PRELIMINARY STUDY ON MORPHOTECTONIC EVIDENCE ALONG THE MOEI–MAE PING FAULT ZONE, TAK PROVINCE, NORTHWESTERN THAILAND

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KEY WORDS: Moei-Mae Ping Fault Zone, Tak, morphotectonic, surface rupture length.

ABSTRACT

The Moei-Mae Ping Fault Zone (MPFZ) in Tak area, northwestern Thailand is selected for morphotectonic investigations using remote-sensing interpretation. The prime objective is to delineate faults and lineaments, their orientations, and past movements. Results from remote-sensing interpretation indicate that the MPFZ is the 230 km-long, roughly northwest-trending oblique-slip fault and can be traced from easternmost Myanmar through northwestern Thailand to central Thailand. Three minor trends of lineaments and faults are recognized in the northeast-southwest, east-west and north-south directions. About 10 fault segments, ranging from 8 to 43 km in length are defined, they pass both Cenozoic basins and pre-Cenozoic landforms. The segment at Ban Tha Song Yang fault segment is regarded as the most active morphotectonic and was responsible for the earthquake occurring on 17 February 1975 (magnitude of 5.6 Mb). Based on our reconnaissance surveys, several kinds of morphotectonic landforms, especially those bordering the basins, suggest the Ban Tha Song Yang fault segment is the most active fault. Additionally, the morphotectonic landforms, indicate the right-lateral movement with a minor vertical slip, whereas pre-Cenozoic structures indicate the left-lateral moment. Neotectonically, the surface rupture length of about 26 km together with preliminary TL dates indicate the movement of the MPF in the Quaternary with the maximum earthquake at M_w 6.7.

1. INTRODUCTION

1.1 Background and location

Thailand has been subject from minor to moderate earthquake damages over times. Stronger earthquakes frequently happen in the neighboring countries, e.g. Myanmar, China, Laos, and Vietnam. Recent geologic and geochronological investigations reveal that late Quaternary faults in northern Thailand appear to be characterized by long recurrence intervals of thousands to tens of thousands of years (Bott et al., 1997, Fenton et al., 1997, Kosuwan et al., 1999).
Two earthquakes along Myanmar-Thailand fault zone occurred on 23 September 1933 and 17 February 1975 (TMD, 2002), the one in 1975 had a magnitude of 5.6 on the Richter scale and was felt throughout central Thailand, causing minor damage (Nutalaya, 1985). Therefore it is important

to understand landforms which were formed by earthquake activity. So, the aims of this paper are to apply remote-sensing interpretation based on JERS and enhanced Landsat TM7 images to delineate lineaments (faults and fractures) and to locate major active faults using morphotectonic features. The study area (25,000 km^2) covers much the Moei-Mae Ping Fault (MPF), in Tak Province, northwestern Thailand (Figure 1).

1.2 Methodology

The methodology of this study is divided into four steps. The first step was conducted in order to contribute general data into a database for supporting further steps of study. This data is composed of relative previous works, enhanced remote-sensing images and digital files, aerial photographs, geologic maps, topographic maps, earthquake distribution information, and other related technical and nontechnical documents. The second step involves remote-sensing interpretation commencing on a small scale using digitally enhanced satellite imagery (1:250,000) and interpretation on a large scale with aerial photographs (1:50,000). Both from the basic data for lithological and structural interpretation, lineaments were then interpreted to locate their attitudes, orientations, and past movement of the fault zones. The third step commences with all morphotectonic landforms, and interpretation from remote-sensing data was verified in the field. For this step geomorphic mapping related to neotectonic evidences was launched in evaluating locations and the nature of active faults, identifying sequences of faulting in the focus area. The fourth step includes integration of all the results from all morphotectonic evidences from all available investigations and fieldwork study to construct a fault map. In addition paleoearthquake events, estimation of paleomagnitude from surface rupture length, and the thermoluminescence dating are discussed.

2. REGIONAL GEOLOGIC STRUCTURE

The study region has been disturbed by several sets of faults. However, the major fault is the MPF and cuts through various rocks. The MPF always follows the roughly northwest-trending major structures of the region. The MPF comprises straight lines to curvilinear of several fault branches and seems to deviate to become concentrated in the middle part of the regional study area. The MPF is actually called a spray fault when the southern portion passes the metamorphic rocks. To the north, the MPF also sprays and cuts the sedimentary rock strata. More interesting is the area in the central part where the MPF fault represents the principal displacement zone. The MPF seems to concave and concentrate in the Tha Song Yang area of Tak province. Faults in the Cenozoic unconsolidated deposits are notably important since they indicate seismic tectonic activity which occurred during Cenozoic times. The MPF which passes the Paleozoic strata shows relatively left lateral movement along the MPF. However, some deformed Mesozoic strata show a virgin structure and indicate a right lateral movement along the fault. This perhaps points to the fact that the MPF moved sinistraly in pre-Cenozoic period and moved dextrally in the Cenozoic period.

3. MORPHOTECTONIC EVIDENCES

3.1 Satellite Image Interpretation

We applied the digitally enhanced Landsat TM7 (Figure 1) and JERS images for neotectonic evidence along the MPF. The false colored composite red, green and blue are digitally added to the image data of bands 4, 5, and 7, respectively. Practically, visual interpretation is to assist in delineating large-scale neotectonic features and to define orientations and directions of the investigated fault segments. The result shows the appearance of several neotectonic features

including fault scarps, triangular facets, offset streams, shutter ridges. Lineaments and faults can be traced from easternmost Myanmar to the border zone of northwestern Thailand (Figure 2). The result from remote-sensing interpretation indicates the major trend of lineaments and faults along the MPF in the northwest-southeast direction, and its branches may extend northward to the Mae Hong Son area. Three other minor trends of lineaments and faults are in northeast-southwest, east-west and north-south directions. The advent of satellite image study is to assist in delineating the large-scale deformation features and to define the fault segmentation. The latter involves the identification of individual segments that appear to have continuity, character, and orientation. Delineation of segments involves identification of discontinuities in the fault zone. In this study, we apply four criteria for subdividing discontinuities of faults including earthquake discontinuity e.g., historic rupture-geometric discontinuity, geologic discontinuity, and structural discontinuity, following the recommendation of McCalpin (1996). Based upon such criteria we can recognize 10 fault segments and they were determined, from north to south, via. the Sob Moei segment (10 km), the Huai Mae Lo segment (8 km), the Ban Tha Song Yang segment (26 km), the Khao Mae Song segment (24 km), the Huai Mae La segment (35 km), the Doi Kala segment (23 km), the Doi Khun Mae Tho segment (25 km), the Doi Luang segment (43 km), the Khao Yao segment (23 km), and the Khlong Phri segment (15 km).
Some north-trending lineaments bound Cenozoic alluvial basins in the Tha Song Yang village. Several lineaments are parallel to the Mae Nam Moei, in the northwestern part of the MPF and the Mae Ramat basin.

3.2 Aerial Photo Interpretation

For detailed investigation, we have selected one small area (the inserted box in Figure 2) based on results of lineament analysis by satellite images for aerial photographic investigation. At the Tha Song Yang village. A right-lateral movement has caused shifting of the stream for about 50 m. The Huai To No stream near Tha Song Yang village, which may have caused the shift of stream for about 500 m and the occurrence of a shutter ridge with the northwest-southeast trend and the average base width of about 200 m and height of about 65 m from the base. A fault scarp clearly observed in limestone at Pha Man village is almost vertical and rather continuous. The scarp plane strikes in the northwest-southeast direction, following the main fault. In some places, the fault planes dip steeply to the northeast. The Nam Mae Tun and Huai O E at Ban Tha Song Yang village, show the linear valley, controlled by the northeast-trending fault.

3.3 Field Evidence

Field reconnaissance survey in the Tha Song Yang village indicates that the Tha Song Yang fault segment has a continuous length of 26 km. Additionally, we recognized one fault scarp trending in the northwest-southeast direction and the outcrop of shear zone in limestones. In an area of the Mae Ramat village, the Doi Kala fault segment indicates a set of large well-preserved, southwest-dipping triangular facets limestones. There also exists a few beheaded streams developed near Yang Pang Chang village in response to the sudden change of relief and slopes. Additionally, the hot spring at Mae Kala village definitely indicating the active tectono-magmatism, is found nearby the fault with triangular facets and fault scarps.

4. DISCUSSION

Several pieces of morphotectonic evidence including triangular facets, offset streams, fault scarps, shutter ridges and beheaded streams, has clearly indicated the young oblique strike-slip movements with both horizontal and vertical slip components along the studied fault.

Hinthong, (1995) and Charusiri et al (2001), stated, based on results on thermoluminescence dating (TL-dating) of fault-related sediments and fault gouges, that the ages of paleoearthquake events of this fault zone occurred within Quaternary period. Result on the preliminary TL dates suggest the latest movement occurring 0.16 Ma ago. Additionally, there are two earthquakes along this fault zone on 23 September 1933 and 17 February 1975. The latter was of magnitude 5.6 and was felt throughout central Thailand causing minor regional damage (Nutalaya, 1985). Estimation of the 26-km-long surface rupture for the Ban Tha Song Yang segment indicate that the maximum earthquake is about M_w 6.7.

5. CONCLUSIONS AND RECOMMENDATIONS

1) Moei-Mae Ping Fault Zone is the northwest-trending, 230 km-long fault extending from easternmost Myanmar to northwestern Thailand.

2) The major trend of MPF lineaments is in the northwest-southeast direction and are regarded as the principle fault zone.

3) MPF can be divided, based on discontinuity criteria, into 10 segments. All segments align in the northwest-southeast direction, but Doi Kala segment is in a north-south direction.

4) Significant and well-defined pieces of present-day morphotectonic evidence are triangular facets, fault scarps, beheaded streams, offset streams, shutter ridges, and linear valleys.

5) The MPF has an oblique strike-slip movement with the horizontal slip more than the vertical slip. The right lateral senses of movements are recognized for almost all fault segments, however the right-lateral movements are much more common and seem younger than those of the left ones.

6) The maximum earthquake may have occurred in this area with the magnitude of 6.7. The latest movement based on TL dating result is 0.16 Ma.

7) Geophysical surveys, such as ground penetration radar and resistivity, together with 1:1,000 detailed field mapping are suggested to delineate subsurface configuration of the selected fault segments before TL-age dating on samples in the trench will be done.

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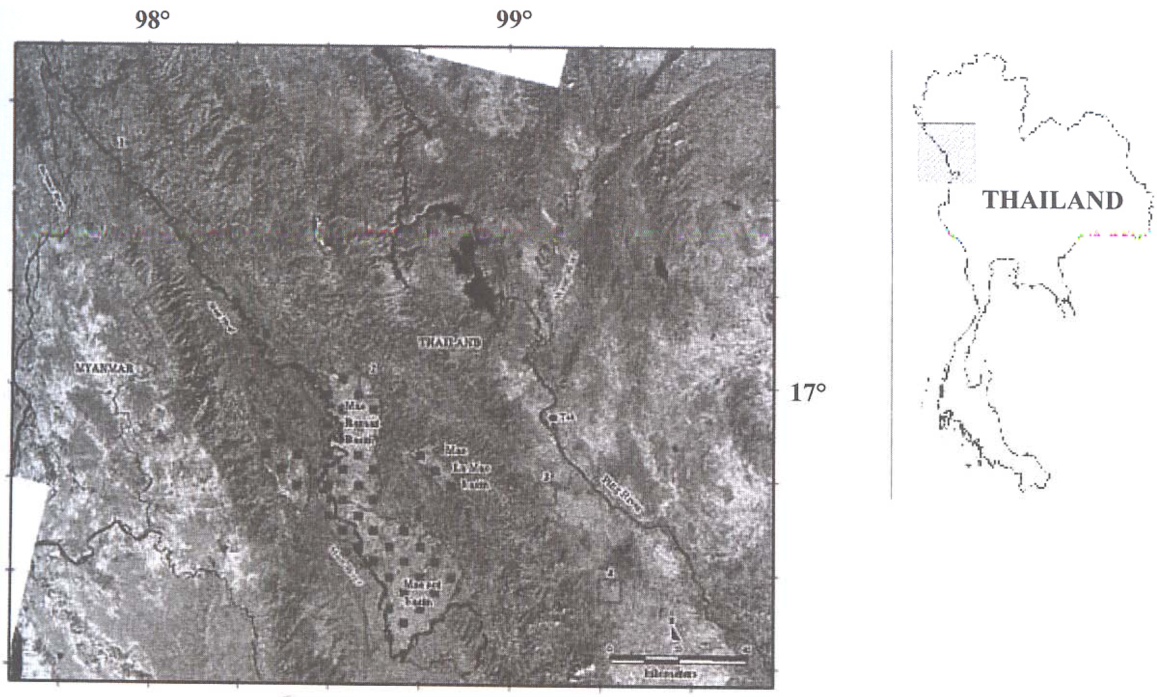

Figure 1 Enhanced Landsat TM7 image showing lineament patterns and physiographic features of the study and surrounding areas.

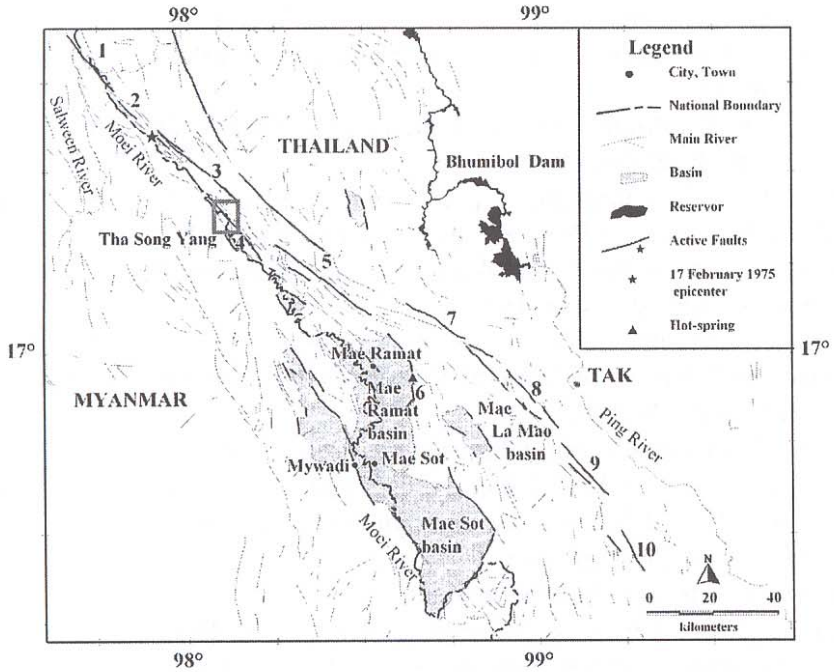

Figure 2 Lineament map showing orientation, continuity and sharpness of fault lineaments and Cenozoic basins. The box area is the detailed aerial photographic interpretation. Red line in the Moei-Mae Ping Fault Zone major active fault segments, 17 February 1975 epicenter and hot-spring. Not that 1=Sob Moei segment, 2=Huai Mae Lo segment, 3=Ban Tha Song Yang segment, 4= Khao Mae Song segment, 5=Huai Mae La segment, 6=Doi Kala segment, 7=Doi Khun Mae Tho segment, 8=Doi Luang segment, 9=Khao Yao segment, and 10= Khlong Phri segment.

Defining earthquake - risk areas along the active faults in Lampang – Phrae area, northern Thailand using enhanced Landsat TM image data and GIS software programs

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ABSTRACT We applied results of both remote-sensing interpretation and field survey to map the settlement distribution as well as the active faults along the Lampang – Phrae Fault Zone, northern Thailand. The objective of this research work is to define seismic risk areas in Lampang - Phrae area using multi-disciplinary approaches.

With the application of ENVI 3.4 software, we are able to process and enhance the Landsat TM5 and TM7 images using image registration, image mosaicking, image enhancement, and digital image interpretation. Based on geological, seismological, and geomorphic data, the Lampang – Phrae Fault Zone with the total length of 130 km and the width of 20 km are recognized. The fault zone can be subdivided into 10 segments as Ton Ngun Segment (18 km), Mae Paun Segment (20 km), Sobprab Segment (42 km), Ban Mai Segment (40 km), Long Segment (49 km), Thoen Segment (19 km), Wangchin Segment (74 km), Wangkhon Segment (28 km), Phrae Segment (48 km), and Mae Man Segment (13 km). Tectonic geomorphology and morphometric analysis indicate that along these fault segments the Ban Mai, Sobprab, Long, Thoen and Phrae segments are interpreted to represent the "most active faults". Landsat image interpretation maps, topographic maps, political administration maps, active fault maps, morphometric maps, road net map, and population density data, were overlain, integrated and analyzed using ArcView 3.2 GIS software to point out the earthquake risk - areas. A strip zone measured equally from both sides of each fault segment covering the total width of 10 km was applied for defining earthquake ruptures in the seismic risk zones.

Our result with the GIS application indicates that 7 densely populated district areas in the study area are seismically risked, including Wangchin, Thoen, Sobprab, Long, Muang Phrae, Sung Men, and Denchai district areas . Based on the overall result, we also inferred the most densely populated areas in Long and Sobprab districts have been regarded the most risk areas for fault - induced earthquakes.

1. INTRODUCTION

1.1 Background and Objective

Thailand has not been considered to be a seismically active country due to the disappearance of large earthquakes in the past. Judging form the distribution of earthquake epicenters in Southeast Asia, Thailand lies close to the east of the Andaman-Sumatra (or Alpine) earthquake belt. Although not all of the earthquake events have felt in Thailand, the awareness and fearfulness of such events stimulate the acquisition of earthquake research studies in this region. This probably leads to the systematic compilation of the historical earthquake data in Thailand

and adjoining areas which appears as the scientific report of series on Seismology Volume II by Nutalaya et al. (1985). So far there have been only few studies on earthquakes in Thailand (e.g., Nutalaya et al., 1985; Siripakdi, 1986; Prajuab, 1990; Hinthong, 1991; Charusiri et al., 2003). The historical earthquakes in Thailand were summarized in chronological order by Nutalaya et al. (op. cit.) and later by Charusiri et al. (2003) from the historical texts, annals, stone inscriptions and astrological documents. About 50 earthquakes were recognized from their studies to have occurred in Thailand and Myanmar since 624 B.C. There are only few studies in the past which mainly concerned about application of remote sensing information to geological structure. Sarapirome and Khundee (1994) studied neotectonics in the Mae Hong Son and Khun Yuam area. They applied trends and lengths of lineaments interpreted from remote sensing data along with hot spring and epicenter locations to interpret Quaternary faults in the Mae Hong Son area. Charusiri et al. (2003) applied Landsat TM5 to a detailed analysis on fractures to locating mineralization in Mae Hong Son area and later reinvestigated by Charusiri et al. (2000). Chusuthisakul (2003) applied Landsat TM7 image for delineating neotectonic features and define the direction of fault segments in part of Mae Hon Son fault zone.
The prime objective of this paper is to define earthquake-risk areas along the Lampang-Phrae Fault Zone.

1.2 The study area

The study area is located between latitudes 16° 45' to 18° 30' and longitudes 99° 00' to 100° 30'. The area covers much of the Lampang-Phrae fault zone, northern Thailand. The total study area (29,725 km^2) occupies the main administrative districts, including Amphoe Muang Phrae, Amphoe Long, Amphoe Sung Men, Amphoe Den Chai, and Wang Chin in Phrae province and Amphoe Muang Lampang, Amphoe Mae Tha, Amphoe Thoen and Amphoe Sobprab in Lampang province.
Nutalaya et al. (1985) studied the characteristic earthquakes and first described seismic source zone in Myanmar, Thailand, and Indochina areas into 12 zones. Charusiri et al. (2000) redefined the seismic sources, and new 12 zones have been proposed in Thailand and mainland SE Asia. The study area in Lampang – Phrae is located in the seismic active belt called Zone H (Sukhothai-Loei)" by Charusiri et al. (2000). Fenton et al. (1997) studied late quaternary faulting in northern Thailand and concluded, based on field and remote-sensing analyses, that the Lampang- Phrae fault zone has been seismologically active. To the northeast of the study area, Udchachon (2002) studied neotectonics of the Phrae basin based on remote sensing interpretation, field investigation, dating data seismic profiles, and focal mechanism data. He also concluded that the southeastern segment of the Phrae fault system is a potentially active fault.

2. MATERIAL AND METHODOLOGY

2.1 Material

In this study, we used the Landsat TM 5 and Landsat TM7 digital files provided by Department of Mineral Resources (Fig. 1). Apart from the satellite images, all the previous geological maps (Charusiri et al., 2004), topographic maps, population density data, and road net data, were also used for data integration into GIS format. In this study ENVI 3.4 and Arc View 3.2 GIS were also applied for data enhancement and evaluation.

2.2 Methodology

The methodology of this study can be divided into 4 steps, viz. data preparation step, image processing step, field survey step and map evaluation/production step.

2.2.1. Data Preparation. This step involves gathering of the available existing data and reformatting all data into a database for supporting further steps of the study.

2.2.2. Image Processing. The second step includes image registration, image enhancement, and image interpretation, following the work of Gupta (1991). The ENVI 3.4 software program was used for image processing.
Image registration (or deocoding) is the process of superimposing an image over a map or another already registered data by using the technique of coordinate-transformation. Selected image data of this study was rectified with reference to the 1:50,000 scale topographic maps (image to map registration).
Image enhancement is the modification of an image in order to alter its impact on the viewer. Major tools applied for the image enhancement were contrast stretching, edge enhancement, and RGB color composite.
Image interpretation is the pixel classification into several interesting groups, based on the multispectral responses. In this study, an automatic interpretation technique, includeing unsupervised and supervised classification, was used to classify settlement and road net information. Fault segments were classified from enhanced Landsat images by visual interpretation.

2.2.3. Field survey. This step is conducted to support the remote sensing interpretation. Field checking was carried out in order to verify image interpretation results and to recheck result from automatic classification.

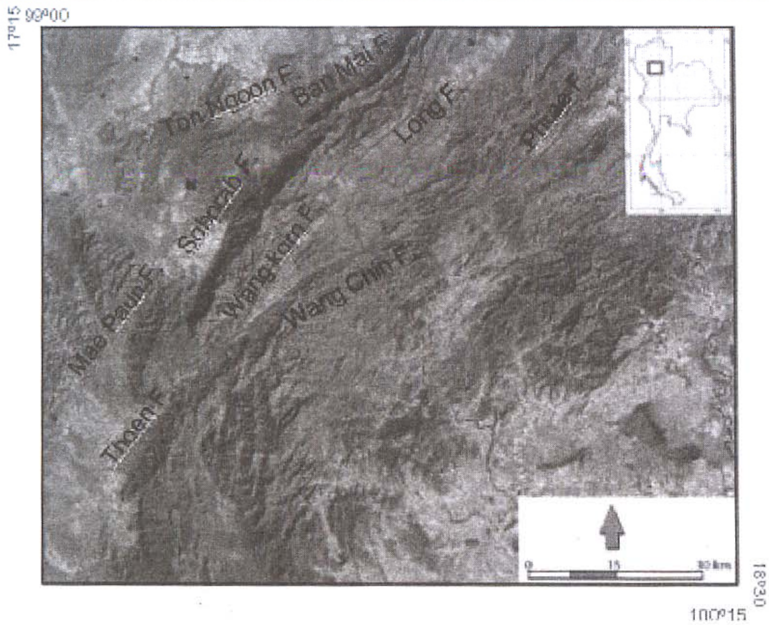

Fig. 1. Enhanced image from Landsat TM5 and TM7 showing locations of interpreted active-fault segments (solid line). Of the Lampang-Phrae fault zone, northern Thailand Cinserted box1.

2.2.4. Map evaluation and production. This step is assigned to integrate population distribution map, road net map, and the active fault map. All the available output maps were overlain, and analyzed using ENVI 3.4 and ArcView 3.2 The final map, therefore, displays the earthquake-prone areas.

3. RESULT AND DISCUSSION

Landsat TM images in this study were processed and interpreted in order to extract the active fault zone and relevant infrastructures (Fig.2), including settlement distribution and road net. The fault zone was mapped using a combination of visual interpretation, geomorphic, and seismological data.

Based on our result, the total length of this fault zone is about 130 km with the width of 20 km. The fault can be subdivided into 10 segments, as Ton Ngun Segment (18 km), Mae Paun Segment (20 km), Sobprab Segment (42 km), Ban Mai Segment (40 km), Long Segment (49 km), Thoen Segment (19 km), Wangchin Segment (74 km), Wangchin Segment (28 km), Phrae Segment (48 km), and Mae Man Segment (13 km) (Fig.1).

Result from morphometric analyses (Charusiri et al., 2003) using mountain-front sinuosity of the Sobprab and Ban Mai segments in Lampang show the average value close to 1 (~1.05), suggesting the new vertical movement. Mae Paun and Thoen Segments have the average value of 1.09 and 1.08, respectively. In Phrae, the Wang Chin and Phrae segments yield the equal the average value of 1.08. Additionally, the similar result obtained from the stream length ratio, a high value indicates the new movement. The Ban Mai, Sobprab, and Long segments display the highest average value (>300) whereas the Thoen, Phrae and Mae Puan segments have values ranging from 50 to 300. Based on the morphometric analyses together with TL age dating results (Charasiri et al., 20003), we define active faults in the Lampang-Phrae fault zone into 3 classes, as 1) class-I fault: these indicating the most active fault and including Ban Mai, Sobprab and Long segments, 2) class-II fault: indicating the intermediate active fault and including Thoen and Phrae segments, and 3) class-III fault: indicating the least active fault and including Mae Paun, Ton Ngun, Wangchin, Wangchin, and Mae Man.

For the population density, we used the data obtained from the National Statistical Office of Thailand (1998). Three groups of population density were classified based on amount of population and road networks in this study (Fig.2). The high density is for more than 100 citizens per sq km and dense roads, the intermediate density is for 50-100 citizens per sq km and fairly dense roads, and the low density is for less than 50 citizens per sq km with less dense roads. This result together with the overlaid road network display that although Lampang city seems to be the most densely populated area, it is not regarded to be strongly seismically risked when compared with the other districts which are located in the fault zone.

Tectonic geomorphology and morphometric studies indicate that among these faults, 5 segments are regarded as the most active segments, including Ban Mai, Sobprab, Thoen, Long and Phrae segments. Landsat image interpretation map, political administration map, active fault map, morphometric map, preliminary field survey and population density data, were overlain, integrated, and analyzed using ArcView 3.2 GIS to produce a map for earthquake risk areas. Moreover, following the works of Summervill et al. (1995) and Hutchings et al. (1996) for the 1995 Kobe earthquake, strip zones measured equally from both sides of the fault segments covering the total width of 10 km, ware applied for defining earthquake ruptures in the seismic risk zones. Our result with the GIS application (Fig.3) indicates that 7 district areas of the study area are seismically risked. They are those of Wangchin, Thoen, Sobprab, Long, Muang Phrae, Sung Men, and Denchai districts. So on the basis of the overall senario, we infer that two populated areas in Long and Sobprab districts are probably the most risk areas for fault - induced earthquakes.

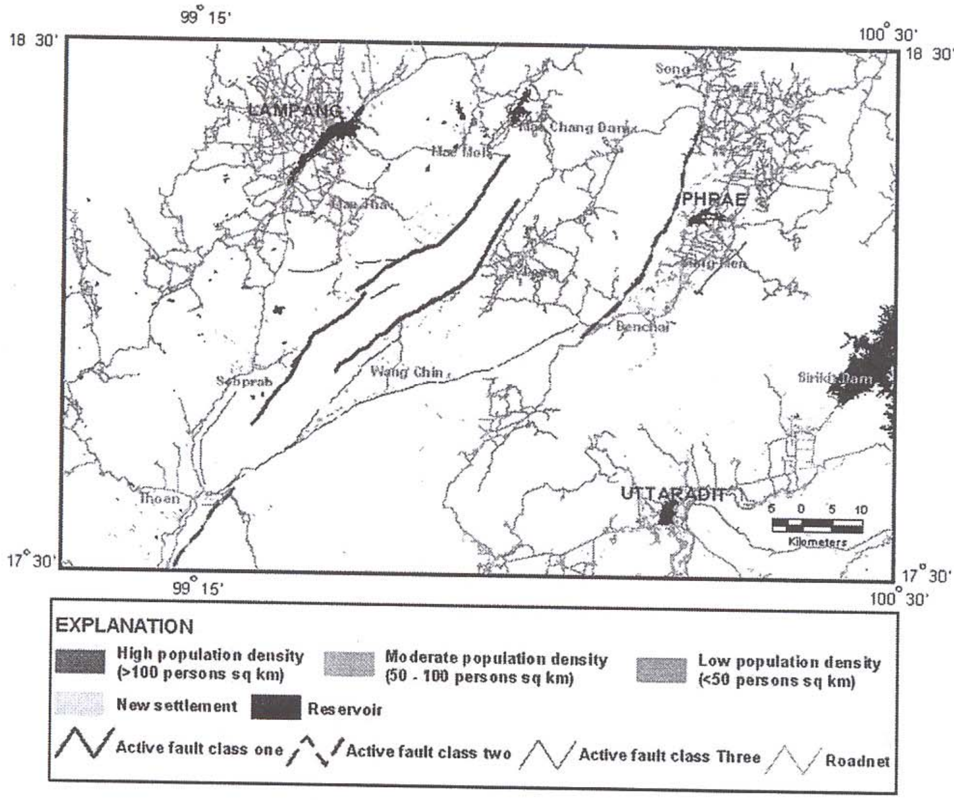

Fig. 2. Interpreted map showing active faults overlain onto the populated-density map and road net map.

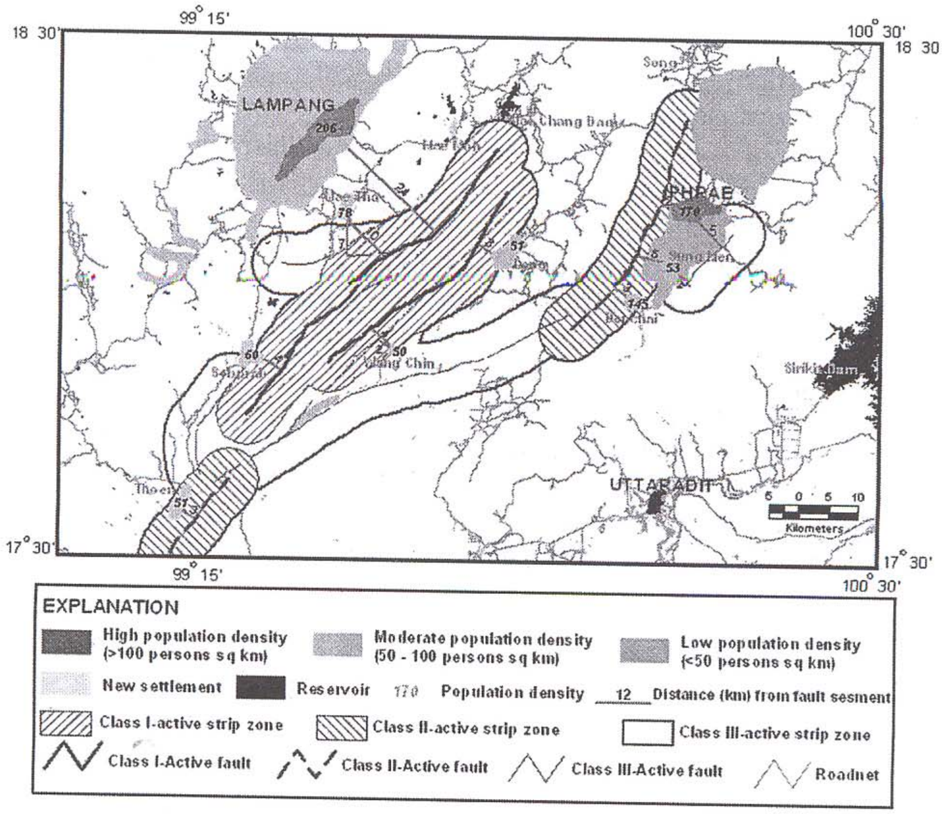

Fig. 3. GIS-assisted map showing earthquake-risk areas, active faults with strip zones overlain on to population density and road net mop, Lampang and Phrae ares, northern Thailand.

4. CONCLUSION

Based on the result of lineament analysis along with those of morphometric analyses using the GIS application. Ten active fault segments were recognized from the Lampang-Phrae fault zone. Among the active fault segments, the Long and Sobprab segments are inferred to be the most active. Our result also indicates that the populated Subparb and Long areas are defined as earth quake risk areas.

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