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Additional occurrence report on early Carboniferous radiolarians from southern peninsular Thailand

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Abstract

Moderately-preserved radiolarians have been identified from black chert interbedded with layers of medium- to coarse-grained sandstone and variegated siliceous shale outcropped at a quarry near Ka Bang, Songkhla Province, southern peninsular Thailand. The following radiolarians (13 species belonging to seven genera) were identified and systematically investigated: namely *Albaillella* sp., *Ceratoikiscum* sp., *Stigmosphaerostylus variospina*, *Stigmosphaerostylus* cfr. *vulgaris*, *Stigmosphaerostylus* cfr. *delvolei*, *Stigmosphaerostylus* sp., *Stigmosphaerostylus*? sp. A, *Stigmosphaerostylus*? sp. B, *Stigmosphaerostylus*? sp. C, *Trilonche*? sp., *Spongentactnia exilispina*, *Pylentonema antiqia*, and *Archocyrtium* sp. These radiolarians indicate the Tournaisian–Visean, Mississippian (early Carboniferous) in age. The present authors have already reported a Tournaisian radiolarian fauna which is slightly older than the present fauna from black bedded chert in the Saba Yoi--Kabang area. This is an additional report on the occurrence of early Carboniferous radiolarians from southern peninsular Thailand. The radiolarian-bearing chert reported in this study may have been deposited in the upper continental rise to open deep-sea basins within the Paleotethys Ocean on the basis of the lithological and radiolarian characteristics.

Keywords: Carboniferous, depositional setting, paleogeography, Paleotethys Ocean, radiolarian fauna, Sibumasu terrane

1. Introduction

Mainland Thailand tectonically consists the Sibumasu Terrane, Inthanon Zone, Sukhothai Terrane, and Indochina Terrane, from west to east (e.g., Metcalfe, 2017) (Fig. 1 A). Lower Carboniferous siliceous rocks, such as chert and siliceous shale, are distributed in southern peninsular Thailand and the northwestern part of peninsular Malaysia (e.g., Sashida, Salyapongse and Charusri, 2002; Basir and Zaiton, 2011). Several researchers have reported radiolarian occurrences from these siliceous rocks (e.g., Caridroit, Fontaine, Jongkanjanasoontorn, Suteethorn and Vachard, 1990; Sashida, Igo, Hisada, Nakornsri and Ampornmaha, 1993; Sashida, Igo, Adachi, Ueno, Nakornsri and Sardsud, 1998; Sashida, Nakornsri, Ueno and Sardsud, 2000; Sashida et al., 2002; Wonganan and Caridroit, 2005; Wonganan, Randon and Caridroit, 2007; Saesaengseerung, Sashida and Sardsud, 2007a, 2007b, 2015; Kamata et al., 2015). These radiolarian-bearing siliceous rocks are considered to have been deposited on the slope, upper continental rise, and lower continental rise of the Sibumasu Terrane to the ocean basin of the Paleotethys based on their lithological characteristics and radiolarian faunal analysis (Basir and Zaiton, 2011). The present authors already reported the occurrence of early Carboniferous radiolarians from the Saba Yoi-Kabang areas, southern peninsular Thailand (Sashida et al., 2002), and have continued to investigate the area. A new radiolarian assemblage, distinguishable from the previously-reported one, was obtained from a chert layer intercalated within the sandstone–siliceous shale sequence cropping out in a quarry near the locality of Sashida et al. (2002). Further, the lower Carboniferous radiolarian-bearing siliceous rocks shown in this study differ from contemporary siliceous rocks in neighboring areas (e.g., Sashida et al., 1993, 1998; Wonganan et al., 2007) in containing coarse-grained clastic materials. In this article, we describe an early Carboniferous radiolarian

assemblage from a quarry near Ka Bang, southern peninsular Thailand, as an additional occurrence report of the authors' previous study. In addition, we discuss the depositional setting of the radiolarian-bearing siliceous rocks.

2. Previous studies on southern peninsular Thailand and sample locality of this study

Although most of peninsular Thailand is included in the Sibumasu Terrane in the tectonic subdivision map of mainland Southeast Asia by Metcalfe (2017), southern part is in the Inthanon Terrane (Fig. 1A).

Ueno and Charoentitirat (2011) summarized the Carboniferous–Permian stratigraphy in southern Peninsular Thailand (their Lower Peninsular Thailand) and discriminated the Yaha Formation (?Mississippian), Khuan Klang Formation (Mississippian), Kaeng Krachan Group (?latest Pennsylvanian–early Permian), and Ratburi Limestone (early–late Permian). Concerning the Yaha Formation, this formation was first introduced by Muenlek, Meesook, Tongchit, Tipdhonsab and Skulkaew (1985) in the Geological Map of Changwat Narathiwat and Amphoe Takbai for a mainly siliciclastic succession of shale, sandstone, siliceous shale, chert and conglomerate (Ueno and Charoentitirat, 2011). Muenlek et al. (1985) also introduced the Mayo Formation for similar lithologic characters distributed in the North east of Yala and included both formations in the Kaeng Krachan Group with the Mayo Formation in the lower part and the Yaha Formation in the upper. DMR (1999) regarded the Mayo and Haya formations as identical Carboniferous strata, and mapped the Yaha Formation in Yala, Pattani, Songkhla and Phatthalung provinces. Igo (1973) reported the occurrence of late Tournaisian conodonts from a chert–siliceous shale succession at the northern end of Ko Yo in Songkhla Province which substantiated the Mississippian age for the Yaha Formation. Sashida et al. (2002) discriminated Mississippian radiolarians from a sandstone--chert succession exposed in the Saba Yoi--Kabang area near the Songkhla-Yala provincial boundary. Besides these Carboniferous fossils, late Permian and Middle Triassic radiolarians have been reported from two areas where the distributional area of the Yaha Formation according to DMR (1999): the Chana area (Sashida et al., 2000) and the Rattaphum area (Sardsud and Saengsrichan, 2002; Kamata et al., 2008, 2009) in Songkhla Province. Ueno and Charoentitirat (2011) regarded the Yaha Formation only provisionally as Mississippian due to the controversial litho- and chronostratigraphic characterization of the above mentioned Yaha Formation. DMR (2013) discriminated 12 lithological units of Carboniferous sedimentary rocks in Thailand and set up sandstone, shale, siliceous shale with *Posidonia becheri*, chert, and conglomerate around Songkhla and Yala, in the border areas with Malaysia, as Unit Cy.

The Saba Yoi-Kabang area, study area of this article, is located within the distributional area of Unit Cy of DMR (2013) (Fig. 1B). A study section crops out at the quarry along the road, about 15 km west-southwest of Outcrop 1 of Sashida et al. (2002). A column of the section with outcrop photographs is shown in Fig. 2. Rocks at this outcrop strike N–S and dip 30° to 50° west. The total thickness of the formation of this outcrop attains 12 m. Variegated siliceous shale, mainly dark gray, green, brown, white, yellow, and black, predominates in the section. This siliceous shale is thinly bedded with several millimeters to a few centimeter beds, and it is strongly folded and sheared in the middle part of the section. The folded and sheared parts are cut by faults that are almost parallel to the bedding. Sandstone beds in the lower part intercalate with black chert beds and have a total thickness of about 1.5 m. Sandstone in the middle part of the section is coarse--grained and thickly bedded with intercalated very thin shale. Sandstone beds in the upper part are thickly bedded and have about 2.5 m total thickness. Radiolarian-bearing chert is thinly bedded with intercalated thin siliceous shale, and the total thickness is about 30 cm. This chert is black when fresh and brown to yellow on weathered surfaces. The lower and upper limits of this section are not exposed.

3. Materials and methods

We collected more than 10 samples from variegated siliceous shale and other chert layers of the section. Among them, only one sample (SYK-1) yielded radiolarians. Under thin section,

the samples characteristically contain radiolarian and foraminifer shells within matrices consisting of fine-grained quartz and clay minerals (Fig. 3). Foraminiferal shells are concentrated in some parts and their maximum diameter attains 300 μm. The foraminiferal shells were replaced by silica and are infilled with silica.

Radiolarian specimens were extracted from chert by the procedures, which generally established by Pessagno and Newport (1972), as mentioned below. In addition, we recovered the foraminiferal shells during the procedures. Crushed chert of several centimeters size was soaked in a diluted hydrofluoric acid (HF) solution (3–5%) for about 24 hours at room temperature. The sample was washed and sieved by nylon mesh of 36 μm for collecting residue. This procedure was repeated five times for every samples. The residue was dried in an oven. Well--preserved specimens in the residue were placed on scanning electron microscopy (SEM) plugs and coated with platinum in a vacuum evaporator. SEM images of foraminifers are shown in Fig. 4; those of radiolarians are shown in Figs. 5 and 6. Generic and species name of the foraminifers have not been identified. The systematic paleontology of radiolarians will be described in Section 6.

4. Age of radiolarian fauna

We discriminated radiolarians of 13 species belonging to seven genera from the chert sample (SKY-1). Identified radiolarians are *Albaillella* sp., *Ceratoikiscum* sp., *Stigmosphaerostylus variospina* (Won), *Stigmosphaerostylus* cfr. *delvoli* (Gourmelon), *Stigmosphaerostylus* cfr. *vulgaris* (Won), *Stigmosphaerostylus* sp., *Stigmosphaerostylus*? sp. A, *Stigmosphaerostylus*? sp. B, *Stigmosphaerostylus*? sp. C, *Trilonche*? sp., *Spongentactnia exilispina* (Foreman), *Pylentonema antiqua* (Deflandre), and *Archocyrtium* sp.

Stigmosphaerostylus vulgaris and *Stigmosphaerostylus variospina* was originally described by Won (1983) from the lower Carboniferous the Rheinisches Schiefergebirge, Germany. Subsequently, Gourmelon (1987) reported these two species from the Tournaisian of the Montagne Noire and the central Pyrenees in France. Saesaengseerung et al. (2007a) reported the occurrence of these two species from a sequence of chert, siliceous shale, and sandstone from the Pak Chom area, Loei Province, northeastern Thailand. The occurrence of these two species has been reported by Sashida et al. (2002) from the Saba Yoi-Kabang area. *Stigmosphaerostylus delvoli* was first reported from the Tournaisian of the Montagne Noire and Central Pyrenees by Gourmelon (1987). *Spongentactinia exlispina* was described as *Entactinia exlispina* by Foreman (1963) from the Upper Devonian Ohio Shale. Subsequently this species was reported from the Tournaisian of the Montagne Noire by Gourmelon (1987). *Pylentonema antiqua* was first described from the lower Carboniferous of France by Deflandre (1963) and subsequently Holdsworth (1973) and Holdsworth, Jones and Allison (1978) reported this species from the Upper Devonian of Alaska and the lower Carboniferous of Istanbul, Turkey, respectively. Sandberg and Gutshik (1984) reported this species from the Mississippian (lower Carboniferous) of North America. This species is also known from the Montagne Noire, France (Gourmelon, 1987), Southern Thailand (Sashida et al., 2002), and northwestern Peninsular Malaysia (Basir and Zaiton, 2011).

We discriminate poorly preserved species *Albaillella* sp. whose shell features are slightly similar to *Albaillella indensis* Won. According to Aitchison, Suzuki, Caridroit, Danelian and Noble (2017), *Albaillella idensis* has a range from the late Tournaisian to middle Visean (Mississippian) and this species is an index of the boundary between the upper Tournaisian through lower Visean. As mentioned above, our radiolarian fauna is similar to those from the lower Carboniferous Rheinisches Schiefergebirge, Germany (Won, 1983) and the Montagne Noire, France (Gourmelon, 1987).

The geologic age of the chert sample (SKY-1) may be late Tournaisian to early Visean (Mississippian). In our previous study, *Albaillella deflandrei* Gourmelon occurred in all of the samples (Sashida et al., 2002). *Albaillella deflandrei* is regarded as an index species of the late middle Tournaisian by Aitchison et al. (2017); therefore, our present radiolarian is younger than the samples from our previous study.

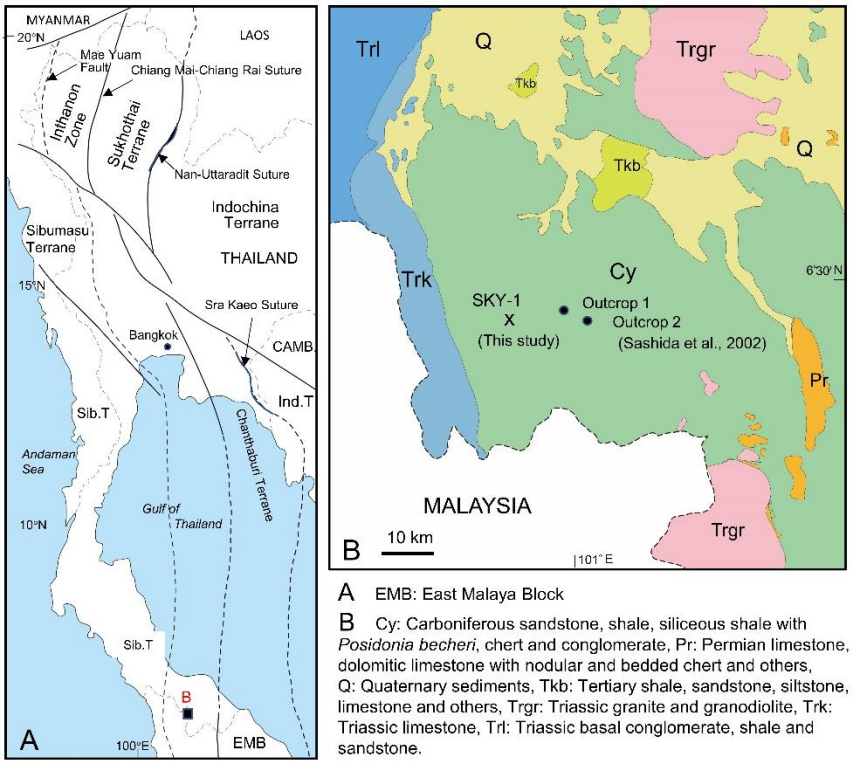

Fig 1: Location map of our study area. A. tectonic subdivision of Thailand and study area. The base map is modified from Metcalfe (2017). B. Location map of our study area, SKY-1, our examined sample. The basic geologic map is modified from DMR (2013).

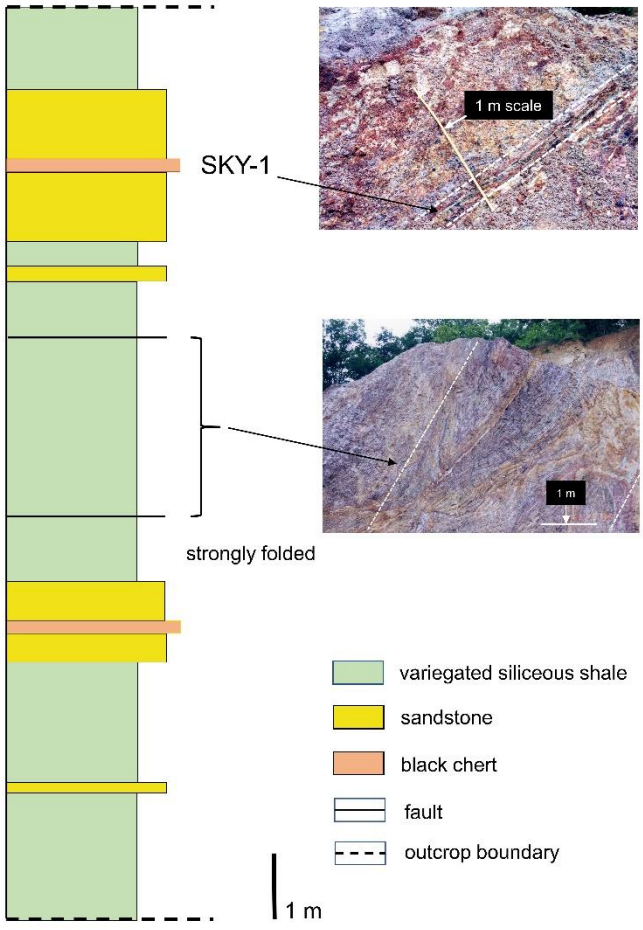

Fig 2: Columnar section and outcrop photos of study section.

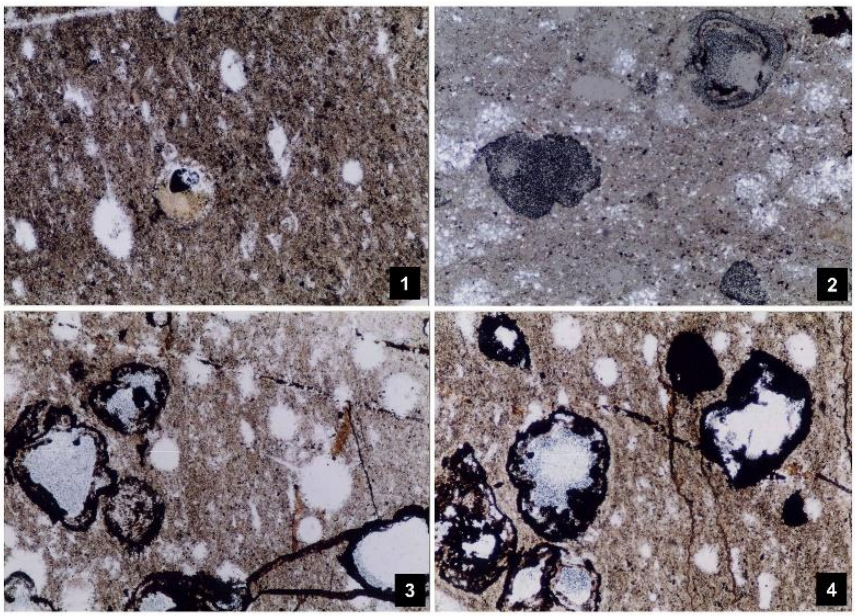

Fig 3: Thin section microphotographs of radiolarian-bearing chert. 1, 3, and 4 are under plane polarized light; 2 is under cross polarized light.

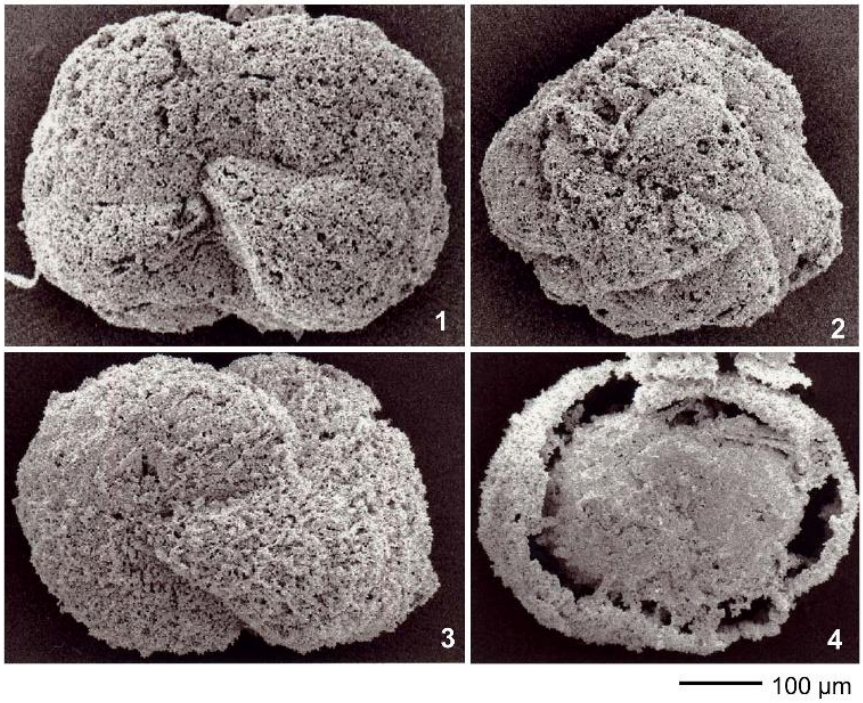

Fig 4: SEM (Scanning Electron Microscope) photos of foraminiferal shells.

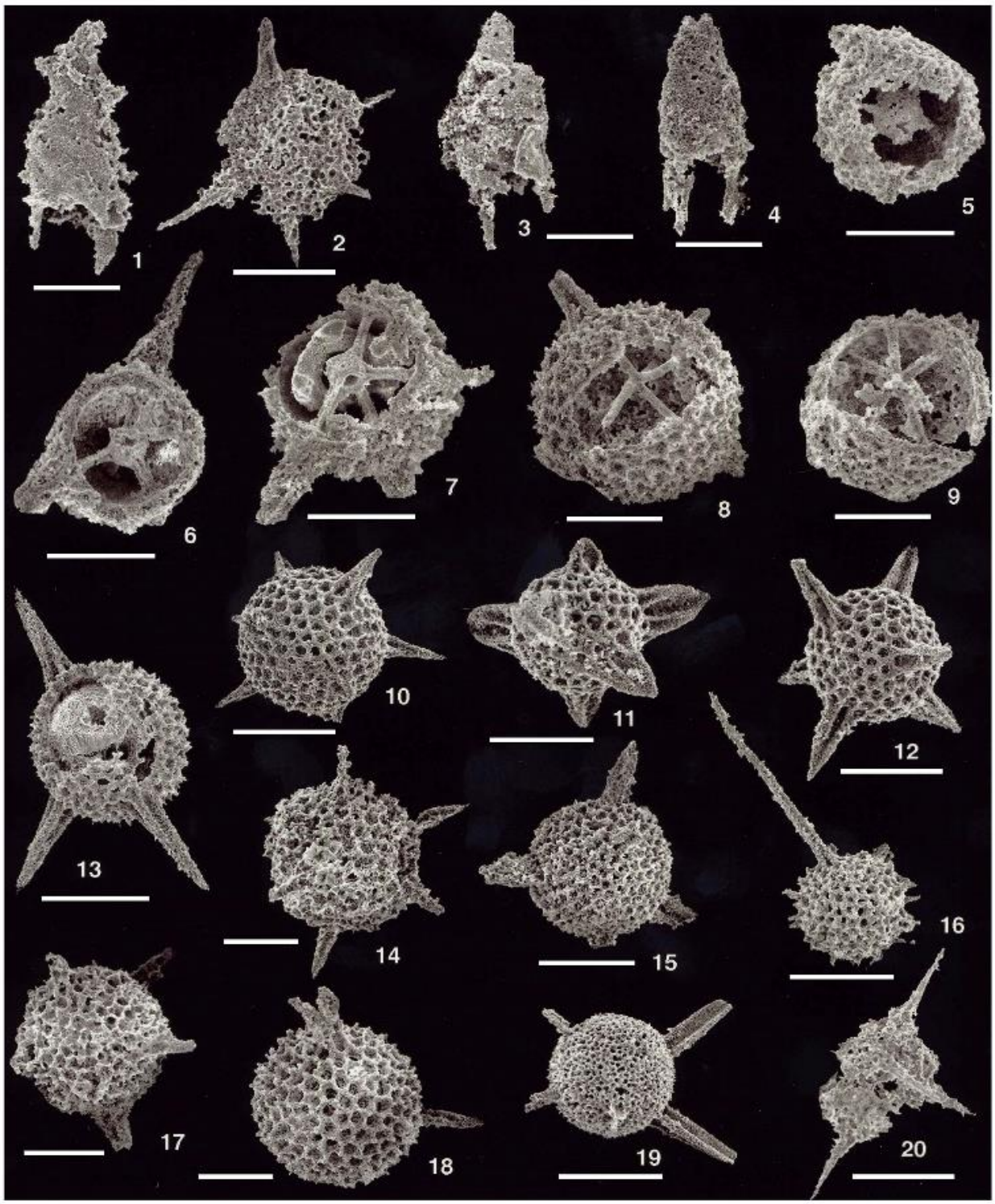

Fig 5: Radiolarian SEM photos of Mississippian chert from southern peninsular Thailand. All scale bars indicate 100 μm. 1, 3, 4. *Albaillell*a sp., 1, EES-KS-ST-0001, 3, EES-KS-ST-0003, 4, EES-KS-ST-0004, 2, 20. *Ceratoikiscum* sp., 2, EES-KS-ST-0002, 20, EES-KS-ST-0020, 5, 6, 7. *Trilonch*e? sp., 5, EES-KS-ST-0005, 6, EES-KS-ST-0006, 7, EES-KS-ST-0007, 8, 9. *Stigmosphaerostylus* sp., 8, EES-KS-ST-0008, 9, EES-KS-ST-0009, 10, 14, 17, 18. *Stigmosphaerostylus*? sp. A, 10, EES-KS-ST-0010, 14, EES-KS-ST-0014, 17, EES-KS-ST-0017, 18, EES-KS-ST-0018, 11. *Stigmosphaerostylus variospina* (Won), EES-KS-ST-0011, 12. *Stigmosphaerostylus* cfr. *vulgaris* (Won), EES-KS-ST-0012, 13. *Stigmoshpaerostylus*? sp. B, EES-KS-ST-0013, 15. *Stigmoshpaerostylus*? sp. C, EES-KS-ST-0015, 16. *Stigmoshpaerostylus* cfr. *delvolei* (Gourmelon), EES-KS-ST-0016, 19. *Spongentactinia exillispina* (Foreman), EES-KS-ST-0019.

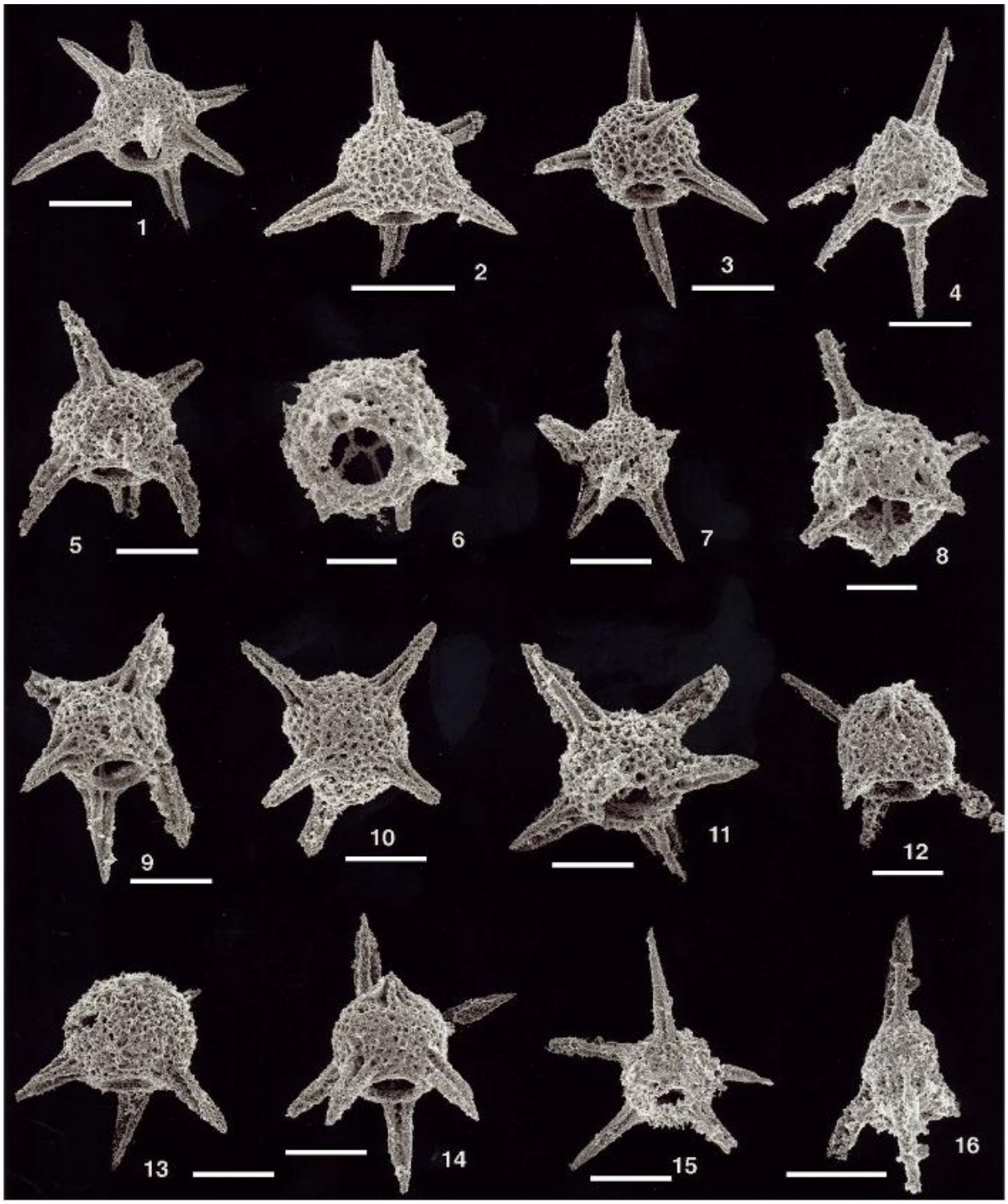

Fig 6: Radiolarian SEM photos of Mississippian chert from southern peninsular Thailand. All scale bars indicate 100 μm. 1–15. *Pylentonema antiqua* Deflandre, 1, EES-KS-ST-2001, 2, EES-KS-ST-2002, 3, EES-KS-ST-2003, 4, EES-KS-ST-2004, 5, EES-KS-ST-2005, 6, EES-KS-ST- 2006, 7, EES-KS-ST-2007, 8, EES-KS-ST-2008, 9, EES-KS-ST-2009, 10, EES-KS-ST-2010, 11, EES-KS-ST-2011, 12, EES-KS-ST-2012, 13, EES-KS-ST-2013, 14, EES-KS-ST-2014, 15, EES-KS-ST-2015, 16. *Archocyrtium* sp., EES-KS-ST-2016.

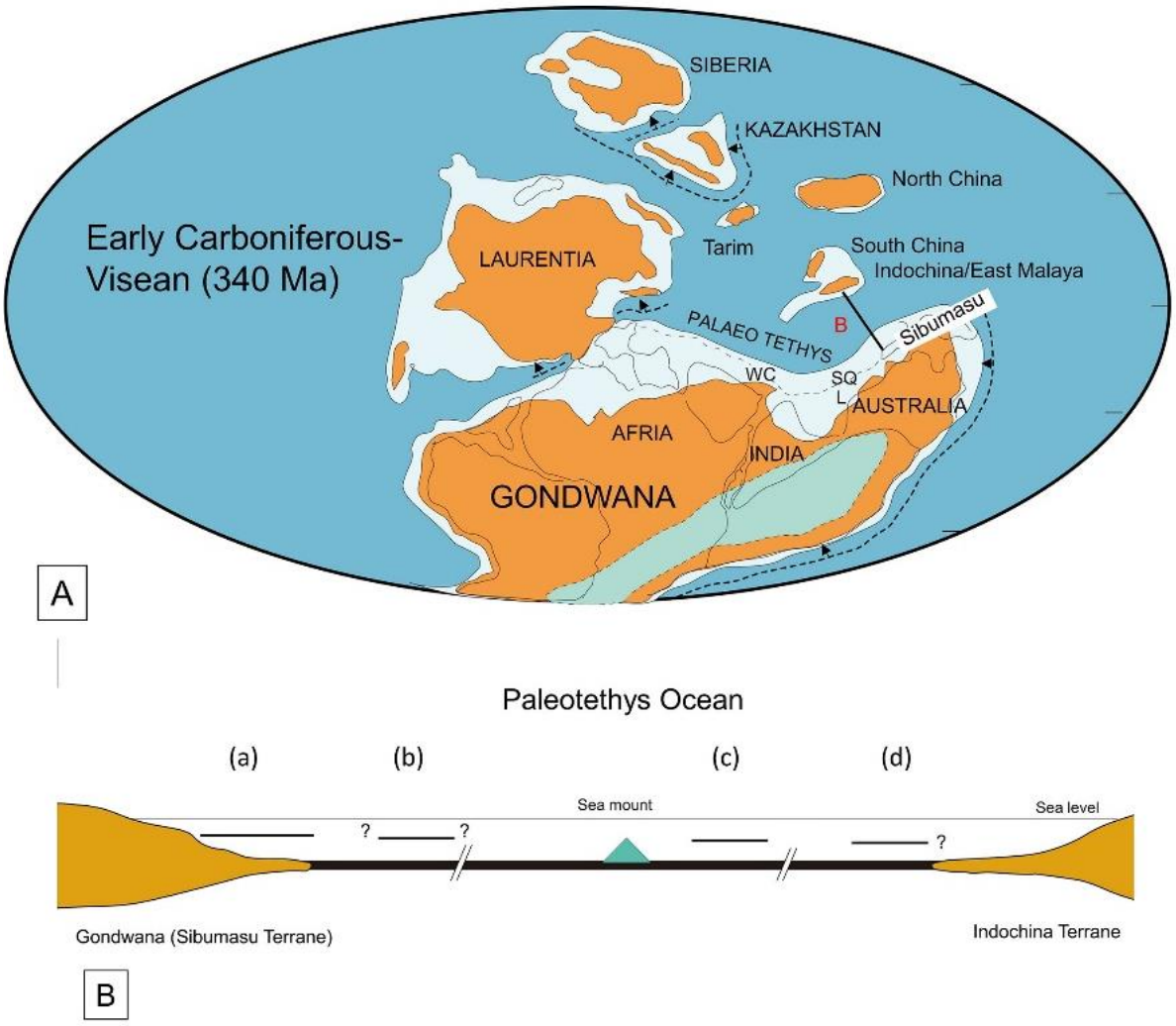

Fig 7: Image of depositional environment of radiolarian bearing siliceous sedimentary rocks. A Paleogeographic map at Mississippian (Tournaisian–Visean: (340 Ma). Map is modified from Metcalfe (2017). B. Image of the depositional sites of radiolarian-bearing sediments across the Paleotethys Ocean. (a): Sashida et al. (2002), Saesaengseerung et al. (2015), The present study. (b): Feng et al. (2004), (c): Sashida et al. (1998), Wonganan and Caridroit (2005), Wonganan et al. (2007), (d): Saesaengseerung et al. (2007a), L=Lhasa, SQ= South Qiangtang, WC=Western Cimmerian

5. Depositional environment of radiolarian--bearing chert

This article reports the late Tournaisian to early Visean (Mississippian) radiolarians from the chert in the Inthanon Zone. Middle–Late Devonian and early Carboniferous radiolarians have been reported from the "Fang Chert" distributed in north of Chiangmai, within the Inthanon Zone (e.g., Ueno, 1999) northern Thailand (Sashida et al., 1993, 1998; Wonganan et al., 2007). These siliceous rock sequence basically does not contain any coarse-grained clastic materials and they are thought to have been deposited in the offshore, far from land and deeper environments of the Paleotethys Ocean (Wonganan et al., 2007). In contrast, the radiolarian--bearing chert is intercalated in the medium to coarse-grained sandstone as described by Sashida et al. (2002) and the present study (Fig. 2). The presence of sandstone beds indicates that the depositional site is near the continent, not far from land. Furthermore, the chert sample (SYK-1) contains foraminiferal shells (Figs. 3 & 4), suggesting that depth of chert accumulation is not deeper than a carbonate compensation depth. Saesaengseerung et al. (2015) discriminated detrital quartz grains in siliceous shale distributed in the Uthai Thani area which means that Devonian to lower Carboniferous radiolarian-bearing siliceous shale has been deposited in hemipelagic, not pelagic

environment. For these reasons, we speculate that the radiolarian-bearing chert of Sashida et al. (2002) and this study deposited on shallower area near land.

In addition to the above-mentioned characteristics, the radiolarian faunal characteristic supports the speculation of the depositional setting. Catalano, Stefano and Kozur (1991), Feng and Ye (1996), Feng, Helmcke, Chonglakmani, Helmcke and Liu (2004), and others mentioned that early Carboniferous radiolarian assemblages from shallow-water sediments are scarce and low diverse: only by members of the Spumellaria and/or Entactinaria usually represented. On the other hand, early Carboniferous radiolarian assemblages from deep-water basins are characterized by abundant and high diversity radiolarians including Spumellaria and/or Entactinaria, Nassellaria, and Albaillellaria, and they usually make radiolarites and/or radiolarian chert. Basir and Zaiton (2011) reported the occurrence of early Carboniferous (Tournaisian) radiolarians from Peninsular Malaysia. They discriminated following three radiolarian assemblages based on the faunal composition and lithology: the *Stigmosphaerostylus*, *Archocyrtium*, and *Albaillellara* assemblages. The *Stigmosphaerostylus* Assemblage is characterized by the occurrence of *Stigmospharostylus variospina* and spherical entactinarians but its specific diversity is very low. The *Archocytrium* Assemblage is characterized by moderate diversity and is dominated by cone-shaped archocyrtiids such as *Archocyrtium*. This assemblage consists of 20 radiolarian species. The *Albaillella* assemblage is characterized by the common occurrence of *Albaillella* and high species diversity (more than 34 species identified). Basir and Zaiton (2011) inferred that The *Stigmosphaerostylus* Assemblage is due to the shallow water environment (upper continental rise), the *Archocyrtium* Assemblage is rather deeper environment (continental rise), and the *Abaillella* Assemblage is open deep-sea marine environment (Ocean basin). They recognized the radiolarian absence in the fauna is attributed to a strong diagenesis and selective dissolution (O'Dogherty, Rodriguez-Canero, Gursky, Matin-Algarra, and Caridroit, 2000). Our examined radiolarian fauna from the chert sample is correlated to the transitional assemblage between the *Arhcocyrtium* and *Albaillella* assemblages based on radiolarian faunal similarity, implying that the chert has been deposited in the upper continental rise to the open deep-sea marine environment (Ocean basin).

The depositional sites of the Devonian to lower Carboniferous radiolarian-bearing siliceous rocks in Thailand are located in roughly four sites in the Paleotethys Ocean based on the lithological characteristics and present geological settings (Fig. 7). The radiolarian-bearing chert reported in this study may have been deposited in the upper continental rise to the open deep-sea basins within the Paleotethys Ocean on the basis of the lithological and faunal characteristics. Seamount consisting of basaltic rocks and carbonate rocks completely lacks of coarse-grained terrestrial materials which may indicate that it formed far from land in the Paleotethys Ocean.

6. Systematic paleontology

Radiolarian description was made by K. S. and T. I. All specimens treated in this paper are stored at the Earth Evolution Sciences, University of Tsukuba, Japan with registered EES-KS. Taxonomic scheme of radiolarians is followed from that of Noble et al (2017).

Order Albaillellaria Deflandre, 1953
Family Albaillellidae Deflandre, 1953 sensu Holdsworth (1977)
Genus *Albaillella* Deflandre, 1952
Type species. - *Albaillella paradoxa* Defladre, 1952

Albaillella sp.
Figs. 5.1, 5.3, 5.4

Remarks. - We collected more than 10 specimens attributed to this species. However, all of them are poorly preserved. Our examined specimens may have cylindrical shell with a smooth surface and conical apical part, and a well-developed H-frame. At the pseudo-abdomen, ventral and dorsal wing may be present. Although we cannot compare precisely our specimens, their outer shell features, short conical and short wing are slightly similar to those of *Albaillella indensis* Won. Our specimens may be distinguished from *Albaillella deflandre* Gourmelon by having above mentioned shell characters.

Sample, occurrence, and range. - This species occurs from Sample SKY-1 and is known from southern Thailand. Mississippian (Tournaisian–Visean).

Family Ceratoiksicidae Holdsworth, 1969
Genus *Ceratoikiscum* Deflandre, 1953
Type species. - *Ceratoikiscum avimexpectans* Deflandre, 1953

Ceratoikiscum sp.
Figs. 5.2, 5.20

Remarks. - Three incomplete specimens were examined. Our specimens are characterized by having a sturdy and conical a.a (a-rod: extra-triangular) and long needle-like i.d (intersector: extratriangular), i.v. (intersetor: extratriangular) and a.p. (a-rod: extratriangular) (nomenclature of *Ceratoikiscum* is from Holdsworth, 1969). However, cavaeal ribs are not clear which may be covered by spongy patagial structure.

Sample, occurrence, and range.- This species occurs from Sample SKY-1 and is known from southern Thailand. Mississippian (Tournaisian–Visean).

Order Entactinaria Kozur and Mostler, 1982
Family Entactiniidae Riedel, 1967
Genus *Spongentactinia* Nazarov, 1975
Type species. - *Spongentactinia fungosa* Nzarov, 1975

Spongentactinia exilispina (Foreman, 1963)
Fig. 5.19

1963 *Entactinia exilispina* Foreman, p. 273, pl. 1, fig. 8.
1987 *Spongentactinia exilispina* (Foreman), Gourmelon, p. 56, 57, pl. 5, figs. 6-8.

Remarks. - We identified only one specimen of this species. Our specimen is characterized by having a spongy spherical shell with may be six spines which are three bladed. Although our examines specimen is an incomplete one, general outer shell features are identical to those of *S. exilispina*.

Sample, occurrence, and range.- This species occurs from Sample SKY-1 and is known from Ohio shale and Montagne Noire, France. Upper Devonian (Famennian) to Mississippian (Tournaisian–Visean).

Genus *Stigmosphaerostylus* Rüst, 1892
Type species. - *Stigmosphaerostylus notabilis* Rüst, 1892

Stigmosphaerostylus variospina (Won, 1983)
Fig. 5.11

1983 *Palaeoxyphostylus variospina* Won, p. 156, 156, pl. 8, figs. 1–4, 6–22.
1986 *Entactinia variospina* (Won), Gourmelon, pl. 4, fig. 1.
1987 *Entactinia variospina* (Won), Gourmelon, p. 49, 50, pl. 3, figs.6, 11.
1989 *Entactinia variospina* (Won), Braun, p. 368, pl. 2, figs. 3, 4, pl. 4, fig. 5.
1990 *Entactinia variospina* (Won), Braun, pl. 7, figs. 4.1–4.13, 4.14.
1994 *Entactinia variospona* (Won), Kiessling and Tragelehn, p. 236, pl. 4, figs. 23, 24.
1995 *Entactinia variospina* (Won), Basir, p. 78, pl. 1, figs.2–4.
1996 *Entactinia variospina* (Won), Spiller, pl. 2, figs. 7, 8.
1997 *Entactinia variospina* (Won), Feng et al., p. 86, pl. 3, figs. 12, 13.
1998 *Entactinia variospina* (Won), Sashida et al., p. 13, 15, figs. 9.1–9.10.
1998 *Entactinia variospina* (Won), Wang et al., pl. 2, figs. 6, 7.
1998 *Entactinia variospina* (Won), Won, p. 238, pl. 2, fig. 18.
2000 *Entactinia variospina* (Won), Sashida et al., p.83, figs. 6.5–6.12.
2002 *Stigmosphaerostylus variospina* (Won), Spiller, p. 43, pl. 6, figs. g, h, i.
2002 *Stigmosphaerostylus variospina* (Won), Sashida et al., p. 132, 133, pl. 1, figs. 18,22,23, pl. 3, fig.12?
2007a *Stigmosphaerostylus variospina* (Won), Saesaengseerung et al., p. 115, 116, figs. 8,7, 8.8, 8.17.
2011 *Stigmosphaerostylus variospina* (Won), Basir and Zaiton, pl. 1, figs. 1–4.
2015 *Stigmosphaerostylus variospina* (Won), Saesaengseerung et al., p. 123, pl. 2, figs. 1–14.

Remarks. - Only one specimen was examined. Our specimen has a spherical shell with short, and sturdy six spines. Shell has many small circular pores surrounded by pentagonal to circular shell frames. Length of spines is generally half of the shell diameter. Won (1983) showed the various types of the spines; number, shape and length of this species. Our examined specimen has shorter and more sturdy spines compared with any of her examined specimens. Gourmelon (1987) also showed several shell morphology of this species. Our specimen is similar to his specimens (pl. 3, figs. 7, 8) which have shorter spines. Our specimen is also similar to the species reported by Saesaengseerung et al. (2007) by having short and sturdy three-bladed spines. This species is distinguished from *E. vulgaris* by having above mentioned shell characters.

Sample, occurrence, and range.- This species occurs from Sample SKY-1 and is known from northern and southern Thailand, Peninsular Malaysia, Europe, and South China. Upper Devonian (Famennian) to Mississippian (Tournaisian–Visean).

Stigmosphaerostylus cfr. *delvolei* (Gourmelon, 1987)
Fig. 5.16

cfr.
1987 *Entactinia*? *delvolvei* Gourmelon, p. 45, 46, pl. 7, figs. 8–10.

Remarks. - Two specimens attributed to this species have been identified. Examined specimens characteristically have a spherical shell with 6 to 7? thin and long spines with small needle-like bi-spines. Illustrated specimen has a long and thin spine whose length is almost twice as the diameter of a spherical shell. Our specimens are similar to the type species of this species which has only two long spines. Our specimens are incomplete, therefore we identified this species with cfr.

Sample, occurrence, and range. - This species occurs from Sample SKY-1 and is known from the Montagne Noire, France. Mississippian (Tournaisian).

Stigmosphaerostylus cfr. *vulgaris* (Won, 1983)
Fig. 5.12

cfr.
1983 *Entactinia*? *vulgaris* Won, pl. 4, figs. 1-3
1986 *Entactinia vulgaris* Won, Gourmelon, p. 184, pl. 2, fig. 4.
1987 *Entactinia vulgaris* Won, Gourmelon, p. 50, 51, pl. 4, figs. 1-6.

Remarks. - We examined two specimens. An illustrated specimen has a spherical shell with 6 three-bladed long conical spines. Many small circular pores surrounded by pentagonal to circular frames are present on the surface of the shell. The original specimens attributed to this species by Won (1983) have more sturdy and longer spines. Therefore, we put cfr. for our specimens.

Sample, occurrence, and range.- This species occurs from Sample SKY-1 and is known from Germany and France, Mississippian (Tournaisian–Visean).

Stigmosphearostylus sp.
Figs. 5.8, 5.9

Remarks. - Several incomplete specimens were examined. Illustrated specimens have a rather small spherical shell with may be six or seven spines. Small circular pores surrounded by square to circular pore frames are present. Thin to moderately thick internal spicule systems consisting of six-rayed spicules are observed in our specimens. Internal spicule system does not have median bar, point centered. This species is distinguished from *S.* sp. B of the present study by having smaller spherical shell.

Sample, occurrence, and range.- This species occurs from Sample SKY-1 and is known from southern Thailand. Mississippian (Tournaisian–Visean).

Stigmosphaerostylus? sp. A
Figs. 5.10, 5.14, 5.17, 5.18

Remarks. - Seven specimens of this species were examined. This species has a spherical shell with six, short, three-bladed and conical spines. This

species is similar to *S. deflendrei* (Won, 1991) described from Germany in general shell feature. However, latter species has longer and more sturdy spines. This species also resembles *S. vulgaris* (Won, 1983), but it differs from the latter by smaller and shorter spines. We questionably assigned this species in *Stigmosphaerostylus* because the internal shell structure cannot be detected.

Sample, occurrence, and range.- This species occurs from Sample SKY-1 and is known from southern Thailand. Mississippian (Tournaisian--Visean).

Stigmosphaerostylus? sp. B
Fig. 5.13

Remarks. – One specimen has been identified. This species is characterized by a spherical shell with may be six or seven spines. Spherical shell is thick and has many and small circular pores on its outer surface. Small conical spines are present at the junction of each neighboring pore flame. Spines are three-bladed and sturdy and long conical shale. We cannot observe the inner side of the spherical shell and determine the presence of spicule system or inner shell. Therefore, we questionably assigned this species in *Stigmosphearostylus*. This species is distinguished from *Stigmosphearostylus*? sp. A of the present study by having longer and more sturdy spines.

Sample, occurrence, and range.- This species occurs from Sample SKY-1 and is known from southern Thailand. Mississippian (Tournaisian–Visean).

Stigmosphaerostylus? sp. C
Fig. 6.15

Remarks. – Only one specimen has been examined. This species has a spherical shell with more than four spines whose length is almost two-thirds of the diameter of shell. Shell has many small circular pores surrounded by polygonal to circular frames. This species similar to *Stigmosphaerostylus*? sp. A of the present study but it has thicker spines.

Sample, occurrence, and range.- This species occurs from Sample SKY-1 and is known from southern Thailand. Mississippian (Tournaisian--Visean).

Genus *Trilonche* Hinde, 1899 sensu Aitchison and Stratford, 1997
Type species.- *Trilonche vetusta* Hinde, 1899

Trilonche? sp.
Figs. 6.5, 6,7

Remarks. - Three specimens were examined. This species has a spherical shell with three to more three-bladed spines and an internal spherical shell. Inner and outer shells are connected by six three--bladed thick spines. The presence of an internal spicule system cannot be determined. The outer shell is thick and has many small pores on the surface of the outer shell. The internal surface of the outer shell is fine sponge. Inner shell has a circular phylome. We questionably placed this species in *Trilonch* because we did not observe the internal spicules in the inner shell and the inner shell has a pylome.

Sample, occurrence, and range.- This species occurs from Sample SKY-1 and is known from southern Thailand. Mississippian (Tournaisian--Visean).

Family Pylentonemidae Deflandre, 1963
Genus *Pylentonema* Deflandre, 1963 sensu Holdsworth et al., 1978
Type species.- *Acanthopyle antiqua* Deflandre, 1960

Pylentonema antiqua (Deflandre, 1960)
Figs. 6.1–6.15

1960 *Acanthopyle antiqua* Deflandre, p. 216, pl. 1, fig. 14
1963 *Pylentonema antiqua* (Deflandre), p. 3981–3984, figs. 1–5.
1973 *Pylentonema antiqua* (Deflandre), Holdsworth, p. 122-125, pl. 1, fig. 4.
1978 *Pylentonema antiqua* (Deflandre), Holdsworth et al, p. 785, figs. 3d, 3e.
1984 *Pylentonema antiqua* (Deflandre), Sandberg and Gutshick, pl. 6, figs. P, T.
1986 *Pylentonema antiqua* (Deflandre), Gourmelon, p. 188-189, pl. 1, figs. 7, 8.

1987 *Pylentonema antiqua* (Deflandre), Gourmelon, p. 102, pl. 15, figs. 1–6.
1998 *Pylentonema antiqua* (Deflandre), Won, p. 255, 256, pl. 6m figs. 9–14, 16.
2002 *Pylentonema antiqua* (Deflandre), Sashida et al., P. 131, 132, pl. 1, figs. 14–17, 20–22, pl. 2, fig. 2, pl. 3, figs. 2, 6, 8, 9, 11?.

Remarks. - More than 30 specimens identified to this species have been obtained. Our forms are characterized by having a spherical shell with 7 spines, among which one is generally small and others are three bladed and sturdy, and their length is almost same as the diameter of spherical shell. Small circular pores surrounded by pentagonal to circular pore rim are present. Internal surface of spherical sell is generally spongy. A large circular pylome is present surrounded by a narrow pylome rim. We can see the internal spicule system (e.g., fig. 6.6), but the presence of inner shell is not sure due to the mesh structure of the internal surface of spherical shell. Position of spines around pylome is variable as discussed by Won (1998), but the type of four spines around pylome (her type Bs and Bd) may be most predominate.

Sample, occurrence, and range.- This species obtained from Sample SKY-1 and is known from Germany, France, North America, Turkey, Thailand. Upper Devonian (upper Famennian) to Mississippian (Tournaisian–Visean).

Order Nassellaria Ehrenberg, 1875
Family Archocyrtidae Kozur and Mostler, 1981
Genus *Archocytrium* Deflandre, 1972 sensu Holdsworth (1973)
Type species. - *Archocyrtium riedeli* Deflandre, 1960

Archocyrtium sp.
Fig. 6.16

Remarks. - Three specimens attributed this species were identified. An illustrated specimen has a subspherical cephalis with three bladed apical horn and three three-bladed feet. Length of apical horn is almost equal with the diameter of cephalis. Small pores are observed on the surface of cephalis. Length of three feet are not known. Our specimens may have week pyrome. This species is similar to *Arhocyrtium venustum* Cheng and *A. riedeli* Deflandre, however, precise comparison cannot be made.

Sample, occurrence, and range. - This species occurs from Sample SKY-1 and is known from southern Thailand. Mississippian (Tournaisian--Visean).

7. Conclusions

1. Radiolarians of 13 species belonging to seven genera have been identified from a black chert bed intercalated within sandstone and variegated siliceous shale at the Kabang area, Songkhla Province, southern peninsular Thailand.
2. The age of the radiolarians may indicate the Tournaisian to Visean, Mississippian (early Carboniferous). The age is slightly younger than that of the previously reported radiolarians in the Saba Yoi-Kabang area in our previous study.
3. The radiolarian-bearing chert characteristically contains foraminiferal shells and therefore the chert may have been deposited in shallower ocean than the carbonate compensation depth. The chert is intercalated within sandstone beds, so that the chert was deposited near land.
4. The radiolarians from the chert sample is correlated to the transitional assemblage between the *Arhcocyrtium* and *Albaillella* assemblages. Consequently, the chert has probably been deposited in the upper continental rise to the open deep-sea marine environment.
5. On the basis of the lithological and radiolarian faunal characteristics, the radiolarian-bearing chert may have been deposited in the upper continental rise to the open deep-sea basins within the Paleotethys Ocean. However, further study such as sedimentary structure and zircon provenance analyses are required to clarify this interpretation.

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References

Aitchison, J.C. & Stratoford, J.M.C. (1997). Middle Devonian (Givetian) radiolarians from eastern New South Wales, Australia: A reassessment of the Hinde (1899) funa. *Neues Jarbuh Fur Geologie und Palaeontologie, Abhandlung*, 203, 369–390.

Aitchison, J.C., Suzuki, N., Caridroit, M., Danelian, T. & Noble, P. (2017). Paleozoic radiolarian biostratigraphy. *Geodiversitas, 39*, 419–502.

Basir, J. (1995). Occurrence of bedded radiolarian chert in the Kubang Pasu Formation, North Kedah, Peninsular Malaysia. *Warta Geologi, 21*, 73–79.

Basir, J. & Zaiton, H. (2011). Lower Carboniferous (Tournaisian) radiolarians from peninsular Malaysia and their significance. *Bulletin of the Geological Society of Malaysia, 57*, 47–54.

Braun, A. (1989). Unterkarbonishe Radiolarien aus Kieslschifergeronllen des Marine bei Frankfurt am Main. *Jahresber, Mitt. Oberrhein. Geologische, 71*, 357–380.

Braun, A. (1990). Radiolarien aus dem Unter-Karbon Deutschlands. Courier *Forschung-sinstitute Senckenberg, 133*, 1–177.

Caridroit, M., Fontaine, H., Jongkanjanasoontorn, Y., Suteehorn, V. & Vachard, D. (1990). First results of a palaeontological study of Northwest Thailand. In Fontaine, H. ed., Ten Years of CCOP *Research on the Pre-Tertiary of East Asia*. CCOP/TP, 20, 337–350.

Catalano, R., Stefano, P.D. & Kozur, H. (1991). Permian circumpacific deep-water faunas from western Tethys (Sicily, Italy)-new evidence for the position of the Permian Tethys. *Palaeogeography, Palaeoclimatology, Palaeoecology*, 87, 75–108.

Deflandre, G. (1952). *Albaillella* nov. gen., radiolaire fossile du Carbonifere inferieur, type d7ne lignee aberrante eteinte. *Comptes Rendus hebdomadaires des Seances delAcademie des Sciences (Paris), Serie D: Sciences naturelles, 234*, 872–874.

Deflandre, G. (1953). Radiolaires fossils. In Grasse P. P. ed., *Traite de Zoologie*. Masson, Paris, 389–436.

Deflandre, G. (1960). A propos du developpment des recherches sur les Radiolaires fossils. Revue de *Micropaleonotologie*, 2, 212–218.

Deflandre, G. (1963). Pylentonema, nouveau genre de Radiolarie du Viseen: Sphaerellaire ou Nassellaire? *Comptes Rendus hebdomadaires des Seanace de lAcademie des Sciences (Paris), Serie D: Science naturelles, 257*, 3981–3984.

Deflandre, G. (1972). Le systeme trabeculaire interne chez les pylentonemides et les Popofskyllides, Radiolaires du Paleozoique. Pylogenese des Nassellaries. Comptes *Rendus Academie des Sciences, Paris 274, series D*, 3535–3540.

DMR (Department of Mineral Resources of Thailand). (1999). *Geological Map of Thailand, Scale 1:1,000,000*. Geological Survey Division, Department of Mineral Resources of Thailand, Bangkok.

DMR (Department of Mineral Resources of Thailand). (2013). *Geological Map of Thailand, Scale 1:1,000,000*. Geological Survey Division, Department of Mineral Resources of Thailand, Bangkok.

Ehrenberg, C.G. (1876). Fortestzung der mikro-geologischen Studien als Gesammt-Uebersichtder mikroskopischen Palaontologie gleichartig analysirter Gebigsarten der Erde, mit specieller Rucksicht aud den Polycystine-Megel von Barbados. *Abhandlungender koniglichen preussichen-Akadeie der Wissenschaften zur Berlin, 1875*, 1–225.

Feng, Q. & Ye, M. (1996). Devonian to Triassic Tethys in Western Yunnan, China, In Fan, N. & Feng, Q., eds. *Sedimentologic, stratigraphic and maicropaleontologic studies on Changning-Menglian Orogenic belt*, 15–22.

Feng, G, Ye, M., & Zhang, Z. (1997). Early Carboni-ferous radiolarians from western Yunnan. *Acta Micropalaeontologica Sinica*, *14*, 79–92.

Feng, Q., Helmcke, D., Chonglakmani, P., Helmcke, I. & Liu, B. (2004). Early Carboniferous radiolarians from North-West Thailand. Palaeogeographical implications. *Palaeontology*, 47, 377–393.

Foreman, H.P. (1963). Upper Devonian Radiolaria from the Huron Member of the Ohio Shale. *Micropale-ontology*, 9, 267–304.

Gourmelon, F. (1986). Etude des Radiolaires dun nodule pjhosphate du Carboniferieur de Bareilles, Hautes Pyrenees, France. *Geobios, 19*, 179–197.

Gourmelon, F. (1987). Les radiolaires tournaisiens des nodulesphtoshate de la Montagne noire et des Pyrenees. *Baiostratigraphie du Paleozoique, 6*, 1–172.

Hinde, G.J. (1899). On the Radiolaria in the Devonian rocks of New South Wales. *Quarterly Journal of the Geological Society of London, 55*, 38–64.

Holdsworth, B.K. (1969). Namurian Radiolaria of the genus *Ceratoikiscum* from Staffordshire and

Derbyshire, England. *Micropaleontology, 15*, 221–229.

Holdsworth, B.K. (1973). The Radiolaria of the Baltalimani Formation, Lower Carboniferous, Istanbul. *In* Kaya, Q., ed., *Paleozoic of Istanbul*, 117-134, Ege Universites Fen Fakaltesi Kitaplor, 40.

Holdsworth, B.K. (1977). Paleozoic Radiolaria of the genus Ceratoikiscum from Staffordshire and Derbyshire, England. *Micropaleontology, 15*, 221–229.

Holdsworth, B.K., Jones, D.L. & Allison, C. (1978). Upper Devonian radiolarians separated from chert of the Ford Lake Shale, Alaska. *Journal of Research, U.S. Geological Survey, 6*, 775–788.

Igo, H. (1973). Lower Carboniferous conodonts from Ko Yo, Songkhla, peninsular Thailand. *Geology and Paleontology of Southeast Asia, 12*, 29–42.

Kamata, Y., Ueno, K., Saengsrichan, W., Sardsud, A., Charoentitirat, T., Charsiri, P., & Hisada, K. (2008). Stratigraphy and geological ages of siliceous sedimentary rocks distributed in the Hat Yai area, southern peninsular Thailand. In Choowong, M. & Thitimakorn, T., eds. *Proceedings of International Symposium on Geoscience Resources and Environ--ments of Asian Terranes (Great 2008), 4th IGCP516, and 5th APSEG. Bangkok, 24–26, November 2008* (pp. 349–352). Bangkok, Thailand.

Kamata, Y., Ueno, K., Hara, H., Ichise, M., Charoentitirat, T., Charusiri, P., Sardsud, A., & Hisda, K. (2009). Classification of the Sibumasu and Paleo-Tethys tectonic division in Thailand using chert lithofacies. *Island Arc, 18*, 21–31.

Kamata, Y., Kato, M., Ueno, K., Miyahigashi, A., Charoentitirat, T. & Sardsud, A. (2015). Middle-Late Devonian radiolarians from Klaeng District, Rayong Province, southeastern Thailand. Geotectonic signify-cance of the Rayong area as a continental margin of the Sibumasu Block. *Journal of Asian Earth Sciences, 104*, 197–204.

Kiessling, W. & Tragelehn, H. (1994). Devonian radiolarian faunas of conodont-dated localities in the Frankenwald (northern Bavaria, Gemany). *Abhand-lungen der Geologischen Bundesnanstalt, 50*, 219–255.

Kozur, H. & Mostler, H. (1981). Beitrage zur Erforschnung der mesozoischen Radiolarien. Teil IV: Thalasso-spharacea Haeckel, 1862, Hexastylacea Haeckel 1882, emend. Petrushevskaya, 1979, Sponguracea Haeckel, 1862 emend, und weitere triassische Lithocycliacea, Trematodiscaea, Actiommadea und Nassellaira. *Gologische-Palaontologische Mitteilungea Innsbruck, Sonderband, 1*, 1–208.

Kozur, H. & Mostler, H. (1982). Entactinaria suborder nov., a new radiolarian suborder. *Geologische-Palaontologische Mitteilugen Innsbruck*, 11/12, 399–414.

Metcalfe, I. (2017). Tectonic evolution of Sundaland. *Bulletin of the Geological Society of Malaysia, 63*, 27–60.

Muenlek, S., Meesook, A., Tongchit, P., Tipdhonsab, C., & Skulkaew, P. (1985). *Geologic Map of Changwat Narathiwat and Amphoe Takbai (Sheet NB 47-8,5, Scale 1:250,000)*. Geological Survey Division, Department of Mineral Resources, Bangkok.

Nazarov, B.B. (1975). Radiolaria of the Lower-Middle Paleozoic of Kazakhstan. Trudy *Geologischeskii Institut Akademia Nauk SSSR, 275*, 203 p.

Noble, P., Aitchison, J.C., Danelian, T., Dumitrica, P., Maletz, J., Suzuki, N., Cuvelier, J., Caridroit, M., & O'Dogherty, L. (2017). Taxonomy of Paleozoic radiolarian genera. *Geodiversitas, 39*, 419–502.

O'Dogherty, L., Rodriguez-Canero, R., Gursky, H.J., Matin-Algarra, A. & Caridroit, M. (2000). New data on Carboniferous stratigraphy and palaeogeography of the Malaguide complex (Betic Cordillera, southern Spain). *Comptes Rendus-Academie des Sciences, Serrie II: Sciences de la Terra, et des Planetes, 331*, 533–541.

Pessagno, E.A. and Newport, R. L. (1972). A technique for extracting Radiolaria from radiolarian cherts. *Micropaleontology, 18*, 231–234.

Riedel, W.R. (1967). Some new families of Radiolaria. *Proceedings of the Geological Society of London, 1640*, 148–149.

Rüst, D. (1892). Beitrage zur Kenntnis der fossilen Radiolarien aus Gesteinen der Trias und der palaeozoischen. *Schichten. Palaeontolographica*, 38, 107–192.

Saesaengseerung, D., Sashida, K., & Sardsud, A. (2007a). Late Devonian to early Carboniferous radiolarian fauna from the Pak Chom area, Loei Province, northeastern Thailand. *Paleontological Research, 11*, 109–121.

Saesaengseerung, D. Sashida, K., & Sardsud, A. (2007b). Devonian to Triassic radiolarian faunas from northern and northeastern Thailand. In Tantiwanit, W. ed., *Proceedings of the International Conference on Geology of Thailand: Towards Sustainable Development and Sufficiency Economy* (pp. 54–71). Bangkok, Thailand.

Saesaengseerung, D., Kawinae, T., & Pothichaiya, C. (2015). Discovery of Devonian to Carboniferous radiolarians from central Thailand and its significance of these fauna in Thailand and Laos. *The 3rd Lao-Thai Technical Conference, July 8-8, 2015* (pp. 115–134). Bangkok, Thailand.

Sandberg, C. & Gutschick, R.C. (1984). Distribution, microfauna and source-rock potential of Mississippian Della Phosphatic member of Woodman Formation and equivalents, Utah and adjacent states. In Woodward, J. et al. (Eds.), *Hydrocarbon source rocks of the Greater Rocky Mountain region* (pp. 135–178),

Rocky Mountain Association of Geologists, Denver, Colorado.

Sardsud, A. & Saengsrichan, W. (2002). *Geological Map of Amphoe Hat Yai Sheet (5023II)*. Department of Mineral Resources, Technical report, no. 16, 1–77. (in Thai with English summary)

Sashida, K., Igo, H., Hisada, K., Nakornsri, N., & Amprnmaha, A. (1993). Occurrence of Paleozoic and Early Mesozoic Radiolaria in Thailand (preliminary report). *Journal of Southeast Asian Earth Sciences*, 8, 97–108.

Sashida, K., Igo, H., Adachi, S., Ueno, K., Nakornsri, N., & Sardsud, A. (1998). Late Paleozoic radiolarian faunas from northern and northeastern Thailand. Science *Reports of the Institute of Geosciences, University of Tsukuba, section B, 19*, 1–27.

Sashida, K., Nakornsri, N., Ueno, K., & Sardsud, A. (2000). Carboniferous and Triassic radiolarian fauna from the Saba Yoi area, southernmost part of peninsular Thailand and their paleogeographic significance. *Science Reports of the Institute of Geoscience, University of Tsukuba, section B, 21*, 71–99.

Sashida, K., Salyapongse, S., & Charusri, P. (2002). Lower Carboniferous radiolarian fauna from the Saba Yoi-Kabang area, southernmost part of peninsular Thailand. *Micropaleontology, 48*, supplement 1, 129–143.

Spiller, F.C.P. (1996). Late Paleozoic radiolarians from the Bentong-Raub suture zone, Peninsular Malaysia. *The Island Arc, 5*, 91–103.

Spiller, F.C.P. (2002). Radiolarian biostratigraphy of Peninsular Malaysia and implications for regional palaeotectonic and palaeogeography. Palaeontographica Abteilung A: *Palaeozoologie-Stratigraphie, 266*, 1–91.

Ueno, K. (1999). Gondwana/Tethys divide in East Asia: solution from Late Paleozoic foraminiferal paleobiogeography. In Ratanasthien, B. & Rieb, S.L. (Eds.), *Proceedings of the International Symposium on Shallow Tethys (ST) 5*, (pp. 45–54), Chiang Mai, Thailand.

Ueno, K. & Charoentitirat, T. (2011). Carboniferous and Permian. In Ridd, M.F. et al., eds., *The Geology of Thailand*, 71–136, The Geological Society, London.

Wakita, K. & Metcalfe, I. (2005). Ocean plate stratigraphy in East and Southeast Asia. *Journal of Asian Earth Sciences, 24*, 679–702.

Wang, Y.J., Luo, H., Kuang, G., & Li, J. (1998). Late Devonian-Late Permian strata of cherty facies at Xiadong and Banchen countries of the Qinzhou area, SE Guangxi. *Acta Micropalaeonotoliglca Sinica, 15*, 351–366.

Won, M.Z. (1983). Radiolarian aus dem Unterkarbon des Rheinischen Schiefergebireges. *Palaeontographica, Abteilung A: Palaozoologie-Stratigraphie, 182*, 116–175.

Won, M.Z. (1991). Lower Carboniferous radiolarians from siliceous boulders in western Germany. *Journal of Paleontological Society of Korea, 7*, 77-106.

Won, M. (1998). A Tournaisian (Lower Carboniferous) radiolarian zonation and radiolarian of the A. pseudoparadoxa Zone from Oese (Rheinische Schifergebirege) Germany. *Journal of Korean Earth Science Society, 19*, 216–259.

Wonganan, N. & Caridroit, M. (2005). Middle and Upper Devonian radiolarian faunas from Chiang Dao area, Chiang Mai Province, northern Thailand. *Micropaleontology, 51*, 39–57.

Wonganan, N., Randon, N. & Caridroit, M. (2007). Mississippian (early Carboniferous) radiolarian biostratigraphy of northern Thailand (Chang Dao area). *Geobios, 40*, 875–888.