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Structural Style of Songkhla Basin, Gulf of Thailand

Heliosita Anggraeni Kartikasari

Department of Geology, Faculty of Science, Chulalongkorn University, Bangkok 10330, Thailand

*Corresponding author email: heliosita@yahoo.com

Abstract

Gulf of Thailand is composed of number of Cenozoic basins. The Ko Kra Ridge divides the Gulf of Thailand into two parts, which are Western Graben and Basinal Areas. Songkhla Basin is located in the Western Graben of the Gulf of Thailand. There is no detail study about the structure style of the Songkhla basin so far. In this study, in order to understand the tectonic evolution of the basin, I observed major geological structures by using 2D & 3D seismic data set. Seismic interpretation revealed four main types of geological structures that are; border faults, intrabasinal ridge, compressional structures and interbasinal fault. The basin has thicker sediments in the Western part as the sediments accumulated along the growth fault surface. Basin has geometry of an asymmetric half-graben bounded by major extensional faults (boundary faults) oriented NNW-SSE. Most of the faults are east dipping, but there are also some antithetic conjugated faults. Tectonic activity of the basin has three phases. The initial rifting occurred in Eocene or in Early Oligocene, which initiated the basin formation. The rifting phase was followed by inversion tectonic phase in Early Miocene. In the Middle Miocene extensional tectonics resumed.

Keywords: Structural Style, Gulf of Thailand, Songkhla basin.

1. Introduction

The basins of Gulf of Thailand are asymmetrical half-graben or full graben bounded by the major extensional faults controlling the basin development and sedimentation. These basins were filled with non-marine to marginal marine Tertiary sediments. Different tectonic evolution models had been presented based on the study of Patani and Malay basins, but there is no detail study available for structure style of Songkhla basin. Therefore, to fill this knowledge gap I selected this area and the main aim of this study was to report major structures and to discuss about the evolution of the basin. This study will enhance the regional understanding about tectonics of Gulf of Thailand.

2. Methodology

The first step was to tie the well to seismic. In order to tie depth domain formation tops to time domain seismic data, check shot data was used. Then I interpreted the vertical seismic section to identify key structure types and mark key reflectors on available 2D seismic lines and 3D seismic volume. The key reflectors selected for picking on the seismic data; Middle Miocene, Early Miocene, Early Oligocene, Eocene (?), and pre-rift basement. In order to examine spatial extent of the structures and their geometry, depth structure maps were prepared for each selected reflectors. Isopach maps were used to show variation in sediment thicknesses related to the growth faults during rifting period.

3. Results

3.1 Well-to-Seismic Ties

The wells were tied to the seismic by using check shot data and velocity survey provided by the company. Only one well has the biostratigraphic data and the ages of well tops were assigned based on that information (Figure 1).

3.2 Vertical Seismic Interpretation

3.2.1 Pre-Rift Basement

This is the deepest interpreted horizon. No well was penetrated to this reflector. The horizon named as pre-rift basement because the reflection packages indicating a pre-rift characteristics. The main boundary fault is located in the western part of the area and half graben structures can be observed within the basement. The section in the center part is dominated by east dipping half graben. Northern part has horst structure, which is not present in center and southern part.

3.2.2 Eocene (?)

The seismic character of this horizon is not prominent and at some places. According to company well report, the age of this horizon is Eocene, but in literature, it has been cited that the oldest syn rift stratigraphic sequence is Late Oligocene (Lian & Bradely, 1986). This horizon overlay the pre-rift basement and has thicker sediments along major fault, as the pre-rift sequence had been tilted and created accommodation space for the sediments. The faults in this sequence are growth faults and dipping eastward.

3.2.3 Early Oligocene

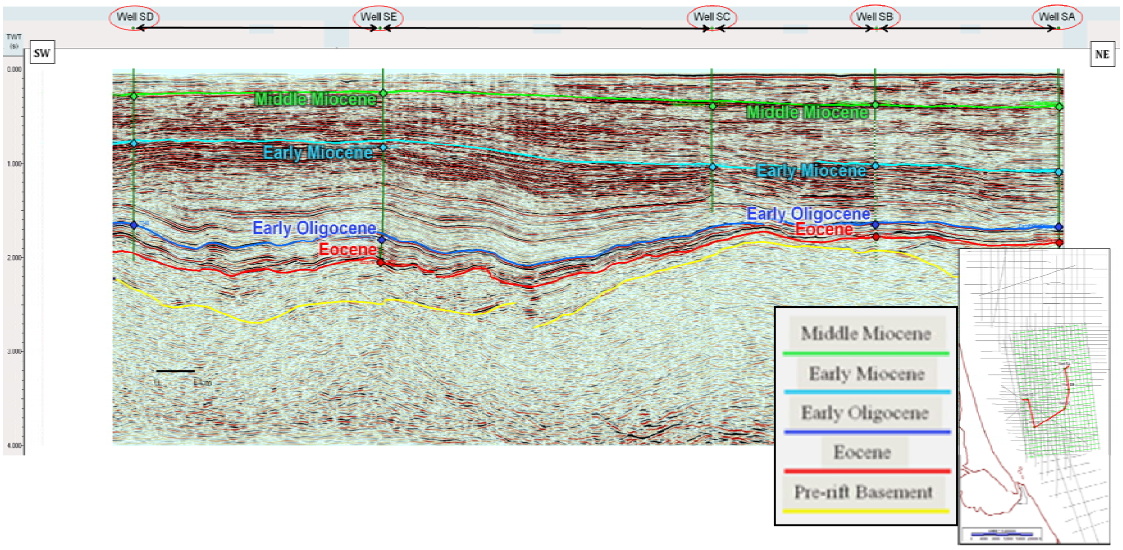

Figure 1. Well-to-seismic ties result, well-to-well correlation showing five key horizons.

This horizon has good strong reflection throughout the area and this sedimentary package is relatively very thin in whole of the area. This horizon as compared to deeper ones is relatively less faulted. The significant throw in this horizon can be only seen in the western part of the area along major faults of the basin, which are east dipping. The horst type structure was also observed in this horizon in the northern part.

3.2.4 Early Miocene

This horizon shows flexure downward throughout the area under investigation. The western part of this sequence show the continuation of the same faults as observed in older sequences, but the fault angle is higher. In Eastern part of the area, both synthetic and antithetic fault assemblages were observed.

3.2.5 Middle Miocene

This horizon is almost flat and does not have faults, except minor normal faulting with East dipping only in northern part. The reflection are significantly good quality and easy to track over the whole area.

3.3 Depth Structure Maps

3.3.1 Pre-rift Basement Map

The deepest sedimentation part is bounded by faults oriented N-S or NNW-SSE, while in the southern part direction of major fault changes to NW-SE and this southern part is less faulted as compared to central part.

3.3.2 Eocene Map

The fault direction and pattern in Eocene map is almost same to the faults interpreted in Pre-rift basement. In the northern part of the area the horizon could not be interpreted, due to poor quality of seismic reflections, therefore map of this part is not contoured.

3.3.3 Early Oligocene Map

Early Oligocene map indicates that this sequence is also dominated by faults of the same pattern as observed in previous sequences. In the northern part, new faults appear oriented NE-SW.

3.3.4 Early Miocene Map

The Early Miocene map shows less faulting as some faults discontinued and some faults became short. The other significant change observed on Early Miocene Map is location of the deepest part of the basin as compared Early Oligocene. Early Miocene map shows that deepest part shifted to Eastern margin.

3.3.5 Middle Miocene Map

Middle Miocene depth structure map shows almost no faulted structure except one fault in the northeastern part of the area oriented in N-S direction. The deepest part of the basin shifted to northeastward as compared to previous older sequences.

3.4 Isopach Maps

3.4.1 Isopach Map of Early Syn-rift sequence (top Pre-rift Basement to Eocene (?))

This isopach map showed two zones of thick sediments, one located at Northwestern part while other is located at the Northeastern corner and both thick sediment portions are bounded by faults.

3.4.2 Isopach Map of Early Oligocene

Generally, the thickness of this sequence is around 1,200 to 1,400 feet except three different depocenters at the margin of the basin. These maximum thicknesses are located perpendicular to major faults.

3.4.3 Isopach Map of Top Early Oligocene to Top of Early Miocene

This isopach map shows the thickest sedimentation in the southwest part of the area bounded by faults and another thick sediment portion is at its Western part. The maximum thickness observed for this interval is about 4,400 feet.

3.4.4 Isopach Map of Middle Miocene

The thick layer accumulated in the center of the area, spread relatively North-South direction. The depocenter shifted eastward for this interval and the maximum thickness is about 2,700 feet.

4. Discussion

4.1 Structural Style of Songkhla Basin

The Songkhla basin is a small, narrow and elongated basin as observed on depth structure and isopach maps. Based on seismic interpretation the important geological structures of the Songkhla basin are border fault, intrabasinal faults, compression structures and interabasinal ridge (A-A’ in Figure 2).

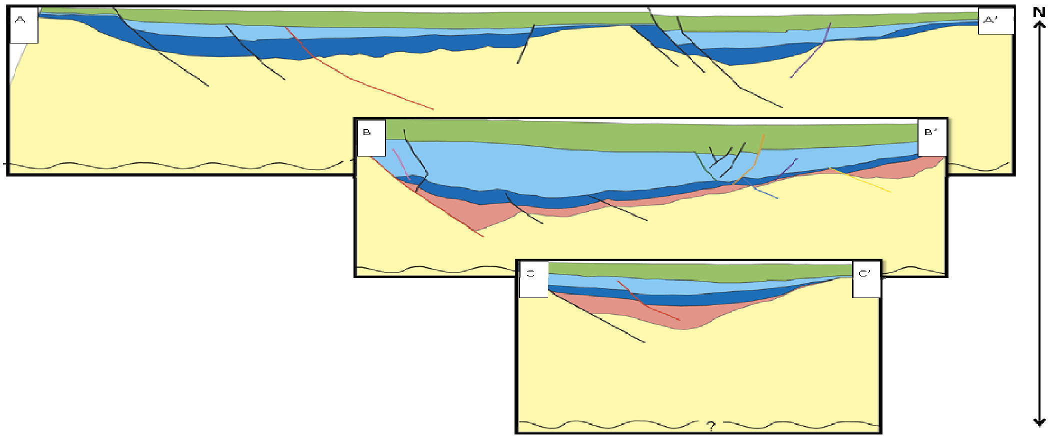

Figure 2. Cross-sections showing basin geometry for brief basin evolution of Songkhla basin from North to South.

4.2 Basin Evolution

The interpretation indicates three phases of tectonic activity (Figure 3). The initial basin forming was due to extensional phase, after this, compression forces were dominant followed by again extensional episode. The stage of initial extensional was due to rifting in Oligocene. Then the compressional force created inversion structure, which probably occurred at about Lower Early Miocene. The time slices showed strike-slip movement in the same age as of inversion. This inversion might be due to compression component of strike slip movement in the center part of the area. Thermal subsidence in this area was recognized by the bent down surface and conjugate faults in the Eastern part and has a small displacement along the fault in the Western area. This thermal subsidence is the second extensional feature.

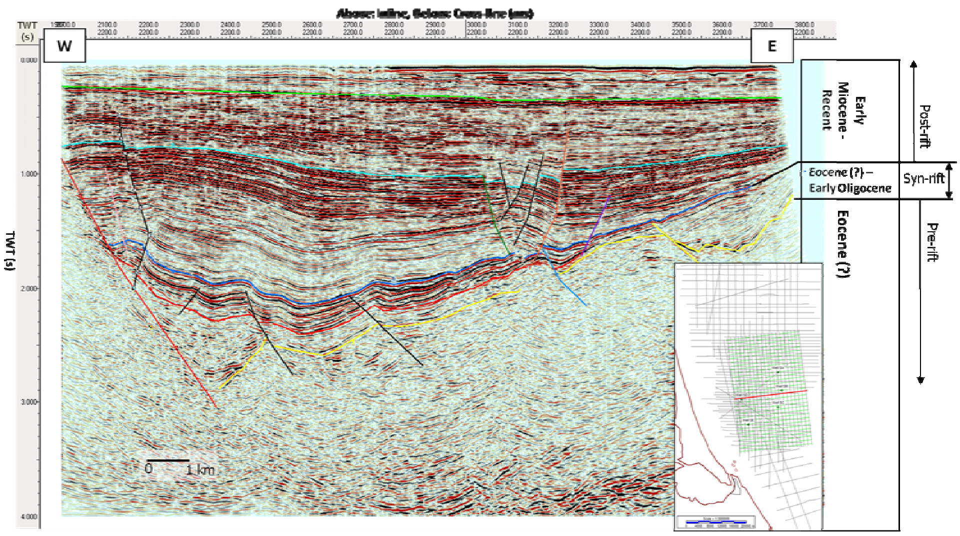

Figure 3. Seismic cross-section of cross-line 2200 in central part of the area showing the structure style of Songkhla Basin.

4.3 Depocenter Determination

Depocenter of structure could be determined by looking to the isopach maps and searching for the thickest part of the map. As seen on the isopach maps, the thickest part is at different location in different geological times (Figure 4). At Pre-rift basement to Eocene interval, the thickest part was located on the Northeast margin, while in Early Oligocene interval (lower to upper Early Oligocene sequence) the thickest part has been shifted westward. Moving to Early Miocene, the maximum thickness shifted in south direction approaching the southwestern margin. Then in the Middle Miocene, the depocenter was in the center of the area.

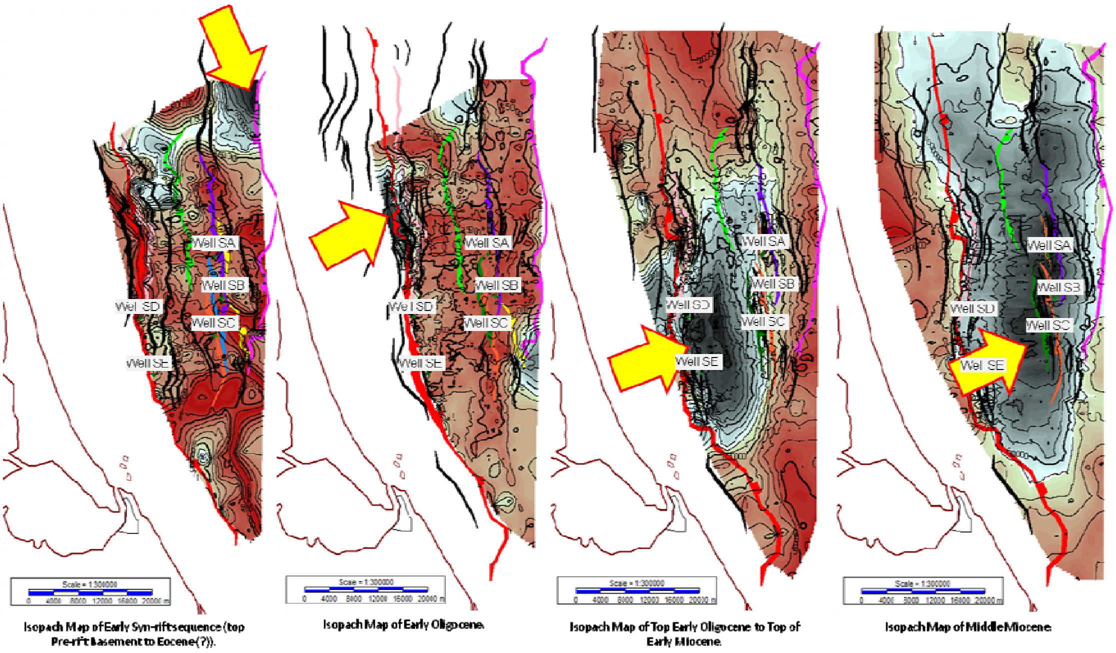

Figure 4. Maximum thickness changes of in different geological times.

4.4 Fault Measurement

Horizontal displacement was measured along two selected major faults for different horizons; fault F1 and F2 in Early Oligocene and Early Miocene. These faults were selected because both have the largest throw among all faults. They are located on Western margin of the area and oriented in N-S direction with Eastward dips. The purpose of this is to estimate the amount of extension in different geological times. The maximum displacement of about 1.2 km was observed along fault F1 in Early Oligocene (Figure 5).

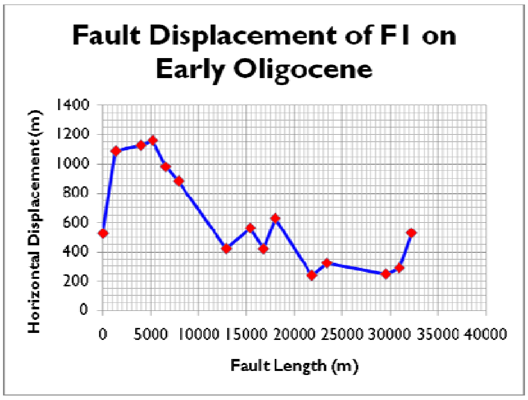

Figure 5. One of the fault displacement chart showing the fault F1 has the largest throw appeared in Early Oligocene.

Table 1. Songkhla basin structure evolution.

Structure	Age	Major Features
Rifting	older than Eocene (?)	on vertical seismic: half-graben or tilted fault blocks, wedges-shaped deposit
Inversion & Strike-slip	Lower Early Miocene (or Late Oligocene (?))	on vertical seismic for inversion features: compressional feature such as folds and small anticlines on time slices for strike-slip features: shifted contour
Second Rifting	Early Miocene	on isopach map: thick sediment adjacent to fault surface
Thermal Subsidence	Lower Middle Miocene	on vertical seismic: conjugated faults structure, sagging structure

5. Conclusions

The major findings and conclusions are

(1) The important structures in the Songkhla basin are half-graben geometry, intrabasinal normal faults, compressional structures, interbasinal ridge and inversion structures. The general orientation of the faults is NNW-SSE.

(2) Rifting started in Eocene or Early Oligocene, followed by inversion within Early Miocene and finally thermal subsidence occurred.

(3) Strike slip motion is observed on time slices and this corresponds to the compression structures observed on vertical seismic section.

(4) The maximum displacement along one of the main boundary fault is about 1.2 km in Early Oligocene. See Table 1 for compilation.

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