CHAPTER I

INTRODUCTION

Landslide is a world-wide natural hazard, which in most cases occur debris flow and is caused by intense and continuous rainfall (Cruden and Varnes, 1996). Debris flows are commonly mixed of water, mud, sand, rock, and wood fragments and resulted in severe risks to people, farmlands, buildings and urban infrastructures. The world's largest landslide occurred during the 1980 eruption of Mount St. Helens, a volcano in the Cascade Mountain Range in the State of Washington, Western United States (Voight *et al.*, 1983). For Thailand, the most famous landslide event occurred in November 1988 in Kathun District, Nakhon Si Thammarat Province. Approximately 230 persons were killed, 1,500 houses were damaged, and the total amount of 1,000 million baht was estimated for the economic lost (Tantiwanit, 1992). Since then, Thailand suffered from landslide disaster from times to times. In 2006 the disastrous landslide and flood in Uttaradit, Sukhothai, Phrae and Nan Provinces of northern Thailand made hundreds of people lost their lives or and some became injured. Many parts of high mountainous areas in Thailand are exposed to landslide hazard occurrences, which are damaged to people and properties, and infrastructures. Consequently, it is necessary to document landslides to assess the hazards, and to reduce the risks remediate.

1.1 Introduction

On 23 August 2006, a landslide was initiated in many areas of Nan Province after five days of the unusual heavy rainfalls (Figure 1.1). This landslide was transformed into debris flow due to intense and continuous rains. The debris flow moved extremely rapidly and was transported by flood along the stream channel and eventually inundated the low land area. This event caused many houses and bridges completely destroyed. This resulted in the death of 6 local people and more than 200 people injured and over 100 houses severely destroyed (DDPM, 2006). Large areas of agriculture farms were damaged due to this flooding and debris flow. The landslide is a destructive natural hazards affected on human lives and their properties in the local area. This event seriously damaged the living area, transportation lines and agriculture areas of several districts including Chalermprakiet, Thung Chang, and Chiang Klang (Figure 1.2).

The serious problem in landslide hazards assessment is to find out where and when landsliding will occur. The reliable answers will be able to help regional and urban planners to plan for protection against landslide hazards and risk. Consequently, it is necessary to delineate on landslide hazard assessment particularly in the landslide-prone areas that will be affected by probable landslide hazards in the future.

At present, remote sensing and GIS are the most important application for landslide assessment analysis. There are many landslide prediction models using remote sensing and GIS to identifying hazard areas affected by landslide-prone ground (e.g., Wang and Unwin, 1992; Greenbaum *et al.*, 1995; Chang *et al.*, 1998; Lee, 2004). Most of them are different in terms of methodology and type of factors that are used for landslide hazard analysis. These differences depend largely on experience of researchers, geographic locations, and types of landslides. Most of these methods, GIS were used to compile and manipulate data, and to produce final landslide hazard maps, which require remotely sensed data as 1) to spatially detect and classify landslides, 2) to monitor the activity of existing landslides, and 3) to analyse and to predict slope failures spatially and temporally (Mantavani, 1995). Landslide hazard map was produced based on mathematical algorithms, such as regression and probability functions (Chang *et al.*, 1998).

This study is aimed to contribute to improving the methodology for landslide hazard assessment. It is also aimed to assess landslide hazard (or susceptibility) at a regional scale 1:1,000,000. Existing landslides location and physical factors related to landslide occurrences are collected from available sources, and derived from remote sensing data. Remote sensing data are used to map existing landslide locations and factors that are important in landslide initiation. Individual factors will be involving determined and described in more detail. The results from the remote sensing interpretation were verified by field investigation. All data related to landslide occurrences in the study area were transformed to digital formats and stored in the database of the GIS.

The methodology used for the landslide hazard assessment in this study is "The Bivariate Probability and Weighting Analysis". The probability and weighting of landslide occurrence on each factor are analysed a using Geographic Information System (GIS) technique modified from the method of Greenbaum *et al.* (1995) and Lee (2004). Landslide hazard map and landslide prediction model are produced based on probability and weighted values of landslide occurrence of each factor, which shows the degree of landslide occurring in the study area. In addition, ranking and weighting of causative factors, which control landslide occurrences are analysed.

The goal of landslide hazard or susceptibility analysis is to assess the landslide hazard areas in order to reduce the risks to people, urban areas, infrastructures and farmlands. An essential part of this landslide hazard mapping is to validate the significance of the prediction result, so that it can be used to predict landslide-prone ground in further areas with similar physical factors related to landsliding.

Figure 1.1 Landslide occurrences are shown as a bare ground on the mountainous area at Ban Kok Village, Chiang Klang District, Nan Province.

Figure 1.2 Flood Inundation due to up stream debris flow at Nam Phi Village, Thung Chang District, Nan Province, on August 20, 2006.

1.2 Objective of Research

The main objective of this thesis research is to generate landslide hazard zonation map of the study area. The following sub-goals are formulated:

1) To study cause and feature of landslide occurrence in Nan Province.
2) To understand relation between landslides occurrence and causative factors for landslide hazard in the study areas; and
3) To validate the results of probability of landslides occurrence and classifies landslide hazard level in the study area.

1.3 Scope and Limitation

This research integrates remote sensing and GIS techniques with field mapping and verification for landslide hazard assessment. The analysis focuses on the relationship between existing landslide distributions and physical factors affected to landslide occurrences. These physical factors will be described in a great detail. The landslide hazard or susceptibility analysis was based on the bivariate probability and weighting methods. Landslide hazard or susceptibility map was derived by incorporating physical factors related to landing in term of probability on landslide occurrences using GIS technique. The study will not focus on engineering properties of rocks and earthy materials. Event of landslides will be relied on the previous available interpreted data. Emphasis will be placed on landslide scars detected mainly by remotely sensed data.

1.4 Expected Results

The following results will be expected by this study.

1) General improvement of methodology for landslide hazards detection.
2) Landslide hazard (or susceptibility) maps of the Nan study area.
3) Landslide prediction model using a bivariate probability and weighting model, which can serve as an improved method to identify areas affected by future landslide events.

1.5 Characterization of the Study Area

1.5.1 Location and Accessibility

The study area covers the entire areal extent of the Nan Province, which is located in the eastern part of northern Thailand between 18°00′45'' to 19°37′05'' N and 100°24'03'' to 101°06′29'' E (Figure 1.3). Neighboring provinces are Uttaradit and Phrae in the south, Phayao in the west, and Xaignbouli of Laos PDR in the north and the east. The study area is situated in the catchments of the Mae Nam Nan River. It is called Mae Nam Nan Valley of which surface accounts are approximately 11,500 square kilometres, and the study area is approximately 668 kilometres north of Bangkok, the capital city of Thailand. The study area can be accessed all year by the Highway no.101 from Wiang Sa district.

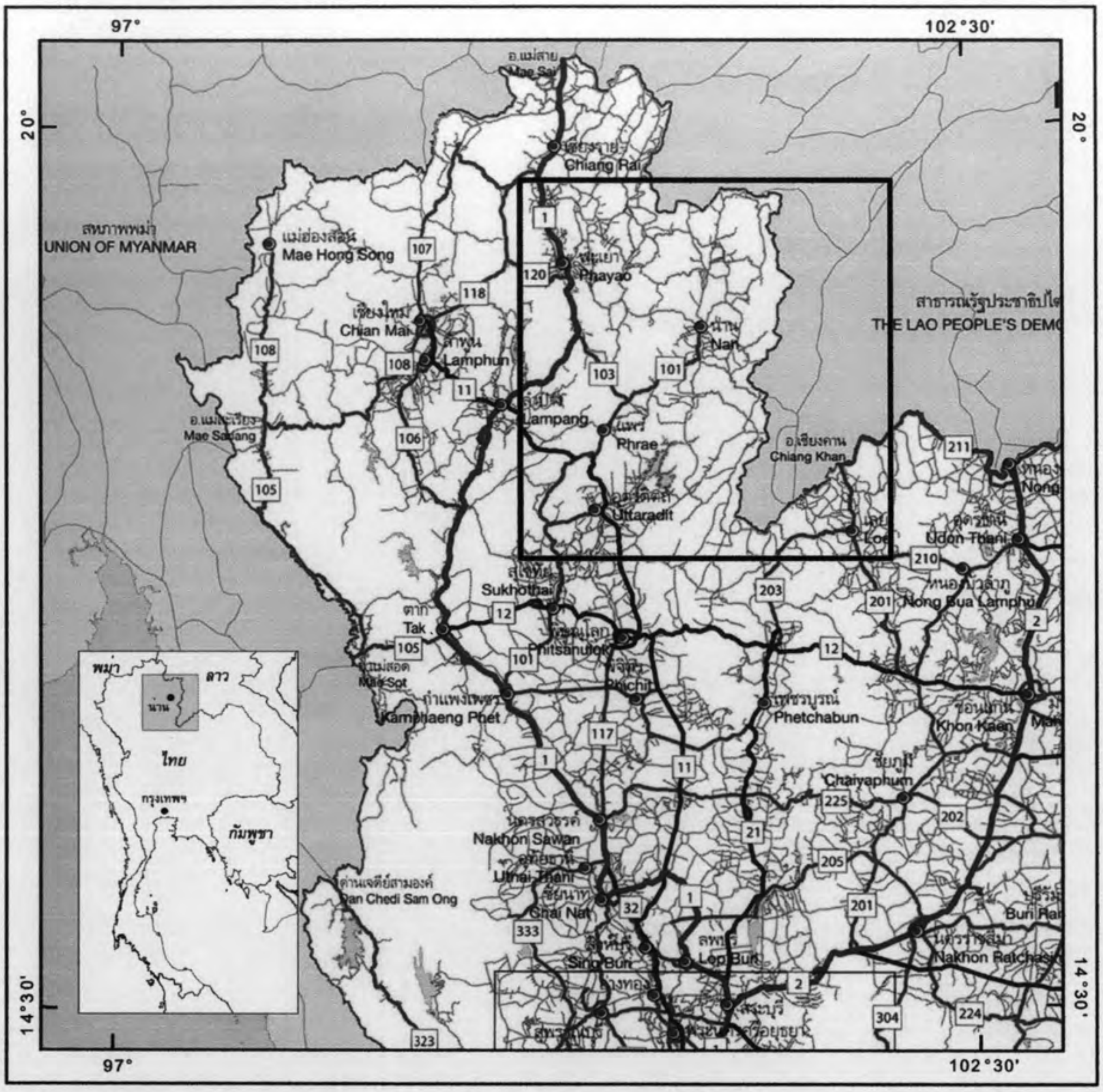

Figure 1.3 Map of northern Thailand showing the location of the study area (black square), and covering area of Nan Province (Department of Highways, 2007).

1.5.2 Topography

Nan Province is located in the remote valley of the Nan River, surrounded by mountains covered with several kinds of forest. The topography of the area is characterized by mountains, terraces, and flood Plains (as shown in Figures 1.4 and 1.5). The elevation of the study area is approximately 600-1,200 meters above mean sea level at Luang Phrabang range – Phi Pan Nam range. Both mountainous ranges are covered by moderate to dense natural forests, which has been partly deforested several times. The highest mountain is Doi Phu Kha which high 2,079 meters, located in Amphoe Pua, northeastern of the city of Nan toward the border with Laos. The central part of the study area shows an undulated terrain with elongated shape trending in approximately N-S direction. The terrain consists of small and low hills, lying closely to the high mountain range. The teak plantation dominates the land use in this area. The lowest portion of the terrain is floodplain, where many important rivers flow through, namely the Nan River, the Sa River, the Wa River, the Samun River, the Long River, the Pua River, and the Gon River. The Nan River is the main river in the study area and flows from the north to the south. Paddy field, mixed orchards, and crops are the main land use units of this flood plain.

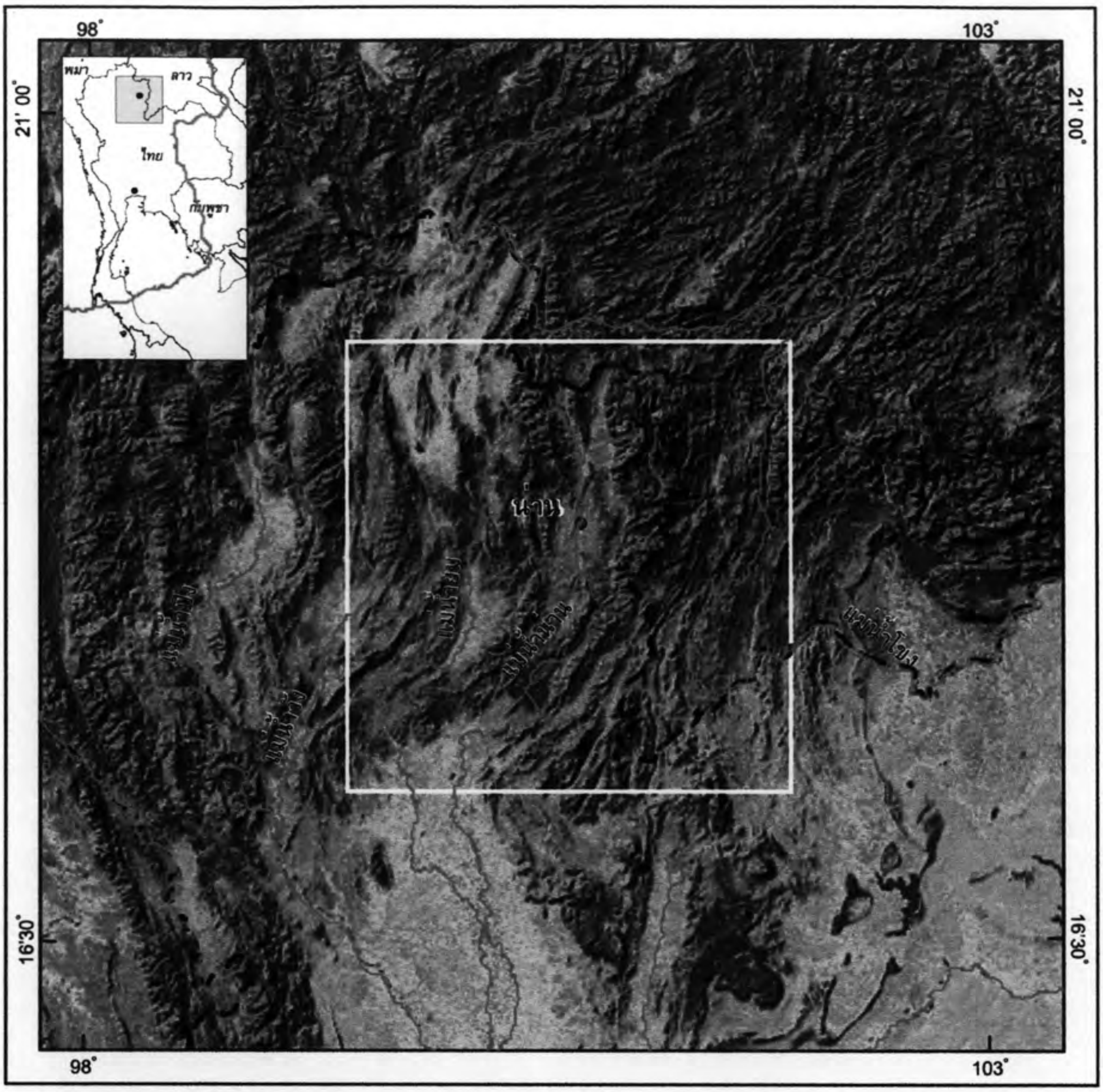

Figure 1.4 Topographic map of the study area (white square) showing mountain ranges (brown), Cenozoic basins and plains (yellow), and major streams oriented in the north-south direction.

Figure 1.5 Nan topographic model showing the mountain ranges and basins in three dimensions (3D) view (http://www.nan.go.th).

1.5.3 Climate

The weather at the Nan province can be divided into 3 seasons, including summer (March-May), when the study area is affected by the summer monsoon blowing from the southeast of Andaman Sea; the rainy season (June-October), when the study area is affected by the southwestern monsoon; and winter season (November-February), when the study area is influenced by the northeastern monsoon blowing the coldness from the North Pole and China-Siberia to Thailand.

The average annual rainfall of 1,206.3 mm can be measured at the Meteorological station of Nan Province during year 1998-2008. The average maximum rainfall of 320 mm is recorded in August; and the average minimum rainfall of 6.2 mm can be measured in January. The average temperature of 27°C can be measured during 1995-1998. The average highest temperature of 30°C can be measured in May; and the average lowest temperature of 22°C is recorded in January.

The average relative humidity of 76 percent is measured during year 1998-2008. The average highest relative humidity of 85 percent can is recorded in August. The average lowest relative humidity of 63 percent can be measured in March; and the average annual relative humidity is 77 percent.

1.5.4 Geological Setting

The regional landforms of the eastern of the Northern Thailand consist of mountain range and elongated basins with north to northeastern strikes. The main rivers are mostly lie following the basin shape those are mostly controlled by regional geology and structures. The structures of the study area are almost parallel to the main structures in the same direction. The geological map, scale 1:1,000,000 (Figures 1.6 and 1.7) that revised by Department of Mineral Resources (1998-1999) was used to explain the regional geology and structure. The preliminary and systematic geological investigation in Nan area was performed by staff numbers of the Department of Mineral Resources (1999) on the scale 1:250,000, including as Xaignbouri (NE47-4) and Changwat Nan (NE47-8). The more detailed geological maps on the scale 1:50,000 include those of Ban Nam Muab (5145 I) by Sukwattananan *et al.* (1990), Ban Na Nam (5145 II) by Chaturongkavanit *et al.* (1987), Amphoe Na Mun (5145 III) by Chaturongkavanit *et al.* (1987), Amphoe Na Noi (5145 IV) by Thammadussadee (1990), Changwat Nan (5146 I) by Sukwattananan *et al.* (1990), Amphoe Sa (5146 II) by Sukwattananan *et al.* (1990), Ban Pang Chompu (5146 III) by Thammadussadee (1990), Ban Khuan Kaew (5146 IV) by Sukwattananan *et al.* (1990), Amphoe Thung Chang (5147 I) by Sophonpongpipat *et al.* (1989), Amphoe pua (5147 II) by Sophonpongpipat *et al.* (1989), Amphoe Mae Charim (5246 III) by Wannapeera *et al.* (1987), Ban Huai Pu (5246 IV) by Wannapeera *et al.* (1987), The study area is underlain by various kinds of rocks ranging in ages from Silurian to recent Quaternary sediments. Below are the detailed description compiled from those earlier mentioned map.

<u>**Sedimentary and Metamorphic Rocks**</u>

Silurian-Devonian Rocks: Rocks of the Silurian to Devonian ages represent the oldest rocks in the study area. This rock unit is dominantly observed to the western part of the study area in Nan Province. It is assigned as the Pha Som Group (Bunopas, 1969) with the thickness of 1,500 meters. These rocks are sedimentary and metamorphic rocks as phyllite, schist and quartzite. The minority of hornblendite is regarded as the igneous origin (Bunopas, 1981). The attitudes of beds strike south and dip west.

Carboniferous Rocks: This unit contains marine clastic rocks which is assigned as the Mae Tha Group (Piyasin, 1972). In study area, this unit as thick as 400 meters and is mainly exposed at the southern part of Nan Province. It is composed mainly of conglomerate, sandstone, shale and slate. There are limestone and chert beds interbedded within. The upper part of the unit in the study area is largely volcanic and volcaniclastic rocks, including rhyolite, andesite, agglomerate and tuff. The attitudes of rocks strike southwest and dip northwest.

Carboniferous-Permian Rocks: The Carboniferous to Permian rocks of the Phrae Group (Bunopas, 1981) are unconformably underlain by rocks of the Pha Som Group. The Phrae Group rocks are well exposed at the central part of the research area; west of Amphoe Tha Wang Pha, Changwat Nan. Thickness of the Phrae Group is more than 4,000 meters. The Phrae can be divided into 2 units – the lower and the upper units. The lower unit is composed of red chert, agglomerate, andesite and diorite, top of the unit contains sandy shale, coarse-grain sandstone and conglomerate. The upper unit is composed of volcanic rocks, quartzitic sandstone, shale, limestone, and calcareous shale. The rocks strike south and dip west.

Permain Rocks: The Permian rocks which are collectively called the Ratburi Group (Bunopas and Vella, 1983) are also widely exposed. This unit has the maximum thickness of 600 meters and the average thickness of 100 meters. The Ratburi Group can be separated into 3 parts. The lower are mainly exposed in Amphoe Na Mun, Changwat Nan. It consists of sandstone, siltstone, shale, chert, conglomerate, tuff and volcanic rocks and conformably underlain by the Carboniferous rocks. The middle part is mainly exposed in Changwat Nan and contains micaceous sandstone, shale and well bedded limestone. The upper part is mainly exposed in east of Changwat Nan and contains sandstone, tuffaceous shale, limestone chert, and conglomerate. The attitudes of beds strike southwest and dip northwest.

Permain-Triassic Rocks: Permo-Triassic rocks occur as a linear belt and largely exposed throughout the central part of Changwat Nan. The rock unit has the thickness of 500 to 900 meters and consists of sandstone, tuffaceous sandstone, shale, chert, argillaceous limestone, limestone lenses, rhyolite to tuff, and meta-andesite. They are collectively called Lampang Group by Chaodumrong (1992). The major strike is in south direction and dip to west.

Mesozoic Rocks: Based on the geological map at scale of 1:1,000,000, Mesozoic rocks in the northern part of Thailand, can be separated into 2 parts, marine and non-marine sedimentary rocks. **The Marine Mesozoic Rocks** in study area are widely exposed in the west of Changwat Nan. This rock unit can be divided into 2 parts, the marine Triassic rocks of the Lampang Group and marine Jurassic rocks of Nam Pat Group (Bunopas, 1981). Sediments of the Lampang Group (Chaodumrong, 1992) was deposited in deep sea graded to shallow water during Triassic period. These lithologic units are composed mostly of mudstones, limestones, sandstone, and subordinate conglomerates with the total thickness of about 5,000 meters. Marine Triassic rocks are both unconformably and conformably underlain by Permian rocks of the Saraburi Group. The Marine Jurassic rocks are exposed nearby Amphoe Na Noi, Changwat Nan, and consist mainly of mudstone interbedded sandstone with marine fossils. **The Non- Marine Mesozoic Rocks** was deposited in the alluvial system during the Mesozoic period and composed of mudstone, sandstone, and conglomerate. The non-marine Mesozoic rocks are widely exposed along the Thai-Lao PDR border, eastern part of Changwat Nan. The non-marine Triassic rock unit distributed around Amphoe Wiang Sa and Ban Luang, Changwat Nan. This rock unit contains sandstone, mudstone, and conglomerate with clasts of marine clastic rocks. The Jurassic non-marine clastic rocks are conformably underlain by Triassic rock and the Jurassic rocks unit which consists of conglomerate, arkosic sandstone interbedded with shale, conglomerate, and mudstone. In general, these rocks are mainly subhorizontal. However in some parts, they show inclined strata with the main strikes of south and dips to west.

Tertiary Rocks: These rocks of Tertiary age in northern Thailand are important as sources of coal and clay minerals. These rocks have deposited in the intermontane and rift basins. There are 2 significant Tertiary basins in the study area, such as Pua and Nan basins. The former attains to the thickness of 300 meters and the latter is as thick as 200 meters (Hess and Koch, 1975). The Tertiary rocks have been deposited in these basins consist mainly of semi-consolidated clastic sediments as claystone, siltstone, sandstone and conglomerate. Based on several kinds of fossils including plants, bivalves, gastropod, and vertebrates, they indicated the age of Tertiary. In the satellite images the tertiary rocks are shown as low-relief and gentle slopes as compared with those of the older rocks. Several Tertiary are mainly horizontal to subhorizontal. However, some of them are also tilted.

Quaternary Sediments: The Quaternary sediments in the study area were chiefly deposited in the intermontane basin. They are deposited by colluvial and alluvial processes and well exposed at foot hills and along the Nan River. The processes of rivers developed broad flood plain and river terraces, in the higher elevation which is undulated terrains covering with colluviums and alluvial fan sediments. These alluvial and colluvial processes are also related to the landsliding phenomena of the study area. The Quaternary sediments are deposited in this area, characterized by unconsolidated sediment such as sands, silts, clays and gravels. Based on the stratigraphic correlation, the sediments in terrace area assign in Pleistocene age, while the flood plains and the sediments on the upper of alluvial deposits are Holocene age.

Igneous rocks

Plutonic rocks: Most plutonic rocks in the study area are granitic rocks belonging to Granite belt of Thailand (Charusiri, 2002). Based on the stratigraphic correlation and dating results, the granite rocks can be divided into 2 catagories, Permo-Triassic Granite and Triassic Granite, however both are I-type. The Permo-Triassic granite is well exposed in the east of the study area. It is composed of micro granite and quartz monzonite, grano-diorite, and plagio-granite. The Triassic granite is mainly characterized by biotite granites, and biotite-tourmarine granites. This granite is well exposed in the central and east of the study area, especially at Amphoe Pua, Changwat Nan.

Volcanic Rocks: In the study area, volcanic rocks occur as small, semicircular and elongate shapes. These volcanic rocks can be separated into 3 suites based on their age. Permo-Triasic volcanic, consisting of rhyolite, andesite, agglomerate, rhyolitic tuff, and andesitic tuff. Jurassic volcanic rocks are exposed in the western of Changwat Nan, which composed of andesite and rhyolite. Cenozoic basalt or the so called Denchai basalt.

Structural Geology

In the study area, the major structure can be well recognized in satellite images is the faults and fractures. The major faults and fractures are in the northeast – southwest and north – south directions. The important fault in the study area is the Nan – Uttaradit Fault Zone (UFZ) (Figure 1.8). It is considered to tectonically control regional attitudes of the above – mentioned rock units. Not only the major NE – SW trending fault but also there are the other important faults in the north to north – northeast strike, including Pua Fault and Pua Fault (Fenton et al., 1997). Parts of these faults cut through the Tertiary and Quaternary sedimentary unit as well. They also represent the contact zone of sediments deposited in the Tertiary basins.

Figure 1.6 Regional geological map of the eastern part of northern Thailand of initial scale 1:1,000,000 covered the study area (Department of Mineral Resources, 1999).

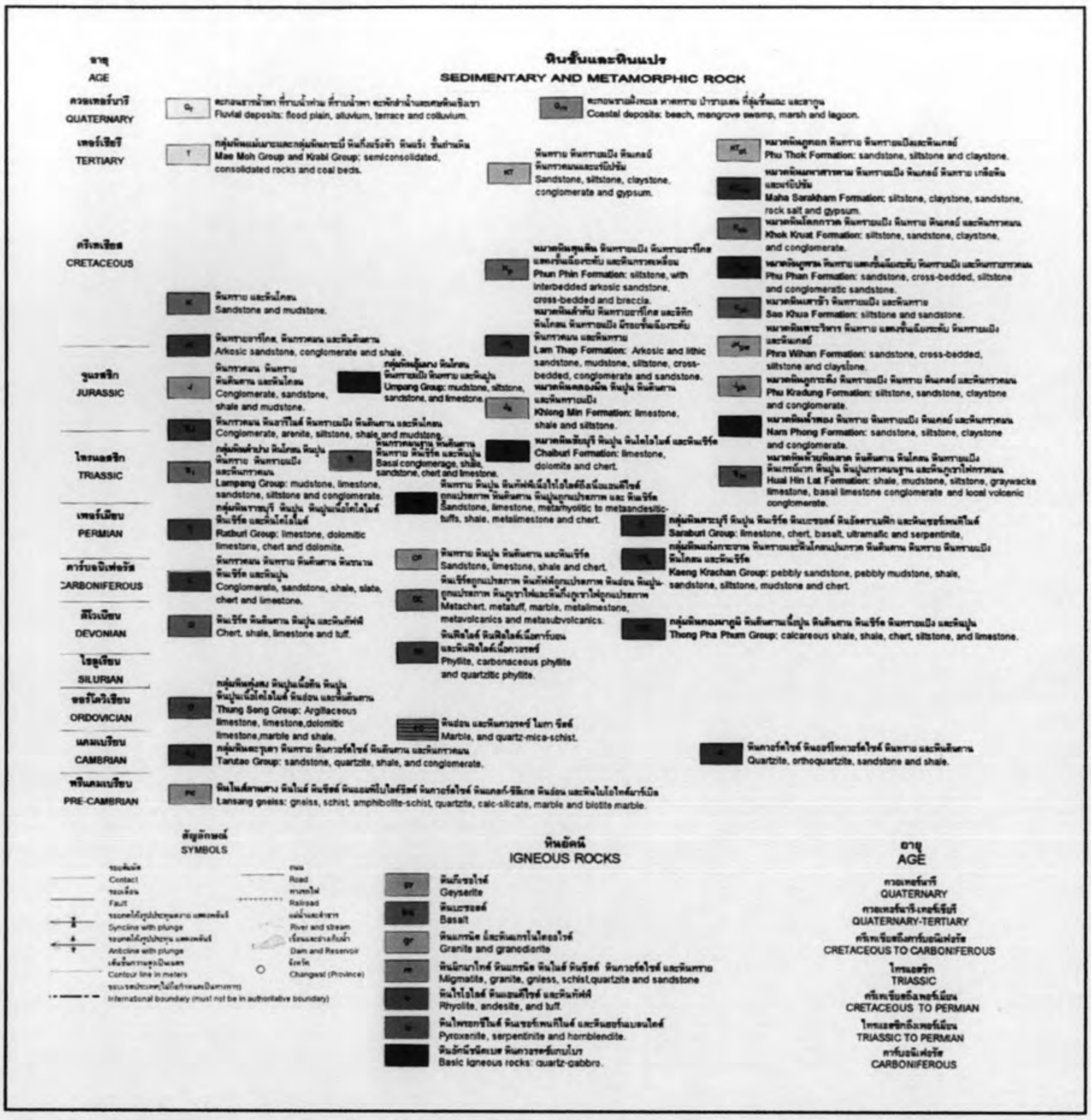

Figure 1.7 Explanation of geological map (Department of Mineral Resources, 1999), showing in Figure 1.6.

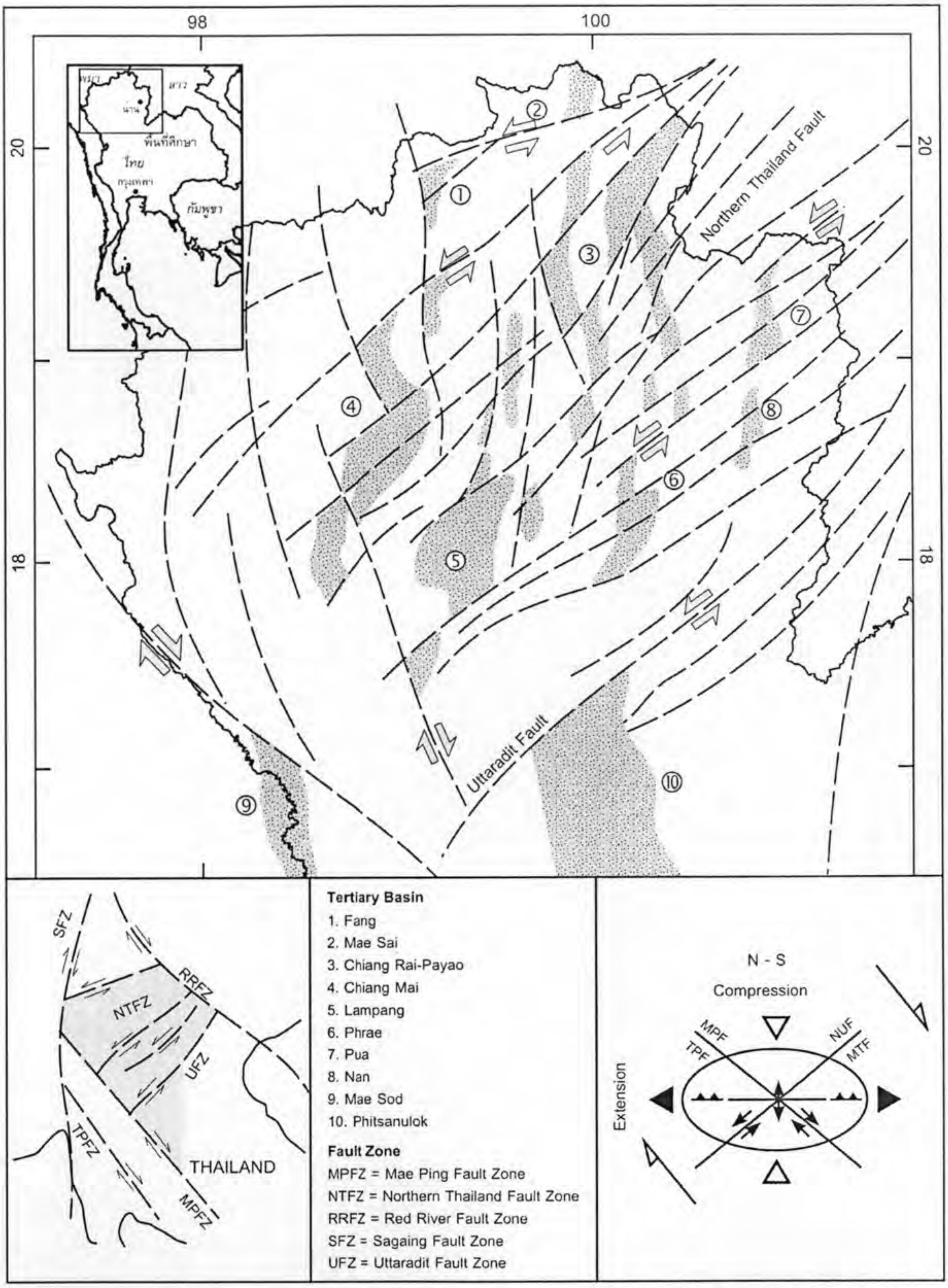

Figure 1.8 Structural map of Northern Thailand showing relationship between conjugate strike – slip faults and the development of N-S trending pull – apart basins (after Polachan and Sattayarak, 1989)

1.6 A Brief Guide to the Thesis

This thesis provides a landslide hazard data of the Nan Province area in succession of 6 Chapters, including:

Chapter I – Introduction, mentioned about an introduction, objective, characterization of the study area and geological setting of the study area and nearby.

Chapter II – Literature Review, including overview of landslide, technical aspects of remote sensing, GIS and their integration for landslide hazard assessment, including previous works and the case study of landslide in Thailand.

Chapter III – Methodology, is about research methodology of this project, including part of remote-sensing interpretation, preliminary field investigation, GIS data preparation, spatial data analysis and data integration.

Chapter IV – Results, including of landslide information construction, landslide assessment analysis, and shows landslide hazard zonation map, includes verification of result.

Chapter V – Discussion, with special emphasis on the role of the scars and their relationships to the other physical factors and on the comparison between results of the present study with that of DMR.

Chapter VI – Conclusion and recommendation of results gathered from the study project.