CHAPTER 1

INTRODUCTION

1.1 PRE-CRETACEOUS VOLCANIC ROCKS IN THAILAND AND VICINITY

The tectonic evolution of Thailand and vicinity is still a subject of debate. The widely different opinions reflect both complicated geology and insufficient informative data. The problems include numbers and sources of cratons, locations of suture zones, timing of cratonic collision and a tectonic model. To solve these problems, many branches of geology are needed. Petrochemistry of igneous rocks, particularly mafic volcanic rocks, is one of such branches that can be used as a clue to ascribe tectonic setting of formation.

Research work related to tectonic evolution of Thailand and vicinity was carried out mainly in Thailand as she was more conveniently accessible relative to the surrounding countries. Consequently, a number of informative volcanic data in Thailand are available. Although there is a general consensus that the continent-continent collision between Shan-Thai and Indochina cratons took place in the Late Triassic (Bunopas, 1981; Hada, 1990; Hada *et al.*, 1991, 1999; Panjasawatwong, 1991; Bunopas and Vella, 1992; Chaodumrong, 1992; Intasopa, 1993; Singharajwarapan, 1994; Crawford and Panjasawatwong, 1996; Sashida and Igo, 1999; Kamata *et al.*, 2002; Singharajwarapan and Berry, 2000), very few workers (e.g. Bristow, 1990) have argued that the age for continental amalgamation is the Cretaceous. Accordingly, the pre-Cretaceous volcanic rocks are crucial in depicting the tectonic history of this region.

The pre-Cretaceous volcanic rocks in Thailand may be separated into four belts: Chiang Rai - Chiang Mai volcanic belt, Chiang Khong - Tak volcanic belt, volcanic rocks along Nan - Chanthaburi suture zone, and Loei - Phetchabun - Nakhon Nayok volcanic belt (Fig. 1.1) as mentioned by Kosuwan (2004). The Chiang Rai - Chiang Mai volcanic belt extends in a NNE-SSW direction from the western part of Chiang Rai Province through the eastern part of Chiang Mai Province to Li District, Lamphun Province. The Chiang Khong - Tak volcanic belt is to the east of Chiang Rai - Chiang Mai volcanic belt, extending from Chiang Khong District, Chiang Rai Province through Lampang Province and Phrae Province to Tak Province. The volcanic rocks along the Nan - Chanthaburi suture zone is located between the Chiang Khong - Tak volcanic belt and the Loei - Phetchabun - Nakhon Nayok volcanic belt, and extends southward to the Gulf of Thailand. The Loei - Phetchabun - Nakhon Nayok volcanic belt runs in a NNE-SSW direction from Loei Province through Phetchabun Province to Nakhon Nayok Province.

The Chiang Rai - Chiang Mai volcanic belt is characterized by lava flow, hyaloclastite and pillow breccia that might have been erupted in a Carboniferous time (Macdonald and Barr, 1978; Hess and Koch, 1979; Barr *et al.*, 1990) or a Permian to Permo-Triassic period (Bunopas and Vella, 1978; Chuaviroj *et al.*, 1980; Bunopas, 1981; Panjasawatwong, 1999; Phajuy *et al.*, 2004, 2005). The mafic volcanic rocks in the Chiang Rai region may have formed above a subduction zone, whereas those in the Chiang Mai region were erupted in a continental intraplate environment (Macdonald and Barr, 1978; Barr *et al.*, 1990). However, Panjasawatwong et al. (1995), Panjasawatwong (1999), and Phajuy *et al.* (2004, 2005) mentioned that the intraplate basalts have an oceanic affinity and might have formed either in a major ocean basin or in a mature backarc basin. Phajuy *et al.* (2005) also reported the local occurrence of mid-ocean ridge basalt in the Chiang Mai region. The oceanic affinity is well-supported by stratigraphy (Metcalfe, 2002; Wakita and Metcalfe, 2005); and paleontology and biostratigraphy (Caridroit, 1993; Sashida and Igo, 1999; Chonglukmanee, 1999; Feng *et al.*, 2002; Wonganan, 2005) along the Chiang Rai - Chiang Mai volcanic belt.

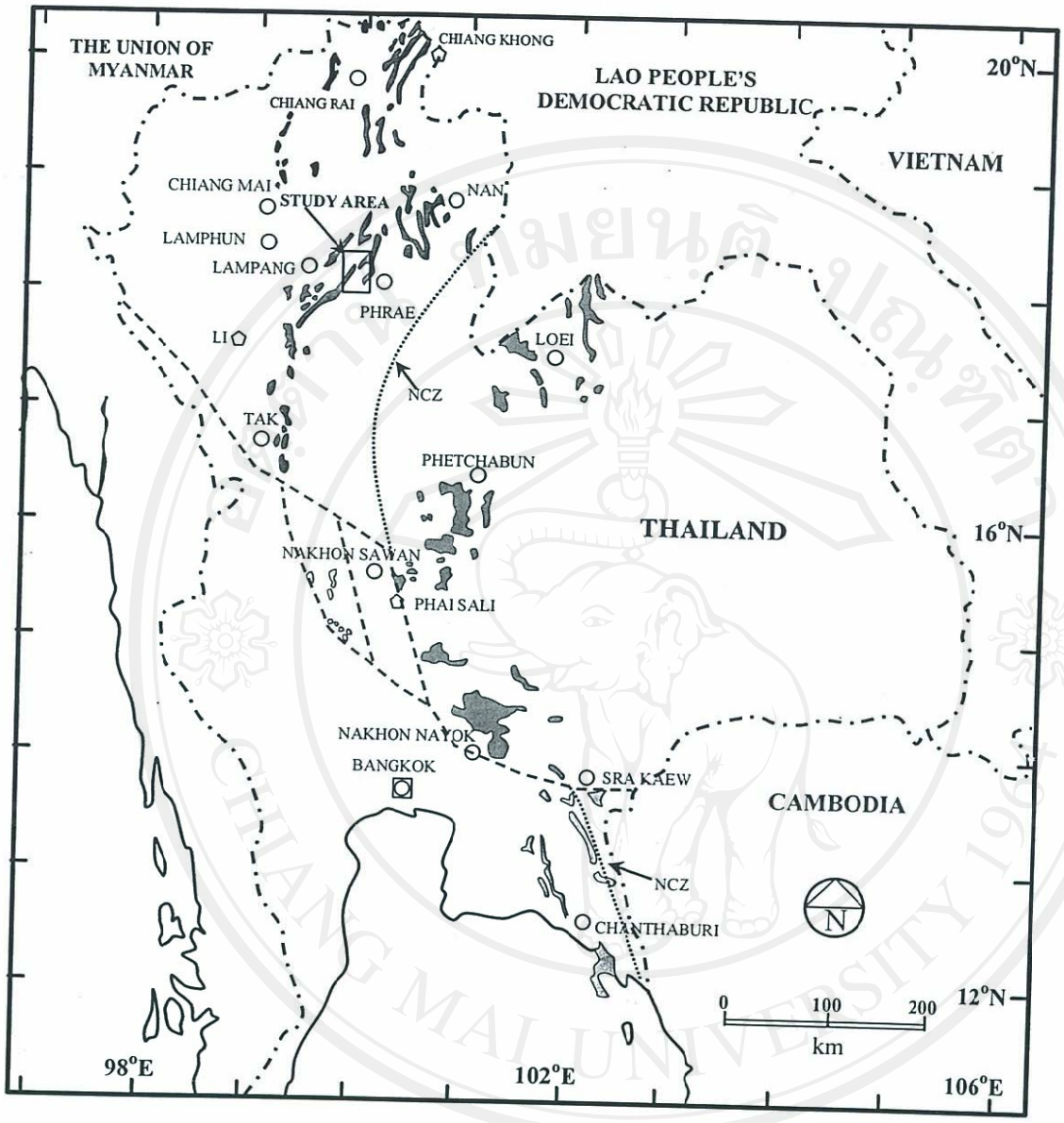


Figure 1.1 Distribution of pre-Cretaceous volcanic rocks in Thailand (after Kosuwan, 2004). Note that the exposures of volcanic rocks along the northern part of Nan - Chanthaburi suture zone are too small to locate on the map.

The Chiang Khong - Tak volcanic belt comprises basalt/andesite, dacite and rhyolite, with their pyroclastic equivalents that are more voluminous relative to those of the other volcanic belts. They have been erupted in two episodes on the basis of stratigraphic correlation, i.e. the Permo-Triassic and the younger, highly possible to be the Late Triassic-Early Jurassic (Jungyusuk and Khositanont, 1992). Prior to the year 2000, the Permo–Triassic volcanic rocks were commonly assumed to be the products of subduction-related volcanism. The assumption was well supported by recent informative geochemical data for volcanic rocks. The felsic to mafic volcanic rocks along the western edge of Mae Moh Basin and the northern end of Chiang Khong - Tak volcanic belt are interpreted to be continental and calc-alkalic, and have U-Pb zircon ages of 240 ± 1 (Middle Triassic)(Barr *et al.*, 2000) and 232.9 ± 0.4 Ma (Middle Triassic)(Barr *et al.*, 2006), respectively. Panjasawatwong *et al.* (2003) have carried out geochemical studies of mafic volcanic rocks along the northern end of Chiang Khong - Tak volcanic belt and reached similar conclusions to Barr *et al.* (2000, 2006) but for the tholeiitic series of mafic volcanic rocks. In addition, Khositanont (pers. comm., 2006) has determined a number of U-Pb zircon ages from the volcanic rocks in the Tak, Lampang and Phrae areas, parts of the Chiang Khong - Tak volcanic belt, and the results show that they have been erupted in a period of Early to Late Triassic.

The Nan - Chanthaburi suture zone is an extensive melange zone, characterized by variably sized blocks of igneous, metamorphic and sedimentary rocks embedded in the foliated serpentinite matrix. The pre-Jurassic volcanic rocks, as blocks in the northern part of the Nan - Chanthaburi suture zone, include Early to Middle Permian ocean-island basalt, Carboniferous (?) incipient backarc basin basalt and andesite, and oceanic island-arc basalt and andesite (Panjasawatwong, 1991; Crawford and Panjasawatwong, 1996). These volcanic rocks are less predominant relative to the associated pre-Carboniferous arc-related mafic and ultramafic rocks. Singharajwarapan *et al.*, (2000) have also reported that the coherent volcanic rocks, located immediately east of the Nan-Chanthaburi suture zone in northern Thailand, are oceanic island-arc basalt. In the Sra Kaew - Chanthaburi area (the Eastern Gulf of

Thailand), the southern part of Nan - Chanthaburi suture zone, the mafic volcanic blocks are ocean-island basalt and mid-ocean ridge basalt (Yoshikura, 1990). The Nan - Chanthaburi suture zone has long been considered to represent the paleotethys ocean between Shan-Thai and Indochina cratons (Bunopas, 1981, Panjasawatwong, 1991; Chaodumrong, 1992; Singhrajwarapan, 1994 and Hada *et al.*, 1999). However, a number of geologists reported that the northern part of Nan - Chanthaburi suture zone represent a back-arc basin, which opened in the Carboniferous, rather than the major ocean basin (Barr and Macdonald, 1987; Fontaine *et al.*, 2002; Metcalfe, 2002).

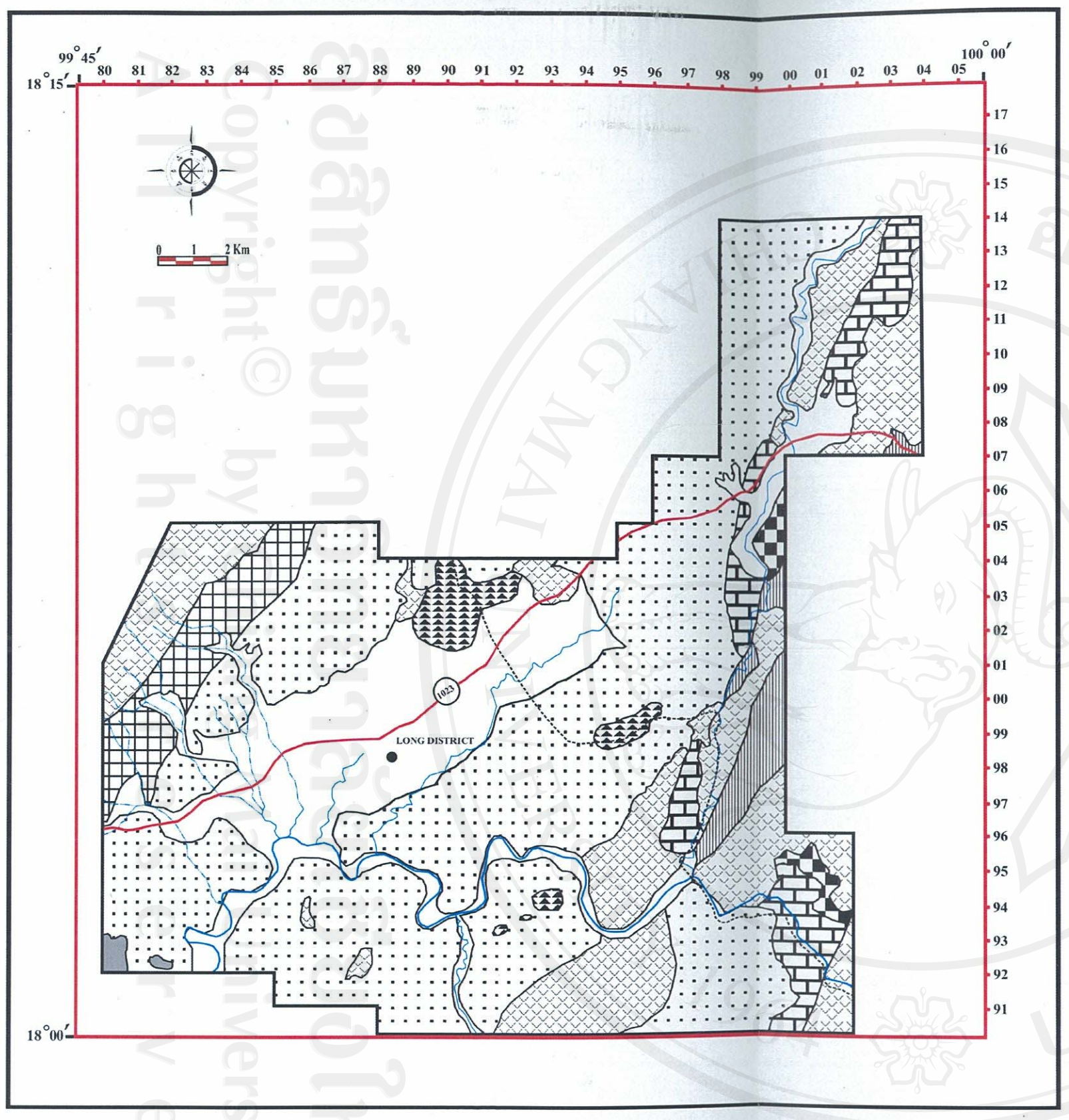
The Loei - Phetchabun - Nakhon Nayok volcanic belt is composed of acid to basic lavas, and pyroclastic rocks compositionally equivalent to the lavas. In the Loei area, these volcanic rocks may be further separated into eastern, central and western subbelts. The volcanic rocks of eastern subbelt are mainly rhyolitic, whereas those of western subbelt are largely andesitic (Jungyusuk and Khositanont, 1992). Both have been interpreted to be the products of arc volcanism that took place in the Permo – Triassic (e.g. Bunopas, 1981). The arc-related rhyolitic samples of eastern subbelt, however, yielded a whole-rock Rb-Sr isochron age of 374 ± 33 Ma (Late Devonian)(Intasopa, 1993; Intasopa and Dunn, 1994). The central subbelt is composed mainly of pillow lava, hyaloclastite and pillow breccia. These mafic volcanic rocks have been assigned to be those erupted in mid-oceanic ridge environment and have a whole-rock Rb-Sr isochron age of 361 ± 11 Ma (Late Devonian)(Intasopa and Dunn, 1994). In addition, Panjasawatwong *et al.* (2006) have reported that the mid-ocean ridge basalt exists along with oceanic island-arc mafic lava in the central subbelt. The arc lavas might have been built on an oceanic basement in a major ocean basin or in a mature back-arc basin. The volcanic rocks of western subbelt in the Phetchabun area have an intercept ^{40}Ar-^{39}Ar age of 237 ± 12 Ma (Middle Triassic) and a plateau age of 238 ± 4 Ma (Middle Triassic)(Intasopa, 1993; Kamvong *et al.*, 2006), and have been interpreted as the results of volcanism along an active continental margin. The volcanic rocks in the Nakhon Nayok area, a southern part of the western subbelt, are also geochemically arc-related magma (Kosuwan, 2004).

1.2 SCOPE OF STUDY

The Upper Triassic - Lower Jurassic volcanic rocks presented in this thesis are from the Long District area, Phrae Province (Fig. 1.2). They are part of the previously discussed Chiang Khong - Tak volcanic belt. The specific task of this study is to carry out petrochemical studies of the least-altered, Upper Triassic - Lower Jurassic, mafic volcanic rocks to achieve the tectonic setting of eruption. This research work includes sample collection and sample selection to obtain least-altered volcanic samples. The least-altered samples are then petrographically and geochemically studied, and followed by geochemical interpretation relevant to tectonic setting of eruption. Chemical analyses for each carefully selected sample cover major oxides and a range of trance elements. The representatives of the studied samples are carried out rare-earth-element analyses. To avoid ambiguous interpretation, concentration focuses on the relatively least-mobile elements and their ratio.

1.3 LOCATION AND ACCESSIBILITY

The Long District, Phrae Province, Thailand appears in the topographic map of Royal Thai Survey Department (1996) at a scale of 1: 50,000, series L7017, sheet 4945 II (Amphoe Long), approximately between latitudes 18°00' N and 18°15' N, and longitudes 99°45' E and 100°00' E (Fig. 1.3). The journey to the Long District can be conveniently made by a car via two routes (Fig. 1.4). One is the route from Muang Lampang District, Lampang Province to Mae Khaem Village via Highway Number 11 (Lampang-Denchai), about 45 kilometers distant, and then turning left to National Road Number 1023 (Wang Chin – Long), about 15 kilometers distant. The other one is the route from Muang Phrae District, Phrae Province via National Road Number 1023 (Phrae – Long), about 45 kilometers distant.



CORRELATION OF MAP UNIT

PLUTONIC ROCKS

UPPER TRIASSIC

SEDIMENTARY AND VOLCANIC ROCKS

QUATERNARY

TERTIARY

UPPER TRIASSIC- LOWER JURASSIC

TRIASSIC

TRIASSIC

TRIASSIC

TRIASSIC

PERMIAN

SYMBOLS

Stream

National Road

Railway

LEGENDS

Unconsolidated sediments

Basalt

Volcaniclastic rocks with rhyolitic, dacitic, andesitic and basaltic compositions, and minor chemically equivalent lava flows

Gray, shale and calcareous shale, with sandstone interbeds

Dark gray, micaceous shale, gray siltstone and greenish gray sandstone in the upper part; purplish tuffaceous sandstone with local shale intercalation in the middle part, and conglomerate with local dark gray shale and gray sandstone intercalation in the lower part

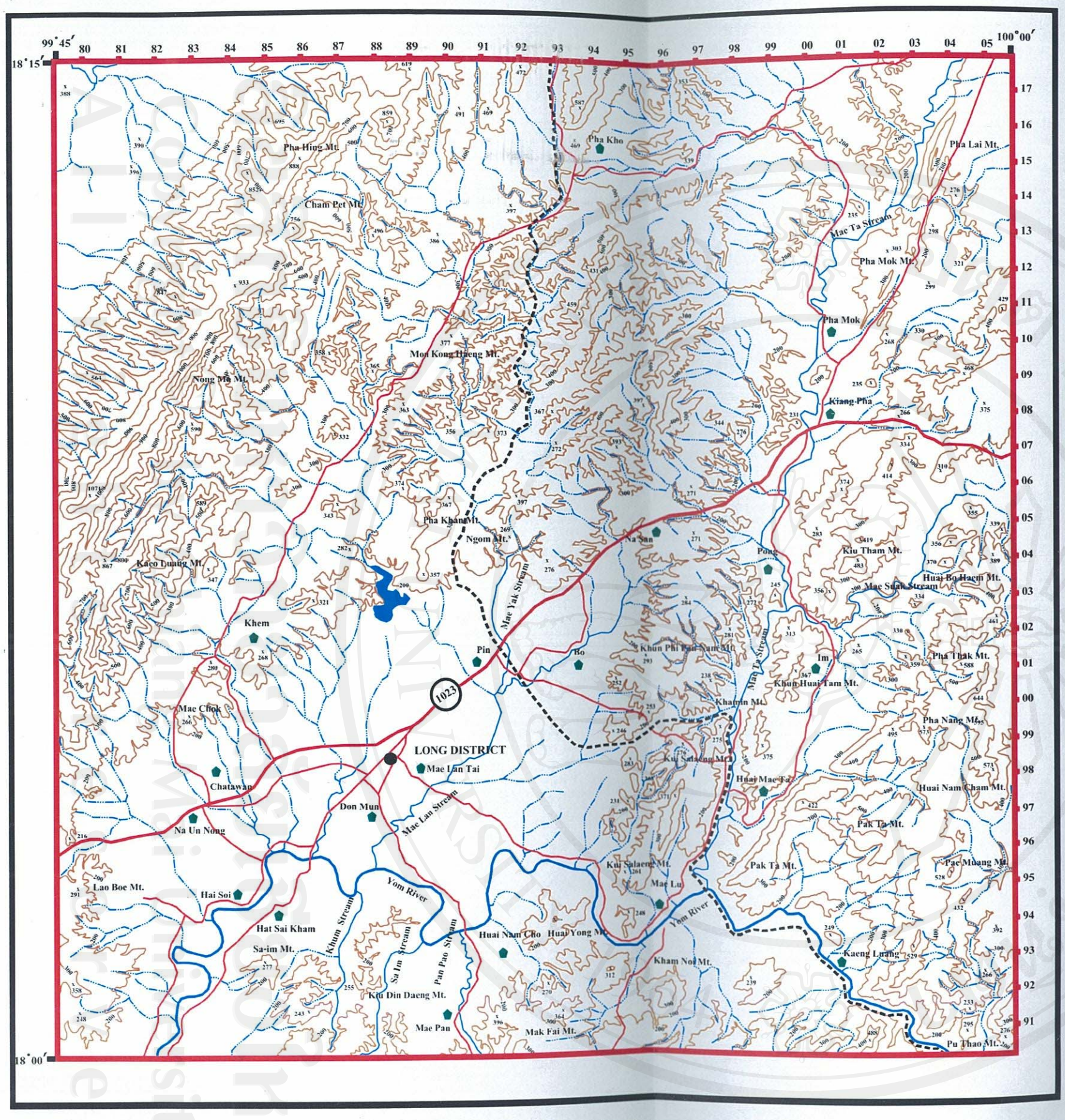
Dark gray limestone, with dark gray to grayish green shale and light gray sandstone interbeds

Reddish purple sandstone and shale interbeds

Gray to dark gray limestone, with minor dark gray shale, greenish gray sandstone and red paraconglomerate interbeds

Granodiorite and diorite

Figure 1.2 Geological map of the Long District area (modified from Chaiyasan *et al.*,2003; Chumpukawin *et al.*, 2003; Nondedgoon *et al.*,2003; Janejitpaiboon *et al.*, 2003; Yodthon *et al.,* 2003; Chantaragumthorn *et al.*,2003; Mansawatapaiboon *et al.*, 2003; Wanagoon *et al.*,2003; and Chankaew *et al.*, 2003).



SYMBOLS

- Stream
- Creek
- National road (1023)
- Paved provincial road
- X 729 — Spot elevation in meters
- Contour
- Village
- Mt. — Mountain
- Railway

Contour Interval 100 meters

0 2 4 Km

Figure 1.3 Topographic map of the Long District area

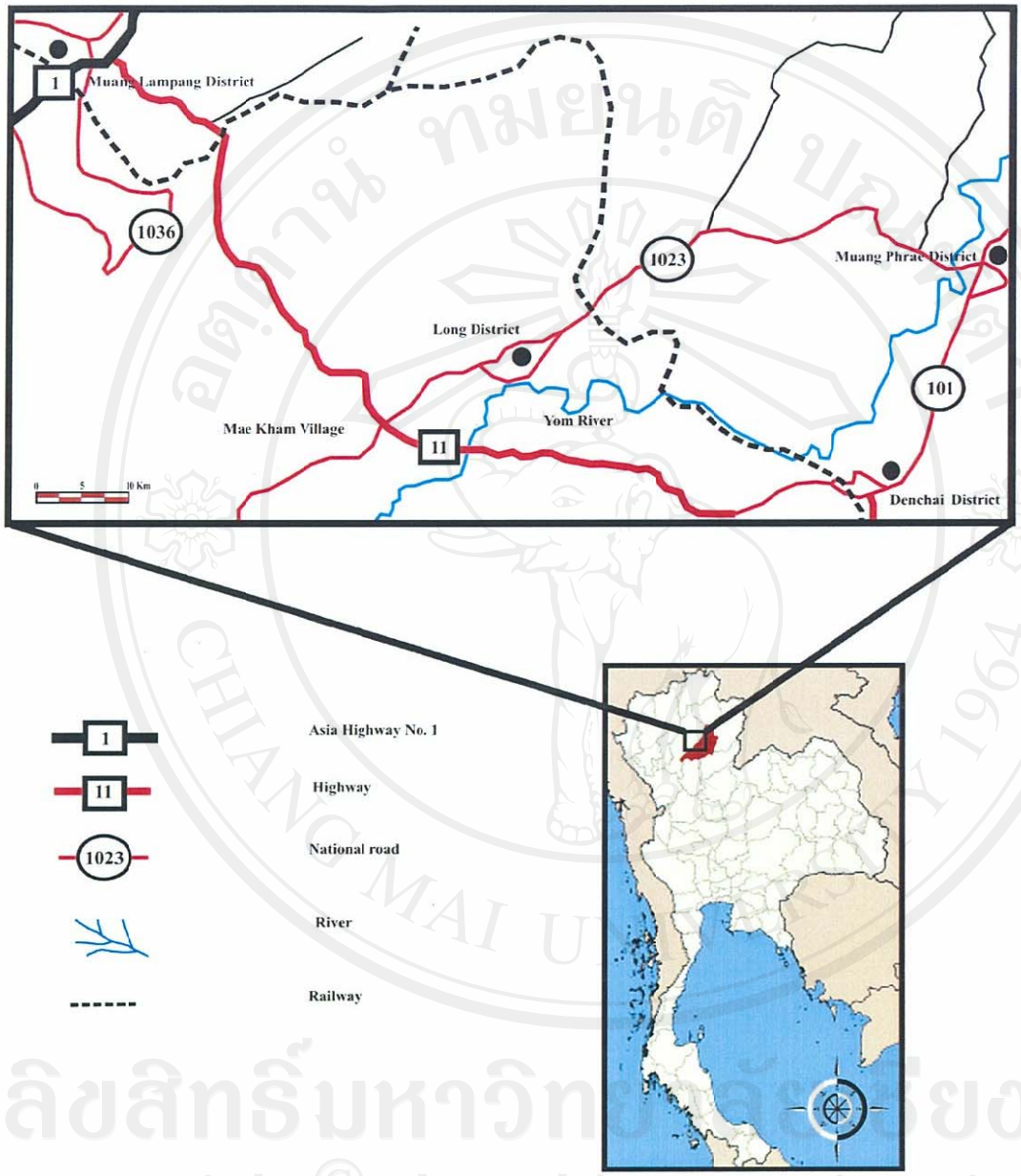


Figure 1.4 Road map of the Long District area.

1.4 PHYSIOGRAPHIC DESCRIPTION

The Long District area is located in the valley of Yom River, irregular east-west trending, and consists of high mountain ranges (Fig. 1.3). The high mountains include Nong Ma, Kaeo Luang, and Cham Pet in the northwestern part. They form northeast-southwest trending ridge and are about 1000 meters high above mean sea level. Limestone mountains, including Pha Lai, Pha Mok, and Kaeng Luang, are present in the eastern part. Many streams and creeks in the study area, such as the Mae Ta, the Mae Lan, the Pan Pao, the Mae Suak, and the Khum, have dendritic patterns. They run parallel/subparallel to the mountain ranges. Most of these rivers flow into the Mae Ta stream that finally joins the Yom River. The area is a mixed deciduous forest with a lot of small softwoods and bamboos.