ธรณีวิทยาและบรรพชีวินวิทยาของซิตตะโกซอรัส จากอำเภอคอนสวรรค์ จังหวัดชัยภูมิ

นางสาว ชยารัศมิ์ เซ็นทองหลาง

รายงานนี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรวิทยาศาสตร์บัณฑิต

ภาควิชาธรณีวิทยา คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2554

GEOLOGY AND PALEONTOLOGY OF *PSITTACOSAURUS* FROM AMPHOE KHON SAWAN, CHANGWAT CHAIYAPHUM

Miss Chayarus Centhonglang

A Report Submitted in Partial Fulfillment of the Requirements

for the Degree Bachelor of Science, Department of geology,

Faculty of Science, Chulalongkorn University

Academic Year 2011

Date of Submit……...

Date of Approval……

Advisor's signature……

(Dr. Yoshio Sato)

ชื่อโครงการ	: ธรณีวิทยาและบรรพชีวินวิทยาของซิตตะโกซอรัสจากอำเภอคอนสวรรค์ จังหวัดชัยภูมิ
ผู้ทำการวิจัย	: นางสาว ชยารัศมิ์ เซ็นทองหลาง
อาจารย์ที่ปรึกษา	: ดร. โยชิโอะ ซาโตะ
ภาควิชา	: ธรณีวิทยา
ปีการศึกษา	: 2554

จากการศึกษาของ Buffetaut, Sattayarak และ Suteethorn (1989) ได้ค้นพบโครงกระดูกของไดโนเสาร์ชนิดใหม่ พบในชั้นหินกรวดมน ของหมวดหินโคกกรวด ที่หมู่บ้านดงบังน้อย อำเภอคอนสวรรค์ จังหวัดชัยภูมิ ซึ่งจัดอยู่ในตระกูล Ceratopsians วงศ์ *Psittacosauridae* จึงตั้งชื่อใหม่ว่า *Psittacosaurus sattayaraki* โครงกระดูกดังกล่าว จุดประสงค์ในการวิจัยคือทำการศึกษาลักษณะสภาพแวดล้อมโบราณของชั้นหินที่สะสมตัวบริเวณบ้านดงบังน้อย และบริเวณใกล้เคียง

ผลการศึกษาสามารถจำแนกชุดหินทรายในพื้นที่ศึกษาเป็น 2 กลุ่มคือ ชุดหินตอนบน และชุดหินตอนล่าง ชุดหินตอนบนประกอบด้วยหินทรายสีน้ำตาลแดง มีเม็ดตะกอนขนาดทรายละเอียดถึงปานกลาง และหินกรวดมนซึ่งประกอบด้วยเศษชิ้นตะกอนของ calcareous nodule หินทรายแป้ง หินโคลน และโครงกระดูกไดโนเสาร์ การคัดขนาดตะกอนดี เม็ดตะกอนกลมมน ขนาดเม็ดตะกอนอาจใหญ่ถึง 1 เซนติเมตร ภายในหินกรวดมนอาจพบการแทรกตัวของหินทรายสีน้ำตาลแดง รูปเลนส์ชั้นบาง แสดงลักษณะแนวเฉียงระดับขนาดเล็กที่เกิดจากการกระทำของคลื่น (small ripple cross-bedded) ชุดหินตอนล่างประกอบด้วยหินทรายสีม่วงแดง ขนาดเม็ดตะกอนใหญ่กว่าชุดหินตอนบน ประกอบด้วยหินทรายทั้งหมดซึ่งมีการแทรกสลับระหว่างหินทรายที่แสดงแนวชั้นเฉียงระดับ (cross-bedded sand) และหินทรายที่แสดงชั้นหินบาง (parallel laminated sand) โดยมีความหนา 25 เมตร ผลจากการลำดับชั้นหินตามลักษณะหินและการแบ่งหินทรายตามลักษณะปรากฏของหิน สามารถนำไปวิเคราะห์หาสภาพแวดล้อมการสะสมตัวโบราณได้ คือ ชุดหินตอนล่างและตอนบนต่างสะสมตัวบริเวณ point bar ในระบบทางน้ำแบบโค้งตะหวัด (meandering river) หินกรวดมนได้จากการสะสมตัวในช่วงเวลาที่น้ำไหลด้วยความเร็วสูง จึงสามารถพาตะกอนที่ยังไม่แข็งตัวและตะกอนขนาดใหญ่มาสะสมตัวร่วมกันได้

Title : GEOLOGY AND PALEONTOLOGY OF *PSITTACOSAURUS* FROM AMPHOE KHON SAWAN, CHANGWAT CHAIYAPHUM

Student : Miss Chayarus Centhonglang

Advisor : Dr. Yoshi Sato

Department : Geology

Academic year : 2011

Abstract

According to Buffetaut, Sattayarak and Suteethorn (1989), new species of Ceratopsians, *Psittacosaurus* was collected from Ban Dong bang Noi in Changwat Chaiyaphum, within conglomerates bed of Khok Kruat Formation in Khorat Group. To determine biostratigraphic position and paleo-environments are the purpose of this study. Lithostratigraphy of study area can be divided into 2 successions; Lower and Upper successions. Upper succession composes mostly of reddish-brown sandstone and conglomerate with calcareous nodule, fine to medium grained sandstones. Conglomerate contains granule to small pebbles of calcareous nodule, sub-rounded to rounded pebbles up to 1 cm., sand lens in conglomerates shows small ripple cross-bedded, therefore lithofacies is transition from clast-supported through sand matrix-supported which horizontally stratification. Lower succession composes mostly of purple sandstone, varies in grained size. The sandstone succession contains of sandstone which interbedded between cross-bedded sand and parallel laminated sand at the lower part and shows small ripple-cross bed interbedded with parallel lamination at the upper part. The total thickness is 25 m. The results from lithostratigraphic column and lithofacies, paleoenvironments can be reconstructed. The lower sandstone succession are deposit on point bar in meandering river system and continued accumulated in the upper succession. Conglomerates are transported by high-velocity current and deposited in point bar. Biostatigraphic position can be fixed on top of Upper successions within conglomerates bed which accumulate in point bar of meandering river.

Acknowledgements

This project is could not successfully completed without the aid of Department of geology, Faculty of Science, Chulalongkorn University for the financial support and all facilities for this work. I would like to thank Dr. Yoshio Sato for his helpful suggestion. I deeply express my thank to all professors in Department of geology for giving me all suggestions.

Thanks are due to Miss Thanatchaporn Phanomphongphaisarn and Miss Maneenuch Pansorn for helpful in field investigation and laboratory work. Finally, I specially thank to my friend for their stimulation and encouragement.

Content

List of Figures

List of Tables

Chapter 1: Introduction

1.1 General Statement

New species of *Psittacosaurus* was named as "*Psittacosaurus suttayaraki*" (Buffetaut, Sattayarak and Suteethorn, 1989). The first fossil fragment is right dentary which is founded in conglomerate bed at Ban Dong Bang Noi, Amphoe Khon Sawan, Changwat Chaiyaphum. Fossil locality is belong to Khok Kruat Formation where is reddish purple sandstone-conglomerate dominant with calcareous cement. Focusing on conglomerate, mostly clast-support contains caliche and calcareous nodule, small pebble of siltstone and mudstone. Therefore, lithology is significantly Khok Kruat Formation. According to previous work, focusing on fossil detailed description and relationship with other species (especially from China). The result is not referred to paleoenvironments of fossil locality, only reference from DMR that is fluvial system. Thus, the reconstruction of paleoenvironments have been determined in this study.

This work is begins from lithofacies analysis, following on Miall (1996) which considered dominant primary sedimentary structure. Moreover, supported data of petrography which including thin-section and polished-slab are used to classified type of sandstone (follow on Pettijohn, 1972) and determined characteristic of conglomerate (follow on Miall, 1978). Lithofacies is divided by using bed-by-bed of lithostratigraphic section and applied to depositional environment analysis.

According to geologic map of Changwat Chaiyaphum (scale 1:250,000) by Department of Mineral Resource which is compiled by Niwat Boonnop (2010). Fossil locality is in area of Maha Sarakham Formation, but lithology which founded is mostly sandstone and conglomerate. Well exposed succession in artificial pond at Ban Huai Bong

Nuea is excellent outcrop of reddish-purple sandstone indicated clearly to Khok Kruat Formation. Therefore, geologic map of study area will be modified from DMR map.

1.2 Objectives

1. To fix the stratigraphic position of fossil locality in Khok Kruat Formation.
2. To reconstruct the paleoenvironments during *Psittacosarus* had been living.
3. To compare the specimens with holotype in China.

1.3 Scope of work

To investigate the stratigraphic position of *Psittacosaurus* in study area, make the stratigraphic sections from exposed successions for reconstructing the depositional environments. Moreover, compare *Psittacosaurus* specimens in Chaiyaphum and holotype in China and recognize the taxonomical relationships between them.

1.4 Study area

Study area is located in Amphoe Khon Sawan, Changwat Chaiyaphum, covers an area about 130 square kilometers, comprising 7 villages, along the road no. 2054 (Ban Lat Yai – Khon Sawan – Chong Sam Mo). Shown in topographic map is shown in Fig. 1.1, scale 1:50,000, map sheet 5440 I (Amphoe Khonsawan) and 5440 IV (Changwat Chaiyaphum)

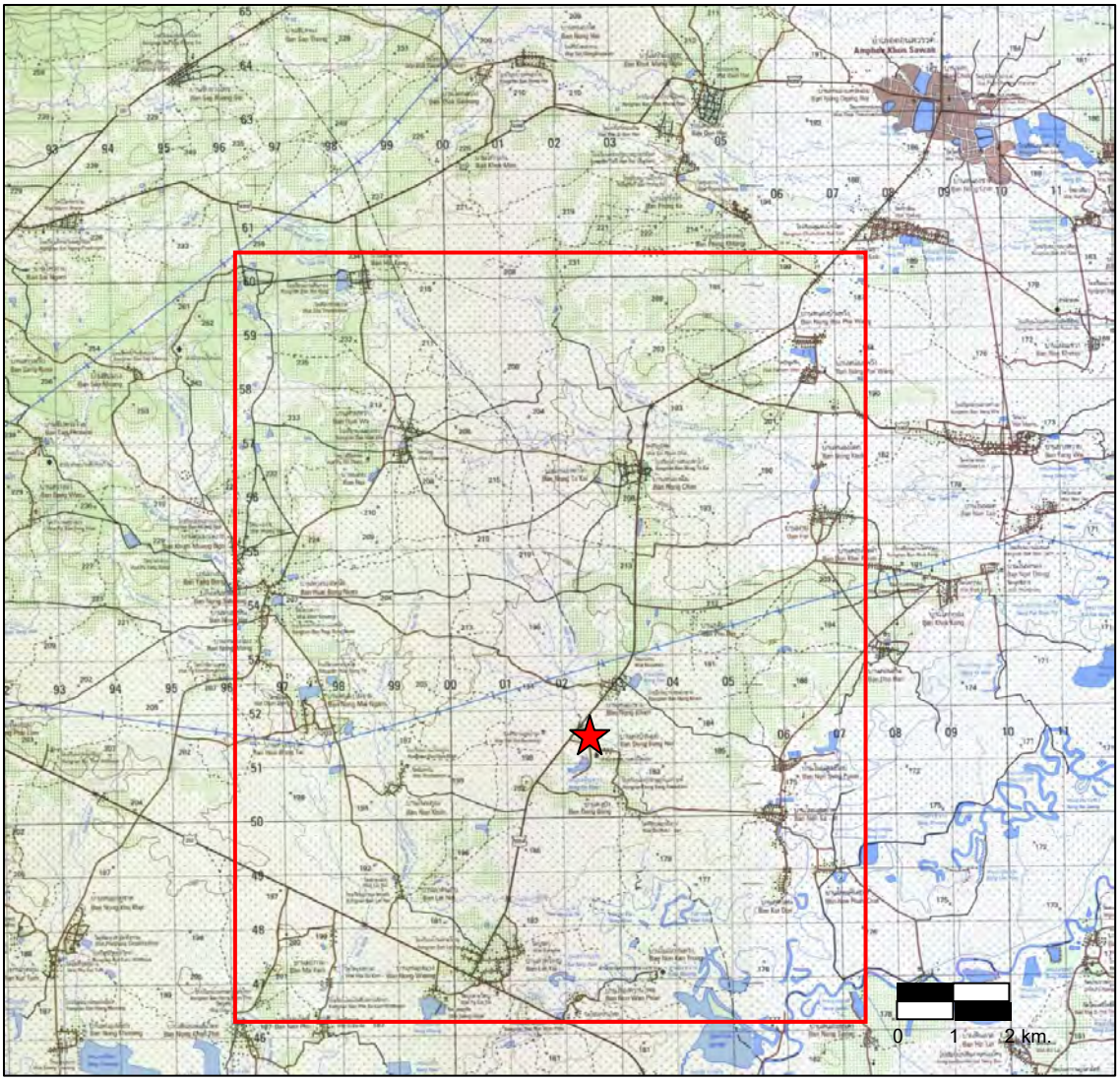


Fig 1.1 Study area (red box)along the road no. 2054. Amphoe Khonsawan, Changwat Chaiyaphum (Topographic map, scale 1:50,000), WGS84, Edition 1-RTSD, Series L7018), Map Sheet: 5440 I (Amphoe Khonsawan) and 5440 IV (Changwat Chaiyaphum) and red star is fossil locality.

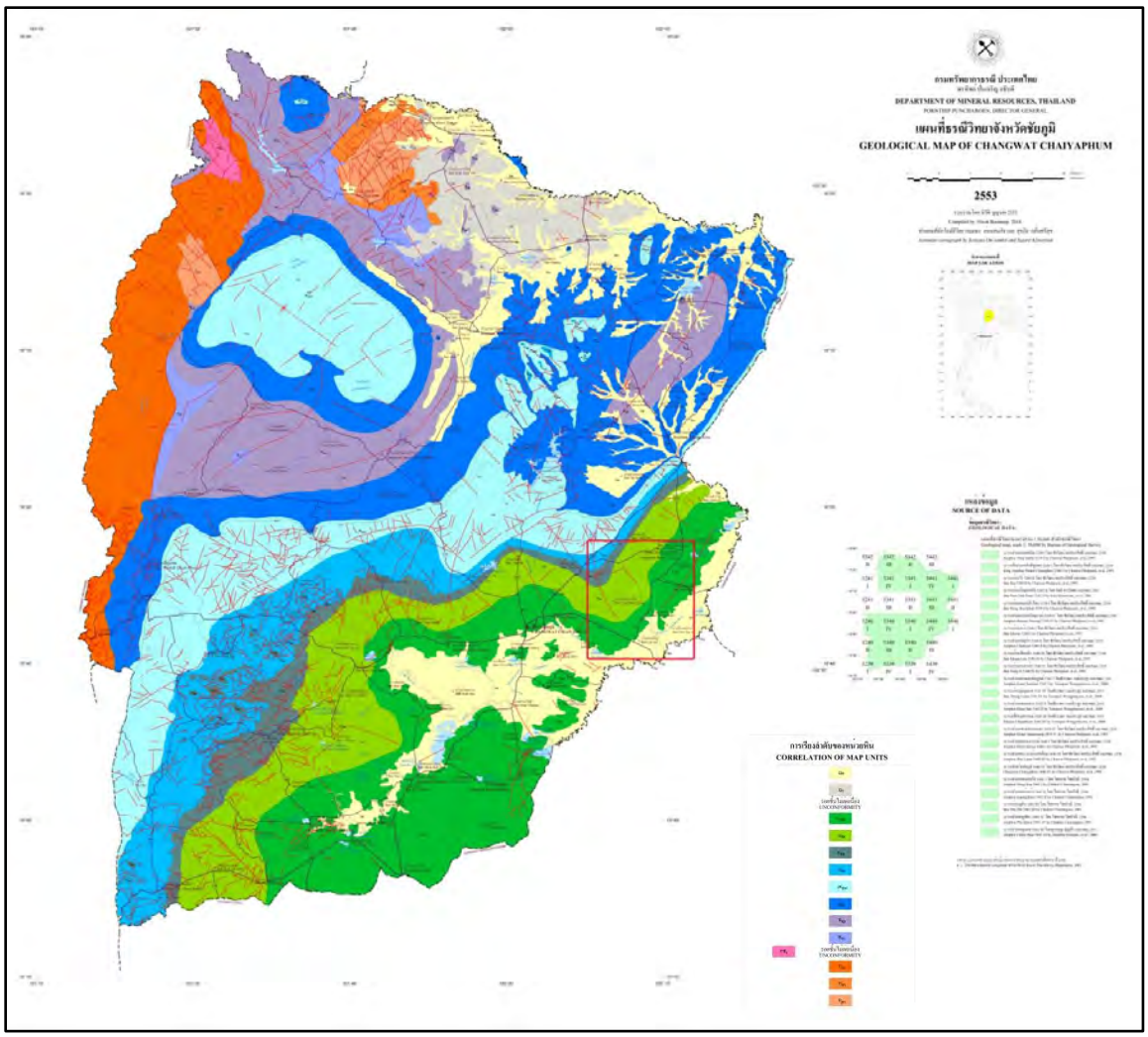


Fig 1.2 Geologic map of Changwat Chaiyaphum, scale 1:250,000, Department of Mineral Resource, compiled by Niwat Boonnop, 2010. Red box shows geologic map around study area.

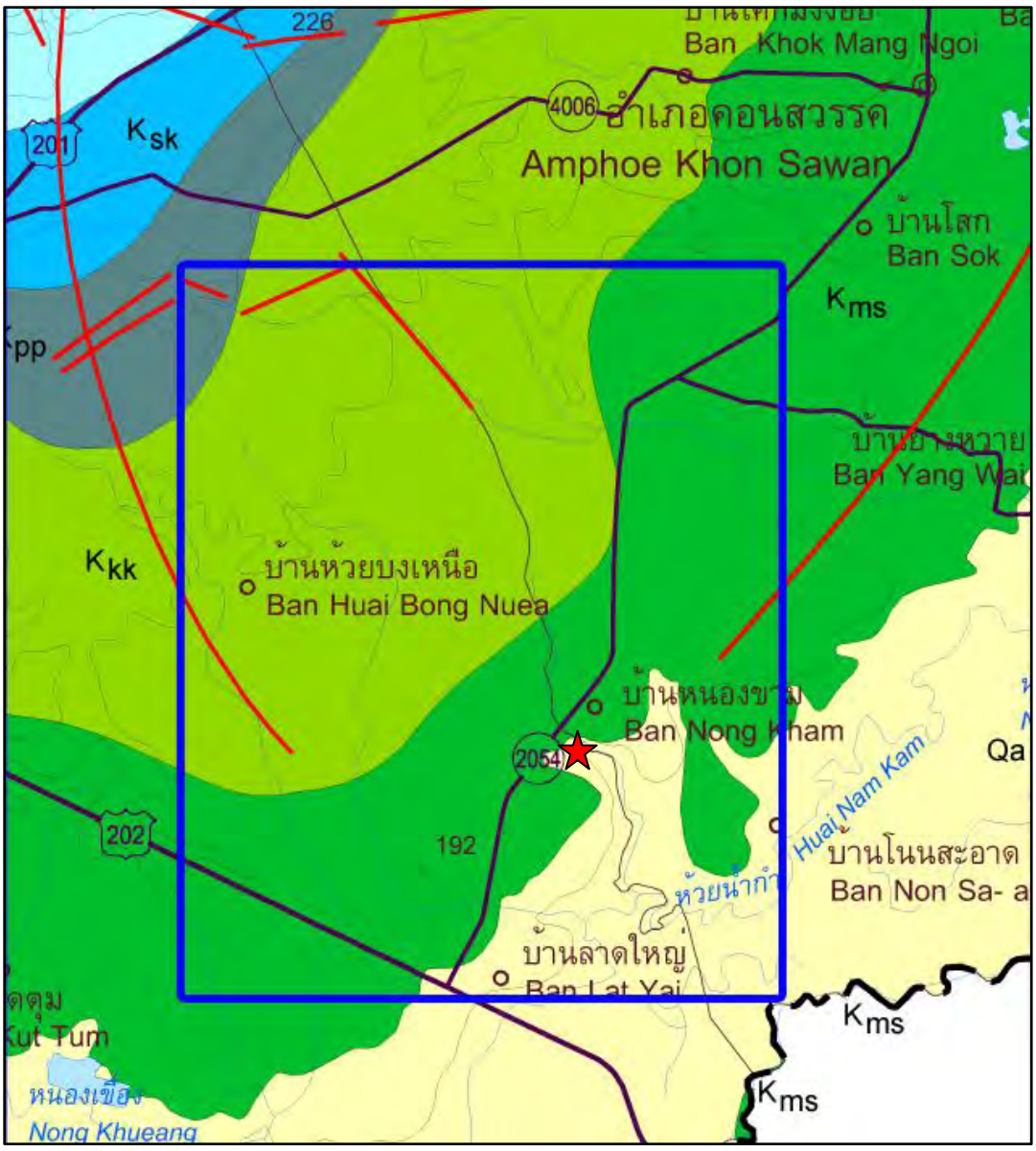


Fig 1.3 Blue box shows study area. Part of Geologic map of Changwat Chaiyaphum, Department of Mineral Resource (Fig 1.2) and red star is fossil locality.

Fig 1.4 Explanation of geologic map of Changwat Chaiyaphum, Department of Mineral Resource)

1.5 Theoretical Background and Relevant Research

Khorat Group is distributed in Northeast Thailand, which contain non-marine red beds aged in range of Late Jurassic to Cretaceous. Khorat Group consists of sandstone, conglomerate, siltstone and mudstone, which overlay on Paleozoic rocks with unconformable contact. Total thickness is about 4,000 meters. Khorat Group can be divided into 9 units; Huai Hin Lat, Nam Phong, Phu Kradung, Phra Wihan, Sao Khua, Phu Phan, Khok Kruat, Maha Sarakham and Phu Thok Formation, in ascending order (DMR, 2007).

Khok Kruat Formation was named by Ward and Bunnag (1964) which includes in the lower part of unnamed upper member of the Khorat Series of Jalichan and Bunnag (1954). The type section is in Changwat Nakhon Ratchasima along the road no.1 (Friendship Highway) from kilometer posts 207 to 239. The measured thickness of type section is 709 meters.

The Khok Kruat Formation overlies on the Phu Phan Formation, nearly horizontal and underlie by unnamed rocks at the top of the Khorat Group (Ward and Bunnag, 1964). The thin bed gypsum in the upper part of the formation is the boundary zone between Khok Kruat and overlying rocks.

The detailed information is provided by using core-drilling of water well, reveal that about 30% of the formation is sandstones (thickness up to 15 meter). The sandstone content decrease from 60% near base to 20% near the top. Grain size vary from medium to very fine and usually pale red to grayish-red (some beds are reddish-brown). In generally, the Khok Kruat Formation consists of siltstone and sandstone with caliche-silt conglomerate. The repeated of caliche-siltstone pebble conglomerates (origin discussion in the description of Phu Kradung Formation) is evident that land was exposed to subaerial erosion at these times. According to Pettijohn (1949, p.308, 384), the present of caliche in geologic section is indicative of arid or semiarid climatic conditions.

Vertebrate fossils are common in this formation, especially dinosaurs. Besides dinosaurs, hybodont shark teeth, fishes and turtles has been reported (Tong *et al*.). The first Ceratopsians, Psiittacosaurus was found at Ban Dong Bang Noi in Changwat Chaiyaphum (Buffetaut, Sattayarak and Suteethorn, 1989).

The fossil specimens were found in outcrop of in the pond along the road (no.2054) at Ban Dong Bang Noi, 20 km east of Chaiyaphum (Buffetaut and Suteethorn, 1992). They occurred at the boundary between fine-grained red sandstone and thin bed conglomeratic sediments of Khok Kruat Formation. Biostratigraphy data of fossil vertebrates referred to the Early Cretaceous age. The dinosaur fragments including the a well-preserved right dentary and a maxilla fragment, it described as the primitive Ceratopcian which differs from previously described species from Mongolia and China so they named to the new species of *Psittacosaurus sattayaraki* (Buffetaut and Suteethorn, 1992).

1.6 Expected Result

Reconstruction of paleoenvironments during Psittacosaurus had been living (Cretaceous).

1.7 Methodology

1) Literature review and study on previous works.
   - Introduction of Dinosaurs, Dinosaurs in Thailand, Characteristic of Psittacosaur (both in Thailand and China), Geology of Khorat Group especially the Khok Kruat Formation.

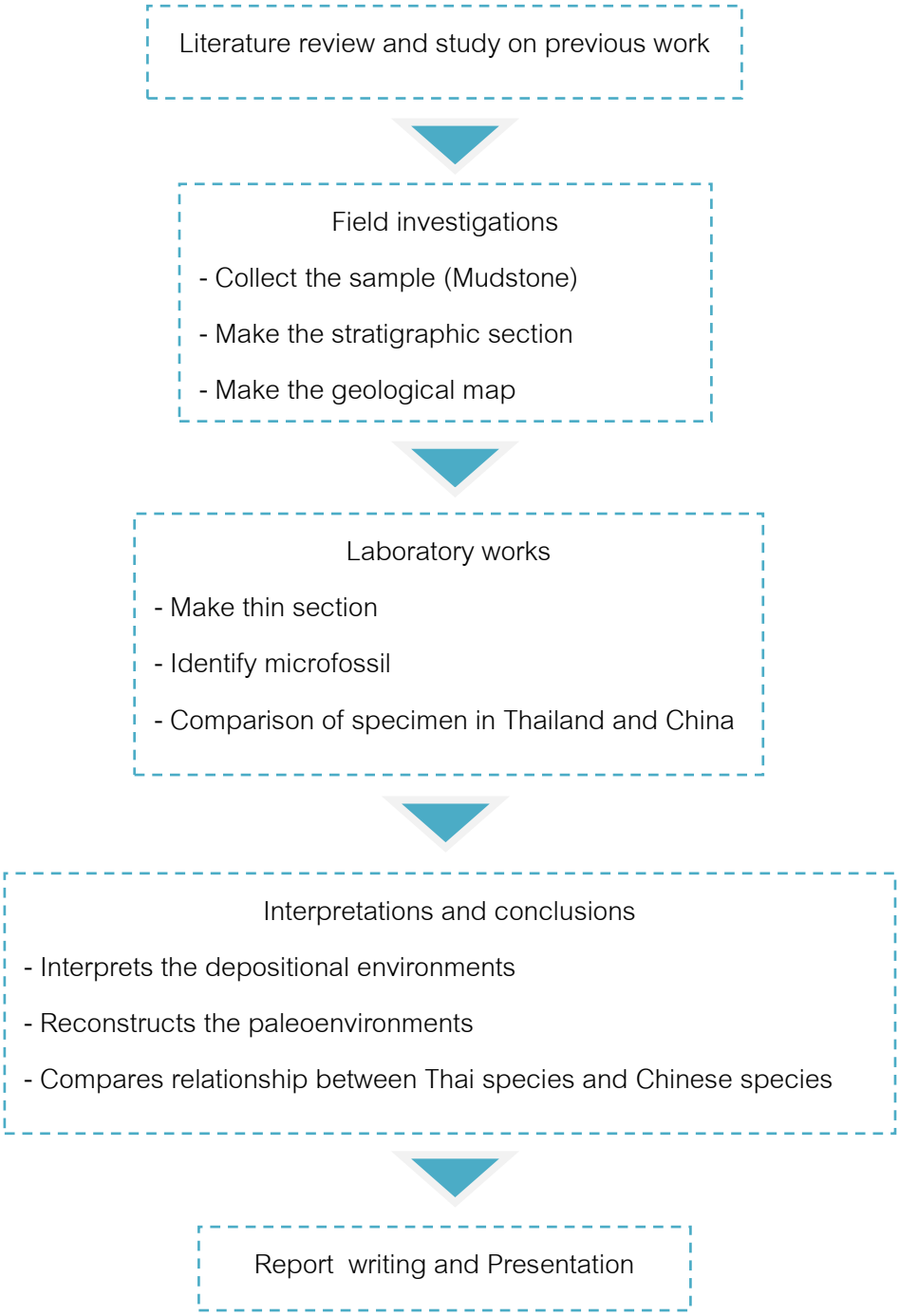
2) Field investigation
   - 2.1 Collect the sample
   - 2.2 Make the stratigraphic section to fix the stratigraphical position of fossil locality in Khok Kruat Formation
   - 2.3 Make the geological map around fossil locality

3) Laboratory works
   - 3.1 Make thin sections and polished slab
   - 3.2 Preparation and identification microfossil (Ostracods) by using HF + NaTPb methods
   - 3.3 Making the replica of the specimen, measurements and taking photos in Kalasin Dinosaur Museum

4) Interpretation and conclusion
   - 4.1 Interprets the depositional environments by using facies analysis (by using lithology, sediment structure)
   - 4.2 Reconstructs the paleoenvironments.
   - 4.3 Compares relationship between Thai species and China species.

5) Report writing and Presentation.

Methodology Flow Chart



Chapter 2: Results

2.1 Field Investigations

According to previous works, fossil locality (Ban Dong Bang Noi) and around the study area are in the Khok Kruat Formation (Buffetaut and Suteethorn, 1992). But geologic map of Changwat Chaiyaphum by Department of Mineral Resource in 2010, shows the study area is classified to Mahasarakham Formation. After field work, by the lithology characteristic and sedimentary structure exactly it is belonged to Khok Kruat Formation so geological map of study area is modified from DMR (2010). Almost of rocks are reddish-brown sandstone and conglomeratic sandstone at the upper part with caliche and calcareous nodule.

Along the road no. 2054, distance about 30 km. (N-S trending). The outcrops always exposed nearly the road but sediment structure imperfectly shows at the quarry in Ban Dong Bang shows succession of sandstones, conglomeratic sandstone and mudstone, attitude of bed nearly horizontal. Study area was divided in to 2 successions; upper succession (east side of road) and lower succession (west side of road).

Upper succession: including fossil locality and around where are poorly exposed outcrops, composed mostly reddish-brown sandstone and conglomerate with calcareous nodule, fine to medium grained sandstones. Conglomerate containing granule to small pebbles of calcareous nodule, sub-rounded to rounded pebbles up to 1 cm. sand lens in conglomerates shows small ripple cross-bedded, discontinuous deposited on gravel beds.

Lower succession: including outcrop at Ban Non Khun and Ban Huai Bong Nuea, outcrops well exposed in artificial pond, composed mostly purple sandstone, medium to coarse grained sandstones. Succession of sandstones, which interbedded between planar cross-

bedded sandstone and parallel laminated sandstone. Top of succession shows ripple-cross bedded sandstone interbedding with conglomeratic sand lens.

The lithostratigraphic section was constructed from outcrop of Ban Dong Bang Noi (Upper succession) and Ban Huai Bong Nuea (Lower succession) which distinguished each bed by using apparently sedimentary structure.

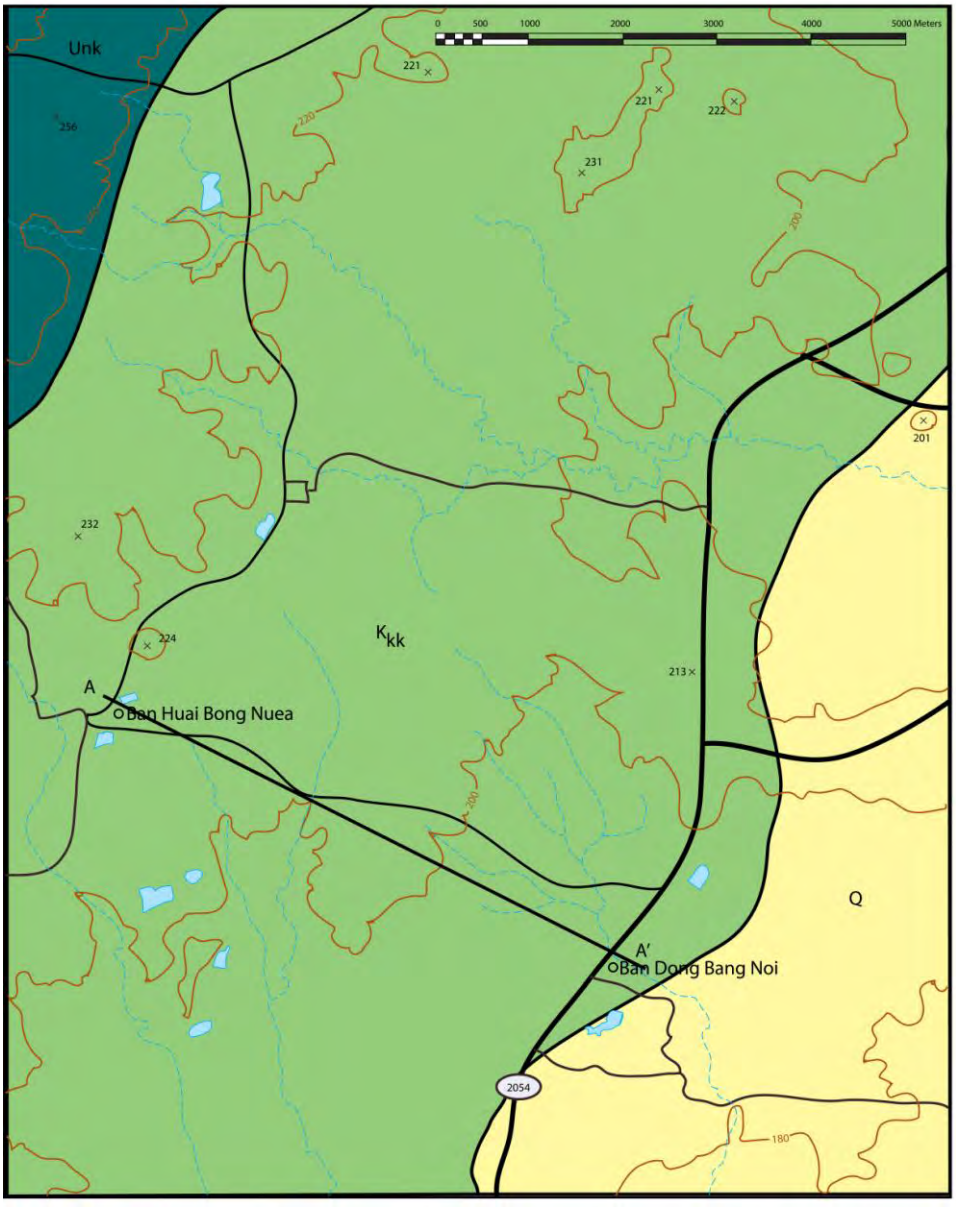


Fig 2.2 Geologic Map of study area, modified from DMR (2010), show boundary of Khok Kruat Formation (K_{kk}), Gravel bed (Q) and unknown rock (Unk).

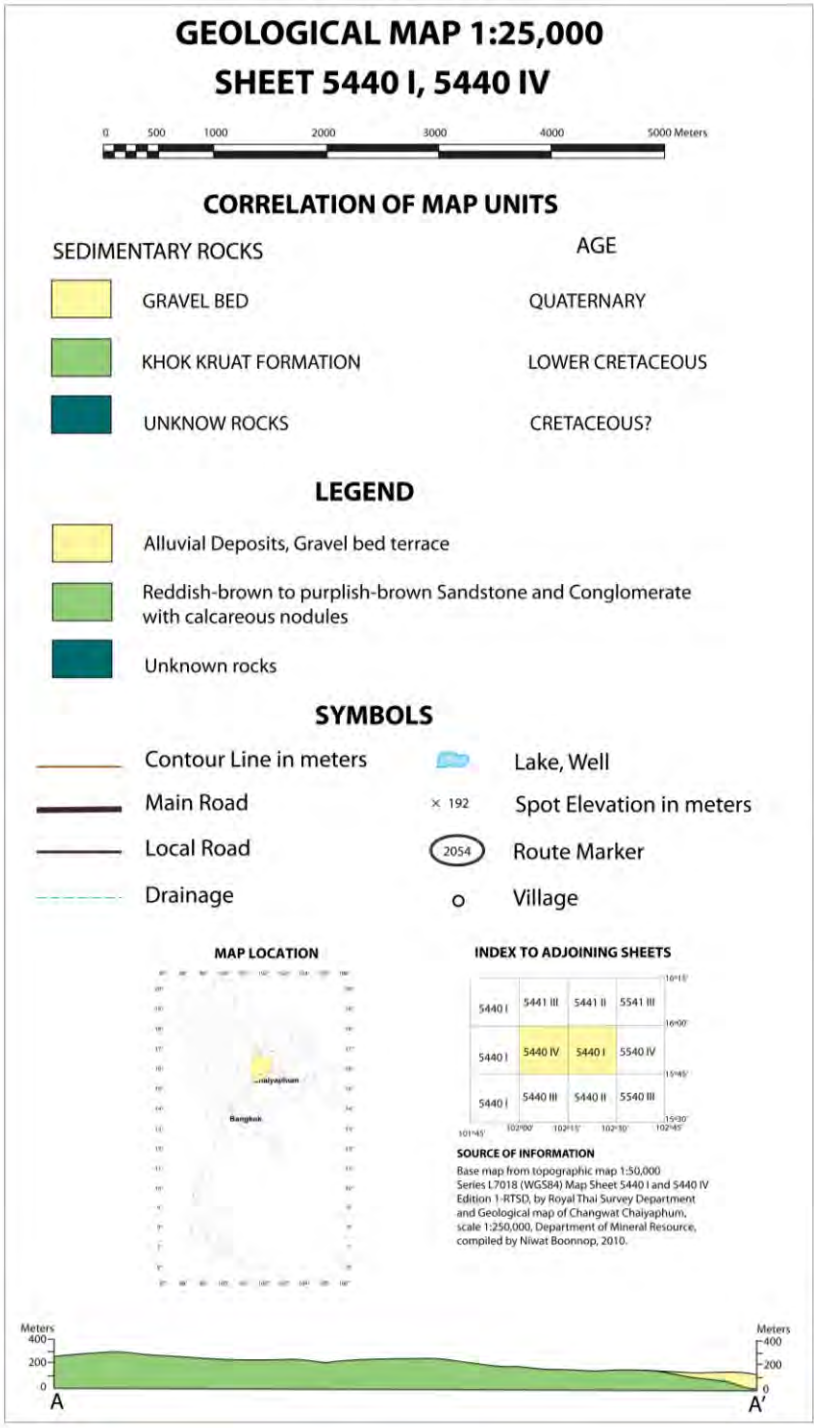
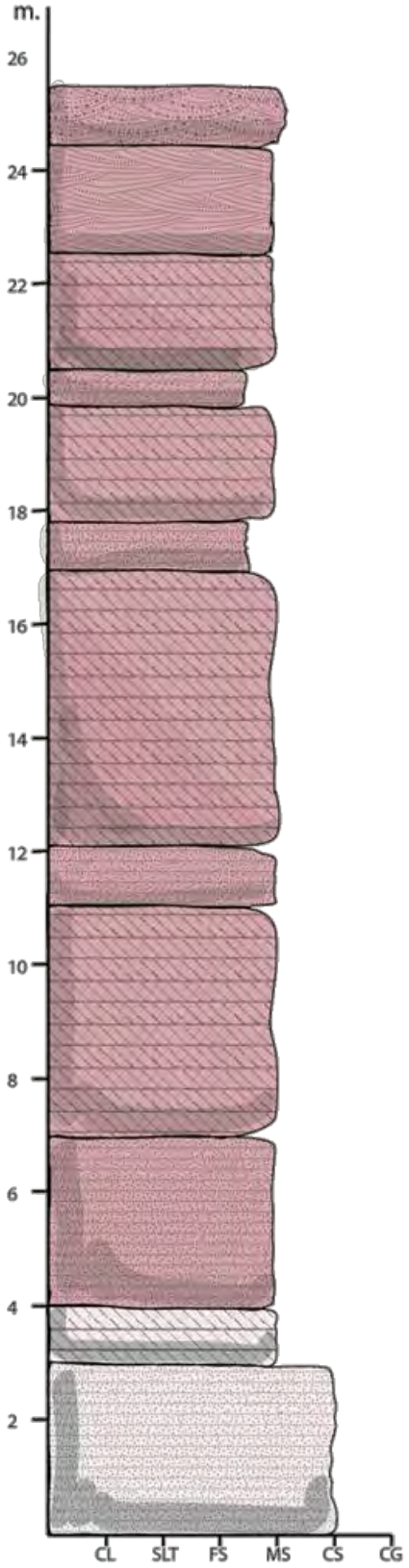


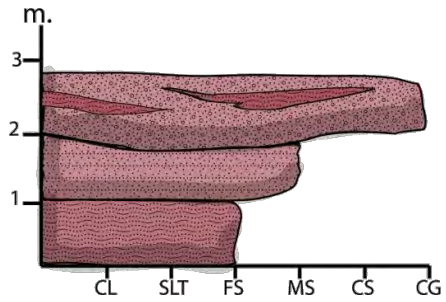
Fig 2.3 Explanation of Geological map of study area, scale 1:25,000, modified from DMR (2010)

(A) Lithostratigraphic column of Ban Huai Bong Nua (Lower horizons)



Facies	Description
B	- Purple SS with CG lens, planar cross-bedding
C	- Ripple cross-bedding, poorly cemented
B	- Planar cross-bedding, poorly cemented
A	- Parallel lamination
B	- Planar cross-bedding, well cemented, hard
A	- Parallel lamination
B	- Planar cross-bedding, well cemented, hard
A	- Parallel lamination
B	- Purple sandstone, well cemented, hard, Planar cross-bedding
A	- Purple sandstone with parallel lamination
B	- White sandstone with planar cross-bedding
A	- White sandstone with parallel lamination

(B) Lithostratigraphic column of Ban Dong Bang Noi; Fossil locality (Upper horizons)



Facies	Description
E	- CG with sand lens and calcareous nodule
A	- SS with parallel lamination interbedded and structureless SS
D	- SS with sandy mudstone lens (wavy)

Fig 2.3 Lithostratigraphic section of A; Ban Huai Bong Nuea (Lower successions) and B; Ban Dong Bang Noi; Fossil locality (Upper successions)

According to the detail of lithology and sedimentary structure by using bed-by-bed of lithostratigraphic section in study area, lithofacies are divided and depositional environment are reconstructed

Facies A: Parallel lamination sand

Facies B: Planar cross-bed sand

Facies C: Ripple cross-laminated sand

Facies D: Wavy-laminated sand

Facies E: Conglomerate with calcareous nodule

Table 1 Lithofacies, sedimentary structure and depositional environment classification

(*Lithofacies follow on Miall (1996), which are based on sedimentary structure dominant.)

Facies	Lithofacies*	Sedimentary structure	Depositional environment
A	Parallel laminated sand	Parallel lamination	Point Bar deposit
B	Planar cross-bed sand	Low-angle cross-bedding (10-15^{o})	Point Bar deposit
C	Ripple cross-bedding sand	Ripple cross-bedding	Point Bar deposit
D	Wavy-laminated sand	Small ripple cross-bedding (wavy ripple)	Point Bar deposit
E	Conglomerate with calcareous nodule	Structureless and graded- bedding	Point Bar deposits (rework of top soil)

Fig 2.4 Outcrop in the pond near Ban Dong Bang Noi (Fossil locality), sandstone bed is nearly horizontal and loose block of conglomerates were commonly found around the pond.

Fig 2.5 Loose block of laminated conglomerates near the pond, at fossil locality.

Fig 2.6 Loose block of parallel-laminated sandstone at Ban Non Khun.

Fig 2.7 Weathering surface of wavy-laminated sandstone at Ban Non Khun.

Fig 2.8 Wavy sandstone, coarse to medium grained, at Ban Non Khun.

Fig 2.9 Artificial outcrop in the pond at Ban Huai Bong Nuea.

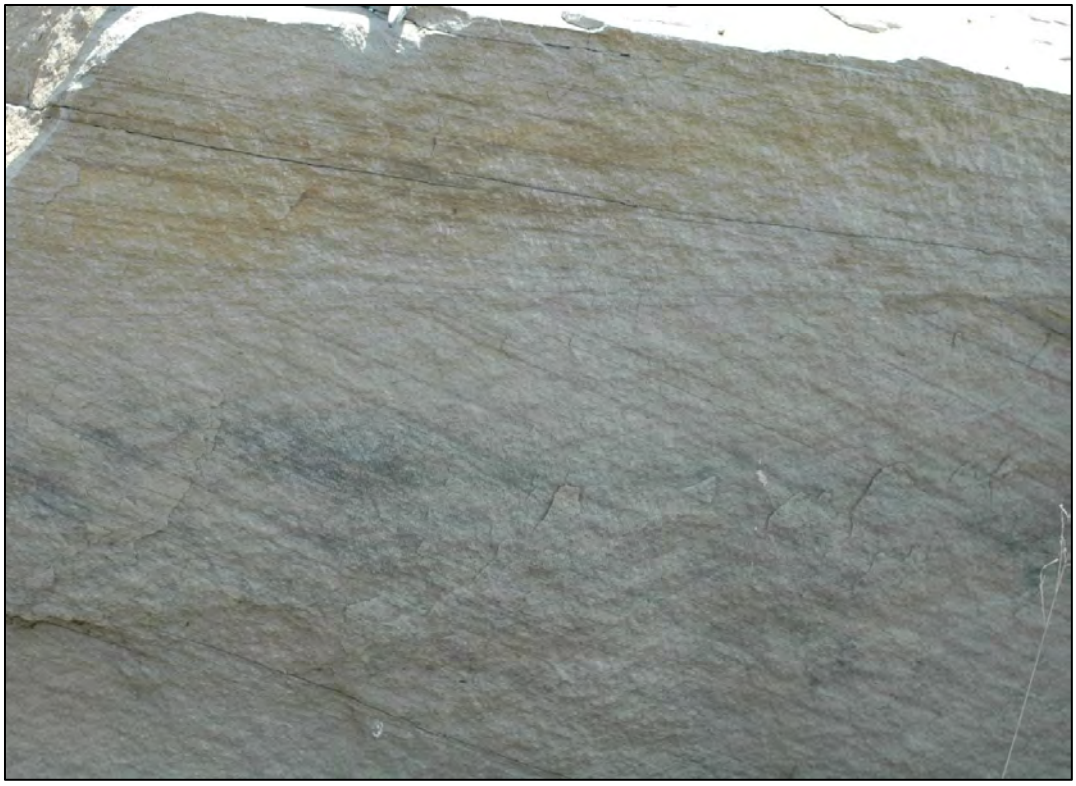


Fig 2.10 Cross-bedding in coarse to medium sandstone at Ban Huai Bong Nuea.

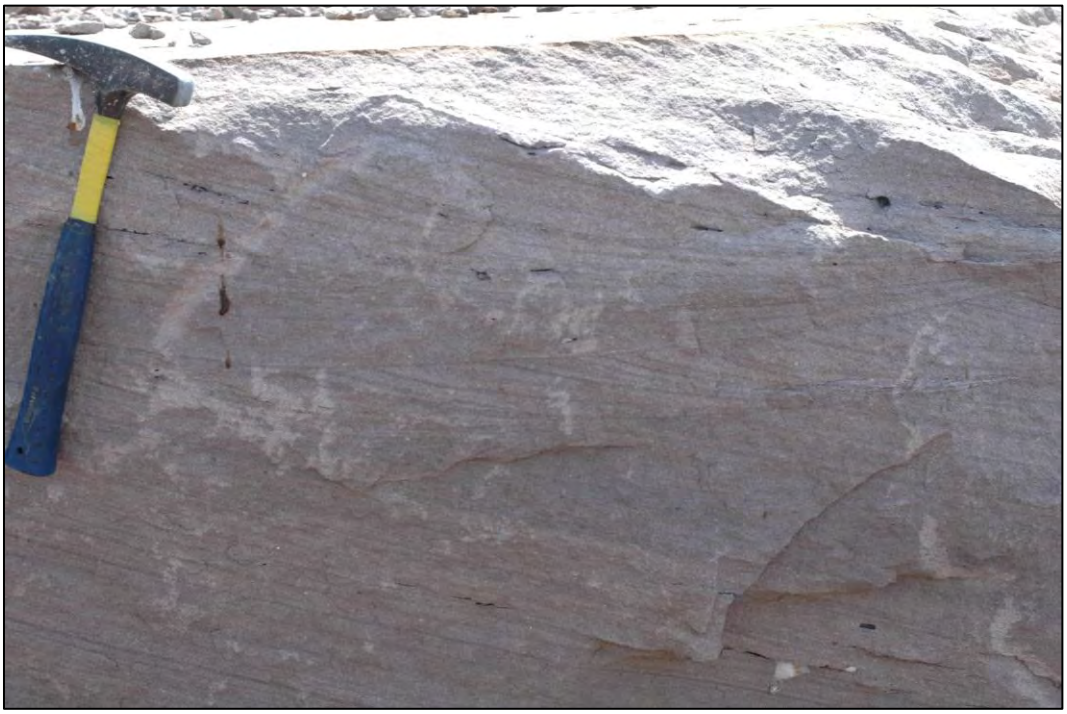


Fig 2.11 Ripple cross-bedding, coarse to medium sandstone at Ban Huai Bong Nuea

Fig 2.12 Cross-bedding sandstone and Ripple cross-bedding sandstone, coarse to medium grained at upper part of lower successions

2.2 Petrography

Collected samples were totally picked 10 samples from 2 successions (Upper and Lower succession). The samples of Upper succession are collected 7 specimens; consist of 5 specimens of conglomerates and 2 specimens of sandstone. The samples of Lower horizons were picked only 3 specimens of sandstone.

2.2.1. Polished-slabs:

5 specimens of conglomerate and 2 specimens of sandstone from Upper succession (fossil locality) were cut and polished (Fig. 2.12 and 2.15) which had been analyzed especially conglomerate samples. Conglomerate polished-slab are considered on sedimentary texture; grain size, grain shape, roundness and matrix. Moreover, sedimentary structure in sandstone (Fig. 2.16) had been studying.

Following to Miall (1978), conglomerate classified to 4 main types; clast-supported with imbricated gravel, matrix-supported, clast-supported with trough cross-bedded gravel and mixed clast-matrix supported with planar cross-bedded gravel. Alluvial conglomerate deposit in three related depositional environments; gravel-fill channel, fans and braided rivers. But channel fill dominated by fined-grain sediment so gravel bed are rarely present.

Conglomerate in fossil locality are classified to clast-supported (Fig. 2.12 and 2.14) and matrix-supported conglomerate (Fig. 2.15). Sedimentary grain size ranges of granule to small pebble which containing reddish-brown to purple mudstone, siltstone and calcareous nodule, rounded to well-rounded clast shape and moderately sorted (Fig. 2.12 and 2.13) to poorly sorted (Fig. 2.14) with calcareous cement.

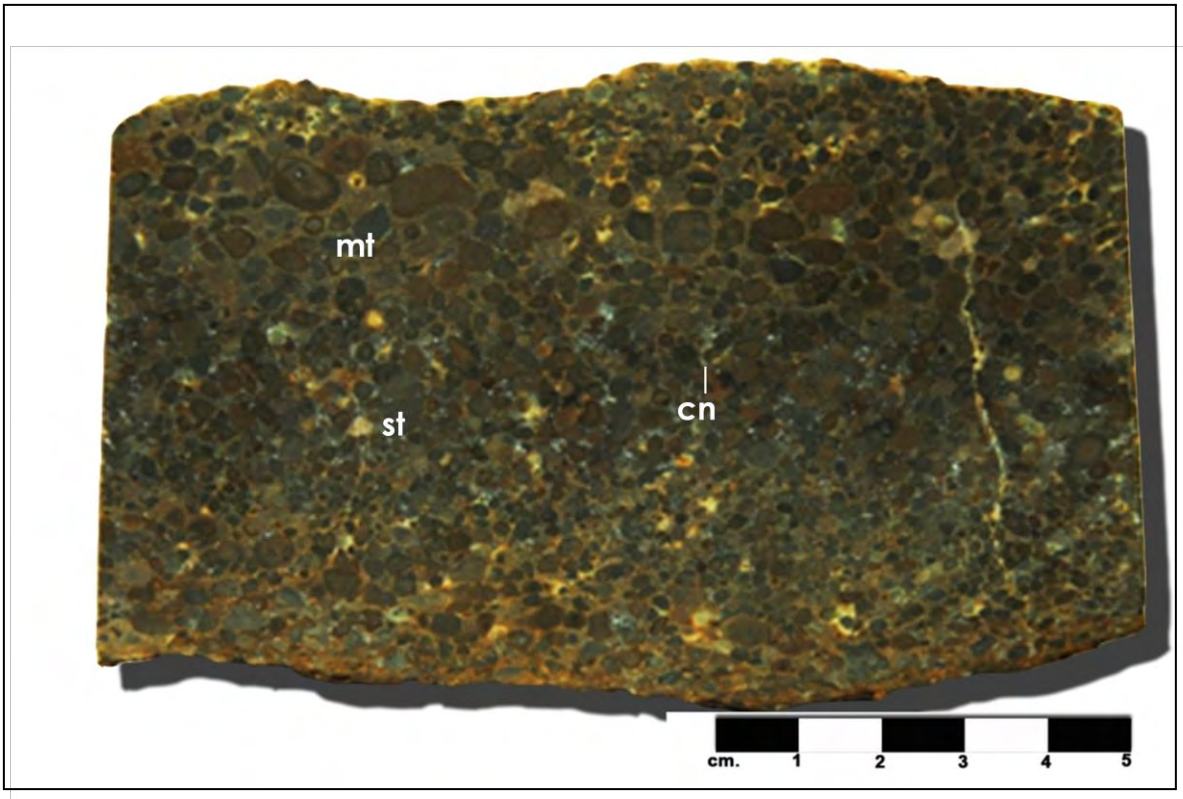


Fig 2.13Clast-supported conglomerate, granule clast size, poorly sorted, Presents clasts of mudstone (mt), siltstone (st) and calcareous nodule (cn).

Fig 2.14 Clast-supported conglomerate, granule clast size, moderately sorted.

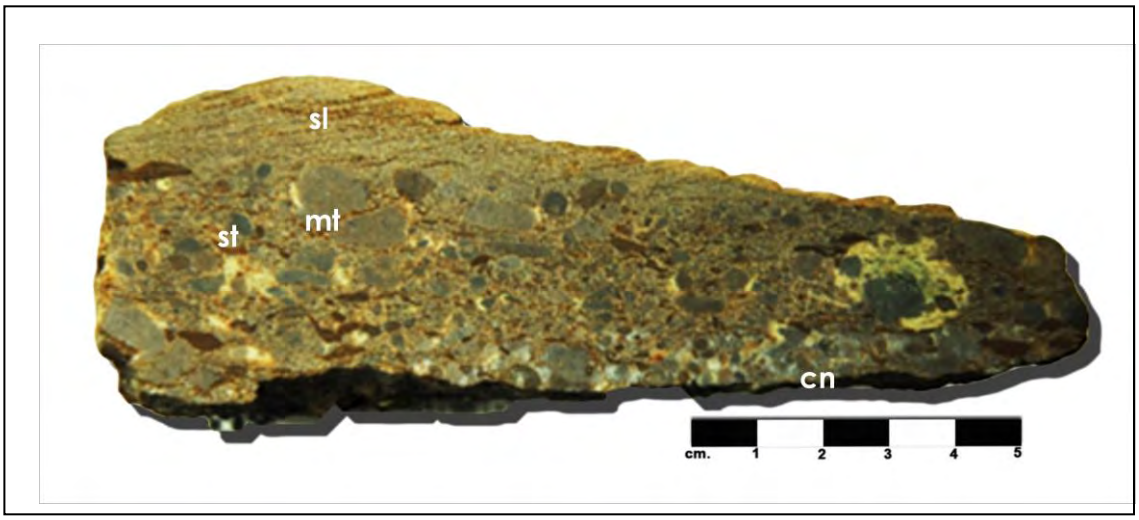


Fig 2.15Clast-supported conglomerate, moderately sorted with reverse graded-bedding. Presents clasts of mudstone (mt), siltstone (st) and calcareous nodule (cn)

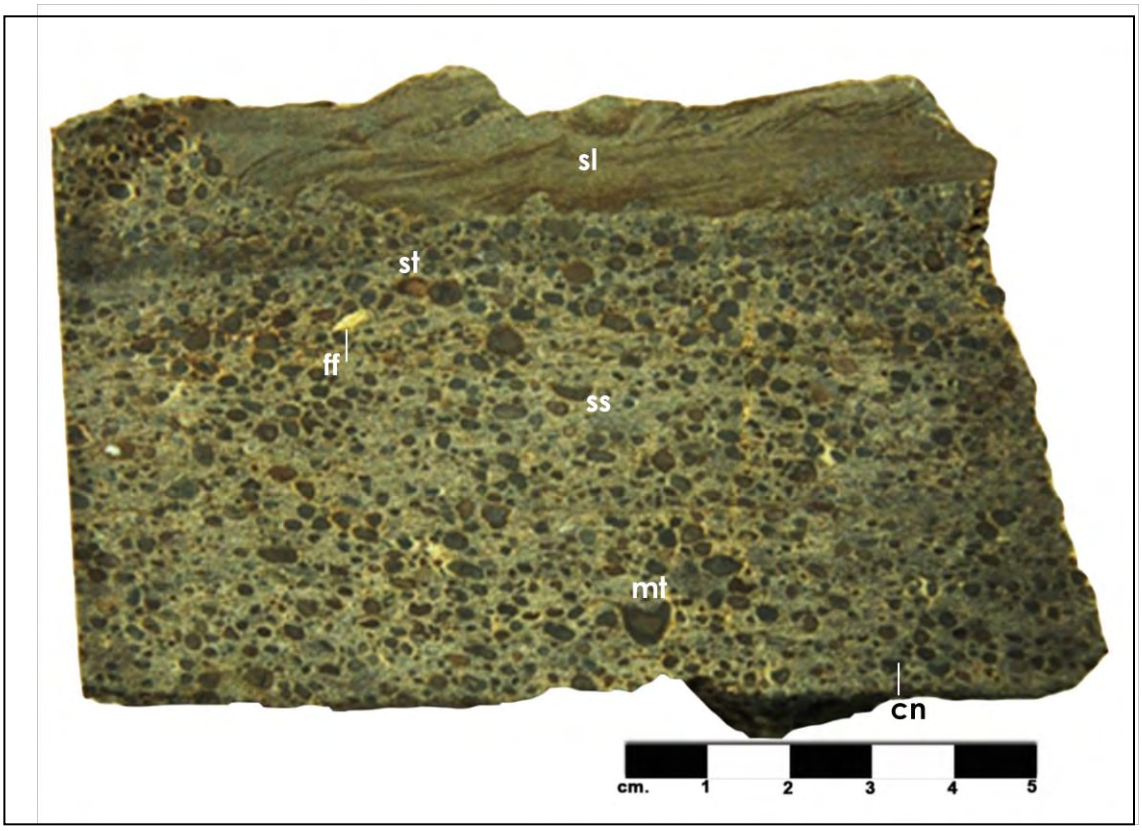


Fig 2.16 Matrix-supported conglomerate, granule to pebble clast size, poorly sorted. Matrix are grey fined-sand (ss). Presents clasts of mudstone (mt), siltstone (st) and calcareous nodule (cn) and fossil fragment (ff) with sand lens (sl) in upper part.

Fig 2.17 Fined-grained sandstone shows cross-bedding in lower and upper, and wavy structure in middle.

2.2.2. Thin section:

Samples of sandstone both upper and lower succession had been studied in thin section under the polarized-microscope, comprises 2 samples from Upper succession and 3 samples from Lower succession. Only two thin sections were point counted (200 grains per thin section) and plotted on a tertiary diagram which following on Pettijohn (1972), grain size analysis base on Wentworth scale.

Sample WP6 and HB7 collected from Ban Non Khun and Ban Huai Bong Nuea, respectively. Sandstone contain more than 15 percent matrix. Therefore, this study will be use second ternary diagram.

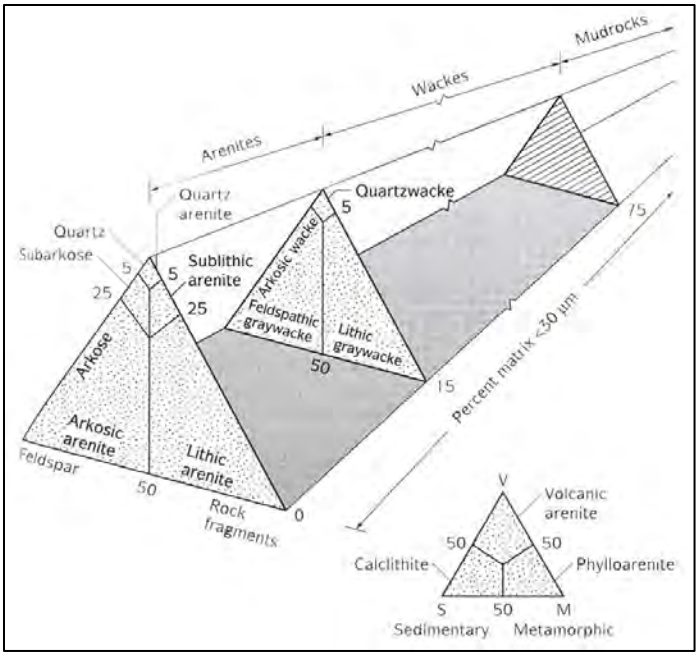


Fig 2.18 Classification of terrigenous sandstones (Pettijohn, 1972)

		US Standard sieve mesh	Millimeters	Phi (ϕ) units	Wentworth size class
GRAVEL			4096	−12	
			1024	−10	Boulder
			256	−8	
			64	−6	Cobble
			16	−4	Pebble
		5	4	−2	
		6	3.36	−1.75	
		7	2.83	−1.5	Granule
		8	2.38	−1.25	
		10	2.00	−1.0	
SAND		12	1.68	−0.75	
		14	1.41	−0.5	Very coarse sand
		16	1.19	−0.25	
		18	1.00	0.0	
		20	0.84	0.25	
		25	0.71	0.5	Coarse sand
		30	0.59	0.75	
		35	0.50	1.0	
		40	0.42	1.25	
		45	0.35	1.5	Medium sand
		50	0.30	1.75	
		60	0.25	2.0	
		70	0.210	2.25	
		80	0.177	2.5	Fine sand
		100	0.149	2.75	
		120	0.125	3.0	
		140	0.105	3.25	
		170	0.088	3.5	Very fine sand
		200	0.074	3.75	
		230	0.0625	4.0	
MUD		270	0.053	4.25	
		325	0.044	4.5	Coarse silt
			0.037	4.75	
	SILT		0.031	5.0	
			0.0156	6.0	Medium silt
			0.0078	7.0	Fine silt
			0.0039	8.0	Very fine silt
			0.0020	9.0	
			0.00098	10.0	Clay
	CLAY		0.00049	11.0	
			0.00024	12.0	
			0.00012	13.0	
			0.00006	14.0	

Fig 2.19 Terminology and class intervals for grade scales by Wentworth.

Sample WP6: average grain size 0.1-0.2 mm. (very fine to fine sand), angular to sub-angular cemented by calcite, moderately to well sorted. Mineral compositions contain 49% quartz, 37% feldspar and 14% rock fragment. Some of feldspar is subhedral which shows twin.

Sample HB7: average grain size 0.1-0.2 mm. (very fine to fine sand), angular to sub-angular, calcareous cement, well sorted. Mineral compositions contain 45% quartz, 37% feldspar and 18% rock fragment (including mica grain). Some of feldspar is subhedral which shows twin (carlsbad and albite twin).

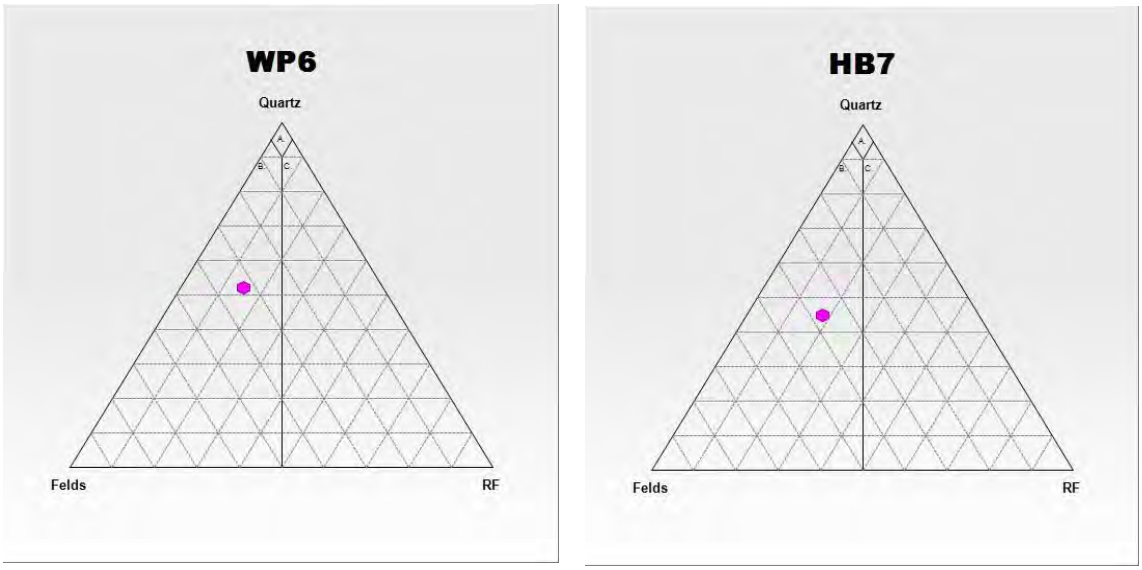


Fig 2.20 Ternary diagrams show position of sample WP6 and HB7 (pink point) as Arkosic wack, following classification of Pettijohn (1972). The diagrams represent percentage of quartz, feldspar (Felds), and rock fragment (RF)

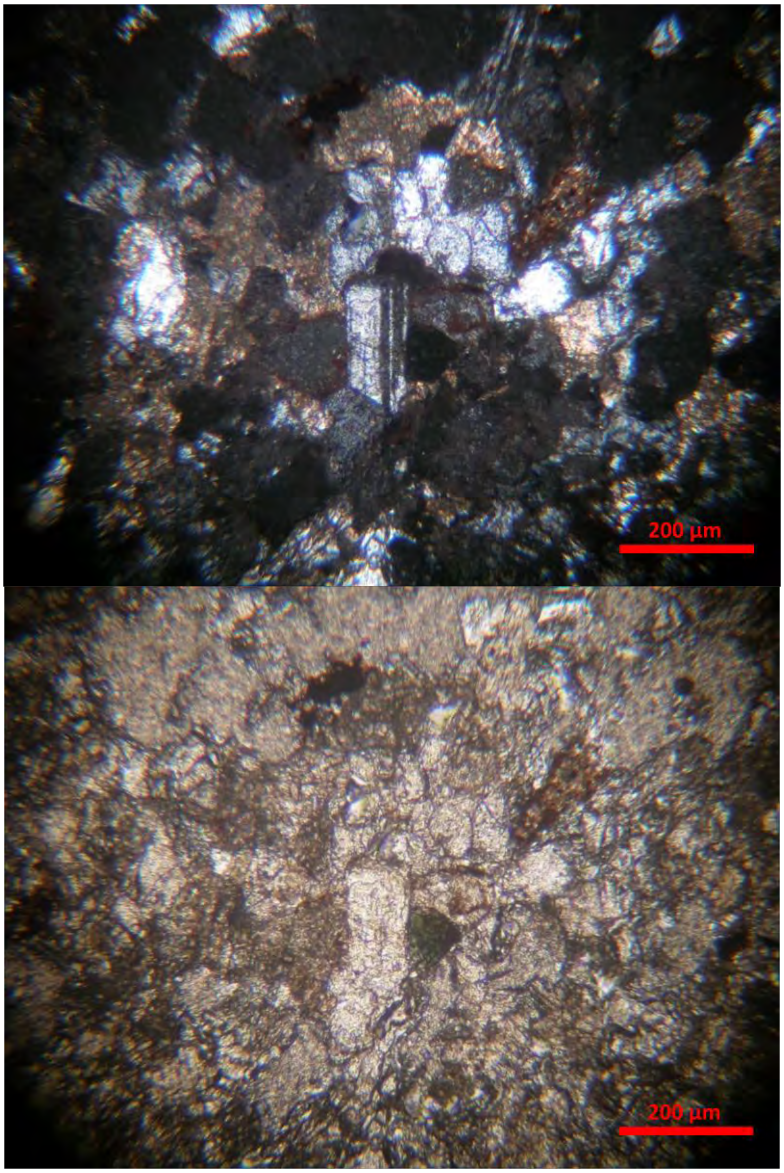


Fig 2.21 Fined-grained Arkosic wacks of sample WP6, show angular to sub-angular quartz (Q), subhedral to euhedral feldspar (F) with calcareous cement. (Photomicrographs a. is cross-polarized)

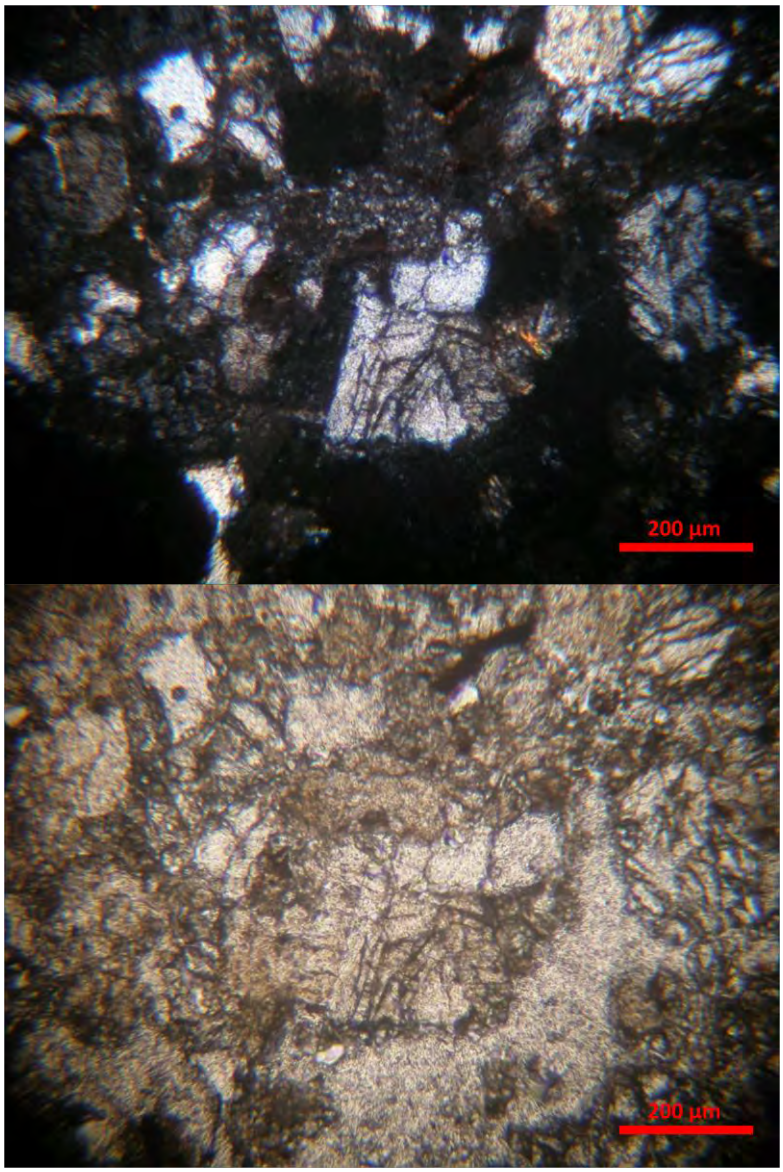


Fig. 2.22 Fined-grained Arkosic wacks of sample HB7, show angular to sub-angular quartz (Q), subhedral feldspar (F), rock fragment (RF) and micaceous grain (M) with calcareous cement. (Photomicrographs a. is cross-polarized)

2.3 Fossil Descriptions

Description of fossil fragment detail is following on Buffetaut and Suteethorn (1992). The dentary is the anterior bone of lower jaw which bears the teeths. The socket in a jaw bone which a teeth fits call as “alveolus”. The dentary fragment is nearly complete, sub-angular in shape. The length of bone is 53 mm, its maximum height 31 mm and its greatest breadth 12 mm (Fig 2.22). Dorsal edge of the bone is convex to anterior part. The posterior edge is irregular contact, angular to sub-angular which has damage. The ventral edge is nearly straight.

In medial view (Fig 2.22-A), the dentary shows a very large and deep Meckelian groove which triangular in shape. Beside the deeply groove has five teeths which are attached in dentary. The position of dentary teeth and Meckelian groove indicate right side dentary. Other teeths were loose and present in alveolus on dorsal side, one in anterior edge and three in posterior edge.

Classification of species used the detail of cranial features, but not preserved in *P. sattayaraki* dentary. Nevertheless, the dentary shape and lower teeth can use to separate them from other species. Comparisons have been made on the basis of descriptions of best-know Mongolian and Chinese species of Psittacosaurus: *P. meileyingensis*, *P. mongoliensis* and *P. youngi* (Fig 2.23).

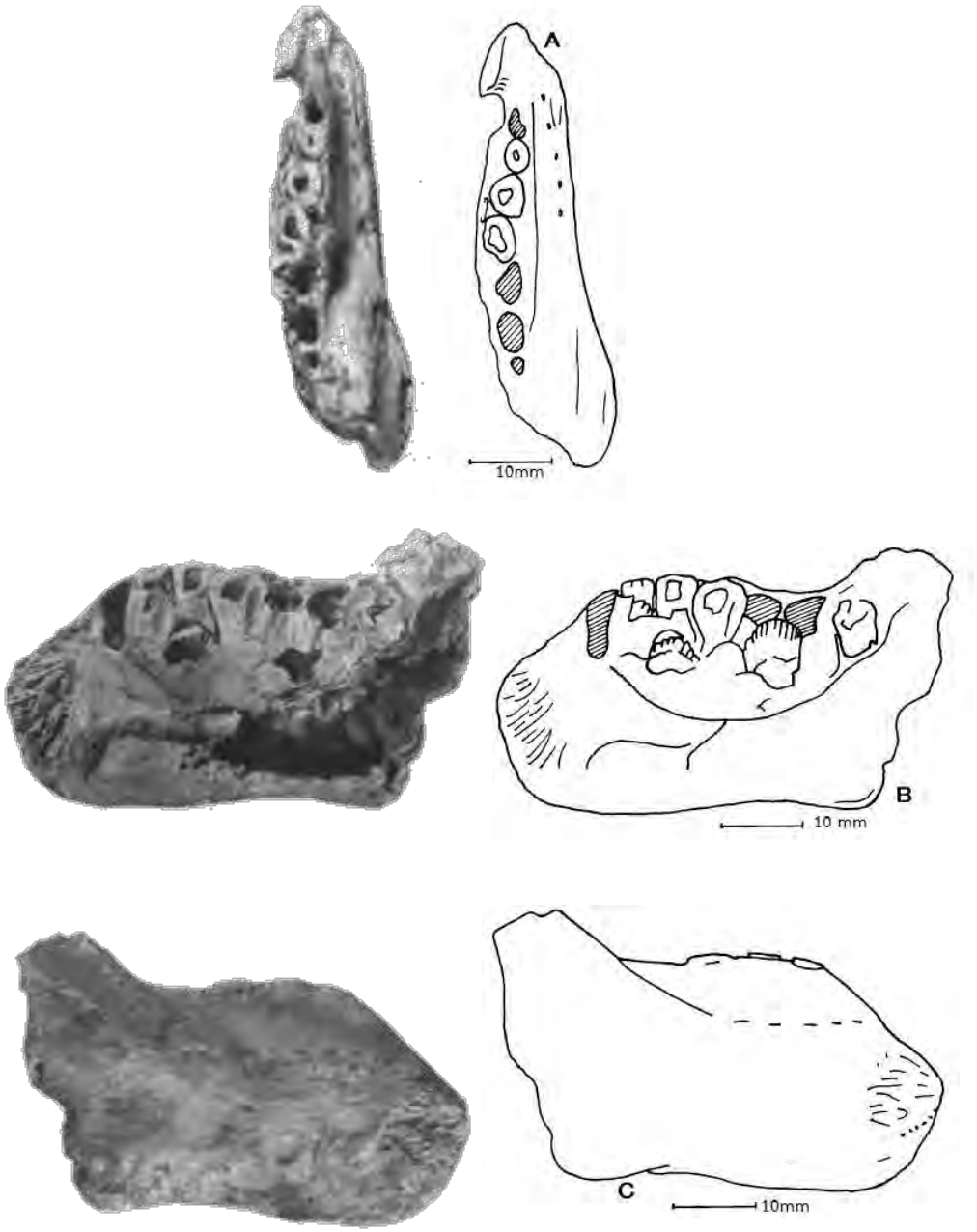


Fig 2.23 Right dentary of *P. sattayaraki* in dorsal (A), medial (B) and lateral (C) views, scale bar represent 10 mm.

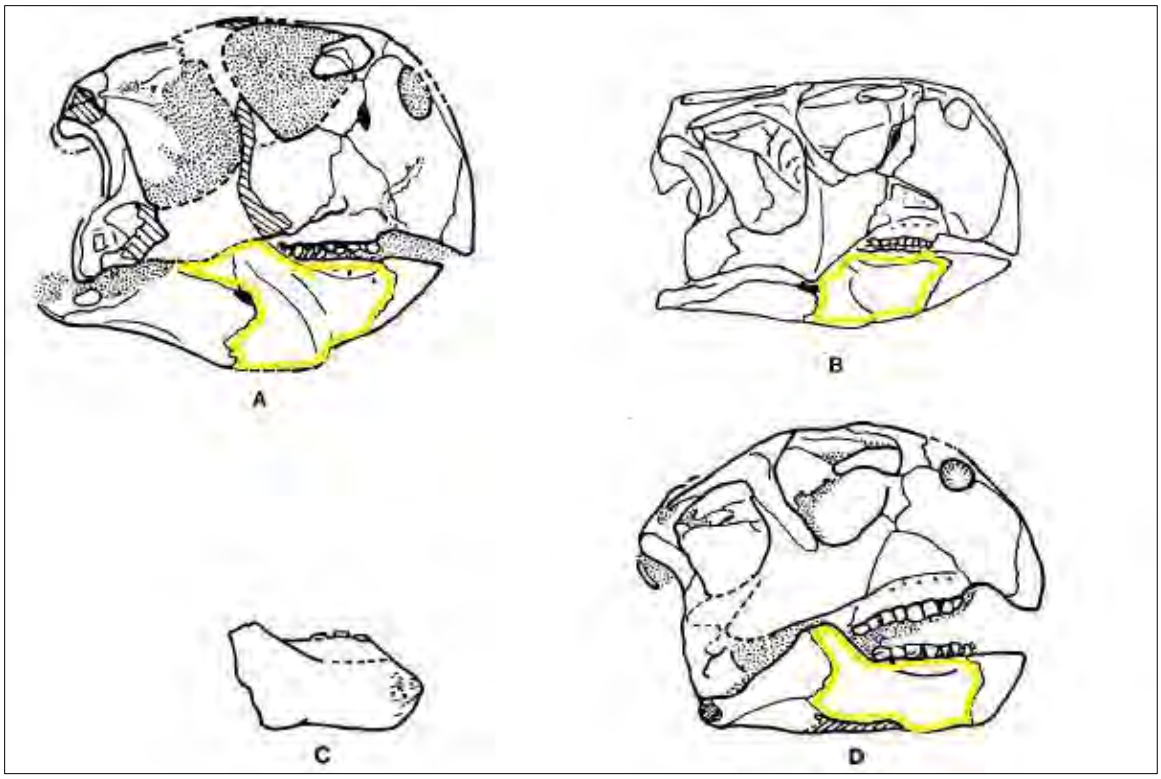


Fig 2.24 Comparison of the holotype of *P. sattayaraki* (C) with skull and lower jaw of other species of *Psittacosaurus*: *P. meileyingensis* (A), *P. mongoliensis* (B) and *P. youngi* (D)

Chapter 3: Discussion

3.1 Lithofacies Descriptions

According to the detail of lithology and sedimentary structure by using bed-by-bed of lithostratigraphic columns in study area, lithofacies are divided and depositional environment are reconstructed. Classification of lithofacies following on Miall (1996), which based on dominant primary sedimentary structure.

Facies A: Parallel laminated sand

This lithofacies is accumulation of fine to medium sand, several meters thick. Sediments deposit continuously over a few meter and form as horizontal or nearly horizontal bed. Flat layer typically represents the beginning of upper-flow regime (Fig.4.1) with high sediment supply and indicates rapid flow in gently slope area such subaqueous point bar. Therefore, this lithofacies are reconstructed as “Point Bar deposit”

Facies B: Planar -cross-bedded sand

Deposition of very-fine to fine grained sand with low angle cross-bedding (10-15º), nontangential foresets, commonly 0.5-3 meters thick. Interbedding of parallel lamination unit and planar cross bedding unit indicates upper plane-bed condition. While water depth increases or flow velocity increases, cross-strata forms by lateral migration of point bar. Thus, depositional environment are constructed as “Point Bar deposit”

Facies C: Ripple cross-laminated sand

This lithofacies shows fine to medium sand which generated from ripple migration at low flow state. Older ripple set was eroded where flow direction and overlie by younger ripple set (Fig. 4.3), occurs at top of plane-bed lamination. Characteristics of sedimentary

structure is closely similar to Type-A ripple cross-laminated which is determined by Jopling and Walkers (1968).

Facies D: Wavy-laminated sand

Wavy-laminated sand contains thin muddy sand layer in fine to very fine sand and sequence of muddy sand is discontinuous (look like muddy sand lens) as call as “flaser bedding”. This lithofacies deposits in low energy condition while ripple-sand generated and muddy sand accumulated after. In meandering channel, fine-grain sediments occur within sand-size sediments. Therefore, reconstruction of this lithofacies is “Point-bar Deposits” (Low flow state at upper part of point-bar)

Facies E: Conglomerate with calcareous nodule

Conglomerate is classified to clast-support which contains feldspar, mudstone, rock fragments, fossil fragment and calcareous nodule with calcareous cement. Grain size up to 1 cm. in diameter, angular to sub-round. Shape of clast indicates short distance transportation and sedimentary reworks which is accumulate at upper part of point-bar. In semi-arid to arid condition, sediments are commonly filled by calcareous cements. Reconstruction of paleoenvironments is “Coarse-grained Point-Bar Deposit”

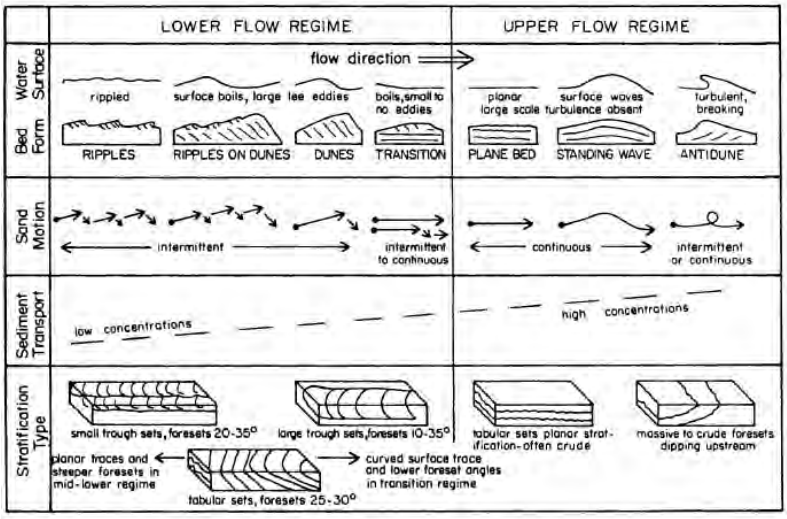


Fig. 3.1 Flow regime and its relationship to bed forms and other characteristics (Lewis, 1984)

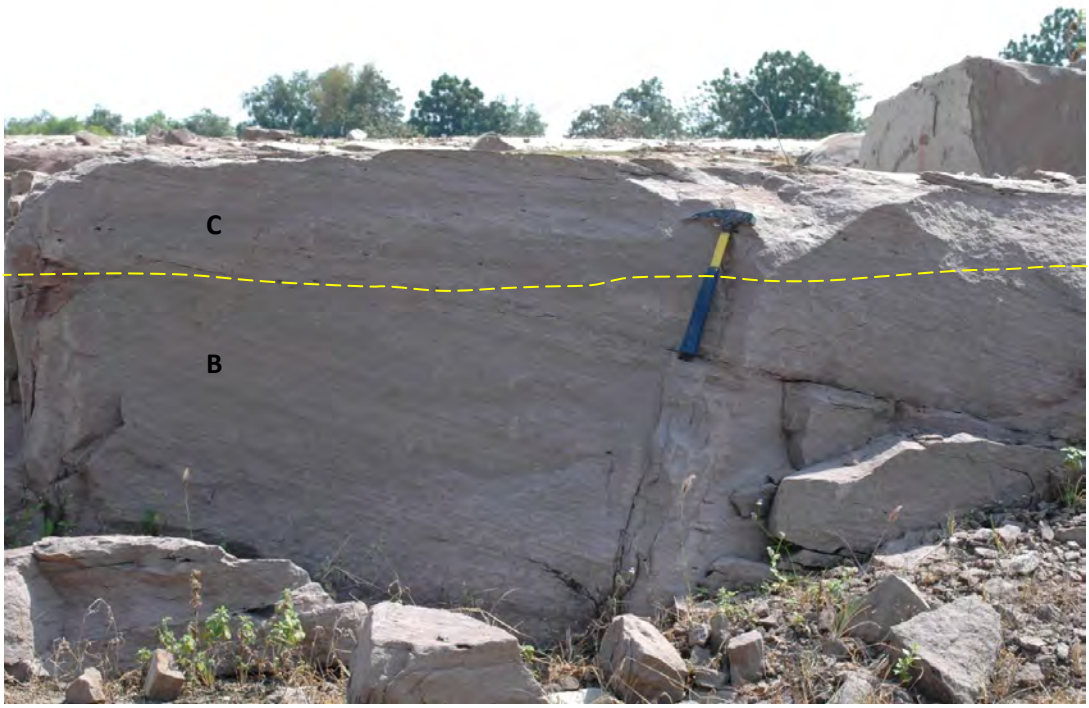


Fig. 3.2 Outcrop of Ban Huai Bong Nuea show planar-cross bedding (B) at lower part and ripple-cross lamination (C) at upper part.

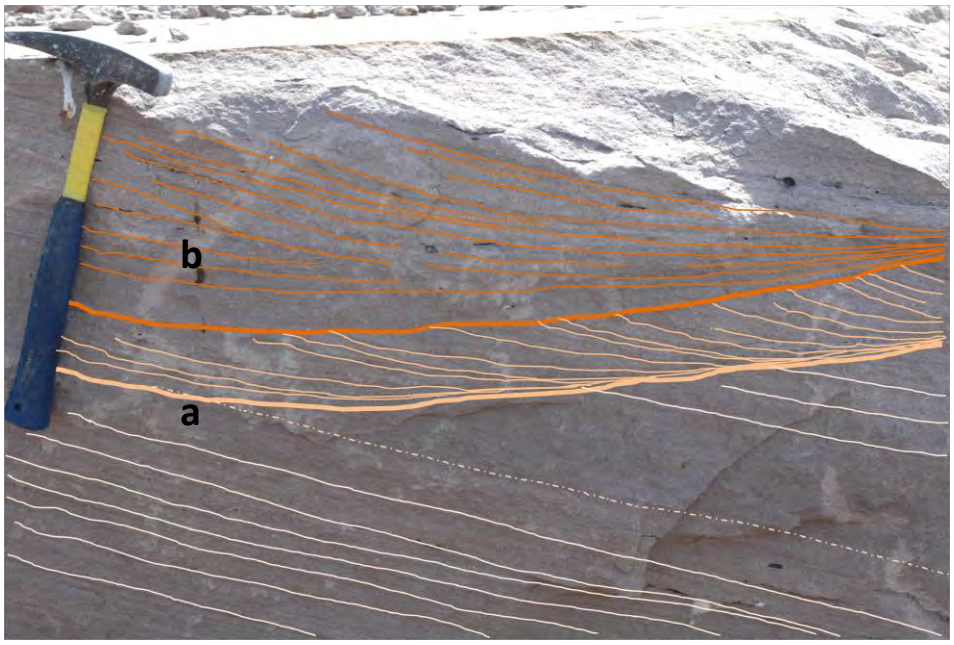


Fig. 3.3 Outcrop of Ban Huai Bong Nuea show ripple-cross lamination, older ripple set (a) overlain by younger ripple set (b) where boundary is erosional surface by current.

3.2 Reconstruction of Paleoenvironments

The sedimentary structure which show in each lithofacies can represent depositional condition and sub-environment. All of unit in study area (lower and upper succession) classified to fluvial deposit; meandering channel that can be divided in to 2 sub-environments, point-bar sand deposit and channel-fill deposit. Lithofacies A, B and C (Lower Succession) show sequence of sandstone up to 20m., which is interbedded between parallel-lamination and cross-bedding. Both of two structure commonly found in point-bar area result from lateral migration during high water level and continuous current. Lithofacies D and E forms by low flow and high flow state, respectively. When water level (stream) decrease, current speed commonly decrease. Only fine grain can come and deposit as wavy lamination. After water came up, flow current has higher speed when coarser grain can deposit. Increased flow current can carry semi-consolidated to be reworked-clast in conglomerate.

Thus, reconstruction of paleoenvironments is Point-Bar deposit in Meandering river system when high water level and Low water level (Low flow and high flow speed), respectively.

3.3 Stratigraphic Position and correlative formation

Stratigraphic position was fix to upper part of Khok Kruat Formation that determine from litho stratigraphic section and correlative of columnar section of Khorat Group (Meesook and . Saengsrichan, 2011). *Psittacosaurus* and fossil assemblage in Khok Kruat formation is perfectly refer to Early Cretaceous age (Buffetaut and Suteethorn, 1992). It's can correlate with dinosaur bearing formation in China; Jehol Group which also found *Psittacosaurus*. *P. sattayaraki* is closely species with *P. mongoliensis* which found in Jiufotang Formation of Jehol Formation (Osborn, 1923).

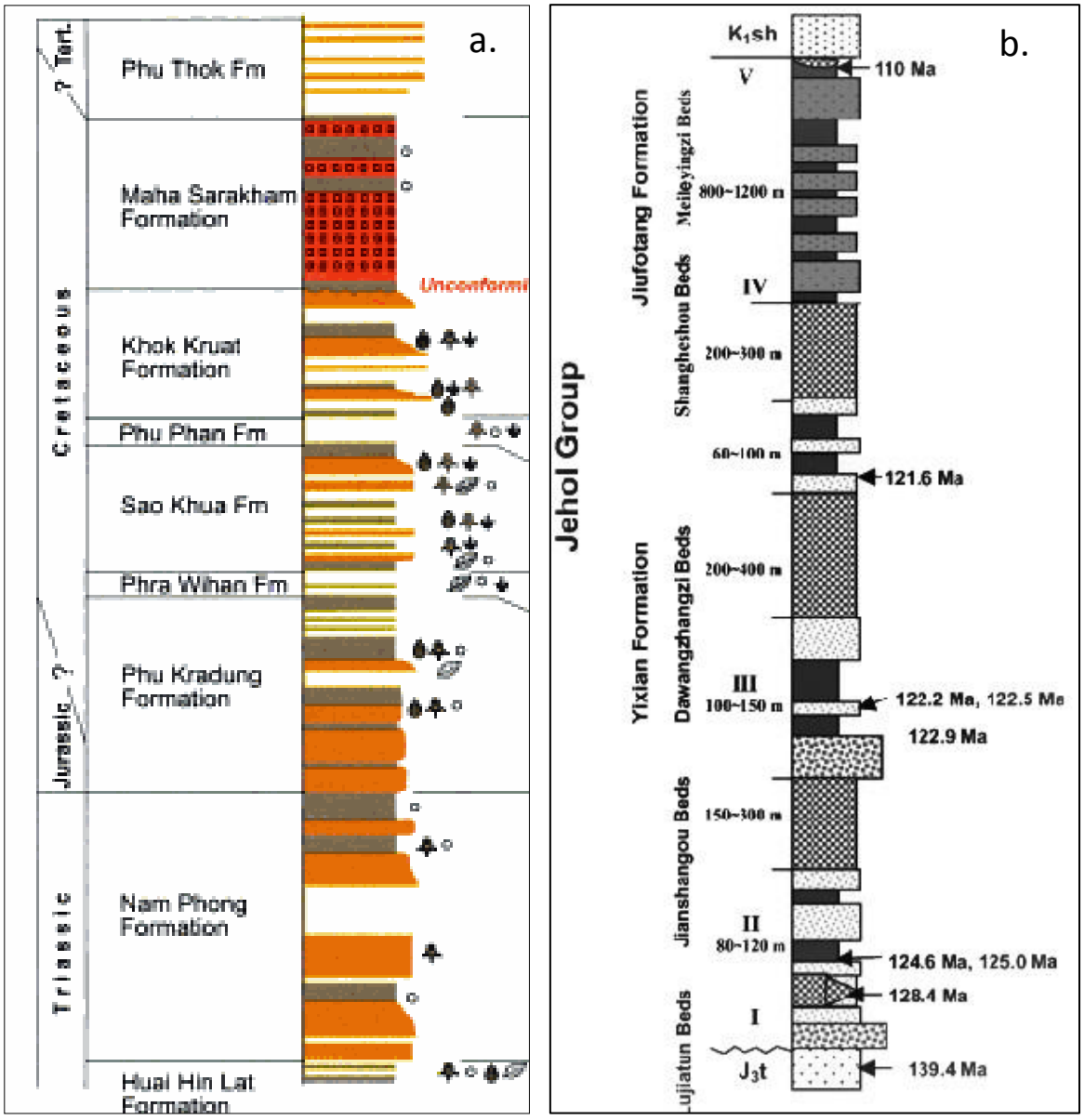
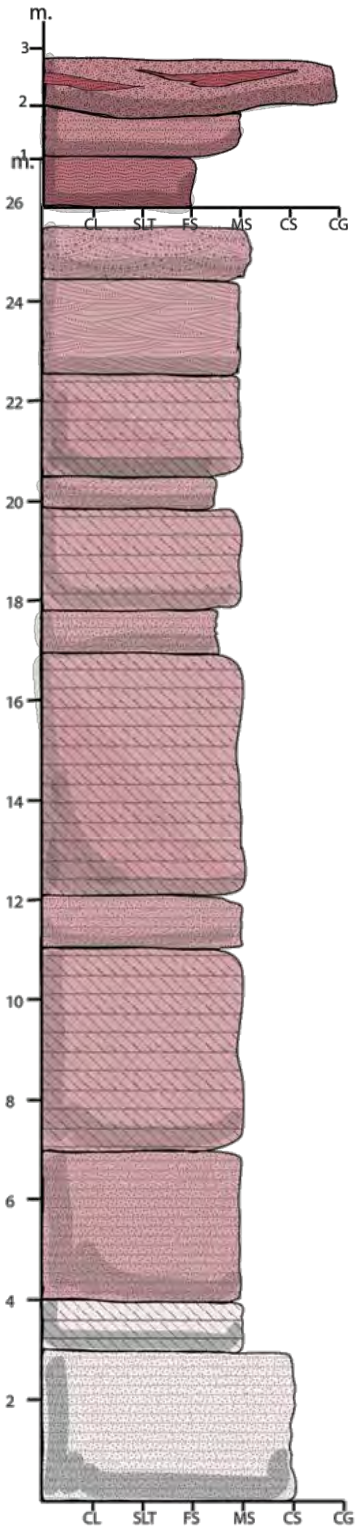


Fig. 3.4 Columnar section of Khorat Group, Meesook and Saengsrichan, 2011 (a) and Jehol Group, Xu & Norell, 2006 (b)



Lithofacies	Depositional Condition	
E	Low water level	High speed current
A		Low speed current
D		
E	High water level	High flow speed
C		
B		
A		
B		
A		
B		
A		
B		
A		
B		
A		

Fig. 3.5 Universal lithostratigraphic section of study area (correlative section) show lithofacies classification, paleoenvironments and depositional conditions.

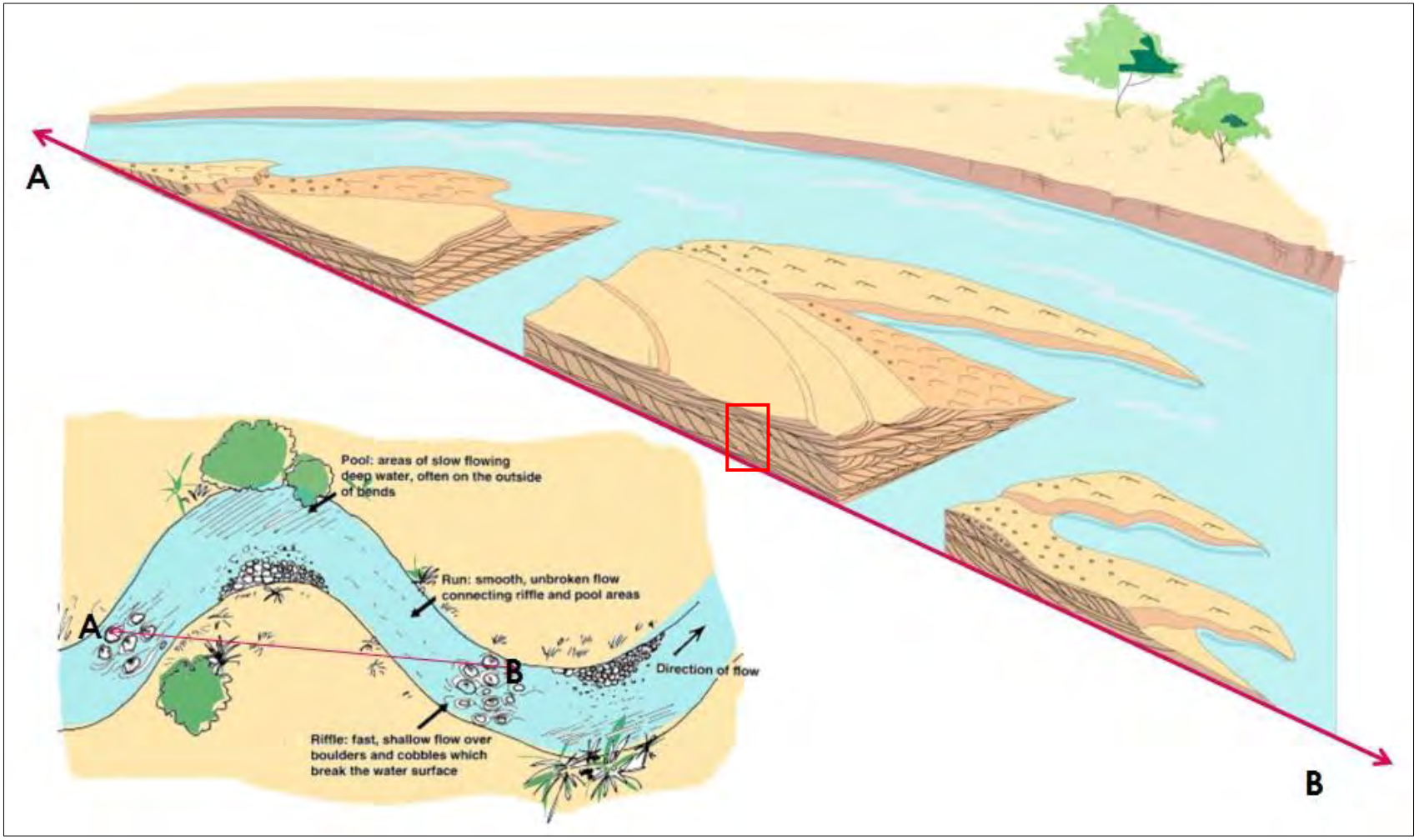


Fig. 3.6 Model of point bar sedimentation, shows lateral accretion, which forms plane bed lamination and planar cross lamination (red box), modified from Bristow (1993).

Chapter 4: Conclusion

1. According to lithostratigraphy of study area, paleoenvironments has been reconstructed. Thick sequence of cross-bedding and parallel-laminated sandstone (fine to medium grain size) which represents point-bar deposit in meandering river system where is high speed current. Also, conglomerate and wavy-laminated sandstone indicates point-bar deposit in low water level. The depositional environments high water level to low water level, decreased stream cause grain-size decreasing (very fine to fine grain size).

2. Roundness of gravel (rounded to well-rounded) within conglomerate forms by reworked sedimentation, high velocity current can carry semi-consolidated fine-grained sediment and accumulate again with sand size sediments. Gravel contains reddish-purple mudstone grain, siltstone grain, calcareous nodule and fossil fragment. And surrounded by calcite look like concretion (in carbonate rocks) in semi-arid to arid condition.

3. Fossil fragments may transport and deposit at the same time with conglomerate. Right dentary is nearly complete, five teeth are still attached to the jaw bone as same as teeth in additional jaw. Therefore, nearly completed fossil fragments refers to short distant transportation.

4. Stratigraphic position of fossil bed is belong to upper part of Khok Kruat Formation which show in lithostratigraphic section, uppermost conglomerate with calcareous nodule is nearly change to Maha Sarakham Formation.

5.Geological age of Khok Kruat is correlated to formation of Jehol Group in China where associated animal is more diversity than Khok Kruat Formation.

6. We need much more comparalative anatomical comparison with Chinease holotype

References

Boggs Jr., Sam. 1995. Principles of Sedimentology and Stratigraphy, 2nd ed. Englewood Cliffs, London: Prentice-Hall International, New Jersey.

Buffetaut, E. and Suteethorn, V.1992. A new species of the ornithischian dinosaur *Psittacosaurus* from the Early Cretaceous of Thailand. Palaeontology, 35, 801-812.

Buffetaut, E., Suteethorn, V., Loeuff, J. L., Khansubha, S., Tong, H., and Wongko, K. 2005. The dinosaur fauna from the Khok Kruat Formation (Early Cretaceous) of Thailand. In: L. Wannakao, K. Srisuk, W. Youngme, and R. Lertsirivorakol (eds.), Proceedings of the International Conference on Geology, Geotechnology and Mineral Resources of Indochina, Khon Kean, Thailand, 28-30 November 2005: 575-581.

Davis, R. A., JR. 1983. Depositional Systems; A Genetic Approach to Sedimentary Geology. Englewood Cliffs, London: Prentice-Hall International, New Jersey.

Fraser, G. S. 1989. Clastic Depositional Sequences; Process of Evolution and Principles of Interpretation. Englewood Cliffs, London: Prentice-Hall International, New Jersey.

Maill, A. D. 1996. The Geology of Fluvial Deposits; Sedimentary Facies, Basin Analysis, and Petroleum Geology. Springer-Verlag, Italy.

Osborn, H. F. 1923. Two Lower Cretaceous dinosaurs of Mongolia. American Museum Novitates, 95, 1-10.

Pettijohn, F. J., P. E. Potter, and R. Siever. 1972. Sand and sandstone. Springer-Verlag, New York.

Sereno, P.C. 1990. New data on parrot-beaked dinosaurs (Psittacosaurus).In: K. Carpenter and P.J. Currie (eds.), Dinosaur Systematics: Perspectives and Approaches, 203–210. New York: Cambridge University Press.

Ward, D. E., and Bunnag, D. 1964. Stratigraphy of the Mesozoic Khorat Group in Northeastern
Thailand. Report of investigation no.6, Bangkok: Department of Mineral Resources.