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. 168

日 本 古 生 物 学 会

Palaeontological Society of Japan

December 30, 1992

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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), length about 18.5 cm)

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Trans. Proc. Palaeont. Soc. Japan, N.S., No. 168, pp. 1265-1295, 12 Figs., December 30, 1992

944. PERMIAN FORAMINIFERS FROM THE TAKAKURAYAMA GROUP OF THE SOUTHERN ABUKUMA MOUNTAINS, NORTHEAST JAPAN*

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Abstract. Permian foraminifers are abundantly discriminated from the limestone pebbles and matrix of the conglomerate member in the Motomura Formation of the Takakurayama Group distributed in the southern Abukuma Mountains. Based on microfacies and fossil contents, these limestone pebbles are classified into five types, denoted Types Ia, Ib, Ic, IIa and IIb. Type I pebbles contain *Toriyamaia laxiseptata* Kanmera, *Minojapanella* (*M.*) *elongata* Fujimoto and Kanuma, *Chalaroschwagerina vulgaris* (Schellwien), *Pseudofusulina fusiformis* (Schellwien), and *Misellina (Brevaxina)* sp., and are considered to be of Yakhtashian to early Bolorian age. Type IIa pebbles yield *Yangchenia* cf. *iniqua* Lee, *Pseudodoliolina* cf. *ozawai* Yabe and Hanzawa, and *P.* aff. *pseudolepida* (Deprat), and are surely referable to an early Murgabian age. Type IIb pebbles contain *Wutuella* cf. *wutuensis* (Kuo), *Minojapanella (M.) parva* Sheng, and *Lantschichites* ? sp., and are considered to be of late Murgabian age. *Colania* sp., indicative of a late Murgabian age, occurs in the matrix of the conglomerate. Fusulinaceans in the Type IIb pebbles and matrix indicate a geologic age of, at least, the Motomura Formation. Judging from stratigraphic and paleontologic evidence in the Iriishikura and Kashiwadaira Formations, the Takakurayama Group, as a whole, seems to be correlated with the late Middle Permian (late Murgabian). In this paper, 19 species of foraminifers including one new genus, *Quasireichelina*, and four new species, *Codonofusiella abukumaensis, Dunbarula planata, Quasireichelina expansa,* and *Neodiscus mirabilis,* are described.

Key words. Abukuma Mountains, limestone pebble, Motomura Formation, Murgabian, Permian foraminifer, Takakurayama Group.

Introduction

In the Abukuma Mountains of northeast Japan, paleontologic information concerning fusulinaceans is still poor as compared with the Kitakami Mountains. In this region, the Permian fusulinaceans have been reported only from the Uwano and Oashi Formations in the Soma area and the Motomura Formation in the Takakurayama area (Toriyama, 1967).

The Takakurayama area is about 10 km north of Taira (Figure 1). Yanagisawa (1967) and O'hara *et al.* (1976) reported Early Permian fusulinaceans, which are very close to those known in the Sakamotozawa Formation of the Southern Kitakami Mountains. However, the evidence they provide is too poor to discuss the geologic age of the Takakurayama Group, because they were all obtained from the limestone pebbles of the conglomerate member in the Motomura Formation.

During the course of my graduation study on the geology and paleontology of the Takakurayama-Yaguki area, I obtained rich materials of Early and Middle Permian foraminifers from the limestone pebbles and

*Received September 30, 1991; accepted August 17, 1992

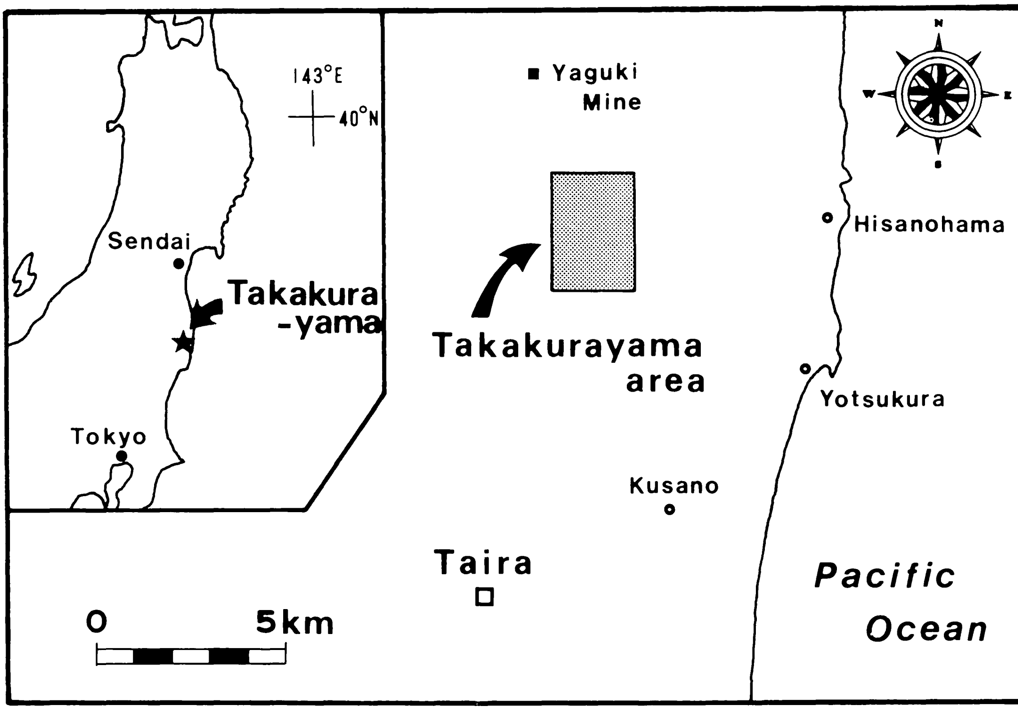


Figure 1. Index map of the Takakurayama area.

matrix of the conglomerate member in the Motomura Formation of the Takakurayama Group. I list and illustrate these foraminifers herein with the description of some interesting foraminifers.

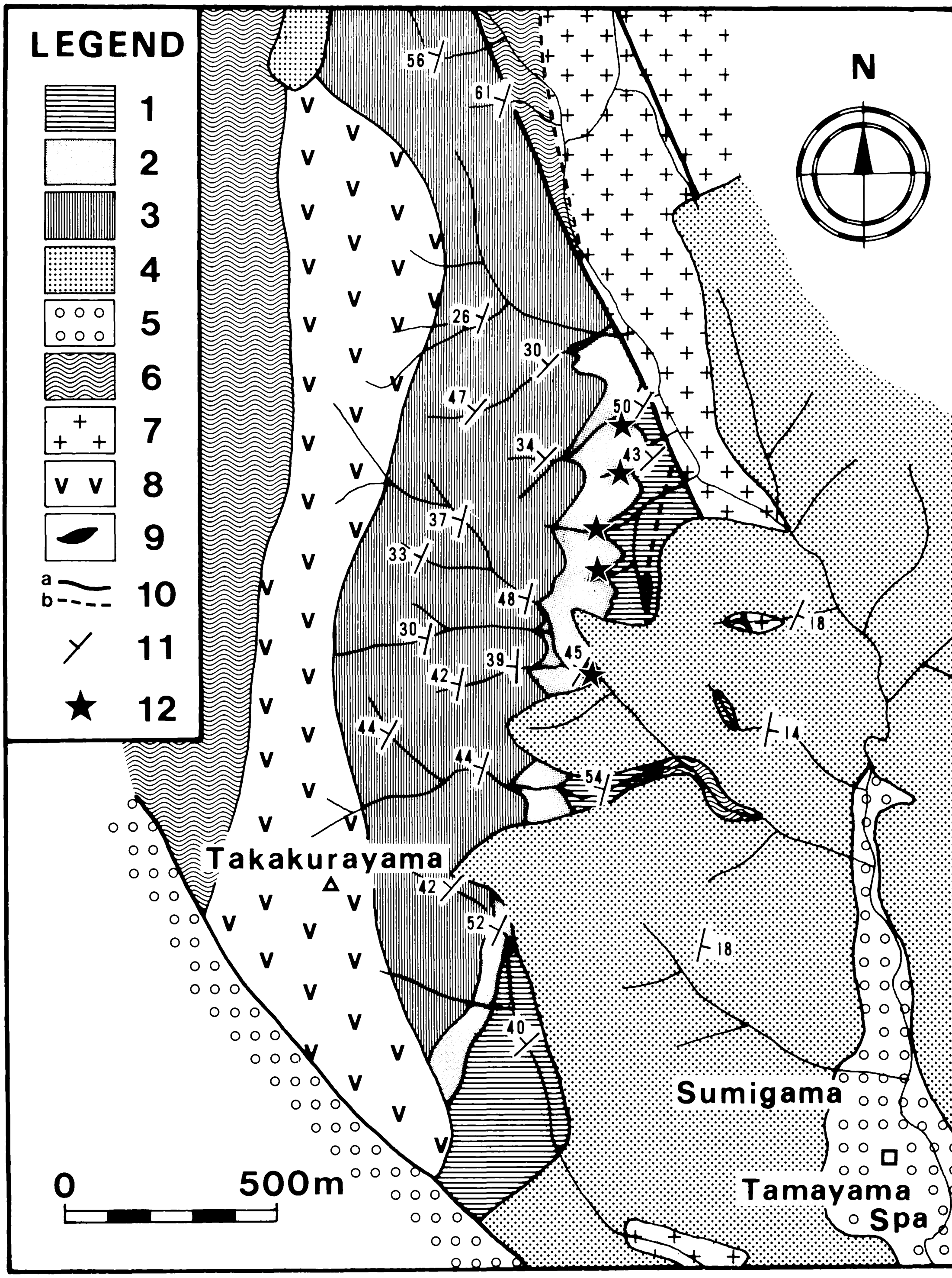
Geologic summary

The Takakurayama Group was first introduced by Yanagisawa and Nemoto (1961) for non-metamorphic Paleozoic strata in this area, and was subdivided into three formations; the Iriishikura, Motomura, and Kashiwadaira in ascending order. Subsequently, Yanagisawa (1967) reported rich shallow-marine invertebrate fossils from several horizons in the Takakurayama Group and concluded that the group correlates with the Early to Middle Permian.

As shown in Figure 2, the Takakurayama Group is a small block in fault contact with the granite in the northeast and with the Quaternary deposit in the southwest. In the western part of the surveyed area, the Takakurayama Group is in contact with the intrusion of porphyrite. In the eastern part, on the contrary, the Takakurayama Group is widely overlain unconformably by the Cretaceous Futaba Group. The Takakurayama Group is divided into the following three formations in ascending order; the strata strike N10°-50°E and dip 30°-60°NW, and are in normal order.

Iriishikura Formation The Iriishikura Formation, about 200 m in maximum thickness, consists mainly of black shale with a subordinate amount of sandstone and fine-grained conglomerate. The lower boundary was not

→ **Figure 2.** Geological map of the Takakurayama area. **1-3.** Takakurayama Group, **1**: Iriishikura Formation, **2**: Motomura Formation, **3**: Kashiwadaira Formation, **4**: Futaba Group (Cretaceous), **5**: Quaternary, **6**: metamorphic rock, **7**: granite, **8**: porphyrite, **9**: serpentinite, **10**: fault (a: confirmed, b: assumed), **11**: dip and strike, **12**: fossil locality studied herein.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examined because of the covering by the Cretaceous Futaba Group. Yanagisawa (1967) reported *Bellerophon* sp. and *Paraceltites* aff. *elegans* Girty from the upper part of this formation.

Motomura Formation This formation conformably overlies the Iriishikura Formation. The total thickness is about 70 to 160 m. It consists of conglomerate, sandstone, and sandstone with a minor intercalation of black shale from the base upward. The conglomerate member is about 45 m thick in the northern part of the surveyed area, and becomes thinner and finer-grained to the south. This conglomerate is mainly composed of well rounded pebbles of sandstone, black shale, chert, limestone, and andesite. The matrix is calcareous, poorly sorted, and composed of medium- to coarse-grained sandstone. Yanagisawa (1967) and O'hara *et al.* (1976) reported such Early Permian fusulinaceans as *Chalaroschwagerina vulgaris* (Schellwien), *Pseudofusulina fusiformis* (Schellwien), *P. ambigua* (Deprat), *Nagatoella minatoi* Kanmera, *Toriyamaia laxiseptata* Kanmera, and *Nankinella kawadai* (Igo) from the limestone pebbles in the conglomerate member.

Kashiwadaira Formation The Kashiwadaira Formation is in conformable contact with the Motomura Formation and attains about 760 m in maximum thickness. It is composed of black shale and alternating beds of black shale and sandstone in the lower part, and mainly of black shale with a subordinate amount of sandstone in the upper part. The upper limit is not confirmed in the field because of the poor exposure, but is probably in contact with the porphyrite intrusion. Hayasaka (1957, 1965) once described the early Guadalupian (Socio Stage) cephalopods including *Tainoceras abukumaense* Hayasaka, *Tylonautilus permicus* Hayasaka, *T.* aff. *unklesbayi* Miller and Youngquist, *Paraceltites* aff. *elegans* Girty, *Agathiceras* cf. *suessi* Gemmellaro, *Stacheoceras* aff. *grunwaldti* Gemmellaro, *Waagenoceras* cf. *dieneri richardsoni* Miller and Furnish from the middle part of this formation. Yanagisawa (1967) also described rich shallow marine invertebrates, such as brachiopods, pelecypods, gastropods, and cephalopods from several horizons.

Foraminiferal fauna and geologic age

As shown in Table 1, 74 taxa of Permian foraminifers including one new genus, *Quasireichelina,* and four new species, *Codonofusiella abukumaensis, Dunbarula planata, Quasireichelina expansa,* and *Neodiscus mirabilis,* were identified from several localities of the conglomerate member in the lower part of the Motomura Formation (Figure 2). Most of them were found from the limestone pebbles contained in the conglomerate. On the basis of microfacies and fossil contents, they are classified into five types as shown in Table 2.

Type I pebbles are pure limestone without detrital or volcanoclastic materials, and are further subdivided into three types, namely Type Ia, Type Ib, and Type Ic based on microfacies. Type Ia limestone pebbles are light gray algae-foraminiferal grainstone, and most abundant among the limestone pebbles in the conglomerate. They contain *Chalaroschwagerina vulgaris* (Schellwien), *Pseudofusulina fusiformis* (Schellwien), *Toriyamaia laxiseptata* Kanmera, *Mesoschubertella* aff. *thompsoni* Sakagami, *Minojapanella* (*M.*) *elongata* Fujimoto and Kanuma, and others. This fusulinacean fauna is very close to that reported from the Sakamotozawa Formation of the Southern Kitakami Mountains, and most probably to that in the Sc and Sd members by Kanmera and Mikami (1965). It is considered to be of early Yakhtashian age.

Type Ib limestone pebbles are light gray crinoid-foraminiferal grainstone. The fusulinacean fauna includes *Chalaroschwagerina vulgaris* (Schellwien), *Pseudofusulina* sp., *Parafusulina* ? sp., and *Schubertella* cf. *simplex* Lange, and is consid-

Table 1. List of foraminifers from the Motomura Formation.

FUSULINACEANS	Type I			Type II		M	SMALLER FORAMINIFERS	Type I			Type II	
	a	b	c	a	b			a	b	c	a	b
Rauserella ? sp.				+			*Tuberitina* spp.		+	+	+	
Toriyamaia laxiseptata Kanmera	+						*Eotuberitina* spp.			+	+	+
Biwaella sp.	+						*Ammovertella* sp.	+				
Yangchenia cf. *iniqua* Lee				+			*Glomospira* sp.			+		
Schubertella irumensis (Huzimoto)	+						*Ammodiscus*? sp.				+	
S. cf. *simplex* Lange		+					*Spiroplectammina* spp.			+	+	
S. sp. A			+				*Globivalvulina* spp.	+			+	
S. sp. B					+		*Tetrataxis* sp. A				+	
S.? sp. C					+		*T*. sp. B	+				
Mesoschubertella aff. *thompsoni* Sakagami	+						*T*. sp. C	+				
Neofusulinella sp.					+		*T*. sp. D			+		
Minojapanella (*M*.) *elongata* Fujimoto &	+						*T*. spp.			+	+	+
Kanuma							*Polytaxis* sp.				+	
M. (*M*.) *parva* Sheng					+		*Climacammina tenuis* Lin			+		
Wutuella cf. *wutuensis* (Kuo)					+		*C*. sp. A					+
Codonofusiella abukumaensis, sp. nov.				+			*C*. sp. B				+	
C. sp.			+				*C*. sp. C				+	
Dunbarula planata, sp. nov.				+			*Deckerella* spp.		+		+	
D. sp. A				+			*Lasiodiscus* spp.			+		+
D. sp. B				+			*Langella* spp.		+		+	+
Lantschichites ? sp.					+		*Pachyphloia ovata* Lange				+	
Chalaroschwagerina vulgaris (Schellwien)	+	+					*P*. spp.			+	+	+
Pseudofusulina fusiformis (Schellwien)	+		+				*Neoendothyra reicheli* Reitlinger					+
P. cf. *exigua* (Schellwien)	+		+				*N*. spp.			+		+
P. cf. *houziguanica* Sheng			+				*Neohemigordius* ? sp.	+	+			
P. sp. A	+		+				Involutinidae gen. et sp. indet. A	+				
P. sp. B			+				Involutinidae gen. et sp. indet. B		+			
P. spp.	+	+	+	+	+		*Agathammina magna* Xia &				+	
Chusenella sp.			+				Zhang					
Parafusulina ? sp.		+					*A*. sp. A				+	
Nankinella kawadai (Igo)			+				*A*. spp.	+			+	
N. spp.	+		+		+		*Multidiscus* sp.					+
Quasireichelina expansa, gen. et sp. nov.				+			*Neodiscus ovata* (Grozdilova)				+	
Misellina (*Brevaxina*) sp.			+				*N*. *mirabilis*, sp. nov.				+	
Pseudodoliolina cf. *ozawai* Yabe & Hanzawa				+			*N*. sp. A				+	
P. aff. *pseudolepida* (Deprat)				+			*N*. spp.				+	
P. sp.						+	*Nodosaria* ? sp.	+				
Colania sp.						+	*Ichthyolaria* ? sp.				+	

M : Matrix

ered to be of Yakhtashian age.

Type Ic limestone pebbles are dark gray algae-foraminiferal wackestone and contain *Pseudofusulina fusiformis* (Schellwien), *P*. cf. *houziguanica* Sheng, *Chusenella* sp., *Nankinella kawadai* (Igo), *Misellina (Brevaxina)* sp., and others. These fusulinaceans are indicative of early Bolorian age.

Type II limestone pebbles are, on the contrary, impure limestone with a small amount of volcanoclastic materials, and are further subdivided into two types, Type IIa and Type IIb. Type IIa limestone pebbles are black crinoid-algae-foraminiferal grainstone and

Table 2. Classification of limestone pebbles from the conglomerate member in the Motomura Formation.

TYPE I			TYPE II	
pure limestone without detrital or volcanoclastic material			impure limestone with volcanoclastic material	
a	b	c	a	b
light gray algae-foraminiferal grainstone	light gray crinoid-foraminiferal grainstone	dark gray algae-foraminiferal wackestone	black crinoid-algae-foraminiferal grainstone	black crinoidal grainstone
early Yakhtashian	Yakhtashian	early Bolorian	early Murgabian	late Murgabian

contain *Yangchenia* cf. *iniqua* Lee, *Codonofusiella abukumaensis*, sp. nov., *Dunbarula planata*, sp. nov., *Quasireichelina expansa*, gen. et sp. nov., *Pseudodoliolina* cf. *ozawai* Yabe and Hanzawa, *P.* aff. *pseudolepida* (Deprat), and others. *Yangchenia iniqua* Lee was reported from the upper part of the Chihsia Limestone (*Cancellina* Zone) in South China (Sheng, 1963). However, Leven (1967) described this species from the Kubergandian and also from the lower part of the Murgabian (*Neoschwagerina simplex* Zone) of the Pamirs. The genus *Codonofusiella* flourished in the early Late Permian, but some species occur from the upper part of the Middle Permian (Toriyama, 1971). *Pseudodoliolina ozawai* Yabe and Hanzawa is common in the Murgabian and its equivalents in the Tethyan province (Leven, 1980 and others). From the discussion mentioned above, this fusulinacean fauna is considered to be of early Murgabian age.

Type IIb limestone pebbles are black crinoidal grainstone. They contain *Minojapanella* (*M.*) *parva* Sheng, *Wutuella* cf. wutuensis (Kuo), *Lantschichites* ? sp., and others. The first species was originally described from the upper part of the Maokou Limestone (Sheng, 1963), the second one was also reported from the same horizon (Sheng, 1963), and from the upper part of the Murgabian (Leven, 1967). The fusulinacean fauna, therefore, is referable to the late Murgabian.

Besides the above-mentioned fusulinaceans from several types of limestone pebbles, *Colania* sp. and *Pseudodoliolina* sp. were found from the matrix of the conglomerate in the Motomura Formation. The genus *Colania* is considered to be a good indicator of late Murgabian age (Ozawa, 1970 and others).

Concerning the geologic age of the Takakurayama Group, Hayasaka (1957, 1965) correlated it, as a whole, with the Socio Stage, which is almost equivalent to the early Murgabian. Later, Yanagisawa (1967) considered that the Takakurayama Group correlates with the Sakamotozawa and Kanokura Formations of the Southern Kitakami Mountains, based on paleontologic evidence afforded by fusulinaceans, brachiopods, cephalopods, and pelecypods, and assigned to the Early to Middle Permian. He also stressed that the occurrence of *Pseudofusulina* cf. *ambigua* (Deprat), *P.* cf. *fusiformis* (Schellwien), and *Chalaroschwagerina* cf. *vulgaris* (Schellwien) is important because they are quite similar to those observed in the Sakamotozawa Formation. This fusulinacean fauna is almost identical with that in Type Ia limestone pebbles in this study. However, it is evident that these fusulinaceans do not indicate the geologic age of the Takakurayama Group directly, because they are all obtained from the limestone pebbles of the conglomerate member. In fact, there exist late Murgabian fusulinaceans both in the Type IIb limestone pebbles and the matrix of the conglomerate member in the Motomura Formation. This is in conflict with Yanagisawa's (1967) conclusion that the Motomura Formation correlates with the Early Permian. From the discussion mentioned above, the Motomura Formation, at least, correlates with the late Murgabian. Moreover, it is probable that the Takakurayama Group as a whole, is of late Murgabian age, based not only on paleontologic evidence by cephalopods from the Iriishikura and Kashiwadaira Formations, but also on the stratigraphic ground that the Takakurayama Group is considered to be a single stratigraphic succession (Hayasaka, 1965 and others).

Systematic description

All specimens identified in this paper are deposited in the collection of Institute of Geoscience, the University of Tsukuba (IGUT).

Order Foraminiferida Eichwald, 1830
Suborder Fusulinina Wedekind, 1937
Superfamily Fusulinacea
von Möller, 1878
Family Schubertellidae Skinner, 1931
Subfamily Yangcheninae Leven, 1987
Genus *Yangchenia* Lee, 1933

Remarks.—As has been already confirmed by Leven (1987), the genus *Yangchenia* is not a scant survivor of the subfamily Fusulinellinae in Middle Permian time but is an offshoot of the family Schubertellidae.

Yangchenia cf. *iniqua* Lee, 1933

Figures 6-1–3

Compare.—

Yangchenia iniqua Lee, 1933, p. 14, pl. 1, figs. 1, 1a; Chen, 1934, p. 18-19, pl. 1, figs. 8-9 (same as pl. 1, figs. 1, 1a of Lee, 1933, p. 14); Thompson, 1935, pl. 17, figs. 3-4 (same as pl. 1, figs. 1, 1a of Lee, 1933, p. 14); Thompson, 1948, pl. 5, figs. 1-2 (same as pl. 1, figs. 1, 1a of Lee, 1933, p. 14); Sheng, 1963, p. 38-39, 163, pl. 4, figs. 30-35; Thompson, 1964, figs. 313-1a–b (same as pl. 1, figs. 1, 1a of Lee, 1933, p. 14); Sheng, 1966, p. 60, pl. 9, fig. 5 (same as pl. 1, fig. 1 of Lee, 1933, p. 14); Leven, 1967, p. 128, pl. 2, figs. 1-2; Zhang and Wang, 1974, p. 292, pl. 151, fig. 8; Sheng and Sun, 1975, p. 10-11, pl. 1, fig. 26; Rozovskaya, 1975, pl. 7, figs. 15-17 (15: same as pl. 1, fig. 1a of Lee, 1933, p. 14, 16-17: same as pl. 2, figs. 1-2 of Leven, 1967, p. 128); Lin *et al*., 1977, p. 36, pl. 7, fig. 5 (same as pl. 4, fig. 30 of Sheng, 1963, p. 38-39, 163); Liu *et al*., 1978, p. 32, pl. 4, fig. 19; Kahler and Kahler, 1979, p. 231, pl. 3, fig. 6; Wang *et al*., 1982, p. 45, pl. 8, figs. 6-7 (7: same as pl. 1, fig. 1 of Lee, 1933, p. 14): Zhou and Zhang, 1984, pl. 2, figs. 14-15; Chediya *et al*., 1986, pl. 3, fig. 7; Loeblich and Tappan, 1988, pl. 269, figs. 8-9 (same as pl. 1, figs. 1, 1a of Lee, 1933, p. 14).

Yangchenia ex gr. *iniqua* Lee. Rauser-Chernoussova and Fursenko, 1959, pl. 7, fig. 9.

non *Yangchenia iniqua* Lee. Xie, 1982, p. 16, pl. 6, fig. 10.

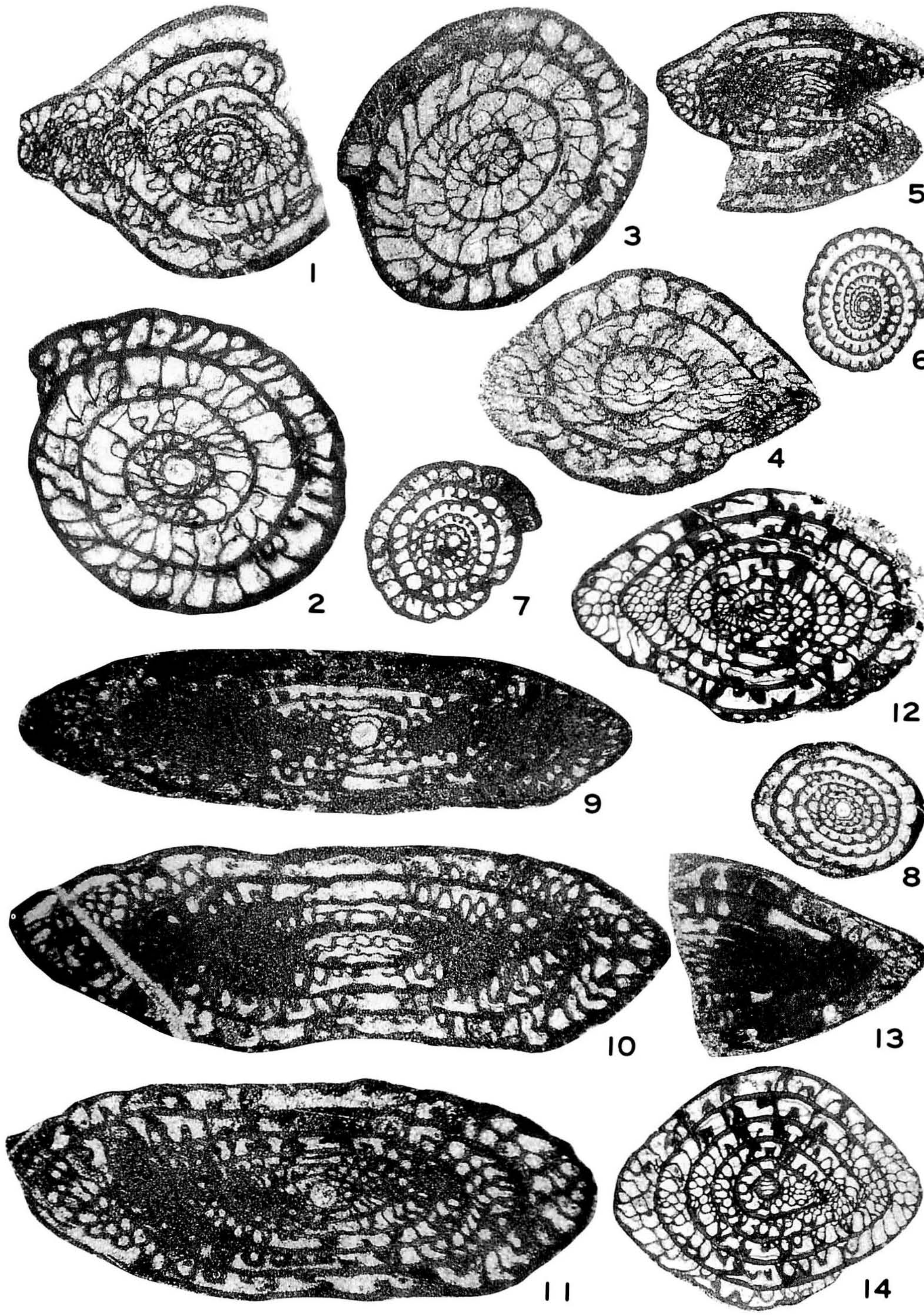
Remarks.—One tangential and two diagonal sections were prepared for this study. The present form almost agrees with *Yangchenia iniqua* Lee. However, the specific name is left tentative because of the insufficient material.

This species somewhat resembles *Yangchenia compressa* originally described by Ozawa (1927) from the Akasaka Limestone of Gifu Prefecture, central Japan. However, the former can be distinguished from the latter in having a larger shell and smaller form ratio.

Occurrence.—Rare in Type IIa limestone pebbles.

Material.—Tangential section; IGUT-KU0072. Diagonal sections; IGUT-KU0073, IGUT-KU0074.

Subfamily Schubertellinae Skinner, 1931
Genus *Mesoschubertella* Kanuma
and Sakagami, 1957
Mesoschubertella aff. *thompsoni*
Sakagami, 1957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Figures 4-13–20

Compare.—

Mesoschubertella thompsoni Sakagami in Kanuma and Sakagami, 1957, p. 43-44, pl. 8, figs. 1-10; Sakagami, 1958, p. 77-78, pl. 1, figs. 12-16; Thompson, 1964, figs. 303-2a–c (same as pl. 8, figs. 2, 4, 6 of Kanuma and Sakagami, 1957, p. 43-44); Pasini, 1965, pl. 4, fig. 2 (same as pl. 8, fig. 6 of Kanuma and Sakagami, 1957, p. 43-44); Sakagami and Iwai, 1974, p. 58, pl. 4, figs. 28-39; Ozawa, 1975, pl. 7, fig. 22; Rozovskaya, 1975, pl. 3, figs. 9-10 (same as pl. 8, figs. 1, 6 of Kanuma and Sakagami, 1957, p. 43-44); Loeblich and Tappan, 1988, pl. 260, figs. 18-22 (same as pl. 8, figs. 1, 3-4, 6-7 of Kanuma and Sakagami, 1957, p. 43-44).

? *Mesoschubertella thompsoni* Sakagami. Leven, 1987, pl. 2, fig. 5.

Description.—Shell small, ellipsoidal to fusiform with bluntly pointed polar ends. Mature specimens having 5 to 6 volutions, 1.13 to 1.40 mm in length and 0.73 to 0.95 mm in width, giving form ratio of about 1.90. Inner 1 or 2 volutions coiled at large angles to outer ones. Radius vectors of the first to fifth volutions of illustrated typical axial section (Figure 4-14) 0.08, 0.14, 0.21, 0.30, and 0.41 mm, and form ratios 1.00, 1.00, 1.24, 1.63, and 1.76, respectively. Proloculus small and spherical, 0.040 to 0.055 mm in outside diameter, averaging 0.049 mm for 7 specimens. Spirotheca thin and composed of a tectum, a rather thick less dense lower layer (diaphanotheca) and a thin lower tectorium. Septa almost plane and slightly bend anteriorly. Septal counts of the third to sixth volution of specimen illustrated on Figure 4-16, 10, 13, 17, and 21. Chomata well developed beyond the third volution. Tunnel path regular and straight.

Remarks.—The present species somewhat resembles *Mesoschubertella thompsoni* Sakagami, but differs from the latter in having a larger shell and form ratio.

This species is easily distinguished from *Mesoschubertella shimadaniensis* Kanuma in having no rugosity in the spirotheca.

Occurrence.—Common in Type Ia limestone pebbles.

Material.—Axial sections; IGUT-KU0047, IGUT-KU0048, IGUT-KU0050, IGUT-KU0051. Sagittal sections; IGUT-KU0046, IGUT-KU0049. Tangential sections; IGUT-KU0052, IGUT-KU0053.

Genus *Schubertella* Staff and Wedekind, 1910

Schubertella irumensis (Huzimoto, 1936)

Figure 4-8

Fusulinella irumensis Huzimoto, 1936, p. 38-40, pl. 2, figs. 1-8, 27 ?.

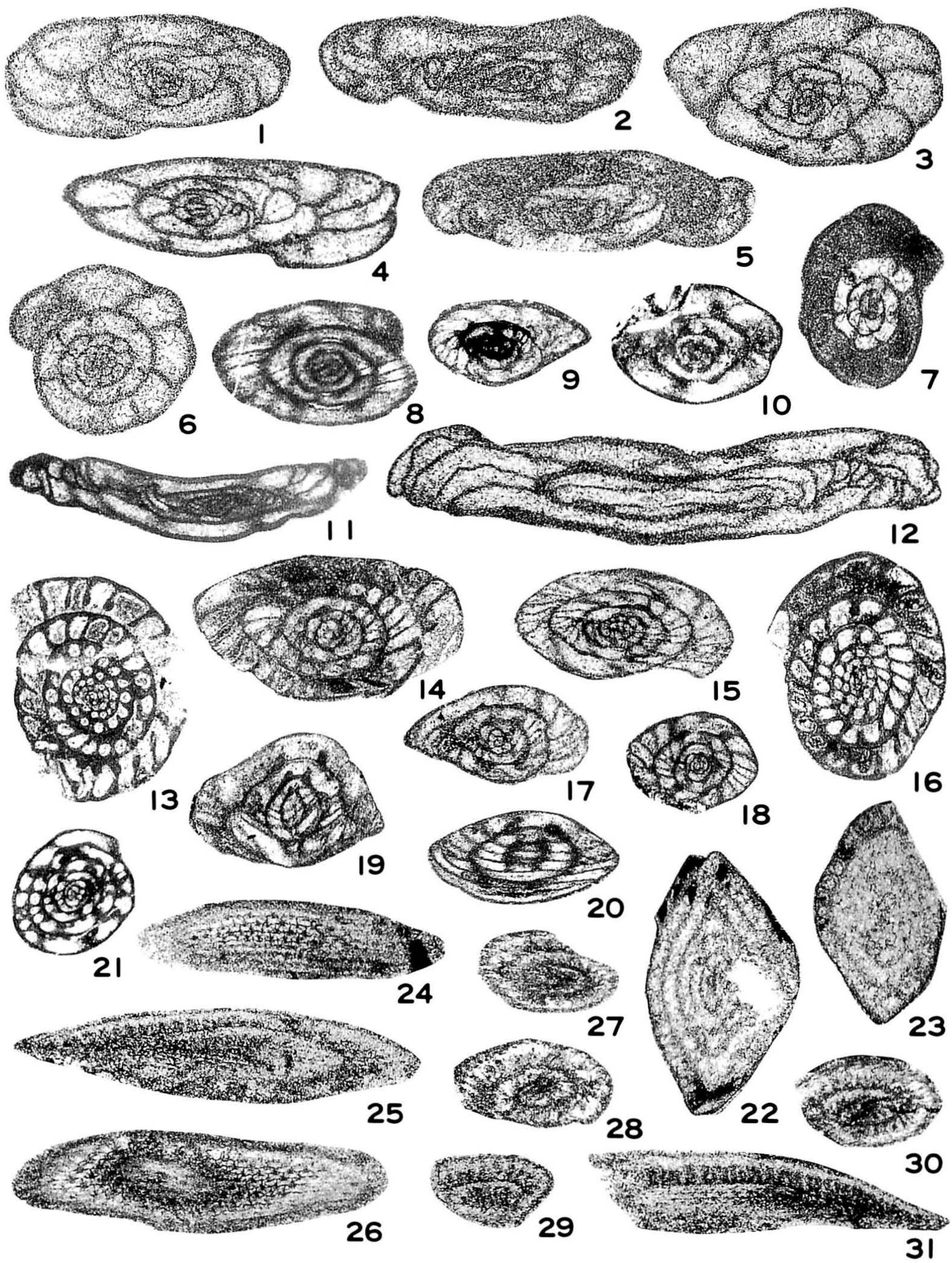
Schubertella cf. *irumensis* (Huzimoto). Sakagami, 1958, p. 76-77, pl. 1, figs. 10-11.

Schubertella irumensis (Huzimoto). Choi, 1973, p. 15, pl. 2, figs. 3-7.

Descriptive remarks.—Shell small, ellipsoidal with rounded periphery. Specimen having 5 ½ volutions, 0.80 mm in length and 0.49 mm in width, giving a form ratio of 1.63. Shell expands gradually through growth. Spirotheca thin and composed of a tectum and a lower less dense layer (diaphanotheca). Chomata broad and asymmetrical. Tunnel path straight.

I obtained only one axial section referable to this species. *Schubertella irumensis* was originally described by Huzimoto (1936) from the Kwanto Mountains, where it is

← **Figure 3.** Fusulinaceans from Type I limestone pebbles. **1-4.** *Chalaroschwagerina vulgaris* (Schellwien), **1**: axial section, IGUT-KU0020, **2**: sagittal section, IGUT-KU0021, **3**: parallel section, IGUT-KU0022, **4**: tangential section, IGUT-KU0023. **5, 6.** *Pseudofusulina* cf. *exigua* (Schellwien), **5**: tangential section, IGUT-KU0024, **6**: sagittal section, IGUT-KU0025. **7-11.** *Pseudofusulina fusiformis* (Schellwien), **7, 8**: sagittal sections, IGUT-KU0026, IGUT-KU0027, **9, 11**: axial sections, IGUT-KU0028, IGUT-KU0030, **10**: tangential section, IGUT-KU0029. **12, 14**: *Pseudofusulina* sp. B, tangential sections, IGUT-KU0031, IGUT-KU0033. **13**: *Chusenella* sp., tangential section, IGUT-KU0032. **1-12, 14**: ×10, **13**: ×20.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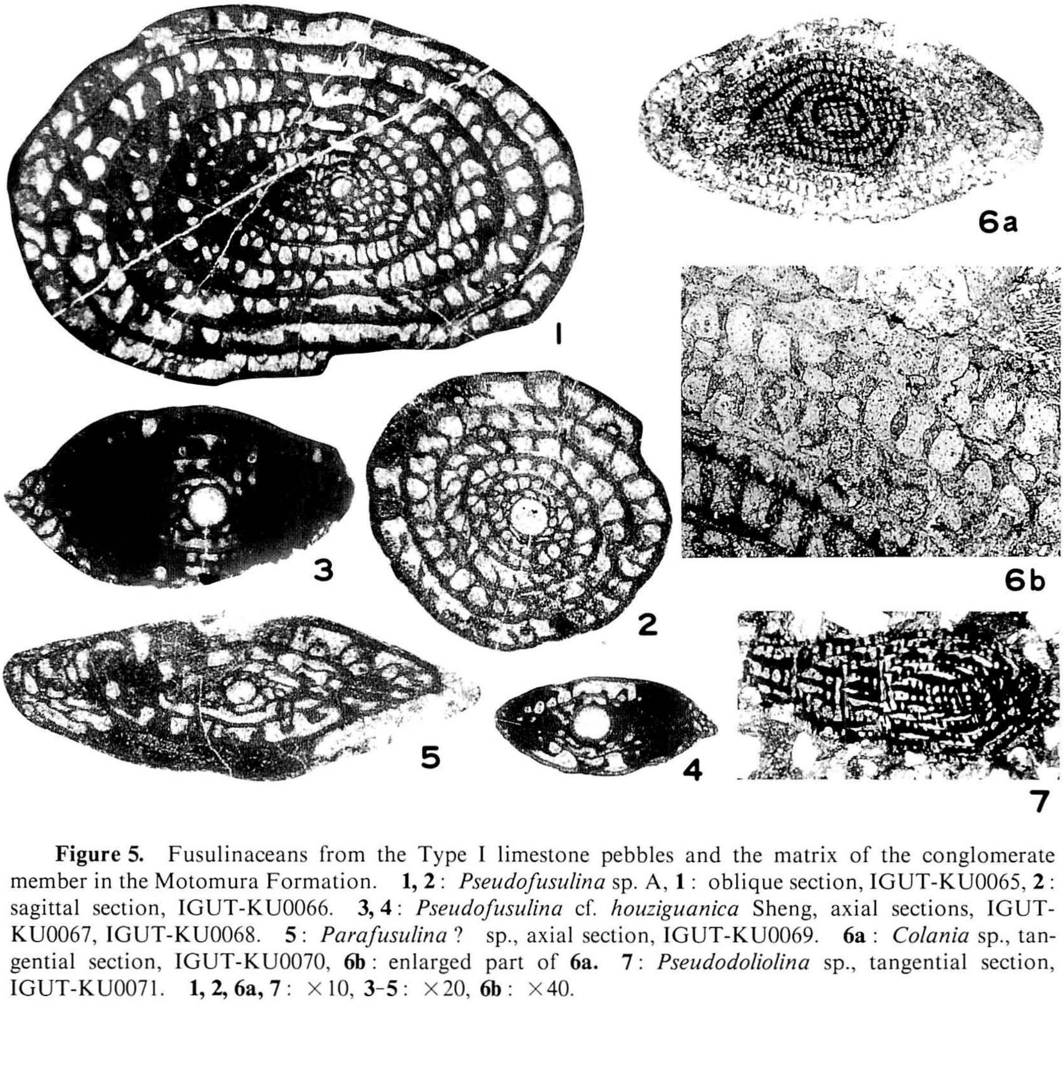


Figure 5. Fusulinaceans from the Type I limestone pebbles and the matrix of the conglomerate member in the Motomura Formation. **1, 2** : *Pseudofusulina* sp. A, **1** : oblique section, IGUT-KU0065, **2** : sagittal section, IGUT-KU0066. **3, 4** : *Pseudofusulina* cf. *houziguanica* Sheng, axial sections, IGUT-KU0067, IGUT-KU0068. **5** : *Parafusulina* ? sp., axial section, IGUT-KU0069. **6a** : *Colania* sp., tangential section, IGUT-KU0070, **6b** : enlarged part of **6a.** **7** : *Pseudodoliolina* sp., tangential section, IGUT-KU0071. **1, 2, 6a, 7** : ×10, **3-5** : ×20, **6b** : ×40.

← **Figure 4.** Fusulinaceans from Type I limestone pebbles. **1-7.** *Toriyamaia laxiseptata* Kanmera, **1-3** : axial sections, IGUT-KU0034, IGUT-KU0035, IGUT-KU0036, **4, 5** : tangential sections, IGUT-KU0037, IGUT-KU0038, **6** : sagittal section, IGUT-KU0039, **7** : parallel section, IGUT-KU0040. **8** : *Schubertella irumensis* (Huzimoto), axial section, IGUT-KU0041. **9** : *Schubertella* sp. A, axial section, IGUT-KU0042. **10** : *Schubertella* cf. *simplex* Lange, axial section, IGUT-KU0043. **11, 12** : *Biwaella* sp., tangential sections, IGUT-KU0044, IGUT-KU0045. **13-20.** *Mesoschubertella* aff. *thompsoni* Sakagami, **13, 16** : sagittal sections, IGUT-KU0046, IGUT-KU0049, **14, 15, 17, 18** : axial sections, IGUT-KU0047, IGUT-KU0048, IGUT-KU0050, IGUT-KU0051, **19, 20** : tangential sections, IGUT-KU0052, IGUT-KU0053. **21** : *Misellina* (*Brevaxina*) sp., slightly oblique axial section, IGUT-KU0054. **22, 23** : *Nankinella kawadai* (Igo), tangential sections, IGUT-KU0055, IGUT-KU0056. **24-31.** *Minojapanella* (*M.*) *elongata* Fujimoto and Kanuma, **24-26, 31** : tangential sections, IGUT-KU0057, IGUT-KU0058, IGUT-KU0059, IGUT-KU0064, **27-30** : parallel sections, IGUT-KU0060, IGUT-KU0061, IGUT-KU0062, IGUT-KU0063. **22, 23** : ×15, **4, 11, 12, 21** : ×20, **1-3, 5-7, 13-20** : ×30, **8-10, 24-31** : ×40.

associated with Early and Middle Permian fusulinaceans such as *Pseudofusulina ambigua* (Deprat), *P. kraffti* (Schellwien), *Misellina* (*M.*) *claudiae* (Deprat), and *Neoschwagerina craticulifera* (Schwager).

Occurrence.—Rare in Type Ia limestone pebbles.

Material.—Axial section ; IGUT-KU0041.

Subfamily Biwaellinae Davydov, 1984
Genus *Toriyamaia* Kanmera, 1956

Remarks.—Kanmera (1956) originally assigned the genus *Toriyamaia* to the family Ozawainellidae, because it has a long axis of coiling and rather loosely coiled shell which are similar to those of the genera *Leella* and *Rauserella*. Later, Sheng (1963) questionably assigned it to the family Staffellidae. As Leven (1987) has already pointed out, however, *Toriyamaia* is most probably to be referred to the family Schubertellidae, on the basis of essential morphological similarity between the genus *Toriyamaia* and certain Bolorian representatives of the genus *Biwaella*, although the former genus has no alveolar keriotheca in the spirotheca.

Toriyamaia laxiseptata Kanmera, 1956

Figures 4-1–7

Rauserella ? sp., Kobayashi, 1956, p. 227, pl. 32, figs. 11-12 ; Kobayashi, 1957, pl. 1, figs. 29-30 (same as pl. 32, figs. 11-12 of Kobayashi, 1956, p. 227).
Toriyamaia laxiseptata Kanmera, 1956, p. 252-255, pl. 36, figs. 1-14 ; Sheng, 1963, p. 33-34, 157, pl. 4, figs. 36-37 ; Kanmera, 1963, p. 87-88, pl. 11, figs. 1-4, pl. 19, figs. 8-9 ; Thompson, 1964, fig. 299-2a–d (same as pl. 36, figs. 1-2, 11, 18 of Kanmera, 1956, p. 252-255) ; Pasini, 1965, pl. 3, fig. 6 (same as pl. 36, fig. 1 of Kanmera, 1956, p. 252-255) ; Kanmera and Mikami, 1965, p. 277-279, pl. 46, figs. 9-10 ; Choi, 1973, p. 20, pl. 2, figs. 8-10 ; Zhang and Wang, 1974, p. 290, pl. 150, fig. 8 (same as pl. 4, fig. 37 of Sheng, 1963, p. 33-34, 157) ; Ozawa, 1975, pl. 7, fig. 18 ; Rozovskaya, 1975, pl. 3, figs. 14-15 (same as pl. 36, figs. 1, 11 of Kanmera, 1956, p. 252-255) ; Lin *et al.*, 1977, p. 19, pl. 3, fig. 17 ; Liu *et al.*, 1978, p. 22, pl. 2, figs. 9-10 (same as pl. 4, figs. 36-37 of Sheng, 1963, p. 33-34, 157) ; Kahler and Kahler, 1979, p. 226-227, pl. 4, fig. 7 ; Zhou *et al* 1987, pl. 2, fig. 7 ; Loeblich and Tappan, 1988, pl. 259, figs. 12-14 (same as pl. 36, figs. 1-2, 11 of Kanmera, 1956, p. 252-255).
Rauserella sp., Kawano, 1961, p. 58, pl. 1, fig. 1.
? *Toriyamaia* cf. *laxiseptata* Kanmera. Igo, 1967, pl. 4, figs. 1-5.

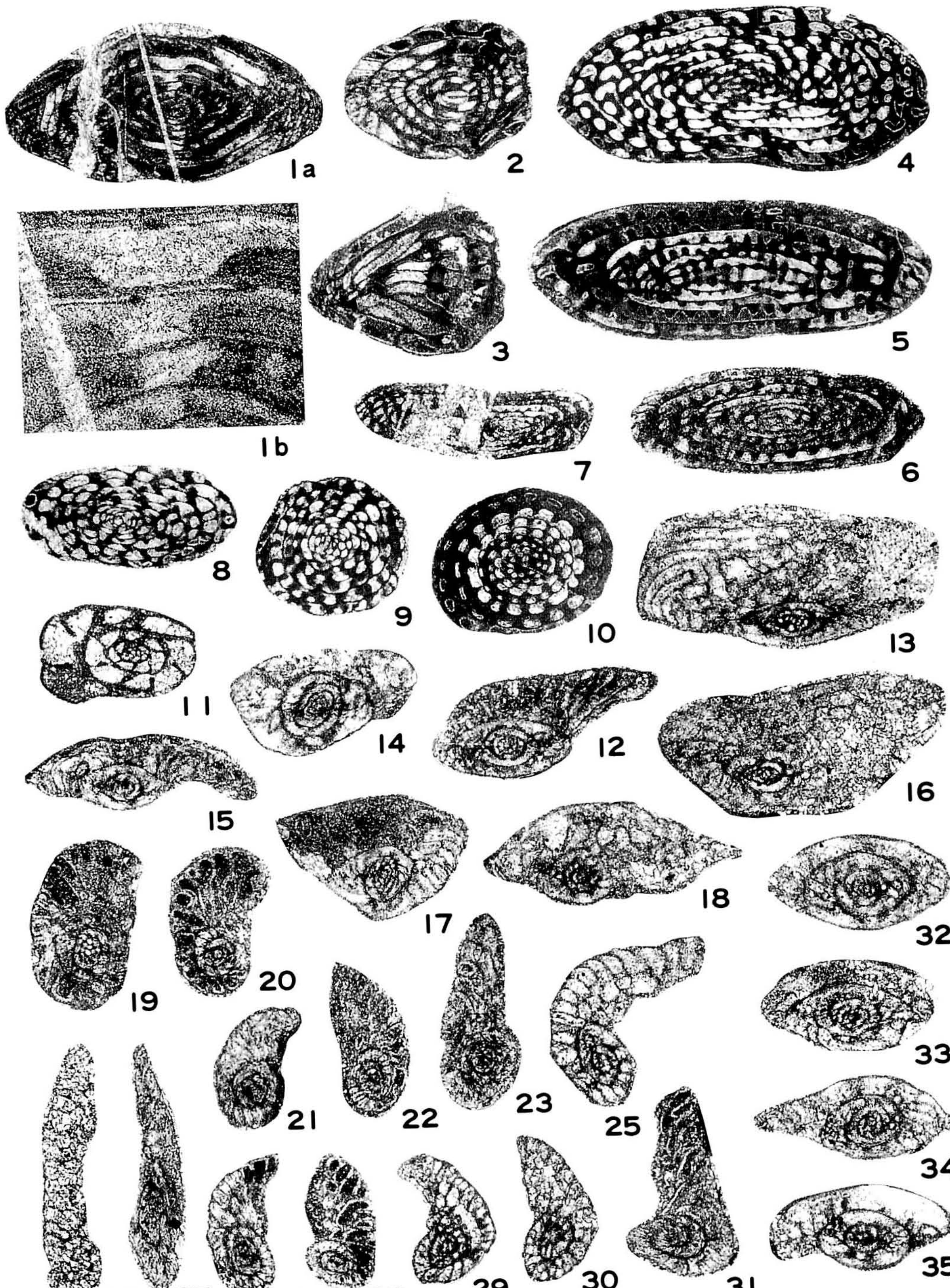
Remarks.—The Takakurayama specimens are quite comparable to the original ones described by Kanmera (1956) from the Middle Permian Kozaki Formation in the Kuma Massif, Kyushu, except for having a slightly smaller shell.

Toriyamaia laxiseptata Kanmera differs from *T. americana* described by Stewart (1966) from the Hueco Formation of El Paso County, Texas, in having a smaller proloculus and more volutions.

Occurrence.—Abundant in Type Ia limestone pebbles.

Material.—Axial sections ; IGUT-KU0034, IGUT-KU0035, IGUT-KU0036.

→ **Figure 6.** Fusulinaceans from Type IIa limestone pebbles. **1-3.** *Yangchenia* cf. *iniqua* Lee, **1a**: tangential section, IGUT-KU0072, **2, 3**: diagonal sections, IGUT-KU0073, IGUT-KU0074, **1b**: enlarged part of **1a**, showing *Fusulinella*-type 4 layered spirotheca. **4-10.** *Pseudodoliolina* cf. *ozawai* Yabe and Hanzawa, **4-6**: tangential sections, IGUT-KU0075, IGUT-KU0076, IGUT-KU0077, **7**: axial section, IGUT-KU0078, **8, 9**: sagittal sections, IGUT-KU0079, IGUT-KU0080, **10**: parallel section, IGUT-KU0081. **11**: *Rauserella* ? sp., sagittal section, IGUT-KU0082. **12**: *Codonofusiella* sp., axial section, IGUT-KU0083. **13-31.** *Codonofusiella abukumaensis*, sp. nov., **13**: axial section of the holotype, IGUT-KU0084, **14-18**: axial sections of paratypes, IGUT-KU0085, IGUT-KU0086, IGUT-KU0087, IGUT-KU0088, IGUT-KU0089, **19-24**: sagittal sections of paratypes, IGUT-KU0090, IGUT-KU0091, IGUT-KU0092, IGUT-KU0093, IGUT-KU0094, IGUT-KU0095, **25-31**: parallel sections of paratypes, IGUT-KU0096, IGUT-KU0097, IGUT-KU0098, IGUT-KU0099, IGUT-KU0100, IGUT-KU0101, IGUT-KU0102. **32-35**: *Dunbarula* sp. A, axial sections, IGUT-KU0103, IGUT-KU0104, IGUT-KU0105, IGUT-KU0106. **1a, 2-10**: ×20, **11-35**: ×40, **1b**: ×100.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Sagittal section ; IGUT-KU0039. Tangential sections ; IGUT-KU0037, IGUT-KU0038. Parallel section ; IGUT-KU0040.

Genus *Biwaella* Morikawa and Isomi, 1960

Biwaella sp.

Figures 4-11–12

Remarks.—This unidentified species can be easily distinguished from others referable to the genus *Biwaella* in having a highly elongate cylindrical shell.

Occurrence.—Rare in Type Ia limestone pebbles.

Material.—Tangential sections ; IGUT-KU0044, IGUT-KU0045.

Family Boultoniidae Skinner and Wilde, 1954

Genus *Minojapanella* Fujimoto and Kanuma, 1953

Subgenus *Minojapanella* Fujimoto and Kanuma, 1953

Minojapanella (*M.*) *elongata* Fujimoto and Kanuma, 1953

Figures 4-24–31

Minojapanella elongata Fujimoto and Kanuma, 1953, p. 152, pl. 19, figs. 1-11 ; Thompson, 1954, pl. 2, figs. 1-5 (2-3, 5 : same as pl. 19, figs. 1, 10-11 of Fujimoto and Kanuma, 1953, p. 152) ; Morikawa and Isomi, 1961, p. 7, pl. 2, figs. 10-15 ; Thompson, 1964, fig. 304-2a–d (2a, 2d : same as pl. 19, figs. 1, 11 of Fujimoto and Kanuma, 1953, p. 152, 2b-c : same as pl. 2, figs. 1, 4 of Thompson, 1954) ; Pasini, 1965, pl. 7, fig. 7 (same as pl. 19, fig. 1 of Fujimoto and Kanuma, 1953, p. 152) ; Choi, 1973, p. 14-15, pl. 1, figs. 8-11 ; O'hara *et al*., 1976, p. 72, pl. 1, fig. 11 ; Loeblich and Tappan, 1988, pl. 264, figs. 3-5 (same as pl. 19, figs. 1, 10-11 of Fujimoto and Kanuma, 1953, p. 152) ; Ozawa and Kobayashi, 1990, pl. 8, fig. 7 ; Zhang, 1992, p. 146, pl. 1, fig. 7.

Minojapanella (*M.*) *elongata* Fujimoto and Kanuma. Sheng, 1965, p. 565, pl. 1, figs. 1-6, 10-15 ; Rozovskaya, 1975, pl. 4, figs. 10-12 (10 : same as pl. 2, fig. 4 of Thompson, 1954, 11 : same as pl. 19, fig. 1 of Fujimoto and Kanuma, 1953, p. 152) ; Lin *et al*., 1977, p. 37, pl. 7, fig. 10 (same as pl. 1, fig. 5 of Sheng, 1965, p. 565) ; Kahler and Kahler, 1980, p. 191, pl. 2, fig. 3.

Remarks.—Several tangential and parallel sections having a highly elongate fusiform shell, slightly recrystallized spirotheca, and intensely and regularly fluted septa were prepared for this study. They are all safely referable to *Minojapanella* (*M.*) *elongata* Fujimoto and Kanuma in spite of their poor orientation.

Occurrence.—Common in the Type Ia limestone pebble.

Material.—Tangential sections ; IGUT-KU0057, IGUT-KU0058, IGUT-KU0059, IGUT-KU0064. Parallel sections ; IGUT-KU0060, IGUT-KU0061, IGUT-KU0062, IGUT-KU0063.

Minojapanella (*M.*) *parva* Sheng, 1963

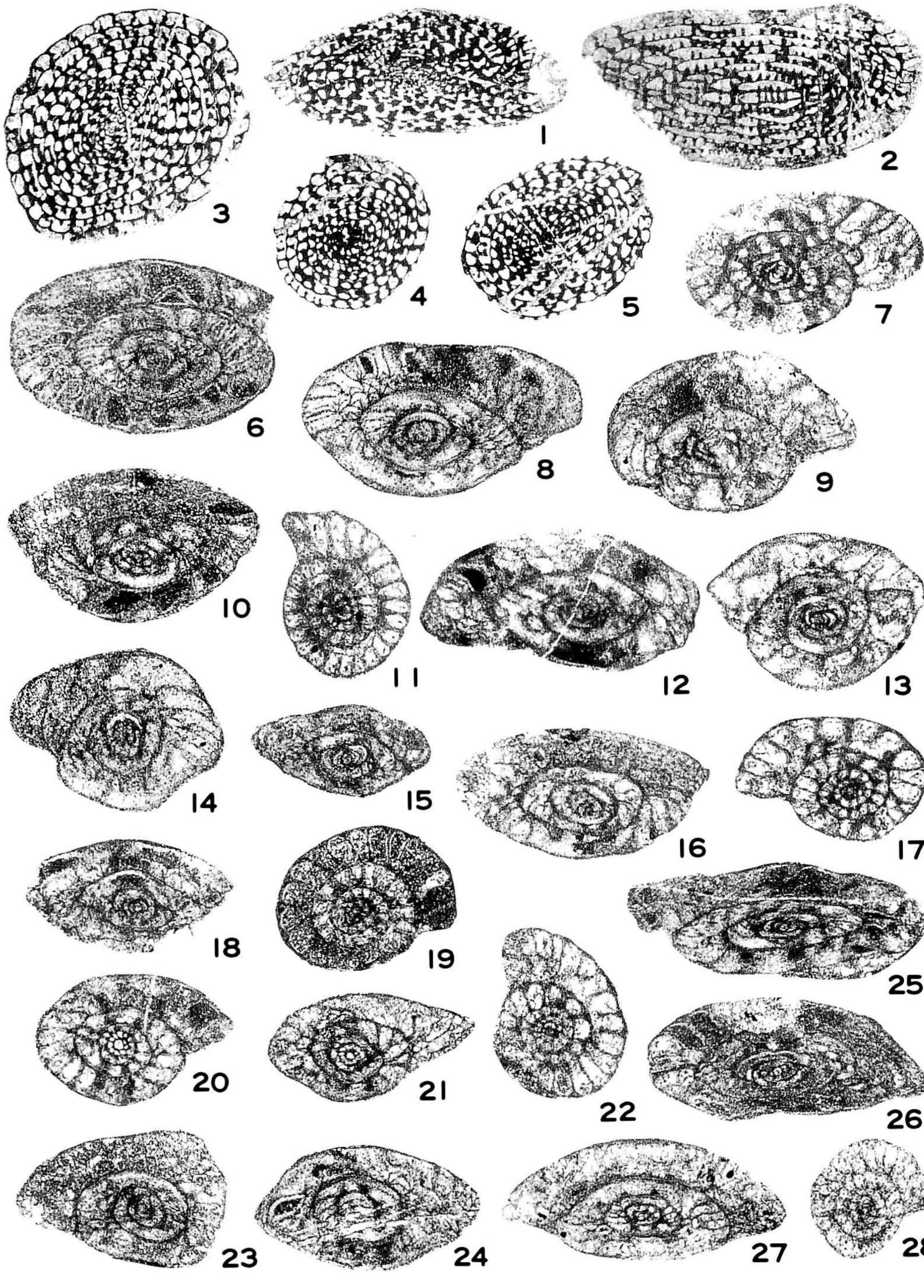
Figures 9-13–19

Minojapanella (*M.*) *parva* Sheng, p. 40, 164-165, pl. 12, figs. 23-24 ; Lin *et al*., 1977, p. 37, pl. 7, fig. 12 (same as pl. 12, fig. 24 of Sheng, 1963, p. 40, 164-165).

non *Minojapanella parva* Sheng. Han, 1976, p. 29, pl. 9, fig. 17.

Descriptive remarks.—Shell highly elongate fusiform with bluntly pointed poles.

→ **Figure 7.** Fusulinaceans from Type IIa limestone pebbles. **1-5.** *Pseudodoliolina* aff. *pseudolepida* (Deprat), **1** : oblique section, IGUT-KU0107, **2** : tangential section, IGUT-KU0108, **3-5** : sagittal sections, IGUT-KU0109, IGUT-KU0110, IGUT-KU0111. **6-24.** *Dunbarula planata,* sp. nov., **10** : axial section of the holotype, IGUT-KU0116, **12, 15, 18** : axial sections of paratypes, IGUT-KU0118, IGUT-KU0121, IGUT-KU0124, **6, 7, 9, 13, 20, 21, 23** : slightly oblique axial sections of paratypes, IGUT-KU0112, IGUT-KU0113, IGUT-KU0115, IGUT-KU0119, IGUT-KU0126, IGUT-KU0127, IGUT-KU0129, **8, 14, 16, 24** : tangential sections of paratypes, IGUT-KU0114, IGUT-KU0120, IGUT-KU0122, IGUT-KU0130, **11, 17, 19, 22** : sagittal sections of paratypes, IGUT-KU0117, IGUT-KU0123, IGUT-KU0125, IGUT-KU0128. **25-28.** *Dunbarula* sp. B, **25-27** : axial sections, IGUT-KU0131, IGUT-KU0132, IGUT-KU0133, **28** : sagittal section, IGUT-KU0134. **1-5** : ×10, **6-28** : ×40.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Specimen of 4 volutions 1.33 mm in length and 0.27 mm in width, giving a form ratio of 4.91. Outside diameter of proloculus about 0.05 mm. Spirotheca thin and slightly recrystallized, composed of a tectum and lower less dense layer (diaphanotheca). Septa intensely and regularly fluted. Chomata small but prominent.

This species was originally described by Sheng (1963) from the upper part of the Maokou Limestone of Guangxi (Kwangsi). It can be distinguished from *Minojapanella* (*M.*) *elongata* Fujimoto and Kanuma by its smaller shell and fewer volutions.

Occurrence.—Common in Type IIb limestone pebbles.

Material.—Axial sections; IGUT-KU0160, IGUT-KU0161. Sagittal section; IGUT-KU0159. Tangential sections; IGUT-KU0155, IGUT-KU0156, IGUT-KU0157, IGUT-KU0158.

Genus *Wutuella* Sheng, 1963

Discussion.—Xia (1982) established the subgenus *Neimonggolina* for the genus *Minojapanella*, with *Minojapanella* (*Neimonggolina*) *fusiformis* Xia as the type species. He noted that *Neimonggolina* is closely related to *Wutuella*, but can be distinguished from the latter in having visible chomata and tunnel. Sheng's (1963) illustration of *Wutuella wutuensis* (Kuo) on Figure 1 of Plate 13, however, shows the presence of small and poorly developed chomata and tunnel in the early volutions of this species, although he did not describe these morphological features. From the fact mentioned above, *Neimonggolina* is, therefore, considered to be a junior synonym of *Wutuella*.

Wutuella cf. *wutuensis* (Kuo, 1948)

Figures 9-1—6

Compare.—

Gallowaiinella wutuensis Kuo, 1948, p. 233, pl. 1, figs. 1-3.

Minojapanella (Wutuella) wutuensis (Kuo). Sheng, 1963, p. 41, 165-166, pl. 13, figs. 1-7; Leven, 1967, p. 131, pl. 2, figs. 11-12; Rozovskaya, 1975, pl. 4, figs. 13-14 (same as pl. 1, figs. 1, 3 of Kuo, 1948, p. 233); Lin *et al.*, 1977, p. 38, pl. 7, fig. 13 (same as pl. 13, fig. 2 of Sheng, 1963, p. 41, 165-166); Kahler and Kahler, 1979, p. 230, pl. 3, fig. 8.

Minojapanella wutuensis (Kuo). Sheng, 1966, p. 63-64, pl. 9, fig. 18 (same as pl. 1, fig. 1 of Kuo, 1948, p. 233).

Wutuella wutuensis (Kuo). Sheng and Sun, 1975, p. 7-8, pl. 2, fig. 16; Han, 1976, p. 29, pl. 9, figs. 13-16; Liu *et al.*, 1978, p. 29, pl. 4, fig. 3; Nie and Song, 1983, p. 44, pl. 3, figs. 11-12; Loeblich and Tappan, 1988, pl. 266, figs. 9-11 (9: same as pl. 13, fig. 2 of Sheng, 1963, p. 41, 165-166, 10: same as pl. 1, fig. 3 of Kuo, 1948, p. 233, 11: same as pl. 2, fig. 11 of Leven, 1967, p. 131).

Remarks.—The intense and regular septal fluting and heavy axial fillings in the present form suggest that it is assigned to *Wutuella wutuensis* (Kuo). Exact identification, however, is postponed because of the poor material.

Wutuella wutuensis (Kuo) has been described from the upper part of the Maokou Limestone and its equivalents in South China, and the upper part of the Murgabian in the Pamirs, Tadzhikistan.

Occurrence.—Common in Type IIb limestone pebbles.

Material.—Tangential sections; IGUT-KU0143, IGUT-KU0144, IGUT-KU0145, IGUT-KU0146. Parallel sections; IGUT-KU0147, IGUT-KU0148.

Genus *Codonofusiella* Dunbar and Skinner, 1937

Codonofusiella abukumaensis Ueno, sp. nov.

Figures 6-13—31

Diagnosis.—Small *Codonofusiella* having a fusiform coiled part with bluntly pointed axial regions and well developed uncoiled flaring lip. Inner few volutions skew coiled. Spirotheca thin. Septa weakly fluted.

Description.—Shell small, consisting of 2 parts. The first part having 3 or 4 volutions, fusiform with bluntly pointed polar ends. Inner 1 or 1 ½ volutions skew coiled. The second part of last half-volution abruptly expanded, forming an uncoiled flaring lip. Length and width of shell 0.77 to 1.23 mm and 0.30 to 0.94 mm, giving form ratios of 1.57 to 3.00. Radius vectors of the first to fourth volution of the holotype 0.04, 0.05, 0.07, and 0.40 mm, and form ratios 0.63, 2.00, 2.57, and 1.57, respectively. Proloculus small and spherical. Its outside diameter ranges from 0.030 to 0.045 mm, averaging 0.039 mm for 8 specimens. Spirotheca thin and composed of a tectum and a lower, less dense layer (diaphanotheca). Septa weakly fluted throughout length of shell. Chomata developed only in middle volutions.

Remarks.—*Codonofusiella kueichowensis* originally described by Sheng (1963) from the Wujiaping (Wuchiaping) Limestone of Guizhou (Kueichow) is the closest to the present new species. However, the former has a slightly larger and more loosely coiled shell than the latter.

Codonofusiella abukumaensis, sp. nov. is

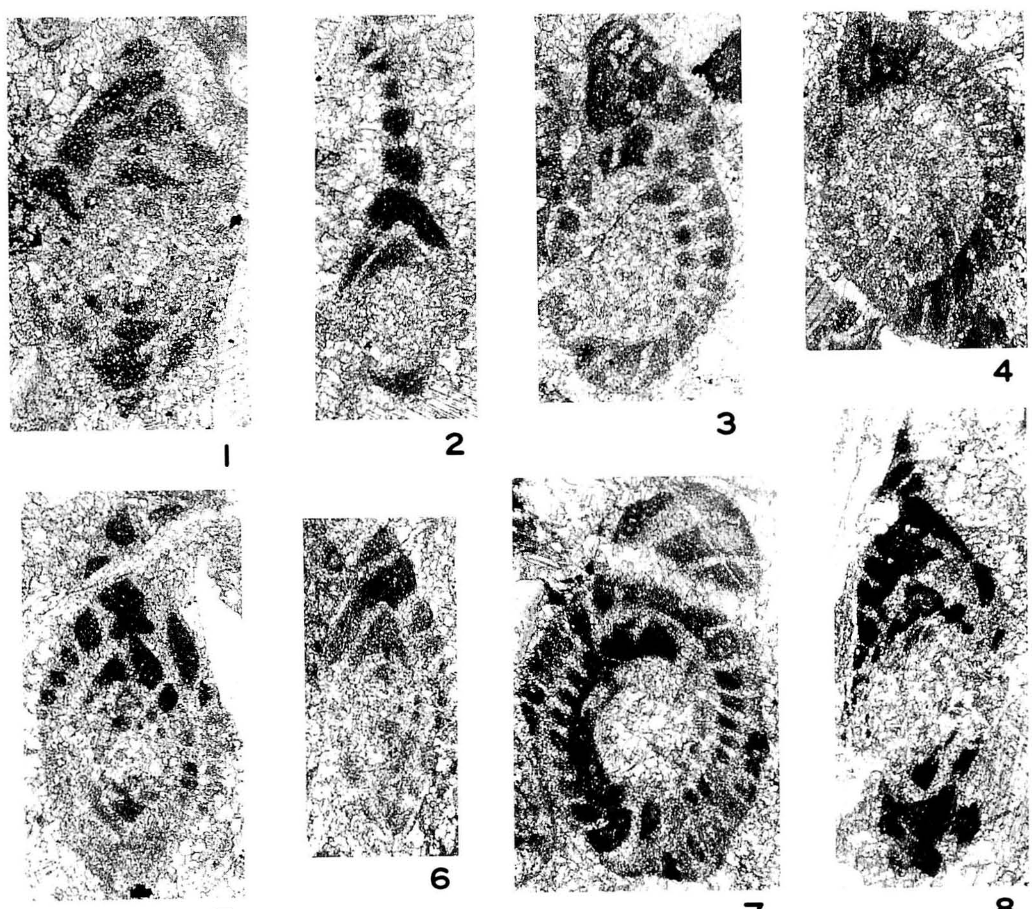


Figure 8. Fusulinaceans from Type IIa limestone pebbles. **1–8.** *Quasireichelina expansa,* gen. et sp. nov., **2**: axial section of the holotype, IGUT-KU0136, **1, 5, 6, 8**: axial sections of paratypes, IGUT-KU0135, IGUT-KU0139, IGUT-KU0140, IGUT-KU0142, **3, 4, 7**: sagittal sections of paratypes, IGUT-KU0137, IGUT-KU0138, IGUT-KU0141. All ×40.

easily distinguished from *C. explicata* Kawano and *C. extensa* Skinner and Wilde in having a less developed flaring lip, and from *C. cuniculata* Kanmera in having less fluted septa.

Occurrence.—Abundant in Type IIa limestone pebbles.

Material.—Axial section of the holotype; IGUT-KU0084. Axial sections of paratypes; IGUT-KU0085, IGUT-KU0086, IGUT-KU0087, IGUT-KU0088, IGUT-KU0089. Sagittal sections of paratypes; IGUT-KU0090, IGUT-KU0091, IGUT-KU0092, IGUT-KU0093, IGUT-KU0094, IGUT-KU0095. Parallel sections of paratypes; IGUT-KU0096, IGUT-KU0097, IGUT-KU0098, IGUT-KU0099, IGUT-KU0100, IGUT-KU0101, IGUT-KU0102.

Codonofusiella sp.

Figure 6-12

Descriptive remarks.—Small shell of 4 volutions consists of an early coiled part and a later abruptly expanded uncoiled part. Length 0.90 mm and width 0.43 mm with a form ratio of 2.09. Inner 1 ½ volutions skew coiled. Last half-volution coiled almost perpendicularly to preceding ones. Outside diameter of proloculus 0.035 mm.

This species somewhat resembles *Codonofusiella abukumaensis,* sp. nov. described previously, but differs from the latter in having a peculiar mode of coiling.

Occurrence.—Rare in Type IIa limestone pebbles.

Material.—Axial section; IGUT-KU0083.

Genus *Dunbarula* Ciry, 1948

Dunbarula planata Ueno, sp. nov.

Figures 7-6—24

Diagnosis.—Small *Dunbarula* having an ellipsoidal shell with bluntly pointed polar ends, skew coiled juvenile volutions and rather loosely coiled last half-volution. Septa numerous and weakly fluted. Small chomata in middle volutions.

Description.—Shell small for genus and ellipsoidal with bluntly pointed poles. Mature specimens of 4 ½ to 5 volutions 0.88 to 1.10 mm in length and 0.43 to 0.70 mm in width. Form ratio ranges from 1.54 to 1.96, averaging 1.76 for 6 specimens. Inner 1 or 1 ½ volutions compactly coiled at large angles to outer ones. Last half-volution rather loosely coiled. Radius vectors of the first to fifth volutions of the holotype 0.04, 0.07, 0.10, 0.17, and 0. 32, and form ratios 0.63, 1.21, 1.50, 1.76, and 1.53, respectively. Proloculus small and spherical. Its outside diameter ranges from 0.030 to 0.050, averaging 0.046 mm for 9 specimens. Spirotheca thin and composed of a tectum and lower, less dense layer (diaphanotheca). In some specimens, fine alveolar structure discernible in diaphanotheca. Thickness of spirotheca of the first to fifth volutions of the holotype 0.010, 0.020, 0.020, 0.025, and 0.015 mm. Septa numerous and weakly fluted in extreme polar regions. Septal counts of the third to fifth volution of illustrated sagittal section of paratype (Figure 7-11) 13, 18, and 25. Chomata small and developed in middle volutions. Septal pores present.

Remarks.—*Dunbarula planata,* sp. nov. somewhat resembles *D. kitakamiensis* originally described by Choi (1970) from the uppermost part of the Iwaizaki Limestone of the Southern Kitakami Mountains. However, the former has a slightly smaller shell and less fluted septa than those of the latter.

The present new species can be distinguished from *Dunbarula tumida* Skinner by its smaller shell, and *D. pusilla* Skinner by its smaller form ratio and less developed skew coiled juvenile volutions.

Occurrence.—Abundant in Type IIa limestone pebbles.

Material.—Axial section of the holotype; IGUT-KU0116. Axial sections of paratypes; IGUT-KU0118, IGUT-KU0121, IGUT-KU0124. Slightly oblique axial sections of paratypes; IGUT-KU0112, IGUT-

KU0113, IGUT-KU0115, IGUT-KU0119, IGUT-KU0126, IGUT-KU0127, IGUT-KU0129. Sagittal sections of paratypes; IGUT-KU0117, IGUT-KU0123, IGUT-KU0125, IGUT-KU0128. Tangential sections of paratypes; IGUT-KU0114, IGUT-KU0120, IGUT-KU0122, IGUT-KU0130.

Dunbarula sp. B

Figures 7-25–28

Remarks.—This unidentified species somewhat resembles *Dunbalula planata,* sp. nov. described above, but differs from the latter in having a larger form ratio.

Occrrence.—Rare in Type IIa limestone pebbles.

Material.—Axial sections; IGUT-KU0131, IGUT-KU0132, IGUT-KU0133. Sagittal section; IGUT-KU0134.

Genus *Lantschichites* Tumanskaya, 1953
Lantschichites ? sp.

Figure 9-20

Remarks.—The genus *Lantschichites* is most suitable for assigning this species, which has an elongate fusiform shell and rather intensely fluted septa. However, the generic assignment is tentative because an aberrant flaring lip, which is one of the most diagnostic features of the genus *Lantschichites,* is not seen in this specimen.

Occurrence.—Rare in Type IIb limestone pebbles.

Material.—Axial section; IGUT-KU0162.

Family Schwagerinidae Dunbar and Henbest, 1930
Subfamily Schwagerininae Dunbar and Henbest, 1930
Genus *Pseudofusulina* Dunbar and Skinner, 1931
Pseudofusulina fusiformis (Schellwien, 1909)

Figures 3-7–11

Fusulina vulgaris var. *fusiformis* Schellwien, 1909, p. 165-168, pl. 15, figs. 1-4.

Pseudofusulina fusiformis (Schellwien), Thompson, 1948, pl. 12, fig. 3 (same as pl. 15, fig. 2 of Schellwien, 1909, p. 165-168); Morikawa, 1955, p. 98-99, pl. 13, figs. 1-7; Igo, 1959, p. 246-247, pl. 3, fig. 5; Morikawa and Isomi, 1961, p. 19-20, pl. 7, figs. 11-12, pl. 8, figs. 12-13, pl. 10, figs. 1-10, pl. 11, figs. 1-10, pl. 12, figs. 1-10, pl. 13, fig. 5; Sheng, 1963, p. 66, 192-193, pl. 16, figs. 19-21; Kanmera and Mikami, 1965, p. 301-302, pl. 52, figs. 1-6; Kalmykova, 1965, p. 122-123, pl. 3, figs. 1-4; Kalmykova, 1967, p. 181-182, pl. 9, figs. 1-5; Choi, 1972, pl. 2, fig. 7; Choi, 1973, p. 46-47, pl. 9, figs. 1-3, pl. 11, fig. 4; Sakaguchi and Yamagiwa, 1975, p. 182-183, pl. 2, figs. 1-2, 11; Ozawa, 1975, pl. 9, fig. 16; Liu *et al.*, 1978, p. 59-60, pl. 13, fig. 1; Kahler and Kahler, 1980, p. 217-220, pl. 6, fig. 4, pl. 8, fig. 1; Ozawa and Kobayashi, 1990, pl. 8, fig. 14.

Pseudofusulina vulgaris var. *fusiformis* (Schellwien), Kanuma, 1959, p. 75-76, figs. 7-11.

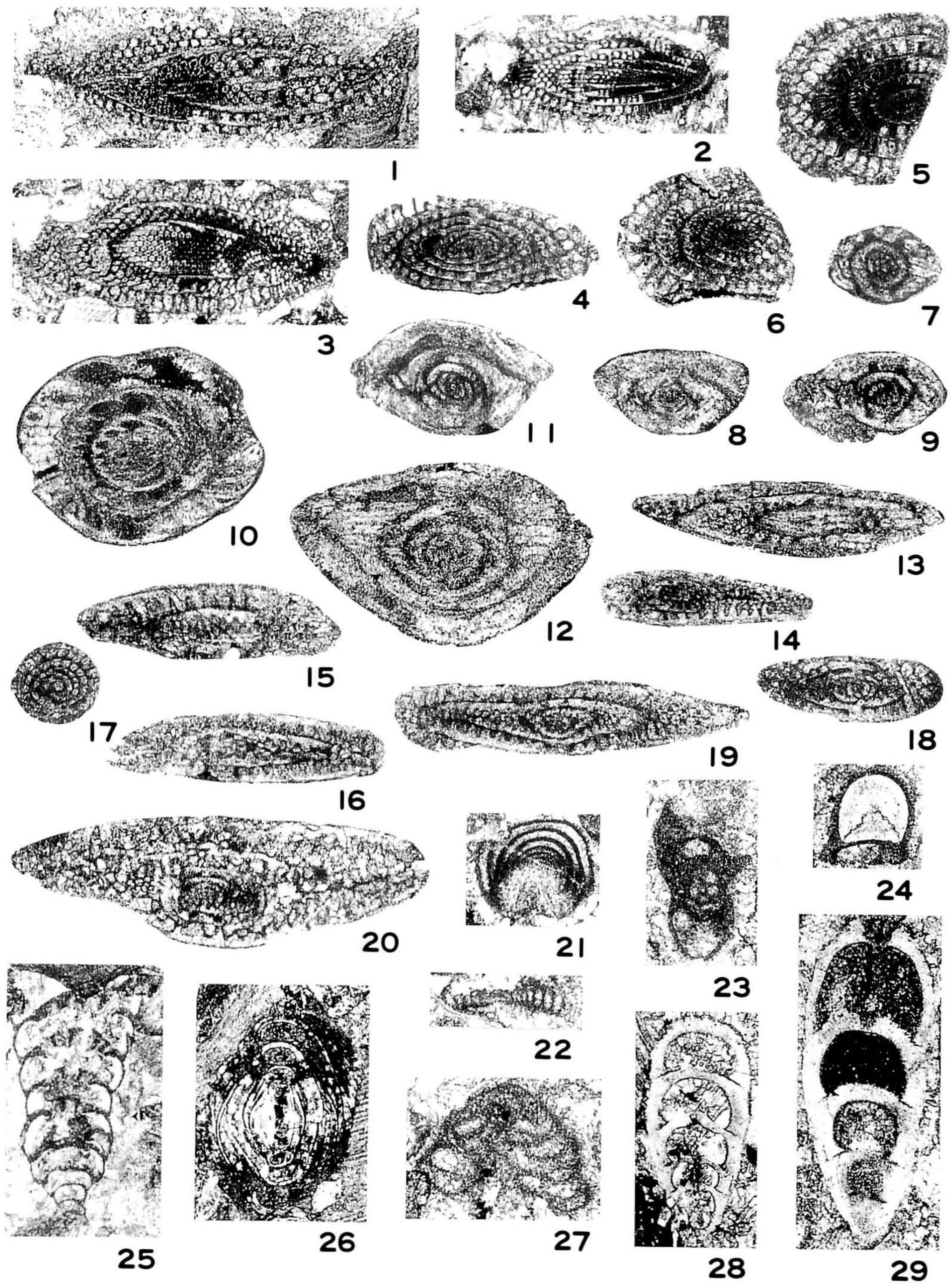
Schwagerina fusiformis (Schellwien), Suyari, 1962, p. 26, pl. 8, figs. 7-9.

Pseudofusulina cf. *fusiformis* (Schellwien), Yanagisawa, 1967, pl. 6, figs. 8, 10-11.

non *Schellwienia vulgaris* var. *fusiformis* (Schellwien), Lee, 1927, p. 67-68, pl. 9, figs. 3, 5.

Description.—Shell large, elongate cylindrical with bluntly pointed polar ends. Mature specimens having 5 ½ to 6 ½ volutions, 9.00 to 10.50 mm in length and 2.10 to 3.30 mm in width, giving form ratios of 2.72 to 3.70. Shell expands gradually through growth. Axis of coiling straight throughout. Radius vectors of the first to fifth volutions of illustrated axial section (Figure 3-9) 0.31, 0.48, 0.66, 0.90, and 1.13 mm, and form ratios 1.61, 2.50, 3.08, 3.44, and 3.70, respectively. Proloculus large and almost spherical. Its outside diameter ranges from 0.300 to 0.440 mm, averaging 0.390 mm for 3 specimens. Spirotheca composed of a tectum and keriotheca. Thickness of spirotheca of the first to fifth volutions of above-mentioned specimen 0.040, 0.050, 0.060, 0.100, and 0.070 mm. Septa intensely and regularly fluted except for central part of shell. Rudimentary chomata developed in inner volutions. Heavy axial fillings present.

Remarks.—The Takakurayama specimens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have a slightly larger form ratio than the topotypes restudied by Kalmykova (1965).

Occurrence.—Common in Type Ia limestone pebbles and rare in Type Ic limestone pebbles.

Material.—Axial sections; IGUT-KU0028, IGUT-KU0030. Sagittal sections; IGUT-KU0026, IGUT-KU0027. Tangential section; IGUT-KU0029.

Family Staffellidae Miklukho-Maklay, 1949

Genus *Quasireichelina* Ueno, gen. nov.

Type species.—*Quasireichelina expansa,* gen. et sp. nov.

Diagnosis.—Small staffellid having an early thickly lenticular and regularly coiled part and a later uncoiled, abruptly expanded one. Early part similar to *Nankinella.* Spirotheca thin and recrystallized. Septa numerous and unfluted. Secondary deposits as small chomata.

Remarks.—Previously, the Permian aberrant staffellids, both uncoiled and rectilinear forms, have been erroneously referred to a single genus, *Pseudoreichelina.* Recently, I discussed aberrant shell morphologies in the ozawainellid and staffellid fusulinaceans, and suggested the necessity to establish a new genus for the Permian uncoiled staffellids, if *"Pseudoreichelina" serbica* (Kochansky-Devidé) is surely included in the family Staffellidae (Ueno, 1992). The present new genus is created for those Permian aberrant staffellids having an uncoiled shell in the final stage of growth.

Quasireichelina, gen. nov. is most similar to the ozawainellid aberrant fusulinacean genus *Reichelina.* However they differ in spirothecal composition. This new genus differs from the staffellid aberrant fusulinacean genera *Palaeoreichelina* and *Pseudoreichelina* in having an uncoiled shell in the final stage of growth.

Besides the type species, *Reichelina serbica* described by Kochansky-Devidé (1960) from western Serbia should be referred to the present new genus.

Geologic age.—Middle Permian.

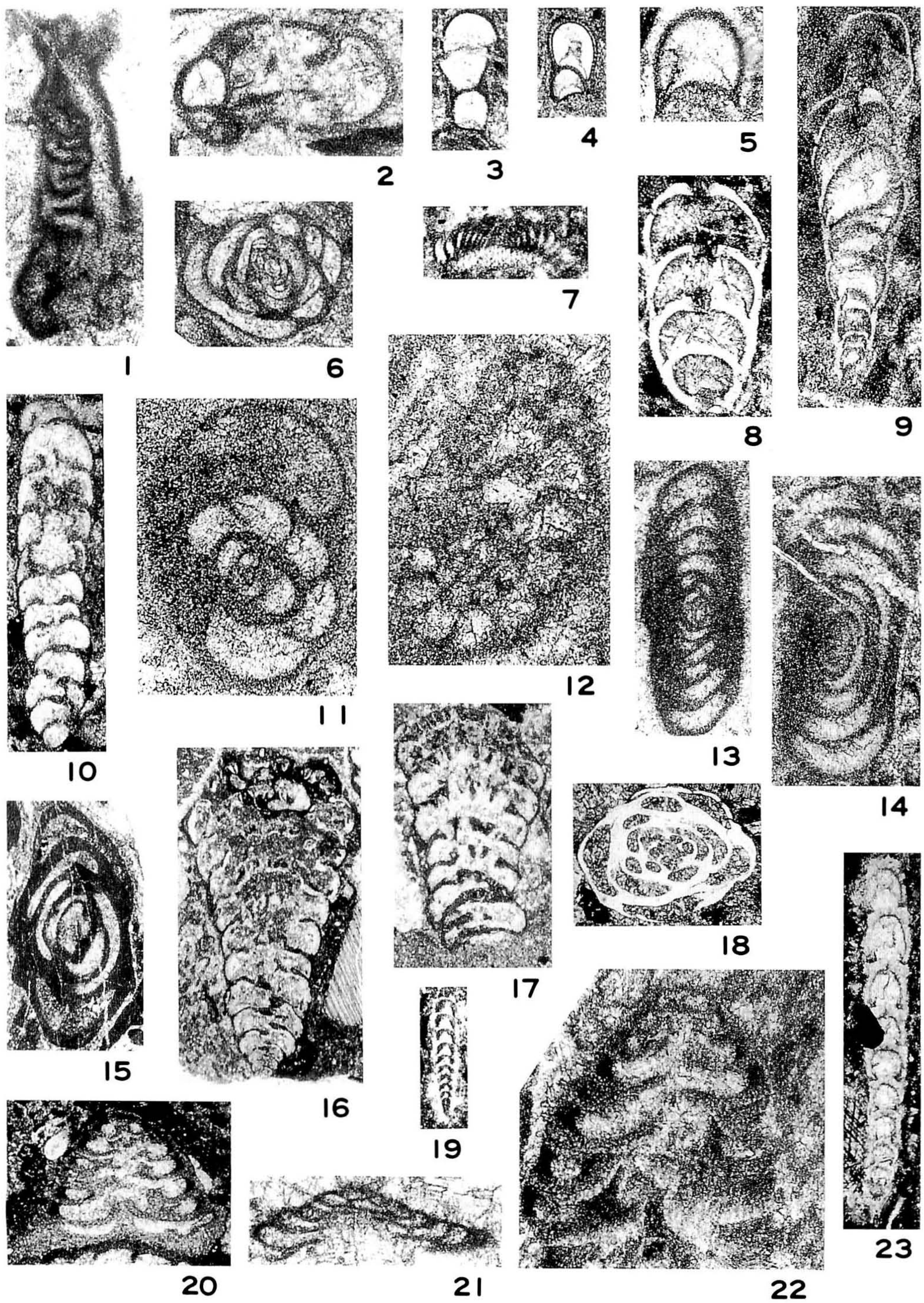
Quasireichelina expansa
Ueno, gen. et sp. nov.

Figures 8-1–8

Diagnosis.—Small *Quasireichelina* having a thickly lenticular early part with angular periphery and a later abruptly expanded uncoiled one. Septa numerous and slightly bend anteriorly.

Description.—Shell small, consisting of 2 parts and 1.25 to 1.38 mm in total length. Early part of probably 4 to 5 volutions thickly lenticular with angular periphery, and similar to *Nankinella.* Axial length and median width of early part 0.45 to 0.75 mm and 0.75 to 1.23 mm, giving form ratios of 0.44 to 0.61. Later part of last half-volution abruptly expanded and finally uncoiled. Coiling of inner few volutions usually uncertain because of high recrystallization of shell.

← **Figure 9.** Fusulinaceans and smaller foraminifers from Type IIb limestone pebbles. **1-6.** *Wutuella* cf. *wutuensis* (Kuo), **1-4**: tangential sections, IGUT-KU0143, IGUT-KU0144, IGUT-KU0145, IGUT-KU0146, **5, 6**: parallel sections, IGUT-KU0147, IGUT-KU0148. **7-9**: *Schubertella* sp. B, axial sections, IGUT-KU0149, IGUT-KU0150, IGUT-KU0151. **10**: *Neofusulinella* sp., tangential section, IGUT-KU0152. **11, 12**: *Schubertella*? sp. C, axial sections, IGUT-KU0153, IGUT-KU0154. **13-19.** *Minojapanella* (*M.*) *parva* Sheng, **13-16**: tangential sections, IGUT-KU0155, IGUT-KU0156, IGUT-KU0157, IGUT-KU0158, 17: sagittal section, IGUT-KU0159, **18, 19**: axial sections, IGUT-KU0160, IGUT-KU0161. **20**: *Lantschichites*? sp., axial section, IGUT-KU0162. **21, 22.** *Lasiodiscus* sp., **21**: equatrial section, IGUT-KU0163, **22**: tangential section, IGUT-KU0164. **23**: *Neoendothyra reicheli* Reitlinger, axial section, IGUT-KU0165. **24**: *Eotuberitina* sp., longitudinal section, IGUT-KU0166. **25**: *Climacammina* sp. C, longitudinal section, IGUT-KU0167. **26**: *Multidiscus* sp., axial section, IGUT-KU0168. **27**: *Tetrataxis* sp., axial section, IGUT-KU0169. **28, 29**: *Langella* spp., longitudinal sections, IGUT-KU0170, IGUT-KU0171. **1-3, 25**: ×20, **4-24, 26-29**: ×40.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Spirotheca *Nankinella*-type and replaced by secondary mineralization. Septa numerous and slightly bend anteriorly. Secondary deposits probably small chomata.

Remarks.—*Quasireichelina expansa,* gen. et sp. nov. is somewhat similar to Q. *serbica* (Kochansky-Devidé), but differs from the latter in having a smaller and more thickly lenticular shell.

The early regularly coiled part of *Quasireichelina expansa,* gen. et sp. nov. quite resembles certain species of the genus *Nankinella,* such as *N. kawadai* (Igo). However, the former can be easily distinguished from the latter in having an uncoiled shell in the final stage of growth.

Occurrence.—Common in Type IIa limestone pebbles.

Material.—Axial section of the holotype; IGUT-KU0136. Axial sections of paratypes; IGUT-KU0135, IGUT-KU0139, IGUT-KU0140, IGUT-KU0142. Sagittal sections of paratypes; IGUT-KU0137, IGUT-KU0138, IGUT-KU0141.

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 4-21

Descriptive remarks.—Shell small and almost spherical with 6 volutions, 0.96 mm in length and 0.85 mm, giving a form ratio of 1.13. Inner 2 volutions slightly skew coiled. Spirotheca composed of a tectum and keriotheca. Parachomata semicircular in transverse section and developed beyond the third volution.

This unidentified species somewhat resembles *Misellina* (*Brevaxina*) *dyhrenfurthi* (Dutkevich). At any rate, exact identification is postponed until additional specimens are obtained.

Occurrence.—Rare in Type Ic limestone pebbles.

Material.—Slightly oblique axial section; IGUT-KU0054.

Subfamily Pseudodoliolininae Leven, 1963

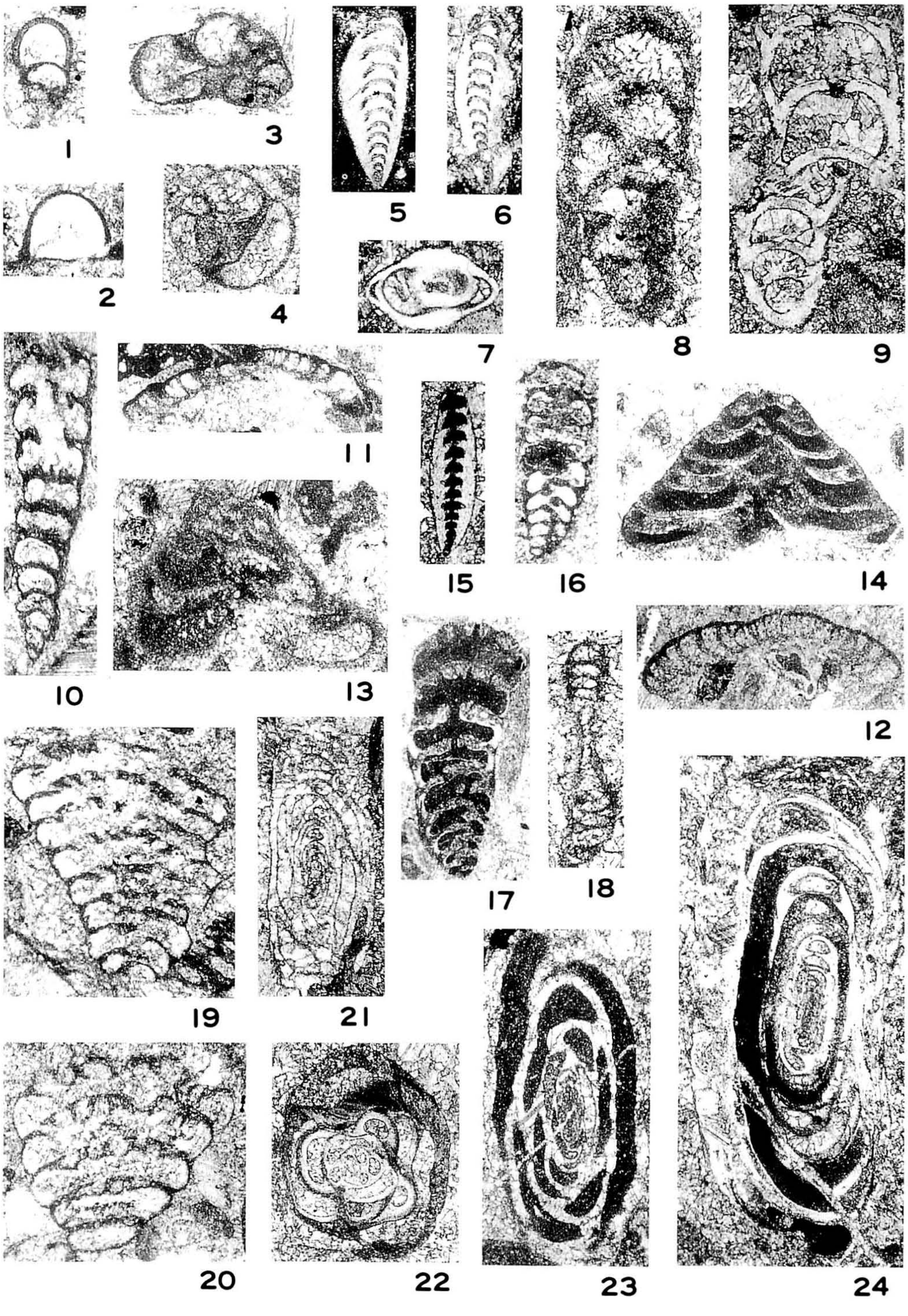
Genus *Pseudodoliolina* Yabe and Hanzawa, 1932

Pseudodoliolina aff. *pseudolepida* (Deprat, 1912)

Figures 7-1–5

Remarks.—The synonym list is followed by Ueno (1991). The present form somewhat resembles *Pseudodoliolina pseudolepida* (Deprat) in general shell form and the nature of parachomata. However, the former has a much smaller proloculus than the latter.

← **Figure 10.** Smaller foraminifers from Type I limestone pebbles. **1**: *Ammovertella* sp., longitudinal section, IGUT-KU0172. **2**: *Globivalvulina* sp., lateral section, IGUT-KU0173. **3, 4**: *Tuberitina* spp., longitudinal sections, IGUT-KU0174, IGUT-KU0175. **5**: *Eotuberitina* sp., longitudinal section, IGUT-KU0176. **6**: *Glomospira* sp., horizontal section, IGUT-KU0177. **7**: *Lasiodiscus* sp., axial section, IGUT-KU0178. **8**: *Langella* sp., longitudinal section, IGUT-KU0179. **9**: *Ichthyolaria*? sp., longitudinal section, IGUT-KU0180. **10**: *Deckerella* sp., lateral section, IGUT-KU0181, **11**: *Neoendothyra* sp., axial section, IGUT-KU0182. **12**: *Spiroplectammina* sp., longitudinal section, IGUT-KU0183. **13, 14**: *Neohemigordius* sp., axial sections, IGUT-KU0184, IGUT-KU0185. **15**: Involutinidae gen. et sp. indet. B, tangential section, IGUT-KU0186. **16, 17**: *Climacammina tenuis* Lin, longitudinal sections, IGUT-KU0187, IGUT-KU0188. **18**: *Agathammina* sp., transverse section, IGUT-KU0189. **19**: *Pachyphloia* sp., lateral section, IGUT-KU0190. **20**: *Tetrataxis* sp. D, axial section, IGUT-KU0191. **21**: *Tetrataxis* sp. B, axial section, IGUT-KU0192. **22**: *Tetrataxis* sp. C, axial section, IGUT-KU0193. **23**: *Nodosaria*? sp., longitudinal section, IGUT-KU0194. **10, 15–17, 20**: ×20, **1–4, 6–8, 13, 14, 18, 21–23**: ×40, **19**: ×60, **9**: ×75, **5, 11, 12**: ×100.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Occurrence.—Common in the Type IIa limestone pebble.

Material.—Oblique section; IGUT-KU0107. Sagittal sections; IGUT-KU0109, IGUT-KU0110, IGUT-KU0111. Tangential section; IGUT-KU0108.

Family Neoschwagerinidae Dunbar and Condra, 1927
Subfamily Lepidolininae Miklukho-Maklay, 1958
Genus *Colania* Lee, 1933
Colania sp.

Figure 5-6

Remarks.—I obtained only one tangential section of this form, which has a fusiform shell, thin spirotheca and septa, well developed primary transverse septula, and no secondary ones (see Figure 5-6b). Although the present specimen is not exactly oriented, it can be assigned to the genus *Colania* by its shell shape and nature of spirotheca, septa, and primary transverse septula.

Occurrence.—Rare in the matrix of the conglomerate member in the Motomura Formation.

Material.—Tangential section; IGUT-KU0070.

Suborder Miliolina Delage and Hérouard, 1896
Superfamily Miliolacea Ehrenberg, 1839
Family Fischerinidae Millett, 1898
Subfamily Hemigordiopsinae Nikitina, 1969
Genus Neodiscus Miklukho-Maklay, 1953

Type species.—*Neodiscus milliloides* Miklukho-Maklay, 1953.

Diagnosis.—Shell discoidal to thickly lenticular, usually involute. Last few volutions evolute in some forms. Spherical proloculus followed by enrolled undivided tubular second chamber. Coiling streptospiral in inner few volutions, but essentially planispiral in outer ones. Wall calcareous, porcelaneous and imperforate, resulting in a brown-colored and fibrous appearance. Dark microgranular lateral fillings prominent. Aperture at end of tubular chamber.

Remarks.—Miklukho-Maklay (1953) originally assigned the genus *Neodiscus* to the family Archaediscidae. However, this genus has a porcelaneous wall with brown colored and fibrous appearance, whereas archaediscid foraminifers have a clear hyaline wall with radial structure. The genus *Neodiscus* is surely referable to the suborder Miliolina in its wall composition.

Lin *et al.* (1990) considered that the genus *Neohemigordius,* which Wang and Sun (1973) originally established with *N. maopingensis* as the type species, is a junior synonym of the genus *Neodiscus.* However, the former genus has a dark granular wall and should be assigned to the suborder Involutinina, although their general shell form and the mode of

← **Figure 11.** Smaller foraminifers from Type IIa limestone pebbles. **1**: *Tuberitina* sp., longitudinal section, IGUT-KU0195. **2**: *Eotuberitina* sp., longitudinal section, IGUT-KU0196. **3, 4**: *Globivalvulina* spp., lateral sections, IGUT-KU0197, IGUT-KU0198. **5-7.** *Pachyphloia ovata* Lange, **5**: longitudinal section, IGUT-KU0199, **6**: lateral section, IGUT-KU0200, **7**: transverse section, IGUT-KU0201. **8**: *Spiroplectammina* sp., longitudinal section, IGUT-KU0202. **9**: *Langella* sp., longitudinal section, IGUT-KU0203. **10**: *Deckerella* sp., lateral section, IGUT-KU0204. **11, 12**: *Polytaxis* sp., axial sections, IGUT-KU0205, IGUT-KU0206. **13, 14**: *Tetrataxis* sp. A, axial sections, IGUT-KU0207, IGUT-KU0208. **15**: *Pachyphloia* sp., lateral section, IGUT-KU0209. **16, 17**: *Climacammina* sp. A, longitudinal sections, IGUT-KU0210, IGUT-KU0211. **18**: *Ammodiscus*? sp., axial section, IGUT-KU0212. **19, 20.** *Climacammina* sp. B, **19**: longitudinal section, IGUT-KU0213, **20**: lateral section, IGUT-KU0214. **21**: *Agathammina* sp. A, longitudinal section, IGUT-KU0215. **22-24.** *Agathammina maxima* Xia and Zhang, **22**: transverse section, IGUT-KU0216, **23**: slightly oblique longitudinal section, IGUT-KU0217, **24**: longitudinal section, IGUT-KU0218. **10-12, 16, 17, 19, 20**: ×20, **1-7, 9, 13-15, 21-24**: ×40, **8, 18**: ×100.

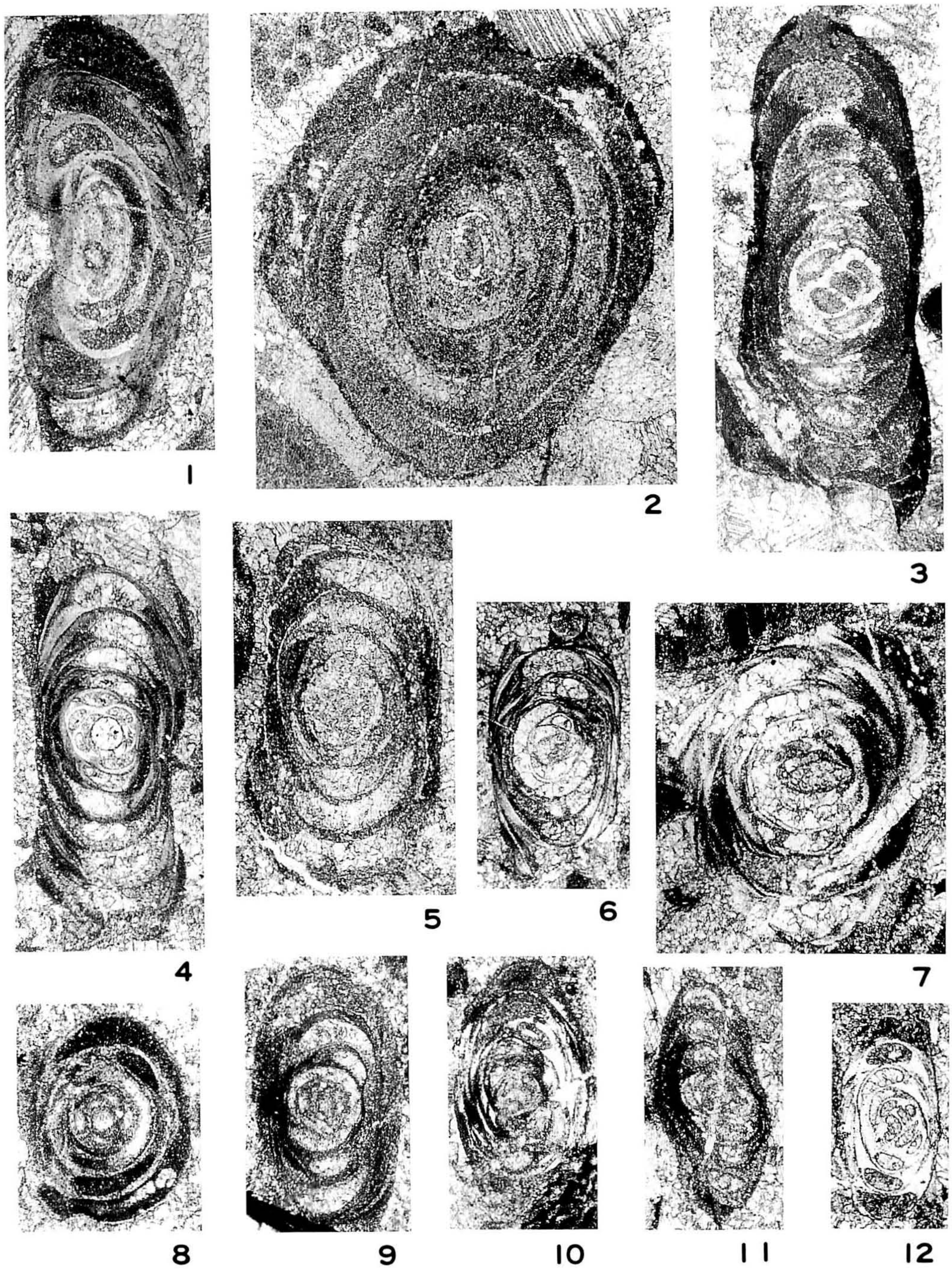

Figure 12. Smaller foraminifers from the Type IIa limestone pebble. **1–4.** *Neodiscus mirabilis,* sp. nov., **4**: axial section of the holotype, IGUT-KU0222, **1, 3**: tangential sections of paratypes, IGUT-KU0219, IGUT-KU0221, **2**: sagittal section of paratype, IGUT-KU0220. **5–10.** *Neodiscus ovata* (Grozdilova), **5, 6, 9, 10**: axial sections, IGUT-KU0223, IGUT-KU0224, IGUT-KU0227, IGUT-KU0228, **7**: oblique section, IGUT-KU0225, **8**: sagittal section, IGUT-KU0226. **11**: *Neodiscus* sp. A, axial section, IGUT-KU0229. **12**: *Neodiscus* sp., tangential section, IGUT-KU0230. All ×40.

coiling in the second tubular chamber are quite similar to each other.

This genus somewhat resembles *Hemigordius,* but differs from the latter in having a more thickly lenticular and almost involute shell and well developed microgranular lateral fillings.

Neodiscus mirabilis Ueno, sp. nov.

Figures 12-1–4

Diagnosis.—Large *Neodiscus* having a discoidal shell with rounded periphery and shallow umbilicus. Outer few volutions evolute. Juvenalium consisting of 3 volutions and coiled glomospirally. Dark microgranular lateral fillings present in planispiral volutions.

Description.—Shell discoidal with rounded periphery and slightly umbilicated axial regions, and involute except for outer 2 volutions. Spherical proloculus followed by enrolled undivided tubular second chamber. Mature specimens having 8 to 9 volutions, 0.55 to 0.68 mm in axial length and 1.63 to 1.98 mm in median width, giving form ratio of about 0.35. Initial chamber spherical, being 0.14 mm in outside diameter. Second chamber gradually enlarging in height through growth. Coiling streptospiral in inner 3 volution but essentially planispiral in outer ones. Radius vectors of the first to ninth volution of the holotype 0.10, 0.14, 0.16, 0.17, 0.24, 0.36, 0.48, 0.63, and 0.81 mm, respectively. Wall calcareous and porcelaneous with fibrous and brown colored appearance. Wall thickness of the first to eighth volutions of the holotype 0.005, 0.010, 0.015, 0.020, 0.025, 0.025, 0.020, and 0.020 mm. Dark microgranular lateral fillings well developed in all volutions except for glomospirally coiled juvenile ones, resulting in the formation of a one-sidedly depressed oval lumen. Aperture at end of tubular chamber.

Remarks.—*Neodiscus mirabilis,* sp. nov. differs from *N. milliloides* Miklukho-Maklay, the type species of the genus, in having a smaller and more discoidal shell.

The present new species somewhat resembles *Neodiscus ovata, N. longus,* and *N. permicus* originally described by Grozdilova (1956) from the upper Artinskian of the eastern slope of the Ural Mountains. However, the former can be distinguished from *Neodiscus ovata* (Grozdilova) in having a larger and more discoidal shell, and from *N. longus* (Grozdilova) and *N. permicus* (Grozdilova) in having a larger shell.

Occurrence.—Rare in Type IIa limestone pebbles.

Material.—Axial section of the holotype; IGUT-KU0222. Sagittal section of paratype; IGUT-KU0220. Tangential sections of paratypes; IGUT-KU0219, IGUT-KU0221.

Acknowledgments

I wish to thank Prof. Hisayoshi Igo of the University of Tsukuba for critical reading of this manuscript, and Prof. Sumio Sakagami of Chiba University for valuable suggestion during the course of this work. I also wish to thank Mr. Yutaka Tanaka for his kind cooperation in the field.

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南部阿武隈山地，高倉山層群からのペルム紀有孔虫類：阿武隈山地南部，高倉山層群元村層下部の含石灰岩レキ岩から 74 タクサの有孔虫類を識別した。このレキ岩層中に見られる石灰岩レキはその岩相と含まれる有孔虫類によってタイプ Ia, Ib, Ic, IIa, IIb の 5 種類に分けられる。タイプ I に属する石灰岩レキは砕屑物質を含まない pure limestone で，*Chalaroschwagerina vulgaris* (Schellwien), *Pseudofusulina fusiformis* (Schellwien), *Toriyamaia laxiseptata* Kanmera, *Minojapanella (M.) elongata* Fujimoto and Kanuma,

Misellina (Brevaxia) sp. 等の前期ペルム紀の Yakhtashian から前期 Bolorian を示すフズリナ類が含まれている。一方，タイプ II の石灰岩レキは少量の火山砕屑物を含む impure limestone で，タイプ IIa からは *Yangchenia* cf. *iniqua* Lee, *Pseudodoliolina* cf. *ozawai* Yabe and Hanzawa, *P.* aff. *pseudolepida* (Deprat) が，タイプ IIb からは *Wutuella* cf. *wutuensis* (Kuo), *Minojapanella (M.) parva* Sheng, *Lantschichites* ? sp. が識別された。これらタイプ IIa, タイプ IIb の示す時代はそれぞれ前期 Murgabian, 後期 Murgabian と考えられる。さらに，このレキ岩の基質中からは後期 Murgabian を示す *Colania* sp. が発見された。高倉山層群はこれまで主に柏平層から産出する頭足類によって中期ペルム紀の前期 Guadalupian とされていた。今回，元村層レキ岩中のタイプ IIb および基質中より後期 Murgabian (後期 Guadalupian) を示すフズリナ類が発見されたことにより，高倉山層群の時代も中期ペルム紀後期（後期 Murgabian）と考えることができる。本論ではこれら有孔虫類のうち 1 新属 (*Quasireichelina*), 4 新種 (*Codonofusiella abukumaensis, Dunbarula planata, Quasireichelina expansa, Neodiscus mirabilis*) を含む 19 種 (フズリナ類 18 種，小型有孔虫類 1 種) を記載する。 上野勝美

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 168, pp. 1296-1310, 6 Figs., December 30, 1992

945. TRIASSIC RADIOLARIANS FROM A LIMESTONE EXPOSED AT KHAO CHIAK NEAR PHATTHALUNG, SOUTHERN THAILAND*

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Abstract. We recovered well-preserved Triassic radiolarians from a thin-bedded limestone exposed at Khao Chiak, near Phatthalung, southern Thailand. This radiolarian fauna is associated with conodonts indicating a latest Spathian to earliest Anisian age and composed of families such as "Paleozoic-type" Entactiniidae, Actinommidae, spicule-type Palaeoscenidiidae, and acanthodesmid Nassellaria. We propose a new genus and four new species herein. The occurrence of the genera *Entactinia* Foreman and *Polyentactinia* Foreman is the first record from the Triassic.

Key words. Triassic radiolarians, conodonts, bedded limestone, Entactiniidae, southern Thailand.

Introduction

Limestones distributed around Phatthalung, southern Thailand have been regarded as the southern extension of the Permian Rat Buri (or Ratburi) Limestone by Thailand geologists. Recently, Igo *et al.* (1988) reported the occurrence of Anisian (early Middle Triassic) conodonts from a limestone exposed at the quarry of Khao Chiak, near Phatthalung. From this discovery, it becomes clear that the limestones of this area range from the Permian to Middle Triassic.

In 1990, we made a field survey in the Phatthalung area and collected limestone samples from the same quarry of Khao Chiak. These samples were dissolved by acetic acid, and we obtained abundant well-preserved radiolarian remains in association with discrete elements of conodonts, which indicate latest Spathian to earliest Anisian from residue of one sample. This radiolarian fauna includes abundant "Paleozoic-type" entactiniids and actinommids, which exceed more than 90% of the total identified specimens. Spicule-type palaeoscenidiids and acanthodesmid Nassellaria are also discriminated in this fauna. To date, the occurrence of the genera *Entactinosphaera* and *Helioentactinia* of the family Entactiniidae has been reported only from the Triassic limestone of the European Alps by Kozur and Mostler (1979, 1981). The entactiniid genera *Entactinosphaera* Foreman and *Polyentactinia* Foreman have never been known to occur in the Mesozoic. The occurrence of these entactiniid radiolarians from Triassic rocks provides important evidence in understanding evolution and phylogeny of this family.

*Received June 5, 1992; revised manuscript accepted September 27, 1992

Acknowledgments

Our field survey was supported by a grant under the Monbusho International Research Program, No. 02140210. We would like to acknowledge the Department of Mineral Resources of Thailand for facilities to carry out our research in Thailand. We also express our sincere thanks to Mr. Nikorn Nakornsri of the Geological Survey Division, Department of Mineral Resources, Thailand and Dr. Ken-ichiro Hisada and Miss Apsorn Ampornmaha of the University of Tsukuba for their kind cooperation in the field.

Geologic setting

Limestones forming many isolated hills surrounded by steep cliffs and with spectacular pinnacles at their tops or with a flat top are distributed around Phatthalung City, southern Peninsular Thailand. Series of these limestone hills extend further south and cross the national border of Thailand and Malaysia. These limestones had long been regarded as the Permian Rat Buri (or Ratburi) Limestone or Group in Thailand (*e.g.*, Brown *et al.*, 1951 ; Bunopass, 1983) and the Chuping Limestone in Perlis and north Kedah, Malaysia (*e.g.,* Jones, 1962). Jones *et al.* (1966) proposed a new term of the Kodiang

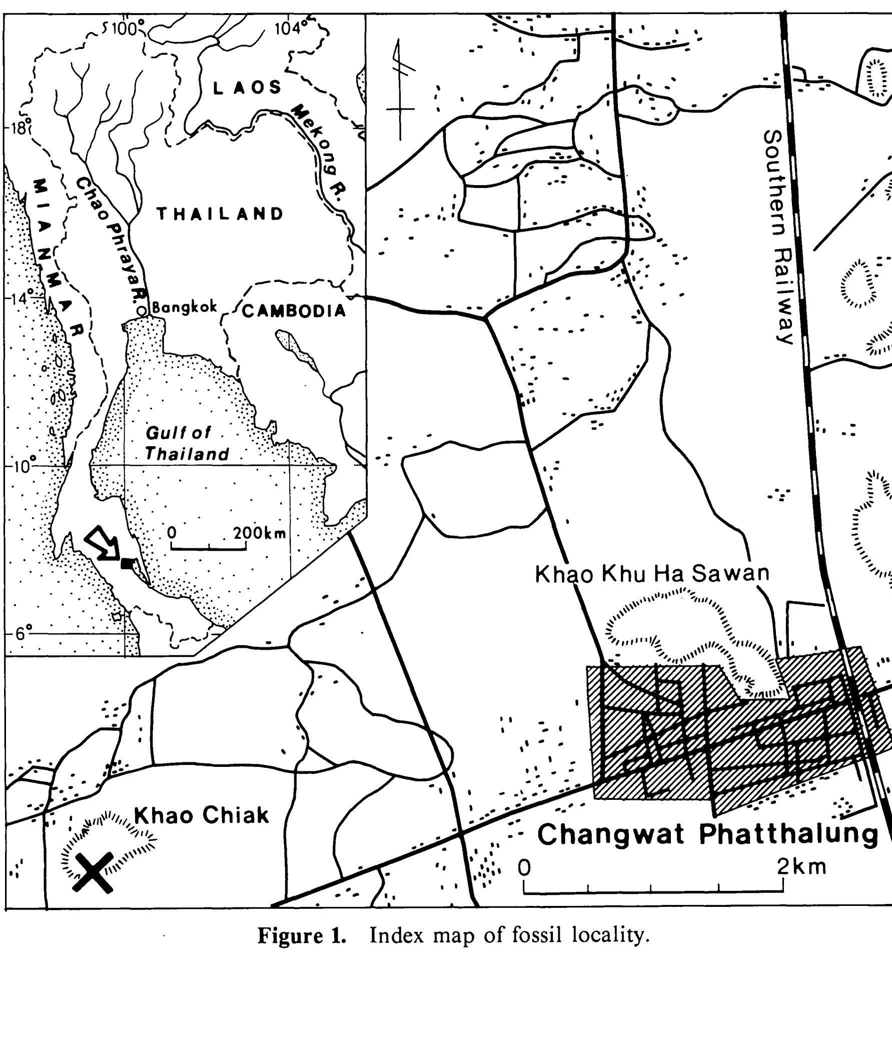


Figure 1. Index map of fossil locality.

Limestone because Triassic microfossils were recovered from some of these limestones, which were regarded as the Chuping Limestone (*e.g.*, Ishii and Nogami, 1966; Koike, 1973; Fontaine *et al.*, 1988).

Lithology and fossil contents of this limestone differ from that of the typical Permian Ratburi Limestone (*e.g.*, Sakagami, 1966, 1969; Yanagida, 1970). Therefore, a new term for these Triassic limestones seems to be necessary, but the proposal should be postponed because the stratigraphic relationship between the Permian and Triassic limestones cannot be settled in the Phatthalung area at present.

Khao Chiak, one of these isolated lime-

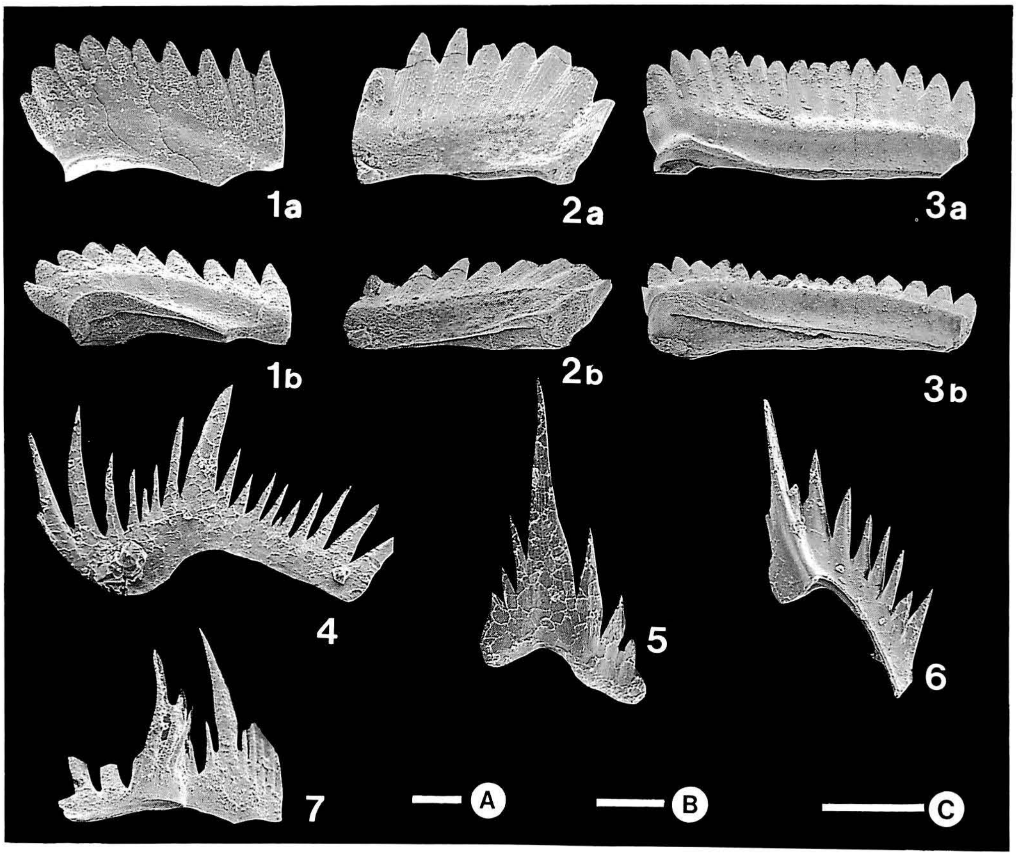
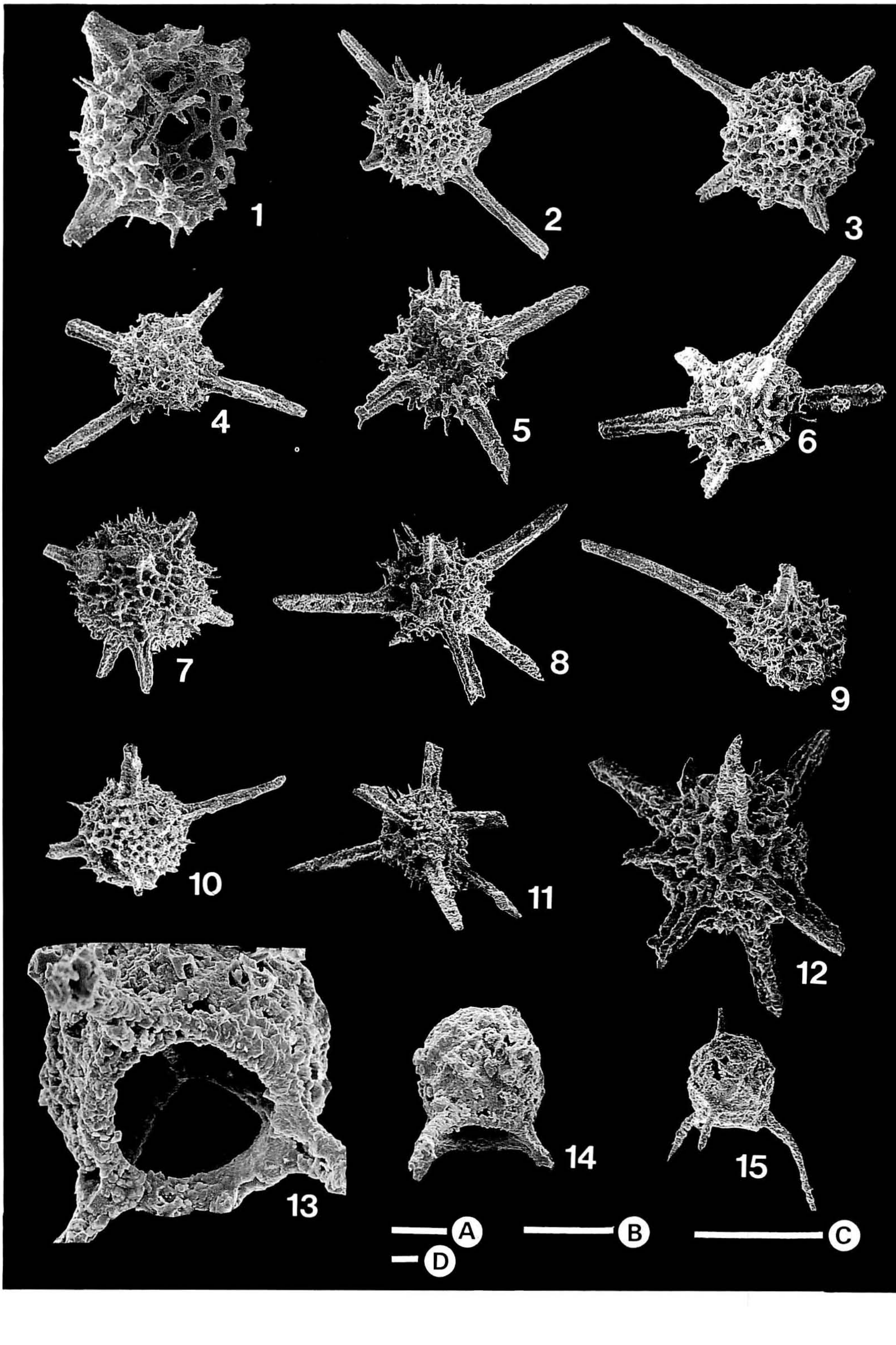


Figure 2. Conodonts from the sample PAT-1. **1, 2,** *Neospathodus homeri* (Bender), **1**: Lateral (a) and lateral aboral (b) views; **2**: Lateral (a) and lateral aboral (b) views. **3,** *Neospathodus timorensis* (Nogami), Lateral (a) and lateral aboral (b) views. **4**: *Neohindeodella aequiramosa* Kozur and Mostler. **5, 6**: *Enantiognathus* sp. **7**: *Veghella* ? sp. Scale bars, A to C equal to 100 μm; A applies to **1, 3,** B to **2, 6, 7** and C to **4, 5.**

→ **Figure 3.** **1–12,** *Entactinia nikorni* Sashida and Igo, n. sp., **1**: Internal view showing the internal spicule, IGUT-KS0015; **2**: Holotype, IGUT-KS0001; **3**: Paratype, IGUT-KS0017; **4**: Paratype, IGUT-KS0019; **5**: Paratype, IGUT-KS0016; **6**: Paratype, IGUT-KS0020; **7**: Paratype, IGUT-KS0021; **8**: Paratype, IGUT-KS0022; **9**: IGUT-KS0025; **10**: Paratype, IGUT-KS0029; **11**: Paratype, IGUT-KS0031; **12**: IGUT-KS0035. **13–15,** *Hozmadia* ? sp., **13**: Internal view showing disposition of the internal spicule, IGUT-KS0050; **14**: IGUT-KS0050; **15**: IGUT-KS0049. Scale bars, A to C equal to 100 μm and D to 10 μm; A applies to **2, 4, 7, 9–11,** B to **3, 5, 6, 12,** C to **1, 14,** and D to **13.**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stone hills, lies 5 to 6 km west of the city area of Phatthalung and is mostly thickly covered by heavy tropical scrubby vegetation. Fortunately, the southern cliff of this hill is quarried for construction rubble by local people and one can measure almost successively an about 150-m thick section. This limestone generally strikes N-S and dips 30 to 80 degrees eastward and is characteristically thin bedded, frequently laminated, fine grained, pale gray to dark gray and partly pinkish to maroon. Dark-gray to transparent, cobble- to pebble-size lenticular to nodular chert, and thin rather continuous layers of chert are frequently intercalated in the micritic part. Stylolites developed mostly parallel with a bedding plane are very common in micritic limestone. Megafossils are rare throughout this limestone, but fragments of small-sized gastropods and pelecypods are occasionally seen in several levels.

We collected 20 samples, each weighing about 2 kg, from different stratigraphic levels at about 5-m intervals along the quarry wall. Most of the samples yielded well-preserved conodonts in association with fish teeth and holothurian sclerites (Figure 6-3—8), but the well-preserved radiolarians described in this paper were recovered only from one sample (PAT-l), which came from the lowest level of this section. Moreover, radiolarian remains can be occasionally seen in limestones of other higher levels, but we failed to recover them by the ordinary acetic acid treatment mentioned below.

Method and techniques

Radiolarian specimens were separated from limestone samples in the following manner:

1) Limestone samples are crushed into small fragments of several centimeters size.

2) Crushed samples are placed in a dilute acetic acid solution (5 to 10%) for 24 hours.

3) Samples are washed and sieved using a mesh of 50-μm opening. The residue is dried in an oven.

Radiolarian specimens are placed on the stubs for Scanning Electron Microscopy observation and also mounted on glass slides with Enthelan New or Canada Balsam for measurements by using a transmitted-light microscope.

Age of sample

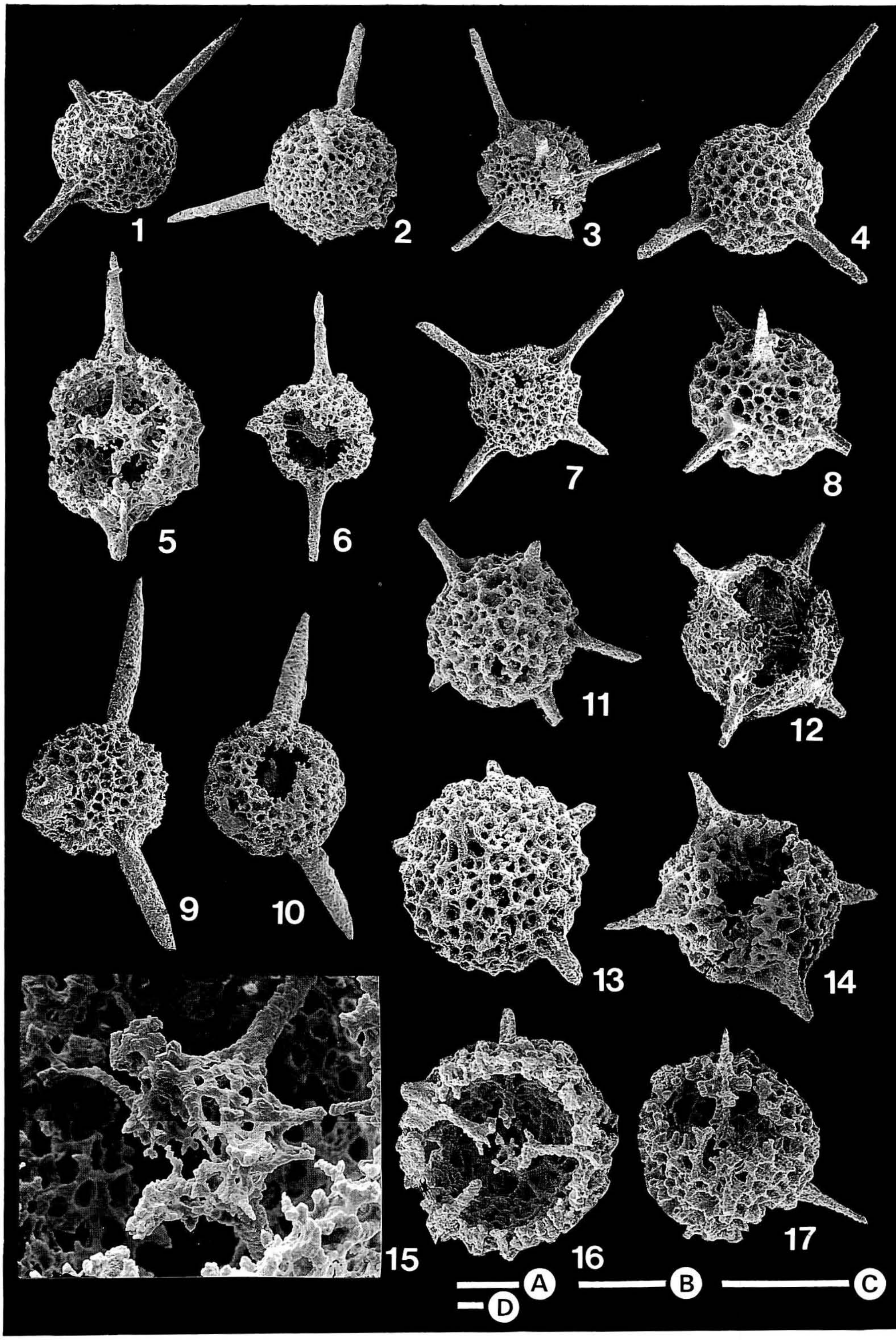
The sample (PAT-1) yielded abundant well-preserved discrete elements of conodont including *Neospathodus homeri* (Bender), *N. timorensis* (Nogami), *Neohindeodella acquiramosa* Kozur and Mostler, *N. triassica* (Müller), and others. The joint occurrence of *Neospathodus homeri* and *N. timorensis* indicates that this conodont fauna is of latest Spathian to early Aegian (earliest Anisian) age and seems to be slightly older than that described by Igo *et al.* (1988) from the same limestone quarry.

Systematic description

All types and figured specimens in this paper are deposited in the Institute of Geoscience, University of Tsukuba (IGUT).

Suborder Spumellaria Ehrenberg, 1875
Superfamily Entactiniacea Riedel, 1967
Family Entactiniidae, Riedel 1967

→ **Figure 4. 1-7, 9, 10, 15,** *Entactinosphaera chiakensis* Sashida and Igo, n. sp., **1**: Paratype, IGUT-KS0003; **2**: Paratype, IGUT-KS0041; **3**: Paratype, IGUT-KS0044; **4**: Paratype, IGUT-KS0042; **5**: Broken specimen showing the internal shell, IGUT-KS0042; **6**: Broken specimen showing the internal shell and internal spicule, IGUT-KS0063; **7**: Paratype, IGUT-KS0045; **9**: IGUT-KS0046; **10**: IGUT-KS0048; **15**: Enlargement of the internal shell of **5**, showing the internal spicule. **8, 11-14, 16, 17,** *Thaisphaera minuta* Sashida and Igo, n. gen. and n. sp., **8**: Holotype, IGUT-KS0004; **11**: Paratype, IGUT-KS0073; **12**: Paratype, IGUT-KS0072, note needlelike by-spines on the outer surface of internal shell; **13**: Paratype, IGUT-KS0075; **14**: IGUT-KS0077; **16**: Broken specimen showing the internal shell, IGUT-KS0074; **17**: IGUT-KS0071. Scale bars, A to C equal to 100 μm and D to 10 μm; A applies to **1-4, 6, 7, 9, 10,** B to **5, 8, 11, 12,** C to **13, 14, 16, 17,** and D to **15.**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emend. Holdsworth 1977

Remarks.—Goodbody (1986) emended this family as the superfamily Entactiniacea with a latticed spherical shell and inner spicule, irrespective of the type of inner spicule. As already discussed by Furutani (1990) and Wakamatsu *et al.* (1990), however, disposition of the inner spicule is a distinguishing criterion between the families Palaeoscenidiidae and Entactiniidae. In this study, we follow the definitions of these two families by the latter authors.

Genus *Entactinia* Foreman, 1963
Entactinia nikorni Sashida and Igo, n. sp.

Figures 3-1—12.

Diagnosis.—*Entactinia* with a small, spherical and latticed shell, six to eight three-bladed main spines and numerous by- spines on shell surface.

Description.—Shell small and spherical with six to eight massive main and numerous secondary spines. The main spine is sturdy, three-bladed and gradually tapers distally. Its length is about one and a half to twice the shell diameter. Internal framework consists of eccentrically placed six-rayed spicule, which is very short bar (median bar) centered, thin, rodlike, and joins main spines at the inner surface of shell. In the present new species, projection of spicule to a perpendicular plane to median bar (Furutani, 1983), has the spicule of Type 1 (Furutani, 1990). Secondary spines arising from corners of interpore lattice are rodlike and taper rapidly. Shell wall is rather thick, penetrated by variously sized rounded pores. More than 30 pores are counted on the hemisphere.

Remarks.—No species belonging to this genus have been reported from Mesozoic strata. *Entactinia nikorni,* n. sp. resembles *Entactinosphaera triassica* Kozur and Mostler and *Parentactinosphaera oertlii* Kozur and Mostler reported from the Triassic limestone of Austria in general shell shape. The latter two Austrian species, however, differ from the former in having two spherical shells. The present new species is also similar to *Entactinia itsukaichiensis* Sashida and Tonishi reported from a chert of the Upper Permian in the Kanto Mountains, central Japan, but the latter species is distinguished from the former in having a smaller spherical shell and sturdier main spines.

Dimensions.—Based on 25 specimens (in μm): shell diameter 165-210 (average 175); length of main spine 185-290 (average 220); length of secondary spine 65-95 (average 78); wall thickness 25-40 (avergae 32); pore diameter 15-65 (average 22).

Etymology.—The species *nikorni* is named for Mr. Nikorn Nakornsri, senior geologist of the Geological Survey Division, Department of Mineral Resources, Thailand in honor of his contribution to the Paleozoic and Mesozoic geology in Thailand.

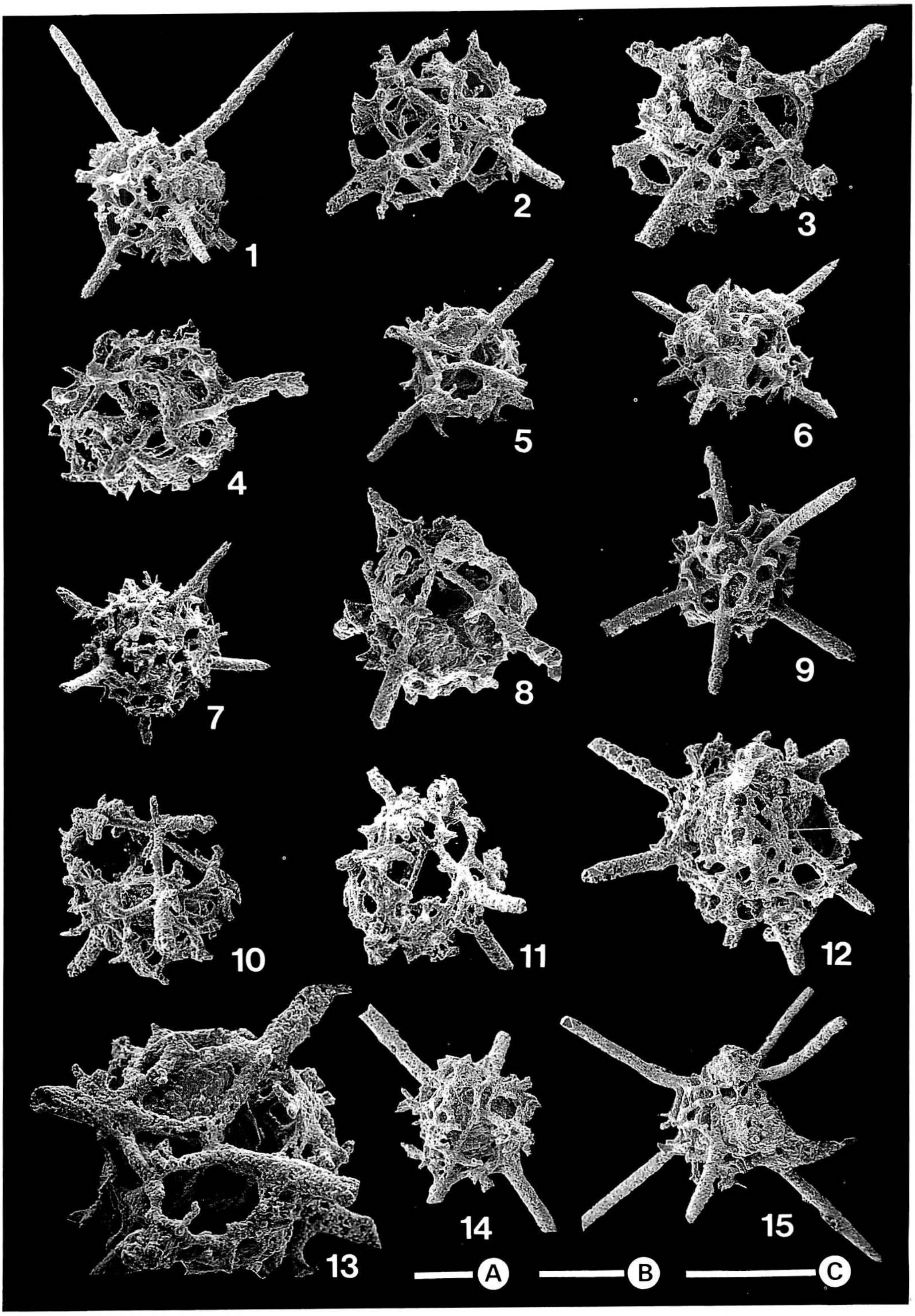
Type.—Holotype (Figure 3-2), IGUT-KS0001.

Genus *Entactinosphaera* Foreman, 1963
Entactinosphaera chiakensis Sashida and Igo, n. sp.

Figures 4-1—7, 9, 10, 15.

Diagnosis.—*Entactinosphaera* with a small, spherical, latticed shell, and three to six rodlike spines.

→ **Figure 5. 1-15,** *Polyentactinia* ? *phatthalungensis* Sashida and Igo, n. sp., **1**: Holotype, IGUT-KS0005; **2**: IGUT-KS0085; **3**: Paratype, IGUT-KS0081; **4**: IGUT-KS0082; **5**: Paratype, IGUT-KS0081; **6**: Paratype, IGUT-KS0087; **7**: Paratype, IGUT-KS0089; **8**: IGUT-KS0088; **9**: Paratype, IGUT-KS0090; **10**: IGUT-KS0091; **11**: Paratype, IGUT-KS0095; **12**: Paratype, IGUT-KS0093; **13**: Enlargement of **5,** showing the entactinid internal spicule; **14**: Paratype, IGUT-KS0097; **15**: Paratype, IGUT-KS0094. Scale bars, A to C equal to 100 μm; A applies to **1, 2, 6, 7, 9, 14, 15,** B to **3-5, 8, 10-12** and C to **13.**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Description. — Shell spherical with three to six main spines. The outer shell has small circular to subcircular pores and bears no by-spines, but sometimes very small nodes are present at the lattice. Wall of outer shell is rather thick. Main spines are thin, rodlike, and with acutely pointed distal end. Some specimens (Figures 4-9, 10) have thick, rodlike and conical main spines. Length of main spines is generally equal with the diameter of outer shell. Three short and deep grooves are present at the base of main spines. The internal shell is much smaller than outer one. Diameter of internal shell is about a half of the outer shell. Internal framework represented by a six-rayed spicule occupying an eccentric position in the internal shell. The internal and outer shells are united by rodlike, primary and secondary radial beams. Numerous, thin and rodlike spines arising from the internal shell also connect to the outer shell, but these are rarely preserved entirely.

Remarks. — The present new species rather resembles *Entactinosphaera triassica* reported from the European Tethys (Kozur and Mostler, 1979), but the former differs from the latter in having rodlike main spines. *Entactinosphaera chiakensis* is also similar to *Entactinosphaera* ? *brevispinosa* Sashida and Tonishi from Upper Permian chert of the Kanto Mountains, but the latter species is easily distinguished from the former in having short and three-bladed main spines. As already stated, some specimens (Figures 4-9, 10) have rather thick main spines. These specimens might be classified as another species, but we tentatively included them in this new species.

Dimensions. — Based on 40 specimens (in μm): diameter of outer shell 168-250 (average 210); wall thickness of outer shell 28-35 (average 30); diameter of internal shell 55-80 (average 70); wall thickness of internal shell 8-15 (average 10); length of main spines 135-240 (average 220).

Etymology. — Species name *chiakensis* comes from Chiak, the name of the hill (isolated mountain), from where the limestone samples were obtained.

Type. — Holotype (Figure 4-1), IGUT-KS0003.

Genus *Polyentactinia* Foreman, 1963

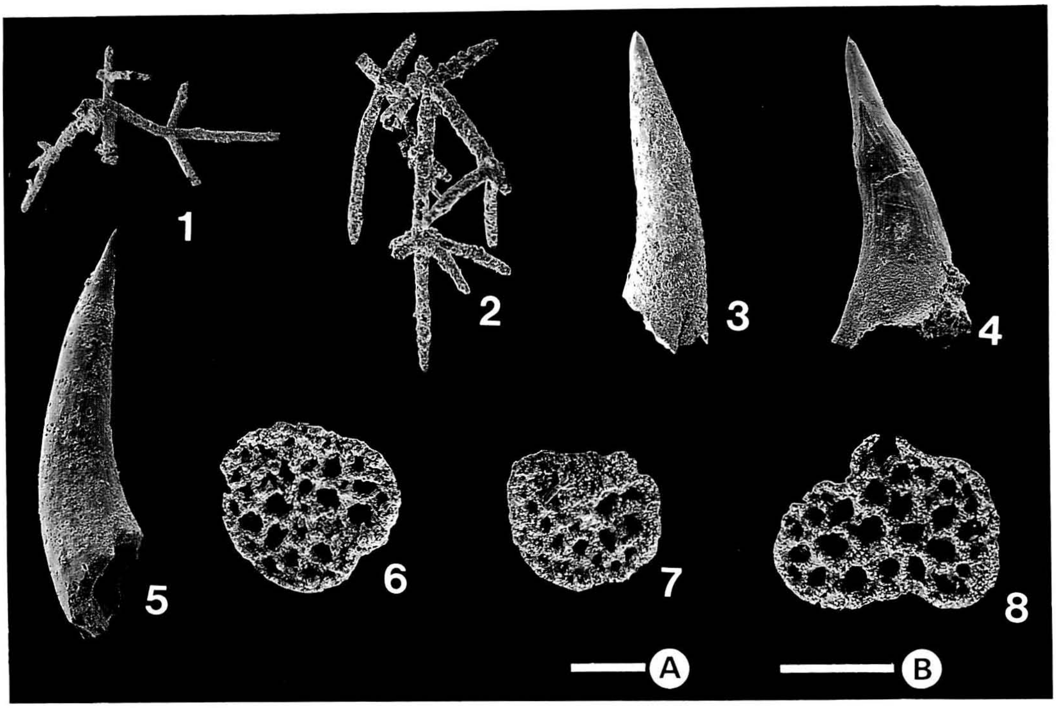
Remarks. — Nazarov and Ormiston (1985) transferred this genus to the family Orosphaeridae Haeckel from the family Entactiniidae Riedel, because of the stable central position of internal framework in the shell and structure of skeletal fabric of the single latticed shell (Nazarov and Ormiston, 1985). The distinctive forms attributable to *Polyentactinia* and Orosphaeridae, however, have never been reported from the Mesozoic (*e.g.*, Friend and Riedel, 1967; Nazarov and Ormiston, 1985). According to the original description and plates, the type species of the genus *Polyentactinia* (*P. craticulata*) and *P. polygonia* have very eccentric internal spicules (Foreman, 1963, p. 281, pl. 5, figs. 1a-c, 3a-b), and the shell structure of this genus is generally delicate-latticed. The eccentric position of internal spicules and this kind of shell structure should be considered as criteria of the family Entactiniidae Riedel. Based on the above, we assign the genus *Polyentactinia* to the family Entactiniidae Riedel.

Polyentactinia ? *phatthalungensis* Sashida and Igo, n. sp.

Figures 5-1 – 15.

Diagnosis. — *Polyentactinia* ? with an irregular latticed shell and six or seven rodlike main spines.

Description. — Single, small, nearly spherical, and irregular latticed shell with six or seven rodlike main spines. Shell framework is composed of intersections of rodlike bars. These bars partly create a double layered shell. Unequal triangular to quadrangular pores resulting from intersections of bars are present. Very small conical nodes and irreg-



Figures 6. **1, 2,** *Archaeothamnulus* sp., **1**: IGUT-KS0110; **2**: IGUT-KS0109. **3–5,** fish teeth. **6–8,** holothurian sclerites. Scale bars, A and B eqaul to 100 μm; A applies to **1, 3–8** and B to **2**.

ularly shaped protuberances sometimes observed at the junction of bars. Main spines are long, rodlike and taper distally. The length of main spines is one and a half shell diameters in well-preserved specimens. Internal spicule with seven to eight rays arising from the median bar occupying a quite eccentric position. Internal spicules give rise to main spines.

Remarks.—Previously known Paleozoic *Polyentactinia* have a polygonal and delicate-latticed shell with thin main spines. Although our specimens have a nearly spherical shell composed of intersections of rodlike bars, other shell characters coincide with the definition of the genus *Polyentactinia.* We questionably include this new species in the genus *Polyentactinia*. Features of internal spicule and shell in some specimens identified with the present new species (*e.g.*, Figures 5-8, 10) are similar to *Parentactinia nakatsugawaensis* Sashida reported from the Kanto Mountains, central Japan. Disposition of internal spicule of this new species, however, differs from that of the latter. The internal spicule of *Parentactinia nakatsugawaensis* is characterized by four apical and basal spines.

Dimensions.—Based on 50 specimens (in μm): diameter of shell 175–225 (average 190); length of main spines of completely preserved specimens 210–255 (average 225).

Etymology.—Species name *phatthalungensis* comes from the geographical name Phatthalung, southern Thailand.

Type.—Holotype (Figure 5-1), IGUT-KS0005.

Family Palaeoscenidiidae Riedel, 1967 emend. Furutani, 1983

Remarks.—Dumitrica (1982) and Wakamatsu *et al.* (1990) have argued that the post-Paleozoic palaeoscenidiid-like forms such as the genera *Archaeosemantis*

Dumitrica, *Archaeothamnulus* Dumitrica, and *Palhindeolithus* Deflandre should be transferred to another or other families from the Family Palaeoscenidiidae. Sashida (1991) tentatively included Early Triassic palaeoscenidiid-like genera in the family Palaeoscenidiidae, as we do here.

Genus *Archaeothamnulus* Dumitrica, 1982
Archaeothamnulus sp.

Figures 6-1, 2.

Remarks.—We obtained only fragmental specimens. One of them (Figure 6-1) more or less resembles *Archaeothamnulus verticillatus* (Dumitrica) described from the Middle Triassic Buchenstein Limestone. Detailed comparison between them, however, is almost impossible because the present material is very poor.

Family Actinommidae Haeckel, 1862 emend. Riedel, 1967

Remarks.—Since Haeckel (1862) set up this family, many genera and species belonging to it have been described. Taxonomic studies of the Triassic radiolarians belonging to this family, however, are scarce except for Kozur and Mostler (1979, 1981). Nazarov and Ormiston (1984) introduced the family Inaniguttidae, which has the same shell character as the palaeoactinommids. Holdsworth (1977) informally grouped palaeoactinommids to the Paleozoic Spumellaria, which has one latticed shell or more lacking the internal spicule system. Nevertheless, the phylogenetic relationship between the families Inaniguttidae and Actinommidae is still uncertain. We employ the family Actinommidae herein.

Genus *Thaisphaera* Sashida and Igo, n. gen.

Type species.—*Thaisphaera minuta* Sashida and Igo, n. sp.

Diagnosis.—Two spherical latticed shells with four to six main spines. Three-bladed radial beams cross spaces between outer and inner shells, but do not extend inward beyond inner shell. Numerous conical by-spines arise from the surface of inner shell. These spines sometimes reach rodlike or contrary conical spines from the inner surface of outer shell.

Remarks.—The above mentioned diagnostic character of this new genus, *Thaisphaera,* is quite identical with the criteria of the family Actinommidae Haeckel emend. Riedel 1967. This new genus is monotypic at present and we cannot discuss the phylogenetic relation with any other Triassic genera of the family Actinommidae.

Etymology.—*Thaisphaera* (feminine gender) is so named to describe a spherical form which comes from Thailand.

Thaisphaera minuta Sashida and Igo, n. sp.

Figures 4-8, 11–14, 16, 17.

Diagnosis.—*Thaisphaera* with small, rather thick latticed shell and conical main spines. Inner shell far smaller than outer shell.

Description.—Skeleton consists of two spherical latticed shells with four to six main spines. The outer shell is small and rather thick for the size of shell and has circular to subcircular or rarely irregular pores of various size. Small nodes are rarely observed at the junction of intervening bars. Rodlike or thin conical bars arise from the inner surface of outer shell and sometimes combine with the conical by-spines from the outer surface of inner shell. The main spine is conical and rather short for the size of outer shell. It is generally three-bladed, rarely rodlike. Its length is variable, but the longest spine is almost two-thirds of the diameter of outer shell. Three-bladed radial beams connect with the outer and inner shells. The inner shell is spherical and small, and has circular or subcircular pores. More than 25 thin and conical by-spines are observed on the outer surface of inner shell hemisphere.

Remarks.—This new species resembles *Entactinosphaera phatthalungensis* in general outer shell shape, but it is easily distinguished from the latter species in having a smaller shell and conical, three-bladed main spines. Kozur and Mostler (1979) described and discussed many genera and species of the family Actinommidae from European Triassic rocks. The present new species, however, does not have any similarity to those described by them.

Dimensions.—Based on 20 specimens (in μm): diameter of outer shell 175–205 (average 185); thickness of outer shell 18–25 (average 20); diameter of inner shell 58–70 (average 65); thickness of inner shell 5–20 (average 15); length of main spine 65–85 (average 70).

Etymology.—Latin *minutus,* meaning minute.

Type.—Holotype (Figure 4-8), IGUT-KS0004.

Suborder Nassellaria Ehrenberg, 1875
Family Acanthodesmidae Haeckel, 1862
Genus *Hozmadia* Dumitrica, Kozur and Mostler, 1980

Hozmadia ? sp.

Figures 3-13—15.

Descriptive remarks.—Shell is small and composed of globular cephalis with an apical horn and three feet. Costae or alveoli are present on the surface of globular shell in moderately well-preserved specimens. The apical horn is conical and eccentrically positioned. Three long feet are rodlike and downward-curved. Internal structure is formed of **MB** (median bar), **A** (apical spine), **D** (dorsal spine), **l** (secondary lateral spine), **L** (primary lateral spine), but internal arches are not clear in our collections. According to the original description of the genus *Hozmadia* (Dumitrica *et al*., 1980), bladed feet and arches of **AV**, **Al**, **Vl**, **Ll** and **ID** are diagnostic characters. As briefly described above, our specimens lack bladed feet and distinct arches. Therefore, we questionably include our specimens in the genus *Hozmadia.* The present unidentified species is rather similar to *Saitoum* sp. reported by Sashida (1991) from the Kanto Mountains of central Japan.

Dimensions.—Based on 6 specimens (in μm); diameter of cephalis 95–105 (average 100); height of cephalis 105–115 (average 110); length of feet 87–130 (average 125).

Radiolarian fauna

As discussed in the systematics, we discriminated the following radiolarians from the sample (PAT-1); namely, *Entactinia nikorni,* n. sp., *Entactinosphaera chiakensis,* n. sp., *Polyentactinia* ? *phatthalungensis,* n. sp., *Thaisphaera minuta,* n. gen. and n. sp., *Archaeothamnulus* sp., and *Hozmadia* ? sp. Among these radiolarians, *Entactinosphaera chiakensis, Polyentactinia* ? *phatthalungensis,* and *Thaisphaera minuta* are particularly abundant and represent about 90% of the total number of the identified radiolarian specimens. *Entactinia nikorni* is estimated to be about 6%. *Archaeothamnulus* sp. and *Hozmadia* ? sp. are rare and constitute 3% and 1%, respectively.

The genera *Entactinia* and *Polyentactinia* have hitherto never been reported from Triassic rocks. The family Entactiniidae Riedel, which comprises these two genera, is one of the most important groups of Paleozoic radiolarians. Recent investigations clarified the development of this family from the Early Ordovician (*e.g*., Fortey and Holdsworth, 1971) to Late Permian (Sashida and Tonishi, 1985). Kozur and Mostler (1979, 1981) introduced several species of the genera *Entactinosphaera, Helioentactinia,* and *Parentactinosphaera,* which have shell structure comparable to the family Entactiniidae from the Triassic limestone of the European Alps.

Our present collections from Thailand, however, cannot be identified with *Entactinosphaera* described by them at the specific level.

Many genera and species attributable to the family Actinommidae were recorded from Triassic limestones in the European Tethys by Kozur and Mostler (1979, 1981). Their definition of the family Actinommidae is broad with respect to shell shape, numbers of shell and spines, and internal structure. Among these radiolarians, several species belonging to the genera *Acanthosphaera* Ehrenberg, *Heliosoma* Haeckel, *Triactoma* Rüst, and *Spongechinus* Haeckel have characteristically a polygonal to spherical shell and three to 20 or more spines. Our new species, *Thaisphaera minuta,* however, is not identifiable to these forms from the European Alps.

The genus *Archaeothamnulus,* spicule-type palaeoscenidiids, introduced by Dumitrica (1982) from the European Tethys, commonly occurs in the Japanese Triassic chert sequences (*e.g.*, Sashida, 1991). However, this genus is rather long-ranging, that is from Early to Late Triassic (Yoshida, 1986). An unidentified species of this genus from Khao Chiak has a close similarity with *Archaeothamnulus pterostephanus* Dumitrica from the Middle Triassic limestone of Europe.

Hozmadia ? sp. is rather similar to *Saitoum* sp. described by Sashida (1991) from Early Triassic chert of the Kanto Mountains in Japan. The genus *Hozmadia* is also an important constituent of the Middle Triassic radiolarian faunas (Dumitrica *et al*., 1980; Kozur and Mostler, 1981).

As briefly discussed above, the present radiolarian fauna has both Paleozoic and Mesozoic affinities, but is less similar to that described from Early Triassic chert of the Kanto Mountains except for one spicule-type palaeoscenid and tripod Nassellaria. The Early Triassic radiolarian fauna reported from the Kanto Mountains (Sashida, 1983, 1991) is characterized by several genera and species of the families Palaeoscenidiidae, Sponguriidae, Eptingiidae and Acanthodesmiidae.

Concerning paleobiogeographical significance, the present Triassic radiolarian fauna can be expected to have affinities of transition between high-latitude Southern Hemisphere and Tethys faunas based on the recent terrane analyses of Southeastern Asia (*e.g*., Metcalfe, 1988; Hutchison, 1989). According to Metcalfe (1988), Peninsular Thailand (Sibumas Terrane) began to rift from Gondwanaland in the Early Permian and collided with the Indo-china Terrane during Late Triassic. The present fauna will provide important data in future discussions of paleogeography of Peninsular Thailand based on radiolarian faunas. Our present knowledge of the Triassic radiolarian fauna of the high-latitudes of Southern Hemisphere and southeastern Asian Tethys is very sparse.

POSTSCRIPT. After our manuscript of this paper was accepted, an important paper concerning an Early and Middle Triassic radiolarian fauna from the Mino Terrane, central Japan was published by Sugiyama (1992: Lower and Middle Triassic radiolarians from Mt. Kinkazan, Gifu Prefecture, central Japan. *Trans. Proc. Palaeont. Soc. Japan, N.S*., no. 167, p. 1180-1223). In our present paper, we stressed the first occurrence of the genera *Entactinia* and *Polyentactinia* from the Triassic, but Sugiyama also pointed out their Triassic occurrences in his paper. He transferred several radiolarian families possessing an internal spicule and spherical shell into the Order Entactinaria Kozur and Mostler (1982). He proposed four new genera and 26 new species including the genera *Entactinia* Foreman and *Polyentactinia* Foreman. As pointed out by him, however, separation at the order rank of these radiolarians still remains disputed.

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タイ国南部パッタルング付近のカオ・チアックに分布する石灰岩から産する三畳紀放散虫：タイ国南部パッタルング付近のカオ・チアックに分布する層状石灰岩は保存良好な三畳紀放散虫を産する。この放散虫化石動物群は“古生代型” Entactiniidae, Actinommidae, 針状骨格型 Palaeosceniidae 及び acanthodesmid Nassellaria から成り，後期スパシアン～前期アニシアンを示すコノドント化石と共存する。本研究では 1 新属，*Thaisphaera* 及び 4 新種，*Entactinia nikorni, Entactinosphaera chiakensis, Polyentactinia ? phatthalungensis* 及び *Thaisphaera minuta* を記載・報告する。*Entactinia* 属及び *Polyentactinia* 属の三畳紀からの産出は最初の報告である。

指田勝男・猪郷久義

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 168, pp. 1311-1328, 10 Figs., December 30, 1992

946. *INOCERAMUS (PLATYCERAMUS) TROEGERI* SP. NOV. (BIVALVIA) FROM THE CONIACIAN (CRETACEOUS) OF HOKKAIDO AND ITS SYSTEMATIC IMPLICATIONS*

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Abstract. A new species of *Inoceramus* from the Coniacian of the Obira area, northwestern Hokkaido, is described on a population sample. The phylogenetic relationships between *I.* (*Inoceramus*) and *I.* (*Platyceramus*) are also discussed. *I.* (*P.*) troegeri sp. nov. shows a large extent of variation, with one extreme form resembling a form of *I.* (*I.*) *teshioensis* Nagao and Matsumoto from the upper Turonian of Japan while the other extreme is similar to the typical form of *I.* (*P.*) *mantelli* de Mercey from the upper Coniacian to Santonian of Japan. The two forms are linked with each other by various grades of intermediate forms within the species. This fact may imply that some species of *I.* (*Platyceramus*) were derived from *I.* (*I.*) *teshioensis* at or near the Turonian/Coniacian boundary. *I.* (*P.*) *troegeri* is also assumed to be a common or ultimate ancestor of various successive species of *Inoceramus* (*Platyceramus*) in later ages.

Key words. *Inoceramus* (*Inoceramus*), *Inoceramus* (*Platyceramus*), Coniacian, population, phylogeny.

Introduction

Inoceramus (*Platyceramus*) Seitz, 1961 is one of the important species-groups belonging to the genus *Inoceramus* Sowerby, 1814. *Platyceramus* was originally proposed by Heinz (1932) but was invalid because of no diagnosis. The valid subgeneric diagnosis of *Platyceramus* was first given by Seitz (1961). Subsequently, some emendation has been attempted by Noda (1983). Noda and Toshimitsu (1990) considered *I.* (*P.*) *mantelli* de Mercey as a common or ultimate ancestor of successive species of *I.* (*Platyceramus*) of later ages. However, they reserved the phylogenetic origin of *I.* (*Platyceramus*) as a further problem to be solved later.

Recently numerous well-preserved inoceramid specimens have been obtained from the lower to middle Coniacian of the Obira area. Most of them represent one species, which is undoubtedly identical with a species described by Nagao and Matsumoto (1939), who left it unnamed because of insufficient number of specimens and uncertainty about its locality and stratigraphic position. Now this new species is proposed on population material. The species is important in connecting the missing link left undetermined by Noda and Toshimitsu (1990).

Note on geology

The Obira area in northwestern Hokkaido is famous for its well-exposed Cretaceous sequence and occurrence of well-preserved fossils. In addition to the classical works of Jimbo (1894) and Yabe (1909), the

*Received May 13, 1992; Revised manuscript accepted September 27, 1992

Cretaceous stratigraphy of this area has been recently described by Tanaka (1963), Matsumoto *et al.* (1978), Tanabe *et al.* (1977) and Asai and Hirano (1990) with lists of fossil species from the subdivided units. A geological map by Tsushima *et al.* (1958) is also available.

The Cretaceous strata exposed along the River Obirashibe are divided into the Middle and Upper Yezo Groups, which are subdivided into Units Ma to Mo and Ua to Ul, respectively (Tsushima *et al.,* 1958 ; Tanaka, 1963). The specimens examined were collected from the outcrops along the main course of the R. Obirashibe (Figure 1). In the section which includes the type locality Ob0003 (=loc. NH76 of Tanaka, 1963), the Units Ual, Ua2, Ub and Uc-d are successively exposed downstream for a distance of 200 m. In another section near the Bridge Takimi-Ohashi and the confluence of a tributary called the Jugosen-zawa, the Cretaceous strata Ual, Ua2, Ub, Uc and Ud are successively well exposed along the river floors and banks, and various kinds of fossils occur there.

The stratigraphic units concerned with this study are Ual, Ua2, Ub and Uc. For details of the above units, readers may refer to Tanaka (1963, fig. 4). Megafossils of inoceramids and ammonites are listed as follows :

Ua 1. Fossils rare. *Inoceramus* (*Inoceramus*) *teshioensis* Nagao and Matsumoto, *Mytiloides incertus* (Jimbo), *Scalarites scalaris* (Yabe) and *Tragodesmoceroides subcostatus* Matsumoto, of which *M. incertus* is a cosmopolitan zonal index of the upper

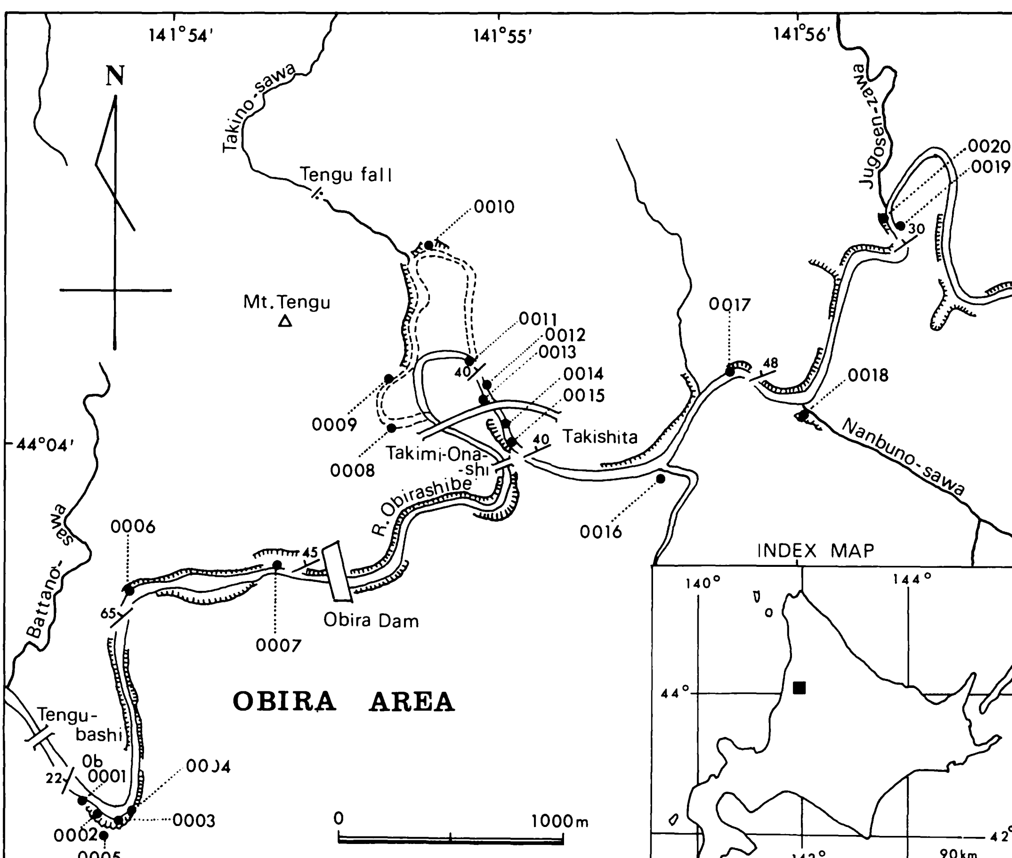

Figure 1. Locality map of the Obira area.

Turonian and *I.* (*I.*) *teshioensis* also indicates the upper Turonian in Japan.

Ua2. Fossils common. *I.* (*I.*) aff. *tenuistriatus* Nagao and Matsumoto, *I.* (*Cremnoceramus*) *rotundatus* Fiege, *I.* (*P.*) *troegeri* sp. nov. (this paper), *Didymotis* cf. *akamatsui* (Yehara), *Gaudryceras denseplicatum* (Jimbo), *Mesopuzosia yubarensis* (Jimbo), *Eubostrychoceras muramotoi* Matsumoto and *Baculites yokoyamai* Tokunaga and Shimizu, of which *I.* (*C.*) *rotundatus* is an effective zonal index of the lower lower Coniacian of Europe, Western Interior of U.S.A. and Japan.

Ub. Fossils abundant. *I.* (*I.*) *uwajimensis uwajimensis* Yehara, *I.* (*I.*) aff. *pedalionoides* Nagao and Matsumoto, *I.* (*C.*) *ernsti* Heinz, *I.* (*C.*) cf. *deformis* Meek, *I.* (*P.*) *troegeri, Didymotis akamatsui, Damesites damesi* (Jimbo), *Neophylloceras subramosum* Spath, *Tetragonites glabrus* (Jimbo), *Mesopuzosia yubarensis* and *Barroisiceras onilahyense* Basse, of which *I.* (*I.*) *uwajimensis uwajimensis* indicates the lower to middle Coniacian in Japan, and *I.* (*C.*) *ernsti* and *I.* (*C.*) *deformis* occur in the lower part of the middle Coniacian.

Uc. Fossils abundant. *I.* (*I.*) *uwajimensis uwajimensis, I.* (*I.*) *uwajimensis yeharai* Nagao and Matsumoto, *I.* (*C.*) *mihoensis* Matsumoto and *Gaudryceras denseplicatum,* of which *I.* (*C.*) *mihoensis* is a zonal index of the upper Coniacian, but it is associated with *I.* (*I.*) *uwajimensis uwajimensis* in this unit.

Method

In this paper, biometric analyses are applied for some selected characters in addition to general observations. The basic linear measurements and angles are shown in Figure 2. The procedure of biometric examination is as follows.

1. Measurements of selected characters. A caliper of JIS standard 200 mm in measurable extent and 1/20 mm in accuracy and a contact goniometer were used for measurements of length and angle respectively, and a flexible gauge was applied for measurements of shell convexity. Measurements were made three times for the same part and the mean values were adopted.

2. Evaluation of normal distribution by means of the chi-square test.

3. Statistics of the measurement values. *i.e.,* mean value, standard deviation and Pearson's coefficient of variation.

4. Examination of individual relative growth as to shell length versus shell height and shell breadth versus shell height, obtain the growth index (α), Y intercept (β) and coefficient of correlation (r). The bivariate analysis is made by the method of reduced major axes on double logarithmic graph paper, and the null hypothesis of isometry is tested.

5. Examination of the ontogenetic change of selected characters.

6. Evaluation of the significance for morphological difference with allied species by means of Student's t-test. The characters showing allometry in relative growth and ontogenetic changes are evaluated at the growth stage of H = 60 mm. Welch's method is applied for the characters showing significant value in F-test.

For calculation, readers may refer to Hayami (1969), Hayami and Matsukuma (1971) and Tanabe (1973).

Systematic description

Family Inoceramidae Zittel, 1881

Genus *Inoceramus* Sowerby, 1814

Type species.—*Inoceramus cuvierii* Sowerby, 1814.

Remarks.—Matsumoto *et al.* (1987) have already remarked on the genus *Inoceramus,* which includes heterogeneous species-groups. Noda (1979) preliminarily discussed nomenclature with regard to the "subgenera" *Cordiceramus, Endocostea, Platyceramus,*

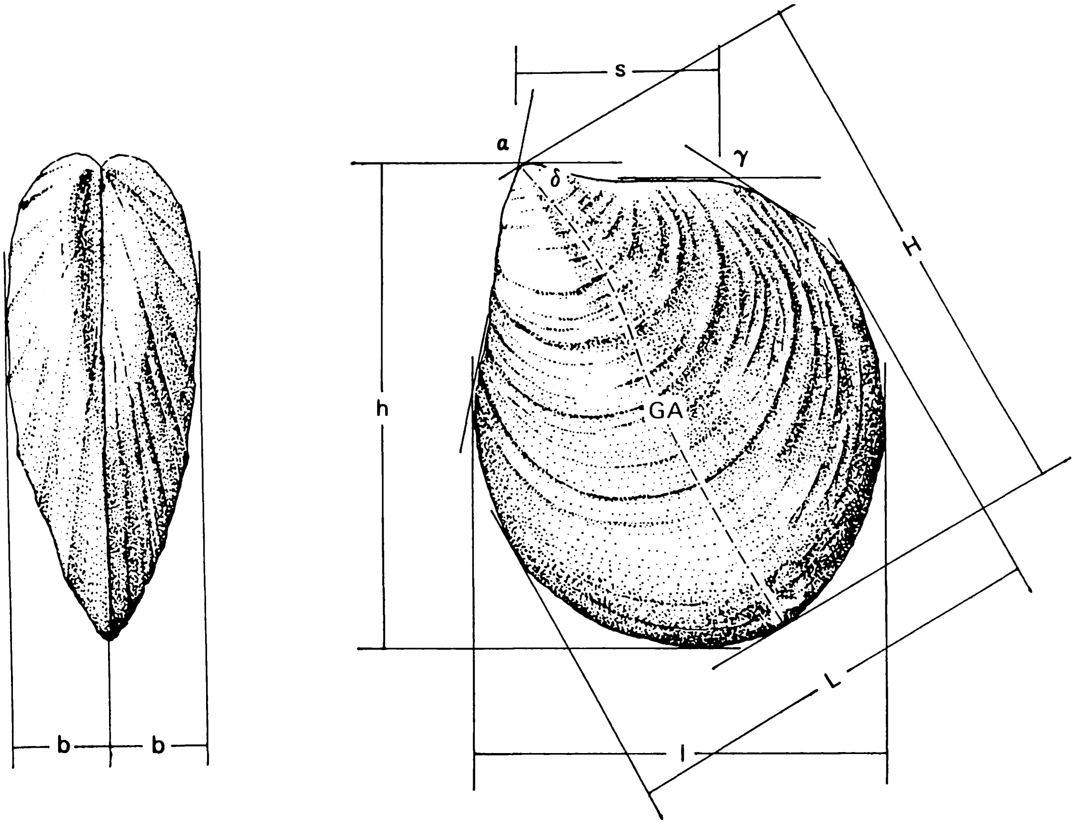

Figure 2. Basic morphology for measurements. h : shell height, l : shell length, b : shell breadth, H : maximum linear dimension from umbo to ventral extremity, L : maximum linear dimension perpendicular to H, GA : growth axis, s : length of hinge line, α : anterior hinge angle, γ : posterior hinge angle, δ : obliquity, angle between hinge line and H.

Cataceramus, Selenoceramus and *Haenleinia,* some of which were regarded as invalid. It is also doubtful whether *Cremnoceramus* and *Magadiceramus* constitute genus-group taxa. More comprehensive survey for taxonomic ranking has yet to be worked out. The hierarchical rank of the taxa cited above may not be uniform among researchers and were sometimes used without any comment.

Subgenus *Platyceramus* Seitz, 1961

Type species.—Inoceramus mantelli de Mercey, 1877 by original designation (Seitz, 1961 *ex* Heinz, 1932).

Remarks.—Platyceramus Heinz, 1932 was an independent genus of Family Inoceramidae, but it was a *nomen nudum* in accordance with the I.C.Z.N. (Art. 50). Seitz (1961) gave the diagnosis of *Platyceramus* as a subgenus of *Inoceramus,* and consequently the name became valid, as Matsumoto, Noda and Kozai (1982) have already mentioned. Thus the original author of *Platyceramus* should be Seitz, 1961. Despite this situation, Vokes (1967, 1980) wrongly regarded the name as still invalid and Cox (1969) regarded *Platyceramus* as a junior synonym of *Inoceramus (Inoceramus).* Noda (1983, p. 202) revised Seitz's definition of *Platyceramus* so as to include the subgenus *Cladoceramus* Seitz, 1961 and gave his reasons for doing so.

Inoceramus (Platyceramus) *troegeri* sp. nov.

Figures 3, 4, 5 and 6

Inoceramus sp. nov. Nagao and Matsumoto, 1939, p. 280-281, pl. 27, fig. 1a, b ; pl. 28, fig. 1.
Inoceramus sp. nov. Nagao and Matsumoto ; Kauffman, 1977, p. 176.
Inoceramus sp. indet. (sp. nov.). Nagao and Matsumoto ; Matsumoto and Noda, 1986, p. 416.

Types.—Holotype : JG.H3023, at loc. Ob0003f. lower part of Ua2, the lower part of the Upper Yezo Group, about 2 m upper horizon above the Tu/Co (Turonian/ Coniacian) boundary. Paratypes : JG. H3007, 3008, 3009, 3010, 3011a, 3011b, 3022, 3025b-f, 3036, 3038, 3040a-d, 3041a-d and 3064a from the type locality. UMUT. MM6492 (=TK.I-710) and IGPS22709 (= Sd22709) from the Obirashibe valley, presumably the same locality as the holotype. JG. H3039 at loc. Ob0012 and JG.H3036 and 3065 at loc. Ob0020. See caption of Figures 3-6 for the names of the collectors.
Repositories—IGPS : Institute of Geology and Palaeontology, Tohoku University, Sendai, JG : Collection of the Jonan Geological Association, kept tentatively in Noda's personal laboratory, Oita ; UMUT : University Museum, the University of Tokyo, Hongo, Tokyo.

Diagnosis.—Shell medium to large, equivalve or slightly inequivalve. Valve higher than long showing some variation in rough outline, and gently and uniformly convex. Umbo small, situated at the anterior end. Concentric ribs variable in shape and intensity and in addition to concentric lirae or rings.

Description.—The holotype (JG.H3023, Figure 3), JG.H3022, JG.H3025c, UMUT. MM6492 (Figures 4-2, 5-2) and IGPS22709 (Figure 4-1) are closed valves and equivalve. The specimens JG.H3008, 3009 (Figure 6-1) and JG.H3037 (Figure 5-3a–c) are also closed valves but they are more or less inequivalve, with the umbo somewhat projected over the hinge line and curved inward and forward in the left valve.

Valves higher than long or almost as high as long, orbicular to oval, more or less elongated along the straight growth axis. Umbonal portion moderately inflated in the left valve and remaining part gently and uniformly convex. Anterior side narrow and steep or almost perpendicular to the commissure plane, posterior half a flattened to winglike area without sharp boundary. Outline fairly variable ; anterior margin long and straight or slightly convex but for slightly concave portion near the umbo ; anteroventral margin broadly arcuate or rarely subangularly bent. Ventral margin curved asymmetrically, continuing to broadly rounded posterior margin, which forms an obtuse angle with hinge line. Hinge line somewhat shorter than a half of the shell length on average. Winglike area variable in extent.

Surface ornamented with major and minor concentric sculptures ; the former consists of concentric ribs and/or undulations. Concentric ribs appear on the umbonal portion, crowded, sharp-topped and irregular in breadth, interspace and intensity. Concentric undulations developed somewhat later than ribs, low, round-topped and irregular in breadth, interspace and intensity. Minor rings superposed on the major sculpture and clearly visible on outer shell layer, round-topped and regular in breadth and height.

Biometry.—The measurements of selected characters *i.e.*, h, l, b, H, L, s, α, γ, δ, l/h, b/h, $b/h_{H=60mm}$, L/H, and s/l are shown in Table 1. Before taking the statistics, the chi-square test was applied for the characters to evaluate their normal distribution. The chi-square values were calculated with degree of freedom 3. As shown in Table 2, in some characters, *i.e.*, l/h, b/h, $b/h_{H=60mm}$ and s/l, the values are more than 7.81 which is a 5 percent significant limit at the degree of freedom 3. Thus, the hypothesis of random sampling from a normally distributed population is quite doubtful. The significant val-

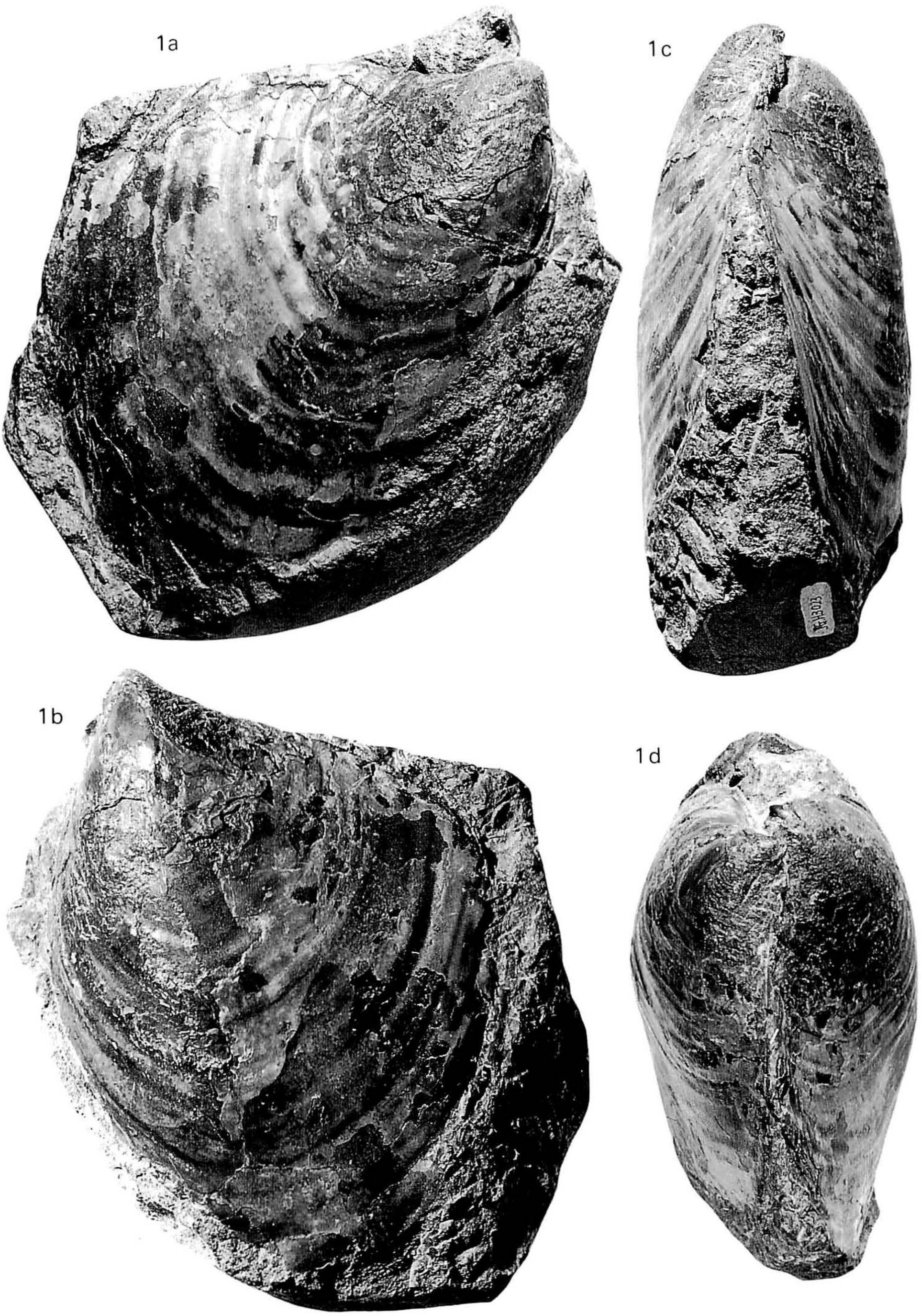

Figure 3. *Inoceramus* (*Platyceramus*) *troegeri* Noda sp. nov. JG.H3023, holotype. ×0.75. From loc. Ob0003f (coll. H. Kokubun).

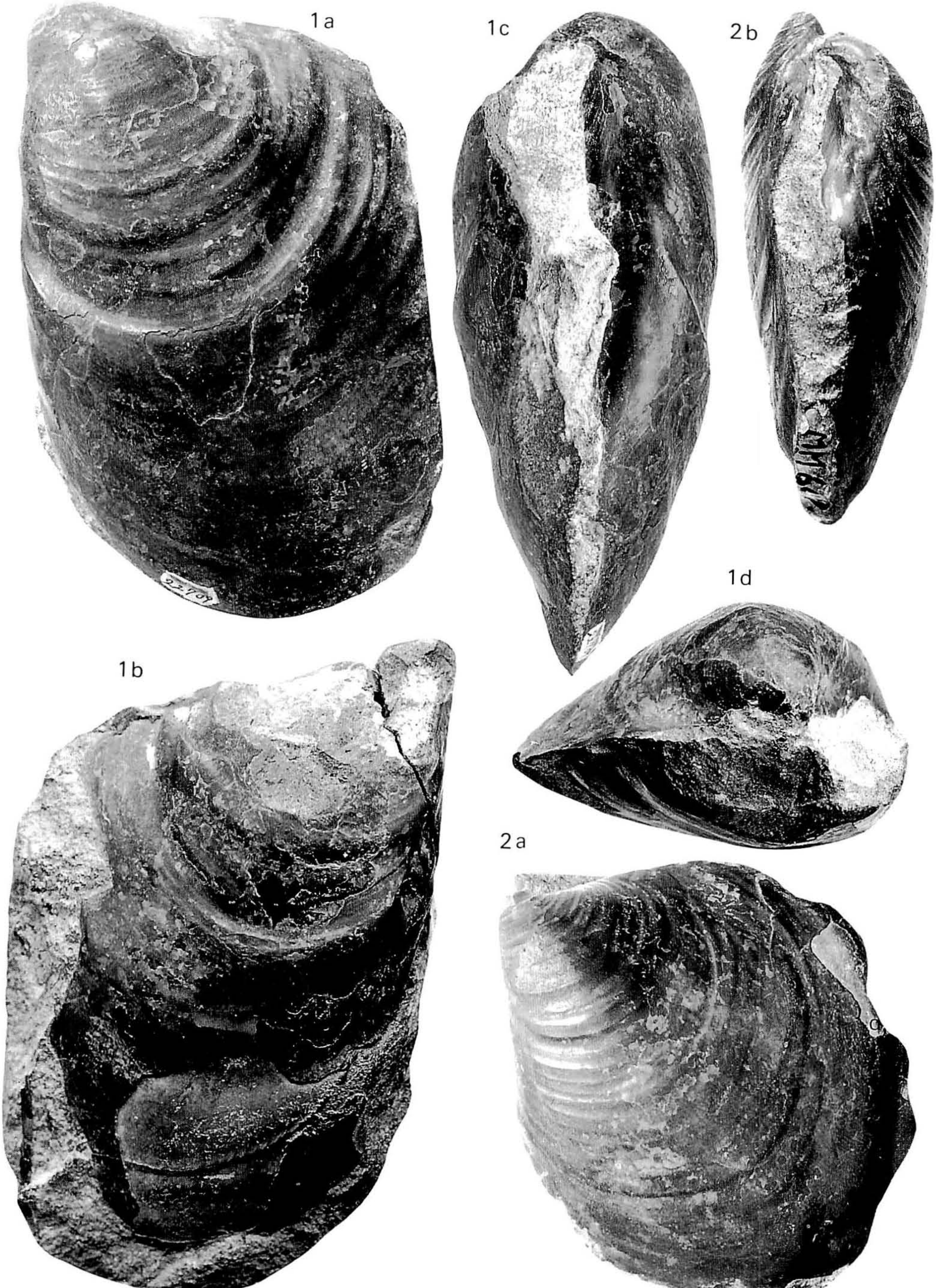

Figure 4. *Inoceramus* (*Platyceramus*) *troegeri* Noda, sp. nov.
1. IGPS22709 (=Sd22709). ×0.72. From Obirashibe valley; precise locality unknown.
2. UMUT.MM6492 (=TK.I-710). ×0.9. From Obirashibe valley; precise locality unknown.

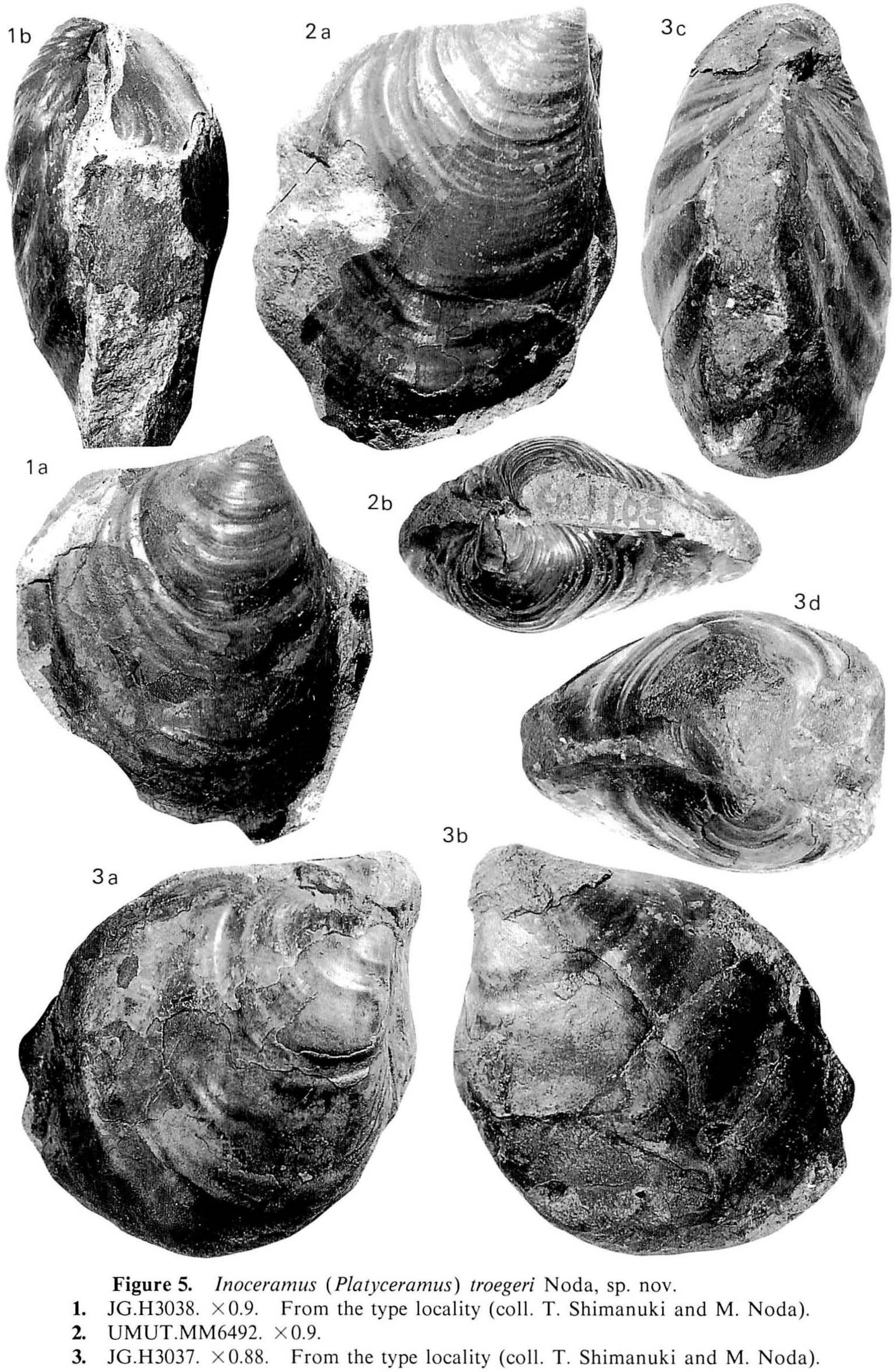

Figure 5. *Inoceramus* (*Platyceramus*) *troegeri* Noda, sp. nov.

1. JG.H3038. ×0.9. From the type locality (coll. T. Shimanuki and M. Noda).

2. UMUT.MM6492. ×0.9.

3. JG.H3037. ×0.88. From the type locality (coll. T. Shimanuki and M. Noda).

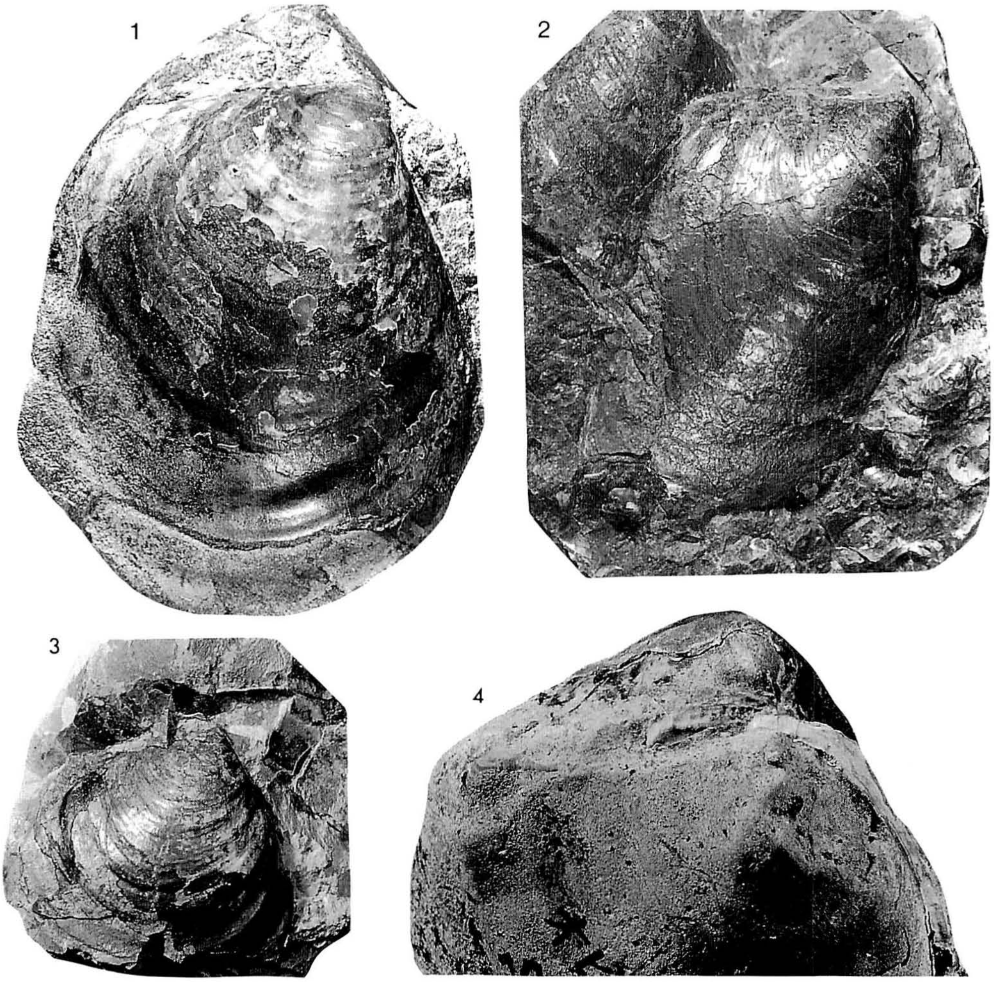

Figure 6. *Inoceramus* (*Platyceramus*) *troegeri* Noda, sp. nov.
1. JG.H3009. ca ×0.88. From the type locality (coll. H. Kokubun).
2. JG.H3064a. ×0.9. From the type locality (coll. H. Kokubun).
3. JG.H3065. ×0.9. From loc. 0b0020 (coll. T. Shimanuki and M. Noda).
4. JG.H3007. ×0.9. Showing the hinge structure, from the type locality (coll. H. Kokubun).

ues, however, are probably ascribed to a contingency because of the small sample size and the large extent of variation as discussed below. Thus the numerical values, *i.e.*, mean value, standard deviation and Pearson's coefficient of variation may be meaningful. As is clear from Table 2, Pearson's coefficient of variation shows fairly large values in α, l/h, b/h, $b/h_{H=60mm}$ and s/l. The simple ratio b/h is shown at a definite stage of growth (H = 60 mm) for the reason mentioned below.

The individual relative growth of shell length (l) versus shell height (h) and shell breadth (b) versus shell height (h) in the well-preserved specimens are demonstrated in Figure 7. The growth index (α), *Y* intercept (β) of the reduced major axis and the coefficient of correlation (r) for every specimen were calculated. According to Hayami and Matsukuma (1971, p. 150, table 2, p. 151, fig. 8), the relative growth l versus h is within

Table 1. Measurements of *Inoceramus* (*Platyceramus*) *troegeri* sp. nov. from Hokkaido. Linear dimension in mm.

Specimen	valve	h	l	b	H	L	s	α	γ	σ
JG. H3009	RV	80.5	73.6	20.5	86.0	72.0	35.0	102°	134°	65°
JG. H3010	LV	73.5	64.7	13.2	82.6	65.1	31.8	88°	142°	61°
	RV	72.5	64.5	16.0	83.3	65.1	31.6	90°	143°	60°
JG. H3011a	LV	73.2	67.0	15.0	85.3	69.0	33.5	94°	146°	59°
JG. H3011b	RV	106.0	100.2	22.7	119.6	90.9	44.8	90°	135°	63°
JG. H3022	LV	88.0	82.7	17.0	97.9	78.6	42.0	91°	142°	61°
	RV	82.0	77.9	16.3	94.0	76.1	40.5	92°	143°	62°
JG. H3023	LV	103.7	93.0	18.4	118.7	90.7	43.7	91°	139°	59°
	RV	106.8	95.2	17.9	118.8	92.0	44.7	90°	141°	61°
JG. H3024	LV	45.7	41.0	9.0	48.5	37.3	—	93°	141°	59°
JG. H3025a	RV	34.1	32.5	7.8	41.8	32.6	—	93°	134°	56°
JG. H3025b	RV	79.6	73.2	16.0	90.3	69.5	33.5	94°	140°	61°
JG. H3025c	LV	39.2	34.5	9.5	45.4	34.4	17.9	90°	143°	62°
	RV	40.2	34.6	9.4	45.5	35.8	17.0	92°	136°	63°
JG. H3025d	RV	47.2	41.7	10.2	54.8	43.1	19.8	92°	136°	60°
JG. H3037	LV	71.4	62.4	20.0	78.5	59.4	29.0	98°	142°	60°
	RV	62.8	60.0	13.8	70.3	58.0	29.0	94°	142°	56°
IG. H3038	RV	60.9	53.6	13.0	65.9	54.0	26.7	104°	140°	60°
JG. H3039	RV	70.0	64.0	14.6	76.1	62.2	29.0	102°	142°	62°
JG. H3040a	RV	70.0	64.8	14.8	78.4	61.0	32.3	99°	138°	58°
JG. H3064a	RV	63.0	51.4	12.4	70.3	53.0	28.0	89°	139°	59°
UMUT. MM6492	LV	73.0	64.0	16.0	79.0	61.7	32.0	97°	135°	61°
	RV	70.3	61.2	15.2	79.3	61.0	—	96°	—	61°
IGPS22709	LV	126.6	94.0	30.5	130.0	95.0	50.0	86°	145°	59°
	RV	125.0	91.3	—	131.0	95.7	—	84°	145°	60°

a scope of isometry, whereas that of b versus h shows negative allometry.

The ontogenetic changes of l/h, b/h and obliquity (δ) are also demonstrated in Figure 8A, B and C, respectively. As is clear from Figure 8A and C, the simple ratio l/h and obliquity are nearly constant throughout growth, whereas the simple ratio b/h decreases gradually with growth as shown in Figure 8B.

The profiles of the best preserved holotype and a paratype in three directions are illus-

Table 1. (continued)

Specimen	valve	l/h	b/h	$b/h_{H=60mm}$	L/H	s/l	remarks
JG. H3009	R.	0.91	0.25	0.25	0.84	0.48	
JG.H3010	L.	0.88	0.18	0.20	0.79	0.49	closed valves posterior part eroded
	R.	0.89	0.22	0.21	0.78	0.49	
JG.H3011a	L.	0.92	0.20	0.24	0.81	0.50	
JG.H3011b	R.	0.95	0.21	0.22	0.76	0.45	
JG.H3022	L.	0.94	0.19	0.22	0.80	0.51	closed valves surface ornament eroded
	R.	0.95	0.20	0.22	0.81	0.52	
JG.H3023	L.	0.90	0.18	0.21	0.76	0.47	closed valves
	R.	0.89	0.17	0.22	0.77	0.47	
JG.H3024	L.	0.90	0.20	—	0.77	—	less than 60 mm in H
JG.H3025a	R.	0.95	0.23	—	0.78	—	less than 60 mm in H
JG.H3025b	R.	0.92	0.20	0.20	0.77	0.46	
JG.H3025c	L.	0.88	0.24	—	0.76	0.52	closed valves less than 60 mm in H
	R.	0.86	0.23	—	0.79	0.49	
JG.H3025d	R.	0.88	0.22	—	0.79	0.47	less than 60 mm in H
JG.H3037	L.	0.87	0.28	0.28	0.76	0.46	closed valves
	R.	0.96	0.22	0.23	0.83	0.48	
JG.H3038	R.	0.88	0.21	0.22	0.82	0.50	
JG.H3039	R.	0.91	0.21	0.23	0.82	0.45	
JG.H3040a	R.	0.93	0.21	0.23	0.79	0.50	
JG.H3064a	R.	0.82	0.20	0.20	0.75	0.54	
UMUT MM6492	L.	0.88	0.22	0.23	0.78	0.50	closed valves
	R.	0.73	—	—	0.73	—	
IGPS22709	L.	0.74	0.24	0.24	0.73	0.53	closed valves
	R.	0.73	—	—	0.73	—	

l/h : simple ratio of l vs. h, b/h : simple ratio of b vs. h, $b/h_{H=60mm}$: simple ratio of b vs. h at the growth stage of 60 mm in H, L/H : simple ratio of L vs. H, s/l : simple ratio of s vs. l, L. : left valve, R. : right valve. vs. : abbreviation of "versus."

trated in Figure 9.

Comparison and discussion.—In addition to the results clarified biometrically, the specimens examined show a considerable extent of variation in the development of winglike area, outline, inequivalveness and surface ornamentation, which are hardly expressed biometrically. For example, JG.H3064a (Figure 6-2) has a well-developed winglike area, whereas IGPS22709 (Figure 4-1a–d)

Table 2 Biometric characters of *Inoceramus* (*Platyceramus*) *troegeri* sp. nov. from Hokkaido.

	α	γ	δ	l/h	b/h	$b/h_{H=60mm}$	L/H	s/l
N	25	24	25	25	24	19	25	21
m	93.2	140.1	60.3	0.888	0.214	0.225	0.782	0.490
s	4.95	3.66	2.04	0.0569	0.0243	0.0193	0.0286	0.0256
ν	5.31	2.61	3.38	6.41	11.36	8.58	3.66	5.22
X^2	6.37 $\nu=3$	7.46 $\nu=3$	6.37 $\nu=3$	26.37 $\nu=3$	11.08 $\nu=3$	12.56 $\nu=3$	5.26 $\nu=3$	8.43 $\nu=3$

N : sample size, m : mean value, s : standard deviation, ν : Pearson's coefficient of variation, X^2 : chi-square value, ν : degrees of freedom

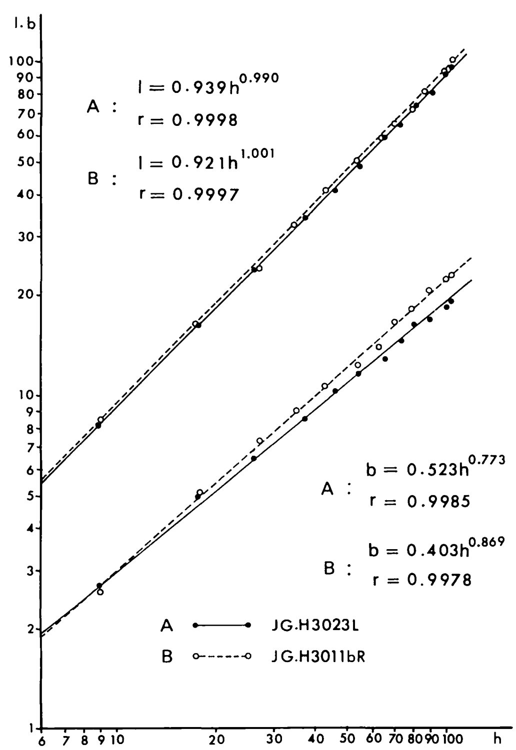

Figure 7. Diagram showing the individual relative growth between l vs. h and b vs. h, for selected specimens of *I.* (*P.*) *troegeri* Noda, sp. nov.

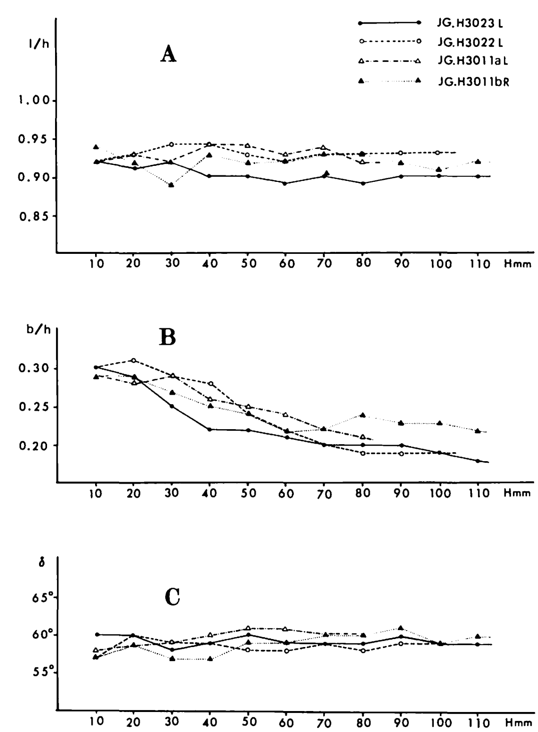

Figure 8. Diagram showing the ontogenetic change of selected characters of *I.* (*P.*) *troegeri* Noda, sp. nov.

A: simple ratio l/h, B: simple ratio b/h, C: obliquity δ.

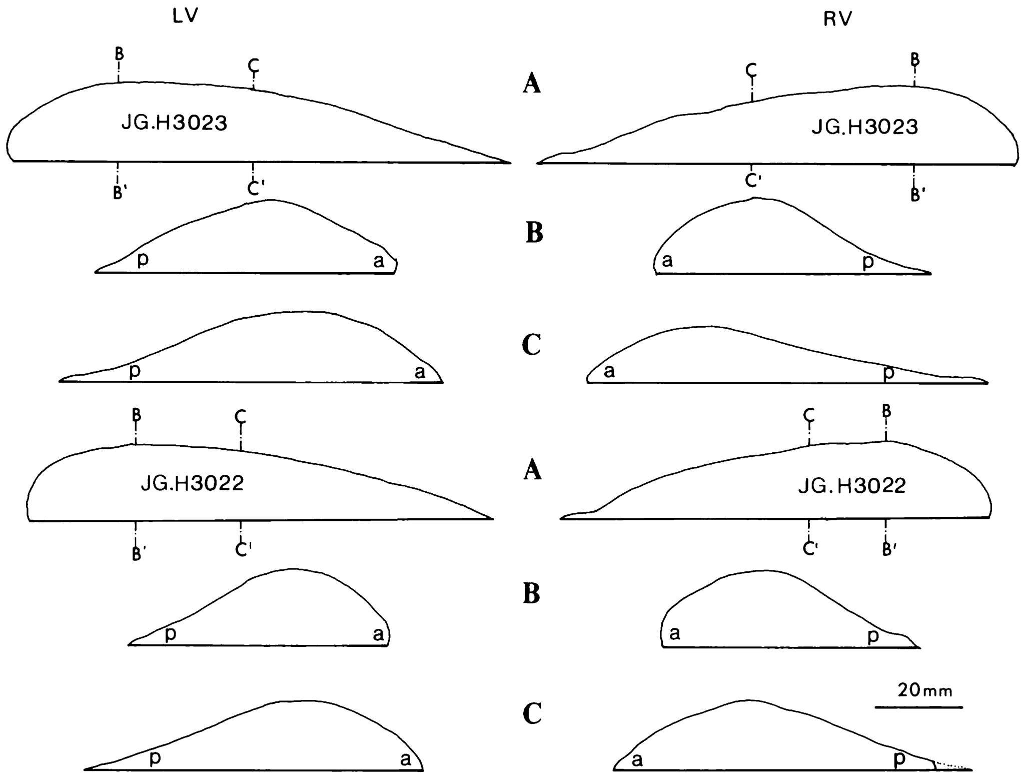

Figure 9. Profiles of two selected specimens of *I.* (*P.*) *troegeri* Noda, sp. nov. in three directions. A : vertical section along the growth axis, B : transverse section at the highest point of shell convexity, perpendicular to the growth axis, C : transverse section at the broadest part perpendicular to H.

shows only a scarcely developed one. The two forms, however, are linked with various grades of intermediate forms, such as JG. H3023 (holotype, Figure 3) and JG.H3038 (Figure 5-1). Likewise, JG.H3064a and JG. H3037 (Figure 5-3) show a clearly different outline, but these are linked with JG.H3009 (Figure 6-1) and JG.H3038. The surface ornament of JG.H3064a is clearly distinct from that of IGPS22709, but those of JG. H3023 and JG.H3011 show transitional characters linking the above two specimens. A specimen JG.H3064a resembles the typical form of *I.* (*P.*) *mantelli* de Mercey, but the two species are clearly discriminated morphologically at the population level by means of Student's *t*-test (Table 3). Moreover, in the present sample the simple ratio l/h and obliquity (δ) are constant throughout growth and the simple ratio b/h decreases with growth, whereas the simple ratio l/h decreases rapidly and obliquity (δ) increases with growth in *I.* (*P.*) *mantelli* (see Noda and Toshimitsu, 1990, p. 50, fig. 10A and C). JG. H3064a may be an extreme form foreshadowing the characters of *I.* (*P.*) *mantelli.*

I. (*P.*) *mantelli* ? *rhenanus* Heinz figured by Lõpez (1986a, pl. 1, fig. 5 ; 1986b, pl. 1, fig. 4) from the lower Coniacian of St. Cornell in the southcentral Pyrenees somewhat resembles a form of the present species, but as his photograph shows, the specimen no. 35009 has a larger ratio of l/h and larger obliquity in comparison with those of any specimen of the present sample (Lõpez, 1986, p. 27, α : 39° is probably a misprint of 93°).

The specimen UMUT.MM6492 and IGPS22709 were originally assigned to the

Table 3. *F*-test and Student's *t*-test for selected characters of *Inoceramus* (*Platyceramus*) *troegeri* sp. nov. and *I.* (*P.*) de Mercey.

		α	γ	δ	l/h	b/h	L/H	s/l
A	*N*	25	24	25	25	(19)	25	21
	m	93.2	140.1	60.3	0.888	(0.225)	0.782	0.490
	s	4.95	3.66	2.06	0.0569	(0.0193)	0.0286	0.0256
F value		3.6523	6.5402	3.2437	2.1278	3.4600	6.3026	6.5864
significance		●	●	●	○	●	●	●
t value		5.791	7.799	3.087	2.807	1.893	3.046	1.455
significance		●	●	●	●	○	●	○
B	*N*	27	24	16	14	14	14	24
	m	105.2	124.1	57.2	0.951	0.205	0.843	0.511
	s	9.46	9.36	3.67	0.0830	0.0359	0.0718	0.0657

A : *I.* (*P.*) *troegeri*, B : *I.* (*P.*) *mantelli*, ● : significant, ○ : not significant,
The values in parentheses showing at the growth stage of 60 mm in H.
For others readers may refer to Tables 1, 2 and Figure 2.

"group of *I. concentricus*" (Nagao and Matsumoto, 1939) but their precise locality and stratigraphic position were unknown at that time. Kauffman (1977) pointed out, without examining the actual specimens, that the figures in Nagao and Matsumoto (1939, pl. 27, fig. 1a, b ; pl. 28, fig. 1) closely resemble *I. heinzi* Sornay from the middle and upper Cenomanian of Europe, Madagascar and the Western Interior, U.S.A., especially the one illustrated by Sornay (1965, fig. 3). However, as Kauffman mentioned, the specimens from Hokkaido are broader and flatter than the type of *I. heinzi* (Sornay, 1965, pl. B, fig. 4). The actual specimens of Nagao and Matsumoto are clearly distinct from the type of *I. heinzi* in the flatter valves, broader outline, less significant inequivalveness and much higher horizon (lower to middle Coniacian).

To sum up, the present sample examined is not identical, at population level, with any other species hitherto described. A new species *Inoceramus* (*Platyceramus*) *troegeri* is established herein.

Etymology.—This species is dedicated to Professor Dr. Karl-Armin Tröger of Bergakademie Freiberg for his great contribution to Cretaceous biostratigraphy and molluscan palaeontology.

Remarks on the subgeneric assignment.—This species is certainly ascribed to the genus *Inoceramus* (s.l.) on the grounds of the characters described above. It is, however, clearly distinct from the species assigned to *I.* (*Inoceramus*) because of its subequivalveness, broad outline and too flat valves, except for the somewhat convex umbonal part. On the other hand it is closely related to *I.* (*Platyceramus*) *mantelli*, that is, to the type species of *I.* (*Platyceramus*), because it includes a form which foretells the characters of *I.* (*P.*) *mantelli.* Moreover, the hinge plate of *I.* (*Inoceramus*) is, as observed in *I.* (*I.*) *cuvierii* and *I.* (*I.*) *hobetsensis,* considerably thick, with coarse, deep and elongate-ovate ligament pits separated by angular ridges, whereas that of *I.* (*Platyceramus*) is not so thick with finer, shallower and multiovate pits and flatter ridges (Crampton, 1988). The hinge structure of this new species (Figure 6-4) is intermediate between the two morphological types.

The above facts may imply that the important characters for subgeneric criteria change gradually with age and some of the varieties foretell the characters of the next younger species-group. In such a case it may be arbitrary to decide which of the two subgenera should be adequate for the species in question. I agree with Matsumoto (personal communication) that this species should be ascribed to the younger subgenus, so far as new characters do appear in that species, even if some of the older or ancestral characters may remain in it. The criteria of a certain taxon are not necessarily completed simultaneously. From the above discussion, it is reasonable to assign the present species to *I.* (*Platyceramus*).

Occurrence.—The locality map is shown in Figure 1.

Loc. Ob0003f (=loc. NH76 of Tanaka, 1963). Topographic map of Takishita Quad., scale 1 : 25,000, the type locality. Long. 141°03′50″E, Lat. 44°03′09″N. A cliff on the left side of the main course of the R. Obirashibe, about 500 m upstream from the Tengu-bashi (Tengu-bridge), Obira area, northwestern Hokkaido. A sketch of the outcrops of Ob0001-0003 (=locs. NH74-76 of Tanaka, 1963) is shown in Figure 10. The specimens examined were obtained from calcareous nodules of the layer marked as f in Figure 10. The f-layer consists of silty sandstone, the kind of sediments of Unit Ua2 (Tanaka, 1963) of the lower part of the Upper Yezo Group. For the associated species see p. 48. From locality Ob0003b, a river floor about 4 m upstream from loc. Ob0003f (stratigraphically 2 m lower horizon from loc. Ob0003f), *I.* (*I.*) *teshioensis* and *Mytiloides incertus,* effective zonal indices of the upper Turonian, were obtained. Therefore Ob0003b-0003f must be very close to the Tu/Co boundary, although the actual boundary is not yet confirmed with certainty.

Loc. Ob0012 (=loc.NH78 of Tanaka, 1963). Topographic map ditto. Long. 141° 54′57″E, Lat. 44°04′13″N. A river floor of the R. Obirashibe about 4,000 m upstream of loc. Ob0003, below the Bridge Takimi-Ohashi. Silty sandstone bed at the base of Unit Ub. For the associated species see p. 1313.

Loc. Ob0020. Topographic map ditto. Long. 141°56′19″E, Lat. 44°04′28″N. A left bank of the R. Obirashibe somewhat downstream from the confluence with the Jugosenzawa. Mudstone bed containing siderite nodule of Unit Ub. For associated fossils see p. 1313.

Range.—From the associated inoceramid and ammonite species the range of *I.* (*P.*)

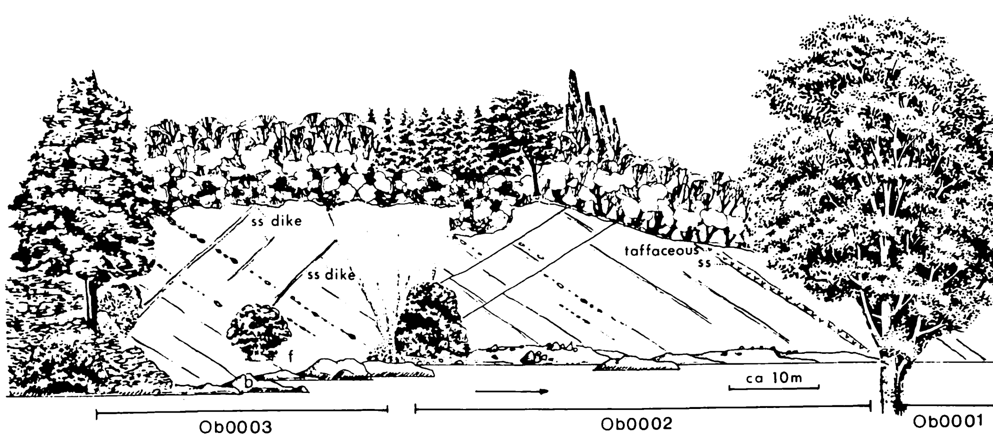

Figure 10. Sketch of the outcrops 0b0001-0003. f: fossil-bearing bed, basal Coniacian. b: Turonian sediments.

troegeri sp. nov. in the Obira area is the Lower to Middle Coniacian. The true range should be made clear on the basis of further stratigraphic work in various regions.

Discussion of phylogeny

The sample of *I.* (*P.*) *troegeri* from the lower to middle Coniacian is sufficiently large (but rather insufficient in number for the chi-square test), and it shows a considerable extent of variation in both of the measurable and unmeasurable characters. Some specimens of *I.* (*P.*) *troegeri*, *e.g.*, JG.H3037 and 3065, show the characters of *I.* (*I.*) *teshioensis* in the inequivalveness, shell convexity and surface ornamentation especially in its younger stage of growth, whereas some other specimens, *e.g.*, JG.H3009 and 3064a, resemble the typical form of *I.* (*P.*) *mantelli*. However, the above forms are extremes, which are linked by various grades of intermediate forms. In the case of a large extent of variation within a species, an ancestral character may or may not remain in some specimens, whereas a new character may begin to appear in other specimens. Such new characters would be settled more firmly in the descendants.

From the above discussion, *I.* (*P.*) *troegeri* can be regarded as an ultimate or common ancestor of various kinds of species of *I.* (*Platyceramus*), linking the latter with *I.* (*I.*) *teshioensis*, and *I.* (*P.*) *troegeri* may be an immediate ancestor of *I.* (*P.*) *mantelli*. Thus, some species of *I.* (*Platyceramus*) were assumably derived from *I.* (*I.*) *teshioensis* at or near the beginning of the Coniacian.

Conclusion

1. *Inoceramus* (*Platyceramus*) *troegeri* sp. nov. from the lower to middle Coniacian of the Obira area shows a large extent of variation in both measurable and unmeasurable characters.
2. Some specimens of this species resemble the typical form of *I.* (*P.*) *mantelli* from the upper Coniacian to Santonian in Japan and some others closely resemble specimens of *I.* (*I.*) *teshioensis* from the upper Turonian. These two forms are extremes of variation which are linked by various grades of intermediate forms.
3. *I.* (*P.*) *troegeri* is probably an immediate ancestor of *I.* (*P.*) *mantelli* and can be regarded as an ultimate or common ancestor of various later species of *I.* (*Platyceramus*). *I.* (*P.*) *troegeri* shows an intimate relationship with *I.* (*I.*) *teshioensis*. Thus, *I.* (*Platyceramus*) may have been derived from *I.* (*Inoceramus*) through *I.* (*P.*) *troegeri* at or near the Tu/Co boundary.

Acknowledgements

I express my sincere thanks to Emeritus Professor Tatsuro Matsumoto of Kyushu University for his kind help in the field and laboratory work, and also for his critical reading of the typescript with instructive suggestions. I thank Dr. Jacques Sornay of France for his valuable comments and interesting suggestion on *I.* (*P.*) *mantelli* through a letter to Matsumoto. I am indebted to Professor Itaru Hayami of the University of Tokyo and Professor Kei Mori and Dr. Kenshiro Ogasawara of Tohoku University (at present, Professor of Tsukuba University) for their kindness in providing facilities for the study of the original specimens of Nagao and Matsumoto. My gratitude is extended to Messrs. Hiroji Kokubun of Mikasa, Toshio Shimanuki of Kurisawa, Shigehiro Uchida of Iwamizawa and Kenji Sanada of Sapporo for their help in the field work, and offering a great number of useful specimens from their collections to this study.

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北海道の白亜系コニアシアン階から産出した *Inoceramus (Platyceramus) troegeri* sp. nov. とその系統的意義について：本論では北海道北西部小平地域の白亜系コニアシアン階から産した *Inoceramus* の 1 新種について記載し，あわせて個体群の立場からいくつかの形質について測定学的検討を試みる。また，本種をかいして *I. (Inceramus)* と *I. (Platyceramus)* との系統的関係を考察する。ここに新種として提唱する *Inoceramus (Platyceramus) troegeri* Noda は輪郭や表面装飾の変異が大きく，その極端なものでは日本のチュロニアン階上部の *I. (I.) teshioensis* Nagao and Matsumoto に似た特徴を示す個体もあるが，他方，日本のコニアシアン階上部からサントニアン階にかけて産する *I. (P.) mantelli* de Mercey に近い特徴を示す個体もある。しかし，両型はいろいろな程度の中間型で繋がれ，個体群の立場からは同一種に属すると考えざるを得ない。このことは *I. (Platyceramus)* のいくつかの種がチュロニアン-コニアシアンの境界期か，または，それに近いコニアシアンの早い時期に *I. (I.) teshioensis* から分化したことを示唆している。したがって，本種は後に続く *I. (Platyceramus)* の主流，傍系をふくめていろいろな種の，共通のあるいは究極の先祖と考えられる。 野田雅之

Trans. Proc. Palaeont. Soc. Japan, N.S., No. 168, pp. 1329-1338, 6 Figs., December 30, 1992

947. COLEOID *SPIRULIROSTRA* (CEPHALOPODA, MOLLUSCA) FROM THE MIOCENE MIZUNAMI GROUP, CENTRAL JAPAN*

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Abstract. A coleoid phragmocone with a rostrum was found from the Miocene Tsukiyoshi Member of the Akeyo Formation, Mizunami Group in Mizunami City, central Japan. It is identical with the holotype of *Spirula mizunamiensis* Tomida and Itoigawa, 1981, found from the Nataki Conglomerate Member of the Oidawara Formation, Mizunami Group. However, the present careful taxonomic examination concludes that *mizunamiensis* belongs to the genus *Spirulirostra* d'Orbigny, 1842. Therefore, *Spirulirostra mizunamiensis* (Tomida and Itoigawa) should be used for the Mizunami specimens. *Spirulirostra mizunamiensis* differs from *Spirulirostra bellardii, Spirulirostra baetensi* and *Spirulirostrina lovisatoi*, of the Miocene in Europe, and also from *Amerirostra americana* of the Miocene in Mexico. The Tsukiyoshi specimen was obtained in association with the autochthonous embaymental molluscan fauna of *Cyclina-Vicarya* assemblage from a tuffaceous sandy mudstone. This occurrence indicates that a pelagic spirulirostrid has been transported to the intertidal muddy bottom of the inner bay after post-mortem drifting from the open sea.

Key words. *Spirulirostra mizunamiensis*, Cephalopoda, Miocene, Mizunami Group, Central Japan

Introduction

A coleoid fossil was found in 1985 from Tsukiyoshi, Akeyo-chô, Mizunami City (Figure 1). It was entrusted to the Mizunami Fossil Museum, which gave me the opportunity to study it. The specimen was examined by soft-X-ray radiography, computed tomography and scanning electron microscope. The purpose of this paper is to give an account of the taxonomic position and paleontological significance of the Tsukiyoshi specimen, and to reexamine the holotype of *Spirula mizunamiensis* described from the Miocene Nataki Conglomerate Member of the Oidawara Formation, Mizunami Group (Tomida and Itoigawa, 1981). Reports of fossil coleoids in Japan are restricted to the Miocene Mizunami Group, in contrast to their rather common occurrence in the European Miocene. The occurrence of this species seems to be useful in determining the phylogenetic relation between the fossil and the Recent coleoids.

*Received May 17, 1992 ; revised manuscript accepted October 1, 1992

Geological occurrence

The Early to Middle Miocene Mizunami Group is distributed in and around Mizunami City. The Mizunami Group is divided into the Toki Lignite-bearing Formation, the Hongô Formation, the Akeyo Formation and the Oidawara Formation, as shown in Figure 2 (Itoigawa, 1980). The upper two formations, the Akeyo and the Oidawara, are marine in origin. The Akeyo Formation is divided into four members, namely, the Tsukiyoshi Member, the Togari

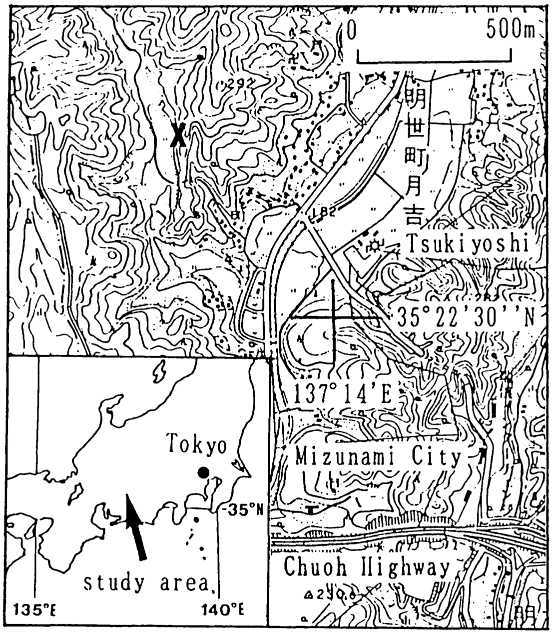


Figure 1. Index map showing the locality of the Tsukiyoshi specimen of *Spirulirostra*. × = Fossil locality. (Topographic map cited, Quadrangle "Toki," 1 : 25,000-scale topographic map of Japan, Geographical Survey Institute).

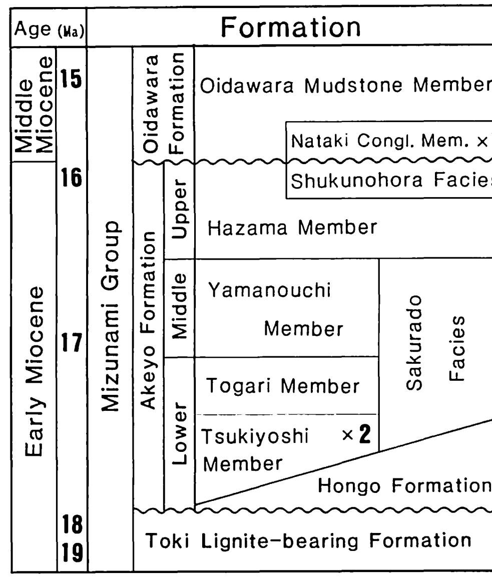


Figure 2. Stratigraphical classification of the Mizunami Group in the Mizunami basin (cited from Itoigawa, 1980) × = Occurrence of *Spirulirostra mizunamiensis*. ×1 denotes horizon reported by Tomida and Itoigawa (1981); ×2 marks present record.

Member, the Yamanouchi Member and the Hazama Member, in ascending order. The Oidawara Formation, which is unconformably underlain by the Akeyo Formation, is composed of mudstone with the basal Nataki Conglomerate Member.

The Tsukiyoshi Member which yielded the present spirulirostrid specimen is the lower part of the Akeyo Formation. It is distributed in Shômasamabora, Tsukiyoshi, Akeyo-chô, and is mainly composed of a massive tuffaceous sandy mudstone and sandstone of about 30 m thick (Figure 3). This member yields abundant subtropical marine molluscan fossils (Itoigawa, 1989; Itoigawa and Yamanoi, 1990) associated with some plant fossils of the Daishima type. The age of the Akeyo Formation is assumed to be 18 to 16+ Ma (Itoigawa, 1988).

Description of the Tsukiyoshi specimen

The Tsukiyoshi specimen (Figures 4-1−6, 5-1−7 and 6), has the following characteristics.

Description.—Phragmocone moderate in size, slender and endogastrical; adoral orthocone straight with small apical angle and adapical cyrtocone; posterior end abruptly curved and completely turned. Surface of phragmocone ornamented with a netlike structure, constrictions corresponding to divisions of internal septae and fine growth lines. Chamber length shorter than diameter; transverse section elliptical and dorsoventrally compressed, with ratio ranging from 0.84 to 0.87. Chamber wall slightly convex. Septum with shallow and posteriorly convex surface; septal suture straight and nearly horizontal on lateral side, and v-shaped on center of ventral side. Siphuncle somewhat thick, tubular, oval, dorsoventrally elongated

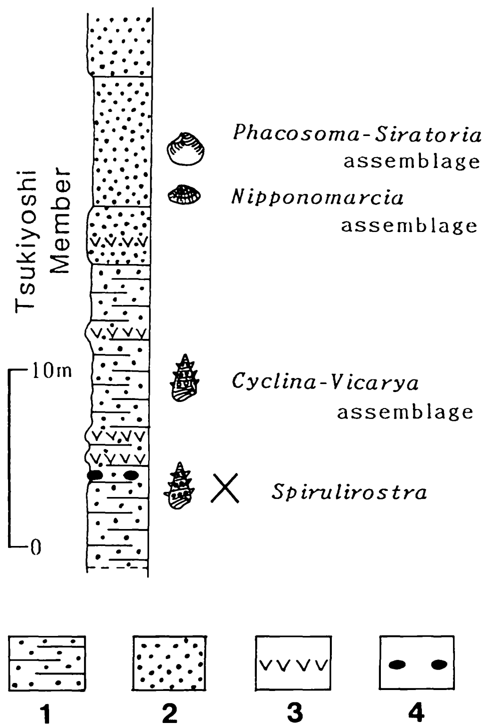


Figure 3. Columnar section with the horizons of molluscan assemblages and *Spirulirostra* in Shômasamabora, Tsukiyoshi. 1. sandy mudstone, 2. sandstone, 3. tuff, 4. nodule.

in section and situated closely to ventral side; septal neck holochoanitic. Rostrum rather large, somewhat short and pointed rather acutely at posterior end; transverse section composed of honeycomb structure; ventral and ventrolateral surface ornamented with many hemispheric nodes; dorsal and dorsolateral surface smooth. Lateral wings rather narrow, elongate and longitudinally expanded; ventrolateral flanges obliquely extended from the 4th chamber downwards to near capitulum. Capitulum single, round, blunt and voluminous.

Measurements.—Whole length 37.6 mm, whole width 10.2 mm, length of phragmocone 29.3+mm, max. diameter of phragmocone 7.4 mm, apical angle of phragmocone ca. 10°(lateral), and 8-9°(dorsal).

Measurements of chambers (in mm) are as follows:

Chamber	Length	Diameter	L/D ratio	Chamber	Length	Diameter	L/D ratio
1	—	—	—	11	1.3	4.0	0.33
2	2.6	—	—	12	1.4	3.8	0.37
3	2.5	—	—	13	1.25	3.6	0.35
4	2.15	7.4	0.29	14	1.2	3.4	0.35
5	1.9	6.8	0.28	15	1.15	3.2	0.36
6	2.0	6.7	0.30	16	0.95	2.9	0.33
7	2.0	6.4	0.31	17	0.8	2.7	0.30
8	1.8	5.5	0.33	18	1.1	—	—
9	1.5	4.8	0.31	19	—	—	—
10	1.5	4.3	0.35	20-?24	not visible		

Repository.—Mizunami Fossil Museum (reg. cat. no. MFM11025)

Remarks.—The Tsukiyoshi specimen was damaged in the adoral half of the ventral side of the phragmocone and the proostracum, as shown in the soft-X-ray radiographic photograph (Figure 5-5) and the computed tomographic photograph (Figure 5-6). The dorsal side of the phragmocone is covered with the rostrum, of which the outer shell layer is composed of the crossed lamellar structure (Figure 5-4), but the adoral half of the ventral side of the phragmocone is not covered at all, so this part seems to be subject to damage.

The netlike structure (Figure 5-7) on the surface of the phragmocone, just the same as that of the Recent *Spirula,* and the honeycomb structure situated inside of the rostrum, as shown in Figure 5-3, are first described in this paper. The sections of rostra figured by d'Orbigny (1842) and Naef (1922), do not show the honeycomb structure but the stratified one. This structure indicates the rostrum is light and useful for floating.

Taxonomic examination

Tomida and Itoigawa (1981) reported a fossil coleoid phragmocone which was obtained from the Nataki Conglomerate Member of the Oidawara Formation, Mizunami Group in Sakuradô, Toki-chô, Mizunami City. This Sakuradô specimen

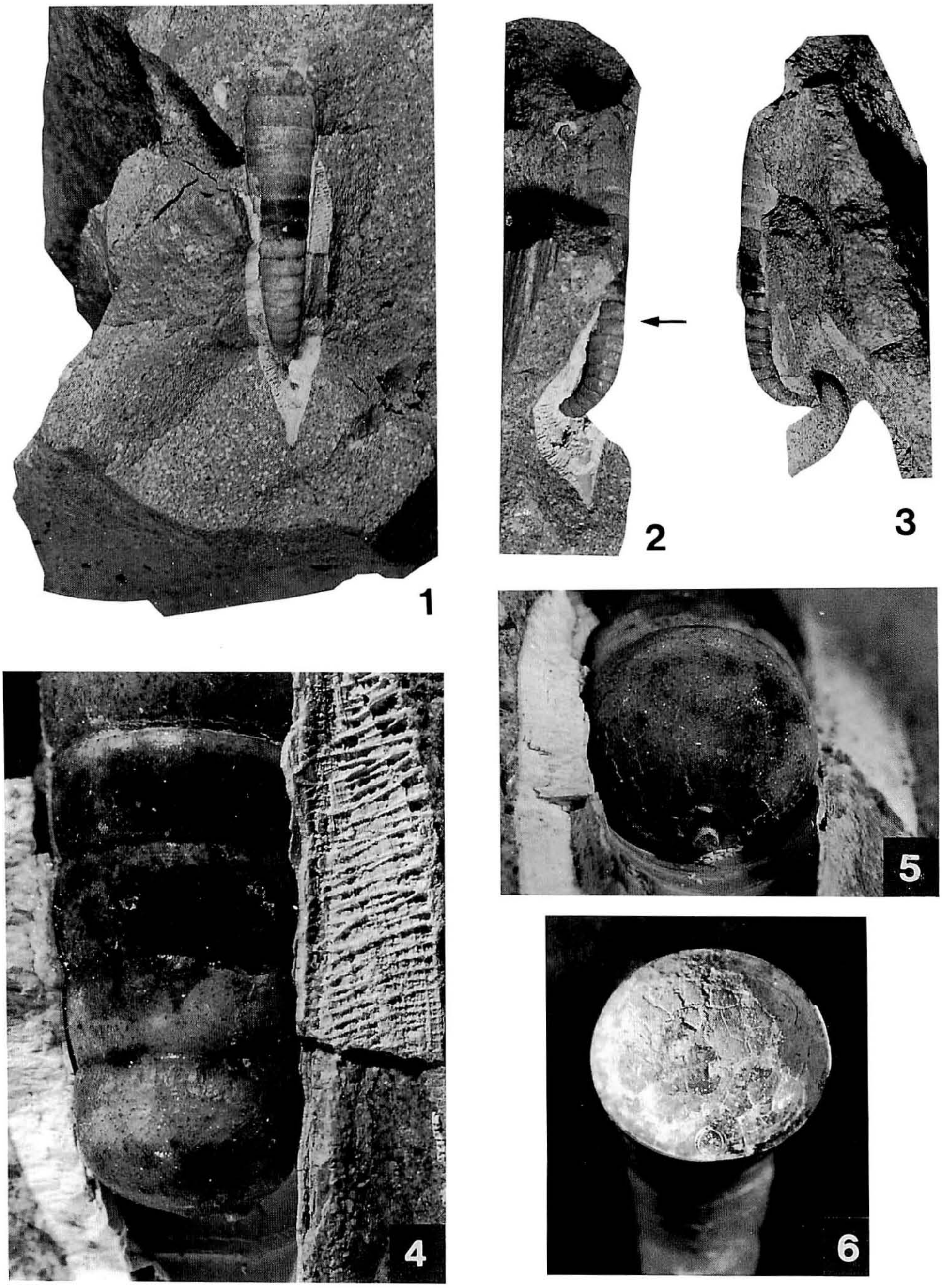


Figure 4. *Spirulirostra mizunamiensis* (Tomida and Itoigawa, 1981), Miocene Tsukiyoshi Member of Akeyo Formation, Mizunami Group. **1**, Dorsal view, ×1.5 ; **2**, Left-lateral view, ×1.5 (Arrow indicates positions of **5** and **6**) ; **3**, Right-lateral view, ×1.5 ; **4**, Dorsal side of phragmocone and lateral wing, ×8 ; **5**, Adapical view of septum, ×8 (Position marked by arrow in **2**) ; **6**, Adoral view of septum, ×9 (Position marked by arrow in **2**).

was first described as *Spirula mizunamiensis* n. sp. because it has a phragmocone with an elliptical transverse section and a nearly coiled posterior end.

The Tsukiyoshi specimen is referable to the genus *Spirulirostra* because of having a phragmocone of straight adoral orthocone, adapical cyrtocone, a rather large and posteriorly pointed rostrum, and elongately expanded lateral wings.

The Tsukiyoshi specimen is distinguished from *Spirulirostrina lovisatoi* Canavari, 1892, a Miocene Langhian species of Sardinia, Italy, because the latter has a phragmocone with a very elongate and elliptical transverse section, a smaller rostrum and shortly expanded lateral wings.

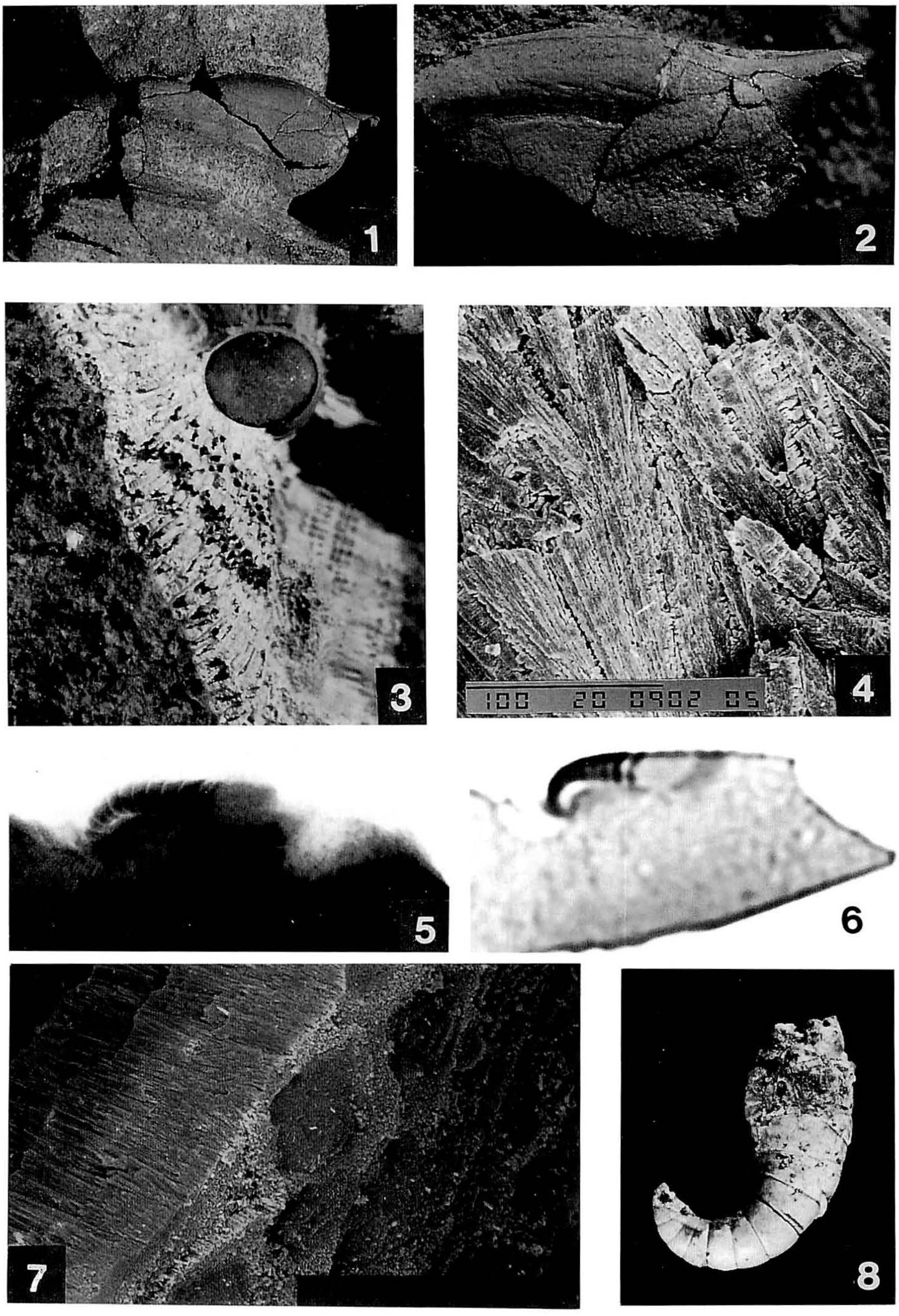
Jeletzky (1969) described a new genus *Amerirostra* on the basis of *Spirulirostra americana* Berry, 1922, a Miocene species of Vera Cruz, Mexico, which is characterized by a phragmocone forming a complete turn with a protoconch almost touching the ventral wall and with a somewhat rounded trapezoidal transverse section, two bosslike midventral capitula and a rostrum ornamented with hemispheric nodes. The Tsukiyoshi specimen differs from *Amerirostra americana* (Berry, 1922), in its phragmocone with a more loosely curved adapical part, a smaller apical angle, an elliptical transverse section and longer chambers, and also in having no dorsal shield, a shorter rostrum and longer lateral wings.

The phragmocone of the Tsukiyoshi specimen is entirely identical with the Sakuradô specimen in having an elliptical transverse section of the ratio 0.84±, a septum with shallow and posteriorly convex surface, a slightly convex chamber wall, a rather thick siphuncle situated close to the ventral side and a completely turned posterior end. Hence the two specimens seem to belong to the same taxon. The small Sakuradô specimen seems to be identical with a posterior part of the phragmocone of the Tsukiyoshi specimen. From the featuresdescribed above (Table 1), I propose the combination *Spirulirostra mizunamiensis* (Tomida and Itoigawa, 1981) for the Tsukiyoshi and Sakuradô specimens.

Spirulirostra mizunamiensis resembles *Spirulirostra bellardii* d'Orbigny, 1842, the type species of the genus from the Middle Miocene of Torino, Piemonte, North Italy, but it is distinguished from *bellardii* by having a phragmocone with an abruptly curved and completely turned posterior end and with an elliptical transverse section and by having a smaller rostrum with a less pointed and shorter posterior end. Two European species, *Spirulirostra hoernesi* Koenen, 1867, described from the Miocene of Dingden and Berssenbrück, northwestern Germany, and *Spirulirostra sepioidea* Naef, 1922, from Torino, North Italy, were reduced to formae of *Spirulirostra bellardii* d'Orbigny, 1842 by Janssen in Janssen and Müler (1984). These species are easily distinguished from *Spirulirostra mizunamiensis*.

Spirulirostra mizunamiensis resembles *Spirulirostra baetensi* Janssen in Janssen and Müller (1984), reported from the Middle Miocene of Ramsel, Antwerpen, Belgium. But it differs from *S. baetensi* by having a phragmocone with a smaller apical angle, an elliptical transverse section, longer chambers, and a larger rostrum with longer lateral wings.

The fossil rostra, phragmocones and separated chambers identified with *Spirulirostra bellardii*, were reported from the Miocene of North Italy (d'Orbigny, 1842 ; Parona, 1898 ; Naef, 1922 ; Janssen and Müller, 1984), northwestern Germany (Koenen, 1867 ; Naef, 1922 ; Janssen and Müller, 1984), southwestern France (Benoist, 1889) and Belgium (Janssen and Müller, 1984). These reports show that the phragmocones of *Spirulirostra bellardii* are circular in transverse section. Parona (1898) reported the occurrence of fragments of chambers and phragmocones of *Spirulirostra bellardii* which had been obtained from the Middle Miocene Serravallian (=Elveziano) Formation at the type locality in Torino, and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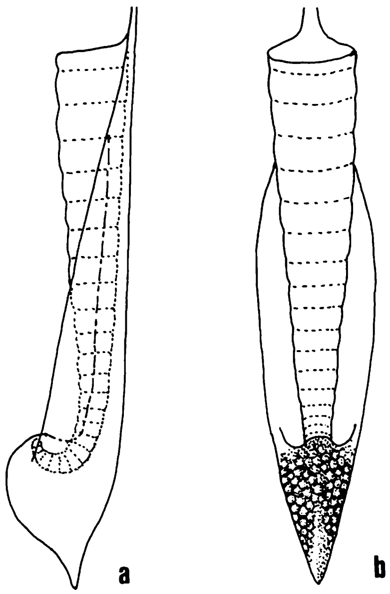

Figure 6. *Spirulirostra mizunamiensis* (Tomida and Itoigawa, 1981); reconstructed figure. a: left lateral view; b: ventral view, ×2.

he figured the circular tranverse section of phragmocone. *Spirulirostra baetensi* Janssen in Janssen and Müller (1984), also has a phragmocone which is circular in transverse section.

On the contrary, *Spirulirostrina lovisatoi* Canavari is characterized by a dorsoventrally compressed phragmocone which is very elongately elliptical in transverse section. Naef (1922) pointed out the morphological similarity of the phragmocone of *Spirulirostrina* to that of the Recent *Sepia*. However, the reconstructed figures of *Spirulirostrina lovisatoi* by Naef (1922, figs. 29a-d), are not faithful to the original figures of Canavari (1892). Janssen in Janssen and Müller (1984) subsequently revised Naef's opinion on the basis of the Stuttgart specimen obtained from the type locality in Sardinia, and he pointed out that *Spirulirostrina lovisatoi* has the chambers in a nearly horizontal position instead of an oblique position, and short lateral wings instead of very long lateral wings, like Canavari's original figures. It seems the differences between the genera *Spirulirostra* and *Spirulirostrina* are not so significant as shown by Naef (1921), who proposed a new family name and used Spirulirostridae and Spirulirostrinidae, respectively.

The feature described above suggests that diagnosis on the basis of the transverse section of the phragmocone should be reexamined because *Spirulirostra mizunamiensis* has a dorsoventrally compressed phragmocone with an elliptical transverse section. However, considering the major differences in transverse sections of the phragmocone presented by *Spirulirostra mizunamiensis* and *Spirulirostrina lovisatoi*, it seems more logical to separate them at the genus rather than family level, as shown by Roger (1952) and Müller (1965). Jeletzky (1969) also mentioned that the Spirulirostrinidae should be placed in synonymy with the Spirulirostridae.

Considerations on the occurrence of *Spirulirostra mizunamiensis*

Tuffaceous sandy mudstone, from where the Tsukiyoshi specimen was found, yields abundant molluscan fossils. In particular,

← **Figure 5.** *Spirulirostra mizunamiensis* (Tomida and Itoigawa, 1981), Miocene Tsukiyoshi Member of the Akeyo Formation, Mizunami Group. **1**, Left-lateral view of rostrum, ×1.5; **2**, Enlarged surface of the dorso-lateral side of rostrum, ×4; **3**, Section of rostrum, showing the honeycomb structure inside, ×8; **4**, Scanning electron microscopic photograph of the dorsal shell layer showing the crossed lamellar structure, ×300; **5**, Soft-X-ray radiographic photograph showing septal structure inside and damaged anterior half of phragmocone, ×1.5; **6**, Computed tomographic photograph, ×1.3; **7**, Scanning electron microscopic photograph of the phragmocone, showing superficial netlike structure and sectional prismatic layer, ×275; **8**, Sakuradô specimen for comparison (holotype: MFM10080, Tomida and Itoigawa, 1981), ×4.

Table 1. Comparison of Miocene spirulirostrid fossils.

Species		*Spirulirostra mizunamiensis* (Tomida & Itoigawa, 1981)	*Spirulirostra bellardii* d'Orbigny, 1842	*Spirulirostra baetensi* Janssen, 1984	*Spirulirostrina lovisatoi* Canavari, 1892	*Amerirostra americana* (Berry, 1922)
Localities		Mizunami, Gifu, Japan	Torino, Italy & N.W. Germany	Antwerpen, Belgium	Sardinia, Italy	Vera Crus, Mexico
Phragmocone	Apical angle	Dorsal ca. 10° Lateral 8-9°	8-9°	15°	Dorsal 13-15° Lateral 5-6°	Dorsal ca. 15° Lateral 10-12°
	Section	elliptical	circular	circular	long elliptical	round, trapezoidal
	(Ratio)	0.84±	1.0	1.0	0.37-0.38	0.94
	Chambers	22-24, short	?, long	22, short	25-30, short	24±, short
	Adapical part	abruptly curved, completely turned	loosely curved, not turned	abruptly curved, almost turned	abruptly curved, completely turned	small coiling attached to wall
Rostrum	Shell	rather large	large	small	very small	large
	Lateral	long	rather long	short	short	rather long
	wings	moderate	wide	rather narrow	rather narrow	wide
	Spine	rather acute	acute	blunt	very acute	acute
	Capitulum	1 capitulum	1 capitulum	1 capitulum	1 capitulum	2 capitula
Numbers of materials cited		1; Tomida & Itoigawa, 1981 1; present report	1; d'Orbigny, 1842 2; Koenen, 1867 2; Naef, 1922 3; Janssen in Janssen & Müller, 1984	1; Janssen in Janssen & Müller, 1984	3; Canavari, 1892 1; Janssen in Janssen & Müller, 1984	1; Berry, 1922 4; Jeletzky, 1969

Cerithideopsilla minoensis, Vicarya yokoyamai, Vicaryella ishiiana, Tateiwaia sp., *Rhizophorimurex tiganouranus, Cyclina japonica* and *Hiatula minoensis*, are predominant. These molluscs are recognized as the *Cyclina-Vicarya* assemblage (Itoigawa, 1980). Most of the *Cyclina japonica* and *Hiatula minoensis* are obtained as conjoined valves, and the gastropods are mainly obtained in a fair state of preservation. These seem to show autochthonous or semiautochthonous occurrence. Concerning the depositional condition of the Tsukiyoshi Member, the lower part of the Akeyo Formation, Itoigawa (1980) proposed that the paleoenvironment was the intertidal zone of the inner bay based on the molluscan fauna cited above. In addition, Itoigawa (1989), and Itoigawa and Yamanoi (1990) mentioned that southwest Japan including the Mizunami area was influenced by tropical and subtropical paleoclimatic conditions during the late Early Miocene.

The Recent species *Spirula spirula* is known as a mesoplanktonic form, living at depths of 300-2,000 m worldwide in warm and tropical seas. Its coiled phragmocone is known to float on the surface of the ocean after death and often reaches the coast. Because of ecological features and postmortem transportation, the specimens are usually damaged like the Tsukiyoshi specimen. The rostrum of *Spirulirostra mizunamiensis* is light and is useful for flotation. Moreover, *Spirulirostra mizunamiensis* seems to have been a mesoplanktonic form in the warm and pelagic sea like *Spirula spirula* because of its similar phragmocone. The Tsukiyoshi specimen was damaged in the phragmocone and was accompanied by the embaymental molluscan fauna as already mentioned. Therefore, the Tsukiyoshi specimen was likely transported to the intertidal muddy bottom of the inner bay after the postmortem drifting from the open sea and mixed into the characteristic embaymental molluscan fauna.

Spirulirostra mizunamiensis was obtained from the Tsukiyoshi Member of the Akeyo Formation and the Nataki Conglomerate Member of the Oidawara Formation (Figure 2). Subtropical sea molluscs are also predominant in the Nataki Conglomerate Member of the Oidawara Formation (ltoigawa, 1989). Both occurrences of *Spirulirostra mizunamiensis* coincide with the horizons bearing tropical or subtropical faunas in the two formations. *Spirulirostra mizunamiensis* accordingly seems to have been a tropical or subtropical inhabitant.

Acknowledgements

I am very grateful to Professor Junji Itoigawa of the Department of Earth and Planetary Sciences of Nagoya University for his helpful advice and critical reading of the manuscript. Sincere thanks are extended to Mr. Hiroaki Karasawa of the same department, and also to Mr. Yoshitsugu Okumura and Mr. Atsushi Naruse of the Mizunami Fossil Museum, for their aid in preparing the specimen and photographs. Thanks are also due to Mr. Shinji Yano of Seto City, for his offering the Tsukiyoshi specimen.

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Akeyo 明世, Gifu 岐阜, Mizunami 瑞浪, Nataki 名滝, Sakuradô 桜堂, Shômasamabora 正馬様洞, Tsukiyoshi 月吉.

岐阜県の中新統瑞浪層群からの頭足類 *Spirulirostra*：岐阜県瑞浪市明世町月吉の中新統瑞浪層群月吉層から *Spirulirostra* が採集された。これは，房錐断面が楕円形を呈し，鞘はやや大きく，側翼が前後に長いこと，などで，ヨーロッパの中新統の *Spirulirostra bellardii* や *S. baetensi*，および *Spirulirostrina lovisatoi* と区別できる。1981 年筆者らが瑞浪市桜堂の名滝層から記載した *Spirula mizunamiensis* は房錐の標本に基くが，月吉標本と房錐の特徴が一致し，同種と判断され，*Spirulirostra mizunamiensis* (Tomida and Itoigawa) と結論する。楕円形の房錐断面をもつ月吉・桜堂標本とヨーロッパの近縁の種との比較により，長楕円形の螺環断面をもつ *Spirulirostrina* を，科としてよりは属として分けることが支持される。月吉標本は，凝灰質の砂質泥岩から現地性の *Cyclina-Vicarya* 群集に伴って産出し，堆積環境は内湾の潮間帯泥底と推定されるので，暖海の外洋から死後漂着したものと思われる。

冨田　進

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Mollusca

Arthropoda

Cnidaria

Bryozoa

Mammalia

Palaeoecology

Palaeoenvironment

PALAEOBOTANY

Palaeobotany

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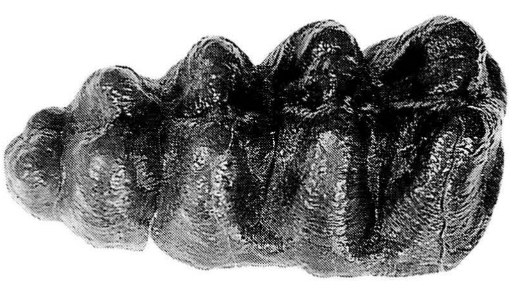

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The illustration is of a molar of *Trilophodon sendaicus* Matsumoto, an extinct elephant described from the Pliocene Tatsunokuchi Formation developed in the environs of Sendai, Northeast Honshu, Japan. (IGPS coll. cat. no. 87759 (A), length about 18.5 cm).

CONTENTS

Number 161 (published April 30, 1991)

Number 162 (published June 30, 1991)

SHORT NOTES

Number 165 (published April 30, 1992)

TRANSACTIONS

Number 168 (published December 30, 1992)

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ダイヤコンサルタント　帝国石油株式会社　日鉱石油開発㈱探査部
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。

1992年12月25日 印刷
1992年12月30日 発行

ISSN 0031-0204
日本古生物学会報告・紀事
新篇168号
2,500円

発行者 日本古生物学会
〒113 東京都本駒込5－16－9
日本学会事務センター内
電話 03－5814－5801
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. 168 December 30, 1992

CONTENTS