

# STRATIGRAPHY AND PALAEONTOLOGY OF MID-CARBONIFEROUS SEQUENCES IN LOEI PROVINCE, THAILAND

SATHAPORN KAVINATE

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Sathaporn Kavinate



ชื่อเรื่อง	การลำดับชั้นหินและบรรพชีวินวิทยาของชั้นหินยุคคาร์บอนิเฟอรัสตอนกลาง ในพื้นที่จังหวัดเลย ประเทศไทย						
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## บทคัดย่อ

หินตะกอนยุคคาร์บอนิเฟอรัสโผล่ปรากฏในหลายแห่งของประเทศไทย และมีการสะสมตัวใน หลากหลายสภาพแวดล้อมบรรพกาล วัตถุประสงค์ของการศึกษาครั้งนี้ประกอบด้วย การศึกษาทางด้าน ธรณีวิทยา การสะสมตัวของหินตะกอน การลำดับชั้นหิน บรรพชีวินวิทยา เพื่อการตีสภาพแวดล้อมบรรพ กาลของการสะสมตะกอน ในยุคคาร์บอนิเฟอรัสตอนกลางในพื้นที่จังหวัดเลย โดยกำหนดพื้นที่ศึกษาบริเวณ พื้นที่ภูบ่อบิด อำเภอเมือง และพื้นที่ภูผาหม้อ อำเภอวังสะพุง จังหวัดเลย

ลักษณะธรณีวิทยาของทั้งสองพื้นที่สำรวจนั้นประกอบด้วยหินปูนเป็นส่วนใหญ่แทรกสลับกับ หินดินดานตลอดแนว โดยการศึกษาครั้งนี้พบซากดึกดำบรรพ์สัตว์ไม่มีกระดูกสันหลังจำพวกหอยตะเกียง ปะการัง ไบรโอซัว และไครนอยด์ ซึ่งบ่งบอกถึงสภาพแวดล้อมการสะสมตัวบริเวณทะเลติ้น หรือไหลทวีป บริเวณภูบ่อบิด ส่วนใหญ่เป็นพบเป็นเลนส์ของหินปูนชั้นหนาที่แทรกสลับอยู่ในหินดินดาน พบซากดึกดำ บรรพ์ปะการังจำพวก Tabulata และ Rugosa ซึ่งบ่งบอกอายุในช่วงสมัย Bashkirian ตอนปลาย และซาก ดึกดำบรรพ์ฟิวซูลินิด Profusulinella sp. และ สาหร่าย Beresella erecta บ่งบอกอายุอยู่ในช่วงสมัย Moscovian ตอนต้น ส่วนหินปูนบริเวณภูผาหม้อมีอายุในช่วงสมัย Moscovian ตอนต้น เนื่องจากพบซาก ดึกดำบรรพ์ สาหร่าย Beresetta erecta ฟอรามินิเฟอราขนาดเล็ก ได้แก่ Geinitzina, Bradyina, Climacammina และEndothyra ฟิวซูลินิด Profusulinella sp. และปะการัง Citronites citronoides ตามที่มีการระบุชุดลักษณ์หินและบรรพชีวินวิทยา ทำให้ทราบว่าชุดหินภูบ่อบิดมีอายุแก่กว่าหรือมีการสะสม ตัวของตะกอนทั้งตะกอนคาร์บอเนตรวมทั้งตะกอนเนื้อเม็ดก่อนชุดหินภูนาหม้อ

้คำสำคัญ: ยุคคาร์บอนิเฟอรัสตอนกลาง, บรรพชีวินวิทยา, การเรียงลำดับชั้นหิน, จังหวัดเลย



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#### ABSTRACT

Carboniferous sedimentary rocks are widely exposed in several areas of Thailand. They show a multitude of facets indicating that they have been deposited in very diverse environments. The purpose of this study was to investigate on the geology, sedimentology, stratigraphy, palaeontology and palaeoenvironment interpretation of Middle Carboniferous in Loei area. The materials were obtained from field work at Loei area especially Phu Bo Bit at Muang Loei and Phu Pha Mo at Wang Saphung Loei Provience.

The rocks from both section consisting of shale, limestone along with abundance and diverse invertebrate faunas; brachiopods, corals, bryozoans and crinoids are interpreted as having been deposited in shallow marine or shelf environments. At Phu Bo Bit, thick limestone lenses in shale contain microfossils, Tabulata and solitary Rugosa; they have been assigned to Late Bashkirian and fusulinaceans (*Profusulinella* sp.), algae *Beresella erecta*, have been assigned to Early Moscovian. The stratigraphic sequence of Phu Bo Bit extends from Late Bashkirian to Early Moscovian. The age of Phu Pha Mo limestone is Early Moscovian because of the occurence of algae (*Beresetta erecta*), smaller foraminifera (*Geinitzina, Bradyina magna* Roth & Skinner and smaller *Bradyina, Climacammina, Endothyra*), a few fusulinaceans (*Profusulinetta* sp., *Citronites citronoides* Manukalova 1948, *Eoschubertetta* sp.). According to lithofacies and palaeontology identification, Phu Bo Bit section is older than Phu Pha Mo section. And the change of the carbonate to siliciclastic sedimentation on Phu Bo Bit section is active before carbonate accumulation on the Phu Pha Mo section.

Keywords: Mid - Carboniferous, Palaeontology, Stratigraphy, Loei Province



# CONTENTS

			Page	
Acknowled	dgeme	ent	i	
Abstract in	ii			
Abstract is	n Eng	g	iii	
List of Tab	oles		vi	
List of Fig	ures		vii	
Chapter 1	Intro	oduction	1	
	1.1	Background	1	
	1.2	Purposes of the Research	3	
	1.3	Scope of the Study	3	
	1.4	Significance of the research	3	
	1.5	Analysis and conclusion	5	
Chapter 2	Liter	rature Review	6	
	2.1	Stratigraphy of Loei	6	
	2.2	Geological setting	13	
	2.3	Core log of gypsum drilling at Wang Saphung	24	
	2.4	Continental event	31	
	2.5	Sedimentology	33	
	2.6	Morphology of fusulinid	35	
Chapter 3	Met	hodology	41	
	3.1	Study localities	41	
	3.2	Field work	44	
	3.3	Laboratory work	44	
Chapter 4	Resi	ults	45	
	4.1	Sedimentology and stratigraphy	45	
	4.2	Palaeontology	57	
	4.3	Microfacies analysis	64	
Chapter 5	Con	Conclusion		
	5.1	Conclusion	66	



		Page
5.2	Suggestion	66
References		67
Appendix		73
Apppendix	x A List of Illustrations	74
Apppendix	x B The drillhole logging of gypsum exploration	
	in the Wang Saphung area (Utha-Aroon et al., 1995)	85
Biography		115



# List of Tables

		Р	age
Table	1.1	Subdivision of the Carboniferous system according to	
		the ICS geologic time scale 2012	3
Table	2.1	Stratigraphical distribution of Carboniferous limestone in Loei area	17
Table	2.2	Stratigraphical distribution of Carboniferous limestone in Loei area	
		(Fontaine <i>et al.</i> , 1991)	18
Table	2.3	These fossils indicate that the limestones of Wang Saphung and Na	
		Duang area belong to a span of time from Bashkirian to Moscovian	
		(Middle Carboniferous)	32
Table	4.1	These fossils indicate that the limestones of Phu Bo Bit and	
		Phu Pha Mo area belong to a span of time from Bashkirian to	
		Moscovian (Middle Carboniferous)	63
Table	4.2	Summary the microfacies types identified in the study area	64

# List of Figures

			Page
Figure	1.1	Location of the study area, (a) Phu Bo Bit Section and	
		(b) Phu Pha Mo Section and its vicinity illustrating the	
		network of the national and provincial highway	4
Figure	1.2	The study methodology	5
Figure	2.1	Geological map of Loei Province on the scale 1:250,000	
		(Department of Mineral Resources, 2009)	8
Figure	2.2	Explanation of Geological map of Loei Province	
		(Department of Mineral Resources, 2009)	9
Figure	2.3	Index map of Thailand showing distribution of Carboniferous	
		and Permo-Carboniferous rocks (modified after Geological	
		Map of Thailand on 1:2,5000,000 scale, Department of Mineral	
		Resources, 1992)	15
Figure	2.4	Carboniferous localities of Loei – Wang Saphung area	
		(Fontaine <i>et al.</i> , 1991)	19
Figure	2.5	Huai Nam Suai area (Fontaine et al., 1991)	20
Figure	2.6	Columnar section of Huai Nam Suai area (Fontaine et al., 1991)	21
Figure	2.7	Ban Pha Noi section (Fontaine et al., 1991)	22
Figure	2.8	Columnar section of Ban Pha Noi section (Fontaine et al., 1991)	23
Figure	2.9	The drillhole locations of the gypsum exploration in	
		the Wang Saphung area (Kuttikul et al., 1997)	27
Figure	2.10	Lithologic log of borehole No. WP-1 from Wang Saphung	
		District, Loei Province (Utha-Aroon, et al., 1995)	28
Figure	2.11	Lithologic log of borehole No. WP-2 from Wang Saphung	
		District, Loei Province (Utha-Aroon, et al., 1995)	29
Figure	2.12	Lithologic log of borehole No. WP-3 from Wang Saphung	
		District, Loei Province (Utha-Aroon, et al., 1995)	30

Mahasarakham University

			Page
Figure	2.13	The classification of carbonate sedimentary rocks. These	
		schemes are commonly used for description of limestone	
		in the field and in hand specimen. above scheme after	
		Folk (1959) and below scheme after Dunham (1962)	33
Figure	2.14	Generalized subdivision of carbonate ramps (Flugel, 2004)	34
Figure	2.15	Diagram of fusulines test showing structure features	
		(Moore, 1964)	36
Figure	2.16	Spirotheca and septal structures of fusulinaceans (Moore, 1964)	37
Figure	2.17	Diagram of spirotheca showing pendant-like walls of alveoli,	
		choma and septal pore of Schwagerina campensis THOMPSON,	
		L.Perm (Moore, 1964)	38
Figure	2.18	Fusulinidae (Fusulininae; 1-4, Profusulinella) (Moore, 1964)	39
Figure	2.19	Stratigraphic distribution of fusulinacean (Moore, 1964)	40
Figure	3.1	Topographic map Index of the study area on the scale 1: 50,000	
		by ArcGIS	41
Figure	3.2	Topographic map of the study area and its vicinity by ArcGIS	42
Figure	3.3	Geologiical map of the study area (Department of Mineral	
		Resources, 2009)	43
Figure	4.1	Topographic map of the study area and its vicinity	
		(Royal Thai Survey Department, 1999)	47
Figure	4.2	Topographical map showing Phu Bo Bit section located to	
		the east of Muang district, Loei Province; Map sheet Amphoe	
		Wang Saphung (5343 I) and Ban Sup (5344 II) of the 1:50,000	
		(Royal Thai Survey Department, 1999)	48
Figure	4.3	Lithostratigraphy of Phu Bo Bit	49
Figure	4.4	Field photograps showing view from south of Phu Bo Bit (a),	
		intercalation of limestone and shale layers (b), very thick	
		bedded to massive limestone (c, d), the massive coral (e)	
		and solitary coral (f) at Phu Bo Bit section	50

Mahasarakham University

			Page
Figure	4.5	(a) A quary near the foot hill of Phu Bo Bit.; (b, c, d)	
		A close-up outcrop of limestone of Phu Bo Bit section.,	
		(e) solitary Rugosa, (f) Tabulata	51
Figure	4.6	A,a: A rock slab and photomicrograph of sample no. LST18,	
		B,b: A rock slab and photomicrograph of sample no. LST021,	
		C,c: A rock slab and photomicrograph of sample no. LST016,	
		and D,d: A rock slab and photomicrograph of sample no.	
		LST015 from Phu Bo Bit section.	52
Figure	4.7	Topographical map showing the Phu Pha Mo section, Wang	
		Saphung district, Loei Province; Map sheet Amphoe Wang	
		Saphung (5343 I) of the 1:50,000 (Royal Thai Survey	
		Department, 1999)	54
Figure	4.8	Field photograps showing outcrop bedded limestone (A, B),	
		and limestone with chert nodule (C), Tabulata (D), amonoid (E),	
		and massive Rugosa (F) at Phu Pha Mo section	55
Figure	4.9	A,a: A rock slab and photomicrograph of sample no. LST031,	
		B,b: A rock slab and photomicrograph of sample no. LST029,	
		C,c: A rock slab and photomicrograph of sample no. LST032,	
		and D,d: A rock slab and photomicrograph of sample no.	
		LST026 from Phu Pha Mo section.	56
Figure	4.10	Reconstruction palaeoenvironment of the study area	
		showing, marine depositional environments (Richard, 1989)	65



#### **CHAPTER 1**

### **INTRODUCTION**

#### 1.1 Background

Thailand is a country with a wide spectrum of interesting geological settings. The country comprises rocks ranging in age from Precambrian to Quaternary. Various aspects of geology have long been studied in various parts of the country by a great number of researchers. One of the most fascinating areas in the upper part of northeastern Thailand is the Loei region where a lot of mineral commodities and fossils are known. This is mentioned in a number of publications on upper Paleozoic fossil and mineral deposits, both metallic and industrial, such as gold, copper, magnetite, manganese, barite, gypsum, coal, etc. (Fontaine *et al.*, 2005)

In the 1950s, the Department of Mineral Resources was very active in the geologic reconnaissance of the diverse mineral deposits of Thailand (Brown *et al.*, 1951), but it was also interested to extend its investigations to other geologic problems, for instance, it was eager to find good sections of sedimentary rocks, to study their fossils, and then, to distinguish biozones easy to correlate with the rocks of other countries (Sethaput, 1956).

Near Wang Saphung, Middle-Upper Carboniferous and Permian fossils were collected in a fair quantity. They were diverse and consisted of trilobites, foraminifera, conodonts, brachiopods and ammonoids described in many publications (Ishibashi *et al.*, 1997).

Until 1980 information on rocks older than Middle Carboniferous was very poor in Loei region. Fossils, supposed to be Devonian in age, had been mentioned as early as 1925, but at a single locality, without good identification and description (Fontaine *et al.*, 2005).

Due to the geological significance of the area, especially during the Silurian and Devonian periods through Carboniferous and Permian where significant geologic events occurred, many valuable documents of geological interest were published by various experts and researchers. Fontaine *et al.*, (2005) published an important work about Stratigraphy, Paleontology and Sedimentology of the Loei Region, Northeast Thailand

The important regression observed in Pha Chom Nang Belt between Lower and Middle Carboniferous is more easily observed in Ban Sa Ngao Belt because of wider exposures of continental sediments.

Gypsum has been known in Loei-Wang Saphung area for a long time (Haworth *et al.*, 1966; Jacobson *et al.*, 1969). In 1995, an exploration of the gypsum was carried out by cored wells and geophysical techniques southeast of Wan Saphung; gypsum was found at different depths, from 7 m to more than 50 m (Utha-Aroon and Surinkum, 1995). A limestone bed was discovered above gypsum at a depth of 41 m. It was moderatedly rich in diverse Late Moscovian fossils including fusulinaceans (*Beedeina elegans* Rauser & Beliaev, 1940 and *Eostaffella lepida* Grozdilova & Lebedeva, 1950) and a fragment of a small solitary coral without dissepiments (Fontaine *et al.*, 1996). The gypsum appears to be slightly younger than the sediments with continental plants.

The Carboniferous is thus known in great detail in Northeast Thailand where important studies have been carried out during the last 35 years. Access to the outcrops is easy. Fossils are diverse and in abundance. In Northwest, Central and East Thailand, research has been more limited; it has been found differences in the sedimentation of these regions. In West and Peninsular Thailand, the tectono-sedimentary history of the Carboniferous is clearly distinct from the other parts of Thailand. Fossils are much less diverse. In Northern Thailand, the Carboniferous remains almost unknown. In the area of Uttaradit, Thanasuthipitak (1978) described a Carboniferous marine sedimentary sequence, about 2000 m thick, with an unconformity at the base of the Carboniferous and another unconformity at the top of the Middle Carboniferous. The Lower Carboniferous consisted of volcanogenic sediments, the Middle Carboniferous of flysch type sediments and the Upper Carboniferous of mollasse type sediments. No actual evidence was provided on the ages of these rocks (Fontaine *et al.*, 2005).



System	Subsystem/ Stage		Age
	Series		(Ma)
Permian	Cisuralian	Asselian	Younger
		Gzhelian	298.9-303.7
	Donneylyonion	Kasimovian	303.7-307.0
	1 chiisyivaman	Moscovian	307.0-315.2
Carboniferous		Bashkirian	315.2-323.2
		Serpukhovian	323.2-330.9
	Mississipplan	Visean	330.9-346.7
		Tournaisian	346.7-358-9
Devonian	Late	Famennian	older

Table 1.1 Subdivision of the Carboniferous system according to the ICS geologic time scale 2012.

#### **1.2 Purposes of the Research**

The purposes of the research are to build a stratigraphic sequence of the Mid -Carboniferous in Loei area (Figure 1.1) using sedimentological and palaeontological data, to identify fusulinids and associate fossil for age discrimination and to reconstruct palaeoenvironment of the study area.

#### **1.3 Scope of the Study**

This study was carried out on the geology, sedimentology, stratigraphy, palaeontology and palaeoenvironment interpretation of Mid - Carboniferous in Loei area. The materials were obtained from field trip in Loei area especially at Na Duang coal mine; core log of gypsum drilling at Wang Saphung was also analyzed. Identification of the specimens was conducted at the Department of Mineral Resources.

#### 1.4 Significance of the research

Our results allow a revision the geological map of this area and improve the basic knowledge about Middle Carboniferous palaeoenvironments, including continental and shallow marine environments, ancient coastlines and climates in Thailand, especially in the Loei area.



Figure 1.1 Location of the study area, (a) Phu Bo Bit Section and (b) Phu Pha Mo Section and its vicinity illustrating the network of the national and provincial highways.



#### 1.5 Analysis and conclusion

The orientation of fossils was checked in outcrop on both vertical section and excavated site were analyzed. These results are combined with the analysis of lithologic composition, grain size, sorting and shape, sedimentary structures, indurations and type of cement. The results are shown in the lithostratigraphic columnar sections and were correlated with locality database. All these data were discussed and used for reconstruction of palaeoenvironment.

The study methodology employed in the present study can be summarized in Figure 1.2.



Figure 1.2 The study methodology.



#### **CHAPTER 2**

#### LITERATURE REVIEW

#### 2.1 Statigraphy of Loei

### 2.1.1 Palaeozoic sedimentary rocks

The oldest Palaeozoic rocks in the study area are metasediments. They are quartzites and phyllites which make up a north-south trending escarpment in the middle of the map area (Figure 2.1 and 2.2).

The quartzite are light-to medium grey and mostly fine-to medium grained. They are often massive or from thick unit, but frequently they are distinctly and well bedded with light grey, slightly coarser grained layers alternating with fine-grained, medium grey layers a few centimeters thick. These well bedded quartzites are often intensely folded. Occasionally there are also layers of quartzitic conglomerate with pebbles a few centimeters in size. The phyllites represent regionally metamorphosed shales and siltstones. They display a streaked foliation and mostly have a grey or occasionally greenish-grey or reddish-grey colour, which may indicate that the regional metamorphic rocks include former redbeds, but a red colour could also have been caused by intense weathering of the phyllites.

The quartzites and phyllites were obviously affected by tectonic deformation and metamorphism much more intensely than all other rocks in the area; they are therefore regarded as the oldest rocks. The second oldest rocks for which a definite age is known are of middle-late Silurian age. Thus the Lower Palaeozoic metasediments are at least of middle Silurian in age but probably older, i.e. pre-Silurian.

**Silurian-Devonian**: The Silurian to Devonian sedimentary rocks consist of white, grey and yellowish-brown shale, reddish-brown fine-grained tuffaceous sandstone and siltstone, occasionally with lenses of light grey dolomitic limestone or bluish-grey crystalline limestone. They are sporadically exposed along some valleys in the eastern map area (sheets 5445 III and 5444 IV).

Sakagami and Nakornsri (1987) found several corals such as *Heliolites* sp. cf. *H. barrandei* (Hoernes), *Heliolites* sp. cf. *H. bohemicus* Wentzel, and *Favosites* sp. indet. in association with brachiopods in calcareous mudstones about 5 km south of Ban Nong or 5 km west of Ban Muang (sheet 5445 III). *Heliolites* is known from the middle

Silurian of several localities in Europe and Asia. *H barrandei* is known from middle Silurian to Lower Devonian. Encrinurid trilobites that occur together with the corals support a middle to Late Silurian age for the fauna.

Fontaine *et al.* (1981:5) found colonies of *Favosites* sp., *Heliolites* sp., and a few Stromatoporoidea in two small outcrops of black limestone about 2 km west of Ban Muang (loco T265 and T312-321, sheet 5445III). Fontaine (1990a) considered an Emsian-Eifelian age for these limestones west of Ban Muang. Limestones 2 km northwest of Ban Na Ngiu (loco T274-277 and T279-280, sheet 5445 III) mentioned by Fontaine (1990a:59) contain the coral *Favosites* and the algae *Renalcis*, suggesting an age of Silurian to Middle Devonian. Shales with thin lenses of silty and sandy limestone near Ban Na Khae (loco T2537-2540 and T2541-2545, sheet 5444 IV) yielded a fauna of brachiopods, corals and a trilobite, which Fontaine (1990a:59) interprets as Early to Middle Devonian (Emsian-Eifelian).

Devonian Chert: Chert is a hard, splintery, glass-like rock mostly dark grey in colour, but there are also light grey and rare reddish varieties. The chert is mostly well stratified in layers several ern to 10 em thick separated by mm-thick layers of mudstone and occasionally tuff. Pure chert consists almost entirely of cryptocrystalline quartz coloured by very small amounts of organic matter or iron oxide.

Chert occurs in huge masses in the western part of the map area (sheets 5345 II, 5344 I), where it forms long, north-south trending anticlinal cores of variable width. It is absent in the eastern part; whether it is concealed beneath younger rocks or whether it is missing completely is uncertain. It is unlikely that the chert was sedimented uniformly over the whole area; moreover there appear to be some facies changes. The westernmost occurrences of chert are less pure and are associated with a larger proportion of clastic material such as shales, siliceous shales and thick interbeds of quartzite, which may have originated from sandstone beds impregnated by siliceous solutions.





Figure 2.1 Geological map of Loei Province on the scale 1:250,000 (Department of Mineral Resources, 2009)



## คำอธิบาย EXPLANATION

ตะกอน ทินชั้น และทินแปร	ชื่อหมวด/กลุ่มหิน	ยุค	อายุ (ล้านปี)
SEDIMENT, SEDIMENTARY AND METAMORPHIC ROCKS	FORMATION/GROUP	PERIOD	AGE (my.)
aะกอบน้ำพาพวกทราช ทรายอเปล้ ดินเคอย์ และกรวจแม็ดละเดียด Alluvial deposit : sand, silt, clay and fine-grained gravel. aะกอบละพักลุ่มน้ำ : กรวด พราย ทรายแว้ง และดิน Terrace deposits : gravel, sand, silt and clay.		ควอเทอร์นารี QUATERNARY	0.01-1.6
<ul> <li>พันธราช สีนั้งสามแกมเดง หันทรรขยกไง พินทรดย์ และพินกรวดมน Sandstone, reddiab brown; claystone and conglomerate.</li> <li>พันธราชกินสงิธ จิงชีน้ำหาอแกมแดง หินทรรขยุโช และพินกลอย์เชี้ยประปูปรับไปเข้าแอกง แร้ยิปรับไม่ต่ายล่าง จันธรรรม (and the code of the</li></ul>	หมวดพินดูจัด PHU KHAT Pm. หมวดพินพชพบปุก KHAO YA PUK Pm. พมวดพินปิภทกรวด กลุ่มพินโคราช KHOK KRUAT Pm., KHORAT Gp. พมวดพินอูพาน กลุ่มพินโคราช	กวีทาเชียส CRETACEOUS	66.4-140
Congromerate sandstone, sindstone and tens of congromerate, grayin write, meaturn-coarse grained, poorsed, subanguar to subrounded, composed of chert, quartz and silicecous clay, well bedded, thim-mediam bed, cross bedding in common.           พื้นหรารออาราสาส นั้นคากแกนเดง เป็ดตระบือครั้งปานกอง แสดงการวางรับเดืองระดับบนาดเอ็ก สถับรั้นค่วยกันการวงแป้ง สนิเตอย           และหินกราสอน มีขึ้นคากแกนเดง เป็ดตระบือครั้งปานกอง แสดงการวางรับเดืองระดับบนาดเอ็ก สถับรั้นค่วยกันการวงแป้ง สนิเตอย           และหินกราสอน มีขึ้นคาดเกินเดง เป็ดตระบือครั้งปานกอง แสดงการวางรับเดืองระดับบนาดเอ็ก สถับรั้นค่วยกันการวงแป้ง สนิเตอย           หน่าราสอน มีขึ้นคาดเลือกกราสอง และหินกราสอง และหน่ง และหินกราสอง และหินกราสอง และหินกราสอง และหินกราสอง และหินกราสอง และหินกราสอง และหินกราสอง และหินกราสอง และหินกราสอง และหน่ง และหินกราสอง และหินกราสอง และหินกราสอง และหินกราสอง และหินกราสอง และหน่ง และห นกราสอง และหน่ง และ	านบาคทิมเสาขัว กฤมพิมโคราช รลด KIIUA Fm., KIIORAT Gp.		
ทีนทราย สีขาวขุ่น สีทาขาว เม็ดอะเอ็อกฉีนหอาบ คัดขนาดปานกลาง แสดงการวางขั้มเอียงระดับ มีที่แทรายหนึ่งกรวด ทีมกรวดมนแลนส์ ที่นทรายเป็น และทินแกลร์ ครับรับกฎ่าง Sandstone, duil white, Empision white, Emernedium grained, moderately sorted, tabular cross bedding in common, occasionally interbedded with conglomeratic sandstone, lens of conglomerate, siltstone, and claystone.	หมวดทีมพระวิหาร กุมพินโกราษ PHRA WIHAN Fm., KHORAT Gp.	ครีเทเซียสอึงจูแรสซิก CRETACEOUS to JURASSIC	66.4-210
ทีนทราชเนื้อในกำ แสงงการวางรั้นเพื่องระดับขามางสัก หันกราชแป็งและหินเทลย์ สีน้ำตาลแดงปนม่วง สลับชั้นด้วยทินทราอ สีเทาเรียว นี่ขึ้นมีลปุน และขึ้นเกิดซิลิกา หากลึกด้านระห์ทางการสรดรูหมดน Micaceous sandstone, silutone, and claystone, maroon, intercalated with grayish green sandstone, with calcrete and silerete horizone ; trace fossils with small scale cross bedding.	หมวดที่นถูกระดิง กลุ่มทินโคราช PHU KRADUNG Fm., KHORAT Gp.	จูแรสชิก JURASSIC	140-210
พิมทราย สีน้ำควยแกมเดง เม็สอะเอียดุจึมปานกอาง ก็คงนาดดี เม็ดก็มหลี่ยมก็เสี่มน สลับขั้นด้วย พิมทรายแปมนี้อปูนประชาน และหินดกอร์ไม่มีกปุ่ม สีหา ถึงหนกมมาว Sandstone, reddish brown, fine-medium grained, well sorted, subangular-subrounded, interbedded with calcareous siltstone and claystone containing carbonate nodules, gray and purplish gray.	หมวลที่หน้ำพอง กลุ่มทินโกราช NAM PONG Fm., KHORAT Gp.	ไทรแอสชิก TRIASSIC	210-245
ที่เหราะขา้นหรายเป็นหรายเป็น ที่แห้นตาม ถึงกาปนบริหาดถึงสังหา เนื่อปนปุ่น และที่แกรวดมน Sandstone, siltstone shale and conglomerate, brownish gray-gray, calcareous.	ทมวดที่นหวยพื้นธาต กลุมพื้นโคราช HUAI HIN LAT Fm., KHORAT Gp.		
<ul> <li>หินพิมหาน พิมพราย พิมพรายแป้ง และหิมกรวดภูเขาไฟ Pha Dua Formation shale; sundstone, silistone, and aggiomerate.</li> <li>พิมพิมพาแสนับพิมพราย พิมปุนเลนเช้สิหา</li> <li>Shale intercalated with sandstoner, gray limestone lens,</li> <li>พิมปุน สิหา ซึ่งเพิ่มหลีกายเล</li> <li>พิมพานี้มาหลีกายเล</li> <li>และหลับหลีกายเล</li> <li>Limestone, gray shiftsh gray, well bedded, thin-thick bed, fossils in common of fusulinids, corals,</li> </ul>	หมวดทินหาเดื่อ PILA DUA Fm. หมวดทิบอีเอิต E-LERT Fm. หมวดทิบอันมันมโหพาร NAM MAHOLAN Fm.	เพอร์เมียน PERMIAN	245-286
sponges, algues and crinoids. หินดิบลาน ทินทรายแป้ง มีชีบบางของหอบปูนสลับ Wang Saphung Formation shale, silistone, thirb-edded limestone. หินทราชเนื้อกวอรลช์ ที่บลินลายนนี้ออาราชแป้ง ทีนปูนแสนส์ และที่และรวดมน Cet Nong Dok Bia Formation Quartose sandstone, shale, sily shale, lanestone lens and conglomerate.	หมวดก็หวังสะทุง WANG SAPHUNG Fm. หมวดกินทนดงดอกบัว WANG SAPHUNG Fm.	คาร์บอนิเฟอรัส CARBONIFEROUS	286-360
ทีมตรีวัลสสับเกินทัพษ์ กับปูนเลนส์ และมีรั้นของสับดันด แน่ว้าง Chert with layer of tuff, limestone lens, and locally shale.	หมวดที่แปกหม PAK CHOM Fm.	ดีโวเนียน DEVONIAN	286-360
ทีมฟิลไลส์ ทีมควอว์คไซด์ ทีมเชิสด์ ทีมชนวน ทีมกวายและทีมทวาย Phylline, quartzite, schist, state and sandstone.		ดีโวเนียน-ไซลูเรียน DEVONIAN- SILURIAN	286-360
พินอักนี้ IGNEOUS ROCKS	ยุก PERIOD		
ทีนไปไอไหล์แกรนิส ทีมพัวนั้มาอินแกรนิล ทีนแกรไมไดออไรด์ ทีนไปไอไหล์-มัสไคไวล์แกรนิส ทีมมัสไคไวล์-ทัวร์มาอินแกรนิล ทีนไปได้-ทัวร์มาอินแกรนิล Biolic granic, toamaline granic, granodioric, biolic-muscovile granic, muscovic=tournaline granic, biolic=tournaline granit Granodiorice.	c. ไทรแอสซิง TRIASSIC		210-245
ทีมแอนดีไขด์ หินไรโอไรด์ หินบัทที่ที่ ที่แกรวดเหลื่อมภูเขาไฟแอะหินแกรโนไดออไรด์ Ambaina duolina แก้ anolona แก้ anolona (	ไทรแอสซิก ถึง เพ TRIASSIC - DR	อร์เมียน	210-286
Ausessie, injourie, duit, aggiometrie ina granoonome. ที่มหาปีอิทีกประชอกต์และกันทัศษ์ Spillshie hasalt and tuff: มีอาสู Serpentimite.	TRIASSIC to PE การบอนิเฟอรัส อึง CARBONIFEROUS to	สฟาลก สีโวเนียน DEVONIAN	345-395

Figure 2.2 Explanation of Geological map of Loei Province

(Department of Mineral Resources, 2009)



Devonian Limestone: Isolated patches of reef limestone, which are either of Devonian or Carboniferous age occur at many places in the western part of the map area. In most cases it is a medium or dark grey massive limestone, rather fine grained and lacking visible bedding. Occasionally it contains corals, both solitary and colonial. Some irregular streaky inclusions, apparently with lower solubility than the surrounding limestone, stand out on the weathered surfaces; they may be stromatoporoid structures. But apart from this the Devonian limestone in general is relatively homogeneous and not visibly different from similar limestones of other ages. The limestone often forms rugged cliffs which rise several tenths of meters above the surroundings. Other limestone occurrences are only a few tens of meters long and wide, and had to be exaggerated on the map in order to render them visible. They are often arranged in long, north-south trending rows, which may be several kilometers long. The Devonian limestone mostly occurs in close connection with chert the reef-limestone bodies lying at the flanks or on top of the chert anticlines. Where the chert is in contact with reef bodies, cm-thick beds of limestone alternate with medium grey chert beds (sheet 5344 I), or the limestone rests unconformably on folded chert.

The limestone bodies accumulated as smaller or larger patches of algal and stromatopora reefs, which grew in certain places for limited periods, occasionally also containing corals. The most important corals in the Devonian reef limestone identified by Fontaine (1990a) are *Phillipsastrea* sp. and *Heliolites* sp.. The genus *Phillipsastrea* lived around the Middle/Late Devonian boundary and is restricted to the period from middle Givetian to Frasnian. The genus *Heliolites* lived from Silurian until late Givetian time. If both genera of corals occur together the age of the rock can only be middle to late Givetian. Other corals emphasize an upper Givetian age. Only at places where no *Heliolites* is found a Frasnian age cannot completely be excluded.

**Devonian-Carboniferous shale and greywacke**: Shales make up by far the major part of the sedimentary rocks of the map area. They are predominantly black to dark grey, only in some central northern parts of the map area reddish shales locally occur also. The shales are more or less silicified and therefore hard or very hard when fresh. The bedding is rarely visible suggesting deposition was uniform. Moreover the bedding has been partially obscured by a streaky, uneven cleavage which dissects the

shales. Cleavage and bedding, as far as it can be seen, are often almost parallel or cross each other at a very acute angle, which makes the bedding even more indistinct.

Other rocks such as siliceous shale, chert, siltstone, sandstone, quartzite, greywacke, and conglomerate are frequently intercalated with the shales. Some of these intercalations are thick enough to be shown on the map; but very often they hardly extend far beyond a single outcrop. Silt and sandstone layers occasionally alternate with shale and give rise to a light and dark grey striping on the scale of a few centimeters.

Greywacke occurrences within the thick sequence of shale are locally large enough to be shown on the map. They are found mainly in a north-south trending strip in the center of the map area but they also occur in the northwest and southwest. The best outcrops are to be seen at the side of the road along the River Mekong near Ban Pak Niam 4.640-5. 180 km northeast of Pak Chom (loc. 18, sheet 5345 II).

In the shale layers between greywacke and conglomerate near Ban Pak Niam, small badly preserved plant remains are easily found, but the shale and greywacke contains almost no recognizable fossils. The plant remains are tectonically distorted and the organic matter has such a degree of coalification that determinable spores could not be extracted (Koch, 1986). Fontaine *et al.*, (1981) made almost the same experience but succeeded in identifying *Densosporites* sp., *Lycospora* sp., *Aucyrospora* sp., *Particulatisporites* sp., and *Endosporites* sp., which indicate a latest Devonian to very early Carboniferous age of the shale and greywacke.

Fontaine and Ingavat (1983) inferred that the greywacke and conglomerate occurrences are of stratigraphic significance, and are typical of the base of the Carboniferous. They compare the greywacke and conglomerates of the Loei province with conglomerates which, according to Baum *et al.*, (1970), mark the base of the Carboniferous in northern Thailand.

Lower Caboniferous reef limestone: The lithology is similar to that of the Devonian and Upper Carboniferous reef limestone. In most cases they consist of medium or dark-grey massive limestone, rather fine-grained and without visible bedding. Some irregular streaky inclusions apparently with lower solubility than the surrounding limestone stand out on weathered surfaces; they may be stromatoporoid structures. At some places in the western part of the map area lenses and layers of an impure detrital limestone or calcareous sandstone with Lower Carboniferous fossils indicate erosion and sedimentation of calcareous material during or shortly after the growth of the Lower Carboniferous reefs.

Apart from these exceptions the Lower Carboniferous limestone is rather homogeneous and not visibly different from similar limestones of other age. The limestone often forms rugged cliffs which may rise to over a hundred meters above the surrounding. Other occurrences of reef limestone are only a few tens of meters long and about the same thickness, and had to be exaggerated on the map in order to make them visible. They are mostly arranged in north-south trending rows, which may be several kilolmeters long; Fontaine (1990b) uses the term 'Pha Chom Nang Belt' for the occurrences of Lower Carboniferous reef- limestone about 14-24 km west of Pak Chom and 'Ban Sangao Belt' for those about 15 km east of Pak Chom (Sheet 5345 II). The Lower Carboniferous reef limestone is always embedded in shale and never occurs in association with chert. The north-south trending belts of limestone mark the positions of the main synclinal structures and are used to draw the border line between the Devonian and Carboniferous parts of the shale and greywacke sequence.

The limestone bodies accumulated as smaller or larger patches of algal and stromatopora reefs which grew at certain places for a limited period; they occasionally also contain a few corals. The most important corals in the Lower Carboniferous reef limestone, which were identified by Fontaine (1990b), belong to the genera *Arachnolasma, Aulakoninckophyllum, Caninia, Hetrophyllia, Hexaphyllia, Kueichouphyllum, Siphonodendron, Solenodendron, Yuanophyllum.* The corals, together with algae and foraminifera identified by Vachard (1990) fix the age of the Lower Carboniferous reef-limestone reasonably precisely. It cannot be older than middle Visean and reaches up to the latest Visean. Lower Serpukhovian cannot definitely be excluded, but growth of the reefs took place mainly during the middle and late Visean. Determinations carried out on conodonts by Stoppel (1986-87) confirm this age.

**Upper Caboniferous reef limestone:** The lithology is similar to that of the Devonian and Upper Carboniferous reef limestone. In most cases they consist of medium or dark-grey massive limestone, rather fine-grained and without visible bedding. Some irregular streaky inclusions apparently with lower solubility than the surrounding limestone stand out on weathered surfaces; they may be stromatoporoid structures. At some places in the western part of the map area lenses and layers of an

impure detrital limestone or calcareous sandstone with Lower Carboniferous fossils indicate erosion and sedimentation of calcareous material

**Permian limestone :** The Permian limestone in the Loei area consists of massive, grey and light grey crystalline limestone with chert nodules. In some p;aces it is layered and brecciated. The Permian limestone forms mountains showing karst features and steep cliffs, shich probably follow faults. The Permian limestone occurs in the central part of Loei area and strikes NW-SE. It has yielded fusulinids, corals and crinoids stems. The occurrence of *Verbeekina* suggests that the limestone in mid Permian in age.

## 2.1.2 Mesozoic

Mesozoic sediments were deposited only in continental environments. They are widespread outside the Loei area around the exposures of the Paleozoic sedimentary rocks; they rest unconformably upon these rocks. They build up a thick succession of non-marine rocks, exceeding 4000 m in thickness.

#### 2.1.3 Cenozoic

Cenozoic does not deserve special comments. It is extremely restricted in the Loei area. Tertialry deposits remain unknown. Alluvial deposits belonging to Quaternary are restricted to a few very small areas, eapecially along rivers (Charoennpravat *et al.*, 1976; Chonglakmani *et al.*, 1979). In the large flat areas, they are thin, commonly less than 4 m thick; because of that, they are not shown on the geological maps.

#### 2.2 Geological setting

In Thailand, research on the Carboniferous started in 1889, when a Cambridge expedition to Southern Thailand discovered diverse fossils (Tabulate, bivalves, brachiopods, cephalopods, trilobites) at "Kuan Din So" in Phatthalung Province. In 1900, these fossils were considered Permo-Carboniferous in age in a brief report after a rough determination (cf. Fontaine *et al.*, 2005). Later on, a more detailed examination of the material was carried out by Reed and the results were published in 1920, clearly indicating a Lower Carboniferous age. Also in 1899, limestone samples were collected in Central Thailand form Chon Daen area (Phetchabun Province) by Mr. W.M. Daly, working for the Forestry Department (Garrentt, 1924). They were sent to the British

Museum and did not contain fusulinaceans. They were considered Carboniferous in age because of the occurrence of small foraminifera, which actually display a large stratigraphic range. According to recent studies, the limestone of this area belongs to the Lower Permian, and maybe to the Upper Carboniferous at its base (Figure 2.3).

After the discoveries of 1899, the Carboniferous of Thailand was ignored for many years until, in 1960, two Visean corals collected east of Loei from the vicinities of Sa Ngao (*Siphonodendron*) and Pak Chom (*Heterocaninia*) were described by Hamada. In 1961, a new trilobite genus (*Thaiapis*) was found in shale near Wang Saphung in Loei Province. It was assigned a probable Middle or Upper Carboniferous age (see Fontaine *et al.*, 2005).

Bleakley *et al.*, (1965) (Overseas Geological Surveys) investigated lead-zinc deposits of Loei Province. They made an attempt to elucidate the stratigraphy of the region. The sediments were described and, according to their lithological facies, were divided into 3 types of rocks referred to the Upper Devonian-Lower Carboniferous, the Lower-Middle Carboniferous and the Upper Carboniferous-Permian, respectively. Palaeontological results were still very rare at that time; in addition to that, the similarity of lithologies of different ages did not help to establish a strong stratigraphy.

Later on, in Northeast Thailand, studies were focused mainly on the Wang Saphung area. They were organized by the Department of Mineral Resources and carried out with the collaboration of Japanese geologists; brachiopods, trilobites and microfossils were identified (see below).

In Rat Buri Province, "Lower Carboniferous" Fenestellidae (Sakagami, 1965, 1966) were found at Khao Noi (0.5 km east of the road from Rat Buri to Khao Yoi) and at Khao Khok (Tambon Huai Phai, Amphoe Muang). Because of their poor preservation and their wide stratigraphic distribution, they were considered of little value for precise stratigraphy (Toriyama *et al*, 1975).





Figure 2.3 Index map of Thailand showing distribution of Carboniferous and Permo-Carboniferous rocks (modified after Geological Map of Thailand on 1:2,5000,000 scale, Department of Mineral Resources, 1992)

Upper Carboniferous (Lower Uralian) Fenestellidae were collected from pale green siliceous rocks near Petchabun (Sakagami, 1967). This information appears to be very interesting, but the geographic coordinates, indicated for this locality (16° 29'21''N, 101° 53'18"E), are apparently erroneous (Fontaine *et al.*, 2005).

In southern Thailand, a Carboniferous (Visean) brachiopod was mentioned in Andaman Sea at Ko Kiang between Ko Adang and Ko Tarutao in Satun Province (Hamada, 1960). The material was poor and the identification rather difficult (Toriyama *et al.*, 1975). North of Chumphon, Lower Carboniferous Fenestellidae were reported by Sakagami (1971), an age assignment not fully accepted by Toriyama *et al.* (1975). An Early Carboniferous or more likely Middle Carboniferous brachiopod fauna was described from Ko Muk in the Andaman Sea (Hamada, 1960). It has been discussed by Waterhouse (1982), Shi and Waterhouse (1991) and Shi and Archbold (1995). Some previous generic assignments have not been accepted; the fauna has been considered Late Asselian to Early Sakmarian in age.

According to Toriyama (1984), Early Carboniferous fusuline faunas were still unknown in Thailand in 1984. Carboniferous was not clearly differentiated from younger or older systems at that time. Local stratigraphic names were used; they were based on regional studies, without precise lithostratigraphy and biostratigraphy in several areas (For instance, the Mae Hong Son Formation ranged from Silurian to Carboniferous). In 1983, a general information was: "Carboniferous sediments which are fossiliferous in the upper part occur in the environs of Loei and Phetchabun" (Bunopas, 1983, p. 42). In fact, species of Visean fusulines were mentioned in Loei area, for the first time in 1981 by Fontaine et al.. Middle and Upper Carboniferous fusulines were described in Northeast Thailand as early as 1972 (Igo, 1972). Lower Carboniferous fossils were known in Peninsular Thailand (Reed, 1920; Igo, 1973). In 1980, the most important studies on the Carboniferous paleontology had been carried out in Loei-Wang Saphung area. Elsewhere, a few localities had yielded Carboniferous samples, of which the age was sometimes debatable. In 1991, a book was published on the "Carboniferous corals of Thailand" (Fontaine et al., 1991); new Carboniferous localities were described. Since then, other Carboniferous localities have been found (Fontaine et al., 2003). Thailand is an attractive country for the study of the Carboniferous because of diverse faunas and floras as well as a great variety of



depositional environments. The Carboniferous seas extended to Laos and Vietnam. In these two countries, Carboniferous sedimentary rocks are widely exposed in several areas. In the past, an important orogenic phase was believed to have occurred during the Moscovian in these two countries, with a general stratigraphic break and large intrusion of granites. This point of view is no more accepted; a complete succession of the sediments through the Middle Carboniferous has been evidenced (Fontaine and Workman, 1978; Fontaine and Vachard, 1981).

	Age	IMPORTANT FOSSILS	LOCALITIES		
Upper	Gshelian	Algae: Connexia, Chuvashovia, Epimasto-	Northwest of Pai,		
Carboni-		pora, Eflugelia	northwest of Pang		
ferous	Kasimovian	Foraminifers: Triticites, Staffella, Schuber-	Mapha, Ban Na Wai		
		tella, Schellwienia	area		
		Algae: Dvinella, Beresella, Komia	Ban Chabu, Ban Bo		
		Foraminifers: Profusulinella, Fusulinella,	Khrai, Ban Mae Suya,		
	Moscovian	Aljutovella, Neostaffella, Beedeina	Ban Pang Tong, Ban		
Middle		Corals : Caninophtllum, Caninia, Yuano-	Mae Yan, Ban Na Wai		
Carboni-		phylloides, Multithecopora	areas		
ferous		Algae: Atractyliopsis sp., Velebitlla n. Sp. aff.	Ban Tat So Area, Ban		
	Bashkirian	Simplex, Dasycladaceae indet., Beresella, rear	Tham Pha Tang, Ban		
		Ungdarella	Sup, west of Ban Na		
		Foraminifers: Eostaffella, Millerella,	Duang, Ban Na		
		Ozawainella, Profusulinella, Schubertella	Charoen,		
		Smaller foraminifera: Climacammina,			
		Globivalvulina, Bradyina, Tetrataxis,			
		Nodosariidae			
		Fusulinaceans: Profusulinella spp.,			
		Ozawainella sp., Staffella sp., Aljutovella sp.,			
		Pseudostaffella sp.			
		Corals: Chaetetes, Caninia, Lublinophyllum,			
		Ivanovia			
	Serpukhovian	Algae: Koninckopora, Windsoporella			
		Foraminifers: Eostaffella, Endostaffella,			
Lower		Endothyranopsis, Asteroarchaediscus,			
Carboni-	Visean	Vavulinella			
ferous		Corals: Arachnolasma, Kueichouphyllum,			
		Solenodendron, Hexaphyllia, Syringopora			
	Tournaisian	Conodonts: Apatognathus, Hindeodella,	Ban Sa Kgao, Near		
		Neoprionodus	Ban Pak Niem, Pphu		
		Radiolarians: Entactinia variospina,	Sang ak Chom,		
		Heleniforme laticlavium			

Table 2.1 Stratigraphical distribution of Carboniferous limestone in Loei area



Localities	Pha Chom Nang area	Huai SaNhao, Khao Sam Nge	Phu Tham Pha Tang, Ban Tat So, Km 13, Pha Tha, Phu Bo Bit	Huai Nam Suai Section	Huai Pot, Ban Sup	Ban Pha Noi	Huai Lugng	Ban Na Charoen	Phu Ki Kai
Fossils	For. Cor. Al.	For. Cor.	For. Cor.	Corals	For. Brach.	For. Cor.	Brach.	For. Cor.	Corals
Authors	Fontaine et al 1981	Fontaine et al 1981, Fontaine 1989, Vachard 1989	Fontaine et al 1983, Fontaine 1989, Fontaine 1991, Vachard 1989	Fontaine et al 1991,	Igo 1972, Yanagida 1976	Igo 1972, Fontaine et al 1991	Yanagida 1976	Fontaine et al 1983	Fontaine et al 1991
Gzhelian						i			?
Moscovian					Ī			i	
Bashkirian				I	-				
Serpukhovian									
Visean									
Tournaisian									

Table 2.2 Stratigraphical distribution of Carboniferous limestone in Loei area (Fontaineet al., 1991).





Figure 2.4 Carboniferous localities of Loei – Wang Saphung area (Fontaine *et al.*, 1991)





Figure 2.5 Huai Nam Suai area (Fontaine et al., 1991)



Figure 2.6 Columnar section of Huai Nam Suai. (Fontaine et al., 1991)







Figure 2.7 Ban Pha Noi section (Fontaine et al., 1991)





Figure 2.8 Columnar section of Ban Pha Noi section (Fontaine et al., 1991)



#### 2.3 Core log of gypsum drilling at Wang Saphung

Gypsum is known in Loei-Wang Sapung area for a long time (Haworth *et al.*, 1966; Jacobson *et al.*, 1969). It has been found by water wells drilled in the town of Loei and south of the town. It is associated with mudstone, shale and dolomitized limestone. Near Wang Saphung, the same sequence has also been observed. In the past, these rocks were tentatively placed within the Kanchanaburi Series, belonging to the Silurian-Devonian?-Early Carboniferous? (Brown *et al.*, 1951), although gypsum had not been reported elsewhere in these series (Jacobson *et al.*, 1969). In 1992, a water well found gypsum 2 km northwest of Loei at Nong Pak Kham, and about a year later, gypsum boulder were uncovered 1 km south of Wang Saphung. In 1995, an exploration of the gypsum was carried out by cored wells and geophysical techniques (Utha-Aroon and Surinkumm, 1995). A limestone bed was discovered above gypsum at a depth of 41 m. It was moderately rich in diverse Late Moscovian fossils including fusulinaceans (*Beedeina elegans* Rauser & Beliaev, 1940) and *Eostaffella lepida* Grozdilova & Lebedeva, 1950) and a fragment of a small solitary coral without dissepiments (Fontaine *et al.*, 1996).

The three wells from which the studied samples have been collected are located near Wat Non Sawang: they are in an east-west row: WP1 is to the west whereas WP2 and WP3 are respectively 100 and 500 m east of WP1. Gypsum is deep in the three wells, but is closer to the surface in other wells dug further south and a large gypsum anhydrite body has been found a kilometer south of WP3 between depths of 19.4 and 34.1 meters: see the contour map of the gypsum distribution in depth presented by Utha-Aroon and Surinkum (1995, fig 8)

**WP1**: A single sample from this well (2 thin sections T5076 and T5077) has been studied. It had been collected from a depth of 96.0 meters. It is a slightly and finely recrystallized micstone with some traces of shear. It contains a thin gypsum vein. A recrystallization in concentric layers suggests a stromatolite structure (T5077). No real fossil has been observed in all the thin sections. Small quartz crystals are occasionally present; they are not abundant and are due to diagenesis (Figure 2.10).
**WP2**; Three samples from this well (6 thin sections T5070 to T5075) have been studied. They had been collected at depths of 41.0, 51.2 and 56.1 meters (Figure 2.11).

<u>At a depth of 41.0 meters</u> (2 thin sections T5070 and T5071), limestone (wackestone) is relatively rich in diverse fossils consisting of the following taxa:

<u>Calcispheres;</u> *Eotuberitina retlingerae* Mikiukho Maklay 1958, Tuberitina bulbacea Galloway et Hadton 1928 **Pseudoalgae**: Claracrusta catenoides (Homann, 1972) *Gyroporella*? (Dasycladaceae) Algae: Smaller foraminifer: Climacammina sp. *Globivalvulina* sp. Globivalvulina bulloides (Brady 1876) Bradyina lepida Reitlinger 1950 Fusulinidae: *Ozawainella* sp. Eostaffella lepida Grozdilova et Lebedeva 1950 Fusulina elegans Rauser et Beliaev 1940 Bryozoans (with Fenestellidae), Other fossils: Gastropods, ostracods and crinoids. Fusulina elegans is known by a single specimen: it indicates a Late Moscovian

(Podolskian-Miatchkovian) age.

- <u>At a depth of 54.2 meters</u> (3 thin sections T5072 and T5073), limestone (micstone to wackstone) contains only spongiostromids: other fossils are entirely absent. The nature of the limestone, the presence of abundant spongiostromids and the absence of other fossils indicate a strongly confined environment.
- <u>At a depth of 56.1 meters</u> (3 thin sections T5074 and T5075), spongiostromids are less common. However, depositional environment is still confined. Limestone is a micstone. Fossil are few and consist of calcispheres (*Eotuberitina reitlingerae* Miklukho-Maklay, 1958), ostracods, brachiopods and gastropods.

**WP3:** A single sample has been studied: it had been collected from a depth of 40.3 meters (4 thin sections T5078 and T5079) (Figure 2.12). Limestone is wackestone to packstone. Fossils are common and display abundant traces of tiny borings. They consist of;

**Smaller foraminifer**: *Endothyra* sp.

	Bradyina sp.
	Tetrataxis sp.
	Calcivertellidae
	Hemigordius sp.
Other fossils:	Brachiopods, bryozoans (with Fenestellidae), bivalves,
	gastropods, ostracods, crinoids and trilobites.

The trilobites and the Fenestellidae indicate clearly a Paleozoic age whereas some foraminifers focus on a Carboniferous-Permian age. *Hemigordius* is known form the late Moscovian to the late Permian in the Tethyan realm.





Figure 2.9 The drillhole locations of the gypsum exploration in the Wang Saphung area (Kuttikul *et al.*, 1997)













# WP-3





#### 2.4 Continental event

The important event mentioned in Pha Chom Nang Belt between Lower and Middle Carboniferous is more easily observed in Ban Sa Ngao Belt because of wider exposures of continental sediments.

About 6 km east of Ban Pak Niem and about 7 km south of Mekong River, a sequence of shale and sandstone contains a small coal deposit, which was investigated by core drillings in 1985-1986. This occurrence of coal is located about 60 km north of Ban Na Duang coal. Brachiopods in the shale indicated a near-coast marine environment; they suggested a Carboniferous to Permian age (Chairangsee *et al.*, 1990). This sequence unconformably overlies serpentinite. To the south, Chairangsee *et al.*, 1990 (bc. 71) mentioned plant remains in a Carboniferous shale east of Ban Pak Huai Na.

East of Ban Chom Noi and 1.5 km northwest of Ban Loeung (1743'07"N, 102200'02"E; locality 45 of fig. 2; samples T6968 to T6982), a weathered shale is exposed along a small road. It dips 30 towards the east. It is rich in plant imprints which have not been studied yet and seem to belong to the end of the Lower Carboniferous according to J. Broutin of Paris University. This outcrop is 10.5 km east of Ban Chom Noi and 11 km south-southeast of Ban Chiang Kiom. It is 27 km north of Ban Na Duang where similar fossil plants have been described (see the following paragraph). East of Ban Loeung, metamorphic rocks are widespread east of longitude 10201 '20'E.

Northeast of Ban Na Duang (locality 49 of fig. 2), a clastic sequence of shale, tuffaceous sandstone and siltstone contains lenses of anthracitic coal, which was exploited in the past. Plant leaves, roots, branches and trunks are visible in some beds. They consist of large frond fragments of *Eusphenopteris* associated with fragments of *Stigmaria, Lepidodendron, Adiantites, Archaeocalamites, Rhodeopteridium.* This flora indicates a Namurian B age and displays affinities with the floras of the regions located north of the paleotethys (Laveine *et al.,* 1993, 1994, 1999). Because of the other information on the stratigraphy of the region, the age should be restricted to a Serpukhovian-Lower Bashkirian age.

In conclusion, exposures of continental Carboniferous sediments appear to extend over a long distance from Mekong River to Ban Na Duang coal mine.

Table 2.3 These fossils indicate that the limestones of Wang Saphung and Na Duang area belong to a span of time from Bashkirian to Moscovian (Middle Carboniferous)

Fossil		Wang Saphung	Na Duang
Calcispheres	Eotuberitina retlingerae	+	
Pseudoalgae	Claracrusta catenoides	+	
U			
Algae	Gyroporella? Tuberitina bulbacea	+ +	
Foraminifers			
Small foraminifera	Climacammina sp.,	+	
	Globivalvulina sp.,	+	
	Globivalvulina bulloides, Bradvina lepida	+	
	Calcivertellidae	+	
	Hemigordius sp.	+	
	<i>Tetrataxis</i> sp.	+	
Fusulines	Ozawainella sp.,	+	
	Eostaffella lepida,	+	
	Fusulina elegans,	+	
	Endothyra sp.,	+	
	Bradyina sp.,	+	
Corals			
Other fossil	bryozoans,	+	
	gastropods,	+	
	ostracods	+	
	crinoids, and	+	
Eossil plants	tritobite Stiemania	+	
rossii piants	Lepidodendron		+
	Adiantites.		+
	Archaeocalamites,		+
	Rhodeopteridium.		+



# 2.5 Sedimentology

# 1. Limestone classification

The main purpose of petrographic analyses of limestone is for depositional environment interpretation. In fact the most widely used classification are based on the concept of textural (fabric) maturity which is believed to concern to the energy level during the limestone deposition. The basis of the classification is given by many authors, however, Folk (1959) and Dunham (1962) systems are the most widely used. (Figure 2.13)

Original con	nponents not b					
(particles	Contains mud of clay and fin	e silt size)	Lacks Mud	Original components bound together at deposition. Intergrown		
Mud-supported		Grain-supported		skeletal material, lamination contrary to gravity, or cavities		
Less than 10% Grains	More than 10% Grains			floored by sediment, roofed over by organic material but too large to be interstices		
Mudstone	Wackestone	Packstone	Grainstone	Boundstone		

C. G. St. C. Kendall, 2005 (after Dunham, 1962, AAPG Memoir 1)

Figure 2.13 The classification of carbonate sedimentary rocks. These schemes are commonly used for description of limestone in the field and in hand specimen. above scheme after Folk (1959) and below scheme after Dunham (1962).



# 2. Standard Microfacies Types

With the aid of sedimentological as well as paleoecological data, the microfacies types of limestones of various ages can be combined into major types which reflect the depositional and ecological conditions in a certain sedimentary environment (Flugel, 2004). The major types or Standard Microfacies Types (SMF Types) have often proved useful as a basis for considering depositional environments by Flugel (2004) as show in Figure 2.14



Figure 2.14 Generalized subdivision of carbonate ramps (Flugel, 2004).



# 2.6 Morphology of fusulinid

Many textbooks contain valuable information on the morphology of fusuline. Particularly useful ones include Moore and others (1964) and Boardman and others (1987). They are considered and concluded to this part as follows:

The fusuline tests are mostly fusiform, globular or subsylindrical in shape (Figure 2.15) and coiled around an axis. The tests of many different genera are similar in the external appearance, but the internal structure may be quite dissimilar. Classification on internal shell features can be determined from thin sections or polished slices. Two sections are indispensable which cut through the beginning chamber. They disclose most internal features of the shell. One of these slices bisecting the shell with parallel to the axis of coiling and including the center of the proloculus, is called an axial section. The other, slices through the test with vertical to the axis of coiling and passing the proloculus, is called a sagittal section. A section parallel to the axis of coiling but not through the initial chamber is a tangential section. A section vertical to the axis of coiling but no passing the proloculus, is called a parallel section. Sections cut in directions neither parallel to the axis of coiling nor normal to it are referred to oblique section.

Fusuline growth starts with a minute sub-sphercal initial chamber called the Proloculus (Figure 2.15) Chambers are added around the proloculus with an axis of coiling to form a coiled test. The outer or upper wall of test encloses the chamber, is called spirotheca (Figure 2.16). Shell increases in size by secretion at the outer margin of the shell, forming new chambers. Parition between chambers, commonly consisting of previous outer wall is called septum. As each chamber is added, the last formed septum becomes the antetheca. Septal pore (Figure 2.15 - 2.18) is the small perforation in septum and antetheca. The external view of shell is devided by shallow closely spaced meridional grooves, external furrow which mark the position of the septa. Folding or corrugation of septum and antetheca transverse to the axis of coiling, are septal fluting. The septa are essentially plane in many of the primitive fusulines. They evolve fluting in more complex forms and chamberlets develop where opposing folds touch and partly divide the chambers. Cuniculus is tunnel-like passageways between alternate chamberlets formed by strong septal fluting. Resorbed area at base of septa in

the central part of fusuline is tunnel (Figure 2.16-2.18). Choma is a ridge of dense calcite which deposited beside the tunnel.

Many fusulinids resemble grains of wheat; the internal structure, however, is very complex and distinctive. The shell consists of a series of chambers formed about a central longitudinal axis. Complex patterns in the number and arrangement of internal walls and deposits are present and aid in classification and the working out of evolutionary relationships.

Members, especially of the Fusulinacea, are excellent index fossils for determining ages and correlating Upper Mississippian to Permian strata (Figure 2.19). In some places fusulinaceans may be so abundant as to be a significant component of limestone.



Figure 2.15 Diagram of fusulines test showing structure features (Moore, 1964).





Figure 2.16 Spirotheca and septal structures of fusulinaceans (Moore, 1964).



Figure 2.17 Diagram of spirotheca showing pendant-like walls of alveoli, choma and septal pore of *Schwagerina campensis* THOMPSON, L.Perm. (Moore, 1964).





Figure 2.18 Fusulinidae (Fusulininae; 1-4, Profusulinella). (Moore, 1964).





Figure 2.19 Stratigraphic distribution of fusulinacean (Moore, 1964).



# **CHAPTER 3**

# METHODOLOGY

# 3.1 Study localities

The study area is located in Loei Province, in northeastern Thailand, between 101° 30' to102° 30' E and 16° 45' to18° 15' N (Figure3.1). It covers topographic map on the scale 1: 50,000 Series WGS84 (39 Map sheet). This study contains two main localities including the Phu Bo Bit and Phu Pha Mo in the east of Loei and Wang Saphung, respectively (Figure 3.2).



Figure 3.1 Topographic map Index of the study area on the scale 1: 50,000 by ArcGIS.





Figure 3.2 Topographic map of the study area and its vicinity by ArcGIS.



EXPLANATION

	ดะกอน ทินขั้น และทินแปร	ชื่อหมวดเคลุมพิน	ยุค	อายุ (ล้านปี)
SEDIMENT, SEDIMENTARY AND METAMORPHIC ROCKS		FORMATION/GROUP	PERIOD	AGE (my.)
\$	<ul> <li>พิษตินตาน พิษตราย พิษตรายเปล้ และพิษตรารกฎหาไฟ</li> <li>Pla Das Formation shale, sandstone, silitstone, and aggiomerate.</li> <li>พิษตินตาน สอังพิษตราย พิษปุณสนสลังกา</li> <li>Shale intercalated with sandstoner, gray limestone lens.</li> <li>พิษปุณสเทร สิมพิษตรรร สินตินสลังเรียงคร. อางารสงครรรรรรรรรรรรรรรรรรรรรรรรรรรรรรรรร</li></ul>	หมวลที่หมาเสื้อ PHA DUA Fm. หมวลทินส์เส็ต E-LERT Fm. หมวลทินล้ามไททาร NAM NAHOLAN Fm.	เพอร์เมียน PERNIIAN	245-286
	ริมาที่ผลินลาน ฟินทรายแป้ง บิชั่นบางของหอนปูนลดับ Wang Saplung Formation thale, เป็นtone, fain-bedded limestone. ฟินทรายเนื่ออาจระดร์ ฟินดินลานเนื้อทรายแป้ง ฟินปูนเลนส์ และฟินกรรถยน Nong Dok Bas Formation Quartzose stadistone, thale, silly shale, lamestone lens and conglomerate.	านวลที่หวังอะพง WANG SAPHUNG Fm. หมวลที่หาหองตองบัว WANG SAPHUNG Fm.	ดาร์บอมิเฟอรัส CARBONIFEROUS	
	ที่เมษีรักสลับพิษที่ฟร์ พื้นปู่แลนด์ และบิยั้งบองพิษลินดางบ้าง Chert with layer of tuff, limestone lens, and locally shale.	หมวลที่หน่าลชม PAK CHOM Fm.	ดีโวเนียน DEVONIAN	
	ฟันฟัล ไลด์ พันอาจร์ดไวด์ พันอัดด์ พันอนวน พันทราย และพิมพราย Phyllie, quartzite, schist, slate and sandstone.		ดีโวเนียน-ไซลูเรียน DEVONIAN- SILURIAN	286-360
	หิแอ้คนี้ IGNEOUS ROCKS	ยุค PERIOD	•	
	พิษโบโอโทส์และฟิล ฟินฟัวร์บาลีนและนิด ฟินและโนโดออโรก์ ฟินโบโอโทล์-บัธโอโวล์และนิด ฟินบัธโอโวล์-ทัวร์บาลีนและนิด ฟินโบโอโทล์-ทัวรบาลีนและนิด Biotic granic, sourcasline granice, granodiorite, biotic-muscovite granice, noncovite-tournaline granice, biotic-tournaline granice. ฟินและโนโลออโรล์ Granodiorite.	ไทรแอสซีง TRIASSIC	1	-210-245

Figure 3.3 Geological map of study area (Department of Mineral Resources, 2009)

# 3.2 Field work

Field work consists in collect data, preparation for field survey, collect of fossil;

# Planning and collecting.

After the review of literature, the first step involved mainly data collection in order to get new information about the study area and relevant information for subsequent step.

#### **Field survey**

Field investigation, geological map and sample collection. The lithostratigraphic columnar section has been carried out into two steps, notably, the reconnaissance field investigation and detailed field investigation. (see Figure 3.3, 3.4, 3.5 and 3.6)

The geography, general stratigraphy, and more detailed information on Carboniferous sequences in Loei area have been studied. A geological map was established and paleontological samples.

Description of a rock unit should include colour (fresh and weathered); lithologic composition; grain size, sorting and shape; sedimentary structures; indurations; type of cement; fossil content and pedogenic features. The nature of the contacts bounding a unit is extremely important to understand the palaeoenvironment. Contacts are most often characterized as erosional (underlying beds or structures are truncated), sharp (no truncations but knife – edge change in lithology) or gradational. The geometry of a rock unit (lenticular, tabular, wedge - shaped) should be determined whenever possible. Field descriptions can be augmented by detailed petrography.

#### **3.3 Laboratory work**

In the laboratory, all collected rock specimens were slab-cut and polished for megascopic observation of sedimentological features. And thin sections of limestone have been prepared for petrographic and palaeontologic identifications. They will provide the ages and depositional environments of the rocks under study.

**Petrography:** This study mainly investigates the area of Loei. The limestones were sampled to make thin sections for petrography.

**Paleontology:** Identification of fossil; algae, foraminifers and corals which was conducted at the department of mineral resources (DMR).

# **CHAPTER 4**

# RESULTS

#### 4.1 Sedimentology and stratigraphy

The discussion is focus on lithology and lithofacies based on the field investigation, and laboratory studies. This study contains two main localities including the Phu Bo Bit and Phu Pha Mo in the east of Loei and Wang Saphung, respectively. Details on sedimentology and stratigraphy of these sections are below (Figure 4.1).

# 4.1.1 Lithology of the Phu Bo Bit section

The overall rock unit of the Phu Bo Bit section were mapped from two measured sections oriented approximately in the east-west direction and the traverses are shown in Figure 4.2. The total distance of traverses was about 5 km. long and rock samples were collected for detailed petrographic study. The representative sedimentary sequence of section of the Phu Bo Bit sction is shown in Figure 4.3. From the results of field observation, there are 2 rock units. The description of each unit is presented in ascending order as follows:

A hill 2 km east of Loei, thick limestone lenses in shale contain microfossils, Tabulata and solitary Rugosa; they have been assigned to Upper Bashkirian (Fontaine and Suteethorn, 1988; Fontaine, 1990; Fontaine *et al.*, 1991, Fontaine *et al.*, 2005).

Along the northern foot of Phu Pho Bit, a section of shale, calcareous mudstone, argillaceous limestone, limestone and sandstone is well exposed along the road from Ban Na Bon (5 km south of Pha Tha) to Ban Phia. It is rich in fossils at many levels: foraminifera, solitary Rugosa with and without dissepiments, *Chaetetes*, bryozoans, brachiopods, gastropods. Beds dip towards East. Samples have been collected from west to east.

At the first locality (fig. 4.2; 793900E, 1937300N; samples T7795 to T7797), variously argillaceous limestone and calcareous mudstone.

At the second locality (fig. 4.2; 794300E, 1937500N; samples T7641 to T7650), a dark grey limestone is associated with shale and sandstone.

At the third locality (fig. 4.2; 794200E, 1937500N; samples T7798 to T7801), 2.3 km east of Ban Na Bon, limestone beds in shale.

At the fourth locality (fig. 4.2; 794800E, 1937700N; sample T7802), shale starts to be prominent.

At the fifth locality (fig. 4.2; 796300E, 1937400N; samples T7803 to T7805), 3.5 km east of Ban Na Bon, lenses of small black limestone occur in the shale. Limestone is packstone.

At the sixth locality (fig. 4.2; 797100E, 1936300N; sample T7806), sandstone beds appear in the shale.

At the seventh locality (fig. 4.2; 797900E, 1936100N; samples T7807 to T7812), small limestone (wackestone to packstone) lenses in shale

South of Phu Bo Bit, a few hills are built up by shale, siltstone, sandstone, limestone lenses and igneous rocks. Brachiopods locally occur in shale. Limestone is recrystallized at some places. Elsewhere, it is difficult to find fossils useful for stratigraphy.





Figure 4.1 Topographic map of the study area and its vicinity. (Royal Thai Survey Department, 1999)





Figure 4.2 Topographical map showing Phu Bo Bit section located to the east of Muang district, Loei Province; Map sheet Amphoe Wang Saphung (5343 I) and Ban Sup (5344 II) of the 1:50,000. (Royal Thai Survey Department, 1999)





Figure 4.3 Lithostratigraphy of Phu Bo Bit.





Figure 4.4 Field photograps showing view from south of Phu Bo Bit (a), intercalation of limestone and shale layers (b), very thick bedded to massive limestone (c, d), the massive coral (e) and solitary coral (f) at Phu Bo Bit section.



Figure 4.5 (a) A quary near the foot hill of Phu Bo Bit.; (b, c, d) A close-up outcrop of limestone of Phu Bo Bit section., (e) solitary Rugosa, (f) Tabulata



Figure 4.6 **A,a**: A rock slab and photomicrograph of sample no. LST18, **B,b**: A rock slab and photomicrograph of sample no. LST021, **C,c**: A rock slab and photomicrograph of sample no. LST016, and **D,d**: A rock slab and photomicrograph of sample no. LST015 from Phu Bo Bit section.



## 4.1.2 Lithology of the Phu Pha Mo section

A hill 3 km southeast of Wang Saphung (fig 4.5; 797033E, 1914049N; samples T7586 to T7591, LST010 to LST014 and LST024 to LST032), consists of shale and sandstone with some limestone interbeds. Consisting of a grey packstone.

The overall rock unit of the Phu Pha Mo section were mapped from a measured sections and the traverses are shown in Figure 4.7. The total distance of traverses was about 1 km. long and about 50 rock samples were collected for detailed petrographic study. The representative sedimentary sequence of section of the Phu Pha Mo sction is shown in Figure 4.8. From the results of field observation. The description of rock unit is presented in ascending order as follows:

The unit is characterized by the succession of thin-to thick –bedded dark gray to black limestone and limestone with nodular and thin-bedded chert intercalation. Limestone are mostly fine-grained and black in colour. Moderately to poorly sorted skeletal, poorly sorted packed biomicrite, biosparite are generally recognized. Fossil of relatively abundant algae, fusulinaceans, and smaller foraminifers are identified.





Figure 4.7 Topographical map showing the Phu Pha Mo section, Wang Saphung district, Loei Province; Map sheet Amphoe Wang Saphung (5343 I) of the 1:50,000. (Royal Thai Survey Department, 1999)





Figure 4.8 Field photograps showing outcrop bedded limestone (A, B),and limestone with chert nodule (C), Tabulata (D), amonoid (E), and massive Rugosa (F) at Phu Pha Mo section.





Figure 4.9 **A,a**: A rock slab and photomicrograph of sample no. LST031, **B,b**: A rock slab and photomicrograph of sample no. LST029, **C,c**: A rock slab and photomicrograph of sample no. LST032, and **D,d**: A rock slab and photomicrograph of sample no. LST026 from Phu Pha Mo section.

# 4.2 Palaeontology

**4.2.1 Phu Bo Bit section**, it is rich in fossils at many levels: foraminifera, solitary Rugosa with and without dissepiments, *Chaetetes*, bryozoans, brachiopods, gastropods. Beds dip towards the East. Samples have been collected from west to east.

At the first locality (fig. 4.1; 793900E, 1937300N; samples T7795 to T7797), variously argillaceous limestone and calcareous mudstone contain diverse fossils: dissepimented solitary corals, bryozoans, brachiopods and gastropods. Fragments of algae and fusulinaceans are rare and poorly preserved.

At the second locality (fig. 4.1; 794300E, 1937500N; samples T7641 to T7650), a dark grey limestone is associated with shale and sandstone. It is locally very rich in fossils. Algae (*Beresella erecta* Maslov & Kulik 1956) are commonly in great abundance; they are similar to those found at Phu Pha Mo (see below) and to those of the Moscovian limestone exposed in a pond at Ban Na Duang (Fontaine and Suteethorn, 2000b). Other fossils are rare: smaller foraminifera (Nodosariidae), fusulinaceans, dissepimented solitary corals and crinoids.

At the third locality (fig. 4.1; 794200E, 1937500N; samples T7798 to T7801), 2.3 km east of Ban Na Bon, limestone beds in shale contain very rare dissepimented solitary corals. Algae are still in abundance; fusulinaceans are very rare.

At the fourth locality (fig. 4.1; 794800E, 1937700N; sample T7802), shale starts to be prominent.

At the fifth locality (fig. 4.1; 796300E, 1937400N; samples T7803 to T7805), 3.5 km east of Ban Na Bon, lenses of small black limestone occur in the shale. Limestone is packstone, again very rich in tubular algae; it contains rare fusulinaceans (T7805).

At the sixth locality (fig. 4.1; 797100E, 1936300N; sample T7806), sandstone beds appear in the shale.

At the seventh locality (fig. 4.1; 797900E, 1936100N; samples T7807 to T7812), small limestone (wackestone to packstone) lenses in shale contain calcispheres, smaller foraminifera (*Globivalvulina*), scattered and poorly preserved fusulinaceans (*Profusulinella* sp.), *Chaetetes, Multithecopora*, solitary corals with and without dissepiments. The shale is locally rich in brachiopods.

The solitary corals with dissepiments belong to *Caninophyllum*. They are about 3 cm in diameter, with 40 to 44 major septa and extremely short minor septa. Dissepiments are arranged in about 8 rows. Other solitary corals are small, 5 to 6 mm in diameter. They display a columella and they probably belong to *Amygdalophylloides*. *Chaetetes* consists of 2 species: a species with corallites 0.6 mm in diameter, the other species with corallites 0.4 mm in diameter. The corallites of *Multithecopora* are 1.5 mm in diameter. East of that locality, the topography is flat and only rare outcrops of shale are visible at ground surface. The section exposed at the northern foot of Phu Bo Bit extends from Late Bashkirian to Early Moscovian.

4.2.2 Phu Pha Mo section, It contains algae (Beresetta erecta Maslov & Kulik 1956, Ungdaretla uratica Maslov), calcispheres (Eotuheritina), smaller foraminifera (Geinitzina, Bradvina magna Roth & Skinner and smaller Bradvina, Ctimacammina, Endothyra), a few fusulinaceans (Profusulinetta sp., Citronites citronoides Manukalova 1948, *Eoschubertetta* sp.), solitary corals and crinoids. It is commonly packed with fragments of algae and must he considered algal mound. The algae do not build a true framework, the mound appears to be -imply an accumulation of algal debris. Among fusulinaceans, Citronites is interesting. It is known in the Lower Moscovian, it is a small form close to Beedeina and a transition to Aijutovetla. The solitary corals are small, hornshaped, 12 to 22 mm in diameter near the calice. They are dissepimented corals, belonging to Cyathopsidae (Caninia, without columella and with a short cardinal septum in an open fossula) and Geyerophyllidae (Kionophyttum, with a solid axial structure and lonsdaleoid dissepiments; probably to Amygdatophyltoides, with a slightly more complex columella and sporadic lonsdaleoid dissepiments). Geyerophyllidae were already known in Loei region, at Pha Tha and near Ban Pha Noi (Fontaine et al., 1991). Corals are far less important than the algae. They are only scattered solitary Rugosa and cannot suggest reef building. The age of Phu Pha Mo limestone is Early Moscovian (most probably Vereyan) because of the occurence of *Profusutinella* with *Citronites* citronoides.

#### 4.2.3 Systematic Palaeontology

Systematic description of Fusulinids

Phylum PROTOZAO Class SARCODINA Order FORAMINIFERIDA Eichwald, 1830 Suborder FUSULININA – Wedekind, 1937 Superfamily FUSULINACEA – Moller, 1878 Family PSUDOSTAFFELLIDAE – Putria, 1956 Subfamily FUSULINELLINAE – Staff and Wedekind, 1910 Genus Profusulinella – Rauser and Beliaev, 1936

Profusulinella sp.

1982 Profusulinella rhombiformis – Fontaine et al., p. 52 (N.F.)

(Plate 1 Figure A1-A2, A4-A7, Plate 2 Figure B1-B3, from the Phu Bo Bit section and plate 3 Figure C10, Plate 4 Figure D2, D6, Plate 5 Figure E3 from the Phu Pha Mo section)

**Description** Shell minute, inflated fusiform to subellipsoidal, with bluntly rounded poles. Mature specimens possess 4-6 volutions and measure from 0.9 to 1.25 mm in length and from 0.5-1 mm. in diameter. Tunnel rather narrow, about half as high as chambers. Chomata massive and wide.

Age/Remark Carboniferous, late Bashkirian to early Moscovian.

**Occurrence** Phu Bo Bit, Sample LST015, LST016, LST017, LST018, Phu Pha Mo, Sample LST031.

#### Family OZAWAINELLIDAE – Thompson & Foster, 1937

Genus Ozawainella - Thompson, 1935

# Ozawainella sp.

(Plate 1 Figure A7, Plate 2 Figure B1-B3, from the Phu Bo Bit section and plate 3 Figure C10, Plate 4 Figure D2, D6, Plate 5 Figure E3 from the Phu Pha Mo section)

**Description** Shell umbilicate to spherical or elongate, evolute in early forms, involute or irregularly uncoiled in later ones, axis of coiling short or long, first few volutions discoidal, others spherical to unevenly elongate; spirotheca composed of

tectum with upper and lower tectoria in early forms but diaphanotheca occurring below tectum and above lower tectorium in later ones; septa plane; shell generally planispiral but may be asymmetrical, discoidal in at least part of shell with coiling axis in shortest diameter; tunnel singular (\*1929)

Age/Remark Late Mississippian – Late Permian.

Occurrence Phu Bo Bit, Sample LST016, LST018, Phu Pha Mo, Sample LST031.

# Superfamily ENDOTHYRACEA – Brady, 1884 Family ENDOTHYRIDEA – Brady, 1884 Subfamily ENDOTHYRINAE – Brady, 1884

Genus Endothyra – Phillips, 1846

# Endothyra sp.

(Plate 1 Figure A7, from the Phu Bo Bit section and plate 5 Figure E5 from the Phu Pha Mo section)

**Description** Test enrolled, partially involute, plane of coiling changes during growth, turning through  $30^0 - 90^0$ , may turn gradually as in plectogyral coiling, or abruptly nearly  $90^0$ , few chambers to whorl, whorls few; wall calcarour, with 2 layers, thin dark outer layer (tectum) and thicker, fibrous alveolar, inner layer (diaphanotheca); partial recrystallization may result in granular appearance, secondary deposits in form of nodes, rigdes, or forward directed hooks secreted on chamber floors; external aperture not always evident, but interiomarginal, equatorial to asymmetrical slit may be present, relatively large intercameral foramina in same position.

Age/Remark Late Devonian (Famennian), Early Carboniferous – Permian. Occurrence Phu Bo Bit, Sample LST016, Phu Pha Mo, Sample LST032.

# **Family** ENDOTHYRIDEA – Brady, 1884

# Subfamily BRADYININAE – Reytlinger, 1950

Genus Bradyina – Moller, 1878

Bradyina sp.

(Plate 3 Figure C6, and plate 4 Figure D2 from the Phu Pha Mo section)

**Description** Test free, robust, planispiral, involute; few chambers and whorls; chamberlets or canals formed by converging septal lamellae or infolding of outer wall to
form septa, chamberlets extending into umblical region; wall calcareous, microgranular, perforate, with distinct radial lamellae; primary interiomarginal aperture, with additional large areal pores forming cribrate aperture, and supplementary septal pores opening into septal chamberlets.

Age/Remark Early Carboniferous – Late Carboniferous.Occurrence Phu Pha Mo, Sample LST029, LST031 and LST032.

#### Family PALAEOTEXTULARIIDAE - Galloway, 1933

Genus *Climacammina* – Brady in Etheridge, 1873 *Climacammina* sp.

(Plate 5 Figure E6, from the Phu Pha Mo section)

**Description** Test biserial or may become uniserial; wall granular calcareous, with inner layer and thin adventitious coating; aperture simple or multiple.

Age/Remark Carboniferous – Permian.

Occurrence, Phu Pha Mo, Sample LST032.

### Family BISERIAMMINIDAE - Chernysheva, 1941

Genus Globivalvulina – Schubert, 1921

Globivalvulina sp.

(Plate 1 Figure A6, from the Phu Bo Bit section)

Description Test biserial, involute; aperture at inner border of septal face.

Age/Remark Early Carboniferous – Permian.

Occurrence, Phu Bo Bit, Sample LST016.

Systematic description of Algae

**Order** BERESELLALES – Maslov and Kulik, 1956 nomen translat. herein

Family BERESELLACEAE – Maslov and Kulik, 1956

nomen translat. H. Termier *et al.*, 1977 see also G. Termier *et al.*, 1977, p. 141 (ex tribe) orth mut. Shuysky, 1985 (ex Beresellidae)

(non Deloffre, 1987, nec Shuysky, 1987, nec Deloffre, 1988)

Tribe Bereselleae Maslov and Kulik, 1956

Genus Beresella – Makhaev, 1937 ex Maslov and Kulik, 1956 Beresella erecta Beresella erecta– Maslov and Kulik, 1956

(Plate 1 Figure A3, Plate 2 Figure B5, from the Phu Bo Bit section and plate 3 Figure C1,C7, Plate 4 Figure D1, Plate 5 Figure E1, E4, E6 from the Phu Pha Mo section)

**Description** Cylindrical microproblematic algae, undivided but with internal diaphragms more or less numerous according to the. The tubular undivided skeletons are occasionally bifurcated, and have an outer surface smooth or finely costulate, and a internal cavity. In between, the re-entrants, darker rings, are finely canaliculate. The canalicules are blind, because they are overlain by a continuous external yellow layer. (Vachard, 1991, fig 4.4) can occupy the entire central cavity.

Age/Remark Carboniferous, late Bashkirian to Orenburgian (acme in Moscovian).

Occurrence Phu Bo Bit, LST015, T7589, Phu Pha Mo, Sample LST026, LST032.



Table 4.1 Generic level of major fossil groups observed in the Phu Bo Bit Section and Phu Pha Mo Section. These fossils suggest Bashkirian - Moscovian (Middle Carboniferous) of the studied sections.

Age			Fossils	Phu Bo Bit	Phu Pha Mo
		A.1.000	Beresella sp.		+
		Algae	<i>Ungdarella</i> sp.		+
			Profusulinella sp.	+	+
		Foraminifer	<i>Citronites</i> sp.		+
	an		Eoschubertella sp.		+
	ovi		<i>Geinitzina</i> sp.		+
	osc	Small foraminifera	Bradyina sp.	+	+
	Mc		Climacammina sp.	+	+
			Endothyra sp.	+	+
			Caninophyllum sp.	+	
		Corals	<i>Caninia</i> sp.	+	+
SI			Multithecopora	+	+
rou		A.1.000	Beresella sp.	+	+
iife		Algae	<i>Ungdarella</i> sp.		+
loc			Profusulinella sp.	+	+
Carl		Foraminifer	<i>Eostaffella</i> sp.	+	+
-			<i>Ozawainella</i> sp.	+	
Iid		Small foraminifera	<i>Climacammina</i> sp.	+	+
2			Globivalvulina sp.	+	
	an		<i>Bradyina</i> sp.	+	+
	kiri		Endothyra sp.	+	+
	ish		Chaetetes sp.	+	+
	$\mathrm{B}_{\mathcal{E}}$	Corals	Multithecopora sp.	+	+
			<i>Caninia</i> sp.		+
			brachiopods	+	+
			bryozoans	+	+
		Other forgil	gastropods	+	+
		Outer 105811	ostracods	+	+
			crinoids	+	+
			trilobite	+	



#### 4.3 Microfacies analysis

Outcrop observations are combined with detailed microfacies studies comprising the description and interpretation of the sedimentary facies as well as the occurrence and composition of the biota. The investigations form the basis for the reconstruction of two fundamentally different depositional settings.

### 4.3.1 Selective microfacies recognition and interpretation

Thin-section observation are served as the basis for describing carbonate texture, and identifying allochemical constituents. The facies are defined on the bases of lithology, allochemical constituents, texture, and fossil associations in order to reconstruct their depositional environment. The carbonate facies are named following the carbonate rock classification either developed by Folk (1959, 1962) or Dunham (1962) and also Embry and Klovan (1971). Additionally the fabric characteristics are complementary. These selective microfacies are summarized in Table 4.2

Microfacies	Lithological characteristic	Depositional environments
I Algal lamination	Very thin-laminae, algal decayed, detrital quartz grains	Shallow subtidal.
II Pelmicrite	Decret peloids, fine fossil fragments	Subtidal zone of inner shelf, low-water energy.
III Sparse biomicrite	Poorly sorted, floating grain, micrite matrix	Subtidal and/or subwave base of the shelf sea close to the shore
IV Packed biomicrite	In-situ deposition of unfragment fossils, micrite matrix, fragmental fossils, intraclasts, carbonaceous matter	Subtidal zone below the active wave base.
V Biosparite	Intraclasts, fragmentals and unfragment fossils, lumped pellets, poorly to moderately sorted	Intertidal to near shore subtidal above the wave base



#### 4.3.2 Depositional environment

The carbonate rocks in the study area are recognized into six microfacies based on limestone classifications those developed either by Folk (1959, 1962), or Dunham (1962), and Embry and Klovan (1971) as well as carbonate textures. Excluding crystalline microfacies, the packed biomicrite, sparse biomicrite, biosparite, pelmicrite and algal- lamination are present in decreasing order of abundant. These microfacies representing carbonate facies develop under influent from low to high energy water in subtidal to intertidal regims. (Figure 4.10, and Table 4.2)



Figure 4.10 Reconstruction palaeoenvironment of the study area showing, marine depositional environments. (Richard, 1989)



#### **CHAPTER 5**

#### CONCLUSION

#### 5.1 Conclusion

According to this thesis study, on the geology, sedimentology, stratigraphy, palaeontology of the two main localities including the Phu Bo Bit section and Phu Pha Mo sections in the east of Loei and Wang Saphung towns, revealed that

1. At Phu Bo Bit, thick limestone lenses in shale contain microfossils, Tabulata and solitary Rugosa; they have been assigned to Late Bashkirian and fusulinaceans (*Profusulinella* sp.) *Beresella*, have been assigned to Early Moscovian. The stratigraphic sequence of Phu Bo Bit extends from Late Bashkirian to Early Moscovian.

2. The age of Phu Pha Mo limestone is Early Moscovian (most probably Vereyan) because of the occurrence of *Profusutinella* with *Citronites citronoides*.

3. According to lithofacies and fossil identification, Phu Bo Bit section is older than Phu Pha Mo section. And the change of the carbonate to siliciclastic sedimentation on Phu Bo Bit section is active before carbonate accumulation on the Phu Pha Mo section. The high sea level in Bashkirian age has been suggested as the major time of carbonate built up of the Phu Bo Bit , but the younger, the Moscovian age is the major time for carbonate built up of the Phu Pha Mo.

4. The rocks from both section consisting of shale, limestone along with abundance and diverse invertebrate faunas; brachiopods, corals, bryozoans and crinoids are interpreted as having been deposited in shallow marine or shelf environments.

#### **5.2 Suggestion**

The history of the Carboniferous of northeast Thailand is turning to be more complicated than what was thought previously. So far, the answer is difficult, a more intensive study has to be carried out. References



#### REFERENCES

- Baum F, Von Braun E, Hahn L, Hess A, Koch KE, Kruse G, Quarch H and Siebenhuner M. (1970). On the Geology of Northern Thailand. *Beih. Geol. Jb.*, 102, 1-23.
- Bleackley D, Stephens A E, Cretchley CR, Workman DR, Newmann D, Cogger N, Sanevong P, Thavarachorn P, Intrakhao B and Chaungpaisal S. (1965). The Regional Geology of the Loei-Chienkarn Area of Thailand and Detailed Investigations of the Phu-Khum Lead-Zinc Mineral Prospects. In: Overseas Geol. Suvey London and Dept. Miner. Resourc. Bangkok: Bangkok-London. p. 20.
- Brown GF, Buravas S, Charaljavanaphet J, Jalichandra N, Johnston WD, Sresthaputra V and Taylor GC. (1951). Geologic reconnaissance of mineral deposits of Thailand. US Geol. Surv. Bull, 1, 183.
- Bunopas S. (1983). Paleozoic succession in Thailand. In: Proc. Workshop on stratigraphic Correlation of Thailand and Malaysia, 8-10 september 1983, Haad Yai, Thailand: s.n. pp. 39-76.
- Chairangsee C, Hinze C, Macharoensap S, Nakornsri N, Silpalit M and Sinpool-Anunt S. (1990). Geological Map of Thialand 1:50,000. Explanation for the sheets: Amphoe pak Chom, Ban Huai Khop, Ban Na Kho and King Amphoe Nam Som. *Geol. Jb.*, 73, 3-55.
- Charoenprawat A, Wongwanich T, Tanitiwanit W and Theetiparivatra U. (1976). Geological Map of Loei (NE47-12), scale 1:250,000. Bangkok: Department of Mineral Resources.
- Chonglakmani C and Sattayarak N. (1979). *Geological Map of Changwat Phetchabun* (*NE47-16*), *scale 1:250,000*. Bangkok: Department of Mineral Resources.
- Chonglakmani C, Fontaine H and Vachard D. (1983). A Carboniferous -Lower Permian
  (?) section in Chon Daen, Central Thailand, In: Symposium on Stratigraphy of Thailand, Bangkok: Department of Mineral Resources. pp. 1-5.
- Dunham RJ. (1962). Classification of carbonate rocks according to depositional texture. In: Classification of Carbonate Rocks (Ed. W.E. Ham), Amer. Assoc. Petrol. Geol. Mem., 1, 108–121.
- Embry AF, Klovan JE. (1971). A late Devonian reef tract on northeastern Banks Island, N.W.T. *Bulletin of Canadian Petroleum Geology*, 19(4), 730–781.
- Folk RL. (1959). Practical petrographical classification of limestone. *Amer. Assoc. Petrol. Geol. Bull.*, 43, 1-38.
  - \_\_\_\_. (1962). Spectral Subdivision of Limestone Types. In: W.E. Ham (ed.), Classification of Carbonate Rocks: A Symposium, American Association of Petroleum Geologist Memoirs 1 America: s.n. pp. 62-84.
- Fontaine H. (1990). Carboniferous corals from Northeast Thailand (northeast of Loei). *Geol. Jb.*, 73, 81-89.

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- Fontaine H, Jongkanjanasoontorn Y and Suteethorn V. (1987). Spectacular karstic area of Thailand. *CCOP Newslet*, 12(4), 23-26
- Fontaine H and Ingavat R. (1985). *The Lower Carboniferous in Thailand. In: Compte Rendu 10eme Cong, Intern. Strat. Geol. Carbon.*, Spain: Madrid, 129-132.
  - \_\_\_\_\_. (1987). The Carboniferous of Thailand: its fossils and sediments. In: *11th International Congress of Carboniferous Stratigraphy and Geology*, August 31-September 4, 1987, China: Beijing, 2, 31-35.
- Fontaine H, Ingavat, R, and Vachard, D, (1982). Carboniferous corals from Northeast Thailand: *Bulletin Geological Society of Malaysia*, 15, 47-56.
- Fontaine, H, Lovacharasupaporn, S, Tien, ND, and Vachard, D, (1983). New data on the Lower Carboniferous in Thailand. *CCOP Newsletter*, 10, 13-18.
- Fontaine, H., Poumot, C, and Songsirikul, B, (1981). New Upper Palaeozoic formations of Northeast Thailand in Devonian and Lower Carboniferous. CCOP Newsletter, Bangkok, 8(4), 1-7.
- Fontaine, H, and Salyapongse, S, (1997). Unexpected discovery of Early Carboniferous (Late Visean-Serpukhovian) corals in East Thailand, In: Dheeradilok, P, Hinthong, C, Chaodumrong, P, Putthaphiban, P, Tansathien, W, Utha-aroon, C, Sattarak, N, Nuchanong, T, and Techawan, S, (eds.), *Proceedings of the International Conference on Statigraphy and Tectonic Evolution of Southeast Asia and the South Pacific (Geothai'97)* V.1, *19-24 August 1997*, Bangkok: s.n. pp. 48-52.
- Fontaine, H., Salyapongse, S., Utha-Aroon, C., and Vachard, D., (1996). Age of limestones associated with gypsum deposits in northeast and central Thailand. *CCOP Newsletter*, 22(1), 6-7.
- Fontaine H, Salyapongse S and Vachard D. (1998). The Carboniferous of East Thailand new information from microfossils. *Geol. Soc. Malaysia Bull.*, 43, 461-465.

\_\_\_\_. (1999a). New Carboniferous fossils found in Ban Bo Nam area, central Thailand, In: Khantaprab, C., (ed.), *Symposium on mineral, energy, and water resources of Thailand: Towards the year 2000: 1999*, Bangkok: Chulalongkorn University. pp. 201-211.

- \_\_\_\_\_. (1999b). Fossils from Khao Sak and the adjacent hills, Amphoe Chon Daen, Central Thailand. *CCOP Newsletter*, 24(1), 9-14.
- \_\_\_\_\_. (1999c). Permian limestone from Chantaburi to Sa Kaeo, and Upper Carboniferous limestone at Khao Sing To, East Thailand. *CCOP Newsletter*, 24(4), 13-17.
  - \_\_\_\_\_. (2002). Paleozoic sediments west of the road from Chiang Khian to Loei and Wang Saphung. *Journal of the Geological Society of Thailand*, (1), 47-53.



- Fontaine H, Salyapongse S and Vachard D. (2003). Note on the area east and southeast of Wang Saphung, Northeast Thailand, with emphasis on Permian limestone, *Journ. Geol, Soc.* Thailand, in press.
- Fontaine H, Salyapongse S, Suteethorn V, Tian P and Vachard D. (2005). Sedimentary rocks of the Loei Region, Northeast Thailand: Stratigraphy, Paleontology, Sedimentology In: *Bureau of Geological Survey, Department of Mineral Resources*, Bangkok: s.n, 165.
- Fontaine H and Suteethorn V. (2000a). Devonian and Lower Carboniferous corals found in Ban Na Klang area, Loei province, Northeast Thailand. *Journal of the Geological Society of Thailand*, (1), 27-33.
  - (2000b). Moscovian to Gshelian coral assemblages in northeastern Thailand: Field-relationship between Carboniferous and Permian strata. *Journal of the Geological Society of Thailand*, (1), 34-41.
- Fontaine H, Suteethorn V and Jongkanjanasoontorn Y. (1991). Carboniferous corals of Thailand. *CCOP Technical Bulletin*, 22(82), 1-82.
- Fontaine, H, Suteethorn, V, and Vachard, D. (1993). Carboniferous and Permian limestones in Sop Pong area: Unexpected lithology and fossils, In: Thanasuthipitak, T, (ed.), *Proceedings of the international symposium on biostratigraphy of mainland Southeast Asia: Facies & Paleontology*. Chiang Mai: Chiang Mai University. pp. 319-336.
- Fontaine H, Suteethorn V and Vachard D. (1994). Carboniferous corals of southeast Asia with new discoveries in Laos and Thailand, In: Angsuwathana, P., Wongwanich, T, Tansathien, W, Wongsomsak, S, and Tulyatid, J, (eds.), *Proceedings of the international symposium on stratigraphic correlation of southeast Asia*. Bangkok: Department of Mineral Resources, IGCP 306. pp. 25-42.
  - \_. (1995). The Carboniferous of northeast Thailand: a review with new data. *Journal of Southeast Asian Earth Science*, 12(1-2), 1-17.
- Fontaine H and Tantiwanit W. (1993). Note on fossiliferous localities between Ban Na Klang and the coal mine east of Ban Na Duang. *CCOP Newslet*, 18(4), 7-10.
- Fontaine H. and Vachard D. (1981). A note on the discovery of Lower Carboniferous (Middle Visean) in Central Sumatra. *CCOP Newslet*, 8(1), 14-18.
  - \_\_\_\_. (1981). Carboniferous stratigraphy of the Indochinese Peninsula, In: *Proceedings of the 18th Ann: CCOP Session*, Korea: Seoul. 86-200.
  - \_\_\_. (1989). Discovery of a chernyshinellid assemblage (foraminifera) in West Thailand, its bearing on the Tournaisian of Thailand and Southeast Asia. *Compte Rendu 11eme Cong. Intern. Strat. Geol. Carbon.*, 3, 41-49.
- Flugel E. (2004). Microfacies of Carbonate Rocks. Germamy: Springer.
- Garrett NB. (1924). Limestone in Siam. Journ. Siam. Soc., 18, 63-64.



- Hamada T. (1960). Some Permo-Carboniferous fossils from Thailand. *Scient. Pap. Coll. Gen. Educat.*, University of Tokyo, 10(2), 337-361.
- Haworth HF, Chiangmai PN and Phiancharoen C. (1966). Ground water resources development of Northeast Thailand. *Ground Water Bulletin*, (2), 18-55
- Igo H. (1972). Fusulinacean fossils from Thailand. Part VI: Fusulinacean fossils from North Thailand. *Geol. Palaeont. Southeast Asia*, 10, 63-116.
- Igo H. (1998). Some Carbboniferous corals from Northeast Thailand. Bull. Nat Sci. Mus. Tokyo, ser. C. 24(3-4), 151-162.
- Ishibashi T, Fujikawa M and Nakornsri N. (1997). Biostratigraphy of Carboniferous and Permian ammonoids in Thailand, in Dheeradilok, P, Hinthong, C, Chaodumrong, P, Putthapiban, P, Tansathien, W, Utha-aroon, C., Sattayarak, N, Nuchanong, T, and Techawan, S, (eds.), *Proceedings of the international conference on stratigraphy and tectonic evolution of southeast Asia and the south Pacific*, Bangkok: Department of Mineral Resources. pp. 53-55.
- Jacobson HS, Pierson CT, Danusawad T, Japakasetr T, Inthuputi B, Siriratanamongkol C, Prapassornkul S and Pholpan N. (1969). Mineral investigations in Northeastern Thailand. US Geol. Surv., 618, 1-96.
- Koch KE. (1973). Geology of the Region Si Sawat-Thong Pha Phum-Sangkhlaburi (Kanchanaburi Province/Thailand). *Bulletin of Geological Society of Malaysia*, (6), 77-185.
- Laveine JP, Ratanasthien B and Sithirach S. (1993). The Carboniferous flora of northeastern Thailand: its paleogeographic importance. *Comptes Rendus de l' Académie de Sciences de Paris*, 317(Série II), 279-285.
  - \_\_\_\_\_\_. (1994). The Carboniferous flora of Na Duang coal mine, Northeastern Thailand. Its paleogeographic interest. In: Angsuwathana P, Wongwanich T, Tansathien W, Wongsomsak S and Tulyatid J (eds.) *Proc. Internat. Symposium on Stratigraphic Correlation of Southeast Asia, 15-20 November 1994,* Bangkok, Thailnad: Department of Mineral Resources and IGCP 306. pp. 83-90.
- Moore RC. (1964). *Treatise on invertebrate palaeontology*. New York: McGraw-Hill Book Co.
- Mouret C. (1994). Geological History of Northeastern Thailand since the Carboniferous. Relation with Indochina and Carboniferous to Early Cenozoic Evolution Model. In: Angsuwathana P, Wongwanich T, Tansathien W, Wongsomsak S and Tulyatid J (eds.) Proc. Internat. Symposium on Stratigraphic Correlation of Southeast Asia, 15-20 November 1994, Bangkok, Thailnad: Department of Mineral Resources and IGCP 306. pp. 132-158.
- Pitakpaivan K, Ingavat R and Pariwatvorn P. (1969). Fossils of Thailand. *Geol. Surv. Memoir*, 3(1), 28-36.

Reed FRC. (1920). Carboniferous fossils from Siam. Geol. Magazine, 57, 113-121



- Sagami S and Nakornsri N. (1987). On some Silurian corals from Northeast Thailand. *Proc. Japan Acad.*, 63(7), 242-245.
- Sakagami S. (1965). Three Carboniferous species of Bryozoa from Khao Noi, Central Thailand, *Jap. Journ. Geol. Geogr.*, 36(2-4), 143-147.
- Sakagami S. (1966). The cryptostomatous Bryozoa from Ko Muk, Penissular Thailand., *Jap. Journ. Geol. Geogr.*, 37(2-4), 157-168.
- Sakagami S. (1967). On the Paleozoic Bryzoa collected by R.D. Stewart. Near Phetchabun, Thailand. *Geol. Palaeont. Southeast Asia.*, 3, 39-45.
- Sethaput V. (1956). Thailand. In: Lexique Stratigraphique International, 3(6), 35-57.
- Shi GR and Waterhouse JB. (1991). Early Permian brachiopods from Perak, West Malaysia. *Journ, Southeast Asian Earth Sci.*, 6, 25-39.
- Shi GR and Archbold NW. (1995). Permian brachiopod faunal sequence of the Shan-Thai terrane: biostratigraphy, palaeobiogeographical affinities and plate tectonic/palaeoclimatic implications. *Journal of Southeast Asian Earth Sci.*, 6, 25-39.
- Thanasuthipitak T. (1978). Geology of Uttaradit area and its implications on tectonic history of Thailand. In: *Third Regional Conf. on Geol. And Miner. Res.* of *Southeast Asia*. Thailand : Khonkhan. 187-197.
- Toriyama R. (1984). Summary of the Fusuline Faunas in Thailand and Malaysia. *Geol. Palaeont. Southeast Asia.*, 25, 137-146.
- Toriyama R, Hamada T, Igo H, Ingavat R, Kanmera K, Kobayashi T, Koike T, Ozawa T, Pitakpaivan K, Piyasin S, Sakagami S, Yanagida J and Yin EH. (1975). The Caboniferous and Permian Systems in Thailand and Malaysia. *Geol. Palaeont. Southeast Asia.*, 15, 39-76.
- Utha-Aroon C and Surinkum A. (1995). Gypsum exploration in Wang Saphung, Loei. In: Internat. Conf. on Geology, Geotechnology and Mineral Resources of Indochina. Thailand : Khonkhan, 255-266.
- Waterhouse JB. (1982). New Carboniferous brachiopods from Huai Bun Nak, Northeast Thailand. *Paleont. Zeit.*, 56, 39-52.
- Vachard D. (1990). New data on foraminifera, algae and pseudo-algae from Carboniferous and Permian of Northwest Thailand. *Rev. Paleobiol.*, 11, 137-147.



Appendix



Appendix A List of Illustrations



# EXPLANATION PLATE 1: FIGURE A

## Phu Bo Bit Section Late Bashkirian to Early Moscovian

Figure A1 – Profusulinella sp. Sample LST015.

Figure A2 – *Profusulinella* sp. Sample LST015.

Figure A3 – Beresella sp. and Profusulinella sp. S. Sample LST015.

Figure A4 – *Profusulinella* sp. Sample LST016.

Figure A5 – *Profusulinella* sp. Sample LST015.

Figure A6 – *Profusulinella* sp. and *Globivalvulina* sp. Sample LST016.

Figure A7 - *Profusulinella* sp. and *Ozawainella* sp. Sample LST016.





# EXPLANATION PLATE 2: FIGURE B

## The section exposed at the northern foot of Phu Bo Bit. Late Bashkirian to Early Moscovian

- Figure B1 *Profusulinella* sp. Sample LST017.
- Figure B2 *Profusulinella* sp. Sample LST016.
- Figure B3 *Profusulinella* sp. Sample LST018.
- Figure B4 Ozawainella sp. (center and center right), Sample LST018.
- **Figure B5** *Beresella* sp., longitudinal section and transverse section of *Beresella* . Sample T7589.

PLATE 2



## EXPLANATION PLATE 3: FIGURE C

### The western side of a hill 3 km southheast of Wang Saphung, Phu Pha Mo Early Moscovian

Figure C1 – Beresella sp. Sample LST026.

- Figure C2 and C3 Transverse section and longitudinal section of solitary Rugosa, apparently belonging to *Caninia*. Sample LST028.
- Figure C4 and C5 Poorly preserved fasciculate Tabulata, transverse section and longitudinal section, apparently belonging to *Multithecopora* sp., Sample LST029.
- Figure C6 *Bradyina* sp. Sample LST029.
- Figure C7 Beresella sp. Sample LST032.
- Figure C8 and C9 Transverse section and longitudinal section of fasciculate Rugosa Sample LST030.

Figure C10 – *Profusulinella* sp., Sample LST031.



PLATE 3



# EXPLANATION PLATE 4: FIGURE D

## The western side of a hill 3 km southheast of Wang Saphung, Phu Pha Mo Early Moscovian

Figure D1 – Beresella sp. Sample LST026.

Figure D2– Profusulinella sp. and Bradyina sp. (bottom left) Sample LST031.

Figure D3 and D4 –Transverse section and longitudinal section massive coral, , Sample LST011.

Figure D5 – Chaetetes sp. Sample LST010.

Figure D6 – *Profusulinella* sp. and *Ozawainella* sp. (left) Sample LST031.



PLATE 4





## EXPLANATION PLATE 5: FIGURE E

## The western side of a hill 3 km southheast of Wang Saphung, Phu Pha Mo Early Moscovian

- Figure E1 Beresella sp. (center), Profusulinella sp. (bottom center) and Bradyina sp. (top left) Sample LST032.
- Figure E2 Longitudinal section of solitary Rugosa Sample LST031.
- Figure E3 *Profusulinella* sp. and *Ozawainella* sp. (left) Sample LST031.
- Figure E4 Beresella sp. (right), and Bradyina sp. (left) Sample LST032.
- Figure E5 *Endothyra* sp. (center) and *Beresella* sp. Sample LST032.
- Figure E6 Beresella sp., and Climacammina sp. (top right) Sample LST032.

PLATE 5



### Appendix B

The drillhole logging of the gypsum exploration in the Wang Saphung area (Utha-Aroon, *et al.*, 1995)



Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
_5		Top soil,laterite and limonitic clays with small amount of rock fragments
10		Karst filling breccias and rock fragments
10		Karst filling breccias and rock fragments
20		Thick calcite vein then carb
_25		mudstone
30		Two sets of stylolites paralell and perpendicular to bedding,
35		Wackstone (hiomicrite) hivalve.
45		Foraminifera,Ostracods,Brachiopod?
_55		Irregular contact
_ _ 60		Gypsum, sugary texture with 80° dipping carbonate laminae karst fillino breccias
65 70		Caruonate muostone, light gray, highly fractured, calcite fills
-	1.1	Gypsum, sugary texture, 45°
75 	69-69 69-6	thicker lam broken-up in blocks. Thick greenish gray mudstone
80 85	ระหารา ระหารา	Karst filling breccias
90		Gradational change to anhydrite
-	1111	A zone of about 3 m. of karst filling
_95		anhydrite
	1,111	Carbonate mudstone, light gray
_100		







Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
_ _ 5		Laterite, brick red
10		Fragments of wackstone
15 		Wackstone, light gray, fegtureless Wavy stylolites
20	31	broken beddy until 25g > Cavity
25 		34° - 39° broken
35 		
45 45	a 1 a 1	carb mudstone "rich" in fauna > brachiopod, small solitary corals, or leached,> yel.,brn.,mudstone
50 55 55	2(	contact not clear Featureless, dull gry. Looking mudstone slightiy calcareous
60 60 65		From app 61° downward, the rock becomes carb mudstone, fractured and cacite fill
70	aditate	Anhydrite,dull white with vertical aligriment of xtal fabric becoming donser like "normal" anhydrite below
75  80		Anhydrite,dull white with vertical aligriment of xtal fabric becoming donser like "normal" anhydrite below Dark grn. sandstone, tuffaceous?, massive > lam not clear. fractures fill



Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
5		Laterite crust, brick red
_ _ 10		Mottled clay with pisolites, light brn. to yellow brn., rock fragments dominantly brn. shale
_ 15 		Wackstone, gry. to light gry., broken badly, brn. mudstone indill and coat along fracture walls
20  25  		Alabaster gypsum, lam 50° - 60°, grn. Gry. mudstone. Clast common dip 15° - 20° dip 30°
30		Wackstone, gry., probably containing cronoid, Two intercalating cgl. limestone with grn. gry. angular clasts
40		Wackstone, light gry., fractures filled with calcite
45 45 50		wavy - laminated carb mudstone, bioturbated, parthy abliterated due to loaching > light brn., dull calc mudstone, leached, brown stain walls of fractures



WP5





Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
		Laterite, reddish brn.
-	000000	Mottled clay, light brn., with rock fragments
10 	020	Shale, brn. to grn. brn.,featureless, gradual change to carb mudstone 40°
15		16° Shale, brn. to grn. brn.,featureless, gradual change to carb mudstone 40°
20 		Vertical fractured filled with calcite Thin calc sandstone, wispy lam at 19°, 10° - 15° dipping Vertical fractured filled with calcite
25		Thin calc sandstone, wispy lam at $19^\circ$ , $10^\circ - 15^\circ$ dipping Thin calc sandstone, wispy lam at 19, $10^\circ - 15^\circ$ dipping Linestence intraclasts around 20
- 30		Wackstone, light gry. to brn. gry. (due to leaching by oxidizing gw.), Aboudant microfractures fill with
35		Massive to plane - bedded fine to medium sandstone, grn. gry., calcarous with small vertical fractures fill with cacite
40		Karst pil - filling clay Massive to plane - bedded fine to medium sandstone, grn. gry.,
_ _ 45		Vackstone, some as above,
50	5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5 5	cgl. Limestone Wackstone, same as above grn. grv. clay
_ _ 55		Karst pil - filling clay Wackstone, same as above
60	10 10 10 10 10 10 10 10 10 10 10 10 10 1	Wackstone intercalated with grn. gry., caic, rine tomeaium grainea sandstone, Poor core recovery due to dissolution fractures or karstpits with
_ _ 65	NCN NCN	clayey infills> grn. gry. sandstone fragments
70		Wackstone and mudstone with faint wispy-lam, Karst pits with limonite - bearing clay infills
75 	D 1	fossiliferous bed, shell fragments, oncoid?, ostracods? Crinoid, Small ostracods? And crinoid or fusulinids?



Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)	
5		Topsoil, lateritic with rock fragments > shale yellow brn.	
10  	5 6 7 5 7 5	Rock fragments becoming limestone in last 2 meters	
15 20 225 30 30 35		Wackstone to mudstone, gry. to light gry., locally Crinoid Dissolution cavities with no preforred orientation Wackstone to mudstone, gry. to light gry., locally Crinoid Poor recovery < 10 % locally, Highly fractured, limonitic clay infills in fractures no bedding seen	
40 40 45 		Dark gry. carb mudstone, wavy lam, algal lam, then highly brecciated Lost drill stem and bit	



epth (m)	/mbols	(rock type, joint infilling, joint roughness, etc.)
ă	Ś	
_		Lateritic topsoil, yellow
-		angular rock fragments
5 		dominonthy mudstone on shale
	6 - 6 6 4 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	Lateritic topsoil vellow
-	8 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	brn. and mottled, with
10	1 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	angular rock fragments
-	6 4 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	dominonthy mudstone on Grav to brn. arv. of the
E	4 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9 9	same material the rock
15	6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6 6	appears to be more of
	4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4 4	mudstone > featureless in
-	9999	large cobbles of limestone
20		breccia, gry. carbonate
		Alabaster gypsum, vagve
-		carb lamination dipping
25		60°
-	0000	45°carb lam
_	00000	Small dissolution carities in
- 20	0 0 0	mudstone breccies are
_ 50		child's drawing
-		deformation stc.
_ 35	7	gypsum/anhydrite smaller
-	00	xtals, denser and heavier
		core
- 40		
- 40	11	Selenite veins, originallly
F		fracturs?
45		Carb mudstone and
		laminae)
50		NI ST STOLET STOLET
E		Noticeable increase in mudstone clasts 70°
-		
55	11	
-		gypsum/anhydrite smaller
		xtals, denser and heavier
- 60		Alabaster
_ 00	c.l.l.	





Г

Т

T

Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
-		Laterite, brick red,donse
5		Sandy clay, mottled, yellow brn. to brn. with pisolites
_ _ 10		
-		Light gry. carb mudstone,
15		Abundant microfractures, Alabaster gypsum, contains clasts of lam mudstone mm-
		size fracture filled with lst
_ 20		wackstone, fractures and yellow brn. infills, i.e., at 20-22, 28, 32 - 34, 42, 46
- - -		
_ 30		
	ַרָּדָּרָ וְרָדָרָרָ	gry. of darker tone, burrowed carb mudstone with irregular
35 		dissolution haloes
_ 40		
-		
_ 45	∓ * ∓ + + + + + + + + + + + + + + + + + + +	
_ 50		







T

Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
-		Topsoil, laterite, reddish brn.
- 5 -		Decomposed rhyolite tuff, becoming fresh around 5 m. Rhyolitic tuff, dark reddish purple, locally dark grn. fragments are coarse sand
- 10 - -		size, locally with some 1 cm.? Veinlets are filled with apaque calcite
15 		
20 		
25		
30		
- 35 		
40		


Depth (m) Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
	Topsoil, lateritic with pisolites, brn. to reddish brn.
_5	Wackestone common, highly fractured Wackestone, gry. horizontal stylolites common, highly fractured
_ 15	Dark grn. intrusive tuff volcanic rock, feldspar laths apparent Collapse brecias, originally wackstone, resulting porous rock iron stain more dominant in lower half
20	Fine-grained sandstone & siltstone gry. to grn. gry. calcareous to various degree, coarseer grain ? more effusive, thin intercalation of dark grn. valcanic tuff, calcite fills microfractures
_30	Mudstone & carbonate mudstone, dark gry., massive looking, lamination apparent locallyanddipping 80? - 90?, A few thin intercalation of f.g. sandstone, calcareous, lighter arv. Small bivalves shalls in nassive -looking cath mdst-ostracods? Crinoids
_45	Vertical and high - angle slickersides common



Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
5		Topsoil, laterite crust of a four meters, then mottled clay ? reddish brn., light gry. with pisolites becoming yellow brn. below 10 m. where "sandstone" cobbles present
15  20 		Alabaster gypsum, apparently coarser xtals at top dull white and tranerse randomlysparent bands alternate gry. mudstone fragments disp
25  30 		Anhudrita
35  40 		Annyante
45  50 		
55		



Image: Constraint of the second sec			
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Image: Constraint of the second sec			LITHOLOGIC DESCRIPTION
Image: section of the seccond of the section of the section of the section of th			(rock type, joint infilling, joint
OptionOption100Image: Construct of the sector of	Ê	S	roughness, etc.)
A B CK F10Topsoil, laterite crust, brick red, dense5Mottled clay, light to pinkish brn., with pisolites10Highly weathered limestone, light yellow brn., muddy appearance115Highly weathered limestone, shight yellow brn., muddy appearance20Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahte and transparent gypsum probably due to diffarent degree of rehydration40Gypsum, gry. clay clots, alternating dull Gypsum, gry. clay clots, alternating dull white/transparent40Gypsum, gry. clay clots, alternating dull white/transparent	h (	8	
0       00         10       Topsoil, laterite crust, brick red, dense         10       Mottled clay, light to pinkish brn., with pisolites         10       Highly weathered limestone, light yellow brn., muddy appearance         115       Light gry. mudstone to wackstone, abundant microfractures ? calcite filled, crinoid sparse, Karst pit with karst pit with laterite infill         20       Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration         40       Gypsum, gry. clay clots, alternating dull         41       Gypsum, gry. clay clots, alternating dull         420       Mottle/transparent	ept	E	
Image: Second Structure       Topsoil, laterite crust, brick red, dense         Image: Second Structure       Mottled Clay, light to pinkish brn., with pisolites         Image: Second Structure       Highly weathered limestone, light yellow brn., muddy appearance         Image: Second Structure       Light gry. mudstone to wackstone, abundant microfractures ? calcite filled, crinoid sparse, Karst pit with karst pit with laterite infill         Image: Subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration         Image: Subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration         Image: Subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating dull transparent gypsum probably due to diffarent degree of rehydration         Image: Subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating dull         Image: Subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating dull         Image: Subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating dull         Image: Subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating dull         Image: Subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating dull         Image: Subhorizontal beding coarser xtals at top and becoming smaller         Image: Subhorizontal beding coarser		S	
4       dense         5       Mottled clay, light to pinkish brn., with pisolites         10       Highly weathered limestone, light yellow brn., muddy appearance         115       Light gry. mudstone to wackstone, abundant microfractures ? calcite filled, crinoid sparse, Karst pit with karst pit with laterite infill         20       Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration         40       Gypsum, gry. clay clots, alternating dull         41       Gypsum, gry. clay clots, alternating dull         42       Mottle/transparent			Topsoil, laterite crust, brick red,
5       Mottled clay, light to pinkish brn., with pisolites         10       Highly weathered limestone, light yellow brn., muddy appearance         115       Light gry. mudstone to wackstone, abundant microfractures ? calcite filled, crinoid sparse, Karst pit with karst pit with laterite infill         20       Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration         40       Gypsum, gry. clay clots, alternating dull         41       Gypsum, gry. clay clots, alternating dull white/transparent         42       Mottled clay, light to pinkish brn., muddy appearance         43       Gypsum, gry. clay clots, alternating dull         44       Gypsum, gry. clay clots, alternating dull         45       Gypsum, gry. clay clots, alternating dull         46       Gypsum, gry. clay clots, alternating dull         47       Gypsum, gry. clay clots, alternating dull         48       Gypsum, gry. clay clots, alternating dull         49       Gypsum, gry. clay clots, alternating dull         40       Gypsum, gry. clay clots, alternating dull         41       Gypsum, gry. clay clots, alternating dull         42       Gypsum, gry. clay clots, alternating dull         43       Gypsum, gry. clay clots, alternating dull         44 <td></td> <td></td> <td>dense</td>			dense
5       Mottled clay, light to pinkish brn., with pisolites         10       Highly weathered limestone, light yellow brn., muddy appearance         11       Light gry. mudstone to wackstone, abundant microfractures ? calcite filled, crinoid sparse, Karst pit with karst pit with laterite infill         20       Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration         40       Gypsum, gry. clay clots, alternating dull         41       Gypsum, gry. clay clots, alternating dull white/transparent         42       Mottled clay, light to pinkish brn., muddy appearance         43       Gypsum, gry. clay clots, alternating dull         44       Gypsum, gry. clay clots, alternating dull         45       Gypsum, gry. clay clots, alternating dull         46       Gypsum, gry. clay clots, alternating dull         47       Gypsum, gry. clay clots, alternating dull         48       Gypsum, gry. clay clots, alternating dull         49       Gypsum, gry. clay clots, alternating dull         40       Gypsum, gry. clay clots, alternating dull         41       Gypsum, gry. clay clots, alternating dull         42       Gypsum, gry. clay clots, alternating dull         43       Gypsum, gry. clay clots, alternating dull         44 <td></td> <td></td> <td></td>			
Mottled clay, light to pinkish brn., with pisolites Highly weathered limestone, light yellow brn., muddy appearance Light gry. mudstone to wackstone, abundant microfractures ? calcite filled, crinoid sparse, Karst pit with Karst pit with laterite infill Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration Gypsum, gry. clay clots, alternating dull Gypsum, gry. clay clots, alternating dull white/transparent	_5		
<ul> <li>Focue City, light to printshift brn., with pisolites</li> <li>Highly weathered limestone, light yellow brn., muddy appearance</li> <li>Light gry. mudstone to wackstone, abundant microfractures ? calcite filled, crinoid sparse, Karst pit with Karst pit with laterite infill</li> <li>Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration</li> <li>Gypsum, gry. clay clots, alternating dull</li> <li>Gypsum, gry. clay clots, alternating dull</li> <li>white/transparent</li> </ul>		1 1 1	Mottled clay, light to pinkish
<ul> <li>Highly weathered limestone, light yellow brn., muddy appearance</li> <li>Light gry. mudstone to wackstone, abundant microfractures ? calcite filled, crinoid sparse, Karst pit with Karst pit with laterite infill</li> <li>Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration</li> <li>Gypsum, gry. clay clots, alternating dull</li> <li>Gypsum, gry. clay clots, alternating dull white/transparent</li> </ul>		± ± ± ±	brn with pisolites
<ul> <li><sup>10</sup></li> <li><sup>11</sup>Highly weathered limestone, light yellow brn., muddy appearance</li> <li>Light gry. mudstone to wackstone, abundant microfractures ? calcite filled, crinoid sparse, Karst pit with Karst pit with laterite infill</li> <li><sup>26</sup></li> <li><sup>36</sup></li> <li><sup>37</sup></li> <li><sup>38</sup></li> <li><sup>39</sup></li> <li><sup>39</sup></li> <li><sup>39</sup></li> <li><sup>30</sup></li> <li><sup>30</sup></li> <li><sup>31</sup></li> <li><sup>31</sup></li> <li><sup>32</sup></li> <li><sup>33</sup></li> <li><sup>34</sup></li> <li><sup>35</sup></li> <li><sup>35</sup></li> <li><sup>36</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>38</sup></li> <li><sup>39</sup></li> <li><sup>39</sup></li> <li><sup>39</sup></li> <li><sup>30</sup></li> <li><sup>31</sup></li> <li><sup>31</sup></li> <li><sup>32</sup></li> <li><sup>34</sup></li> <li><sup>35</sup></li> <li><sup>35</sup></li> <li><sup>35</sup></li> <li><sup>36</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>38</sup></li> <li><sup>39</sup></li> <li><sup>39</sup></li> <li><sup>39</sup></li> <li><sup>39</sup></li> <li><sup>31</sup></li> <li><sup>31</sup></li> <li><sup>32</sup></li> <li><sup>34</sup></li> <li><sup>35</sup></li> <li><sup>35</sup></li> <li><sup>37</sup></li> <li><sup>36</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>38</sup></li> <li><sup>39</sup></li> <li><sup>39</sup></li> <li><sup>39</sup></li> <li><sup>39</sup></li> <li><sup>31</sup></li> <li><sup>32</sup></li> <li><sup>34</sup></li> <li><sup>35</sup></li> <li><sup>35</sup></li> <li><sup>35</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>38</sup></li> <li><sup>39</sup></li> <li><sup>39</sup></li> <li><sup>31</sup></li> <li><sup>31</sup></li> <li><sup>32</sup></li> <li><sup>34</sup></li> <li><sup>35</sup></li> <li><sup>35</sup></li> <li><sup>35</sup></li> <li><sup>35</sup></li> <li><sup>37</sup></li> <li><sup>36</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>37</sup></li> <li><sup>38</sup></li> <li><sup>39</sup></li> <li><sup>39</sup></li> <li><sup>39</sup></li> <li><sup>31</sup></li> <li><sup>31</sup></li> <li><sup>32</sup></li> <li><sup>35</sup></li> <li><sup>35</sup></li> <li><sup>35</sup></li> <li><sup>35</sup></li> <li><sup></sup></li></ul>		1 × 1	brit, with pisolites
<ul> <li><sup>15</sup></li> <li><sup>16</sup></li> <li><sup>17</sup></li> <li><sup>18</sup></li> <li><sup>19</sup></li> <li><sup>19</sup></li> <li><sup>19</sup></li> <li><sup>19</sup></li> <li><sup>19</sup></li> <li><sup>10</sup></li> <li><sup>10</sup></li> <li><sup>10</sup></li> <li><sup>10</sup></li> <li><sup>11</sup></li> <li><sup>11</sup></li> <li><sup>11</sup></li> <li><sup>11</sup></li> <li><sup>11</sup></li> <li><sup>11</sup></li> <li><sup>11</sup></li> <li><sup>11</sup></li> <li><sup>11</sup></li> <li><sup>12</sup></li> <li><sup>11</sup></li> <li><sup>11</sup></li> <li><sup>11</sup></li> <li><sup>12</sup></li> <li><sup>11</sup></li> <li><sup>11</sup></li> <li><sup>12</sup></li> <li><sup>11</sup></li> <li><sup>12</sup></li> <li><sup>11</sup></li> <li><sup>12</sup></li> <li><sup>11</sup></li> <li><sup>12</sup></li> <li><sup>12</sup></li> <li><sup>14</sup></li> <li><sup>14</sup></li> <li><sup>15</sup></li> <li><sup>15</sup></li> <li><sup>16</sup></li> <li><sup>16</sup></li> <li><sup>17</sup></li> <li><sup>17</sup></li> <li><sup>17</sup></li> <li><sup>17</sup></li> <li><sup>18</sup></li> <li><sup>19</sup></li> <li><sup>19</sup></li> <li><sup>19</sup></li> <li><sup>10</sup></li> <li><sup>11</sup></li> <li><sup>12</sup></li> <li><sup>12</sup></li> <li><sup>14</sup></li> <li><sup>14</sup></li> <li><sup>14</sup></li> <li><sup>15</sup></li> <li><sup>15</sup></li> <li><sup>15</sup></li> <li><sup>16</sup></li> <li><sup>17</sup></li> <li><sup>17</sup></li> <li><sup>17</sup></li> <li><sup>17</sup></li> <li><sup>17</sup></li> <li><sup>18</sup></li> <li><sup>19</sup></li> <li><sup>19</sup></li> <li><sup>11</sup></li> <li< td=""><td>_ 10</td><td>1 × 1 × 1</td><td></td></li<></ul>	_ 10	1 × 1 × 1	
<ul> <li>Highly weathered limestone, light yellow brn., muddy appearance</li> <li>Light gry. mudstone to wackstone, abundant microfractures? calcite filled, crinoid sparse, Karst pit with Karst pit with laterite infill</li> <li>Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration</li> <li>Gypsum, gry. clay clots, alternating dull</li> <li>Gypsum, gry. clay clots, alternating dull</li> <li>Mite/transparent</li> </ul>		1 1 1 1 1 1 1	
115       Highty weathered limestone, light yellow brn., muddy appearance         200       Light gry. mudstone to wackstone, abundant microfractures? calcite filled, crinoid sparse, Karst pit with Karst pit with laterite infill         201       Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration         201       Gypsum, gry. clay clots, alternating dull         202       Gypsum, gry. clay clots, alternating dull white/transparent		1 + 1 · · · ·	10.11
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appearance         Light gry. mudstone to         wackstone, abundant         microfractures ? calcite filled,         crinoid sparse, Karst pit with         Karst pit with laterite infill         Gypsum, alabaster, wiggle         subhorizontal beding coarser         xtals at top and becoming         smaller downward, Alternating         bands of dull ahite and         transparent gypsum probably         due to diffarent degree of         rehydration         Gypsum, gry. clay clots,         alternating dull         Gypsum, gry. clay clots,         alternating dull         white/transparent         %	0		light yellow brn., muddy
Light gry. mudstone to wackstone, abundant microfractures ? calcite filled, crinoid sparse, Karst pit with Karst pit with laterite infill Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration Gypsum, gry. clay clots, alternating dull Gypsum, gry. clay clots, alternating dull Gypsum, gry. clay clots, alternating dull mite/transparent			appearance
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<ul> <li>microrractures ? calcte filled, crinoid sparse, Karst pit with Karst pit with laterite infill</li> <li>Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration</li> <li>Gypsum, gry. clay clots, alternating dull</li> <li>Gypsum, gry. clay clots, alternating dull white/transparent</li> </ul>	_20	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	wackstone, abundant
<ul> <li>Crinoid sparse, Karst pit with Karst pit with laterite infill</li> <li>Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration</li> <li>Gypsum, gry. clay clots, alternating dull</li> <li>Gypsum, gry. clay clots, alternating dull white/transparent</li> </ul>		1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	microfractures ? calcite filled,
<ul> <li>Karst pit with laterite infili</li> <li>Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration</li> <li>Gypsum, gry. clay clots, alternating dull</li> <li>Gypsum, gry. clay clots, alternating dull</li> <li>white/transparent</li> </ul>	a i		crinoid sparse, Karst pit with
<ul> <li><sup>225</sup></li> <li><sup>236</sup></li> <li><sup>337</sup></li> <li><sup>338</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>331</sup></li> <li><sup>335</sup></li> <li><sup>335</sup></li> <li><sup>336</sup></li> <li><sup>336</sup></li> <li><sup>337</sup></li> <li><sup>337</sup></li> <li><sup>338</sup></li> <li><sup>338</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>331</sup></li> <li><sup>335</sup></li> <li><sup>331</sup></li> <li><sup>335</sup></li> <li><sup>335</sup></li> <li><sup>336</sup></li> <li><sup>336</sup></li> <li><sup>337</sup></li> <li><sup>337</sup></li> <li><sup>337</sup></li> <li><sup>338</sup></li> <li><sup>338</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>331</sup></li> <li><sup>335</sup></li> <li><sup>335</sup></li> <li><sup>335</sup></li> <li><sup>336</sup></li> <li><sup>336</sup></li> <li><sup>337</sup></li> <li><sup>337</sup></li> <li><sup>337</sup></li> <li><sup>337</sup></li> <li><sup>338</sup></li> <li><sup>338</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>331</sup></li> <li><sup>331</sup></li> <li><sup>331</sup></li> <li><sup>332</sup></li> <li><sup>335</sup></li> <li><sup>335</sup></li> <li><sup>335</sup></li> <li><sup>335</sup></li> <li><sup>335</sup></li> <li><sup>335</sup></li> <li><sup>335</sup></li> <li><sup>335</sup></li> <li><sup>335</sup></li> <li><sup>336</sup></li> <li><sup>336</sup></li> <li><sup>337</sup></li> <li><sup>337</sup></li> <li><sup>337</sup></li> <li><sup>337</sup></li> <li><sup>338</sup></li> <li><sup>338</sup></li> <li><sup>337</sup></li> <li><sup>337</sup></li> <li><sup>338</sup></li> <li><sup>338</sup></li> <li><sup>339</sup></li> <li><sup>339</sup></li> <li><sup>331</sup></li> <li><sup>335</sup></li> <li><sup>336</sup></li> <li><sup>336</sup></li> <li></li></ul>		-00	Karst pit with laterite infill
<ul> <li>Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration</li> <li>Gypsum, gry. clay clots, alternating dull</li> <li>Gypsum, gry. clay clots, alternating dull white/transparent</li> </ul>	_ 25	÷ ÷ ÷ ÷ ÷	
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<ul> <li><sup>35</sup></li> <li><sup>36</sup></li> <li><sup>37</sup></li> <li><sup>38</sup></li> <li><sup>39</sup></li> <li><sup>39</sup></li> <li><sup>40</sup></li> <li><sup>40</sup></li> <li><sup>40</sup></li> <li><sup>41</sup></li> <li><sup>40</sup></li> <li><sup>40</sup></li> <li><sup>41</sup></li> <li><sup>40</sup></li> <li><sup>41</sup></li> <li><sup>42</sup></li> <li><sup>42</sup></li> <li><sup>43</sup></li> <li><sup>44</sup></li> <li><sup>44</sup></li> <li><sup>44</sup></li> <li><sup>44</sup></li> <li><sup>45</sup></li> <li><sup>45</sup></li> <li><sup>45</sup></li> <li><sup>45</sup></li> <li><sup>46</sup></li> <li><sup>46</sup></li> <li><sup>47</sup></li> <li><sup>47</sup></li> <li><sup>48</sup></li> <li><sup>50</sup></li> <li><sup>50</sup></li> <li><sup>50</sup></li> <li><sup>51</sup></li> <li><sup>52</sup></li> <li><sup>53</sup></li> <li><sup>54</sup></li> <li><sup>55</sup></li> <li><sup>56</sup></li> <li><sup>57</sup></li> <li><sup>58</sup></li> <li><sup>59</sup></li> <li><sup>59</sup></li> <li><sup>59</sup></li> <li><sup>50</sup></li> <li><sup>50</sup></li> <li><sup>50</sup></li> <li><sup>51</sup></li> <li><sup>52</sup></li> <li><sup>53</sup></li> <li><sup>54</sup></li> <li><sup>55</sup></li> <li><sup>56</sup></li> <li><sup>57</sup></li> <li><sup>57</sup></li> <li><sup>58</sup></li> <li><sup>59</sup></li> <li><sup>59</sup></li> <li><sup>59</sup></li> <li><sup>59</sup></li> <li><sup>50</sup></li> <li><sup>51</sup></li> <li><sup>52</sup></li> <li><sup>53</sup></li> <li><sup>54</sup></li> <li><sup>55</sup></li> <li><sup>54</sup></li> <li><sup>55</sup></li> <li><sup>56</sup></li> <li><sup>57</sup></li> <li><sup>57</sup></li> <li><sup>58</sup></li> <li><sup>59</sup></li> <li><sup>59</sup></li> <li><sup>59</sup></li> <li><sup>59</sup></li> <li><sup>50</sup></li> <li><sup>51</sup></li> <li><sup>52</sup></li> <li><sup>53</sup></li> <li><sup>54</sup></li> <li><sup>55</sup></li> <li><sup>55</sup></li> <li><sup>56</sup></li> <li><sup>57</sup></li> <li><sup>57</sup></li> <li><sup>58</sup></li> <li><sup>59</sup></li> <li><sup>59</sup></li> <li><sup>59</sup></li> <li><sup>51</sup></li> <li><sup>52</sup></li> <li><sup>53</sup></li> <li><sup>54</sup></li> <li><sup>55</sup></li> <li><sup>55</sup></li> <li><sup>55</sup></li> <li><sup>56</sup></li> <li><sup>57</sup></li> <li><sup>58</sup></li> <li><sup>59</sup></li> <li><sup>59</sup></li> <li><sup>51</sup></li> <li><sup>51</sup></li> <li><sup>52</sup></li> <li><sup>53</sup></li> <li><sup>54</sup></li> <li><sup>55</sup></li> <li><sup>55</sup></li> <li><sup>55</sup></li> <li><sup>56</sup></li> <li><sup>56</sup></li> <li< td=""><td></td><td>1 · · ·</td><td></td></li<></ul>		1 · · ·	
Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration Gypsum, gry. clay clots, alternating dull Gypsum, gry. clay clots, alternating dull white/transparent		_ +	
<ul> <li>Gypsum, alabaster, wiggle subhorizontal beding coarser xtals at top and becoming smaller downward, Alternating bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration</li> <li>Gypsum, gry. clay clots, alternating dull</li> <li>Gypsum, gry. clay clots, alternating dull white/transparent</li> </ul>	-	1 <u>+ +</u>	
Subirizontal bedring coarser         xtals at top and becoming         smaller downward, Alternating         bands of dull ahite and         transparent gypsum probably         due to diffarent degree of         rehydration         45         50         Gypsum, gry. clay clots,         alternating dull         Gypsum, gry. clay clots,         alternating dull         Gypsum, gry. clay clots,         alternating dull         white/transparent         .60         .65         .70	_ 35		Gypsum, alabaster, wiggle
40       Alternating         40       smaller downward, Alternating         41       bands of dull ahite and         42       transparent gypsum probably         43       due to diffarent degree of         45       Gypsum, gry. clay clots,         46       Gypsum, gry. clay clots,         47       Gypsum, gry. clay clots,         48       Gypsum, gry. clay clots,         49       white/transparent         40       white/transparent			subhorizontal bearing coarser
<ul> <li><sup>40</sup> bands of dull ahite and transparent gypsum probably due to diffarent degree of rehydration</li> <li><sup>50</sup> Gypsum, gry. clay clots, alternating dull</li> <li><sup>53</sup> Gypsum, gry. clay clots, alternating dull white/transparent</li> <li><sup>66</sup> Gypsum, gry. clay clots, alternating dull</li> </ul>			smaller downward Alternating
<ul> <li>transparent gypsum probably due to diffarent degree of rehydration</li> <li>Gypsum, gry. clay clots, alternating dull</li> <li>Gypsum, gry. clay clots, alternating dull white/transparent</li> <li>white/transparent</li> </ul>	40		bands of dull ahite and
due to diffarent degree of rehydration Gypsum, gry. clay clots, alternating dull Gypsum, gry. clay clots, alternating dull white/transparent			transparent gypsum probably
<ul> <li>rehydration</li> <li>Gypsum, gry. clay clots, alternating dull</li> <li>Gypsum, gry. clay clots, alternating dull white/transparent</li> <li>white/transparent</li> </ul>			due to diffarent degree of
<ul> <li><sup>45</sup></li> <li><sup>50</sup></li> <li><sup>50</sup></li> <li><sup>50</sup></li> <li><sup>51</sup></li> <li><sup>53</sup></li> <li><sup>60</sup></li> <li><sup>65</sup></li> <li><sup>70</sup></li> </ul>			rehydration
Gypsum, gry. clay clots, alternating dull Gypsum, gry. clay clots, alternating dull white/transparent	45		
Gypsum, gry. clay clots, alternating dull Gypsum, gry. clay clots, alternating dull white/transparent			
50       Gypsum, gry. clay clots, alternating dull         Gypsum, gry. clay clots, alternating dull         60         60         60         70			
<ul> <li><sup>50</sup> alternating dull</li> <li>Gypsum, gry. clay clots, alternating dull white/transparent</li> <li><sup>60</sup></li> <li><sup>60</sup></li> <li><sup>65</sup></li> <li><sup>70</sup></li> </ul>			Gypsum, gry. clay clots,
Gypsum, gry. clay clots, alternating dull white/transparent	_ 50		alternating dull
alternating dull white/transparent			Gypsum, gry. clay clots,
<ul> <li>white/transparent</li> <li>white/transparent</li> <li>white/transparent</li> </ul>			alternating dull
.60	55		white/transparent
.66	_ 00		
.60 .65			
.60 .65			
.65	_ 60		
.65	- m 128) 1)		
.65			
.65			
70	_ 65		
.70			
70			
70			
	_70		



Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
		Laterite crust, hard and
_5		becoming softer around 4 m. downward, more clayey material
		Yellow to mattled clay with lower pisolite concretion
_ 10		Highly-fractured but well-sealed by secondary calcite filling, wackestone to mudstone,
15		probably metamorphosed, original stc. obliterated, crinoid vertical stylolites
		common
_20	100000	Breccia zone, framework dominantly siliciclastics, fine -
	10000000000000000000000000000000000000	grianed, grn gry., brn. to light brn. matrix
_ 25		Fine - grain sandstone gry. grn. to be locally, alternating with
		calc except between 31-34 ? finely to wavy lam, mudstone
_ 30	Ē	45? dipping
_ 35		Alabaster.grv, white sharp
		Anhydrite,gry., dense
40		
_ 45		
50		



Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
-		Laterite crust, brick red, hard, Anhydrite fragment at 3.5 m.?
5  10 		Becoming more clayey downward, and more yellowsh, rock fragments ? limestone mostly
- 15    20		Alternating zones of limestone fragments and clayey matial
-		Yellow grn., carb mudstone, highly - fractured but sead, prominent karst pits as marked
25 		"Exposed"
35 - - - - 40 - -		
- 45 - _ 50		



E LITHOLOGIC DESCRIPTIC (rock type, joint infilling, join roughness, etc.)	N It
Laterite crust, 4-5 m. thick,	
with still more concretion and rock fragment down to 10 m	1
Mottled clay, yel brn	
Sandy clay, yel brn to light b	'n
- 🧼 Rock fragment in gry. clay	
Algal boundstone,dark gry., wavy lam	
Light brn., exposed limestone original stc. obliterated	2,
wackstone, slightly matamorphosed, vuggy due dissolution? Iron - stained	to
_40 Ilikely algal boundstone original" ckl.	_
45	
-	
50	



Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
-	• • • • • • • • •	Laterite crust ~ 3 m. thick,
-	°*•••°	Zone of rock fragments
10 		Mottled clay yellow brn.
_	° ° ° ° °	Zone of rock fragments, brick
15 		red sandstone common Alabaster gypsum, translucent white
- 20		
-		
_		
25		
_		
-		
- 30		
_		Anhydrite, uniform grysum, variable bedding from 45-70?
35		
-		
40		
-		
-		
45 		
-		
50		



		LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint
Depth (m)	Symbols	roughness, etc.)
5		Greenish gry. clay, slightly mottled
-		Zone of rock fragments with a few iron mineral ? hematite?
10 	0	Alabaster gypsum, gry. white, usuallly very vagve lam. At 13, wavy and vertically oriantal lam. distimetively bisher
15 		content of carb clasts
20 		
25 		
- 30 - 		Transition zone, dominanty anh with gypsum along fractures dull white alternating with transparent gypsum
35   		
40 		
- 45 -		
- 50		



	Ĩ I	
		LITHOLOGIC DESCRIPTION
-		(rock type, joint infilling, joint
E	S	roughness, etc.)
÷	q	
be	Nu	
	0)	
	· · · ·	Laterite crust, hard, reddish
	•••••	brown
_	· · · ·	
-8	• • • • • •	
-2	· · · ·	
_ 5	• • •	
-22	· · · · ·	
	°., °.	
	0.000	Mottled clay yellow brn. with
		some pisolites and rock
40	0,000	fragments
10	0 0 0 0	
-	° ° ° °	
-3	0000	
		Alabaster gypsum, grysum
-		white, veriation in crrvstal sizes
_ 15		
20		
-8		
-1		
-		
25		
		Transition zone 1.2 m.
Ē.	**************************************	
-		Alabaster gypsum, grysum
-		white, veriation in crrystal sizes
-		
30		
-2		
-		
-0		
35		
<b></b>		
-2		
-1		
40		
L		
-		
45		
-		
H.		
-10		
L		
50		
	A . A . A .	



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Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
-		Topsoil, brown,sandy
_ 5 _		Laterite crust, dark brn., paler colour ? yellow brown near base, Mottled clay, yellow brn. and white, sandy with small gypsum blebs and rock fragments ? tuff
_ 10 _	8 9 8 9 8 9 8 9 8 9 8 9 8 9 8 9 8 9 8 9	Mixture of rock fragments ? carb mudstone, carb breccia, reddish brn. sandstone of medium grain; yellow brn. to brn. clay,
_ 15 _ _ _		Very low carb, clay content in form of lamination
20    25		
- - - 30		
_ 35 		X-cutting relationship bewteen phasses and lam, lam more broken-up sharp changess anhvdrite/avnsum: transition Dull white anhydrite, probably gypsum/anhydrite mixture, but still heavy, broken - up lam, extraordinary coarse xtals, Closer spacing of lam from 42.5 - 43.5, sub angular carb clasts present but not as abundant as in WP-23



Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Topsoil, sandy with clay, dark brown, containing gypsum Semi-consolidated laterite crust, reddish to dark brn., larger concretion in the middle and grades downward to vellow Mixture of lst boulders and tel. brn. clay, dissolution walls in boulder, algal boundstone, laterite concretion
25 30 35 35 40 45 		Alabaster gypsum dull to light grayish white, gently inclined bedding
50 55 60 		Remnant anhydrite bands Thin zone of gypsum/anhydrite alternation, cross-cutting relationship between gypsum/anhydrite bands and Interval 56-76 dominates by
70 70 75 80 85	9 10 10 10 10 10 10 10 10 10 10 10 10 10	Collonge brogging 2 light and
90	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Collapse breccias ? light gry. mud containg breccias of carb mudstone, "vuggy" limestone,



Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
-		Laterite crusts, dark red
- - - -		Rock fragments and clay mixture
10  15 		Collapse, limestone clasts in mud, light gry. ~ 17 a chunk of dark gry. mudstone with fluidize features
20 		Metamorphosed limestone,rex., light gry.
25  		
30  		
35  		
40  		
45  		



Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
_ _ 5		Topsoil, light grn. brn. Lateritic and mottled clay, consolidated in first meter
- - - - - - - - - - - - - - - - - - -		Mttled cly., brn. to light yellow brn. becoming paler ? light grn. Gry. at base angular rock fragments in particular intervals
_ 30		Carb mudstone, light gry., stylolite, containing some oncoids and probably ooids
Ē		Semi-consolidated mixture of
		limestone, sandstone (grn gry)
- 35 -		in ma, ? coolapsse, pale grn.
-		
-		
40		Karstified, stained, carb mdst
-		
-		
_ 45		
_		
-		
_ 50	2442	



		LITHOLOGIC DESCRIPTION
		(rock type, joint infilling, joint
E	<u>s</u>	roughness, etc.)
맞	pd	
Dep	yn	
	0)	
	ရက်ပုံးရက် စန်းပြားစာနံ	Highy - weathered and Fe -
10	ရက်လုံးရက် စဉ်းပါးဆန်	staine, carb mudstone, locally
	Ŷŕ¢'nŶŕ	algal boundstone, yellow brn.
	tir on tir	or pinkish, badly broken due to
-	စစ္ မျဖစ္ ရက္ခ်က္ရက္ရက္ရ	karstification from 31 -34 semi
_ 5	후 후 마마 후 우리가 가구가 우리	- consolidated mixture of large
-	- Adam (A	clasts and sand - sized in
-	e i konst e konst k	muddy matrix
-	a¢iyina¢i a¢¢ono¢it	
10	1 y 12 j	
	a in frank in a fri frank fr	
-	144.14	
-	a state	
-	144.94	
15	i feirif	
-	α¢ιγια¢ φ¢φαφφ	
	a di bina di Sulici na di	
	≈ ¢ i k i i i i i	
	a di bina di a di bina di	
20		
	= ∳ :  , == ∲	
-	e à chine à	
-	စု ရက်ကာစု ဖ စစ်၊ မှားစာစု	
-	ခုန်းရုံးရုံးဆွေးနှ ခု ရ ၊ ရ ၊ ရ န	
-	र्वविक्रिड्वे इ.स.	
_25	ទុំទៅលុះទៅទេ	
-	ခ စုံးမှုံးအ စု စုံးချီးပုံးအစိုးခ	
-	ခ ခုံးမှားဆန် ခုံးချီးရုံးဆွေးနှ	
-	ခ ခုံးမှားဆွေန ခုံးချီးရုံးဆွေးခု	
-	و مانغاني و مانغاني	
_ 30		
-		
-	91910-919 2919-029	
_	ရားနားရားဆွေးနှ စ ရဲ ၊ မူးစာ စု	
_	ရက်ကို အရက် ခြောက်ကြောင်းခြ	
35	rining a	
	e done d	
	မှ နှင့်သူတွေ မှ နှင့်သူတွေ	
-	२ २ १ १ मार्ड ने इन्हें की ज्वान	
	ခန်းမှုံးဆွေနဲ့ ရက်လုံးရက်နဲ့	
-	e A , lune A e di Quee d	Mdst and carb mdst dark and
_ 40	e¢iķine¢ ¶i¢iuqi¢	to black locally organic - rich
-53	م م بين الم م بين م الم	oncoid crinoid laver showing
	≈‡:¢ic≈‡	30? bedding mdst touds to be
-	e ji ture j	massive but varue lam ~202
-	ရာက်လုံးရောက် စန်းပုံးစာန	can be seen small opcoid
_ 45	နှင့်နှင့် မြောင် နှင့် ပြင်သည်	crinoid at base
_	e de conserve	
	မှ မှ မှ ကျောင် ရက်နှင့်ကျောင်	
- 55	ခန်းမိုးဆန် စိုးနိုင်းလွှုံးနှ	
	ទទំរប់ទទំន ទំរប់ទំរបទ់ទៅ	
	e e lyne e	
FO	10.100.0 House	



		<u></u>
_		LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint
E	ols	roughness, etc.)
epth	dm,	
ă	S	
-	12,12	Topsoil, lateritic
-	122	
	24.00	Laterite crust, quite dense,
_5	•••••	brick red
-	••••	
-	tiinti Aastaa	Conglomeratic lst. framework ?
		op to 2 cm., stylolite surfaecs
_ 10	8.692° 8.5	70? inclined oncoids locally,
F	Anton An	childo
[	11111 18:15-16 - 81o	
-	85016786 - 880	
_ 15		
Ē	111511 11151 8.458 8.	
-	11111 8,618 8,6	
-	8.001° 8.0	
20	Serie at the	
	Moth al. Ma	
-	19071-11 89o	
25		
-	21010 10 010 	
-	alleys 15 - 690	
Ē		Carb mudstone, light grn., thin
_ 30		layers of oncoid - bearing
-	542954 545555 545555	limestone, framework
		lenticular, poorly sortted
2		
35		F.g. sandstone and dark gry mudstone, abrupt change in
-		colour from gry to black,
		apparently sharp change from limestone to mdst too. Mdst is
-		feature less
_ 40		
_		
-		Carb mdst with sst interbeds, in
-		sandstone around 45.7 rip-up
- "		sandstone matrix, bedly
-		broken, vertical lam (not reliable) just above 49 lst
-		conglomerate, pinkish ?
50		recvorked



·		
Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
-	••••	Topsoil, brn to. dark brn., gyp
	•	DIEDS
-	· · ·	
 	• • •	
-	° ° °	
10		
- 1	1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1	Carb mdet alternated with thin
		f.g.sst, grn gry or massive non
15	· · · ·	- clac, mdst
-		
_		
20	· · · · · · · · · · · · · · · · · · ·	
	1 - 1 1 - 1 1 - 1	Intraclasts , light grn gry non-
-	· · · · ·	calc mdst, ? 2-3bcm. (slide)
25	1 1 1 1 1 1 1 1	some are mely-lam
_	· · · ·	
-	1 <sup>1</sup> 111	
30	1 + 1 1 + 1 1 + 1	
-	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
_	1 1 1 1 1 1 1 1 1 1 1 1 1 1	
35	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
-	· · · · · · · · · · · · · · · · · · ·	
-	1 - 1 1 - 1 1 - 1	
40	1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	
-	1 1 1 1 1 1 1 1 1 1 1 1	
-		and here as non-more survey and here
_ 45		Alabaster gypsum, curved topo top grn mud clasts
-		
-		
_ 50		
-		
-		
- 55		
-		
-		
- 00		
- 60		



Depth (m)	Symbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
5		Topsoil, dark brn to almost black
15 20 25 30		Sandy clay with rock fragments,brn. limestrone float rocks
35		Alabaster gypsum
40 45 		_carb musdstone, finely-lam
50	0.0	Karstified and filled with semi-
- - 55 -		Laminated carb mudstone, alternated with fig to medium grain sandstone, light grn. gry.
60 65		Mudstone,gry., massive and wavy-lam, low-angle lam
70		bioturbation
75 		
85		
90		plane bed with mud clasts bioturbation or fluidization
95 		evidence of karstification, Fe- staining more fregment
105 110		



epth (m)	ymbols	LITHOLOGIC DESCRIPTION (rock type, joint infilling, joint roughness, etc.)
	S	Mattle datase tone collections
5		Mottled clay, brn. yellow, gry.
-		Prominent laterite layer, drak brn., Lateritic clay and small amount of rock fragments
10 		Mudstone, light bluish gry, featureless, with thin intercalation of f.g. sandstone,
15 		light grn. gry., Some finely lam (mm-scale) present fragmently
- 20 		
_ 25		
_ _ 30		
- - - 35 -		Alabaster gypsum, gry. white, thin carb lam, thick clots locally ? the carb clots are finely-lam, tear-apart during expansion
- 40		
- - 45		
- - 50		
- 55 -		Mudstone, alternation massive, non - calc, anhydrite lam. carb mudstone ? thin zone , wiqqling, similar to 37.5
60		are data a children anno 1



Biography



## **Biography**

Name		Sathaporn Kavinate
Date of brith		22 January 1976
Place of birth		Lamphun Province, Thailand
Institution at	tended	
	1993	Secondary Education, Theerakarn Banhong School,
	1998	Bachelor of Science (B.Sc.) Geology, Chiang Mai University
	2018	Master of Science (M.Sc.) Palaeontology,
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## **Research output**

- Fontaine H, Kavinate S, Hoang TT and Vachard D. (2012). Permian Limestone of Peninsular and Western Thailand in Khao Yoi, Chaam and Thong Pha Phum Areas. *Nat. Hist. Bull. Siam Society.* Bangkok, 58, 39-47.
- Fontaine H, Hoang TT, Kavinate S, Suteethorn V and Vachard D. (2013). Upper Permian (Late Changhsingian) marine strata in Nan Province, northern Thailand. *Journal of Asian Earth Sciences*. 76(2013), 115-119.
  - . (2013). Wide Extension of Carboniferous Limestone in Northwest Thailand with an Interesting Stratigraphy. *Journal of The Geological Society of Thailand* (*GST*). Special Issue, 65.

