

CHAPTER 1

INTRODUCTION

1.1 Late Cenozoic Basalts in Thailand

The Late Cenozoic basalts in Thailand occur as scattered small plugs, vents and flows that are totally distributed in the Northern and Upper Western Highlands, the Khorat Plateau, the Eastern Region, and the Loei-Phetchabun Ranges (Figure 1.1). Their local distribution is commonly controlled by topographic and structural grains of the areas. The Late Cenozoic basalts in the Northern Highland commonly occur along Chiang Khong-Tak volcanic belt, particularly in Phrae Province (Denchai basalt and Long basalt), Lampang Province (Mae Tha basalt, Sob Prap basalt and Nam Cho basalt), and Chiang Rai Province (Chiang Khong basalt and Thoeng basalt). Mae Ngao basalt (Mae Lama basalt) in Tha Song Yang District, Tak Province, and Bo Phloi basalt in Bo Phloi District, Kanchanaburi Province; and Ngom Tham basalt along the Nan-Uttaradit suture zone, Uttaradit Province have also been reported in the Upper Western Highland and Northern Highland, respectively. In the Loei-Phetchabun Ranges, the Late Cenozoic basalts are locally distributed in Lamnarai District, Lopburi Province (Lamnarai basalt) and Wichian Buri District, Phetchabun Province (Wichian Buri basalt). The Late Cenozoic basalts in the Eastern Region and the Khorat Plateau are those in the Chanthaburi-Trat area (Tha Mai basalt, Pong Nam Ron basalt, Saphan Hin basalt, Nong Bon basalt, Bo Rai Basalt, Sae O basalt, and Ko Kut basalt) and those in the areas lying along the southern margin of the Khorat Plateau, consisting of basaltic rocks from Nakhon Ratchasima Province (Nakhon Ratchasima basalt), Buriram Province (Khao Kradong basalt, Khao Phanom Rung basalt, Phu Phra Angkhan basalt, and Khao Prai Bat basalt), Surin Province (Surin basalt/Khao Phanom Sawai basalt), Sisaket Province (Phu Fai diabase, Phu Ngoen basalt, Phu Kom basalt and Phu Khmint basalt) and Ubon Ratchathani Province (Nong Nam Khun basalt and Nam Yun basalt).

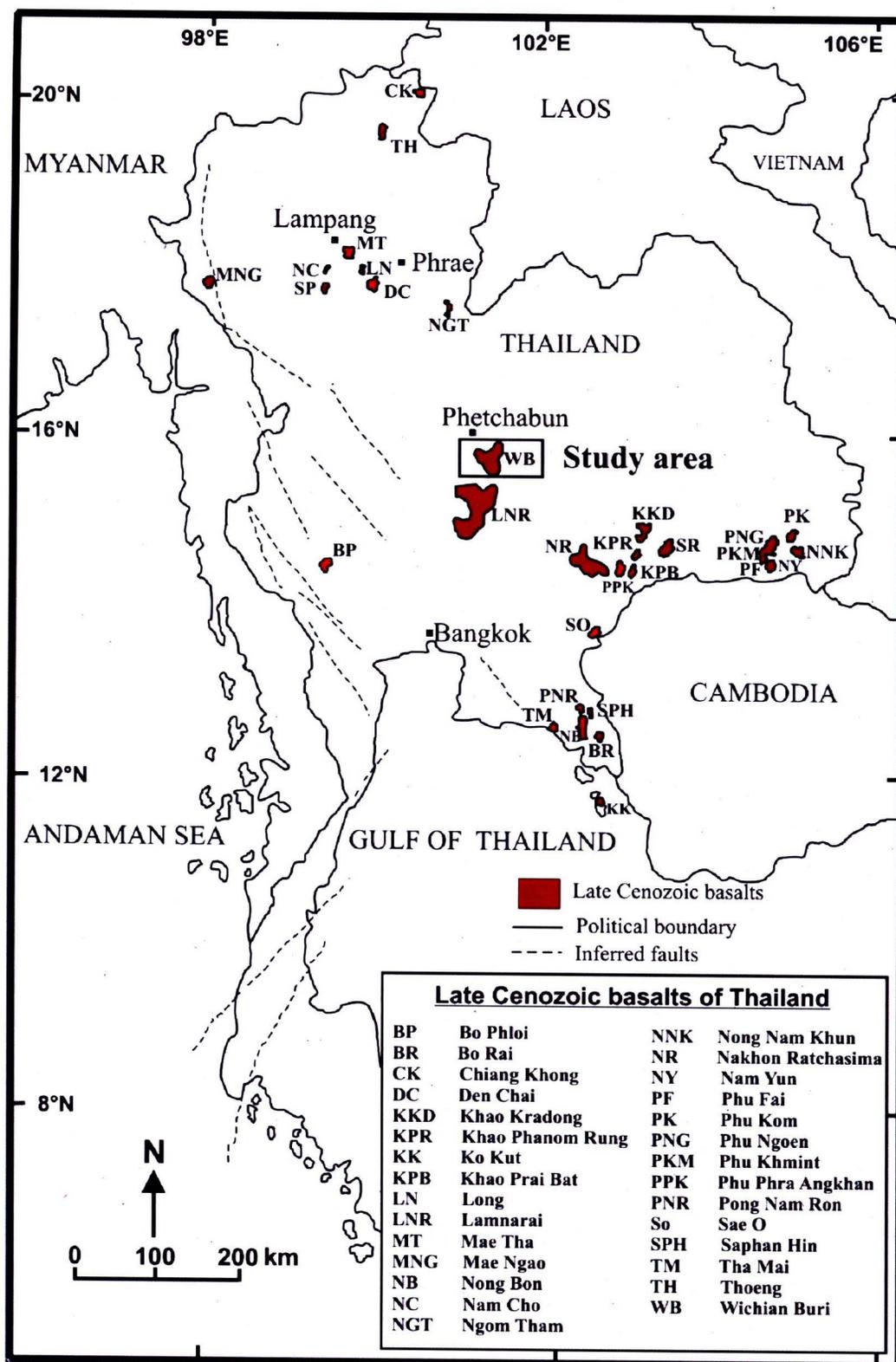


Figure 1.1 Map showing the location of study area and the distribution of Late Cenozoic basalts in Thailand (after Limtrakun *et al.*, 2005).

The petrochemical studies of the Late Cenozoic basalts in Thailand were first published by Barr and MacDonald, 1978 and Vichit *et al.*, 1978). Following the pioneer works, more detailed studies have been done on the Denchai basalt (Barr and Macdonald, 1979; Limtrakun, 2002), the Nong Bon Basalt (Sirinawin, 1981), the Bo Phloi basalt (Yaemniyom, 1982; Srithai, 2005), the Mae Tha basalt (Yamamoto, 1991; Boonsoong, 1997), the Phu Fai diabase (Barr and Macdonald, 1981; Sutthirat, 1992; Sutthirat *et al.*, 1995b), the Lamnarai basalt and the Wichian Buri basalt (Intasopa, 1993), the Ngom Tham basalt (Panjasawatwong and Yaowanoyothin, 1993), the Nam Cho basalt and the Sop Prap basalt (Sutthirat, 1995), the Surin basalt/Khao Phanom Sawai basalt (Panjasawatwong, 1995), the Khao Kradong basalt (Charusiri *et al.*, 1995; Charusiri *et al.*, 2004), the Chiang Khong basalt (Panjasawatwong and Youngsanong, 1996), the Thoeng basalt (Sriprasert, 1997), the Long basalt (Limtrakun *et al.*, 2005) and the Mae Ngao basalt (Limtrakun *et al.*, 2007).

The available petrochemical data show that the Cenozoic basalts in Thailand are predominantly alkalic, except for the Thoeng basalt and the lowermost flow of the Denchai basalt, which are transitional tholeiites (Barr and Macdonald, 1978, 1979, 1981; Charusiri *et al.*, 1995; Panjasawatwong, 1995; Yamamoto, 1991; Sriprasert, 1997). The alkalic basalts are mainly of mildly alkalic series, with subordinate basanitic series and minor nephelinitic series.

In the northern Highland, the Nam Cho basalt is mainly basanite (Sutthirat *et al.*, 1994 and Sutthirat *et al.*, 1995a), while the Sop Prap basalt is mildly alkalic, comprising hawaiiite (Vichit *et al.*, 1978; Barr and Macdonald, 1978, 1981) and alkali-olivine basalt (Sutthirat, 1994). The Mae Tha basalt was designated to basanitic series by Barr and Macdonald (1978), but transitional basalt from trachybasaltic to basanitic series, constituted largely by basanite, basaltic trachyandesite and trachybasalt, with very few phonotephrite (Boonsoong, 1997). The Denchai basalt consists of seven flows. The lowermost flow (flow 1) is transitional tholeiite as previously mentioned. Flows 2 to 4 and 5 to 6 are of mildly alkalic series, consisting of transitional hawaiiite and hawaiiite, respectively, while the uppermost flow (flow 7)

is basanite (Vichit *et al.*, 1978; Barr and Macdonald, 1979, 1981). Limtrakun (2002), however, reported that the Denchai basalt is all alkalic in character, compositionally varying from basanite, basalt, basaltic trachyandesite to trachybasalt. The Long basalt is a mildly alkalic rock, comprising trachybasalt, basalt and basaltic trachyandesite (Limtrakun *et al.*, 2005). The Chiang Khong basalt is made up of two basanite flows (Panjasawatwong and Youngsanong, 1996). The Ngom Tham basalts are evolved mildly alkalic rocks, consisting of hawaiite, mugearite, and benmoreite (Panjasawatwong and Yaowanoyothin, 1993). The Thoeng basalt is compositionally transitional tholeiitic, and includes abundant basalt in restricted sense, with subordinate basaltic andesite and a few trachybasalt (Sriprasert, 1997)

Two occurrences of the Late Cenozoic basalt (Mae Ngao basalt and Bo Phloi basalt) have been known in the Upper Western Highland. The Mae Ngao basalt was formerly reported to be tholeiite by Barr and Macdonald (1978, 1981). Recently, Limtrakun *et al.* (2007) have performed more detailed study and reported that the Mae Ngao basalts are, in fact, mildly alkalic rocks, comprising trachybasalt, basaltic trachyandesite and basalt. The Bo Phloi basalt is of basanitic series that has been reported as basanite by Vichit *et al.* (1978), and nepheline hawaiite by Barr and Macdonald (1981) and Yaemniyom (1982). It contains ultramafic xenoliths that are unlikely to be co-genetic (Srithai, 2005).

The Cenozoic basalts along the southern margin of the Khorat Plateau are almost all mildly alkalic basalt, except for the Phu Fai diabase. The Nakhon Ratchasima basalt, Burirum basalt (Khao Phanom Rung basalt and Phu Phra Angkhan basalt), Sisaket basalt (Phu Ngoen basalt, Phu Kom basalt and Phu Khmint basalt) and Nam Yun basalt are hawaiite (Barr and Macdonald, 1978; Barr and Macdonald, 1981; Jungyusuk and Sirinawin, 1983; Jungyusuk and Khositanont, 1992). The Khao Kradong basalt is hawaiite to alkali olivine basalt (Charusiri *et al.*, 2004), whereas the Khao Phanom Sawai basalt is mugearite (Barr and Macdonald, 1978; Panjasawatwong, 1995). The Phu Fai diabase is chemically classified as nepheline mugearite (strongly alkalic series) by Barr and Macdonald (1981), but as hawaiite (mildly alkalic rock) by Sutthirat (1992).

The alkalic lavas in the Chanthaburi-Trat area (Eastern Region) are underlain by Permo-Carboniferous sediments (Sutthirat *et al.*, 2001). The alkalic lavas include nephelinitic series, basanitic series and mildly alkalic rocks (Vichit *et al.*, 1978; Barr and Macdonald, 1978, 1981; Sirinawin, 1981). The Tha Mai basalt and the Pong Nam Ron basalt are classified as nepheline hawaiiite and basanite of basanitic series (Barr and Macdonald, 1978, 1981). The Saphan Hin basalt comprises alkali olivine basalt and hawaiiite of mildly alkalic series (Vichit *et al.*, 1978; Sirinawin, 1981), while the Nong Bon basalt and the Bo Rai basalt are nephelinite and olivine nephelinite of nephelinitic series (Barr and Macdonald, 1978, 1981; Vichit *et al.*, 1978; Sirinawin, 1981).

The Late Cenozoic basalts in Thailand have whole rock radiometric ages ranging from 24 Ma to less than 0.5 Ma (Sutthirat *et al.*, 1994; Sutthirat, 1995; Sutthirat *et al.*, 1995a; Boonsoong, 1997; Chualaowanich *et al.*, 2008) as summarized in Table 1.1. They might have been erupted in a continental rift environment and related to fracture opening operated in the Gulf of Thailand and the South China Sea as the result of an interaction between Indian and Eurasian plates (e.g. Jungyusuk and Kositanont, 1992; Smith, 1996).

1.2 Wichian Buri Basalt

The Wichian Buri basalt located in the Loei – Phetchabun volcanic belt (Intasopa, 1993) and covers an area of approximately 300 km² in Wichian Buri District, Phetchabun Province. The generation of Wichian Buri basalt has been closely related to the development of Late Oligocene Wichian Buri basin as the result of simple shear tectonics associated with right lateral movement on the NW – SE trending Mae Ping fault and three Pagoda fault, and left lateral movement along NNE – SSW trending conjugate strike-slip faults (Polachan and Sattayarak, 1989). The Wichian Buri basin is a graben/half-graben infilled with alluvial and fluvial sediments of Late Oligocene to Holocene ages and has Permo-Triassic meta-sedimentary and volcanic rocks as the basement (Remus *et al.*, 1993). Volcanic rocks, diorite and gabbro are present throughout the late Oligocene to Holocene stratigraphic sequence.

Table 1.1 Absolute ages of the Late Cenozoic basalts in Thailand (after and modified from Boonsoong, 1997).

Localities	Age (Million Years)	Method of Determination	Reference
Ban Chang Khian, Chiang Rai (Thoeng basalt)	1.69 ±1.25	K-Ar	Barr and Macdonald (1981)
Chiang Khong, Chiang Rai (Chiang Khong basalt)	1.749 ±0.18	K-Ar	Barr and Macdonald (1981)
Mae Tha, Lampang (Mae Tha basalt)	0.80 ±0.30	K-Ar	Sasada <i>et al.</i> (1987)
	0.60 ±0.20	K-Ar	Sasada <i>et al.</i> (1987)
	0.50 ±0.05	K-Ar	Sutthirat <i>et al.</i> (1994)
	0.69 ±0.95	Paleomagnetic	Barr <i>et al.</i> (1976)
Sop Prab, Lampang (Sop Prab basalt)	2.30±0.13	Ar-Ar	Sutthirat (1995)
	2.36±0.31	Ar-Ar	Sutthirat <i>et al.</i> (1995a)
			Sutthirat (1995)
	2.38±0.17	Ar-Ar	Sutthirat <i>et al.</i> (1995a)
	2.41±0.17	Ar-Ar	Sutthirat (1995)
Sop Prab, Lampang (Nam Cho basalt)	2.02±0.10	Ar-Ar	Sutthirat (1995)
			Sutthirat <i>et al.</i> (1995a)
Denchai, Phrae (Denchai basalt)	5.64±0.28	K-Ar	Barr and Macdonald (1981)
Bo Phloi, Kanchanaburi (Bo Phloi basalt)	3.14±0.17	K-Ar	Barr and Macdonald (1981)
	4.17±0.11	Ar-Ar	Sutthirat <i>et al.</i> (1994)
Lamnarai, Lopburi (Lamnarai basalt)	11.29±0.64	K-Ar	Barr and Macdonald (1981)
	18.10±0.70	Ar-Ar	Intasopa (1993)
	24.10±1.00	Ar-Ar	Intasopa (1993)
Wichian Buri, Phetchabun (Wichian Buri basalt)	9.7-11.6	Ar-Ar	Charusiri (1989)
	9.08±0.29	Ar-Ar	Intasopa (1993)
	8.82±0.09	Ar-Ar	Sutthirat <i>et al.</i> (1994)
	11.03±0.03	Ar-Ar	Sutthirat <i>et al.</i> (1995a)
	9.84±0.06	Ar-Ar	Chualaowanich <i>et al.</i> (2008)
Khao Kradong, Buriram (Khao Kradong basalt)	0.92±0.30	K-Ar	Barr and Macdonald (1981)
	0.43±0.02	Ar-Ar	Chualaowanich <i>et al.</i> (2008)
	0.32±0.01		
Phu Fai, Sisaket (Phu Fai basalt)	3.28±0.48	K-Ar	Barr and Macdonald (1981)
East of Chanthaburi (Tha Mai basalt)	2.57±0.20	Fission track	Carbonnel <i>et al.</i> (1972)
Khao Phloi Waen, Chantaburi (Tha Mai basalt)	0.44±0.11	K-Ar	Barr and Macdonald (1981)
Ban Ta Bat, Trat	1.13±0.17	K-Ar	Barr and Macdonald (1981)
Ko Kut, Trat (Ko Kut basalt)	8.50±1.00	K-Ar	Bignell and Snelling (1977)

Webster *et al.* (1990) evaluated lithostratigraphic and biostratigraphic data from core samples and concluded that igneous rocks in the Wichian Buri basin can be divided in 2 groups, i.e. those emitted lower gamma radiation and those emitted higher gamma radiation. The rocks emitted lower gamma radiation are mafic intrusives and tuff, composed mainly of plagioclase, pyroxene and hornblende, whereas the rocks emitted higher gamma radiation are intrusive rocks, composed significantly of K-feldspar and biotite. The mafic volcanic mass is underlain by Permian and Tertiary strata (Wongwitayayont, 1981; Jungyusuk and Sinsakul, 1989), and has K/Ar ages of 15.6 – 16.1 Ma (Webster *et al.*, 1990) and 15 Ma (Remus *et al.*, 1993). and an $^{40}\text{Ar}/^{39}\text{Ar}$ age of 9.1 ± 0.3 Ma (Intasopa, 1993), 8.82 ± 0.09 Ma (Sutthirat *et al.*, 1994), 11.03 ± 0.03 Ma (Sutthirat *et al.*, 1995a) and 9.84 ± 0.06 Ma (Chualaowanich *et al.*, 2008).

The Wichian Buri basalt is constituted by at least two lava flows (Vichit *et al.*, 1988). Two volcanic facies have been recognized, i.e. coherent facies and incoherent facies, particularly in the Ban Sap Sawat area. The coherent basalt flows are fine-grained and commonly columnar jointed, and have dark gray, grayish black and black colors. They are partly vesicular, with amygdale quartz, chalcedony, zeolites and calcite, and have been intruded by mafic hypabyssal rocks at many locations (Vichit *et al.*, 1988; Sutthirat *et al.*, 1994). These coherent facies basalts may contain lherzolite and other ultramafic nodules, spinel megacrysts, xenoliths of gneiss and gabbro, and gem-bearing quality corundum. All the Wichian Buri basalts are chemically alkalic (Barr and MacDonald, 1978; Jungyusuk and Sirinawin, 1983; Vichit *et al.*, 1988; Jungyusuk and Khositanont, 1992; Intasopa, 1993). The incoherent facies rocks are basalt breccia, which shows poorly sorted fabric, angular to rounded mafic volcanic fragments, and fine-grained, glassy matrix.

In the Ban Sap Sawat area, basalt breccia commonly occurs as in situ float along with coherent facies basalt in a flat plain, however, it is not associated with coherent facies basalt at higher elevations. The coexisting of basalt breccia and coherent facies basalt in the low-land area is well-supported by the core samples from five drill holes of the Mineral Resources Exploration and Evaluation Project: 5/2547

(Chon Daen Area), no. 25/2547, carried out by O.P. Exploration and Drilling Ltd. (Department of Mineral Resources, 2005).

1.3 Purposes of Study

As earlier mentioned, the low-land area of Ban Sap Sawat is underlain by coherent facies basalt and basalt breccia. So far, there is no positive evidence to elucidate the formation of breccia, and therefore the project on “the origin of basalt breccia” has been established in the Ban Sap Sawat area. The main purposes of this study are to characterize coherent facies basalt and basalt breccia either from outcrops or from drill holes, in terms of lithology, petrography and whole-rock chemistry (major oxides, trace elements and rare-earth elements), and to performed logging and facies analysis of available core samples. These informative data are integrated to ascertain the origin of basalt breccia.

1.4 Study Location and Accessibility

The study area, Ban Sap Sawat, is located about 20 km north of Wichian Buri District, and 20 km southeastern of Nong Phai District, Phetchabun Province (Figure 1.2). It appears on the geological map sheet NE47-17 (Ban Mi) at a scale of 1:250,000, and on two 1:50,000 topographic maps: sheets 5240 IV (Amphoe Nong Phai) and 5240 III (Amphoe Wichian Buri) and cover an area of approximately 45 km² (Figure 1.3).

Accessibility to the study area can be done via many convenient routes. From Bangkok, the journey can be most comfortably done using the paved national highway no. 2 to Sara Buri Province, then following the paved national highway no. 21 (Lopburi-Lamnarai-Wichian Buri), turning right at Ban Ra Hul to the paved provincial highway no. 225 (Nakhon Sawan-Chaiyapum), and turning right again at Ban Sap Bon to the provincial highway no. 2275. The access to the project area is made by travelling from Ban Sap Bon about 5 km along the provincial highway no. 2275 and then turn right to Ban Sap Sawat.

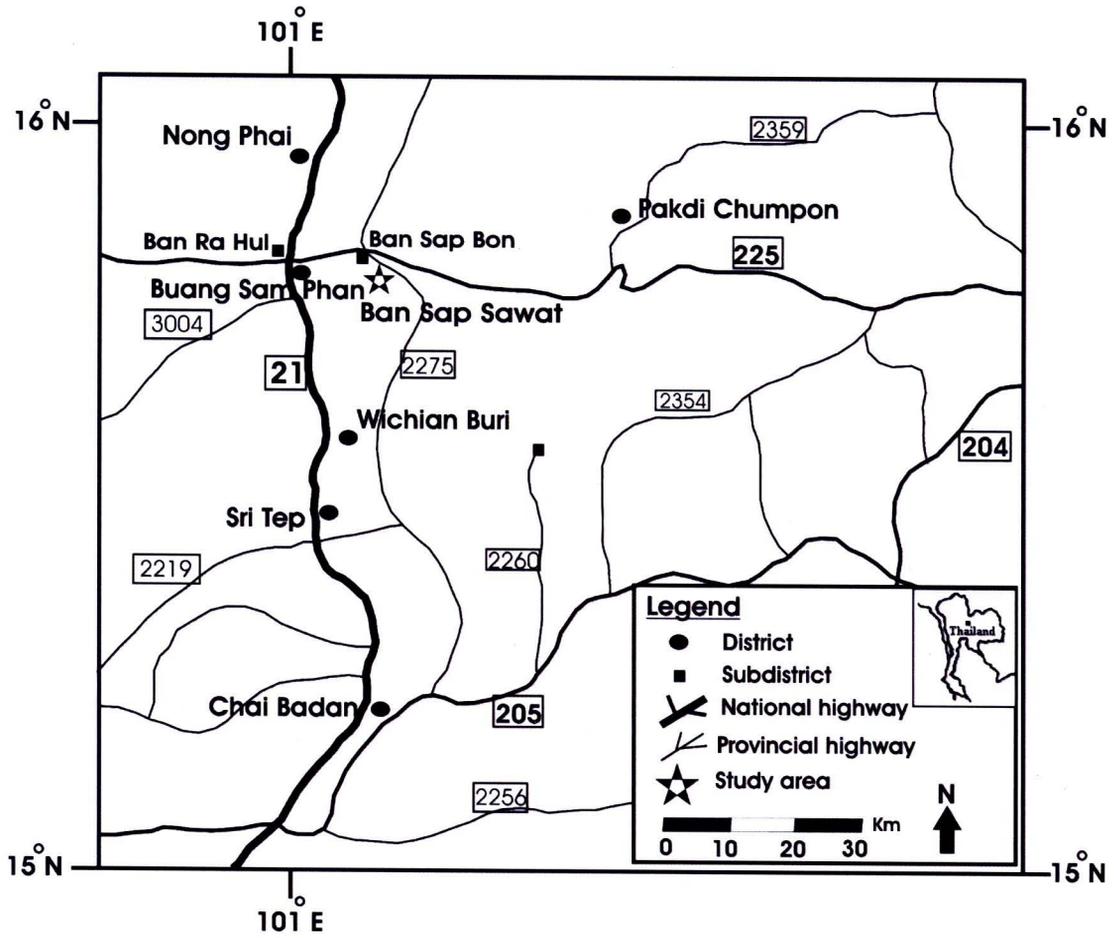


Figure 1.2 Map showing the location of study area, and paved national and provincial highways (modified from Roads Association of Thailand, 2004).

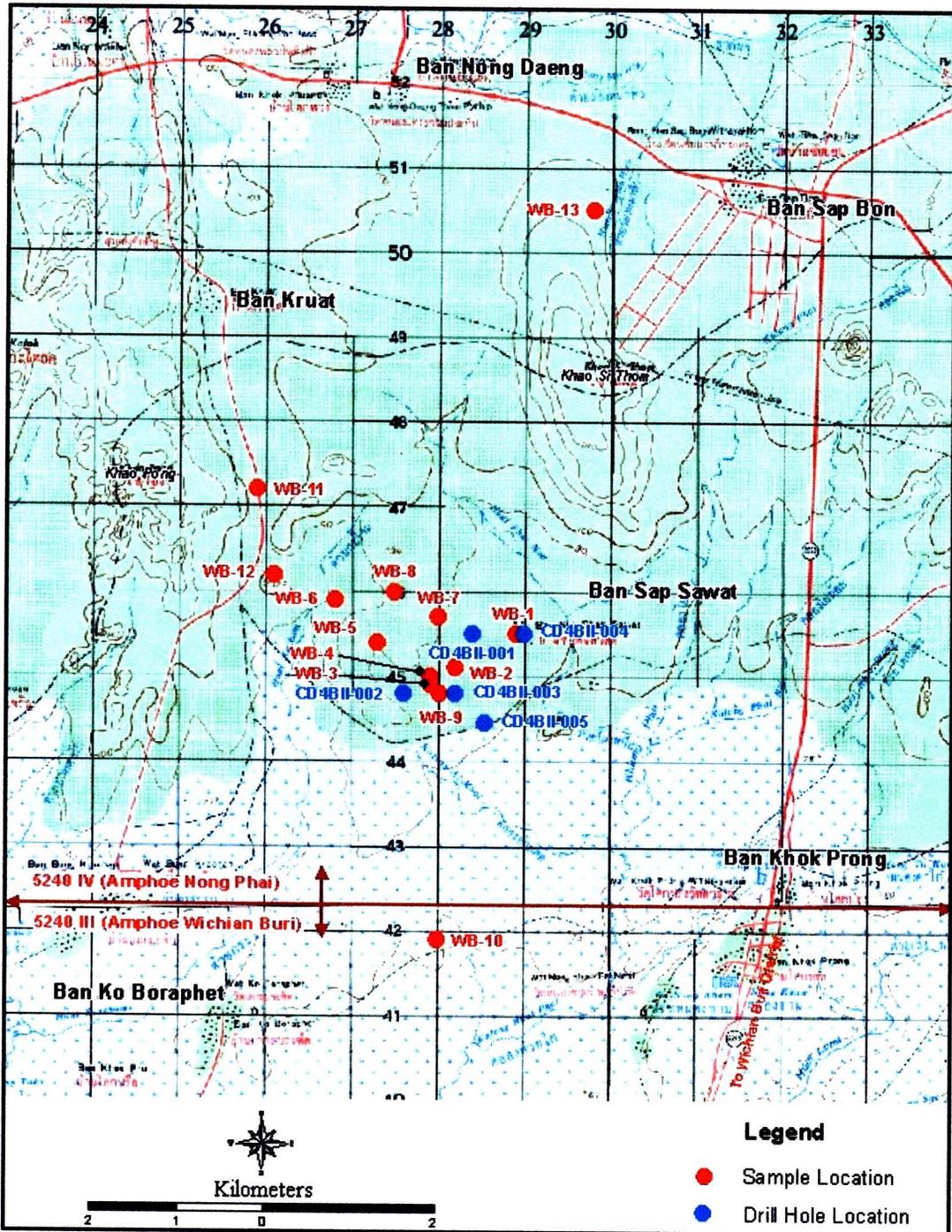


Figure 1.3 Topographic map showing the study area (Ban Sap Sawat) and the locations of collected samples (red circles) and drill holes (blue circles)