CHAPTER II

GENERAL GEOLOGY

Geology of the Khorat Group

The Khorat Group is known as a sequence of continental Mesozoic sedimentary rocks which form the bed rocks of the Khorat Plateau. Patches of equivalent rocks are also exposed in northern and southern Thailand. The Khorat Group consists mainly of continental red and gray sandstone, siltstone, and shale with some paralic and salt deposits, ranging in age from Upper Triassic to Cretaceous Period. The term "Khorat Series" was first proposed by Brown and others (1951), and was subdivided into members for the first time by Jalichan and Bunnag (1954). Subsequently, Ward and Bunnag (1964) proposed that the term "Khorat Group" be adopted in stead of Khorat Series, in order to follow the international lithostratigraphic nomenclature. In their study, the Khorat Group was divided into seven formations. Iwai and others (1966) divided the Khorat Group into six formations. Since then the Khorat Group has been reclassified by several geologists, but most of their classification followed either the works of Ward and Bunnag (1964) or of Iwai and others (1966), while new formations were proposed only to the upper and lower parts of the Group. The Khorat Group is formally divided into eight formations (Bunopas, 1992) based on lithostratigraphic cycles including Maha Sarakam, Khok Kruat, Phu Phan, Sao Khua, Phra Wihan, Phu Kradung, Nam Phong and Huai Hin Lat Formations.

1. Lithostratigraphy and Depositional Environment

The lowest formation of the Khorat Group, the Huai Hin Lat Formation (Iwai and others, 1966), consists of basal conglomerate with pebbles of limestone, rhyolite porphyry and other rock fragments with the thickness of up to 140 m, overlied by interbedded gray to dark gray sandstone to shale and lime-conglomerate with fossil leaves and marly beds with no fossils. The formation is comformably overlain by the Nam Phong Formation which consists of soft, gray red to pale red siltstone interbedded thick resistant beds of brownish-red sandstone and conglomerate. The top of the Nam Phong Formation is ended up by 85 m thick interval of hard calcareous siltstone and limestone. At its type section the Nam Phong formation is 1,456 m thick. Phu Kradung Formation (Ward and Bunnag, 1964) which is the overlying formation, consists largely of interbedded pink sandstone, red siltstone and red shale with occasional thin fine conglomerates (1,000 m thick). The basal part of the Phu Kradung Formation is pelletal, micritic limestone and the overlying formation, the Phra Wihan Formation (Ward and Bunnag, 1964) consisting predominantly of white to pink, thick-bedded, well-sorted, medium-grained, quartz-rich sandstone with some thin interbedded siltstone. Thickness of the formation varies considerably from 5 to 136 m.

Sao Khua Formation (Ward and Bunnag, 1964) consists largely of interbedded red to pink quartz sandstone and red to purplish shales and ranges in thickness from 404 to 720 m thick. The overlying Phu Phan Formation (Ward and Bunnag, 1964), is mostly white to pink, well-sorted, medium- to coarse-grained quartz sandstone, with some conglomerate sandstone horizons. The upper formation of Phu Phan is Khok Kruat Formation (Ward and Bunnag, 1964) in Khorat basin and Ban Na Yo Formation (Iwai and others, 1966) in Sakon Nakhon basin, consists mainly of interbedded moderately consolidated red siltstone, and red to white quartz sandstones and fine conglomerate, with the thickness of 700 m thick. The formation is poorly exposed and the best sections are from cored boreholes. Overlying the Khok Kruat Formation is the Maha Sarakam Formation (Gardner and others, 1967) of about 1,000 m thick, consists mostly of halite, carnellite and sylvite, with subordinate anhydrite

and gypsum intercalating with shale, and with less than 100 m-thick covering detritus. It includes distinguished three layers of rock salt with the red clay in between. From the drilling wells the formation is thought to rest unconformity on the underlying Khok Kruat Formation.

Depositional environment of the Khorat Group is believed to be either continental environments (Sattayarak, 1983) or coastal environments (Piyasin, 1985). Depositional environment of the Huai Hin Lat Formation is suggested to be the fluvio-lascustrine (Chonglakmani and Sattayarak, 1978) or tidal marshy swamp (Piyasin, 1985). Nam Phong Formation was deposited in the fluvio-lacustrine environment (Sattayarak, 1983), or meandering rivers and alluvial plain (Mouret, 1994). Depositional environment of the Phu Kradung Formation regarded as the fluvio-lacustrine (Hahn, 1982), or meandering river and alluvial plain (Mouret, 1994). Environment of Phra Wihan Formation is suggested as the braided streams (Sattayarak, 1983), or braided streams and fluvio-lacustrine (Hahn, 1982), or semi-distal braid rivers (Mouret, 1994) environments.

Sao Khua Formation is determined as lacustrine and floodplain with river channel environment (Hahn, 1982) or deltaic environment (Inthuputi and Suwanasing, 1978), or alluvial plain and meandering river (Mouret, 1994) environments. Phu Phan Formation may have occurred in the typical fluviatile (Hahn, 1982) with low sinuosity braided rivers (Mouret, 1994). Depositional environment of Khok Kruat Formation is explained to fluvatile in arid region (Sattayarak, 1983) or meandering river (Mouret, 1994). Maha Sarakam Formation is acquired by the alternation of evaporites and alluvial plain sediments (Mouret, 1994) or salt marsh to tidal flat (Sattayarak, 1983).

2. Age of Khorat Group

Among the formations described in previous section, the age of Huai Hin Lat Formation are more conclusive (Buffetaut and Ingavat, 1985). The vertebrate fossils, and plants, spores and pollens from the Huai Hin Lat Formation indicate the

Early Norian age. Recently, Racey and others (1994), however, suggested the age based on palynological data to Early Norian (middle Late Triassic). Nam Phong Formation's age is rely on dinosurous remains as late Triassic (Buffetuat and others ,1995). The data of Racey and others (1994) described the Nam Phong age from palynology as Late Norian (late Late Triassic) to Rhaetian (Early Jurassic). The age of Phu Kradung Formation is given using vertebrate fossils, bivalves and pollen to be Lower Jurassic age (Chonglakmani and others, 1985) or Middle Jurassic (Buffetuat and others, 1993).

Phra Wihan Formation's age is defined from carbonized and silicified woods, and leave fossils were considered to indicate Jurassic to Cretaceous (Chonglakmani and others, 1985). Buffetuat and others (1993) record the new vertebrate fossils and trace fossils which surprisingly gave quite similar age. The age of Sao Khua Formation is certainly defined by vertebrate fossils and plants. Buffetuat and others (1993) assigned the age of Sao Khua as Late Jurassic. Phu Phan Formation, as suggested by vertebrate fossils, dinosaurous footprints and bivalves is Lower Cretaceous in age (Buffetuat and others, 1993). Fossils of Ichthyosaur teeth, vertebrate and fauna yield the age of Khok Kruat as Aptian-Albian (Buffetaut and Suteethorn, 1992). The age is obviously similar to that of Racey and others (1994). Age of Maha Sarakam Formation age is referred from isotope dating as well as pollen and some vertebrate which is from Albian to Late Cenomanian (late Early Cretaceous to early Late Cretaceous) (Sattayarak and others, 1991).

Geology of the Phu Thok and Phu Wua areas

Since there are several geological aspects - chronology, correlation, and genesis of Phu Thok rock unit that are now controversial and disputable, so the geology of the Phu Thok area was required to remap with emphasis on the areal extent of Phu Thok formation. The boundaries of this rock unit (see Fig 2.3) are slightly modified from the previous studies (i. e., Chonglakmani and others, 1979). The age of rock unit is also changed in order to conform with geologic and paleomagnetic studies.

The regional trend of the Phu Thok terrain is roughly elongated in the NW-SE direction following the regional strike of the Phu Phan range in Thailand and Phu Kadan in Laos (Figs. 2.1 and 2.2). The area consists of high-relief mountain of the Phu Thok formation and low terrain of the Maha Sarakam Formation, the latter being occasionally covered by semi-consolidated Quaternary sand and gravel beds. Geology of the area concerned is shown in Figure 2.3.

1. Stratigraphy

The oldest Phu Thok unit is only exposed in the mountainous area (Fig. 2.3). Measuring section was performed in the western part of Khao Phu Thok Noi (or Phu Thok section) and the eastern part of Khao Phu Wua Lang Tham Pai (or Phu Wua section). Geological boundaries of this formation is constrained by NW-trending fault bounded in the eastern and the western parts parallel to the trend of the mountains. Lithology of this unit (formation) is characterized by alternation of two major sandstone types. The first type is thick bedded (up to 2-3 m), whitish purplish brownish red to purplish brownish red, indurated, calcareous, very fine-grained sandstone to siltstone, which usually have wavy structure and some ripple structures. The other is reddish brown to brownish red, more friable to rather indurated, fine- to medium- grained arkosic sandstone (up to 20 m thick), with large-scale, multi-directional, cross-bedding (Fig. 2.4). Fossils are not observed in the sequence.

The younger unit, or the so-called mudstone- clastic unit (Fig. 2.5) is widely exposed in the low terrain undulating area and extent to Changwat Sakon Nakhon and Nakhon Phanom. The lithology of this unit is characterized by the white to yellowish white, partially compacted, relatively weathered siltstone to mudstone and some lateritic semi-consolidated rocks (Fig.2.6). It frequently shows small pores and columnar (or polygonal) joints on weathered surfaces. Clasts of angular, red silt grains (0.5 to 1 cm in diameter) are rarely mixed in its texture. This rock is occasionally overlain by white to reddish white pebbly silt to mud. Phenoclasts of this

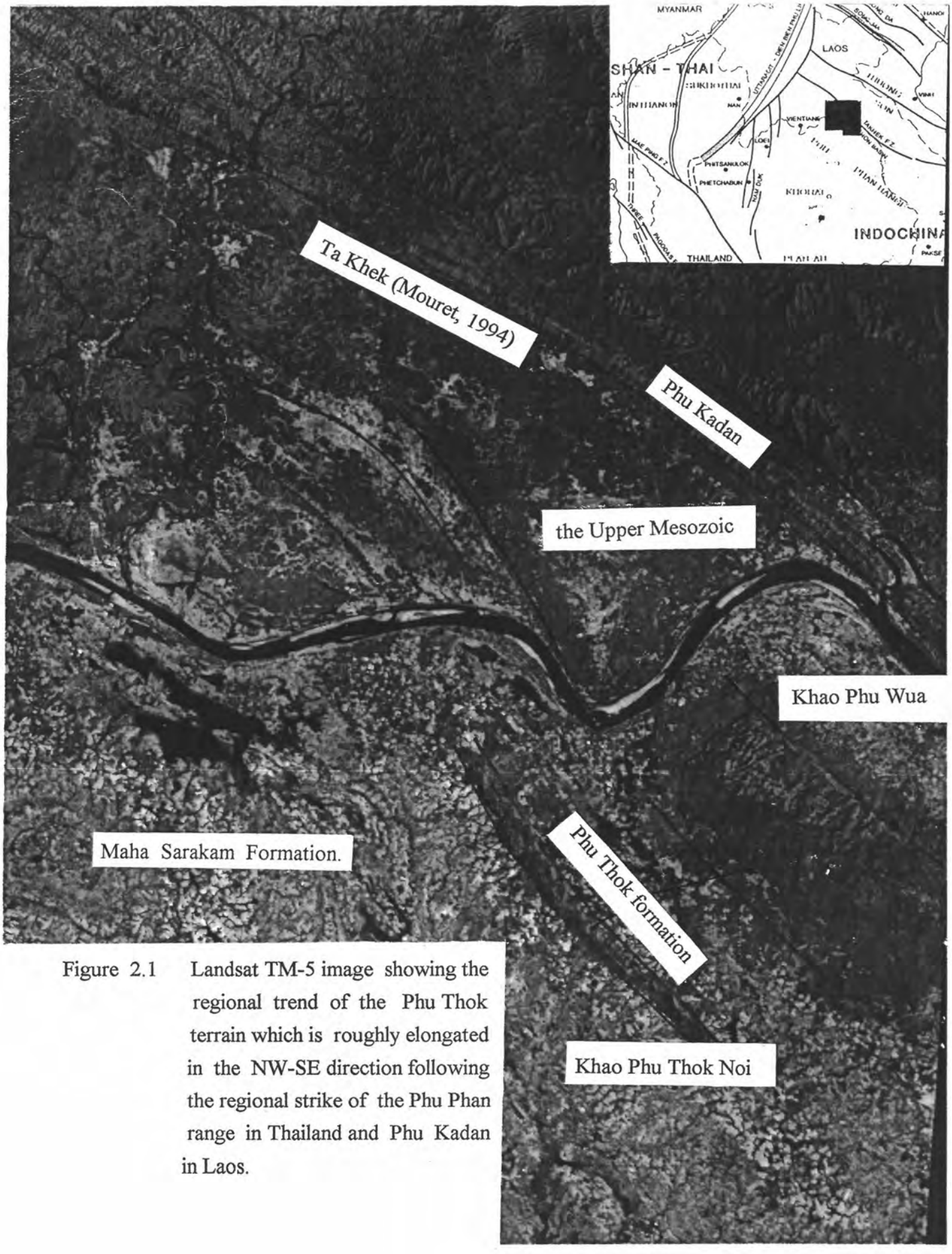

Figure 2.1 Landsat TM-5 image showing the regional trend of the Phu Thok terrain which is roughly elongated in the NW-SE direction following the regional strike of the Phu Phan range in Thailand and Phu Kadan in Laos.

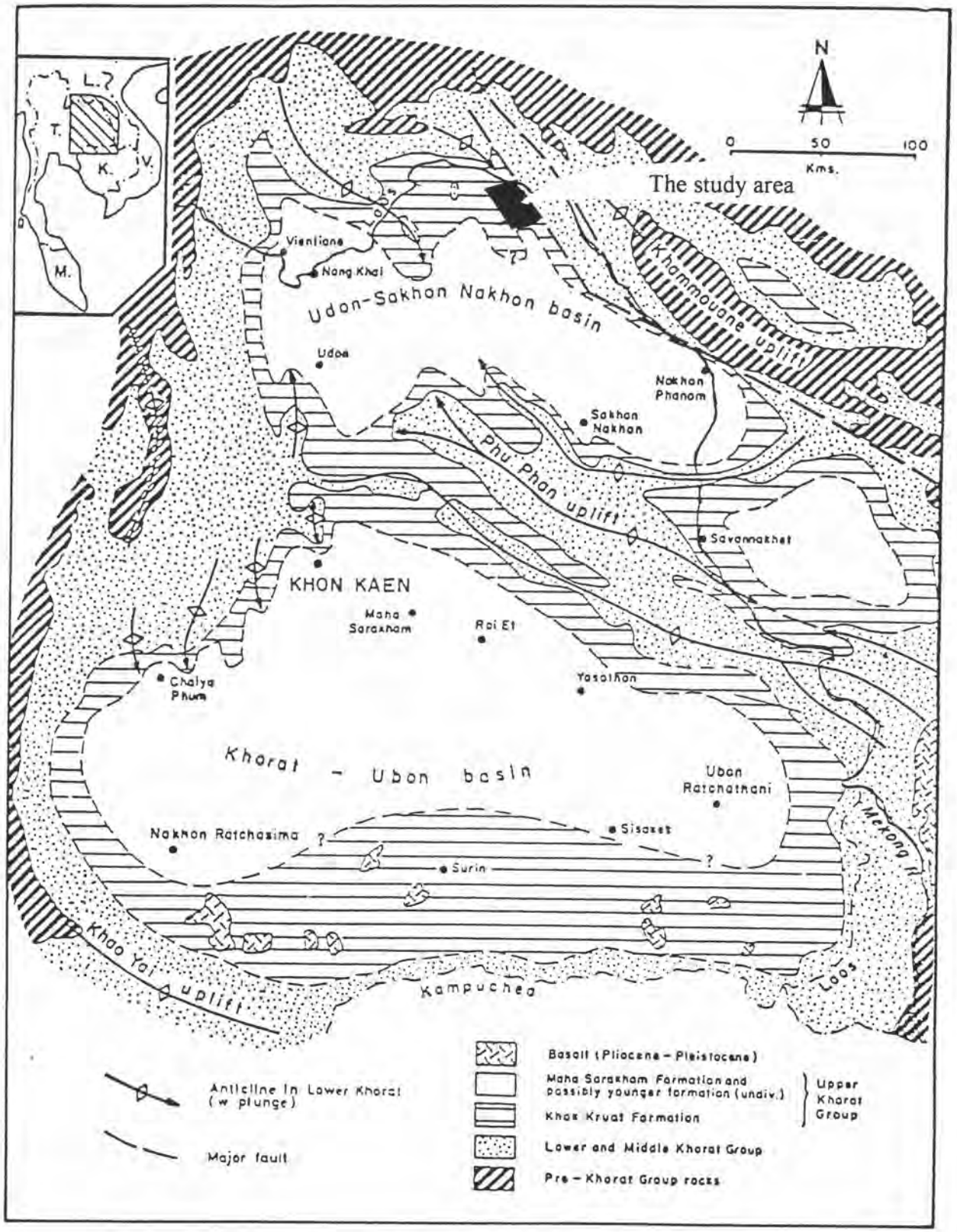

Figure 2.2 Generalized geologic map of northeastern Thailand and neighbouring area of Laos (after Japakasetr and Workman, 1981).

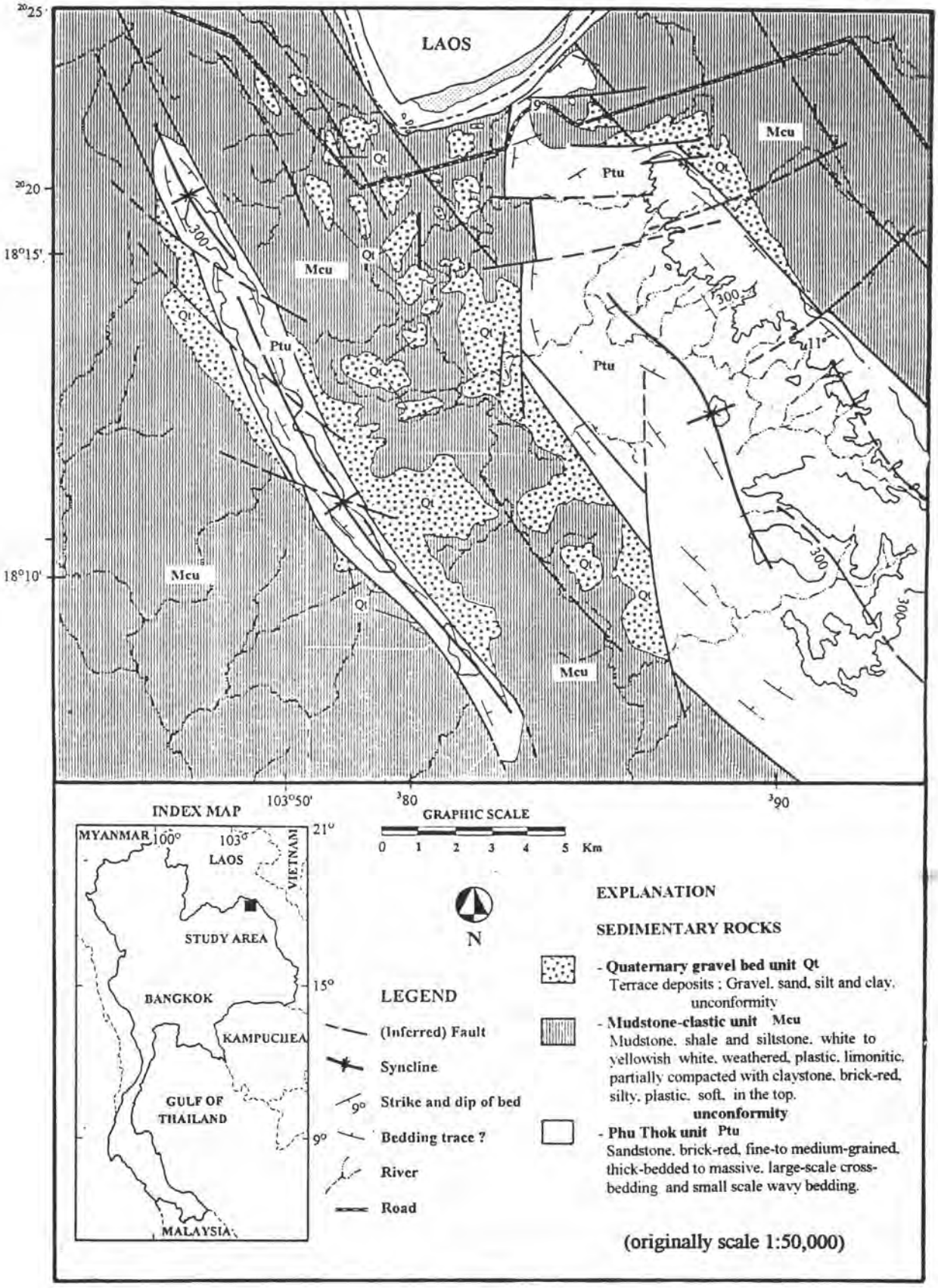

Figure 2.3 Geologic map of the study area.

Figure 2.4 Natural outcrop of the Phu Thok unit (formation), showing the resistant cliff which is composed of thick bedded, multi-directional, cross-bedded sandstone (photo taking at Phu Wua section; grid reference 910161).

Figure 2.5 Outcrop of Mudstone-clastic unit showing a subhorizontal, well-bedded (up to 0.5 m thick), grayish white siltstone at roadcut, the northern part of the area (photo taking near the highway no.212 at km 165 to 166 ; grid reference 855222).

rock are reddish brown to red siltstone, colorless quartz fragments, mica, caliche nodules and iron concreted grains. The grains of phenoclasts are angular and can be easily recognized from weathered surfaces of rock. The approximate thickness of this unit in the area (by detailed field mapping) exceeds 5 m. However, the unpublished data from ground water drilling in 1978 suggested the thickness of mudstone-clastic unit in the area ranging from 0 to 10 m. The general attitude of bedding is horizontal.

The youngest unconsolidated gravel bed occurred as small hills in the central part of the area. It unconformably overlies the strata of Maha Sarakam Formation. The semi-consolidated sediments comprises of imbricated, quartz pebbles in the pale orange red silty clay to sandy silt. The quartz gravels are somewhat semi-rounded to suboval and are averagely 2-3 cm in diameter (Fig.2.7). The oriented pebbles indicate the river current to the NW-SE direction. The thickness of this gravel bed is estimated to be over 5 m in the field. However, subsurface data from groundwater drilling reveal the thickness ranging from 30 up to 50 m in some places. It is noted that the alluvial deposit is rarely found in the study area.

2. Structure

Major structural trend in the area lies approximately in the NW - SE direction. This trend is a part of the regional trend of the Khorat rock sequences in the northeastern Thailand. In fact, the mountain swings from northwest to roughly north, becoming part of the Phu Phan range (see Fig.2.1). It is also noted that only the Phu Thok unit (formation) in the mountainous area is conformed with the regional trend. Fault systems in the area have two trends. One is the NW-SE fault, extending from Phu Kadan to Ta Khek Fault (Mouret, 1994) in Laos. The trend of the fault is normally conformable with orientation of the mountain ranges. The escarpment of the mountains in the mapped area may act as the fault scarp (Pattarametha and others,1988). The other is the N-S fault, occurring at Khao Phu Wua, certainly forms the boundary between the Phu Thok and the mudstone-clastic units. There are also

Figure 2.6 The weathered surface of Mudstone-clastic unit showing angular-shaped red siltstone on weathered grayish white siltstone to mudstone (photo taking near the highway no. 212 at km 166-167; grid reference 856227).

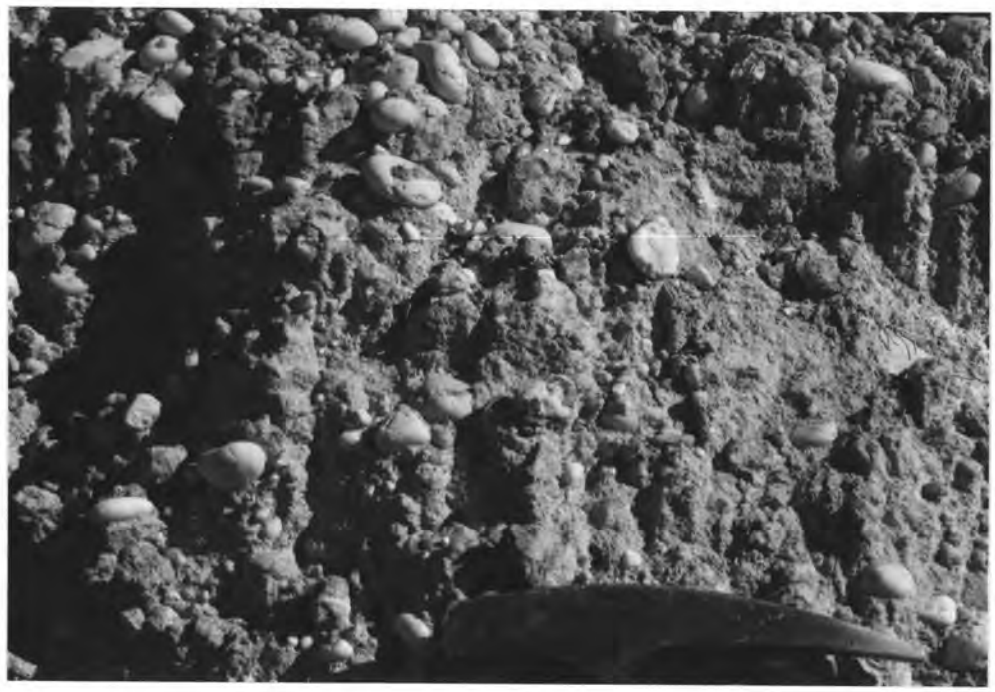

Figure 2.7 The oriented, clean-surfaced quartz and feldspar gravels in the pale orange-red silty clay to silty sand of the Quaternary deposit in the area, at small hill near Ban Nong Yao, the central part of the study area (grid reference 791171).

minor faults and fractures in the area trending approximately NW-SE and NE-SW directions.

Foldings of the area are only shown at the Phu Thok terrain. The Phu Sink Range, where the southernmost end is the Phu Thok, is the syncline which oriented approximately in the NW-SE direction in the lower part of the Phu Thok formation and slightly N-S direction in the upper part. The Phu Sink syncline is about 20 km in length and 1-2 km in width. Dipping of the western side of the syncline is about 5° to 10° NE and that of the eastern part is about 3° to 7° SW. This fold is rather symmetrical and its axis roughly parallel to some extent with the drainage divide of the mountain range (see Fig. 2.2). The other range, the Phu Wua, is a broad syncline with the axis of folding in the NW-SE direction. Both flanks of this Phu Wua fold are easily revealed by the escarpment topography. The Phu Wua syncline is asymmetrical and with about 25 km in length and 8-10 km in width. Dipping of the western side of the syncline is 7° to 10 ° NE and the eastern part is about 11° to 15° SW.

3. Unconformity

Generally, the mudstone-clastic unit is unconformably underlain by the Phu Thok unit and lies unconformably beneath the semi-consolidated sediments. Aerial-photographic interpretation indicates that the rims of Phu Sink and Phu Wua ranges are fault-bounded and almost parallel to the strike of Phu Thok rocks. Field checking certainly considered the sharp contact along the flanks of the mountains. However, the angular unconformity of both units is shown at the stream near Khao Phu Thok Noi, the north of Phu Wua range (Grid ref. 849221). The inclined beds of the Phu Thok unit are covered with gently dipping mudstone-clastic bed. The abrupt change in lithology of the gravel beds and the mudstone-clastic bed may be an unconformable event.