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Devonian Tentaculite of the Thong Pha Phum Group in Si Sawat District, Kanchanaburi Province

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Abstract

The Thong Pha Phum Group is well exposed in the study area. It consists mainly of shale, siltstone, sandstone, limestone, argillaceous limestone, calcareous shale, calcareous mudstone, and laminated mudstone with many fossils such as graptolites, tentaculites, ostracods, brachiopods, nautiloids and trilobites. These strata are conformably underlain by the Thung Song Group and are conformably overlain by the Khuan Klang Formation. The purposes of this study are to clarify the detailed stratigraphy, age and paleoenvironment of the Thong Pha Phum Group in Kanchanaburi Province. The results show that abundant tentaculites were recognized and they consist of 7 species belonging to 3 genera: *Nowakia acuaria*, *Nowakia* (Cepanowakia) *pumilio*, *Styliolina fissurella*, *Styliolina clavulus*, *Styliolina* sp. A, *Homoctenus tikhyi*, and *Homoctenus arctus*. They indicate Lower to Upper Devonian age. In addition, the lower rock strata under Thong Pha Phum Group yield graptolites (*Monograptus* sp. and *Diplograptus* sp.) indicating probably Silurian? to Lower Devonian age. Based on lithofacies and sedimentary structures, they suggest that the Thong Pha Phum Group was deposited on the slope environment to deep marine basin in low energy condition.

Keywords: Thong Pha Phum Group, lithostratigraphy, tentaculites, depositional environment

1. Introduction

Silurian- Devonian rocks of Thailand, located in Sibumasu terrane, are well exposed in the northern, western, and peninsular Thailand. They generally belong to marine sequences of the Thong Pha Phum Group (Bunopas, 1981). The type section of this group is well seen along the banks of Huai Thong Pha Phum (Huai U-Long) north of Thong Pha Phum district. It contains various kinds of fossil such as nautiloids, tentaculites, graptolites, ostracods, trilobites, conodonts, bivalves, brachiopods and radiolarian (Bunopas, 1981; Hagen & Kemper, 1976; Hahn & Siebenhüner, 1982; Wongwanich et al., 1990 and Wongwanich et al., 2002). However, the age of the Thong Pha Phum Group is still questionable because no detailed study on stratigraphy and fossil studies have been done. This study will focus on tentaculite fossil and petrography in order to define the age and to reconstruct the paleoenvironment. The study area, Ban Tha Kradan (latitude 14° 25' 06" N to 14° 29' 59" N and longitude 99° 05' 34" E to 99° 10' 34" E), is located in Si Sawat District of Kanchanaburi Province, western Thailand (Figure 1). Its lithology is composed of calcareous shale to mudstone, siltstone, sandstone, limestone, argillaceous limestone, and marl yielding abundant fossils. Sedimentary structure found in the area contains parallel lamination, very thin- to thin-bedded, and graded bedding. Structural trend in the area lies approximately in the NW- SE direction with dipping to NE- SW. Tentaculite fauna are abundant and well-preserved in study area which can be identified and used as a correlation tool.

2. Materials and methods

We collected rock samples from 14 localities (KB 01 to 14) around the study area (Figure 1). The rocks consist of thin-bedded argillaceous limestone alternation with highly weathered mudstone or shale and chert. Although argillaceous limestone has yielded abundant tentaculites, the preservation of tentaculites was not good. This made difficult to extract tentaculite fossil from the rock. Thin section of mostly argillaceous limestone yielding tentaculites was made in order to see and compare their morphologies. In addition, we have examined the detailed microfacies of sedimentary rocks and other fossils.

Terminology of sedimentary rock in this study are based on Pettijohn et al., (1987) and Wright (1992). Eighty thin sections were made for petrography and tentaculite classification. The classification of tentaculites (Figure 2) followed the works of Fisher (1962; Larsson (1979); Wittmer & Miller (2011); Wei et al., (2012); and Wei (2019).

3. RESULTS

3.1 Petrography

Based on the field observation and petrographic study, the lithofacies of the Thong Pha Phum Group is composed of many rock types: shale, calcareous shale to mudstone, arkosic sandstone, bioclastic wackestone, bioclastic packstone, calci-mudstone and chert.

The shale is light grey and black gray, silt-size, lamination interbedded with very fine- to fine- grained, laminated to thin- bedded, siltstone to fine sandstone and abundant fossils of graptolites. This graptolite fauna (*Monograptus*? and *Diplograptus*?) was collected from highly weathered siliceous shale (sample no. KB 11) that indicated a Silurian? to early Devonian age (Figure 3D-3E). A similar graptolite fauna is also known to occur in the Chiang Dao area (Wonganan 2005), Thong Pha Phum area (Hahn & Siebenhüner, 1982; Savage et al., 2006), Si Sawat area (e.g., Kobayashi, 1958) Satun area (e.g., Agematsu et al., 2006b; Wongwanich et al., 1990) and northwestern Malaysia (e.g., Hassan et al., 2013; Ong & Jasin, 2007). In addition, calcareous shale to mudstone from samples KB 02 area is pale grey to medium grey and reddish brown to yellowish brown in color, silt- to very fine-grained sized, laminated to very thin-bedded and graded bedding with abundant tentaculite fossils that indicate an early to late Devonian age.

Calcareous mudstone is recognized from grey to dark grey in color, thin- to medium-bedded limestone (e.g., sample no. KB 05, KB 06, KB 07 and KB 08. It shows mainly matrix-supported texture (less than 10 % grains) with carbonate mud matrix and cemented by calcite.

Bioclastic packstone containing abundant tentaculites, few ostracods, and brachiopods (shell fragment) (Figure 4) were found from KB 08. The tentaculites specimens are well preserved and abundant. They contain *Nowakia acuaria, Styliolina fissurella, Styliolina clavulus* indicating the Eifelian to Frasnian (early Middle to early Upper Devonian) age.

Moreover, radiolarian cherts have been recognized but there are no specific radiolarian species for age determination. Chert is greenish grey to yellowish brown, very thin- to thin-bedded (1-5 cm, well bedded, highly weathered and intercalated with siliceous shale). Chert outcrops are widely distributed throughout the study area, especially in the northern and northeastern part (KB 03, KB 09 and KB 12). Microscopically, chert contains very fine-grained quartz with abundant radiolarians. Radiolarian grains are in small-size, spherical-shaped, silica skeletons ranging from 50-200 µm. Although we cannot get the age from bedded-cherts, we found that chert was underlian by shale beds of the upper Thong Pha Phum Group. However, Polwichai (2013) reported chert bed with radiolarian assemblage (*Albaillella* sp., *Albaillella* sp. cf. *A. pennata, Albaillella* sp. cf. *A. paradoxa, Latentifistula* sp., *Strigmosphaerostylus* sp., *Trilonche* sp., and *Latentifistula concentric*) from Ban Tha Kradan area. They indicated Lower Carboniferous age and their paleoenvironment was in pelagic deep marine.

Stratigraphic correlation of isolate localities in the Thong Pha Phum Group is shown in Figure 5. Shale, siltstone and very fine-grained sandstone with graptolite fauna in the lower part of this group overlie Ordovician limestone (Thung Song Group). Calcareous shale to mudstone, bioclastic wackestone, bioclastic packstone and calcareous mudstone in the middle part of this group gradually change to laminated shale in the upper portion which is observed in the lower part of section KB 09.

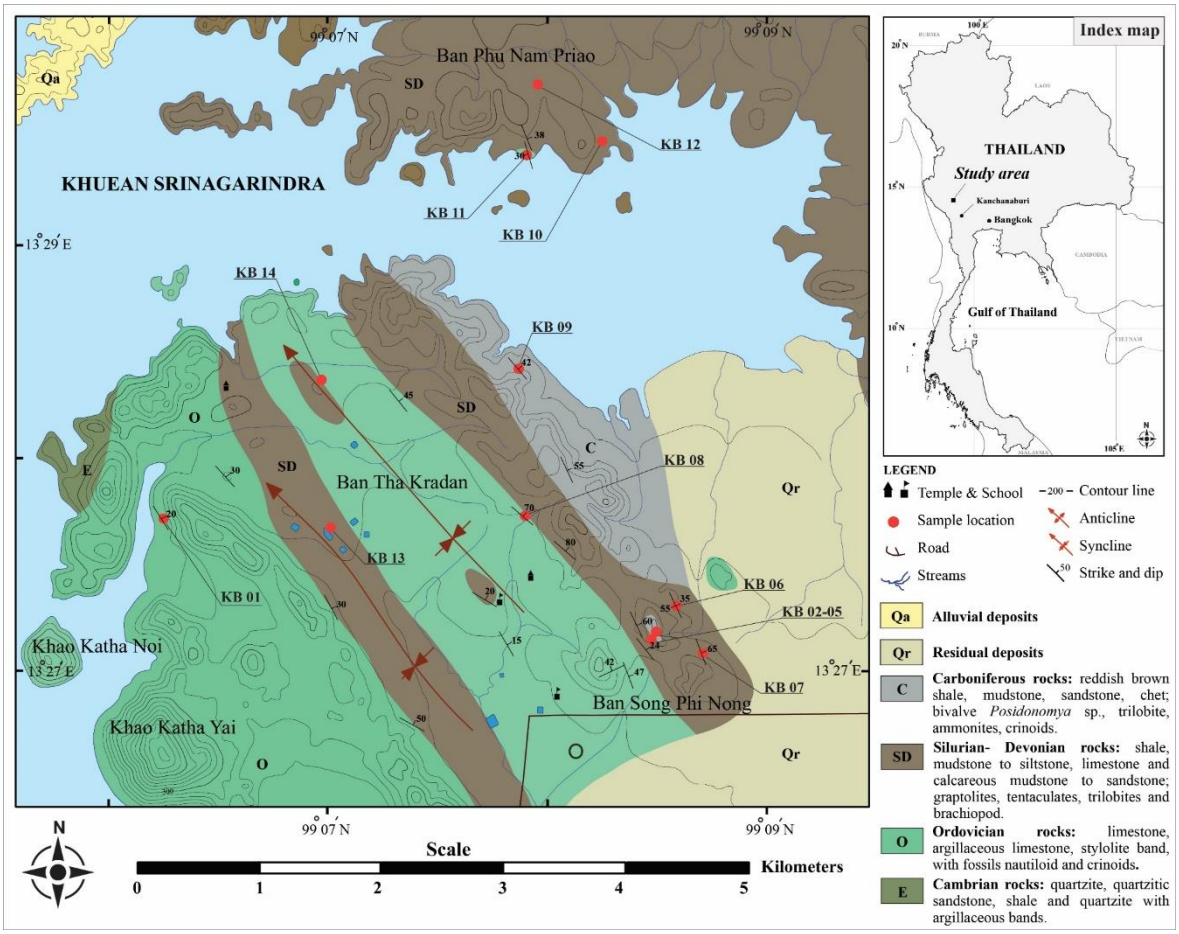

Figure 1. Geologic map of the Ban Tha Kradan area, Si Sawat District, Kanchanaburi Province in western Thailand (modified after Khaowwiset et al., 2010 and Meesook, 2013).

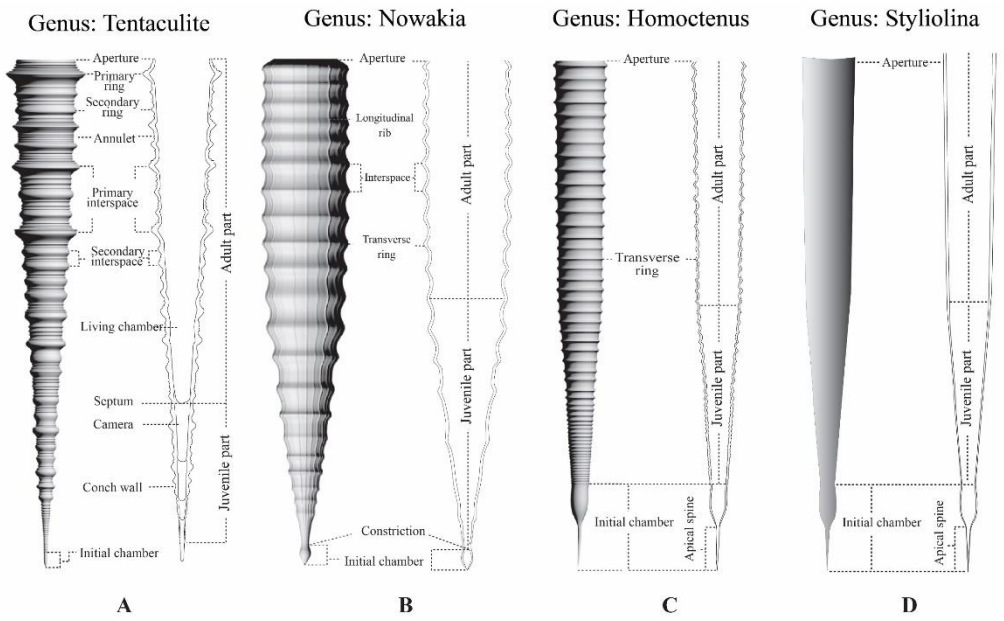

Figure 2. Drawing longitudinal section of tentaculite conchs of 4 characteristic genera; A: *Tentaculite*, B: *Nowakia*, C: *Homoctenus*, and D: *Styliolina* (modified after Fisher, 1962; Larsson, 1979; Wittmer and Miller, 2011; Wei et al., 2012; Wei, 2019).

3.2 Age determination

The Lower Paleozoic rocks covering the western region of Kanchanaburi Province, have been dated by using fauna assemblages (nautiloids, graptolites, tentaculites, trilobites and brachiopods) as Ordovician to Devonian (Hagen & Kemper 1976; Bunopas, 1981; Wongwanich et.al., 1990; Hahn & Siebenhüner, 1982).

According to previous tentaculites paleontology studies by Fisher (1962), Boucek (1967), Hagen & Kemper (1976); Larsson (1979), Agematsu et al. (2006a), Wittmer & Miller (2011), Wei *et al*. (2012) and Wei (2019), the rocks are assigned as the Silurian-Devonian age. Our data show that seven species belonging to three genera of tentaculite specimens are mentioned. They contain *Nowakia acuaria*, *Nowakia* (Cepanowakia) *pumilio, Styliolina fissurella, Styliolina clavulus*, *Styliolina* sp. A, *Homoctenus tikhyi*, and *Homoctenus arctus,* indicating Lower to Upper Devonian age. Tentaculite fauna (*Nowakia* sp., Styliolina sp.) similar to those of Ban Tha Kradan area have been reported from several localities in Thailand and Malaysia including Thong Pha Phum area (Hahn & Siebenhüner, 1982; Savage et al., 2006), Si Sawat area (e.g. Kobayashi, 1958) Satun area (e.g. Agematsu et al., 2006a, 2006b; Wongwanich et al., 1990) and Kampung Guar jentik and Perlis areas of northwester Malaysia (e.g., Hassan et al., 2013; Ong & Jasin, 2007). In addition, graptolites collected from shale to mudstone of sample KB 11 contain *Monograptus*? and *Diplograptus*? They probably indicate Silurian? - Lower Devonian in age (Wonganan, 2005; Agematsu et al., 2006a, 2006b; Wongwanich et al., 1990). Based on paleontological evidences, the age of the Thong Phum Phum Group in the study area is probably ranging from Silurian? to Upper Devonian.

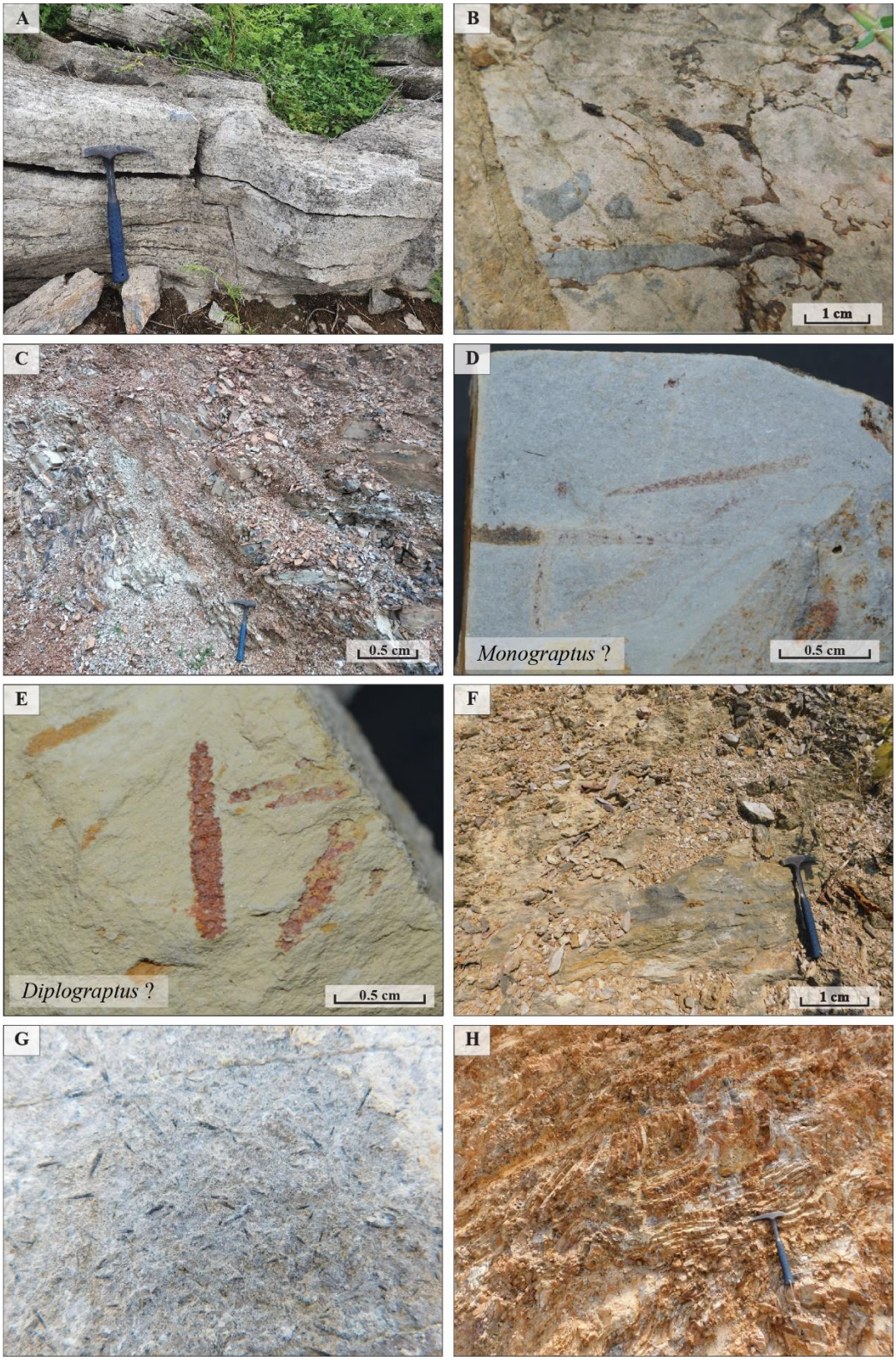

Figure 3. Outcrop of the Thong Pha Phum Group in study area. A: Quarry outcrop of section KB11 (looking NW). B: Closed-up of limestone texture of KB11. C: Laminated, thin-bedded, shale with graptolite (KB 11). D and E: Closed-up of graptolite in the dark gray shale (KB 11). F: Calcareous cement, laminar to thin-bedded, graded bed, shale to mudstone interbedded with argillaceous limestone (KB 04). G: Closed-up of tentaculites in KB 08. H: Outcrop of pale grey to greyish brown, very thin- to thin-bedded, chert (KB 09).

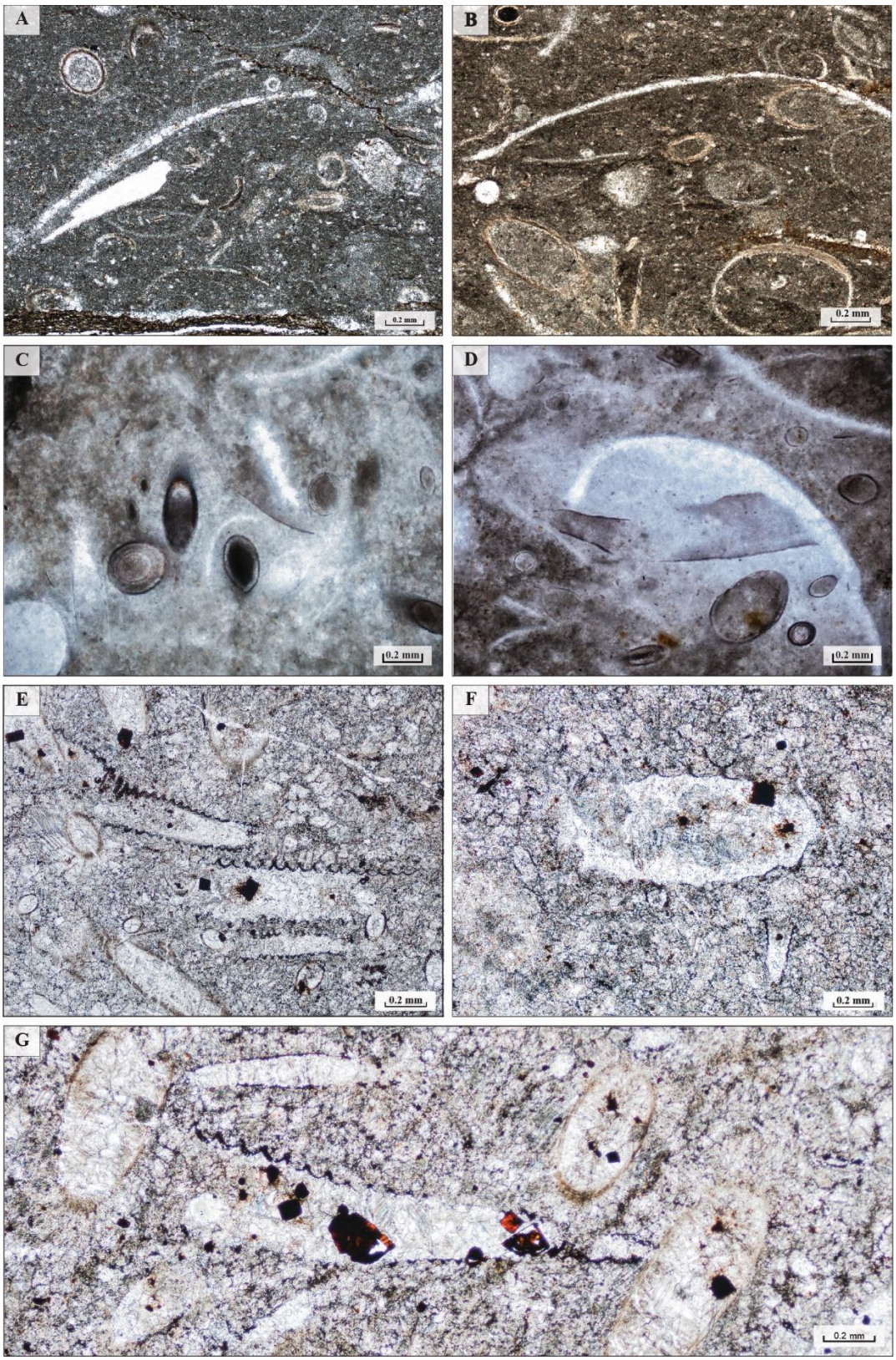

Figure 4. Photomicrographs of rocks of the Thong Pha Phum Group. A-B: Bioclast wackestone with abundant fossils (KB 06). C-D: Bioclast wackestone with abundant tentaculites and brachiopods (KB 05). E - G: Bioclastic packstone (sample no. KB 08) showing grain-supported texture which grains composed of abundant tentaculites and pyrite. Scale bar is 0.2 mm.

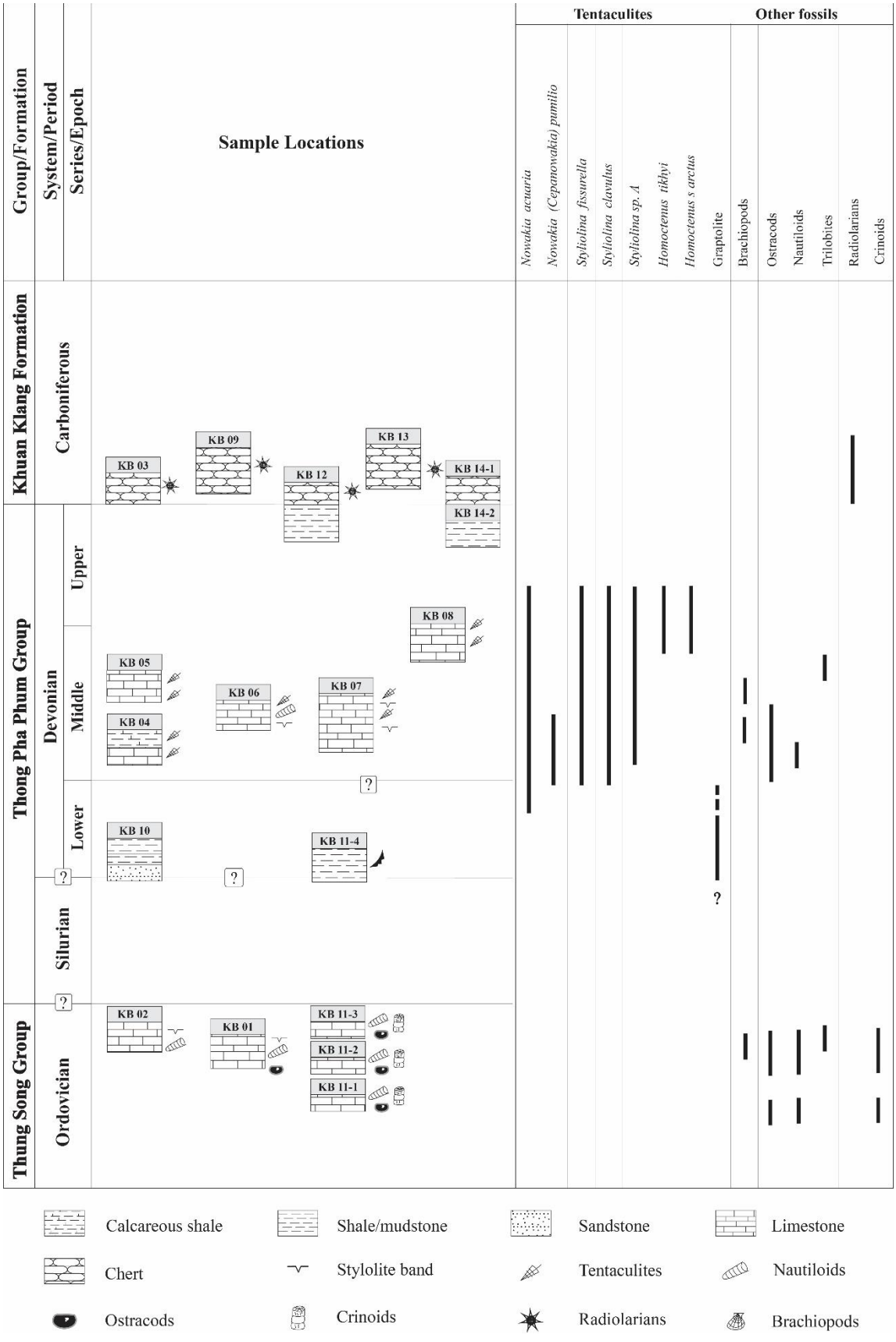

Figure 5. Stratigraphic correlation of lithology and fossil distribution of the Thong Pha Phum Group in study area.

3.3 Systematic Paleontology

All specimens of tentaculites collected from the Thong Pha Phum Group at Ban Tha Kradan area, Si Sawat District, Kanchanaburi Province (at KB 04, KB 05, KB 06, KB 07 and KB 08). Morphology, classification, and description for tentaculite in this study are based on the works of Fisher (1962); Bouček (1964); Larsson (1979); Wei et al., (2012); Wei (2019); Wittmer and Miller (2011).

Class TENTACULITOIDAE Ljaschenko, 1955
Order DACRYOCONARIDA Fisher, 1962
Family NOWAKIDAIDAE Bouček and Prantl, 1960
Genus Nowakia Gürich, 1896

Nowakia acuaria (Richter, 1854)
Figure 6A and 6B

1854 *Tentaculites acuarius*; Richter, 1854, p.285, pl.3, figs.3-9.
1962 *Nowakia acuaria*; Fisher, p. W112, fig.55-3.
1964 *Nowakia acuaria*; Bouček, p.60-69, pl.1, figs. 1-7, pl.3, figs 1-6, pl.4, figs 1-4, text-figs.10,11,13-17.
1967 *Nowakia* aff. *Acuaria*; Sherrard, pl.38, figs.14-15.
1970 *Nowakia acuaria*; Alberti, 391-392; Churkin &Carter, p.62, pl.16, figs 1-8.
2006 *Nowakia acuaria*; Agematsu et al., p. 608, figs. 4.1-4.15.
2007 *Nowakia acuaria*; Theng and Jasin, p. 5. pl. 1, figs. 1-4.

Material: 2 specimens from the dark gray, micritic limestone (KB 08) on the thin section.
Description: The conch is elongate conical-shape and straight, medium to large size for the genus. It is about 3.5-5.6 mm in length and approximately 0.5-1.5 mm in distal width. Initial chamber is not preserved. The density of transverse rings is 8-12/mm and well-distributed. Interspaces are concave and smooth. Growth angle varies between 8º - 13º. The conch wall thickness is 10-22 µm. The internal surface of the wall is wavy.
Stratigraphic range: Lower to Upper Devonian (Emsian - Frasnian).
Occurrences: Section of Thong Pha Phum Group, Ban Tha Kradan area, Kanchanaburi Province.

Nowakia (Cepanowakia) *pumilio* Alberti,1987
Figure 6C and 6D

1987 *Nowakia pumilio*; Alberti, p.638, fig.2.
2004 *Nowakia* (Cepanowakia) *pumilio*; Berkyova, p.149, figs. 3, A-C.

Material: 2 specimens from KB 05 on the thin section.
Description: Conch is a small for the genus, conical shape which slightly curved in the proximal part and straight in the middle part to distal part. Estimated length is approximately 0.5-0.8 mm and maximum outer distal diameter is 0.1 mm. The initial chamber is well-preserved and having a cone shape. Density of transverse ring is 10-12/0.5 mm and well-distributed. Growth angle varies between 7º-15º. Interspaces are smooth and rounded concave. The conch wall thickness is 10-20 µm. the internal surface of the conch wall is wavy.
Stratigraphic range: Middle Devonian (Eifelian-Givetian)
Occurrences: Middle part of section of The Thong Pha Phum Group, Kanchanaburi Province.

Family STYLIOLINIDAE Grabau&Shimer, 1910
Genus *Styliolina* Karpinsky, 1884

Styliolina fissurella (Hall, 1843)
Figure 6E and 6F

1843 *Tentaculites fissurella* Hall, p.182. fig.71/10
1964 *Styliolina fissurella*; Bouček, p. 127-131, pl.31. fig 1-2, pl.32, figs.3-9.
1970 *Styliolina* sp. cf. *Styliolina fissurella*; Churkin &Carter, pl.16, figs 1-8.
1972 *Styliolina sp.* cf. *Styliolina fissurella*; Ludvigsen p.308, pl.2, figs. 24-26, p.310, pl.3, fig. 6.
2004 *Styliolina fissurella*; Berkyová, p.152. fig.4a.

2007 *Styliolina sp*; Theng and Jasin, p. 5. pl. 1, figs. 5-7.
2016 *Styliolina* cf. *Styliolina fissurella*; Comniskey, p. 152, fig.26.

Material: 2 specimens preserved from KB 08 on the thin section.
Description: Conch is elongate conical shape, straight and has medium to large size. Estimated maximum length is 3.70 mm and maximum distal diameter is 0.6 mm. Apical angle is 9º-11º and growth angle varies between 5º-8º. The initial chamber is well preserved, slightly elongate, and drop-shaped that is 0.08-0.1 mm in width and 0.10-0.15 mm in length and merges with proximal part of conch. A small apical spine extends from the initial chamber. The conch wall thickness is about 10-20 µm. The surface of external and internal conch wall is flat and smooth.
Stratigraphic range: Middle to Upper Devonian (Eifelian-Frasnian)
Occurrences: Section of Thong Pha Phum Group, Ban Tha Kradan area, Kanchanaburi Province.

Styliolina clavulus Barrande, 1867
Figures 7A, 7B, and 7C

1867 *Styliolina clavulus*; Barrande, p. 59, pl.13, fig.23-30.
1962 *Styliolina clavulus*; Fisher, pl. 112, fig.55-2.
1970 *Styliolina* sp.; Churkin&Carter, pl.16, figs. 8-10.
2016 *Styliolina clavulus*; Comniskey, pl. 83, figs. 27(A-D).

Material: 3 specimens, KB 08 on the thin section.
Description: Conch is 0.5-2 mm in length and 0.1-0.4 mm in distal width. It is small to medium in size and has conical shape. Slightly curvature in the proximal part and straight in the distal part. The initial chamber is drop-like but a little different from the proximal part of the conch. Apex of initial chamber extended into a small apical spine. The conch wall (internal and external) is flat surface and approximate 10-20 µm in thickness (the relatively thick-walled conch).
Measurements: Show in the table 1.
Stratigraphic range: Middle-Upper Devonian (Eifelian-Frasnian)
Occurrences: Section of Thong Pha Phum Group, Ban Tha Kradan area, Kanchanaburi Province.

Styliolina sp. A
Figures 7D, 7E, 7F, and 7G

Material: 4 specimens, KB 08 on the thin section.
Description: The conch has small size and curve conch that curves in the proximal part and slightly curves in the distal part. It is about 1-2.7 mm in length and 0.1-0.33 mm in distal width. The external and internal of wall surface are flat and smooth. Conch wall thickness is approximately 10-19 µm. The initial chamber is complete and well-preserved. The apex of the initial chamber has a short spine that extends from this part.
Stratigraphic range: Middle to Upper Devonian
Occurrences: Section of Thong Pha Phum Group in Ban Tha Kradan area, Kanchanaburi Province.

Order HOMOCTENIDA Boucek, 1964
Family HOMOCTENIDAE Lyashenko, 1955
Genus Homoctenus Lyashenko, 1955

Homoctenus tikhyi Lyaschenko, 1959
Figures 7H, 7I, and 7J

1959 *Homoctenus tikhyi*; Lyaschenko, 1959, p. 98, pl.17, figs. 1-4.
2000 *Homoctenus* sp. cf. *Homoctenus tikhyi*; Li, p. 972, fig. 4.2.
2015 *Homoctenus* sp. cf. *Homoctenus tenuicinctus* Roemer, 1885; Hansan et al., p. 555, figs. 4 and p. 556, figs. 5.

Material: 3 specimen, KB 08 on the thin section.

Description: The conch is straight to slightly curved. It is small – medium in size and has conical shape that is approximately 1-3 mm in length and 0.2 mm in distal width. Transverse rings decrease into the distal part. Density of transverse rings is 18-22/1 mm. Interspaces are concave and have smooth surface. The internal and external conch wall is wavy in the proximal part to distal part. Conch wall thickness is 10-15 µm. The initial chamber is well-preserved and has elongated shape or like-conical with flat surface. This part is about 0.1 mm in width and approximately 0.1-0.2 mm in length.

Stratigraphic range: Upper Devonian (Frasnian)

Occurrences: Section on Thong Pha Phum Group in Ban Tha Kradan area, Kanchanaburi Province.

Hommoctenus arctus Li, 1995
Figures 7K and 7L

1995 *Homoctenus arctus*; Li, p.164-165, figs. 6-7.
2000 *Homoctenus arctus*; Li, p. 972, figs. 4.5-4.6.
2018 *Homoctenus* sp. A; Komatsu et al., p. 9, figs. 6 (e-l).

Material: 2 specimen, KB 08 on the thin section.

Description: The conch has small size as well as conical shape in the proximal part and slightly cylindrical in the distal part. It is curved in initial chamber to the proximal part. Maximum length is approximately 1.4-1.5 mm with outer distal width of 0.1-0.3 mm. Transverse ring is wavy and the density is 20-23 mm/1mm. Interspaces are concave and smooth. Initial chamber is drop-shape with flat surface. The conch wall is thin with is about 8-10 µm in thickness. The internal surface of conch wall is wavy.

Stratigraphic range: Upper Devonian (Frasnian)

Occurrences: Upper part of section of Thong Pha Phum Group in Ban Tha Kradan area, Kanchanaburi Province.

5. Depositional environment

Depositional environments of the Thong Pha Phum Group have been clarified based on its lithology, sedimentary structure, petrography, and fossil contents. The lithofacies in the study area is composed of the marine siliciclastic and carbonate rock sequences. Parallel lamination and small scale of graded bedding have been observed. They show that the depositional environment might be in slope to deep marine environment in low energy condition.

In conclusion, it shows that the Thong Pha Phum Group was developed during Silurian? to Upper Devonian along continental slope to basin plain.

6. Conclusions

(1) Lithology of the Thong Pha Phum Group is composed of siliciclastic and carbonate rocks.

(2) Graptolites (*Monograptus*? and *Diplograptus*?) found in study area indicate Silurian? to Lower Devonian age.

(3) Tentaculites can be classified into 7 species belonging to 3 genera: *Nowakia acuaria*, *Nowakia* (Cepanowakia) *pumilio*, *Styliolina fissurella*, *Styliolina clavulus*, *Styliolina* sp. A, *Homoctenus tikhyi* and *Homoctenus arctus*. They indicate Emsian to Frasnian (Lower to Upper Devonian) age.

(4) Sedimentary rocks of the Thong Pha Phum Group were deposited in slope to deep marine environments within low energy condition.

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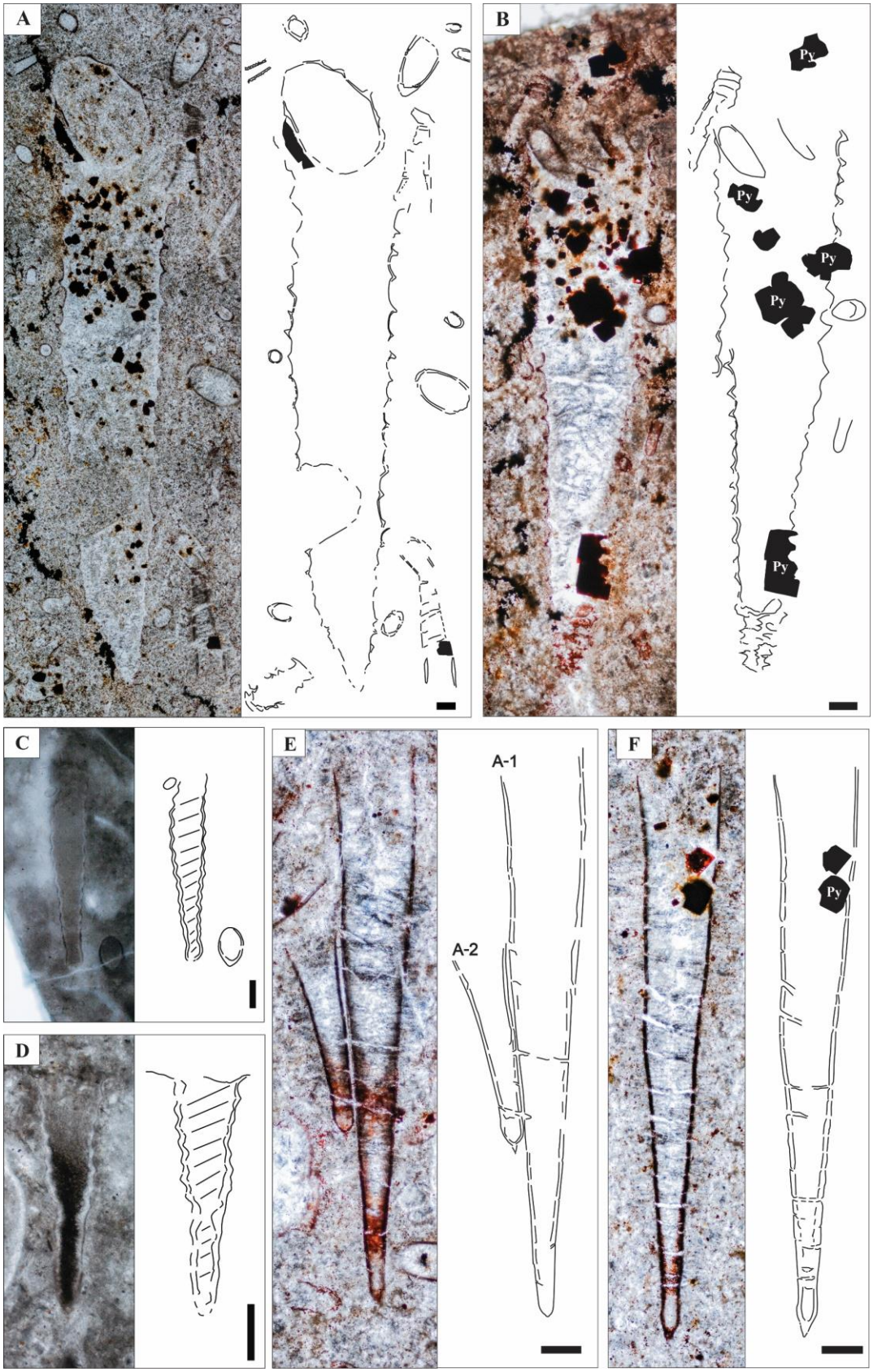

Figure 6. Photomicrographs of tentaculites and drawing. A and B: *Nowakia acuaria* (Sample No. KB 08). C and D: *Nowakia (Cepanowakia) pumilio* (Sample No. KB 05). E and F: *Styliolina fissurella* (Sample No. KB 08). Py=Pyrite; Scale bar is 0.2 mm.

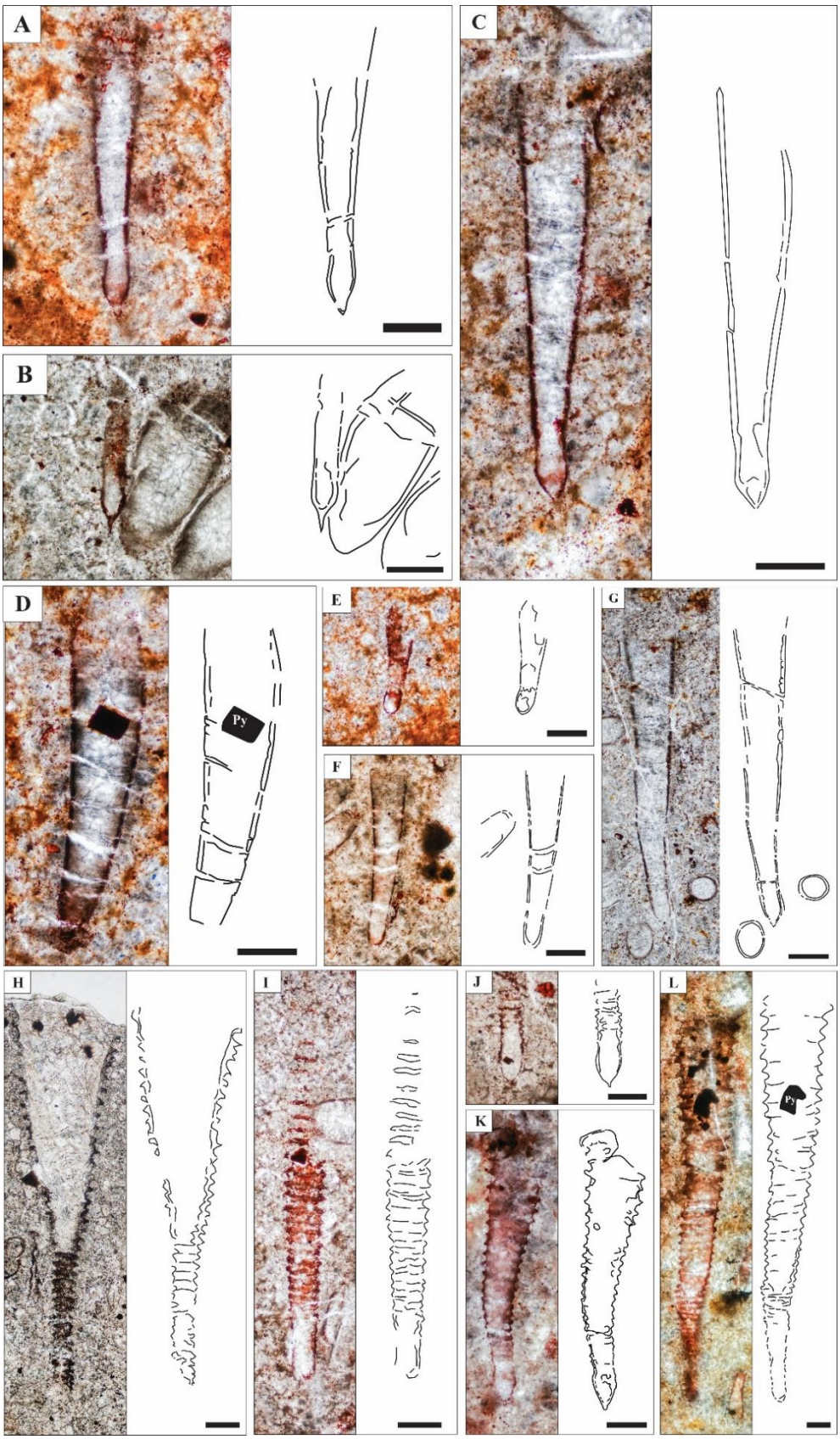

Figure 7. Photomicrographs of tentaculites and drawing. A, B and C: *Styliolina clavulus* (Sample No. KB 08). D, E, F and G: *Styliolina* sp. A (Sample No. KB 08). H, I and J: *Homoctenus tikhyi* (Sample No. KB 08). K and L: *Hommoctenus arctus* (Sample No. KB 08). Py=Pyrite; Scale bar is 0.2 mm.

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