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Permian radiolarians from cherts of the Tamba Terrane in the Nishizu district, Fukui, Southwest Japan

Satoshi NAKAE[1]

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Abstract: Permian radiolarians are detected from cherts of the Tamba Terrane in the Nishizu district, southwestern Fukui Prefecture. The Tamba Terrane exposed in the district is mainly composed of basalt, limestone, chert, mudstone and sandstone. It is characterized by a chaotic mixture of these rocks; *i.e.*, slabs of basalt, limestone, chert, mudstone and sandstone are embedded in pelitic mixed rocks. Only a few biostratigraphical studies in the district have previously been appeared and some of them described the occurrence of Permian, Triassic and Jurassic radiolarians, but the ages of the rocks constituting the Tamba Terrane in the district are still uncertained. Newly recovered radiolarians treated herein can give the chert sequence in the Nishizu district additional ages of late Early, middle Middle and middle Late Permian. Moreover, cherts generally occur as slabs, which are classified into small-scale lenticular and large-scale sheet-like types, both of which are assigned to Permian in age.

1. Introduction

The Nishizu district in a southwestern part of Fukui Prefecture is situated in a mountainous region and underlain by the Tamba Terrane (Fig. 1). Only a few geologic works in the district have been carried out since the 1950's, because of the complicated lithologic assemblages and geologic structures of the Tamba Terrane. Isomi and Kuroda (1958) first surveyed a wide area including the Nishizu district to make a brief geological map in a short time, and then discriminated five formations from the district. However, the stratigraphy and structure proposed by Isomi and Kuroda (1958) are not acceptable for the recent concept of complex geologic bodies such as the Tamba Terrane, because all the rocks were erroneously determined to be the Middle Permian on the basis of the fusuliniids in limestones. After that, Ito *et al.* (1982) made a geologic mapping in a western part of the Nishizu district, and clarified the outline of lithologic assemblages and geologic structures. Through this work, Triassic and Early Jurassic radiolarians were detected from cherts, but their precise ages are not clear, because no photographs nor descriptions about the obtained radiolarians is seen in the text of Ito *et al.* (1982). Next, Fujii (1991) , who followed the work of Ito *et al.* (1982), reported the occurrence of Early to probably Middle Jurassic radiolarians from cherts within the Nishizu district. On the other hand, Late Permian radiolarians were obtained from the basalt-chert sequence at an outcrop in the most southeastern part of this district (Kido, 1986).

The above previous studies made great efforts to reveal the geology of the Nishizu district, especially the rock ages based on microfossils. Nevertheless, the ages are still uncertain due to the few reports on the fossil evidence. I have studied the geology of the Nishizu district under the mapping project of the Geological Survey of Japan. I found many radiolarians of Permian, Triassic and Jurassic ages from various kinds of the rocks in the district. I intend to describe a part of the radiolarians, *i.e.*, Permian radiolarians, in detail in this paper, and the other parts of the study will be presented in future articles.

2. Geologic setting

The Tamba Terrane in Southwest Japan is generally considered to be formed along the eastern margin of Asia in the Jurassic period, and is mainly composed of late Paleozoic basalt-limestone-chert complexes, Triassic to middle or late Jurassic chert-clastics complexes together with pelitic mixed rocks (*e.g.*, Nakae, 1993). The pelitic mixed rocks consist of early to late Jurassic foliated mudstones including metric-sized blocks of late Paleozoic basalt and limestone, Permian to middle Jurassic chert and early to middle Jurassic clastic rock. The late Paleozoic complexes,

[1] Institute of Geoscience, GSJ

Key words: Permian, radiolaria, chert, Tamba Terrane, Nishizu district, Fukui

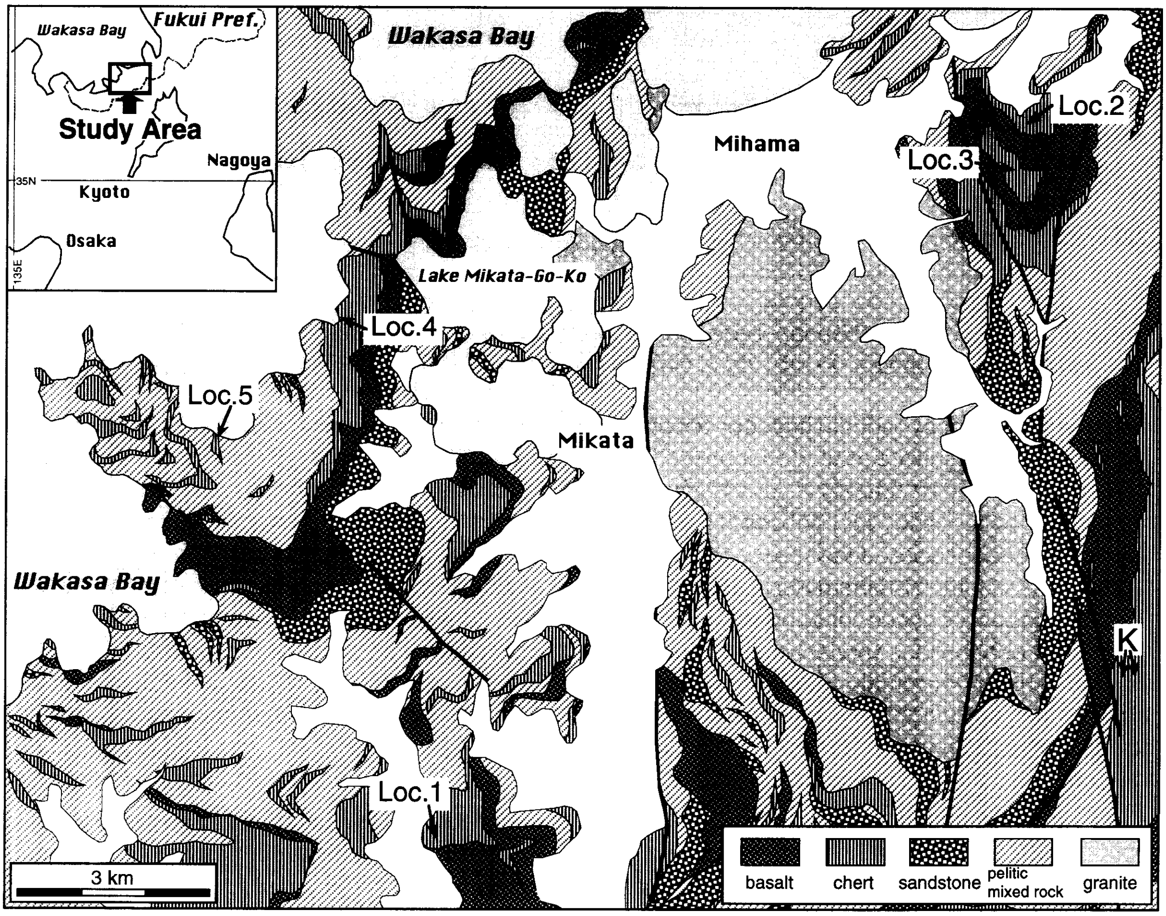

Fig. 1 Index map showing the outline of geology in a part of the Nishizu district, southwestern Fukui Prefecture, and sample localities.
Detailed localities are given in Fig. 2 and the symbol K indicates the sample locality of Kido (1986).

most of which are Permian, commonly occur as sheet-like shaped slabs on a large-scale. The Triassic to Jurassic chert-clastics complexes are also exposed as large sheet-like slabs, in which the cherts and clastic rocks are arranged in sequence. Two mica granites, which are probably Late Cretaceous in age, and related aplites widely occur and boldly intrude into the Tamba Terrane in the eastern part of the district. The rocks on the both sides of the intrusives are poorly correlated to each other due to their lack of lateral extension.

The Tamba Terrane is divided into several tectonostratigraphic units on the basis of the lithologic assemblage, age and internal geologic structure. For example around the Nishizu district, the Tada, Shimonegori, Kouchi and Mukugawa Complexes in the Kumagawa district (Nakae and Yoshioka, 1998) and the Kashimagari, Obanashi, Suganami, Tone and Arihara Complexes in the Tsuruga district (Kurimoto et al., 1999) are distinguished from each other. In the Nishizu district, equivalents of the Tada, Shimonegori and Kouchi Complexes are present, and their detailed discrimination and description will be given by the next report (Nakae, in press).

The Tamba Terrane in the Nishizu district has a chaotic mixture of the constituent rocks, and strikes at nearly E-W or NNE-SSW with gently to steeply dipping (Fig. 1). The mixed feature is characterized by slabs of basalt, limestone, chert and clastic rock which are embedded in the pelitic mixed rock. As mentioned above, slabs can be classified into two types based on scale and shape for convenience' sake; one is small-scale lenticular and the other is large-scale sheet-like. The former has a width of 100 to 500 m and a length of 300 m to 5 km. In general, basalt, limestone, chert, mudstone and sandstone individually make a single slab. On the contrary, the latter is commonly more than 500 m wide and 5 km long, and is composed mostly of basalt, chert and sandstone. In particular, larger-scale slabs of basalt, for example more than 1 km wide and 10 km long, are usually accompanied by chert. Therefore in this case, they will be called 'basalt-chert composite' hereafter.

3. Sample localities and description

About 230 rock samples were all collected from cherts in the Nishizu district. In the laboratory, the

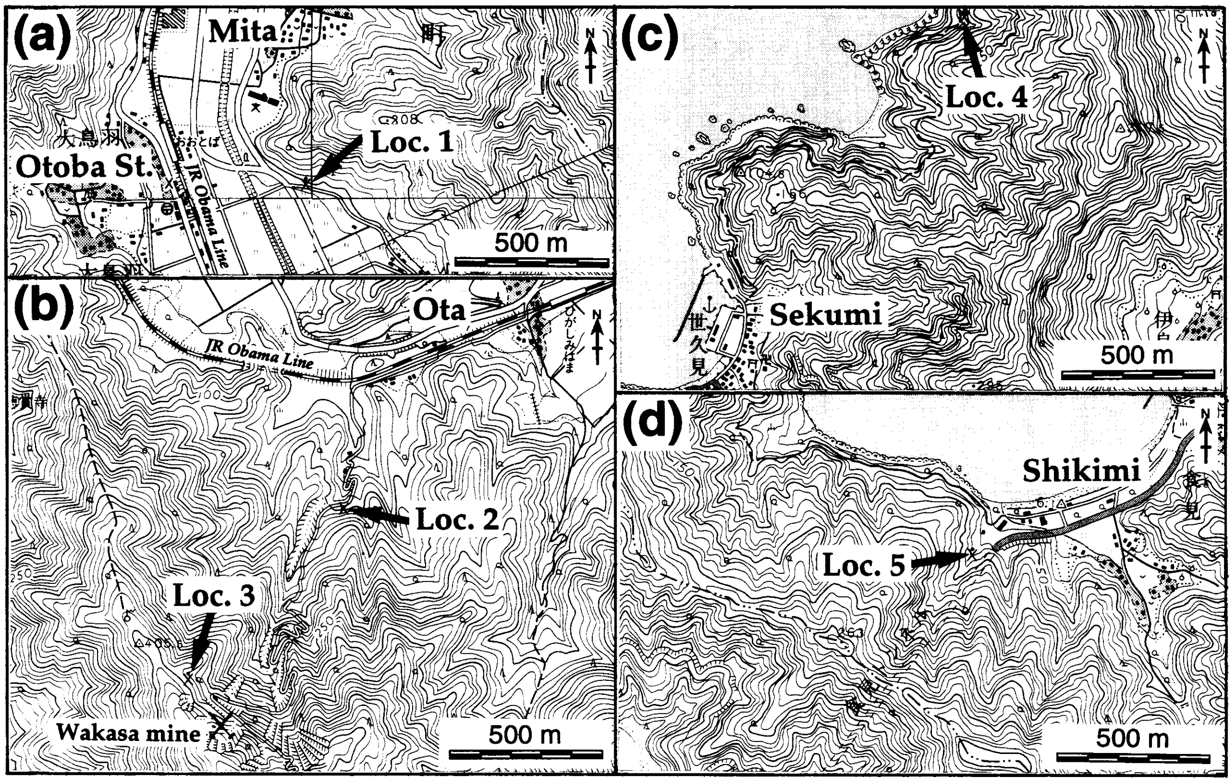

Fig. 2 Localities of Permian radiolarian fossils in the Nishizu district.
(a) Sample NZ20-05 (Loc. 1) at Mita, (b) samples NZ42-01 (Loc. 2) and NZ42-05 (Loc. 3) south of Ota, (c) sample NZ80-05 (Loc. 4) northeast of Sekumi, and (d) sample NZ83-07 (Loc. 5) west of Shikimi. Parts of 1:25,000 topographic maps published by Geographical Survey Institute of Japan, are used as follows; "Nishizu", "Mikata", "Onyu" and "Kumagawa" for (a), "Hayase" for (b) and "Nishizu" for (c) and (d).

samples were soaked in dilute HF solution (5%) for 10 to 15 hours, and sieved through a 200 mesh. After the procedure, radiolarians were obtained from 18 samples, five samples of which yielded Permian species.

The rock samples treated herein are described as follows and their localities are shown in Figs. 1 and 2.

The sample **NZ20-05** was collected from chert exposed along a road cut at Mita, Kaminaka Town (Loc. 1 ; 0.5 km east of JR Otoba Station). Chert, including this locality, together with basalt occurs as a thick sheet-like 'basalt-chert composite' slab, and strikes at N-S to NEE-SWW with westward to northward dip. Individual chert beds are 2 to 5 cm thick and intercalated with thin beds, less than 5 mm thick, of black clay. The chert sample is hard and dark grey in color.

South of Ota, Mihama Town, the samples **NZ42-01** (Loc. 2) and **NZ42-05** (Loc. 3) were gotten from chert occurring along the road connecting the closed Wakasa silica mine with the JR Obama Line. Chert and basalt around the closed mine form a thick and large sheet-like 'basalt-chert composite' slab and are exposed with NEE-SWW strike and northward dip. The chert is bedded with thin interbeds of clay and the thickness of individual chert and clay beds are 1 to 2 cm and 5 mm, respectively. The chert sample NZ42-01 is reddish brown in color, whereas the sample NZ42-05 is dark grey.

The sample **NZ80-05** was taken from chert at Loc. 4, 1.5 km northeast of Sekumi, Mikata Town. The chert occurs along a footpath on the mountainside, where chert and basalt widely outcrop as a 'basalt-chert composite' slab with NW-SE or NNE-SSW strike and westward dip. The chert sample is black to dark grey in color and bedded with thin clay beds. Thickness of individual chert and clay beds are 5 to 10 cm and 5 mm, respectively.

The sample **NZ83-07** was obtained from chert in a small valley 0.7 km west of Shikimi, Mikata Town (Loc. 5). The chert, light grey in color, strikes at nearly N-S with westward dip, and occurs as a small-scale lenticular slab surrounded by the pelitic mixed rock of mudstone and sandstone. The chert sample is hard and bedded with very thin beds of clay, and thickness of individual chert beds is 2 or 3 cm.

4. Radiolarian assemblage

All radiolarians detected from the Nishizu district are listed in Fig. 3 and SEM-microphotos of some identified species are shown in Figs. 4 and 5.

Early to Late Permian radiolarian assemblages are recognized in the chert samples. Radiolarian specific diversity in these assemblages is not so high, and is

Locality No.	1	2	3	4	5
Sample No.	NZ 20-05	NZ 42-01	NZ 42-05	NZ 80-05	NZ 83-07
Lithology	Chert				
Albaillella sp. cf. *A. protolevis*	■				
Albaillella sinuata					■
Albaillella sp. cf. *A. sinuata*					■
Albaillella sp. aff. *A. sinuata*					■
Albaillella sp. A					■
Albaillella spp.	■			■	
Follicucullus ? spp.				■	
Pseudoalbaillella sp. cf. *P. fusiformis*			■		
Pseudoalbaillella sp. cf. *P. longicornis*					■
Pseudoalbaillella sp. cf. *P. scalprata*					■
Pseudoalbaillella sp. A					■
Pseudoalbaillella spp.		■	■		■
Pseudoalbaillella ? spp.		■			■
Gustefana obliqueannulata	■				
Latentifistula sp.				■	
Latentifistula ? sp. A		■			
Latentifistula ? sp. B		■			
Latentifistula ? sp. C	■				
Latentifistula ? sp. D	■				
Entactinosphaera ? sp.					■
Entactinaria? gen. et sp. indet.	■				

Fig. 3 List of Permian radiolarian fossils from cherts in the Nishizu district.

characterized by abundant individuals of Albaillellidae Deflandre, Latentifistulidae Nazarov et Ormiston, Entactiniidae Riedel. Although most radiolarians are unidentified at the species level due to their poor preservation, some of radiolarian species; *Albaillella sinuata* Ishiga et Watase, *Albaillella* sp. cf. *A. protolevis* Kuwahara, *Albaillella* sp. A, *Pseudoalbaillella* sp. cf. *P. longicornis* Ishiga et Imoto, *Pseudoalbaillella scalprata* Holdsworth et Jones, *Pseudoalbaillella* sp. cf. *P. fusiformis* Holdsworth et Jones and *Gustefana obliqueannulata* Kozur, can be identified.

Outline of Permian radiolarian biostratigraphy was established in the 1980's (e.g., Holdsworth and Jones, 1980; Nazarov and Ormiston, 1985), and more than ten radiolarian zones were discriminated in Japan by Ishiga (1986) and in Europe by Kozur and Mostler (1989) through summarizing Permian radiolarian occurrences. On the biostratigraphy and zonations used herein, Ishiga (1986, 1991) is mainly adopted for the Lower and Middle Permian and Kuwahara *et al.* (1998) is applied for the Upper Permian, respectively. Fig. 6 illustrates the distribution of the selected Permian radiolarian species. The range of each species is referred from Ishiga (1986, 1991) and Kuwahara *et al.* (1998).

Albaillella sinuata, first reported as *Albaillella* sp. D by Ishiga *et al.* (1982) and later described as a new species (Ishiga *et al.*, 1986), represents the *Albaillella sinuata* Range-zone of the uppermost Lower to lowest Middle Permian, together with co-occurrence of *Albaillella asymmetrica* and *Pseudoalbaillella scalprata* (Ishiga *et al.*, 1986). *Albaillella protolevis* described by Kuwahara (1999) is similar to *Albaillella levis*, but the former is distinguished from the latter by an inflated shell. According to Kuwahara (1999), this species occurs from the *Neoalbaillella ornithoformis* to the *Neoalbaillella optima* Assemblage-zones, ranging the middle to upper Upper Permian, but is especially abundant in the lower part of the former zone. An unidentified species named *Albaillella* sp. A herein is similar to some species of *Albaillella* in its shape and having horizontal bands on their shell surface, but differs by lacking long wings.

Pseudoalbaillella longicornis is distinguished from other species of *Pseudoalbaillella* by having a long apical cone and short pseudoabdomen. Ishiga and Imoto (1980) shows that *P. longicornis* occurs together with *P. lomentaria*, *P. ornata* and others in the *Pseudoalbaillella lomentaria* Range-zone of the middle Lower Permian. *Pseudoalbaillella scalprata* morphologically includes three types; *scalprata*, *postscalprata* and *rhombothoracata*, and the range of morphotype *rhombothoracata* is slightly later than the others, which are almost coeval (Ishiga, 1983). According to Ishiga (1986), the occurrence of *Pseudoalbaillella scalprata* corresponds to the interval from upper part of the *Psedualbaillella lomentaria* Range-zone to middle part of the *Albaillella sinuata* Range-zone, and is assigned to the upper Lower Permian. Holdsworth and Jones (1980) described *Pseudoalbaillella fusiformis* from Alaska and considered its occurrence ranging from late Early Permian to early Guadalupian on the North American time scale. Ishiga *et al.* (1982) mentioned that *P. fusiformis* occurs preceding the first appearance of *Pseudoalbaillella globosa* in the middle part of the *P. globosa* Assemblage-zone. However, Ishiga (1986) later revised this zone and correlated it with the upper horizon of "the *P. globosa* Assemblage-zone" of Ishiga *et al.* (1982). In the result, the range of *Pseudoalbaillella fusiformis* is included in the uppermost of the *Pseudoalbaillella longtanensis* and the *P. globosa* Assemblage-zones, corresponding to middle Middle Permian in age (Ishiga, 1986, 1990).

5. Age of cherts

Although specific diversity and preservation of the radiolarian assemblages in the chert samples are relatively low and poor, there are some maker taxa

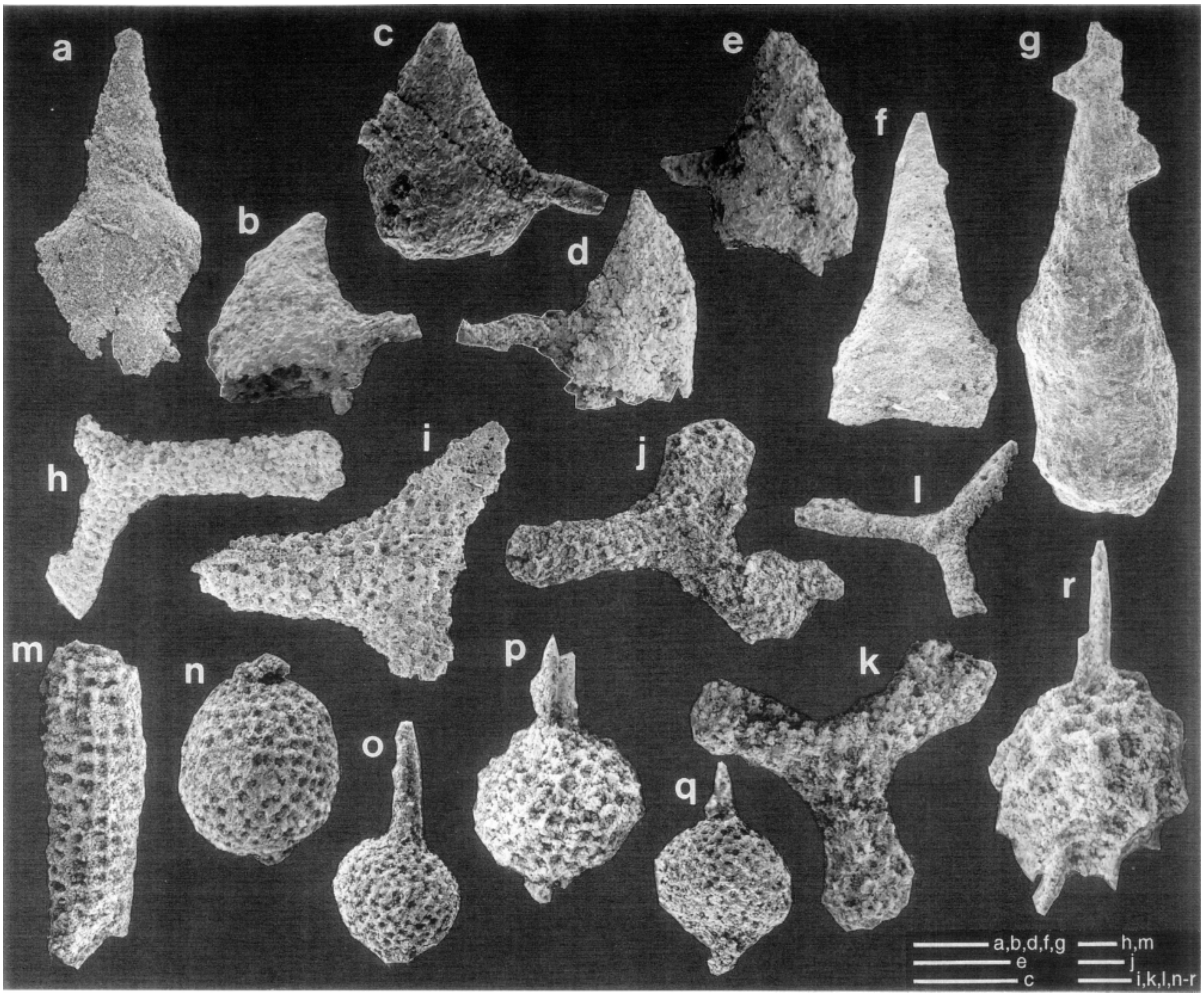

Fig. 4 SEM-photos of Middle to Late Permian radiolarian fossils from cherts in the Nishizu district. (a) *Pseudoalbaillella* sp. : (NZ42-01), (b)-(e) *Albaillella* sp. cf. *A. protolevis* : (NZ20-05), (f)-(g) *Follicucullus* (?) sp. : (NZ80-05), (h) *Latentifistula* (?) sp. A: (NZ42-01), (i) *Latentifistula* (?) sp. B: (NZ42-01), (j)-(k) *Latentifistula* (?) sp. C: (NZ20-05), (l) *Latentifistula* (?) sp. D: (NZ20-05), (m) *Gustefana obliqueannulata* Kozur : (NZ20-05), (n)-(r) Entactinaria (?) gen. et sp. indet. : (NZ20-05). All scale bars are equal to 50 μm.

which can correlate the samples with the Permian radiolarian zones proposed by Ishiga (1986, 1991) and Kuwahara *et al*. (1998), as mentioned above.

The sample NZ20-05 yields *Albaillella* sp. cf. *A. protolevis* (Fig. 4b-e), *Albaillella* sp., *Gustefana obliqueannulata* (Fig. 4m), *Latentifistula* (?) sp. C (Fig. 4j-k) and *L.* (?) sp. D (Fig. 4l), and is probably assigned to the *Neoalbaillella ornithoformis* Assemblage-zone of Kuwahara *et al*. (1998). Radiolarian assemblages including *Albaillella* sp., *Pseudoalbaillella* sp. (Fig. 4a), *Follicucullus* (?) sp. (Fig. 4f-g), *Latentifistula* (?) sp. A (Fig. 4h) and/or *L.* (?) sp. B (Fig. 4i) are obtained from the samples NZ42-01 and NZ80-05. It is impossible to determine their age in detailed, because some of these genera have long chronologic ranges; *e.g.*, *Pseudoalbaillella* ranging from the Upper Carboniferous to Middle Permian, or generic names are somewhat doubtful. *Albaillella* and *Follicucullus*, however, are abundantly recognized in the Middle to Upper Permian and Upper Permian, respectively, in contrast with *Pseudoalbaillella*. Therefore, it may be concluded that the samples NZ42-01 and NZ80-05 are the Upper Carboniferous to Middle Permian and the Upper Permian, respectively. The sample NZ42-05 yields *Pseudoalbaillella* sp. cf. *P. fusiformis* (Fig. 5m) together with other species of *Pseudoalbaillella* (Fig. 5k-l). Thus, it may range from the uppermost of the *Pseudoalbaillella longtanensis* to the *P. globosa* Assemblage-zones, indicative of a part of the Middle Permian. Radiolarian assemblage from the sample NZ83-07 is composed of *Albaillella sinuata* (Fig. 5a-c), *Pseudoalbaillella* sp. cf. *P. longicornis* (Fig. 5h-i), *P.* sp. cf. *P. scalprata* (Fig. 5e) and many poorly-preserved individuals of *Albaillella* and *Pseudoalbaillella*. The ranges of *A. sinuata*, *P. longicornis* and *P. scalprata* are different, but they slightly overlap one another;

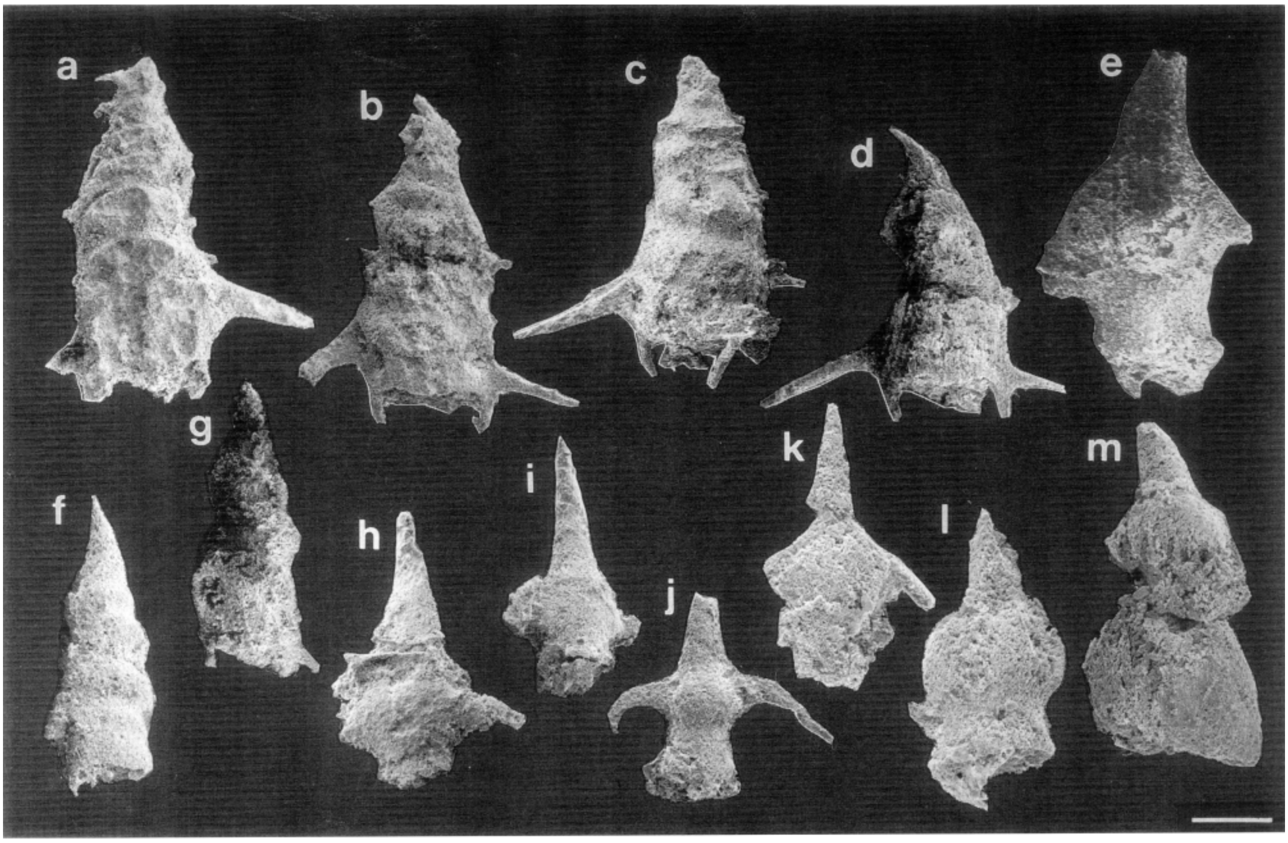

Fig. 5 SEM-photos of Early to Middle Permian radiolarian fossils from cherts in the Nishizu district. (a)-(c) *Albaillella sinuata* : (NZ83-07), (d) *Albaillella* sp. cf. *A. sinuata* : (NZ83-07), (e) *Pseudoalbaillella* sp. cf. *P. scalplata* : (NZ83-07), (f)-(g) *Albaillella* sp. A : (NZ83-07), (h)-(i) *Pseudoalbaillella* sp. cf. *P. longicornis* : (NZ83-07), (j) *Pseudoalbaillella* sp. A : (NZ83-07), (k)-(l) *Pseudoalbaillella* sp. : (NZ42-05), (m) *Pseudoalbaillella* sp. cf. *P. fusiformis* : (NZ42-05). Scale bar is equal to 50 μm.

they can coexist in a part of the *Pseudoalbaillella lomentaria* to the *Albaillella sinuata* Range-zones. Therefore, this sample is most probably assigned to the upper Lower Permian.

6. Discussion

6.1 Age of chert sequences in the Nishizu district

In this paper, radiolarian assemblages including *Pseudoalbaillella* sp. cf. *P. longicornis*, *P.* sp. cf. *P. scalprata*, *P.* sp. cf. *P. fusiformis*, *Albaillella sinuata* and *A.* sp. cf. *A. protolevis* are described from cherts at three localities in the Nishizu district. They almost correspond to a part of the *Pseudoalbaillella lomentaria* to the *Albaillella sinuata* Range-zones, the uppermost of the *Pseudoalbaillella longtanensis* and the *P. globosa* Assemblage-zones, and the *Neoalbaillella ornithoformis* Assemblage-zone (Fig. 6). Moreover, it may be possible that the chert samples from another two localities indicate the age of latest Carboniferous to Late Permian, although their ages cannot be confirmed definitely. Kido (1986) preliminarily reported that radiolarians; *Follicucullus* sp. cf. *F. monacanthus* Ishiga et Imoto, *F.* sp. cf. *F. ventricosus* Ormiston et Babcock and *F. scholasticus* Ormiston et Babcock of the *Follicucullus monacanthus* and the *F. scholasticus* Assemblages of Ishiga (1986) were detected from two localities in the series of outcrop of a 'basalt-chert composite' slab in the southeastmost part of this district. The radiolarian zones consisting of these assemblages are respectively correlated to a lower part of the *F. porrectus* (=*F. japonicus* of Ishiga, 1991) Zone of Ishiga (1991), and an upper part of the *F. porrectus* Zone and *F. charveti* — *Albaillella yamakitai* Assemblage-zone of Kuwahara *et al.* (1998), totally indicating late Middle to early Late Permian in age. Based on the above discussion, it seems that the cherts at five localities including Kido's (1986) two localities range in age from Early to Late Permian at intervals of barren of radiolarians; *i.e.*, late Early, middle Middle and late Middle to middle Late Permian.

Because the presence of some established radiolarian zones is still unknown within the examined cherts in the Nishizu district, chronologic duration of the chert sequence is quite difficult to confirm, even for Permian, through this work in addition to previous studies. It's ascribed to some factors such as the sampling method and preservation of radiolarians. In this work, the chert samples were not sequentially collected from successive sections, but were gathered

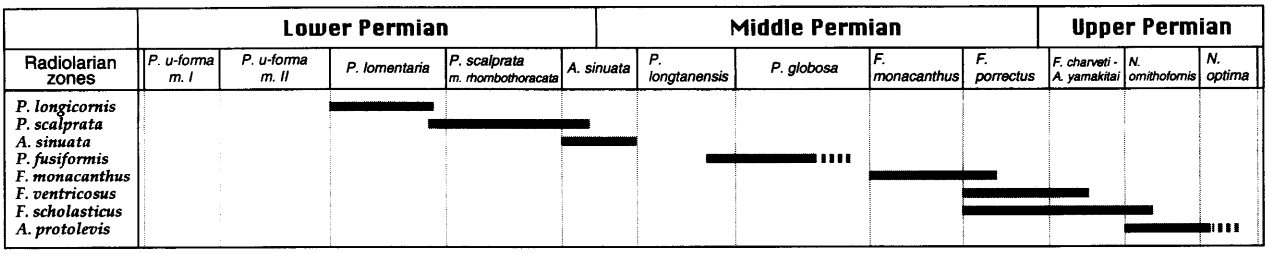

Fig. 6 Stratigraphic distribution of the selected Permian radiolarian fossils.
The radiolarian zones and the range of each species are referred from Ishiga (1986, 1991) and Kuwahara *et al*. (1998). *P.* : *Pseudoalbaillella*, *A.* : *Albaillella*, *F.* : *Follicucullus*, *N.* : *Neoalbaillella*, m: morphotype.

randomly from sporadic outcrops. In order to determine the whole age of the chert sequence, a great effort to collect many samples will be necessary and inevitable.

6.2 Relation between the age and dimension of chert slabs

Cherts in the Nishizu district occur as slabs in two forms; small-scale lenticular and large-scale sheet-like. The small-scale chert slabs are commonly not accompanied by other rocks such as basalt, limestone, mudstone or sandstone, and are enveloped in the pelitic mixed rock. On the other hand, cherts are always associated with basalts in the case of large-scale sheet-like slabs. As mentioned before, such occurrence of the large-scale slabs of chert and basalt is called 'basalt-chert composite'.

This study reveals that most of the chert samples yielding the examined Permian radiolarians were taken from 'basalt-chert composite' slabs, but only the sample NZ83-07 came from a small slab. In addition, Permian radiolarians were also detected from a 'basalt-chert composite' slab by Kido (1986) (See Locs. 1 to 5 and K in Fig. 1). From the above evidence, it may be said that both types of the slab are assigned to Permian, irrespective of the size and shape of the slabs. Nevertheless, the existence of small-scale slabs having Triassic and Jurassic radiolarians has already been recognized in this district (Ito *et al*., 1982; Fujii, 1991). Consequently, it is not clear now whether the chert slabs have some kinds of relation to their age, size and shape or not.

7. Conclusions

Permian radiolarians from cherts of the Tamba Terrane in the Nishizu district, southwestern Fukui Prefecture, were identified and examined. The results are as follows;

(1) Cherts generally occur as slabs, which are classified into small-scale lenticular and large-scale sheet-like types.
(2) Both the two types of slabs yielded Permian radiolarians.
(3) Five chert samples yielded Permian radiolarian assemblages, three of which are late Early, middle Middle and middle Late Permian in age, on the basis of previously known chronologic ranges of index species.
(4) No relationship is recognized between the age and dimension of chert slabs whom Permian radiolarians were detected from.

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福井県西津地域における丹波テレーンのチャートから産出したペルム紀放散虫

中江　訓

要　旨

福井県南西部の西津地域に分布する丹波テレーンのチャートからペルム紀放散虫化石を産出した．この地域の丹波テレーンは主に玄武岩・石灰岩・チャート・泥岩・砂岩から構成され，これらが複雑に混在した特徴をもっている．本地域における従来の化石層序学的研究はあまり多くないが，これまでにペルム紀・三畳紀・ジュラ紀の放散虫化石の産出が報告されていた．しかしながら本地域の丹波テレーン構成岩類の詳細な地質年代は明らかにされていない．本研究で新たに得られた放散虫化石によって，本地域のチャートの年代が前期ペルム紀の後半，中期ペルム紀の中頃，後期ペルム紀の中頃を示すことが判明した．またチャートは様々な規模と形態の岩体をなして露出するが，本研究によって，チャート岩体の規模とは関係なくペルム紀の放散虫化石が産出することが示された．

難読・重要地名： Tamba：丹波，Nishizu：西津，Mita：三田，Kaminaka：上中，Ota：太田，Mihama：美浜，Sekumi：世久見，Shikimi：食見，Mikata：三方