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Article

Middle and Late Permian radiolarians from the Nanjo Mountains, Fukui Prefecture, Southwest Japan

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Abstract: The Nanjo Mountains located in Fukui Prefecture, Southwest Japan are chiefly underlain by sedimentary complexes of various rock-types such as basalt, limestone, chert, mudstone and sandstone. A lot of reports on the occurrence of Mesozoic radiolarians mainly from mudstones in the mountains have been appeared in the last three decades, however litho-chronological information on Paleozoic rocks of the complexes is still not obtained enough because Paleozoic radiolarians have rarely been found. Through the present work, moderately- to poorly-preserved radiolarians recovered from tuffaceous and siliceous mudstones and cherts in the Nanjo Mountains are described and illustrated herein; they include genera *Albaillella, Follicucullus, Pseudoalbaillella, Latentifistula, Pseudotormentus, Cauletella, Ishigaum, Raciditor, Srakaeosphaera* and *Stigmosphaerostylus*, most of which are representatives of Middle and Late Permian periods. These radiolarian species are very important for giving an age constraint to the sedimentary complex in the Nanjo Mountains.

Keywords: radiolaria, Permian, Nanjo Mountains, Fukui Prefecture, Southwest Japan

1. Introduction

Situated at central part of Fukui Prefecture, the Nanjo Mountains with a total area of ca. 40 km x 20 km (Fig.1) are mainly underlain by sedimentary complexes of various rock-types ranging in age from Carboniferous to Jurassic. Previous geological works have been carried out since 1950's and have revealed the outline of general geology including regional distribution of the sedimentary complexes and their lithological features throughout the mountains (*eg*, Isomi, 1955; Nishida, 1962; Hattori and Yoshimura, 1979). Nevertheless, stratigraphic framework of the complexes has still been a controversial issue due to opposing standpoints (*eg*, Hattori and Yoshimura, 1982; Wakita, 1992). Aside from this, huge amounts of Triassic and Jurassic radiolarians from cherts and mudstones in the Nanjo Mountains have been found during the last three decades (*eg*., Hattori and Yoshimura, 1982; Hattori, 1987, 1988; Umeda, 1990; Takamura and Hayami, 1985; Matsuoka, 2004). In contrast, chronological information on Permian radiolarians can be little used because of only eight localities from where they were detected (*eg*., Hattori and Yoshimura, 1982; Umeda, 1986, 1996).

This paleontological study is a part of the mapping project in the Nanjo Mountains conducted from 2001 by the Geological Survey of Japan. By this study, about 530 samples were recently collected and processed for the radiolarian fossil extraction, four of which yield Permian species. Therefore, results of the study on the Permian radiolarians are presented and their age assignments are also discussed in this paper.

2. Geologic Setting

The Nanjo Mountains are chiefly underlain by sedimentary complexes and geotectonically divided into the Mino and the Ultra-Tamba belts of the Inner Zone of Southwest Japan. The sedimentary complex in each belt has different features in lithologic assemblage from the other; the complex in the Mino belt consists of thrust-bounded units of Carbonifero-Permian basalt and limestone of oceanic island/seamount origin, Permo-Triassic chert of pelagic realm and Jurassic terrigenous clastic rocks, and associated with the their chaotic mixtures (Isomi, 1955; Nishida, 1962; Hattori and Yoshimura, 1979), whereas the complex in the Ultra-Tamba belt is dominated by pale or greenish gray sandstone with subordinate chert and phyllitic mudstone of Permian age (Nakaya and Saito, 1986; Umeda *et al*., 1996). Along a northern margin of the Nanjo Mountains, these complexes are covered by minor amounts of Cretaceous

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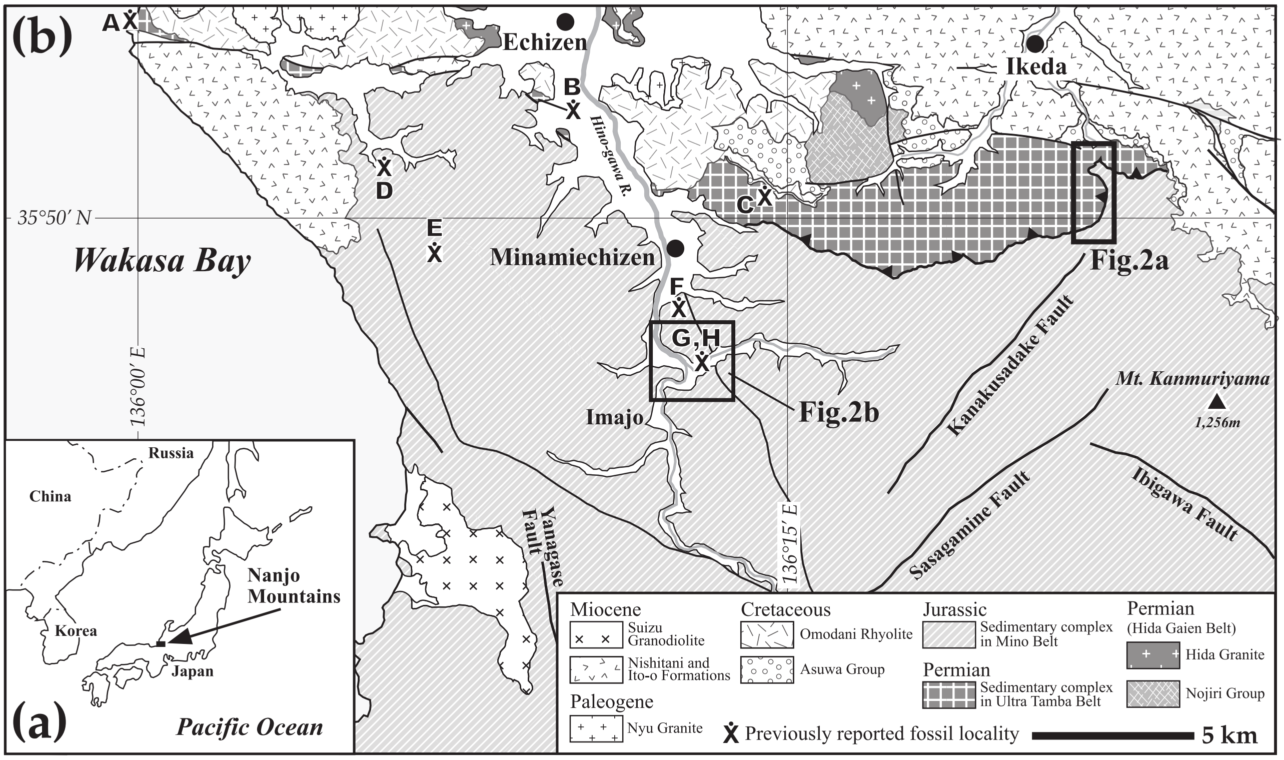

Fig. 1 Index map of the Nanjo Mountains, Fukui Prefecture, Japan.
(a): The Nanjo Mountains are situated in a central part of Fukui Prefecture, geotectonically belonging to the Inner Zone of Southwest Japan. (b): Simplified geological map of the Nanjo Mountains. Open squares indicate the sample localities of this study, details of which are given in Fig.2. Previously reported fossil localities are shown by symbols with A–H.

non-marine deposits (Asuwa Group) and volcanic rocks (Omodani Rhyolite), and Miocene volcaniclastic rocks (Nishitani and Ito-o formations). Furthermore, Paleogene and Miocene granitic rocks locally intrude into the complexes. The northern marginal area of the mountains contains the boundary between the Mino and the Ultra-Tamba belts (Fig.1b). Along the boundary, the complexes in both belts are generally distributed in the E-W direction with gentle to moderate northward-dipping.

Eight localities of the previously reported Permian radiolarians are shown in Fig.1b; Locs. A to C are in the Ultra-Tamba belt (Umeda, 1986, 1996; Umeda *et al*., 1996), and Locs. D to H are in the Mino belt (Hattori and Yoshimura, 1982, Taga, 1997; Umeda and Taga, 2003).

3. Sample Localities and lithology

Four rock samples collected from three localities (Fig.2) yielded Middle and Late Permian radiolarians. Loc.1 (35°50’43”N, 136°22’5”E) is situated along the Waridani-gawa River, 1.7 km south of Shizuhara, Ikeda Town (Fig.2a). Rock at this locality is composed of greenish gray sandstone, pale gray tuffaceous mudstone and dark gray foliated siliceous mudstone in ascending order (from east to west), and a steeply-dipping fault and a shear zone produce the distinctive change in lithology among these rocks (Fig.3a). However, it can be presumed that there was an originally conformable relation between the tuffaceous and siliceous mudstones, based on the mixed feature of the two rocks within the shear zone; lenticular blocks of tuffaceous mudstone is enveloped by sheared siliceous mudstone. From this locality, two rock samples (KJ5205A, KJ5205B) were collected; rock of KJ5205A from the siliceous mudstone, and that of KJ5205B from the tuffaceous mudstone. Loc.2 (35°49’51”N, 136°21’52”E) is also situated along the Waridani-gawa River, 3.4 km south of Shizuhara (Fig.2a). Outcrop with about 10 m wide at this locality is composed of alternation of mudstone and chert layers, steeply dipping to the south (Fig.3b). The mudstone layers are accompanied with lenticular blocks or interbeds of gray sandstone. The chert layers are gray in color and characterized by rhythmical thin-bedding. KJ5301C was sampled from the chert on the left end of this outcrop. On the other hand, Loc.3 (35°47’29”N, 136°12’41”E) is located on a roadside outcrop near Yaotome, Minamiechizen Town (Fig.2b). Cherts, mudstones and sandstones are distributed in the E-W or NW-SE direction with moderate northward-

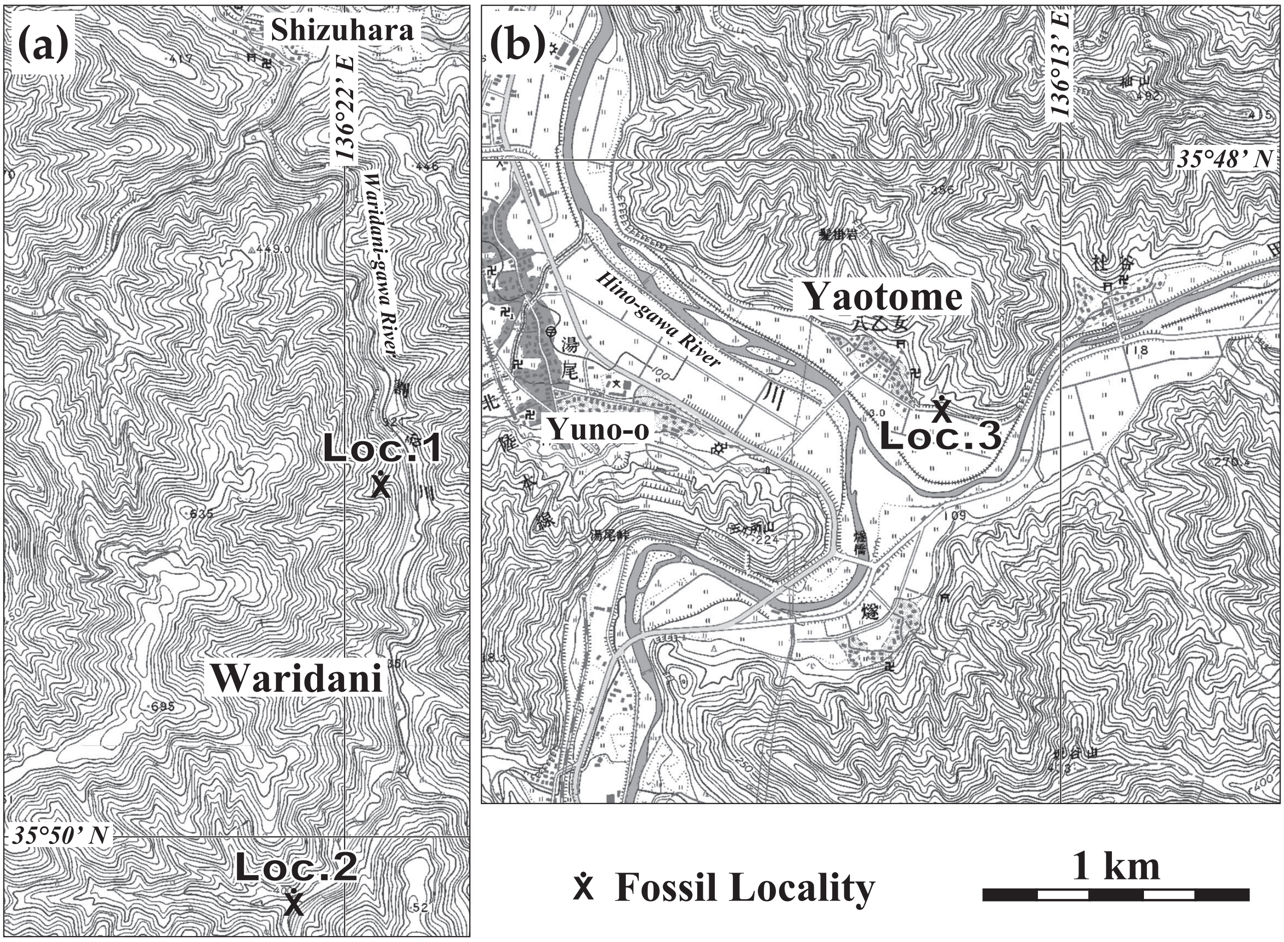

Fig. 2 Localities of the rock samples yielding Permian radiolarians.
(a): Loc.1 (KJ5205A, KJ5205B) and Loc.2 (KJ5301C) are south of Shizuhara, Ikeda Town. (b): Loc.3 (IJ2903) is near Yaotome, Minamiechizen Town. Parts of 1:25,000 topographical maps of “Inari”, “Furuki” and “Imajo” published from the Geospatial Information Authority of Japan are used.

dipping, and are randomly exposed about 1,000 m long along this road. Permian radiolarians have formerly been detected from the cherts at the localities marked by G (Umeda and Taga, 2003) and H (Hattori and Yoshimura, 1982) (Fig.1b). IJ2903 was collected from the light gray chert, where is probably the same outcrop as the locality G (Fig.3c).

4. Materials and Method

Through the course of this study, about 530 samples were collected from the Nanjo Mountains and were undertaken by the usual techniques of radiolarian extraction; the rock samples were individually soaked in dilute HF solution (5%) for 10 to 15 hours, and sieved through 235# mesh (aperture: 62μm). After this procedure, age-diagnostic radiolarians representative of Permian age recovered from four samples, as stated above. The residues of each sample processed were examines under a stereomicroscope, and radiolarian remains were picked for taking their pictures by a scanning electronic microscope (SEM). All figured specimens are deposited and registered at the Geological Survey of Japan with catalogue numbers (GSJ R).

5. Discussion

5.1 Faunal characteristics

All the extracted radiolarians of each sample are in state of moderate to poor preservation and are indicative of Permian faunas, respectively. They are characterized by the abundance of Albaillellaria, Latentifistularia and Entactinaria, totally nine representative forms of which are identified as follows.

Albaillella sp. cf. *A. yamakitai* Kuwahara,
Pseudotormentus kamigoriensis De Wever and Caridroit,
Cauletella manica (De Wever and Caridroit),
Ishigaum sp. cf. *I. trifustis* De Wever and Caridroit,
Ishigaum sp. cf. *I. obesum* De Wever and Caridroit,

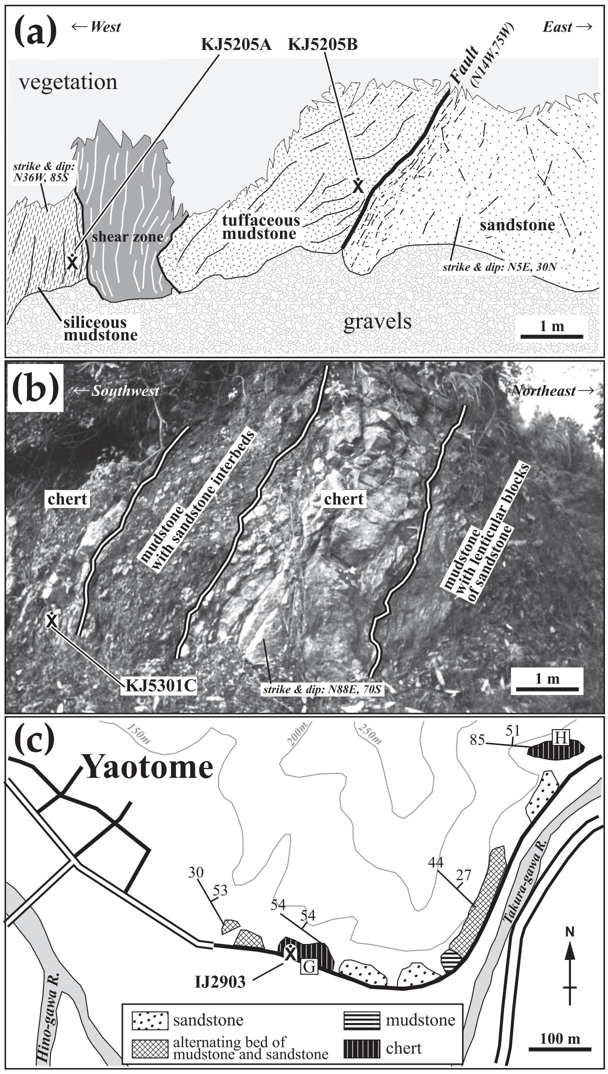

Fig. 3 Occurrence of the rock samples yielding Permian radiolarians with their associated rocks.
(a): Tuffaceous mudstone (KJ5205A) and siliceous mudstone (KJ5205B) at Loc.1, south of Shizuhara. (b): Chert (KJ5301C) at Loc.2, south of Shizuhara. (c): Chert (IJ2903) at Loc.3, near Yaotome. G and H are the inferred localities of previously reported fossils by Umeda and Taga (2003) and Hattori and Yoshimura (1982).

Raciditor gracilis (De Wever and Caridroit),
Srakaeosphaera sp. cf. *S. minuta* Sashida,
Stigmosphaerostylus sp. cf. *S. itsukaichiensis* (Sashida and Tonishi),
Stigmosphaerostylus sp. cf. *S. ichikawai* (Caridroit and De Wever).

On the basis of Table 1, it is clear that the diversity of radiolarian species included in each fauna is not high and that these fauna of respective samples are not same in taxonomic composition. Although KJ5205A (siliceous mudstone) and KJ5205B (tuffaceous mudstone) are slightly different in lithology, both the faunas are almost same in having Latentifistularia and Entactinaria in spite of lack of Albaillelaria. Fauna of IJ2903 from a chert sample resembles the above two faunas in having Latentifistularia and Entactinaria, but different from them in having Follicucullidae. On the other hand, fauna of KJ5301C, which is also extracted from a chert sample, is mainly composed of Albaillellidae. Therefore, it might be said that no relation is recognized between lithology of the sampled rocks and their radiolarian taxonomic composition.

Table 1 List of Permian radiolarians obtained from the Nanjo Mountains.

Locality no.	1		2	3
Sample no.	KJ 5205A	KJ 5205B	KJ 5301C	IJ 2903
Albaillella sp. cf. *A. yamakitai*			●	
Albaillella sp.			●	
Albaillella? sp.			●	
Follicucullus spp.				●
Pseudoalbaillella sp.				●
Albaillellidae? gen. indet.		●		
Latentifistula spp.	●			●
Pseudotormentus kamigoriensis				●
Cauletella manica		●		
Cauletella sp.	●			
Ishigaum sp. cf. *I. trifustis*		●		
Ishigaum sp. cf. *I. obesum*		●		
Raciditor gracilis				●
Raciditor spp.	●			
Latentifistulidae gen. indet.	●	●	●	
Copiellintra? sp.		●		
Cenosphaera? sp.	●			
Srakaeosphaera sp. cf. *S. minuta*	●			
Stigmosphaerostylus sp. cf. *S. itsukaichiensis*				●
Stigmosphaerostylus sp. cf. *S. ichikawai*				●
Stigmosphaerostylus spp.	●	●		
Stigmosphaerostylus? spp.	●			●

5.2 Age determination

Most of radiolarians listed above are well-known Permian species, thus the radiolarian biostratigraphic zonation proposed by Kuwahara *et al*. (1998), one of the most useful upper Middle to Upper Permian zonation, is fundamentally adopted in this paper. Kuwahara *et al*. (1998) examined the occurrence and stratigraphic distribution of *Follicucullus*, *Albaillella* and *Neoalbaillella* in chert sections at the Gujo-

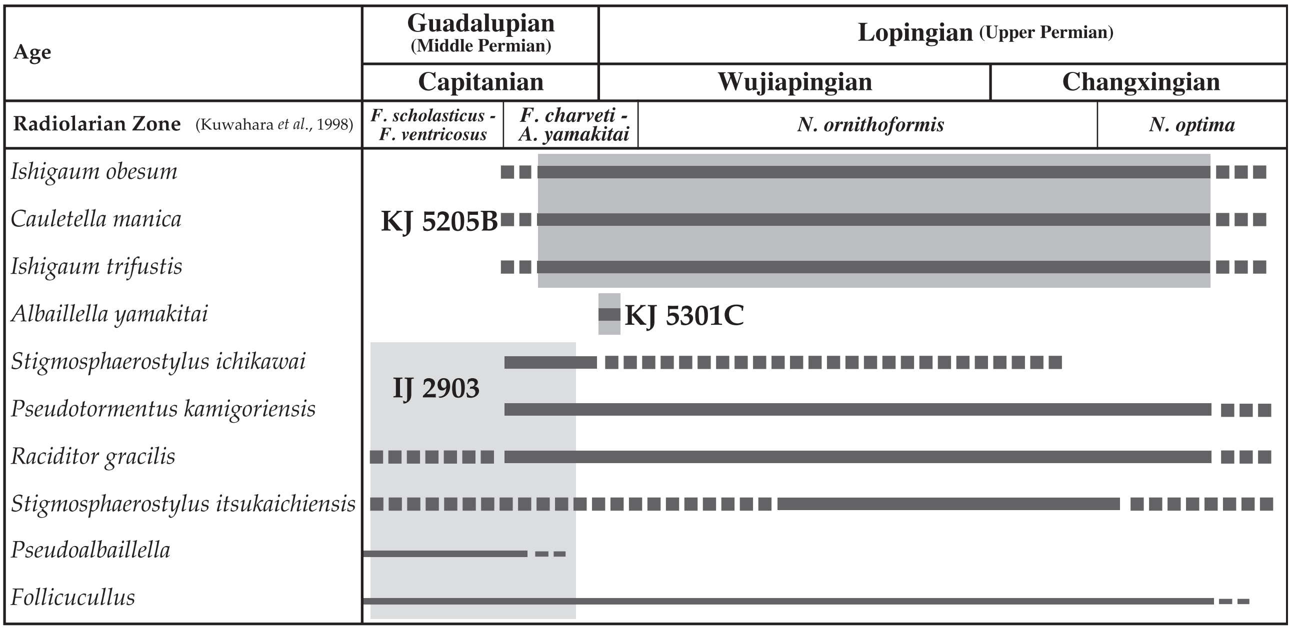

Fig. 4 Biostratigraphic ranges of selected Permian radiolarians and age of the rock samples.
Ranges are given by the previous studies described in the text. The ages determined are shown by gray zones with the sample numbers. Abbreviations are as follows. *A: Albaillella, F: Follucucullus, N: Neoalbaillella.*

hachiman and Neo areas in Southwest Japan, and established four radiolarian zones as a result; the *Follicucullus scholasticus – Follicucullus ventricosus*, the *Follicucullus charveti – Albaillella yamakitai*, the *Neoalbaillella ornithoformis* and the *Neoalbaillella optima* Assembladge Zones in ascending order. At that time, these zones have been correlated respectively to the middle Wuchiapingian, the middle to upper Wuchiapingian, the lower Changhsingian and the middle to upper Changhsingian stages (Yao *et al*., 2001). Nevertheless, Xia *et al*. (2005) mentioned that the first appearances of *Albaillella yamakitai* and *Albaillela cavitata* at the same level can identify the Guadalupian (Middle Permian) – Lopingian (Upper Permian) boundary, although the occurrence of *Albaillella yamakitai* begins from the uppermost Capitanian (*eg*., Nestell and Nestell, 2010; Nishikane *et al*., 2011). On the other hand, Xia *et al*. (2004) indicated that the occurrence of *Albaillella triangularis* almost coincides with the middle to upper Changhsingian conodont zones. According to Xia *et al*. (2005), the *Follicucullus charveti – Albaillella yamakitai* Assemblage Zone ranges from the upper Capitanian (uppermost Middle Permian) to the lowermost Wuchiapingian (lowermost Upper Permian) stages, because *Albaillella yamakitai* occurs for a relatively short period in an upper part of the *Follicucullus charveti – Albaillella yamakitai* Assemblage (Kuwahara *et al*., 1998). In addition, the *Neoalbaillella optima* Assembladge Zone, which is characterized by the abundant occurrence of *Albaillella triangularis*, ranges from the middle to upper Changhsingian stage on the basis of the occurrence of *Albaillella triangularis* (Kuwahara *et al*., 1998; Kuwahara,1999; Xia *et al*., 2004) (Fig.4).

De Wever and Caridroit (1984) found and described new species belonging to Latentifistularia from the Upper Permian Tatsuno Formation in the Kamigori area, Southwest Japan, five of which were obtained from the Nanjo Mountains by this study; they are *Pseudotormentus kamigoriensis*, *Cauletella manica*, *Ishigaum* sp. cf. *I. trifustis, Ishigaum* sp. cf. *obesum* and *Raciditor gracilis*. The following study in the same area by Caridroit and De Wever (1986) presented the stratigraphic distribution of the above species; according to this, *Pseudotormentus kamigoriensis, Cauletella manica, Ishigaum trifustis* and *Raciditor gracilis* occur together with *Albaillella triangularis* in the lower part of the section, and with *Follicucullus bipartitus, Follicucullus charveti* and *Follicucullus orthogonus* in the middle and upper parts of the section. *Ishigaum obesum* is presented only in the upper part with *Follicucullus orthogonus*. In addition to the above species, co-occurrence of *Stigmosphaerostylus ichikawai*, which was defined by Caridroit and De Wever (1984) and also obtained from the Nanjo Mountains, and *Follicucullus bipartitus, Follicucullus charveti* and *Follicucullus orthogonus* is recognized in the middle to upper part of the same section. On the basis of the comparison between the stratigraphic distributions in the Kamigori section (Caridroit and De Wever, 1984) and those in the Gujo-hachiman and Neo sections (Kuwahara *et al*., 1998), it is clear not only that the stratigraphic position of the Kamigori section is situated between the *Follicucullus charveti – Albaillella yamakitai* and the *Neoalbaillella optima* Assemblage Zones, but also that the section is upside-down. In contrast to the evidence of the Kamigori section, however, four species including *Cauletella manica, Ishigaum trifustis, Ishigaum obesum* and *Raciditor gracilis* successively yield from the Liuqiao section of the upper Changhsingian Dalong Formation, Guangxi Province, South China (Feng *et al*., 2006). In other words, these species appear from the *Follicucullus charveti – Albaillella yamakitai* Assemblage Zone to the *Neoalbaillella optima* Assembladge Zone. Furthermore, Blome and Reed (1992) has already illustrated the co-occurrence of *Cauletella manica, Ishigaum trifustis, Ishigaum obesum* and *Raciditor gracilis* with *Follicucullus charveti*.

On the other hand, Sashida and Tonishi (1985) described many Albaillellarian and Spumellarian species from a chert section exposed at Kashiwara, Itsukaichi area, central Japan, and summarized that this section is situated within the *Neoalbaillella ornithoformis* Sub-assemblage zone of Ishiga *et al*. (1982), which is roughly correlated with the *Neoalbaillella ornithoformis* Assemblage Zone of Kuwahara *et al*. (1998). In this Kashiwara section, co-occurrence of *Stigmosphaerostylus itsukaichiensis* and other taxa such as *Follicucullus scholasticus, Follicucullus ventricosus, Albaillella levis, Neoalbaillella grypa* and *Neoalbaillella ornithoformis*, is recognized. Furthermore, *Stigmosphaerostylus itsukaichiensis* occurs together with *Neoalbaillella optima, Albaillella triangularis, Albaillella levis* and *Raciditor gracilis* from chert sections at Klaeng, Thailand (Sashida *et al*., 2000a). From the above evidences, the range of *Stigmosphaerostylus itsukaichiensis* is at least from a middle part of the *Neoalbaillella ornithoformis* to a lower part of the *Neoalbaillella optima* Assemblage Zones of Kuwahara *et al*. (1998). At the Sra Kaeo area in eastern Thailand, *Srakaeosphaera minuta* was first discovered together with Middle to Late Permian species (Sashida *et al*., 1993) and later found in the Lower Permian chert succession (Saesaengseerung *et al*., 2009). Thus, *Srakaeosphaera minuta* has a relatively long range during Permian period.

In addition to the above radiolarian species, the occurrence mode of *Pseudoalbaillella* and *Follicucullus* is finally mentioned here; it is commonly well known that *Pseudoalbaillella* and *Follicucullus* first occurred respectively in Late Carboniferous and in late Middle Permian, and that in late Middle Permian, *Pseudoalbaillella* gradually diminished and *Follicucullus* in turn became dominant (Ishiga, 1990).

According to the discussion mentioned above, it is possible to summarize the stratigraphic ranges of selected radiolarian species from the Nanjo Mountains as shown in Fig.4. Therefore, the radiolarian assemblages, which mean the co-occurrence of extracted radiolarians, can constrain the age of each sample as follows. The age of KJ5205B corresponds with a relatively long period ranging from the *Follicucullus charveti – Albaillella yamakitai* Assemblage Zone to the *Neoalbaillella optima* Assemblage Zone, and the age of IJ2903 is correlated with late Middle Permian. The age of KJ5301C can be settled within a short period in the limits of an upper part of the *Follicucullus charveti – Albaillella yamakitai* Assemblage Zone. On the other hand, the precise age of KJ5205A cannot be determined due to the absence of age-diagnostic species, but it is Permian in age.

5.3 Contribution of radiolarian age to the regional geology

On the basis of the above correlation of the radiolarian faunas with the biostratigraphic zonations, the age of each rock sample is assigned as follows (Fig.4); KJ5205A of siliceous mudstone is a certain period in Permian, KJ5205B of tuffaceous mudstone is indicative of a long range from late Capitanian (latest Middle Permian) to Changhsingian (Late Permian) ages, KJ5301C of chert is earliest Wuchiapingian age (earliest Late Permian), and IJ2903 of chert is correlated with late Middle Permian period.

Hereafter, discussion will focus especially on the rocks from Loc.1 along the Waridani-gawa River. It is thought that the rocks at this locality containing KJ5205A and KJ5205B belong to the Ultra-Tamba belt on the basis of its lithologic assemblage and stratigraphical position; these rocks consist of greenish gray sandstone, tuffaceous and siliceous mudsrtone (Fig.3a), and further overlie pelitic mixed rocks in the Mino belt. As stated before, Permian radiolarians have previously been found from eight localities in the Nanjo Mountains, three (Locs. A, B and C in Fig.1b) of which are came from rocks in the Ultra-Tamba belt. According to Umeda (1986, 1996) and Umeda *et al*. (1996), radiolarian assemblages mainly composed of Middle – Late Permian genera *Follicucullus, Pseudoalbaillella, Latentifistula, Ishigaum, Raciditor, Stigmosphaerostylus* and others were recognized in these localities; especially Loc. C yielded *Follicucullus ventricosus* and *Follicucullus bipartitus*, which appear in a lower part of the *Follicucullus charveti – Albaillella yamakitai* Assemblage Zone of Kuwahara *et al*. (1998), indicating latest Middle Permian period. The radiolarian faunas of KJ5205A and KJ5205B obtained by this study are similar to those of Locs. A, B and C in the presence of *Latentifistula, Ishigaum, Raciditor, Stigmosphaerostylus*, although any specimens of *Follicucullus* are not included. Finally, it can be summarized based on the above that the rocks in the Ultra-Tamba belt in the Nanjo Mountains are in latest Middle to Late Permian period.

6. Systematic Paleontology

To describe the examined species in this study, the taxonomic classification is basically referred from De Wever *et al*. (2001).

Class **ACTINOPODA**
Subclass **RADIOLARIA**
Superorder **POLYCYSTINA**
Order **ALBAILLELLARIA** Deflandre 1953
Family **Albaillellidae** Deflandre 1953
Genus ***Albaillella*** Deflandre 1952
Type species *Albaillella paradoxa* Deflandre 1952

Albaillella* sp. cf. *A. yamakitai Kuwahara
(Fig. 6.1-6.2)
Remarks: This specimen is not well preserved, but main characteristics such as a conical shell whose apex slightly curves to the ventral side, five transversal bands and a dorsal bulge, are conformable to those of *Albaillella yamakitai* Kawahara. Although intensely damaged, the ventral wing protrudes from the point between the third and fourth transverse bands.
Range: Upper Permian.
Occurrence: Southwest Japan, South China.

Order **LATENTIFISTULARIA** Caridroit, De Wever and Dumitrica 1999
Family **Ruzhencevispongidae** Kozur 1980
Genus ***Pseudotormentus*** De Wever and Caridroit 1984
Type species *Pseudotormentus kamigoriensis* De Wever and Caridroit 1984

Pseudotormentus kamigoriensis De Wever and Caridroit
(Figs. 7.9-7.13)
Pseudotormentus kamigoriensis n. sp. – De Wever and Caridroit, 1984, p. 101-104, pl. 2, figs. 1-7.
Pseudotormentus kamigoriensis De Wever and Caridroit – Caridroit, Ichikawa and Charvet, 1985, pl. 1, figs. 10-12
Pseudotormentus kamigoriensis De Wever and Caridroit – Caridroit and De Wever, 1986, p. 85-86, pl. V, figs. 7-11.
Pseudotormentus kamigoriensis De Wever and Caridroit – Blome and Reed, 1992, p. 372-374, figs. 12.13-12.18,12.21.
Pseudotormentus kamigoriensis De Wever and Caridroit – Kuwahara, Yao and An, 1997, pl. 3, figs. 5-6.
Pseudotormentus kamigoriensis De Wever and Caridroit – Kuwahara and Yao, 2001, pl. 1, fig. 22.
Pseudotormentus kamigoriensis De Wever and Caridroit – Kuwahara, Yao, Yao and Li, 2004, pl. 1, fig. 18.
Pseudotormentus kamigoriensis De Wever and Caridroit – Wang, Yang, Cheng and Li, 2006, pl. 13, figs. Q-T; pl. 14, fig. DD.
Remarks: In the presented materials, parts of the arms are broken and eroded. Structures of the arms, consisting of smooth and imperforated proximal parts and lattice-like arrangement of pores on the distal parts, are the definitive features of *Pseudotormentus kamigoriensis* De Wever and Caridroit.
Range: Upper Permian.
Occurrence: Southwest Japan, South China, Oregon.

Family **Cauletellidae** Caridroit, De Wever and Dumitrica 1999
Genus ***Cauletella*** Caridroit, De Wever and Dumitrica 1999
Type species *Cauletella manica* (De Wever and Caridroit) 1984

Cauletella manica (De Wever and Caridroit)
(Fig. 5.15)
Deflandrella manica n. sp. – De Wever and Cardroit, 1984, p. 99, pl. 1, figs. 1-7.
Deflandrella manica De Wever and Cardroit – Cardroit and De Wever, 1986, p. 78, pl. II, figs. 20-25; pl. III, figs. 1-2.
Deflandrella sp. B – Ishiga, Watase and Naka, 1986, pl. III, fig. 5.
Deflandrella manica De Wever and Cardroit – Blome and Reed, 1992, p. 370-372, figs. 12.3-12.4.
Cauletella manica (De Wever and Cardroit) – Caridroit, De Wever and Dumitrica, 1999, p. 608, figs. 1-2.
Deflandrella manica De Wever and Cardroit – Kuwahara and Yao, 2001, pl. 1, fig. 16.
Deflandrella manica De Wever and Cardroit – Wang, Yang, Cheng and Li, 2006, pl. 11, fig. PP; pl. 13, fig. P; pl. 14, fig. U.
Cauletella manica (De Wever and Cardroit) – Feng, He, Zhang and Gu, 2006, p. 833, figs. 7.9-7.11.
Remarks: The extracted specimen, represented by broken and eroded form, are same as *Cauletella manica* (De Wever and Caridroit) in shape, size and position of the terminal spine and arrangement of the pores.
Range: Middle to Upper Permian.
Occurrence: Japan, South China, Thailand and Oregon.

Genus ***Ishigaum*** De Wever and Caridroit 1984
Type species *Ishigaum trifustis* De Wever and Caridroit 1984

Ishigaum* sp. cf. *I. trifustis De Wever and Caridroit
(Fig. 5.17)
Remarks: The examined specimen is not well preserved. Although distal ends of the spongy part are

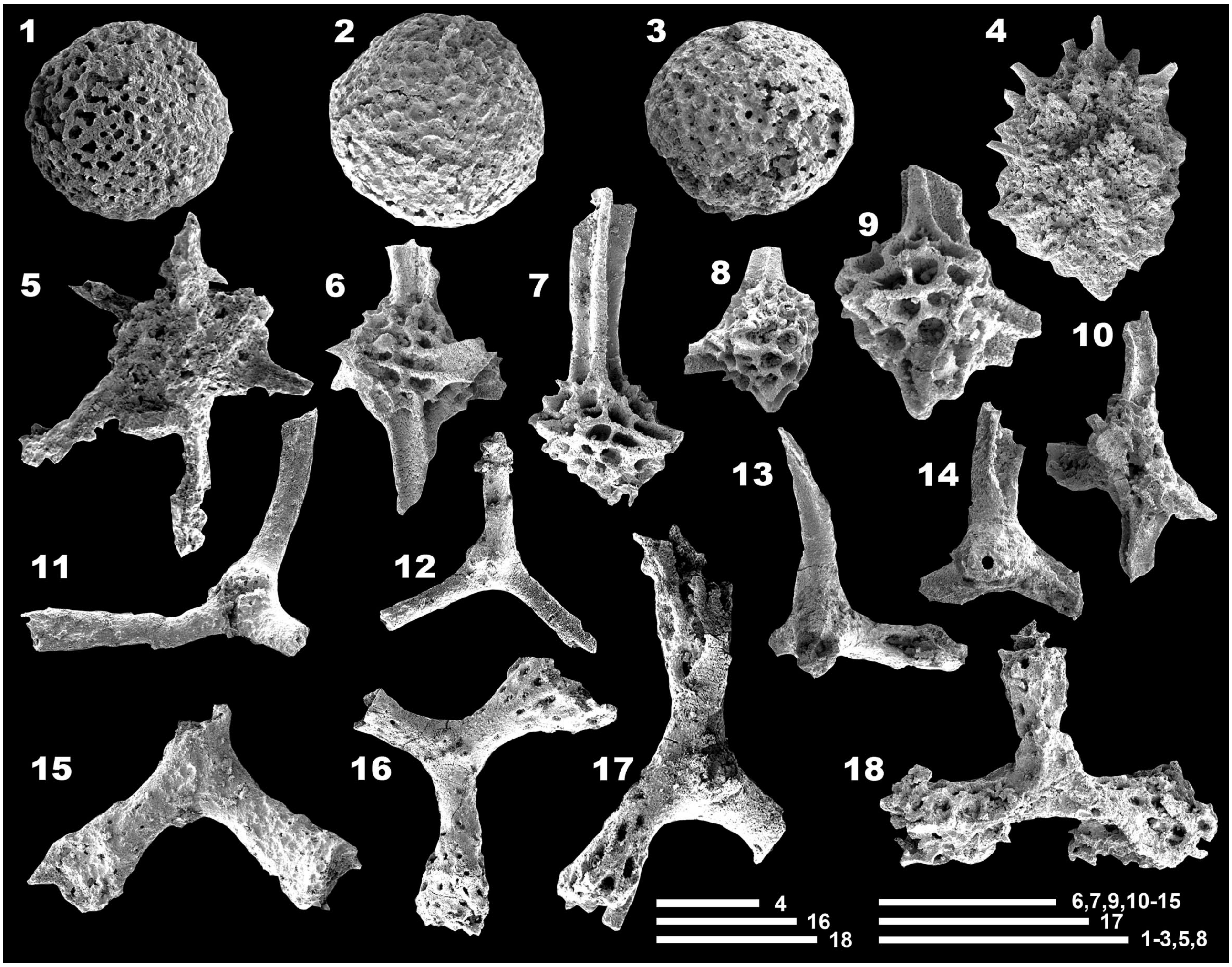

Fig. 5 Scanning electron microphotos of selected radiolarians from the Loc.1, south of Shizuhara.
1: *Srakaeosphaera* sp. cf. *S. minuta* Sashida (KJ5205A, GSJ F17614-015). 2-3: *Cenosphaera*? spp. (KJ5205A, 2: GSJ F17614-016, 3: GSJ F17614-010). 4: *Copiellintra*? sp. (KJ5205B, GSJ F17615-014). 5: *Stigmosphaerostylus* sp. (KJ5205B, GSJ F17615-004). 6-9: *Stigmosphaerostylus* spp. (KJ5205A, 6: GSJ F17614-007, 7: GSJ F17614-011, 8: GSJ F17614-014, 9: GSJ F17614-008). 10: *Stigmosphaerostylus*? sp. (KJ5205A, GSJ F17614-004). 11-12: *Latentifistula* spp. (KJ5205A, 11: GSJ F17614-012, 12: GSJ F17614-009). 13-14: *Raciditor* spp. (KJ5205A, 13: GSJ F17614-006, 14: GSJ F17614-003). 15: *Cauletella manica* (De Wever and Caridroit) (KJ5205B, GSJ F17615-013). 16: *Cauletella* sp. (KJ5205A, GSJ F17614-001). 17: *Ishigaum* sp. cf. *I. trifustis* De Wever and Caridroit (KJ5205B, GSJ F17615-008). 18: *Ishigaum* sp. cf. *I. obesum* De Wever and Caridroit (KJ5205B, GSJ F17615-007).
All scale bars equal to 0.1mm.

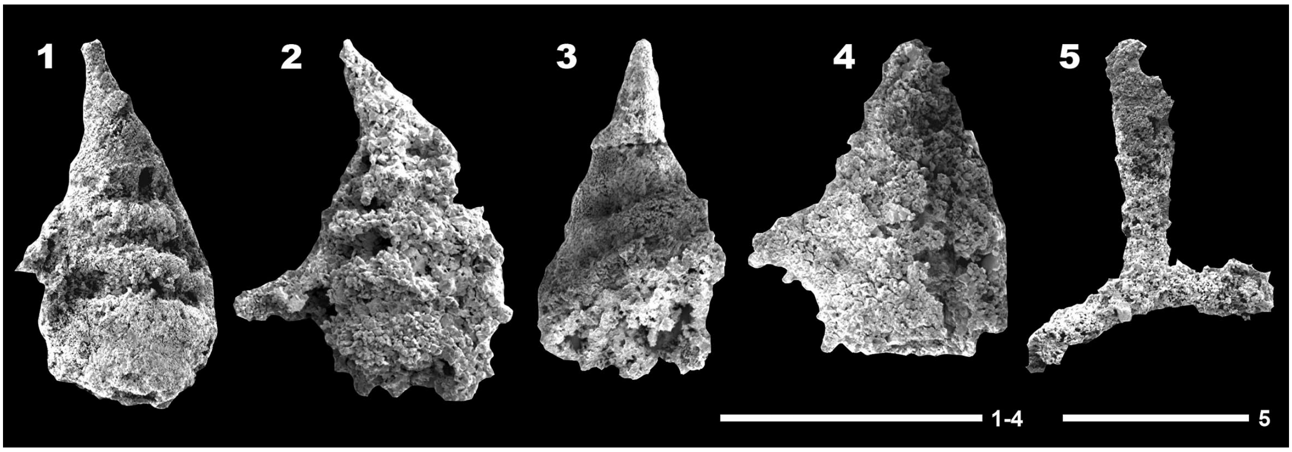

Fig. 6 Scanning electron microphotos of selected radiolarians from the Loc.2, south of Shizuhara.
1-2: *Albaillella* sp. cf. *A. yamakitai* Kuwahara (KJ5301C, 1: GSJ F17616-001, 2: F17616-003). 3: *Albaillella* sp. (KJ5301C, GSJ F17616-005). 4: *Albaillella*? sp. (KJ5301C, GSJ F17616-002). 5: Latentifistulidae gen. indet. (KJ5301C, GSJ F17616-006).
All scale bars equal to 0.1mm.

eroded, proximal tubular parts of the arms can be seen. Thus, it is probably similar to *Ishigaum trifustis* De Wever and Caridroit in having the same wall structure of the central part as well as the above features.
Range: Middle to Upper Permian.
Occurrence: Japan, South China, Thailand and Oregon.

Ishigaum* sp. cf. *I. obesum De Wever and Caridroit
(Fig. 5.18)
Remarks: The examined specimen is poorly preserved and moderately broken. The central part is massive and the surface of the arms rough more than those of *Ishigaum trifustis* De Wever and Caridroit, thus this specimen is similar to *Ishigaum obesum* De Wever and Caridroit in having the above characteristics.
Range: Middle to Upper Permian.
Occurrence: Japan, South China.

Family **Ormistonellidae** De Wever and Caridroit 1984
Genus ***Raciditor*** Sugiyama 2000
Type species *Raciditor gracilis* (De Wever and Caridroit) 1984

Raciditor gracilis (De Wever and Caridroit)
(Fig. 7.18)
Nazarovella gracilis n. sp. – De Wever and Caridroit, 1984, p. 101, pl. 1, figs. 14-15, 17.
Nazarovella gracilis De Wever and Caridroit – Caridroit and De Wever, 1986, p. 82-83, pl. IV, figs. 9-15.
Nazarovella gracilis De Wever and Caridroit – Sashida and Tonishi, 1986, p. 10, pl. 3, figs. 10-12; pl. 4, fig.7.
Nazarovella gracilis De Wever and Caridroit – Blome and Reed, 1992, p. 375-376, fig. 13.9-13.10.
Nazarovella gracilis De Wever and Caridroit – Sashida, Adachi, Igo, Koike and Amnan, 1995, p. 53-55, figs.11.17, 11.19.
Nazarovella gracilis De Wever and Caridroit – Kuwahara, Yao and An, 1997, pl. 3, figs. 1-2.
Nazarovella gracilis De Wever and Caridroit – Sashida, Adachi, Igo, Nakornsri and Ampornmaha, 1997, p. 8, figs. 5.20-5.24.
Nazarovella gracilis De Wever and Caridroit – Yao and Kuwahara, 1999, pl. 2, fig. 9.
Nazarovella gracilis De Wever and Caridroit – Sashida, Salyapongse and Nakornsri, 2000a, p. 253-254, pl. 2, fig. 11.
Nazarovella gracilis De Wever and Caridroit – Sashida, Igo, Adachi, Ueno, Kajiwara, Nakornsri and Sardsud, 2000b, p. 803, fig. 8.12.
Nazarovella gracilis De Wever and Caridroit – Feng and Gu, 2002, p. 807, figs. 7.8-7.13.
Raciditor gracilis (De Wever and Caridroit) – Kuwahara, Yao, Ezaki, Liu, Hao and Kuang, 2003, pl. 2, fig. 11.
Raciditor gracilis (De Wever and Caridroit) – Kuwahara, Yao, Yao and Li, 2004, pl. 1, fig. 20.
Raciditor gracilis (De Wever and Caridroit) – Kuwahara, Yao, Yao and Li, 2005, pl. 1, figs. 11-12, 15.
Nazarovella gracilis De Wever and Caridroit – Feng, He, Zhang, and Gu, 2006, p. 841, figs. 10.1-10.4.
Raciditor gracilis (De Wever and Caridroit) – Saesaengseerung, Agematsu, Sashida and Sardsud, 2009, p. 133, fig. 8.23.
Raciditor gracilis (De Wever and Caridroit) – Mitsumura and Kamata, 2009, pl. 4, fig. 22.
Remarks: The illustrated specimen is not complete but its form is characterized by four imperforated arms disposed tetrahedrally. Three of the arms are slender, elongate and U-shaped in cross section. Distal ends of the three arms are lacked by erosion. The fourth arm is perpendicular to the plane of the other arms. These features are same as *Raciditor gracilis* (De Wever and Caridroit).
Range: Permian.
Occurrence: Southwest Japan, South China, Thailand, Urals, Oregon, Alaska.

SPUMELLARIA *incertae sedis*
Srakaeosphaera* sp. cf. *S. minuta Sashida
(Fig. 5.1)
Remarks: Outermost shell of the examined specimen has numerical oval pores and no spines. Although diameter of the shell is slightly longer, this specimen is similar to *Srakaeosphaera minuta* Sashida in its overall form.
Range: Permian.
Occurrence: Thailand.

Order **ENTACTINARIA** Kozur and Mostler, 1982
Family **Entactiniidae** Riedel 1967
Genus ***Stygmosphaerostylus*** Rüst 1892
Type species *Stygmosphaerostylus notabilis* Rüst

Stygmosphaerostylus* sp. cf. *S. itsukaichiensis (Sashida and Tonishi)
(Figs. 7.19-7.24)
Remarks: The examined specimens are characterized by a small spherical shell and three-bladed main spines, but are slightly different from *Stygmosphaerostylus itsukaichiensis* (Sashida and Tonishi) in lack of thorn-like by-spines, which were probably eroded.
Range: Upper Permian.
Occurrence: Southwest Japan, South China, Thailand, Oregon.

Stygmosphaerostylus* sp. cf. *S. ichikawai (Caridroit and De Wever)
(Figs. 7.28, 7.29)

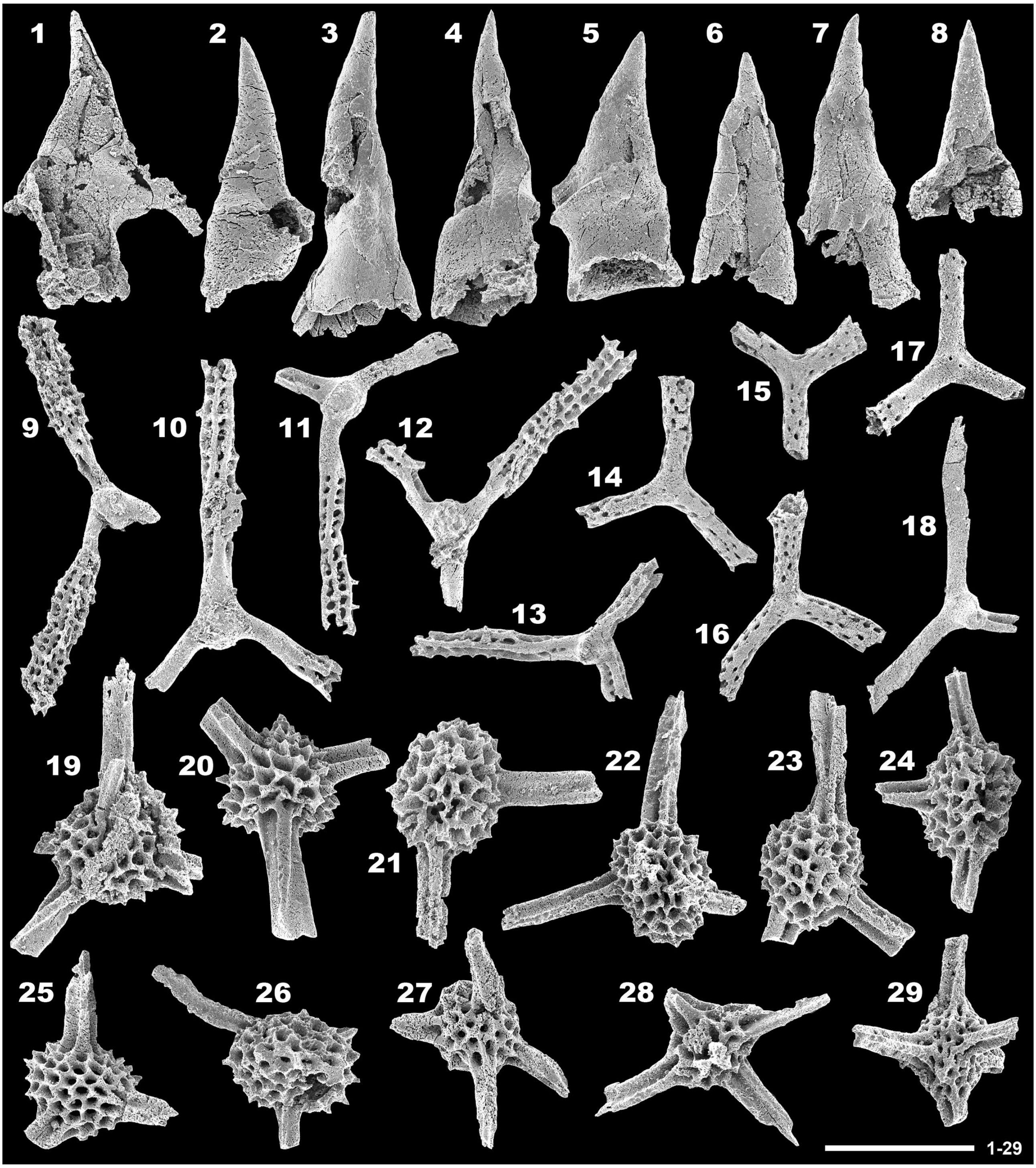

Fig. 7 Scanning electron microphotos of selected radiolarians from the Loc.3, at Yaotome.
1: *Pseudoalbaillella* sp. (IJ2903, GSJ F17502-001). 2-8: *Follicucullus* spp. (IJ2903, 2: GSJ F17502-008, 3: GSJ F17502-009, 4: GSJ F17502-010, 5: GSJ F17502-011, 6: GSJ F17502-005, 7: GSJ F17502-007, 8: GSJ F17502-003). 9-13: *Pseudotormentus kamigoriensis* De Wever and Caridroit (IJ2903, 9: GSJ F17502-012, 10: GSJ F17502-013, 11: GSJ F17502-018, 12: GSJ F17502-016, 13: GSJ F17502-015). 14-17: *Latentifistula* spp. (IJ2903, 14: GSJ F17502-019, 15: GSJ F17502-021, 16: GSJ F17502-020, 17: GSJ F17502-014). 18: *Raciditor gracilis* (De Wever and Caridroit) (IJ2903, GSJ F17502-017). 19-24: *Stigmosphaerostylus* sp. cf. *S. itsukaichiensis* (Sashida and Tonishi) (IJ2903, 19: GSJ F17502-025, 20: GSJ F17502-026, 21: GSJ F17502-023, 22: GSJ F17502-032, 23: GSJ F17502-022, 24: GSJ F17502-033). 25-27: *Stigmosphaerostylus*? spp. (IJ2903, 25: GSJ F17502-028, 26: GSJ F17502-031, 27: GSJ F17502-024). 28: *Stigmosphaerostylus* sp. cf. *S. ichikawai* (Caridroit and De Wever) (IJ2903, GSJ F17502-027). 29: *Stigmosphaerostylus*? sp. (IJ2903, GSJ F17502-29).
Scale bar equals to 0.1mm.

Remarks: These specimens are characterized by small spherical shell with large pores and six radiating spines which arise from the pores. The arms, broken and eroded, are three-bladed in the cross section. These features are ones of the definitives of *Stygmosphaerostylus ichikawai* (Caridroit and De Wever)

Range: Upper Permian.

Occurrence: Southwest Japan, South China, Oregon.

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西南日本，福井県南条山地からの中期－後期ペルム紀放散虫

中江　訓

要　旨

福井県内に位置する南条山地には，玄武岩・石灰岩・チャート・泥岩・砂岩などの様々な岩石からなる堆積岩複合体が主に分布する．最近30年間にわたり泥岩から産出した中生代放散虫化石が多数報告されてきたが，古生代放散虫化石の産出報告はわずかなため，古生代岩石の岩相－年代に関する情報は充分に得られているとは言い難い．本研究では，南条山地の凝灰質泥岩・珪質泥岩・チャートから産出した放散虫化石群集（*Albaillella*, *Pseudoalbaillella*, *Follicucullus*, *Latentifistula*, *Cauletella*, *Ishigaum*, *Raciditor*, *Pseudotormentus*, *Stigmosphaerostylus*, *Srakaeosphaera*）を記載し，その多くが中期ペルム紀から後期ペルム紀を代表するものであることを示す．更に，これらの放散虫化石は，南条山地の堆積岩複合体に対し時代的制約を与えることができる点で重要である．

難読・重要地名等

Asuwa：足羽，Ikeda：池田，Ito-o：糸生，Minamiechizen：南越前，Mino：美濃，Nanjo：南条，Nishitani：西谷，Omodani：面谷，Shizuhara：志津原，Ultra-Tamba：超丹波，Waridani：割谷，Yaotome：八乙女