

CARBONIFEROUS CORALS OF PANG MAPHA DISTRICT, NORTHWEST THAILAND

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ABSTRACT

Abundant Carboniferous corals have been described in Central Thailand (Noen Maprang to Chon Daen area west of Phetchabun) and Northeast Thailand (Loei and Nong Bua Lamphu Provinces) (FONTAINE *ET AL.*, 1991). They were previously unknown in Northwest Thailand where limestone exposures were commonly assigned to the Permian. Since then, Carboniferous fossils have been discovered at many limestone localities of Northwest Thailand and corals have been collected mainly in Pang Mapha District (District established in 1997 with its administration offices built near Sop Pong Village). In fact, Carboniferous limestone is widespread in Northwest Thailand and spans the whole Carboniferous (FONTAINE *ET AL.*, 1993). New and more detailed information on the corals is given in this paper.

Corals are common in the Lower Carboniferous limestones of Northwest Thailand. They consist mainly of Tabulata (*Syringopora* is widespread) and diverse solitary Rugosa (*Arachnolasma*, *Kueichouphyllum* and others). Compound Rugosa locally occur and are sporadically in abundance. They consist of fasciculate corals (*Solenodendron*, *Diphyphyllum*); massive Rugosa have not been encountered up to now. At some localities, the corals are fragments accumulated by water currents. Elsewhere, they are better preserved.

Middle Carboniferous limestone containing solitary Rugosa (*Caninophyllum*, *Bothrophyllum* and others) occurs at a few localities of Northwest Thailand. Tabulata are very rare and consist of massive corals (*Chaetetes*) and fasciculate corals (*Multithecopora*).

A small number of Upper Carboniferous limestone exposures have been studied. Corals are extremely rare in these places.

Key words: Karst topography, Limestone, Rugosa, Tabulata, Moscovian, Viséan-Serpukhovian

STUDY AREA

Fossil hunters get landscape shock when they arrive in the district of Pang Mapha in Mae Hong Son Province (Fig. 1). Limestone exposures are very widespread. Karstic topography with castellated hills and deep sinkholes does not help the geological research, but it provides wonderful landscapes (Figs. 2 and 3), an immediate enchantment even during a first trip in the region (FONTAINE *ET AL.*, 1987). In addition, caves are common and many attract tourists; they are locally followed by underground rivers. Many caves have been investigated by archaeologists, especially during the last 10 years. In the distant past, they were significant places of human activity, temporary or permanent habitation sites, and occasionally burial

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sites. They contain tools, pottery, bones and rock paintings. This prehistoric material includes stone tools as old as 12,500 years in the lowest levels. In the more recent layers, iron tools have been found. TREERAYAPIWAT (2005) gives information on excavations carried out at a rock shelter near Ban Huai Rai, a village along the Lang River 3.5 km west of Pang Mapha. Other localities of the Pang Mapha District have been studied, for instance Tham Lod (unpublished reports of Silpakorn University). In addition to the wonderful prehistoric remains, limestone hills and caves are “important biodiversity hotspots” (SRIKOSAMATARA *ET AL.*, 2004). People living in Amphoe Pang Mapha area belong to several tribes; they increase the interesting diversity of this region.

Southwest of Amphoe Pang Mapha or Ban Sop Pong, limestone, hundreds of meters thick, forms a plateau oscillating between 1,000 and 1,300 m in elevation above sea level, extending over at least 130 km². The topography is characterized by the absence of valley and surface drainage, but by the presence of many dolines (sinkholes). Few people live in the area. Streams appear around the area, starting at elevations ranging from 600 to 950 m. Susa Waterfall, 9 km south of Ban Mae Suya, is an important underground stream coming out at the foot of a limestone cliff and falling into Khong River. In other areas north and northwest of Pang Mapha, rivers appear, but shortly disappear into holes or seep slowly into the soil. Many surprises await the visitor.

In 1970, the general understanding of the geology of northern Thailand was: “The Carboniferous is in its lower part distinct flysch facies, followed by a mainly basic volcanic section. The Upper Carboniferous is represented by locally terrestrial deposits and overlapping reef-limestone” (BAUM *ET AL.*, 1970). The limestone was assigned mainly to Permian. The recent paleontological results in the district of Pang Mapha show that limestone also represents the Lower, Middle and Upper Carboniferous (FONTAINE *ET AL.* 1993, 2005, and unpublished data).

DESCRIPTION OF THE CORALS

During the Carboniferous, marine shallow water environments with diverse faunas characterized the Amphoe Pang Mapha area. Green algae were common. Corals flourished when conditions were good, for instance with clean and well aerated water. Some corals had a simple horn-shaped form (solitary *Rugosa*); other corals were compound and branching (fasciculate *Rugosa* and most of the *Tabulata*). Massive corals appear to be very rare in the Pang Mapha area.

Solitary *Rugosa*

Solitary corals are commonly scattered and in a small number, with a diameter of 2 cm at the maximum. Very locally, they are in abundance or display larger diameters. They are not always very well preserved; because of that, it is difficult to identify all the species occurring in the Pang Mapha area.

LOPHOPHYLLIDAE Grabau, 1928

Some fragments of very simple solitary corals without dissepiments have been found west of Ban Pha Phueak (19° 38' 59.7"N, 98° 12' 15.3"E; samples T9546 and T9547).

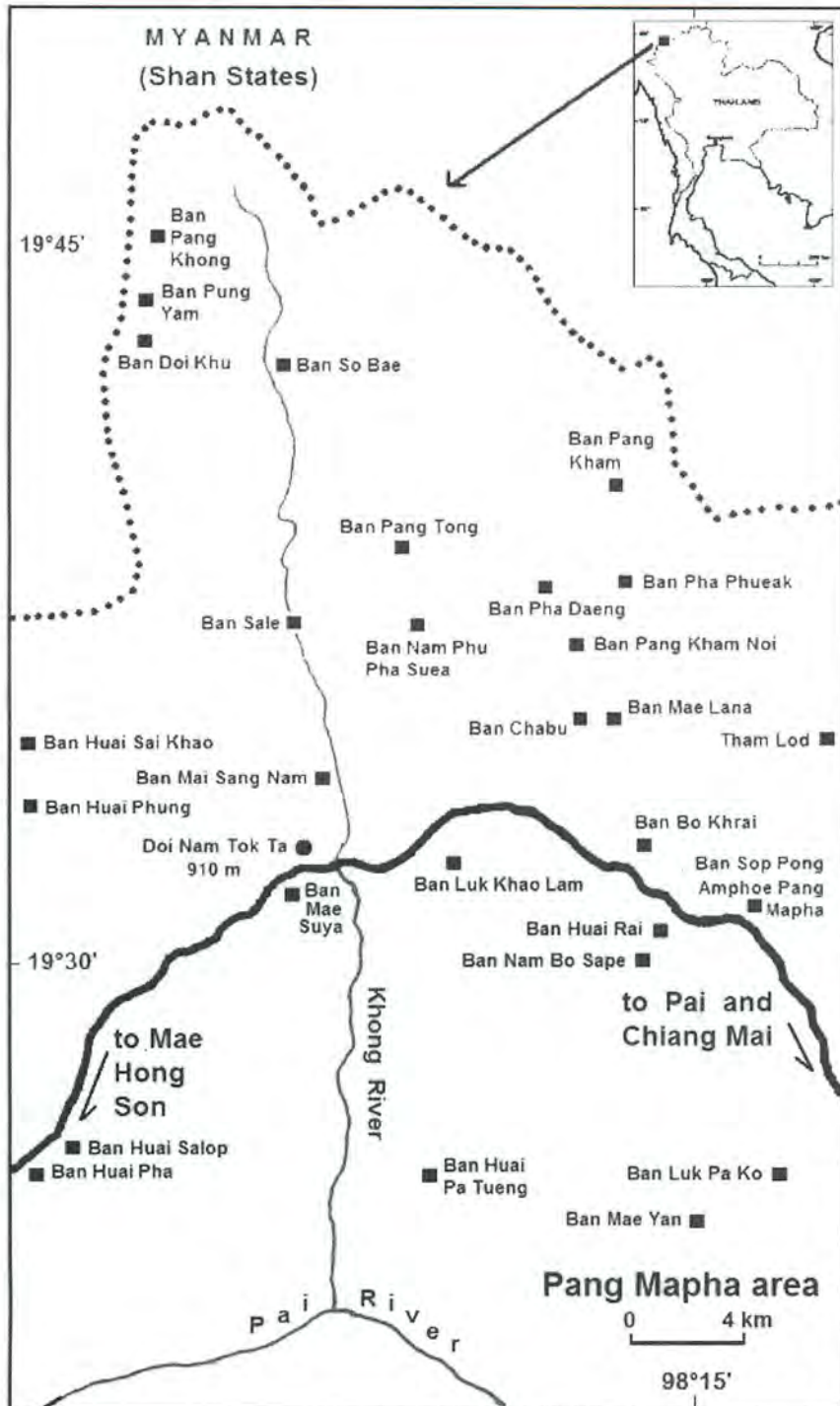


Figure 1. Pang Mapha District area.



Figure 2. Limestone hills south of Ban Pha Phueak.



Figure 3. Photograph towards the east from a shale outcrop halfway between Ban Chabu and Ban Mae Lana. The shale has yielded Lower Pennsylvanian ammonoids at a locality to the north. The photograph shows the Early Carboniferous limestone hill near Ban Mae Lana. West of the shale outcrop outside of the photograph, Moscovian limestone builds up hills near Ban Chabu; it is locally rich in *Fusulinidae*.

They reach only 1 cm in diameter at the maximum. Septa are of two orders. The counter septum is long and thickened in the axial part of the coral. The cardinal septum is shorter than the other major septa. These corals are in a packstone containing calcispheres, rare algae, and locally abundant Fusulinidae. They belong to Moscovian as the Bothrophyllidae described in the following lines. Lophophyllidae are common in the Permian limestones of Thailand. In the Carboniferous limestones, they were known only at Phu Ki Kai in Northeast Thailand where a limestone has been considered Moscovian in age (FONTAINE *ET AL.*, 1991, 2005).

Sample T9514, collected south of Ban Nam Hu Pha Suea, contains a poorly preserved solitary coral only 9 mm in diameter. Septa are of two orders, 28+28 in number. Counter septum is connected to a thick median plate. This coral possibly belongs to Lophophyllidae. It does not display dissepiments.

CYATHOPSIDAE Dybowski, 1873

Two small fragments of transverse thin sections obtained from a sample (T9371) collected north of Ban Mae Lana show lonsdaleoid dissepiments and appear to belong to *Siphonophyllia* Scouler, 1844. The occurrence of this genus was so far known in Thailand only from poor material collected from a single locality (Pha Chom Nang) in Northeast Thailand (FONTAINE *ET AL.*, 1991).

Caninia Michelin, 1840

Caninia, another genus of the Cyathopsidae, is well known in the Carboniferous of Northeast and Central Thailand. A few specimens have been noticed in Northwest Thailand.

Caninia cf. lipoensis (Chi, 1931)

1991 — *cf. Caninia lipoensis* (Chi), FONTAINE *ET AL.*, p. 32–33, pl. 1, figs. 5–7; pl. 5, fig. 7

Studied material. — Sample T9550 collected west of Ban Pha Phueak (19° 38' 59.7"N, 98° 12' 15.3"E; fig. 4).

Description. — Small solitary coral, 5 mm in diameter, known by a single transverse section. Septa are of two orders, 18+18 in number. Major septa are not very long and do not occupy the axial part of the coral. They are slightly thicker in the cardinal quadrants. Cardinal septum is a little shorter than the other major septa. Minor septa are very short. Tabulae are flat in the axial part of the coral. Dissepiments have commonly been destroyed by the erosion of the coral periphery; they are arranged in 1 or 2 rows.

Age. — Moscovian. *Caninia lipoensis* is a species described in the Moscovian of China. In Northeast Thailand, it has been found near Ban Pha Noi (FONTAINE *ET AL.*, 1991).

Associated fossils. — *Caninia cf. lipoensis* is associated in sample T9550 with calcispheres, smaller foraminifers, abundant Fusulinidae (including *Neostaffella subquadrata* Grozdilova & Lebedeva), fragments of *Mutithecopora* and of crinoids.

BOTHROPHYLLIDAE Fomichev, 1953

Bothrophyllidae have been found in limestone largely exposed between Ban Pha Phueak and Ban Pha Daeng. They appear to be widespread, but are poorly preserved, slightly to moderately crushed or in pieces. They are associated with diverse other fossils: *Tubiphytes*, calcispheres, smaller foraminifers, Fusulinidae (in abundance in samples T9549 to T9551), other corals (Lophophyllidae, *Chaetetes*, and fragments of tubes probably belonging to *Multithecopora*), brachiopods and crinoids. The limestone is wackestone to packstone and belongs to the Moscovian.

Bothrophyllidae were previously known only in Northeast Thailand by two genera: *Caninophyllum* found in a Moscovian limestone exposed along Huai Nam Suai, and *Bothrophyllum* collected in Ban Pha Noi area (FONTAINE ET AL., 1991).

Caninophyllum Lewis, 1929

Studied material.—Sample T9337 collected in 2005 from a small limestone hill west of Ban Pha Phueak (Fig. 5).

Description.—Solitary coral, partly crushed, 3 cm in diameter. It is known by only one oblique section. Septa are of two orders, 54+54 in number. Major septa are thickened in the tabularium, more intensely in the cardinal quadrants. They display a black median line. Cardinal septum is short. Minor septa are short and thin; they are confined to the dissepimentarium. Tabulae are flat in the axial part of the coral, 12 in a vertical distance of 1 cm. Dissepiments are arranged in at least 7 rows.

Age.—Moscovian (upper part of Middle Carboniferous). In the thin section studied above, *Caninophyllum* is associated with Fusulinidae belonging to *Neostaffella subquadrata* (Grozdilova & Lebedeva, 1950).

Additional material.—Sample T9551 collected in 2006 from the same area as the coral described in the preceding lines, along a road from Ban Pha Phueak to Ban Pha Daeng (19° 38' 59.7"N, 98° 12' 15.3"E), is only a fragment; it seems to belong also to *Caninophyllum*.

Bothrophyllum Trautschold, 1879

Studied material.—Sample T9338 collected west of Ban Pha Phueak. See Fig. 6.

Description.—Solitary coral, 2.5 cm in diameter, known by 2 transverse sections; slightly crushed. It belongs probably to *Bothrophyllum* Trautschold, 1879. Septa are of two orders, at least 45+45 in number. Major septa are long and extend almost to the axis of the coral. They are thickened in the tabularium; they display a black median line. They are thin in the dissepimentarium. The thickened part of the cardinal septum is short, but is prolonged by a thin lamina. Minor septa are short. Dissepiments are arranged in about 4 rows. The wall of the coral is thin and partly destroyed.

Age.—Moscovian. Sample T9338 contains Fusulinidae belonging to *Fusulinella* and *Aljutovella* while sample T9337 from the same locality contains *Neostaffella subquadrata* Grozdilova & Lebedeva.

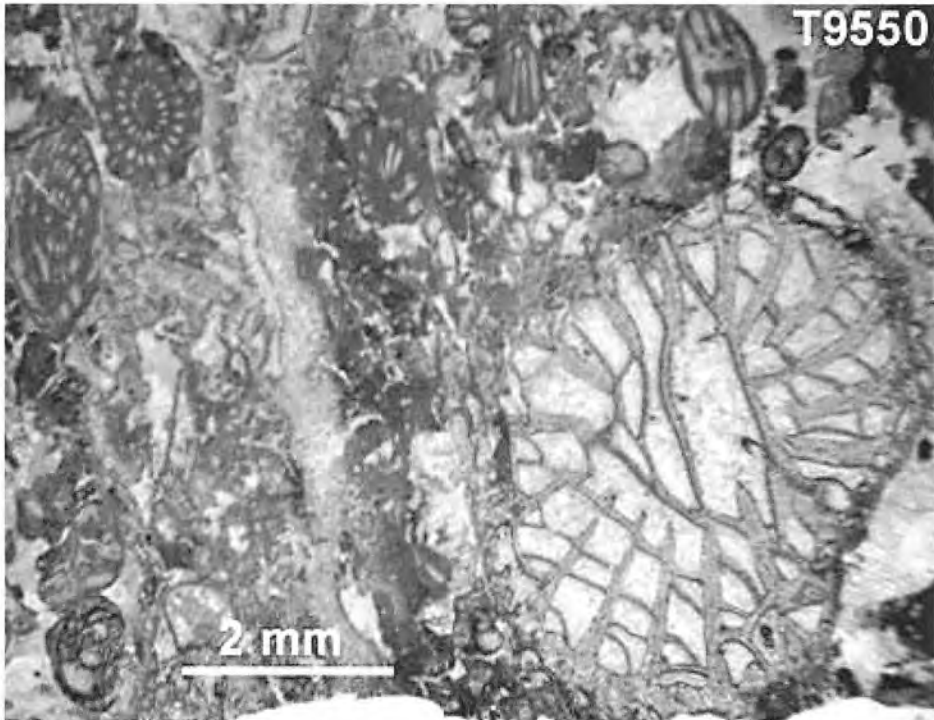


Figure 4. Sample T9550: *Caninia* cf. *lipoensis* in a limestone (packstone) rich in Fusulinidae.

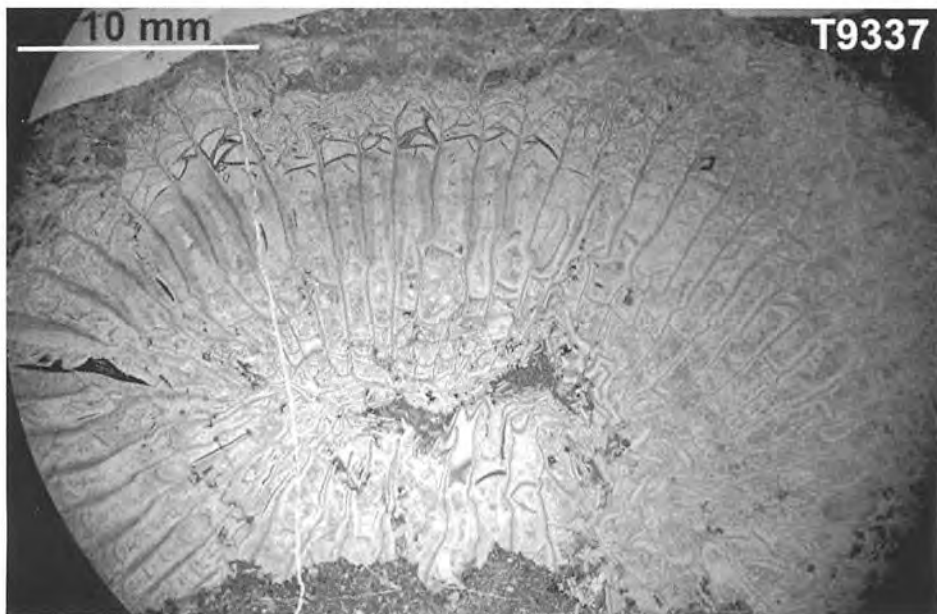
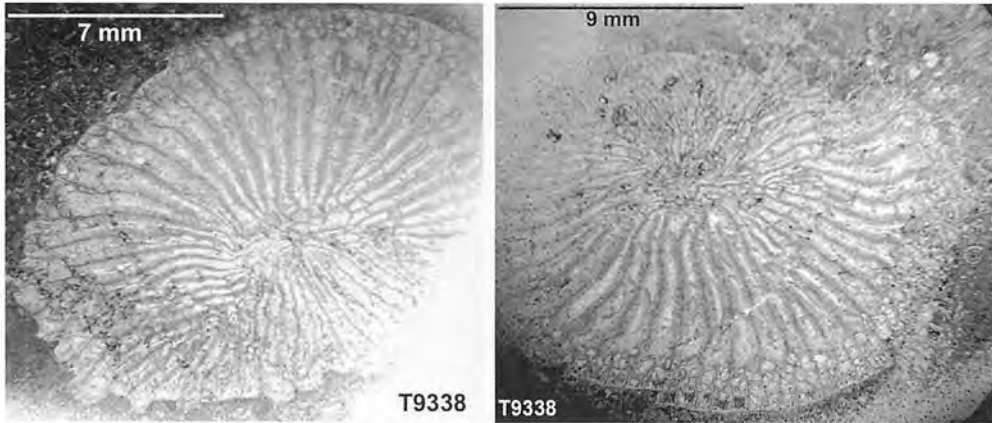
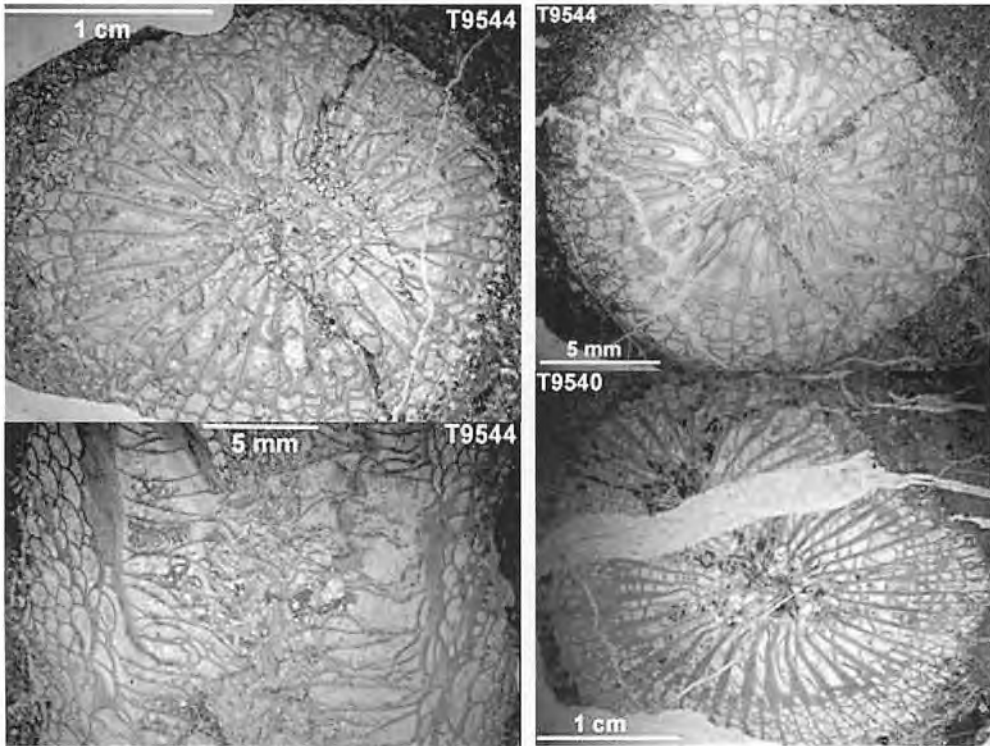


Figure 5. Sample T9337 (*Caninophyllum*) is not perfectly preserved. It is associated with other corals, commonly with the same type of preservation or even more poorly preserved.



Figures 6. Sample T9338: *Bothrophyllum*. This sample was associated in the field with sample T9337 (*Caninophyllum*).



Figures 7. Samples T9544 and T9540: *Bothrophyllum* collected west of Ban Pha Phueak. Sample T9544, transverse and longitudinal sections; sample T9540, transverse section.

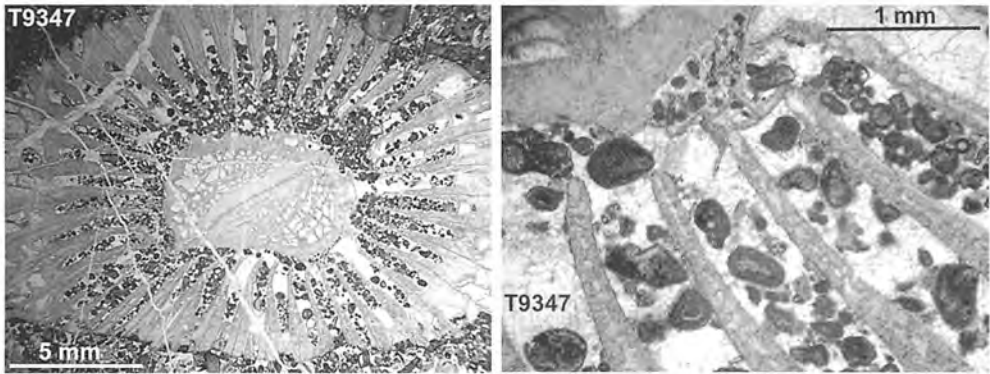
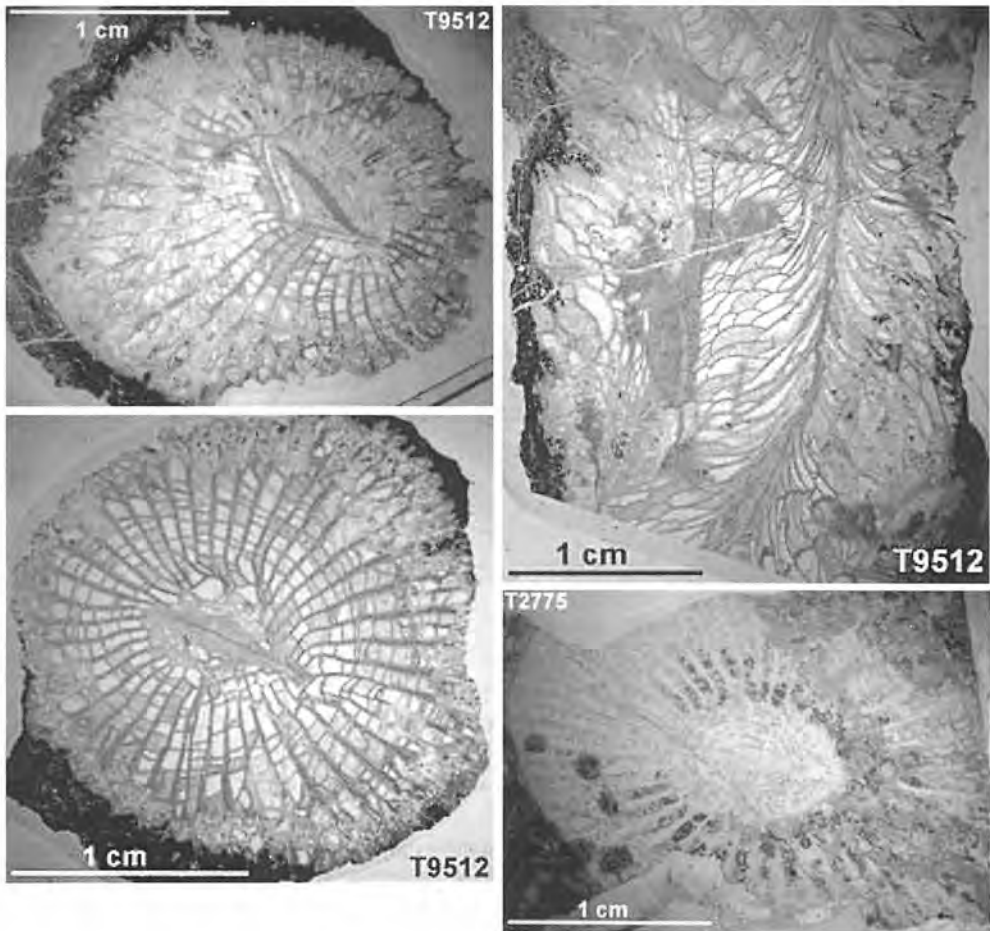


Figure 8. Sample T9347: *Neoclisiophyllum* from Ban Pha Phueak area.



Figures 9. Sample T9512: *Arachnolasma sinense* (transverse and longitudinal sections). Sample T2775 might belong to *Arachnolasma cylindricum* (transverse section).

Additional material.—Samples T9540, T9544 and T9549 have been collected from the same area as T9338, along a road from Ban Pha Phueak to Ban Pha Daeng (19° 38' 59.7"N, 98° 12' 15.3"E; Fig. 7). Solitary corals are common in this place. A little farther along the same road (19° 39' 22.0"N, 98° 12' 13.2"E), corals are scattered in the limestone (samples T9559 and T9560). All these corals are more or less crushed and not easy to study. They are about 2 cm in diameter in their upper part. Septa are of two orders, up to 36+36 in number. They are similar to those of sample T9338. In a vertical section (sample T9544; Fig. 7), tabulae are 16 in a vertical distance of 1 cm. They are almost flat; they are commonly incomplete. Dissepiments are arranged in 4 to 6 rows.

AULOPHYLLIDAE Hill, 1981

Aulophyllidae are the most common and diverse solitary Rugosa of the Amphoe Pang Mapha area, where they belong to the upper part of the Lower Carboniferous. They are diverse. They are also abundant at some Lower Carboniferous localities of Central and Northeast Thailand from where specimens of *Arachnolasma*, *Kueichouphyllum* and *Yuanophyllum* have been collected (FONTAINE *ET AL.*, 1991).

Kueichouphyllum Yu, 1931 is a large solitary coral, belonging mainly to Upper Viséan. It is already known in Northeast, Central and East Thailand (summary of the discoveries in FONTAINE *ET AL.*, 2005). It is in abundance in some limestone beds of Central Thailand. In central Laos, it is common at Ban Phit and Ban Na Hi east of Thakkek (FONTAINE, 1961). In Northwest Thailand, *Kueichouphyllum* does not appear to be widely distributed. At Km 9.4 of the road along Khong River north of Ban Mai Sang Nam, a single sample of this genus has been observed in the field; it was 5 cm in diameter.

CLISIOPHYLLINAE Nicholson, 1889

Few samples of Clisiophyllinae have been collected. Only a single sample is described in the following lines.

Neoclisiophyllum Wu 1964

Studied material.—Sample T9347 collected near and west of Ban Pha Phueak (Fig. 8).

Description.—Sample T9347 was looking like a beautiful solitary coral at the surface of the rock. It was only a fragment and it has been possible to obtain only a transverse section, corresponding to a mature growth stage. The coral is presently 1.4 cm in diameter, but is strongly eroded at its periphery. Its original size was larger. Major septa are 42 in number and extend almost to the axial structure. They are thickened in the tabularium and display a clear microstructure. Counter septum is thinner than the other major septa and moderately long, extending towards an angular elongation of the axial structure. Cardinal septum is shorter than counter septum. Minor septa are thin, short and rarely visible because of the erosion of the coral periphery. Dissepiments are arranged in more than two rows. The axial structure is well defined by a bounding wall. It is 4 mm in diameter. It is densely constructed by axial tabellae and moderately by septal lamellae. It has a thick median plate. Tabulae are entirely unknown because of the lack of a longitudinal section.

Associated fossils.—A few algae, rare foraminifers (*Archaediscus*), Tabulata (*Syringopora*, *Multithecopora potisati*), brachiopods and abundant fragments of crinoids.

DIBUNOPHYLLINAE Wang, 1950

Dibunophyllinae are rather widespread. They have been collected from the vicinities of Ban Mae Lana, Ban Nam Hu Pha Suea and Ban Pang Kham.

Arachnolasma Grabau, 1922

Genus *Arachnolasma* appears to be a solitary coral common in the Lower Carboniferous of Pang Mapha District, but the preservation of the collected specimens is moderate to poor. In the past, *Arachnolasma* was known in the Loei area of Northeast Thailand and at Noen Maprang of Central Thailand (FONTAINE ET AL., 1991). This genus is widespread in China (for instance, see WANG ET AL., 1991).

Arachnolasma sinense (Yabe & Hayasaka, 1920)

1933—*Arachnolasma sinense* (Yabe & Hayasaka) Yu, p. 34–35, pl. I, figs. 6a–c; pl. II, figs. 4a–c.

1937—*Arachnolasma sinense* (Yabe & Hayasaka) Yu, p. 26–29, pl. V, fig. 9; pl. VI, figs. 1–7.

1964—*Arachnolasma sinense* (Yabe & Hayasaka) Wu, p. 57, pl. XII, figs. 1–2.

Studied material.—A fragment of a solitary coral has been collected along the road from Ban Mai Sang Nam to two villages (Ban Nam Hu Pha Suea and Ban Pang Tong) south of the bifurcation (19° 35' 44.3"N, 98° 07' 40.1"E; sample T9512, 3 thin sections; Fig. 9). It is straight and almost cylindrical, 4.5 cm long, 2 cm in diameter in its upper part and 0.8 cm in its lower part. Its periphery is slightly eroded. This coral is in a wackestone containing calcispheres, rare smaller foraminifers, and fragments of crinoids.

Transverse sections.—Septa are of two orders, 42+42 in number in the lower part of the coral and 48+48 in its upper part. Major septa are long and may reach the axial structure; they are thin in the dissepimentarium, thicker at the periphery of the tabularium; they become thin again near the axial structure. Counter septum is connected to the median plate of the axial structure. Cardinal septum is shorter than the other major septa. Minor septa are very short. The axial structure is elongated along the plane of the cardinal and counter septa; it consists of a long thickened median plate, wrapped in a few weak lamellae.

Longitudinal section.—The axial plate is surrounded by steeply declined lamellae, and periaxially, less declined and discontinuous tabulae. Dissepiments, locally absent because of the erosion, are arranged in 3 to 5 rows. They are small, of unequal size.

Additional material.—Sample T9270 (Fig. 10), collected along the small road to Ban Nam Hu Pha Suea in the same area as T9512, is very similar to sample T9512. It is a cylindrical fragment of solitary coral, 3.2 cm long and 1.8 cm in diameter at its upper part. It is moderately preserved. Septa are of two orders, 52+52 in number. Major septa are long. Cardinal

septum is shorter than the other major septa. Minor septa are very short. The axial structure, 5 mm in diameter, displays a long median plate in connexion with the counter septum. Tabular floors consist of tabellae steeply declined abaxially in the axial part of the coral, less strongly declined towards the periphery. They are 14 in a vertical distance of 1 cm. Dissepiments are well developed and arranged in 4 to 5 rows.

Associated fossils.—These corals (T9512 and T9270) are associated with *Solenodendron* (T9513) and common *Syringopora* (T9515). They belong to the Lower Carboniferous, to the Viséan and maybe to the Serpukhovian.

Geographic distribution.—*Archnolasma sinense* has been found in China at several localities of Kwangsi and Hunan Provinces; it has been described by several authors. It is associated with other corals such as *Yuanophyllum*, *Kueichouphyllum* and *Diphyphyllum* (YU, 1933). WU (1964) mentioned a great number of genera and species in association with *Archnolasma sinense* in the Lower Carboniferous of Central Hunan. Near Ban Phit in central Laos, this species is probably present (FONTAINE, 1961).

Archnolasma cf. *cylindricum* Yu 1933

1933—*Archnolasma cylindricum* Yu, p. 35–36, pl. II, figs. 1a–c, 2a–e and 3a–d.

1989—*Archnolasma cylindricum* Yu in WU & ZHAO, p.87, pl. XVI, figs. 4a–c.

1991—*Archnolasma cylindricum* Yu in FONTAINE *ET AL.*, p.37, pl. 2, figs. 3–4.

Studied material.—Sample T2775 found at Ban Pang Kham; see Fig. 9.

Description.—Sample T2775 has been already mentioned by FONTAINE *ET AL.* 1993. It is the upper part of a solitary coral, 15 mm in diameter at its calice, associated with algae (*Ungdarella*) and foraminifers (*Archaediscus*). Septa are of two orders, 40+40 in number. Many major septa reach the columella. They are thick in the tabularium. Minor septa are half as long as major septa; they are thin. Columella, 4 mm in diameter, is densely constructed by axial tabellae and numerous septal lamellae. It displays a thick median plate. Dissepiments are well developed.

Age.—Upper part of Lower Carboniferous.

Additional material.—Sample T2770, collected north of Ban Mae Lana and already mentioned in a previous publication (FONTAINE *ET AL.*, 1993), is a poorly preserved solitary coral. It has appeared to belong to *Archnolasma*. It had been collected in association with *Hexaphyllia*.

Fasciculate Rugosa

Fasciculate Rugosa have been found at a few localities. They are complete colonies or fragments of corallites. They are not very diverse; they belong only to two genera. A sample collected 1 km south-southwest of Ban Nam Hu Pha Suea, Mae Hong Son Province (19° 36' 04.4"N, 98° 08' 04.3"E; sample T9278) appears to be very interesting, but it is too poorly preserved for an identification.

LITHOSTROTIONIDAE d'Orbigny, 1852

Lithostrotionidae are common in three places: (1) at Km 11 of the road along Khong River 2 km south of Ban Sale (19° 36' 30"N, 98° 06' 32"E; samples T8882 to T8884, T9218); (2) south of Ban Nam Hu Pha Suea (sample T9266). They are up to 0.5 m in diameter at these two first localities. (3) North of Ban Mai Sang Nam at Km 9.4 of the road along Khong River (19° 35' 45.8"N, 98° 06' 52.4"E; samples T8873, T9246), they are only small fragments of corallites.

So far, Lithostrotionidae have appeared less diverse in Northwest Thailand than in the Lower Carboniferous of Central and Northeast Thailand.

Diphyphyllum Lonsdale, 1845

A few fragments of corallites are assigned to *Diphyphyllum*. They are not well preserved and they are mixed with fragments of other corals. They have been collected from the limestone exposure of Km 11 of the road along Khong River.

Diphyphyllum sp.

Studied material.—Samples T8881 and T8884.

Description.—The corallites are 5 to 8 mm in diameter. Septa are of two orders, about 34+34 in number. Tabulae, horizontal in the axial part of the corallites, are about 18 in a vertical distance of 1 cm. They are downturned at their periphery. An axial structure is sporadically present. Dissepiments are arranged in 2 to 3 rows.

Geographic distribution.—*Diphyphyllum* was known only from Central Thailand (FONTAINE ET AL. 1991).

Solenodendron Sando, 1976

Solenodendron is a Lower Carboniferous fasciculate genus, known from Europe to China. It is characterized by the presence of an aulos formed by the deflected axial ends of major septa. It is locally in abundance in Northeast, East and Central Thailand as well as at Ban Phit in Thakkek area of Laos. In Northwest Thailand, it has been found: (1) at Km 9.4 of the road along Khong River north of Ban Mai Sang Nam (19° 35' 45.8"N, 98° 06' 52.4"E; samples T8873 and T9246); (2) at a limestone exposure on a slope exactly at Km 11 of the road along Khong River, 2 km south of Ban Sale (19° 36' 30"N, 98° 06' 32"E; samples T8881, T8882, T8884, T9218); (3) on the slope of a hill along the small road to Ban Nam Hu Pha Suea (19° 35' 44.3"N, 98° 07' 40.1"E; samples T9266, T9513).

Solenodendron furcatum Smith, 1925

1991—*Solenodendron furcatum* Smith. FONTAINE ET AL., p. 50–52, pl. 2, fig. 6; pl. 3, fig. 1; pl. 13, figs. 1 and 3.

Studied material.—Samples T8873, T8885 and T9246 (only fragments of corallites); samples T8881, T8884 (Fig. 11), T9218 and T9266 (fragments of a corallum). These corals are moderately to poorly preserved. Samples T9266 and T9513 are corals reaching 50 cm (T9266) and 40 cm (T9513) in diameter.

Description.—Corallites are 3–5 mm in diameter. Septa are of two orders, 16+16 to 22+22 in number. Major septa are connected by an aulos, 2–3 mm in diameter. This aulos is largely destroyed by recrystallization of the axial part of the corallites in sample T8873. Minor septa are 1/3 as long as the major septa. Tabulae are flat in the inside of the aulos; they are 12 to 14 in a vertical distance of 1 cm. Dissepiments are arranged in 1 or 2 rows.

Remarks.—Some corals, found at Km 11 of the road along Khong River and south of Ban Nam Hu Pha Suea, appear peculiar because of the size of their corallites which are only 2.0–3.5 mm in diameter. There is apparently no other difference with the corals described above. They can be considered a variety of the species *Solenodendron furcatum*.

Associated fossils.—At Km 11 of the road along Khong River, fossils are poorly preserved; they include *Syringopora* and long crinoid stems. At Km 9.4 of the same road, a richer fauna has been found and consists of: *Syringopora*, *Kueichouphyllum*, *Hexaphyllia* and a few foraminifers. South of Ban Nam Hu Pha Suea, *Solenodendron* is associated with rare microfossils (*Endothyra*), *Syringopora*, solitary Rugosa (*Arachnolasma*), long crinoid stems, and very locally, oncolites.

Geographic distribution.—*Solenodendron furcatum* has been described in Laos (FONTAINE, 1961), in Northeast and Central Thailand (FONTAINE ET AL., 1991) and in East Thailand (FONTAINE & SALYAPONGSE, 1997).

Heterocorallia Schindewolf, 1941

Heterocorallia are well known in many regions of the world, for instance in Europe, China and Japan, where they have been actively studied. They are in abundance at many localities belonging to the upper part of the Lower Carboniferous (= Datangian in China), and particularly, to the Upper Viséan and the Serpukhovian. Two genera, *Hexaphyllia* and *Heterophyllia*, have been found in Northeast Thailand. *Hexaphyllia* is common at several localities while *Heterophyllia* occurs much more rarely (FONTAINE ET AL., 1991). *Heterophyllia* is abundant near Ban Sa Ngao (SUGIYAMA ET AL., 1995). Until now, only *Hexaphyllia* is known in Northwest Thailand, and by specimens less than 3 mm in diameter. In Japan in the Akiyoshi Limestone, *Hexaphyllia* has been found in 88% of the 356 studied thin sections while *Heterophyllia* occurs in less than 1% of the thin sections (SUGIYAMA, 1997).

Hexaphyllia Stuckenberg, 1904

The Genus *Hexaphyllia* is known in Northeast, Central (locally in abundance) and East Thailand (FONTAINE ET AL., 1991, 2005; FONTAINE & SALYAPONGSE, 1997). In Central Laos, it is common at Ban Phit and Ban Na Khieu east of Thakkek (FONTAINE, 1961). In Laos and Thailand, *Hexaphyllia mirabilis* (DUNCAN, 1867) was described and consisted of specimens 0.3 to 1.2 mm in diameter (FONTAINE ET AL., 1991). In the same publication, specimens from Khao Sam Nge in Northeast Thailand, 2.2 mm in diameter, were assigned to *Hexaphyllia*

marginata (FLEMING, 1828). In Peninsular Malaysia, *Hexaphyllia* is locally common in the Panching Limestone of Kuantan area (FONTAINE *ET AL.*, 2003). In Vietnam, it has been mentioned by Nguyen Duc Khoa in 1983, for the first time in Vietnam, 4 km north of Qui-dat where it is associated with foraminifers (*Archaeodiscus*, *Pseudoendothyra*, *Eostaffella*) and other corals (*Arachnolasma*).

The skeleton of *Hexaphyllia* is simple and consists of a small and long corallite. At many localities it is known only by fragments and transverse sections; the specific identification is not always easy. Many paleontologists have used corallite diameter and tabulae density for specific discrimination (for instance, see SUGIYAMA, 1984, pp. 37–42). In China, more than 40 new species have been described during the last 30 years. COSSEY (1997) studied exceptionally well preserved and abundant specimens of *Hexaphyllia*, found in North Derbyshire of England and locally appearing to be in life position. He discovered considerable intraspecific variation in shape, wall thickness and tabulae spacing, reflecting adaptations to diverse environments. He considered that too many species had been described in the past and *Hexaphyllia mirabilis* (DUNCAN, 1867) became a junior synonym of *Hexaphyllia marginata* (FLEMING, 1828).

In Northwest Thailand, *Hexaphyllia* is known by small fragments; it has been impossible to get longitudinal sections, and accordingly, to know the increase of diameter with growth and the density of the tabulae. The specimens collected in Pang Mapha District appear to belong to two species differing in the size of their corallites. They have been found at Km 9.4 of the road along Khong River (samples T8872, T9244) and north of Ban Mae Lana (sample T2770).

Hexaphyllia marginata (Fleming, 1828)

1997—*Hexaphyllia marginata* (Fleming, 1828), COSSEY, p. 1045–1052, pl. 1, figs. 1–8; pl. 2, figs. 1–7; pl. 3, figs. 2–15 (with a very long synonymy list)

2005—*Hexaphyllia marginata* (Fleming, 1828), FONTAINE *ET AL.*, pl. X, figs. 3 to 5 of specimens in sample T8872.

Studied material.—Samples T2770, T8872, T9244 (Fig. 12).

Description.—Corallites are commonly much less than 1 mm in diameter; they are around 0.5 mm in diameter and the largest ones rarely reach 1 mm. All the specimens show characteristics of the well-known skeleton of *Hexaphyllia*. They have only 6 septa arranged in the particular way of this genus.

Geographic distribution.—*Hexaphyllia marginata*, known in other parts of Thailand, has been found so far at two localities of Northwest Thailand: (1) north of Ban Mae Lana along the road to Ban Pang Kham (sample T2770; FONTAINE *ET AL.*, 1993); (2) at Km 9.4 of the road along Khong River (samples T8872 and T9244). *Hexaphyllia marginata* was first described by Fleming in a Carboniferous limestone of Scotland.

Associated fossils.—North of Ban Mae Lana, *Hexaphyllia marginata* is associated with algae (including *Koninckopora*) and foraminifers (*Endothyra*, *Archaeodiscus*). At Km 9.4 of the road along Khong River, it is associated with *Syringopora*, *Kueichouphyllum* and *Solenodendron*.

Hexaphyllia sp.

Studied material.—sample T9244. This type of *Hexaphyllia* is known by a single transverse section (Fig. 12).

Description.—The corallite is 2 mm in diameter at the minimum. It is more than twice larger than the common corallites of the specimens described as *Hexaphyllia marginata* in the preceding lines. Elsewhere in Thailand, this exceptional size has been noticed in a limestone sample (T334) collected from Khao Sam Nge east of Pak Chom in Northeast Thailand. Up to now in Thailand, samples with intermediate diameters between 1 and 2 mm have not been found. Is it because of the occurrence of two species or because of too few specimens? The diameter of the corallite of *Hexaphyllia marginata* ranges continuously from 0.1 to 2.6 mm according to COSSEY (1997) and, accordingly, the samples T334 and T9244 might also belong to this species.

Tabulata

Tabulata are common at the Lower Carboniferous localities of Northwest Thailand, but consist of only two genera belonging to Syringoporidae and Multithecoporidae.

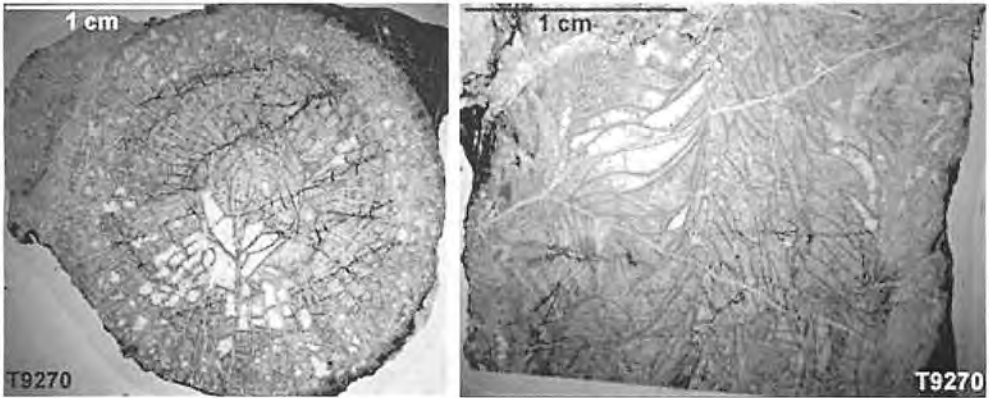
SYRINGOPORIDAE de Fromentel, 1861

Syringoporidae are widespread and locally abundant in the Amphoe Pang Mapha area.

Syringopora Goldfuss, 1826

Syringopora is a fasciculate coral known in beds ranging from Devonian (and even Silurian) to Lower Carboniferous. It is widely distributed in the Lower Carboniferous of the world from Australia (WEBB, 1990) to North America (SANDO & BAMBER, 1985). It disappeared at the end of the Lower Carboniferous. In Southeast Asia, it is known at several Lower Carboniferous localities of Laos and Vietnam (FONTAINE, 1961). It has been found at the Kuantan Gorge in Central Sumatra (FONTAINE & GAFOER, 1989) and at some localities of Peninsular Malaysia. In Thailand, it has been collected from several limestone exposures in the northeastern and central parts of the country (for instance, see FONTAINE *ET AL.*, 1991, 2005).

Syringopora is in abundance at some localities of Northwest Thailand. Because the corallites are branching rapidly, the colonies reach up to 60 cm in diameter, but commonly are not more than 20 cm in height. These corals have been found: (1) at Km 1 of the road along Khong River (19° 32' 33"N, 98° 06' 57"E; samples T9286, T9287, T9291, T9292 (= sample given to the Natural History Museum of Mae Sa, Chiang Mai Province), T9619, T9621, T9623); (2) at Km 9.4 of the road along Khong River (19° 35' 45.8"N, 98° 06' 52.4"E; samples T8872, T9245, T9248 and T9249); (3) at Km 11 of the road along Khong River (19° 36' 30"N, 98° 06' 32"E; poorly preserved samples T9219 to T9221); (4) and (5) at two localities south of Ban Nam Hu Pha Suea (19° 35' 44.3"N, 98° 07' 40.1"E; sample T9515) and (19° 36' 04.4"N, 98° 08' 04.3"E; sample T9277); (6) near Ban Pha Phueak (19° 38' 44.0"N, 98° 12' 52.9"E; samples T9352, T9537).



Figures 10. Sample T9270: *Arachnolasma sinense*. Transverse and longitudinal sections.

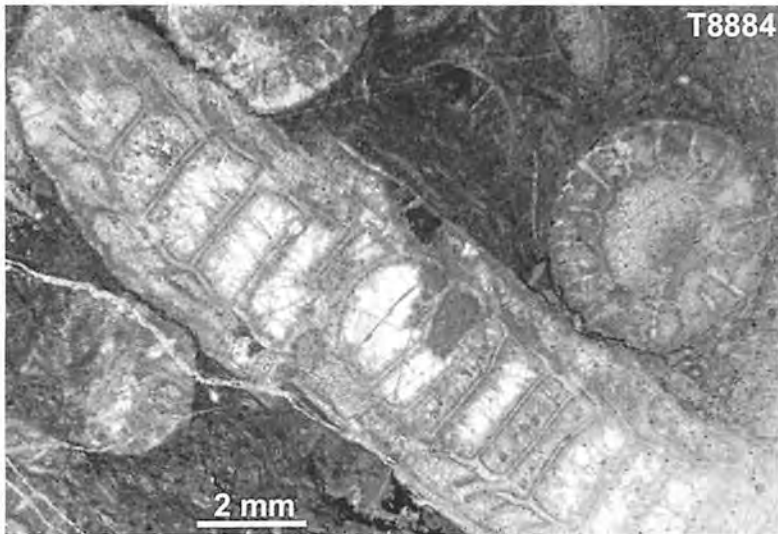
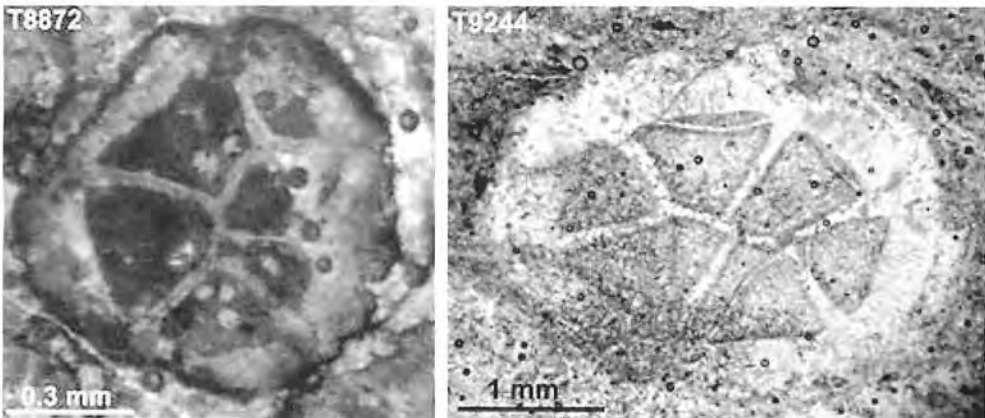
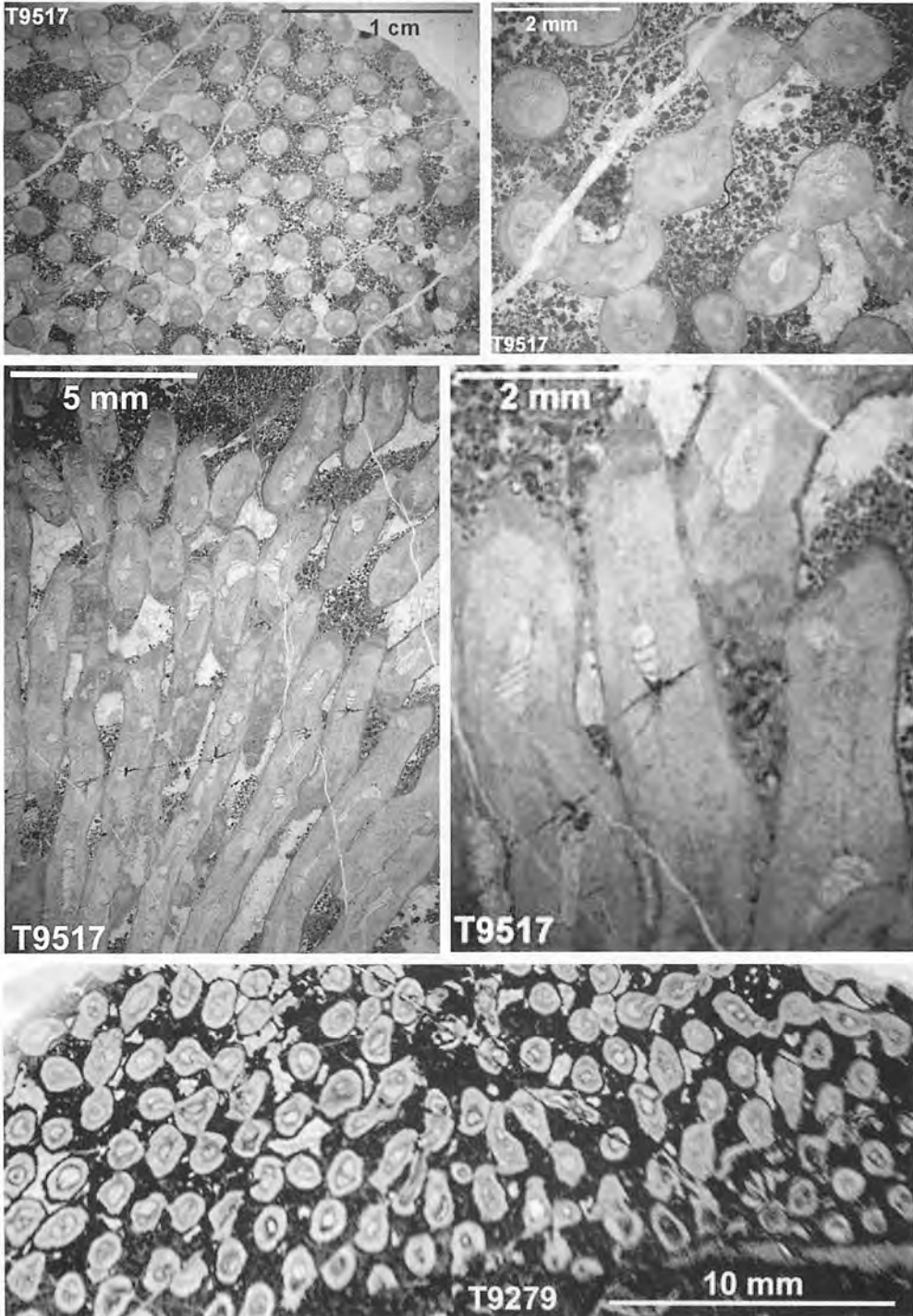


Figure 11. Sample T8884: *Solenodendron*. Transverse and longitudinal sections.



Figures 12. Samples T8872 and T9244: *Hexaphyllia*, with different diameters.



Figures 13. Samples T9517 and T9279 are considered a new species: *Multithecopora potisati* n. sp.

Syringopora distans Fischer, 1828

See FONTAINE (1955: 66–67, pl. 1, figs. 1–3)

2005—*Syringopora*, FONTAINE ET AL., pl. X, figs. 1 and 2 of a coral in sample T8872.

Studied material.—samples T8872, T9277, T9286, T9291, T9537.

Description.—The corallum is fasciculate, bush-like. The corallites are cylindrical, 2 to 2.5 mm in diameter, long, almost parallel, very slightly flexuous. They are separated by spaces commonly of 1 to 5 mm. Their walls are thick, with traces of a lamellar microstructure. Septal spinules appear to be absent. The tabulae are strongly infundibuliform and they are 12 to 18 in a vertical distance of 1 cm. They form an axial canal. Connecting tubuli are scattered, irregularly spaced.

In Northwest Thailand, many samples of *Syringopora* have been observed and collected from a similar stratigraphic level. They show only very small variations in their skeleton. They apparently belong to a single species.

Geographical distribution.—*Syringopora distans* is known in several countries of Western Europe, Russia, China, Laos.

Age.—Upper part of Lower Carboniferous.

MULTITHECOPORIDAE Sokolov, 1950

In Northwest Thailand, the materials assigned to the Multithecoporidae consist of two types: (1) Fragments of tubes scattered in limestone and difficult to observe in the field. (2) Beautiful fasciculate corals, well preserved and easy to notice in the field.

Multithecopora Yoh, 1927

Multithecopora is a genus common in Middle and Upper Carboniferous, but it has been found also in older beds, down to Visean (for instance, see SANDO & BAMBER, 1985).

According to WEBB (1990), the Australian members of Genus *Multithecopora* Yoh 1927 “have well developed septal spines whereas septal spines are poorly developed or absent in many overseas species” (WEBB 1990, p. 128). In *Multithecopora repens* (STUCKENBERG, 1895), a species of the Urals, septal spines are, only locally, well developed (CHUDINOVA, 1975). In Northeast Thailand, *Multithecopora* is known at several Middle Carboniferous localities; it sporadically displays one or two septal spines in a transverse section (FONTAINE ET AL., 1991).

Multithecopora sp.

Small fragments of tubes have been found in some thin sections of the Moscovian limestone exposed west of Ban Pha Phueak (samples T9540 and T9550) and rich in solitary Rugosa. These tubes are 2 to 2.5 mm in diameter and are apparently connected by a few short tubules. The wall of the tubes is thick. Septal spines have been rarely observed. Tabulae are flat or very slightly concave; they are rare. These fragments of tubes are considered belonging very probably to *Multithecopora*.

Multithecopora potisati nov. sp.

Studied samples.—Complete fasciculate corals have been found: (1) at Km 1 of the road along Khong River (19° 32' 33"N, 98° 06' 57"E; samples T8853, T8854, T9283, T9284, T9285); (2) at a locality about 1 km south-southwest of Ban Nam Hu Pha Suea (19° 36' 04.4" N, 98° 08' 04.3"E; samples T9276, T9279 and T9517; Fig. 13); (3) in the vicinity of Ban Pha Phueak to the west (19° 38' 44.0"N, 98° 12' 52.9"E; samples T9349 and T9350).

Holotype.—Sample T9517.

Species name.—This name honours Mr. Somsak Potisat, Director General of the Department of Mineral Resources, who has promoted paleontological research.

Description.—The collected samples are fasciculate corals, 5 to 20 cm in diameter. The corallites are subcylindrical tubes, ranging from 0.8 to 1 mm in diameter. They are not widely spaced, the distance between them is small and does not commonly exceed 1 mm. They have a thick wall, moderately preserved. The axial part of the corallites is very narrow; it appears to be largely empty. Tabulae are flat and horizontal, locally slightly curved. They are rare and irregularly distributed. In long parts of a corallite, tabulae are absent while in small parts, they are up to 4 in a vertical distance of 1 mm. There is no trace of septal material; no septal spine has been observed in the studied thin sections. Connecting tubuli are sparse.

Age.—These specimens are very interesting because of their biostratigraphic implications. They belong to the end of the Lower Carboniferous. They are associated with calcispheres (*Eotuberitina*), foraminifers (*Archaediscus*, *Endothyra*, *Tetrataxis*, *Bradyina*, *Eostaffella* and others), other Tabulata (*Syringopora*), fasciculate corals (*Solenodendron*). In China, *Multithecopora* has also been found in the upper part of the Lower Carboniferous.

CHAETETIDAE Milne-Edwards & Haime, 1850

Chaetetidae are rare in the Amphoe Pang Mapha area.

Chaetetes Fischer von Waldheim, 1829

Chaetetes is rare in Northwest Thailand and has been found only west of Ban Pha Phueak (19° 38' 59.7"N, 98° 12' 15.3"E; sample T9340). It was known at several Middle Carboniferous localities of Northeast Thailand (FONTAINE *ET AL.*, 1991, 2005).

Studied material.—Sample T9340.

Description.—This massive coral is 5 cm in diameter. It is poorly preserved. Corallites are prismatic, 0.3 mm in diameter. Tabulae, horizontal, are about 20 in a vertical distance of 1 cm. Septal spines and mural pores are absent.

Age.—Moscovian. This coral is associated with *Tubiphytes*, algae, calcispheres, smaller foraminifers (*Climacammina*), Fusulinidae (locally in abundance: samples T9335, T9539, T9542, T9543, T9545), numerous solitary Rugosa (*Caninophyllum*, *Bothrophyllum*), brachiopods, rare gastropods, and crinoids (samples T9333 to T9341, T9539 to T9555).

CONCLUSION

Fossils appear different from the skeletons of modern organisms. Two centuries ago, pioneers such as Cuvier (1769–1832) convincingly suggested a long pre-human history with large catastrophes and extinctions. In Thailand, this history is more and more apparent in the field, even in the remote areas of Northwest Thailand. Nowadays, a limited group of fossils, as the corals studied in this paper, can provide important information (Table 1).

Some small simple solitary corals lived at different depths in the sea; other corals needed shallow environments. The fossils associated with them indicate also such types of environments, for instance the green algae in the need of sunlight, such as *Koninckopora* found at several localities of the Lower Carboniferous of Pang Mapha area.

Some corals such as *Solenodendron*, *Hexaphyllia*, *Kueichouphyllum*, *Neoclisiophyllum* and *Arachnolasma* indicate precise ages, belonging to Lower Carboniferous. The stratigraphic range of other corals such as Lophophyllidae is not restricted to Carboniferous; it may extend to Permian. *Syringopora* is already known in the Devonian, but it is interesting for stratigraphy because it disappeared at the end of the Lower Carboniferous.

Table 1. Stratigraphic distribution of the corals

Stratigraphy		Localities	Corals
Upper Carboniferous			
Middle Carboniferous = Lower Pennsylvanian	Moscovian	Between Ban Pha Phueak and Ban Pha Daeng	<i>Bothrophyllum</i> , <i>Caninophyllum</i> , <i>Caninia</i> , Lophophyllidae, <i>Chaetetes</i> , <i>Multithecopora</i>
	Bashkirian		
Lower Carboniferous = Mississippian	Serpukhovian	1 to 3: Localities of the road along Khong River (Km 1, Km 9.4, Km 11) 4 and 5: Localities along the road to Ban Nam Hu Pha Suea	<i>Neoclisiophyllum</i> , <i>Arachnolasma sinense</i> , <i>Arachnolasma</i> , <i>Dibunophyllum</i> , <i>Kueichouphyllum</i> , <i>Diphyphyllum</i> , <i>Solenodendron furcatum</i> , <i>Hexaphyllia marginata</i> , <i>Hexaphyllia</i> , <i>Syringopora</i> (in abundance), <i>Multithecopora potisati</i>
	Visean	6: Ban Mae Lana 7: Ban Pang Kham Noi 8: Ban Pha Phueak 9: Ban Pang Kham 10: West of Tham Lod	
	Tourmaisian		

When discussing corals, one thinks of reefs which build up important structures in the sea, resistant even to strong waves. In the Lower Carboniferous of Amphoe Pang Mapha area, corals were locally diverse and abundant, but they did not build true reefs. They lived scattered at the bottom of the sea.

Paleogeographically, the corals suggest some similarities with Eurasia. In addition to that, they belong to diverse fossil assemblages spanning the entirety of the Carboniferous, and indicate a strong difference with the Carboniferous of Peninsular Thailand which clearly belongs to the Shan-Thai (or Sibumasu) Block. In Peninsular Thailand, there is no Middle Carboniferous to Lower Permian limestone rich in diverse fossils. In contrast, exposures of Middle Carboniferous, Upper Carboniferous and Lower Permian limestone are known in Northwest Thailand and contain a great variety of fossils (FONTAINE *ET AL.*, 2005).

ACKNOWLEDGMENTS

The peculiarities of the Amphoe Pang Mapha area are very important and wonderful. Mr. Somsak Potisat, Director General of the Department of Mineral Resources, and Dr. Sompoad Srikosamatara, Associate Professor at Mahidol University, have been attracted by a move to a recognition of these peculiarities and by geological research in the area. Results have already been obtained and this paper is a step in the accomplishment of this project. The help of geologists (Mr. Sirot Salyapongse, Ms. Pannipa Tian) from the Geological Survey during fieldworks has been highly appreciated. The help of Dr. Hoang Thi Than in the preparation of the text and the photographs must be greatly acknowledged. As usual, Dr. W. Brockelman, editor of the *Natural History Bulletin of the Siam Society*, has strongly helped in the editing of the paper; the authors express their sincere thanks to him.

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