CHAPTER I

INTRODUCTION

1.1 General

Basically, tectonics refers to the process, structures and landforms associated with deformation of the Earth's crust. In Thailand, major tectonic evolution can be divided into four episodes; archeotectonic, paleotectonic, mesotectonic, and neuvotectonic episodes (Charusiri et al., 1997). Archeotectonic episode is tectonic event that occurred during Prepaleozoic era, whereas Paleotectonic, Mesotectonic, and Neuvotectonic are limited in Paleozoic, Mesozoic, and Cenozoic times, respectively.

Tectonics occurring in Cenozoic times has played an important role in our ways of life since its time span covers Tertiary and Quaternary times. Neotectonics in this study is a technical term referred to new tectonic event, located in the neuvotectonic episode in Thailand. Many scientists had tried to explain the definition of neotectonics for several decades since the effect of neotectonics, such as catastrophic earthquakes are concerned to society. For examples, Obruchev (1948) mentioned that neotectonics is referred to the study of the young and recent movements taking place at the end of the Tertiary and the first half of the Quaternary. Neotectonic phase starts at different time in different places, depending on tectonic regime (Morner, 1990). Neotectonics can be boardly described as tectonic events and process that have occurred in post Miocene time (Slemmons, 1991). Neotectonic structures develop in the current tectonic regime to embrace the prevailing state of deformation within an intraplate region (Muir Wood & Mallard, 1992). Neotectonics is, therefore, the branch of tectonic concerned with the past and are continuing at the present day (Stewart& Hancock, 1994).

Other disciplines related to neotectonic terminology consists of active tectonics, which is referred to tectonic processes that produce deformation of the Earth's crust on a time of scale of significance to human society (Wallace, 1986). Paleoseismology is the study of prehistoric earthquakes, especially their location, timing, and size (Solonenko, 1973; Wallace, 1981). Paleoseismic data can be used in neotectonic investigation and can provide relatively short-term geological data on regional fault behavior and deformation style (Wesnousky et al, 1984). Seismotectonics is a branch of geosciences that is concerned with the relationship between the seismological characteristics of present-day earthquakes and tectonics. Seismogeology is the study of geological (e.g. soft-sediment deformation, fault scarp analysis) of contemporary seismicity. Archeoseismology can be referred to the study of archeological evidence for historical and pre-historical earthquakes. Morphotectonics is the study of all aspects of relationship between geological structures and landforms; others restrict it to relationships between neotectonic structures and landforms. Tectonic geomorphology is the study of the relations of vertical and horizontal ground movements to erosional and depositional processes and landforms (Stewart & Hancock, 1994).

According to tectonically active regions in the world, they are usually observed around active margins and subduction zones of the major plates. The common evidence of this tectonism is characterized by large earthquakes. However, depending on historical and instrumental records, many of earthquakes had also found experiences within intraplate regions, even not frequent and large compared to the former. In western Basin and Range province of United Stataes of America, it has long been recognized as earthquake region (Wallace, 1990). Tectonism influence in this region is generated from two main sources; the San Andreas Fault system and the subduction zone in eastern Pacific. Note that, only on the San Andreas Fault and its major branches have average recurrence intervals as short as 10-200 years (Wallace, 1990). In Turkey, conventional tectonic evidence in this region is expressed by Anatolian fault. This fault is characterized by extentional tectonic asssociated with transcurrent displacement, which is the result of N-S relative convergence of Eurasia and Africa-Arabia (McKenzie, 1972). In New Zealand, for example, Awatere fault, which is a system of dextral strike-slip faults constituting the Australia-Pacific plate boundary. At least six ground-rupturing events younger than 8,330-8,610 yr was generated by this fault (Benson et al, 2001). In China, several fault systems are located in this region of high historical seismicity. For example, Altyn Tagh fault, Nan Shan-Kansu Fault system, Kun Lun fault, Kang Ting fault, and Red River fault, are of the major important faults. In addition, all of the recent tectonics of China are related to the convergence of India and Eurasia during the Cenozoic at a rate of about 5 cm/yr (Tapponnier & Molnar,1977). In 1995, the Kobe earthquake in Japan is believed to be related to right-lateral strike-slip on the Nojima fault. Net offset was found to be about 1.5 m with several vertical displacements. The hypocenter was far from the tectonic plate boundary between the Philippine Sea plate and the Eurasia plate about 200km (Bolt, 1999).

In Thailand and mainland SE Asia, present-day tectonics in this region is the result of the collision between Indian and Eurasian plates since middle Tertiary time (Fenton et al, 1997, Charusiri et al, 1997, Bunopas, 1994, Hinthong, 1991). Although the majority of deformation at present occurred on the faults to the north (e.g., Kun Lun, Red River, and Altyn Tagh faults), however, moderate earthquake activity throughout the mainland southeast Asia indicates contemporary deformation in this region (Fenton et al., 1997). Progressive rotation of SE Asia results in an increasing strike-slip faults with the associated development of pull-apart basins in Thailand (Figure 1.1)(Polachan & Sattayarak, 1989).

There are NW-SE and NNE-SSW major conjugate sets of strike-slip faults influenced in contemporary tectonism in Thailand, particularly in the western and northern regions. According to earthquake fault plane solution, the NW-SE set is undergoing with dextral strike-slip movement, for example, the Mae Ping and the Three-Pagoda faults, and NNE-SSW set is undergoing with sinistral strike-slip movement, for instance, Mae Chan and Phrae faults (Bott et al.,1997). Won-in (1999) revealed that many geological evidences along Three-Pagoda fault correspond to those results such as triangular facets, shutter ridges, offset stream channels. However, there are many schools of thought on the idea of contemporary tectonism of Thailand (see Bott et al., 1997., Pollachan & Sattayarak, 1989., Chauviroj, 1995., and Tapponnier et al., 1986). In fact, the study on this context and related fields, especially on neotectonic study in Thailand, is still at the pilot stage. Consequently, this thesis is an introductory part for a neotectonic knowledge database of Thailand.

1.2 Objectives

The objectives of this study are of four folds as shown below:

1. to identify tectonic evidences which relate to displacement of southeastern segment of the Phrae fault system;

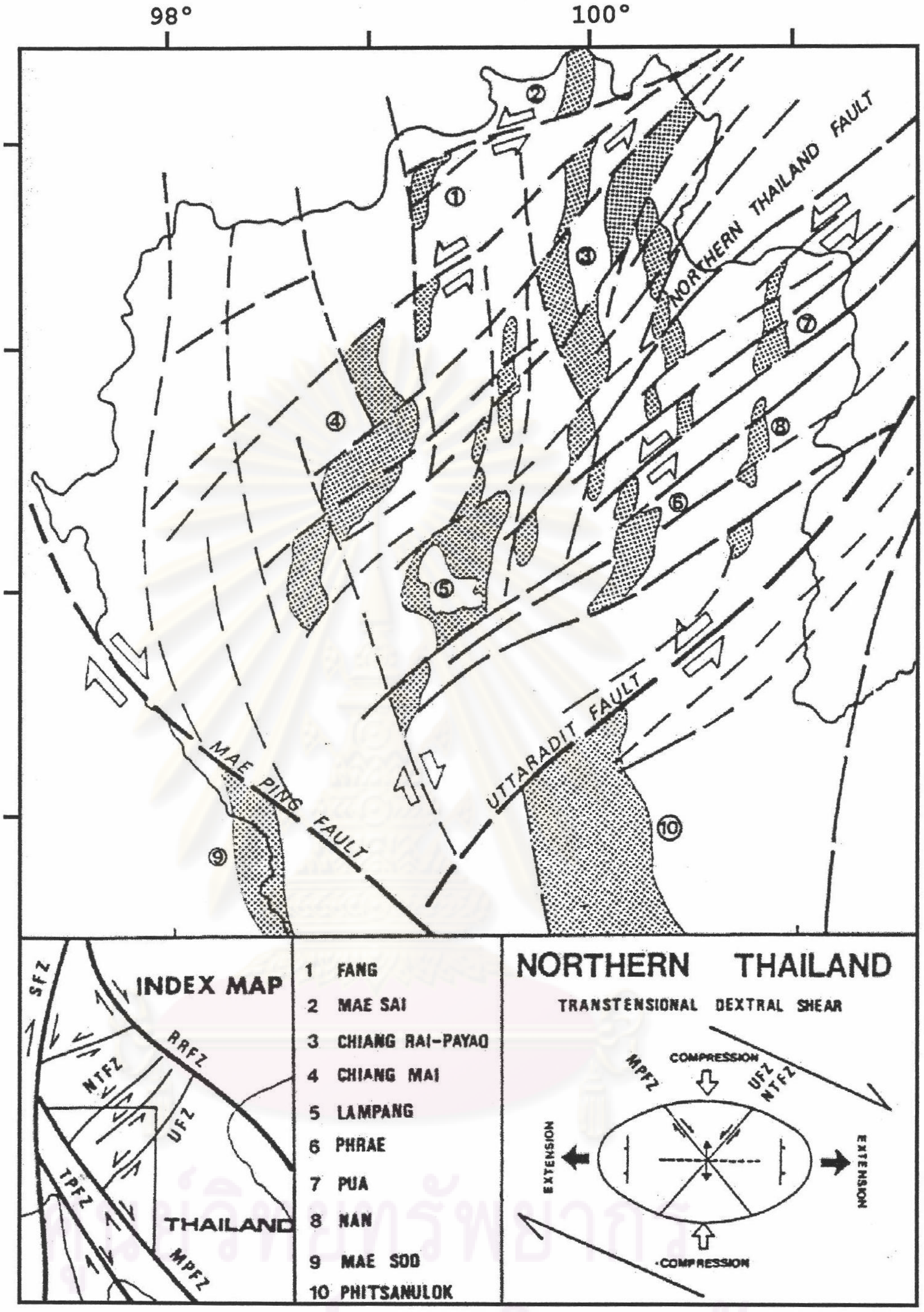


Figure 1.1 Structural map of Northern Thailand showing conjugate sets of strike-slip faults and offset Tertiaty basins. This evidence of tectonism can be explained by transtensional dextral shear model(after Polachan & Sattayarak, 1989).

2. to analyze stress axis orientation acting on the study area and nearby;

3. to determine age of fault-related sediments and to recognize past movement events of southeastern segment of the Phrae fault system; and

4. to classify activeness characteristic of southeastern segment of the Phrae fault system.

1.3 The Study Area

The Phrae basin has long been recognized as a graben-controlled Tertiary basin. It is located in northern Thailand, approximately 480 km from the capital city of Bangkok. The basin is displayed with rhomboidal shape, the major and minor axes lie in NNE-SSW and WNW-ESE directions, respectively. Its longest axis is about 60 km and the shortest axis is about 15 km. Additionally, the short axis is found narrow at the southern part of the basin and gradually widening up to 20 km in the north (Figure 1.2).

Both eastern and western rims of the basin are bounded by mountain ranges with altitudes ranging from 500 m to 1,000 m. Basin ground surface is gently inclined, dip-to-the west. Altitude is about 150 m in the south and up to 200 m in the north. Maximum depth is penetrated to 3.36 km based on gravity investigation (G.M.T, 1996a). The Mea Nam Yom River is the main river flowing from north to south and passing the westernmost side of the basin. In addition, mostly tributary streams are found running from east to connect the main river in west.

According to photo-geomorphological interpretation in the southern part of the Phrae basin by Won-in (2002), six types of geomorphology are recognized; namely, flood plain, alluvial fan, colluvium, low terrace, high terrace, and mountainous area (Figure 1.3). Flood plain is located covering the main area in the central part of the basin, indicated as the lowest elevation of geomorphology in this area. Low terrace morphology mostly lies in the central axis of the basin except the large one which is located in the western margin. High terrace is mostly situated in the eastern margin, characterized as small hills lying along the eastern portion. Alluvial fan is observed on both sides of the basin, found closed to the mountain front. In addition, fan shape morphology

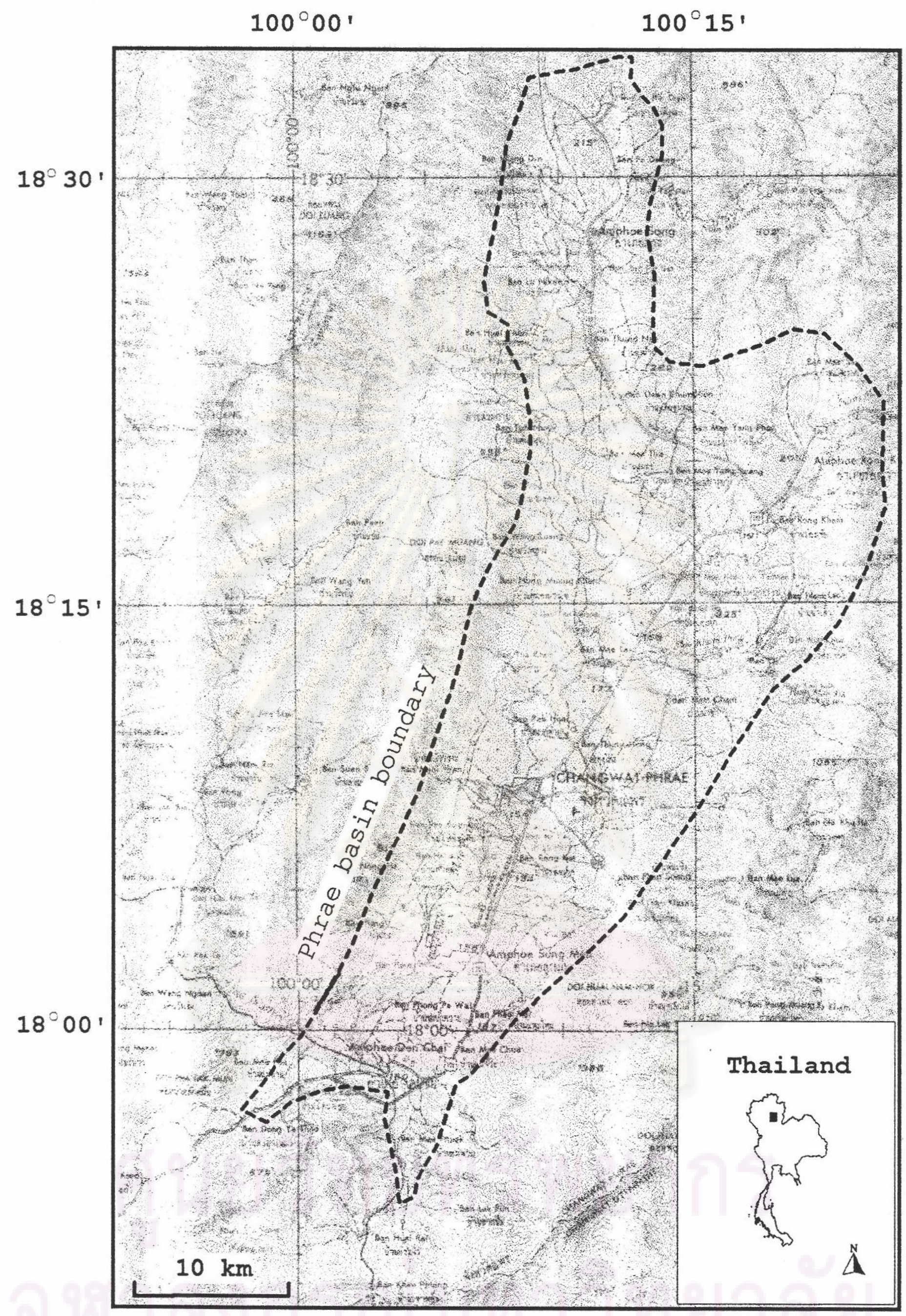
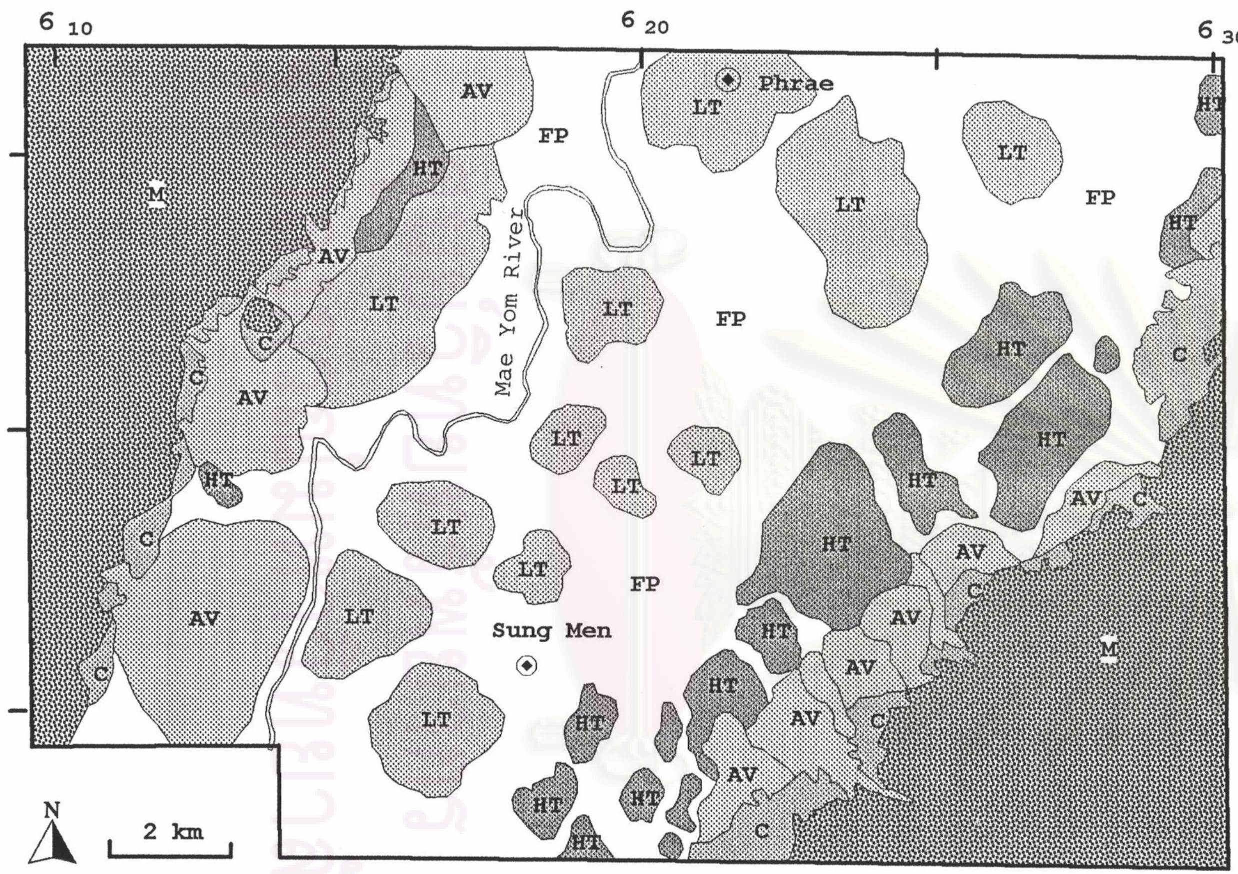


Figure 1.2 Topographic map of the Phrae basin.
(data source:Royal Thai Survey Department(RTSD),1983a & 1983b)



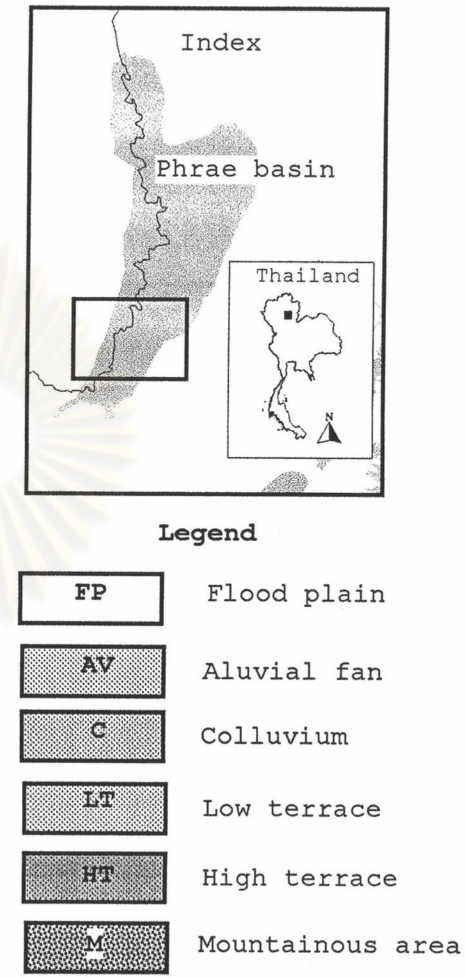


Figure 1.3 Photo-geomorphological map of southern portion of the Phrae basin. (modified after Won-in, 2002)

in the western margin is larger than that of the east. Colluvium is located between alluvial fan and mountain front. The colluvium is found in a small area compared to each other. Finally, mountainous areas are observed bounded on both sides of the basin margins, thereby the Phrae basin can be determined as an intermontain basin.

The southeastern portion of the basin, where the southeastern segment of the Phare faults is located, is selected for the study area. At the south of study area, there is the location of Ban Thung Charoen at grid reference 0620714E, 1993124N and at the north is Ban Pa Deang at grid reference 6280003E, 200014N. Additionally, the study area has been offset from those points to the east and the west approximately 2.0 and 3.0 km, respectively (Figure 1.4).

The study area has been selected for this current investigation based upon three main reasons as follows.

1. There were intensive evidences of contemporary seismic movements in this area. For instance, 1983 earthquake swarms just south of the Phrae basin, started with magnitude(M_L) 3.5 on 19 December and last until 1 January 1984. The greatest magnitudes were reported on 22 and 23 December with M_L 4.0 and 4.3, respectively. Moreover, another event reported at the same location in May 1984. However, no detailed study on neotectonic has ever been conducted.

2. Due to the previous study of Fenton et al., (1997), it is indicated that the Phrae and the Phrae basin faults have maximum credible earthquake up to M_W 7. If this is correct, then there is a chance for destructive earthquakes to occur in this area. In fact, the fault characteristics and its past experience are still non-clarified.

3. Quaternary faulting, which is a clear evidence of recent tectonic movement, has been exposed along the main axis of the study area (Fenton et al., 1997), yielding valuable data for carrying out investigation.

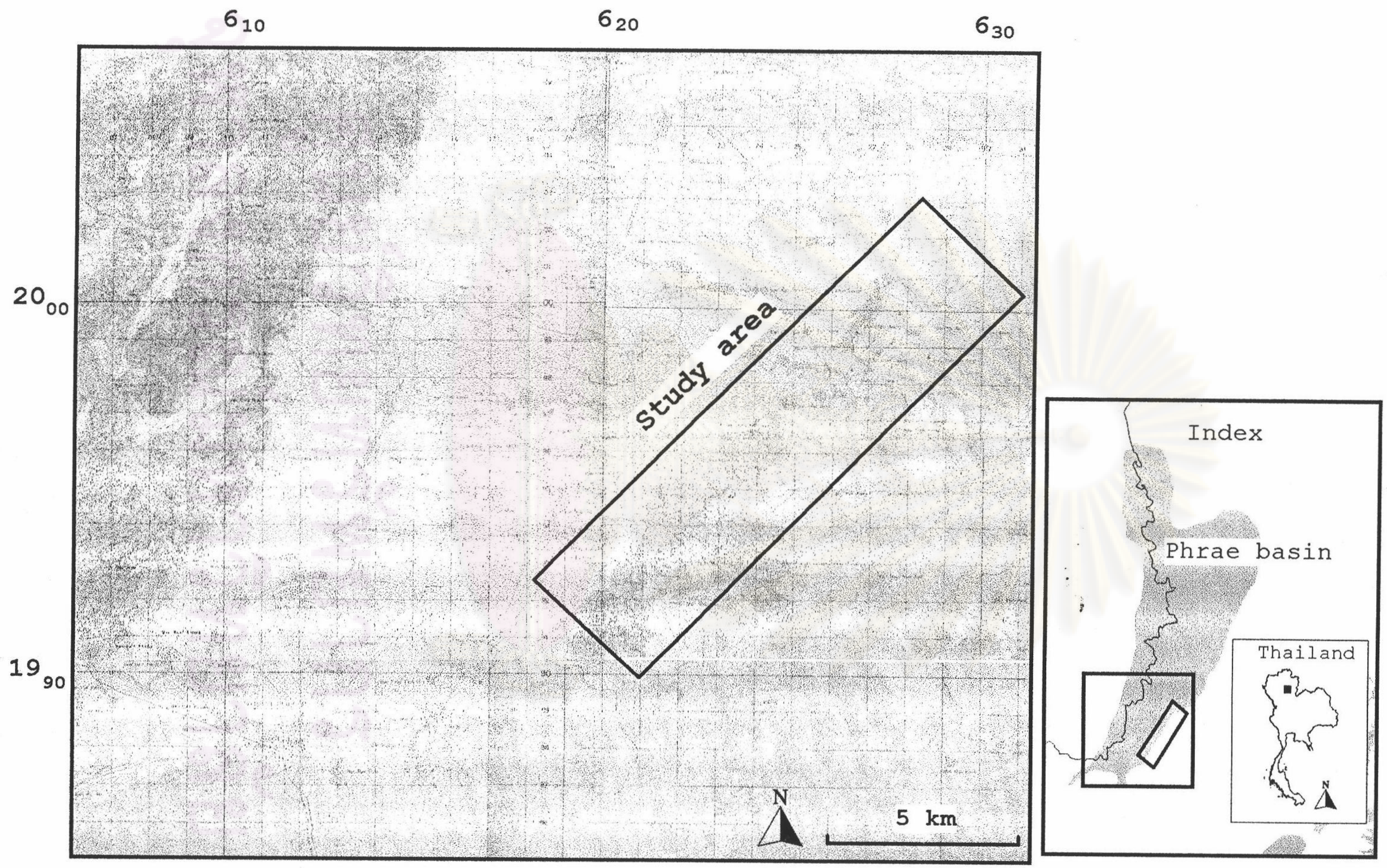


Figure 1.4 Topographic map showing location of the study area
(data source: Royal Thai Survey Department (RTSD), 1995a & 1995b)

1.4 Methodology

To accomplish the objectives, research methodology has been divided into six major tasks in order to construct a systematic track of study. The main tasks are classified and described below. In addition, all of these steps have simplified as a flow chart shown in Figure 1.5.

1. Planning and Preparation

Basically, this step has been conducted in order to contribute general relevant data into a database for supporting further steps of study. These data are composed of relative previous works, remote-sensing images, aerial photographs, geologic maps, topographic maps, earthquake distribution, seismic reflection profiles, focal mechanism solution, hot spring location, and other related documents.

2. Field Reconnaissance

Field reconnaissance to the study area was launched in order to construct general guidelines for detail investigation. Condition of transportation routes, how to reach the area, how to collect field data, duration, time and budget to spend for field work, etc., are examples for this step.

3. Remote-sensing and Aerial Photographic Interpretation

The third step of this thesis study involves interpretation of several preliminary data. Delineation of geological lineaments and fault segmentation using Landsat TM5 and JERS SAR imageries, and tectonic geomorphology identification via aerial photograph constitute the main part of this step. In addition, fault segmentation is investigated in further detail using aerial photograph.

4. Field Investigation

In this step, two individual tasks include their observations on; ground-truth tectonic geomorphology and survey for Quaternary faulting and other stratigraphic deformation.

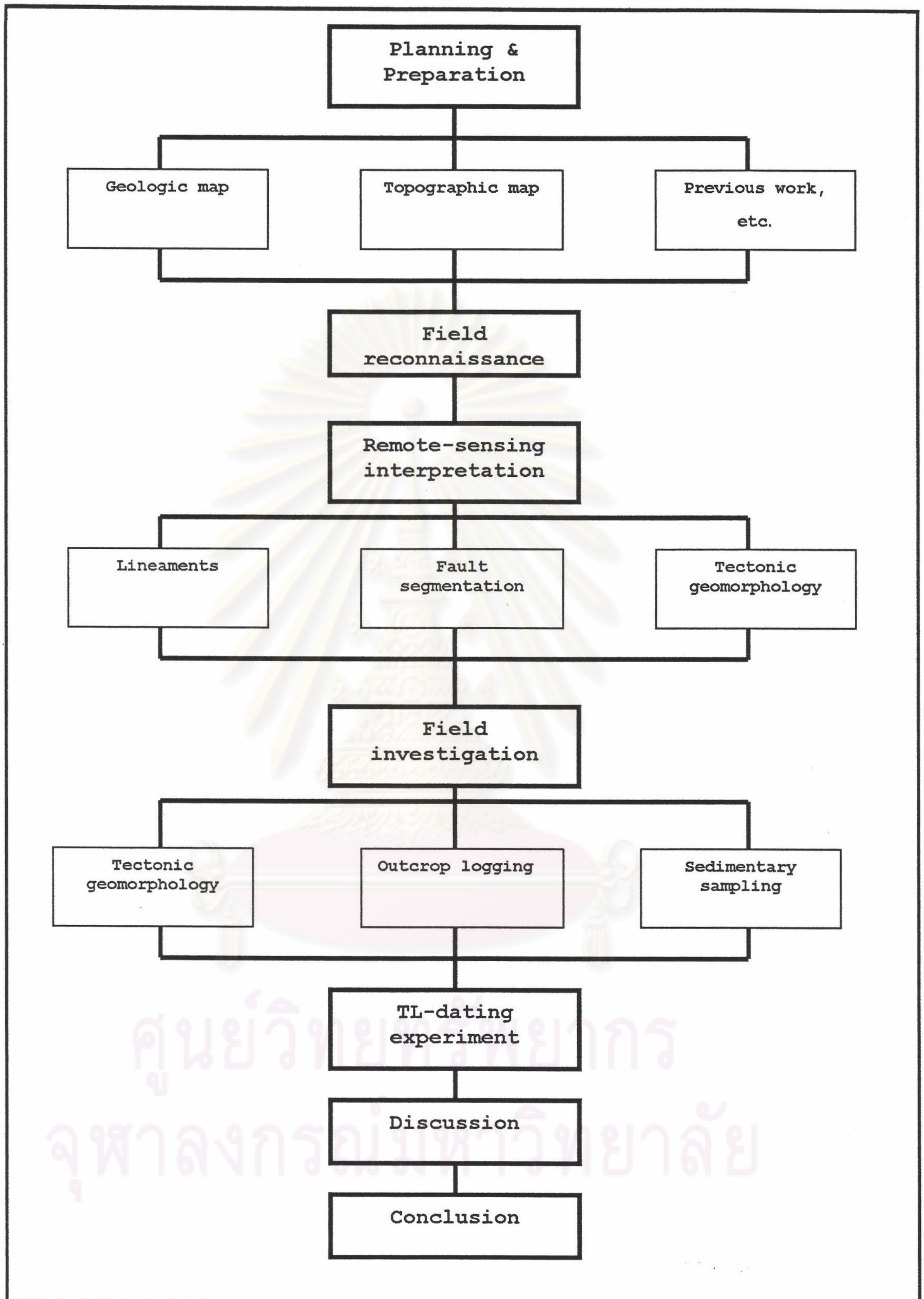


Figure 1.5 Methodological diagram of this thesis study.

The first task is proposed to determine field evidences of landform characterized by tectonic forces, for instant, triangular facet, linear range front, offset stream channel, shutter ridge, etc. Aerial photographic interpretation of tectonic geomorphology mentioned in the third step is applied as a guideline for this task. The later task includes outcrop stratigraphic logging of abandoned quarries based on palaeoseismological method and sample collection of fault-related sediments. Additionally, the outcrops are systematically explored along the delineated lineament or fault traces.

5. Laboratory Experiment

Collected samples, which are mostly fault-related sediments, have been carried out for dating approach using Thermoluminescence (or TL) geochonological method.

6. Discussion and Conclusion

Ultimately, all results are analyzed for discussion. In discussion part, there are four main targets of discussion that have been categorized; neotectonic features, tectonic stress field, palaeoearthquake recognition, classification of active fault, and seismic hazard assessment. At last, all of the discussed results have been concluded in this part.

1.5 Previous Works

In an attempt to understand neotectonic and earthquake characteristics of Thailand and neighboring regions, the results of related documents and papers from previous studies are necessary. They are listed below.

Nutalaya (1986) had characterized and described seismic source zones in Myanmar, Thailand, and Indochina areas into twelve seismic source zones. In Thailand, it is covered by zone F and zone G on the west and the north, respectively. The Phrae basin, where the study area of this thesis is located, is situated in zone G, governed by NE-SW trending fault zones, namely the Thoen fault zone located on the west and the Phrae fault zone lay on the east. Approximately 20 microearthquakes ranging from magnitude of 3 to 4 were recorded just south of the Phrae basin during 1980-1983, the Phrae fault is believed to be probably active.

Siribhakdi (1986) had interpreted previous data together with his own field investigation on seismogenic regimes of Thailand and periphery. The study suggested that the compression stress axis lies in the southwestern direction which may be generated from spreading ridges and subduction zone in Andaman Sea. Furthermore, the most seismicity area in Thailand is located in the west, and the present day seismicity might be related to the opening activities of Cenozoic basins.

Thiramongkol (1986) observed neotectonism and rate of uplift in the eastern margin of the lower central plain of Thailand. The evidence of neotectonic movement is found on the difference of elevation between foot-wall and hanging-wall of Bang Pakong fault, which is 18 m. Uplift rate is found 2.4 mm annually, calculated from topographic difference and timing. C14-dating on a wood fragment indicated 7,300 ±35 years B.P. for the brackish clay bed.

Hetrakun et al.(1991) evaluated reservoir-triggered seismicity in Khao Laem dam using seismic parameters, earthquake pattern, and focal mechanism solutions. The result revealed that swarm earthquakes have caused by reservoir induced seismicity (RIS) which located along NE direction. Additionally, the movement of the Three-Pagoda and Tak faults in the past has increased stress accumulation along faults in this area.

Hinthong (1991) integrated many of previous works to conclude the roles of tectonic setting to earthquake events in Thailand. The study cited that earthquakes in Thailand are closely related to two seismic source zones, namely the Tenasserim Range zone (zone F) and the northern Thailand zone (zone G) of Nutalaya et al. (1985)'s division. The faults within zone F are believed to be active more than those of zone G which are inferred to be possibly potentially active.

Klaipongpan et al.(1991) studied on geological and seismicity evaluation of Srinagarin dam. The evaluation was carried out using several parameters, i.e., earthquake catalogs, focal mechanism solutions, earthquake relocation studies, aerial and ground geologic reconnaissance, analysis of remote-sensing imagery and review of the pre-instrumental and instrumental seismicity of Thailand. The study cited that the 1993 earthquakes in Srinagarin dam is triggered by water load. Epicentral distribution is coincided with a north-west trending geological lineaments.

Sarapirome & Khundee.(1994) investigated neotectonics in the Mae Hong Son-Khun Yuam valley using Landsat TM imagery and aerial photograph for geological lineament and geomorphic interpretations. The results had been analyzed together with statistic analysis of lineaments, earthquake epicentral distribution, hot spring location and Quaternary faulting data. The result of this study revealed that northwestern Thailand has been tectonically active since Late Paleozoic to Recent times.

Bott et al.(1997) mentioned that northern Thailand is similar to the Basin and Range province in the western United States of America in term of earthquake processes and tectonics. However, the largest known earthquake in the north has not exceeded M_L 6 compared to the Basin and Range province in which record on paleoseismic investigation indicated maximum capable earthquake is about magnitude (M_W) 6 and greater. The result based on focal mechanisms reveals that both regions have been formed by undergoing E-W extension.

Fenton et al.(1997) studied on late Quaternary faulting in northern Thailand. Several tectonic geomorphological features, which indicate recent movements, had been observed along seven faults. These faults are the Phrae, the Phrae basin, the Long, the Nam Pat and the Phayao faults. Recurrence intervals of these faults range from thousand to ten of thousands years. These faults are capable to generate earthquakes equal or greater than M_W 7.

Won-in (1999) studied on neotectonic evidences of Three-Pagoda fault using remote-sensing approaches from data on Landsat TM5, JERS-SAR and aerial photograph, and ground-truth surveys as main tools to delineate the fault trace. In addition, TL and ESR dating methods were used to determine age of faulting events. The study revealed that Three-Pagoda fault consists of five segments based on geological and geomorphological analyses. Several tectonic geomorphology which are frequently observed along the fault, indicated the main right lateral movement. Five events of earthquake faulting are reported based on geological evidences and dating results.

Charusiri et al.(2001) categorized active faults in Thailand into five seismically active belts (SAB) using geologic, geotectonic, geochonological, and seismological criteria. These belts are composed of northern, western-northwestern, central peninsular, southern peninsular and eastern-northeastern SABs. In northern and western-northwestern SABs, most of faults are inferred to be active, with the exception of the Mea Tha, the Nam Pat and the Phayao faults, which are believed to be tentatively active faults.