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Contributed Paper

Tectonic Evolution of the Thonburi Basin in the Lower Central Plain, Thailand

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ABSTRACT

The Thonburi Basin, one of the Cenozoic basins in Central Thailand, covers the western part of Bangkok and eastern Samut Sakhon province. The interpretation of seventeen seismic reflection profiles (total length of 467 km), correlated with data from two well logs indicated that the Thonburi Basin is composed of five stratigraphic units. Unit A is the Oligocene shales and alternating thin layers of sandstone and limestone overlies uncomfomably beneath the Miocene alluvial plain deposits (Unit B). The fluvial deposits of units D and C, which are thicker to the western center of the basin and thin outwards to all directions overlie under the uppermost layer (Unit E) which is a thin Quaternary deposit. All units is about 1.0-2.5 sec (TWT) thick and is underlain by quartzite basement. This study indicates increased sedimentation of units A and B to the western side of the depocenter, and a relatively uniform deposition over the entire basin for the younger units (units C+D, and E). This stratigraphic setting is coupled with a presence of the western boundary normal fault that controls the rifting and was primary active between the Early Oligocene and the Pliocene. The E-W extension of the Thonburi Basin started just before the Oligocene and had been active until it ceased in the Late Miocene-Pliocene time. This evolution of the Thonburi Basin is consistent with those of other Tertiary basins in the Central Plain of Thailand.

Keywords: tertiary basin, structural style, tectonic evolution, Thonburi basin, Thailand

1. INTRODUCTION

The Thailand Central Plain (TCP), one of the largest plains in the country, covers more than 40,000 km^2. It is a forming basin bounded by the mountainous Thai highlands to the north and the west. The eastern limit of the basin is marked by the Phetchabun and the Dong Phaya Yen ranges. The Central Plain extends southwards into the Gulf of Thailand. Geographically, the northern part is adjacent to Sukhothai, Uttaradit and Phitsanulok provinces; the western part is bounded by Kampangpetch, Kanchanaburi and Ratchaburi provinces; and the eastern part is bounded by Phetchabun and Saraburi provinces. The Thailand Central Plain (TCP) can be divided into two distinct parts: the Phitsanulok Basin to the north and the Lower Central Plain (LCP) (also called the Chao Phraya Basin) to the south [1]. The study area covers the entire Thonburi Basin in the southern part of Lower Central Plain encompassing Samut Prakarn, Samut Sakorn, Bangkok, Nakhon Pathom and Nontaburi provinces (Figures 1-2).

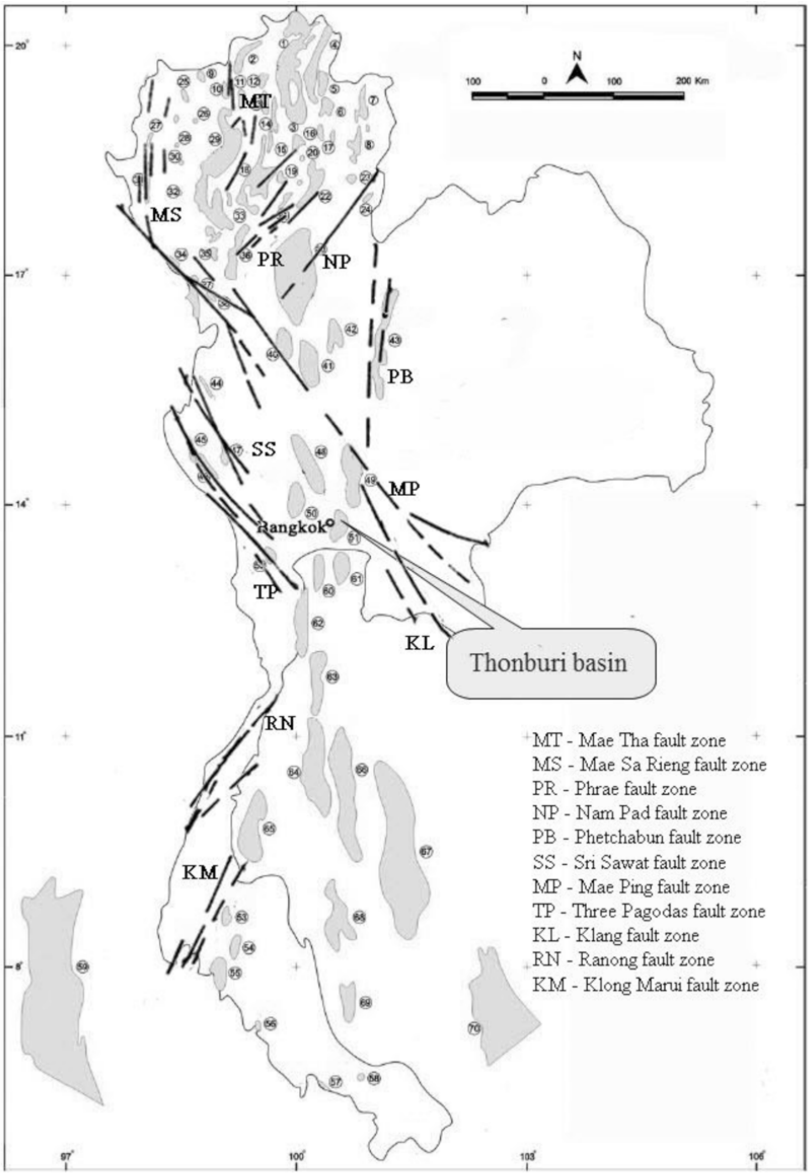

Figure 1. Locations map of Tertiary basins and major faults in Thailand. (modified from Department of Mineral Resources [1]).

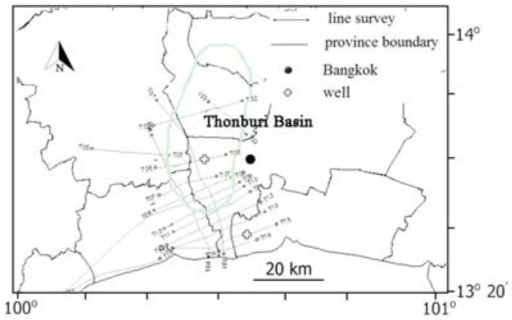

Figure 2. Map locating the seismic survey lines and the boreholes used in this study. Across section of seismic line crossing a well is shown in Figure 3.

The geological structure of sedimentary basins in Central Thailand has been extensively investigated by petroleum exploration through seismic and borehole data, however detailed information about the Thonburi Basin has been rarely available to the public. In addition, since it is covered with very thick flood plain deposits, most of the geomorphological and structural evidence in the basin is concealed. This work therefore aims to characterize the subsurface geological structure and to assess the tectonic evolution of the Thonburi Basin in order to develop a better understanding of the tectonic regime of the region.

The Cenozoic tectonic evolution of Southeast Asia is strongly related to the Himalayan orogeny, which results from the collision between India and Eurasia plates since the Eocene [2-5]. This convergence has been accommodated by an escape extrusion system (with more than 1,000 km displacement) active from Oligocene to Miocene times (20-30 Ma) [6]. Events include clockwise rotationing of the Sunda Shelf and temporary causative of motion on the Red River and Mae Ping faults [3]. This was followed by the uplift of the Phetchabun Mountain, Phu Phan Mountains, and Phanom Dong Rak Range [7]. The progress of the India-Eurasia collision during the Miocene also caused a shifts from right- to left-lateral movement for the NE-SW fault and conversely from left- to right-lateral movement for NW-SE strike-slip faults [3, 8]. Such a reversal of movement in these strike-slip faults can be used to explain the tectonics in the South East Asia and the openings of the South China Sea, the Gulf of Thailand and the Andaman Sea [6].

During the Eocene to Miocene period the basins in Central Thailand were marked by a general E-W extension generating basins that were aligned in N-S direction with typical half grabens, and being filled by continental sediments [9]. The basins in the LCT are controlled by the Three Pagodas and the Mae Ping fault which are major strike-slip faults oriented in the N-S direction with some component of normal slip[1].

The TCP is related to Himalayan Orogeny through the generation of pull-apart basins by simple shear tectonics along strike-slip faults system during Tertiary [10-14]. *Morley and Racey* [15] divide basins of Central Thailand into two different types. The first type is associated with the strike - slip Mae Ping and Three Pagodas fault belts occurring as intermontane basins in the western highlands. The second type is related to extensional features that are located beneath the flat Central Plain and formed larger basins than the first type [16-19]. These authors suggest that the origin of these basins may be related to pre-existing structures.

The Thonburi Basin

The Thonburi Basin is located in the lower Central Plain region of Thailand, between latitude 13° and 15° N and longitude 99° 30′ and 101° 30′ E. The study area includes Samut Sakorn, Samut Prakarn, Bangkok, Pathum Thani, Nontaburi, Ayutthaya and Nakorn Pathom provinces. The Thonburi

Basin is approximately 52 km long and 28 km wide. The basin is one of the north - south trending Tertiary basins and covers more than 9,000 km^2 [1].

The Thonburi basin has no significant topography and most of its area covered by 300 to 2,000 meters of Quaternary sediments [1]. *Nutalaya and Rau* [20] reported that the basement is Paleozoic to Mesozoic sedimentary, igneous and metamorphic rocks. Tertiary sedimentary layers were deposited during the extension and subsidence of the basin and overlie the basement [21]. These sedimentary rocks are characterized by claystone, sandstone, siltstone and conglomerate. Unconsolidated sediments were deposited overlying those units in the Quaternary by the Chao Phraya River.

Database and Methodology

Structural and stratigraphic interpretations of 2D seismic data were used to describe geometry, angles, displacements and variations of the faults that controlled the development of the sedimentary basins. In this study, we used a 2D seismic dataset comprising seventeen seismic reflection lines for a total length of 467 kilometers and data from two geophysical well logs (Figure 2) provided by the Department of Mineral Fuels (DMF), Ministry of Energy, Thailand. The combination of observed seismic reflectors and horizon unconformities interpreted from the well log data strengthens the interpretation of the subsurface geological structure of the basin. These data were interpreted using the Kingdom Suite (IHS Inc.) software. Seismic interpretation consists of stratigraphic and structural interpretations. For the stratigraphic interpretations, well log data were correlated with seismic data to define unit boundaries, unconformities and rock types. The seismically interpreted horizon and units are correlated with the wells where the seismic data intercepts the wells (see example in Figure 3). This was then extended throughout the basin. Structural interpretations identified fault type, structural style, geometry and orientation of the faults. The results of both stratigraphic and structural interpretation were used to create time structure maps and isochron maps for each unit, including subsurface structures (Figures 4 and 5). Then schematic tectonic evolution models of the basins were constructed.

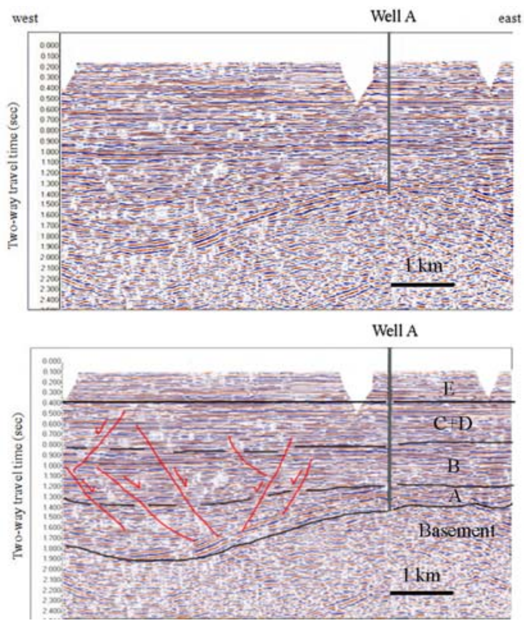

Figure 3. Seismic E-W section passing by the well A and its location. Location of this seismic line is shown in Figure 2.

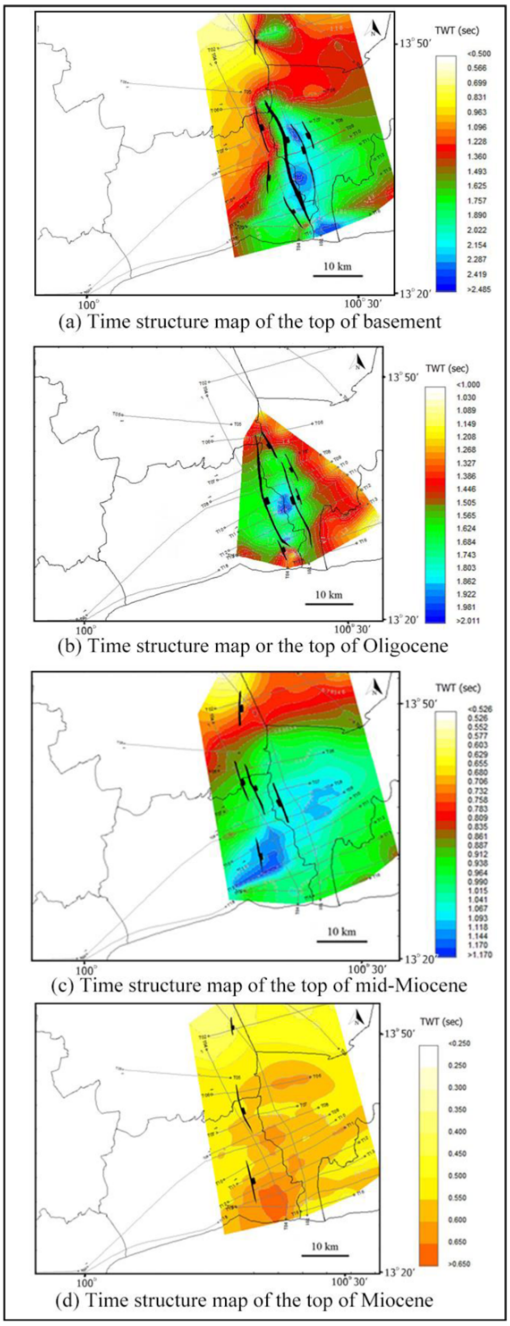

Figure 4. Time structure maps of each unit of the Thonburi Basin.

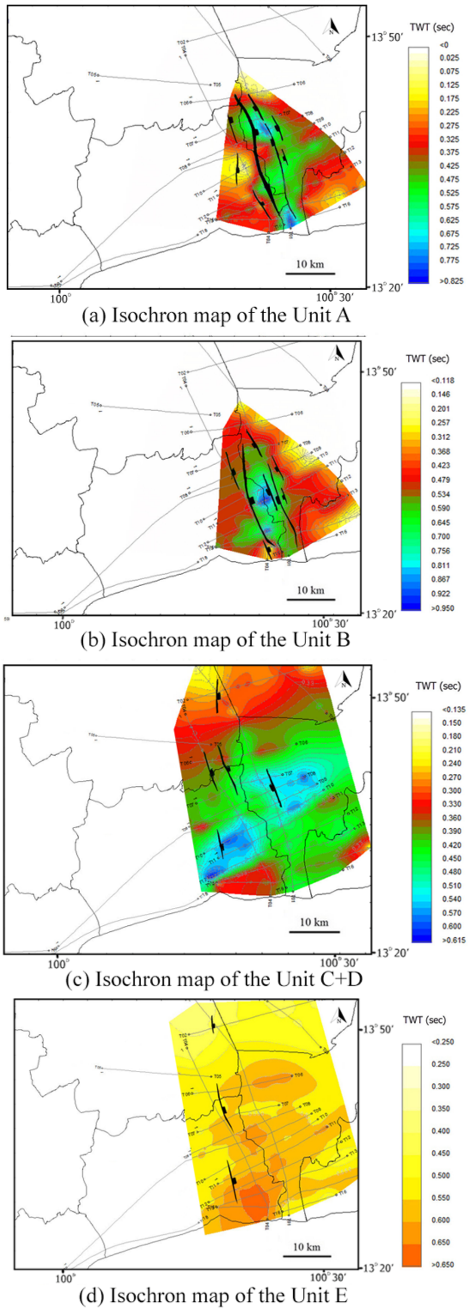

Figure 5. Isochron maps of the Thonburi Basin.

RESULTS AND DISCUSSION

Stratigraphy and Sedimentology of the Thonburi Basin

The interpreted stratigraphic units in the Thonburi Basin were divided into five units, from A to E, based on the analysis of well logging data from the Gulf Oil exploration well in late 1960s. As much as possible, we have used the same notation for these units as those of Morley (2011) [15] and correlate the seismic data with the borehole data in well A, which was drilled to the quartzite basement in 1974 with total depth of 1,860 meters. These units are as follows:

- **Unit E**

The thin, uppermost Quaternary sediment layer (Unit E) consists of clays and sands, with mainly sandstone, mudstone, and minor limestone in well B [22, 23, 15]. Seismic reflectors at the bottom of this unit are horizontal and continuous (Figure 3) with a uniform thickness throughout a study area (Figure 5d). By correlation with the thicknesses in boreholes A and B, the seismic velocity (V_p) of this unit has been calculated to be about 1200-1350 m/s.

- **Unit C+D**

This sediment layer (Unit C+D) is composed of Middle to the Late Miocene fluvial sediments [22, 23, 15]. This unit has uniform thickness (0.5-0.55 sec (TWT)) in the center of the basin and gently thins outwards in the north-south direction (Figure 5c). In general, seismic reflectors are parallel and very continuous (Figure 3). The seismic velocity (V_p) for this unit is 1730-2230 m/s. Boreholes A and B show the thickness of these units as 825 m and 360 m respectively.

- **Unit B**

The Late Oligocene to Middle Miocene alluvial plain deposits [22, 23, 15] (Unit B) are clearly thicker in the center of the basin (0.6 to 0.9 sec (TWT)) and thin outwards in all directions (0.2 to 0.3 sec (TWT)) (Figure 5b). The 2D seismic section (Figure 3) illustrates the parallel and poorly continuous character of this layer with strong amplitude. Wells A and B have a thickness for this unit as 620 m and 900 m respectively, the average seismic velocity (V_p) of this unit is 1580 - 2980 m/s.

- **Unit A**

Oligocene flood plain and lacustrine deposits [22, 23, 15] form Unit A. This unit is thicker on the western side of the Thonburi Basin's depocenter (up to 0.8 sec (TWT)) but thins in all other directions (Figure 5a) to about 0.2 sec (TWT) to the edges of the basin. As shown by the example of the 2D seismic section (Figure 3), upper reflectors are semi parallel, show poor continuity, and the amplitude of reflector of this layer is medium to low. Wells A and B show a thickness for this unit as 80 m and 195 m respectively. The average seismic velocity (V_p) of this layer are 2500-3210 m/s.

- **Basement**

The Pre-Tertiary quartzite basement [22, 23, 15] is found at depths between 2.5 sec (TWT) at the depocenter of basin and 1.0 sec at the north-eastern flank of the basin (Figure 4a). Its average seismic velocity (V_p) is between 5100-5900 m/s.

Thonburi Basin Faults

Most of the faults in the Thonburi Basin are N-S to NNW-SSE trending normal faults, east dipping in the western boundary of the basin and west dipping along eastern side of basin. The fault located on the western boundary appears to be the one that controlled the opening of the basin. This can be deduced by the fact that this 40° dipping normal fault cuts through almost the entire basin and is relayed to parallel faults at the southern part of the basin (Figures 6-7). It also cuts through the units A, B and to a lesser extent- C+D and some parts of the unit E (Figure 6). The minor west dipping faults on the eastern side of the Thonburi Basin can be described as a set of antithetic faults. The east dipping fault in the western boundary cuts the Pre-Tertiary basement producing a 0.7 sec (TWT) offset.

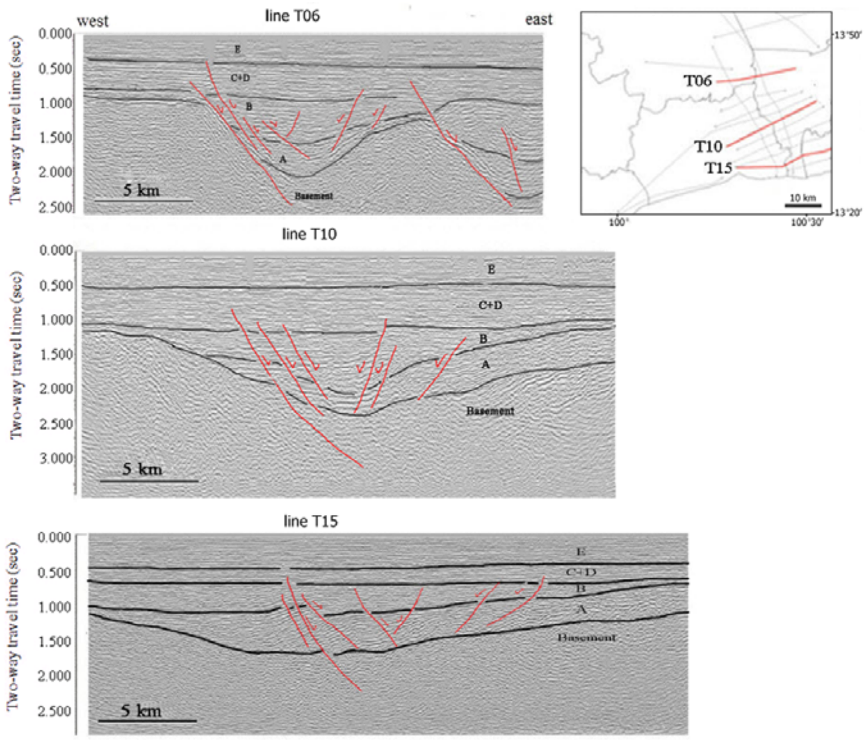

Figure 6. Interpreted seismic sections of the Thonburi Basin.

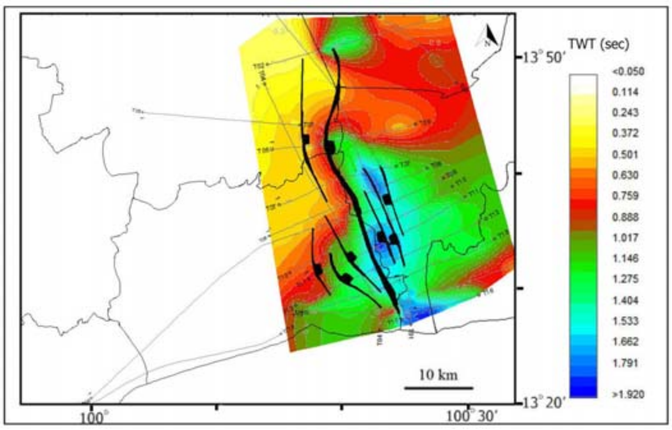

Figure 7. Isochron map of the syn-rift sequences and the observed faults system of Thonburi Basin.

Tectonic Evolution of the Thonburi Basin

Integrated stratigraphic and structural interpretations using both 2D seismic and borehole data help us generate both time structure and isochron-isopach maps of each sedimentary unit (Figure 7). The tectonic evolution of the Thonburi Basin can be inferred as follow:

1. Early Oligocene to Late Oligocene: (Deposition of Unit A) Sediments were deposited in a flood plain and lacustrine environment [15] overlying the Pre-Tertiary quartzite basement. These sediments bacame the green-red-brown shales. The basement might already have been affected by previous east-dipping displacement, as the main normal fault was active on the western part of the basin during this period (Figure 8a).

2. Late Oligocene to Mid Miocene: (Deposition of Unit B) Miocene alluvial plain sediments [15] accumulated on top of the unit A while extension across the basin continued. The west-dipping antithetic faults started during this time (Figure 8b).

3. Mid Miocene to Late Miocene: (Deposition of Units C+D) Fluvial sediments are deposited [15] overlying unit B. Extension with the basin and activity of the west-dipping antithetic faults continued (Figure 8c).

4. Pliocene to Present: (Deposition of Unit E) Accumulation of a thin Quaternary sediment layer [15] that conformably covers unit C+D. The hanging wall moved slightly down but the thickness of the unit E was approximately the same for the entire basin which might indicate that the extension has decreased (Figure 8d).

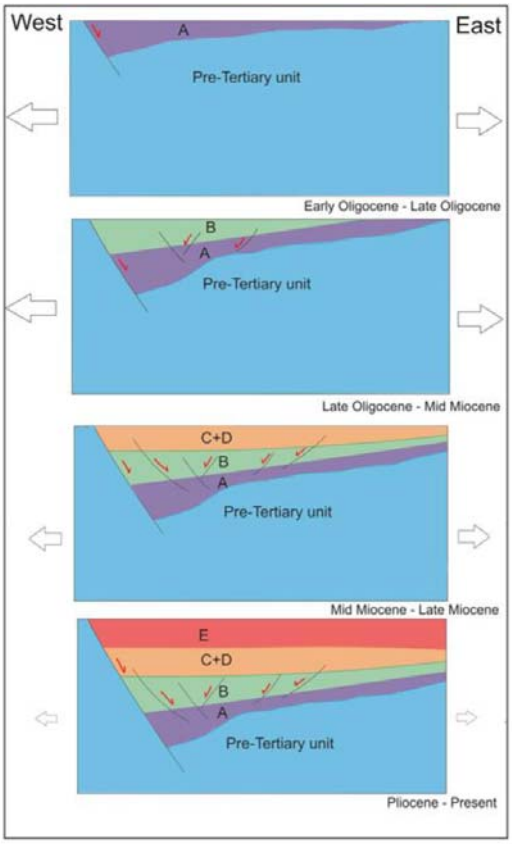

Figure 8. Tectonic evolution model of the Thonburi Basin from Early Oligocene to Recent (a) Early Oligocene - Late Oligocene, b) Late Oligocene - Mid Miocene, c) Mid Miocene - Late Miocene, d) Pliocene - Present).

There are very few studies related to the Thonburi Basin publically available, so it is difficult to compare of our interpretation with previous studies. However, most Tertiary basins in Thailand have N-S to NNW-SSE trending normal faults that control basin rifting (e.g. the Phitsanulok Basin that is one of the largest individual rift basin complexes in Thailand [15]). The Thonburi Basin is controlled by a N-S striking and east-dipping western boundary fault [24 and this study]. Moreover, *Ronghe and Surarat* [25] suggested that both the Suphan Buri and the Kamphaeng Saen basins shared this characteristic setting of typical N-S trending western boundary fault system which was confirmed later by *Pananont and Charusiri* [26]. These normal faults are associated with Middle Miocene, east - west extension that was especially active in the Central Thailand [14, 17, 27, 14]. This extension continued until the Late Miocene - Pliocene. In the specific case of the Thonburi Basin, extension started before Oligocene time and decreased after the beginning of the Pliocene, which is consistent with the general dynamic of the whole regional context [28, 13].

CONCLUSION

This study developed structural and tectonic models of the Thonburi Basin using structural and stratigraphic interpretations of 2D seismic and borehole data. Thonburi Basin is composed of five stratigraphic units. Unit A is the Oligocene shales and alternating thin layers of sandstone and limestone overlies uncomfomably beneath the Miocene alluvial plain deposits (Unit B). The fluvial deposits of units D and C, which are thicker to the western center of the basin and thin outwards to all directions overlie under the uppermost layer (Unit E) which is a thin Quaternary deposit. All units is about 1.0-2.5 sec (TWT) thick and is underlain by quartzite basement. This study shows that the main fault that controls the opening of the basin is the western boundary normal fault that was mainly active between the Early Oligocene and the Pliocene. This may reflect that the E-W extension of the Thonburi Basin started just before the Oligocene and had been active until it ceased in Late Miocene-Pliocene time. The structural style, tectonic evolution and timing of the Thonburi Basin are in good agreement with the observations made on other Tertiary basins of Central Thailand such as the Phitsanulok, Suphan Buri, and Kamphaeng Sean basins: that is, extension with boundary normal faults controlling the opening of the basin during the Tertiary.

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