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QUATERNARY STRATIGRAPHY OF THAILAND

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INTRODUCTION

Quaternary sediments cover about fourty percent of the total area of Thailand, especially the Central Plain comprises almost 60,000 square kilometers. These lowland areas are composed mainly of thick Tertiary and Quaternary sediments. They are rich in mineral resources, ground water and construction materials. Until recently, Quaternary geology of Thailand was very little known. The first general outlined of Quaternary deposits in Thailand was made by Brown and others (1951). Subsequently, Alexseev and Takaya (1967) and Takaya (1968, 1971a, 1972a) made detailed studies and descriptions of Quaternary outcrops in the Central Plain. Hattori (1972a, 1972b) made geochemical analysis of Quaternary sediments in the same plain. Though, systematic study of Quaternary deposits has been carried out recently by Geological Survey Division, Department of Mineral Resources of Thailand (Worakoon and Kruse, 1981; Dheeradilok and others, 1982; and Sinsakul and Chaimanee, 1982), Quaternary stratigraphic subdivisions of the country are not firmly established yet.

According to the physiography, Quaternary basins can be divided into five regions namely, the Central Plain, the northern region, the northeastern region, the eastern coast region and the southern region.

QUATERNARY STRATIGRAPHY

The Central Plain

The plain is situated over a large structural depression that was filled with an assortment of clastic sediments chiefly of fine to medium grain size. It is characterized by strong undulating terrain with alternating swells and swales in the northern part of the plain. Many monadnocks made of Paleozoic limestones and igneous rocks aligning N-S give a somewhat archipelago-like appearance to the middle part of the plain. The southern basin is represented by the spacious flat Bangkok plain.

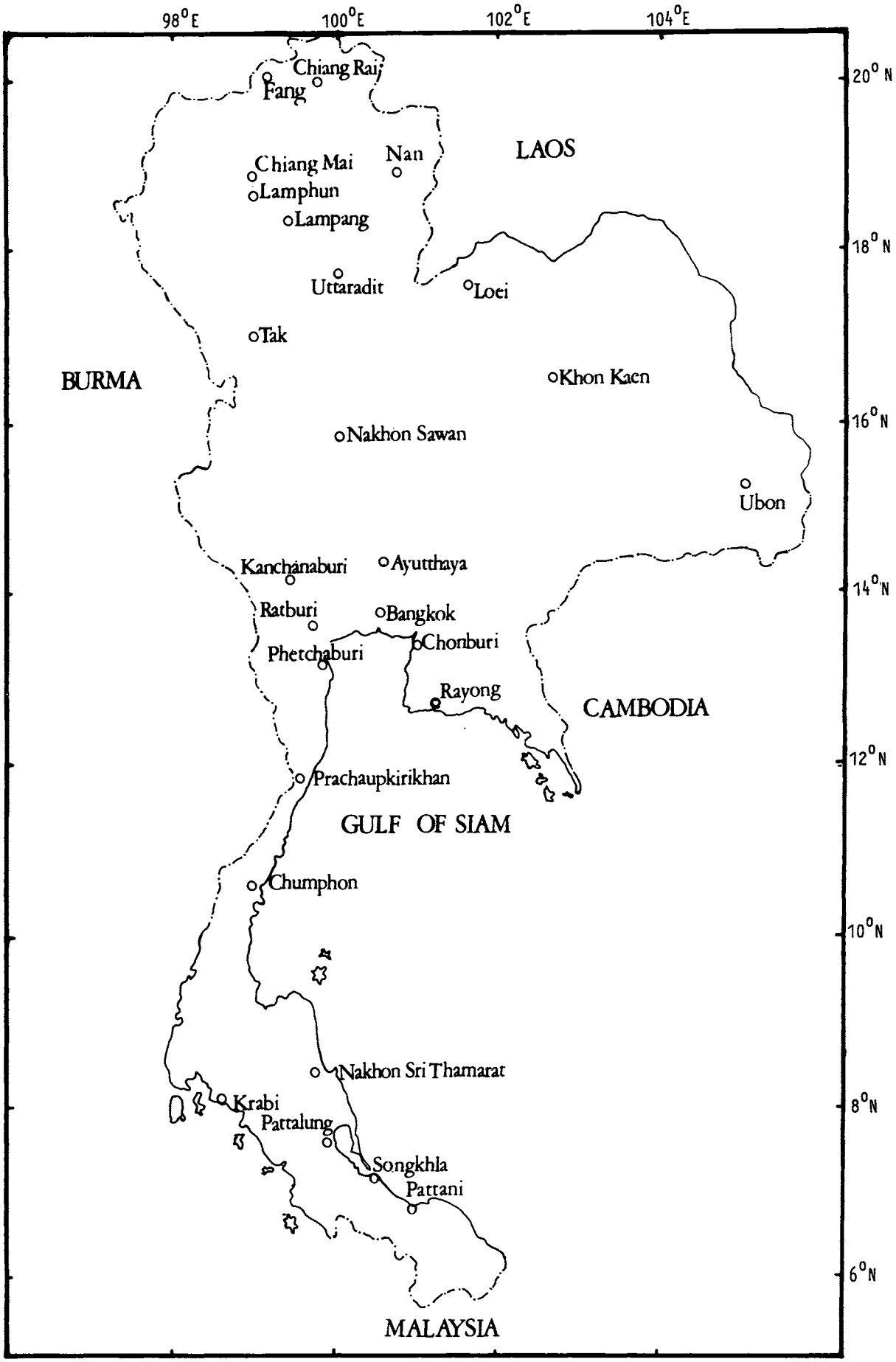


Fig. 1 Map of Thailand showing locatities mentioned in the text.

The first general outline of the Quaternary deposits in the Central Thailand was made by Brown and others (1951). The authors described briefly the physiography of the Chao Phraya Plain and its surrounding areas, and summarized the general lithologic characteristics of the Quaternary Sediments. It was noted that, according to boring data, the thickness of alluvium in the central part of the Chao Phraya Valley exceeds 300 m. The seaward portion of this valley includes beds of deltaic character and consists of dark gray heavy clay overlies marine or estaurine marly beds, sands and gravels. In addition, two different kinds of laterites were recognised; young laterites developed on the low level terraces or planated surfaces and the mature high level laterites. The latter was found on uplifted dissected terraces of other surfaces which have been preserved from erosion.

The first attempt to establish Quaternary stratigraphy in the Central Plain was made by Alexseev and Takaya (1967). Their study was restricted to the Chao Phraya basin and the Mae Khlong drainage. They classified the Quaternary sediments into 5 different deposits, namely, floodplain deposits with no iron oxide concretions, Terrace I with iron oxide concretions, Terrace II with pisolitic iron oxide concretions, Terrace III with thin laterite caps, Terrace IV which consists of strongly weathered alluvial gravels cemented by lateritic material, and a peneplain with occasional thick laterite or calcareous deposits capping. However, Takaya (1968, 1972a) distinguished seven young geological bodies based on stratigrapic position (morphology), degree of weathering of the deposits, and by dating of fossils. They are floodplain deposits, Formation I, Formation II, Formation III, Formation IV, Thick Laterite Formation (Peneplain) and Calcareous Formation (Fig. 2). The characteristics of these Quaternary deposits are summarized as follows :

Floodplains comprise of low-level Floodplain and high-level Floodplain and consist of sand, silty sand and gravel. Fragments of the wellknown "Sawankalok earthenware" which are believed to be 800 years old were found in the high-level Floodplain deposits (Takaya, 1968). Takai (1961) identified a wild dog which was excavated from river sand near Ang Thong as Cuon alpinus. Thus, Floodplain deposits are very young and most probably of historical age.

Formation I (Terrace I) occurs as a narrow belt along the present and abandoned river courses. The thickness of the formation is more than 10 m at the channel filling part. But the massive loamy upper part maintains a comparatively constant thickness of 4 to 6 m throughout the Central Plain. Loose iron concretions and very small iron concretions are the only weathering products evolved in this formation.

Formation II (Terrace II) appears as zonal strips in the northern basin, but appears more broadly throughout the middle part of the southern basin. This bed, however seems to disappear a few meters beneath the present surface in Bangkok area. The pisolitic concretions of iron oxide are characteristic material associated with Formation II.

Formation III (Terrace III) develops throughout the Central Plain. The distribution of this Formation does not seem to parallel the present river system and is marked by heavily weathered sediments with a thin

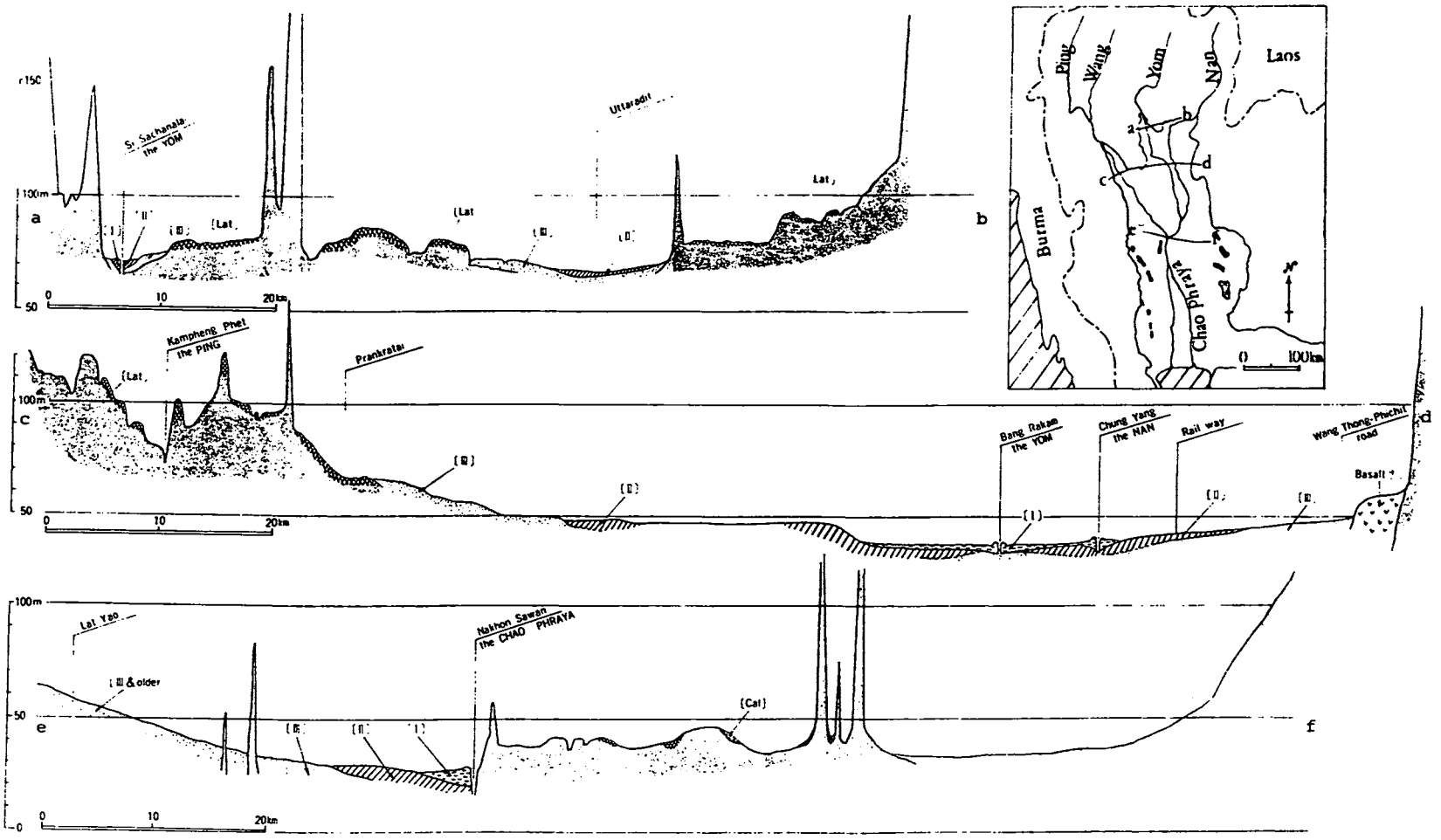


Fig. 2 Typical E-W cross-sections through the Central Plain (After Takaya, 1968)

lateritic cap. In the Lower Central Plain this Formation forms semi-fossilized fan throughout marginal zones of the plain.

Koenigswald (1959) identified a Hippopotamus skull, a Bubalus horn, and an upper molar of a Stegodon from the mammalian fossils which were excavated at Nakhon Sawan as Middle Pleistocene.

Formation IV (Terrace IV) occurs as thin lateritic layer beneath Formation III.

Thick Laterite Formation. Thick and hard laterite is usually found capping on high and low-level peneplains. It occurs extensively in the northern part of the basin but along marginal zones in the southern part of the basin.

The thick laterite in Central Thailand can be correlated with Early Pleistocene (or older) terrace with lateritic rock in the Narmada valley, Central India (Alexseev and Takaya, 1967).

Calcareous Formation. This formation can be divided into high and low calcareous deposits based on surface elevation. It occurs near the foothill of Paleozoic limestones and as small patches on an undulating limestone plateau in Sara Buri Lop Buri and Nakhon Sawan areas. These calcareous deposits (or marls) comprise of pure calcium carbonate with a very small amount of clayey material. Takaya (1972a) supposed that the deposition has been developing intermittently throughout the Quaternary period.

The stratigraphy of the Central Plain is summarized in Table 1.

Table 1 Tentative stratigraphy of the Central Plain (After Takaya, 1968)

Area / Stratigraphical unit		Northern basin	Nakhon Sawan area	Southern basin	Calcareous deposits
Holocene		Floodplain (sandy)	Floodplain (sandy)	Deltaic plain (clayey)	Floodplain (sandy)
		Terace I / Formation I (loamy)	Terrace I / Formation I (clayey)	Deltaic plain / Formation I (clayey)	Terrace I / Formation I (clayey)
Pleistocene	Last glaciation	Terrace II / Formation II (clayey)	Terrace II / Formation II (clayey)	Terrace II / Formation II (clayey)	Terrace II / Formation II (clayey)
	Penultimate glaciation	Terrace III / Formation III (sandy)	Terrace III / Formation III (sandy)	?	
	Antepenultimate glaciation	Terrace IV (?) / Formation IV (sandy)	Terrace IV (?) / Formation IV (sandy)		Calcareous deposits
		Low-level peneplain	Low-level peneplain		
Plio-cene	?	High-level peneplain	High-level peneplain		

Hattori (1969, 1972a, 1972b) made detailed study on chemistry and mineralogic compositions of the Quaternary sediments of the same area. His study was to examine the relationship between mineral composition of the deposits and their stratigraphic positions and found that the behaviour of clay mineral assemblage is consistent with the weathering degree of the deposits and consequently is closely related to the stratigraphic sequence.

Takaya (1971a, 1972b) reported two brackish clay beds which are the Formation I and II in the southern basin. The older one is from 4 to 6 m above MSL in the upper part of the Lower Central Plain, and the equivalent bed is found at an 11 m level below the ground surface near the gulf coast. The younger one extends over a broad area facing the gulf and forms a very flat plain 2 m above MSL. Brackish sediments consist of jarosite, gypsum crystals and crab claws which all indicate brackish environment.

The old and young brackish clay beds are equivalent to old and young delta deposits of Takaya and Thiramongkol (1982).

Rau and Nutalaya (1980) also discussed the stratigraphy and the characteristics of Holocene Bangkok Clay, which is equivalent to the old and young brackish clay beds of Takaya.

C 14 dating for 5 wood fragments collected from young brackish caly bed gives the ages ranging from 4030 $\pm$ 120 to 7440 $\pm$ 150 years B.P. (Takaya, 1972b). Takaya assumed the age of the older bed to be Upper Pleistocene. This correspond to Dent and Cheuthongdee (1966) suggestion of an 8 to 15 m rise in the sea level during Upper Pleistocene age resulted in the formation of a shallow sea deposit in the Lower Central Plain.

It can be concluded that sea transgressed into the Lower Central Plain two times during last interglacial (Late Pleistocene) and postglacial (Early Holocene).

Deep borehole data from ground water and petroleum exploitations reveal the characteristics of the deep unconsolidated deposits. Brenner and others (1978) studied the physical and chemical properties, as well as of the approximate clay mineral composition of samples from a 88 m deep bore hole in Khlong Luang District approximately 40 km north of Bangkok. They recognized nine stratigraphic units in the borehole. The deposits consist of alternated sand and stiff and hard clay beds.

Drilling of deep borehole for ground water exploitation led to the classification the upper 550 m of sediments in Bangkok area into six aquifers (Phiancharoen, 1972). However, the deposits have been differentiated into eight aquifers later (Phiancharoen and Chuamthaisong, 1976; Chuamthaisong and Yuthamanop, 1980). These aquifers are as follows :

1. Bangkok Aquifer (50 m zone)
2. Phra Pradaeng Aquifer (100 m zone)
3. Nakhon Luang Aquifer (150 m zone)
4. Nonthaburi Aquifer (200 m zone)
5. Sam Khok Aquifer (300 m zone)

6	Phaya Thai Aquifer	(350 m zone)
7.	Thon Buri Aquifer	(450 m zone)
8.	Pak Nam Aquifer	(550 m zone)

These aquifers are composed mainly of thick sand and gravel layers with clay lenses intercalated and separated by thick clay beds. The topmost aquifers (Bangkok Aquifer) is overlain by the "Bangkok Clay" which is 20-30 m thick(Muktaphant, 1963).

Drilling in the vicinity of Ayudhaya and Bangkok encountered basement of leucogranite and metamorphic rocks ranging in depth from 353 m to over 1,800 m (Achalabhuti, 1974, 1976). Results of micropaleontologic and palynologic analyses of the Gulf of Thailand rocks reveal that the deeper well penetrated sedimentary sequences ranging in age from Holocene to Oligocene (Achalabhuti, 1976). The thickness of Quaternary sediments with the presence of pollen Podocarpus in the Pattani trough is 126 m (Paul and Lian, 1975). However, there is no report on the Plio-Pleistocene boundary in the Central Plain so far.

Northern Region

Geomorphologically northern Thailand is a basin and range province, trending NS following the regional strike of the older formations. Many large basins, e.g., Chiang Mai, Lampang and Fang Basins are known to contain great thickness of lacustrine and fluviatile Cenozoic sediments, mainly Miocene to Quaternary. The thickness of Tertiary sediments in some basins is over 3,000 m and overlain by thick beds of Quaternary deposits.

Takaya (1971b) and Hattori (1970) outlined Quaternary deposits in Lampang Basin based on morphology and sediment characteristics. They classified the deposits into 6 different kinds of young geologic bodies. The general characteristics of the deposits are summarized as follows :

Recent alluvial and low terrace occur along the river course and the deposits are composed mainly of sand and silt, containing no iron nodules and concretions. Recent fan deposit consists of sand and gravel and is probably Holocene in age. Fan-colluvial deposits are composed mainly of coarser deposits. High terraces are usually capped by thick gravel bed mainly of cobble size and occasionally are lateritic in character. Pliocene (?) plains consist of varying geologic bodies ranging from clayey lacustrine strata to angular gravelly alluvium.

Piyasin (1972) named the unconsolidated gravel bed with sand and clay matrix, that form terraces in various Tertiary basins in northern Thailand as Mae Taeng Formation.

At Ban Don Mun, 12 km east of Ban Mae Tha, basalt flows directly overlie a laterized gravel deposit (high terrace). Samples of the basalt were collected by Barr and others (1976) for paleomagnetic studies and age dating by fission track and potassium- argon methods. Dating by fission track and the paleomagnetic studies give the age of the basalt at 0.69-0.95 m.y. Thus, the age of the gravel deposit is definitely older than 0.69 m.y. and

probably older than 0.95 m.y. according to paleomagnetic study (Barr and others, 1976)

In addition, many workers (Piyasin, 1972; Buravas, 1973; Ukakimapan and others, 1981) reported the sequences of Tertiary sediments that are overlain by thick gravel beds in various basins in northern Thailand (e.g., Chae Hom, Mae Taeng, Mae Tib, Mae Tune, Chiang Mai and Fang Basins) ranging in thickness from tens of meters to over 1,000 m. The gravel beds are usually considered to be Pleistocene or Quaternary in age without any direct evidence except superposition.

The author has investigated gravel bed formation at Mae Taeng, and along Lampang-Thoen-Tak Highway. These gravel beds or weak consolidated conglomerate occur along marginal zone of basins and form low hilly terrain. The occurrence of this formation is very extensive. Moreover, the gravel beds are usually capped by thick and hard laterite. Views from these points the author is of the opinion that this formation is most probably Late Tertiary in age.

Reports of Quaternary deposits in small intermontane basins in the northern region are limited. Thiramongkol (1983) investigated Quaternary deposits of two small intermontane basins in northern Thailand. He classified landforms in the area into Pleistocene terraces, and Holocene floodplain and infilled valley bottoms on the beses of morphology, weathering degree and characteristic of sediments. The general characteristic of various Quaternary deposits are summarized as follows :

High terrace deposits consist of gravel beds alternating with sandy and silty layers with thick and hard laterite capping. Middle terrace deposits are composed of thin laterite intercalated in gravel beds of 5-6 m thick below the terrace surface. Low terrace deposits are composed mainly of sandy and silty layers. Floodplain deposits occur along the river courses and consist of sandy and silty layers alternating with gravel beds, and infilled valley deposits largely comprise bed load sediments. In conclusion, Thiramongkol concluded that these landforms are influenced by Tertiary and Quaternary tectonisms in association with Pleistocene climatic changes.

Northeastern Region

ESCAP (1977) outlined sedimentation in the Nam Mun and Nam Chi Basins, northeastern provinces of Thailand. The basins can be subdivided into several units. A brief description of the deposit in each unit is as follows :

Laterite on erosional surface, an old eroded and lateritized surface, occurs extensively in the marginal zone of the basins. High terrace deposit flanks the erosional surface and is composed of sand and lenses of pebbles with lateritic gravel capping. Low terrace deposit is generally characterized by thin lateritic layer in the upper part. High and low terraces can be correlated with Middle Pleistocene (or older) fluviatile high and low terraces found all over southern Indochina.

Floodplain alluvium occurs extensively along the Mun and the Chi.

There is no lateritic feature in this formation. Low basin deposit is composed mainly of clayey sediments in lowland area in Ubon and west of Ubon. The deposit is comparatively very recent.

In 1964, Moormann and others claimed that most of the upland soils in the Khorat Plateau owe their origin to young alluvial deposits of the Maekong River and its major tributaries. The alluvial deposits were classified into 5 units. They are recent alluvium, low terrace alluvium, middle terrace alluvium (sand), middle terrace alluvium (clay) and high terrace alluvium (see Fig. 3). The deposits are composed mainly of clay to coarser texture, ranging from sandy clay loam to loamy sand.

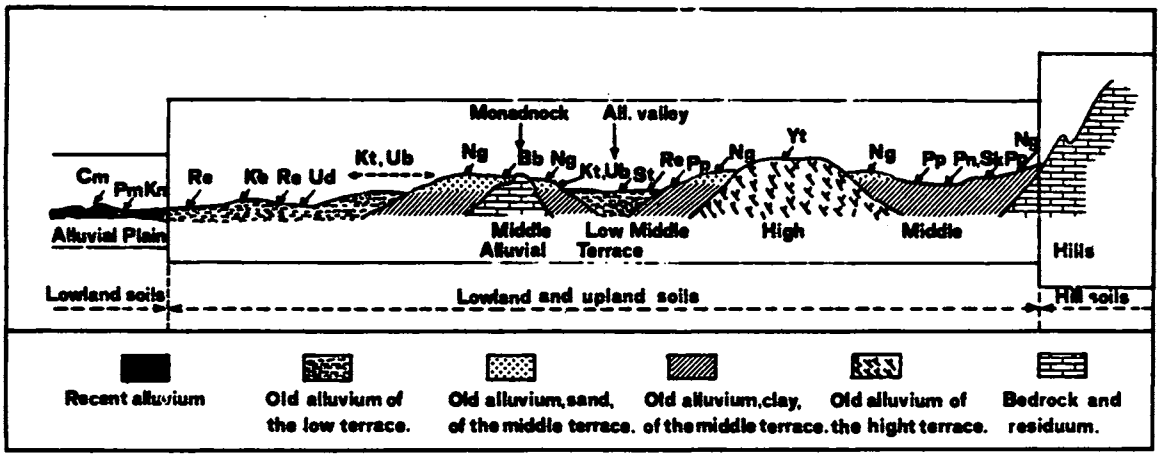


Fig. 3 Schematic cross-section, indicating the physiographic position of the principal soil series and Quaternary deposits in N.E. Thailand (After Moormann and others, 1964).

However, Moormann and others's model was rejected by Michael (1981) on the ground that fossil alluvial patterns or structures are not recognizable in these sediments. He had the opinion that Moormann and others's model was inaccurate and believed that residuum and colluvium are more importance than fluvial deposits.

According to Boonsaner (1977) certain surface deposits observed in Khon Kaen Province are loess or wind blown sands that cover a physiography dominated by "stream terraces". Fig.4 showing surface sediments determined to be wind blown because of their monotonous character and also from a textural size class analysis.

It can be concluded that Quaternary deposits comprise of fluvial deposits, eolian deposits, residual and colluvial deposits.

The stratigraphy of Quaternary deposits in the northeastern region are therefore very complicated and questionable.

Eastern Coast Region

Phiancharoen and Ramnarong (1976) observed three types of unconsolidated deposits in Pattaya, a famous beach resort of Eastern Thailand. The deposits are terrace deposit, alluvium and beach sand. These deposits are the main sources for ground water.

Dheeradilok and others (1982) made a survey of Quaternary sediments in Laem Chabang area and divided the deposits into seven different map units based on stratigraphic positions and sediment characteristics. They are Terrace level II sand; Terrace level I clayey sand; Lagoonal clayey sand,

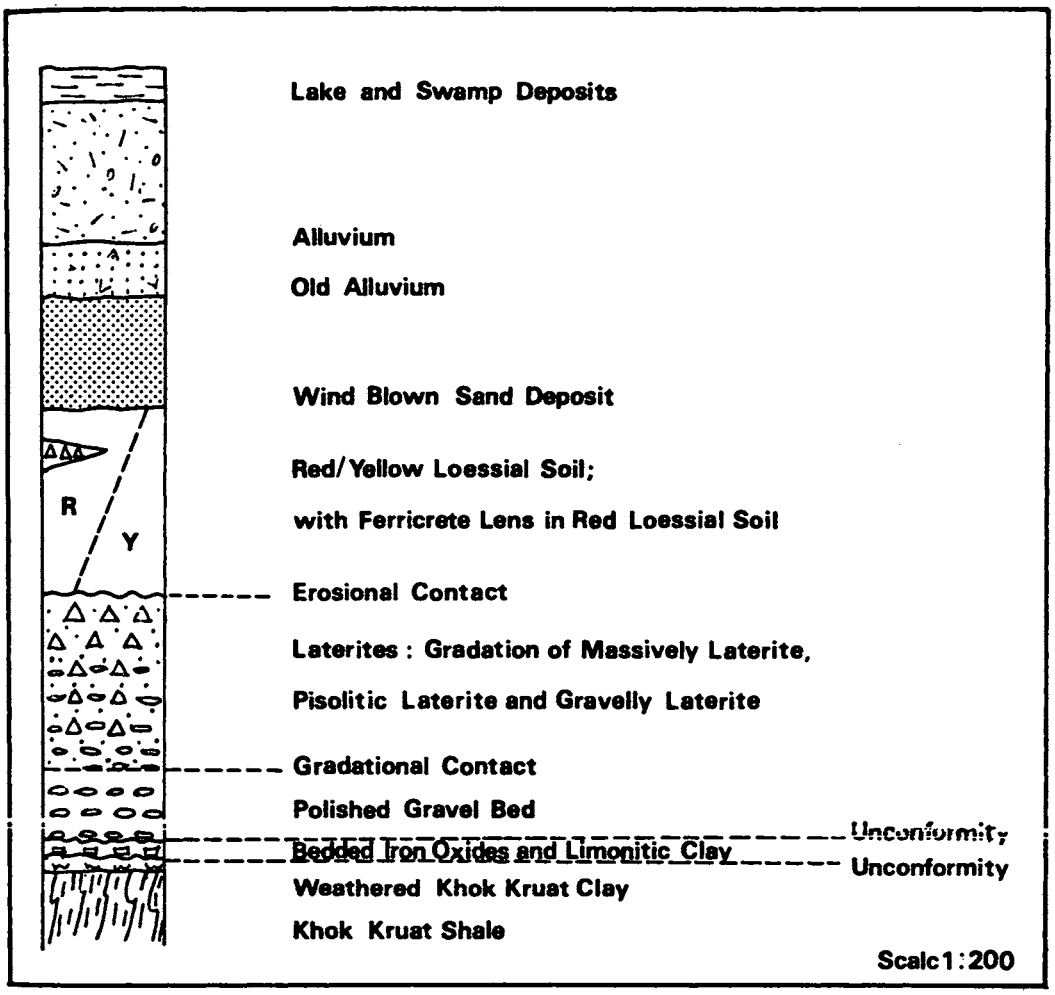


Fig. 4 Interpertive Stratigraphic Section of the soils in the Town of Khon Kaen (After Boonsaner, 1977).

older phase; Bay mouth bar sand; Lagoonal clayey sand, younger phase; Beach ridge sand and Alluvial and colluvial sand. A brief description of the characteristic of the deposits is as follows :

Terrace level II sand unit is composed mainly of fine to coarse sand and silt.

Terrace level I clayey sand consists of fine to coarse sand with clay lense and gravel intercalated.

Lagoonal clayey sand, older phase unit is composed mainly of medium sand and clay with small amount of silt and gravel. Some wood fragments are found in sand and clay layers.

Bay mouth bar sand unit is a bay mouth bar sand of older lagoon. The deposits are composed mainly of sand with clay lenses and gravel intercalated. There is no fossil in this young geologic body.

Lagoonal clayey sand, younger phase. This unit consists of alternating coarse sand and clay layers with gravel intercalated. Plant remains and bivalves are found in clay bed.

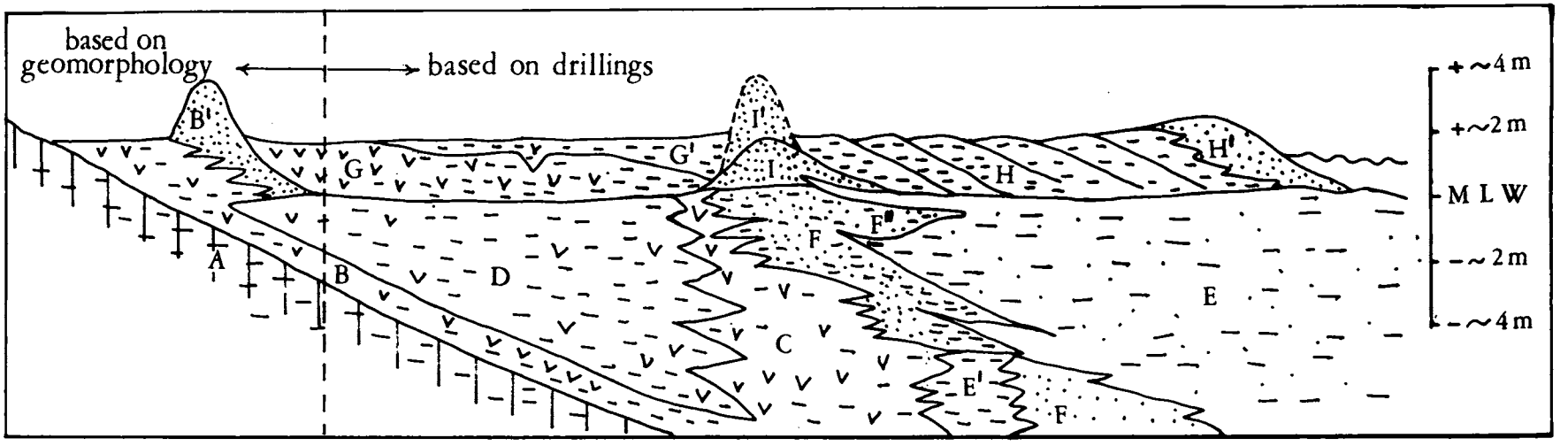
Beach ridge is the most recent deposit, made up of sand and gravel. Plant remains, bivalves and recent foraminifera are found in the deposit. These microfossils were identified by Jumnongthai (1982) as Recent foraminifera and comprises of 29 species.

Alluvial fan and colluvial deposits consist of sand and silt overlying hardpan layer was cemented by iron and manganese oxides. The age of the deposit is believed to be Holocene by Dheeradilok and others. However, judging from the stratigraphic position and the weathering degree of the sediments, the authors assumed that this unit is Upper to Middle Pleistocene. If this view is correct Terrace level III is older than Middle Pleistocene.

Sinsakul and Chaimanee (1982) reported a preliminary survey of Quaternary geology in Rayong area, eastern coast of Thailand. Quaternary deposits in the area comprise terrace deposits, alluvial deposits and coastal deposits. Terrace deposits consist of laterite and lateritic soil (residual deposits) and fluvial deposits. Fluvial deposits are probably wash deposits. Alluvial deposits are composed of floodplain alluvium, natural levee and meander belt deposits whereas coastal deposits consist of old and young beach sand, lagoonal and estaurine deposits. The ages of the deposits are not given due to lack of available dating data. However, based on morphology and weathering degree of sediments laterite on terrace can be correlated with early Pleistocene laterite elsewhere in Thailand. Coastal deposits can be correlated to that in Laem Chabang area.

Southern Region

In the southern region, Quaternary sediments occur mainly along the east coast of the peninsular of Thailand (Takaya, 1972; Pramojanee, 1979;



Sand

S:H & Clay;idem with much plant remains, with few plant remains, with sand

Peat/plant remains

Silt with weathered top and paleosol

The Holocene deposits overly an older land surface with a paleosol, A. A eustatic peat layer is formed at the fringe of the transgressing sea, B. A mangrove high tide flat, C, kept pace with the rising sea level. Inshore and offshore of this flat material is deposited below MHNW, respectively D and E. On the open coast of the flat, very fine sand accumulates, F. After the transgression stopped a beach ridge. B', formed. The area west the mangrove high tide flat is protected by this flat and it builds out to the west, G. A transgression with formation of tidal creek systems follows, the associated deposits are, G and perhaps F". A new shoreline subsequently forms with a beach ridge, or merely a beach, I. The coast builds out with open coast high tide flats, H with repeated phases of accretion and erosion. The small beach ridge of the present coast, H', consists of fine and medium sand pointing to increased energy in the conditions along the coast.

Fig. 5 Idealized cross-section showing coastal deposits in an area north of Songkhla, southern Thailand (After Kaewyana and Kruse, 1981).

Worakoon and Kruse, 1981; Hastings, 1983). Takaya (1972) categorized the deposits into three groups, old fan-terrace deposit, young fan deposit and coastal deposit.

Old fan-terrace deposit is the highest and oldest terrain of Pleistocene age, occurring extensively along mountain slope. Iron oxide concretions, lateritic fragments or thick laterite up to 3-4 m are found capping on the top layers. Young fan is generally occurred in between old fan-terrace and coastal plain, and consists of sand, clayey sand and gravel. Coastal deposit is composed mainly of beach sand, silt and clay of marine and brackish water deposits.

Kaewyana and Kruse (1981) reported coastal deposits in an area north of Songkla, southern Thailand. The results of investigation based on shallow borehole data are shown in Fig. 5. The sediments are of a "muddy coast" type; the open coast deposits contain more fine sand and the inshore deposits contain more plant remains of Holocene age. The high tidal flat deposits (the inshore deposits) are distinguished by either a rather distinct increase in amount of plant remains or by a sudden decrease in grain size. Besides, the deeper part of the deposits investigated, show a progradational sequence with a eustatic, peat layer overlying an older land surface with a paleosol. The silty weathered deposit with paleosol is believed to be Pleistocene-Holocene in age, underlying the Holocene progradational deposits (Kaewyana and Kruse, 1981).

Hastings (1983) investigated lowland Holocene peat swamp in Narathiwat, southern Thailand by means of palynology. The peat swamps are usually associated with undulating beach and lagoonal deposits that alternate with one another in a pattern characteristic of a prograding shoreline. Alluvial sediments, both continental and tidal inlet types, are also present. Hastings postulated that peat development began under an herbaceous transitional to fresh water marsh, characterized by a relatively diverse arboreal component and notable amounts of GRAMINEAE and Lycopodium. Evidence was presented suggesting a possible change in sea level during the development of the swamp. Dating data for this site is not available. However, peat swamp in this area can be correlated with lowland peats elsewhere in the Malaysia region in which radiocarbon dates ranging from 5,000 to 6,000 yrs. BP, mid-Holocene (Hastings, 1983).

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