CHAPTER 2
GEOLOGY

2.1 Study area

2.1.1 Location

The Mae Moh coal field is located in Mae Moh District in Lampang Province, northern Thailand, and lies within the Mae Moh basin. It is about 630 kilometers north of Bangkok. The nearest city is Lampang, 25 kilometers to the west. Chiang Mai is 125 kilometers to the northwest (Figure 2.1).

2.1.2 Physiography

The Mae Moh basin trends north northeast and has an oval shape. It covers an area of 107 square kilometers. The average basin elevation is about 330 meters. The east and west sides of the basin are bounded by steep and sub-parallel mountains. The highest peaks are Doi Pha Tob, 921 meters above sea level, in the east and Doi Prarang, 895 meters above sea level, in the west (Figure 2.2). To the north, the basin is enclosed by northeast-trending mountains consisting of Triassic rocks. Quaternary basalt overlies the southern part of the basin.

2.2 Regional geologic setting of Thailand

Thailand is located in the northern part of Southeast Asia and comprises two major continental blocks (Gatinsky and others, 1978; Mitchell, 1981; Bunopas, 1981). These blocks are the Shan-Thai and Indochina blocks. The Thai-Malay mobile belt is an intervening band between these two blocks (Stauffer, 1973; Ridd, 1980; Hahn and others, 1986) (Figure 2.3). The Shan-Thai block comprises east Burma, west Thailand, and west Peninsular Malaysia. The block consists of Pre-cambrian granitoids and high-grade

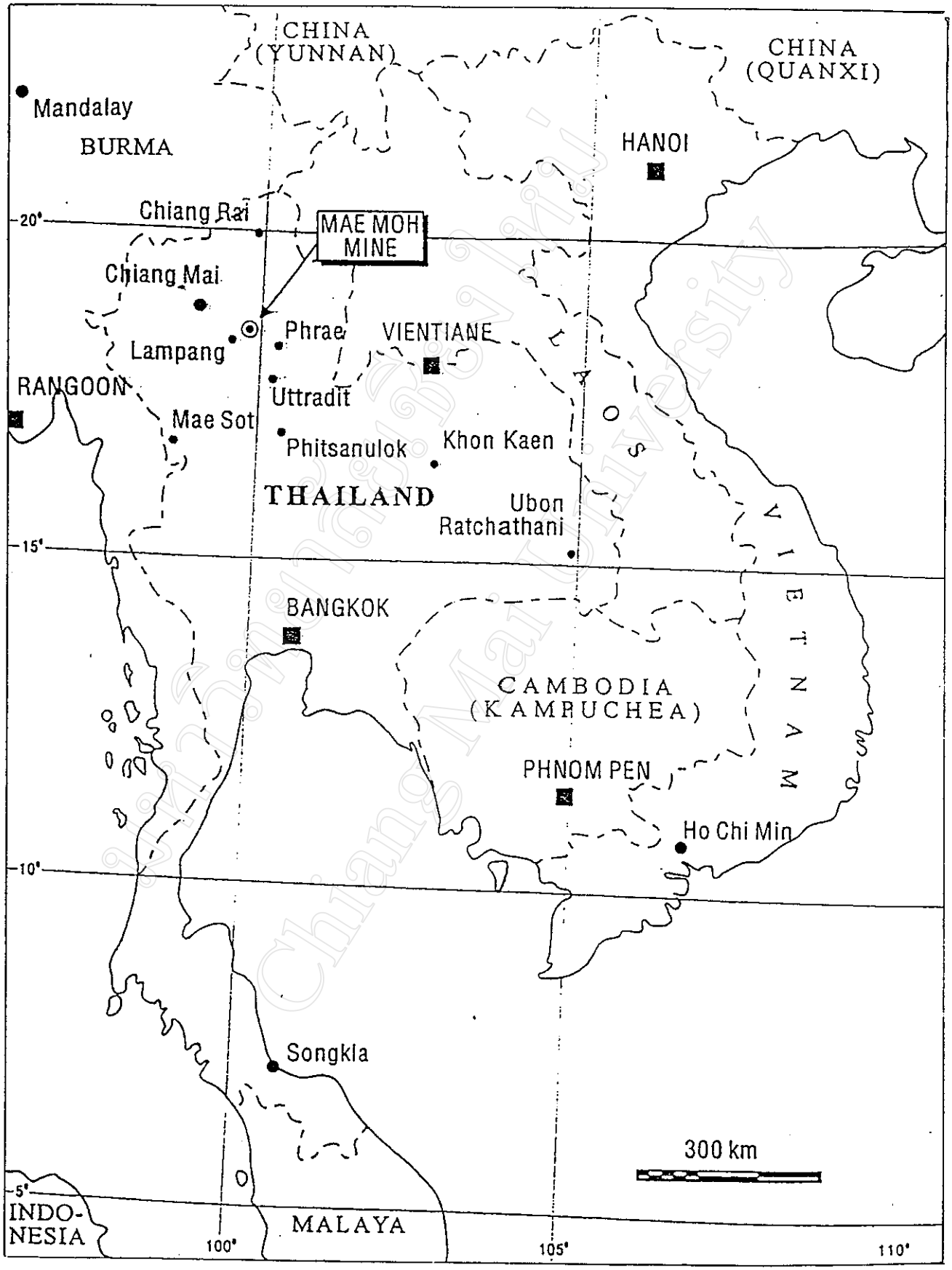


Figure 2.1 Location map of Mae Moh coal field in northern Thailand (after Electricity Generating Authority of Thailand, 1996)

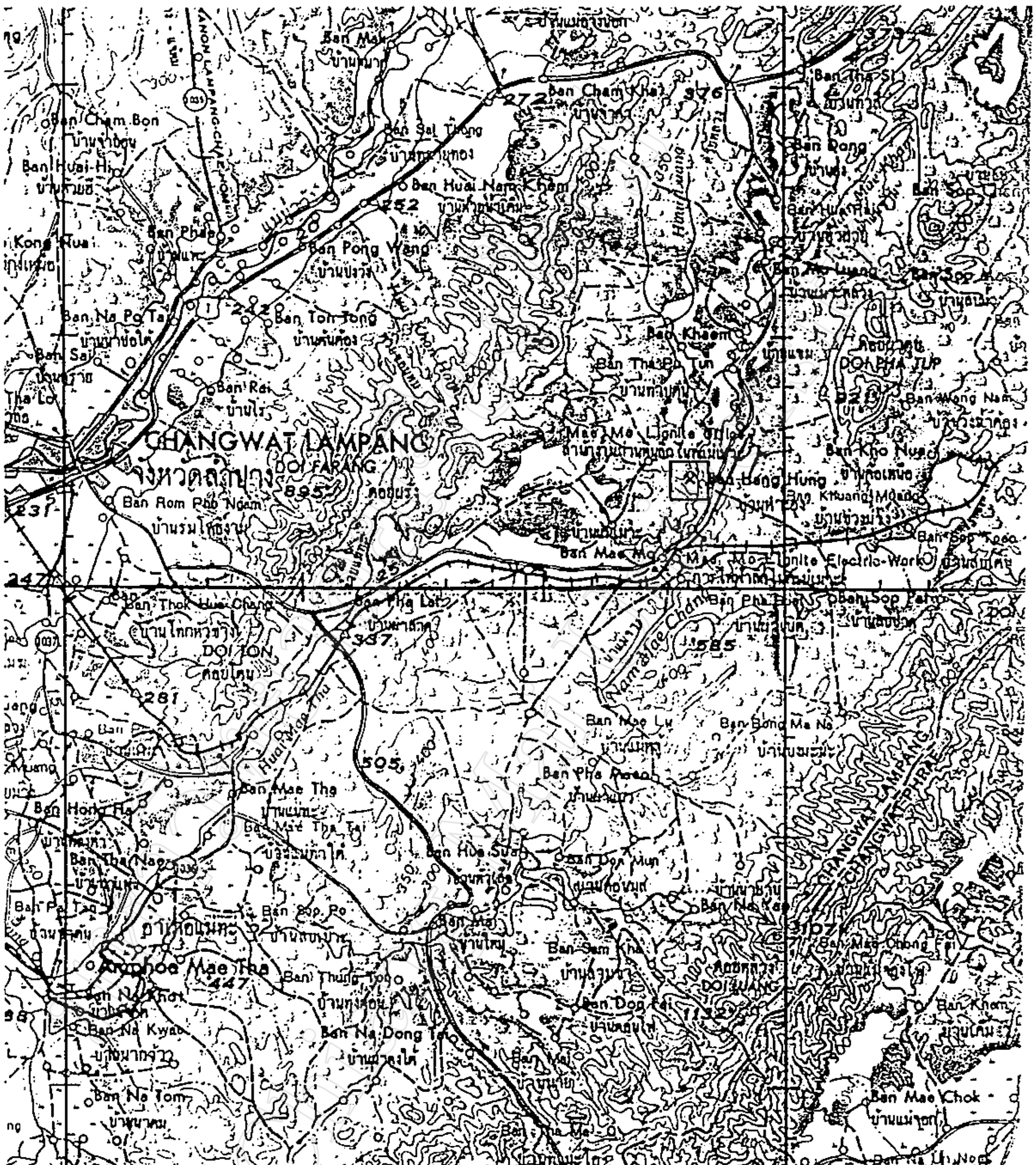


Figure 2.2 Topographic map of Mae Moh coal field and surrounding area (after Royal Thai Survey Department, 1983)

metamorphic rocks overlain by folded Paleozoic and Mesozoic rocks (Bunopas, 1981; Fontaine, 1986). The Indochina block in eastern Thailand is composed mainly of the gently folded Mesozoic continental sedimentary sequences of the Khorat Group, Permian platform carbonate and deep water clastic facies (Wielchowsky and Young, 1985), and older Paleozoic rocks. The Thai-Malay mobile belt, which is a structurally complex area with folding and overthrusting towards the east, extends from northern Thailand through central Thailand and the Gulf of Thailand to Sumatra. This area is characterized by strong volcanism (calc-alkaline volcanic rocks) that, especially, occurred during Late Permian to Middle Triassic time. The Nan suture zone is believed to be the Late Triassic collision belt between the Shan-Thai and Indochina continental blocks (Bunopas, 1981; Mitchell, 1981; Hahn and others, 1986).

2.3 Geologic setting of Tertiary basins in Thailand

Northern Thailand has more than 40 Tertiary basins that range in size from 30 to 1,400 square kilometers (Natasilapa and Sucontanikorn, 1979). These basins are mainly north-south trending half grabens and grabens. They are filled with sedimentary rocks having thicknesses of 1,000 to 3,000 meters. The pre-Tertiary basement underlying these basins is complex igneous, metamorphic, and sedimentary rocks. These Tertiary basins are dominated by syn-sedimentary extensional and strike-slip faults. These faults suggest that the basins are pull-apart basins that formed by simple shear tectonics rather than by pure extension processes. (Molnar and Tapponnier, 1975; Tapponnier and others, 1982) Movement along major strike-slip fault systems in this region during the Cenozoic is attributed to the northward progressive collision of the Indian craton with southern Asia and the consequent southeastward extrusion of Southeast Asia away from the front of India. Much of this movement is said to be accommodated by predominantly left lateral slip on northwest-southeast-trending strike-slip faults.

The Mae Moh basin is located in the rhomb-shaped Shan-Thai block (Bunopas, 1981). This block of Sundaland was further distorted during the collision of the Indian craton with Eurasia that began in the Eocene, 45 million years ago (Johnson, Powell, and Veevers, 1976). According to Metcalfe (1993), the Cenozoic modification of Southeast Asia involved substantial movements along, and rotations of, strike-slip faults, rotations of continental blocks, and the development and spreading of marginal seas. These

modifications were due to the combined effect of the interaction of the Eurasian, Pacific, and Indo-Australian plates and the collision of India with Eurasia.

Sundaland was not deformed as a coherent block. Strain was accommodated by movement on many strike-slip faults and considerable block rotation (Huang and Opdyke, 1993; Yang and others, 1993; Haihong and others, 1995). Clock-wise block rotation and strike-slip faulting were significant at least as late as the Miocene (Haihong and others, 1995). The corridor of fault-bounded Cenozoic basins in northern Thailand that included the Mae Moh basin was created and deformed at this time. Later Neogene movements uplifted northern Thailand. In the process, the Mae Moh basin was subjected to erosion.

2.4 Geologic setting of the Mae Moh basin

The Mae Moh basin is mainly flanked by marine Triassic rocks, the Lampang Group. These rocks consist of limestone, shale, and sandstone. Quaternary basalt overlies the Tertiary sequence in the southern part of the basin (Figure 2.4). Unconsolidated fluviatile deposits form a thin veneer cover throughout the basin. These unconsolidated deposits consist of superficial gravel overlain by alluvium (Jitapunkul and others, 1985). The major trends of deformation around the basin are northeast to north-south. The Tertiary succession in the basin is bounded by north-south trending normal faults that resulted from an extensional tectonic regime in the Tertiary and which continued close to Recent time (Bunopas, 1982).

2.5 Stratigraphy

The Tertiary succession in the Mae Moh basin can be separated into three formations (Figure 2.5). These formations form the Mae Moh Group. Each formation consists of strata that strongly differ in lithology, sedimentary structure, degree of consolidation, and fossil content.

Huai King Formation: This formation is the lowermost formation of the Tertiary succession. It consists of semi-consolidated mudstone, siltstone, sandstone, conglomeratic sandstone, conglomerate, and some claystone. It is varigated in colour, being red, gray,

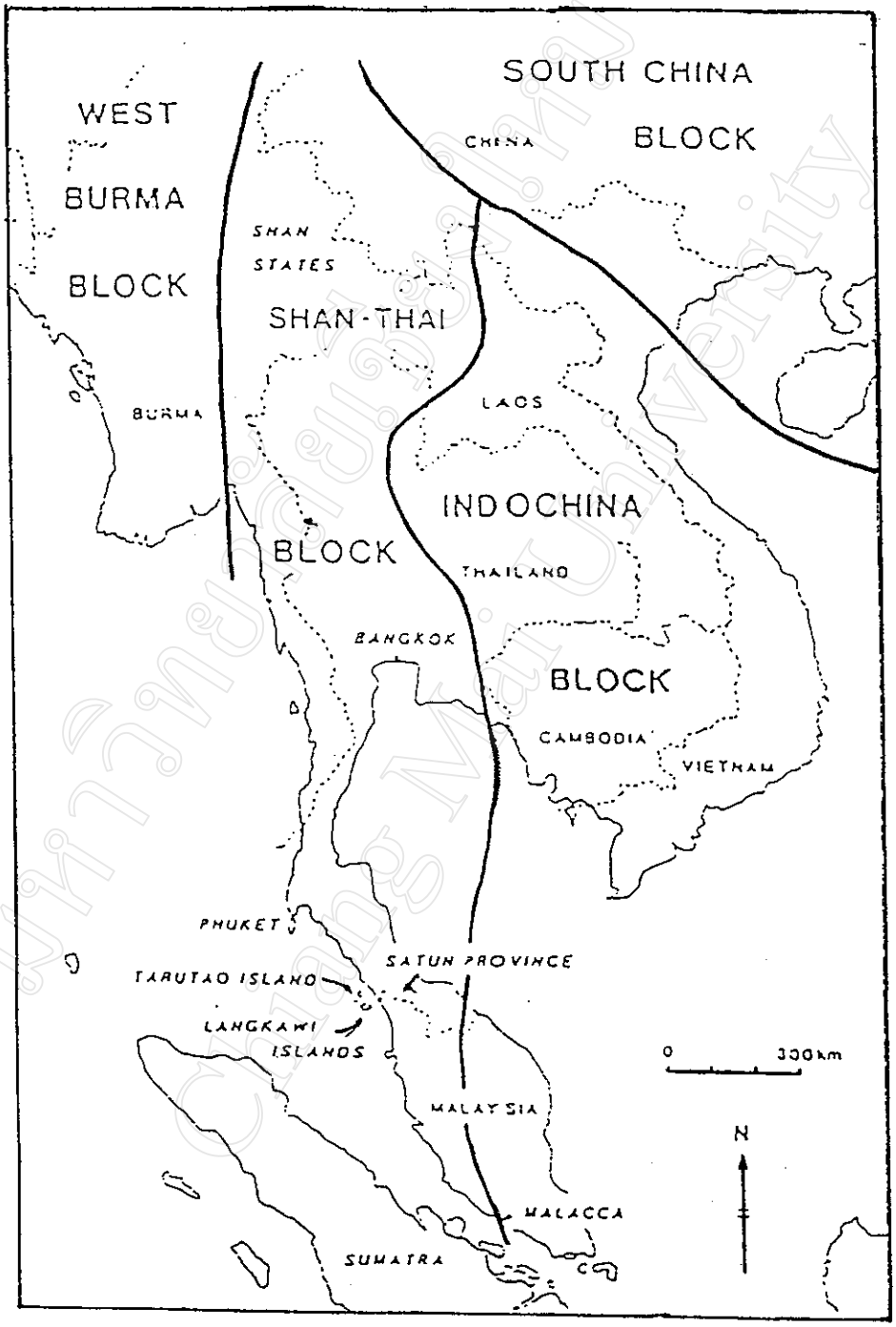
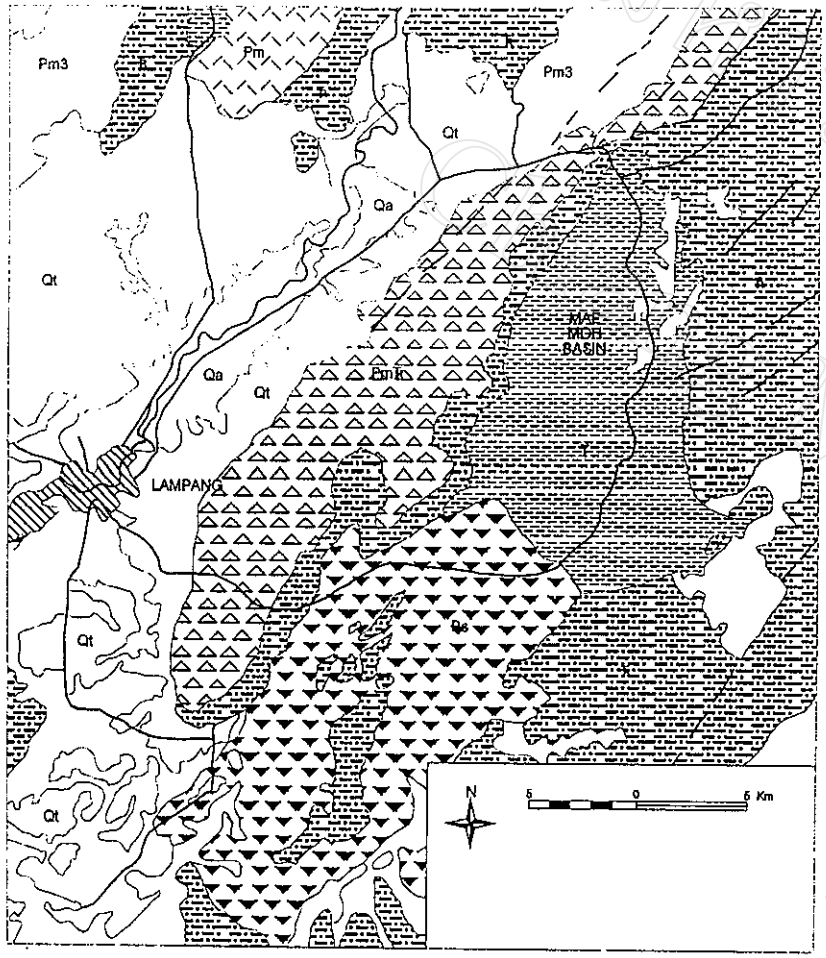


Figure 2.3 Tectonic map of SE Asia and South China showing the crustal blocks in response to the collision of Indian with Asia (After Bonopas, 1992)



MAP ILLUSTRATION

SYMBOL	DESCRIPTION	FORMATION	GROUP	AGE
Qa	River gravel, sand, clay and mud	-	-	-
Qt	River terraces, gravel, sand, silt, clay	-	Mae Taeng	Quaternary
T	Fresh water sandstone, shale, carbonaceous shale, limestone, viviparus beds, lignite	-	Mae Moh	Tertiary
TR	Reddish-brown sandstone, shale, conglomerate, greenish-grey siltstone, shale sandstone Limestone, limestone conglomerate, with fossil of gastropods, brachiopods *Claraia, Halobia, daonella, posidonia*, ammonites reenish-gray shale, sandstone, tuffaceous sandstone, laminated shale, conglomerate, with fossils of *Halobia, Daonella, Posidonia, Trachyceras, Paratrachyceras, Joannites*, etc. Basal conglomerate; reddish-brown sandstone, shale, agglomerate, tuff		Lampang	Triasic
Pm1	Shale, calcareous shale, carbonaceous shale, tuffaceous shale and sandstone, laminated shale with fossils of *Dielasm Leptodus, Orthotichia, Echinochus, Neospirifera, Schizophoria, Aviculopecten*, etc.	Huai Thak		Permian
Pm3	Tuffaceous shale and sandstone lens, andesitic tuff, agglomerate, rhyolitic tuff, agglomerate, andesite, rhyolite	Kui Lom		
Pm	Rhyolite, tuff, agglomerate; andesite, tuff, agglomerate	Volcanic	Voncanic	Permo-Triassic
Bs	Basalt; vesicular, amygdaloidal	-	-	Pleistocene

Figure 2.4 Geologic map of Mae Moh basin (after Ratanasthien *et al.*, 1997)

green, yellow, blue and purple, commonly calcrets in part, has a slight amount of calcareous cement, and has no macro fossils except *Viviparus* sp. The typical character is a fining upward sequence that grades from conglomerate at the base to mudstone or claystone on top. Thickness varies from less than 15 meters on basin borders to 150 meters on the central part of the basin.

Na Khaem Formation: This is a coal-bearing formation that consists of semi-consolidated mudstone and five zones of lignite. The mudstone is grey to greenish grey and very fossiliferous, including gastropods, fish remains, ostracods, and plant remains. It is highly calcareous, contains load structures, flaser bedding, burrows, and borings and has an intraformational conglomeratic texture in some layers near lignite zones. The formation's thickness varies from 250 to 400 meters. There are two major economic lignite seams in the formation that can be separated by lithological criteria and economic aspects into three members.

Member III (underburden). This lowest unit is a sequence of grey to greenish grey claystone and mudstone. These beds are laminated to thick bedded, planar type, are highly calcareous, and have abundant gastropod beds in the upper part, fish remains, ostracods, and plant roots. The texture is intraformational conglomeratic and the claystone is varigated near the lignite seams and layers. Burrows and borings and load casts are present. Two thin seams of lignite, from 1 to 6 meters thick, are interbedded in the middle and lower portion. These seams are called the R-zone and S-zone. Thickness of this member varies from 150 to 230 meters.

Member II is the most economically attractive coal sequence. It has three distinct zones.
K-Zone: This is a sequence of coal in the upper part of member II. The coal is black to brownish black, brittle, and has calcareous white spots, numerous gastropods, and rare fish and plant remains. It is interbedded with some soft lignite and it has partings of light yellowish grey to grey silty claystone. The thickness varies from 10 to 30 meters. However, it is split in the north and south with thicker silty claystone partings and changes laterally to ligniteous claystone/clay. The coal units are named K1 to K4.

Interburden: This is a 10- to 30-meter thick sequence of brown, brownish grey, grey, green, and greenish grey claystone. This claystone lies between two major coal seams. The beds are laminated to thickly bedded, planar type, and commonly have lignite flakes, fish remains, plant roots, and, rarely, ostracods. Intraformational conglomeratic textures are common in the lower part. Gastropods and load casts are common. Micro slip planes are abundant. This interburden is thickest in the east part of the main basin and thins toward the west flank of the main basin.

Q-Zone: This lower zone is a sequence of coal called the Q-zone. The coal is black to brownish black, brittle, has abundant siliceous calcareous white spots (diatoms), pyritized gastropods (*Viviparus* sp.), and plant remains. It is interbedded with soft lignite and partings (about 30 percent) of light brown claystone/silty claystone. Technically, the seams are divided into Q1 to Q4 with a thickness that varies from 25 to 30 meters. However, it is split in the north and south with thicker silty claystone partings and changes laterally from lignite layers to ligniteous claystone/clay.

Member I (J-zone) is a sequence of grey and greenish grey claystone and mudstone that occasionally has siltstone in some parts. These beds are laminated to massive, planar type, and highly calcareous. Fine pyrite spots are common in some parts. The unit has abundant gastropods, fish remains, ostracods, plant remains, reptile skeletons, and load structures. Its has an intraformational conglomeratic texture and is varigated near lignite seams or lignite layers. Burrows and borings are present. The upper part of this zone consists of two thin argillaceous layers, both less than 2 meters thick, and 13 thin seams of lignite. These lignite seams are named J1 to J6.

Huai Luang Formation: This formation consists of semi-consolidated and unconsolidated sediments. Red to brownish red colours are typical, though there are some grey layers interbedded in some parts. The lithology is claystone, siltstone, and mudstone and some lenses of sandstone and conglomerate in the central part of the basin. There are no macro fossils. Gypsum and pyrite are abundant, root structures and flame structures are rare. The formation varies in thickness from less than 5 meters to 350 meters. It is thickest in the central part of the main basin and in the western sub-basin. It thins rapidly towards the eastern and western margins, where it is entirely absent or only a few meters thick. This

formation was called red beds by Longworth-CMPS-Engineers (1981), who concluded that its red-brown colour was likely due to oxidation of fine-grained pyrite disseminated throughout some layers. These oxidation products combined with the abundant calcareous material within the basin to form gypsum.

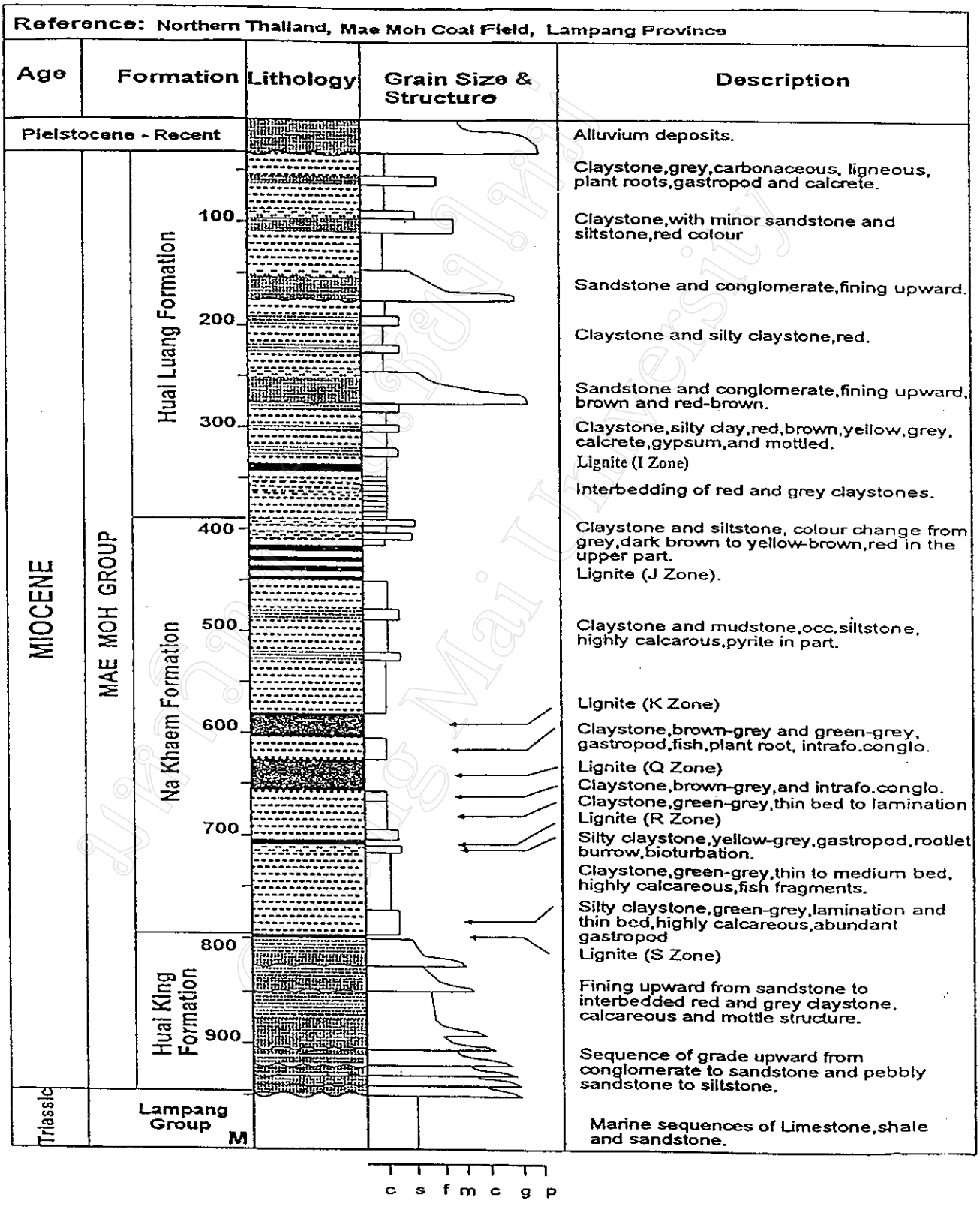


Figure 2.5 Cenozoic stratigraphy of Mae Moh basin (Modified from UNOCAL, 1998)

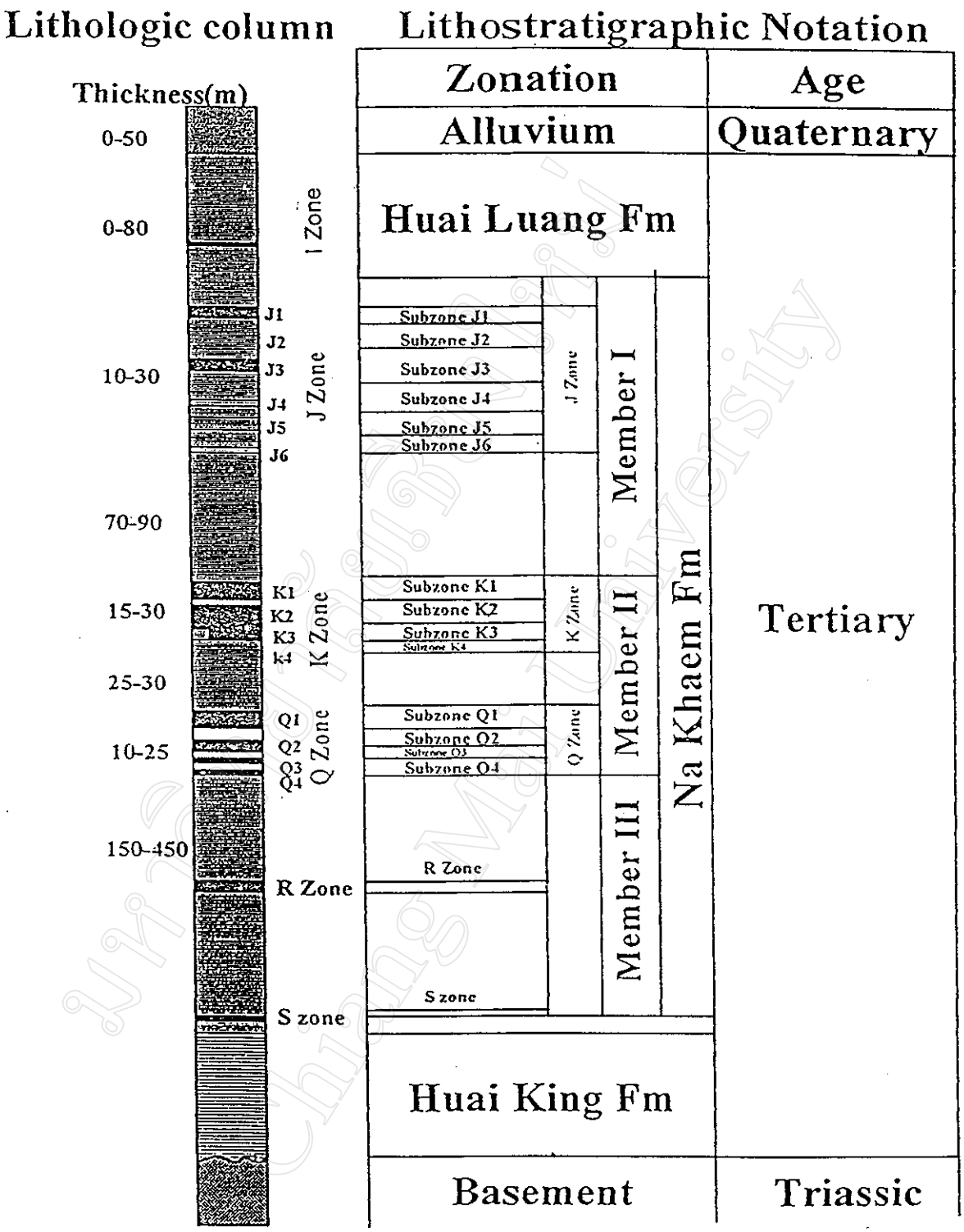


Figure 2.6 Schematic lithostratigraphy of Mae Moh Tertiary sedimentary sequences (after Jitapunkul, 1985)