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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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922. UPPER CARBONIFEROUS FUSULINACEANS FROM THE AKIYOSHI LIMESTONE GROUP, SOUTHWEST JAPAN*

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Abstract. Twelve species belonging to seven genera of fusulinaceans from the *Protriticites* sp. and *Quasifusulinoides toriyamai* Zones of the Akiyoshi Limestone Group distributed in the Akago-Managatake area in the northeastern part of Akiyoshi Plateau, Yamaguchi Prefecture are described herein. Among them, *Protriticites robustus, Obsoletes horridus* and *Quasifusulinoides toriyamai* are new taxa. This fusulinacean fauna is characterized by the genera *Protriticites, Obsoletes* and *Quasifusulinoides*, and is closely related to those reported from the Moscow Syneclise, Donetz Basin, southern Fergana of Central Asia and Tadushi River Basin of southern Sikhote-Alin in the generic composition. Its geologic age is referable to the early Kasimovian.

Key words. Akiyoshi Limestone Group, Kasimovian, *Obsoletes, Protriticites, Quasifusulinoides*, Upper Carboniferous.

Introduction

Until the discovery of fusulinacean fauna characterized by *Triticites* (s.l.) *matsumotoi* in the Akiyoshi Limestone Group by Ota (1968), the Upper Carboniferous strata had been considered to be entirely lacking not only in the Akiyoshi Limestone Group but also in the most of limestone plateaus of Southwest Japan. At that time, he established the *Triticites* (s.l.) *matsumotoi* Zone, which overlies the Middle Carboniferous *Beedeina akiyoshiensis* Zone. Later, Ota *et al.* (1973) described a fusulinacean fauna of this zone and correlated it to the Kasimovian of USSR or the lower part of the Kawvian of North America.

The distribution of the *Triticites* (s.l.) *matsumotoi* Zone, however, is much restricted and has been known only in a small area about 200 m north of the check point on the Akiyoshi-dai toll road. Therefore, paleontological and stratigraphical knowledge of the Upper Carboniferous in the Akiyoshi Limestone Group still remains to be poor.

Recently, I clarified a foraminiferal biostratigraphy of the lower part of the Akiyoshi Limestone Group distributed in the Akago-Managatake area of the northeastern part of Akiyoshi Plateau, and established the *Protriticites* sp. and *Quasifusulinoides toriyamai* Zones in a stratigraphic interval between the *Beedeina akiyoshiensis* and *Triticites* "*simplex*" Zones (Ueno, 1989).

In the present paper, I describe 12 species of fusulinaceans including three new ones, *Protriticites robustus, Obsoletes horridus* and *Quasifusulinoides toriyamai*, from the *Protriticites* sp. and *Quasifusulinoides toriyamai* Zones.

All of the described specimens are kept in the Akiyoshi-dai Museum of Natural History. The abbreviation ASM is prefixed to the specimens' repository number.

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Geologic setting

In the Akago-Managatake area situated in the northeastern part of Akiyoshi Plateau, Yamaguchi Prefecture, the Akiyoshi Limestone Group comprises a thick basaltic basement rock and the overlying white to gray, pure, massive limestone. The limestone in this area has nearly a complete succession from the late Visean to Gzhelian and yields rich shallow-marine organic remains.

Based on mainly fusulinacean foraminifers, Ueno (1989) subdivided the Carboniferous sequence of the Akiyoshi Limestone Group in this area into the following 13 zones in descending order.

Triticites "simplex" Zone
Quasifusulinoides toriyamai Zone
Protriticites sp. Zone
Beedeina akiyoshiensis Zone
Pseudofusulinella taishakuensis Zone
Fusulinella biconica Zone
Akiyoshiella ozawai Zone
Pseudostaffella antiqua Zone
Millerella yowarensis Zone
Eostaffella bigemmicula Zone
Eostaffella mosquensis Zone
Mediocris breviscula Zone
Endothyra Zone

These zones are distributed in a trend parallel to an almost NW to SE direction and become younger southwestwards. Strikes and dips measured in the field and also from oriented rock samples trend N10°-50°W and 20°-40°NE, respectively. Judging from the available data, the Akiyoshi Limestone Group in the Akago-Managatake area is completely overturned and dips monoclinally

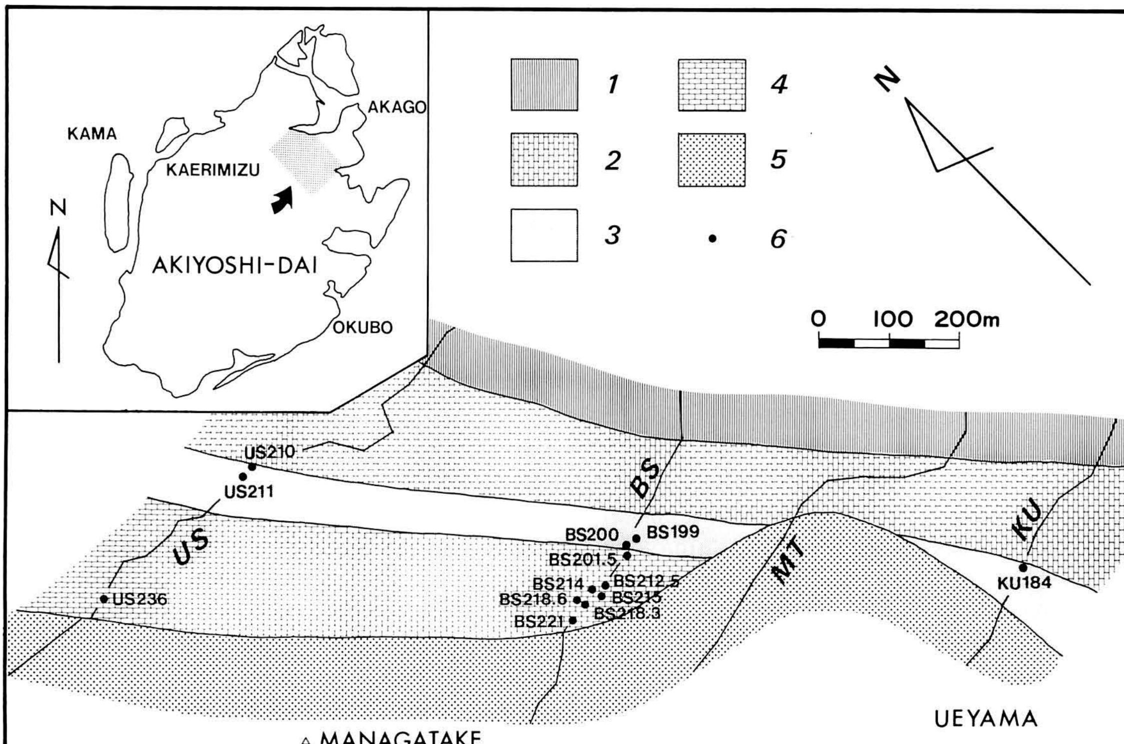


Figure 1. Map showing the distribution of foraminiferal zones and fossil localities studied herein. 1 : *Pseudofusulinella taishakuensis* Zone, 2 : *Beedeina akiyoshiensis* Zone, 3 : *Protriticites* sp. Zone, 4 : *Quasifusulinoides toriyamai* Zone, 5 : *Triticites "simplex"* Zone, 6 : fossil locality.

northeastwards.

The distribution of the *Protriticites* sp. and *Quasifusulinoides toriyamai*, and their overlying and underlying zones are shown in Figure 1. The *Protriticites* sp. Zone, about 15 m thick, conformably overlies the Moscovian *Beedeina akiyoshiensis* Zone and is recognized in the US, BS and KU sections. This zone is defined as the stratigraphic interval between the first occurrence of the genus *Protriticites* and that of *Quasifusulinoides toriyamai*. An algal sparitic limestone is predominant in this zone with a subordinate amount of algal micritic limestone.

The *Quasifusulinoides toriyamai* Zone, about 50 m in maximum thickness, conformably overlies the *Protriticites* sp. Zone and is observed only in the US and BS sections. Lithology of the limestone is similar to that of the *Protriticites* sp. Zone.

The *Triticites "simplex"* Zone has a clino-unconformable contact with the underlying *Quasifusulinoides toriyamai, Protriticites* sp. and *Beedeina akiyoshiensis* Zones. Consequently, it directly overlies the *Beedeina akiyoshiensis* Zone in the MT section.

Faunal affinity and correlation

The following fusulinaceans are discriminated in the *Protriticites* sp. and *Quasifusulinoides toriyamai* Zones.

Protriticites sp. Zone

Protriticites robustus, sp. nov., *P.* sp., *Obsoletes horridus*, sp. nov., *O.* cf. *obsoletus* (Schellwien), *Pseudofusulinella* (*Kanmeraia*) *praeantiqua* Nassichuk and Wilde, *P.* (*K.*) cf. *delicata* Skinner and Wilde, and *Staffella pseudosphaeroidea* Dutkevich.

Quasifusulinoides toriyamai Zone

Quasifusulinoides toriyamai, sp. nov., *Pseudofusulinella* (*Kanmeraia*) *praeantiqua* Nassichuk and Wilde, *Schubertella* aff. *kingi* Dunbar and Skinner, *S.* sp., *Eostaffella* sp. A and *E.* sp. B.

Among these fusulinaceans, the following three genera, *Protriticites, Obsoletes* and *Quasifusulinoides*, are characteristic and are important to discuss faunal affinity and age determination.

At present, the fusulinacean fauna characterized by the genera *Protriticites, Obsoletes* and *Quasifusulinoides* is known in a stratigraphic interval between the Middle Carboniferous *Fusulina* (or *Beedeina*) Zone and the Upper Carboniferous *Triticites* Zone in several regions of USSR, such as the Moscow Syneclise, Donetz Basin, southern Fergana of Central Asia and Tadushi River Basin of southern Sikhote-Alin (Figure 2). This stratigraphic interval corresponds to the lower Kasimovian. The stratigraphy of the Kasimovian in the above-mentioned areas is summarized as follows:

Moscow Syneclise: The stratotype of the Kasimovian Stage is located in the Moscow Syneclise of the Russian Platform. The Kasimovian is represented mainly by marine carbonate rocks and conformably overlies the Moscovian. It is subdivided into the following four horizons, namely, Kreviakinsky, Khamovnichesky, Dologomilovsky and Yauzsky in ascending order. Each horizon corresponds to the *Protriticites pseudomontiparus* - *Obsoletes obsoletus* Zone (C_3A_1),

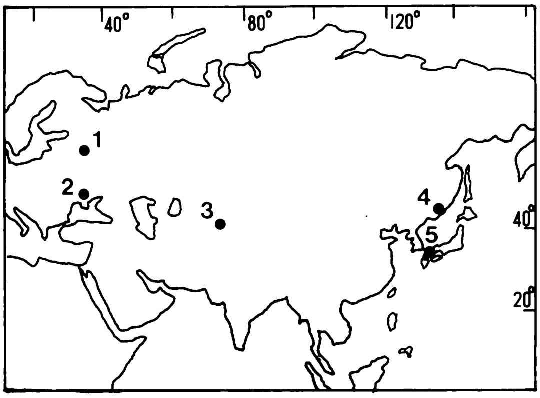


Figure 2. Geographic distribution of the *Protriticites-Obsoletes-Quasifusulinoides* fauna. 1: Moscow Syneclise, 2: Donetz Basin, 3: Southern Fergana, 4: Tadushi River Basin, 5: Akiyoshi.

Montiparus montiparus Zone (C_3A_2), *Triticites arcticus-T. ohioensis* Zone (C_3B_1) and *T. irregularis-T. acutus* Zone (C_3B_2), respectively. The stratigraphic distribution of fusulinaceans in the stratotypic section was shown by Rauser-Chernoussova *et al*. (1979). According to them, the genus *Protriticites* (*P. globulus, P. pseudomontiparus* and *P. sphaericus*) is abundant in the Kreviakinsky Horizon, but its actual range is slightly wider and the genus first appears in the upper Myachkovsky Horizon of Moscovian. The genus *Obsoletes* (*O. obsoletus* and *O. gapeevi*) which flourished in the Kreviakinsky Horizon ranges up to the Khamovnichesky Horizon. The genus *Quasifusulinoides* (*Q. fusiformis*) appears in the Myachkovsky Horizon, but becomes common in the Kreviakinsky Horizon. These three genera coexist only in the Kreviakinsky Horizon.

Donetz Basin: The Donetz Basin contains an almost complete and practically uninterrupted Carboniferous succession of strata up to 12,000 m in thickness. The Carboniferous stratigraphy in the Donetz Basin described by Aisenberg *et al*. (1979) indicates that the Kasimovian in this basin corresponds to the interval from the N_2-N_3 limestones to limestone P_1. It is further subdivided into three zones, C_3^a, C_3^b and C_3^c. The C_3^a Zone contains *Quasifusulinoides* and *Protriticites* with some other genera that ranged upward from the Moscovian. In the lower part of C_3^b Zone (limestones O_1-O_2), the genera *Protriticites, Obsoletes* and *Quasifusulinoides* are abundant, whereas the upper part of C_3^b Zone (limestones O_3-O_4) contains the genus *Montiparus* (*M.* ex gr. *montiparus*). The C_3^c Zone is characterized by the abundant occurrence of *Triticites*.

Southern Fergana of Central Asia: Bensh (1972) reported the Upper Carboniferous and Lower Permian stratigraphy and fusulinaceans of southern Fergana and established the following three zones in the Kasimovian: the *Protriticites pseudomontiparus-Obsoletes obsoletus, Montiparus montiparus* and *Triticites arcticus-T. acutus* Zones. Several species of *Protriticites, Obsoletes* and *Quasifusulinoides* are contained only in the lowest zone.

Tadushi River Basin of southern Sikhote-Alin: In the Tadushi River Basin of southern Sikhote-Alin, a fusulinacean fauna consisting of the genera *Obsoletes, Protriticites* and *Quasifusulinoides* was reported by Nikitina (1969) from a limestone lens in the basal part of the Upper Carboniferous. From a somewhat lower horizon in the same section, typical Moscovian fusulinaceans, such as *Fusiella* cf. *typica. Fusulinella bocki, F. pseudobocki* and others, are recorded together with *Protriticites* ? sp. and *Obsoletes* ? sp. She concluded that the *Obsoletes-Protriticites* Zone characterized by *Obsoletes, Protriticites* and *Quasifusulinoides* can be established in the basal part of the Upper Carboniferous.

In the Akiyoshi Limestone Group, the fusulinacean zones characterized by the genera *Protriticites, Obsoletes* and *Quasifusulinoides* are situated between the *Beedeina* (*B. akiyoshiensis*) and *Triticites* (*T.* "*simplex*") Zones, although a stratigraphic hiatus exists between the *Triticites* "*simplex*" and *Quasifusulinoides toriyamai* Zones. The fusulinacean faunal assemblage of the *Protriticites* sp. and *Quasifusulinoides toriyamai* Zones has a close similarity to those reported from the Moscow Syneclise, Donetz Basin, southern Fergana of Central Asia and Tadushi River Basin of southern Sikhote-Alin and is surely referable to the lower Kasimovian of USSR.

Systematic paleontology

Order Foraminiferida Eichwald, 1830
Suborder Fusulinina Wedekind, 1937
Superfamily Fusulinacea
von Möller, 1878
Family Eostaffellidae Mamet, in Mamet, Mikhailov and Mortelmans, 1970
Genus *Eostaffella* Rauser-Chernoussova, 1948

Eostaffella sp. A

Figure 5-1

Material studied.—Axial section; ASM-25078A from Loc. BS218.6.

Description.—Shell small, involute and highly lenticular. Periphery angular, and umbilical regions slightly depressed in the last volution. Specimen having 2 ½ volutions, measuring 0.09 mm in length and 0.35 mm in width, with a form ratio of 0.26. Proloculus spherical and 0.05 mm in its outside diameter. Spirotheca very thin, consisting of a tectum and upper and lower tectoria. Chomata low, broad and asymmetrical. Tunnel angle of the second volution 8 degrees.

Remarks.—The present species is characterized by a highly lenticular shell and resembles somewhat *Eostaffella mutabilis* described by Rauser-Chernoussova (in Rauser-Chernoussova *et al*., 1951) from the Moscovian of the Russian Platform. However, the former has a fewer number of volution and smaller form ratio than the latter.

Occurrence.—Rare in the upper part of the *Quasifusulinoides toriyamai* Zone.

Eostaffella sp. B

Figure 5-2

Material studied.—Axial section; ASM-25062 from Loc. BS215.

Description.—Shell small and discoidal with rounded periphery. Illustrated specimen having 3 volutions, measuring 0.13 mm in length and 0.31 mm in width, giving a form ratio of 0.42. Proloculus spherical and relatively large for shell size, being 0.055 mm in its outside diameter. Composition of spirotheca not clear owing to its poor preservation. Chomata present in the last volution. Tunnel angle of the third volution 22 degrees.

Remarks.—The present form is similar to *Eostaffella pseudostruvei* forma *minima* described by Kireeva (1949) from central Donbass. However, specific identification of this specimen is postponed because of its ill-preservation. *Eostaffella* sp. B can be easily distinguished from *E*. sp. A of this study by the broad shell periphery and large form ratio of the former.

Occurrence.—Rare in the upper part of the *Quasifusulinoides toriyamai* Zone.

Family Schubertellidae Skinner, 1931
Genus *Schubertella* Staff and Wedekind, 1910
Schubertella aff. *kingi* Dunbar and Skinner, 1937

Figures 5-4—11

Compare.—

Schubertella kingi Dunbar and Skinner, 1937, p. 610-611, pl. 45, figs. 10-15; Thompson and Wheeler in Thompson *et al*., 1946, p. 24-25, pl. 8, figs. 6-10; Thompson and Hazzard in Thompson *et al*., 1946, p. 40-41, pl. 10, figs. 1-9; Thompson, 1948, pl. 4, fig. 21 (same as pl. 45, fig. 12 of Dunbar and Skinner, 1937, p. 610-611); Thompson, 1954, p. 33-34, pl. 5, figs. 11-42, pl. 7, figs. 11-13; Igo, 1957, p. 192-194, pl. 4, figs. 9-15; Sakagami and Omata, 1957, p. 249-250, pl. 19, fig. 1; Toriyama, 1958, p. 73-75, pl. 7, figs. 1-8; Kochansky-Devidé, 1959, p. 17-18, 47, pl. 1, figs. 7-12; Suyari, 1962, p. 8, pl. 1, figs. 10-11; Douglass in Mudge and Yochelson, 1962, p. 60-61, pl. 8, figs. 5-7; Sabins and Ross, 1963, p. 360-361, pl. 38, figs. 9-12; Skinner and Wilde, 1965, p. 25, pl. 27, figs. 4-11; Kauffman and Roth, 1966, p. 6, pl. 1, figs. 1-4; Stewart, 1966, p. 84, pl. 1, figs. 13-14 (same as pl. 45, figs. 14, 12 of Dunbar and Skinner, 1937, p. 610-611); Stewart, 1968, p. 326, pl. 41, figs. 13-14 (same as pl. 45, figs. 14, 12 of Dunbar and Skinner, 1937, p. 610-611); Han, 1976, p. 25, pl. 3, figs. 2-3; Igo *et al*, 1977, p. 100, pl. 17, figs. 9-10, pl. 18, figs. 11-14; Leven and Scherbovich, 1978, p. 85, pl. 1, figs. 7-8; Chen and Wang, 1983, p. 35-36, pl. 1, figs. 31-33, pl. 2, figs. 1-3; Han and Zhao, 1984, p. 62-63, pl. 2, figs. 37-40; Sheng and Wang, 1984, p. 33-34, pl. 1, figs. 25-26; Niko and Watanabe, 1987, p. 46, figs. 4-A-H; Han, 1988, pl. 1, fig. 5.

Material studied.—Axial sections; ASM-25070, ASM25079, ASM25067, ASM25073, ASM25078B from Loc. BS218.6 and ASM25059B from Loc. BS201.5. Sagittal sections; ASM25077 and ASM25065 from Loc. BS218.6.

Description.—Shell small and fusiform to elongate fusiform. Polar regions bluntly to sharply pointed. Mature specimens having 4 to 5 volutions, measuring from 0.60 to 0.80 mm in length and 0.28 to 0.40 mm in width. Form ratio ranging from 2.03 to 2.57, averaging 2.12 for 6 specimens.

Inner 2 or 2½ volutions coiled almost perpendicularly to remaining planispiral ones. Average radius vectors of the first to fifth volutions for 8 specimens being 0.04, 0.06, 0.09, 0.14 and 0.19 mm. Average form ratios of the first to fifth volutions for 6 specimens being 0.91, 0.99, 1.20, 1.81 and 2.09, respectively.

Proloculus small and almost spherical. Its outside diameter ranging from 0.03 to 0.045 mm, averaging 0.04 mm for 8 specimens.

Spirotheca thin and composed of a single homogeneous layer in inner 2 or 3 volutions, but a tectum and lower discontinuous less dense layer (diaphanotheca) in outer ones. Average thickness of spirotheca of the first to fifth volutions for 8 specimes being 0.005, 0.008, 0.010, 0.010 and 0.015 mm, respectively.

Septa short, straight and unfluted in central part of shell, but weakly fluted in extreme polar regions. Massive chomata well developed in outer 3 volutions. Average tunnel angles of the third to fifth volutions for 6 specimens measuring 17, 31 and 35 degrees, respectively.

Remarks.—This species resembles *Schubertella kingi* Dunbar and Skinner which was originally described from the Wolfcampian of Texas. However, development of the lower less dense layer (diaphanotheca) in the present specimens seems to be more feeble and discontinuous than that in the original ones. In addition, the former shell is smaller than the latter.

Occurrence.—Abundant in the *Quasifusulinoides toriyamai* Zone.

Schubertella sp.

Figures 5-12—13

Material studied.—Axial sections; ASM-25063 from Loc. BS218.3 and ASM25080 from Loc. BS221.

Description.—Shell small and bulged to thickly fusiform with rounded polar regions. Mature specimens having 4½ volutions, measuring from 0.73 to 0.78 mm in length and 0.43 mm in width. Form ratio varying from 1.70 to 1.81. Inner 2 volutions tightly coiled at a large angle to outer ones. Form ratios of the first to fifth volutions of typical specimen (Figure 5-13) being 0.75, 1.17, 1.20, 1.48 and 1.91, respectively. Proloculus small and spherical. Its outside diameter ranging from 0.04 to 0.06 mm. Spirotheca thin, composed of a single homogeneous layer in inner few volutions, and an extremely thin tectum and a discontinuous lower less dense layer (diaphanotheca) in outer ones. Septa almost plane. Chomata weakly developed in outer 3 volutions.

Remarks.—The present species is similar to *Schubertella* aff. *kingi* of this study, but differs from the latter in having a smaller form ratio in the mature stage. This unidentified species has a shell smaller than that of *Schubertella kingi exilis* described from the Lower Permian of South Urals by Suleimanov (1949).

Occurrence.—Rare in the upper part of the *Quasifusulinoides toriyamai* Zone.

Family Fusulinidae von Möller, 1878
Subfamily Fusulinellinae Staff and Wedekind, 1910
Genus *Protriticites* Putrja, 1948

Protriticites Putrja, 1948, p. 90-91.

Diagnosis.—Shell small to moderate in size, inflated fusiform to subcylindrical in shape, with rounded to bluntly pointed polar ends. Axis of coiling straight throughout. Proloculus commonly small. Spirotheca thin to rather thick, composed of 4 layers in inner volutions, a tectum, diaphanotheca and upper and lower tectoria, but of 3 layers in outer ones, a tectum, alveolar keriotheca and thin, inconstant upper tectorium. Upper tectorium not seen in the last volution. In well-preserved specimens, minute pores penetrating all 4 layers in inner volutions. Septa weakly to moderately fluted in polar regions, but unfluted in central part of shell. Chomata well developed and massive. Tunnel path straight. Axial fillings absent.

Remarks.—The genus *Protriticites* was introduced by Putrja (1948) with *Protriticites globulus* as the type species. This genus is characterized by its peculiar spirothecal structure that has a *Fusulinella*-like spirotheca in the inner volutions and *Triticites*-like spirotheca in the outer ones. In the original generic diagnosis, Putrja described minute pores (fine alveolar structure) penetrating all 4 layers in the inner volutions, but this delicate structure can be seen only in well-preserved specimens.

Protriticites robustus Ueno, sp. nov.

Figures 3—1-4

Material studied.—Axial section of holotype ; ASM25040B. Slightly oblique axial section of paratype ; ASM25040A. Sagittal section of paratype ; ASM25042.

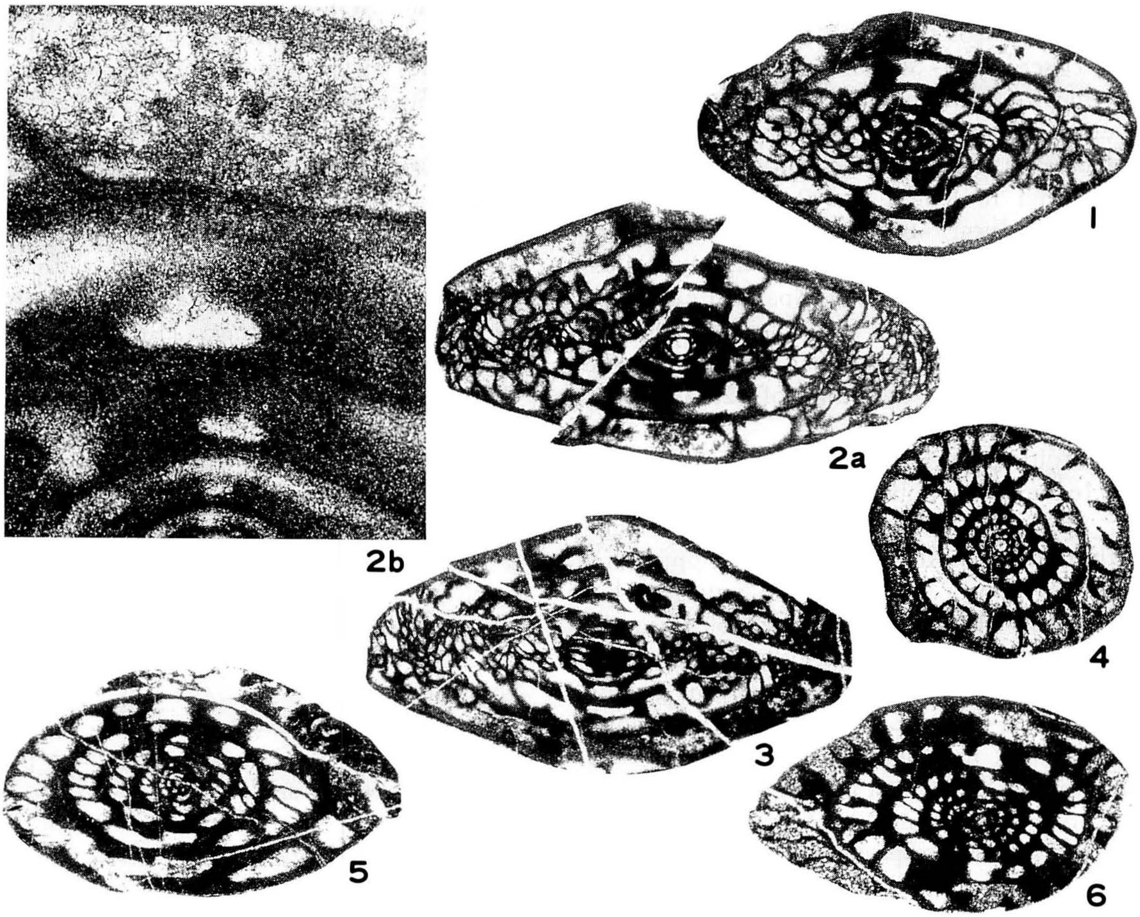


Figure 3. **1-4**. *Protriticites robustus*, sp. nov., **2a** : axial section of holotype, ASM25040B, **1** : slightly oblique axial section of paratype, ASM25040A, **3** : tangential section of paratype, ASM25035, **4** : sagittal section of paratype, ASM25042, ×15, **2b** : enlarged part of **la**, ×75. **5, 6** : *Protriticites* sp., oblique sections, ASM25081, ASM25029, ×20.

Table 1. Measurements of *Protriticites robustus*, sp. nov. (in mm).

	Specimen number	Figure	Length	Width	F.R.	D.P.	Radius vector					
							1	2	3	4	5	6
1	ASM25040A	3-1	3.88	2.13	1.82	0.12	0.12	0.20	0.33	0.52	0.81	1.15
2	ASM25040B	3-2	4.45	2.03	2.19	0.16	0.13	0.22	0.38	0.68	1.03	1.40*

	Form ratio						Thickness of spirotheca						Tunnel angle (degrees)					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1	1.29	1.49	1.48	1.52	1.60	1.70	—	0.040	0.050	0.065	0.090	0.090	25	17	23	26	39	—
2	1.28	1.82	1.89	2.06	2.17	1.85*	0.015	0.030	0.060	0.090	0.070	0.090*	23	20	27	28	—	—

F.R. : Form ratio, D.P. : Diameter of proloculus, * : 5 ½ volution

Tangential section of paratype ; ASM25035. All specimens from Loc. BS199.

Description.—Shell medium in size and typically fusiform with bluntly pointed polar ends. Lateral slopes almost straight. Holotype having 5 ½ volutions, measuring 4.45 mm in length and 2.03 mm in width, giving a form ratio of 2.19. Axis of coiling straight. The first volution tightly coiled, but later ones becoming expanded gradually. Radius vectors of the first to fifth volutions of the holotype being 0.13, 0.22, 0.38, 0.68 and 1.03 mm, giving form ratios of 1.28, 1.82, 1.89, 2.06 and 2.07, respectively.

Proloculus spherical, ranging from 0.12 to 0.16 mm in its outside diameter.

Spirotheca thin, composed of a tectum, thin, indistinct diaphanotheca and upper and lower tectoria in the second volution, but relatively thick and composed of a tectum, thick lower alveolar keriotheca and inconstant upper tectorium in subsequent 2 volutions, and composed of a tectum and alveolar keriotheca in outermost one. Thickness of spirotheca of the first to fifth volutions of the holotype measuring 0.015, 0.030, 0.060, 0.090 and 0.070 mm, respectively.

Septa nearly plane in central part of shell, but weakly to moderately fluted in polar regions. Septal counts of the first to sixth volutions of illustrated specimen (Figure 3-10) being 8, 12, 16, 18, 24 and 22, respectively.

Chomata broad, massive and observed from the first to penultimate volutions. Tunnel angles of the first to fourth volutions of the holotype being 23, 20, 27 and 28 degrees, respectively. Axial fillings absent.

Remarks.—*Protriticites robustus*, sp. nov. can be distinguished easily from *Protriticites globulus* Putrja by its less-developed chomata, larger proloculus and smaller form ratio.

Ota (1977) illustrated *Triticites* (s.l.) *matsumotoi* from the *Triticites* (s.l.) *matsumotoi* Zone of the Akiyoshi Limestone Group. *Triticites* (s.l.) *matsumotoi* can be distinguished from the present new species in having a smaller shell and well-defined, *Fusulinella*-like, 4-layered spirotheca in the inner volutions.

Protriticites robustus, sp. nov. resembles some species of *Montiparus* in the shell morphology, but differs from the latter in having a 4-layered spirotheca in the inner volutions.

Measurements.—See Table 1.

Occurrence.—Rare in the uppermost part of the *Protriticites* sp. Zone.

Protriticites sp.

Figures 3-5—6

Material studied.—Oblique sections ; ASM25081 from Loc. KU184 and ASM25029 from Loc. US210. Some additional, but poorly oriented specimens from the *Protriticites* sp. Zone were also studied.

Description.—Two oblique sections (Figures 3-5, 6) having 6 volutions, measuring 2.60 and 2.70 mm in length, and 1.45 and 1.50 mm in width. Proloculus spherical, measuring 0.10 and 0.08 mm in outside diameter. Spirotheca composed of a single homogeneous layer in inner 2 volutions, a tectum, diaphanotheca and upper and lower tectoria in middle ones, and a tectum and finely alveolar keriotheca in outer 2 volutions. Septa almost plane. Chomata present.

Remarks.—Because all the examined specimens are poorly oriented, specific identification is impossible. The present form can be distinguished from *Protriticites robustus*, sp. nov. in having a smaller shell.

Occurrence.—Common in the *Protriticites* sp. Zone.

Genus *Obsoletes* Kireeva, 1950

Obsoletes Kireeva, 1950, p. 201-202.

Diagnosis.—Shell small to moderate in size, elongate fusiform to cylindrical in shape. Axis of coiling almost straight. Proloculus spherical, small to medium. Spirotheca usually thin and quite complicated, composed of a tectum, diaphanotheca and very thin, discontinuous lower tectorium in inner volutions. Outer ones consisting of a tectum, rather thick alveolar keriotheca and thin, inconstant upper tectorium. Very minute pores penetrating a diaphanotheca observable in well-preserved specimens. Septa not fluted in central part of shell, but weakly fluted in extreme polar regions. Chomata present, weak to massive. Axial fillings absent.

Discussion and remarks.—The genus *Obsoletes* was established by Kireeva (1950) with *Fusulina obsoleta* Schellwien as the type species. She described the ontogenetic change of spirothecal structure in this genus. Later, Rauser-Chernoussova and Fursenko (1959) briefly stated that the spirotheca of the genus *Obsoletes* is thin, porous and composed of a tectum, protheca and inconstant, very thin upper tectorium. They did not refer to its peculiar spirothecal structure which Kireeva had pointed out. Some fusulinacean students, however, recognized that a diaphanotheca and discontinuous thin lower tectorium can be observed in the inner volutions of the genus *Obsoletes* (*e.g.*, Chen, 1963; Bensh, 1972; Rozovskaya, 1975). Such a spirothecal structure somewhat resembles that of the genus *Protriticites*, and this causes ambiguity in the generic status of *Obsoletes*.

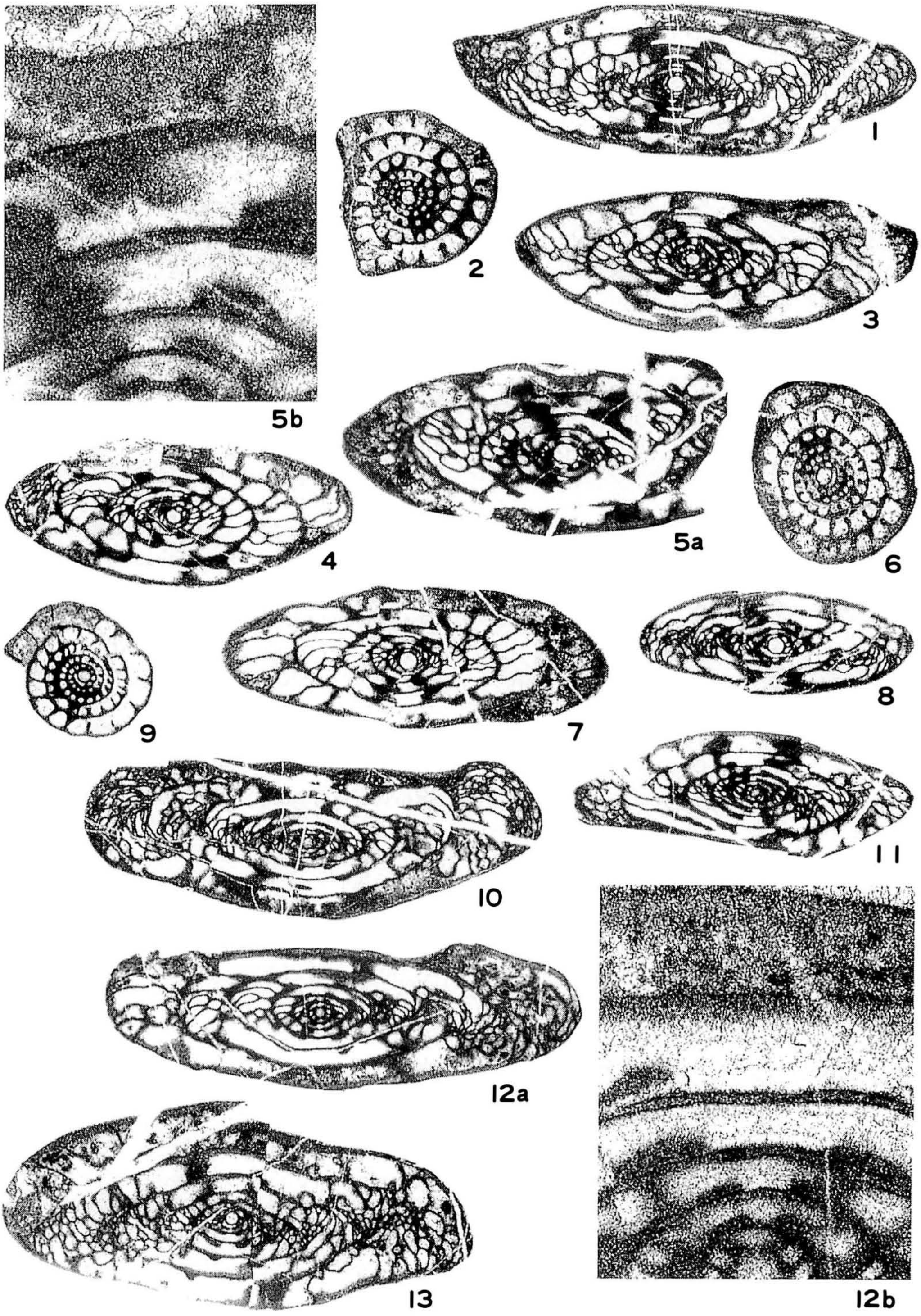
Rozovskaya (1975) stated that the genus *Obsoletes* can be distinguished from the genus *Protriticites* in having a spirotheca with the alveolar structure (keriotheca) in the outermost volution. However, the alveolar keriotheca also exists in the genus *Protriticites*.

As mentioned above, the taxonomic status between these two genera is confused, especially in their spirothecal composition. However, the genus *Obsoletes* can be distinguished from the genus *Protriticites* in having a more elongate shell, slightly larger form ratio, less developed chomata and thinner spirotheca. Moreover, concerning their spirothecal composition in the inner volutions, the former genus has a 3-layered spirotheca, composed of a tectum, diaphanotheca, and thin discontinuous lower tectorium. On the other hand, the latter genus has a 4-layered spirotheca, composed of a tectum, diaphanotheca, and upper and lower tectoria. The spirothecal composition in the outer volutions is closely allied to each other.

Obsoletes horridus Ueno, sp. nov.

Figures 4-1—8

Material studied.—Axial section of holotype; ASM25037A. Axial section of immature paratype specimen; ASM25038. Slightly oblique axial sections of paratypes; ASM25043, ASM25039, ASM25033A and ASM25041. Sagittal sections of paratypes;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ASM25045 and ASM25041. Sagittal sections of paratypes; ASM25045 and ASM 25033B. In addition, some other specimens were studied. All specimens from Loc. BS199.

Description.—Shell large for the genus and elongate fusiform in shape. Polar regions bluntly pointed. Mature shell having 5 ½ to 6 volutions, measuring from 4.30 to 5.08 mm in length and 1.53 to 2.03 mm in width. Form ratio of complete axial section (holotype) being 3.12.

Axis of coiling straight. Shell expanding gradually through growth. Average radius vectors of the first to sixth volutions for 8 specimens being 0.14, 0.21, 0.33, 0.50, 0.75 and 0.82 mm. Form ratios of the first to sixth volutions of the holotype being 1.84, 2.17, 2.51, 2.38, 2.73 and 2.98, respectively.

Proloculus large and spherical. Its outside diameter varying from 0.16 to 0.24 mm, averaging 0.20 mm for 13 specimens.

Spirotheca thin and composed of a tectum, diaphanotheca and thin lower tectorium in inner volutions. Spirotheca in outer 2 volutions consisting of a tectum, finely alveolar keriotheca and thin, inconstant upper tectorium. Average thickness of spirotheca of the first to sixth volutions for 8 specimens being 0.015, 0.020, 0.030, 0.037, 0.054 and 0.080 mm.

Septa straight and not fluted in central part of shell, but weakly to moderately fluted in polar regions. Septal counts of the first to sixth volutions of illustrated specimen (Figure 4-6) numbering 7, 15, 17, 17, 19 and 18, respectively.

Chomata massive and well developed in all volutions except for the last one. Tunnel angles of the first to sixth volutions for 6 specimens averaging 24, 27, 33, 51, 57 and 71 degrees. Axial fillings absent.

Remarks.— The present new species is

Table 2. Measurements of *Obsoletes horridus*, sp. nov. (in mm).

	Specimen number	Fig.	Length	Width	F.R.	D.P.	Radius vector					
							1	2	3	4	5	6
1	ASM25037A	4-1	5.08	1.63	3.12	0.19	0.13	0.18	0.28	0.42	0.62	0.86
2	ASM25043	4-3	4.43	1.53	2.90	0.14	0.11	0.18	0.25	0.38	0.57	0.82
3	ASM25033A	4-5	5.00	1.90	2.63	0.24	0.19	0.23	0.44	0.67	0.93	
4	ASM25038	4-8	3.00	1.14	2.63	0.18	0.11	0.18	0.26	0.39	0.59*	

	Form ratio						Thickness of spirotheca						Tunnel angle (degrees)					
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
1	1.84	2.17	2.51	2.38	2.73	2.98	0.020	0.020	0.030	0.035	0.050	0.070	24	39	39	59	65	71
2	1.55	1.60	1.66	1.97	1.80	2.38	0.015	0.020	0.035	0.030	0.045	0.090	18	17	18	37	53	70
3	1.68	2.58	2.18	2.69	2.63		0.015	0.020	0.040	0.065	0.070		26	27	39	50	61	
4	1.64	2.28	2.55	2.92	2.50*		0.010	0.015	0.020	0.030	0.060*		30	27	27	41	54*	

* : 4 ½ volution

← **Figure 4.** **1-8**. *Obsoletes horridus*, sp. nov., **1**: axial section of holotype, ASM25037A, **2, 6**: sagittal sections of paratypes, ASM25045, ASM25033B, **3-5a, 7**: slightly oblique axial sections, paratypes, ASM25043, ASM25039, ASM25033A, ASM25041, **8**: axial section of immature paratype specimen, ASM25038, ×15, **5b**: enlarged part of **5a**. ×75. **9-13**. *Obsoletes* cf. *obsoletus* (Schellwien), **9**: sagittal section, ASM25037B, **10-12a, 13**: axial sections, ASM25036, ASM25044, ASM25032, ASM25034, ×15, **12b**: enlarged part of **12a**, ×75.

allied to *Obsoletes fusiformis* described by Bensh (1972) from the Kasimovian *Protriticites pseudomontiparus* - *Obsoletes obsoletus* Zone of southern Fergana. However, the former possesses a larger shell than the latter.

The present form also resembles *Obsoletes magnus* Kireeva from the C_3^3 Suite of the Donetz Basin, but differs from the latter in having a larger shell.

Measurements.—See Table 2.

Occurrence.—Common in the uppermost part of the *Protriticites* sp. Zone.

Obsoletes cf. *obsoletus* (Schellwien, 1908)

Figures 4-9—13

Compare.—

Fusulina obsoleta Schellwien, 1908, p. 167-168, pl. 19, figs. 5-7.

Neofusulina obsoleta (Schellwien); Lee, 1927, p. 18-19, pl. 2, fig. 19.

Protriticites obsoletus (Schellwien); Putrja, 1948, p. 94, pl. 1, fig. 7; Rozovskaya, 1950, p. 10-11, pl. 1, figs. 1-4.

Obsoletes obsoletus (Schellwien); Rauser-Chernoussova and Fursenko, 1959, pl. 7, fig. 8 (same as pl. 1, fig. 2 of Rozovskaya, 1950, p. 10-11); Chen, 1963, pl. 1, figs. 2-3, pl. 2, fig. 3; Pasini, 1965, pl. 7, fig. 1 (same as pl. 19, fig. 7 of Schellwien, 1908, p. 167-168); Rozovskaya, 1975, pl. 12, figs. 5-6 (fig. 5: same as pl. 19, fig. 7 of Schellwien, 1908, p. 167-168, fig. 6: same as pl. 1, fig. 2 of Rozovskaya, 1950, p. 10-11); Niikawa, 1978, p. 562-563, pl. 12, figs. 1-2; Ozawa and Kobayashi, 1990, pl. 3, figs. 16-18.

Obsoletes obsoleta (Schellwien); Loeblich and Tappan, 1988, pl. 267, figs. 10-12 (same as pl. 19, figs. 6-7, 5 of Schellwien, 1908, p. 167-168).

Protriticites aff. *obsoletus* (Schellwien); Sheng, 1958, p. 36-37, 95-96, pl. 10, fig. 12.

Material studied.—Axial sections; ASM25036, ASM25044, ASM25032 and ASM25034. Sagittal section; ASM25037B. Some additional specimens were also studied. All specimens from Loc. BS199.

Description.—Shell large for the genus and elongate fusiform to cylindrical in shape with bluntly pointed or rounded polar ends. Lateral slopes slightly convex. Mature specimens of 6 volutions, measuring from 5.08 to 5.30 mm in length and 1.53 to 2.05 mm in width. Form ratio varying from 2.58 to 3.48, averaging 3.01 for 4 specimens.

Axis of coiling straight throughout and shell expanding gradually through growth. Average radius vectors of the first to sixth volutions for 5 specimens being 0.12, 0.21, 0.31, 0.47, 0.71 and 0.93 mm. Form ratios of the first to sixth volutions for 4 specimens being 1.45, 1.81, 2.05, 2.32, 2.58 and 2.57, respectively.

Proloculus small and spherical. Its outside diameter ranging from 0.12 to 0.16 mm, averaging 0.14 mm for 4 specimens.

Spirotheca thin, composed of a tectum, diaphanotheca and thin lower tectorium in inner volutions, but a tectum and finely alveolar keriotheca in outer ones. Inconstant upper tectorium sometimes observed in outer volutions. Average thickness of spirotheca of the first to sixth volutions for 5 specimens measuring 0.022, 0.027, 0.031, 0.040, 0.062 and 0.105 mm, respectively.

Septa weakly fluted only in axial regions. Septal counts of the first to fifth volutions of illustrated sagittal section (Figure 4-9) numbering 7, 15, 21, 20 and 15.

Chomata low and small. Average tunnel angles of the second to fifth volutions for 4 specimens measuring 23, 32, 41 and 57 degrees, respectively. Axial fillings absent.

Remarks.—The Akiyoshi specimens are almost identical with *Obsoletes obsoletus* which Schellwien (1908) originally described from the Upper Carboniferous in the Donetz Basin of USSR, in their essential morphological characters. However, the former has a larger shell and less-developed chomata than the latter. Exact identification is postponed pending the availability of better materials.

Obsoletes cf. *obsoletus* differs from *O. horridus* described herein in having less developed chomata and smaller proloculus.

Occurrence.—Common in the uppermost part of the *Protriticites* sp. Zone.

Genus *Pseudofusulinella* Thompson, 1951
Subgenus *Kanmeraia* Ozawa, 1967
Pseudofusulinella (*Kanmeraia*) *praeantiqua* Nassichuk and Wilde, 1977

Figures 5-15—26

Pseudofusulinella praeantiqua Nassichuk and Wilde, 1977, p. 24, pl. 1, figs. 7-13.

Material studied.— Axial sections; ASM 25046, ASM25048, ASM25058, ASM25051, ASM25052, ASM25056, ASM25050, ASM25057, ASM25047 and ASM25049. Sagittal sections; ASM25054 and ASM25053. All specimens from Loc. BS200. In addition to the illustrated specimens, several others were studied.

Description.—Shell small for the genus, elongate fusiform in shape with bluntly pointed polar ends and slightly concave lateral slopes. Mature specimens having 6 ½ to 7 volutions, measuring from 3.70 to 4.55 mm in length and 1.38 to 1.93 mm in width. Form ratio varying from 2.13 to 3.15, averaging 2.54 for 11 specimens.

Axis of coiling straight throughout. Inner few volutions tightly coiled. Average radius vectors of the first to seventh volutions for 12 specimens being 0.10, 0.17, 0.25, 0.36, 0.50, 0.70 and 0.89 mm. Average form ratios of the first to seventh volutions for 10 specimens being 1.61, 1.89, 2.01, 2.08, 2.27, 2.31 and 2.29, respectively. Chamber heights almost constant throughout shell length.

Proloculus spherical and small. Its outside diameter ranging from 0.11 to 0.18 mm, averaging 0.14 mm for 27 specimens.

Spirotheca thin and composed of a tectum, diaphanotheca and lower thin and upper thick tectoria related to dense deposits of chomata. Thickness of tectoria usually inconstant and decreasing toward polar ends. In some specimens, very fine perforations observable in a diaphanotheca of outer volutions. Average thickness of spirotheca of the first to seventh volutions for 12 specimens measuring 0.020, 0.025, 0.027, 0.031, 0.036, 0.040 and 0.035 mm, respectively.

Septa almost plane, but weakly fluted only in extreme polar regions. Septal counts of the first to sixth volutions of typical sagittal section (Figure 5-26) numbering 10, 14, 15, 17, 20 and 21.

Tunnel path narrow and straight. Average tunnel angles of the first to seventh volutions for 10 specimens measuring 9, 12, 13, 14, 17, 21 and 21 degrees, respectively. Chomata prominent and highly asymmetrical. Tunnel sides of chomata very steep, overhanging in some specimens. Outside slopes very gentle and extending into polar regions. Chomata reaching nearly roof of chamber in central part of shell. Axial fillings absent or very weakly developed in some specimens.

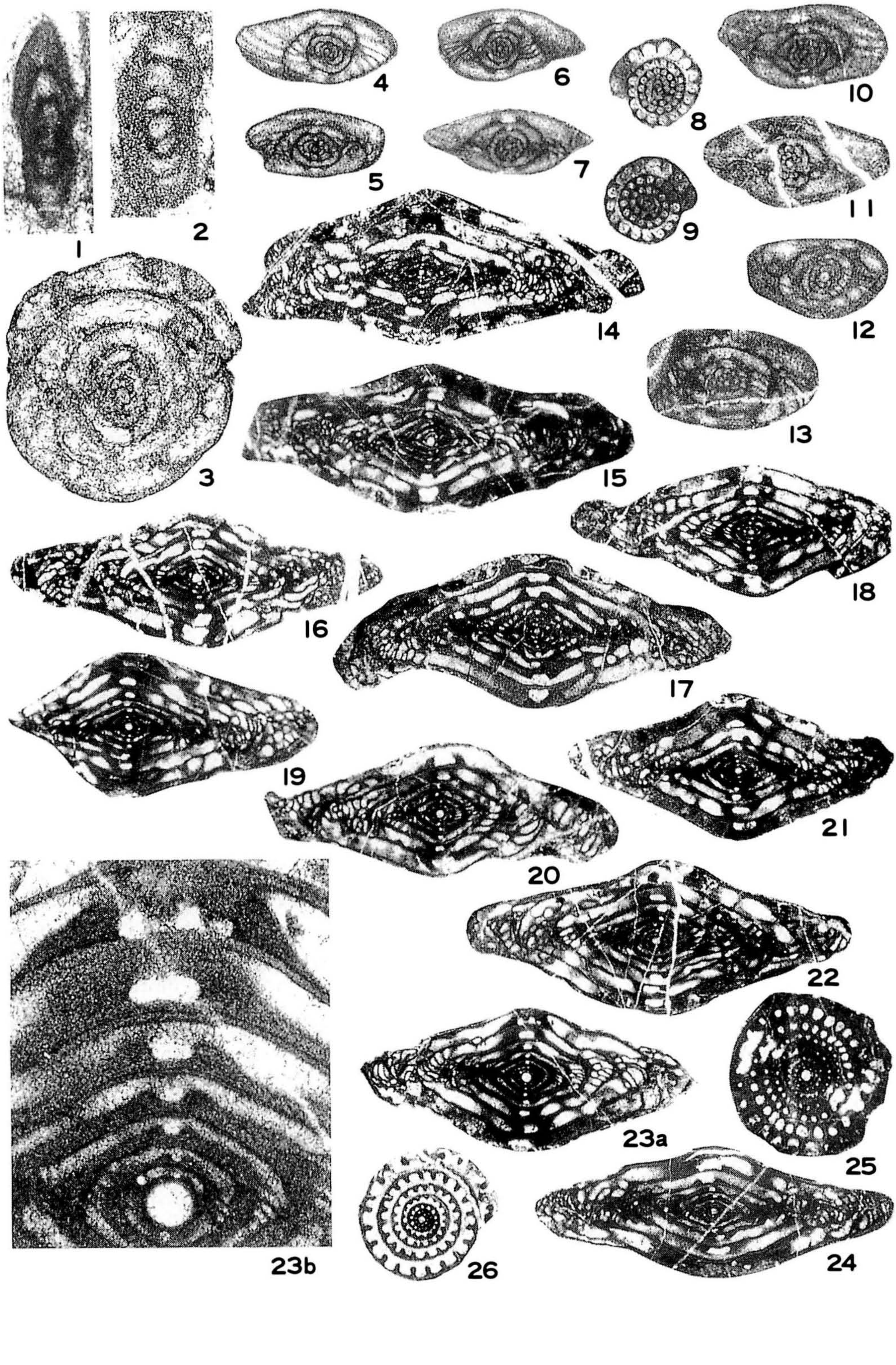
Remarks.—*Pseudofusulinella* (*Kanmeraia*) *praeantiqua* was originally described by Nassichuk and Wilde (1977) from the *Pseudofusulina plana* Assemblage Zone of the Belcher Channel and Hare Fiord Formations in Ellesmere Island of Canada, which they correlated with the Asselian. The Akiyoshi specimens are quite referable to the originally described ones.

This species resembles somewhat *Pseudofusulinella* (*Kanmeraia*) *antiqua* and *P.* (*K.*) *meeki*, which were described by Skinner and Wilde (1965) from the McCloud Limestone of California. However, the former has a smaller shell than the latter two.

Pseudofusulinella (*Kanmeraia*) *praeantiqua* can be distinguished from *P.* (*K.*) *japonica* described by Ozawa (1967) from the Raidenyama Formation of the Kwanto Mountains in having more concave lateral slopes, slightly larger shell and narrower tunnel path.

Occurrence.—Common in the uppermost part of the *Protriticites* sp. Zone and rare in the lower part of the *Quasifusulinoides toriyamai* Zone.

Pseudofusulinella (*Kanmeraia*) cf. *delicata* Skinner and Wilde, 1965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Figures 5-14

Compare.—

Pseudofusulinella delicata Skinner and Wilde, 1965, p. 28-29, pl. 8, figs. 23-28.

Material studied.— Axial section; ASM 25055 from Loc. BS200.

Description.—Shell small for the genus and elongate fusiform in shape with bluntly pointed poles. Lateral slopes straight. Specimen having 7 volutions, measuring 5.07 mm in length and 1.70 mm in width, giving a form ratio of 2.98. Inner 3 volutions tightly coiled. Radius vectors of the first to sixth volutions being 0.08, 0.13, 0.21, 0.30, 0.47 and 0.68 mm, and form ratios 2.00, 2.23, 2.73, 3.08, 2.79 and 2.72, respectively.

Spirotheca thin and composed of a tectum, diaphanotheca and upper and lower tectoria. Chomata prominent and highly asymmetrical. Tunnel angles of the second to sixth volutions measuring 17, 18, 19, 27 and 22 degrees, respectively.

Remarks.—The present species is characterized by a slender shell and is similar to *Pseudofusulinella* (*Kanmeraia*) *delicata* Skinner and Wilde. However, the former has a slightly larger shell and smaller form ratio than the latter.

Occurrence.—Rare in the uppermost part of the *Protriticites* sp. Zone.

Subfamily Fusulininae von Möller, 1878
Genus *Quasifusulinoides* Rauser-Chernoussova and Rozovskaya in Rauser-Chernoussova and Fursenko, 1959

Quasifusulinoides Rauser-Chernoussova and Rozovskaya in Rauser-Chernoussova and Fursenko, 1959, p. 210.

Remarks.—The genus *Quasifusulinoides* closely resembles the genus *Fusulina*, but the former is distinguished from the latter in having fine perforations in a diaphanotheca. Moreover, the former occupies a slightly younger stratigraphic position than the latter.

Quasifusulinoides toriyamai Ueno, sp. nov.

Figures 6-1—13

Material studied.—Axial section of holotype; ASM25068 from Loc. BS218.6. Axial sections of paratypes; ASM25059A from Loc. BS201.5, ASM25060 from Loc. BS212.5, ASM25071, ASM25074, ASM25072, ASM25064, ASM25076 from Loc. BS218.6 and ASM25031 from Loc. US236. Slightly oblique axial sections of paratypes; ASM25061 from Loc. BS214 and ASM25069 from Loc. BS218.6. Sagittal sections of paratypes; ASM25075 and ASM25066 from Loc. BS218.6. In addition, many other specimens from the *Quasifusulinoides toriyamai* Zone were studied.

Description.—Shell medium for the genus and fusiform in shape with bluntly pointed polar regions. Mature specimens having 6 to 7 ½ volutions, measuring from 4.90 to 6.35 mm in length and 2.03 to 2.80 mm in width. Form ratio ranging from 2.25 to 2.57, averaging 2.40 for 9 specimens.

Inner 1 or 1 ½ volutions tightly coiled, but outer ones becoming gradually expanded. Axis of coiling straight throughout. Aver-

← **Figure 5. 1**: *Eostaffella* sp. A, axial section, ASM25078A, ×100. **2**: *Eostaffella* sp. B, axial section, ASM25062, ×100. **3**: *Staffella pseudosphaeroidea* Dutkevich, axial section, ASM25030, ×30. **4-11.** *Schubertella* aff. *kingi* Dunbar and Skinner, **4-7, 10, 11**: axial sections, ASM25067, ASM25073, ASM25078B, ASM25070, ASM25079, ASM25059B, **8, 9**: sagittal sections, ASM25077, ASM25065, ×40. **12, 13**: *Schubertella* sp., axial sections, ASM25063, ASM25080, ×40. **14**: *Pseudofusulinella* (*Kanmeraia*) cf. *delicata* Skinner and Wilde, axial section, ASM25055, ×15. **15-26.** *Pseudofusulinella* (*Kanmeraia*) *praeantiqua* Nassichuk and Wilde, **15-23a, 24**: axial sections., ASM25058, ASM25057, ASM25046, ASM25051, ASM25056, ASM25052, ASM25047, ASM25049, ASM25048, ASM25050, **25, 26**: sagittal sections, ASM25054, ASM25053, ×15, **23b**: enlarged part of **23a**, ×75.

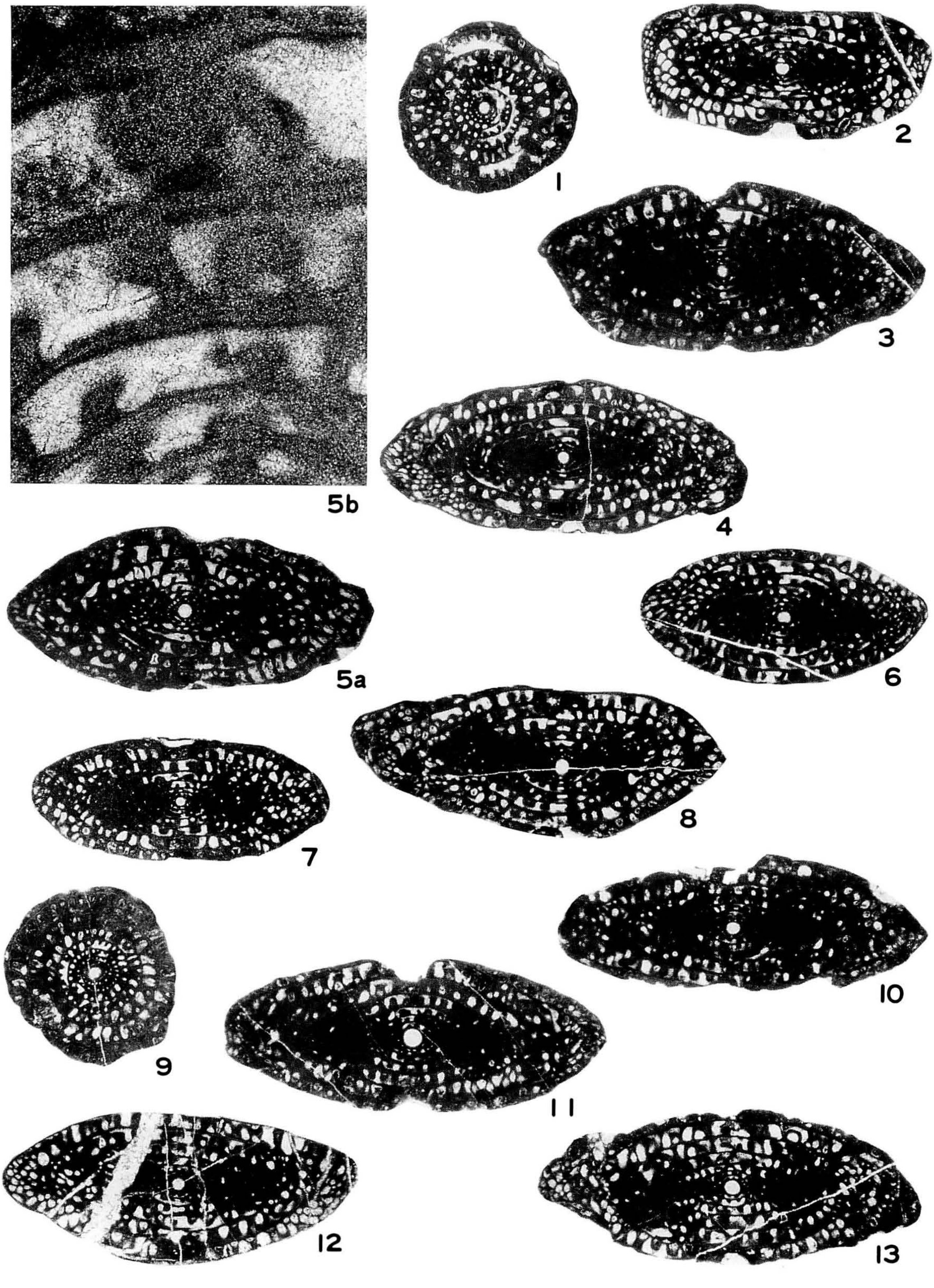
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Table 3. Measurements of *Ouasifusulinoides toriyamai*, sp. nov. (in mm).

Specimen number		Fig.	Length	Width	F.R.	D.P.	Radius vector 1	2	3	4	5	6	7
1	ASM25074	6-3	6.50	2.80	2.32	0.24	0.24	0.35	0.49	0.68	0.89	1.15	1.40
2	ASM25064	6-4	6.13	2.58	2.38	0.24	0.20	0.24	0.35	0.51	0.70	1.96	1.28
3	ASM25031	6-7	4.90	2.03	2.42	0.19	0.13	0.20	0.29	0.42	0.58	0.80	—
4	ASM25060	6-8	6.30	2.45	2.57	0.31	0.23	0.32	0.44	0.59	0.78	0.98	1.23
5	ASM25072	6-10	6.15	2.40	2.56	0.24	0.18	0.28	0.41	0.56	0.80	1.02	—
6	ASM25068	6-11	6.32	2.70	2.34	0.35	0.27	0.38	0.50	0.72	0.97	1.25	—
7	ASM25059A	6-12	5.90	2.43	2.43	0.28	0.22	0.31	0.46	0.67	0.89	1.10	1.28*
8	ASM25076	6-13	6.35	2.68	2.37	0.30	0.21	0.33	0.47	0.68	0.99	1.25	1.38*

	Form ratio 1	2	3	4	5	6	7	Thickness of spirotheca 1	2	3	4	5	6	7
1	1.29	1.42	1.68	1.65	1.65	1.72	1.88	0.020	0.025	0.030	0.030	0.040	0.045	0.040
2	1.33	2.13	2.31	2.38	2.38	2.37	2.41	0.020	0.025	0.025	0.030	0.040	0.045	0.060
3	1.77	1.65	2.00	2.32	2.46	2.41	—	0.020	0.020	0.025	0.035	0.030	0.040	—
4	1.26	1.65	1.99	2.39	2.53	2.62	2.65	0.035	0.055	0.040	0.035	0.055	0.045	—
5	1.67	1.93	2.12	2.32	2.06	2.36	—	0.015	0.025	0.030	0.040	0.045	0.045	—
6	1.33	1.64	1.87	2.01	2.23	2.40	—	0.025	0.030	0.030	0.035	0.045	0.060	—
7	1.27	1.85	2.12	2.16	2.22	2.48	2.31*	0.020	0.025	0.025	0.030	0.040	0.025	0.020*
8	1.33	1.94	2.26	1.95	1.87	2.08	2.29*	0.020	0.025	0.030	0.045	0.055	0.020	—

	Tunnel angle (degrees) 1	2	3	4	5	6	7
1	14	18	14	24	—	—	—
2	14	12	12	13	22	14	—
3	19	16	20	19	23	20	—
4	18	15	19	20	24	23	—
5	14	22	23	—	—	—	—
6	8	16	15	14	—	—	—
7	13	21	27	23	—	—	—
8	16	18	22	24	—	—	—

* : 6 ½ volution

← **Figure 6. 1-13**. *Quasifusulinoides toriyamai,* sp. nov., **11** : axial section of holotype, ASM25068, **1, 9**: sagittal sections of paratypes, ASM25075, ASM25066, **2-4, 7, 8, 10, 12, 13**: axial sections of paratypes, ASM25071, ASM25074, ASM25064, ASM25031, ASM25060, ASM25072, ASM25059A, ASM25076, **5a, 6**: slightly oblique axial sections of paratypes, ASM25069, ASM25061, × 10, **5b**: enlarged part of **5a**, showing the peculiar spirothecal structure, × 100.

age radius vectors of the first to seventh volutions for 11 specimens being 0.21, 0.30, 0.42, 0.58, 0.80, 1.03 and 1.23 mm, and average form ratios being 1.40, 1.75, 2.03, 2.17, 2.19, 2.25 and 2.22, respectively. Chamber heights almost constant throughout shell length.

Proloculus spherical and medium to large. Its outside diameter ranging from 0.19 to 0.46 mm, averaging 0.28 mm for 56 specimens.

Spirotheca thin, composed of a tectum and upper and lower tectoria in inner 2 or 3 volutions, but becoming relatively thick and composed of a tectum, diaphanotheca and thin upper and rather thick lower tectoria in outer ones. Clear fine perforations sometimes observable in a diaphanotheca. Average thickness of spirotheca of the first to seventh volutions for 11 specimens measuring 0.022, 0.028, 0.030, 0.035, 0.043, 0.041 and 0.052 mm, respectively.

Septa intensely and regularly fluted throughout length of shell, except for its central part. Rudimentary chomata developed in inner 2 or 3 volutions. Tunnel path almost straight. Average tunnel angles of the first to sixth volutions for 11 specimens measuring 14, 17, 20, 20, 23 and 18 degrees, respectively. Axial fillings prominent.

Remarks.— The present new species can easily be distinguished from *Quasifusulinoides fusiformis* (Rozovskaya), *Q. parafusiformis* Bensh and *Q. juvenatus* Kireeva in having a smaller form ratio and the prominent axial fillings.

Quasifusulinoides toriyamai, sp. nov. is somewhat similar to *Q. turgida* described by Nikitina (1969) from the *Obsoletes-Protriticites* Zone of the Tadushi River Basin of southern Sikhote-Alin. However, the former has a larger shell than the latter.

The present form also resembles *Q. oblonga* Nikitina which occurred in association with *Q. turgida*. However, the former can be distinguished from the latter by a smaller form ratio.

Fusulina kurikiensis and *F. otanii* described by Kanmera (1954) from the *Fusulina* Zone of the Yayamadake Limestone in Kyushu somewhat resemble *Quasifusulinoides toriyamai*, sp. nov. in the shell morphology, but the former two species have a different spirothecal composition from the latter.

Measurements.—See Table 3.

Occurrence.—Abundant and restricted in the *Quasifusulinoides toriyamai* Zone.

Family Staffellidae A.D. Miklukho-Maklay, 1949

Genus *Staffella* Ozawa, 1925

Staffella pseudosphaeroidea Dutkevich, 1934

Figure 5-3

Staffella pseudosphaeroidea Dutkevich, 1934, p. 17-22, 66-68, pl. 3, figs. 2-10; Kanmera, 1954, p. 123-126, pl. 12, figs. 1-13; Chen and Wang, 1983, p. 34, pl. 1, figs. 9-10.

Staffella ex gr. *pseudosphaeroidea* Dutkevich; Ginkel, 1965, p. 15-16, pl. 6, figs. 1-10.

Staffella cf. *pseudosphaeroidea* Dutkevich; Ginkel, 1965, p. 14-15, pl. 5, figs. 8-11.

Parastaffella pseudosphaeroidea (Dutkevich); Rauser-Chernoussova *et al*., 1951, p. 152-153, pl. 13, figs. 1-2.

Pseudoendothyra pseudosphaeroidea (Dutkevich); Grozdilova and Lebedeva, 1960, p. 105, pl. 12, fig. 3; Kahler and Kahler, 1979, p. 206-207, pl. 1, fig. 1.

Pseudostaffella ? *pseudosphaeroidea* (Dutkevitch); Ross and Dunbar, 1962, p. 15-17, pl. 2, figs. 1-8.

Material studied.— Axial section; ASM 25030 from Loc. US211.

Description.—Shell spherical, relatively large for the genus and having 5 ½ volutions. Axial regions slightly depressed. Length 1.29 mm and width 1.39 mm, giving a form ratio of 0.93. Shell loosely coiled. Radius vectors of the first to fifth volutions being 0.10, 0.17, 0.27, 0.41 and 0.58 mm, and form ratios 0.64, 0.76, 0.89, 1.02 and 1.01, respectively.

Proloculus spherical and 0.11 mm in outside diameter. Spirotheca highly recrystallized and probably composed of a thin tectum, thick diaphanotheca and upper and lower tectoria. Thickness of spirotheca of the second to fifth volutions measuring 0.02, 0.03, 0.06 and 0.05 mm, respectively. Septa not fluted. Chomata present but inconspicuous. Axial fillings absent.

Remarks.—The present specimen is quite identical to Dutkevich's original ones in the essential shell characters.

Staffella pseudosphaeroidea described by Kanmera (1954) from the Yayamadake Limestone of Kyushu and *S.* ex gr. *pseudosphaeroidea* described by Ginkel (1965) from the Cantabrian Mountains of Spain have a more quadrate shell than that of the Akiyoshi specimen.

Occurrence.—Rare in the lower part of the *Protriticites* sp. Zone.

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Akago 赤郷, Akiyoshi 秋吉, Akiyoshi-dai 秋吉台, Kyushu 九州, Kwanto 関東, Managatake 真名ケ岳, Raidenyama 雷電山, Yamaguchi 山口, Yayamadake 矢山岳.

秋吉石灰岩層群からの上部石炭系紡錘虫類：秋吉台北東部の赤郷一真名ケ岳地域に分布する秋吉石灰岩層群の *Protriticites* sp. 帯と *Quasifusulinoides toriyamai* 帯より，3新種（*Protriticites robustus, Obsoletes horridus, Quasifusulinoides toriyamai*）を含む7属12種の紡錘虫類を記載する。この紡錘虫群集は *Protriticites, Obsoletes, Quasifusulinoides* の3属を含むことで特徴づけられており，モスコー陸向斜，ドネツ盆地，南部フェルガナ，沿海州のタドゥシ川盆地より産する紡錘虫群集と属構成において高い類似度を示す。その時代は石炭紀後期の前期 Kasimovian と考えられる。 上野勝美

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923. CAMPANIAN INTERMEDIATE WATER BENTHIC FORAMINIFERA FROM CENTRAL HOKKAIDO, JAPAN*

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Abstract. Although Late Cretaceous sublittoral and bathyal mudstones are widely distributed in central Hokkaido, Japan and contain abundant calcareous microfossils, studies on benthic formaminifera have been few. I obtained many well-preserved foraminifera numbering about 50,000 specimens from two 10 kg-samples from the Campanian Kashima Formation of the Yezo Group. This study presents a description of benthic foraminiferal faunas that include three new species and clarifies a faunal composition in the Campanian intermediate water. The benthic foraminiferal faunas are dominated by *Silicosigmoilina futabaensis* Asano (85-90%), *Notoplanulina rumoiensis* Takayanagi, *Nuttallinella florealis* (White), *Haplophragmoides asanoi* Takayanagi, and *Dorothia hokkaidoana* Takayanagi. They are also characterized by a high species diversity of the suborder Lagenina (66% Lagenina species) including such genera as *Lenticulina, Frondicularia, Saracenaria* and *Astacolus*, and by a low species diversity of the suborder Rotaliina (9% Rotaliina species). These faunas indicate an upper bathyal depositional water depth.

Key words. Benthic foraminifera, Campanian, Cretaceous, intermediate water, Hokkaido, Japan.

Introduction

Late Cretaceous mudstones deposited in the intermediate water depth are widely distributed in central Hokkaido, Japan. These strata contain abundant calcareous microfossils. Takayanagi (1960) described foraminifera from the Late Cretaceous formations of central Hokkaido. As most of his specimens are not well preserved, I tried to obtain well-preserved foraminifera by washing a large quantity of samples from the Campanian mudstone of the Kashima Formation (Motoyama *et al.,* 1991).

The purpose of this paper is to describe these well-preserved benthic foraminiferal species and to clarify faunal compositions in the Campanian intermediate water depth. This is the first description of Campanian benthic foraminifera from Hokkaido, Japan, with the exception of a benthic foraminiferal study of northern Hokkaido done by Yasuda (1986). All the specimens described herein are deposited in the collections of Institute of Geology and Paleontology, Tohoku University, Sendai (IGPS) with their repository numbers being from IGPS 101470 to 101539. The planktonic foraminifera and Ostracoda will be reported elsewhere by Kaiho (in press, a) and Ishizaki (in press), respectively.

Geological setting

I selected the Sanushube River section for a study of calcareous microfossils out of various sections measured in Hokkaido. The section is located in the northwestern part of

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Hobetsucho, south-central Hokkaido (Figure 1). The upper part of the thick marine Upper Cretaceous sediments developed along this section is stratigraphically separated as the Kashima Formation, which represents the uppermost part of the Yezo Group. The Kashima Formation consists of a dark gray massive soft mudstone which contains *Inoceramus* shell fragments, foraminifera, Radiolaria, calcareous nannofossils, ostracodes, ammonites and plesiosaurian fossils (Nakaya, 1989). It is conformably overlain by shallow marine sediments of the Hakobuchi Group, characterized by sandstone, alternations of siltstone and sandstone, and coal measures, that contain rare fossils. The Kashima Formation would have been about 1000 m in thickness if it were not disturbed by faulting, but, in reality, may be separated and overlapped by faults (Kito *et al*., 1986). From the upper half of the Kashima Formation, I collected studied samples. Kito *et al*. (1986) assigned an early Campanian age to the middle part of the Kashima Formation (sam-

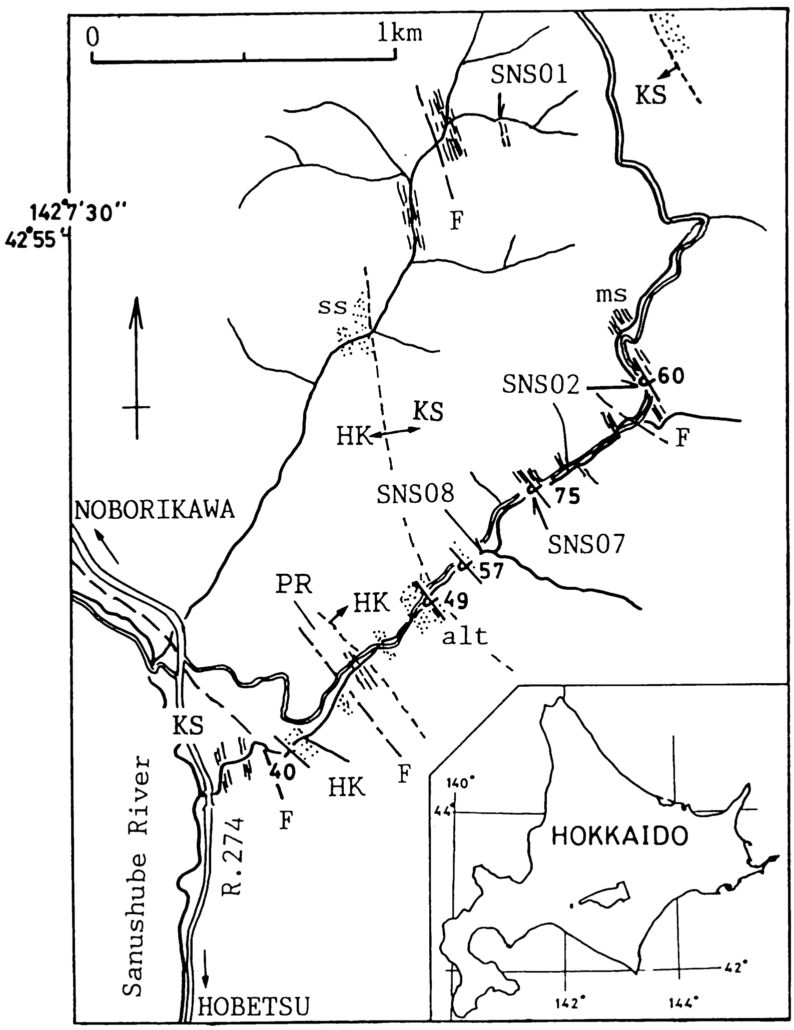


Figure 1. Location map of the Sanushube River section and sample localities. KS : Kashima Formation ; HK : Hakobuchi Group ; PR : Poronai Formation (upper Middle-Upper Eocene) ; ms : mudstone ; ss : sandstone ; alt : alternation of siltstone and sandstone ; F : fault.

ple SNS01 : plesiosaurian localilty) based on radiolarians, planktonic foraminifera, ammonites and *Inoceramus*. Kaiho (in press, a) assigned a Campanian age to the upper half of the Kashima Formation (samples SNS02 and SNS07) exposed along the studied section. Calcareous nannofossils from the uppermost part of the Kashima Formation (sample SNS08) from the same section also show a Campanian age (Motoyama *et al*., 1991).

Materials and methods

Although I obtained in 1979 well-preserved calcareous foraminifers from five localities along this section, the number of specimens was not sufficient for detailed studies. Accordingly, I collected a large quantity of sample (about 10 kg) from each of the two localities (SNS02 and SNS07) (Figure 1) in the following year.

In the laboratory, 10 kg of dry sediment were disaggregated by using a sodium sulphate and naphtha solution (Maiya and Inoue, 1973), wet sieved through a 63-μm screen and dried again. Foraminifera were then picked up from the processed samples and identified. The type specimens of Takayanagi (1960) were examined for comparative studies. All the identified species are shown in the accompanying plates. These species were also illustrated in Kaiho (1990) without detailed descriptions.

Benthic foraminiferal fauna and depositional water depth

The benthic foraminiferal fauna in the two samples SNS02 and SNS07 show a very similar specific composition (Table 1). I recognized 47 benthic foraminiferal species in about 50,000 specimens from these two samples. Of these species, 55% of them are discovered for the first time from Japan. Three species are new species. *Silicosigmoilina futabaensis* Asano occupies 85-90% of the total specimens. Other abundant taxa include *Notoplanulina rumoiensis* (Takayanagi), *Nuttallinella florealis* (White), *Haplophragmoides asanoi* Takayanagi and *Dorothia hokkaidoana* Takayanagi. The benthic foraminiferal faunas are also characterized by a high species diversity of the suborder Lagenina, comprising such genera as *Lenticulina, Frondicularia, Saracenaria,* and *Astacolus*, and a low species diversity of the suborder Rotaliina, represented by 66% Lagenina, 9% Rotaliina, and 25% Textulariina species. Based on the bathymetric distribution of Cretaceous benthic foraminifera reconstructed by Sliter and Baker (1972) with data from southern California, most of the genera occurring in the Sanushube section are interpreted to have inhabited the upper-bathyal zone.

Systematic description

In this section, I describe 47 species including three new species which were encountered during the course of present study. Among these, six tentatively identified species are given their names in alphabetic letters. Although some of these species may represent a new species, no scientific name is given to them pending examination of additional specimens in order to establish their range of variation. At the suprageneric levels, the present classification follows the scheme proposed by Loeblich and Tappan (1988).

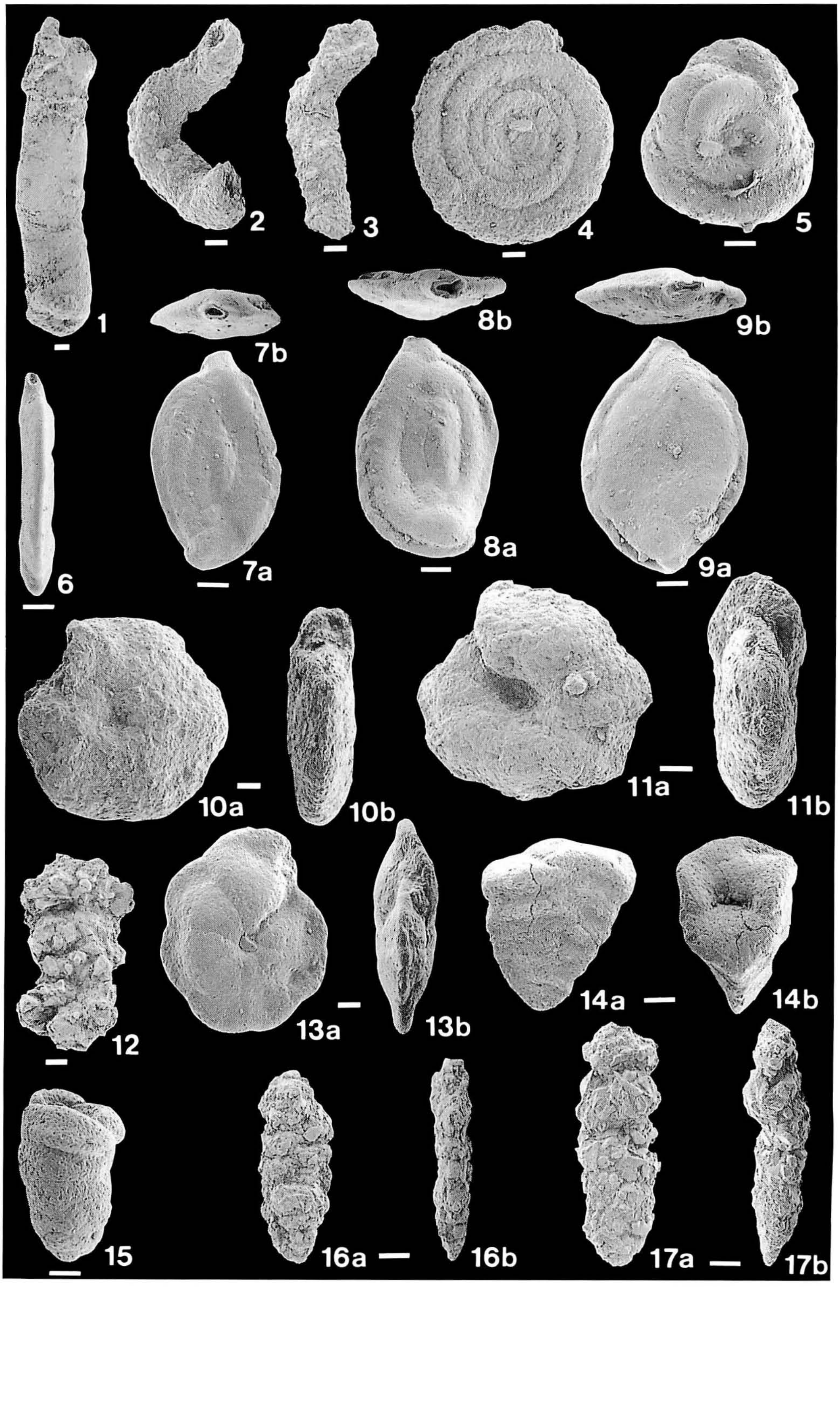
Order Foraminiferida Eichwald, 1830
Suborder Textulariina Delage and Hĕrouard, 1896
Superfamily Astrorhizacea Brady, 1881
Family Bathysiphonidae Avnimelech, 1952
Genus *Bathysiphon* M. Sars, 1872
Bathysiphon vitta Nauss

Figure 2-1

Bathysiphon vitta Nauss, 1947, p. 334, pl. 48, fig. 4; Takayanagi, 1960, p. 64, 65, pl. 1, figs. 5a, b;

Table 1. Abundance of benthic foraminifera from two Campanian samples. Each sample weighs about 10 kg in dry weight. Number of specimens shown by the following symbols. VA : >10,000 ; A : 100-1000 ; C : 10-99 ; F : 3-9 ; R : 1-2 ; – : barren.

Species \ Sample	SNS02	SNS07
Bathysiphon vitta	F	C
Rhizammina indivisa	F	F
Ammodiscus sp. A	C	C
Glomospira charoides	F	—
Glomospira gordialis	R	—
Silicosigmoilina futabaensis	VA	VA
Haplophragmoides asanoi	A	A
Ammobaculites sp.	—	R
Cyclammina asanoi	C	C
Gaudryina pyramidata	F	—
Dorothia hokkaidoana	A	A
Marssonella sp. A	—	R
Dentalina basiplanata	F	C
Dentalina gracilis	C	R
Nodosaria affinis	R	—
Nodosaria aspera	R	—
Frondicularia bicorsis	C	C
Frondicularia durrelli	F	F
Frondicularia mucronata	—	C
Frondicularia whaingaroica	—	R
Frondicularia sp. A	—	R
Lenticulina extruatus	C	C
Lenticulina haboroensis	—	F
Lenticulina obirashibensis	C	C
Lenticulina rotulata	C	C
Lenticulina williamsoni	R	—
Lenticulina yabei	C	C
Lenticulina sp. A	—	R
Lenticulina sp. B	—	R
Lenticulina sp. C	F	F
Saracenaria triangularis	C	C
Saracenaria tunesiana	C	C
Pravoslavlevia sp.	—	R
Astacolus elongatus, n. sp.	C	C
Astacolus nagaoi	C	C
Astacolus polandensis	R	C
Marginulina bullata	R	—
Citharina multicostata	—	R
Psilocitharella ezoensis, n. sp.	F	C
Psilocitharella triangulata, n. sp.	—	F
Globulina lacrima	R	R
Ramulina aculeata	C	C
Ramulina tetrahedralis	F	F
Stilostomella alexanderi	F	C
Stilostomella stephensoni	C	C
Nuttallinella florealis	C	A
Notoplanulina rumoiensis	A	A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Trujillo, 1960, p. 302-303. pl. 43, figs. 2a-b; Tappan, 1962, p. 128-129, pl. 29, figs. 6-8; Graham and Church, 1963, p. 17-18, pl. 1, figs. 1a-2b; Sliter, 1968, p. 40, 41, pl. 1, figs. 13a-15b.

Type.—Hypotype, IGPS 101470, sample SNS07.

Description.—Test large, elongate, tubular, compressed, with transverse growth constrictions, but no internal partitions; wall finely agglutinated, with considerable amount of cement, surface rather smoothly finished, gray to white in color; aperture at open end of tube.

Remarks.—This finely walled large species is common in the Upper Cretaceous of Japan and has a cosmopolitan distribution in Cretaceous oceans.

Family Rhabdamminidae Brady, 1884
Subfamily Rhabdammininae Brady, 1884
Genus *Rhizammina* Brady, 1876
Rhizammina indivisa Brady

Figures 2-2, 3

Rhizammina indivisa Brady, 1884, p. 277. pl. 29, figs. 5-7; Sliter, 1980, p. 368, pl. 1, fig. 1; Yasuda, 1986, p. 40, 41, pl. 1, fig. 4.

Types.—Hypotype, figure 2-2, IGPS 101471; hypotype, figure 2-3, IGPS 101472. Both from sample SNS02.

Description.—Test elongate, tubular, irregulary curved, with transverse growth constriction; wall coarse, thin, made of firmly cemented coarse sand grains, surface roughly finished; aperture terminal and rounded.

Remarks.—This species has a wall and test diameter similar to those of *Bathysiphon akanosawaensis* Takayanagi.

Superfamily Ammodiscacea Reuss, 1862
Family Ammodiscidae Reuss, 1862
Subfamily Ammodiscinae Reuss, 1862
Genus *Ammodiscus* Reuss, 1862
Ammodiscus sp. A

Figure 2-4

Type.—Hypotype, IGPS 101473, sample SNS07.

Description.—Test large, planispiral, closely coiled, evolute, very compressed, periphery rounded; chamber increasing gradually and uniformly in size as added with many coils; spiral suture distinct, deep; wall coarsely arenaceous, surface rather roughly finished; aperture formed at open end of tube.

Remarks.—The diameter of the figured hypotype is 0.96 mm and its thickness 0.11 mm. This species has a test smaller than that of *A. pennyi* Cushman and Jarvis. It differs from *A. cretaceous* in having a coarser wall.

Subfamily Ammovertellinae Saidova, 1981
Genus *Glomospira* Rzehak, 1885
Glomospira charoides (Jones and Parker)

Trochammina squamata Jones and Parker var. *charoides* Jones and Parker, 1860, p. 304.
Trochammina charoides Jones and Parker. Carpenter, 1862, p. 141, pl. 11, fig. 3.
Ammodiscus charoides (Jones and Parker). Brady, 1884, p. 334, pl. 38, figs. 10-16.
Glomospira charoides (Jones and Parker). Cushman, 1925, p. 25, pl. 2, fig. 12; Galloway and Morrey, 1931, p. 331, pl. 37, figs. 1-2; Marie, 1937, p. 260; Gandolfi, 1942, p. 31; Noth, 1951, p. 28, pl. 2, fig. 7; Takayanagi, 1960, p. 69, pl. 1, figs. 17a-18b.
Gordiammina charoides (Jones and Parker). Franke, 1928, p. 15, pl. 1, fig. 16.

Type.—Hypotype, IGPS 101474, sample SNS02.

← **Figure 2.** Scale bar = 100 μm. **1,** *Bathysiphon vitta* Nauss. SNS07. **2, 3,** *Rhizammina indivisa* Brady. **2**; SNS02, **3**; SNS07. **4,** *Ammodiscus* sp. A. SNS07. **5,** *Glomospira gordialis* (Jones and Parker). SNS02. **6-9,** *Silicosigmoilina futabaensis* Asano. **6-8**; SNS07. **9**; SNS02. **10, 11,** *Haplophragmoides asanoi* Takayanagi. **10**; SNS07. **11**; SNS02. **12,** *Ammobaculites* sp. SNS07. **13,** *Cyclammina asanoi* Takayanagi. SNS07. **14,** *Gaudryina pyramidata* Cushman. SNS02. **15,** *Marssonella* sp. A, SNS07. **16, 17,** *Dorothia hokkaidoana* Takayanagi. **16**; SNS07. **17**; SNS02.

Remarks.—Three juvenile specimens are found in sample SNS02. It is a cosmopolitan, long-ranging species.

Glomospira gordialis
(Jones and Parker)

Figure 2-5

Trochammina squamata gordialis Jones and Parker, 1860, p. 304; Brady, 1876, p. 77, pl. 3, figs. 1-3.
Ammodiscus gordialis Jones and Parker [*sic*]. Brady, 1884, p. 333, pl. 38, figs. 7-9.

Type.—Hypotype, IGPS 101475, sample SNS02.

Description.—Test convolute, compressed, oval, asymmetrical, composed of a tube of nearly even diameter, and exhibiting low trochospiral and twisted coiling arrangement; wall very finely arenaceous, with much cement, surface smooth, colored in white; aperture formed at open end of tube.

Remarks.—A single juvenile specimen is recognized in sample SNS02.

Superfamily Rzehakinacea Cushman, 1933
Family Rzehakinidae Cushman, 1933
Genus *Silicosigmoilina* Cushman and Church, 1929
Silicosigmoilina futabaensis Asano

Figures 2-6—9

Silicosigmoilina futabaensis Asano, 1950, p. 159, pl. 1, figs. 6, 7; Trujillo, 1960, p. 303, pl. 44, figs. 8a, b.
Bramletteia ezoensis Takayanagi, 1960, p. 84, pl. 3, figs. 14a-17.

Types.—Hypotype, figure 2-6, IGPS 101476, sample SNS07; hypotype, figure 2-7, IGPS 101477, sample SNS07; hypotype, figure 2-8, IGPS 101478, sample SNS07; hypotype, figure 2-9, IGPS 101479, sample SNS02.

Description.—Test compressed, oval to elliptical in outline, sigmoid in end view; periphery broadly rounded, edge subrounded to subacute; chambers planispiral in early stage, sigmoidal in adult stage; wall finely arenaceous, with much siliceous cement, smoothly finished, white in color; sutures generally indistinct; aperture simple, oval, terminal.

Remarks.—This species resembles *Silicosigmoilina californica* Cushman and Church described from California and from Maastrichtian and Danian intervals of Hokkaido, but differs in having a more flattened and smaller test. *Silicosigmoilina futabaensis* is the most dominant species in the Campanian intermediate water in Hokkaido.

Superfamily Lituolacea
de Blainville, 1827
Family Haplophragmoididae
Maync, 1952
Genus *Haplophragmoides*
Cushman, 1910
Haplophragmoides asanoi
Takayanagi

Figures 2-10, 11

Haplophragmoides asanoi Takayanagi, 1960, p. 69-70, pl. 1, figs. 19a-b.

Types.—Hypotype, figure 2-10, IGPS 101480, sample SNS07; hypotype, figure 2-11, IGPS 101481, sample SNS02.

Description.—Test compressed, planispiral, involute, biumbilicate, nearly circular in outline, nearly parallel in side view, peripheral margin broadly rounded, peripheral outline commonly lobulate; six to seven chambers in final whorl, slightly inflated, increasing gradually in size as added; sutures straight, radial, slightly depressed; wall coarsely agglutinated, surface not smoothly finished, pale brown in color; aperture equatorial, a low interiomarginal arch.

Remarks.—This species resembles both *Haplophragmoides incognatus* Martin and *Haplophragmoides fraseri* Wickenden of Trujillo (1960), but differs in having fewer numbers of chamber. It resembles *Haplophragmoides rugosus* Cushman and Waters, but differs in having finer wall surface and chambers that increase more slowly in size.

Family Lituolidae de Blainville, 1827
Subfamily Ammomarginulininae
Podobina, 1978
Genus *Ammobaculites* Cushman, 1910
Ammobaculites sp.

Figure 2-12

Type.—Hypotype, IGPS 101482, sample SNS07.

Description.—Test elongate, compressed, early portion close-coiled, with five chambers per coil, later portion with a few uniserially arranged chambers, nearly parallel sided, peripheral margin subangular; chambers inflated, approximately twice as broad as height in uniserial portion; sutures depressed, radial in coiling portion, right angle to test axis in uniserial portion; wall coarsely agglutinated, surface roughly finished; aperture terminal, ovate, centrally located.

Superfamily Loftusiacea Brady, 1884
Family Cyclamminidae Marie, 1941
Subfamily Cyclammininae
Marie, 1941
Genus *Cyclammina* Brady, 1879
Cyclammina asanoi Takayanagi

Figure 2-13

Cyclammina asanoi Takayanagi, 1960, p. 75, 76, pl. 11, figs. 11a, b, 16.

Type.—Hypotype, IGPS 101483, sample SNS07.

Description.—Test medium in size, much compressed, planispiral, involute, biumbilicate, periphery subacute, lobulate; chambers seven to eight in the final whorl; sutures distinct, slightly depressed, radial, slightly curved or slightly sigmoidal; wall finely arenaceous, smoothly finished, interior labyrinthic; aperture a curved slit at base of apertural face.

Remarks.— This species is characterized by its lobulate peripheral outline and in having seven to eight chambers in the final whorl.

Superfamily Verneuilinacea Cushman, 1911
Family Verneuilinidae Cushman, 1911
Subfamily Verneuilininae Cushman, 1911
Genus *Gaudryina* d'Orbigny, 1839
Gaudryina pyramidata Cushman

Figure 2-14

Gaudryina laevigata Franke var. *pyramidata* Cushman, 1926, p. 587, pl. 16, fig. 8.
Gaudryina (*Pseudogaudryina*) *pyramidata* Cushman. Cushman and Goudkoff, 1944, p. 56, pl. 9, figs. 7, 8.
Gaudryina pyramidata Cushman. Trujillo, 1960, p. 308, pl. 44, figs. 9a-c; Graham and Clark, 1961, p. 109, fig. 2, 1; Sliter, 1968, p. 48, 49, pl. 3, fig. 9.

Type.—Hypotype, IGPS 101484, sample SNS02.

Description.—Test elongate, triangular in transverse section, early stage triserial, later becoming biserial; chambers distinct, low, increasing gradually in size, slightly inflated in biserial portion; sutures oblique, slightly curved, depressed; wall finely agglutinated, surface smooth, white to pale brown in color with black minerals; aperture, a low interiomarginal arch.

Remarks.—This species is similar to *Gaudryina* sp. a described by Takayanagi (1960) from the Cretaceous of Hokkaido, but the latter is too poorly preserved to establish the positive identification.

Superfamily Textulariacea Ehrenberg, 1838
Family Eggerellidae Cushman, 1937
Subfamily *Dorothiinae* Balakhmatova, 1972
Genus *Dorothia* Plummer, 1931
Dorothia hokkaidoana Takayanagi

Figures 2-16, 17

Dorothia hokkaidoana Takayanagi, 1960, p. 83, pl. 3, figs. 9a-12b.

Types.—Hypotype, fig. 2-16, IGPS 101485, sample SNS07; hypotype, fig. 2-17, IGPS 101486, sample SNS02.

Description.—Test small, elongate, narrow, sides nearly parallel, compressed in adult; early portion with four or more chambers per whorl, later becoming triserial, then being regularly biserial; chambers in earlier portion almost indistinct, later rather distinct, inflated, relatively low and broad, very gradually increasing in size as added; sutures obscure in early portion, later becoming rather distinct, depressed; wall coarsely arenaceous, surface rather roughly finished; aperture indistinct, a low arch at base of last chamber.

Remarks.—The present specimens have more inflated chambers and more roughly finished surface than the holotoype and paratypes, partly because the present specimens are much better preserved. Common species in the Upper Cretaceous of Hokkaido.

Genus *Marssonella* Cushman, 1933
Marssonella sp. A

Figure 2-15

Dorothia crassa (Marsson). Yasuda, 1986, p. 55, pl. 4, figs. 10a, b (not of Marsson).

Type.—Hypotype, IGPS 101487, sample SNS07.

Description.—Test small, elongate, the earliest portion rounded, later portion nearly parallel sided, circular in transverse section, early trochospiral portion with four to five chambers per whorl, followed by biserial stage, terminal face concave; chambers distinct, low very slightly inflated; sutures slightly depressed; wall finely arenaceous, surface smooth, colored in white; aperture low, at inner margin of last-formed chamber.

Remarks.—This species is similar to *Marssonella ellisorae* Cushman and *Dorothia beloides* Hillebrandt, but differs in having a lower trochospiral test in the earliest portion. It resembles *Gaudryna crassa* Marsson, but differs in having a concave terminal face.

Suborder Lagenina Delage and Hérouard, 1896
Superfamily Nodosariacea Ehrenberg, 1838
Family Nodosariidae Ehrenberg, 1838
Subfamily Nodosariinae Ehrenberg, 1838
Genus *Dentalina* Risso, 1826
Dentalina basiplanata Cushman

Figure 3-1

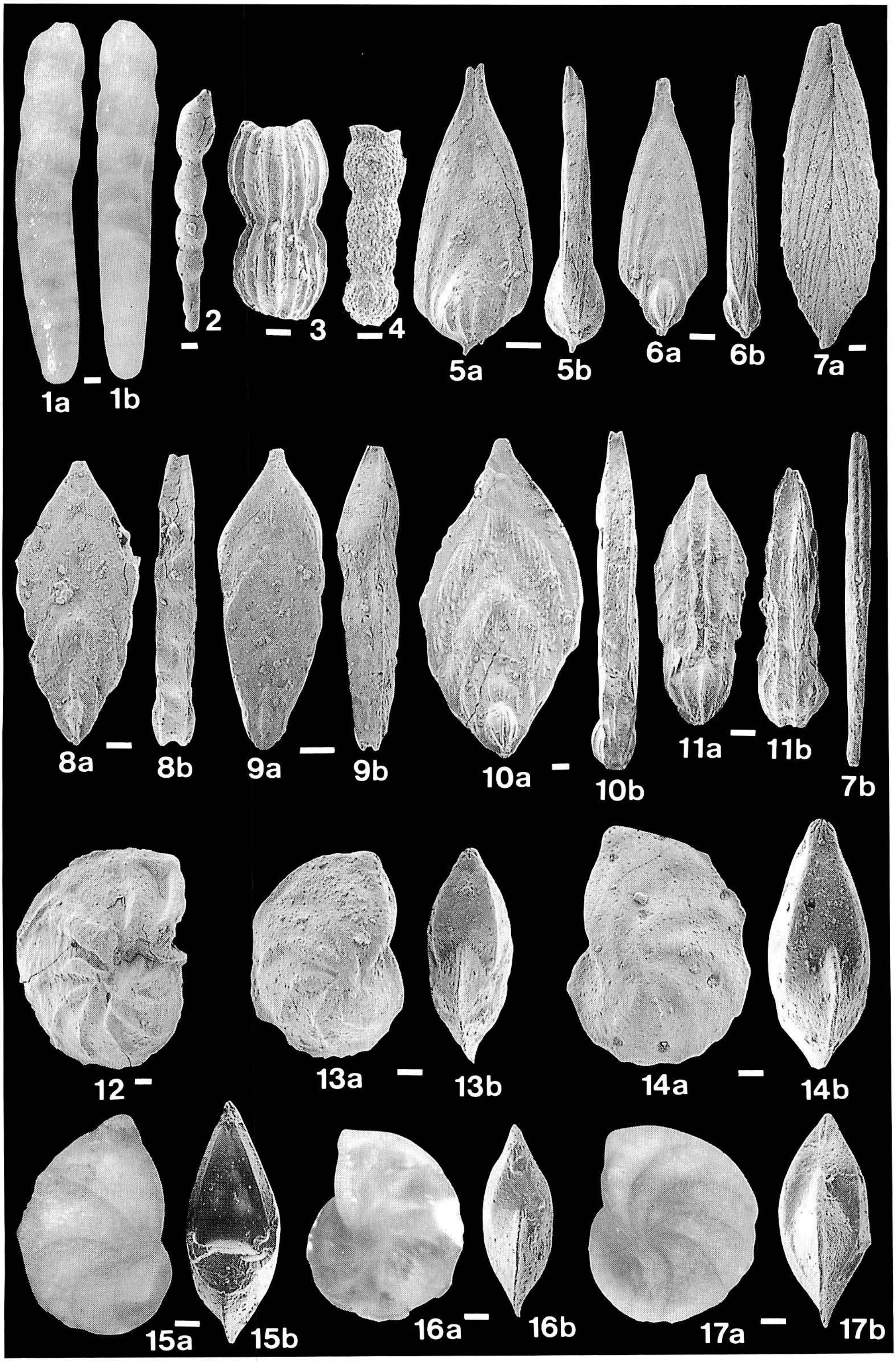
Dentalina basiplanata Cushman, 1938. p. 38-39, pl. 6, figs. 6-8; Cushman, 1946, p. 68, pl. 24, figs. 1-6; Takayanagi, 1960, p. 94, pl. 5, fig. 6; Graham and Church, 1963, p. 27, pl. 2, fig. 11.

Type.—Hypotype, IGPS 101488, sample SNS07.

Description.—Test large, elongate, gently arcuate, gently tapering toward rounded initial end, which is circular in cross section; chambers 11 in total, initial eight chambers being low, overlapping, not inflated, later becoming slightly inflated and slightly elongated; sutures mostly normal to long axis of test, initially flush, limbate, later slightly depressed; wall calcareous, smooth, finely perforate; aperture radiate, placed toward concave side.

Remarks.—Length of hypotype, 2.18 mm; diameter, 0.39 mm. Compared with the holotype, studied specimens have a larger test, thicker chambers, and relatively longer and non-lobulate initial portion. They have a much larger test and lower and thicker chambers than the specimens from the K/T boundary section of Hokkaido (Kaiho, in press, b) and that of Takayanagi.

→ **Figure 3.** Scale bar = 100 μm. **1,** *Dentalina basiplanata* Cushman. SNSO7. **2,** *Dentalina gracilis* d' Orbigny. SNS02. **3,** *Nodosaria affinis* Reuss, SNS02. **4,** *Nodosaria aspera* Reuss. SNS02. **5, 6,** *Frondicularia mucronata* Reuss. SNS07. **7,** *Frondicularia whaingaroica* Stache. SNS07. **8, 9,** *Frondicularia bicornis* Reuss. **8**; SNS07. **9**; SNS02. **10,** *Frondicularia* sp. A. SNS07. **11,** *Frondicularia durrelli* Trujillo. SNS07. **12, 13,** *Lenticulina extruatus* (Cushman). SNS07. **14,** *Lenticulina* sp. A. SNS07. **15,** *Lenticulina yabei* Takayanagi. SNS02. **16,** *Lenticulina rotulata* (Lamarck). SNS02. **17,** *Lenticulina obirashibensis* Takayanagi, SNS02.



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Dentalina gracilis d'Orbigny

Figure 3-2

Dentalina gracilis d'Orbigny, 1840, p. 14, pl. 1, fig. 5 (Inaccessible, *fide* Catalogue of Foraminifera); Cushman, 1946, p. 65, pl. 23, figs. 3-6.
Dentalina inornata d'Orbigny, 1846, p. 44, pl. 1, figs. 50, 51; Papp and Schmid, 1985, p. 28, pl. 9, figs. 5-8.

Type.—Hypotype, IGPS 101489, sample SNS02.

Description.—Test long, slender, uniserial, somewhat arcuate; chamber inflated except for early stage of microspheric forms; sutures distinct, oblique; wall calcareous, smooth, finely perforate; aperture radiate, placed toward concave side.

Remarks.—It resembles *Dentalina luma* Belford from the Campanian of western Australia, but differs in having more inflated chambers in the early stage and more oblique sutures.

Genus *Nodosaria* Lamarck, 1812
Nodosaria affinis Reuss

Figure 3-3

Nodosaria affinis Reuss, 1845, p. 26, pl. 13, fig. 16.
Nodosaria paupercula Ruess. Cushman, 1946, p. 75, pl. 27, figs. 10-12 (not of Reuss).

Type.—Hypotype, IGPS 101490, sample SNS02.

Remarks.—This fragmented specimen possesses a uniserial rectilinear chamber arrangement and wall ornamented by 16 longitudinal and nearly continuous costae.

Nodosaria aspera Reuss

Figure 3-4

Nodosaria aspera Reuss. Graham and Church, 1963, p. 41, pl. 4, figs. 17, 18; Cushman, 1946, p. 72, pl. 26, fig. 6.

Type.—Hypotype, IGPS 101491, sample SNS02.

Description.—Test uniserial, rectilinear, rounded in cross-section, chambers slightly overlapping, increasing rather uniformly in size as added; sutures normal to long axis of test, depressed; wall ornamented with small, closely set spines covering entire surface; aperture rounded with a short cylindrical neck projecting well beyond outline of final chamber.

Remarks.—The single specimen has more elongate and less overlapping chambers than the holotype of *Nodosaria aspera* Reuss.

Subfamily *Frondiculariinae* Reuss, 1860
Genus *Frondicularia* Defrance, 1826
Frondicularia bicornis Reuss

Figures 3-8, 9

Frondicularia bicornis Reuss, 1845, p. 32, pl. 13, fig. 45.
Frondicularia bicornis Reuss var. *etiola* Marie, 1941, p. 129, pl. 15, fig. 185.
Frondicularia bicornis Reuss var. *rhomboidalis* Marie, 1941, p. 129, pl. 15, fig. 184.
Frondicularia cf. *elegans* d'Orbigny. Takayanagi, 1960, p. 112, pl. 6, figs. 21a, b. (not of d'Orbigny)
Frondicularia verneuiliana d'Orbigny. Sliter, 1968, p. 62, 63, pl. 6, figs. 8-10c. (not of d'Orbigny)

Types.—Hypotype, IGPS 101492, figure 3-8 (megalospheric), sample SNS07; hypotype, IGPS 101493, figure 3-9 (microspheric), sample SNS02.

Description.—Test elongate-leaf-shaped, compressed, sides flat or slightly concave, periphery truncate, greatest breadth near the apertural end; chambers elongate, low, increasing gradually in size; sutures distinct, oblique, limbate, slightly elevated; wall calcareous, finely perforate, surface smoothly finished, with a single costa on globular proloculus and sometimes very fine short costae on later chambers; aperture terminal, radiate.

Remarks.—The megalospheric test has a broader width than the microspheric test.

Frondicularia durrelli Trujillo

Figure 3-1

Frondicularia durrelli Trujillo, 1960, p. 323, pl. 46, fig. 8; Sliter, 1968, p. 60, pl. 6, figs. 1a, b.

Type.—Hypotype, IGPS 101494, sample SNS07.

Description.—Test elongate-leaf-shaped, compressed, sides nearly parallel, peripheral margins truncate, carinate; chambers low, increasing gradually in size; sutures flush, oblique; wall calcareous, finely perforate, with three to six, sinuate, high, longitudinal costae extending length of test; aperture terminal, radiate.

Remarks.—It has a much slender test than *Frondicularia striatula* Reuss described by Takayanagi (1960).

Frondicularia mucronata Reuss

Figures 3-5, 6

Frondicularia mucronata Reuss, 1845, p. 31, pl. 13, figs. 43, 44.
Frondicularia mucronata Reuss subsp. *costata* Balakhmatova, 1960, p. 93, pl. 16, figs. 1, 2, 5 (Inaccessible, *fide* Catalogue of Foraminifera).

Type.—Hypotype, figure 3-5, IGPS 101495; hypotype, figure 3-6, IGPS 101496; Both from sample SNS07.

Description.—Test leaf-shaped, flat, with a basal spine, greatest breadth of test not at middle but rather near aboral end, periphery truncate, narrow, flat; initial chamber nearly globular with a few distinct short longitudinal costae, remaining two to four, angularly curved chambers narrow; sutures limbate, slightly curved; wall calcareous, finely perforate; aperture distinct, on a long quadrangular neck.

Remarks.—This species is characterized by having a basal spine and the greatest breadth of the test near the aboral end.

Frondicularia whaingaroica Stache

Figure 3-7

Frondicularia whaingaroica Stache, 1865, p. 210, pl. 22, fig. 43 (Inaccessible, *fide* Catalogue of Foraminifera).
Frondicularia fragilis Karrer, 1870, p. 175, pl. 2, fig. 3 (Inaccessible, *fide* Catalogue of Foraminifera).

Type.—Hypotype, IGPS 101497, sample SNS07.

Description.—Test large, elongate-leaf-shaped, flat, broadest near middle; chambers numerous, angularly curved at longitudinal axis, very narrow, with a longitudial depression along longitudinal axis; septal sutures depressed; wall calcareous, finely perforate, surface smooth except for a longitudinal and sutural depression; aperture terminal.

Remarks.—This species is distinguished from other species in having a large, thin test with numerous narrow chambers which are very angularly curved at the longitudinal axis.

Frondicularia sp. A

Figure 3-10

Type.—Hypotype, IGPS 101498, Sample SNS07.

Description.—Test large, leaf-shaped, flat, periphery truncate, greatest breadth about middle, length approximately twice as long as width; chambers elongate, curved, low, increasing gradually in size; sutures curved, depressed; wall calcareous, finely perforate with numerous short fine longitudinal costae on each chamber; aperture terminal, radiate.

Remarks.—This specimen is similar to *F. bicornis* Reuss, but differs in having a broader test and depressed sutures.

Family Vaginulinidae Reuss, 1860
Subfamily Lenticulininae Chapman, Parr and Collins, 1934
Genus *Lenticulina* Lamarck, 1804
Lenticulina extruatus (Cushman)

Figures 3-12, 13

Robulus navarroensis (Plummer) var. *extruatus* Cushman, 1938, p. 31, pl. 5, fig. 1; Cushman, 1941, p. 56, pl. 15, fig. 2; Cushman, 1946, p. 52, pl. 16, figs. 9-10b, pl. 17, fig. 2a, b.
Lenticulina spissocostata (Cushman). Perlmutter and Todd, 1965, p. 11, pl. 1, fig. 13; Sliter, 1968, p. 67, 68, pl. 7, figs. 7a-8b.

Types.—Hypotype, figure 3-12, IGPS 101499; hypotype, figure 3-13, IGPS 101500. Both from sample SNS07.

Description.—Test large, lenticular, periphery acute, with a keel; chambers distinct, nine in last whorl, gradually increasing in size as added: sutures curved, distinctly limbate, strongly raised; wall may have several obliquely curved costae, which are nearly parallel to outer edge of test; aperture radiate, at peripheral angle.

Remarks.—This species is distinguished from other species in having strongly raised sutures. It has a more elliptical test and high apertural face than *Robulus venustus* Takayanagi which has a rounded outline.

Lenticulina haboroensis (Takayanagi)

Figures 4-4, 5

Hemicristellaria haboroensis Takayanagi, 1960, p. 109, pl. 6, figs. 14a, b.

Types.—Hypotype, figure 4-4, IGPS 101501; hypotype, figure 4-5, IGPS 101502. Both from sample SNS07.

Description.—Test ovate in outline, flattened, side roughly parallel, dorsal periphery keeled, apertural face narrow, elongate, flat, depressed between two marginal keels; chambers broad and low, enrolled in very early stage, later uncoiling, added on slightly curved axis, increasing gradually in size; sutures curved, raised; wall calcareous, finely perforate, often with short longitudinal costae in early portion; aperture radial, at dorsal edge.

Remarks.—The studied specimens have a smaller coiling part and a broader uncoiling part than the holotype.

Lenticulina obirasibensis Takayanagi

Figure 3-17

Lenticulina obirasibensis Takayanagi, 1960, p. 103, pl. 5, figs. 28a, b; Yasuda, 1986, p. 66, 67, pl. 6, figs. 7a-c.

Lenticulina sp. cf. *L. lobata* (Reuss) of Egger. Graham and Church, 1963, p. 34, pl. 3, figs. 17a, b.

Robulus sp. A. Martin, 1964, p. 69, pl. 7, figs. 1a, b.

Type.—Hypotype, IGPS 101503, sample SNS02.

Description.—Test planispiral, involute, completely lenticular, elliptical in outline, compressed, periphery acute with slight to distinct keel; seven to nine chambers in last whorl, gradually increasing in size; sutures gently curved, limbate, flush with surface or very slightly raised; wall calcareous, finely perforate, surface smooth; aperture radiate at peripheral angle, usually with a ventral slit on apertural face.

Remarks.—This species is characterized by its elliptical outline, seven to nine chambers in the final whorl, gently curved suture and by having a thickness/diameter ratio of the test being about two-fifths. This species has a much compressed test than *Lenticulina williamsoni* (Reuss) occurring in the K/T boundary section of Hokkaido (Kaiho, in press, b) and *Robulus sorachiensis* Takayanagi.

Lenticulina rotulata (Lamarck)

Figure 3-16

Lenticulites rotulata Lamarck, 1804, p. 188; 1806, pl. 62, fig. 11 (Inaccessible, *fide* Catalogue of Foraminifera).

Lenticulina rotulata (Lamarck). Cushman, 1927, p. 142, pl. 28, figs. 7a, b (holotype redrawn); Frizzell, 1943, p. 341, pl. 56, figs. 2a, b; Cushman, 1946, p. 56-57, pl. 18, fig. 19, pl. 19, figs. 1-7; Takayanagi, 1960, p. 103, 104, pl. 5, figs. 29a, b; Yasuda, 1986, p. 67, 68, pl. 6, figs. 10a, b.

Lenticulina muensteri (Roemer). Sliter, 1968, p. 66, pl. 7, figs. 9, 13.

Type.—Hypotype, IGPS 101504, sample SNS02.

Description.—Test, lenticular, closely coiled, roughly circular in outline, biumbonate, periphery acute with slight to distinct keel; chambers eight to eleven in final whorl, increasing gradually in size; sutures gently curved, limbate, flush with surface or slightly raised; wall calcareous, finely perforate, surface smooth ; aperture radiate at peripheral angle, slightly protruded, with a ventral slit on an apertural face.

Remarks.—This species is characterized by its circular outline, biumbonate and distinct keel. It has a thicker keel and larger test than *L. rotulata* of Takayanagi (*loc. cit.*). It resembles *Lenticulina tanakai* Takayanagi, but differs in having a more compressed test, better developed keel and circular umbonal boss.

Lenticulina williamsoni (Reuss)

Figure 4-2

Cristellaria williamsoni Reuss, 1862, p. 327, pl. 6, figs. 4a-b.
Robulus williamsoni (Reuss). Cushman, 1931, p. 37, pl. 5, figs. 2a, b ; Cushman, 1946, p. 54, pl. 18, figs. 2a-3b.

Type.—Hypotype, IGPS 101505, sample SNS02.

Description.—Test lenticular, thick, periphery slightly lobulate, slightly keeled, large apertural face ; chambers six in final whorl, inflated, rapidly increasing in size ; sutures curved, depressed ; wall calcareous, finely perforate, surface smooth ; aperture radiate, at peripheral angle.

Remarks.—The present specimens differs from *L. williamsoni* occurring from the K/T boundary section of Hokkaido (Kaiho, in press, b) in having depressed sutures and inflated chambers.

Lenticulina yabei Takayanagi

Figure 3-15

Lenticulina yabei Tkayanagi, 1960, p. 106, pl. 6, figs. 2a-3b : Yasuda, 1986, p. 68, pl. 6, figs. 13a-c.

Type.—Hypotype, IGPS 101506, sample SNS02 (megalospheric form).

Description.—Test semi-heart-shaped, lenticular, compressed, periphery distnctly keeled ; large proloculus followed by four to five chambers in megalospheric forms and eight chambers in microspheric forms in last whorl, chambers increasing very slowly in thickness, but rapidly in breadth ; sutures limbate, curved, flush with surface ; wall calcareous, finely perforate, thick, surface smooth ; aperture radiate at peripheral angle.

Remarks.—This species is characterized by its semi-heart-shaped outline, thick wall, distinct keel and large proloculus followed by four to five chambers in the megalospheric forms.

Lenticulina sp. A

Figure 3-14

Type.—Hypotype, IGPS 101507, sample SNS07.

Remarks.—This species differes from *L. extruatus* Cushman in having more weakly raised sutures and longer apertural face.

Lenticulina sp. B

Figure 4-1

Type.—Hypotype, IGPS 101508, sample SNS02.

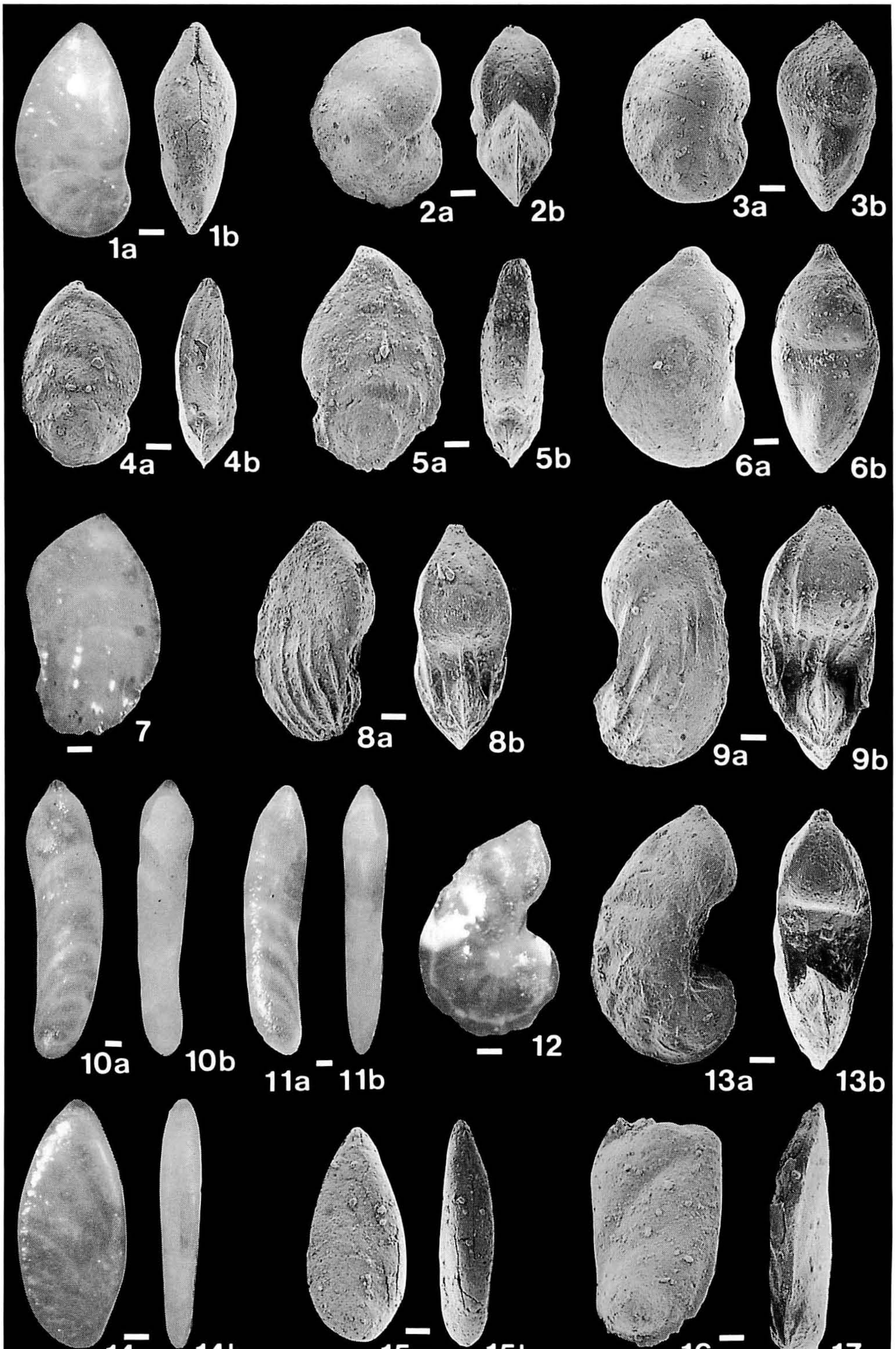
Description.—Test long elliptical, compressed, periphery acute, without distinct keel ; chambers increasing rapidly in size, somewhat inflated in last chamber ; sutures gently curved, flush with surface ; wall calcareous, finely perforate, surface smooth ; aperture radiate, at peripheral angle, with a ventral slit on apertural face.

Remarks.—This species is characterized by a long elliptical outline and lack of distinct keel. It has an outline similar to that of *Lenticulina yabei* Takayanagi, but differs in having a slit on the apertural face and more thicker chambers in later portion. It differs from *L. obirashibensis* in having a more elongate test, inflated last chamber and relatively higher apertural face.

Lenticulina sp. C

Figure 4-3

Type.—Hypotype, IGPS 101509, sample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SNS07.

Description.—Test lenticular, thick, roughly ovate in outline, planispiral, involute ; chambers seven in final whorl, increasing gradually in size ; sutures curved, raised ; wall calcareous, finely perforate, surface smooth except for raised sutures ; aperture radiate at peripheral angle.

Remarks.—This specimen is distinguished from *L. williamsoni* Reuss in having raised sutures.

Genus *Pravoslavlevia* Putrya, 1970
Pravoslavlevia sp.

Figure 4-12

Type.—Hypotype, IGPS 101515, sample SNS07.

Remarks.—The specimen differs from *Saracenaria tunesiana* ten Dam and Sigal in having a larger, more closed, and biumbonate initial coiling stage, narrower chambers in lectilinear stage, and smooth surface.

Genus *Saracenaria* Defrance, 1824
Saracenaria triangularis (d'Orbigny)

Figure 4-6

Cristellaria triangularis d'Orbigny, 1840, p. 27, pl. 2, figs. 21, 22. (Inaccessible, *fide* Catalogue of Foraminifera)
Saracenaria triangularis (d'Orbigny). Cushman and Church, 1929, p. 505, pl. 37, figs. 13, 14 ; Cushman, 1946, p. 58, pl. 28, figs. 1a-3.
Saracenaria cf. *triangularis* (d'Orbigny). Takayanagi, 1960, p. 106, pl. 6, figs. 8a, b.
Saracenaria sp. A. Yasuda, 1986, p. 70, 71, pl. 7, figs. 6a-c.

Type.—Hypotype, IGPS 101510, sample SNS07.

Description.—Test planispirally enrolled in early stage, later flaring and tending to become rectilinear, chestnut-shaped in transverse section, dorsal angle acute, apertural face broad and inflated ; chambers low and broad, increasing gradually in size ; sutures much curved in enrolled portion, but becoming gently curved later, flush with surface ; wall calcareous, finely perforate, surface smooth ; aperture radial, at edge of dosal side.

Remarks.—This species is characterized by its smooth surface and acute non-keeled dorsal periphery. Common in the Upper Cretaceous of Hokkaido.

Saracenaria tunesiana ten Dam and Sigal

Figures 4-7—9, 13

Saracenaria tunesiana ten Dam and Sigal, 1950, p. 36, pl. 2, fig. 21 ; Trujillo, 1960, p. 316, 317, pl. 45, figs. 11a, b.

Types.—Hypotype, IGPS 101511, figure 4-7 ; hypotype, IGPS 101512, figure 4-8 ; hypotype, IGPS 101513, figure 4-9 ; hypotype, IGPS 101514, figure 4-13. All from sample SNS07.

Description.—Test elongate, triangular in transverse section, angled acute, keeled in early dorsal portion, early stage closely coiled, later three to four chambers uncoiling and becoming rectilinear, with broad inflated ventral face of last chamber and strongly depressed middle part of ventral side ; chambers broad and low, highest at dorsal margin ; sutures gently curved, slightly depressed ; wall calcareous, finely perforate, with longitudinal costae, curved and almost parallel with dorsal periphery ; aperture radiate at dorsal angle.

Remarks.—This species is distinguished in having a long uncoiling part, deeply depressed middle part of the ventral side, and several distinct longitudinal costae.

← **Figure 4.** Scale bar = 100 μm. **1,** *Lenticulina* sp. B. SNS02. **2,** *Lenticulina williamsoni* (Reuss). SNS02. **3,** *Lenticulina* sp. C. SNS07. **4, 5,** *Lenticulina haboroensis* (Takayanagi). SNS07. **6,** *Saracenaria triangularis* (d'Orbigny) . SNS07. **7-9, 13,** *Saracenaria tunesiana* ten Dam and Sigal. SNS07. **10, 11,** *Astacolus elongatus,* Kaiho, n. sp. **10**; SNS07. **11**; SNS02. **12,** *Pravoslavlevia* sp. SNS07. **14, 15,** *Astacolus nagaoi* (Takayanagi). SNS07. **16, 17,** *Astacolus polandensis* Trujillo. SNS07.

Subfamily Marginulininae Wedekind, 1937
Genus *Astacolus* de Montfort, 1808
Astacolus elongatus Kaiho, n. sp.

Figures 4-10, 11

Types.—Holotype, figure 4-10, IGPS 101516, sample SNS07; paratype, figure 4-11, IGPS 101517, sample SNS02.

Description.—Test elongate, flattened, periphery rounded; chambers numbering up to eight, broad and low, but last chamber relatively high, added on a slightly curved axis, sutures strongly oblique, curved; wall calcareous, finely perforate, surface smooth; aperture radiate at dorsal angle.

Remarks: This new species is distinguished from other related species in having a very elongate test. It resembles *Astacolus jarvisi* (Cushman), but differs in having a more slender test.

Astacolus nagaoi (Takayanagi)

Figures 4-14, 15

Hemirobulina nagaoi Takayanagi, 1960, p. 117, pl. 7, figs. 13a-14b.

Types.—Hypotype, figure 4-14 (microspheric form), IGPS 101518; hypotype, figure 4-15 (megalospheric form), IGPS 101519. Both from sample SNS07.

Description.—Test ovate in outline, nearly three times as long as broad, flattened, periphery subacute to rounded, not keeled, apertural face very narrow, high, flat, truncate; chambers five to seven, broad and low, enrolled in very early stage, later becoming uncoiled, added on a slightly curved axis, increasing very slowly in size, strongly oblique, dorsal side higher than ventral; sutures distinct, strongly oblique, very slightly curved, flush with surface; wall calcareous, finely perforate, very thin, translucent, surface smooth; aperture radiate, terminal, at dorsal angle.

Remarks.—The microspheric form is composed of a small proloculus followed by six low chambers. The megalospheric form has a large proloculus followed by four higher chambers. The megalospheric form has a thicker test than the microspheric form.

Astacolus polandensis Trujillo

Figures 4-16, 17

Astacolus polandensis Trujillo, 1960, p. 317, 318, pl. 45, figs. 14a, b.

Types.—Hypotype, figure 4-16, IGPS 101520; hypotype, figure 4-17, IGPS 101521. Both from sample SNS07.

Description.—Test ovate in outline, nearly three times as long as broad, flattened, dorsal periphery acute with narrow keel in early portion, apertural face very narrow, high, flat, truncate; large proloculus followed by four triangular chambers, increasing rapidly in size, oblique, dorsal side higher than ventral, slightly inflated; sutures distinct, oblique, slightly curved, depressed; wall calcareous, finely perforate, surface smooth; aperture radiate, terminal, at dorsal angle.

Remarks.—This species differs from *A. nagaoi* in having a keeled dorsal periphery, depressed sutures and inflated higher chambers.

Genus *Marginulina* d'Orbigny, 1826
Marginulina bullata Reuss

Figures 5-1, 2

Marginulina (*Marginulina*) *bullata* Reuss, 1845, p. 29, pl. 13, figs. 34-38.

Marginulina bullata Reuss. Cushman, 1946, p. 62, pl. 21, figs. 32a-37; Bandy, 1951, p. 498, pl. 72, figs. 13a, b; Graham and Church, 1963, p. 37, pl. 4, figs. 1a, b; Martin, 1964, p. 63-64, pl. 5, figs. 10a-b; Sliter, 1968, p. 70, pl 8, figs. 6a-7.

Marginulina cf. *M. glabra* d'Orbigny. Cushman, 1951, p. 18, pl. 5, figs. 25-27. (not of d'Orbigny)

Marginulina texasensis Cushman. Takayanagi, 1960, p. 90, pl. 4, figs. 13a, b (not of Cushman).

Marginulina troedssoni Brotzen. Trujillo, 1960, p. 325-326, pl. 46, figs. 14a-c (not of Brotzen).

Types.—Hypotype, figure 5-1 (microspheric form), IGPS 101522; hypotype, figure 5-2 (megalospheric form), IGPS 101523. Both from sample SNS02.

Description.—Test elongate, coiled in early stage, later stage becoming uncoiled, circular in cross section, initial edge compressed in microspheric forms, rounded in megalospheric form ; five or six chambers, slightly inflated in early portion, more inflated in later portion ; sutures distinct, flush in early stage, later depressed, nearly transverse ; wall calcareous, finely perforate, smooth ; aperture radiate, terminal, at dorsal angle.

Remarks.—This is a cosmopolitan, Late Cretaceous species.

Subfamily Vaginulininae Reuss, 1860
Genus *Citharina* d'Orbigny
Citharina multicostata (Cushman)

Figure 5-3

Vaginulina multicostata Cushman, 1930, p. 28, pl. 4, fig. 4 ; Cushman, 1946, p. 79, pl. 29, figs. 9-16.
Citharina sp. A. Graham and Church. 1963, p. 26, pl. 2, fig. 9.
Citharina multicostata (Cushman). Sliter, 1968, p. 55, 56, pl. 5, fig. 6.
Citharina strigillata (Reuss). Loeblich and Tappan, 1988, p. 116 pl. 452, figs. 1, 2.

Type.—Hypotype, IGPS 101524, sample SNS07.

Description.—Test elongate, much compressed throughout, dorsal edge straight, ventral edge convex, tapering on both sides, periphery truncate ; chambers elongate, curved, strongly oblique, low and broad ; sutures not depressed, very oblique, curved ; wall ornamented with numerous costae, parallel to straight dorsal edge of test, and continuous in early portion, but independent of individual chambers in later portion ; aperture terminal.

Remarks.—The present specimens have stronger costae in early portion than the holotype. This species differs from *Citharina suturalis* Cushman described from the Cretaceus of Arkansas, but differs in having a truncate periphery, independent costae of the individual chambers in later portion and strong continuous costae in early portion.

Genus *Psilocitharella* Loeblich and Tappan, 1986
Psilocitharella ezoensis Kaiho, n. sp.

Figures 5-4, 5

Types.—Holotype, fig. 5-4, IGPS 101525 ; paratype, fig. 5-5, IGPS 101526. Both from sample SNS07.

Description.—Test elongate, two sides nearly parallel, rectilinear, compressed, periphery truncate, margin carinate, straight on dorsal side, lobulate in ventral side ; chambers inflated, half as low as breadth in early portion, but as high as breadth in later portion ; sutures oblique, highest at dorsal side, straight, depressed ; wall calcareous, finely perforate, surface ornamented by longitudinal or slightly oblique costae not continued beyond sutures ; aperture radiate at the dorsal angle, protruded.

Remarks.—This new species has a much larger test and lower chambers than those of *Citharina geisendorferi* (Franke) *costata* Takayanagi.

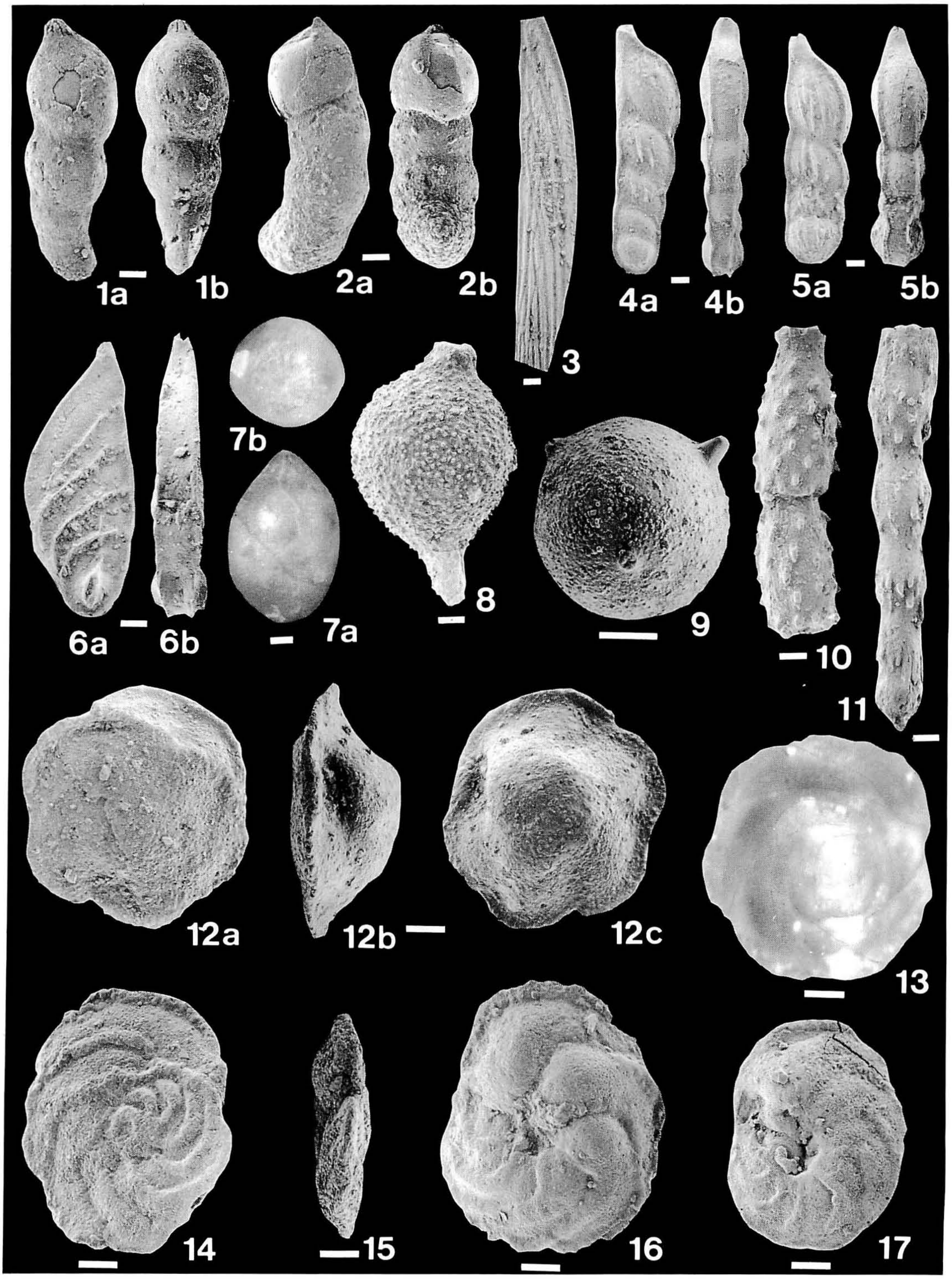
Psilocitharella triangulata Kaiho, n. sp.

Figure 5-6

Type.—Holotype, IGPS 101527 ; paratype, IGPS 101528. Both from sample SNS07.

Description.—Test subtriangular in outline, elongate, compressed, periphery truncate, margin carinate ; chambers broad, low, not inflated ; sutures elevated, curved oblique in early portion, straight, strongly oblique in later portion ; wall calcareus, finely perforate, surface smooth, without elevated costae ; aperture radiate, at dorsal angle, slightly protruded.

Remarks.—This new species resembles *Citharina* cf. *recta* Reuss of Takayanagi (1960), but differs in having broader chambers.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Family Polymorphinidae d'Orbigny, 1839
Subfamily Polymorphininae d'Orbigny, 1839
Genus *Globulina* d'Orbigny, 1839
Globulina lacrima (Reuss)

Figure 5-7

Polymorphina (*Globulina*) *lacrima* Reuss, 1845, p. 40, pl. 12, fig. 6, pl. 13, fig. 83.
Globulina lacrima Reuss. Cushman and Ozawa, 1930, p. 77, pl. 19, figs. 1-2; Cushman, 1946, p. 96, pl. 40, figs. 11a-12; Hofker, 1957, p. 170, 171, text-figs. 212, 213; Sliter, 1968, p. 77, pl. 9, figs. 17a-c, pl. 10, figs. 1a-c.
Globulina lacrima lacrima Reuss. Graham and Church, 1963, p. 48, pl. 5, figs. 15a-c.

Type.—Hypotype, IGPS 101529, sample SNS07.

Description.—Test subglobular, ovate in cross section; chambers strongly appressed, extending nearly to base, becoming sigmoidal; suture distinct, flush; wall calcareous, finely perforate, surface smooth; aperture terminal, radiate.

Subfamily Edithaellinae Fuchs, 1967
Genus *Ramulina* T.R. Jones, 1875
Ramulina aculeata (d'Orbigny)

Figure 5-8

Dentalina aculeata d'Orbigny, 1840, p. 13, pl. 1, figs. 2, 3 (Inaccessible, *fide* Catalogue of Foraminifera); Cushman, 1946, p. 67, pl. 26, figs. 17, 18?; Martin,1964, p. 60, pl. 4, figs. 12a, b.
Ramulina sp. a Takayanagi, 1960, p. 118, pl. 7, figs. 17, 18.
Ramulina pseudoaculeata (Olsson). Sliter, 1968, p. 79, pl. 10, fig. 8.
Ramulina sp. Scheibnerová, 1974, p. 180, pl. 35, fig. 1.

Type.—Hypotype, IGPS 101530, sample SNS02.

Remarks.—These segmented specimens have a pyriform test with numerous short spines and with remnants of connecting tubes at both ends.

Ramulina tetrahedralis Ludbrook

Figure 5-9

Ramulina tetrahedralis Ludbrook. Scheibnerová, 1974, p. 178, pl. 34, figs. 4, 5.

Type.—Hypotype, IGPS 101531, sample SNS02.

Remarks.—This species has a spherical test with four cylindrical arms and very finely hispid surface.

Suborder Rotaliina Delage and Hérouard, 1896
Superfamily Stilostomellacea Finlay, 1947
Family Stilostomellidae Finlay, 1947

Genus *Stilostomella* Guppy, 1894
Stilostomella alexanderi (Cushman)

Figure 5-10

Ellipsonodosaria alexanderi Cushman, 1936, p. 52, pl. 9, figs. 6-9; Cushman, 1946, p. 135, pl. 56, figs. 12-15.
Ellipsonodosaria alexanderi var. *impensia* Cushman, 1938, p. 48, pl. 8, figs. 4, 5; Cushman, 1946, p. 136, pl. 56, figs. 16-18; Cushman, 1949, p. 9, pl. 4, fig. 11.
Stilostomella alexanderi (Cushman). Skinner, 1962, p. 47, pl. 5, fig. 31; Yasuda, 1986, p. 81, pl. 11, figs. 2a, b.

Type.—Hypotype, IGPS 101532, sample SNS07.

Remarks.—Those segments characterized by a wall ornamented with short backwardly pointing spines, which are irregularly scattered over the wall surface, are referred to the present species. It is a cosmopolitan Creta-

← **Figure 5.** Scale bar = 100 μm. **1, 2,** *Marginulina bullata* Reuss. SNS02. **3,** *Citharina multicostata* (Cushman). SNS07. **4, 5,** *Psilocitharella ezoensis* Kaiho, n. sp. SNS07. **4**; holotype. **5**; paratype. **6,** *Psilocitharella triangulata* kaiho, n. sp. SNS07, holotype. **7,** *Globulina lacrima* (Reuss). SNS07. **8,** *Ramulina aculeata* (d'Orbigny). SNS02. **9,** *Ramulina tetrahedralis* Ludbrook. SNS02. **10,** *Stilostomella alexanderi* (Cushman). SNS07. **11,** *Stilostomella stephensoni* (Cushman). SNS07. **12, 13,** *Nuttallinella florealis* (White). SNS07. **14-17,** *Notoplanulina rumoiensis* (Takayanagi). **14, 16**; SNS07. **15, 17**; SNS02.

ceous species.

Stilostomella stephensoni (Cushman)

Figure 5-11

Ellipsonodosaria stephensoni Cushman, 1936, p. 52, pl. 9, figs. 10-15; Cushman, 1946, p. 134, pl. 56, figs. 2-7; Cushman, 1949, p. 9, pl. 4, fig. 10.
Stilostomella stephensoni (Cushman). Frizzell, 1954, p. 121, pl. 18, figs. 22, 23 (in text as *Ellipsonodosaria stephensoni* Cushman); Said and Kenawy, 1956, p. 146, pl. 4, fig. 37; Takayanagi, 1960, p. 121, pl. 8, fig. 3; Skinner, 1962, p. 47, pl. 5, fig. 30; Yasuda, 1986, p. 82, pl. 11, figs. 3a-4.
Siphonodosaria pseudoscripta (Cushman) of Graham and Church, 1963, p. 56, pl. 6, fig. 13.

Type.—Hypotype, IGPS 101533, sample SNS07.

Description.—Test elongate, rectilinear, tapering, with short, longitudinal, costae-like spines surrounding mostly lower half of its pyriform chambers.

Remarks.—This species resembles *Stilostomella stephensoni* Cushman of Takayanagi (1960) and *Siphonodosaria pseudoscripta* (Cushman) of Graham and Church (1963), but has a much larger test (about twice in length).

Superfamily Asterigerinacea d'Orbigny, 1839
Family Epistomariidae Hofker, 1954
Subfamily Eponidellinae Seiglie and Bermúdez, 1965
Genus *Nuttallinella* Belford, 1959

Nuttallinella florealis (White)

Figures 5-12, 13

Gyroidina florealis White, 1928, p. 293, pl. 40, fig. 3.
Nuttallina florealis (White). Takayanagi, 1960, p. 128, pl. 9, figs. 3a-5.

Type.—Hypotype, figure 5-12, IGPS 101534; hypotype, figure 5-13, IGPS 101535. Both from sample SNS07.

Description.—Test planoconvex, spiral side flattened, umbilical side strongly convex, with umbilical boss, nearly flat, peripheral outline lobulate, peripheral margin acute, keeled; chambers five in final whorl; sutures limbate, strongly curved, flush in spiral side, radial, slightly curved, slightly depressed in umbilical side; wall calcareous, finely perforate, surface smooth; aperture interiomarginal, an elongate slit opening near periphery.

Remarks.—Abundant in the Campanian Kashima Formation, in the Oyubari area, Hokkaido.

Superfamily Chilostomellacea Brady, 1881
Family Gavelinellidae Hofker, 1956
Subfamily Gyroidinoidinae Saidova, 1981
Genus *Notoplanulina* Malumian and Masiuk, 1976

Notoplanulina rumoiensis (Takayanagi)

Figures 5-14—17

Planulina rumoiensis Takayanagi, 1960, p. 139, pl. 11, figs. 1a-c.

Types.—Hypotype, figure 5-14, IGPS 101536, sample SNS07; hypotype, figure 5-15, IGPS 101537, sample SNS02; hypotype, figure 5-16, IGPS 101538, sample SNS07; hypotype, figure 5-17, IGPS 101539, sample SNS02.

Description.—Test flattened, low trochospiral, planoconvex, two whorls visible on spiral side, umbilicus open, bordered with a lip and partly covered by umbilical chamber extensions, periphery angular and carinate; seven to eight chambers in final whorl, low and broad, inflated on umbilical side; sutures strongly curved and depressed on umbilical side; wall calcareous, finely perforate except for imperforate thickened sutures; aperture, an elongate interiomarginal slit, extending from near periphery to open umbilicus.

Remarks.—I recognized that the holotype of this species is indeed a juvenile form because of the discovery of abundant adult specimens from the two samples treated herein. This species resembles *Notoplanulina rakauroana* Finlay, but differs in having a smaller, less evolute test.

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Hobetsu-cho 穂別町.

北海道中央部のカンパニアン期の中層水底生有孔虫：北海道中央部穂別町に分布する蝦夷層群鹿島層の 10 kg の試料 2 つから，カンパニアン期の浮遊性有孔虫に随伴する中層水底生有孔虫約 50,000 個体を検出した。この底生群集を構成するのは，個体数の 85-90% を占める *Silicosigmoilina futabaensis* と，*Notoplanulina rumoiensis, Nuttallinella florealis, Haplophragmoides asanoi, Dorothia hokkaidoana* など，47 種である。これらの種を記載し，群集構成を明らかにした。種数から見ると，Lagenina 亜目が 66% を占め，Rotaliina 亜目は，9% と少ない。この群集は，上部半深海帯 (200-500 m) の水深を示す。 海保邦夫

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924. *THALASSINA ANOMALA* (HERBST, 1804) (THALASSINIDEA: DECAPODA) FROM THE MIOCENE BIHOKU GROUP, SOUTHWEST JAPAN*

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Abstract. *Thalassina anomala* (Herbst, 1804), a thalassinid decapod, is described from the early Middle Miocene Bihoku Group exposed at Munekane, Yuki-cho, Jinseki-gun, Hiroshima Prefecture, Southwest Japan. *Thalassina anomala* is a living species which inhabits mangrove swamps and this occurrence shows the existence of mangrove swampy paleoenvironment in the Middle Miocene. It is closely related to the tropical spike recognized in the early Middle Miocene of Southwest Japan.

Key words. Bihoku Group, early Middle Miocene, Hiroshima Prefecture, *Thalassina anomala*.

Introduction

The burrowing mangrove mud lobster, *Thalassina anomala* (Herbst), is one of the characteristic thalassinid decapods which inhabits mangrove swamps in the tropical Indo-West Pacific regions. It is well known to be a large, active burrower living in mangrove swamps on the high spring tide zone, forming large mounds.

The junior author, Nishikawa, has collected and reported many thalassinid shrimps from the Miocene Bihoku Group exposed at Munekane, Hiroshima Prefecture (Nishikawa, 1972; 1974). As a result of our subsequent study, these decapod fossils were identified with *Thalassina anomala* (Herbst). Fossil *Thalassina* has been described from the Pleistocene to Holocene formations in Australia (Etheridge and MacCulloch, 1916; Förster and Barthel, 1978, *etc.*), New Guinea (Van Straelen, 1928) and Japan (Imaizumi, 1953). Imaizumi (1969) also reported *Thalassina* sp. from the early Middle Miocene Kawaminami Formation in Kaga City, Ishikawa Prefecture. The occurrence of fossil *Thalassina* in the Bihoku Group is the second record from Japanese Miocene formations.

In this paper, we describe *Thalassina anomala* from the Bihoku Group and discuss its paleoecological and geological significance.

Occurrence and geological note

Thalassinid decapods were collected from the Miocene Bihoku Group exposed at Mune-

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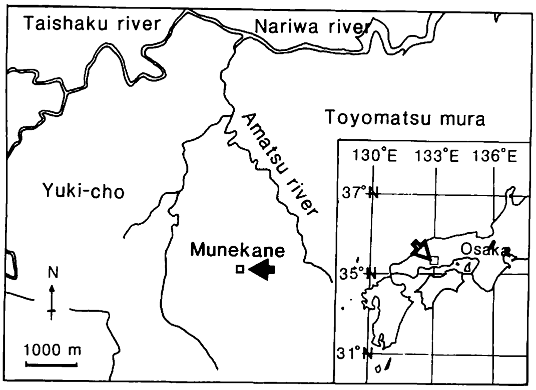


Figure 1. Locality map.

kane, Yuki-cho (Figure 1). In Yuki area, the Bihoku Group overlies the basement rocks belonging to the Cretaceous Inai Formation and the Paleozoic Yoshii Group. Stratigraphic studies of the Bihoku Group in this area have been made by Imamura (1953), Itoigawa and Nishikawa (1976) and Matsuoka (1978). In this paper, we use the stratigraphic classification of Matsuoka (1978), who divided the Group into the Yuki Conglomerate, the Jinseki Formation and the Kibi Formation in ascending order.

Thalassina anomala, associated with many plants and the brachyuran decapod, "*Sesarma*" sp., occurs in an ill-sorted siltstone bed of the lower member of the Jinseki Formation.

Itoigawa and Nishikawa (1976) have reported a molluscan fauna represented by the *Cyclina-Hiatula-Siratoria* assemblage from the Kibi Formation exposed at Kozuike near the decapod-bearing locality. Matsuoka (1978) has also reported *Operculina complanata japonica* Hanzawa and such molluscan fossils as the *Batillaria* and "*Vasticardium*"-*Phacosoma* assemblages from the Kibi Formation. Brackish-water molluscs, *Batissa bihokuensis* Matsuoka, *Melanoides* sp., *Novaculina* sp., and plant *Comptonia naumanii* (Nathorst) are also known from the Jinseki Formation developed at Kozuike (Matsuoka, *op. cit.*).

Paleontological description

Order Decapoda Latreille, 1803
Suborder Pleocyemata Burkenroad, 1963
Infraorder Thalassinidea Latreille, 1831
Superfamily Thalassinoidea Latreille, 1831
Family Thalassinidae Latreille, 1831
Genus *Thalassina* Latreille, 1806

Type species.—*Cancer* (*Astacus*) *anomalus* Herbst by original description.

Thalassina anomala (Herbst, 1804)

Figures 3-1–3, 4-1–4

Cancer (*Astacus*) *anomalus* Herbst, 1804, p. 45, pl. LXII. (*non bidi.*)
Thalassina scorpionoides Latreille, 1806, p. 51. (*non bidi.*)
Thalassina antiqua Bell, 1844, p. 455. (*nomen nudum*)
Thalassina emeryi Bell, 1845, p. 93, figs. a, b, c; A. Milne Edwards, 1860, p. 349, pl. 15, figs. 1a, b.
Thalassina gracilis Dana, 1852, p. 514, pl. 32, figs. 5a-g.
Thalassina maxima Hess, 1865, p. 37, pl. 7, fig. 18.
Thalassina anomala (Herbst), de Man, 1886, p. 260; Ortmann, 1891, p. 52; Borradaile, 1903, p. 541; Balss, 1914, p. 88; Etheridge and MacCulloch, 1916, p. 7, p. l, figs. 1-3; de Man, 1928, p. 5; Van Straelen, 1928, p. 64, pl. 12, figs. 1-5; Imaizumi, 1953, p. 68, pl. 9; Sakai, 1965MS, p. 53, fig. 11; Sankolli, 1970, p. 242, figs. 3, 4; Hirata, 1973, p. 24; Miyake, 1982, p. 91, pl. 31, fig. 2; Kamesaki *et al.*, 1988, p. 25.
Thalassina sp., Imaizumi, 1969, N-7, figs. 8, 9 (*non.* figs. 7a, b).
Thalassina sp., Förster and Barthel, 1978, p. 302, fig. 8.
Crustacea, Nishikawa, 1972, p. 217, figs. 1-3.
Thalassinoidea fam. gen. et sp. indet., Nishikawa, 1974, p. 3, figs. 17-19.

Material.—MFM39101-MFM39106.

Repository.—Mizunami Fossil Museum.

Description.—Carapace: rostrum, gastric region, anterior cardiac region, hepatic region and anterior branchial region well-preserved. Rostrum with a weak median furrow, large, acute triangular, about one-fifth the length of the gastric region; the lateral margins weakly dentate or smooth, extending onto the gastric

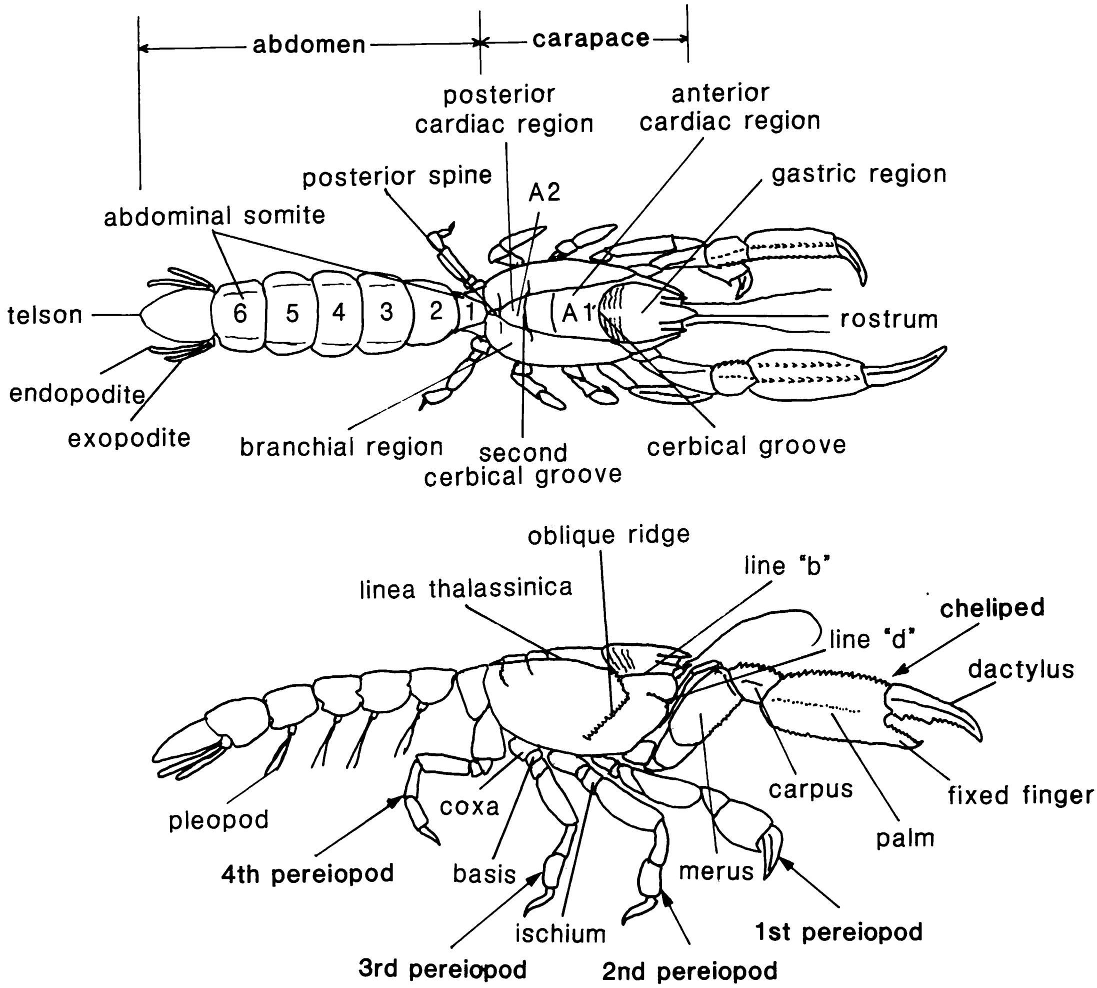
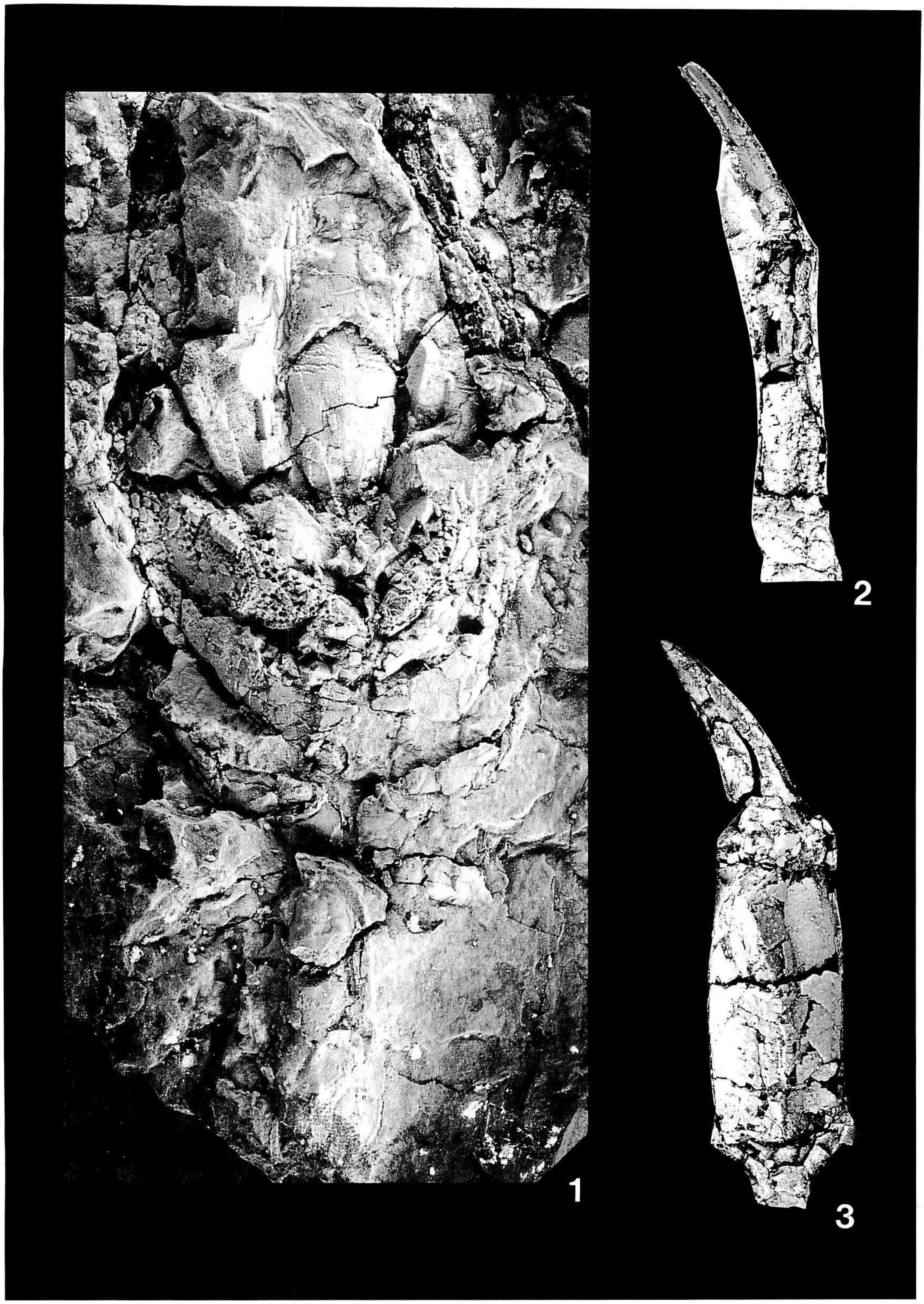


Figure 2. Terminology of *Thalassina anomala* (Herbst, 1804) (modified by Sankolli, 1970)

region as a distinct carina reaching one-third the length of the gastric region. Anterior margin of the carapace bears a small spine behind the orbit, and a carina runs from the base of the spine parallel with the rostral carina. Gastric region slightly convex, smooth except posteriorly where it is covered with transverse ridges. Cervical groove distinct, deep. Anterior cardiac region divided into two (A1 and A2 regions of Sankolli, 1970; see Figure 2) by the first transverse furrow; A1 region armed with 5 small granulose tubercles on each side; A2 region covered with 4 small tubercles. Anterior half of branchial region coarsely decorated with granulose tubercles which diminish in size posteriorly, the posterior half smooth. Oblique ridge on the branchial region visible, finely dentate and the upper part not preserved. Hepatic region densely covered with granulose tubercles. The region between the line "b" and "d" (see Figure 2) smooth, and the anterior margin fringed with fine teeth.

Dactylus, fixed finger, propodus, carpus,

→ **Figure 3.** *Thalassina anomala* (Herbst, 1804). Bihoku Group. ×1.0. **1,** Carapace, abdomen, chelipeds and 1st to 3rd pereiopods, MFM39101; **2,** Left cheliped, outer view, MFM39101; **3,** Right cheliped, inner view, MFM39103.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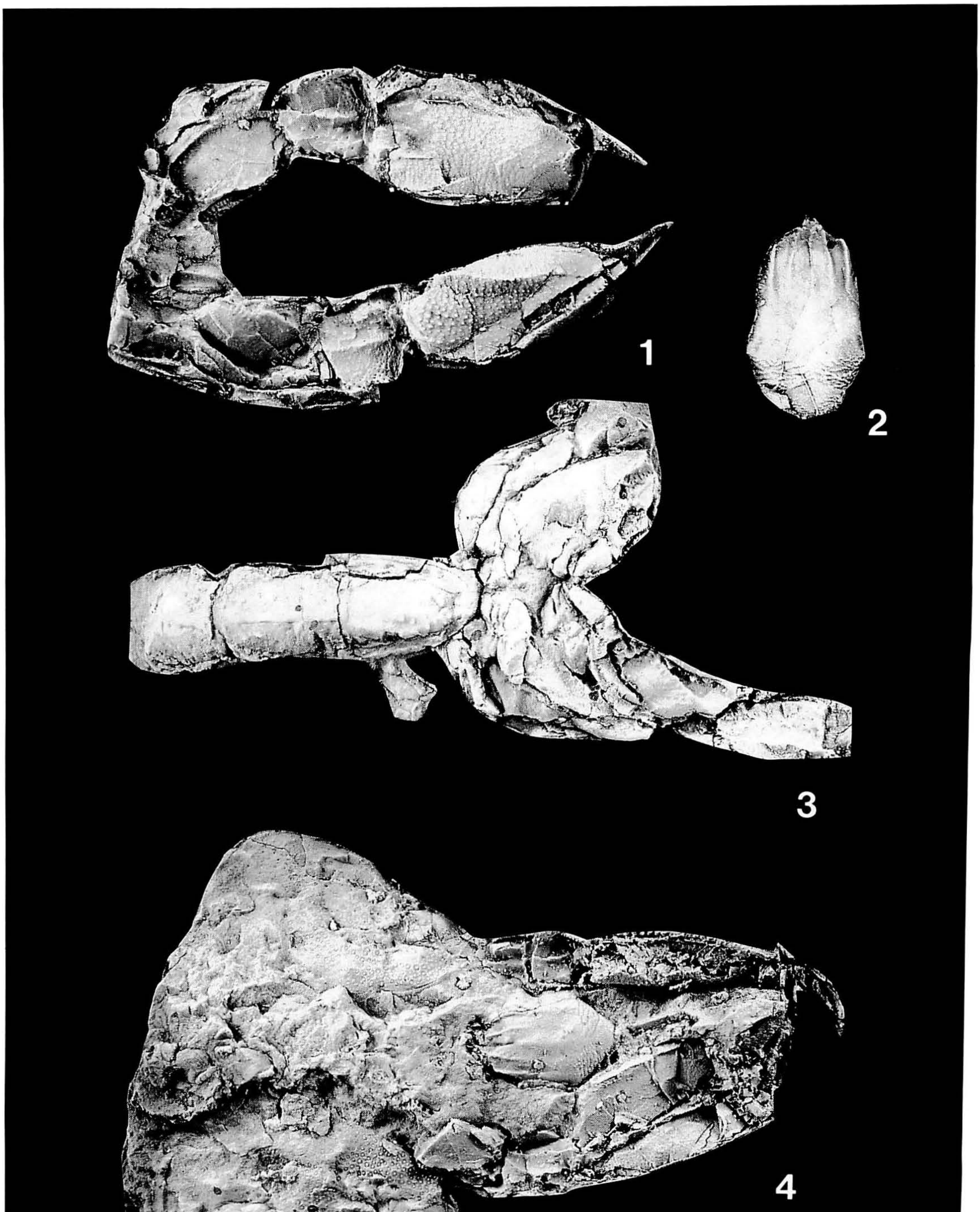
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merus and ischium of cheliped are preserved and the impressions of some parts remain. Chelipeds subchelate and equal or subequal; dactylus long, elongate and the apex sharp; upper margin bears 15-20, low, small teeth diminishing in size towards the front, the lower margin is finely dentate. Fixed finger very short, one-third to one-fourth the length of the dactylus; upper margin denticulate and lower margin smooth. Palm 1.2 to 1.4 times as long as the dactylus and rectangular in outline; the length of the larger cheliped about 1.3 times as long as the width, and that of the smaller one 1.8 to 2.0 times as long as the width; upper outer margin being provided with 16 to 20 sharp spines directed forward; upper inner border armed with 20 spinules; lower margin also spinelike; distal margin near the articulation of the dactylus bearing fine serrations; outer surface densely granulate, the denticules varying in size, and becoming denser on the lower half; a median longitudinal carina with conical tubercles running from the carpus to the articulation of the dactylus; inner surface also covered with many granules; longitudinal row of similar tubercles on the inner surface along the lower margin; surface below a longitudinal row of tubercles densely decorated with granules. Carpus about two-fifths to one-half as long as the propodus, rectangular, tapering proximally; lower and upper margins marked by some spines; outer distal surface sparsely granulate. Merus as long as or slightly longer than the carpus; lower inner and outer margins bearing some spines. Ischium short, about three-fourths as long as the merus; lower margin armed with two sharp spines distally, and the upper margin irregularly denticulate. Basis very short with the outer inner margin composed of a row of small conical granules.

1st pereiopods: dactylus, merus, ischium and basis are ill-preserved. Dactylus slender, elongate; upper margin smooth and lower margin finely denticulate; on the outer surface a longitudinal ridge extends along the upper margin. Lower margin of the ischium is provided with some spines of which the distal one is the largest. Lower margin of the basis is also provided with some small spines.

2nd pereiopods: merus, ischium, basis and coxa remain. Merus flattened. Ischium also flattened about five-ninths as long as the merus. Basis short about seven-tenths as long as the basis. Both margins of the merus, ischium and basis smooth.

3rd pereiopods: proximal part of the merus, ischium and basis remain; they are flattened with smooth margins.

Abdomen: telson and six abdominal segment remain. Telson about 1.4 times as long as broad, convex; lateral margin rounded and the dorsal surface smooth. Uropods without suture on the endopodite and the exopodite are not preserved. Sixth abdominal segment about 1.5 times as long as broad, and the dorsal surface longitudinally vaulted, smooth; both pleura missing.

Remarks.—The living species, *Thalassina scorpionoides* Latreille, *T. gracilis* Dana and *T. maxima* Hess are synonyms of *T. anomala* (Herbst) (Borradaile, 1903; de Man, 1928). One fossil species, *Thalassina emeryi* Bell (= *T. antiqua* Bell, *nomen nudum*) is also synonymous with *T. anomala* (Glaessner, 1929; Van Straelen, 1928).

Imaizumi (1969, figs. 7a, b, 8, 9) reported the cheliped of *Thalassina* sp. from the early Middle Miocene Kawaminami Formation developed at Kawaminami, Kaga City, Ishikawa Prefecture; his figures 8, 9 are clearly identified with *T. anomala,* whereas figures 7a, b are clearly distinguishable from *T. anomala* by the presence of a longitudinal carina on the outer surface of the merus, the long carpus and its flattened outer surface, and this specimen can safely be placed in

← **Figure 4.** *Thalassina anomala* (Herbst, 1804). Bihoku Group. ×1.0. **1,** Abdomen, chelipeds and 1st to 3rd pereiopods, MFM39105; **2,** Gastric region, MFM39106; **3,** Chelipeds and 1st pereiopods, MFM39102; **4,** Carapace and chelipeds, MFM39104.

Callianassa.

De Man (1928) discriminated two varieties, *T. anomala* var. *gracilis* Dana, 1852 and *T. anomala.* var. *squamifera* de Man, 1915. Poore and Griffin (1979) elevated one variety, *T. anomala* var. *squamifera* to species level as *T squamifera.* Though they quoted dissimilarities in the scaphocerite, sternal ridge between the pleopods on pleonites 2 to 5 and the fixed finger, we consider it to be doubtful as to whether or not these differences deserve specific rank.

Distributions.—Miocene ; Japan (Ishikawa, Fukui, Hiroshima, Tanegashima) (Imaizumi, 1969 ; Karasawa, 1990). Pleistocene to Holocene ; Japan, Ehime (Imaizumi, 1953), Australia (Etheridge and McCulloch, 1916 ; Förster and Barthel, 1978), New Guinea (Bell, 1844, 1845 ; Van Straelen, 1928). Recent ; Japan (Okinawa-jima, Kume-jima, Ishigaki-jima, Iriomote-jima), India (Bombay, Maha, Nicobar Islands), Sri Lanka (Ceylon), Burma (Mergui Archipelago), Indonesia (Pulau Simeulue, Pulau Nias, Sumatra, Tandjoing-pandan, Borneo, Celebes, Java, Seram, Lesser Sunda Islands, Teluk Sarera), Singapore, New Guinea, Australia (Thursday Island, Port Moresby, Nicol Bay, Port Curtis, Sydney), Fiji Islands, Philippine Islands (de Man, 1928 ; Imaizumi, 1953 ; Sakai, 1965-MS).

Measurements.—See Table 1.

Table 1. Measurements of specimens, in millimeters

	MFM39101		MFM39102		MFM39103	MFM39104	
Rostrum length	3.1		—		—	—	
Gastric region length	31.8		—		—	22.8	
Gastric region width	19.7		—		—	14.0	
Telson length	20.3		—		—	—	
Sixth abdominal segment :							
length	25.4		—		—	—	
width	17.2		—		—	—	
	L	R	L	R	L	L	R
Dactylus length of cheliped	30.6	—	—	—	35.2	21.7	—
Fixed finger length of cheliped	12.0	12.6	10.8	9.4	—	10.4	—
Propodus length of cheliped	42.6	39.4	34.9	33.7	47.8	26.2	26.3
Propodus length of cheliped	—	—	19.2	17.8	21.7	21.3	—
Carpus length of cheliped	—	—	13.1	16.3	—	—	—
Carpus width of cheliped	—	—	14.2	14.8	—	—	—
Merus length of cheliped	—	29.8	14.5	18.8	—	—	—
Ischium length of cheliped	19.7	21.8	—	—	—	—	—
Dactylus length of lst pereiopod	14.8	—	—	—	—	—	—
Merus length of lst pereiopod	24.9	26.3	—	—	—	—	—
Ischium length of lst pereiopod	11.0	11.4	—	—	—	—	—
Basis length of lst pereiopod	5.7	5.8	—	—	—	—	—
Ischium length of 2nd pereiopod	11.2	9.4	—	—	—	—	—
Basis length of 2nd pereiopod	5.2	5.4	—	—	—	—	—
Coxa length of 2nd pereiopod	8.5	9.1	—	—	—	—	—
Ischium length of 3rd pereiopod	9.5	—	—	—	—	—	—
Basis length of 3rd pereiopod	5.7	—	—	—	—	—	—

Discussion

Disassociated chelipeds of thalassinoid fossils are usually the only parts preserved; most of our specimens, however, also retain parts of the carapace, walking limbs, or both. Fossil *Thalassina* commonly found in the Pleistocene to Holocene deposits are preserved in a phosphatic hard nodule and they are considered to be moult or in moulting position (Förster and Barthel, 1978). Preservations are near to that of the Pleistocene to Holocene *Thalassina* though our specimens occur in a siltstone. Judging from their proximal parts, the limbs clearly remain in their natural position. The abdomen is bent forwards. The gastric region is reversed, and the apex of the rostrum is directed backwards. Nevertheless, the hepatic and branchial regions remain in the natural position and they are situated on both sides of the thoracic sternum, separated from the cardiac region at *the linea thalassinica*. Most of the fossil specimens show their ventral side, and posterior cardiac regions and the first to fifth abdominal segments are lacking. Considering the nature of preservation, our specimens also are possibly moults and are thought to be semi-autochthonous.

The decapod crustacean assemblage from the stated locality is characterized by the predominance of *Thalassina anomala*. Living forms inhabit mangrove swamps in the tropical Indo-West Pacific regions and are distributed in the northwestern Pacific Ocean south of Okinawa-jima. They produce several mounds (1 m or more in maximum height) around the high spring tide zone and seem to live at depths of 1-2 m below the surface (Hirata *et al*., 1973; Macintosh, 1988). Referring to these ecological data, the *Thalassina* assemblage at the stated locality is thought to indicate a mangrove swampy paleoenvironment at the high tide level. The occurrence of *Thalassina,* together with molluscs, reef building corals, mangrove pollen and others (Itoigawa, 1978; Itoigawa and Tsuda, 1986; Tsuda *et al*., 1986; Itoigawa, 1989) supports the existence of the tropical spike in early Middle Miocene time (16 Ma) in Southwest Japan.

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広島県の中新統備北層群より産したオキナワアナジャコ：広島県神石郡油木町宗兼に分布する備北層群神石累層下部（中期中新世初頭）より産したオキナワアナジャコ *Thalassinia anomala* (Herbst) を記載した。*T. anomala* は現生種で，インドー西太平洋の熱帯地域のマングローブ沼生活者であり，その産出を中新世まで遡らせた。この種の産出は，中期中新世初頭の西南日本の熱帯的古環境を支持する。 柄沢宏明・西川 功

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925. TWO NEW GENERA FROM THE OMMA-MANGANJI OSTRACODE FAUNA (PLIO-PLEISTOCENE) OF JAPAN — WITH A DISCUSSION OF THEORETICAL *VERSUS* PURELY DESCRIPTIVE OSTRACODE NOMENCLATURE

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Abstract. In this paper, descriptive terms derived from the one continuous sheet theory of the ostracode carapace are proposed to replace traditional, purely descriptive terms such as the trichoid sensilla. Traditional sieve *versus* open, and normal *versus* radial pore canal classifications are replaced by a new classification based on constant (c-type) *versus* variable (v-type) pore canals. The normal *versus* radial pore canal system of classification is only a subdivision of the v-type pore canal system. The description of surface ornamentation becomes more theoretical when the disposition of the underlying epidermal cells is taken into consideration.

Two new genera, *Yezocythere* (type species, *Y. hayashii)* and *Johnnealella* (type species, *J. nopporensis*), are described in terms of this proposed idiographic approach.

Key words. Cold water species, idiographic approach in taxonomy, *Johnnealella nopporensis*, Omma-Manganji Ostracoda, trichoid sensilla, *Yezocythere hayashii*.

Introduction

In the process of taxonomic classification of ostracodes, what we try to classify is not the real nature of ostracodes, but rather the ostracodes that we are able to observe and understand. This is due in part to the fact that it is impossible to comprehend the nature of ostracodes only by means of a single or a few biological laws. Yet, ostracodes, which are understood partly in terms of biological laws but mostly by means of purely descriptive observation, certainly exist and swim actively under our microscope. Therefore when we try to understand these organisms *via* taxonomy, our approach should be idiographic. An idiographic approach is required not simply due to the influence of inductive reasoning in the narrow sense, but rather as a consequence of the nature of the objects being observed. In this paper, we develop this theme of an idiographic approach to ostracode classification within the general context of the "continuous sheet theory" of the ostracode cuticle and specifically apply to the description of two new genera.

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The history of the study on ostracodes from the time of Linnaeus to the present suggests two fundamental notions. One way of viewing the ostracode organism is that, after Darwin's theory of evolution through natural selection found wide acceptance, classification became a method with poor resolving power for presenting the tested hypothesis of evolutionary relations among taxa in the form of a classificatory hierarchy. This hierarchy consists, more or less, of arbitrary "packages" of convenience (Gould and Johnston, 1972), but it does offer an efficient means of referring to information stored in the detailed biological descriptions (Hanai, 1988, p. 17, 18; Mayr, 1988, p. 270).

The second notion is that the knowledge resulting from understanding ostracode morphology, which is stored in taxonomic descriptions, has been advanced through new findings based on field observations and aided by laboratory techniques. This knowledge has been advanced more through hypothetical-deductive generalization at the descriptive level than through explanation by generalities known as biological laws.

These two notions have vital importance in taxonomy because they inevitably suggest that the construction of the classification is merely a short term goal of ostracode taxonomy, whereas the ultimate purpose is to understand the very nature of ostracodes. Further, the improved comprehension of ostracodes is a prerequisite for a better classification.

To understand the nature of any taxon through generalization at the descriptive level is important, because the hypothesis produced through such generalization may always have the possibility of not being confined to one taxon. It may turn out to be a law of great generality covering a wide range of higher taxa.

As biological understanding of ostracodes has been advanced mainly through generalization at the descriptive level, the shift from predominately descriptive to increasingly theoretical methodology has occurred. In the process, the purely descriptive terms such as "normal pore" have been replaced with terms of theoretical derivation, such as "opening of trichoid sensillum" (Hempel, 1965, p. 140). This has been discussed by the senior author with documentation and solid evidence from ostracode studies (Hanai, 1988, p. 19).

Viewed from this modern idiographic approach, our descriptions of ostracodes appear to be still too conservative and modest to adequately express the present status of our understanding of ostracodes. In fact, our knowledge is vast and covers wide fields of the biological sciences. It seems, therefore, appropriate to reconsider the systematic descriptions of ostracodes in terms of an idiographic approach. The following discussion of the "continuous sheet theory" of the ostracode carapace will serve as an example. We hope that our proposed methodology improves the way ostracode taxonomists present descriptions of new taxa.

Continuous sheet theory of ostracode carapace

First, we wish to briefly outline the one continuous sheet theory of ostracode carapaces. This theory was first proposed by Harding (1964, p. 1, 2) and later developed by Kornicker (1969, p. 109-119). It holds that the valves of an ostracode shell and the soft cuticle joining them together are one continuous piece of cuticle. This theory replaces descriptive terms with terms of theoretical derivation. For example, the descriptive term *calcified portion of the inner lamella* is replaced by the more theoretical term *marginal infold of the calcified procuticle.* The same is true for the terms *upper and lower elements of the hinge structure,* which are replaced by the two elements of hinge structure that are the *outside and the inside of the body cavity.* Thus, the theory may provide an explanation for a wide variety of facts (for additional examples, refer to Hanai, 1988, p. 20-23) that may even include the occurrence of exclusively intact valves in Cambrian ostracodes, and the continuous shield-like carapace of nauplius and metanauplius in *Manawa staceyi* (Swanson, 1989, p. 16).

The one continuous sheet theory of the ostracode carapace, and, the viewing of the marginal area with this theory in mind, will also suggest as its logical extension the possibility that the basic structure of radial pore canals is essentially the same as that of normal pore canals. This is simply because both normal and radial pore canals are openings through one and the same continuous sheet of the ostracode carapace. The marginal areas are merely an infold of the marginally thickened area of the carapace. The differences are found only in the elongate structure and marginal location of the radial pore canals. This was shown by the comparative study of the marginal and normal pore canals of *Bicornucythere bisanensis* by Okada (1982, p. 254).

A natural extension of this theory leads us to reconsider the traditional classification of normal *versus* radial pore canals in terms of another fact — that two other types of pores occur that are always quite distinct on a single carapace, regardless of their location. This distinction is always sharp and detectable through a wide range of higher taxonomic groups. Thus, we propose here a new classification of two types of openings for sensilla that is based on probable function.

The first type of pore is termed the constant-type (c-type) pore, which keeps constant its relative position and its morphology of the sensilla on one carapace. If it increases in number through moltings, there is only an addition of one or so pores. There are usually about thirty total c-type pores on the carapaces of genera that have been investigated.

The second is termed the variable-type (v-type) pore, which varies its morphology in accordance to its location on one carapace ranging from sieve to sunken sieve type trichoid sensilla. It increases its number distinctly during moltings. V-type pores number from about 400 to 500 on a single carapace. The contrast between c- and v-types of sensilla is seen in the lip type and sieve type openings for trichoid sensilla in *Cythere omotenipponica* (Hanai, 1988, p. 20-23). The type 3 pore system of Tsukagoshi (1990, p. 228) in *Cythere schornikovi* is equivalent

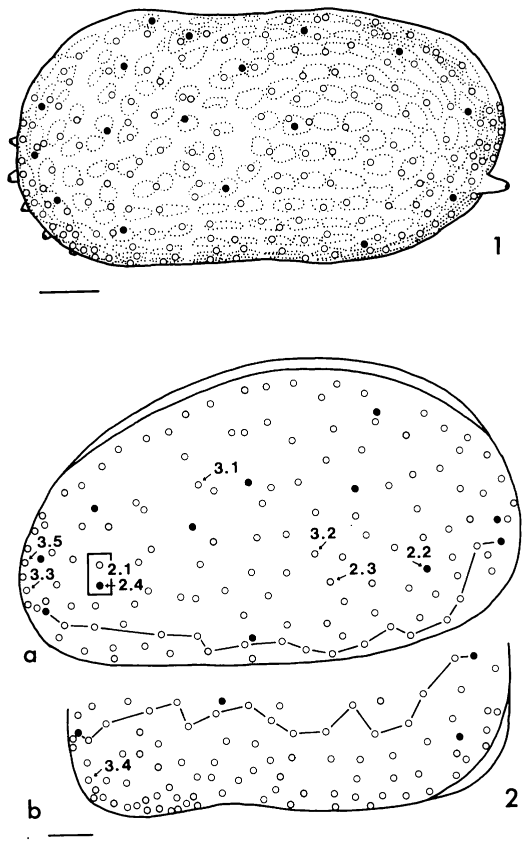
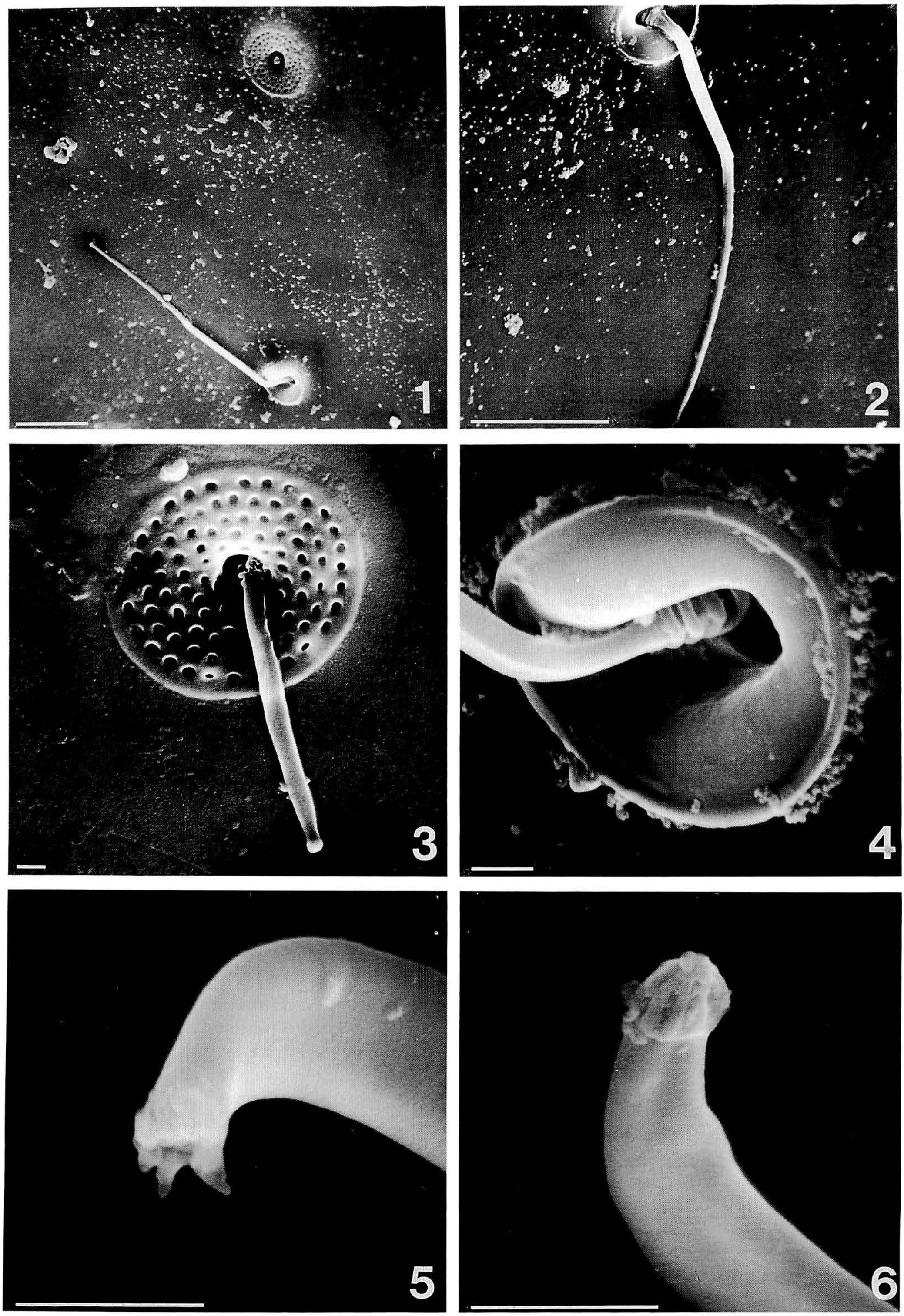


Figure 1. Distribution of c-type (black circles) and v-type (open circles) sensilla on carapace. **1.** *Bicornucythere bisanensis* (Okubo, 1975) from Recent, Shibukawa, Tamano-shi, Okayama Prefecture. Left lateral view of complete carapace of male (IGSU-O-102). **2a.** *Xestoleberis hanaii* Ishizaki, 1968 from Recent, Aburatsubo Cove. Complete carapace of male (IGSU-O-682). Left lateral (slightly dorsal) view. **2b.** Left ventrolateral (slightly posterior) view. The lines connecting the same series of pores in **Figures 1-2a** and **1-2b** are for reference only to show the relative position of sensilla between the two figures. Numbers refer to SEM photos in **Figures 2** and **3.** Scale bars indicate 100 μm.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to the c-type, and Tsukagoshi's types 1, 2, 4 and 5 are equivalent to the v-type. Tsukagoshi's classification of v-type pores is probably a reflection of secondary modification. The peculiar Ben-type openings without trichoid structure, and the sunken sieve type openings for trichoid sensilla in *Bicornucythere bisanensis* (Hanai, 1982, p. 10; Hanai *et al.*, 1985, p. 428) correspond to the c-type and v-type, respectively (Figure 1-1). Kamiya's "twisted" type bristle of *Loxoconcha* (Kamiya, 1989, p. 40-42) corresponds to our c-type sensillum. The distinction between these two types of sensilla is even more clearly noticeable in the both pores and setae of *Xestoleberis hanaii,* which is illustrated in this paper as an additional example in Figures 1-2, 2, 3. Compare the distal half of seta of c-type pore (Figure 2-2) with that of v-type pore (Figure 2-3).

As mentioned above, the c-type pores are constant in morphology, location on carapace and are virtually constant in number within a species. However, the c-type pore may vary morphologically from lip type in one genus to Ben-type in another. In contrast to c-type pores, the v-type varies in the shape of the openings from the sieve type to the sunken sieve type that have variously differentiated sensory setae. However, their structure is essentially quite constant, always keeping the form of the trichoid sensillum even among different higher taxa. The origination of the distinction between c- and v-type pores is traceable ontogenetically back into the young instars, and may be in a stage younger than the differentiation found among v-type pores. Thus, it is quite likely that the classification of v type pores based on the various shapes of the pore openings and the setae seems to be a classification based on secondary modification.

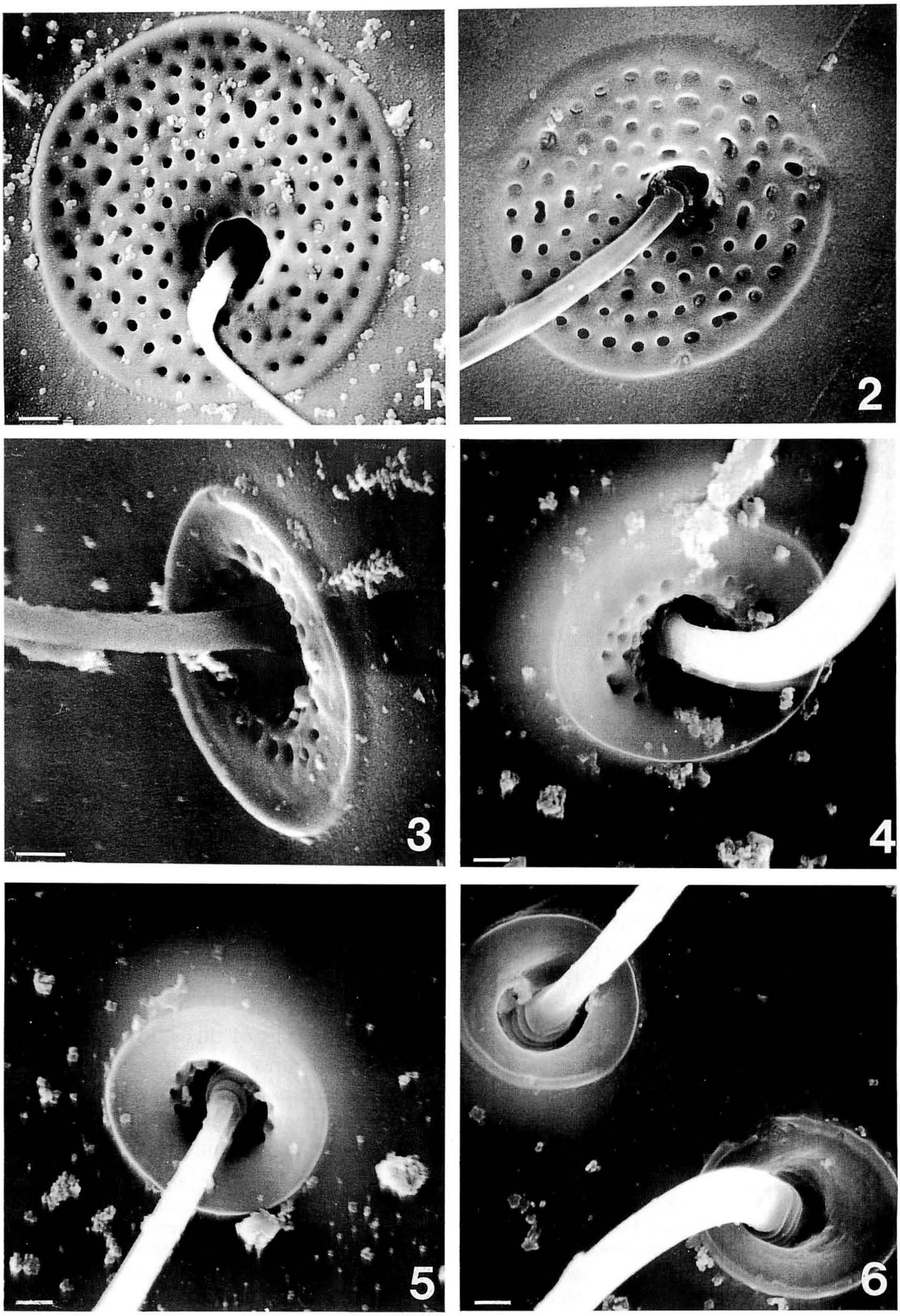
Intermingled distribution of differentiated v-type pores is seen in various forms of setae. This can be seen, for example, by comparing a pore with a long non-branched sensory seta and a pore with a branched sensory seta in *Bicornucythere bisanensis.* The long setae without apparent branches are mechanoreceptors which might evaluate stimuli from the surrounding objects, while the short ramifying setae are those that sense weak currents and vibrations of water. In other cases, a more or less regular transition from the sieve type to the sunken sieve type pores is traceable on the lateral side of a carapace from the center toward the venter, suggesting that the sunken sieve of bottom-dwelling species is merely an adaptation of sieve type pores to particular types of substratum. An example is seen in *Xestoleberis hanaii* (see Figure 3).

The traditional sieve *versus* open classification of pore canals in several cytheraceans might actually mark the adaptation of taxa to sand or rocky bottom habitats with turbulent waters *versus* mud bottom habitats with calm waters. Therefore, the open or simple type pores in the traditional sense are not homologous, including both v-type sunken sieve pores and c-type open pores. The adaptive distinction appears to reflect the difference in habitat preference (Hanai *et al.*, 1985, p. 428). This distinction may be formed through traditional phenotypic selection.

Ornamentation and epidermal cells

A second part of this study describes ornamental structures on carapaces in light of the fact that carapaces are the calcified cuticle of the integument that directly reflects the arrangement of the underlying epidermal cells

← **Figure 2.** *Xestoleberis hanaii* Ishizaki, 1968. Aburatsubo Cove. Recent. Location of four sensilla on carapace is shown in **Figure 1-2a, b. 1.** Figure shows coexistence of c- and v-type sensilla on anterolateral area of carapace. **2.** A complete external view of a c-type sensillum. **3.** A complete external view of a v-type sensillum. **4.** An external view of pore opening of c-type sensillum. **5, 6.** Tips of two v-type trichoid sensilla on posteroventral area of carapace. Scale bars of **1** and **2** indicate 5 μm, and bars of **3-6** indicate 0.5 μm.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(Okada, 1982, p. 232). This situation is quite unlike the valves of bivalves and it supports Triebel's (1958, p. 206) classification of broad and fine ornamentation of the carapace surface. Thus, the surface ornamentation of ostracodes can be classified into two elements. One is the primary relief, which is controlled mainly by the shape of the main "soft" body (internal organs), and the other is the secondary relief or ornamentation whose configuration is regulated mainly by the calcium carbonate secretion of underlying epidermal cells.

The overall shape of the main "soft" body is determined by the shape of the constricted appendages and reproductive organs, and its relief is controlled by the location of various muscles. The sulcus and central node of the cytheracean genera may directly reflect the constricted and domed reliefs of the body surface, representing the different constructional reaction of the carapace against the tensile force of the muscles. The general shape of the "soft" body is a conservative character being consistent at least within the same genus. An example is seen in the genus *Paijenborchella* where the shape of "soft" body remains constant, whereas the shape of the carapace varies from spinose, bean-shaped to winged (Hanai, 1970, p. 697-700). This type of variation seems also to be found among forms of the family Trachyleberididae. The surface of the epidermis which keeps the conservative bean-shape just after ecdysis, seems to develop into variously shaped adult forms by secretion of the carapace material.

The hard carapace is formed by secretion of calcium carbonate into the space called the procuticle between the epicuticle and the membranous layer. The basic pattern of ridges of reticulation corresponds to the pattern of the boundaries between epidermal cells, and is therefore controlled by the arrangement of the underlying epidermal cells. A plausible explanation for this is the fact that the trichoid sensilla always open on the ridge or side of wall that is the boundary between two adjacent epidermal cells. When they open on the floor of the reticulum, they often develop a bridge between the opening and the ridge. This is simply because a nerve cell will run between epidermal cells or will be surrounded by an epidermal cell with a single nucleus, and will never pierce the epidermal cell.

Architectural construction and taxonomic comparison of certain features of carapace ornamentation, including reticulations, spines, and ridges, can be described in relation to the underlying epidermal cells. Thus, the analysis of reticulation pattern and of the distribution of pore canals acquires a biological meaning. When the numbering of each reticulum is carried out in terms of the one sheet theory of the ostracode carapace, we recommend that the reticulation is traced in U-shaped concentric patterns running parallel to the free margin of the carapace. This was done on certain paleocopid ostracodes by Jones (1988, p. 268).

Other complex structural patterns may be developed secondarily to re-enforce carapace strength. A sophisticated architectural explanation of these ornamental structures has been given by Benson (1975, p. 25-44). Typical examples are seen in box-frame ridges of *Schizocythere kishinouyei* and in the concentrically disposed corrugate ornamentation of *Loxoconcha optima.*

In summary, we have applied an idiographic approach to the way in which we study and classify higher taxonomic groups of ostracodes, with special reference to the continuous sheet theory of the carapace. We

← **Figure 3.** All v-type pores of *Xestoleberis hanaii* Ishizaki, 1968. Aburatsubo Cove. Recent. Figure shows transition from sieve type trichoid sensillum to open type trichoid sensillum. Location of four sensilla is shown in **Figure 1-2a, b. 1, 2.** Sieve type. **3, 4.** Partially sunken sieve type. **5.** Completely sunken sieve type. **6.** Marginal trichoid sensilla. Scale bars indicate 0.5 μm.

find this approach unifies many aspects of carapace morphology—pore types and distributions, ornament, and epidermal cell distributions, for example—allowing a more cohesive and biologically meaningful explanation of the ostracode organism.

The sequence of presentation of taxonomic descriptions

In describing the carapace of the two new genera below, the familiar and widely used character nomenclature will be retained as far as possible, and the characters will be treated in a standardized sequence. Thus, the description will be given in the order, first on the general outline, the lateral view from anterior to posterior, the dorsal and then the ventral view, and finally on the internal view. This is because this more or less standardized sequence facilitates the comparative study and is also an efficient way to prevent overlooking anything important (Mayr, 1969, p. 268). At the same time, it is desirable that the sequence of characters in the description will also be biological, coordinating with the description of living forms. This position reflects even on the paleontological description of carapaces. The carapace can be described in order of epidermal organ (integument), sense organs (eyes, sensilla) and locomotory organs (scars of various muscles). Thus, although the description of the carapace in paleontology is necessarily a partial and imperfect presentation of the entire animal, we must keep in mind that we are trying to present as accurate a restoration of the animal as is possible based on its carapace morphology.

Systematic descriptions

All illustrated and measured specimens have been deposited in the collections of the Institute of Geosciences, Faculty of Science, Shizuoka University (IGSU). Abbreviations used in the descriptions include: O = ostracodes, L = length, H = height, W = width, S = specimens, RV = right valve, LV = left valve, X = arithmetic mean, and OR = observed range. All measurements are in mm.

Family Hemicytheridae Puri, 1953
Subfamily Hemicytherinae Puri, 1953
Genus *Yezocythere* Hanai and Ikeya, n. gen.

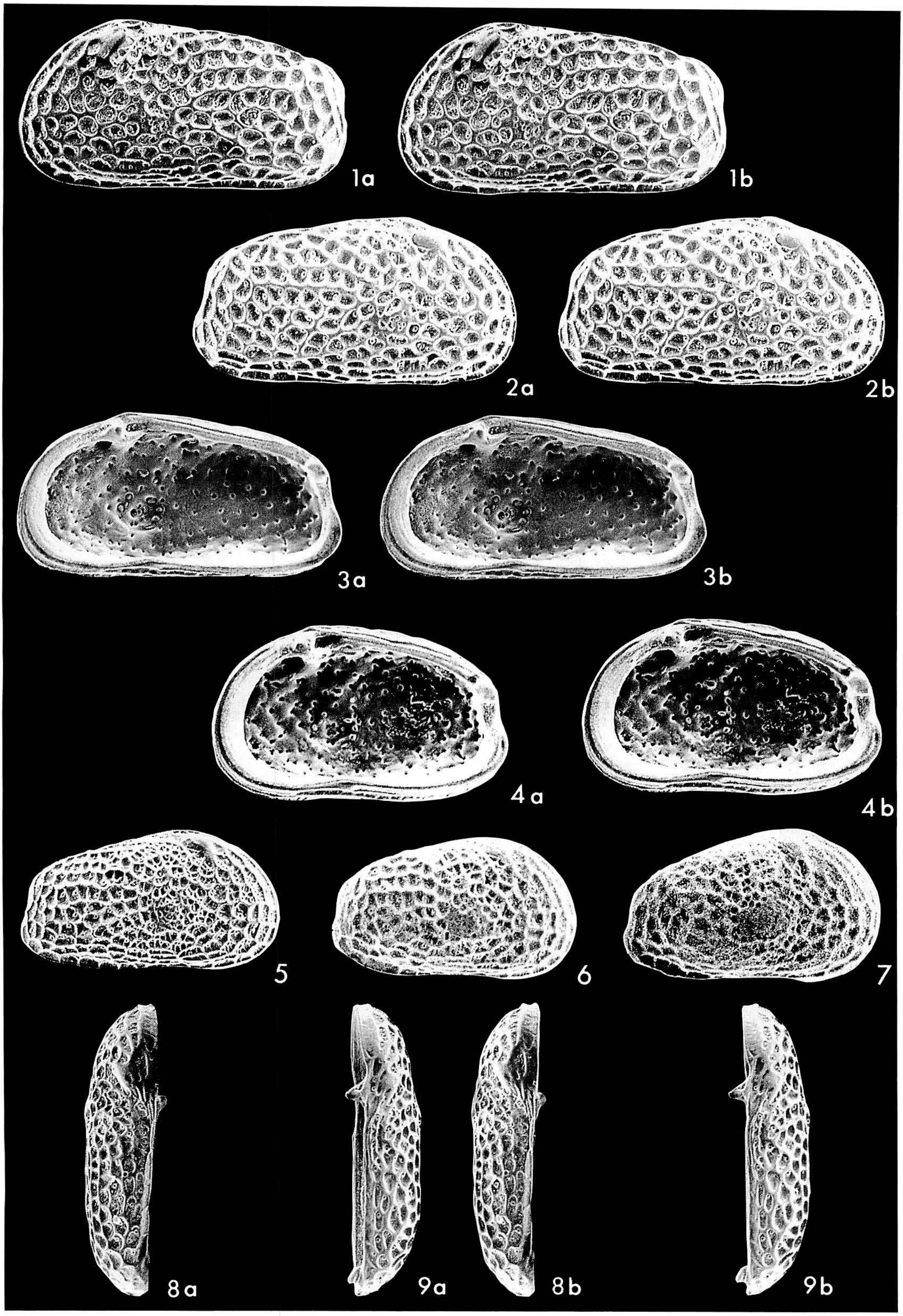
Type species.—*Yezocythere hayashii*, n. gen., n. sp.

Etymology.—After Yezo, the ancient name of Hokkaido.

Diagnosis.—Large tumid carapace. Subcentral tubercle low but distinct. Reticulation of carapace surface divided into three general areas, anteroventral, posterodorsal and posteroventral. A nearly straight and somewhat prominent ridge divides the last two areas. Bean-shaped eye tubercle marked posteriorly with a narrow depression but not projected in lateral view. Middle of three frontal scars distinctly small. Younger instars with more prominent subcentral tubercle and posteroventral and posterodorsal swellings.

Remarks.—*Urocythereis* Ruggieri, 1950 is perhaps the closest relative to this new genus. In fact, the lateral outline, general pattern of reticulation, distributional pattern of muscle scars, and hinge structure are all closely simi-

→ **Figure 4.** *Yezocythere hayashii*, sp. nov. Loc. Hayashi-818a, Setana Formation. Lower Pleistocene. **1a-b.** Stereo pair of lateral view, LV of male (Holotype, IGSU-O-150). ×53. **2a-b.** Stereo pair of lateral view, RV of male (IGSU-O-151). ×53. **3a-b.** Stereo pair of interior lateral view, RV of male (IGSU-O-151). ×53. **4a-b.** Stereo pair of interior lateral view, RV of female (IGSU-O-153). ×53. **5.** Right lateral view, young instar (Adult-1) (IGSU-O-154). ×53. **6.** Right lateral view, young instar (Adult-2) (IGSU-O-155). ×69. **7.** Right lateral view, young instar (Adult-3) (IGSU-O-156). ×88. **8a-b.** Stereo pair of dorsal view, LV of male (Holotype, IGSU-O-150). ×48. **9a-b.** Stereo pair of dorsal view, RV of male (IGSU-O-151). ×48.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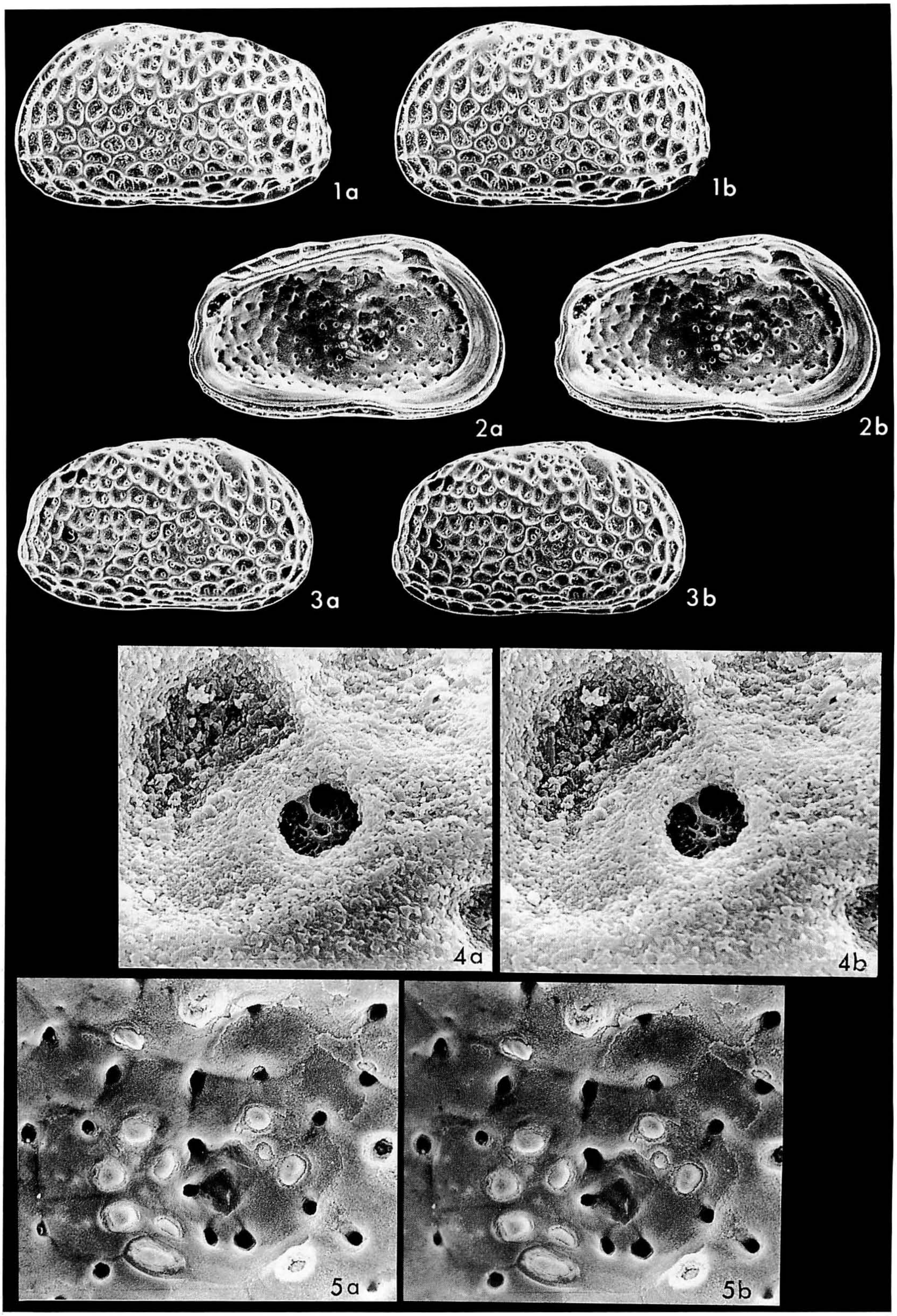
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lar to each other. However, the presence of a low but distinct subcentral tubercle and the distinctly small size of the middle muscle scar is diagnostic of this new genus. The general muscle scar pattern is similar to that of *Elofsonella* Pokorný, 1955. As far as the distributional pattern of the frontal scars is concerned, *Normanicythere* Neale, 1959 and *Baffinicythere* Hazel, 1967 are close to this new genus in having a distinctly small middle scar, but are quite different in the distributional pattern of adductor muscle scars.

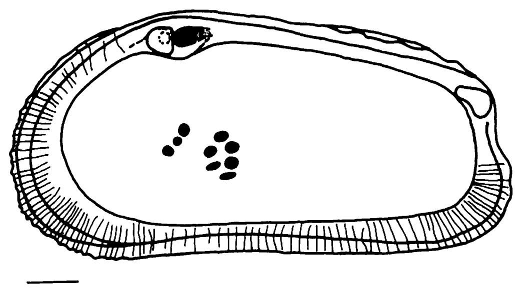


Figure 6. *Yezocythere hayashii,* sp. nov. from Recent Mutsu Bay (M-10). RV of male (IGSU-O-681). Interior lateral view. Scale bar indicates 100 μm.

Yezocythere hayashii Hanai and Ikeya, n. sp.

Figures 4-1–4-9, 5-1–5-5, 6.

Urocythereis gorokuensis : Ishizaki, 1971, p. 83, 84, pl. 3, figs. 4, 5.
Urocythereis ? sp. Tabuki, 1986, p. 74, pl. 6, fig. 1.
Urocythereis sp. A. Cronin and Ikeya, 1987, p. 82, pl. 1, fig. 17.

Type.—Holotype, LV of male, IGSU-O-150 (Figure 3-1a, b, 3-8a, b, L=0.99 mm; H=0.51 mm), lower Pleistocene Setana Formation, loc. Hayashi-818a.

Illustrated specimens.—RV of male, IGSU-O-151 (Figure 4-2a, b, 4-3a, b, 4-9a, b); RV of female, IGSU-O-153 (Figures 4-4a, b, 5-3a, b, 5-4a, b); RV of young instars, IGSU-O-154-156 (Figure 5-5–5-7); lower Pleistocene Setana Formation, loc. Hayashi-818a. LV of female, IGSU-O-152 (Figure 5-1a, b, 5-2a, b, 5-5a, b), lower Pleistocene Setana Formation, loc. Hayashi-45. RV of male, IGSU-O-681 (Figure 6), Recent, Mutsu Bay, station M-10.

Etymology.—After Mr. Kei-ichi Hayashi who provided specimens of this species and contributed to the stratigraphy of the Plio-Pleistocene formations, southwestern Hokkaido.

Diagnosis.—Species is characterized by regular reticulum over most of the carapace surface, running in parallel longitudinal rows posterodorsally. Genus is monotypic as far as is known.

Description.—Adult form : Carapace large, tumid, elongate and sub-quadrangular. Anterior margin obliquely rounded; dorsal margin nearly straight, slightly inclined posteriorly; ventral margin slightly sinuate at middle; posterior margin dorsally and ventrally convex and thus slightly sinuate at middle; posteroventral margin slightly projecting posteriorly. Maximum height at anterior cardinal angle. Viewed dorsally, carapace elliptical, sides parallel with a low projection of subcentral tubercle. Subcentral tubercle low but distinct, located slightly anterior to middle. Surface coarsely reticulate. Reticulation tending to align in parallel rows along anterior to anteroventral margins, in nearly horizontal rows in posterodorsal area, and in posteroventrally directed oblique rows in posteroventral area.

Marginal area moderately wide, inner margin nearly parallel to free margin. Vestibule

← **Figure 5.** *Yezocythere hayashii,* sp. nov. Specimen IGSU-O-152 from loc. Hayashi-45 and specimen IGSU-O-153 from loc. Hayashi-818a, Setana Formation. Lower Pleistocene. **1a-b.** Stereo pair of lateral view, LV of female (IGSU-O-152). ×53. **2a-b.** Stereo pair of interior lateral view, LV of female (IGSU-O-152). ×53. **3a-b.** Stereo pair of lateral view, RV of female (IGSU-O-153). ×53. **4a-b.** Stereo pair of normal pore canal opening with sunken sieve type on lateral surface of central muscle scar area, RV of female (IGSU-O-153). ×1600. **5a-b.** Stereo pair of adductor muscle scars, LV of female (IGSU-O-152). ×230.

moderately deep, crescent-shape along anterior inner margin, shallow along posteroventral margin. Hinge amphidont, with smooth posterior element. Muscle scars consisting of three frontal scars of which the middle one is distinctly smaller, four adductor muscle scars of which the two middle scars are distinctly divided. Two dorsal muscle scars and a mandibular scar distinct.

Eye tubercle bean-shaped, marked with a narrow depression just behind it. V-type pore canals large, distributed over lateral surface concentrically, surrounding central muscle scar area, and opening close to side of reticulum wall ; pores sunken sieve, having a central protruded micro-pore for the sensory bristle connected with wall of pore by a pier-like ridge. Pore canals opening along marginal contact zone are straight and numerous along anterior and posteroventral margins. Relatively few c-type simple small pores also scattered on the ridges.

Sexual dimorphism distinct, male more elongate and slender than female.

Young instars : Young instars from adult -4 to adult-1 were available for study. Lateral outline of carapace changes from subtriangular in adult-3 to subquadrangular in adult-1. Subcentral tubercle moving from central in adult-3 to slightly anterior to middle in adult-1. Posteroventral and posterodorsal nodes varying from visible in adult -4 to obscure in adult-1. Reticula of anterior half of carapace have a nearly constant number ; the pattern of arrangement is parallel to anterior margin in about 5 concentric rows. Reticulation of posterior half changing from irregular pattern in adult-3 to regularly radiating pattern in adult-1. Small second order reticulations dividing large first order reticulation into a few to several partitions in dorsocentral area of carapace. Transformation through ecdysis more prominent in younger instar.

Dimensions. — Measurements of specimens from localities Hayashi-818a and 45 are as follows :

	S	N	LX	HX	L OR	H OR
Adult ♀	RV	1	—	—	0.89	0.53
	LV	2	0.95	0.57	0.56-0.57	0.94-0.96
Adult ♂	RV	3	0.95	0.48	0.94-0.97	0.46-0.50
	LV	1	—	—	0.99	0.51
Adult-1	RV	2	0.76	0.43	0.74-0.78	0.43
	LV	4	0.75	0.43	0.74-0.76	0.41-0.45
Adult-2	RV	10	0.58	0.34	0.55-0.60	0.32-0.36
	LV	11	0.57	0.34	0.54-0.61	0.33-0.36
Adult-3	RV	8	0.46	0.29	0.43-0.47	0.27-0.30
	LV	8	0.46	0.28	0.42-0.47	0.25-0.30
Adult-4	RV	2	0.36	0.24	0.36	0.23-0.24
	LV	4	0.37	0.23	0.35-0.39	0.22-0.25

Stratigraphic range. — Lower Pleistocene to Holocene.

Remarks. — This species is characteristic of Japanese lower Pleistocene cold water ostracode assemblages.

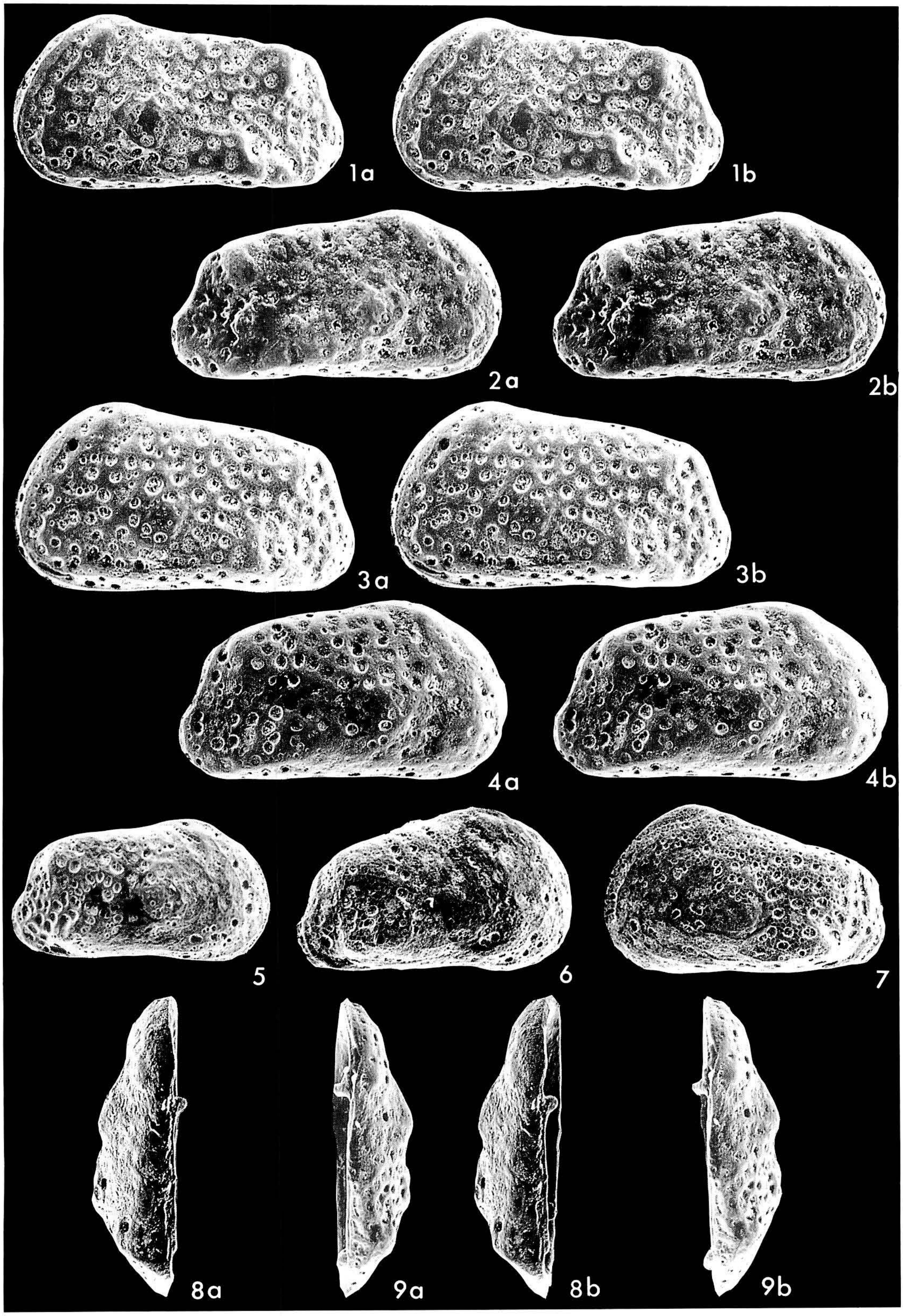
Genus *Johnnealella* Hanai and Ikeya, n. gen.

Type species. — *Johnnealella nopporensis*, n. gen., n. sp.

Etymology. — In honor of Professor John W. Neale who gave us much information and helpful comments on related genera.

Diagnosis. — Large, elongate and with thickly calcified carapace. Hingement holamphidont. Surface foveolate with large cone-shaped pits. Most pits have a large pore canal opening the center. Hemicytherid ad-

→ **Figure 7.** *Johnnealella nopporensis,* sp. nov. Loc. Hosoda-N2, Shimonopporo Formation. Lower Pleistocene. **1a-b.** Stereo pair of lateral view, LV of male (IGSU-O-158). ×53. **2a-b.** Stereo pair of lateral view, RV of male (IGSU-O-159). ×53. **3a-b.** Stereo pair of lateral view, LV of female (Holotype, IGSU-O-160). ×53. **4a-b.** Stereo pair of lateral view, RV of female (IGSU-O-161). ×53. **5.** Right lateral view, young instar (Adult-1) (IGSU-O-164). ×53. **6.** Right lateral view, young instar (Adult-2) (IGSU-O-165). ×69. **7.** Left lateral view, young instar (Adult-3) (IGSU-O-166). ×88. **8a-b.** Stereo pair of dorsal view, LV of male (IGSU-O-163). ×48. **9a-b.** Stereo pair of dorsal view, RV of male (IGSU-O-162). ×48.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ductor muscle scars with widely spaced double scars, and elongate and almost separated lower adductor scars. Frontal scars consisting of two round scars, of which the upper scar is small but distinct. Two large mandibular scars are elongate and easily observed; mandibular scar widely separated from central muscle scar field.

Remarks.—Although the holamphidont hingement of this genus is quite different from that of the genus *Finmarchinella* Swain, 1963, the distributional pattern of the muscle scars, especially that of the widely separated double adductor scars, and the wide spacing of the mandibular scars from central muscle field, and marked sexual dimorphism suggest a very close relationship of this genus to the merodont *Finmarchinella.*

Johnnealella nopporensis Hanai and Ikeya, n. sp.

Figures 7-1–7-9, 8-1–8-5, 9.

Urocythereis ? gorokuensis: Tabuki, 1986, p. 71, pl. 6, figs. 10-17.
Urocythereis sp. C. Cronin and Ikeya, 1987, p. 82, 84, pl. 3, fig. 16.

Type.—Holotype, LV of female, IGSU-O-160 (Figures 7-3a, b, 8-3a, b, L=1.02 mm; H=0.57 mm), lower Pleistocene Shimonopporo Formation, loc. Hosoda-N2.

Illustrated specimens.—RV of female, IGSU-O-161 (Figures 7-4a, b, 8-4a, b); LV of male, IGSU-O-158 (Figure 7-1a, b); RV of male, IGSU-O-159 (Figures 7-2a, b, 9); LV of male, IGSU-O-163 (Figures 7-8a, b, 8-2a, b, 8-5a, b); RV of male, IGSU-O-162 (Figures 7-9a, b, 8-1a, b); RV of adult-1 and adult-2, IGSU-O-164 and 165 (Figure 7-5, 7-6); LV of adult-3, IGSU-O-166 (Figure 7-7), lower Pleistocene, Shimonopporo Formation, loc. Hosoda-N2.

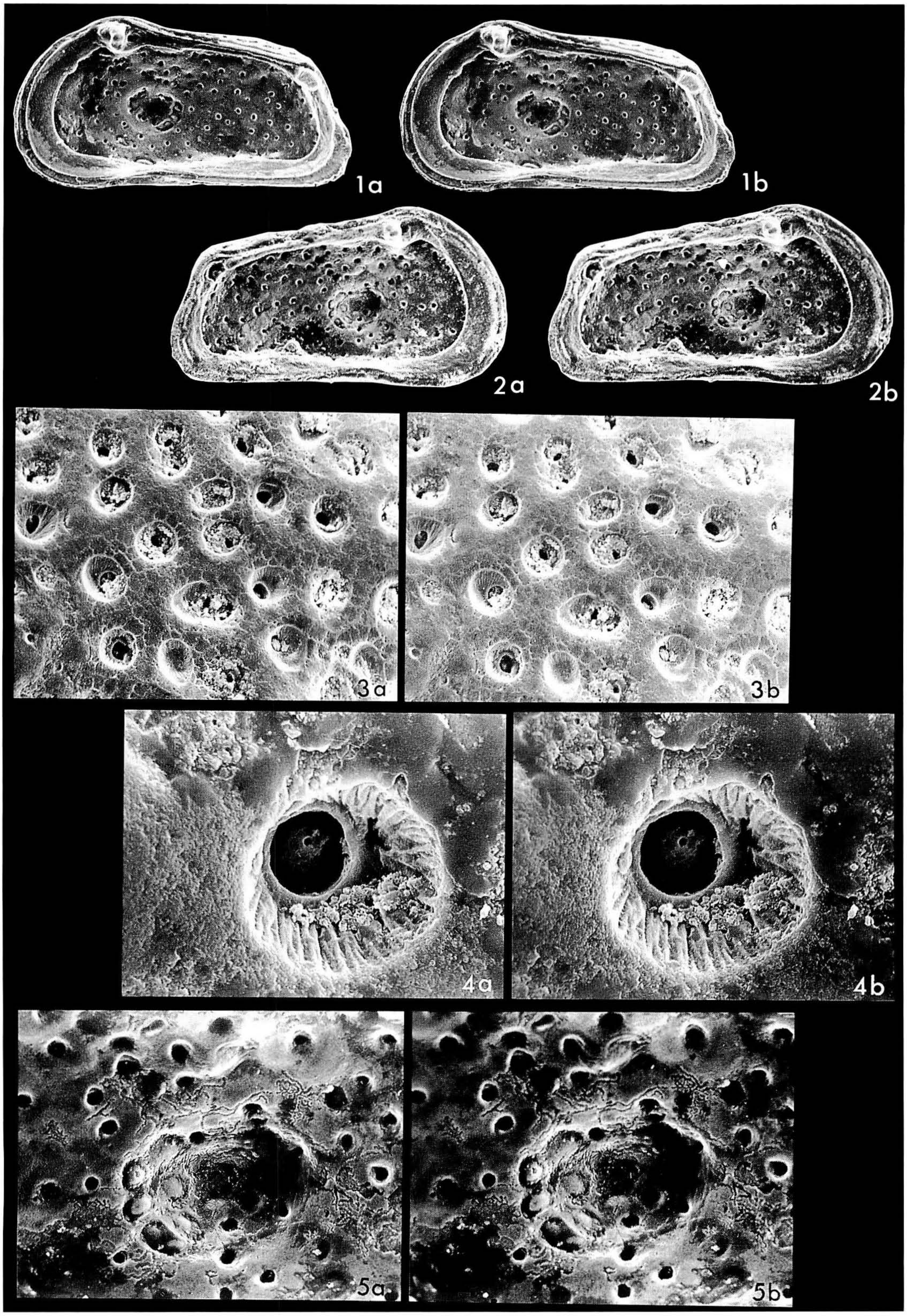
Etymology.—From the type locality, Nopporo, near Sapporo City, Hokkaido.

Diagnosis.—Species is characterized by heavily calcified carapace, a raised muscle platform, large posterodorsal and posteroventral nodes, and ovate fossae. Genus is monotypic as far as is known.

Description.—Adult form: Carapace very large and heavily calcified. Lateral outline subquadrangular. Anterior margin broadly and obliquely rounded; dorsal and ventral margins nearly straight, slightly sinuate and nearly parallel to each other but slightly tapering posteriorly; posterior margin nearly straight or slightly sinuate in its upper half and narrowly rounded in its lower half. Highest at anterior cardinal angle. Viewed dorsally, carapace fusiform with a distinct subcentral tubercle slightly anterior to middle, strong posteroventral node posterior to middle and a small posterodorsal node near posterior cardinal angle. A thick ridge runs close to anterior margin; another ridge starts at the eye spot and runs also along the anterior margin, leaving a rather depressed area in between the two ridges. Posterior area of carapace compressed. Surface foveolate with large pits. Pits cone-shaped; most pits with a central pore canal opening. Walls of pits minutely, horizontally corrugated. Strongly calcified surface of carapace in between pits ornamented with extremely fine microreticulations. Ridges of microreticulations low and minute pits align along inner margin of the ridges.

Marginal infold moderately wide, nearly parallel to free margin. Vestibule crescent-shaped along anterior margin, reaching to depth of two-thirds of width of marginal infold. Deep vestibule also developed along

→ **Figure 8.** *Johnnealella nopporensis,* sp. nov. Loc. Hosoda-N2, Shimonopporo Formation. Lower Pleistocene. **1a-b.** Stereo pair of interior lateral view, RV of male (IGSU-O-162). ×54. **2a-b.** Stereo pair of interior lateral view, LV of male (IGSU-O-163). ×54. **3a-b.** Stereo pair of lateral surface ornamentation on posterodorsal area, LV of female (Holotype, IGSU-O-160). ×178. **4a-b.** Stereo pair of normal pore canal opening on lateral surface of centroventral area, RV of female (IGSU-O-161). ×880. **5a-b.** Stereo pair of adductor muscle scars, LV of male (IGSU-O-163). ×178.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4b
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5b

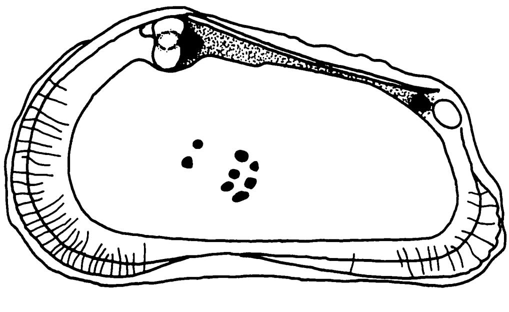

Figure 9. *Johnnealella nopporensis,* sp. nov. from lower Pleistocene Shimonopporo Formation, Loc. Hosoda-N2. RV of male (IGSU-O-159). Interior lateral view. Scale bar indicates 100 μm.

posteroventral margin. Hinge holamphidont. Muscle scar field located on wall of subcentral cavity.

Eye spot large and round; located just below anterior cardinal angle. V-type pore canals large and round, scattered over the valve surface, and always located on floor of the cone-shaped pits and occupy nearly the entire floor surface. Pores sunken sieve type; sieve plate forms a dome with a central micropore for the sensory bristle. Pier-like ridge connecting inner wall of pore with area surrounding central micropore. Pore canals with opening along marginal contact zone straight, numerous along anterior and posteroventral margins. Relatively few simple small c-type pores also scattered over the microreticulated surface.

Muscle scar consisting of a row of four adductor scars of which two middle scars very widely separated; lower scar elongate and almost but not entirely separated into two scars. Two distinct round frontal scars. Two dorsal muscle scars and two mandibular scars also easily observed.

Sexual dimorphism distinct; male more elongate in lateral outline and has a more pronounced surface ornamentation.

Young instars: Young instars from adult -3 to adult-1 were available for investigation. Lateral outline of carapace changes from subtriangular in adult-3 to subquadrate in adult-1. Subcentral tubercle being located at center of carapace in adult-3. Posterodorsal node is less well developed than the posteroventral node in adult-3, becoming stronger in adult-1. Micro-reticulation first appearing in adult-3.

Dimensions.—Measurements of specimens from locality Hosoda-N2 are as follows:

	S	N	LX	HX	L OR	H OR
Adult ♀	RV	3	1.00	0.55	0.98-1.01	0.54-0.56
	LV	1	—	—	1.02	0.57
Adult ♂	RV	6	0.99	0.51	0.92-1.02	0.46-0.53
	LV	5	1.00	0.54	0.99-1.01	0.54-0.55
Adult-1	RV	2	0.81	0.46	0.78-0.83	0.43-0.48
	LV	—	—	—	—	—
Adult-2	RV	2	0.64	0.38	0.62-0.65	0.36-0.39
	LV	2	0.64	0.38	0.62-0.65	0.36-0.39
Adult-3	RV	—	—	—	—	—
	LV	1	—	—	0.50	0.31

Stratigraphic range.—Lower Pleistocene to Holocene.

Remarks.—This species is characteristic of Japanese middle Pleistocene cold water ostracode assemblage.

Acknowledgments

We thank Kei-ichi Hayashi, Ichiro Hosoda and Ryoichi Tabuki for specimens and stratigraphic documentation; John W. Neale, Joseph E. Hazel, Thomas M. Cronin and Katsumi Abe for reviews of various versions of the manuscript. Hazel and Cronin kindly read the final manuscript and gave us important advice.

Localities

Materials for this study came from the following outcrops and Recent bottom samples:

Hayashi-45: Lower Pleistocene Setana Formation (2nd fossil bed from the bottom of 2nd cycle of sedimentation). A junction of Kaigarazawa-gawa and an unnamed stream, west of Kuromatsunai, Suttsu-gun, Hokkaido (Lat. 42°39′26″N, Long. 140°16′28″ E). Second fossil bed above the base of the Upper Cycle (Hayashi, 1988). Greenish gray, very fine-grained sandstone.

IGSU-O-152.

Hayashi-818a: The same horizon. Northern entrance of the Kuromatsunai Tunnel of JR Hakodate Main Line, south of Kuromatsunai, Suttsu-gun, Hokkaido (Lat. 42°38′39″N, Long. 140°18′29″E). Greenish gray, very fine-grained sandstone. IGSU-O-150, 151, 153-156.

Hosoda-N2: Lower Pleistocene Shimonopporo Formation. 1,800 m east of Prefectural Library, Ebetsu City, Hokkaido (Lat. 43°03′58″N, Long. 141°32′57″E). Basal fine-grained sandstone. IGSU-O-158-166.

Recent bottom sample: St. M-10. 5 km SE of Mutsuyokohama, 31 m in depth, Mutsu Bay, Aomori Prefecture (Lat. 41°03.0′N, Long. 141°12.1′E). Substratum, blue black compact mud. Sediment water interface oxidized and yellowish brown, and with abundant bivalve shells (*Pecten, Macoma,* predominate). IGSU-O-681.

Recent tide pool sample: Rocky tide pool, backyard of the Marine Biological Station, Tokyo University. Aburatsubo Cove, Miura Peninsula, Kanagawa Prefecture (Lat. 139°37′N, Long. 35°09′40″ E). Rocky bottom with calcareous (*Corallina pilulifera* and *Amphiroa dilatata*) and other algae. IGSU-O-682.

Recent bottom sample: 20 m off the shore of Shibukawa, Tamano-shi, Okayama Prefecture (Lat. 133°48′N, Long. 34°18′E). Mud, water depth about 10 m. IGSU-O-102.

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大桑万願寺動物群からの介形虫の2新属，付介形虫分類における理論的および記載的用語法に関する議論：介形虫殻の連続一枚説が元来の記述的な術語を理論的な術語に置き換えることを，介形虫の毛状感覚子などの例を使って説明した。従来の篩型対単孔型および垂直管孔対縁辺管孔の分類は定常型対多変型の分類によって置き換えられる。記載は殻下の細胞組織を考慮にいれれば一層理論的となる。この理論的術語を使って大桑万願寺動物群より寒流系介形虫の2新属，*Yezocythere* (type species, *Y. hayashii*) と *Johnnealella* (type species, *J. nopporensis*) を記載した。

花井哲郎・池谷仙之

PROCEEDINGS OF THE PALAEONTOLOGICAL SOCIETY OF JAPAN

日本古生物学会　第140回例会

日本古生物学会第140回例会が1991年6月22日—23日に千葉県立中央博物館で開催された (参加者250名).

シンポジウム

「新しい自然史学と博物館」
…………………………世話人　糸魚川淳二・浜田隆士
自然史学のこれからと博物館…………………糸魚川淳二
博物館活動における新しい自然史学志向
………………………………………浜田隆士・舘野聡子
新しい博物館の目指すもの……………………大場達之
複合文化施設としての徳島県文化の森 — 総合公園と博物館 — …………………………………………両角芳郎
地域調査と普及活動……………………………青島睦治
私設自然史博物館のめざすもの…………………酒井佑太
地域特性と博物館………………………………橋本一雄
博物館ネットワークの提唱………………………松岡敬二
日本の博物館ブーム……………………………竹内　健

個人講演

伊豆半島，下田湾周辺の底生有孔虫群集
……………………………………武藤朝子・北里　洋
AMS法による有孔虫 ^{14}C 年代と深層水循環 — 四国沖 KT89-18 P4 コアの解析 —
………………………村山雅史・岩倉央和・松本英二・中村俊夫・安田尚登・岡村　真・平　朝彦
底生有孔虫からみた最終氷期以降の深層海洋古環境 — 四国沖 KT89-18 P4 コアの解析 —
……………安田尚登・大場忠道・村山雅史・岡村　真
親潮域および津軽暖流域における古環境………大場忠道
房総半島養老川ルートにおける上総層群の浮遊性有孔虫化石群集………………………………………五十嵐厚夫
北海道白糠丘陵地域，古第三系の渦鞭毛藻化石群集
………………………………………栗田裕司・松岡數充
福島県棚倉地域の中新統久保田層より産する放散虫化石群集………………………………竹谷陽二郎・相田　優
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Palaeontological Society of Japan (PSJ) Council Actions

During its meeting on June 21, 1991, the PSJ Council enacted the following changes to its membership.

New members elected :

Osamu Fujiwara,	Yasushi Furuta,	Motoko Higuchi,
Yoshihito Kamata,	Masaichi Kimura,	Tetsuo Matsumura,
Sumito Mizushima,	Akihiro Murata,	Hisao Nakagawa,
Tsutomu Nakazawa,	Masakazu Nara,	Ken Narita,
Hiroshi O'shima,	Haruki Sato,	Shin'ichi Sato,

Takumi Sato,	Hiroyuki Shinzawa,	Hiroyuki Sugie,
Hideyuki Uematsu,	Nobuyuki Yagi.	

Resigned members :

(Fellow)

Masuoki Horikoshi.

(Ordinary members)

Hiroshi Funatsu,	Minoru Harada,	Kyoichi Nagata.

Membership revoked :

(Fellow)

Kouji Minoura.

(Ordinary members)

Toshiaki Futagawa,	Norio Iyoda,	Yoshiyuki Kansha,
Tatsuya Matsumoto,	Akio Miki,	Yasuo Sumi,
Hitoshi Ueda,	Bai-ming, Zhen.	

Errata

KITAMURA, AKIHISA

Paleoenvironmental transition at 1.2 Ma in the Omma Formation, central Honshu, Japan. *Trans. Proc. Palaeont. Soc. Japan, N.S.*, no. 162, p. 767-780, June, 1991.

On page 780, left-hand column, lines 28-34. Reference of Takayama *et al.*, 1988, printed in an out-of-order sequence, should replace the one incomplete reference of Takayama *et al.* printed on the same page, right-hand column, lines 29-32.

報告・紀事への投稿のお願い

1991年8月末の時点で，1992年号に印刷予定の手持ちの原稿が皆無です．最近の号を見ていただくとお分かりのように，原稿に問題がなければ，投稿後数カ月で出版になることが可能です．編集委員会は，会員の皆様からの論文の投稿を切に願っております．

行事予定

◎1992年年会•総会は，1992年1月25日，26日，27日に九州大学理学部で開催されます。講演申込は12月10日（必着）締切です。講演申込の方法が変更になっています。詳しくは「化石」48号をご覧下さい。

◎1992年例会（第141回例会）は，6月後半，盛岡市の岩手県立博物館で開催の予定です。

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