CHAPTER II

GEOLOGY

In order to understand the origin of the formation of the Wichian Buri sub-basin, therefore, the discussion in this chapter will focus upon the physiography, geological setting, structure and geological history of not only the Wichian Buri sub-basin, but covering the Phetchabun Basin and neighboring area.

Physiography

The Phetchabun Basin, is located onshore in central Thailand and is one of a series of north-south trending basins identified in Thailand. The basin covers an area within the Loei Fold Belt at the western edge of the Khorat Plateau. Both eastern and western margins of the basin are generally sharp and fault controlled. Paleozoic carbonates and marine clastics and Mesozoic continental sediments crop out around and within the basin margin; the Teriary sequence deposited within the basin is largely covered by Quaternary alluvial sediments and Cenozoic basalts. The Phetchabun Basin is currently drained by the Mae Nam Pa Sak and its tributaries flowing from north to south.

The Phetchabun Basin (Figure 2.1) consists of several north-south trending half-garbens/ garbens as a result of transtensional shear tectonics associated with right lateral movement on the nortwest-southeast trending Mae Ping and Three Pagoda faults and left lateral movement along north / northeast - south / southwest trending conjugate strike-slip faults (Polachan and Sattayarak, 1989). Several conjugate strike

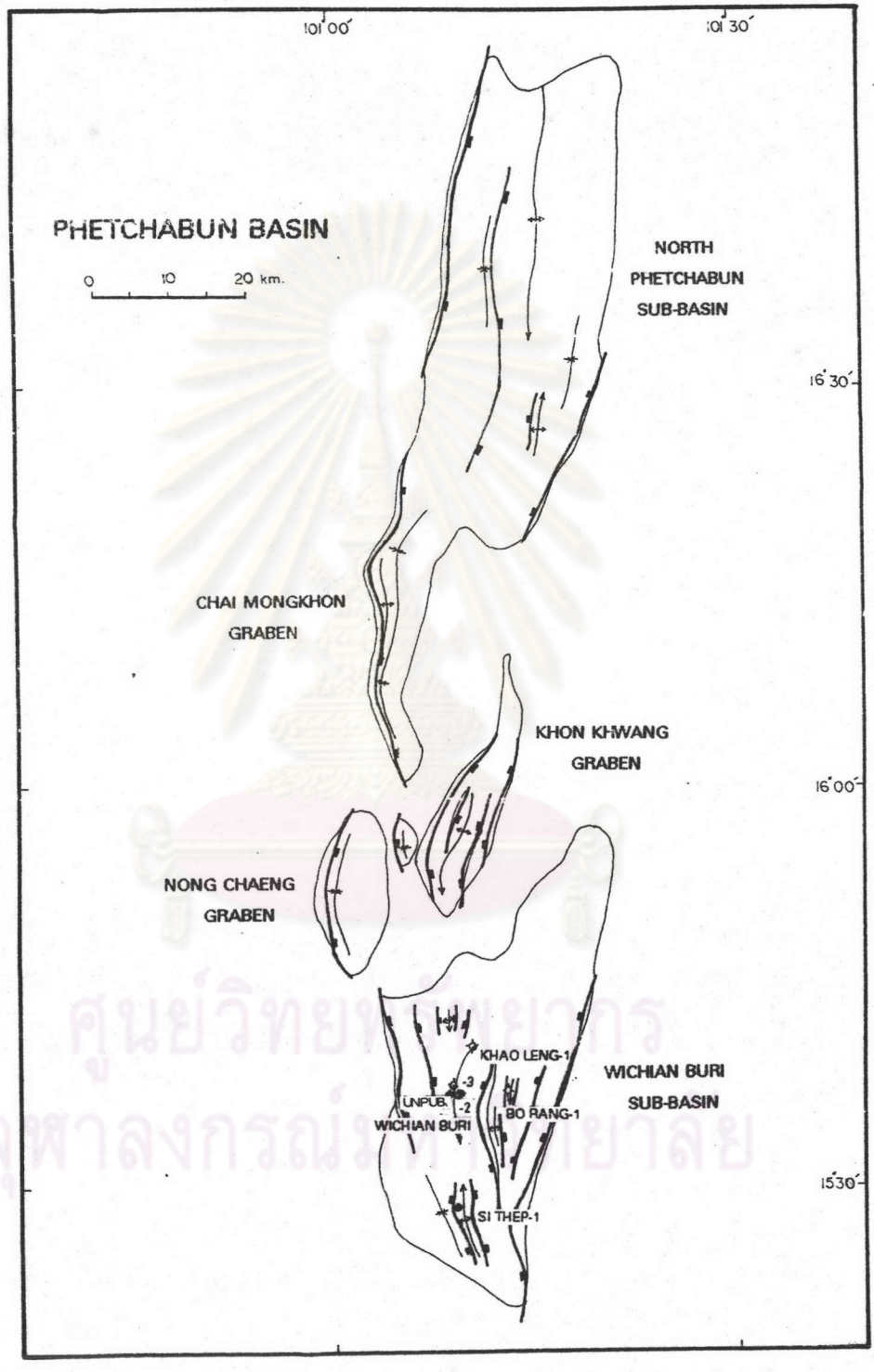

Figure 2.1 Map showing shape and internal structure of the Wichian Buri sub-basin and others in the Phetchabun Basin (after Remus et al., 1993).

-slip faults cut the basin and may have acted as the mechanism controlled the formation of individual half-garbens/garbens. These sub-basins vary in depth from 2,500 m. to 1,100 m. with the deepest being in the south and progressively shallowing northwards (Remus et al., 1993)

The Wichian Buri sub-basin, one of five garben of Phetchabun Basin is a N-S trending rift basin. It is bounded to the west and east by faults that divided the basin into 2 parts. Form the seismic data, its maximum sediment thickness is estimated at 2,500 metres.

There are 4 sub-basins to the north of the Wichian Buri sub-basin, namely, Nong Chaeng Garben, Khon Khwang Garben, Chai Mongkhon Garben and North Phetcabun sub-basin. They contain sediments about 1,500 - 1,000 m. thick. These garbens including the Wichian Buri sub-basin are blanketed by Quaternary alluvial deposits.

Geological Setting

The geological setting in the Phetchabun Basin and its vicinity was reviewed using available published reports and geological maps in order to fully understand the geological history and tectonic evolution of the area. They are listed as follow:

- Geological map of Amphoe Ban Mi, sheet ND 47-4, scale 1:25,000 (Nakornsri,1976)
- Geological map of Changwat Phetchabun, sheet ND47-16, scale 1:25,000 (Chonglakmani and Sattayarak, 1979)
- Geological map of Khao Phra, sheet 5140 I, scale 1 : 50,000 (Jungyusuk and Khositanont, 1984)
- Geological map of Amphoe Chon Daen, sheet 5141 II, scale 1 : 50,000 (Jungyusuk, 1985)

- Geological map of Ban Maha Pho and Amphoe Sri Thep, sheet 5139 I and 5239 I, scale :50,000 (Jungyusuk and Suriyachai, 1987)
- Geological map of Ban U-Sok, sheet 5140 II, scale 1:50,000 (Jungyusuk, 1988)
- Geological map of Ban Wang Pong and Changwat Phetchabun , sheet 5141 I and 5241 IV, scale 1:50,000 (Polprasit and Prasomtrap, 1988)
- Geological map of SW1 Concession, Thailand, scale 1:250,000 (Webster, 1988)
- Geological map of Ban Na Chaliang, Amphoe Nong Phai and Amphoe Wichian Buri, sheet 5241 III , 5240 IV and 5240 III, scale 1:50,000 (Jungyusuk and Sinsakul, 1989)

The geological map and stratigraphic correlation is included as Table 2.1 and Figure 2.2.

1. Paleozoic

1.1 Carboniferous

Dok Du Formation

Only two small isolated hills of the Dok Du Formation (Chonglakmani and Sattayarak, 1978) crop out in the northern part of King Amphoe Wang Pong. The formation consists predominantly of grey to black, massive to thick bedded limestones, interbedded with sandstones, siltstones, shales and chert beds. Most of these sediments were intruded by igneous rocks, producing marble and calc-silicates at contact.

The Dok Du Formation contains abundant fossils indicating Early to Middle Carboniferous in age. The depositional environment varies from subarial to shallow marine (continental shelf) and brackish water (Chonglakmani, 1983).

Table 2.1 Stratigraphic correlation of Phetchabun area (Modified from Chonglakmani and Sattayarak, 1979; Webster, 1988).

AGE		FORMATION		THICKNESS	GENERAL DESCRIPTION
QUATERNARY		UNNAMED		0-200m	Gravel, sand, silt and laterite
PLIOCENE-OLIGOCENE		UNDIFFERENTIATED TERTIARY		Maximum 3000m?	Claystone, siltstone, shale, mudstone, basalt
CRETACEOUS	UPPER	KHORAT GROUP	KHOK KRUAT	700m	Claystone, siltstone : red, brown, micaceous Sandstone : reddish brown
	LOWER-MIDDLE		PHU PHAN	80-200m	Sandstone : white, pale orange, conglomeratic Shale, conglomerate
JURASSIC	UPPER		SAO KHUA	400-700m	Siltstone, claystone : reddish brown Sandstone : greyish brown-reddish brown
	LOWER-MIDDLE		PHRA WIHAN	60-400m	Sandstone : white, pink, quartzose, cross-bedded Siltstone, shale : reddish brown, grey
	LOWER		PHU KRADUNG	300-1500m	Siltstone : purple, brown, micaceous Sandstone, shale : red, brown, purple, micaceous
TRIASSIC	UPPER		NAM PONG	410-1500m	Sandstone : pink, reddish grey-reddish brown, cross-bedded, conglomeratic Shale, siltstone : red
			HUAI HIN LAT	140-1300m	Conglomerate, sandstone : grey, reddish brown Shale : grey, black, reddish brown Limestone, volcanics
PERMO- TRIASSIC		UNNAMED		?	Andesite, rhyorite, gabbro, diorite, granite,volcanics
PERMIAN	MIDDLE	RATBURI GROUP	HUA NA KHAM	70-800m	Limestone : grey, massive to thick bedded Conglomerate, sandstone : grey Shale, volcanics
	LOWER-MIDDLE		NAM DUK	2000m	Limestone : grey, well bedded Shale, sandstone : brown Chert, tuff
	LOWER-MIDDLE		PHA NOK KHAO	650-1300m	Limestone : grey, massive to thick bedded Shale , chert
CARBO-NIFEROUS	UPPER		HUAI SOM	?	Tuffaceous sandstone, shale, conglomerate
	LOWER-MIDDLE		DOK DU	?	Limestone : grey, black Sandstone, siltstone, shale

FIGURE 2.2 GEOLOGICAL MAP OF PHETCHABUN BASIN AND NEIGHBOURING AREA

(Modified from Nakornsri, 1976; Chonglakmani et al., 1979; Jungyusuk, 1984, 1985, 1988; Jungyusuk et al., 1987, 1989; Polpresit et al., 1988; Webster, 1988)

EXPLANATION OF FIGURE 2.2

SEDIMENTARY AND METAMORPHIC ROCKS

Qa Alluvium : Sand, silt and clay.

Qt Terrace : Gravel, sand, silt, clay and laterite.

T Tertiary : Claystone, siltstone, shale, mudstone.

Kkk Khok Kruat : Claystone, siltstone, red to brown, micaceous ; some intercalations of reddish brown sandstone.

Kpp Phu Phan : Sandstone, white, pale orange, cross - bedded, pebbly, cross-bedded ; pebbles consisting of quartzite, chert and igneous rocks ; with intercalation of shale and conglomerate.

Jsk Sao Khua : Siltstone, claystone, reddish brown ; sandstone, greyish brown to reddish brown.

Jpw Phra Wihan : Sandstone, white pink, quartzose, cross-bedded, massive, with pebbly layers on the upper bed ; some intercalation of reddish brown and grey siltstone and shale.

Jpk Phu Kradung : Siltstone, purple-brown, micaceous ; sandstone, shale, red, brown, purple, micaceous ; with some lime-nodule conglomerate.

TRnp Nam Phong : Sandstone, pink, reddish grey - reddish brown, cross-bedded ; conglomerate, pebbles consisting of quartz, quartzite, chert, limestone and volcanic rocks ; shale and siltstone, red.

TRhl Huai Hin Lat : Conglomerate, grey, reddish brown ; sandstone, grey, reddish brown ; shale, grey to black, reddish brown, calcareous ; argillaceous limestone ; volcanic rocks.

Phn Hua Na Kham : Limestone, grey, massive to thick bedded ; conglomerate, sandstone, greenish grey to brownish grey, pebbles consists of chert, limestone and quartzite ; shale ; volcanic rocks.

Pnd Nam Duk : Limestone, grey, well and thinly bedded ; shale, brown ; sandstone, yellowish brown ; chert and tuff.

Ppk Pha Nok Khao : Limestone, light to dark grey, massive to thick bedded ; shale and bedded chert.

CPhs Huai Som : Tuffaceous sandstone ; shale and conglomerate.

Cdd Dok Du : Limestone, grey to black, massive to thick bedded ; sandstone ; shale and siltstone.

IGNEOUS ROCKS

bs : Basalt, alkali olivine basalt.

an : Andesite, basaltic andesite, pyroxene andesite, andesite porphyry, andesitic tuff.

rh : Rhyolile, rhyolitic tuff, welded tuff.

gb : Fine-grained gabbro.

gr : Granite, hornblende-biotite granodiorite.

di : Quartz diorite, grayish-brown.

Huai Som Formation

The Huai Som Formation (Chonglakmani and Sattayarak, 1979) exposures are limited small hills and irregularly distribute over the areas of King Amphoe Wang Pong and Amphoe Chon Daen, west of the Phetchabun Basin.

The formation consists of tuffaceous sandstones, shales, conglomerates and cherts, with occasional limestone lenses. The strata occurred in close association with igneous rocks. The sediments were intruded by igneous rocks in many places.

From its fossil assemblage, the age of the Huai Som Formation is considered to be Late Carboniferous to Early Permian (Polprasit and Prasomtrap, 1988).

1.2 Permian

Pha Nok Khao Formation

The Pha Nok Khao Formation (Chonglakmani and Sattayarak, 1979) is best exposed along the south-western margin of the Phetchabun Basin, west and northwest of Wichian Buri, where it forms a distinctive karst topography.

The formation consists predominantly of massive or thick bedded limestones, with some intercalations of shales and cherts. The limestones are light to dark grey , generally microcrystalline carbonate mud and wackestones containing abundant fusulinids, corals, brachiopods, crinoids and bryozoa.

The Pha Nok Khao Formation are cut and overflowed by volcanic rocks of andesite and basalts, producing marble at contact.

The Pha Nok Khao Formation is interpreted as a shallow marine(carbonate platform) deposits. The formation is conformably overlain by the Hua Na Kham Formation and may be a lateral equivalent, in part, of the Nam Duk Formation (Webster, 1988). This formation have been referenced to Upper Carboniferous to Middle Permian (Jungyusuk, 1988).

Nam Duk Formation

The Nam Duk Formation (Chonglakmani and Sattayarak, 1978) forms the north northeast - south southwest trending range of hills that define the eastern boundary of the Phetchabun Basin. It is composed of deformed complex Permian rocks which were tectonically severly disturbed. These strata are intensely folded, faulted and cut by igneous dikes of andesitic and dioritic types.

The Nam Duk Formation (along the Lom Sak - Chum Phae highway in Phetchabun Province) can be subdivided into three distinctive facies :

(a) Pelagic Facies : it comprises of geosynclinal strata of allodapic limestones, cherts, shales, sandstones and tuffites which were deposited in a deep marine basin. Allodapic limestone and tuffite beds exibit features characteristic of sedimentation by turbidity currents. The pelagic sediments are the lower part of the Nam Duk Formation. Many outcrops along the Nam Duk river show a transitionaly contact to the roofing flysch sediments. According to the foraminifera fossils found in allodapic limestone, the facies is in Lower to early Middle Permian age.

(b) Flysch Facies : it comprises of thin to thick bedded greywackes and shales exhibiting sedimentary structures such as complete Bouma sequence such as gradded and convolute bedding. These units were transported by turbidity currents

and deposited in a deep marine basin (Helmcke and Kraikhpong, 1982). Flysch-type sediments are strongly folded, faulted and cleavages are well developed. This flysch has been dated as Middle Permian base on macrofossils (Helmcke, 1983).

(c) Molasse Facies : it comprises of sandstones and shales, with some minor intercalations of limestones in the upper part. Some beds are rich in fossils and plant remains. The limestones contain foraminifera and corals, indicating a shallow marine environment (Helmcke and Kraikhong , 1982). The molasse-type sediments generally do not show strong cleavage and folding. The molasse facies have been dated as upper Middle to Upper Permian (Altermann et al., 1983).

The Nam Duk Formation is a lateral equivalent of the Hua Na Kham Formation and possibly also the upper Pha Nok Khao Formation; the formation is unconformably overlain by Triassic sediments (Webster, 1988).

Hua Na Kham Formation

The Hua Na Kham Formation is a poorly defined unit which crops out along the western margin of the Phetchabun Basin, north of Amphoe Nong Phai. It consists of limestones, conglomerates, sandstones, shales, volcanic agglomerates and tuff. It is cross-cut by andesite in the form of dykes, sills and small body intrusions. The limestones are massive or thick bedded, medium to dark grey, recrystallised micrites, very similar to those of the Pha Nok Khao Formation. They are occasionally bioturbated and contain corals, brachiopods, echinoid spines and crinoids. The associated conglomerates and conglomeratic sandstones are greenish grey to brownish grey and very hard, with small pebbles of chert, limestone and quartzite. The sandstones are similar to sandstones of the Nam Duk Formation and differentiated from younger sandstones by their colour and high proportion of volcanic and metamorphic

lithic fragments.

The Hua Na Kham limestones and clastics are exposed as high relief N-S trending mountains in Amphoe Chon Daen, west of the Phetchabun Basin.

The Hua Na Kham Formation is interpreted to be a shallow marine (intertidal and carbonate platform) deposits (Webster,1988). The formation is unconformably overlain by Triassic sediments and volcanics.

2. Permo - Triassic Volcanics

Jungyusuk and Khositanont (1992) described the volcanic rocks in the area as the Phetchabun volcanic province (Figure 2.3) :

Volcanic rocks in this province formed north-south trending along the mountain range between central plain and the Phetchabun Basin from south of Phetchabun province extending southward to Amphoe Sri Thep. These volcanic rocks commonly show flow structure, consisting of pyroclastic, dykes and sills which vary in composition from basalt to basaltic andesite, andesite and rhyolite. These rocks are commonly associated with shallow intrusive bodies of microgabbro, diorite, quartz diorite, granodiorite and microgranite. However, basaltic andesite and andesite are the major rock types occurred in the Phetchabun volcanic province. Andesite is abundant in Amphoe Chon Daen area. Andesitic tuffs and agglomerate were found interbedded with sandstone of the Hua Na Kham Formation along the Phetchabun - Chon Daen road cut suggesting that the volcanic eruption in this area were active in Middle Permian age. Most of andesite were found as lava flow over and locally cross-cut the Middle Permian sedimentary rocks.

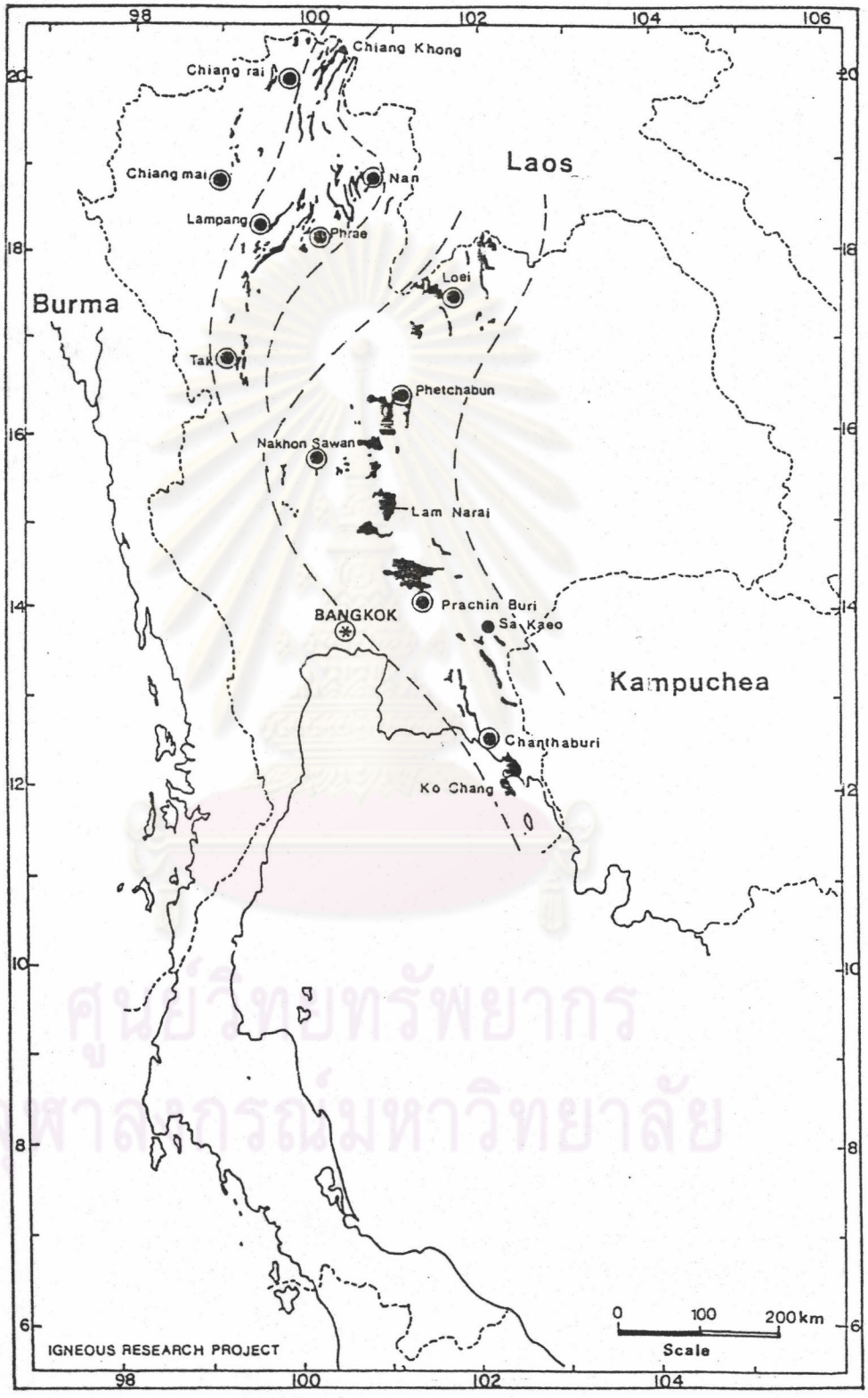

Figure 2.3 Map of Thailand showing distribution of Carboniferous to Tertiary volcanic rocks (Jungyusuk and Khositanont, 1992).

In addition, andesite dykes locally cross-cut the Late Triassic sandstone of the Huai Hin Lat Formation in the Chon Daen area.

The Permo-Triassic volcanics overlie unconformably on the Paleozoic sediments, and are unconformably overlain by Triassic sediments, or are intercalated with sediments of the Huai Hin Lat Formation (Chonglakmani and Sattayarak, 1978).

3. Mesozoic

3.1 Triassic

Huai Hin Lat Formation

At the present, the Huai Hin Lat Formation is separated from the Khorat Group. It is composed of sequence of grey and red sediments exposed in northeastern and north-central Thailand, the sequence in addition includes the volcanic rocks which at many places from basal part of the unit. The formation are largely lacustrine, deltaic and fluviatile sediments unconformably overlying the Paleozoic sequence and conformably underlying the Nam Phong Formation of the Khorat Group. At its type section, east of Lom Sak, the Huai Hin Lat Formation has been subdivided into five members (Chonglakmani and Sattayarak, 1978) : the lower sequence consists of tuff, agglomerate, rhyolite and andesite with occasional intercalations of sandstone and conglomerate (Pho Hai Member) and basal limestone conglomerate (Sam Khaen Member) and the upper sequence of grey to black shale and argillaceous limestone (Dat Fa Member) and grey sandstone, shale and argillaceous limestone with some intercalation of conglomerate (Phu Hi Member). At some places, the upper sequence may comprise of a sedimentary unit intercalated with diorite and its related extrusive facies including tuff and agglomerate in the forms of sills, dikes and

small stocks (I Mo Member).

The Huai Hin Lat Formation are widespread around the northern margin of the Phetchabun Basin and irregularly distributed around the southern margins of the basin. The Sam Khean Member, the most widespread member of the Huai Hin Lat Formation, is exposed in narrow area covering Khao Samo Rat, Khao Khi Klang Khao and Khao Keng, southwest of the Wichian Buri sub-basin where it consists predominantly of limestone conglomerates with occasional intercalations of red sandstones that overlie unconformably on the limestones of the Pha Nok Khao Formation. In northeast of Amphoe Chai Badan, it consists predominantly of angular limestone pebbles and cobbles, with common subangular to subrounded pebbles of chert, volcanics and red shale in red argillaceous matrix. For exposures of the Huai Hin Lat Formation along the western margin of the Wichian Buri sub-basin is red and brown chert conglomerates. Along the northern and western margin of the Phetchabun Basin, the Huai Hin Lat Formation consists of red and grey, hard lithic sandstones containing common red shale clasts and well bedded purple red to red sandstones, and siltstones. At the east of Lom Sak, the Huai Hin Lat Formation here overlies on the Paleozoic strata with unconformity.

The age of the Huai Hin Lat Formation is Norian indicated by flora evidence (Konno and Asama, 1973). The formation can be chronostratigraphically correlated with part of the Lampang Group in northwestern Thailand (Chlonglakmani, 1983). The formation represents a post - orogenic terrestrial sequence which was deposited mainly in lacustrine environment.

Nam Phong Formation

The Nam Phong Formation is the lowest formation of the Khorat Group. It

overlies conformably on the Huai Hin Lat Formation and underlies the Phu Kradung Formation conformably (Webster, 1988).

In the vicinity of SW1 Concession, the Nam Phong Formation consists predominantly of cross-bedded conglomeratic sandstones. Sandstones are pink, reddish grey to reddish brown, moderately hard, fine to medium grained, friable to well cemented, with poor visible porosity; they contain varying proportions of rounded pebbles of quartzite, chert, limestone, volcanics and angular clasts of red shale and siltstone. Elsewhere the sandstones are interbedded with red shale and siltstone with many intercalated resistant conglomerate beds (Chonglakmani and Sattayarak, 1978). The sandstone contains pebbles and shale clasts that crops out at west of Khao Sap Daeng, west of the Wichian Buri sub-basin, is included in the Nam Phong Formation.

To the north of the Wichian Buri sub-basin, the Nam Phong Formation shows fault contact with Permian limestone.

Fossils are unknown in the Nam Phong Formation, but the age is considered to be between the Huai Hin Lat and the Phu Kradung Formation, i.e., Rhaetian (Sattayarak, 1983). Maranate (1984) on his paleomagnetic study of the Khorat Group considered the age of the Nam Phong Formation to be lowermost Jurassic with its base possibly extending to Upper Rhaetian. The fluvio-lacustrine environment was its depositional environment (Chonglakmani and Sattayarak,1978).

3.2 Jurassic

Jurassic outcrops are limited to the northern margins of the Phetchabun Basin; the sediments are best exposed northwest of the concession and along the western margin of the Khorat Plateau, east of SW1.

Phu Kradung Formation

The Phu Kradung Formation crops out on the northern margin of the Phetchabun Basin, where it consists of dark purple, brown micaceous siltstone. The formation is characterized by its red, brown and purple colours. They comprise of shale, fine-grained micaceous sandstone and minor limestone. Near the top of the formation, thin seams of lignite and carbonized wood occur locally (Ramingwong, 1978). The formation overlies conformably on the Nam Phong Formation.

The formation contains sprase vertebrate fossils, non-marine pelecypod and Pleisiosaur tooth indicating Early Jurassic age (Hayami, 1968). Maranate (1984) studied the paleomagnetic of the Phu Kradung strata, its age of about 185-175 Ma. intervals in Early Jurassic. The depositional environment of the formation is fluvio-lacustrine (Hahn, 1982).

Phra Wihan Formation

The Phra Wihan Formation is a distinctive cliff-forming quartzose sandstone unit which crops out northwest and southeast of the Phetchabun Basin. Sandstones are pink or white, fine- to coarse-grained, subangular to subrounded, moderately sorted to well sorted , occasionally pebbly, massive and cross-bedded and are interbedded with minor siltstones and shales; they are easily differentiated from Triassic sandstones by their high quartz content.

The formation is conformably overlain by the Sao Khua Formation. The age of the formation is considered to be the Middle Jurassic (Sattayarak, 1983). The Phra Wihan Formation was also deposited under a fluvial environment.

Sao Khua Formation

The Sao Khua Formation is known as the less-resistance, consists predominantly of reddish brown siltstones and claystones interbedded with thick greyish brown and reddish brown, fine-grained sandstone. Vertebrate assemblages indicate an Upper Jurassic age.

The Sao Khua Formation has been interpreted as lacustrine to brackish deposits since marine fossils of pelecypod and fish were found at Phu Wiang (Hahn, 1982). The age of the formation is Upper Jurassic (Sattayarak,1983). The Sao Khua Formation is conformably overlain by the Phu Phan Formation.

3.3 Cretaceous

Phu Phan Foramation

The Phu Phan Formation consists of thick bedded conglomeratic sandstones. The sandstones are white or pale orange, friable, cross bedded, fine- to coarse-grained, angular to subrounded and poorly sorted with common pebbles of quartzite, chert and volcanics. The unit crops out north of the Phetchabun Basin and along the western margin of the Khorat Plateau and is conformably overlain by the Khok Kruat Formation.

The pelecypods found in the middle part of the Phu Phan Formation indicate Lower to Middle Cretaceous in age (Kobayashi,1968). And Hahn (1982) considered this formation as a typical fluvial sediments.

Khok Kruat Formation

The Khok Kruat Formation consists predominantly of red to brown micaceous claystones and siltstones with minor interbeds of very fine- to medium-grained reddish brown sandstones. Gypsum occurs as thin beds and scattered crystals in some of the siltstone and sandstone. The formation was eroded easily and is limited in outcrop. The Khok Khruat Formation is conformably overlain by evaporites of the Maha Sarakham Formation on the Khorat Plateau, but is unconformably overlain by Cenozoic units in the vicinity of SW1 Concession.

The fossils found in its equivalent beds, the Ban Na Yo Formation, point to the Upper Cretaceous age (Kobayashi, 1968).

4. Cenozoic

4.1 Tertiary

The Tertiary sediments are blanketed by Quaternary alluvial deposits and Cenozoic volcanics throughout the Phetchabun Basin. Only two small outcrops of the sequence exposed in the area, near Ban Chaliang Lab, east of Amphoe Muang and Ban Nam Duad, northeast of Amphoe Wichian Buri.

The sequence at Ban Chaliang Lab comprises predominantly of massive and thin bedded grey claystones, with occasional intercalation of marls and siltstones. Plant debris and fresh water angiosperms are common, suggesting the sediments were deposited in a freshwater lacustrine environment and indicating Late Miocene to Early Pliocene (Promet Energy Services, 1985).

For Tertiary outcrop at Ban Nam Duad exposed in a shallow pit, consists of mudstones, calcareous mudstones, shales and limestones. Thick beds of *Viviparous sp.* were found in this outcrops. The sequence lies within the area of extensive Cenozoic volcanism (Jungyusuk,1989).

4.2 Cenozoic Volcanics

Cenozoic basalts namely Wichian Buri basalt are widely distributed around the central and southern Phetchabun Basin, extending from Amphoe Nong Pai and Amphoe Wichian Buri in Phetchabun Province(Jungyusuk and Khositanont, 1992) (Figure 2.4).

Wichian Buri basalt is exposed at about 50 km. north of Lam Narai basalt. It covers an area of about 200 sq.km. The Wichian Buri basalt occurs as hilly terrain, high relief and usually shows columnar joints. This basalt occurs on top of the sequence of Permian and Tertiary sedimentary rocks (Jungyusuk and Suriyachai, 1987). The basalt is black, fine-grained, and contains some ultramafic nodules and black spinel. The petrography of the Wichian Buri basalt is similar to basaltic rocks, that associated with gem-quality corundum. K/Ar age determination yield 9.7 to 11.6 Ma. (Charusiri, et al., 1990).

4.3 Quaternary

Quaternary deposits in and around the Phetchabun Basin comprise of gravel, sand, silt, clay and lateritic soil, which were deposited in a river system of ancestral to the present day Mae Nam Pa Sak and its tributaries. These unconsolidated sediments can be divided into two units; recent alluvial deposits and terraces.

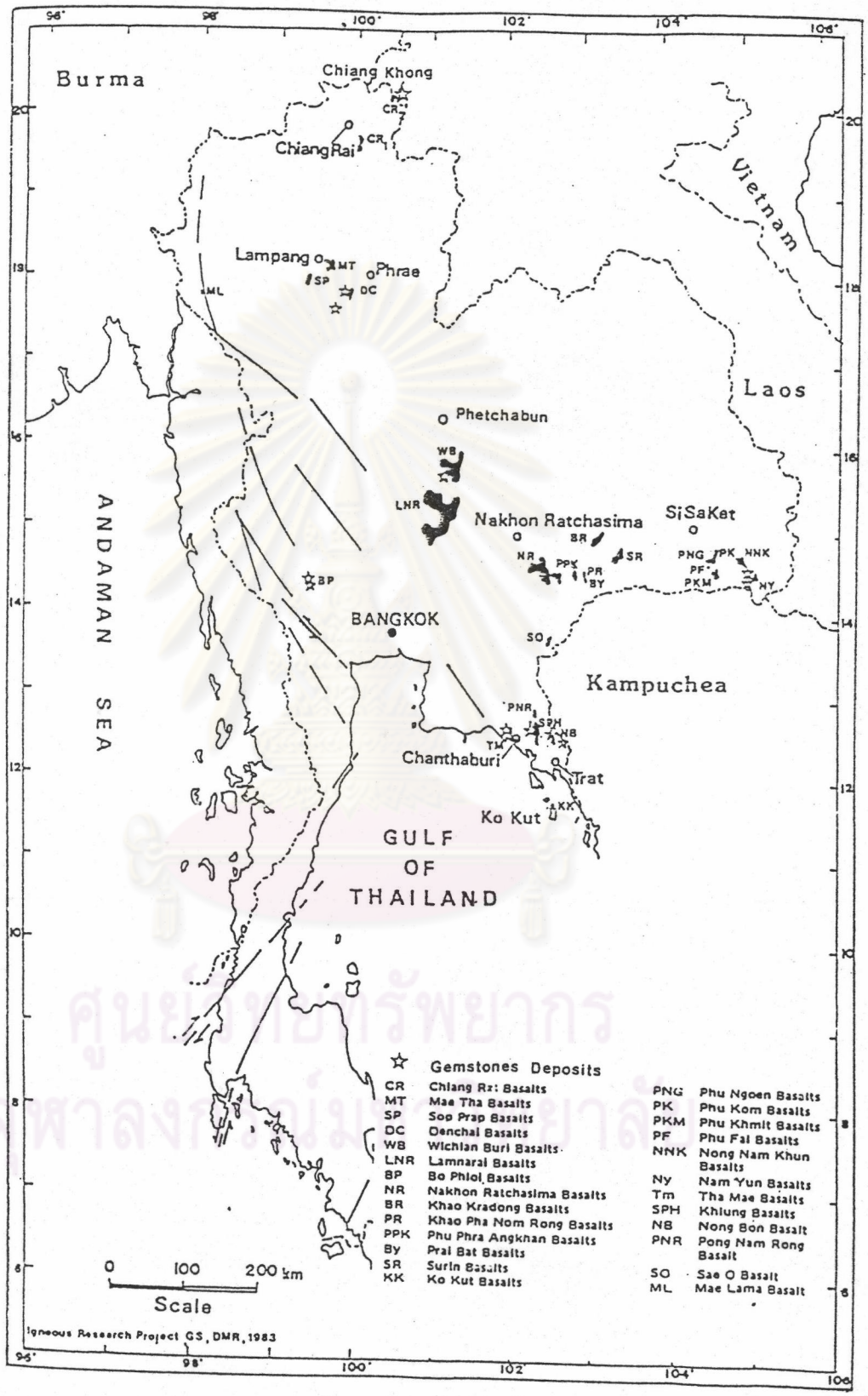

Figure 2.4 Map of Thailand showing distribution of basalts (Jungyusuk and Khositanont, 1992).

Structure

1. Faults

In the vicinity of the study area, the major fault trends are generally oriented in the north/northeast-south/southwest and northwest-southeast directions. (Figure 2.5). The trend of faults is normally conformable to the orientation of the mountain ranges.

(a) NNE-SSW fault trend : It forms the eastern boundary of the basin and corresponds to the primary tectonic fabric of the Loei Fold Belt, within which the basin is located. These faults were first formed during the Indosinian Orogeny in the Early Triassic (Webster et al., 1989).

(b) NW-SE fault trend : It is associated with an overthrusted sheet of Permo-Triassic sediments that forms the western margin of the basin. The overthrusting occurred during Late Triassic.

2. Foldings

Foldings in the study area are found in three zones. The first one is the north/northeast - south/southwest trend along the eastern margin of the basin within the Nam Duk Formation, which forms the eastern range, and is characterized by tight and isoclinal horizontal and horizontal inclined folds with north-south trending axes. The degree of deformation decreases further to the east within the molasse facie of the formation (Helmcke, 1982).

The second zone is the northeast-southwest trend that occurred along the western margin of the basin within Paleozoic and Triassic sequences. It is defined by very steeply inclined east-dipping.

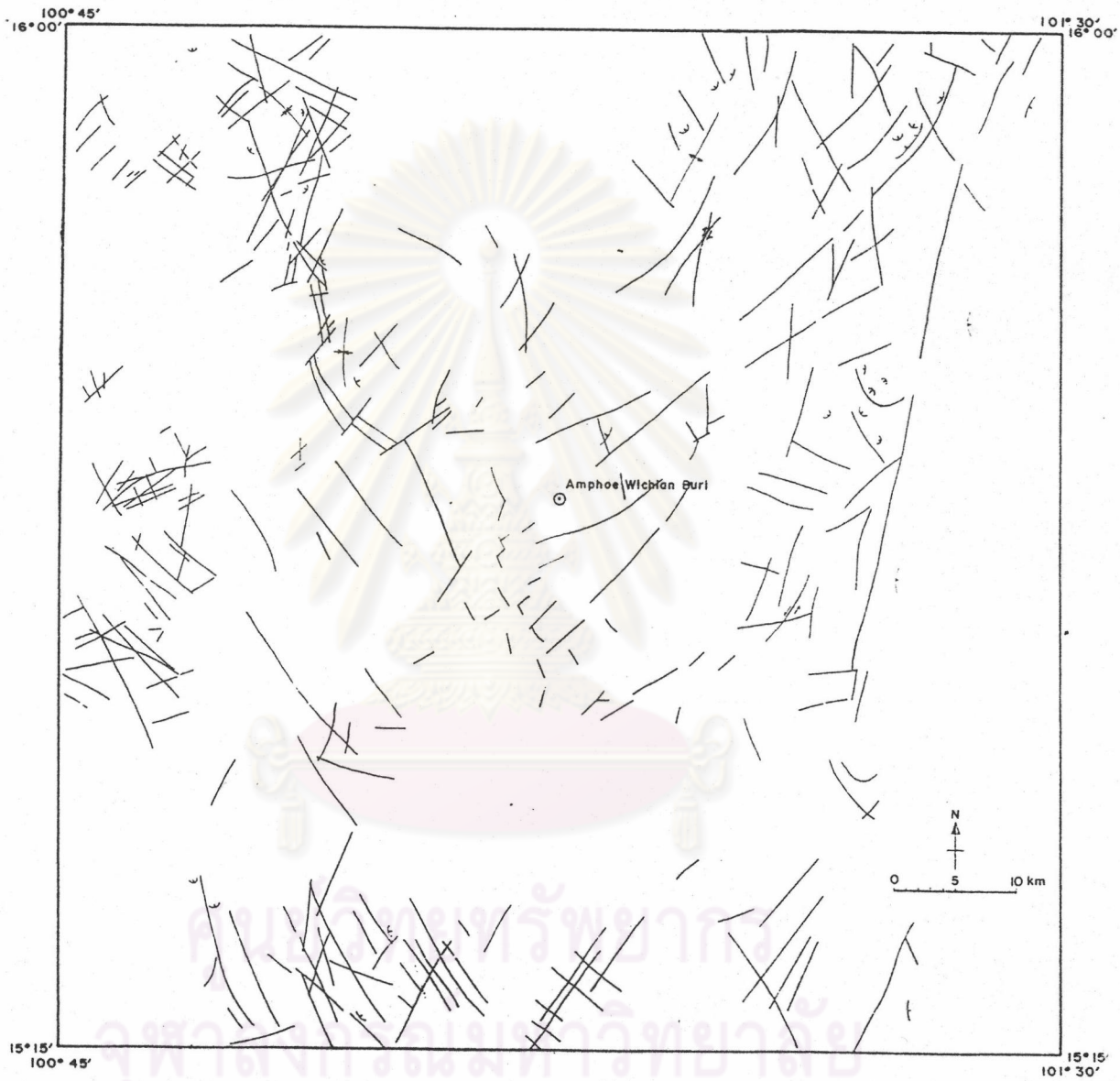

Figure 2.5 Lineament map of the Wichian Buri sub-basin and neighbouring area.

The third zone consists of openly folded Jurassic and Cretaceous sequences north and east of the basin. Fold axes trend northeast-southwest and north-south.

3. Unconformities

There are at least four significant unconformities within the stratigraphic sequence in the area. The two older unconformities which related to tectonism and igneous activity lie within the Permo-Triassic. The volcanics overlie unconformably on the Paleozoic strata, and are themselves unconformably overlain by Triassic sediments, or are intercalated with sediments of the Upper Triassic Huai Hin Lat Formation.

The most widespread and well defined unconformity is the Cretaceous-Tertiary unconformity. In the area, the Khok Kruat Formation is unconformably overlain by Cenozoic units.

The last unconformity lies within the Tertiary-Quaternary. Generally, the Tertiary strata in Central Thailand overlies unconformably on the pre-Tertiary sediments of the Khorat group.

Geological History

Geological history of the Phetchabun area which displays shallow marine to continental environments started from the Early Carboniferous. The region is considered to be a part of passive continental margin of the Indochina Craton and has been separated from the Shan Thai Craton by the Nam Duk Basin due to a consequence of the extensional event.

During Carboniferous, west of Phetchabun area shallow marine sediments are located.

During the Lower Permian, limestones, shales and cherts (Pha Nok Khao Formation) were deposited on a carbonate platform which extend over the Phetchabun area and extending eastwards over what is now the Khorat Plateau.

A north-south trending volcanic arc developed parallel to the western margin of this platform (part of the Indochina Craton) during the Lower Permian, as a oceanic crust was subducted eastwards below the Indochina Craton. Calc-alkaline volcanics were erupted into the platform where they interfingered with sediments of the Pha Nok Khao Formation.

During the Lower Permian and most of the Middle Permian, the north-south trending marine Nam Duk Basin occupied the areas, east of the volcanic arc which is now known as the Phetchabun foldbelt. The basin was deep enough to host a pelagic sequence built up predominantly allodapic limestones and shales. The pelagic sequence was followed by a facies of transition and by a thick flysch sequence which also required a rather deep basin. Only during the sedimentation of the molasse facies the basin became more and more shallow.

Wielchowsky and Young (1985) established the presence of three Permian paleogeographic zones in the Phetchabun fold and thrust belt, i.e, the Khao Khwang carbonate platform to the west, the central Nam Duk mixed siliciclastic carbonate basin, and the Pha Nok Khao mixed carbonate-siliciclastic platform to the east. They suggested that the Nam Duk Basin acted as a barrier to clastic influx from the Pha Nok Khao and the Khao Khwang Platforms.

Along the time of the Lower Permian, the Nam Duk Basin of the Phetchabun fold and thrust belt was deposited by a pelagic sequence built up predominantly by allodapic limestones, cherts, shales, sandstones and tuffites (Wielchowsky and Young, 1985) . Limestones and tuffites were transported from carbonate platform in the western part (Khao Khwang platform) as well as in the eastern part (Pha Nok Khao platform) into the deep marine basin as turbities. The presence of tuffites and sandstones rich in volcanic fragments within the pelagic facies of the Nam Duk Formation indicates a sediment input from the volcanic arc which might be located on a land-area west of the Nam Duk Basin; the Nam Duk Basin was therefore interpreted to be a back-arc basin which probably formed along the junction of oceanic and continental crust (Indochina Craton)(Webster, 1988).

In the lower Middle Permian, the sedimentation by turbidity currents reached a maximum (Winkel et al., 1983) and a thick widespread flysch sequence often exhibiting complete Bouma-cycles was deposited. At this time there was a significant clastic influxes occurred on the Pha Nok Khao Platform (Wielchowsky and Young, 1985). On the Khao Khwang Platform during the same time the rate of carbonate accumulation apparently decreased.

The pelagic and flysch sediments of the Nam Duk Formation were intensely deformed, resulted from a strong orogenic activity during the Middle Permian. The basin was isoclinally folded and overthrusted. Because the eastern parts of the basin exhibit steep dipping fold axes, they are affected by at least two folding events (Altermann, 1987).

In the eastern, marginal parts of the basin, the molasse was deposited from the new rising fold belt as the Nam Duk Basin shallowed during the upper Middle to Upper Permian. The intensity of folding of the molasse decreases towards the east or

the younger strata (Altermann, 1987). In the Upper Permian carbonate sedimentation become dominant in the molasse. Obviously no strong siliciclastic influx occurred during the end of the orogeny.

The sedimentation sequence of pelagic , flysch and molasse strata presents a thick coarsening-upwards sequence, typical of subduction-related suture. The accretion of the Nam Duk Formation was most likely related to a cessation of subduction as the Shan-Thai and Indochina Plates collided; the closure of interving ocean was evidenced by the obducted Nan-Uttaradit Permian Ophiolite Belt. . The Nam Duk Basin was closed by a westward dipping subduction. Because the main continental mass was located to the east (Indochina Craton) and the volcanic arc was in the west (Shan-Thai Craton).

The western Khao Khwang platform was not strongly affected by the closure of the Nam Duk Basin and the sedimentation patterns there remained the same from the Carboniferous to Upper Permian. Also, the eastern Pha Nok Khao platform did not show the effects of strong tectonic activity.

The orogeny persisted through the Upper Permian and probably containing to the Lower to Middle Triassic, with widespread uplift and erosion and continued volcanism.

During the Upper Permian, the shallow sea withdrew from this area and an erosional surface was formed. This may have been accompanied by weak folding. Later in Late Triassic, sedimentation of the Huai Hin Lat Formation, started. According to Helmcke (1980, 1981) the intermediate volcanic rocks (tuff, agglomerate and lava flows) within the base of the Huai Hin Lat Formation were spread over parts of the erosional surface on top of the folded Paleozoic strata.

The Upper Triassic and Permian sediments were involved in a second major orogenic event during the lastest Triassic or Early Jurassic, as evidenced by the northeast trending overthrusts in the Phetchabun area. This phase was most likely related to the collision of the Indochian Plate with the South China Plate (Hayashi, 1988) which was marked by the Song Da Ophiolite Belt.

An important accumulation of mainly continental sediments continued through out the Jurassic and went on the rest of the Mesozoic (Chonglakmani and Fontaine, 1990). Marine Jurassic sediments were recognised only in the west and northwest of the country (Chonglakmani, 1983). The continental sediments were not widespread and their deposition was probably limited by pre-existing structural highs.

For Permo-Triassic volcanic activity, the second volcanic event, resulted in the most abundant volcanic rocks found in Thailand. They were represented by volcanic rocks of intermediate to acid in composition covering in the Phetchabun and Lam Narai volcanic provinces. In Upper Triassic-Lower Jurassic, the third minor volcanic activity and its related intrusion occurred, resulting the intercalation of diorite and its extrusive variety with the grey shale (I Mo Member) of the Huai Hin Lat Formation .

The lastest activity was recorded in the Cretaceous - Tertiary time. During Late Cretaceous, after the deposition of sediments of the Khorat Group, there were two tectonic events occurred which caused deformation of the area. There seems to be no indication of tectonic events happening during the deposition of the Khorat sediments. The first tectonic event was a weak compressional deformation, which caused the Khorat strata to be folded widespacedly northwest-southeast and north-south trending axes and also faulted at km. 21.5 of the highway Lom Sak - Chum Phae, where Paleozoic rocks were thrusted on sediments of the Lower Jurassic

Nam Phong Formation. The second event the garben-structure of the Phetchabun area was formed by the extensional tectonic (Helmcke and Kraikhong, 1982).

The Tertiary Phetchabun Basin is likely to have been formed under the same tectonic stresses that formed the Pattani Basin in the Gulf of Thailand and the onshore Chao Phraya and Phitsanulok Basins (Oligocene). The most likely mechanism was wrench faulting associated with right lateral movement along major northwest-southeast fault zones (Red River, Mae Ping and Three Pagoda fault zones). The basin was filled with fluvial and lacustrine sediments during the Oligocene and Miocene (Webster, 1988).