CHAPTER II

REGIONAL GEOLOGICAL SETTING

The whole Thailand (Figure 2-1) was constructed by adjoining of two paleo-microcontinents named "Shan-Thai" in the west and "Indochina" in the east (Bunopas, 1978, 1981;Gatinsky et al., 1979; Mitchell,1981; Piyasin, 1991; Polachan and Sattayarak 1989, 1991).The Shan-Thai microcontinent is believed to be detached from the Australian Gondwanaland in early Permain (Bunopas, 1981; Waterhouse, 1982) whilst the Indochina microcontinent drifted away from the Australian Gondwanna at earlier period probably during Devonian (Bunopas, 1981; Metcalfe, 1990). Stratigraphic sequences of the Shan-Thai terrane underlie successively by Precambrain granitoids and high grade metamorphic rocks, Paleozoic and Mesozoic sedimentary and low grade metamorphic rocks (Bunopas,1981; Fontain1986). While the Indochina terrane consists of mainly Paleozoic rocks and Permain platform carbonate and deep-water clastic rocks (Wiclchowsky and Young, 1985). It is subsequently covered by gently folded Mesozoic continental sedimentary sequence of the Khorat Group.

During the Middle Triassic Shan-Thai microcontinent sutured to Indochina and South China microcontinents(Bunopas and Vella, 1992). The continentent-continent collision formed at the culmination of the Indosinian Orogeny which had begun with the Indochina tended to underthrust the Shan-Thai. This westward subduction beneath Shan-Thai, prior to collision, was also proposed by several workers, i.e., Asnachinda (1978), Barr and MacDonald (1987), Bunopas (1981), Bunopas

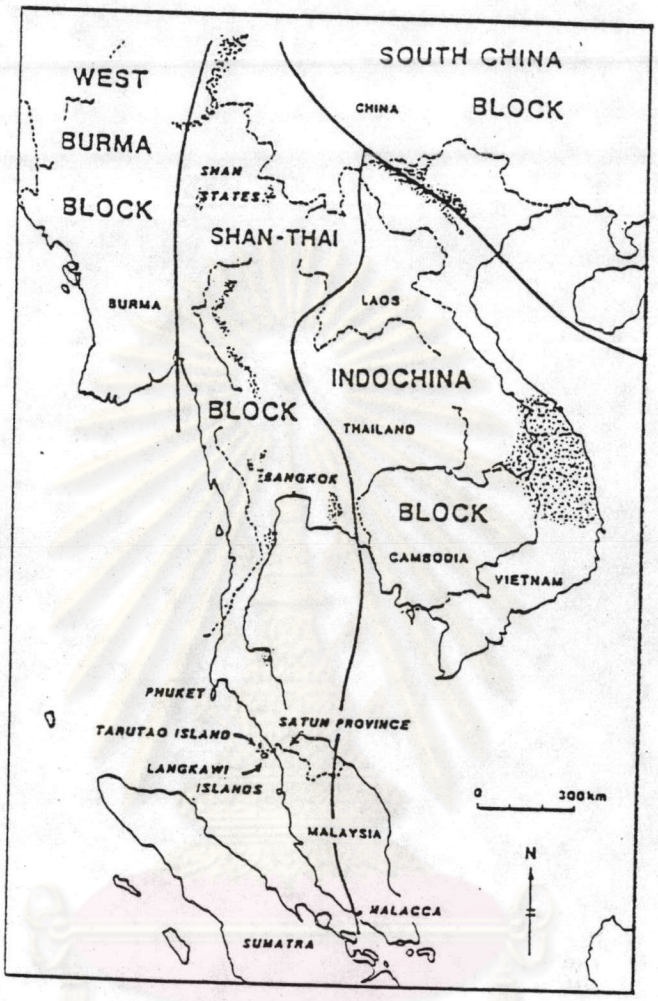


Figure 2-1 Map showing two adjoined paleogeographic microcontinents, Shan-Thai and Indochina blocks, with some distribution of Precambrian outcrops (after Bunopas and Vella, 1992).

and Vella (1978),Chantaramee (1978), and Sengor (1984). Geological evidences cited by them are based on the wide distribution of volcanic rocks in central north Thailand and on the eastward structural divergence. However, Beckinsale et al.(1979) and Cooper et al. (1989) suggested eastward subduction of the Shan-Thai beneath the Indochina by basing on the position of the S-type and the I-type granitic intrusions.

The welded boundary between the Shan-Thai and the Indochina terranes is known as the Nan-Chanthaburi Suture Zone (Hada et al., 1991) or Nan Suture or Nan-Uttaradit Suture (Barr and MacDonald, 1978). This suture zone was a mobile area of repeated orogenic movements since the Paleozoic (Burri, 1989) to the late Triassic (Bunopas, 1981;Chaodumrong, 1992). However the time of suturing is still problematic and has been suggested in varying opinions.These are Devono-Carboniferous (Altermann,1991 ; Hahn et al., 1986), middle to late Carboniferous (Wolfort, 1987),middle Permian(Helmcke, 1985;Helmcke and Lindenberg, 1983),late Permian(Burton, 1985), late Permian to early Triassic(Cooper et al., 1989;Piyasin, 1991; Sattayarak, 1985;Thanasuthipitak,1978), early Triassic (Metcalfe, 1990),middle to late Triassic (Bunopas and Vella, 1978, 1983,Gatinsky et al,1978; Hada, 1990; Panjasawatwong, 1991), and even middle-late Cretaceous (Audley-Charles, 1988).

After the collision, mountains arosed along the suture, particularly along the overthrusting Shan-Thai margin, and at the same time granites were intruded to high levels in the sediments, and extensive rhyolites

were extruded on the land surface. Erosion of the mountains produced mollasse doposits (mostly alluvial plain red-beds)which occur on both sides of the suture, but are most fully developed in the Khorat Basin that formed on the underthrusting west side of the Indochina continent(Bunopas and Vella, 1992).

Bunopas (1992) subdivided Thailand based on major pre-Jurassic stratigraphic belts into seven belts;BS-1, BS-2, BS-3, BS-4, BS-5 and BI-6, BI-7 (Figure 2-2). The belts BS-1 to BS-5, located on the Shan-Thai Craton (Terrane),represent the ancient passive margin,the cratonic area,and the active margin of the accumulation of the Middle Paleozoic to Triassic strata,whereas the belts BI-6 and BI-7 represent the sites for the deposition of Middle Paleozoic to Triassic strata on the western margin of the Indochina Craton. The belts BS-4 and BS-5 are called the Sukhothai Fold-Belt of the Shan-Thai, and the belt BI-6the Loei Fold-Belt of the Indochina. Combined fold-belts of the Sukhothai and the Loei is equivalent to the Central Fold-Belt (Bunopas,1981) or Central Province of Thailand(Bunopas, 1992 ;Bunopas and Vella, 1992) (Figure 2-3). Figure 2-3 also shows that belts or provinces are dislocated by two strike-slip faults, Mae Ping and Three Pagodas, in the sinistral fashion during the Neotectonic stage (Polachan et al.,1991).

The Loei area is located in the northern portion of the Loei Fold-Belt which runs approximately from Chiang Khan via Loei to west of Chum Phae.

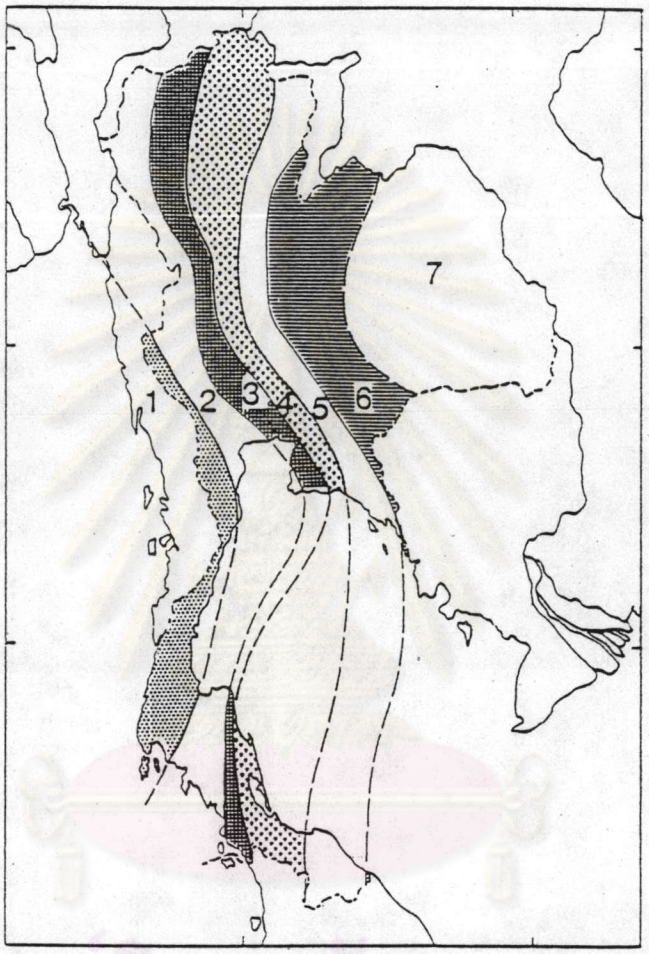
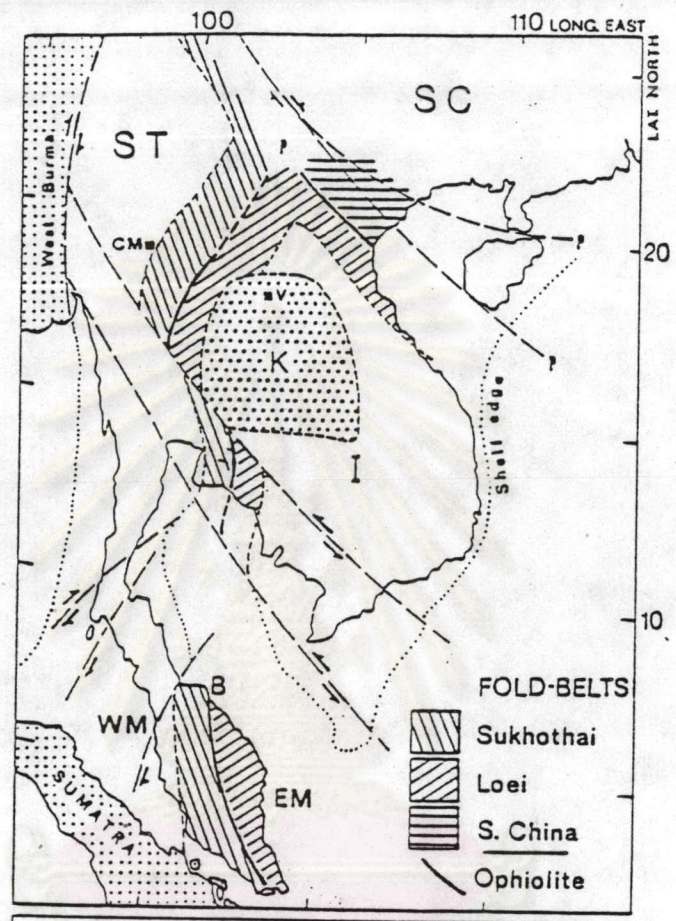


Figure 2-2. Seven stratigraphic belts of Thailand. Belts 1-5 on Shan-Thai and 6-7 on Indochina terranes (after Bunopas, 1992).



Ancient cratonic areas; I, Indochina (including eastern Thailand); SC, South China and ST, Shan-Thai (eastern Burma, western Thailand and Northwestern Malay Peninsula). Adjacent fold-belts are formed of thick mainly marine Paleozoic to Triassic sediments and tholeitic volcanic rocks that accumulated along the margins of the cratons. Ophiolites lie between contiguous fold belts. Sinistral faulting and oroclinal bending occurred mainly during the Jurassic and Cretaceous. K, Khorat Basin; CM, Chiengmai; V, Vietiane; WM, West Malay Peninsula; EM, East Malay Peninsula; B, Bentong ophiolite line.

Figure 2-3. Map showing major geological features and crustal structures of Southeast Asia (after Bunopas and Vella, 1992).

General geology of this area may be generally divided into three major rock sequences (Figure 2-4). They are, i) the pre-Permo-Triassic (Paleozoic) sequence, ii) the Permo-Triassic sequence and, iii) the post-Permo-Triassic sequence. Figure 2-5 is geologic map of Loei-Chiang Khan area published by Royal Thai Department of Mineral Resources in 1984 while Figure 2-6 is unpublished geologic map of the DMR. It is clearly seen from these two figures that the pre-Permo-Triassic sequences are generally metasedimentary rocks of two main separated subsequences,the Silurian-Devonian to Lower-Upper Carbonifereous subsequence and the Lower-Middle Permian subsequence. The Permo-Triassic sequences are calc-alkali igneous rocks(Pongsapich et al., 1981).The post-Permo-Triassic sequences are the Mesozoic sediments which unconformably overlie the folded sediments of the Late Paleozoic (the Permo-Carbonifereous).

The Silurian-Devonian strata (SD) (Figure 2-6) in the Loei area are referred to as the "Hard Khum Bhee Formation" (DMR , 1987 ; unpublished report) or as the "Na Mo Formation" (Bunopas, 1992). Rocks of this strata are low grade regional metamorphic of greenschist facies (Bunopas,1981 ; Workman, 1975) including chlorite schist, phyllite,metatuff and quartzite. Almost all of the rocks show foliation or schistosity more explicit than any other rock formations in this area. These rock stratas occur mainly in eastern side of Amphoe Pak Chom at Hard Khum Bhee, Mekhong River, extend southward trending to the west of Ban Chok Chai, Amphoe Nam Som, Changwat Udorn Thani. For the Devonian strata (D) (Figure 2-6), they are referred to as the"Ban Nong Shales Member" (Bunopas et al.

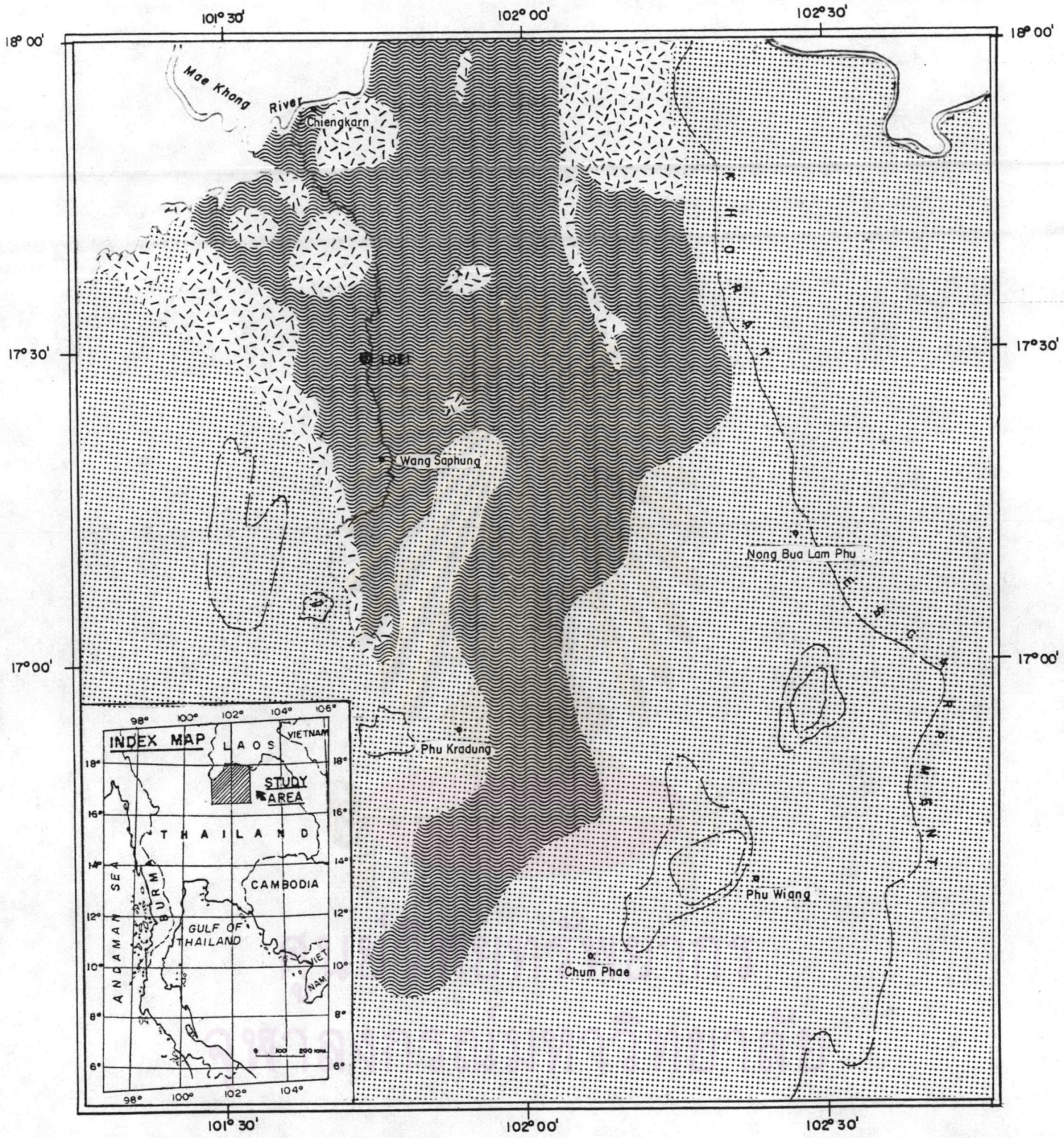


Figure 2-4. Regional general geological setting of the North-Western of the Khorat Plateau.

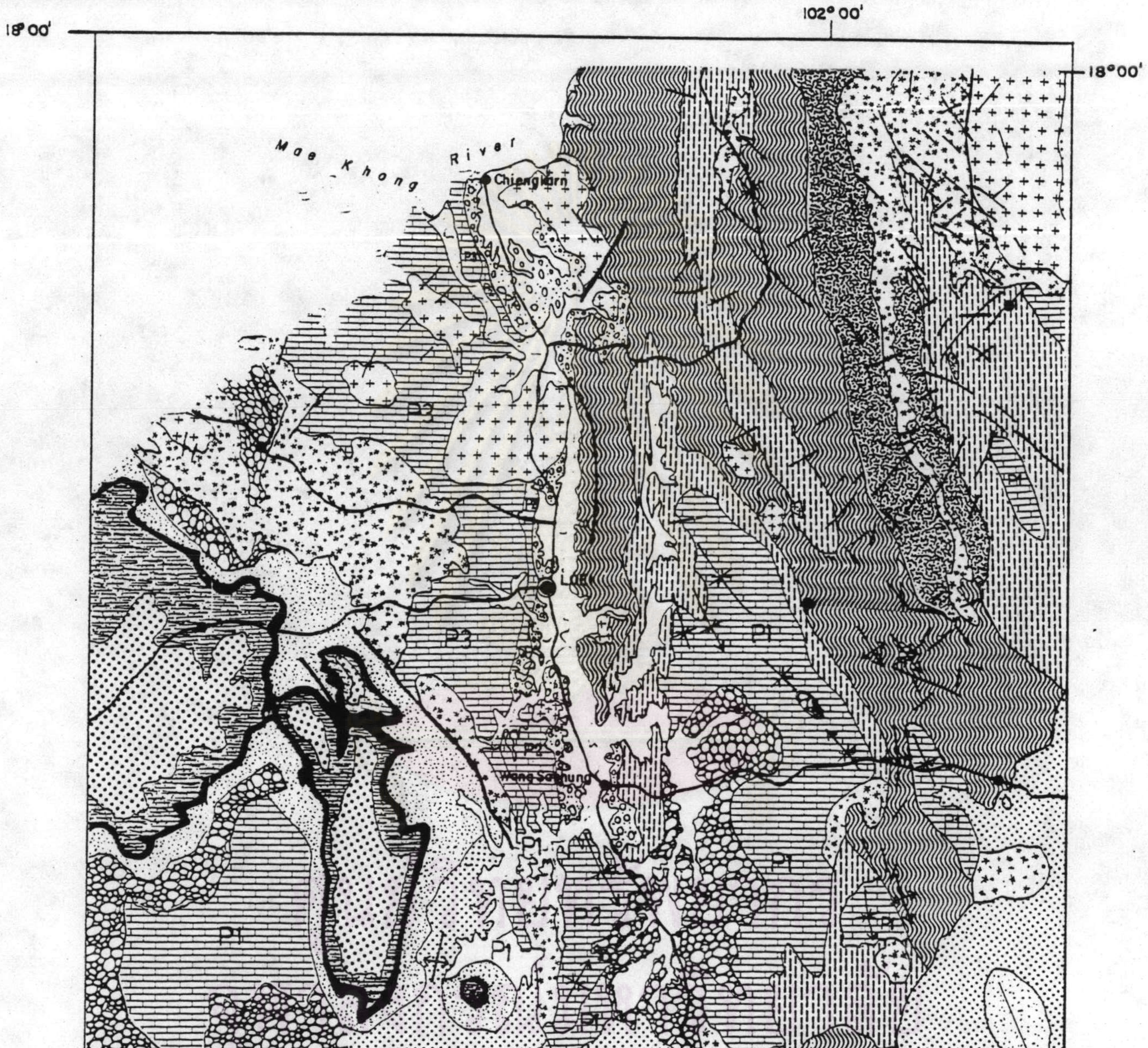
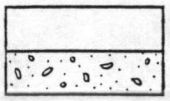


Figure 2-5. Geologic Map of the Loei-Chiang Khan area (modified after DMR, 1983 ; DMR, 1984).

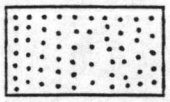
EXPLANATION



: Alluvial deposit ; sand, silt, and clay.

: Terrace deposit ; gravel, sand, silt, laterite, and lateritic soil.

-----UNCONFORMITY----------



: PHU PHAN FORMATION

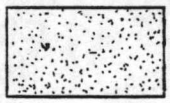
; gray, brown, orange, pink, cross-bedded, thick bedded sandstone; siltstone, conglomeratic sandstone, and intercalated shale.

: SAO KHUA FORMATION

; purple, gray and red calcareous siltstone end sandstone ; siltstone, conglomeratic sandstone, and intercalated shale.

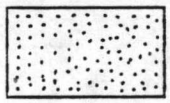
: PHRA WIHAN FORMATION

; white to purple red, cross-bedded, thick bedded quartz arenite sandstones ; intercalated claystone and redish brown and gray siltstone.



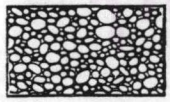
: PHU KRADUNG FORMATION

; red and purple, calcareous and micaceous siltstone, sandstone and some local lime-noduled conglomerates.



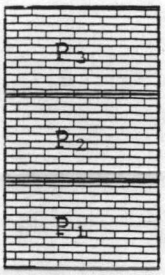
: NAM PHONG FORMATION

; brown, redish brown, cross-bedded sandstone conglomerate, siltstone and claystone.



: HUAI HIN LAT FORMATION

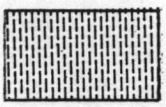
; interbedded shale, mudstone, siltstone, graywacke, argillaceous limestone ; basal lime-noduled conglomerate, and local volcanic-nodule conglomerate with pebble of various kine of volcanic rocks.



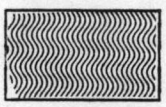
: P_3 ; shale and sandstone

: P_2 ; gray, dark gray to black shale ; yellowish brown, and gray sandstone.

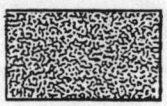
: P_1 ; light to dark gray,thick bedded to massive limestone with chert noduled ; light gray to whiteish well bedded dolomitic limestone ; shale, sandstone, and bedded chert.



: C_2 ; greenish gray, black and red shale ; sandstone, limestone, dolomitic limestone, chert, conglomerate, and tuff.

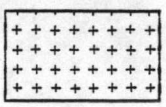


: C_1 ; thin to thick bedded limestone and shale ; red sandstone and shale ; and tuff.

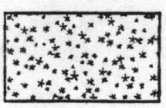


: SD ; gray, black and yellow phyllite, quartzose phyllite, and phyllitic schist, and metatuff.

IGNEOUS ROCKS



:Trgr; whiteish gray, greenish gray, and pink granite, alkali-feldspar granite, granodiorite, quartz, monzonite, and quartz syenite.



:V ; rhyolite, andesite, basaltic andesite, spilite, tuff and agglomerate.

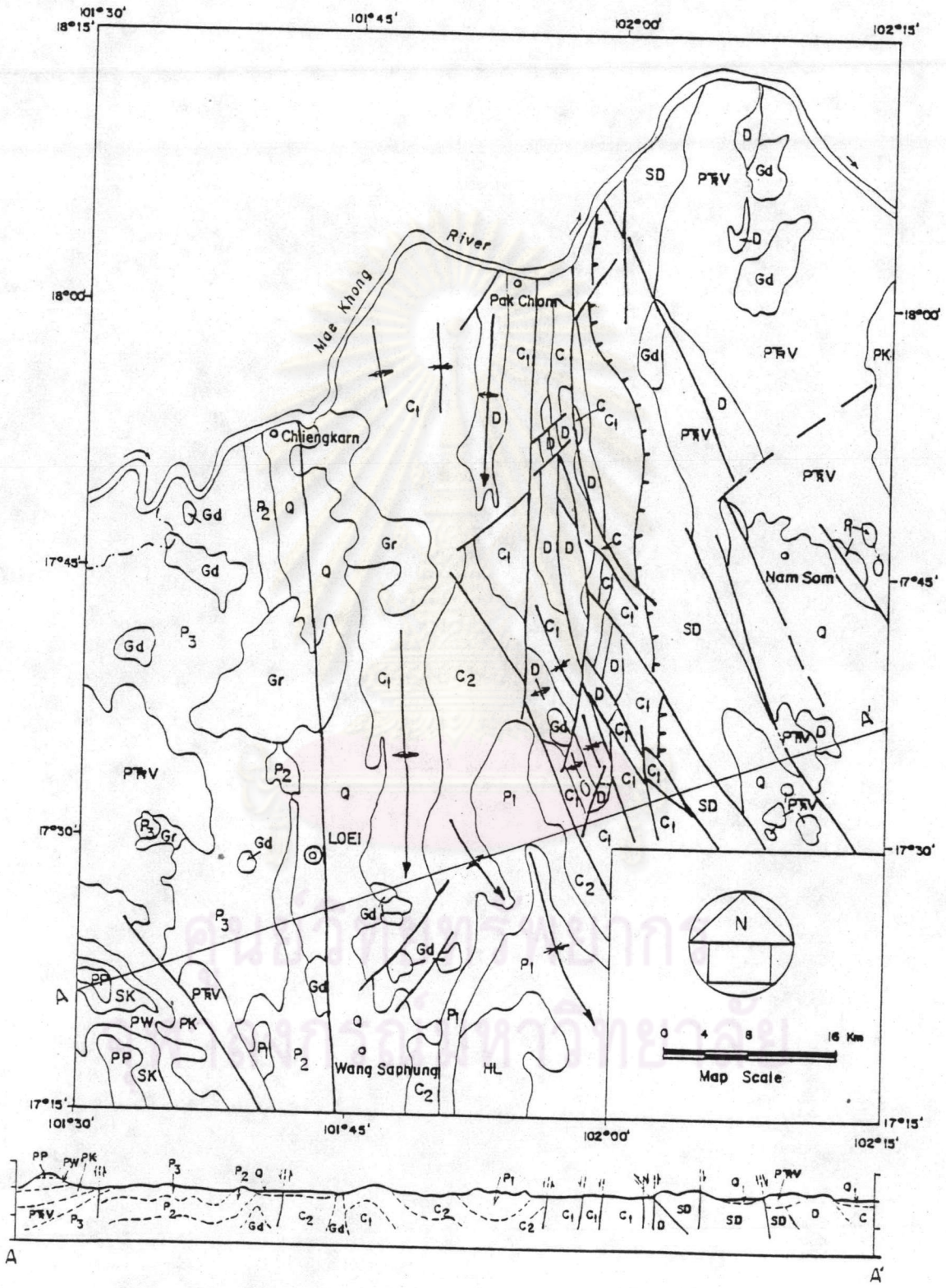


Figure 2-6. Sketch geologic map illustrates main structures of the Loei-Chiang Khan Area (modified after DMR 1987, unpublished).

, 1988) in the lower part and the "Pak Chom Cherts Member" (Bunopas, 1992; Putthapiban, 1987) in the upper part. Both of these members are grouped to be the "Pak Chom Formation". It comprises of shales, limestone, tuff and chert with intercalations of tuff, shale and limeston bands(lenses) from lower beds to upper beds, respectively. These rocks are more widespread in the east of Loei area especially in Pak Chom district. They have gradational contact with the younger Carboniferous strata (Putthapiban,1987). The younger Carboniferous strata are comprised of the Lower Carbonifereous (C_1) Ban Sangao-Pak Nium Formation (Fontain et al., 1982) and the Upper-Carbonifereous "Wang Saphung Formation" (Bunopas, et al., 1988). The bottom part of C1 formation includes grey sandstone, conglomerate, mudstone and shale which occur at Ban Pak Nium. Whereas the upper part occurs at Ban Sangao including shale, limestone and chert. The Upper-Carbonifereous, the Wang Saphung Formation, consists mainly of sandstone shale with some thin limestone beds, conglomerates, siltstone and limestone lenses. In the upper part of these strata the rocks are interbedded by thin bedded limestone and show gradational contact to Permian limestone (P_1) at Phu Pha Sing, on Wang Saphung-Udorn Thani Highway.

The latest Permian rocks of the Paleozoic stratigraphic succesions have been divided into three formations,the Lower Permian (P_1)- "Thum Nam Mahoran Formation", the Middle Permian (P_2)-"Huai I Lert Formation", and the Upper Permian (P_3)- "Pha Duia Formation" (Putthapiban, 1987).These formations are comprised mainly of white to light grey to grey massive

and thick bed limestone intercalated by minor clastic sedimentary rock and chert (P_1), and white, light grey to grey limestone and few slightly recrystalline limestone (P_2), and interbedded shale,siltstone and sandstone (P_3). These rocks occur mainly in the central-southern and western portions of the area.

The Paleozoic rocks were strongly folded during the Hercynian and Indosinian orogenies. The NNW-SSE (plunge SE)and the NNE-SSW (plunge NE) folds are the two main systems that tought to be generated during Lower-Middle Permian and Upper Permian respectively (Thanaomsap, 1987). There are at least three systems of fault associated (Figure 2-7).These faults are including of the NW-SE/NE-SW conjugate strike-slip faults (later Upper Permian to Lower Permian),the N-S main wrench faults (Lower-Middle Triassic), and the E-W normal/reverse faults (Middle Triassic) (Ramsay, 1983;Thanoamsap,1987 ; Wilcox, 1973).

Igneous Activities.

Deformation of the Late Paleozoic sediments by the Indosinian Tectonics has resulted in, among other things, thrust-fauting having sinuosly north-south trend which accompanied by volcanism and emplacement of calc-alkaline igneous rocks taking place during the period of Late Permian to Early Triassic (Pongsapich et al., 1981). The Loei volcanic province may be delineated and subdivided into three major zones, the Central zone,the Eastern zone and the Western zone based on occurrence, lithology and age of eruption. The central zone volcanic rocks are

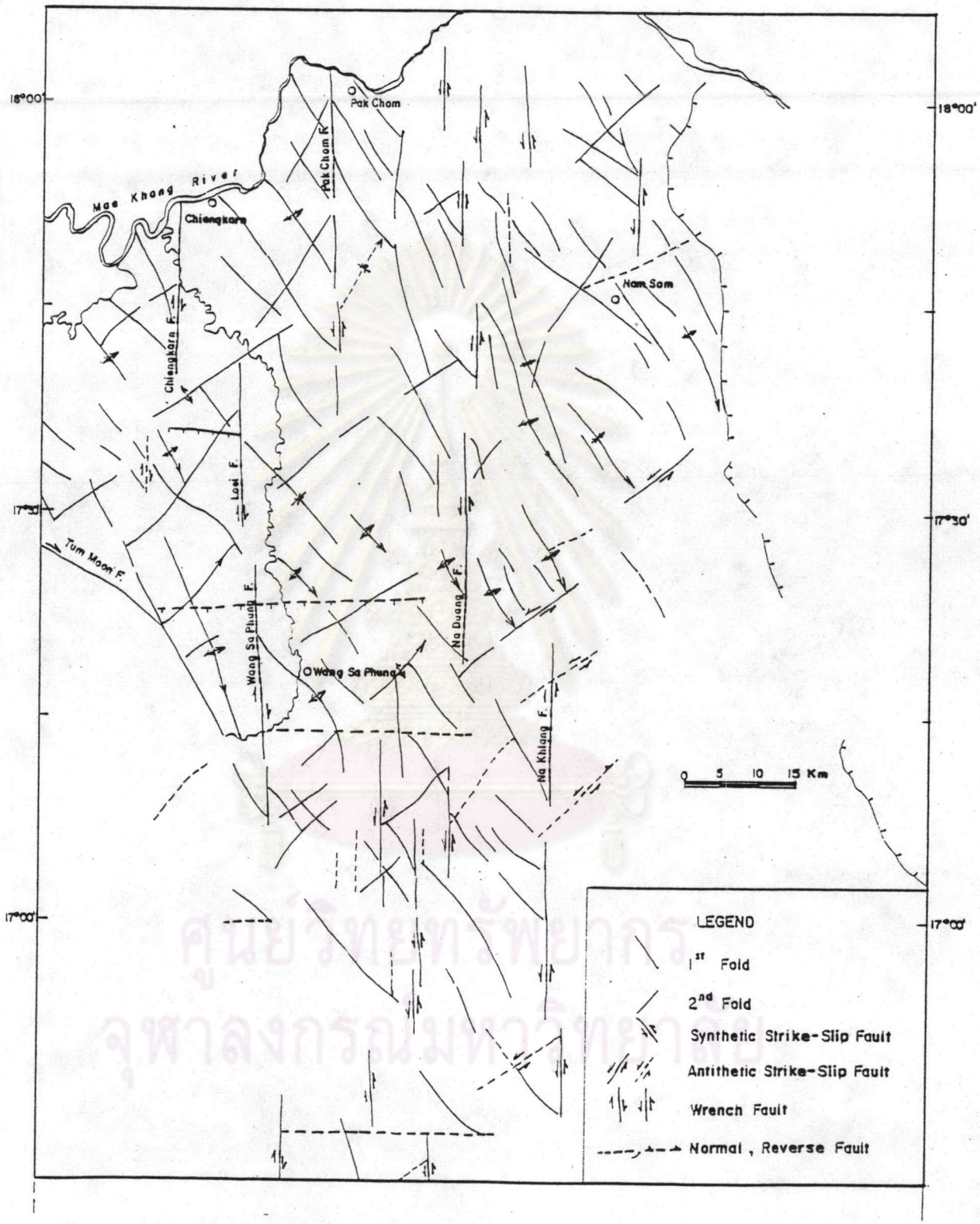


Figure 2-7 Summarized structural geological map of the Loei area (from Thanoamsap, 1987).

mostly grayish black to grayish green basaltic andesite and serpentinite (Chairangsee et al., 1988). It is believed that this basic magmatism active during the Middle Devonian and mainly during its upper part,the Givetian (Chairangsee et al., 1988, 1990). It occurs near Pak Chom and forms narrow elongate north-south trending extends southward direction to Ban Na Kho and Ban Sup. The Eastern and Western zones of volcanic rocks are comprised of the rocks of Permo-Triassic age which include mainly rhyolite,rhyolitic tuff, andesite,andesite and rhyolite porphyry and dacite. They occur along the eastern and western portions of the area. Both portions are commonly associated and emplaced by small bodies of diorite, granodiorite and granite with subordinate hornblendite which believed to be more or less genetically link to each other.

For the plutonic rocks, almost all of them in Loei area are granitoid and syenitoid rocks, including predominant of normal granites, alkali-feldspar granite, granodiorite, quartz syenite and quartz monzonite, and subordinate diorite and hornblendite.

Field occurrences of these granitic rocks are generally batholiths and small stocks such as Phu Sanao batholith, Pha Baen stock and Nam Khaem stock. They are relatively homogeneous isotropic fabric pluton with fine- to medium-grained and medium- to coarse-grained equigranular textures.

Phu Sanao batholith (inwhich the study area is included) is the largest pluton in this area and covers an

area of about 270 - 290 Km^2. It shows distinctive petrographical and textural zonation of fractionation crystallization, both in field occurring and microscopic-petrographic features.

Radioactive age determination using K/Ar Method (H) at Phu Kwai Ngoen suggests that age of plutonic rocks in Loei area is approximately 230 Ma (Charusiri,1989 , 1991:Jacobson et al., 1969). This leads to conclude that plutonic intrusions in this area are in the Triassic period.

Mesozoic Formations

Several formations (except KoK Kruat and Maha Sarakham) of the Khorat Group are outcropping in the area. They consist of lower to upper formations, i.e., lime to lime-volcanic nodules basal conglomerate the "Huai Hin Lat Formation", maroon-micaceous siltstone and sandstone the"Phu Kradung Formation", white-clean sandstone, conglomeratic to orthoquartzite the "Pra Wihan Formation", sandstone and siltstone the "Sao Khau Formation", and medium- to coarse-grained and quartz pebbly to conglomeratic sandstone the "Phu Phan Formation". The lower (oldest) Huai Hin Lat Formation is overlying the older strata (Permian)as unconformable contact. Lime-nodule and/or volcanic nodule basal conglomerates are commonly found along the contact zone, i.e., at Wang Saphung area, Ban A rawan along the Wang Saphung-Udorn Thani Highways, and at Ban San Tom which differs from other areas by their volcanic and volcanic-nodule basal conglomerate, appear as thin beds.