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Late Carboniferous and Permian Radiolarian Biostratigraohy of Southwest Japan

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(With 1 Figure)

Abstract

Late Carboniferous and Permian radiolarian zones of Southwest Japan are recognized mainly on the basis of characteristic species of the genera *Albaillella* DEFLANDRE, *Pseudoalbaillella* HOLDSWORTH and JONES, *Follicucullus* ORMISTON and BABCOCK and *Neoalbaillella* TAKEMURA and NAKASEKO. Until now, thirteen zones have been discriminated within the bedded chert sequences in the Tamba-Mino Belt. Radiolarians are also found in the standard sequence of the Japanese Permian, such as the *Lepidolina kumaensis* Zone of the Maizuru and the Kuma Formations. In this paper, thirteen radiolarian zones of the Japanese Permian and Upper Carboniferous are redefined and some of them are correlated with conodont and fusulinid zones.

I. Introduction

Much progress has been made in Late Carboniferous and Permian radiolarian biostratigraphy of Japan. It is established within continuous sequences of the bedded chert in the Tamba-Mino Belt, Southwest Japan (ISHIGA and IMOTO, 1980; ISHIGA *et al.*, 1982a, b, c; ISHIGA, 1982; ISHIGA *et al.*, 1984 etc.). Because the Permian bedded chert of the Tamba-Mino Belt of the B terrane-group (ICHIKAWA, 1984; see ISHIGA, 1986) are usually strongly deformed and occur as olistolith within the Jurassic clastic formation, a complete section of bedded chert covering the whole of the Permian has not been found out yet. However, sequences including two or more radiolarian zones often occur in the Tamba Belt and adjacent areas, Southwest Japan. Samples from bedded cherts were collected bed by bed and radiolarians and conodonts are extracted by using HF solution and are picked up by fine brush under stereoscopic binocular-microscope. In addition, SEM is used for the detailed observation and photographing.

Radiolarians in the bedded chert are composed of a large amount of Spumellarians and a small amount of Albaillellarians. Among these radiolarians, Albaillellarians have the very characteristic shape and rather short range of occurrence on specific level. Thus, radiolarian zones are recognized mainly on the basis of the characteristic species of the genera *Albaillella* DEFLANDRE, *Pseudoalbaillella* HOLDSWORTH and JONES, *Follicucullus* ORMISTON and BABCOCK and *Neoalbaillella* TAKEMURA and NAKASEKO. Until now, thirteen radiolarian zones have been discriminated and some of them are correlated with the conodont zones through the study of coexisting conodonts. Permian (and Upper

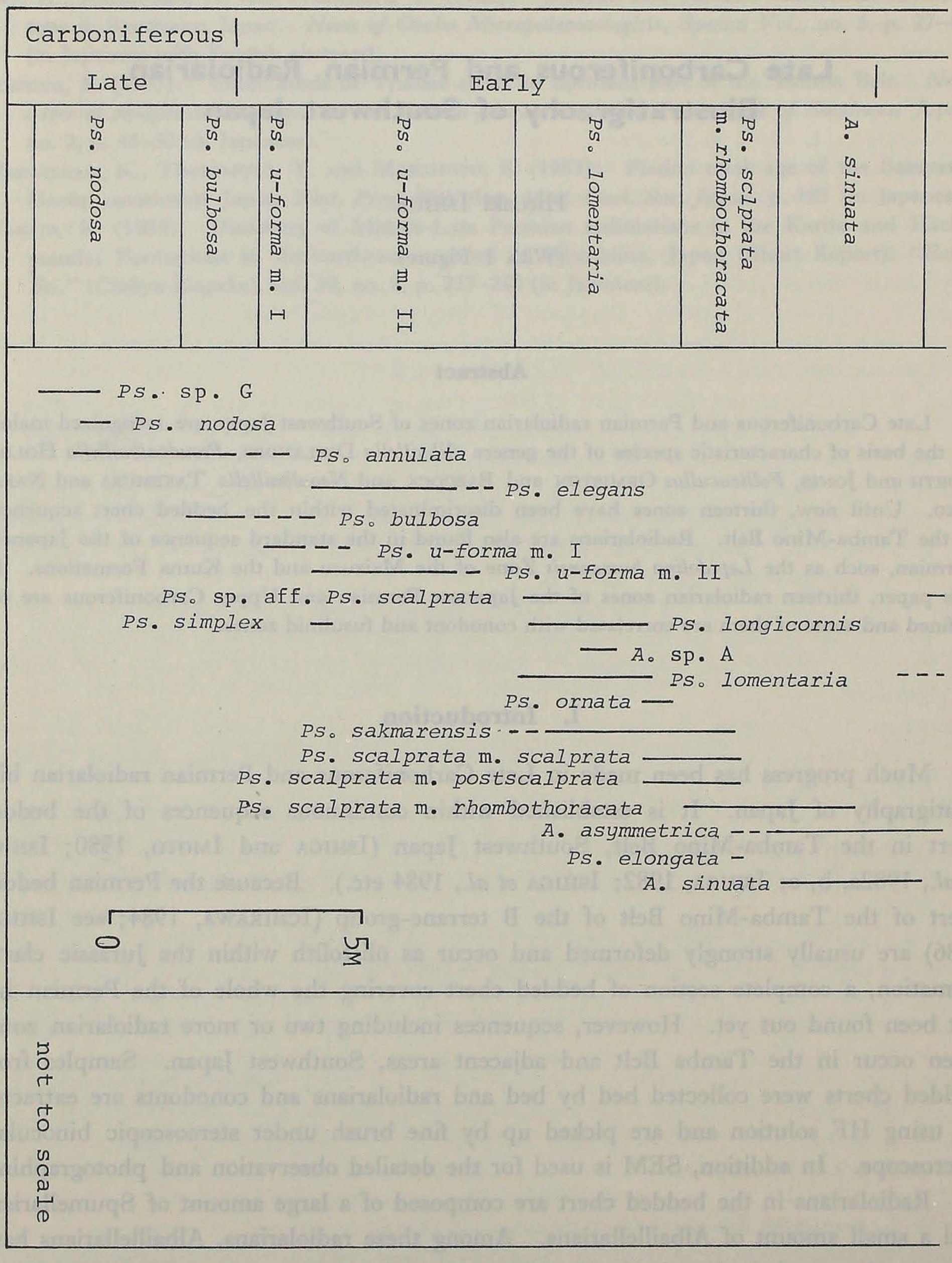
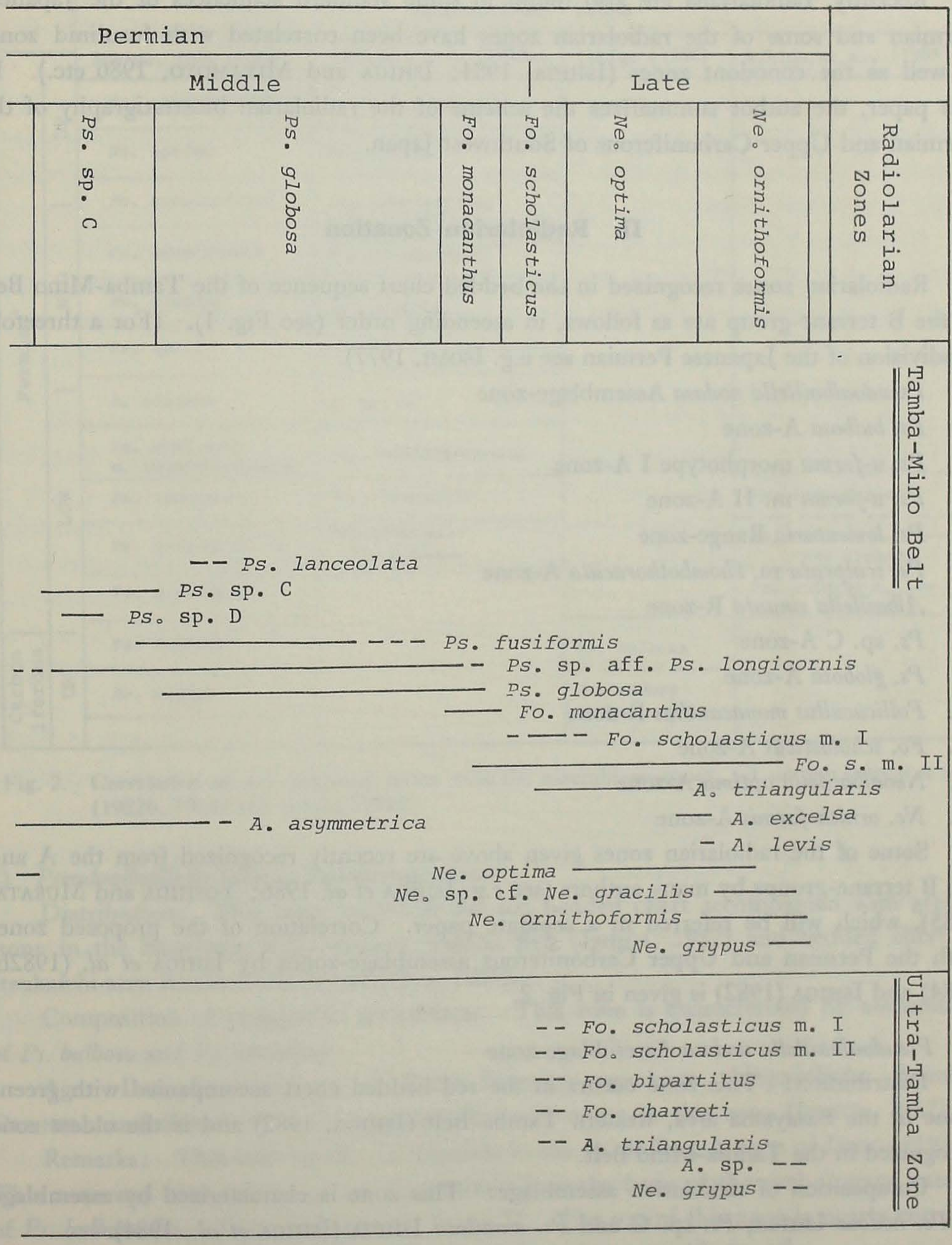


Fig. 1. Late Carboniferous and Permian radiolarian zonation and range chart of the characteristic species of Japan after ISHIGA *et al.* (1982a, b, c; 1984; 1986), ISHIGA (1982) and other unpublished data of the author.
Abbreviation: A *A.*; *Albaillella, Ps.*; *Pseudoalbaillella, Fo.*; *Follicucullus, Ne.*; *Neoalbaillella.*



Carboniferous) radiolarian zones have been identified not only in the Tamba-Mino Belt but also in the Maizuru, the Chugoku and the Hida marginal Belts of the A terrane-group and the Chichibu Belt of the B terrane-group. Permian and Late Carboniferous radiolarians have been found mostly from bedded chert of the B terrane-group, but some of them were found also from mudstone of the A and the B terrane-groups.

Recently, radiolarians are also found in some standard sequences of the Japanese Permian and some of the radiolarian zones have been correlated with fusulinid zones as well as the conodont zones (ISHIGA, 1984; ISHIGA and MIYAMOTO, 1986 etc.). In this paper, the author summarizes the scheme of the radiolarian biostratigraphy of the Permian and Upper Carboniferous of Southwest Japan.

II. Radiolarian Zonation

Radiolarian zones recognized in the bedded chert sequence of the Tamba-Mino Belt of the B terrane-group are as follows, in ascending order (see Fig. 1). (For a threefold subdivision of the Japanese Permian see e.g. ISOMI, 1977).

1. *Pseudoalbaillella nodosa* Assemblage-zone
2. *Ps. bulbosa* A-zone
3. *Ps. u-forma* morphotype I A-zone
4. *Ps. u-forma* m. II A-zone
5. *Ps. lomentaria* Range-zone
6. *Ps. scalprata* m. *rhombothoracata* A-zone
7. *Albaillella sinuata* R-zone
8. *Ps.* sp. C A-zone
9. *Ps. globosa* A-zone
10. *Follicucullus monacanthus* R-zone
11. *Fo. scholasticus* A-zone
12. *Neoalbaillella optima* A-zone
13. *Ne. ornithoformis* A-zone

Some of the radiolarian zones given above are recently recognized from the A and the B terrane-groups by many authors (see e.g. ISHIGA *et al.* 1986; YOSHIDA and MURATA, 1985), which will be referred in a separate paper. Correlation of the proposed zones with the Permian and Upper Carboniferous assemblage-zones by ISHIGA *et al.* (1982b, 1984) and ISHIGA (1982) is given in Fig. 2.

1) *Pseudoalbaillella nodosa* Assemblage-zone

Distribution: This zone occurs in the red bedded chert accompanied with greenstone in the Sasayama area, western Tamba Belt (ISHIGA, 1982) and is the oldest zone recognized in the Tamba-Mino Belt.

Composition of radiolarian assemblage: This zone is characterized by assemblage of *Ps. nodosa* ISHIGA, *Ps.* sp. G and *Ps. annulata* ISHIGA (ISHIGA *et al.*, 1984).

Age: Late Carboniferous (Morrowan to Atokan) conodonts such as *Idiognathoides sinuatus* GUNNELL, *I. roundyi* GUNNELL and *Gondolella clarki* KOIKE occur in this zone together with *Idiognathodus delicatus* GUNNELL (ISHIGA, 1982).

Remarks: This zone nearly corresponds to the *Ps. nodosa* A-zone of ISHIGA (1982). The top of this zone nearly corresponds with the horizon of the first appearance of *Ps. bulbosa* ISHIGA.

		Radiolarian Zones			
		Ishiga, this paper	Ishiga *et al.* (1982b)	Ishiga (1982)	Ishiga *et al.* (1984)
Permian	UP	*Ne. ornithofornis*	*Ne. ornithoformis*		
		Ne. optima	*Ne. optima*		
		Fo. scholasticus	*Fo. scholasticus*		
	MID	*Fo. monacanthus*	*Fo. monacanthus*		
		Ps. globosa	*Ps. globosa*		
		Ps. sp. C			
	LOW	*A. sinuata*	*A.* sp. D		
		Ps. scalprata m. *rhombothoracata*	*Ps. rhombothoracata*		
		Ps. lomentaria	*Ps. lomentaria*		*Ps. lomentaria*
		Ps. u-forma m. II	*Ps. u-forma*— *Ps. elegans*		*Ps. u-forma* m. II— *Ps. elegans*
		Ps. u-forma m. I			*Ps. u-forma* m. I— *Ps. annulata*
Carboniferous	UP	*Ps. bulbosa*		*Ps. bulbosa*	
		Ps. nodosa		*Ps. nodosa*	

Fig. 2. Correlation of the proposed zones with the assemblage-zones, set up by ISHIGA *et al.* (1982b, 1984) and ISHIGA (1982).

2) *Pseudoalbaillella bulbosa* Assemblage-zone

Distribution: This zone occurs in the red bedded chert accompanied with greenstone in the Sasayama area, western Tamba Belt (ISHIGA, 1982) and bedded chert in Itsukaichi area Kanto Mountains (SAITO, 1984).

Composition of radiolarian assemblage: This zone is characterized by assemblage of *Ps. bulbosa* and *Ps. annulata*.

Age: Late Carboniferous to Early Permian conodonts, *Idiognathodus delicatus* GUNNELL and *Streptognathodus elongatus* ELLISON occur in this zone (ISHIGA, 1982).

Remarks: This zone nearly corresponds to the *Ps. bulbosa* A-zone of ISHIGA (1982). This zone and next two zones are discriminated on the basis of the evolutionary lineage of *Ps. bulbosa–Ps. u-forma* morphotype I and II. The top of this zone is nearly correlative with the horizon of the first occurrence of *Ps. u-forma* morphotype I.

3) *Pseudoalbaillella u-forma* morphotype I Assemblage-zone

Distribution: This zone is distributed in the red bedded chert accompanied with greenstone in the Sasayama area, western Tamba Belt (ISHIGA, 1982), the Ohmori area in the central Tamba Belt (ISHIGA *et al.*, 1984) and bedded chert in the Itsukaichi area,

Kanto Mountains (SAITO, 1984).

Composition of radiolarian assemblage: This zone is characterized by assemblage of *Ps. u-forma* m. I, *Ps. annulata* and *Ps. bulbosa*.

Age: This zone corresponds to the lower to middle part of Wolfcampian of North America, for *Hindeodus expansa* PERLMUTTER, *Idiognathodus delicatus* and *Streptognathodus elongatus* occur in this zone in the Sasayama area (ISHIGA, 1982) and the Ohmori area in the Tamba Belt (ISHIGA *et al.*, 1984).

Remarks: This zone is equivalent to the *Ps. annulata–Ps. u-forma* m. I A-zone of ISHIGA *et al.* (1984). The base of this zone is defined by the horizon of the first appearance of *Ps. u-forma* m. I and the top of the zone, by the first occurrence of *Ps. u-forma* m. II.

4) *Pseudoalbaillella u-forma* morphotype II Assemblage-zone

Distribution: This zone occurs in the bedded chert in the Tamba-Mino Belt (ISHIGA and IMOTO, 1980; ISHIGA *et al.*, 1984 etc.).

Composition of radiolarian assemblage: This zone is characterized by assemblage of *Ps. u-forma* m. II, and *Ps. elegans* ISHIGA and IMOTO. *Ps. simplex* ISHIGA and IMOTO occurs in the lowest part of this zone.

Age: Considering the stratigraphic position of this zone above the *Ps. u-forma* m. I A-zone, this zone is regarded to be correlative with middle part of Wolfcampian of North America.

Remarks: This zone is equivalent to the *Ps. u-forma–Ps. elegans* A-zone of ISHIGA *et al.* (1982b) and the *Ps. u-forma* (m II)–*Ps. elegans* A-zone of ISHIGA *et al.* (1984).

5) *Pseudoalbaillella lomentaria* Range-zone

Distribution: This zone is distributed in the bedded chert in the Tamba-Mino Belt (ISHIGA and IMOTO, 1980; ISHIGA *et al.*, 1984).

Composition of radiolarian assemblage: The diagnostic species of this zone is *Ps. lomentaria* ISHIGA and IMOTO. *Ps. longicornis* ISHIGA and IMOTO and *Ps. sakmarensis* KOZUR occur in this zone. In the lower part of this zone, *Ps.* sp. aff. *Ps. scalprata* occurs, while in the upper part, *Ps. scalprata* morphotype *scalprata, Ps. scalprata* m. *postscalprata* occur. In addition, *Ps. ornata* ISHIGA and IMOTO occurs in the upper part of this zone.

Age: *Ps. sakmarensis* was originally described from the Sakmarian of Cis-Urals (KOZUR, 1980). *Haplodiacanthus anfractus* NAZAROV and RUDENKO which is closely related with *Ps. lomentaria* was described from the Artinskian of the South Urals (NAZAROV and RUDENKO, 1981). However, this zone is correlated with the middle part of Wolfcampian of North America based on the stratigraphic position of this zone under the *Ps. rhombothoracata* A-zone mentioned below.

Remarks: This zone is equivalent to the *Ps. lomentaria* A-zone of ISHIGA *et al.* (1982b).

6) *Pseudoalbaillella scalprata* morphotype *rhombothoracata* Assemblage-zone

Distribution: This zone is distributed in the red bedded chert in the Tamba-Mino Belt (ISHIGA and IMOTO, 1980; ISHIGA *et al.*, 1982c).

Composition of radiolarian assemblage: This zone is characterized by assemblage of *Ps. scalprata* morphotype *rhombothoracata* which occurs also in the lower part of the next higher *Albaillella sinuata* Range-zone. In the lower part of that zone, *Ps. scalprata* m. *scalprata* and *Ps. scalprata* m. *postscalprata* occur, while in the upper part *Albaillella asymmetrica* occurs. In the middle part of this zone, *Ps. elongata* ISHIGA and IMOTO occurs, which shows short range of occurrence.

Age: Latest Wolfcampian *Sweetognathus whitei* (RHODES) occurs in this zone.

Remarks: This zone is equivalent to the *Ps. rhombothoracata* A-zone of ISHIGA *et al.* (1982b).

7) *Albaillella sinuata* Range-zone.

Distribution: This zone is included in the chert formation of the Nishiki Group in the Muikaichi area, Shimane Prefecture (ISHIGA *et al.*, 1986) and the Shimomidani Formation in the "Chugoku Belt", Kyoto Prefecture (ISHIGA and SUZUKI, 1984), of the A terrane-group, while in the B terrane-group, it occurs in the bedded chert in the Tamba Belt (ISHIGA *et al.*, 1982b, c).

Composition of radiolarian assemblage: The diagnostic species of this zone is *Albaillella sinuata* ISHIGA and WATASE (ISHIGA *et al.*, 1986). In addition, *A. asymmetrica* ISHIGA and IMOTO and *Ps. scalprata* m. *rhombothoracata* occur in this zone. *Ps.* sp. aff. *Ps. longicornis* occurs from the horizon just below the boundary between this zone and the superjacent *Pseudoalbaillella* sp. C Assemblage-zone.

Age: This zone is set up above the latest Wolfcampian *Pseudoalbaillella scalprata* morphotype *rhombothoracata* A-zone (ISHIGA *et al.*, 1982b; ISHIGA, 1983) and is assigned to Leonardian in age based on the co-occurrence of Leonardian conodonts (ISHIGA and SUZUKI, 1984).

Remarks: This zone is equivalent to the *Albaillella* sp. D A-zone of ISHIGA *et al.* (1982b). This zone is the range-zone of *Albaillella sinuata* (=*A.* sp. D of ISHIGA *et al.*, 1982b, c). The top of this zone nearly corresponds to the horizon of the first occurrence of *Ps.* sp. C of ISHIGA *et al.* (1982c).

8) *Pseudoalbaillella* sp. C Assemblage-zone.

Distribution: This zone is recognized in the chert and the mudstone formations of the Nishiki Group in the Chugoku Belt of the A terrane-group (ISHIGA *et al.*, 1986) and the red bedded chert of the Yagi and the Ashimi-dani areas in the Tamba Belt of the B terrane-group (ISHIGA *et al.*, 1982b, c).

Composition of radiolarian assemblage: This zone is characterized by assemblage of *Ps.* sp. C of ISHIGA *et al.* (1982c), *Albaillella asymmetrica*, *Ps.* sp. aff. *Ps. longicornis*, and *Ps.* sp. D of ISHIGA *et al.* (1982c). *Ps. fusiformis* occurs in the upper part of this zone.

Age: This zone is set up between the *Albaillella sinuata* R-zone and the *Pseudo-*

albaillella globosa A-zone. Based on the age of the overlying and the underlying zones, the present zone is probably assigned to late Leonardian in age.

Recently, *Ps. longtanensis* SHENG and WANG and *Ps. nanjingensis* SHENG and WANG [=*Ps. fusiformis* (HOLDSWORTH and JONES)] have been reported from the Kufeng Formation, Nanjing, which is situated between the Chihisian and the Longtan Formations and is correlated with the Maokouan (SHENG and WANG, 1985). *Ps. longtanensis* is closely related with *Ps.* sp. C of ISHIGA *et al.* (1982c) and the assemblage reported by SHENG and WANG from the Kufeng Formation, is regarded to correspond to that from the upper part of *Ps.* sp. C A-zone, considering co-occurrence of *Ps. longtanensis* and *Ps. fusiformis* in the Kufeng Formation. Therefore, this zone is assigned to certain part of the Maokouan in age.

Remarks: The base of this zone nearly corresponds to the horizon of the first appearances of *Ps.* sp. C of ISHIGA *et al.* (1982c) and *Ps.* sp. aff. *Ps. longicornis*. The top of this zone is defined by the horizon of the first occurrence of *Ps. globosa* ISHIGA and IMOTO. This zone corresponds to the unnamed zone of 3.3 m thickness and the lower part of the *Ps. globosa* A-zone in ISHIGA *et al.* (1982b), which are characterized by the occurrence of *Ps.* sp. C. *Albaillella asymmetrica* ranges from the *A. sinuata* Range-zone to this zone and abundantly occurs in this zone.

9) *Ps. globosa* Assemblage-zone.

Distribution: This zone is recognized in the mudstone formation of the Nishiki Group in the Chugoku Belt of the A terrane-group (ISHIGA *et al.*, 1986) and in the bedded chert in the Tamba-Mino Belt of the B terrane-group (ISHIGA *et al.*, 1982b, c).

Composition of radiolarian assemblage: This zone is characterized by assemblage of *Ps. globosa, Ps.* sp. aff. *Ps. longicornis*, *Ps. fusiformis*, *Ps. lanceolata* ISHIGA and IMOTO and *A. asymmetrica*.

Age: The *Ps. fusiformis* Group Assemblage, which is closely resembling the *Ps. globosa* Assemblage in Japan, occurs from the latest Leonardian Bone Spring Limestone of Texas (MURCHEY *et al.*, 1983). Furthermore, *Ps. globosa* and *Ps.* sp. D of ISHIGA *et al.* (1982c) occur from the Born Spring Limestone, West Texas (CORNELL and SIMPSON, 1985). From the radiolarian locality in the Born Spring Limestone, Roadian (Late Leonardian or latest Early Permian of North America) ceratitoid ammonoids, *Paraceltites elegans* GIRTY was described (SPINOSA *et al.*, 1975). The *Ps. globosa* A-zone is probably assigned to late Leonardian to Guadalupian based on the age of the subjacent zone of *Ps.* sp. C A-zone and that of the allied assemblage from Texas.

Remarks: The base of this zone is marked by the horizon of the first occurrence of *Ps. globosa*, while the top of this zone corresponds to the horizon of the first occurrence of *Fo. monacanthus* ISHIGA and IMOTO. This zone corresponds to the upper part of the "*Ps. globosa* Assemblage-zone" of ISHIGA *et al.* (1982b), because the lower part of their zone is now referred to the *Ps.* sp. C A-zone in the lower part and the *Ps. globosa* A-zone.

10) *Follicucullus monacanthus* Range-zone

Distribution: This zone is distributed in the grey bedded chert in the Tamba-Mino Belt of the B terrane-group (ISHIGA *et al.*, 1982b, c). It is also recognized in the black mudstone of the Maizuru Group, Kyoto Prefecture (ISHIGA, 1984), the black mudstone and acidic tuff of the Nishiki Group in Shimane Prefecture (ISHIGA *et al.*, 1986) and black mudstone in Katsuyama area, Okayama Prefecture (MIYAKE, 1985) of the A terrane-group.

Composition of radiolarian assemblage: Diagnostic species of this zone is *Follicucullus monacanthus*. In the lower part of this zone, *Ps. globosa* occurs, while in the upper part, *Fo. scholasticus* m. II occurs.

Age: This zone is set up below the Late Permian *Follicucullus scholasticus* Assemblage-zone (ISHIGA *et al.*, 1982b, c) and is assigned to Late Leonardian or Early Guadalupian of North America in age.

Remarks: This zone is equivalent to the *Fo.* sp. A A-zone of ISHIGA *et al.* (1982b). This zone is the range-zone of *Follicucullus monacanthus* (=*Fo.* sp. A of ISHIGA *et al.*, 1982b, c). The top of this zone nearly corresponds with the horizon of the first occurrence of *Fo. scholasticus* m. I.

11) *Follicucullus scholasticus* Assemblage-zone

Distribution: This zone is distributed in the grey bedded chert in the Tamba-Mino Belt of the B terrane-group (ISHIGA and IMOTO, 1980; ISHIGA *et al.*, 1982b, c). This zone is recognized in the black mudstone of the Maizuru Group (ISHIGA, 1984) and Nishiki Group (ISHIGA *et al.*, 1986) of the A terrane-group.

Composition of radiolarian assemblage: Concerning the characteristic species, radiolarian content of this zone is different from each other between the A and the B terrane-groups. In the B terrane-group, this zone is generally characterized by *Fo. scholasticus* m. II which occurs abundantly in this zone among the radiolarian species including Spumellarians, Albaillellarians and others. In the chert sequence of the B terrane-group *Fo. scholasticus* m. I occurs exceptionally in the Sasayama area. In the A terrane-group, on the other hand, both *Follicucullus scholasticus* morphotype I and II occur together within this zone and the former is the diagnostic of this zone. In the upper part of this zone both in the A and the B terrane-group, *Albaillella triangularis* ISHIGA, KITO and IMOTO occurs. These two assemblages in the A and the B terrane-groups are contemporaneous with each other (e.g. ISHIGA, 1984, 1985; ISHIGA *et al.*, 1986).

Age: *Follicucullus scholasticus* m. I and m. II and *Albaillella triangularis* occur from the Late Permian *Lepidolina kumaensis* Zone, Kyushu (MIYAMOTO *et al.*, 1985; ISHIGA and MIYAMOTO, 1986). *Fo. scholasticus* m. II occurs in the upper formation of the Maizuru Group which is assigned to the *Lepidolina kumaensis* Zone (ISHIGA, 1984).

Remarks: *Follicucullus bipartitus–Fo. charveti* Assemblage characteristically occurs in the thinly alternating siliceous rock and pelitic rock of the Oi Formation of the Ultra-Tamba Zone (CARIDROIT *et al.*, 1985; ISHIGA, 1985, 1986), which is correlated with

the assemblage from the upper part of the *Fo. scholasticus* A-zone (ISHIGA, 1985; ISHIGA and MIYAMOTO, 1986). This assemblage also occurs in the *Lepidolina kumaensis* Zone of the Kuma Formation, Kyushu (MIYAMOTO *et al.*, 1985; ISHIGA and MIYAMOTO, 1986).

12) *Neoalbaillella optima* Assemblage-zone

Distribution: This zone is distributed in the grey bedded chert of the Tamba-Mino Belt of the B terrane-group (ISHIGA *et al.*, 1982a, b).

Composition of radiolarian assemblage: This zone is characterized by assemblage of *Neoalbaillella optima* ISHIGA, KITO and IMOTO, *Albaillella triangularis* and *Follicucullus scholasticus* m. II. In the upper part of this zone, *Albaillella levis* ISHIGA, KITO and IMOTO and *A. excelsa* ISHIGA, KITO and IMOTO occur.

Age: This zone is set up above the Late Permian *Follicucullus scholasticus* A-zone. Conodonts resembling Dzhulfian (Late Permian) *Gondollella orientalis* BARSKOV and KOROLEVA occurs in this zone (ISHIGA *et al.*, 1982a).

Remarks: This zone is equivalent to the *Ne. optima* A-zone of ISHIGA *et al.* (1982b).

13) *Neoalbaillella ornithoformis* Assemblage-zone

Distribution: This zone is distributed in the grey bedded chert in the Tamba-Mino Belt of the B terrane-group (ISHIGA *et al.*, 1982b).

Composition of radiolarian assemblage: This zone is characterized by assemblage of *Neoalbaillella ornithoformis* and *Follicucullus scholasticus* m. II. *Albaillella excelsa, A. levis, Ne. optima* occur in the lower part of this zone, while *Ne. grypus* ISHIGA, KITO and IMOTO occurs in the upper part of this zone.

Age: This zone corresponds to some part of Upper Permian (probably upper part of the Upper Permian), for it is set up two-over the early Late Permian *Follicucullus scholasticus* Assemblage-zone mentioned above.

Remarks: This zone is equivalent to the *Ne. ornithoformis* A-zone of ISHIGA *et al.* (1982b).

III. Phyletic lineage of Albaillellaria in Late Carboniferous and Permian times

Main features of the evolutionary trend of Late Carboniferous and Permian Albaillellaria are summarized as follows: (1) Successive occurrence of species of *Pseudoalbaillella* HOLDSWORTH and JONES, *Follicucullus* ORMISTON and BABCOCK and *Neoalbaillella* TAKEMURA and NAKASEKO are recognized; (2) Their diversity rapidly increased with time; namely, *Albaillella* gave rise to *Pseudoalbaillella* in Late Carboniferous time (e.g. HOLDSWORTH and JONES, 1980) which in turn gave rise to *Follicucullus* in late Middle Permian time (ISHIGA *et al.*, 1982c); (3) A certain species of *Pseudoalbaillella* such as *Ps.* sp. C is regarded to have been the ancestor of *Neoalbaillella* (ISHIGA *et al.*, 1986) which was remarkably diversified in Late Permian time (ISHIGA *et al.*, 1982a);

(4) *Albaillella* declined in Late Carboniferous, but still survived until Late Permian time (ISHIGA, 1982a). Horizon of first appearance of many species belonging to Albaillellaria prove important in defining Late Carboniferous and Permian biostratigraphic datum planes as shown in this paper.

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