# CHAPTER 1

# INTRODUCTION

The gemstone and ornament industries produced many income to Thailand. The industry ranges into number 6 of the first 20 commodities exported from Thailand and it has the tendency to increase income (Table 1.1). Thailand has to import gemstones from other countries to be raw materials supporting the industries. Because gemstones from the important sources in Thailand such as blue sapphire from Kanchanaburi Province, ruby – sapphires, garnet, spinel, pyroxene, and zircon from Chanthaburi, Trat, Ubon Ratchathani and Si Sa Ket Provinces are decreasing. Accordingly, the gemstones areas, previously been evaluated as low potential, are re – considering for exploration.

Si Sa Ket and Ubon Ratchathani Provinces are the only discovered gemfields in northeastern Thailand. However, there are rare data for the sedimentary aspects in terms of lithofacies and sedimentology of the gemfields, especially the lithofacies of paleochannel sediments which gemstones are found. The lithofacies study of gemstone-bearing sediments in these gemfields should be a first step in understanding the fluvial environment of the paleochannels in these areas. The method to be used for this study involves two main steps: satellite imageries and sedimentological analyzes. The first method provides useful information to trace the distribution of sediments, paleochannels and geological structures. The second also provides data concerning provenance and depositional environments of gem - bearing sediments. The results of the study can be applied for interpretation of provenance and depositional environments for the same type of corundum deposits.

Table 1.1 The first 20 commodities exported from Thailand during 2002-2006 (modified from www.ops2.moc.go.th/trade/trade_exp.html).

| No. | Kind of commodity | 2003 | 2004 | 2005 | 2006 (Jan.-May.) |
|---|---|---|---|---|---|
| | | Million baht | Million baht | Million baht | Million baht |
| 1 | computer hardware and accessories | 339,939.8 | 368,875.9 | 474,950.5 | 221,802.6 |
| 2 | car equipment and accessories | 164,705.8 | 220,801.5 | 310,524.2 | 143,872.2 |
| 3 | electronic curcuit | 191,540.3 | 196,444.3 | 221,450.7 | 105,609.5 |
| 4 | rubber | 115,796.9 | 137,465.5 | 148,868.4 | 78,517.3 |
| 5 | Plastic grain | 89,204.8 | 124,808.6 | 168,138.9 | 70,404.8 |
| 6 | Gemstone and ornament | 104,525.6 | 106,278.9 | 129,357.3 | 61,134.1 |
| 7 | radio set, television set and accessories | 103,764.7 | 129,542.5 | 126,995.9 | 50,230.1 |
| 8 | ready-made clothes | 114,744.6 | 124,267.2 | 126,693.9 | 48,707.9 |
| 9 | Chemistry products | 65,897.4 | 82,847.9 | 106,015.3 | 47,670.8 |
| 10 | Instance oil | 42,404.8 | 71,074.2 | 95,012.5 | 47,378.1 |
| 11 | Steal and steal products | 70,222.3 | 99,588.2 | 116,078.2 | 47,019.4 |
| 12 | Rubber products | 64,668.2 | 78,050.0 | 94,385.0 | 45,209.5 |
| 13 | Air conditioner and accessories | 59,779.0 | 79,947.8 | 87,394.5 | 44,769.5 |
| 14 | Canned and transformed sea food | 88,789.1 | 90,711.6 | 100,602.6 | 41,186.8 |
| 15 | Electrical equipment and accessories | 44,722.8 | 77,753.4 | 92,152.9 | 37,427.9 |
| 16 | Rice | 75,733.1 | 108,293.2 | 93,470.8 | 37,268.4 |
| 17 | Machinery and machine equipments | 51,721.4 | 67,155.8 | 85,333.4 | 36,387.5 |
| 18 | Plastic products | 51,447.4 | 56,658.8 | 71,470.7 | 28,708.0 |
| 19 | Internal explode machine and accessories | 22,720.0 | 49,873.2 | 55,096.8 | 24,977.4 |
| 20 | Crude oil | 27,020.9 | 33,575.6 | 56,308.2 | 24,089.5 |
| Total of 20 commodities | | 1,600,688.0 | 1,889,348.9 | 2,304,014.1 | 1,242,371.3 |
| others | | 1,323,253.4 | 1,436,281.2 | 1,570,809.7 | 693,957.9 |
| Cost of exported commodities | | 2,923,941.4 | 3,325,630.1 | 3,874,823.8 | 1,936,329.2 |

Source : the technology of information and communication centre with helping of Customs Department note : in 2006 is from January to May.

## 1.1 OBJECTIVE OF STUDY

i) To investigate the occurrence and trend of Quaternary palaeochannels in the gemstone deposit areas.

ii) To study lithofacies and depositional environments of gemstone-bearing sediments including the study in relationship between corundum, zircon and sediments they are deposited.

## 1.2 SCOPE AND METHOD

**1.2.1) SCOPE**: This thesis intends to study lithofacies and occurrences of gemstone-bearing sediments in areas of Si Sa Ket and Ubon Ratchathani Provinces in northeastern Thailand.

**1.2.2) METHODS:**

i) Interpretating the extent of palaeochannels and other geomorphic units from satellite imageries;

ii) Study of Quaternary stratigraphy and associated gemstone-bearing sequences using lithologic logs from existing boreholes and pit data;

iii) Study of lithofacies and depositional environments of gemstone-bearing sediments using sedimentary characteristics including grain size, grain texture, grain composition, and sedimentary structures;

iv) Analyzes of data and interpretation.

v) Thesis writing

## 1.3 LOCATION AND TOPOGRAPHY OF THE STUDY AREAS

### 1.3.1 LOCATION OF THE STUDY AREAS

The study areas are located at the latitude 14° 20′00″ - 14° 35′ 00″ north and the longtitude 104° 15′ 00″ - 105° 00′ 00″ east (at the 1586000-161200 meter north and 419000-500000 meter east according to UTM system zone 48) on the topographic maps: sheet 5838 II, 5838 I, 5938 III, 5938 IV, 5938 II and 5937 I, (scale 1 : 50, 000) covering an area of 1,200 square kilometers approximately.

The gemfields are discovered unevenly in Khun Han and Kantaralak Districts of Si Sa Ket Province, and in Nam Khun and Nam Yuen Districts of Ubon Ratchathani Province as shown in Figure 1.1.

Generally, Si Sa Ket Province is located adjacent to Ubon Ratchathani Province bounded with a stream called Lam Som as the provincial boundary. However, they are also located in the northeastern part of the Kingdom of Thailand at the southern edge of the Khorat Plateau.

Si Sa Ket Province, having an area of 8,839.976 square kilometers, is also adjacent to Ya Sothon and Roi Et Provinces to the north, Surin Province to the west, Ubon Ratchathani Province to the east, and to the south with the 127 kilometer – long borderline between the Kingdom of Thailand and the Kingdom of Cambodia. There are 26 gateways to enter to Cambodia under the control of the Thai military force and border police.

Ubon Ratchathani Province, having an area of 16,112.650 square kilometers, is adjacent to Amnat Charoen and Ya Sothon Provinces, and Lao People's Democratic Republic (Lao PDR), all to the north, Si Sa Ket Province to the west, Lao PDR to the east, and Si Sa Ket Province, Lao PDR (361 kilometers) and Cambodia (67 kilometers) all to the south.

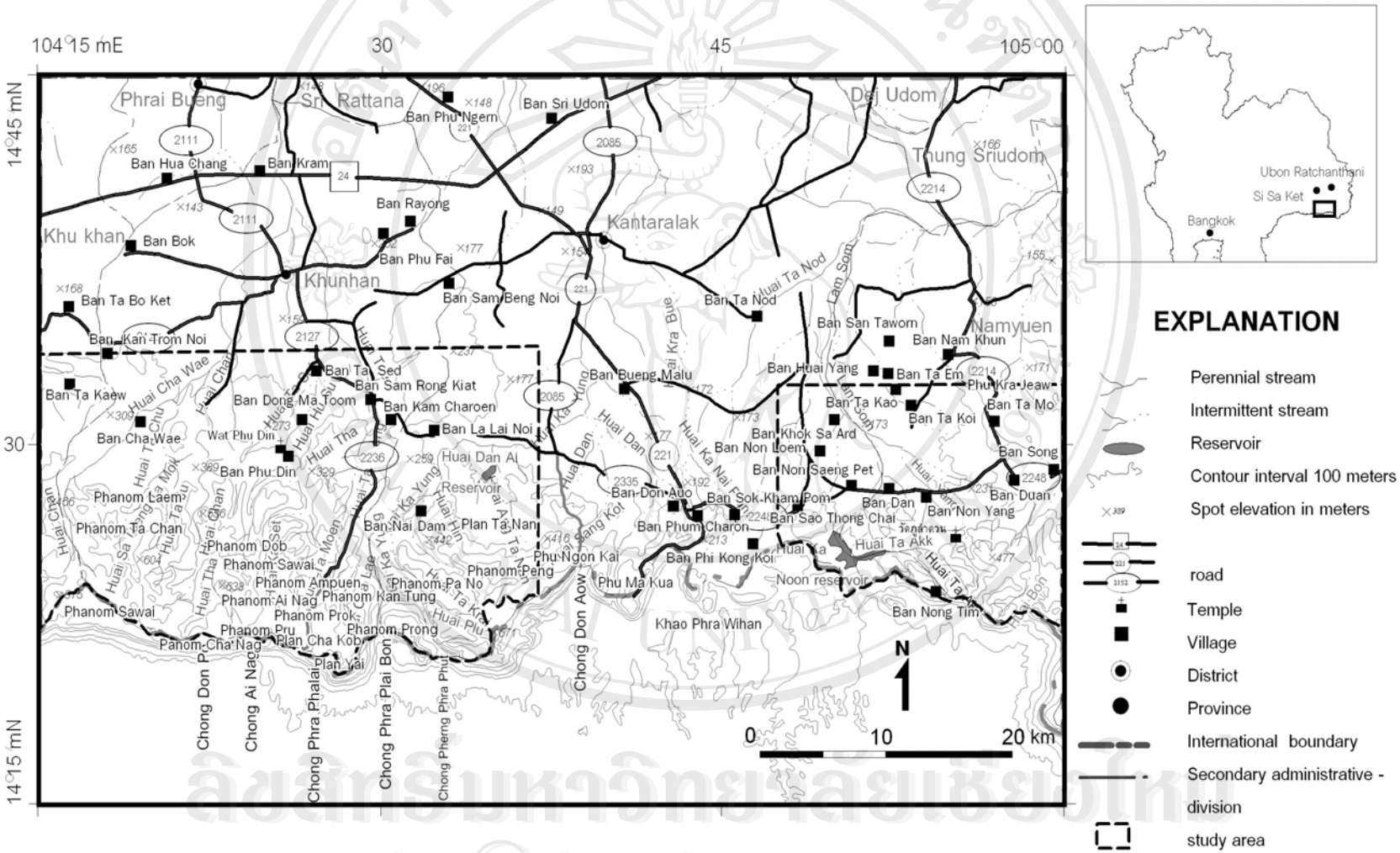


Figure 1.1 Location, topography and transportation of the study areas

### 1.3.2 TOPOGRAPHY OF THE STUDY AREAS

The study areas are a part of the southern edge of the Khorat Plateau. It is composed of Phanom Dongrak mountainous range in the south, the foothills and plains in the north. The volcanic outcrops demonstrating such kind of lava flow and small knolls, are scattering around the areas. These volcanic outcrops are seen around the south edge of the Khorat Plateau. The study areas are slightly tilted from south to north. On the average, the elevation of Si Sa Ket and Ubon Ratchathani Provinces are 102 and 68 meters above mean sea level, respectively.

The gemfields in the study areas can be divided into two parts, the western and eastern portions (Figure 1.1). The important streams in the western part consist of Huai Chan, Huai Ta Chu, Huai Tha, Huai Ta Moen, Huai Ta Beng and Huai Fung (Huai; stream). The direction of these streams is from south to north and rather straight following geologic structures. They always have their tributaries flowing perpendicular to main stream flows. All streams flow to the bigger streams and reservoirs in the north.

In the eastern part, the important stream (Huai Ta Akk) has the northwest-southeast flow direction and has its tributaries flowing in perpendicular direction. Huai Ta Akk runs to Huai Kanoon reservoir which is a part of Huai Dan; both of them joins other streams such as Huai Plan, Huai Yang, Huai Chong Panuang to be Lam Som which runs passing the flood plain areas. Lam Som runs to the bigger streams and reservoirs located in the northeastern part.

The characteristics of drainage pattern in the Panom Dongrak mountainous area are always straight lines and perpendicular tributaries, resulted from lineament structures of basement rocks. The dendritic drainage pattern is always seen in the floodplain areas where underlying sediments are homogeneous.

## 1.4 GEOLOGY OF THE STUDY AREAS

### 1.4.1 TECTONIC SETTING

Basaltic rocks discovered in the study and adjacent areas are determined geochemically as Hawaiite (Jungyusuk and Sirinawin, 1983; Suthirat *et al*., 1994). This indicates continental setting related to hot spots (Simandl and Paradis, 1999). On the other hand, the occurrence of Hawaiite confirms primarily that the sediments in the study areas including the gemstones are originated in the continental setting related to hot spots.

Sattayarak *et al.* (1998) mentioned about tectonic evolution of the northeastern part of Thailand including the Khorat Plateau. Northeastern Thailand comprises two main areas: the mountains of the Loei – Petchabun Foldbelt and the Khorat Plateau. The geology of these areas consists of a sequence of Permo - Carboniferous carbonates and shallow marine siliclastics which are unconformably overlain by the Triassic Pre-Khorat lacustrine sequence, the continental Khorat redbeds and younger sediments. Basement rocks consist of Early Carboniferous granites and metamorphic rocks (Figure 1.2).

The Khorat Plateau covers the northeastern part of Thailand and extends across Mae Khong river to Laotian Territory and is divided into 2 areas: The Udon-Sakhon Nakhon area in the north and the Khorat – Ubon area in the south. Piyasin (1995) illustrated all sub-basins of the Khorat Plateau as shown in Figure 1.3. The study areas are located in the southeastern rim of Ubon sub-basin.



Bunopas (1981, 1992, 1994) proposed that the tectonic events of Thailand had been resulted from the collision of Shan – Thai terrane and the rest of Indochina terrane. Cooper *et al.* (1989) proposed the tectonic evolution of the Khorat Plateau as follows:

**Late Permian – Early Triassic** The first Indosinian orogeny occurred from the double side collision of Indochina with Shan –Thai and south China. A result

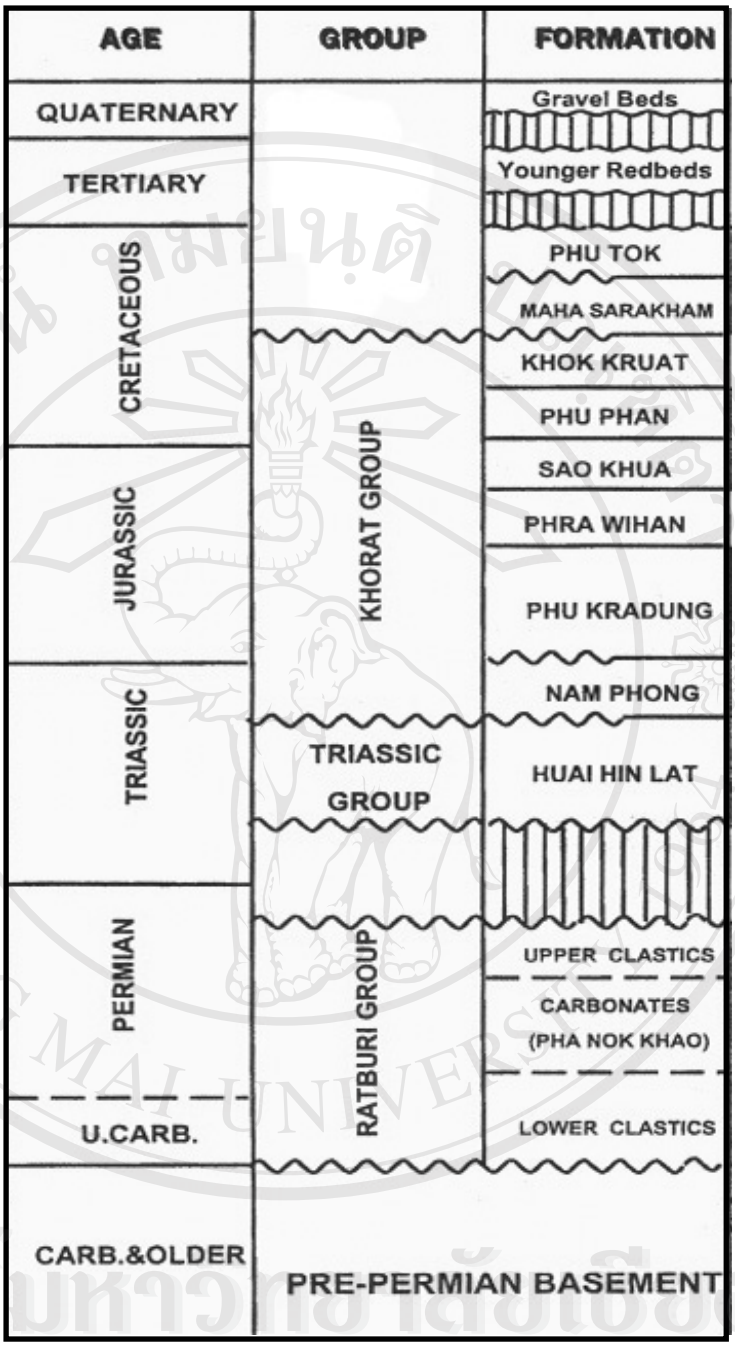


Figure 1.2 General stratigraphy of the Northeastern Thailand (modified from Sattayarak *et al*., 1998).

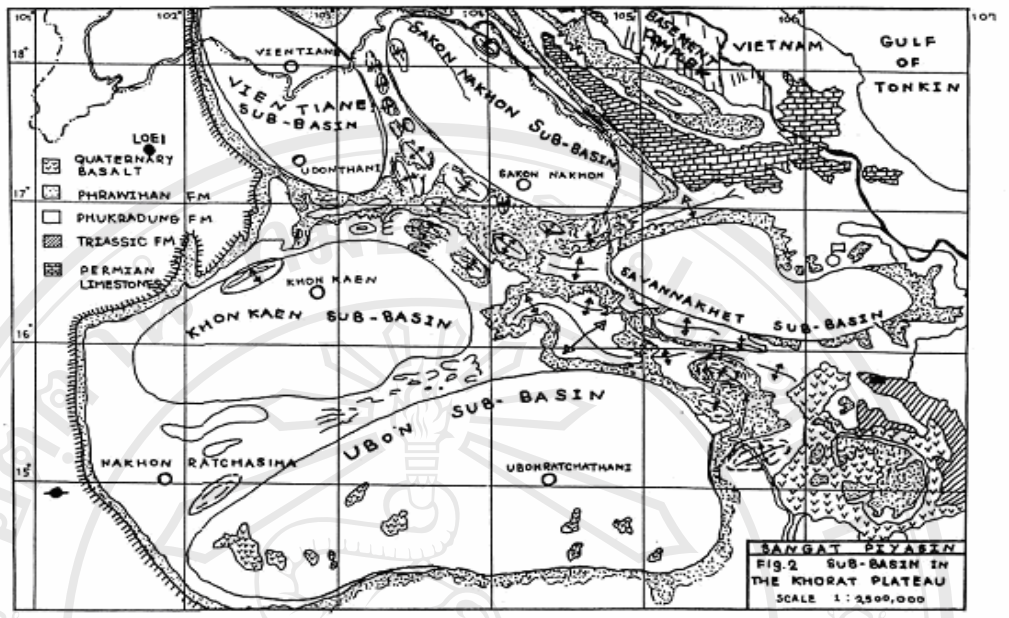


Figure 1.3 The locations of 5 sub – basins of the Khorat Plateau (after Piyasin, 1995 *in* Monjai, 2001).

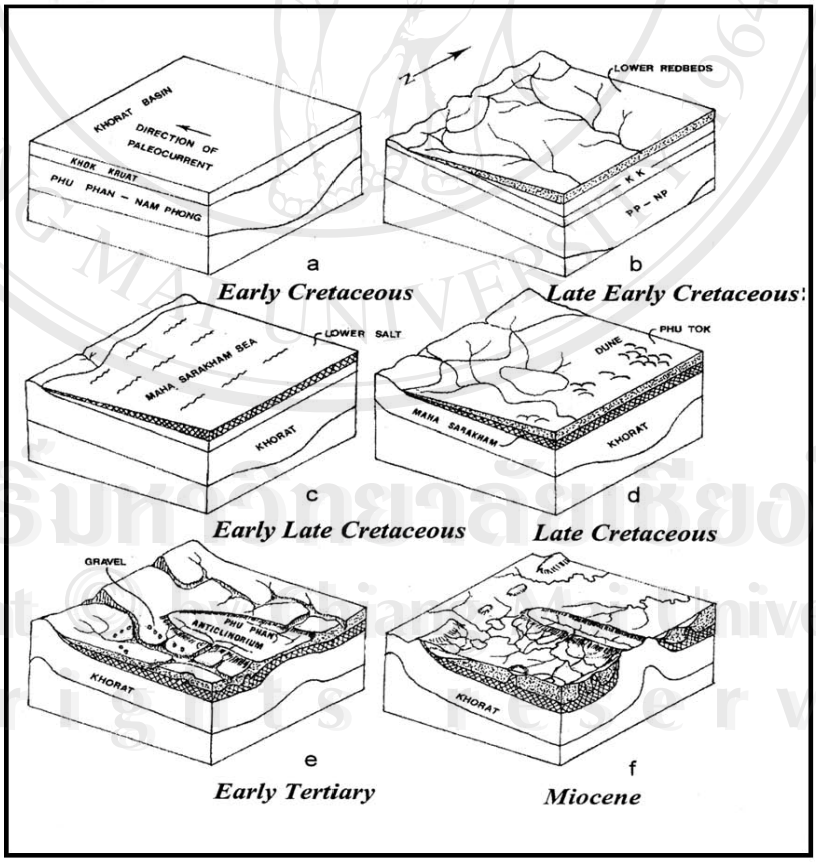


Figure 1.4 3D depositional modeling showing the tectonic events during Cretaceous to Tertiary (after Sattayarak *et al.*, 1998).

was the Permian sediments in an area called Loei – Petchabun Foldbelt were folded, uplifted and eroded (Wielchowsky and Young, 1985 *in* Sattayarak *et al*., 1998). Higher degrees of tight and trust folds decreased eastward into the Khorat Plateau. This orogeny was accompanied by granitic intrusion and volcanic eruption.

**Late Triassic** The overthickened crust was resulted from Indosinian orogeny collapsed. It was caused from the Permian strata subsided, and a NW-SE trending isolated half basins developed in the northeast on eroded Permian strata. Data from petroleum well drilling suggest that the environment of deposition in these Triassic half graben basins varied in both own inner and outer parts of each basin, such as from open lake to semi - arid fluvial plain. During this time there was the deposition of the Huai Hin Lat Formation.

At the end of Triassic, a mild compression occurred locally along major faults, resulting in a minor inversion and erosion of Triassic sediments (the inversion is hypothesized that results from changing of the sinistral transtensional to transpressional of corresponding faults).

After the termination of Triassic rifting basins, basin of deposition was changed from isolated basin to be pervassive fluvial and flood plains. Meesook (2001) concluded that the Nam Phong Formation was deposited during Late Triassic and followed by the Phu Kradung Formation during the Jurassic.

**Early Cretaceous** The Khorat Basin was terminated, and the Phra Wihan, the Sao Khua, the Phu Phan, and the Khok Kruat Formations occurred (Meesook, 2001). And the hypersaline sedimentary basins were developed (Figure 1.4 a-c). The Loei – Petchabun Foldbelt was brought up from the collision between West and East Burma. There were the Nakhon Thai basin in the west and the Maha Sarakham basin in the east of the Foldbelt.

The Maha Sarakham Formation was begun to form in the western part. Previously, this formation was eroded and transported to the east. Later the late Cretaceous Phu Tok Formation was formed (Figure 1.4 d).

Chantong (2005) studied the structural evolution of the Khorat Plateau by seismic stratigraphy comparing to the litho – stratigraphy and summarized that the major deformation of the Khorat Plateau would be caused by the collision of the West Burma and Shan Thai Block during the Middle Cretaceous. This event affected the Khorat Plateau uplift. Also, the inversion/ reactivation was driven again by the Himalayan Orogeny. Whereas Bunopas (1981; 1992; 1994) proposed as below:

**Early Tertiary** The distinguished evidence was Himalayan Orogeny because of the collision of India and Asia continental plates. A large wave length fold of the Khorat sequence, including the Phu Phan Anticlinorium and uplifting of Khorat Plateau occurred (Figure 1.4 e).

Hence, it can conclude that the Himalayan Orogeny was occurring during Middle Cretaceous - Early Tertiary.

**Miocene** The top of the Phu Tok Formation was formed (Figure 1.4 f).

**Tertiary – Recent** There is the deposition of gravel bed consisting of pebbles mixing with silicified wood and petrified wood. This gravel bed is proven that originated in the Tertiary age and was reworked from young redbeds underlying it. And the important geologic event of the Khorat Plateau is the uplifting of the southeastern rim, together with the intrusion of basaltic volcano and lava in the southern part of the Plateau (Figure 1.3).

Bunopas (1994) illustrated the tectonic events of the Khorat Plateau from Cambrian to Quaternary as seen in Figure 1.5.



### 1.4.2 GENERAL GEOLOGY OF THE STUDY AREAS

The main basis of geology in the study areas was from the Geological map of Chomkrasarn scale 1 : 250000 sheet ND48-5 (Pholprasit and Rattanajarurak, 1985) and Meesook (2001), and additional data from the investigation by author (Saraphanchotwitthaya and Tangpong, 2001) (during 1996 and 2001). The rocks

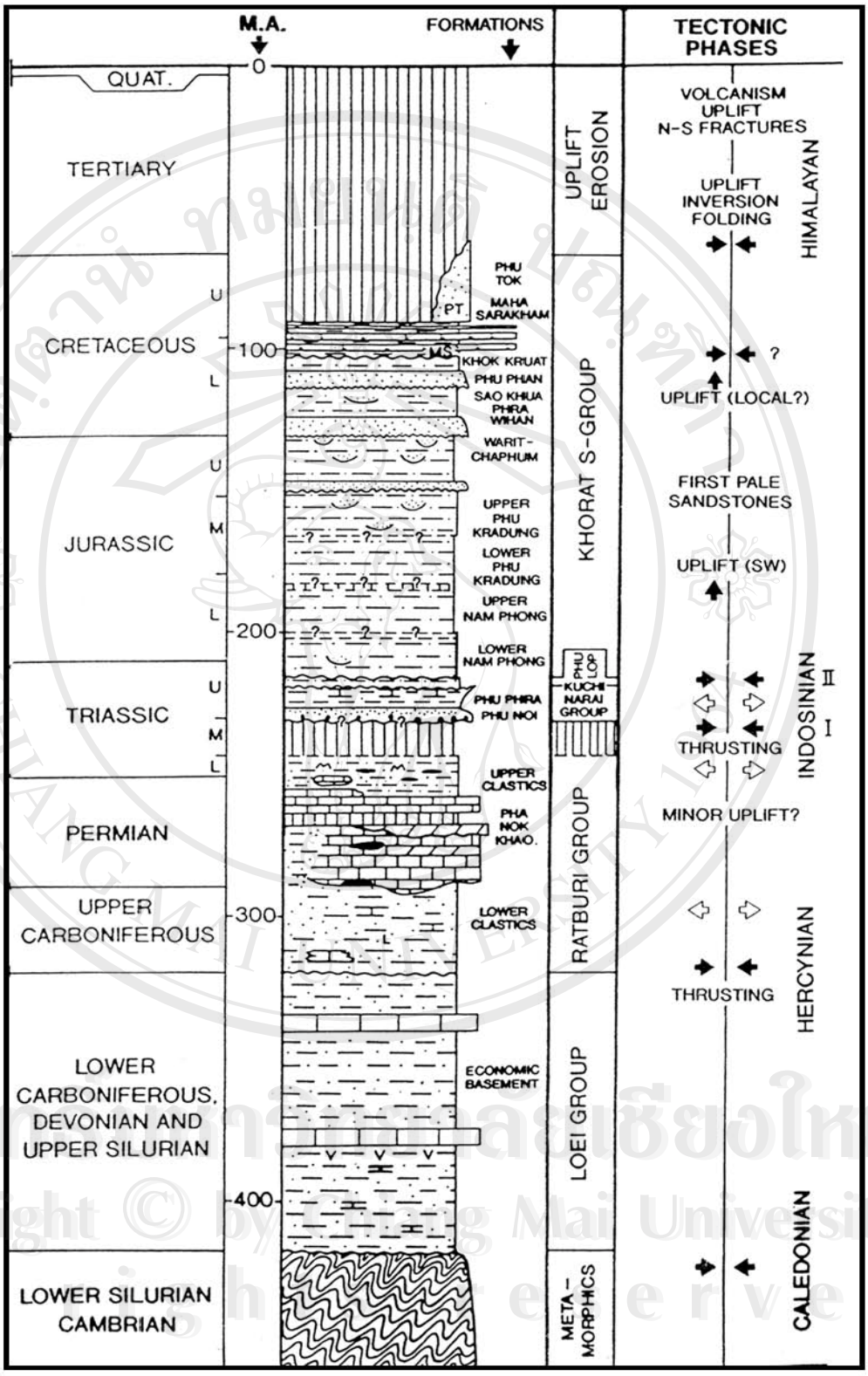


Figure 1.5 The stratigraphy of the Khorat Group which is correlating to times and important tectonic events (after Bunopas, 1994 *in* Monjai, 2001).

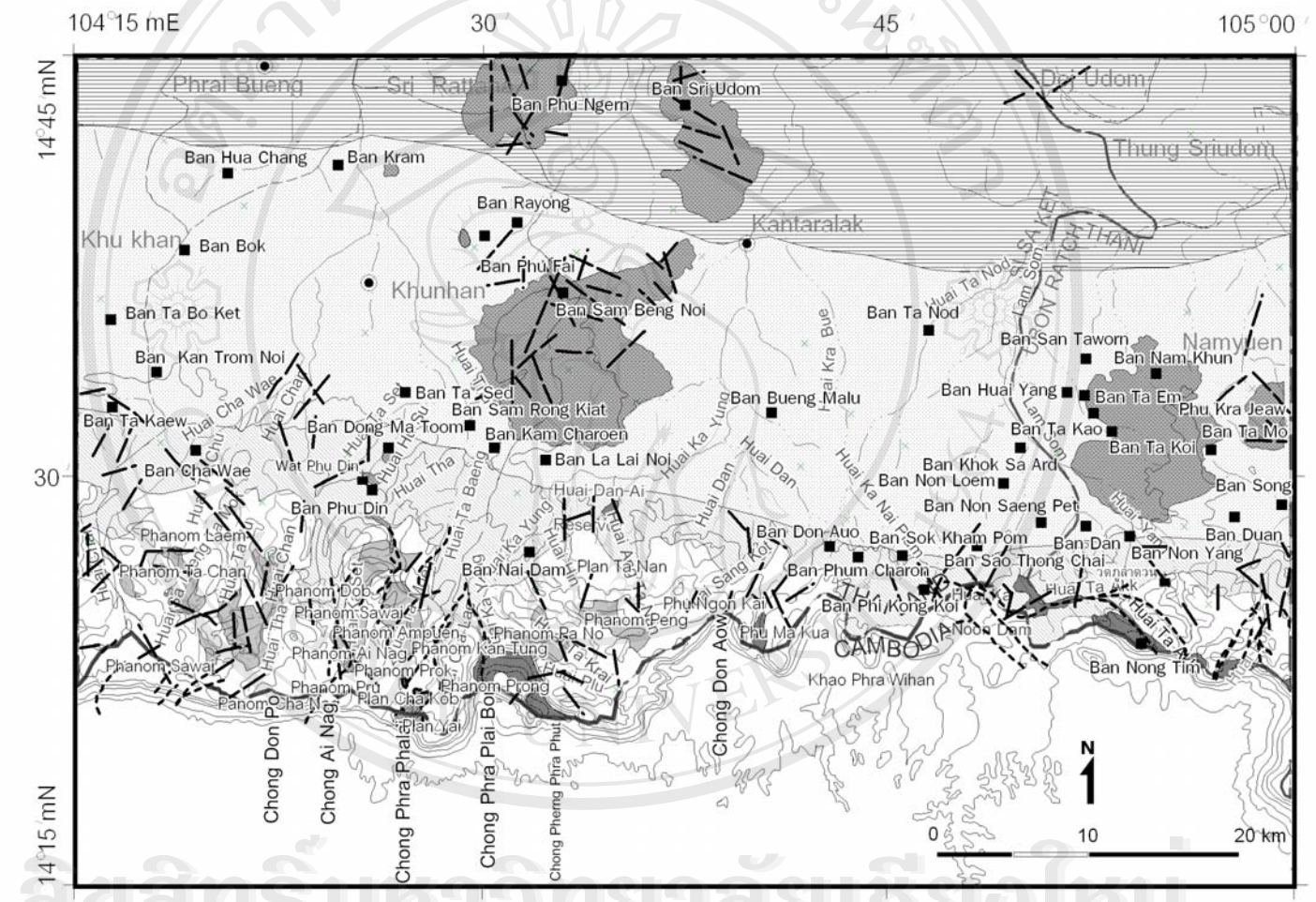


Figure 1.6 A General geology of the study areas ( modified from Pholprasit and Rttanajarurak, 1985 ).

The explanation is on Figure 1.6 B.

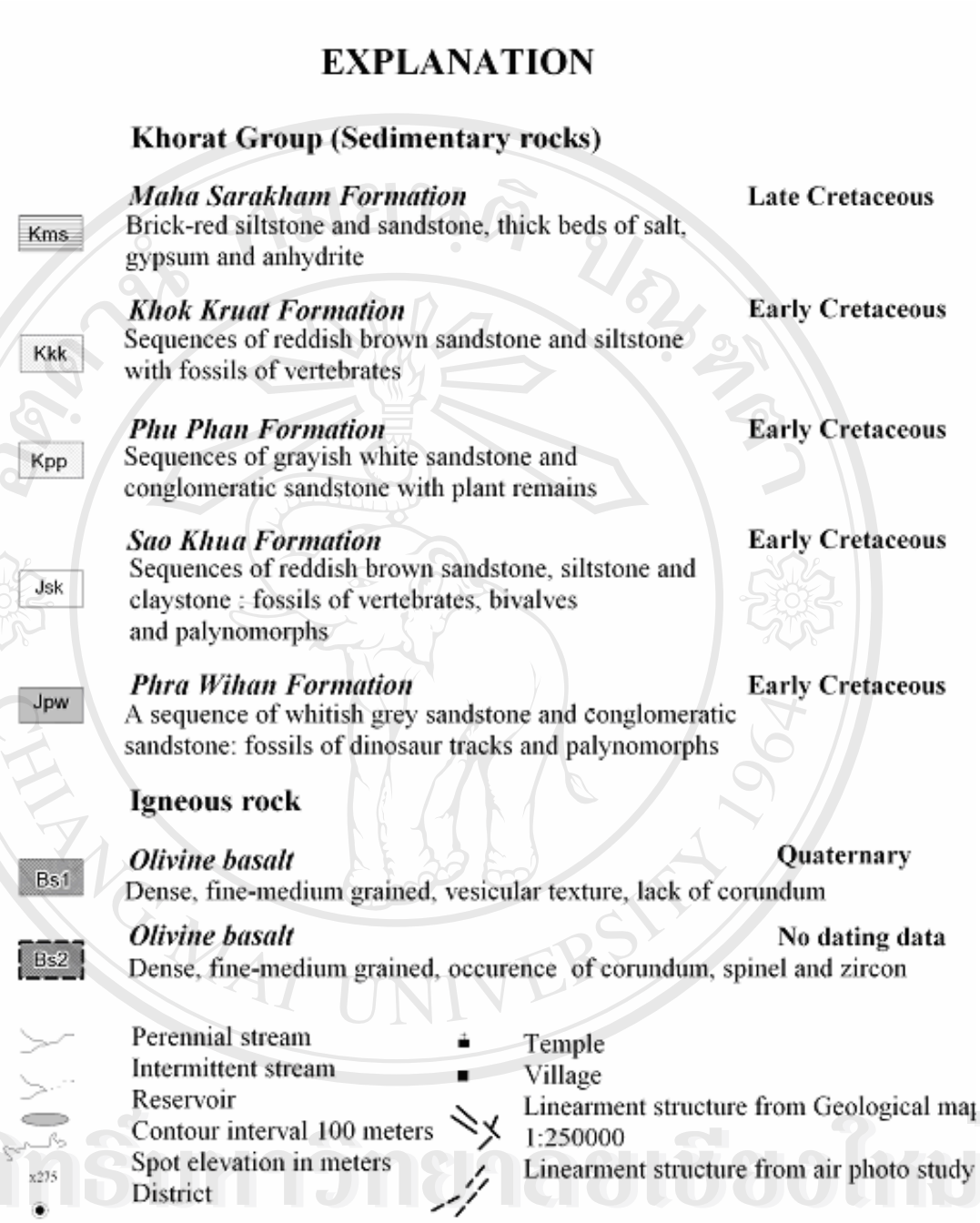




Figure 1.6 B The explanation for geological map of the study areas ( Pholprasit and Rattanajarurak, 1985; Meesook, 2001; Saraphanchotwitthaya and Tangpong, 2001).

discovered in the study areas can be divided into 2 groups. The first group is the sedimentary rocks of the Khorat Group ranging in age from Mesozoic – Cenozoic and the unconsolidated sediments ranging in age from Tertiary – Recent. The second is extrusive – igneous rocks of Tertiary age (Figure 1.6 a - b).

### 1.4.2.1 STRATIGRAPHY OF THE STUDY AREAS

#### *SEDIMENTARY ROCKS AND SEDIMENTS*

All sedimentary rocks discovered in the study areas are in the Khorat Group which comprises 6 formations; the Phra Wihan, Sao Khua, Phu Phan, Khok Kruat, and Maha Sarakham Formations, and unconsolidated sediments.

#### *i. THE PHRA WIHAN FORMATION*

This formation can be discovered along fault scarps. This is a sequence of whitish gray sandstone and conglomeratic sandstone, very thick bed showing cross bedding. The fossils of dinosaur tracks and palynomorphs are discovered. The Phra Wihan Formation is underlain by the Phu Kradung Formation and overlain by the Sao Khua Formation.

#### *ii. THE SAO KHUA FORMATION*

This rock unit is underlain by the Phra Wihan Formation and overlain by the Phu Phan Formation. Generally, it is seen along the fault scarp line and extent to northward but this unit is always absent scatteringly along fault scarps. The fresh rocks are rare for this formation so the topography of areas created by the Sao Khua Formation looks hilly or plains between hills of the Phra Wihan and Phu Phan Formations.

The Sao Khua Formation is composed of the sequences of reddish brown sandstone, siltstone and claystone. The fossils of vertebrates, bivalves and palynomorphs are found in these rocks.

### *iii. THE PHU PHAN FORMATION*

The formation lies on the Sao Khua Formation and underlies the Khok Kruat Formation. This rock unit is always discovered in front of moutainous ranges, showing the butte or mesa having long ridge topography. The Phu Phan Formation comprises the sequences of grayish white sandstone and conglomeratic sandstone with plant remains.

### *iv. THE KHOK KRUAT FORMATION*

The Khok Kruat Formation covers widely in the middle to almost upper part of the study areas and inclines to the middle part of the Khorat Plateau. Rocks of the Khok Kruat Formation are rather brittle and loosed, not resistant to weathering, so this formation is always weathered and changed to the mounds covered by sediments. The topography of land covered by the Khok Kruat Formation is always corrugated and no scarps. The Khok Kruat Formation is composed of sequences of reddish brown sandstone and siltstone with fossils of vertebrates. The formation is overlain by the Maha Sarakham Formation.

### *v. THE MAHA SARAKHAM FORMATION*

The Maha Sarakham Formation is unconformably underlain by the Khok Kruat Formation. This rock unit covers the upper part of the study areas. It is composed of brick-red siltstone, siltstone and claystone. This formation is covered by recent sediments in some places.



### *vi. THE UNCONSOLIDATED SEDIMENTS*

Unconsolidated sediments are dicovered in stream channels, terraces, flood plains and foot hills. The sediments in the mountainous area always show the angularity of fragments just broken from country rocks. If the well rounded gravels are discovered in the mountainous area, then they are derived from gravel beds of

country rocks. Fine sands are always seen in the flood plain areas and weathered hills. Paleochannel sediments comprise gravels and sands, and rare gemstones. These sediments always changes to be lateritic beds found beneath the recent sediments (Saraphanchotwitthaya and Tangpong, 2001).

### *IGNEOUS ROCK*

The igneous rocks in the study areas consists of 2 types; basaltic and diabasic rocks. They are dated as Tertiary- Quaternary in age. Most of them have no potential of corundum.

According to the geological map, it is clear to separate the igneous outcrops into 2 areas ; the western area in Khun Han District and the eastern area in Kantaralak and Nam Yuen Districts. No basaltic outcrop between both areas is discovered (Saraphanchotwitthaya and Tangpong, 2001).

#### *i. IGNEOUS ROCK IN THE KHUN HAN DISTRICT*

#### *1. BASALTIC OUTCROP AT BAN PHU NGERN (BAN : VILLAGE)*

This outcrop locates along the boundary of Khun Han and Kantaralak Districts. It covers approximately 40 square kilometers. The body of outcrop altered to be very thick soil horizon. No gemstone was discovered from pitting and panning.

#### *2. BASALTIC OUTCROP AT BAN KRAM*

The outcrop is located in Phrai Subdistrict of Khun Han District, covering 1.10 square kilometers. The body of outcrop altered to be very thick soil horizon. No gemstone was discovered from pitting and panning in the area.

#### *3. DIABASIC OUTCROP AT KHAO PHU FAI*

This 70 meters hill is located in Khun Han District covering 0.50 square

kilometers. It is diabasic rock which is grayish black color, hard rock with the dark reddish brown garnet, black pyroxene, and green olivine embedding in the rocks. The soil altered from the outcrop is mixing with these gemstones. The rock from Khao Phu Fai was dated as 3.28 + 0.48 Ma (Jungyusuk and Khositanont, 1992 *in* Rattanaruangamphai and Trakoontewin, 2001).

***4. BASALTIC OUTCROP AT BAN SAM BENG***

The outcrop is located along the boundary of Khun Han and Kantaralak Districts. This outcrop is the continuity of small basaltic soil corrugations, covering an area of 118.0 square kilometers. The results from panning and pitting show a few potential of very small crystals of garnet and zircon.

***5. BASALTIC OUTCROP AT BAN DONG MATOOM AND BAN PHU DIN PATTANA***

The basalt is situated in Bak Dong Subdistrict of Khun Han District. The basaltic outcrop overlies the country rock of sandstone, particularly at Ban Dong Matoom where the outcrop is approximately 1 square kilometer with deep weathering as basaltic soil. Another basaltic outcrop at Ban Phu Din Pattana, 500 m southwest of Ban Dong Matoom, covers an area approximately 2.0 square kilometers. Most of outcrop bodies are altered except some parts at Phu Din Pattana Temple where fresh rock can be seen as being grayish brown color, very fine texture with a few vesiculars, and the surface is medium to high weathered. The results from panning and pitting show no potential of the gemstones from basaltic outcrops according to the previous investigations (Tritrangan, 1992; Tonthongchai and Monjai, 1998; Rattanaruangamphai and Trakoontewin, 2001). However, some corundum and zircon were discovered in old channel sediments underlying the basaltic outcrops (Tonthongchai and Monjai, 1998).



***6. BASALTIC OUTCROP AT KHAO PANOM KANTUNG (KHAO : HILL)***

Khao Panom Kantung, called 610 hill by the Thai military force, is located at the scarp fault (longitude 441300 meter east and latitude 1586950 meter north). This

area is very difficult to investigate because of many landmines. The basaltic area is estimated about 3 square kilometers but the position at the field army camp is a basaltic outcrop covering about 0.5 square kilometer. The outcrop shows columnar joint structure. The gemstones are discovered from basaltic soil of outcrop and vicinities. Those gemstones are garnet, zircon, black pyroxene, including very rare corundum.

### *7. BASALTIC OUTCROP IN HUAI KAYUNG AT BAN LA LAI*

Tonthongchai and Monjai (1998) reported a narrow-long body about 200 meters of basaltic outcrop along Huai Khayung (Huai: stream) is exposed at Ban La Lai in Kantaralak District. Potential of gemstone was not discovered.

## *ii. IGNEOUS ROCKS IN KANTARALAK AND NAM YUEN DISTRICTS*

### *1. BASALTIC OUTCROP AT BAN SRI UDOM*

The outcrop, about 41.0 square kilometers, is exposed at Ban Sri Udom. The basaltic body changes to be reddish brown color basaltic soil. The results from panning and pitting show no potential of gemstone.

### *2. BASALTIC OUTCROP AT BAN NAM KHUN – BAN TA MO*

This large outcrop is in Nam Khun and Nam Yuen Districts. It covers about 54.0 square kilometers. Most of rocks are altered to be basaltic soil mixing with organic matter especially in the top soil layer. No potential of gemstones as corundum, zircon and garnet are discovered in basaltic soil, but in lateritic sediments underlying basaltic soil.



### *3. BASALTIC OUTCROP AT PHU KRA JEAW*

This basaltic area is located in Nam Yuen District. The area consists of the continuity of small basaltic outcrops as Khao Noi, Phu Kra Jeaw, and other unnamed hills. It covers 20.0 square kilometers and the fresh of outcrops can be seen as an

quarry (Figure 1.7). The cross section from Phu Kra Jeaw mine shows 3 layers of basaltic outcrop; the top is 0.5 meter thick, reddish brown basaltic soil mixing with pumice and vesicular basalt; the middle is 4.2 meters thick, gray color-weathered basaltic rock showing 2-3 layered flows in its upper part; the bottom is rather fresh dark gray color rock, 4.7 meters thick, but still not the end of outcrop, very fine – grained texture.

No potential of gemstone is discovered in this basalt but very few amounts of zircon are found in lateritic sediments underlying the outcrop.

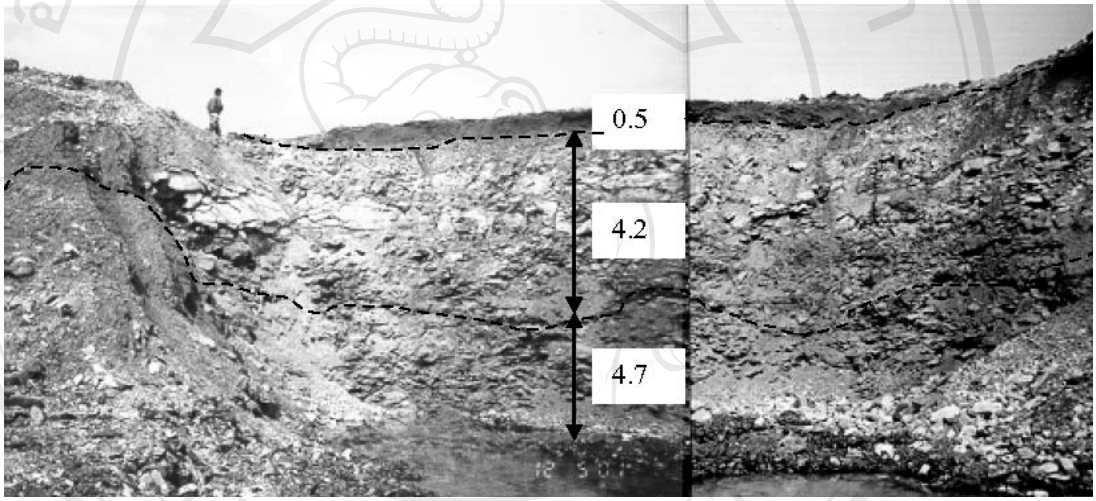


Figure 1.7 The cross section of Phu Kra Jeaw quarry, representing an outcrop of none gemstone basalt in the southern rim of the Khorat Plateau.

### 1.4.2.2 GEOLOGICAL STRUCTURE

The lineament structures of the Khorat Plateau including ones in the study areas are exhibited in the Figure 1.8. The structures in the study areas comprise small scale faults and fractures and they can be divided into 2 groups according to their directions as follows:

NW-SE and a few number of the almost 90 degree lineament structures.

NE-SW lineament structures.

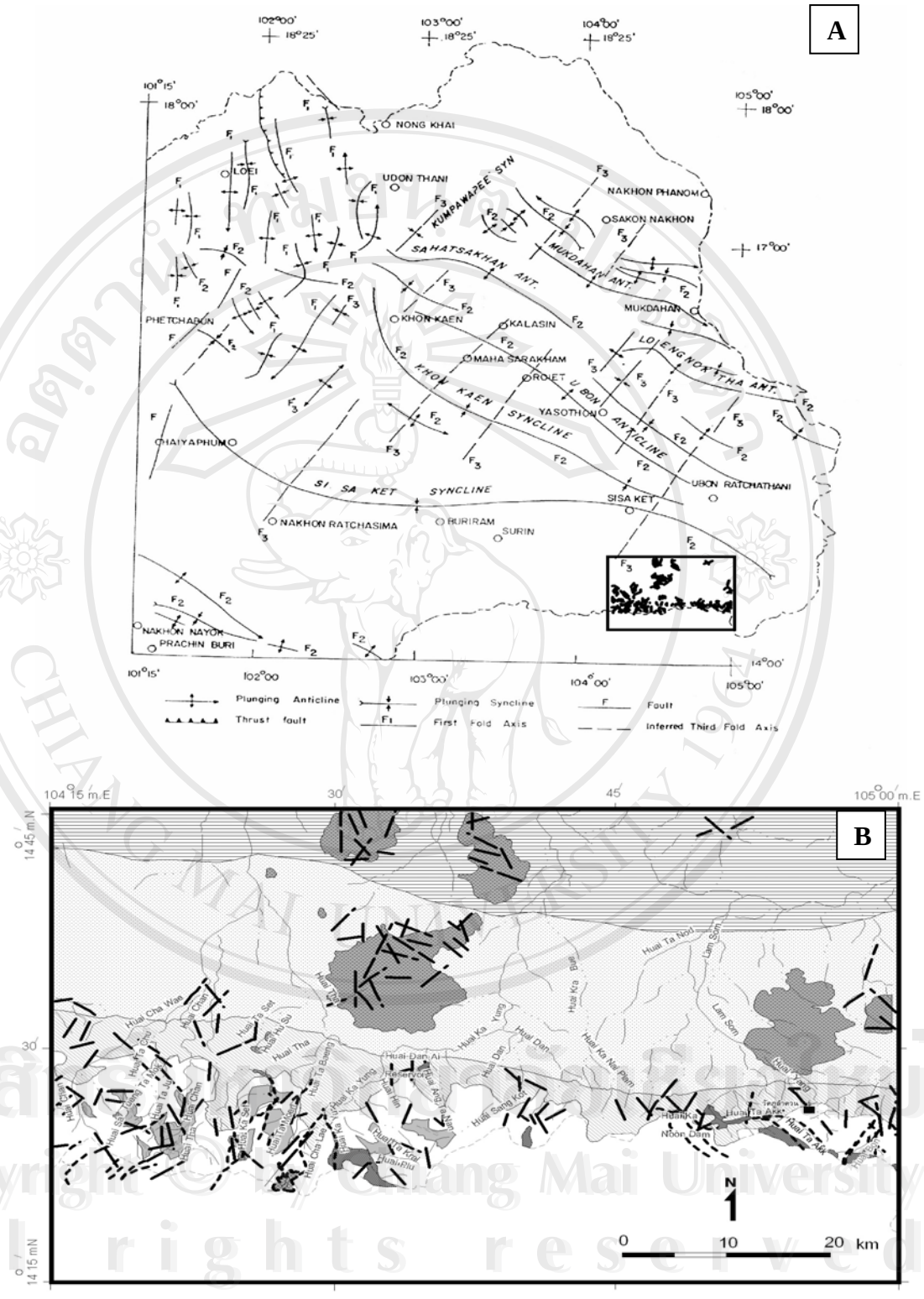


Figure 1.8 (A) Fault structures of the Khorat Plateau comparing to (B) lineament structures discovered in the study areas [modified from Chuaviroj (1997) *in* Monjai (2001)].

Chuaviroj (1997) analyzed the big scale of lineament structures consisting of folding and faulting in the Khorat Plateau by using satellite imageries and air photo images, and concluded that these lineament structures can be divided into 3 groups:

***The F1*** group has almost N-S direction, associated with the tectonic setting called Indosinian Orogeny.

***The F2*** group has NW-SE direction and ***the F3*** group has NE-SW direction, associated with the tectonic setting called Himalayan Orogeny.

Palmström (1995) quoted that "Faults constitute characteristic regional patterns in the earth's crust consisting of several mutual independent sets or systems. The main directions, which mainly were determined by the state of stress, have often the same orientations as the joint sets within the same structural area." The lineament structures in the study areas, therefore, correspond to ***The F2*** and ***the F3*** groups which are bigger scale structures. On the other hand, it can be concluded that both directions of lineament structures in the study areas are associated with the Himalayan Orogeny (Early Tertiary) compared to the bigger scale.

Rattanajarurak (1990); Sattayarak and Pholachan (1990); Mouret (1994); Bunopas (1994) *in* Tonthongchai and Monjai (1998) described the lineament structures in the Khorat Plateau that the uplifting of the Khorat Group both in northeastern Thailand and in Cambodia during the Eocene resulted in the formation of the Panom Dongrak mountainous ranges and fractures occurred generally in rocks. Then about Eocene, South China sea and Gulf of Thailand started up to open, so the compression relating with the southern part of Indochina including the Panom Dongrak mountainous ranges decreased. The fractures remaining in rock beds magnify especially in vertical direction, and first phase lava basalt flow can be erupted on to the ground.

### 1.4.3 ECONOMIC GEOLOGY

The appearance of gemstones as corundum, zircon, garnet, black pyroxene, etc. in the Khorat Plateau is hypothetically associated to the extrusive rocks as well as other corundum areas discovered in Thailand (Vichit, 1987). The distinctive characteristic is zircon found in enormous quantities comparing to other gemstones especially corundum.

Data from investigations in the Khorat Plateau [Aranyakanont *et al.*, 1970, Jungyusuk and Sirinawin, 1983, Pradabb *et al.*, 1990; Rattanaruangamphai and Trakoonthewin, (2001, Saraphanchotwitthaya and Tangphong, 2001, Tonthongchai and Monjai, 1998] reveal that the gemstone areas discovered scatteringly are confined to Khun Han, Kantaralak and Nam Yuen Districts (Figure 1.9). The gemfields can be separated into the western and eastern areas discontinuously because of no gemstone potential discovered between the western and eastern gemfields. The names of gemfields are derived from geologic localities when gemstones are found. Thus the western area is called Khun Han gemfield and Kantaralak gemfield is for the eastern area.

The Khun Han gemfield covers an area of approximately 630 square kilometers. The main kinds of gemstones discovered there are zircon, corundum, garnet and black pyroxene. The Kantaralak gemfield, about 200 square kilometers, zircon and corundum are dominant.

There are 2 types of depositions: Residual deposit in which gemstones are deposited in basaltic soil mixing basaltic fragments; and Alluvial deposit in which gemstones are deposited by fluvial system, mostly embedding in sediments. The distinction of both gemfields is concluded as shown in Table 1.2.



## 1.5 LITERATURE REVIEW

Aranyakanont *et al.* (1970) reported that there are gemstones in Si Sa Ket and Ubon Ratchathani Provinces; the main kinds are zircon, blue sapphire, and green sapphire. The minor amounts are garnet and magnetite.

Table 1.2 The distinction of Khun Han and Kantaralak gemfields.

| **Khun Han gemfield (Western study area)** | **Kantaralak gemfield (Eastern study area)** |
|---|---|
| 1. Gemstone area covers about 630 square kilometers. | 1. Gemstone area covers about 200 square kilometers. |
| 2. Residual deposit and alluvial deposit. | 2. Alluvial deposit. |
| 3. Gemstones in alluvial deposit show near-source characteristics. | 3. Gemstones in alluvial deposit show far-source characteristics, and widespread occurrence than Khun Han gemfield. |
| 4. Discovered zircon has smaller size (average size is 1-2 mm.) and fewer quantity than in Kantaralak gemfield. Other discovered gemstones are corundum, garnet, magnetite, ilmenite, sarnidine. | 4. Discovered zircon has bigger size (average size is 3-5 mm. or more) and more quantity than in Khun Han gemfield. Other discovered gemstones are corundum, garnet, magnetite, ilmenite , sarnidine. |
| 5. New gemstone deposit is discovered but very dangerous from enormous landmines. It is residual deposit type having potential of zircon, garnet, pyroxene, spinel, corundum, magnetite. The alluvial deposit type is presumed around this outcrop. | 5. Some small gemfields still have potential for small scale mining in the future when landmines are absent. |



Jungyusuk and Sirinawin (1983) studied many basalt outcrops of Thailand including the whole area in Kantaralak District of Si Sa Ket Province. They described that those basalt rocks display dark gray and small phenocrysts of olivine in a pyroxene and plagioclase groundmass.

Pholprasit and Rattanajarurak (1985) investigated the geology in Surin, Buri Ram, and Si Sa Ket Provinces for the purpose of compiling geologic maps. In

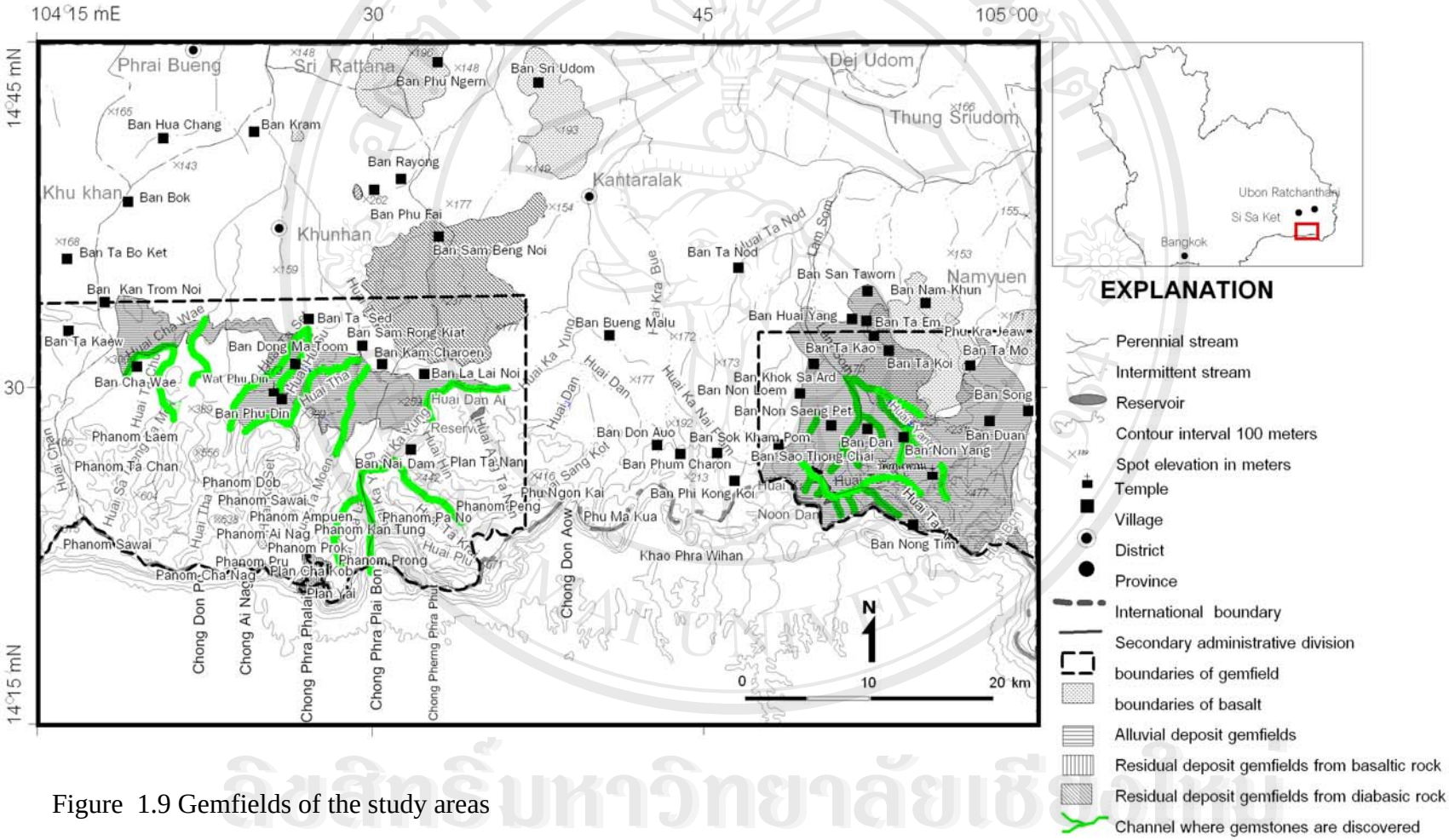


Figure 1.9 Gemfields of the study areas

these provinces, many Cenozoic basaltic outcrops were found, especially in Kantaralak District of Si Sa Ket Province.

Pradabb *et al.* (1990) investigated basaltic rock outcrops in the northeastern part of Nam Yuen District, Ubon Ratchathani Province. They concluded that there was no potential for gemstones within residual deposits.

Vichit (1992) reported that gemstone deposits occur in Kantaralak District in Si Sa Ket Province at Ta-akk stream, Nongtim Village, Dan Village, and Noenkamkaew Village. Gemstones have also been found in Nam Yuen District in Ubon Ratchathani Province at Santhaworn, Ta-em, Ta-koi, Ta-kao, Non Yang, and Non Saeng Phet Villages.

Tonthongchai and Monjai (1998) investigated the gemstone deposits in Khun Han and Kantaralak Districts. They concluded that gemstones were transported from basaltic rocks occurred in some parts of the Phanom Dongrak mountainous ranges.

Rattanaruangamphai and Trakoonthewin (2001) investigated the possibility of new gemstone deposits along the Thailand-Cambodia border in Buri Ram, Surin, and Si Sa Ket Provinces in 1996. An occurrence of zircon and a small amount of corundum was found in Khun Han District in Si Sa Ket Province. However, this deposit has low potential.

Saraphanchotwitthaya and Tangphong (2001) carried out an exploration for gemstone deposits in the flood plain of Lam Som stream. This stream forms the boundary between Kantaralak and Nam Yuen Districts and 125 holes were drilled into it. Some gemstone deposits were discovered by this drilling and they indicate that the Lam Som floodplain had a moderate potential for gemstone mining.