CHAPTER 1
INTRODUCTION

1.1 General Introduction

There are about sixty Cenozoic basins distributed both onshore and offshore in Thailand (Figure 1.1). Coal exploration has taken place only in some of the onshore basins. Recent coal mines and coal fields are mostly in northern basins, though there are a few coal deposits in the central and southern parts of Thailand. Most basins developed during Tertiary time as an effect of extensional rifting related to the collision of the Indian plate against the Asian plate (Burri, 1989). Many basins are half-grabens that resulted from strike-slip movement. This horizontal movement, in combination with extensional faulting, created very complex, densely faulted basin margins. Most of the Tertiary basins unconformably overlie pre-Tertiary sequences and, in turn, are overlain by Quaternary sediments.

In northern Thailand there are more than 40 Tertiary basins. These basins range in area from 30 to 2,000 square kilometers (Figure 1.2). They were mostly formed by north-south trending half-grabens and grabens and have been filled with 1,000 to 3,000 meters of sedimentary rocks (Uttamo, 1998). These sedimentary strata overlie Mesozoic and older rocks. Some of these basins have rich coal and oil shale deposits. Small oil fields have been found in the Fang basin. Large lignite deposits have been mined in the Mae Moh and Li basins. Gibling and Ratanasthien (1980) found thin layers of gypsum in many basins in northern and western of Thailand, this indicating that deposition occurred in lacustrine environments having high salinity.

The Tertiary deposits of the Mae Moh basin contain the largest coal deposit in Thailand (Ratanasthien and Ruangvatanasirikul, 1994). This coal-bearing sequence was deposited in lacustrine and fluvial environments. The Mae Moh basin is mainly flanked by the marine Triassic rocks of the Lampang Group. Quaternary basalt overlies the Tertiary strata in the southern part of the basin. Unconsolidated Quaternary fluviatile deposits form a thin veneer cover throughout the basin. The Tertiary sequence in the Mae Moh basin, the

Mae Moh Group, can be divided into three formations: the Huai Luang Formation, the Na Khaem Formation, and the Huai King Formation (Jitapunkul, 1985).

Coal is defined as a compact stratified mass of plant debris that has been modified chemically and physically by natural agencies. It is usually interspersed with smaller amounts of inorganic matter (Francis, 1961). This plant debris is derived mainly, though not exclusively, from vegetation growing within the basin. The chemical properties of a coal depend upon the different constituents present in the parent vegetable mass, the nature and extent of the changes that these constituents have undergone since their deposition, and the nature and quantity of the inorganic matter present (Francis, 1961).

High sulfur content in coal may be the effect of marine transgression during the formation of peat. Although decomposition of plant debris can result in a low sulfur content coal, a low sulfur content in coal can also result from volcanic eruptions and the weathering of gypsum layers.

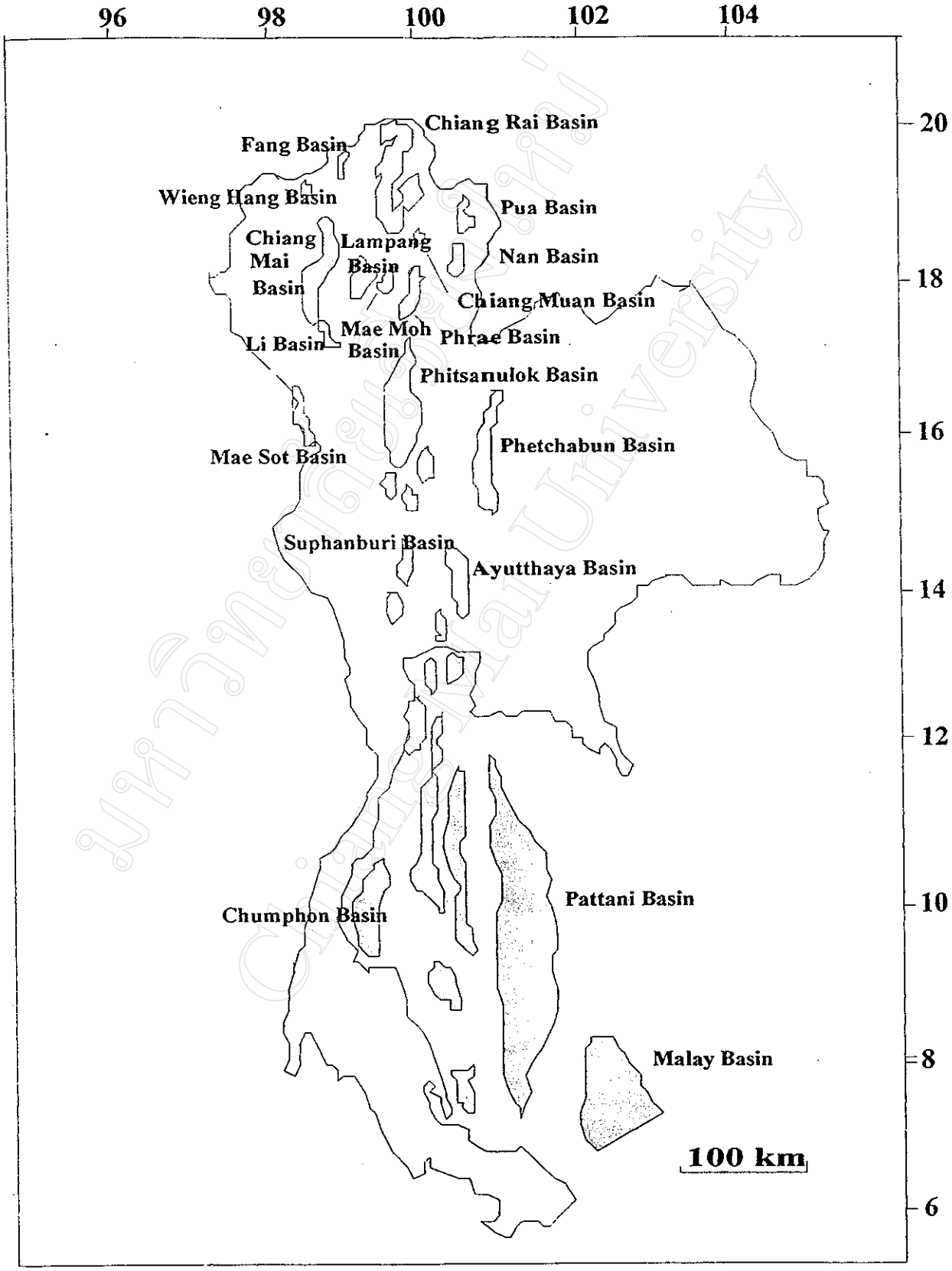

Figure 1.1 Cenozoic basins in Thailand (After Chinbunchon et al., 1989)

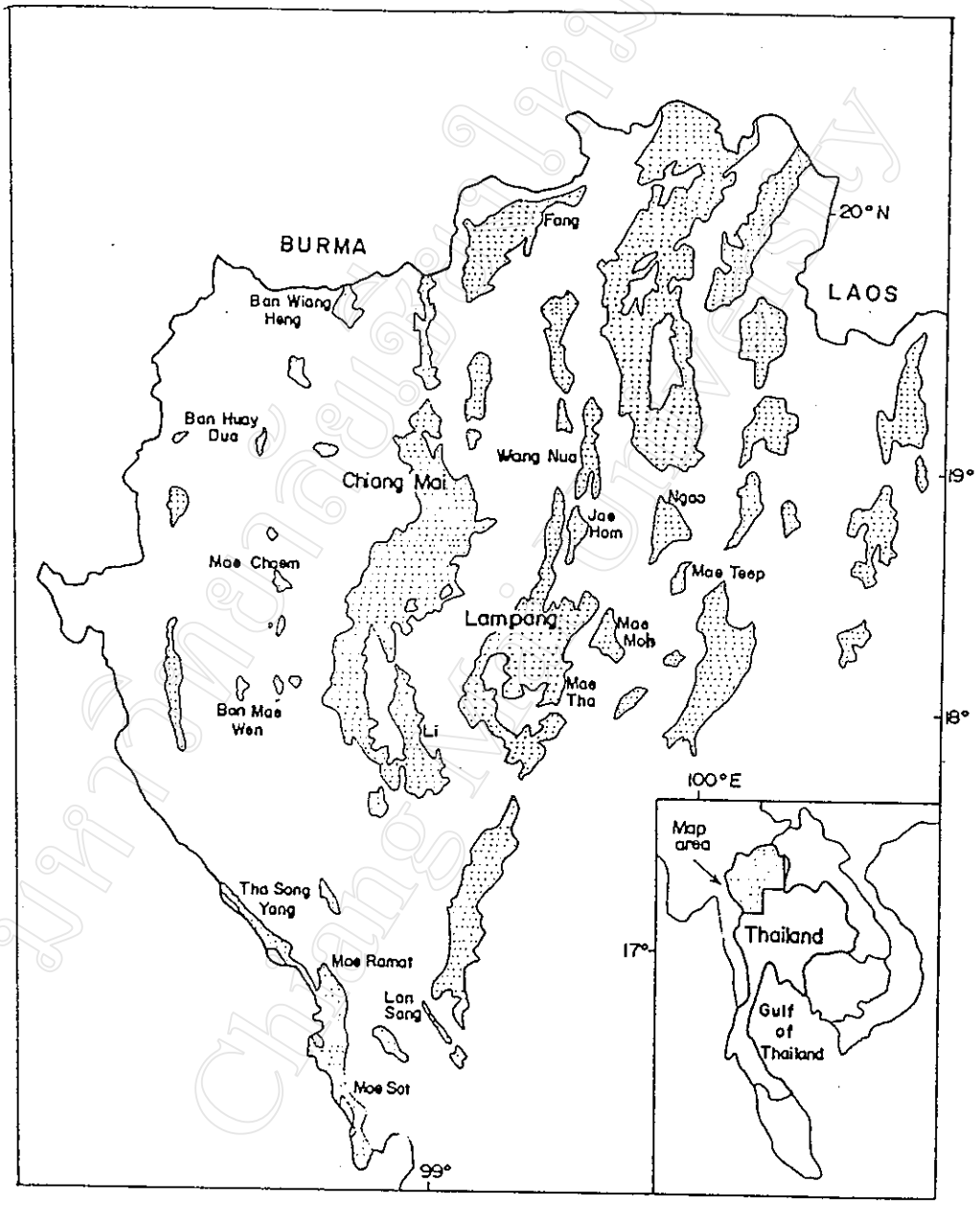

Figure 1.2 Cenozoic basins in northern Thailand (After Uttamo, 1998)

1.2 Objective

The objective of this research was to use geochemical techniques to determine sediment source, depositional processes, and changes in depositional environments of Tertiary rocks in the Mae Moh coal field.

1.3 Scope, planning, and methodology

1.3.1 Review previous work

1.3.2 Collection of sedimentary rock and coal samples from the Mae Moh mine face

1.3.3 Sample preparation for geochemical analyses

1.3.4 Proximate and ultimate analyses to determine chemical composition and coal quality

1.3.5 Study of minerals and elements of sedimentary rocks and coal samples using x-ray diffractometry technique, x-ray fluorescence spectrometry, and induced couple plasma to define the chemical composition of fly ash coal, sediment sources, processes of deposition, and depositional environments

1.3.6 Making polished sections of coal samples and studying coal petrography to determine coal macerals

1.3.7 Data compilation and analysis to construct the pattern of depositional environments of the Mae Moh coal field

1.3.8 Discussion and conclusion

1.4 Education advantages

1. This research will indicate the changes of depositional environments in the Mae Moh coal field during several geologic time intervals.

2. The geochemical data of the Mae Moh coal field from this study may be used for comparison and correlation with surrounding Tertiary coal fields.

3. The depositional environments of the Mae Moh coal field determined from this study may be correlated with other Tertiary coal deposits.

1.5 Previous investigations

1.5.1 Structural geology and tectonic setting

Longworth-CMPS Engineers (1981) reported the nature of late Cenozoic faults based on sparse surface exposures, high resolution reflection seismic profiles, and drillholes. This report indicated that in the middle of the area there is a graben that is about 2 kilometers wide. This graben trends about 015 degrees and is bounded on both eastern and western sides by major fault zones. These faults have throws of more than 200 meters along much of their lengths. Evans and Jitapunkul (1990) recognized two phases of deformation. These two phases are the products of strike-slip movements in basement. The first deformation phase was right lateral strike-slip movement along the basin axis. The second deformation phase was left lateral movement. Rui Lin (1999) concluded that the Mae Moh basin is an intermontane basin largely comprised of fluvial, alluvial, and lacustrine sedimentary facies deposited on a pre-Tertiary basement. The basin is one of a series of intermontane basins that developed as intra-cratonic extensional and trans-tensional basins oriented roughly north-south. The extension process that formed these basins and the resulting sedimentation probably started in the Oligocene.

Ratanasthien and Kandharosa (1986) studied the depositional environments of Tertiary coal formations in northern Thailand and concluded that granitic magma intrusion in the Late Cretaceous led to uplift and formed north-south oriented sedimentary basins. The sedimentary rocks that were deposited in these basins were well-sorted and their thickness increased as deposition progressed. Eventually, subsidence ceased and these basins became sites of swamp deposition. These swamp deposits were eventually transformed to coal and petroleum-bearing rocks.

1.5.2 Sedimentology

Chaodumrong (1985) studied the depositional environments in the Mae Moh basin and found that the lower sedimentary sequence of the basin was deposited in a fluvial braided river environment in its lower part and in a meandering river environment with overbank deposits in its upper part. The basin's middle sedimentary sequence is indicative of a calcium-rich lacustrine environment. The basin's upper sequence was deposited in

both low energy and relatively higher energy environments. The lower and upper parts of this upper sequence are low energy overbank flood plain deposits. The middle part of this upper sequence is relatively higher energy fluvial meandering river deposits.

Ratanasthien (1990) recognized that volcanic activity had occurred in the Mae Moh basin. She found lava flows associated within the basin. She also found a series of volcanic ash and diatomaceous beds associated with coal beds. The mastodon *Stegolophodon* fossils found in the Mae Moh basin indicate a Middle Miocene age (Ginsburg, 1990). This age agrees with the conclusion of Srinivasan (1987) that the highest volcanic activity of the Mae Moh basin occurred between 20.5 and 17.2 million years ago.

Uttamo (1998) studied the lithofacies of part of the sedimentary sequence in the Mae Moh basin. He concluded that there was a change in the depositional environment of the basin during the Late Miocene. The depositional environment changed from a semi-arid, brackish water flood basin that had small debris flows to a fresh water, lacustrine environment with peat and back swamps and eventually to a flood plain and large braided river environment.

1.5.3 Stratigraphy

Brown and others (1953) used the term Mae Sot Series to denote all Tertiary sedimentary rocks of northern Thailand and referred to the Mae Moh lignite.

Gloe (1955) and Sithiprasasna (1959) used the term Mae Moh Tertiary sediments to describe the Tertiary sequence that contained lignite in the Mae Moh basin. Four major lignite beds were recognized and assigned in alphabetical

sequence from bottom to top: L shale, L lignite, M shale, M lignite, N shale, N lignite, O shale, O lignite, and P shale (Table 1.2).

Garder (1967) measured and described a type section of the Mae Moh Tertiary rocks using data from outcrops and boreholes. He used the name Mae Moh Formation (formerly spelled Mae Mo Formation) and subdivided the formation using an alphabetical sequence similar to that of Gloe (1955). Garder recognized nine beds and two concealed zones: lower unexposed zone, L claystone bed, L lignite bed, M claystone bed, M lignite bed, N claystone bed, N lignite bed, O claystone bed, O lignite bed, P claystone bed, and

concealed zone, in ascending order. The thickness of the Mae Moh Formation was estimated to be 937 meters.

Piyasin (1971) used the term Mae Moh Group to denote Tertiary rocks in northern Thailand, deriving the name from the Mae Moh mine site.

Longworth CMPS Engineering (1981) divided and described the stratigraphic sequence within the Mae Moh basin using general terms. From top to bottom, these are: surficial gravel and alluvium, red beds, grey claystone, upper lignite seam K, interburden grey claystone, lower lignite seam Q, and grey claystone. The maximum thickness of the Mae Moh stratigraphic sequence was estimated to be 1,030 meters. Chaodumrong (1985) recognized that in the code of stratigraphic nomenclature a group is composed of formations and that formations include members. He did not apply formal names to divisions of the Mae Moh group, but developed an alpha-numeric nomenclature, Table 1.2. He recognised three formations, A, B, and C in ascending order, and divided these into members, such as B1, and B2, for example. He further divided the lignite members B-2 and B-4 into four and five beds, respectively.

Corsiri and Crouch (1985) established the stratigraphic nomenclature for the Cenozoic of the Mae Moh basin that is in current use. They recognised the Huai King, Na Kheam, and Huai Luang Formations. These correspond to Chaodumrong's formations A, B, and C, respectively. Corsiri and Crouch informally used Roman numerals to label three members of the Na Kheam Formation I, II, and III. They also retained the K and Q designations of the lignite horizons assigned by Longworth-CMPS Engineers (1981), but identified them as zones. They expanded this nomenclatural system by additionally identifying the lignite J, R, and S zones.

1.5.4 Paleontology and Palynology

Von Koenigswald (1959) described mastodon molars from the Mae Moh basin as a new species, *Stegolophodon praelatidens*. This species is supposedly more primitive than *S. latidens* from Burma and he referred it to the Lower or Middle Pliocene, which, according to modern usage, would correspond to the Upper Miocene or the Lower Pliocene. According to Ginsburg and Tassy (1985), who have described additional mastodon material from the Mae Moh basin, the available material is insufficient for

identification at the species level. *Stegolophodon praelatidens* should, thus, be considered as a *nomen dubium* and the Mae Moh teeth should be allocated to *Stegolophodon species*.

Other mammal remains found at the Mae Moh mine in the course of mining operations have been described by Ginsburg and others (1983) and by Ginsburg and Tassy (1985). They include a mustelid carnivore, *Siamogale thailandica,* represented by a single tooth, and a rhinoceros resembling *Gaindatherium,* represented by a tooth fragment and various postcranial elements. The available mammal remains from the Mae Moh mine do not permit a very accurate dating. According to Ginsburg and Tassy (1985), the rather primitive features of the Mae Moh *Stegolophodon* suggest that it may be Middle Miocene or early Late Miocene in age.

Ginsburg and Tassy (1985), Ginsburg and other, (1988), Buffetaut and others, (1989), and Ginsburg (1989) addressed the age of the Mae Moh Group and deduced from the evidence of fossil vertebrates that the sequence's age is Miocene. Ginsburg (1989) stated the group's age to be Middle Miocene. Ducrocq and others (1995) concluded from a survey of mammalian fossils that all the Cenozoic continental basins of northern Thailand were created within a time ranging from 16 to 14 million years during the early Middle Miocene.

Gibling and Ratanasthien (1980) found fossil assemblages in mudstone at the Mae Moh mine. A mudstone 6 meters thick contains fish fragments in its lower part and has gastropods and fish and plant fragments in its upper part. This mudstone is overlain by coal. Their study showed a cyclicity of regressive depositional environments, with the depositional environments repeatedly changing from open water to swamps to peat bogs.

Watanasak (1988, 1989) concluded on the basis of pollen and spore content of core samples from a drill hole that the Mae Moh Group ranges in age from the base of the Early Miocene, SIAM-1 spore-pollen zone, to above the Middle Miocene, SIAM-2 spore-pollen zone. He correlated the lignite-bearing Q and K zones with the post-SIAM-2 zone, but still referred to them as Middle Miocene. Watanasak (1988) identified the age of the spore pollen zones through the association of microfloral assemblages with foraminifera and coccoliths in marine strata in the Andaman Sea.

Brown *Et al.* 1953	Gloe 1955		Gardner 1967		Piyasin 1971	Longworth-CMPS Engineers 1981		Chaodumrong 1985		Corsiri & Crouch 1985		
			Recent sediments							Alluvium		
Mae Sot Series	Mae Moh Tertiary Sedi-ments		Pleistocene? Sediments		Mae Mo(h) Group	Over-burden	Red Bed	C Forma-tion	C-3 C-2 C-1	Huai Luang Formation		
		'P' shale	Concealed					B Forma-tion	B-6	Na Khaem Forma-tion	I	I zone
		'O' lignite	'O' lignite bed	Mae Moh Forma-tion								
		'O' shale	'O' claystone				Grey clay-stone		B–5			
		'N' lignite	'N' lignite or upper bed			'K' Seam			B–4		II	K zone
		'N' shale	'N' claystone bed			Interburden			B–3			Interburden
		'M' lignite	'M' lignite bed or lower bed			'Q' Seam			B–2			Q zone
		'M' shale	'M' claystone bed			Grey Claystone			B–1		III	R zone
		'L' lignite	'L' lignite									
		'L' shale	'L' claystone									S zone
			Unexposed					A Forma-tion	A-2	Huai King Formation		
									A-1			

Table 1.1 History of stratigraphic nomenclature applied to the Cenozoic of the Mae Moh Basin (after Chaodumrong, 1985)