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Lithostratigraphy of the Late Triassic Huai Hin Lat Formation

at Amphoe Nam Nao, Changwat Phetchabun

Chineenart Prachaiboon

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### บทคัดย่อ

หมวดหินห้วยหินลาด จัดเป็นชั้นหินก่อนกลุ่มหินโคราช (Racey, 1996) มีการกระจายตัวในพื้นที่บริเวณขอบด้านตะวันตกของที่ราบสูงโคราช สามารถแบ่งออกเป็น 5 หนุ่หิน (Chinglakmani and Sattayarak, 1978) ซึ่งส่วนใหญ่ประกอบด้วย หินดินดาน หินโคลน หินทรายแป้ง หินทราย หินกรวดมน หินปูน สีเทาไปจนถึงสีดำ หินตะกอนภูเขาไฟและหินอัคนีพุ โดยบริเวณอำเภอน้ำหนาว จังหวัดเพชรบูรณ์ แสดงการกระจายตัวของหมวดหินห้วยหินลาดทั่วทั้งบริเวณ การศึกษานี้เน้นศึกษาลำดับชั้นหินหมวดหินห้วยหินลาด ในพื้นที่อำเภอน้ำหนาว จังหวัดเพชรบูรณ์

ผลการศึกษาพบว่าหน่วยหินในพื้นที่ศึกษาแบ่งออกเป็น 4 หน่วยหินเรียงตามลำดับล่างขึ้นบน ได้แก่ หน่วยหิน A ประกอบด้วยหินดินดาน สีดำ มีสารเชื่อมประสานแคลเซียมคาร์บอเนต มีลักษณะเป็นชั้นอย่างชัดเจน สละสมตัวในบริเวณทะเลสาบน้ำลึก หน่วยหิน B ประกอบด้วยหินดินดาน หินโคลน หินทรายแป้ง หินปูนเนื้อดิน สีเทา และชั้นถ่านหิน สละสมตัวบริเวณขอบแอ่งไปจนถึงบริเวณน้ำขัง หน่วยหิน C ประกอบด้วย หินดินดาน หินโคลน หินทรายแป้ง และหินทราย สีเทา มีสารเชื่อมประสานแคลเซียมคาร์บอเนต สละสมตัวบริเวณที่มีการเปลี่ยนแปลงจากแอ่งน้ำไปเป็นแม่น้ำ หน่วยหิน D ประกอบด้วย หินทรายและหินกรวดมน สีม่วงแดง ซึ่งไม่จัดอยู่ในหมวดหินห้วยหินลาด

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Project title: Lithostratigraphy of the Late Triassic Huai Hin Lat Formation  
at Amphoe Nam Nao, Changwat Phetchabun

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### ABSTRACT

The Huai Hin Lat Formation is the pre-Khorat Group strata (Racey, 1996) distributed at the western edge of the Khorat plateau. It can be divided into 5 members (Chonglakmani and Sattayarak, 1978) which almost all consist of grey to black shale, mudstone, siltstone, sandstone, conglomerate, limestone, volcanic clastic rock and volcanic rock. In the study area, Amphoe Nam Nao, Changwat Phetchabun, the distribution of Huai Hin Lat Formation is from the northwestern side to the southeastern side of the area. The aim of this report is to study in detail the lithostratigraphy of Huai Hin Lat Formation in the area of Amphoe Nam Nao, Changwat Phetchabun.

It is found that rock units in the study area can be classified into 4 units from ascending order as follows; unit A consists of black calcareous shale, well bedded and likely to be deposited in deep lacustrine environment. Unit B consists of grey calcareous shale, mudstone, siltstone, argillaceous limestone and coal seam which were deposited in the lacustrine margin and swamp environment. Unit C consists of grey calcareous shale, mudstone, siltstone and sandstone which was deposited in the transitional zone from lacustrine to fluvial system. Unit D consists of purplish red sandstone and conglomerate which is not classified into Huai Hin Lat Formation.

Keywords: Lithostratigraphy, Huai Hin Lat Formation, Khorat Group, Late Triassic, Amphoe Nam Nao

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# CHAPTER 1

## INTRODUCTION

### 1.1. BACKGROUND AND RATIONALE

The Huai Hin Lat Formation is the Triassic Pre-Khorat Group (Racey et al, 1996), it is angular unconformably underlain by the Permian sedimentary rocks of Saraburi Group and overlain by the Triassic Nam Phong Formation. In the past, there have been several studies of the stratigraphy of Huai Hin Lat Formation in the western edge of Khorat Plateau as shown in Table 1-1. Iwai and Asama (1964) divided the Khorat Group into 6 units of rock and established Huai Hin Lat Formation which type section is originally at Huai Hin Lat in Amphoe Chum Pae, Changwat Khon Khaen and classified it into upper and lower parts. Bunopas (1971) studied the stratigraphy at Nam Phom Dam (Chulabhorn Dam) and named it the Nam Pha Formation and assigned it as an underlying strata of Huai Hin Lat Formation. Chonglakmani and Sattayarak (1978) gathered Nam Pha and Huai Hin Lat Formation together according to common lithology and stratigraphy and divided it into 5 members; Pho Hai, Sam Khaen, Dat Fa, Phu Hi and I Mo members, and gave the age of Huai Hin Lat Formation as Late Triassic. Racey et al, (1996) classified the Huai Hin Lat Formation not a part of the Khorat Group. According to Department of Minerals Resources (DMR, 2012), reported the stratigraphy of the Huai Hin Lat Formation and concluded that it is a basal strata of the Khorat Group.

Period		Iwai and Asama. (1964)	Bunopas (1971)	Chonglakmani and Sattayarak (1978)	Racey et al, et al. (1996)	DMR (2012)					
Cretaceous	U	K H O R A T	Lom Sak	K H O R A T	K H O R A T	K H O R A T	Phu Tok	K H O R A T	Phu Tok		
	M		Ban Na Yo				Khok Kruat		Khok Kruat	Mahasarakham	Mahasarakham
	L		Phu Phan				Phu Phan		Phu Phan	Phu Phan	Phu Phan
Jurassic	U	O R A T	Phra Wihan	O R A T	O R A T	O R A T	Phu Kradung	O R A T	Phra Wihan		
	M						Phra Wihan		Phu Kradung	Phu Kradung	Phu Kradung
	L		Phu Kradung				Phu Kradung		Nam Phong	Upper Nam Phong	Phu Kradung
Triassic	U	G R O U P	Huai Hin Lat	G R O U P	G R O U P	G R O U P	Upper Nam Phong	G R O U P	Nam Phong		
			Huai Hin Lat				Huai Hin Lat		Lower Nam Phong	Nam Phong	
			Nam Pha				Huai Hin Lat		Huai Hin Lat		

Table 1-1 Stratigraphic subdivision of Khorat Group in northeastern Thailand.

According to several studies involved with the Huai Hin Lat Formation in northeastern Thailand, the definition and detail of Huai Hin Lat Formation vary in each area depending on the researcher. This research aims to study the litho-stratigraphy of Huai Hin Lat Formation in the area of Amphoe Nam Nao, Changwat Petchabun. Based on the geological map of Changwat Petchabun sheet NE47-16 (1:50,000), DMR, the Huai Hin Lat Formation distributes from the northwestern to southeastern parts of the area.



## 1.2. STUDY AREA

The study area is located in Amphoe Nam Nao, Changwat Phetchabun. It is in the northeastern region of Thailand connected to Amphoe Lom Kao and Amphoe Phu Luang, Changwat Loei at the north, Amphoe Phu Kra Dung, Changwat Loei and Amphoe Phu Pha Man, Changwat Khon Khaen at the east, Amphoe Khon San, Changwat Chai Ya Phum at the south and Amphoe Lom Suk at the west (Figure 1-1).

Figure 1-2 shows the distribution of rock units in Amphoe Nam Nao and surrounding area; Sraburi Group (Ps) in yellow, Huai Hin Lat Formation (Trhl) in light purple, Nam Phong Formation (Trnp) in fairy purple, Phu Kradung Formation (Jpk) in dark purple, Phra Wihan Formation (JKpw) in dark blue, Sao Khua Formation (Ksk) in fairy blue and Phu Pan (Kpp) Formation in light blue.

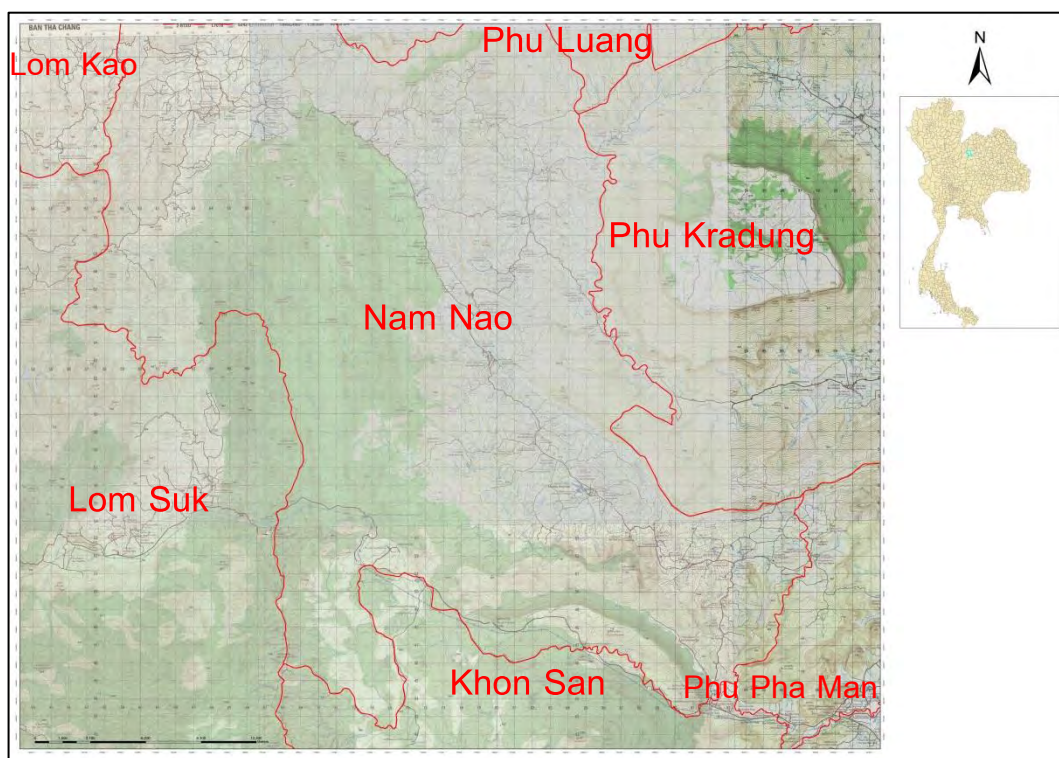


Figure 1-1. Topographic map of Amphoe Nam Nao, Changwat Phetchabun in map sheet 5342 IV (Amphoe Nam Nao), 5342 III (Khuean Chulabhorn), 5342 II (Amphoe Khon San) and 5342 I (Amphoe Phu Kra Dung).

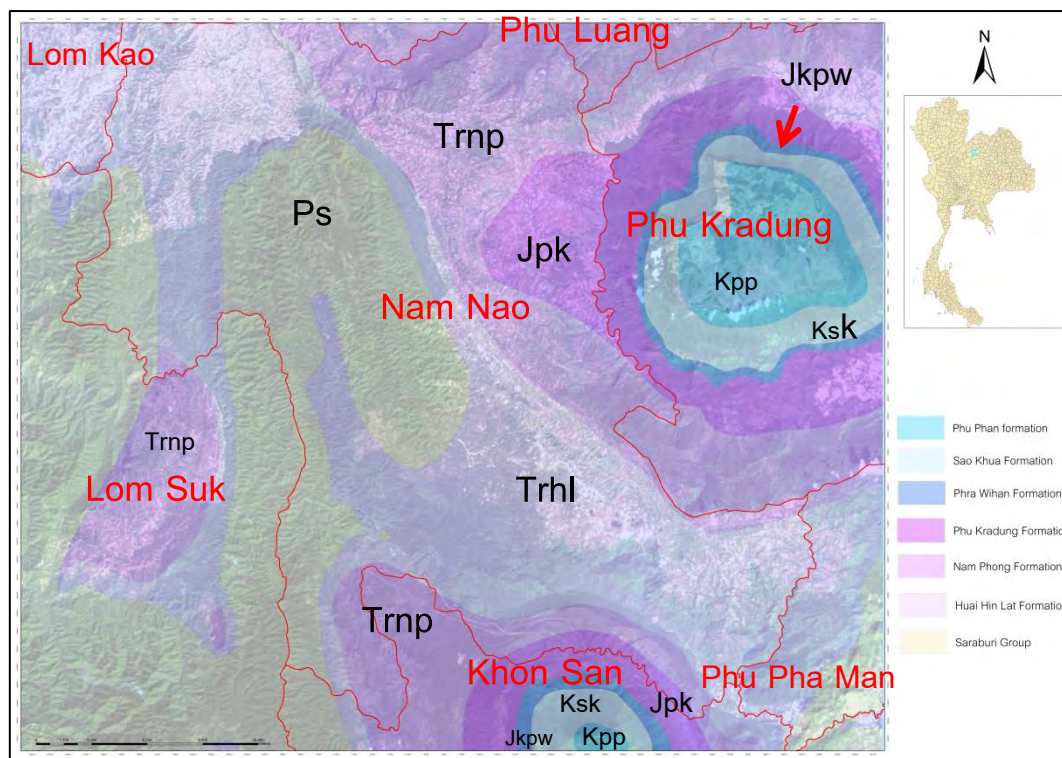


Figure 1-2. Geologic map of Amphoe Nam Nao, Changwat Phetchabun showing the distribution of Huai Hin Lat Formation in light purple area (DMR, 2007).

### 1.3. OBJECTIVES

1. To study the lithostratigraphy of Huai Hin Lat Formation in Amphoe Nam Nao.
2. To correlate each rock unit of Huai Hin Lat Formation in the study area.
3. To study the depositional environment of Huai Hin Lat Formation in the study area, according to the correlation of lithostratigraphy.

### 1.4. SCOPE OF STUDY

This study focuses on making lithostratigraphy column of Huai Hin Lat Formation in the area of Amphoe Nam Nao, Changwat Phetchabun in order to correlate each rock units in the whole area then study the depositional environment of the Huai Hin Lat Formation in the study area.

## 1.5. LITERATURE REVIEW

Huai Hin Lat Formation was first mentioned as a basement of Khorat Group by Iwai and Asama (1964) about the type section in Huai Hin Lat, Amphoe Chum Pae, Changwat Khon Khaen. It is 140 m thick and consists of lower and upper parts. The lower part consists of limestone conglomerate interbedded with some limestone and the upper part consists of grey sandstone, shale, siltstone with some limestone. The age was defined as Rathian from the evidence of land plant (*Neocalamites*)

Bunopas et al, (1971) established Nam Pha Formation as the lower strata of Huai Hin Lat Formation and also reported finding *Estheria* Sp. and some pollen (Haile et al, 1973) at Nam Phom Dam (Chulabhorn Dam) which indicates Carnian-Norian age (Upper Triassic).

Chonglakmani and Sattayarak (1978) established the Huai Hin Lat Formation which unconformably overlies Permian Saraburi Group and conformably underlies Nam Phong Formation of the Khorat Group. Its type section is along Huai Hin Lat, a small creek along highway number 12 in Amphoe Chum Pae, Changwat Khon Khaen and another 2 sections at Ban Dat Fa and Nam Phom Dam (Chulabhorn Dam). It can be classified into 5 members (Figure 4-3) in ascending order as follows;

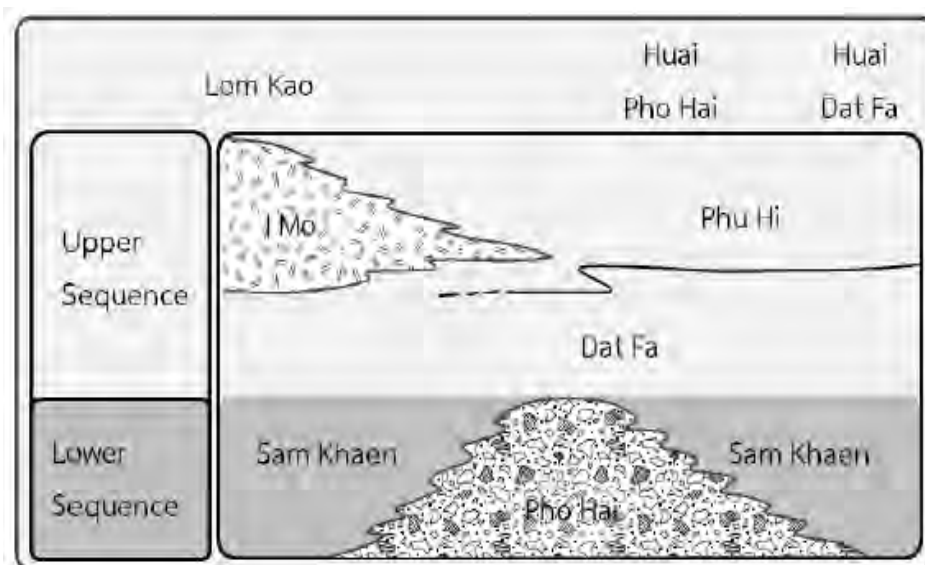


Figure 1-3. Illustration of distribution and correlation of each rock units in Huai Hin Lat Formation (Chonglakmani and Sattayarak, 1978).

#### 1. Pho Hai member

Consisting of volcanic sedimentary rocks such as tuff, agglomerate and volcanic igneous rock such as rhyolite and andesite interbedded with sandstone and conglomerate. The type section is along highway road number 12 Lom Sak-Chum Pae at Km 42-44.5. Pho Hai member overlies grey-black shale and siltstone or fossiliferous limestone of Permian age by angular unconformity.

#### 2. Sam Khaen Member

Sam Khaen conglomerate is the most distributed member of Huai Hin Lat Formation. It mostly consists of grey basal conglomerate (limestone conglomerate) interbedded with some limestone lens. In some areas, Sam Khaen conglomerate appears as red polymictic interbedded with red sandstone and shale. The type section is at Huai Hin Lat, a small creek 1 km. away from Ban Sam Khaen.

### 3. Dat Fa member

Dat Fa member consists of grey-black calcareous shale which is rich in carbon content. It appears as well bedded sometimes interbedded with argillaceous limestone, the type section is at Haui Dat Fa, Ban Tad Fa in Amphoe Phu Pah Man, Changwat Khon Khaen. Fossils found in Dat Fa member are *Estheria* Sp. and land plants.

### 4. Phu Hi member

Phu Hi member consists of grey sandstone, shale and argillaceous limestone which sometimes at the bottom of strata are interbedded with conglomerate. The type section is at Huai Phu Hi, Ban Tad Fa in Amphoe Phu Pah Man, Changwat Khon Khaen.

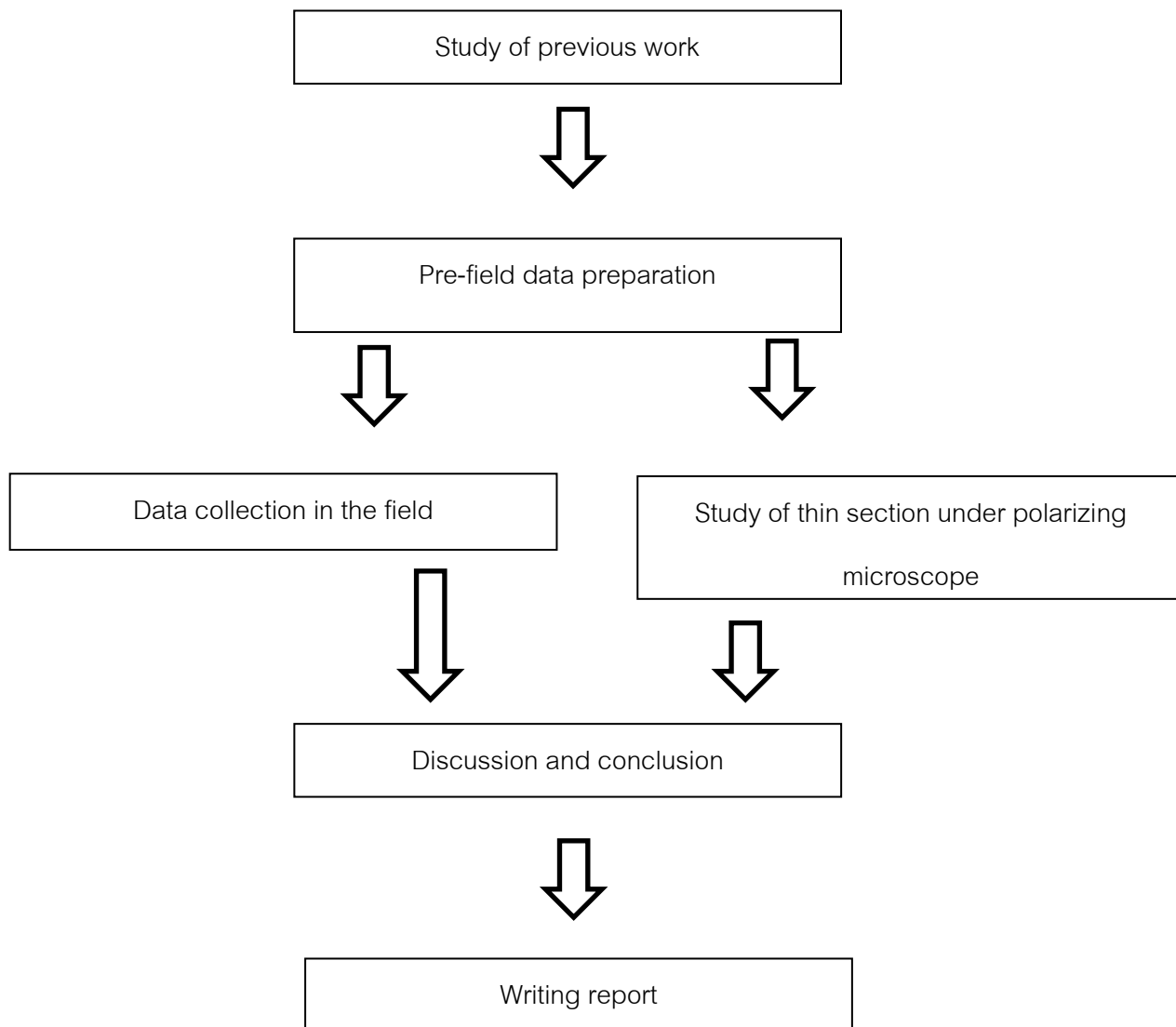
### 5. I Mo member

It is the uppermost part of Huai Hin Lat Formation. Consisting of facies of diorite and volcanic igneous rocks interbedded with shale, grey well bedded sandstone and bedded limestone. The type section of I Mo is at Khao I Mo, a small mountain 420 m. high in Ban Huai I Chin, Amphoe Lom Kao, Changwat Phetchabun.

Racey et al.,(1996) studied the stratigraphy and evolution of Khorat Group in northeastern Thailand. According to the petrography, Huai Hin Lat Formation and Nam Phong Formation have common sedimentary and igneous materials which are not generally found in other upper formations in the Khorat Group. So, they proposed that the Huai Hin Lat and Nam Phong Formations should be separated from the Khorat Group (Pre-Khorat Group).

## CHAPTER 2

### METHODOLOGY



1. Study of the previous work
  - Study the previous work (literature review) and report related to the Huai Hin Lat Formation in the study area.
2. Pre-field data preparation
  - Study the geological map, aerial photo and satellite image interpretation in order to plan for field work.
  - Use topographic map to plan for the accessibility of study area
3. Data collection in the field
  - Record the bed orientation, define rock type, make lithostratigraphy column (for the strata more than 1.5 m. thick) and collect rock sample.
4. Study of thin section under polarizing microscope
  - Make the thin section of collected rock sample
  - Study the thin section under polarizing microscope.
5. Discussion and conclusion
6. Report
  - Gather all data from the field work and laboratory work to write a report.

## CHAPTER 3

### RESULT

#### 3.1 DATA COLLECTION AND LITHOSTRATIGRAPHIC COLUMN ILLUSTRATION

Field work and data collection took place in the area of Amphoe Nam Nao, Changwat Phetchabun at 17 stations, as follows;

##### STATION 1

LOCATION: Road cut outcrop along rural road number 2216 at Ban Huai Sanam Sai, Tambon Khok Mon. The location is shown on the topographic map in Figure 3-1.

GRID REFERENCE: UTM 47Q 723063E 1845759N (Lat. 16°41'39.59" Long. 98°44'24.86")

DESCRIPTION: Road cut outcrop along rural road number 2216 at Ban Huai Sanam Sai, Tambon Khok Mon is approximately 15 m. long and 6 m. high (Figure 3-2). It consists of sedimentary rocks; calcareous shale, argillaceous limestone, mudstone, siltstone and coal seam. Attitude of bedding is 153/29°.

The lithostratigraphic section of this station includes 2 sections; Sec.1 (Figure 3-3) in the southern part and Sec.2 (Figure 3-4) in the northern part of the road cut. According to the bed orientation Sec. 2 is overlain by Sec.1. Two samples of shale are collected from Sec.1 and Sec.2 to make thin section. Photographs of thin section of section 1 are shown in Figure 3-5, while those of section 2 are shown in Figure 3-6.



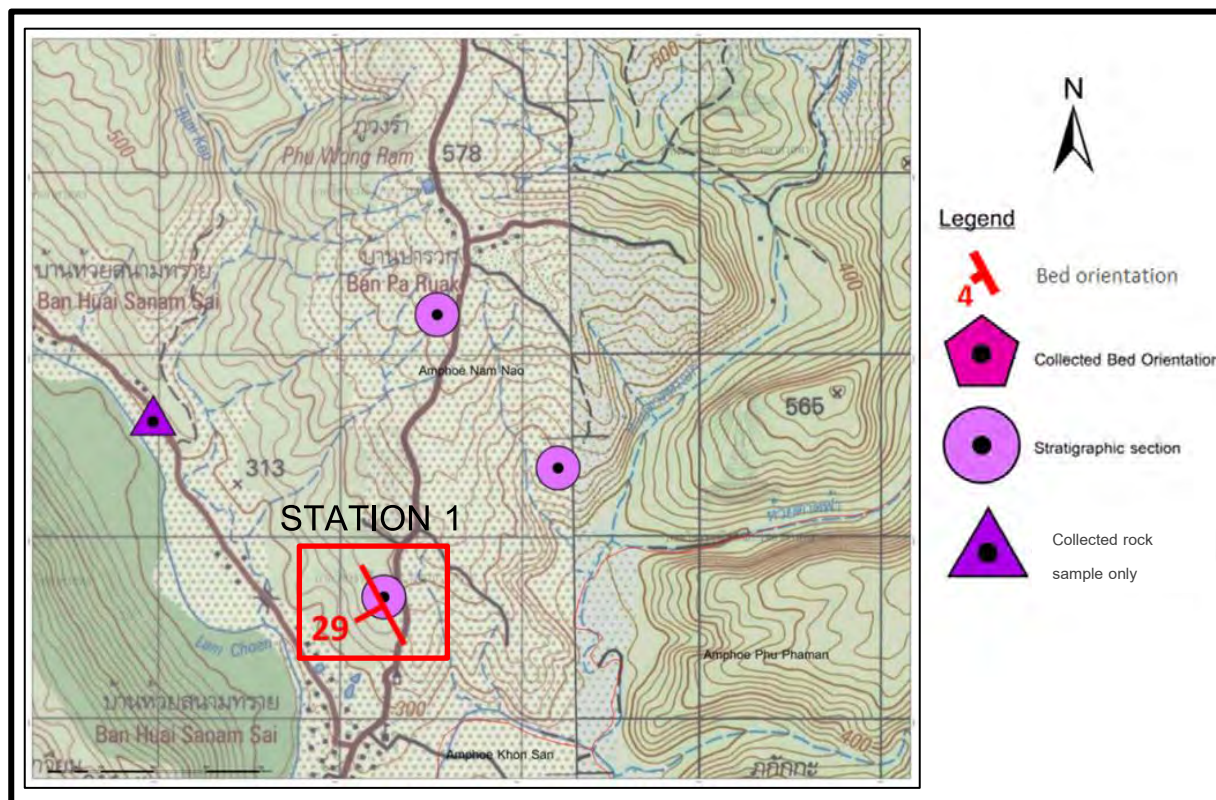


Figure 3-1. Location of Station 1 in the red square. Stratigraphic section is measured at this location as well as bed orientation measurement and rock sample collection.

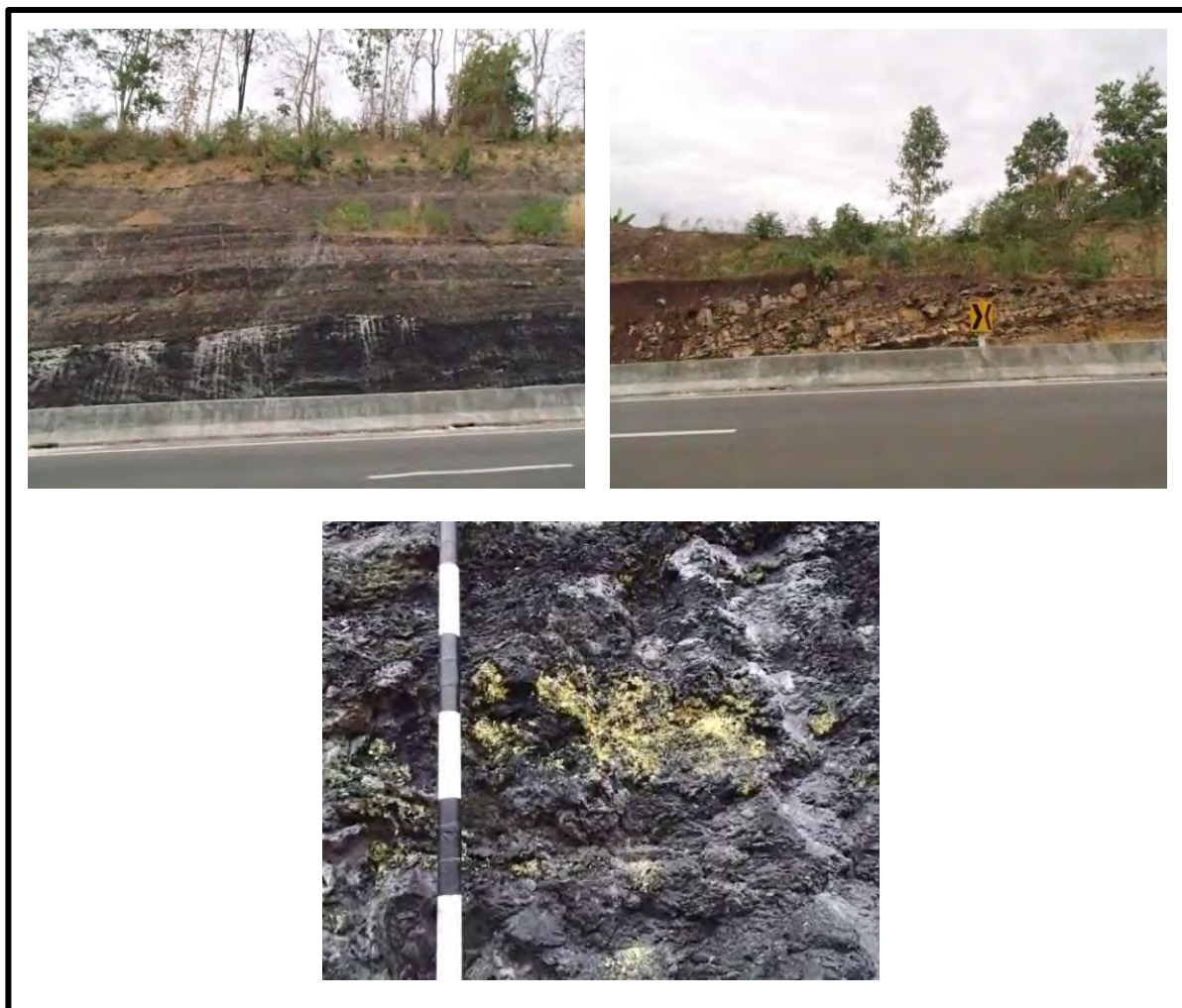


Figure 3-2. Outcrop of Station 1. The upper left picture shows strata of Sec.1 the upper right picture shows strata of Sec.2 consisting of argillaceous limestone, calcareous shale, siltstone and mudstone. The lower picture shows yellow powder of sulfur on the coal seam (Sec.1) indicating an anoxic environment.

## LITHOSTRATIGRAPHIC COLUMN

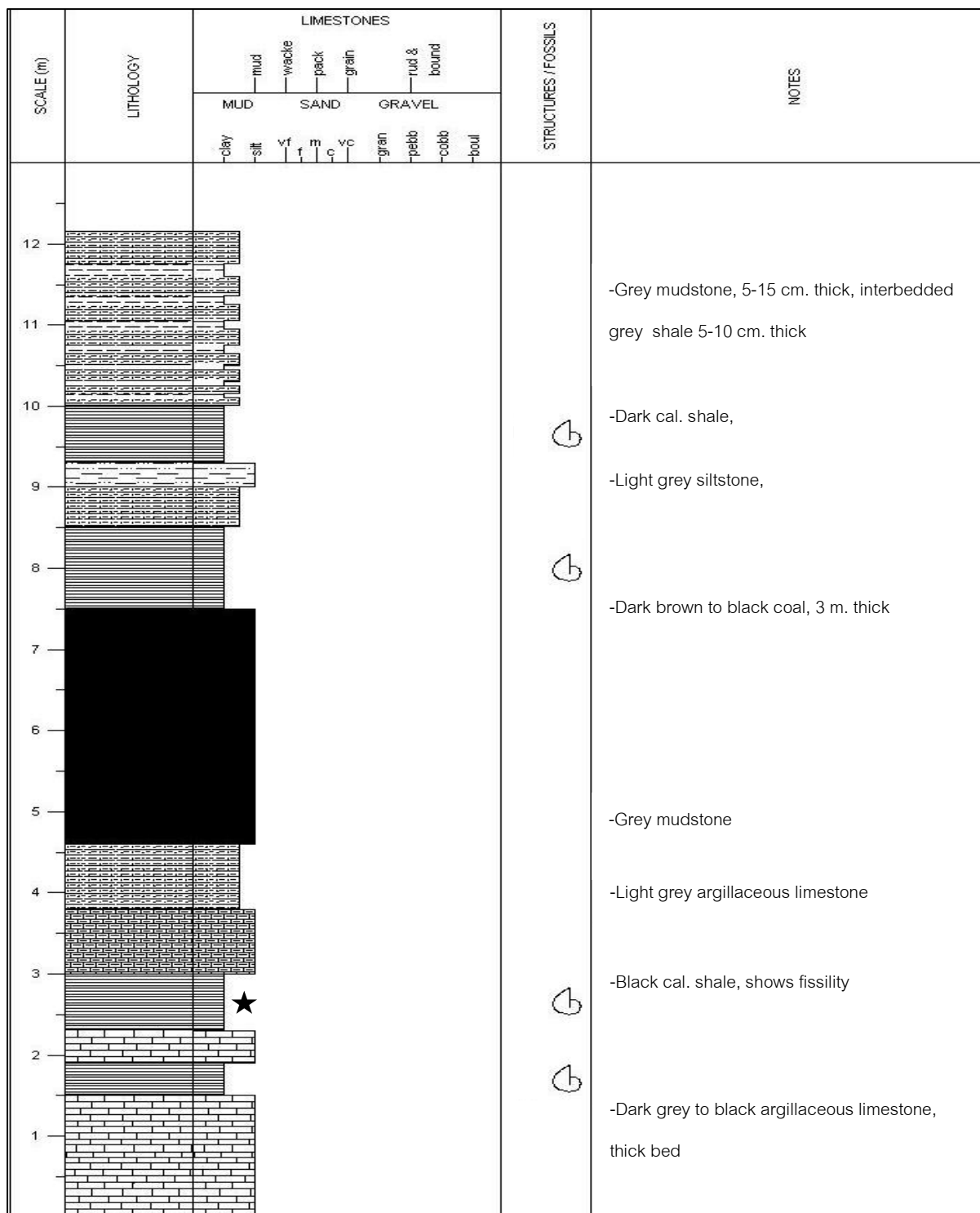


Figure 3-3. Lithostratigraphic column of Station 1, Sec. 1 (S). The star symbol shows the location of where the rock sample was collected. Fossil symbols present shell fragments which are found in calcareous shale.

## LITHOSTRATIGRAPHIC COLUMN

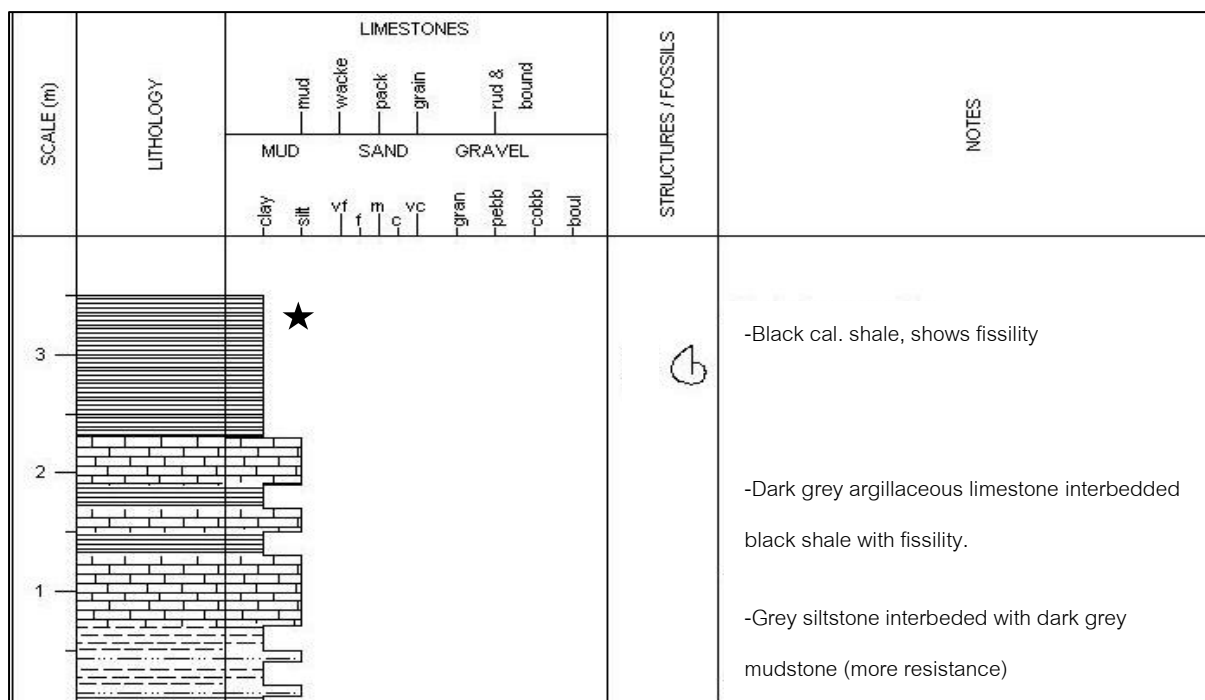


Figure 3-4. Lithostratigraphy column of station 1, Sec. 2 (N). The star symbol shows the location of where the rock sample was collected. Fossil symbol presents shell fragments which are found in calcareous shale.

### LITHOLOGY:

1. Calcareous Shale: showing fissility when fresh is black in color, clay-silt grain size. It is exposed in both sections 1 and 2 with a thickness of between 20-100 cm.
2. Argillaceous Limestone: light-dark grey when fresh, no fossils, its thickness varies, some are 1-5 cm. thick and some are 10-20 cm. thick. They are exposed in both sections.
3. Mudstone: grey when fresh, clay- silt grain size, 10-15 cm. thick, exposed in both sections.
4. Siltstone: light to moderate grey when fresh, silt grain size, well sorted, 10-50 cm. thick and exposed in both sections.
5. Coal: dark brown-black in color, brittle, almost 3 m. thick. Exposed only in Section. 1. Some yellow powder of sulfur was found in the coal bed.

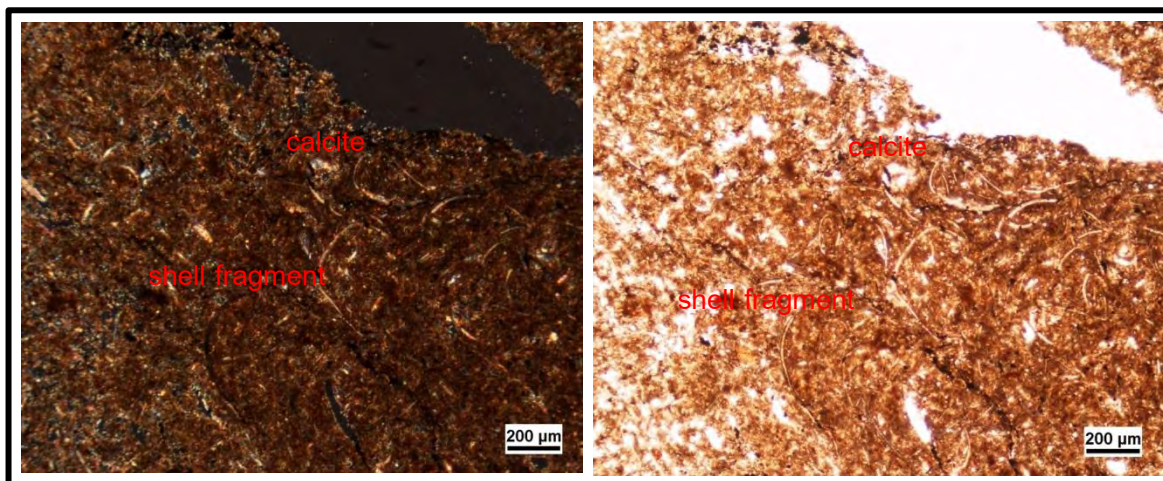


Figure 3- 5. Thin section of shale from Station 1 Sec.1. Left (PPL) Right (XPL) shows clay-silt grain size of clay minerals (80%), fossils shell fragments (15%) and silt grain size of calcite (5%).

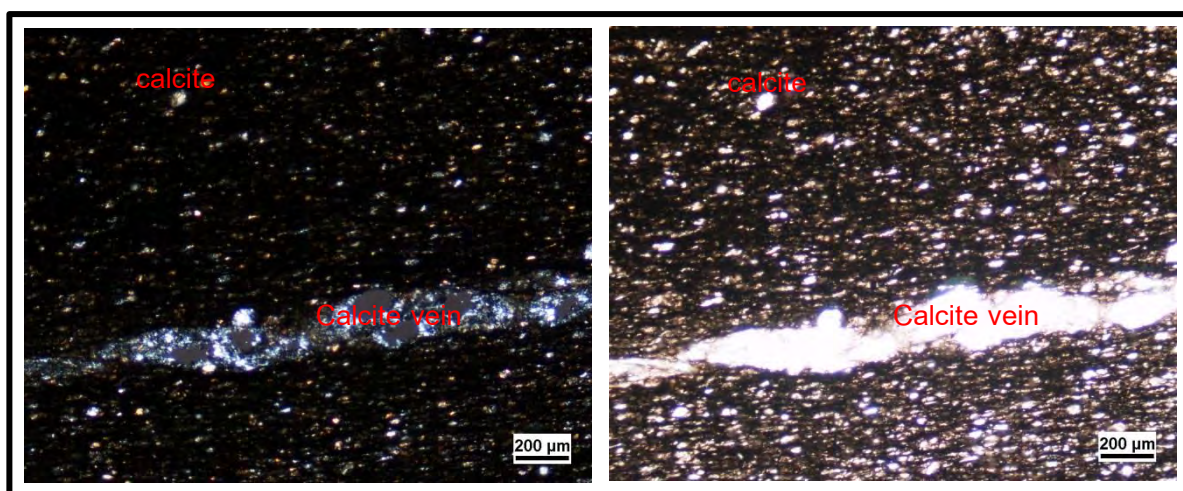


Figure 3-6. Thin section of shale from Station 1 Sec.2. Left (PPL) Right (XPL) shows clay-silt grain size of clay minerals (90%) with silt grain size of calcite and calcite vein (10%).

## STATION 2

LOCATION: Road cut outcrop along rural road number 2216 at Ban Pa Ruak (Ban Pa Ruak 1), Tambon Khok Mon. Its location is shown on the topographic map in Figure 3-7.

GRID REFERENCE: UTM 47Q 792737E 1847242N (Lat.  $16^{\circ}41'22.88''$  Long.  $101^{\circ}44'41.32''$ )

DESCRIPTION: The outcrop exposed in this area has 2 locations (Figure 3-8), along the road cut which is 1.5 m thick which appears as beds 10-40 cm. thick, where rock sample were collected to make a thin section as shown in Figure 3-9. Another location is at the pond near the road cut outcrop which is 1.5 m thick. Its weathering surface appears as layers with 5-10 cm. thick. The orientation of bed is  $154/4^{\circ}$ . The lithostratigraphic column (Figure 3-10) is 3 m. thick in total showing the strata of argillaceous limestone from both locations.

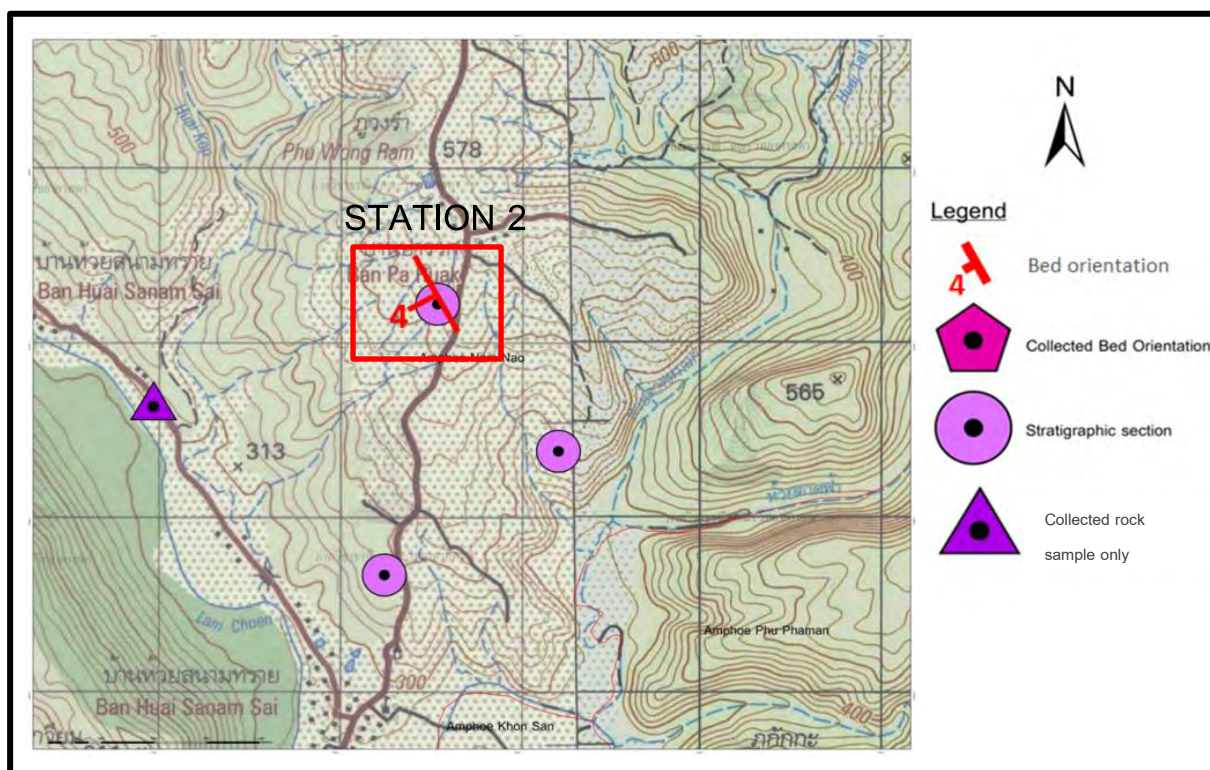


Figure 3-7. Location of Station 2 in the red square. Stratigraphic section is measured at this location as well as bed orientation measurement and rock sample collection.



Figure 3-8. Outcrop of Station 2 showing the strata of argillaceous limestone.

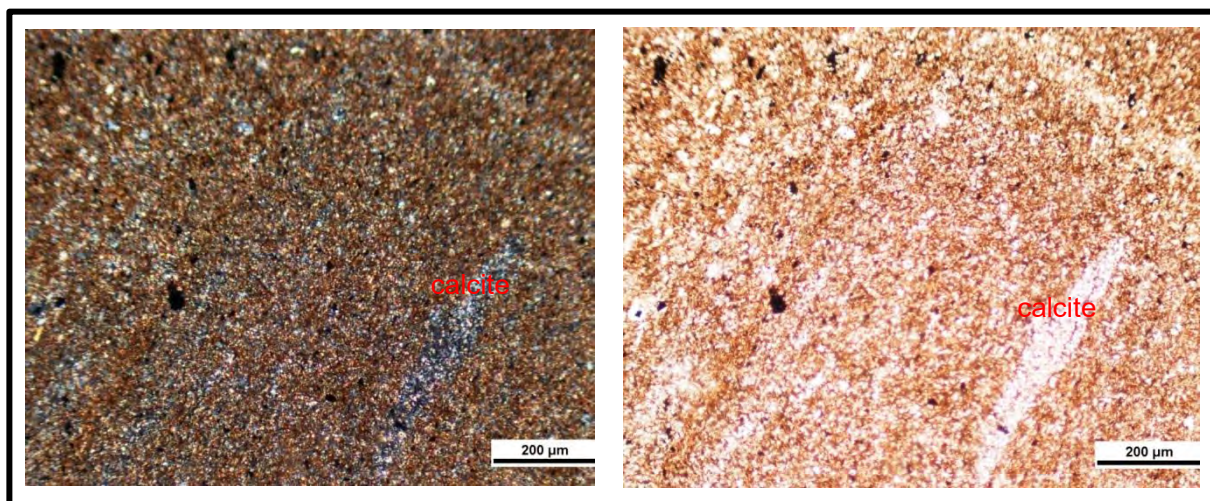


Figure 3-9. Thin section of argillaceous limestone from Station 2. Left (PPL) Right (XPL) show silt size of calcite (60%) with clay minerals (40%).

### LITHOSTRATIGRAPHIC COLUMN

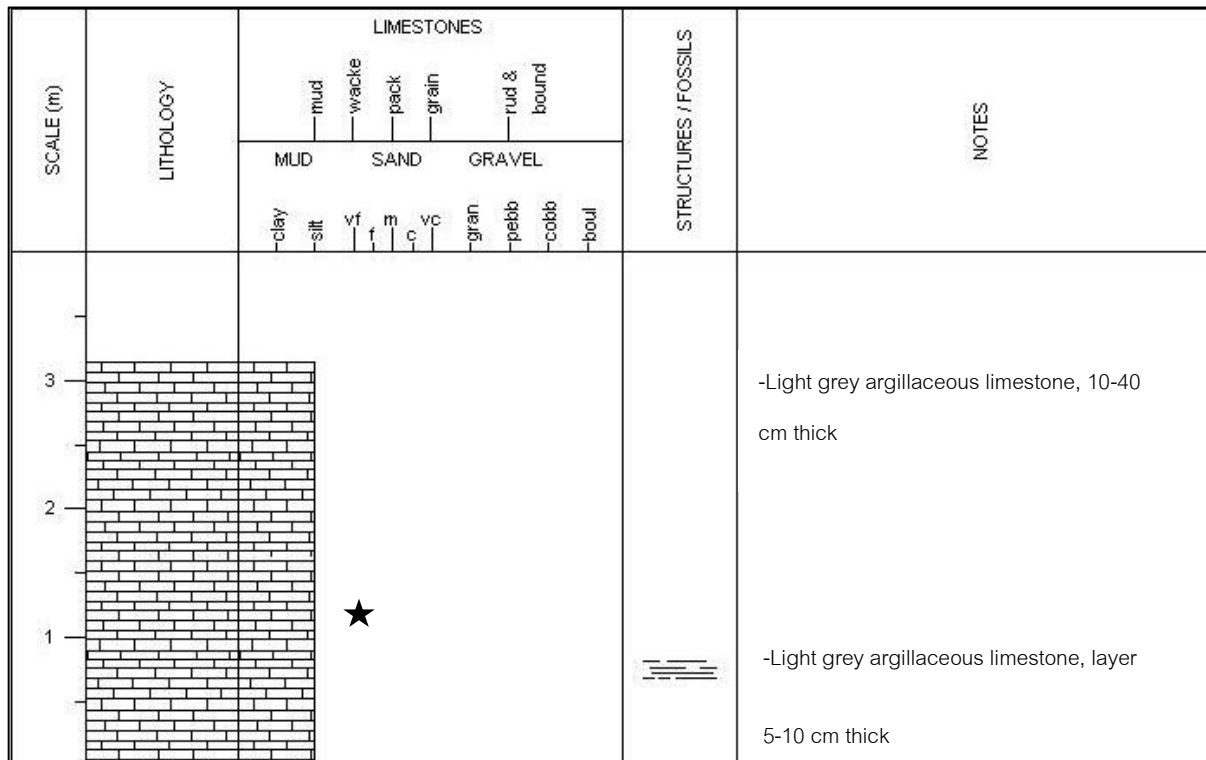


Figure 3-10. Lithostratigraphy column of Station 2. The star symbol shows the location where the rock sample was collected.

LITHOLOGY:

1. Argillaceous limestone: light-dark grey argillaceous limestone. At the bottom of the section (pond) the rock is shown as layers 5-10 cm.



### STATION 3

LOCATION: Road cut outcrop along rural road number 2216 at Ban Khok Mon, Tambon Khok Mon. Its location is shown on the topographic map in Figure 3-11.

GRID REFERENCE: UTM 47Q 792990E 1849994N (Lat.  $16^{\circ}42'52.2''$  Long.  $101^{\circ}44'51.11''$ )

DESCRIPTION: The outcrop is at the turning point of the rural road number 2216, Ban Khok Mon (Figure 3-12) with total 3 m. thick. The lithostratigraphic column (Figure 3-13) shows the strata of shale and argillaceous limestone. Bed orientation is 240/20. Thin section in Figure 3-14 showing shale interbedded with argillaceous limestone.

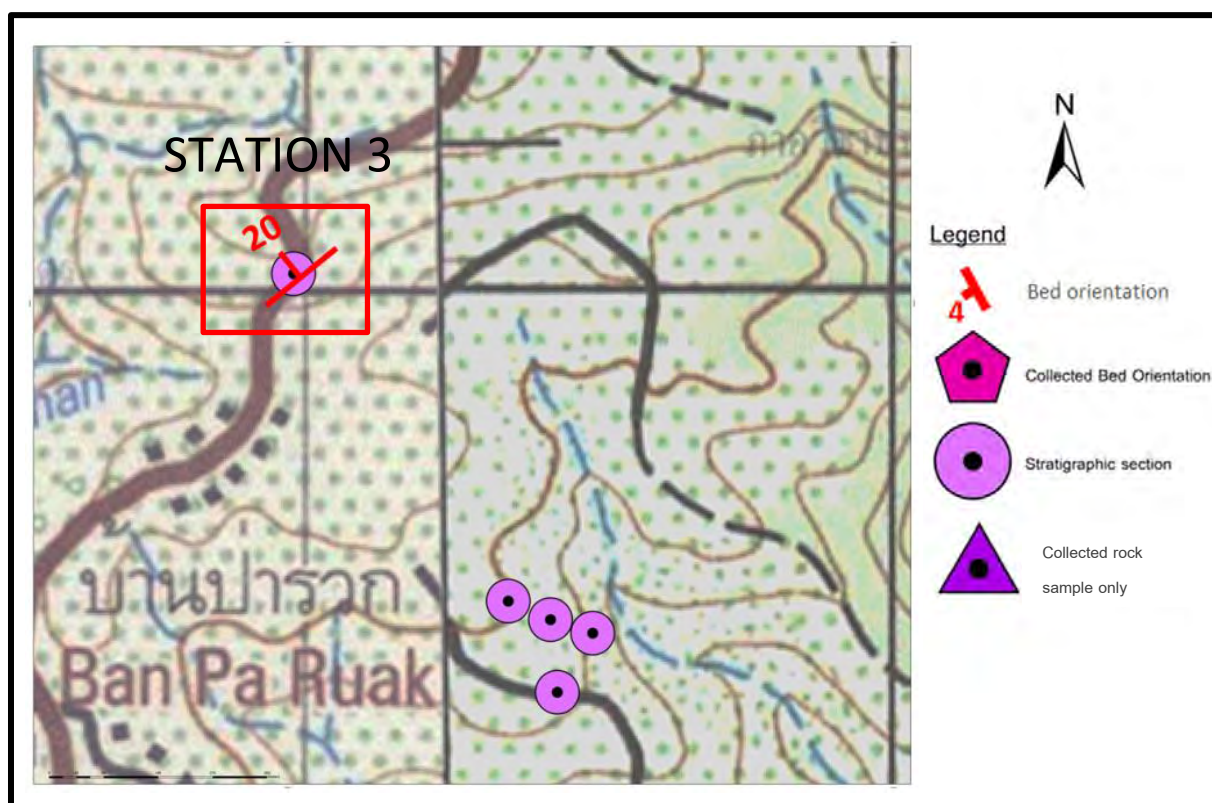


Figure 3-11. Location of Station 3 in the red square. Stratigraphic section is measured at this location as well as bed orientation measurement and rock sample collection.



Figure 3-12. Outcrop of Station 3. The left picture is at the northern end and the right picture is at the southern end of the road cut.

### LITHOSTRATIGRAPHIC COLUMN

SCALE (m)	LITHOLOGY	LIMESTONES								STRUCTURES / FOSSILS	NOTES		
		MUD		SAND			GRAVEL						
		clay	silt	vf	f	m	vc	gran	pebb			cobb	boul
3	[Lithology pattern]												
2	[Lithology pattern]												-Grey shale interbedded black argillaceous limestone
1	[Lithology pattern]												-Thick bed of black argillaceous limestone

Figure 3-13. Lithostratigraphic column of Station 3. The star symbol shows the location of where the rock sample was collected.

## LITHOLOGY:

1. Argillaceous Limestone: Dark grey when fresh, 50-100 cm. thick.
2. Shale: Grey when fresh, clay-silt grain size. It is interbedded with limestone, 2-10 cm. thick.

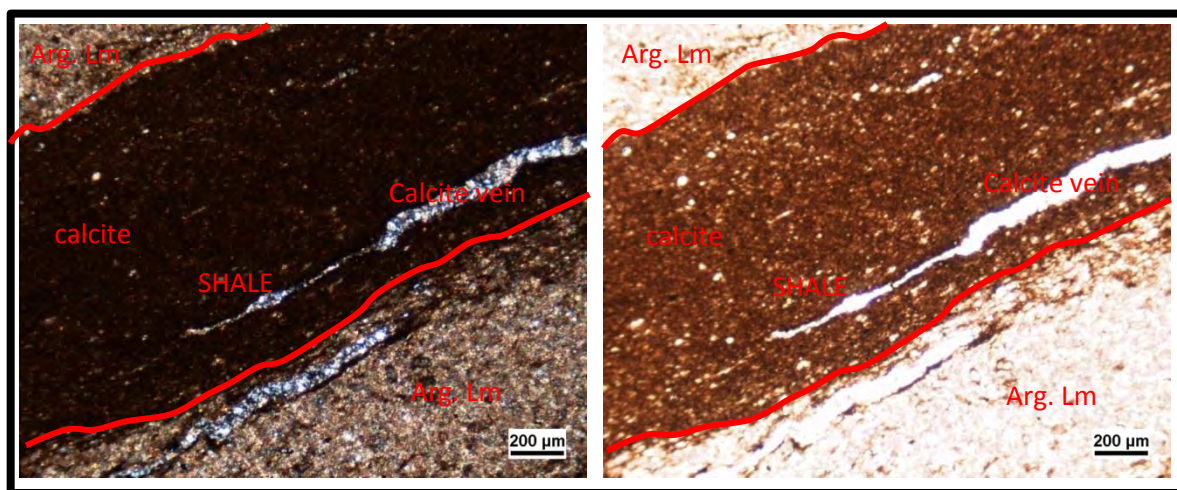


Figure 3-14. Thin section of shale interbedded with argillaceous limestone from Station 3.

Left (PPL), Right (XPL)

- Shale: clay-silt grain size of clay minerals (95%) with silt size calcite (5%)
- Argillaceous limestone: silt size of clay minerals (40%) calcite (60%).

## STATION 4

LOCATION: Phu Thay Suan Dhamma retreat at Ban Pa Ruak, Tambon Khok Mon. Its location is shown on the topographic map in Figure 3-15.

GRID REFERENCE: UTM 47Q 793344E 1846435N (Lat.  $16^{\circ}40'56.35''$  Long.  $101^{\circ}45'1.4''$ )

DESCRIPTION: The outcrop is at Phu Thay Suan Dhamma retreat, Ban Pa Ruak at the eastern side of the study area. It is at the base of a dried creek with attitude of bedding of  $166/13^{\circ}$  (Figure 3-16 left). Orientation of bedding at the slope of the hill is  $150/15^{\circ}$  (Figure 3-16 right). The outcrop consists of black calcareous shale that clearly shows fissility. Thin section as shown in Figure 3-17.

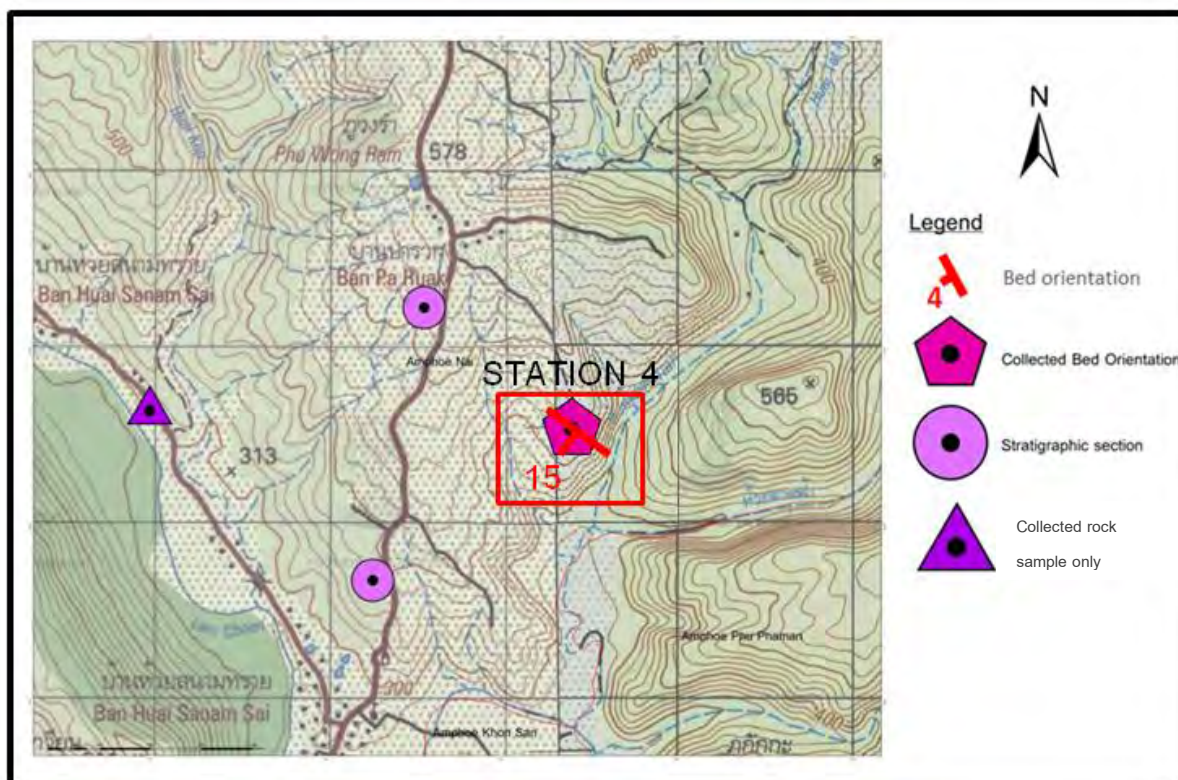


Figure 3-15. Location of Station 4 in the red square. Bed orientation and rock sample are collected from this location.



Figure 3-16. Outcrop of Station 4. The left picture is an outcrop at the base of a dried creek and the right picture is an outcrop at the slope of a hill.

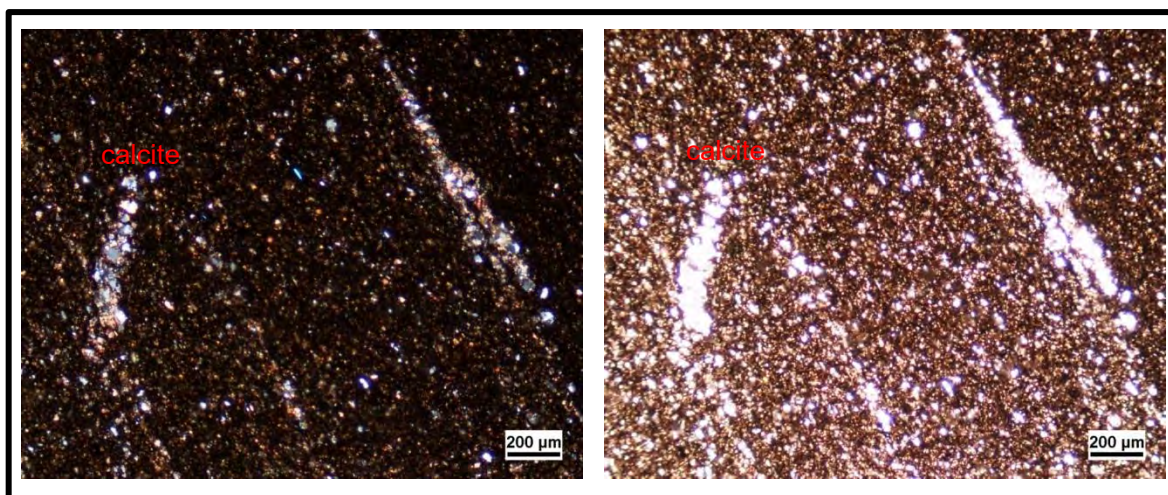


Figure 3-17. Thin section of shale from Station 4. Left (PPL) Right (XPL) show clay-silt grain size of clay minerals (90%) with silt grain size of calcite (10%).

## STATION 5

LOCATION: Tad Yai waterfall at Ban Dong Mafai, Tambon Khok Mon. Its location is shown on the topographic map in Figure 3-18.

GRID REFERENCE: UTM 47Q 796734E 1850785N (Lat. 16°43'16.25" Long.101°46'57.79")

DESCRIPTION: Tad Yai Waterfall (Figure 3-19) is located in Phu Pha Man National Park. It is 60-70 m. high. It consists of black calcareous shale all along the section which is 19 m. long as shown in the lithostratigraphic column (Figure 3-20). The attitude of bedding is  $158/12^\circ$ . Thin section is shown in Figure 3-21.

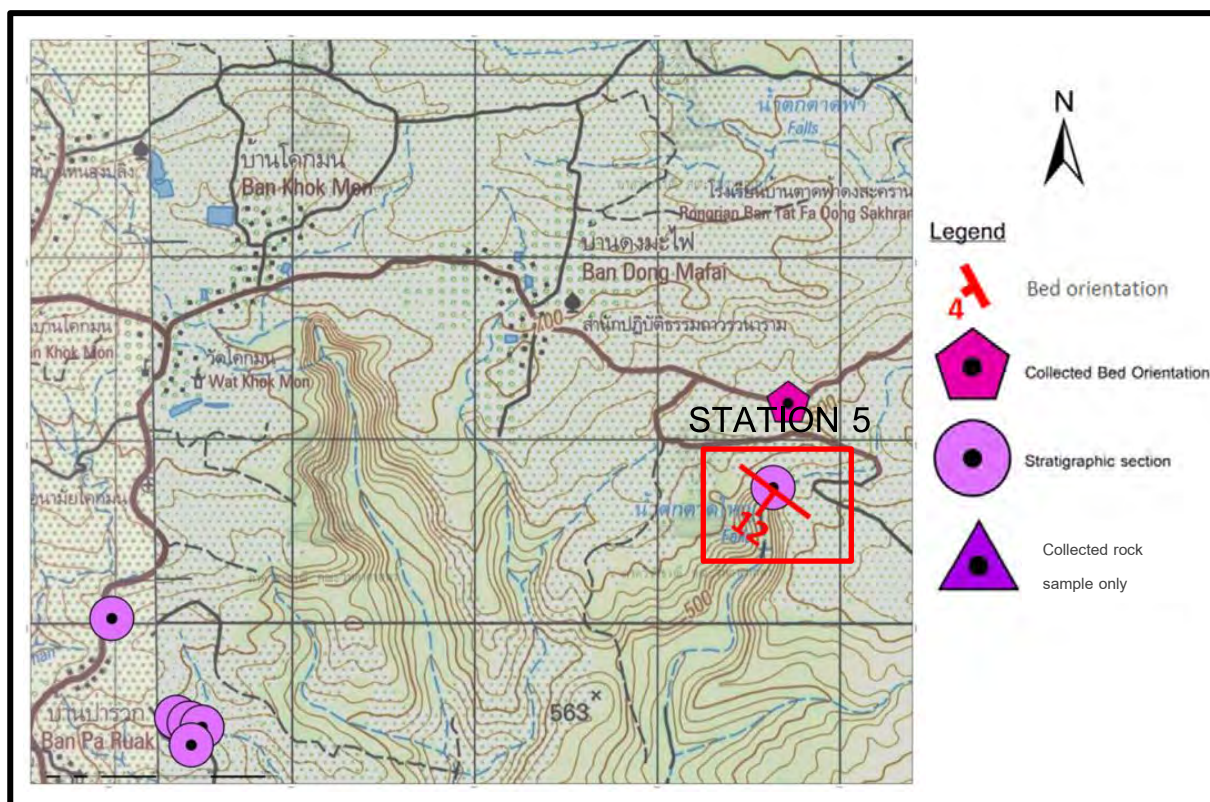


Figure 3-18. Location of Station 5 in the red square. Stratigraphic section is measured at this location as well as bed orientation measurement and rock sample collection.



Figure 3-19. Outcrop of Station 5 showing the section of Tad Yai waterfall in thick and thin beds of calcareous shale.

# LITHOSTRATIGRAPHIC COLUMN

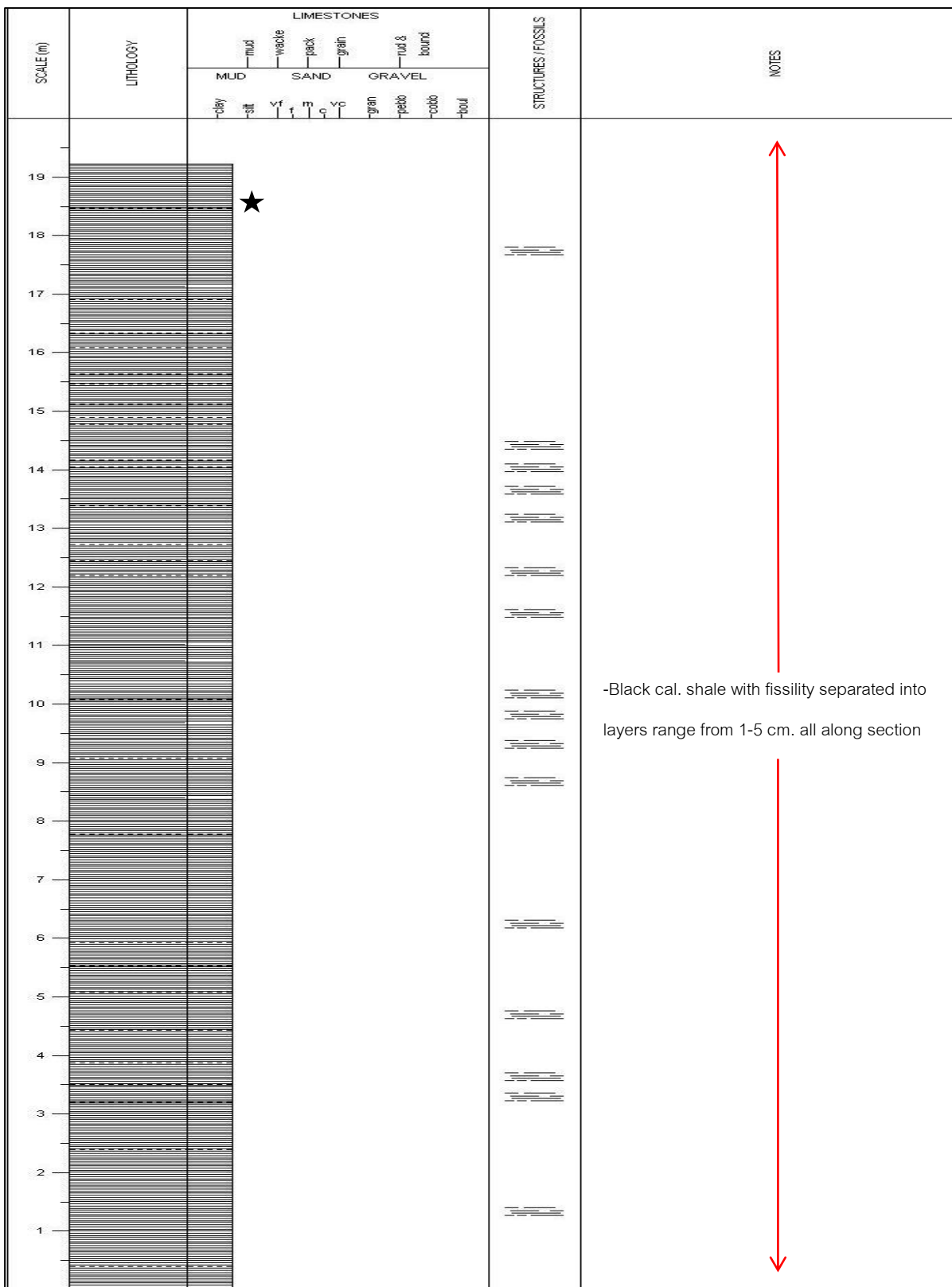


Figure 3-20. Lithostratigraphic column of Station 5. The star symbol shows the location of rock sample collect.



## LITHOLOGY:

1. Calcareous Shale: black when fresh, dark brown and dark grey when weathered, clay to silt grain with fissility. It is well bedded with thickness ranging from 1-5 cm and 10-50 cm.

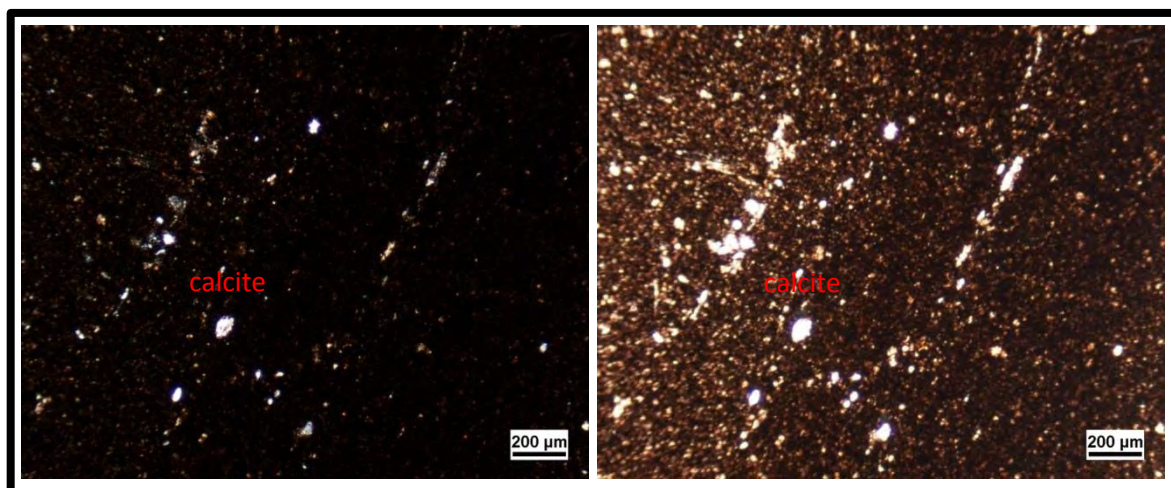


Figure 3-21. Thin section of shale from Station 5. Left (PPL) Right (XPL) shows clay-silt grain size of clay minerals (90%) with silt size of calcite (10%).

## STATION 6

LOCATION: Ban Pa Ruak 2, Tambon Khok Mon. Its location is shown on the topographic map in Figure 3-22.

GRID REFERENCE: UTM 47Q 793474N 1849357E (Lat. 16°42'31.28" Long.101°45'7.16")

DESCRIPTION: The outcrop is a steep waterway almost 30 m. long with bedding orientation of 110/12° (Figure 3-23). At the northern end of this section there are also some strata exposed which have common lithology and bed orientation. The lithostratigraphic column of this station is 17 m. long and consists of black calcareous shale, the same as the section at Tad Yai waterfall (Figure 3-24). The rock sample was collected to make a thin section as shown in Figure 3-25.

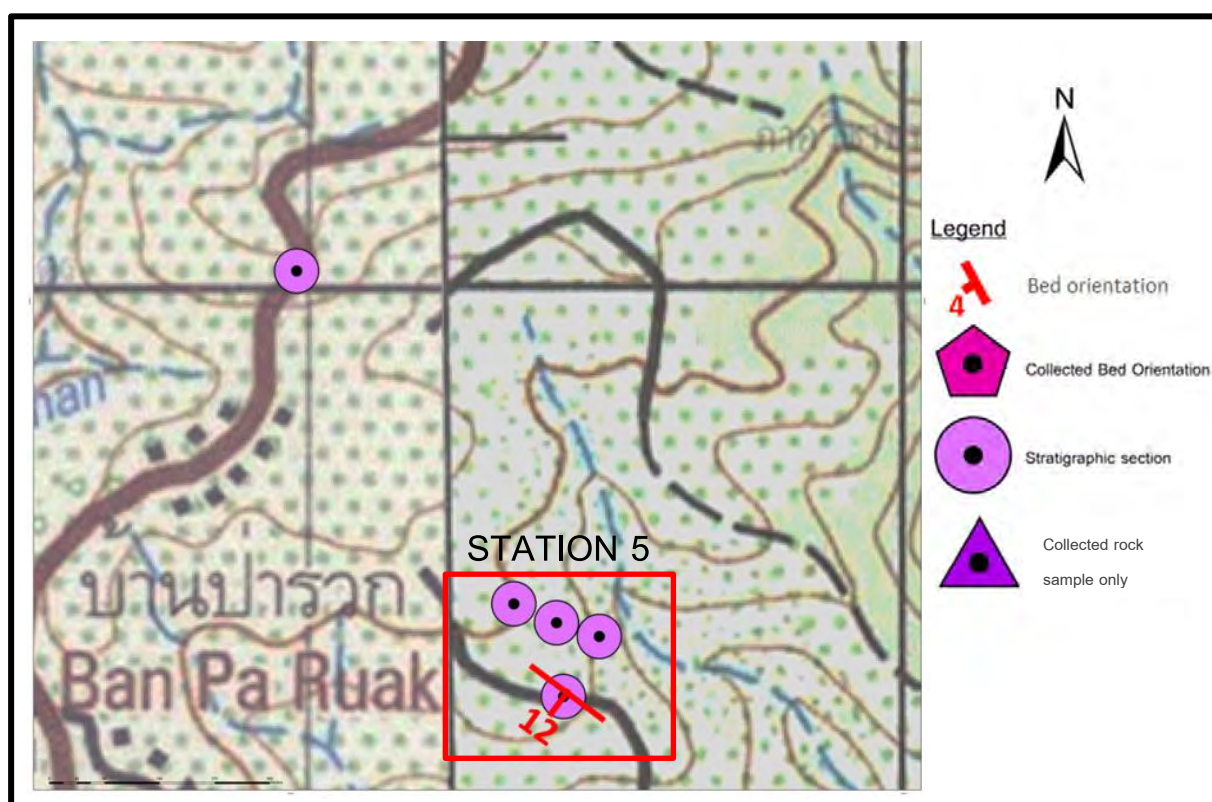


Figure 3-22. Topographic map of Station 6 in the red square. Stratigraphic section is measured at this location as well as bed orientation measurement and rock sample collection.



Figure 3-23. Outcrop of Station 6 showing sections of thick and thin beds of calcareous shale.

# LITHOSTRATIGRAPHIC COLUMN

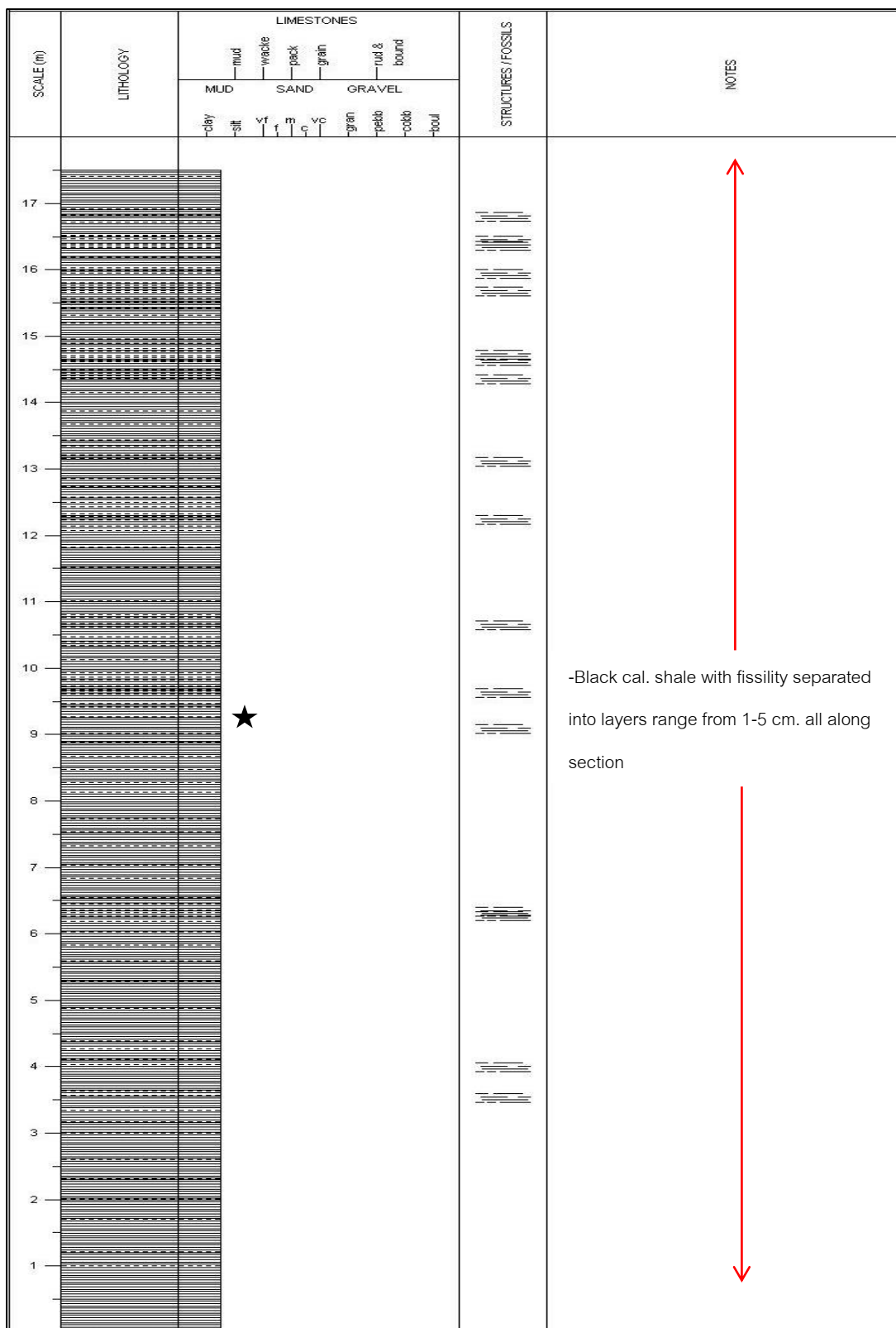


Figure 3-24. Lithostratigraphic column of Station 6. The star symbol shows the location of where the rock sample was collected.

## LITHOLOGY:

1. Calcareous Shale: black when fresh, dark brown and dark grey when weathered, clay to silt grain with fissility. It is well bedded with thickness ranging from 1-5 cm and 10-50 cm.

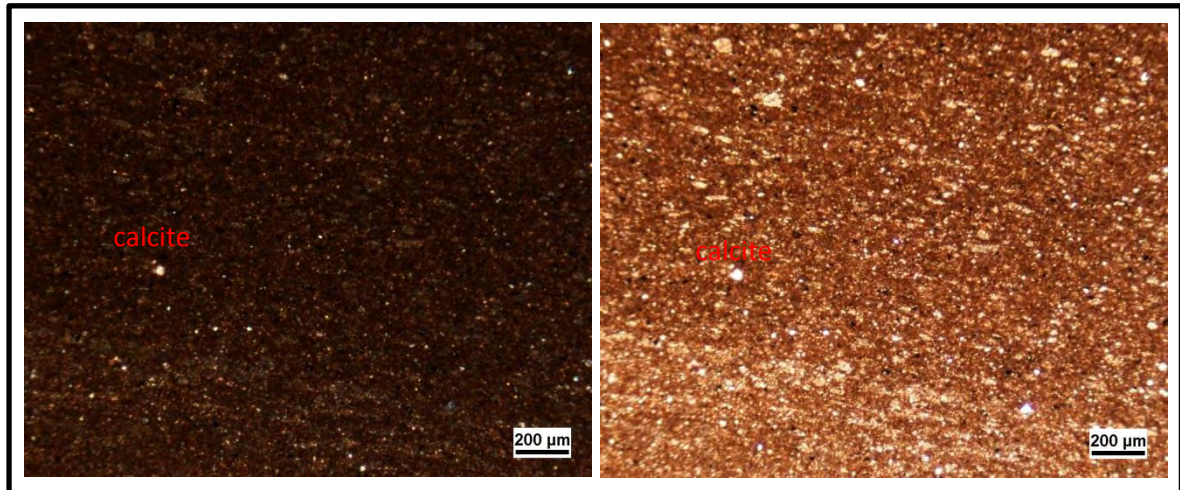


Figure 3-25. Thin section of shale from Station 6. Left (PPL) Right (XPL) show clay-silt grain size of clay minerals (90%) with silt grain size of calcite (10%).

## STATION 7

LOCATION: Ban Huai Sanam Sai, Tambon Khok Mon. Its location is shown on the topographic map in Figure 3-26.

GRID REFERENCE: UTM 47Q 788124N 1849612E (Lat. 16°42'41.98" Long. 101°42'6.8")

DESCRIPTION: Lam Nam Chern is the main channel in Ban Hui Sanam Sai. This location is a stream-cut outcrop (Figure 3-27) 1.5 km. along Lam Nam Chern. The outcrop exposure composes only greenish grey sandstone. The rock sample was collected to make a thin section as shown in Figure 3-28.

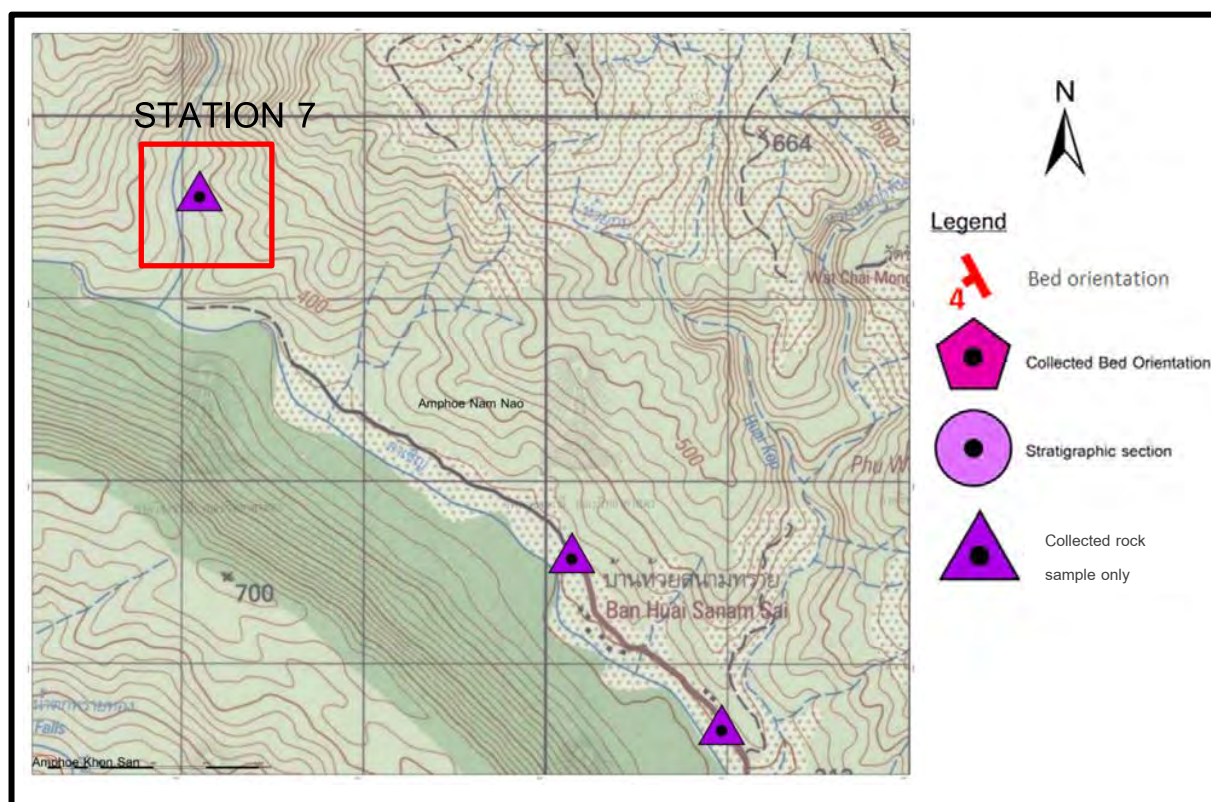


Figure 3-26. Topographic map of Station 7 in the red square. Only rock sample is collected from this location.



Figure 3-27. Outcrop of Station 7 shows a stream cut outcrop showing greenish grey sandstone.

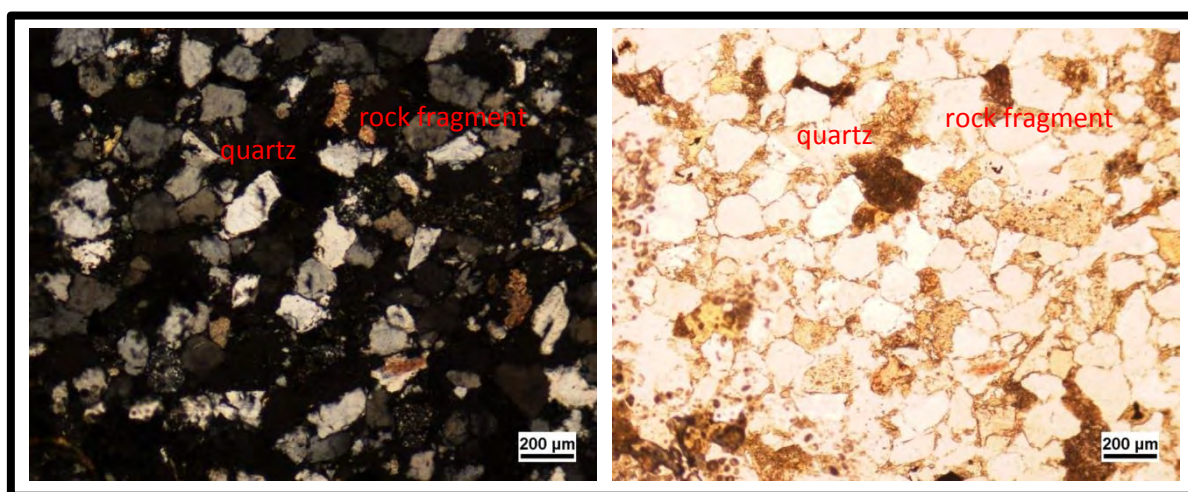


Figure 3-28. Thin section of lithic greywacke sandstone (Dott, 1964) from station 7. Left (PPL) Right (XPL) shows subangular-subrounded shape, poorly sorted fine- to medium-grained quartz (60%), medium-grained rock fragment (35%) and fine-grained feldspar (5%).

## STATION 8

LOCATION: Pran Ba waterfall, Ban Na Pho Song, Tambon Nam Nao. Its location is shown on the topographic map in Figure 3-29.

GRID REFERENCE: UTM 47Q 782621E 1852597N (Lat. 16°44'21.41" Long.101°39'2.52")

DESCRIPTION: Pran Ba waterfall is composed of sandstone, siltstone, mudstone and some matrix support conglomerate (Figure 3-30). Conglomerate shows graded bedding as shown in the lithostratigraphy (Figure 3-31). The attitude of bedding is  $164/13^\circ$ . The rock sample was collected to make a thin section as shown in Figure 3-32.

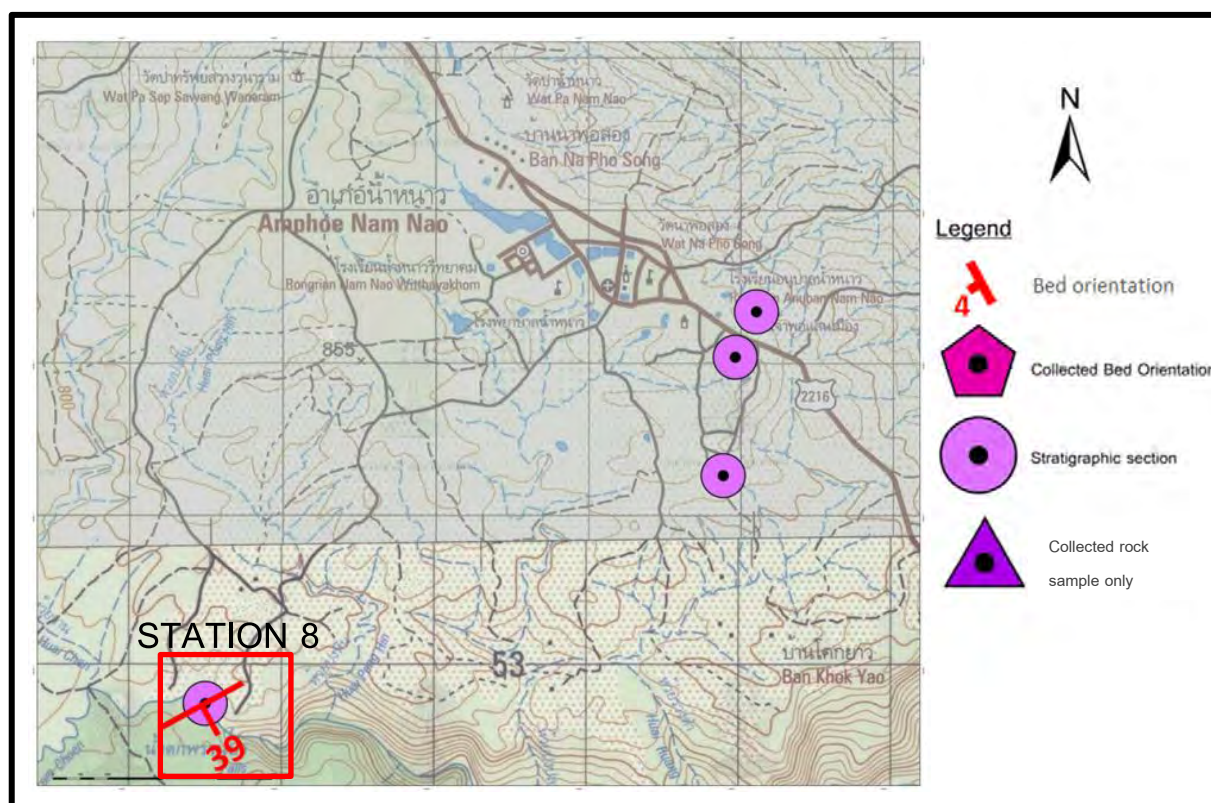


Figure 3-29. Location of Station 8 in the red square. Stratigraphic section is measured at this location as well as bed orientation measurement and rock sample collection.





Figure 3-30. Outcrop of Station 8 of Pran Ba water fall.

### LITHOSTRATIGRAPHIC COLUMN

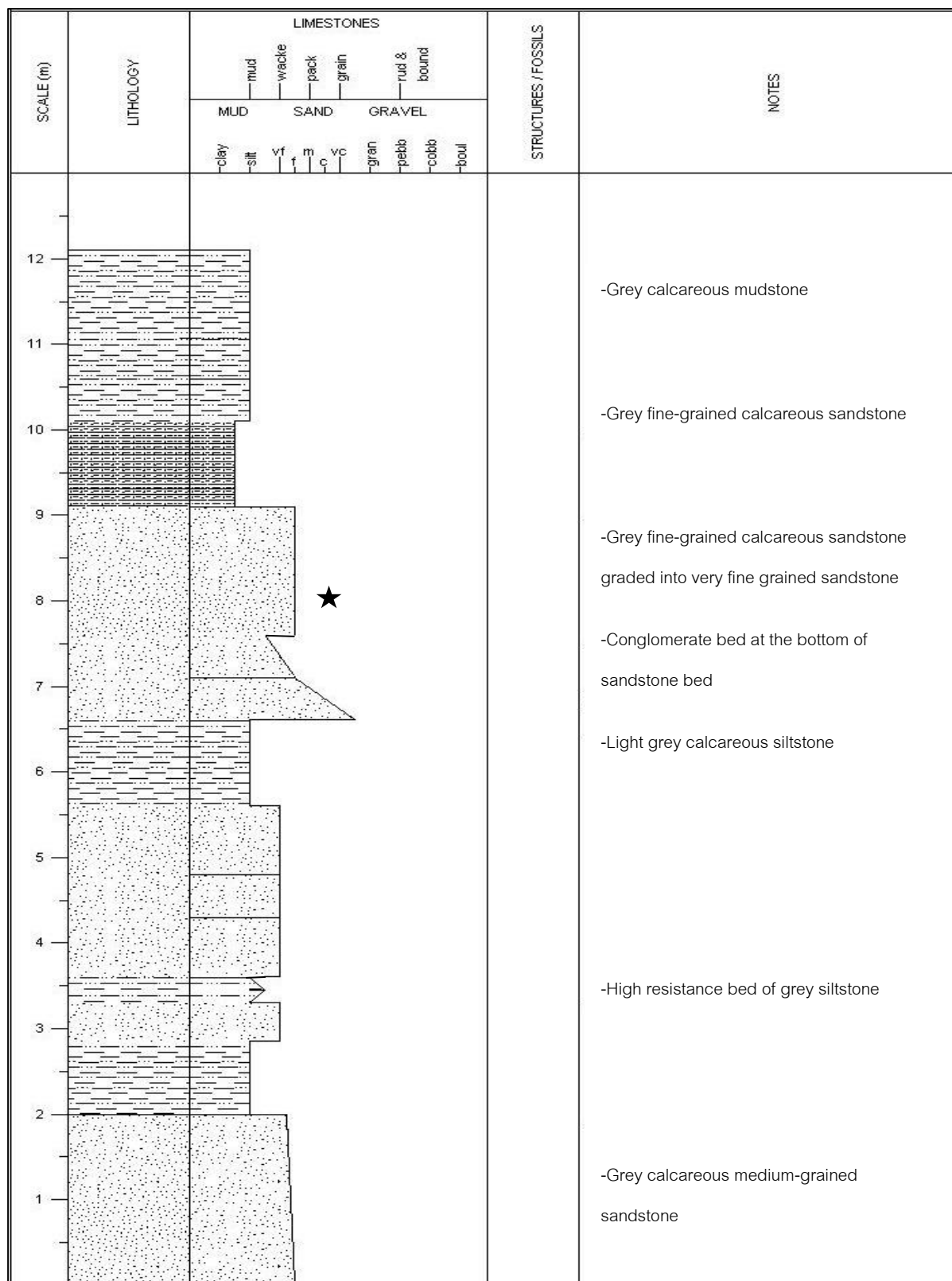


Figure 3-31. Lithostratigraphic column of Station 8. The star symbol shows the location of where the rock sample was collected.

## LITHOLOGY:

1. Siltstone: Grey siltstone with silt size and subrounded grain, calcareous cement.
2. Mudstone: Grey-greenish grey mudstone with clay-silt size, well compacted, calcareous cement.
3. Conglomerate: Grey, matrix support conglomerate at the bottom of the bed that grades into sandstone bed. Average clast size is pebble size with fine-medium sand size as matrix.
4. Sandstone: Light-dark grey sandstone, grain size ranges from fine-coarse size, well compacted with calcareous cement.

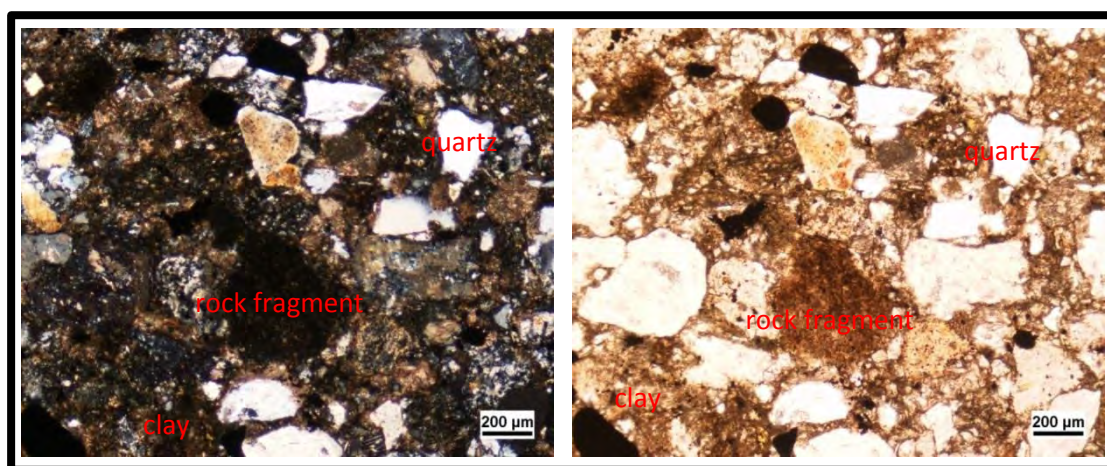


Figure 3-32. Thin section of lithic greywacke sandstone from station 8. Left (PPL) Right (XPL) show subangular-subrounded shape, poorly sorted of medium-coarse size of quartz (40%), fine-coarse grain size of rock fragment (50%) and fine grain size of clay minerals (10%).

## STATION 9

LOCATION: Ban Nam Nao homestay, Ban Na Pho Song, Tambon Nam Nao. Its location is shown on the topographic map in Figure 3-33.

GRID REFERENCE: UTM 47Q 786299E 1855355N (Lat. 16°45'49.46" Long.101°41'7.87")

DESCRIPTION: The outcrop is cut by a branch of Huai Phu Hi showing strata of clastic sedimentary rocks (Figure 3-34) . It consists of shale, mudstone, siltstone, sandstone in a greenish grey color. Sandstone, siltstone and mudstone samples were collected to make a thin section which is shown in Figure 3-35 and 3-36. Attitude of bedding is  $350/15^{\circ}$ . Graded bedding is not observed at this outcrop as shown in the lithostratigraphic column in Figure 3-34.

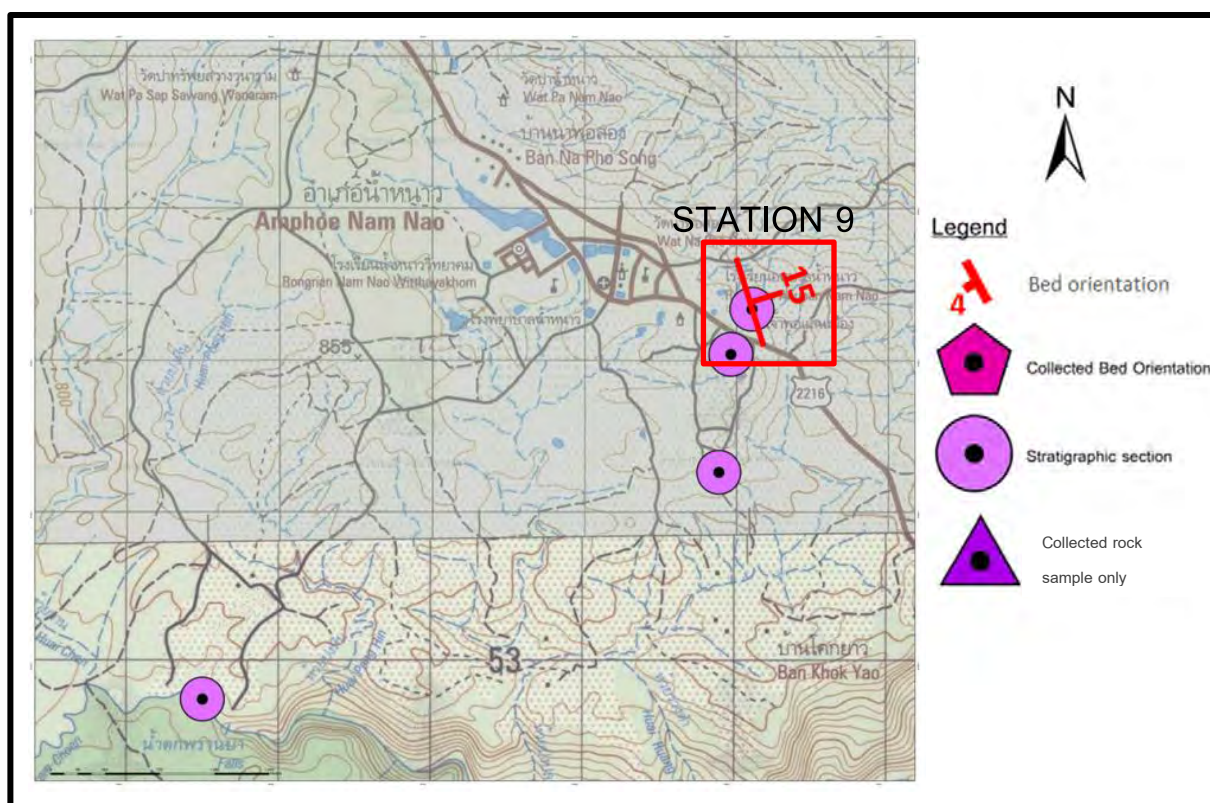


Figure 3-33. Topographic map of Station 9 in the red square. Stratigraphic section is measured at this location as well as bed orientation measurement and rock sample collection.



Figure 3-34. Shows the stream cut outcrop of station 9.

#### LITHOLOGY:

1. Sandstone: Greenish grey sandstone, very fine-grained, well sorted, well compacted with calcareous cement
2. Mudstone: Dark grey mudstone, clay-silt grain size, well sorted with calcareous cement
3. Siltstone: Grey siltstone, well sorted with calcareous cement
4. Shale: Dark grey shale, clay and silt grain size with fissility, well sorted and calcareous cement. In some parts of the outcrop, shale is interbedded with sandstone.

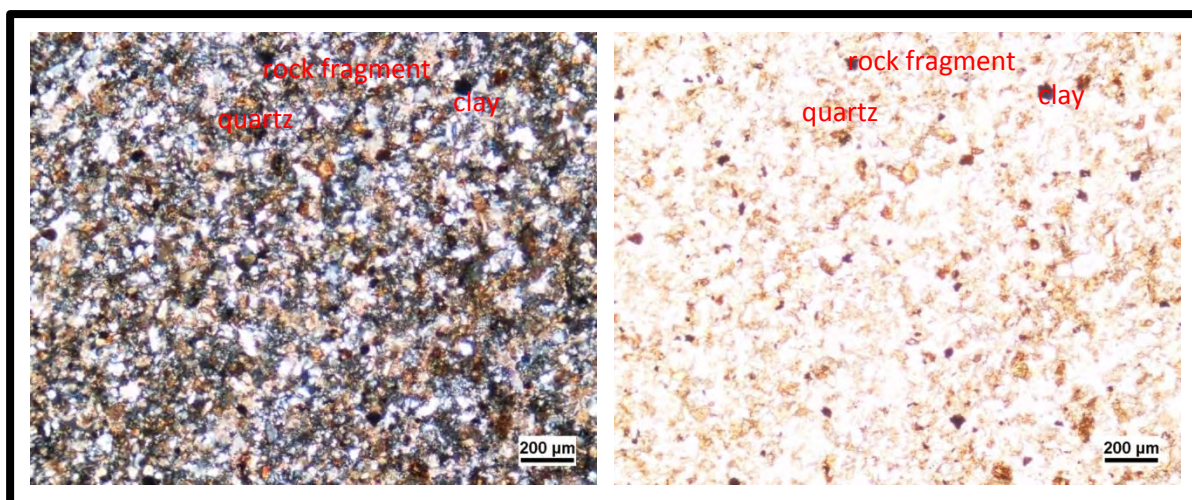


Figure 3-35. Thin section of lithic greywacke sandstone (Dott, 1964) from station 9. Left (PPL) Right (XPL) show subangular grain, well sorted, very fine grain size of quartz (70%), fine grain size rock fragment (25%) and very fine grain size clay minerals (5%)

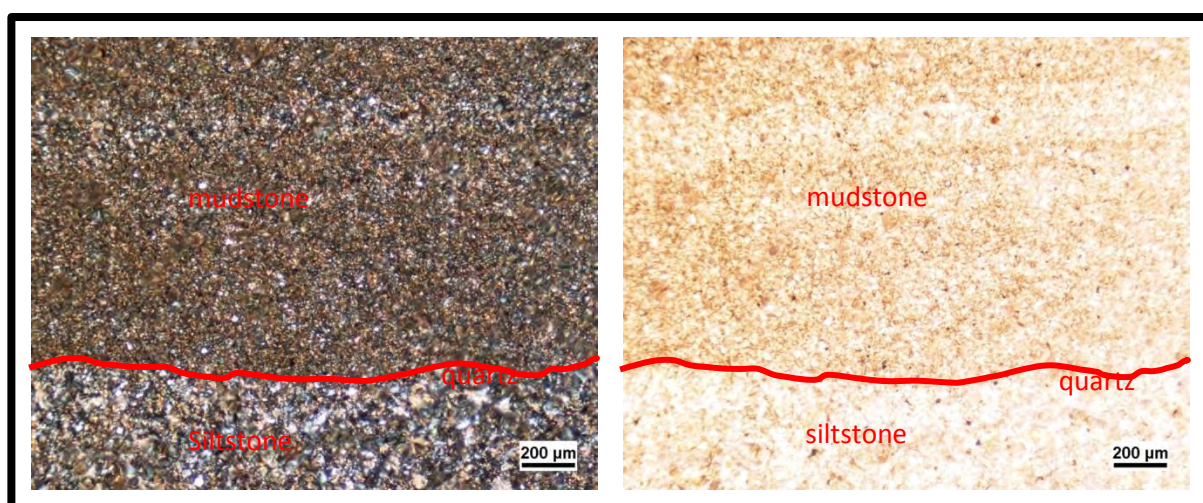


Figure 3-36. Thin section of siltstone and mudstone from station 9. Left (PPL) Right (XPL) show

- Siltstone: angular in shape, well sorted silt grain size quartz (70%) and rock fragment (30%)
- Mudstone subangular in shape, well sorted clay-silt grain size clay minerals (60%), quartz (20%) and rock fragment (20%).

# LITHOSTRATIGRAPHIC COLUMN

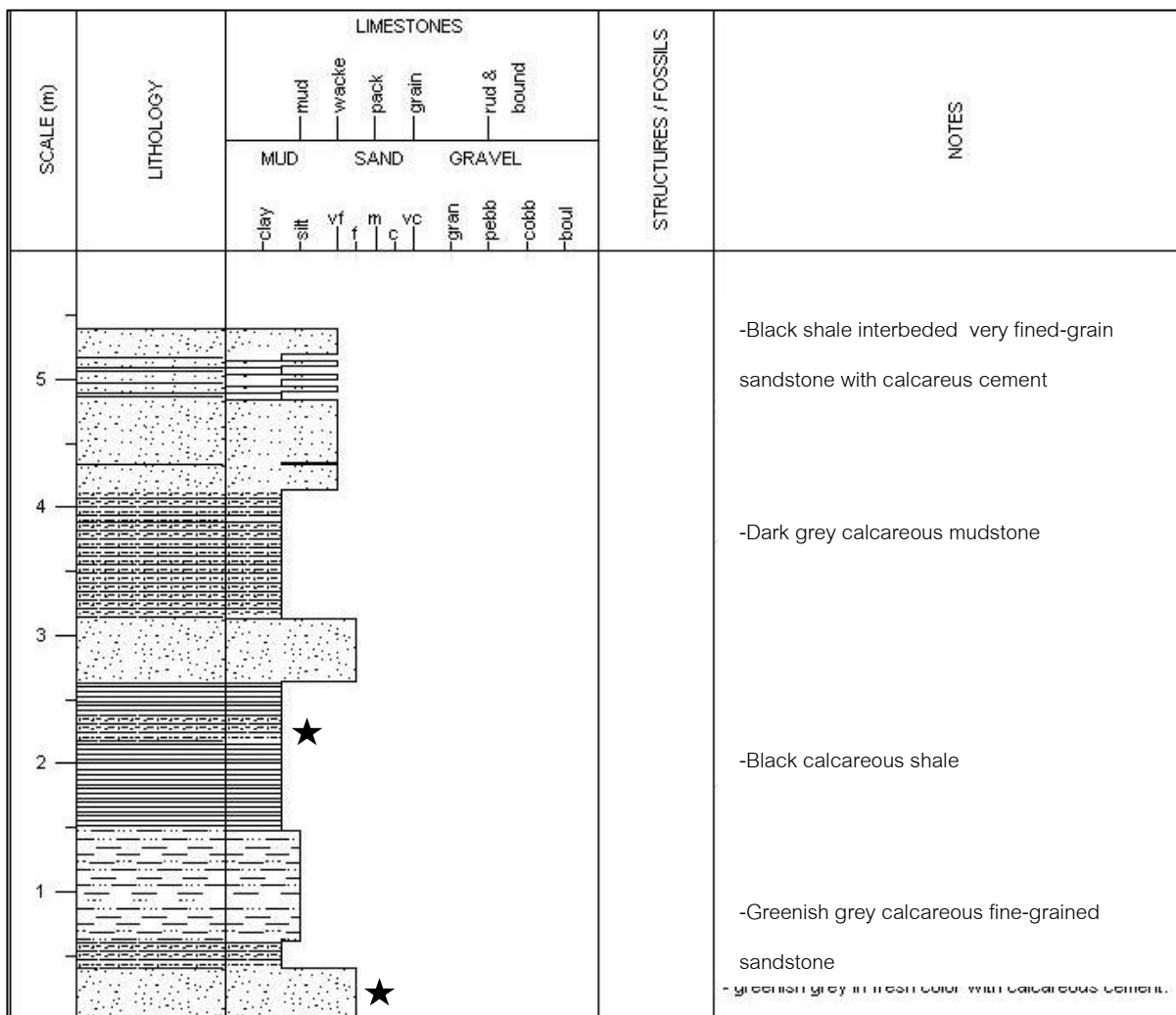


Figure 3-37. Lithostratigraphic column of Station 9. The star symbols show the location of where the rock samples were collected.

## STATION 10

LOCATION: Ban Nam Nao homestay, Ban Na Pho Song, Tambon Nam Nao. Its location is shown on the topographic map in Figure 3-38.

GRID REFERENCE: UTM 47Q 786151E 1855130N (Lat.16°45'42.19"Long.101°41'2.76")

DESCRIPTION: The outcrop is along rural road number 2216. It is 1.2 m. thick (Figure 3-39 left) and connects to Ban Nam Nao Homestay at the base of a pond which is 1.5 m. thick (Figure 3-39 right). The orientation of bedding is  $318/16^\circ$ . It consists of shale, siltstone and sandstone with calcareous cement as shown in the lithostratigraphic column in Figure 3-40. Sandstone sample was collected to make a thin section which shown in Figure 3-41.

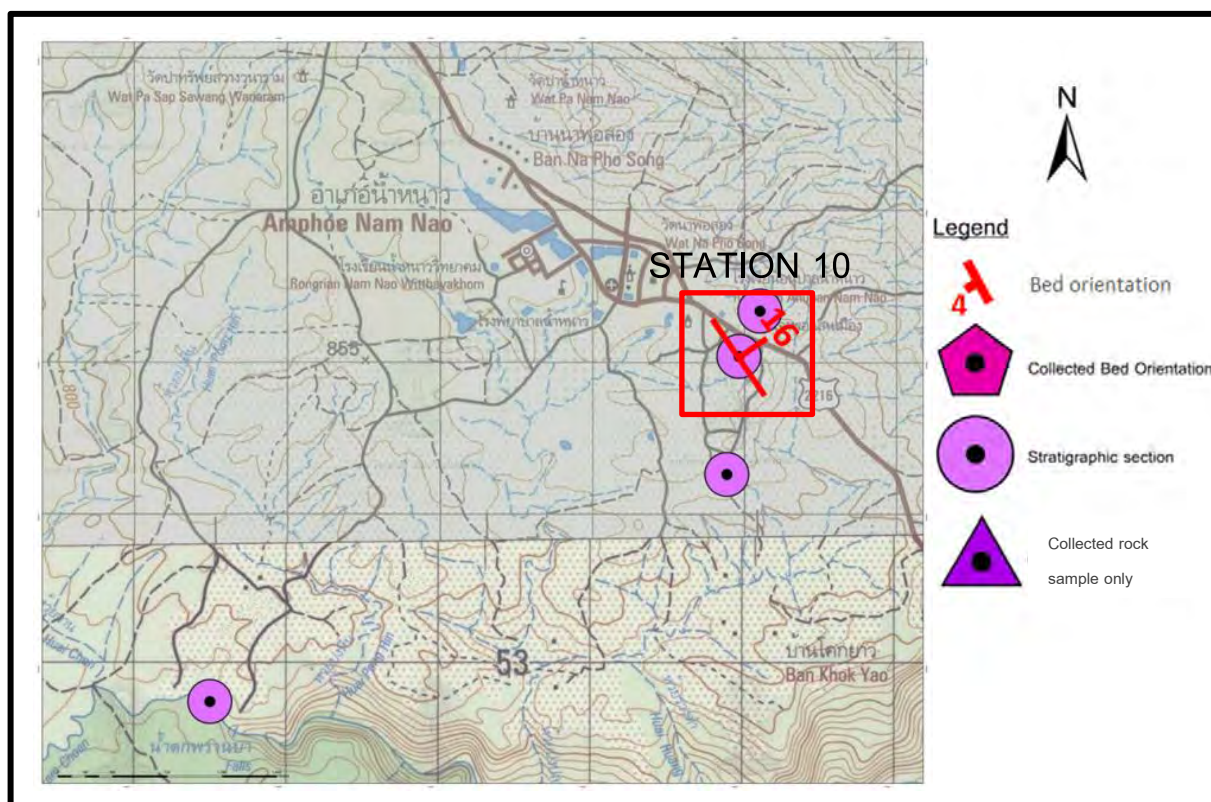


Figure 3-38. Topographic map of Station 10 in the red square. Stratigraphic section is measured at this location as well as bed orientation measurement and rock sample collection.





Figure 3-39. Shows the outcrop of station 10. The left picture shows the road cut outcrop and the right picture shows outcrop at the base of a pond.

### LITHOSTRATIGRAPHIC COLUMN

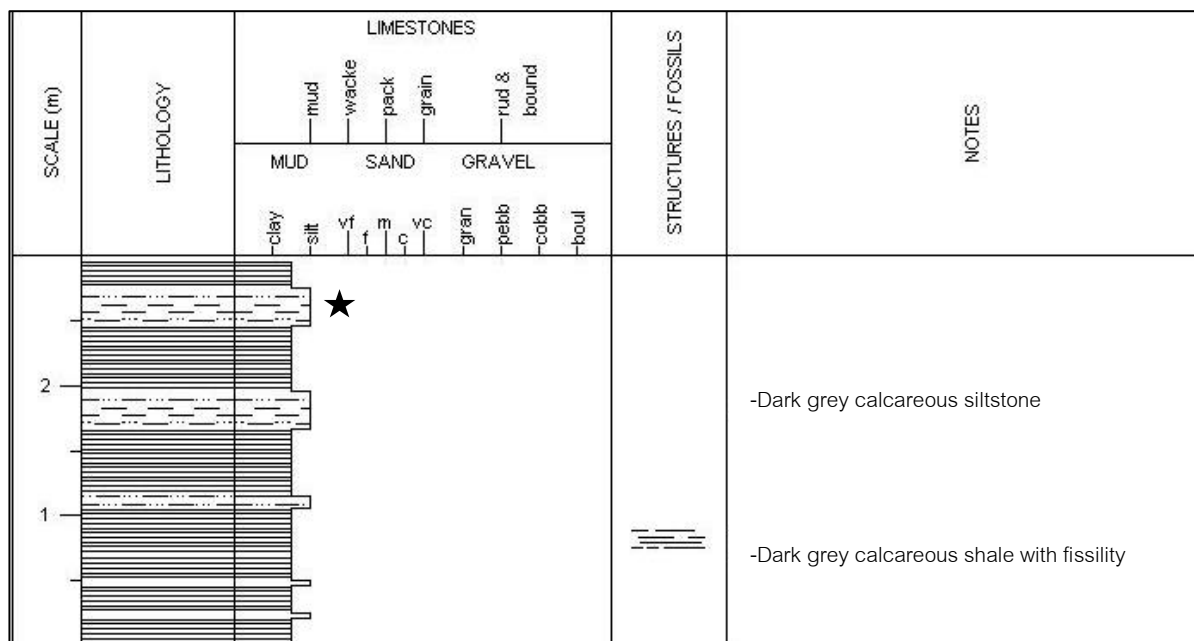


Figure 3-40. Lithostratigraphy column of Station 10. The star symbol shows the location of where the rock sample was collected.

## LITHOLOGY:

1. Shale: Black shale, clay-silt grain size with fissility, well sorted, calcareous cement
2. Siltstone: Dark grey mudstone, silt grain size, well sorted with calcareous cement

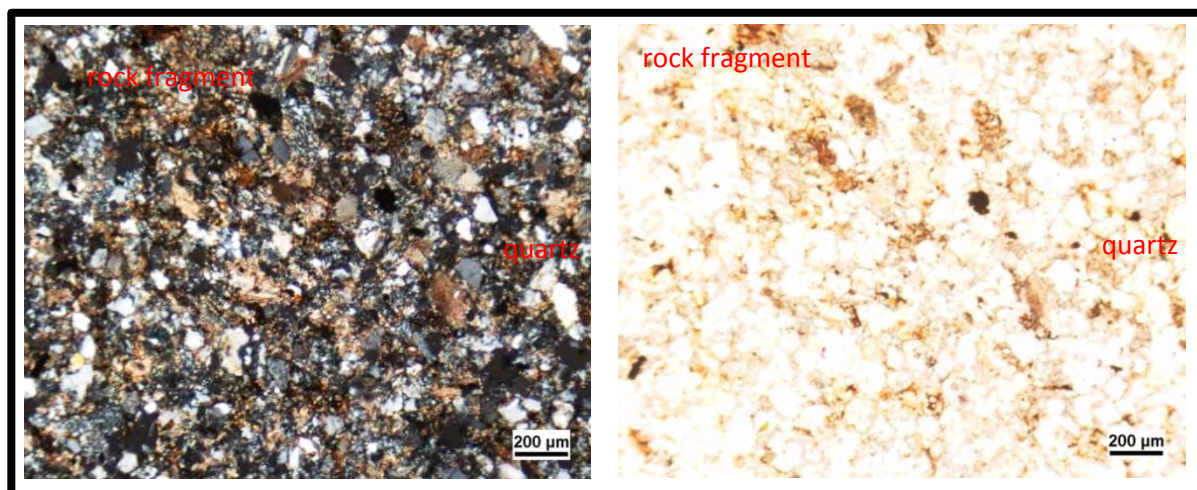


Figure 3-41. Thin section of lithic greywacke sandstone from station 10. Left (PPL) Right (XPL) show subangular-angular in shape, moderately sorted of fine grain size quartz (70%), fine grain size rock fragment (25%) and very fine grain size clay minerals (5%).

## STATION 11

LOCATION: Ban Non Chat, Tambon Lak Dan. Its location is shown on the topographic map in Figure 3-42.

GRID REFERENCE: UTM 47Q 766799E 1878075N (Lat. 16°58'16.39" Long. 101°30'19.58")

DESCRIPTION: The channel cut across the outcrop shows the bed of sedimentary rocks (Figure 3-43) including mudstone, shale, siltstone and sandstone which are highly weathered. The orientation of bed is 265/27°. Sandstone sample was collected to make a thin section which is shown in Figure 3-45. The outcrop is 5 m. long as shown in the lithostratigraphic column (Figure 3-44).

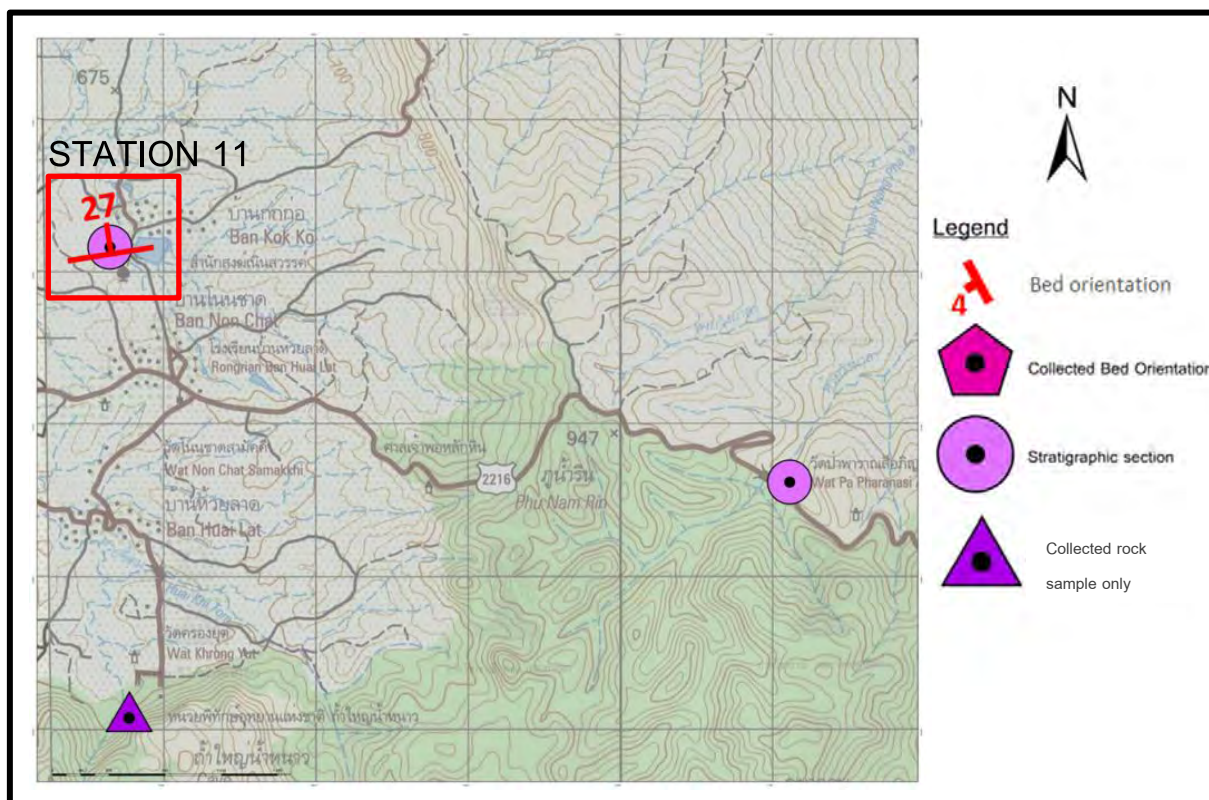


Figure 3-42. Location of Station 11 in the red square. Stratigraphic section is measured at this location as well as bed orientation measurement and rock sample collection.



Figure 3-43. Shows the stream cut outcrop of Station 11.

**LITHOSTRATIGRAPHIC COLUMN**

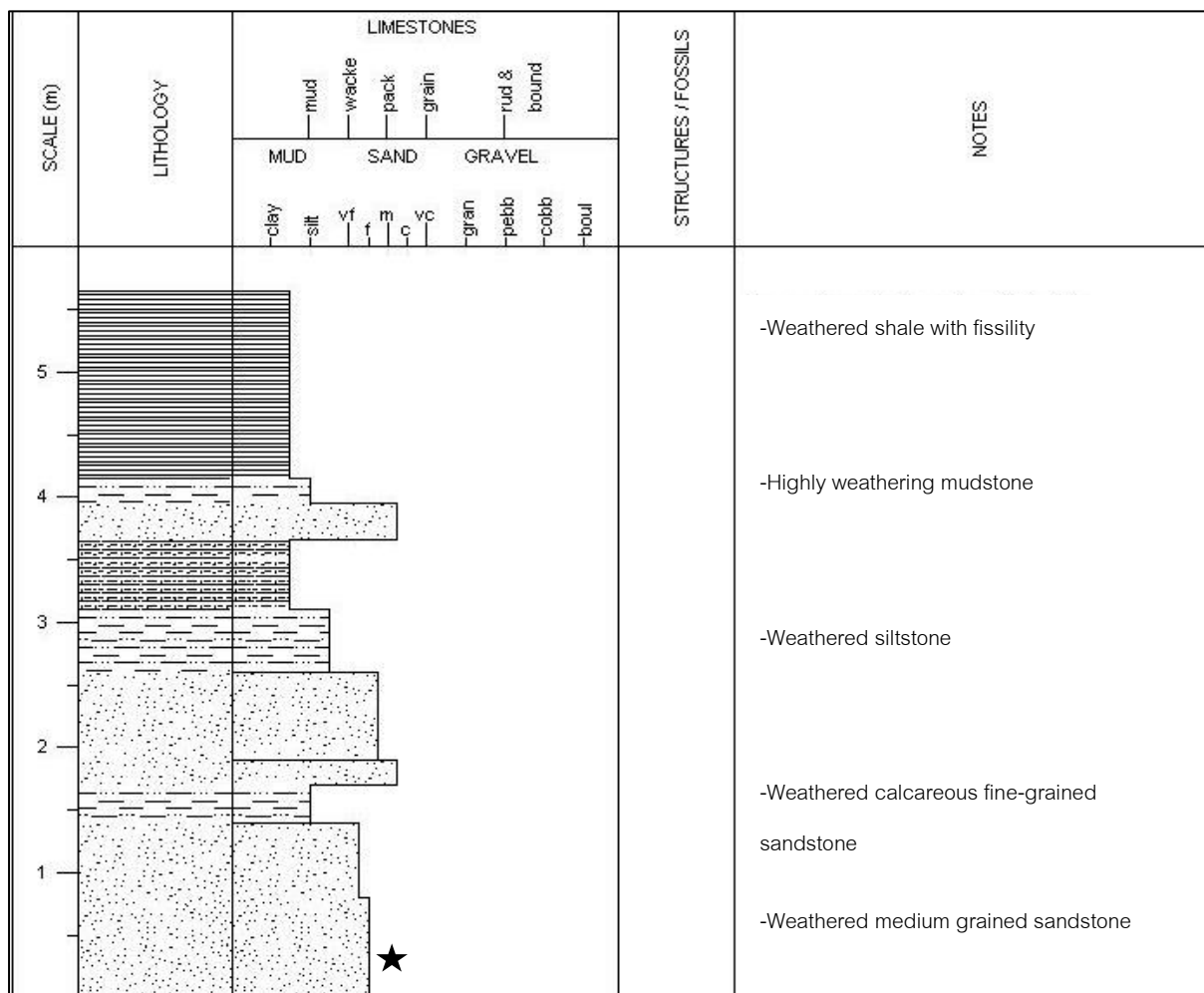


Figure 3- 44. Lithostratigraphic column of Station 11. The star symbol shows the location of rock samples collected.

## LITHOLOGY:

1. Sandstone: yellow when weathered, fine sand grain size, angular shape, poorly sorted with some mica.
2. Sandstone: brown when weathered, coarse sand grain size, subangular shape, moderately sorted with calcareous cement.
3. Siltstone: yellowish brown when weathered, silt grain size, subrounded shape and well sorted.
4. Mudstone: dark brown and highly weathered.
5. Shale: brown when weathered, clay-silt grain size, moderately sorted with fissility.

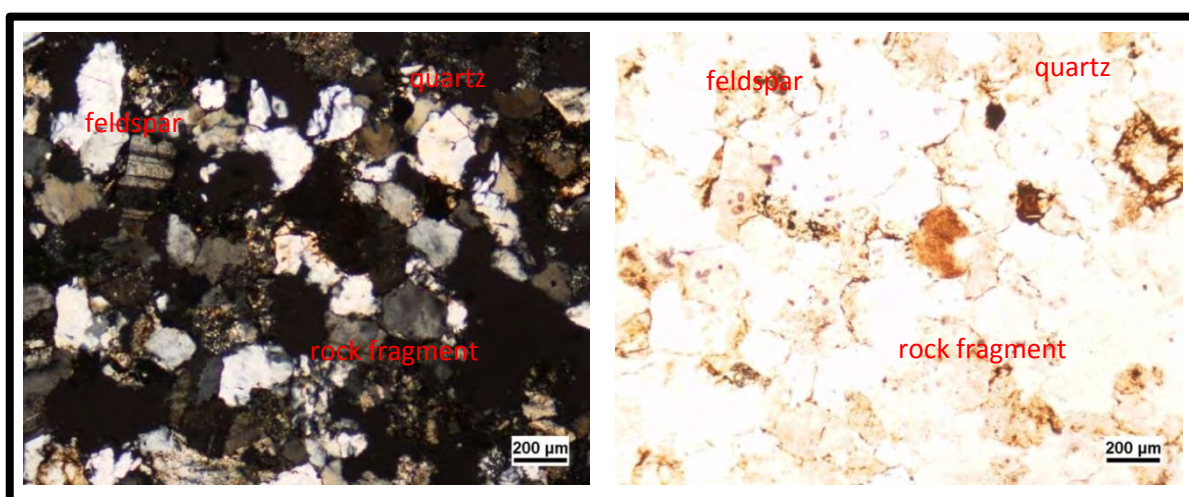


Figure 3-45. Thin section of lithic greywacke sandstone from Station 11. Left (PPL) Right (XPL) shows angular in shape, moderately sorted medium grain size quartz (80%), fine-medium grain size rock fragment (15%) and medium grain size feldspar (5%).

## STATION 12

LOCATION: Phu Mok, Ban Lak Dan, Tambon Lak Dan. Its location is shown on the topographic map in Figure 3-46. It is located on a high mountain in the western side of the study area.

GRID REFERENCE: UTM 47Q 761149N 1871052E (Lat. 16°54'30.38" Long. 101°27'5.76")

DESCRIPTION: The outcrop consists of highly weathered clastic sedimentary rock (Figure 3-47), with bedding of 164/55°. It is 13 m. long as shown in the lithostratigraphic column (Figure 3-48).

A siltstone sample was collected to make a thin section which shown in Figure 3-49.

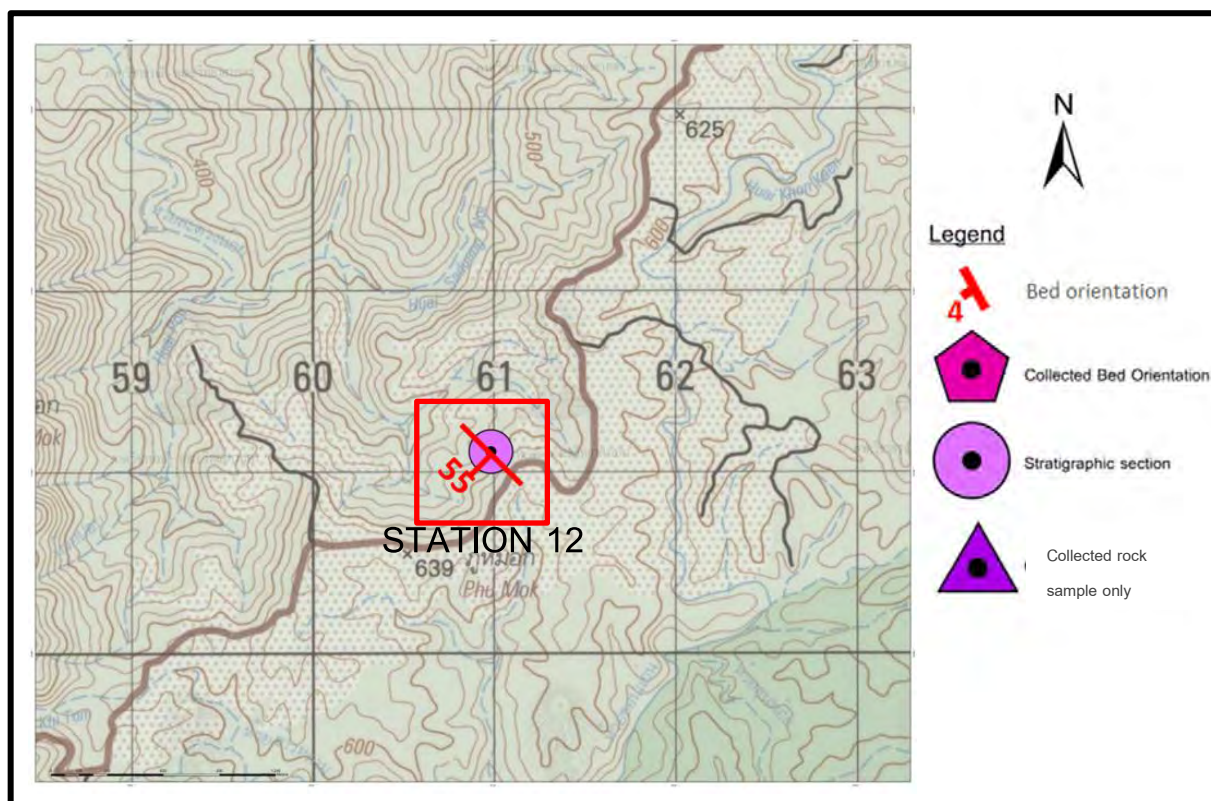


Figure 3-46. Topographic map of Station 11 in the red square. Stratigraphic section is measured at this location as well as bed orientation measurement and rock sample collection.



Figure 3-47. Outcrop of station 12.

### LITHOSTRATIGRAPHIC COLUMN

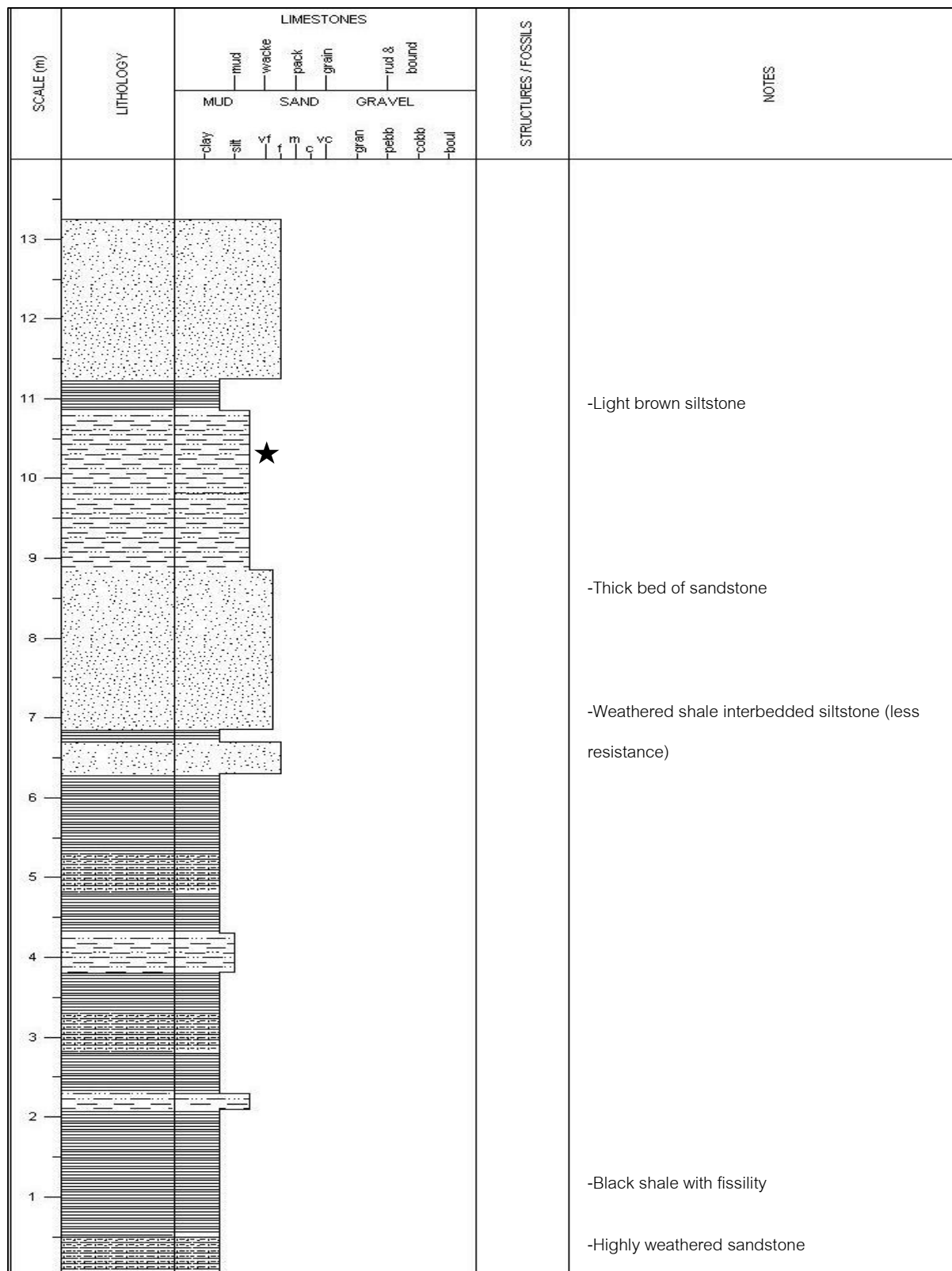


Figure 3-48. Lithostratigraphic column of Station 12. The star symbol shows the location of where the rock samples were collected.



## LITHOLOGY:

1. Mudstone: The rock is highly weathered and yellowish brown in color.
2. Shale: black shale, clay-silt grain size with fissility. Some parts of the shale outcrop is interbedded with siltstone which is of higher resistance.
3. Siltstone: light brown when weathered, silt grain size, well sorted.
4. Sandstone: yellowish brown when weathered, medium sand grain size, well sorted.

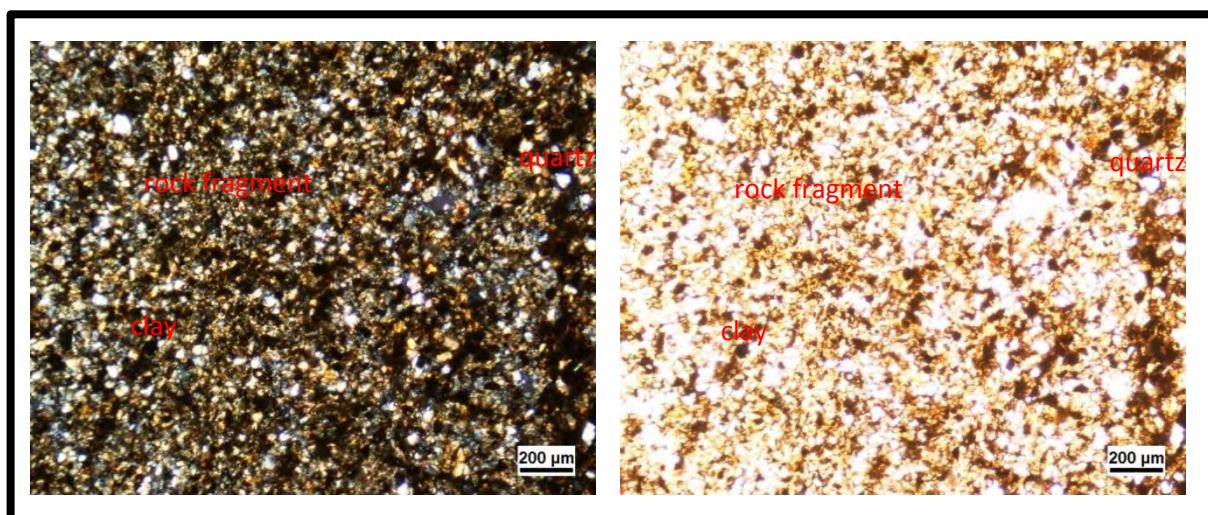


Figure 3-49. Thin section of siltstone from station 12. Left (PPL) Right (XPL) shows subangular in shape, well sorted silt grain size quartz (80%), silt grain size rock fragment (15%) and silt grain size clay minerals (5%).

## STATION 13

LOCATION: Huai Pha La, Ban Pha La Noi, Tambom Wang Kwang. Its location is shown on the topographic map in Figure 3-49.

GRID REFERENCE: UTM 47Q 770912E 1876588N (Lat. 16°57'26.35" Long. 101°32'37.9")

DESCRIPTION: The outcrop was cut by Hui Pha La. Attitude of bedding is  $320/10^\circ$ . It is almost 15 m high. The outcrop consists mostly of purplish red sandstone and conglomerate (Figure 3-50). The lithostratigraphic column in Figure 3-51. A sandstone sample was collected to make a thin section which shown in Figure 3-52.

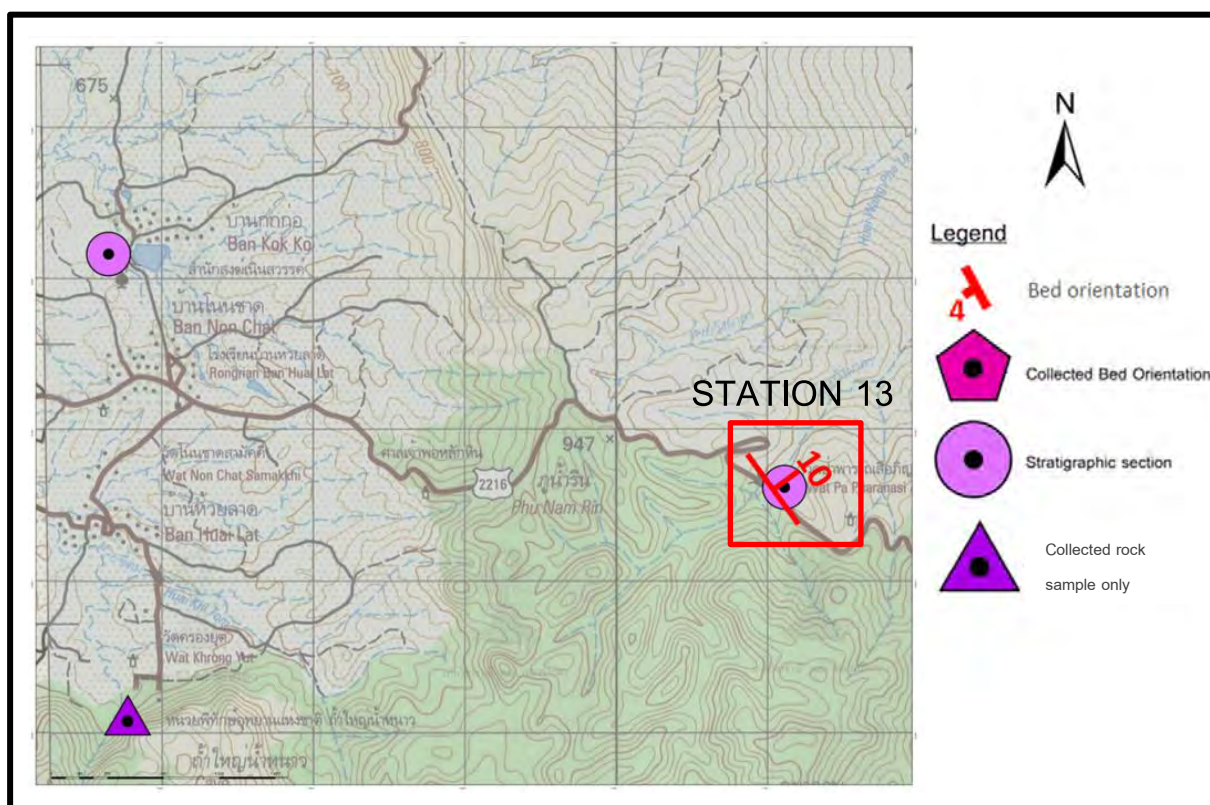


Figure 3-50. Topographic map of Station 13 in the red square. Stratigraphic section is measured at this location as well as bed orientation measurement and rock sample collection.



Figure 51. Outcrop of station 13.

### LITHOSTRATIGRAPHIC COLUMN

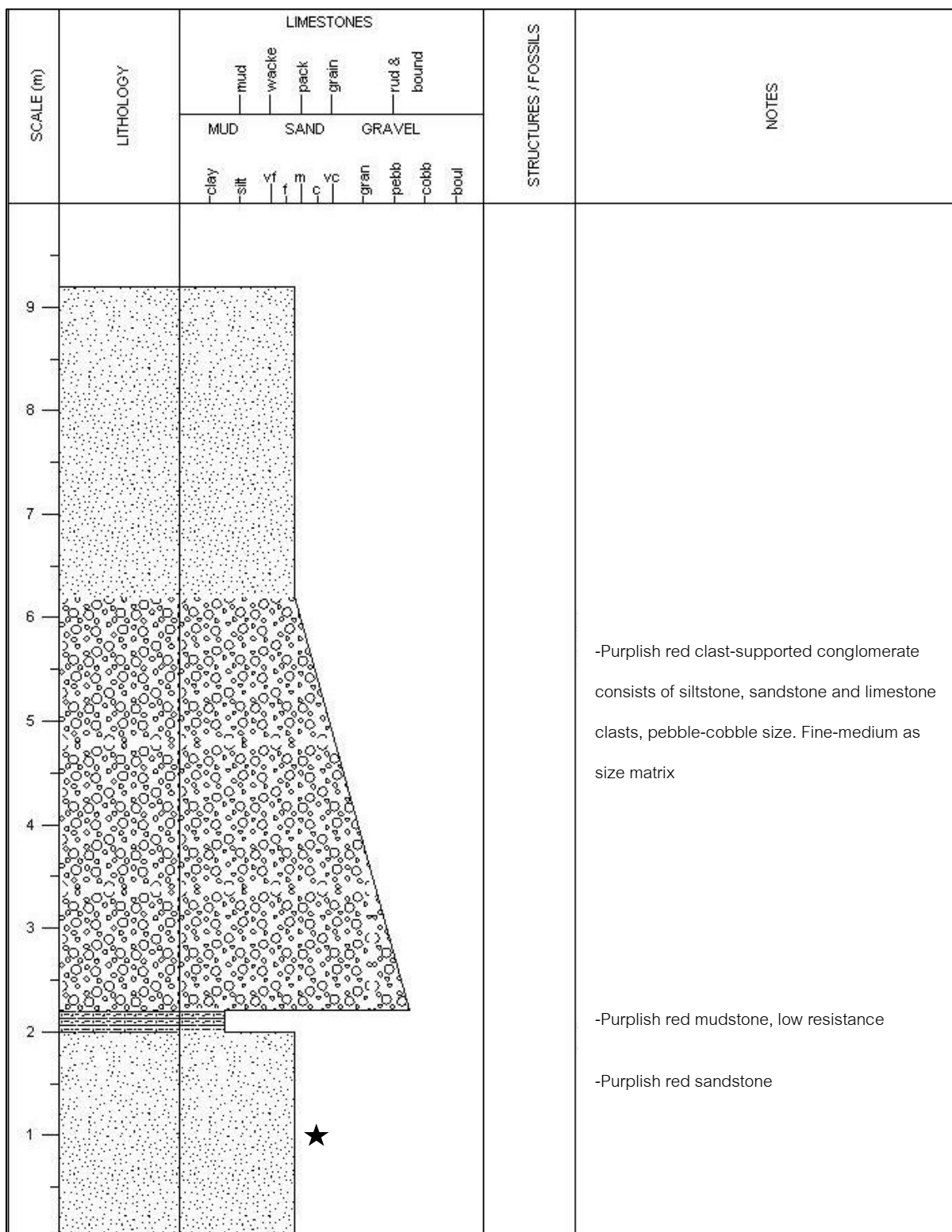


Figure 3-52. Lithostratigraphic column of Station 13. The star symbol shows the location of where the rock sample was collected.

## LITHOLOGY:

1. Conglomerate: Clast-supported conglomerate, purplish red when fresh. Clast size ranges from cobble to pebble from the bottom to the top. Clasts consist of siltstone, limestone and sandstone with fine to medium sand matrix.
2. Sandstone: Purplish red when fresh, fine-medium sand grain size, well rounded and well sorted.
3. Mudstone: Purplish red when fresh, clay-silt grain size, well compacted.

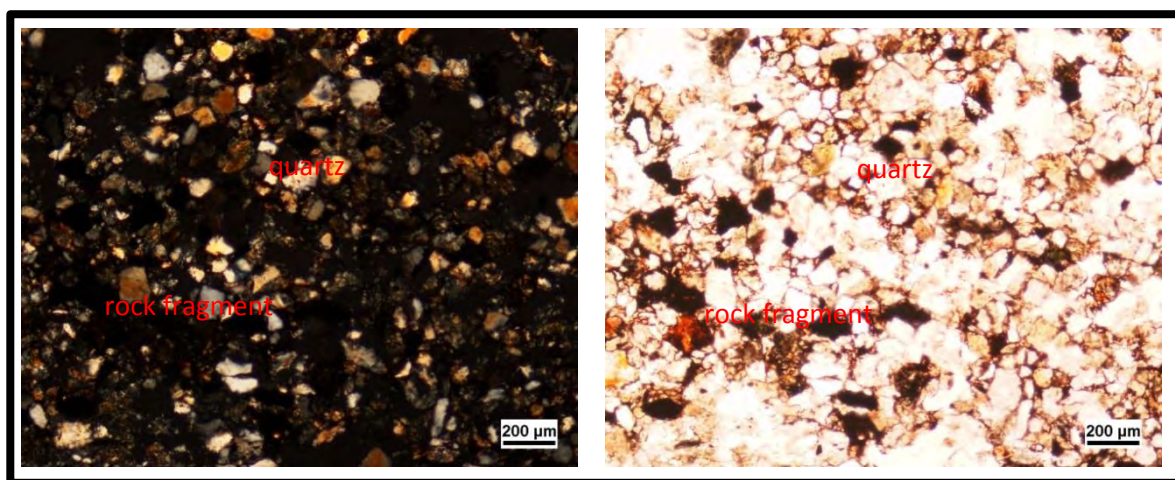


Figure 3-53. Thin section of lithic greywacke sandstone from Station 13. Left (PPL) Right (XPL) shows subangular in shape, well sorted, fine-medium sand grain size quartz (75%) and fine sand grain size rock fragment (25%)

## CHAPTER 4

### DISCUSSION AND CONCLUSION

#### 4.1. DISCUSSION

##### 4.1.1. CLASSIFICATION OF ROCK UNITS

Lithostratigraphy of the study area can be divided into 4 rock units from ascending order as follows;

**Unit A:** Black calcareous shale which shows as a thick bed of 10-40 cm. as well as a layer of 1-5 cm.

- Representative area: Tad Yai waterfall, Ban Pa Ruak.

**Unit B:** Dark grey-black calcareous shale, dark grey argillaceous limestone, grey siltstone, light-dark grey mudstone, coal seam and fresh water fossils in calcareous shale are presented in some areas.

- Representative area: Ban Huai Sanamsai, Ban Kok Mon.

**Unit C:** Light-dark grey calcareous clastic sedimentary rock ranges from mudstone to coarse-grained sandstone in some area shows conglomerate bed with graded bedding.

- Representative area: Pran Ba waterfall, Ban Nam Nao homestay, Ban Non Chat, Phu Mok.

**Unit D:** Purplish red clastic sedimentary rocks ranges from mudstone to medium sandstone and conglomerates.

- Representative area: Huai Pha La.

Each rock unit can be represented by lithostratigraphic column from the representative area (Figure 4-1); Tad Yai section represents Unit A, Ban Huai Sanam Sai section represents Unit B, Pran Ba section represents Unit C and Huai Pha La section represents Unit D

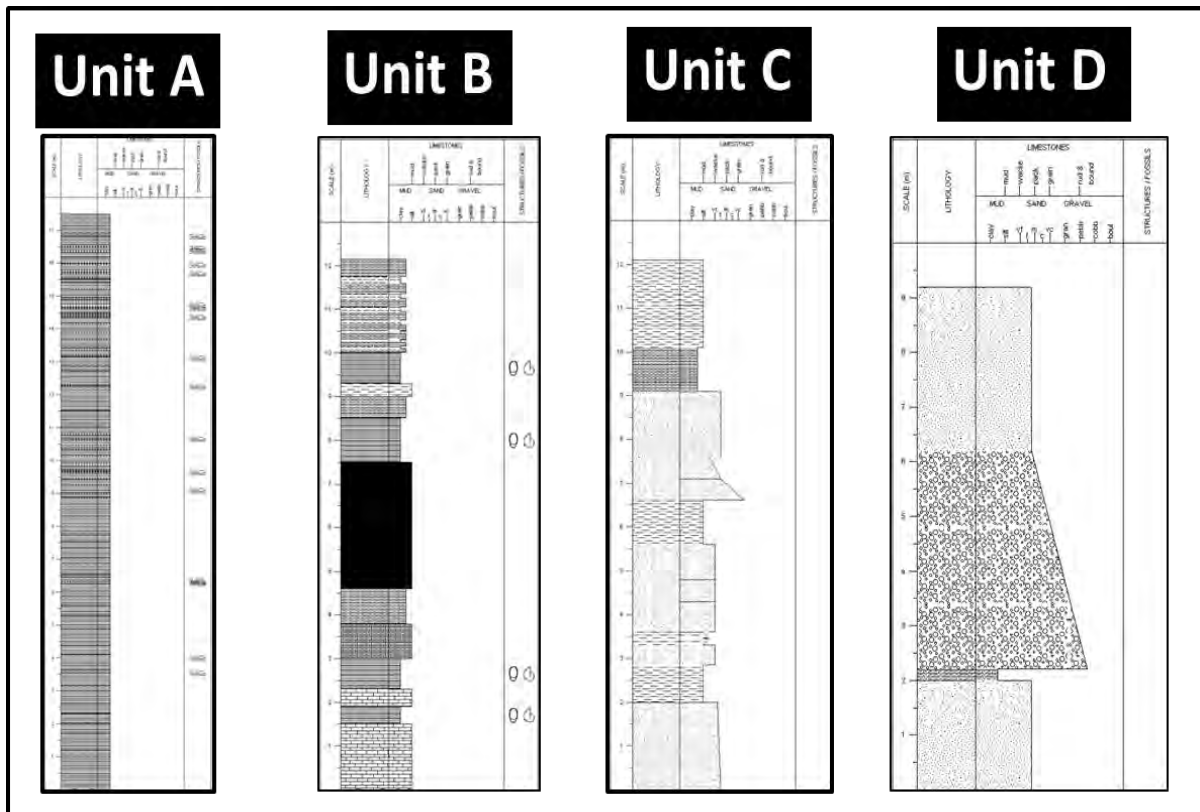


Figure 4-1. Stratigraphic column of units A-D in the study area.

#### 4.1.2. CORRELATION

All locations and bed orientation gained from the field work are plotted on a topographic map of the study area (Figure 4-2) in order to study the correlation of whole rock units.

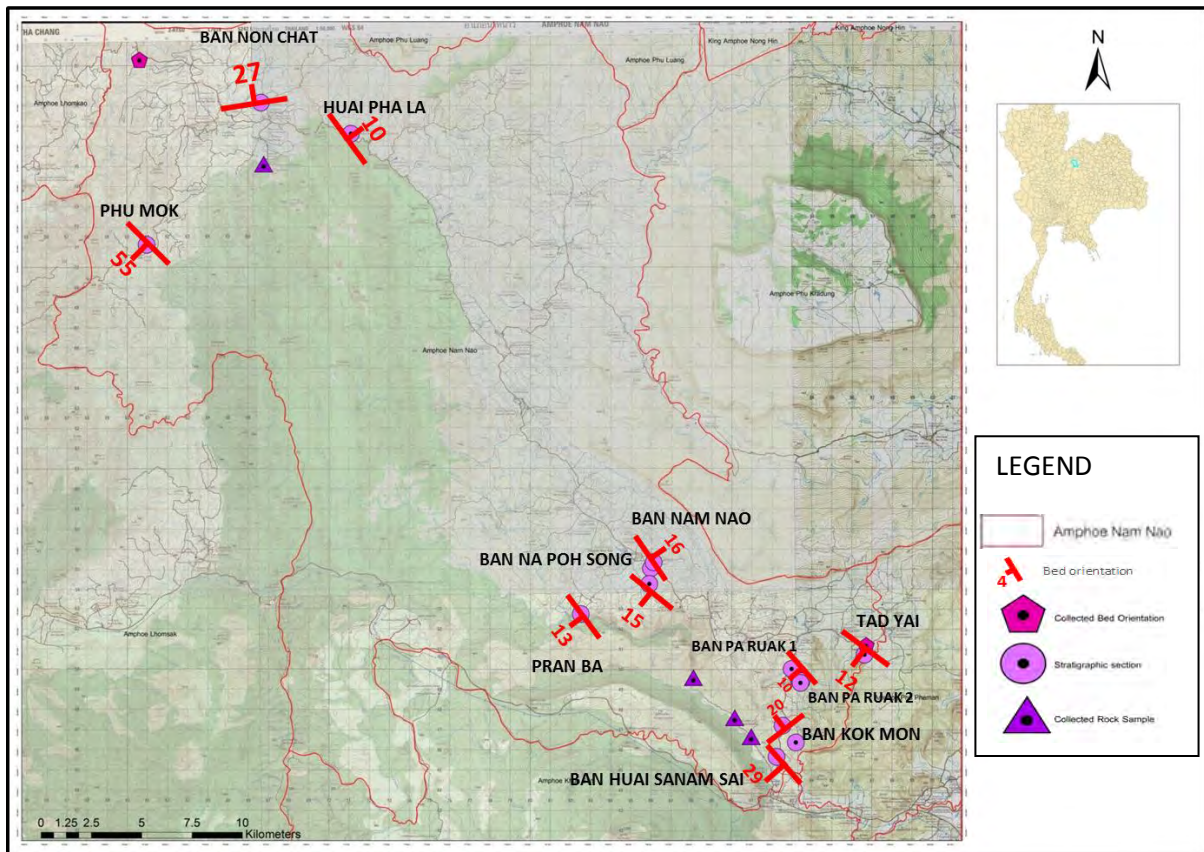


Figure 4-2. Topographic map of Amphoe Nam Nao showing locations of study.

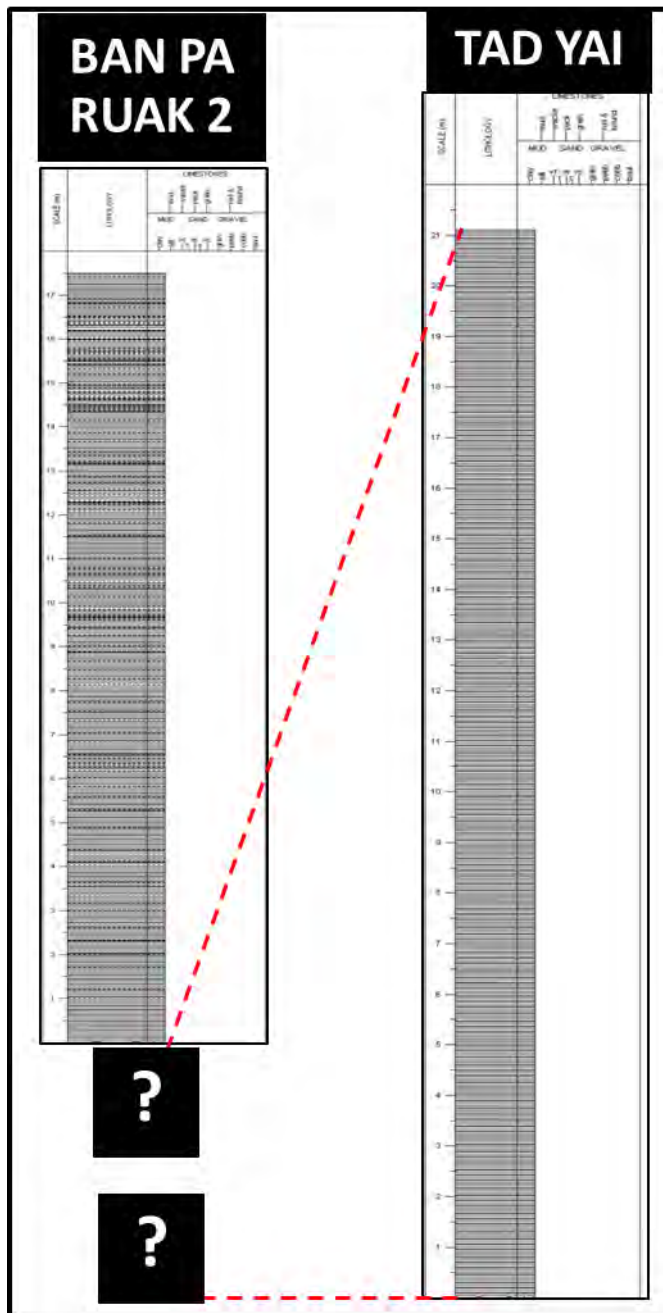
From the geological field survey, each stratigraphic column from all stations can be correlated to each other depending on rock classification (rock unit) and bed orientation as follows;



Unit A

SW

NE



Tad Yai section (Station 5) can be correlated to Ban Pa Ruak 2 section (Station 6) (Figure 4-3) which have common lithological properties: they both compose of only black calcareous shale. Due to there being only one rock type in both sections, it is hard to correlate the lithostratigraphy. Therefore, the only evidence that can be used for correlation is the orientation of bedding. The dip direction of Unit A is southwest therefore the strata exposed at eastern side are older than the western one. Based on bed orientation and topography of the area, it can be concluded that Tad Yai section lies beneath Ban Pa Ruak 2 section or it is part of the lower Ban Pa Ruak section.

Figure 4-3. Stratigraphic correlation of Unit A between Tad Yai waterfall section and Ban Pa Ruak 2 section.

Unit B

SW

NE

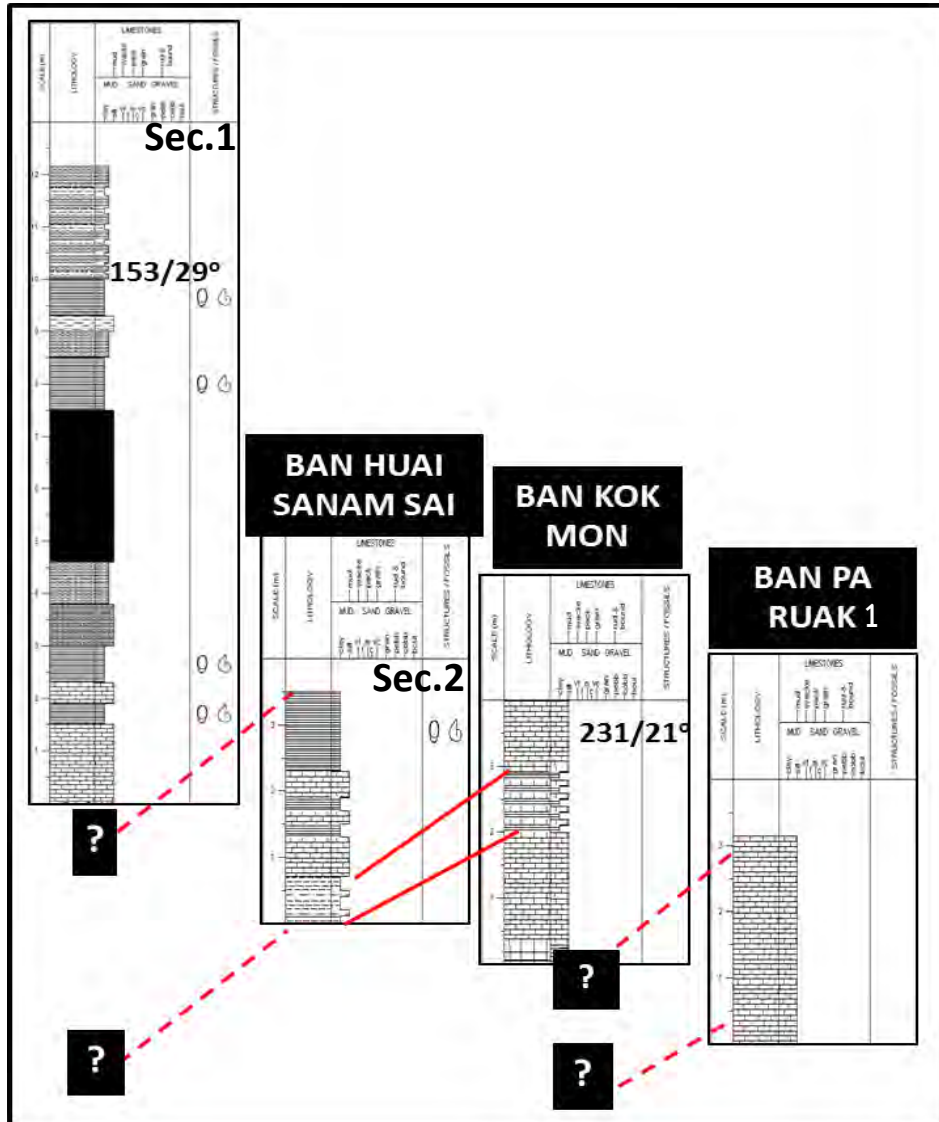


Figure 4-4. Stratigraphic correlation of Unit B including Ban Huai Sanam Sai section, Ban Kok Mon section and Ban Pa Ruak 1 section.

The correlation of Unit B (Figure 4-4) includes Ban Huai Sanam Sai sections (Station 1), Ban Khok Mon section (Station 3) and Ban Pa Ruak 1 section (Station 2) have common lithology. The lower section of Ban Huai Sanam Sai can be correlated with the upper part of Ban Khok Mon section, so Ban Khok Mon section is likely to be overlain by Ban Huai Sanam Sai section. From lithological sequence it can be concluded that Ban Pa Ruak 1 section underlies Ban Khok Mon Section.

## Unit C

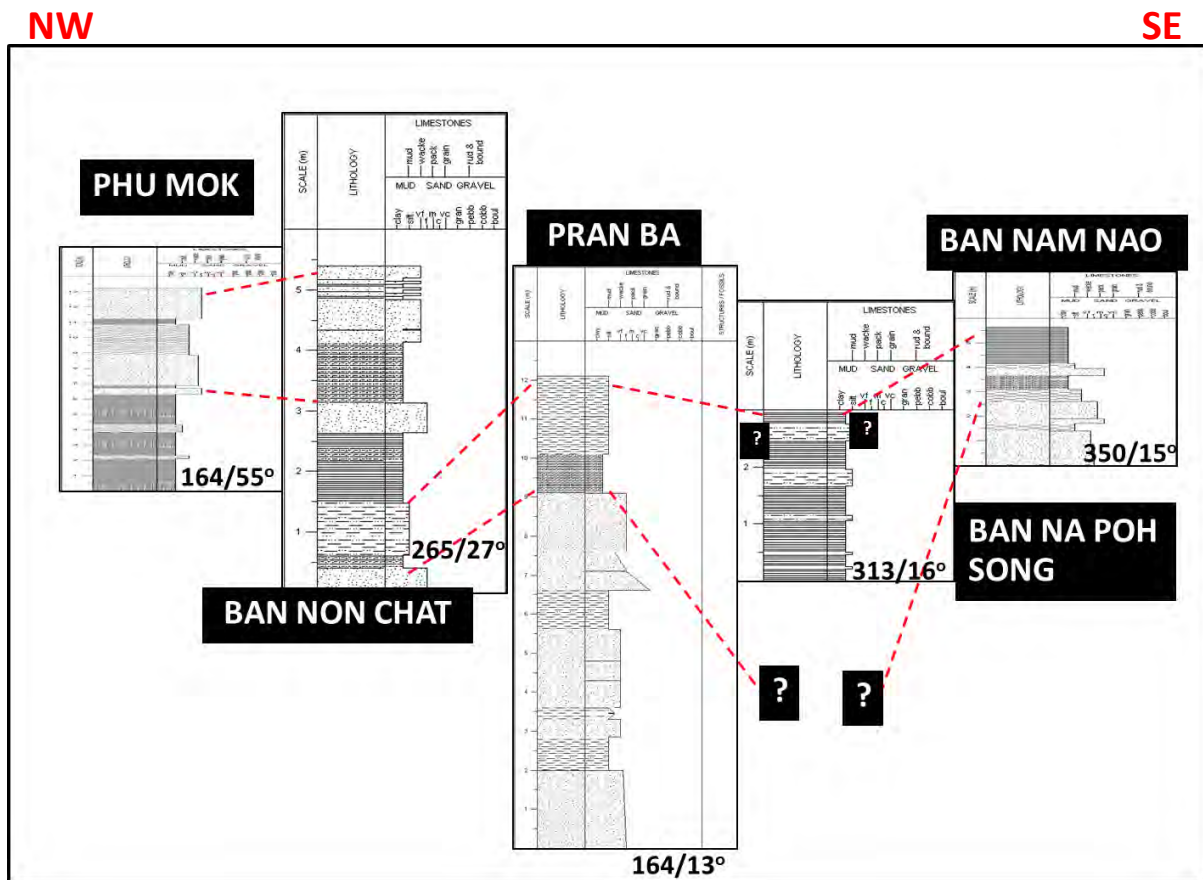


Figure 4-5. Stratigraphic correlation of Unit C including Phu Mok section, Ban Non Chat section, Pran Ba section, Ban Nam Nao section and Ban Na Poh Song section.

The correlation of Unit C (Figure 4-5) includes Phu Mok (Station 12), Ban Non Chart (Station 11), Pran Ba (Station 8), Ban Nam Nao (Station 9) and Ban Na Poh Song (Station 10) sections is shown in Figure 4-5. The top part of Phu Mok section can be correlated to the upper part of Ban Non Chart section while the lower part of Ban Non Chart section can be correlated to the top part of Pran Ba section. The upper part of Ban Nam Nao section can be correlated with upper Ban Na Poh Song section and upper part of Pran Ba section. Therefore, the lowest section of Unit C is Pran Ba section and the highest part of Unit C is Phu Mok section. Paleoenvironment of Unit C is possibly lake margin with influence of fluvial in some part of the Unit C (i.e. lower part of Pran Ba section).

Unit D (Station 13) composes of purplish red sandstone with fine-medium grained sand, well rounded and well sorted. Conglomerate in this section is purplish red with matrix-supported texture clast consist of siltstone, limestone and sandstone with fine to medium sand matrix. Other rock units in the study area have common lithology, grey color when fresh, calcareous cement and are well compacted, Unit D is clearly different. It is likely that Unit D is not part of Huai Hin Lat Formation.

#### Correlation of stratigraphy in the study area

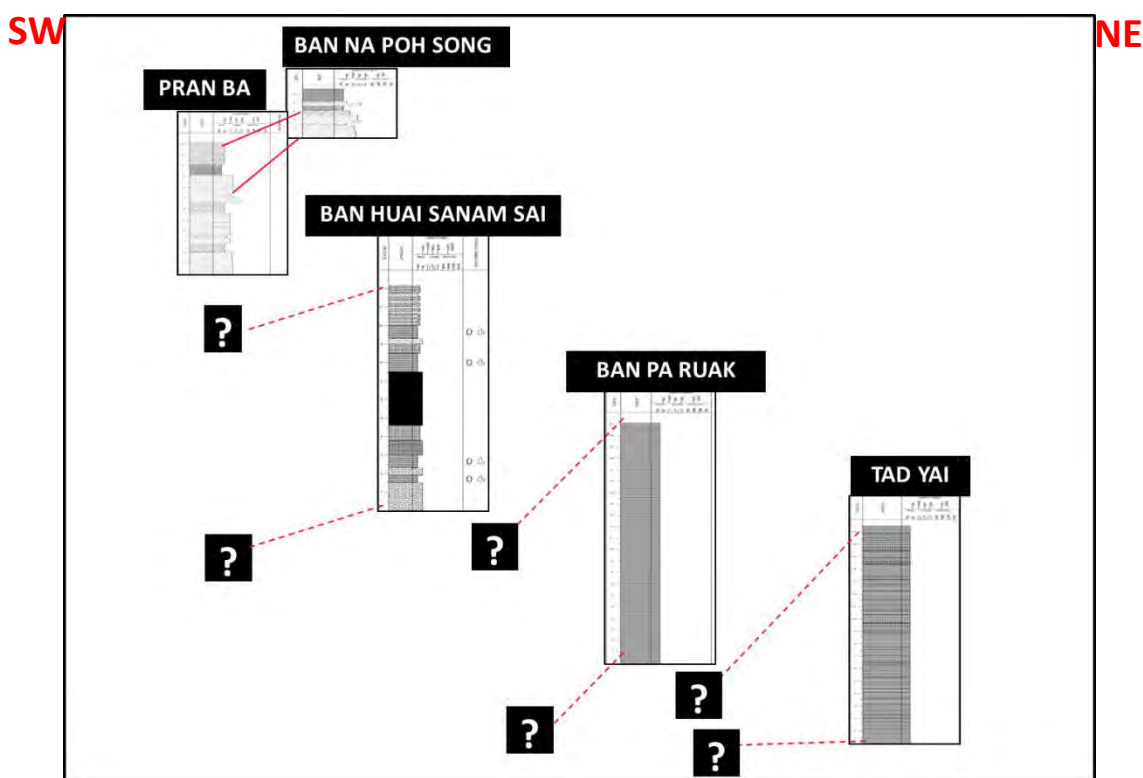


Figure 4-6. Stratigraphic correlation of all rock units in the study area showing Tad Yai and Ban Pa Ruak section (Unit A) is the lowest unit, overlain by Ban Huai Sanam Sai section (Unit B) and Pran Ba and Ban Na Poh Song section (Unit C) is the uppermost unit.

According to the lithostratigraphy and bed orientation of the 4 rock units, Unit A, at the eastern part of the study area is the lowest sequence that underlies Unit B which is found at the eastern area of Unit A. Overlying Unit B, is Unit C at the central and western parts of the study area (Figure 4-6).

### 4.1.3. DEPOSITIONAL ENVIRONMENT

Unit A: Lithology of Unit A is black calcareous shale, well bedded up to one hundred meters in total thickness. The dark color of rock in Unit A is a result of high organic matter content, thus it can be concluded that the depositional environment of Unit A was in a low energy condition such as the bottom of the lake.

Unit B: Lithology of Unit B is fine-grained calcareous clastic sedimentary rocks with coal seam. Thin section of calcareous shale from Unit B, contain fossils of shell fragments, therefore the depositional environment of Unit B is likely to have been lacustrine environment as follows;

- Calcareous shale, argillaceous limestone, mudstone and siltstone deposited in lacustrine to lacustrine margin environments
- Coal seam deposited in swamp environment near lake margin

Unit C: Lithology of Unit C is coarser grain sedimentary rocks with some conglomerate and graded bedding indicates transitional zone from lacustrine to fluvial environment.

Unit D: Lithology of Unit D is mostly sandstone and conglomerate indicating fluvial environment.

## DEPOSITIONAL ENVIRONMENT MODEL

The depositional environment model of the Huai Hin Lat Formation in Amphoe Nam Nao is shown in Figure 4-7. The model of a basin showing the deposit place of each rock unit, Unit A at the bottom of a lake where thick bed of shale can be deposited in a low energy condition, Unit B at the basin margin where argillaceous limestone can be deposited and other clastic sedimentary rocks and at swamp area where coal can be deposited, Unit C at the transitional area of lake and river gave the strata of shale which grades into coarser grained sedimentary rocks of fluvial environment.

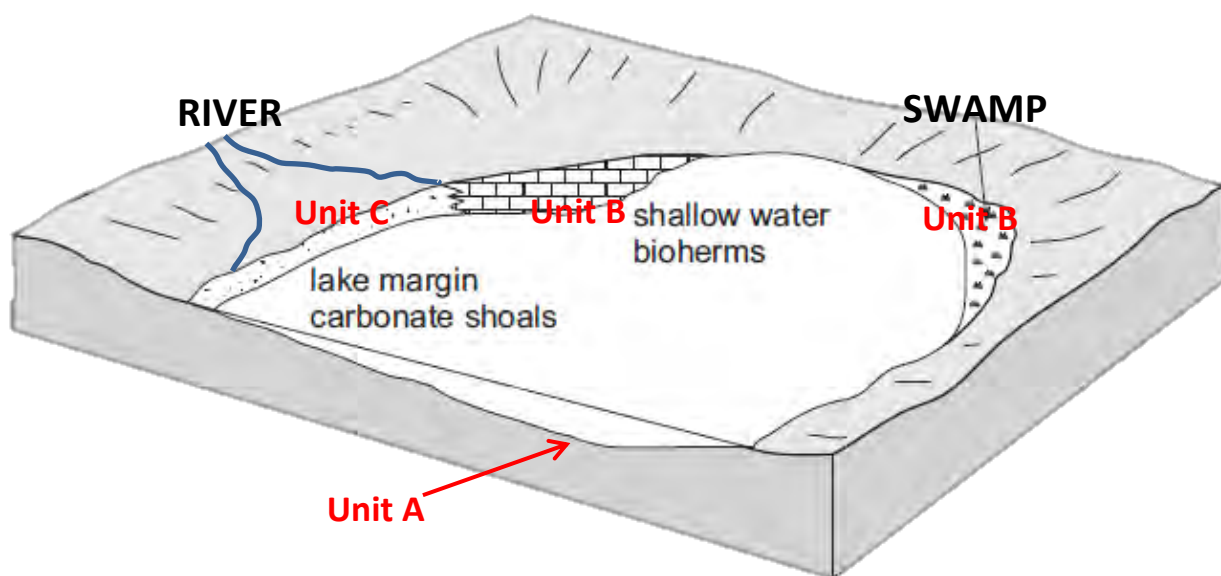


Figure 4-7. Illustration of depositional environment model (modified after Nichols, 2009)

## 4.2. CONCLUSION

Three rock units, A, B and C probably belong to the Huai Hin Lat Formation, according to the field survey and lithological data. The lowest sequence, Unit A exposes at the easternmost part of the study area, it consists of black calcareous shale deposited in deep lacustrine environment. Overlying Unit A, Unit B exposes at the eastern side of Unit A and consists of calcareous fine-grained sedimentary rocks and coal seam, it likely deposited in lacustrine margin and swamp environments. Overlying Unit B, Unit C exposes at the central part of the study area and consists of calcareous coarse grain sedimentary rocks which are likely to have been deposited in transitional between lacustrine and fluvial environment.

However, based on a report by DMR (2012), the area of Pran Ba waterfall (Unit B) was classified into Sam Khaen Member, the lowermost member of Huai Hin Lat Formation which mostly includes limestone conglomerate and sandstone indicating deep lacustrine environment. DMR (2012) also assigned the area of Tad Yai waterfall (Unit A) into Tad Fa member of Huai Hin Lat Formation which consists of black calcareous shale and grey sandstone deposited in lacustrine environment and overlies Sam Khaen Member. Therefore, according to DMR, Unit B is older (underlies) Unit A which is different from interpretation in this report which is based on the bedding orientation and the lack of evidence of overturn or faulting in these rock units.

DMR (2012) assigned Unit D in the area Huai Pha La to Nam Phong Formation of Khorat Group which normally overlies Huai Hin Lat Formation.

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