CHAPTER II

GEOLOGY

2.1 Physiography

In the northern region of Thailand which is situated in the Northern and Western Folded Mountain physiographical province, the average elevation of the mountains is about 1,600 metres above the mean sea level; the highest peak, Doi Inthanon, is about 2,650 metres above the mean sea level (Mantajit, 1975). The slope is generally steep, in places exceeding thirty degrees. Despite the steep slopes, they are covered with deep residual soil, hold in place by luxuriant vegetation (Lee, 1923). The mountain ranges are up to 40 kilometres wide, oriented more or less in the north-south to northnortheast-southsouthwest trend as a broad "S" shape.

There are many Cenozoic intermontane basins such as the Chiang Mai, the Lampang, the Chiang Rai, and the Phrae basins, etc. which are often 15 to 16 kiometres wide or more. The flat alluvial plain in the central part of the basins is dependent on the size of the basin and size of the stream, but usually not over one to two kilometres wide. The elevation of the basin ground surface is between 250 and 800 metres above the mean sea level. The basin streams are sluggish and commonly meander widely. Between the alluvial plains and the mountains, there are often broad belts of low rolling hills (Lee, 1923).

The mountain streams also occur as the narrow and cut-steep ravines. It seems likely that the course of the stream is modified by the irregularities of the geological structure. Almost all streams or rivers drain southwardly such as the Ping, the Wang, the Yom, and the Nan, etc. as the tributaries of the Chao Phraya river.

The Fang basin is also one of the Cenozoic intermontane basins of the northern Thailand (Figure 2.1). The central lowland with the elevation about 480 metres above the mean sea level is mostly flat. This flat terrain is the flood plain of approximately 1 to 3 kilometres wide, extending on both sides of the Mae Fang (also called Nam Fang) river. However, in the central part of the basin, the flood plain increases in width to 6 kilometres. This flood plain as well as the basin is bisected by a longitudinal trunk stream, the Mae Fang river, which more or less meanders with amplitude often less than 250 metres, up to 500 metres and about 90 kilometres long. It can be classified as meandering river with the sinuosity about 1.7 according to channel classification of Miall (1982). This stream is almost not more than 10 metres wide, and drains northnortheast to the Mae Kok river, a tributary of the Mae Khong river. Beyond the central lowland, the area is occupied by many hills up to 120 metres high above the lowland. It seems likely that at

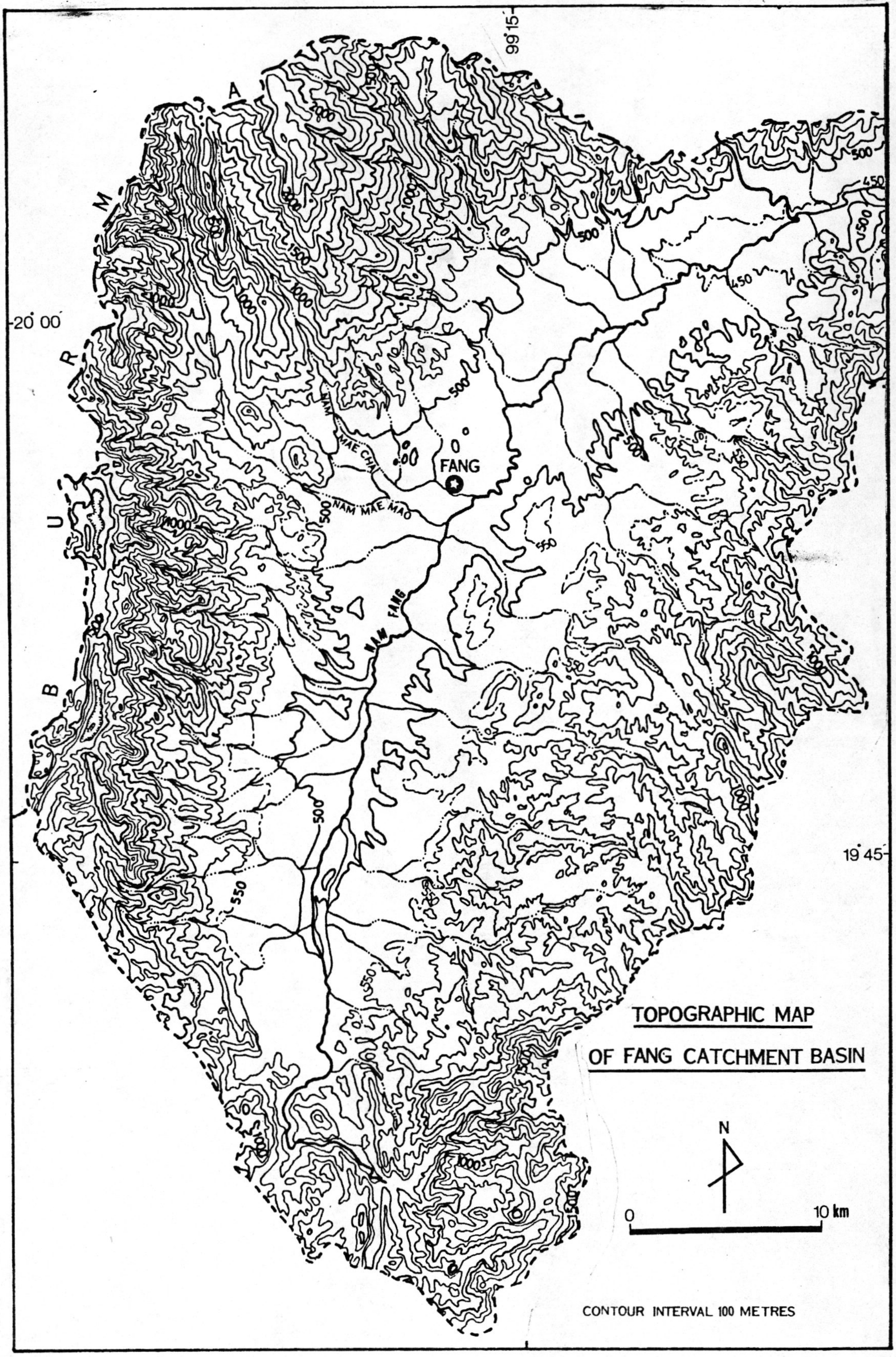

Figure 2.1 The topographic map of Fang catchment basin.

least one-level terrace has been developed in the basin. These hills are also dissected by many small transverse tributaries of the Mae Fang river. Towards the border area, the basin is bounded by relatively high mountains. On the western and the southern sides of the basin in particular, the inner hilly belt ends abruptly against a high rugged mountain range whose summits rise about 1,400 metres above the basin floor. The eastern margin is the lower elevated area which deos not have abrupt relief. Presumably, the eastern margin is geomorphologically more mature than that of the western one.

A series of mountains on the northwestern convex side of the Fang basin are San Doi Leam, Doi Ton Phung, Doi leam, Doi Ang Khang, Mon Hin Lai, Doi Khun Huai Khi, and Doi Pha Daeng from north to south. For the southeastern concave side of the basin, a series from north to south are Doi Sang, Doi Lum Khao, Doi Mae Wang Noi, Doi Lieam, Doi Phrao, and Doi Khun Huai Fang.

2.2 Geological Setting of Northern Thailand

Geological investigation of the northern Thailand were previously conducted by Bertil Hogbom (1911), Lee (1923), Heim and Herschi (1938), Brown et al.(1951), Javanaphet(1969), Baum et al.(1972), etc..

Geological map of northern Thailand shown in Figure 2.2.a was compiled by A. Lumjuan and S. Lavachala Supaporn (1981) then edited and modified by Suensilpong et

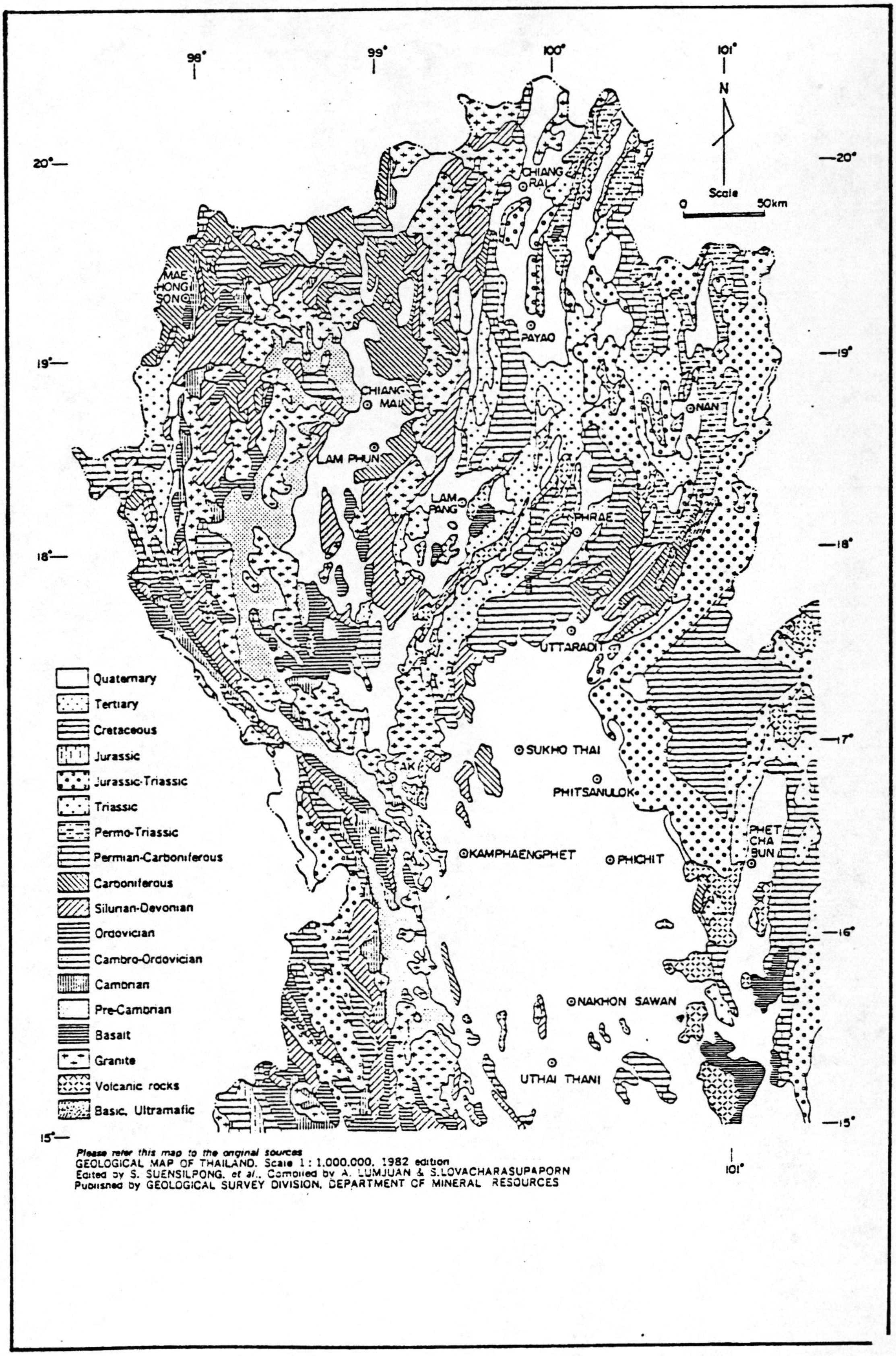

Figure 2.2.a The geological map of Northern Thailand.

al. (1982). Generally, thick complete sequences of the Precambrian to Jurassic with some Tertiary sediments are exposed in the western region, while the eastern region the known sediments are only of the Silurian-Devonian to the Cretaceous and possibly Tertiary age (Bunopas, 1976). The successions of the Precambrian to Tertiary sediments were correlated by GGM(1972) as shown in Figure 2.2.b. The following description on the northern geology of Thailand was mostly based on Chuaviroj & Chaturongkawanich(1984).

The Precambrian rocks are exposed with north-south trend in the western mountain of Chang wat Chiang Mai to the west and the further south to Changwat Tak. The rocks are mainly composed of magmatised paragneisses including quartz schist, biotite schist, calsilicate schist, and marble (Campbell, 1975; GGM, 1972). They are penetrated by concordant and discordant veins and irregular masses of granodiorite and pegmatite. Apparently, Precambrian gneiss series are unconformably overlain by less metamorphosed or unmetamorphosed Cambrian rocks (GGM, 1972).

East of Changwat Mae Hong Son and west of Changwat Kamphaengpheat, the rocks are well bedded to massive quartzite, often cross-bedded with some conglomerate beds of up to 500 metres in thickness. These rocks are Cambrian in age and described by Bunopas (1976) and they are conformably overlain by Ordovician limestone. The Lower Paleozoic sediments of Cambro-Ordovician age consist of quartzitic rocks with locally increasing amounts of shaly

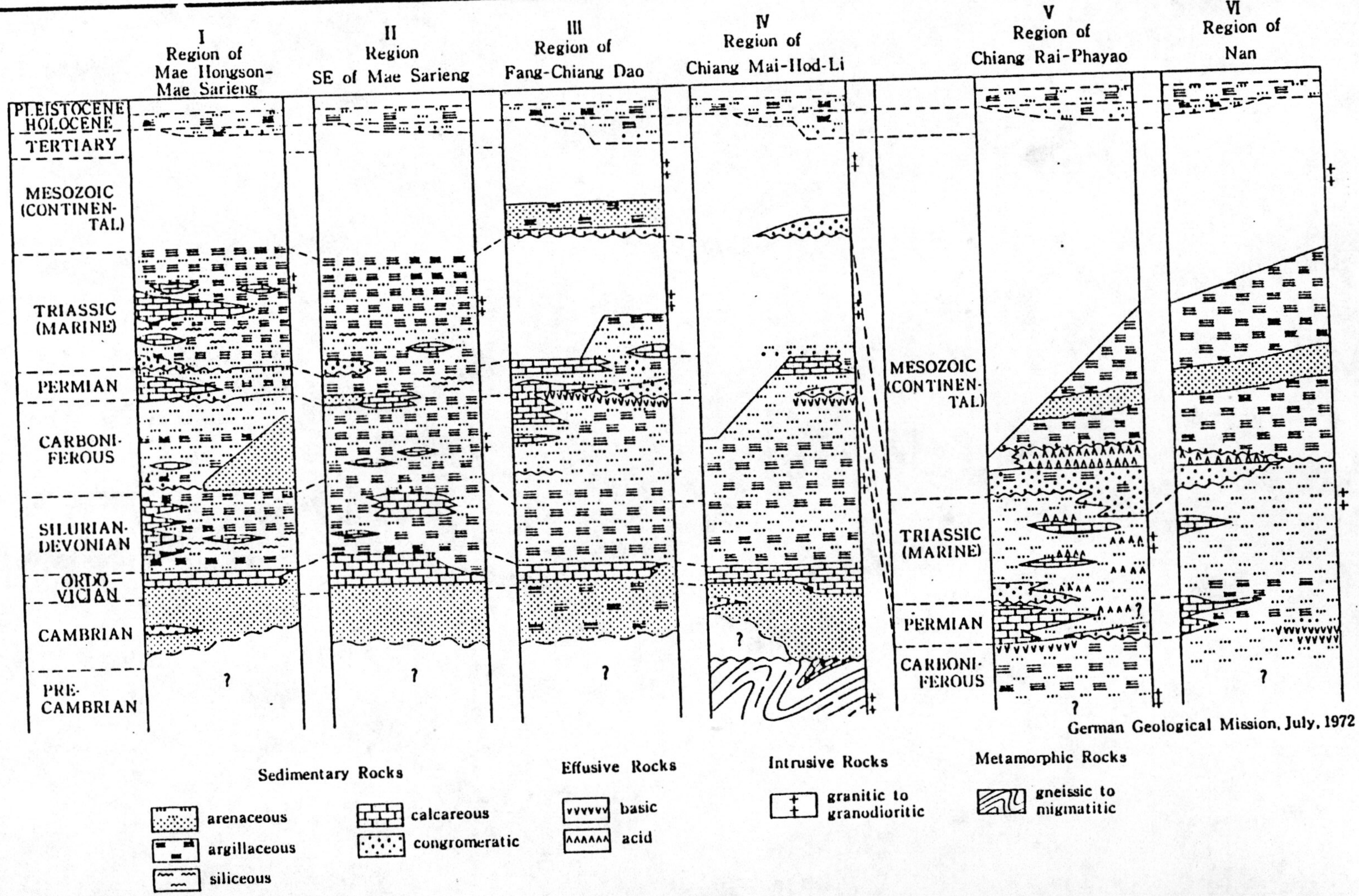

Figure 2.2.b The generalized stratigraphic columns of Northern Thailand.

and calcareous intercalations in the upper part. The average thickness of the Ordovician limestone in the north ranges from 80 to 100 metres.

The Silurian-Devonian sediments occur in Changwat Mae Hong Son and throughout northern Thailand particurlarly to the southeast, west of Changwat Chiang Mai, Changwat Lumpang and northeastern of Changwat Uttaradit. These rocks are graywackes, cabonaceous shales, cherts, and thin-bedded limestones. The thickness of the series does not exceed 500 metres (GGM, 1972) and the distribution generally corresponds with that of the Ordovician limestone.

The Carboniferous rocks are characterized by clastic sediment with some limestones or chert intercalations. They are mainly exposed to the west of Changwat Mae Hong Son, north of Changwat Chiang Mai, southwestern part of Changwat Lampang and northern Changwat Uttaradit. The end of the Lower Carboniferous is marked by orogenic movements with magmatic activities (GGM, 1972). The Upper Carboniferous sequence shows both marine and terrestrial facies. Marine sediments are chert, limestone, shale, and conglomerate. Deposition of continental or non-marine clastic facies is documented by a thick red conglomerate, shale, sandstone and chert. They laterally interfinger with marine Permo-Caboniferous limestone. In many places, the uppermost Carboniferous formation contains mafic volcanics (GGM, 1972). Macdonald and Barr(1978) found that the volcanic rocks or basalts have the composition of island arc tholeiites. They suggest that the rocks represent part of a volcanic island arc extruded through oceanic crust. Clastic and marine facies continue into the Permian.

The Permian rocks consist mainly of limestone and minor sandstone and conglomerate, agglomerate and tuff. In the central part of the northern Thailand, particularly between Changwat Lampang and Changwat Nan, the most complete succession is exposed. The rocks, however, are predominantly clastic and rhyolitic, with some interbedded limestones. North of Changwat Chiang Mai and northeastern Changwat Mae Hong Son, the Permian rocks consists mostly of a thick limestone formation, the Ratburi Limestone. The thickness of the Permian limestone is about 100-150 metres.

The Permo-Triassic rocks are predominantly rhyolitic and andesitic in nature distributed in almost north-south direction from east of Changwat Chiang Rai to southern part of Changwat Lampang.

The Mesozoic in northern Thailand is characterized by a distinct depositional subdivision. The marine Triassic sediments rest unconformably on the Permian sediments to the south of Changwat Mae Hong Son and southeast of Amphoe Mae Sariang (see columns I and II Figure 2.2.b) and overlie the volcanic sequence in

Changwat Lampang and Changwat Phrae. In general, the marine Triassic sediments consist of shale and limestone with the facies change into a sandstone-shale sequence, described as resembling Alpine flysch (Bunopas, 1976).

The continental sedimentary environment appeared in Jurassic. These terrestrial sediments consist of red sandstone, mudstone, shale and a characteristic volcanic member of mafic to intermediate composition particularly in Changwat Nan (column VI, Figure 2.2.b) and the east of Changwat Uttaradit, Changwat Sukhothai area and Changwat Phichit area (Figure 2.2.a).

The Cretaceous rocks are exposed in the eastern part of Changwat Uttaradit and Thai-Laos border. They consist mainly of quartz-sandstone and conglomeratic sandstone. In the area surveyed by the GGM, maximum thickness of the continental Mesozoic sediments may reach 1,000 metres.

In northern Thailand, the Tertiary sediments predominantly occur in isolated intermontane basins with distinct north-south trend, overlying the regional structure of the older formations. It consists of shale, sandstone, marl beds, fresh water limestone and local accumulation of coal, oil shale and carbonaceous shale.

Pleistocene terraces and Holocene flood plains are developed in basins all over the area, they lie unconformably over the older rocks.

Regarding igneous activities, large areas of Precambrian rocks and also areas adjoining older Paleozoic formation have been affected by high grade regional metamorphism and granitization. In several areas, plutonic acticity provided intrusive rocks and they have been dated to of middle Carboniferous age (GGM,1972), After widespread deposition of felsic to intermediate volcanics, the tectonic activity started again in the early Upper Carboniferous age.

There are serveral granite complexes in northern Thailand, they were considered to be of late Carboniferous, late Triassic to early Jurassic, Cretaceous and Tertiary ages. Main batholiths intruded only during the Triassic, perhaps extending into the very earliest Jurassic. This period of intrusion coincides with the age of andesitic and rhyolitic volcanic activities. Bunopas & Vella(1972) suggested that the age of volcanics in the central part of northern Thailand extended from late Permian to early Triassic according to their category of volcanic belts. They also believe that the collision of the Shan-Thai with the Indochina cratons took place in early Jurassic time marked by scattered occurrences of ultramafic rock to the east of Changwat Nan and northeastern Changwat Uttaradit.

The Pleistocene basalt at Changwat Lampang have been investigated using paleomagnetic and dating techniques by Barr et al.(1976). The basalts to the north of Changwat Payao, Changwat Phrae and the eastern of Changwat Nakorn Sawan areas are probably of the same age as the Lampang basalt.

In addition, the terrestial heat flow in Northern Thailand as well as the Fang basin has been studies by Thienprasert and and Raksaskulwong .(1983, 1984). With respect to the Fang basin, the heat flow values are 1.62 to 3.58 HFU and the geothermal gradients are approximately 40.0° to 95.0° C/km. (Figure 2.2.c) .

2.3 Structural Framework

The regional structural framework of Northern Thailand in general is strongly influence by the Indosinian orogeny during late Triassic, so-called Sukhothai/Loei fold belts. These regional structures had been subsequently modified by major sinistral faults, Himalaya orogeny, namely, Red River Fault, and Mae Ping Fault during Eocene to early Miocene. As a result, the regional structural framework of Northern Thailand appears roughly as the S-shaped. The last episode of tectonic movement was the time when tensional faulting commenced in late Tertiary and early Quaternary with wide spread occurrences of alkaline basalts (Figures 2.3.a, and 2.3.b).

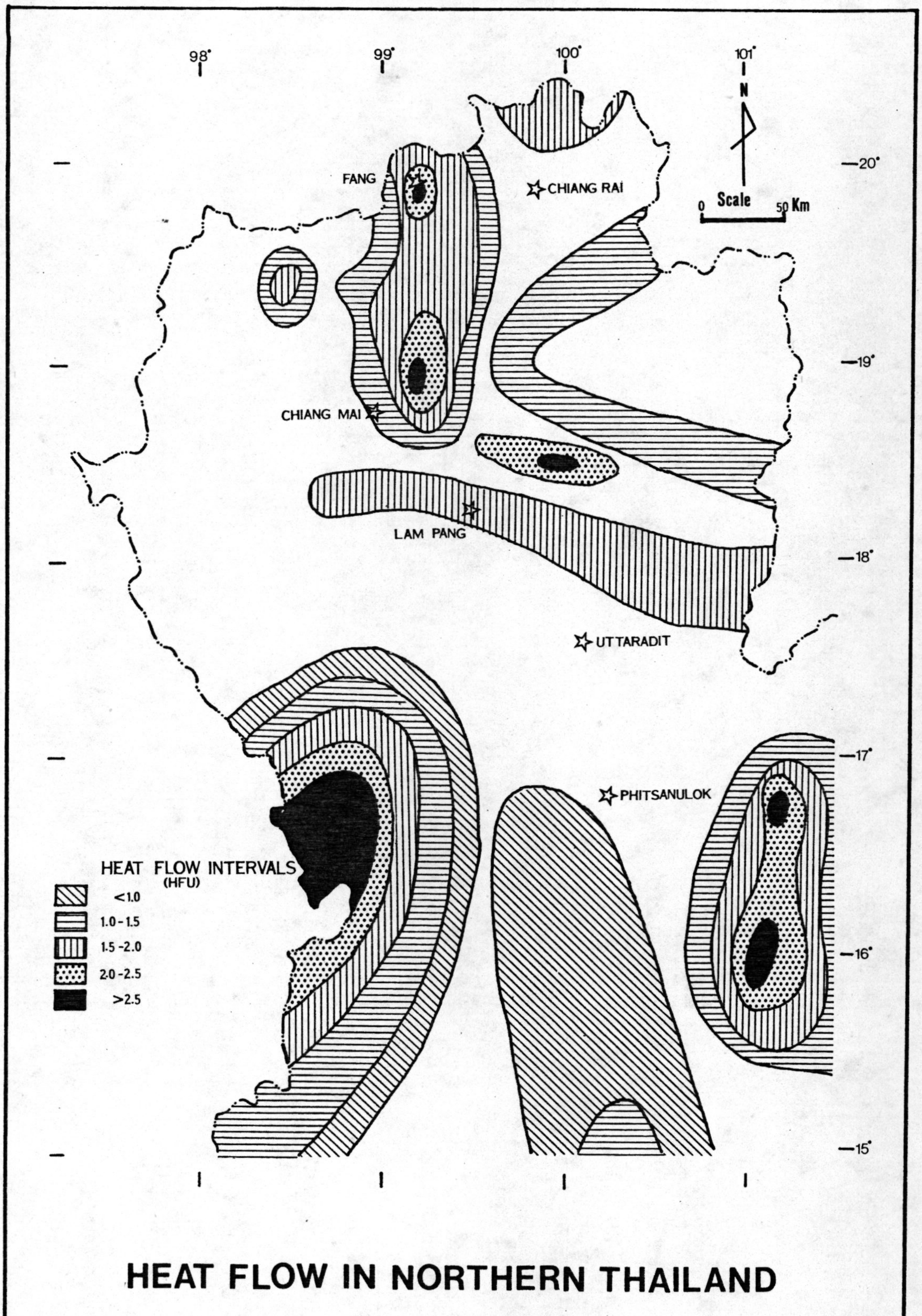

Figure 2.2.c The contour map of terrestial heat flow in Northern Thailand after Thienprasert et al. (1984

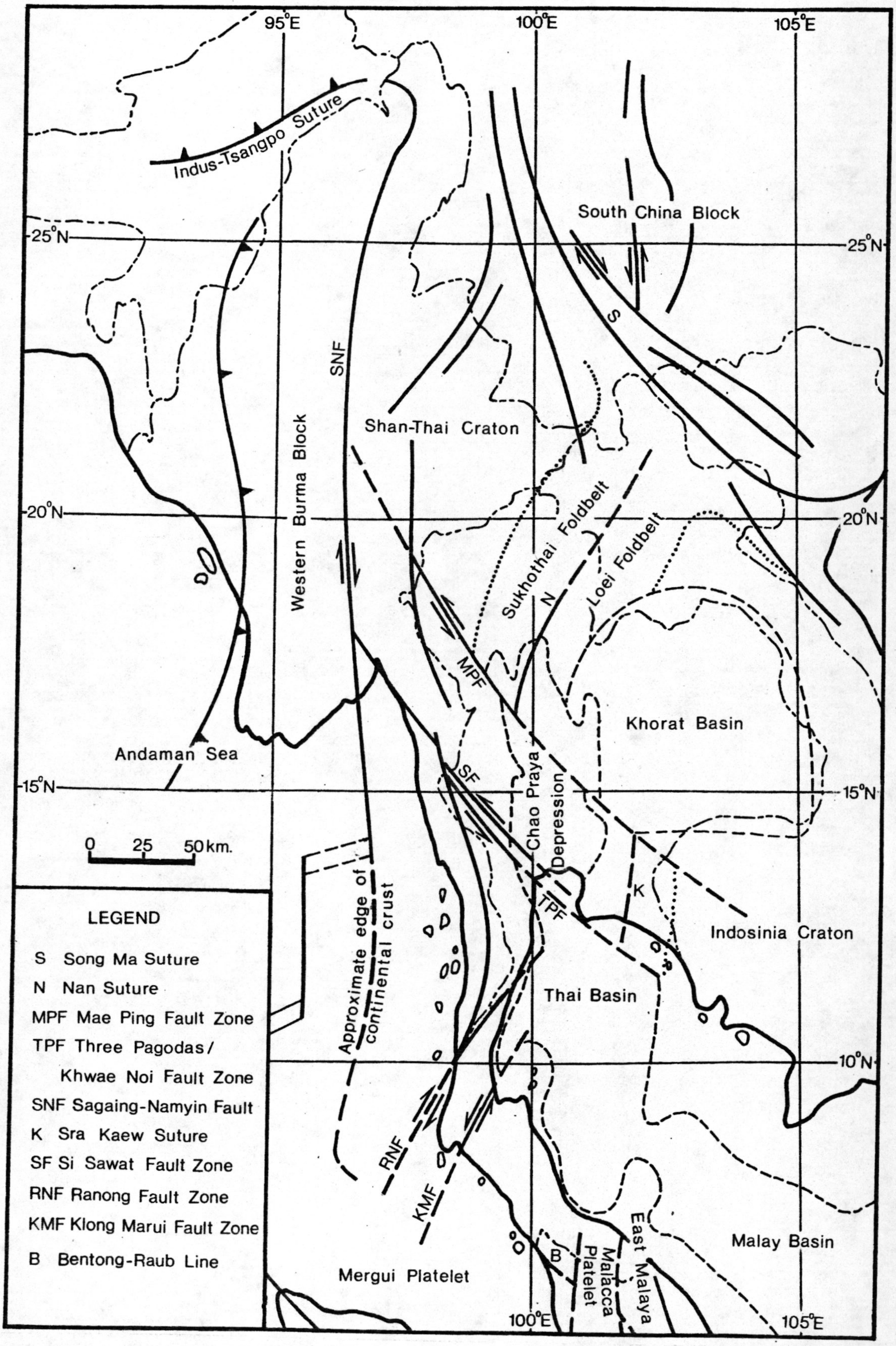

Figure 2.3.a Major tectonic features of mainland Southeast Asia after Bunopas (1981).

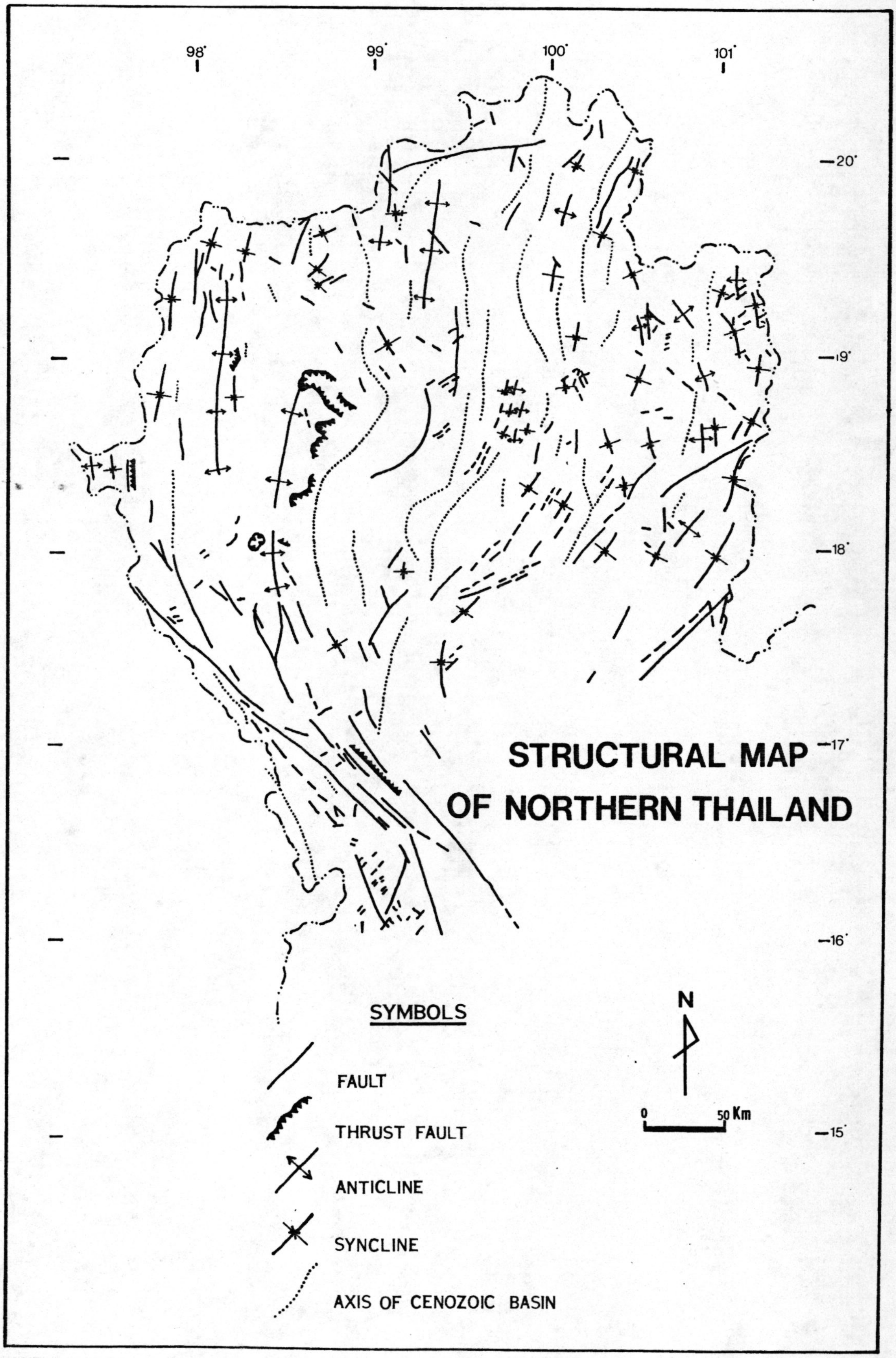

Figure 2.3.b Structural map of Northern Thailand.

The photolineament, fault and fracture, of Paleozoic rocks in the vicinity of the Fang area indicates that there are at least five sets. They are, namely, northnorthwest-southsoutheast, westnorthwest-eastsoutheast ,northeast-southwest, north-south, and eastnortheast-westsouthwest or east-west (Figure 2.3.c).

The most apparent major fault set is that appears at the northwestern margin of the upper portion of the Fang basin. This fault is in the eastnortheast-westsouthwest direction marking the boundary between Cenozoic sediments of the Fang basin and adjacent older rocks. This fault set is considered to be strike-sliped faults or normal faults dipping approximately towards the basin in the the southsoutheast direction. The evidence of Doi Kia Fault extending from Fang to Changwat Chiang Rai, which is as belonging to this set, indicates that it is a mormal fault (Braun et al., 1976; Chaturongkawanich et al. ,1980).

Another major fault set is in the north-south or northnorthwest-southsoutheast direction. The most obvious fault of this set appears on the western margin of the southern portion of the Fang basin, so-called Mae Mao I Fault (Chaturongkawanich et al., 1980). For the northnorthwest-southsoutheast fault, the most obvious one is Mae Chai Fault which is considered to be normal fault, dipping towards northeast direction. Nam Mae Chai is, therefore, the fault-controlled stream (Figure 2.4.a).

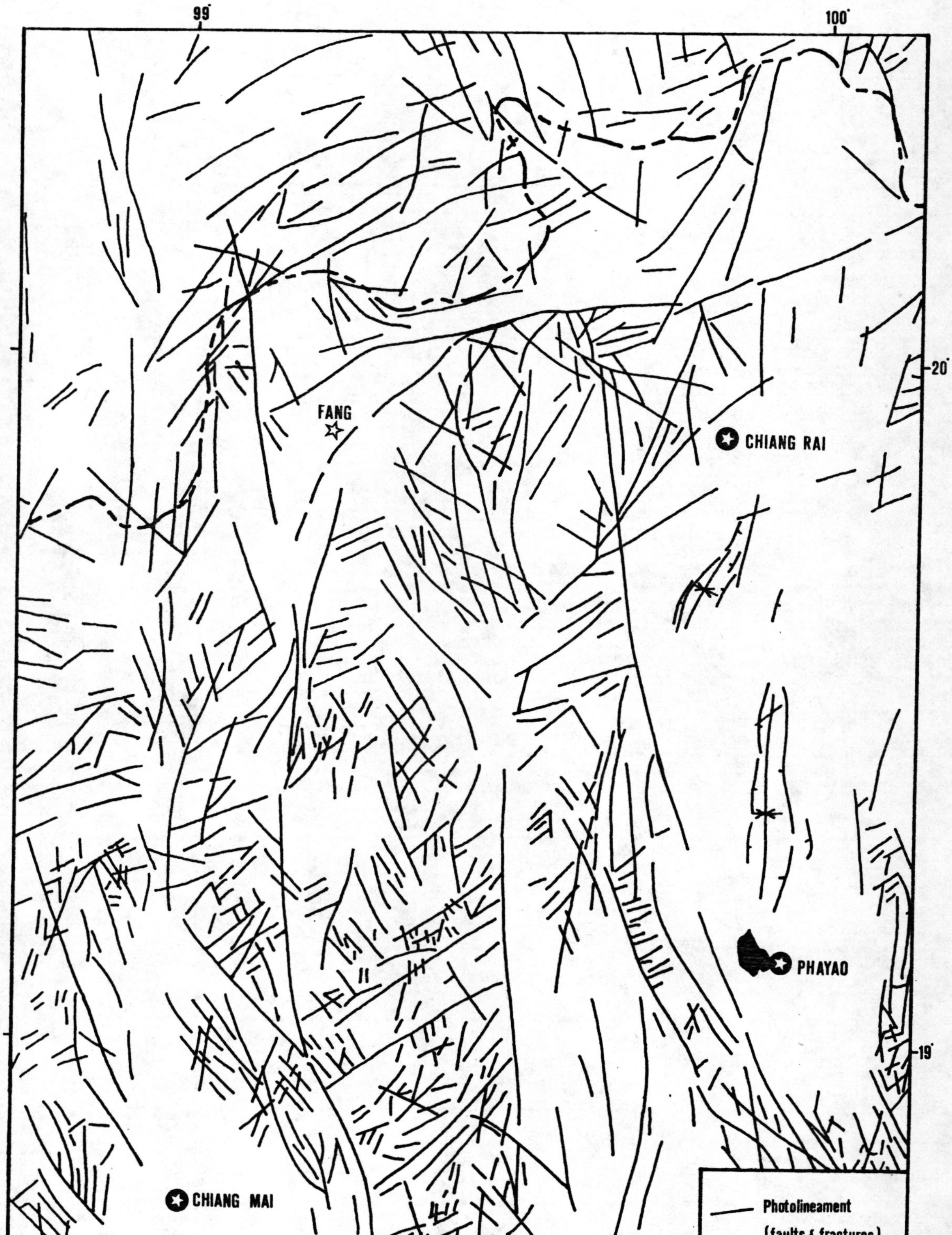

Figure 2.3.c Photolineament map of the Fang basin and adjacent areas after Aramprayoon (1981)

The Fang basin is considered to be a tilted-fault block Cenozoic sedimentary basin. Two sets of fault, notably, eastnortheast-westsouthwest and north-south to northnorthwest-southsoutheast sets, on the northern and western margins respectively, are believed to be responsible for the tilted-fault block structure of the basin.

2.4 Geology of the Fang Basin

The geology of the Fang basin and the adjacent areas were previously reported by numerous workers, namely, Lee(1923), Brown et al.(1951), GGM(1972, 1976), Chaturongkawanich, Wongwanich & Chuaviroj(1980), Chuaviroj & Chaturongkawanich(1984), etc..

There are various rocks exposed in the surrounding areas of the Fang basin ranging in age from Paleozoic to Holocene (Figure 2.4.a). The high-landed range to the west of the basin is composed of Paleozoic rocks ranging from Cambrian to Permian periods. They are both clastic and carbonate rocks, slighly to intensively metamorphosed. The degree of metamorphism appears to depend mainly on the extent of their structural deformation(Brown et al.,1975). In the area of lower part of western margin of the Fang basin, there are intercalations of sericite shale, phyllite, talcose schist, quartzite, sandstone, shale, and recrystalline limestone. These rocks lie in the north-south trend as several parallel strips in decreasing

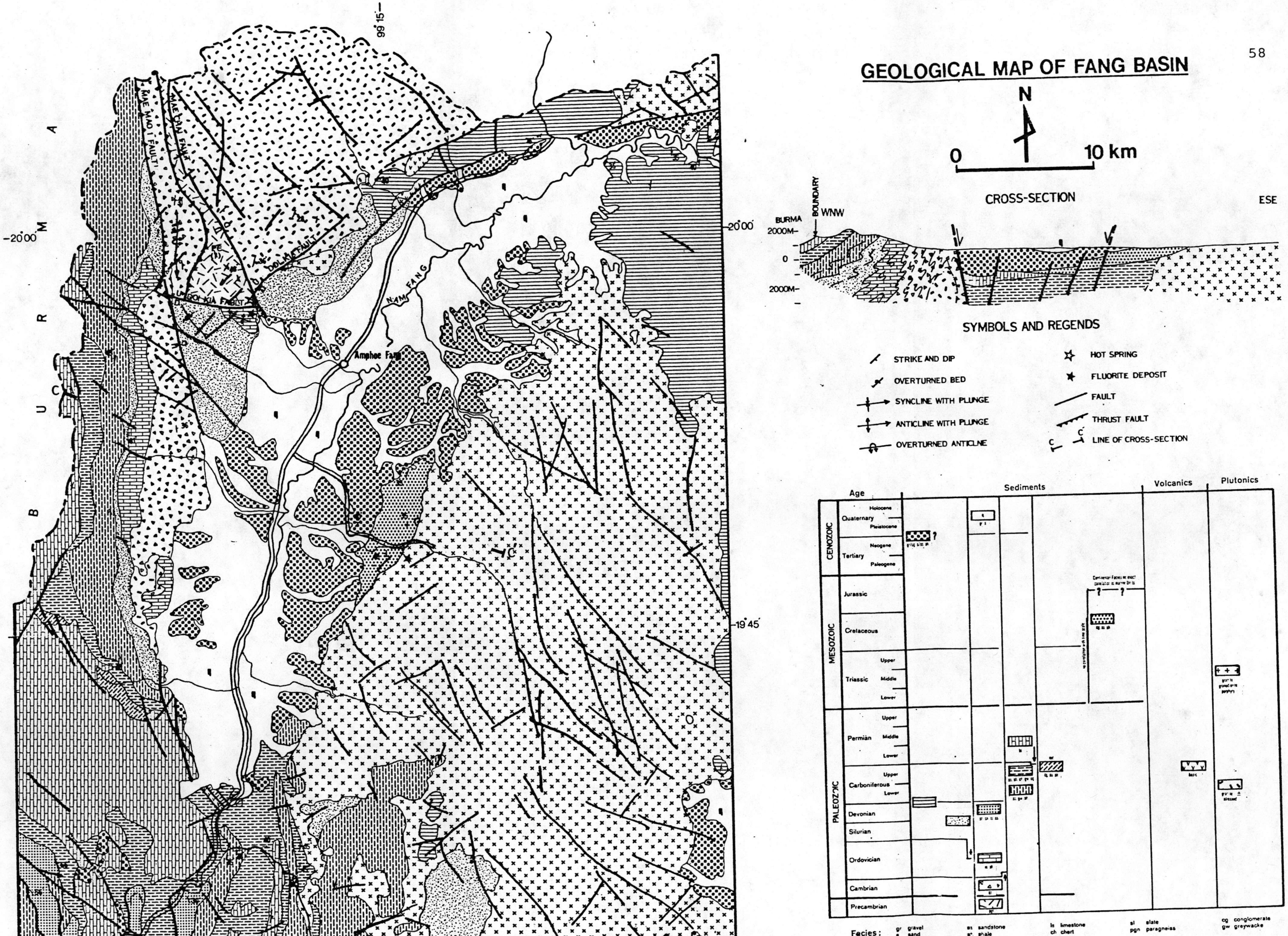

Figure 2.4.a The geological map of the Fang basin and adjacent areas compiled after GGM (1976) and Chaturongkawanich et al. (1980)

chronological order westwardly. The Paleozoic rocks are emplaced by foliated biotite granite of Carboniferous age (GGM, 1976). This granite rocks occurs in the form of small stocks and dike-like body.

The southern part of the basin is bordered by Permian limestone and clastic rocks as well as mafic volcanic rocks of Carboniferous age.

The northwestern convex side of the basin is bordered by the Carboniferous foliated granite which emplaced into the Paleozoic rocks as batholith. Further north, the basin is bordered by Devonian-Carboniferous rocks with some Carboniferous mafic volcanic rocks, and Triassic granite-granodiorite porphyry.

The eastern concave side of the basin is bordered by the Jurassic continental deposits which lie nonconformably on the Triassic granite-granodiorite porphyry. According to Lee(1927) the basal units are gray arkosic sandstones and conglomeratic grits which grade upwardly into well-bedded, medium-grained sandstone intercalated with red and gray shales. This medium- to coarse-grained biotite granite has been Rb/Sr radiometrically dated. It is 232(+ or - 31) million years (Besang et al., 1975) and 229(+ or - 32) million years (Von Braun et al., 1976).

Lying between bordering mountain ranges and the Mae Fang flood plain are belts of low-hilled semiconsolidated terrace of Quarternary age. According to Lee(1923), fossil fragments of vertebrates from the well-cutting show that the deposits are of continental origin. The alluvial flood plain of the Mae Fang is underlain by unconsolidated stream deposits which are somewhat younger than the dissected deposits of the bordering hills.

The northern margin of the Fang basin, there is one hot spring area which is situated on the Carboniferous stress granite (GGM, 1972) or on the probably Precambrian quartz biotite schist, and gneiss (Chaturongkawanich et al., 1980) near the Huai Mae Chai valley. It covers an area of about 60,000 square metres, off northwest of Amphoe Fang about 9 kilometres as shown in Figure 2.4.a. Almost one hundred of spouting pools and seeping pools manifest simultaneous year after year. The size of pools vary from the smallest with the diameter about 5 centimetres to the largest with diameter about 1 metre.

The outcrops in the hot spring area are rarely exposed, except in the southwest corner. It is composed of weathered quartz mica schist and gneiss with north-south trending . The rest of the area is covered by loose blocks or boulders of foliated granite and gneiss which were transported from the nearby mountains. The process of circulating of the thermal water in the hot spring system be driven along the fractures and fault plane of Mae Chai and Doi Khi Faults (Chaturongkawanich et al., 1980). The temperature of the surface hot water ranges from 95°C to

100° C, and the subsurface temperature is 134° C (T(NK)), 160° C (T(NKC), and 183°C (T(SiO_2)), (Ramingwong et al., 1979). The predominant chemical compositions of this thermal water area are Ca, Na, K, Si, Fe, Cl, NO_3, SO_3, whereas toxic elements are generally absent, pH ranges from 7 to 9.2 (Ramingwong et al., 1979), therefore the hot spring water is classified as sodium-bicarbonate type.

The heat sources of the Fang hot spring is not clearly understood. It, however, does not lie on the seismic belt, and there is no active volcanism in the area. The main phenomena indicating that heat sources of the Fang hot spring is believed to be associated with granite intrusion of Triassic age or the rejuvenated younger pluton. According to Chaturongkawanich(1980), the heat source is mainly from magma chamber at depth, the frictional heat along the fracture plane and the decay of the radioactive minerals in granitic plutons are also minor heat sources.

Recently, the study on radioactive elements such as uraniun and thorium from Khun Tan batholith shows a rather high heat production value of about 17 KW/square kilometre (Ramingwong et al., 1980). It may indicate the influence of radioactive elements upon the appearance of high heat flux in the Fang area. The isotopic composition of the Fang thermal area has been studied by Giggenbach in 1977, revealing that the isotopic composition of δD and $\delta^{18}O$ between thermal water and water from nearby river are very similar. This suggests that most of the thermal water of the Fang hot spring area originated from local meteoric water (Chuaviroj et al., 1984). The reservoir rock should be Upper Paleozoic sediments and/or granite rock (Chaturongkawanich et al., 1980).

At the Fang basin, there are two areas of fluorite deposits as shown in Figure 2.4.a. The eastern one is situated in the Triassic granite-granodiorite porphyry according to the geological map of GGM(1976). The geology of this area is scarcely known. The western one is situated near the Nam Muang stream, about 1.2 kilometres southwardly of the Fang thermal area. The area is underlain by gray to dark gray , thick-bedded to massive cryptocrystalline to partly crystalline Ordovician limestone with calcite veins and veinlets, some thin-bedded argillaceous and some volcanic rocks. Most andesite appears as sills intercalated with this limestone (Chaturongkawanich et al., 1980).

According to Premgamone(1980), there are two generations of fluorite mineralization, the first generation occurs as open-space filling fluorite with some rock fragments, mostly concentrated in the lower portion of the ore body, and the second generation occurs as botryoidal and concentrically layered fluorite around rock nuclei, and aggregates of fine-radiated crystals. The homogenization temperature is mostly between 251.3° to 357.2° C (mean 300.5°C) for the first one, and 60.4° to

251.6° C (mean 136.3° C) for the second one. The age of the mineralization is still problematic. It, however, probably occurs in the Cenozoic time on accounts of almost all fluorite deposits in the northern Thailand are often associated with the hot spring (thermal) areas close to the Cenozoic intermontane basins.

2.4.1 Basin Configuration

The Fang basin, generally, has a crescent shape with the longitudinal axis slightly curved in the northnortheast-southsouthwest concaving towards the northwest. The maximum width of the basin is approximately 16 kilometres, and the length of the basin is approximately 50 kilometres.

Evidences of the bouguer gravity survey of the entire basin by GSI in 1961 reveals that there are at least three separate sub-basins or depressions elongated in the basinal axis. The centres of these sub-basins are in the vicinity of Ban Pa Ngew, Ban Huai Ngu, and Ban Huai Pa Sang from the south to north, respectively. These three sub-basins have the negative gravity anomalies indicating that there are relatively thick sedimentary sequences overlying the pre-Cenozoic basement rocks (Figure 2.4.1)

In addition, the ground seismic reflection survey conducted by CGG in 1962, subsequently interpreted by Dutescu in 1980 reconfirms the configuration of these three sub-basins earlier identified. The thicknesses of

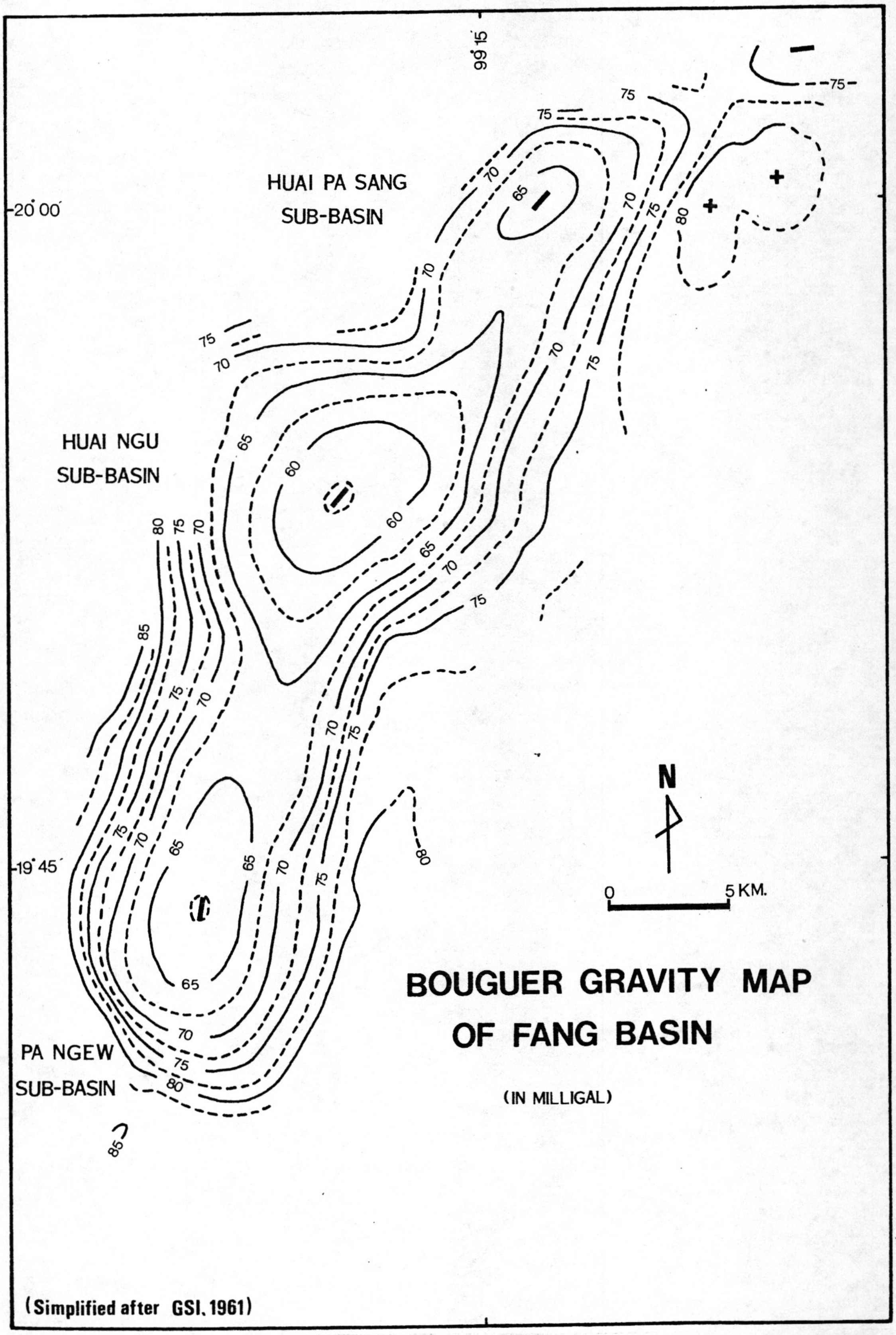

Figure 2.4.1 Bouguer gravity map (simplified after GSI, 1961) showing three sub-basins within the Fang basin.

sediment accumulations from the ground surface to the basinal basement rocks as revealed from the ground geophysical survey are estimated to be approximately less than 2,500 metres for the southern sub-basin, 3,000 metres for the middle sub-basin, and 2,000 metres for the northern sub-basin. However, the most recent ground seismic reflection survey by GSI in 1985 further reveals that the thickness of the sediment accumulation in the middle sub-basin is approximately 2.5 kilometres.

Therefore, all lines of available evidence indicate that the configuration of the pre-Cenozoic basement rocks of the Fang basin, at the present time, can be subdivided into three sub-basin, tentatively referred to in the present study as Pa Ngew sub-basin, Huai Ngu sub-basin, and Huai Pa Sang sub-basin from south to north, respectively.

Apart from the evidences obtained from ground geophysical survey, the results of the drilling exploration also indicate the depth of basinal basement from ground surface as well as the lithological characteristics of the basement rocks. Data on the drill-holes concerned are summarized in Table 2.4.a as follows:

Table 2.4.a Data from deep drill-holes penetrating the basement illustrating the depth to the basement and lithological characteristics of the basement rocks.

drill-hole number	location	Depth to basement (m.)	Lithology of basement rocks
Chaiprakarn Area			
HL-1		452.39	Quartzite and phyllite
HL-2		981.75	Quartzite and phyllite
F-11 [?]		325.00	Quartzite and phyllite
F-12 [?]		202.60	Quartzite and phyllite
F-31		314.02	Serpentinite [?]
Pong Nok Area			
IF-3-18	19° 48' 38" N 99° 12' 11" E	774.40	Plutonic rock,weathered on the top
IF-4-19	19° 49' 06" N 99° 33' 12" E	1085.36	Limestone, crystalline, ligth gray
IF-11-26	19° 48' 24" N 99° 12' 35" E	595.46	Andesite, grayish green
BS-108-11	19° 48' 38" N 99° 12' 19" E	734.45	Andesite, dark green in fresh, brown to reddish brown in weathered, very hard, fractured dipping approximately 45°

Huai Bon Area

IF-12-27	19° 56' 29" N 99° 14' 10" E	722.56	Quartzite (Ordovician), pale brown, fine-grained, composing mostly of colourless to translucent gray quartz with few of weathered feldspar, and black hornblend.
IF-17-32	19° 56' 44" N 99° 13' 40" E	669.51	Quartzite, light brown and light gray to gray , fine-grained, hard, composing mostly of colourless to translucent gray quartz.

Pa Daeng

BS-98-1	19° 54' 12" N 99° 15' 28" E	724.39	Sandstone to siltstone (Carboniferous ?), yellowish to reddish brown and grayish blue ,fine-grained, angular , well sorted, composing of colourless to translucent white quartz and dull white feldspar, with consi-

			derable interstitial clay, good porousity, cracks and joints.
BS-105-8	19° 54' 57" N 99° 25' 54" E	514.46	Sandstone & siltstone (Mesozoic ?), reddish brown to reddish purple and greenish gray, fine-grained, angular to subangular, well sorted, well cement, composing of colourless to translucent white quartz, with rare dull white-weathered feldspar, considerable amount of interstitial clay.
<u>Pa Ngew Area</u>			
BS-99-2	19° 44' 50" N 99° 13' 23" E	849.94	Granite (Triassic ?) gray, white, and some reddish brown, composing of 30-40% white, pink, and some smoky quartz, 40-60% feldspar sligthly weathered to dull white grain and slightly

			altered to greenish of fine-grained mixtures of albite and epidote, 10-20% chlorite, and alteration product of biotite, and small amuont of iron oxides from completely weathering of a few biotite grains.
BS-100-3	19° 45' 33" N 99° 11' 23" E	423.78	Granite (Triassic ?) pink, brown, and green medium to coarse-grain-ed, composing of 60-70% slightly weathered feldspar, 20-30% quartz, and 10% partly altered ferromagnesian minerals, sheared
BS-101-4	19° 45' 28" N 99° 11' 16" E	554.88	Sandstone & siltstone (Mesozoic ?) with minor conglomerate and shale, reddish brown and greenish gray to dark gray, mostly fine to medium-grained composing of quartz.

BS-102-5	19° 44' 10" N 99° 11' 16" E	538.11	Sandstone (Mesozoic ?) , pinkish gray, very coarse-grained,angular to subrounded, moderately well sorted , composing of translucent white to gray and pink to brown quartz, gray to dark gray chert, a few of weathered feldspar and granet, and Conglomerate, polymictic, light to pinkisk gray and dark gray in some parts, granule to pebble, subahgular to sunrounded, well sorted [?], very hard composing of quartz, gray chert, white feldspar, pink to red garnet, and other rock fragments, matrix composing of fine-grained paticles and white clay.

BS-58-1(?)	755.18	Limestone, crystalline gray to white, calcite vein, overlying on conglomerate, gray and green, phenoclasts composing of limestone , green shale and gray quartz, calcareous matrix [?], many calcite veins, bedding dipping about 5 to 10 , low porosity and permiability, alternating with andisite [?] and shale of at least up to 1071 metres depth.
BS-59-2(?)	1111.80	Limestone (Permian ?) white to light gray, fine-crystalline, firm tight, with 50% white, chaiky soft limestone, interbedded with shale and sandstone, calcite veinlets and fracture.

It is evident from the avialable deep drilling data penetrating through the pre-Tertiary basement that the configuration of basement rocks is more or less conformable with those obtained from the gravity and seismic surveys previously illustrated.

With respect to the lithological characteristics of the pre-Tertiary basement rocks, the drill-hole data indicate that they are of assorted types of different geological ages. The areas of Chaiprakarn and Huai Bon of the Huai Ngu sub-basin are partly underlain by Ordovician metamorphic basement of quartzite, phyllite, and serpentinite [?]. The area of Pa Daeng of Huai Ngu sub-basin is partly underlain by Carboniferous sediments of sandstone and siltstone, whereas the area of Pong Nok between Pa Ngew and Huai Ngu sub-basins, and Pa Ngew area of Pa Ngew sub-basin are partly underlain by Permian limestone. Some areas of Pa Daeng of Huai Ngu sub-basin and most of Pa Ngew area of Pa Ngew sub-basin are also underlain by the Mesozoic sediments of sandstone, siltstone ,conglomerate, and shale. In addition, the area of Pong Nok between Huai Ngu and Pa Ngew sub-basins is reported to be partly underlain by [Triassic ?] plutonic rocks and andesite. For Pa Ngew area of Pa Ngew bub-basin, it is also reported to be partly underlain by the Triassic granite.

2.4.2 Tertiary Stratigraphy

The Tertiary stratigraphy of Thailand as well as of the Fang basin has been reviewed by many authors, namely Nutalaya(1975), Buravas(1976), Gibling & Ratanasthien (1980), Snansieng & Chaodumrong(1981), Chaodumrong, Janmaha, Ukakimapan, Pradidtan, Snansieng and Leow(1983), Snansieng, Chaodumrong, Pradidtan and Boripathosol(1983).

The Cenozoic stratigraphy of the Fang basin had been first defined by Lee(1923). According to his report, it seems that he did not know whether the basin-filled sediments were Tertiary or not, and it probably belongs to Pleistocene deposits. However, it is very clear according to Lee(1927) that no Tertiary beds were known to be present in the country including the Fang basin on account of the absence of fossils to determine its age. These deposits, however, consist of interbedded gravel, sand, clay, and seams of coal.

According to Brown(1951), the Fang dedosits consist of fluviatile and lacustrine sediments of late Tertiary or Quaternary age.

The term "Mae Sot Formation" which appears in general usage was first used in the report of Brown et al.(1951) to represent the Tertiary rocks of semiconsolidated fluvialtile and lacustrine sediments in the north of Thailand after the deposits in Mae Sot basin.

According to Sherman(1956), the Mae Sot Series was first used in the Fang basin representing the late Tertiary deposits of fluviatile, lacustrine, deltaic(?), and lagoonal(?). He classified the stratigraphy of Fang deposits at the Chaiprakarn area as follows:

Table 2.4.2.a Stratigraphy of the Fang basin (Sherman, 1956)

Geochronology	Time-rock units	Description
Quaternary	Terrace	Gravel, sand, silt, etc.
late Tertiary	Mae Sot Series	Loose sand, fine to coarse-grained gravel or conglomerate clays and clay shale, lignite, aphaltic sand, and oil sand (900 metres thick)
	Unconformity	
Jurassic	Khorat Series	Gray arkosic sand and conglomerate grading upward into well-bedded, medium-grained red sandstones interbedded with gray and red shales containing marl and concretionary limestone nodules non-marine or continental bed (500 meters thick)

According to the report on the geology of the Mae Fang oil field by the Refining Associates of Long Beach , California (RALB), during the contract period of August 17, 1958 through August 19, 1959, it was suggested that the correlation of the section of the Fang and the Mae Sot basins was very loose as without any fossil evidence or continuity. However, since the two basins have the feature of being oil-bearing and similar relatioships to the older rocks, the name was used in referrence to the Fang section which contains the productive member of the Fang oil field, particularly regarding the Chaiprakarn Sand. They continued to state that in previous works, the entire section below terrace deposits had been referred to as the Mae Sot Series, as a result of their study it had been found that the upper portion is composed of a series of cross-bedded channel sands and clay which unconformably overlies the Upper Clay Shale Member of the Mae Sot Series which conformably overlies the Chaiprakarn Sand Member. This bunch of channel sands would be called the Mae Fang Formation. The stratigraphic classification is shown below:

Table 2.4.2.b Stratigraphy of the Fang basin (RALB, 1959).

Geochronology	Rock Units	Description
Quaternary	Terrace	Terrace sand and gravel, allluvial fans, etc.
	Unconformity	

Age	Formation	Member	Description
Tertiary (Miocene- Pliocene)	Mae Fang Formation		Predominantly arkosic sand, gray, fine to coase to conglomeratic poorly, to fair sorted, angular to sub-rounded, cross-bedded. Clay and clay shale, gray, interbedded with above sand but minor constituent. Occasional asphalt/tar sand. Regard it as fluviatile deposits. Thickness 90 to 600 feet (possibly 1800 feet in the central valley)
			_ _ _ _ _ _ _ Unconformity _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _
	Mae Sot Formation	Upper Member	Clay and clay shale, gray, blue gray to chocolate brown, brittle to plastic and soft, occasionally asphastic and oil sand; the lower the more organic, lignite [coal], colour change to gray, tan, and brown harder and brittle in places, a few fresh water gastopods, fragment of fish teeth, plant leaves, and reed stems, Thickness up to 300 feet or more.
			.....Gradational facies change or diastem.....
		Lower Member (Chaiprakarn Sand)	Predominantely arkosic sand, gray, fine- to coarse-grained,occasionlly pebbly sand and/or conglomerate. Generally clean, porous and permeable sand with gradational

variation in the producing zones, the upper portion of this member interbedded with gray clay and clay shale of 6 inches to 10 feet thick.

. . . .

Below the oil zone, sand becomes very kaolinitic and clayey with more variable in character with depth and to the east of producing area. Thickness up to 900 feet. this formation had been regarded as lacustrine deposits.

_ _ _ _ _ _ _ _ _ _ _ _ Unconformity _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

Khorat & Kanchanaburi Series

Buravas(1970) who stated that the discovery of Oligocene oil shale and mature lignite of Fushun age [?] at Li, Changwat Lumpoon since 1961, had proved decidedly that sediments were deposited through Tertiary Period. His stratigraphic classification can be summarized below:

Table 2.4.2.c Stratigraphy of the Fang basin summarized from Buravas(1970).

Geochronology	Time-rock Units		Description
Pleistocene	Mae Fang Formation	Upper [part]	Boulder and gravel with elephant remain at it base, thickness more than 200 feet.
		Lover [part]	Arkosic sand with carbonized

			interbedded with blue and brown clay, not well consolidated, thickness nearly 1,000 in the Mae Soon area.
		Transitional zone	Arkosic sand and dark sandy clays, dark lignite[fragment?] (appear suddenly) 300 to 400 feet
Neogene (tentative Miocene-Pliocene)	Mae Sot Series	Mae Sot Shale & Clay Member	Dark mudstone, clay, sandy clay with lignitic coal, shale (calcareous cement)
		Chaiprakarn Sand Member	Sandstone, pebbly sandstone with cross-bedding, about 310 feet in thickness.
		Mae Moh Member	Gray sandy shale, Viviparous and (15 to 30 feet) thick lignite [coal] bed, thickness 200 to 240 feet [may be similar to Li Series ?].
Oligocene	Li Series		Brown organic clay shale carrying thin beds of mature lignite and and thin-bedded intercalated sandstone, some oil-bearing, may be some oil shale, 300 to 400 feet at Mae Soon area.

Probably early Tertiary, Paleocene	[Basal conglomerate]	Conglomerate of older rocks such as clayey conglomerate of pebble to boulder of Permain limestone, red Khorat sandstone, shale, about 400 - 500 feet thick (at 117-118 kilometres Chiang Mai -Fang Highway)
	Unconformity	
	Khorat Series	Conglomerate, red sandstone, red pebbly sandstone and shale

Buravas(1973b) in his study on the succession of rocks in Fang and Chiang Mai areas has shown that the sequence of Cenozoic deposits, not only of the Fang and the Chiang Mai areas, but also of other areas is as follows:

Table 2.4.2.d The Cenozoic sequence of the Fang and Chiang Mai area (Buravas, 1983b)

Geochronology	Rock Units	Description
Recent	Chao Phya Formation	Including 164 feet of saline sands, pebbles, and clay overlain by 75 feet thick of saline Bangkok Clay ,marine shalls and mangrove plant remains
Pleistocene	Mae Fang Formation	composing of 2,000 feet of alter-nating blue and brown clay with

		thin-bedded arkosic sand with oil seep at the base. This basal unit is overlain by 225 feet of arkosic sand, and blue and yellow clay with carbonized wood together with 200 feet of white arkosic sand and clay, it is overlain by 200 feet of terrace pebble and on the top.
Pliocene	Mae Sot Formation	contains 350 feet of Chaiprakarn Sand Member at its base, and 900 feet of dark clay and shale with streak of lignite and interstitial sand bed in the middle, followed by 300 feet of arkosic sand alternating with dark clays and streak of lignite on the top.
Miocene	Mae Moh Formation	composing of calcareous mudstone, shale and thin-bedded Viviparous limestone. Lignite beds are over 100 feet thick at the Mae Moh basin , its total thickness is about 240 feet.
Oligocene	Li Formation	composing of oil shale, mature lignite, shale and sandstone at the Li basin; at the Fang basin, this formation consists of brown organin clay shale, thin-bedded mature

		lignite, thin-bedded sandstone with oil impregnated, it is about 360 feet thick.
Paleocene	Nam Pat Formation	composing of Conglomerate of pebble , cobbles, and boulders of red sandstone, red shale, diabase, quartz, marble, quartzite and schist, with sandy clay cement [?]; red shale and dark shale occur at the base, thickness is 600 feet.

According to Piyasin (1979) who has been more engaged in the Pong Nok and the Mae Soon oil pools, had described many stratigraphic aspects which can be summarized in Table 2.4.2.e:

Table 2.4.2.e Stratigraphic classification of the Fang basin (Piyasin, 1979).

Geochronology	Rock Units	Description
Pleistocene	Mae Fang Formation	Upper part is composed of gravel, sand and clay; the lower part is composed of shale and intraformational basal conglomerate with of the Mae Sot shale phenoclasts.
	Unconformity	
Tertiary	Mae Sot Formation	Gray shale, arkosic sand, lignite, and the lower part is composed of sandstone, reddish brown to bluish

gray and green shale overlying the basal conglomerate of the older rocks (at the central part of the basin).

_ _ _ _ _ _ _ _ _ _ _Unconformity_ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _ _

According to Dutescu and Enache (1980) the stratigraphy of the Mae Soon oil pool at thattime can only be divided into two obscure distinct formations, notably:

a) The Upper Formation: predominantly made up of sand, argillaceous sand, gravel and conglomerate interbedded with thin bunch of clay.

b) The Lower Formation: where porous rocks are subordinate and intercalated in argillaceous section, sometimes are oil saturated.

According to Dutescu and Enache (1980) at the Pong Nok oil pool the simple stratigraphy had been divided as follows:

a) The Arkosic Sand Formation: made up of arkosic sands usually with coarse grain of gray colour; the component elements are quartz, feldspar and some mica. At the same intervals there are intercalation of gravel which is included in argillaceous matrix.

b) The Upper Petroliferous Formation: is made up of an alternative of sands, sandstone beds with argillaceous beds. Sometimes sand and sandstone beds can be traced to the great extension, but sometimes they lateraliy change into shale or other types of siltstone. The size of sand range from fine to coarse grained with different grading.

c) The Carbonaceous and Bituminous Shale Formation: is made up principally of shale and coal bed; between those shale and coal there are intercalation of sand of different thicknesses.

d) The Lower Petroliferous Formation: underlying the carbonaceous and bituminous shale formation is made up in the upper part of a bunch of clay then the granulation increases gradually and finally passing into coarse sand. This formation overlies the basement.

According to Dutescu (1981), the bore-hole stratigraphy of IF-12 Well of Huai Bon area had been divided into two formations as below:

a) Mae Fang Formation: (0-440 feet) consisting of yellow to brownish clay and sandy clay, alternating with blue and brown clay and sandy clay and arkosic sands with small percentage of carbonized wood. The lower part of the Mae Fang Formation is predominantly made up of blue to gray shale alternating with thin-bedded arkosic sand.

b) Mae Sot Formation: preliminarily divided into three members:

b.1) Upper Clay Member: (440-1324 feet) fairly uniform in lithological character throughout the section, consisting of clay and sandly clays, dark gray to blueish gray with some interbedded quartzite [? quartzitic] sands which are predominant mainly in the lower part. The clay are fossiliferous, however, the microfossils are pooly preserved and usually weathered.

b.2) Middle Red Clay Member: (1324-2041 feet) lies conformably upon the Lower Shale Member and consists of red, greenish yellow and mottled bluish gray clay, silty clay, poorly bedded, sometimes micaceous. Within this clay medium- to coarse-grained, poorly sorted, pebbly sandstone, quartzitic sanbd and sandy clay beds occurs.

b.3) Lower Shale Member: (2041-2373 feet) overlies unconformably the basement, consisting of dark gray shales with some interbedded quartzitic sand.

Snansieng et al. (1983) had presented composite stratigraphy of Cenozoic sediments in the Fang basin compiled from Buravas (1973), Piyasil (1981), and Vella (1983) in Table 2.4.2.f

Table 2.4.2.f Stratigraphy of the Fang basin (Snansieng at al. 1983)

Geochlonology	Rock-Unit	Description
Holocene-Upper Pleistocene	Alluvium Terrace	Unconsolidated gravel, sand, silt, clay, 300+ metres thick
Lower Pleistocene	Mae Fang Formation (? Mae Tang Formation)	Sand, silt, clay Basal conglomerate, 300+ metres thick
Neogene (Pliocene-Miocene)	Mae Sot Formation (? Mae Moh Formation)	Gray shale, arkosic sand, lignite, and sandstone (petroleum source and cap rocks), 2,000+ metres thick

According to Sethakul et al. (1984) and Sethakul (1985),the lithostratigraphy of the Pong Nok area can be classified as in Table 2.4.2.g.

Table 2.4.2.g The lithostatigraphy of the Pong Nok oil pool (Sethakul et al. 1984) and Seṭhakul (1985).

Geochronology	Rock-Unit	Description
Recent-Pleistocene	Mae Fang Formation	Lateritic sand, loose sand, arkosic sand, gravels, yellowish brown and grayish blue in colour, poorly sorted, angular, with carbonized wood and lignite through depth, 150

			to 1250 feet thick.
Tertiary	Mae Sot Formation	Upper Mae Sot Member	Light brown to light gray shale, Viviparous, insect remain, lignite fragment, interbedded with thin-bedded siltstone, 600 - 1230 metres thick.
		Middle Mae Sot Member	Gray shale, interbedded with sandstone at the middle level, at the lower part found insect remain, Viviparous, and lignite fragment, 830 - 1260 metres thick.
		Lower Mae Sot Member	Thick lignite seem up to 75 feet on the top, sandstone 8 - 9 cycles, each 5 - 15 feet thick, interbedded with brown shale and siltstone (up to 1650 feet thick.

Sethakul (1985) has also classified the lithostratigraphy of the Mae Soon oil pool which can be summarized in Table 2.4.2.h as below:

Table 2.4.2.h The lithostratigraphy of the Mae Soon area (Sethakul, 1985)

Geochronology	Rock Unit	Description
Recent - Pleistocene	Mea Fang Formation	Soil, lateritic sand about 20 feet on the top, loose sand, coarse- to

		very coarse-grained, angular to sub-angular, mixed with gravel (pebble to cobble), poorly sorted, with feldspar 5 per cent, fragments of carbonized wood, interbedded with yellow and grayish blue clay. It represents the energetic alluvial and fluvial deposits. 1100 to 1500 feet thick.
Tertiary	Mae Sot Formation	Shale, claystone, fine-grained sandstone interbedded with sandstone 2 - 5 cycles, each 1 - 30 feet thick, the lower part dominant with shale, up to 3,500 feet or more in thickness.

It is interesting to note that the stratigraphy of the Fang oil field had been classified only in each separate oil pool. The correlation of these oil-bearing and oil-barren areas have scarcely been done. Moreover, it seems that the useful concepts of sedimentary facies as well as depositional environment are obviously proved to be the most valuable tool in the exploration criteria have been insufficiently recognized in the past.

2.4.3 Paleontology and Age Indication

According to Lee(1923), leaves, teeth, and small plants (probably of turtles) at the depth of 50 feet; small bones of mainly vertebrates, and teeth of small animals embedded in clay at the depth of 555 feet; were fould in the drill-hole cutting in the Chaiprakan area, somewhere next to Boh Luang Well. He, however, was not sure whether it belonged to Tertiary or not.

The Fang basin was regarded as late Tertiary or Quaternary in age for the first time by Brown et al.(1951).

In 1952, Vija Sethabut sent some megafossils from Chaiprakarn area of well HL-3 of 1000 - 1028 metres depth of the Fang basin to be identified by Gardner, the U.S. Geological Survey. The fossils are probably Naticoid or Viviparous of early Tertiary to Recent in age (Gardner, unpublished data).

According to fossils collected by Wallace Lee in 1921-1922 which were identified and assigned to late Tertiary by Sherman(1956). This is the first time that the Fang basin is assuredly known as Tertiary basin.

According to the report on Geology of the Mae Fang oil field by the Refining Associated of Long Beach, California, in 1959, some fossils had beenfound, namely fresh-water gastopod, fragment of fish teeth, plant leaves, and reed stems in the Upper Shale Member of the Mae Sot Formation.

In 1968 the palynological investigation by Miss Vanunee Buyannanonda from the Department of Geology, Chulalongkorn University, revealed that the pollens and spores are

Microhenrici

Henrici

Coryphaeus

Salix

Pollenites fallax, and

Pinus Hapoxylon

the Oligocene Epoch has been assigned to them(Buravas, 1973, 1975).

In 1968, the palynological investigation by Dr. P.R. Evans from the Department of Mineral Resources, Canberra, Australia, has also discovered plant remains, resin, conidiophores of mold families, spores of ferns, and plant pollens of 1860 depth of drill-hole BS-85-28. These indicated the Oligo-Miocone Epoch (Buravas, 1975).

According to Snansieng et al.(1983) cited the writing of Hahn and Siebenhuner(1982) that in their explanation notes (paleontology) on the geological maps of Northern and Western Thailand in the 1:250,000 scale, reported that the identification of fossils collected from the eastern rim of the Fang basin as:

Quercus sp. Carya

Ulmus (Zelkora and Celtis type)

Combretaceae

with an age not older than Upper [late ?] Miocene and probably Quarternary by H. Muller in 1970.

According to Buravas(1970), elephant remain had been found somewhere of around 200 feet deep in the Mae Fang Formation. And according to Buravas(1975) the Mio-Pliocene Epoch had been assigned to the Fang basin deposits on account of the comparison the Fang coal to that of other basins. Besides, carapaces of insects, imprints of high plant leaves and of reed plant, Viviparous, and Unio had also been found in the Fang basin.

In 1984, Professor Dr. M. Streel from the Leige University, Belgium, as preceeding mentioned under the heading 1.4, found some spores and pollens as :

Tricopites

Tricoporite

Appendicisporites tricornitatus

Spinozonocopites cf. echinatus, and

Rugubivesiculites sp.

and the Senonian Epoch or Paleogene Period is proposed for them (Ratanasthien, 1984).

2.5 Geological Evolution

Nowadays, Southeast Asia is situated in the southern part of the Eurasian Plate, the western part of the Philippine Plate, and a part of the Pacific Plate to the east, according to Plate and Plate Boundaries of the world (Derry, 1980). Southeast Asia is really a part of the Asian composite continent (Kropttin, 1927; Dickenson, 1973; Burrett, 1973 and 1974). Most recent authors divided mainland Southeast Asia into three major blocks, namely, the Western Burma Block, the Shan-Thai Block, and the Indochina Block (Burrett, 1974 and 1986; Bunopas, 1981; Gatinsky et al., 1978; Hutchison,1975; Mitchell, 1984; Ridd, 1980; Stauffer, 1974). Thailand is a part of the Shan-Thai Block and a part of the Indochina Block, on the western and on the eastern parts of the country, respectively. The sutured boundary between the Shan-Thai and the Indochina Blocks is taken as the Pha Som-Sra Kaeo ophiolite belt in Thailand.

An early Paleozoic placement of the Shan-Thai Block against northwest Australia (Australian Gondwanaland) has been proposed by many authors (e.g. Bunopas, 1981; Bunonas et al., 1983; Burrett & Staitt, 1986; Ridd, 1971; Webby, 1978). It is nearly believed that the Indochina Block was also a microcontinental fragment of Australian Gonwanaland in the southern hemisphere during the Precambrian to lower Paleozoic.

According to Bunopas et al. (1983), during middle Paleozoic to early Triassic the Shan-Thai Block and Indochina Block rifted and drifted to the Paleotethys. They moved from a low latitude southern hemisphere to a low latitude northern hemisphere position, while had been rotating nearly 180 degree clockwise in the horizontal plane, during early Carboniferous to early Traiassic. During the middle Triassic the Shan-Thai Block sutured to the Indochina Block trended to underthrust the Shan-Thai Block. Contraly to this view, it seems to Burton (1984) that the Shan-Thai and the Indochina Blocks were probably in contact by middle to late Permian times.

For the other school of thought, it is suggested that the Shan-Thai Block [as well as the Indochina Block] was never a part of Gondwana, and was never divided from Paleo-Eurasia by a wide ocean terrain, Paleotethys, (Helmcke, 1983). Recent investigation found evidence that the true geosyncline history, closure of the Paleotethys or one branch of the Paleotethys, of Southeast Asia region ended during a Late Variscian Orogeny approximately at the middle Permian (Helmche, 1983, 1984, 1985, and 1986). It seems likely that this event accords with the first peak of the latest Permian - early Triassic Indosinian I Orogeny of Fontaine and Workman (1978). And the well-known Triassic Deformation, Indosinian Orogeny, in the northern Thailand is only interpreted as strictly intracontinental (reactivation) and of minor importance (Helmcke, 1983,1984

, 1985, 1986).

This subject is still controversial, and left to be proved. After the major orogeny, Late Variscan Orogeny and/or Indosinian Orogeny, however, mountains arose along the suture (paticularly along the overthrusting Shan-Thai Block margin). At the same time or soon after, granite intruded to high levels in the sediments [at the eastern and as well as northwestern ? margins of the Fang basin, Ladinian-Carnian granite emplaced into the Paleozoic rocks], and extensive rhyolite extruded on the land surface. The Indosinian Orogeny terminates marine deposits on Thailand territory almost permanently. The mollasse deposits also took place on the both sides of the suture, at the Fang basin the post-Carnian and pre-Tertiary depoisits on the Shan-Thai Block have been found, but mostly developed in the Khorat basin on the Indochina Block.

During Jurassic and Cretaceous, the tectonism was mainly sinistral strain manifested by the Mae Ping and Kwae Noi [or Three Padodas] strike-sliped faults which ceased moving in late Cretaceous or in early Tertiary (Bunopas et al., 1983b).These sinistral strike-sliped faults dislocate the main geological province of Thailand, and their trends were modified by sinistral orodinal bending that appears to be associated with these faults (Chaodumrong, 1985).

The northwards drift of the Indian Plate resulted in subduction along the eastern margin of the present Bay of Bengal, opening of the Andaman Sea, initiation of the Andaman-Nicobar chain, and opening of the Indian Ocean (Tanasithipitak, 1978; Bunopas et al., 1983b). The tin-bearing Cretaceous granites were probably resulted from this phase of subduction (Bunopas, 1983). The effects on the Himalayan Orogeny on the Indosinian were also found as the form of broad regional folding and block fault [?]; and it was probably during the late stage of tectonic activity, in Paleocene or early Eocene, that the emplacement of the Tertiary granite took place (Chaodumrong, 1985). This phase of granite intrusion can be regarded as post-orogenic and is generally found as dikes, stock, or sub-batholiths superimposed on the pre-existing granites (Suensilpong et al., 1979).

But according to Helmcke (1984), the drift of the Indian part of nowadays Indo-Australian Plate towards the north and it collision with the Paleo-Eurasian Plate is the most severe event during Cenozoic time. Molnar and Tapponnier (1975) demonstrated that the collision generated movements of composition along huge strike-sliped faults; especially the eastern part of Paleo-Eurasia evaded towards the east. As a result of these movements Southeast Asia started to rotated clockwise (Hamilton, 1979;Bannert & Helmcke, 1981; Trapponnier et al., 1982). This rotation centred around a point which is situated somewhere in area of Assam. It is very likely that this rotation caused the formation of the graben strutures (extensional tectonics) in Thailand during Tertiary times; and it is even more important to stress the point that the structures of mainland Southeast Asia were not north-south trending in pre-Tertiary times but more or less west-east (Helmcke, 1984, 1985).

According to the school of Gondwana, the India collion may have put a stop of clockwise motion of South China [as well as mainland Southeast Asia] (Bunopas et al. 1983b). Certainly the twisting stress disappeared, Southeast Asia relaxed, on its western side gentle basin began to develop. During Tertiary, a tensional regime developed and a system of north-south trending faults appears. The faults are nearly parallel to the present-day motion of oceanic crust descending beneath Indonesia along Java trench. Tension probably started in the south with the opening of the Gulf of THailand. Then faults extend northwardly into northern Thailand. Rifting was east-west, at right angle to the trend of normal faults.

According to the study of Tertiary Mae moh basin by Vella (1983)in Norhtern Thailand, he found that the Mae Moh basin was formed by post-middle to late Miocene normal faulting. Other basins in Northern Thailand, some much larger than the Mae Moh basin, were probably formed at the same time and in same tensional regime. And he suggested that the regional structure of Northern Thailand seems to be like that of the northern half of the Gulf of Thailand.

According to Knox and Wakefield (1983), the Tertiary basins of Thailand were probably initiated on an eroded pre-Tertiary surface with varying degree of topographic expression during Paleogene time [Oligocene]. As in the Phitsanulok basin, the basin fill consists of Oligocene to Lower Miocene alluvial clastics with local development of lacustrine facies which was followed by wide spread of Lower to Middle Mioecne lacustrine facies (also in other basin). During middle Miocene time, major tectonic and/or climatic change result in the disappearance of the paleo-lake as indicated by K/Ar radiometric age (10.3+or-0.2 million years) of the basaltic lava provides a dating for the shallow basin-wide unconformity. Other onland basalt which is found on Ko Kut Island, eastern Gulf of Thailand, dated as 8.5+or-o.1 million years (Bignell and Snelling, 1977; Barr & Macdonald, 1981). The middle Miocene unconformity is also cleary identifiable in the Gulf of Thailand (Woollands & Haw, 1976; Lian & Bradley, 1986). It appears that the unconformity represents a major episode of uplift which is followed by an influx of coarse clastics. Afterthat, the present-day topography of Northern Thailand has been determined by the late Tertiary and/or Pleistocene events such as normal faulting and uplifting (Baum et al., 1970).