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# Lower Devonian tentaculite bed in the Satun area, southern peninsular Thailand

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**Abstract**

A Lower Devonian (Emsian) tentaculite fauna including *Nowakia acuaria* [Richer, R., 1854. Thüringische Tentaculiten. Zeitschr. Deutsch. Geol. Gesellsch. 6, 275–290] occurs in black shale in the basal part of a siliciclastic sequence exposed north of Satun, southern peninsular Thailand. Similar tentaculite beds with *Nowakia* have been reported from several areas in the Fang, Sri Sawat, and Trang areas of Thailand, the Langkawi Islands and the Mahang–Baling areas of Malaysia. The depositional environments in which the tentaculite-bearing black shale accumulated extended from modern northern Thailand to northwestern Malaysia during the Early Devonian (Emsian).


*Keywords:* Devonian; Thailand; Satun; Tentaculite

## 1. Introduction

Lower to Middle Paleozoic rocks with a variety of fossils are present in the northern and western parts of Thailand, southern peninsular Thailand, and northwestern Malaysia (Bunopas, 1992). Regional and international correlations of the Devonian part of these sedimentary rocks have not been attempted, owing to the stratigraphically and geographically limited distribution of index fossils, including graptolites, conodonts, and trilobites. Middle Paleozoic black shale-bearing tentaculite (we use 'tentaculite' as a common name of animals into the Class CRICOCONARIDA Fisher, 1962) has been reported in several parts of Thailand and Malaysia (e.g. Burton, 1967a). Kobayashi and Hamada (1968) reported '*Tentaculites*-Beds', from Thailand, Malaysia, Myanmar, and Yunnan in southwestern China. Comparisons among these sequences are important for reconstructing their depositional environments (e.g. Burton, 1967b). These tentaculite beds contain several species, including *Nowakia* and *Styliolina*, that are of Early to Middle Devonian age and frequently coexist with graptolites and trilobites.

In February 2001 and March 2003, we undertook field work in the Satun area, southern peninsular Thailand, and investigated a black shale bed containing abundant tentaculites. In the present study, we delineate the lithological characteristics of this tentaculite bed, which occupies the basal part of a siliciclastic sequence in the Satun area, and describe one tentaculite species. Furthermore, we propose to correlate the present tentaculite bed with those in surrounding areas.

## 2. Geological setting

There is general agreement that Southeast Asia is a complex assembly of several continental blocks that rifted from Gondwanaland (e.g. Metcalfe, 1999). Thailand comprises two main continental blocks, the western Shan–Thai and eastern Indochina Blocks. These two blocks are separated by a suture zone made up of the northern Nan–Uttradit and southern Sra (Sa) Kaeo–Chanthaburi zones. The area is bordered to the west by the Sukhothai Fold Belt and to the east by the Loei–Petchabun Fold Belt

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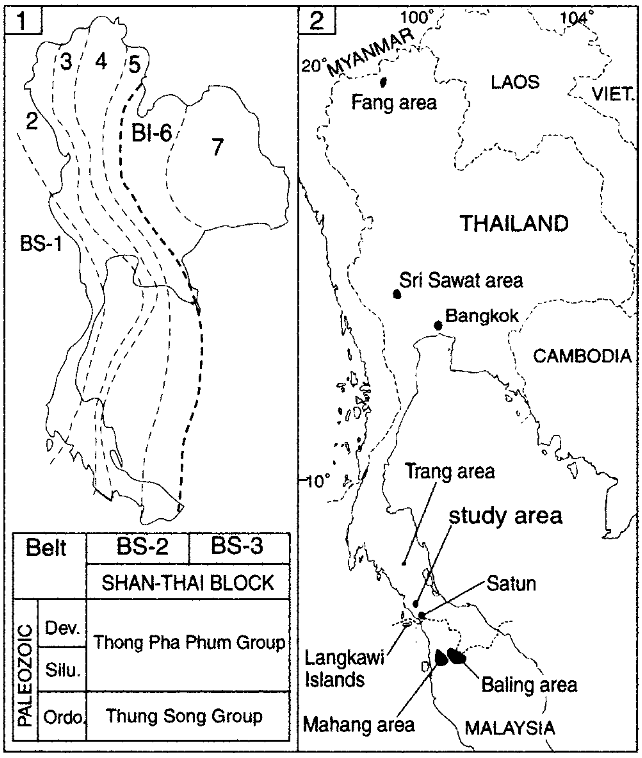


Fig. 1. (1) Seven stratigraphic belts of Thailand and generalized stratigraphic nomenclature within the BS-2 and three belts (after Bunopas, 1992). (2) Index map showing the study area and other areas in which the tentaculite beds are distributed.

(e.g. Bunopas, 1981). Bunopas (1992) recognized seven longitudinal stratigraphic belts, designated BS-1 to BS-5, that belong to the Shan–Thai Block, and belts BI-6 to BI-7 that belong to the Indochina Block (Fig. 1). The present study area is within belt BS-3. The Lower to Middle Paleozoic was divided into the following stratigraphic units by Bunopas (1992): the Cambrian Tarutao Group, Ordovician Thung Song Group, and Silurian to Carboniferous Thong Pha Phum Group (Fig. 1).

Lower to Middle Paleozoic rocks are present in an area extending about 200 km, with northern and southern limits in the Surat Thani and Satun areas, respectively. Wongwanich et al. (1990) described the following lithostratigraphy in the Satun area: the Cambrian Tarutao Group, Ordovician Thung Song Group, and Silurian to Devonian Wang Tong, Kuan Tung, and Pa Samed Formations. Our study area is located close to the type localities of the Silurian to Devonian formations established by Wongwanich et al. (1990).

## 3. Lithology of the tentaculite bed

This study focuses on a stratigraphic sequence situated about 30 km north of Satun and exposed on the northwestern side of Route 4078 (Fig. 2(1)). This sequence is 250 m thick and composed of shale, mudstone, limestone,

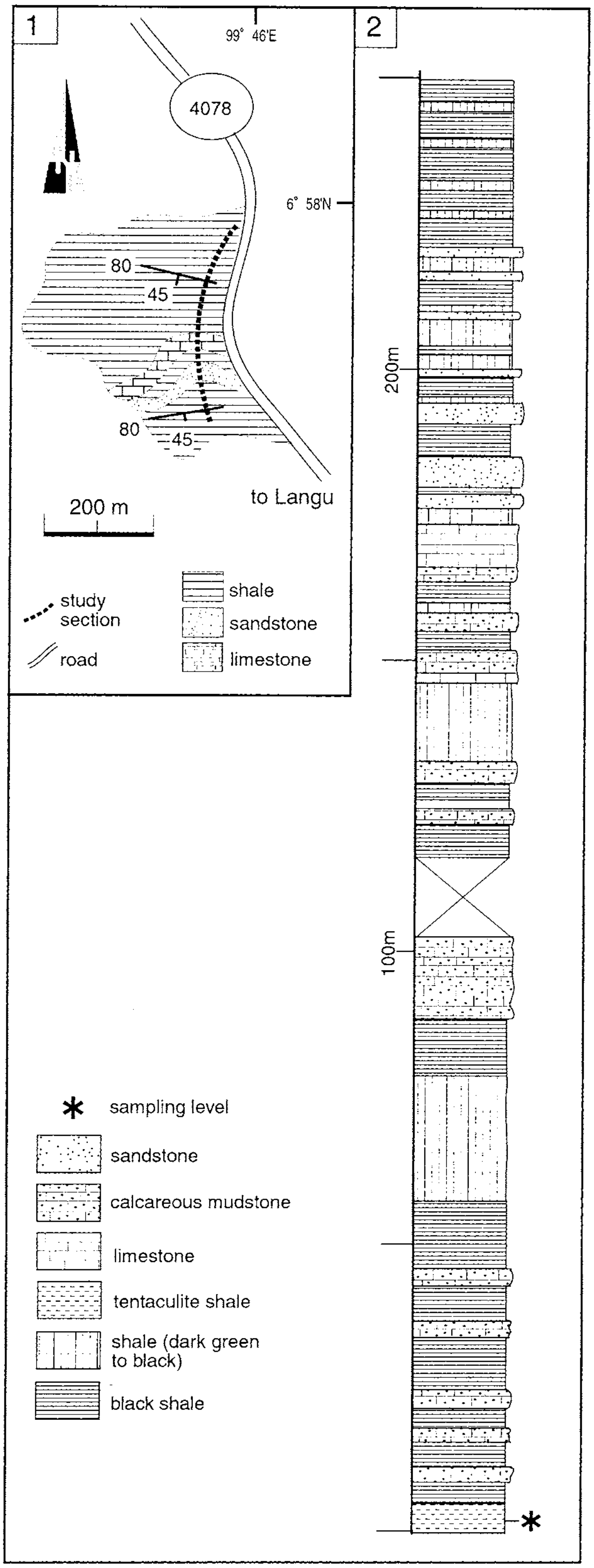


Fig. 2. (1) Route map showing the study section and the distribution of sedimentary rocks in the Satun area. (2) Lithologic column of the study section.

and sandstone. It strikes N80°E to 80°W and dips 45° to the south. The lower 170 m of this section is made up of alternating black to dark green shale and calcareous mudstone, and includes several limestone beds in its uppermost part. The upper 80 m of this section consists mainly of black to dark green shale, intercalated with sandstone beds in its lowermost part. The tentaculite bed, a basal part of this sequence, is a 5 m thick black shale bed containing many small, triangular shells (Fig. 2(2)). These siliciclastic rocks have been correlated with the Devonian Pa Samed Formation by Wongwanich et al. (1990).

Although some horizons of the tentaculite bed contain concentrated tentaculites, other horizons yield sparse specimens. Nearly all shells lie horizontally on a bedding plane and orientations of their axes are variable (Fig. 3(1) and (2)). Moreover, these shells exhibit no characteristic trends in size, direction of axis, or abundance in each horizon. Fisher (1962) mentioned that tentaculites

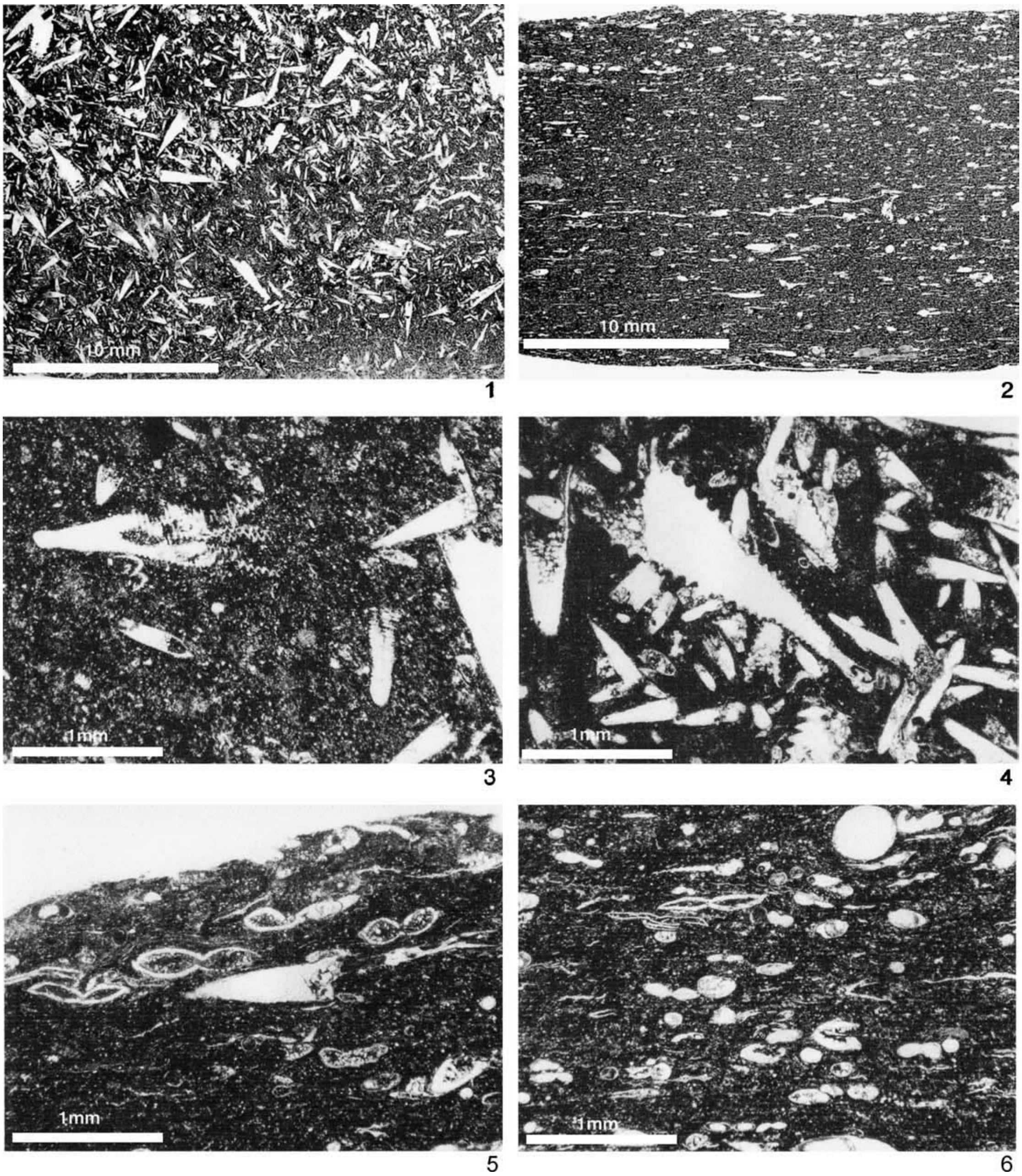


Fig. 3. Photographs of thin sections of black shale in the tentaculite bed. (1) A parallel section with a bedding plane. Black shale includes many tentaculites. Scale bar indicates 10 mm. (2) A vertical section with a bedding plane. Most of white bodies are cross sections of tentaculetes. Scale bar is 10 mm. (3) A parallel section with a bedding plane. Black shale is mainly composed of quartz grains and black matter. Some tentaculite specimens are completely preserved while others are broken or compressed. Scale bar indicates 1 mm. (4) A parallel section with a bedding plane. Scale bar is 1 mm. (5) A vertical section with a bedding plane. Black shale includes some compressed specimens that are shaped like a figure eight and filled with matrix. Scale bar indicates 1 mm. (6) A vertical section with a bedding plane. White circles are cross sections of complete specimens. Inner side of white specimens are hollow. Scale bar is 1 mm.

generally have two patterns of occurrence: the first exhibits many complete shells, whose longitudinal axes have a particular direction along a bedding plane; the second exhibits a few broken shell fragments, with no distinct orientation of the longitudinal axes. However, several horizons in our study bed contain abundant shells, but do not show these two patterns. Burton (1967a) stated that tentaculite beds with abundant fossils in Malaysia contain complete and incomplete shells of various sizes and show no uniformity in the orientation of their longitudinal axes. The occurrence of tentaculites in the Satun area is similar to that of Malaysia.

Under microscopic observation, this black shale is seen to be composed mainly of quartz grains less than 0.03 mm in diameter, clay minerals, and black organic matter. The tentaculite shells have been replaced by silica. We recognized at least two morphologies of the shell: the first has an undulatory wall, and the second is smaller than the first and shows a smooth surface (Fig. 3(3) and (4)). Most of the proximal parts of shells are not broken and the distal parts are generally compressed and broken (Fig. 3(3)–(6)). The insides of shells are commonly filled with matrix or are hollow.

## 4. Depositional age

Although the tentaculite bed in the Satun area seems to contain several species of tentaculite, we could identify only one species herein, *Nowakia acuaria* (Richer, 1854) (Fig. 4). This species has been reported from the Lockhovian to Emsian (Lower Devonian) rocks in Europe, Morocco, and Australia and from Pragian (Lower Devonian) rocks in Alaska, northern Africa, and Czechoslovakia (Bouček, 1964; Lardeux, 1969; Churkin and Carter, 1970; Chlupáč and William, 1989). Tentaculite beds in northwestern Malaysia yield many allied species of *Nowakia* (e.g. Burton, 1967a) and some beds also yield graptolites.

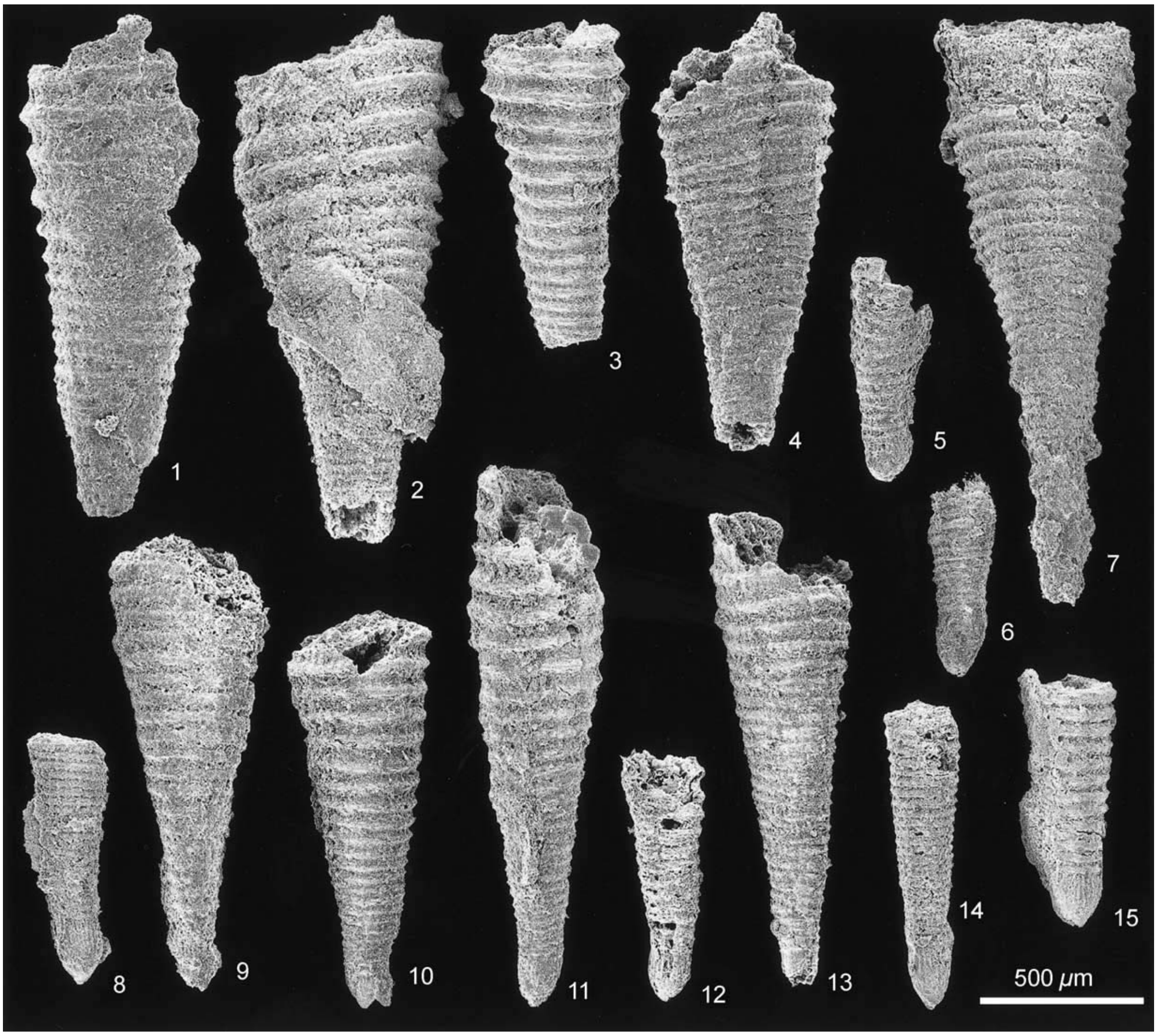


Fig. 4. Photographs of isolated tentaculite specimens. Scale bar is 500 μm. 1–15, *Nowakia acuaria* (Richer, 1854). 1, IGUT-ag00652; 7, IGUT-ag0056; 8, IGUT-ag0053; 9, IGUT-ag0062; 10, IGUT-ag0061; 11, IGUT-ag0051; 12, IGUT-ag0064; 13, IGUT-ag0065; 14, IGUT-ag0054; 15, IGUT-ag0057.

Wongwanich et al. (1990) reported occurrences of several fossils, including *Nowakia*, *Styliolina*, *Metastyliolina* (tentaculite), *Monograptus* (graptolite), and *Plagiolaria* (trilobite) from the present study tentaculite bed; they cited the depositional age of the bed as Early to Middle Devonian. Boucot et al. (1999) also mentioned this tentaculite bed of the Pa Samed Formation and concluded that tentaculite fauna from their samples appear to be late Pragian to earliest Emsian in age. The tentaculite fauna in the Satun area is similar to that of the Trang area, southern peninsular Thailand, where Kobayashi and Hamada (1968) reported *Nowakia*, *Styliolina*, *Monograptus*, and *Plagiolaria*. The fauna of the Trang area is thought to be coeval with graptolite fauna including *Monograptus yukonensis* and *M. pacificus* (Hamada et al., 1975). According to Yolkin et al. (1997), these graptolites occur in the *Polygnathus dehiscens* conodont biozone, which is lowest in the Emsian stage.

In summary, the age of the tentaculite bed in the Satun area is earliest Emsian (Lower Devonian).

## 5. Correlation and depositional environment

Tentaculite beds yielding the *Nowakia–Styliolina* fauna have been reported from the following areas of Thailand and Malaysia: the Fang (e.g. Hamada, 1968), Sri Sawat (e.g. Brown et al., 1951), Trang (Kobayashi and Hamada, 1968), and Satun areas of Thailand, the Langkawi Islands (e.g. Jones, 1978) and the Mahang and Baling areas (e.g. Burton, 1967a; Hamada et al., 1975) of northwestern Malaysia (Fig. 1(2)). There are many reports that merely refer to occurrences of this fauna in the northern to western areas of Thailand (e.g. Hahn and Siebenhüner, 1982). On the basis of graptolites and trilobites coexisting with tentaculites and their ages, Hamada et al. (1975) subdivided the Devonian tentaculite faunas in Thailand and Malaysia into four faunal units, labeled TN1 to TN4. They are assigned Lochkovian, early Emsian (Early Devonian), Emsian to Eifelian (Early to Middle Devonian), and Eifelian (Middle Devonian) ages, respectively (Fig. 5). The TN1 fauna corresponds to the fauna of Langkawi Islands. The TN2 fauna is known from the Fang, Sri Sawat, Trang, and Baling areas. The TN3 fauna occurs in the Trang and Baling areas. The TN4 fauna correlates with a part of the tentaculite beds in the Fang and Sri Sawat areas (Hamada et al., 1975). The faunal composition of the tentaculite bed in the Satun fauna area is compared with that of the Trang area, and the depositional age of the Satun fauna is earliest Emsian. Therefore, the tentaculite bed in the present study belongs to TN2.

Although some Devonian tentaculite beds consist of black limestone within calcareous strata in western Thailand (Hagen and Kemper, 1976), other tentaculite beds are common in black shale. Burton (1967a) discussed a depositional environment for tentaculite beds in Malaysia and suggested that a euxinic environment may have spread to these basins. It is difficult to know the duration in time and space of the depositional environment for the black shale, owing to a lack of data about the lithologies and

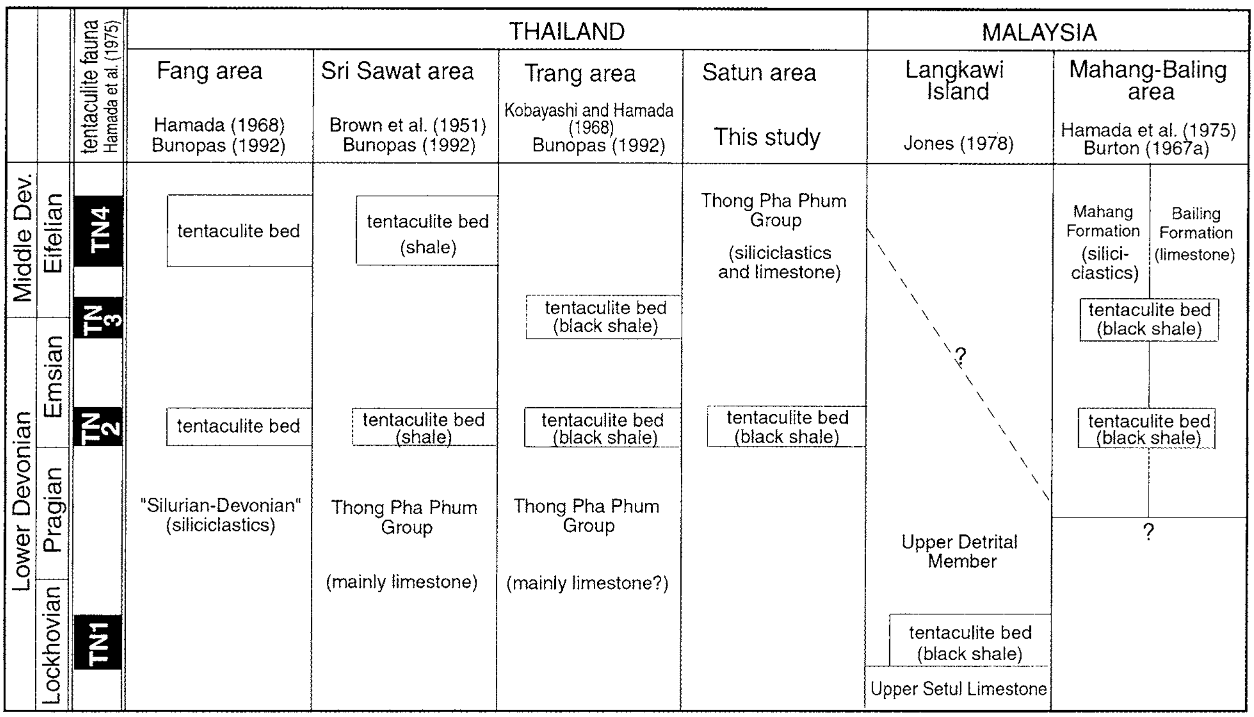


Fig. 5. Correlation among tentaculite beds of the Fang, Sri Sawat, Trang and Satun areas in Thailand with the Langkawi Islands and the Mahang and Baling areas in Malaysia.

fossils of the strata overlying and underlying each tentaculite bed. In the earliest Emsian, at least, a uniform depositional environment covered a wide area of northern, western, and southern Thailand and northwestern Malaysia. Similar sediments with tentaculite fauna TN2 accumulated in these basins.

## 6. Conclusions

A siliciclastic sequence in the Satun area of southern peninsular Thailand contains a tentaculite bed that is composed of black shale and contains *Nowakia acuaria* in the lowermost part. Based on occurrences of *Nowakia acuaria* and correlations with surrounding areas, the depositional age of the tentaculite bed is earliest Emsian. A number of similar tentaculite-bearing beds are present over a wide area of northern, western, and southern Thailand and northwestern Malaysia. The depositional environments in which this tentaculite-bearing black shale accumulated prevailed from present northern Thailand to northwestern Malaysia during the earliest Emsian.

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## Appendix A. Systematic paleontology

The paleontological work presented here was undertaken by S. Agematsu and K. Sashida who take full responsibility for the taxonomy. All specimens described in this study have been deposited in the Institute of Geoscience, University of Tsukuba and bear the prefix IGUT.

Order DACRYCONARIDA (Fisher, 1962)
Family NOWAKIIDAE (Bouček and Prantl, 1960)
Genus NOWAKIA (Gürich, 1896)

*Type species*. *Tentaculites elegans* (Barrande, 1852)

*Diagnosis*. Tube is straight, medium in size, and commonly 3–5 mm long, mainly with a conical shape that is often nearly cylindrical distally. Transverse rings are sharp, with various height and width. Longitudinal ribs are present. Inner side of wall reflects the outer relief. Drop-shaped initial chamber is differentiated from a tube. It ranged from Llandvery (Lower Silurian) to Frasnian (Upper Devonian) and is known worldwide (Churkin and Carter, 1970; Tunnicliff, 1983, 1989; Yochelson and Kirchgasser, 1986).

NOWAKIA ACUARIA (Richer, 1854)
Figs. 6.1–6.15

*Tentaculites acuarius*. (Richer, 1854, p. 285, pl. 3, Figs. 3–9).

*Nowakia acuaria* (Richter). (Bouček, 1964, p. 60–69, pl. 1, Figs. 1–7, pl. 3, Figs. 1–6, pl. 4, Figs. 1–4, text-Figs. 10, 11, 13–17; Lardeux, 1969, p. 91–96, pl. 30, Figs. 1–3, pl.31, Figs. 1–8, pl. 32, Figs. 1–4, text-figs. 64–66; Alberti, 1970, p. 391, 392; Churkin and Carter, 1970, p. 62, pl. 16, Figs, 1–8).

*Diagnosis*. Tube is straight and conical-shaped, and covered with relatively close spaced transverse rings with sharp crests. An initial chamber is teardrop-shaped and pointed slightly downward.

*Description*. Tube is straight, conical, less than 3.3 mm in length, and gradually increases in width to 0.5 mm; angle of divergence is 10–15°. An initial chamber, which is differentiated from a tube, has a teardrop shape slightly pointed downward, 0.15–0.2 mm in length, 0.12–0.16 mm in diameter, and has distinct longitudinal ribs. Transverse rings with sharp crests are present on a tube, with highest density (10–17 per 0.5 mm) proximally, and lower density (10 per 0.5 mm) distally. Longitudinal ribs of the tube are weak.

*Material examined*. 15 specimens (IGUT-ag0051 to 0065).

*Occurrence*. Specimens from a horizon located 2 m above the base of a siliciclastic sequence in the Satun area.

*Discussion*. Our specimens are smaller than those described by Churkin and Carter (1970), which are 7 mm in maximum length. Although our specimens indicate a high density of transverse rings proximally, *N. acuaria* shows a variety of density and ring spacing (Churkin and Carter, 1970). The initial chamber in our specimens shares several characteristics with *Nowakia barrandei* (Bouček and Prantl, 1959), and *N. cancellata* (Richer, 1854). However, our specimens differ from those two species in having no distinct longitudinal ribs, numerous transverse rings, and a distal, cone-shaped tube.

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