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Guadalupian (Middle Permian) Radiolarian and Sponge Spicule Faunas from the Bancheng Formation of the Qinzhou Allochthon, South China

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ABSTRACT: The Gujingling (古井岭) Section in Xiaodong (小董), Guangxi (广西) Zhuang Autonomous Region, China, consists of cherts and siliceous siltstones, which belongs to the Bancheng (板城) Formation of the Qinzhou (钦州) allochthon. Three successive radiolarian assemblage-zones related to the Guadalupian (Middle Permian) appear in the section in the following ascending order: *Pseudoalbaillella* sp. aff. *Pseudoalbaillella longicornis-Pseudoalbaillella fusiformis*, *Follicucullus monacanthus*, and *Follicucullus scholasticus-Follicucullus porrectus*. The radiolarian content in this section is generally greater than that of sponge spicules. The radiolarian fauna commonly consists of abundant Albaillellaria and spherical radiolaria with minor Latentifistularia and Entactinaria. The sponge fauna is composed mainly of hexactinellids with minor demosponges. These siliceous fossil faunal features, comparable with those in a deep basin of the western belt of the Phosphoria Basin in the western United States, indicate that the Bancheng Formation in the Gujingling Section was deposited in a basin deeper than 1 000 m. The siliceous siltstones in the section are characterized by inclusion of silt-sized quartz and no inclusion of sand-sized materials, suggesting that the Gujingling Section was located at least a few hundred kilometers from the South China Block in the Guadalupian.

KEY WORDS: radiolarian fossil, sponge spicule, Guadalupian (Middle Permian), Bancheng Formation, Qinzhou allochthon, paleobathymetry.

INTRODUCTION

The Ordovician to Upper Permian siliceous rock

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strata, included in the Qinzhou allochthon, are distributed in the Qinzhou Basin, South China (Wang and Jin, 2000). Strata from the Upper Carboniferous to Upper Permian sequences comprise the Bancheng Formation (Wang Y J et al., 1998; Bureau of Geology and Mineral Resources of Guangxi Autonomous Region, 1997), the lithofacies that are characterized by siliceous fossil-bearing rocks. These features indicate that the Bancheng Formation is suitable for analysis of long-term paleoenvironmental fluctuation during the Late Paleozoic. However, the paleoenvironment of this formation has been vaguely considered as deep facies. Radiolarians and sponge spicules are useful indicators of paleowater depth (e.g., He, 2006; Murchey, 2004; He et al., 1999; Kuwahara, 1999; Kozur, 1993). Although Late Permian radiolarian assemblages from Qinzhou have been studied in detail (e.g., Wang et al., 2006; Sun and Xia, 2003), the previous studies of Lower or Middle Permian have been limited to Albaillellaria, which is a major index order among Late Paleozoic radiolarians (Wang and Yang, 2011, 2007; Zhang et al., 2010; Wang Y J et al., 2006, 1998; Sun et al., 2002; Wu et al., 1994).

We obtained well-preserved radiolarian fossils and sponge spicules from Guadalupian (Middle Permian) bedded siliceous rocks of the Gujingling Section belonging to the Bancheng Formation of the Qinzhou allochthon in the Xiaodong area of Guangxi Zhuang Autonomous Region, South China. In this contribution, we report Guadalupian radiolarian and sponge spicule assemblages from the Gujingling Section and their faunal features. In addition, we discuss the paleoenvironment of the Bancheng Formation in Guadalupian based on its lithological and faunal characteristics.

GEOLOGICAL SETTING AND LITHOSTRATIGRAPHY OF THE STUDY SECTION

Defined by gray-yellow or brown-gray thin-bedded siliceous rocks, muddy siliceous rocks, siliceous shales, and mudstones, the Bancheng Formation is lithostratigraphically located between the Devonian–Carboniferous Shijia and Upper Permian Pengjiu formations (Bureau of Geology and Mineral Resources of Guangxi Autonomous Region, 1997). It conformably overlies the former and unconformably underlies the acidic lava of the latter. In addition to radiolaria and sponge, several fossils such as conodonts, brachiopods, and bivalves have been observed in this formation (Zhang et al., 2010; Wang C Y et al., 1998; Bureau of Geology and Mineral Resources of Guangxi Autonomous Region, 1997). Wang et al. (1995) deduced the paleoenvironment of the Bancheng Formation from geochemical data of cherts in the Qinzhou area. Based on the abundant siliceous fossils and absence of intense Ce anomaly, they concluded that the cherts were deposited under a deep or bathyal sea with minor contribution of hydrothermal activity. Wang and Jin (2000) determined from the lack of clastic influx that the Qinzhou allochthon was located hundreds of kilometers east of the South China Block, which supplied the clastic debris.

The Gujingling Section (22°12.196′N, 108°36.943′E), situated 2 km southwest of Xiaodong, Guangxi Zhuang Autonomous Region, China (Fig. 1), outcrops along the south side of the Nanning-Beihai railway. These strata approximately strike N-S and dip 70°W. This section belongs to the Bancheng Formation and is composed of red-to-yellow red cherts and yellow-to-yellow brown siliceous siltstones (Fig. 2). Microscope observation revealed that these siliceous siltstones consist of scattered subrounded quartz and siliceous microfossils such as radiolaria and sponges with clay materials (Figs. 3a, 3c, and 3d). In addition, these siltstones contain silt-sized quartz and no sand-sized materials. Microscope observation revealed that the cherts in the Gujingling Section consist mainly of cryptocrystalline quartz and siliceous microfossils with a few clay minerals (Fig. 3b).

MATERIALS AND METHODS

We divided the Gujingling Section into 13 subsections for sampling purposes (Fig. 2). Twenty-six samples were collected from the section. The samples were crushed to fragments of approximately 1 cm and were soaked in an approximately 3% hydrofluoric acid (HF) solution for 24 hours at room temperature. The HF solutions were removed and the containers holding the etched samples were subsequently refilled with a fresh HF solution. This process was repeated about 10 times.

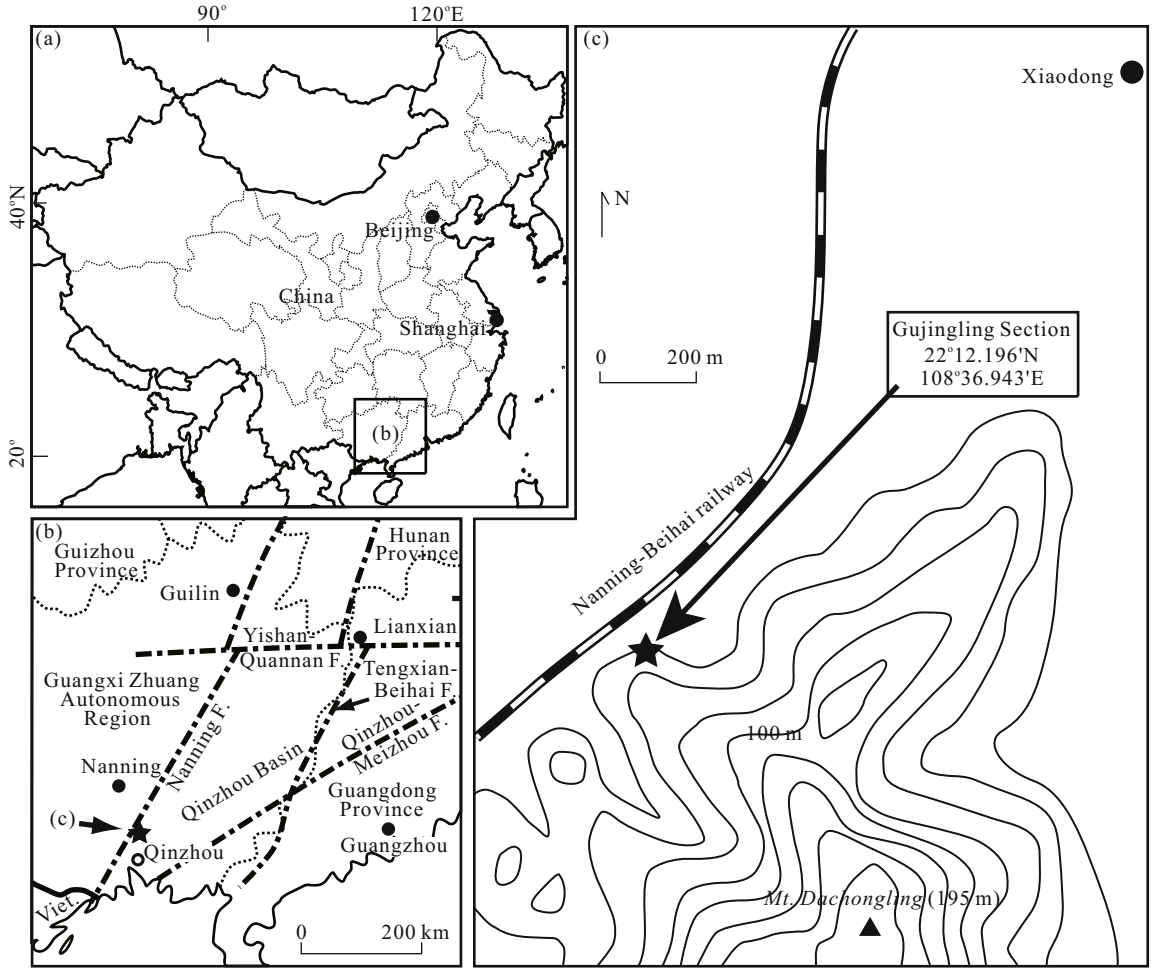

Figure 1. Index map of the study area (modified from Wang and Jin, 2000).

Adequate residues were then collected through a sieve with a mesh diameter of 0.054 mm and dried for examination under a binocular microscope. The well-preserved radiolarians were later mounted on stubs and photographed with a scanning electron microscope for more detailed observation.

FOSSIL OCCURRENCE

The occurrences of microfossils and their horizons are shown in Fig. 2. Most samples contained radiolarians and sponge spicules. Selected radiolarian photomicrographs are shown in Figs. 4 and 5; photomicrographs of selected sponge spicules are shown in Fig. 6. Radiolarians were generally more abundant than sponge spicules in all samples, except sample 2-B; their preservation varied from good to slightly poor. Twenty-five radiolarian species were identified from the Gujingling Section. The faunas of the section commonly consisted of abundant Albaillellaria and spherical radiolaria with minor Latentifistularia and Entactinaria. Samples 3-A, 4-A, 5-A, and 6-A yielded a greater amount of Latentifistularia and Entactinaria than Albaillellaria. The faunas of sponge spicules were generally composed of abundant monaxons and common triaxons with rare anatriaene and very rare polyaxons.

RADIOLARIAN BIOSTRATIGRAPHY

Three successive radiolarian assemblage-zones were recognized in the Gujingling Section in the following ascending order: *Pseudoalbaillella* sp. aff. *Pseudoalbaillella longicornis-Pseudoalbaillella fusiformis*, *Follicucullus monacanthus*, and *Follicucullus scholasticus-Follicucullus porrectus*.

The *Pseudoalbaillella* sp. aff. *P. longicornis-P. fusiformis* assemblage-zone comprises the lower part of the Gujingling Section (GJL 1-G to 6-A). The characteristic species of this zone are *Pseudoalbaillella* sp. aff. *P. longicornis* Ishiga and Imoto, *P. fusiformis* (Holdsworth and Jones), *Pseudoalbaillella* sp. A,

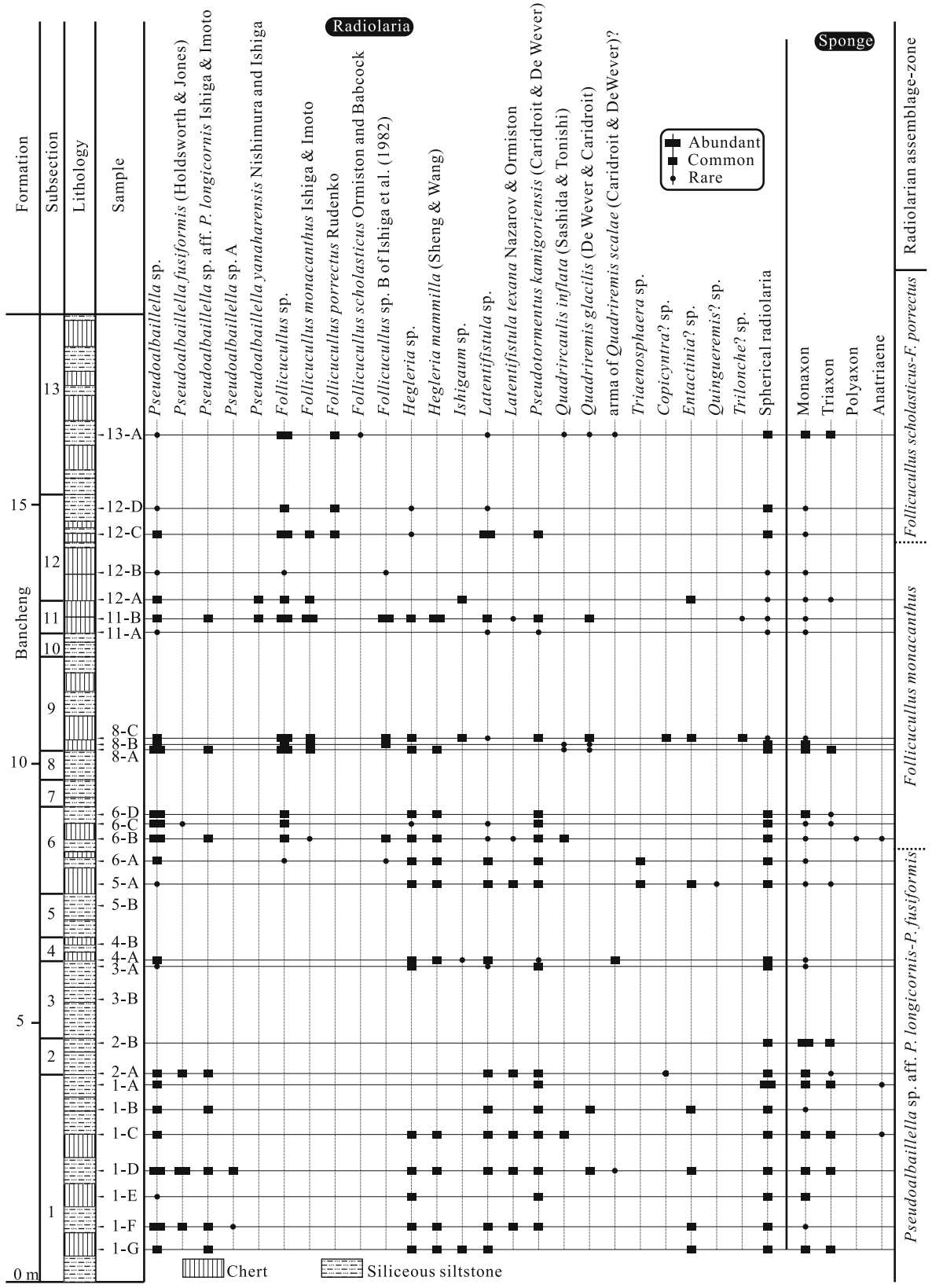

Figure 2. Columnar section and microfossil occurrences in the Gujingling Section.

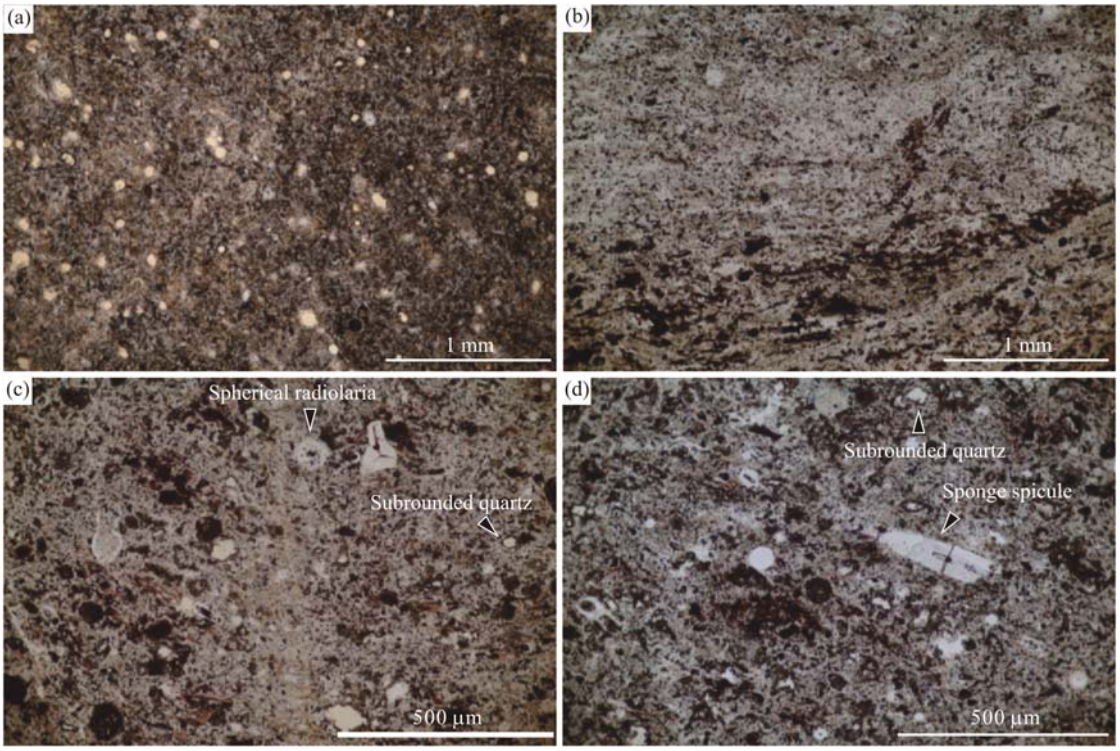

Figure 3. Thin-section photomicrographs of siliceous rocks from the Gujingling Section. (a) Siliceous siltstone (sample 5-B); scattered subrounded quartz and siliceous microfossils (white color) such as radiolarians and sponges with clay materials; plain light. (b) Chert (sample 4-B); cryptocrystalline quartz and siliceous microfossils (white color) with a few clay minerals; plain light. (c) Spherical radiolaria and subrounded quartz within clay materials in siliceous siltstone (sample 3-B); plain light. (d) Sponge spicules and subrounded quartz within clay materials in siliceous siltstone (sample 3-B); plain light.

Hegleria mammilla (Sheng and Wang), *Latentifistula texana* Nazarov and Ormiston, *Pseudotormentus kamigoriensis* (Caridroit and De Wever), and *Quadriremis glacilis* (De Wever and Caridroit). The *Pseudoalbaillella* sp. aff. *P. longicornis-P. fusiformis* assemblage-zone corresponds to the *Pseudoalbaillella globosa* assemblage-zone from the pelagic cherts of Southwest Japan (Ishiga, 1990, 1986) and the oceanic facies of South China (Wang and Yang, 2011) in addition to the *Pseudoalbaillella longtanensis-P. fusiformis* assemblage-zone from the outer shelf facies of the Yangtze region in South China (Kametaka et al., 2009). According to Kametaka et al. (2009), the *P. longtanensis-P. fusiformis* assemblage-zone correlates to the Wordian age or younger based on conodont and ammonoid occurrences.

The *F. monacanthus* assemblage-zone is situated in the middle part of the Gujingling Section (GJL 6-B to 12-B). The characteristic species of this zone are *F. monacanthus* Ishiga and Imoto, *Follicucullus* sp. B, *Pseudoalbaillella yanaharensis* Nishimura and Ishiga, *H. mammilla*, *P. kamigoriensis*, and *Q. glacilis*. The *F. monacanthus* assemblage-zone corresponds to the *F. monacanthus* range-zone from the pelagic cherts of Southwest Japan (Ishiga, 1990, 1986), the *F. monacanthus* interval-zone from the oceanic facies of South China (Wang and Yang, 2011), and the *F. monacanthus* assemblage-zone from the outer shelf facies of the Yangtze region in South China (Kametaka et al., 2009). *F. monacanthus* occurs with *Jinogondolella postserrata* (Behnken), which is a characteristic species of the Capitanian age from the pelagic cherts in Southwest Japan (Kusunoki et al., 2004).

The *F. scholasticus-F. porrectus* assemblage-zone is located in the upper part of the Gujingling Section (GJL 12-G to 13-A). The characteristic species of this zone are *F. porrectus* Rudenko, *F. scholasticus* Ormiston and Babcock, *F. monacanthus*, and *P. kamigoriensis*. The *F. porrectus* assemblage-zone corresponds

to the *F. scholasticus-Follicucullus ventricosus* assemblage-zone from the pelagic cherts of Southwest Japan (Kuwahara et al., 1998) and the oceanic facies of South China (Wang and Yang, 2011). This zone is also correlated with the *F. scholastcus-Ruzhencevispongus uralicus* assemblage-zone from the outer shelf facies of the Yangtze region in South China (Kametaka et al., 2009). Nishikane et al. (2011) concluded that the *F. scholasticus-F. ventricosus* assemblage-zone corresponds to the Upper Capitanian excluding the Uppermost Capitanian based on biostratigraphical research in the pelagic cherts of

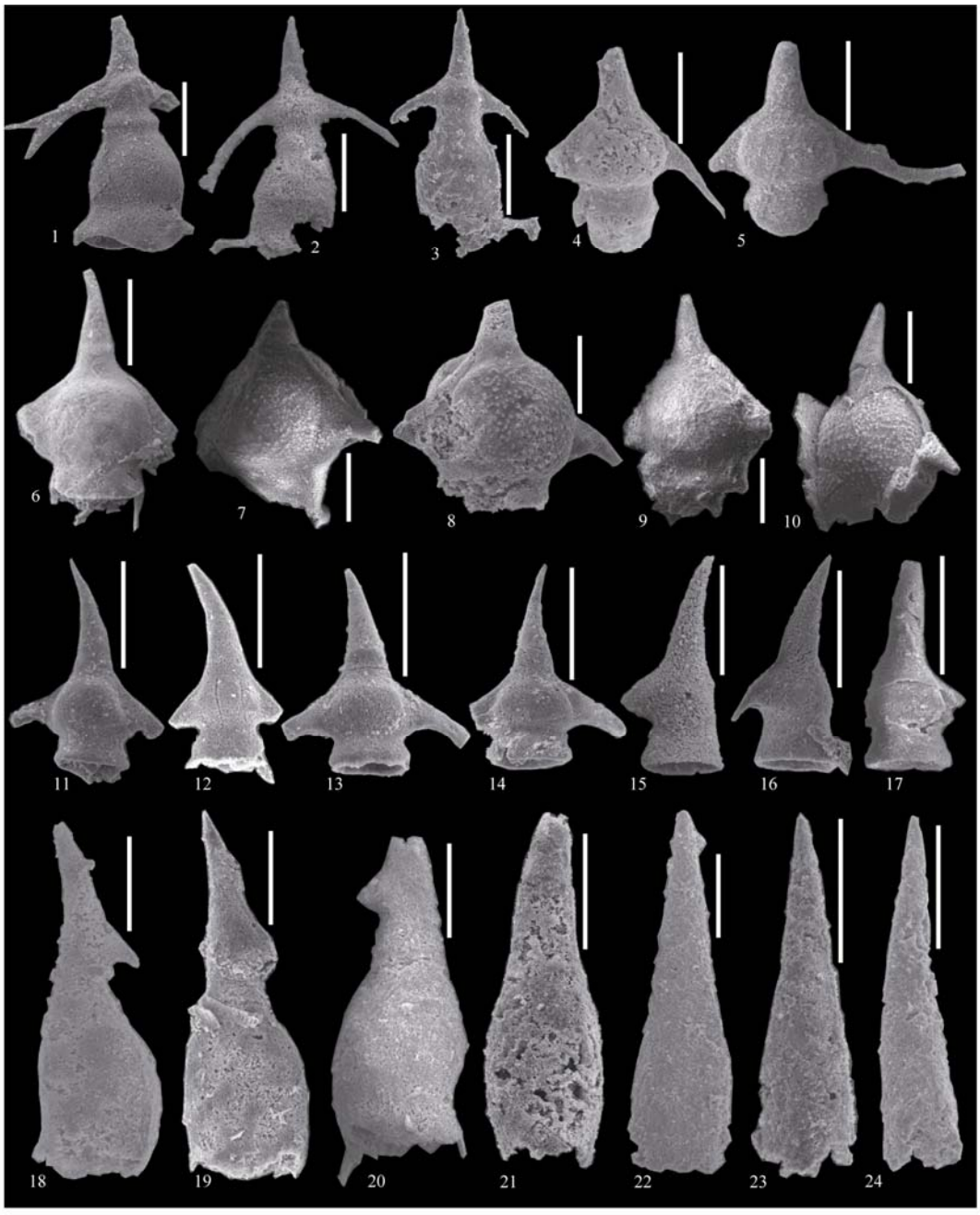

Figure 4. Radiolarian fossils from the Gujingling Section. 1–3. *P. fusiformis* (Holdsworth and Jones); 4 and 5. *P. yanaharensis* Nishimura and Ishiga; 6–10. *Pseudoalbaillella* sp. A; 12–14. *Pseudoalbaillella* sp. aff. *P. longicornis* Ishiga and Imoto; 15–17. *Follicucullus* sp. B of Ishiga et al. (1982); 18–20. *F. monacanthus* Ishiga and Imoto; 21–23. *F. porrectus* Rudenko; 24. *F. scholasticus* Ormiston and Babcock. Sample numbers: 1–3 and 6–11. 1-D; 4, 5, 19, and 20. 11-B; 12. 2-A; 13. 1-F; 14. 1-D; 15 and 16. 8-C; 17. 6-A; 18. 12-A; 21. 12-C; 22. 12-D; 23 and 24. 13-A. Scale bar, 100 µm.

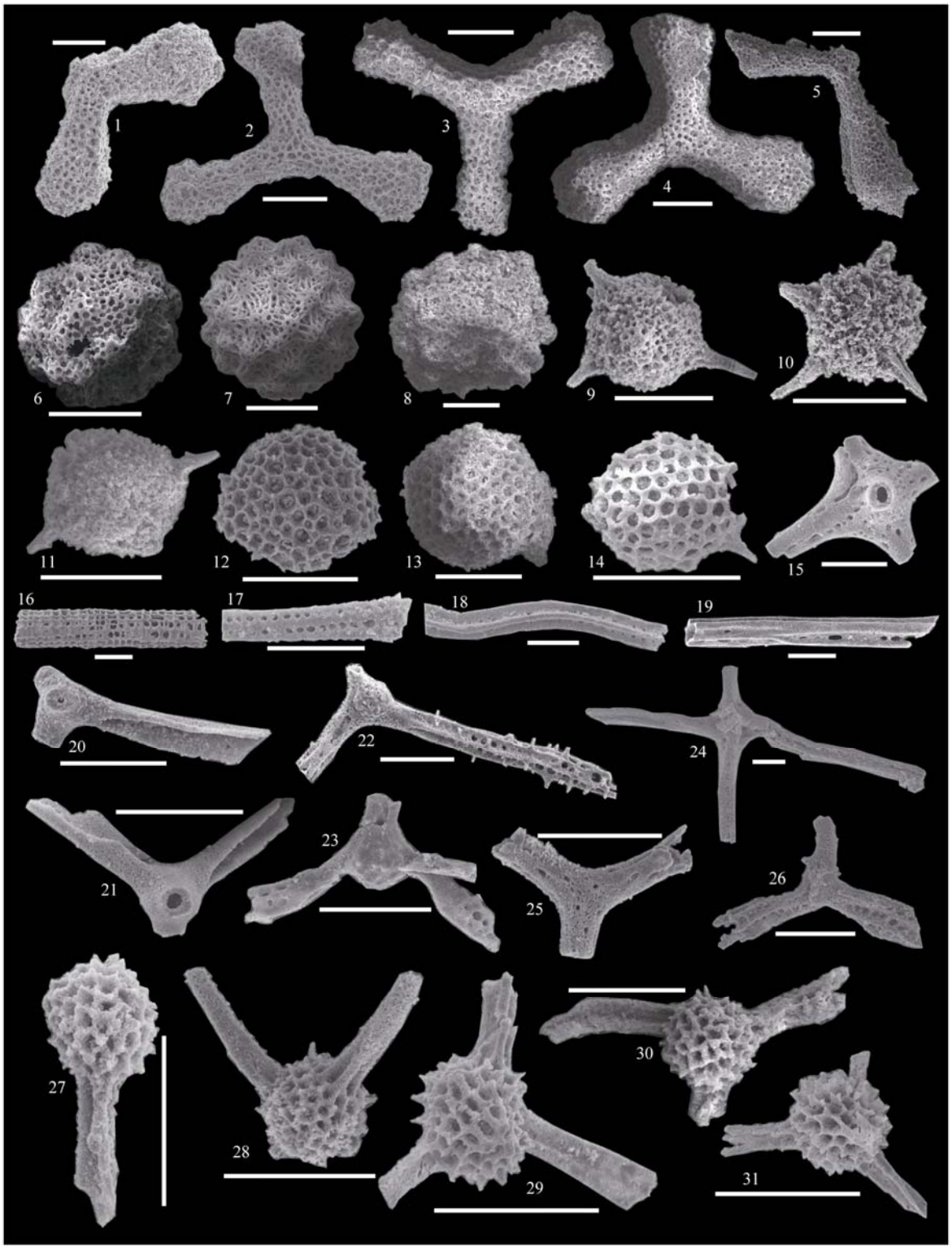

Figure 5. Radiolarian fossils from the Gujingling Section. 1–4. *L. texana* Nazarov and Ormiston; 5. *Latentifistula* sp. cf. *L. texana* Nazarov and Ormiston; 6 and 7. *H. mammilla* (Sheng and Wang); 8. *Hegleria* sp.; 9–11. *Copicyntra*? sp.; 12–14. *Trilonche*? sp.; 15–17. *Quadricaulis inflata* (Sashida and Tonishi); 18 and 19. *Quadriremis scalae* (Caridroit and De Wever); 20 and 21. *Q. glacilis* (De Wever and Caridroit); 22 and 23. *P. kamigoriensis* Caridroit and De Wever; 24. *Quinqueremis*? sp.; 25 and 26. *Ishigaum* sp.; 27 and 28. *Entactinia*? sp.; 29–31. *Triaenosphaera* sp. Sample numbers: 1, 7, and 15. 1-C; 2, 22, 26, and 29. 5-A; 3. 11-B; 4 and 30. 1-F; 5, 6, 14, 16, 19, 21, and 23. 1-D; 8. 12-C; 9, 10, 12, 13, and 28. 8-C; 11. 2-A; 17, 27. 1-B; 18. 4-A; 20. 6-C; 24. 6-C; 25. 13-A; 31. 6-A. Scale bar, 100 μm.

Figure 6. Sponge spicules from the Gujingling Section. 1–7. monaxon; 8 and 10. bended monaxon or rhabdostyle; 9. acanthostyle; 11–15. triaxon; 16. polyaxon; 17 and 18. anatriaene. Sample numbers: 1. 6-C; 2. 12-D; 3, 7, 9, 10, and 12. 1-G; 4. 2-A; 5 and 17. 10-C; 6. 11-B; 8. 4-A; 11. 13-A; 13. 5-A; 14 and 15. 1-D; 16. 6-A; 18. 1-A. Scale bar, 100 μm.

Southwest Japan.

In summary, the radiolarian assemblage-zones are assignable to the following chronostratigraphic units: the *Pseudoalbaillella* sp. aff. *P. longicornis-P. fusiformis* assemblage-zone correlates to the Wordian, the *F. monacanthus* assemblage-zone to the Lower Capitanian, and the *F. scholasticus-F. porrectus* assemblage-zone to the Upper Capitanian.

PALEODEPTH OF THE GUJINGLING SECTION

The proportion of siliceous microfossils from the Gujingling Section is generally characterized by the dominance of radiolaria. The radiolarian assemblages of the section commonly consist of abundant Albaillellaria and spherical radiolaria with minor Latentifistularia and Entactinaria. The sponge spicules from the Gujingling Section are composed of abundant monaxons and common triaxons with rare anatriaene and very rare polyaxons. The triaxons originate from hexactinellids; anatriaene originates from demosponges (Murchey, 2004). Hence, the sponge fauna consists mainly of hexactinellids with minor demosponges.

Murchey (2004) investigated the relationship between the fauna and proportion of siliceous microfossils from the siliceous rocks and divided the Phosphoria Basin in the western United States into the eastern, central, and western belts. The results showed that the fauna and proportion of radiolarians and sponges are well correlated with water depth. Beds in

the eastern belt deposited in a shallow basin are characterized by a high proportion of sponge spicules to radiolaria and dominant demosponge-derived sponge spicules such as rhax and strongyle. In contrast, the deeper western belt shows a low ratio of sponge spicules to radiolarians and dominant hexactinellid-derived sponge spicules such as triaxons. The central belt exhibits intermediate features between the eastern and the western belts. The Bancheng Formation in the Gujingling Section resembles the cherts and siliceous mudstones from the western belt with characteristic low proportions of sponge spicules and dominant hexactinellid-derived sponge spicules. Based on the paleobathymetric model of spicule population in Murchey (2004), the minimum inferred paleobathymetric range of the Gujingling Section is approximately 1 000 m.

Kozur (1993) also investigated the relationship between radiolarian fauna and paleobathymetry from the Delaware Basin in West Texas, United States. According to his results, Copicyntrinae is dominant in basins shallower than 50 m, whereas Entactinaria is dominant in an intermediate basin from 50 to 500 m in depth. Albaillellaria and Phanicosphaera are dominant in basins deeper than 500 m. The radiolarian fauna of the Gujingling Section is dominated by Albaillellaria, which indicates that the section was formed in a basin deeper than 500 m.

These results indicate that the Gujingling Section belonging to the Bancheng Formation was deposited in a basin deeper than 1 000 m.

PALEOLOCATION OF THE GUJINGLING SECTION

Wang and Jin (2000) speculated that the Qinzhou allochthon including the Bancheng Formation was located hundreds of kilometers east of the South China Block until the Guadalupian because its lithofacies do not include clastic rocks of continental origin.

The siliceous siltstones from the Gujingling Section are characterized by an inclusion of silt-sized quartz and no inclusion of sand-sized materials. The latter characteristic suggests that the Gujingling Section was not formed near a continent. Silt-sized quartz grains can move several thousand kilometers as eolian dust in a Cenozoic ocean. Okamoto et al. (2002) discovered quartz from the Pleistocene deep-sea sediment core in the Hess Rise in the central North Pacific. They compared the grain size distribution of quartz from the core with that from the Chinese Loess Plateau. They concluded that the quartz moved as eolian dust from the Chinese Loess Plateau positioned several thousand kilometers from the core. Therefore, the silt-sized quartz in the section may originate from a continent as eolian dust.

These results suggest that the Bancheng Formation in the Gujingling Section was located at least a few hundred kilometers from the South China Block in Guadalupian, which supports the speculation of Wang and Jin (2000).

CONCLUSIONS

1. The Gujingling Section consists of red-to-yellow red cherts and yellow-to-yellow brown siliceous siltstones.

2. Three successive radiolarian assemblage-zones are recognized in the Gujingling Section in the following ascending order: *Pseudoalbaillella* sp. aff. *P. longicornis-P. fusiformis*, *F. monacanthus*, and *F. scholasticus-F. porrectus*. These assemblage-zones correlate to the Wordian, Lower Capitanian, and Upper Capitanian, respectively.

3. The radiolarian contents are generally higher than that of sponge spicules. The radiolarian fauna from the section commonly consists of abundant Albaillellaria and spherical radiolaria with minor Latentifistularia and Entactinaria. The sponge faunas from the section are composed mainly of hexactinellids with minor demosponges.

4. The siliceous fossil faunal features are comparable with those from a deep basin of the western belt of the Phosphoria Basin in the western United States, which indicates that the Bancheng Formation in the Gujingling Section was deposited in a basin deeper than 1 000 m.

5. The siliceous siltstones in the section are characterized by inclusion of silt-sized quartz and no inclusion of sand-sized materials. These characteristics suggest that the Gujingling Section belonging to the Bancheng Formation was located at least a few hundred kilometers from the South China Block in the Guadalupian time.

APPENDIX: SYSTEMATIC PALEONTOLOGY

All specimens described in this article are placed in the Geological Museum of China University of Geosciences, Wuhan, People's Republic of China. Here, we discuss only *Pseudoalbaillella* sp. A and *Follicucullus* sp. B of Ishiga et al. (1982) to compensate for the lack of their descriptions in previous studies. In particular, the former may be an endemic species in the Qinzhou area.

Order Albaillellaria (Deflandre, 1953)

Family Follicucullidae (Ormiston and Babcock, 1979)

Genus *Pseudoalbaillella* (Holdsworth and Jones, 1980)

Type species: *Pseudoalbaillella scalprata* (Holdsworth and Jones, 1980)

Pseudoalbaillella sp. A

Figs. 4.6–4.10

Remarks Apical cone is short and slender without constriction. Pseudothorax is strongly inflated, similar to a globular form with two wings. Pseudoabdomen is short and cylindrical without segmentation. The species differs from *P. globosa* Ishiga and Imoto in having large pseudothorax. The diameter of the pseudoabdomen of the holotype is approximately 150 μm; the average of that of *Pseudoalbaillella* sp. A is approximately 200 μm.

Occurrence The lower *Pseudoalbaillella* sp. aff. *P. longicornis-P. fusiformis* assemblage-zone (Wordian: Middle Guadalupian) in the Bancheng Formation of South China.

Genus *Follicucullus* (Ormiston and Babcock, 1979)

Type species: *F. ventricosus* (Ormiston and Babcock, 1979)

Follicucullus sp. B

Figs. 4.15–4.17

Follicucullus sp. B (Ishiga et al., 1982, Pl. 4, Figs. 18–20)

Follicucullus sp. B (Tazawa et al., 1984, p. 265, Fig. 2.6)

Follicucullus sp. B (Miyake, 1985, p. 478, Pl. 3, Figs. 5 and 6)

Follicucullus sp. B (Yoshida and Murata, 1985, p. 535, Pl. 2, Fig. 2)

Albaillella sp. (Wang, 1995, p. 147, Pl. 1, Fig. 8)

Follicucullus sp. cf. *F. monacanthus* Ishiga and Imoto (Kametaka et al., 2009, p. 116, Figs. 6.24 and 6.25)

Remarks Shell consists of apical cone, pseudothorax with dorsal wing and skirt-like pseudoabdomen. The species resembles *F. monacanthus* Ishiga and Imoto, which lost its pseudoabdomen therefore more detailed research is necessary. We tentatively assign *Follicucullus* sp. B as different species from *F. monacanthus*.

Occurrence Uppermost part of the *Pseudoalbaillella* sp. aff. *P. longicornis-P. fusiformis* assemblage-zone to the *F. monacanthus* assemblage-zone (Wordian to Capitanian: Middle to Upper Guadalupian) of South China and Japan.

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REFERENCES CITED

Bureau of Geology and Mineral Resources of Guangxi Autonomous Region, 1997. Stratigraphy (Lithostratic) of Guangxi Autonomous Region. China University of Geosciences Press, Wuhan. 310 (in Chinese)

Deflandre, G., 1953. Radiolaires Fossiles. In: de Zoologie, T., Grasse, P. P., eds., Masson et Cie. Paris, 1. Pt. 2, Masson et Cie., Paris. 389–436

He, W. H., 2006. Changhsingian Radiolarian Fauna from the Meishan D Section and Sea Level Changes. *Earth Science—Journal of China University Geosciences*, 31(2): 159–164 (in Chinese with English Abstract)

He, W. H., Wu, S. B., Zhang, K. X., et al., 1999. Classification of Radiolarian Fossil Zones and Environmental Analysis of Gufeng Formation in Lower Yangtze Region. *Jiangsu Geology*, 24(1): 17–23 (in Chinese with English Abstract)

Holdsworth, B. K., Jones, D. L., 1980. Preliminary Radiolarian Zonation for Late Devonian through Permian Time. *Ge-*

ology, 8: 281–285

Ishiga, H., 1986. Late Carboniferous and Permian Radiolarian Biostratigraphy of Southwest Japan. *Journal of Geosciences*, *Osaka City University*, 29: 89–100

Ishiga, H., 1990. Paleozoic Radiolarians. In: Ichikawa, K., Mizutani, S., Hara, I., et al., eds., Pre-Cretaceous Terrane of Japan. Publication of IGCP Project No. 224, Pre-Jurassic Evolution of Eastern Asia. 285–295

Ishiga, H., Kito, T., Imoto, N., 1982. Middle Permian Radiolarian Assemblage from the Tamba District and Adjacent Area, Southwest Japan. *Earth Science*, 36: 272–281 (in Japanese with English Abstract)

Kametaka, M., Nagai, H., Zhu, S. Z., et al., 2009. Middle Permian Radiolarians from Anmenkou, Chaohu, Northeastern Yangtze Platform, China. *Island Arc*, 18(1): 108–125, doi:10.1111/j.1440-1738.2008.00649.x

Kozur, H., 1993. Upper Permian Radiolarians from the Sosio Valley Area, Western Sicily (Italy) and from the Uppermost Lamar Limestone of West Texas. *Jahrbuch der Geologischen Bundesanstalt Wien*, 136(1): 99–123 doi:10.1111/j.1440-1738.2008.00649.x

Kusunoki, T., Ohara, M., Musashino, M., 2004. Carboniferous-Permian Microbiostratigraphy in Chert Sequence from the Southeastern Part of the Tamba Belt, Shizukawa District, Uji City (Outline Note). *Earth Science*, 58: 37–54 (in Japanese with English Abstract)

Kuwahara, K., 1999. Middle−Late Permian Radiolarian Assemblages from China and Japan. In: Yao, A., Hao, W. C., Wang, X. P., eds., Biotic and Geological Development of the Paleo-Tethys in China. Peking University Press, Beijing. 43–54

Kuwahara, K., Yao, A., Yamakita, S., 1998. Reexamination of Upper Permian Radiolarian Biostratigraphy. *Earth Science*, 52: 391–404 (in Japanese with English Abstract)

Miyake, K., 1985. Permian Oliststrome Complex in the Katsuyama Area, Okayama Prefecture, Southwest Japan. *Journal of Geological Society of Japan*, 91(7): 463–475 (in Japanese with English Abstract)

Murchey, B. L., 2004. Regional Analysis of Spiculite Faunas in the Permian Phosphoria Basin: Implications for Paleoceanography. In: Hein, J. R., ed., Life Cycle of the Phosphoria Formation: From Deposition to the Post-Mining Environment. *Handbook of Exploration and Environmental Geochenmistry*, 8: 111–135

Nishikane, Y., Kaiho, K., Takahashi, S., et al., 2011. The Guadalupian-Lopingian Boundary (Permian) in a Pelagic Sequence from Panthalassa Recognized by Integrated Conodont and Radiolarian Biostratigraphy. *Marine Micropaleontology*, 78: 84–95

Okamoto, T., Matsumoto, E., Kawahata, H., 2002. Eolian Dust Fluctuation during the Past 200 000 Years Revealed from Quartz in North Pacific Deep-Sea Sediments. *The Quaternary Research*, 41(1): 35−44 (in Japanese with English Abstract)

Ormiston, A., Babcock, L., 1979. *Follicucullus*, New Radiolarian Genus from the Guadalupian (Permian) Lamar Limestone of the Delaware Basin. *Journal of Paleontology*, 53(2): 328–334

Sun, D. Y., Xia, W. C., 2003. Characteristics of Albaillella (Albaillellarian, Radiolarian) Fauna from Guadalupian to Lopingian Series in Permian, South China. *Journal of China University of Geosciences*, 14(4): 314–320

Sun, D. Y., Xia, W. C., Liu, D. J., 2002. Reexamination of Radiolarian Biostratigraphy in Permian in Pelagic Chert Sequences at Dachongling Section, South China. *Journal of China University of Geosciences*, 13(3): 207–214

Tazawa, J., Aita, Y., Yuki, T., et al., 1984. Discovery of Permian Radiolarians from the "Non-Calcareous Paleozoic Strata" of Omi, Central Japan. *Earth Science*, 38: 264–267 (in Japanese)

Wang, C. Y., Wu, J. J., Zhu, T., 1998. Permian Conodonts from the Penglatan Section, Laibin County, Guangxi and the Base of the Wuchiapingian Stage (Lopingian Series). *Acta Micropalaeontologica Sinica*, 15(3): 225−235

Wang, R. J., 1995. Radiolarian Fauna from Gufeng Formation (Lower Permian) in Hushan Area of Nanjing, Jiangsu Province. *Scienta Geologica Sinica*, 30(2): 139–148

Wang, Y. J., Luo, H., Kuang, G. D., et al., 1998. Late Devonian–Late Permian Strata of Cherty Facies at Xiaodong and Bancheng Counties of Qinzhou Area, SE Guangxi. *Acta Micropalaeontologica Sinica*, 15(4): 351–366 (in Chinese with English Abstract)

Wang, Y. J., Yang, Q., 2007. Carboniferous–Permian Radiolarian Biozones of China and Their Palaeobiogeographic Implication. *Acta Micropalaeontologica Sinica*, 24(4): 337–345 (in Chinese with English Abstract)

Wang, Y. J., Yang, Q., 2011. Biostratigraphy, Pylogeny and Paleobiogeography of Carboniferous−Permian Radiolarians in South China. *Paleoworld*, 20: 134–145

Wang, Y. J., Yang, Q., Cheng, Y. N., et al., 2006. Lopingian (Upper Permian) Radiolarian Biostratigraphy of South China. *Paleoworld*, 15: 31–53, doi:10.1016/j.palwor.

2006.03.004

Wang, Y., Jin, Y. G., 2000. Permian Palaeogeographic Evolution of the Jiangnan Basin, South China. *Palaeogeography*, *Palaeoclimatology*, *Palaeoecology*, 160(1): 35–44

Wang, Z. C., Wu, H. L., Kuang, G. D., 1995. Geochemistry and Origin of Late Paleozoic Cherts in Guangxi and Their Explanation of Tectonic Environments. *Acta Petrologica Sinica*, 11(3): 449–455 (in Chinese with English Abstract)

Wu, H. R., Xian, X. Y., Kuang, G. D., 1994. Late Paleozoic Radiolarian Assemblages of Southern Guangxi. *Scientia Geologica Sinica*, 29(4): 339–345 (in Chinese with English Abstract)

Yoshida, H., Murata, M., 1985. Permian Radiolarian Biostratigraphy from the North-Eastern Part of Saiki City, Oita Prefecture, Japan. *Journal of Geological Society of Japan*, 91(8): 525–533 (in Japanese with English Abstract)

Zhang, N., Henderson, C. M., Xia, W. C., et al., 2010. Conodonts and Radiolarians through the Cosuralian-Guadalupian Boundary from the Pingxiang and Dachongling Sections, Guangxi Region, South China. *Alchetinga: An Australian Journal of Palaeontology*, 34(2): 135–160