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Permian radiolarians from the Qinfang Terrane, South China, and its geological significance

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Abstract

Three sections of chert-clastics sequence in the Qinfang Terrane, Guangxi, South China were lithostratigraphically and biostratigraphically examined. Nine radiolarian zones of Early to Late Permian age were distinguished in the chert sequences. These radiolarian zones are correlated with those defined in the Permian chert sequences of Southwest Japan.

The timing of lithofacies change from chert to clastics differs among the sections of the Qinfang Terrane. The timing between middle Maokouan and early Changxingian age indicates that the span among the sections depended on individual local paleogeographic and sedimentary conditions. It is considered that the deep oceanic setting represented by chert facies disappeared until middle Changxingian age, and changed into the continental margin setting represented by clastic facies in the Qinfang Terrane.

Key-words : Permian radiolarians, chert-clastics sequence, Qinfang Terrane, South China.

Introduction

The occurrences of Middle to Late Paleozoic radiolarians have been reported from the Qinzhou area of the southern part of Guangxi Zhuang Autonomous Region, South China since the 1990's (Sun et al., 2002; Wang, 1994; Wang et al., 1994; Wang and Li, 1994; Wang et al., 1998; Wu et al., 1994a, b; Zhang et al., 2002). Since 1996 the present authors have studied the Middle and Upper Paleozoics of the Qinfang Terrane (Figs. 1 and 2). The Qinfang Terrane is a differential zone between the Yangzi Block and the Cathaysia Block. The Paleozoic and Mesozoic tectonic interpretation of this terrane has not yet been agreed upon by researchers, since the geological information, especially age data of the siliceous rocks of this terrane are not sufficient as yet. It is important to determine the age of siliceous rocks, and to interpret the basin development and the tectonic process of not only the Qinfang Terrane but also South China.

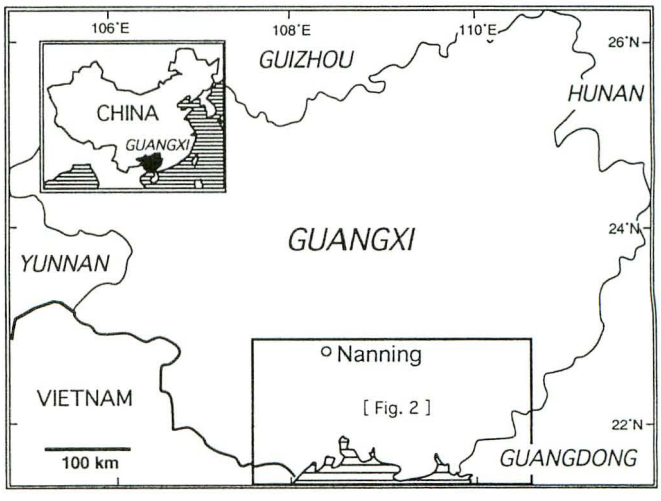

Fig. 1 Index map of the study area in Guangxi, China.

Our studies on the Qinfang Terrane were carried out as a part of cooperative research between Osaka City University and Peking University on the Paleozoic and Mesozoic of South China. A part of our results on the Qinfang Terrane was reported by Kuwahara (1999), Kuwahara et al. (2001), Yao and Kuwahara (2000) and Yao et al. (2001a, b, c, 2002). We report the occurrence of Permian radiolarians from three sections of chert-clastics sequence in the Qinfang Terrane, and discuss their geological significance.

Geologic Setting

The Qinfang Terrane is newly defined herein as a differential zone in its rock association, and in structural features in comparison with those of the Yangzi Block and the Cathaysia Block (Fig. 2). The geologic bodies of this terrane are characterized by sedimentary rocks formed in the Qinfang Trough during Middle Paleozoic and Early Mesozoic age (e.g. Bureau of Geology and Mineral Resources of Guangxi Zhuang Autonomous Region, 1985). This terrane has a SW - NE trend, and its width is about 100 km in the west part and contracts eastward. The northern limit of the terrane is a fault contact with the Jiangnan Terrane that is situated in the southern margin of the Yangzi Block. The southern limit is also a fault contact with the Yunkai Terrane which is situated in the northern margin of the Cathaysia Block.

The northern part of the Qinfang Terrane is characterized by the piles of tectonic slices composed of bedded cherts and clastics. The trend of the slices is concordant with that of the terrane, and fault-bounded slices deeply dip to north. The bedded cherts consist of rhythmically alternating beds of chert and thin claystone. The bedded cherts are occasionally intercalated with tuff beds. It is scarcely observed that the bedded chert sequence changes upward into clastics sequence. The chert sequence ranges from Devonian to Permian in age which were determined by radiolarian fossils (e.g. Wang, 1994). Three sections described in this paper, namely the Migong, Dachongling and Shiwu sections are situated in the northern part of the Qinfang Terrane (Fig. 2).

The central and southern parts of the Qinfang Terrane are composed mainly of Silurian - Devonian clastic rocks. These strata show folded structures with SW - NE trending axes.

Study Sections

Migong Section (Fig. 3)

This section is about 37 km west of Qinzhou and about 22 km northwest of Fangcheng (Fig. 2). The GPS value of this section is 21° 56.96'N, 108° 15.84'E. Several slices of cherts and clastics are distributed around the Migong Section. The outcrops are on the both sides of road cuttings (Fig. 6-1). The bedded cherts strike northeastward, and dip vertically, and the upward direction of the Migong Section is SE. The section is composed, in ascending order, of tuff beds, bedded cherts (Fig. 6-2), alternating beds of tuffaceous claystone and siltstone, alternating beds of sandstone and mudstone, and conglomerates. These rocks have conformable relationships, and form the chert-clastics sequence. The estimated thickness of bedded cherts is about 60 m. The rock samples for radiolarian biostratigraphical research were collected from 36 horizons

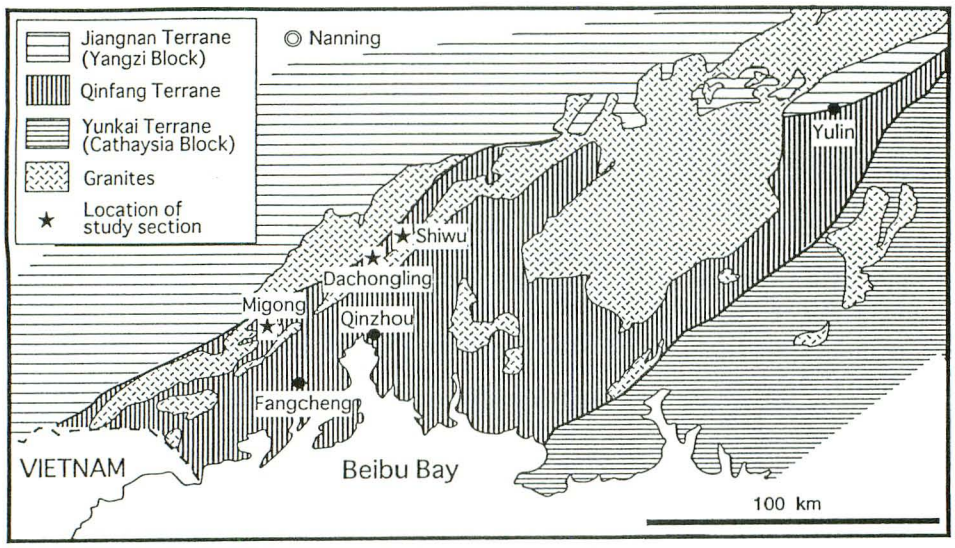

Fig. 2 Geologic sketch map of the Southern Guangxi area, showing the location of study sections.

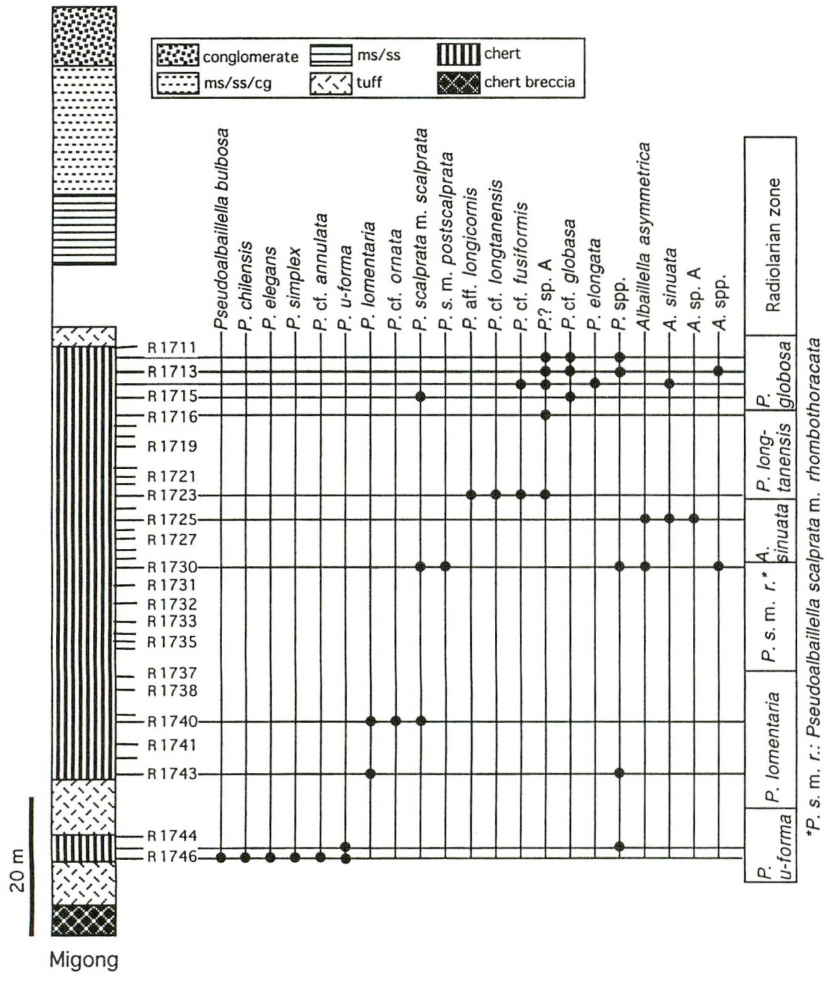

Fig. 3 Columnar section showing the horizons of radiolarian occurrence and radiolarian zones in the Migong Section, Guangxi, China.

(R1711-R1746) of bedded cherts in this section (Fig. 3).

Dachongling Section (Fig. 4)

This section is about 28 km north of Qinzhou and about 1.5 km southwest of Xiaodong which is a capital town of Xiaodong County. The outcrop of this section is partly the same as that of Wang et al. (1998; Fig. 4) and Sun et al. (2002). The section is composed of bedded cherts (Fig. 6-4) and occasionally intercalated with tuffaceous beds, and is about 45 m in thickness. This chert sequence is conformably covered by clastics sequence composed of mudstone, sandstone and conglomerate beds. The beds strike N 20°-30°W and dip 70°-75°N. The rock samples for radiolarian biostratigraphical research were collected from 11 horizons (R842-R844, R1471-R1478) of bedded cherts in this section (Fig. 4).

Shiwu Section (Fig. 5)

This section is about 38 km NNE of Qinzhou and about 0.7 km SE of Bancheng which is a capital town of Bancheng County. The outcrop is on the small road side cutting (Fig. 6-5). The main part of this section is composed of bedded chert, which is conformably covered by siliceous mudstone in the upper part of this section. This chert-clastics sequence is estimated to be about 25 m thick. The chert beds strike N 25° E and dip 50° S. The rock samples for radiolarian biostratigraphical research were collected from 18 horizons (R708-R718, R720-R726) of bedded cherts and 1 horizon (R719) of siliceous mudstone in this section (Fig. 5).

Methods

All rock samples used for the extraction of radiolarian fossils were collected from bedded chert and siliceous mudstone. These were about 100 g to 200 g per one sample.

The rock samples were immersed in a 5% hydrofluoric acid (HF) solution for 24 hours. After removing HF solution, the residues were collected by using 35 and 200 mesh sieves. In some samples, the same treatment was conducted several times in order to obtain

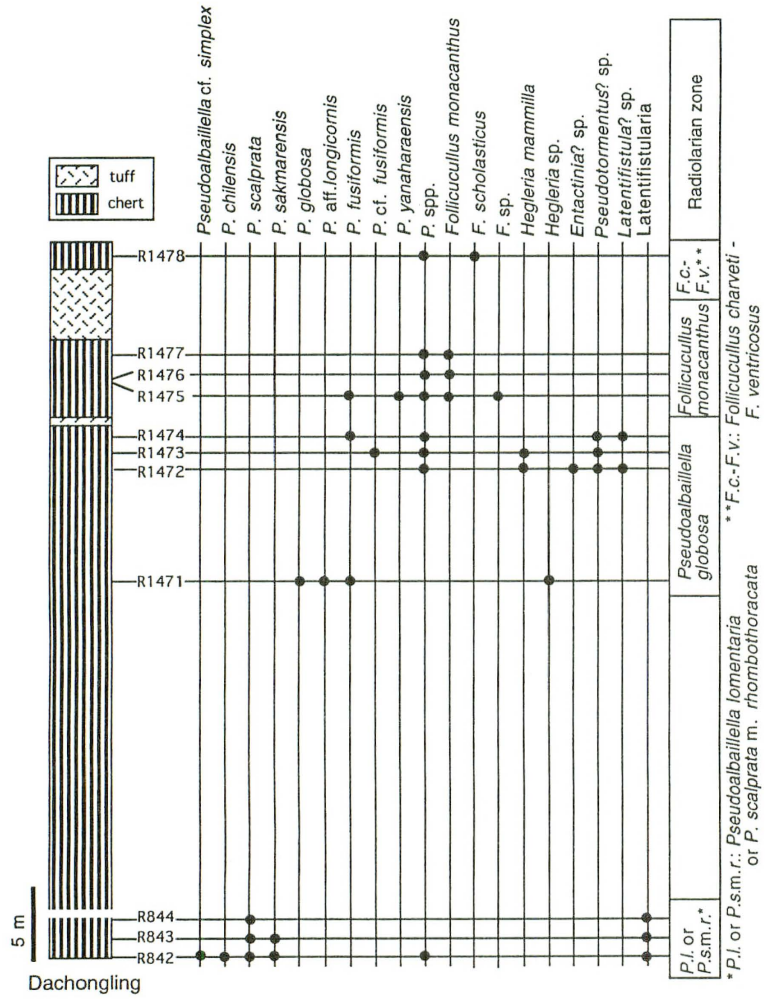

Fig. 4 Columnar section showing the horizons of radiolarian occurrence and radiolarian zones in the Dachongling Section, Guangxi, China.

sufficient radiolarian fossils.

The residues, in which radiolarian fossils were concentrated by panning, were mounted on a glass slide, a medium (Entellan new) added, and covered with a cover-glass.

Radiolarian specimens on slides were observed under a transmitted light microscope. In case of necessity, a scanning electron microscope was used to observe and to take photographs of radiolarian specimens.

Radiolarian Biostratigraphy

Radiolarian fossils and radiolarian zones

Occurrences of radiolarian species characteristic of each section are described below. Photomicrographs of characteristic radiolarian species are shown in Plates 1 and 2. The identification of radiolarian zones is based mainly on Ishiga (1990) and Kuwahara et al. (1998).

(1) Migong Section (Fig. 3)

The basal horizon (R1746) of this section yields *Pseudoalbaillella bulbosa* (Pl. 1, figs. 1-2), *P.* cf. *annulata* (Pl. 1, figs. 3-4), *P. chilensis* (Pl. 1, fig. 5), *P. elegans* (Pl. 1, fig. 6), *P. simplex* (Pl. 1, fig. 7) and *P. u-forma* (Pl. 1, fig. 8). The R1745 horizon yields *P. u-forma* (Pl. 1, fig. 9). These species are characteristic of those of the *P. u-forma* Zone.

The R1743 and R1740 horizons yield *Pseudoalbaillella lomentaria, P.* cf. *ornata* (Pl. 1, fig. 11), *P. scalprata* m. *scalprata* (Pl. 1, figs. 12-13), the first of which is a diagnostic species of the *P. lomentaria* Zone.

The R1730 horizon yields *Pseudoalbaillella scalprata* m. *scalprata, P. scalprata* m. *postscalprata* (Pl. 1, fig. 14) and *Albaillella asymmetrica* which are characteristic of those of the *P. scalprata* m. *rhombothoracata* Zone.

The R1725 horizon yields *Albaillella sinuata* and *A. asymmetrica*. The former species is diagnostic of the *A. sinuata* Zone.

The R1723 horizon yields *Pseudoalbaillella* aff. *longicornis* (Pl. 1, fig. 17), *P.* cf. *longtanensis* and *P.* cf. *fusiformis* (Pl. 1, fig. 15). The original species of

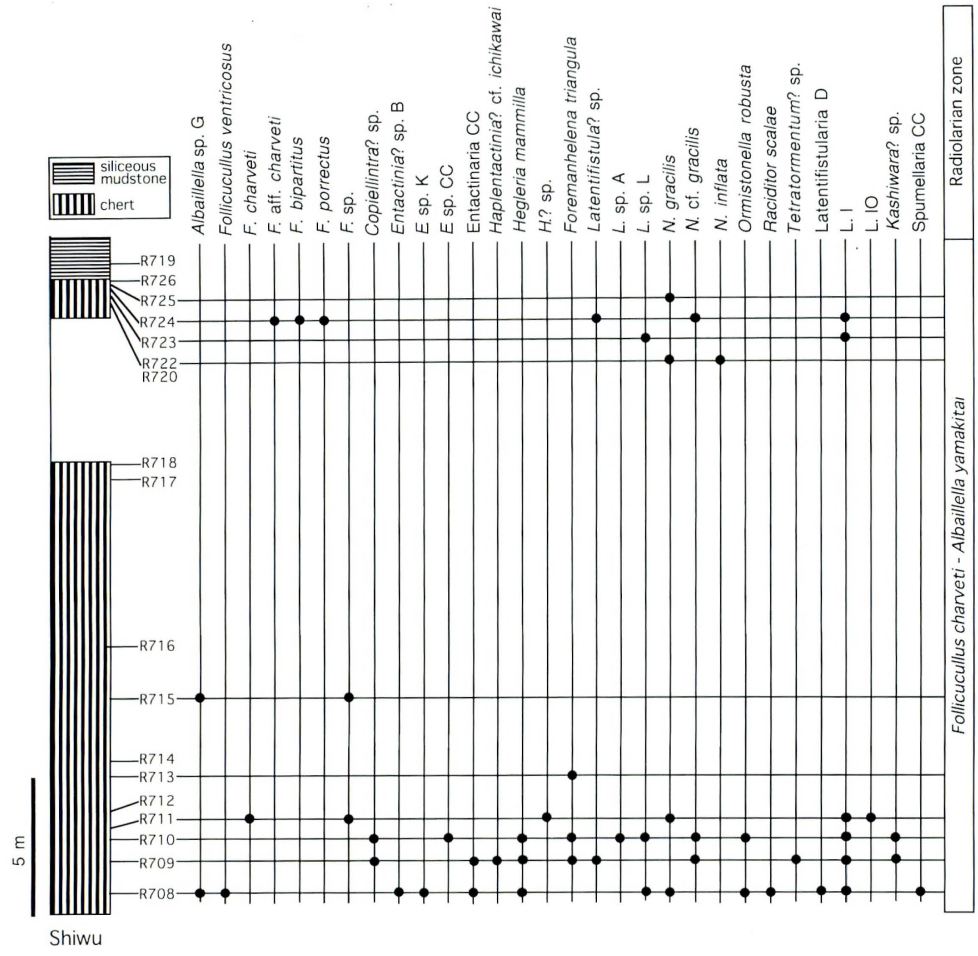

Fig. 5 Columnar section showing the horizons of radiolarian occurrence and radiolarian zones in the Shiwu Section, Guangxi, China.

them are characteristic of the *P. longtanensis* Zone.

The horizons from R1715 to R1712 yield *Pseudoalbaillella* cf. *fusiformis, P.* cf. *globosa* (Pl. 1, figs. 18-19), *P. elongata* (Pl. 1, fig. 16), *P.*? sp. A (Pl. 1, fig. 20) and *Albaillella sinuata* (Pl. 1, figs. 22-23). The original species of them are characteristic of the *P. globosa* Zone.

Six radiolarian zones, which are biostratigraphically continuous from the *P. u-forma* Zone to the *P. globosa* Zone, are distinguished in the chert sequence of the Migong Section.

(2) Dachongling Section (Fig. 4)

The basal part (R842-R844) of this section yields *Pseudoalbaillella chilensis, P. scalprata* (Pl. 2, figs. 4, 5 and 8), *P. sakmarensis* (Pl. 2, figs. 2, 6-7) and *P.* cf. *simplex* (Pl. 2, fig. 1). The former three species are characteristic of the *Pseudoalbaillella lomentaria* Zone or the *P. scalprata* m. *rhombothoracata* Zone.

The middle part (R1471-R1474) yields *Pseudoalbaillella globosa* (Pl. 2, figs. 9, 11), *P.* aff. *longicornis* and *P. fusiformis* (Pl. 2, fig. 12). The former species is diagnostic of the *P. globosa* Zone.

The upper part (R1475-R1477) yields *Follicucullus monacanthus* (Pl. 2, figs. 14 and 15) and *Pseudoalbaillella yanaharaensis* (Pl. 2, fig. 16). The former is diagnostic of the *F. monacanthus* Zone.

The uppermost horizon (R1478) yields *Follicucullus scholasticus* (Pl. 2, figs. 20-21) which is diagnostic of the *F. scholasticus* - *F. ventricosus* Zone.

Four radiolarian zones, namely the *P. lomentaria* or *P. scalprata* m. *rhombothoracata* Zone, the *P. globosa* Zone, the *F. monacanthus* Zone and the *F. scholasticus* - *F. ventricosus* Zone, are distinguished in the chert sequence of the Dachongling Section. It is thought that some radiolarian zones will be set up in the interval between the *P. lomentaria* or *P. scalprata* m. *rhombothoracata* Zone and the *P. globosa* Zone.

Sun et al. (2002) found *Albaillella protolevis* and *A. levis* from bedded cherts in the uppermost part of the

Fig. 6 Photographs of the study sections.
1-3: bedded cherts of the Migong Section. 4: bedded cherts of the Dachongling Section. 5: bedded cherts of the Shiwu Section.

Dachongling Section, and set up the *Neoalbaillella ornithoformis* Zone (Fig. 7).

(3) Shiwu Section (Fig. 5)

The main part (R708-R725) of chert sequence of this section yields *Albaillella* sp. G of Kuwahara (1999) (Pl. 2, fig. 23), *Follicucullus ventricosus* (Pl. 2, fig. 22), *F. charveti, F. bipartitus, F. porrectus* and many species of Latintifustularia. *F. charveti* is diagnostic of the *F. charveti* - *Albaillella yamakitai* Zone. *A.* sp. G and *F. bipartitus* are also characteristics species of this zone.

		Ma	Guangxi, South China (Wang Y. et al., 1998)	Dachongling, South China (Sun D. et al., 2002)	Southwest Japan and this paper (modified from Ishiga, 1990 and Kuwahara et al., 1998)
TRIASSIC					
PERMIAN	Changxingian	251			*Neoalbaillella optima*
					Neoalbaillella ornithoformis
		255			
	Wujiapingian		*Follicucullus bipartitus - F. charveti*	*Neoalbaillella ornithoformis*	*F. charveti - A. yamakitai*
		259	*Follicucullus scholasticus - F. ventricosus*	*Follicucullus charveti*	*Follicucullus scholasticus - F. ventricosus*
				Follicucullus scholasticus	
	Maokouan (Guadalupian)		*Follicucullus monacanthus*	*Follicucullus monacanthus*	*Follicucullus monacanthus*
			Pseudoalbaillella globosa	*Pseudoalbaillella globosa*	*Pseudoalbaillella globosa*
		269	*Pseudoalbaillella ishigai*	*Pseudoalbaillella longtanensis*	*Pseudoalbaillella longtanensis*
	Qixianian (Leonardian)		*Albaillella sinuata*		*Albaillella sinuata*
			Albaillella xiaodongensis		
		283	*Pseudoalbaillella scalpratam. rhombothoracata*		*Pseudoalbaillella scalpratam. rhombothoracata*
	Chuanshanian (Wolfcampian)		*Pseudoalbaillella lomentaria - Ps. sakmarensis*		*Pseudoalbaillella lomentaria*
			Pseudoalbaillella u-forma - Ps. elegans		*Pseudoalbaillella u-forma*
			Pseudoalbaillella bulbosa		*Pseudoalbaillella bulbosa*
		295			
CARBONIFEROUS					

Fig. 7 Permian radiolarian zonation in South China and Japan. Radiometric ages are based on Klein et al. (1994).

Geologic Age of Radiolarian Zones and Correlation

Ishiga (1990) summarized the Permian radiolarian zonation in the Permian chert sequences of Southwest Japan, and discussed the geologic age of radiolarian zones. Kuwahara et al. (1998) re-examined the Upper Permian radiolarian biostratigraphy in the Mino Terrane, Southwest Japan, and revised Ishiga's zonation.

Wang et al. (1998) have proposed the Upper Devonian to Upper Permian radiolarian zonation at Xiadong and Bancheng Counties of the Qinzhou area, Southeast Guangxi. The Permian radiolarian zones in their zonation (Wang et al., 1998) are shown in Fig. 7. They gave the geologic age of each Permian radiolarian zone using the American Permian succession, which was correlated with the Chinese Permian succession as shown in Fig. 7. Sun et al. (2002) recognized six radiolarian zones from the *P. longtanensis* the Zone to the *Neoalbaillella ornithoformis* Zone in the chert sequence of the Dachongling Section (Fig. 7).

The Permian radiolarian zones of this paper are well correlated with those in South China set up by Wang et al. (1998) as follows: (1) three zones from the *Pseudoalbaillella u-forma* Zone to the *P. scalprata* m. *rhombothoracata* Zone are correlated with those of Chuanshanian (Wolfcampian) age, (2) the *A. sinuata* Zone and the *P. longtanensis* Zone are correlated with those of Qixianian (Leonardian) age, (3) three zones from the *P. globosa* Zone to the *Follicucullus scholasticus - F. ventricosus* Zone are correlated with those of Maokouan (Guadalupian) age, and (4) the *F. charveti - Albaillella yamakitai* Zone is correlated with that of early Wujiapingian age, except for a small difference between Japanese zonation and Wang's zonation (Fig. 7). Sun et al. (2002) assigned the geologic age of the *Neoalbaillella ornithoformis* Zone to the earliest Wujiapingian based on the co-occurrence of characteristic conodonts such as *Clarkina postbitteri* and *C. dukouensis* that are the index fossils of the lowest Wujiapingian (e.g., Henderson et al., 2002). On the other hand, Yao et al. (2001) correlated the *Neoalbaillella ornithoformis* Zone with the *Clarkina subcarinata* Zone which is assigned to the earliest Changxingian.

Discussion

It has been generally considered that the Qinfang Terrane is composed of the sediments deposited in the "Qinfang Trough" during Middle Paleozoic to Early Mesozoic age (e.g. Bureau of Geology and Mineral Resources of Guangxi Zhuang Autonomous Region, 1985). This consideration is based mainly on the fact that this terrane contains remarkable radiolarian cherts of Late Paleozoic age. Wu (1999) reconstructed the paleogeography of South China during Middle to Late Permian age. According to Wu (1999), the Middle - Upper Permian radiolarian cherts of the Qinfang Terrane indicate the existence of a deep sedimentary basin along the Yangzi Block margin. This basin disappeared dur-

ing the collision between the Damingshan Terrane and the Yunkai Terrane (Wu et al., 2001). Yin et al. (1999; Fig. 3) showed the Maokouan paleo-oceanic reconstruction of South China as the "Tethyan Archipelagic Ocean" system. They pointed out that the Permian sediments and igneous rocks of the Qinfang Terrane indicate the existence of micro-ocean between the Yangzi Block and the Cathaysia Block. Zhang et al. (2002) examined the radiolarian succession and the rare earth element variation of the Lower to Middle Permian chert sequence in the Bancheng Section, Qinzhou area and other sections. They pointed out that part of the chert sequence was formed under the pelagic deep ocean environment. These papers referred here mention that the deep ocean basin existed between the Yangzi Block and the Cathaysis Block during Permian age. However, the closure process of this basin remains unknown.

The chert sequence grades upward into clastics sequence in the Migong and Shiwu sections (Figs. 3 and 5) and also in the Dachongling Section. In the Migong Section, the bedded chert of the *Pseudoalbaillella globosa* Zone is covered directly by tuff which grades upward into mudstone. The mudstone is intercalated with sandstone beds and conglomerate beds in the upper horizon. The alternating beds of mudstone, sandstone and conglomerate grade upward into thick and massive conglomerate in the uppermost part of this section. In the Shiwu Section, the bedded chert of the *Follicucullus charveti - Albaillella yamakitai* Zone grades upward into siliceous mudstone. The bedded chert of the *Neoalbaillella ornithoformis* Zone (Sun et al., 2002) in the Dachongling Section is conformably covered by mudstone beds which grade upward into alternating beds of mudstone, sandstone and conglomerate. This lithofacies change in the Migong, Shiwu and Dachongling sections indicates the upward coarsening sedimentation. It is considered that the deep oceanic setting represented by chert facies, changed into the continental margin setting represented by clastic facies during Maokouan to Wujiapingian age.

The timing of lithofacies change from chert facies to clastic facies differs among the sections of the Qinfang Terrane. It is middle Maokouan age in the Migong Section, middle - late Wujiapingian age in the Shiwu Section, and early Changxingian age in the Dachongling Section. It is considered that the differences among the sections reflected local paleogeographic settings in relation to continental collision and resultant change of each sedimentary site. There is no chert sequence of post-middle Changxingian age in the Qinfang Terrane. This fact indicates that the deep oceanic setting in the Qinfang Terrane disappeared until middle Changxingian age.

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Plate 1. Scanning photomicrographs of Permian radiolarians (Albaillellaria) from the Migong Section, Guangxi, China.

Figs. 1-2 *Pseudoalbaillella bulbosa* Ishiga, R1746
Figs. 3-4 *Pseudoalbaillella* cf. *annulata* Ishiga, R1746
Fig. 5 *Pseudoalbaillella chilensis* Ling and Forsythe, R1746
Fig. 6 *Pseudoalbaillella elegans* Ishiga and Imoto, R1746
Fig. 7 *Pseudoalbaillella simplex* Ishiga and Imoto, R1746
Fig. 8 *Pseudoalbaillella u-forma* Holdsworth and Jones, R1746
Fig. 9 *Pseudoalbaillella u-forma* Holdsworth and Jones, R1745
Fig. 10 *Pseudoalbaillella* sp., R1745
Fig. 11 *Pseudoalbaillella* cf. *ornata* Ishiga and Imoto, R1740
Figs. 12-13 *Pseudoalbaillella scalprata* m. *scalprata* Holdsworth and Jones, R1740
Fig. 14 *Pseudoalbaillella scalprata* m. *postscalprata* Ishiga, R1730
Fig. 15 *Pseudoalbaillella* cf. *fusiformis* (Holdsworth and Jones), R1723
Fig. 16 *Pseudoalbaillella elongata* Ishiga and Imoto, R1714
Fig. 17 *Pseudoalbaillella* aff. *longicornis* Ishiga and Imoto, R1723
Figs.18-19 *Pseudoalbaillella* cf. *globosa* Ishiga and Imoto, R1713
Fig. 20 *Pseudoalbaillella*? sp. A, R1714
Fig. 21 *Pseudoalbaillella* sp.. R1713
Figs. 22-23 *Albaillella sinuata* Ishiga and Watase, R1714
Fig. 24 *Albaillella* sp., R1712
Scale bar = 100 μm.

Plate 1

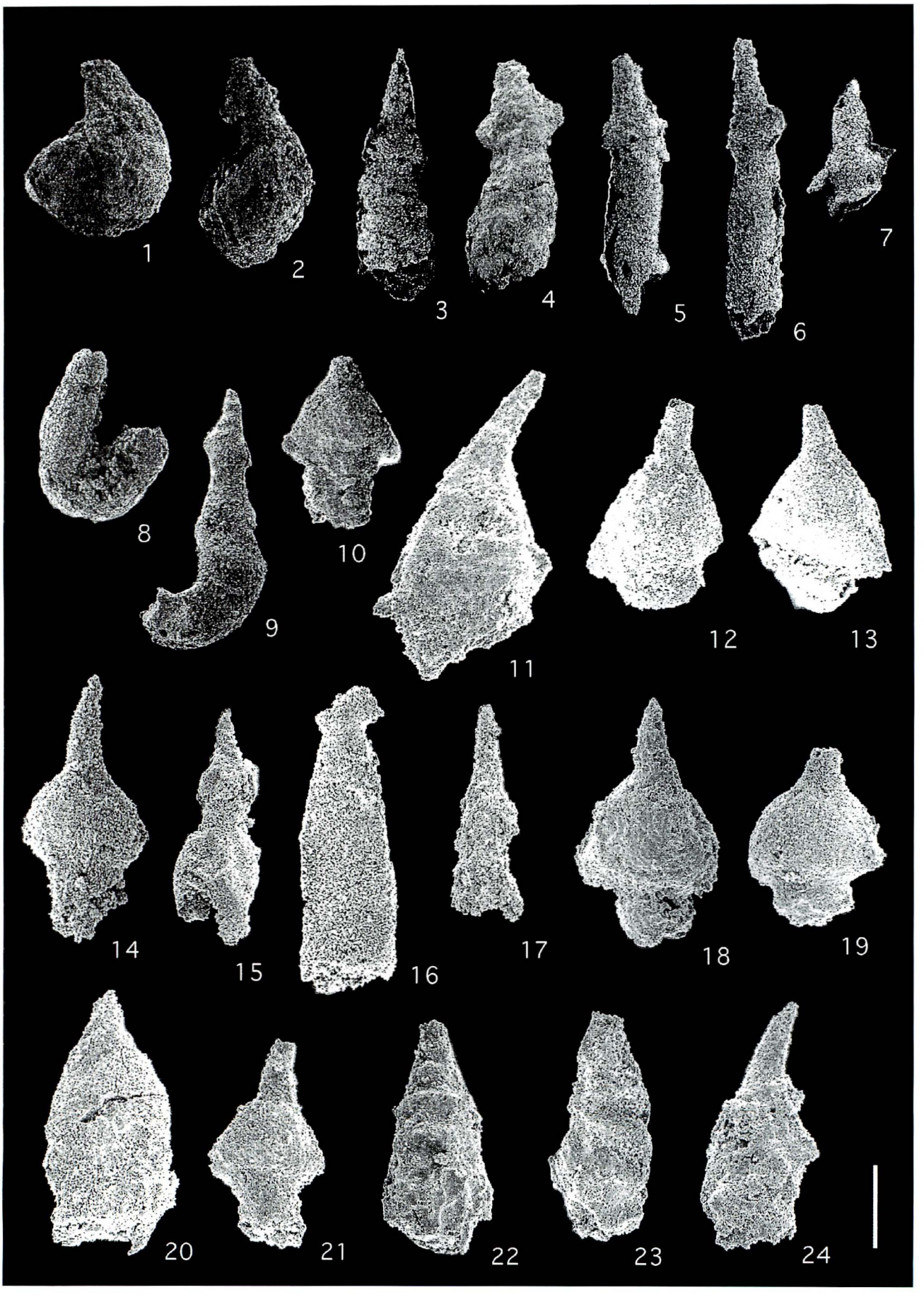

Plate 2. Photomicrographs of Permian radiolarians (Albaillellaria and Latentifistularia) from the Shiwu and Dachongling sections, Guangxi, China.

Fig. 1. *Pseudoalbaillella* cf. *simplex* Ishiga and Imoto, Dachongling, R842
Fig. 2. *Pseudoalbaillella sakmarensis* (Kozur), Dachongling, R842
Fig. 3. *Pseudoalbaillella* sp., Dachongling, R842
Fig. 4. *Pseudoalbaillella scalprata* Holdsworth and Jones, Dachongling, R842
Fig. 5. *Pseudoalbaillella scalprata* Holdsworth and Jones, Dachongling, R842
Fig. 6. *Pseudoalbaillella sakmarensis* (Kozur), Dachongling, R843
Fig. 7. *Pseudoalbaillella sakmarensis* (Kozur), Dachongling, R843
Fig. 8. *Pseudoalbaillella scalprata* Holdsworth and Jones, Dachongling, R843
Fig. 9. *Pseudoalbaillella globosa* Ishiga and Imoto, Dachongling, R1471
Fig. 10. *Pseudoalbaillella* sp., Dachongling, R1471
Fig. 11. *Pseudoalbaillella globosa* Ishiga and Imoto, Dachongling, R1471
Fig. 12. *Pseudoalbaillella fusiformis* (Holdsworth and Jones), Dachongling, R1471
Fig. 13. *Pseudoalbaillella*? sp., Dachongling, R1474
Fig. 14. *Follicucullus monacanthus* Ishiga and Imoto, Dachongling, R1474
Fig. 15. *Follicucullus monacanthus* Ishiga and Imoto, Dachongling, R1475
Fig. 16. *Pseudoalbaillella yanaharensis* Nishimura and Ishiga, Dachongling, R1475
Fig. 17. *Pseudoalbaillella*? sp., Dachongling, R1475
Fig. 18. *Follicucullus* sp., Dachongling, R1475
Fig. 19. *Pseudoalbaillella* sp., Dachongling, R1478
Fig. 20. *Follicucullus scholasticus* Ormiston and Babcock, Dachongling, R1478
Fig. 21. *Follicucullus scholasticus* Ormiston and Babcock, Dachongling, R1478
Fig. 22. *Follicucullus ventricosus* Ormiston and Babcock, Shiwu, R708
Fig. 23. *Albaillella* sp. G of Kuwahara (1999), Shiwu, R715
Fig. 24. *Foremanhelena triangula* DeWever and Caridroit, Shiwu, R713
Fig. 25. *Raciditor scalae* (Caridroit and DeWever), Shiwu, R708

Plate 2