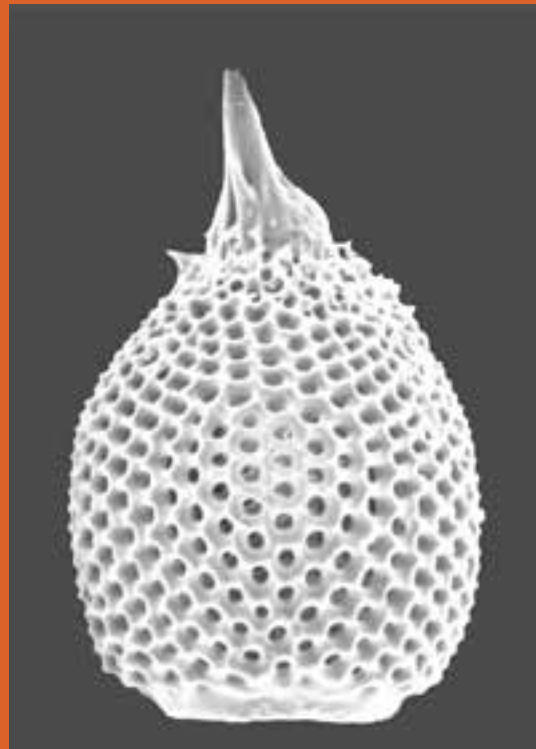


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A tribute to Prof. Kojiro NAKASEKO

編集 堀 利栄・竹村 厚司



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Swollen type of *Albaillella sinuata* Ishiga and Watase (Permian radiolaria) from a chert boulder in Ie-jima Island, Okinawa Prefecture, Japan

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Abstract Cisuralian (Early Permian) radiolarians occurred in a chert boulder within Pleistocene limestones in Ie-jima Island, Okinawa Prefecture, Japan. The upper and lower parts of the chert boulder are correlated to the *Pseudoalbaillella rhombothoracata* Assemblage-Zone and the *Albaillella sinuata* Range-Zone in Southwest Japan, respectively. Swollen type of *Albaillella sinuata* Ishiga and Watase occurred commonly in one horizon of the upper part. The population ratios of typical swollen type and intermediate form to the total number of *Albaillella sinuata* from the horizon are 27.1% and 13.6%, respectively. The morphological distribution of the species from this horizon is characterized by high percentage of both typical normal type and swollen type, while the intermediate form is not common. The occurrence of swollen type of *Albaillella sinuata* has distributional differences among areas, like other *Albaillellaria* species. The previous study suggested that the appearance of swollen type *Albaillellaria* is caused by the alternating generations in sexual and asexual reproductive stages. If the appearance of swollen type of *Albaillella sinuata* was also caused by the alternating generations, the horizon had been formed under the special environment inducing appearance of sexual generation.

Key words dimorphism, Cisuralian (Early Permian), radiolaria, Japan, Okinawa Prefecture, swollen type

Introduction

Albaillellaria (inc. *Albaillella* Deflandre, *Pseudoalbaillella* Holdsworth and Jones, *Follicucullus* Ormiston and Babcock, and *Neoalbaillella* Takemura and Nakaseko) is a major index order among late Paleozoic radiolarians. Most of upper Paleozoic radiolarian zones have been constructed on the basis of *Albaillellaria* occurrence (e.g., Ishiga, 1986, 1990; Blome and Reed, 1995; Kuwahara et al., 1998; De Wever et al., 2001). Ishiga (1991) pointed out the dimorphism of *Albaillellaria*: normal type and swollen type. The latter type is characterized by having a strongly-swollen conical part (e.g., apical cone, apical portion) as its name suggests. Ishiga (1991) examined the ratios of swollen and normal types with Permian *Albaillellaria* (*Pseudoalbaillella* sp. aff. *P. longicornis* Ishiga and Imoto, *Pseudoalbaillella ornata* Ishiga and Imoto, *Pseudoalbaillella sakmarensis* (Kozur), *Pseudoalbaillella*

elongata Ishiga and Imoto, *Pseudoalbaillella rhombothoracata* Ishiga, and *Neoalbaillella ornithoformis* Takemura and Nakaseko). He showed that the ratios of swollen type are different among these species. Wu et al. (2010) described swollen type of *Neoalbaillella* as a new species for a practical usage. Previous studies have shown a few illustrated specimens in literatures of swollen type.

We obtained Cisuralian (Early Permian) radiolarian fossils from a chert boulder in Ie-jima Island, Okinawa Prefecture, Japan. Swollen type of *A. sinuata* Ishiga and Watase occurred commonly in one horizon of the boulder. Although the locality of the radiolarian occurrence in this study is probably the same as that in Ujiie and Ohba (1991), they illustrated only two specimens of swollen type. Additionally, they did not identify it as swollen type of *A. sinuata* but as gen. et sp. indet. because the study had been done before the establishment of the swollen

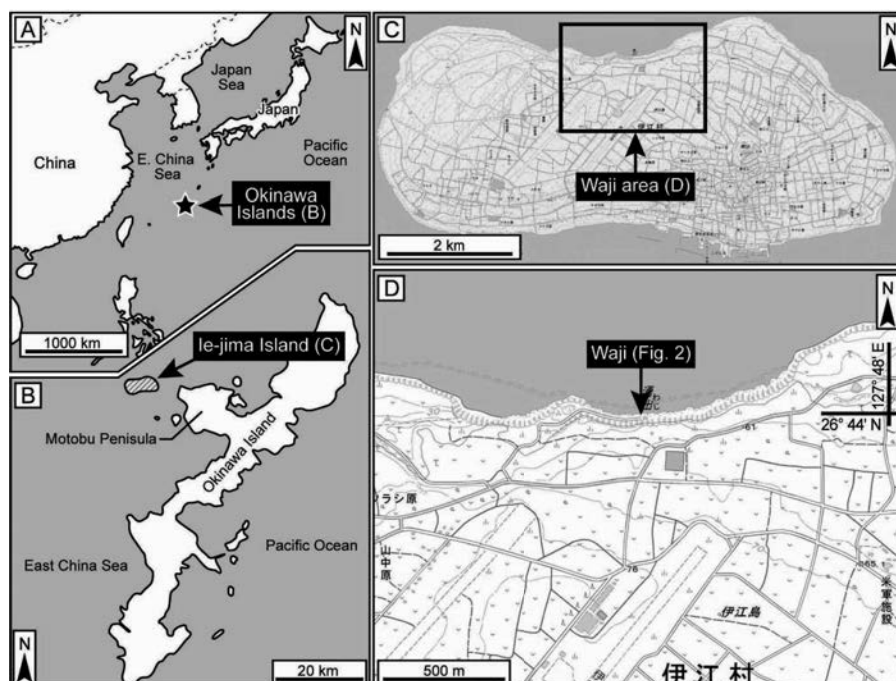


Fig. 1. Index map of Waji in Ie-jima Island, Okinawa Prefecture, Japan. Maps C and D are from topographic maps published by Geospatial Information Authority of Japan.

type by Ishiga (1991). Xia and Zhang (1998) found swollen type of *A. sinuata* from the Gufeng Formation in South China. They identified it as *A. sp. aff. A. sinuata*. In this paper, we describe normal and swollen types of *A. sinuata* with photomicrographs to show its morphological variation.

Geological setting

Ie-jima Island is situated about 9 km northwest of the Motobu Peninsula of Okinawa Island, Okinawa Prefecture, Japan (Fig. 1). Most areas of Ie-jima Island are covered by Pleistocene limestones belonging to the Ryukyu Group except for Paleozoic–Mesozoic basement rocks exposed around Mt. Gusuku-yama (Nakae et al., 2010). Mountain Gusuku-yama, located at the center of Ie-jima Island, is composed of cherts ranging from Lopingian (Late Permian) to Late Jurassic in age (Shen et al., 1996). There are some red chert clasts at Waji in the north margin of Ie-jima Island (Fig. 1). Permian radiolarian occurrences had been reported from Waji (Ujii and Ohba, 1991; Shen et al., 1996). Ujii and Ohba (1991) recognized *Albaillella sinuata*, *Albaillella sp.*, *Pseudoalbaillella sp.*, *Follicucullus monacanthus* Ishiga and Imoto, *F. scholasticus* Ormiston and Babcock, *Latentifistula patagilaterala* Nazarov and Ormiston, *Hegleria sp.*, *Quadrirremis sp.*, and gen. et sp.

indet. (= swollen type of *A. sinuata*). Shen et al. (1996) found *A. triangularis* Ishiga, Kito and Imoto, *Entactinia modesta* Sashida and Tonishi, *Heiloentactinia sp.*, and *Palaeoscenidium sp.* from some red cherts at Waji.

Red cherts at Waji are exposed as clasts within Pleistocene limestones belonging to the Ryukyu Group (Fig. 2). The chert clasts are scattered in the limestones (Figs. 2A, 2B). These clasts are not rounded but are irregular in shape. The rims of the chert clasts are intricately-shaped (Fig. 2C). The chert clasts vary in size ranging from several millimeters to about 6 m in diameter. We named the chert sequence in the biggest chert boulder in Waji as the Waji section (Fig. 2D). The Waji section is 480 cm in total thickness. The section consists of red cherts with intercalated claystones. The red cherts are well-bedded; a few chert beds are amalgamated. The thicknesses in each bed of the red cherts are 4 mm to 115 mm; those of the intercalated claystone are 2 mm to 64 mm. The thickest part, where three beds are amalgamated, is 142 mm.

Materials and Methods

Seven samples were collected from the Waji section (Figs. 2D and 3). The samples were crushed into fragments of about 1 cm size, and the fragments were soaked in a hydrofluoric acid

Swollen type of *Albaillella sinuata*

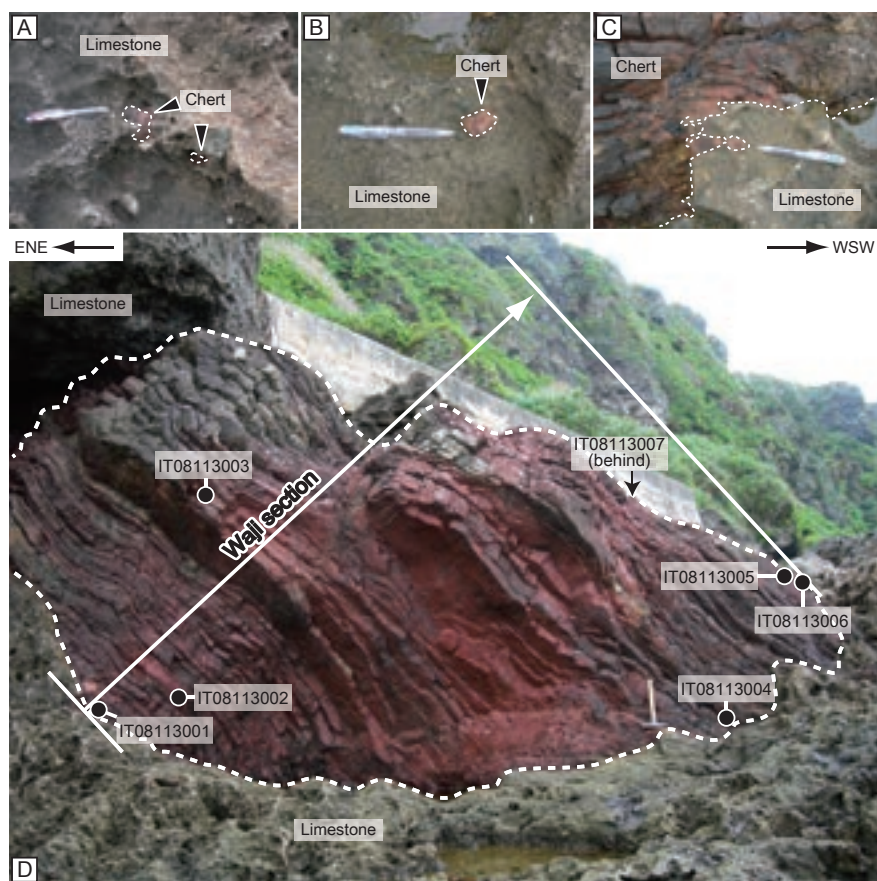


Fig. 2. Exposures of cherts in the Waji area. A, B: chert pebbles in limestone. C: boundary between chert boulder and limestone matrix. D: overall view of the Waji section at Waji.

(HF) solution (about 5%) for 24 hours at room temperature. This procedure was repeated by changing the HF solution until adequate residues were collected. After that, the adequate residues were collected through a sieve with a mesh diameter of 0.054 mm and dried for examination under a binocular microscope. A part of the residues was enclosed within prepared slides with a mounting medium (Entellan new) and photographed with a transmitted light microscope. The well-preserved radiolarians were later mounted on stubs and photographed with a scanning electronic microscope (SEM) for more detailed observations.

Radiolarian assemblages

Figure 3 shows the radiolarian distribution in the Waji section. Photomicrographs of selected specimens are shown in Figs. 4 and 5. We divided the section into the upper and lower parts on the basis of radiolarian assemblages. The radiolarian assemblage of the lower part consists of *Pseudoalbaillella postscalprata* Ishiga, *Albaillella asymmetrica*, *Albaillella* sp.,

Latentifistula sp., *Hegleria mammilla* (Sheng and Wang), *Pseudotormentus kamigoriensis* Caridroit and De Wever, *Triaenosphaera* sp., *Entactinia itsukaichiensis* Sashida and Tonishi, and *Entactinia?* sp. The lower part corresponds to the *Pseudoalbaillella scalprata* m. *rhombothoracata* Assemblage-Zone in Southwest Japan of Ishiga (1986, 1990). We rename this *Pseudoalbaillella scalprata* m. *rhombothoracata* Assemblage-Zone as the *Pseudoalbaillella rhombothoracata* Assemblage-Zone according to re-description of *Pseudoalbaillella rhombothoracata* by Shimakawa and Yao (2006). The radiolarian assemblage of the upper part is composed of *Albaillella sinuata*, swollen type of *A. sinuata*, *Albaillella* sp., *Pseudoalbaillella longtanensis* Sheng and Wang, *Latentifistula texana* Nazarov and Ormiston, *Latentifistula* sp., *Hegleria mammilla*, *Quadricaulis inflata* (Sashida and Tonishi), *Pseudotormentus kamigoriensis*, *Triaenosphaera* sp., *Entactinia itsukaichiensis*, and *Entactinia?* sp. The upper part corresponds to the *Albaillella sinuata* Range-Zone in Southwest Japan of Ishiga (1986, 1990).

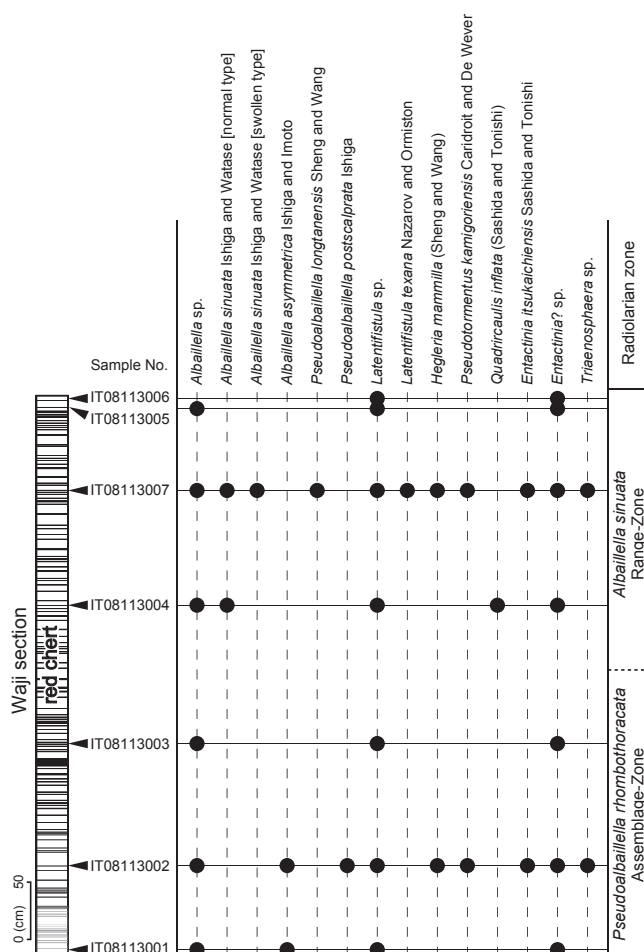


Fig. 3. Lithological columnar section and radiolarian distribution in the Waji section. White part: chert bed; black part: intercalated claystone.

Systematic paleontology

In this chapter, we deal with only normal and swollen types of *A. sinuata* among radiolarian assemblages of the present study. Swollen type of *A. sinuata* occurred commonly in sample IT08113007. Swollen type of *Albaillellaria* other than *A. sinuata* was not obtained from the sample. No swollen type of *Albaillellaria* is found in other samples.

Order ALBAILLELLARIA Deflandre, 1953

Family Albaillellidae Deflandre, 1952, sensu emend.

Holdsworth, 1977

Genus *Albaillella* Deflandre, 1952, sensu emend.

Holdsworth, 1966

Type species: *Albaillella paradoxa* Deflandre, 1952

Albaillella sinuata Ishiga and Watase, 1986

Figs. 4.1–4.6

Albaillella sp. D. Ishiga et al., 1982a, pl. 4, figs. 1–3, 5–7.

Albaillella sp. D. Ishiga et al., 1982b, p. 24, pl. 1, figs. 17, 18.

Albaillella sp. D. Ishiga and Suzuki, 1984, pl. 1, figs. 1–7, 11.

Albaillella sp. A. Yamamoto, 1985, pl. 1, fig. 1.

Albaillella sinuata Ishiga and Watase n. sp. Ishiga et al., 1986, p. 126, pl. 1, figs. 1–8.

Albaillella sinuata Ishiga and Watase. Sano, 1988, pl. 2, fig. 5.

Albaillella sinuata Ishiga and Imoto. Ishiga, 1990, p. 293, pl. 1, fig. 15.

Spinodeflandrella sinuata (Ishiga and Watase). Rudenko and Panasenko, 1990, p. 190, pl. 19, fig. 5.

Spinodeflandrella acutata Rudenko n. sp. Rudenko and Panasenko, 1990, p. 191, pl. 19, fig. 6.

Spinodeflandrella bicornuta Rudenko and Panasenko n. sp. Rudenko and Panasenko, 1990, p. 191, pl. 19, fig. 7.

Albaillella sinuata Ishiga and Watase. Ujiie and Ohba, 1991, p. 51, pl. 2, figs. 7, 8.

Albaillella sinuata Ishiga and Watase. Blome and Reed, 1992, p. 363, figs. 9.7, 9.8.

Albaillella sinuata Ishiga and Watase. Sashida et al., 1993, p. 105, fig. 6.7.

Albaillella sinuata Ishiga and Watase. Takemura and Yamakita, 1993, p. 49, pl. 1, fig. 7.

Albaillella sinuata Ishiga, Kito and Imoto. Wang et al., 1994, p. 200, pl. 2, fig. 13.

Albaillella sinuata Ishiga and Watase. Kuwahara, 1997, p. 70, pl. 1, fig. 8.

Albaillella sinuata Ishiga and Watase. Kuwahara and Yao, 1998, p. 42, pl. 1, fig. 6.

Pseudoalbaillella sinuata Ishiga and Watase. Sashida et al., 1998, p. 21, fig. 11.19. (written as *Albaillella sinuata* Ishiga and Watase in the text)

Albaillella sinuata Ishiga and Watase. Xia and Zhang, 1998, p. 198, pl. 1, figs. 2, 4.

Albaillella sinuata Ishiga and Watase. Wang et al., 1998, p. 369, pl. 3, fig. 1.

Albaillella sinuata. Nakae, 2001, p. 250, figs. 5a–5c.

Swollen type of *Albaillella sinuata*

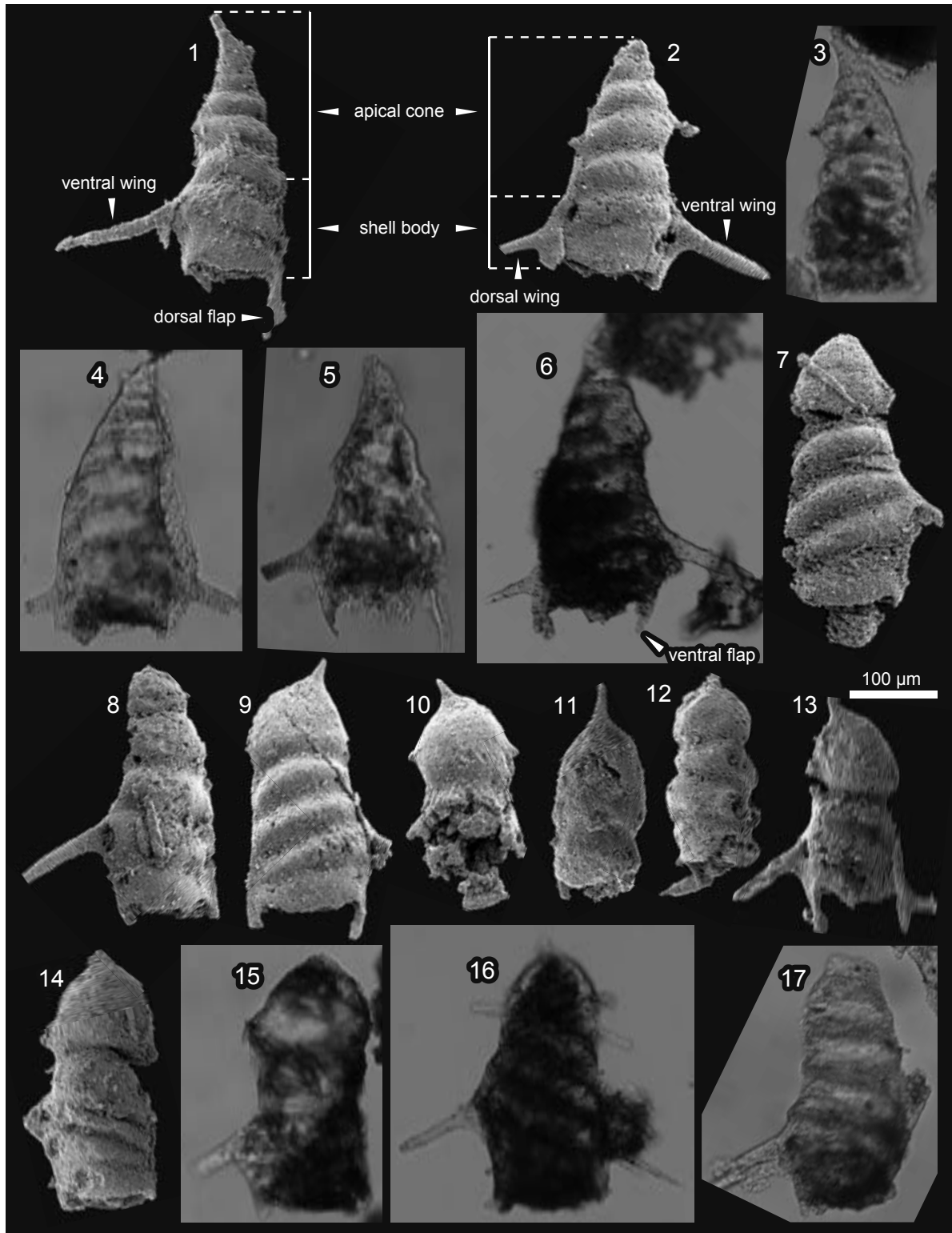


Fig. 4. Photomicrographs of normal and swollen types of *Albaillella sinuata* Ishiga and Watase from the red chert (IT08113007) of the Waji section. 1–6: normal type; 8, 17: intermediate form (weakly-inflated) between normal and swollen types; 7, 9–16: swollen type.

Pseudoalbaillella sinuata Ishiga and Watase. Sashida and Salyapongse, 2002, p. 695, fig. 3.19. (written as *Albaillella sinuata* in the text)

Albaillella sinuata Ishiga and Watase. Sun et al., 2002, p. 211, *Albaillella sinuata* Ishiga and Watase. Hori, 2004, p. 300, pl. 4, figs. 16–23, 27–29.

Albaillella sinuata Ishiga and Watase. Kametaka, 2006, p. 537, figs. 4.1–4.5.

Albaillella sinuata. Kurihara and Kametaka, 2008, p. 537, fig. 3.17–3.19.

Albaillella sinuata Ishiga, Kito and Imoto. Mitsumura and Kamata, 2009, p. 568, pl. 3, fig. 3.

Albaillella sinuata Ishiga and Watase. Xie et al., 2011, p. 212, figs. 3N, 3O.

Albaillella sinuata Ishiga and Watase. Wang and Yang, 2011, p.

138, figs. 4.E, 4.F.

Albaillella sinuata Ishiga and Watase. Wang et al., 2012; pl. 14, figs. 1–3, 17, 24–26, 46, 47, pl. 15, figs. 22, 23, pl. 17, figs. 1, 2.

Albaillella sinuata Ishiga and Watase. Burrett et al., 2015, p. 123, figs. 13i, 13j.

Albaillella sinuata Ishiga and Watase. Ito and Matsuoka, 2015, p. 158, figs. 7.1–7.5.

Materials: Thirty-five specimens were collected from sample IT08113007 and 25 specimens were examined by a SEM or an optical microscope. Six specimens were illustrated.

Remarks: Shell, which consists of apical cone and shell body, is conical and inclines toward the ventral side. Shell surface is obliquely traversed by six or more bands. Rod-like wings extend from dorsal and ventral sides of shell body. Both wings

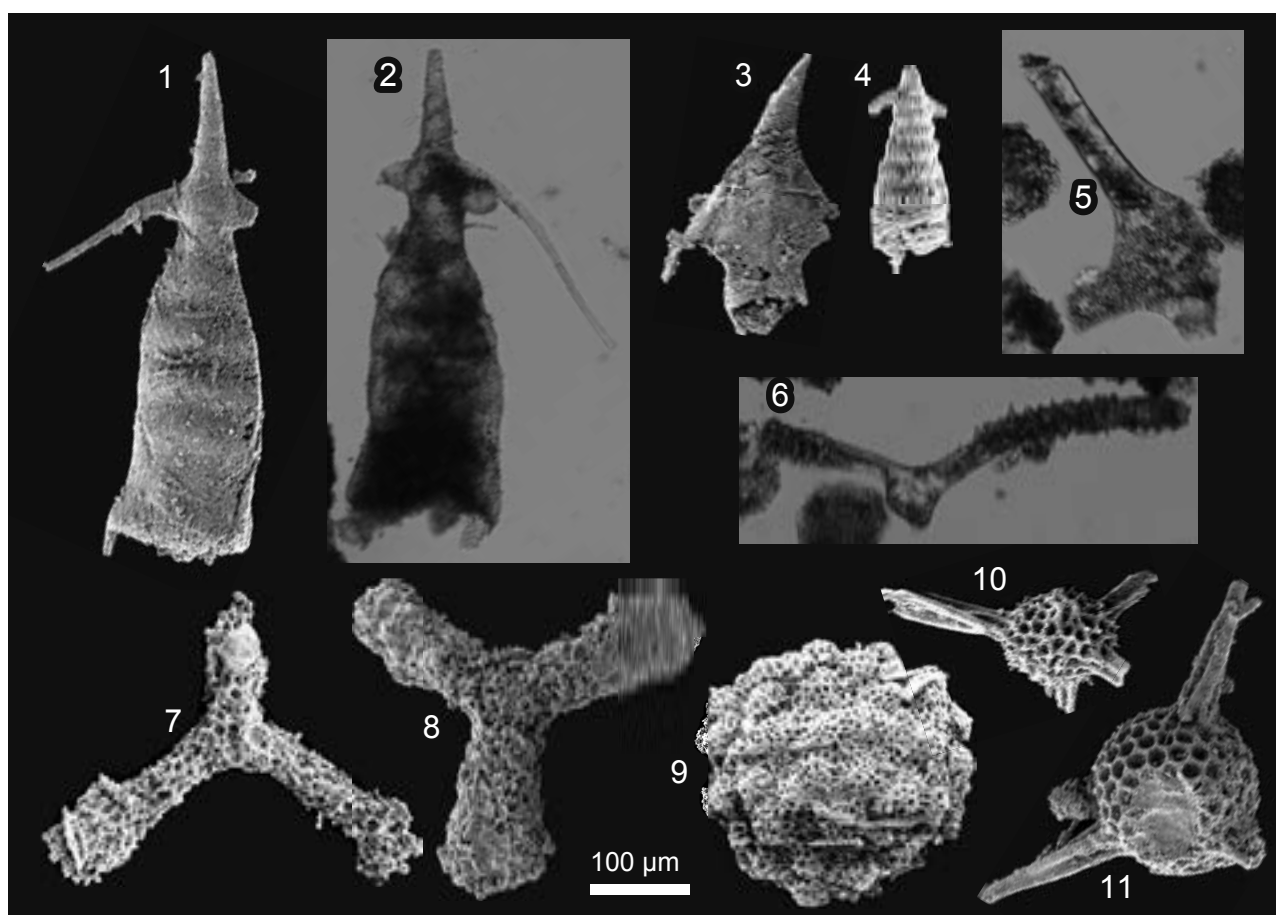


Fig. 5. Photomicrographs of Ciszurialian (Early Permian) radiolarians from cherts in the Waji section. 1, 2: *Pseudoalbaillella longtanensis* Sheng and Wang; 3: *Pseudoalbaillella postscalprata* Ishiga; 4: *Albaillella asymmetrica* Ishiga and Imoto; 5: *Quadricaulis inflata* (Sashida and Tonishi); 6: *Pseudotormentus kamigoriensis* Caridroit and De Wever; 7: *Latentifistula texana* Nazarov and Ormiston; 8: *Latentifistula* sp.; 9: *Hegleria mammilla* (Sheng and Wang); 10: *Entactinia itsukaichiensis* Sashida and Tonishi; 11: *Triaenospaera* sp. 1, 2, 7, 8, 10, 11: IT08113007; 3, 4, 9: IT08113002; 5: IT08113004; 6: IT08113003.

are slightly curving downward. Flaps extend from dorsal and ventral sides of the base of shell body. Morphological comparisons between normal and swollen types of *A. sinuata* will be mentioned later.

Occurrences: Normal type of *A. sinuata* occurred abundantly in the upper part of the Waji section. This species had been reported from the Cisuralian–Guadalupian in Japan, U.S.A., South China, Russia, and Thailand. Normal type of *A. sinuata* has co-occurred with the Lopingian radiolarian assemblage in Southwest Japan (Takemura and Yamakita, 1993; Kuwahara, 1997; Kuwahara and Yao, 1998). However, Takemura and Yamakita (1993) considered it as a reworked fossil because of the scarcity of this species within the assemblage.

Swollen type of *Albaillella sinuata* Ishiga and Watase, 1986

Figs. 4.7–4.17

Albaillella sp. D. Ishiga et al., 1982a, p. 54, pl. 4, fig. 4.

Gen. et sp. indet. Ujiie and Ohba, 1991, p. 55, pl. 4, figs. 9–10.

Albaillella sp. aff. *A. sinuata* Ishiga and Watase. Xia and Zhang, 1998, p. 198, pl. 1, figs. 5–7.

? *Albaillella sinuata* Ishiga and Watase. Xia and Zhang, 1998, p. 198, pl. 1, figs. 1, 3.

? *Albaillella sinuata* Ishiga and Watase. Zhang et al., 2010, p. 144, fig. 5.R.

? *Spinodeflandrella obtusa* Rudenko n. sp. Rudenko and Panasenko, 1990, p. 192, pl. 20, figs. 5, 6.

Materials: Sixteen strongly-inflated specimens of swollen type were collected from sample IT08113007 and 15 specimens of them were examined by a SEM or an optical microscope. Eight

weakly-inflated specimens of swollen type were collected and examined by a SEM or an optical microscope from sample IT08113007. Eleven specimens of swollen type were illustrated in this paper.

Remarks: Shell is conical with swollen apical cone or cylinder-like form. Shell surface is obliquely traversed by five or less bands; bands in middle–upper parts of apical cone are unobservable in strongly-inflated specimens (e.g., Figs. 4.10, 4.11). Rod-like wings extend from dorsal and ventral sides of shell body. Both wings are slightly curving downward. Flaps extend from dorsal and ventral sides of the base of shell body. There is no broad difference in total length of its shell between normal and swollen types. An inflated part of all swollen type specimens is situated above its wings. Specimens of swollen type vary from weak (e.g., Figs. 4.8, 4.17) to strong (e.g., Fig. 4.10) in swollenness.

Occurrences: Swollen type of *A. sinuata* occurred commonly in one horizon of the Waji section (sample IT08113007). Swollen type of *A. sinuata* has occurred in the Cisuralian–Guadalupian in the Tamba area of Southwest Japan and the Xiaodong area of South China.

Discussion

We obtained 59 specimens of *A. sinuata* from sample IT08113007 of the Waji section. The population ratios of each type to the total number are as follows: non-inflated specimens (typical normal type): 59.3%; weakly-inflated specimens (intermediate form between normal and swollen types): 13.6%; strongly-inflated specimens (typical swollen type): 27.1% (Fig. 6). This indicates that normal type specimens are more

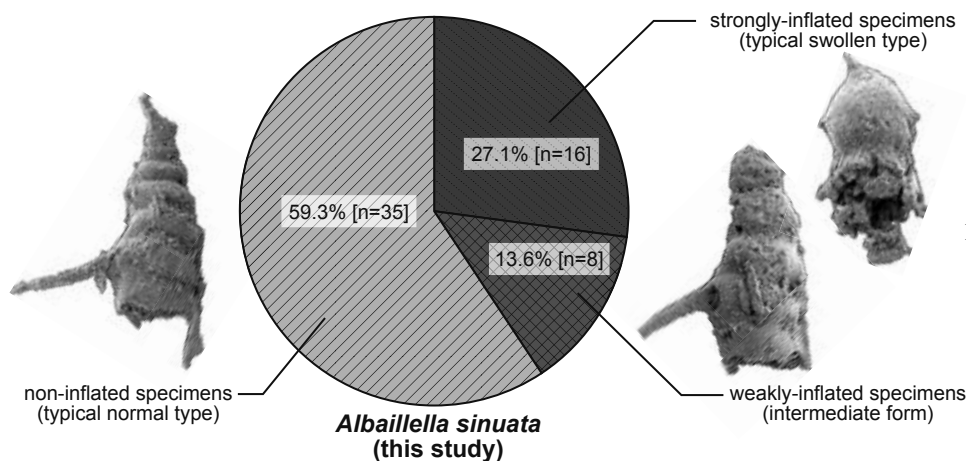


Fig. 6. A pie graph showing the ratios of non-, strongly-, and weakly-inflated specimens of *Albaillella sinuata* Ishiga and Watase from the red chert (IT08113007) of the Waji section.

abundant than that of swollen type. In addition, intermediate form is less abundant than those of both typical types. Ishiga (1991) examined the ratios between normal and swollen types in several species of *Pseudoalbaillella* and *Neoalbaillella*. According to him, the ratios of swollen type to total number of the species are not more than 10% (Fig. 7). However, the ratio of swollen type of *A. sinuata* of sample IT08113007 in the Waji section is over 40%.

The occurrence of strongly-inflated specimens of *A. sinuata* is confined to a few areas. Although a weakly-inflated specimen was reported from the Tamba area (Ishiga et al., 1982a, pl. 4, fig. 4), strongly-inflated specimen has never been reported yet. The specimens of swollen type in the Waji section are morphologically similar to those from the Gufeng Formation in the Xiaodong area (Xia and Zhang, 1998). Meanwhile, swollen type specimens of *P. globosa* Ishiga and Imoto (described as morphotype of *P. globosa* in the original paper) co-occurred in the Xiaodong area; no swollen type other than *A. sinuata* was found from the Waji section.

The occurrence of swollen type *Albaillellaria* significantly differs among areas and depends on species (Ishiga, 1991).

Ishiga (1991) suggested that the dimorphism is caused by alternating generations in sexual and asexual reproductive stages. De Wever et al. (2001) indicated the presence of radiolarian sexual dimorphism which could be result of alternating generations in the reproductive cycle as is known for foraminifera. Foraminifera has two forms in the life cycle, namely agamont (sexual generation) and gamont (asexual generation) (Goldstein, 1999). In the case of foraminifera, the population ratio of agamont to gamont is extremely low (lower than 0.1%) (e.g., Fujita et al., 2000). The present study reports high percentage of swollen type of *A. sinuata* (higher than 40%). Leutenegger (1977) pointed out the possibility that sexual reproduction is limited to certain ecological zones. If the dimorphism of *Albaillellaria* was also caused by the alternating generations in the reproductive cycle, the horizon had been formed under the special environment inducing appearance of sexual generation. Meanwhile, swollen type has morphological features different from each holotype. Therefore, it seems that few swollen type specimens had been illustrated with figures in literatures. It is necessary to show illustrated specimens for more-detailed study.

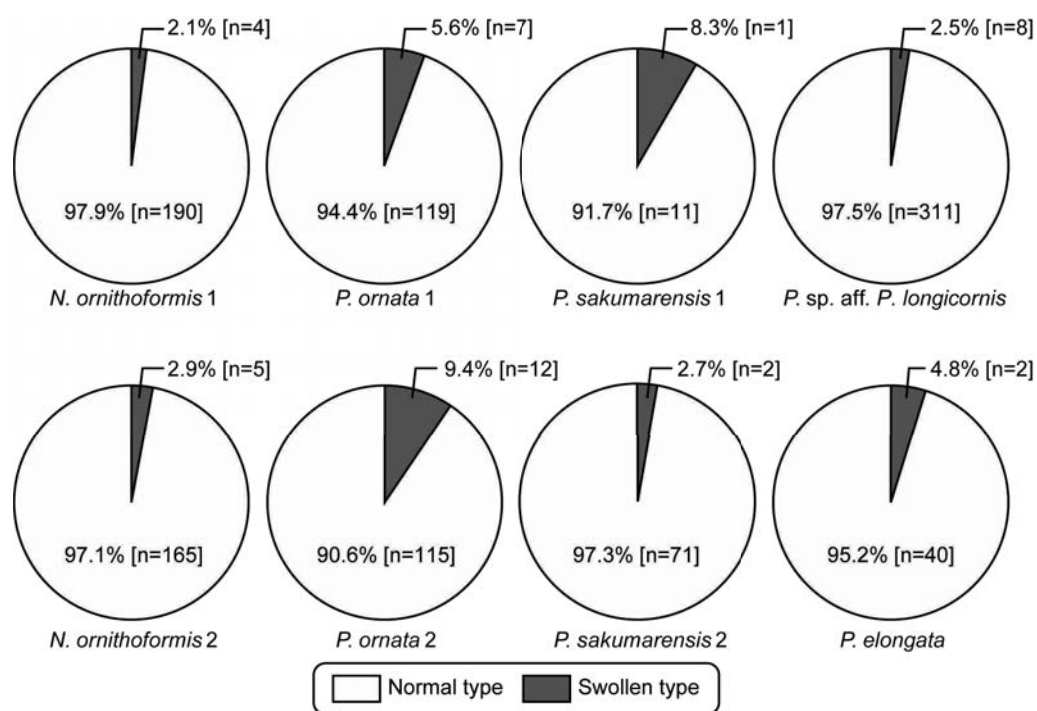


Fig. 7. Pie graphs showing the ratio of normal and swollen types of some species of *Pseudoalbaillella* and *Neoalbaillella* (*Albaillellaria*). The data are based on those of Ishiga (1991). Note: Ishiga (1991) did not divide weakly-inflated and strongly-inflated specimens. The specimens identified as *P. sp. aff. P. longicornis* may include short forms of other species sensu Ito et al. (2015).

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A tribute to Prof. Kojiro NAKASEKO

Editors: HORI S. Rie and TAKEMURA Atsushi

Special Issue on The 11th Radiolarian Symposium in Matsuyama, Japan

-A memorial meeting for Prof. Kojiro Nakaseko

