Problems of Neogene biostratigraphic correlation in Thailand and surrounding areas

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ABSTRACT

Neogene stratigraphic correlation in Thailand was based on lithology until exploration for fossil fuel deposits in 1918 led to the discovery of vertebrate fossils at Mae Moh coalfield. This area became the key to biostratigraphic correlation in Thailand. The main tools in Neogene correlation are vertebrate fossils (including those of small mammals) and palynology. Lithological correlation is now used only as a tool in comparing tectonic events, especially during Neogene, where repeated rifting has occurred throughout Southeast Asia.

Though biostratigraphy has become the preferred tool in stratigraphic correlation, there are still areas of disagreement on correlations for many parts of Thailand. In the north, vertebrate fossils, mammals, and palynological floras seem to agree very well (or differ within a close range). In the south, recent work on small mammal fossils does not correlate well and contradicts results from palynology and microinvertebrate fossils. The disagreements stem from the use of different methods, although there are also problems arising from trying to correlate sparse paleoclimatic evidence.

For advances to occur in the 21st Century, a well-funded, cooperative correlation program acquiring data from multidisciplinary studies is required.

Keywords: Neogene, biostratigraphy, vertebrate fossils, palynology, paleoclimate.

RESUMEN

La correlación estratigráfica correspondiente al Neógeno en Tailandia se basaba en la litología, hasta que la exploración de depósitos de combustibles fósiles en 1918 llevó al descubrimiento de fósiles vertebrados en la región carbonífera de Mae Moh. Esta área se convirtió en la clave para la correlación bioestratigráfica en Tailandia. Las principales herramientas para la correlación Neógena son los fósiles vertebrados (incluyendo los de mamíferos pequeños) y la palinología. La correlación litológica se usa hoy en día sólo como una herramienta para comparar eventos tectónicos, especialmente los ocurridos durante el Neógeno, cuando tuvieron lugar repetidos eventos de "rifting" en el Sureste Asiático.

Aunque la bioestratigrafía se ha convertido en la herramienta preferida para la correlación estratigráfica, existen todavía áreas de desacuerdo para la correlación en muchas partes de Tailandia. En el norte, los fósiles vertebrados, los mamíferos y la flora palinológica parecen coincidir muy bien (o difieren muy poco). En el sur, investigaciones recientes sobre fósiles de mamíferos pequeños no dan una buena correlación y contradicen los resultados de la palinología y de fósiles de microinvertebrados. Los desacuerdos surgen del uso de diferentes métodos, aunque también se presentan problemas que surgen por tratar de correlacionar la escasa evidencia paleoclimática.

Para que puedan lograrse avances en el siglo XXI, se requiere de un programa de cooperación bien financiado que permita obtener datos fundamentados en estudios multidisciplinarios.

Palabras clave: Neógeno, bioestratigrafía, vertebrados, palinología, paleoclima.

INTRODUCTION

Neogene deposits in Thailand (Figure 1) are very important because they contain fossil fuels: coal, oil-shale, oil and gas. The biostratigraphic correlation and ages of these deposits have been a subject of much discussion and argument. (Table 1).

Earlier work assigned Pliocene to Pleistocene ages to the lignite deposits in Mae Moh basin following the discovery of Stegolophodon in the N (K-Zone) lignite layer (Koenigswald, 1959). However, later work in northern Thailand has refined this age assignment (Ginsburg, 1985, 1989; Ginsburg and Mein, 1987; Ginsburg and Tassy, 1985; Ginsburg and Thomas, 1987; Ginsburg and Ukkakimapan, 1983; Ginsburg *et al.*, 1983, 1988, 1991). Mammalian fossils have helped in these refinements (Mein and Ginsburg, 1985; Mein *et al*., 1990; Tassy 1983, 1990; Tassy *et al*., 1992) in Mae Moh, Li, and other basins. These vertebrate fossils are rich in the upper parts of large basins (*e.g*., in the Mae Moh K-1 lignite Zone or in the Na Sai basin of Li) and in small basins (*e.g*., Pong, Chiang Muan, Payao, Sop Mae Tham, Lampang, and Mae Lai, Chiang Mai). However, they have never been recorded in the lower parts of these large basins. Leaves, fruit, spores and pollen of the Ban Pa Kha Coal Field are believed to lie in the lower part of the Li mammal deposits because they occur with coals of much higher rank than fossils from other deposits.

Flora from the Ban Pa Kha Coal Field also show evidence of temperate elements (Endo 1964, 1966; Watanasak 1988, 1989). Evidence of temperate paleoclimates has also been frequently observed by the author during coal petrographic studies. The mammallian records were put into MN 4 for Na Sai by Mein and Ginsburg (1985) and Mein *et al.* (1990). This age is older than K-1 of Mae Moh, on the basis of Stegolophodon teeth. Biostratigraphic correlation based on plant fossils and palynology, together with the vertebrate fossils including small mammals, put the age of the development of the northern Thailand Tertiary basins as late Oligocene to early Miocene, with deposition continuing into the late middle Miocene. Many tectonic events occurred during this period of basin development.

In southern Thailand, biostratigraphy is based on palynological assemblages and foraminifera. Vertebrate fossils have been found only in the Krabi basin. In northern Thailand sequences can be correlated using both microfossils and vertebrate fossils. However, in southern Thailand, a combination of age of basin formation, dated tectonic events and foraminiferal and palynological assemblages is used. This latter approach gives ages greatly different to those from vertebrate fossils. Buffetaut *et al*. (1989), Ducrocq (1993), Ducrocq *et al.* (1992a, 1992b, 1993, 1995a, 1995b, 1997) and Chaimanee *et al.* (1997) dated Krabi basin deposits as middle Eocene to early Oligocene, and palynological and foraminiferal dates give consistent correlations for not only in the Gulf of Thailand and the Andaman Sea regions, but also for Susan Hoi of the Krabi basin. Also, fossil fuel deposits of the the Chao Phraya Group were dated as Oligocene using palynology (Woodland and Haw, 1976), on the basis of the presence of *Floschutzia trilobata* to extend into the late Miocene–Quaternary in the upper part of the Gulf, based on *F. semilobata*, *F. levipoli*, *F. meridionalis*, *Dacrydium* and *Podocapus* zones (Muller, 1966, 1972). In the Mergui basin of the Andaman Sea, deposits thought to be upper Oligocene have been extended to up into the Pleistocene (Woodlands and Haw, 1976, Polachan *et al*., 1991) Praditan and Dook, 1992, Highton *et al*., 1997).

RADIOMETRIC DATING OF TECTONIC EVENTS

Dating the formation and fill of Thailand's Tertiary basins has been found to be more reliable using radiometric age dating of clay minerals, zircon/apatite fission track analysis (AFTA) and correlation of tectonic events, rather than by paleontology. The collision of the Indian Plate with the Eurasian Plate, and the northward movement of the Australian Plate, are the main causes of tectonism in the region. Dating denudation radiometrically using clays has proven a useful method of establishing age of basin development. Fossils are commonly lacking in the early deposits of basins because of rapid accumulation in high energy fluvial settings. The lowermost parts of Thailand's basins contain coarse-grained, fining-upward sequences and fossils are usually found only in lacustrine or fluvio-lacustrine environments that post-date the strong tectonism associated with basin formation.

Charusiri *et al.* (1991) used $^{40}Ar/^{39}Ar$ radiometric dating to refine the ages of some late Oligocene to middle Miocene events. They obtained ages of 29 Ma from ceramic pegmatite in the Tak area, 23 Ma from alkali feldspar of Cretaceous granite and 19-30 Ma from K-Ar dating of several Triassic and metamorphic rocks in northern Thailand. They suggested that these ages reveal the time of fault rifting and thermal events. The ages of these tectonic events are supported by the dating by Ahrendt *et al.* (1993, 1994, 1997) of the development of the Lansang or Mae Ping fault zone as ~ 29-31 Ma. The major phase of faulting and rapid uplift during the late Oligocene to middle Miocene (~ 19-31 Ma) is believed to record the age of initiation of the northern Thailand Tertiary basins in which fossil fuel source rocks and coals with ranks higher than that of lignite accumulated.

Sixteen AFTA dates from samples collected from Mae Hong Son, Chiang Mai, Lampang and Tak provinces, northwestern Thailand (Upton *et al.*, 1997) fall into two groups. The first group, from granite, gneiss (both orthogneiss and paragneiss), granodiorite, dyke into gneiss and biotite gneiss, with rapid cooling

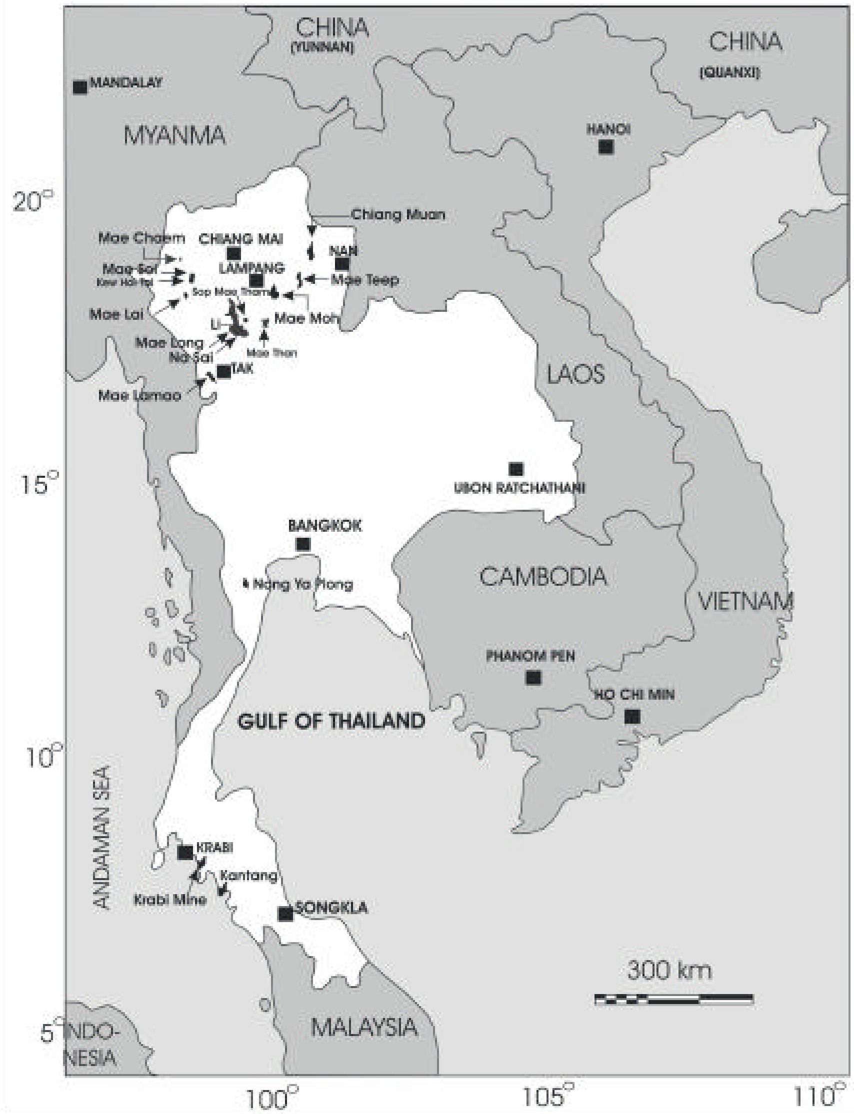

Figure 1. Map showing Neogene deposits with lignite, oilshale and petroleum resources.

histories, had ages ranging from 18 ± 1 to 40 ± 2 Ma. The second group, from Triassic granite, showed complex cooling histories with the age ranges from 80 ± 6 to 23 ± 2 Ma. The most interesting cooling histories are in group 1, where the samples from granitic and gneissic body exhibit rapid cooling through the apatite fission-track partial anealing zone (60-110 °C) during the late Oligocene to early Miocene (~28-22 Ma). The results have clarified timings of the main tectonic events. The rapid cooling is thought to record unroofing of the Doi Intanon metamorphic complex in an extensional setting rather than under a compressional regime. It also indicates the time of tectonic uplift in northwestern Thailand and the source of sediment supply into the Tertiary basins of both northern Thailand and the Gulf of Thailand. There were two phases of clastic sedimentation: fine-grained lacustrine deposits of early basin infill, suggesting low rates of sediment supply due to slow thermal subsidence during the late Oligocene to lower Miocene; and later, coarser dastic infill which is thought due to the rebound of the surrounding metamorphic complex supplying more sediments to the basins during the middle Miocene.

Pradidtan and Dook (1992) put the age of the basin initiation in the Gulf of Thailand as 44 Ma based on maximum AFTA ages for the lowermost sediments on the early Tertiary unconformity. This is consistent with Tulyatid’s (1991) inference that early Oligocene denudation ages from the Pranburi-Hua Hin metamorphic complex were close to the time of opening of the Gulf of Thailand and basin development.

Three major, regional unconformities coincide

Table 1. Tectonic events and Biostratigraphic correlation of Neogene deposits in Thailand (Modified from Mein and Ginsburg, 1985; Ratanasthien, 1990; Watanasak,;1995; Ratanasthien and Kundaros,1996; Highton *et al*., 1997; and Songtham, 2000).

<table>
<tr><th>Age and geological time</th><th>Tectonic events inferred from radiometric age dating</th><th colspan="3">Biostratigraphic correlation in northern Thailand</th><th colspan="2">Biostratigraphic correlation in the Gulf and southern Thailand</th></tr>
<tr><td rowspan="2">Pliocene / Pleistocene</td><td></td><td colspan="3"></td><td colspan="2">Podocapus zone</td></tr>
<tr><td>3 Ma sea-level change</td><td colspan="3"></td><td colspan="2">Dacrydium zone</td></tr>
<tr><td>Late Miocene</td><td>10.4-13.6 Ma
Basaltic volcanism</td><td colspan="3">Unconformity</td><td colspan="2">Unconformity</td></tr>
<tr><td>Middle Miocene</td><td></td><td>Melanoides zone (J3-J6)
Viviparus zone(K1-K2)
Planorbis zone(K3-K4)</td><td>Diatomys liensis zone(Mae Long)</td><td>Siam II</td><td colspan="2">F. meridionalis zone</td></tr>
<tr><td rowspan="4">Early Miocene</td><td>17 Ma Fault/
18.1 Ma/19.1 Ma Fault</td><td colspan="3">Unconformity</td><td colspan="2">Unconformity</td></tr>
<tr><td></td><td>Paludina zone
(Q-zone)</td><td colspan="2">Steolophodon nasaiensis zone</td><td colspan="2">F. levipoli zone</td></tr>
<tr><td>Unconformity (23 Ma Intrusion of granite and/or thrust)</td><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td></td><td colspan="3">Siam I / Alnipollinite zone /
Inaperturopollinites dubius zone</td><td>F. semilobata zone</td><td rowspan="3">F. trilobata zone</td></tr>
<tr><td rowspan="3">Late Oligocene</td><td>24.5 Ma</td><td colspan="3">Unconformity</td><td rowspan="2">Unconformity</td></tr>
<tr><td></td><td colspan="3">Pediastrum zone</td></tr>
<tr><td>29-31 Ma fault</td><td colspan="3">Basin rifting</td><td colspan="2">Basin opening</td></tr>
</table>

approximately with epoch boundaries and these assist age determination in the basins. Unconformities occur at the late Oligocene and early Miocene boundary (~24.5 Ma), the early / middle Miocene boundary (~17 Ma) and at the late / middle Miocene boundary (~13.6 Ma-10.4 Ma). Charusiri *et al.* (1991) also reported an overprint of 17-19 Ma on Pranburi-Hua Hin cataclastic rocks and emphasized middle Miocene region-wide events.

BIOSTRATIGRAPHIC SUPPORTS FOR TECTONIC EVENTS

In northern Thailand, early works of Endo (1963, 1964, 1966), placed the Li (Ban Pa Kha) basin-fill into the Oligocene by correlation with temperate paleoclimate elements found in the Ban Pa Kha coalfield. This correlation was called into question when a fossil small mammal from Na Sai basin, situated in the southern part of Li basin, was dated as within the MN4, or lower part of the middle Miocene (Mein and Ginsburg 1985; Mein *et al.* 1990; Ginsburg *et al.* 1991). The fossil layer overlies lignite beds where large mammal remains were found associated with the lignite as scattered, broken pieces. Its discovery suggested there was an unconformity between the "Oligocene" and Miocene lignites, though no sharp boundary could be recognized. Songtham (2000) recorded temperate elements of late Oligocene to early Miocene age in the Na Hong basin, Chiang Mai, a high-rank coalfield in northern Thailand. He divided the palynological assemblage into two zones: the *Pediastrum* zone and the *Inaperturopollinites dubius* zone. Unfortunately, no fauna has been found in either Ban Pa Kha or Na Hong, so faunal correlations cannot be made. However, I have recorded needle ends of *Pinus* sp. in many leaf beds, coal seams and carbonaceous shales associated with the coal deposits not only in the Li Basin, but also in the Na Hong coalfield (Chiang Mai), Mae Tun coalfield (Tak) and the Mae Than coalfield (Lampang). They indicate temperate elements. The problem at this point is whether this reflects only a temporary cooling due to ice advance or whether this area was at a higher latitude than at present or the position of the Earth's pole of rotation was different at that time.

Tectonism is inferred to have been the main cause of differences in coal quality and the cessation of coal deposition in the Na Hong, Ban Pa Kha, basin and in Ban Pu, Ban Hong and the Li basins (Ratanasthien, 1994). Basin development due to slow thermal subsidence could have occurred during the rifting events recorded in western Chiang Mai and Tak involving the Lansang or Mae Ping fault zone during ~ 29-31 Ma. The main depositional environment at this time was lacustrine, and these and associated deposits are major sources for oil, not only in northern Thailand but also in the Gulf of Thailand. The trends of rifting are north-northwest, similar to the Mae Ping fault zone, and comparable with the orientation of many coal beds, such as in the Ban Huai Dua, Na Hong (Chiang Mai) and Mae Tun deposits (Tak). Jitapankul (1992) also reported the same trend for coal beds in the Ban Pa Kha coalfield.

The tectonism associated with the western Chiang Mai granite and gneiss (~23 Ma) could be responsible for a lower main seam split in coal deposits at Ban Pa Kha coalfield. These deposits contain tree trunks buried in sandy sediments. The most severe tectonism probably occurred during denudation, ~18-19 Ma. Rapid uplift would have resulted in the slumping of large amounts of fine to coarse sediment and, later, fining-upward sequences. Such successions have been found in many coalfields. This catastrophic event also caused large numbers of tree trunks to accumulate in Ban Pu, Ban Hong and, most importantly, the Na Sai coalfields.

At Na Sai, partial skeletons of various large mammals were found associated with tree trunks and rotten leaves. These mammals include *Brachiodus, Conohyus cf. sindensis, Gaindatherium sp*. and *Stegolophodon nasaiensis* (Ginsburg and Tassy, 1985, Tassy *et al*., 1992, Ducrocq *et al*., 1994). They are mostly isolated teeth and bony elements. A partial skeleton of a rhinoceratid (known as "Lady Li") was found in 1996. Its more important features, the left and right nasal bones in the skull, are more flattened and unfused compared with those of *Gaindatherium* from Siwailik. This suggests it is not a *Gaindatherium* but, rather, some other more primitive Rhinocerotidae (Saegusa and others, 1999). The partial nature of these skeletons suggests transportation after some catastrophic incident, when the animals were already rotten.

Vertebrate remains with morphologies between *Archeobelodon* and *Gomphotherium*, found in the Neogene sediments at Doi Chang (Mae Soi, Chomtong District, Chiang Mai and known as "Praya Come Soi") were thought to be late early Miocene or middle Miocene by Saegusa *et al.* (1999). The fossils were found buried in a fluvial muddy sandstone layer in a fining-upward sequence of conglomerate, sand and silt. The same level extends to Kew Hoi Tal, where a large number of skeletons of mastodon, rhinoceratid, suid and many other mammals were found in the form of rounded clasts in gravels, some with encrustations or cementation by calcite.

The silicified tree trunks associated with the Doi Chang sediments record a temperate climate and could indicate the boundary of the climatic change during early Miocene to late early Miocene or middle Miocene, and be contemporaneous with the 18-19 Ma age overprinted in the surrounding rocks. In fact, Mickein (1997) and Mickein *et al.* (1995) obtained radiometric ages of 19 ±1 Ma on zircon and 18 ±1 Ma on apatite grains from Hot, Chiang Mai, along the same north-south trend, ~15 km south of Doi Chang.

Catastrophism in these two basins could have occurred over a relatively short period of time. According to Saegusa (personal communication), the *Archeobelodon* or *Gomphotherium* is slightly more primitive form than that of the *Stegolophodon nasaiensis.* However, the *Stegolophodon nasaiensis* is more primitive than the *Stegolophodon* those found in Mae Moh basin which Ginsburg *et al.* (1991) placed in the middle Miocene. Thus the K-1 zone of Mae Moh should be younger than the 18 Ma boundary. This also applies for the *Stegolophodon* sp. found in Mae Moh, Chiang Muan and the Sop Mae Tham areas as they are more modern forms than those at Li. Furthermore, at Mae Moh, the *Paludina* zone is used to recognize the Q-zone, and the *Viviparus* zone is used to recognise the K-1 and K-2 zones, whereas *Planorbis* was used to recognize K-3 and K-4 zone and *Melanoides* is used for the J-3 - J-6 zones (Ratanasthien and Kuntaros, 1996).

Above the 18-19 Ma tectonic boundary, faunal fossils are correlated by many means, including the most reliable method: small mammal biostratigraphy. In the Mae Long deposits of Li basin, the small mammal assemblage from the upper part of Mae Long Formation (Ratanasthien, 1990) was placed in MN4 (~17 Ma). The formation includes the remains of the cervid, *Stephanocemas rucha*, the Primate, *Tarsius thailandica,* and four new species of small mammals, *Prokanisamys benjavuni*, *Neocomates orientalis*, *Potwarmus thailandicus*, and *Diatomys liensis*.

Above the 10.3-13 Ma boundary, the index fossils were not useful for biostratigraphic correlation because of the highly oxidized nature of the fluvial sediments in which they occur. The index fossils could either occur too sparsely to have been found or the conditions did not allow the fossils to be preserved.

In southern Thailand, biostratigraphic correlation can be achieved using palynology both onshore and offshore in the Andaman Sea (Anderson *et al.*, 1994, Watanasak, 1988, Watanasak *et al.*, 1995, Sektheera, 1995, Songtham and Watanasak, 1999, Woodland and Haw, 1976, Polachan, 1988, Polachan and Racey, 1993). The ages assigned by Ducrocq (1993), Ducrocq and Chaimanee (1995), Ducrocq *et al.* (1992a, 1992b, 1993, 1995a, 1995b, 1997), Chaimanee *et al.* (1997), and Suteethorn *et al.* (1988) can be made more precise and consistent but the stratigraphic sequences have to be carefully investigated to achieve this.

Much new work, using a variety of methods and tools is required to obtain more precise ages of deposition. This work will require a large amount of research funding and also agreement on the best tools to use for dating.

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