ISSN 0031-0204

日本古生物学會
報告・紀事

Transactions and Proceedings of the Palaeontological Society of Japan

New Series No. 161

日 本 古 生 物 学 会

Palaeontological Society of Japan

April 30, 1991

Co-Editors **Tsunemasa Saito and Kei Mori**

Editorial Board

Yoshikazu Hasegawa (Yokohama National University), Itaru Hayami (University of Tokyo), Hisayoshi Igo (University of Tsukuba), Makoto Kato (Hokkaido University), Itaru Koizumi (Hokkaido University), Yasumochi Matoba (Akita University), Kei Mori (Tohoku University), Hiroshi Noda (University of Tsukuba), Kazushige Tanabe (University of Tokyo), Tsunemasa Saito (Tohoku University), Kazuhiko Uemura (National Science Museum), Akira Yao (Osaka City University)

Officers for 1991–1992

President: Kiyotaka Chinzei
Honorary President: Teiichi Kobayashi
Councillors: Kiyotaka Chinzei, Takashi Hamada, Yoshikazu Hasegawa, Itaru Hayami, Hiromichi Hirano, Hisayoshi Igo, Noriyuki Ikeya, Junji Itoigawa, Tomoki Kase, Makoto Kato, Tatsuaki Kimura, Itaru Koizumi, Kei Mori, Hiroshi Noda, Ikuwo Obata, Kenshiro Ogasawara, Tomoo Ozawa, Tsunemasa Saito, Yokichi Takayanagi, Kazushige Tanabe
Members of Standing Committee: Hiromichi Hirano (General Affairs), Tomoki Kase (Finance), Tsunemasa Saito (Editor in Chief, TPPSJ), Kei Mori (Co-Editors, TPPSJ), Noriyuki Ikeya (Planning), Hiroshi Noda (Membership, Co-Editor, Special Paper), Kazushige Tanabe (Foreign Affairs), Itaru Hayami (Editor, "Fossils"), Juichi Yanagida, (Co-Editors, Special Paper), Tatsuaki Kimura (Friends of Fossils)
Secretaries: Akito Asai, Tatsuo Oji (General Affairs), Masanori Shimamoto (Editorial of TPPSJ), Hiroshi Kitazato (Planning), Katsuo Sashida (Membership), Yukimitsu Tomida (Foreign Affairs), Katsumi Abe (Editorial of "Fossils"), Takeshi Ishibashi (Editorial of Special Paper), Tamiko Ohana (Friends of Fossils)
Auditor: Kuniteru Matsumaru

The fossil on the cover is *Trilophodon sendaicus* Matsumoto, an extinct elephant, which was described from the Pliocene Tatsunokuchi Formation developed in the vicinity of Sendai, Northeast Honshu, Japan. (IGPS coll. cat no. 87759 (A), lenght is about 185 cm)

All communication relating to this journal should be addressed to the
PALAEONTOLOGICAL SOCIETY OF JAPAN
c/o Business Center for Academic Societies,
Yayoi 2-4-16, Bunkyou-ku, Tokyo 113, Japan

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 161, pp. 681-696, 7 Figs., April 30, 1991

912. EARLY TRIASSIC RADIOLARIANS FROM THE OGAMATA FORMATION, KANTO MOUNTAINS, CENTRAL JAPAN. PART 2*

KATSUO SASHIDA

Institute of'Geoscience, University of Tsukuba,
Ibaraki, 305

Abstract. Chert beds of the Ogamata Formation exposed in the upper reaches of the Nakatsugawa River, Kanto Mountains, yield abundant Early Triassic radiolarians. A part of this radiolarian fauna including the spicular type Palaeoscenidiidae was already described by the present author. As an addition to the study of this fauna, several newly discriminated Spumellaria and Nasellaria are described in this paper. The families Palaeoscenidiidae with a latticed shell, Pantanellidae, and Sponguriidae are included in the Spumellarians. The families Eptingiidae having a spumellarian-like affinity and Acanthodesmiidae are classified as Nassellaria in this study. Five new species, *Archaeothamnulus okuchichibuensis, Parentactinia virgata, Pactarentinia koikei, Pantanellium ? virgeum,* and *Spongostephanidium longispinosum*, are proposed herein.

Key words. Kanto Mountains, Ogamata Formation, radiolarian, Triassic.

Introduction

Our knowledge of Mesozoic radiolarian biostratigraphy has been rapidly increased in various land sections and through the Deep Sea Drilling Project for the past 15 years. However, Triassic radiolarian biostratigraphy seems to be rather behindhand compared with Jurassic and Cretaceous ones because of the lack of continuous rock sequence including well-preserved radiolarians except for the Upper Triassic in the Pacific Coast Side of North America (*e.g.*, Blome, 1984) and Middle Triassic calcareous rocks in the European Tethys (*e.g.,* Kozur and Mostler, 1981 ; Dumitrica, 1982). In Japan, several biostratigraphic works through the taxonomic studies of Triassic radiolarians were also undertaken by Nakaseko and Nishimura (1979), Yao (1982), Kishida and Hisada (1985), and Yoshida (1986). These works, however, were mainly focused on Middle to Late Triassic radiolarians. Biostratigraphic and taxonomic works on Early Triassic radiolarians are quite scarce except for my previous study on the spicule type radiolarians from the Ogamata Formation (Sashida, 1983).

Recently, I have succeeded to recover many conodonts and radiolarians from the same rock sample and also another chert bed exposed in the middle course of the Oyamazawa Valley near the type section of the Ogamata Formation. These two samples contain the same radiolarian fauna, which is characterized by abundant spumellarians, such as those belonging to the families Palaeoscenidiidae of both spicule and latticed shell types, Pantanellidae, Sponguriidae and several unidentified genera and species of Entactiniidae. The families Eptingiidae of spumellarian-like Nassellaria and Acanth-

---

*Received March 26, 1990 ; revised manuscript accepted December 20, 1990

odesmiidae are also discriminated in this fauna.

The geologic age of this radiolarian fauna is estimated as a late Spathian based on the co-occurring conodonts.

Acknowledgments

I thank Professor Hisayoshi Igo (University of Tsukuba) for his valuable suggestion and critical reading of this manuscript. I also thank Professor Toshio Koike (Yokohama National University) for his identification of conodonts. The present report was funded in part by the Grant-in-Aid for Cooperative Research from the Ministry of Education, Science and Culture (Grant no. 01304008) and the Project Research of the University of Tsukuba in 1988.

Geologic setting

The Ogamata Formation exposed in the area of the upper reaches of the Nakatsugawa River in Saitama Prefecture, was investigated by Fujimoto *et al.* (1950, 1957), Ishii (1962) and, Ishii and Matsukawa (1980). These authors regarded that the Ogamata Forma-

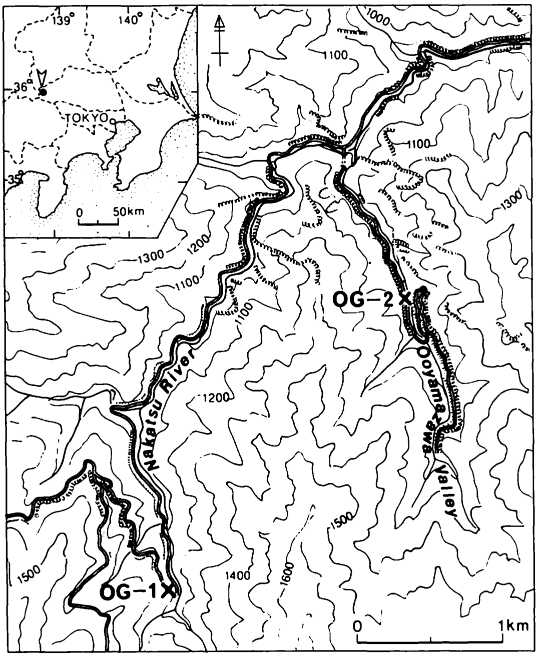


Figure 1. Map showing the sample localities.

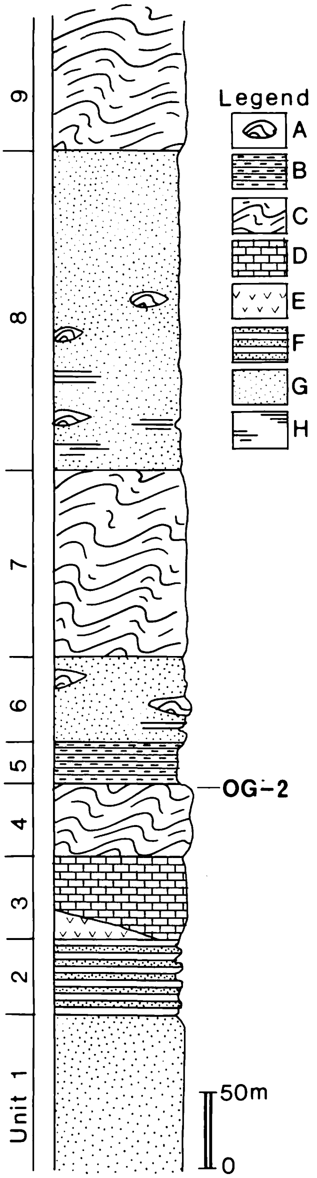


Figure 2. Generalized columnar section of the Ogamata Formation along the Oyamazawa Valley. **A** : chert block, **B** : dark green to gray siliceous shale, **C** : chert, **D** : limestone, **E** : basaltic rock, **F** : alternation of sandstone and shale, **G** : massive sandstone, **H** : black shale.

tion occupies the highest stratigraphic position of the so-called Chichibu System and is the Upper Permian. Sato *et al.* (1981) and Sashida *et al.* (1982), however, reported the occurrence of Jurassic radiolarians from argillaceous rocks of this formation and pointed out the necessity to revise the stratigraphy, geologic structure, and geochronology of the Ogamata Formation.

I summarized the stratigraphy of this formation in the type section, as follows (Sashida, 1983). The Ogamata Formation, about 1,200 m thick, consists mainly of argillaceous rocks including abundant exotic blocks of Carboniferous to Middle Permian limestone, Early Triassic to Early Jurassic chert, basaltic rock and sandstone. Based on the sedimentological features, the Ogamata Formation is presumed to be a subduction product of oceanic plate during the Middle Jurassic Period.

Recently, I have established the detailed superficial stratigraphy of this formation in the Oyamazawa Valley (Figures 1, 2) as follows in ascending order.

1. Medium- to fine-grained massive sandstone ; more than 200 m thick.
2. Alternation of sandstone and shale ; about 40 m thick.
3. White massive limestone with basaltic rock in the lower part ; about 50 m thick.
4. Black chert ; about 40 m thick.
5. Dark green to gray siliceous shale ; about 30 m thick.
6. Fine-grained sandstone including chert blocks of about 5 m in the maximum diameter and intercalating black shale in the lower part ; about 60 m thick.
7. Dark gray to green chert ; about 120 m thick.
8. Coarse- to medium-grained sandstone frequently including black shale beds and chert blocks in the lower to middle parts ; about 200 m thick.
9. Gray to green chert ; more than 150 m thick.

A thin-bedded black chert (OG-2) of the uppermost part of Unit 4 yields Early Triassic radiolarians, which are described in this paper. Late Middle Jurassic radiolarians

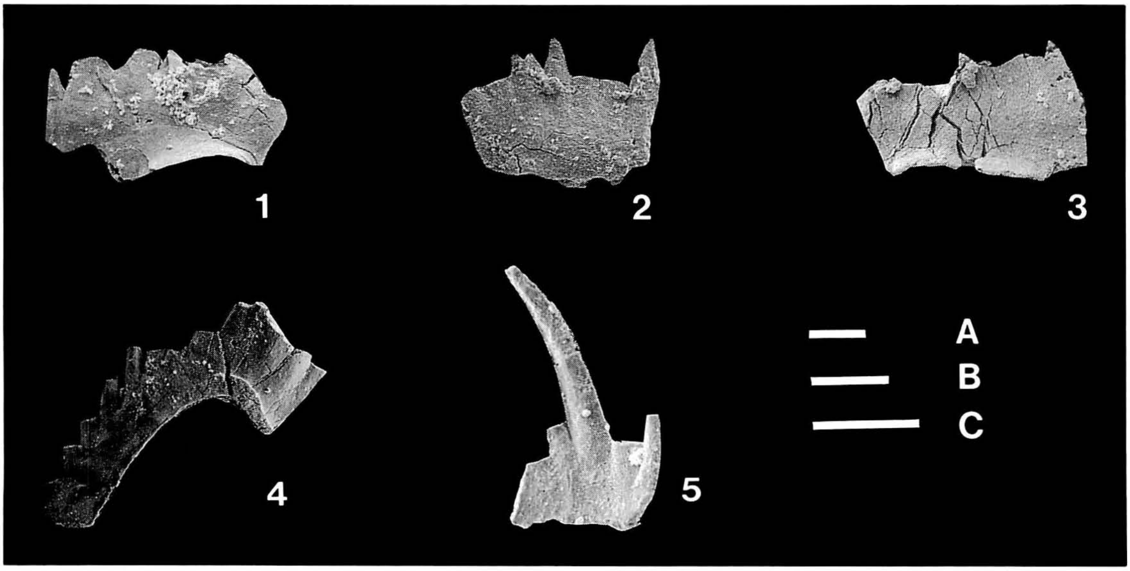


Figure 3. **1–3,** *Neospathodus* cfr. *homeri* (Bender), **1** : OG-1 ; **2** : OG-2 ; **3** : OG-1. **4,** *Ozarkodina* sp., OG-2. **5,** *Ellisonia* sp., OG-1. Scale bars, **A** to **C** equal to 100 μm ; **A** applies to **2, B** to **1, 3, 4,** and **C** to **5**.

occur abundantly in Unit 5 and a black shale interbedded with the sandstone of Unit 8. Chert beds of Unit 7 yield Middle to Late Triassic radiolarians. Early Jurassic radiolarians were recovered from a green chert of Unit 9. Each unit mentioned above is in contact with a northward dipping fault with a gouge of less than 20 cm thick except for the contact between Units 1 and 2. The alternation of sandstone and shale of Unit 2 conformably overlies the sandstone of Unit 1.

Geologic age of samples

Two chert samples OG-1 and OG-2 are studied in this study. The former one is the same sample, which was studied in my previous paper (Sashida, 1983). As mentioned above, OG-2 was collected from Unit 4, which crops out along the Oyamazawa Valley. These two samples yield abundant but poorly preserved conodonts, such as *Neospathodus* cfr. *homeri* (Bender), *Xaniognathus* sp., *Ellisonia* sp. and many unidentified ramiform elements. *N. homeri* is a well known age diagnostic species and has been reported from an interval from the Spathian to lower Anisian (Aegean) of Greek, Nevada, Italy, West Pakistan, British Columbia, Japan, and other areas. *Neospathodus timorensis* (Nogami) is frequently associated with *N. homeri* in the Aegean of the above mentioned areas, but the former species does not found in samples OG-1 and OG-2. The geologic age of two chert samples including these conodonts is considered to be Spathian rather than early Anisian.

Systematic description

All specimens described herein are deposited in the collection of Institute of Geoscience, the University of Tsukuba (IGUT).

Suborder Spumellaria Ehrenberg, 1875
Superfamily Entactiniacea Riedel, 1967
Family Palaeoscenidiidae Riedel, 1967 emend. Furutani, 1983

Remarks.—Although the family Palaeoscenidiidae is one of the representative groups of the Paleozoic Radiolaria, there are some confusions regarding the diagnosis of this family. The study of this group has been reviewed by Furutani (1983, 1990), Goodbody (1986), and Wakamatsu *et al.* (1990). The main differences of diagnosis of the family Palaeoscenidiidae between Furutani (1983) and Goodbody (1986) are obvious in number and disposition of spicule and with or without latticed shell. Goodbody (1986) emphasized the presence or absence of latticed shell as a distinguishing criterion between the families Palaeoscenidiidae and Entactiniidae. Namely, the latter family is characterized by a latticed or spongy and essentially spherical shell. Recently, Furutani (1990) has discriminated seven types of the skeletal construction in Silurian to Devonian spicule radiolarians. According to his study, the basic skeleton of many genera belonging to the family Palaeoscenidiidae differs clearly from that of the genera *Haplentactinia* Foreman, *Entactinia* Foreman, and others of the family Entactiniidae. Among the Furutani's seven types of spicule, the Type 4 is a typical skeleton of the genus *Palaeoscenidium* Defrandre, because it has four apical and basal spines and a tetrahedral projection, which is a perpendicular plane to the median bar. This type is also almost the same as that of the genera *Pactarentinia* Furutani and *Tlecerina* Furutani bearing a completely spherical outer shell. Furutani (1990) emphasized the skeletal similarity among these genera and insisted that the discriminative criteria between the families Palaeoscenidiidae and Entactiniidae should not be the presence or absence of latticed outer shell but the basic nature of spicule such as the number and disposition of

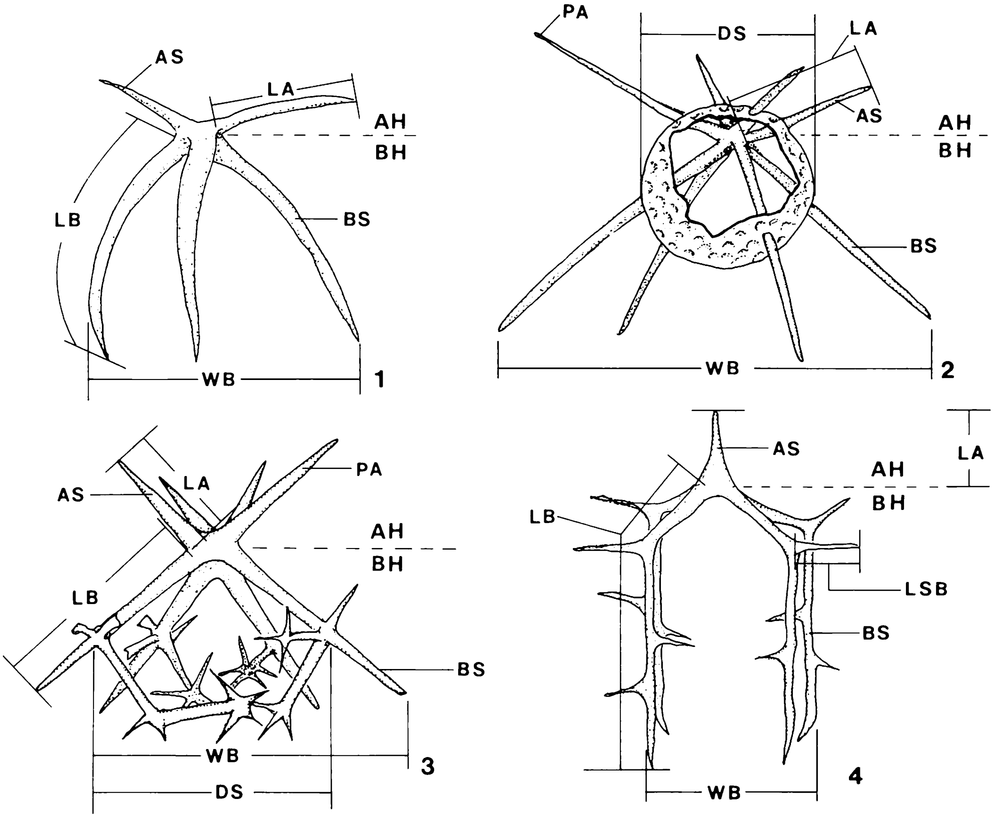


Figure 4. Schematically illustrated and measured parts of the subfamily Palaeoscenidiinae, and their letter indices. **1**: *Archaeosemantis* sp. **2**: *Pactarentinia koikei* Sashida, n. sp. **3**: *Parentactinia virgata* Sashida, n. sp. **4**: *Archaeothamnulus okuchichibuensis* Sashida, n. sp. Abbreviations; **AH**: apical hemisphere, **BH**: basal hemisphere, **AS**: apical spine, **BS**: basal spine, **PA**: primarily apical spine, **LA**: length of apical spine, **LB**: length of basal spine, **WB**: width of basal hemisphere, **DS**: diameter of shell, **LSB**: length of spine on the basal spine.

spicule. Wakamatsu *et al.* (1990) followed the mentioned Furutani's opinion.

Dumitrica (1982) suggested that the post-Paleozoic palaeoscenidiid-like taxa such as the genera *Archaeosemantis* Dumitrica, *Aarchaeothamnulus* Dumitrica, and *Palhindeolithus* Deflandre should belong to two or even three families. Wakamatsu *et al.* (1990) also pointed out the possibility that these post-Paleozoic forms may be transferred to another or other families. However, the present Early Triassic forms with the basic skeleton of four basal and apical spines have almost the same skeletal features (Types 3 and 4) shown by Furutani (1990) and the post-Paleozoic palaeoscenidiid-like taxa have not yet been sufficiently documented. Under these circumstances, I tentatively included Early Triassic spicule radiolarians into the family Palaeoscenidiidae.

The measured parts and terminology of the family Palaeoscenidiidae treated in this paper are shown in Figure 4.

Genus *Archaeosemantis* Dumitrica, 1978

Remarks.—Dumitrica (1978b) included various morphological types of this genus into one species, *Archaeosemantis pterostephanus* Dumitrica. Subsequently, he split this species into three species and pointed out the homologies of skeletal disposition of some species of this genus with that of Nassellaria (Dumitrica, 1982). One of the redefined species, *A. pterostephanus* is characterized by having one to three rings caused by the fusion of spines, while *A. cristianensis* Dumitrica does not have any ring. The species criteria of these two species are the presence or absence of ring formed by fusion of two or more spines. Another species, *A. longivirga* Dumitrica has a long median bar and eight dissimilar spines. The species of the genus *Archaeosemantis* recovered from the Ogamata Formation do not have any fused spines.

Archaeosemantis venusta Sashida

Figures 5-4—8

Archaeosemantis venusta Sashida, 1983, p. 171, pl. 36, figs. 1, 2, 4-9, non fig. 3.

Remarks.—In my previous paper, I included the specimens with three apical and basal spines into this species but excluded them from this species in the present study. This species is easily distinguished from other species of the genus *Archaeosemantis* by having four apical and basal spines and a short median bar.

Occurrence.—Common in OG-1 and OG-2.

Types.—Illustrated specimens, Figure 5-4, OG-1, IGUT-KS4231 ; Figure 5-5, OG-1, IGUT-KS4216 ; Figure 5-6, OG-2, IGUT-KS4239 ; Figure 5-7, OG-2, IGUT-KS4241 ; Figure 5-8, OG-1, IGUT-KS4240.

Archaeosemantis aff. *venusta* Sashida

Figure 5-9

Aff. *Archaeosemantis venusta* Sashida, 1983, p. 171, pl. 36, figs. 1, 2, 4-9.

Description.—Spicule skeleton with eight spines arising from a short median bar. Four basal spines are usually longer and the distal half curved inward. Two from each end of bar. Two basal spines are divergent rather laterally and curved downward on a half. These two basal spines form an angle of 110-120 degrees with their opposite spines. The divergent apical spines are rod-like and distally tapering. The length of apical spines is about a fourth to sixth of the basal spines.

Remarks.—The present specimens slightly resemble *A. cristianensis* Dumitrica in having laterally directed and slightly curved two basal spines, however they commonly have two apical spines. These specimens differ from *A. venusta* in having two basal spines, which are laterally directed and slightly curved downward.

Dimensions.—Based on four specimens (in μm) : length of apical spine, 20-35 (average 30) ; basal spine, 95-130 (average 105) ; width of basal hemisphere, 110-150 (average 130).

Occurrence.—Rare in OG-1 and OG-2.

Types.—Illustrated specimen, Figure 5-9, OG-1, IGUT-KS3615.

Archaeosemantis sp.

Figures 5-1—3

Aechaeosemantis venusta Sashida, 1983, pl. 36, fig. 3. non figs. 1, 2, 4-9.

Description.—Spicule commonly with five to six spines arising from a very short median bar. Three basal spines having gradually taperd end are long and distal half of two of them curved inward. One of the basal spines is straight or its distal part curved outward. Apical spines are two to three, long, conical and diverge on a plane including a median bar. These apical spines form an angle of 120 degrees with their neighborhood. In the case of two apical spines, they form a line in almost the same direction as a median bar. All of spines are commonly armed with numerous very short spinules or nodes on their lateral and external sides.

Remarks.—In the present study, the specimens having five to six spines are excluded from *Archaeosemantis venusta* Sashida, and these forms are included into the present unnamed species. This unnamed species is quite similar to *Archaeosemantis cristianensis* Dumitrica in number of spines and general feature. The latter species, however, has strongly curved apical spines.

Dimensions.—Based on six specimens (in μm): length of apical spines 18-22 (average 20); length of basal spines 140-180 (average 160); width of basal hemisphere 70-80 (average 75).

Occurrence.—Rare in OG-1 and OG-2.

Types.—Illustrated specimens, Figure 5-1, OG-1, IGUT-KS4218; Figure 5-2, OG-2, IGUT-KS4219; Figure 5-3, OG-1, IGUT-KS4229.

Genus *Archaeothamnulus* Dumitrica, 1982
Archaeothamnulus okuchichibuensis Sashida, n. sp.

Figures 5-10—14

Diagnosis.—Skeleton formed with four sturdy basal spines and one short apical spine. Basal spines commonly armed with numerous spinules.

Description.—Skeleton consists commonly of five spines diverging from the center of shell. Four basal spines are rod-like, sturdy and long. They diverge downward at an angle of about 30 degrees to the horizontal plane including the center of shell, and curved inward at about one third of basal spines toward the end of basal region. Basal spines from the turning point to their end stretch almost parallel to each other and gently taper. Numerous long conical spines arise from the basal spines at a right angle to them. The longest spine is present at the turning point of basal spines. The length of the longest spine is less than one third of basal spine from the turning point to end. The length of verticils being shorter toward the end of basal spine. Ten spines are counted on one basal spine in well-preserved specimens. Apical spine is short and conical, and its length is less than one tenth of basal spine.

Remarks.—This new species is characterized by its basal spines, which are parallel each other, many long conical spines, and a short apical spine. The present new species is more or less similar to the specimen described by Dumitrica (1982, pl. 7, fig. 7) as *Archaeosemantis* cfr. *longivirga* Dumitrica in general feature and having verticils on the basal spines. However, the former species has only one short apical spine and rod-like spines. This new species also resembles *Archaeothamnulus ramosus* Sashida, however, the latter species is easily distinguished from the former by having outwardly diverging basal spines.

Dimensions.—Based on ten specimens (in μm): length of basal spines 160-250 (average 200); length of apical spines 15-25 (average 20); length of spines on basal spines 20-25 (average 23); width of basal hemisphere 120-170 (average 150).

Etymology.—The species name is from the geographical name, *okuchichibu* where the Ogamata Formation crops out.

Occurrence.—Common in OG-1 and OG-2.

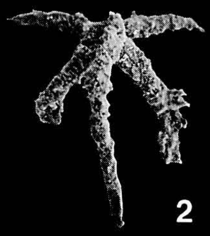
Types.—Holotype, Figure 5-13, OG-1, IGUT-KS3773: Paratypes, Figure 5-10, OG-2, IGUT-KS3623; Figure 5-11, OG-2, IGUT-KS8993; Figure 5-12, OG-1, IGUT-KS8994; Figure 5-14, OG-1, IGUT-KS3622.

Genus *Parentactinia* Dumitrica, 1978
Parentactinia nakatsugawaensis Sashida, 1983

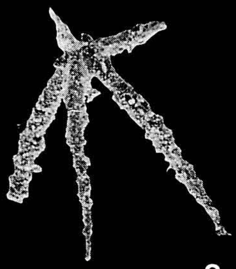
Figures 5-15, 16; 6-1, 3—6

Parentactinia nakatsugawaensis Sashida, 1983, p. 172-173, pl. 37, figs. 1-9.

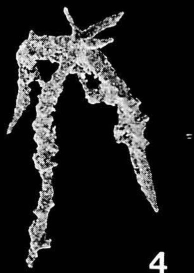
1



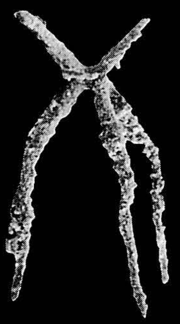
2



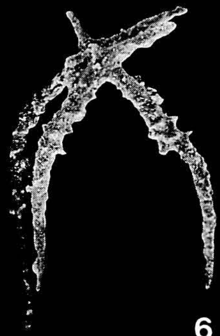
3



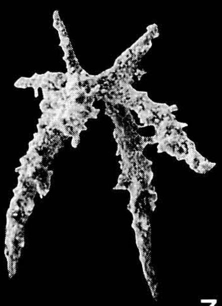
4



5

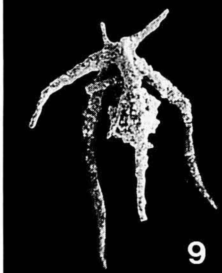


6

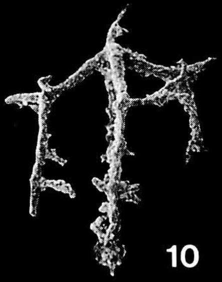


7

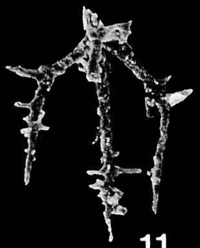
8



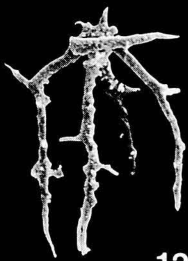
9



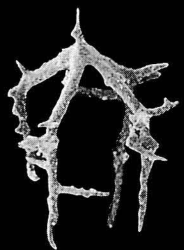
10



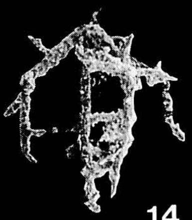
11



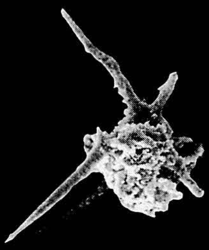
12



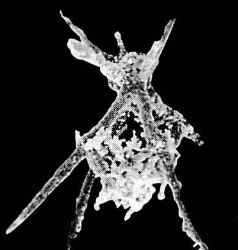
13



14



15



16

Remarks.—This species shows rather wide variation in size of incomplete shell. Some specimens (*e.g.* Figure 5-15) have a very small shell. The intersection of basal spine and shell is quite near to the junction of spines. This form rarely occurs, less than 15%, but other specimens (*e.g.* Figures 6-1, 4) have a large shell, whose intersection with the basal spines is almost at the middle of basal spines.

Dimensions.—Based on 25 specimens (in μm): length of basal spines 160-220 (average 200); length of apical spines 30-120 (average 100); diameter of shell 110-170 (average 130); width of basal hemisphere 220-300 (average 245).

Occurrence.—Common in OG-1 and OG-2.

Types.—Illustrated specimens, Figure 5-15, OG-1, IGUT-KS3701; Figure 5-16, OG-1, IGUT-KS3640; Figure 6-1, OG-2, IGUT-KS3608; Figure 6-3, OG-2, IGUT-KS4242; Figure 6-4, OG-1, IGUT-KS3601; Figure 6-5, OG-1, IGUT-KS3690; Figure 6-6, OG-1, IGUT-KS3677.

Parentactinia virgata Sashida, n. sp.

Figure 6-7

Diagnosis.—Skeleton consists of short median bar and eight stout spines, of which four rather long. Basal spines bear stout and inwardly directed branches. These branches trifurcate or much more and in some cases fused each other to make incomplete cubic shell.

Description.—Four apical spines conical, obliquely directed, one of them (PA spine) rather long, rod-like and tapers. Other three apical spines short. The length of the longest apical spine is one third to half that of basal spine. Four basal spines cylindrical, stout and straight. At the end or near the end of basal spine, one or two, rarely three stout and rod-like branches present. The thickest branch directed inward. This branch bears verticils of two to five, commonly four spinules near the end of branches. Spinules are straight, anastomosed with the other spinules to form a very loose reticulate shell.

Remarks.—This new species is characterized by its very loosely reticulated cubic incomplete shell bordered by four stout branches. The diagnosis of the genus *Parentactinia* Dumitrica is having a single globular incomplete shell. The present new species does not bear any globular shell but the basic disposition of both apical and basal spines is quite identical to that of *Parentactinia.* Therefore I tentatively included this species under the genus *Parentactinia.* At first sight, this species has a close similarity to *Tandarnia arachnoconcha* Dumitrica, however, the latter species has a different disposition of spines.

Dimensions.—Based on four specimens (in μm): length of PA spines 40 to 70 (average 50); length of short apical spine 15 to 30 (average 20); diameter of incomplete shell 89-130 (average 105); width of basal hemisphere 120-150 (average 135).

Etymology.—Latin, *virgatus,* made of twigs.

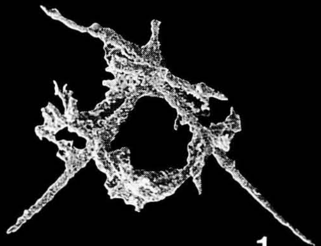
Occurrence.—Rare in OG-1 and OG-2.

Type.—Holotype, Figure 6-7, OG-1, IGUT-KS3699.

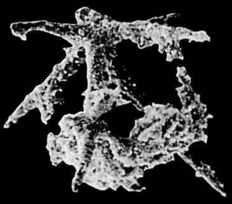
Genus *Pactarentinia* Furutani, 1983

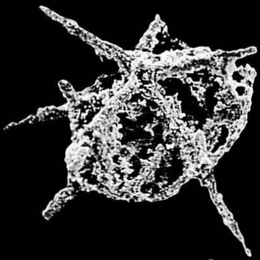
Remarks.—This genus differs from *Par-*

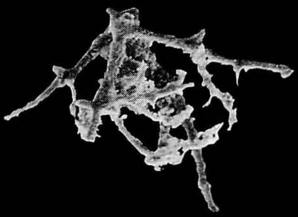
← **Figure 5. 1—3,** *Archaeosemantis* sp., **1**: OG-1, IGUT KS-4218; **2**: OG-2, IGUT-KS4219; **3**: OG-1, IGUT-KS4229. **4-8,** *Archaeosemantis venusta* Sashida, **4**: OG-2, IGUT-KS4231; **5**: OG-1, IGUT-KS4216; **6**: OG-2, IGUT-KS4239; **7**: OG-2, IGUT-KS4241; **8**: OG-1, IGUT-KS4240; **9,** *Archaeosemantis* aff. *venusta* Sashida, OG-1, IGUT-KS3615. **10—14,** *Archaeothamnulus okuchichibuensis* Sashida, n. sp., **10**: Paratype, OG-2, IGUT-KS3623; **11**: Paratype, OG-2, IGUT-KS8993; **12**: Paratype, OG-1, IGUT-KS8994; **13**: Holotype, OG-1, IGUT-KS3773; **14**: Paratype, OG-1, IGUT-KS3622. **15, 16,** *Parentactinia nakatsugawaensis* Sashida, **15**: OG-2, IGUT-KS4242; **16**: OG-1, IGUT-KS3640. Scale bars, **A** and **B** equal to 100 μm; **A** applies to **10—16** and **B** to **1** to **9**.

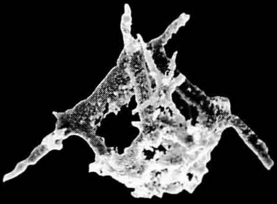

1

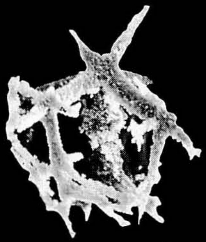

2

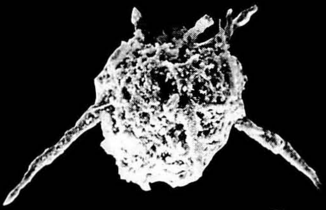

3

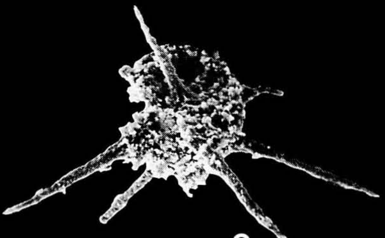

4

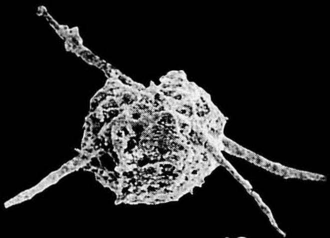

5

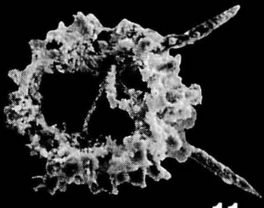

6

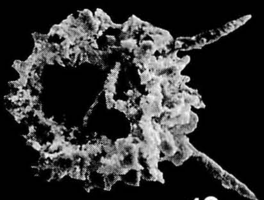

7


8


9

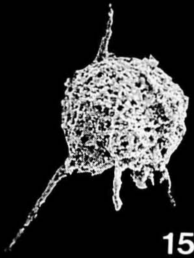

10

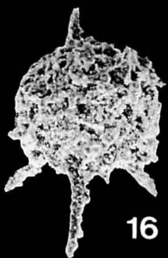

11


12


13


14


15


16

A

B

entactinia in having a complete spherical shell, which cover a part of basal spines. The present Triassic *Pactarentinia* slightly differs from that of the Devonian. Namely, the former has a spongy spherical shell but lacks tent-like lamellae at the junction of apical and basal spines.

Pactarentinia koikei Sashida, n. sp.

Figures 6-2, 8–12

Diagnosis.—Shell consists of rather large spongy spherical shell and rod-like long basal and apical spines.

Description.—Shell comprises eight spines and a bar-centered spicule with a single spherical spongy shell. The spicule consists of a short median bar and four downward rod-like basal spines and four upward rod-like apical spines of which PA spine is predominant. The longest apical spine (PA spine) attains more than 150 μm. The basal spines are also long and each of them forms an angle of approximately 90 degrees with its neighbors. The basal spines gently taper, rarely they fuse directly to the spongy shell to form a rather large spongy fabric. The spongy shell is almost spherical and sometimes slightly compressed in the apical and basal directions, and its internal surface is usually smooth.

Remarks.—The present new species is quite similar to *Pactarentinia holdsworthi* Furutani in general shell shape. However, *P. holdsworthi* has a small latticed and tent-like shell formed by lamellae connecting with the proximal portions of basal spines and median bar. The basal spine of *P. holdsworthi* has small needle-like spines in latticed shell.

Dimensions.—Based on 20 specimens (in μm): diameter of spongy shell 120-150 (average 130); length of basal spines 130-170 (average 135); length of short apical spines 100-120 (average 110); length of PA spine 125-150 (average 135); width of basal hemisphere 370-430 (average 410).

Etymology.—The species name *koikei* is named for Professor Toshio Koike of Yokohama National University in honor of his contribution to the study of Triassic conodonts.

Occurrence.—Common in OG-1 and OG-2.

Types.—Holotype, Figure 6-8, OG-2, IGUT-KS3893; Paratypes, Figure 6-9, OG-2, IGUT-KS3894; Figure 6-10, OG-1, IGUT-KS3707; Figure 6-11,12, OG-2, IGUT-KS3706; Figure 6-2. OG-1. IGUT-KS3709.

Superfamily Shaerollacea Haeckel, 1881
emend. Pessagno, 1977
Family Pantanellidae Pessagno, 1977
Subfamily Pantanellinae Pessagno, 1977
Genus *Pantanellium* Pessagno, 1977

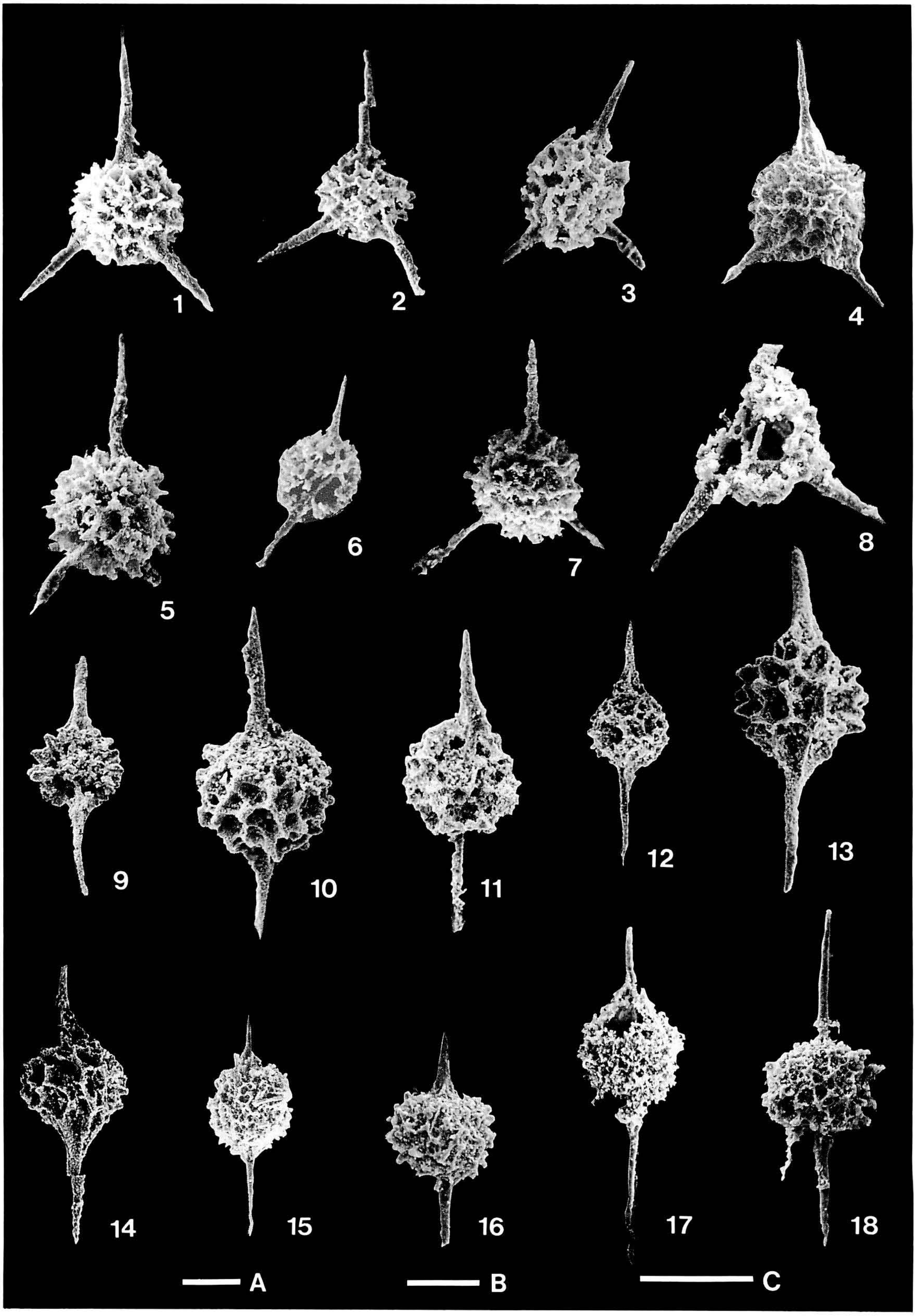
Pantanellium ? *virgeum* Sashida, n. sp.

Figures 7-9–14

Diagnosis.—Shell comprises first medullary and spherical cortical ones with bipolar rod-like primary spines.

Description.—Cortical shell spherical with large hexagonal and rarely pentagonal pore frames. All pore frames have rather high nodes at bars between pore frame vertices. Bars of pore frames rather thin along Y and two to three times thicker along Z. Six pore

←— **Figure 6.** **1, 3–6,** *Parentactinia nakatsugawaensis* Sashida, **1**: OG-2, IGUT-KS3608; **3**: OG-2, IGUT-KS4242; **4**: OG-1, IGUT-KS3601; **5**: OG-1, IGUT-KS3690; **6**: OG-1, IGUT-KS3677; **2, 8–12,** *Pactarentinia koikei* Sashida, n. sp., **2**: OG-1, IGUT-KS3709; **8**: Holotype, OG-2, IGUT-KS3893; **9**: Paratype, OG-2, IGUT-KS3894; **10**: Paratype, OG-1, IGUT-KS3707; **11–12**: a stereo pair showing internal feature, OG-2, IGUT-KS3706. **7,** *Parentactinia virgata* Sashida, n. sp., Holotype, OG-1, IGUT-KS3699; **13, 16,** *Poulpus* sp., **13**: OG-1, IGUT-KS3654; **16**: OG-2, IGUT-KS3655. **14, 15,** *Saitoum* sp., **14**: OG-2, IGUT-KS3665; **15**: OG-1, IGUT-KS3604. Scale bars, **A** and **B** equal to 100 μm; **A** applies to **1, 2, 5, 8–10, 15,** and **B** to **3, 4, 6, 7, 11–14, 16.**


1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
A
B
C

frames visible along both AA′ and BB′. Shorter polar spines about three-fourths of the length of longer one. Almost all portions of spines circular in the axial section, but usually the proximal one-fourth to two-fifths portion of shorter spine tends to become triradiate. Grooves become wider proximally. The first medullary shell seems to have hexagonal and pentagonal fragile pore frames and is connected with two rod-like polar spines and several thin secondary radial beams.

Remarks.—One of the diagnostic characters of the genus *Pantanellium* Pessagno is having triradiate polar spines. Although the present new species has a triradiate portion only at the proximal part of shorter polar spines, the longer spine and the middle and distal parts of shorter spine lack longitudinal ridges and grooves. These characters may indicate that of the ancestor of typical *Pantanellium*. However, the shell morphology of the present new species is quite identical to the criteria of the genus *Pantanellium*. I tentatively included this new species in the genus *Pantanellium*.

The present new species is slightly similar to *Pantanellium browni* Pessagno and Blome described from the Rhaetian (?) to Hettangian Black argillite Member of the Kunga Formation, Queen Charlotte Islands, Canada. However, they are distinguished from each other by the above described character of polar spines.

Dimensions.—System of dimension described below is based on that of Pessagno and Blome's description (1980, p. 241, text-fig. 5). Based on 14 specimens (in μm): AA′ 82-108 (average 94); A′S′ 92-115 (average 100); AS 108-135 (average 118); BB′ 93-110 (average 105); CC′ 41-68 (average 48); dd′ 41-58 (average 49).

Etymology.—Latin, *virgeus* means rods.

Occurrence.—Common in OG-1 and OG-2.

Types.—Holotype, Figure 7-13, OG-1, IGUT-KS4209; Paratypes, Figure 7-9, OG-1, IGUT-KS3616; Figure 7-10, OG-2, IGUT-KS4232; Figure 7-11, OG-2, IGUT-KS4238; Figure 7-12, OG-2, IGUT-KS4236; Figure 7-14, OG-1, IGUT-KS3603.

Superfamily Spongodiscacea Haeckel, 1881 emend. Pessagno, 1971, 1973

Subsuperfamily Pseudoaulophacilae Riedel, 1971 emend. Pessagno, 1971

Family Sponguriidae Haeckel, 1862 emend. Pessagno, 1978

Subfamily Archaeospongopruninae Pessagno, 1973

Genus *Protopsium* Pessagno and Poisson, 1981

Remarks.—The diagnostic character of this genus is the presence of ellipsoidal spongy shell with two polar spines and patagium-like mass. The genus *Protopsium* has clear four types in shell character. Namely, the first one has a flattened ellipsoidal fine spongy shell with long polar spines with or without alternating grooves and ridges (*e.g. Protopsium ehrenbergi* Pessagno and Poisson). The second is characterized by having fine to loose spongy meshwork and a conical polar spine with deep grooves and ridges (*e.g. P. ispartaense* Pessagno and Poisson, *P. gesponsa* De Wever). The third one has very fine spongy meshwork with three to five fine coni-

← **Figure 7.** **1—8,** *Spongostephanidium longispinosum* Sashida, n. sp., **1**: Holotype, OG-1, IGUT-KS3643; **2**: Paratype, OG-2, IGUT-KS3663; **3**: Paratype, OG-1, IGUT-KS3664; **4**: Paratype, OG-2, IGUT-KS3653; **5**: Paratype, OG-1, IGUT-KS3675; **6**: OG-2, IGUT-KS3698; **7**: Paratype, IGUT-KS3661; **8**: OG-2, IGUT-KS3669; **9—14,** *Pantanellium* ? *virgeum* Sashida, n. sp., **9**: Paratype, OG-1, IGUT-KS3661; **10**: Paratype, OG-2, IGUT-KS4232; **11**: Paratype, OG-2, IGUT-KS4238; **12**: Paratype, OG-2, IGUT-KS4236; **13**: Holotype, OG-1, IGUT-KS4209. **15—18,** *Protopsium* sp., **15**: OG-2, IGUT-KS3672; **16**: OG-1, IGUT-KS3685; **17**: OG-2, IGUT-KS3645; **18**: OG-1, IGUT-KS3676. Scale bars, **A** to **C** equal to 100 μm; **A** applies to **15, B** to **2, 6, 9, 12, 14, 16—18** and **C** to **1, 3—5, 7, 8, 10, 11, 13.**

cal polar spines (*e.g. P. libidonosum* De Wever). The last one is characterized by having shell form like the genus *Gorgansium* Pessagno and Blome, which has an ellipsoidal to spherical shell with three polar spines (*e.g. P. posinos* De Wever). However, the fourth one has a slightly different morphology in having a lattice shell. The taxonomic position of this type may be removed into another genus.

Protopsium sp.

Figures 7-15–18

Description.—Primary shell small, spherical to ellipsoidal with tetragonal pore frames with small nodes at vertices. Secondary spines extending from primary test into circular to ellipsoidal spongy shell. Polar spines rod-like, long but usually not equal in length.

Remarks.—This unidentified species is easily distinguished from other species of this genus by having rod-like polar spines. This is slightly similar to *Protopsium ehrenbergi* Pessagno and Poisson reported from the Lias of Gümüslü, Turkey in general shell shape. However, the former is distinguishable from the latter by having long and thin rod-like polar spines.

Dimensions.—Based on 15 specimens (in μm): diameter of spongy shell 130-163 (average 146); length of polar spine 74-200 (average 175).

Occurrence.—Rare in OG-1 and OG-2.

Types.—Illustrated specimens, Figure 7-15, OG-2, IGUT-KS3672; Figure 7-16, OG-1, IGUT-KS3685; Figure 7-17, OG-2, IGUT-KS3645; Figure 7-18, OG-1, IGUT-KS3676.

Suborder Nassellaria Ehrenberg, 1875
Family Eptingiidae Dumitrica, 1978

Remarks.—Since Dumitrica (1978) set up the family Eptingiidae, many radiolarians are included in this family. However, most of the authors did not illustrate any internal skeletal structure of this group except for the Jurassic genus *Perispheridium* (*e.g.*, Pessagno and Blome, 1982; MacLeod, 1988). I discriminated several forms belonging to this family in the present study, but only one genus *Spongostephanidium* was described herein because the detailed internal skeleton of other forms was not determined.

Genus *Spongostephanidium* Dumitrica, 1978
Spongostephanidium longispinosum Sashida, n. sp.

Figures 7-1–3

Diagnosis.—*Spongostephanidium* with spherical rather coarse spongy-like cephalis and three rod-like horns.

Description.—Cephalis spherical with coarse spongy mesh. Arches of basal skeleton included within the inner parts of spongy cephalis. Three horns rod-like with pointed ends. They are usually unequal and shorter than the diameter of cephalis and situated in the same plane. The longest horn rarely attains two times in length that of shorter one in a specimen. One of the horns L is commonly shorter and making with the apical horn an angle smaller than with the other horn L. Sometimes wide and short three grooves present near the base of horn. Internal surface of spongy shell is rather smooth.

Remarks.—The internal skeleton of this species is not fully observed and it could not be determined whether this species bears a dorsal spine or not. I tentatively included this species in the genus *Spongostephanidium*. *S. longispinosum* slightly resembles *S. spongiosum* Dumitrica.

Dimensions.—Based on 20 specimens (in μm): diameter of cephalis 110-140 (average 125), length of longest horn 110-160 (average 130), length of shorter spines 45-80 (average 65).

Etymology.—Latin, *longi* means long, spinose spine.

Occurrence.—Common in OG-1 and OG-

2.

Types.—Holotype, Figure 7-1, OG-1, IGUT-KS3643; Paratypes Figure 7-2, OG-2, IGUT-KS3663; Figure 7-3, OG-1, IGUT-KS3664; Figure 7-4, OG-2, IGUT-KS3653; Figure 7-5, OG-1, IGUT-KS3675; Figure 7-6, OG-2, IGUT-KS3698; Figure 7-7, OG-1, IGUT-KS3661; Figure 7-8, OG-2, IGUT-KS3669.

Family Acanthodesmiidae Haeckel, 1862
Subfamily Poulpinae De Wever, 1981

Remarks.—De Wever (1981) set up the subfamily Poulpinae under the family Pylentonemidae Deflandre. Recently, Takemura (1985) investigated the internal skeletal structure of Jurassic Nassellaria, and he defined Poulpinae De Wever as the subfamily of the family Acanthodesmiidae Haeckel, because of the existence of a sagittal ring.

Genus *Poulpus* De Wever, 1979
Poulpus sp.

Figures 6-13, 16

Remarks.—I obtained three specimens referable to this unidentified species. *Poulpus* sp. slightly resembles *P. oculatus* De Wever described from the Lias of Turkey and Greek in general shell shape. The latter, however, has triradiate tripods and an apical spine. Giving the specific name is rendered until a number of well-preserved specimens are accumulated.

Occurrence.—Rare in OG-1 and OG-2

Types.—Illustrated specimens, Figure 6-13, OG-1, IGUT-KS3654; Figure 6-16, OG-2, IGUT-KS3655.

Genus *Saitoum* Pessagno, 1977
Saitoum sp.

Figures 6-14, 15

Remarks.—Ten ill-preserved specimens are obtained. Owing to silica fillings in the cephalis, the disposition of morphological elements was not determined. However, a general view of these specimens is assigned to the genus *Saitoum* Pessagno. This unidentified species is slightly similar to *S. curuipedatum* De Wever and *S. keki* De Wever in general shell shape.

Occurrence.—Rare in OG-1 and OG-2.

Types.—Illustrated specimens, Figure 6-14, OG-2, IGUT-KS3665; Figure 6-15, OG-1, IGUT-KS3604.

References cited

Blome, C.D., 1984: Upper Triassic Radiolaria and radiolarian zonation from Western North America. *Bull. Amer. Paleontol.*, vol. 85, no. 318, p. 1-88, pls. 1-17.

De Wever, P., 1981: Une nouvelle sous-famille, les Poulpinae, et quatre nouvelles especes de *Saitoum,* Radiolaires mesozoiques tethysiens. *Geobios*, no. 24, p. 5-15, pl. 1.

Dumitrica, P., 1978a: Family Eptingiidae n. fam., extinct Nassellaria (Radiolaria) with sagittal ring. *D.S. Inst. Geol. Geofiz.*, vol. 64 (1976-1977), Part 3, Palaeont., p. 27-38, pls. 1-4.

——, 1978b: Triassic Palaeoscenidiidae and Entactiniidae from the Vicentinian Alps (Italy) and the Eastern Carpathians (Romania). *Ibid.*, p. 39-54, pls. 1-5.

——, 1982: Middle Triassic spicular Radiolaria. *Revista Espanola Micropal.*, vol. 14, p. 401-428, pls. 1-7.

Fujimoto, H., Kawata, K., Miyazawa, S., Morikawa, R., Arai, F., Takano, T., Yoshida, S., Hara, K., Tazuke, H. and Mado, H., 1950: Geological study of Okuchichibu. *Bull. Chichibu Mus., Nat. Hist.*, no. 1, p. 1-28. (*in Japanese with English abstract*)

——, Watanabe, K., Akagi, S., Iijima, H., Kaneko, S., Takano, J. and Matsuzaki, S., 1957: Geology of the north-western part of the Kanto Mountainland. *Ibid.*, no. 7, p. 17-28. (*in Japanese with English abstract*)

Furutani, H., 1983: Middle Palaeozoic Palaeoscenidiidae (Radiolaria) from Mt. Yokokura, Shikoku, Japan. Part I. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 130, p. 96-116, pls. 21-27.

——, 1990: Middle Paleozoic radiolarians from Fukuji area. Gifu Prefecture, central Japan. *Jour. Earth Sci., Nagoya Univ.*, vol. 37, p. 1-56, pls. 1-14.

Goodbody, Q.H., 1986: Wenlock Palaeoscenidiidae and Entactiniidae (Radiolaria) from the Cape Phillip Formation of the Canadian Arctic Archipelago. *Micropaleontology*, vol. 32, no. 2, p. 129-157, pls. 1-7.

Ishii, A., 1962: Upper Paleozoic of the Nakatsugawa area, Okuchichibu, Kanto-massif. *Bull. Chichibu Mus., Nat. Hist.*, no. 20, p. 178-195. (*in Japanese with English abstract*)

—— and Matsukawa, M., 1980: Ogamata Formation, Kanto Mountains, central Japan. *Bull. Tokyo Gakugei Univ., Ser. 4*, vol. 32, p. 195-207. (*in Japanese with English abstract*)

Kishida, Y. and Hisada, K., 1985: Late Triassic to Early Jurassic radiolarian assemblages from the Ueno-mura area, Kanto Mountains, central Japan. *Mem. Osaka Kyoiku Univ., Ser. 3*, vol. 34, no. 2, p. 103-129, pls. 1-4.

Kozur, H. and Mostler, H., 1981: Beiträge zur Erforschung der mesozoischen Radiolarien. Teil IV: Thalassosphaeracea Haeckel, 1862, Hexastylacea Haeckel, 1882 emend, Petrusevskaja, 1979, Sponguracea Haeckel, 1862 emend. und weiter triassische Lithocycliacea, Trematodiscacea, Actinommacea und Nassellaria. *Geol. Paläont. Mitt. Insbruck*, vol. 11, p. 1-208, pls. 1-69.

MacLeod, N., 1988: Lower and Middle Jurassic *Perispyridium* (Radiolaria) from the Snowshoe Formation, east-central Oregon. *Micropaleontology*, vol. 34, no. 4, p. 289-315, pls. 1-5.

Nakaseko, K. and Nishimura, A., 1979: Upper Triassic Radiolaria from southwest Japan. *Sci., Rep., Coll. Educ. Osaka Univ.*, vol. 29, no. 2, p. 61-109, pls. 1-11.

Pessagno, E.A. and Blome, C.D., 1980: Upper Triassic and Jurassic Pantanellinae from California, Oregon and British Columbia. *Micropaleontology*, vol. 26, no. 3, p. 225-273, pls. 1-11.

—— and ——, 1982: Bizarre Nassellariina (Radiolaria) from the Middle and Upper Jurassic of North America. *Ibid.*, vol. 28, no. 3, p. 289-318, pls. 1-8.

—— and Poisson, A., 1981: Lower Jurassic Radiolaria from the Gümüslü allochton of southwest Turkey (Taurides Occidentales). *Min. Res. Explor. Inst. Turkey, Bull.*, 92, p. 47-69, pls. 1-15.

Sashida, K., 1983: Lower Triassic Radiolaria from the Kanto Mountains, central Japan Part 1: Palaeoscenidiidae. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 131, p. 168-176, pls. 36-37.

——, Igo, Hh., Igo, Hy., Takizawa, S., Hisada, K., Shibata, T., Tsukada, K. and Nishimura, H., 1982: On the Jurassic Radiolaria from the Kanto Mountains. *News Osaka Micropal., Special Vol.*, 5, p. 51-66, pls. 1-2.

Sato, T., Takizawa, S., Kuwahara, T., Sashida, K., Hisada, K., Aono, H., Fuseya, M. and Arakawa, Y., 1981: Exotic nappes of probably sliding origin in the South Belt of the Kanto Mountains. *Ann. Rep., Inst. Geosci., Univ. Tsukuba*, no. 7, p. 56-59.

Takemura, A., 1986: Classification of Jurassic Nassellarians (Radiolaria). *Palaeontgr.* A, vol. 195, p. 29-74, pls. 1-12.

Wakamatsu, H., Sugiyama, K. and Furutani, H., 1990: Silurian and Devonian radiolarians from the Kurosegawa Tectonic Zone, southwest Japan. *Jour. Earth Sci., Nagoya Univ.*, vol. 37, p. 157-192, pls. 1-13.

Yao, A., 1982: Middle Triassic to Early Jurassic radiolarians from the Inuyama area, central Japan. *Jour. Geosci. Osaka City Univ.*, vol. 25, p. 53-70, pls. 1-4.

Yoshida, H., 1986: Upper Triassic to Lower Jurassic radiolarian biostratigraphy in Kagamigahara City, Gifu Prefecture, central Japan. *Jour. Earth Sci., Nagoya Univ.*, vol. 34, p. 1-21, pls. 1-17.

Kanto 関東，Nakatsugawa 中津川，Okuchichibu 奥秩父，Ogamata 大ガマタ，Oyamazawa 大山沢，Saitama 埼玉.

関東山地大ガマタ層産の前期三畳紀放散虫化石，その2：関東山地奥秩父に分布する大ガマタ層からは保存良好な前期三畳紀放散虫化石が豊富に産する。この放散虫化石群のうち，中津川流域に分布するチャートから得られた針状骨格だけからなる Palaeoscenidiidae 科の一部はすでに筆者により記載・報告されている。本研究は新たに大山沢のチャートの資料も加え，Spumellaria と Nassellaria について検討し，5新種を識別し記載した。Spumellaria では球形の殻をもつ Palaeoscenidiidae 科，Pantanellidae 科，Sponguriidae 科が含まれ，Nassellaria では Spumellaria 様形態をもつ Eptingiidae 科と Acanthodesniidae 科が識別された。この放散虫化石群の示す年代は，共存するコノドントから前期三畳紀の late Spathian と考えられる。
指田勝男

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 161, pp. 697-713, 12 Figs., April 30, 1991

913. DISCRIMINATION OF TWO NEW *ANADARA* SPECIES USING SHELL GROWTH PARAMETERS AND FOURIER DESCRIPTORS

OSAMU SASAKI

Institute of Geology and Paleontology,
Tohoku University, Sendai, 980

Abstract. Two new *Anadara* species, *Anadara (Scapharca) omaruensis*, n. sp. and *A.* (*S.*) *takanabensis*, n. sp., are discriminated statistically from allied species using new methods. The ontogenetic changes in shell characters are described to interpret their differences in form within the framework of the spiral tube model. It becomes clear that these species differ in the spiral mode around the coiling axis. The commissure shapes of these species are compared in the Fourier Descriptors space. The variants of these species are distributed in the one-dimensional region of the space and they can be discriminated by using the clustering method. It is therefore possible to discriminate these allied species based on the degree to which the commissure shape is inequilateral.

Key words. *Anadara,* clustering method, Fourier Descriptors, Fourier Distance, spiral tube model.

Introduction

Various spiral tube models have been proposed for the description of the geometry of the molluscan shell, which is a product of accretionary growth (Lison, 1949; Owen, 1953; Rudwick, 1959; Stasek, 1963; Raup and Michelson, 1965). Raup (1966) estimated the morphological effects of change in three parameters of the spiral tube model. Sasaki (1990) applied the knowledge of the spiral model to the classification of the genus *Anadara.*

There have been a few successful methods for the description of the generating curve shape, though several sets of parameters have been proposed. The description of the shape of objects in a scene is one of the important problems in picture processing. There are many techniques available to describe closed curves, but there is theoretical and experimental evidence that the Fourier Descriptors are one of the most useful techniques (Ehrlich and Weinberg, 1970; Zahn and Roskies, 1972; Granlund, 1972). Persoon and Fu (1977) used the Euclidean metric in the space of the Fourier Descriptors to compute the distance between different closed curve shapes. One advantage of the application of this method to the problem facing morphological taxonomists is that it puts each form in the Euclidean space that makes possible statistical analysis of the distribution of morphological variation involved in a taxonomic unit.

The purpose of this work is the application of new methods to discriminate two new *Anadara* species collected from the Koyu Formation in Miyazaki Prefecture. The new species are allied to *Anadara* (*Hataiarca*) *castellata* (Yokoyama) and *Anadara* (*Scapharca*) *ommaensis* (Otuka), but differ from

---

*Received April 12, 1990; revised manuscript accepted December 20, 1990

these species. The differences and similarities of the shell morphologies of these allied species will be interpreted in the framework of the spiral tube model.

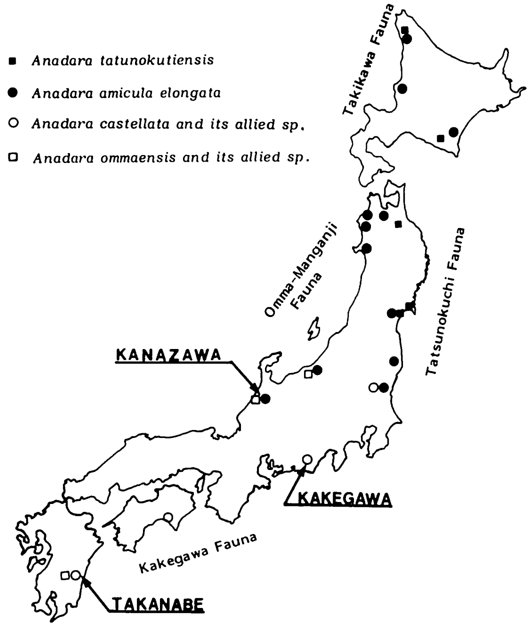


Figure 1. Index map of localities of *Anadara* specimens.

Geological setting and occurrence

Four populations of *Anadara* species studied here were collected from 4 localities in 3 areas; Iwasebashi and Toriyama in the Takanabe area in Miyazaki Prefecture, Dainichi in the Kakegawa area in Shizuoka Prefecture, and Omma at the Kanazawa area in Ishikawa Prefecture (Figure 1).

(1) Takanabe area in Miyazaki Prefecture

The Miyazaki Group is divided into the Saito and Koyu Formations, which are distributed around Takanabe Town in Miyazaki Prefecture (Suzuki, 1987: Figure 2). The geological age of the upper part of the Koyu Formation is 3.4–2.5 Ma, based on microfossil data (Suzuki, 1987). The two new *Anadara* species were collected from the Koyu Formation at 5 localities around Takanabe Town, where they were associated with such characteristic species of the Kakegawa Fauna as *Megacardita panda* and *Suchium suchiense suchiense*. Several specimens of *Anadara* (*Scapharca*) *omaruensis*, n. sp. were collected at each of the localities at Iwasebashi, Namikake and Kurotai, and *A.* (*S.*) *takanabensis*, n. sp. at Toriyama and Nihonmatsu (Figure 3).

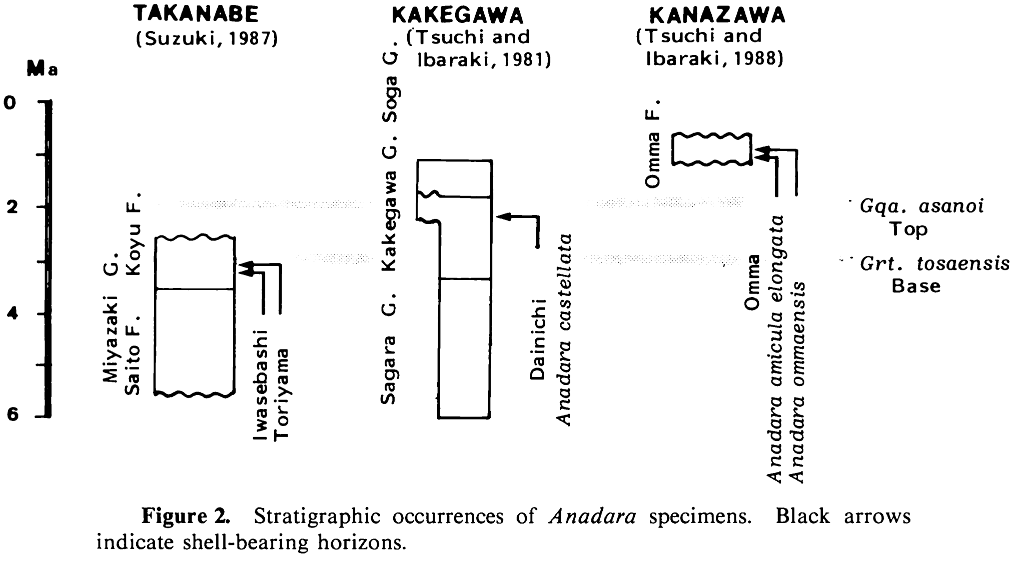


Figure 2. Stratigraphic occurrences of *Anadara* specimens. Black arrows indicate shell-bearing horizons.

At Iwasebashi, Namikake and Kurotai, mudstone interbedded with thin, fine-grained sandstone is well exposed, and it is correlated with the middle part of the Koyu Formation. Molluscan fossils are scattered in the fine-grained sandstone. *Anadara* (*Scapharca*) *omaruensis* is a dominant species in the molluscan assemblages at these localities, and specimens occur in a range of sizes from small to large. Preservation of the shells is fairly good.

At Toriyama and Nihonmatsu, alternation of siltstone and fine-grained sandstone is exposed and correlated with the upper part of the Koyu Formation. Molluscan fossils are found in closely packed shell beds in the fine-grained sandstone. *Anadara* (*Scapharca*) *takanabensis* is dominant in these molluscan assemblages. Preservation of these fossils is fairly good.

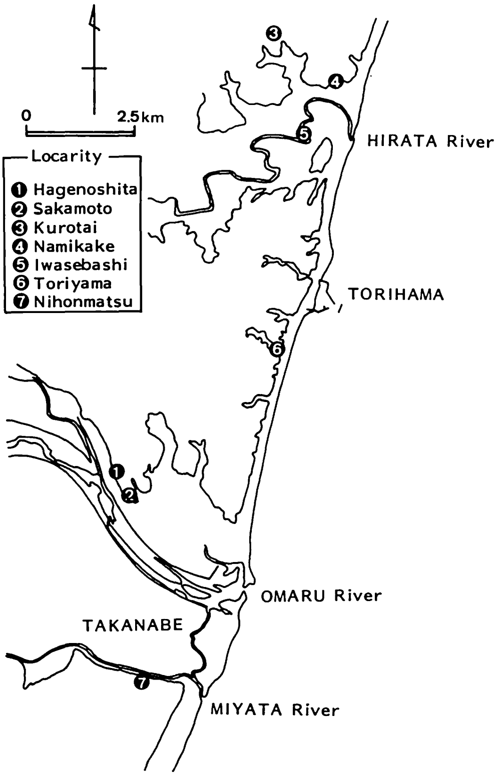


Figure 3. Index map of localities of *Anadara* specimens at Takanabe area in Miyazaki Prefecture.

(2) Kakegawa area in Shizuoka Prefecture

The Dainichi Sandstone of the Kakegawa

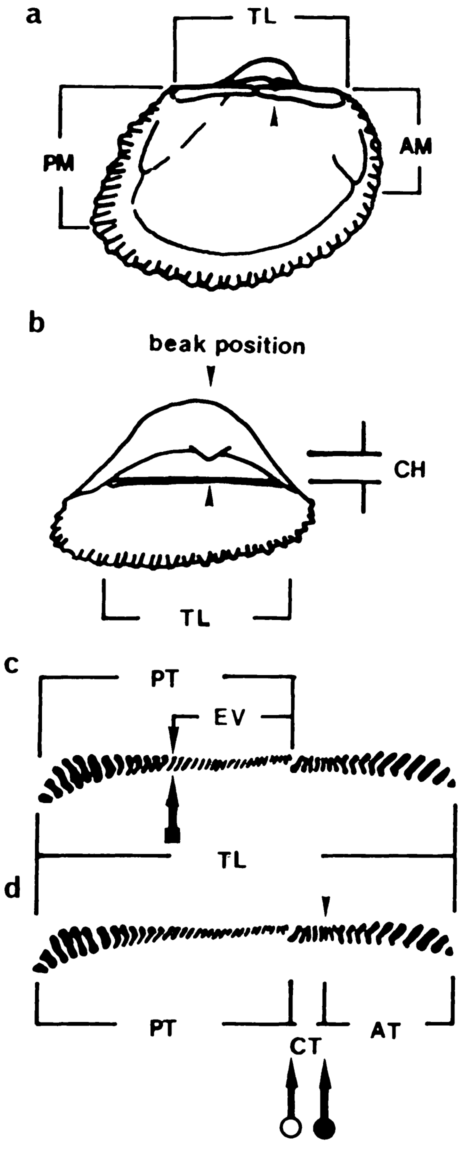


Figure 4. Linear dimensions measured for the analysis of ontogenetic change in shell form. TL : length of the toothed portion of the hinge line. AM, PM : heights of the anterior and posterior margins of the commissure. CH : height of the cardinal area. EV : length of the divergent-toothed portion of the posterior teeth segment. PT, CT, AT : lengths of the posterior, central and anterior segmental teeth series.

Group at Dainichi was correlated with the Horinouchi Formation (3.2–2.0 Ma) (Tsuchi and Ibaraki, 1988). Molluscan fossils are found as closely packed shell beds in sandstone at Dainichi. *Anadara castellata* is a dominant species of Dainichi assemblages. Shells are well preserved, but very fragile.

(3) Kanazawa area in Ishikawa Prefecture

The Omma Formation is composed mainly of fine- to medium-grained sandstone around Kanazawa City. The geological age of the lower part of this formation is 1.17–1.02 Ma, based on microfossils and on fission track dating (Tsuchi and Ibaraki ,1988). Molluscan fossils form shell beds in fine-grained sandstone, and there are more than 25 shell beds in the Omma section along the Sai River. Three *Anadara* species zones were proposed by Ogasawara (1977) in the Omma Formation. These are the *Anadara* (*Anadara*) *amicula elongata* Zone, the *Anadara (Scapharca) ommaensis* Zone, and the *Anadara* (*Hataiarca*) *pseudosubcrenata* Zone, in ascending order. Specimens of *A.* (*S.*) *ommaensis* were collected from the middle part of the Omma Formation. Preservation of the *Anadara* shells is fairly good.

Statistical description of shell growth

The shape of the *Anadara* shell has traditionally been described with respect to the size of shell, shape of cardinal area, degree of shell inflation, position of beak, ratio between height and length of shell, degree of curvature of posterior, anterior and ventral margins of commissure, and arrangement of hinge teeth (Reinhart, 1943).

Nine intervals shown in Figure 4 will be defined here in order to represent these shell characters. TL is the length of toothed portion of hinge line. CH is the height of cardinal area. PM and AM are the heights of the posterior and anterior margins of commissure. PT, CT and AT are the lengths of posterior, central and anterior segments of toothed portion of hinge line. EV is the length of divergent toothed portion of the posterior segment of hinge line.

Most of the shell characters mentioned above can be represented by using the ratios between these intervals. The ratio CH/TL represents the shape of cardinal area and degree of shell inflation. The ratio AT/TL corresponds to the position of beak. The ratio AM/PM represents the ratio between the degrees of curvature of anterior and posterior margins of commissure. The ratio EV/PT represents the arrangement of hinge teeth.

1) Size-dependent change in the cardinal area (CH–TL relationship)

Figure 5a shows the relationship between TL and the general logarithm of CH of *Anadara* (*Scapharca*) *ommaensis* and *A.* (*S.*) *omaruensis.* Figure 5b shows the same relationship of *A.* (*Hataiarca*) *castellata* and *A.* (*S.*) *takanabensis.* A symbol in the diagram represents the values of one specimen, and the broken lines represent the approximate range of linear distribution of the symbols. The plotting of the relationship produces a linear distribution in the diagram if the height (CH) increases against the length (TL) of the cardinal area in a logarithmic mode.

The approximate lines of *Anadara* (*Scapharca*) *ommaensis* and *A.* (*S.*) *omaruensis* are at a higher angle to the TL axis than that of *A.* (*H.*) *castellata* and *A.* (*S.*) *takanabensis.* The cardinal areas of the high-angle species are taller than those of the low-angle species throughout ontogeny. For example, *A.* (*S.*) *omaruensis,* a high-angle species, is CH = 2.2 mm at TL = 20 mm, while *A.* (*S.*) *takanabensis,* a low-angle species, is CH = 0.5- 1.5 mm at the same TL.

In Figure 5, the range of distribution of *Anadara* (*Scapharca*) *omaruensis* overlaps that of *A.* (*S.*) *ommaensis,* and the range of *A.* (*H.*) *castellata* partly overlaps that of *A.* (*S.*) *takanabensis.* A degree of overlap between the ranges of these species in the diagrams is thought to be due to the similarity of these species in the shape of their cardinal areas.

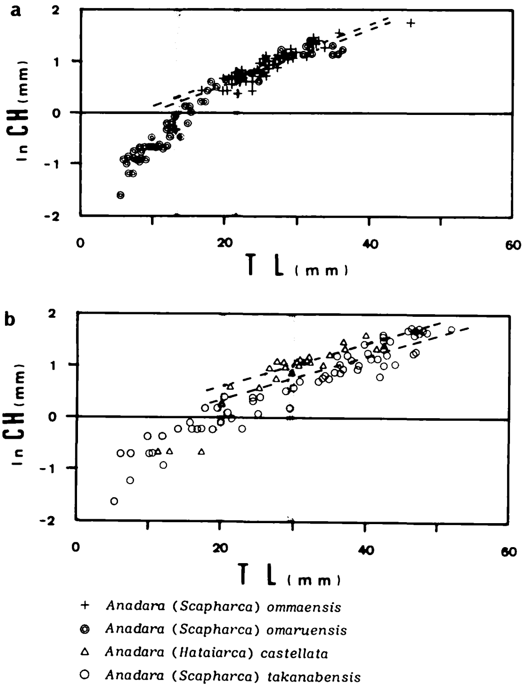


Figure 5. Distribution of ontogenetic variation in the relationship between the height (CH) and length (TL) of the cardinal area.

Therefore, *A.* (*S.*) *omaruensis* is similar to *A.* (*S.*) *ommaensis* in the shape of its cardinal area, and also *A.* (*S.*) *takanabensis* is similar to *A.* (*H.*) *castellata.*

2) Size-dependent change in the teeth arrangement (EV/PT-TL relationship)

The relationship between EV/PT and TL represents the ontogenetic change in the arrangement of hinge teeth. Noda (1966) classified the arrangement of *Anadara* hinge teeth into 3 types: the convergent type, divergent type, and divergent type with v-shaped teeth. At EV/PT=0, *Anadara* shells have the convergent type of teeth arrangement, and at EV/PT>0, it has the divergent type with v-shaped teeth. *Anadara* species change their teeth arrangement during shell growth.

It is therefore impossible to represent *Anadara* species by using only one type of teeth arrangement. The critical size can be determined for the growth of a species, at which its teeth arrangement is transformed from the convergent type to divergent type with v-shaped teeth. Therefore, the growth of teeth arrangement that is peculiar to each *Anadara* species can be represented by using the critical size (Sasaki, 1990).

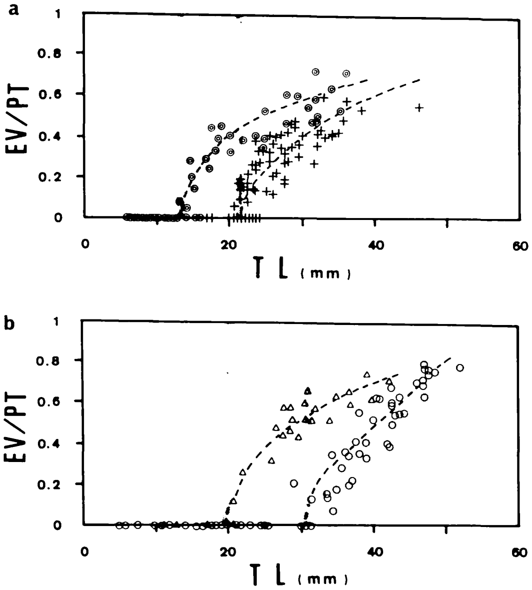


Figure 6. Distribution of ontogenetic variation in teeth arrangement represented by change in the value of EV/PT. A shell has the convergent type of teeth arrangement at EV/PT=0, and the divergent type with v-shaped teeth at EV/PT>0. Symbols as in **Figure 5.**

Figure 6a shows the relationships between EV/PT and TL of *Anadara* (*Scapharca*) *ommaensis* and *A.* (*S.*) *omaruensis*. *A.* (*S.*) *omaruensis* changes its teeth arrangement at TL=13 mm, and *A.* (*S.*) *ommaensis* transforms it at TL=21 mm, as shown by the shaded zones in the scatter diagram. Figure 6b shows the same relationships of *A.* (*H.*) *castellata* and *A.* (*S.*) *takanabensis*. *A.* (*H.*) *castellata* transforms its teeth arrangement at TL=20 mm, and *A.* (*S.*) *takanabensis* changes at TL=30 mm.

The difference in their critical size represents a difference in the ontogenetic change in teeth arrangement between these species, so that both *A.* (*S.*) *omaruensis* and *A.* (*S.*)

takanabensis differ from both *A.* (*S.*) *ommaensis* and *A.* (*H.*) *castellata.*

3) Size-dependent change in the position of the beak (AT/TL-TL relationship)

The ratio of AT/TL corresponds to the position of beak on the hinge line. The position of beak represents proximity of the shell shape to equilateral. The beak position of *Anadara* species migrates during growth, and the change can be represented by the relationship between AT/TL and TL. It is therefore concluded that the extent to which the shell is equilateral can be described by using the relationship of AT/TL to TL.

Figure 7a shows the relationship between AT/TL and TL of both *A.* (*S.*) *ommaensis* and *A.* (*S.*) *omaruensis.* Figure 7b shows the relationships between AT/TL and TL of both *A.* (*H.*) *castellata* and *A.* (*S.*) *takanabensis.* The relationships of these species are similar to each other throughout ontogeny.

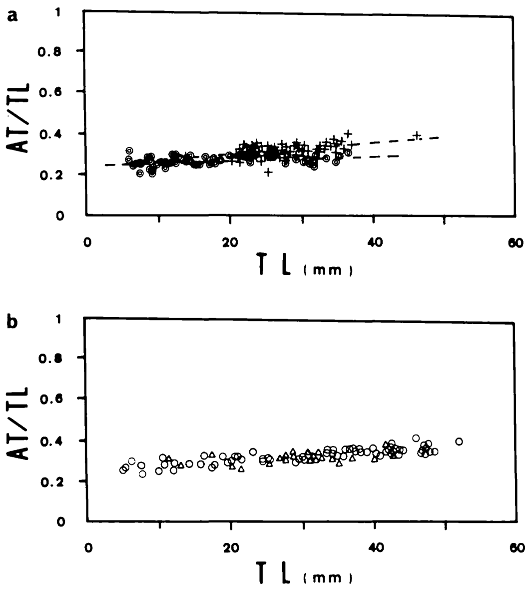


Figure 7. Ontogenetic change in the ratio of the length of the anterior teeth segment (AT) to the length of the toothed portion of the hinge line (TL); the ratio represents the migration of the beaks. Symbols as in **Figure 5.**

4) Size-dependent change in the shape of the commissure (AM/PM-TL relationship)

AM/PM is the ratio between the heights of the anterior and posterior margins of the commissure, which partly represents the shape of the commissure. Figure 8 shows the relationship between AM/PM and TL of the four populations studied here. The ranges of AM/PM of these species are smaller than AM/PM = 1, so that the commissure shapes of these species are somewhat expanded towards the posterior margin. The difference in the ratios of these species therefore will express the difference between the degree of expansion of the posterior and anterior parts. At the same value of TL, the AM/PM values of *A.* (*S.*) *ommaensis* and *A.* (*S.*) *omaruensis* are greater than those of *A.* (*H.*) *castellata* and *A.* (*S.*) *takanabensis.* The large ratio species are *A.* (*S.*) *ommaensis* and *A.* (*S.*) *omaruensis,* which are somewhat equilateral in the height of the commissure. The small ratio species are *A.* (*H.*) *castellata* and *A.* (*S.*) *takanabensis,* which are more expanded posteriorly than anteriorly.

Shape discrimination using Fourien Distance

In the light of the mathematical models, a difference in the shape of the commissure will produce an important difference in the shell shape. However, it has been difficult to

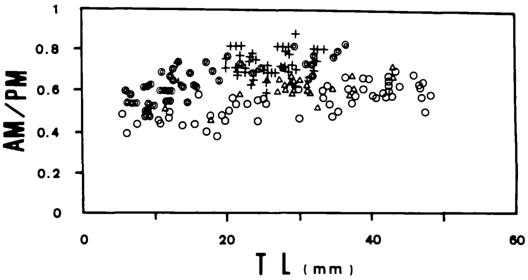


Figure 8. Ontogenetic change in the ratio between the heights of the anterior (AM) and posterior (PM) margins of the commissure. Symbols as in **Figure 5.**

measure the degree of difference between shapes of commissures, and also to analyse statistically the distribution of different shapes in a population. In this paper, the shape of the commissure will be described by using the Fourier Descriptors (Granlund, 1972), and the difference between the shapes will be measured by using the Fourier Distance in the Fourier Descriptors space (Persoon and Fu, 1977).

The Fourier Descriptors (FDs) given in Granlund (1972) are defined as follows: we assume r is a clockwise-oriented simple closed curve of the commissure with parametric representation $[x(l),\ y(l)]=z(l)$, where l is the arc length along r. A point moving along the boundary generates the complex function $u(l)=x(l)+iy(l)$ which is periodic with period L. The FDs become now

$$a_n=\frac{1}{L}\int_o^L u(l)e^{-i(2\pi/L)nl}$$

and

$$u(l)=\sum_{-\infty}^{\infty}a_n e^{in(2\pi/L)l}$$

If we denote by $\{a_n\}$ the FDs of a curve of the commissure α and by $\{b_n\}$ the FDs of a curve of the commissure β and M harmonics are used, then the distanced $(\alpha,\ \beta)$ given in Persoon and Fu (1977) are defined as follows:

$$d(\alpha,\ \beta)=\left[\sum_{n=-M,n\neq 0}^{M}|a_n-b_n|^2\right]^{1/2}$$

Suppose α and β are the commissure of specimens so we will scale (s), rotate (ϕ), and adjust the starting point (α) such that the distance is minimized. We have then to determine ϱ, ϕ, α such that

$$\sum_{n=-M,n\neq 0}^{M}|a_n-se^{i(n\alpha+\phi)}b_n|^2$$

is minimized.

The defined distance is the Euclidean metric in the space of the Fourier Descriptors $\{a_n\}$. The commissure shape of each specimen will be transformed by the Fourier Function to plot in the Fourier Descriptors space. Hence, the Fourier Distance between the place in the space represents the degree of difference between the commissural shapes.

Table 1. Exmample of the Fourier Distance between *Anadara* specimens analyzed here. T01 is a specimen of *Anadara* (*Scapharca*) *takanabensis*, n. sp. from Toriyama, and O19 is a specimen of *Anadara* (*Scapharca*) *ommaensis* (Otuka) from Omma.

	T02	T03	T04	T05	T06	T07	………	O15	O16	O17	O18	O19	O20
T01	14.69	11.10	9.06	9.22	11.26	8.53	………	19.92	30.95	16.00	21.29	14.83	20.23
T02		13.85	15.00	10.16	8.80	8.36	………	11.59	22.64	13.72	15.78	11.53	13.89
T03			16.05	7.82	7.24	7.58	………	16.92	24.31	11.60	14.68	13.96	17.30
T04				16.58	17.38	13.43	………	26.49	39.03	23.80	29.09	22.01	27.10
T05					5.18	6.15	………	13.91	25.44	10.53	15.14	9.79	15.06
T06						5.28	………	12.25	23.42	9.72	13.46	10.00	13.65
⋮							⋱	⋮	⋮	⋮	⋮	⋮	⋮
O14								10.67	7.58	12.65	7.25	14.34	10.26
O15									15.60	10.05	10.29	8.02	5.83
O16										16.98	11.35	18.70	14.30
O17											8.46	9.07	28.92
O18												10.09	8.00
O19													6.82

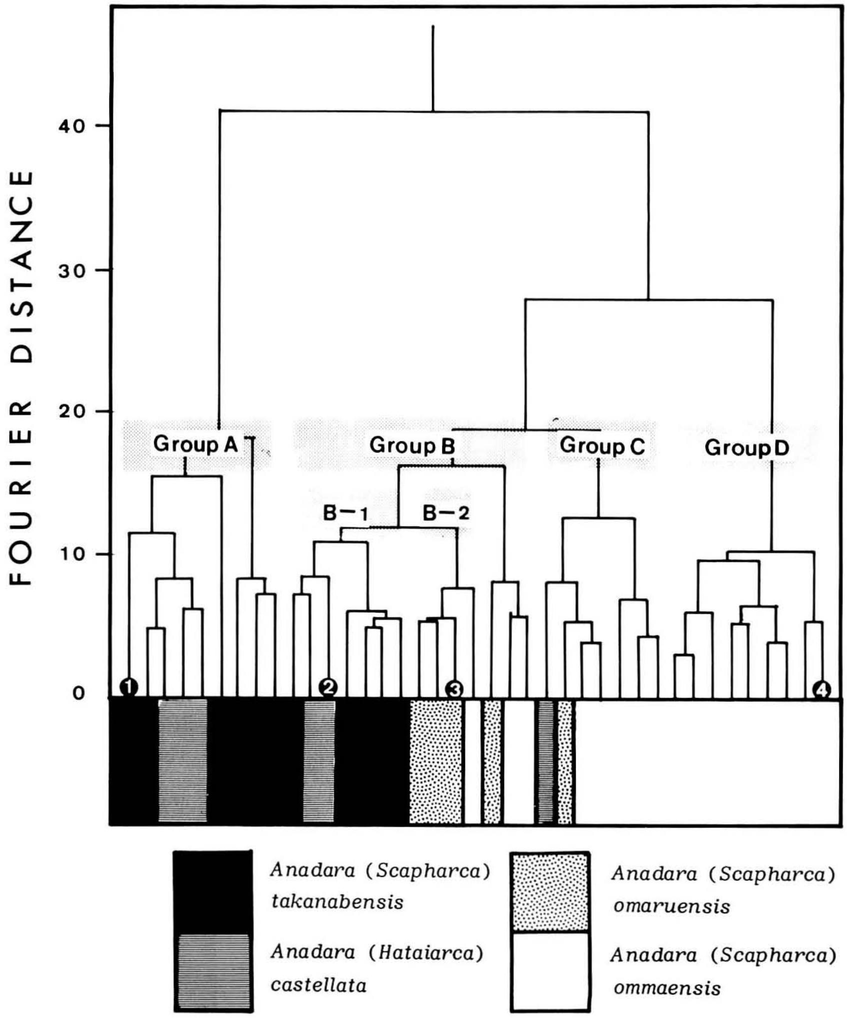


Figure 9. Dendrogram calculated by using the complete linkage clustering method based on the matrix of the Fourier Distance, of which an example is shown in Table 1.

The value of the Fourier Distance is 0 between specimens with the same shape of commissure.

Table 1 shows part of the matrix of the Fourier Distances between the specimens selected from the four populations, which are calculated by using 16 harmonics. The number of specimens used here is 15 of *Anadara* (*Scapharca*) *ommaensis*, 7 of *A.* (*S.*) *omaruensis*, 6 of *A.* (*H.*) *castellata*, and 11 of *A.* (*S.*) *takanabensis*, all of which are left valves of almost the same size.

Figure 9 shows the dendrogram constructed by using the complete linkage clustering method applied to the values in Table 1. Figure 10 shows typical commissural shapes analysed here. The numbers of each form in Figure 10 correspond to the numbers in the dendrogram in Figure 9.

As shown in Figure 9, these specimens can be classified into 4 groups based on the Fourier Distance. The least similarity is between the groups A and D, and the greatest similarity is between the specimens in the

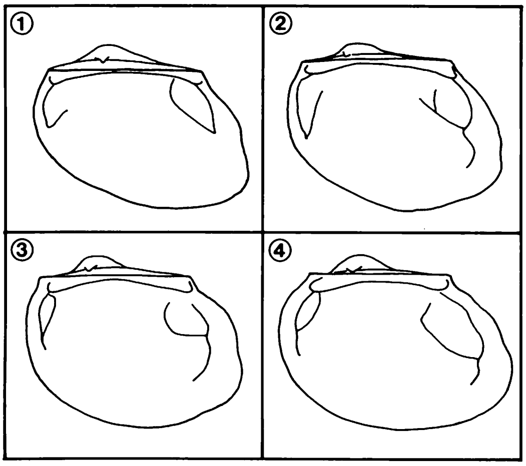


Figure 10. Examples of commissural shapes analysed by the Fourier Descriptors. The numbers correspond to the numbers in **Figure 9**, showing the positions of these examples in the dendrogram.

group B.

The shape of the commissure placed in the group A is characterized by a narrowly rounded anterior margin and a broad, truncated posterior margin, as is shown by the specimen 1 in Figure 10. The shape of the commissure placed in the group D is with broadly rounded anterior and ventral margins, as is shown by the specimen 4 in Figure 10. The specimens placed in the groups B and C have intermediate shapes between those in the groups A and D, as is shown by the specimens 2 and 3 in Figure 10.

Specimens of a species are distributed in a restricted range of the space, so that each group in the dendrogram includes only one or two species. Specific elements of these groups in the dendrogram are as follows ; the groups A and B-1 are composed of *Anadara* (*Scapharca*) *takanabensis* and *A.* (*H.*) *castellata,* the groups B-2 and C are mainly composed of *A.* (*S.*) *omaruensis* and *A.* (*S.*) *ommaensis,* and the group D is composed of *A.* (*S.*) *ommaensis.*

The possibility of discrimination of each species is dependent on the degree of overlapping of the ranges of distribution in the Fourier Descriptors space. As shown by the dendrogram in Figure 9, the range of *Anadara* (*Hataiarca*) *castellata* is completely overlapped by that of *A.* (*S.*) *takanabensis.* It is therefore impossible to discriminate these species based on the shape of the commissure. *A.* (*S.*) *takanabensis* and *A.* (*S.*) *omaruensis* in the group B have very similar commissural shape, but the range of *A.* (*S.*) *takanabensis* does not overlap that of *A.* (*S.*) *omaruensis,* so these species can be discriminated. It is difficult to discriminate *A.* (*S.*) *omaruensis* from *A.* (*S.*) *ommaensis* based on their commissural shapes because the ranges of these species overlap in the groups B and C.

Discussion

In this paper, shell form is described with respect to shell growth and the shape of the commissure. Shell growth is described by the size dependent change in the characters of the shell : 1) size-dependent change in CH, 2) size dependent change in EV/PT, 3) size dependent change in AT/TL, and the shape of the commissure is described by the parameters of 4) size-dependent change in AM/PM and 5) Fourier Descriptors. Differences among the *Anadara* species described by using these parameters will be interpreted in the framework of the spiral tube model, and the applicability of these parameters to the discrimination of species will be appraised.

Several spiral tube models have been proposed in studies of molluscan shell geometry (Owen, 1953 ; Rudwick, 1959 ; Raup and Michelson, 1965 ; Raup,1966). Raup and Michelson (1965) proposed 4 parameters for the description of shell form : 1) D, distance from the coiling axis to the generating curve, 2) W, rate of expansion of the generating curve, 3) T, rate of translation of the generating curve along the coiling axis, and 4) S, shape of the generating curve. The first three of these are parameters for the description of shell coiling.

The ratios between the defined intervals used for the description of *Anadara* shells correspond to the parameters of the model of Raup and Michelson (1965), which represents the basic geometry of any molluscan shells. CH/TL and EV/PT corresponds to D/W, representing the mode of shell coiling around the coiling axis. AT/TL corresponds to T, translation of the generating curve along the axis, and AM/PM can be compared with S, the shape of the generating curve of this model (Sasaki, in 1990).

1) Shell coiling around the coiling axis

In the framework of the spiral tube model, the CH-TL relationship directly represents ontogenetic change in the mode of shell coiling around the coiling axis, and the EV/PT-TL relationship indirectly represents the same character of coiling.

As shown in Figures 5a, b, the linear distribution in the diagram of the CH-TL relationship suggests that the shell forms a logarithmic spiral around the coiling axis (Sasaki, 1990). The angle which the approximate line forms to the TL axis can be interpreted as the degree of openness of a logarithmic spiral. Therefore, *Anadara* (*Scapharca*) *ommaensis* and *A.* (*S.*) *omaruensis* have more open logarithmic spiral shells than *A.* (*H.*) *castellata* and *A.* (*S.*) *takanabensis* have.

The *Anadara* shells change their teeth arrangement during ontogeny. The change in teeth arrangement is caused by the change in the shell coiling mode during growth. At EV/PT$>$0, the *Anadara* shell is growing in a logarithmic spiral around the coiling axis (Sasaki, 1990.). Therefore, the critical size is the size at which the *Anadara* shells change their mode of shell coiling to a logarithmic spiral. The logarithmic spiral model explains well the rapid increase in the inflation of a shell in old age compared with its slow expansion of the commissure. The critical size appears to be a useful index of the maturity of a shell. The ontogenetic change in teeth arrangement measured for an *Anadara* species always produces a restricted distribution in the scatter diagram of the relationship of EV/PT to TL. In many cases, however, the measurement in a population of two or more species produces a wide range of distribution in a scatter diagram (Sasaki, 1990). The EV/PT-TL relationship of the *Anadara* species can be interpreted as the characters of growth peculiar to each species, hence the critical size is a useful criterion for discrimination of these *Anadara* species. Therefore, each *Anadara* population studied here could contain a single species, because each population is distributed in a restricted range in the diagram. Also these species differ in their critical size of the change in teeth arrangement, hence they are different species.

2) Translation of the generating curve along the coiling axis

The AT/TL-TL relationship represents the translation along the coiling axis. As shown in Figures 7a, b the relationships of these species are very similar during growth, so that these species are similar in the degree of the translation of the generating curve along the coiling axis.

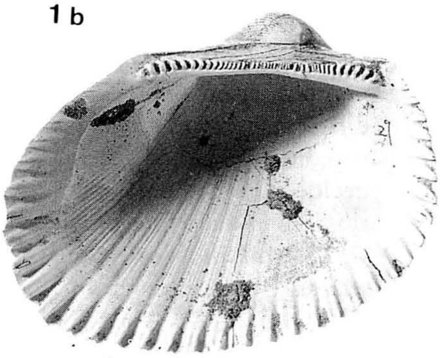
3) Shape of the generating curve

In the Fourier Descriptors space, variation of a population will be characterized by the extent and the number of dimension of the region where the specimens of the population are distributed. In this analysis, specimens of these *Anadara* species are distributed in an one-dimensional region in the Fourier Descriptors space, and the typical forms in

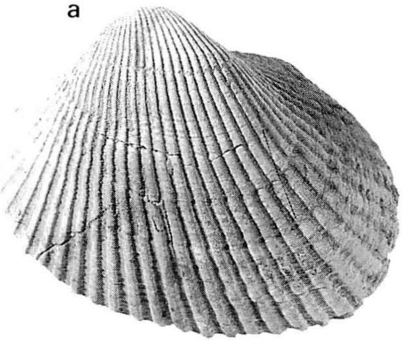
---

→ **Figure 11.** **1a, b**: *Anadara* (*Scapharca*) *ommaensis* (Otuka) from the Omma Formation (×1). **2a, b**: *Anadara* (*Scapharca*) *omaruensis*, n. sp. from the Koyu Formation, IGPS coll. cat. No. 10325 (Holotype) (×1). **3a, b**: *Anadara* (*Hataiarca*) *castellata* (Yokoyama) from the Kakegawa Group (Dainichi Sandstone) (×1). **4a, b**: *Anadara* (*Scapharca*) *takanabensis*, n. sp. from the Koyu Formation, IGPS coll. cat. No. 101327 (Holotype) (×1).

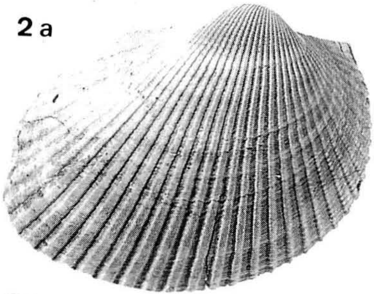
1 b



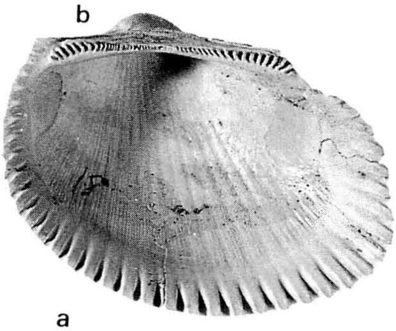
a



2 a

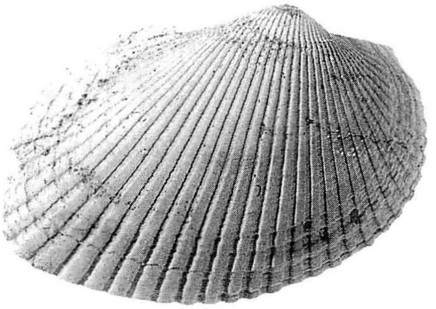


b

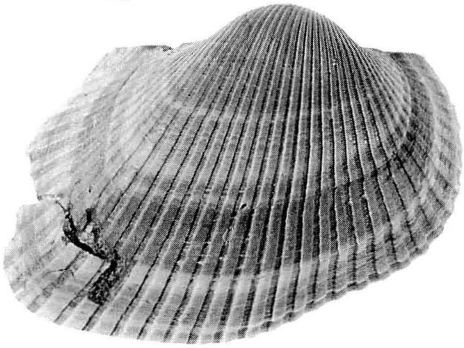


3 b

a



4 a



b

different position in the dendrogram are different in the degree to which their commissure shape is inequilateral. It is therefore possible to represent most of the variation in the commissure shape of these species by using the ratio AM/PM.

In the AM/PM-TL diagram (Figure 8), the range of *Anadara* (*Scapharca*) *ommaensis* overlaps that of *A.* (*S.*) *omaruensis,* and the range of *A.* (*H.*) *castellata* overlaps that of *A.* (*S.*) *takanabensis.* This shows that *A.* (*S.*) *ommaensis* is similar to *A.* (*S.*) *omaruensis* in commissural shape, and *A.* (*H.*) *castellata* is similar to *A.* (*S.*) *takanabensis.* Therefore, the ratio AM/PM is a useful parameter for the discrimination of a new species from its allied species.

Anadara (*Scapharca*) *takanabensis* from Toriyama was first classified as *Anadara inflata* by Yokoyama (1928). Shuto (1961) reported it under the name *Anadara castellata* and Noda (1966) identified it as *A.* (*S.*) *iwashibaraensis.* Yoshida (1987) placed the species in *A.* (*H.*) *castellata.* The comparison in this paper suggests that *A.* (*S.*) *takanabensis* is allied to *A.* (*H.*) *castellata* but is a different species.

Anadara (*Scapharca*) *iwashibaraensis* was originally described by Noda (1965) based on a specimen from the Dainichi area. According to the original description, this species is characterized by a narrowly rounded anterior margin and a broadly truncated posterior margin. Therefore the commissure shape of *A.* (*S.*) *iwashibaraensis* seems to be similar not only to that of *A.* (*S.*) *takanabensis* but also to that of *A.* (*H.*) *castellata,* which plotted in the group A in the dendrogram (Figures 9, 10). It is therefore impossible to discriminate these species on the basis of commissural shape.

The range of rib numbers is an important measurement in specific determination of *Anadara* species (Reinhart, 1943). The shell surface of *Anadara* (*Scapharca*) *iwashibaraensis* is sculptured with 31 radial ribs. However, *A.* (*S.*) *takanabensis* ranges in rib numbers from 36 to 39. These species are different in rib numbers provided it is remembered that on some specimens it is difficult to decide which threads should be counted as ribs. It is therefore possible to discriminate *A.* (*S.*) *takanabensis* from *A.* (*S.*) *iwashibaraensis* by the number of ribs.

Conclusion

1) *Anadara* (*Scapharca*) *omaruensis*, n. sp. from Iwasebashi is allied to *A.* (*Hataiarca*) *castellata* and *A.* (*S.*) *ommaensis.* It differs, however, from allied species in the mode of shell coiling around the coiling axis, which is represented by the size-dependent change in EV/PT. *A.* (*S.*) *omaruensis* is more allied to *A.* (*S.*) *ommaensis* than to *A.* (*H.*) *castellata* in the shape of the commissure, which is represented by the size-dependent change in AM/PM.

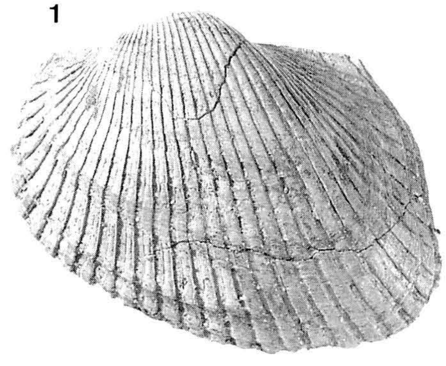
2) *Anadara* (*Scapharca*) *takanabensis*, n. sp. from Toriyama is closely allied to *A.* (*H.*) *castellata* in commissural shape, but differs from in the mode of shell coiling around the coiling axis.

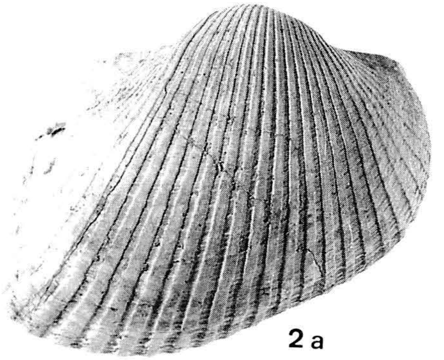
3) *Anadara* (*Scapharca*) *takanabensis* is allied to *A.* (*S.*) *iwashibaraensis* in commissural shape, but it differs from the latter in the number of radial ribs.

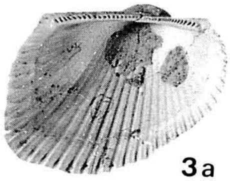
Acknowledgments

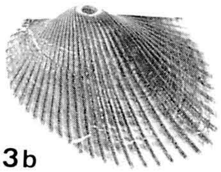
The author wishes to express deep gratitude to Prof. Kenshiro Ogasawara of Institute of Geoscieme, University of Tsukuba for his continuous guidance and kind encouragement during this study. Deep appreciation is due to Dr. Alan G. Beu of New Zealand Geological Survey for his kind suggestions and critical reading of the manuscript.

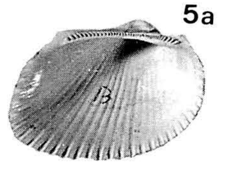
→ **Figure 12. 1, 2a – 4b** : *Anadara* (*Scapharca*) *takanabensis*, n. sp. from the Koyu Formation, IGPS coll. cat. No. 10326, (×1). **5a – 8b** : *Anadara* (*Scapharca*) *omaruensis*, n. sp. from the Koyu Formation, IGPS coll. cat. No. 101328 (×1).

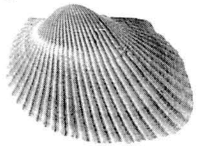

1

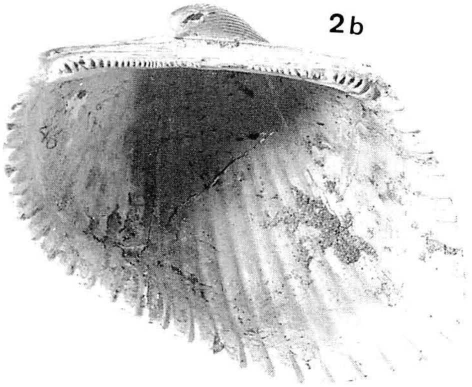

2 a

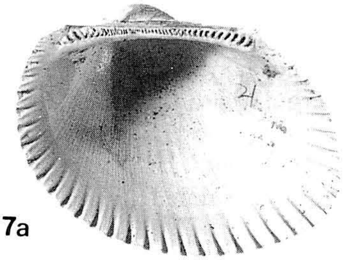

3a

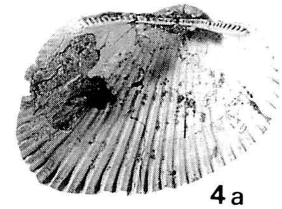

3b


5a

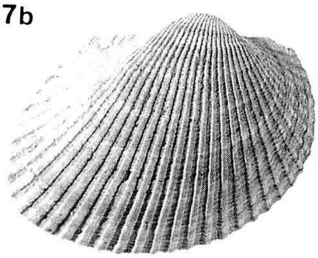

5b

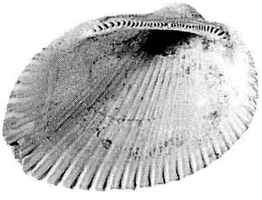

2b

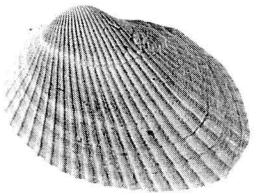

7a

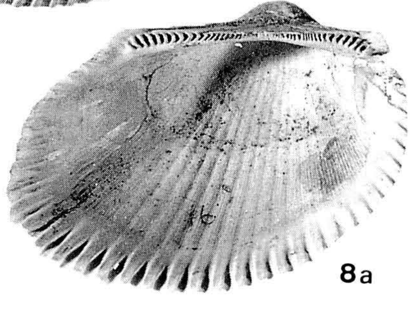

4a

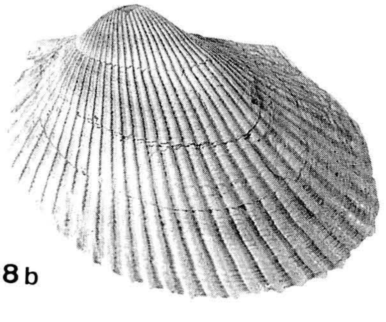

4b


7b


6a


6b


8a


8b

Systematic discription

Family Arcidae Lamarck, 1809
Subfamily Anadarinae Reinhart, 1935
Genus *Anadara* Gray, 1842
Subgenus *Scapharca* Gray, 1847
Anadara (*Scapharca*) *omaruensis*, n. sp.

Figures 11-2a, b; 12-5a-8b

Description.—Shell medium in size, moderately thick, slightly inequivalve and inequilateral; beaks prosogyrate, situated at anterior third of shell; shell elongate in outline, hinge margin straight, interrupted by prominent narrow umbones; ventral margin broadly curved, anterior margin smoothly rounded, posterior margin sharply curved below, straight above without depressed area along posterior side.

External surface sculptured with 36-39 radial ribs (commonly 37-39); surface of ribs strongly granulated on left valve, rather smooth on right valve; most ribs narrower than their interspaces.

Cardinal area narrowly trigonal, with chevron-shaped grooves. Hinge somewhat arched, rather narrow, slightly wider at extremities than at center of shell; taxodont teeth small and numerous; teeth diverge ventrally near center of hinge line, and converge with v-shaped teeth at extremities in adult shells; all teeth convergent in juvenile shells. Inner ventral margin sculptured accordance with external ribs.

Comparison.—The present species resembles *Anadara* (*Scapharca*) *ommaensis* (Otuka) from the Omma Formation and *Anadara* (*Hataiarca*) *castellata* (Yokoyama) from the Dainichi Sandstone, but as shown above the teeth arrangement of *A.* (*S.*) *omaruensis* is different from those of these allied species at the same shell size. *A.* (*S.*) *broughtonii* (Schrenck) is allied to *A.* (*S.*) *omaruensis*, but has a larger number of radial ribs than this species.

Localities.—Iwasebashi, Matsubara, Kawaminami-machi, IGPS coll. cat. No. 101325 (Holotype), IGPS coll. cat. No. 101326; Kurotai, Kawaminami-machi, Namikake, Kawaminami-machi, Koyu Formation in the Miyazaki Group, Pliocene.

IGPS is the abbreviation for Institute of Geology and Paleontology, Tohoku University, Sendai.

Anadara (*Scapharca*) *takanabensis*, n. sp.

Figures 11-4a, b; 12-1, 4b

Anadara (*Scapharca*) *iwashibaraensis*, Noda, 1966, pl. 2, fig. 26, pl. 12, figs. 16-17.

Description.—Shell large, inflated, inequilateral, beaks prosogyrate, situated at anterior third to fourth of length; shell elongate, hinge margin long and straight, anterior margin narrowly rounded, ventral margin broadly rounded, posterior margin truncated, with depressed area along posterior side. External sculpture similar on right and left valves, consisting of 35-39 radial, rather flat-topped ribs (commonly 36-37); interspaces between ribs of same width as one rib, crossed by commarginal growth lines. Ligamental area rather narrow. Hinge straight and narrow; taxodont teeth small and numerous; inner margin crenulated in accordance with external ribs.

Comparison.—The present species resembles *Anadara* (*Hataiarca*) *castellata* (Yokoyama), but as shown above these species differ in their ontogenetic change of the teeth arrangement. This species is allied to *A.* (*S.*) *iwashibaraensis* Noda, but the latter has only 31 radial ribs. *A.* (*S.*) *taiwanica* Noda resembles *A.* (*S.*) *takanabensis*, but its shell is more inflated and more equilateral than this species.

Localities.—Toriyama, Kawaminami-machi, Koyu-gun, Miyazaki Prefecture, IGPS coll. cat. No. 101327 (Holotype), IGPS coll. cat. No. 101328: Nihonmatsu, Takanabe-machi, Koyu-gun, Miyazaki Prefecture, Koyu

Table 2. Measurements of *Anadara* (*Scapharca*) *omaruensis*, n. sp.

Specimen	L	H	C	TL	CH	EV	PT	AT	PM	AM	Ribs	L/R
101328- 1	9	8	2.5	5.9	0.2	0	3.8	1.6	5.5	3.3	38	R
- 2	10	9	3	7	0.3	0	4.4	1.7	6.5	3.5	37	L
- 3	11.5	10	3	7.5	0.3	0	4.8	1.9			37	R
- 4	16	13	4	9.3	0.5	0	6.5	1.9	8.5	4	37	L
- 5	20	16	6	12.5	0.7	0	7.8	3.7	10	6.5	38	R
- 6	20	15	5.5	12.1	0.5	0	7.8	3.4	10	6	38	R
- 7	25	20	7	15.8	0.4	0	10.8	4	13	8	38	L
- 8	28.5	24	8	17.8	1.5	5.2	11.8	5	16	7	38	L
- 9	46	34	12	28	3.3	11.2	18.7	7.5	20	14	36	L
-10	15	13	4	8.8	0.5	0	5.9	1.9	8.5	4	37	L
-11	16	14	5	10.1	0.6	0	6.6	2.5	8.5	4.5	36	L
-12	15	15	3.5	9.1	0.4	0	5.8	2.4	8	4	39	L
-13	26	19	7	15	0.8	1.9	9.8	3.9	12.5	8.5	38	L
-14				19	1.6	5.5	12.3	5.4	17	11	37	L
-15				28	2.7	8	17.3	8.9			39	L
-16	52	42	14	32	3.7	9.3	20.4	9.1	24	16	39	L
-17	54	40	15	32	3.9	12.3	21.2	8.5	27	18	38	R
-19				24.8	1.8	5.5	14	7.3			38	R
-20				15.3	1.1	1.5	10.3	3.9			38	R
-21	54	41	15	32	3.5	15.5	21.9	8	25	18	39	R
-30	12	10	4	7.4	0.4	0	5	1.5	6.5	3.5	36	R
-31	14	11.5	4.5	9.1	0.5	0	5.7	2.6	7.5	4	38	L
-32	13.5	11	4	8.6	0.4	0	5.5	2.4	6.5	4		R
-33	14	11.5	4	8.7	0.5	0	6	1.9	8	4	38	L
-34	16.5	14	5	11	0.5	0	7.2	2.8	10	6	38	R
-35	17	13.5	6	11	0.5	0	7.5	2.5	8	5.5	36	R
-36				10.5	0.5	0	6.9	2.7			37	R
-37	20	16	6	12.4	0.8	0	8.3	3.2	10	6	38	L
-38	20	16	6	12.5	0.6	0	8	3.4	10	7	37	R
-39	23	18	6.5	14.1	0.6	0	9.5	3.7	12	7.5	39	L
-40	25	19.5	7	15.5	1	0	10.5		12	7.5	39	R
-41			8	16.9	1.2	3.1	10.9	4.9			38	L
-51	61	45	16	36.7	3	12	24	12	27	22	37	L
-52	58	56	17	35.5	3	12	23.1	11	28	22	38	R
-53	55	40	16	32.2	3	10	20.3	10	25	19	37	L
-54	55	42	15	35	3	10	23.6	10	25	19	37	R
-55	49	35	14	29.5	3	11.3	19	8.5	21	17	38	L
-56	50	36	17	31	3	11	20.5	8.5	22	16	38	R
-57	37	28	10	20.2	1.9	5.4	13.5	6	17	13	39	L
-58	40	30	10	23.7	2.1	6.2	15.5	7	19	13	38	L
-59	37	28	10	22.1	2.1	5.5	14.5	6.5	18	13	39	L
-60	34	27	9	18.2	1.8	4	12.3	4.8	16	11	37	L
-61	40	30	11	25	1.8	6.3	16.2	7.4	17	12	39	R
-62	29	22	8	17.4	1.2	2.7	11.3	4.5	13	9.5	39	R
-63	23	19	6.5	13.2	0.9	0		3.6	11.5	8.5	38	L
101327	51	40	14	31.5	3.5	9.5	20.2	8.8	26	17	39	R

All specimens from the Koyu Formation, Miyazaki Prefecture

Table 3. Measurements of *Anadara* (*Scapharca*) *takanabensis*, n. sp.

Specimen	L	H	C	TL	CH	EV	PT	AT	PM	AM	Ribs	L/R
101326- 1	8	6.2	2	5.3	0.2	0	3.9	1.4	5.3	2.5	35	R
- 2				5	0.1	0	3.7	1.3			36	L
- 3				7.6	0.3	0	5.5	2.1			37	L
- 4	9.2	12.5	3	6.1	0.5	0	4.3	1.8	6.5	2.5	36	L
- 5				7.6	0.5	0	5.8	1.8	7.9	3.4	35	R
- 6	16	12	4	10.7	0.5	0	7.2	3	10	4.3	36	R
- 7	11	13.5	4.5	9.9	0.7	0	7.4	2.5	9.7	5	35	L
- 8	18	14	4.5	12.2	0.4	0	8.7	3.5	11.3	5.5	37	R
- 9	22	17	5.5	14.2	0.8	0	10.1	4.1	13	5.5	38	L
-10	19	15	5	12.1	0.7	0	9	3.1	10.5	4.8	37	R
-11	29	24	8	19.2	1.1	0	12.9	5	17	7	36	L
-12	16	12.5	4.5	10.5	0.5	0	7.2	3.3	9	4	38	R
-13	23	18.5	6.5	15.8	0.9	0	11.3	4.5	14	6	37	L
-14	27	22	7	18.9	0.8	0	12.8	6.1	16	6	38	R
-15	26	20	8	17.4	0.8	0	12.8	4.6	15	6	38	L
-16	30	23	9	19.5	1.2	0	13.9	5.6	17	8	37	R
-17	31	25	8.5	20.9	1.1	0	14.2	6.7	18	10	37	L
-18	33	26.5	9	20.5	1.5	0	14	6.5	20	10	37	L
-19				16.3	0.8	0	11	5.3	14	8	37	L
-20	26.5	21.5	8	17.8	1.2	0	12.8	5	16	7.5	37	L
-21	32	24	8.5	21.5	1	0	15	6.5	17	9	36	L
-22	30	23	8	20	0.9	0	14	6	17	7.5	35	R
-23	37.5	28	11	24.5	1.4	0	17	7.5	20	11	37	R
-24	35	26	10	23	0.8	0	15.2	7.8	19	10	36	L
-25	38	30	10	25.5	1.5	0	17.8	7.7	20.5	11	39	L
-26	37	28	10	25.2	1.1	0	17.4	7.8	20	11	37	R
-27	45	35	13	30	1.8	0	20.4	9.6	25	15	37	L
-28	55	40	14	35.7	2.4	6.5	23.7	11.3	30	15	37	L
-29	49	35	14	33.5	2	3.4	21.2	11.6	27	15	36	R
-30	48	35	12.5	30.1	1.8	0	20.9	9.2	26	12	37	L
-31	50		13.5	31	2	0	21	10			36	R
-32	49	40	13.5	34.9	2.1	3.8	21.5	11.2	27.5	13	35	L
-33	50	40	13	33.6	2	3.1	22	11	27	16	37	L
-34	55	40	15	34.2	2.1	7.5	21.8	11.8	28	17	37	R
-35	53	40	15	34.4	2.2	1.5	20.7	12	28	15	36	L
-36	55	42	15.5	37	2.5	5	23	13.2	30	18	39	L
-37	54	44	14	36.5	2.8	7.4	22.1	13.1	29	19	37	L
-38	57	41	16	37.4	3.3	9.5	23.4	12.9	30	16	36	R
-39	62	49	17	41.8	3.1	10	25.4	14.4	34	20	36	L
-40				36	3.3	8	22.3	12.8			37	R
-41	55		16	36.5	2.3	4.5	22.6	13			35	L
-42		45	17.5	38	3	8.2	23.3	13.3	35	20	38	R
-43	61	45	18	43	3.3	13	24.2	15.2	30	17	39	R
-44	60	46	18	40.3	3.5	15.7	25.3	13.4	33	19	37	R
-45	63	46	18	40.8	3.1	15.1	24.5	13.1	32	18	35	R
-46	63	51	22	42	4.8	17	25	15.7	33	21	36	R
-47	63	45	19	39	2.5	8	24.6	13.3	32	21	37	R
-48	63	44	17	39	2.7	10	24.8	13.3	30	18	35	R
-49	59	45	19	42	2.2	9.9	25.5	14.8	33	19	36	R
-50	68	50	21	42.5	4.7	15.1	25.3	15.4	34	20	35	L
-51	65	50	18	19.9	4.1	13	25.5	14.2	32	21	36	L
-52	63	49	19	42.5	3.8	15.3	26.1	14.5	33	22	37	R
-53	61	52	19	42.5	2.7	12.5	25.5	16	34	21	36	R
-54	70	55	22	47	5.3	21	29.3	16	35	22	37	L
-55	68	52	22	47	5.3	21.3	27	17.3	36	22.5	36	R
-56	70	53	19	43.5	4.3	17.3	27.7	14.7	32	22	37	L
-57	71	54	22.5	47.5	5.4	21.3	28.3	16	36	23	37	R
-58			19	46.8	4.8	19	27.5	15.7			37	L
-59			20	46.6	3.4	20	28.9	15.4			36	L
-60	74	58	23	48.4	5.1	22.5	29.8	16.2	40	23	35	R
-61	70	57	21	47	5.2	21.5	28	17.3	37	23	36	L
-62	74	57	23	46	5.3	18.5	26.4	18.5	40	27	38	R
-63	66	53	21	44	2.8	14.5	26.5	15.5	37	23	39	L
101325	66	51	17.5	41.5	3	14	25.5	14.5	32	21	38	R

All specimens from the Koyu Formation, Miyazaki Prefecture

Formation in the Miyazaki Group, Pliocene.

References

Ehrlich, R. and Weinberg B., 1970 : An exact method for characterization of grain shape. *Jour. Sed. Petrology,* vol. 40, no. 1, p. 205-212.

Granlund, G.H., 1972 : Fourier preprocessing for hand print character recognition. *IEEE Trans. Computers,* vol. C-21, p. 195-281.

Noda, H., 1965, Some fossil *Anadara* from Southwest Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 81, p. 27-51, pls. 10-11.

——, 1966 : The Cenozoic Arcidae of Japan. *Sci. Rep., Tohoku Univ., 2nd Ser.*, (*Geol.*), vol. 38, no. 1, p. 1-163, pls. 1-14.

Ogasawara, K., 1977 : Paleontological analysis of Omma Fauna from Toyama-Ishikawa Area, Hokuriku Province, Japan. *Ibid.*, vol. 47, no. 2, p. 43-156, pls. 3-22.

Owen, G., 1953 : The shell in the Lamellibranchia. *Quart. Jour. Micros. Soc.*, vol. 94, p. 57-70.

Persoon, E. and Fu, K.S., 1977 : Shape discrimination using Fourier Descriptors. *IEEE Trans. Systems, Man. Cyber.,* vol. SMC-7, no. 3, p. 170-179.

Raup, G.M., 1966 : Geometric analysis of shell coiling ; General problems. *Jour. Paleont.,* vol. 40, no. 5, p. 1178-1190.

—— and Michelson, A., 1965 : Theoretical morphology of the coiled shell. *Science,* vol. 147, p. 1294-1295.

Reinhart, P.W., 1943 : Mesozoic and Cenozoic Arcidae from the Pacific Slope of North America. *Geol. Soc. America, Special Paper*, vol. 47, p. 1-117, pls. 1-15.

Rudwick, M.J.S, 1959 : The growth and form of brachiopod shells. *Geol. Mag.*, vol. 96, p. 1-24.

Sasaki, O., 1990 : Parameters for description of the shell form of the genus *Anadara. Trans. Proc. Palaeont. Soc. Japan, N.S.,* no. 158, p. 513-534.

Shuto, T., 1961 : Paleontological study of the Miyazaki Group—A general account of the faunas—. *Kyushu Univ., Mem. Fac. Sci.*, vol. 10, no. 2, p. 73-206, pls. 11-13.

Suzuki, H., 1987 : Stratigraphy of the Miyazaki Group in the southeastern part of Miyazaki Prefecture, Kyushu, Japan. *Contr., Inst. Geol. Paleont., Tohoku Univ.,* no. 90, p. 1-24.

Tsuchi, R. and Ibaraki, M., 1981 : Stratigraphic outlines of selected Neogene sequences 2) Kakegawa area. *In* Tsuchi, R., *ed.*, *Neogene of Japan—Its biostratigraphy and chronology—*, p. 37-41.

—— and —— 1988 : Notes on the Omma-Manganji Molluscan Fauna : Its geologic age and paleoceanographic implications. *Saito Ho-on Kai Spec. Pub.* (*Prof. T. Kotaka Commem. Vol.*), p. 557-565.

Yokoyama, M., 1923 : Tertiary Mollusca from Dainichi in Totomi. *Jour., Coll. Sci., Tokyo Imp. Univ.*, vol. 44, p. 1-18, pls. 1-2.

Zahn, C.T. and Roskies, R.Z., 1972 : Fourier descriptors for plane closed curves. *IEEE Trans. Computers,* vol. C-21, p. 269-281.

殻成長計数とフーリェ記述子を用いた *Anadara* 属2新種の判別：二つの方法を用いて，*Anadara* 属の2新種，*Anadara* (*Scapharca*) *omaruensis* と *Anadara* (*Scapharca*) *takanabensis* をそれぞれの類似種から判別した。ひとつの方法は殻の成長変化を記述し，成長変化の差異から殻の螺管モデルの枠組みの中で殻形態の差異を評価する方法である。これらの結果，2新種を含む4種は殻の巻軸回りでの螺旋の様式に違いがあることがわかった。もうひとつの方法は，殻開口部の形態をフーリェ記述を用いて記述し，2個体間の殻開口部の形態の差異をフーリェ記述子間の違いを表すフーリェ距離によって示す方法である。4種を含む標本群の個体間のフーリェ距離をクラスタリング法によってデンドログラムにまとめた結果は，4種の形態の類似は殻開口部の不等側の程度によって表され，大きく2つのグループに分けられることを示している。 佐々木　理

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 161, pp. 714-719, 3 Figs., April 30, 1991

914. MIDDLE CARBONIFEROUS BACTRITOIDEA (MOLLUSCA: CEPHALOPODA) FROM THE AKIYOSHI LIMESTONE GROUP, YAMAGUCHI PREFECTURE (MOLLUSCAN PALEONTOLOGY OF THE AKIYOSHI LIMESTONE GROUP-X)*

SHUJI NIKO

Department of Environmental Studies, Faculty of Integrated Arts
and Sciences, Hiroshima University, Hiroshima 730

TAMIO NISHIDA

Department of Earth Sciences, Faculty of Education,
Saga University, Saga 840

and

YUKO KYUMA

Nishiurakami Elementary School,
Nagasaki 850

Abstract. A Middle Carboniferous bactritoid fauna is described from the Akiyoshi Limestone Group at Isa, Mine City, Yamaguchi Prefecture. The components of this fauna and those age based on the associated foraminifers are: *Bactrites nagatoensis*, sp. nov. (Late Bashkirian-Early Moscovian), *B*. sp. (Late Bashkirian), and *Ctenobactrites* sp. (Early Moscovian). This is the first detailed systematic report of bactritoids in Japan.

Key words. Middle Carboniferous bactritoids, *Bactrites, Ctenobactrites,* Akiyoshi Limestone Group.

Introduction

Many well-preserved bactritoids, which have not previously been described in Japan, were recovered by two of us (T. Nishida and Y. Kyuma) from the Akiyoshi Limestone Group at Isa, Mine City, Yamaguchi Prefecture (Figure 1). On the basis of these specimens, the present report describes three species including a new taxon. Details of the mode of occurrence and the associated molluscan fauna were previously reported by Nishida and Kyuma (1986) with preliminary assignment (*Bactrites* spp.) of the bactritoids.

Specimens utilized in this report are reposited in the paleontological collections of the Akiyoshi-dai Museum of Natural History (ASM), Yamaguchi Prefecture.

Systematic paleontology

Subclass Bactritoidea Shimansky, 1951
Order Bactritida Shimansky, 1951
Family Bactritidae Hyatt, 1884
Genus *Bactrites* Sandberger, 1843

---

*Received April 18, 1990; revised manuscript accepted March 1, 1991

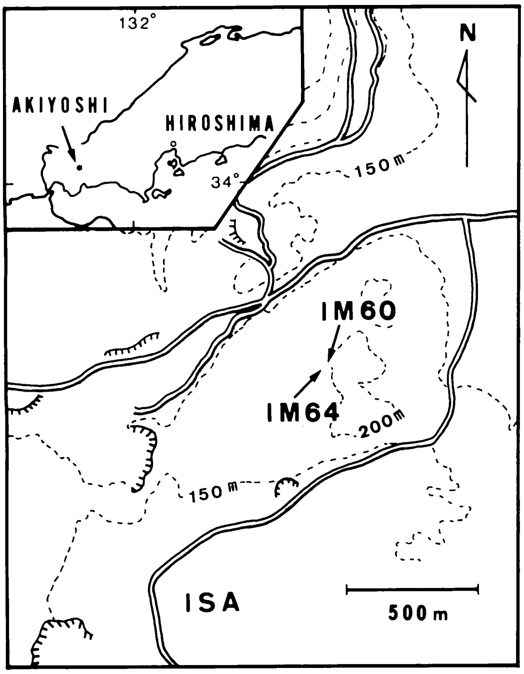


Figure 1. Index map of Isa, Yamaguchi Prefecture, showing the bactritoid localities.

Bactrites nagatoensis Niko, Nishida and Kyuma, sp. nov.

Figures 2, 3-1–5

Material.—Twenty-nine incomplete phragmocones were examined. Holotype, ASM 51310; paratypes, ASM 51311-51313, 51351-51355, 51384.

Diagnosis.—Large-sized *Bactrites* with compressed cross section in mature shell and well-developed dorsal carina; camera relatively long with deeply concaved septa; sutures simple.

Description.—Phragmocone longiconic orthocone, large; largest paratype (ASM 51355) having maximum diameter 62 mm; cross section of shell circular in juvenile phragmocone and laterally compressed in later stages; holotype, 108 mm in length, expands from 17 to 25 mm over 82 mm. A single dorsal carina well-developed, pointed in early juvenile phragmocone, later it becomes indistinct ridge; weak transverse lirae developed in later juvenile and mature shell. Septal concavity deep; sutures simple, slightly oblique, forwards aperture on venter, possess a ventral lobe at siphuncle; cameral length relatively long, width/length ratio of dorsoventral section through siphuncle ranges from 0.6 to 0.7; siphuncle ventral and marginal with orthochoanitic necks.

Remarks.—*Bactrites nagatoensis,* sp. nov. most resembles *B. peytonensis* Mapes, 1979, from the Chesterian (Lower Carboniferous) of Arkansas, in that both taxa possess a compressed cross section in the later stages, a dorsal carina and simple sutures. However, the longitudinal surface lirae and the transverse ribs on the mature shell of the latter species are not observed in *B. nagatoensis.*

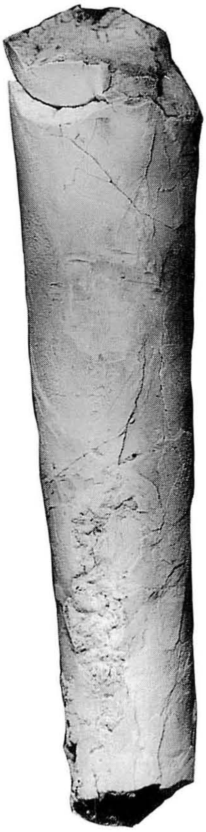
This new species also resembles *Bactrites finisensis* Mapes, 1979, from the Virgilian (Upper Carboniferous) of Texas and *B. mexicanus* Miller, 1944, from the Guadalupian (Upper Permian) of Las Delicias, Mexico in the possession of a dorsal carina. *B. finisensis* differs from *B. nagatoensis* by the lower ratio of cameral length/shell diameter. *B. mexicanus* can be differentiated from *B. nagatoensis* in having a dorsal saddle.

Occurrence and age.—*Bactrites nagatoensis,* sp. nov. is locally a common component of the Middle Carboniferous strata of the Akiyoshi Limestone Group. With the exception of a paratype (ASM 51384), which was collected from a bioclastic grainstone in the *Profusulinella beppensis* Zone (Late Bashkirian) at loc. IM 64, specimens were found in a coquinoid limestone of the *Fusulinella biconica* Zone (Early Moscovian) at loc. IM 60.

Etymology.—The species is named for Nagato, which is a medieval country name of the type locality.

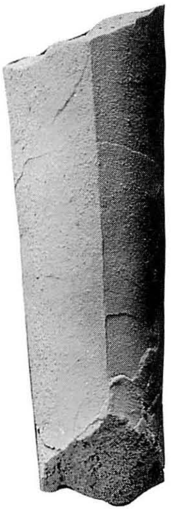
Bactrites sp.

Figures 3-6–9

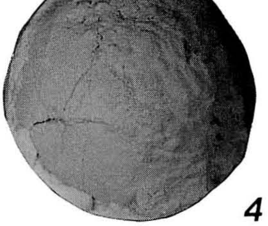

1


2


3

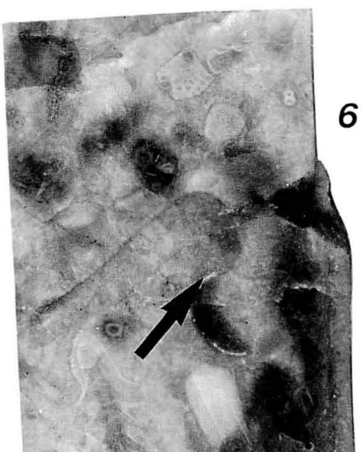

7


8


4


9


5


6


10

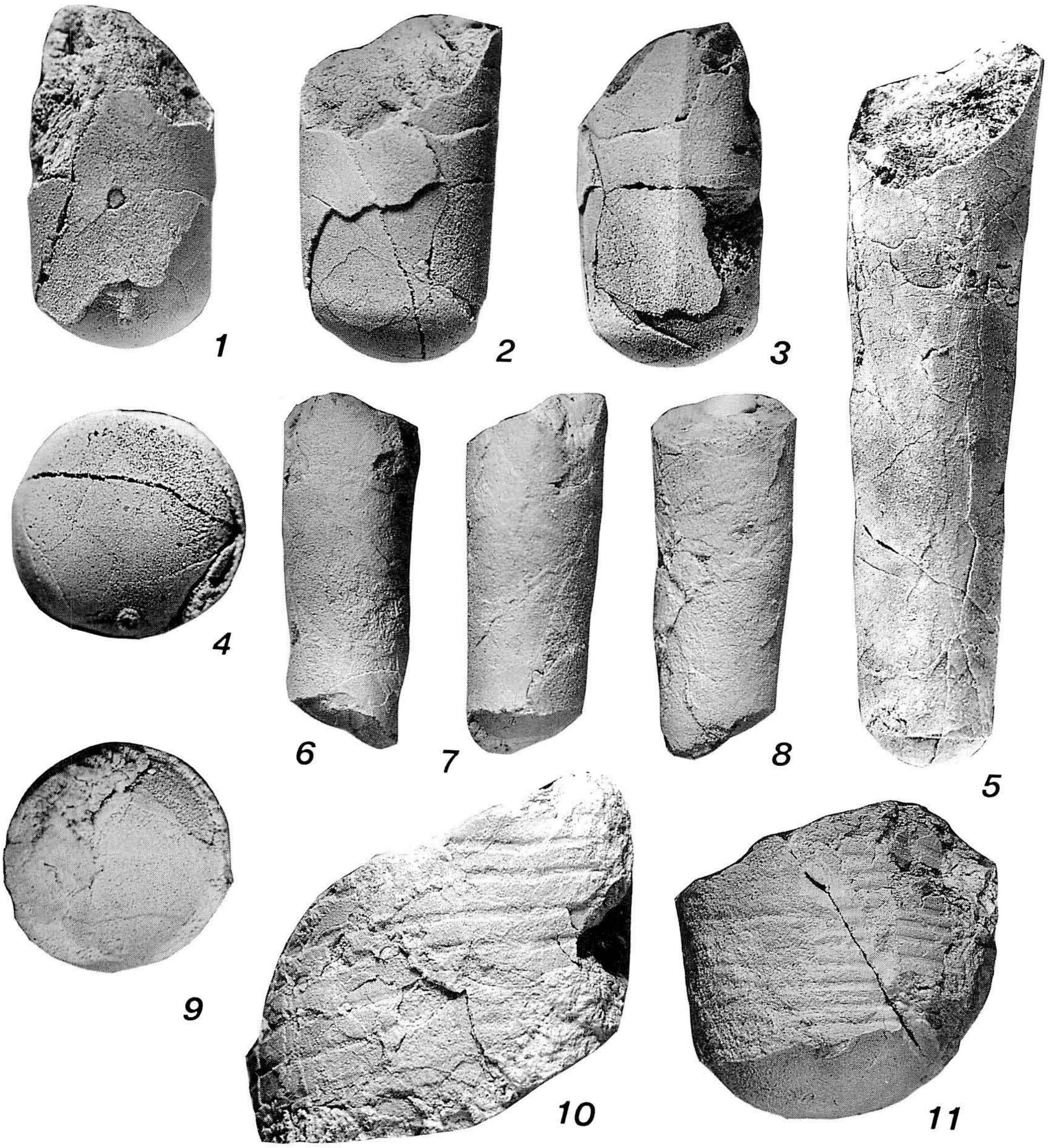


Figure 3. **1–5**, *Bactrites nagatoensis,* sp. nov. **1–4**, paratype, ASM 51312. **1**, ventral view, ×3 ; **2**, lateral view, venter on left, ×3 ; **3**, dorsal view, ×3 ; **4**, septal view, venter down, ×4. **5**, paratype, ASM 51311, dorsal view, ×0.98. **6–9,** *Bactrites* sp., ASM 51385. **6**, ventral view, ×2 ; **7**, lateral view, venter on right, ×2 ; **8**, dorsal view, ×2 ; **9**, septal view, venter down, ×4. **10, 11,** *Ctenobactrites* sp. **10**, ASM 51223, side view, ×2 ; **11**, ASM 51220, side view, ×1.

← **Figure 2.** *Bactrites nagatoensis,* sp. nov. **1–6**, holotype, ASM 51310. **1**, ventral view, ×1 ; **2**, lateral view, venter on right, ×1 ; **3**, dorsal view, ×1 ; **4**, septal view, venter down, ×2 ; **5**, details of siphuncle and ornamentation from adoral part of the holotype as viewed in **Figure 2–1**, ×4, **6**, dorsoventral polished section showing septal neck (arrow), ×6. **7**, paratype, ASM 51351, dorsal view, ×2. **8**, paratype, ASM 51313, dorsal view, ×3. **9**, paratype, ASM 51352, dorsal view, ×3. **10**, paratype, ASM 51353, ventral view, ×1.

Material.—Single specimen (ASM 51385) of incomplete phragmocone.

Remarks.—The specimen of an incomplete phragmocone, 25 mm in length, is a longiconic orthocone with the circular cross section and smooth shell surface. It can be distinguished from the associated *Bactrites nagatoensis* by the absence of dorsal carina. The diameter of the conch is 8 mm at near the apical end and expands up to approximately 10 mm over 19 mm. The siphuncle is relatively small and ventral position.

The morphology of the specimen is closely related to some Carboniferous forms including *Bactrites carbonarius* Smith, 1903, *B. fayettevillensis* Mapes, 1979, *B. longocameratus* Shimansky, 1968, *B. milleri* Mapes, 1979, and *B. quadrilineatus* Girty, 1909. However, the specimen is not complete enough for a confident specific identification.

Occurrence and age.—*Bactrites* sp. was recovered from a bioclastic grainstone in the *Profusulinella beppensis* Zone (Late Bashkirian) at loc. IM 64.

Genus *Ctenobactrites* Shimansky, 1951

Ctenobactrites sp.

Figures 3-10, 11

Material.—Four specimens (ASM 51220, 51223-51225) of fragmentary phragmocones.

Description.—Phragmocone longiconic orthocone, moderately large; largest specimen (ASM 51220) having maximum diameter 34 mm. Surface ornamentation consists of flat-topped transverse ribs and a single longitudinal ridge; width of grooves separating ribs amounts to 1.2 mm in largest specimen; each rib ranges from 1.2 to 2.9 mm in width, and forming shallow sinus at ridge. Septa moderately curved with simple, slightly oblique sutures.

Remarks.—The present specimens have characteristic ornamentation of the flat-topped transverse ribs with a longitudinal ridge that is the typical morphology of *Ctenobactrites mirus* Shimansky, 1954, from the Asselian to Sakmarian (Lower Permian) of the Urals, Soviet Union. The Russian species is represented by a juvenile phragmocone. Thus, direct comparison with the present specimens is not possible.

The Virgilian (Upper Carboniferous) species from Texas, *Ctenobactrites* sp. recorded by Mapes (1979) can be distinguished from the present form in that the latter possesses much coarser rib spacing.

The combination of the transverse ribs and a longitudinal ridge in ornamentation of the present specimens also is reminiscent of mature modification of some *Bactrites,* such as *B. peytonensis* Mapes, 1979. However, the ribbing on septate part of the shell and the flat-topped rib shape of the present specimens are diagnostic of *Ctenobactrites.*

Occurrence and age.—*Ctenobactrites* sp. was recovered from a coquinoid limestone in the *Fusulinella biconica* Zone (Early Moscovian) at loc. IM 60.

Acknowledgments

We thank Drs. Takashi Hamada and Kazushige Tanabe (University of Tokyo) for helpful comments. Dr. Royal H. Mapes (Ohio University) reviewed the manuscript and provided the North American bactritoid specimens. Laboratory research was supported by a grant from the Japanese Ministry of Education, Science and Culture (No. 01790346) to S. Niko.

References

Girty, G.H., 1909: The fauna of the Caney Shale of Oklahoma. *U.S. Geol. Surv., Bull.*, 377, 106 p.

Hyatt, A., 1883-1884: Genera of fossil cephalopods. *Proc. Boston Soc. Nat. Hist.*, vol. 22, pt. 3, p. 253-338.

Mapes, R.H., 1979: Carboniferous and Permian Bactritoidea (Cephalopoda) in North America. *Univ. Kansas Paleont. Contrib.*, Art. 64, 75 p., 41 pls.

Miller, A.K., 1944: Geology and paleontology of the

Permian area northwest of Las Delicias, southwestern Coahuila, Mexico, Part IV, Permian cephalopods. *Geol. Soc. America, Special Paper*, 52, p. 71-127, pls. 20-45.

Nishida, T. and Kyuma, Y., 1986: On the molluscan fauna. *Abstracts of Palaeontological Society of Japan, 135th Annual Meeting at Kitakyushu,* p. 41-42. (*in Japanese*)

Sandberger, G., 1843: Schilderung der paläontologischen Verhältnisse der älteren Formationen Nassaus. *Amtl. Naturf. Aerzte Mainz,* p. 154-160.

Shimansky, V.N., 1951: K voprosu ob evoliutsii verkynepaleozoishikh pryamkh golovongikh. *Akad. Nauk SSSR Dokl.*, vol. 79, no. 5, p. 867-870. (*in Russian*)

——, 1954: Pryamye nautiloidei i baktritoidei sakmarskogo i artinskogo yarusov Yuzhnogo Urala. *Akad. Nauk SSSR, Paleont. Inst. Trudy,* vol. 44, 156 p., 12 pls. (*in Russian*)

——, 1968: Kamennougoinye Orthoceratida, Oncoceratida, Actinoceratida i Bactritida. *Ibid.*, vol. 117, 151 p., 20 pls. (*in Russian*)

Smith, J.P., 1903: The Carboniferous ammonoids of America. *U.S. Geol. Surv., Monogr.*, vol. 42, 211 p.

Akiyoshi 秋吉，Isa 伊佐，Mine 美禰，Nagato 長門.

秋吉石灰岩層群からの中期石炭紀バクトリテス類：山口県伊佐地域の秋吉石灰岩層群からは，多数のバクトリテス類を産出する。この動物群の構成種，および随伴する有孔虫化石より判断される時代は，*Bactrites nagatoensis*, sp. nov. (バシュキール世後期からモスコー世前期), *Bactrites* sp. (バシュキール世後期), *Ctenobactrites* sp. (モスコー世前期) である。本報告は，国内からのバクトリテス類の初記載となる。

児子修司・西田民雄・久間裕子

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 161, pp. 720-738, 11 Figs., April 30, 1991

915. EARLY JURASSIC RADIOLARIANS FROM THE NANJO MASSIF IN THE MINO TERRANE, CENTRAL JAPAN
PART 1. *TRICOLOCAPSA, STICHOCAPSA,* AND *MINOCAPSA*, N. GEN.*

ATSUSHI MATSUOKA

Department of Earth Sciences, College of General Education,
Niigata University, Niigata 950-21

Abstract. Well-preserved Early Jurassic radiolarians are obtained from a manganese band in the Nanjo Massif, Mino Terrane, central Japan. This paper is Part 1 of a serial descriptive work on an Early Jurassic radiolarian fauna from the Nanjo Massif and deals with nassellarians which possess a constricted or closed distal end. One new genus, *Minocapsa,* is erected, and 9 new species and 2 new subspecies are described : *Tricolocapsa minoensis, T.* (?) *megaglobosa, T.* (?) *fera, Stichocapsa plicata plicata, S. plicata semiplicata, S. elegans, S. biconica, S. nanjoensis, Minocapsa cylindrica* and *M. globosa.*

The fauna from the Nanjo Massif is very similar to that of the upper *Archicapsa pachyderma* Zone of Jurassic radiolarian zones in Japan. The fauna is correlative with the lower Toarcian fauna in east-central Oregon, North America.

Key words. Early Jurassic, Mino Terrane, Nanjo Massif, Nassellaria, Radiolaria.

Introduction

In this decade, Early Jurassic radiolarians have been described from Turkey (De Wever, 1981a, 1981b, 1982 ; Pessagno and Poisson, 1981), from North America (Carter *et al.*, 1988 ; MacLeod, 1988 ; Pessagno and Blome, 1980 ; Pessagno and Whalen, 1982 ; Pessagno *et al.*, 1986 ; Yeh, 1987a, 1987b) and from Japan (Hori, 1988 ; Hori and Otsuka, 1989 ; Hori and Yao, 1988 ; lsozaki and Matsuda, 1985 ; Kishida and Hisada, 1985 : Sashida, 1988 ; Takemura, 1986 ; Takemura and Nakaseko, 1982, 1983, 1986 ; Yao, 1982). In spite of these descriptive works, we often encounter undescribed forms in Lower Jurassic rocks. In order to establish more detailed radiolarian zonation and to recognize faunal provinces of radiolarians, the entire specific composition of assemblages needs to be clarified.

Manganese bands within Early to Middle Jurassic chertsiliceous mudstone sequences in the Mino Terrane, central Japan yield excellently preserved radiolarian tests. Since Yao (1972) introduced some "spongosaturnalids" from the manganese bands in the Inuyama area, several radiolarian workers have described new species from the manganese bands in the Mino Terrane (Baumgartner, 1984 ; Ichikawa and Yao, 1976 ; Isozaki and Matsuda, 1985 ; Takemura, 1986 ; Takemura and Nakaseko, 1982, 1983, 1986 ; Yao, 1979). In a series of works by this author, a well preserved radiolarian fauna from a manganese band of Early Jurassic age (early Toarcian) in the Nanjo Massif, Mino Terrane, central Japan is systematically described. In this paper (Part 1 of this series), one new genus is erected, and 9 new species and 2 new

---

*Received August 14, 1990 ; revised manuscript accepted January 10, 1991

subspecies of nassellarians with a constricted or closed distal end (*i.e. Tricolocapsa, Stichocapsa,* and *Minocapsa*, n. gen.) are described.

Acknowledgments : The author is grateful to Drs. Akira, Yao and E.S. Carter for their suggestion to this study and for critical reading of the manuscript. This work is supported by the Grant-in-Aid for Scientific Research of the Ministry of Education, Science and Culture of Japan (Grant No. 02740392).

Geologic setting

The Mino Terrane, one of the Jurassic-Early Cretaceous accretionary complexes in Japan, is distributed in the central part of Japan (Figure 1). This terrane is composed mainly of Jurassic-Early Cretaceous clastic rocks associated with chert (Permian-Early Jurassic), limestone (Carboniferous-Permian) and greenstone. This terrane is considered to be constructed through accretionary processes at a convergent plate boundary during Jurassic and Early Cretaceous time. The Nanjo Massif (Figure 1) occupies the northwestern part of the Mino Terrane. The Jurassic complex in this area is divided into three units characterized by distinct litho-facies; namely Kasugano, Imajo, and Kohkura facies

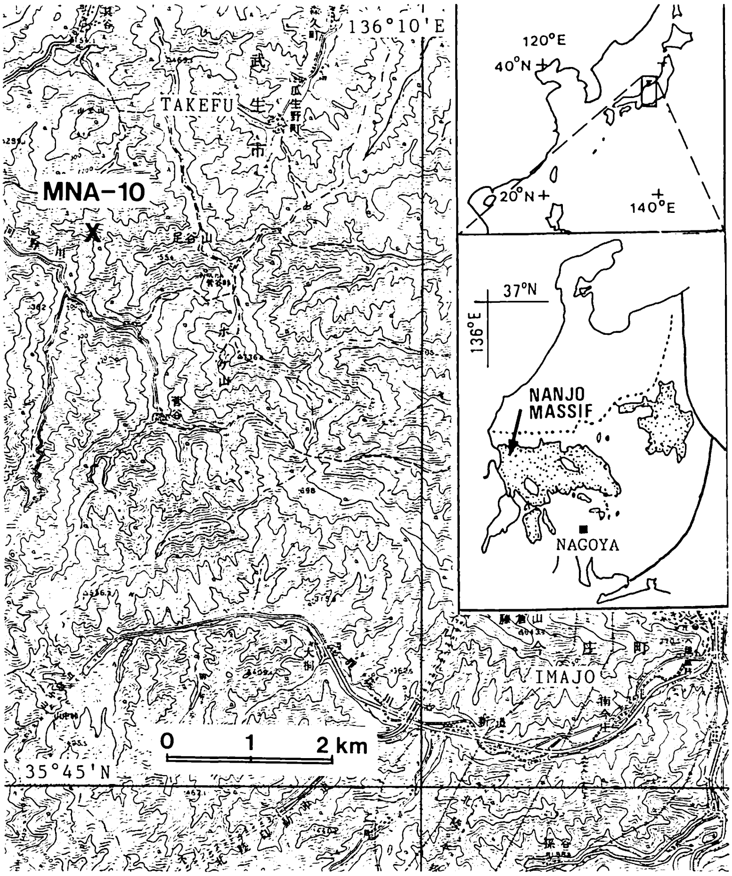


Figure 1. Map showing the fossil locality, MNA-10 (using 1 : 50,000 topographic map of "Imajo" published by Geographical Survey Institute of Japan). The dotted area in the inset map shows the distribution of the Jurassic-Early Cretaceous accretionary complex of the Mino Terrane, central Japan.

(Hattori and Yoshimura, 1982). According to Hattori and Yoshimura (1982), the Kasugano unit consists of Early Jurassic mudstone, greenstone, and olistoliths of Paleozoic limestone, greenstone and chert. The Imajo unit is composed of sandstone and mudstone with a lesser amount of siliceous mudstone. The chert encountered in this unit is Triassic in age and occurs as major olistoliths in Jurassic sequences. The Kohkura unit is characterized by coarse-grained massive sandstone. This unit also belongs to the Middle Jurassic and contains laterally-traceable thick chert of Triassic age.

Since Ito and Shiratake (1980), and Ito and Matsuda (1980) reported Jurassic radiolarians from the Nanjo Massif, the fossil record of Jurassic radiolarians has rapidly accumulated (Hattori, 1984, 1987, 1988, 1989; Hattori and Sakamoto, 1989; Hattori and Yoshimura, 1982, 1983; Takamura and Hayami, 1985; Yoshimura *et al*., 1982). Among these, Hattori (1987, 1988, 1989), and Hattori and Sakamoto (1989) figured a great number of radiolarians from mudstone, siliceous mudstone and manganese band samples, and discussed the geologic age of the terrane based on the radiolarian assemblages.

Material and methods

Radiolarian fossils treated throughout this series of studies are from a manganese band contained in a siliceous mudstone layer belonging to the Imajo unit. The band has a lenticular shape with a maximum thickness of 20 cm. It was obtained from an outcrop along a road cutting. Figure 1 shows the locality of rock sample MNA-10. This band contains manganese carbonate spherules ranging 0.5-2.0 mm in diameter from which well preserved radiolarian tests were extracted.

The rock sample was broken into small fragments of a few centimeters size and put in HCl solution for one day. The residue was gathered using #35 and #200 sieves. For scanning microscope observation, radiolarian tests were picked under a binocular microscope and mounted on aluminium stubs. For optical microscope observation, the unpicked residue containing radiolarian tests was mounted on a slide glass with the synthetic medium "Entellan New".

Radiolarian fauna and its age assignment

Sample MNA-10 contains more than 200 species of radiolarians. The following taxa are identified at species level: *Acanthocircus bispinus* (Yao), *Archicapsa pachyderma* (Tan Sin Hok), *Bistarkum rigidium* Yeh, *Canoptum artum* Yeh, *Canoptum poissoni* Pessagno, *Canoptum spinosum* Yeh, *Cuniculiformis aristotelis* De Wever, *Hsuum acutum* Yeh, *Hsuum gratum* Yeh, *Hsuum lucidum* Yeh, *Hsuum* (?) *unicum* Yeh, *Katroma kurusuensis* Hori, *Paracanoptum anulatum* (Pessagno and Poisson). In addition to them, forms belonging to genera *Higmastra* Baumgartner, *Canutus* Pessagno and Whalen, *Combusta* Yeh, *Lantus* Yeh, *Pleesus* Yeh and *Pseudopantanellium* Yeh are obtained.

Because sample MNA-10 contains no age-diagnostic fossils other than radiolarians, age assignment is inferred from comparisons with radiolarian faunas in regions where age is controlled by fossil groups such as ammonites. The fauna of sample MNA-10 contains many taxa which Yeh (1987a, 1987b) described from the Hyde Formation and the basal Warm Springs Member of the Snowshoe Formation in the Suplee-Izee area, east-central Oregon, North America, as listed above. The Hyde Formation and the basal Warm Springs Member are regarded as lower Toarcian based on stratigraphic relationships with the under- and overlying formations which yield age-diagnostic ammonites (Pessagno *et al*., 1986; Yeh, 1987a). This fauna includes forms assignable to the genus *Canutus* Pessagno and Whalen which Pessagno *et al.* (1987) used as a corporeal taxon disappearing within the Subzone 01B (Lower Toarcian) of their Jurassic radiolarian zonation in North America. The fauna also contains forms assignable to the genus *Higmastra* Baumgartner, a supplementary zonal marker, which appears near the base of the Subzone 01B. In addition, no mesosaturnalids are obtained from the sample, although various other forms of saturnalid spumerallians are present. Species of *Mesosaturnalis* (*M. hexagonus* Yao and *M*. sp. cf. *M. septispinus* Yao) are found in the middle to upper Toarcian of the Maude Group, Queen Charlotte Islands, British Columbia (Carter *et al*., 988). Above-mentioned data suggest that the fauna of sample MNA-10 is correlative with the lower Toarcian fauna in eastcentral Oregon, North America.

Matsuoka and Yao (1986) proposed eight radiolarian zones for the Jurassic of Japan on the basis of biostratigraphic investigations on continuous stratigraphic sequences in Southwest Japan. These zones are the *Parahsuum ovale* (= *Parahsuum* sp. C in Matsuoka and Yao, 1986), *Archicapsa pachyderma, Laxtorum* (?) *jurassicum, Tricolocapsa plicarum, Tricolocapsa conexa, Stylocapsa* (?) *spiralis, Cinguloturris carpatica* and *Pseudodictyomitra primitiva* Zones in ascending order. The faunal composition of sample MNA-10 is very similar to that of the upper *Archicapsa pachyderma* Zone (middle Lower Jurassic).

Systematic paleontology

The genera treated in this paper are not assigned to families because classification at the family level is not adequately settled at present.

Type and figured specimens are registered and deposited in the Department of Earth Sciences, College of General Education, Niigata University. In the systematic description and explanation of figures, the NU MR number is the register number of the specimens in that Department. In explanation of figures, the number in parentheses following the NU MR number indicates the registered film number.

Subclass Radiolaria Müller, 1858
Superorder Polycystina Ehrenberg, 1838, emend. Riedel, 1967
Order Nassellaria Ehrenberg, 1875
Genus *Tricolocapsa* Haeckel, 1881
Type species : *Tricolocapsa theophrasti* Haeckel, 1881

Tricolocapsa minoensis Matsuoka, n. sp.

Figures 2-1a–5b

1982 *Tricolocapsa* sp. cf. *T. plicarum* Yao, Yoshimura *et al*., pl. 6, fig. 4.
1982 *Tricolocapsa* (?) sp. A, Yoshimura *et al*., pl. 6, fig. 5.
1985 *Tricolocapsa* sp. A, Takamura and Hayami, pl. 3, fig. 4.
1987 *Tricolocapsa* sp. A, Hattori, pl. 13, fig. 1.
1987 *Tricolocapsa* sp. B, Hattori, pl. 13, fig. 2.
1989 *Tricolocapsa* sp. A, Hattori, pl. 10, fig. A.
1989 *Tricolocapsa* spp., Hattori, pl. 10, fig. D.

Description.—Shell of three segments, drop-like shaped. Cephalis hemispherical, poreless. Thorax truncate conical. Abdomen large, subspherical with a constricted aperture. Collar and lumber strictures slightly recognizable or indistinct externally. Outer surface of shell ornamented with continuous longitudinal plicae. Eleven to 15 moderately spaced plicae visible on outer shell. One row of pores present between longitudinal plicae. Pores small to moderate in size, circular and uniform in shape. Aperture moderate in size, circular.

Measurements (in μm).—Numbers of specimens measured are in parentheses. TH ; total height of shell, MW ; maximum width of shell, DA ; diameter of aperture.

	Holotype	max.	min.	mean	
TH	115	115	93	105	(15)
MW	94	94	72	83	(15)
DA	13	14	12	13	(6)

Remarks.—Pores vary in size among specimens, from small (Figures 2-1a, b) to moderate (Figure 2-3).

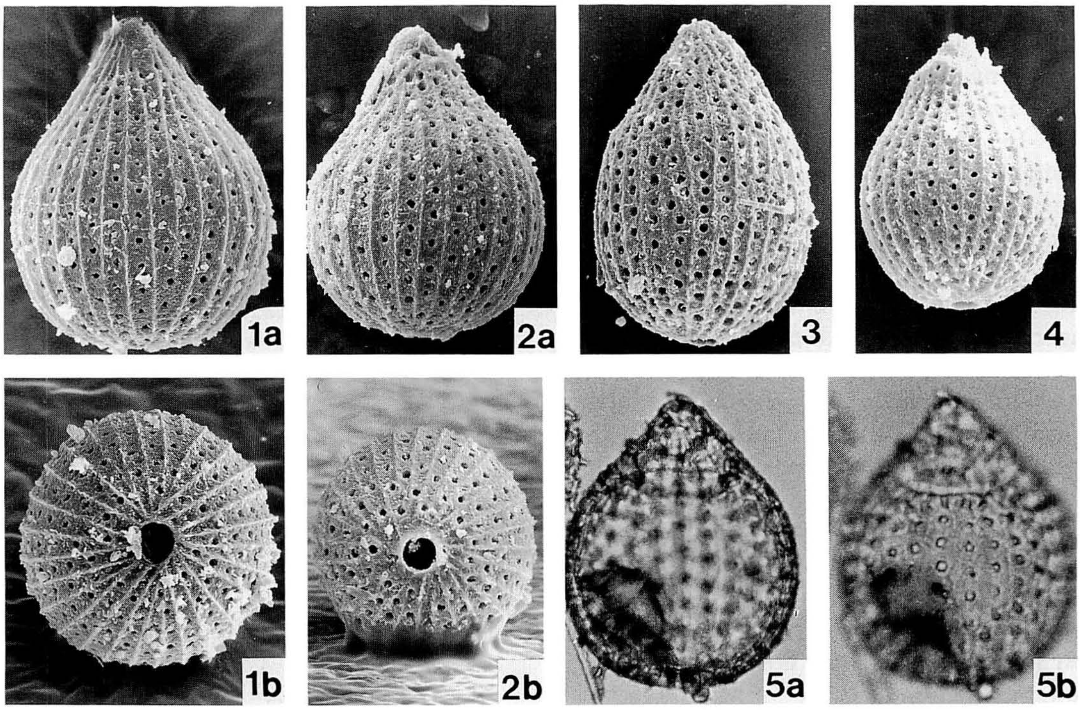


Figure 2. *Tricolocapsa minoensis* Matsuoka, n. sp. **1-4**; Scanning electron micrographs, **5**; transmitted light micrographs. All figures ×380. **1a, b.** Holotype, NU MR 0001 (**a**; 11859, **b**; 11860), **b**; basal view. **2a, b.** Paratype, NU MR 0002 (**a**; 11801, **b**; 11802), **b**; basal view. **3.** Paratype, NU MR 0003 (11415). **4.** Paratype, NU MR 0004 (11057). **5a, b.** Paratype, NU MR 0005 (**a**; 93-21, **b**; 93-22).

Tricolocapsa minoensis, n. sp. differs from *T. plicarum* Yao by lacking a dish-like basal appendage, by having more spaced plicae and by its smaller size.

Etymology.—This species is named for the Mino Terrane which includes the type area, Nanjo Massif.

Type specimens.—Holotype NU MR 0001 (Figures 2-1a, b); Paratypes NU MR 0002 (Figures 2-2a, b), NU MR 0003 (Figure 2-3), NU MR 0004 (Figure 2-4), NU MR 0005 (Figures 2-5a, b).

Type locality.—MNA-10, Nanjo Massif, Mino Terrane, central Japan.

Occurrence.—Nanjo Massif, Mino Terrane, central Japan. Kuma area, Southern Chichibu Terrane, western Kyushu (Matsuoka, unpublished data).

Range.—*Archicapsa pachyderma* Zone (middle Lower Jurassic) as far as known.

Tricolocapsa (?) *megaglobosa* Matsuoka, n. sp.

Figures 3-1a—5b

Description.—Shell of three segments with a dish-like basal appendage. Cephalis hemispherical, poreless. Thorax truncate-conical with circular, densely spaced pores. Abdomen large, inflated, barrel-shaped with circular, densely spaced pores larger than those in thorax. Collar stricture distinct externally. Lumber stricture slightly recognizable externally. Joint between abdomen and basal appendage marked by a row of pores slightly larger than those in abdomen. Basal appendage half to a third of abdomen in width, with circular to subcircular densely spaced pores smaller than those in remaining part of shell surface.

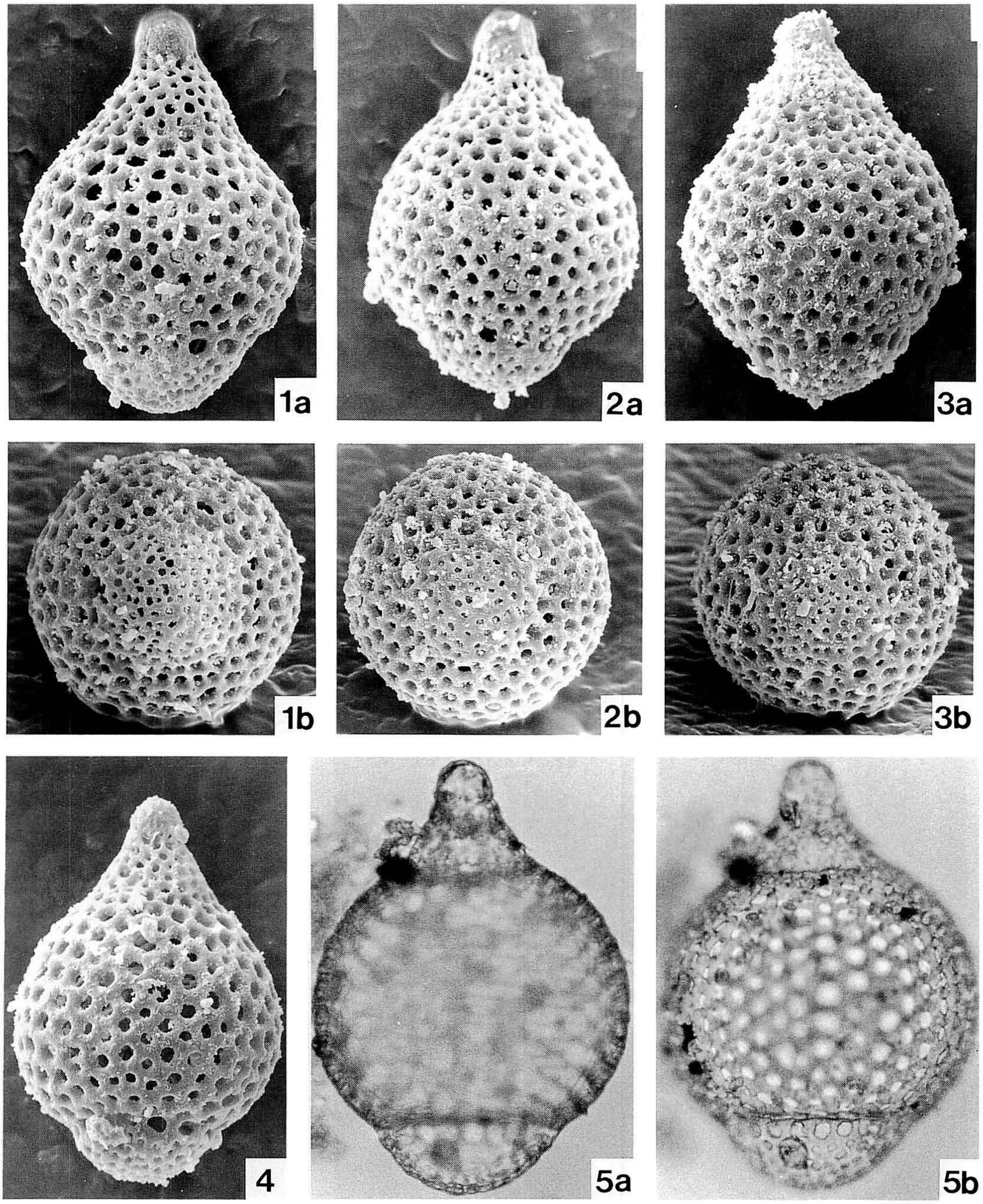


Figure 3. *Tricolocapsa* (?) *megaglobosa* Matsuoka, n. sp. **1-4**; Scanning electron micrographs, **5**; transmitted light micrographs. All figures ×380. **1a, b.** Holotype, NU MR 0006 (**a**; 11827, **b**; 11828), **b**; basal view. **2a, b.** Paratype, NU MR 0007 (**a**; 11825, **b**; 11826), **b**; basal view. **3a, b.** Paratype, NU MR 0008 (**a**; 11771, **b**; 11772), **b**; basal view. **4.** Paratype, NU MR 0009 (11810). **5a, b.** Paratype, NU MR 0010 (**a**; 96-05, **b**; 96-06).

Measurements (in μm).—Numbers of specimens measured are in parentheses. TH; total height of shell, MW; maximum width of shell, AW; width of basal appendage.

	Holotype	max.	min.	mean	
TH	153	160	120	145	(12)
MW	105	117	88	101	(12)
AW	55	61	47	55	(11)

Remarks.—This species is questionably assigned to *Tricolocapsa* because it possesses a dish-like basal appendage. This species is distinguished from *Tricolocapsa* (?) *fusiformis* Yao by having a large, inflated abdomen, densely spaced pores and a distinct collar stricture.

Etymology.—This specific name is derived from the Latin mega (=large) and *globosus-a-um* (=spherical).

Type specimens.—Holotype NU MR 0006 (Figures 3-1a, b); Paratypes NU MR 0007 (Figures 3-2a, b), NU MR 0008 (Figures 3-3a, b), NU MR 0009 (Figure 3-4), NU MR 0010 (Figures 3-5a, b).

Type locality.—MNA-10, Nanjo Massif, Mino Terrane, central Japan.

Occurrence.—Nanjo Massif, Mino Terrane, central Japan.

Range.—*Archicapsa pachyderma* Zone (middle Lower Jurassic) as far as known.

Tricolocapsa (?) *fera* Matsuoka, n. sp.

Figures 4-1a—3b

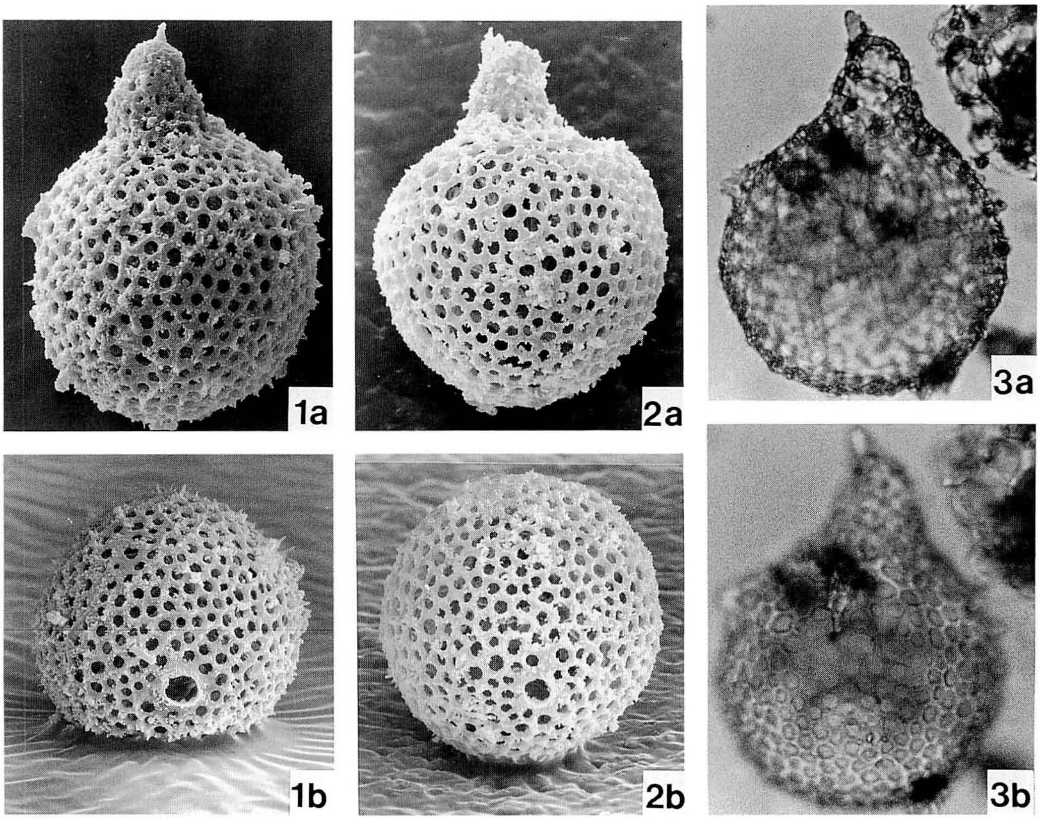


Figure 4. *Tricolocapsa* (?) *fera* Matsuoka, n. sp. **1-2**; Scanning electron micrographs, **3**; transmitted light micrographs. All figures ×380. **1a, b.** Holotype, NU MR 0011 (**a**; 12299, **b**; 12300), **b**; oblique basal view. **2a, b.** Paratype, NU MR 0012 (**a**; 11735, **b**; 11736), **b**; oblique basal view. **3a, b.** Paratype, NU MR 0013 (**a**; 90-17, **b**; 90-18).

Description.—Shell of three segments, pyriform. Cephalis hemispherical, poreless with a small apical horn. Thorax truncate conical or cylindrical with small pores. Abdomen large, subspherical with a constricted aperture. Collar stricture slightly recognizable externally. Lumber stricture pronounced. Pores moderate in size, circular to subcircular, densely spaced and set in polygonal (largely hexagonal) pore frames. Abdomen possessing small pointed spines situated at the pore frame vertices. Aperture moderate in size, circular with a short protruding rim.

Measurements (in μm).—Numbers of specimens measured are in parentheses. TH; total height of shell, MW; maximum width of shell, DA; diameter of aperture.

	Holotype	max.	min.	mean	
TH	139	146	125	133	(6)
MW	100	125	96	107	(6)
DA	11	14	8	11	(5)

Remarks.—This species is questionably assigned to *Tricolocapsa* because it possesses a small apical horn. However, it is uncertain whether the presence of an apical horn is an important criterion for classification at generic level of three-segmented nassellaria. The horn seems to be an extension of apical spine. *Tricolocapsa* (?) *fera*, n. sp. is similar to *T. tetragona* Matsuoka and *T.* sp. cf. *T. ruesti* Tan Sin Hok (in Yao, 1979) in general outline but differs from both by having an apical horn and by densely spaced pores on the abdomen.

Etymology.—This specific name is derived from the Latin *ferus-a-um* (=wild).

Type specimens.—Holotype NU MR 0011 (Figures 4-1a, b); Paratypes NU MR 0012 (Figures 4-2a, b), NU MR 0013 (Figures 4-3a, b).

Type locality.—MNA-10, Nanjo Massif, Mino Terrane, central Japan.

Occurrence.—Nanjo Massif, Mino Terrane, central Japan.

Range. Archicapsa pachyderma Zone (middle Lower Jurassic) as far as known.

Genus *Stichocapsa* Haeckel, 1881
Type species : *Stichocapsa jaspida* Rüst, 1885

Stichocapsa plicata Matsuoka, n. sp.

Figures 5-1a–5b: 6-1a–6b

1989 *Tricolocapsa* sp. B, Hattori, pl. 10, fig. B.
1989 *Tricolocapsa* spp., Hattori, pl. 10, fig. F.
1989 *Tricolocapsa* sp. D, Hattori, pl. 29, fig. D.
1989 *Tricolocapsa* sp., Hattori and Sakamoto, pl. 19, fig. B.

Description.—Shell of four to six segments, drop-like or spindle shaped. Cephalis hemispherical, poreless. The last segment large, inverted hemispherical or inverted conical with a constricted aperture. Remaining segments including thorax and abdomen truncate conical. Strictures between segments indistinct externally. Fifteen to 22 densely spaced longitudinal plicae visible on outer shell except for cephalis. The longitudinal plicae distinct or partly obscure. One row of pores present between the plicae. Pores uniform, small and circular. Aperture small, circular, occasionally with a short protruding rim.

Measurements (in μm).—Numbers of specimens measured are in parentheses. TH; total height of shell, MW; maximum width of shell, DA; diameter of aperture.

	Holotype	max.	min.	mean	
TH	154	170	110	142	(29)
MW	108	124	80	96	(29)
DA	8	8	6	7	(12)

Remarks.—Two subspecies are included under this species; these are *S. plicata plicata*, n. subsp. and *S. plicata semiplicata*, n. subsp. *S. plicata*, n. sp. differs from *S. convexa* Yao by having longitudinal plicae between which one row of pores is present.

Etymology.—This specific name comes from the Latin *plicatus-a-um* (=plicate).

Type specimens.—Holotype NU MR 0014 (Figures 5-1a, b); Paratypes NU MR 0015 (Figures 5-2a, b), NU MR 0016 (Figures 5-

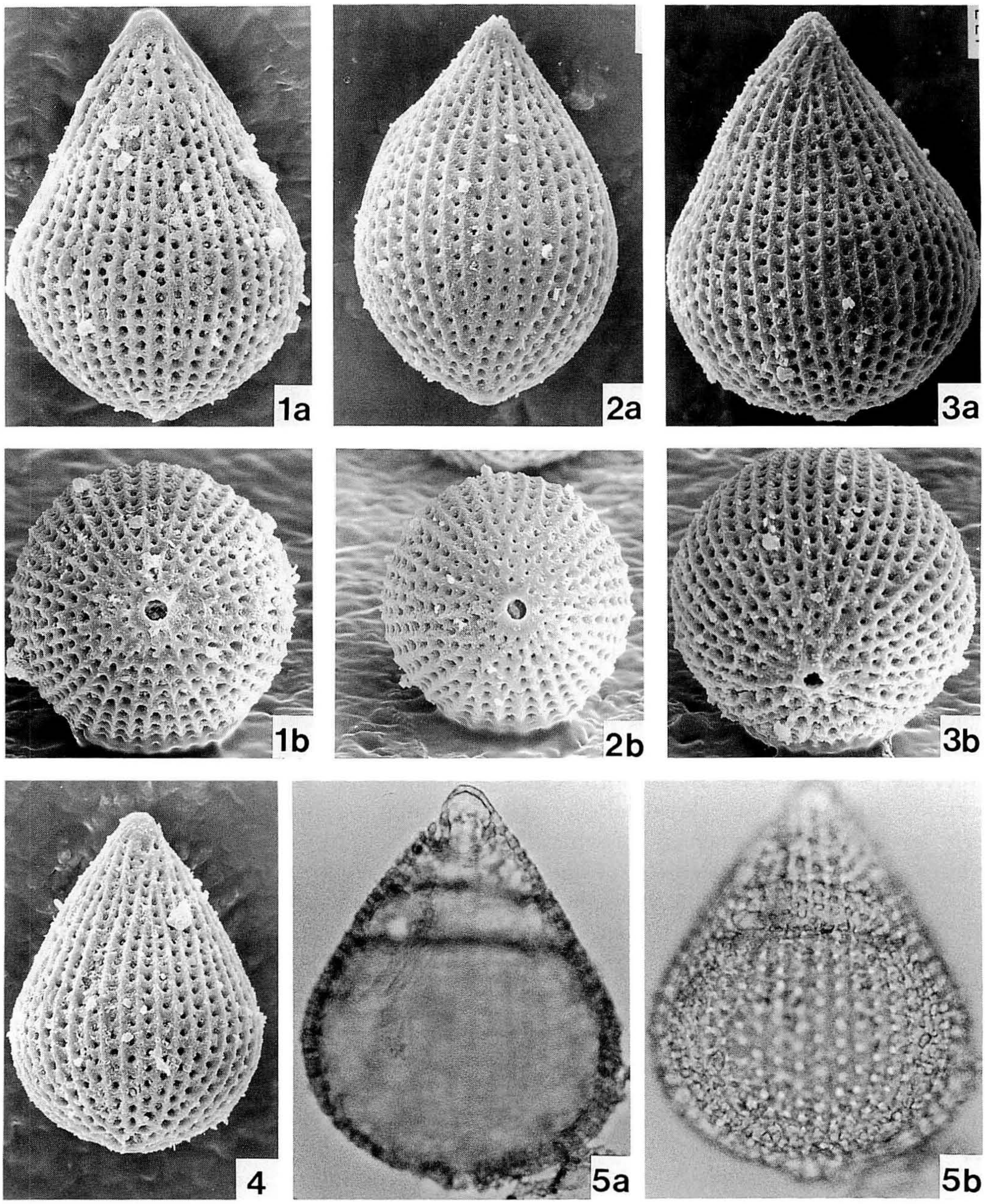


Figure 5. *Stichocapsa plicata plicata* Matsuoka, n. subsp. **1-4**; Scanning electron micrographs, **5**; transmitted light micrographs. All figures ×380. **1a, b.** Holotype, NU MR 0014 (**a**; 11823, **b**; 11824), **b**; basal view. **2a, b.** Paratype, NU MR 0015 (**a**; 11757, **b**; 11758), **b**; basal view. **3a, b.** Paratype, NU MR 0016 (**a**; 11776, **b**; 11777), **b**; oblique basal view. **4.** Paratype, NU MR 0017 (11731). **5a, b.** Paratype, NU MR 0018 (**a**; 94-23, **b**; 94-24).

3a, b), NU MR 0017 (Figure 5-4), NU MR 0018 (Figures 5-5a, b).

Type locality.—MNA-10, Nanjo Massif, Mino Terrane, central Japan.

Occurrence.—Nanjo Massif, Mino Terrane, central Japan.

Range.—*Archicapsa pachyderma* Zone (middle Lower Jurassic) as far as known.

Stichocapsa plicata plicata Matsuoka, n. subsp.

Figures 5-1a–5b

1989 *Tricolocapsa* sp. B, Hattori, pl. 10, fig. B.
1989 *Tricolocapsa* spp., Hattori, pl. 10, fig. F.
1989 *Tricolocapsa* sp. D, Hattori, pl. 29, fig. D.
1989 *Tricolocapsa* sp., Hattori and Sakamoto, pl. 19, fig. B.

Description.—Shell of four to five segments, drop-like or spindle shaped. Cephalis hemispherical, poreless. The last segment large, inverted hemispherical or inverted conical with a constricted aperture. Remaining segments including thorax and abdomen truncate conical. Strictures between segments indistinct externally. Fifteen to 22 densely spaced longitudinal plicae visible on outer shell. The plicae distinct on whole shell except for cephalis. One row of pores present between the plicae. Pores uniform, small and circular. Aperture small, circular, occasionally with a short protruding rim.

Measurements (in μm).—Numbers of specimens measured are in parentheses. TH; total height of shell, MW; maximum width of shell, DA; diameter of aperture.

	Holotype	max.	min.	mean	
TH	154	170	110	142	(20)
MW	108	124	82	102	(20)
DA	8	8	6	7	(9)

Remarks.—Shape varies among specimens; some are drop-like shaped (Figure 5-1a, 3a, 4, 5a, b) and others spindle shaped (Figure 5-2a). *Stichocapsa plicata plicata*, n. subsp. differs from *S. plicata semiplicata*, n. subsp. by having distinct longitudinal plicae that extend from the thorax to the distal end.

Etymology.—This subspecies is the nominotypical subspecies of *Stichocapsa plicata*, n. sp.

Type specimens.—Holotype NU MR 0014 (Figures 5-1a, b); Paratypes NU MR 0015 (Figures 5-2a, b), NU MR 0016 (Figures 5-3a, b), NU MR 0017 (Figure 5-4), NU MR 0018 (Figures 5-5a, b).

Type locality.—MNA-10, Nanjo Massif, Mino Terrane, central Japan.

Occurrence.—Nanjo Massif, Mino Terrane, central Japan.

Range. Archicapsa pachyderma Zone (middle Lower Jurassic) as far as known.

Stichocapsa plicata semiplicata Matsuoka, n. subsp.

Figures 6-1a–6b

Description.—Shell of five to six segments, drop-like shaped. Cephalis hemispherical, poreless. The last segment large, truncate subspherical with a constricted aperture. Remaining segments including thorax and abdomen truncate conical. Strictures between segments indistinct externally. Fifteen to 22 densely spaced longitudinal plicae visible on outer shell except for cephalis and the middle part of shell. Pores small, circular and arranged longitudinally. One row of pores present between the plicae. Aperture small, circular, occasionally with a short protruding rim.

Measurements (in μm).—Numbers of specimens measured are in parentheses. TH; total height of shell, MW; maximum width of shell, DA; diameter of aperture.

	Holotype	max.	min.	mean	
TH	139	149	123	142	(9)
MW	95	99	80	94	(9)
DA	7	8	7	7	(3)

Remarks.—*Stichocapsa plicata semiplicata*, n. subsp. is compared to *S. plicata plicata*, n. subsp. under the latter subspecies.

Etymology.—The subspecific name comes

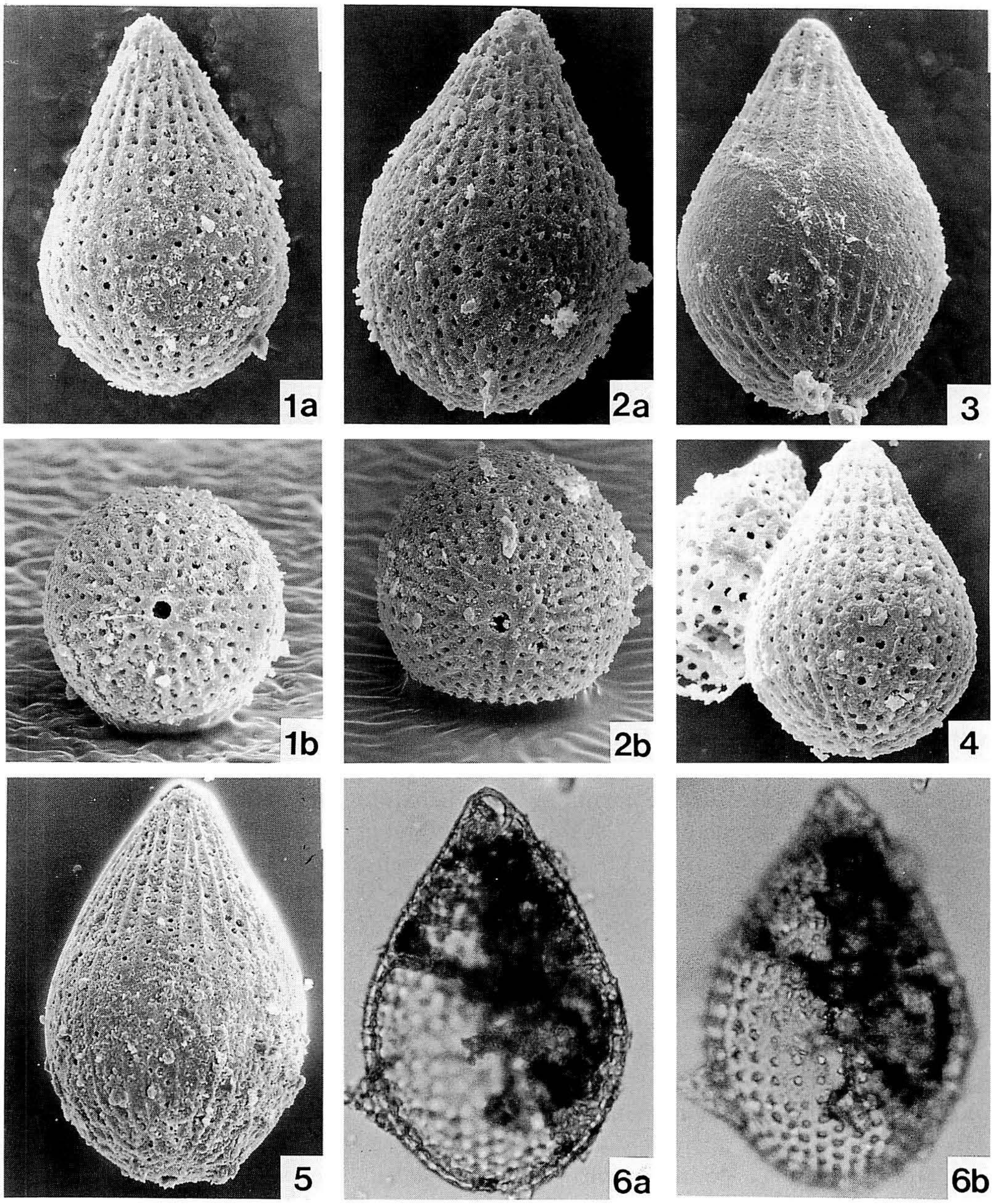


Figure 6. *Stichocapsa plicata semiplicata* Matsuoka, n. subsp. **1-5**; Scanning electron micrographs, **6**; transmitted light micrographs. All figures ×380. **1a, b.** Holotype, NU MR 0019 (**a**; 11819, **b**; 11820), **b**; basal view. **2a, b.** Paratype, NU MR 0020 (**a**; 12296, **b**; 12297), **b**; oblique basal view. **3.** Paratype, NU MR 0021 (11805). **4.** Paratype, NU MR 0022 (11072). **5.** Paratype, NU MR 0023 (11349). **6a, b.** Paratype, NU MR 0024 (**a**; 80-02, **b**; 80-03).

from the Latin *semi* (=half) and *plicatus-a-um* (=plicate).

Type specimens.—Holotype NU MR 0019 (Figures 6-1a, b); Paratypes NU MR 0020 (Figures 6-2a, b), NU MR 0021 (Figure 6-3), NU MR 0022 (Figure 6-4), NU MR 0023 (Figure 6-5), NU MR 0024 (Figures 6-6a, b).

Type locality.—MNA-10, Nanjo Massif, Mino Terrane, central Japan.

Occurrence.—Nanjo Massif, Mino Terrane, central Japan.

Range. *Archicapsa pachyderma* Zone (middle Lower Jurassic) as far as known.

Stichocapsa elegans Matsuoka, n. sp.

Figures 7-1a–5b

Description.—Shell of four to five segments, elongate ovoidal. Cephalis hemispherical, poreless. Thorax, abdomen and the fourth segment in the case of five-segmented specimens truncate conical. All segments but the last one form conical proximal part; the last

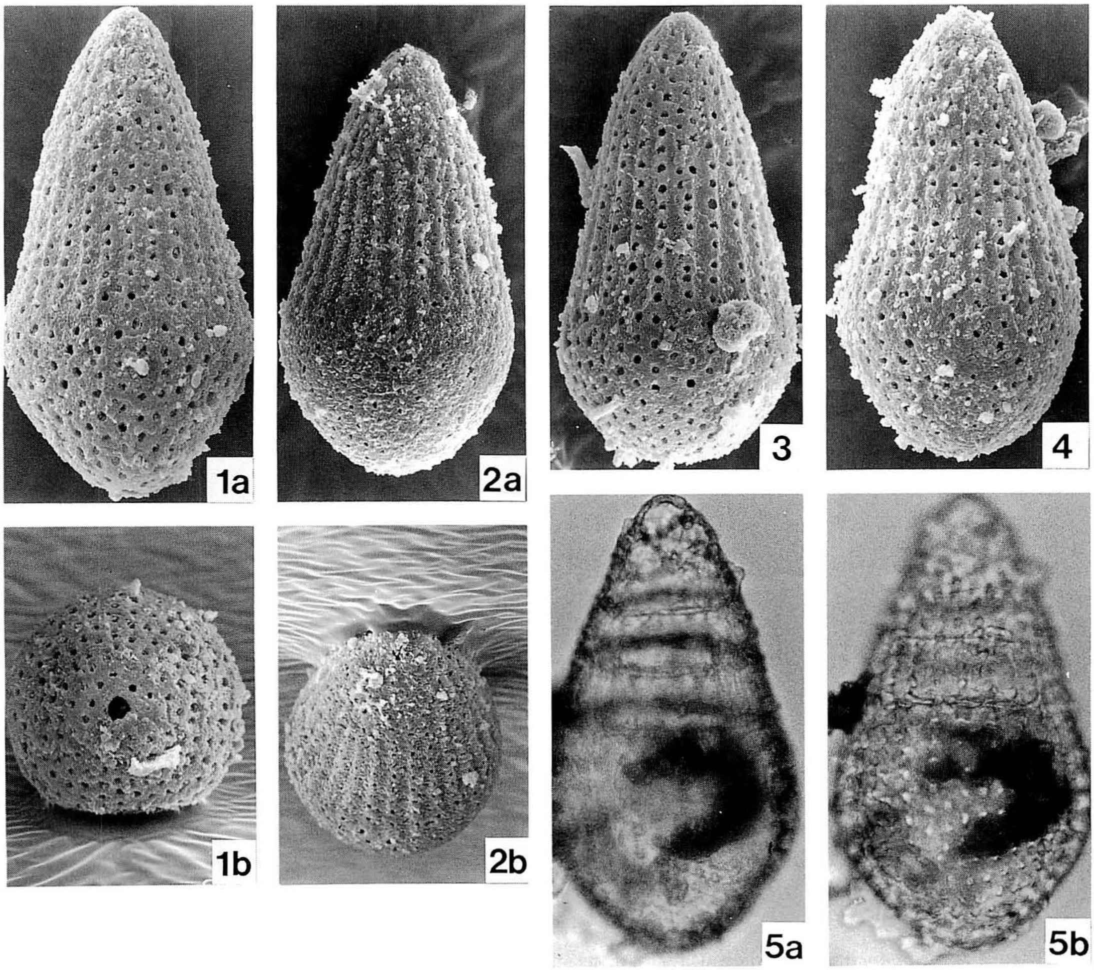


Figure 7. *Stichocapsa elegans* Matsuoka, n. sp. **1-4**; Scanning electron micrographs, **5**; transmitted light micrographs. All figures ×380. **1a, b.** Holotype, NU MR 0025 (**a**; 12233, **b**; 12234), **b**; basal view. **2a, b.** Paratype, NU MR 0026 (**a**; 12237, **b**; 12239), **b**; oblique apical view. **3.** Paratype, NU MR 0027 (11834). **4.** Paratype, NU MR 0028 (11835). **5a, b.** Paratype, NU MR 0029 (**a**; 95-14, **b**; 95-15).

segment large, hemispherical with a strongly constricted aperture. Strictures between segments indistinct externally. Ten to 12 longitudinal plicae observed on the conical proximal portion of shell in lateral view. One row of pores runs on the plicae. The distal portion of shell with smooth, perforated surface. Pores small and circular.

Measurements (in μm).—Numbers of specimens measured are in parentheses. TH ; total height of shell, MW ; maximum width of shell, DA ; diameter of aperture.

	Holotype	max.	min.	mean	
TH	170	179	152	165	(15)
MW	89	105	81	89	(15)
DA	8	8	6	7	(2)

Remarks.—*Stichocapsa elegans*, n. sp. differs from *S. plicata*, n. sp. by its slender form and by possessing perforated longitudinal plicae on the conical proximal portion of the shell.

Etymology.—The specific name comes from the Latin *elegans* (=elegant).

Type specimens.—Holotype NU MR 0025 (Figures 7-1a, b) ; Paratypes NU MR 0026 (Figures 7-2a, b), NU MR 0027 (Figure 7-3), NU MR 0028 (Figure 7-4), NU MR 0029 (Figures 7-5a, b).

Type locality.—MNA-10, Nanjo Massif, Mino Terrane, central Japan.

Occurrence.—Nanjo Massif, Mino Terrane, central Japan.

Range. Archicapsa pachyderma Zone (middle Lower Jurassic) as far as known.

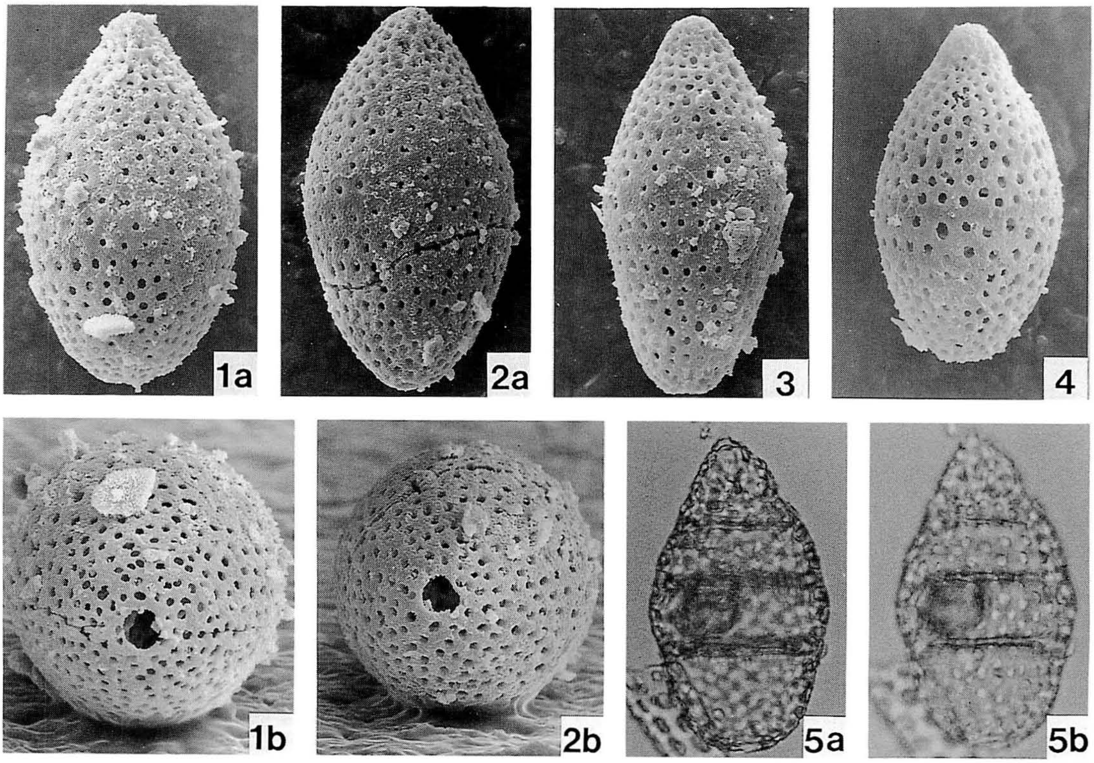


Figure 8. *Stichocapsa biconica* Matsuoka, n. sp. **1-4** ; Scanning electron micrographs, **5** ; transmitted light micrographs. All figures ×380 except for **1b** and **2b** (×500). **1a, b.** Holotype, NU MR 0030 (**a** ; 11727, **b** ; 11728), **b** ; basal view. **2a, b.** Paratype, NU MR 0031 (**a** ; 11725, **b** ; 11726), **b** ; basal view. **3.** Paratype, NU MR 0032 (11722). **4.** Paratype, NU MR 0033 (11778). **5a, b.** Paratype, NU MR 0034. (**a** ; 90-13, **b** ; 90-14).

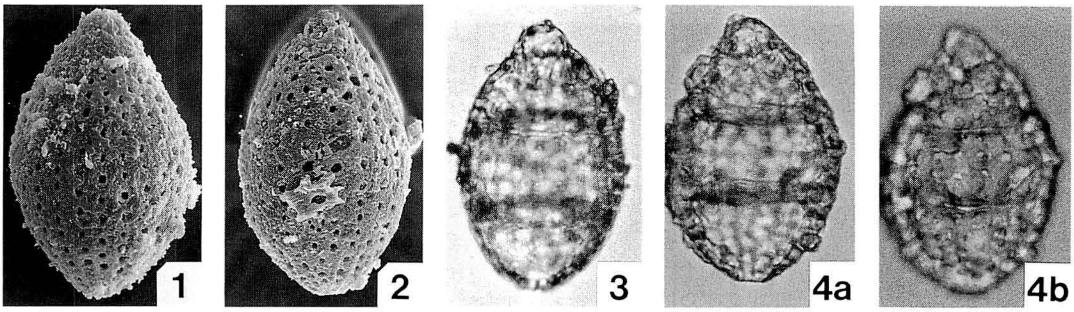


Figure 9. *Stichocapsa nanjoensis* Matsuoka, n. sp. **1-2**; Scanning electron micrographs, **3-4**; transmitted light micrographs. All figures ×380. **1.** Holotype, NU MR 0035 (12298). **2.** Paratype, NU MR 0036 (12295). **3.** Paratype, NU MR 0037 (80-11). **4a, b.** Paratype, NU MR 0038 (**a**; 90-04, **b**; 90-05).

Stichocapsa biconica Matsuoka, n. sp.

Figures 8-1a–5b

Description.—Shell of five segments, spindle-shaped. Cephalis hemispherical, poreless, occasionally with rough surface. Thorax and abdomen truncate conical. Forth segment barrel-shaped. The last segment inverted conical with a constricted aperture. Collar stricture rather distinct. Strictures between segments, except for the collar one, indistinct. Pores small to moderate and circular to subcircular. Aperture moderate in size, circular.

Measurements (in μm).—Numbers of specimens measured are in parentheses. TH; total height of shell, MW; maximum width of shell, DA; diameter of aperture.

	Holotype	max.	min.	mean	
TH	153	153	110	130	(15)
MW	77	77	57	68	(15)
DA	9	9	9	9	(2)

Remarks.—This species differs from *Cyrtocapsa* (?) *kisoensis* Yao by consisting of five segments rather than four and by lacking an apical horn.

Etymology.—The specific name is derived from the Latin *bi* (= two) and *conicus-a-um* (= conical).

Type specimens.—Holotype NU MR 0030 (Figures 8-1a, b); Paratypes NU MR 0031 (Figures 8-2a, b), NU MR 0032 (Figure 8-3), NU MR 0033 (Figure 8-4), NU MR 0034 (Figures 8-5a, b).

Type locality.—MNA-10, Nanjo Massif, Mino Terrane, central Japan.

Occurrence.—Nanjo Massif, Mino Terrane, central Japan.

Range.—*Archicapsa pachyderma* Zone (middle Lower Jurassic) as far as known.

Stichocapsa nanjoensis Matsuoka, n. sp.

Figures 9-1–4b

Description.—Shell of four segments, spindle-shaped. Cephalis hemispherical, poreless. Thorax truncate conical, abdomen barrel-shaped and fourth segment inverted conical with a constricted, circular aperture. Collar stricture pronounced externally. Other segmental joints indistinct externally. Eight to 10 weakly developed longitudinal plicae run from thorax to the distal end in lateral view. One row of pores arranged between the longitudinal plicae. Pores circular to subcircular, small and uniform in size.

Measurements (in μm).—Numbers of specimens measured are in parentheses. TH; total height of shell, MW; maximum width of shell, DA; diameter of aperture.

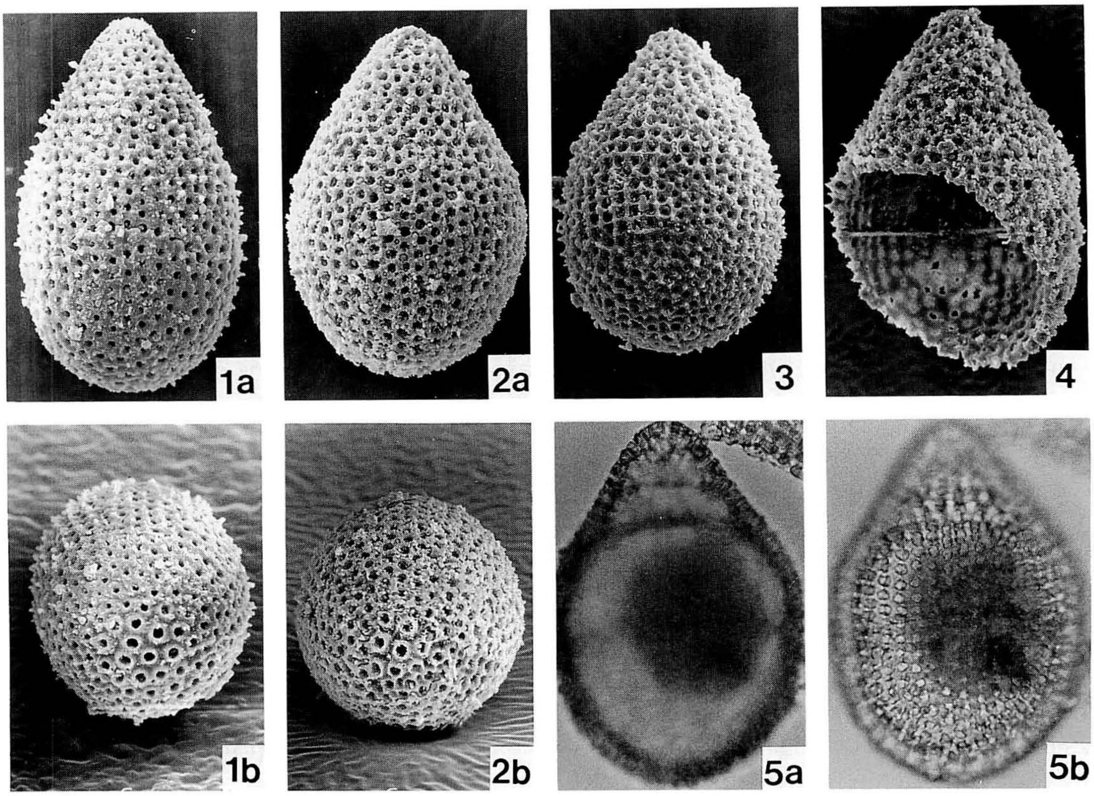


Figure 10. *Minocapsa cylindrica* Matsuoka, n. gen. et n. sp. **1-4**; Scanning electron micrographs, **5**; transmitted light micrographs. All figures ×250. **1a, b.** Holotype, NU MR 0039 (**a**; 11853, **b**; 11854), **b**; oblique basal view. **2a, b.** Paratype, NU MR 0040 (**a**; 12247, **b**; 11248), **b**; oblique basal view. **3.** Paratype, NU MR 0041 (12275). **4.** Paratype, NU MR 0042 (12246). **5a, b.** Paratype, NU MR 0043 (**a**; 94-11, **b**; 94-12).

	Holotype	max.	min.	mean	
TH	104	104	90	96	(10)
MW	62	63	54	59	(10)
DA	–	8	7	8	(5)

Remarks.—*Stichocapsa nanjoensis*, n. sp. is distinguished from *S. biconica*, n. sp. by its small size, by consisting of four segments rather than five and by having longitudinal plicae. It also differs from *Cyrtocapsa* (?) *kisoensis* Yao by having longitudinal plicae and by lacking an apical horn.

Etymology.—The species is named for the Nanjo Massif, its type locality.

Type specimens.—Holotype NU MR 0035 (Figure 9-1); Paratypes NU MR 0036 (Figure 9-2), NU MR 0037 (Figure 9-3), NU MR 0038 (Figures 9-4a, b).

Type locality.—MNA-10, Nanjo Massif, Mino Terrane, central Japan.

Occurrence.—Nanjo Massif in the Mino Terrane, central Japan.

Range.—*Archicapsa pachyderma* Zone (middle Lower Jurassic) as far as known.

Genus *Minocapsa* Matsuoka, n. gen.

Type species: *Minocapsa cylindrica* Matsuoka, n. sp.

Diagnosis.—Closed cyrtid. Shell consisting of four or more segments, pyriform to ovoidal. Cephalis hemispherical without apical horn. Thorax and abdomen truncate conical. Final segment large, hemispherical without aperture. Pores, circular to subcir-

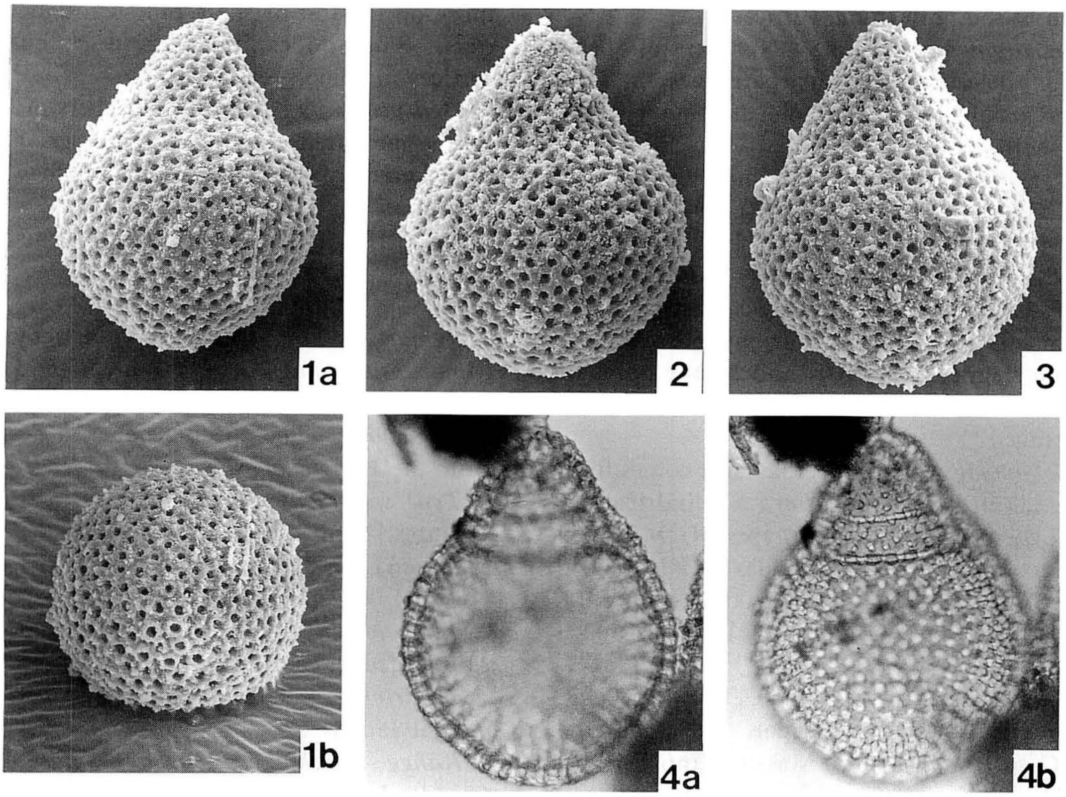


Figure 11. *Minocapsa globosa* Matsuoka, n. gen. et n. sp. **1-3**; Scanning electron micrographs, **4**; transmitted light micrographs. All figures ×250. **1a, b.** Holotype, NU MR 0044 (**a**; 11843, **b**; 11844), **b**; oblique basal view. **2.** Paratype, NU MR 0045 (12244). **3.** Paratype, NU MR 0046 (12276). **4a, b.** Paratype, NU MR 0047 (**a**; 95-22, **b**; 95-23).

cular and closely spaced.

Remarks.—*Minocapsa*, n. gen. is distinguished from *Stichocapsa* Haeckel by lacking aperture. It also differs from *Zhamoidellum* Dumitrica and *Cryptamphorella* Dumitrica by not being cryptothoracic and by consisting of four or more segments rather than three.

Etymology.—The generic name is named for the Mino Terrane which includes the type area, Nanjo Massif.

Minocapsa cylindrica Matsuoka, n. sp.

Figures 10-1a–5b

1987 *Bagotum* sp. E, Hattori, pl. 15, fig. 4.
1989 *Bagotum* sp. aff. *B. modestum* Pessagno and Whalen, Hattori and Sakamoto, pl. 13, fig. K.

Description.—Shell of five segments, ovoidal. Cephalis spherical; thorax and abdomen truncate conical. The proximal three segments form a conical proximal part. The distal two segments form a cylindrical to ovoidal distal part. The last segment hemispherical without aperture. Segmental joints generally indistinct externally; joint between abdomen and fourth segment faintly marked by change in contour from the conical proximal part to the cylindrical to ovoidal distal part. Pores circular to subcircular, rather densely spaced and set in tetragonal to hexagonal pore frames. Pores on the distal part tend to be arranged longitudinally. Pores around distal end slightly larger than those on the rest of shell; these pores surrounded by circular rims. Small nodes or spines situated at the pore frame vertices.

Measurements (in μm).—Numbers of specimens measured are in parentheses. TH; total height of shell, MW; maximum width of shell.

	Holotype	max.	min.	mean	
TH	193	193	165	181	(6)
MW	120	135	115	125	(6)

Remarks.—This species differs from *Minocapsa globosa*, n. sp. by consisting of five segments rather than four, by possessing a more slender distal part and by the pores of the distal part tending to be longitudinally arranged.

Etymology.—The specific name comes from the Latin *cylindricus-a-um* (=cylindrical).

Type specimens.—Holotype NU MR 0039 (Figures 10-1a, b); Paratypes NU MR 0040 (Figures 10-2a, b), NU MR 0041 (Figure 10-3), NU MR 0042 (Figure 10-4), NU MR 0043 (Figures 10-5a, b).

Type locality.—MNA-10, Nanjo Massif, Mino Terrane, central Japan.

Occurrence.—Nanjo Massif, Mino Terrane, central Japan.

Range.—*Archicapsa pachyderma* Zone (middle Lower Jurassic) to *Laxtorum* (?) *jurassicum* Zone (upper Lower Jurassic) as far as known.

Minocapsa globosa Matsuoka, n. sp.

Figures 11-1a–4b

Description.—Shell of four segments, pyriform. Cephalis spherical; thorax and abdomen truncate conical. The proximal three segments form a conical proximal part. The fourth segment large, subspherical without aperture. Collar and lumber strictures indistinct externally. Joint between abdomen and fourth segment marked by rapid change in contour from the conical proximal part to spherical distal part. Pores circular to subcircular, densely spaced and set in polygonal (largely hexagonal) pore frames. Pores around distal end slightly larger than those on the rest of shell and surrounded by rims. Small nodes situated at the pore frame vertices in some specimens.

Measurements (in μm).—Numbers of specimens measured are in parentheses. TH; total height of shell, MW; maximum width of shell.

	Holotype	max.	min.	mean	
TH	173	185	170	177	(6)
MW	140	149	135	142	(6)

Remarks.—This species is compared to *Minocapsa cylindrica*, n. sp. under the latter species.

Etymology.—The specific name is derived from the Latin *globosus-a-um* (=spherical).

Type specimens.—Holotype NU MR 0044 (Figures 11-1a, b); Paratypes NU MR 0045 (Figure 11-2), NU MR 0046 (Figure 11-3), NU MR 0047 (Figures 11-4a, b).

Type locality.—MNA-10, Nanjo Massif, Mino terrane, central Japan.

Occurrence.—Nanjo Massif, Mino Terrane, central Japan.

Range.—*Archicapsa pachyderma* Zone (middle Lower Jurassic) as far as known.

References

Baumgartner, P.O., 1984: A Middle Jurassic-Early Cretaceous low-latitude radiolarian zonation based on Unitary Associations and age of Tethyan radiolarites. *Eclogae geol. Helv.*, vol. 77, no. 3, p. 729-837, pls. 1-10.

Carter, E.S., Cameron, B.E B. and Smith P.L. 1988: Lower and Middle Jurassic radiolarian biostratigraphy and systematic paleontology, Queen Charlotte Islands, British Columbia. *Geol. Surv. Canada, Bull.*, 386, p. 1-109, pls. 1-18.

De Wever, P., 1981a: Hagiastridae, Patulibracchiidae et Spongodicidae (Radiolaires Polycystines) du Lias de Turquie. *Rev. Micropaléont.*, vol. 24, no. 1, p. 27-50, pls. 1-7.

——, 1981b: Parasaturnalidae, Pantanellidae et Sponguridae (Radiolaires Polycystines) du Lias de Turquie. *Ibid.*, vol. 24, no. 3, p. 138-156, pls. 1-5.

——, 1982: Nassellaria (Radiolaires Polycystines) du Lias de Turquie. *Ibid.*, vol. 24, no. 4, p. 189-232, pls. 1-13.

Hattori, I., 1984: Alternating clastic limestone and red chert as olistolith in the Mino Terrane, central Japan. *Jour. Geol. Soc. Japan,* vol. 90, no. 1, p. 43-54, pls. 1-2.

——, 1987: Jurassic radiolarian fossils from the Nanjo Massif, Fukui Prefecture, central Japan. *Bull. Fukui Municipal Museum, Natural History,* no. 34, p. 29-101, pls. 1-23. (*in Japanese with English abstract*)

——, 1988: Radiolarian fossils from manganese nodules at the upper reach of the Tarumigawa in the Nanjo Massif, Fukui Prefecture, central Japan, and the tectonic significance of the northwestern Mino Terrane. *Ibid.,* no. 35, p. 55-101, pls. 1-14. (*in Japanese with English abstract*)

——, 1989: Jurassic radiolarians from manganese nodules at three sites in the western Nanjo Massif, Fukui Prefecture, central Japan. *Mem. Fac. Educ. Fukui Univ.,* no. 39, p. 47-134, pls. 1-45. (*in Japanese with English abstract*)

—— and Sakamoto, N., 1989: Geology and Jurassic radiolarians from manganese nodules of the Kanmuriyama-Kanakusadake area in the Nanjo Massif, Fukui Prefecture, central Japan. *Bull. Fukui Municipal Museum, Natural History,* no. 36, p. 25-79, pls. 1-19. (*in Japanese with English abstract*)

—— and Yoshimura, M., 1982: Lithofacies distribution and radiolarian fossils in the Nanjo area in Fukui Prefecture, central Japan. *News of Osaka Micropaleontologists, Spec. Vol.,* no. 5, p. 103-116, pls. 1-4. (*in Japanese with English abstract*)

—— and ——, 1983: Late Triassic to Middle Jurassic ages for greenstones within the Mesozoic Nanjo Massif of the Mino Terrane, central Japan. *Mem. Fac. Educ. Fukui Univ.,* no. 32, p. 67-80, pls. 1-9. (*in Japanese with English abstract*)

Hori, R., 1988: Some characteristic radiolarians from Lower Jurassic bedded cherts of the Inuyama area, Southwest Japan. *Trans. Proc. Palaeont. Soc. Japan, N.S.,* no. 151, p. 543-563.

—— and Otsuka T., 1989: Early Jurassic radiolarians from the Mt. Norikuradake area, Mino terrane, central Japan. *Jour. Geosci., Osaka City Univ.,* vol. 32, p. 175-199, pls. 1-4.

—— and Yao, A., 1988: *Parahsuum* (Radiolaria) from the Lower Jurassic of the Inuyama area, central Japan. *Ibid.,* vol. 31, p. 47-61, pls. 1-2.

Ichikawa, K. and Yao, A., 1976: Two new genera of Mesozoic cyrtoid radiolarians from Japan. *In,* Takayanagi, Y. and Saito, T. *eds. Progress in micropaleontology,* p. 110-117, pls. 1-2, Amer. Mus. Natural History, New York.

Isozaki, Y. and Matsuda, T., 1985: Early Jurassic radiolarians from bedded chert in Kamiaso, Mino Belt, central Japan. *Earth Sci.* (*Chikyu Kagaku*), vol. 39, no. 6, p. 429-442, pls. 1-3.

Ito, M. and Matsuda, T., 1980: Discovery of Triassic and Jurassic radiolarians and Triassic conodonts from the Nanjo Mountains, western Mino Belt, central Japan. *Bull. Fukui Municipal Museum, Natural History,* no. 27, p. 7-12, pl. 1. (*in Japanese*)

—— and Shiratake, T., 1980: A review of the Paleozoic radiolarian fossils found around Mt. Kanmuri on the Fukui-Gifu Prefectural border in central Japan —New findings Triassic-Jurassic period radiolarians—. *Ibid.,* no. 27, p. 1-6, pl. 1. (*in Japanese*)

Kishida, Y. and Hisada, K., 1985: Late Triassic to Early Jurassic radiolarian assemblages from the Ueno-mura area, Kanto Mountains, central Japan. *Mem. Osaka Kyoiku Univ., Ser. 3,* vol. 34, no. 2, p. 103-129, pls. 1-4.

Matsuoka, A. and Yao, A., 1986: A newly proposed radiolarian zonation for the Jurassic of Japan. *Marine Micropaleontology,* vol. 11, p. 91-106, pls. 1-3.

MacLeod, N., 1988: Lower and Middle Jurassic *Perispyridium* (Radiolaria) from the Snowshoe Formation, east-central Oregon. *Micropaleontology,* vol. 34, no. 4, p. 289-315, pls. 1-5.

Pessagno, E.A. Jr. and Blome, C.D., 1980: Upper Triassic and Jurassic Pantanelliinae from California, Oregon, and British Columbia. *Ibid.,* vol. 26, no. 3, p. 225-273, pls. 1-11.

——, ——, Carter, E.S., MacLeod, N., Whalen, P.A. and Yeh, K.-Y., 1987: Preliminary radiolarian zonation for the Jurassic of North America. Part II of studies of North American Jurassic Radiolaria. *Cushman Found. Foram. Res., Spec. Pub.,* no. 23, p. 1-18.

—— and Poisson, A., 1981: Lower Jurassic radiolaria from the Gumuslu Allochton of southwestern Turkey (Taurides Occidentales). *Bull. Mineral Research and Exploration Institute of Turkey,* no. 92, 1979, p. 47-69, pls. 1-15.

—— and Whalen, P.A., 1982: Lower and Middle Jurassic Radiolaria (multicyrtid Nassellariina) from California, east-central Oregon and the Queen Charlotte Islands, B.C. *Micropaleontology,* vol. 28, no. 2, p. 111-169, pls. 1-13.

——, —— and Yeh, K.-Y., 1986: Jurassic Nassellariina (Radiolaria) from North American Geologic Terranes. *Bull. Am. Paleontology,* vol. 91, no. 326, p. 1-75, pls. 1-11.

Sashida, K., 1988: Lower Jurassic multisegmented Nassellaria from the Itsukaichi area, western part of Tokyo Prefecture, central Japan. *Sci. Rep., Inst. Geosci., Univ. Tsukuba, Sec. B,* vol. 9, p. 1-27, pls. 1-4.

Takamura, Y. and Hayami, T., 1985: On the Paleozoic and Mesozoic strata in the eastern area of Imajo-cho, Fukui Prefecture, central Japan. *Bull. Fukui Municipal Museum, Natural His-*

tory, no. 31, p. 1-16, pls. 1-6. (*in Japanese*)

Takemura, A., 1986: Classification of Jurassic Nassellarians (Radiolaria). *Palaeontographica, Abt. A*, Bd. 195, p. 29-74, pls. 1-12.

—— and Nakaseko, K., 1982: Two new Jurassic genera of Family Palaeoscenidiidae (Radiolaria). *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 128, p. 452-464, pls. 70-73.

—— and ——, 1983: *Perseus*, a new genus of Jurassic Palaeoscenidiidae and the phylogeny of Subfamily Hilarisirecinae. *Mem. Fac. Sci., Kyoto Univ.*, (*Ser. Geol. Mineral.*), vol. 49, nos. 1-2, p. 111-118, pls. 9-10.

—— and ——, 1986: The cephalic skeletal structure of Jurassic "*Eucyrtidium*" (Radiolaria). *Jour. Paleontology*, vol. 60, no. 5, p. 1016-1024.

Yao, A., 1972: Radiolarian fauna from the Mino Belt in the northern part of the Inuyama area, central Japan. Part I: Spongosaturnalids. *Jour. Geosci., Osaka City Univ.*, vol. 15, p. 21-64, pls. 1-11.

——, 1979: Radiolarian fauna from the Mino Belt in the northern part of the Inuyama area, central Japan. Part II: Nassellaria 1. *Ibid.*, vol. 22, p. 21-72, pls. 1-12.

——, 1982: Middle Triassic to Early Jurassic radiolarians from the Inuyama area, central Japan. *Ibid.*, vol. 25, p. 53-70, pls. 1-4.

Yeh, K.-Y., 1987a: Taxonomic studies of Lower Jurassic radiolaria from east-central Oregon. *Nat. Museum Nat. Science, Spec. Pub.*, no. 2, p. 1-169, pls. 1-30.

——, 1987b: A revised classification for Family Canoptidae (Radiolaria). *Mem. Geol. Soc. China*, no. 8, p. 63-72, pls. 1-2.

Yoshimura, M., Kido, S. and Hattori, I., 1982: Stylolitic cherts and radiolarian fossils in the Imajo area of the Nanjo Massif, Fukui Prefecture, central Japan. *Bull. Fukui Municipal Museum, Natural History*, no. 31, p. 65-77, pls. 1-6. (*in Japanese with English abstract*)

Imajo 今庄，Kasugano 春日野，Kohkura 高倉，Nanjo 南条.

美濃帯南条山地からの前期ジュラ紀放散虫 (その 1) *Tricolocapsa, Stichocapsa, Minocapsa*, n. gen.: 美濃帯南条山地のマンガンバンドから得られた前期ジュラ紀放散虫記載の第1報として, 表題の Nassellaria3 属 (*Minocapsa* は新属) について, 以下の 9 新種 (2 新亜種を含む) を命名，記載した。*T. minoensis*, *T.* (?) *megaglobosa*, *T.* (?) *fera*, *S. plicata plicata*, *S. plicata semiplicata*, *S. elegans*, *S. biconsica*, *S. nanjoensis, M. cylindrica, M. globosa.* このマンガンバンドから産出した放散虫群集は，わが国で設立されたジュラ紀化石帯のうち *Archicapsa pachyderma* 帯上部の群集に類似する。また，この群集は，北アメリカのオレゴン州中東部のトアルシアン階下部から産出する放散虫群集に比較される。 松岡 篤

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 161, pp. 739-750, 4 Figs., April 30, 1991

916. *PAMIRINA* (PERMIAN FUSULINACEA) FROM THE AKIYOSHI LIMESTONE GROUP, SOUTHWEST JAPAN*

KATSUMI UENO

Division of Environmental Science, Graduate School
of Science and Technology,
Chiba University, Chiba 260

Abstract. The genus *Pamirina* is considered as the direct ancestor of verbeekinid and neoschwagerinid fusulinaceans, and two distinct groups of *Pamirina* which have different spirothecal structure each other are so far known in this genus. The different stratigraphic distribution of two groups of *Pamirina* in the Akiyoshi Limestone Group distributed in the Kaerimizu area, the northeastern part of Akiyoshi Plateau, supports to subdivide the genus into two subgenera. In this paper, *Levenia*, n. subgen. is proposed and three species of *Pamirina*; *P.* (*P.*) *darvasica, P.* (*Levenia*) *leveni, P.* (*L.*) *evoluta,* and *Misellina* (*Brevaxina*) ? sp. coexisting with *P.* (*P.*) *darvasica* from the *Pamirina* (*Levenia*) *leveni* Zone are described and illustrated. This *Pamirina* fauna is referable to the late Artinskian or the late Yakhtashian age.

Key words. Akiyoshi Limestone Group, Artinskian, Kaerimizu, *Levenia, Pamirina,* Yakhtashian.

Introduction

The family Staffellidae had been long regarded as an ancestral stock of the family Verbeekinidae until Leven (1970) established the genus *Pamirina* with *Pamirina darvasica* as the type species. He explained that the genus is the direct ancestor of the verbeekinid fusulinaceans, and the family Verbeekinidae is derived from the family Ozawainellidae.

Later, Kobayashi (1977) described three species of *Pamirina* from the Itsukaichi, Shomaru and Otaki areas in the Kwanto Mountains and confirmed the presence of two distinct groups of *Pamirina* having different spirothecal structure. One group includes *Pamirina darvasica,* the type species of this genus, and has a subspherical shell and spirotheca composed of a single structureless layer in the inner volutions, tectum and protheca in the middle volutions, and tectum and fine alveolar keriotheca in the outer volutions. The other one is represented by *Pamirina tethydis* and *P. leveni,* and has a thickly lenticular shell. Their spirotheca is composed of a structureless single layer in the inner volutions, and tectum and protheca in the outer ones. Kobayashi (1977) considered that the latter group is more primitive than the former one and recognized the following four evolutionary stages from the genus *Pamirina* to the most primitive member of the family Verbeekinidae, the genus *Misellina,* through the detailed observation of ontogenic change of spirothecal structure and growth curve of *Pamirina* and also certain species of *Misellina.* Namely, primitive *Pamirina* (*P. tethydis* and *P. leveni*), advanced *Pamirina* (*P. darvasica*), primitive *Misellina* (*M. dyhrenfurthi* — *M. otakiensis* group, which are now referred to the subgenus *Brevaxina* of the genus *Misellina*), and

---

*Received September 4, 1990; revised manuscript accepted February 25, 1991

advanced *Misellina* (*M. claudiae* etc.). He concluded that these four evolutionary stages from *Pamirina* to *Misellina* construct the single evolutionary series. All of the materials treated in Kobayashi (1977), however, were obtained from limestone blocks or limestone pebbles in the middle and southern belts of the Chichibu Terrain, which are now thought to have comprised accretionary complexes during Mesozoic time (Ozawa and Kobayashi, 1985 and others). Therefore, their phylogeny based on stratigraphic evidence is still incomplete.

In the course of the reexamination of the fusulinacean biostratigraphy of the Akiyoshi Limestone Group in the Kaerimizu area, the northeastern part of Akiyoshi Plateau, I found many individuals of *Pamirina* from the *Pseudofusulina ambigua* Zone by Ota (1977). In this paper, *Levenia*, n. subgen. is introduced for the group of *Pamirina* without a fine alveolar keriotheca in the spirotheca, and three species of *Pamirina* besides *Misellina* (*Brevaxina*)? sp. coexisting with *Pamirina* (*P.*) *darvasica*, which is considered to be the transitional form between *Pamirina* and *Brevaxina*, are described and illustrated. The fusulinacean biostratigraphy and stratigraphic distribution of *Pamirina* in the Akiyoshi Limestone Group are also briefly noted.

All of the illustrated specimens are kept in the Department of Earth Sciences, Faculty of Science, Chiba University.

Geologic setting and fusulinacean biostratigraphy

The Kaerimizu area is situated in the northeastern part of Akiyoshi Plateau (Figure 1). The Akiyoshi Limestone Group ranging from the late Middle Carboniferous to the late Middle Permian which contains rich shallow marine organic remains such as foraminifers, algae, corals and mollusks is well exposed in this area. It has been investigated by many students in the focus of geologic structure and fusulinacean biostratigraphy (Ozawa, 1923; Toriyama, 1954, 58; Hasegawa, 1958, 63; Sakaguchi *et al.*, 1966; Ota *et al.*, 1973; Ota, 1977). Ota (1977) divided the Akiyoshi Limestone Group in this area into the following 10 fusulinacean zones in ascending order: the *Fusulinella biconica, Triticites simplex, Pseudofusulina vulgaris, Pseudofusulina ambigua, Misellina claudiae, Parafusulina kaerimizensis, Afghanella schencki, Neoschwagerina craticulifera, Verbeekina verbeeki* and *Colania douvillei* Zones.

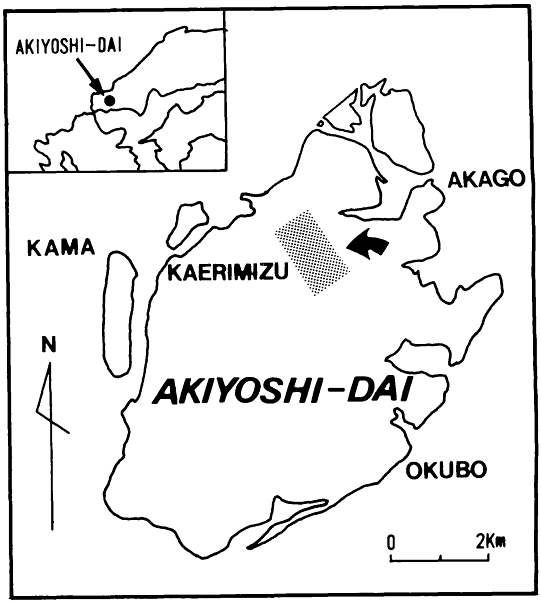


Figure 1. Map showing the Kaerimizu area in the Akiyoshi Plateau.

My recent investigation in the Kaerimizu area makes it possible to divide Ota's *Pseudofusulina ambigua* Zone into the lower *Pseudofusulina* ex gr. *kraffti* and upper *Pamirina* (*Levenia*) *leveni* Zones. The distribu-

⟶ **Figure 2.** Distribution of biozones and *Pamirina* localities studied herein. **1**: *Chalaroschwagerina vulgaris* Zone, **2**: *Pseudofusulina* ex gr. *kraffti* Zone, **3**: *Pamirina* (*Levenia*) *leveni* Zone, **4**: *Misellina* (*Brevaxina*) *dyhrenfurthi otai* Zone, **5**: *Misellina* (*Misellina*) *claudiae* Zone (M: *Misellina* (*M.*) *claudiae* swarmed layer), **6**: *Parafusulina kaerimizensis* Zone, **7**: fossil locality.

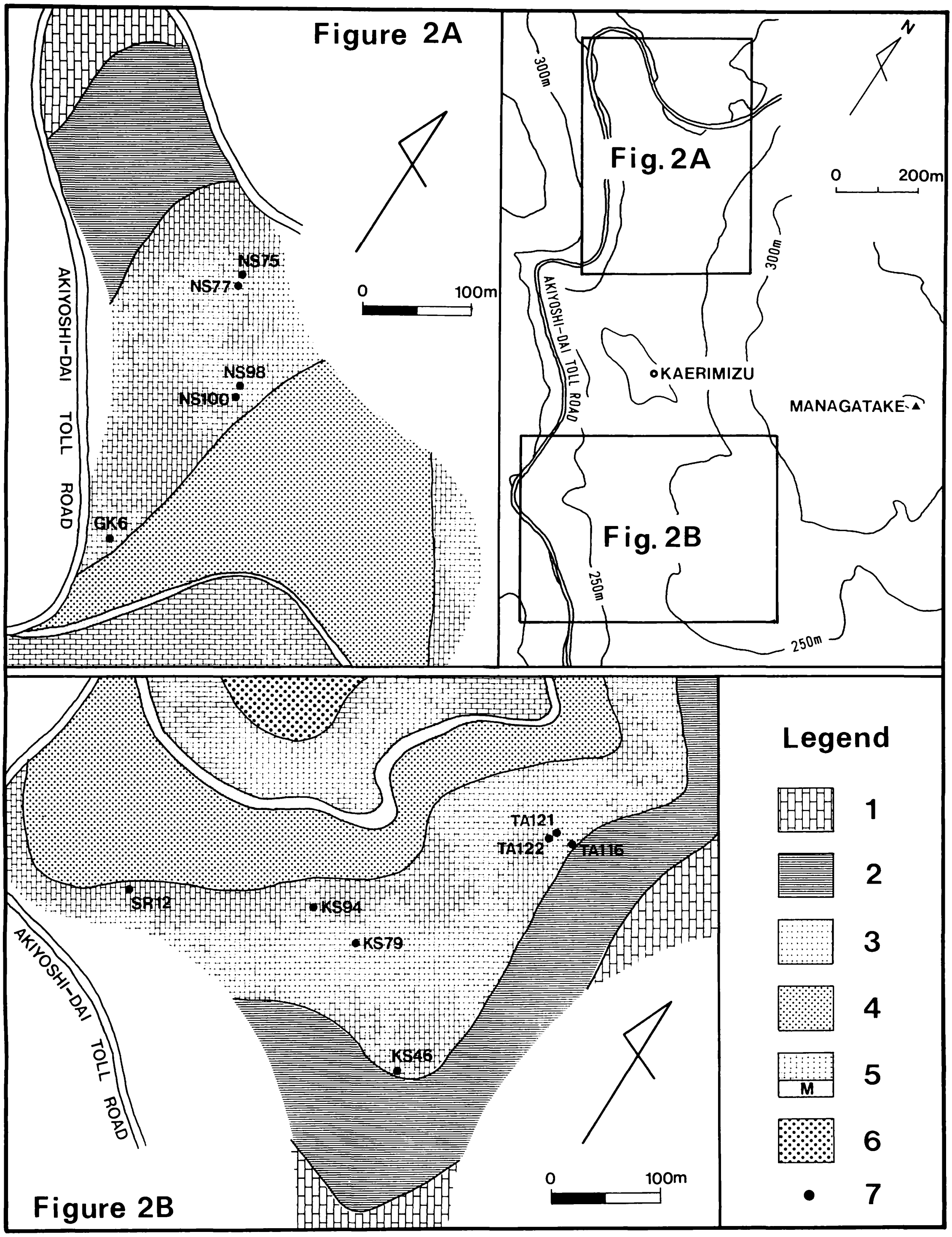


Figure 2A
NS75
NS77
NS98
NS100
GK6
AKIYOSHI-DAI TOLL ROAD
0
100m
300m
Fig. 2A
N
0
200m
300m
AKIYOSHI-DAI TOLL ROAD
KAERIMIZU
MANAGATAKE
Fig. 2B
250m
250m
TA121
TA122
TA116
SR12
KS94
KS79
KS46
AKIYOSHI-DAI TOLL ROAD
0
100m
Figure 2B
Legend
1
2
3
4
M
5
6
7

tion of biozones in the Kaerimizu area is shown in Figure 2.

The *Pamirina* (*Levenia*) *leveni* Zone is defined as the stratigraphic interval from the first appearance of *Pamirina* (*Levenia*) *leveni* and *P.* (*L.*) *evoluta* to that of *Misellina* (*Brevaxina*) *dyhrenfurthi otai.* Algal oncoidal limestone is predominant in this zone with a subordinate amount of bioclastic sparitic limestone and muddy limestone. The following fusulinaceans are discriminated: *Pamirina* (*P.*) *darvasica* Leven, *P.* (*Levenia*) *leveni* Kobayashi, *P.* (*L.*) *evoluta* Sheng and Sun, *Toriyamaia laxiseptata* Kanmera, *Minojapanella* (*M.*) cf. *elongata* Fujimoto and Kanuma, *Schubertella* spp., *Pseudoreichelina darvasica* Leven, *P.* spp., *Pseudoendothyra obiniouensis* Leven, *P.* spp., *Pseudofusulina* ex gr. *kraffti* (Schellwien), *P. fusiformis* (Schellwien), *P.* spp., *Chalaroschwagerina vulgaris* (Schellwien), *Misellina* (*Brevaxina*) aff. *otakiensis* (Huzimoto) and *M.* (*B.*)? sp. Accordingly, its geologic age is referable to the late Artinskian or the late Yakhtashian.

Concerning the stratigraphic distribution of *Pamirina* in the Akiyoshi Limestone Group, *Pamirina* (*Levenia*) *leveni* and *P.* (*L.*) *evoluta* appear first in the basal part of the *Pamirina* (*Levenia*) *leveni* Zone and range up to the middle part of the zone. While *Pamirina* (*P.*) *darvasica* is obtained from the upper part of the *Pamirina* (*Levenia*) *leveni* Zone associated with *Misellina* (*Brevaxina*)? sp. From immediately above this horizon, *Misellina* (*Brevaxina*) aff. *otakiensis* is detected and this horizon is succeeded by the *Misellina* (*Brevaxina*) *dyhrenfurthi otai* Zone through a short stratigraphic interval. In the Akiyoshi Limestone Group, *Levenia* occupies slightly lower stratigraphic position than that of *Pamirina* (s.s.). This fact is concordant with Kobayashi (1977)'s conclusion on the phylogenetic relationship between *Pamirina* (*Levenia*) *leveni* and *P.* (*P.*) *darvasica.*

In the Permian Period of the Tethyan region, eight zones by the fusulinacean genera can be recognized. They are *Pseudoschwagerina, Pseudofusulina-Chalaroschwagerina, Misellina, Cancellina-Maklaya, Neoschwagerina, Lepidolina-Yabeina, Codonofusiella-Reichelina* and *Palaeofusulina* Zones in ascending order. Judging from the known occurrence of *Pamirina* together with its stratigraphic distribution in the Akiyoshi Limestone Group, the genus *Pamirina* is most characteristic in the upper part of *Pseudofusulina-Chalaroschwagerina* Zone, which indicates the late Artinskian or the late Yakhtashian age, although some forms are found together with *Misellina.* Moreover, as far as the present knowledge of its geographic distribution is concerned, it seems that *Pamirina* is paleobiogeographically restricted to the Tethyan Realm.

Systematic paleontology

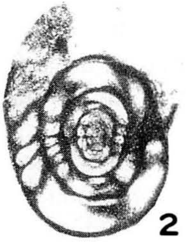
Order Foraminiferida Eichwald, 1830
Suborder Fusulinina Wedekind, 1937
Superfamily Fusulinacea von Möller, 1878
Family Ozawainellidae Thompson and Foster, 1937
Subfamily Ozawainellinae Thompson and Foster, 1937
Genus *Pamirina* Leven, 1970 emend. Kobayashi, 1977

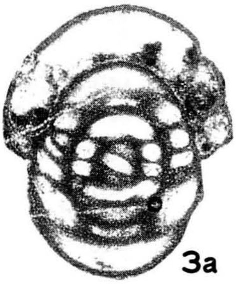
Type species.—*Pamirina darvasica* Leven, 1970.

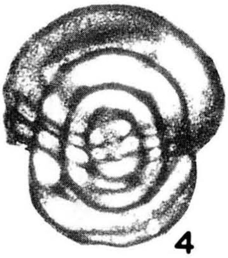
Pamirina Leven, 1970, p. 23; Rozovskaya, 1975, p.

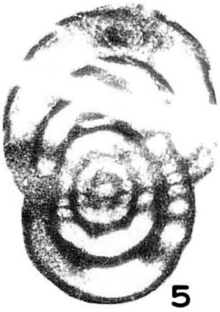
—→ **Figure 3. 1-7.** *Pamirina* (*Pamirina*) *darvasica* Leven, **1, 2**: axial sections, GK6-18, SR12-2, **3a, 4, 5**: tangential sections: SR12-12, GK6-24, GK6-10, **6, 7**: sagittal sections: GK6-7, GK6-1, **3b**: enlarged part of **3a. 8-23.** *Pamirina* (*Levenia*) *leveni* Kobayashi, **8, 9a. 10-16**: axial sections, TA122-14, TA122-5, TA122-1a, KS94-1, TA122-29, TA122-32, TA122-24a, TA121-2, TA122-25b, **17-20**: tangential sections, TA122-25a, TA122-1b, TA122-7, TA122-24b, **21-23**: sagittal sections, TA122-40, TA122-47, TA122-A, **9b**: enlarged part of **9a. 24.** *Misellina* (*Brevaxina*)? sp., **24a**: axial section, GK6-11, **24b**: enlarged photograph of **24a.** All ×40, exept for **3b, 9b** and **24b**; ×100.

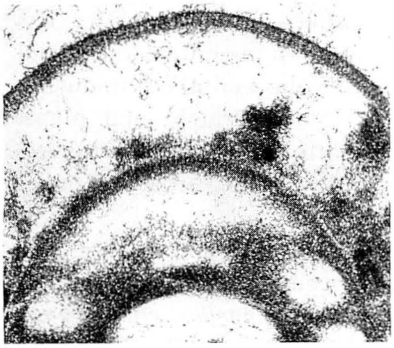

1

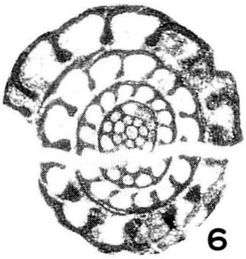

2

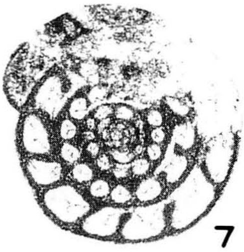

3a


4

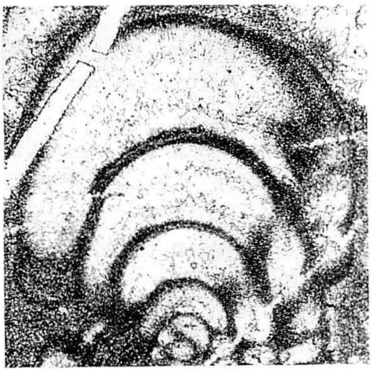

5

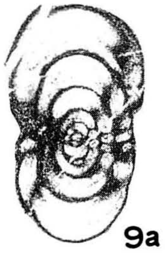

3b


6


7

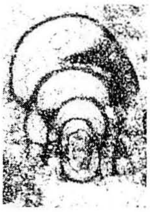

8


9b


9a


10

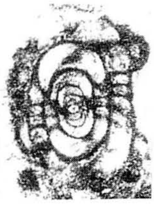

11

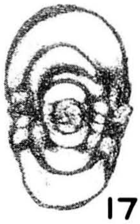

12

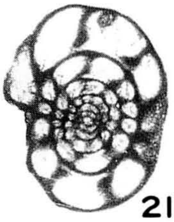

13

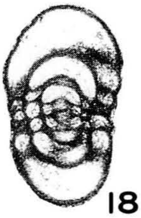

14

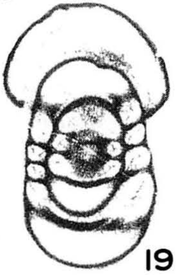

15


16

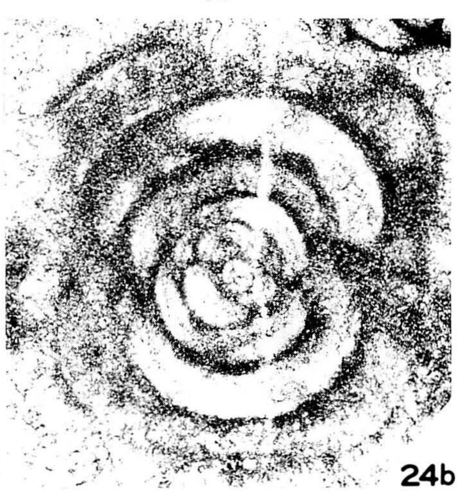

17

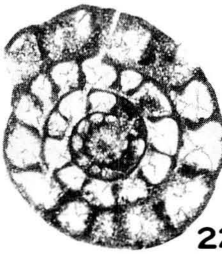

21

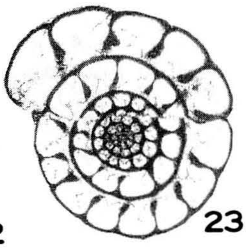

18

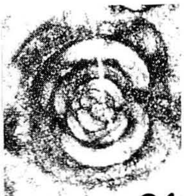

19


20


24b


22


23


24a

114-115 ; Lin *et al*., 1977, p. 19-20 ; Kobayashi, 1977, p. 10-11 ; Liu *et al.,* 1978, p. 80 ; Sun *et al.,* 1983, p. 9 ; Loeblich and Tappan, 1988, p. 286 ; Sheng *et al.,* 1988, p. 175.

Chinlingella Wang and Sun, 1973, p. 152, 171-172 ; Sheng *et al.,* 1988, p. 176.

Diagnosis.—Shell small, thickly lenticular to subspherical, rarely spherical with broadly rounded periphery. Axial regions slightly to moderately umbilicated. Mature shell usually having 3 to 6 volutions. Axis of coiling usually straight throughout except for juvenarium of some forms. Shell expands gradually. Proloculus spherical, small to large for shell size. Spirotheca thin and 2 types in structure. Spirotheca of primitive forms composed of structureless single layer in inner volutions, and tectum and lower less dense layer (protheca) in outer ones. Besides outer volutions of advanced forms have spirotheca, consisting of tectum and fine alveolar keriotheca. Septa straight and plane. Tips of septa swollen in sagittal section. Chomata weak and low, sometimes rudimental. Tunnel path low and broad.

Remarks.—The original diagnosis of *Pamirina* by Leven (1970) is summarized as follows. "Shell small, subspherical, more or less depressed in axial regions. Coiling axis in inner few volutions unstable. Rate of shell expansion uniform. Proloculus spherical and small. Spirotheca with fine alveolar keriotheca. Aperture single and chomata distinct."

As stated by Lin *et al.* (1977), the genus *Chinlingella* Wang and Sun is quite identical with *Pamirina* and is a junior synonym of the latter.

The genus *Pamirina* can be divided into the following two subgenera, *Pamirina* and *Levenia*, n. subgen., by the difference in general shell shape, the spirothecal structure and stratigraphic occurrence.

Subgenus *Pamirina* Leven, 1970

Type species.—*Pamirina darvasica* Leven, 1970.

Diagnosis.—Shell small, subspherical to rarely spherical with broadly rounded periphery and slightly umbilicated axial regions. Mature shell consists of 5 to 6 volutions. Axis of coiling usually straight throughout except for juvenarium of some forms. Proloculus small and spherical. Spirotheca thin and composed of single structureless layer in inner volutions, tectum and lower less dense layer (protheca) in middle ones, and tectum and fine alveolar keriotheca in outer 1 or 2 volutions. Septa straight and plane. Tips of septa slightly swollen in sagittal section. Chomata low and broad. Tunnel path regular and wide.

Remarks.—The following species are included in this subgenus, *Pamirina darvasica* Leven, 1970 (=*Chinlingella chinlingensis* Wang and Sun, 1973 ; *C. nobilis* Wang and Sun, 1973) ; *P. pulchra* Wang and Sun, 1973 ; *P. orbiculoidea* Sheng and Sun, 1975 ; *P. staffellaeformis* Zhou, Sheng and Wang, 1987.

Geologic age.—Late Artinskian or late Yakhtashian (Early Permian).

Geographic distribution.—Carnic Alps (Kahler and Kahler, 1980). Darvas Range (Leven, 1970), North Thailand (Sakagami and Iwai, 1974), Chinling Range (Wang and Sun, 1973), Guizhou (Liu *et al.,* 1978), Guangxi (Lin *et al.,* 1977), Qinghai (Sheng and Sun, 1975), Yunnan (Zhou *et al*., 1987), Xinjiang (Sun and Zhang, 1988), Kwanto Mountains (Kobayashi, 1977) and Akiyoshi (present study).

Pamirina (*Pamirina*) *darvasica*
Leven, 1970

Figures 3-1—7

Pamirina darvasica Leven, 1970, p. 23-24, pl. 1, figs. 1-9, 23-24 (not pl. 1, figs. 10-11) ; Rozovskaya, 1975, pl. 35, figs. 4-5 (same as pl. 1, figs. 1-2 of Leven, 1970, p. 23-24) ; Kobayashi, 1977, p. 14-15, pl. 2. figs. 1a, 1b, 2-3 ; Liu *et al.,* 1978, p. 80, pl. 18, figs. 8, 12 ; Kahler and Kahler, 1980, p. 187-188, pl. 3, fig. 8 (not pl. 3, fig. 7) ; Loeblich and Tappan, 1988, pl. 295, fig. 11 (not pl. 295, fig. 12, same as pl. 1, fig. 1 of Leven, 1970, p. 23-24).

Chinlingella chinlingensis Wang and Sun, 1973, p. 152-153, 172, pl. 1, figs. 12, 17-32, pl. 3, figs. 1, 5, 10.

Chinlingella nobilis Wang and Sun, 1973, p. 153-154, 173, pl. 1, figs. 1-5, 9-11.

Staffella aff. *mölleri* Ozawa, Sakagami and Iwai, 1974, p. 54-55, pl. 4, figs. 1-13.

Pamirina nobilis (Wang and Sun), Lin *et al.*, 1977, p. 20, pl. 3, figs. 21-22 ; Sun *et al.*, 1983, p. 9, pl. 2, fig. 15 (same as pl. 1, fig. 1 of Wang and Sun, 1973, p. 153-154, 173) ; Zhou *et al.*, 1987, pl. 2, figs. 3, 4.

Pamirina chinlingensis (Wang and Sun), Sun *et al.*, 1983, p. 9, pl. 2, fig. 17 (same as pl. 1, fig. 19 of Wang and Sun, 1973, p. 152-153, 172) ; Zhou *et al.*, 1987, pl. 2, figs. 1, 2 ; Loeblich and Tappan, 1988, pl. 295, figs. 8-10 (same as pl. 1, figs. 19-20, 31 of Wang and Sun, 1973, p. 152-153, 172) ; Sun and Zhang, 1988, pl. 3, figs. 7, 15.

Material studied.—Axial sections ; GK6-18 from Loc. GK6 and SR 12-2 from Loc. SR12. Sagittal sections ; GK6-1 and GK6-7 from Loc. GK6. Tangential sections ; GK6-10 and GK6-24 from Loc. GK6 and SR12-12 from Loc. SR12. Additional specimens were obtained from Locs. GK6 and SR12.

Description.—Shell small, involute throughout and subspherical with broadly rounded periphery. Axial regions slightly depressed. Mature specimens having 5 to 5 ½ volutions 0.53 to 0.63 mm in axial length and 0.77 to 0.92 mm in median width, giving form ratio of about 0.70.

Axis of coiling slightly rotated in juvenarium. Shell expands gradually through growth. Average radius vectors of the first to fifth volutions for 4 specimens 0.05, 0.10, 0.17, 0.28 and 0.43 mm. Average form ratios of the first to fifth volutions for 2 specimens 0.70, 0.72, 0.81, 0.76 and 0.70, respectively.

Proloculus small and spherical. Its outside diameter about 0.05 mm.

Spirotheca thin and composed of single structureless layer in inner 1 or 2 volutions, tectum and lower less dense layer (protheca) in the next 2 volutions, and tectum and fine alveolar keriotheca in outer 1 or 2 volutions. Average thickness of spirotheca of the first to fifth volutions for 4 specimens 0.009, 0.011, 0.015, 0.020 and 0.022 mm.

Septa straight and plane. Tips of septa in sagittal section swollen. Septal counts of the first to fifth volutions of specimen illustrated in Figure 3-6 ; 6, 11, 13, 14 and 14. Chomata low, broad and well developed in outer volutions. Tunnel path wide and regular.

Remarks.—The Akiyoshi specimens are quite similar to the Darvas ones in the essential morphological characters.

Pamirina (*P.*) *darvasica* somewhat resembles *P.* (*P.*) *eostaffellaeformis* originally described by Zhou *et al.* (1987) from the *Pamirina chinlingensis* and *Misellina ovalis* Zones of eastern Yunnan. However, the former has a smaller shell than the latter.

Staffella aff. *mölleri* Ozawa described by Sakagami and Iwai (1974) from the Pha Duk Chik Limestone and Huai Hin Lat limestone conglomerate of North Thailand has a subspherical shell and its spirotheca composed of a tectum and fine alveolar keriotheca, and coexists with typical Artinskian fusulinaceans such as *Chalaroschwagerina vulgaris, Pseudofusulina krotowi, Mesoschubertella thompsoni* and others. Judging from the above mentioned facts, the Thailand specimens are apparently assigned to the genus *Pamirina* and identical with *P. darvasica.*

Occurrence.—Common in the upper part of the *Pamirina* (*Levenia*) *leveni* Zone.

Subgenus *Levenia* Ueno, n. subgen.

Type species.—*Pamirina leveni* Kobayashi, 1977.

Diagnosis.—Shell small and thickly lenticular with broadly rounded periphery. Axial regions slightly to deeply depressed. Mature shell consists of 3 to 5 ½ volutions. Coiling planispiral throughout, but slightly rotated in juvenarium of some forms. Shell expands gradually. Proloculus spherical and small to large for shell size. Spirotheca thin, composed of single structureless layer in inner volutions, but tectum and lower less dense layer (protheca) in outer ones. Septa straight and plane. Tips of septa slightly swollen in sagittal section. Chomata hardly observed or rudimentarily developed. Tunnel path low and regular.

Remarks.—The following five species can be referred to the subgenus *Levenia, Pamirina tamanouchiensis* (Sakagami, 1956) ; *P. evoluta* Sheng and Sun, 1975 ; *P. leveni* Kobayashi, 1977 ; *P. tethydis* Kobayashi, 1977 ; *P.* ? *hataii* (Suyari, 1962).

This new subgenus differs from *Pamirina* (s.s.) in having a thickly lenticular shell, smaller form ratio and different spirothecal structure. Moreover the former occupies slightly lower stratigraphic position and is considered the direct ancestor of the latter as Kobayashi (1977) pointed out.

Geologic age.—Late Artinskian or late Yakhtashian (Early Permian).

Geographic distribution.—Qinghai (Sheng and Sun, 1975), Kwanto Mountains (Sakagami, 1956 ; Takaoka, 1966 ; Kobayashi, 1977), Mino Mountains (Kanuma, 1960), Kochi (Suyari, 1962) and Akiyoshi (present study).

Pamirina (*Levenia*) *leveni* Kobayashi, 1977

Figures 3-8—23

Pamirina pulchra (Wang and Sun), Sheng and Sun, 1975, p. 46, pl. 1, figs. 16-18.
Pamirina leveni Kobayashi, 1977, p. 11-14, pl. 1, figs. 13-38.

Material studied.—Axial sections ; TA121-2 from Loc. TA121, TA122-1a, TA122-5, TA122-14, TA122-24a, TA122-25a, TA122-25b, TA122-29, TA122-32 from Loc. TA122 and KS94-1 from Loc. KS94. Sagittal sections ; TA122-40, TA122-47 and TA122-A from Loc. TA122. Tangential sections ; TA122-1b, TA122-7 and TA122-24b from Loc. TA122. Additional specimens were also obtained from some localities in the *Pamirina* (*Levenia*) *leveni* Zone.

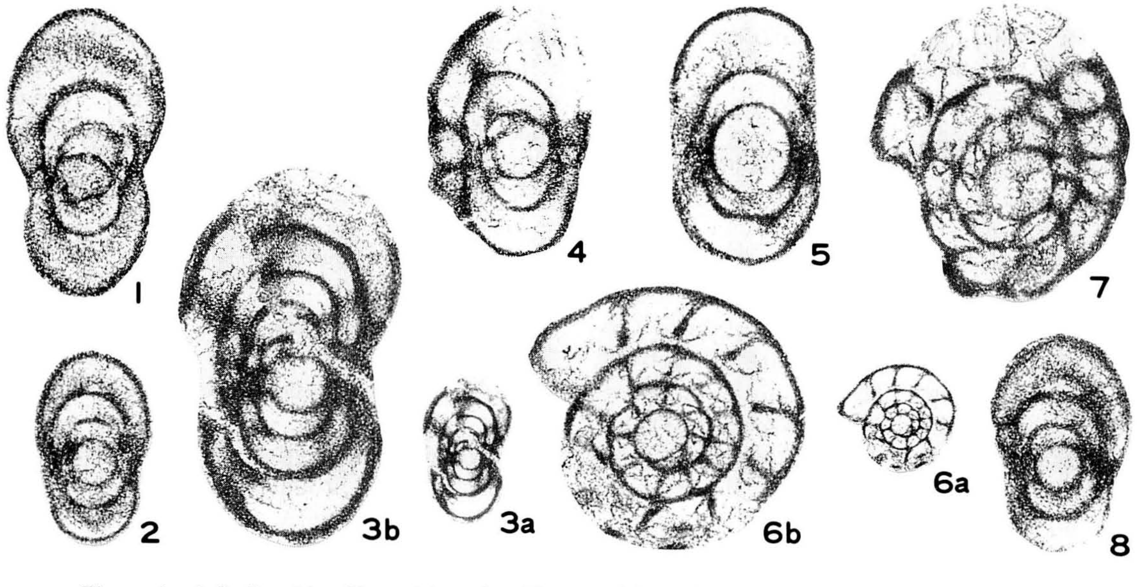


Figure 4. **1-8.** *Pamirina* (*Levenia*) *evoluta* Sheng and Sun, **1-5, 8** : axial sections, KS46-1, NS77-2a, TA116-2, NS77-2b, NS75-1, NS98-2, **6, 7** : sagittal sections, KS79-2, NS100-1. **3a, 6a,** ×40, **1, 2, 3b, 4, 5, 6b-8,** ×100.

Description. — Shell small, involute throughout and thickly lenticular with broadly rounded periphery. Axial regions almost straight to slightly depressed. Mature specimens of 5 volutions 0.31 to 0.43 mm in axial length and 0.69 to 0.895 mm in median width, giving form ratios of 0.40 to 0.57.

Axis of coiling straight throughout but slightly rotated in juvenarium of some specimens. Shell expands gradually through growth. Average radius vectors of the first to fifth volutions for 11 specimens 0.05, 0.09, 0.15, 0.26 and 0.41 mm. Average form ratios of the first to fifth volutions for 9 specimens 0.69, 0.58, 0.51, 0.48 and 0.42, respectively.

Proloculus small and spherical. Its outside diameter ranges from 0.04 to 0.06 mm, averaging 0.05 mm for 11 specimens.

Spirotheca thin and composed of single structureless layer in inner few volutions, and tectum and lower less dense layer (protheca) in outer ones. Average thickness of spirotheca of the first to fifth volutions for 12 specimens 0.006, 0.009, 0.013, 0.016 and 0.017 mm.

Septa straight and plane. Tips of septa swollen in sagittal section. Septal counts of the first to fifth volutions of illustrated specimen (Figure 3-23) 7 ?, 10, 12, 12 and 13. Chomata inconspicuous or rudimentarily developed. Tunnel path low and broad.

Remarks. — The Akiyoshi specimens are quite referable to the original ones described by Kobayashi (1977) in the essential morphological characters, except for having a slightly larger shell in the former.

Sheng and Sun (1975) described *Pamirina pulchra* (Wang and Sun) from the Qinghai district of China. According to their description and illustration, it has a thickly lenticular shell and two layered spirotheca composed of a tectum and lower homogeneous tectorium. This spirothecal structure is identical with that in the subgenus *Levenia* rather than *Pamirina* (s.s.). Judging from the shell shape and spirothecal structure, this species is referable to *Pamirina* (*Levenia*) *leveni* Kobayashi.

Occurrence. — Abundant in the lower and middle parts of the *Pamirina* (*Levenia*) *leveni* Zone.

Pamirina (*Levenia*) *evoluta*
Sheng and Sun, 1975

Figures 4-1 – 8

Pamirina ? *evoluta* Sheng and Sun, 1975, p. 46, pl. 1, fig. 15.

Material studied. — Axial sections; KS46-1 from Loc. KS46, NS75-1 from Loc. NS75, NS77-2a and NS77-2b from Loc. NS77, NS98-2 from Loc. NS98 and TA116-2 from TA116. Sagittal sections; KS79-2 from Loc. KS79 and NS100-1 from Loc. NS100.

Description. — Shell small and thickly lenticular with broadly rounded periphery. Mature specimen having 3 ½ volutions (Figure 4-3) 0.21 mm in axial length and 0.46 mm in median width, giving a form ratio of 0.46. Specimens of 2 ½ volutions 0.13 to 0.19 mm in axial length and 0.225 to 0.38 mm in median width, giving form ratios of 0.41 to 0.58.

Coiling planispiral and involute in inner 2½ volutions but evolute in last one. Shell expands gradually through growth. Radius vectors of the first to third volutions of mature individual 0.08, 0.13 and 0.21 mm, and form ratios 0.69, 0.62 and 0.57, respectively.

Proloculus spherical and large for genus. Its outside diameter ranges from 0.07 to 0.125 mm, averaging 0.09 mm for 9 specimens.

Spirotheca thin and composed of single homogeneous layer in inner volutions, but tectum and thin lower less dense layer (protheca) in outer ones. Thickness of spirotheca of the first to third volutions of typical specimen (Figure 4-3) 0.01, 0.015 and 0.015 mm.

Septa straight and plane. Septal counts of the first and second volutions of specimen illustrated in Figure 4-6 ; 7 and 12. Chomata present but inconspicuous.

Remarks.—This species is characterized by an evolute shell and umbilicated axial regions in the mature stage and larger proloculus for the genus. It was originally decribed by Sheng and Sun (1975) from the Chihsian of the Qinghai district in China. In the Akiyoshi specimens, deep umbilicuses are observed in only one axial section (Figure 4-3). The rest is considered as immature individuals of this species.

Occurrence.—Common in the lower and middle parts of the *Pamirina* (*Levenia*) *leveni* Zone.

Family Verbeekinidae Staff and Wedekind, 1910
Subfamily Misellininae Miklukho-Maklay, 1958
Genus *Misellina* Schenck and Thompson, 1940
Subgenus *Brevaxina* Schenck and Thompson, 1940
Misellina (*Brevaxina*) ? sp.

Figure 3-24

Compare—

Pamirina darvasica Leven, 1970, p. 23-24, pl. 1, figs. 11-12 (not pl. 1, figs. 1-10, 23-24) ; Loeblich and Tappan, 1988, pl. 295, fig. 12 (not pl. 295, fig. 11, same as pl. 1, fig. 11 of Leven, 1970, p. 23-24).

Material studied.—Axial section ; GK6-11 from Loc. GK6.

Description.—Shell small, subspherical with slightly depressed axial regions. Axial length 0.52 mm and median width 0.66 mm, giving a form ratio of 0.79. Shell consists of 5 volutions and inner 1 ½ volutions skew coiled but remains planispirally coiled. Radius vectors of the first to fifth volutions 0.065, 0.11, 0.17, 0.25 and 0.34 mm, and form ratios 0.77, 0.82, 0.71, 0.74 and 0.74, respectively. Proloculus spherical and measures 0.05 mm in outside diameter. Spirotheca thin and composed of single structureless layer in inner 2 volutions, tectum and lower less dense layer (protheca) in the third one, and tectum and fine alveolar keriotheca in outer 2 volutions. Thickness of spirotheca of the first to fifth volutions 0.005, 0.01, 0.02, 0.02 and 0.02 mm. Septa not fluted. Rudimentary parachomata developed in the third and fourth volutions.

Remarks.—General shell shape and the spirothecal structure of the present specimen are similar to those of *Pamirina* (*P.*) *darvasica,* but the presence of rudimentary parachomata in the present specimen indicates the intimate relationship to the subgenus *Brevaxina* of the genus *Misellina.* The present specimen is seemingly intermediate between *Pamirina* and *Brevaxina.* In this paper, it is tentatively assigned to *Brevaxina.*

Leven (1970) illustrated two specimens of *Pamirina darvasica* with rudimentarily developed parachomata in the outer volutions (Leven, 1970, pl. 1, figs. 11-12). The Akiyoshi specimen is quite referable to those Leven's ones.

Occurrence.—Rare in the upper part of the *Pamirina* (*Levenia*) *leveni* Zone and coexisting with *P.* (*P.*) *darvasica.*

Acknowledgments

I would like to express my appreciation to Prof. Sumio Sakagami of Chiba University for reading of the manuscript. Thanks are also extended to Messrs. Akihiro Sugimura and Takehiko Haikawa of Akiyoshi-dai Museum of Natural History for their continuous advice and encouragement, to Mr. Yasuyuki Miyama of Chiba University for the useful discussion on the fusulinacean taxonomy, and to Prof. Hisayoshi Igo of the University of Tsukuba for his kind loan of the necessary literatures.

References cited

Hasegawa, Y., 1958 : Note on the geological structure of the Akiyoshi Plateau, S.W. Honshu. *Earth*

Science (*Chikyu Kagaku*), no. 39, p. 15-18. (*in Japanese with English abstract*)

——, 1963: New find of fossils in the reddish tuffaceous shale in the Akiyoshi Province. *Ibid.*, no. 64, p. 32-36.

Kahler, F. and Kahler, G., 1980: Fusuliniden aus den Kalken der Trogkofel-Schichten der Karnischen Alpen. *In*, Flügel, E. *ed.*, *Die Trogkofel-Stufe im Unterperm der Karnischen Alpen.* Sonderhefte der Carinthia II, 36, p. 183-254, pls. 1-9.

Kanuma, M., 1960: Stratigraphical and paleontological studies of the southern part of the Hida Plateau and north-eastern part of the Mino Mountainland, central Japan, Part 2. Paleontology, No. 4, Ozawainellinae, Schubertellinae, Verbeekininae and Neoschwagerininae. *Bull. Tokyo Gakugei Univ.*, vol. 11, p. 55-73, pls. 10-13.

Kobayashi, F., 1977: Some considerations on the ancestor of the family Verbeekinidae (Fusulinacea). *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 105, p. 1-16, pls. 1-2.

Leven, E. Ya., 1970: O proiskhozhdenii vysshikh fuzulinid [On the origin of the advanced fusulinids]. *Paleont. Zhurnal.*, 1970, no. 3, p. 18-25, pl. 1. (*in Russian*)

Lin, J.X., Li, J.X., Chen, G.X., Zhou, Z.R. and Zhang, B.F., 1977: Fusulinida. *In*, Hubei Inst., Geol. Sci. *et al. eds.*, *Palaeontological Atlas of Central South China,* no. 2 (Late Paleozoic), p. 4-96, pls. 1-30. Geol. Publ. House, Beijing. (*in Chinese*)

Liu, Z.A., Xiao, X.M. and Dong, W.L., 1978: Protozoa. *In*, Working Group of Stratigraphy and Paleontology of Guizhou *ed.*, *Palaeontological Atlas of Southwest China*, Guizhou vol., no. 2 (Carboniferous to Quarternary), p. 12-98, pls. 1-24. *Ibid.* (*in Chinese*)

Loeblich, A.R., Jr. and Tappan, H., 1988: *Foraminiferal genera and their classification.* 970 p., 847 pls. Van Nostrand Reinhold Comp., New York.

Ota, M., 1977: Geological studies of Akiyoshi, Part I. General geology of the Akiyoshi Limestone Group. *Bull. Akiyoshi-dai Mus. Nat. Hist.* , no. 12, p. 1-33, pls. 1-3.

——, Toriyama, R., Sugimura, A. and Haikawa, T., 1973: Restudy on the geologic structure of the Akiyoshi Limestone Group, Southwest Japan. *Jour. Geogr.*, vol. 82, no. 3 (795), p. 115-135. (*in Japanese with English abstract*)

Ozawa, T. and Kobayashi, F., 1985: Stratigraphy and geological structure of the Paleozoic and Mesozoic strata in the southern part of the Kwanto Mountains, central Japan. *Hyogo Univ., Teacher Educ. Jour., Ser. 3* (*Natural Science and Practical Life Studies*), vol. 6, p. 103-141, pl. 1. (*in Japanese with English abstract*)

Ozawa, Y., 1923: Stratigraphical study on the so-called Upper Chichibu Paleozoic System including the Akiyoshi-dai Limestone. *Jour. Geol. Soc. Japan,* vol. 30, no. 357, p. 222-243. (*in Japanese*)

Rozovskaya, S.E., 1975: Sostav, sistema i filogeniya otryada fuzulinida [Composition, phylogeny and system of the order Fusulinida]. *Akad. Nauk SSSR, Trudy Paleont Inst.*, vol. 149, p. 1-267, pls. 1-35. (*in Russian*)

Sakagami, S., 1956: Fusulinids from the limestone conglomerate in the Yagooki valley, Tamanouchi, Hinode-mura, Nishitama-gun, Tokyo-to, Japan. *Trans. Proc. Palaeont. Soc. Japan, N.S.,* no. 24, p. 259-265, pl. 37.

—— and Iwai, J., 1974: Fusulinacean fossils from Thailand, Part VIII. Permian fusulinaceans from the Pha Duk Chik Limestone and in the limestone conglomerate in its environs, North Thailand. *Geol. Palaeont. Southeast Asia,* vol. 14, p. 49-81, pls. 4-9.

Sakaguchi, S., Sugano, K., Nakamura, T. and Kunugi, K., 1966: A study on the biostratigraphy of the Kaerimizu doline, Akiyoshi Limestone Plateau, Yamaguchi Prefecture, Japan. *Mem. Osaka Gakugei Univ., B, Nat. Sci.*, no. 14, p. 220-229. (*in Japanese with English abstract*)

Sheng, J.Z. and Sun, D,D., 1975: *Fusulinids of Qinghai.* 97 p., 14 pls. Geol. Publ. House, Beijing. (*in Chinese*)

——, Zhang, L.X. and Wang, J.H., 1988: *Fusulinida.* 240 p. Sci. Publ. House, Beijing. (*in Chinese*)

Sun, Q.L. and Zhang, L.X., 1988: Early Permian fusulinids from the Kongkashan pass of Xinjiang. *Acta Micropalaeont. Sinica,* vol. 5, no. 4, p. 367-378, pls. 1-4. (*in Chinese with English abstract*)

Sun, X.F., Gao, C.X. and Zhang, X.L., 1983: Fusulinida. *In*, Xi'an Inst., Geol. Mineral Resour. *ed.*, *Paleontological Atlas of Northwest China,* Shaanxi, Gansu and Ningxia vol., Part 2 (Upper Palaeozoic), p. 3-40, pls. 1-10. Geol. Publ. House, Beijing. (*in Chinese*)

Suyari, K., 1962: Geological and paleontological studies in central and eastern Shikoku, Japan, Part 2. Paleontology. *Jour. Gakugei, Tokushima Univ.*, vol. 12, p. 1-63, pls. 1-12.

Takaoka, Y., 1966: Fusulinid from the Mt. Tatoro, Mt. Kano, Mt. Futago and Mt. Shiraishi areas of the Kwanto-massif, central Japan. *Bull. Chichibu Mus., Nat. Hist.*, no. 13, p. 39-70, pls. 5-16. (*in Japanese with English description of species*)

Toriyama, R., 1954: Geology of Akiyoshi, Part I.

Study of the Akiyoshi Limestone Group. *Mem. Fac. Sci., Kyushu Univ., Ser. D, Geol.*, vol. 4, no. 1, p. 39-97.

——, 1958: Geology of Akiyoshi, Part 3. Fusulinids of Akiyoshi. *Ibid.*, vol. 7, p. 1-264, pls. 1-48.

Wang, K.L. and Sun, X.F., 1973: Carboniferous and Permian foraminifera of the Chinling Range and its geologic significance. *Acta Geol. Sinica,* 1973, no. 2, p. 137-178, pls. 1-7. (*in Chinese with English abstract and description of new species*)

Zhou. T.M., Sheng, J.Z. and Wang, Y.J., 1987: Carboniferous-Permian boundary beds and fusulinid zones at Xiaodushan, Guangnan, eastern Yunnan. *Acta Micropalaeont. Sinica,* vol. 4, no. 2, p. 123-160, pls. 1-6.

Akiyoshi 秋吉, Chinling 秦嶺, Guangxi 広西, Guizhou 貴州, Itsukaichi 五日市, Kaerimizu 帰り水, Kochi 高知, Kwanto 関東, Mino 美濃, Otaki 大滝, Qinghai 青海, Shomaru 正丸, Yunnan 雲南, Xinjiang 新疆.

秋吉石灰岩層群からの二畳紀紡錘虫類 *Pamirina*: 二畳紀中期に繁栄した Verbeekinidae 科および Neoschwagerinidae 科紡錘虫類の直系の祖先とされている *Pamirina* 属には外部旋回壁に fine alveolar keriotheca を持つグループと持たないグループが知られており，後者の方がより原始的であると考えられている。筆者は秋吉台，帰り水地域の秋吉石灰岩層群より3種の *Pamirina* を検出しその産出層準を検討したところ，fine alveolar keriotheca を持つグループの方が持たないグループより明らかに上位の層準から産出することを確認した。この結果は，Kobayashi (1977) が考察した *Pamirina* の系統と一致しており，外部旋回壁に fine alveolar keriotheca を持たないグループに対して新亜属 *Levenia* を提唱する。さらに本論では秋吉石灰岩層群の *Pamirina* (*Levenia*) *leveni* 帯から得られた *Pamirina* (*P.*) *darvasica*, *P.* (*Levenia*) *leveni*, *P.* (*L.*) *evoluta, Misellina* (*Brevaxina*) ? sp. を記載する。これらの紡錘虫類は前期二畳紀の後期 Artinskian あるいは後期 Yakhtashian を示す。

上野勝美

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 161, pp. 751-755, 3 Figs., April 30, 1991

SHORT NOTES

25. A NEW SPECIES OF *PETALAXIS* (RUGOSA) FROM THE HUANGLONG FORMATION, ZHEJIANG, SOUTHEAST CHINA*

NOBUO YAMAGIWA

Department of Earth Science, Faculty of Education,
Osaka Kyoiku University, Osaka 543

ANDE WANG

Department of Geology, Zhejiang University,
Hangzhou 310027, China

and

SHIRO MAEDA

c/o Department of Earth Sciences, Faculty of Science,
Chiba University, Chiba 260

A new rugose coral species, *Petalaxis hangzhouensis* is described in this paper. We collected the present specimen from a limestone bed, exposed along the Manjuelong Highway near Longjing-Wengjiashan, Hangzhou City, Zhejiang Province, Southeast China (Figure 1). According to Wang, Lin, Luo and Chen (1987), this bed, 0.88 m thick, consists of sparry echinoderm and micritic limestone with bioclasts, and is the third higher bed from the base of the Upper Huanglong Formation, which is assigned to the Weiningian Stage (Moscovian), Middle Carboniferous. Besides the present new species of coral, this limestone yields *Fusulinella mosguensis* Rauser and Safonova, *F.* sp., *Eofusulina* sp., *Textularia* sp., *Nodosaria* sp., *Uraloporella* sp., and *Anthracoporella* sp.

Acknowledgments : We thank to Dr. Guowei Lin (Zhejiang Institute of Petroleum Geology), Messrs. Hending Wang and Yanshao Chen (Zhejiang University) for their kind advice and suggestion in the field survey. We acknowledge Prof. Hideo Ishikawa (Chiba University), Messrs. Ushio Fujimoto, Tadashi Endo, Hideo Shimizu and Michiji Goto for their assistance in the field. We also thank Dr. Yoichi Ezaki (Osaka City University) for his discussion, and Prof. Hisayoshi Igo (University of Tsukuba) and

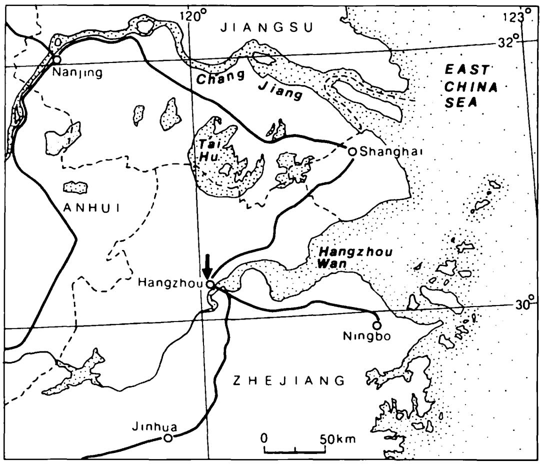


Figure 1. Map showing the location of Hangzhou City (arrrow).

---

*Received October 3, 1989 ; revised manuscript accepted January 10, 1991

Prof. Toshio Koike (Yokohama National University) for their offer of references.

Description of species

Family Petalaxidae Fomichev, 1953
Genus *Petalaxis* Milne-Edwards and Haime, 1852

Petalaxis hangzhouensis Yamagiwa, Wang and Maeda, n. sp.

Figures 2-1–2; 3-1–2

Diagnosis.—Small *Petalaxis* with thin columella, lonsdaleoid and concentric dissepiments and relatively long minor septa. Tabulae slope gently upwards to center.

Description.—A single corallum obtained. Corallum compound, massive, cerioid and attains 8 cm in diameter.

Transverse section: Corallites polygonal, five to six sided and 3.0 to 5.0 mm in diameter in mature stage. Wall thick and rather regularly zig-zagged; median dark line present. Septa of two orders, major and minor in alternation, thin and straight or slightly sinuous. Septal spines on the wall always correspond to major and minor septa in disposition. Fine structure of septa is diffuso-trabecular to fibro-normal. Major septa are 11 to 13 in number, long and often attain to center of corallite. One of them is continuous with columella. Minor septa are relatively long, ranging from 1/2 to 4/5 length of major ones in mature stage. Dissepimentarium relatively wide and consists of one to two rows of lonsdaleoid dissepiments of varying size and one to two or three rows of concentric ones. Besides, several rows of lonsdaleoid dissepiments rarely observable. Tabularium wide and clearly differentiated from dissepimentarium by inner wall. Columella consists of a thin axial plate and straight or slightly sinuous.

Longitudinal section: Dissepimentarium occupies less than 1/2 to 1/3 radius of corallite and consists of large, medium and occasionally small vesicles of dissepiments. Dissepiments generally arranged in one row, but occasionally in a few rows. Their convex sides facing upwards as well as inwards. Wide tabularium consists of complete or incomplete tabulae, which gently ascending towards the center. Clinotabellae occasionally present. Two to four tabulae are counted in a vertical distance of 1 mm. Columella thin, straight or slightly sinuous.

Comparison.—The present new species resembles *Petalaxis orboensis* (de Groot), which was described from the Upper Moscovian Orbo Limestone, northern Palencia, Spain in having a thin columella, similar character of dissepiments, relatively long minor septa, and gently ascending tabulae. The former, however, differs from the latter in having smaller corallites and less numerous septa.

Fan (1978) also described *Petalaxis orboensis* (as *Lithostrotionella orboensis*) from the Weiningian of Sichuan Province, southwestern China. The present new species is similar to Fan's specimen, but the former differs from the latter in having smaller corallites, less numerous septa, some well-developed lonsdaleoid dissepiments and a more simple columella. Wu and Zhao (1989) also reported *Petalaxis orboensis* from the Weiningian of eastern Yunnan. The present our species is easily distinguished from the latter by the above mentioned character.

This new species is similar to *P. mohikanus* (Fomichev) described from the Moscovian of the Donetz Basin, but the present species has smaller corallites, less numerous septa and a more simple columella. It is also distinguished from *P. stylaxis* (Trautschold) reported from the Middle Carboniferous of the Moscow Basin and other areas (Stuckenberg, 1888; Dobrolyubova, 1935a,b; Fomichev, 1939; Sando, 1983, Wu and Zhao, 1974; Wang, 1978) by lack of complex columella and having more weakly developed lons-

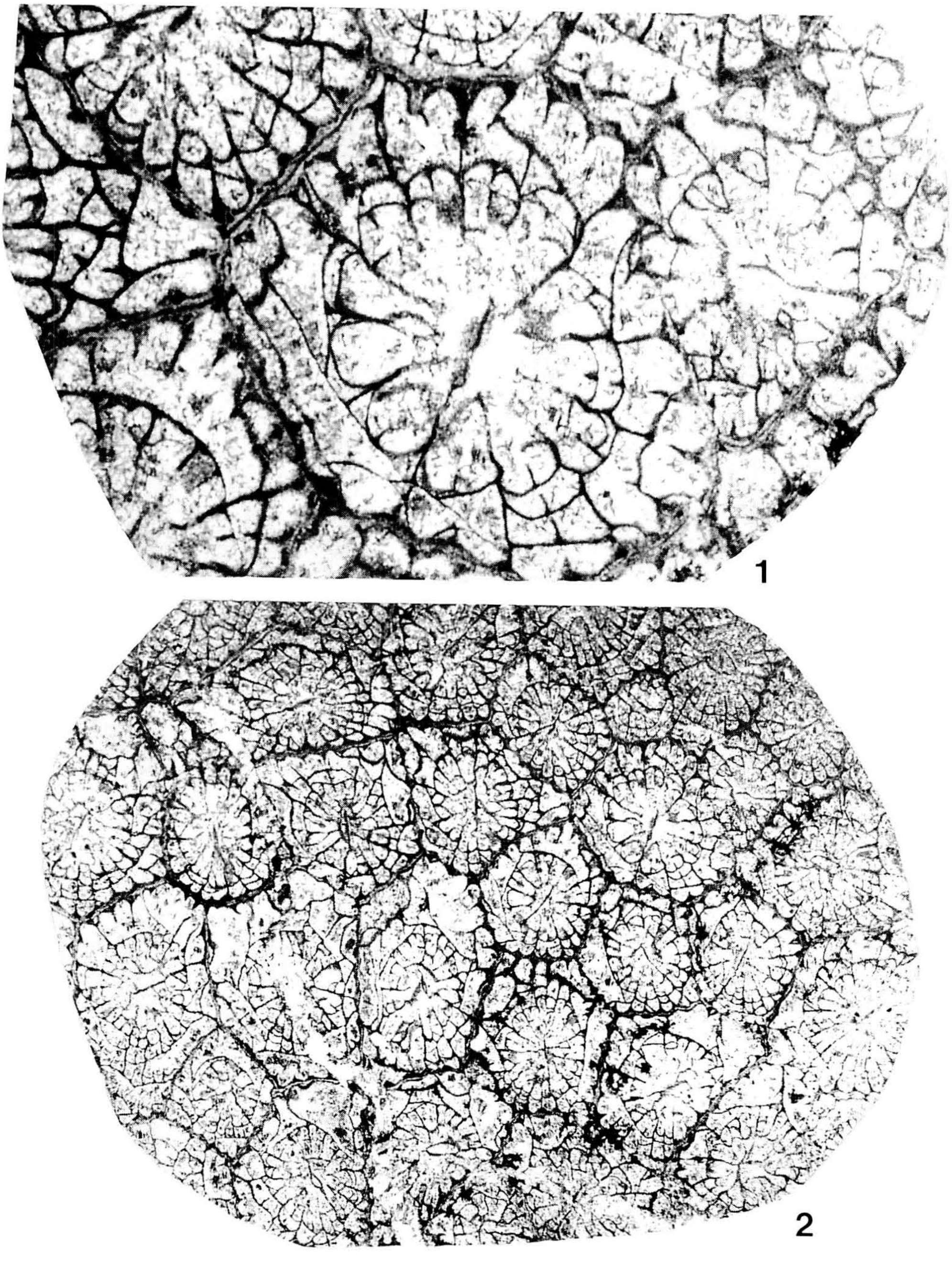


Figure 2. *Petalaxis hangzhouensis* Yamagiwa, Wang and Maeda, n. sp. **1, 2,** Transverse sections, ×14, ×5, respectively (Reg. no. CF-8701a).

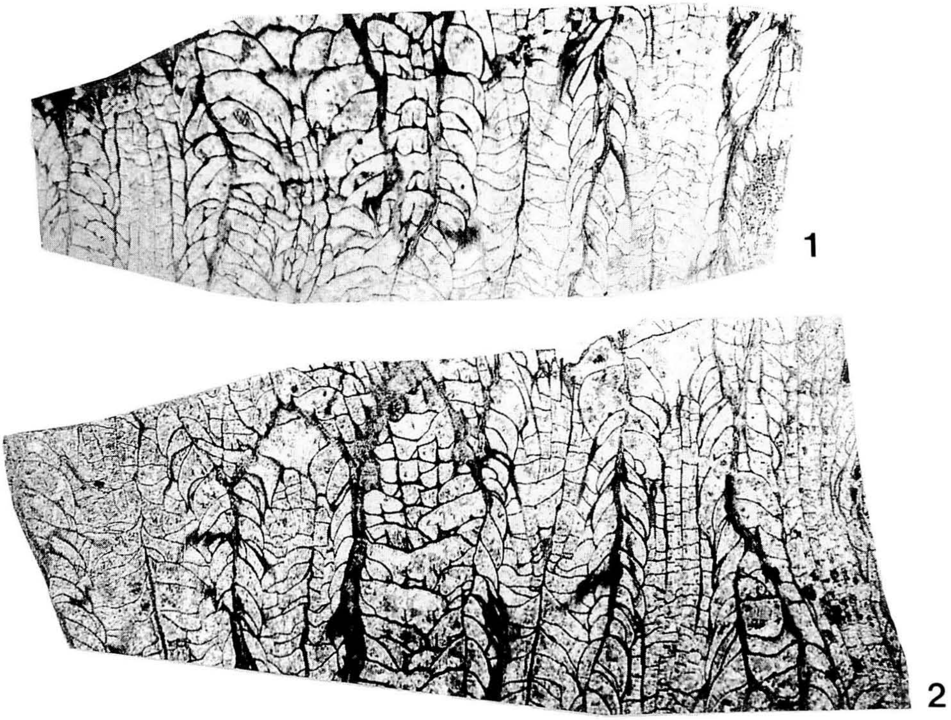


Figure 3. *Petalaxis hangzhouensis* Yamagiwa, Wang and Maeda, n. sp. **1, 2,** Longitudinal sections, ×5 (Reg. nos. CF-8701c, 8701d, respectively).

daleoid dissepiments and gently ascending tabulae towards the center.

Etymology.—This species is named for Hangzhou City.

Occurrence.—Near the base of the Upper Huanglong Formation exposed along the Manjuelong Highway, Hangzhou City, Zhejiang Province, China.

Geological age.—Weiningian (Moscovian), Middle Carboniferous.

Repository.—Reg. no. CF-8701 (Holotype), housed at the Department of Geology, Zhejiang University, China.

References cited

Dobrolyubova, T.H., 1935a : Determinant of Middle Carboniferous colonial Rugose corals of the Moscow Basin. *Vses. Naucho-Issled. Inst. Mineral. Syrya*, p. 1-14. (*in Russian*)

——, 1935b : Rugosa colonial corals in the Middle Carboniferous of the Moscow Basin. *Ibid., Trudy*, no. 81, p. 1-50, pls. 1-14. (*in Russian with English summary*)

Fan, Y.N., 1978 : Rugosa. p. 149-207, pls. 50-76. *In, Paleontological Atlas of southwestern China, Sichuan Province*, vol. 2, Geological Press, Beijing. (*in Chinese*)

Fomichev, V.D., 1939 : Phylum Coelenterata. p. 50-64, pls. 6-11. *In*, Gorskiy, I.I., *ed., Atlas of the leading forms of the fossil faunas of the USSR.*, vol. 5, *Middle and Upper Carboniferous. TSNIGRI*, Leningrad. (*in Russian*)

——, 1953 : Rugose corals and stratigraphy of Middle and Upper Carboniferous and Permian deposits of the Donetz Basin. *VSEGEI, Tr.*, p. 1-622, atlas, pls. 1-64. (*in Russian*)

Groot, G.E., de, 1963 : Rugose corals from the Carboniferous of northern Palencia (Spain). *Leidse Geol. Meded.*, vol. 29, p. 1-123, pls. 1-26.

Sando, W.J., 1983 : Revision of *Lithostrotionella* (Coelenterata, Rugosa) from the Carboniferous and Permian. *U.S. Geol. Surv., Prof. Paper* 1247, p. 1-52, pls. 1-20.

Stuckenberg, A.A., 1888 : Anthozoen und Bryozoen des oberen mitterlrussischen Kohlenkalks. *Russian Mem. Com. Geol.*, vol. 4, p. 1-54, pls. 1-4.

(*in Russian with German summary*)

Wang, H.D., 1978: Tetracoralla. p. 106-189, pls. 29-61. *In, Paleontological atlas of southwestern China, Guizho Province, vol. 2, Carboniferous – Quaternary*. Geological Press (Beijing). (*in Chinese*)

Wang, Y., Lin, G., Luo, Z., and Chen, X., 1987: Hangzhou district. p. 24-30. *In, Carboniferous and Permian stratigraphy in Jiangsu and Zhejiang. Guide Book for Excursion 8* (*11th International of Carboniferous Stratigraphy and Geology*).

Wu, W.S. and Zhao, J.M., 1974: Carboniferous corals. p. 265-273, pls. 134-139. *In, Handbook of the stratigraphy and paleontology of southwest China*. Nanjing Inst. Geol. Pal., Acad. Sinica. (*in Chinese*)

—— and ——, 1989: Carboniferous and early Early Permian Rugosa from western Guizhou and eastern Yunnan, SW. China. *Pal. Sinica*, no. 177, p. 1-230, pls. 1-63. (*in Chinese with English summary*)

PROCEEDINGS OF THE PALAEONTOLOGICAL SOCIETY OF JAPAN

日本古生物学会　1991年年会・総会

日本古生物学会年会・総会が1991年1月31日～2月2日に東北大学理学部で開催された (参加者198人).

シンポジウム

古生物学の課題と展望 —21世紀に向けて— (古生物学研究連絡委員会と共催)
……世話人: 森　啓・池谷仙之・大野照文
シンポジウム開催にあたって……森　啓
Biochronologyの展望……丸山俊明
コメント (1)……斎藤常正
コメント (2)……八尾　昭
古生物情報を利用した地球環境の解析……近藤康生
コメント (1)……大野照文
コメント (2)……大場忠道
化石記録から見た大量絶滅……海保邦夫
コメント……平野弘道
形態レベルの進化と分子レベルの進化……千葉　聡
コメント……棚部一成
古生物学に何を望むか……河田雅圭
コメント (1)「自律性と進化のための理論生物学」……郡司幸夫
コメント (2)「飼育実験の重要性」……北里　洋
21世紀にむけての古生物学
無侵襲計測による化石形態情報取得と3D映像研究……濱田隆士・鈴木直樹・舘野聡子
21世紀までの10年間, 古生物学者は何をすべきか……氏家　宏
シンポジウムの総括……池谷仙之

総　会

国際学術集会報告

第3回テチス国際会議 (仙台: 1990年9月20日～23日)……森　啓
第4回ベントス国際会議 (仙台: 1990年9月28日～10月2日)……高柳洋吉

特 別 講 演

現生および第四紀渦鞭毛藻シスト研究 — 現状と展望 —……松岡數充
中生代アンモナイト類の進化古生物学的研究…平野弘道

会 長 講 演

進化古生物学の素材としてのイタヤガイ類……速水　格

個 人 講 演

北海道における *Umbonium akitanum* の時空分布について……赤松守雄・鈴木明彦
北海道歌登町中新統タチカラウシナイ層の貝類化石群 — その古環境と地史的意義 —……小笠原憲四郎
秋田県出羽丘陵の須郷田層貝化石群集……佐々木拓真
通山浜層の貝類群集の分布と変遷……中尾賢一
新潟県東頸城郡松代町の鮮新世貝化石群集……天野和孝・菅野三郎
貝殻拡散における“ゆらぎ”のタホノミー的意義……下山正一
貝化石群集に基づく下総層群中部層の古環境解析……佐藤慎一・下山正一
シラスナガイ科二枚貝の幼生形態: フネガイ目における幼形進化的傾向とそれに伴う繁殖生態の調整の証拠……松居誠一郎・仲岡雅裕
上総層群中部における環境勾配に沿ったオオシラスナガイ属の分布, 及び成長様式の変化 (予報)……松居誠一郎・磯　政道・浜野聖一
Phanerolepida pseudotransenna Ozakiの種内変異と異時性……間嶋隆一・村田昭浩
Rhizonolenia norwegica Schraderおよび *Rh. praebarboi* Schr. は珪藻でなく黄色鞭毛藻である……小村精一
北海道夕張地域, 幌内層・紅葉山層の渦鞭毛藻化石群集……栗田裕司・松岡數充
北海道大夕張 — 穂別地域の上部白亜系の岩相層序と浮遊性有孔虫生層序……長谷川卓・本山　功・藤原　治・海保邦夫
北海道大夕張・穂別地域のエゾ層群から産出する石灰質ナノ化石…室田　隆・長谷川卓・本山　功・藤原　治
上部白亜系セノマニアン階のイノセラムス化石分帯について……浅井明人
ソビエト連邦サハリン州ナイバ川 (=内淵川) 流域の上部白亜系層序と化石群の概要……前田晴良・重田康成・加瀬友喜

北海道における白亜系セノマニアン・チュロニアン両階境界について……………………松本達郎・米谷盛寿郎

北海道白亜系チュロニアン・コニアシアン境界上下の生層序……………………………松本達郎・米谷盛寿郎

白亜紀テトラゴニテス科アンモナイトの初期生活史……………………………………………………重田康成

上部蝦夷層群より産する *Sphenoceramus naumanni* (Yokoyama)について ……………………植松伴三郎

古環境復元の鍵としてノジュールの形成過程：北海道上部蝦夷層群下部泥岩相中の大型イノセラムスを含む菱鉄鉱ノジュール…………………………………早川浩司

サンゴ礁生態系における物質生産 (I) — 沖縄県白保における生態学的見積…阿部 理・中森 亨・井龍康文

サンゴ礁生態系における物質生産 (II) — 溶存成分測定によるアプローチ……鈴木 淳・中森 亨・芽根 創

サンゴ礁生態系における物質生産 (III) — 光合成と石灰化の共存モデル……中森 亨・鈴木 淳・阿部 理

スウェーデン，ゴトランド島の上部シルル系層孔虫の成長様式および群集と古環境の関係……………狩野彰宏

無節サンゴモの自己修復 — 実験 — ……………井龍康文・松田伸也・中村隆志・郡司幸夫

無節サンゴモの自己修復 — モデル — ……………中村隆志・郡司幸夫・井龍康文・松田伸也

有柄ウミユリ *Metacrinus rotundus* Carpenter の飼育実験，再生現象，および茎の機能的・タフォノミー上の意義…………………………………大路樹生・雨宮昭南

実験的方法による底生有孔虫類の殻形態の評価 — 溶存酸素量をコントロールした実験 — ………………………北里 洋・Christoph Hemleben

古生物学が形態進化論構築に参画するために…森田利仁

自己発生境界システム (1)：内因/外因の相克を越えて…………………………郡司幸夫・今野紀雄・中村隆志

フーリエ記述子による個体群変異の定量的表現……………………………………………佐々木理・小浜耕治

房総半島の下部鮮新統千畑層より産出したアシカ科鰭脚類の意義……………………………甲能直樹・井上浩吉

青森県岩木山麓から産出したザトウクジラ属化石と東北日本中新—鮮新世のナガスクジラ科化石について……………………………………………大石雅之・佐藤 功

"ニッポンキリン *Giraffa* (*Orasius*?) *nipponica* Matumoto" の検討 ……………………………………大塚裕之

奄美諸島徳之島より初のアマミノクロウサギ及びネズミ科齧歯類化石の発見………………冨田幸光・大塚裕之

北九州市産出前期白亜紀のオステオグロッサム目等魚類化石群の発見…………籔本美孝・青木建論・佐藤政弘

新たに発見されたメタスクアロドン頭骨………岡崎美彦

山中湖湖底堆積物の花粉分析に基づく完新世後半の植生変遷史とその意義……………池田光理・小杉正人・田場 穣・遠藤邦彦

ベネチテス目植物の花形態 (I) 胚珠及び合着子嚢の構造と進化…………………………………………………西田治文

現生および化石の雌性球果に基づくスギ科の系統分類………………………………………………………斎木健一

山口県第四系地福層産針葉樹類……………………………………内藤源太朗・宇多村卓光

山口県小郡町西部に露出する脇野亜層群相当層から *Cupressinocladus* sp. の産出とその植物地理学的意義…………………………大村達明・大花民子・内藤源太朗

内湾域における介形虫の環境指標種群の設定 — その古生態上の意義 — ……佐藤直弘・小杉正人・塚越 哲

東京湾東岸，小櫃川河口干潟における有孔虫生産の季節変動 — 環境指標種群の基礎的研究 — ………………………片岡久子・小杉正人・長谷川四郎

複数化石群 (貝・介形虫・有孔虫・珪藻) による海域の古生態系復元のための基礎的研究 — 分布の重複関係の検討 — ………………小杉正人・佐藤直弘・片岡久子

Spinileberis 属 (介形虫類) の棲み分けと種間関係…………………………志村神奈・池谷仙之・岩崎泰頴

浜名湖における底生有孔虫 *Ammonia beccarii* (Linne) の経年変化……………………………………小汐真由美

底生有孔虫 *Trochammina hadai* Uchio の生活史………………………………………………………松下 訓

Microforaminiferal linings and their potential paleoenvironmental significance, with an example from the Holocene sediments off northern Kyushu…………………Stancliffe, R.P.W. and Matsuoka, K.

サンゴ礁域の底生有孔虫 Soritinae 亜科の分類について……………………………………………………小林万里子

底生有孔虫 *Articulina tubulosa* の形態変異 — 地中海の深海環境の形成と関連して — ……………………………………長谷川四郎・根本直樹

発生過程における貝形虫殻の形態変化解析 — *Baffinicythere, Elofsonella* 属を例として — ………………………………………入月俊明・佐々木理

オスタラコーダ *Schizocythere* 属と *Cythere* 属の系統関係と地理的分布………………………………塚越 哲

介形虫 *Xestoleberis hanaii* Ishizaki における殻構造の個体発生変化…………………………………湯本道明

広原市宮内町貝石谷地区の中新世備北層群からの貝化石群集…………………………………………………岡本和夫

掛川層群産 *Siphonalia* の分類学的再検討 ……水野淳一

Calyptogena nipponica Oinomikado & Kanehara, 1938 について…………………………菅野三郎・天野和孝

同一殻層に共存する Shell microstructure とその意義—

Veneridae (マルスダレガイ科；二枚貝) の種属について一 ……………………………………島本昌憲

秋吉石灰岩層群より産する *Palaeoaplysina* について ……………………………………町山栄章

カンボジア西部のペルム系から産出した *Euryphyllum* 属 (Rugosa) について ………鎌田友紀子・加藤　誠

岐阜県郡上郡八幡町安久田産前期ペルム紀石灰藻類 ……………………………………猪郷久治

中琉球弧伊平屋帯におけるペルム紀～ジュラ紀放散虫化石の産出と地質構造……………………氏家　宏

北上山地の鳶ヶ森層からの後期デボン紀および前期石炭紀アンモナイト……………………永広昌之・高泉幸浩

宮城県牡鹿町網地島産前期白亜紀エビ化石…小関　攻・濱田隆士・花松俊一・小出　精・鈴木雄太郎

熱水噴出孔周辺からの原始的なフジツボ類……山口寿之

現生オウムガイ (*Nautilus belauensis*) の胚発達様式：その発生学的ならびに古生物学的意義 ……………棚部一成・塚原潤三・福田芳生・田谷雄三

白亜紀中期二枚貝 *Didymotis akamatsui* の系統分類学的位置……………………………………安藤寿男

北海道上部白亜系産 *Inoceramus* (*Platyceramus*) の2種について……………………………野田雅之・内田繁比郎

北海道上部白亜系産 *Inoceramus* (*Cordiceramus*) の2種について……………………………野田雅之・利光誠一

香川県財田町の和泉層群から産出したイノセラムス ……………………………利光誠一・山崎啓司・田代正之

九州の秩父帯下部白亜系より産する腹足類化石 ……………………………………黒沢範一

生痕化石 *Zoophycos* をつくる生物の棲息密度および年齢構成……………………………………小竹信宏

宮古層群よりサンゴと厚歯二枚貝の構成するビルドアップの発見……………………………………佐野晋一

日本海溝 JT-03・04・05 からの浮遊性有孔虫群集 (予報) ……………………………………尾田太良

三浦半島津久井累層産単体サンゴの ^{230}Th/^{234}U 年代 ……………………………大村明雄・小林由幸・澤　祥

東インド洋における暁新世と下部始新世の底生有孔虫群集と安定同位体比の変化 ……………………………瀬戸浩二・野村律夫・新妻信明

熱帯インド洋での第四紀後期の環境変化に対応した石灰質ナノ化石群集……………………松岡真理子・岡田尚武

微化石群集による房総半島三浦層群天津層上部の堆積環境の推定……………………………内田英一・尾田太良

男鹿半島西黒沢層の中期中新世底生有孔虫群集 ……………………………………的場保望・深沢和恵

北・西部九州の古第三系から産出する石灰質ナノ化石と生層序……………………………………岡田尚武

ポスターセッション

オストラコーダの行動様式 (VTR 使用) ……………………………阿部勝巳・塩崎正道・池谷仙之

夜間小集会

エゾ層群フィールド情報交換会 ……………………………世話人　室田　隆・長谷川卓

自律性/プログラム不可能性と進化 …世話人：井龍康文・中村隆志・佐々木理・郡司幸夫

New members approved at the Council Meeting on January 30, 1991

Akihisa Kitamura,
Hisashi Suzuki,
Mitsuru Marukawa,
Norie Tanaka,
Kazuhiro Nakamura,
Takashi Nakamura,
Hideshi Wakabayashi,
Naoki Suzuki,
Takayoshi Fukudomi,
Shigenori Ogihara,
Saneatsu Saito,
Kiyohiro Kakusaka,
Kazuo Nagasawa,
Hiroshi Takahashi,
Masamichi Yamazaki,
Takuya Tanikawa,
Naohiro Sato,
Satoko Tateno,
Yasuto Ariga,
Kenichi Takahashi.
Mariko Miuchi,
Keiichi Takahashi,
Tomio Adachi,
Shigeo Shinozaki
Tetsuya Shimazaki
Pothuri Divakar Naidu,
Isao Sarashiya,
Ayahide Kamemaru,
Satoshi Funakawa,

New fellows approved

Masayuki Ehiro, Hiroshi Furutani, Ken-ichiro Hisada,
Norihisa Inuzuka, Hiroaki Ishiga, Takahiro Kamiya,
Atsushi Kaneko, Masanori Shimamoto, Hirokazu Takahashi,
Atsushi Takemura.

Seceding members

(Fellow)
Takehiko Iwai.

(Ordinary members)
Ryuichi Arikawa, Fumitoshi Kojima, Keiji Matsubara,
Rie Tajiri, Yataro Yamada.

Deceased member

(Fellow)
Akira Morishita.

日本古生物学会特別号の原稿募集

PALAEONTOLOGICAL SOCIETY OF JAPAN, SPECIAL PAPERS, NUMBER 34の原稿を公募します。本会会員で適当な原稿をお持ちの方は，日本古生物学会特別号投稿規定（1988年1月27日制定，化石44号69頁参照）を熟読の上，原稿及び同コピーその他必要書類をそえて，下記宛に申し込んでください。

申し込み先：〒812 福岡市東区箱崎6-10-1
九州大学理学部地球惑星科学教室気付
日本古生物学会特別号編集委員会
(代表者　柳田　壽一)
申し込み及び原稿提出締切：1991年9月30日

採否は編集委員会が必要に応じレフェリーと相談の上内定し，1992年1月または6月の評議員会で審議決定の上，申込者に回答の予定です。ただしその前または後に，申込者との細部の交渉を編集委員から求めることがあるかもしれません。

なお他からの印刷経費支出の見込みがない場合は，文部省刊行助成金（研究成果刊行費補助金）を申請します。この申請は編集委員が行い（例年は12月上旬に申請締切），その採否・金額など決定後印刷にとりかかります。ただし，現在32号及び33号の刊行助成金を申請中であり，その結果次第では34号の助成金申請の時期を繰り延べることがあるかもしれません。

行事予定

◎1991年例会（第140回例会）は6月22日，23日に千葉県立中央博物館で開催されます。講演申込は4月30日（必着）締切です。講演申込の方法が変更になっています。詳しくは「化石」48号をご覧下さい。

◎1992年年会・総会は九州大学理学部で開催の予定となっております。

申込先：
〒422　静岡県静岡市大谷836　静岡大学理学部地球科学教室　☎054（237）1111
Fax. 054（238）0491
池谷仙之（内線5801）北里　洋（内線5810）　（行事係）

なお本号は編集業務移行のため旧編集委員長・編集委員会で編集されました。

本誌の発行に要する費用は会員の会費以外に文部省科学研究費補助金ならびに賛助会員からの会費が当てられています。現在の賛助会員は下記の通りです。

インドネシア石油株式会社　関東天然ガス株式会社　北九州市立自然史博物館
石油資源開発株式会社　ダイヤコンサルタント　帝国石油株式会社
日本石油開発株式会社　三井石油開発株式会社（アイウエオ順）

○文部省科学研究費補助金（研究成果公開促進費）による。

1991年4月25日　印刷
1991年4月30日　発行
ISSN　0031-0204
日本古生物学会報告・紀事
新篇161号
2,500円

発行者　日本古生物学会
〒113　東京都文京区弥生2-4-16
日本学会事務センター内
電話　03－3817－5801
編集者　斎藤常正・森　啓
編集幹事　島本昌憲
印刷者　仙台市若林区六丁の目西町8-45
笹氣出版印刷株式会社　笹氣幸緒
本社 022-288-5555 東京 3455-4415

Transactions and Proceedings of the Palaeontological Society of Japan

New Series No. 161 April 30, 1991

CONTENTS

TRANSACTIONS

SHORT NOTES