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Permian radiolarians from the so-called Gufeng Formation of the Laibin - Liuzhou area, Guangxi, China

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Abstract

Middle – Late Permian radiolarians were found from siliceous rocks of the so-called Gufeng Formation of the Laibin - Liuzhou area, Guangxi, China. The radiolarian assemblages from the formation of the study sections could be assigned to those of the *Pseudoalbaillella globosa*, *Follicucullus scholasticus*, and *Follicucullus charveti- Albaillella yamakitai* zones of Southwest Japan. The radiolarian ages of the formation range from Middle Permian to early Late Permian. The siliceous rocks of the so-called Gufeng Formation directly cover the limestones of the Qixia Formation and the Maokou Formation, and are covered by the limestones of the Heshan Formation. The radiolarian ages of the basal part of the so-called Gufeng Formation are different among the sections within the Laibin - Liuzhou area. This difference may indicate the varied paleogeographic settings within the narrow sedimentary basin in the central Guangxi area during Middle to early Late Permian age.

Key-words : Radiolaria, Permian, Gufeng Formation, Guangxi, China

Introduction

The Permian strata of limestone and chert facies are well exposed around Guangxi, China. In the Laibin – Liuzhou area, the central Guangxi, along the Hongshuihe River, the Penglaitan section of limestone facies was settled as the Global Boundary Stratotype Section and Point (GSSP) for the Guadalupian-Lopingian boundary (Jin et al., 2001). The so-called Gufeng Formation of chert facies is widely distributed in the Laibin – Liuzhou area (Bureau of Geological and Mineral Resources of Guangxi Zhuang Autonomous Region, 1985). In the southern Guangxi, the Permian siliceous sequences are thickly developed in the Qinfeng Terrane (Yao et al., 2004).

The Permian radiolarian study has progressed in the above-mentioned sections of Guangxi (e.g., Yao et al., 1993; Xia and Zhang, 1998; Shang et al., 2001; Kuwahara et al., 2003, 2004, 2005; Xia et al., 2005; Feng et al., 2006; Wang et al., 2006). Previous radiolarian reports from the so-called Gufeng Formation in Guangxi are as follows:

Yao et al. (1993) reported the late Middle Permian radiolarian fauna from the Tongtianyan section, Liuzhou. Xia and Zhang (1998) reported the Early to Middle Permian radiolarians from the Bancheng area of the Qinfeng Terrane, and mentioned the radiolarian-bearing strata as the Gufeng Formation. Kuwahara et al. (2003, 2004) reported the late Middle to Late Permian radiolarians from the Chituao section, Laibin, and from the Tongtianyan section respectively, and Kuwahara et al. (2004) mentioned the Upper Permian strata should be separated from the Middle Permian Gufeng Formation. Moreover, many research reports treating the Late Permian (Lopingian) radiolarians from Guangxi were published

during the last decade (e.g., Shang et al., 2001; Xia et al., 2005; Feng et al., 2006; Wang et al., 2006).

The radiolarian biostratigraphy of the Permian strata in Guangxi is important as the global standard. Moreover, the Permian radiolarian paleontology has rapidly progressed in Guangxi mainly in the field of morphology and classification. These studies will become one of the useful tools for the reconstruction of paleoenvironment. In Guangxi, abrupt lithological change from limestone to siliceous rock (chert) is known in the Permian. The age of this lithofacies change could be dated by radiolarians. The radiolarian faunal features of the Permian will provide an important key to the understanding of the paleo-environment of South China during Permian age.

The senior author (YA) has conducted the Japanese-Chinese cooperative work by means of micro-biostratigraphical and micropaleontological research on the Paleozoic – Mesozoic of South China since 1991. We did field surveys as a part of cooperative work (Project No. 16) in March 2004 in the Laibin - Liuzhou area of the central part of Guangxi (Fig. 1). In this paper, we report the preliminary results of radiolarian biostratigraphy on the siliceous sequences of Middle and Late Permian age, the so-called Gufeng Formation, and discuss its geological significance.

Geologic setting

The Laibin – Liuzhou area, the central Guangxi, is situated on the Jiangnan Terrane which mainly consists of the deformed Lower Paleozoic and the un-deformed Upper Paleozoic and Lower Mesozoic. The Permian strata of this area consist mostly of shallow marine carbonate deposits except for siliceous or clastic deposits. The geologic structure of the Permian strata in the area is represented by the gentle folding with N-S axis and the N-S and E-W faults (Bureau of Geological and Mineral Resources of Guangxi Zhuang Autonomous Region, 2002).

The Permian of the Laibin – Liuzhou area is divided into six stratigraphic units as follows: the Chuanshan Formation (limestone facies; the lower Lower Permian), the Qixia Formation (limestone facies; the upper Lower Permian), the Maokou Formation (limestone facies; the Middle Permian), the so-called Gufeng Formation (chert facies; the Middle – lower Upper Permian), the Heshan Formation (limestone/chert facies; the lower Upper Permian) and the Dalong Formation (chert facies; the upper Upper Permian). The division of the Permian series and the Permian radiolarian biostratigraphy in this paper are based on the scheme of Menning et al. (2006) and Yao and Kuwahara (2004) respectively.

Since Li et al. (1941) correlated the Middle Permian siliceous sequences of Guangxi with the Gufeng Formation of the type area, the name of the Gufeng Formation has been adopted in Guangxi (Bureau of Geological and Mineral Resources of Guangxi Zhuang Autonomous Region, 1985). The exact age of "the Gufeng Formation", however, has still not been settled around Guangxi. Therefore the name of the so-called Gufeng Formation is adopted in this paper for the siliceous sequences of Middle to early Late Permian age,

The so-called Gufeng Formation is mainly composed of siliceous sequences, namely chert, siliceous mudstone, and alternating beds of chert and mudstone. This formation

Fig. 1 Index map of study area in Guangxi, China.

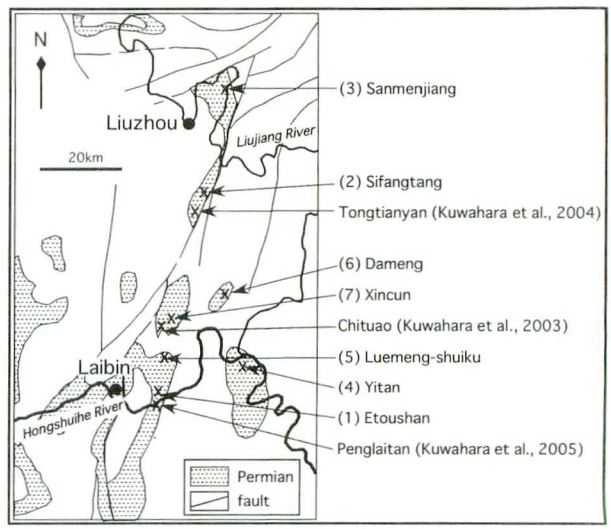

Fig. 2 Distribution of the Permian and location of study sections in the Laibin – Liuzhou area of the central Guangxi (after Bureau of Geological and Mineral Resources of Guangxi Zhuang Autonomous Region, 2002).

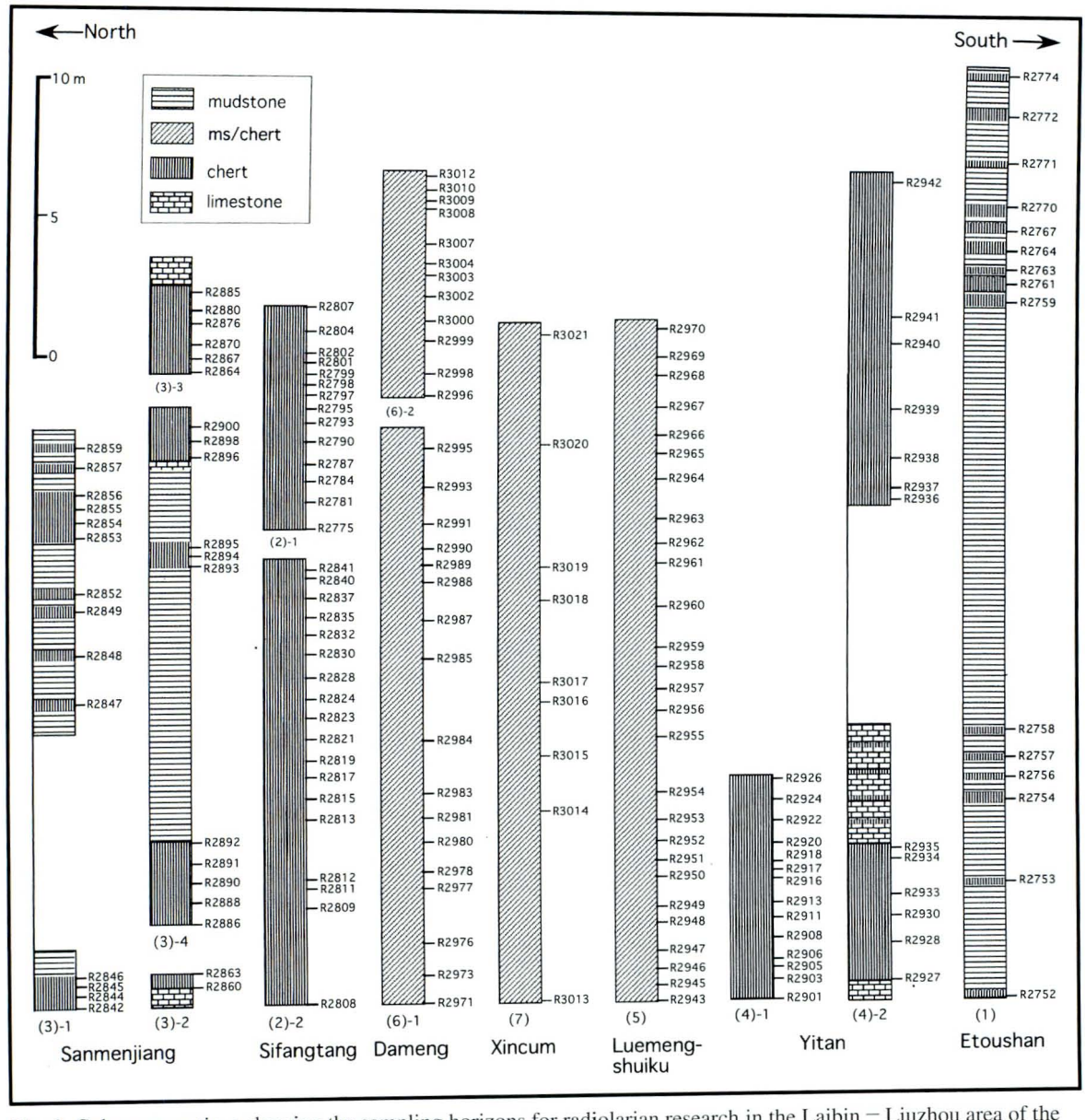

Fig. 3 Columnar sections showing the sampling horizons for radiolarian research in the Laibin – Liuzhou area of the central Guangxi.

conformably overlies the Qixia Formation and the Maokou Formation of limestone facies. The lithological change is abrupt from limestone of the Qixia and Maokou formations to chert of the so-called Gufeng Formation. The basal part of the so-called Gufeng Formation is characterized by red bedded cherts in the Laibin – Liuzhou area. The formation is conformably covered by limestone of the Heshan Formation.

Study sections and samples

The seven study sections (Figs. 2 and 3) of the so-called Gufeng Formation in the Laibin – Liuzhou area are described as follows: The geographical site of each section is shown by the GPS (Global Positioning System) reading.

(1) Etoushan section

Site: N23°42.408′, E109°19.405′

The thickness of the section is 34.4 m. The section is mainly composed of calcareous mudstone layers interbedding with siliceous black mudstone layers in some horizons (Fig. 4-6). The siliceous mudstone layer is about 1 to 30 cm in thickness, and is partly interbedded with gray chert layers. Twenty-three samples (R2752-R2774) were collected from this section.

(2) Sifangtang 1-2 sections

Site: 1 section; N24°09.284′, E109°25.014′, 2 section; N24°09.739′, E109°25.621′

The thickness of the Sifangtang 1 section is 8 m and the Sifangtang 2 section is 16 m. The 1 and 2 sections are composed of gray bedded chert, siliceous and tuffaceous

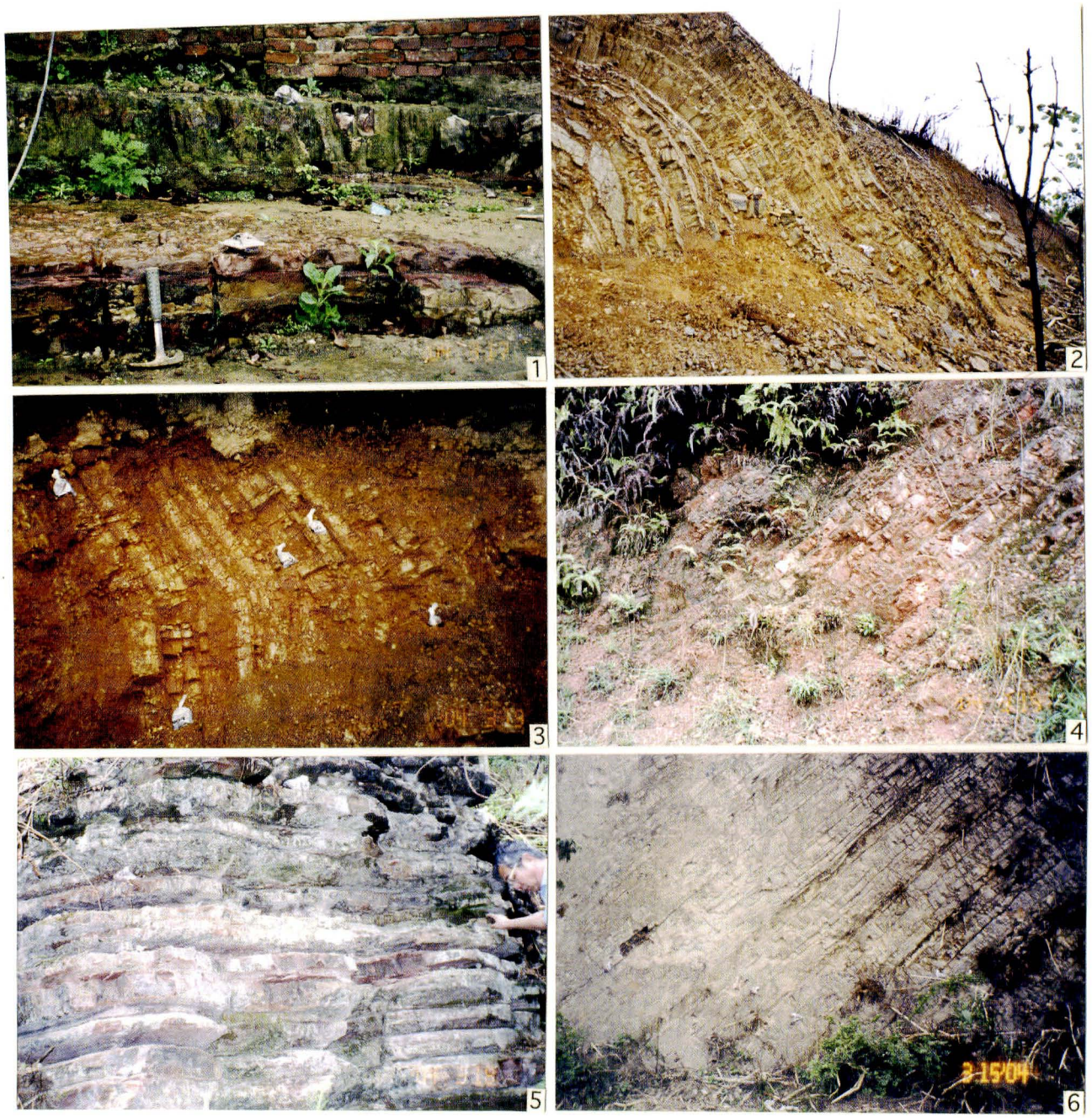

Fig. 4 Photographs of the study sections in the Laibin – Liuzhou area of the central Guangxi.
1. Red bedded chert of the basal part of the so-called Gufeng Formation in the Sanmenjiang 2 section, 2. Bedded chert of theSifangtang 2 section, 3. Mudstone interbedding with chert in the Dameng 2 section, 4. Mudstone interbedding with siliceous mudstone and chert in the Luemeng-shuiku section, 5. Red bedded chert of the basal part of the so-called Gufeng Formation in the Yitan 2 section, 6. Calcareous mudstone interbedding with siliceous mudstone in the Etoushan section.

mudstone (Fig. 4-2). Single bed of chert is about 3 to 15 cm in thickness. The siliceous and tuffaceous mudstones range in color from dark gray when fresh to pale yellow when exposed to the weather. Thirty-three samples (R2775-R2807) were collected from the 1 section and thirty-four samples (R2808-R2841) were collected from the 2 section.

(3) Sanmenjiang 1-4 sections

Site: 1 section; N24°21.341′, E109°29.552′, 2 section; N24°21.363′, E109°29.605′, 3 section; N24°21.458′, E109°29.633′, 4 section; N24°21.786′, E109°29.684′

The thickness of the Sanmenjiang 1 section is 21 m, the Sanmenjiang 2 section is 1.3 m, the Sanmenjiang 3 section is 4 m and the Sanmenjiang 4 section is 18.7 m. In the 2 section, the basal part of the so-called Gufeng Formation is composed of red bedded cherts (Fig. 4-1) which directly cover limestone of the Qixia or Maokou Formation. The main part of the formation consists of dark

gray mudstone interbedding with siliceous mudstone and black chert. The uppermost part of the formation (the 3 section) is composed of black bedded chert which is covered by limestone of the Heshan Formation. Eighteen samples (R2842-R2859) were collected from the 1 section, four samples (R2860-R2863) from the 2 section, twenty-two samples (R2864-R2885) from the 3 section and fifteen samples (R2886-R2900) from the 4 section.

(4) Yitan 1-2 sections

Site: 1 section; N23°45.856′, E109°31.609′, 2 section; N23°45.968′, E109°31.611′

The thickness of the Yitan 1 section is 8.3 m and the Yitan 2 section is 30.4 m. The basal part of the so-called Gufeng Formation (the 2 section) is composed of red bedded chert (Fig. 4-5) which directly covers limestone of the Qixia or Maokou Formation. This bedded chert is about 5 m in thickness and grades upward into alternating beds of chert and limestone. The main part of the formation (the 1 section and the upper part of the 2 section) consists of gray bedded cherts. Twenty-six samples (R2901-R2926) were collected from the 1 section and sixteen samples (R2927-R2942) from the 2 section

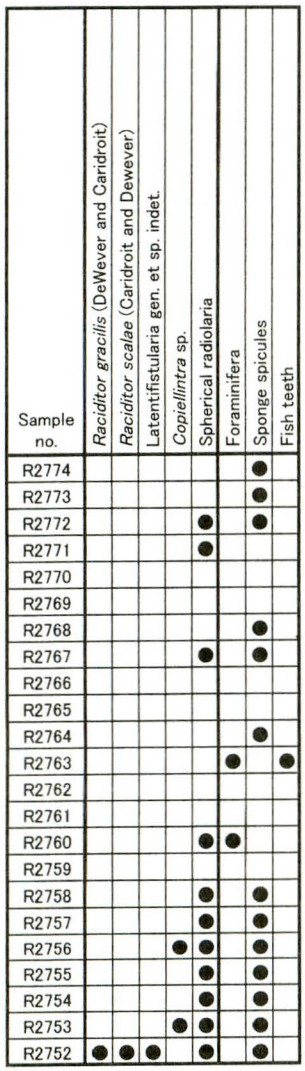

Fig. 5 Stratigraphic distribution of microfossils in the Etoushan section.

(5) Luemeng-shuiku section

Site: N23°48.806′, E109°21.492′

The Luemeng-shuiku section is 25m in thickness. The section, as a whole is weathered, consists of mudstone interbedding with siliceous mudstone and chert layers (Fig. 4-4). Twenty-eight samples (R2943-R2970) were collected from this section.

(6) Dameng 1-2 sections

Site: 1 section; N23°55.901′, E109°28.068′, 2 section; N23°55.850′, E109°28.488′

The thickness of the Dameng 1 section is 20.9 m and the Dameng 2 section is 8.3 m. As both sections are weathered, the original lithology is not clear, but it is inferred to be mudstone interbedding with siliceous mudstone and chert layers (Fig. 4-3), Rock samples were collected from 25 horizons (R2971-R2995) in the 1 section and 17 horizons (R2996-R3012) in the 2 section.

(7) Xincun section

Site: N23°51.587′, N109°20.742′

The Xincun section is 24.8 m in thickness. The section, as a whole is weathered, consists of mudstone interbedding with siliceous and tuffaceous mudstone layers. Rock samples were collected from 9 horizons (R3013-R3021).

Methods

Totally 270 samples were collected from the seven stratigraphic sections of the Laibin - Liuzhou area. Every rock sample was washed and immersed in hydrofluoric acid (HF) solution (5%) for 24 hours. After removing HF, the residue was sieved using 36 and 200 mesh sieves. Every residue was observed under stereoscopic binocular microscope and radiolarians were identified. Some samples were observed under transmitted light microscope. Photomicrographs of transmitted light were taken. Other microfossils (foraminifers, ostracoda, conodonts and sponge spicules) in the residue were also checked.

Microfauna from the so-called Gufeng Formation

(1) Etoushan section

In the lower part of the Etoushan section (about 10 m thickness; from the R2752 to R2758 horizons), radiolarians and sponge spicules were recovered (Fig. 5). In the sample R2752, the lowermost horizon, rich and well-preserved radiolarians were found. The assemblage contains

Raciditor gracilis, Raciditor scalae, Latentifistularia gen. et sp. indet. and abundant spherical radiolarians of spongy test. No albaillellarians were found. Sponge spicules are especially abundant from the sample R2756 to R2758. In the middle and upper parts of the section, spherical radiolarians, sponge spicules, foraminifers and fish teeth were sporadically detected.

(2) Sifangtang 1-2 sections

Sifangtang 1 section: Moderately to well-preserved radiolarians were found from every sample in the Sifangtang 1 section (Fig. 6). Abundant spherical and latentifistulid radiolarians occur throughout the section. Albaillellarians occur sporadically. In the lower and middle parts of the section (samples from R2775 to R2787), species of follicucullid characteristically occurred (Fig. 14). These species include *Follicucullus scholasticus, Follicucullus* cf. *charveti, Follicucullus bipartitus, Follicucullus ventricosus* and unidentified follicucullid. In

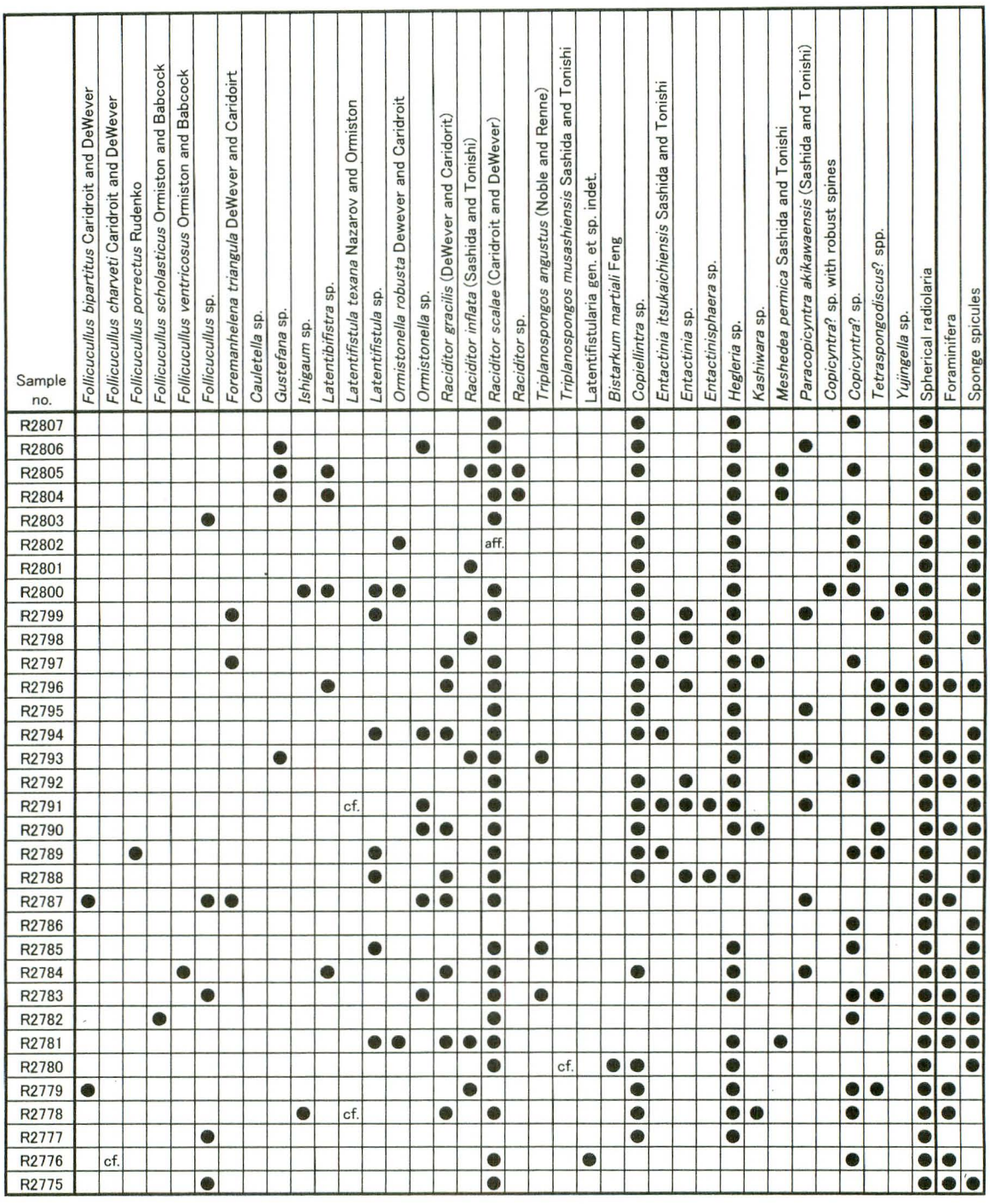

Fig. 6 Stratigraphic distribution of microfossils in the Sifangtang 1 section.

the samples R2787, R2797 and R2799, of the middle and upper parts of the section, *Foremanhelena triangula* was recovered. In the upper part of the section, *Paracopicyntra* sp. with robust spines and *Meshedea permica* were recognized characteristically.

Sifangtang 2 section: Moderately preserved radiolarians were recovered from all samples throughout the Sifangtang 2 section (Fig. 7). Five assemblages were preliminary distinguished by the first occurrence of characteristic species (Yao et al., 2006), that is, 1: *Follicucullus* cf. *ventricosus*, 2: *Foremanhelena triangula*, 3: *Latentibifistula*? sp., 4: Latentifistularia A and 5: *Albaillella* (or *Imotoella*) sp. It may be worth to note that abundant *Follicucullus* sp. was obtained from the sample

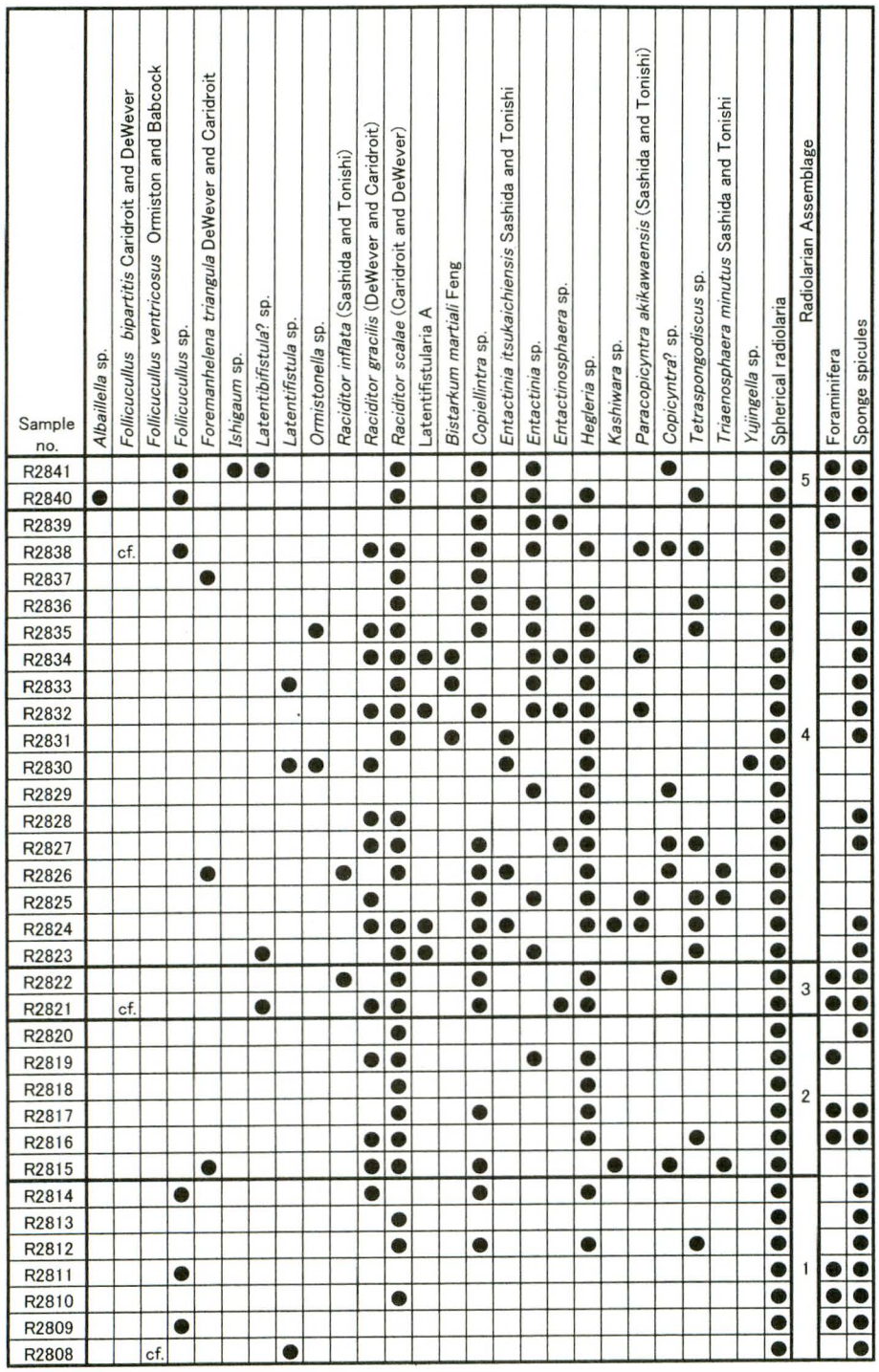

Fig. 7 Stratigraphic distribution of microfossils in the Sifangtang 2 section.

R2811. *Latentibifistula*? sp., which was obtained from the sample R2821, has large spongy triangular test. Latentifistularia A, which was found from the sample R2823, has extremely large lattice arm, like *Gustefana. Albaillella* (or *Imotoella*) sp., which was found from the sample R2840, is similar to *Albaillella* sp. G of Kuwahara (1999), but the wing protrudes from the middle part of the test.

(3) Sanmenjiang 1-4 sections

Sanmenjiang 1 section: In the samples R2842-R2846 of the lower part of this section, moderately preserved radiolarians were found with sponge spicules and foraminifers (Fig. 8). The radiolarian assemblage may be characterized by the sporadical occurrence of *Triplanospongos*. In the samples R2847-R2859 of the upper part of this section, sponge spicules were abundant, and no radiolarians were found.

Sample no.	*Latentifistula* sp.	*Ormistonella* sp.	*Raciditor inflata* (Sashida and Tonishi)	*Raciditor gracilis* (DeWever and Caridroit)	*Raciditor scalae* (Caridroit and DeWever)	*Triplanospongos dekkasensis* (Noble and Renne)	*Triplanospongos* sp.	Latentifistularia A	*Bistarkum martiali* Feng	*Copiellintra* sp.	*Entactinia* sp.	*Hegleria* sp.	*Paracopicyntra akikawaensis* (Sashida and Tonishi)	*Copicyntra*? sp.	*Yujingella* sp.	Spherical radiolaria	Foraminifera	Sponge spicules
R2859																		●
R2858																	●	●
R2857																		●
R2856																		●
R2855																		●
R2854																	●	●
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R2849																		●
R2848																		●
R2847																	●	●
R2846					●						●					●		●
R2845	●				●	cf.		●	●	●		●	●			●	●	●
R2844				●	●			●		●	●	●		●		●		
R2843			cf.	●	●			●			●	●		●		●	●	●
R2842		●		●	●		●			●	●	●			●	●		●

Fig. 8 Stratigraphic distribution of microfossils in the Sanmenjiang 1 section.

Sanmenjiang 2 section: In the sample R2863, *Follicucullus porrectus, Abaillella*? sp. *Raciditor gracilis*, and *Hegleria* sp. were found. The sample yielded some fragments of conodonts. Radiolarian preservation is poor and only small amounts of specimens were recovered.

Sanmenjiang 3 section: Moderately to poorly preserved radiolarians were found from all samples (Fig. 9). Almost all samples yielded sponge spicules, eight samples yielded conodont and six samples yielded foraminifers. Radiolarian assemblage is mainly composed of spherical radiolarians with latentifistularians, but no albaillellarians were detected. *Raciditor gracilis* and *Raciditor scalae* were common, and *Triplanospongos angustus* and Latentifistularia A were characteristically recovered.

Sanmenjiang 4 section: No radiolarians were found. Sponge spicules were found throughout the section, especially abundant in the samples R2894-R2900 of the upper part of the section. Foraminifers were found in R2900, in the uppermost horizon of this section.

(4) Yitan 1-2 sections

Yitan 1 section: Radiolarians were found from all samples. Sponge spicules, foraminifers, and ostracoda were also recovered (Fig. 10). Sponge spicules and foraminifers are abundant in several samples. Radiolarian preservation is moderate or poor in the lower and middle parts of this section (the sample R2917 and below). Only the sample R2905 yielded well-preserved radiolarians. In the upper part of the section, radiolarians decrease in abundance and are poor in preservation. The radiolarian assemblage is composed of spherical radiolarians mainly. Species of Latentifistularia, as *Raciditor scalae, Raciditor gracilis, Triplanospongos angustus* and Latentifistularia A, were sporadically recovered. Albaillellarians were not detected. In the upper part of this section, only *Hegleria* sp. and spherical radiolarians were recovered.

Yitan 2 section: Radiolarians were only recovered from the four samples, R2939, R2940, R2941 and R2942. Fossil preservation is moderately (R2940) or ill-preserved (R2939, R2941 and R2942). In the sample R2940, *Raciditor scalae, Latentibifistula*? sp., *Hegleria* sp., *Copiellintra* sp., and *Paracopicyntra* sp. were recovered. Sponge spicules, foraminifers, ostracoda, conodonts were sporadically found throughout the section.

(5) Luemeng-shuiku section

Foraminifers, ostracoda and sponge spicules were found from many samples, and ostracoda and foraminifers were especially abundant (Fig. 11). Microfaunal abundance seems to change upwards in the section. Radiolarians were recovered from the three samples, R2946, R2965 and R2966. In the sample R2946, well-preserved

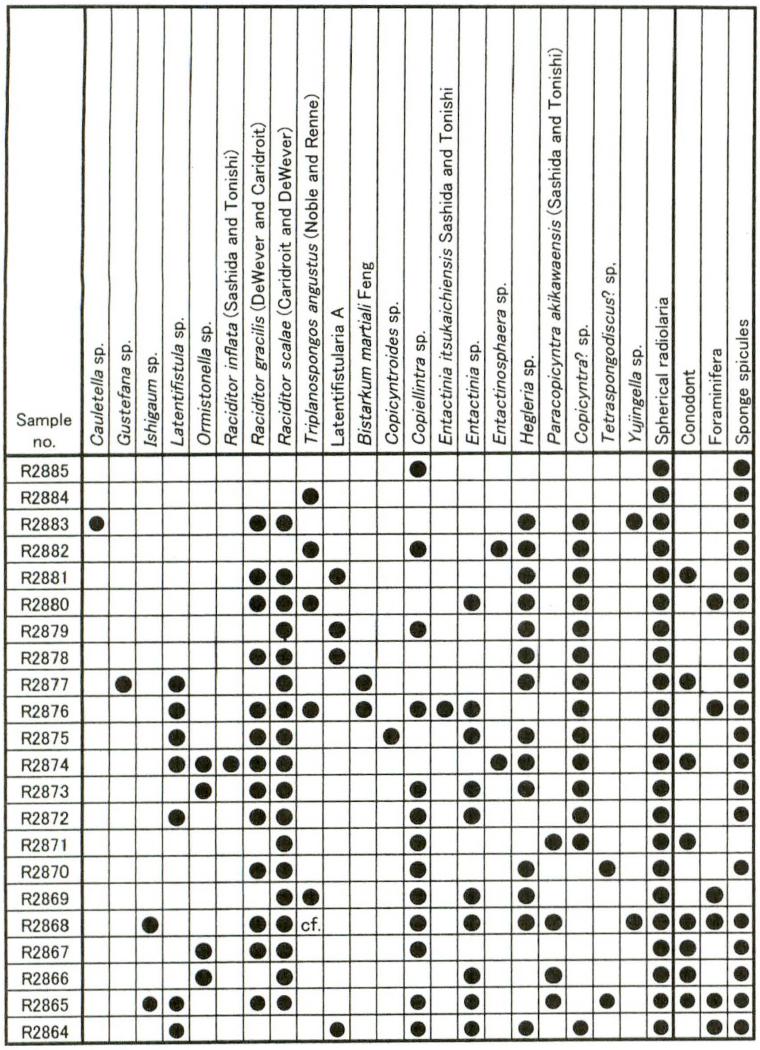

Fig. 9 Stratigraphic distribution of microfossils in the Sanmenjiang 3 section.

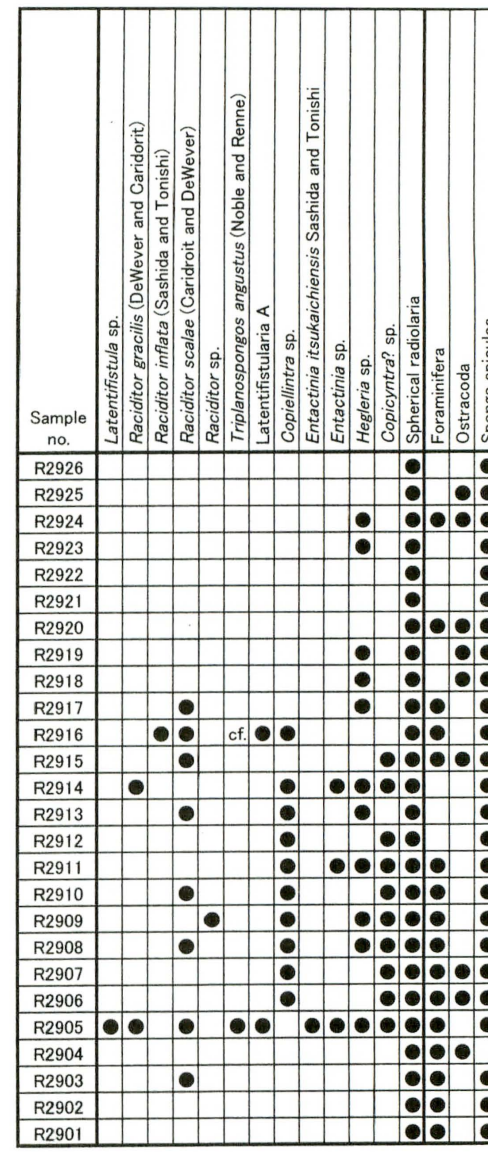

Fig. 10 Stratigraphic distribution of microfossils in the Yitan 1 section.

Pseudoalbaillella aff. *fusiformis* were found. In the sample R2965, moderately preserved *Pseudoalbaillella* cf. *fusiformis, Latentifistula* cf. *texana, Copiellintra*? sp. and *Hegleria* sp. were recovered.

(6) Dameng 1-2 sections

Dameng 1 section: In the lower part of this section (samples R2971-R2976), small unknown shells (gastropods or ammonite?) were abundantly found, and no radiolarians were detected. In the middle part of this section (samples R2977-R2987), foraminifers, sponge spicules and ostracoda were obtained (Fig. 12). In the samples R2988 and R2989, poorly preserved *Pseudoalbaillella* sp. and *Hegleria* sp. were recovered (Fig. 14). In the sample R2991, *Latentifistula* sp. was found. In the sample R2995 of the uppermost horizon, *Hegleria* sp., foraminifers and sponge spicules were recovered, though poor in preservation.

Dameng 2 section: Radiolarians and sponge spicules were found from all samples (Fig. 13). Foraminifers were found from the samples R2996-R3000 in the lower part of this section, and the samples R3002 and R3009 in the middle and upper parts of this section. Ostracoda was recovered from the sample R3000. Preservation of radiolarians varies ill-one to well-preserved one. *Raciditor*

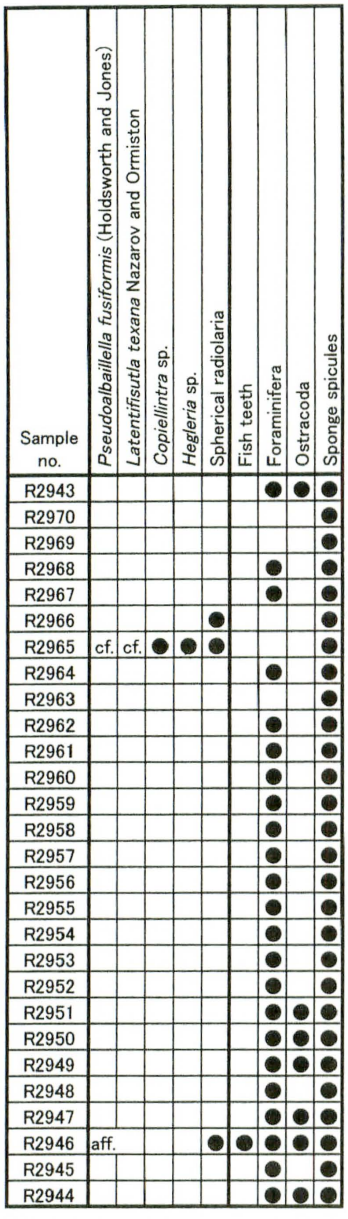

Fig. 11 Stratigraphic distribution of microfossils in the Luemeng-shuiku section.

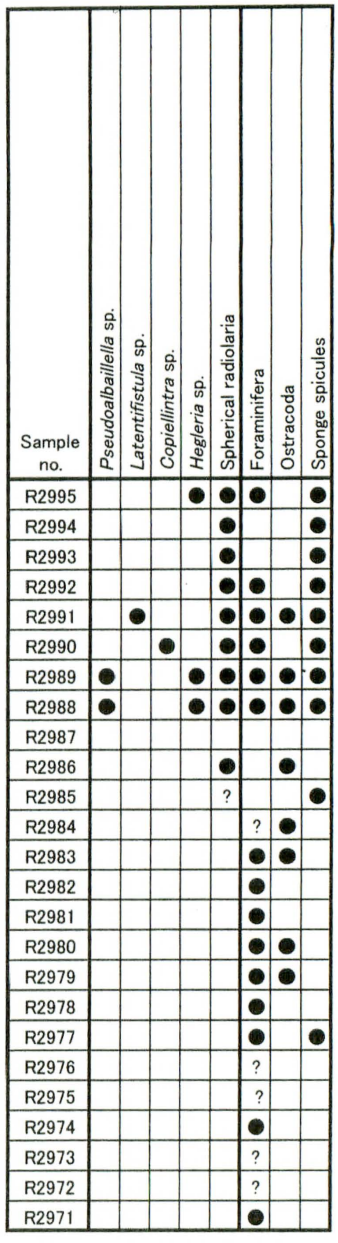

Fig. 12 Stratigraphic distribution of microfossils in the Dameng 1 section.

scalae and *Raciditor gracilis* are abundant throughout the section. In the sample R2996 of the lowermost horizon, *Copiellintra* sp. and *Paracopicyntra* sp. were recovered, though poor in preservation. Only one specimen of *Pseudoalbaillella*? sp. was found in the sample R3001. In the sample R3004, which is the middle part of this section, radiolarian species including *Ormistonella* sp., *Raciditor inflata, Hegleria* sp., *Kashiwara*? sp., *Entactinia* sp., *Copiellintra* sp. and *Bistarkum martiali* were recovered, though poor in preservation. In the sample R3012, *Raciditor scalae*, *Raciditor gracilis*, *Hegleria* sp. and *Copiellintra* sp. were found and the radiolarian preservation is moderate.

(7) Xincun section

Poorly preserved spherical radiolarians were obtained from the sample R3020. Radiolarian ghosts? were obtained from the samples R3014 and R3018. Sponge spicules were recovered from the samples R3014 and R3017-R3020. Foraminifers were obtained from the samples R3015 and R3018-R3020. Ostracoda fossils were found from the samples R3018 and R3020.

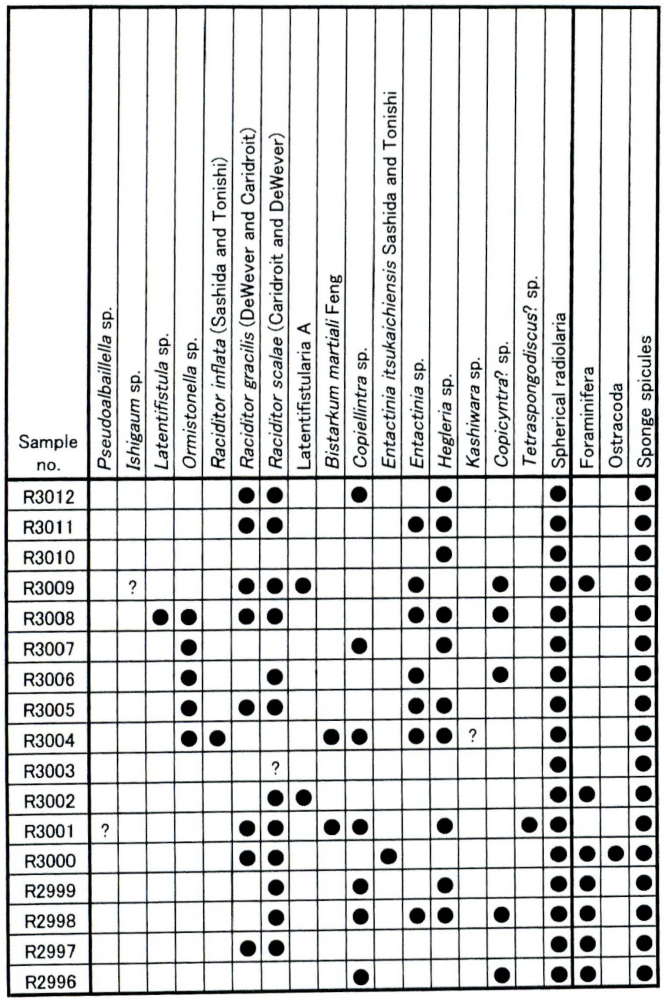

Fig. 13 Stratigraphic distribution of microfossils in the Dameng 2 section.

Discussion

Radiolarian age of the study sections

(1) Etoushan section

Raciditor scalae occurs characteristically in the lowest horizon (R2752) of this section (Fig. 5). This species has the biostratigraphic range from the *Pseudoalbaillella globosa* Zone to the *Neoalbaillella optima* Zone in China (Wang et al., 1994). Therefore the age of the Etoushan section is Middle or Late Permian (Fig. 15). Because no albaillellarians were found from this section, precise age assignment is difficult.

(2) Sifangtang 1-2 sections

Based on the composition of albaillellarians and latentifistularians, the Sifangtang 1 section (Fig. 6) is correlated with the *Follicucullus charveti* – *Albaillella yamakitai* Zone (Kuwahara et al., 1998). It is considered that the radiolarian assemblage 1 zone of the Sifangtang 2 section (Fig. 7) may tentatively correspond with the *Follicucullus scholasticus* Zone. The radiolarian assemblages 2-5 zones are correlated with the *Follicucullus charveti-Albaillella yamakitai* Zone. From these correlation, the lower part of the Sifangtang 2 section may be late Middle Permian in age, and the Sifangtang 1 section and the middle and upper parts of the Sifangtang 2 section are early Late Permian in age (Fig. 15).

(3) Sanmenjiang 1-4 sections

The sample R2845 of the Sanmenjiang 1 section yields *Triplanospongos* cf. *dekkasensis* (Fig. 8), and the middle and upper parts of the Sanmenjiang 3 section yield *Triplanospongos angustus* (Fig. 9). *Triplanospongos dekkasensis* and *Triplanospongos angustus* were newly described from the lower Upper Permian of California, USA, where *Albaillella yamakitai* occurred with them (Noble and Renne, 1990). These radiolarians bearing horizons can be correlated with the *Follicucullus charveti* – *Albaillella yamakitai* Zone, and are assigned to early Late Permian in age. The red bedded chert of the

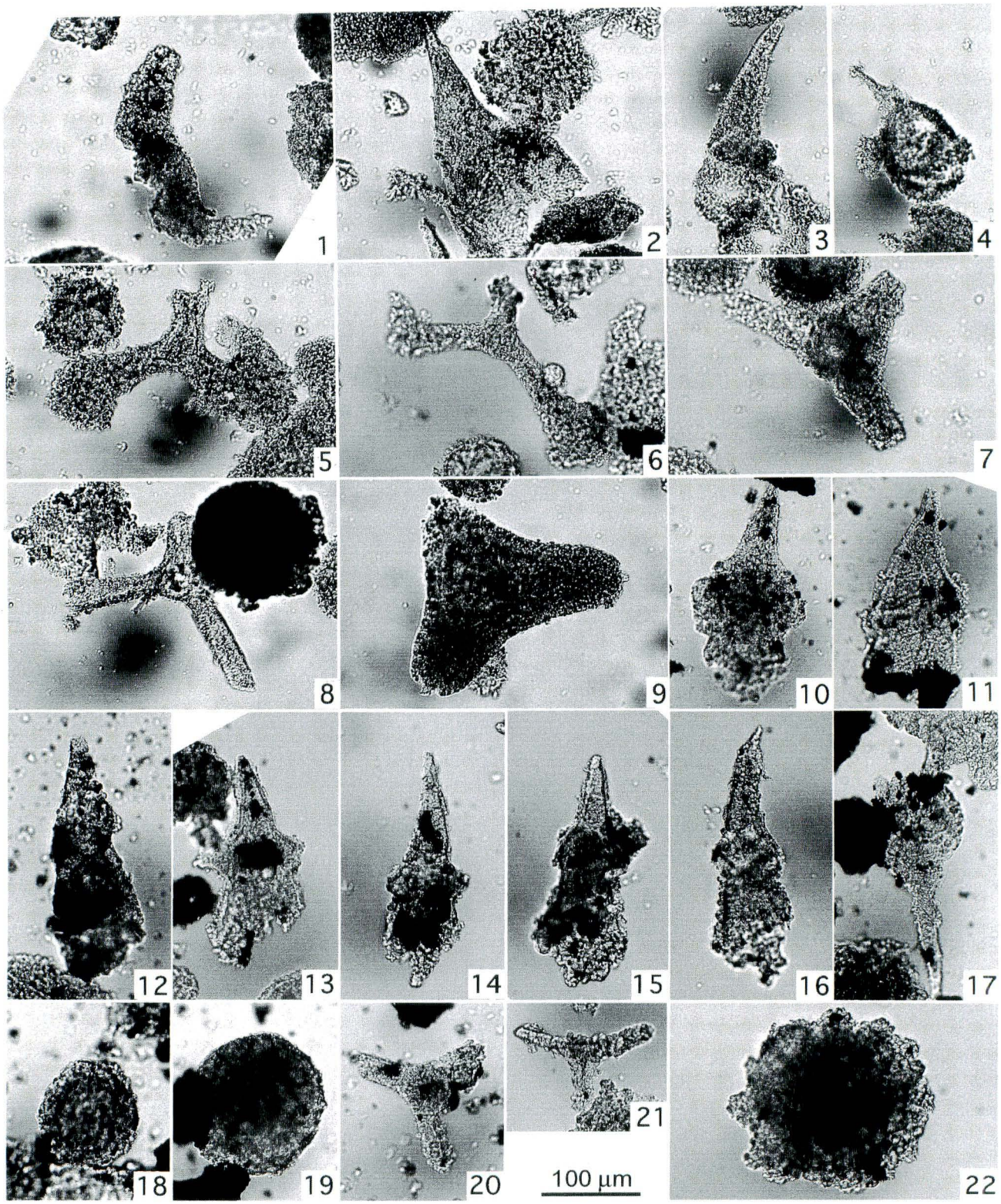

Fig. 14 Photomicrographs of radiolarians from the Laibin - Liuzhou area of the central Guangxi.
1. *Follicucullus charveti* Caridroit and DeWever (R2776), 2-3. *Follicucullus* sp. (R2778), 4. *Albaillella*? sp. (R2776), 5-6. *Ishigaum* sp. (R2776), 7-8. *Raciditor gracilis* (DeWever and Caridroit) (7:R2776, 8:R2787), 9. *Foremanhelena triangula* DeWever and Caridroit (R2787), 10-16. *Pseudoalbaillella* spp. (10-12:R2988, 13-16:R2989), 17-19. Entactinaria? (R2988), 20-21. *Raciditor* cf. *gracilis* (DeWever and Caridroit) (20:R2988, 21:R2989), 22. *Hegleria* sp. (R2989)
Localities - 1-9:Sifangtang 1 section, 10-22:Dameng 1 section.

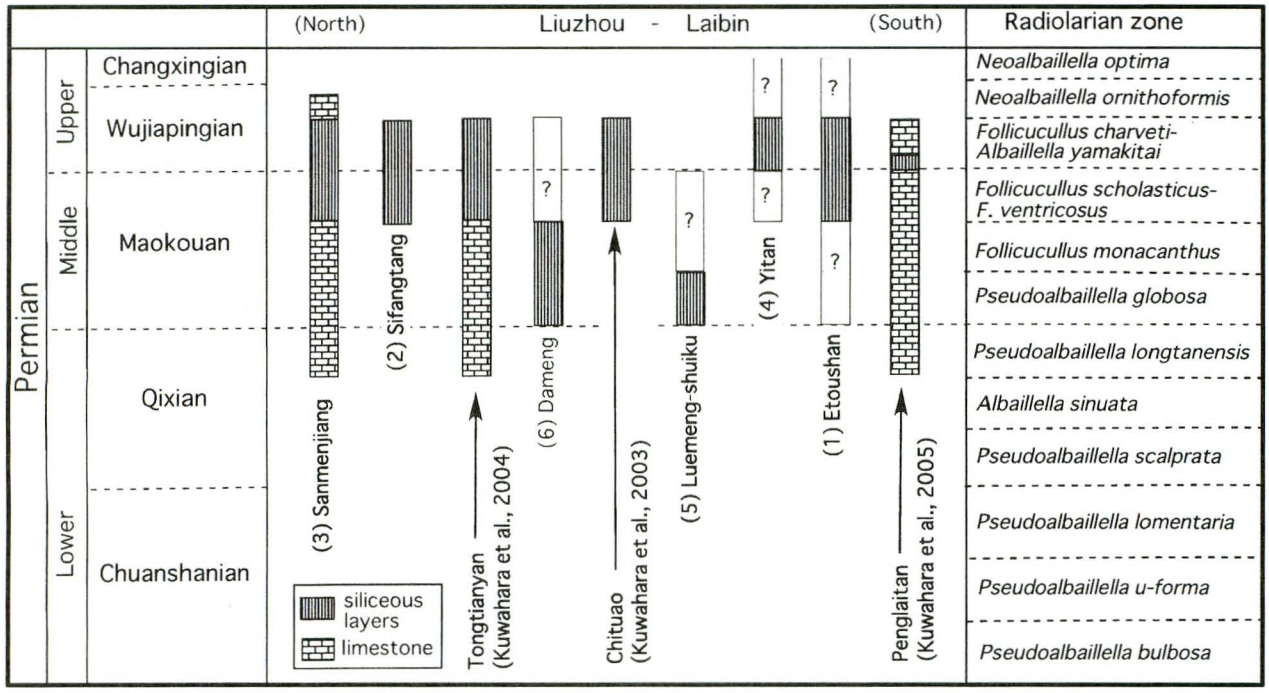

Fig. 15 Radiolarian biostratigraphic correlation of the sections in the Laibin – Liuzhou area of central Guangxi.

Sanmenjiang 2 section yields some species of *Follicucullus*, *Albaillella*, *Raciditor* and *Hegleria* (mentioned before). From these species, the Sanmenjiang 2 section may be correlated with the *Follicucullus scholasticus* Zone. On the basis of above-mentioned correlation, the siliceous sequences of the Sanmenjiang section has the range from late Middle Permian to early Late Permian in age (Fig. 15).

(4) Yitan 1-2 sections

The Yitan 1 section yields *Triplanospongos angustus* (Fig. 10). From the same basis mentioned in the Sanmenjiang 3 section, the Yitan 1 section is correlated with the *Follicucullus charveti – Albaillella yamakitai* Zone (Fig. 15). The Yitan 2 section yields *Raciditor scalae*. This species has the biostratigraphic range from the *Pseudoalbaillella globosa* Zone to the *Neoalbaillella optima* Zone in China (Wang et al., 1994). Therefore the age of the Yitan 2 section is Middle or Late Permian.

(5) Luemeng-shuiku section

The sample R2946 of this section yields *Pseudoalbaillella* aff. *fusiformis*, and the sample R2965 yields *Pseudoalbaillella* cf. *fusiformis* (Fig. 11). *Pseudoalbaillella fusiformis* is one of the common species of the *Pseudoalbaillella globosa* Zone. From this basis, the age of this section is Middle Permian and may be restricted to the lower Middle Permian (Fig. 15).

(6) Dameng 1-2 sections

The samples R2988 and R2989 of the Dameng 1 section yield *Pseudoalbaillella* sp. (Fig. 12). This species has the Middle Permian features in morphology. From the occurrence of this species, it is considered that the Dameng 1 section is Middle Permian in age. The Dameng 2 section yields *Raciditor scalae* and the sample R3001 yields *Pseudoalbaillella*? sp. (Fig. 13). From the same basis mentioned before, the Dameng 2 section may be restricted to Middle Permian in age (Fig. 15).

(7) Xincun section

No useful radiolarians for age determination were found from this section.

Geologic significance

The Gufeng Formation (the lower Maokouan) and the Dalong Formation (the Changxingian) are the typical Permian siliceous sequences in the Yangzi Platform and the Jiangnan Terrane. The Gufeng (Kuhfeng) Formation, which was originally named by Ye and Li (1924) in Gufeng Village, Jingxian, Anhui Province, is described by Bureau of Geology and Mineral Resources of Anhui Province (1987) as follows:

The Gufeng Formation of Anhui Province conformably overlies the Qixia Formation, and is conformably overlain by the Longtan Formation, and consists of black, gray yellow thin-bedded chert, siliceous shale, silty mudstone, carbonaceous shale, and manganese shale. The Gufeng Stage (Kuhfengian) was set up as the Lower part of the Maokouan on the basis of the Gufeng

Formation (Jin et al., 1994), and the Kuhfengian was adopted in one of the South China Stage as the Permian Regional Subdivisions of Geologic Time Scale (Wardlaw et al., 2004). According to Menning et al. (2006), the Kuhfengian is the stage of the middle Maokouan. Subsequently, the age of the Gufeng Formation of the type area was examined by means of radiolarian biostratigraphy (e.g. Sheng and Wang, 1985). As a result, the formation was correlated with the *Pseudoalbaillella globosa* Zone to the *Follicucullus scholasticus* Zone, that is the Maokouan in age.

The so-called Gufeng Formation is distributed in the Laibin – Liuzhou area, central Guangxi. The basal part of the formation is composed of red bedded chert and directly covers limestone of the Qixia or Maokou formations. Yao et al. (1993) and Kuwahara et al. (2004) reported the occurrence of *Follicucullus scholasticus* from the red bedded cherts of the Tongtianyan section, and assigned its age to latest Middle Permian (latest Maokouan). Moreover, Kuwahara et al. (2003, 2004) found the early Late Permian (early Wujiapingian) radiolarians in the Chituao and Tongtianyan sections.

In this study, it is clear that the siliceous sequences of the so-called Gufeng Formation yield the latest Maokouan and early Wujiapingian radiolarians in the Sanmenjiang, Sifangtang and Yitan sections of the Laibin – Liuzhou area (Fig. 15). Moreover, the radiolarian species of the *Pseudoalbaillella globosa* Zone and the *Follicucullus monacanthus* Zone were found from the Dameng and Luemeng-shuiku sections (Fig. 15). These facts indicate that the so-called Gufeng Formation of the Laibin – Liuzhou area was simultaneously formed with the Gufeng Formation of the type area during Maokouan age, and the siliceous sedimentation of the so-called Gufeng Formation continued up to early Wujiapingian age.

The limestone of the Maokou Formation of Maokouan age is developed around the Laibin – Liuzhou area. The limestones of the Heshan Formation of Wujiapingian age directly cover the bedded cherts of the so-called Gufeng Formation of early Wujiapingian age in the Sanmenjiang 3 section. On the other hand, the Heshan Formation overlies the limestones of the Maokou Formation in the Penlaitang section (Jin et al., 2001; Kuwahara et al., 2005) which is the Global Stratotype Section and Point (GSSP) for the Guadalupian-Lopingian boundary. These facts indicate that the so-called Gufeng Formation was formed in the interfingering relationships with the Maokou and Heshan formations.

The paleogeographic extent of sedimentary basin of the so-called Gufeng Formation is not reconstructed in detail because the study sections are limited to the Laibin – Liuzhou area in this time. However, it is pointed out that the paleogeographic setting was varied within the narrow sedimentary basin in the central Guangxi area during Maokouan to early Wujiapingian age. From the geologic relationships among the formations around the Laibin – Liuzhou area, it is inferred that the depositional site of siliceous sequences was near to the shallow depositional site of carbonate sequences. This paleogeographic reconstruction for the so-called Gufeng Formation is suggested by the diversified microfaunas such as foraminifers, ostracoda and sponge spicules.

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