

CHAPTER 2

STUDY AREA

The study area are composed of five localities, 1) Chiang Muan basin, Phayao province, 2) Mae Soi village, Chiang Mai province, 3) Na Sai sub-basin, Lamphun province, 4) Sop Mae Tham village, Lampang province, and 5) Tha Chang village, Nakhon Ratchasima province. The study site is natural crop out in Mae Soi and Sop Mae Tham villages. The other localities are in a mine. Chiang Muan and Na Sai localities are the coal mines and Tha Chang is sand pit. At present, the Tha Chang sand pit operation is over, due to deep flooding, the Somsak Pit or sand pit no. 8. The Chiang Muan coal mine will be closed in the year 2008. The Na Sai is currently operated (Figure 2.1).

2.1 Chiang Muan Basin, Phayao Province, northern Thailand

Chiang Muan is one of districts of Phayao province. Chiang Muan district ($18^{\circ} 53' 32.42''\text{N}$ and $100^{\circ} 17' 00.77''\text{E}$) located 50 kilometers southeast of Phayao ($19^{\circ} 10' 05.03''\text{N}$ and $99^{\circ} 54' 31.32''\text{E}$) and is 10 kilometers west of a border of Nan province. The city can be accessed by highway no. 1021 via Jun and Pong district, and take highway no. 1120 to Chiang Muan. Another route is highway no. 1021 via Dhok Kham Tai district and then takes highway no. 1251 to Chiang Muan. The total distance is 19 and 86 kilometers, accordingly. The basin area is about 8 km in width and 25 kilometers in length and 200 square kilometers. The basin base level is 295 meters above means sea level. Chiang Muan Coal Mine is a lignite-rank coal mine, operated by BANPU Public Company Limited. The mine is an open pit mine, located

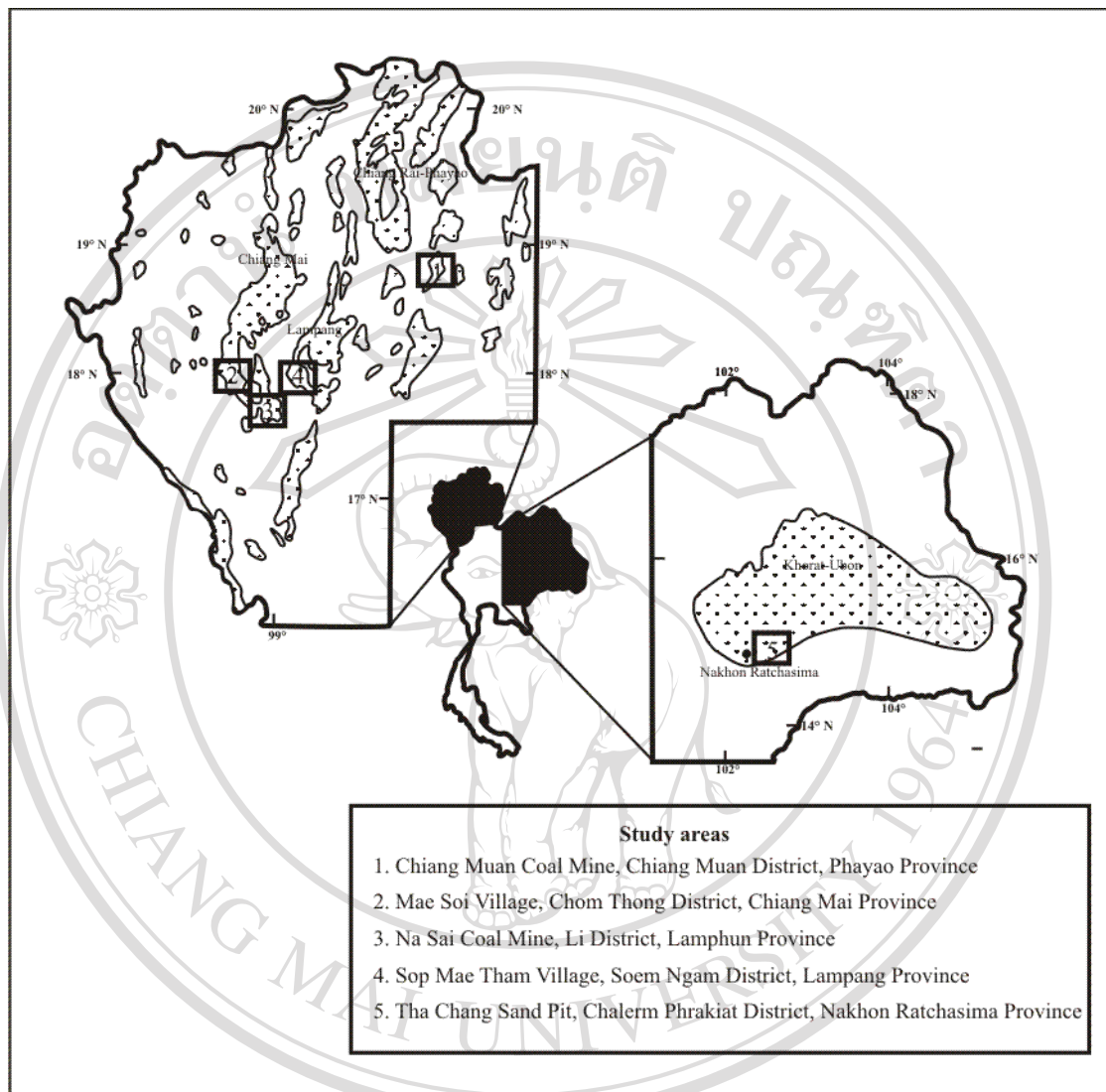


Figure 2.1 Five localities of study areas (modified from Ratanasthien, 1990 and Chaodamrong, 1985).

in the Ban Sa village, Ban Sa sub-district, Chiang Muan district, Phayao province. It is located at latitude 18° 56' 06" to 18° 56' 00" N and longitude 100° 13' 39" to 100° 14' 42" E (Figure 2.2).

2.1.1 Geological setting of Chiang Muan Basin

Chiang Muan Basin is underlain by Triassic marine sedimentary rock and Jurassic non-marine and volcanic rock (Figure 2.3).

Marine Triassic sedimentary rock unit

The marine Triassic sedimentary rock unit is the lowest unit (t and t'1 of Baum and Hahn, 1977; Tr6 and Tr7 of Charoenprawat *et al.*, 1994). This unit is of Kang Pla Formation, Lampang Group (Chaodamrong and Burrett, 1997). The rocks are composed of shale and sandstone, gray to greenish gray; siltstone; mudstone; conglomerate; and limestone; with fossils *Halobia* sp., *Cassianella* sp., *Liostrea* sp., *Unionites* sp., and bivalves (Tr6) and gray, massive to bedded limestone; gray to greenish gray shale and sandstone with fossils *Costatoria* sp., and brachiopods (Tr7).

Non-marine sedimentary rock unit

1) Unit J1 (or ms1 in Baum and Hahn, 1977)

The unit is composed of red, sandy claystone and fine-grained sandstone of red, light red, reddish brown, purple, gray-brown, gray, and beige color.

The sandstone is composed and show good bedding. Often the sandstone beds forms

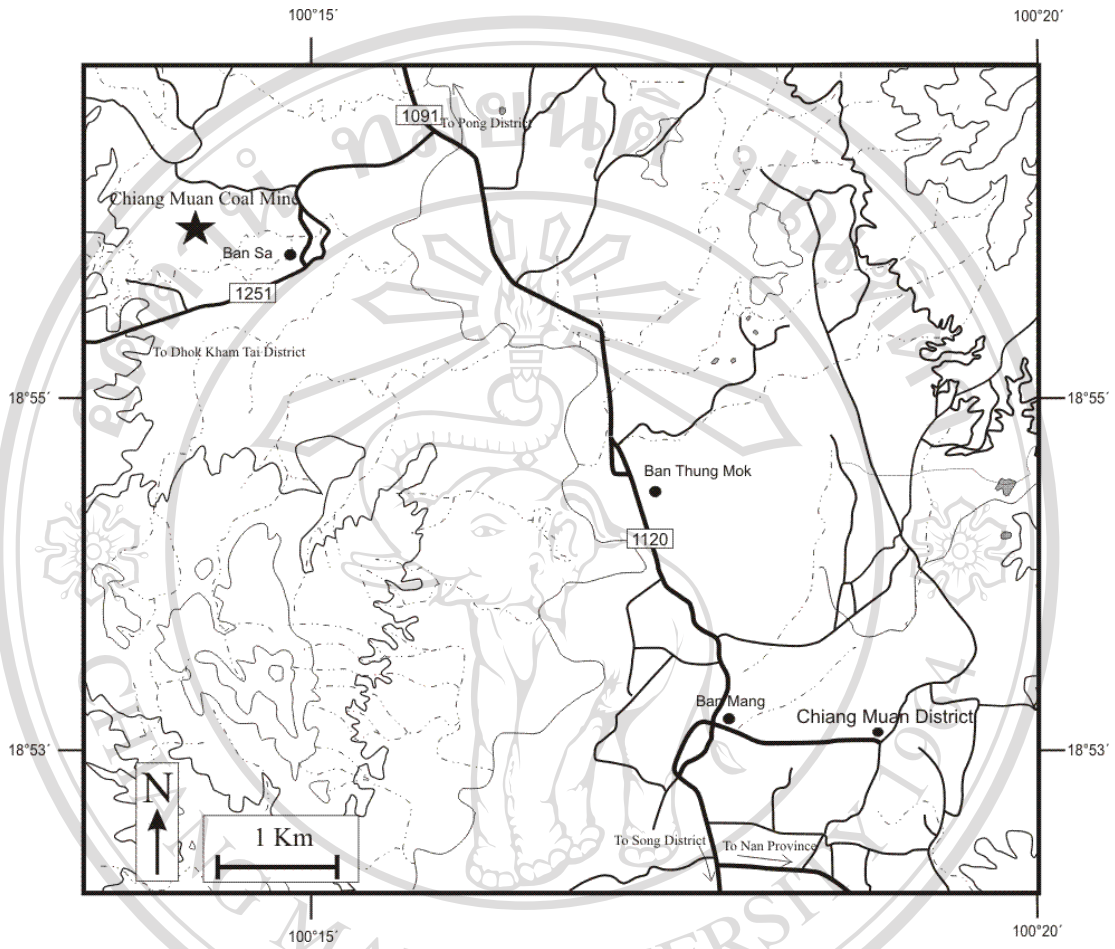


Figure 2.2 The route accessed to Chiang Muan Coal Mine, Phayao via Dhok Kham Tai (no. 1251) and Phayao-Chun-Pong (no. 1091) (modified from Topographic map 1:50,000 sheet 5046 I (Amphoe Chiang Muan) and 5046 IV (Ban Sa), (Royal Thai Survey Department, 1991c, d).

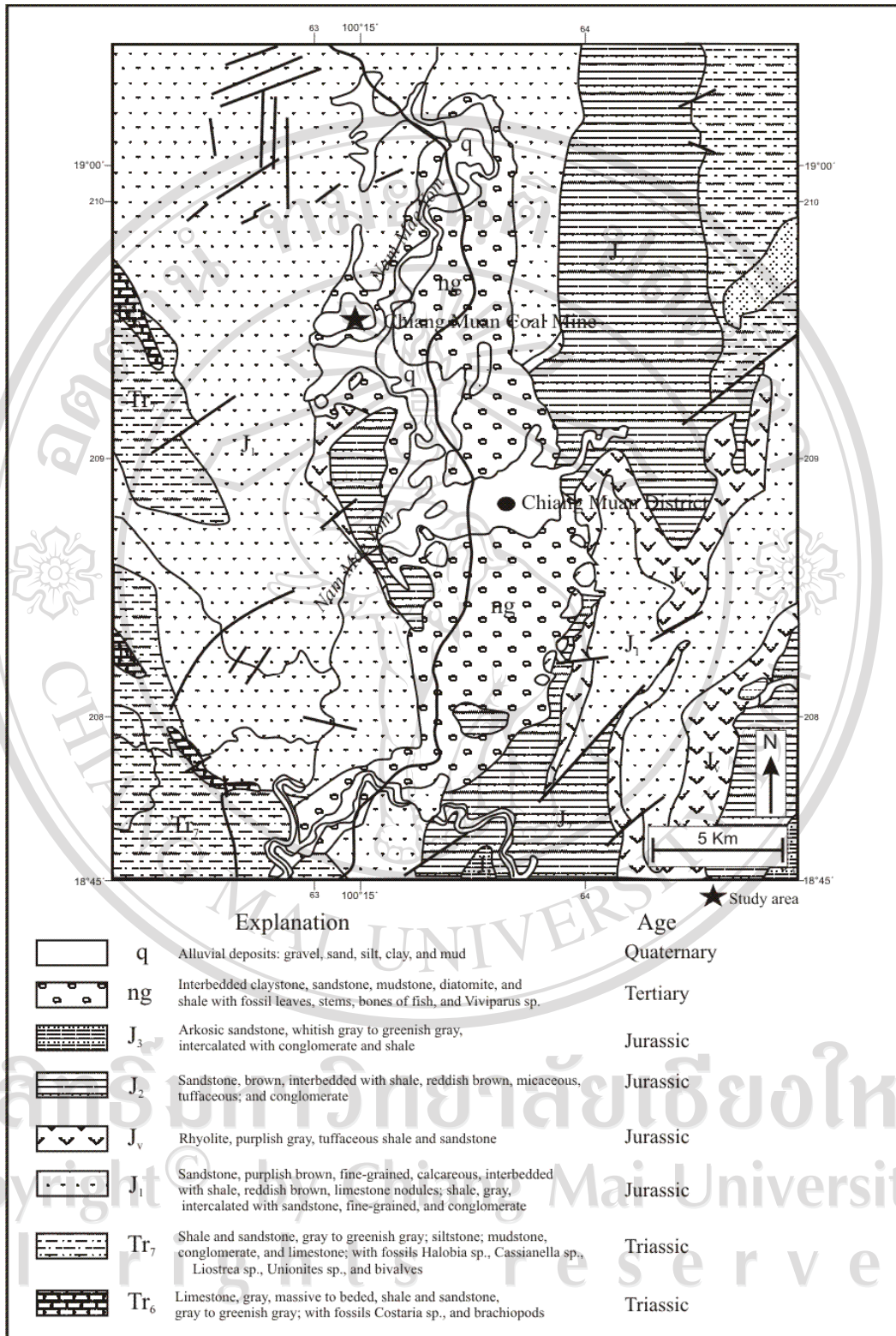


Figure 2.3 Geology of Chiang Muan and surrounding area (modified from Charoenprawat *et al.*, 1994).

units 2-3 m to maximum of 20 meters. Thin bedding is common. Subordinate cross-bedding is present. The cement is mostly calcareous. The shale and claystone intercalated with the sandstone. The shale is sandy and calcareous, with increasing carbonate content in a transition into nodular marly limestone. The red color of the shale and the marly limestone has been reduced to green or gray-green. There is no basal conglomerate in the central part of the basin. The maximum thickness is 300 meters (Hahn, 1976).

2) Unit Jv (or L-ms2 in Baum and Hahn, 1977)

Unit ms2 is characterized by intermediate to acid extrusive rocks, andesite, rhyodacite, and rhyolite, and associated with tuff. The Volcanic rocks rest more or less on the non-marine red beds. In places, the basal contact of the volcanic rocks is characterized by a slight thermal metamorphism of the underlying rocks. Shale altered to hornfels and limestone to marble. Generally, the volcanic rocks are red, purple, gray and gray-green. The rocks are accompanied by reddish or yellowish, mostly fine-grained tuff that only locally thick. The tuff is rich in quartz and feldspar. Volcanic slag and bombs with typical shrinkage cracks are present. Thickness is 300-350 meters (Hahn, 1976).

3) Unit J2 (or ms3 in Baum and Hahn, 1977)

Unit ms3 directly overlies unit ms2. The rock is conglomerate with rhyolite pebbles in the lower part, 25-60 meters thick. The upper part is conglomerate transitional to fine-grained sandstone. The conglomerate consists of pebbles of quartz, rhyolite, red nodular marly limestone and claystone. The poorly rounded pebbles have average diameters of 1-2 cm, maximum 10 cm. The matrix is sandy-argillaceous.

Thickness is 300-400 meters. Limestone breccias are found in the river bed of the Nam Pi east of Chiang Muan (Hahn, 1976).

4) Unit J3 (or ms4 in Baum and Hahn, 1977)

Unit ms4 is characterized by quartzitic, partly arkosic sandstone of white, whitish gray, yellowish, gray, gray-green, light brown and, subordinately, reddish and reddish brown color. The sandstone is predominantly fine-grained and well-sorted and only locally medium to coarse-grained or gravelly. There is conglomeratic beds with well rounded pebbles up to a centimeter in diameter and composed of white or colored quartz. The mostly dense and hard sandstone shows thick, well developed bedding. Cross bedding is common. Thickness is 400-500 meters (Hahn, 1976). The fossils of freshwater fish, pelecypods and plant remains occurs within the claystone intercalations (Baum *et al.*, 1970).

Within the basin, there are Tertiary (T) and Quaternary (q) rock unit. The Tertiary rock unit is composed of gravel, sand, silt, and clay with intercalations of lignite, freshwater-limestone, calcareous tufa (Baum *et al.*, 1970) and interbedded claystone, sandstone, mudstone, diatomite, and shale with fossils leaves, stems, bone of fish, and *Viviparus* sp. (Charoenprawat *et al.*, 1994). The Quaternary rock unit composed of unconsolidated gravel, sand, silt, and clay.

2.1.2 Lithostratigraphy

Several works on the Tertiary sedimentary rock was carried out at Chiang Muan coal mine. Chiang Muan Coal Mine (CMMC) had divided this Tertiary sedimentary rock into nine units which composed of 1) underburden (UB), 2) lower split coal seam (LS), 3) lower massive coal seam (LM), 4) interburden2 (IB2), 5)

upper coal seam (U2), 6) interburden1 (IB1), 7) upper split coal seam (U1), 8) Tertiary overburden (OB2), and 9) Quaternary overburden (Q or OB1) from bottom to top. Later, these Tertiary sedimentary rocks were assigned to Chiang Muan Formation by Fukuchi (Fukuchi, 2007; Fukuchi *et al.*, 2007). The Chiang Muan Formation is composed of five members which are 1) Sa Nua Member (included UB), 2) Sa Tai Member (included LS and LM), 3) Sa Member (included IB2), 4) Kon Member (included U2, IB1, and U1), and 5) Thung Nong (included OB) (Figure 2.4).

1) Sa Nua Mudstone Member

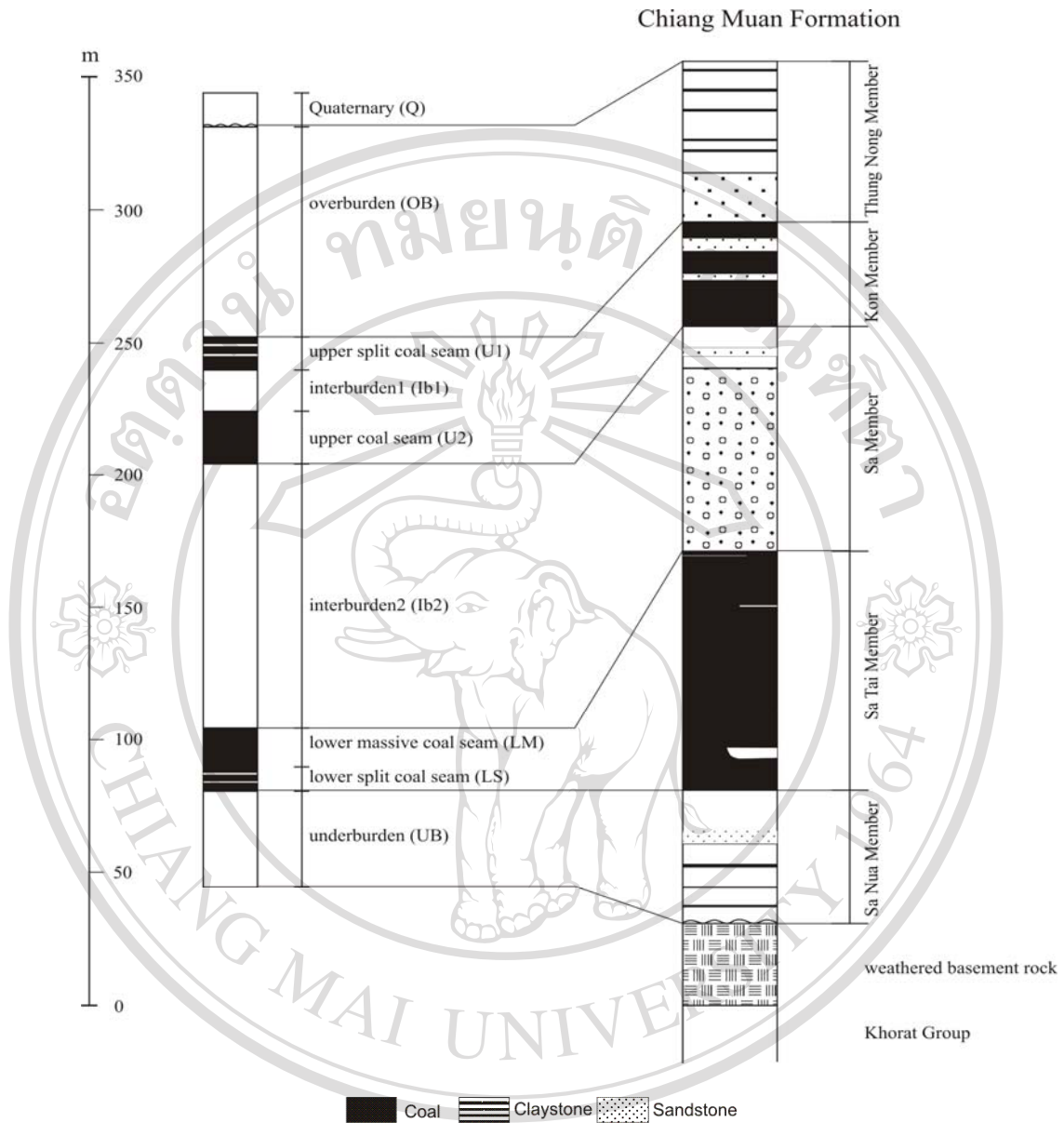
This member is composed of reddish sandy mudstone, paleosols and interbedded with coarse-grained sands and granules of quartz, sandstone, chert and shale. The thickness of the member is approximately 40 meters (Fukuchi, 2007).

2) Sa Tai Lignite Member

This member is consisted lignite, carbonaceous mudstone and mudstone. This member yields the vertebrate fossils, including of proboscideans, rhinocerotids, hominoids, bovids, tragulids, rodents, birds, reptiles, amphibians, and fishes. The thickness ranges from 30 to 120 meters (Fukuchi, 2007).

3) Sa Member

This member is characterized by alternating beds of reddish sandy paleosols and channel-fill deposits. The reddish sandy paleosols consist of poorly sorted very fine- to medium-grained sandstone with granule to pebble clasts. The Sa Member is 70 to 90 meters in thickness (Fukuchi, 2007).



ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
 Copyright © by Chiang Mai University
 All rights reserved

Figure 2.4 Lithostratigraphy of Chiang Muan coal mine, left column is constructed by CMMC correlated to 'Chiang Muan Formation', right column, (modified from CMMC, unpublished report and Fukuchi, 2007).

4) Kon Member

Alternation of lignite beds with claystones are characteristics of this member. The rock composed of mudstone, sandstone and gravelly sandstone intercalated within lignite. This member yields the vertebrate fossils, including hominoids, rhinocerotids, suids, crocodiles, turtles and fishes. The thickness is approximately 40 meters (Fukuchi, 2007).

5) Thung Nong Member

It consists of unoxidized zone in the lower part and the oxidized in the upper part. The oxidized zone is the characteristic of this member which is brownish paleosols. The impermeable calcic soil horizons (K horizon) were formed and containing of ferruginous rhizoconcretions and ferric concretions. The crevasse splay were deposited and intercalated within paleosol beds. The thickness is approximately 60 meters (Fukuchi, 2007).

2.1.3 Paleontology

A number of mammalian fossils have been found and collected by mine geologists, Mr. Arong Sritulakarn and Mr. Nikorn Wongchai. They found a number of teeth of proboscidean, suids, ruminants, and rhinos. Nakaya *et al.* (2002a, b; 2003a, b; 2007) listed the mammalian and other vertebrate fossils and reported the discovery of gomphotherid proboscidean, *Tetralophodon* cf. *xiaolongtanensis*. A first hominoid tooth fragment was reported by Mr. Nikorn Wongchai (Kunimatsu *et al.*, 2000) and another fragment was found by Miss Bantita Udomkan (Kunimatsu *et al.*, 2002). Later, several well-preserved teeth of the hominoid were found and named to a new species, *Khoratpithecus chiangmuanensis* (Chaimanee *et al.*, 2003; 2004).

Pickford *et al.*, 2004 reported well-preserved suid specimens which belong to Suinae, *Hippopotamodon* cf. *hyotherioides*, and Tetraconodontinae, *Parachleuastochoerus sinensis* and *Conohyus sindiensis*, and one tayassuid, *Pecarichoerus sminthos*. The other mammalian fossils are composed of rhinocerotid, *Chilotherium* (*Subchilotherium*) *intermedium*, and tragulid, *Dorcatherium* sp. The mammalian fauna of Chiang Muan suggests The end of Middle Miocene to earliest Late Miocene in age or MN7/8 to 9 (Nakaya *et al.*, 2007). The mammalian which were reported from Chiang Muan are composed of primates, hominidae, *Khoratphithecus chiangmuanensis* (Chaimanee *et al.*, 2004); proboscidea, gomphotheriidae, *Tetralophodon* cf. *xiaolongtanensis*; perissodactyla, rhinocerotidae, *Chilotherium* (*Subchilotherium*) *intermedium*; artiodactyla, tayassuidae, *Pecarichoerus sminthos*, suidae, *Hippopotamodon* cf. *hyotherioides*, *Parachleuastocherus sinensis*, *Conohyus sindiensis*, tragulidae, *Dorcatherium* sp., cervidae, indeterminate gen. *et* sp., bovidae, indeterminate gen. *et* sp, and rodentia. Other vertebrates are composed of aves indeterminate ord., fam., gen *et* sp.; reptilia, testudines, indeterminate fam., gen. *et* sp.; squamata, serpentes, indeterminate fam., gen. *et* sp.; crocodylia, indeterminate fam., gen. *et* sp.; osteichthyes, cyprinidae, indeterminate gen. *et* sp., pangasiidae, indeterminate gen. *et* sp., clariidae, indeterminate gen. *et* sp. indet., channidae, indeterminate gen. *et* sp (Nakaya *et al.*, 2002a, b; 2003a, b; 2007; Fukuchi, 2006, 2007; Fukuchi *et al.*, 2007).

2.2 Mae Soi Locality, Chiang Mai Province, northern Thailand

Mae Soi is a village in Mae Soi sub-district, Chom Thong district, Chiang Mai province. The village is located 75 kilometers along highway no. 108,

south of Chiang Mai city. The study area is 5 kilometers west of the village along the local road to the longan farm garden and further 1 kilometer by walk to the outcrop. The study locality is a hilly and dry area with sparse vegetation. The area is elevated 300-370 meters above the mean sea level. There are two sub-localities, Doi Chang which mean 'elephant hill' and Kiu Hoi Tan 'gastropod valley'. The Kiu Hoi Tan is 500 meters south of Doi Chang. Both localities yield the mammalian fossils (Figure 2.5).

The drainage is an intermittent stream. Two intermittent streams, Huai Pong Bai and Huai Khao Phuang, drain Doi Chang and Kiew Hoi Tan. Huai Pong Bai flowing to Nam Mae Soi in the north and Nam Mae Soi ultimately flows to 'Mae Nam Ping' or the Ping River, which flowing southward. Huai Khao Phuang is directly flow to the Ping River at Huai Khao Phuang village, 2 kilometers south of Mae Soi village.

2.2.1 Geological setting of Mae Soi

The geology of the area is composed of Precambrian gneiss-series unconformably overlain by less metamorphosed Cambro-ordovician rocks (Baum *et al.*, 1970). The Precambrian gneiss series is included of paragneiss, schistose augen-gneisses, anatexite, biotite-schist, and marble (Baum *et al.*, 1970). These rocks formed the Western mountain range of Thailand which extended to the south peninsular. This mountain range has a domal structure broadly divided into core orthogneisses and mantling paragneisses (Macdonald *et al.*, 1993). The core orthogneisses are comprised two main units; silimanite-bearing, muscovite-biotite orthogneiss and megacrystic

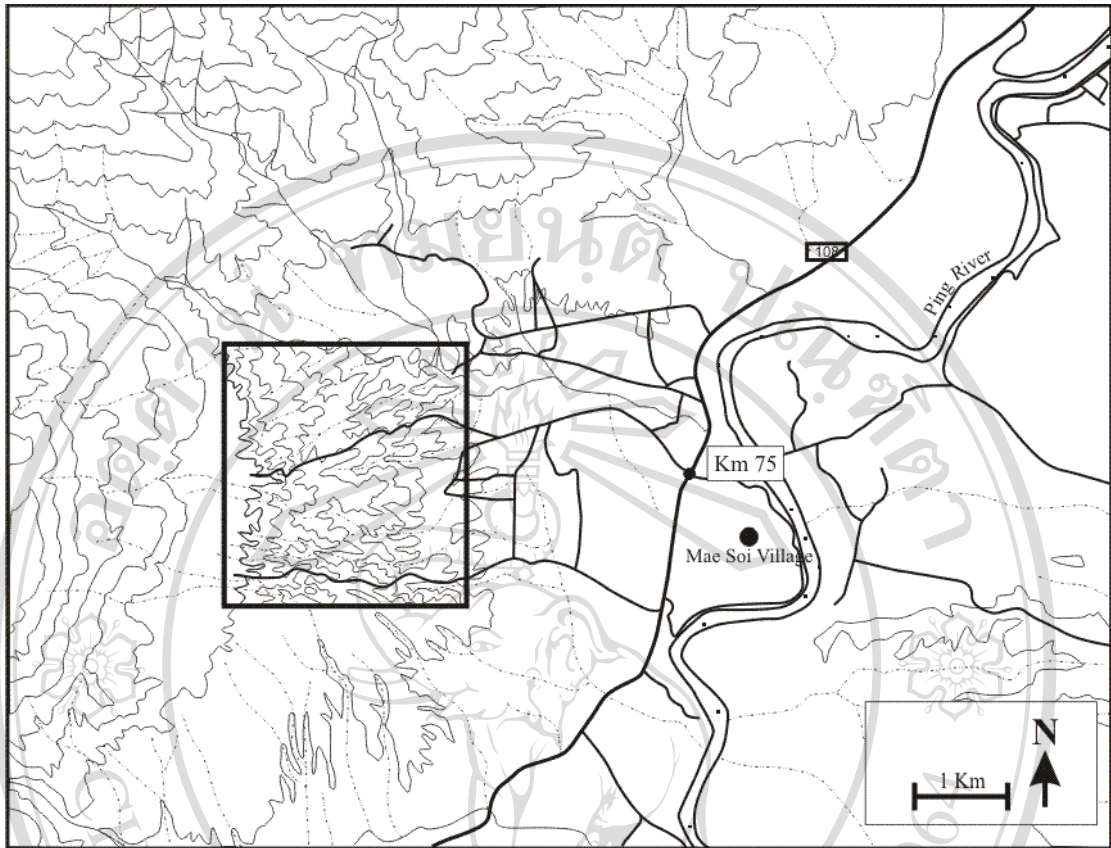


Figure 2.5 Route to Mae Soi area, highway no. 109 (Chiang Mai-Hod) and a square is study area (modified from Topographic map scale 1:50,000 Sheet 4745 IV Amphoe Chom Thong, Royal Thai Survey Department, 1991a).

ลิขสิทธิ์มหาวิทยาลัยเชียงใหม่
Copyright© by Chiang Mai University
All rights reserved

biotite orthogneiss. The paragneisses mantle the core zone is exposed only on the eastern side of the dome. The paragneisses are layered gneisses, fine to medium grained quartzo-feldspathic layers (5-50 centimeters thick) alternated with coarser, more biotite-rich, schistose layers containing plagioclase porphyroblasts of variable size. The dome was covered with quartz schist and biotite schist and overlain by fine-grained marble, gradational to limestone. On the east side of the dome, the marble rests on the detachment fault. Mae Soi is on the eastern flank of Inthanon summit, part of the western range. The Ordovician limestone lied above the paragneiss in the east of Mae Soi. The Silurian-Devonian rocks lies in the west and are composed of phyllite and schist (Baum *et al.*, 1970), and gray to black argillite, sandstone, and chert (Macdonald *et al.*, 1993).

The plutonic rock in the NW of the area is the granite and is called the foliated Mae Klang pluton (Cobbing and Pitfield, 1986). It intruded both core and mantling gneisses. The granite varies from fine- to medium- grained biotite granite to medium- grained leucogranite. The foliation is typically a weakly to moderately developed preferred orientation of biotite.

The Neogene unit distributes largely at the foot hill and adjacent to the Ping River. The rocks are conglomerate, sandstone, and shale. The Quaternary unit is a Recent sediment of an alluvial deposits which composed of gravel and sand (Baum *et al.*, 1970), (Figure 2.6)

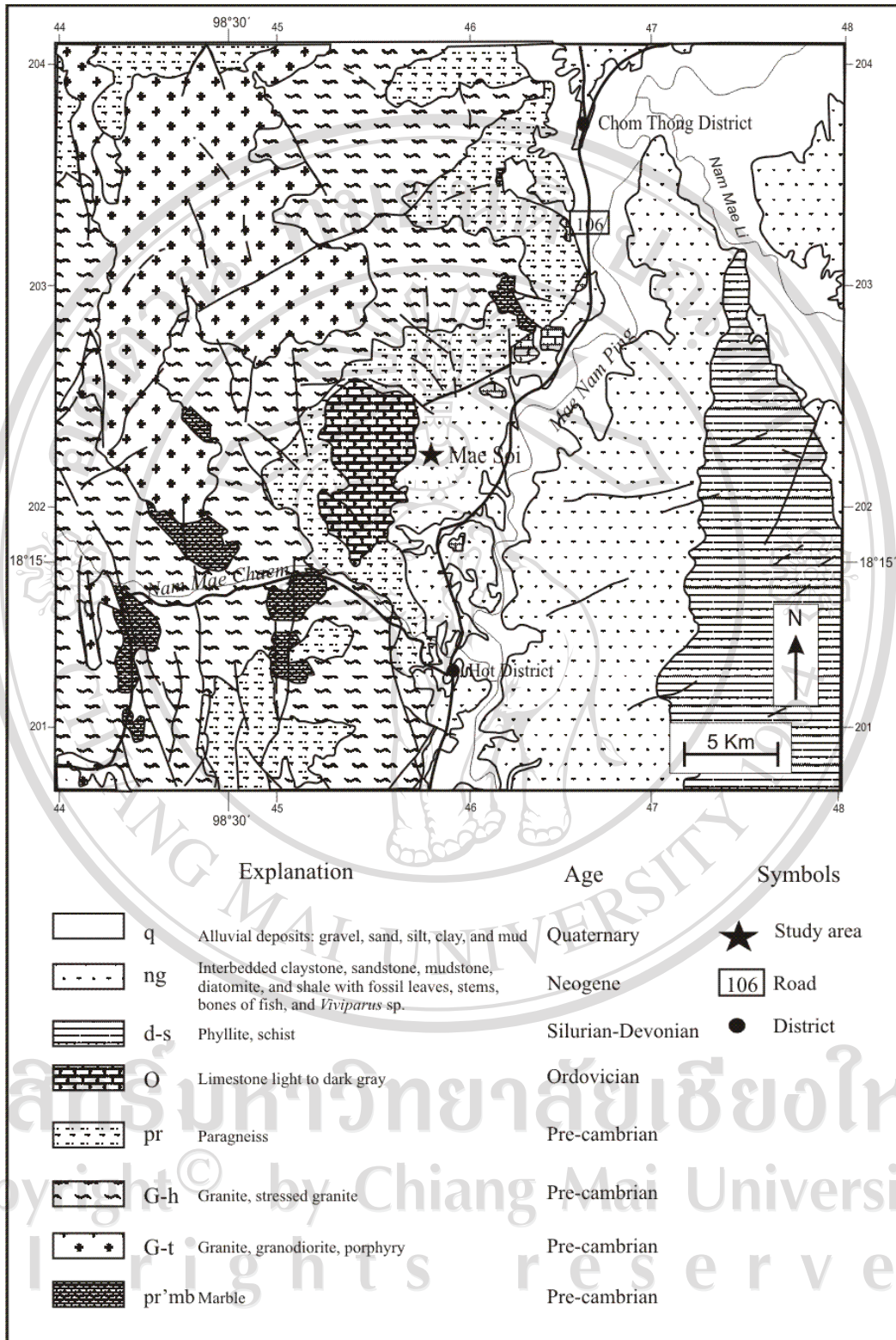


Figure 2.6 Geology of Mae Soi and surrounding area (modified from Baum *et al.*, 1970).

2.2.2 Lithostratigraphy

Doi Chang and Kiu Hoi Tan are of Neogene formation, directly overlie Ordovician and Precambrian basement. Doi Chang is largely siltstone and contains much intercalated sandstone and conglomerate. In Kiu Hoi Tan, The rock is mainly siltstone and intercalated sand and conglomerate beds. The lithology of Kiu Hoi Tan and of Doi Chang are similar to each other, however, the stratigraphic relationship is not clear (Saegusa *et al.*, 1999, 2000), (Figure 2.7).

2.2.3 Paleontology

The Mae Soi site originated from the discovery of the proboscidean skeleton by the villagers of Mae Soi village in March, 1997. The posterior half of the body were excavated and brought to the temple by villagers. After the drought happened in that year, the villagers returned the skeleton at the original site (Saegusa *et al.*, 1999, 2000). In December, the same year, the left and right pelvis and anterior half of the body, included a skull and tusks, were found buried with short relocated first by the villagers and later excavated by Japanese paleontologists, Dr. Benjavun Ratanasthien, staffs of the Chiang Mai National Museum, and villagers. This proboscidean remains is of cf. *Archeobelodon* sp. (Saegusa *et al.*, 1999, 2000). The remains was deposited at the lowermost part of the yellowish sandstone layer which underlain by pale-color silt layer (Kunimatsu *et al.*, 2000). Beside the *Archeobelodon* skeleton, a phalanx of perissodactyl, dental remains and tibia of rhinocerotids, deciduous molar of

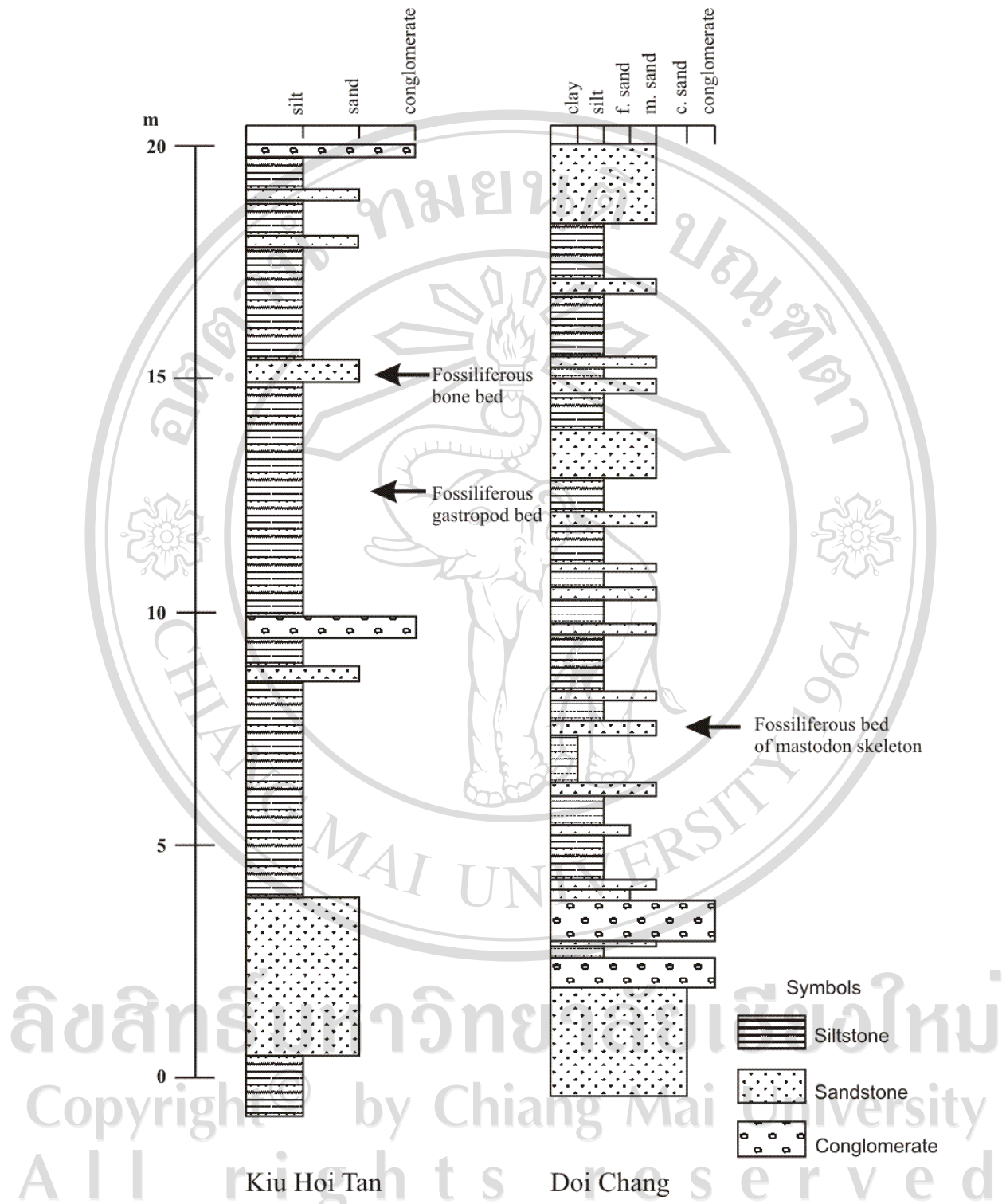


Figure 2.7 Lithostratigraphy of Mae Soi, Doi Chang and Kiu Hoi Tan (Saeguse *et al.*, 1999).

Gomphothere were also found nearby the Doi Chang hill. These remains were found on the surface (Kunimatsu *et al.*, 2000).

Another fossil yielded locality is Kiu Hoi Tan, a valley of gastropod, which is about one kilometer south of Doi Chang hill. This site is well known among the villagers for years for the fossil gastropod shells. Not only the gastropod was found, but also the proboscidean and suid remains and petrified wood fragment. These remains of Kiu Hot Tan were scattered on hill surface. The mammalian and other vertebrates fossils of the Mae Soi site are listed as the following (Kunimatsu *et al.*, 2000; Nakaya *et al.*, 2002; Saegusa *et al.*, 1999, 2000). The Mae Soi Fauna suggests the end of Early Miocene in age or MN4 to the area (Nakaya *et al.*, 2007; Saegusa *et al.*, 1999, 2000). The mammalian fossil which were reported from Mae Soi are composed of proboscidea, amebelodontidae, *Archaeogelodon* sp.; perissodactyla, rhinocerotidae, indeterminate gen. *et sp.*, artiodactyla, anthracotheriidae, indeterminate gen. *et sp.*, suidae, indeterminate gen. *et sp.*, tragulidae, gen. *et sp.* Other vertebrates are composed of reptilia, chelonia, testunidae, indeterminate gen. *et sp.*, trionychidae indeterminate gen. *et sp.*, crocodylia, indeterminate fam., gen. *et sp.*

2.3 Na Sai Sub-basin, Lamphun Province, northern Thailand

Na Sai is a village in Na Sai sub-district, Li district, Lamphun province. Na Sai village, 17° 41' 24" N and 98° 58' 39" E, is located 15 kilometers south of Li city. Li town, 17° 48' 20" N and 98° 57' 12" E, is accessed by highway no. 106 (Muang, Lamphun - Thoen district, Lampang), then take a local road on the west side of the road to Na Sai village and Na Sai coal mine. The mine is an open pit and

currently operated. The area is situated 550-600 meters above mean sea level and located north foot hill of Doi Kiu Hong. The area is drained by Huai Bong, an intermittent stream, flowing to Huai Mae La in the NW and Huai Mae Tae in the NE and ultimately flowing to Mae Nam Li, the largest river drained Li basin (Figure 2.8). Na Sai sub-basin is one of the four sub-basins of Li Basin. The Li basin comprised of Ban Pu, Ban Pa Kha, Mae Long, and Na Sai sub-basins (Snansieng and Maneekut, 1985). Only Mae Long and Na Sai sub-basin yielded the mammalian fossils. These two is relatively younger than Ban Pu and Ban Pa Kha sub-basin based on the floral and pollen studies (Endo, 1963, 1966; Songtham *et al.*, 2003). Ban Pa Kha coal deposit yielded a fossil plant of temperate region.

2.3.1 Geological setting of Na Sai Basin

The rocks which underlain the Na Sai sub-basin are of Ordovician, Silurian-Devonian, Carboniferous, Permian, Triassic in age. The Ordovician rock unit is limestone, light gray to dark gray laminated, recrystallized with interbedded dark gray calcareous shale (Buravas and Pitakpaivan, 1974). The limestone is thick beds with stylolitic layering. Strongly deformed with angular folding and kink bands with fossil cephalopod *Amenoderas* sp. (Thanasuthipitak and Sinthusan, 1982). The mineralogy of limestone is compose of calcite (micritic texture) 70-85%, quartz 2-15%, mica 10%, clay 5% and opaque minerals 2% (Uttamo, 1982). The Silurian-Devonian rock unit consists of phyllite, quartzite, quartz-schist, schist, chlorite-schist, greenschist facies, with rhyolitic tuff and andesitic tuff (Buravas and Pitakpaivan, 1974). This unit is a conformably overlying the Ordovician unit with gradational contact.

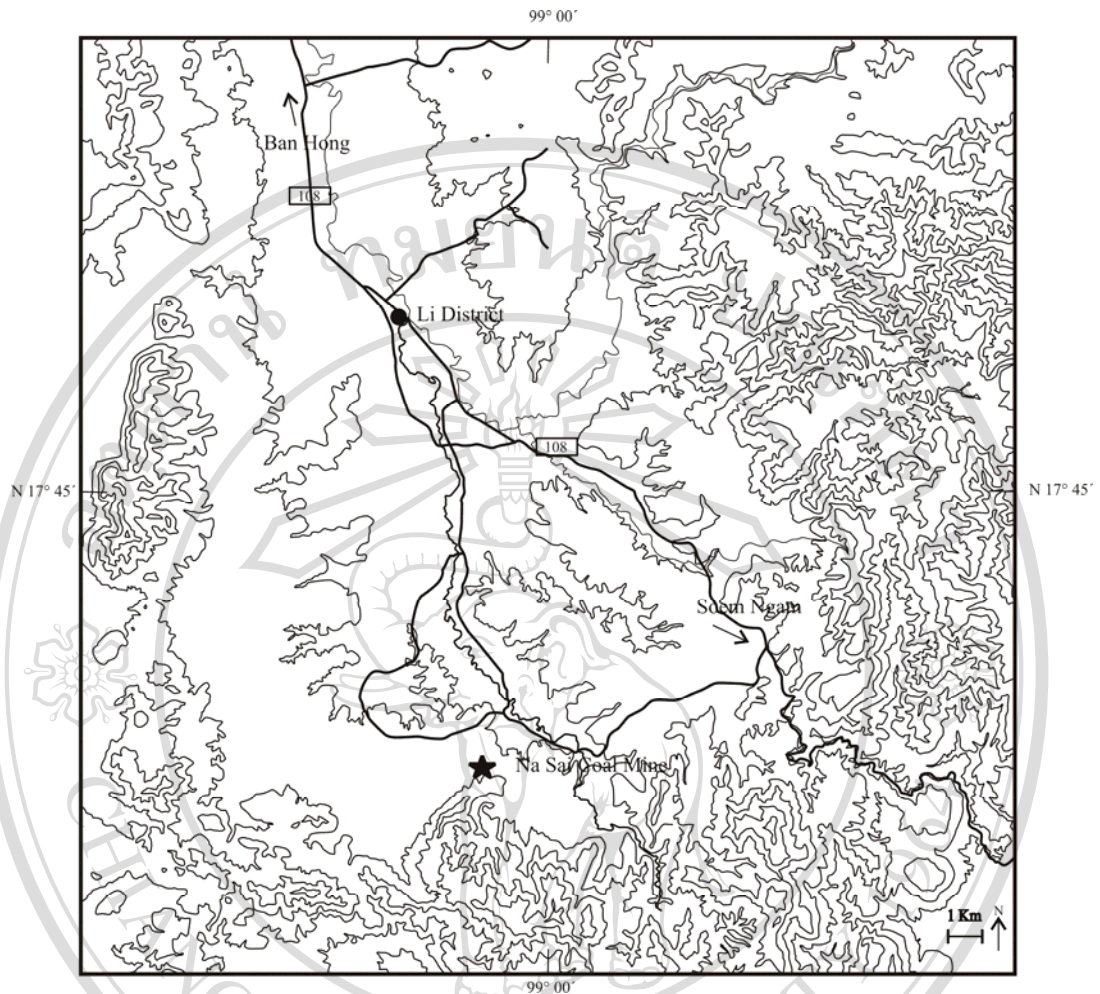


Figure 2.8 Route to Na Sai coal mine, star mark, by highway no. 108 (Bang Hong-Li) (modified from Topographic map scale 1:50,000 Sheet 4744 I, 4744 II, 4844 III, and 4844 IV , Royal Thai Survey Department, 1979a, b, c, and d).

It is lithologically composed of four units which are phyllites, black shales, black slates, and shales (Thanasuthipitak and Sinthusan, 1982).

The Carboniferous rock unit is composed of the rhyolite, andesite, tuff, agglomerate, conglomerate, sandstone, shale, chert beds; limestone, massive to well bedded, recrystallized, light gray to pinkish gray (Buravas and Pitakpaivan, 1974). The Permian rock unit is composed of gray and light gray massive limestone with fossils Bryozoa, Fusulinid, and Crinoid (Thanasuthipitak and Sinthusan, 1982). The Triassic rock is a marine Triassic sedimentary rock of Lampang Group (Piyasin, 1972). The rocks are conglomerate, reddish-brown, with rhyolite and andesite pebbles, sandstone; tuffaceous sandstone, shale, gray to reddish brown with calcareous shale and limestone lenses. This rock unit is of Pra That Formation, the lower most unit of the group (Buravas and Pitakpaivan, 1974).

The Triassic granite is including of granite, granodiorite, porphyry (Baum *et al.*, 1970). The Neogene rock unit is composed of interbedded claystone, sandstone, mudstone, diatomite, and shale with fossil leaves, stems, bones of fish, and *Viviparus* sp. (Department of Mineral Resources, 1974). The Quaternary unit is the deposition of alluvial sediment which included of gravel, sand, silt, clay, and mud (Buravas and Pitakpaivan, 1974) (Figure 2.9).

2.3.2 Lithostratigraphy

The lithostratigraphic sequence of Na Sai coal mine is part of Mae Long Formation which given by Ratanasthien (1990). It is Tertiary coal-bearing formation which underlain by Pre-Tertiary quartzite, phyllite and limestone. The underburden rock of coal bed is composed of claystone, shale, sandstone and conglomeratic sandstone. The layer underneath and adjacent to coal layer is composed of claystone, shale, sandstone and oil shale. It is gray to dark gray color. The coal is

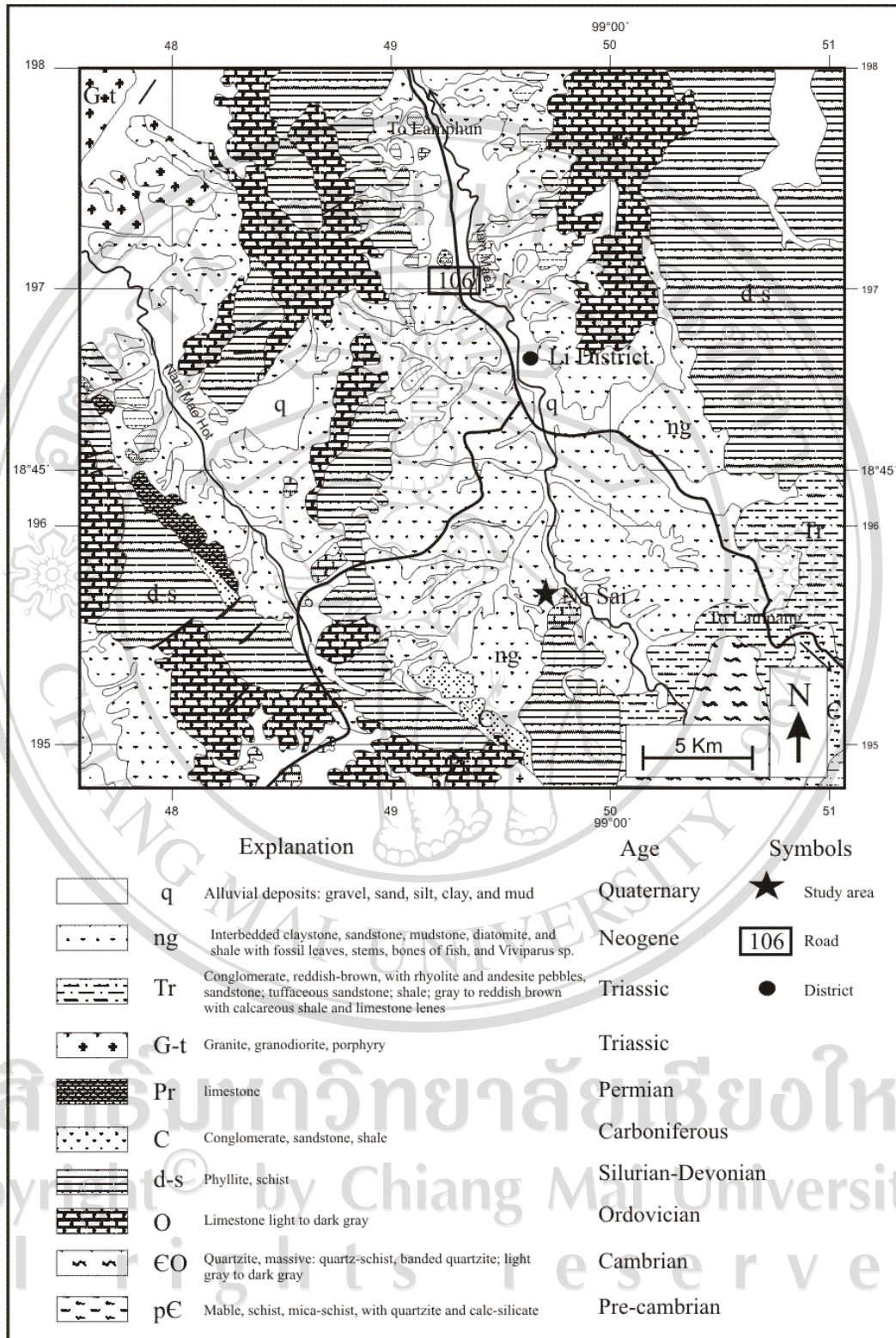


Figure 2.9 Geology of Na Sai and surrounding area (modified from Baum *et al.*, 1970)

black, brown to dark brown coal of lignite to sub-bituminous ranks. It is composed mainly of tree trunk remains with black to pale gray, very poorly consolidated claystone, sandstone and conglomerate parting. Pyrite is found associated. The overburden rock is composed of mudstone, shale, sandstone and conglomeratic sandstone. It is light gray mudstone, shale, sandstone and conglomeratic sandstone with intercalation of alternated layer of 1-2 mm thick greenish gray mudstone (Ratanasthien, 1990) (Figure 2.10).

2.3.3 Paleontology

The mammalian fossils which discovered in Na Sai coal mine were listed as the following (Ducrocq *et al.*, 1994, 1995, 2003; Ginsburg *et al.*, 1991; Ginsburg and Ukkakimapan, 1983; Hanta *et al.*, 2006; Tassy *et al.*, 1992). These fossils were found from 1-7 meters thick coal seam. The estimated age is 18-16 Ma (Ducrocq *et al.*, 2003) or Middle Miocene, Neogene Mammal (MN) units 5-8. The mammalian fossils which were reported from Na Sai are composed of proboscidea, stegodontidae, *Stegolophodon nasaiensis*; perissodactyla, rhinocerotidae, *Gaiotherium* sp.; artiodactyla, tragulidae, *Siamotragulus sanyathanai*; anthracotheriidae, *Brachyodus* cf. *onoideus*, suidae, *Conohyus thailandicus*.

2.4 Sop Mae Tham Locality, Lampang Province, northern Thailand

Sop Mae Tham is a village in Soem Sai sub-district, Soem Ngam district, Lampang province, northern Thailand. Soem Ngam district is located ca 40 kilometers south of Lampang city. Sop Mae Tham is in Soem Ngam sub-basin, one of sub-basins of Lampang basin. The study area is ca 2.0 kilometers north of Sop Mae

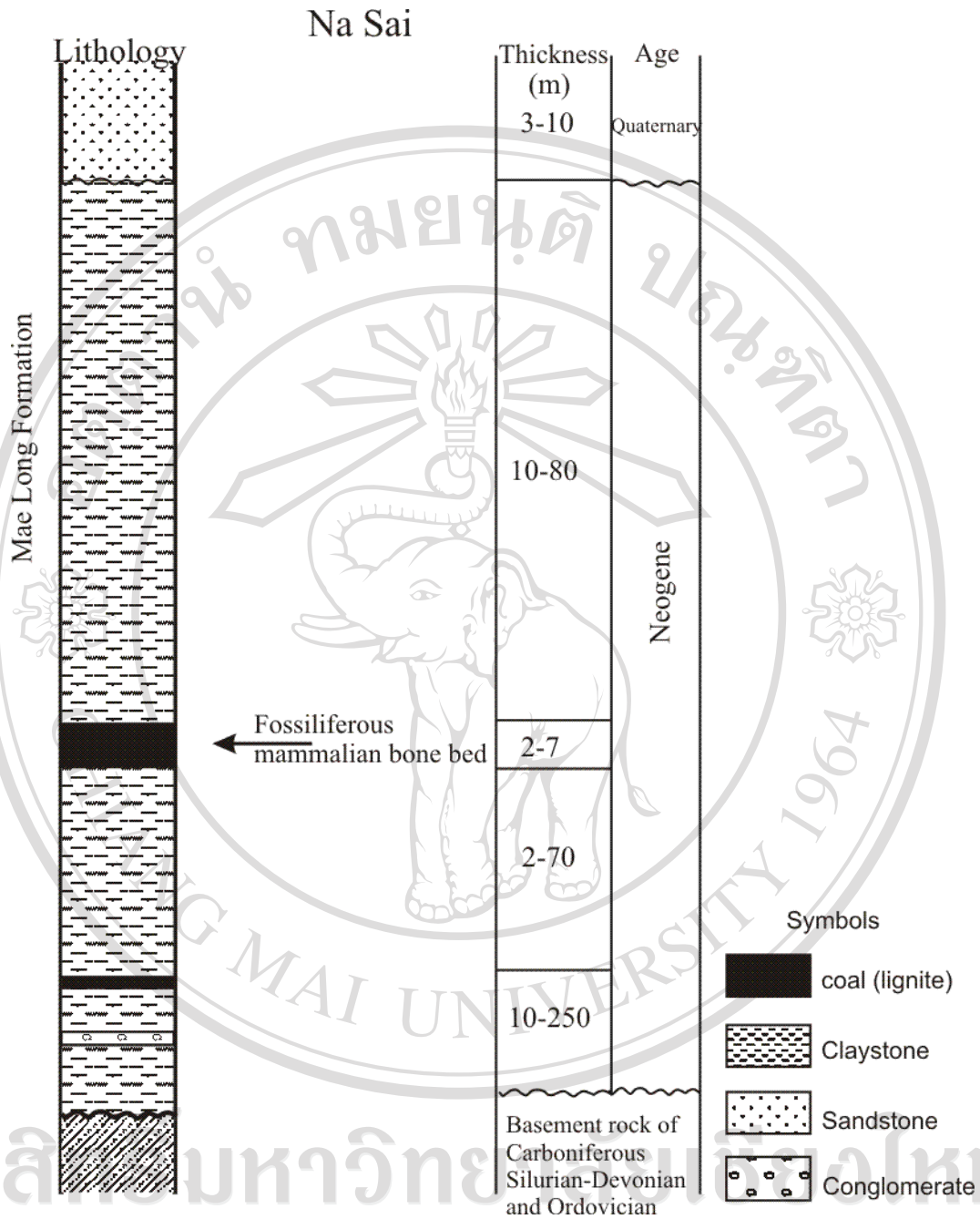


Figure 2.10 Lithostratigraphy of Na Sai coal mine (Modified from Ratanasthien, 1990).

Tham village. It is located at latitude N 18° 01' 46" to 18° 02' 08" and longitude E 99° 08' 50" to 99° 09' 20" or UTM 47Q 1993200-1994000 N and 515600-516300 E.

Soem Ngam sub-basin covers area ca. 140 square kilometer. of Soem Ngam district. Soem Ngam district is bordered with Hang Chat district, in the north, Koh Kha district, in the east, Sop Prab district, in the south, and Thung Hua Chang sub-district, Lamphun province, in the west. The basin lays north-south direction. It is 20 kilometers in length and 12 kilometers in width. The basin has floodplain and hilly area which ranged 220-340 meters above mean sea level (Figure 2.11).

Several streams are located in the basin. Nam Mae Tham flows from the mountain range in the south into the basin at Ban Huafai. Huai Mae Liang Luang and Nam Mae Phung flow from the Khun Tan range in the northwest to the basin at Ban Mae Liang. Nam Mae Some and Nam Mae La flow from the west.

2.4.1 Geological setting of Soem Ngam sub-basin

Triyam and Jaita-Butra (1991) made a detailed geological investigation in Soem Ngam sub-basin. They report that the basement rock composed of Silurian-Devonian, Permian limestone, and Triassic rock. The rocks bound and underlie the basin. The Permo-Triassic igneous extends at the east and the south. Cenozoic rock lies within the basin. These rock units were classified according to Piyasin (1972), ranging from older to younger unit (Figure 2.12).

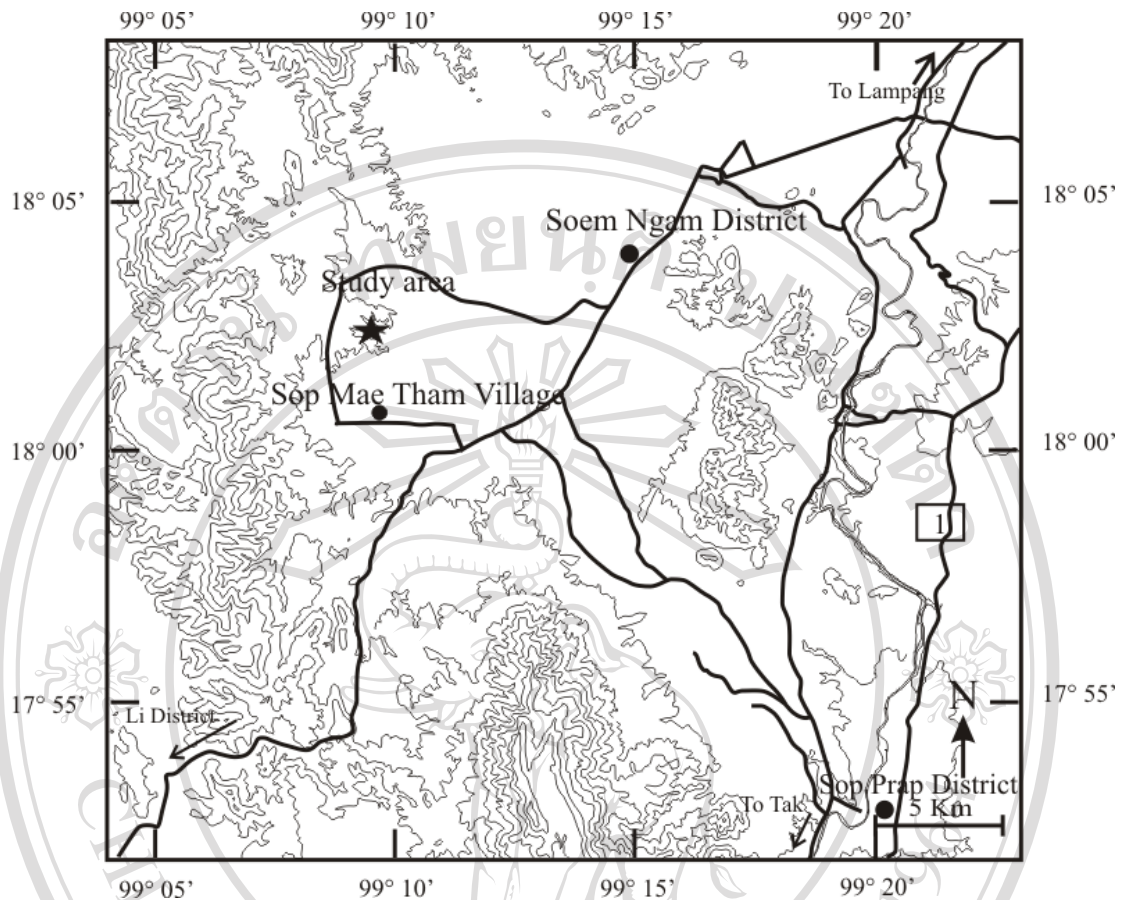


Figure 2.11 Route to Sop Mae Tham area, 2 km north of Sop Mae Tham village (modified from Topographic map scale 1:50,000 sheet 4845 III (King Amphoe Thung Hua Chang), Royal Thai Survey Department, 1991b).

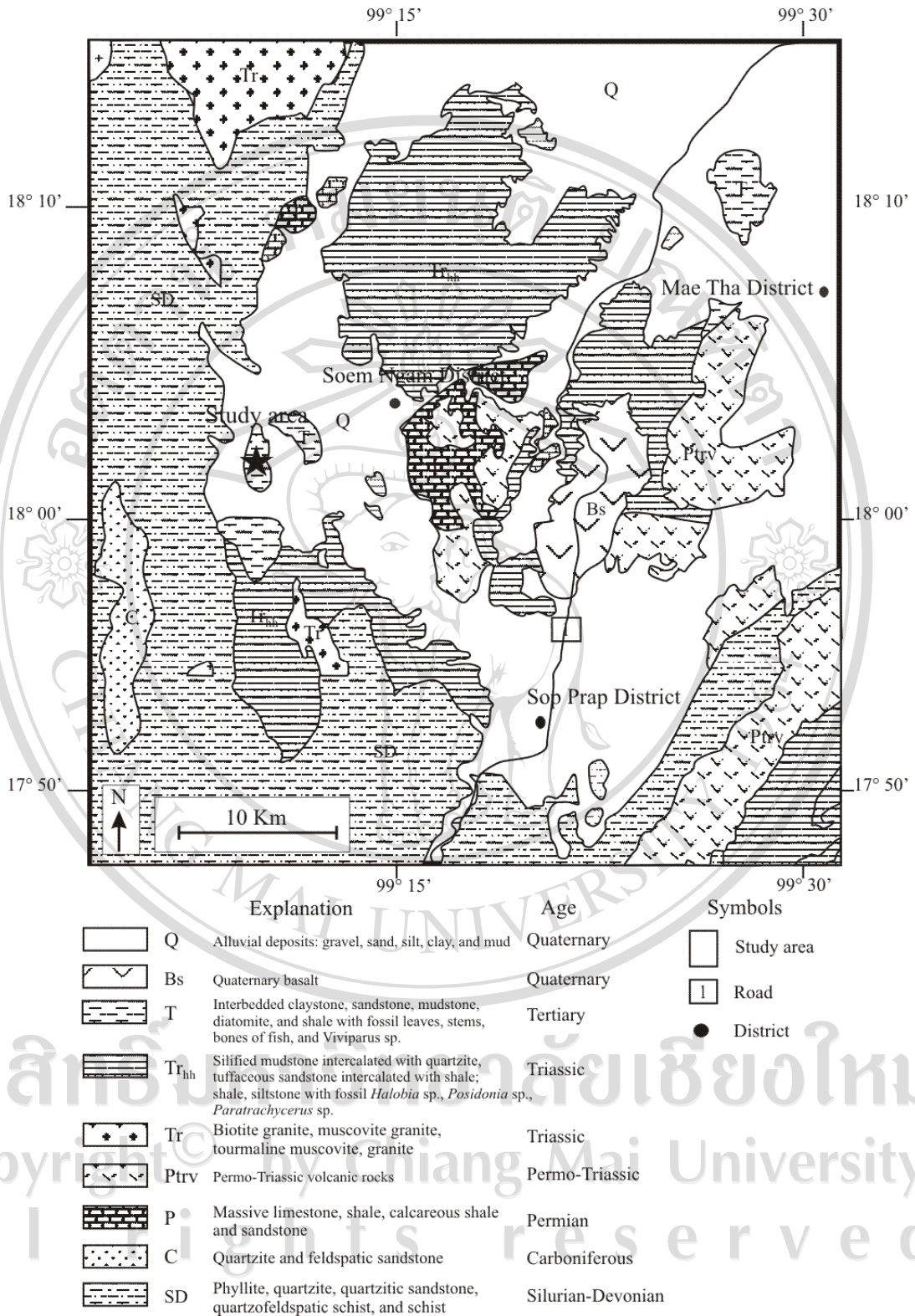


Figure 2.12 Geology of Sop Mae Tham and surrounding area (Buravas and Pitakpaivan, 1974 and Charoenprawat *et al.*, 1994).

1) Silurian-Devonian rock unit

It is metamorphic and oldest rock in this area. It is composed of quartzite, quartz-schist, and quartz-mica schist of Donchai group. Quartzite is hard and dense, gray to light brown, well-developed suture texture. Quartzite and quartz-mica schist is green and greenish gray with schistosity texture. These rocks lie north to south in the west of the basin.

2) Permian rock unit

This rock unit is included limestone, shale, calcareous shale of Ratburi group. The limestone is massive, light green and pinkish gray, very thick bed. Shale and calcareous shale is gray and brown and weathered to reddish brown. Permian limestone lies north-south in the north of basin and disseminated at Ban Lao Yao.

3) Triassic rock unit

The rock composed of an intercalation of sandstone, tuffaceous sandstone, siltstone, shale. The color is olive green and greenish gray. These rocks are of Hong Hoi formation, Lampang group. The cement material is silica. The fracture is conchoidal and ellipsoidal. Small calcite vein, 1-15 centimeters in width, found along fracture and void in the rock. This rock unit lies north-south in the east and continue to the south. It is low hill topographic due to low-resistant to weathering.

4) Permo-Triassic igneous rock unit

This unit is volcanic rock which composed of rhyolite and andesite. Rhyolite is light brown and white contained feldspar, quartz and fine mica. Andesite is greenish gray. These rock are high-resistant to weathering forming high mountain lie north-south in the east and patchy at the south of the basin.

5) Tertiary rock unit

The Tertiary rock unit is comprised of 2 sub-units, lower and upper Tertiary which are older and younger, respectively. This Tertiary rock unit distributes in southern part of the basin. It is low hills and is covered with Quaternary unconsolidated sediment. The rock exposed along the streams. The Lower Tertiary rock sub-unit is composed of an intercalation of thin layer of brown shale and oil shale, greenish-gray mudstone, dark brown lignitic shale, gray and dark-gray mudstone, and coal. The fossil plant leaves were found in shale layer. It is believed that it was deposited in lacustrine environment. The Upper Tertiary rock sub-unit exposed in dried hilly area covered with patchy of small-sized tree. This rock unit is lie above the Lower Tertiary unit. It is composed of semi-consolidated conglomerate, siltstone, and mudstone and freshwater limestone. The color is brown, yellowish brown, reddish brown and light gray. This rock unit also included unconsolidated sediment of conglomerate, sand, silt as well. This area is called “Phae Pla Kang” (Triyarn and Jaita-Butra, 1991).

6) Quaternary rock unit

This rock unit is composed of unconsolidated gravel, sand, and mud. The color is brown. It is found at the terrace and along flood plain. The gravel is granule to boulder size. The gravel composition is rock fragment of quartzite, quartzschist, and vein quart. The thickness is over 10 meters. The sand and mud along floodplain is several meters thick.

2.4.2 Lithostratigraphy

The lithostratigraphy of Sop Mae Tham can be largely divided into three units, lower, middle, and upper units. The lower unit is comprised of the alternation of sand, silt, and clay with approximately 15 meters in thickness. The middle unit is a thick clay/silt unit with sand intercalation. The thickness is approximately 20 meters. The upper unit is composed largely of sand with intercalation of gravel beds. The thickness of upper unit is approximately 20 meters (Nagaoka and Suganuma, 2002), (Figure 2.13).

2.4.3 Paleontology

Kunimatsu *et al.* (2000) recorded the specimens and positions of mammalian and vertebrate fossils which were found in the area called “Phae Pla Kang”, a hilly area 2 km north of Sop Mae Tham village. Nagaoka (per.comm.) made the stratigraphic column in each position which the mammalian and vertebrate fossils were discovered at Phae Pla Kang. The Phae Pla Kang is in the Upper Tertiary unit, which was proposed by Triyarn and Jaita-Butra (1991). This geological age is obtained from the separation between the overlying semi-consolidated sediment, upper Tertiary and the underlying mudstone and coal-bearing unit, lower Tertiary.

The mammalian and vertebrate fossils which were found in this area were listed as the following (Kunimatsu *et al.*, 2000; Nakaya *et al.*, 2002a, b, 2003, 2007). This mammalian assemblage suggests that the Sop Mae Tham is early Late Miocene in age or Neogene Mammal units 9 (Nakaya *et al.*, 2002a, 2007). The mammalian fossils which were reported from Sop Mae Tham are composed of proboscidea, gomphotheriidae, cf. *Paratetralophodon* sp.; perissodactyla,

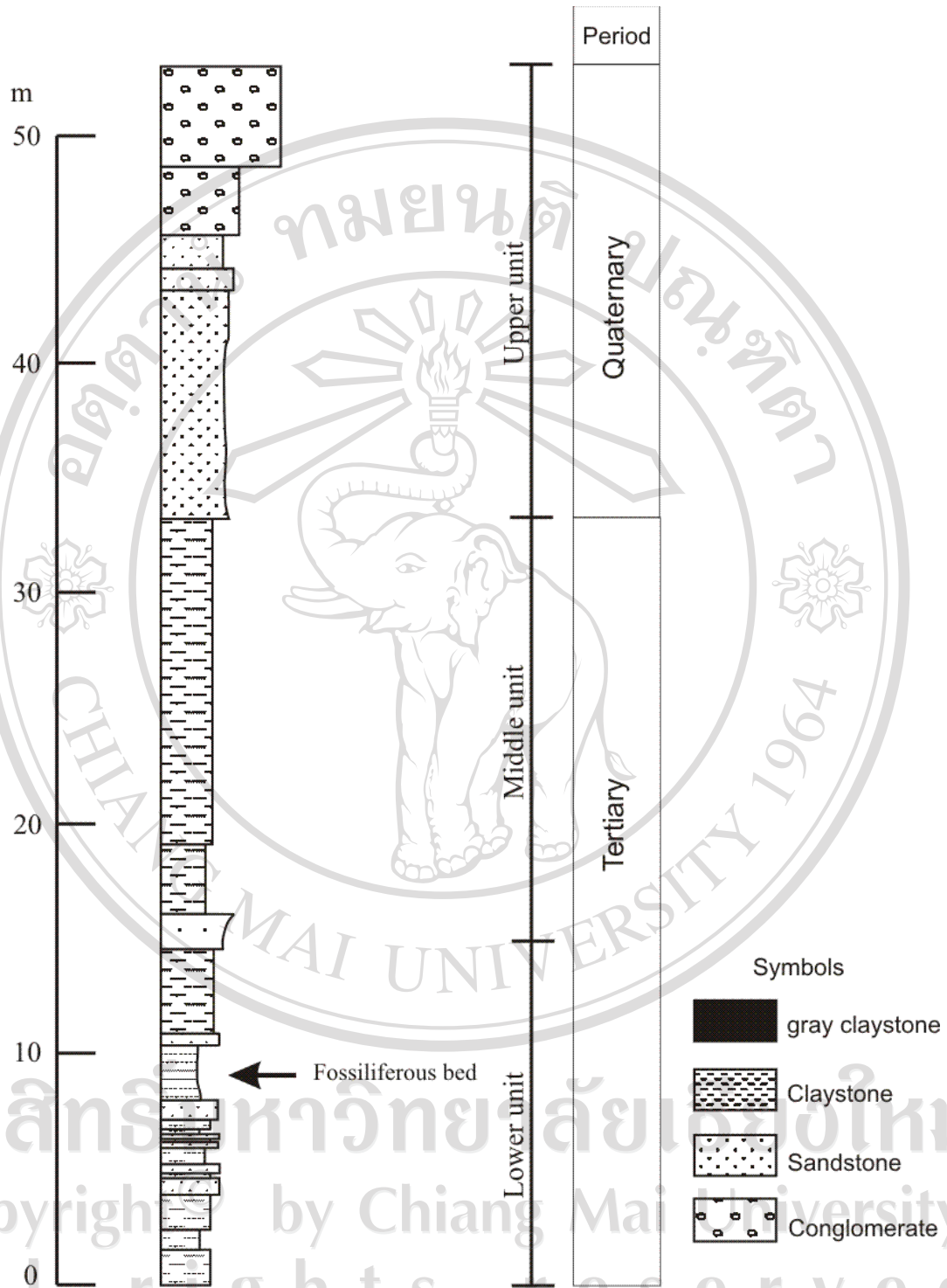


Figure 2.13 Lithostratigraphy of Sop Mae Tham which composed of lower, middle, and upper units (Nagaoka, per. comm.).

rhinocerotidae, indeterminate gen. *et* sp., equidae, Hippaionini, indeterminate gen. *et* sp., artiodactyla, suidae, *Listriodon* sp., indeterminate gen. *et* sp., tragulidae, indeterminate gen. *et* sp., cervidae, indeterminate gen. *et* sp., Bovidae, Boselaphini, indeterminate gen. *et* sp. Other vertebrate are composed of reptilian, testudines, *Geochelone* sp. and indeterminate gen. *et* sp., crocodylia, indeterminate fam., gen. *et* sp., Squamata, serpents, indeterminate fam., gen. *et* sp., Osteichthyes, Cypriniformes, indeterminate fam., gen. *et* sp., and Siluriformes, indeterminate, fam., gen. *et* sp.

2.5 Tha Chang Locality, Nakhon Ratchasima Province, northeastern Thailand

Tha Chang is a village in Tha Chang sub-district, Chalerm Phrakiat district, Nakhon Ratchasima province, or 'Khorat'. The Tha Chang village (15° 00' 19.83"N and 102° 16' 28.90"E) is located approximately 20 kilometers east of Khorat city (14° 58' 09.19"N and 102° 06' 08.66"E) on highway no. 2162. Nine sand pits were operated nearby Tha Chang village along the Mun River. Sand pits no. 1 to no. 7 were abandoned before 2001. But sand pit number 8 (Somsak pit) was operated until year 2002, and finished due to a deep flooding. Sand pit number 9 (Siam pit) was flood in the year 2006. The study was done at the sand pit number 8. The area is situated 160-180 meters above mean sea level. The Mun River is drained the Khorat-

Ubon Ratchathani basin and flowing eastward to The Mekong River. The Mun River is a meandering stream and several oxbow lakes distributed on both flank of the river

(Figure 2.14)

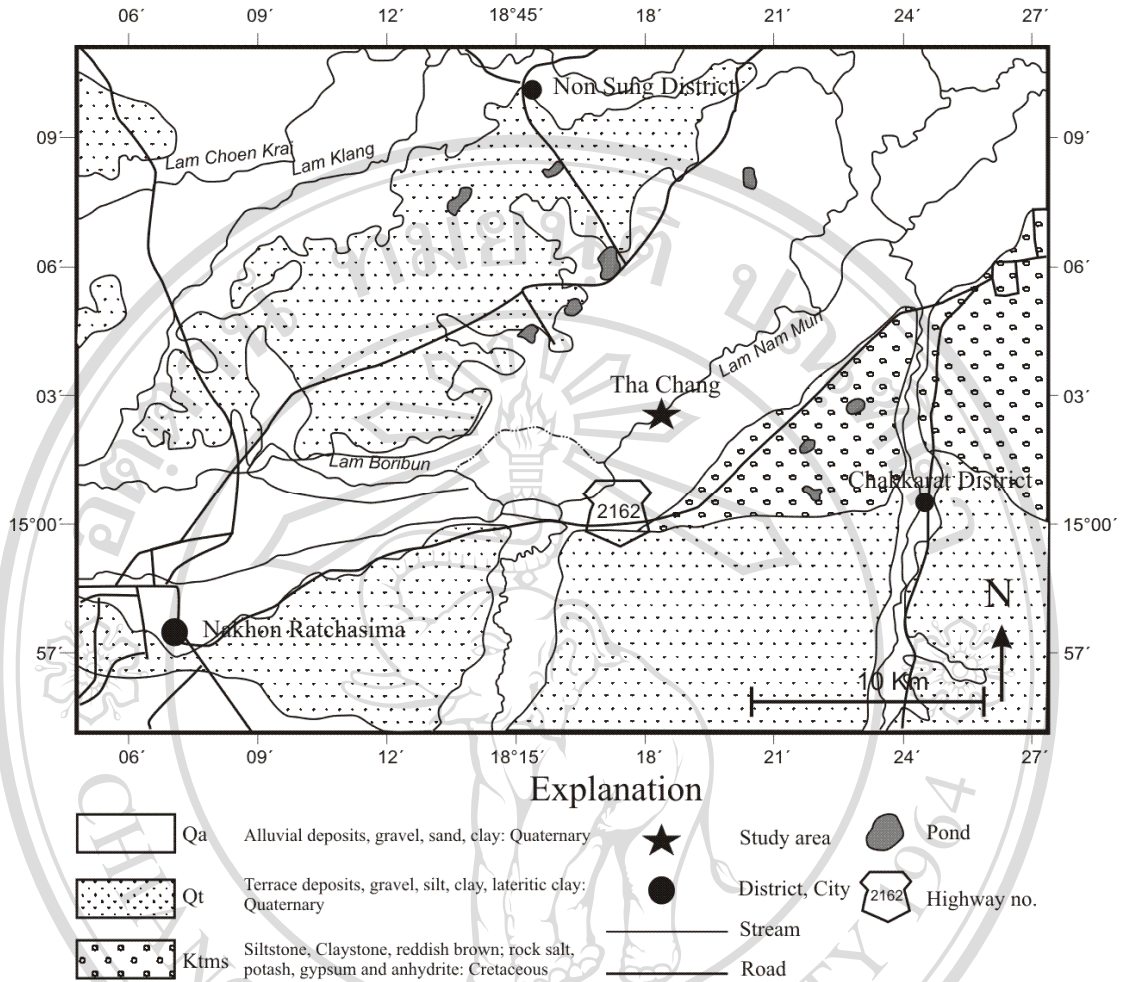


Figure 2.14 Map showing route to Tha Chang area, highway no. 2162, Nakhon Ratchasima-Chakkarat (modified from Chakapag and Veeraburus, 1979; Sudasna and Pitakpaivan, 1976).

2.5.1 Geological setting of Tha Chang

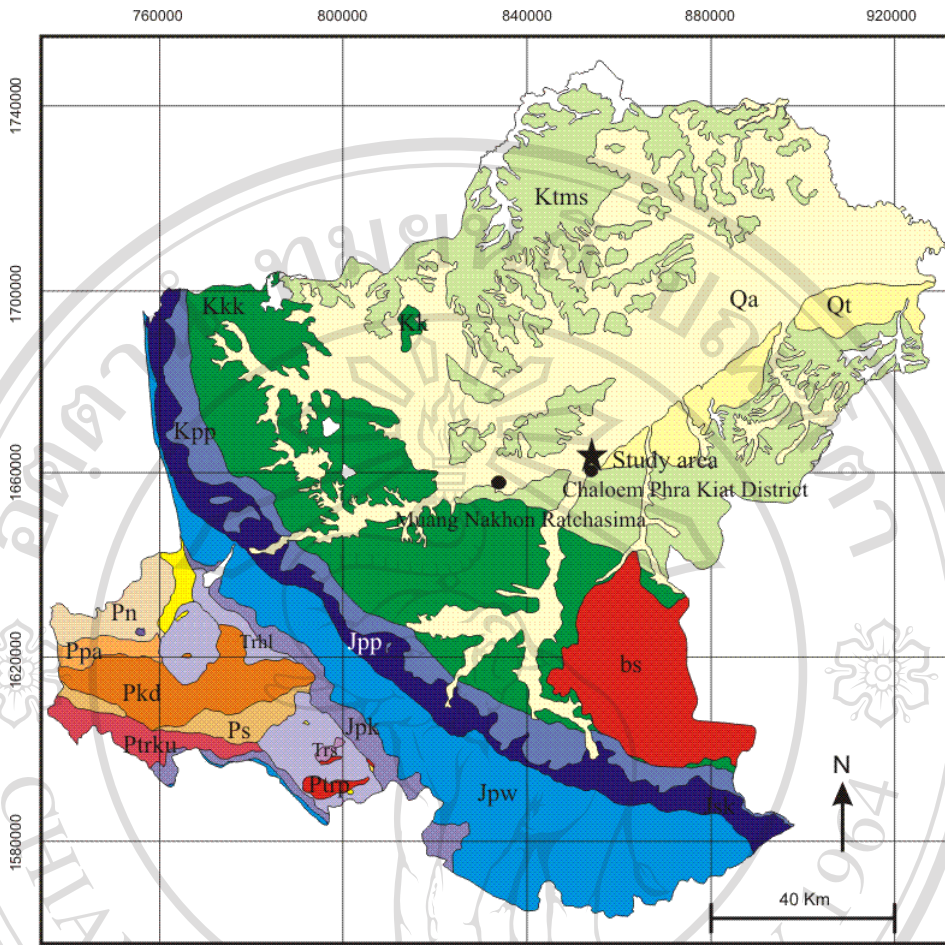
Tha Chang is located on the Quaternary deposit and bounds by Quaternary terrace in the East. The Quaternary rocks are underlain by Maha Sarakham and Khok Kruat Formations of Khorat Group. The Maha Sarakham Formation crops out in the northwest, south and southeast of the study area. The Khok Kruat Formation is exposed in the southwest.

The Maha Sarakham (KTms) Formation contains the siltstone and sandstone which is reddish-brown and pale red. These rocks are frequently interbedded with rock-salt and gypsum. The KTms is Upper Cretaceous to probably Lower Tertiary. The lithology of Khok Kruat (Kkk) Formation is consists of siltstone, sandstone, and calcareous conglomerate. The siltstone and sandstone are grayish-red, brown to pale red in color. The Kkk unit is Lower to Upper Cretaceous.

The Quaternary terrace (Qt) unit is composed of colluvial gravel, sand, and silt. The laterite and lateritic soil distributed locally. The Quaternary alluvial (Qa) unit is consisting of unconsolidated gravel, sand, silt, and clay. These unconsolidated rocks are the deposition of the fluvial, floodplains, and swamps (Figure 2.15).

2.5.2 Lithostratigraphy

The lithostratigraphy of Tha Chang was constructed by researchers (Chaimanee *et al.*, 2004; Haines *et al.*, 2004; Howard *et al.*, 2003; Sato, 2002; Nagaoka per.comm.). The deposits in Tha Chang can be divided largely into two units, oxidized and reduced zone (Howard *et al.*, 2003). The oxidized zone is upper unit and the reduced in the lower unit. The upper unit is about five meters in thickness, comprises sand, fine gravel and silt considered to represent normal channel



Explanation

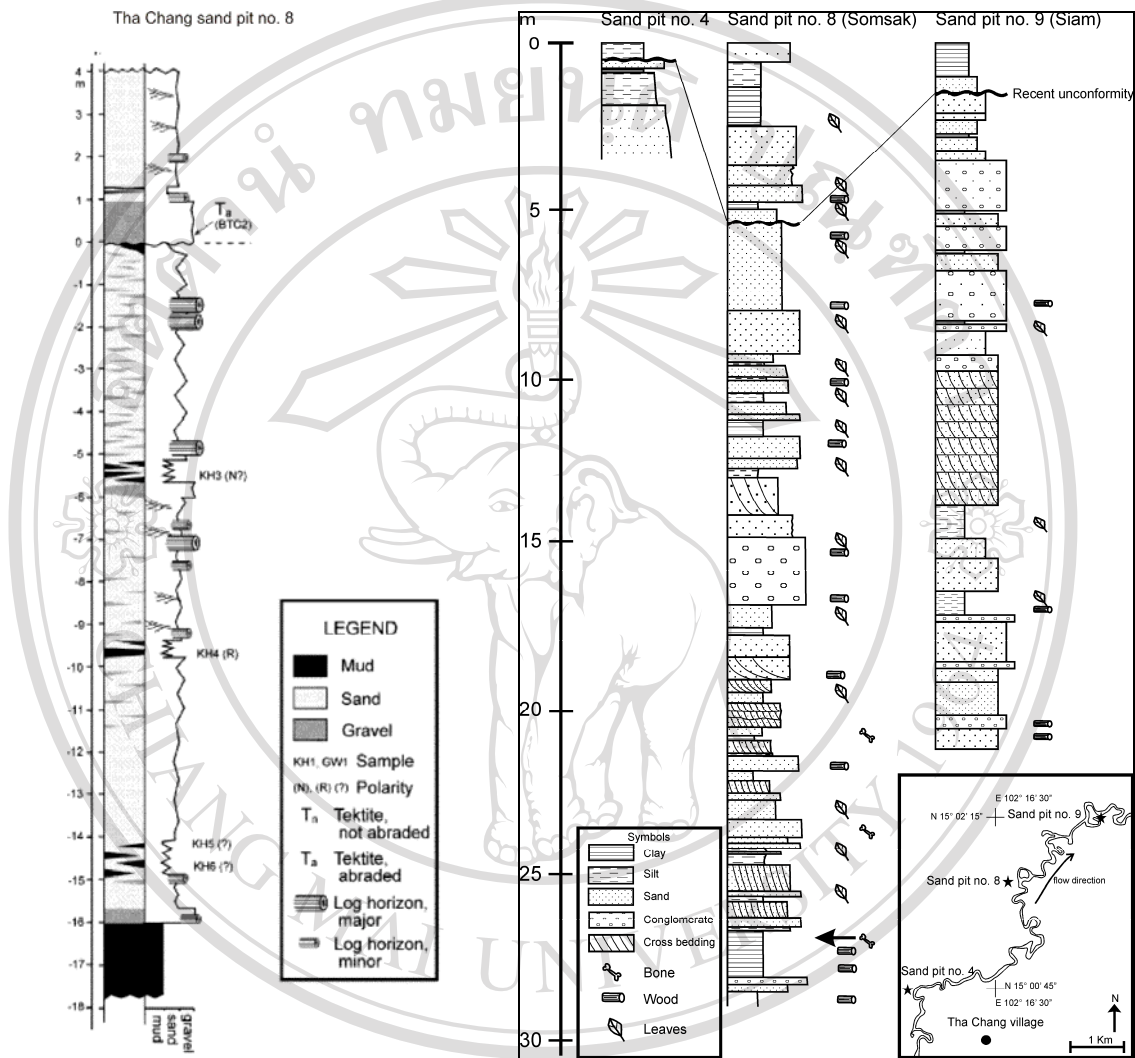
Qa	Alluvial deposits, gravel, sand, clay: Quaternary
Qt	Terrace deposits, gravel, silt, clay, lateritic clay: Quaternary
Bs	Basalt, dark gray, massive, hard; olivine basalt: Quaternary
Ktms	Siltstone, Claystone, reddish brown; rock salt, potash, gypsum and anhydrite: Cretaceous
Kk	Sandstone, siltstone, shale, brown: Cretaceous
Kkk	Siltstone, sandstone, brown, calcareous; claystone and conglomerate: Cretaceous
Jpp	Siltstone, micaceous, reddish purple; sandstone, greenish gray, yellowish brown, claystone, conglomerate: Jurassic
Jpw	Sandstone, whitish gray; siltstone; shale, gray to brown: Jurassic-Cretaceous
Jsk	Sandstone, quartzitic, thick bedded, white, pinkish, gray; siltstone; shale: Jurassic-Cretaceous
Jpk	Siltstone, sandstone, shale, reddish brown, reddish purple, calcareous: Jurassic-Cretaceous
Trhl	Basal conglomerate, shale, siltstone, gray-brown, graywacke, muddy limestone: Upper Triassic
Trs	Shale, sandstone, siltstone and conglomerate: Upper Triassic
Kpp	Sandstone, whitish gray, thick bedded; siltstone; poorly-sorted conglomerate: Permian-Triassic
Ptrku	Rhyolite, andesite, tuff, pyroclastic, agglomerate: Permian-Triassic
Ptrp	Diorite, Hornblende-diorite: Permian-Triassic
Ps	Limestone, dark gray, shale, sandstone, chert lens, fossiliferous: Lower-Middle Permian
Pkd	Limestone, dark gray; tuff, chert, local hornfels, quartzite: Lower-Middle Permian
Pn	Shale, slaty shale, gray to dark gray, sandstone, limestone, hornfels: Lower-Middle Permian
Ppa	Limestone, tuffaceous sandstone, sandstone, shale, gray, brown, chert, pillow basalt: Middle-Upper Permian

Figure 2.15 Geology of Nakhon Ratchasima (modified from Geology Survey Division, DMR, 2004).

and floodplain deposition produced by the migrating meander belts of the Mun River (Hain *et al.*, 2004). The color is brown-yellow color. The lower unit comprises stratified and cross-bedded sands and gravels. Logs of wood are found and the lengths of some logs are more than 10 meters and complete with tap roots are common throughout the unit. Some of the wood is partly or wholly replaced by silica and pyrite, but most is preserved as original woody tissue. The mammalian fossils are found from this reducing zone of sand pit no. 8, which below the dash line in Figure 2.16A (Haines *et al.*, 2004). The lithostratigraphic successions of sand pit no. 8 were correlated to other sand pits, no. 4 and no. 9, which also yielded mammalian fossils as shown in Figure 2.16B.

2.5.3 Paleontology

The occurrence of mammalian fossils in Tha Chang was first mentioned by Suteethorn *et al.* (1997). Consequently, several preliminary studies were reported (Nakaya *et al.*, 2002a, b, 2003). Nakaya *et al.*, (2002a, b, 2003, 2007) categorized the mammalian fossils into three age assemblages, middle Miocene, late Late Miocene, and Early Pleistocene. Middle Miocene assemblage is based on amebelodontid gomphothere, cf. *Protoanancus chinjiensis*) and *Prodeinotherium* which were from sand pit no. 4. The late Late Miocene assemblage is based on *Stegodon* cf. *stegodontoides*, primitive, *Stegodon*, *Hipparion*, and primitive *Merycopotamus* which were from sand pit no. 8. The Early Pleistocene assemblage is based on advanced *Stegodon* and *Elephas* which were from sand pit no. 9. A very complete mandible of hominoid was also found from Tha Chang and it is named to new genus and new species, *Khoratpithecus piriyai* (Chaimanee *et al.*, 2004).



A)

B)

Figure 2.16 Lithostratigraphy of Tha Chang A) sand pit no. 8 (Haines *et al.*, 2004) and correlated with B) sand pit no. 4 and no. 9 (Nagaoka, per. com.).

A considerably complete cranium of *Merycopotamus* has several distinct characters which differ from known species and it could be a new species (Hanta *et al.*, 2005). The mammalian fossils which were reported from Tha Chang are composed of proboscidea, amebelodontidae, cf. *Protanancus chinjiensis*, gomphotheriidae, *Gomphotherium* sp., deinotheriidae, *Prodeinotherium pentapotamiae*, cf. *Protanancus macinnensi*; perissodactyla, rhinocerotidae, *Brachypotherium* sp., which are Middle Miocene fauna; carnivore, felidae, machairodontinae; proboscidea, stegodontidae, *Stegolophodon* cf. *stegodontoides* and primitive form of *Stegodon* sp., *Gomphotherium* sp. 1 and 2, *Gomphotherium* n. sp. 1, *Sinomastodon* aff. *yangziensis*, *Sinomastodon* n. sp. 1, *Anancus* sp., *Stegolophodon* cf. *stegodontoides*, *Stegolophodon* n. sp. 1 to 4, *Stegodon* n. sp. 1 to 3, perissodactyla, rhinocerotidae, *Chilotherium* sp., equidae, *Hipparion* spp.; artiodactyla, anthracotheriidae, *Merycopotamus* sp.1, hippopotamidae, suidae, cf. *Hippopotamodon* sp. and cf. *Tetraconodon* sp., bovidae spp., giraffidae, cf. *Samotherium* sp.; primates, hominoidae, *Khoratpithecus piriayii*, which are Late Miocene fauna, and proboscidea, stegodontidae, advanced form of *Stegodon* sp., Elephantidae, *Elephas* sp.; artiodactyla, bovidae, Bovini sp., and cervidae which are Early Pleistocene fauna.