CHAPTER 2

GEOLOGICAL OVERVIEW

The geology of Fang Basin and adjacent areas was reviewed by various workers including, Lee (1923); Brown et al., (1951); GGM (1972); Chaturongkawanich and others (1980); Chuaviroj and Chaturongkawanich (1984) etc.

Before describing the geology of Fang Basin, it will be useful to place the basin into the regional context of northern Thailand geology and tectonics.

2.1 REGIONAL GEOLOGICAL SETTING

A brief survey of the geological systems found in northern Thailand follows below, and the geological map is shown in Figure 2.1.

Precambrian : The oldest known rocks in northern Thailand are a group of medium to high grade metamorphic rocks (paragneises, orthogneises and schists) of the Precambrian age. The rocks are intensively deformed and underlie the fossiliferous and less metamorphosed Cambro-Ordovician strata. They are well exposed in linear belts extending all the way from Chiang Mai to Kanchanaburi provinces.

Cambro-Ordovician : Well bedded quartzites characterise the Cambrian successions in the north (Baum et al., 1970). The Ordovician sequence consists of quartzite, well bedded siltstones, sandstones, shaly dolomite and dolomitic limestones. The successions as a whole are presumed to have been deposited in shallow-water environments. They occur east of Mae Hong Son, south of Tak and Kanchanaburi provinces.

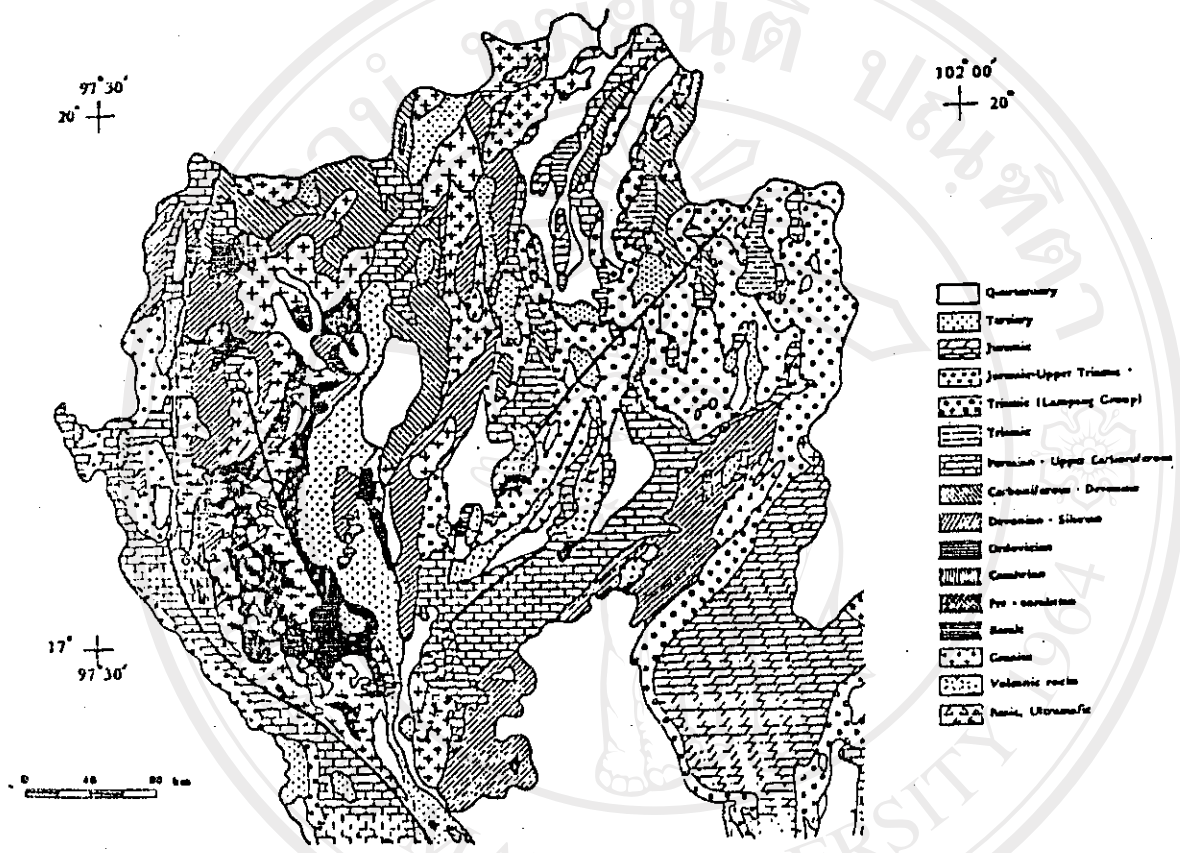


Figure 2.1 Geological map of northern Thailand (after Suensilpong, 1978).

Silurian-Devonian : The succession is represented by carbonaceous shales, graywackes, and chert with local limestone intercalations metamorphosed in the greenschist facies. No fossils of definite age are found for rocks of this period. They are exposed at Mae Hong Son, west of Chiang Mai and Lampang, and to the northeast of Uttaradit province.

Carboniferous : The lower Carboniferous rocks are mainly clastic sediments with some limestone or chert intercalations and minor agglomeratic rocks. Both marine (chert, limestone, shale, conglomerate) and terresterial facies (red conglomerates, shales, sandstones, and chert) are characteristics of the upper Carbonifeous. Towards the close of the Carboniferous, a number of granitic intrusions were emplaced and intermittent volcanic extrusions (of basic to intermediate composition) had taken place. Sedimentation continued into the Permian as to form the Permian limestones (Ratburi limestones) and subordinate clastic and volcanogenic sediments. They are exposed west of Mae Hong Son, north of Chiang Mai, southwest of Lampang and north of Uttaradit provinces. The Permo-Triassic rocks are predominantly rhyolitic and andesitic in composition.

Mesozoic : The Permian limestones are unconformably overlain by Mesozoic strata of both marine and non marine origin. Marine sedimentation was widespread during early Triassic and is characterised by shales and limestones with facies change into a sandstone-shale sequence comparable to the alpine flysch (Bunopas, 1976). Continental sedimentation appeared in late Triassic and intermittently continued into the Jurassic (red sandstones, mudstone, shale, mafic to intermediate volconogenic sediments)

and Cretaceous (quartose and conglomeratic sandstones) as to be represented by the Khorat Group.

Cenozoic : Cenozoic liminic, fluviatile, and alluvium of weakly consolidated clays, sands, gravels, rare limestones and occassional organic sediments tend to fill both small and large scale structurally controlled basins. Back arc extensional tectonics during late Cretaceous and early Tertiary led to the formation of these basins (Asnachinda, 1978).

There are several granitic complexes in northern Thailand and are considered to be of late Carboniferous, late Triassic to early Jurassic, Cretaceous and Tertiary ages. Main batholiths were emplaced during Triassic and perhaps extended into early Jurassic. This phase of intrusion coincides approximately with the age of andestic and rhyolitic volcanic extrusions which extended from late Permian to early Triassic. Pleistocene basalts are also known to exist.

2.2 STRUCTURAL FRAMEWORK OF NORTHERN THAILAND

Northern Thailand can be subdivided into several distinct geological provinces that extend into adjacent parts of southeast Asia. There are three major geological provinces; the Sukhothai, Loei and southern China fold belts (Bunopas, 1981; Burton, 1984; Figures 2.2a and 2.2b), alternatively referred to as the western, central and eastern provinces. The regional structural framework of northern Thailand is largely influenced by the Indosinian Orogeny (so-called Sukhothai/Loei fold belts) during late Triassic. These regional tectonic elements were subsequently dislocated and their trends modified by sinistral strike slip faults of the Himalayan

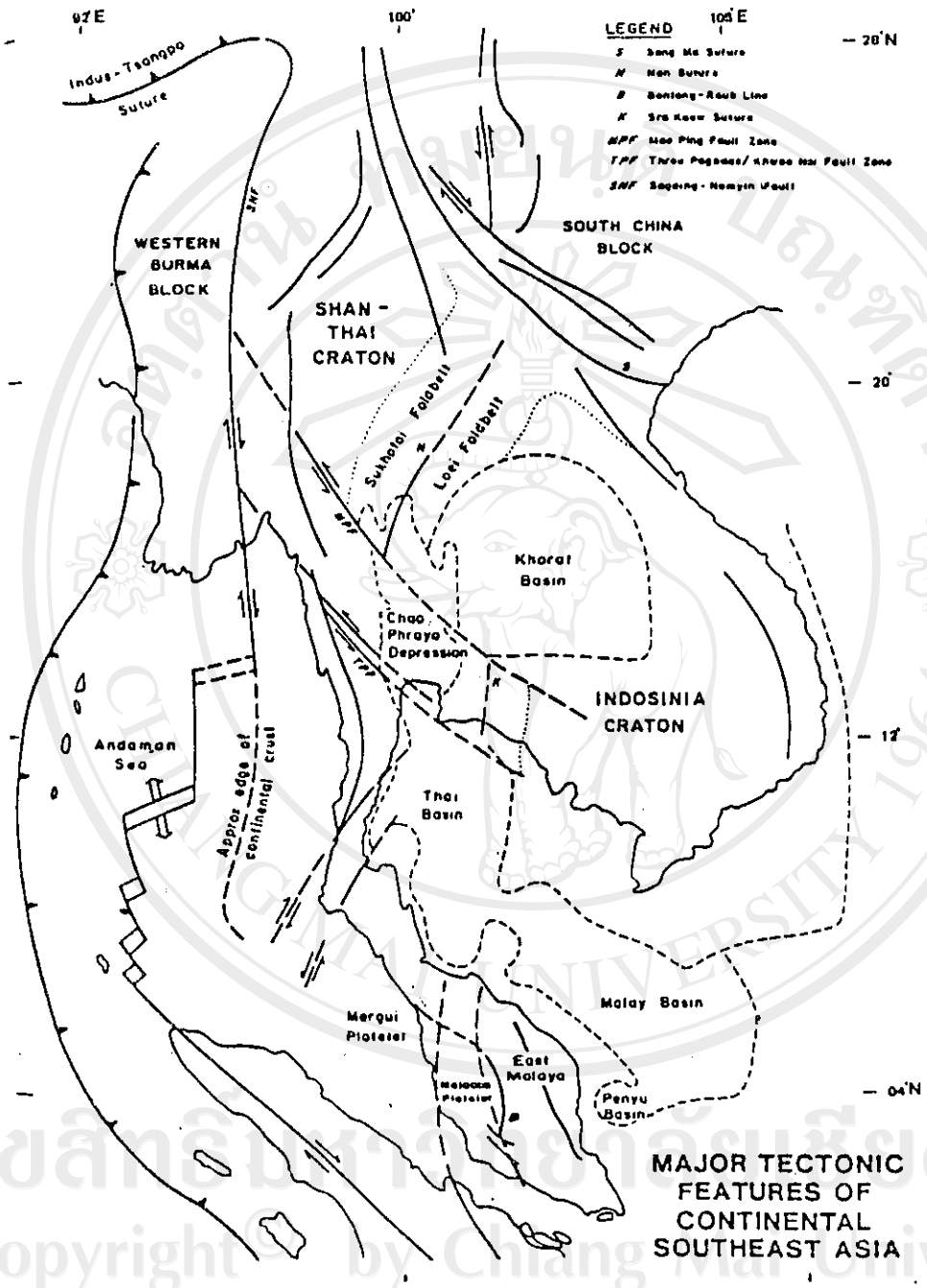
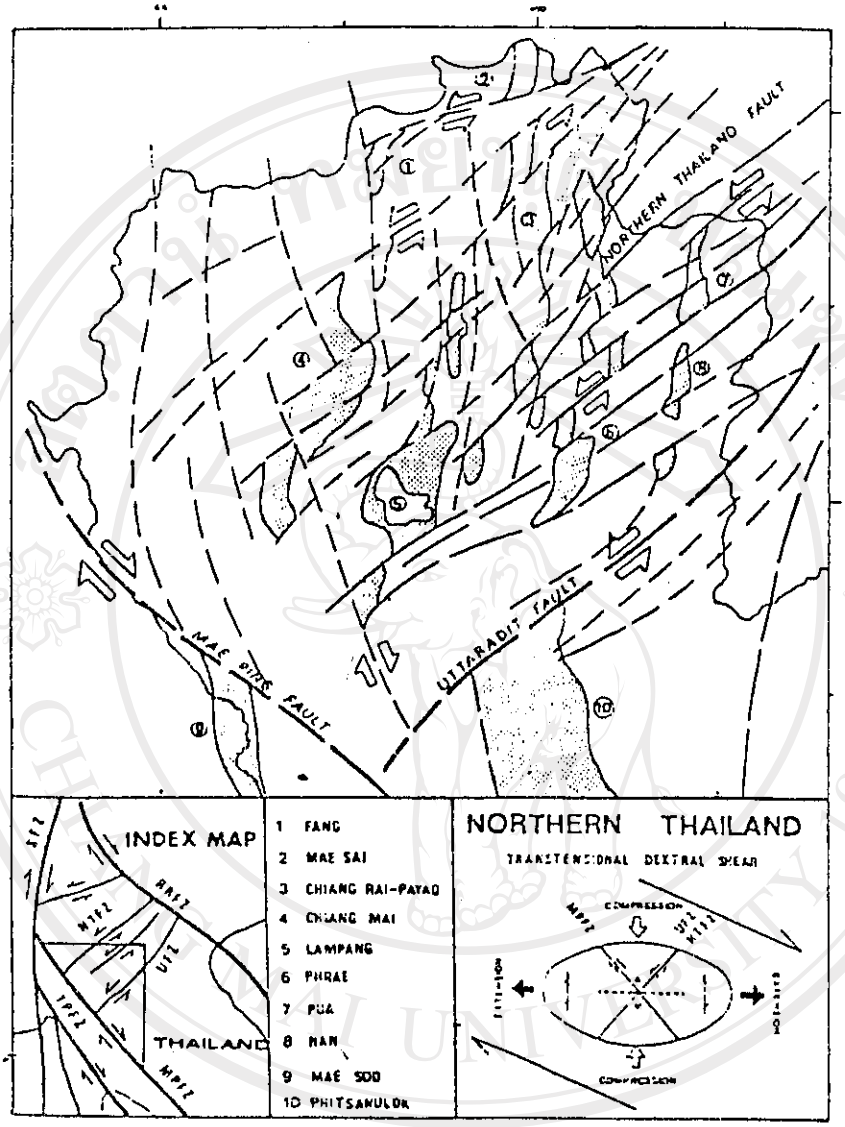


Figure 2.2a Major tectonic features of continental Southeast Asia (After Burton, 1984).



Structural map of Northern Thailand showing relationship between conjugate strike-slip faults and the development o. N-S trending pull apart basins.

Figure 2.2b Structural map of northern Thailand

(After Songpope Polachan and Nares Sattayarak, 1989).

Orogeny (the Red River and Mae Ping Faults). The last tectonic episode which took place during late Tertiary and Quaternary periods is approximately coeval with alkaline basaltic extrusions. As a result of all these, complex networks of fault and fracture systems developed, and at least five sets are considered to be the most prominent ones. These include the NNW-SSE, WNW-ESE, NE-SW, N-S and ENE-WSW or E-W faults.

The most obvious major fault is the ENE-WSW set marking the boundary between the Cenozoic sediments and older units at the northwestern margin of the Fang Basin. This set is either a strike slip or normal fault approximately dipping to the SE direction. The Doi Kai Fault belongs to this catagory. The other prominent faults trend in the N-S or NNW-SSE direction and appear in the western margin of the southern portion of the Fang Basin. The Mae Mao I (Chaturongkawanich et al., 1980) and Mai Chai Faults are the most significant as far as this set is concerned. A photolineament map of the Fang Basin and adjacent areas is shown in Figure 2.3.

2.3 GEOLOGY OF FANG BASIN

The Fang Basin is an intracratonic basin owing its origin to tilted block faulting closely related to the Chiang San Fault Zone in the north and the Mai Tha Fault Zone's extension in the west. The main basin was initiated in response to extensional rifting during early Tertiary period (Khanthaprab and Kaewsaeng, 1987). The basin had been tectonically active throughout much of the Cenozoic as deduced from the thick sedimentary fill and numerous intrabasinal faults. A basin wide unconformity of Miocene-

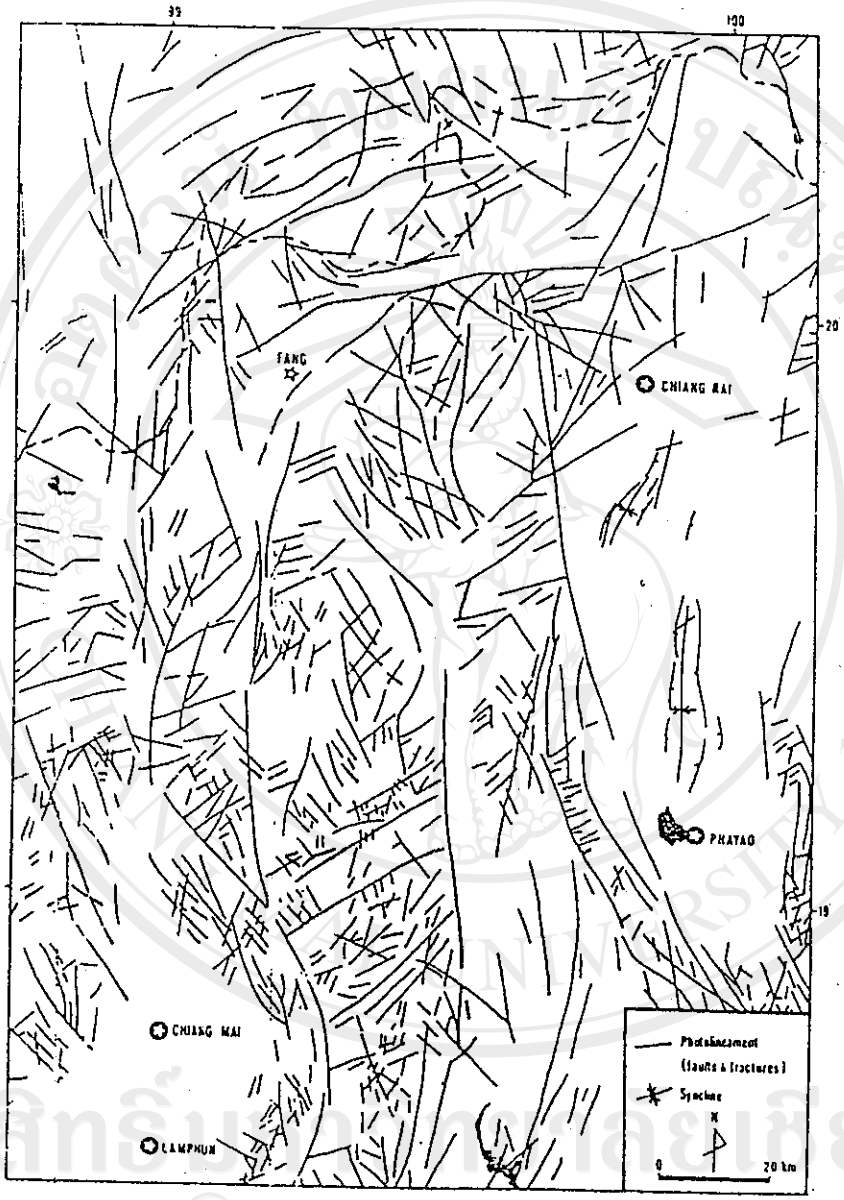


Figure 2.3 Photolineament map of the Fang Basin and adjacent areas (after Aramprayoon, 1981)

Pliocene age represents a major episode of uplifting and erosion followed by coarser clastic sedimentation.

The modern basin is approximately 575 km^2. From seismic, gravity and structural surveys it is suggested that the basin can be subdivided into three distinct subbasins (Huai Pa Sang, Huai Ngu, and Pa Ngew). The maximum thickness of the sediments, as inferred from seismic reflection surveys (GSI, 1985), is 2500 m. at the middle sub-basin. Six structural oil fields are recognised (Chai Prakarn, Mae Soon, Pong Nok, Huai Bon, Pa Daeng, and Pa Ngew; Figure 1.1). The first four structures are known for their petroleum accumulations.

Various rocks ranging in age from Paleozoic to Holocene are well exposed in the immediate vicinity of the basin (Figure 2.4). Topographic highs to the west of the basin are underlain by slightly to intensively metamorphosed Paleozoic (Cambrian to Permian) clastics and carbonates. Topographic lows in the western margin of the basin are covered by a north-south trending linear belt of phyllite, talcose schist, quartzitic sandstone, sericitic shale and recrystalline limestone. The lithologies apparently tend to be younger to the west. The Paleozoic rocks are intruded by biotite granites of Carboniferous age.

Permian limestones and clastics as well as mafic volcanics, for the most part, underlie the southern part. Carboniferous foliated granites, emplaced into the Paleozoic rocks, border the northwestern side of the basin. Further north, Devonian-Carboniferous rocks with some Carboniferous mafic volcanics and granite-granodiorite porphyry are well exposed.

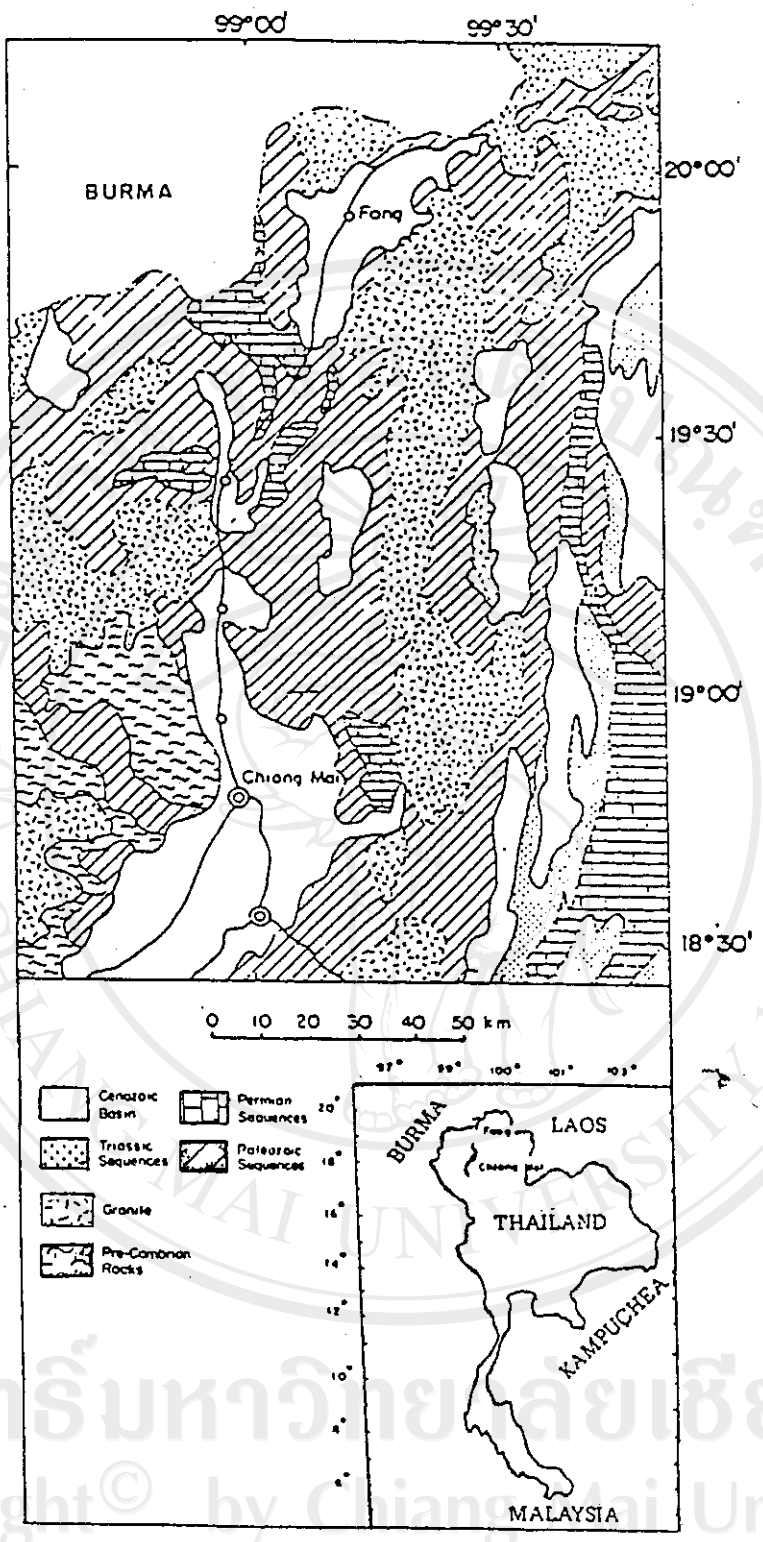


Figure 2.4. Geological map of Chiang Mai - Fang area (after Uttamo, 1989).

Continental sediments of Jurassic age, lying non-conformably on the Triassic granite-granodiorite porphyry, are well known from the eastern extreme. Here, the basal unit, comprising of arkosic and conglomeratic sandstones, grades upward into well-bedded, medium grained sandstones intercalating with red and gray shales.

The Tertiary strata are represented by fluvio-lacustrine, fluviatile and lacustrine deposits composed of conglomerate, sandstones, claystones, clay-shales and oil sands of excellent reservoir character. The Quaternary deposits are composed of silts, clays, sands and gravels from stream channels, terrace deposits and alluvial fans. These are capped by recent sediments composed of soil and lateritic sand.

The Pre-Tertiary rocks, as inferred from drill holes penetrating to the basement, are Ordovician metamorphics (quartzites and phyllites), Carboniferous clastics (sandstones, and siltstones), Permian limestones, Triassic granites and Mesozoic clastics (sandstones, siltstones, conglomerates and shales).

Potential reservoirs in the basin are considered to be the sandstones contained in the middle and lower Mae Sot members (Settakul, 1985). Thickness of the sandstone bodies varies between 5 and 10 ft. and they commonly occur in 2-3 groups. These reservoir sandstones (conventionally referred to as the "G" and "H" units; Figure 2.5) have porosities reaching upto about 27 % and permeabilities ranging between 231-3440 md., suggesting a relatively good reservoir quality. The reservoir sandstones are surrounded by impermeable rocks and are characterised by lateral facies changes from permeable to impermeable rocks with subsurface water available

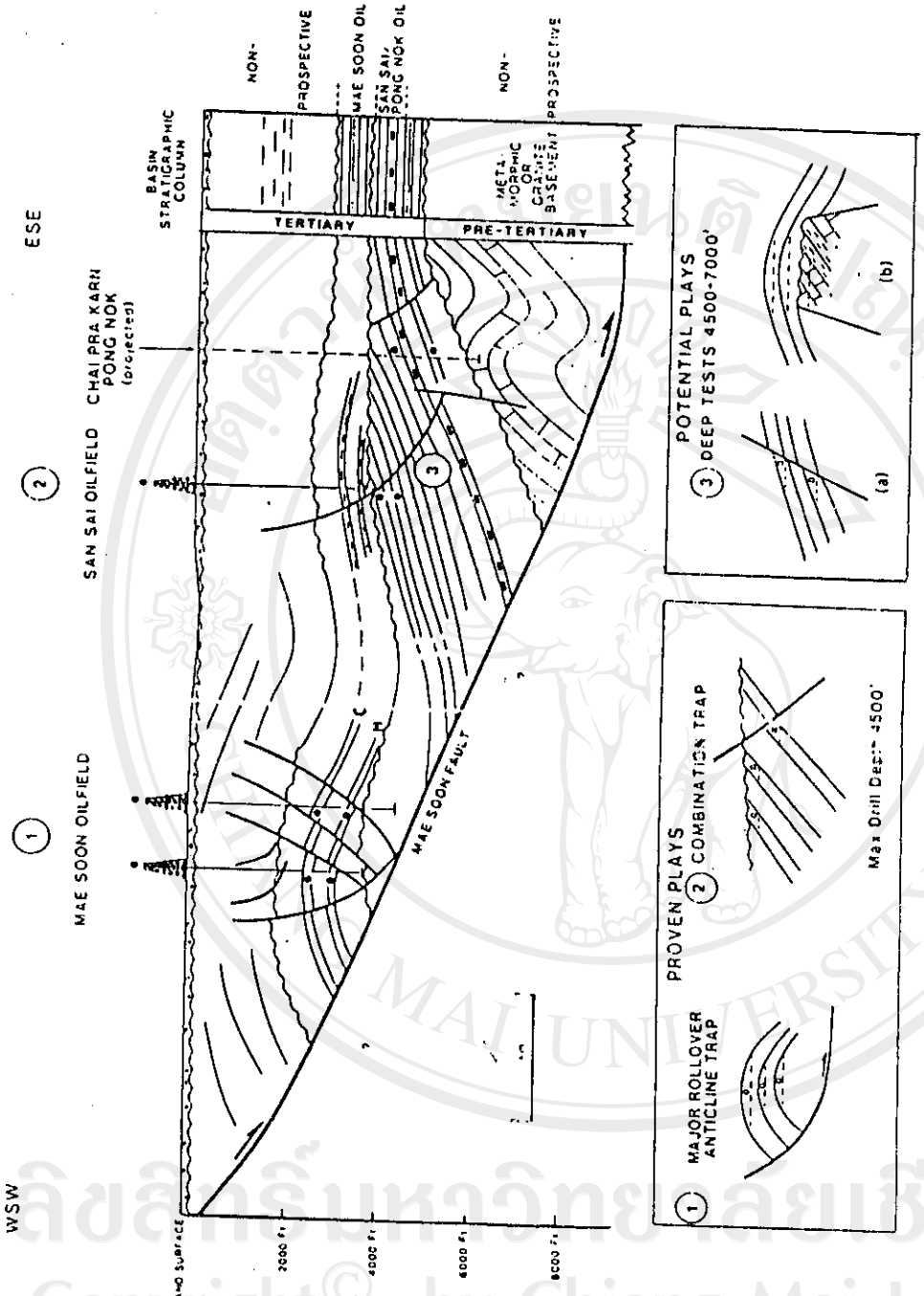


Figure 2.5. Fang Basin play types (Based on GSI), seismic line F2/F6 (after Settakul and Pimsarn, 1991).

under the reservoir rocks. Analysis results of the physical characteristics of fluid contents of the "H" sand unit are given in appendix A. Recoverable reservoir estimate in "H" sand unit is 3,789,500 Bbl (Settakul, 1985).

Characteristic traps in the basin are a combination of structural and stratigraphic types at Mae Soon oil field and of stratigraphic type at Pong Nok oil field (Figure 2.5). Structural traps at Mae Soon are caused by folding of sedimentary rocks overlying the basement. These are associated with NE-SW trending faults that act as tectonic barriers against migration. Stratigraphic traps at Mae Soon and Pong Nok are caused by lithologic changes and at Pong Nok they show an updip pinching out characteristics. Asphaltic dope type stratigraphic traps are also found at Chaiprakarn oil field. Potential seals in the basin are represented by poorly permeable to impermeable siltstones and shales.

Total potential producing zones in IF 30 03S are approximately 28 ft. thick and are confined within the "G" and "H" sands (Appendix A). The interesting depth occurs between 2630-2642 ft. The interval analysed yields 20 % effective porosity, and 20 and 80 % water and oil saturation, respectively. The calculated permeability is upto 200 md. The Nong Yao crude oil is similar to that of the Mae Soon crude oil and has the following properties.

Specific gravity at	$60^{o}F$	0.914
API gravity at	$60^{o}F$	23.3
Viscosity	($122^{o}F$) sus. sec	217
Flash point	(^{o}F)	104
Pour point	(^{o}F)	99

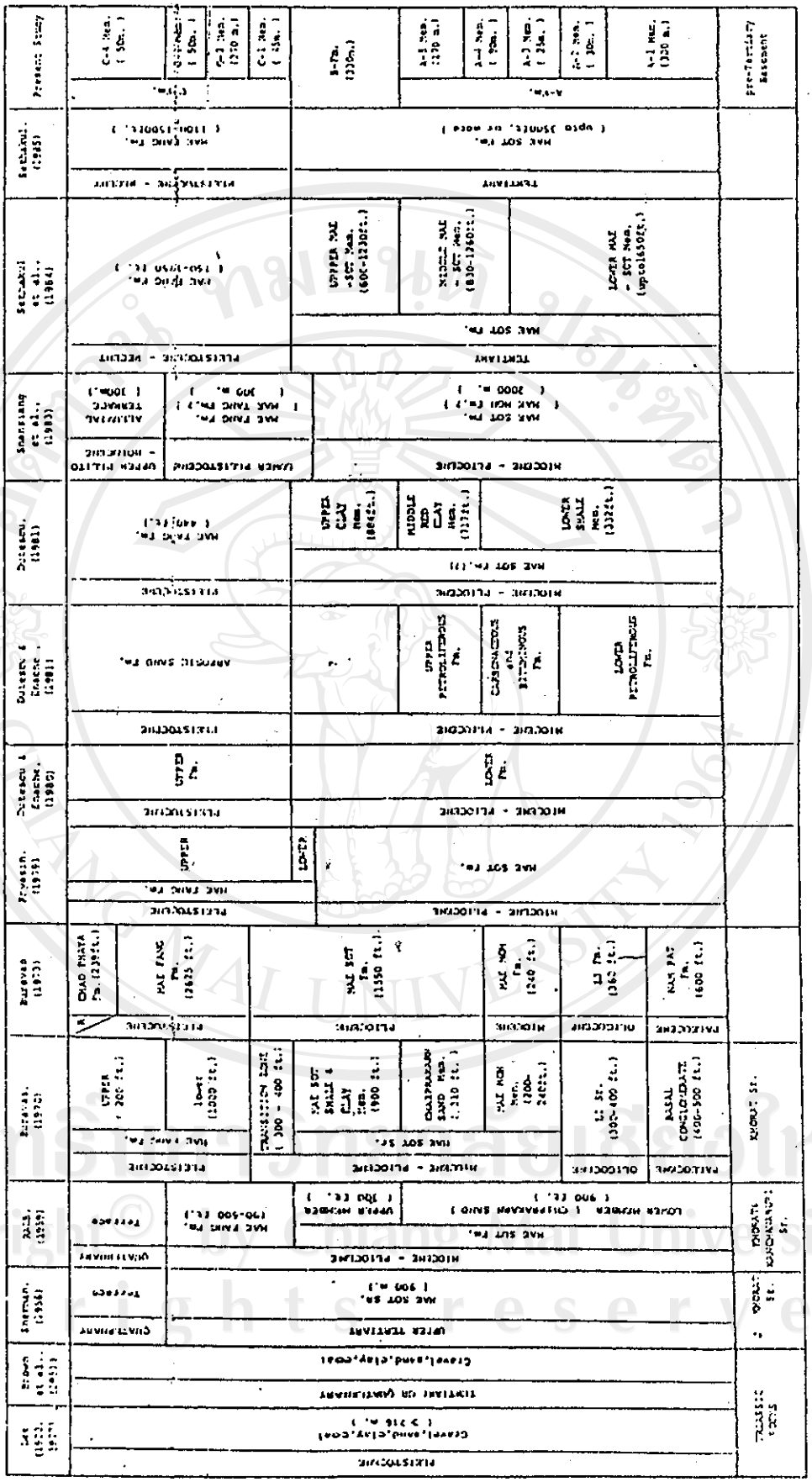
Temperature gradient in the western part of the basin (Mae Soon and Nong Yao) is almost twice as greater as that of the rest of the basin (3.54^{O}F/100 ft.). Measured borehole temperature for IF 30 03S is 240^{O}F at 4524 ft.

Source rocks of the basin are presumed to be the lacustrine and/or the fluvio-lacustrine shales. Type II kerogen is the main organic constituent, although a wide range of mixture between types II and III kerogens are noted. In the deepest part of the basin, where the sediments are as thick as 3000 m, the source rock facies are considered to have fallen within the oil window (Chinbunchorn and others, 1989). Khantaprab and Kaewsaeng (1987) indicated that the oil window of the Fang Basin (with a geothermal gradient of approximately 95^{O}C/1000 meters) is within the depth range of 1100-1400 mts. Favorable petroleum generating zones, and Kitchen areas are suggested from the middle sequence of Huai Ngu, Pa Ngew and Huai Pa Sang sub-basins. The Nong Yao structure has a small anticline associated with normal faults and is considered to be suitable for oil accumulation.

2.4 CENOZOIC STRATIGRAPHY OF FANG BASIN

The Tertiary stratigraphy of Thailand has been discussed by Nutalaya (1975); Buravas (1975); Gibling and Ratanasthien (1980); Chaodumrong and others (1983) etc. Further, the Cenozoic strati-graphy of the basin is defined by serveral workers as illustrated in Table 2.1. For the purpose of mere simplification, the lithostragraphy as discussed by Settakul (1985) and Khantaprab and Kaewsaeng (1987), will be described here.

Table 2.1. Comparative stratigraphic classifications and nomenclatures of Cenozoic deposits of the Fang Basin (after Khantaprab and Kaewsaeng, 1987).



Settakul (1984) subdivided the lithostratigraphic succession into the Mae Fang and Mae Sot Formations, in decending order. The Mae Sot Formation is further subdivided into three distinct units referred to as the lower, middle and upper members.

2.4.1 MAE SOT FORMATION

The Mae Sot Formation is an alterating sequence of shales, and claystones interbedded with sandstones. The overall thickness at the Mae Soon Oilfield is approximated at 3500 ft. or more. The shales are gray and brown coloured and occassionally, individual beds are as thick as 60 m. or more. The sandstone horizons occur somewhat erratically at the top of the succession, commonly in a group of 2-5 m. thick. The sequence is deposited both in oxidizing and reducing environments.

Lower Mae Sot (MS_1) : consists of reddish brownish and brown sandstones and mainly occurs in the central deep. The bulk thickness is upto 1650 ft but thins out to the east at the basin margin, where it is interbedded with argillaceous sediments. The sandstones occur in 8 to 9 cycles, each being 5-15 ft. thick. A thick lignite seam upto 75 ft. occurs on top of the sequence.

Middle Mae Sot (MS_2) : mainly comprises of gray shales containing gastropods (*Viviparous*) and insect remains with sandstone intercalations. Thin lignite beds are common in the lower part. The upper part of this member is interbedded with arkosic sandstones of variable thicknesses. The overall thickness varies between 830 and 1260 m. and the strata dip in approximately $15^{o}W$.

Upper Mae Sot (MS_3) : predominantly consists of light brown-light gray shales interbedded with thin siltstone beds. Fossils of insects and *Viviparous* (gastropods) are commonly observed in the lignite bands at the lower and middle parts of the sequence. Bulk thickness varies between 600 and 1230 m.

2.4.2 Mae Fang Formation

The Mae Fang Formation is approximately a 1100-1800 ft. thick sequence containing a 20 ft thick. lateratic soil and sand at the top, and loose sands, gravels, pebbles and cobbles alternating with clays in its lower part. The upper part is interpreted as an energetic alluvial and fluvial facies while the lower part is regarded as a fluvio-lacustrine sequence characterising a tropical and an oxidizing facies. The formation is presumed to have developed in Quaternary to Recent periods.

Very lately, Khanthaprab and Kaewsaeng (1987) classified the Cenozoic sequence into the group, formation and member levels. The "Fang Group" was taken as to represent the largest lithostratigraphic unit. Accordingly, the "Fang Group" was subdivided into the A-Formation, B-Formation and C-Formation.

A-Formation : It is the lowermost lithostratigraphic unit of the "Fang Group" and in all cases unconformably overlies the Pre-Cenozoic basement rocks. Lithologically, it is mainly represented by sandstones and shales of meandering fluviatile, fluvio-lacustrine and coal swamp facies. It is further subdivided into five members.

B-Formation : The formation is characterised by fine clastic sediments with minor sandstones of lacustrine and/or fluvio-lacustrine facies. It overlies conformably the "A-Formation", with abrupt change in lithology. It shows a marginal lacustrine character typical of a lacustrine delta at Mae Soon and Chaiprakarn. No further subdivision into members was made.

C-Formation : This is the uppermost lithostratigraphic unit and overlies unconfomably the "B-Formation". An association of braided/meandering fluviatile and fluvio-lacustrine facies characterise this formation. It is further subdivided into four distinct members.

Base on his rift model, Pradidatan (1989) subdivided the succession into syn-and post rift sequences.