

## CHAPTER II

### REGIONAL GEOLOGY

#### 2.1 Geology and Stratigraphy of Khorat Plateau

Numerous investigations on the geology and stratigraphy of Khorat Plateau have been done in the Northeast of Thailand. Previously, most of the study conducted was mainly concerned with geologic mapping emphasizing on the stratigraphic correlation. The widespread occurrence of the continental Mesozoic red beds especially in the Khorat Plateau has attracted many geologists and researchers alike resulting in various interpretations with regard to the stratigraphic sequence of the area. However, investigations were usually conducted on a regional basis.

Nakhon Ratchasima Province is located in the southwestern part of Khorat plateau, Northeastern Thailand. The Khorat plateau is divided into two basins, the Sakonnakorn and the Khorat basins, which are separated by the Phu Phan mountain range (see Figure 2.1). The basins are saucer shaped tilted to the southeast, with the western escarpment formed by the flat topped mountains, gently dipping east, and the southern escarpment dipping north. The area is mostly covered by the Khorat Group (Ward & Bunnag, 1964), and the unconsolidated deposits. Underneath the Khorat Group is the basement complex. A thin sequence of Paleozoic series may be found in between (Workman, 1977).

The central areas of the two basins are relatively featureless and consist of low hills and ridges separated by broad, shallow alluvial valleys. The Khorat basin is drained by two major rivers, the Mun and Chi Rivers, which join at Ubon Ratchathani. The smaller Sakon Nakorn basin is drained by a number of disconnected shorter rivers, most of which drain directly into the Mekong River.

The main landscape features of the low lying areas are broad flood plains with under fit meandering streams, oxbow lakes, abandoned river channels, numerous shallow lakes and swamps and solution sinks. At higher elevations flat or slightly undulating plains and isolated low hills or chains of hills are the predominant landform features.

Moormann and Rojanasoonthon (1972) recognized three river terraces i.e., the low, middle, and high terraces. The low terrace is supposedly dominant in the catchments area of the Mun river system. Most of the northern part of the plateau is presumably occupied by middle terrace. Isolated remnants of high terrace are found in many places in the valleys of the Chi and Mun rivers. The largest high terrace occurs south of Nakhon Ratchasima. Flood plains are found along all streams.

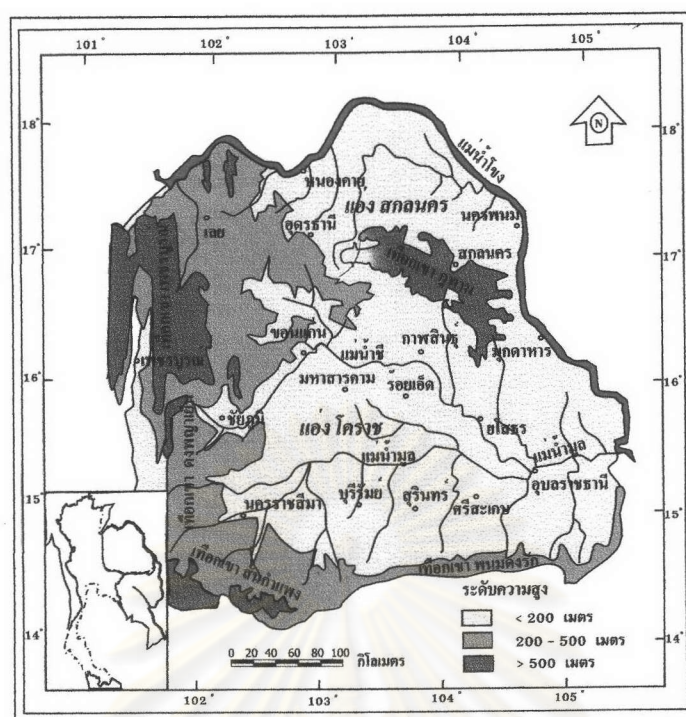


Figure 2.1 Geomorphologic map of Khorat Plateau. (Department of Mineral Resources, 2001)

The Khorat Group is composed a sequence of continental Mesozoic sediments. The sedimentary rock of the Khorat group consists of sandstone, siltstone, shale, claystone and conglomerate, which were deposited by fluvio-lacustrine processes (Piyasin, 1985). The lithologic description of each formation in the Khorat group from the oldest to the youngest is explained below:

1. Huai Hin Lat Formation comprised conglomerate, limestone conglomerate, gray to very dark sandstone; siltstone; shale and marl containing plant fossils, *Neocalamites* sp., *Clathropteris* sp. The thickness is 140 m at the type section. The type section is located in Huai Hin Lat, Km 108 of Khon Kaen-Loei Highway. This formation was interpreted as deposited in fluvio-lacustrine depositional environment. The age was proposed to be Carnian to Rhaetian (Late Triassic) by Department of Mineral Resources (2001).

2. Nam Phong Formation which is consisted of alternating thick-bedded siltstone and resistant sandstone and conglomerate were deposited on top of the Huai Hin Lat Formation. The thickness is 1,465 m at the type section. The type section is located in Nam Phong, Amphoe Phu Kradung, Changwat Loei. This formation was interpreted as deposited in fluvio-lacustrine depositional environment. The age was proposed to be Rhaetian (Late Triassic) by Department of Mineral Resources (2001).



3. Phu Kradung Formation which consists of soft siltstone and non resistant sandstone with greenish gray calcareous conglomerate were deposited. Bone fragments and teeth were collected. The thickness is 1,001 m at the type section. The type section is located in Phu Kradun, Amphoe Phu Kradung, Changwat Loei. This formation was interpreted as deposited in fluvio-lacustrine depositional environment The age was proposed to be Berriasian to Barremian (Early Cretaceous) by Racey *et al.* (1994) and Middle to Late Jurassic by Department of Mineral Resources (2001).

4. After that a resistant bed of white quartzitic sandstone and thin laminated red siltstone were deposited by a fluvatile shallow marine system. The thickness is 56-136 m. It is called the Phra Wihan Formation. The type section is located in the southern slope of Khao Phra Wihan. The age was proposed to be Berriasian to Barremian (Early Cretaceous) by Racey *et al.* (1994) and Middle Jurassic to Early Cretaceous by Department of Mineral Resources (2001).

5. Sao Khua Formation was deposited on top of the Phra Wihan Formation. The formation consists of non resistant siltstone and conglomeratic sandstone. The thickness is 404-720 m. The type section is located at Km 35.2-41.5 of Udon Thani-Nong Bua Lamphu Road, which this formation was interpreted as continental deposit. The age was proposed to be Barremian to Aptian (Late Early Cretaceous to Early Middle Cretaceous) by Racey *et al.* (1994) and Early Cretaceous by Department of Mineral Resources (2001).

6. A light colour, massive beds of pebbly sandstone, cross-bedded conglomeratic sandstone and conglomerate, namely the Phu Phan Formation were deposited on top of the Sao Khua Formation. The thickness is 183 m. The type section is located in Phu Pha Phung in Phu Phan Range, which this formation was interpreted as fluvatile depositional environment. The age was proposed to be Barremian to Aptian (Late Early Cretaceous to Early Middle Cretaceous) by Racey *et al.* (1994) and Early Cretaceous by Department of Mineral Resources (2001).

7. Khok Kruat Formation, which comprised of soft siltstone, moderately resistant sandstone and caliche-siltstone pebble of calcareous conglomerate were deposited. The thickness is 709 m. The type section is located at Km. 207 and Km. 209 of Friendship Highway. This formation was interpreted as fluvatile depositional environment. The age was proposed as Aptian to Albian (Middle Cretaceous) by Racey *et al.* (1994) by Department of Mineral Resources (2001).

8. Mahasarakam Formation which is commonly known as the Rock Salt Formation was deposited. The formation comprises salt-bearing claystone, mudstone, siltstone and sandstone. The thickness is 1,000 m. The type section is located at Amphoe Borabu, Changwat Mahasarakam. The Mahasarakam



Formation shows angular unconformity contact with the Khok Kruat Formation at the edge of the Khorat basin. The age was proposed as Cenomanian (Late Cretaceous) by Department of Mineral Resources (2001).

9. Overlying the Khorat group is the Tertiary rock of the Phu Tok Formation (Sattayaruk, 1985). The Phu Tok Formation consists of sandstone which is reddish brown, fine to medium grained semi-consolidated, thick-bedded to massive, very large scale cross bedding and small scale wavy bed. The thickness is 100 m. The type section is located at Phu Thok, Amphoe Srivili Changwat Nong Khai. This formation was interpreted as deposited by fluvio eolian. The age was proposed as Cretaceous to Early Tertiary by Department of Mineral Resources (2001).

Tectonic events which occurred during the deposition of the Khorat Group were the Indosinian orogeny and Himalayan epeirogeny. The two basins of the Khorat plateau were created by the Himalayan epeirogeny as was the third at Muang Phalane in Laos. The main economic mineral deposits in the Khorat and Sakolnakorn basin are the sodium and potassium salts, halite, canallite and sylvite (Japakasetr, 1985). They are certainly of marine origin, and were laid down in the late Cretaceous or post Cretaceous (Kobayashi *et al.*, 1963). The contact of Mahasarakam and Khok Kraut Formation is defined at bottom of the anhydrite and gypsum bed. The deposits of rock salt formation was deposited during the Eocene and Oligocene epochs. (Piyasin, 1985)

Deformation events affecting the Khorat plateau are middle Carboniferous folding, thrust faulting of Permian strata. The post Cretaceous deformation caused the uplift of the Khorat Plateau, and faulting and fracturing of the Mesozoic strata (Cambell and Nutalaya, 1975)

During the Pleistocene epoch deposits of the Khorat basin have been affected by the tectonic movements which have warped the various terraces in certain areas, The Pleistocene deposits commonly known as old alluvium. It is composed of sand, gravel, sand, silt and clay interbedded. The Pleistocene deposits commonly have laterite bed at the top of the succession. Textites have been found in the gravel beds. The old alluvium in Cambodia and Vietnam was also overlain by basalt whose ages range from 650,000 to over 4 million years. The tektite age is 700,000 years old. (Fleischer *et al.*, 1965) Consequently, the old alluvium belongs to the Pleistocene age.

Moormann *et al.* (1964) divided the Quaternary deposits on the Khorat Plateau into four units as follows:

1. High Terrace Deposits: This unit consists of homogeneous red-yellow latosols. It is found on high elevation of rolling topography. This unit was probably developed during early Pleistocene epoch.



2. Middle Terrace Deposits: This unit is found in the lower elevation and consists of homogeneous sand and very low clay content at the surface. The composition gradually changed with depth to loamy sand and sandy loam with reddish and yellowish mottles in the lower stratum.

3. Lower Terrace Deposits: This unit was probably developed during the Upper Pleistocene time and is characterized by a wide, slightly undulated plain bounded on both sides by older terraces and hills. On the upper part of this landform, medium to fine-grained deposits are predominant, whereas the sediments of medium to coarse-grained deposits were found in the lower parts.

4. Alluvial Plain Deposits: This unit includes river levee of sands and back swamp deposit of clay to clayey loam (Udomchoke, 1988).

Boonsener (1977) reported that a stratigraphic section of the Quaternary sediments in the town of Khon Kaen consists of nine sedimentary units of eolian and fluvial deposits overlying the weathered Khok Kruat clay. The summary of Boonsener's stratigraphic succession from bottom to top is described below.

i. Bedded Iron Oxides Goethitic Mottled Clay: This soil overlies unconformably the top of the weathered Khok Kruat clay. It is reddish brown to brownish black in color. It is found mostly as iron oxide bed and occasionally as layered nodules. The goethitic stained patches are scattered in the soil. It is overlain unconformably by the polished gravel bed.

ii. Polished Gravel Bed: This unit lies on the bedded iron oxides and consists of moderately well sorted gravels.

iii. Laterite: Laterites lie on the top of the polished gravel bed and underlies the red and yellow loess. The contact between the laterite and the gravel bed is a gradational one.

vi. Red Loessial Soil: It is red to pinkish orange silty sand, and has no internal structure. Sometimes it contains ferricrete lenses.

v. Yellow Loessial Soil: This unit is brown to buff and yellow silty sand, moderately well sorted, and has no internal structure.

vi. Windblown Sand Deposit: It consists of gray to buff well-sorted fine sand, with no internal structure

vii. Old Alluvium : Old alluvium (reworked loess) is found as remnants of an elevated floodplain as well as on the yellow loessial soil and the pisolitic laterite. It is gray to brown loam with small iron oxide pisolites on indurated surface.

viii. Alluvium: The alluvium occupies low lying plain. It consists of yellowish to pale brown clean medium sands, sometimes with interbedding clay seams, and gravels.

viii. Lake and Swamp Deposit: This deposit is found in the lake floor and swampy areas. It is gray to pale brown sandy stiff clay with soft dark gray organic clay on top.



A study of the Quaternary deposits along the Mun basin has been conducted at the Thung Kular Rong Hai. The sediments are composed of weathered Mahasarakam shale and three units of soils which were developed during the climatic change. They are composed of early humid stages of organic sand, fine organic sand coarse organic sand and clayey sand, late dry stage of fine sand, medium sand, inorganic sand and late humid stage to recent. The age of organic sands were dated at 34000, 32000 and 20000 years. That is in the upper most Pleistocene (Loeffler *et al.*, 1983).

Takaya *et al.*, (1984) reported that during the Plio-Pleistocene time the main clay minerals of the weathered rocks of the Khorat Group are montmorillonite and kaolinite. These units underly the 700,000 years old tektite horizon. During the Holocene epoch alluvium was deposited on top of the tektite horizon.

Wongsomsak (1986) reported that the Quaternary deposits at Buri Rum Province consist of three chronostratigraphic units i.e., and "Unnamed" Formation, the Kham Sakae Saeng Formation and the Khu Muang Formation. His Stratigraphic section is based on the degree of weathering, the major clay minerals, tektite and petrified wood. They are described as follows:

i. Weathered Red Siltstone and Shale : The weathered red siltstone and shale of the Mahasarakham Formation lies at the bottom of the section and is unconformably contact with the overlying basalt.

ii. Basalt: The alkaline hawaiite basalt lies unconformably underneath the Unnamed Formation.

iii. Unnamed Formation: It is light gray clay loam to sandy clay loam and includes the cloudy mottles of bright yellowish brown to dull yellow in color. It lies under the Kham Sakae Saeng Formation.

vi. Kham Sakae Saeng Formation : This units consists of four subunits. The lowest subunit is brownish gray sandy clay loam with orange to reddish brown cloudy mottles and a few carbonate nodules. The second subunit is grayish clay with cloudy mottles. It also contains some tektites and abundant carbonate nodules. The third subunit is the same grayish clay with cloudy mottles, but with abundant iron oxide concretions. The uppermost subunit is grayish clay with yellow cloudy mottles.

v. Khu Muang Formation : This unit consists of two proposed type section. The first type section includes three subunits; the petrified wood fragments lie at the basal horizon, the middle subunit is the yellow silty sand of yellow cloudy mottles, and the upper subunit is the yellow orange silty sand with orange mottles. The second type section consists of four subunits; the bottom subunit is dark red silty sand with gravels and petrified wood pieces with distinct cross-bedding, the second subunit is dark red silty sand and ubiquitous gravels, the third subunit consists of dark red silty sand and yellowish brown cloudy mottles with small



gravels and traces of petrified wood fragments, and the uppermost subunit includes dark red silty and ubiquitous small gravels.

vi. Recent Wash and Alluvium Formation : This unit is grayish clay with red cloudy mottles or orange sandy loam with reddish brown cloudy mottles. It overlies the light gray sand or gravels with brown cloudy mottles. (Udomchoke, 1988)

Sataragsa (1987) analyzed the stratigraphic section of the Quaternary deposits at the town of Nakhon Ratchasima. She reported that the deposits of this area were the results of fluvial and eolian processes as described below from bottom to top.

i. The Khorat Group: The Khok Kruuat Formation is the oldest rock unit in this area. It is capped by residual soil of weathered claystone, mudstone, and shale. This formation underlies the gravel bed.

ii. The Phu Khao Thong Formation : This formation is composed of the top most fluvial sands and gravels probably deposited during the Miocene to Lower Pleistocene age. The underlying rock units are reddish brown, light brown, cross-bedded sandstone and conglomeratic sandstone, as well as conglomerate and gray, grayish green calcareous siltstone. Fragments and logs of petrified woods are found in this formation.

iii. Gravel Bed : This unit consists of subrounded pebbles and cobbles of white quartz, gray, grayish green, brown and black chert, with small amount of clay, silt, sand and fragments of petrified wood.

iv. Laterite : The massive and pisolitic laterites are found in this unit. The massive laterite is 0.3-0.5 m thick and lies on top of the gravel bed. The iron oxide posolith forms an undulating layer and is overlain by loess.

v. Loess : The loess is generally reddish brown or yellowish brown fine sand and silt. It has no internal structure and is horizontally lying.

vi. Alluvium : The alluvial deposits consist of yellowish brown, grayish brown, reddish brown silty clay, sandy clay, and clayey sand. They are found in the flood plain and undulating terrain of Khorat where the elevation is less than 190 m above MSL.

Udomchoke (1988) summarized the stratigraphy of the Quaternary deposits of the Khorat Plateau consists of nine sedimentary units. The summary of the stratigraphy from top to bottom are as follows: (Figure 2.2)

i The Weathered Rocks of the Khorat Group : This unit lies at the bottom of the stratigraphic section. The weathered rocks of the Khorat Group include residual soils, pallid zone and the geothitic mottled clay, saprolites, weathered claystone, weathered sandstone, weathered shale, weathered siltstone, and weathered mudstone.

ii. Basalt : It is an alkaline basalt of hawaiiite type. It is dark gray colored, fine grained, and vesicular on the upper part, but massive at the lower part. The basalt erupted during Plio-Pleistocene age.



iii. Gravel Beds : There are two units of gravel beds-the older and the younger. The older gravel bed is fine-grained, semiconsolidated, and tilted. The type section is at Ban Phu Khao Thong, Nakhon Ratchasima Province. Late Tertiary was the proposed age of this unit.

The younger gravel bed are larger-sized and the beds are horizontally or slightly undulating lying with iron oxides coated or cemented or with ferricrete caps on the upper portion.

iv Organic Sand : This unit was deposited in the shallow depression area at Tung Kula Ronghai. It accumulated during the humid phase prior to the last glacial maximum (34,000 to 20,000 years B.P.). It underlies unconformably the red and yellow loess.

v. Red and Yellow Loessial Soil : The red and yellow loess are presumably deposited at the same time and same environment during the cold and dry climate of the last glacial maximum 18,000 year B.P. (Tuckson *et al*, 1983). Nutalaya *et al.* (1987) explained that loess deposition occurred during the drier climate, when the Mun river was not meandering as nowadays but was braided and aggrading its flood plain with sand derived from weathered Khorat Group bed rocks from the adjacent hills.

vi. Lake Bed and Swamp Deposits : This unit is a grayish to dark gray organic clay. Dating of the organic carbon from the lake bed yielded the ages between 7,600 and 5,200 years B.P. which is contemporaneous with the age of +4 m transgression of sea level in the Chao Phraya Plain. The depositional environment of this unit was warm and humid.

vii. Windblow Sand : This unit is characterized by well sorted, loose, medium-grains, pale to buff colored sand. It was laid down during the dry period prior to the flood deposit.

viii. Flood Deposits : This unit consists of loose grayish brown silty sand and interspersed gravels. Sherds, bones fragments, shells and charcoal are found embedded in this deposit. The age of flood deposits range from 2,100 to 1,850 years B.P.

ix. Alluvium : It is always found in the flood plain area of present streams. Interbedded clayey sand, sandy clay and silty sand are the main components.

Nutalaya *et al.* (1988) is summarized the Quaternary stratigraphy of the Khorat Plateau in the vicinities Khon Kaen (Boonsener, 1977; Chong, 1988), Tung Kula Ronghai (Loeffler *et al.*, 1983), Nakhon Ratchasima (Satarugsa, 1987), and Buriram (Wongsomsak, 1986) (see in Figure. 2.3)

1. Deep weathering profile of the Mahasarakham Formation and a gently undulating erosional surface (an unconformity) on top of it represent a stratigraphy break between the Mesozic Khorat Group and the Tertiary-Quaternary Formations.

2. Two gravel bed units are reconizd. The older unit (the Phu Khao Thong Formation) consists of fluviatile conglomerates sandstone with petrified logs. The



older gravel beds unconformably overlie the weathered Mahasarakham Formation and underlie also unconformably the younger gravel beds.

3. The younger gravel beds, (the Kham Sakae Saeng Formation), are composed of pebbles, cobbles of quartz and chert in sandy, silty matrix. Massive or pisolitic laterite was found on the top part of this unit. Some chert gravels are quite angular and well polished with faceted faces. These polished gravels were probably wind-abraded ventifacts which were subsequently transported by streams. The age of this unit is indicated by the occurrence of contemporaneous textites (700,000 years) which are found embedded in the gravel beds without any sign of transport wear. The younger gravel beds probably represent the erosion and redistribution of the older gravel beds by fluvial process.

4. Loeffler *et al.* 1983 reported the occurrence of an organic rich sand unit which occurs over most of the Tung Kula Ronghai. Wood samples from this organic sand unit gave  $^{14}\text{C}$  date between 34,000 and 20,000 years B.P.

5. In other places the younger gravel beds are unconformably overlain by the red/yellow loess (Khu Muang Formation). The loess deposit is quite extensive and blankets all preexisting landforms including hills and structural mounds, valleys and flood plains. The loess represented drier environment.

6. Overlying the loess in the low lying area is 2 to 4 m thick organic sand and silt. It represents the lake bed deposit.

7. Overlying the organic rich lake beds is yet another distinctly different wind blown sandy silt deposit. The wind blown sand is found mainly bordering the flood plain in Khon Kaen area.

8. The unit which partly overlies the wind blown sand is the flood deposit. This unit is at least 5 m thick and its  $^{14}\text{C}$

9. The youngest sedimentary unit of the Khorat Plateau is the alluvial deposit. It occupies the flood plain of all streams.

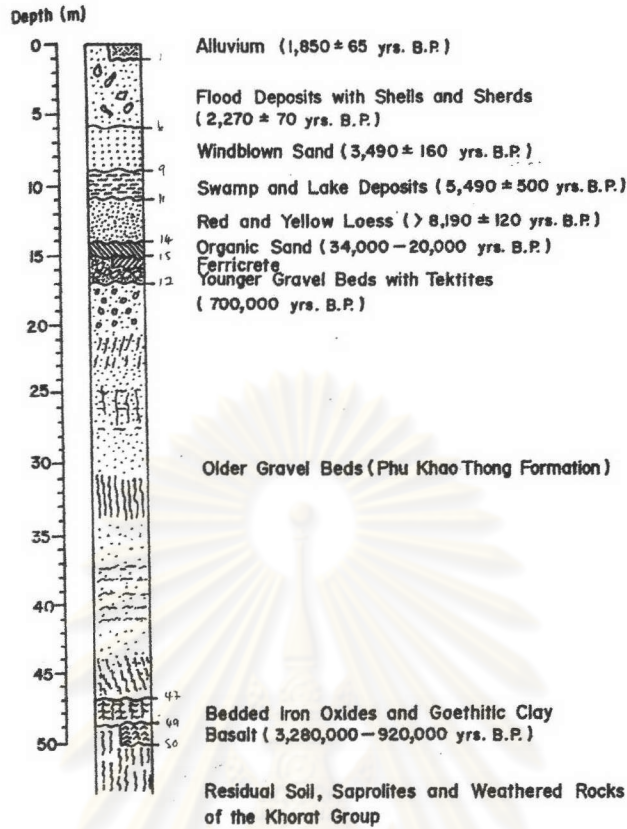


Figure 2.2 Quaternary stratigraphy sections of the Khorat Plateau (Udomchoke, 1988)

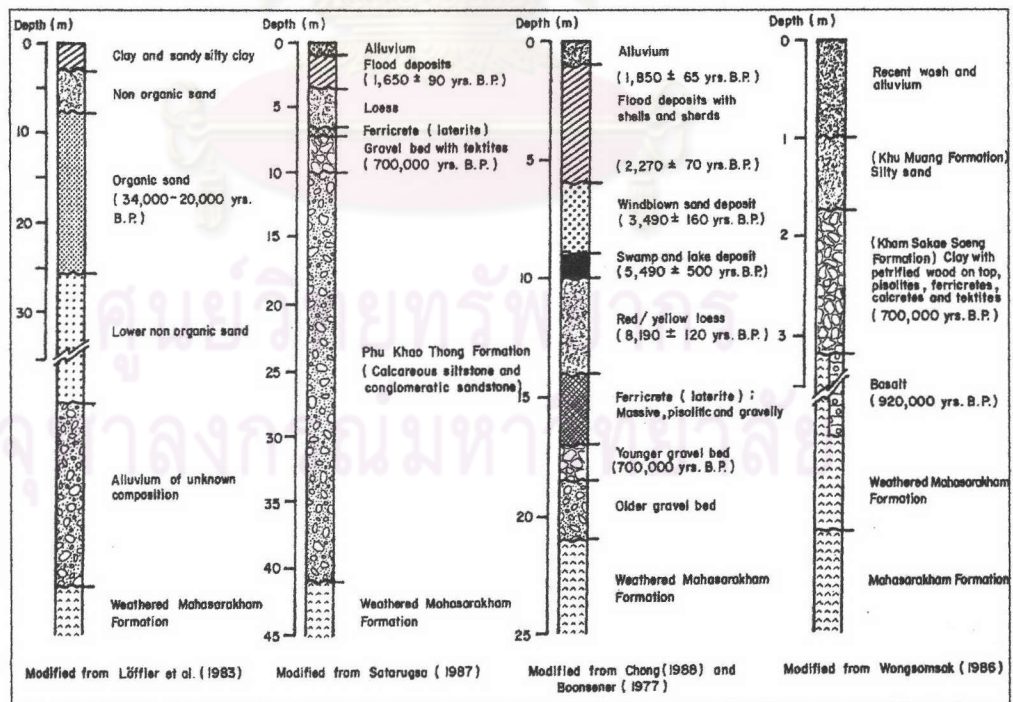


Figure 2.3 Showing the comparison of Quaternary sediment that found in other area of Khorat Plateau (Nutalaya *et al.*, 1988)



## **2.2 Geology and Geomorphology of the Study area**

The study area is in the plain of Nakhon Ratchasima Province, northeastern part of Thailand. It comprises of the landscape features found in the Khorat Plateau, such as rivers, alluvial plains, low terraces and high terraces.

The topography of the study area comprises mainly of broad river terraces and flood plain low land. Generally, the terraces, floodplain lie approximately 170-245 m. and 150-180 m. above MSL respectively. There are three major rivers, Lum Boribun, Lum Takhong and Lum Nam Mun. Lum Boribun and Lum Takhong flow west and eastward direction while Lum Nam Mun flow south and northward direction.

### **The Geological Setting.**

The detail geological setting was studied by interpretation from aerial photos and field checked (see Figure 2.4). Most of the study area is generally covered by Quaternary deposits. The Quaternary deposits as fluvial deposits are localized on a flood plain and low terraces. The Khok Kruat Formation was found in southwestern part of area along the Mun river, UTM Grid reference 1650411.

#### **2.2.1 Geomorphology**

Aerial Photographic interpretation indicates that the landform can be divided into 4 units, namely high terrace, low terrace, floodplain, and natural levees. The landform features of the study area is shown on the geomorphological map. The details of the landform features are discussed below.

##### **1. High Terrace (Old flood plain terracedeposit)**

The high terrace of Mun River occupies the Southeastern to Northeastern Part approximately 30% of the map. It is predominantly occurred in the southwestern part which occupies approximately 19% of the map. The characteristic of the high terrace of Lum Takhong appears as a flat low lying plain which is flooded during the wet season. An irregular drainage pattern developed on this terrace. It is generally used as rice paddies (Satarugsa, 1987). The characteristic of the high terrace of Mun River is undulated terrain and formed a large scale rolling surface. It usually occupies the highest elevations and normally above 170 m. up to 245 m. It is generally used for the plantation.

Undulated terrain consists of reddish brown yellowish brown soil. It is the highest and oldest terrace, generally flat top surface with gentle slope. It usually occupies the highest elevations and normally above 170 m. up to 245 m. The typical top surface, reddish brown colored of sandy mud. It is generally used for the plantation.

## 2. Low Terrace

The characteristic of the low terrace is undulated terrain and formed a large scale rolling surface. Most of the undulated terrain consists of reddish brown yellowish brown soil.

## 3. Floodplain

This floodplain was formed by the Lum Boribun, Lum Takhong and Lum Nam Mun. Generally the floodplain appears as a flat low lying plain along the stream courses with low gradient, and gentle sloping toward the east along the course of the Lum Boribun and Lum Takhong, and toward the north along the course of the Mun river. The stream which occupies the floodplain is mostly the underfit stream. This terrain type lies approximately between 150-180 m. above MSL. The Mun flood plain consists of natural levee, oxbow lakes, and swamps meander scars which were shown as Old River. It constitutes about 5% of the map area. Floodplain consist of yellowish brown, grayish brown, reddish brown, dark with reddish stain and /or yellowish stain silty clay, sandy clay, clay and clayey and sand.

### 2.2.2 Geology and stratigraphy of study area

The study area is located near the edge of the Khorat Basin. It is composed of rocks of Khorat group and unconsolidated sediments which consist of gravel bed, laterite, alluvium and loesses. (see. Figure 2.5)

#### (1) The Khorat Group

The oldest rock units found in this area is the Khok Kruat Formation. It is capped with residual soil of weathered claystone, mudstone and shale. This formation underlies the gravel bed in most places in the study area. It is composed of sandy mudstone and interbedded by calcareous horizon cement texture. It is shown in Figure 2.6, 2.7 and 2.8

#### (2) Tertiary sandstone

This oldest rock units found in the sandpit along the Mun River. It was covered by Quaternary sediment about 3.5-6 m, in thickness.

#### (3) Gravel bed

The gravel is composed of round to subround pebbles of white quartz, grey and black chert, sand, and fragments of petrified wood. The gravel bed is underlain by weathered claystone, mudstone and shale of the Khorat Group. This unit is



Quaternary (Middle Pleistocene) in age. The gravel bed age is contemporaneous with the age of the tektites (about 700,000 years) (Satarugsa, 1987). (Figure 2.7)

#### (4) Laterite

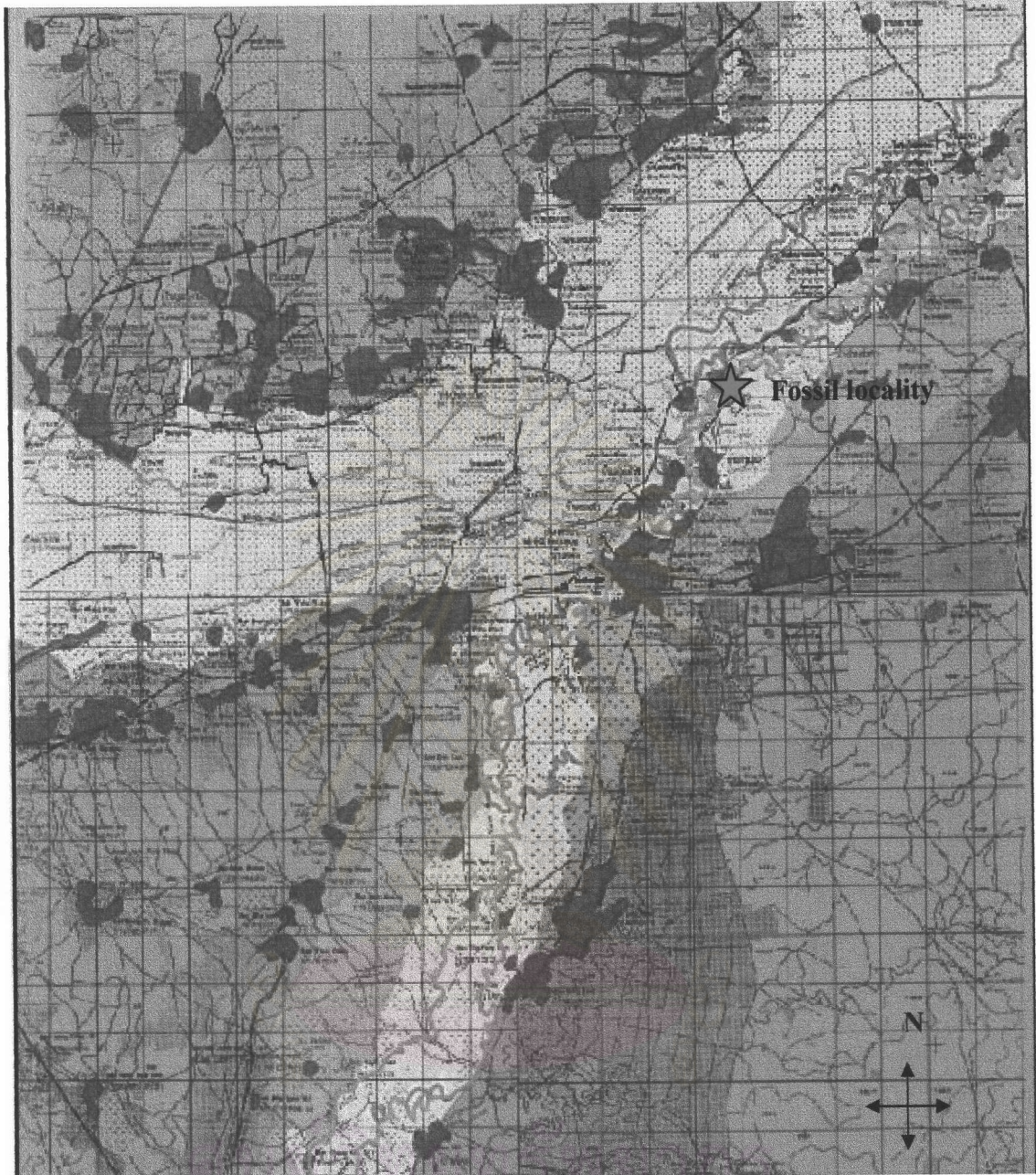
One type of laterite are present in the area. It is a hard pan massive laterite. The massive laterite is thick and is found on the top of the gravel bed. It is 30 cm. thick. At Ban Kook, laterite outcrop reveal the wavy massive layers following the undulation of the gravel beds. This unit is overlain by loess. (Figur. 2.8)

#### (5) Loess

The loess is yellowish brown, structureless and horizontally laid. A thin layer of loess at the elevation about 190 m above the MSL is preserved in some places, such as at Ban Kook, found on the top of laterite unit and in the fossil locality of the sand pit. The loess overlies silty sandy clay bed.

#### (6) Alluvium

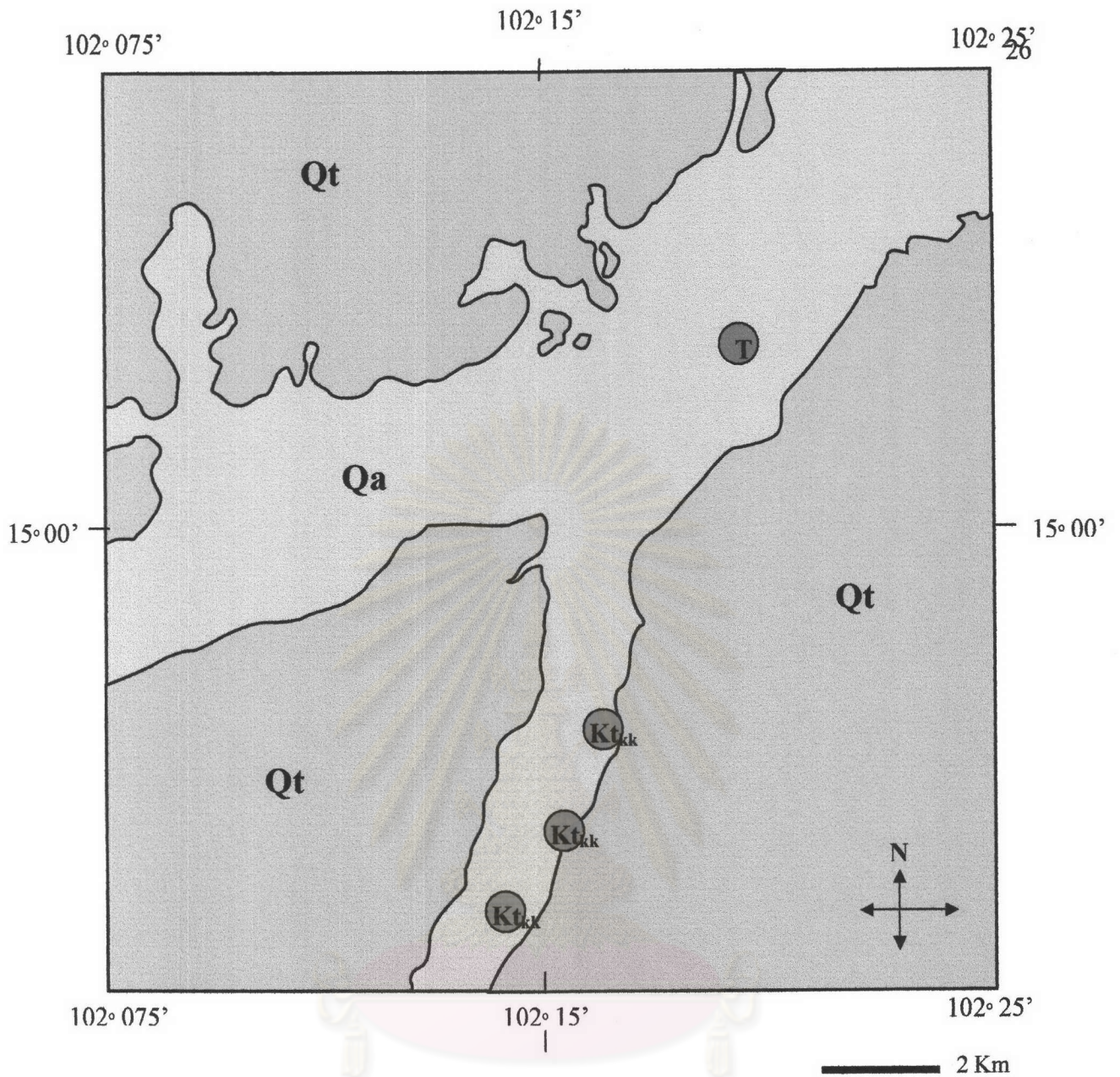
The alluvial deposits cover about 30 % of the area. They consist dominantly of yellowish brown, grayish brown, reddish brown, dark with reddish stain (of haematite) and/ or yellowish stain silty clay, sandy clay, clay and clayey sand. They are found in the flood plain and low terrain where the elevation is less than 190 m. above the MSL (Satarugsa, 1987).



LEGEND	
■	Village
■	River
■	Old river
■	Flood plain
■	Terrace I
■	Terrace II

Figure 2.4 Geomorphologic map of the study area and adjacent (Modified from Raksaskulvong *et al.*, 2003)





**EXPLANATION**

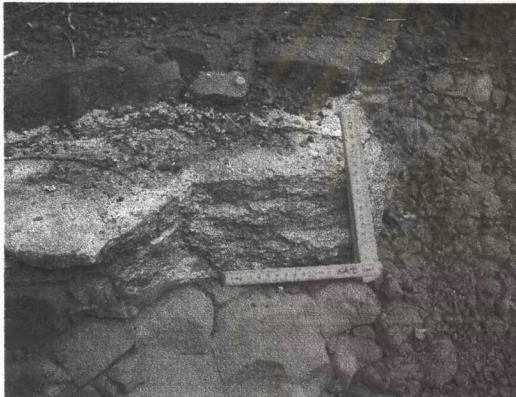
<b>Qa</b>	Alluvial gravel, sand silt and clay of floodplain and swamp deposits
<b>Qt</b>	Terrace gravel, sand silt; locally laterite and lateritic soil
<b>Kt<sub>kk</sub></b>	<b>Khok Kruat Formation</b> : Grayish-red, reddish brown, and pale red siltstone, sandstone, and fine conglomerate
<b>T</b>	<b>Tertiary</b>

Figure 2.5 Geological map of the study area and adjacent (Modified from Raksaskulvong *et al.*, 2003)





a.



b.



c.

Figure 2.6 a. Showing the outcrop of the Khok Kruat Formation at Ban Kook, UTM Grid reference 1650411  
 b. Showing the calcreat horizon which interbed in Khok Kruat sandstone  
 c. Showing a closed up of the typical rocks of the Khok Kruat Formation at Ban Kook



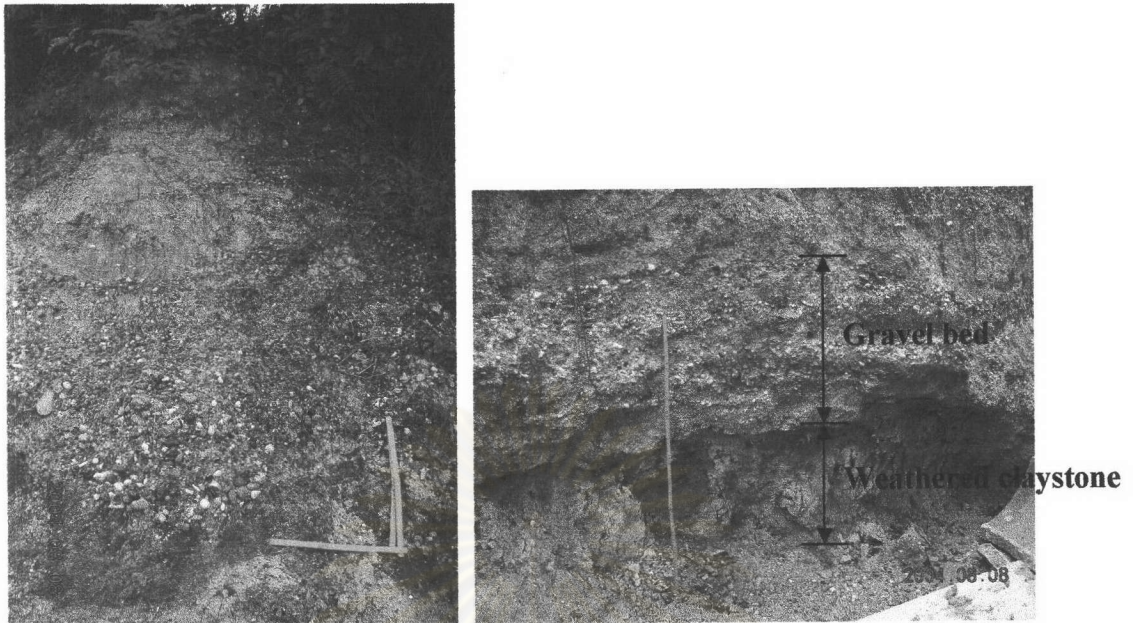


Figure 2.7 Showing the weathered claystone underlies the gravel bed

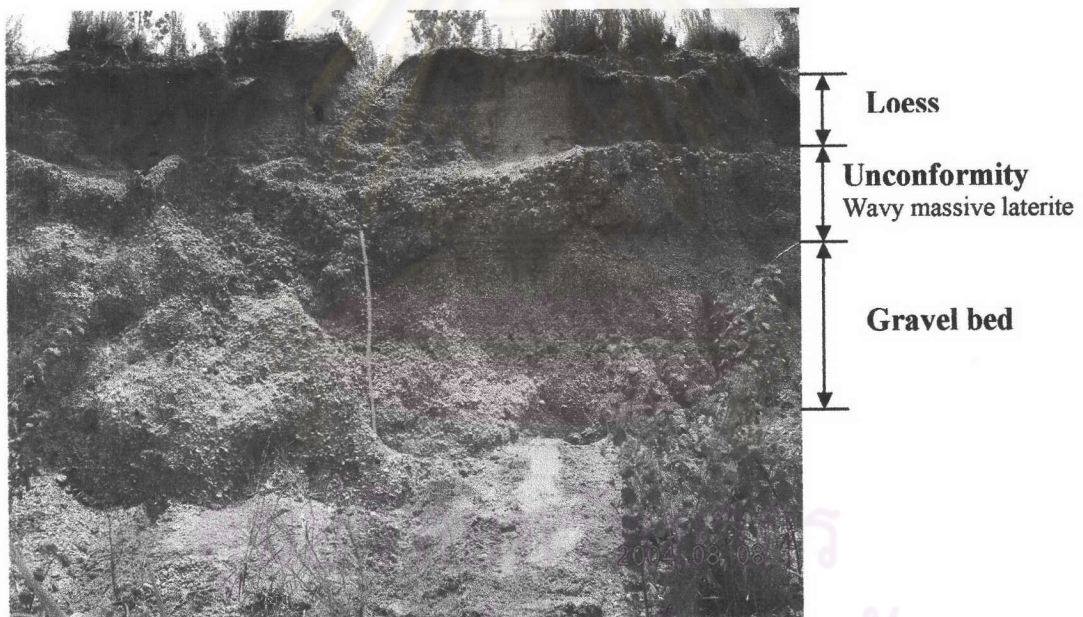


Figure 2.8 Showing the typical stratigraphic section of the study area, UTM Grid reference 1650411