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## **Radiolarian faunal change in the Middle Permian Gufeng Formation in the Liuhuang section, Chaohu, South China**

Tsuyoshi ITO\*, Qinglai FENG\*\* and Atsushi MATSUOKA\*\*\*

### **Abstract**

Middle Permian (Guadalupian) radiolarians were obtained from bedded siliceous rocks collected from the Gufeng Formation in the Liuhuang section in Chaohu, Anhui Province, South China. Three radiolarian assemblages, named as *Pseudoalbaillella fusiformis*, *Follicucullus monacanthus*, and *Ruzhencevispongus uralicus*, were recovered from the Liuhuang section in an ascending stratigraphic order. The quantitative analysis of radiolarian fauna in the Liuhuang section shows the following characteristics. Albaillellarians and spherical radiolarians occurred more commonly than stauraxon radiolarians, in the lower part; spherical radiolarians are extremely dominant in the middle part; and spherical and stauraxon radiolarians dominate the upper part. In other words, albaillellarians decrease upward in the Liuhuang section, whereas stauraxon and spherical radiolarians increase. This vertical radiolarian faunal change has been reported from the Gufeng Formation in other sections and areas in the Lower Yangtze region. Our findings are in keeping with previous reports, which supports a conclusion that radiolarian faunal change is common throughout the Gufeng Formation in the Lower Yangtze region.

*Keywords:* Radiolarian assemblage, Middle Permian (Guadalupian), Gufeng Formation, Lower Yangtze region, South China.

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\* Graduate School of Science and Technology, Niigata University, Niigata 950-2181, Japan; State Key Laboratory of Geo-processes and Mineral Resources, China University of Geosciences, Wuhan 430074, China

\*\* State Key Laboratory of Geo-processes and Mineral Resources, China University of Geosciences, Wuhan 430074, China

\*\*\* Department of Geology, Faculty of Science, Niigata University, Niigata 950-2181, Japan  
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## Introduction

The Gufeng Formation, distributed in South China, is composed mainly of radiolarian-bearing deposits on the Yangtze platform formed during the Middle Permian. Some researchers have pointed out the radiolarian vertical faunal change in the Gufeng Formation in the Lower Yangtze region (e.g., Sheng and Wang, 1985; Kametaka et al., 2009). However, few quantitative researches showed the precise nature of this faunal change.

We carried out a field survey of the Chaohu area, Anhui Province, South China and collected samples for radiolarian research. We describe a new section composed mainly of siliceous rock of the Gufeng Formation. This paper reports on the occurrence of radiolarians from the new section, named the Liuhuang section, and shows quantitative faunal change.

## Geological outline and study section

The Gufeng Formation, distributed across South China, is well-exposed in the lower reaches of the Yangtze River, which is called the Lower Yangtze region. The Gufeng Formation in this region conformably joins with the underlying Qixia and overlying Longtan (Yinping) formations (Bureau of Geology and Mineral Resources of Anhui Province, 1987; Jiang et al., 1994). Kametaka et al. (2005) divided the Gufeng Formation in the Anmenkou section into the Phosphate Nodule-bearing Mudstone Member (PNMM) and the Siliceous Rock Member (SRM) in an ascending stratigraphic order. The former is composed of mudstones including abundant phosphate nodules; the latter consists mainly of alternating beds of black cherts, mudstones, and siliceous mudstones, with minor tuffaceous mudstones and porous cherts.

The Liuhuang section (31° 37' 04.36" N, 117° 48' 30.69" E) is situated 5 km northwest of Chaohu, Anhui Province, South China (Figs. 1.A–1.C). The section outcrops at an east slope of a hill just west of Liuhuang Village. The Anmenkou section, which has been surveyed by some researchers (e.g., Nagai et al., 1998; Kametaka et al., 2002, 2005, 2009; Takebe et al., 2007), is located just southwest of the Liuhuang section. The Maokou, Gufeng, and Longtan formations are exposed in the Liuhuang section. The Maokou Formation is composed of white limestones including some brachiopods and fusulinids and conformably underlies the Gufeng Formation. The Gufeng Formation consists mainly of cherts, siliceous mudstones, mudstones, and phosphate-nodule-bearing mudstones. The Longtan Formation, consisting of sandstones and mudstones with coal beds, conformably overlies the Gufeng Formation. These strata approximately strike N50° E and dip 60° NW with some small folds and are overturned (Fig. 1.D). We divided the Gufeng Formation in this section into 12 subsections. The features of each subsection are as follows in an ascending stratigraphic order (numbers in parenthesis indicate the thickness of each subsection) (Fig. 2): subsection 1: mudstones

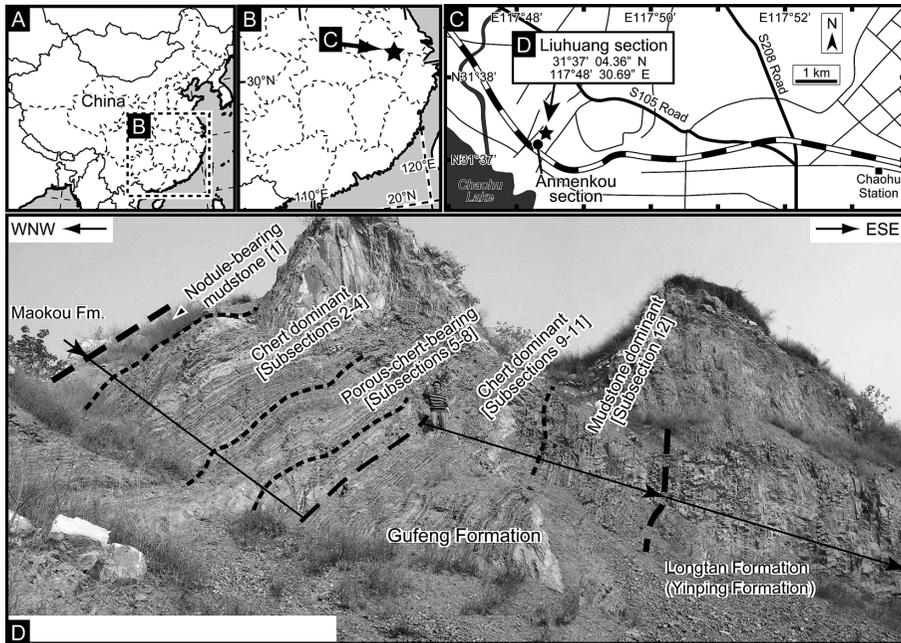


Fig. 1. A-C: Index map of the Liuhuang section. D: Field occurrence of the Liuhuang section.

including phosphate nodules with ammonoids and bivalves (330 cm); subsection 2: alternating beds of black cherts and siliceous mudstones interbedding dark-brown mudstones (160 cm); subsection 3: dark-brown mudstones interbedding black cherts (42 cm); subsection 4: thin bedded cherts interbedding mudstones (210 cm); subsection 5: gray porous cherts interbedding mudstones (40 cm); subsection 6: black cherts interbedding mudstones (160 cm); subsection 7: alternating beds of mudstones and cherts (40 cm); subsection 8: alternating beds of cherts and mudstones (75 cm); subsection 9: thin bedded black cherts interbedding mudstones (145 cm); subsection 10: alternating beds of siliceous mudstones and mudstones (165 cm); subsection 11: mudstones interbedding cherts and siliceous mudstones (550 cm); subsection 12: mudstone interbedding siliceous mudstones (510 cm). Subsection 1 corresponds to the PNMM in the Anmenkou section; subsections 2-12 correspond to the SRM in the Anmenkou section.

### Materials and Methods

We collected 49 samples from the Liuhuang section (Fig. 2). The samples were crushed then soaked in an approximately 3% hydrofluoric acid (HF) solution for 24 hours at room temperature. The HF solution was removed and the containers holding the etched samples were subsequently refilled with fresh HF solution. Adequate residues were then collected

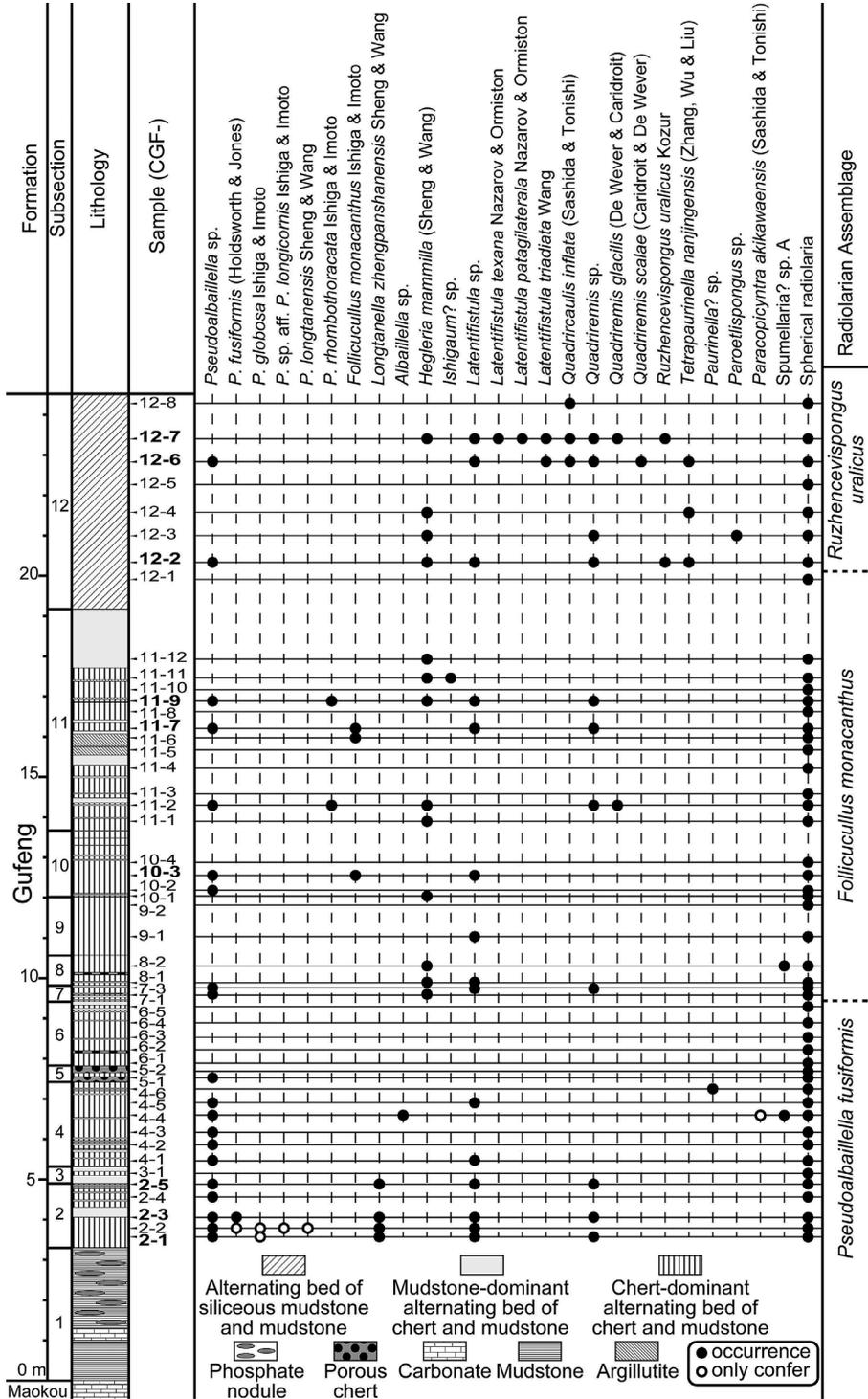


Fig. 2. Columnar section of the Liuhuang section and vertical distribution of collected radiolarians. Boldface represents samples used for quantitative analysis.

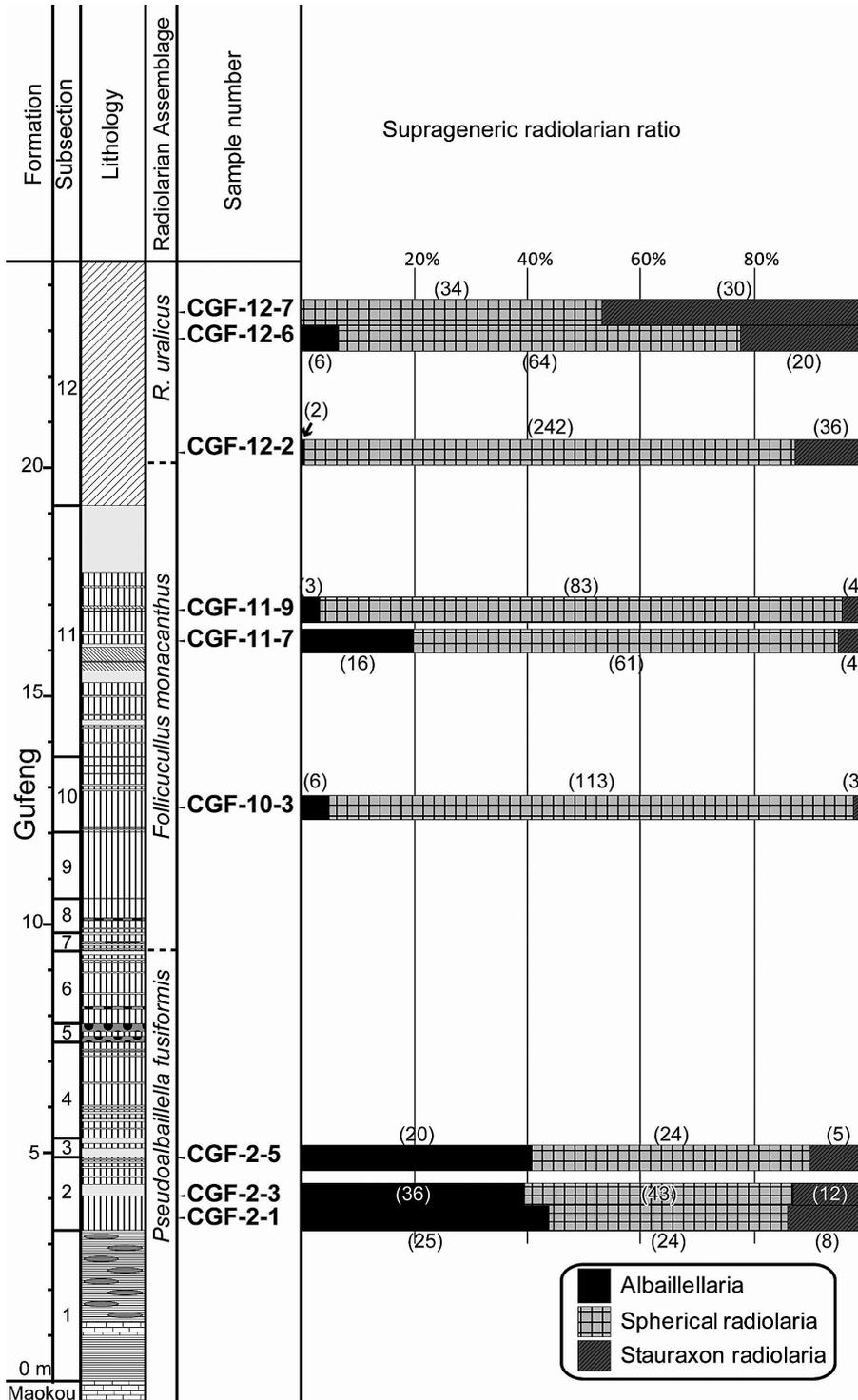


Fig. 3. Suprageneric compositional ratios of radiolarians in the selected samples of the Liuhuang section. Figures in parentheses indicate numbers of counted individuals.

through a sieve with a mesh diameter of 0.054 mm. Some of the well-preserved radiolarians in the residues were mounted on stubs and photographed with a scanning electronic microscope (Quanta 200). Selected radiolarian photomicrographs are shown in Plate 1.

Among the samples collected from the Liuhuang section, nine samples including better-preserved radiolarians (Fig. 3) underwent the above-mentioned processes. These residues were enclosed within one or several slides prepared with a mounting medium (Entellan new) for every sample. Quantities of the following suprageneric radiolarians in each slide were counted under a transmitted light microscope: albaillellarians, spherical radiolarians (involve spumellarians and entactinarians), and stauraxon radiolarians.

### Radiolarian occurrences

Some samples from the lower part of the Liuhuang section are moderately preserved, while most samples from the upper part are poorly preserved.

Several researchers had reported occurrence of radiolarians in the Gufeng Formation in the Lower Yangtze region (e.g., Sheng and Wang, 1985; Kametaka et al., 2009). Most researchers since Wang and Qi (1995) have divided the Gufeng Formation into three radiolarian assemblage-zones. We also recognize three radiolarian assemblages in the Liuhuang section in the following ascending order: *Pseudoalbaillella fusiformis*, *Follicucullus monacanthus*, and *Ruzhencevispongus uralicus* (Fig. 2). The characteristic species of the *Ps. fusiformis* assemblage are *Ps. fusiformis* (Holdsworth and Jones) and *Longtanella zhengpanshanensis* Sheng and Wang. This assemblage corresponds to those of the *Ps. globosa* Assemblage-Zone of Wang et al. (1994) and Ishiga (1990), and the *Ps. longtanensis*-*Ps. fusiformis* Assemblage-Zone of Kametaka et al. (2009). The characteristic species of the *F. monacanthus* assemblage are *F. monacanthus* Ishiga and Imoto and *Hegleria mammilla* (Sheng and Wang). This assemblage corresponds to those of the *F. monacanthus* Assemblage-Zone of Wang et al. (1994) and Kametaka et al. (2009), and the *F. monacanthus* Range-Zone of Ishiga (1990). The characteristic species of the *R. uralicus* assemblage are *R. uralicus* Kozur, *Tetrapaurinella nanjingensis* (Zhang, Wu, and Li), *Latentifistula triadiata* Wang, *Quadriacaulis inflata* (Sashida and Tonishi), and *H. mammilla*. This assemblage corresponds to those of the *F. scholasticus*-*F. ventricosus* Interval-Zone of Wang et al. (1994), the *F. scholasticus* m. I Assemblage-Zone of Ishiga (1990), and the *F. scholasticus*-*R. uralicus* Assemblage-Zone of Kametaka et al. (2009).

The counts showed the following results (Fig. 3). Albaillellarians and spherical radiolarians occurred more commonly than stauraxon radiolarians from the lower Liuhuang section (CGF-2-1, CGF-2-3, and CGF-2-5; *Ps. fusiformis* assemblage). Spherical radiolarians are extremely dominant in the middle Liuhuang section (CGF-10-3, CGF-11-7, CGF-11-9, and CGF-12-2; *F. monacanthus* assemblage). In the upper Liuhuang section (CGF-12-6 and CGF-

12-7; *R. uralicus* assemblage), spherical and stauraxon radiolarians are dominant.

### **Radiolarian faunal change**

Suprageneric composition of the radiolarian fauna differs by horizons in the Liuhuang section (Fig. 3). Albaillellarians decrease upward, while stauraxon and spherical radiolarians increase upward. This tendency has been reported from the Gufeng Formation in other sections in the Lower Yangtze region. Sheng and Wang (1985) brought up the observation that radiolarians from the Longtan area are divided into two faunas: *Pseudoalbaillella* and *Phanicosphaera* in ascending order. Kametaka et al. (2009) showed that albaillellarians decrease and latentifistularians increase upward in the Anmenkou section. In the Gufeng Formation in the Tongling area, the upper parts of some sections yielded abundant spherical radiolarians (Kuwahara et al., 2007). The results of this study and interpretations of previous studies indicate that this compositional change is a common tendency of the Gufeng Formation in the Lower Yangtze region.

It has been suggested that the ratio of suprageneric composition is indicative of paleoenvironmental conditions, such as water-depth (e.g., Kozur, 1993; Kuwahara, 1999). Kametaka et al. (2009) referred to these studies, but they pointed out that changes in water depth cannot be the chief cause of faunal change, because there are no remarkable changes in significant sedimentological features from the Anmenkou section. If water-depth change is a critical factor for faunal change, the water-depth of the Anmenkou section had changed by several hundred meters. In the Gufeng Formation of the Tongling area, radiolarian faunal and lithological changes were also not strongly correlated with each other (Kuwahara et al., 2007).

Although dominant rock facies change upward from cherts to muddy rocks in the Liuhuang section, a decrease of albaillellarians and an increase of spherical radiolarians are shown in chert-dominant parts (any horizon between CGF-2-5 and CGF-10-3). Hence, this faunal change has no remarkable correlation with lithological change. In contrast, stauraxon radiolarians seem to increase between CGF-11-9 and CGF-12-2. The lithological boundary between chert-dominant parts and muddy-rock-dominant parts (between the subsections 11 and 12) is also located between CGF-11-9 and CGF-12-2. Increase of stauraxon radiolarians may have a correlation with lithological change. Further quantitative study is necessary to better understand the relationship between lithological and radiolarian faunal changes.

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**Plate 1**

- 1–3: *Longtanella zhengpanshanensis* Sheng and Wang: 1, 2: CGF-2-3; 3: CGF-2-5  
 4, 5: *Pseudoalbaillella fusiformis* (Holdsworth and Jones): CGF-2-3  
 6: *Pseudoalbaillella* sp. cf. *P. globosa* Ishiga and Imoto: CGF-2-2  
 7, 8: *Follicucullus monacanthus* Ishiga and Imoto: CGF-10-3  
 9: *Pseudoalbaillella longtanensis* Sheng and Wang: CGF-2-2  
 10: *Pseudoalbaillella* sp. aff. *P. longicornis* Ishiga and Imoto: CGF-2-3  
 11: *Pseudoalbaillella scalprata* (Holdsworth and Jones): CGF-11-9  
 12: *Albaillella* sp.: CGF-2-3  
 13: *Paroetlispongus* sp.: CGF-12-3  
 14, 15, 19: *Tetraaurinella nanjingensis* (Zhang, Wu and Liu): 14, 15: CGF-12-7;  
 19: CGF-12-6  
 16, 17: *Paracopicyntra* sp. cf. *P. akikawaensis* (Sashida and Tonishi): CGF-4-4  
 18: *Paurinella?* sp.: CGF-4-6  
 20, 21: *Hegleria mammilla* (Sheng and Wang): 20: CGF-10-1; 21: CGF-7-1  
 22, 23: *Spumellaria?* sp. A: 22: CGF-4-4; 23: CGF-8-2  
 24, 25: *Ruzhencevispongus uralicus* Kozur: 24: CGF-12-7; 25: CGF-12-2  
 26: *Ishigaum?* sp.: CGF-11-11  
 27: *Latentifistula texana* Nazarov and Ormiston: CGF-8-1  
 28, 29: *Latentifistula patagilaterala* Nazarov and Ormiston: CGF-12-7  
 30: *Latentifistula* sp.: CGF-12-7  
 31, 32: *Latentifistula triadiata* Wang: 31: CGF-12-7; 32: CGF-12-6  
 33: *Latentifistula?* sp.: CGF-4-5  
 34: *Quadriremis scalae* (Caridroit and De Wever): CGF-12-6  
 35, 36: *Quadriremis glacilis* (De Wever and Caridroit): 35: CGF-11-2; 36: CGF-  
 12-7  
 37: *Quadriremis* sp.: CGF-2-1  
 38, 39: *Quadricaulis inflata* (Sashida and Tonishi): CGF-12-7

