

CHAPTER 1

INTRODUCTION

1.1 Pre-cretaceous volcanic rocks in Thailand

Thailand is generally believed as being the product of the collision between several microcontinents, including two main microcontinents, i.e. Shan-Thai continent to the present west and the Indochina continent to the present east (Bunopas, 1981; Barr and Macdonald, 1991; Barr *et al.*, 2006; Panjasawatwong, 1991; Singharajwarapan, 1994; Hada *et al.*, 1999; Ueno, 1999; Metcalfe, 2000; Metcalfe and Sone, 2008; and Phajuy, 2008). Barr and MacDonald (1991) divided Thailand into four zones, namely, from West to East, Western thai zone, Inthanon zone, Sukhothai zone and Phetchabun zone. This study focuses on Chiang Rai-Chiang Mai volcanic belts, in Inthanon zone.

The Pre-Cretaceous volcanic belts in Thailand are generally divided into five belts (Fig. 1.1), including Chiang Rai-Chiang Mai volcanic belt, Chiang Khong-Lampang-Tak volcanic belt, Nan-Chanthaburi suture, Loei-Phetchabun-Nakhon Nayok and Sra Kaew-Chanthaburi volcanic belt. The Sra Kaew-Chanthaburi volcanic belt may be part of one of four volcanic belts but it was destroyed and translated by Mae Ping fault. Therefore, this volcanic belt cannot be related to the other volcanic belts.

1.1.1 The Chiang Rai-Chiang Mai volcanic belt

The Chiang Rai-Chiang Mai volcanic belt extends southward from the Changning-Menglian suture in south China (Haoruo *et al.*, 1995; Yang *et al.*, 1994; Charusiri *et al.*, 1999; Ueno, 1999; Barr *et al.*, 2000; Metcalfe, 2002a, 2002b; Metcalfe and Sone, 2008; and Feng *et al.*, 2005). Chiang Rai-Chiang Mai volcanic belt is a scattered zone, extending from Chiang Rai Province, to the northeast, to the Thai-Burma border, in the Mae Hong Son region (Ferrari *et al.*, 2008), to Lamphun

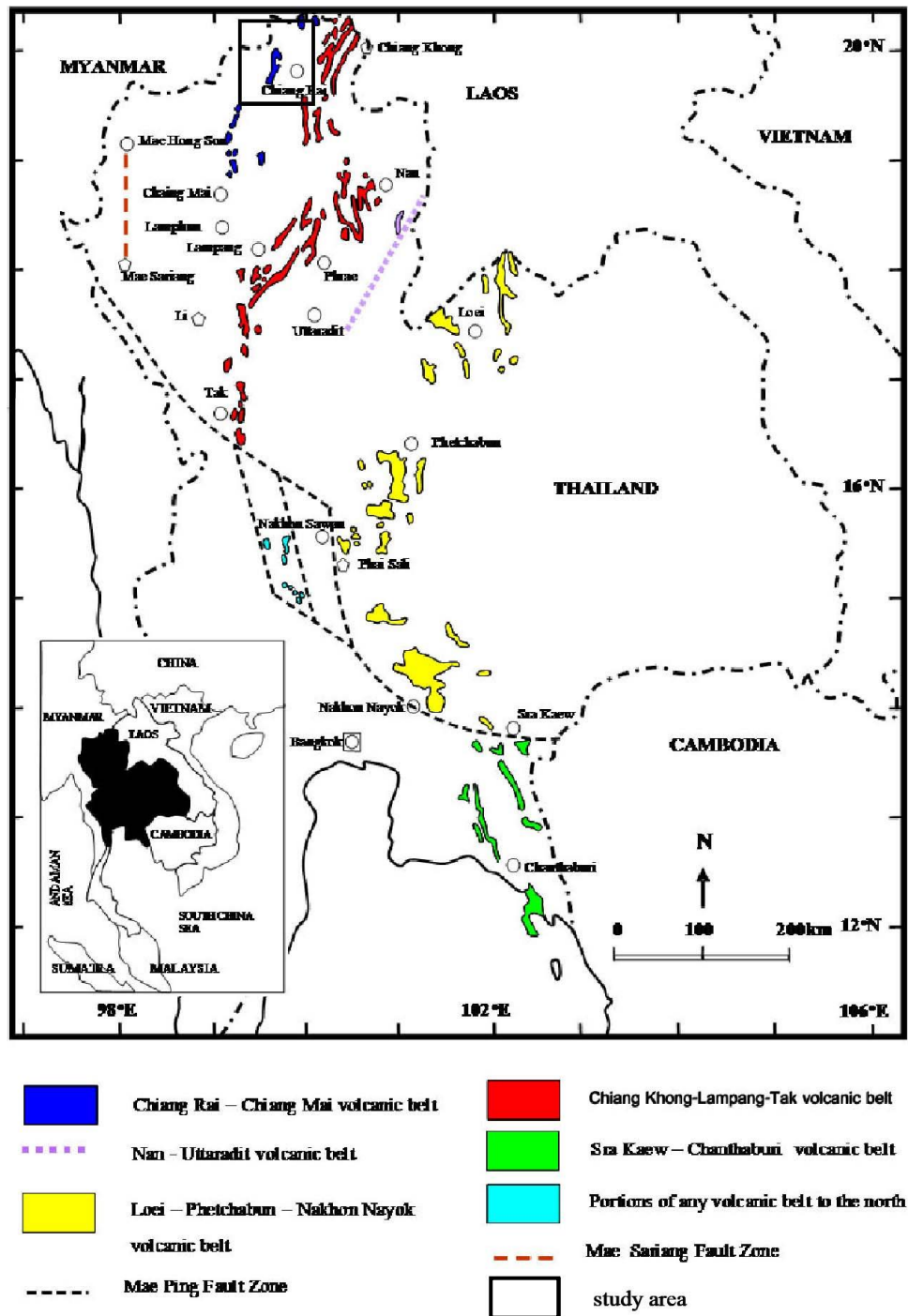


Figure 1.1 Distribution of Pre-Cretaceous mafic volcanic rocks in Thailand (modified from Jungyusuk and Khositantont, 1992; Kosuwan, 2004; Panjasawatwong *et al.*, 2006; and Phajuy, 2008). The Mae Ping fault zone and the Mae Sariang fault zone are taken from Morley (2002), and Hisada *et al.*, (2004), respectively. The inset shows a portion of Thailand that is enlarged in this figure.

Province (Li District) (Panjasawatwong *et al.*, 1995). This volcanic belt is made up largely of mafic igneous rocks (i.e. mafic volcanic rocks, pillow breccias/hyaloclastite and dike rocks) and small amount of ultramafic rocks (i.e. werhlite) (Phajuy, 2008). However, tonalite and diorite with gabbro xenoliths present in Mae Sai and Mae Chan Districts were reported by Putthaphiban and Ya-anan (1988). Mafic volcanic rocks in Chiang Rai-Chiang Mai volcanic belt commonly associate with limestone. They are overlain by Lower Carboniferous and Upper Permian shallow water carbonate rocks (Ferrari *et al.*, 2008; and Shangyue *et al.*, 2009). Also, this volcanic belt is associated with Carboniferous-Devonian quartzite, quartz schist, phyllite and calcsilicate rock (Putthaphiban and Ya-anan, 1988). Researchers suggested that the Chiang Rai-Chiang Mai volcanic basalts were erupted in Upper Carboniferous (Braun and Hahn, 1976), Permo-Carboniferous (Ferrari *et al.*, 2008) or Permian (Barr *et al.*, 1990; and Phajuy *et al.*, 2005). Diorite crops out around Doi Tung were dating by U/Pb zircon to be 430 ± 3.8 Ma (Silurian) (Fan *et al.*, 2010; Wang *et al.*, 2010). Geochemically, Barr *et al.* (1990) and Panjasawatwong (1999) classified the mafic volcanic rocks in Chiang Rai-Chiang Mai volcanic belt as tholeiitic basalts and/or transitional tholeiitic basalts. Later, Phajuy *et al.* (2005) and Phajuy (2008) classified into two groups as subalkalic basalts and alkali basalts. It has also been claimed that volcanic rocks in the Chiang Rai-Chiang Mai volcanic belt erupted in a subduction environment by Barr and Macdonald (1987). Later on, Barr *et al.* (1990) interpreted that this volcanic belt is related to a continental within-plate environment, while Panjasawatwong *et al.* (1995) and Panjasawatwong (1999) believed that they formed in an oceanic within-plate environment as ocean islands and seamounts in either a major ocean basin or a mature back-arc basin. Phajuy *et al.* (2005) reported that there are mid-ocean ridge and ocean-island basalts in this region. After that, Phajuy (2008) analyzed that this belt formed in back-arc basin, ocean-island and mid-ocean ridge environment.

1.1.2 The Chiang Khong-Tak-Lampang volcanic belt

The Chiang Khong-Tak-Lampang volcanic belt, central part of Sukhothai fold belt, extends southward from the Lincang-Jinghong volcanic belt in the south China (Yang *et al.*, 1994; Yang, 1998; and Barr *et al.*, 2006) and the southwestern Yunnan

can be correlated with Triassic Lampang-Phrae basin in Thailand (Feng *et al.*, 2005). The Chiang Khong-Tak-Lampang volcanic belt is to the east of the Chiang Rai-Chiang Mai volcanic belt, extending from Chiang Khong District, Chiang Rai Province via Lampang and Phrae Province to Tak Province (Panjasawatwong *et al.*, 2003). This belt consists of mafic to felsic volcanic, volcanoclastic and associated intrusive rocks (Panjasawatwong *et al.*, 2003; Srichan *et al.*, 2009). Associated sedimentary rocks are largely non-marine red bed and conglomerates. Igneous rocks of this belt were erupted in two episodes on the basis of stratigraphy correlation, i.e., the Permo-Triassic and the younger; highly possible to be Late Triassic-Early Jurassic (Jungyusuk and Khositantont, 1992). Geochemically, Researchers classified the volcanic rocks in the Chiang Khong-Tak-Lampang volcanic belt as continental calc-alkalic volcanic rocks along the western edge of Mae Moh Basin (Lampang Province) (Barr *et al.*, 2000) and the northern end of Chiang Khong-Tak-Lampang volcanic belt (Chiang Rai and Phayao Province) (Barr *et al.*, 2006), and in the Long area (Phrae Province) (Osataporn, 2007). Panjasawatwong *et al.* (2003) have classified as tholeiitic series of mafic rocks along the northern end of Chiang Khong-Tak-Lampang volcanic belt. After that, Srichan *et al.* (2008, 2009) provided into two groups as tholeiitic series and calc-alkalic series. The researchers believe that the volcanic rocks in this belt were erupted in a subduction-related environment or continental arc environment (e.g. Bunopas, 1981; Singharajwarapan, 1994; Crawford and Panjasawatwong, 1996). Later on, Srichan (2008) and Srichan *et al.* (2009) reported that this belt formed in post-orogenic origin. U-Pb Zircon dating was carried out on the Permo-Triassic arc-related volcanic rocks along the western edge of Mae Moh Basin (Barr *et al.*, 2000) and the northern end of this belt (Barr *et al.*, 2006). The results revealed that the volcanic rocks had U-Pb Zircon ages of 240 ± 1 Ma (Middle Triassic) and 232.9 ± 0.4 Ma (Middle Triassic), respectively. On the other hand, Khositantont (2008) has determined U-Pb Zircon ages from the volcanic rocks in the Tak, Lampang and Phrae areas and mentioned that they were erupted in a period of Early to Late Triassic (247 ± 5 to 219 ± 3 Ma), correspond to Srichan (2008) reported that the Chiang Khong-Tak-Lampang volcanic rocks occurred in the Middle-Late Triassic (233 ± 5 to 220 ± 5 Ma).

1.1.3 Nan –Uttaradit volcanic belt

Nan –Uttaradit volcanic belt is an extensive mélange zone that may related to Jinghong suture (Metcalf and Sone, 2008; Metcalfe, 2011) in the southwestern China. The Nan-Uttaradit volcanic belt is exposed in the eastern-most part of Northern Thailand along the Nan river, at the Eastern margin of Sukhothai fold belt, between the Sukhothai zone and the Indochina block (Ueno, 1999; Ferrari *et al.*, 2008, Sone and Metcalfe, 2008). It is composed of blocks of mafic-ultramafic rocks and minor sedimentary rocks in a sheared serpentinite matrix. Igneous rocks are constituted by lavas, microgabbro/dolerites, isotropic gabbros, cumulus gabbroic and ultramafic rocks, and chromitites. Of these, lavas and microgabbro/dolerites are the least abundant, whereas cumulus gabbroic and ultramafic rocks are the most abundant rock types. The mafic volcanic blocks include Middle Permian (256 Ma) ocean-island basalts, Carboniferous incipient back arc basin basalts/andesites, and ocean island-arc basalts/andesites (Panjasawatwong, 1991; Crawford and Panjasawatwong, 1996). Also, Singharajwarapan and Berry (2000) and Singharajwarapan *et al.* (2000) have mentioned that coherent volcanic rocks located east of the Nan-Uttaradit mélange zone are oceanic island-arc basalts. This belt regarded as representing the main Paleotethys ocean (Bunopas, 1981; Panjasawatwong, 1991; Chaodumrong, 1992; Singharajwarapan, 1994; Hada *et al.*, 1999; Wakita and Metcalfe, 2005), has recently been re-interpreted as the back arc basin which opened in Carboniferous (Barr and Macdonald, 1987; Fontaine *et al.*, 2002; Metcalfe, 2002a, 2002b; Wakita and Metcalfe, 2005) or Permian (Sone and Metcalfe, 2008; Ferrari *et al.*, 2008; Metcalfe, 2011). In case of the Paleotethys ocean, the volcanic belt is northern extension of the Sra-Kaew Chanthaburi volcanic belt (Sone and Metcalfe, 2008; Metcalfe, 2011).

1.1.4 Loei-Phetchabun-Nakhon Nayok volcanic belt

Loei-Phetchabun-Nakhon Nayok volcanic belt trends NE-SW from Loei Province through Phetchabun, Nakhon Sawan and Prachinburi Provinces to Sra Kaew Province (Panjasawatwong *et al.*, 2006). It consists lavas and pyroclastic rocks of compositionally from felsic to mafic. In the Loei area, they can be provided into Eastern, Central and Western sub-belts. Igneous rocks of the Eastern sub-belt are

mainly rhyolite, whereas those of the Western sub-belt are largely andesite (Jungyusuk and Khositant, 1992; Della-Pasqua and Khin Zaw, 2002). It can be interpreted that the Eastern and Western sub-belts formed arc volcanism in the Permo-Triassic (e.g. Bunopas, 1981). Panjasawatwong *et al.* (2006) reported that the Central sub-belt is made up largely of pillow basaltic lava, hyaloclastite and pillow breccia with some intrusions. They were formed in the Late Devonian–Early Carboniferous and can be separated into three magmatic groups: transitional tholeiitic basalt, tholeiitic microgabbro and calc-alkalic basalt/andesite. The Central Loei volcanic rocks are comprised of MORBs and oceanic island-arc lavas. These arc lavas may have erupted on an oceanic basement in the same ocean basin as those in the Chiang Rai–Chiang Mai volcanic belt. The rhyolites of the Eastern sub-belt, however, have a Devonian–Carboniferous whole-rock Rb–Sr isochron age of 374 ± 33 Ma (Intasopa and Dunn, 1994). The Central sub-belt has a whole-rock Rb–Sr isochron age of 361 ± 11 Ma (Upper Devonian-Lower Carboniferous) (Intasopa and Dunn, 1994) and the Western sub-belt has an intercept Ar–Ar age of 237 ± 12 Ma (Intasopa, 1993). Also, Khositant (2008) reported U–Pb Zircon ages of 425 ± 7 and 433 ± 4 Ma. The volcanic rocks in the Phetchabun areas have been erupted along an active continental margin in the Middle Triassic as evidence by An Ar–Ar dating amphibolites which gave age of 238 ± 4 Ma (Intasopa, 1993; Kamvong *et al.*, 2006). Also, The U–Pb zircon from Khao Lek yield the age of 254 ± 10 Ma and the U–Pb isotopic from Khao Mae Kae granodiorite yield the result of 250 ± 5 Ma (Khositanont, 2008). The volcanic rocks in the Nakhon Nayok area, a southern part of the Western sub-belt, are also geochemically arc-related magma (Kosuwat, 2004). Phajuy *et al.* (2005) reported that the basaltic dikes intrude into the Permian sedimentary sequence of Nam Duk Formation that formed in a volcanic arc environment. Pajasawatwong *et al.* (2006) and Kamvong *et al.* (2006) suggested that the Loei-Phetchabun-Nakhon Nayok volcanic belt may be correlative with the Sra-Kaew-Chanthaburi volcanic rocks.

1.1.5 Sra Kaew-Chanthaburi volcanic belt

The Sra Kaew-Chanthaburi volcanic belt is situated between the Tak-Chiang Khong volcanic belt and the Loei-Phetchabun. The Sra Kaew-Chanthaburi volcanic belt was interpreted to represent the Late Triassic continental suture formed when

westward subduction beneath the Shan-Thai Terrane resulted in collision between this block and the Indochina Terrane to the east (Panjasawatwong, 1991; Singharajwarapan, 1994; Crawford and Panjasawatwong, 1996; Hada *et al.*, 1999; Singharajwarapan and Berry, 2000). The Pre-Jurassic volcanic rocks along this suture zone occur as variably sized blocks embedded in foliated serpentinite matrix (serpentinite melange?). Recent studies indicate that they are comprised of Early to Middle Permian ocean-island basalt, Carboniferous incipient backarc basin basalt and andesite, Permo-Triassic (?) arc basalt and andesite, and mid-ocean ridge basalt (Yoshikura, 1990; Crawford and Panjasawatwong, 1996).

1.2 Scope of study

Mafic igneous rocks will be collected from the Mae Sai and Mae Chan Districts, Chiang Rai Province. The study includes field investigation, sample collection, petrography, and chemical compositions of least-altered rocks. Tectonic setting of eruption of these rocks could be interpreted based on their petrochemistry. Petrographic study (Cox *et al.*, 1979; Hess, 1989; Wilson, 1989; and Winter, 2010) under polarizing microscope is used for analyzing mineral composition and texture of rocks, including alteration, replacements or metamorphism, resulting in classification of rocks and their alteration/weathering. These results are evidence for field relation and modes of field occurrence. Geochemical composition can be divided by volume into major oxides, minor elements, trace elements and rare earth elements. These chemical compositions, especially immobile incompatible elements, can be used for identification of rocks and determining magma characteristics because they are closely representative of magma. Moreover, the chemical compositions will provide for interpretation of tectonic setting by using discrimination diagram and comparison with modern magma suites.

1.3 Location and accessibility

This study focuses on northern part of Chiang Rai-Chiang Mai volcanic belt, which mainly lies in the Intanon zone. The study areas are located in the Mae Sai and Mae Chan Districts. It is located in the topographic maps at scale 1:50,000, series

L7018, sheet 4949I (Amphoe Mae Sai) and sheet 4949II (Amphoe Mae Chan), Chiang Rai District, approximately between latitudes 20°00' N and 20°30' N and longitudes between 99°45' E and 100°00' E. The study area can be conveniently accessed by car via the route from Chiang Mai, take highway number 118 to Chiang Rai province (approximately 200 kilometers). The studied samples were collected from two areas as follows: (1) Mae Sai District, and (2) Mae Chan District. Mae Chan District can be accessed using highway number 1, from Mueang District to Mae Chan District for distance of approximately 250 kilometers. Travelling to Mae Sai District can be made from Mae Chan District via highway number 1 for distance of approximately 15 kilometer and turn left to highway number 1149 to the Doi Tung Royal Palace area for distance of approximately 10 kilometers (Fig 1.2).

1.4 Topography and Physiography

The project area has two areas as follow: (1) Mae Sai District, and (2) Mae Chan District (Fig1.3 and 1.4). Mae Sai area contains mountains and plain. Mountains are mostly located on the right side of topographic map Amphoe Mae Sai that has the highest mountains are 1,321 meters high above mean sea level (e.g. Doi Phu Thao and Doi Nang Non). Plain areas are mostly distributed on the central and left side of topographic map Amphoe Mae Sai that has many built-up areas, villages, rice swamps, streams (e.g. Nam Mae Chan, Nam Ruak, Nam Mae Cham, Nam Chat). They mostly flow north to south direction. Mae Chan area consists of mountains, intermountain basin and plains. Granite mountains are mostly scattered on the right side of topographic map Amphoe Mae Chan and has the highest mountain is 1,255 meters high above mean sea level (e.g. Doi Sao Thong). Plains are distributed around the north of the map that consists of built-up areas, villages, rice swamps, important stream (Nam Mae Cham flows NE to SW direction. The left side of the map is made up largely of mountains, and intermountain basins. The highest mountain is Doi Ngaem 667 meters high above mean sea level. Intermountain basins contain villages, rice swamps and important rivers (e.g. Mae Nam Kok flows approximately north to south direction).

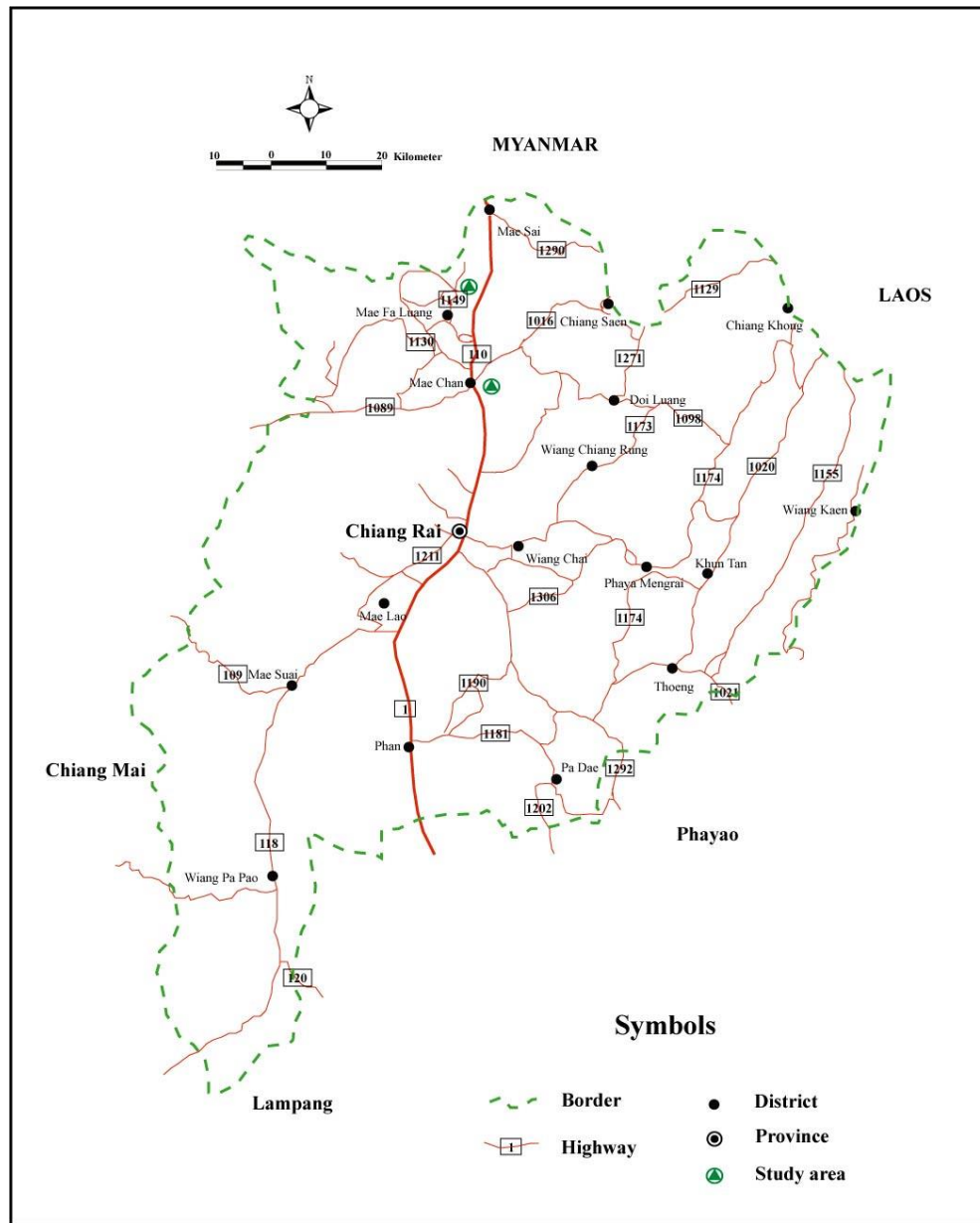


Figure 1.2 Map of Chiang Rai Province of Thailand showing accessibility to the study areas (modified from Tourism Authority of Thailand, 2007).

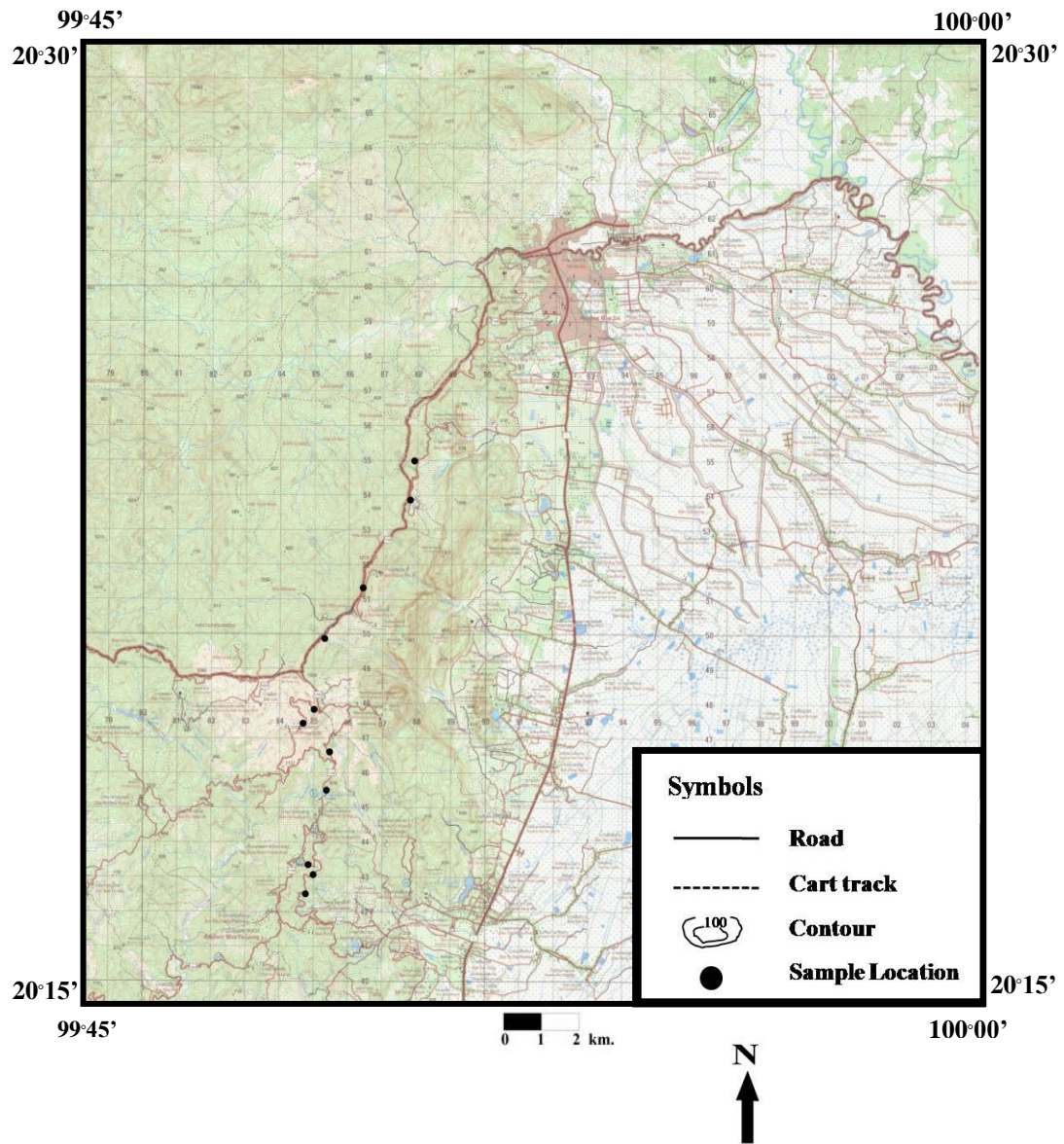


Figure 1.3 Topographic map showing the study area of Mae Sai area and the locations of collected mafic igneous rocks (solid circles) (modified from the Royal Thai Survey Department, 1999a)

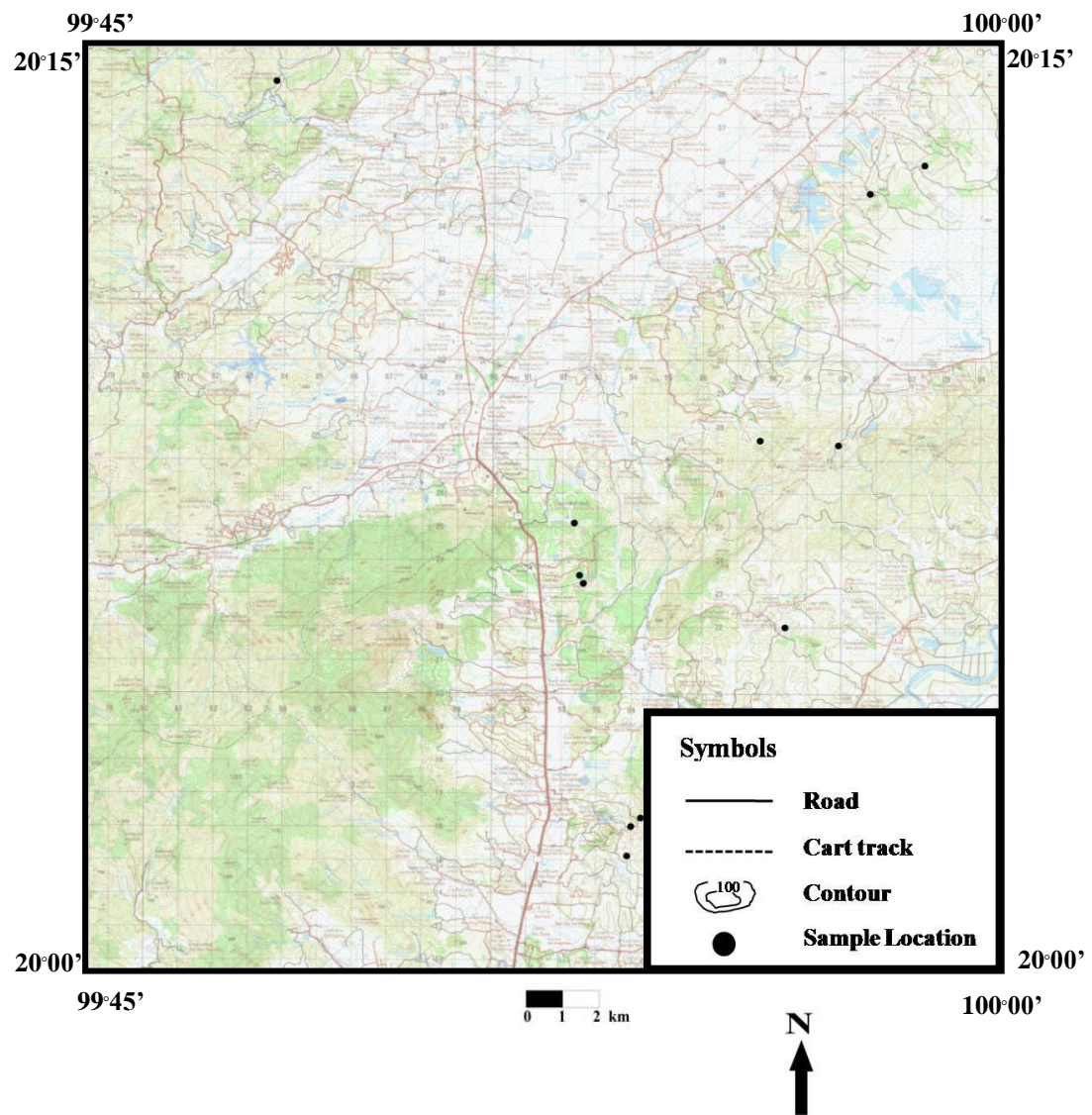


Figure 1.4 Topographic map showing the study area of Mae Chan area and the locations of collected mafic igneous rocks (solid circles) (modified from the Royal Thai Survey Department, 1999b)