CHAPTER 6

DISCUSSION

6.1 SAMPLE TREATMENT

There are at least two types of sedimentary samples used in this study, warm temperate sporomorph-bearing samples and tropical ones. These two kinds of samples need different techniques in sample preparation. The warm temperate sporomorphs are distinctly more acid-resistant than the tropical ones. At the beginning of the research, the samples were always soaked in concentrated nitric acid (HNO_3), at least overnight. The warm temperate samples yielded common to abundant sporomorphs. On the other hand, the tropical samples usually yielded no sporomorphs. A hypothesis was that the concentrated nitric acid is a strong oxidant which probably destroyed the sporomorphs, especially the tropical ones. The tropical samples, particularly lignite, were, thereafter, soaked in acid for usually less than five minutes. Some samples then yielded common to abundant sporomorphs. The warm temperate samples were also treated in the same manner as the tropical samples. It is strongly reliable that the properties of the exines between the warm temperate and tropical pollen are different in some ways but their real nature is still questionable.

6.2 RECOGNITION OF TWO STRATIGRAPHIC ZONES

Sediments in the Tertiary basins of northern Thailand are clearly recognizable as having two biostratigraphic zones. One is the zone containing warm temperate pollen and another one containing tropical pollen. The two zones also contain different faunal assemblages. The tropical zone has much more biological diversity than the warm temperate zone. Several forms of bones of elephant, barking deer, deer, rhinoceros, hippopotamus, otter, pig, fish, crocodile, turtle, monkey, and so on were reported from the tropical biostratigraphic zone including Na Sai, Mae Long, Chiang Muan, and Mae Moh localities. On the other hand, none of these bones have been reported from the warm temperate zone such as the Na Hong, Ban Pa Kha, and Mae Lamao localities. These difference in the floral and faunal assemblages of the two zones correspond to a fact that animals and plants in the tropical areas are today much more diversified than in the temperate areas. Accordingly, the tropical areas have much more opportunity to preserve the animals as fossils than in the temperate areas.

Furthermore, coal from the warm temperate zone seem to be better quality than the coal from the tropical zone. In addition, coals from the tropical zone normally have a high sulfur content. This is probably because the warm temperate coals are older than the tropical coal or they deposited in different environments. In addition, the warm temperate coals and the tropical coals were derived from different plant materials. However, further research is needed to better explain this observation.

6.3 MICROFOSSILS VS MACROFOSSILS

The occurrence of two palynological assemblages, warm temperate and tropical, may not strongly support the existence of climatic changes. The fossil sporomorphs were possibly *ex situ* and were considered as allochthonous materials. The warm temperate pollen may come from other places like higher latitudes and/or higher altitudes by wind dispersal. Macrofossils are, thus, important materials to help support this existence. Macrofossils together with microfossils provide complementary evidence with respect to past vegetation type (Morley, 1999). Macrofossils like plant remains from Ban Pa Kha coalfield are relevant. Those plant remains were reported by Endo (1964, 1966) and Yabe (2002) as warm temperate floras. The plant remains include leaves, catkins, and cones as shown against the pollen from this study taxon by taxon are given in Figure 6-1 and Figure 6-2. The catkins and leaf of *Alnus thaiensis* (Figure 6-1, a and b) are supposed to be parts of the alder tree producing the pollen *Alnipollenites verus* (Figure 6-1, c). Leaves of *Sequoia langsdorfii* (Figure 6-1, d) and cone of *Taxodium thaiensis* (Figure 6-1, e) belonging to trees of the family Taxodiaceae producing pollen that is similar to *Inaperturopollenites dubius* (Figure 6-1, f). Leaf of *Fagus feroniae* (Figure 6-2, a) belong to a beech tree producing the pollen *Faguspollenites* (Figure 6-2, b) as well as the leaves of *Quercus* cf. *Q. lanceaefolia* (Figure 6-2, c) and *Quercus protoglauca* (Figure 6-2, d) were from oak trees producing the pollen *Quercoidites* (Figure 6-2, e). These warm temperate plant remains and pollen are persistent, suggesting that warm temperate forests occupied the basin and vicinity during the basin formation without any tropical taxa being present. Eventhough the plant macrofossils like the leaves, catkins, and cones may be transported over a short distance by wind and river flows the distances are generally not significant to distort their real mother plant communities and origin. The occurrences of warm temperate pollen in association with warm temperate leaves, catkins, and cones in any horizon are regarded as powerful evidence in reconstructing a reliable paleophytogeographic setting.

The occurrence of tropical vertebrate remains in the tropical pollen bearing formation also confirms the existence of tropical rainforests with animal communities. This reconstruction provides a good picture of an ecosystem showing the relationship

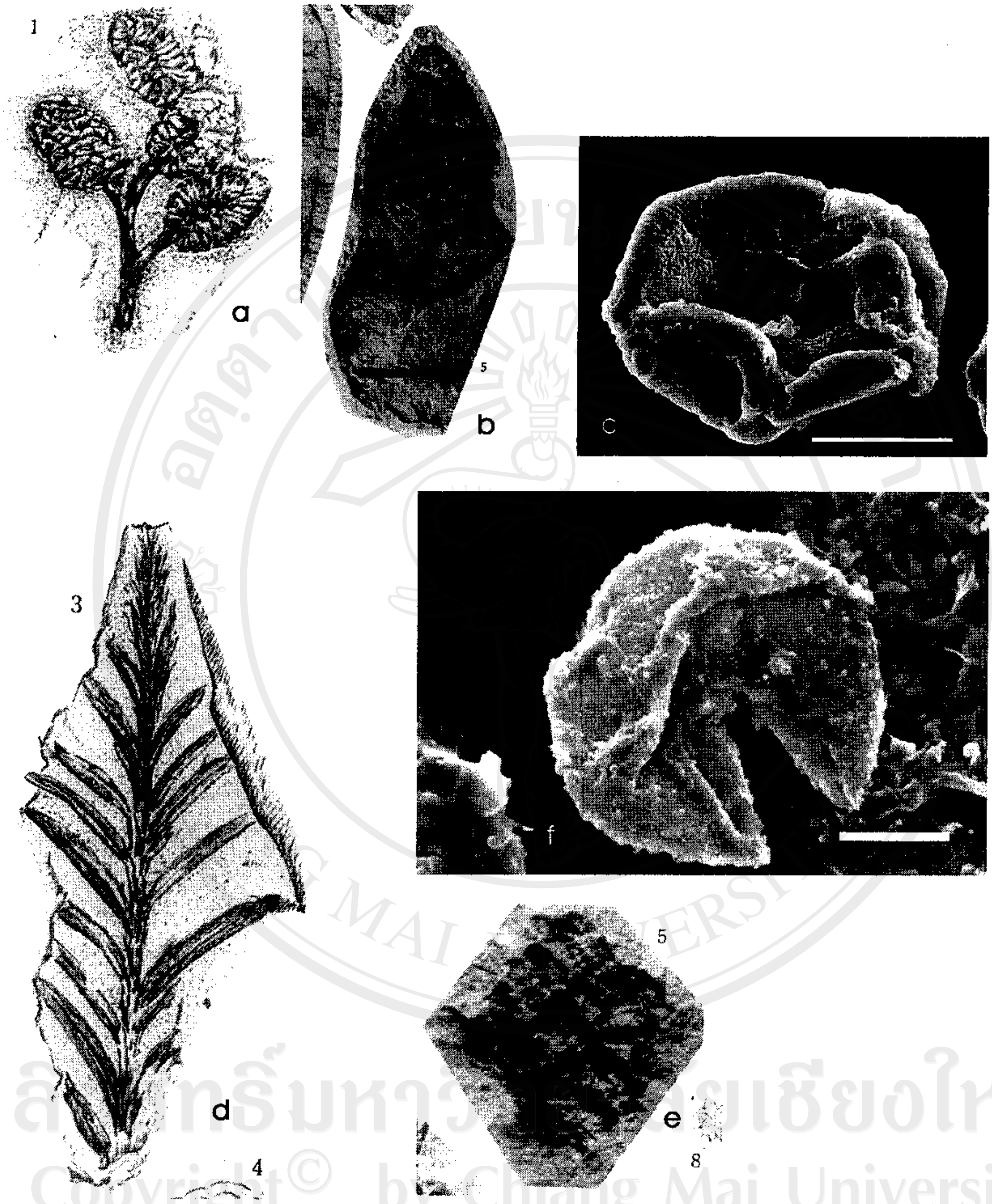

Figure 6-1 Fossil macrofloras vs palynofloras from Ban Pa Kha coalfield: a) *Alnus thaiensis* Endo (catkins); b) *Alnus thaiensis* Endo (leaf); c) *Alnipollenites verus* Potonié (pollen); d) *Sequoia langsdorfii* Heer (leaves); e) *Taxodium thaiensis* Endo (cone); f) *Inaperturopollenites dubius* Pflug & Thomson (pollen). All scale bars are 10 µm. The macrofloras are from Endo (1964, 1966).

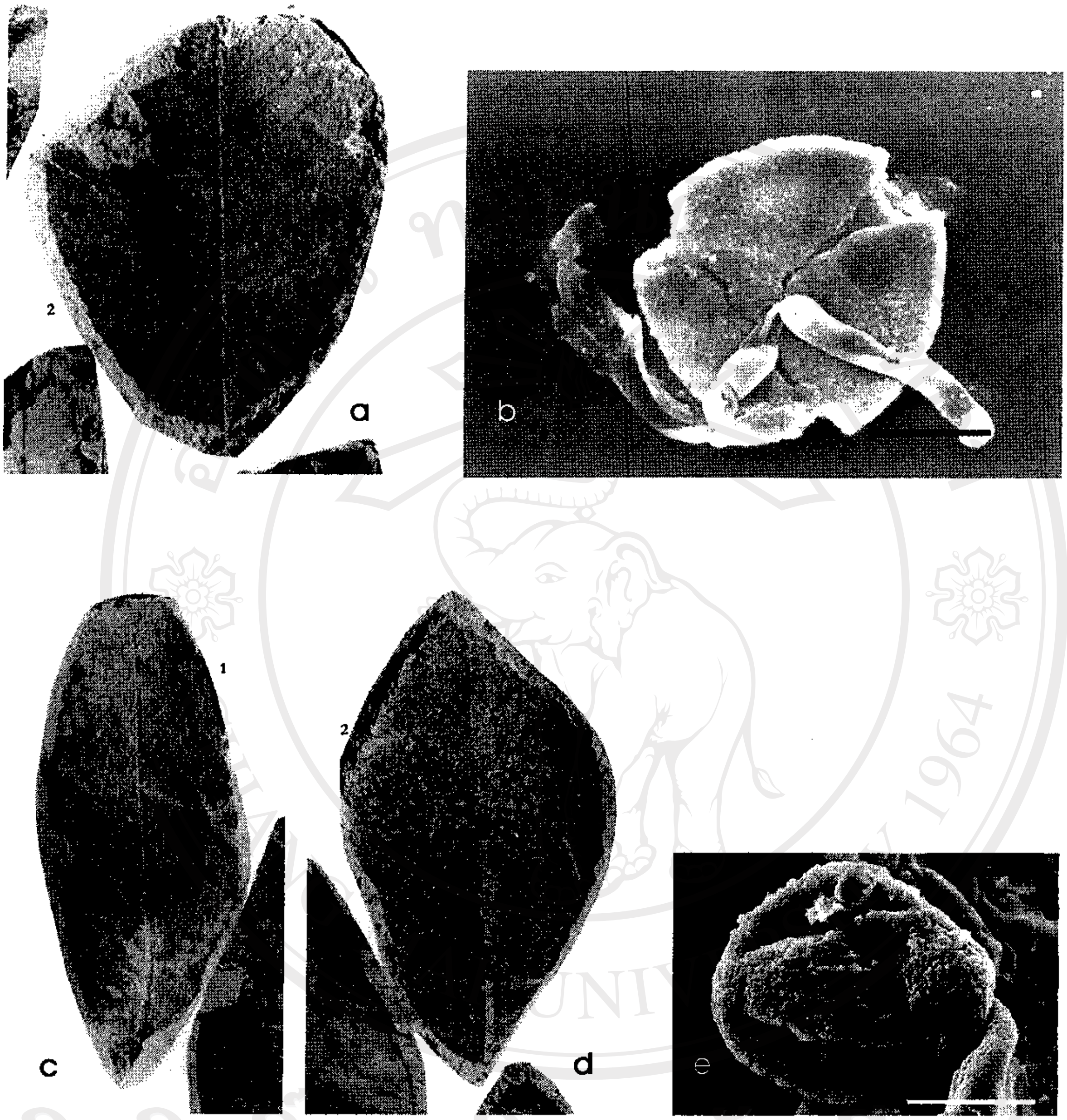

Figure 6-2 Fossil macrofloras vs palynofloras from Ban Pa Kha coalfield: a) *Fagus feroniae* Endo (leaf); b) *Fafuspollenites* Raatz (pollen); c) *Quercus* cf. *lanceaefolia* Roxb (leaf); d) *Quercus protoglauca* Endo (leaf); e) *Quercoidites* Potonié (pollen). All scale bars are 10 μm. Macrofloras are from Endo (1966).

between forests and animals. The tropical rainforests were the habitats of several tropical animals like elephant, hippopotamus, pig, otter, deer, barking deer, rhinoceros, monkey, and so on with crocodile, turtle, fish, and mollusk in ponds and rivers. The presence of sporomorphs and other macrofossils confirm the existence of warm temperate and tropical biostratigraphic formations giving rise to the understanding of the climate change history during the period of deposition in northern Thailand.

6.4 CAUSE OF CLIMATIC CHANGES

The warm temperate and tropical floral elements found in the Tertiary sediments in this study are significant evidence of a major climatic change during Oligocene to Miocene. The boundary between the two climatic regimes is placed at about MN3 to MN4 in the Early Miocene (~18 Ma), dated by the oldest faunal assemblage from the Na Sai coalfield, or probably a little bit older. No published evidence of such a dramatic climatic change was found from country now situated at the same latitude as Thailand, namely Laos, Vietnam and Myanmar. Likewise, there has been no report on fossil leaves, wood, or sporomorphs from the Oligocene-Miocene sediments of Laos and Vietnam. There are some reports from Myanmar of Neogene tropical wood remains (Gupta, 1936; Mukherjee, 1942; Chowdhury and Tandon, 1964; Prakash, 1971; Prakash and Bonde, 1980). On the other hand, hundreds of reports were from India and Nepal. Fossil leaves, woods, and pollen from Tertiary sediments of the Indian subcontinent are definitely tropical, recovered from Paleocene to Recent deposits (*e.g.* Bande and Prakash, 1980; Awasthi and Ahuja, 1982; Mehrotra, 1988; Awasthi and Srivastava, 1992; Bande, 1992; Mandaokar, 1993; Guleria, 1994; Awasthi and others, 1996; Rao, 1996; Singh, 1999;

Mandaokar, 2000). This difference in Tertiary floral assemblages between Thailand and India has great significance in plate tectonics. The extrusion tectonic model proposed by Tapponnier and others (1982, 1986) explains this difference.

The Indian subcontinent broke from the southern hemisphere Gondwana supercontinent during the Late Mesozoic, about 132 Ma (Barron, 1987; Veevers and Li, 1991) then rapidly moved northward at a rate of about 10 to 18 centimeters a year (Molnar and Tapponnier, 1975). Early in the Tertiary period, India passed into the latitudinal range of the tropics (Lee and Lawver, 1995) colliding with the Eurasian continent around 40 to 50 Ma (Molnar and Burke, 1977; Le Pichon and others, 1992; Jolivet and others, 2001) and that is why Tertiary sediments in the Indian subcontinent yield only tropical elements. The India-Eurasia collision set up a series of chain reactions and caused the formation and destruction of sedimentary basins within the region of the collision belt (Lee and Lawver, 1995). The rigid indenter India collided with the plastic Eurasia (Tapponnier and others, 1982) resulting in uplifting of the Himalayan ranges and the Tibetan plateau, and the formation of a number of large strike slip fault zones (Willett and Beaumont, 1994). With respect to Thailand and Southeast Asia in general, the nearby Ailao Shan-Red River (ASRR) fault zones which demarcate the South China and Indochina blocks (Leloup and others, 1995) is relevant. The Southeast Asian landmass (Sundaland) was confined within two large strike slip fault zones, left lateral ASRR fault zone, extending from Tibet to South China Sea (left lateral in Tertiary but right lateral in Quaternary (Tapponnier and others, 1986; Leloup and others, 1995)) and right lateral Sagaing fault zone, a N-S trend fault passing through central Myanmar (Figure 6-3). The force from the India-Eurasia collision induced the extrusion of the Southeast Asian

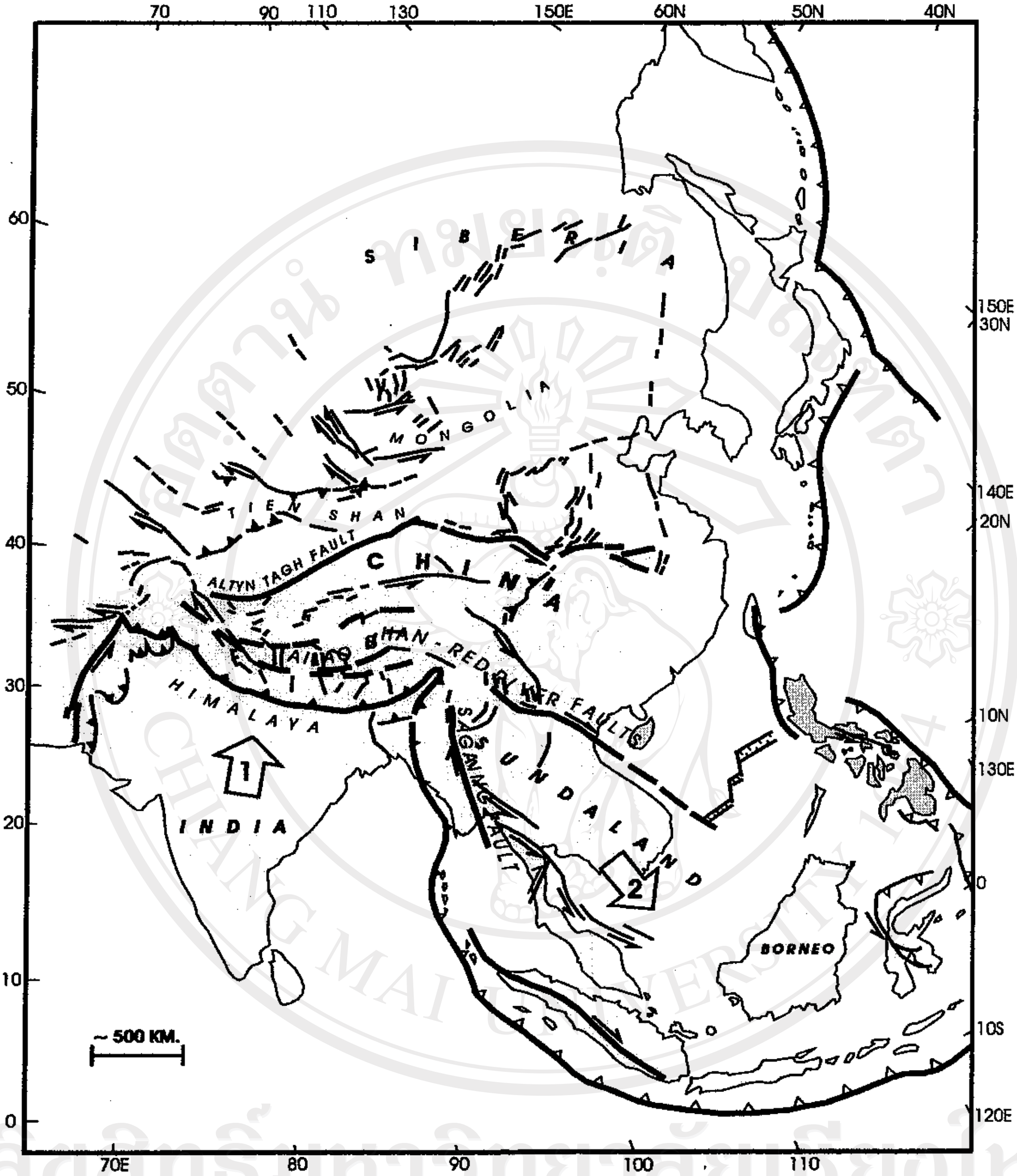

Figure 6-3 Schematic map of Cenozoic extrusion tectonics and large faults in eastern Asia. Heavy lines are major faults or plate boundaries; thin lines are less important faults. Open barbs indicate subduction; solid barbs indicate intracontinental thrusts. White arrows represent qualitatively major block motions with respect to Siberia (rotations are not represented) (Tapponnier and others, 1982,1986).

landmass moving southeastward with simultaneous clockwise rotation (Tapponnier and others, 1986). The offset between the South China and Indochina blocks , along the Red River fault zone, was estimated to be at least 800 kilometers and probably up to 1000 kilometers (Tapponnier and others, 1982). The surface area loss due to the extrusion amounts to about 830,000 km^2 with about 640,000 km^2 and about 190,000 km^2 due to movement along the Ailao Shan-Red River and Wang Chao-Three Pagodas fault zones respectively (Leloup and others, 1995) (Figure 6-4). The extrusion of the Southeast Asian landmass is postulated to have been from a high latitude position to a low latitude position. This mechanism is proposed as the reason for the change in vegetational pattern during the Oligocene to Miocene from a warm temperate to a tropical forest in northern Thailand.

Various evidence from Japan provide an interesting fact that during the Early Miocene the Japanese Islands were in climatic conditions fluctuating from subtropical to temperate climates (Ogasawara and others, 2003). The climate change to be warmer in the Middle Miocene to tropical conditions at the Miocene climatic optimum (Itoigawa and Yamanoi, 1990) which was warmer than the present climate (Matsuoka, 1990). This conformed to global climatic changes from an Oligocene cooling period to a Miocene climatic optimum (Savin and others, 1975; Traverse, 1988; Pocknall, 1989). The boundary between the temperate and tropical climatic regimes in Japan is at the boundary between the Early and Middle Miocene, about 16 Ma (Ogasarawa and others, 2003). The climatic change boundaries in northern Thailand and Japan are, slightly different, about 2 million years old. The difference is possibly because Japan and Thailand were in slightly different latitudes. The exact difference in the paleolatitude needs paleomagnetic data as

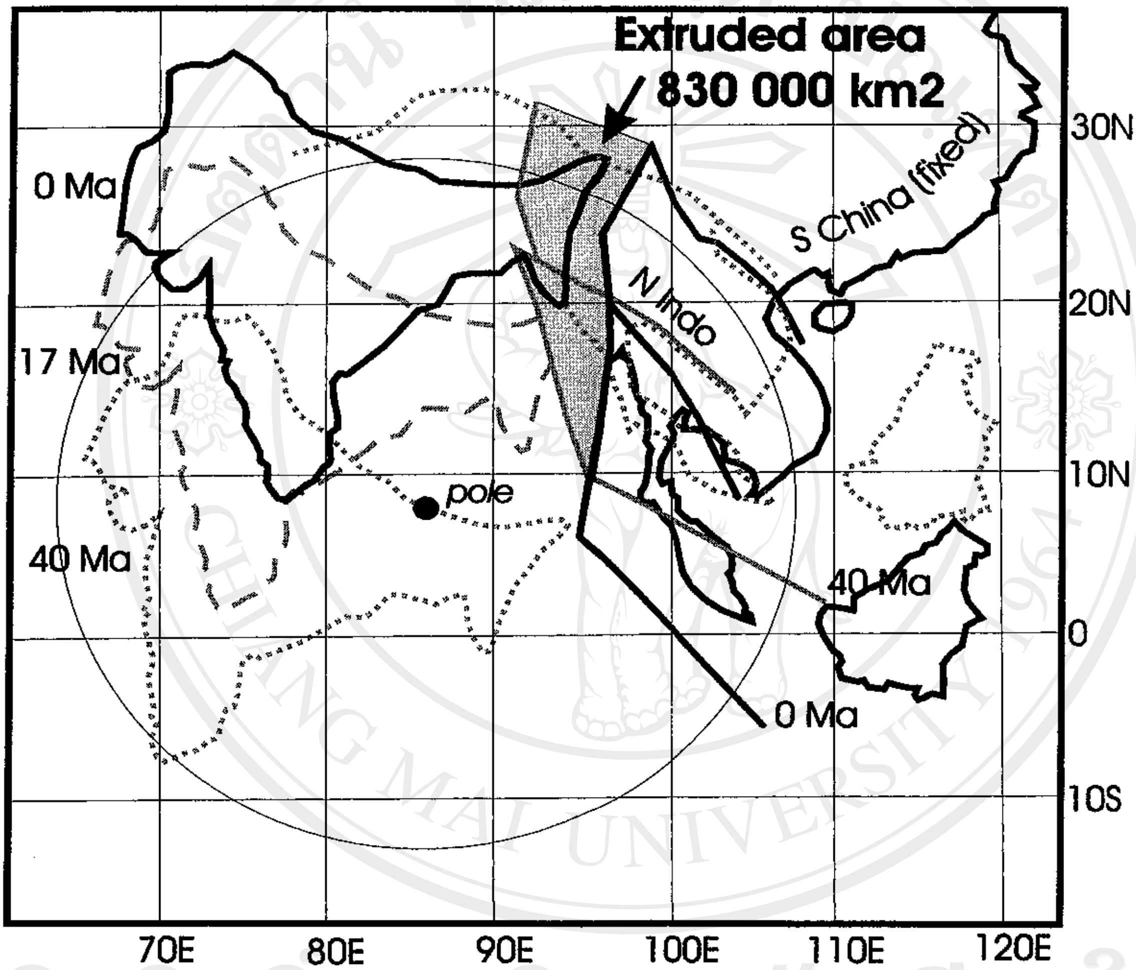

Figure 6-4 Minimum estimate of extrude area. Present day coastlines of South China, Indochina, and India (continuous lines) are plotted together with their position before Indochina extrusion (40 Ma. dotted lines) (Leloup and others, 1995).

well as understanding the precise mechanism of the extrusion tectonics of the Southeast Asian landmass. However, the opening history of the Sea of Japan during 15-17 Ma reveals that the latitude position of the Japanese Islands between the Mid-Tertiary and present day are not much different (Chiji and others, 1990). Therefore, the climate change in northern Thailand during Oligocene to Miocene was primarily caused by global temperature changes from an Oligocene global cooling period to a Miocene climatic optimum. The climate change caused by extrusion tectonics is also possible with simultaneous induction along with the ambient global temperature changes.

6.5 MARINE INCURSION

There are some reports claiming that there was a marine incursion in northern Thailand. Ratanasthien (1989) reported an assemblage of tropical pollen with mangrove elements from the Mae Lamao basin. The pollen assemblage includes rare to common mangrove pollen including *Florschuetzia* spp. (sonneratioid type), *Zonocosites ramonae* (rhizophoroid type), and *Spinizonocolpites* spp. (nypoid type). This pollen assemblage is evidence of coastal vegetation, suggesting there was a marine incursion in the Mae Lamao basin during deposition. Waton (1996) also reported mangrove pollen from some horizons of core samples from Phrae basin including *Acrostichum aureum*-type, *Acrostichum speciosum*-type, *Florschutzia trilobata*, *Florschuetzia semilobata*, and *Zonocosites ramonae*. Waton concluded that the depositional environment was a preponderance of continental lacustrine (deep and shallow water/ ephemeral?) depositional settings and tentative evidence from several samples suggested the possibility of slight marine influences on deposition for those samples (Figure 6-5).

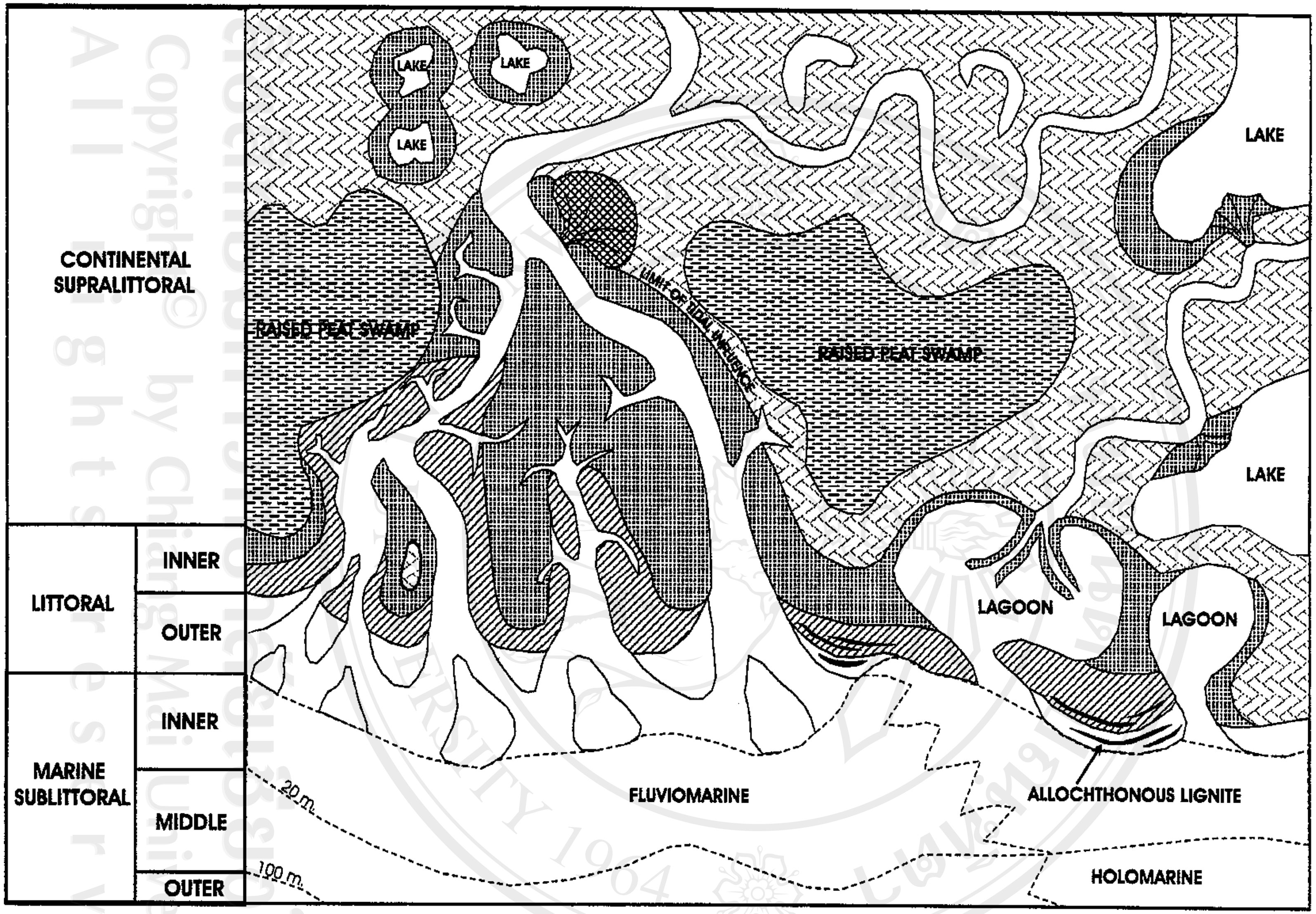

Figure 6-5 Classification of Miocene environments of Phrae basin reconstructed from palynological analyses showing affect of marine incursion during deposition (Waton, 1996).

Tankaya (2001) and Silaratana and others (2002, 2003) reported sulfur isotope values from Mae Moh and Chiang Muan basins respectively. The results of the sulfur isotope values suggested that sedimentation of some parts of both basins were affected by a marine incursion.

In this study, there are two forms of sporomorph having a morphology close to that of extant mangrove pollen, abundant cf. *Scyphiphora* from the Ban Pa Kha coalfield and a grain of *Florschuetzia* from a Chiang Muan sedimentary sample. The recent pollen of *Scyphiphora* is so far not available for comparison, however. Pollen *Scyphiphora hydrophyllacea* has granular pattern on the pollen surface but inferred *Scyphiphora* has finely reticulate. Identification as *Scyphiphora* is, thus, in question. Three species of sonneratiaceous pollen were used to compare with the form genus *Florschuetzia* including *Sonneratia caseolaris*, *Sonneratia ovata*, and *Duabanga grandiflora*. The fossil form is clearly *Florschuetzia* as originally described by Germeraad and others (1968) and Yamanoi (1984) but it does not match any extant sonneratiaceous pollen. According to the original designation of the form genus *Florschuetzia*, there are five species namely *F. trilobata*, *F. semilobata*, *F. levipoli*, *F. meridionalis*, and *F. claricolpata*. The two former species were considered as ancestors of the recent genus *Sonneratia*, but matching with recent species has not been possible and they cannot claim to be mangrove elements. *Florschuetzia levipoli* and *Florschuetzia meridionalis* compares well to the recent pollen of *Soneratia caseolaris* and *Sonneratia alba*, respectively, the mangrove taxa. Even though, *Florschuetzia claricolpata* does not match with any *Sonneratia* species, but the fossil occurred with brackish water faunal and floral assemblages (Yamanoi, 1984; Itoigawa and Yamanoi, 1990), it is, therefore, most likely to be a mangrove element.

Therefore, *Florschuetzia* is not always definable as representing a mangrove element and a precise identification to species is needed. Faunal and floral assemblages containing mangrove-like sporomorphs need to be checked to see if the assemblages contain other mangrove evidence. Watanasak (1988) also reported an occurrence of a species of the genus *Florschuetzia* from the Fang basin in Chiang Mai Province but the species was not identified and it was not claimed as a mangrove element.

The occurrence of mangrove elements in the Mae Lamao basin reported by Ratanasthien (1989) conflicts with this study. Sediments from the Mae Lamao basin in this study yielded warm temperate pollen without any mangrove elements. This is because the mangrove elements-bearing sediments and the warm temperate pollen-bearing sediments came from different sections.

At the present day northern Thailand has two species of tree belonging to the families Sonneratiaceae and Rhizophoraceae. The two species are *Duabanga grandiflora*, Sonneratiaceae, and *Carallia brachiata*, Rhizophoraceae. The two species are native to Thailand occurring even on mountainous areas in northern Thailand, Khao Yai in Central Thailand, and the far south peninsula rather than in mangrove forests. The two species are probably the evolutionary products of ancestral mangroves but they are now absolutely isolated from the mangrove environment but they still produce mangrove-like pollen.

At this stage of the research, the marine incursion in northern Thailand is indicated by palynology (Ratanasthien, 1989; Waton, 1996) and the sulfur isotope analyses (Tankaya, 2001; Silaratana and others, 2002, 2003) but is not confirmed by this research. Further palynological research is recommended with high precision on the sporomorph identification.