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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.

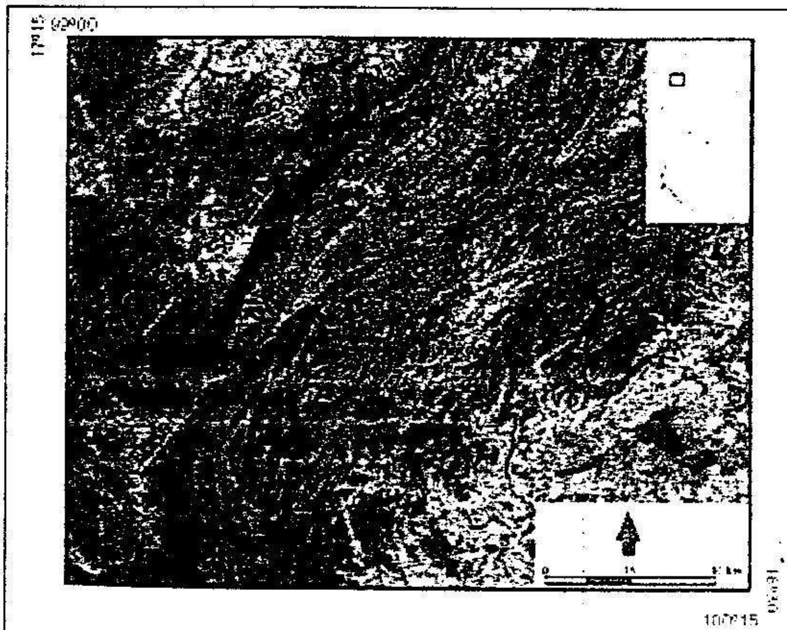

Fig. 1. Enhanced image from Landsat TM5 and TM7 showing locations of interpreted active-fault segments (solid line). Of the Lampang-Phrae fault zone, northern Thailand Cinserted box1.

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, were 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.

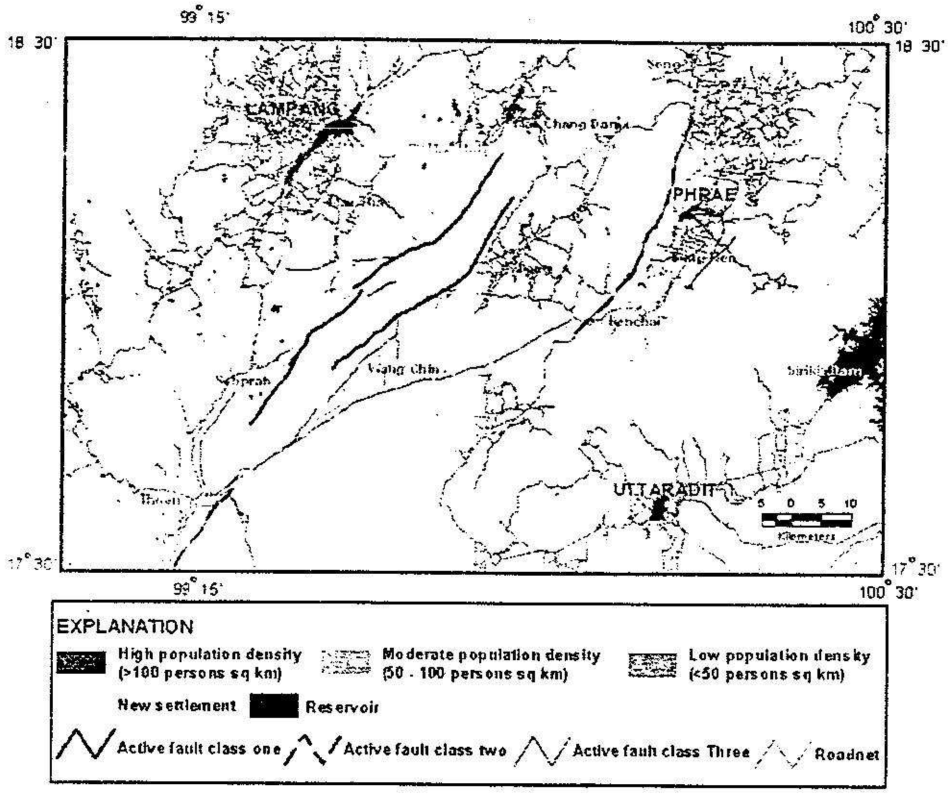

Fig. 2. Interpreted map showing active faults overlain onto the populated-density map and road net map.

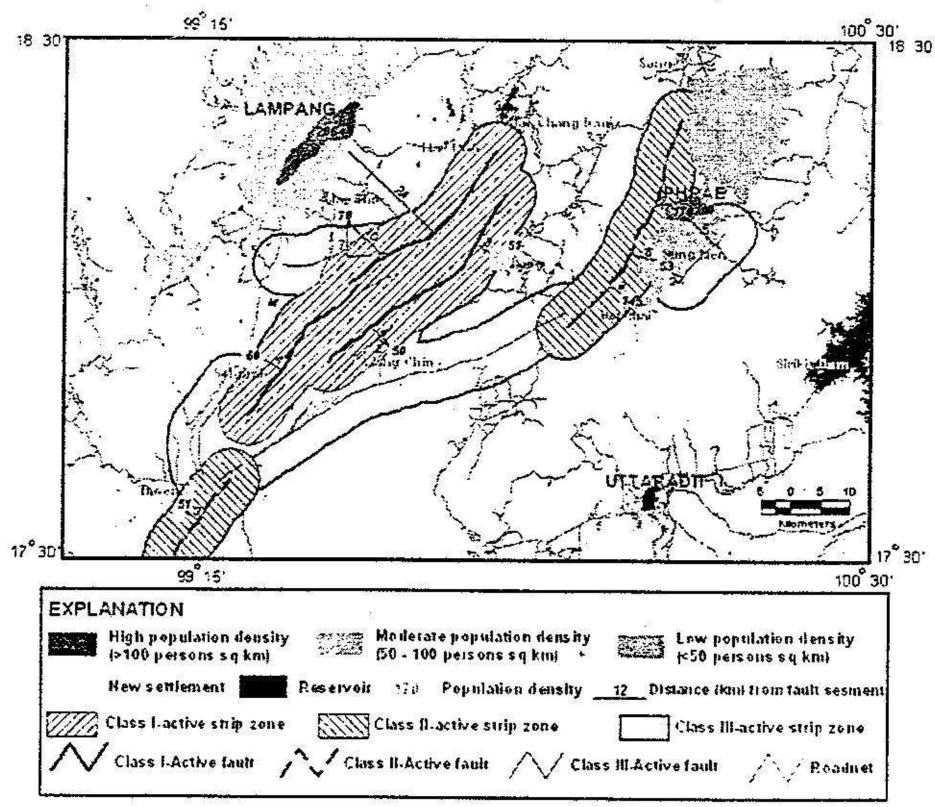

Fig. 3. GIS-assisted map showing earthquake-risk areas, active faults with strip zones overlain on to population density and road net mop, Lampang and Phrae ares, northern Thailand.

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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