabs in cross section (Figure 3).

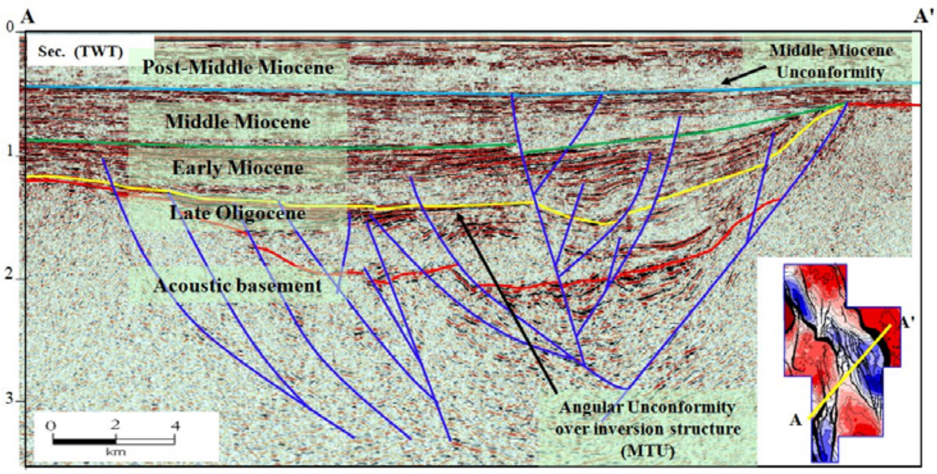

Figure 2. Example of seismic facies which is commonly associated with growth faults and non-growth faults. Horizons Pre-rift basement (red), Late Oligocene (yellow), Early Miocene (green) and Middle Miocene (blue) are shown. Faults are shown as blue lines.

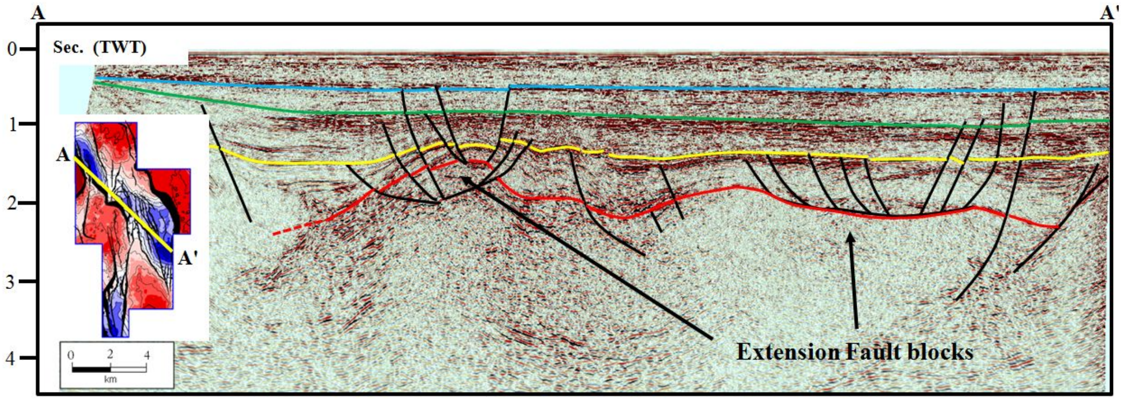

Figure 3. Interpretation of extension fault block structures. Horizons Pre-rift basement (red), Late Oligocene (yellow), Early Miocene (green) and Middle Miocene (blue) are shown. Faults are also shown as black lines. This figure represents two events of fault termination, one is Late Oligocene and another one is in Middle Miocene.

The other observed feature is syn-depositional detached normal fault assemblages. Generally, this structure style comprises of both synthetic and antithetic faults. These detached normal fault assemblages can be seen similarly in the whole area but in the northern part, these are steeper as compared to the south.

In term of fault orientations three sets of normal faults, trending NW-SE, N-S and rarely NE-SW developed in this basin (Figures 4). The NW-SE faults bounds the basin and are roughly parallel to rift axis of the Nakhon basin, whereas the N-S faults are minor faults detached onto NW-SE faults in en echelon pattern (Figure 4).

Cross-basin faults are in the central part of the basin and these are predominately high angle dipping to the east. These cross faults are generally NNW-SSE directing and suggest some extension across this area. The northern part of the area is marked by the east-dipping flanking fault, while the southern part is marked by the west-dipping flanking fault (Figure 4).

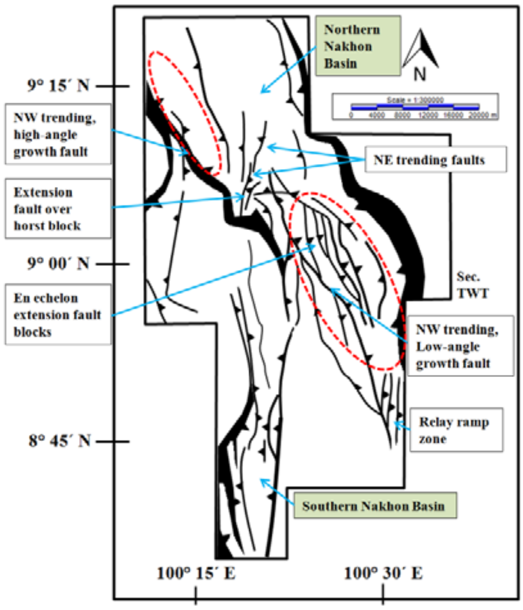

Figure 4. Interpreted structural map of pre-rift basement, faults are shown in black lines and depocenter areas are shown in red dot circles.

The Late Oligocene isopach map (Figure 5) shows that sediment package in this period deposited in a limited narrow shape during the initiation of the regional extension of the basin. The greatest thicknesses are in northern and southern part of the basin. The geometry of syn-rift sediment wedge orientates in NW-SE direction. The geometry of the sediment wedge on isopach maps may be caused by the growth normal fault and major fault displacement.

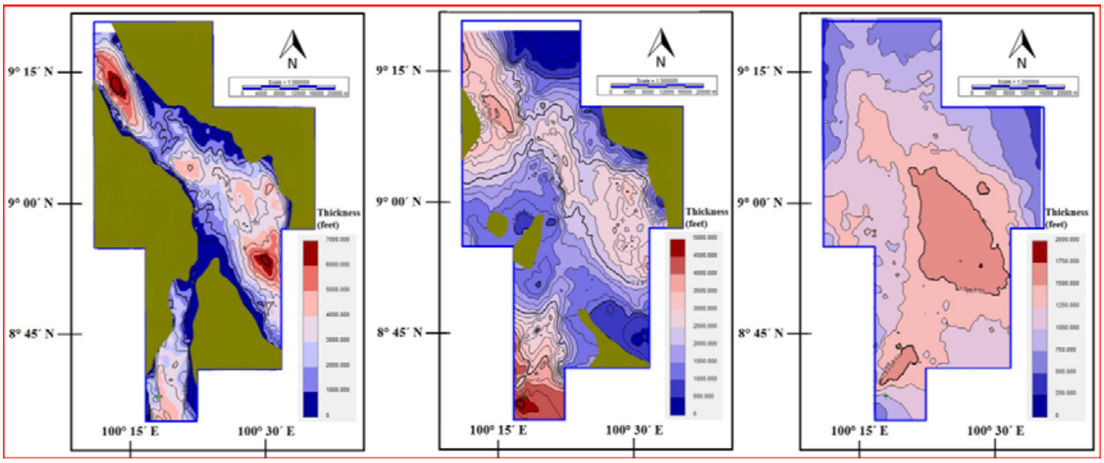

Figure 5. Isopach map showing various thickness of sedimentary of various subsurface geological horizons derived from Late Oligocene, Early Miocene and Present (left to right, respectively).

3. Discussion

The syn-rift structures in this area are characterized by growth faults. The observed faults can be classified as major and minor faults. Major faults are spatially large with low angle dip (<30°). Minor faults form as domino-like fault block assemblages and sole out onto major low angle faults. The presence of faults parallel or sub-parallel to syn-rift depocenter indicates that these faults were developed during rifting period.

The complicated fault pattern of the area is different from typical simple rift system. The map view of structural style and basin shape is compared to analogue model of oblique en echelon half-graben rift system proposed by Corti (2011) (Figure 6). The analogue model is 30° oblique rift model. The result shows that the Nakhon basin is comparative to the analogue model (Figure 6).

The fault pattern in the basin suggests that the syn-rift faults in this basin were possibly developed by oblique-extension system. The origin of these faults is related to the reactivation of weak zones of basement during Late Oligocene.

The N-S geometry of the basin in the south is orthogonal to the extension direction (E-W extension) while the oblique trend of the basin in the north is following the oblique fabric. On the other hand, internal faults are trending more or less N-S i.e. perpendicular to the extension direction because they are away from the pre-existing fabric. The pre-existing fabric may caused the weak zone resulting en echelon, oblique boundary faults followed trend of the weak zone. Therefore, σ_1 would not be oriented NW-SE that would place it parallel to the main faults trends. The basin formed in response to oblique extension resulting from a component of right-lateral motion caused by the on-going northward movement of the Burma block along the Sagaing Fault in Myanmar.

Nakhon basin initially formed as a half-graben rift basin in Late Oligocene followed by an inversion period at the end of Late Oligocene. In Early Miocene re-activation of the Late Oligocene normal faults occurred. Post rift thermal subsidence is prominent in Middle Miocene and continues until recent.

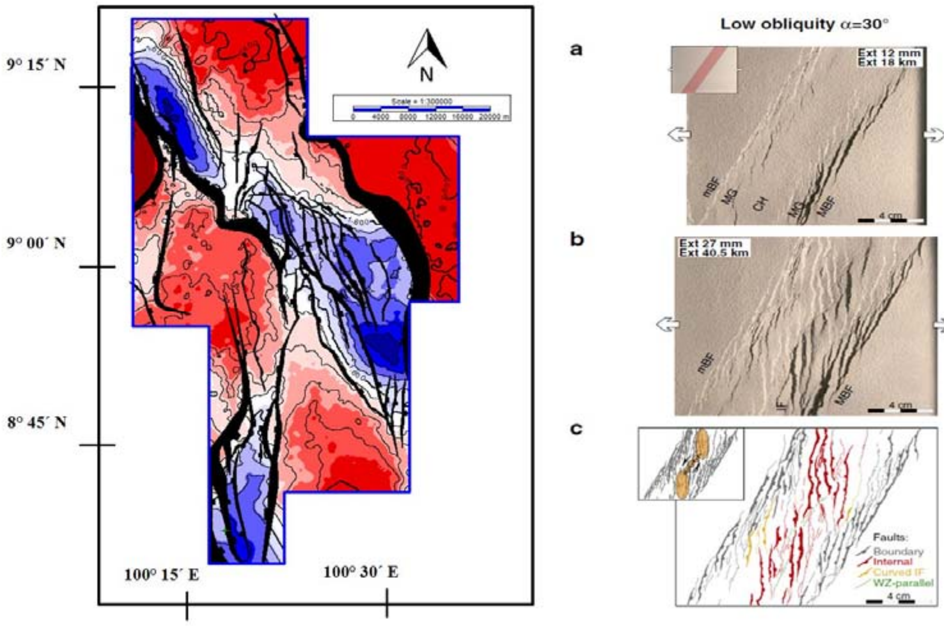

Figure 6. Comparison of the geometry of the rift of the Northern Nakhonbasin (left) with analogue model proposed by Corti (2011), 30° oblique rift model characterised by en echelon border faults, internal (roughly extension-orthogonal) faults and rift-parallel faults. Note that: major boundary faults (MBF) marginal grabens (MG) and central horst (CH) a–b) Top-view photos of the low-obliquity model after different amounts of extension; c) line drawing of structures at the end of model deformation.

4. Conclusion

The key findings of this project are

- The Nakhon basin originated during the Late Oligocene due to rifting. At least two phases of rifting were observed in the area these are in Late Oligocene and Early Miocene.
- The main structural styles are; growth faults, extension fault blocks, inversion structures and detached normal fault assemblages.
- The general orientation of the faults is NW-SE and N-S.
- The basin formed in response to oblique extension resulting from

a component of right-lateral motion.

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6. References

Corti, G., 2011, Evolution and characteristics of continental rifting: analogue modeling-inspired view and comparison with examples from the East African Rift System: Tectonophysics, in press.