ธรณีวิทยาและบรรพชีวินวิทยาของรอยตีนไดโนเสาร์จาก อำเภอภูเวียงในภาคตะวันออกเฉียงเหนือ

นางสาวธนัชพร พนมพงศ์ไพศาล

เลขประจำตัว : 5132717123

รายงานนี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรวิทยาศาสตร์บัณฑิต

ภาควิชาธรณีวิทยา คณะวิทยาศาสตร์

จุฬาลงกรณ์มหาวิทยาลัย

ปีการศึกษา 2554

GEOLOGY AND PALEONTOLOGY OF DINOSAUR FOOTPRINTS FROM PHUWIANG IN NOTHEAST THAILAND.

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ID: 5132717123

A Report in Partial Fulfillment of the Requirement

for the Degree of Bachelor 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 : ธรณีวิทยาและบรรพชีวินของรอยตีนไดโนเสาร์จากอำเภอภูเวียงในภาคตะวันออกเฉียงเหนือ

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อาจารย์ที่ปรึกษา : ดร.โยชิโอะ ซาโตะ

ภาควิชา : ธรณีวิทยา คณะวิทยาศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

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บทคัดย่อ

รอยเท้าไดโนเสาร์ในประเทศไทยส่วนใหญ่พบในกลุ่มหินโคราชซึ่งกระจายตัวในภาคตะวันออกเฉียงเหนือของประเทศไทย พื้นที่ศึกษาบริเวณลานหินลาดป่าชาด ในอุทยานแห่งชาติภูเวียงตามการลำดับชั้นหินจัดอยู่ในหมวดหินพระวิหารของกลุ่มหินโคราช พบรอยตีนไดโนเสาร์จำนวน 86 รอยตีน ซึ่งประกอบด้วยรอยตีนของไดโนเสาร์กลุ่มซอโรพอดจำนวน 28 รอยตีน และไดโนเสาร์กลุ่มเพอโรพอดจำนวน 58 รอยตีน โดยแบ่งเป็น 6 รอยทางเดิน และคาดว่าพบรอยตีนจระเข้อีก 1 รอยตีน ขนาดรอยตีนขของไดโนเสาร์กลุ่มเทอโรพอดมีขนาดที่หลากหลายโดยมีความยาว 8.6 ถึง 16.4 เซนติเมตร และมีความกว้าง 4.6 ถึง 11.3 เซนติเมตร

ขนาดความยาวและระยะช่วงก้าวของรอยตีนไดโนเสาร์สามารถนำมาคำนวณเพื่อประมาณหาขนาดหรือระดับความสูงของไดโนเสาร์ถึงสะโพก และความเร็วในการก้าวเท้าของไดโนเสาร์ จากผลการศึกษาพบว่าความสูงถึงระดับสะโพกของเทอโรพอดที่พบมีความสูงตั้งแต่ 45 ถึง 64.4 เซนติเมตร และมีความเร็วในการก้าวตั้งแต่ 2.43 ถึง 3.92 กิโลเมตรต่อชั่วโมง สำหรับรอยตีนจระเข้ที่พบมีจำนวนนิ้วที่ปรากฏ 4 นิ้วและคาดว่าเป็นรอยตีนหลังข้างซ้าย

รอยตีนไดโนเสาร์พบปรากฏอยู่บนหินทรายสีเหลืองอ่อน มีเม็ดตะกอนขนาดทรายหยาบหรือกึ่งปากกลาง ค่อนข้างกลมถึงกลมมน ชั้นหินแสดงลักษณะชั้นเฉียงระดับ รอยริ้วคลื่นและรอยชอนไชของสิ่งมีชีวิตในอดีต คาดว่ารอยตีนไดโนเสาร์ที่พบเกิดจากการที่ไดโนเสาร์เดินบนสันดอนทราย กลางลำน้ำสายประสาน การเกิดของรอยตีนในบริเวณจุดศึกษาแตกต่างจากการเกิดรอยตีนในบริเวณจุดศึกษาที่จังหวัดนครพนมเนื่องจากไม่พบชั้นหินโคลนชั้นบางเคลือบชั้นหินทรายอยู่

Title : GEOLOGY AND PALENOTOLOGY OF DINOSAUR FOOTPRINTS FROM PHUWIANG IN NORTHEAST THAILAND

Researcher : Miss Thanatchaporn Phanomphongphaisarn

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Academic year : 2011

Abstract

Most of footprints in Thailand had been found from Khorat Group which is distributed in northeastern part of Thailand. In Phuwiang National Park, dinosaur footprints are on Hin Lat Pa Chat which of stratigraphical position is belonged to Phra Wihan Formation. In fossil locality were found 86 dinosaur footprints which belong to 28 footprints of sauropod, 58 footprints and 6 trackways of theropod, and possibly 1 footprint of crocodile. The size of theropod footprints are varies between 8.6 cm to 16.4 cm long and 4.6 cm to 11.3 cm wide.

Size of foot length and stride length in the trackways can be calculated to estimate height above the ground of the hip joint and walking speed of dinosaur. From calculation, height at the hip of dinosaur were between 45 cm to 64.4 cm and speed were varies between 2.43 km/h to 3.92 km/h. The crocodile footprint has 4 digits and it is left-back foot.

Footprints are preserved as impression on the upper surface of sandstone layers. Sandstone is yellow-white color, coarse to medium grain and subrounded to rounded. This layer consists of cross-bedded, ripple mark and burrows so that the dinosaurs may be walking on the sandbar. Occurrence of footprints in fossil locality different from Nakhon Phanom because in fossil locality did not find mud film.

Acknowledgements

This project is could not successfully completed without the aid of the Department of Geology, Faculty of Science, Chulalongkorn University for the financial support and all facilities for making this study possible. I would like to thank Phu Wiang National Park and Crocodile farm in Samutprakarn for facilitating access to collect specimens.

I am very grateful to the helps and support from Dr.Yoshio Sato for his advices, encouragement, checking and discussion through preparing recent the report. I deeply express my thank to all professors in the Department of Geology, Faculty of Science, Chulalongkorn University for giving me all suggestions.

Finally, I specially thank to Miss Chayarus Centhonglang and Miss Maneenuch Pansorn for helpful in field investigation and laboratory work, my family and my friends (Geo 52) for their encouragement and supports.

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CHAPTER1

ABOUT THE PROJECT AND DATA

1.1 General statement

The fossil tracks are belonged to trace fossil, which are clues to identify the kinds of dinosaur (Sauropod, Theropod, Ornithopod), body dimensions, walking and running speed. Foundamentary, footprints are all autochthonous.

Geology around the Phu Wiang Mountain in Khon Kaen province consists of Khok Kruat, Phu Phan, Sao Khua, Phra Wihan and Phu Kradung Formations (DMR, 2002). The dinosaur footprints were found on Hin Lat Pa Chat in the Phu Wiang Mountain. Hin Lat Pa Chat contains 8 different trackways of small theropods, a large theropod and several small ornithischians (Loeuff, 2002).

The dinosaur footprints were found on Hin Lat Pa Chat of which stratigraphical position belongs to Phra Wihan Formation. This formation consists of sandstone and siltstone with claystone intercalation (Loeuff, 2002). Hin Lat Pa Chat contains more than 60 tracks those are preserved as impression on the upper surface of sandstone layers (DMR, 2007).

By studying dinosaur footprints, not only paleoenvironments and taphonomy, but paleoecology while they had been living also can be reconstructed.

1.2 Objectives

1. To fix the stratigraphical position of fossil locality.
2. To estimate size and speed from measured data of the dinosaur footprints.
3. To compare footprint of recent crocodile and fossil crocodile.
4. To reconstruct the paleoenvironments at the time that dinosaur were living by the result of facies analysis.
5. To reconstruct the taphonomy of dinosaur footprints.

1.3 Scope of study

This study will focus on the lithology of rocks in footprint locality, paleontological study of dinosaur footprints, identification of the kinds of dinosaurs, and reconstruct paleoenvironments and taphonomy. Moreover, the result of these studies will compare between the fossil crocodile footprint and recent crocodile footprints.

1.4 Definition of terms

Sauropod: a very large quadrupedal herbivorous dinosaur with a long neck and tail, small head, and massive limbs.

Theropod: a carnivorous dinosaur of a group whose members were typically bipedal and ranged from small and delicately built to very large.

Ornithopod: a mainly bipedal herbivorous dinosaur.

1.5 Study area

Study area is located in Phu Wiang Mountain, which is in to Amphoe Phu Wiang. Fossil locality is about 8 km. from the entrance gate of National Park of Dadfa waterfall.

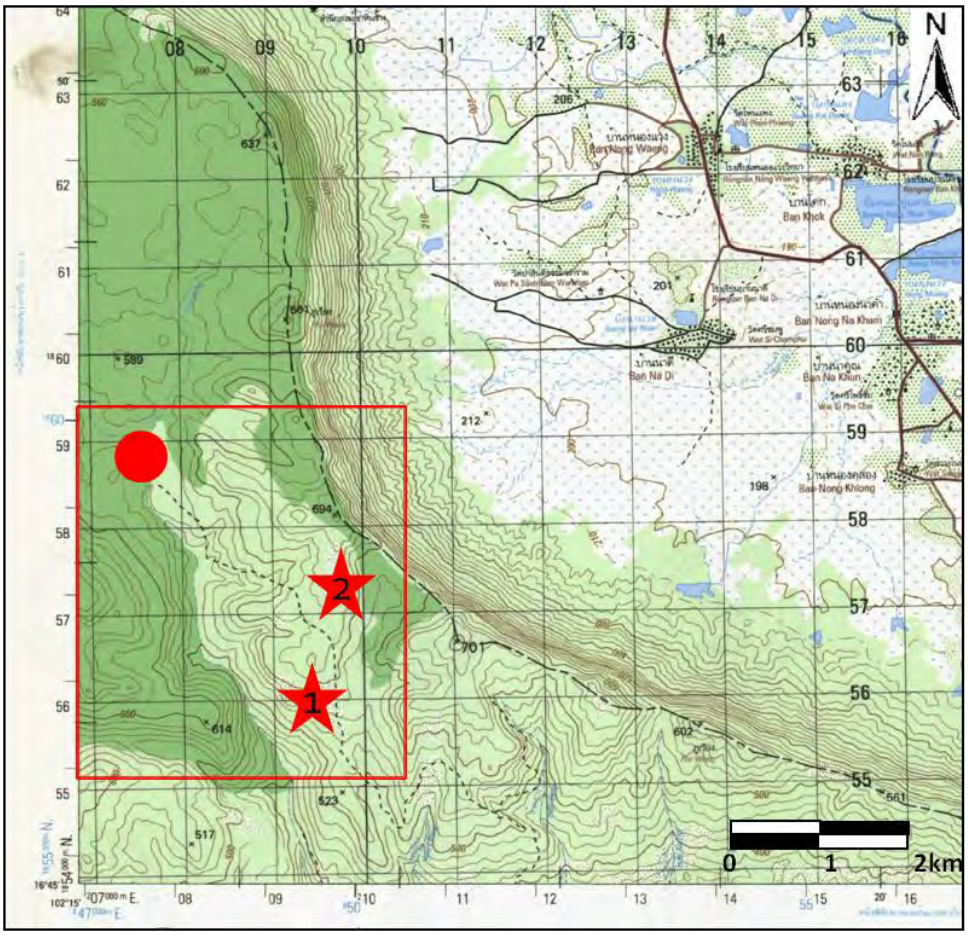


Figure1.1 Study area (Red square), footprint locality (Red star 1), New locality (Red star 2) and Dadfa waterfall (Red circle), part of topographic map scale 1:50,000, Sheet 5442 I (Amphoe Si Boon Rueang).The Royal Thai Survey Department 1997.

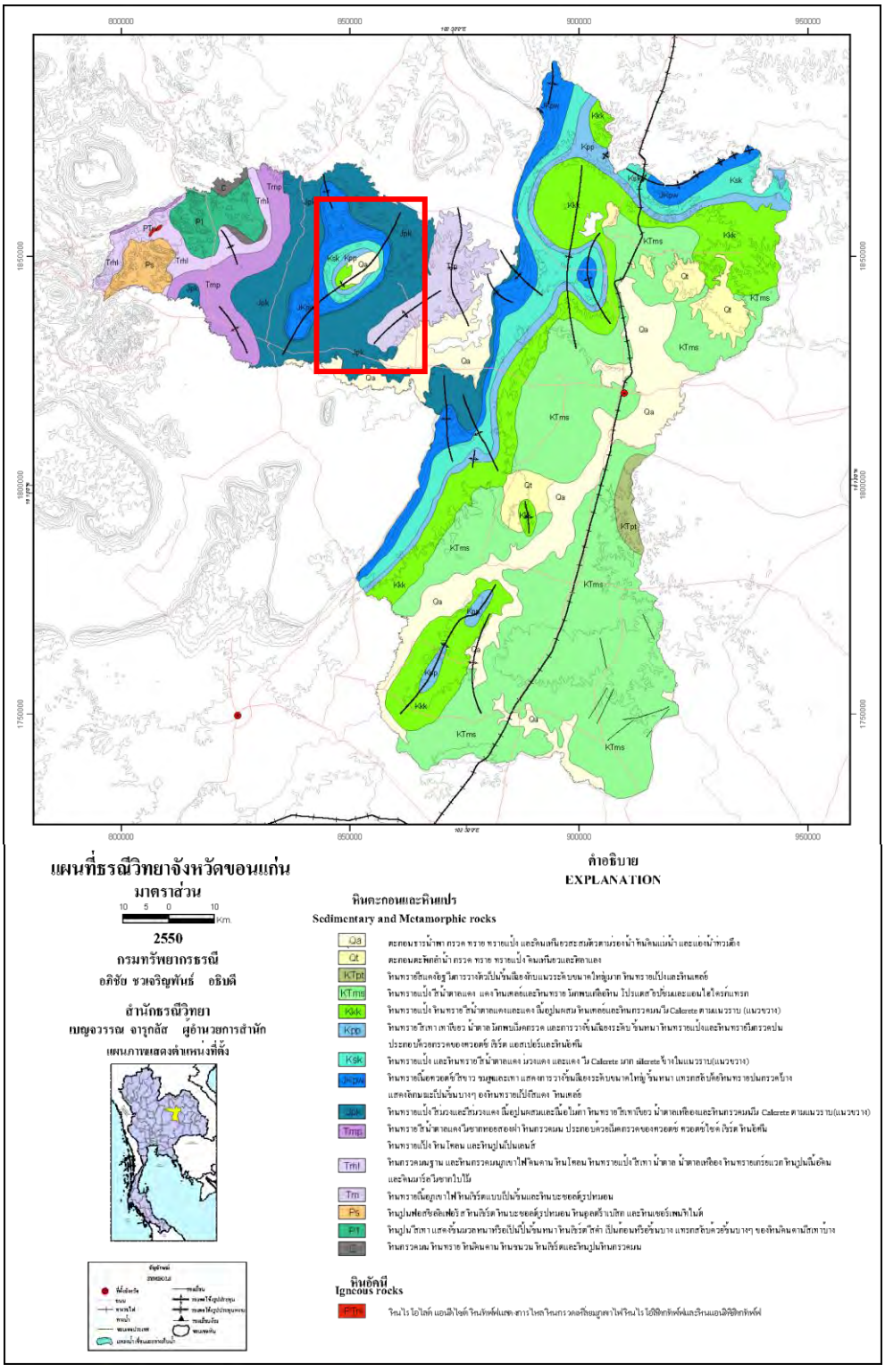


Figure1.2 Geologic map of Province Khon Kaen, Scale 1:250,000, Department of Mineral Resource,2007.Red box is a study area.

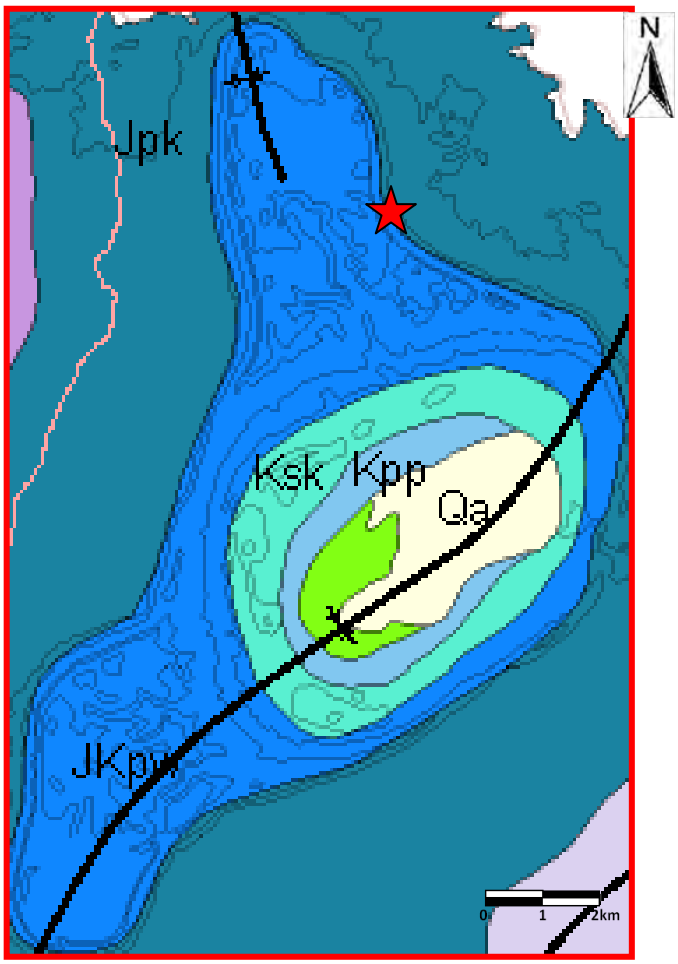


Figure1.3 Part of geologic map of Province Khon Kaen, Department of Mineral Resource, 2007. Red star is the study area.

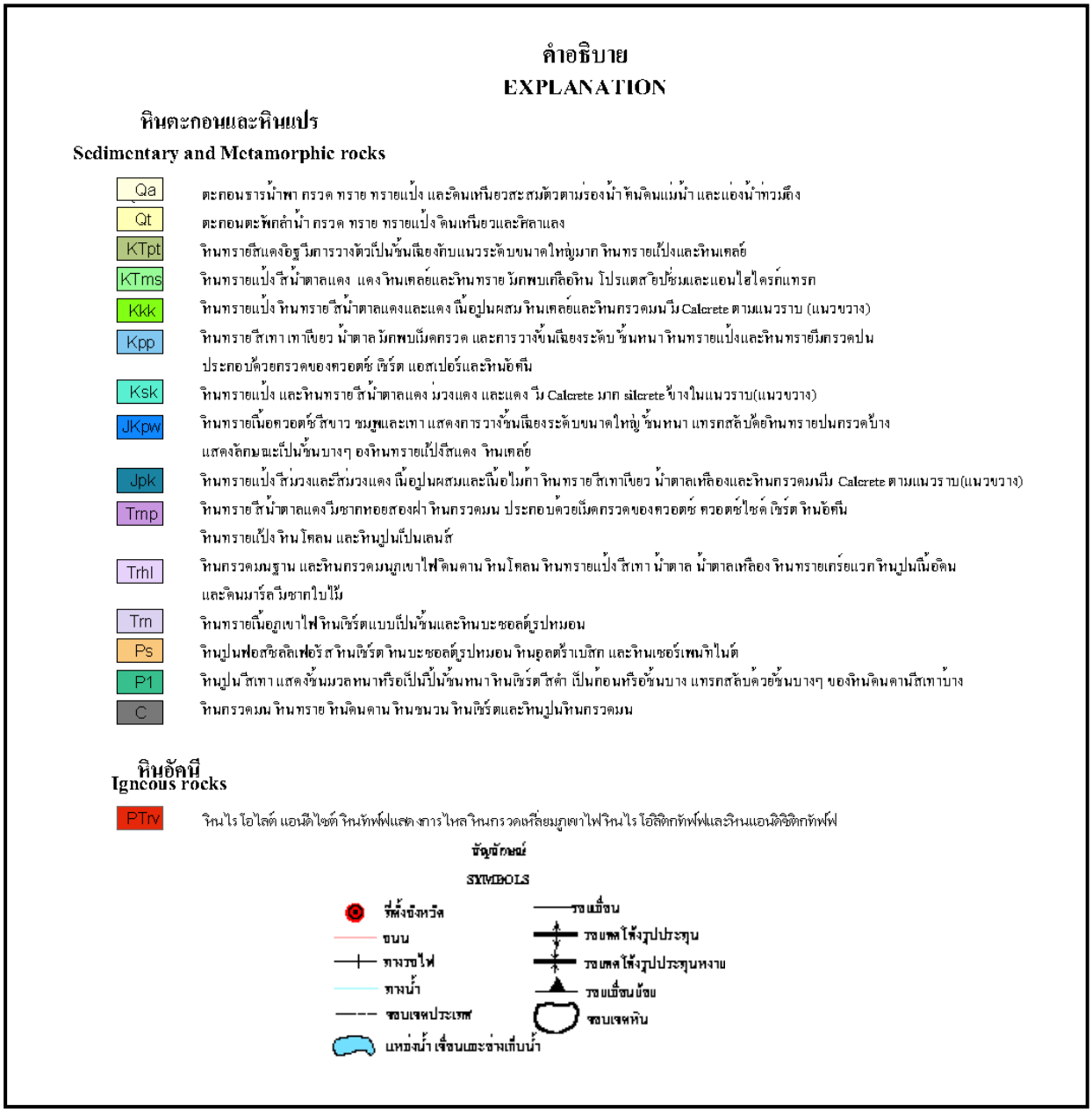


Figure1.4 Explanation of geologic map of Province Khon Kaen. Department of Mineral Resource, 2007.

1.6 Theoretical Background and Relevant Research

Type locality of Phra Wihan Formation is at Phra Wihan Mountain near border between Thailand and Cambodian (DMR, 2002). Thickness of Phra Wihan Formation is about 55 to 136 meters. This formation consists of white to yellow, fine- to coarse-grained sandstone, well sorted and well rounded. Majority composition are quartz and feldspar. The lower bed consists of sandstone and siltstone with claystone intercalations and thin layer lignite bed near Phu Kradung Formation. The Pra Wihan Formation overlies the Phu Kradung Formation and overlain by the Sao Khua Formation. Paleoenvironments and climate can be infered from lithology, relationship between the Phu Kradung and the Sao Khua Formations. The Phra Wihan Formation was to be deposited in braided river in a slightly humid condition. Moreover, this formation is referred to Late Jurassic to Early Cretaceous on basis of palynomorphs.

Le Loeuff *et al*. (2002) studied the early Cretaceous continental formation of the Khorat Group to fill a gap in knowledge of Asian continental vertebrates. The Hin Lat Pa Chad is located in the the Phu Wiang Mountain, situated in a riverbed and footprints are preserved as impressions on the upper surface of a sandstone layer. In this area they reported 8 different trackways of small theropods, a large theropod, and several small ornithischians.

Buffetaut *et al*. (2003) reported a discovery of dinosaur's bones and teeth remains in the Khorat Plateau, Northwestern and Southern peninsula of Thailand, in the non-marine Mesozoic Formations. Khorat Plateau has six formations; Nam Phong, Phu Kradung, Phra Wihan, Sao Khua, Phu Phan and Khok Kruat. In ascending order, which have dinosaur remains in all of formations. But dinosaur footprints were found only in Phra Wihan, Phu Phan and Khok Kruat Formations. The Phra Wihan Formation (early Cretaceous) has three toed prints referable to theropods of various sizes. This formation has two localities such as the Phu Faek (Kalasin Province) and Khal Yai National Park. The Phu Faek area has sauropod footprints occur together with theropods.

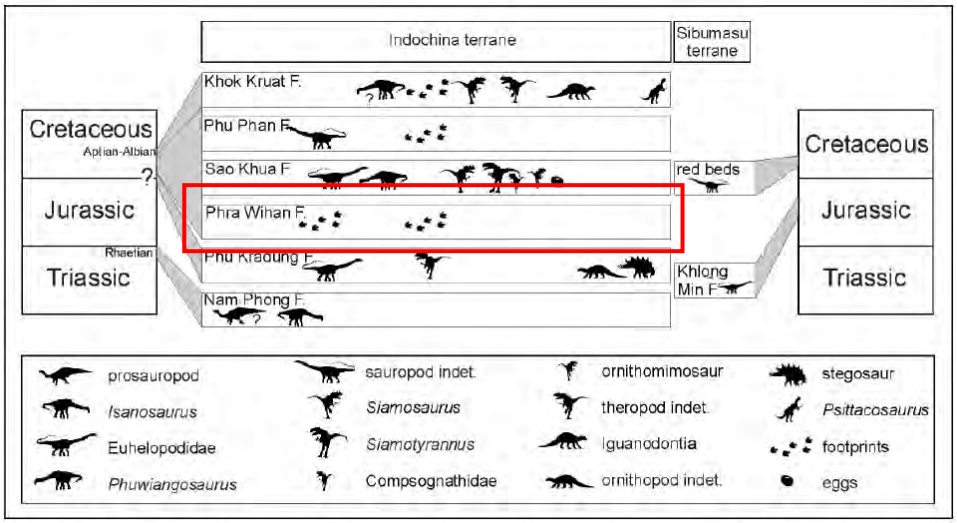


Figure1.5 The distribution of dinosaur fossils in the Khorat Plateau. The Phra Wihan Formation has only the dinosaur footprint. (Buffetaut *et al*.,2003). Footprint locality (Red square) found on Phra Wihan Formation.

Le Loeuff *et al*. (2009) the Phra Wihan Formation (late Jurassic to early Cretaceous) deposits consist of sandstone and siltstones with claystone intercalations. This formation is the main track-bearing unit of Thailand with five footprint sites: Hin Lat Pa Chad (Khon Kaen Province), Khao Yai National Park (Prachin Buri Province), Phu Kao (Nong Bua Lam Phu Province), Phu Hin Rong Kla National Park (Loei Province) and Phu Faek (Kalasin Province). Hin Lat Pa Chad in Khon Kaen Province is located in a river bed in the mountain of Phu Wiang, a few kilometers from the rich dinosaur boned localities of Phu Wiang. Dinosaur footprints occur as concave hyporeliefs on the upper surface of a sandstone layer and have many trackways. At least one trackway was left by a small theropod and others were made by small quadrupedal ornithopods.

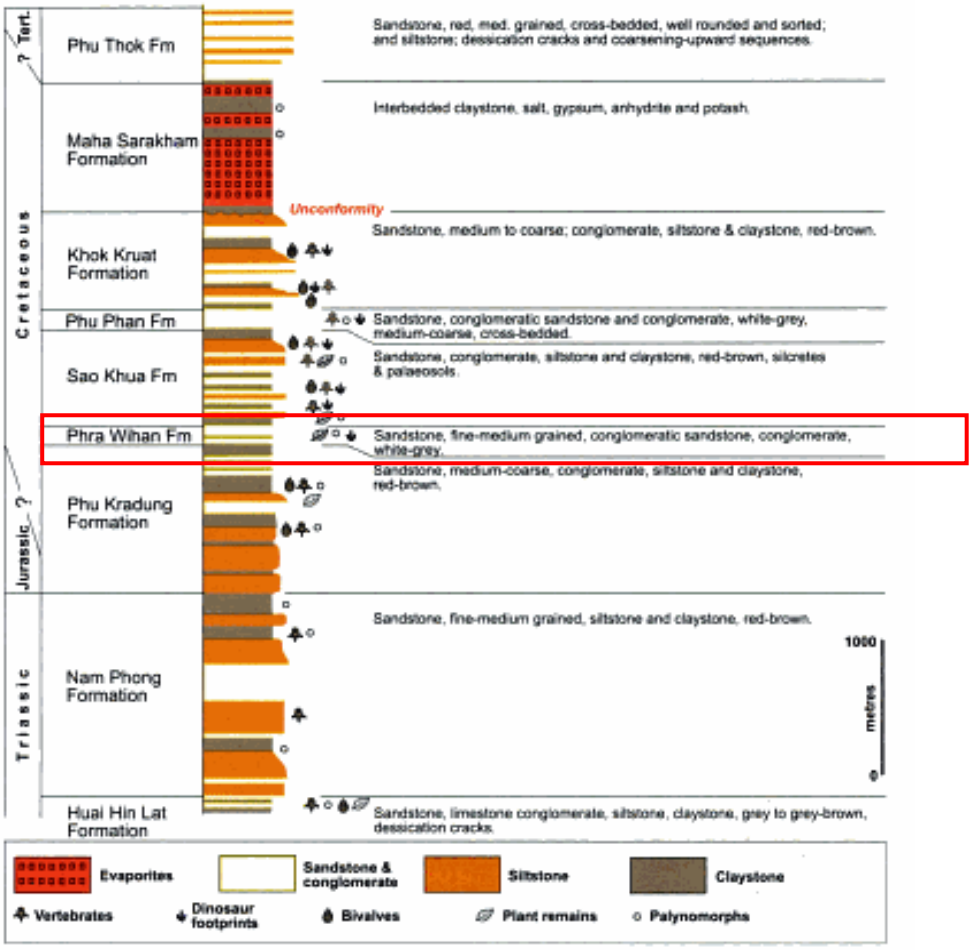


Figure1.6 Stratigraphic table of the Mesozoic rocks in Khorat Plateau, NE Thailand. (Meesook, 2011). Fossil locality (Red square) is belonged to Phra Wihan Formation.

1.7 Expected results

1. Columnar section in fossil locality.
2. Reconstruction paleoenvironments in the Phra Wihan Formation.
3. Identification of dinosaur footprints.
4. Taphonomy of dinosaur footprints.
5. To reconstruct of body size and walking speed of dinosaurs.

1.8 Methodology

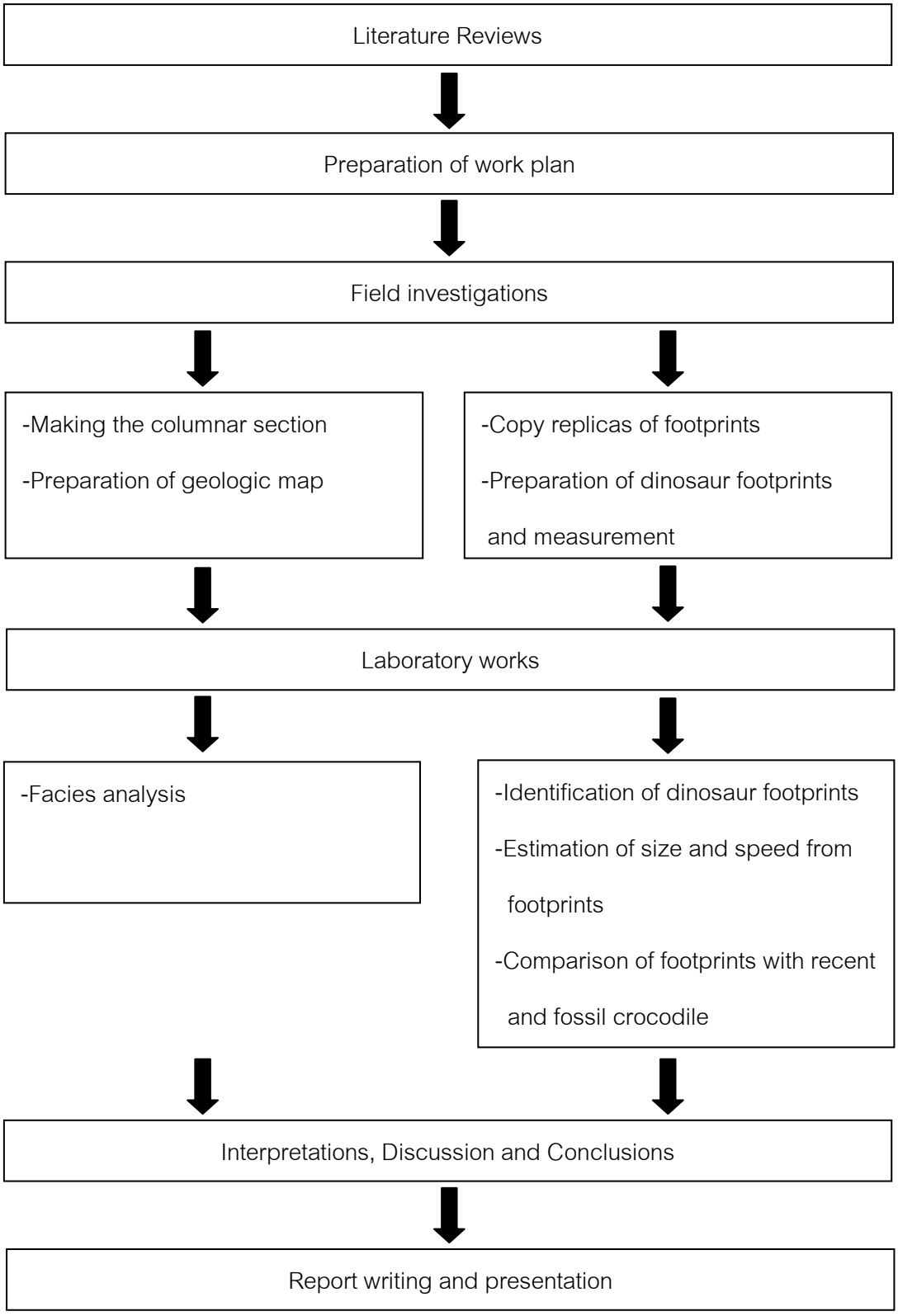


Figure1.7 Schematic diagram showing the study steps of the research project.

1. Literature reviews about the Khorat Group and dinosaur footprints.
    1.1 Data: Geology of Khorat Group; Phra Wihan Formation, dinosaur footprints.
    1.2 Studying previous work.

2. Preparation of work plan.
    2.1 Planning scope of work, methodology and schedule of work.

3. Field investigation.
    3.1 Making the columnar section.
    3.2 Preparation of geologic map.
    3.3 Preparation of replicas of footprints and trails.
    3.4 Measurement of dinosaur footprints.

4. Laboratory works.
    4.1 Making facies analysis of Phra Wihan formation.
    4.2 Estimation of size from footprints.
    4.3 Identification of dinosaur footprints.
    4.4 Comparison of footprints with recent fossil crocodile.

5. Interpretation, discussion and conclusion.
    5.1 Interpretation the depositional environment from columnar section.
    5.2 Reconstruct the paleoenvironments and taphonomy.

6. Report writing and presentation.

CHAPTER 2

RESULTS

2.1 Paleontological study.

2.1.1) General description of dinosaur footprints.

2.1.2) Estimate walking speed and body height by the measured data of dinosaur footprints (Thulborn,1989).

2.1.3) Dinosaur footprints dimension.

2.1.4) Crocodile footprint.

2.2 Sedimentological study.

2.2.1) Lithostratigraphic columns.

2.2.2) Paleoenvironments and taphonomy of footprint.

2.1 Paleontological study.

2.1.1) General description of dinosaur footprints.

At footprint locality, 86 dinosaur footprints were found. There are 28 footprints of sauropod, 58 footprints and 5 trackways of theropod, and possibly 1 footprint of crocodile. All theropod trackways have left-right sequences of similar shaped prints. The digits numbers of theropod footprints are tridactyl and the crocodile footpritnt is tetradactyl.

2.1.2) Estimate walking speed and body height by the measured data of dinosaur footprints (Thulborn,1989).

1. Estimate height at the hip (h) by following this formula.

Small theropods (FL < 25 cm) $h = 4.5 \times FL$

h is height at the hip

FL is footprint length

2. Taxonomy and behavior

Walking: SL/h < 2.0 m

Trotting: SL/h = 2.0-2.9 m

Running: SL/h > 2.9 m

SL is stride length

h is height at the hip

3. Calculation of speed can be depended on the behavior.

Alexander's formula (1976) can be used for walking and running gaits.

$$V \approx 0.25 g^{0.5} SL^{1.67} h^{-1.17}$$

Thulborn's formula (1984) can be used for walking and running gaits.

$$V \approx [gh(\frac{SL}{1.8h})^{2.56}]^{0.5}$$

V is speed

g is the gravitational constant

SL is the stride length

h is height at the hip

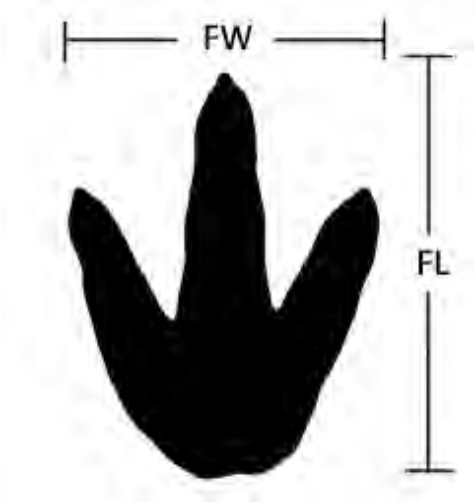


Figure2.1 Measurements of footprint size; footprint length (FL) measured along,or parallel to, the axis of the principal digit and footprint width (FW) measured from the tip of the innermost digitto the tip of the outermost one. (Thulborn, 1990).

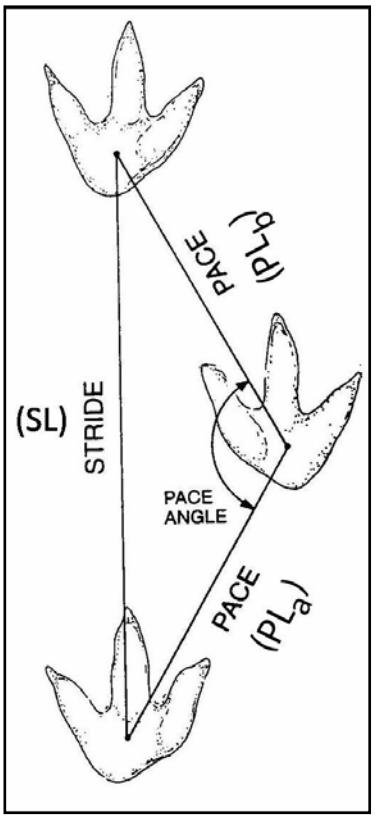


Figure2.2 Stride length (SL) and pace length (PL) in the trackway of bipedal dinosaur can be measured between corredponding points in two footprints. Pace angulation (ANG) can be calculated from two continuous paces (PL_a and PL_b) and stride length (SL).

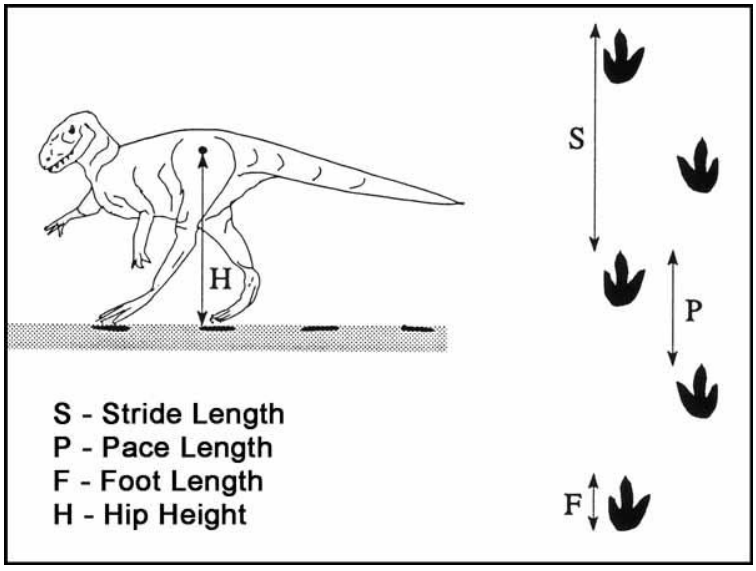


Figure2.3 Height at the hip (H) is height above the ground of the hip joint in a dinosaur skeleton. Alexander (1976) suggested that H ≈ 4F, hip height is about 4 times foot length in both bipeds and quadrupeds.

Figure 2.4 Dinosaur footprints of theropod (right) and sauropod (left) which preserve on the surface of sandstone (Footprint locality).

Figure 2.5 Tracing dinosaur footprints by the plastic film.

Figure 2.6 Making repica of footprints by using low quality white silicone.

2.1.3) Dinosaur footprints dimension.

The size of theropod footprints are between 8.6 cm to 16.4 cm long and 4.6 cm to 11.3 cm wide. The biggest size of footprint is Sally's track way and the smallest size is Daeng's track way.

Name of trackways	N	h(m)	FL/FW	SL/h	V(km/h) Alexander	V(km/h) Thulborn	V (km/h) mean
Helen	11	0.567	1.37	1.041	2.270	4.210	3.240
Wasabi	8	0.468	1.529	0.908	1.660	3.200	2.430
John	15	0.528	1.427	0.981	1.980	3.780	2.880
Jame	3	0.554	1.370	1.200	2.840	5.000	3.920
Daeng	12	0.450	1.562	1.040	2.020	3.740	2.880
Sally	12	0.644	1.571	0.905	1.910	3.740	2.825

Table 2.1. The footprints dimension. N = Number of footprints in trackway, h = height at the hip, FL = footprint length, FW = footprint width and SL = stride length

The ratios of footprint length and footprint width of the mean values are 1.370 to 1.571 that means all of footprints are longer than wide. The height at the hip varies between 45 cm to 64.4 cm. Relative stride length (SL/h) of every footprint shows the dinosaurs were walk. The mean speed were varies between 2.43 km/h to 3.92 km/h.

2.1.4) Crocodile footprint.

Figure 2.7 Crocodile footprint has distinct 4 digits in footprint locality on sandstone layer.

Figure2.8 Freshwater crocodile is 1 year old, male. The total length is 130.5 cm. and weight is 7 kg.

Figure 2.9 Collecting the footprints and track way of crocodile by using gypsum pool.

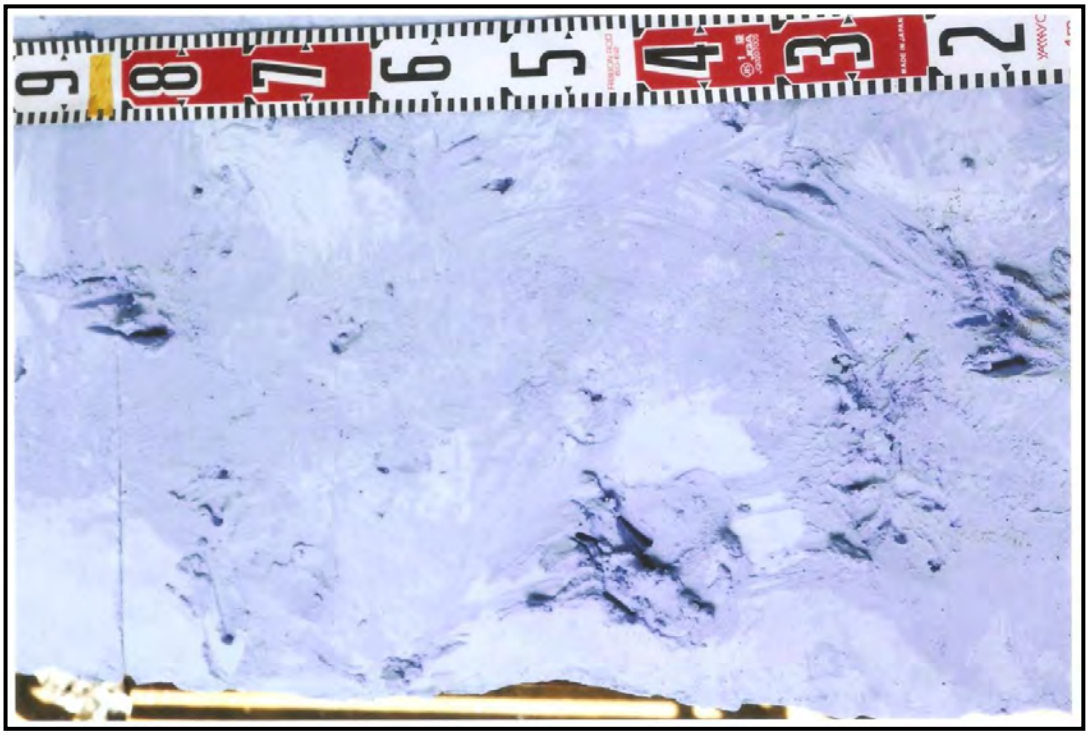


Figure2.10 Some part of crocodile's track way which has difference shape and direction.

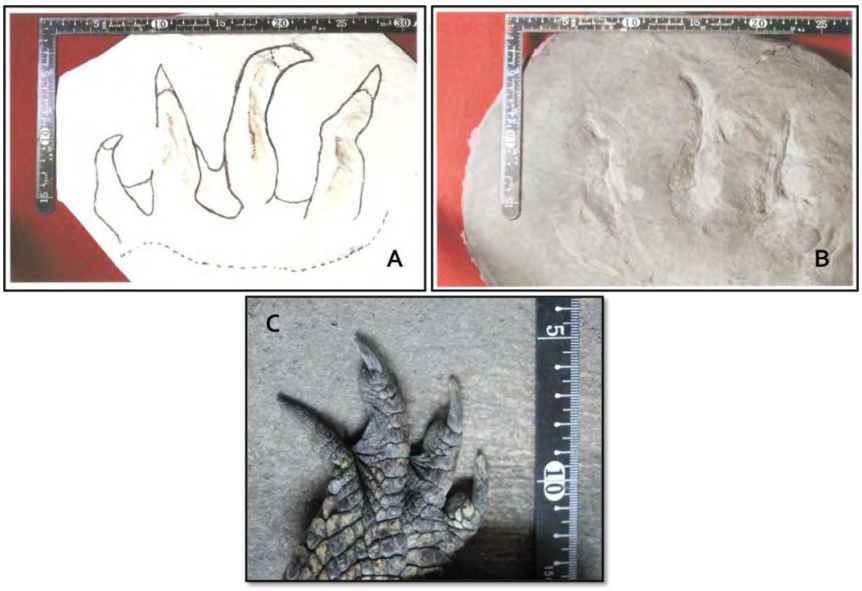


Figure2.11 Comparison between fossil crocodile footprint (A, B) and recent crocodile (C). A, silicone cast of footprint from footprint locality. B, gypsum underprint model. C, left-back foot of recent crocodile.

Crocodile footprint dimension.

No. Digit	Fossil crocodile	Recent crocodile
Digit I	125 mm	40 mm
Digit II	143 mm	50 mm
Digit III	122 mm	40 mm
Digit IV	52 mm	25 mm

Table2.2 Table of crocodile's digits dimension.

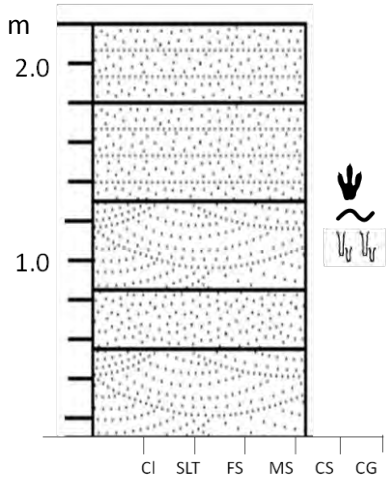
The size of fossil crocodile footprint is 239 mm. long and 199 mm. wide. The longest digit of fossil crocodile and recent crocodile is digit II, 143 mm and 50 mm respectively. The shortest digit are digit IV, 52 mm and 25 mm.

2.2 Sedimentological study.

2.2.1) Lithostratigraphic column.

The total thickness of columns is 2.2 m at footprint locality and about 30 m at Dadfa waterfall. In footprint locality, the lithological succession is divided into 3 units; B, C and D in ascending order (Figure2.12). The footprints appeared between cross-bedded sandstone (Unit C) and lamination sandstone (Unit B). Unit C consists of medium-grained sandstone and sedimentary structures, including cross-bedded, ripple mark and bioturbation. In Dadfa waterfall, the lithological succession is divided into 5 units; A, B, C, D, and E (Figure 2.13 - 2.14). The columns most consist of sandstone which has cross-bedded, lamination and massive structure.

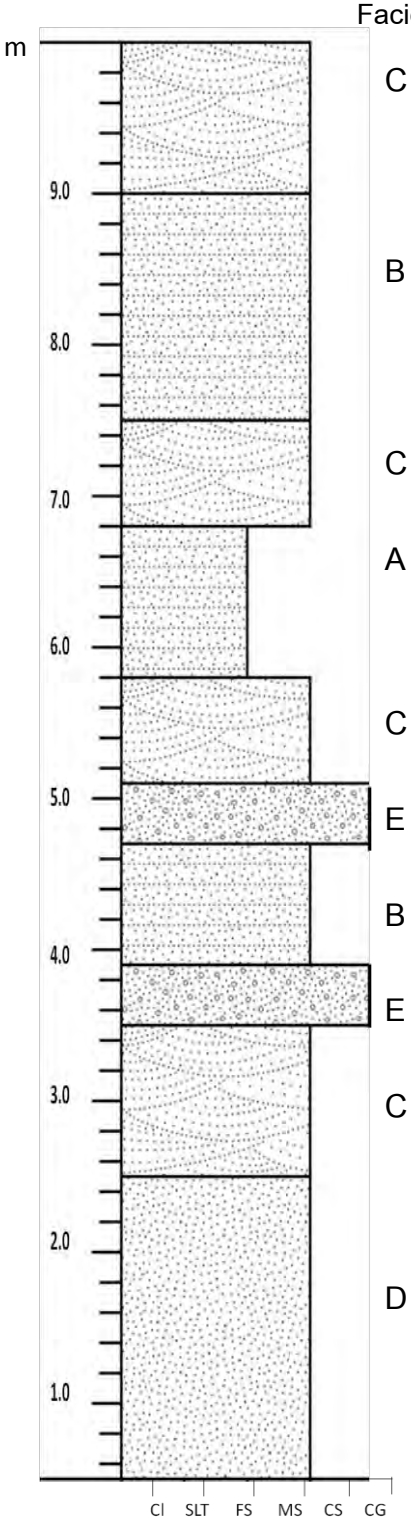
Stratigraphic column of footprint locality at Hin Lat Pa Chad.



Facies	Description of lithology and sedimentary structure
B	-White-grey sandstone, medium grained, lamination and ripple mark
B	-White-grey sandstone, fine to medium grained, lamination
C	-White-grey sandstone, fine to medium grained, cross-bedded lamination
D	-White sandstone, medium grained
C	-Light-brown sandstone, medium grained, cross-bedded

Figure 2.12 Lithostratigraphic column and description of lithology at footprint locality.

Stratigraphic column of Dadfa waterfall at Hin Lat Pa Chad.



Facies	Description of lithology and sedimentary structure
C	-Light-brown sandstone, medium grained, thin and crossbedded.
B	-Light-brown sandstone, very thick bedded and parallel laminated
C	-Light-brown sandstone with cross-bedded lamination
A	-White-grey very fine sandstone
C	-White-grey sandstone, medium grained, cross-bedded
E	-Brown conglomerate, coarse sand with large pebbles of quartz and fragment.
B	-Light-brown sandstone
E	-Light-brown conglomerate, pebbles of fragment and quartz, subrounded to rounded
C	-Light-brown sandstone, fine to medium grained
D	-Light brown sandstone, fine to medium grained, massive and very thick bedded.

Figure2.13 Lithostratigraphic column and description of upper outcrop at Dadfa waterfall.

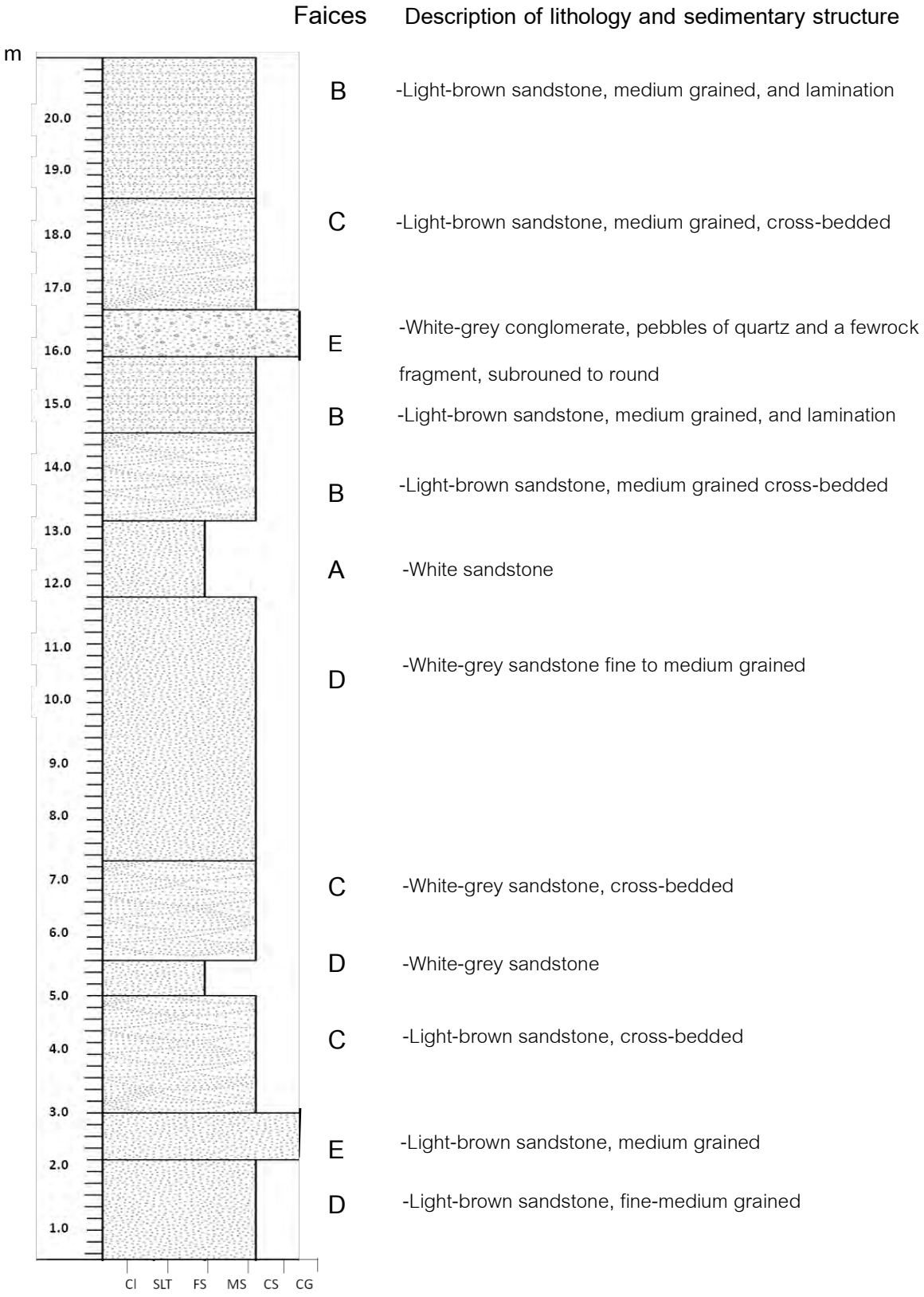


Figure2.14 Lithostratigraphic column and description of lower outcrop at Dadfa waterfall.

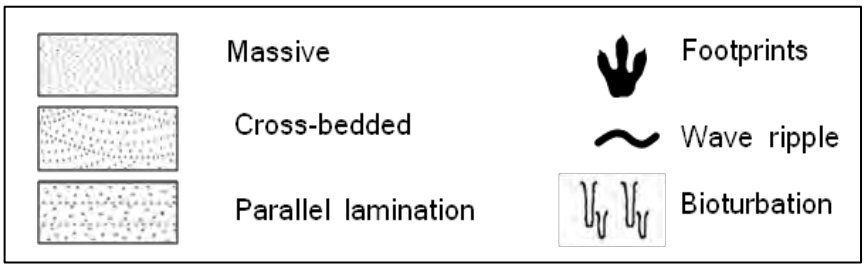


Figure 2.15 Legends of Sedimentary structure.

Facies	Lithofacies	Sedimentary Structures	Depositions
A	Very fine sand	Massive	Overbank deposit
B	Sandstone	Parallel lamination	Channel
C	Sandstone	Cross-bedded	Sandbar
D	Fine to medium sandstone	Massive	Natural levee
E	Conglomeratic sandstone	Massive, lens	Channel-floor, Scour-fill, Lag deposit

Table 2.3 Lithofacies, Sedimentary structures and Depositional reconstructed paleoenvironment by lithostratigraphic coloumns.

Figure 2.16 Dinosaur footprints on the surface of sandstone with ripple marks.

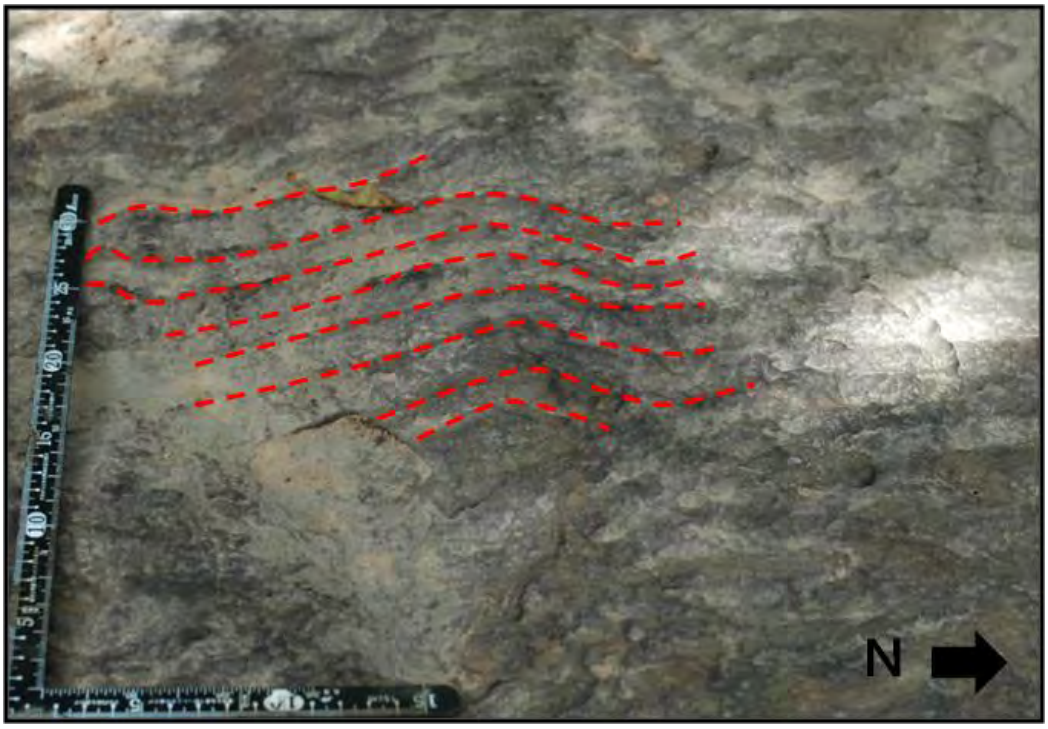


Figure 2.17 The ripple mark on the surface of sandstone.

Figure 2.18 Sandstone with gravel lens.

Figure 2.19 Bioturbation were made into soft sediments which formed in the same time of footprints.

2.2.2) Paleoenvironments and Taphonomy of footprint.

Paleoenvironments reconstruction has been made based on the lithology and sedimentary structures. Paleoenvironments in footprint locality is classified to sandbar in braided river. From field evidence (Figure2.16) shows the theropods were walking on the sandbar while the sediment was soft. Ripple mark and bioturbation (Figure2.17 and 2.19) were developed on the surface.

Taphonomy of footprint in Hin Lat Pa Chad is reconstructed by following this step. First, medium sandstone had been deposited by current, so it had been formed cross-bedded. The water level had been decrease while the dinosaur walking. Therefore some part of outcrop shows the footprints on the ripple mark. After that, thin mud had been deposited by small scale flooding. It covered sandstone layer which has footprints. According to the season change, the water had been flooded and eroded the thin mud layer. After that sandstone had been deposited as planar lamination.

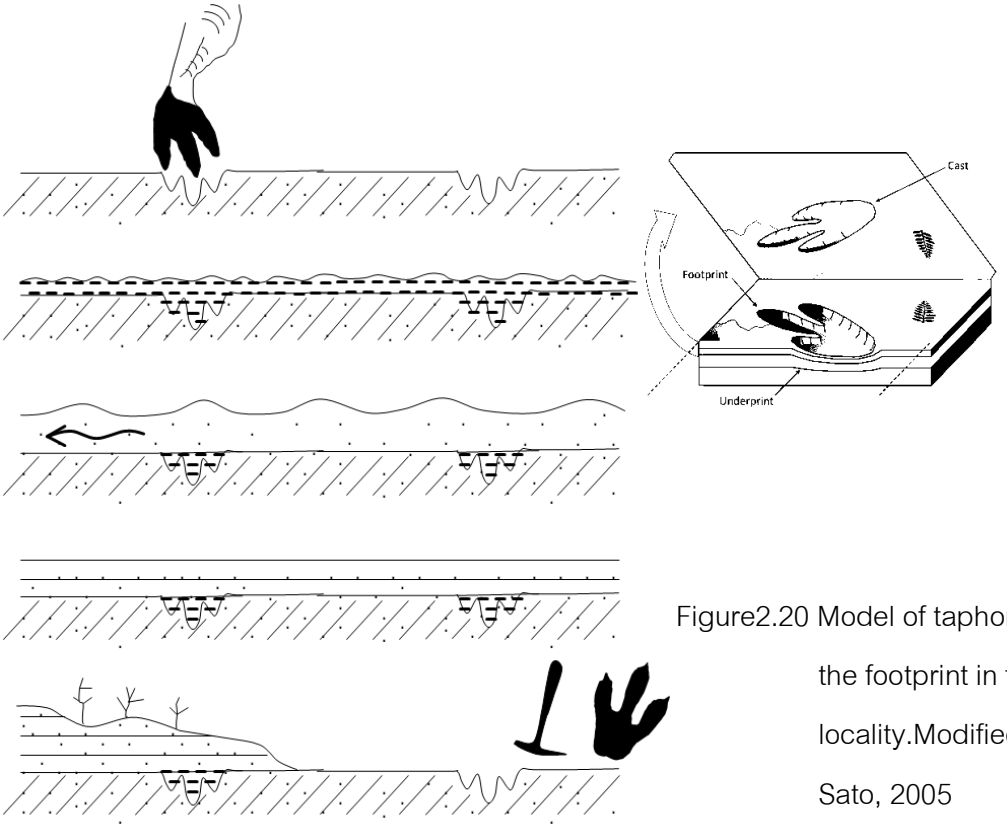


Figure2.20 Model of taphonomy of the footprint in footprint locality.Modified from Sato, 2005

CHAPTER 3

CONCLUSION AND DISCUSSION

3.1 Conclusion

In fossil locality have 2 kinds of animal footprints; dinosaurs and crocodile. There are 85 footprints of dinosaur which belong to 28 footprints of sauropod and 58 footprints, 6 trackways of theropod. One footprint of crocodile is tetradactyl and it is left-back foot. The size of theropod footprints are varies between 8.6 cm to 16.4 cm long and 4.6 cm to 11.3 cm wide.

The footprint length can be calculated in order to estimate size of dinosaur. It shows that height at the hip of dinosaur were between 45 cm to 64.4 cm and walking speed were varies between 2.43 km/h to 3.92 km/h. The size of crocodile may be larger than 6 meters.

Footprints are preserved as impression on the upper surface of sandstone layers. This layers is coarse to medium sandstone, light brown color and subrounded to rounded. Sandstone consists of cross-bedded, ripple mark and burrows. The paleonenvironments are sandbar in braided river system of Early Cretaceous age. Taphonomy of footprints in fossil locality is different from footprints those are best preserved in Nakhon Phanom which has mudfilm layer.

3.2 Discussion

The previous work at Hin Lat Pa Chad reported that had 8 different trackways of theropods (Le Loeuff *et al*.,2002). However, dinosaur footprints in footprint locality have sauropod footprints, theropod footprints in 6 different trackways and crocodile footprint.

According to the mean velocity of theropod footprint, they were walking on sandbar in braided river and probably looking for food or drinking water. Moreover, the crocodile footprint is not far from theropod footprints so maybe it was a predator to attacking other animals.

In the present research, footprints were found on upper surface of sandstone in the Phra Wihan Formation which belongs to Khorat Group. Footprints are always found on the surface of eroded surface (Fig 3.1). The agent of like those power come from water, river and sea water. So we can find them near the river and seashore. Time has been gone, Khorat Group was weathered and eroded by the river. After that, Quaternary deposited and eroded. Only the flat surface remained, we can see the footprints on the upper surface of Khorat Group. In the same way, some part of Quaternary was weathered and eroded. These processes happen many times unit present, the imprint of footprint's layer has been exposed. In the future, much wider bedding planes with dinosaur footprints will be discovered.

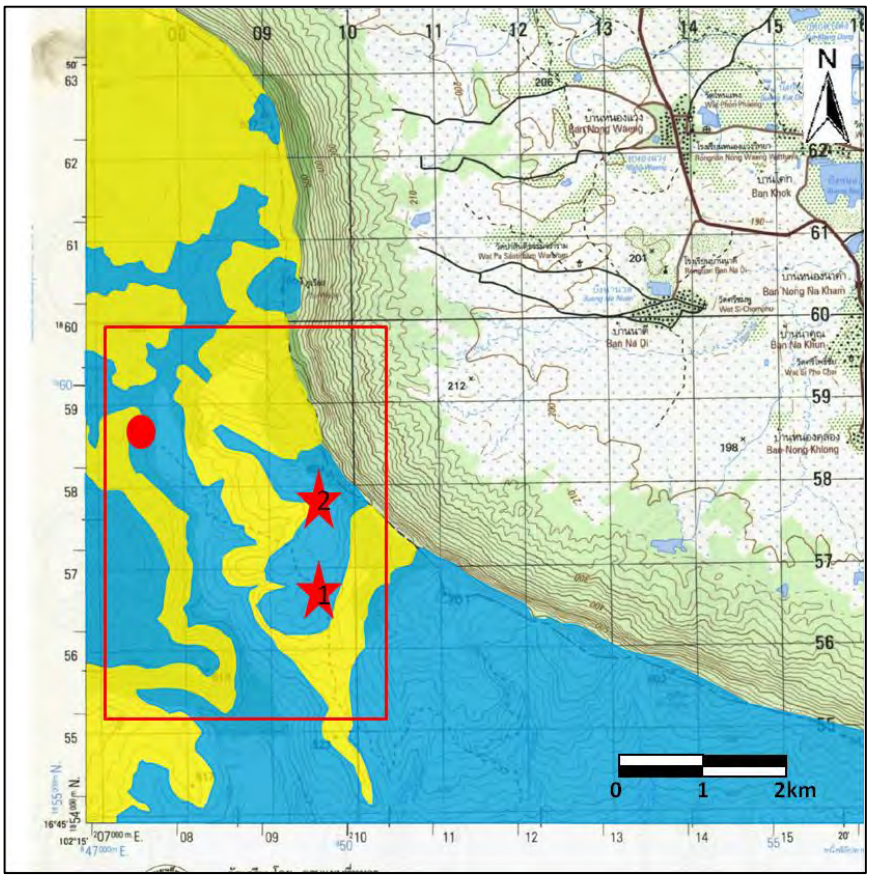


Figure 3.1 Study area (Red square), footprint locality (Red star 1), New locality (Red star 2) and Dadfa waterfall (Red circle), part of topographic map scale 1:50,000, Sheet 5442 I (Amphoe Si Boon Rueang).The Royal Thai Survey Department 1997.

REFERENCES

Buffetaut, E., Suteethorn, V., Cuny, G., Khansubha, S., Tong, H., Le Loeuff, J., and Cavin, L. 2003. Dinosaurs in Thailand. 1st International Conference on Paleontology of Southeast Asia. Mahasarakam University Jour. 22: 69-82.

Buffetaut, E., Suteethorn, V., Le Loeuff, J., et al. 2003. The first dinosaur footprints from the Khok Kruat Formation (Aptian of Northeastern Thailand). 1st International Conference on Paleontology of Southeast Asia. Mahasarakam University Jour. 22: 83-91.

Hickman, C. 2010. Amniote origins and Nonavian reptiles. Integrated Principles of Zoology, pp 568-589: McGraw-Hill.

Irvin Sellers, Willian. and Lars Manning, P. 2007. Estimating dinosaur maximum running speeds using evolutionary robotics. Proceddings of The Royal Society. 274: 2711-2716.

Jennings, Debra. and Hasiotis, S. 2006. Taphonomic analysis of a dinosaur feeding site using geographic information systems (GIS), Morrison Formation, Southern Bighorn basin, Wyoming, USA. Palaios. 21: 480-492.

Le Loeuff, J., Khansubha, S., Buffetaut, E., Suteethorn, V., Tong, H. and Souillat, C. 2002. Dinosaur footprints from the Phra Wihan Formation (Early Cretaceous of Thailand). C.R. Palevol.1:287-292.

Le Loeuff, J., Khanubha, S., Buffetaut, E., Suteethorn, V. and Saenyamoon, T. 2005. Vertebrate Footprints of South East Asia (Thailand and Laos): a Review. International Conference on Geology, Geotechnology and Mineral Resources of Indochina (GEOINDO 2005): 582-587.

Lockley, M., Matsukawa, M., Sato, Y., Polahan, M. and Daorerk, V. 2006. A distinctive new theropod dinosaur track from the Cretaceous of Thailand: Implications for theropod track diversity. Cretaceous Research. 27: 139-145.

Le Loeuff, J., Saenyamoon,T., Souillat, C., Suteethorn, V. and Buffetaut, E. 2009. Mesozoic vertebrate footprints of Thailand and Laos. Geological Society, London, Special Publications. 315: 245-254.

Meesook, A. 2011. Cretaceous. Ridd, M.F., Barber, A.J. and Crow, M.J.(eds.), The Geology of Thailand, pp169-178: The Geological Society.

Pettijohn, F.J., Potter, P.E. and Siever, R. 1972. Sand and Sandstone, Germany: Springer Verlag Berlin Heidelberg.

Radley, J., Barker, M. and Harding, I. 1998. Palaeoenvironment and taphonomy of dinosaur tracks in the Vectis Formation (Lower Cretaceous) of the Wessex Sub-basin, southern England. Cretaceous Research. 19: 471-487.

Romilio, A. and Salisbury, S. 2011. A reassessment of large theropod dinosaur tracks from the mid-Cretaceous (late Albian-Cenomanian) Winton Formation of Lark Quarry, central-western Queensland, Australia: A case for mistaken identity. Cretaceous Research. 32: 135-142.

Sato, Y. and Tumpeesuwan, S. 2005. Superexcellent preservation of dinosaur foot prints in Nakhon Phanom in northeast Thailand. Proceedings of the International Conference on Geology, (GEOINDO 2005): 570-574.

Suraprasit, K. 2008. Sedimentary Characteristics and Dinosaur Footprints at Amphoe Tha-Uthane Changwat Nakhonphanom. Bachelor Degree in Science. Department of Geololgy, Faculty of Science, Chulalongkorn University.

Thulborn, T. 1990. Dinosaur tracks, London: Chapman and Hall.

Thulborn, R. 1982. Speeds and gaits of dinosaurs. Palaeogeography, Palaeoclimatology, Palaeoecology. 38: 227-256.

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

Yul Kim, J., Lockley, M., Mook Kim, H. and Soo Kim, K. 2009. New dinosaur tracks from Korea, *Ornithopodichnus masanensis* ichnogen. et ichnosp. nov. (Jindong Formation, Lower Cretaceous): implications for polarities in ornithopod foot morphology. Cretaceous Research. 30: 1387-1397.

ธีระพล วงษ์ประยูร 2546. ธรณีวิทยาระวางอำเภอภูเวียง (5442II) และระวางบ้านโคกสูง (5542III) กรมทรัพยากรธรณีวิทยา.

APPENDICES

APPENDICES

Measurement of the dinosaur footprints collected on 16th December 2011.

Track No.	N	FL(m)	FW(m)	SL(m)	PL (m)
Helen-1		0.113	0.094	1-3=0.590	1-2=0.288
Helen-2		0.136	0.094	2-4=0.615	2-3=0.298
Helen-3		0.131	0.088	3-5=0.625	3-4=0.318
Helen-4		0.133	0.086	4-6=0.600	4-5=0.319
Helen-5		0.128	0.087	5-7=0.520	5-6=0.299
Helen-6		0.123	0.095	6-8=0.545	6-7=0.245
Helen-7		0.126	0.085	7-9=0.610	7-8=0.321
Helen-8		0.132	0.104	8-10=0.575	8-9=0.305
Helen-9		0.135	0.085	9-11=0.570	9-10=0.276
Helen-10		0.119	0.103	10-12=0.500	10-11=0.300
Helen-11		0.115	0.085	11-13=0.735	
Helen-12					
Mean	11	0.126	0.092	0.590	0.297
wasabi-1		0.131	0.072		
wasabi-2					
wasabi-3		0.100	0.071	15-17=0.420	3-4=0.222
wasabi-4		0.102	0.060		4-5=0.216
wasabi-5		0.097	0.072	17-19=0.430	
wasabi-6					
wasabi-7		0.100	0.070		7-8=0.245
wasabi-8		0.096	0.067		
Mean	8	0.104	0.068	0.425	0.228
John-1		0.126	0.082	1-3=0.490	1-2=0.255
John-2		0.125	0.069	2-4=0.510	2-3=0.233
John-3		0.108	0.082	3-5=0.505	3-4=0.270
John-4		0.116	0.080	4-6=0.485	4-5=0.255
John-5		0.106	0.083	5-7=0.500	5-6=0.251
John-6		0.111	0.074	6-8=0.505	6-7=0.256
John-7		0.122	0.069	7-9=0.510	7-8=0.269
John-8		0.127	0.074	8-10=0.535	8-9=0.276
John-9		0.132	0.103	9-11=0.555	9-10=0.279
John-10		0.117	0.088	10-12=0.590	10-11=0.287
John-11		0.122	0.080		11-12=0.317
John-12		0.118	0.113		
John-13		0.106	0.072		
John-14		0.111	0.077		
John-15		0.114	0.081		
Mean	15	0.117	0.082	0.518	0.268

Track No.	N	FL(m)	FW(m)	SL(m)	PL (m)
Jame-1		0.127	0.091	1-3=0.665	1-2=0.312
Jame-2		0.125	0.092		2-3=0.360
Jame-3		0.118	0.085		
Mean	3	0.123	0.090	0.665	0.336
Daeng-1		0.086	0.059	1-3=0.485	1-2=0.275
Daeng-2		0.088	0.066	2-4=0.477	2-3=0.204
Daeng-3		0.119	0.090		3-4=0.275
Daeng-4					
Daeng-5		0.097	0.066	4-6=0.475	
Daeng-6		0.098	0.072		5-6=0.244
Daeng-7		0.098	0.066		
Daeng-8		0.105	0.057		8-9=0.217
Daeng-9		0.105	0.066		9-10=0.226
Daeng-10		0.104	0.063	10-12=0.435	
Daeng-11					
Daeng-12		0.091	0.062		
Daeng-13					
Daeng-14		0.100	0.057		14-15=0.260
Daeng-15		0.113	0.046		
Mean	12	0.100	0.064	0.468	0.243
Sally-1		0.136	0.089		
Sally-2					
Sally-3		0.134	0.094		3-4=0.267
Sally-4		0.118	0.088		
Sally-5					
Sally-6		0.132	0.089		6-7=0.291
Sally-7		0.132	0.098		
Sally-8		0.150	0.087	8-10=0.580	8-9=0.301
Sally-9		0.158	0.104	9-11=0.595	9-10=0.299
Sally-10		0.153	0.087		10-11=0.311
Sally-11		0.164	0.085	11-13=0.575	
Sally-12					
Sally-13		0.163	0.080	13-15=0.580	13-14=0.275
Sally-14		0.145	0.092		14-15=0.292
Sally-15		0.133	0.094		
Mean	12	0.143	0.091	0.583	0.291