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Contributed Paper

Subsurface Structure of Kanchanaburi Area Interpreted from Aeromagnetic Data

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ABSTRACT

The Three Pagoda Fault Zone (TPFZ) is believed to have developed as a consequence of the Indian-Eurasian Collision, and is considered to originally have been a major left lateral shear zone activated during the Eocene - Oligocene. The fault zone probably reversed its movement to right lateral motion in Early Miocene, marking the opening of the Gulf of Thailand and the Central Plain. The fault zone may have had little or no slip in post mid-Miocene time before reactivation with right-lateral transpression in Pliocene to Holocene. A number of studies have suggested that only the most northwestern part of the TPFZ in Thailand is currently active. The interpretation of aeromagnetic data covering the area over Kanchanaburi and vicinity reveals distinct sets of lineaments believed to be associated with basement structure. Aeromagnetic anomalies have led us to suggest that the dextral-strike-slip movement of TPFZ may be associated with igneous intrusion occurred at the depths of approximately 1000 - 1500 m from the surface. The anomalies strongly reveal the SE-extension of the buried TPFZ path running through downtown Kanchanaburi (Tha Muang and Tha Maka Districts), parts of Ratchaburi and Nakhon Pathom Provinces, and through the southern part of the Bangkok Metropolitan region. Field studies have been carried out to preliminarily evaluate the existence of the major fault. This buried fault may become the location of future seismic activity located at or near to city centers along its path.

Keywords: aeromagnetic, three pagoda fault, structural geology

1. INTRODUCTION

Kanchanaburi Province is located in the western part of the country where major active faults are located. These faults include the NW-SE-trending Three Pagoda Fault Zone (TPFZ) and the NNW-SSE-trending Sri Sawat Fault Zone (SSFZ) [1, 2]. The TPFZ extends from Myanmar through the Three Pagoda Pass, Sangkhlaburi District, and through the Thong Pha Phum District, Kanchanaburi. These faults have been the main sources of seismic activity in this area.

Aeromagnetic data have been successfully applied to the mapping of

geology and geological structures due to the high contrast of magnetizations for various rock types and structures. Mapping faults using aeromagnetic data requires a certain level of magnetization contrast, which may exist due to a number of factors, e.g., geological units, fault displacement, etc. Magnetization of poorly- to semi-consolidated sediments has been generally considered too low for most aeromagnetic applications. Thailand's nationwide aeromagnetic surveys reveal a very definite expression with an exceptionally clear SE-trending negative anomaly covered with thick sediments over the southwestern and southern parts of the Central Plain. Through the use of such magnetic anomalies, several researchers [3, 4] have suggested the existence of a SE-extending part of the TPFZ into the Central Plain, i.e., from downtown Kanchanaburi through Tha Muang and Tha Maka Districts, Kanchanaburi Province; Ban Pong District of Ratchaburi Province; to the southern part of Bangkok Metropolitan (Figure 1).This has raised a serious concern of the potential for future seismic sources near to a number of highly populated urban areas along the fault path.

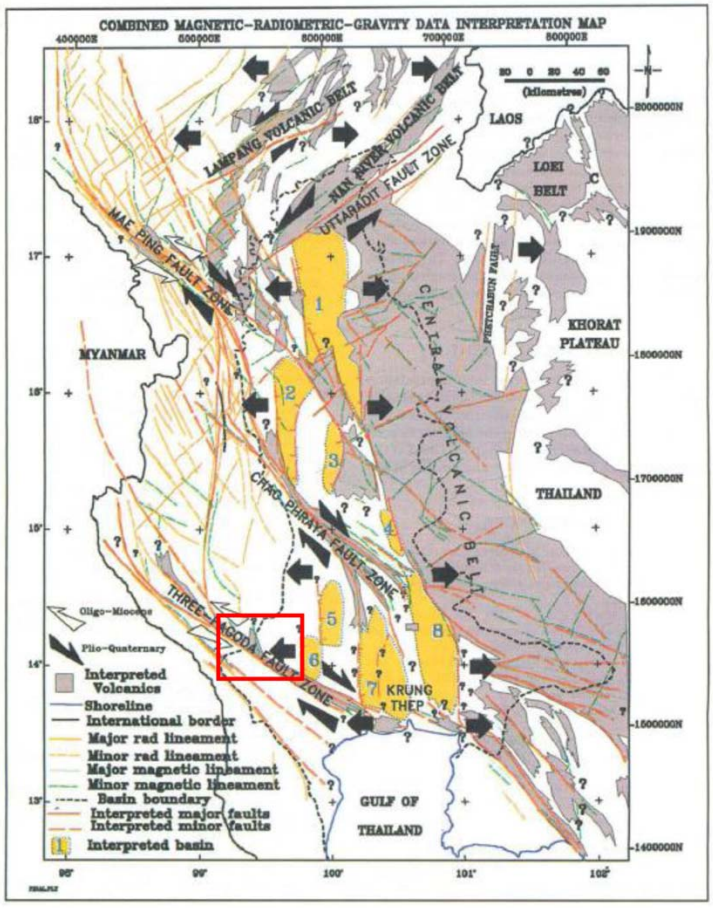


Figure 1. A sketched structural map of the Central Plain area proposed by Tulyatid and Fairhead in 1998 [4]. A red rectangle indicates the study area.

However, most of the active fault studies have focused on a region of exposed outcrops in the northwestern parts, including those of TPFZ and SSFZ. The buried part of TPFZ located to the SE of Kanchanaburi downtown has been less well studied. This was due to a number of difficulties encountered, i.e. the precise locations, depth, orientation and geometry of the fault zone are still unclear; the fault plane is deeply buried making it impossible to carry out above-ground studies. Examples of successful case studies on applying aeromagnetic survey to image buried faults include work of Grauch [5, 6].This study applies aeromagnetic data interpretation techniques to find the precise location, depth, orientation and geometry of the buried parts of TPFZ in Kanchanaburi area. Preliminary field observations and a structural study have been carried out in order to verify the structural elements of the area as indicated by aeromagnetic data. The study results should lead to a better understanding of geological structures of the area, their implication to the history of the TPFZ and possible locations of future seismic sources. The study result can be very useful for local community administrations to use in their geohazard mitigation and urban planning.

GEOLOGY OF THE STUDY AREA:

Kanchanaburi and its vicinity are located in the western part of Thailand, approximately 130 km from Bangkok. The area includes rocks of different ages ranging from Cambrian to Quaternary (Figure 2). The detailed geology has been covered in a number of publications, for example Kosuwan et al. [1] and Songmuang et al. [2].

The TPFZ is a NW-SE-striking fault zone, with an approximately 50 km wide zone of deformation marked by several distinct fault traces and long, resistant strike ridges of Paleozoic limestone. The most northwestern part of the TPFZ extends further into Myanmar and possibly either merges with or is cut by the N-S-striking dextral Sagaing Fault. To the southeast of Kanchanaburi, toward the Central Plain, Tertiary and Quaternary sediments cover the fault zone. The displacement along the TPFZ has resulted in the discontinuity of stratigraphic sequences from one side to the other, i.e., metamorphic rocks of Cambrian - Ordovician Periods, with some Silurian - Devonian rocks, mainly crop out over the northeastern side of the fault, whereas meta-sedimentary rocks of Permian and Triassic Periods occur over the southwestern side of the fault zone. Upanan et al. [7] studied the petrography of high-grade metamorphic rocks located in Thap Sila (Figure 2), approximately 40 km NW of Kanchanaburi downtown, and found rocks (Cambrian Thapsila gneiss/calc-silicates) located near to the center of TPFZ are of amphibolite metamorphic facies, with rocks of green schist facies (Ordovician-Silurian meta-sandstone and limestone) located on both sides. Petrographic study results indicated that the metamorphic core of the fault zone may crop out at the surface (rocks of amphibolite facie) implying that the sinistral movement along the fault occurred at the depth of 10 km or more. The authors suggested that there was only one regional metamorphism event to occur on rocks of Cambrian - Ordovician ages of the area [7].

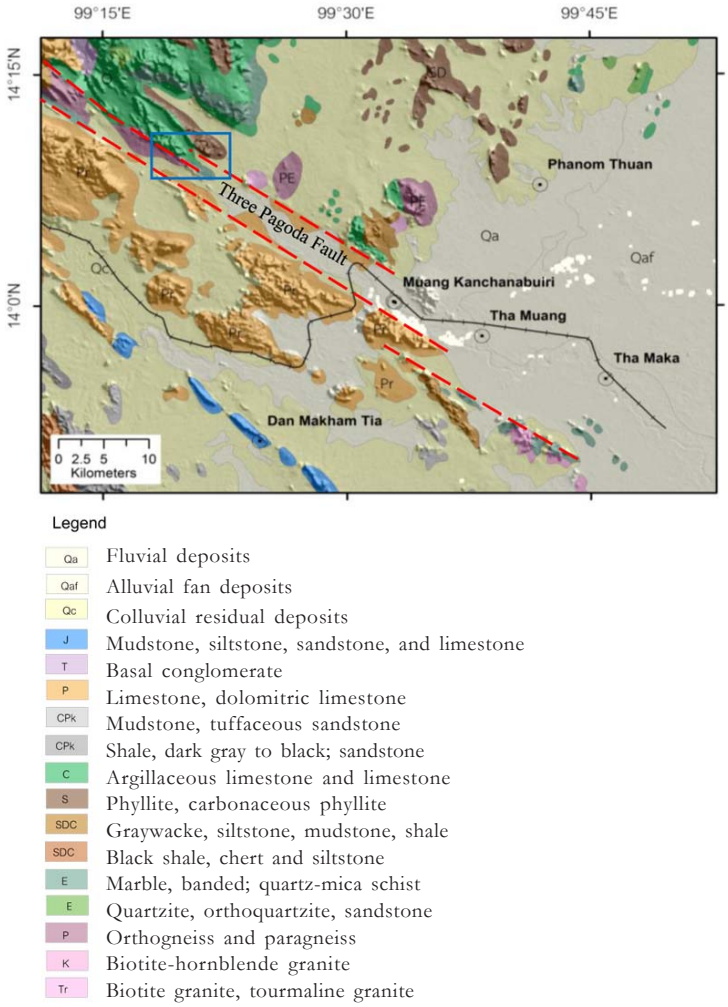


Figure 2. Geological map of the study area covering Kanchanaburi downtown and its vicinity. A small rectangle approximately indicates the study area of Upanan [5].

TPFZ is believed to be developed as a consequence of the Indian-Eurasian Collision. The TPFZ initiated during the Eocene - Oligocene as a large left lateral shear zone. The right lateral motion along the TPFZ probably started in Early Miocene, marking the opening of the Gulf of Thailand and the Central Plain. The fault zone may have had little or no slip in post mid-Miocene before reactivation with right-lateral transpression in Pliocene to Holocene[8].

2. METHODOLOGY

This study involves the use of aeromagnetic data to reveal the subsurface fault structure of the study area. Field investigation was carried out to verify the surficial structural geology of the area in relation to the major fault. Brief information on the aeromagnetic survey and field investigation is given below.

2.1 Aeromagnetic Survey and Data

The Royal Thai Department of Mineral Resources (DMR) carried out airborne magnetic and gamma-ray radiometric surveys covering nearly the entire country during 1984 and 1989. Survey flight-line spacing are: 1 km for aeromagnetic survey; and 1, 2 and 5 km spacing, depending on different types of terrain, for the radiometric surveys. Flight-line directions are N-S and E-W for magnetic and radiometric surveys, respectively. The aeromagnetic data were originally compiled with secular correction to the year 1980. DMR has prepared nationwide aeromagnetic and radiometric grids during 1992 and 1994. The aeromagnetic data of different elevations were downward-continued to the same 300 m elevation. Aeromagnetic and radiometric grids used in this study have a grid cell size of 500 m.

2.2 Aeromagnetic Data Enhancement and Interpretation

Magnetic data enhancement products used in this study include reduction to the pole (REDP)[9] and analytic signal grids. The method was first devised by Thomson [10] using Euler's homogeneity relationship and later developed by Reid et al. [11]. These data grids were used in the qualitative interpretation of the study area. This study utilizes the semi-automated inverse method, 3-D Euler deconvolution, for the depth estimate and structural trend of the major structures. The Euler deconvolution method interprets gridded potential field data to give the indication of the positions, depths and nature of the potential field sources.

The magnetic data interpretation was carried out with the awareness of the limitations inherent in the nature of the data collected, i.e. E-W flight direction and REDP enhancement of data at low magnetic latitudes.

2.3 Field Observations

Field observations were carried out in several quarries located to the north and south of Kanchanaburi downtown in order to verify structural elements and their relation to the major strike-slip faults of the area.

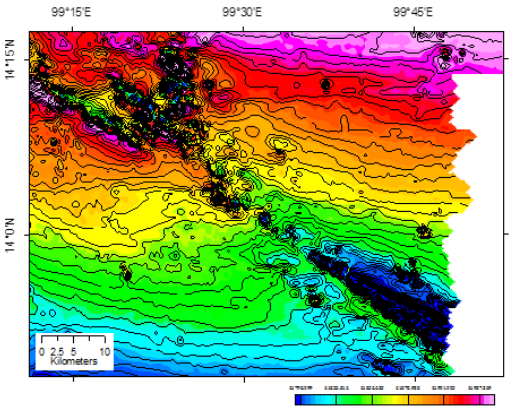
3. RESULTS AND DISCUSSION

3.1 Aeromagnetic Interpretation Result

Aeromagnetic total field data and its enhanced products, analytic signal grid (Figure 3), clearly outline that the major TPFZ runs from longitude 99° 14′E and latitude 14° 14′N passes Kanchanaburi city, Tha Muang and Tha Maka Districts of Kanchanaburi Province, Ban Pong District of Ratchaburi Province, further down to parts of Samut Sakhon Province and continues to the southern part of Bangkok. The TPFZ's strike orientation is approximately N60° W (or 300° azimuth) in the northwestern part. Toward the southeast, the fault splays toward the directions ranging from S55° E - S65° E (or 115 - 125 azimuths).

The results achieved from the Euler deconvolution depth estimate of aeromagnetic data (Figure 4) clearly delineate buried paths of TPFZ with estimated depths of the magnetic body at depths ranging from approximately 300m immediately SE of Kanchanaburi downtown to 1,500 m in the area located south of Tha Muang and Tha Maka Districts. The aeromagnetic data may also indicate that the NW-SE-trending TPFZ steeply dips to the NNE direction. The magnetic anomaly associated with the TPFZ may indicate the intrusion of highly-magnetic rocks into the fault plane, accommodating the E-W-extension along the NW-SE-trending Three Pagoda fault plane.

A. Aeromagnetic total field grid with contours overlay of the study area.



B. Analytic signal grid of the study area.

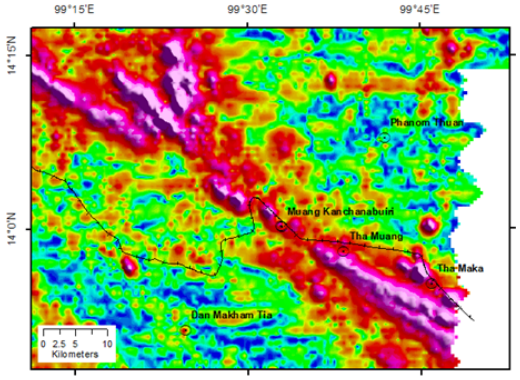


Figure 3. Aeromagnetic maps of Kanchanaburi area.

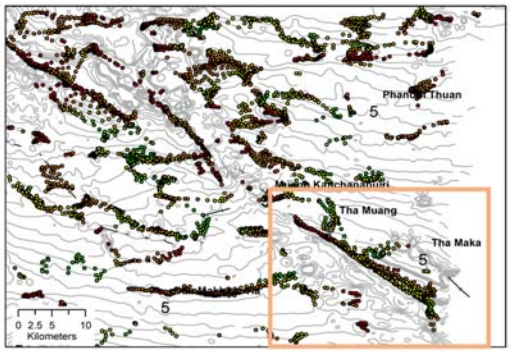


Figure 4. Euler deconvolution depth estimate map derived from using 1.0 structural index and 10x10 window size on 500 m grid cell size magnetic data of Kanchanaburi area. The rectangular area indicates the buried path of TPFZ.

3.2 Field Observation

Permian limestones located south of Kanchanaburi downtown mainly exhibit brittle deformation (Figure 5 A). Ordovician limestones located to the NW of Kanchanaburi downtown show both plastic and brittle-ductile deformation that clearly exhibit fractures and shearing within the rock units (Figure 5 B-D). The orientations of the main structural features in the study area are summarized in Figure 6.

Field evidence confirms the existence of the major TPFZ, oriented N60° W, with its (possible) latest movement being dextral. Brittle-ductile shear zones (N15° E) associated with en echelon filled fractures (striking N40° E) and the plastic deformation in meta-limestone (N70° E) indicates the possible maximum stress is oriented in NE-SW direction. However, field evidence cannot confirm the existence of the SE-extension of the TPFZ fault path that is buried under sediments. Determining the structural development history of the area based on current results is not possible. Further study including petrographic and detailed structural mapping must be carried out to verify the metamorphic facies and structural development of the area. Other ground geophysical surveys including gravity, magnetic and seismic surveys, as well as borehole data, will be required to confirm the existence of buried fault segments beneath sediments located south of Tha Muang and Tha Maka Districts, Kanchanaburi Province.

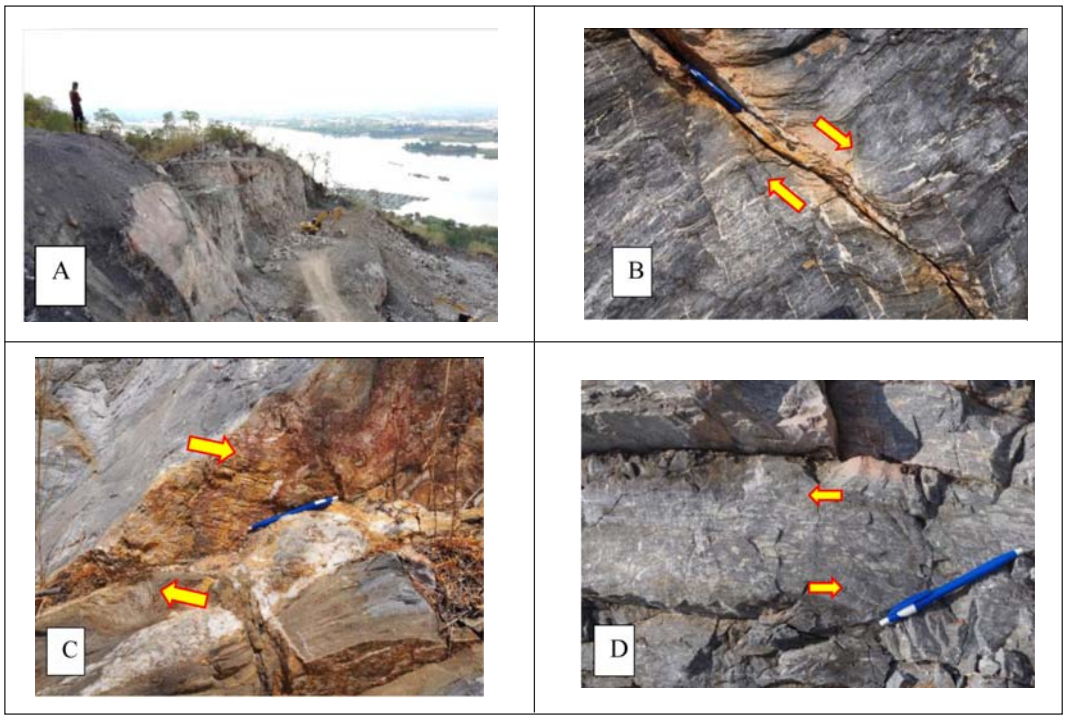


Figure 5 A. series of photographs showing landscape and structural elements observed from the field study of the Kanchanaburi area (A: south of, B-C-D: northwest of Kanchanaburi downtown.
A. photograph overlooking Mae Klong River with Kanchanaburi downtown as a background. The foreground is a quarry site of Permian limestone showing a large fault plane (striking approximately N30° W) located just below man standing to the left.
B. A photograph showing the development of brittle-ductile dextral shear zone (N14° E/ 47° E) associated with calcite-filled en echelon veins (N40° E/66° SE), Permian limestone N of Kanchanaburi.
C. Slickenside surface oriented N65° W/68° NE, clearly showing dextral sense of movement.
D. Meta-limestone exhibits some plastic flow indicating possible sinistral sense of movement along the plane oriented N70° E 60° N

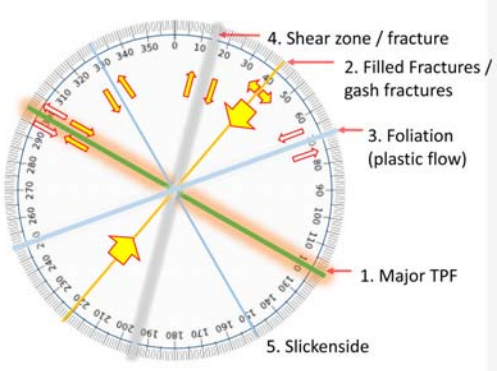


Figure 6. Summary of structural development model achieved from preliminary field survey as shown in Figure 5.

4. CONCLUSION

Aeromagnetic data clearly outline a magnetic body associated with the SE-extension of buried paths of TPFZ with estimated depths of 250-1,500 m beneath the surface along the Mae Klong River. Field observations confirm a NW-SE-trending structure associated with TPFZ. The study also indicates that rocks of the area have been through complex structural development resulting in several reversals of the sense of movement along the TPFZ. At this stage, we are unable to define the

overall tectonic development of the TPFZ and its role on the development of the southern part of Central Plain. Future study on petrography and structural geology, as well as the carrying out of ground geophysical surveys and gathering of information from exploration boreholes, are important to the establishment of this concealed part of the TPFZ in Kanchanaburi, as well as its SE-extension part toward Bangkok.

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