

Middle Permian radiolarian biostratigraphy on the Gufeng Formation in the Songzi-Wufeng area, Hubei Province, China

KUWAHARA Kiyoko¹, YAO Akira¹, YAO Jianxin², FENG Shaonan³,
JI Zhansheng² and YAO Huazhou³

¹ Department of Geosciences, Graduate School of Science, Osaka City University, Sumiyoshi-ku, Osaka 558-8585, Japan. E-mail: kuwahara@sci.osaka-cu.ac.jp; yao@sci.osaka-cu.ac.jp

² Institute of Geology, Chinese Academy of Geological Sciences, Beijing 100037, P. R. China

³ Yichang Institute of Geology and Mineral Resources, Ministry of Land and Resources, Yichang 443003, Hubei, P. R. China

Abstract

Middle Permian radiolarian species were found from siliceous rocks of the Gufeng Formation in the Songzi-Wufeng area, Hubei Province, China. *Pseudoalbaillella fusiformis*, *Pseudoalbaillella* cf. *globosa*, *Pseudoalbaillella lanceolata*, and *Pseudoalbaillella* sp. A were commonly recovered. Sponge spicules and foraminifers were also found from the rock samples. The radiolarian-bearing strata of the Gufeng Formation can be correlated to the *Pseudoalbaillella fusiformis*-*Pseudoalbaillella longtanensis* Zone of Wang and Qi (1995) and the *Pseudoalbaillella globosa* Zone of Ishiga (1986), respectively. The Gufeng Formation of the study area is contemporaneous with the lower part of the Gufeng Formation of Anhui Province on the basis of the radiolarian biostratigraphy.

Key-words : Middle Permian, Gufeng Formation, radiolarians, Hubei.

Introduction

Upper Proterozoic to Triassic marine strata are well developed on the Yangzi (Yangtze) Platform in South China. Most of these strata are composed of shallow marine carbonate sediments. The Middle Permian Gufeng Formation, however, contains abundant siliceous rocks, including radiolarian chert, which indicates a deeper depositional environment. Various depositional settings and models have been proposed for the formation of the Gufeng Formation (e.g., Song and Wang, 1977; Bi, 1981; Tong and Zhou, 1985; Kong and Gong, 1986; Wang and Qi, 1995; Xia et al., 1995; Kametaka et al., 2002, 2005).

Many radiolarian fossils were reported from the Gufeng Formation and its equivalents. The reports ranged from Jiangsu (e.g., Bi, 1981; Sheng and Wang, 1985; Wang, 1993b; Wang and Qi, 1995), Anhui (e.g., Kong and

Gong, 1986; Nagai and Zhu, 1992; Wang, 1993a; Wang and Qi, 1995, Nagai et al., 1998; Kuwahara et al., 2007), and Guangdong (e.g., Song and Wang, 1977) provinces, and Guangxi Zhuang's Autonomous Region (e.g., Kuwahara et al, 2003; Yao et al., 2007). Siliceous rocks of the Gufeng Formation exposed on Hubei Province, however, have not been studied for radiolarians, except for a preliminary report on radiolarian-bearing siliceous rocks (Tong and Zhou, 1985).

We have continued the Japanese-Chinese cooperative work on Permian microbiostratigraphy of South China, since 1991. In March, 2006, we carried out a field survey to study the Permian strata in Hubei Province (Project No. 20 by Yao A.), mainly focused on the Gufeng Formation. We had visited the Songzi, Wufeng and Zigui areas. Here we submit a preliminary report on the occurrence of Middle Permian radiolarians from six sections of the Permian strata in the Songzi-Wufeng area. Another report

on the microfossils for the other sections in the Zigui area will be prepared later.

Study sections and samples

Three sections in the Songzi area, (1) Taoshuao section, (2) Gaojiadong 1 section, and (3) Gaojiadong 2 section, were studied, and other three sections, (4) Shenjiabao section, (5) Qingshubao section, and (6) Niuzhuang section, were studied in the Wufeng area, Hubei Province, China (Fig. 1). Totally 150 samples were collected from these six sections (Fig. 2). The location, lithology and stratigraphy of the study sections and samples are as follows:

(1) Taoshuao section (R3635-R3664)

The Taoshuao section is located about 5 km northwest of Liujiachang, Songzi County, Hubei Province. The GPS value of this section is $N30^{\circ}05.518'$, $E111^{\circ}26.840'$. The Gufeng Formation is well cropped out in a quarry. The beds strike $N35^{\circ}W$ and dip $15^{\circ}N$. The formation consists of black siliceous mudstone, which is well bedded from several to tens of centimeters in thickness. Manganese layers and calcareous nodules occur partly in some horizons. Ammonite (*Altudoceras* sp.) and brachiopod fossils were found from the upper part of the Gufeng Formation. The uppermost part of the formation may consist of tuffaceous mudstone. The Gufeng Formation is overlain conformably by mudstone bed

(about 1 m in thickness) of the Wangpo Formation. The Wujiaping Formation, which consists of gray limestone, covers the Wangpo Formation directly.

Totally 30 samples (from R3635 to R3664) were collected from the Gufeng Formation. The lower subsection is 8 meters in thickness and 20 samples (from R3635 to R3654) were collected along a backyard of a house (Fig. 3-1). The upper subsection is 4.1 meters in thickness and 10 samples (from R3655 to R3664) were collected along a narrow road (Fig. 3-2). These subsections overlap for about 2 meters (Fig. 2).

(2) Gaojiadong 1 section (R3665-R3668)

The location of this section is $N30^{\circ}05.802'$, $E111^{\circ}28.863'$ by GPS. The section mainly consists of muddy limestone. The beds strike $N20^{\circ}W$ and dip $10^{\circ}S$. This section is the basal part of the Wujiaping Formation, and directly covers the coal layer of the Wangpo Formation. Four samples (R3665-R3668) were collected from cherty layers in the Wujiaping Formation (Fig. 2).

(3) Gaojiadong 2 section (R3669-R3684)

The GPS value of this section is $N30^{\circ}05.919'$, $E111^{\circ}28.808'$. The section is composed of the Qixia Formation and the overlying Gufeng Formation. The boundary between two formations is not confirmed at this section. The Qixia Formation mainly consists of gray limestone beds (Fig. 3-4). The strata of the Gufeng

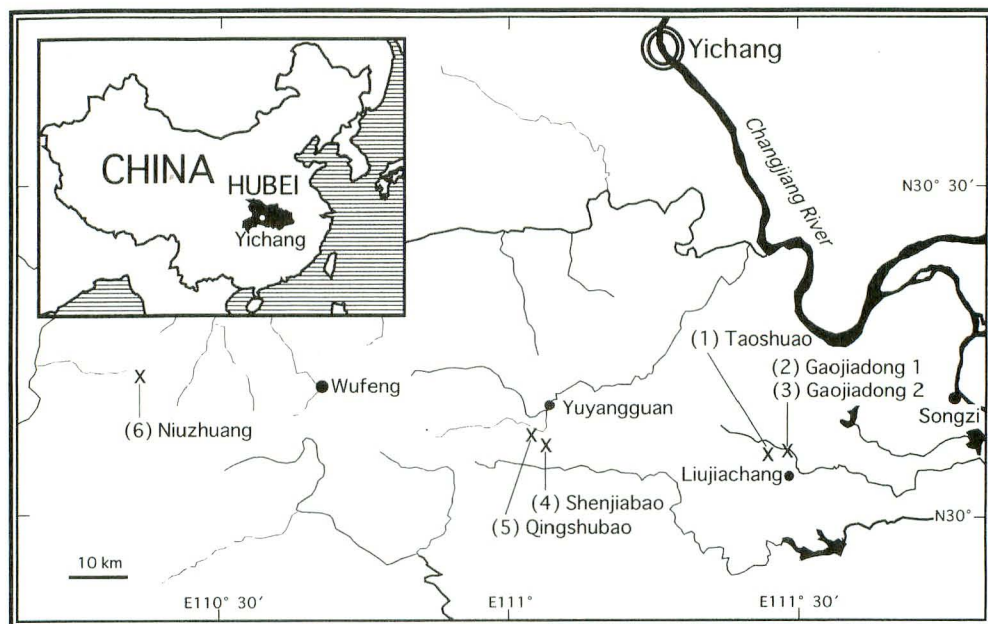


Fig. 1 Index map of the study sections in the Songzi-Wufeng area, Hubei Province, China.

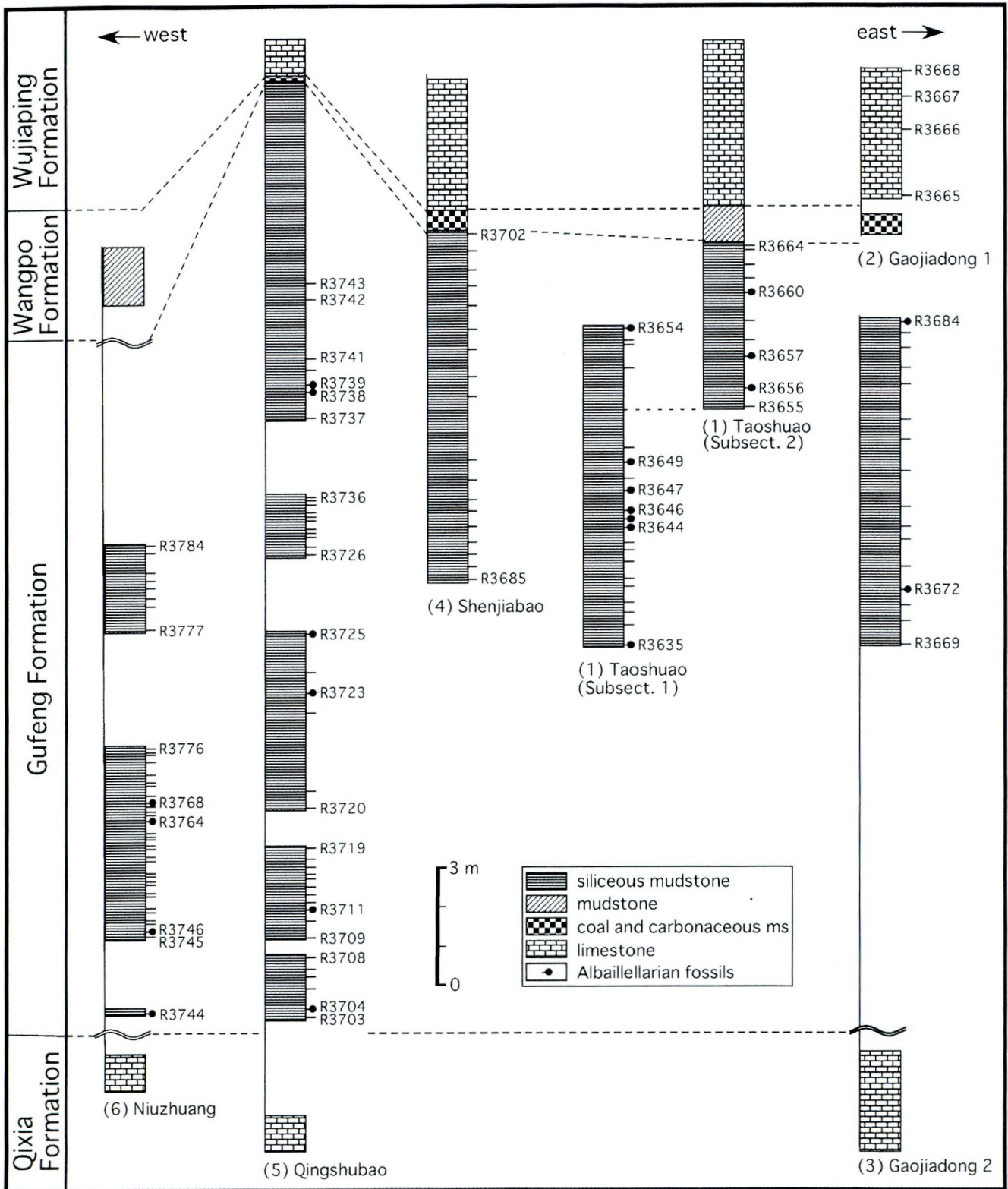


Fig. 2 Columnar sections showing sampling horizons in the Songzi-Wufeng area, Hubei Province.

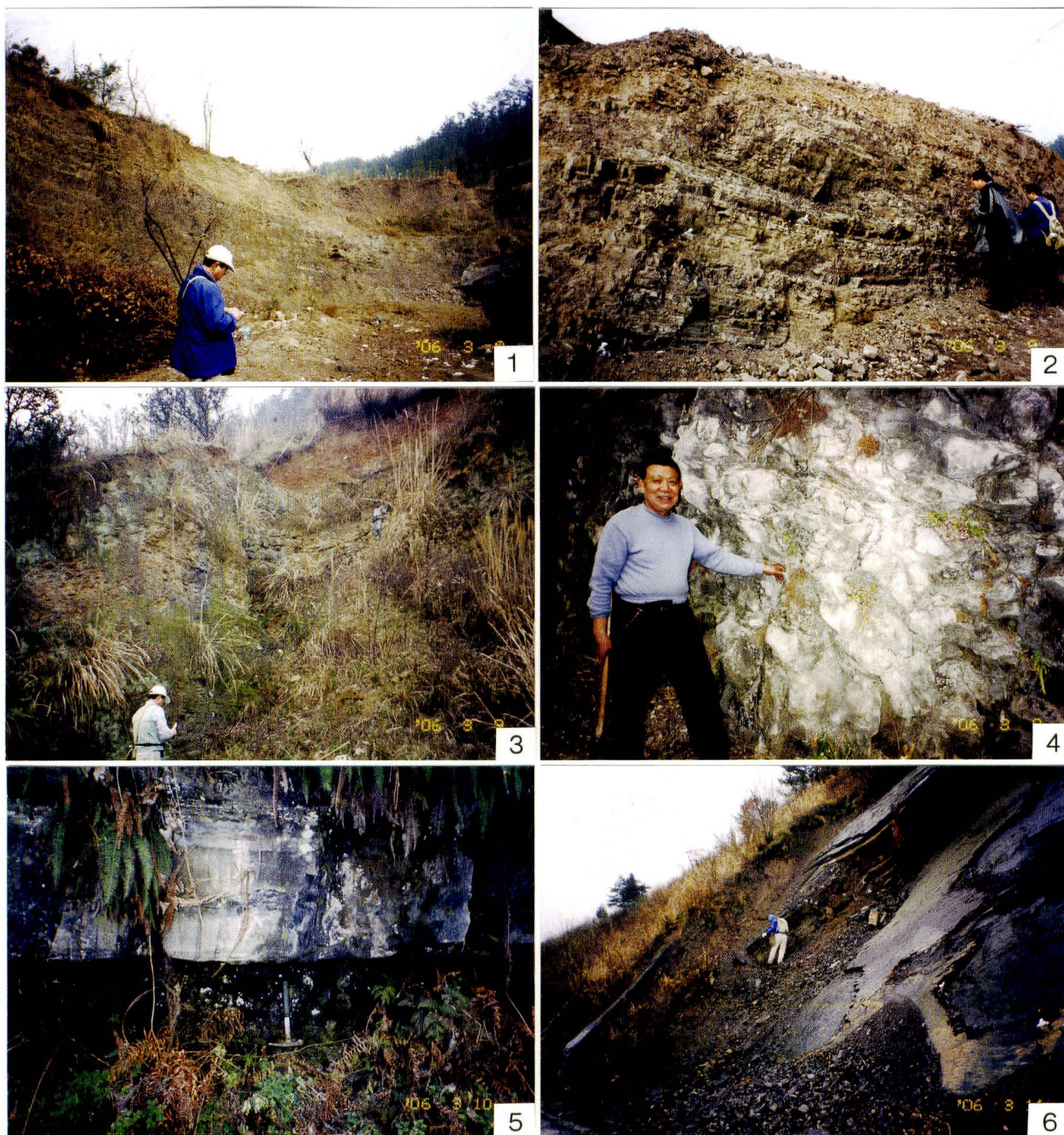


Fig. 3 Photographs of outcrop in the study sections.

- 1: Well-bedded siliceous mudstones of the Gufeng Formation in the Taoshuao section (subject. 1).
- 2: Well-bedded siliceous mudstones of the Gufeng Formation in the Taoshuao section (subject. 2).
- 3: Well-bedded siliceous mudstone of the Gufeng Formation in the Gaojiadong 2 section.
- 4: Limestone of the Qixia Formation in the Gaojiadong 2 section.
- 5: The boundary of the Wangpo Formation (carbonaceous mudstone; lower) and the Wujiaping Formation (limestone; upper) in the Qingshubao section.
- 6: Well-bedded siliceous mudstones of the Gufeng Formation in the Niuzhuang section.

Formation strike N25°W and dip 15°S, composed of well-bedded black siliceous mudstones, and the measured section is 8.3 meters in thickness (Fig. 3-3). The siliceous mudstone beds have thickness changing from several millimeters to several centimeters. Sixteen samples (R3669-R3684) were collected from the Gufeng Formation in this section (Fig. 2).

(4) Shenjiabao section (R3685-R3702)

The geographical location of this section is Shenjiabao, Shatang Village, Yuyangguan, Wufeng County. The GPS value of this section is N30°06.686', E111°03.993'. The section is composed of the Gufeng Formation, the Wangpo Formation and the Wujiaping Formation in ascending order. The Gufeng Formation consists of well-bedded siliceous black mudstones, which is 14.5 meters in thickness. The Wangpo Formation, conformably covering the Gufeng Formation, is composed of carbonaceous mudstone beds of 0.5 meters thick. Eighteen samples (R3685-R3702) were collected from the Gufeng Formation of this section (Fig. 2).

(5) Qingshubao section (R3703-R3743)

The location of this section is N30°07.489', E111°02.416' by GPS. The section exposed along a curved road (Fig. 4), is composed of the Qixia Formation, the Gufeng Formation, the Wangpo Formation, and the Wujiaping Formation in ascending order. The boundary between the Qixia Formation and the Gufeng Formation is not confirmed at this section.

The Gufeng Formation consists of well-bedded black siliceous mudstones, about 22.5 meters in total thickness. The formation is conformably covered by the thin (several tens cm) carbonaceous mudstone of the Wangpo Formation. The limestone of the Wujiaping Formation directly covers the Wangpo Formation (Fig. 3-5). Forty-one samples (R3703-R3743) were collected from the Gufeng Formation in this section (Fig. 2).

(6) Niuzhuang section (R3744-R3784)

The GPS value of this section is N30°12.887', E110°22.283'. The section is composed of the Qixia Formation, the Gufeng Formation and the Wangpo Formation in ascending order. The direct relationships among these formations are not confirmed at this section. The Gufeng Formation consists of well-bedded black siliceous mudstones, and is more than 12 meters in total thickness (Fig. 3-6). Forty-one samples (R3744-R3784) were collected from the Gufeng Formation in this section (Fig. 2).

Methods

Rock samples were immersed in dilute hydrofluoric acid (5 %) for about 24 hours. Residues were collected using 36- and 200-mesh sieves. Microfossils were observed under a binocular microscope, and were identified. Slides for a transmitted light microscope were prepared for photomicrography.

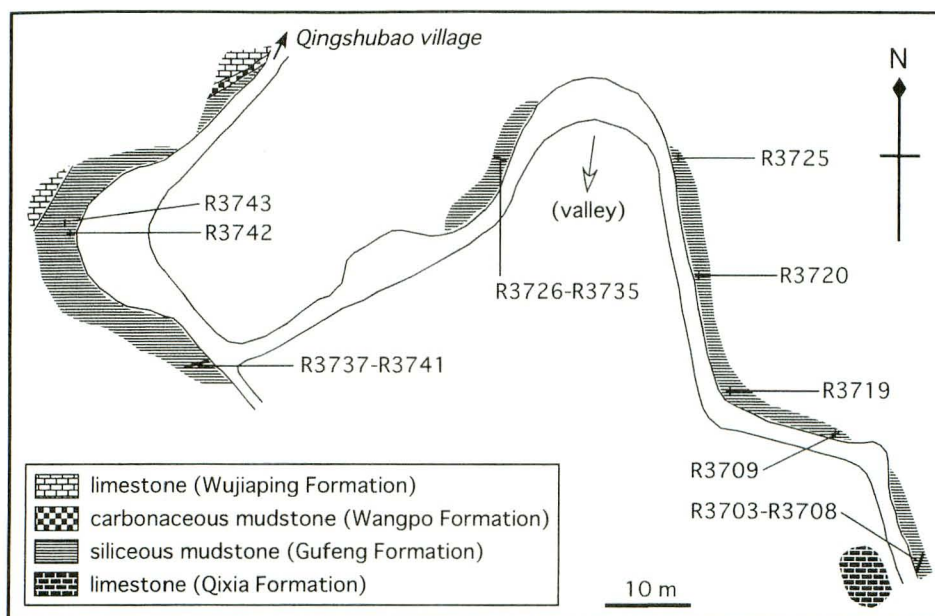


Fig. 4 Route map of the Qingshubao section.

Microfossil assemblages

In this chapter, occurrences of microfossils and their radiolarian zones are reported and discussed. The occurrences of microfossils from each sample are shown in Fig. 6, and photomicrographs of selected albailllellarian species are shown in Fig. 7.

(1) Taoshuao section

No fossils have been found in the lower part of the section from the samples R3635 to R3641. Sponge spicules were found from middle to upper parts of the section. However, their occurrence differs in abundance through the section. Sponge spicules occur abundantly from the samples R3643 to R3649, but decrease remarkably in the upper part of the section.

The preservation of radiolarian fossils is from moderate to poor. Molds of radiolarian test were found frequently in some samples (Figs. 6, 7-2). *Pseudoalbaillella fusiformis* occurs in the samples R3644 (Fig. 7-1), R3645 and R3647 (Fig. 7-3). *Pseudoalbaillella* spp. were found in the several samples from R3646 to R3660. *Pseudoalbaillella* cf. *globosa* was found from the sample R3654 (Fig. 7-8). *Pseudoalbaillella* sp. A was detected from the samples of R 3657 (Fig. 7-11) and R3660 (Fig. 7-12).

Based on the radiolarian composition, the siliceous beds of this section may be correlated to the Middle Permian *Pseudoalbaillella fusiformis*-*Pseudoalbaillella longtanensis* Zone of Wang and Qi (1995).

(2) Gaojiadong 1 section

Sponge spicules were found from all four samples (Fig. 6). Well-preserved sponge spicules were recovered from the sample R3668. Radiolarian dating is impossible due to the absence of radiolarian fossils.

(3) Gaojiadong 2 section

In the sample R3672, *Pseudoalbaillella fusiformis* occurs (Fig. 6). In the sample R3684, *Pseudoalbaillella* cf. *globosa*, which is small in size, and *Latentifistula* cf. *texana* were found.

Based on the radiolarian composition, the siliceous beds of this section is correlated probably to the Middle Permian *Pseudoalbaillella fusiformis*-*Pseudoalbaillella longtanensis* Zone of Wang and Qi (1995).

(4) Shenjiabao section

No fossils were found from lower and middle parts of the section (samples from R3685 to R3697), with the exception of sample R3692 in which well-preserved foraminifers (Fig. 6) could be detected.

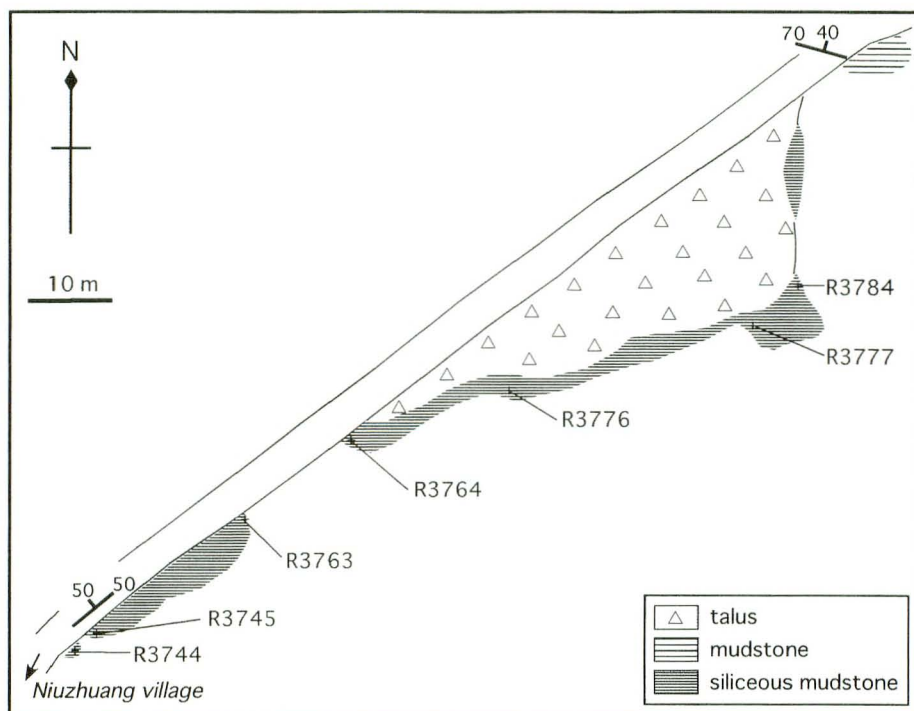


Fig. 5 Route map of the Niuzhuang section.

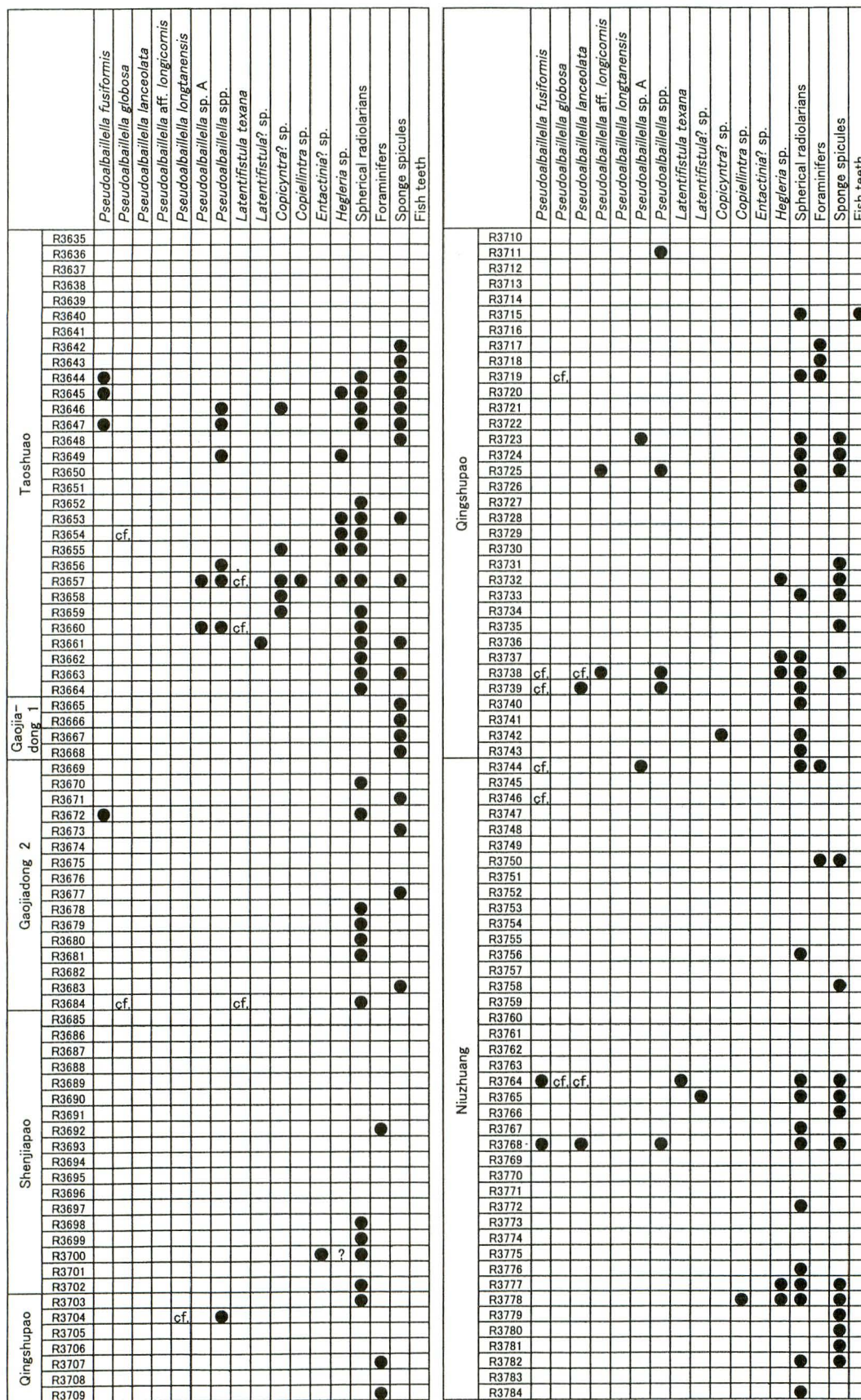


Fig. 6 Stratigraphical distribution of radiolarians and other microfossils in the study sections.

From the upper part of the section, in the samples from R3698 to R3700, and R3702, small radiolarians with spherical spongy tests, were discovered. In the sample R3700, poorly-preserved *Hegleria* sp. and *Entactinia?* sp. with spines were found. Because the species of radiolarians were quite low in diversity and no albaillarians occurred, radiolarian dating is difficult.

(5) Qingshubao section

Foraminifers, radiolarians, sponge spicules and rarely fish teeth sporadically occurred through the section (Fig. 6). The preservation of microfossils is poor, and molds of radiolarian tests are composed of muddy particles in some samples.

Pseudoalbaillella cf. *longtanensis* (Fig. 7-15) and *Pseudoalbaillella* spp. were discovered from the sample R3704. *Pseudoalbaillella?* spp. were found from the sample R3711. In the sample R3723, *Pseudoalbaillella* sp. A (Fig. 7-10) was discovered. The specimen is somewhat similar to *Pseudoalbaillella scalprata* and *Pseudoalbaillella globosa*. In the sample R3725, there are representatives of *Pseudoalbaillella* aff. *longicornis* and *Pseudoalbaillella* spp. In the samples R3732 and R3737, *Hegleria* sp. was found. In the sample R3738, *Pseudoalbaillella* cf. *fusiformis* (Fig. 7-4), *Pseudoalbaillella* cf. *lanceolata* (Fig. 7-17), *Pseudoalbaillella* aff. *longicornis*, *Pseudoalbaillella* spp. (Fig. 7-14) and *Hegleria* sp. were recovered. In the sample R3739, *Pseudoalbaillella* cf. *fusiformis* (Fig. 7-6) and *Pseudoalbaillella lanceolata* (Fig. 7-19) were found.

Based on the radiolarian composition, the siliceous beds of this section can be correlated to the Middle Permian *Pseudoalbaillella fusiformis*-*Pseudoalbaillella longtanensis* Zone of Wang and Qi (1995).

(6) Niuzhuang section

Radiolarians, sponge spicules and foraminifers were sporadically found (Fig. 6). Radiolarian preservation is moderate to poor.

In the sample R3744, poorly preserved *Pseudoalbaillella* cf. *fusiformis* and *Pseudoalbaillella* sp. A occurred. In the sample R3746, molds of *Pseudoalbaillella* cf. *fusiformis* were recovered. In the sample R3764, *Pseudoalbaillella fusiformis* (Fig. 7-5), *Pseudoalbaillella* cf. *globosa* (Fig. 7-9), *Pseudoalbaillella* cf. *lanceolata* (Fig. 7-16) and *Pseudoalbaillella* sp. (Fig. 7-20) were found. In the sample R3768, *Pseudoalbaillella fusiformis* (Fig. 7-7), *Pseudoalbaillella lanceolata* (Fig. 7-18) and *Pseudoalbaillella* spp. (Fig. 7-13) were detected.

Based on the radiolarian composition, the siliceous beds of this section are possible to be correlated with them

of the Middle Permian *Pseudoalbaillella fusiformis* - *Pseudoalbaillella longtanensis* Zone of Wang and Qi (1995).

Discussion

The type section of the Gufeng Formation (Ye and Li, 1924) is located in the Gufeng Village, northwest Jingxian, Anhui Province. Around the type area, the Gufeng Formation consists of black, gray, yellow thin-bedded chert, siliceous mudstone, silty mudstone, carbonaceous mudstone and manganese mudstone (Bureau of Geology and Mineral Resources of Anhui Province, 1987). This formation overlies the Qixia Formation (the Qixian of the upper Lower Permian) and is covered by the Longtan Formation (the Wujiapingian of the lower Upper Permian). Wang and Qi (1995) biostratigraphically divided the Gufeng Formation in Anhui Province into three radiolarian zones, namely in ascending order: the *Pseudoalbaillella fusiformis* - *Pseudoalbaillella longtanensis* Zone, the *Follicucullus monacanthus* Zone, and the *Ruzhencevispongius uralicus* - *Follicucullus scholastics* Zone.

The Gufeng Formation in the Songzi-Wufeng area, Hubei Province, also overlies the Qixia Formation. Although the stratigraphic relationship between two formations has not been observed from our study sections, it is generally conformable in Hubei Province (Bureau of Geology and Mineral Resources of Hubei Province, 1990). The top of the Gufeng Formation is covered by mudstone, carbonaceous mudstone or coal beds of the Wangpo Formation in the Taoshuo (Subsect. 2), the Shenjiabao, and the Qingshubao sections in this area.

In this study, the radiolarian assemblage represented by *Pseudoalbaillella fusiformis* was distinguished in 22 samples from the Gufeng Formation in the Songzi-Wufeng area. This radiolarian assemblage corresponds that of the *Pseudoalbaillella fusiformis* - *Pseudoalbaillella longtanensis* Zone of Wang and Qi (1995). Based on this radiolarian assemblage, the Gufeng Formation of the Songzi-Wufeng area is correlated with the *Pseudoalbaillella globosa* Zone in Guangxi, China (Wang et al., 1994) and in Japan (Ishiga, 1986). The age of the formation is assigned to early Maokouan, and the chronostratigraphic setting of Maokouan is Middle Permian based on the latest time scale (Menning et al., 2006). From this correlation, it is clear that the Gufeng Formation of the study area is limited to the *Pseudoalbaillella fusiformis* - *Pseudoalbaillella longtanensis* Zone (= the *Pseudoalbaillella globosa* Zone), and lacks the *Follicucullus monacanthus* Zone and the *Ruzhencevispongius uralicus* - *Follicucullus scholastics*

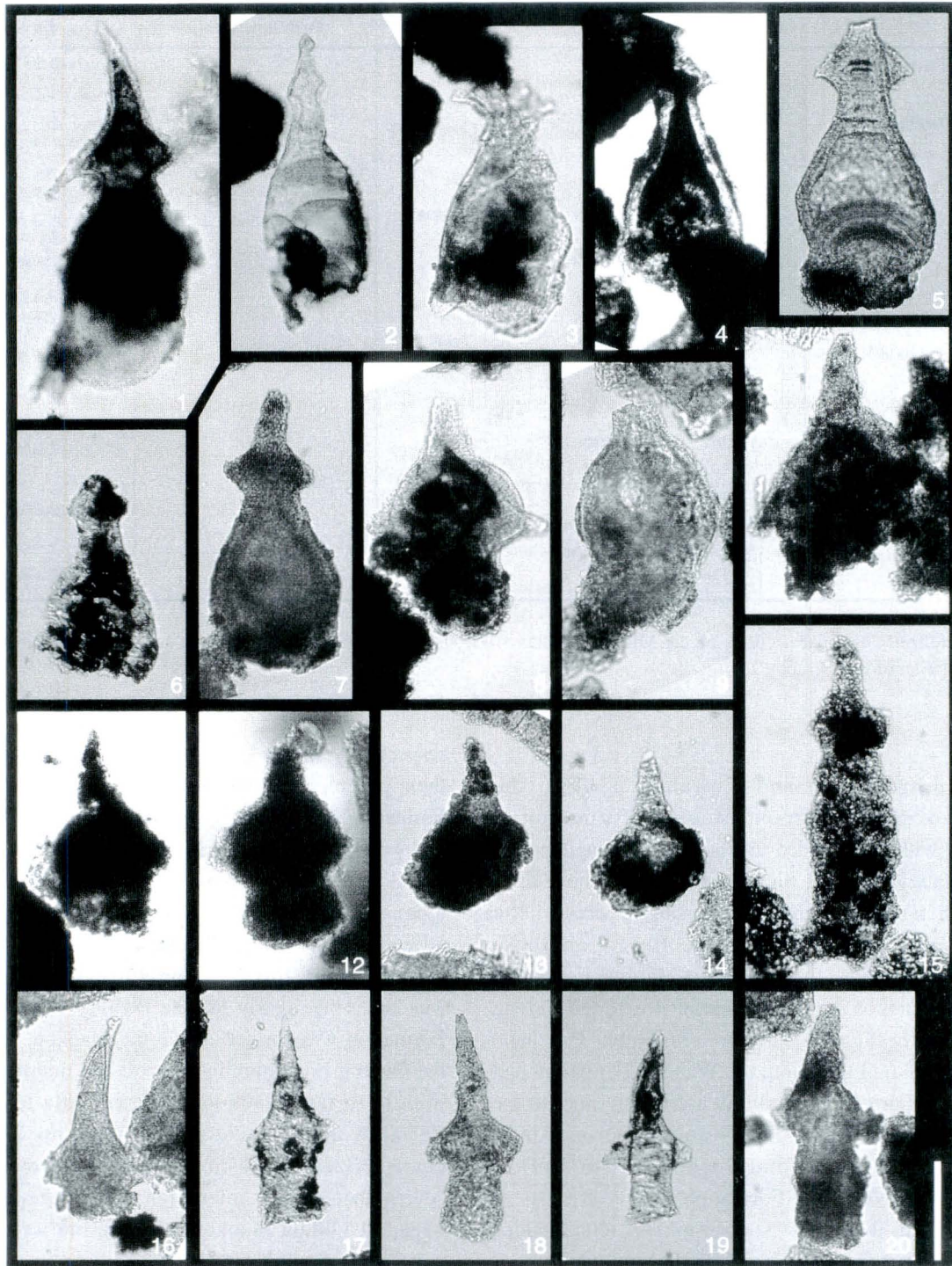


Fig. 7 Photomicrograph of radiolarian fossils from the Gufeng Formation in the Songzi-Wufeng area.

1,3,5,7: *Pseudoalbaillella fusiformis* (Holdsworth and Jones), 1 from sample R3644, 3 from sample R3647, 5 from sample R3764; 7 from sample R3768, 2: mold of *Pseudoalbaillella* cf. *fusiformis* from sample R3644; 4,6: *Pseudoalbaillella* cf. *fusiformis*, 4 from sample R3738; 6 from sample R3739; 8,9: *Pseudoalbaillella* cf. *globosa* Ishiga and Imoto, 8 from sample R3654, 9 from sample R3764; 10-12: *Pseudoalbaillella* sp. A, 10 from sample R3723, 11 from sample R3657, 12 from R3660; 13-14: *Pseudoalbaillella* sp., 13 from sample R3768, 14 from sample R3738; 15: *Pseudoalbaillella* cf. *longtanensis* Sheng and Wang from sample R3704; 16,17: *Pseudoalbaillella* cf. *lanceolata* Ishiga and Imoto, 16 from sample R3764, 17 from sample R3738; 18,19: *Pseudoalbaillella lanceolata*, 18 from sample R3768, 19 from sample R3739; 20: *Pseudoalbaillella* sp. from sample R 3764. Scale bar = 100 μ m.

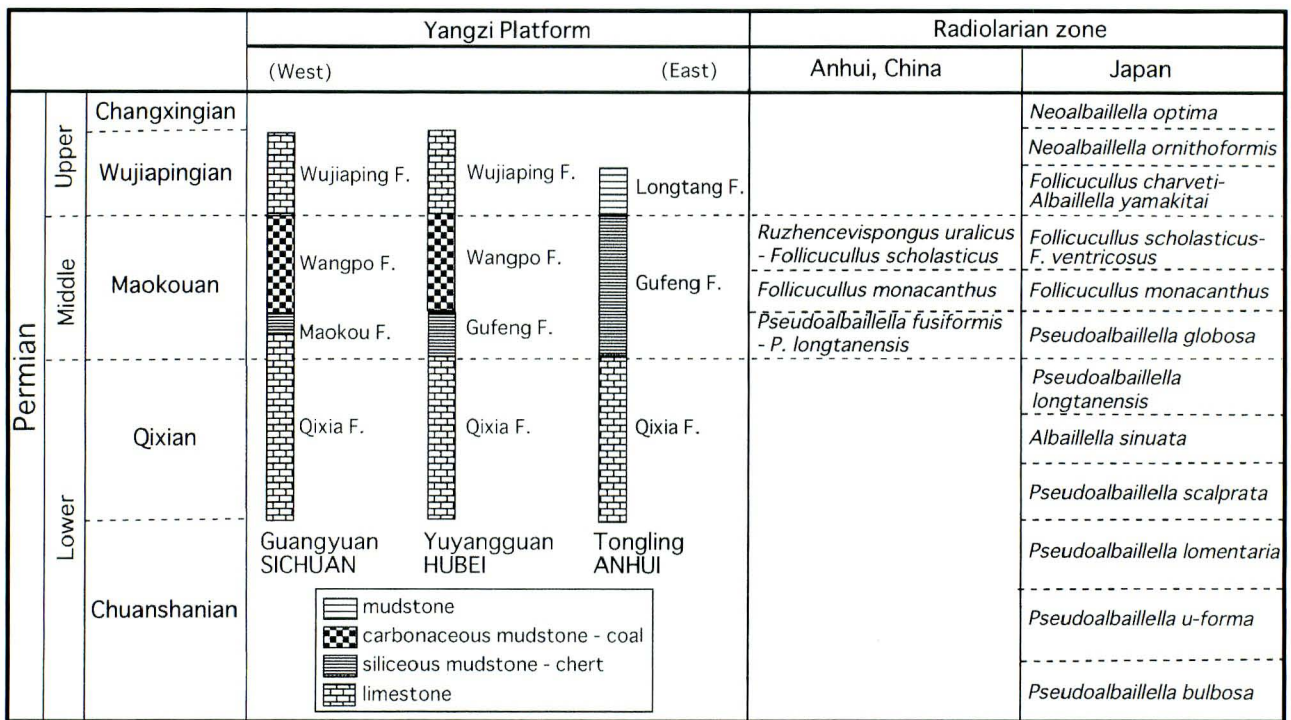


Fig. 8 Generalized columnar sections of the Middle Permian siliceous strata in South China Block and their correlation by means of radiolarian biostratigraphy.

Zone.

According to Yao and Kuwahara (1999), the limestone of the uppermost Maokou Formation is interbedded with thin-bedded cherts in the Changjianggou section, Guangyuan area, Sichuan Province. These thin-bedded cherts yielded the radiolarian species of the *Pseudoalbaillella globosa* Zone. Based on these radiolarian occurrences, the uppermost Maokou Formation in the Changjianggou section is correlated with the Gufeng Formation of the Songzi-Wufeng area, Hubei Province. Above the Maokou Formation, the Wangpo Formation and the Wujiaping Formation overlie in ascending order in the Changjianggou section. The Wangpo Formation is composed of thin beds (total thickness: 2 to 3 m) of claystones. The Wujiaping Formation mainly consists of limestone, 59 m thick. The stratigraphical relationships between these formations are paracomformable or conformable (Li et al., 1989). The stratigraphy and the radiolarian age indicate that the Middle to Upper Permian in the Changjianggou section corresponds well to those of the Songzi-Wufeng area, although the distance between both areas is more than 500 km apart.

The representative columnar sections of the Guangyuan area of Sichuan (Yao and Kuwahara, 1999), the Songzi-Wufeng area of Hubei (this paper) and the Tongling area of Anhui (Kuwahara et al., 2007) are

respectively shown in Fig. 8, which are arranged based on their geographical positions. The duration of the Gufeng Formation was longer in the east area (the Tongling area), and was limited to early Maokouan age in the middle area (the Songzi-Wufeng area). In the west area (the Guangyuan area), the Gufeng Formation was not developed, but the siliceous layers (bedded cherts) were interbedded with limestone of the Maokou Formation during early Maokouan age (early Middle Permian age). The Wangpo Formation was formed above the Maokou Formation and the Gufeng Formation in the west and middle areas during middle to late Maokouan age (middle to late Middle Permian age). Because the Wangpo Formation is characterized by clastics with thin thickness (less than several meters), it is inferred that the upheaval of the basin began at middle Maokouan age in the west and middle areas of the South China Block.

The geographical extent of the Gufeng Formation and the equivalents in South China Block and their exact ages are not yet sufficiently clear. The examination on distribution and exact age of the Gufeng Formation hereafter is necessary at each area. These examinations will lead to clear formative process of the basin of siliceous deposits on the South China Block during Early to Late Permian age.

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