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Cover: A terminally resorbed maxillary tooth of iguanodontids (Ornithischia : Ornithopoda). The specimen is from the Kuwajima Formation, the Neocomian section of the Tetori Group, in Shiramine-mura, Ishikawa County, Ishikawa Prefecture, the west coast of Central Honshu, Japan (Shiramine-mura Board of Education, Coll. Cat. No. SBEI 001, 23 mm in dorsoventral length).

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982 Cenozoic diatom genus *Rossiella* Desikachary et Maheshwari : An emended description

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Abstract. An emended definition of the fossil diatom genus *Rossiella* Desikachary et Maheshwari is presented along with a detailed description of its five member species, including two new ones. The stratigraphic range and geographic distribution of each species based on analysis of some deep-sea cores and literature survey are provided. The genus is closely related to the genera *Bogorovia* Jousé and *Koizumia* Yanagisawa, but is clearly distinguished from them by the absence of transapical costae. On the basis of certain characteristic features, the genus *Rossiella* can be placed in the family Cymatosiraceae Hasle, von Stosch et Syvertsen. Two new species are described, *Rossiella fennerae* Yanagisawa sp. nov.

Key words : Taxonomy, diatom, fossil, Rossiella, biostratigraphy

Introduction

Rossiella is a fossil marine diatom genus created by Desikachary and Maheshwari (1958) based on a species that was originally described as *Stoschia*? *paleacea* Grunow in Van Heurck (1883). Although the genus was monotypic when erected, it has received many species during the past two decades and become a relatively large diatom group including some useful marker species for Paleogene and Neogene diatom marine biostratigraphies (e.g. Fenner, 1985; Barron, 1985b). Recently, the taxonomy of the genus was clarified by Gersonde and Schrader (1984), Desikachary *et al.* (1984) and Fourtanier (1987), but the phylogeny and evolutionary lineage of this genus remain poorly known.

In this study, a detailed morphologic and biostratigraphic examination of the genus *Rossiella* and its related genus *Bogorovia* Jousé was performed, and as a result the presence of three distinct groups of species that merit separate generic recognition was revealed. The three genera are *Rossiella* emend., *Bogorovia* emend. and *Koizumia* gen. nov. In a previovs paper (Yanagisawa, 1994), the new genus *Koizumia* was established and described with its three species, one of which was formerly included in the genus *Rossiella*.

In this paper, an emended definition of the genus *Rossiella* is presented with a detailed description of its five members, *Rossiella symmetrica* Fenner emend. Yanagisawa, *R. fennerae* Yanagisawa sp. nov., *R. fourtanierae* Yanagisawa sp. nov., *R. f*

graphic distribution of each species based on analysis of deep-sea cores and literature survey are provided. The emended description of the genus *Bogorovia* is given separately (Yanagisawa, 1995).

Material and methods

For the biostratigraphic study, samples from the Upper Oligocene to Upper Miocene sections of DSDP Holes 71, 77B and 70A, and from the Lower Miocene through Quaternary section of DSDP Hole 438A were analyzed (Table 1).

Holes 71, 77B and 70A were drilled in the eastern equatorial Pacific, and the composite section of these three cores offers an almost continuous and complete Upper Oligocene to Upper Miocene sequence for diatom biostratigraphy in the low-latitude area (Barron, 1981b, 1983, 1985a). Slides of some selected samples studied by Barron (1983, 1985a) and the slides deposited in the DSDP Reference Center in the National Science Museum (Tokyo) were examined in this study.

Hole 438A is located in the northwestern Pacific, off northeast Honshu, Japan. It contains an almost complete reference section for Lower Miocene through Quaternary North Pacific diatom biostratigraphy (Barron, 1980; Akiba *et al.*, 1982; Maruyama, 1984; Akiba, 1986). In this study, slides analyzed by Akiba *et al.* (1982), Maruyama (1984) and Akiba (1986), together with those deposited in the DSDP Reference Center in the National Science Museum (Tokyo) were re-examined with special attention to the genus *Rossiella*. For taxonomic study and SEM observations, several selected samples were

Table 1. Cores and samples used in this study.

No.	Cores & samples	Area	Location	Formation	References and remarks
1	DSDP Hole 70A	Eastern equatorial Pacific	6°20.08' N, 140°21.72' W	DSDP core	Tracey et al. (1971)
2	DSDP Hole 71	Eastern equatorial Pacific	4°28.28' N, 140°18.91' W	DSDP core	Tracey et al. (1971), Barron (1983)
3	DSDP Hole 77B	Eastern equatorial Pacific	0°28.90' N, 133°13.70' W	DSDP core	Hays et al. (1972), Barron(1981b, 1983)
4	DSDP Hole 438A	Northwest Pacific	40°37.79' N, 143°14.15' E	DSDP core	Scientific Party (1980), Barron(1980)
5	P 225	Central equatorial Pacific	3°13.32' N, 169°41.65' W	Piston core	Nishimura (1986)
6	M 32	Ajigaura, Ibaraki, Japan	36°22.82' N, 140°37.42' E	Isozaki F.	Maruyama (1984)
7	Nmy 13A	Sumon, Niigata, Japan	37°22.11' N, 139°02.04' E	Nishimyo F.	Yanagisawa et al. (1986)

also used (Table 1).

Preparation method for light microscopic (LM) study varied. Slides of some selected samples from DSDP Holes 71 and 77B were prepared by J.A. Barron, following the method described in Barron (1976). The other samples were prepared following the method of Koizumi and Tanimura (1985) or Maruyama (1984). Methods of LM and SEM observations were described in Yanagisawa (1994)

Results

Morphology

Morphologic terminology was given in Yanagisawa (1994). General diatom morphologic terms follow Anonymous (1975), Ross *et al.* (1979), Simonsen (1979) and Round *et al.* (1990).

The valve outline of this genus is linear-lanceolate, but more linear or broadly lanceolate or elongated forms are also observed (Figure 1). *Rossiella symmetrica, R. fen-* nerae and R. fourtanierae are isopolar in valve outline, but the remaining two species, R. paleacea and R. elongata have heteropolar valves with one apex broadly rounded and the other acutely rounded (Figure 1). The apex is more or less rostrate with an apical pore field consisting of fine puncta (Figure 12-5). Transapical costae (ribs) are absent, and this is the most distinctive feature that characterizes this genus. All members of this genus have marginal ridges on both margins. As shown in Figure 1, Rossiella symmetrica and R. fennerae possess fused-type marginal ridges with three longitudinal rows of pores (type 3), whereas the remaining three species are characterized by separate-type marginal ridges with a single row of pores (type 1). Rossiella symmetrica and R. fennerae with fused-type marginal ridges (type 3) may form a long chain colony by the fusion of their marginal ridges. On the contrary, the remaining three species with the separate-type marginal ridge (type 1) may be solitary. Rossiella fennerae sometimes has valves with the separate-type marginal ridge (Figures 8-7, 8-8).



Figure 1. Schematic drawings of *Rossiella* species. Left figure in each species is a valve outline in valve view, showing the location of the rimoportula. Right figure is a girdle view of a valve or set of sibling valves, showing the type of marginal ridge.

Such valves may be separation valves as observed in *Aulacoseira granulata* and *Skeletonema costatum* (Round *et al.*, 1990, p. 26). The separation valve is a special valve that differs from the other ordinary vegetative valves in that it lacks a linking structure for colony chain formation, and may serve to separate an inconveniently long chain into shorter chains.

A rimoportula (labiate process) is present generally in "one per cell pattern"; a frustule consists of a process valve and a non-process valve, and thus this genus is heterovalvate. The genus *Rossiella* has three patterns of the location of the rimoportula; subcentral, apical and



Figure 2. Stratigraphic distribution of *Rossiella* species in DSDP Holes 77B, 71 and 70A. Narrow horizontal lines show samples examined. Each dot indicates the presence of each species. Original data are presented in Appendix table.

central positions (Figure 4 in Yanagisawa, 1994). *Rossiella symmetrica* and *R. fennerae* which make a colony chain by fusion of marginal ridges (type 3) have a subcentral rimoportula (Figure 1). The apical and central positions of rimoportula are observed only in such species as *R. fourtanierae* and *R. paleacea*, both of which have the separated-type marginal ridges (type 1).

The valve face is more or less convex, perforated with areolae. Each areolae is occluded with a mesh-like cribrum (Figure 15-3), but the cribrum is often completely dissolved (Figure 15-2). The areolae of this genus are coarse (ca. 1.2-1.5 μ m in diameter), polygonal in shape and compactly packed (Figure 4).

The cingulum is composed of a few bands with rows with small puncta (Figure 7-6), but its detailed composi-



Figure 3. Stratigraphic distribution of *Rossiella* species. Low-latitude diatom zones after Barron (1985b) and Fenner (1985), and North Pacific diatom zones after Akiba (1986). Correlation to the time scale of Berggren *et al.* (1985) is adjusted through Barron *et al.* (1985) and Oda (1986).

tion is not known at present.

Stratigraphic distribution

The stratigraphic occurrences of *Rossiella* species are presented in Figure 2 and Appendix table for DSDP Holes 77B, 71 and 70A, using the biostratigraphic zonations of Barron (1985b) and Fenner (1985). The result of analysis of DSDP Hole 438A has already been presented in Figure 6 of Yanagisawa (1994).

The stratigraphic ranges of *Rossiella* species are shown in Figure 3, which is mainly based on Figure 2, as well as on some other important biostratigraphic studies such as Schrader (1973, 1974a, 1974b, 1976), Barron (1981a, 1981b, 1983, 1985a, 1985b, 1992), Fenner (1984a, 1984b, 1985), Fourtanier (1987, 1991), Gersonde and Burckle (1990), Baldauf and Barron (1991) and Harwood and Maruyama (1992). Correlation to the time scale of Berggren *et al.* (1985) is adjusted through Barron *et al.* (1985) and Oda (1986).

Geographic distribution

The geographic distribution of each *Rossiella* species was surveyed from literature. The results are shown in Figures 6, 8, 11, 14 and 16. All species of the genus are distributed mainly in the low-latitude oceanic regions in the Pacific, Atlantic and Indian Oceans with rare occurrence in the middle latitudes, indicating that they are essentially oceanic warm-water species.

Systematic descriptions

In this paper, the classification system of Round *et al.* (1990) is adopted for the description of the genus *Rossiel-la* because the system appears to be the most natural system at present.

Class Coscinodiscophyceae Round et Crawford, 1990 Subclass Cymatosirophycidae Round et Crawford, 1990 Order Cymatosirales Round et Crawford, 1990 Family Cymatosiraceae Hasle, von Stosch et Syvertsen, 1983 Subfamily Cymatosiroideae Hasle, von Stosch et Syvertsen, 1983

Genus *Rossiella* Desikachary et Maheshwari, 1958 emend. Yanagisawa

Synonymy: Stoschia?, Grunow in van Heurck, 1883, pl. 128, fig. 6 (Stoschia? paleacea); Cussia, Schrader, 1974a, p. 541 (Cussia paleacea).

Generic type.—Rossiella paleacea (Grunow) Desikachary et Maheshwari 1958

Original description.—Valve elongately elliptical, with tapering rounded ends; valve surface slightly convex or almost flat; central area and rosette absent; areolae polygonal; no distinct marginal arrangement (Desikachary and Maheshwari, 1958).

Emended description.-Cell heterovalvate, rectangular

or lanceolate in girdle view. Solitary, or forming separable or inseparable chain colonies. Some species with separating valve or end valve separates chain colonies. Cingula with several bands with or without fine puncta. Valve slightly convex, linear or linear-lanceolate or broadly lanceolate. Apices with small apical pore field, sometimes slightly rostrate. Marginal ridge always present, separated or completely fused with sibling valve. Rimoportula one per cell ; a frustule consists of a process valve and a non-process valve. Rimoportula located at subcentral position near the margin, or at central or apical positions. Areolae coarse to medium, compactly packed. Transapical costae absent.

Comparison.—The genus *Rossiella* emended here is morphologically very similar to genera *Bogorovia* and *Koizumia*, but is clearly distinguished from the latter two genera in lacking transapical costae and having relatively large areolae that are compactly packed.

Rossiella closely resembles genera in Cymatosiraceae such as Cymatosira Grunow and Campylosira Grunow in Van Heurck in that they commonly possess a generally dipolar outline, chain colonies connected by marginal ridge or linking spines, rimoportula in the pattern of one per cell, and an ocellus or apical pore field at each apex, and therefore the genus Rossiella should be placed in the family Cymatosiraceae as defined by Hasle *et al.* (1983).

Stratigraphic occurrence.—Latest Early Oligocene to Late Miocene. The first species *R. symmetrica* appears at the base of the b Subzone of *Rocella vigilans* Zone of Fenner (1984a, 1985) dated about 32 Ma (Figure 3). The last species *R. paleacea* disappears near the top of the Late Miocene *Nitzschia porteri* Zone (NTD 11).

Habitat.—Because of their dominant occurrence in oceanic sediments, all species of the genus are probably holoplanktonic, and solitary or making a long chain formed by fused marginal ridges.

Geographic distribution.—All members of the genus are distributed mainly in the low-latitude area of the Pacific, Atlantic and Indian Oceans, indicating that they are warm-water species. They are also found rarely and sporadically in middle-to-high-latitude areas.

Discussion.-The diatom genus Rossiella has a very complicated taxonomic history. The genus was created by Desikachary and Maheshwari (1958) to receive a species that was originally described as Stoschia? paleacea Grunow in Van Heurck (1883). The species was later transferred to the genus Coscinodiscus by Rattray (1889) and had been referred to as C. paleaceus (De Toni, 1894; Kolbe, 1954) until 1958 when the genus Rossiella was erected. Unfortunately, however, this generic erection was not generally known until the 1980's, and therefore R. paleacea continued to be referred to as Coscinodiscus paleaceus (Kanaya, 1971; Burckle, 1972; Schrader, 1973), while some species which were later transferred into Rossiella were described under different generic names such as Rhaphoneis, Coscinodiscus or Cymatosira (e.g. Hajós, 1968; Koizumi, 1972; Schrader, 1973; Lohman, 1974). Furthermore, the independent generic erection of the genus Bogorovia (Jousé, 1973) and

Table 2. Key to species based on light microscopy.

1a. Valve isopolar	
1b. Valve heteropolar	
2a. Valve linear	R. symmetrica
2b. Valve lanceolate	
3a. Valve linear lanceolate	R. fennerae
3b. Valve broadly lanceolate	R. fourtanierae
4a. Valve not elongated	R. paleacea
4b. Valve elongated	R. elongata

Cussia (Schrader, 1974a) produced further considerable confusion in the taxonomy.

Schrader (1974a) created a new genus Cussia based on Stoschia? paleacea without knowing of the generic erection of Rossiella, and described two new species (Cussia lancettula and C. moholensis) and proposed four new combinations (Cussia paleacea, C. praepaleacea, C. mediopunctata and C. tatsunokuchiensis). Another genus Bogorovia was established by Jousé (1973) with B. veniamini as the generic type. Although the latter genus was originally monotypic, it later received five species, Bogorovia paleacea, B. praepaleacea, B. mediopunctata, B. tatsunokuchiensis and B. moholensis (Jousé 1976). During the late 1970's, these species were referred to Cussia or Bogorovia, until the generic erection of Rossiella was re-discovered by Gersonde (1980). In 1984, Gersonde and Schrader (1984) and Desikachary et al. (1984) clarified the confused taxonomy of this diatom group, and most of the species formerly included in Cussia or Bogorovia were transferred to Rossiella, exclusive of Bogorovia veniamini which was left in the genus Bogorovia because it has distinct transverse (transapical) rows of areolae with distinct transverse costae (Desikachary et al., 1984). This taxonomic treatment has been accepted by all subsequent diatom studies (Barron, 1985a, 1985b; Akiba, 1986; Fourtanier, 1987; Gersonde and Burckle, 1990; Baldauf and Barron, 1991; Harwood and Maruyama, 1992). However, it is incosistent that R. mediopunctata, R. tatsunokuchiensis and R. moholensis were removed to the genus Rossiella despite the possession of distinct transapical rows of areolae and transapical costae, both of which are characteristic of the genus Bogorovia.

Detailed phylogenetic analysis shows that *Rossiella* species lacking transapical costae constitute a morphologically well-cohesive group bounded by distinct morphological gaps from *Bogorovia* and *Koizumia*. Furthermore, this group has its own characteristic evolutionary trend and ecology.

Key to species of the genus *Rossiella* based on light microscopy is presented in Table 2.

Rossiella symmetrica Fenner, 1984 emend. Yanagisawa

Figures 4-1-6

- Fenner, 1984b, p. 333–334, pl. 1, fig. 2, non pl. 1, figs. 3, 4; 1984a, p. 1264; 1985, p. 737, figs. 5.5–5.7; Fourtanier, 1991, pl. 4, fig. 5.
- Synonymy: Coscinodiscus praepaleaceus Schrader, Burckle, 1978, figs. in p. 261, 262; Bogorovia aff. B. veniamini Jousé, Abbott, 1980, p. 61, pl. 6, fig. 2.

Emended description.—Valve isopolar, linear in outline with rounded apices, 13-51 μ m long, 5-8 μ m wide. Valve face slightly convex, covered with irregularly disposed coarse round areolae, 6-8 areolae in 10 μ m. Apices slightly raised with apical pore field. Marginal ridge, fused-type with three longitudinal rows of subrounded pores (type 3), 7-8 pores in 10 μ m. A subcentral rimoportula, one per cell, located near edge of valve face.

Comparisons.—Rossiella symmetrica resembles R. fennerae, but differs from the latter by the linear valve outline and narrower valve size (less than $8 \,\mu$ m) (Figure 5). The species is also similar to "Rossiella" gombosii* Desikachary in Desikachary et al. (1984) in valve appearance, but is distinct by the absence of transapical costae and larger and more densely packed areolae on the valve face.

The species also shows a slight resemblance to *Praecymatosira monomembranacea* (Schrader) Strelnikova (Jousé *ed.*, 1979, p. 64, figs. 169–176; Gombos, 1983, p. 570, pl. 4, figs. 12, 13), which was originally described as *Pseudorutilaria monomembranacea* Schrader (Schrader and Fenner, 1976, p. 994, pl. 22, figs. 1–6) or as *Cymatosira* sp. B (Dzinordze *et al.*, 1978, pl. 10, figs. 14–17), in having a linear valve outline and medium areolae on the valve face. *Praecymatosira monomenbranacea* was first reported from Middle Eocene deposits in the Norwegian Sea

^{*} The species will be transfered to the genus *Bogorovia* in Yanagisawa (1995)



Figure 4. Light photomicrographs of *Rossiella* species. Scale bar equals 10 μ m. Arrow heads indicate the location of the rimoportula. **1-6.** *Rossiella symmetrica* Fenner. (1-5) DSDP Hole 71, 47-5, 59-60 cm; (6) DSDP Hole 71, 45-2, 61-62 cm. **7-10.** *Rossiella fennerae* Yanagisawa sp. nov. (9) holotype; (7) DSDP Hole 71, 36-2, 125-129 cm; (8) DSDP Hole 71, 39-1, 87-89 cm; (9) DSDP Hole 71, 37-5, 87-89 cm; (10) DSDP Hole 71, 37-5, 87-89 cm. **11-14.** *Rossiella fourtanierae* Yanagisawa sp. nov. (11) holotype, DSDP Hole 71, 36-6, 79-80 cm; (12-14) DSDP Hole 71, 36-2, 125-129 cm. **15-17**. *Rossiella paleacea* (Grunow) Desikachary et Maheshwari (primitive form). (15) DSDP Hole 71, 22-2, 88-90 cm; (16) DSDP Hole 71, 21-6, 91-93 cm; (17) DSDP Hole 71, 23-4, 77-79 cm. **18-20**. *Rossiella paleacea* (Grunow) Desikachary et Maheshwari (advanced form). DSDP Hole 77B, 20-6, 30-31 cm. **21-23**. *Rossiella elongata* (Barron) Desikachary. (21) P 225, VII 20; (22) DSDP Hole 77B, 19-2, 38-40 cm; (23) DSDP Hole 77B, 22-6, 35-37 cm.



Figure 5. Scatter plot of valve width versus length of *Rossiella symmetrica* Fenner and *R. fennerae* Yanagisawa sp. nov. Samples from nos. 1, 2 in Table 1.

(Schrader and Fenner, 1976; Dzinoridze *et al.*, 1978; Jousé ed., 1979) and later found in Eocene sediments in the South Atlantic (Gombos, 1983), and it is of great importance to Eocene diatom biostratigraphy because of its unique features as well as its usual abundance (Strelnikova, 1990). *Praecymatosira monomembranacea* differs fundamentally from *R. symmetrica* in linking structure; *P.* *monomembranacea* forms a colony chain by a longitudinal row of processes along the apical axis, which is never observed in *Rossiella* species.

Stratigraphic range.—32.0-25.5 Ma. The first occurrence of this species defines the base of the b Subzone of the *Rocella vigilans* Zone of Fenner (1984a, 1985) and its last occurrence falls in the *Bogorovia veniamini* Zone of Fenner (1984a, 1985) (Figure 3).

Geographic distribution.—This species has been reported mainly from warm-water regions (Figure 6). It is found in the equatorial Pacific (Barron, 1983; this study), the northwest Atlantic (Fenner, 1984a, 1984b, 1985), the Atlantic coast of the U.S.A. (Abbott, 1980), the equatorial Indian Ocean (Fourtanier, 1991; Fenner and Mikkelsen, 1990) and the Southern Ocean (Fenner, 1984b; Harwood and Maruyama, 1992). It has not been reported from the middle-to-high-latitude North Pacific.

Discussion.—Since the original description of *R. symmetrica* by Fenner (1984b) includes the features of *R. fennerae* sp. nov., the species description is emended here. As Fenner's (1984b) description indicates, she had already noted morphologic change from *R. symmetrica* emend. to *R. fennerae* sp. nov., but she regarded the change as intraspecific variation. However, the two species are distinct enough to be separated at the specific level.



Figure 6. Geographic distribution of *Rossiella symmetrica* Fenner. Closed circles: localities reported with figures. Open circles: localities reported without figures. **1.** DSDP Hole 70A, equatorial Pacific (this study). **2.** DSDP Hole 71, equatorial Pacific (this study). **3.** DSDP Hole 369A, northwest Atlantic, off northwest Africa (Fenner, 1984b, 1985). **4.** Atlantic Slope Project core 22, off Atlantic coast of U.S.A. (Abbott, 1980). **5.** DSDP Hole 758, equatorial Indian Ocean (Fourtanier, 1991). **6.** DSDP Hole 714, equatorial Indian Ocean (Fenner and Mikkelsen, 1990). **7.** DSDP Hole 747A, Indian sector of the Southern Ocean (Harwood and Maruyama, 1992). **8.** DSDP Hole 278, Pacific sector of the Southern Ocean (Fenner, 1984b). **9.** DSDP Hole 366A, equatorial Atlantic off Africa (Fenner, 1984a, 1984b).

Rossiella fennerae Yanagisawa sp. nov.

Figures 4-7-10; 7-1-8.

Synonymy : *Bogorovia veniamini* Jousé, Gombos, 1976, pl. 12, fig. 1 (non pl. 1, figs. 6, 7 ; pl. 12, figs. 2, 4) ; *Rossiella symmetrica* Fenner, 1984b, pl. 1, figs. 3, 4, non pl. 1, fig. 2 ; *Rossiella paleacea* (Grunow) Desikachary et Maheshwari, Barron, 1983, p. 512, pl. V, fig. 4 (non pl. V, figs. 5–6).

Description.-Valve isopolar, linear-lanceolate in out-

line, 38–92 μ m long, 9–15 μ m wide. Apex with apical pore field, variable in shape from broadly rounded to strongly rostrate. Valve face slightly convex, covered with irregularly disposed round areolae, 5–8 areolae in 10 μ m. Marginal ridge, fused-type with three longitudinal rows of subrounded pores (type 3), 7–8 pores in 10 μ m. Separation valve has separeted-type marginal ridge with one row of pores (type 1). A subcentral rimoportula, one per cell, located near edge of valve face, sometimes surrounded by small satellite pores. Internal lip-shaped



Figure 7. Scanning electron photomicrographs of *Rossiella fennerae* Yanagisawa sp. nov. Sample DSDP Hole 71, 36-2, 125-129 cm. Scale bars equal $5 \mu m$. **1.** A set of fused sibling valves. **2.** The opposite side of the specimen in Fig. 7-1. Arrow indicates the outer opening of a rimoportula. **3.** Enlargement of Fig. 7-2. **4.** A set of fused sibling valves. **5.** Frustule composed of two separation valves. **6.** Enlargement of Fig. 7-5. **7, 8.** Inner views of a separation valve. Arrow indicates a rimoportula.



Figure 8. Geographic distribution of *Rossiella fennerae* Yanagisawa sp. nov. Closed circles : localities reported with figures. Open circles : localities reported without figures.
1. DSDP Hole 71, equatorial Pacific (Barron, 1983; this study).
2. DSDP Hole 366A, equatorial Atlantic off Africa (Fenner, 1984b).
3. DSDP Hole 328B, southern Atlantic (Gombos, 1976).
4. DSDP Hole 744A, Indian sector of the Southern Ocean (Baldauf and Barron, 1991).
5. DSDP Hole 748B, Indian sector of the Southern Ocean (Harwood and Maruyama, 1992).

opening of rimoportula diagonally oriented to the longitudinal axis. External opening of rimoportula is a simple pore on marginal ridge. On non-process valve, a small hyaline area present near edge of valve where a rimoportula might be located if it were present. Cingulum bands perforated with fine puncta.

Holotype.—Plate 1, Figure 9 (GSJF 12783 deposited in the Geological Survey of Japan).

Type locality and sample.—DSDP Hole 71, Core 37, Section 5, Interval 87-89 cm, 4°28.28′N, 140°18.91W, eastern equatorial Pacific (Early Miocene in age, the A Subzone of the *Rossiella paleacea* Zone, NTD 1A).

Comparisons.—The species differs from *R. symmetrica* by more lanceolate valve outline, broader breadth (more than $8.5 \,\mu$ m) (Figure 5) and more compactly packed areolae. It shows close affinity with *R. paleacea*, but is distinguished by isopolar shape of valve outline, the fused type marginal ridge with three longitudinal rows (type 3) and the subcentral rimoportula (Figure 1). The species differs from *R. fourtanierae* by more slender valve outline and the location of the rimoportula. *Rossiella elongata* is distinguished from *R. fennerae* by its elongated heteropolar valve outline and the type of marginal ridge.

Stratigraphic range.—25.5-20.6 Ma. In the tropical Pacific, the first occurrence is in the upper part of the *Bogorovia veniamini* Zone and the last slightly below the top of the B subzone of the *R. paleacea* Zone (NTD 1B) (Figure 3).

Geographic distribution.—This species has been reported from low-latitude areas and the Southern Ocean (Figure 8); the equatorial Atlantic (Fenner, 1984b), the equatorial Pacific (Barron, 1983; this study) and the Southern Ocean (Gombos, 1976; Baldauf and Barron, 1991; Harwood and Maruyama, 1992).

Discussion.—The valve apex of this species shows very wide variation in shape, from broadly rounded (Figures 4-7, 4-10) to strongly rostrate (Figure 4-8, 4-9), and therefore this species may be further subdivided.

Etymology.—The species name is dedicated to Dr. Juliane Fenner, who first figured this species and described its direct ancestor *R. symmetrica* (Fenner, 1984b).

Rossiella fourtanierae Yanagisawa sp. nov.

Figures 4-11-14; 9-1-6.

Synonymy : Coscinodiscus paleaceus (Grunow) Rattray, Jousé, 1973, pl. 4, fig. 4, non pl. 5, fig. 15; Bogorovia paleaceus (Rattray) Jousé, 1976, p. 1233-1234, fig. 5, non fig. 6; Bogorovia paleaceus (Grunow) Jousé, Jousé ed., 1977, pl. 54, fig. 11, non pl. 30, fig. 30; Rossiella paleacea (Grunow) Desikachary et Maheshwari (robust form), Barron, 1983, p. 512, pl. V, fig. 6 (not pl. V, figs. 4-5); Rossiella magna (Lohman) Fourtanier, 1991, p. 200, pl. 4, fig. 1 (non Cymatosira magna Lohman, 1974, p. 351, pl. 5, fig. 16).

Description.—Valve isopolar, broadly lanceolate in outline with acutely rounded apices, $42-104 \mu m \log n$, 13.5-34.5 μm wide. Valve face slightly convex, covered with irregularly disposed round areolae, 6-7 in 10 μm . Marginal ridge, separated-type with a single longitudinal row of pores (6-7 in 10 μm). A small pore field present at each apex. A rimoportula, one per cell, located near center of valve face, with its internal lip-shaped opening and external simple pore surrounded by a few small

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Figure 9. Scanning electron photomicrographs of *Rossiella fourtanierae* Yanagisawa sp. nov. Sample DSDP Hole 71, 36-2, 125-129 cm. Broad and narrow scale bars equal 5 μ m and 1 μ m, respectively. **1**, **2**. Inner views of a non-process valve. Note hyaline area where a rimoportula might be located if present. **3**, **4**. Outer views of a process valve. Arrow indicates the outer opening of a rimoportula. **5**. Enlargement of Fig. 9-4, showing the outer opening of a rimoportula (arrow head). **6**. Inner view of a process valve. Arrow indicates a rimoportula.

satellite pores. Non-process valve has a hyaline area on valve face where a rimoportula might be located if it were present.

Holotype.—Plate 1, Figure 11 (GSJF 14592 deposited in the Geological Survey of Japan).

Type locality and sample.—DSDP Hole 71, Core 36, Section 6, Interval 79-80 cm, 4°28.28'N, 140°18.91'W, eastern equatorial Pacific (Early Miocene in age, the A Subzone of the *Rossiella paleacea* Zone, NTD 1A).

Comparisons.—*Rossiella fourtanierae* is characterized by its broadly lanceolate valve outline. It is distinguished from *R. symmetrica* and *R. fennerae* by the more broad valve outline (Figure 10), a separated-type marginal ridge (type 1) and the central rimoportula (Figure 1). This species differs from *R. paleacea* by its isopolar valve outline and broader breadth (Figure 10).

Stratigraphic range.-22.4-19.8 Ma. The occurrence

of this species is confined within the A and B Subzones of the *R. paleacea* Zone (NTD 1A) in DSDP Hole 71 (Figure 2), but Fourtanier (1991) reported that the last occurrence of this species lies near the top of the *R. paleacea* Zone in DSDP Hole 758A in the equatorial Indian Ocean. Barron (1983) also figured this species from the uppermost part of the *R. paleacea* Zone in DSDP Hole 495 of the eastern equatorial Pacific. The last occurrence of *R. fourtanierae* therefore may lie near the top of the *R. paleacea* Zone (Figure 4).

Geographic distribution.—The species is probably a low-latitude species (Figure 11). It has been recorded from the equatorial Pacific (Jousé, 1973, 1976; Jousé ed., 1977; Barron, 1983; this study) and the equatorial Indian Ocean (Fourtanier, 1991).

Discussion.—Fourtanier (1991) first noticed this species as distinct from *R. paleacea*, but she regarded it as



Figure 10. Scatter plot of valve width versus length of *Rossiella fourtanierae* Yanagisawa sp. nov., *R. paleacea* (Grunow) Desikachary et Maheshwari and *R. elongata* (Barron) Desikachary. Samples from nos. 2, 3, 5-7 in Table 1.

Cymatosira magna Lohman and proposed the combination *Rossiella magna* (Lohman) Fourtanier. *Cymatosira magna* Lohman, however, is not *R. fourtanierae*, but can be safely included in the variation of *R. paleacea* because the holotype valve of *C. magna* has an obviously heteropolar outline.

Etymology.—The name of this species is dedicated to Dr. Elisabeth Fourtanier, who first recognized that this species is a distinct taxon (Fourtanier, 1991) and first examined the genus *Rossiella* using a scanning electron microscope (SEM) in detail (Fourtanier, 1987).

Rossiella paleacea (Grunow) Desikachary et Maheshwari, 1958

Figures 4-15-20; 12-1-6.

- Desikachary and Maheshwari, 1958, p. 128, fig. 1; Barron, 1983, p. 512, pl. V, fig. 5 (not figs. 4, 6); Gersonde and Schrader, 1984, p. 104; Desikachary *et al.*, 1984, p. 337-338, pl. 1, figs. 2-5, 8-11; Fenner, 1984a, p. 1264; Barron, 1985a, pl. 8, fig. 2; Barron, 1985b, p. 790, figs. 9.6-9.7; Fourtanier, 1991, pl. 4, fig. 4; Radionova, 1991, p. 82, pl. 23, figs. 1-3.
- Basionym : Stoschia ? paleacea Grunow in Van Heurck, 1883, pl. 128, fig. 6.
- Synonymy: Coscinodiscus paleaceus (Grunow) Rattray, 1889, p. 597; De Toni, 1894, p. 1301-1302; Kolbe, 1954, p. 34, pl. 3, figs. 32a-b; Kanaya, 1971, p. 555, pl. 40.5, fig. 10; Burckle, 1972, pl. 1, figs. 7-8; Schrader, 1973, p. 703, pl. 3, figs. 10-12; Jousé, 1973, pl. 5, fig. 15, non pl. 4, fig. 4; Cymatosira magna Lohman, 1974, p. 351, pl. 5, fig. 16; Cussia paleacea (Grunow) Schrader, 1974a, p. 543, fig. 1 : 11-14; Schrader, 1974b, p. 914; Gombos, 1975, p. 316, pl. 4, figs. 8-10; Barron, 1980, p. 672; Abbott and Ernissee, 1983, p. 299, pl. 12, fig. 2; Bogorovia paleaceus (Rattray) Jousé, 1976, p. 1233-1234, fig. 6, non fig. 5; Bogorovia praepaleaceus (Schrader) Jousé, Jousé ed., 1977, pl. 48, figs. 15-16; Bogorovia paleaceus (Grunow) Jousé, Jousé ed., 1977, pl. 30, fig. 30, non pl. 54, fig. 11; Rossiella paleacea var. paleacea (Grunow) Schrader, Barron, 1981b, pl. II, fig. 1; Bogorovia paleacea var. paleacea (Grunow) Jousé, Barron, 1981a, pl. 4, fig. 13.



Figure 11. Geographic distribution of *Rossiella fourtanierae* Yanagisawa sp. nov. Closed circles : localities reported with figures. **1.** DSDP Hole 71, equatorial Pacific (Barron, 1983; this study). **2.** R/V "Vityaz" Core 5996, equatorial Pacific (Jousé, 1973, 1976, 1977). **3.** DSDP Hole 495, eastern equatorial Pacific, off central America (Barron, 1983). **4.** DSDP Hole 758A, equatorial Indian Ocean (Fourtanier, 1991).

Original description.—Elongately and irregularly elliptical, frequently with shallow lateral undulations, major axis .0425 to almost flat; central space and rosette absent. Markings polygonal, 6 to 7 in .01 mm. Subequal, without order or in obscure rows; around the border a distinct band of areolae (as *Coscinodiscus paleaceus* (Grunow) Rattray, 1889, p. 597).

Additional description.—Valve linear-lanceolate, heteropolar with one apex broadly rounded and the other elongated and acutely rounded, 18–89 μ m long, 7–19 μ m wide. Valve apices somtimes slightly rostrate. Valve face slightly convex, covered with irregularly disposed round areolae, 6–8 areolae in 10 μ m. Areolae might be occluded by cribra in the same manner as in *R. elongata*, though the cribra have been dissolved in all specimens observed. Marginal ridge, separate type with a single longitudinal row of large subrounded pores (type 1), 6–8 pores in 10 μ m. A small pore field present at each apex. A rimoportula present basically in a "one per cell" pattern but some valves with two processes.

The position of the rimoportula on the valve face

changed through time (Figure 13). The rimoportula is located very near the short apex in the primitive forms from NTD 1B to NTD 7 (Figures 4-15—17). The advanced forms from NTD 8-9 have their processes nearly at the central part of valve (Figures 4-18, 4-19, 12-3). Moreover, some valves from NTD 8-9 have an additional rimoportula at the apical position (Figure 4-20, 12-1, 12-2).

Comparisons.—The species closely resembles *R. fennerae*, but differs by the heteropolar valve outline, a separate-type marginal ridge and location of the rimoportula. It differs from *R. fourtanierae* by its heteropolar and more slender valve outline (Figure 10). This species is distinguished from *R. elongata* by a shorter (not elongated) valve (Figure 10) and the location of the rimoportula (Figure 1). Rossiella paleacea has been sometimes confused with Koizumia adaroi (Andrews, 1980; Hajós, 1986), but differs from *K. adaroi* by the absence of transapical costae. In some previous studies, *Cymatosira lorenziana* Grunow has been misidentified as *R. paleacea* (Abbott and Andrews, 1979; Powers, 1988), but the two species are clearly distinguished by the type of colony formation



shwari. Sample P 225, VII 20, equatorial Pacific. Scale bars equal 5 μ m. **1**, **2**. Inner views of a process valve. Note two rimoportulae (arrow heads). **3**. Outer view of a process valve. Arrow indicates a rimoportula. **4**, **6**. Inner views of a non-process valve. Note hyaline structureless area where a rimoportula might be located if present. **5**. Valve apex with an apical pore field.



Figure 13. Change in the location of rimoportula of *Rossiella paleacea* (Grunow) Desikachary et Maheshwari. NTD numbers indicate diatom zone numbers of the Neogene low-latitude diatom zones of Barron (1985b). Closed circles indicate the average location of rimoportula. Open circles show an additional rimoportula recognized in some specimens from NTD 8 and 9. Numbers in parentheses indicate the coordinates of mean location of rimoportulae. n=numbers of specimens measured.

and the areolae pattern on the valve face.

Cymatosira andersoni Hanna, a diatom species described from the Middle Miocene sediments in Sharktooth Hill, California (Hanna, 1932, p. 187–188, pl. 10, fig. 6), seems to be slightly similar to *R. paleacea*, but differs by a central hyaline area and central areolae arranged nearly in longitudinal rows. Further study is needed to make a correct taxonomic placement of this species.

Stratigraphic range.-20.9-6.8 Ma. In this study of DSDP Hole 71 (equatorial Pacific), the first occurrence of this species is recognized in the middle part of the B Subzone of the *R. paleacea* Zone (NTD 1B) (Figure 2). On the contrary, Barron (1983, 1985b) reported it at the base of R. paleacea Zone, utilizing it to define the base of this zone. This difference may be due to species identification; R. paleacea of Barron (1983, 1985b) includes R. fennerae and R. fourtanierae as well as R. paleacea s. str. The base of the R. paleacea Zone defined by Barron (1983) in Hole 71 seems to be coincident with the first abundant occurrence of R. fennerae and so the base of this zone should be redefined (See appendix). The last occurrence of R. paleacea approximates the top of the Nitzschia porteri Zone (NTD 11) in the low-latitude area (Barron, 1985a, 1985b) (Figure 3), estimated at 6.8 Ma (Barron, 1992).

The stratigraphic range of *R. paleacea* is shortened in the middle-to-high-latitude North Pacific (Yanagisawa, 1994, fig. 6) or in the Southern Ocean (Baldauf and Barron, 1990).

Geographic distribution.—Rossiella paleacea was first described from Nancoori and Naparima Islands of India (Grunow *in* van Heurck, 1883; Rattray, 1989), numerous reports of this species have subsequently been made mainly from low-latitude areas and the middle latitudes of the Northern Hemisphere (Figure 14).

Rossiella elongata (Barron) Desikachary in Desikachary et al., 1984

Figures 4-21-23; 15-1-8

Desikachary in Desikachary et al., 1984, p. 338.

Basionym : *Bogorovia paleacea* var. *elongata* Barron, 1981a, p. 528, pl. 4, figs. 11-12.

Synonymy : Coscinodiscus paleaceus ? var. 2, Jousé, 1973, pl. 5, fig. 16 ; Coscinodiscus paleaceus (Grunow) Rattray, Hasegawa, 1977, p. 83, pl. 17, figs. 5a, 5b ; Rossiella paleacea var. elongata (Barron) Schrader, Barron, 1981b, p. 141, pl. II, fig. 2 ; Rossiella paleacea var. elongata (Barron) Barron, 1985a, pl. 8, fig. 3 ; Radionova, 1991, p. 82.

Additional description.—Valve elongated lanceolate, heteropolar with one apex broadly rounded and the other elongated and acutely rounded, 41-104 μ m long, 7-13 μ m wide. Some valves have asymmetric sides with one side more convex and the other side more straight (Figures 15-1, 15-5). Valve face slightly convex, covered with densely packed round areolae, 6-7 in 10 μ m. Areolae occluded by the mesh-like cribra (Figure 15-3). Marginal ridge,



Figure 14. Geographic distribution of Rossiella paleacea (Grunow) Desikachary et Maheshwari. Closed circles : localities reported wth figures. Open circles : localities reported without figures. 1. DSDP Hole 71, equatorial Pacific (this study). 2. DSDP Hole 77B, equatorial Pacific (this study; Barron 1981b, 1983, 1985a, 1985b; Fourtanier, 1987). 3. DSDP Hole 66.1, equatorial Pacific (Gombos, 1975; Radionova, 1991). 4. U.S. "Monsoon" Expedition MSN-132P, equatorial Pacific (Jousé, 1973, 1976). 5. Swedish Deep-Sea Expedition, Core 60, equatorial Pacific (Kolbe, 1954). 6. Swedish Deep-Sea Expedition, Core 76, equatorial Pacific (Kolbe, 1954), 7. Geological Survey of Japan piston core P 225, equatorial Pacific (this study). 8. DSDP Hole 575, equatorial Pacific (Radionova, 1991). 9. DSDP Hole 472, northeast Pacific off Baja California (Barron, 1981a, 1985b). 10. Experimental Mohole Drilling Guadalupe Site, northeast Pacific off Baja California (Kanaya, 1971; Schrader, 1974a). 11. DSDP Hole 173, northeast Pacific off California (Schrader, 1973). 12. DSDP Hole 438A, northwest Pacific off Japan (Barron, 1980; this study). 13. Nishimyo Formation, Sumon area, Niigata, Japan (this study). 14. Nancoori Island in Nicobar Islands, India (Grunow in Van Heurck, 1883; Desikachary et al., 1984). 15. Colebrook Island in Andaman Islands, India (Desikachary and Maheshwari, 1958; Desikachary et al., 1984). 16. DSDP Hole 758, equatorial Indian Ocean (Fourtanier, 1991). 17. Trinidad Island (Lohman, 1974), 18. Pungo River Formation. North Carolina, U.S.A. (Abbott and Ernissee, 1983), 19. DSDP Hole 369A. northwest Atlantic off northwest Africa (Schrader, 1977). 20. La Miranda, Muro, Mallorca Island, Spain (Monjanel, 1987). 21. Lorca, Spain (Gersonde, 1980).

Note: Desikachary et al. (1984) figured R. paleacea from Kamortha Island and Naparima, but the exact location of these sites are unknown at present.

separated-type with a single longitudinal row of pores (type 1), 6-7 pores in 10 μ m. A small pore field present at each apex. A subcentral rimoportula, one per cell, located near the valve margin, with its lip-shaped internal opening oriented diagonally to the apical axis (Figure 15-2). In a non-process valve, a small hyaline area present where a rimoportula might be present (Figure 15-6).

Comparisons.—The elongated valve outline characterizes *R. elongata*. This species differs from *R. paleacea* by its elongated slender valve outline (Figure 10) and a subcentral rimoportula (Figure 1). It is distinguished from *R. symmetrica*, *R. fennerae* and *R. fourtanierae* mainly by its heteropolar elongated valve outline and the separatedtype marginal ridge.

Stratigraphic range.—13.5-7.5 Ma. In low-latitude areas, the first occurrence of this species falls within the *Coscinodiscus lewisianus* Zone (NTD 6) and its last occurrence lies near the top of the B Subzone of the *Coscinodiscus yabei* (*Thalassiosira yabei*) Zone (NTD 10B)

(Figures 2, 3). Although this species first occurs in the *C. lewisianus* Zone (NTD 6), its first continuous occurrence is in the lowermost part of the *Actinocyclus moronensis* Zone (NTD 9) in DSDP Hole 77B (Figure 2), coincident with the estimated age of its first occurrence at 10.6 Ma by Barron (1992).

Geographic distribution.—This species occurs mainly in the equatorial Pacific (Jousé, 1973; Barron, 1981a, 1981b, 1985a; Radionova, 1991; this study) (Figure 16). It is also found relatively rarely at middle latitude areas (Barron, 1981a; Hasegawa, 1977; this study).

Discussion.—This species was described originally as a variety of *R. paleacea* (Barron, 1981a), but was later raised to the specific rank by Desikachary *et al.*, (1984). This taxonomic change is supported by the substantial difference in location of the rimoportula between *R. paleacea* and *R. elongata* (Figure 1).



Figure 15. Scanning electron photomicrographs of *Rossiella elongata* (Barron) Desikachary. Sample M 32, Isozaki Formation, Ajigaura area, Japan. Broad and narrow scale bars equal 10 μ m and 1 μ m, respectively. **1.** Outer view of a non-process valve. **2.** Inner view of a process valve. Arrow indicates a rimoportula. **3.** Outer view of a process valve. Arrow indicates the outer opening of a rimoportula. **4.** Cross-sectional view of a broken valve. **5.** Inner view of a process valve. Arrow indicates a rimoportula. **6.** Inner view of a non-process valve. **7.8.** Valve apex with an apical pore field.



Figure 16. Geographic distribution of *Rossiella elongata* (Barron) Desikachary. Closed circles : localities reported with figures. **1.** DSDP Hole 77B, equatorial Pacific (Barron, 1981a, 1981b; this study). **2.** DSDP Hole 574, equatorial Pacific (Barron, 1985a). **3.** U.S. "Monsoon" Expedition MSN 146P, equatorial Pacific (Jousé, 1973). **4.** DSDP Hole 472, northeast Pacific (Barron, 1981a). **5.** M 32, Isozaki Formation, Ajigaura, Ibaraki, Japan (this study). **6.** Nakayama Formation, Sado Island, Niigata, Japan (Hasegawa, 1977).

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Appendix

Redefinition of a diatom zone

The base of the *Rossiella paleacea* Zone (NTD 1) was defined by the first occurrence of *R. paleacea* (Barron, 1983, 1985b). The present study, however, refined the species concept of *R. paleacea* and therefore the base of the zone is not coincident with the first appearance of *R. paleacea* s. str. Instead, the first abundant occurrence of *R. fennerae* appears to approximate the base of this zone defined by Barron (1983), and therefore this datum plane is proposed to replace the first occurrence of *R. paleacea* as the base of the *R. paleacea* Zone.

References

- Abbott, W.H., 1980 : Diatoms and stratigraphically significant silicoflagellates from the Atlantic Margin Coring Project and other Atlantic margin sites. *Micropaleontology*, vol. 26, p. 49-80.
- Abbott, W.H., and Andrews, G.W., 1979: Middle Miocene marine diatoms from the Hawthorn Formation within the Ridgeland Trough, South Carolina and Georgia. *Micropaleontology*, vol. 25, p. 225-271.
- Abbott, W.H., and Ernissee, J.J., 1983: Biostratigraphy and paleoecology of a diatomaceous clay unit in the Miocene Pungo River Formation of Beaufort County, North Carolina. *In*, Ray, C.E. *ed.*, Geology and paleontology of the Lee Creek Mine, North Carolina, I, *Smithsonian Contributions to Paleobiology*, vol. 53, p. 287-353.
- Akiba, F., 1986 : Middle Miocene to Quaternary diatom biostratigraphy in the Nankai Trough and Japan Trench, and modified Lower Miocene through Quaternary diatom zones for middle-to-high latitudes of the North Pacific. *In*, Kagami, H., Karig, D.E., Coulbourn, W.T., *et al.*, *Initial Reports of the Deep Sea Drilling Project.*, vol. 87, p. 393-481. U.S. Govt. Printing Office, Washington, D.C.
- Akiba, F., Yanagisawa, Y. and Ishii, T., 1982 : Neogene diatom biostratigraphy of the Matsushima area and its environs, Miyagi Prefecture, Northeast Japan. Bulletin of the Geological Survey of Japan, vol. 33, p. 215-239.
- Andrews, G.W., 1980 : Neogene diatoms from Petersburg, Virginia. *Micropaleontology*, vol. 26, p. 17-48.
- Anonymous, 1975: Proposal for a standardization of diatom terminology and diagnoses. *Beihefte zur Nova Hedwigia*, no. 53, p. 323-354.

- Baldauf, J.G. and Barron, J.A., 1991 : Diatom biostratigraphy : Kerguelen Plateau and Prydz Bay regions of the Southern Ocean. *In*, Barron, J.A., Larsen, B., *et al.*, *Proceedings of the Ocean Drilling Program, Scientific Results*, vol. 119, p. 547-598. College Station, TX (Ocean Drilling Program).
- Barron, J.A., 1976: Marine diatom and silicoflagellate biostratigraphy of the type Delmontian Stage and the type *Bolvia obliqua* Zone, California. *Journal of Research, U.S. Geological Survey*, vol. 4, p. 339–351.
- Barron, J.A., 1980 : Lower Miocene to Quaternary diatom biostratigraphy of Leg 57, off northeastern Japan, Deep Sea Drilling Project. *In*, Scientific Party, *Initial Reports of the Deep Sea Drilling Project.*, vols. 56 and 57, p. 641-685. U.S. Govt. Printing Office, Washington, D.C.
- Barron, J.A., 1981a : Late Cenozoic diatom biostratigraphy and paleoceanography of the middle-latitude eastern North Pacific, Deep Sea Drilling Project Leg 63. *In*, Yeats, R.S., Haq, B.U., *et al.*, *Initial Reports of the Deep Sea Drilling Project.*, vol. 63, p. 507-538. U.S. Govt. Printing Office, Washington, D.C.
- Barron, J.A., 1981b : Middle Miocene diatom biostratigraphy of DSDP Site 77B in the eastern equatorial Pacific. *Geoscience Journal*, vol. 2, p. 137-144.
- Barron, J.A., 1983 : Latest Oligocene through early middle Miocene diatom biostratigraphy of the eastern tropical Pacific. *Marine Micropaleontology*, vol. 7, p. 487-515.
- Barron, J.A., 1985a : Late Eocene to Holocene diatom biostratigraphy of the equatorial Pacific Ocean, Deep Sea Drilling Project Leg 85. *In*, Mayer, L., Theyer, F., *et al., Initial Reports of the Deep Sea Drilling Project.*, vol. 85, p. 413-456. U.S. Govt. Printing Office, Washington, D.C.
- Barron, J.A., 1985b: Miocene to Holocene planktic diatoms. In, Bolli, H.M., Saunders, J.B. and Perch-Nielsen, K., eds., Plankton Stratigraphy, p. 763-809. Cambridge University Press, Cambridge.
- Barron, J.A., 1992: Neogene diatom datum levels in the equatorial and North Pacific. *In*, Ishizaki, K. and Saito, T. eds., *Centenary of Japanese Micropaleontology*, p. 413-425. Terra Scientific Publishing Co., Tokyo.
- Barron, J.A., Keller, G. and Dunn, D.A., 1985 : A multiple microfossil biochronology for the Miocene. *Geologi*cal Society of America, Memoir 163, p. 21-36.
- Berggren, W.A., Kent, D.V., Flynn, J.J. and Van Couvering J.A., 1985 : Cenozoic geochronology. *Geological Society of America Bulletin*, vol. 96, p. 1407-1418.
- Burckle, L.H., 1972: Late Cenozoic planktonic diatom zones from the eastern equatorial Pacific. *Beihefte zur Nova Hedwigia*, no. 39, p. 217-248.
- Burckle, L.H., 1978: Marine diatoms. In, Haq, B.U. and Boersma, A. eds., Introduction to Marine Micropaleontology, p. 245-266. Elsevier, New York.
- Desikachary, T.V. and Maheshwari, C.L., 1958: Fossil diatoms from Colebrook Island. *Journal of the Indian Botanical Society*, vol. 38, p. 7-41.
- Desikachary, T.V., Latha, Y. and Ranjitha, Devi, K.A., 1984: *Rossiella* and *Bogorovia*: two fossil diatom genera. *Palaeobotanist*, vol. 32, p. 337-340.
- De Toni, J.B., 1894 : Sylloge algarum omnium hucusque

cognitarum vol. II. Bacillarieae sectio III Cryptoraphideae, p. 818-1556. Typis Seminarii, Patavii.

- Dzinoridge, R.N., Jousé, A.P., Koroleva-Golikova, G.S., Kozlova, G.E., Nagaeva, G.S., Petrushevska, M.G. and Strelnikova, N.I., 1978 : Diatom and radiolarian Cenozoic stratigraphy, Norwegian Basin ; DSDP Leg 38. *In, Initial Reports of the Deep Sea Drilling Project*, Supplement to vols. 38, 39, 40 and 41, p. 289– 427. U.S. Govt. Printing Office, Washington, D.C.
- Fenner, J., 1984a: Middle Eocene to Oligocene Planktonic diatom stratigraphy from Deep Sea Drilling sites in the South Atlantic, equatorial Pacific, and Indian Ocean. *In*, Hay, W.W., Sibuet, J.-C., *et al.*, *Initial Reports of the Deep Sea Drilling Project*, vol. 75, p. 1245–1270. U.S. Govt. Printing Office, Washington, D.C.
- Fenner, J., 1984b : Eocene-Oligocene planktic diatom stratigraphy in the low latitudes and the high latitudes. *Micropaleontology*, vol. 30, p. 319-342.
- Fenner, J., 1985 : Late Cretaceous to Oligocene planktic diatoms. *In*, Bolli, H.M., Saunders, J.B. and Perch-Nielsen, K., *eds.*, *Plankton Stratigraphy*, p. 713-762. Cambridge University Press, Cambridge.
- Fenner, J. and Mikkelsen, N., 1990: Eocene-Oligocene diatoms in the western Indian Ocean: Taxonomy, stratigraphy, and paleoecology. *In*, Duncan, R.A., Backman, J., Peterson, L.C., *et al.*, *Proceedings of the Ocean Drilling Program., Scientific Results*, vol. 115, p. 433-463. College Station, TX (Ocean Drilling Program).
- Fourtanier, E., 1987 : Diatomées Neogènes d'Afrique approche biostratigraphique en milieux marin (sudouest Africain) et continental. Doctoral thesis of University of Paris 6. 365 p. (Mémoires des Sciences de La Terre, Université Curie, Paris no. 87-44). (*in French*)
- Fourtanier, E., 1991: Diatom biostratigraphy of equatorial Indian Ocean Site 757. *In*, Pierce, J., Weissel, J., Taylor, E.A.J., *et al.*, *Proceedings of the Ocean Drilling Program.*, *Scientific Results*, vol. 121, p. 189-208. College Station, TX (Ocean Drilling Program).
- Gersonde, R., 1980: Paläoökologische und biostratigraphische Auswertung von Diatomeenassoziationen aus dem Messinium des Caltanissetta-Beckens (Sizilien) und einiger Vergleichs-Profile in so-spanien, NW-Algerien und auf Kreta. Dissertation zur Erlangung des Doktorgrades der Mathematisch-Naturwissenschaftlichen Fakultät der Chistian-Albrechts-Universität zu Kiel, p. 1-393. (*in German*)
- Gersonde, R. and Burckle, L.H., 1990 : Neogene diatom biostratigraphy of ODP Leg 113, Weddell Sea (Antarctic Ocean). *In*, Barker, P.F., Kennett, J.P., *et al.*, *Proceedings of the Ocean Drilling Program, Scientific Results*, vol. 113, p. 761-789. College Station, TX (Ocean Drilling Program).
- Gersonde, R. and Schrader, H., 1984: Marine planktic diatom correlation of lower Messinian deposits in the western Mediterranean. *Marine Micropaleontology*, vol. 9, p. 93-110.
- Gombos, A.M. Jr., 1975 : Fossil diatoms from Leg 7, Deep Sea Drilling Project. *Micropaleontology*, vol. 21, p. 306-333.
- Gombos, A.M.Jr., 1976 : Paleogene and Neogene diatoms

from the Falkland Plateau and Malvinas Outer Basin : Leg 36, Deep Sea Drilling Project. *In*, Barker, P.F., Dalziel, I.W., *et al., Initial Reports of the Deep Sea Drilling Project*, vol. 36, p. 575-687. U.S. Govt. Printing Office, Washington, D.C.

- Gombos, A.M. Jr., 1983 : Middle Eocene diatoms from the South Atlantic. *In*, Ludwig, W.J., Krasheninnikov, V.A. *et al.*, *Initial Reports of the Deep Sea Drilling Project.*, vol. 71, p. 565–581. U.S. Govt. Printing Office, Washington, D.C.
- Hajós, M., 1967 : Die Diatomeen der Miozänen Ablagerungen des Mátravorlandes. *Geologica Hungarica*, *Series Palaeontologica*, vol. 37, p. 31-401. (*in German*)
- Hajós M., 1986: Stratigraphy of Hungary's Miocene diatomaceous earth deposits. *Geologica Hungarica, Series Palaeontologica*, vol. 49, p. 1–339. (*in German and English*)
- Hanna, G.D., 1932 : The diatoms of Sharktooth Hill, Kern County, California. *Proceedings of the California Academy of Sciences, Fourth Series*, vol. 20, p. 161– 263.
- Harwood, D.M. and Maruyama, T., 1992 : Middle Eocene to Pleistocene diatom biostratigraphy of Southern Ocean sediments from the Kerguelen Plateau, Leg 120. *In*, Wise, S.W., Jr., Schlich, R., *et al.*, *Proceedings of the Ocean Drilling Program, Scientific Results*, vol. 120, p. 683-733. College Station, TX (Ocean Drilling Program).
- Hasegawa, Y., 1977: Late Miocene diatoms from the Nakayama Formation in the Sado Island, Niigata Prefecture, Japan. *Publications from the Sado Museum*, no. 7, p. 7-101. (*in Japanese with English abstract*)
- Hasle, G.R., Von Stosch, H.A. and Syvertsen, E.E., 1983: Cymatosiraceae, a new diatom family. *Bacillaria*, vol. 6, p. 9-156.
- Hays, J.D. et al., 1972: Initial Reports of the Deep Sea Drilling Project, vol. 9, 1025 p. U.S. Govt. Printing Office, Washington, D.C.
- Jousé, A.P., 1973: Diatoms in the Oligocene-Miocene biostratigraphic zones of the tropical areas of the Pacific Ocean. *Beihefte zur Nova Hedwigia* no. 45, p. 333-357.
- Jousé, A.P., 1976 : A review of the genus *Bogorovia* Jousé (Bacillariophyta). *Botanical Journal*, vol. 1, p. 1232– 1234. (*in Russian*)
- Jousé, A.P. ed., 1977 : Atlas of Microorganisms in Bottom Sediments of the Oceans, 196 p. Nauka, Moscow. (in Russian)
- Jousé, A.P. ed., 1979: The History of the Microplankton of the Norwegian Sea (On the Deep Sea Drilling Materials). 192 p. Nauka, Moscow. (in Russian)
- Kanaya, T., 1971: Some aspects of pre-Quaternary diatoms in the oceans. *In*, Funnell, B.M. and Riedel, W.R., eds., *The Micropalaeontology of Oceans*, p. 545-565. Cambridge University Press, London.
- Koizumi, I., 1972: Marine diatom flora of the Pliocene Tatsunokuchi Formation in Fukushima Prefecture. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series.*, no. 86, p. 340-359.
- Koizumi, I. and Tanimura, Y., 1985: Neogene diatom biostratigraphy of the middle latitude western North Pacific, Deep Sea Drilling Project Leg 86. *In*, Heath,

G.R., Burckle, L.H., *et al., Initial Reports of the Deep Sea Drilling Project.*, vol. 86, p. 269–300. U.S. Govt. Printing Office, Washington, D.C.

- Kolbe, R.W., 1954 : Diatoms from equatorial Pacific cores. *Reports of the Swedish Deep-sea Expedition*, vol. 4, no. 1, p. 1–49.
- Lohman, K.E., 1974: Lower Middle Miocene marine diatoms from Trinidad. Verhandlungen der Naturforschenden Gesellschaft in Basel, vol. 84, p. 326-360.
- Maruayma, T., 1984 : Miocene diatom biostratigraphy of onshore sequences on the Pacific side of northeast Japan, with reference to DSDP Hole 438A (Part 2). *Science Reports of the Tohoku University, Sendai, Second Series (Geogogy)*, vol. 55, p. 77–140.
- Monjanel, A.L., 1987: Oligocene to Holocene diatoms from the North Atlantic and the western Mediterranean: Biostratigraphy and paleoceanography. Doctoral thesis for L'Université de Bretagne Occidentale, 320 p. (*in French with English abstract*)
- Nishimura, A., 1986: Deep-sea sediments in the central equatorial Pacific (GH81-4 area). *Geological Survey* of Japan Cruise Report, vol. 21, p. 56-83.
- Oda, M., 1986: Some aspects and problems concerned with microfossil biochronology for the Neogene in central and northeast Honshu, Japan. *In*, Nakagawa, H., Kotaka, T. and Takayanagi, Y. *eds., Essays in Geology*, Professor Nobu Kitamura Commemorative Volume, p. 297-312. (*in Japanese with English abstract*)
- Powers, E.R., 1988 : Diatom biostratigraphy and paleoecology of the Miocene Pungo River Formation, Onslow Bay, North Carolina continental shelf. *Cushman Foundation Specical Publication*, vol. 25, p. 97-161.
- Radionova, E.P., 1991: Stratigraphy of Neogene sediments in a tropical area of the Pacific Ocean based on diatoms. *Transactions of Academy of Sciences of USSR*, vol. 456, p. 1-107. (*in Russian*)
- Rattray, J., 1889 : A revision of the genus *Coscinodiscus* and some allied genera. *Proceedings of the Royal Society of Edinburgh*, vol. 16, p. 449–692.
- Ross, R., Cox, E.J., Karayava, N.I., Mann, D.G., Paddock, T.B.B., Simonsen, R. and Sims, P.A., 1979: An amended terminology for the siliceous components of the diatom cell. *Beihefte zur Nova Hedwigia*, no. 64, p. 513-533.
- Round, F.E., Crawford, R.M. and Mann, D.G., 1990: *The Diatoms*, 747 p. Cambridge University Press, Cambridge.
- Schrader, H.-J., 1973 : Cenozoic diatoms from the northeast Pacific, Leg 18. *In*, Kulm, L.D., Von Huene, R., *et al., Initial. Reports of the Deep Sea Drilling Project.*, vol. 18, p. 637-797. U.S. Govt. Printing Office, Washington, D.C.
- Schrader, H.-J., 1974a: Revised diatom stratigraphy of the experimental Mohole Drillng, Guadalupe Sites. *Proceedings of the California Academy of Sciences, Fourth Series*, vol. 39, p. 517-562.
- Schrader, H.-J., 1974b: Cenozoic planktonic diatom stratigraphy of the tropical Indian Ocean. *In*, Fisher, R.L., Bunce, E.T., *et al.*, *Initial Reports of the Deep Sea Drilling Project*, vol. 24, p. 887-967. U.S. Govt.

Printing Office, Washington, D.C.

- Schrader, H.-J., 1976 : Cenozoic planktonic diatom biostratigraphy of the southern Pacific Ocean. *In*, Hollister, C.D., Craddock, C., *et al., Initial Reports of the Deep Sea Drilling Project*, vol. 35, p. 605-671. U.S. Govt. Printing Office, Washington, D.C.
- Schrader, H.-J., 1977 : Diatoms in DSDP Leg 41 sites. *In*, Lancelot, E., Seibold, E., *et al., Initial Reports of the Deep Sea Drilling Project*, vol. 41, p. 791-812. U.S. Govt. Printing Office, Washington, D.C.
- Schrader, H.-J., and Fenner, J., 1976: Norwegian Sea diatom biostratigraphy and taxonomy. *In*, Talwani, M., Udintsev, G. *et al.*, *Initial Reports of the Deep Sea Drilling Project*, vol. 38, p. 921-1099. U.S. Govt. Printing Office, Washington, D.C.
- Scientific Party, 1980: *Initial Reports of the Deep Sea Drilling Project.*, vols. 56 and 57, 1417 p. U.S. Govt. Printing Office, Washington, D.C.
- Simonsen, R., 1979: The diatom system: Ideas on phylogeny. *Bacillaria*, vol. 2, p. 9-71.
- Strelnikova, N.I., 1990: Evolution of diatoms during the

Cretaceous and Paleogene Periods. *Proceedings of the 10th International Diatom Symposium*, p. 195-204. Koeltz Scientific Books, Koenigstein.

- Tracey, J.I.Jr. et al., 1971: Initial Reports of the Deep Sea Drilling Project, vol. 8, 1037 p. U.S. Govt. Printing Office, Washington, D.C.
- Yanagisawa, Y., 1994 : Koizumia Yanagisawa gen. nov., a new marine fossil araphid diatom genus. Transactions and Proceedings of the Palaeontological Society of Japan, New Series, no. 176, p. 591-617.
- Yanagisawa, Y., 1995: Cenozoic diatom genus Bogorovia: Jousé: an emended description. Transactions and Proceedings of the Palaeontological Society of Japan, New Series, no. 177, p. 21-42.
- Yanagisawa, Y., Kobayashi, I., Takeuchi, K., Tateishi, M., Chihara, K. and Kato, H., 1986 : Geology of the Ojiya district, Geological Survey of Japan Quadrangle Series (Scale 1: 50,000), 177 p. (in Japanese with English abstract)
- Van Heurck, H., 1883 : Synopsis des Diatomées de Belgique, Atlas plate, p. 104-132.

Appendix table. Occurrence of *Rossiella* species in DSDP Holes 70A, 71 and 77B. Diatom zones after Barron (1985b) and Fenner (1985). Preservation: G=good, M=moderate, P=poor. Abundance: A=abundant, C=common, F=few, R=rare. Abundance of each species, A=Abundant (>8%), C=common (5-7%), F=few (2-4%), R=rare (<1%).

Diatom zones	NTD 12B 12A	^{эю} н 77В 77В	200 12 13	1 - 1 - Section	9 Interval	(E) - 30 - 101	D D D Preservation	Rossiella elongata	R. paleacea	R. fourtanierae	R. femerae	. R. symmetrica		Diatom zones	NTD	Por Hole 1	28 28 28	- 2 - 4	0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	E) - 72 - 72 - 72	D Preservation	A DUNGANCE	Rossiela elongata	- H R. paleacea	R. fourtanierae	, , R. fennerae	R. symmetrica
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983 Cenozoic diatom genus *Bogorovia* Jousé : An emended description

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Abstract. An emended definition of the fossil diatom genus *Bogorovia* Jousé is presented along with a detailed description of eight species. The stratigraphic range and geographic distribution of each species are provided based on analysis of deep-sea cores and literature survey. The genus is closely related to the genus *Ressiella* Desikachary et Maheshwari, but is distinguished from the latter mainly by the presence of transapical costae. It also shows a close resemblance to *Koizumia* Yanagisawa, but differs mainly by the structure of the marginal ridge. On the basis of certain characteristic features, the genus *Bogorovia* can be placed in the family Cymatosiraceae Hasle, von Stosch et Syvertsen. Four new species are described and two new combinations are established; *Bogorovia barronii* Yanagisawa sp. nov., *B. curvata* Yanagisawa sp. nov., *B. puncticulata* Yanagisawa sp. nov., *B. gombosii* (Desikachary) Yanagisawa comb. nov. and *B. lancettula* (Schrader) Yanagisawa comb. nov.

Key words : Taxonomy, diatom, Bogorovia, fossil, biostratigraphy

Introduction

Bogorovia is a diatom genus erected by Jousé (1973) for a Late Oligocene marine diatom, *B. veniamini* Jousé, which is of great importance in Late Oligocene to Early Miocene diatom marine biostratigraphy (e.g. Fenner, 1985; Barron, 1985b). A detailed morphologic and biostratigraphic examination of the genus *Bogorovia* and its related genus *Rossiella* Desikachary et Maheshwari has revealed the need for taxonomic revision of this diatom group, showing that there are three distinct subgroups that merit separate generic recognition; *Bogorovia* emended, *Ressiella* emended and *Koizumia* gen. nov. The latter two genera are dealt with elsewhere (Yanagisawa, 1994, 1995).

In this paper, an emended definition of the genus *Bogorovia* is presented along with detailed descriptions of its eight members. Furthemore, the stratigraphic range and geographic distribution of each species are established on the basis of analysis of deep-sea cores and literature survey.

Material and methods

For biostratigraphic study, samples from the Upper Oligocene to Upper Miocene sections of DSDP Holes 71, 77B and 70A in the eastern equatorial Pacific were used (Table 1). Slides of some selected samples studied by

No.	Cores & samples	Area	Location	Formation	References and remarks
1	DSDP Hole 70A	Eastern equatorial Pacific	6°20.08' N, 140°21.72' W	DSDP core	Tracey et al. (1971)
2	DSDP Hole 71	Eastern equatorial Pacific	4°28.28' N, 140°18.91' W	DSDP core	Tracey et al. (1971), Barron (1983)
3	DSDP Hole 77B	Eastern equatorial Pacific	0°28.90' N, 133°13.70' W	DSDP core	Hays et al. (1972), Barron(1981b, 1983)
4	DSDP Hole 438A	Northwest Pacific	40°37.79' N, 143°14.15' E	DSDP core	Scientific Party (1980), Barron(1980b)
5	P 225	Central equatorial Pacific	3°13.32' N, 169°41.65' W	Piston core	Nishimura (1986)
6	Р3	Indian Ocean off Java	11°59.04' S, 113°31.37' E	Piston core	Yanagisawa (1987), Honza et al. (1987)
7	M 32	Ajigaura, Ibaraki, Japan	36°22.82' N, 140°37.42' E	Isozaki F.	Maruyama (1984)
8	A-1	Tomioka, Fukushima, Japan	37°20.26' N, 140°59.31' E	Drill core	Yanagisawa et al. (1989)

Table 1. Cores and samples used in this study.

Barron (1983, 1985a) and the slides deposited in the DSDP Reference Center in the National Science Museum (Tokyo) were examined in this study. Samples from the Lower Miocene through Quaternary section of DSDP Hole 438A in the northwestern Pacific were also analyzed. Slides analyzed by Akiba *et al.* (1982), Maruyama (1984) and Akiba (1986), together with those deposited in the DSDP Reference Center in the National Science Museum (Tokyo) were re-examined with special attention to the genus *Bogorovia*. For taxonomic study and SEM observations, several selected samples were used to supplement the DSDP samples (Table 1).

Preparation methods for light and scanning electron microscopy (SEM) were described in Yanagisawa (1994).

Results and discussion

As a result of taxonomic study, eight species are recognized, including four new species and two new combinations as follows: *Bogorovia barronii* Yanagisawa sp. nov., *B. curvata* Yanagisawa sp. nov., *B. gombosii* (Desikachary) Yanagisawa comb. nov., *B. lancettula* (Schrader) Yanagisawa comb. nov., *B. praepaleacea* (Schrader) Jousé, *B. puncticulata* Yanagisawa sp. nov., *B.* rostrata Yanagisawa sp. nov., *B. veniamini* Jousé ex Yanagisawa

Morphology

Morphologic terminology for the genus was introduced in Yanagisawa (1994), and general terminology for description of frustule follows Anonymous (1975), Ross *et al.* (1979), Simonsen (1979) and Round *et al.* (1990).

The valve outline of this genus is linear-lanceolate and isopolar (Figure 1). The apical axis is generally straight except for *B. curvata* which has a curved apical axis. The apex is rostrate with an apical pore field consisting of fine puncta. All species have transapical costae (ribs) which extend from both valve margins. The costae are generally continuous, but some of them are interrupted at the middle. For description, the spacing of transapical costae is classified into two categories; narrowly spaced type (9-14 costae in 10 μ m) and broadly spaced type (6-8.5 costae in 10 μ m).

All members of this genus have marginal ridges of the fused-type wherein the marginal ridges of sibling valves are completely fused so that a set of fused sibling valves seems as if it were a frustule (Figure 1). The marginal ridge is either of type 3 or type 2 (See Yanagisawa, 1994).



Figure 1. Structure of a chain of frustule of Bogorovia puncticulata Yanagisawa sp. nov.



Figure 2. Stratigraphic distribution of *Rossiella* and *Bogorovia* species in DSDP Holes 77B, 71 and 70A. Narrow horizontal lines show samples examined. Each dot indicates the presence of each species. Original data are presented in Appendix table and appendix table in Yanagisawa (1995).

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The type 3 is a fused-type marginal ridge with three longitudinal rows of pores. The type 2 marginal ridges have two longitudinal rows of pores. *Bogorovia* species may form a long chain colony by the fusion of their marginal ridges (Figure 1). In some species, valves with the separate-type marginal ridge are observed. These may be separation valves that may have a role to separate an otherwise interminably long chain into shorter chains.



Figure 3. Stratigraphic distribution of *Bogorovia* species. Low-latitude diatom zones after Barron (1985b) and Fenner (1985), and North Pacific diatom zones after Akiba (1986). Correlation to the time scale of Berggren *et al.* (1985) is adjusted through Barron *et al.* (1985) and Oda (1986).

A rimoportula (labiate process) is present generally in "one per cell pattern"; a funstule consists of a process valve and a non-process valve, and thus this genus is heterovalvate. In the non-process valve, a small structureless area is present where a rimoportula might be located if it were present. The non-process valve of *Bogorovia puncticulata* has a small knob which may be a reduced rimoportula (Figures 13-1, 13-2), suggesting that the rimoportula of the non-process valve may be secondarily reduced. All species have a subcentral rimoportula without exception.

The valve face is convex. In some species, the valve face is perforated with areolae, but others lack areolae, in which case the valve face is hyaline. The areolae of this genus are classified into four types for description: medium (ca. 0.8 μ m in diameter), fine (ca. 0.4-0.5 μ m in diameter), very fine areolae (less than 0.1 μ m in diameter) and the absence of areolae (hyaline). The areolae are circular in shape and distributed sparsely and randomly on the valve face.

The cingulum is composed of a few bands with a row of small puncta, but its detailed composition is not known at present.

Stratigraphic distribution

The stratigraphic occurrences of *Bogorovia* species are presented in Figure 2 and Appendix table for DSDP Holes 77B, 71 and 70A. The stratigraphic ranges of each species are shown in Figure 3, which is mainly based on Figure 2 as well as on some other important biostratigraphic studies such as Baldauf (1985), Baldauf and Barron (1991), Barron (1981a, 1981b, 1983, 1985a, 1985b, 1992), Fenner (1984a, 1984b, 1985), Fourtanier (1987, 1991), Gersonde and Burckle (1990), Harwood and Maruyama (1992), Sancetta (1982) and Schrader (1973, 1974a, 1974b, 1976). Correlation to the time scale of Berggren *et al.* (1985) is adjusted through Barron *et al.* (1985) and Oda (1986).

Geographic distribution

The geographic distribution of each species was surveyed from literature. The results are shown in Figures 7, 10, 11, 15, 17 and 18. All species of the genus are distributed mainly at low latitudes in the Pacific, Atlantic and Indian Oceans with rare occurrences at middle latitudes, indicating that they are essentially oceanic warmwater species

Systematics

In this paper, the classification system of Round *et al.* (1990) is adopted for the description of the genus *Bogorovia* because the system appears to be the most natural system at present.

Class Coscinodiscophyceae Round et Crawford, 1990 Subclass Cymatosirophycidae Round et Crawford, 1990 Order Cymatosirales Round et Crawford, 1990 Family Cymatosiraceae Hasle,

von Stosch et Syvertsen, 1983 Subfamily Cymatosiroideae Hasle, von Stosch et Syvertsen, 1983

Genus Bogorovia, Jousé, 1973 emend. Yanagisawa

Generic type.-Bogorovia veniamini Jousé ex Yanagisawa

Original description.—Valves lanceolate or linearlanceolate with slightly rostrate ends. No axial area present. Valve surface with closely packed areolae, in transverse rows near the margin of the valve, elsewhere randomly arranged. No intercalary bands or pseudosepta present (Jousé, 1973).

Emended description.—Cell heterovalvate, rectangular or lanceolate in girdle view, forming inseparable chain colonies. Separation valve or end valve separates chain colonies. Cingula with several bands with or without fine puncta. Valve slightly convex, linear-lanceolate. Apices with small apical pore field, mostly rostrate. Marginal ridge always present, completely fused with sibling valve. Rimoportula one per cell; a frustule consisting of a process valve and a non-process valve. Rimoportula located at subcentral position near the margin. Transapical costae developed.

Comparison.—The genus resembles the genus Rossiella Desikachary et Maheshwari, but clearly differs from the latter genus mainly by having transapical costae, relatively small areolae or missing areolae. The genus *Bogorovia* is similar to the genus *Koizumia*, but the two genera are distinguished by the type of marginal ridge; *Bogorovia* has marginal ridges of type 3 or type 2, whereas *Koizumia* is characterized by a type 4 marginal ridge (Yanagisawa, 1994). *Bogorovia* is also discriminated from *Koizumia* in having randomly distributed areolae on the valve face, in contrast to the regularly arranged areolae of *Koizumia* forming transpical and longitudinal rows.

Bogorovia closely resembles genera in the Cymatosiraceae such as *Cymatosira* Grunow and *Campylosira* Grunow in Van Heurck in that they commonly possess a generally dipolar outline, chain colonies connected by marginal ridge or linking spines, rimoportula in the pattern of one per cell, and an ocellus or apical pore field at each apex; the genus *Bogorovia* therefore can be included in the family Cymatosiraceae Hasle, von Stosch et Syvertsen. Jousé (1973) has already suggested that the genus *Bogorovia* has some relationship to *Campylosira* and *Cymatosira*.

Stratigraphic occurrence.—Late Oligocene to Middle Pleistocene. The first species of this genus is *B. gombosii* which appeared in the uppermost part of the b Subzone of the *Rocella vigilans* Zone of Fenner (1984a, 1985). The last species *R. curvata* is found in the *Pseudoeunotia doliolus* Zone (NTD 17).

Habitat.—Because of its dominant occurrence in oceanic sediments, most species of the genus are probably holoplanktonic, making a long chain formed by fused

la. Areolae present	
1b. Areolae absent	6
2a. Areolae medium or fine	
2b. Areolae very fine	
3a. Areolae medium and transapical costae partially developed	B. gombosii
3b. Areolae fine and transapical costae well developed	
4a Transapical costae broadly spaced and valve relatively large	e <i>B veniamin</i>
iu. Tunoupieur eestue ereauly spueee une iu. e renue ery img	
4b. Transapical costae narrowly spaced and valve relatively sm	all
4b. Transapical costae narrowly spaced and valve relatively sm 5a. Valve with slightly rostrate apices	allB. barronia
4b. Transapical costae narrowly spaced and valve relatively sm 5a. Valve with slightly rostrate apices	allB. barroniu B. puncticulata B. rostrata
4b. Transapical costae narrowly spaced and valve relatively sm 5a. Valve with slightly rostrate apices	allB. barronii B. puncticulata B. rostrata 7
4b. Transapical costae narrowly spaced and valve relatively sm 5a. Valve with slightly rostrate apices	allB. barronii B. puncticulata B. rostrata 7 B. praepaleacea
4b. Transapical costae narrowly spaced and valve relatively sm 5a. Valve with slightly rostrate apices	allB. barronin B. puncticulata B. rostrata 7 B. praepaleacea B. lancettula

Table 2. Key to species based on light microscopy.





Figure 5. Scanning electron photomicrographs of *Bogorovia gombosii* (Desikachary) Yanagisawa comb. nov. and *B. barronii* Yanagisawa sp. nov. Scale bars equal 5 μ m. **1, 2.** *Bogorovia gombosii* (Desikachary) Yanagisawa comb. nov. DSDP Hole 71, 36-2, 125-129 cm. (1) Inner view of valve. (2) Oblique view of a set of sibling valves. **3-5.** *Bogorovia barronii* Yanagisawa sp. nov. Sample P 225 VII 20, equatorial Pacific. (3, 4) Outer view of a separation valve. (5) Enlarged view of a valve apex with an apical pore field.

marginal ridges.

Geographic distribution.—All species are distributed mainly in the low-latitude areas of the Pacific, Atlantic and Indian Oceans, and rarely and sporadically occur also in the middle- to high-latitude areas.

Key to species based on light microscopy is presented in Table 2.

Bogorovia gombosii (Desikachary) Yanagisawa comb. nov.

Figures 4-1, 4-2, 5-1, 5-2

Basionym. *Rossiella gombosii* Desikachary in Desikachary *et al.*, 1984, p. 338.

Synonymy. Bogorovia veniamini Jousé, Schrader, 1976, p. 630, pl. 5, figs. 22-23; Gombos, 1976, p. 593, pl. 1, figs. 6, 7, pl. 12, figs. 2, 4 (non pl. 12, fig. 1); Genus et species indet., Schrader, 1976, pl. 5, fig. 16; *Rossiella* sp., Gombos and Ciesielski, 1983, p. 604, pl. 24, figs. 1-2; *Rossiella* aff. *R. symmetrica* Fenner, Fourtanier, 1991, pl. 4, fig. 2.

Additional description.—Valve lanceolate with slightly rostrate rounded apices, $30-64 \ \mu m \log 7-10.5 \ \mu m$ wide (Figure 6). Valve face slightly convex, covered with rounded medium areolae distributed randomly and sparsely, 6-7 in 10 μ m. On both valve sides, numerous transapical costae present, 7-8.5 in 10 μ m, incomplete, not reaching valve center (Figure 5-1). Marginal ridge, fused-type with three longitudinal rows of rounded pores (type 3), 7-8.5 pores in 10 μ m (Figure 5-2). A small pore field present at each apex. A subcentral rimoportula, one per cell, located near edge of valve face.

Figure 4. Light photomicrographs of Bogorovia species. Scale bar equals 10 µm. 1, 2. Bogorovia gombosii (Desikachary) Yanagisawa comb. nov. DSDP Hole 71, 37-5, 87-89 cm. 3. Bogorovia veniamini Jousé ex Yanagisawa (an intermediate form to Bogorovia barronii). DSDP Hole 71, 34-4, 125-129 cm. 4-10. Bogorovia veniamini Jousé ex Yanagisawa. (4, 6) DSDP Hole 71, 37-2, 87-89 cm. (5) DSDP Hole 71, 33-2, 87-89 cm. (7) DSDP Hole 71, 36-2, 125-129 cm. (8) DSDP Hole 71, 42-2, 87-89 cm. (9) DSDP Hole 71, 31-2, 70-72 cm. (10) DSDP Hole 71, 39-1, 87-89 cm. 11-14. Bogorovia barronii Yanagisawa sp. nov. (14) holotype. (11, 13, 14) DSDP Hole 71, 26-4, 70-72 cm. (12) DSDP Hole 71, 29-4, 70-72 cm. 15, 16. Bogorovia puncticulata Yanagisawa sp. nov. (primitive form). (15) holotype, P 225, VII 20, equatorial Pacific. (16) DSDP Hole 71, 29-4, 70-72 cm. 17-20. Bogorovia puncticulata Yanagisawa sp. nov. (advanced form). (17) P 225, VII 20. (18) DSDP Hole 77B, 23-2, 35-37 cm. (19) DSDP Hole 77B, 15-6, 77-78 cm. (20) M 32, Isozaki Formation, Ajigaura area, Japan. 21. Bogorovia rostrata Yanaisawa sp. nov. Holotype, DSDP Hole 77B, 23-2, 35-37 cm. 22-28. Bogorovia lancettula (Schrader) Yanagisawa comb. nov. (22) DSDP Hole 77B, 19-6, 38-40 cm. (23) DSDP Hole 77B, 17-1, 18-20 cm. (24) DSDP Hole 77B, 20-2, 38-40 cm. (25) DSDP Hole 77B, 20-6, 38-40 cm. (26) DSDP Hole 77B, 17-6, 23-25 cm. (27, 28) DSDP Hole 77B, 19-6, 38-40 cm. 29-31. Bogorovia praepaleacea (Schrader) Jousé. DSDP Hole 77B, 12-1, 29-30 cm. 32, 33. Bogorovia puncticulata Yanagisawa sp. nov. (girdle views). (32) M 32, Isozaki Formation. Ajigaura area, Japan. (33) DSDP Hole 71, 29-4, 70-72 cm. 34, 35. Bogorovia lancettula (Schrader) Yanagisawa comb. nov. (girdle views). (34) DSDP Hole 77B, 20-6, 38-40 cm. (35) DSDP Hole 77B, 19-6, 38-40 cm. 36, 37. Bogorovia praepaleacea (Schrader) Jousé (girdle views). DSDP Hole 77B, 17-6, 23-25 cm. 38-40. Rossiella curvata Yanagisawa sp. nov. P 3CC, Sunda Forearc off Java Island. (39) holotype.



Figure 6. Size variation in *Bogorovia gombosii* (Desikachary) Yanagisawa comb. nov. **A.** Scatter plot of valve width versus length. **B.** Scatter plot of valve length versus the number of transapical costae in 10 μ m. **C.** Scatter plot of valve width versus the number of transapical costae in 10 μ m. Samples from no. 2 in Table 1.



Figure 7. Geographic distribution of *Bogorovia gombosii* (Desikachary) Yanagisawa comb. nov. Closed circles: localities reported with figures. Open circle: locality reported without figures. 1. DSDP Hole 71, equatorial Pacific (this study).
2. DSDP Hole 575A, equatorial Pacific (Fourtanier, 1987).
3. DSDP Hole 758, equatorial Indian Ocean (Fourtanier, 1991).
4. DSDP Hole 278, Pacific sector of the Southern Ocean (Schrader, 1976).
5. DSDP Hole 328B, South Atlantic (Gombos, 1976).
6. DSDP Hole 513A, South Atlantic (Gombos and Ciesielski, 1983).

Comparisons.—Bogorovia gombosii bears a close resemblance to Rossiella symmetrica, but differs from the latter species by the presence of transpical costae and more sparsely distributed smaller areolae on valve face. It is also similar to Bogorovia veniamini, but distinguished by its larger and more sparse areolae and the less developed transapical costae.

The species was first recognized by Gombos and Ciesielski (1983) as *Rossiella* sp., but Fenner (1984a, 1984b) regarded it as synonymous with *R. symmetrica*. Desikachary *et al.* (1984) erected the species based on Gombos and Ciesielski's (1983) specimen, but no one else has referred to it to date. Fourtanier (1991) reported it as *Rossiella* aff. *R. symmetrica*.

Stratigraphic range.—At low-latitudes, the first occurrence of this species is in the upper part of the Rocella vigilans Zone. It last occurs near the top of the A Subzone of the *R. paleacea* Zone (NTD 1A) (Figures 2, 3).

Geographic distribution.—The species occurs in the equatorial Pacific (Fourtanier, 1987, this study), the equatorial Indian Ocean (Fourtanier, 1991) and the Southern Ocean (Schrader, 1976; Gombos, 1976, 1983; Gombos and Ciesielski, 1983) (Figure 7).

Bogorovia veniamini Jousé ex Yanagisawa

Figures 4-3-10, 8-1-9.

Jousé, 1973, p. 351, pl. 4, figs. 1-3; Jousé, 1976, p. 1233, figs. 1-3; Jousé ed., 1977, pl. 54, figs. 1-5; Barron, 1983, p. 512, pl. V, fig. 3; Barron, 1985a, pl. 8, fig. 12; Fenner, 1985, p. 727; Barron, 1985b, p. 780, fig. 9.5; Kim and Barron, 1986, p. 177, pl. 5, figs. 11-12; Fourtanier, 1991, pl.



Figure 8. Scanning electron photomicrographs of *Bogorovia veniamini* Jousé ex Yanagisawa. DSDP Hole 71, 36–2, 125–129 cm. Broad and narrow scale bars equal 5 μ m and 1 μ m, respectively. **1**, **2**. Two sets of fused sibling valves. Arrows indicate the outer openings of rimoportulae. **3**, **4**. Inner views of a valve, showing a rimoportula (arrow heads). **5**, **6**. Outer views of a separation valve with separated-type marginal ridge. **7**. Inner view of a non-process valve (the opposite side of the specimen shown in Figs. 8–3, 8–4). **8**, **9**. Enlarged views of an apex with an apical pore field.



Figure 9. Size variation in *Bogorovia veniamini* Jousé ex Yanagisawa and *B. barronii* Yanagisawa sp. nov. **A.** Scatter plot of valve width versus length. **B.** Scatter plot of valve length versus the number of transapical costae in 10 μ m. **C.** Scatter plot of valve width versus the number of transapical costae in 10 μ m. Samples from nos. 2, 3, 5 in Table 1.

4, fig. 3; Radionova, 1991, p. 98, pl. 23, fig. 7.

Additional description.-Valve linear-lanceolate with slightly rostrate rounded apices, 18-82 µm long, 6.5-12 μ m wide (Figure 9). Valve face convex, densely punctuated by fine areolae distributed randomly, 8-10 areolae in 10 μ m. Transapical costae, 5.5-8 in 10 μ m, extend from both sides to form a zigzag-longitudinal line in valve center. Marginal ridge, fused-type with three longitudinal rows of large round pores (type 3), 5-6 pores in 10 μ m (Figure 8-2). A small pore field is present at each apex (Figure 8-8). A subcentral rimoportula, one per cell, located near valve edge with an internal lip-shaped opening (Figures 8-3, 8-4). Non-process valve with a small hyaline area which a rimoportula might occupy if present (Figure 8-7). Cingulum consisting of two or three bands (Figures 8-1, 8-2). Separation valves with a separated-type marginal ridge (type 1) are sometimes observed (Figures 8-5, 8-6; Fourtanier, 1987, pl. 14, fig. 5).

Holotype.—Plate 4, fig. 1 in Jousé (1973) designated in this paper (deposited in the collections of the Micropaleontological Laboratory of the Institute of Oceanology, Academy of Science of Russia).

Type locality and sample.—R/V "Vityaz" Station 5996/ 8, 630 cm depth in a core, 10°58′N, 153°23′W, central equatorial Pacific (Early Miocene in age).

Comparisons.—Bogorovia veniamini resembles B. gombosii but differs by the smaller and denser areolation and the well-developed transapical costae. It is discriminated from B. barronii by the broader and larger valve and wider spacing of transapical costae (Figure 9).

Stratigraphic range.—The first occurrence of this species defines the base of the Bogorovia veniamini Zone

(Fenner, 1984b) (Figure 3). Its last occurrence defines the top of the *R. paleacea* Zone (NTD 1) (Barron, 1983). This species is one of the most abundant constituents of the late Oligocene to earliest Miocene marine diatom assemblage.

Geographic distribution.—The species is found abundantly at low-latitudes in the Atlantic, Pacific, and Indian oceans (e.g. Jousé, 1973, 1976; Barron, 1983; Fenner, 1985; Fourtanier, 1991; Radionova, 1991) and also in the Southern Ocean (e.g. Baldauf and Barron, 1991; Harwood and Maruyama, 1992) (Figure 10). It also occurs in Baja California (Kim and Barron, 1986), the North Atlantic and northern Italy (Monjanel, 1987), but not in the high-latitude North Pacific (Akiba *et al.*, 1993).

Discussion.—As pointed out by Sancetta (1985), no specimen was designated as holotype of this species by Jousé (1973), and as no further action has been taken in this regard, the species has remained invalid according to Article 37 of the International Code of Botanical Nomenclature. It is hereby validated by the above designation of a holotype.

When Desikachary *et al.* (1984) clarified the taxonomy of the genus *Rossiella*, they did not transfer *Bogorovia veniamini* Jousé to *Rossiella* bacause the species is so different from the members of *Rossiella* in having transverse rows of areolae with distinct transverse (transapical) costae. However, this taxonomic treatment of Desikachary *et al.* (1984) is apparently incosistent with their admission of *Rossiella praepaleacea* (Schrader) Gersonde et Schrader and the establishment of *Rossiella gombossi* Desikachary, because the two species have the distinct transapical costae which is one of the important features of the genus *Bogorovia.* Gersonde and Schrader (1984)



Figure 10. Geographic distribution of *Bogorovia veniamini* Jousé ex Yanagisawa. Closed circles : localities reported with figures. Open circles : localities reported without figures.
1. DSDP Hole 71, equatorial Pacific (this study ; Barron, 1983, 1985b).
2. DSDP Hole 575A, equatorial Pacific (Barron, 1985a ; Fourtanier, 1987 ; Radionova, 1991).
3. R/V "Vityaz" 5996, equatorial Pacific (Jousé, 1973, 1976 ; Jousé *et al.*, 1977).
4. San Gregorio Formation, La Ventana, Baja California, Mexico (Kim and Barron, 1986).
5. DSDP Hole 758, equatorial Indian Ocean (Fourtanier, 1991).
6. DSDP Hole 714, equatorial Indian Ocean (Fenner and Mikkelsen, 1990).
7. DSDP Hole 747A, Indian sector of the Southern Ocean (Harwood and Maruyama, 1992).
8. DSDP Hole 748B, Indian sector of the Southern Ocean (Harwood and Maruyama, 1992).
9. DSDP Hole 744A, Indian sector of the Southern Ocean (Fenner, 1984a).
10. DSDP Hole 278, Pacific sector of the Southern Ocean (Fenner, 1984a).
11. DSDP Hole 357, South Atlantic (Fenner, 1984a).
12. DSDP Hole 366A, equatorial Atlantic (Schrader, 1977 ; Fenner, 1984a, 1984b).
13. DSDP Hole 369A, northeast Atlantic (Schrader, 1977 ; Fenner, 1984a, 1984b).
14. DSDP Hole 116, Rockall Plateau, North Atlantic (Monjanel, 1987).
15. Tripoli di Contignaco, north Italy (Monjanel, 1987).

and Barron (1985b) also did not transfer *Bogorovia veniamini* to the genus *Rossiella* without giving any reasons.

Bogorovia barronii Yanagisawa sp. nov.

Figures 4-11-14, 5-3-5.

Synonym. Bogorovia sp., Akiba, 1980, p. 11, pl. 4, fig. 48.

Description.—Valve linear-lanceolate with slightly rostrate rounded apices, $20-43 \ \mu m$ long, $4.5-6.5 \ \mu m$ wide (Figure 9). Valve face convex, covered with fine areolae, 10-12 in $10 \ \mu m$. Transapical costae, 10-11.5 in $10 \ \mu m$. Marginal ridge, fused-type with three longitudinal rows of pores (type 3), 10 pores in $10 \ \mu m$. A small pore field is present at each apex (Figure 5-5). A subcentral rimoportula, one per cell, located near the valve edge. A separation valve with separated-type mariginal ridge (type 1) is observed (Figures 5-3, 5-4).

Holotype.—Figure 4-14 (GSJF12755 deposited in the Geological Survey of Japan).

Type locality and sample.-DSDP Hole 71, Core 26,

Section 4, Interval 70-72 cm, 4°28.28'N, 140°18.91'W, eastern equatorial Pacific (Early Miocene in age, the *Triceratium pileus* Zone, NTD 3).

Comparisons.—This species is very similar to Bogorovia veniamini, but it differs by its more narrowly spaced transapical costae and narrower valve (Figure 9). It also resembles *B. puncticulata* but is distinguished from the latter species by its larger areolae.

Stratigraphic range.—At low-latitudes, the species occurs from the middle part of the B subzone of the *R. paleacea* Zone (NTD 1B) to the uppermost part of the *T. pileus* Zone (NTD 3) (Figure 3). Reworked specimens are sometimes found in the middle Miocene intervals in DSDP Holes 71 and 77B (Figure 2).

Geographic distribution.—This new species has been found in DSDP Holes 71 and 77B, core P 225 recovered in equatorial Pacific (this study), the Early Miocene Hota Group in the Boso Peninsula, Japan (Akiba, 1980) and DSDP Hole 545 in the North Atlantic off Africa (Monjanel, 1987) (Figure 11).

Etymology.-The species name is dedicated to Dr. John Arthur Barron, who has worked extensively on



Figure 11. Geographic distribution of *Bogorovia barronii* Yanagisawa sp. nov. Closed circles : localities reported with figures.
1. DSDP Hole 71, equatorial Pacific (this study).
2. DSDP Hole 77B, equatorial Pacific (this study).
3. Geological Survey of Japan piston core P 225, equatorial Pacific (this study).
4. Hota Group, Boso Peninsula, Japan (Akiba, 1980).
5. DSDP Hole 545, northeast Atlantic off Africa (Monjanel, 1987).

marine diatom biostratigraphy and supplied the author the type material of this species.

and Schrader, Yanagisawa, 1993, pl. 2, fig. 3.

Bogorovia puncticulata Yanagisawa sp. nov.

Figures 4-15-20, 4-33, 4-34, 12-1-5, 13-1-11.

Synonymy. Bogorovia veniamini Jousé, Fourtanier and Macharé, 1988, pl. 2, fig. 17; Rossiella sp. 1, Fourtanier, 1991, pl. 4, fig. 6; Rossiella cf. lancettula (Schrader) Gersonde Description.—Valve linear-lanceolate with slightly rostrate rounded apices, 13–51 μ m long, 4–7 μ m wide (Figure 14). At each apex, an apical pore field is present (Figure 12–5). Valve face convex, punctated by very fine areolae, densely in the primitive form (10–12 in 10 μ m) and sparsely in the advanced form (8–10 in 10 μ m). Transapical ribs, 8.5–14 in 10 μ m. Marginal ridge, fused-type



Figure 12. Scanning electron photomicrographs of *Bogorovia puncticulata* Yanagisawa sp. nov. (primitive form). Sample P 225, VII 20, equatorial Pacific. Broad and narrow scale bars equal $5 \mu m$ and $1 \mu m$, respectively. **1.** Inner view of a set of sibling valves. **2, 3.** Inner views of a separation valve. Arrow indicates a rimoportula. **4.** Enlargement of Fig. 12–1, showing the outer opening of a rimoportula (arrow). **5.** Enlarged view of a valve apex with an apical pore field.



Figure 13. Scanning electron photomicrographs of *Bogorovia puncticulata* Yanagisawa sp. nov. (advanced form). Sample M 32, Isozaki Formation, Ajigaura area, Japan. Broad and narrow scale bars equal 5 μ m and 1 μ m, respectively. **1, 3.** Inner views of a non-process valve. Arrows indicate a small knob which may be a "reduced" rimoportula. **2, 4.** Inner views of a process valve (the opposite side of the specimen shown in Figs. 13-1, 13-2). Arrows indicate a rimoportula. **5.** Girdle view of a set of sibling valves with fused-type marginal ridge (type 3). **6, 7.** Outer views of a separation valve with separated-type marginal ridge (type 1). **8.** Enlarged view of an apex with an apical pore field. **9.** Oblique view of a set of sibling valves. Arrow indicates the outer opening of a rimoportula. **10, 11.** Views of valve interior and marginal ridge. Each arrow indicates a rimoportula.

with three longitudinal rows of pores (type 3), 8-10 pores in 10 μ m (Figure 13-1). Separation valve exceptionally has separated-type marginal ridge with one row of pores (type 1) (Figures 12-2, 13-6). A subcentral rimoportula, one per cell, located near valve edge with its internal lipshaped opening oriented diagonal to apical axis, and with a small external pore at the marginal ridge (Figures 13-4, 13-11). Non-process valve with a small knob at the position which a rimoportula might occupy if present (Figure 13-2).

Holotype.—Figure 4-15 (GSJF14593 deposited in the Geological Survey of Japan).

Type locality and sample.—Piston core sample P225, VII 20 cm (570 cm from the core top); 3°13.32'N, 169°41.65'W, 5,427 m in water depth, central Pacific. The core was recovered by GH81-4 Cruise of the Geological Survey of Japan (Nishimura, 1986). Core P225, 768 cm in thickness, is composed of the upper Pleistocene unit and the lowermost Miocene unit, which are bounded by a hiatus 268 cm from the top. The type sample is taken from the lower unit of dark brown siliceous ooze. The radiolarian fauna indicates Early Miocene age, ranging from 20.7 to 23.2 Ma (Nishimura, 1986). The diatom assemblage from the sample is correlative with the *Triceratium pileus* Zone (NTD 3) of Barron (1985b).

Comparisons.—This species differs from Bogorovia lancettula and B. praepaleacea by the presence of areolae on the valve face. It is distinguished from B. barronii by finer areolation. The species is similar to B. rostrata, but differs by its more slender valve outline and not so strongly rostrate apices (Figure 14).

Stratigraphic range.-This species occurs from the



Figure 14. Size variation in *Bogorovia puncticulata* Yanagisawa sp. nov. and *B. rostrata* Yanagisawa sp. nov. **A.** Scatter plot of valve width versus length. **B.** Scatter plot of valve length versus the number of transapical costae in 10 μ m. **C.** Scatter plot of valve width versus the number of transapical costae in 10 μ m. The samples from nos. 2-5, 7, 8 in Table 1.

upper part of the C Subzone of the *R. paleacea* Zone (NTD 1C) to the top of the B Subzone of the *Coscinodiscus yabei* Zone (NPD 10B) in the equatorial Pacific (Figures 2, 3). It was found from the upper part of the *Denticulopsis praedimorpha* Zone (NPD 5B) to the lower part of the *Thalassiosira yabei* Zone (NPD 5C) in DSDP Hole 438A (Yanagisawa, 1994, fig. 6), but this range is much shorter than that in the low-latitude.

Geographic distribution.—This new species is found commonly in the equatorial Pacific (this study) (Figure 15). The species also has been figured from the equatorial Indian Ocean (Fourtanier, 1991) and the Cabellas Formation in Peru (Fourtanier, 1987, Fourtanier and Macharé, 1988). It occurs in DSDP Hole 438A and several Japanese on-land sections (this study; Yanagisawa, 1993).

Discussion.—The species shows a typical phyletic change with gradual reduction of areolae through time. The older primitive form has densely perforated puncta (Figures 4-15, 12-1—5), whereas the younger advanced form is characterized by sparsely distributed areolae on the valve face (Figures 4-16—20, 13-1—11). The youngest form carries only a few puncta (Figure 4-19), showing very close resemblance to *B. lancettula.*

Etymology.—The species name is derived from its minutely punctated valve face.

Bogorovia rostrata Yanagisawa sp. nov.

Figure 4-21.

Description.—Valve broadly lanceolate with strongly rostrate rounded apices, $29-43 \,\mu$ m long, $8.5-9.5 \,\mu$ m wide (Figure 14). Valve face convex, sparsely punctated by very fine areolae, 8-10 in 10 μ m. Transpical ribs, 9.5-10 in 10 μ m. Marginal ridge, fused-type with three longitu-

dinal rows of pores (type 3), 10 pores in 10 μm. A subcentral rimoportula, one per cell, located near valve edge. *Holotype*.—Figure 4-21 (GSJF12808 deposited in the

Geological Survey of Japan).

Type locality and sample.—DSDP Hole 77B, Core 23, Section 2, Interval 35-37 cm, 0°28.90'N, 133°13.70'W, eastern equatorial Pacific (Middle Miocene in age, the *Coscinodiscus lewisianus* Zone, NTD 6).

Comparisons.—Bogorovia rostrata is very similar to the advanced form of *B. puncticulata* in having sparsely distributed small puncta on the valve face, but distinctly differs from the latter by its very broad form with strongly rostrate apices (Figure 14).

Stratigraphic range.—The species has its first occurrence in the lower part of the *Coscinodiscus lewisianus* Zone (NTD 6) and its last occurrence in the lowermost *Actinocyclus moronensis* Zone (NTD 9) (Figures 2, 3).

Geographic distribution.—At present, this species is found only in DSDP Hole 77B (Figure 15).

Etymology.—The species is named from its strongly rostrate apices.

Bogorovia lancettula (Schrader) Yanagisawa comb. nov.

Figures 4-22-28, 4-34, 4-35.

- Basionym. *Cussia lancettula* Schrader, 1974a, p. 532, fig. 1: 5, 9-10
- Synonymy. Cussia lancettula Schrader, Schrader, 1974b, p. 914, pl. 19, fig. 16 (non pl. 19, figs. 14-15); Schrader and Fenner, 1976, p. 975; Kulm et al., 1981, pl. 1, fig. 11; Cussia sp. cf. C. lancettula Schrader, Barron, 1980a, pl. 6, fig. 18; Rossiella lancettula (Schrader) Gersonde and Schrader, 1984, p. 106.

Additional description.-Valve linear-lanceolate with


Figure 15. Geographic distribution of *Bogorovia puncticulata* Yanagisawa sp. nov. and *B. rostrata* Yanagisawa sp. nov. Closed circles : *R. punticulata* localities reported with figures. Open circles : *R. punticulata* localities reported without figures. Open triangle : *R. rostrata* localities reported with figures. **1.** DSDP Hole 71, equatorial Pacific (this study). **2.** DSDP Hole 77B, equatorial Pacific (this study). **3.** Geological Survey of Japan piston core P 225, equatorial Pacific (this study). **4.** Caballas Formation, Pisco, Peru (Fourtanier and Macharé, 1988; Fourtanier, 1987). **5.** M 32, Isozaki Formation, Ajigaura, Ibaraki, Japan (this study). **6.** Minamiimogawa Formation (Teradomari F.), Imogawa, Niigata, Japan (Yanagisawa, 1993). **7.** DSDP Hole 438A, northwest Pacific off Japan (this study). **8.** DSDP Hole 758, equatorial Indian Ocean (Fourtanier, 1991).



Figure 16. Size variation in *Bogorovia lancettula* (Schrader) Yanagisawa comb. nov. and *B. praepaleacea* (Schrader) Jousé. A. Scatter plot of valve width versus length. B. Scatter plot of valve length versus the number of transapical costae in 10 μ m. C. Scatter plot of valve width versus the number of transapical costae in 10 μ m. Samples from no. 2, 3 in Table 1.



Figure 17. Geographic distribution of *Bogorovia lancettula* (Schrader) Yanagisawa comb. nov. Closed circles : localities reported with figures. Open circle : locality reported without figures. **1.** DSDP Hole 77B, equatorial Pacific (this study; Fourtanier, 1987). **2.** Experimental Mohole Drilling Guadalupe Site, northeast Pacific off Baja California (Schrader, 1974a). **3.** DSDP Hole 420, eastern equatorial Pacific (Barron, 1980a). **4.** Dredge sample 46-16 from sea floor off Peru (Kulm *et al.*, 1981). **5.** DSDP Hole 238, equatorial Indian Ocean (Schrader, 1974b). **6.** DSDP Hole 213, equatorial Indian Ocean (Schrader, 1974b). **7.** Puente Gentil, Guadal-quivir Basin, Spain (Monjanel, 1987). **8.** DSDP Hole 362, South Atlantic off Angola (Schrader, 1978).

slightly rostrate and acutely rounded apices, $17-45 \,\mu$ m long, $3.5-5 \,\mu$ m wide (Figure 16). Valve face convex, hyaline without areolae. Transapical costae, 10-13 in 10 μ m. Marginal ridge, fused-type with two rows of pores (type 2), 9-10 pores in 10 μ m. A subcentral rimoportula, one per cell, located near valve edge. A separation valve with separated-type marginal ridge (type 1) has been observed (Fourtanier, 1987, pl. 15, figs. 6, 7).

Comparisons.—The species differs from *B. puncticulata* by the absence of areolae on valve face and the two rows of marginal ridge (type 2). It is distinguished from *B. praepaleacea* by the narrower interval of transapical costae and smaller valve size (Figure 16). This species differs from *B. curvata* by its transapically symmetric valve outline.

Stratigraphic range.—The first occurrence of the species lies in the middle part of the *Coscinodiscus gigas* var. *diorama* Zone (NTD 7) (Figure 3). Its last occurrence, though not precisely known at present, may be near the top of the *Nitzschia jouseae* Zone (NTD 14) according to Schrader (1974b).

Geographic distribution.—The species is distributed mainly at low latitudes (Figure 17). It was first reported from the Experimental Mohole core off Baja California, Mexico (Schrader, 1974a), but it is rather rare at middle to high latitudes in the Indian and Pacific Oceans, and common in the equatorial Pacific (Barron, 1980a; Kulm *et al.*, 1981; Fourtanier, 1987; this study), the equatorial Indian Ocean (Schrader, 1974b) and the South Atlantic off Namibia (Schrader, 1978). Monjanel (1987) found this species in the Miocene deposits in Spain.

Bogorovia praepaleacea (Schrader) Jousé 1976

Figures 4-29-31, 4-36, 4-37.

- *Bogorovia praepaleacea* (Schrader) Jousé, 1976, p. 1233 ; Barron, 1981a, pl. 4, fig. 14, p. 104.
- Basionym. *Coscinodiscus praepaleaceus* Schrader, 1973, p. 703, pl. 3, figs. 1-9.
- Synonymy. Cussia praepaleacea (Schrader) Schrader, 1974a, p. 543, fig. 1: 8; Schrader, 1974b, p. 914; Koizumi, 1975, p. 876, pl. 4, figs. 36-37; Cussia lancettula Schrader, Gombos, 1975, p. 316, pl. 3, figs. 9-12; Rossiella praepaleacea (Schrader) Gersonde, Barron, 1985a, pl. 8, fig. 1; Rossiella preapaleacea (Schrader) Gersonde and Schrader, 1984, p. 104-105; Yanagisawa et al., 1989, pl. 5, fig. 34; Radionova, 1991, p. 82.

Additional description.—Valve linear-lanceolate with slightly rostrate and acutely rounded apices, $37-64 \,\mu$ m long, $5-7 \,\mu$ m wide (Figure 16). Valve face convex, hyaline without areolae. Transapical costae, 7-8.5 in 10 μ m. Marginal ridge, fused-type with two rows of pores (type 2), about 6 pores in 10 μ m. A subcentral rimoportula, one per cell, located near valve margin. Fourtanier (1987, pl. 15, figs. 1, 2) figured a separation valve with separated-type marginal ridge (type 1).

Comparisons.—Bogorovia praepaleacea shares some common features with *B. lancettula* and *B. curvata*; e.g. the hyaline valve face and type 2 marginal ridge, but it differs from the latter two species by more widely spaced interval of transapical costae (Figure 16). It is different from *B. puncticulata* and *B. barronii* by the absence of valve face areolae. This species has been sometimes confused with "Rossiella" mediopunctata (=Koizumia adaroi (Azpeitia) Yanagisawa) (Barron, 1975; Abbott and Andrews, 1979; Gersonde and Schrader, 1984; Powers, 1988) or with *K. akibae* (Akiba *et al.*, 1982; Akiba, 1986), but it is clearly distinguished from the latter two species in lacking areolae on the valve face. In spite of its specific name, *B. praepaleacea* is not the ancestor of *Rossiella paleacea.*

Stratigraphic range.—This species first occurs from the middle part of the *Actinocyclus moronensis* Zone (NTD 9) in DSDP Hole 77B (Figure 3). In this study, however, the last occurrence of this species could not be determined in DSDP Hole 77B because of the lack of samples.

According to Sancetta (1982) and Baldauf (1985), the last occurrence of *B. praepaleacea* lies in the middle part of the A Subzone of the *Thalassiosira convexa* Zone (NTD 13A) in DSDP Holes 503, 572 and 573 in the eastern equatorial Pacific, and was estimated at about 5.9 Ma (Baldauf, 1985) or 6.0 Ma (Barron, 1985a, 1992) (Figure 3). In this study, the estimated age of Barron (1992) is adopted.

In DSDP Hole 173, northeast Pacific off California, Schrader (1973) recognized *B. praepaleacea* last occurs between the core 20-2 (55-56 cm) and core 20-3 (55-56 cm), a horizon which Barron and Kellar (1983) assigned to the lower part of the c Subzone of the *Denticulopsis hustedtii-D. lauta* Zone which is equivalent to the *Denticulopsis dimorpha* Zone (NPD 5D) of Akiba (1986). The horizon is about 8.9 Ma in age and so *B. praepaleacea* disappeared earlier in the northeast Pacific than in the equatorial Pacific.

Geographic distribution.—The species was first described from the mid-latitude North Pacific (Schrader, 1973) and successively reported from this region (Schrader, 1974a; Koizumi, 1975; Barron, 1981a; Yanagisawa *et al.*, 1989) (Figure 18). However, it appears to be more common in the equatorial Pacific (Gombos, 1975; Sancetta, 1982; Baldauf, 1985; Fourtanier, 1987; this study), and may be a warm-water species.

Discussion.—As pointed out by Fourtanier (1987, p. 107-108), there is some suspicion that the holotype specimen of *B. praepaleacea* chosen by Schrader (1973) may be a valve of *Koizumia adaroi*. Despite the original description by Schrader (1973) that *B. praepaleacea* has a hyaline valve face (absence of areolae), the holotype specimen seems to have circular areolae between the transapical costae on the valve face. However, I cannot assert the presence of areolae with confidence because of the rather poor photograph of the specimen. Another problem is that the holotype of *B. praepaleacea* is from a sample which is far above the main range of the species in DSDP Hole 173 and interpreted as reworked by Schrader (1973, table 1). Detailed examination of the holotype specimen is required to solve these problems. If the holotype of *B. praepaleacea* is proved to be *K. adaroi*, then a new species name needs to be proposed for the taxon.

The species name means that the species is antecedent to *Rossiella paleacea*, probably because Schrader (1973) regarded the species as the ancestor of *R. paleacea*. However, *B. praepaleacea* is not the precursor of *R. paleacea* nor closely related to *R. paleacea*.

Bogorovia curvata Yanagisawa sp. nov.

Figures 4-38-40.

Synonymy. Cussia lancettula Schrader, Schrader, 1974b, pl. 19, figs. 14-15 (non pl. 19, fig. 16); Gen. indet., species indet., Schrader, 1974b, pl. 19, fig. 17; Rossiella cf. lancettula (Schrader) Gersonde et Schrader, Yanagisawa, 1987, pl. 5, figs. 3-5.

Description.—Valve delicately silicified, linear-lanceolate, apically curved with less convex ventral side and more convex dorsal side, 16-30 μ m long, 4.5-5 μ m wide. Apices slightly rostrate and acutely rounded. Valve face hyaline without areolae. Transapical ribs, 12-13 in 10 μ m. A subcentral rimoportula located near the valve edge.

Holotype.—Figure 4-39 (GSJF14591 deposited in the Geological Survey of Japan).

Type locality and sample.—Piston core sample P3CC, Indian Ocean off Java Island, 11°59.04′, 113°31.37′, 4442 m in water depth (Yanagisawa, 1987; Honza *et al.*, 1987). Middle Pleistocene in age. The sample is assigned to the *Pseudoeunotia doliolus* Zone (NTD 17) of Barron's (1985b) low-latitude diatom zonation (Yanagisawa, 1987). According to Nishida (1987), the sample can be placed in the nannofossil CN14b Zone of Okada and Bukry (1980). *Buccinosphaera invaginata* Haeckel (Radiolaria) in this sample suggests a late Middle Pleistocene age younger than 0.2 Ma. In summary, integrating all available age information gives the age of about 0.2 Ma for the sample.

Comparisons.—This new species is typified by its curved valve outline, which is similar to the genus *Campylosia.* This character distinguished this species from all other *Bogorovia* species. The species most resembles *B. lancettula* in having a hyaline valve face and almost the same valve size.

Stratigraphic range.—The stratigraphic range of this species is not well known at present. The oldest known recorded occurrence of this species is in the lower part of the *Nitzschia jouseae* Zone (NTD 14) (Schrader, 1976) (Figure 3). The youngest occurrence of this species is reported in the type sample which is dated about 0.2 Ma.

Geographic distribution.—This species has been reported only from the equatorial Indian ocean at present (Schrader, 1974b; Yanagisawa, 1987) (Figure 18).

Etymology.—The species name is derived from its curved valve outline.



Figure 18. Geographic distribution of *Bogorovia praepaleacea* (Schrader) Jousé and *Bogorovia curvata* Yanagisawa sp. nov. Circle : *Bogorovia praepaleacea* ; Triangle : *Bogorovia curvata* ; Closed circles and triangles : localities reported with figures. Open circles : localities reported without figures. 1. DSDP Hole 77B, equatorial Pacific (this study ; Fourtanier, 1987). 2. DSDP Hole 66.1, equatorial Pacific (Gombos, 1975). 3. DSDP Hole 573, equatorial Pacific (Baldauf, 1985). 4. DSDP Hole 572D, equatorial Pacific (Barron, 1985a; Baldauf, 1985). 5. DSDP Hole 503, eastern equatorial Pacific (Sancetta, 1982 ; Baldauf, 1985). 6. Experimental Mohole Drilling Guadalupe Site, northeast Pacific off Baja California (Schrader, 1974a). 7. DSDP Hole 469, northeast Pacific (Barron, 1981a). 8. DSDP Hole 173, northeast Pacific (Schrader, 1973). 9. DSDP Hole 303, northwest Pacific (Koizumi, 1975). 10. Core A-1, Taga Group, Futaba area, Fukushima, Japan (Yanagisawa *et al.*, 1989). 11. DSDP Hole 238, equatorial Indian Ocean (Schrader, 1974b). 12. Piston core P 3, equatorial Indian Ocean off Java, Indonesia (Yanagisawa, 1987 ; this study).

Note on some species related (?) to Bogorovia

"Bogorovia" sparsipunctata Hendey

Hendey, 1981, p. 99-100, pl. 4, fig. 22.

Remarks.—The species is characterized by its fusiform valve outline and sparsely punctated valve surface. If it is included in the genera *Bogorovia* or *Rossiella*, the species might be placed in *Rossiella* because the species lacks transapical costae. However, *B. sparsipunctata* has no affinity to any species in *Rossiella*. Until its structure is elucidated by electron microscope examination, the correct taxonomic position of this species can not be determined nor transferred to the genus *Rossiella*. Therefore the species is referred to under its original generic name.

Cymatosira lorenziana Grunow

Hasle et al., 1983, p. 19-22, fig. 1-25.

Synonymy. *Cussia* species 1, Schrader, 1974a, p. 543, figs. 1-18, 19; *Bogorovia cypriata* Gardette, 1978, p. 762-763, p. 1, figs. 1-12; *Cussia paleacea* (Grunow) Schrader, Abbott and Andrews, 1979, p. 241, pl. 3, fig. 14; *Cymatosira* sp., Abbott, 1980, pl. 1, fig. 13; *Bogorovia* (?) *cypriata* Gardette, Desikachary *et al.*, 1984, p. 338, pl. 1, fig. 6; *Cussia* (?) *lancettula* Schrader, Desikachary *et al.*, 1984, p. 338, pl. 1, fig. 12

Remarks.—The species found in fossil material have been sometimes reported as species of *Bogorovia* or *Cussia. Bogorovia cypriata* Gardette is a fossil species described from the Upper Miocene deposits of Cyprus (Gardette, 1978). However, its valve outline, size and distribution of areolae and valve architecture are just the same as those of *Cymatosira lorenziana* Grunow (Hasle *et al.*, 1983), and therefore *B. cypriata* is a synonym of *C. lorenziana.*

Cymatosira sp. A

Cussia sp. 1, Schrader, 1974b, p. 914, pl. 18, fig. 12; *Cymatosira* aff. *lorenziana* Grunow, Akiba, 1980, p. 11, pl. 4, fig. 47.

Remarks.—Cussia sp. 1 of Schrader (1974a) closely resembles *C. lorenziana* and therefore can be included in the genus *Cymatosira*. However, *Cymatosira* sp. A is

distinct from the latter species in having a transapical hyaline zone along the transapical axis. This species is found commonly from the Early to Middle Miocene sediments of Japan (e.g. Akiba, 1980). It will be described as a distinct species elsewhere.

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References

- Abbott, W.H., 1980: Diatom and stratigraphically significant silicoflagellates from the Atlantic Margin Coring Project and other Atlantic margin sites. *Micropaleontology*, vol. 26, p. 49-80.
- Abbott, W.H. and Andrews, G.W., 1979: Middle Miocene marine diatoms from the Hawthorn Formation within the Ridgeland Trough, South Carolina and Georgia. *Micropaleontology*, vol. 25, p. 225-271.
- Akiba, F., 1980 : A lower Miocene diatom flora from the Boso Peninsula, Japan, and the resting spore formation of an extinct diatom *Kisseleviella carina* Sheshukova-Poretzkaya. *Bulletin of Technical Laboratory*, *JAPEX*, vol. 23, p. 81-100.
- Akiba, F., 1986 : Middle Miocene to Quaternary diatom biostratigraphy in the Nankai Trough and Japan Trench, and modified Lower Miocene through Quaternary diatom zones for middle-to-high latitudes of the North Pacific. *In*, Kagami, H., Karig, D.E., Coulbourn, W.T., *et al., Initial Reports of the Deep Sea Drilling Project.*, vol. 87, p. 393-481. U.S. Govt. Printing Office, Washington, D.C.
- Akiba, F., Hiramatsu, C. and Yanagisawa, Y., 1993: A Cenozoic diatom genus *Cavitatus* Williams; an emended description and two new biostratigraphically useful species, *C. lanceolatus* and *C. rectus* from Japan. *Bulletin of the National Science Museum.*, *Tokyo, Series C*, vol. 19, p. 11–39.
- Akiba, F., Yanagisawa, Y. and Ishii, T., 1982 : Neogene diatom biostratigraphy of the Matsushima area and its environs, Miyagi Prefecture, Northeast Japan. Bulletin of the Geological Survey of Japan, vol. 33, p. 215-239.
- Anonymous, 1975: Proposal for a standardization of diatom terminology and diagnoses. *Beihefte zur Nova Hedwigia*, vol. 53, p. 323-354.

- Baldauf, J.G., 1985: A high resolution late Miocene-Pliocene diatom biostratigraphy for the eastern equatorial Pacific. In, Mayer, L., Theyer, F., et al., Initial Reports of the Deep Sea Drilling Project, vol. 85, p. 457-475. U.S. Govt. Printing Office, Washington, D.C.
- Baldauf, J.G. and Barron, J.A., 1991 : Diatom biostratigraphy : Kerguelen Plateau and Prydz Bay regions of the Southern Ocean. *In*, Barron, J., Larsen, B., *et al.*, *Proceedings of the Ocean Drilling Program, Scientific Results*, vol. 119, p. 547-598. College Station, TX (Ocean Drilling Program).
- Barron, J.A., 1975: Late Miocene-Early Pliocene marine diatoms from southern California. *Palaeontographica, Abteilung B*, vol. 151, p. 97-170.
- Barron, J.A., 1980a: Upper Pliocene and Quaternary diatom biostratigraphy of Deep Sea Drilling Project Leg 54, Tropical eastern Pacific. *In*, Rosendahl, B.R., Hekinian R., *et al.*, *Initial Reports of the Deep Sea Drilling Project*, vol. 54, p. 455-485. U.S. Govt. Printing Office, Washington, D.C.
- Barron, J.A., 1980b : Lower Miocene to Quaternary diatom biostratigraphy of Leg 57, off northeastern Japan, Deep Sea Drilling Project. *In*, Scientific Party, *Initial Reports of the Deep Sea Drilling Project*, vols. 56 and 57, p. 641-685. U.S. Govt. Printing Office, Washington, D.C.
- Barron, J.A., 1981a : Late Cenozoic diatom biostratigraphy and paleoceanography of the middle-latitude eastern North Pacific, Deep Sea Drillisng Project Leg 63. *In*, Yeats, R.S., Haq., B.U., *et al.*, *Initial Reports of the Deep Sea Drilling Project*, vol. 63, p. 507-538. U.S. Govt. Printing Office, Washington, D.C.
- Barron, J.A., 1981b : Middle Miocene diatom biostratigraphy of DSDP Site 77B in the eastern equatorial Pacific. *Geoscience Journal*, vol. 2, p. 137-144.
- Barron, J.A., 1983 : Latest Oligocene through early middle Miocene diatom biostratigraphy of the eastern tropical Pacific. *Marine Micropaleontology*, vol. 7, p. 487-515.
- Barron, J.A., 1985a : Late Eocene to Holocene diatom biostratigraphy of the equatorial Pacific Ocean, Deep Sea Drilling Project Leg 85. *In*, Mayer, L., Theyer, F., *et al.*, *Initial Reports of the Deep Sea Drilling Project*, vol. 85, p. 13-456. U.S. Govt. Printing Office, Washington, D.C.
- Barron, J.A., 1985b : Miocene to Holocene planktic diatoms. In, Bolli, H.M., Saunders, J.B. and Perch-Nielsen, K., eds., Plankton Stratigraphy, p. 763-809. Cambridge University Press, Cambridge.
- Barron, J.A., 1992 : Neogene diatom datum levels in the equatorial and North Pacific. *In*, Ishizaki, K. and Saito, T. eds., Centenary of Japanese Micropaleontology, p. 413-425. Terra Scientific Publishing Co., Tokyo.
- Barron, J.A. and Keller, G., 1983 : Paleotemperature oscillations in the middle and late Miocene of the northeastern Pacific. *Micropaleontology*, vol. 29 p. 150-181.
- Barron, J.A., Keller, G. and Dunn, D.A., 1985 : A multiple microfossil biochronology for the Miocene. *Geological Society of America, Memoir* 163, p. 21-36.
- Berggren, W.A., Kent, D.V., Flynn, J.J. and Van Couvering

J.A., 1985 : Cenozoic geochronology. *Geological* Society of America Bulletin, vol. 96, p. 1407-1418.

- Desikachary, T.V., Latha, Y. and Ranjitha, Devi, K.A., 1984: *Rossiella* and *Bogorovia*: two fossil diatom genera. *Palaeobotanist*, vol. 32, p. 337-340.
- Fenner, J., 1984a: Middle Eocene to Oligocene planktonic diatom stratigraphy from Deep Sea Drilling sites in the South Atlantic, equatorial Pacific, and Indian Ocean. *In*, Hay, W.W., Sibuet, J.-C., *et al., Initial Reports of the Deep Sea Drilling Project*, vol. 75, p. 1245-1270. U.S. Govt. Printing Office, Washington, D.C.
- Fenner, J., 1984b : Eocene-Oligocene planktic diatom stratigraphy in the low latitudes and the high latitudes. *Micropaleontology*, vol. 30, p. 319-342.
- Fenner, J., 1985 : Late Cretaceous to Oligocene planktic diatoms. *In*, Bolli, H.M., Saunders J.B. and Perch-Nielsen, K., *eds.*, *Plankton Stratigraphy*, p. 713-762. Cambridge University Press, Cambridge.
- Fenner, J. and Mikkelsen, N., 1990: Eocene-Oligocene diatoms in the western Indian Ocean: Taxonomy, stratigraphy, and paleoecology. *In*, Duncan, R.A., Backman, J., Peterson, L.C., *et al.*, *Proceedings of the Ocean Drilling Program, Scientific Results*, vol. 115, p. 433-463. College Station, TX (Ocean Drilling Program).
- Fourtanier, E., 1987 : Diatomées Neogènes d'Afrique approche biostratigraphique en milieux marin (sudouest Africain) et continental. Doctoral thesis of University of Paris 6, 365 p. (Mémoires des Sciences de La Terre, Université Curie, Paris no. 87-44).
- Fourtanier, E., 1991: Diatom biostratigraphy of equatorial Indian Ocean Site 757. In, Pierce, J., Weissel, J., Taylor, E.A.J., et al., Proceedings of the Ocean Drilling Program, Scientific Results, vol. 121, p. 189-208. College Station, TX (Ocean Drilling Program).
- Fourtanier, E. and Macharé, J., 1988: Late Eocene to Pliocene marine diatoms from Peru. *Proceedings of* 9th International Diatom Symposium, p. 151-163. Biopress Ltd., Bristol and Koeltz Scientific Books, Koenigstein.
- Gardette, D., 1978 : A new species of marine diatom from the Upper Miocene of Cyprus : *Bogorovia cypriata*. *Géobios*, vol. 11, p. 761-767.
- Gersonde, R., and Burckle, L.H., 1990 : Neogene diatom biostratigraphy of ODP Leg 113, Weddell Sea (Antarctic Ocean). *In*, Barker, P.F., Kennett, J.P., *et al.*, *Proceedings of the Ocean Drilling Program, Scientific, Results*, vol. 113, p. 761-789. College Station, TX (Ocean Drilling Program).
- Gersonde, R. and Schrader, H., 1984: Marine planktic diatom correlation of lower Messinian deposits in the western Mediterranean. *Marine Micropaleontology.*, vol. 9, p. 93-110.
- Gombos, A.M. Jr., 1975 : Fossil diatoms from Leg 7, Deep Sea Drilling Project. *Micropaleontology*, vol. 21, p. 306-333.
- Gombos, A.M. Jr., 1976: Paleogene and Neogene diatoms from the Falkland Plateau and Malvinas Outer Basin: Leg 36, Deep Sea Drilling Project. *In*, Barker, P.F., Dalziel, I.W., *et al.*, *Initial Reports of the Deep Sea Drilling Project*, vol. 36, p. 575-687. U.S. Govt. Printing Office, Washington, D.C.

- Gombos, A.M. Jr., 1983 : Survey of diatoms in the upper Oligocene and lower Miocene in Holes 515B and 516F. In, Barker, P.F., Carlson, R.L., Johnson, D.A. et al., Initial Reports of the Deep Sea Drilling Project, vol. 72, p. 793-804. U.S. Govt. Printing Office, Washington, D.C.
- Gombos, A.M.Jr. and Ciesielski, P.F., 1983 : Late Eocene to Early Miocene diatoms from the Southwest Atlantic. *In*, Ludwig, W.J., Krasheninnikov, V.A. *et al.*, *Initial Reports of the Deep Sea Drilling Project*, vol. 71, p. 538-634. U.S. Govt. Printing Office, Washington, D.C.
- Harwood, D.M. and Maruyama, T., 1992 : Middle Eocene to Pleistocene diatom biostratigraphy of Southern Ocean sediments from the Kerguelen Plateau, Leg 120. *In*, Wise, S.W., Jr., Schlich, R., *et al.*, *Proceedings of the Ocean Drilling Program, Scientific Results*, vol. 120, p. 683-733. College Station, TX (Ocean Drilling Program).
- Hasle, G.R., Von Stosch, H.A. and Syvertsen, E.E., 1983: Cymatosiraceae, a new diatom family. *Bacillaria*, vol. 6, p. 9-156.
- Hays, J.D. et al., 1972 : Initial Reports of the Deep Sea Drilling Project, vol. 9. 1025 p. U.S. Govt. Printing Office, Washington, D.C.
- Hendey, N.I., 1981: Miocene diatoms from the subantarctic south-west Pacific. *Bacillaria*, vol. 4, p. 65-124.
- Honza, E., Joshima, M., Budhi, A.S. and Nishimura, A., 1987 : Sediments and rocks in the Sunda Forearc. *CCOP Technical Bulletin*, vol. 19, p. 63-68. Committee for Coordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas (CCOP), Bangkok, Thailand.
- Jousé, A.P., 1973: Diatoms in the Oligocene-Miocene biostratigraphic zones of the tropical areas of the Pacific Ocean. *Beihefte zur Nova Hedwigia* no. 45, p. 333-357.
- Jousé, A.P., 1976 : A review of the genus *Bogorovia* Jousé (Bacillariophyta). *Botanical Journal*, vol. 1, p. 1232-1234.
- Jousé, A.P., ed., 1977 : Atlas of microorganisms in bottom sediments of the Oceans. 196 p., Nauka, Moscow.
- Kim, W.H. and Barron, J.A., 1986 : Diatom biostratigraphy of the Upper Oligocene to lowermost Miocene San Gregorio Formation, Baja California Sur, Mexico. *Diatom Research*, vol. 1, p. 169–187.
- Koizumi, I., 1975: Neogene diatoms from the northwestern Pacific Ocean, Deep Sea Drilling Project. In, Karig, D.E., Ingle, J.C.Jr., et al., Initial Reports of the Deep Sea Drilling Project, vol. 32, p. 865-889. U.S. Govt. Printing Office, Washington, D.C.
- Kulm, L.D., Thormburg, T.D., Schrader, H., Masias, A., Resig, J.M. and Johnson, L., 1981: Late Cenozoic carbonate on the Peru continental margin: Lithostratigraphy, biostratigraphy, and tectonic history. *Geological Society of America, Memoir* 154, p. 469-507.
- Maruyama, T., 1984 : Miocene diatom biostratigraphy of onshore sequences on the Pacific side of northeast Japan, with reference to DSDP Hole 438A (Part 2). *Science Reports of the Tohoku University, Sendai, Second Series (Geology)*, vol. 55, p. 77-140.
- Monjanel, A.L., 1987: Oligocene to Holocene diatoms

from the North Atlantic and the western Meditarranean: Biostratigraphy and paleoceanography. Doctoral thesis for L'Université de Bretagne Occidentale, 320 p. (*in French with English abstract*)

- Nishida, S., 1987 : Calcareous nannoplankton biostratigraphy in the Sunda area. CCOP Technical Bulletin, vol. 19, p. 69-72. Committee for Co-ordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas (CCOP), Bangkok, Thailand.
- Nishimura, A., 1986: Deep-sea sediments in the central equatorial Pacific (GH81-4 area). *Geological Survey* of Japan Cruise Report, vol. 21, p. 56-83.
- Oda, M., 1986: Some aspects and problems concerned with microfossil biochronology for the Neogene in central and northeast Honshu, Japan. *In*, Nakagawa, H., Kotaka, T. and Takayanagi, Y. eds., *Essays in Geology, Professor Nobu Kitamura Commemorative Volume*, p. 297-312. (*in Japanese with English abstract*)
- Okada, H. and Bukry, D., 1980: Supplementary modification and introduction of code numbers to the lowlatitude coccolith biostratigraphic zonation (Bukry, 1973; 1975). *Marine Micropaleontology*, vol. 5, p. 321-325.
- Powers, E.R., 1988 : Diatom biostratigraphy and paleoecology of the Miocene Pungo River Formation, Onslow Bay, North Carolina continental shelf. *Cushman Foundation Special Publication*, vol. 25, p. 97-161.
- Radionova, E.P., 1991: Stratigraphy of Neogene sediments in a tropical area of the Pacific Ocean based on diatoms. *Transactions of the Academy of Sciences of USSR*, vol. 456, p. 1-107. (*in Russian*)
- Ross, R., Cox, E.J., Karayava, N.I., Mann, D.G., Paddock, T.B.B., Simonsen, R. and Sims, P.A., 1979: An amended terminology for the siliceous components of the diatom cell. *Beihefte zur Nova Hedwigia*, vol. 64, p. 513-533.
- Round, F.E., Crawford, R.M. and Mann, D.G., 1990: *The Diatoms - Biology and Morphology of the Genera*. 747 p. Cambridge University Press, Cambridge.
- Sancetta, C.A., 1982: Diatom biostratigraphy and paleoceanography, Deep Sea Drilling Project Leg 68. *In*, Prell, W.L., Gardner, J.V., *et al. Initial Reports of the Deep Sea Drilling Project*, vol. 68, p. 301-309. U.S. Govt. Printing Office, Washington, D.C.
- Sancetta, C.A., Carroll, S.E., Hillman N.S., Janal, M.J. and Van Couvering, J.A. *eds.*, 1985: *Catalogue of Diatoms*, Book 1, The Ellis and Messina Catalogues of Micropalenotology, Micropalenotology Press, New York.
- Schrader, H.-J., 1973 : Cenozoic diatoms from the northeast Pacific, Leg 18. *In*, Kulm, L.D., Von Huene, R., *et al., Initial Reports of the Deep Sea Drilling Project*, vol. 18, p. 637-797. U.S. Govt. Printing Office, Washington, D.C.
- Schrader, H.J., 1974a : Revised diatom stratigraphy of the experimental Mohole Drilling, Guadalupe Sites. *Proceedings of the California Academy of Sciences, Fourth Series*, vol. 39, p. 517-562.
- Schrader, H.J., 1974b : Cenozoic planktonic diatom strati-

graphy of the tropical Indian Ocean. *In*, Fisher, R.L., Bunce, E.T., *et al.*, *Initial Reports of the Deep Sea Drilling Project*, vol. 24, p. 887-967. U.S. Govt. Printing Office, Washington, D.C.

- Schrader, H.J., 1976: Cenozoic planktonic diatom biostratigraphy of the southern Pacific Ocean. *In*, Hollister, C.D., Craddock, C., *et al., Initial Reports of the Deep Sea Drilling Project*, vol. 35, p. 605-671. U.S. Govt. Printing Office, Washington, D.C.
- Schrader, H.J., 1977 : Diatoms in DSDP Leg 41 sites. In, Lancelot, E., Seibold, E., et al., Initial Reports of the Deep Sea Drilling Project, vol. 41, p. 791-812. U.S. Govt. Printing Office, Washington, D.C.
- Schrader, H.J., 1978: Opal phytoplankton remains at DSDP Leg 40 sites. *Initial Reports of the Deep Sea* Drilling Project, Supplement to vols. 38, 39, 40 and 41, p. 735-741. U.S. Govt. Printing Office, Washington, D.C.
- Schrader, H.J. and Fenner, J., 1976: Norwegian Sea diatom biostratigraphy and taxonomy. *In*, Talwani, M., Udintsev, G. *et al.*, *Initial Reports of the Deep Sea Drilling Project*, vol. 38, p. 921-1099. U.S. Govt. Printing Office, Washington, D.C.
- Scientific Party, 1980: *Initial Reports of the Deep Sea Drilling Project*, vols. 56 and 57, 1417 p. U.S. Govt. Printing Office, Washington, D.C.
- Simonsen, R., 1979: The diatom system: Ideas on phylogeny *Bacillaria*, vol. 2, p. 9-71.
- Tracey, J.I.Jr. et al., 1971: Initial Reports of the Deep Sea Drilling Project, vol. 8, 1037 p. U.S. Govt. Printing Office, Washington, D.C.
- Yanagisawa, Y., 1987: Age assignments of dredge and piston core samples based on diatom biostratigraphy. *COOP Technical Bulletin*, vol. 19, p. 73-87. Committee for Coordination of Joint Prospecting for Mineral Resources in Asian Offshore Areas (CCOP), Bangkok, Thailand.
- Yanagisawa, Y., 1993 : Middle Miocene diatom assemblages from carbonate concretions in the Nanatani Formation and a formation equivalent to the Teradomari Formation in the Neogene Niigata sedimentary basin of Japan. *Diatom (The Japanese Journal of Diatomology)*, vol. 8, p. 51-62. (*in Japanese with English abstract*)
- Yanagisawa, Y., 1994 : Koizumia Yanagisawa gen. nov., a new marine fossil araphid diatom genus. Transactions and Proceedings of the Palaeontological Society of Japan, New Series, no. 176, p. 591-617.
- Yanagisawa, Y., 1995: Cenozoic diatom genus Rossiella Desikachary et Maheshwari: an emended description. Transactions and Proceedings of the Palaeontological Society of Japan, New Series, no. 177, p. 1-20.
- Yanagisawa, Y., Nakamura, K., Suzuki, Y., Sawamura, K., Yoshida, F., Tanaka, Y., Honda, Y. and Tanahashi, M., 1989: Tertiary biostratigraphy and subsurface geology of the Futaba district, Joban Coalfield, northeast Japan. Bulletin of the Geological Survey of Japan, vol. 40, p. 405-467. (in Japanese with English abstract)

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Appendix table. Occurrence of *Bogorovia* species in DSDP Holes 70A, 71 and 77B. Diatom zones after Barron (1985b) and Fenner (1985). Abundance of each species : A=abundant (>8%), C=common (5-7%), F= few (2-4%), R=rare (<1%).

			(primitive) (advanced)	Girdle views of marginal ridges									(primitive) (advanced)					Cindle views of marginal ridges	
Diatom zones	NTD	Hole Core Section Interval (cm)	Bogorovia gombosii B. veniamini B. barronii B. puncticulata B. puncticulata B. lancettula B. praepaleacea	Type 3 (broad) Type 3 (narrow) Type 2 (narrow) Type 2 (broad)	Diatom zones	NTD	Hole	Core Section	Interval (cm)	Bogorovia gombosii	B. veniamini	B. barronii	B. puncticulata B. puncticulata	B. rostrata	B. lancettula	B. pruepuleacea	Type 3 (broad)	Type 3 (narrow) Type 2 (narrow)	Type 2 (broad)
N. miocenica	12B 12A	77B 12 -1 , 29 -30 77B 13 -1 , 100 -101 77B 13 -3 , 2 -3		 R -	C. elegans	2	71 2 71 2 71 2	28 - 2 , 28 - 4 , 28 - 6 ,	70 - 72 70 - 72 70 - 72		-	F R	 R -	-	-	-		R - R -	-
N. porteri	11B	77B 14 - 6 , 148 - 149	R -	R R	-		71 2	29-2.	70 - 72	. -	-	R		-	-	-	-	R-	-
C. yabei	10B 10A	77B 15 -6 , 77 -78 77B 17 -1 , 18 -20	R - F R R R	R - R			71 2 71 2	29-4. 29-6.	70 - 72 70 - 72	-	-	C R	C - R -	-	-	-	-	F - R -	-
A. moronensis	9	77B 17 -6 23 -25 77B 18 -2 23 -25 77B 18 -6 , 38 -40 77B 19 -2 , 38 -40 77D 10 -2 , 38 -40		R R - R R R - R R R - R R R		ıc	71 1 71 1 71 1 71 1 71 1	30 - 2 . 30 - 4 . 30 - 6 . 30 - 6 .	70 - 72 69 - 72 45 - 46 70 - 72	- -	R R F R	R - C R	R - R - R - R -	- - -	- - -	- - -	R - R R	R - R - R - R -	-
C. coscinodiscus	8	77B 19 -6 38 -40 77B 20 -2 , 38 -40 77B 20 -2 , 59 -60 77B 20 -4 , 30 -31 77D 20 -6 -60 -60		R			71 3 71 3 71 3 71 3	31 - 2, 31 - 4, 31 - 6, 32 - 2,	70 - 72 70 - 72 70 - 72 125 - 12	- - - - -	C C F C	- R -	 	-	-	-	C C C F	 	-
		77B 20 - 6 , 38 - 40	F -	R -			71 3	32-6,	125 - 12	.9 -	Α	R		-	-	-	Α		-
C. gigas		77B 21 - 2 , 38 - 40	R R -	- R R -		1B	71 3	33 - 2 .	87 - 89) -	R	R		-	-	-	R		-
var.	7	77B 21 - 6 , 35 - 37	R -	- R R	R. paleacea		71 3	33-5,	75 - 80) [-	F	-		•	-	-	F		-
diorama		77B 22 - 2 , 35 - 37	R - R R				71 3	34-2,	87 - 89) [-	С	-		-	-	-	F		-
		77B 22 - 6 , 35 - 37	R - R R	- R			71 3	34 - 4 ,	125 - 12	9 -	Α	•		-	-	-	С		-
C. lewisianus	6	77B 23 - 2 , 35 - 37	R R				71 3	34-6,	132 - 13	6 R	F	-		-	•	•	F		•
		77B 23 - 6 , 35 - 37		- R			71 3	35-2.	132 - 13	6 -	С	•		-	-	-	С		•
		77B 24 - 2 , 35 - 37		• • • •			71 3	35-6,	125 - 12	9 R	Α	•		-	-	-	С		-
	5B	77B 24 - 6 , 20 - 22		• • • •			71 3	36-2,	125 - 12	9 R	Α	-		-	-	-	Α	• •	-
		71 19 -2 , 108 - 110					71 3	36-6,	79 - 80) R	Α	•		-	-	-	Α		-
		71 19 -4 , 90 -92	R			1A	71 3	36-6,	125 - 12	9 R	Α	•		-	-	-	F		-
		71 19 - 6 , 86 - 88					71 3	37-2,	87 - 89	R	Α	•		-	-	-	С		-
C. pepulum		71 20 - 2 , 88 - 90		· · ·			71 3	37-4,	100 - 10	2 R	Α	•	• •	-	-	-	С		•
	5A	71 20 - 6 , 108 - 110					71 3	37-5.	87 - 89	R	Α	-		-	-	-	Α	• •	-
		71 21 -4 , 60 -62					71 3	38-2,	125 - 12	9 R	R	-	• •	-	-	-	F	• •	•
		71 21 - 6 , 90 - 93	• • • • • • • •	• • • •			71 3	38-4,	80 - 81	-	R	-		-	•	-	R		•
		71 22 - 2 , 88 - 90					71 3	39-1,	87 - 89	R	R	-		•	•	-	F	<u></u>	-
		71 22 - 4 , 29 - 31	R				71 3	39-2,	87 - 89	R	F	-		•	•	-	R	• •	•
		71 22 - 6 , 116 - 118	R		R. gelida		71 4	10-2,	87 - 89	R	R	-		-	-	-	R	· ·	-
		71 23 - 2 , 117 - 119	R	- R			71 4	10-6.	87 - 89	- י	R	•		-	-	-	R		-
		71 23 - 4 , 77 - 79					71 4	41-1,	87 - 89	R	R	-		-	-	-	R		-
	4B	71 24 - 2 , 78 - 80	• • • • • • • • •				71 4	12 - 1 ,	91, -92	-	R	-	• •	-	-	-	R		-
D. nicobarica		71 24 - 4 , 45 - 46			R. veniamini		71 4	2 - 2 .	87 - 89	R	R	-		•	-	-	R		-
		71 24 - 6 , 45 - 47		· · · ·			71 4	2-4,	87 - 89	R	R	-		• -	•	-	R		-
1		71 25 - 1 , 128 - 130	R	• • • •			71 4	2-6,	87 - 89	R	С	-	• -	-	-	-	A	<u></u>	-
1	4A	71 25 - 3 , 96 - 98	R	- R			71 4	5-2,	61 - 62	R	-	-		-	-	-	R		•
	L	71 25 - 5 , 92 - 94	R	- R			71 4	7-2.	106 - 10	7 -	-	-		-	-	-	С		-
		71 26 -2 , 70 - 72	R	• • • •	R. vigilans	b	71 4	7-5,	59 - 60	• •	•	-		-	-	-	С		•
T. pileus	3	71 26 -4 , 70 -72	R R R	- R			70A	8-4,	83 - 84	·	•	-		•	-	-	A	<u> </u>	•
ļ		71 26 - 6 , 70 - 72	· · · · R · · ·	• • • •		а	70A 1	2 - 3 .	90 - 91	•	•	•		-	•	•	-		-
L	L	/1 27 -1 , 100 - 102	R																

984 Middle and Late Permian radiolarians from the Semanggol Formation, Northwest Peninsular Malaysia

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Abstract. The Semanggol Formation exposed in the northwestern part of Peninsular Malaysia is subdivided into the lower Chert, middle Rhythmite, and upper Conglomerate Members. Previous to the present study, this formation was regarded as Triassic because of the occurrence of *Daonella* and *Halobia* in the middle Rhythmite Member. We newly recovered late Middle Permian radiolarians, including *Follicucullus monacanthus*, from an allochthonous siliceous limestone block contained in the upper part of the lower Chert Member exposed at Bukit Barak, 25 km northeast of Alor Setar. Furthermore, moderately well preserved Late Permian radiolarians belonging to the *Neoalbaillella optima* and *N. ornithoformis* Assemblages were discovered in chert beds of the same member exposed at Bukit Nyan, 20 km east of Alor Setar. These Permian radiolarian faunas are very similar to those reported from Japan, the Philippines, and southern China. We interpret the significance of this occurrence in the paleobiogeography of Peninsular Malaysia during Late Paleozoic to Early Mesozoic times. Eight species and five unidentified species belonging to 10 genera of Radiolaria are systematically described in this paper.

Key words : Neoalbaillella, Peninsular Malaysia, Permian, Radiolaria, Semanggol Formation, Triassic.

Introduction

Peninsular Malaysia is geologically subdivided into two continental blocks, the western Sibumasu and eastern East Malaya blocks. As shown in Figure 1, these two blocks are in contact with the Bentong-Raub Suture, which is continued from the Uttradit-Nan Suture of Thailand and extends into Sumatra as the Lalang Line (Metcalfe, 1988; Hutchison, 1989). Concerning the timing of the collision or amalgamation of these continental blocks, there are diverse opinions such as Carboniferous-Permian (Helmke, 1985); Triassic (Sengör *et al.*, 1988; Metcalfe, 1988; Mitchell, 1989); and Jurassic-Cretaceous (Audley-Charles, 1988).

Sashida, Igo, Hisada *et al.* (1993) pointed out that establishment of detailed geochronology in siliceous and associated fine-grained clastic rocks based on microfossils provides one of the keys to solve the abovementioned problem. We, however, did not have any sufficient micropaleontological data in Peninsular Malaysia for this purpose except for conodont age assignment determined in chert beds exposed at Tawar, Kedah (Koike, 1973). In November and December of 1991, we made a field survey in northwest Peninsular Malaysia to clarify the geologic age of the Semanggol (or Semanggul) Formation. We were fortunate to discover Late Permian radiolarians from the lower Chert Member and late Middle Permian radiolarians from an allochthonous block probably contained in the upper part of the lower Chert Member. The lower and middle members were assigned to Early to Middle Triassic by previous workers (e.g., Tamura *et al.*, 1975; Teoh, 1992). This discovery was preliminarily reported by Sashida, Igo, Adachi *et al.* (1993) and is the first report of Permian radiolarians in Peninsular Malaysia. These faunas are very similar to those reported from Japan, the Philippines, and southern China, and the occurrence in Malaysia is of interesting geologic significance as discussed below.

The first author (K.S.) systematically describes the species of radiolarians belonging to the characteristic genera including *Albaillella*, *Neoalbaillella*, and *Follicucul- lus* herein.

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Figure 1. Index map showing the study area and the tectonostratigraphic terranes which constitute the continental mainland of Southeast Asia. The base map is slightly modified from Metcalfe (1988, 1991).

field survey was funded by a grant under the Monbusho (Government of Japan) International Scientific Research Program (No. 02140210 to H. Igo) and also supported by the Geological Survey of Malaysia. We thank Messrs. Yin Ee Heng (former Director-General), Khoo Hang Peng, and Shu Yeoh Khoon of Geological Survey of Malaysia, who gave permission and facilities for our field survey.

Geologic setting

Jones (1978) first established a geologic framework for the extensive area of northwest Peninsular Malaysia (Perlis and Kedah States), including the Langkawi Islands. He divided Paleozoic and Mesozoic sedimentary rocks into four lithostratigraphic units : the Machinchang Formation (Late Cambrian), Setul Formation (Ordovician to Devonian), Kubang Pasu and Singa Formations (Late Devonian to Early Permian), and Chuping Formation (Middle Permian to Triassic).

Recently, Teoh (1992) has mapped the Sungai Tiang area of central Kedah and divided the Paleozoic and Mesozoic rocks into the following three lithostratigraphic units; the Mahang Formation (Early Silurian), Kubang Pasu (Carboniferous), and Semanggol Formations (Middle to Late Triassic). In Kedah and Perlis, Permian and Triassic limestones occur outside of this mapped area and have been known as the Chuping and Kodiang Limestones. These limestones mostly constitute isolated spectacular tower karst hills in the Quaternary plain. They conformably overlie the Kubang Pasu Formation (e. g., Foo, 1983). Conodonts in the Chuping and Kodiang Limestones were repeatedly studied by Koike (1973, 1982) and Metcalfe (1981, 1990a, 1992), and these authors clarified the detailed geologic age of these limestones.

The name "Semanggol (or Semanggul) Formation" has been informally used by several writers for the large tracts of flysch-type sedimentary rocks of the Middle to Late Triassic distributed in Kedah and Perlis (Khoo, 1983; Foo, 1990; Teoh, 1992). This formation occurs in a wide area east of the Chuping and Kodiang Limestones with an almost NS orientation (Figure 2). The stratigraphic relationship, however, between the Semanggol and both overlying and underlying formations is unclear. Burton (1973) subdivided this formation into three members, the lower Chert Member, the middle Rhythmite Member, and



Figure 2. Map showing the distribution of the Chuping Limestone (1), Kodiang Limestone (2) and Semanggol Formation (3) and locations of two radiolarian localities, Bukit Nyan and Bukit Barak. The base map is after Metcalfe (1990a).

the upper Conglomerate Member, but this subdivision is now thought to be oversimplified by Malaysian geologists (e.g., Ahmad *et al.*, 1987). The detailed stratigraphy and exact thickness of the Semanggol cannot be ascertained due to the tightly folded structure and the absence of marker beds. Foo (1990) and Teoh (1992), however, estimated that the thickness of this formation is no less than 760 to 800 m. Under this circumstance, we compiled an idealized geologic columnar section with the geochronological scale of the Semanggol Formation as shown in Figure 3.

The lower Chert Member consists mainly of chert, forms echelon ridges trending almost NS, and crops out well in the western part of the area mapped as the Semanggol. Good outcrops of this member can be traced along the roadcut from Pokok Sena to Kuala Nerang and in operating and abandoned quarries east of Pokok Sena in central Kedah. The cherts are commonly



Figure 3. Generalized columnar section of the Semanggol Formation (not to scale). 1. conglomerate, 2. limestone lenticle, 3. alternation of sandstone and shale, 4. siliceous shale, 5. chert.

black to gray, thinly bedded, tightly folded, and grade upward into siliceous shales or mudstones.

Calcareous chert or cherty limestone beds and limestone lenses are intercalated in siliceous shale that represents the upper part of the Chert Member, and one of the field occurrences of these intercalations at an active earth quarry of Bukit Barak was described in detail by Ahmed *et al.* (1987). They considered that these limestones are pelagic in origin, and confirmed the occurrence of Triassic conodonts in the lensoid-shaped limestone bodies. Furthermore, in their interpretation these bodies were not slumped-in but were contemporaneous in-situ deposits. Subsequently, Metcalfe (1990a) reported the occurrence of Carnian conodonts, such as *Neogondolella polygnathiformis* (Budrov and Stefanov) in these limestone lenses.

The middle Rhythmite Member conformably overlies the lower member, and consists of rhythmically alternating beds of sandstone and shale. Each bed is commonly less than 10 cm thick. Sandstone beds are interpreted as turbidites, and commonly exhibit numerous syngenetic structures and sedimentary features that are typical of "flysch-type" deposits. Shale beds of this member yield well known Triassic pelecypod fossils such as *Posidonia kedahensis* Kobayashi, *Halobia talauana* Wanner, *Halobia parallela* Kobayashi, *Halobia comata* Bittner and others, indicating an interval of Ladinian to Norian (Kobayashi, 1963).

The upper Conglomerate Member conformably overlies the middle member and is prevalent in eastern Kedah. This member is predominantly irregularly interbedded sandstone and shale with intercalations of numerous conglomerate lenses or bands. Clasts of conglomerate are commonly well-rounded pebble- to cobble-size chert, metamorphosed crystalline quartz, and argillaceous rocks. Some chert clasts contain radiolarian fossils.

The stratigraphic relationship among these three members is not entirely one of superposition, rather they seem to be partly intertonguing each other (Figure 3). The depositional environment of the Semanggol Formation was analyzed by Burton (1973), Metcalfe (1990a, etc.), Teoh (1992), and others. According to them, the Kodiang Limestone and some parts of the Chuping Limestone are heterofacies of the Semanggol Formation, and were deposited in the shelf which was continued to the foreland toward the west. The lower Chert and middle Rhythmite Members of the Semanggol were deposited in the deeper part to the east. The latter member is apparently of turbidite origin. The characteristic sedimentary facies in the upper Conglomerate Member suggests a transition to a shallower water environment.

Permian radiolarians in the Semanggol Formation

Localities

Bukit Barak: Middle Permian radiolarians were recovered from a siliceous limestone block embedded in siliceous shale of the upper part of the lower Chert Member exposed at a quarry of Bukit Barak (Figures 2, 4). A geologic sketch of this quarry was given by Ahmad *et al.* (1987). They showed a 27-m-thick columnar section and pointed out the occurrence of conodonts in lensoid-shaped limestone bodies embedded in the siliceous shale situated at the top of the column. These authors stressed that the lensoid limestone bodies were not slumped-in but were contemporaneous in-situ deposits. Subsequently, Metcalfe (1990a) studied these conodonts and identified *Metapolygnathus* (=*Neogondolella*) *polygnathiformis* (Budurov and Stefanov), which is an excellent indicator of the lower Carnian (lower Upper Triassic).

During our field survey in 1991, we tried to restudy the section shown by Ahmad et al. (1987), but quarry operation was much progressed, and the outcrop measured by them was already quarried out. We, however, could observe a similar sequence and confirmed the intercalation of lensoid limestone bodies in siliceous shales. Several samples of siliceous shales and limestones were collected from various stratigraphic levels (Figure 4). These samples were treated with HF (hydrofluoric acid) at our laboratory with the same technique mentioned by Sashida (1988). As a result, we encountered poorly preserved but apparent Permian radiolarian specimens in residue obtained from the lensoid siliceous limestone (sample BT-1). The only identified species among discreted specimens is Follicucullus monacanthus Ishiga and Imoto. Under the microscope, this limestone is almost



Figure 4. Sketch map showing the Bukit Barak quarry and collected point of Permian radiolarian-bearing siliceous limestone.

completely silicified, and primary microfacies has been obliterated by microcrystalline silica. Calcite crystals are rare, but euhedral crystals of dolomite are commonly scattered. Minute dark brown iron minerals are concentrated in some parts. Minute spheres and spines of radiolarians are also commonly visible.

We could not recover any Triassic conodonts from the limestones as reported by Metcalfe (1990a), but we made several thin sections and discovered some other fossils. Furthermore, there we recognized two types of limestones containing Triassic fossils. Under the microscope, one type is a micritic limestone including abundant peloids and algal clasts, subordinate foraminifers, bryozoans, and fragments of Echinodermata. Preliminarily identified foraminifers are Aulotortus spp., Arenovidalina indosinica Liêm, Endothyra? sp., Glomospira sp., and Dentalina sp. The two first mentioned forms are known to occur in the Middle to Upper Triassic. The other type is also micritic limestone including abundant thin-shelled pelecypods and radiolarian tests. These pelecypod-bearing radiolarian limestones are common in the Middle to Upper Triassic pelagic calcareous facies elsewhere in the world. These paleontological facts indicate that the siliceous shales intercalate both Permian and Triassic lenticular limestones of which depositional environments are different. Our principal new finding, mentioned above, is demonstration that the lensoid limestones intercalated in almost the same level are of three different types, Middle Permian radiolarian-bearing siliceous limestone, Triassic foraminiferal-algal shallow water limestone, and pelagic pelecypod-bearing limestone. Therefore, we concluded that these limestone bodies are allochthonous blocks instead of contemporaneous in-situ deposits as advocated by the previous authors.

Bukit Nyan: We made a geological survey at an abandoned manganese guarry of Bukit Nyan (also spelled Nyah or Nayan) located about 8 km south of Pokok Sena (Figure 2). Bedded cherts about 100 m thick that apparently belong to the lower Chert Member of the Semanggol are exposed at the quarry. Cherts are mostly thin-bedded and show a wide range of color, but are commonly brown, maroon, and pale gray. They strike N10°-30°E and dip almost vertical (Figure 5). Under the microscope these cherts contain aboundant minute spherules (0.2 mm in average diameter) filled with spherulitic calcedony or microcrystalline quartz. We collected more than 10 samples at this quarry of which four samples (CHU-41, 42, 43, and 44) yield moderately well preserved Late Permian radiolarians. They are the species of the genera Neoalbaillella, Albaillella, Entactinosphaera, Nazarovella, Triplanospongos, and others.

Radiolarian fauna and age

As mentioned above, we newly recovered radiolarians from a siliceous limestone block at the quarry of Bukit Barak. These radiolarians are poorly preserved, and *Follicucullus monacanthus* Ishiga and Imoto, which is an apparent indicator of the upper part of the Middle Permian, is the only identified species. Other radiolarians



Figure 5. Sketch map showing the Bukit Nyan quarry and radiolarian localities (after Sashida, Igo, Adachi *et al.*, 1993).

are spumellarians, but are not identified as to species. *F. monacanthus* was first described from bedded cherts in the Yagi area of the Tamba district west of Kyoto, Japan (Ishiga and Imoto, 1980). This species is now accepted as an index of the late Middle Permian *Follicucullus monacanthus* Zone (e.g., Ishiga *et al.*, 1982c).

Samples collected from Bukit Nyan contain 13 species

of Late Permian radiolarians (Table 1). These radiolarians can be grouped into two assemblages. One assemblage occurs in two samples (CHU-41, 42 in Figure 5) and is characterized by the presence of *Albaillella triangularis* lshiga, Kito and Imoto, but lacks *Neoalbaillella* cfr. ornithoformis Takemura and Nakaseko. The other one is confirmed in chert samples (CHU-43, 44 in Figure 5) and characterized by the assemblage of *N*. cfr. ornithoformis and spumellarians including *Entactinosphaera pseudocimelia* Sashida and Tonishi, *Nazarovella gracilis* De Wever and Caridroit, *N. inflata* Sashida and Tonishi, and *Triplanospongos musashiensis* Sashida and Tonishi.

Albaillella triangularis, A. levis, and A. excelsa were first described by Ishiga et al. (1982b) from the Yono area of the Tamba district, west of Kyoto and the Nabejiri-yama area of Shiga Prefecture, Japan. Neoalbaillella ornithoformis was also introduced from the Tamba district (Takemura and Nakaseko, 1981). Associated spumellarians with N. cfr. ornithoformis in CHU-43 and CHU-44, such as Nazarovella gracilis and Triplanospongos musashiensis were described from the Late Permian chert exposed in Itsukaichi, Tokyo (e.g., Sashida and Tonishi, 1985).

Ishiga et al. (1982a) and Ishiga (1986) established assemblage-zones based on the stratigraphic occurrence of the species of Neoalbaillella in the Upper Permian chert facies of Southwest Japan. They set up two zones, the older Neoalbaillella optima Assemblage-zone and younger Neoalbaillella ornithoformis Assemblage-zone in the Upper Permian. The former zone is characterized by the joint occurrence of Albaillella triangularis and Neoalbaillella optima. The latter one is defined by the occurrence of Neoalbaillella ornithoformis. Albaillella excelsa and A. levis have a short range and first appear near the boundary between the two Neoalbaillella zones. Concerning the detailed geologic age of these zones, Ishiga (1986) and others placed it in the Dzhulfian and Dorashamian (Late Permian) based on the co-occurrence of conodonts.

Two newly recovered radiolarian assemblages from chert beds exposed at Bukit Nyan are correlated with the *Neoalbaillella optima* Assemblage-zone and *Neoalbaillella ornithoformis* Assemblage-zone established in Japan; their geologic ages are considered to be Late Permian (Dzhulfian to Dorashamian).

Appraisal of the occurrence of Permian radiolarians in the Semanggol Formation

In this paper, we apprise the above-mentioned newly obtained micropaleontological data and further discuss paleogeography related to the geologic evolution of Peninsular Malaysia and its neighboring regions in Permian to Triassic times.

Our present discovery shows that the geologic age of the Semanggol Formation is not confined within the Triassic as concluded by previous studies but extends down into at least the Middle Permian. The presence of lensoid limestones of two different ages (late Middle Permian and early Late Triassic) in almost the same stratigraphic level of siliceous shale suggests that the

Katsuo Sashida et al.

Localities		CH	IU-	
Таха	41	42	43	44
Neoalbaillella cfr. ornithoformis Takemura and Nakaseko	•••		×	×
Albaillella excelsa Ishiga, Kito and Imoto	···×	×	×	×
Albaillella levis Ishiga, Kito and Imoto	···×	×	×	Х
Entactinosphaera pseudocimelia Sashida and Tonishi	•••-	_	×	×
Entactinosphaera sp. ·····	•••-	—	×	×
Octatormentum? sp. ·····	•••–	_		×
Nazarovella gracilis De Wever and Caridroit	•••-		×	×
Nazarovella inflata Sashida and Tonishi	•••-	_	-	X
Praedeflandrella sp	$\cdots \times$	_		_
Pseudotormentus sp. ·····	···×	_	_	
Ishigaum ? sp. ·····	•••-	_	×	×
Triplanospongos musashiensis Sashida and Tonishi	•••-	×	×	×

Table 1. List of Permian radiolarians from Bukit Nyan. Locality numbers are shown in Figure 5.

 \times , taxon present; -, taxon not found.

limestones are allochthonous and the sedimentary environments of the Semanggol as analyzed by previous authors should be revised.

In Permian time, two different and contrasting lithofacies, the western shallower limestone facies (Chuping and Kodiang Limestones) and eastern deeper-sea siliceous sedimentary rock facies (lower part of the Semanggol Formation) were already present in northwest Peninsular Malaysia as shown in Figure 6. The deposition of these formations was continued in Triassic time, but the depositional site of the Semanggol became shallower as indicated by its sedimentary features. Furthermore, the accretion of the Sibumasu block to the East Malaya block became active in the Late Triassic and provided a different sedimentary setting than that of the Permian as shown in Figure 7. The following lines briefly summarize interpretation of these two diagrammatic figures.



Figure 6. Schematic reconstruction of the sedimentary setting of the Chuping and Kodiang Limestones and Semanggol Formation.



Figure 7. Schematic cross section across the convergent region of Peninsular Malaysia in Late Triassic. This diagram shows the collision of the Sibumasu block to the East Malaya block and development of associated sedimentary basins, wedges, and volcanism.

Carbonate facies is prevalent in the west and represented by almost continuous deposition of the Chuping and Kodiang Limestones. Previously, these limestones were thought to be two distinct lithogenetic units of the Permian and Triassic, respectively. Subsequent studies, however, concluded that the geologic age of these limestone units is Middle (?) Permian to Late Triassic (e.g., Metcalfe, 1981, 1984, 1990a, 1992 ; Fontaine et al., 1988). Similar limestones are also exposed in Peninsular Thailand and have been called the Permian Ratburi Limestone. Recently, Triassic fossils have been discovered from the Ratburi Limestone in Peninsular Thailand (e.g., Igo et al., 1988; Sashida and Igo, 1992), and the Chaiburi Formation was introduced for the Triassic limestone (Ampornmaha, 1993 MS; Adachi et al., 1993). These carbonate facies are also known in north Sumatra and form an elongate Permian and Triassic limestone complex in Sibumasu (Metcalfe, 1989, 1990a).

The boundary between the Permian and Triassic in this limestone complex is roughly settled at Gunong Keriang and Bukit Hantu in Kedah by conodont studies (Metcalfe, 1981, 1984). The boundary is also presumed in the limestone complex of the Phatthalung area of southern Thailand (Ampornmaha, 1993MS). The boundary between the Permian and Triassic in these limestone sections is said to be conformable, but the exact boundary has never been reported because carbonate rocks near the boundary are completely dolomitized and do not successively yield any reliable uppermost Permian (Dorashamian) and lowermost Triassic (Griesbachian) fossils. The limestone that yields Smithian, Spathian, and Anisian conodonts and radiolarians in northwest Peninsular Malaysia and southern Peninsular Thailand are mostly thin-bedded micritic limestone with intercalations of thin chert layers and nodules (e.g., Metcalfe, 1984; Sashida and Igo, 1992). These limestones are considered to have been deposited in off-shore, deeper, and low-energy environments. The upper part of the carbonate complex was represented mainly by thickly bedded algal-foraminiferal limestone with interbeds of coral-sponge buildups in places. It was deposited in a shallow sea of high-energy conditions (Ampornmaha, 1993 MS; Adachi *et al.*, 1993). The age of this part of the limestone is Late Triassic (Carnian and Norian).

As already mentioned, the lower and middle parts of the Semanggol Formation were deposited in the deeper and off-shore pelagic environments which spread in the eastern part of the Permian-Triassic carbonate complex. The present discovery of Upper Permian radiolarians from Bukit Nyan suggests that the boundary between the Permian and Triassic will be settled within the lower Chert Member of the Semanggol in the future. Furthermore, our other discovery of Middle Permian radiolarians from a siliceous limestone block and Carnian algal-foraminifer limestone blocks at Bukit Barak supports our contention that the upper part of the Chert Member is contemporaneous but is a heterofacies with both the middle Rhythmite and upper Conglomerate Members. Allochthonous blocks of Permian siliceous limestone and Triassic limestone were derived from the paleoslope of the carbonate complex in the west and slumped in the siliceous shale sequence of the upper part of the Chert Member.

The middle Rhythmite Member that yields Middle and Late Triassic pelecypods is characterized by thinly bedded alternations of sandstone and shale. Various sedimentary structures observed in these alternations have been interpreted as turbidites (e.g., Teoh, 1992). The source area of these turbidites was located in the east where accretionary wedges were formed associated with the collision of Sibumasu. The absence of carbonate rocks as clastics in these turbidites also supports an eastern sediment source.

Toward the east the accretionary wedges are further continued to the Semantan Basin formed in the East Malaya block. The Semantan Formation (Jaafar, 1976) was deposited in this basin. This formation is a flysch sequence of alternating carbonaceous shale, siltstone, and rhyolitic tuff with very few lenses of crystalline limestone. It locally yields Daonella, Posidonia, and other MiddleTriassic pelecypods (e.g., Kobayashi, 1963, Metcalfe et al., 1982). Provenance of volcanic materials was interpreted as acidic volcanic islands or an island chain (e.g., Metcalfe et al., 1982) aligned along the eastern margin of the Semantan Basin (Figure 7). This model accords well with the scenario of tectonic evolution of Peninsular Malaysia explained by collision of the Sibumasu block with the East Malaya block in Early Triassic time.

Sashida, Igo, Adachi et al. (1993) and Sashida, Igo, Hisada et al. (1993) pointed out the occurrence of Permian to Middle Triassic radiolarians in cherts exposed in the Fang area of northwestern Thailand and also in the Sra Kaeo-Chanthaburi areas of eastern Thailand. These radiolarian faunas are similar to those of Japan, the Philippines, and southern China. This paleontological evidence shows that the radiolarian cherts in these regions were deposited on the same ocean floor "Paleotethys" in the interval of Middle Permian to Middle Triassic times (Figure 8). The Fang area is situated in the western mountains of the Sukhothai Fold Belt (Bunopas, 1981) or the ophiolitic areas of the Plateau Belt in the Shan-Thai Block (Mitchell, 1992). The Sra Kaeo-Chanthaburi areas also rest in the ophiolitic areas of the Loei and Sukhothai Fold Belts. These areas are characterized by a complicated geologic structure that consists of various kinds of sedimentary rocks, ultra mafic and mafic rocks, and volcanic and plutonic rocks of Late Paleozoic to Middle Triassic age. This complex has been regarded as a mobile belt or accretionary wedges formed as a result of collision of the Sibumasu (Shan-Thai) and Indochina blocks. As mentioned above, the youngest age of the deeper marine sedimentary rocks (radiolarian cherts) that constitute these folded belts is the Middle Triassic, hence the timing of collision of these two continental blocks in Thailand is considered to be not prior to the Middle Triassic. Moreover, it is well known that the thick nonmarine strata, the Khorat Group (late



Figure 8. Palinspastic map of the main part of Southeast Asia in Early Triassic time (modified from Hutchinson, 1989).

Triassic to Cretaceous) unconformably and extensively rests on the Indochina block. Our present study shows that the timing of collision of the Sibumasu and East Malaya continental blocks was slightly earlier than in Thailand (Figure 8).

Systematic paleontology

All specimens described in this paper are deposited in the Institute of Geoscience, University of Tsukuba with the prefix IGUT.

> Order Polycystida Ehrenberg, 1838, emend. Riedel, 1967 Suborder Albaillellaria Deflandre, 1952, emend. Holdsworth, 1969 Superfamily Follicucullacea Cheng, 1986 Family Neoalbaillellidae Takemura and Nakaseko, 1981 Genus *Neoalbaillella* Takemura and Nakaseko, 1981 *Neoalbaillella* cfr. *ornithoformis* Takemura and Nakaseko

> > Figures 10-1-4

Compare :

Neoalbaillella ornithoformis Takemura and Nakaseko, 1981, p. 211-213, pl. 33, figs. 1-6; Ishiga *et al.*, 1982b, p. 15-16, pl. 1, figs. 6-8, pl. 2, fig. 1; Nishizono *et al.*, 1982, pl. 2, fig. 7; Sashida and Tonishi, 1985, pl. 7, figs. 8-9; Ishiga, 1990, pl. 1, fig. 5; Tumanda *et al.*, 1990, pl. 2, fig. 21; Ishida *et al.*, 1992, pl. 1, fig. 2.

Neoalbaillella sp., Kojima, 1982, pl. 2, figs. 8-9, pl. 3, fig. 1.



Figure 9a, b. Thin-section microphotographs of foraminifers and pelecypod-radiolarian limestone embedded in the Semanggol Formation exposed at Bukit Barak. 9a (left figure), 1; Arenovidalina indosinica Liêm, \times 60, **2**, **3**; Endothyra? sp., \times 60, **4**; Trochammina? sp., \times 60, **5**; Glomospira sp., \times 60, **6**; Dentalina sp., \times 60, **7**; Aulotortus sp., \times 30. 9b (right figure), Pelecypod-radiolarian limestone, \times 30.

Neoalbaillella sp. cfr. N. ornithoformis, Kojima, 1982, pl. 2, fig. 10.

Remarks.—Although preservation of our present specimens is very poor, the shape of the apical cone and the dorsal wing are identical with that of the type species of Neoalbaillella ornithoformis. Our specimens differ from N. optima in lacking ladder-shaped extension of rods. Occurrence.-CHU-43, 44.

> Family Albaillellidae Deflandre, 1952, emend. Holdsworth, 1977 Genus Albaillella Deflandre, 1952, emend. Holdsworth, 1966. emend. Ormiston and Lane, 1976 Albaillella triangularis Ishiga, Kito and Imoto

Figures 10-18-20

Albaillella sp. C, Ishiga and Imoto, 1980, p. 341, pl. 5, figs. 11-16. Albaillella triangularis Ishiga, Kito and Imoto, 1982b, p. 2, figs. 8-11; Wakita, 1983, pl. 6, fig. 8; Caridroit et al., 1985, pl. 1, fig. 1; Ishiga, 1985, p. 13, pl. 2, figs. 13-19; Yoshida and Murata, 1985, pl. 2, figs. 9, 10; Caridroit and De Wever, 1986, p. 58-59, pl. 1, figs. 1-5; Wu and Li, 1989, pl. 1, fig. 14; Tumanda et al., 1990, pl. 2, fig. 18; Kuwahara et al., 1991, figs. 4-1-2; Ando et al., 1991, pl. 9, fig. 9; Kuwahara and Sakamoto, 1992, pl. 3, figs. 5-6; Yao et al., 1993, pl. 1, fig. 3.

Albaillella sp. cf. A. triangularis, Cheng, 1989, p. 138, pl. 5, figs. 6-9, 11-12.

Remarks.-This species is characterized by having a triangular shell with a ridged H-frame. Owing to illpreservation, our specimens lack the H-frame but other characters such as a triangular shell with horizontal bands on the shell surface are guite identical with the type species and the above-listed reports of this species. Occurrence.-CHU-41, 42.

Albaillella levis Ishiga, Koto and Imoto

Figures 10-16-17, 21

- Albaillellidae gen. et sp. indet., Takemura and Nakaseko, 1981, pl. 34, fig. 10.
- Albaillella levis Ishiga, Kito and Imoto, 1982b, p. 17, pl. 3, figs. 1-4; Kojima, 1982, pl. 3, figs. 5-6; Wakita, 1983, pl. 6, figs. 5-6; Sashida and Tonishi, 1985, pl. 7, figs. 5-6; Yoshida and Murata, 1985, pl. 2, figs. 11-12; Noble and Renne, 1990, pl. 1, figs. 12-15; Tumanda et al., 1990, pl. 2, fig. 24; Ishida et al., 1992, pl. 1, fig. 4; Kuwahara and Sakamoto, 1992, p. 40, pl. 3, figs. 8-9, 12; Yao et al., 1993, pl. 1, figs. 6, 8.
- Albaillella sp. cf. A. levis, Cheng, 1989, p. 138, pl. 1, figs. 5-7, pl. 2, figs. 1-4; Ando et al., 1991, pl. 9, fig. 10.
- ?Albaillella levis, Wu and Li, 1989, pl. 1, fig. 10.

Remarks.—Our specimens assignable to the present species lack an H-frame but the general shell shape with a ventral rod is similar to that of the original specimens. Occurrence.—CHU-41, 42, 43, 44.

Albaillella excelsa Ishiga, Kito and Imoto

Figures 10-5-11

- Albaillella excelsa Ishiga, Kito and Imoto, 1982b, p. 17-18, pl. 3, figs. 5-8; Wu and Li, 1989, pl. 1, figs. 8-9; Kuwahara and Sakamoto, 1992, pl. 39, pl. 1, fig. 8, pl. 3, figs. 1-3; Yao et al., pl. 1, figs. 2, 7.
- Albaillella sp. cfr. A. excelsa, Cheng, 1989, pl. 138, pl. 4, figs. 9-11.

Remarks.-Our specimens are similar to the original



Figure 10. Permian radiolarians from Bukit Barak and Bukit Nyan. **1-4.** *Neoalbaillella* cfr. *ornithoformis* Takemura and Nakaseko, **1**; IGUT-KS0580, CHU-43, ×200, **2**; IGUT-KS0517, CHU-44, ×170, **3**; IGUT-KS0579, CHU-43, ×200, **4**; IGUT-KS0531, CHU-44, ×150. **5-11.** *Albaillella excelsa* Ishiga, Kito and Imoto, **5**; IGUT-KS0536, CHU-41, ×150, **6**; IGUT-KS0555, CHU-41, ×150, **7**; IGUT-KS0542, CHU-42, ×150, **8**; IGUT-KS0547, CHU-42, ×150, **9**; IGUT-KS0575, CHU-41, ×150, **10**; IGUT-KS0545, CHU-42, ×150, **11**; IGUT-KS0537, CHU-42, ×150. **12-15.** *Follicucullus monacanthus* Ishiga and Imoto, **12**; IGUT-KS0591, BT-1, ×100, **13**; IGUT-KS0578, BT-1, ×100, **14**; IGUT-KS0588, BT-1, ×100, **15**; IGUT-KS0589, BT-1, ×100. **16-17, 21.** *Albaillella levis* Ishiga, Kito and Imoto, **16**; IGUT-KS0518, CHU-44, ×150, **17**; IGUT-KS0571, CHU-41, ×150, **21**; IGUT-KS0560, CHU-41, ×150. **18-20**; *Albaillela triangularis* Ishiga, Kito and Imoto, **18**; IGUT-KS0573, CHU-42, ×150, **19**; IGUT-KS0533, CHU-42, ×150, **20**; IGUT-KS0539, CHU-42, ×150.

and other above-listed specimens. The present species is similar to *Albaillella lauta* Kuwahara, but length between the proximal part of wing and aperture in *A. levis* is longer than in *A. lauta. Albaillella flexa* Kuwahara is distinguished from *A. excelsa* in having a diagnostic bending in the apical portion.

Occurrence.-CHU-41, 42, 43, 44.

Family Follicucullidae Ormiston and Babcock, 1979 emend. Kozur, 1981 Genus *Follicucullus* Ormiston and Babcock, 1979 *Follicucullus monacanthus* Ishiga and Imoto

Figures 10-12-15

- *Follicucullus* sp. A, Ishiga and Imoto, 1980, p. 340, pl. 4, figs. 11-15; Ishiga *et al.*, 1982a, pl. 2, figs. 5-6; Ishiga *et al.*, 1982b, pl. 2, figs. 5-7.
- Follicucullus monacanthus Ishiga and Imoto, in Ishiga et al., 1982c, p. 276-277, pl. 4, figs. 15-17; Suyari et al., 1983, pl. 4, figs. 1, 2; Isozaki, 1984, pl. 31, figs. 2-7-8; Tazawa et al., 1984, fig. 2-3; Ishiga, 1984, pl. 431, pl. 1, figs. 9-12; Naka and Ishiga, 1985, pl. 1, figs. 8-11; Yoshida and Murata, 1985, pl. 2, figs. 3-4; Ishiga et al., 1986, p. 128, pl. 2, figs. 4-11; Kojima, 1986, fig. 3-12; Uchiyama et al., 1986, pl. 8, fig. 14; Nishimura and Ishiga, 1987, pl. 1, figs. 7-10; Ishiga and Suzuki, 1988, pl. 1, fig. 1; Ishiga et al., 1988, figs. 5, 13; Wang, 1991, pl. 3, fig. 4; Ando et al., 1991, pl. 9, fig. 4; Blome and Reed, 1992, p. 364, figs. 9. 14-15; Ishida et al., 1992, pl. 2, fig. 2
- *Follicucullus* sp. B, Ishiga and Imoto, in Ishiga *et al.*, 1982c, pl. 4, figs. 18-20.

Remarks.—Follicucullus monacanthus is similar to *F. scholasticus* morphotype II Ishiga in general shell shape. The former species, however, is discriminated from the latter in having a short hook-like spine (or wing) on the dorsal side of the apical cone. Although our specimens are poorly preserved, shell shape with a strongly segmented pseudoabdomen in the dorsal side and a hook-like spine are identical with *F. monacanthus*.

Occurrence.-BT-1.

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

Remarks.—Sugiyama (1992) included this family in the order Entactinaria which was proposed by Kozur and Mostler (1982). He pointed out that the family is characterized by the spherical shell and internal spicule that suggest phylogenetically much closer to nassellarians than to typical spumellarians. Nazarov and Ormiston (1985) systematically listed and classified this radiolarian group. Kozur and Mostler (1989) described many genera and species attributable to the suborder Entactinaria. There are, however, diverse opinions on taxonomy of this kind of radiolarians (e.g., Blome and Reed, 1992). We tentatively classified these radiolarians as the suborder Spumellaria.

Genus Entactinosphaera Foreman, 1963 Entactinosphaera pseudocimelia Sashida and Tonishi

Figures 11-1-3

Entactinosphaera pseudocimelia Sashida and Tonishi, 1988, p. 528-529, figs. 7-1-3, 6-8.

Remarks.—The present materials have longer major spines compared with those of the original species described by Sashida and Tonishi (1988). As already pointed out by them, *Entactinosphaera pseudocimelia* is distinguished from *E. cimelia* Nazarov and Ormiston in the nature of major spines. The latter species has thinbladed and long major spines which are triangular in cross section.

Occurrence.—CHU-43, 44.

Entactinosphaera sp.

Figures 11-4-6

Remarks.—This unidentified species is characterized in having three sturdy major spines, which are triradiate in cross section. The length and width of these major spines are variable.

Occurrence.-CHU-43, 44.

Superfamily Latentifistulidae Nazarov and Ormiston, 1983 Family Ruzencevispongidae Kozur, 1980 Genus Octatormentum Nazarov and Ormiston, 1985 Octatormentum ? sp.

Figure 11-20

Remarks.—The present specimens lack terminal spines. An internal sphere cannot be observed. This unidentified species is referred to the genus *Octatormentum*, which has a spongy shell of double pyramidal form.

Occurrence.—CHU-44.

Family Ormistonellidae De Wever and Cardroit, 1984

Remarks.—This family diagnostically has four rays in a tetrahedral pattern without any surrounding external shell. Two genera, *Nazarovella* De Wever and Caridroit and *Ormistonella* De Wever and Caridroit are grouped in this family. Previously, Sashida and Tonishi (1986) placed these genera in the family Latentifistulidae, but we include these genera in the family Ormistonellidae in this study.

Genus Nazarovella De Wever and Caridroit, 1984 Nazarovella gracilis De Wever and Caridroit

Figures 11-17, 19

Nazarovella gracilis De Wever and Caridroit, 1984, p. 101, pl. 1, figs. 14-15, 17; Ishiga, 1985, pl. 2, figs. 22-23; Naka and



Figure 11. Permian radiolarians from Bukit Nyan. **1-3.** *Entactinosphaera pseudocimelia* Sashida and Tonishi, **1**; IGUT-KS0509, CHU-44, ×100, **2**; IGUT-KS0508, CHU-44, ×100, **3**; IGUT-KS0553, CHU-40, × 100. **4-6.** *Entactinosphaera* sp., **4**; IGUT-KS0506, CHU-44, ×100, **5**; IGUT-KS0507, CHU-44, ×75. **7-11.** *Ishigaum* ? sp., **7**; IGUT-KS0556, CHU-41, ×100, **8**; IGUT-KS0504, CHU-44, ×100, **9**; IGUT-KS0581, CHU-43, ×75, **10**; IGUT-KS0584, CHU-43, **11**; IGUT-KS0583, CHU-43, ×75. **12-13.** *Triplanospongos musashiensis* Sashida and Tonishi, **12**; IGUT-KS0572, CHU-44, ×100, **13**; IGUT-KS0548, CHU-42, ×100. **14.** *Praedeflanderella* sp., IGUT-KS0559, CHU-41, ×100. **15-16.** *Nazarovella inflata* Sashida and Tonishi, **15**; IGUT-KS0525, CHU-44, ×150, **16**; IGUT-KS0514, CHU-44, ×150. **17, 19.** *Nazarovella gracilis* De Wever and Caridroit, **17**; IGUT-KS0572, CHU-41, ×75, **19**; IGUT-KS0582, CHU-44, ×75, **18**; *Pseudotormentus* sp., IGUT-KS0582, CHU-41, ×100. **20.** *Octatormentum* ? sp., IGUT-KS0510, CHU-44, ×75.

Ishiga, 1985, pl. 1, figs. 14-15; Yamakita, 1986, pl. 1, figs. 12-13; Ishiga and Miyamoto, 1986, pl. 64, fig. 16; Sashida and Tonishi, 1986, p. 10, pl. 3, figs. 10-12, pl. 4, fig. 7; Caridroit and De Wever, 1986, p. 82-83, pl. 4, figs. 9-15; Tumanda *et al.*, 1990, pl. 1, fig. 27 ; Blome and Reed, 1992, p. 375, figs. 13. 9-10. *Nazarovella* spp., Cheng, 1989, pl. 2, fig. 12. *Nazarovella* sp., Ishiga *et al.*, 1986, pl. 3, figs. 11-13. Nazarovispongus ? sp. B, Ishiga and Suzuki, 1984, pl. 1, figs. 17-20.

Remarks.—Although all of our specimens are incompletely preserved, they may be identified with *N. gracilis* in having diagnostic features of four arms, one of which, the fourth arm, is perpendicular to the plane of the other three.

Occurrence.-CHU-43, 44.

Nazarovella inflata Sashida and Tonishi

Figures 11-15-16

Nazarovella inflata Sashida and Tonishi, 1986, p. 10-11, pl. 4, figs. 1-6, 10-12; Tumanda *et al.*, 1990, pl. 1, fig. 20; Wang, 1991, pl. 4, fig. 2.

Nazorovella spp., Cheng, 1989, pl. 2, figs. 10-11.

unidentified ? latentifistulid, Blome and Reed, 1992, fig. 13. 21.

Remarks.—An inflated tetrahedron shell with long cylindrical rays is a distinctive feature of this species. Expansion of the tetrahedron shell is fairly variable in specimens. Some specimens (*e.g.*, Figure 10-15) have a less expanded shell compared with other ones (*e.g.*, Figure 10-16). This species is easily distinguished from *N. gracilis* in having a tetrahedral shell and cylindrical rays.

Occurrence.-CHU-44.

Genus Praedeflandrella Kozur and Mostler, 1989 Praedeflandrella sp.

Figure 11-14

Remarks.—Several poorly preserved specimens were obtained. This unidentified species differs from other species of the genus *Deflandrella* De Wever and Caridroit in having chambered arms.

Occurrence.-CHU-41.

Family Ishigidae Kozur and Mostler, 1989 Genus *Pseudotormentus* De Wever and Caridroit, 1984 *Pseudotormentus* sp.

Figure 11-18

Remarks.—This unidentified species slightly resembles *Pseudotormentus kamigoriensis* De Wever and Caridroit from southwest Japan. The shell of the latter species, however, has a bulbous central portion. This unnamed species is also similar to *Latentifistula* sp. described by Sashida and Tonishi (1986) from Itsukaichi, Tokyo, but we refrain from a detailed comparison because of the restricted number of specimens.

Occurrence.--CHU-41.

Genus Ishigaum De Wever and Caridroit, 1984 Ishigaum? sp.

Figures 11-7-11

Remarks.—Completely preserved specimens are rare in our collection. This unidentified species characteristically has a large shell composed of three rays, the length of which attains more than 500 μ m. Rays with coarse spongy club-like tips are composed of a bundle of three thin rods and have weak torsion. A conical terminal spine protrudes from the spongy club-like tips. The generic position of this unidentified species is tentative. *Occurrence.*—CHU-43, 44.

Spumellaria Incertae sedis Genus Triplanospongos Sashida and Tonishi, 1988

Remarks.—This genus has almost the same shell structure as that of *Trifidospongus* Noble and Renne, 1990. Blome and Reed (1992) considered that *Trifidospongus* is a junior synonym of the present genus.

Triplanospongos musashiensis Sashida and Tonishi, 1988

Figures 11-12-13

?Paronaella sp. A, Wakita, 1983, pl. 7, fig. 7.

- *Angulobracchia* ? sp., Yoshida and Murata, 1985, pl. 2, fig. 18. *Triplanospongos musashiensis* Sashida and Tonishi, 1988, p. 536-539 ; Tumanda *et al.*, 1990, pl. 2, fig. 14.
- Triplanospongos sp. cf. T. musashiensis, Cheng 1989, p. 142, pl. 3, figs. 13-16.
- Latentifistula sp. cf. L. similicutis, Cheng, 1989, p. 140, pl. 1, figs. 13-14, 16.
- ?*Trifidospongus dekkaensis* Noble and Renne, 1990, p. 388-389, pl. 1, figs. 1-3, 6; Blome and Reed, 1992, p. 376-379, figs. 13. 13-14.
- ?Trifidospongus angustus Noble and Renne, 1990, p. 389, pl. 1, figs. 4-6.

Remarks.—This species shows broad variation in ray morphology as shown by Sashida and Tonishi (1988). The above-listed species placements may reflect different degrees of preservation.

Occurrence.-CHU-42, 43, 44.

References cited

- Adachi, S., Igo, H., Ampornmaha, A., Sashida, K. and Nakornsri, N., 1993; Triassic coral buildups observed in the Chaiburi Formation near Phatthalung, Peninsular Thailand. *Annual Report of the Institute of Geoscience, the University of Tsukuba*, no. 19, p. 27-31.
- Ampornmaha, A., 1993 MS: Lithostratigraphy and biostratigraphy of carbonate rocks in the Phatthalung area, Peninsular Thailand. Unpublished Thesis of Master of Science, Institute of Geoscience, University of Tsukuba, 74 p.
- Ahmad, J., Brsir, J., Ibrahim, A., Abd. Rahim, S. and Uyop, S., 1987 : Note on the occurrence of limestone in the Semanggol Formation, Kedah, Peninsular Malaysia. *Warta Geologi*, vol. 13, no. 4, p. 151–159.
- Ando, H., Tsukamoto, H. and Saito, M., 1991: Permian radiolarians in the Mt. Kinshozan area, Gifu City,

central Japan. Bulletin of Mizunami Fossil Museum, no. 18, p. 101-106 (in Japanese with English abstract).

- Audley-Charles, M.G., 1988: Evolution of the southern margin of Tethys (North Australian region) from early Permian to late Cretaceous. *In*, Audley-Charles, M.G. and Hallam, A. *eds., Gondwana and Tethys.* p. 79-100, Geological Society, Special Publication, no. 37, Oxford University Press, New York.
- Blome, C. and Reed, K., 1992: Permian and Early (?) Triassic radiolarian faunas from the Grindstone Terrane, central Oregon. *Journal of Paleontology*, vol. 66, p. 351-383.
- Bunopas, S., 1981: Paleogeographic history of western Thailand and adjacent parts of Southeast Asia-A plate tectonics interpretation. *Geological Survey*, *Paper*, no. 5, Department of Mineral Resources, Thailand, 810 p.
- Burton, C.K., 1973 : Mesozoic. *In*, Gobett, D.J. and Huchinson, C.S., *eds. Geology of Malay Peninsula*, p. 97–141, Wiley-Interscience, New York.
- Caridroit, M. and De Wever, P., 1986; Some Late Permian radiolarians from pelitic rocks of the Tatsuno Formation (Hyogo Prefecture), Southwest Japan. *Marine Micropaleontology*, vol. 11, p. 55-90.
- Caridroit, M., Ichikawa, K. and Charvet, L., 1985: The Ultra-Tamba Zone, a new unit in the inner zone of southwest Japan-Its importance in the nappe structure after the example of the Maizuru area. *Earth Science* (*Chikyu Kagaku*), vol. 39, p. 210-219.
- Cheng, Y.E., 1989 : Upper Paleozoic and Lower Mesozoic radiolarian assemblages from the Busuanga Islands, North Palawan Block, Philippines. *Bulletin, National Museum, Natural Science*, no. 1, p. 129-175.
- De Wever, P. and Caridroit, M., 1984: Description de quelques nouveaux Latentifistulidae (Radiolaries Polycystines) Paléozoïques du Japan. *Revue de Micropaléontologie*, vol. 27, p. 98-106.
- Fontaine, H., Khoo, H.P. and Vachard, D., 1988 : Discovery of Triassic fossils at Bukit Chuping, in Gunung Sinyum area, and at Kota Jin, Peninsular Malaysia. *Journal of Southeast Asian Earth Sciences*, vol. 2, p. 145-162.
- Foo, K.Y., 1983: The Paleozoic sedimentary rocks of Peninsular Malaysia-Stratigraphy and correlation. In, Proceedings of the Workshop on Stratigraphic Correlation of Thailand and Malaysia, vol. 1, Technical Paper, p. 1-19, Geological Society of Malaysia.
- Foo, K.Y., 1990: Geology and mineral resources of the Taiping-Kuala Kangar area Perak Darui Ridzuan. Geological Survey of Malaysia, Map Report 1, 145 p.
- Helmke, D., 1985 : The Permo-Triassic "Palaeotethys" in mainland Southeast-Asia and adjacent parts of China. *Geologische Rundschau*, vol. 74, p. 215-228.
- Hutchinson, C.S., 1989 : Geological evolution of Southeast Asia. 368 p., Oxford University Press, New York.
- Igo, H., Nagano, N., and Nakinbodee, V., 1988 : Middle Triassic conodonts from southern Thailand. Annual Report of the Institute of Geoscience, the University of Tsukuba, no. 14, p. 46-50.
- Ishida, K., Yamashita, M. and Ishiga, H., 1992: P/T boundary in pelagic sediments in the Tanba Belt, Southwest Japan. Geological Report of Shimane

University, vol. 11, p. 39–57 (in Japanese with English abstract).

- lshiga, H., 1984 : *Follicucullus* (Permian Radiolaria) from Maizuru Group in Maizuru Belt, Southwest Japan. *Earth Science (Chikyu Kagaku*), vol. 38, p. 427-434.
- Ishiga, H., 1985 : Discovery of Permian radiolarians from Katsumi and Oi Formations along south of Maizuru Belt, Southwest Japan and its significance. *Earth Science* (*Chikyu Kagaku*), vol. 39, p. 175-186.
- Ishiga, H., 1986: Late Carboniferous and Permian radiolarian biostratigraphy of Southwest Japan. *Journal of Geoscience, Osaka City University*, vol. 29, p. 89-100.
- Ishiga, H., 1990 : Paleozoic radiolarians. In, Ichikawa, K., Mizutani, S., Hara, I., Hada, S. and Yao, A. eds., Pre-Cretaceous Terranes of Japan. p. 285-295, Nippon Insatsu, Osaka.
- Ishiga, H., and Imoto, N., 1980: Some Permian radiolarians in the Tamba district, Southwest Japan. *Earth Science (Chikyu Kagaku)*, vol. 34, p. 335-345.
- Ishiga, H., Kito, T. and Imoto, N., 1982a : Permian radiolarian biostratigraphy. News of Osaka Micropaleontologists, Special Volume, no. 5, p. 17-26.
- Ishiga, H., Kito, T. and Imoto, N., 1982b: Late Permian radiolarian assemblages in the Tamba district and an adjacent area, Southwest Japan. *Earth Science* (*Chikyu Kagaku*), vol. 36, p. 10-22.
- Ishiga, H., Kito, T. and Imoto, N., 1982c : Middle Permian radiolarian assemblages in the Tamba district and an adjacent area, Southwest Japan. *Earth Science* (*Chikyu Kagaku*), vol. 36, p. 272-281.
- Ishiga, H. and Miyamoto, T., 1986: Follicucullus (Radiolaria) from the Upper Permian Kuma Formation, Kyushu, Southwest Japan. Transactions and Proceedings of the Palaeontological Society of Japan, New Series, no. 141, p. 322-335.
- Ishiga, H. and Suzuki, S., 1984 : Discovery of Permian radiolarians and conodonts from the Shimomidani Formation in the "Maizuru Belts", Southwest Japan and its significance. *Earth Science* (*Chikyu Kagaku*), vol. 38, p. 197-206.
- Ishiga, H. and Suzuki, S., 1988 : Late Paleozoic radiolarian assemblages from the Shimodani Formation in Akiyoshi Terrane, Southwest Japan. The Journal of the Geological Society of Japan, vol. 94, p. 493-499.
- Ishiga, H., Wakamatsu, M., Takigawa, T., Nishimura, K. and Tokuoka, T., 1988 : Radiolarian biostratigraphy of Maizuru Group in the northwest of Ibara and Kanagawa areas, Okayama Prefecture, Southwest Japan. Geological Report of Shimane University, vol. 7, p. 39-48 (in Japanese with English abstract).
- Ishiga, H., Watase, H. and Naka, T., 1986: Permian radiolarians from Nishiki Group in Sangun-Chugoku Belt, Southwest Japan. *Earth Science (Chikyu Kagaku)*, vol. 40, p. 124-136.
- Isozaki, Y., 1984: Occurrence of Permian radiolarians from the clastic formation in Taishaku area in Hiroshima Prefecture and reexamination of its stratigraphy. Report of cooperative research on DESK (Development of sedimentary basins through late Paleozotic to Paleogene in Kinki and neighbouring district), vol. 3, p. 28-34 (in Japanese).
- Jaafar, B.A., 1976 : The geology and mineral resources of

the Karak and Temerloh areas, Pahang. Geological Survey of Malaysia, District Memoir 15, 138 p.

- Jones, C.R., 1978: Geology and mineral resources of Perlis, north Kedah and the Langkawi Islands. *Geological Survey of Malaysia, District Memoir* 17, 257 p.
- Khoo, H.P., 1983 : Mesozoic stratigraphy in Peninsula Malaysia. In, Proceedings of the Workshop on Stratigraphic Correlation of Thailand and Malaysia, vol. 1, Technical Paper, p. 370-383, Geological Society of Malaysia.
- Kobayashi, T., 1963 : *Halobia* and some other fossils from Kedah, Northwest Malaya. *Japanese Journal of Geology and Geography*, vol. 34, p. 113-128, pl. 6.
- Koike, T., 1973: Triassic conodonts from Kedah and Pahang, Malaysia. Geology and Paleontology of Southeast Asia, vol. 12, p. 91-51, University of Tokyo Press, Tokyo.
- Koike, T., 1982: Triassic conodont biostratigraphy in Kedah, West Malaysia. Geology and Palaeontology of Southeast Asia, vol. 25, p. 9-51, University of Tokyo Press, Tokyo.
- Kojima, S., 1982: Some Jurassic, Triassic and Permian radiolarians from the eastern part of Takayama City, central Japan. News of Osaka Micropaleontologists, Special Volume, no. 5, p. 81-92 (in Japanese with English abstract).
- Kojima, S., 1986 : Occurrence of Permian radiolarians from chert pebbles in conglomerate at Yokoo, Nyukawa Village, Gifu Prefecture, central Japan. News of Osaka Micropaleontologists, Special Volume, no. 7, p. 175-179 (in Japanese with English abstract).
- Kozur, H. and Mostler, H., 1982: Entactinia Suborder nov., a new radiolarian suborder. *Geologisch-Paläontologische Mitteilungen Innusbruck*, vol. 11/12, p. 399-414.
- Kozur, H. and Mostler, H., 1989: Radiolarien und Schwammskeleren aus dem Unterperm des Vorurals. *Geologisch-Paläontologische Mitteilungen Innsbruck*, Sonderband, 2, p. 147-275.
- Kuwahara, K. and Sakamoto, M., 1992 : Late Permian Albaillella (Radiolaria) from a bedded chert section in the Gujyo-Hachiman area of the Mino Belt, central Japan. Journal of Geoscience, Osaka City University, vol. 35, p. 33-51.
- Kuwahara, K., Nakae, S. and Yao, A., 1991 : Late Permian "Toishi-type" siliceous mudstone in the Mino-Tamba Belt. The Journal of the Geological Society of Japan, vol. 97, p. 1005-1008. (in Japanese)
- Metcalfe, I., 1981: Permian and early Triassic conodonts from northwest Peninsular Malaysia. *Bulletin of the Geological Society of Malaysia*, no. 14, p. 119-126.
- Metcalfe, I., 1984: The Permian-Triassic boundary in northwest Malaya. *Warta Geologi*, vol. 10, p. 139-147.
- Metcalfe, I., 1988 : Origin and assembly of South-east Asian continental terranes. *In*, Audley-Charles, M.G. and Hallam, A. *eds.*, *Gondwana and Tethys*, p. 101-118, Geological Society, Special Publication, no. 37, Oxford University Press, New York.
- Metcalfe, I., 1989: Conodont biostratigraphic studies in Sumatra: Preliminary results. *Bulletin of the Geological Society of Malaysia*, vol. 20, p. 243-247.

- Metcalfe, I., 1990a: Stratigraphic and tectonic implications of Triassic conodonts from northwest Peninsular Malaysia. *Geological Magazine*, vol. 127, p. 567-578.
- Metcalfe, I., 1990b : Lower and Middle Triassic conodonts from the Jerus Limestone, Pahang, Peninsular Malaysia. *Journal of Southeast Asian Earth Sciences*, vol. 4, p. 141-146.
- Metcalfe, I., 1991: Allochthonous terrane processes in Southeast Asia. *In*, Dewey, J.F., Gass, I.G., Curry, G.B., Harris, N.B.W. and Sengör, A.M.C. *eds.*, *Allochthonous terranes*, p. 169-184, Cambridge University Press, Cambridge.
- Metcalfe, I., 1992: Upper Triassic conodonts from the Kodiang Limestone, Kedah, Peninsular Malaysia. *Journal of Southeast Asian Earth Sciences*, vol. 7, p. 131-138.
- Metcalfe, I., Sivam, S.P. and Stauffer, P.H., 1982: Stratigraphy and sedimentology of Middle Triassic rocks exposed near Lanchang, Pahang, Peninsular Malaysia. *Bulletin of the Geological Society of Malaysia*, vol. 15, p. 19-30.
- Mitchell, A.H.G., 1989: The Shan Plateau and Western Burma: Mesozoic-Cenozoic plate boundaries and correlations with Tibet. *In*, Sengör, A.M.C. *ed.*, *Tectonic evolution of the Tethyan ragion.*, p. 567– 583, Kluwer Academic Publishers, Amsterdam.
- Mitchell, A.H.G., 1992: Late Permian-Mesozoic events and the Merguli Group Nappe in Myanmar and Thailand. *Journal of Southeast Asian Earth Sciences*, vol. 7, p. 165-178.
- Naka, T. and Ishiga, H., 1985: Discovery of Permian radiolarians from Nishiki Group in western part of Sangun-Chugoku Belt, Southwest Japan. *Earth Science* (*Chikyu Kagaku*), vol. 39, p. 229-233. (*in Japanese with English abstract*)
- Nazarov, B.B. and Ormiston, A.R., 1985 : Radiolaria from the Late Paleozoic of the southern Urals, USSR and West Texas, USA. *Micropaleontology*, vol. 31, p. 1-54.
- Nishimura, K. and Ishiga, H., 1987 : Radiolarian biostratigraphy of the Maizuru Group in Yanahara area, Southwest Japan. *Memoir of the Faculty of Science, Shimane University*, vol. 21, p. 169-188.
- Nishizono, Y., Ohishi, A., Sato, T. and Murata, M., 1982: Radiolarian fauna from the Paleozoic and Mesozoic formations distributed along the mid-stream of Kuma River, Kyushu, Japan. *News of Osaka Micropaleontologists, Special Volume*, no. 5, p. 311-326. (*in Japanese with English abstract*)
- Noble, P. and Renne, P., 1990: Paleoenvironmental and biostratigraphic significance of siliceous microfossils of the Permo-Triassic Redding section, eastern Klamath Mountains, California. *Marine Micropaleontology*, vol. 15, p. 379-391.
- Sashida, K., 1988 : Lower Jurassic multisegmented Nassellaria from the Itsukaichi area, western part of Tokyo Prefecture, central Japan. Science Reports of the Institute of Geoscience, University of Tsukuba, Section B, Geological Sciences, vol. 9, p. 1-27.
- Sashida, K. and Igo, H., 1992 : Triassic radiolarians from a limestone exposed at Khao Chiak near Phatthalung, southern Thailand. *Transactions and Proceedings*

of the Palaeontological Society of Japan, New Series, no. 168, p. 1296–1310.

- Sashida, K., Igo, H., Adachi, S., Koike, T., Hisada, K., Nakornsri, N., Amnan, B. Ibarahim and Ampornmaha, A., 1993 : Occurrence of Paleozoic and Mesozoic radiolarians from Thailand and Malaysia and its geologic significance (preliminary report). News of Osaka Micropaleontologists, Special Volume, no. 9, p. 1–17, pls. 1–2. (in Japanese with English abstract)
- Sashida, K., Igo, H., Hisada, K., Nakornsri, N., and Ampornmaha, A., 1993 : Occurrence of Paleozoic and Early Mesozoic Radiolaria in Thailand (preliminary report). *Journal of Southeast Asian Earth Sciences*, vol. 8, nos. 1-4, p. 97-108.
- Sashida, K. and Tonishi, K., 1985 : Permian radiolarians from the Kanto Mountains, central Japan — Some Upper Permian Spumellaria from Itsukaichi, western part of Tokyo Prefecture —. Science Reports of the Institute of Geoscience, University of Tsukuba, Section B, Geological Sciences, vol. 6, p. 1-19.
- Sashida, K. and Tonishi, K., 1986 : Upper Permian stauraxon polycystine Radiolaria from Itsukaichi, western part of Tokyo Prefecture. *Science Reports of the Institute of Geoscience, University of Tsukuba, Section B, Geological Sciences*, vol. 7, p. 1-14.
- Sashida, K. and Tonishi, K., 1988 : Additional note on Upper Permian radiolarian fauna from Itsukaichi, western part of Tokyo Prefecture, central Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 151, p. 523-542.
- Sengör, A.M.C., Altiner, D., Cin, A., Ustaomer, T. and Hsü, K.J., 1988: Origin and assembly of the Tethyside orogenic collage at the expense of Gondwana land. *In*, Audley-Charles, M.G. and Hallam, A. *eds.*, *Gondwana and Tethys*, p. 119-181, Geological Society, Special Publication, no. 37, Oxford University Press, New York.
- Sugiyama, K., 1992: Lower and Middle Triassic radiolarians from Mt. Kinkazan, Gifu Prefecture, central Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 167, p. 1180-1223.
- Suyari, K., Kuwano, Y. and Ishida, K., 1983 : Biostratigraphic study of the north subbelt of the Chichibu Belt in central Shikoku. *Journal of Science of College of General Education, University of Tokushima*, vol. 16, p. 143-167.
- Takemura, A. and Nakaseko, K., 1981: A new Permian radiolarian genus from the Tamba belt, southwest Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no.

124, p. 208-214.

- Tamura, M., Hashimoto, W., Igo, H., Ishibashi, T., Iwai, J., Kobayashi, T., Koike, T., Pitakpaivan, K., Sato T., and Yin, E.H., 1975: The Triassic System of Malaysia, Thailand and some adjacent areas. *Geology and Palaeontology of Southeast Asia*, vol. 15, p. 103-149, University of Tokyo Press, Tokyo.
- Tazawa, J., Aita, Y., Yuki, T. and Otsuki, K., 1984: Discovery of Permian radiolarians from "Non-calcareous Paleozoic strata" of Omi, central Japan. *Earth Science* (*Chikyu Kagaku*), vol. 38, p. 264-267. (*in Japanese*)
- Teoh, L.H., 1992: Geology and mineral resources of the Sungai Tiang area, Kedah Darulaman. *Geological Survey of Malaysia, Map Report* 5, 93 p.
- Tumanda, F.P., Sato, T. and Sashida, K., 1990: Preliminary Late Permian radiolarian biostratigraphy of Busuanga Island, Palawan, Philippines. *Annual Report of the Institute of Geoscience, the University of Tsukuba*, no. 16, p. 39-45.
- Uchiyama, T., Sano, H. and Kanmera, K., 1986 : Depositional and tectonic settings of cherts around the Akiyoshi Limestone Group, southwest Japan. *Memoir of Faculty of Science, Kyushu University, Series D, Geology*, vol. 26, p. 51-68.
- Wakita, K., 1983 : Allochthonous blocks and submarine slide deposits in the Jurassic formation, southwest of Gujyo-Hachiman, Gifu Prefecture, central Japan. Bulletin of Geological Survey of Japan, vol. 34, p. 329-342. (in Japanese with English abstract)
- Wang, Y., 1991: On progress in the study of Paleozoic radiolarians in China. Acta Micropalaeontologica Sinica, vol. 8, p. 273-251.
- Wu, H. and Li, H., 1989: Carboniferous and Permian Radiolaria in the Menglian area, western Yunnan. Acta Micropalaeontologica Sinica, vol. 6, p. 337-343.
- Yamakita, S., 1986 : Discovery of Late Permian radiolarians including *Follicucullus charveti* from the Kurosegawa terrane in eastern Shikoku. *The Journal of the Geological Sciety of Japan*, vol. 92, p. 909–911 (*in Japanese*).
- Yao, A., Yu, J. and An, T., 1993 : Late Paleozoic radiolarians from the Guizho and Guanxi areas, China. *Journal of Geoscience, Osaka City University*, vol. 36, p. 1-13.
- Yoshida, H. and Murata, M., 1985: Permian radiolarian biostratigraphy from the northeastern part of Saiki City, Oita Prefecture, Japan. The Journal of the Geological Society of Japan, vol. 91, p. 525-533. (in Japanese with English abstract)

985 **Density and relative abundance of microspheric** and megalospheric forms of *Nummulites* as sedimentologic and taphonomic indicators

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Abstract. The density and relative abundance of smaller (megalospheric) and larger (microspheric) forms of *Nummulites* provide excellent indicators of sedimentary condensation, dilution and size-sorting during the formation of fossil assemblages, using an inferred 10:1 original ratio of the two forms. Various degrees of current sorting were recognized in the sandy facies of Nankinhama of Hahajima, Ogasawara Islands; storm condensation in low-angle, cross-bedded sandstone, winnowing in sandstone beds with strongly imbricated *Nummulites* tests, and highly diluted occurrence in debris flow deposits. A poorly sorted, pale green, bedded sandstone is interpreted to represent the least disturbed and perhaps indigenous preservation of *Nummulites*. In this sandstone, the ratio of the two forms is roughly 10:1, as for other published examples.

No significant modification of density and relative abundance between the two forms occurs in an apparently allochthonous occurrence of *Nummulites* in conglomeratic debris flows. Therefore, preservation of the original ratio of the two forms of *Nummulites* does not necessarily exclude transportation.

Key words : Taphonomy, sorting, biofabric, Nummulites, Ogasawara, Eocene

Introduction

Discrimination of in-situ from transported fossils of the epifaunal benthos is difficult, because epifaunal benthos shows no definite indication of *in-situ* growth, such as preserved life position commonly recognized in infaunal bivalves. This is true of Nummulites, an epifaunal larger foraminifer which flourished in the Eocene tropical and subtropical sea. One of the advantages of Nummulites in assessing its post-mortem transportation is its distinct size dimorphism. Iwasaki and Aoshima (1970) first noted current sorting in a Nummulites accumulation in the Eccene of Hahajima, observing variable ratios of microspheric (larger) and megalospheric (smaller) forms. Aigner (1982, 1985) successfully applied the same idea to the Nummulites accumulations in the Eocene of Egypt. He recongnized four types of Nummulites accumulations which were characterized by different biofabrics and ratio of microspheric to megalospheric forms of Nummulites in the accumulations. In-situ and selectively transported fossil assemblages between the two forms were inferred in the study.

In this paper, I evaluate the utility of density as well as relative abundance of the two forms of *Nummulites* as sedimentologic and taphonomic indicators.

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Stratigraphic and paleoenvironmental settings of the Nummulites beds

Hahajima is an oceanic island consisting of Eocene volcanic rocks, and one of the Japanese Ogasawara Islands, located in the western Pacific more than 1,000 km southeast from mainland Japan. The example studied in this paper thus provides a contrasting environmental setting of a *Nummulites* association to the well known example from the Eocene of Egypt, which represents a shallow embayment basin bordering the Tethys sea (Aigner, 1982, 1985).

The island consists mainly of andesitic and basaltic lava, and sedimentary rocks are distributed in the central and southern part. The general stratigraphy and biostratigraphy has been described by Iwasaki and Aoshima (1970), Ujiié and Matsumaru (1977) and Matsumaru (1984), following some early studies made before World War II which are summarized in Ujiié and Matsumaru (1977) and literature therein.

According to Ujiié and Matsumaru (1977), the sedimentary deposits of Hahajima are divided into three formations; basal conglomeratic and sandy sediments containing *Nummulites* and other larger foraminifera (Yusan Formation), fine-grained sandstone with abundant planktonic foraminifera (Okimura Formation) and Sekimon Limestone. The age of the *Nummulites*-bearing strata has been assigned to the Lutetian (middle Eocene; Yabe, 1920, larger foraminifera; Hanzawa, 1925, larger foraminifera; Saito, 1962, planktonic foraminifera). The *Nummulites* of Hahajima was first described as *Nummulites boninensis* by Hanzawa (1947). Ujiié and Matsumaru (1977) and Matsumaru (1984) recognized several other species of *Nummulites*, such as *N. perforatus* (Montfort) and *N. cf. partschi* de la Harpe.

The stratigraphic sequence of the *Nummulites*-bearing strata in Hahajima is best exposed at Nankinhama and Miyukinohama, where a general coarsening-upward facies succession can be recognized above the basal lava. The vertical facies succession is interpreted as representing deepening-upward environmental changes (Kondo, 1993, 1995).

Sedimentary facies and their vertical succession

The basal contact of the sedimentary rock and the underlying lava along the Miyukinohama and Nankinhama coast shows a topography with rugged relief.

The 25-m thick sequence, exposed at Nankinhama and Miyukinohama coasts, displays an overall coarseningupward trend (Figure 1). The sedimentary sequence consists of a lower sandstone and siltstone, a middle sandstone and an upper conglomerate. The following facies designation, description and interpretation of the sedimentary facies are based on Kondo (1995).

Five sedimentary facies are recognized in the succession exposed at Nankinhama and Miyukinohama. Each sedimentary facies is briefly described below in ascending order with a corresponding environmental interpretation.

The Interlaminated Sandstone and Siltstone Facies consists mainly of interlaminated sandstone and siltstone associated with some conglomerate and breccia at the base. This facies is interpreted as the shallowest environment in the sequence studied. No *Nummulites* was found here.

The Cross-bedded Sandstone Facies overlies the Interlaminated Sandstone and Siltstone Facies. Paleocurrent patterns shown by the *Nummulites* test imbrication are multidirectional, representing an unusual current pattern resulting from storm-like high-energy events (Kondo, 1993; 1995). The occurrence of *Nummulites* is generally sparse, but may be very condensed locally.

The Cross-bedded Sandstone Facies changes upward

into the Parallel-bedded Sandstone Facies. This facies contains large numbers of *Nummulites*, both megalospheric and microspheric forms. Pebble- and cobblesized concretionary clasts with *Nummulites* are occasionally contained in this facies. The upper unit of this facies characteristically shows a pale green colour and less common current-generated sedimentary structures, as compared with the lower unit. The upper unit is interpreted as the indigenous environment in which *Nummulites* lived, representing an offshore environment where water agitation was relatively uncommon.

The Interbedded Sandstone and Conglomerate Facies is a transitional facies between the underlying Parallelbedded Sandstone Facies and the overlying Thick-bedded Conglomerate Facies. The sandstone beds in this facies are poorly-stratified or structureless, and the facies is interpreted as a sediment gravity flow deposit. The sparse occurrence of *Nummulites* found is consistent with this facies interpretation.

The Thick-bedded Conglomerate Facies is a matrixsupported cobble to boulder conglomerate, with poorly developed stratification. This clast fabric suggests a debris flow origin. *Nummulites* abundance is as high as in the Parallel-bedded Sandstone Facies.

Taphonomic processes inferred from density and relative abundance of microspheric and megalospheric forms

The vast majority, if not all, of foraminifers are known or thought to undergo both sexual and asexual reproductive phases. The well known morphological dimorphism of Nummulites reflects this phenomenon. Sexual reproduction (gametogenesis) gives rise to diploid microspheric forms, and asexual reproduction (schizogony) to haploid megalospheric forms. Thus, two distinct size classes are found in a single population (Figure 2). Among modern populations of larger foraminifera with symbiotic algae as in Nummulites, microspheric forms are scarce (Hallock, 1982), and similarly, megalospheric forms dominate in original, undisturbed assemblages (Blondeau, 1972; Aigner, 1983, 1985). An original ratio of megalospheric to microspheric forms of approximately 10:1 is inferred in these studies. If we assume that this ratio applied to Nummulites boninensis and other species in the Yusan Formation of Hahajima, the relative abundance of the two forms can be used as a measure of the sorting effect during transport. In this study, numbers of megalospheric and microspheric forms are counted, to represent both relative abundance and also density of the two forms. The mode of occurrence of Nummulites and other biofabric features are described for each facies below.

A quadrat $(15 \times 15 \text{ cm})$ was used to count the density and relative abundances of the forms of *Nummulites* for a vertical section of sandy beds in Nankinhama and conglomeratic beds in Miyukinohama. The measured outcrops were selected to represent all the major sedimentary facies and several different lithologies in the Parallel-



Figure 1. The sedimentary facies and their vertical succession at Nankinhama and Miyukinohama coast, Hahajima. Density of *Nummulites* occurrence is shown on the left side of the columnar section; black (abundant), stripe (common), white (rare or absent). Field photographs of mode of the fossil occurrence are shown for each sedimentary facies. Most of the *Nummulites* tests in the Cross-bedded, Sandstone Facies are dissolved out. Measured units for density and relative abundance of the two forms of *Nummulites* are shown as arrows on the left side of the column.

bedded Sandstone Facies (Figure 1). Three or more randomly selected parts of each outcrop were measured. The measurement was made in a total of 44 quadrats. To confirm sorting phenomena indicated by this method, the size frequency distribution of the diameter of microspheric form was also measured directly in the field in Nankinhama.

Figure 3 shows the abundance of the two forms of Nummulites within the quadrats $(15 \times 15 \text{ cm})$ counted for

each sedimentary facies. This illustrates that the density and relative abundance of the two forms of *Nummulites* are closely related to sedimentary facies, and hence depositional environment and processes. The measurements in different sedimentary facies and lithologies are fairly variable, but easily distinguishable from each other in most cases (Figure 3).

No macrofossils, including *Nummulites*, were found in the Interlaminated Sandstone and Siltstone Facies.



Figure 2. Field photograph of megalospheric and microspheric forms of *Nummulites* in the black silty sand in the Parallel-bedded Sandstone Facies at Nankinhama (Upper), and its close-up view (below).

The density of *Nummulites* occurrence in the Crossbedded Sandstone Facies is higher than for the Thickbedded Conglomerate Facies and the Parallel-bedded Sandstone Facies. The numbers of megalospheric and microspheric forms in the Cross-bedded Sandstone Facies are plotted within the region of the original *Nummulites* population or slightly microspheric-rich, winnowed region (Figure 3). This suggests that the storm reworking and redeposition inferred for this facies (Kondo, 1993, 1995) did not result in distinct size sorting.

The Parallel-bedded Sandstone Facies consists of several different types of lithology; pale-green parallelbedded sandstone distributed mainly in the upper unit, and sandstone with strongly imbricated tests of Nummulites and black silty sand found in the lower unit. The density and relative abundance of the two forms are most variable in this facies, and these lithologies within this facies differ greatly from each other (Figure 3). Palegreen, bedded sandstone beds are roughly constant in their test ratios and similar to those of the Thick-bedded Conglomerate Facies. The sandstone with strongly-imbricated tests shows distinct sorting, with concentration of microspheric forms and smaller forms inferred to have been swept away by currents. Consistent with this, the size frequency distribution of microspheric forms is dominated by larger specimens (Figure 4, lower). In the black, silty sand layer, fossil density is much lower for the other sedimentary facies (Figure 3). This is interpreted as the original low density of Nummulites in the silty



No. microspheric form

Figure 3. The density and relative abundance of megalospheric and microspheric forms of *Nummulites* for various sedimentary facies in the Nankinhama-Miyukino-hama section (upper). Interpretative diagram of post-mortem modification of density and relative abundances of the two forms of *Nummulites* (lower).

substrate.

Yasuo Kondo

In the Interbedded Sandstone and Conglomerate Facies, the smaller forms are sorted away from structureless sandstone beds, though the densities are very much reduced.

The Thick-bedded Conglomerate Facies contains abundant *Nummulites*. The density and relative abundance of the two forms are relatively constant, with megalospheric forms $100-300/225 \text{ cm}^2$, and microspheric forms $10-30/225 \text{ cm}^2$ (Figure 3). The ratio of megalospheric to microspheric forms is thus 10:1. It is, therefore, concluded that there was no distinct size sorting



Figure 4. Comparison of size frequency distribution of microspheric forms of *Nummulites* between fossil assemblages from A) the pale green bedded sandstone in the Parallel-bedded Sandstone Facies in Nankinhama (white) and the Thick-bedded Conglomerate Facies at the western end of Nankinhama (black), and B) the pale green bedded sandstone in Nankinhama (white) and sandstone beds with strongly-imbricated tests (stripe) in the Parallel-bedded Sandstone Facies in Nankinhama. Note the clear deviation toward larger size in sandstone beds with strongly-imbricated tests.

during deposition of these debris flow deposits. The larger forms show a similar size-frequency distribution (Figure 4, upper).

Which sedimentary facies represents the habitat of *Nummulites* ?

Both the Thick-bedded Conglomerate Facies and the pale green bedded sandstone in the Parallel-bedded Sandstone Facies contain large numbers of *Nummulites* tests, and show approximately the expected natural ratio 10:1. The former, however, is interpreted as debris flow deposits, and must be excluded as a candidate of *Nummulites*' natural habitat.

The pale green, bedded sandstone, therefore, probably represents the habitat of *Nummulites*. This facies is little affected by substrate disturbances, although some do occur including well-developed test imbrication and

small-scale ripple bedding. The presence of the concretionary clasts containing similar ratios of Nummulites tests may perhaps indicate reworking of prefossilized Nummulites. Aigner (1982) called attention to the nature of Nummulites tests as a sedimentary particle, stating that the Nummulites test must have been originally very porous (up to 54%) and light (down to 1.28 g/cm3), and therefore very susceptible to being reworked. A similar idea has been suggested by Seilacher (personal communication), who noted the importance of prefossilization in modifying hydrodynamic behavior of crinoid remains (Seilacher, 1973). This suggests that undisturbed preservation of Nummulites occurs only rarely in sheltered environments, and that in-situ reworking and small-scale transportation are involved even in indigenous fossil assemblages.

Nevertheless, the evidence of common reworking found in this facies is not necessarily inconsistent with this facies representing the habitat of *Nummulites*. Considering that the animal had almost none or very little locomotive and escape ability, incessant and rapid dumping of sediments into their habitat would greatly hinder these animals from establishing continuous colonization. In contrast, transportation of the living tests by current or wave may not harm them so long as the tests remained on the sea floor to receive adequate water circulation and sufficient light to sustain the growth of the inferred symbiotic algae (Lee *et al.*, 1979).

As discussed above, *in-situ* deposition of *Nummulites* is inferred, based on the comparison between observed and postulated ratio (10:1) of the megalospheric and microspheric forms of *Nummulites*. The roughly constant ratio of the two fossil forms in the pale-green bedded sandstone is, in turn, strong evidence for the conclusion that the sandstone represents the original habitat of *Nummulites*. Also, this implies that the postulated original ratio of 10:1 for the megalospheric and microspheric forms of *Nummulites* is independently supported by the present study.

Summary

(1) The density and relative abundance of megalospheric and microspheric forms of *Nummulites* is a powerful tool for estimating sedimentary condensation, dilution and current sorting during formation of fossil assemblages. Attention must be paid to other features, however, such as biofabric, sedimentary structures and their vertical succession for an accurate interpretation of the origin of the fossil assemblage, because transportation can occur without significant size sorting, as in debris flows.

(2) The ratio of megalospheric and microspheric forms of the original population of *Nummulites boninensis* and other species is inferred to be roughly 10:1, similar to the ratio reported for *Nummulites gizehensis* studied by Aigner (1982, 1983, 1985).

(3) The natural habitat of *Nummulites* from the volcaniclastic sequence of Hahajima is inferred to have

Hahajima 母島, Nankinhama 南京浜, Miyukinohama 御幸ノ浜.

been transitional to an offshore sandy bottom where current activities causing rapid burial or reworking were relatively uncommon. Evidence of In-situ reworking, and a small amount of transport nevertheless does occur in this facies.

References

- Aigner, T., 1982 : Event stratifications in nummulite accumulations and in shell beds from the Eocene of Egypt. In, Einsele, G. and Seilacher, A. eds., Cyclic and Event Stratification, p. 248-262., Springer Verlag, Berlin.
- Aigner, T., 1983: Facies and origin of nummulitic buildups: an example from the Giza Pyramids Plateau (Middle Eocene, Egypt). Neues Jahrbuch für Geologie und Paläontologie, Abhandlungen, vol. 166, p. 347-368.
- Aigner, T., 1985: Biofabrics as dynamic indicator in Nummulite accumulations. Journal of Sedimentary Petrology, vol. 55, p. 0131-0134.
- Blondeau, A., 1972 : Les Nummulites : Vuibert éd., Paris, 254 n.
- Hallock, P., 1981: Algal symbiosis: a mathematical analysis. Marine Biology., vol. 62, p. 249-255.
- Hanzawa, S., 1925: Notes on some foraminiferous rocks from Okinawa-jima and the Ogasawara Islands. Journal of the Geological Society of Tokyo, vol. 31, p. 10-24. (in Japanese)
- Hanzawa, S., 1947 : Eocene foraminifera from Haha-jima (Hillsborough Island). Journal of Paleontology, vol. 21, p. 254-259.
- Iwasaki, Y. and Aoshima, M., 1970: Report on geology of the Bonin Islands. In, The nature of the Bonin and the Volcano Islands, p. 205-219. Higher Edncation and Science Bureau, Ministry of Education and Cultural Properties Protection Division, Agency for Cultural Affairs, Japan. (in Japanese with English abstract)

Kondo, Y., 1993: Sedimentary facies and depositional

environment of the Eocene volcaniclastic sequence, Hahajima, Ogasawara Islands, western Pacific, with discussion on taphonomy of Nummulites. Programme and Abstracts, Geological Society of New Zealand Inc., 1993 Annual Conference, p. 102, Victoria University of Wellington.

- Kondo, Y., 1995 : Paleocurrent reconstruction, using imbricated tests of Nummulites in the Eocene of Hahajima, Ogasawara Islands. Journal of the Geological Society of Japan, vol. 101, p. 228-234.
- Lee, J.J., McEnery, E.G., Kahn, E.G. and Schuster, F.L., 1979: Symbiosis and the evolution of larger foraminifera. Micropaleontology, vol. 25, p. 118-140.
- Matsumaru, K., 1984: Larger foraminiferal associations useful for the correlation of the Eocene and Oligocene sediments in the Ogasawara Islands, Japan, and an examination of Nummulites boninensis Hanzawa. Benthos '83; 2nd International Symposium on Benthic Foraminifera, p. 415-422.
- Seilacher, A., 1973 : Biostratinomy : the sedimentology of biologically standardized particles. In, Ginsburg, R.N. ed., Evolving concepts and method in sedimentology. Johns Hopkins Univ. Press., p. 159-177. Baltimore and London.
- Saito, T. 1962: Eocene planktonic foraminifera from Hahajima (Hillsborough Islands). Transactions and Proceedings of the Palaeontological Society of Japan, New Series, No. 45, p. 209-225.
- Ujiié, H. 1985: Microfossils from the Ogasawara and Mariana Arcs and history of formation of the Philippine Sea. Gekkan Chikyu (Earth Monthly), vol. 7, p. 657-663. (in Japanese ; title translated)
- Ujiié, H. and Matsumaru, K. 1979 : Stratigraphic outline of Hahajima (Hillsborough Island), Bonin Islands. Memoirs of the National Science Museum, No. 10, p. 5-18, 4 pls. (in Japanese with English summary)
- Yabe, H. 1920: Japanese Tertiary rocks with larger foraminifera (2). The Journal of the Geological Society of Japan, vol. 27, p. 293-300. (in Japanese)

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986 Early Middle Miocene ostracodes from the Suenomatsuyama Formation, Ninohe City, Northeast Japan and their paleoenvironmental significance

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Abstract. Sixty-six species in 44 genera of fossil ostracodes are reported for the first time from the lower Middle Miocene Suenomatsuyama Formation, distributed in Ninohe City, Iwate Prefecture, Northeast Japan. Dominating species throughout the formation are *Elofsonella* cf. *concinna* (Jones), *Neomonoceratina japonica* (Ishizaki), *Pectocythere daishakaensis* Tabuki and *Schizocythere kishinouyei* (Kajiyama). Vertical changes of species composition of ostracode faunas and Q-mode cluster analysis reveal that the lower part of the Suenomatsuyama Formation is dominated by cool and sublittoral species, while the middle to upper part is marked by sublittoral temperate-water species. Thus, cool to temperate water ostracode species, which appeared abundantly in the middle part of the underlying Kadonosawa Formation, lingered on until the deposition time of the Suenomatsuyama Formation, whereas warm-water species became dominant in the upper part. One new species, *Laperousecythere ishizakii*, is described herein.

Key words : Miocene, circumpolar and cryophilic ostracodes, cluster analysis, mid-Neogene Climatic Optimum, Laperousecythere

Introduction

Late Early to early Middle Miocene rocks are well exposed in the vicinity of the Mabechi-gawa River, Ninohe City, in the northernmost part of lwate Prefecture, Northeast Japan. Previous geological and paleontological studies pointed out that only for a short period (ca. 16.5-15 Ma), tropical to subtropical faunas and floras spread widely from southern Kyushu to southern Hokkaido in Japan (e.g. Oyama, 1950; Chinzei, 1986; Itoigawa and Yamanoi, 1990). This event is called the mid-Neogene Climatic Optimum, which was followed by an abrupt cooling occurring ca. 15 Ma (e.g. Tsuchi, 1986). In the study area, tropical to subtropical molluscan faunas called the Kadonosawa Fauna (Otuka, 1939; Chinzei, 1963) have been reported from the Lower Miocene Yotsuyaku Formation (the Koiwai Mudstone, Sandstone and Conglomerate Member) and the lowest part of the Kadonosawa Formation (the Tate Conglomeratic Sandstone Member) (Otuka, 1934 ; Chinzei, 1963, 1979). They are thought to have lived in intertidal to upper sublittoral areas under the influence of a warm-water current (Chinzei, 1978). According to Chinzei (1979), the upper part of the Kadonosawa Formation yields the Shiobara-type molluscan fossils: cool to temperate shallow-water and endemic Japanese molluscan faunas from the Middle to Late Miocene (Chinzei, 1963, 1978; Chinzei and Iwasaki, 1967; Iwasaki, 1970, 1981). Thus, the overlying Suenomatsuyama Formation, which is the object of the present study, must be deposits of post-mid-Neogene Climatic Optimum.

Studies on faunal changes of ostracodes during these periods, however, have been superficial. Hence, it is important to investigate vertical changes of ostracode faunas spanning from the Kadonosawa Formation to the overlying Suenomatsuyama Formation and search for ancestors of Japanese endemic ostracodes. Recently, Irizuki and Matsubara (1994) studied ostracode faunas from the Kadonosawa Formation and proved the existence of a succession of depositional environments in the Kadonosawa Formation: warm inshore, deep offshore and cool inshore in ascending order. They emphasized, moreover, the significance of circumpolar-cryophilic ostracode species first appearing around the base of the diatom Denticulopsis praelauta Zone (the middle part of the Kadonosawa Formation): the appearance of coolwater ostracodes predates that of cool to temperatewater molluscs belonging to the Shiobara-type Fauna.

The aim of this study is to report Middle Miocene ostracodes for the first time from the Suenomatsuyama Formation and to show vertical changes of cool to temperate ostracode faunas after the mid-Neogene Climatic Optimum.

Geological settings

The geology of Ninohe City has been studied by many workers (e.g. Otuka, 1934; Chinzei, 1958a, b; Samata, 1976). The Suenomatsuyama Formation overlies conformably, partly disconformably, the Kadonosawa Formation and is conformably, partly disconformably, overlain by the Tomesaki Formation (Figure 1). Since the Suenomatsuyama Formation has a great variety of rock types, it comprises seven members (Chinzei, 1958a, 1966): 1) Shinden Sandstone (volcanic medium sandstone), 2) Nakuidake Andesite (andesitic volcanic breccia and tuff breccia), 3) Anaushi Conglomeratic Sandstone (conglomerate and coarse sandstone), 4) Itsukamachi Sandstone (tuffaceous medium sandstone), 5) Aikawa Andesite (andesitic volcanic breccia and lapilli tuff), 6) Maisawa Sandstone (medium to coarse sandstone) and 7) Tsukidate Sandstone (pumiceous coarse sandstone) from NNE to SSW. The fossil-bearing rock samples used in the present study were collected from the Itsukamachi Sandstone and Maisawa Sandstone Members.

Many molluscan fossils have so far been reported from the Suenomatsuyama Formation (e.g. Aoki, 1960; Chinzei, 1966, 1979). They are assigned to the cool to temperate Shiobara-type Fauna mentioned above. Some datum planes of planktonic microfossils have also been identified around the study area (Samata, 1976; Akiba, 1977; Koizumi, 1979, 1986; Oda *et al.*, 1983, 1984; Maruyama, 1984). According to the diatom biostratigraphy by Koizumi (1979, 1986) and Maruyama (1984), the



TS: Tsukidate Sandstone AI: Aikawa Andesite AN: Anaushi Coarse Sandstone IT: Itsukamachi Sandstone MA: Maisawa Sandstone



Figure 1. Litho- and biostratigraphy of the studied area. Biostratigraphy is based on the chronology of Oda (1986) and Koizumi (1985). Compiled after Samata (1976), Maruyama (1984) and Koizumi (1986).

base of the *Denticulopsis lauta* Zone is present in the lower part of the Suenomatsuyama Formation and the base of the *Denticulopsis hyalina* Zone is in the lower part of the overlying Tomesaki Formation (the Jumonji Sandstone Member). Samata (1976) and Oda *et al.* (1983, 1984) indentified fossil planktonic foraminifers assignable to Zone N.8 of Blow (1969). The Suenomatsuyama Formation was deposited consequently during the early Middle Miocene (ca. 15.7+ to 14.85+ Ma, according to Koizumi, 1985) (Fig. 1).

Materials and Methods

Samples obtained from the lower Itsukamachi Sandstone and upper Maisawa Sandstone Members of the Suenomatsuyama Formation were selected for investiga-



Figure 2. Map showing the studied area (arrow head) and ostracode fossil localities (a part of 1:50,000 map of "Ichinohe" published by Geographical Survey Institute of Japan). HK: Hokkaido, HN: Honshu, S: Shikoku, K: Kyushu.

tion of ostracode faunas (Figures 2, 3).

The Itsukamachi Sandstone Member exposed well in so-called Basenkyo (large cliffs on the right side of the Mabechi-gawa River) is composed entirely of about 150m-thick tuffaceous fine to medium massive sandstone with many calcareous nodules and siltpipes, and is conformably covered with andesitic volcanic breccia of the Aikawa Andesite Member (BAS in Figure 3). The lower part of this member (around samples BAS 1 and 2) yields abundant molluscan fossils such as *Mizuhopecten kimurai nakosoensis* (Masuda) and *M. ninohensis* (Masuda). The relationship between the Itsukamachi Sandstone Member and the underlying Kadonosawa Formation can not be recognized along the sampling route.

The Maisawa Sandstone Member distributed on the lower Jumonji-gawa River can be divided into three parts: the lower consisting of cross-bedded dark gray to black, medium to coarse sandstone with many volcanic rock fragments reworked from the Aikawa Andesite Member and calcareous fossil fragments of molluscs and barnacles; the middle composed of a random mixture of medium to coarse sandstone as in the lower and dark gray silty sandstone (slumping deposits); the upper consisting of siltstone and black mudstone, which are disconformably covered with medium sandstone of the Metoki Shell Sandstone Member of the overlying Tomesaki Formation. The entire thickness is about 100 m along the Jumonji-gawa River (JMJ in Figure 3).

A total of 36 samples were collected from both members: 20 from the Itsukamachi Sandstone Member and 16 from the Maisawa Sandstone Member. Eighty grams of dried sediments were disaggregated making use of a saturated sodium sulfate solution and naphtha for rock maceration (Maiya and Inoue, 1973), washed through a 200 mesh sieve screen, and dried again. These procedures were repeated until the whole sediment sample disintegrates. A fraction coarser than 125 μ m (115 mesh) was sieved and all the specimens present were picked.

Four groups of ostracodes from the Suenomatsuyama Formation

Sixty-six species in 44 genera of fossil ostracodes were obtained from 14 samples of the Itsukamachi Sandstone Member and nine of the Maisawa Sandstone Member (Table 1).

Ostracodes from the Suenomatsuyama Formation can be divided into four different categories of species: 1) circumpolar, 2) cryophilic, 3) temperate (including species common in Middle to Late Miocene deposits of

Figure 3. Columnar sections of the Suenomatsuyama Formation. BAS: samples from the Itsukamachi Sandstone Member exposed in Basenkyo; JMJ; samples from the Maisawa Sandstone Member along the Jumonji-gawa River. — n shows samples barren of ostracodes. — shows samples used for Q-mode cluster analysis. Ka: the Kadonosawa Formation.



Table 1. List of ostracode species from the Suenomatsuyama Formation.BAS: samples fromthe Itsukamachi Sandstone Member;JMJ: those from the Maisawa Sandstone Member.* showsspecies and samples used for Q-mode cluster analysis.

samples		BAS						JMJ															
sample	*1	*2	*3	*4	*5	*6	*7	8	*9	*10	*11	*12	*13	*14	1	*2	*3	*4	*5	5 *6	7	8	9
* Acanthocythereis dunelmensis	2	7	3	6	-	2	3		2	5	7	4	3	2		3	2	1	2	2 6	1	1	
Acanthocythereis aff. munechikai																						1	
Ambionia sp. * Aurila sp							2								1	1	1		F				
Australimoosella cf. hanaii							2								1 '	2			1	1			
Bythoceratina? sp.	<u> </u>										2		1		f—					1-			
* Callistocythere reticulata						1	1					1	1			3	1		1				
Ciutnia sp.	_		2	4		<u>,</u>	4													1			
* Cornucoquimba moniwensis	1 2	1	3	2	4	4	7		2	4	3	3	4			2	3	4	ç			1	
* Cornucoquimba saitoi	1		1	5	2	4	12	3	-	6	4	6	5	3	1	11	7	- 2	11	<u> </u>	1	<u>.</u>	
Cornucoquimba? sp.			1							1													
* Cythere omotenipponica	1	1	7	10	5	8	15		4	3	2	4	10	5	2	6	3	3	3	3		1	
* Cythere sp				1	- 1	4	· 2	1	2		4					6	2	1	1				
Cytheropteron sawanense	+					t i					+ '	1			+	9	~ ~	3		<u>+</u>	- 1		
Cytheropteron sp. 1											1					1	1						
* Cytheropteron sp. 2				1	1		1	_				3	1										
Fucythere sp	26	26	35	16	2	16	17	5	4	15	9	8	4	7		3	3	1	1	8	18	7	2
* Eucytherura neoalae	+		1	1	1	1	<u>2</u>	1		- 2	$\frac{1}{1}$	4			. <u> </u>						2		
Falsobuntonia taiwanica				i		2	1			1	1 '	4	5	2		1					2	2	
* Finmarchinella hanaii	1		1	2		1	5	1	2	3	3	4	2	1	2	7	7	1	7	1	1	1	
* Finmarchinella japonica				1	2	1	5			3		3	3	2		2			2	2 1			
* Hemicythere ci. gurjanovae	+		1	4	1	1	3	1	1			1		1		2	3				1		
* Hemicythere ochotensis						2					"		1	2		2	1	2	5	2			
* Hemicytherura clathrata		1		2	1	1	4		1	3	1	3	1	1		1			1	η 1			
* Hermanites? posterocostatus			5	2	1	8	2		2	1	1	2	3	1	4	17	7	3	20	1 .			
Hirsutocythere? sp.																	1					5	
Kotoracythere sp	2	1	2	1	1	1	1		3	1	1	5	2		3	6	7	2	7	27	2		
Krithe sp.										1												1	
* Laperousecythere ishizakii									3	'	1	4	2		1	9	3	3	R			2	
Laperousecythere cf. robusta				2							1		2	1	1	2	2	U	Ŭ				
* Laperousecythere yantsensis	1 40	~	~	2	1	6	9	3	4	4	3	5		6	4	5	5	1	12				_
Loxoconcha pulchra	18	8	3	3		4	1														1		
Loxoconcha subkotoraforma							1			1									1				
Loxoconcha aff. uranouchiensis							•			•									1				
* Loxocorniculum kotoraformum				1	1	3	4			5	1	2	1							<u> </u>			-
Munseyella hatatatensis	4							_	1			6											
* Munsevella sp. 1	2	2	1	2		1	4	3	4	~			1	~		1			-				
Munseyella sp. 2	1	2		2			'			3				2		1	4		2	3			1
Neocytherideis sp.			_										1										
* Neomonoceratina japonica	2	_	7	6	1	8	16	9	7	18	7	19	14	12	6	35	19	9	29		1		1
* Pallenborchella hanali	4	3	2	1	1	4	1	1	3	11	2	3	1	3	4	10	9	7	9	1			1
* Palmenella limicola	12	1	1	1	I	2	2	1		2	~	~	~	1			1		1	2			
Palmoconcha sp.	<u> </u>	<u> </u>				2	- 1				- 2	3	2	4			_				_	2	
* Paracytheridea neolongicaudata			3	6	1	5	13	1	4	5	2	6	1	2	2	15	9	2	8	1		2	
* Pectocythere daishakaensis			4	6	2	9	11	4	10	12	2	6	6	11	3	12	9	5	11	1			
Propontocypris? sp							1																
* Robertsonites reticuliforma	<u> </u>		5	- 2	_																1		
Rotundracythere? sp.		1	Ũ	0		4	2			ျ				3						1		4	
* Schizocythere kishinouyei	5		7	12	5	27	31	2	4	13	6	7	3	10	1	20	14	7	13	1	1		
Scierochilus sp.			_								1	1	1		-		••	•			•		
Semicytherura of skippa			2	3	_1	1	_1			2	1	3	2		_	2			1	_1			
Semicytherura sp.	1					1	1				1			T									
Spinileberis cf. rhomboidalis	1						'				I		1		I	2	1						
Typhlocythere sp.							1									2	2		- '				
Xestoleberis sp			_	-												2							
No. of specimens	81	64	97 1	05	36	125	100	20	04	1	74 -	2	0.0										\neg
No. of species	13	13	22	30	21	32	37	38	20	34	<u>74 1</u> 30	23	82	85	39 2	206	128	58 1	89	57	31	30	5
									20	51		29	29	24	18	30	30	19	32	16	12	13	4

CIRCUMPOLAR SPECIES	TEMPERATE SPECIES
Acanthocythereis dunelmensis (Norman, 1865)	Callistocythere reticulata Hanai, 1957
Elofsonella cf. concinna (Jones, 1857)	Cornucoquimba moniwensis (Ishizaki, 1966)
Hemicytherura clathrata (Sars, 1865)	Cornucoquimba saitoi (Ishizaki, 1963)
Munseyella hatatatensis (Ishizaki, 1966)	Cythere omotenipponica Hanai, 1959
Palmenella limicola (Norman, 1865)	Hermanites? posterocostatus Ishizaki, 1966
CRYOPHILIC SPECIES	Kotoracythere cf. abnorma Ishizaki, 1966
Finmarchinella hanaii Okada, 1979	Laperousecythere ishizakii, sp. nov.
Finmarchinella japonica (Ishizaki, 1966)	Laperousecythere sp.
Hemicythere cf. gurjanovae Schornikov, 1974	Loxoconcha pulchra Ishizaki, 1968
Hemicythere kitanipponica (Tabuki, 1986)	Neomonoceratina japonica (Ishizaki, 1966)
Hemicythere ochotensis Schornikov, 1974	Paracytheridea neolongicaudata Ishizaki, 1966
Laperousecythere cf. robusta (Tabuki, 1986)	Schizocythere kishinouyei (Kajiyama, 1913)
Laperousecythere yahtsensis Brouwers, 1993	Semicytherura henryhowei Hanai and Ikeya, 1977
Robertsonites reticuliforma (Ishizaki, 1966)	

Table 2. Circumpolar, cryophilic and temperate ostracodes from the Suenomatsuyama Formation.

northern Japan), and 4) others. Many workers have identified cold-water ostracodes from Plio-Pleistocene formations in northern Japan (Hanai, 1957, 1970; Hanai and Ikeya, 1991; Hanai and Yamaguchi, 1987; Ishizaki, 1966; Ishizaki and Matoba, 1985; Ishizaki et al., 1993; Okada, 1979; Tabuki, 1986; Cronin and Ikeya, 1987; Hayashi, 1988; Irizuki, 1989, 1993). Cronin and Ikeya (1987) recognized 26 circumpolar and 21 cryophilic species from some formations yielding the Omma-Manganji Fauna, a term proposed by Otuka (1939) for the Japanene Pliocene cold water molluscan assemblage. They referred ostracodes known from Recent and/or fossil deposits of the North Atlantic and adjacent Arctic seas to "circumpolar species", and those typically occurring with circumpolar species in Japanese deposits and, in most cases, being members of high-latitude genera to "cryophilic species." It would not be true that in the Miocene circumpolar-cryophilic species ever experienced such subfrigid to frigid environments as in the Recent. It is probable that they have adapted to colder environments during the Late Cenozoic. They are, however, reckoned to be cool water indicators in the present study since they are expected to have preferred living in colder water than other species even in the Miocene. Thus, the present study concerns only relative water temperatures during deposition of the Suenomatsuyama Formation.

Five circumpolar and eight cryophilic species were identified in the Suenomatsuyama Formation (Table 2). *Elofsonella* cf. *concinna* (Jones) is comparable to a reticulate form, *E. concinna*, reported from Plio-Pleistocene formations yielding the Omma-Manganji Fauna (Tabuki, 1986; Cronin and Ikeya, 1987; Irizuki and Sasaki, 1993) by its similar but weaker patterns of reticulation and ridges. It is a representative species also in the middle to upper part of the underlying Kadonosawa Formation (Irizuki and Matsubara, 1994). *Laperousecythere yahtsensis* Brouwers (=*Patagonacythere dubia* of Cronin and Ikeya, 1987) is abundant in Pleistocene to Holocene deposits in the Gulf of Alaska (Brouwers, 1993) and Plio-Pleistocene formations distributed on the Japan Sea side of northern Japan (Cronin and Ikeya, 1987). It should not be a circumpolar species but a cryophilic one since it has not been recorded from the Arctic to northern Atlantic areas. All specimens of such hemicytherin ostracodes as *E. cf. concinna, L. yahtsensis* and *L. cf. robusta* (Tabu-ki) have weaker and thinner ornamentations than their counterparts from younger formations containing the Omma-Manganji ostracodes. This may reflect that this setting was in higher water temperatures than depositional sites for other younger formations.

Thirteen species belong to a temperate species group (Table 2): they are assumed to have preferred inhabiting warmer waters than the above-mentioned indicators. Callistocythere reticulata Hanai, Laperousecythere ishizakii sp. nov. (=Hermanites sp. of Irizuki and Matsubara, 1994) and Loxoconcha pulchra Ishizaki are also recognized in the lowest part of the underlying Kadonosawa Formation (the Tate Conglomeratic Sandstone Member), which was deposited at the time of the mid-Neogene Climatic Optimum. Thus, they are thought to have been warm-water species. Cythere omotenipponica Hanai and Semicytherura henryhowei Hanai and Ikeya live dominantly in coastal areas influenced by the Kuroshio Current (Hanai, 1957, 1959; Hanai et al., 1977; Tsukagoshi and Ikeya, 1987). The other eight species are common in such Middle to Late Miocene deposits in Northeast Japan as the Hatatate and Tsunaki Formations in Sendai City (Ishizaki, 1966; Ishizaki et al., in press), the Togi Formation in the Sekinohana area (Yajima, 1988) and the Fujikotogawa Formation in Kamikoani Village (Yajima, 1988; Irizuki, 1994). Some of these formations contain Shiobara-type molluscan fossils. These eight species are, moreover, minor constituents in Pleistocene formations deposited under subfrigid to frigid environments in northern Japan.

Among others are bathyal to lower sublittoral ostracodes reported from mudstone of the Kadonosawa Formation such as *Falsobuntonia taiwanica* Malz, *Hirsutocythere*? sp. and *Propontocypris*? sp., which are all rare throughout the Suenomatsuyama Formation.

The above four groups are qualitatively assorted at the



Figure 4. Dendrogram resulting from Q-mode cluster analysis based on the index of overlap of Horn (1966). I to III_3 refer to clusters.

discretion of the present study, pending more data on the spatial and temporal distribution of ostracodes are gathered.

Q-mode cluster analysis

Q-mode cluster analysis was used to examine vertical changes of ostracode faunas, which could be in association with varying depositional environments of the Suenomatsuyama Formation. This analysis was conducted by using 17 samples, containing more than 50 individuals, and 35 species represented by three or more individuals in any one of the samples. The used similarities are Horn's overlap indices (Horn, 1966), and clustering is practiced by the unweighted pair group method with arithmetic averages (UPGMA). The result reveals three clusters (I, II, III) bounded by a similarity value of 0.6 (Figure 4).

Cluster I: This cluster is represented by only one sample (JMJ 6; silty sandstone) from the upper part, showing the strongest slump structures, of the Maisawa Sandstone

Table 3. Values of species diversity (H(S)) and equitability (Eq.) calculated by the method of Buzas and Gibson (1969) for ostracode assemblages obtained from samples used for Q-mode cluster analysis. Cl. means clusters.

Sample	H(S)	Eq.	CI.
BAS 1	2.02	0.58	
BAS 2	1.88	0.50	11
BAS 3	2.45	0.53	1
BAS 4	3.00	0.67	
BAS 6	2.96	0.60	III2
BAS 7	3.03	0.56	
BAS 9	2.78	0.81	1113
BAS 10	3.01	0.65	
BAS 11	3.09	0.74	
BAS 12	3.14	0.80	1112
BAS 13	3.01	0.70	
BAS 14	2.83	0.71	
JMJ 2	3.04	0.60	
JMJ 3	2.99	0.66	1113
JMJ 4	2.69	0.78	1110
JMJ 5	3.02	0.64	
JMJ 6	1.92	0.43	
Member. It contains poorly preserved specimens of *Acanthocythereis dunelmensis* (Sars), *Elofsonella* cf. *concinna* and *Kotoracythere* cf. *abnorma* Ishizaki. The fauna in this cluster has low values both of diversity (1.92) and equitability (0.43) as calculated by the method of Buzas and Gibson (1969) (Table 3).

Cluster II: This cluster is composed of two samples (BAS 1, 2, ; medium sandstone) from the lower part of the Itsukamachi Sandstone Member. It is characterized by the dominance of *E.* cf. concinna, Laperousecythere sp. and *Paijenborchella hanaii* Tabuki, and faunas having low values both of diversity (1.88-2.02) and equitability (0.50-0.58).

Cluster III: This cluster comprises ten samples (BAS 3, 4, 6, 7, 9-14; fine to medium sandstone) from the middle part of the Itsukamachi Sandstone Member and four samples (JMJ 2-5; medium sandstone) from the lower part of the Maisawa Sandstone Member. It is characterized by faunas having high diversity (2.45-3.14) and equitability values (0.53-0.80). Three subclusters (III₁, III₂, III₃) bounded by a similarity value of 0.8 can be recognized in this cluster. *Neomonoceratina japonica* (Ishizaki), *Paracytheridea neolongicaudata* Ishizaki, *Laperousecythere ishizakii* and *Pectocythere daishakaensis* Tabuki occur commonly throughout the cluster.

Discussion

1) Depositional environments of the Suenomatsuyama Formation

The Suenomatsuyama Formation contains entirely diversified sublittoral ostracode species; bathyal ostracodes such as Falsobuntonia taiwanica, Hirsutocythere? sp., Krithe sp. and Propontocypris? sp., which are common in the deep water-facies of the underlying Kadonosawa Formation, are rare or absent. It does not yield shallow embayment species either. Many samples show high values of diversity and equitability. The Suenomatsuyama Formation treated in the present study (the Itsukamachi Sandstone and the Maisawa Sandstone Members) is, therefore, reckoned, as a whole, to have been deposited in open sublittoral environments. It is probable that the lowest part of the Itsukamachi Sandstone Member (around BAS 1 and 2) and the Maisawa Sandstone Member were deposited in upper sublittoral areas because of common occurrences of some large Pectinidae such as Mizuhopecten spp.

Figure 5 shows vertical changes both of percentages of four species groups (circumpolar, cryophilic, temperate and others) and clusters (I, II and III). Most formations bearing the Omma-Manganji Fauna contain abundantly circumpolar and cryophilic species, representing around 50% of the total (see Table 2 of Cronin and Ikeya, 1987). In particular, circumpolar and cryophilic ostracodes from the Plio-Pleistocene Setana, Tomikawa and Shibikawa Formations, distributed in northern Japan, comprise about 70% of the total assemblages. The Upper Miocene Fujikotogawa Formation in northern Japan also contains large numbers of circumpolar and cryophilic ostracodes

representing about 40% of the total (Irizuki, 1994). Samples from the lower part of the Suenomatsuyama Formation contain large numbers of cool-water indicators, representing about 40-50%, and are assigned to clusters II and III1. It is certain that surface water temperatures were also low in that time because of the absence of tropical to subtropical planktonic foraminifers at this horizon (Samata, 1976). The middle part of the Suenomatsuyama Formation (subclusters III2 and III3) is dominated by temperate species ; circumpolar and cryophilic species represent around 30% of the total assemblages. All samples from the lower part of the Maisawa Sandstone Member (JMJ 2 to 5) belong to cluster III₃ and contain predominantly temperate-water ostracodes, coolwater indicators are less abundant (less than 30%). It is concordant with the occurrence of tropical to subtropical planktonic foraminifers at this horizon (zone III of Samata, 1976). The results of Q-mode cluster analysis and vertical changes of percentages of each species group indicate that paleotemperatures were lowest in the lower part of the Suenomatsuyama Formation (cluster II), increasing toward the highest in the Maisawa Sandstone Member (cluster III₃).

Cluster I (JMJ 6) and sample JMJ 7 contain poorly preserved specimens of *Acanthocythereis dunelmensis* (Norman), *E. cf. concinna* and *Kotoracythere cf. abnorma*. Sample JMJ 8 also bears poorly-preserved *Hirsutocythere* ? sp., *Kotoracythere* sp. (*=Kotoracythere* sp. 2 of Irizuki and Matsubara, 1994) and *Acanthocythereis* aff. *munechikai* Ishizaki, which are representative species of the black mudstone facies of the lowest part of the Shikonai Siltstone Member in the underlying Kadonosawa Formation (Irizuki and Matsubara, 1994). All these samples were obtained from strata exhibiting signs of subaqueous mudflows, and thus possibly containing some specimens reworked from underlying strata, upheaved due to volcanic activity associated with the Aikawa Andesite Member, as well as those displaced from shallower water.

2) Comparison between ostracode faunas of the Suenomatsuyama Formation and those of the Kadonosawa Formation

Fifteen of the 66 species from the Suenomatsuyama Formation do not occur in the Kadonosawa Formation. These species are low in abundance except for species belonging to the genus Laperousecythere (L. cf. robusta, L. yahtsensis and L. sp.), which are discussed in the Systematics section. Laperousecythere species are characteristic of the Suenomatsuyama Formation, but most of the other ostracodes from the Suenomatsuyama Formation, for example A. dunelmensis, E. cf. concinna, Finmarchinella spp., Neomonoceratina japonica, Normanicythere sp. and S. kishinouyei, are common to the middle and upper parts of the underlying Kadonosawa Formation (clusters D and E of Irizuki and Matsubara, 1994). In the upper part of the Suenomatsuyama Formation (the Maisawa Sandstone Member, cluster III₃), such warm-to-temperate-water ostracodes as Hermanites ? posterocostatus Ishizaki, Paracytheridae neolongicaudata



Figure 5. Diagram showing vertical changes of clusters and percentages of each group of ostracodes. I to III₃ stand for clusters. Columns are the same as in Fig. 3.

and Laperousecythere ishizakii increase in number. This is concordant to the occurrence of warm-water planktonic foraminifers reported by Samata (1976) around this horizon. However, ostracode faunas containing the above-mentioned species are different from faunas characterized by such shallow- and warm-water ostracodes as Loxoconcha pulchra, Spinileberis sp. and Trachyleberis spp. recognized in the lowest part of the Kadonosawa Formation (the Tate Conglomeratic Sandstone and the lowest Shikonai Siltstone Members; clusters A and B of Irizuki and Matsubara, 1994) and those in the Lower

Miocene Akeyo Formation (the Shukunohora Sandstone Member) in the Mizunami area (Yajima, 1992), which were deposited at the time of the mid-Neogene Climatic Optimum. They are similar in containing the Shiobaratype Fauna to those reported from Middle to Late Miocene formations in northern Japan. Therefore, the cooling event (from subtropical to cool temperate) occurring at about 16 Ma in Ninohe district continued to the time of deposition of the lower part of the Suenomatsuyama Formation. After that water temperatures became higher during deposition of the middle to upper part of the Itsukamachi Sandstone Member, Maisawa Sandstone Member and the overlying Tomesaki Formation, and suggested by the dominance of warm-water planktonic foraminifers (Samata, 1976) and diatoms (Maruyama, 1984, 1993) as well as by temperate ostracodes.

Concluding remarks

The following four conclusions were obtained from the study of ostracode faunas from the Suenomatsuyama Formation.

1. Sixty-six ostracode species were found for the first time to occur in the lower Middle Miocene Suenoma-tsuyama Formation.

2. Q-mode cluster analysis and vertical changes of percentages of species groups reveal that the depositional environment of the lower part of the Suenomatsuyama Formation was cool and shallow water and that of the upper sandy facies temperate and shallow water.

3. Slumping deposits in the middle to upper part of the Maisawa Sandstone Member may include some fossil ostracodes reworked from parts of the underlying strata as well as those displaced from shallower water.

4. Many ostracodes from the lower to middle part (sandy facies) of the Maisawa Sandstone Member are warm-water species, but these are different from those in deposits yielding the Kadonosawa Fauna.

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Systematics

Four species under the genus *Laperousecythere* are described and/or discussed in this section because they are representative species of the Suenomatsuyama Formation. All the illustrated and measured specimens are deposited in the collections of the Department of Geoenvironmental Science, Faculty of Science, Tohoku University (IGPS).

Suborder Podocopina Sars, 1866 Superfamily Cytheracea Baird, 1850 Family Hemicytheridae Puri, 1953 Subfamily Hemicytherinae Puri, 1953 Genus Laperousecythere Brouwers, 1993 Laperousecythere ishizakii Irizuki and Matsubara sp. nov.

Figures 6.1-4

Hermanites sp. Irizuki and Matsubara, 1994, p. 140, 141, table 1.

Etymology.-In honor of Professor K. Ishizaki

Materials.-34 specimens.

Diagnosis.—Characterized by quadrate valve shape and some oblique and hook-shaped robust ridges.

Description.—Carapace large, quadrate in lateral view, highest at anterior cardinal angle. Anterior margin broadly rounded and slightly extended below. Dorsal margin sinuate in left valve, slightly convex in right valve. Ventral margin slightly sinuate. Posterior margin triangular: upper half concave but lower half convex. In dorsal view, carapace subhexagonal. Surface ornamented with regularly arranged coarse reticulation, prominent ridges, eye and subcentral tubercles. Sinuate lateral ridge starting from subcentral tubercle and terminating at midheight of anterior margin. In posterior area, four robust ridges obliquely developed. Dorsal ridge starting above eye tubercle and turning downwards at posterodorsal end to form hook-shaped rims. Subcentral tubercle distinct. Eye tubercle large and prominent. Pores scattered on valve surface, moderate in number. Marginal pores straight, about 35 in anterior margin. Marginal infold broad along anterior and posterior margins. Vestibule present along entire free margin, but narrow along ventral and posterior margins. Hinge holamphidont. Muscle scars consist of three frontal scars (middle one is smaller than the others) and a row of four adductor scars : subdivided dorsal and dorsomedian scars, an elongated ventromedian and ventral scars. Sexual dimorphism distinct: males more slender than females.

Types and Dimensions.—Holotype : Figs. 6-3a-c, female LV, Loc. JMJ 3, IGPS 102547, L=0.878 mm, H= 0.529 mm; paratype : Fig. 6-1, male LV, Loc. BAS 12, IGPS 102548, L=0.813 mm, H=0.428 mm; Fig. 6-2, female RV, Loc. BAS 9, IGPS 102549, L=0.831 mm, H= 0.450 mm; Fig. 6-4, female carapace, Loc. JMJ 5, IGPS 102550, L=0.894 mm, H=0.525 mm, T=0.511 mm.

Type locality.—Lower Middle Miocene Suenomatsuyama Formation (the Maisawa Sandstone Member), Loc. JMJ 3.

Occurrence.-BAS 9, 11-13, JMJ 1-5.

Remarks.—This species is also present in the Tate Conglomeratic Sandstone Member in the Kadonosawa Formation. It is similar to *Laperousecythere yahtsensis* and *Laperousecythere* sp. in this study with respect to the reticulation patterns, but differs from them in having more prominent and robust ridges, hook-shaped rims in posterior portion and quadrate valve morphology. It is also similar to *Hermanites*? *posterocostatus*, but differs from the latter in having a different ridge pattern and more inflated carapace.

Laperousecythere cf. robusta (Tabuki, 1986)

Figure 6. 5-7c

Compared with.-

Patagonacythere robusta Tabuki, 1986, p. 77, 78, 116, text-fig. 20, pl. 9, figs. 4-12; Cronin and Ikeya, 1987, p. 81, 82, pl. 3, fig. 13; Irizuki, 1993, p. 189, fig. 2-20.

Laperousecythere robusta (Tabuki); Brouwers, 1993, p. 25, 26, pl. 10, figs. 6-12, pl. 11, figs. 2, 3.



Figure 6. 1-4, Laperousecythere ishizakii sp. nov. 1: lateral view of male LV, Loc. BAS 12, IGPS 102548; 2: lateral view of female RV, Loc. BAS 9, IGPS 102549; **3a-c**: lateral and internal views and muscle scars of female LV, holotype, Loc. JMJ 3, IGPS 102547; **4**: dorsal view of female carapace, Loc. JMJ 5, IGPS 102550. **5-7c**, Laperousecythere cf. robusta (Tabuki, 1986). **5**: lateral view of male LV, Loc. JMJ 3, IGPS 102551; **6**: lateral view of male RV, Loc. JMJ 3, IGPS 102552; **7a-c**: lateral and internal views and muscle scars of female RV, Loc. JMJ 1, IGPS 102553. Scale bars are 0.1 mm: A for 1-3b, 4-7b; B for 3c, 7c. LV: left valve. RV: right valve.



Figure 7. 1a-3, *Laperousecythere yahtsensis* Brouwers, 1993, **1a-c**: lateral and dorsal views of male carapace, Loc. BAS 12, IGPS 102554 ; **2a-c**: lateral and internal views and muscle scars of female LV, Loc. BAS 10, IGPS 102555 ; **3**: lateral view of female RV, Loc. BAS 10, IGPS 102555. **4a-8**, *Laperousecythere* sp., **4a-c**: lateral and internal views and muscle scars of male LV, Loc. BAS 1, IGPS 102557 ; **5**: Lateral view of male RV, Loc. BAS 1, IGPS 102557 ; **5**: Lateral view of male RV, Loc. BAS 1, IGPS 102558 ; **6**: lateral view of female LV, Loc. BAS 1, IGPS 102559 ; **7**: dorsal view of female carapace, Loc. BAS 1, IGPS 102560 ; **8**: lateral view of female RV, Loc. BAS 1, IGPS 102561. Scale bars are 0.1 mm : A for 1a-2b, 3-4b, 5-8 ; B for 2c, 4c.

Materials.-11 specimens.

Dimensions.—Fig. 6-5, male LV, Loc. JMJ 3, IGPS 102551, L=0.879 mm, H=0.465 mm; Fig. 6-6, male R.V., Loc. JMJ 3, IGPS 102552, L=0.869 mm, H=0.456 mm; Figs. 6-7a-c, female RV, Loc. JMJ 1, IGPS 102553, L= 0.925 mm, H=0.500 mm.

Occurrence.—BAS 4, 11, 13, 14, JMJ 1-3.

Remarks.—The present form has less prominent ridges in posterodorsal, posteroventral and anterior areas, and less elongate valve morphology as compared with the type specimens from the Plio-Pleistocene Daishaka Formation, northern Japan (Tabuki, 1986). Its reticulation and ridge pattern are similar to those of the type specimens.

Laperousecythere yahtsensis Brouwers, 1993

Figures 7.1-3

Patagonacythere dubia (Brady); Cronin and Ikeya, 1987, p. 81, 82, pl. 2, fig. 10 (non Patagonacythere dubia (Brady, 1868)).

Laperousecythere yahtsensis Brouwers, 1993, p. 26, 27, pl. 10, figs. 13-18, pl. 11, figs, 4, 5.

Materials.-70 specimens.

Dimensions.—Figs. 7-1a-c, male carapace, Loc. BAS 12, IGPS 102554, L=0.875 mm, H=0.413 mm; Figs. 7-2a-c, female LV, Loc. BAS 10, IGPS 102555, L=0.878 mm, H=0.455 mm; Fig. 7-3, female RV, Loc. BAS 10, IGPS 102556, L=0.856 mm, H=0.453 mm.

Occurrence.-BAS 4-12, 14, JMJ 1-5.

Remarks.—This species was reported from such Plio-Pleistocene formations as the Setana, Sawane, Junicho and Omma Formations yielding the Omma-Manganji Fauna of northern Japan (Cronin and Ikeya, 1987) and Pleistocene deposits of the Gulf of Alaska (Brouwers, 1993). This species is closely related to *Patagonacythere dubia* recorded from the Pleistocene to Recent sediments in the Arctic and North Atlantic areas (e.g. Hazel, 1967), but the former has an elongate and quadrate valve outline, fine muri, wide anterior rim and slightly different distributional patterns of the reticulation. It is also similar to *Patagonacythere sasaokensis* Irizuki, but differs from the latter in being smaller in size, having less inflated valves and lack of antero-marginal ridges.

Laperousecythere sp.

Figures 7. 4-8

Materials.-38 specimens.

Dimensions.—Figs. 7-4a-c, male LV, Loc. BAS 1, IGPS 102557, L=0.829 mm, H=0.455 mm; Fig. 7-5, male RV, Loc. BAS 1, IGPS 102558, L=0.829 mm, H=0.444 mm; Fig. 7-6, female LV, Loc. BAS 1, IGPS 102559, L=0.829 mm, H=0.494 mm; Fig. 7-7, female carapace, Loc. BAS 1, IGPS 102560, L=0.850 mm, H=0.500 mm, T=0.456 mm; Fig. 7-8, female RV, Loc. BAS 1, IGPS 102561, L= 0.863 mm, H=0.506 mm.

Occurrence.—BAS 1-4, 6, 7, JMJ 7.

Remarks.-Ishizaki et al. (in press) described species

similar to this form from the Upper Miocene Tsunaki Formation, northern Japan, as a new species. Its type specimens are more quadrate valves than the present specimens. This form is closely related to *Laperousecythere robusta* with respect to its reticulation pattern, but differs from the latter in having no anteromarginal ridges and thin valves in the anteromarginal area.

References cited

- Akiba, F., 1977: Neogene biostratigraphy of the Ninohe area, Iwate Prefecture. *Journal of the Japanese Association for Petroleum Technology*, vol. 42, no. 4, p. 275. (*in Japanese*)
- Aoki, S., 1960: On the historical change of the molluscan fauna in the Miocene deposits of the northeastern Honshu, Japan. *Earth Science*, no. 48, p. 1-10. (*in Japanese with English abstract*)
- Blow, W.H., 1969: Late middle Eocene to Recent planktonic foraminiferal biostratigraphy. *In*, Brönnimann, P. and Renz, H.H. eds., *Proceedings of the First International Conference on Planktonic Microfossils* (*Geneva, 1967*), Volume 1, p. 199-421. Leiden, E.J. Brill.
- Brouwers, E.M., 1993: Systematic paleontology of Quaternary ostracode assemblages from the Gulf of Alaska. Part 2: Families Trachyleberididae, Hemicytheridae, Loxoconchidae, Paracytherideidae. U.S. Geological Survey, Professional Paper 1531, p. 1-47, pls. 1-16.
- Buzas, M.A. and Gibson, T.G., 1969: Species diversity: benthonic Foraminifera in western North Atlantic. *Science*, vol. 163, p. 72–75.
- Chinzei, K., 1958a : On the Neogene formations in the vicinity of Fukuoka-machi, Iwate Prefecture-Cenozoic geology of the northern margin of the Kitakami Mountains I—. Journal of Geography, vol. 67, no. 1, p. 1-30. (*in Japanese with English abstract*)
- Chinzei, K., 1958b: Pliocene stratigraphy of the northern end of the Kitakami Mountains, northern Japan-Cenozoic geology of the northern margin of the Kitakami Mountains II-. Journal of the Geological Society of Japan, vol. 64, no. 757, p. 526-536. (in Japanese with English abstract)
- Chinzei, K., 1963: Notes on historical changes of Neogene molluscan assemblages in Northeast Japan. *Fossils (Palaeontological Society of Japan)*, no. 5, p. 20-26. (*in Japanese*)
- Chinzei, K., 1966 : Younger Tertiary geology of the Mabechi River Valley, Northeast Honshu, Japan. *Journal* of the Faculty of Science, University of Tokyo, Section 2, vol. 16, part 1, p. 161–208.
- Chinzei, K., 1978: Neogene molluscan faunas in the Japanese Islands: An ecologic and zoogeographic synthesis. *Veliger*, vol. 21, no. 2, p. 155–170.
- Chinzei, K., 1979: Kadonosawa-Sannohe Area (1). In Tsuchi, R. ed., Fundamental data on Japanese Neogene bio- and chronostratigraphy, p. 50-52. (in Japanese)
- Chinzei, K., 1986: Faunal succession and geographic distribution of Neogene molluscan faunas in Japan. Palaeontological Society of Japan, Special Paper, no.

29, p. 17-32.

- Chinzei, K. and Iwasaki, Y., 1967 : Paleoecology of shallow sea molluscan faunae in the Neogene deposits of Northeast Honshu, Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 67, p. 93–113.
- Cronin, T.M. and Ikeya, N., 1987 : The Omma-Manganji ostracod fauna (Plio-Pleistocene) of Japan and the zoogeography of circumpolar species. *Journal of Micrpalaeontology*, vol. 6, no. 2, p. 65-88, 3 pls.
- Hanai, T., 1957 : Studies on the Ostracoda from Japan III. Subfamilies Cytherurinae G.W. Müller (emend. G.O. Sars 1925) and Cytheropterinae n. subfam. *Journal* of the Faculty of Science, University of Tokyo, Section 2, vol. 11, part 1, p. 11-36, pls. 2-4.
- Hanai, T., 1959 : Studies on the Ostracoda from Japan V. Subfamily Cytherinae Dana, 1852 (emend.). Journal of the Faculty of Science, University of Tokyo, Section 2, vol. 11, part 4, p. 409-418, pl. 28.
- Hanai, T., 1970: Studies on the ostracod subfamily Schizocytherinae Mandelstam. *Journal of Paleontology*, vol. 44, no. 4, p. 693-729, pls. 107-108.
- Hanai, T. and Ikeya, N., 1991: Two new genera from the Omma-Manganji ostracode fauna (Plio-Pleistocene) of Japan-with a discussion of theoretical versus purely descriptive ostracode nomenclature. Transactions and Proceedings of the Palaeontological Society of Japan, New Series, no. 163, p. 861-878.
- Hanai, T. and Yamaguchi, T., 1987: Plio-Pleistocene ostracod fauna of Shimokita, Aomori Prefecture (Preliminary report). *Memoirs of the National Science Museum*, no. 20, p. 45-51. (*in Japanese with English summary*)
- Hanai, T., Ikeya, N., Ishizaki, K., Sekiguchi, Y. and Yajima, M., 1977: Checklist of Ostracoda from Japan and its adjacent seas. University of Tokyo Press, 119 p., 4 pls.
- Hayashi, K., 1988: Plio-Pleistocene paleoenvironment and fossil ostracod fauna from southern Hokkaido, Japan. In Hanai, T., Ikeya, N. and Ishizaki, K. eds., Evolutionary Biology of Ostracoda-its fundamentals and applications, p. 557-563. Kodansha, Tokyo and Elsevier, Amsterdam.
- Hazel. J.E., 1967 : Classification and distribution of the Recent Hemicytheridae and Trachyleberididae (Ostracoda) off northeastern North America. U.S. Geological Survey, Professional Paper 564, p. 1-49, pls. 1-11.
- Horn, H.S., 1966 : Measurement of "overlap" in comparative ecological studies. *The American Naturalist*, vol. 100, no. 914, p. 419-424.
- Irizuki, T., 1989 : Fossil ostracode assemblages from the Pliocene Sasaoka Formation, Akita City, Japan-with reference to sedimentological aspects-. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 156, p. 296-318.
- Irizuki, T., 1993: Morphology and Taxonomy of some Japanese hemicytherin Ostracoda-with particular reference to ontogenetic changes of marginal pores-. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 170, p. 186-211.
- Irizuki, T., 1994: Late Miocene ostracods from the Fujikotogawa Formation, northern Japan-with reference

to cold water species involved with trans-Arctic interchange-. *Journal of Micropalaeontology*, vol. 13, part 1, p. 3-15, 3 pls.

- Irizuki, T. and Matsubara, T., 1994: Vertical changes of depositional environments in the lower to middle Miocene Kadonosawa Formation based on analyses of fossil ostracode faunas. *Journal of the Geological Society of Japan*, vol. 100, no. 2, p. 136-149, 1 pl. (*in Japanese with English abstract*)
- Irizuki, T. and Sasaki, O., 1993 : Analysis of morphological changes through ontogeny : genera *Baffinicythere* and *Elofsonella* (Hemicytherinae). *In*, McKenzie, K.G. and Jones, P.J. *eds.*, *Ostracoda in the Earth and Life Sciences*, p. 335–350. A.A. Balkema, Rotterdam.
- Ishizaki, K., 1966 : Miocene and Pliocene ostracodes from the Sendai Area, Japan. Science Reports of the Tohoku University, Second Series (Geology), vol. 37, no. 2, p. 131-163, pls. 16-19.
- Ishizaki, K. and Matoba, Y., 1985: Excursion 5: Akita (Early Pleistocene cold shallow water Ostracoda). Guidebook of excursions for the 9th International Symposium on Ostracoda. July 21-28, July 31, and August 3-7, 1985, p. 1-12, 8 pls.
- Ishizaki, K., Fujiwara, O. and Irizuki, T., in press: Ostracod faunas from the Upper Miocene Tsunaki Formation near the southern border of Sendai City, Northeast Japan. *Proceedings of the 2nd European ostracodologists meeting.*
- Ishizaki, K., Irizuki, T. and Sasaki, O., 1993: Cobb Mountain spike in the lower Omma Formation (Early Pleistocene), Kanazawa City, central Japan: analysis of depositional environments. *In*, McKenzie, K.G. and Jones, P.J. eds., Ostracoda in the Earth and Life Sciences, p. 315-334. A.A. Balkema, Rotterdam.
- Itoigawa, J. and Yamanoi, T., 1990: Climatic Optimum in the Mid-Neogene of the Japanese Islands. In, Tsuchi, R. ed., Pacific Neogene events-their timing, nature and interrelationship, p. 3-14. University of Tokyo Press.
- Iwasaki, Y., 1970: The Shiobara-type molluscan fauna. An ecological analysis of fossil molluscs. *Journal of the Faculty of Science, University of Tokyo, Section 2*, vol. 17, part 3, p. 351-444, pls. 1-7.
- Iwasaki, Y., 1981: The Shiobara-type Fauna-shallow sea molluscan assemblages of the Middle and Upper Miocene in Japan-. In, Habe, T. and Omori, M. eds., Study of molluscan paleobiology (Professor Omori, M. Memorial Volume), p. 251-258. (in Japanese with English abstract)
- Koizumi, I., 1979: Kadonosawa Sannohe Area (2). In, Tsuchi, R. ed., Fundamental data on Japanese Neogene bio- and chronostratigraphy, p. 53-55. (in Japanese)
- Koizumi, I., 1985 Diatom biochronology for late Cenozoic, northwest Pacific. Journal of the Geological Society of Japan, vol. 91, p. 195-211.
- Koizumi, I., 1986 : Siliceous deposits and marine events in Miocene. *Marine Science Monthly (Kaiyo-Kagaku)*, no. 189, p. 146-153. (*in Japanese, title translated*)
- Maiya, S. and Inoue, Y., 1973: On the effective treatment of rocks for microfossil analysis. *Fossils* (*Palaeontological Society of Japan*), nos. 25/26, p.

87-96. (in Japanese with English abstract)

- Maruyama, T., 1984 : Miocene diatom biostratigraphy of onshore sequence on the Pacific side of Northeast Japan, with reference to DSDP Hole 438A (Part 2). *Science Reports of the Tohoku University, Second Series* (*Geology*), vol. 55, no. 1, p. 77-140, pls. 11-15.
- Maruyama, T., 1993: Diatom temperature index and surface water temperature during the middle and late Miocene along the Pacific side of northeast Japan. *Fossils (Palaeontological Society of Japan)*, no. 55, p. 53-64. (*in Japanese with English abstract*)
- Oda, M., 1986: Some aspects and problems concerned with microfossil biochronology for the Neogene in Central and Northeast Honshu, Japan. *In*, Nakagawa, H., Kotaka, T. and Takayanagi, Y. eds., Essays in Geology (Professor Kitamura, N. Commemorative Volume), p. 297-312. (in Japanese with English abstract)
- Oda, M., Hasegawa, S., Honda, N., Maruyama, T. and Funayama, M., 1983 : Progress in multiple planktonic microfossil biostratigraphy for the Middle to Upper Miocene of the Central and Northeast Honshu, Japan. *Journal of the Japanese Association for Petroleum Technology*, vol. 48, no. 1, p. 71-87. (*in Japanese with English abstract*)
- Oda, M., Hasegawa, S., Honda, N., Maruyama, T. and Funayama, M., 1984: Integrated biostratigraphy of planktonic formaminifera, calcareous nannofossils, radiolarians and diatoms of middle and upper Miocene sequences of central and northeast Honshu, Japan. *Paleogeography, Paleoclimatology, Paleoecology*, vol. 46, p. 53-69.
- Okada, Y., 1979: Stratigraphy and Ostracoda from the Late Cenozoic strata of the Oga Peninsula, Akita Prefecture. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 115, p. 143-173, pls. 21-23.
- Otuka, Y., 1934: Tertiary structures of northwestern end

of the Kitakami mountainland, Iwate Prefecture, Japan. Bulletin of the Earthquake Research Institute, Imperial University of Tokyo, vol. 12, part 3, p. 566-638, pls. 44-51.

- Otuka, Y., 1939: Tertiary crustal deformation in Japan (with short remarks on Tertiary paleogeography). Jubilee Publication in the Commemoration of Professor H. Yabe, M.I.A., Sixtieth Birthday, p. 481-519.
- Oyama, K., 1950: Studies on fossil molluscan biocoenosis, no. 1, biological studies of the mangrove swamps, with description of new species from Yatsuo Group. *Report, Geological Survey of Japan*, no. 132, p. 1-16, pls. 1-3.
- Samata, T., 1976: Tertiary planktonic foraminiferal biostratigraphy in the Mabechi River region, northern end of the Kitakami Massif, Northeast Honshu. Journal of the Geological Society of Japan, vol. 82, no. 12, p. 783-793, pl. 1 (in Japanese with English abstract)
- Tabuki, R., 1986 : Plio-Pleistocene Ostracoda from the Tsugaru Basin, North Honshu, Japan. Bulletin of College of Education, University of the Ryukyus, no. 29, p. 27-160, pls. 1-20.
- Tsuchi, R., 1986: Mid-Neogene migration of Tethyan tropical mollusca and larger foraminifera into northern Japan. *In*, McKenzie, K.G. *ed., Shallow Tethys 2*, p. 455-459, A.A. Balkema, Rotterdam.
- Tsukagoshi, A. and Ikeya, N., 1987: The ostracod genus Cythere O.F. Müller, 1785 and its species. Transactions and Proceedings of the Palaeontological Society of Japan, New Series, no. 148, p. 197-222.
- Yajima, M., 1988: Preliminary notes on the Japanese Miocene Ostracoda. *In*, Hanai, T., Ikeya, N. and Ishizaki, K. eds., *Evolutionary biology of Ostracoda its fundamentals and applications*, p. 1073-1085, 2 pls, Kodansha, Tokyo and Elsevier, Amsterdam.
- Yajima, M., 1992: Early Miocene Ostracoda from Mizunami, central Japan. *Bulletin of the Mizunami Fossil Museum*, no. 19, p. 247–268, pls. 29–32.

Suenomatsuyama 末ノ松山, Ninohe 二戸, Kadonosawa 門ノ沢, Mabechi-gawa 馬淵川, Yotsuyaku 四ツ役, Koiwai 小祝, Tate 舘, Shiobara 塩原, Tomesaki 留崎, Shinden 新田, Nakuidake 名 久井岳, Anaushi 穴牛, Itsukamachi 五日町, Aikawa 合川, Maisawa 米沢, Tsukidate 月 舘, Basenkyo 馬仙峡, Jumonji-gawa 十文字川, Metoki 目時, Omma-Manganji 大桑-万願寺, Hatatate 旗立, Tsunaki 綱木, Sendai 仙台, Togi 富来, Sekinohana 関野鼻, Fujikotogawa 藤琴川, Kamikoani 上小阿仁, Setana 瀬棚, Tomikawa 富川, Shibikawa 鮪川, Shikonai 尻子内, Akeyo 明世, Shukunohora 宿洞, Mizunami 瑞浪.

SHORT NOTES

31

On the occurrence of Upper Paleozoic conodonts from central Spitsbergen

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Introduction

In the summer of 1990, I joined the international collaboration field survey in Spitsbergen of the Svalbard Archipelago in the Arctic region. This project was planned by Koji Nakamura of Hokkaido University of Japan in collaboration with staff of the Norwegian Polar Research Institute and financed by a grant under the International Scientific Research Program-Field Research (Project No. 01041005) of the Ministry of Education, Science and Culture, Government of Japan.

During this field survey, I collected many limestone samples for a conodont study from the Nordenskiöldbreen and Kapp Starostin Formations exposed near Skansbukta and Trygghamna in west-central Spitsbergen. Unfortunately, however, most of these samples are barren of conodonts, and only three of them yield a few elements indicating Late Carboniferous and Late Permian ages. Although these conodonts are not numerous, the occurrence provides additional data to discuss the geologic age of both formations.

Geologic setting

The Nordenskiöldbreen Formation (Carboniferous-Permian) is extensively exposed near Skansbukta about 35 km northeast of Longyearbyen (Loc. 1, Figure 1) in westcentral Spitsbergen. We measured a 135-m thick sequence of this formation exposed on the shore cliff along a valley south of a 478-m peak in the Billefjord (Bille fiord). This measured section was designated as the Skansen (478 Peak Valley) section. The Nordenskiöldbreen Formation consists mainly of limestone intercalating with a dolomitic facies, and subdivided into 23 lithologic units; A to G and 1 to 16 in ascending order (Nakamura et al., in Nakamura, 1992). I recovered conodonts from Unit F, 3.2 m in thickness, and the base of which is 25.7 m above the base of this formation. In the field, we collected samples from three different levels (F-1, F-2, and F-3) of this unit. F-1 is the base of Unit F, and F-2 and F-3 are 80 cm and 160 cm above the base, respectively. Samples collected from F-1 are gray, bedded, and dolomitic limestone and yield conodonts in association with fusulinaceans. Limestones at F-2 and F-3 are thickly bedded and yield abundant fusulinaceans, rugose corals, and crinoids.

The other occurrence of conodonts was confirmed in the Upper Permian Kapp Starostin Formation exposed near Trygghamna about 40 km west of Longyearbyen (Loc. 2, Figure 1). We measured a 450-m thick sequence of this formation subdivided into 11 units (Nakamura *et al., in* Nakamura, 1992). Unit 1, the lowest unit of the formation, is 11.5 m thick and consists of bioclastic coquinoid limestone which contains abundant brachiopod shells. Hence, this limestone is conventionally called "Spiriferlimestone." Conodonts are recovered from two levels



Figure 1. Map showing the conodont localities from the Skansen (478 Peak Valley) section of the Nordenskiöldbreen Formation (Loc. 1) and Trygghamna section of the Kapp Starostin Formation (Loc. 2).

(Tr-1 and Tr-2) of this unit. Tr-1 is the base of Unit-1 and Tr-2 is 8.5 m above the base. Limestone collected from Tr-2 includes fish teeth and scales, small gastropods, holothurian sclerites, and foraminifers.

Conodont elements and their geologic age

Conodont elements such as Igiognathodus magnificus Sauffer and Plummer, Ozarkodina sp., and some other unidentified ramiform elements were recovered from F-1 the Nordenskiöldbreen Formation. Idiognathodus of magnificus is known from the Lower and Upper Pennsylvanian (Sweet, 1988). Recently, however, Grayson et al. (1989, 1990) proposed a new phylogenetic classification for the Idiognathodus-Streptognathodus plexus. According to them, Idiognathodus magnificus evolved from I. claviformus Gunnell at the end of the Desmoinesian, and has a range in the Missourian. In Russia, the occurrence of *I. magnificus* has been recorded in the Podol'sk and lower Myachkovo Horizons of the Moscovian of the Moscow Syneclise (e.g., Goreva, 1984). A number of species belonging to the genus Idiognathodus have been known in the Kasimovian of Russia (Barskov and Alekseev, 1975; Barskov et al., 1980; Kozitskaya, 1983: Goreva and Isakova, 1993), but Idiognathodus magnificus has not been recorded in the Kasimovian by these Russian workers. Grayson et al. (1989), however, synonymized several Kasimovian species assigned to the genera Streptognathodus and Idiognathodus to their I. magnificus complex.

Based on the occurrence of I. magnificus, Unit F of the Nordenskiöldbreen Formation can be correlated with the Missourian of North America and the Kasimovian of Russia. This correlation is supported by the occurrence of fusulinaceans in Unit F. Igo and Okimura (in Na-kamura, 1992) reported the following important fusulinaceans from the unit to consider the detailed geologic age: Quasifusulinoides fusiformis (Rozovskaya), Protriticites aff. pseudomontiparus Putrja, Pseudofusulinella tempelensis Ross, and others. Q. fusiformis and Protriticites pseudomontiparus are representatives of the lower Kasimovian and known from C₃A₁ Zone of the Krevyakino Horizon in the stratotype sections of the Russian Platform and the Pre-Urals (e.g., Rauser-Chernousova et al., 1979). These two species are also known to occur in another standard section of the Carboniferous of Russia. The former species is reported in the Isaevian of the Kalinova section of the Donetz Basin. The latter occurs in the lower part of the Kalaikukhna Formation of southwestern Darvas (Davydov, 1990). These levels are correlated with K₁, the lower Kasimovian of the type section in the Moscow Syneclise.

The other conodont locality from which *Neostreptognathodus svalbardensis* Szaniawski and some fragmented ramiform elements were rocovered, is near Trygghamna (Tr-1 and Tr-2). Unfortunately, they are few in number and poorly preserved, but the occurrence of *N. svalbardensis* is worthy of note.

Malkowski and Szaniawski (1975) first reported the

occurrence of Permian conodonts in the "Spirifer-limestone" of the Kapp Starostin Formation in Polakkfjellete, Spitsbergen. Subsequently, Szaniawski and Malkowski (1979) documented the study in detail and described the species belonging to the genera Sweetognathus, Sweetocristatus, Neostreptognathodus, Neogondolella, and others. According to them, these conodonts are similar to those reported from the Meade Peal Member of the Phosphoria Formation of Idaho, Wyoming, and Utah, and the Victorio Peak and Bone Spring Formations of West Texas. From these paleontological data, they assigned the Svalbardian (=the Kapp Starostin Formation) to the Upper Leonardian of the North American standard.

Neostreptognathodus svalbardensis obtained from Tr-1 and Tr-2 in the present study is known to occur in association with Neogondolella idahoensis (Youngquist, Hawley and Miller) in Polakkfjellete. In North America, N. idahoensis ranges from the middle Leonardian to the Roadian (Wardlaw, 1986; Wardlaw and Collinson, 1984). The presence of N. svalbardensis in our collection may indicate that the basal part of the Kapp Starostin Formation at Trygghamna is at least younger than the middle Leonardian.

Recently, Nakrem (1991) reported Permian conodonts from the Kapp Dunér and Hambergjellet Formations of the Gipsdalen Group and the Miseryfjellete Formation of the Tempelfjorden Group exposed in Bjornoya, the southernmost island of the Svalbard Archipelago. The conodont faunas in these formations are similar to those documented from other Arctic regions and correlatable to those reported from the Asselian-Sakmarian to Kungurian-Ufimian of Russia and the Wolfcampian-Leonardian to Roadian-Wordian of U.S.A. N. svalbardensis does not occur in the formations, but the occurrence of N. idahoensis is confirmed almost entirely to the Miseryfjellete Formation. He correlated this formation with the Roadian-Wordian. These new conodont data from Bjornova suggest that our N. svalbardensis-bearing levels of Unit 1 can be correlated with the lower Roadian of North America and the Kungurian of Russia. This age assignment was already supported by preliminary studies of bryozoans (Sakagami, in Nakamura, 1992) and brachiopods (Nakamura et al., in Nakamura, 1992).

Paleontological note

In the present study, only two species, *Idiognathodus* magnificus Stauffer and Plummer and *Neostreptognath*odus svalbardensis Szaniawski, are worthy of note. Specimens treated herein are housed in the paleontological collection of the Department of Astronomy and Earth Sciences, Tokyo Gakugei University.

> Genus Idiognathodus Gunnell, 1931 Idiognathodus magnificus Stauffer and Plummer, 1932

> > Figure 2-1-6

For detailed synonymy refer to Grayson et al. (1989, 1990).

Description.—Platform is slender and curved inward, and has a sharply pointed posterior end. Posterior half of platform is ornamented by distinct transverse ridges. In lateral view, oral surface of platform is slightly arched. Surface of platform is ornamented by discontinuous transverse ridges. Two or three accessory lobes are present in inner side of anterior end of platform. One or two outer accessory lobes appear in a few specimens. The freeblade consists of sharply pointed denticles and continues to a low central carina which extends to one-half of anterior platform. Near anterior end of platform, a shallow trough appears on each side of carina. An adcarinal ridge appears on both sides of carina near the anterior terminal of platform. The blade is almost the same length as the platform.

Remarks.—Since Gunnell's (1931) study, many species belonging to the *Idiognathodus-Streptognathodus* transition series have been erected in the Pennsylvanian System of the U.S.A. Grayson *et al.*, (1989, 1990) discussed the phylogenetic basis for species recognition within *Idiognathodus*, and proposed a new taxonomic concept. They proposed that *Idiognathodus* should be subdivided into unadulterated polymorphic species that consist of similar recurring morphotypes. According to them, *I. magnificus* is an entirely Missourian complex of this genus that is distinguished by the precipitous termination of its anterior platform margin and adcarinal ridges.

Occurrence.-F-1 of the Skansen (478 Peak Valley)



Figure 2. 1-6, *Idiognathodus magnificus* Stauffer and Plummer, Oral views, Reg. nos. TGU 94101, 94102, 94103, 94104, 94105, 94106, 1-4, ×100, 5, 6. ×150. All specimens occurred in F-1 of the Skansen (478 Peak Valley) section, the Nordenskiöldbreen Formation. **7-9**, *Neostreptognathodus svalbardensis* Szaniawski, **8, 9** occurred in Tr-1, and **7** occurred in Tr-2 of the Trygghamna section, the Kapp Starostin Formation. Oral views, Reg. nos. TGU 94107, 49108, 94109. All ×200. **10, 11**, unidentified ramiform elements. All specimens occurred in Tr-1 of the Trygghamna section, the Kapp Starostin Formation, lateral views, Reg. nos. 941010, 941011. All ×150.

section, the Nordenskiöldbreen Formation. Reg. nos. TGU 94101, 94102, 94103, 94104, 94105, 94106.

Genus Neostreptognathodus Clark, 1972 Neostreptognathodus svalbardensis Szaniawski, 1979

Figures 1-7-9

Neostreptognathodus aff. pequopensis Behenken; Szaniawski, 1976, p. 82-83, pl. 1, figs. 6-8, 10 (only).

Neostreptognathodus svalbardensis Szaniawski, 1979, p. 250-251, pl. 6, figs. 2-6 (only), pl. 7, figs, 1a-5c.

Neostreptognathodus pnevi Kozur and Movshovich; Nakrem, 1991, p. 245, fig. 3E.

Remarks.—The anterior part of the present specimens is lost but the characteristic platform is preserved and assignable to this species. The platform has deep median trough, and each carina has five or six large nodes. This species resembles *Neostreptognathodus sulcoplicatus* (Youngquist, Hawley and Miller) but the former is easily distinguished from the latter by numerous transverse ridges. *N. svalbardensis*, however, is difficult to distinguish from the immature stage of *N. sulcoplicatus*. This species is also similar to *N. pnevi* Kozur and Movshovich, but it differs from the latter in a few denticles on the anterior free-blade.

Occurrence.—Tr-1 and Tr-2 of the Trygghamna section, Kapp Starostin Formation.

Reg. nos. TGU 94107, 94108, 94109.

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References cited

- Barskov, I.S. and Alekseev, A.S., 1975 : Conodonts of the Middle and Upper Carboniferous from the vicinity of Moscow. Akademiya Nauk Izvestiya SSSR, Seriya Geologicheskaya, Moscow, no. 4, p. 84–99. (in Russian)
- Barskov, I.S., Alekseev, A.S. and Goreva, N.V., 1980: Conodont stratigraphical scale of the Carboniferous. *Akademiya Nauk Izvestiya SSSR, Seriya Geologicheskaya.*, Moscow, no. 3, p. 43-45. (*in Russian*)
- Clark, D.L., 1972: Early Permian crisis and its bearing on Permo-Triassic taxonomy. *Geologica et Paleontologica*, SB 1, p. 147-158.
- Davydov, V.I., 1990: Zonal subdivision of the Gzhelian stage in the Donets Basin and Pre-Donets trough by fusulinids. *In*, Proceedings of XXIV Session of the All-Union Paleontological Society of Leningrad, p. 29-33. (*in Russian*)

Goreva, N.V., 1984 : Moscovian conodonts from Moscow

Syneclise. In, Menner, V.V., ed., Paleontological characteristics of stratotype and reference sections of Moscow Basin Carboniferous. Moscow University Press, p. 44–122. (in Russian)

- Goreva, N.V. and Isakova, T.M., 1993: Changes in the taxonomic diversity of conodont and foraminiferal assemblages in the Kasimov Stage (Moscow Basin) related to the cycles of sedimentation. *Stratigraphy and geological correlation*, vol. 1, no. 3, p. 358-361.
- Grayson, R.C. Jr., Merrill, G.K., Lambert, L.L. and Turner, J., 1989 : Phylogenetic basis for species recognition within the conodont genus *Idiognathodus* : Applicability to correlation and boundary placement. *Texas Tech University studies in Geology*, 2, p. 75–94, pls. 1–2.
- Grayson, R.C. Jr., Merrill, G.K and Lambert, L.L., 1990: Carboniferous Gnathodontid conodont apparatuses: Evidence of a dual origin for Pennsylvanian taxa. *Courier Forschungsinstitut Senckenberg*, 118, p. 353-396, pls. 1-4.
- Gunnell, F.H., 1931 : Conodonts from the Fort Scott Limestone of Missouri. *Journal of Paleontology*, vol. 5, no. 3, p. 244–252, pl. 29.
- Igo, Hh. and Okimura, Y., 1992 : Carboniferous-Permian foraminifers of west spitsbergen. *In*, Nakamura, K. *ed.*, Investigation on the Upper Carboniferous-Upper Permian succession of West Spitsbergen, 1989-1991. p. 98-103, pls. 1-7. Published by Hokkaido University, Sapporo.
- Kozitskaya, R.V., 1983 : Upper Carboniferous conodonts of the PreDonetz-Donets basin. *Seriya Geologicheskaya*, no. 11, p. 69-76.
- Malkowski, K. and Szaniawski, H., 1976: Permian conodonts from Spitsbergen and their stratigraphic significance; a preliminary note. *Norsk Polarinstitutt Arbok*, 1975, p. 79-87, pl. 1.
- Nakamura, K., Sakagami, S., Okimura, Y., Tazawa, J., Igo, H., Kumon, F., Kawamura, T., Kano, A. and Hilde B. Keilen, 1992 : Preliminary report of stratigraphical study on the Upper Carboniferous-Upper Permian. *In*, Nakamura *ed.*, Investigations on the Upper Carboniferous-Upper Permian succession of West Spitsbergen, 1989-1991, p. 1-36. Published by Hokkaido University, Sapporo.
- Nakrem, H.A., 1991 : Conodonts from the Permian succession of Bjørnøya (Svalbard). *Norsk Geologisk Tidsskrift*, 71, p. 235-248, figs. 3a-p, figs. 4a-k.
- Rauser-Chernousova, D.M., Ivanova, E.A., Grozdilova, L.P. and Makhlina, M.K., 1979: The Carboniferous of the U.S.S.R., p. 147-174, Reports presented to the I.U.G.S. subcommission on Carboniferous stratigraphy at the 8th International Congress on Carboniferous Stratigraphy and Geology held at Moscow, 1975. *In*, Wangner, R.H., Higgins, A.C. and Meyen, S.V., *eds.*, *Yorkshire Geological Society Occasional Publication*, no. 4.
- Sakagami, S., 1992 : Notes on the Permian bryozoans from the Kapp Starostin Formation at Festningen route, Spitsbergen. *In*, Nakamura, K. *ed.*, Investigation on the Upper Carboniferous-Upper Permian succession of West Spitsbergen, 1989-1991, p. 39-57, pls. 1-6. Published by Hokkaido University, Sapporo.

Stauffer, C.R. and Plummer, H.J., 1932: Texas Penn-

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sylvanian conodonts and their stratigraphic relations. *The University of Texas Bulletin*, no. 3201, p. 13-50, pls. 1-4.

- Szaniawski, H. and Malkowski, K., 1979 : Conodonts from the Kapp Starostin Formation (Permian) of Spitsbergen. *Acta Palaeontologica Polonica*, vol. 24, no. 2, p. 231-264, pls. 4-10.
- Sweet, W.C., 1988 : The conodonta : morphology, taxonomy, paleoecology, and evolutionary of a longextinct animal phylum. 212 p. Oxford University

Press, New York.

- Wardlow, B.R., 1986 : Paleontology and deposition of the Phosphoria Formation. *Contributions to Geology, University of Wyoming*, vol. 24, no. 2, P. 107-142.
- Wardlaw, B.R. and Collinson, J.W., 1984: Conodont paleoecology of the Permian Phosphoria Formation and related rocks of Wyoming and adjacent areas. *The Geological Society of America, Special Paper* 196, p. 263–281, pls. 1–5.

PROCEEDINGS OF THE PALAEONTOLOGICAL SOCIETY OF JAPAN

日本古生物学会 1995 年年会・総会

日本古生物学会 1995 年年会・総会が, 2月 2~4 日に名古 屋大学で開催された(参加者 224 名)。

特別講演

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ワークショップ

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夜間小集会

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普及講演会

(名古屋市科学館と共催:名古	古屋市科学館サイエンスホール	V)
日本に象が生きていたころ	一日本の化石動物の発掘・	復
元・研究―		和

Palaeontological Society of Japan (PSJ) Council Actions

During its meeting on Februaly 1, 1995, the Council enacted the following changes to PSJ membership.

New members elected ; Hiroshi Amemiya, Masahiro Gouda, Koji Kameo, Tarou Kiso, Hitoshi Nakagawa, Shigehiro Nukatsuka, Takayuki Oguchi, Minoru Sumita, Toshiyuki Tanaka, Tomoko Usui, Apson Ampornmaha.	Mutsumi Fujimoto, Hiroshi Hase, Toshio Kawamura, Kouji Makino, Hideo Nagato, Akira Obata, Michiko Saito, Masanori Suzuki, Hideto Tsutsui, Morio Yabuki,	Osamu Furuie, Shiyunpei Ishikawa, Fumihisa Kawabe, Hiroshige Matsuoka, Ayumu Nojo, Kiichi Obata, Tamaki Sato, Eiichi Takagi, Morihiro Usami, Tatsuo Yamazaki,
New Fellows approved ; Rie Hori, Tetsuro Ueda.	Akihiko Suzuki,	Minoru Tsukagoshi,
New patron member ; Museum Park Ibaraki	Natural Museum	
Deceased member; Masanobu Kikuchi		
Resigned members ; (Fellow) Norio Fuji, Satoru Uozumi.	Keiichi Ono,	Toshio Saito,
(Ordinary Member) Takao Ito, Kyoichiro Numano,	Shoichi Kiyokawa, Fukumatsu Sugita, Ricardo Franco-Nie	Toshio Nishio, Shigeyuki Suzuki, tro.
(Patron member)		

Mitsui Sekiyu-Kaihatsu Company.

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◎1995 年例会(第 144 回例会)は,横須賀市自然博物館および横須賀市文化会館で
6月 24日,25日に開催の予定です。 ◎1996 年の年会・総会は,1月 26~28日に大阪市立大学理学部で開催予定です。
行事係: 〒169-50 東京都新宿区西早稲田1-6-1 早稲田大学教育学部地学教室
☎ 03 (3203) 4141 FAX 03 (3207) 4950 平野弘道(内線 3908:ダイヤル・イン 03(5286)1516)

編集委員会 (1995-1996)

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森	啓(委員長)	小笠原	憲四郎	谷村	好洋	冨田	幸光
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