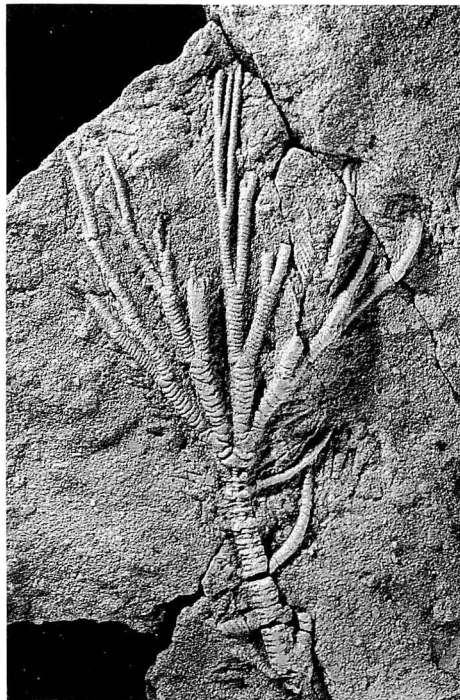


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The fossil on the cover is *Isocrinus (Chladocrinus) hanaii* Oji, an Early Cretaceous (Aptian) crinoid, which was described from the Hiraiga Formation exposed at Haipe, Tanohata-mura, Shimo-Hei County, Iwate Prefecture, Northeast Japan. (University Museum of the University of Tokyo coll. cat. no. ME6950, paratype specimen, length about 11 cm)

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**959. PHYLOGENETIC SIGNIFICANCE OF A NEW
ARAPHID DIATOM SPECIES, *DELPHINEIS*
KAMENOOENSIS SP. NOV.***

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Abstract. A new diatom species *Delphineis kamenooensis* is described from the Lower Miocene Kamenoo Formation in the Joban Coalfield of northeast Honshu, Japan. The species occurs in the upper part of the late Early Miocene *Thalassiosira fraga* Zone (NPD 2) to the lower part of the latest Early Miocene *Crucidenticula kanayae* Zone (NPD 3A) of the North Pacific diatom zonation and serves as a marker species for this interval. The new species is characterized by linear valve outline, relatively sparse areolae and partially developed transverse grooves on valve face. It shows close morphologic resemblance to *Delphineis miocenica* (Schrader) Andrews and is probably its direct precursor. *D. kamenooensis* sp. nov. has features common to the *Delphineis surirella*, *D. lineata* and *D. ovata* subgeneric groups proposed by Andrews (1988) and may be an intermediate form among the three groups.

Key words. Diatom, fossil, marine, *Delphineis*, Miocene, Japan.

Introduction

Delphineis is a marine diatom genus erected by Andrews (1977) for several species formerly assigned to the genus *Rhaphoneis* Ehr. The genus *Delphineis* was then composed of only five fossil species (Andrews, 1977), but subsequent descriptions and generic transfers of many additional extant and fossil species have made *Delphineis* a moderately large genus consisting of at least 23 species at present (Fryxell and Miller, 1978; Andrews, 1981; Hendey, 1981; Sancetta, 1982; Akiba, 1986; Prasad, 1986, 1992; Barron and Baldauf, 1986; Andrews, 1988).

The morphology and phylogeny of *Delphineis* is fairly well understood mainly through continuing research effort by Andrews (1977, 1981, 1988). Andrews (1988)

synthesized its phylogeny and outlined probable evolutionary development and relationships of its subgeneric groups within the genus. He showed that three distinctive affinity groups, the *Delphineis surirella*, *D. lineata* and *D. ovata* groups, had diversified before the Middle Miocene time and he postulated evolutionary sequences within each group. However, the pre-Middle Miocene evolutionary history of *Delphineis* as well as the evolutionary diversification of the three subgeneric groups is not well known at present.

In this study, a new *Delphineis* species, *D. kamenooensis*, is described from the upper Lower Miocene Kamenoo Formation in Japan on the basis of light and scanning electron microscopic observations. In addition, *Delphineis miocenica* (Schrader) Andrews, a species which is quite similar in morphology to *D. kamenooensis* and has the same stratigraphic range as *D. kamenooensis*,

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was also examined in detail by the scanning electron microscope for comparison. *Delphineis kamenooensis* has features common to both the *D. surirella*, *D. lineata* and *D. ovata* subgeneric groups and may be an intermediate species of the three groups.

Materials

Samples studied in this study are as follows (Figures 1, 2):

1. Sample JOB 680; The type material of *Delphineis kamenooensis*, laminated siliceous mudstone of the Lower Miocene Kamenoo Formation of the Yunagaya Group in the Joban Coalfield (Sugai *et al.*, 1957), collected

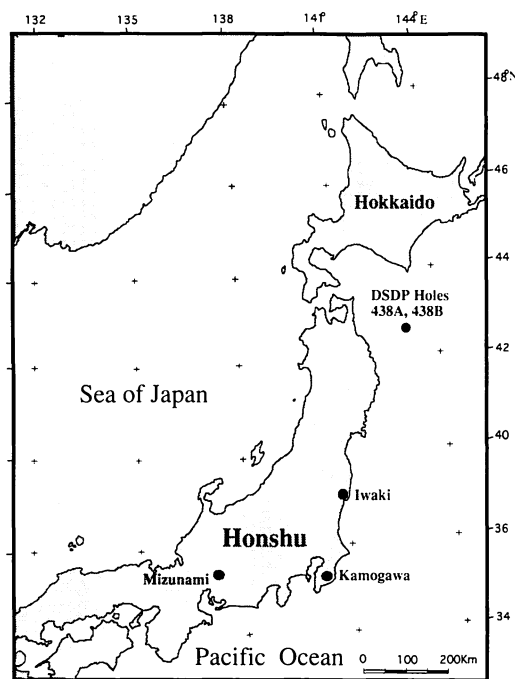


Figure 1. Map showing localities of samples used in this study.

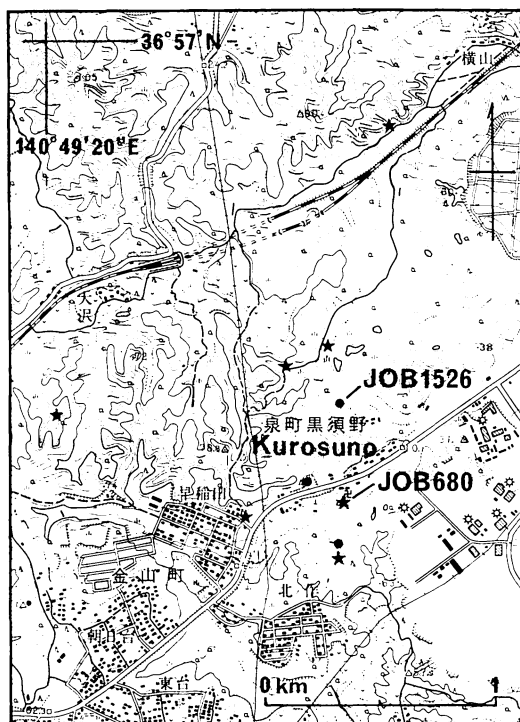
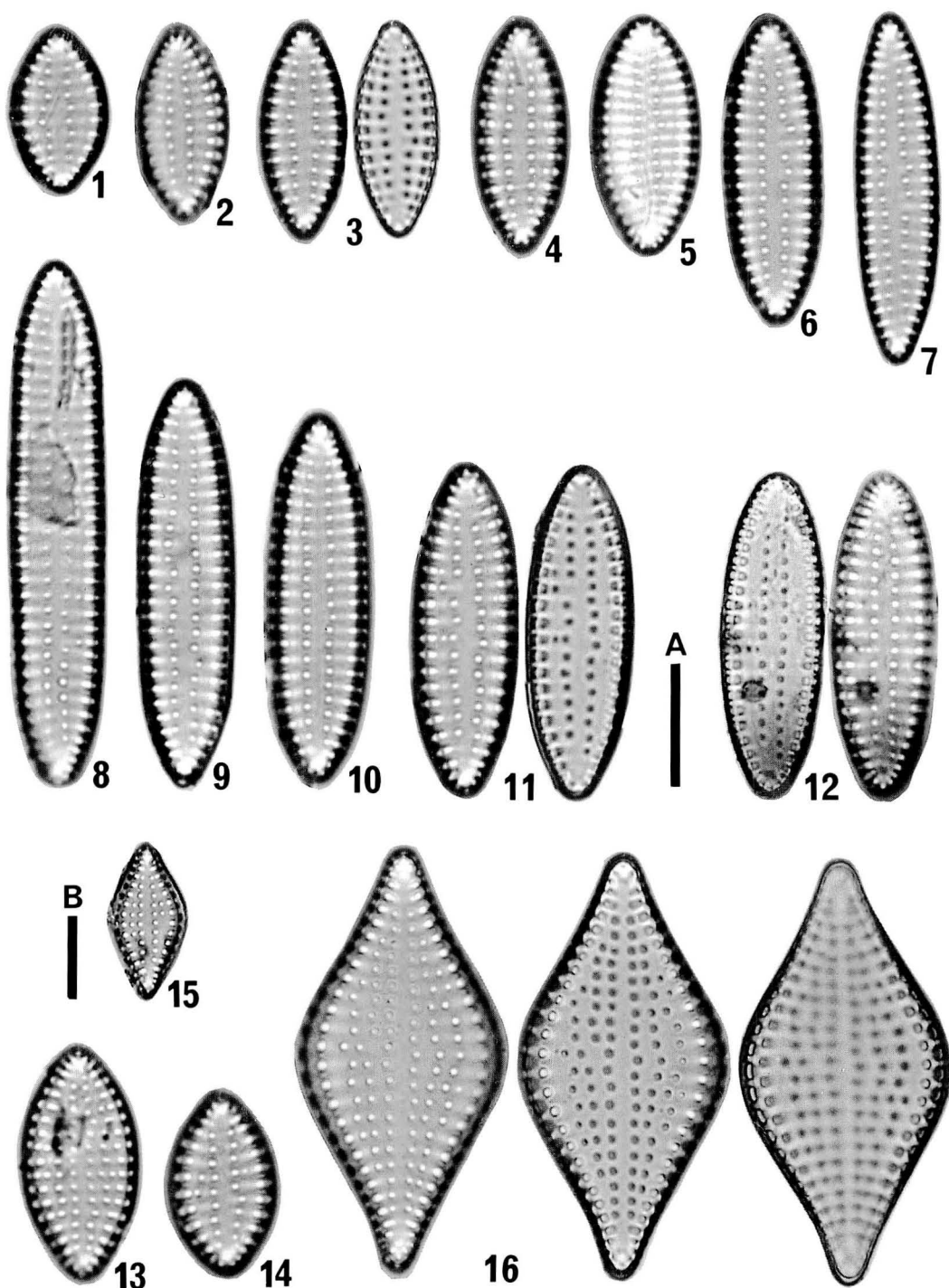


Figure 2. Map showing the locations of the samples including *Delphineis kamenooensis* Yanagisawa sp. nov. and *D. miocenica* (Schrader) Andrews in Kurosuno area, Izumi-machi, Iwaki City, Fukushima Prefecture (Topographic map "Iwaki-izumi", 1:25,000 scale, Geographical Survey Institute). JOB 680: the type sample of *D. kamenooensis* (Kamenoo Formation). JOB 1526: a sample including *Delphineis miocenica* (Schrader) Andrews and *D. kamenooensis* used for observation (Taira Formation). Stars indicate the locations of samples including *D. kamenooensis* (Taira Formation). Closed circles indicate the locations of samples including *D. miocenica* (Taira Formation).

from a small cliff near Kurosuno, Izumi-machi, Iwaki City, Fukushima Prefecture (36°55'54.5"N, 140°50'14.0"E, Figure 2). The diatom assemblage is correlative with the upper part of the *Thalassiosira fraga* Zone

→ **Figure 3.** LM photomicrographs. Scale bars equal 10 μ m (A for 1–14, 16 and B for 15). **1–11.** *Delphineis kamenooensis* Yanagisawa sp. nov., Sample JOB 680, Kamenoo Formation (3. Holotype). **12.** *Delphineis kamenooensis* Yanagisawa sp. nov., Sample Km 41A, Emi Formation. **13, 14.** *Delphineis kamenooensis* Yanagisawa sp. nov. (slightly broad form), Sample JOB 680, Kamenoo Formation. **15.** *Delphineis miocenica* (Schrader) Andrews, Sample JOB 1526, Taira Formation. **16.** *Delphineis miocenica* (Schrader) Andrews, Sample Mzn 06, Oidawara Formation.



(NPD 2) of Akiba (1986).

2. Sample Km 41A; A calcareous concretion taken from the Emi Formation of the Awa Group distributed in the Kamogawa area of Boso Peninsula (Nakajima *et al.*, 1981). It was obtained from an outcrop in Choja River, Wada Town, Awa County, Chiba Prefecture (35°04'9.1"N, 140°01'43.5"E). The occurrence of *Actinocyclus ingens* and *Crucidenticula kanayae* and the lack of *Denticulopsis* species indicate that this sample is correlative with the *C. kanayae* Zone (NPD 3A) of Akiba (1986).

3. Sample JOB 1526; Massive mudstone from the Honya Mudstone Member of the Taira Formation of the Yunagaya Group in the Joban Coalfield, sampled from a small cliff north of Kurosuno, Izumi-machi, Iwaki City, Fukushima Prefecture (36°56'7.6"N, 140°50'13.3"E, Figure 2). This sample is included in the upper part of *Thalassiosira fraga* Zone (NPD 2).

4. Sample Mzn 06; Diatomaceous mudstone from the Oidawara Formation of Mizunami area, central Japan. It was sampled from a road-cut cliff near Shukunohora, Hiyoshi-machi, Mizunami City, Gifu Prefecture (35°24'31.22"N, 137°16'17.8"E). The diatom flora of the sample is assigned to the lower part of the Middle Miocene *Denticulopsis lauta* Zone (NPD 4A) of Akiba (1986).

5. DSDP Leg 57 Holes 438A and 438B (off northeastern Honshu); These holes were examined to check the stratigraphic ranges of *Delphineis kamenooensis* and *D. miocenica*. However, no specimens of *D. kamenooensis* were found.

Methods

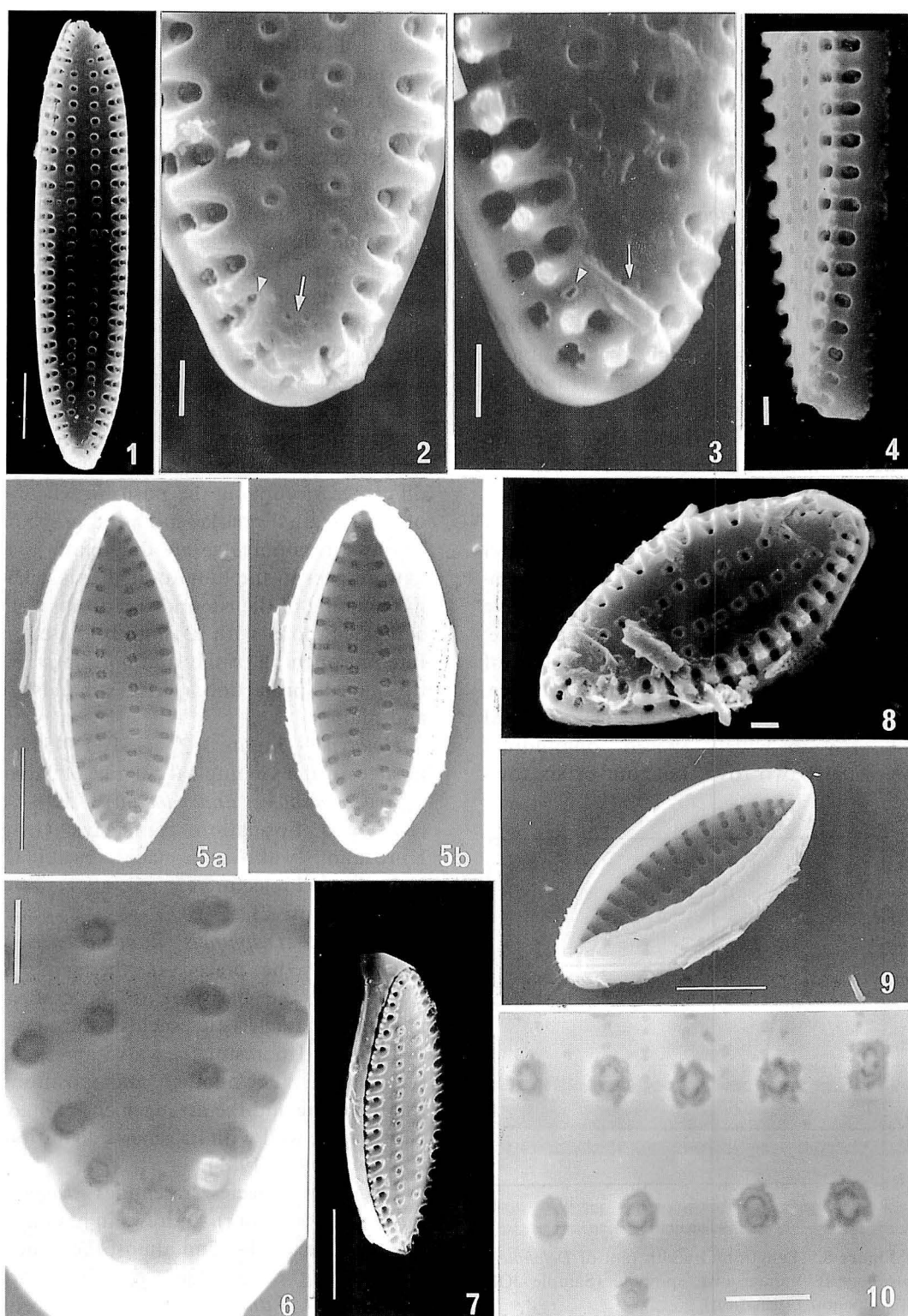
For each sample, approximately 1 g of each dried sediment was placed in a 100 ml beaker. The sediment was disintegrated in hydrogen peroxide (15%) and boiled for about 15 minutes, and 20 ml of hydrochloric acid was then added and the sediment was boiled for about 10 minutes. The acid was removed by at least five successive 3-hour decantations with distilled water. 0.01 N sodium pyrophosphate ($\text{Na}_2\text{P}_2\text{O}_7$) was then added to the liquid and suspended clays were removed by 3-hour decantations. This procedure was repeated at least five times and then sodium pyrophosphate was removed by at least five successive 3-hour decantations with distilled water.

A strewn slide for light microscope (LM) observation was prepared for each sample on an 18×18 mm cover glass and the cover glass was mounted in Pleurax on a glass slide. For scanning electron microscope (SEM) observation, diatom valves were picked from dried samples and mounted on sample stages, using one hair of a tiny paint brush. SEM observation was performed on *D. kamenooensis* and *D. miocenica* using JOEL T330A of Geological Survey of Japan.

Taxonomy

In this paper, the classification system of Round *et al.* (1990) is adopted for description.

→ **Figure 4.** SEM photomicrographs of *Delphineis kamenooensis* Yanagisawa sp. nov. Narrower and broader scale bars equal 5 μm and 1 μm , respectively. All from sample JOB 680 (Kamenoo Formation). **1.** Outer view of relatively long valve. **2, 3.** Outer view of valve apex. Arrows indicate two apical pores and arrow heads indicate external openings of rimoportulae. Note stubby spine-like projections at the shoulder of the valve. **4.** Side view of valve. **5a, 5b.** Inner view of valve with girdle bands (Stereoscopic pair). **6.** Enlargement of Figure 5a showing valve apex and a lip-shaped internal opening of rimoportula. **7.** Oblique outer view of valve with a girdle band. **8.** Outer view of relatively short valve. **9.** Oblique inner view of valve with a girdle band. **10.** Areolae occluded with rota-type cribra.



Class Fragilariophyceae Round, 1990
 Subclass Fragilariophycidae Round, 1990
 Family Rhaphoneidales Round, 1990
 Subfamily Rhaphoneidaceae Forti, 1912
 Genus *Delphineis* Andrews, 1977,
 emend. Andrews, 1981

Delphineis kamenooensis Yanagisawa
 sp. nov.

Figures 3-1-14; 4-1-10.

Description.—Valve linear or linear-elliptical to lanceolate, with slightly acute apices, 9–49 μm long, 7–10 μm wide (Figure 5). Valve face flat, punctated by transverse rows of circular areolae. Cribra of rota-type on the outer surface of valve and connected to the valve by two longitudinally oriented struts (Fig. 4-10). Transverse rows of areolae fairly sparse, 8–10.5 in 10 μm , parallel to transapical axis at the center, and becoming radiate near the apices, finer striae curve completely around the ends of the valve. Marginal areolae in a row along the edge of valve. The other areolae on the valve face, surrounded by slightly raised rims, arranged secondarily in widely spaced longitudinal rows, usually two rows, but four or six rows

in broader specimens. Some areolae are occluded with thin siliceous layer on the outside of the valve and so are invisible on the external surface of valve. Mantle shallow with a row of areolae of the same size as valve face areolae. Hyaline axial area indistinct, because of the widely spaced longitudinal rows of areolae. External grooves partially developed, surrounded by slightly raised rims containing the marginal areolae and the mantle areolae, but not reaching to the valve face areolae. Raised areas between the grooves terminate in stubby spine-like attachment projections with two heads along the shoulder of the valve. At each apex, two small pores penetrate into the valve interior, and a single rimoportula is located slightly off-center, occupying the position where one of the marginal areolae might be positioned. The two rimoportulae are diagonally placed with respect to the longitudinal axis. External opening of the rimoportula forms a small elongated pore with a slightly raised rim. Internal opening of the rimoportula shows a lip-shaped projection. Girdle bands split and plain.

Holotype.—Figure 3-3 (GSJ F14583 deposited in the Geological Survey of Japan).

Type sample and locality.—JOB 680 (Kamenoo Formation, Yunagaya Group), Kurosuno, Iwaki-izumi-machi, Iwaki City, Fukushima Prefecture (36°55'54.5"N, 140°50'14.0"E, Figure 2).

Remarks.—*Delphineis kamenooensis* can undoubtedly be placed in the genus *Delphineis* on the basis of its general morphologic characteristics such as the presence of two small pores at the valve apices, rota-type cribra, the number and position of rimoportulae and the arrangement of areolae, which agree well with its generic definition by Andrews (1977, 1981).

This new species resembles *Delphineis miocenica* (Schrader) Andrews in having relatively sparse areolae and almost the same size and spacing of areolae. Relatively broad forms of *D. kamenooensis* with lanceolate

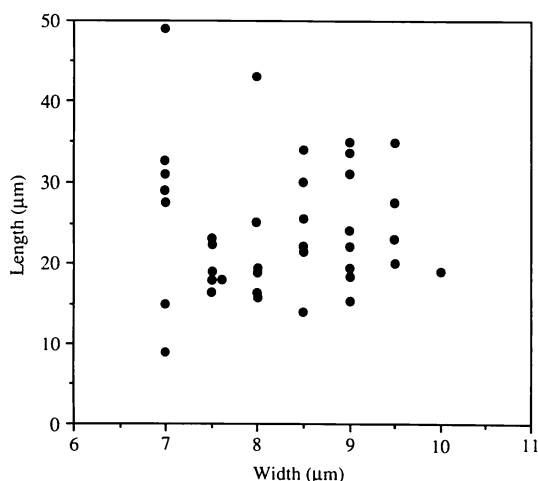


Figure 5. Length and width plot of *Delphineis kamenooensis* Yanagisawa, sp. nov. (Sample JOB 680, Kamenoo Formation).

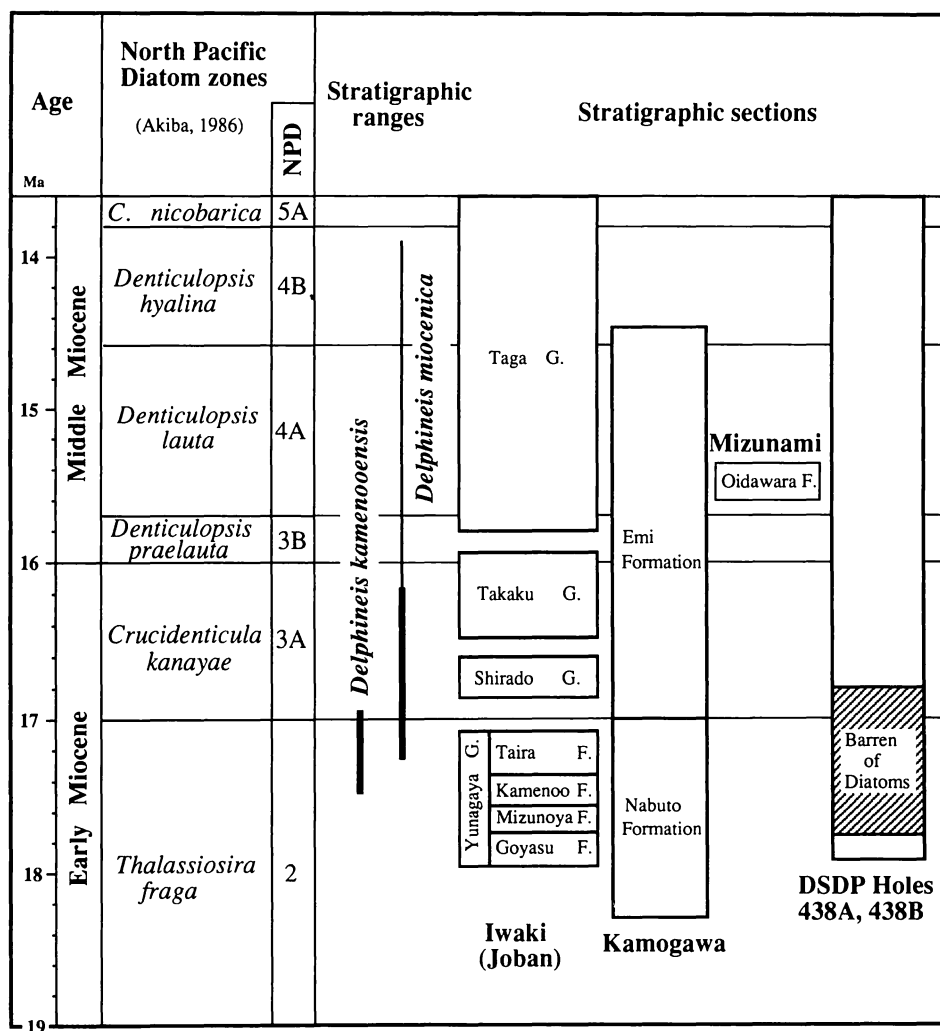


Figure 6. Stratigraphic occurrences of *Delphineis kamenooensis* Yanagisawa sp. nov. and *D. miocenica* (Schrader) Andrews with biochronological distribution of the sections studied in this paper.

outline and four or six longitudinal rows of areolae on the valve face bear very close resemblance to *D. miocenica* (compare Figures 3-13, 14 with Figures 3-15, 16). However, *D. kamenooensis* differs from *D. miocenica* in having a more linear valve outline, and by the presence of external grooves and the prominent stub-like projections on the valve shoulder.

Delphineis kamenooensis is also similar to *Delphineis ovata* Andrews (1977) and *D. penelliptica* Andrews (1977) in valve outline,

but differs from them in having slightly acute apices, sparsely spaced areolae and indistinct axial area. The transapical striae of *D. kamenooensis* are finer than those of the latter two species; *D. kamenooensis* has 8.0-10.5 striae in 10 μm , whereas *D. penelliptica* and *D. ovata* have 7 and 5.5-7 striae in 10 μm , respectively. *D. kamenooensis* shows affinity to *Delphineis lineata* Andrews (1977), but is distinguished by slightly acute apices, the absence of distinct axial area and more sparsely spaced longitudinal rows of areolae.

Delphineis kamenooensis is similar to *Delphineis parallelica* (Schrader) Andrews 1988 (= *Rhaphoneis parallelica* Schrader in Schrader and Fenner, 1976) in having a linear valve outline with slightly acute apices, but differs from it by the absence of a clear axial area.

Stratigraphic occurrence.—Stratigraphic records in the Joban Coalfield and Kamogawa area indicate that the stratigraphic range of *D. kamenooensis* is at least from the upper part of the *Thalassiosira fraga* Zone (NPD 2) to the lowermost part of the *Crucidentacula kanayae* Zone (NPD 3A) (Figure 6).

The species has been found from several samples of the Kamenoo and Taira Formations in the Joban Coalfield (See Figure 2) and also from a calcareous concretion of the Emi Formation distributed in the Kamogawa area of the Boso Peninsula.

The diatom assemblages of the Kamenoo and Taira Formations are assigned to the upper part of the *T. fraga* Zone of Akiba (1986) or the *Kisseleviella carina* Zone of Koizumi (1985) on the basis of the absence of *Actinocyclus ingens* with the abundant occurrence of *Kisseleviella carina* (Koizumi, 1986; Yanagisawa *et al.*, 1989; Taketani *et al.*, 1990; this study). The first occurrence of *D. kamenooensis* therefore ranges down at least to the *T. fraga* Zone. The calcareous concretion from the Emi Formation includes a diatom flora correlative with the lowermost part of the *C. kanayae* Zone. Since *D. kamenooensis* has not been found in the main part of the *C. kanayae* Zone as well as in much younger diatom zones in DSDP Holes

438A and 438B, and also in Joban Coalfield and Kamogawa area, its last occurrence may lie in the lower part of the *C. kanayae* Zone.

Delphineis miocenica (Schrader)
Andrews 1988

Figures 3–15, 16; 7–1–8

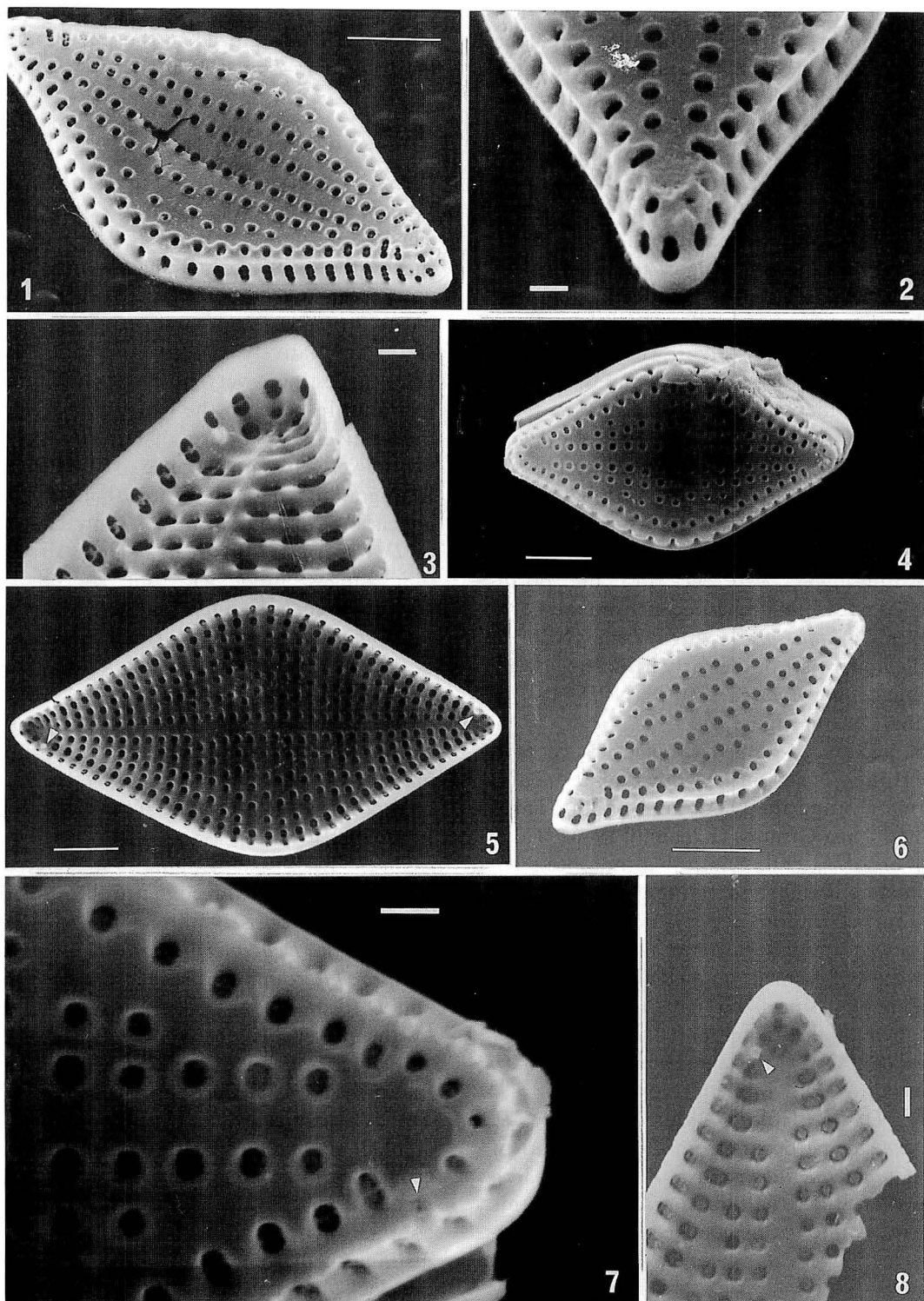
Andrews, 1988, p. 201–202, pl. 1, fig. 2.

Basionym: *Rhaphoneis miocenica* Schrader, 1973, p. 709, pl. 25, figs. 1, 11

Synonymy: *Rhaphoneis ampiceros* Ehrenberg sensu Hanna, 1932, p. 211–212, pl. 15, figs. 3–5; *Rhaphoneis miocenica* Schrader, Akiba *et al.*, 1982, pl. 3, fig. 85; Koizumi, 1986, pl. 1, figs. 8, 9; Yanagisawa *et al.*, 1989, pl. 5, fig. 48.

Observation.—Valve lanceolate with slightly acute apices. Valve face flat, punctated by rows of circular areolae. The areolae surrounded by slightly raised rims and occluded by rotæ. Relatively few transverse rows of areolae parallel to the transapical axis at the center, and becoming radiate near the apices. Marginal areolae in a row along the edge of valve. The other areolae arranged secondarily in a few widely spaced longitudinal rows. Some areolae are occluded with thin siliceous layer on the outside of the valve and so are invisible on the external surface of valve. Mantle shallow with a row of areolae of the same size as the valve face areolae. Hyaline axial area indistinct because of the widely spaced longitudinal rows of areolae. External grooves absent. At the shoulder of valve, marginal ridge present with projections, but the projections are unclear. At each apex, two small pores present, penetrating into the valve interior, and a single rimoportula locat-

→ **Figure 7.** SEM photomicrographs of *Delphineis miocenica* (Schrader) Andrews. Narrower and broader scale bars equal 5 μ m and 1 μ m, respectively. 1–4, 6 and 7 from sample Mzn 06 (Oidawara Formation, Mizumami area) and 5 and 8 from sample JOB 1526 (Honya Member of the Taira Formation, Kurosuno, Izumi-machi, Iwaki City). 1. Oblique outer view of valve. 2. Outer view of valve apex. Note unclear spine-like projections at the shoulder of the valve. 3. Inner view of valve apex showing lip-shaped internal opening of rimoportula. 4. Outer view of frustule with some girdle bands. 5. Inner view of valve. Arrow heads indicate internal openings of rimoportulae. 6. Oblique outer view of valve. 7. Outer view of valve apex. Arrow head indicates external opening of rimoportula. 8. Inner view of valve apex showing lip-shaped internal opening of rimoportula (arrow head).



ed slightly off-center, occupying the position where one of the marginal areolae might be positioned. The two rimoportulae are diagonally placed with respect to the longitudinal axis. External opening of the rimoportula forming a small elongated pore with a slightly raised rim. Internal opening of the rimoportula has a lip-shaped projection.

Remarks.—The observational results of *D. miocenica* of this study agree fairly well with those by Andrews (1988) except for the presence of the stubby spine-like projections at the shoulder of the valve. He reported the lack of the projections, but my specimens from the Oidawara Formation possess these projections although they are very short and unclear. The absence of the projections in Andrews's (1988) specimens is probably due to very poor preservation of his sample as he suggested.

Stratigraphic occurrence.—In the north-west Pacific, this species occurs from the Early Miocene *Thalassiosira fraga* Zone (NPD 2) to the upper part of the early Middle Miocene *Denticulopsis hyalina* Zone (NPD 4B) of Akiba (1986) (Figure 6).

In the Joban Coalfield, this species occurs in the Honya Mudstone Member of the Taira Formation and the overlying Shirado, Takaku and Taga Groups (Koizumi, 1986; Takekuni *et al.*, 1990), but it has not been encountered in the underlying Kamenoo Formation. Therefore, the first occurrence of *D. miocenica* might lie near the boundary between the Kamenoo and Taira Formations (Figure 6). Since the two formations are assigned to the upper part of the *T. fraga* Zone (NPD 2), the first occurrence of *D. miocenica* falls within this zone.

At DSDP Holes 438A and 438B, *D. miocenica* first occurs from the lower part of the *Crucidenticula kanayae* Zone (NPD 3A). However, the true first occurrence of this species can not be detected because the lowermost part of the *C. kanayae* Zone and most of the *T. fraga* Zone are represented by glauconitic sandstone containing no diatoms

(Figure 6). The last occurrence of *D. miocenica* is recognized in the upper part of the *D. hyalina* Zone (NPD 4B) at Hole 438A.

Discussion

Among species of the genus *Delphineis*, *D. kamenooensis* is most similar to *D. miocenica*. The two species share many common features such as the sparsely distributed areolae on the valve face, the medium-size areolae, the secondarily arranged longitudinal rows of areolae and the relatively narrow indistinct axial area, suggesting a very intimate phylogenetic relationship between the two. Furthermore, the relatively broad form of *D. kamenooensis* bears a very close appearance to *D. miocenica*. Stratigraphic data indicate that the first appearance of *D. kamenooensis* predates that of *D. miocenica* (Figure 6). These stratigraphic ranges along with the morphologic resemblance strongly suggest that *D. kamenooensis* is probably the direct ancestor of *D. miocenica*. *Delphineis kamenooensis* might evolve to *D. miocenica* with the change in valve outline from linear to lanceolate shape, the disappearance of external grooves, and the reduction of the stubby spine-like projections at the shoulder of the valve to less prominent forms.

On the basis of some important characteristics, Andrews (1988) recognized three distinct subgeneric groups within the genus *Delphineis*: the *Delphineis lineata*, *D. ovata* and *D. surirella* groups (Table 1). The *D. lineata* and *D. ovata* groups are both characterized by the presence of external grooves on the valve face and the prominent stubby spine-like projections at the shoulder of the valve. The two groups are distinguished mainly by areolae size and spacing; the *D. lineata* group has more compactly spaced and finer areolae than the *D. ovata* group. On the contrary, the *D. surirella* group is clearly distinguished from the other two groups by the lack of such grooves and prominent spine-like projections at the shoulder of the

Table 1. Comparison of characters among *D. miocenica*, *D. kamenooensis* and the three subgeneric groups in *Delphineis*.

Characters	Subgeneric groups			<i>D. miocenica</i>	<i>D. kamenooensis</i>
	<i>D. ovata</i>	<i>D. lineata</i>	<i>D. surirella</i>		
External grooves	Present	Present	Absent	Absent	Present partially
Spine-like projections	Present	Present	Absent	Present (unclear)	Present
Axial area	Narrow	Broad	Narrow or broad	Narrow	Narrow
Areolae	Coarse	Fine	Coarse	Coarse	Coarse

valve. Although he suggested the morphologic uniqueness of *D. miocenica* within the genus *Delphineis*, Andrews (1988) tentatively assigned *D. miocenica* to the *D. surirella* group because of the absence of external grooves and the lack of strong spine-like projections.

As suggested above, the new *Delphineis* species herein described as *D. kamenooensis* is probably the ancestor of *D. miocenica* (Figure 8). However, *D. kamenooensis* can-

not be placed in the *D. surirella* group as *D. miocenica* can be, because it has the valve face grooves and the distinct spine-like projections. It can be rather said that *D. kamenooensis* is much closer to the *D. lineata* and *D. ovata* groups because of the presence of external grooves and the prominent spine-like projections, but the areolae spacing and indistinct axial area as well as the partial development of grooves make me hesitate to place this species in either of these groups.

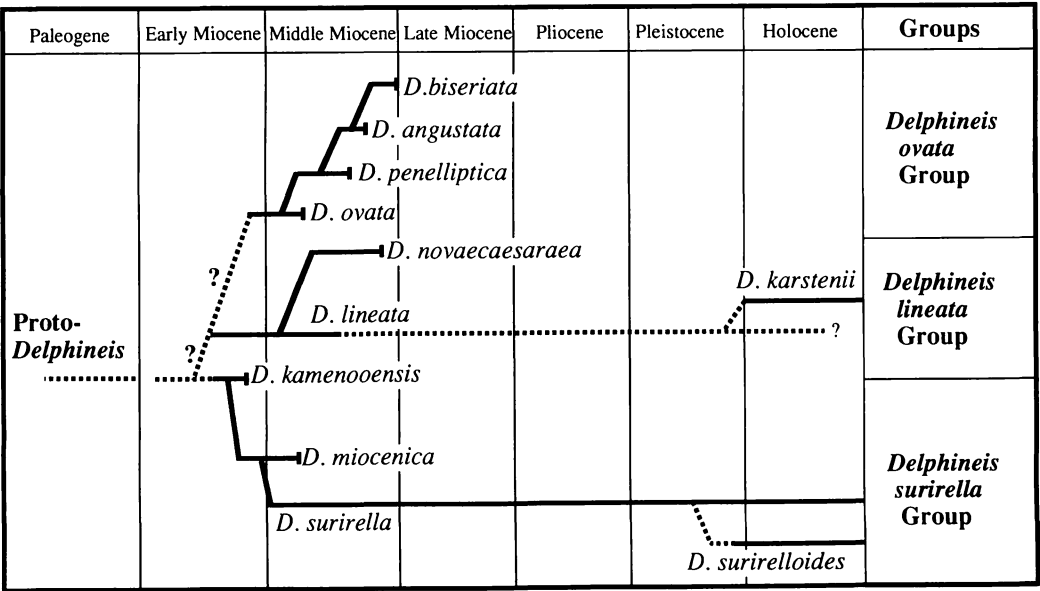


Figure 8. Evolutionary sequence in the genus *Delphineis* modified after Andrews (1988).

Thus *D. kamenooensis* cannot be assigned with confidence to any of the three subgeneric groups and appears to be phylogenetically an intermediate form between the three groups. *D. kamenooensis* may possibly be the common ancestor of the three subgeneric groups. Much stratigraphic and taxonomic study, however, needs to be carried out to confirm such an evolutionary relationship, making use of more continuous and better preserved stratigraphic sequences.

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Kamenoo 亀ノ尾, Honya 本谷, Taira 平, Yunagaya 湯長谷, Joban 常磐, Kurosuno 黒須野, Izumi-machi 泉町, Iwaki いわき, Fukushima 福島, Emi 江見, Awa 安房, Kamogawa 鴨川, Boso 房総, Choja 長者, Wada 和田, Chiba 千葉, Oidawara 生俵, Mizunami 瑞浪, Shukunohora 宿洞, Hiyoshi-machi 日吉町, Gifu 岐阜, Honshu 本州.

無縦溝珪藻の1新種 *Delphineis kamenooensis* の系統学的意義: 化石珪藻の1新種 *Delphineis kamenooensis* Yanagisawa sp. nov. を常磐炭田に分布する下部中新統の亀ノ尾層から記載した。本種は, Akiba (1986) による北太平洋珪藻化石帯区分の *Thalassiosira fraga* Zone (NPD 2) の上部 (前期中新世後期) から *Crucidenticula kanayae* Zone (前期中新世末) にかけて産出し, この区間の指標種となる。光学顕微鏡及び走査型顕微鏡による観察によれば, 本種は, 線形をした外形, 比較的まばらな点紋, および蓋殻表面の溝によって特徴づけられる。本種は, *Delphineis miocenica* (Schrader) Andrews に形態的によく類似し, 層序的産状から, *D. miocenica* の祖先種と考えられる。*D. kamenooensis* は, *Delphineis* 属の中に見られる3つの属内種グループとそれぞれと共通する形質を持ち, 系統的にはこれら3グループの中間に位置する。柳沢幸夫

960. TWO *NEOZAMITES* SPECIES (BENNETTITALES) FROM THE LOWER CRETACEOUS OF NORTHEAST CHINA AND THE INNER ZONE OF JAPAN*

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Abstract. The genus *Neozamites* was established on the basis of bennettitalean pinnate leaves bearing pinnae with markedly toothed margins. This genus is restricted in geographical distribution to Eastern Siberia, Northeast China, Inner Zone of Japan and Southern Primorye, and in stratigraphical distribution to the Lower Cretaceous. This paper deals with the description of *Neozamites elongatus* in external and cuticular features on the basis of newly collected leaves from the Hegan Coal-Field, Heilongjiang, Northeast China, and of *N. intermedius*, sp. nov. in external features on the basis of leaves from the Tetori Basin in the Inner Zone of Japan.

Key words. *Neozamites* (Bennettitales), Lower Cretaceous, Hegan Coal-Field, Tetori-type flora.

Introduction

The bennettitalean genus *Neozamites* was established in 1962 by Vakhrameev [spelled also as Vachrameev in the taxonomic description]. He described the type species *Neozamites verchojanensis* from the Lower Cretaceous Batylykh Formation distributed along the Liampeska River (Figure 1–11), Yakutia, and *N. lebedevii* from the Lower Cretaceous Khatylykh Formation distributed along the Vilui River (Figure 1–15), Yakutia.

Neozamites is characterized by its pinnate leaves [*N. lebedevii* is known to be bipinnate according to Zheng and Zhang (1983)] with markedly toothed pinna margins and with bennettitalean cuticle.

Until now four species have been recorded. They are *Neozamites verchojanensis* Vakhrameev, *N. lebedevii* Vakhrameev, *N. denticulatus* (Kryshtofovich et Prynada) Vakhrameev and *N. elongatus* Kimura et Sekido.

In this paper, we describe two *Neozamites* species: *N. elongatus* Kimura et Sekido with preserved cuticle (by Sun, Ohana and Kimura) and *N. intermedius*, sp. nov. without

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preserved cuticle (by Nakazawa, Ohana and Kimura).

Neozamites elongatus was first described by Kimura and Sekido (1971) on the basis of pinnate leaves without preserved cuticle from the Oguchi Formation in the Inner Zone of Japan (Figure 1-21 and Figure 2-21). The present leaves referable to *Neozamites elongatus* were collected in 1990 from the Lower Cretaceous Shitouhe Formation (an equivalent to the Chengzihe Formation of non-marine origin in the Jixi Coal-Field, south-eastern Heilongjiang) in the Hegan Coal-Field (Figure 1-1), northeastern Heilongjiang.

The leaves of *Neozamites intermedius*, sp. nov. were collected by one of us (Nakazawa) in 1982 from the fossiliferous beds of the Akaiwa Formation equivalent of nonmarine origin (possibly Aptian in age) (Figure 1-22 and Figure 2-22).

The genus *Neozamites* is restricted in stratigraphical and geographical distributions to the Lower Cretaceous plant beds in Eastern Siberia, most of Northeast China and the Inner Zone of Japan (Figures 1 and 2). These regions are characterized phytogeographically by the Siberian and Tetori-type floras (e.g. Kimura, 1987a, b). In addition, exceptional occurrence of *Neozamites* is known in the Early Cretaceous flora of the mixed type from Southern Primorye (Barremian Ussuri and Starosutchan, and Albian Galenka Formations) (Figure 1-17~20).

It is highly probable that *Neozamites* did make its southward migration since the Barremian time together with such genera characterizing the Siberian and Tetori-type floras as *Ctenis*, *Ginkgo* (including *Baiera*) and *Podozamites* (or *Podozamites*-like plants) to Southern Primorye where the Ryoseki-type plants had extensively flourished (e.g. Kimura, 1987a, b).

The present *Neozamites elongatus* has well preserved cuticle. The specimens were first treated with HF (40%), then macerated with Schulze's solution and followed by diluted

KOH. The preparations were observed by the phase contrast microscope and SEM.

It would be worth mentioning that several bennettitalean leaves (e.g. *Neozamites*) and cycadalean leaves (e.g. *Ctenis* and *Nilssonina*) known in the Siberian and Tetori-type floras do represent markedly toothed or serrate pinna margins. Such features have not been recognized in the bennettitalean and cycadalean leaves known in the Ryoseki-type floras extensively distributed in the Outer Zone of Japan, South China and Southeast Asia.

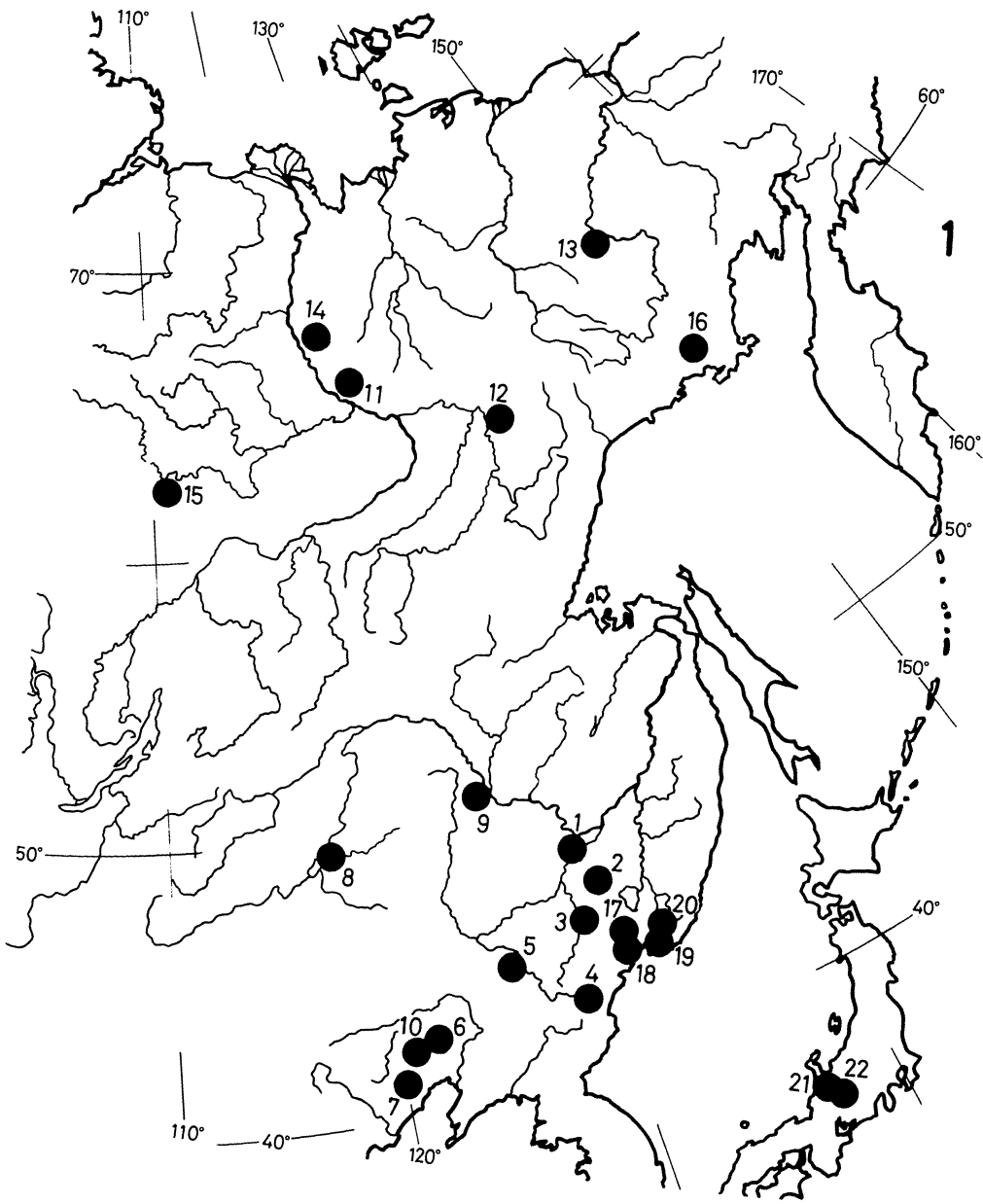
The Japanese specimens examined are kept in the National Science Museum, Tokyo and the Chinese ones in the Nanjing Institute of Geology and Palaeontology, Academia Sinica.

Acknowledgements

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Description

Bennettitales

Genus *Neozamites* Vachrameev, 1962

Neozamites elongatus Kimura et Sekido

Figures 3a, 4a, 5, 6

1971. *Neozamites elongatus* Kimura et Sekido: Kimura and Sekido, p. 192, pl. 24, figs. 1-4, text-figs. 3-4 (Oguchi Formation; Figures 1-21 and 2-21).

1980. *Neozamites* aff. *verchojanensis* Vachrameev: Zhang *et al.*, p. 269, pl. 168, figs. 5, 8 (Sunjiawan Formation; Figure 1-10).

Material.—Examined specimens; C-23 (H29-3) and C-27 (H29-2).

Locality and Horizon: Hegai Coal-Field (roughly 47°20'N, 130°17'E; Figure 1-1), Heilongjiang, Northeast China; Lower Cretaceous Shitouhe Formation (of non-marine origin).

Occurrence (Frequency): Possibly common.

Description of specimens.—The leaves

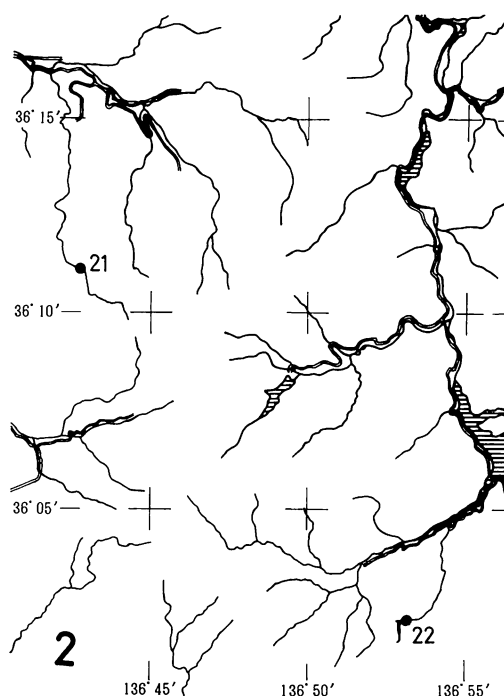


Figure 2. Localities of *Neozamites* in the Inner Zone of Japan.

← **Figure 1.** Localities of *Neozamites* species in China (Northeast China), Eastern Siberia and Japan (Inner Zone). No *Neozamites* species has been recorded from outside areas shown in this map. All specimens of *Neozamites* species mentioned below were derived from Lower Cretaceous plant sites (F; formation).

1. Hegai, Heilongjiang (Shitouhe F.); the present work; *N. elongatus* Kimura et Sekido. 2. Qitaihe, Heilongjiang (Dongshan F.); Zhang *et al.*, 1980; Zheng and Zhang, 1983; *N. denticulatus* (Kryshtofovich et Prynada) Vachrameev, *N. lebedevii* Vachrameev and *N. verchojanensis* Vachrameev. 3. Mudanjiang, Heilongjiang (Houshigou F.); Zhang *et al.*, 1980; *N. verchojanensis* Vachrameev. 4. Liangjiang, Antu and Tongfosi, Jilin (Dalazi F.); Zhang, C. B., 1986 (illustration only), Geological Survey of Jilin, 1989; *N. verchojanensis* Vachrameev. 5. Mengjia, Jiutai, Jilin (Yingcheng F.); Yang and Sun, 1982; *N. verchojanensis* Vachrameev. 6. Fuxin, Liaoning (Shahai F.); Zhang *et al.*, 1980; *N. cf. verchojanensis* Vachrameev. 7. Har-Zuo, Liaoning (Shahai F.); Zhang *et al.*, 1980; *N. cf. lebedevii* Vachrameev. 8. Zalainor, Nei Mongol (Yimin F.); Chen *et al.*, 1988; *N. sp.* (list only). 9. Heihe, Heilongjiang (Bacheligou F.); Zhang *et al.*, 1980; *N. verchojanensis* Vachrameev. 10. Beipiao, Liaoning (Sunjiawan F.); Zhang *et al.*, 1980; *N. aff. verchojanensis* Vachrameev (= *N. elongatus*, in the present work). 11. Liampeska River region, Lena Basin (Batylykh F.); Vachrameev, 1962; *N. verchojanensis* Vachrameev (original description). 12. Lower course of the Aldan River region (Ekseniakh F.); Vachrameev, 1962; ditto. 13. Ganjukha, Zyrianka Basin (Siliap F. ?); Vachrameev, 1962; ditto. 14. Dzigansk Basin (Khatylykh F. and lower part of Ekseniakh F.); Vassilevskaja, 1966 and Abramova, 1970; *N. verchojanensis* Vachrameev and *N. ? sp.* 15. Vilui River region (Khatylykh F.); Vachrameev, 1962; *N. lebedevii* Vachrameev (original description). 16. Omsukchan, Magadan (Omsukchan F.); Samylina, 1976; *N. verchojanensis* Vachrameev. 17. Kanstantinovka, Sujfun Basin (Ussuri and Galenka F.); Krassilov, 1967; *N. denticulatus* (Kryshtofovich et Prynada) Vachrameev. 18. Amba-Bir River region, Sujfun Basin (Galenka F.); ditto. 19. Tchigan Cape, west Sutchan Basin (Starosutchan F.); ditto. 20. Big Eljdugo River region, west Sutchan Basin (Galenka F.); ditto. 21. Mekkodani Valley, Tetori Basin (Oguchi F.); Kimura and Sekido, 1971; *N. elongatus* Kimura et Sekido (original description). 22. Okurodani Valley, Tetori Basin (Akaiwa F. equivalent); the present work; *N. intermedius*, sp. nov.

obtained are fragmental and thus whether the leaves are simply pinnate or bipinnate are unknown, although the leaves of *Neozamites lebedevii* described by Zheng and Zhang (1983) (Figure 1–2) are clearly bipinnate. Therefore, it would be possible that our 'leaves' might correspond to the 'penultimate pinnae' of a bipinnate leaf. In this paper, however, we use 'leaf' or 'leaves' in referring to our specimens hereafter. The largest leaf fragment is more than 7.5 cm long and up to 8.2 cm wide with a thin axis, 1.5–2.0 mm thick, sending off opposite or often subopposite pinnae at a wide angle. The angle is reduced distally. The pinnae are attached to the upper part of the axis by a small central area of pinna base, elongate rectangular in outline, typically 4.5–5.0 cm long and 0.7–1.1 cm wide, with bluntly or subacutely pointed apex and slightly cordate base, pinna base is not auriculated. Pinna margins are markedly toothed by 5–6 alternate pairs of teeth or spines directed forward. Veins are originated from the pinna base, then run in parallel at the proximal half, radiated distally and forked dichotomously at all levels (Figure 3a); the density is 18–22 in number per centimeter. Each tooth or spine receives 1–2 veins. At the proximal median part, veins are often grouped together to give a midvein-like appearance (see the holotype; Kimura and Sekido, 1971).

Cuticle is not preserved in the holotype and others collected from the Oguchi Formation (Figures 1–21 and 2–21). But fortunately at present we have rather well-preserved cuticle as described below.

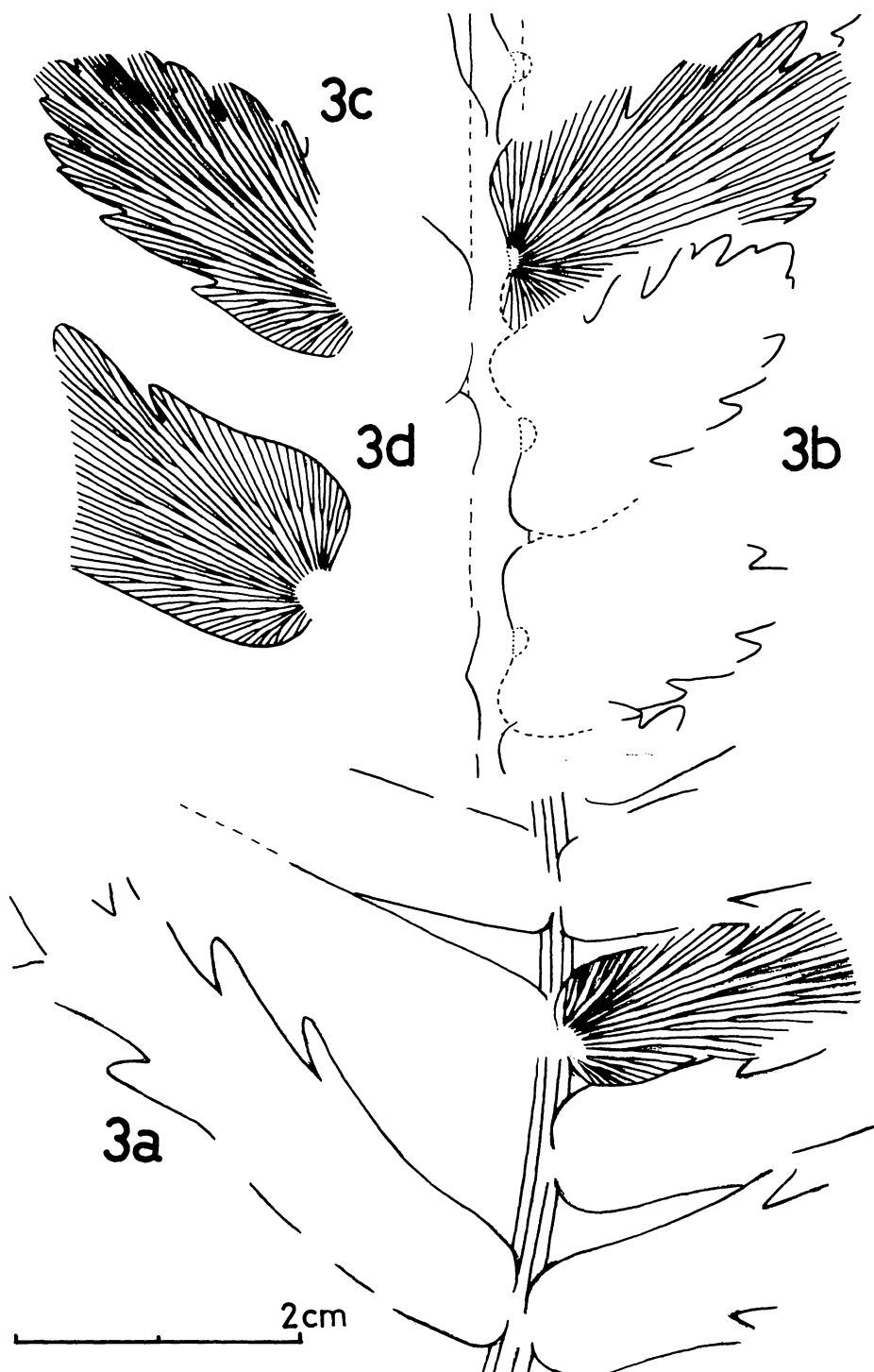
Cuticle is essentially hypostomatic. The upper cuticle is thicker (2–3 μm thick measured at a fold) than the lower one, and

consists mostly of ordinary cells which are rectangular, 70–80 μm long and 50–70 μm wide, forming longitudinal rows (Figure 5a). Their anticlinal and end walls are sinuous (wave length is 15–20 μm and amplitude is 8–10 μm), but the ordinary cells along the upper pinna margin are with nearly straight or slightly undulated walls, 80–200 μm long and 20–25 μm wide, and with occasional abortive stomata [Figures 5b, 5c (left)]. Periclinal walls are unexceptionally smooth.

Lower cuticle consists of alternation of non-stomatal and stomatal zones. Each non-stomatal zone consists of 4–5 longitudinal rows of ordinary cells which are elongate rectangular with less sinuous anticlinal and end walls, and corresponds to each vein course (Figure 5d). Each stomatal zone consists of 3–4 intermittent stomatal rows or sometimes disorderly disposed stomata [Figures 5c (right)–5e]. Stomatal complex is syndetocheilic, round-elliptic in surface view, about 30–35 μm in diameter. Guard cells are sunken and moderately cutinized, but their polar extensions are usually exposed; apertures are usually oblique and occasionally transversely oriented. The ventral (inner) side of subsidiary cell is strongly cutinized, usually with a single papilla which is also strongly cutinized, and covers the middle part of guard cell to some extent (Figures 5f, 6b). The density of stomata is about 80 in number per square millimeter. The ordinary cells in the stomatal zones are not so elongated and irregular (Figure 5e), 40–60 μm (major) and 30–40 μm (minor) in size; their anticlinal and end walls are less sinuous and are usually delicate and indistinct. Reproductive organs are not known.

Discussion and comparison.—Externally,

→ **Figure 3.** *Neozamites* species. **3a.** *Neozamites elongatus* Kimura et Sekido. One of the Chinese specimens drawn partly from Figure 4a, showing the mode of pinna attachment, elongated pinnae with markedly developed marginal teeth, and venation. **3b–d.** *Neozamites intermedius* Nakazawa, Ohana et Kimura, sp. nov. **3b.** Drawn partly from Figure 4c, showing the thick axis (dotted lines), the mode of pinna attachment, shorter pinnae with markedly developed marginal teeth, and venation. **3c.** A pinna fragment drawn from Figure 4b, showing the toothed margins and venation. **3d.** A pinna fragment drawn from NSM PP-9033 (paratype).



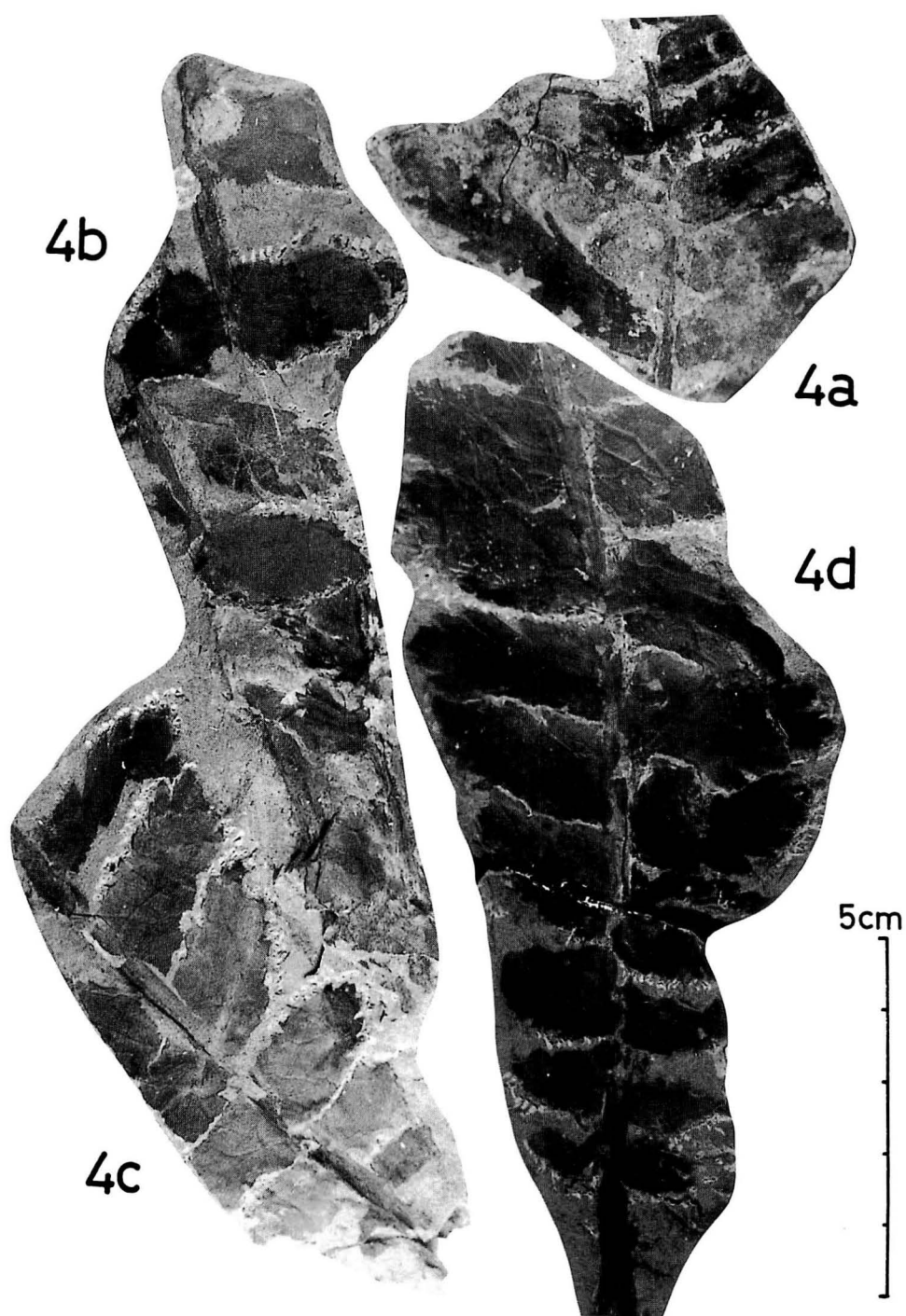


Figure 4. *Neozamites* species. **4a**, *Neozamites elongatus* Kimura et Sekido. One of the Chinese specimens [Reg. no. C-23 (H29-3)]. **4b-d**, *Neozamites intermedius* Nakazawa, Ohana et Kimura, sp. nov. **4b-c**, paratypes (Reg. no. NSM PP-9029). **4d**, holotype (Reg. no. NSM PP-9028). Its right side of leaf is deformed in the course of preservation.

the present leaves agree well with the original leaves of *Neozamites elongatus* Kimura et Sekido. However, they have much more crowded veins than does the original *Neozamites elongatus*, this being the only difference between them. According to additional leaves of the Japanese *Neozamites elongatus* newly collected, the vein density is so variable according to the position of a leaf or individually that it can not be used as a diagnostic feature to make the specific separation.

The leaves of the type species, *Neozamites verchojanensis* resemble externally the present leaves, but differ from the latter in that in the former, pinnae are markedly asymmetrical between their acroscopic and basiscopic sides and the pinna margins are much more toothed, with each tooth further dissected into 2–3 spines distally.

The leaves regarded by Vassilevskaja (1966) as *Neozamites verchojanensis* from the Lower Cretaceous of Lena Basin (Dzigansk; Figure 1–14) have large teeth with acutely pointed tip and much crowded veins (26–30 in number per centimeter in density). Unfortunately in the original leaves of *Neozamites verchojanensis*, cuticle has not been recorded.

Neozamites lebedevii was first described by Vakhrameev (1962) on the basis of external and cuticular features of the leaves, also from the Lower Cretaceous of Lena Basin (Vilui River region; Figure 1–15). Its leaves are distinguished from the present ones in that externally the former pinnae are short rectangular in form, each with a marked pair of auricles at the base, and microscopically the anticlinal and end walls of ordinary cells on the upper cuticle are strongly sinuous. On the lower cuticle a large papilla is well developed at the middle of ventral side of a subsidiary cell and the dorsal walls of subsidiary cells are sinuous.

In the leaves of *Neozamites denticulatus* known from the Lower Cretaceous of Southern Primorye (Kryshtofovich and Prynada, 1932; first described as *Otozamites*

denticulatus; Vakhrameev, 1962; Krassilov, 1967), pinnae are elongated with not auriculated but with cordate base, and the marginal teeth are smaller and sometimes indistinct. Therefore, *Neozamites denticulatus* is easily distinguished from *N. elongatus*.

Under the circumstances, we refer our leaves to *Neozamites elongatus*. *Neozamites* aff. *verchojanensis* illustrated by Zhang *et al.* (1980) from the Lower Cretaceous Sunjiawan Formation (At Beipiao), Liaoning, Northeast China is referable externally to *N. elongatus*. It is highly probable that *Neozamites denticulatus* illustrated also by Zhang *et al.* (1980) from the Lower Cretaceous Dongshan Formation (Boli Basin), Heilongjiang is referable to *N. elongatus*.

Neozamites verchojanensis described by Yang and Sun (1982) from the Lower Cretaceous Yingcheng Formation (Jiutai, Jilin; Figure 1–5) resembles *N. elongatus*. But in the former, pinna teeth are short, triangular and its cuticle is not known. Therefore, it is difficult to make further comparison between the two.

Additional diagnosis (cuticular diagnosis added to the diagnosis of external features): Cuticle essentially hypostomatic. Upper cuticle consisting of elongated ordinary cells forming longitudinal rows. Occasional and abortive stomata present along the pinna margin. Anticlinal and end walls of ordinary cells sinuous but those along the pinna margin nearly straight. Periclinal walls smooth.

Lower cuticle consisting of alternation of non-stomatal and stomatal zones. Vein-courses corresponding to the non-stomatal zone indicated by 3–4 files of much elongated ordinary cells. A stomatal zone consisting of 3–4 intermittent or sometimes disorderly disposed stomata. Stomata syndetocheilic, round-elliptic in form, obliquely and rarely transversely oriented. Ventral side of subsidiary cell strongly cutinized, sending off a single papilla from the middle point, covering the guard cell to some extent. Ordinary cells

in the stomatal zone irregular in form and less sinuous in wall but nearly isodiametric.

Neozamites intermedius Nakazawa,
Ohana et Kimura, sp. nov.

Figures 3b–d, 4b–d

Material.—Holotype; NSM PP-9028.

Paratypes; NSM PP-9029, 9033. Examined specimens: NSM PP-9030, 9032, 9034–9041.

Type locality and horizon: Upper course of the Okurodani Valley (roughly 36°02'12" N, 136°53'09"E) (Figures 1–22 and 2–22), a branch of the Okamigo River, Shokawamura, Ono-gun, Gifu Prefecture: Akaiwa Formation equivalent (Possibly Aptian in age).

Etymology: According to the intermediate pinna form between those of *Neozamites elongatus* (or *N. verchojanensis*) and *N. lebedevii*.

Occurrence (Frequency): Locally common.

Description.—Leaf is pinnate, but whole leaf is unknown; preserved leaf is oblanceolate in outline, narrowing gradually toward the base with a rather thick axis and petiole. The preserved petiole is 0.5 cm thick at base (but its very base is unknown), and bears alternate or subopposite pinnae at a wide angle or often perpendicular. The pinnae are attached to the upper sides of axis by the small region which is 0.5–0.75 mm long and 1.25 mm wide, at or near the middle of pinna base. The pinnae represented at the middle portion of a leaf are oblong or rectan-

gular, typically 3 cm long and 1.4 cm wide, with bluntly pointed apex and slightly cordate base. But they are reduced in size, becoming triangular toward the leaf base, the lowest one being 1 cm long and 0.9 cm wide at the base. The margins of typical pinnae are markedly toothed except for proximal one-third where they are usually entire. The teeth are 3–4 alternate pairs and directed forward. Each tooth is often further dissected into two lobes by a shallow sinus; the distal lobe is usually larger and proximal one smaller in size.

The veins are markedly radiated from the point of attachment, forked dichotomously at all levels; the density is 26 in number per centimeter at the middle of pinna. Each tooth receives 2–6 veins.

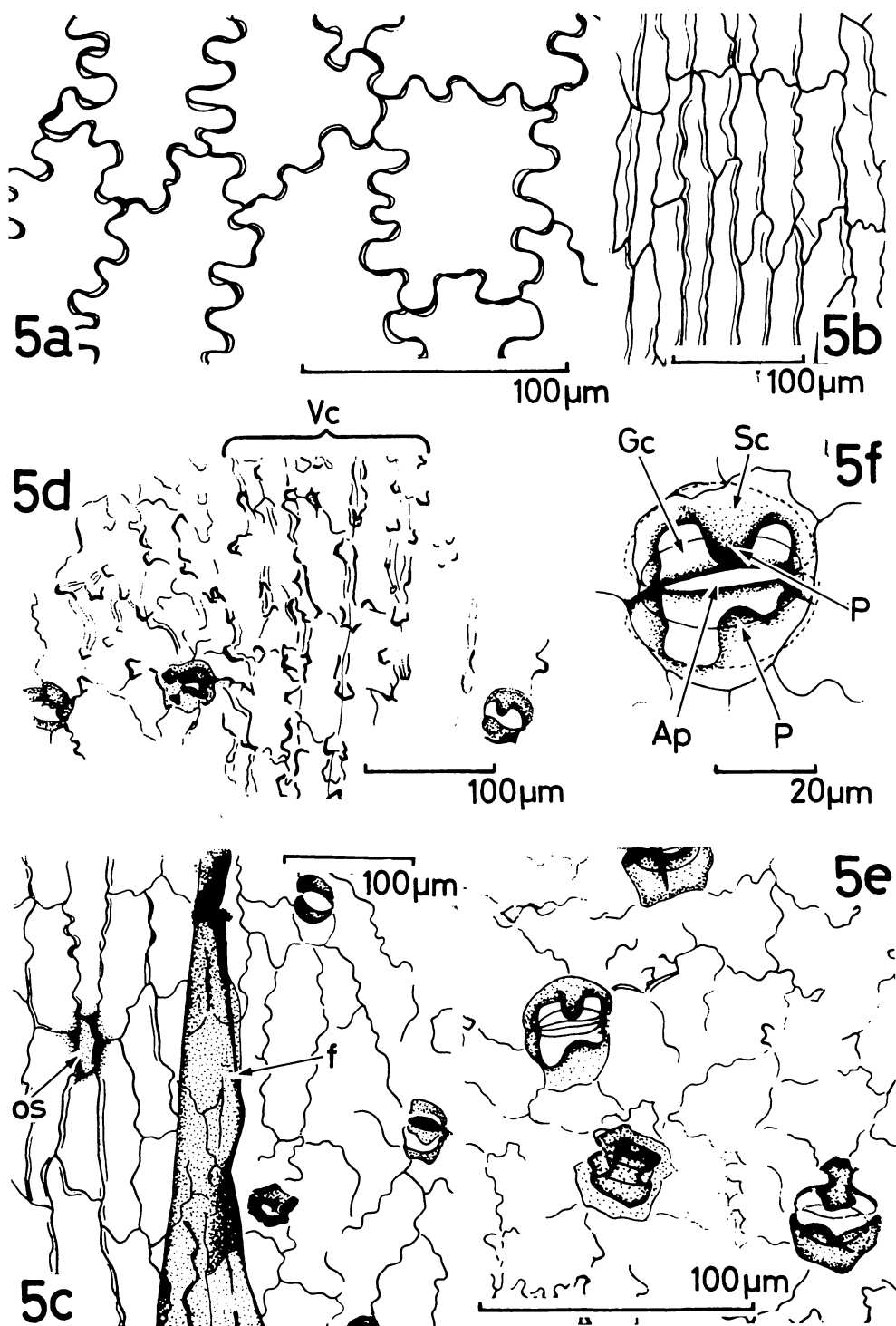
Cuticle is not preserved. Reproductive organs are not known.

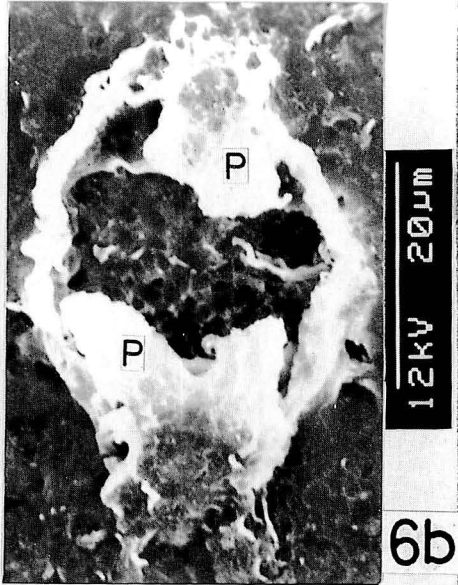
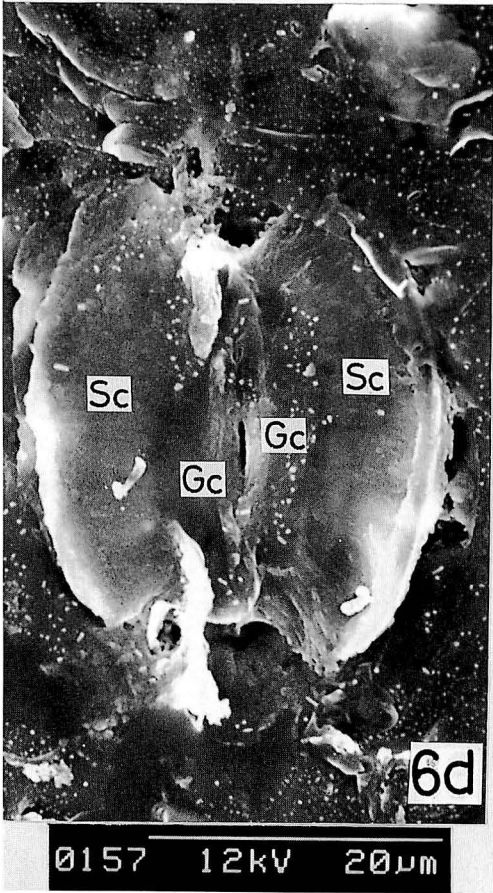
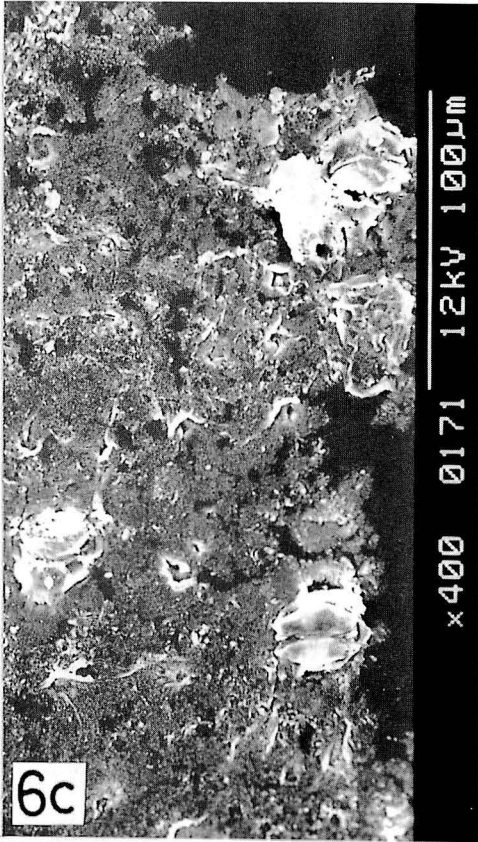
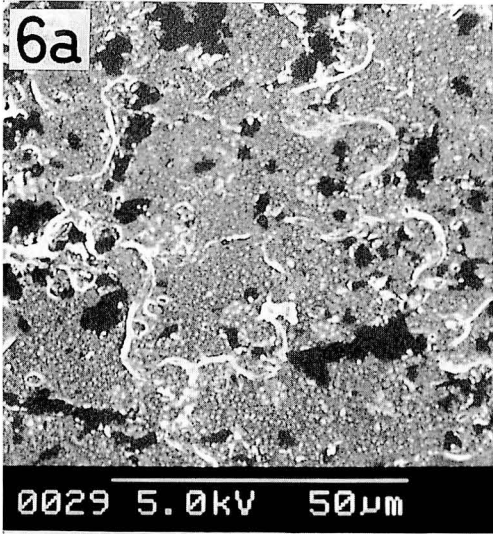
Discussion and comparison.—It is certain that the present leaves belong to the bennettitalean genus *Neozamites* Vachrameev, 1962, because their *Otozamites*-like pinnae are markedly toothed along the margins, and cuticles of two *Neozamites* species, *N. elongatus* and *N. lebedevii* are confirmed by the present work and by Vakhrameev's work (1962) as bennettitaleans respectively.

The present leaves are characterized by their intermediate features in pinna size and form between the species with elongated pinnae (*Neozamites verchojanensis*, *N. elongatus* and *N. denticulatus*) and the species with shorter pinnae (*N. lebedevii*).

The pinnae of *Neozamites lebedevii* resem-

→ **Figure 5.** *Neozamites elongatus* Kimura et Sekido. Prepared from the specimen numbered C-23 (H-29-3). **5a**, Upper cuticle, showing ordinary cells with sinuous anticlinal and end walls, and smooth periclinal walls. **5b**, Upper cuticle along the pinna margin, consisting of longitudinally elongated ordinary cells with less sinuous cell walls. **5c**, Upper cuticle (left side) consisting of marginal ordinary cells and lower cuticle (right side) consisting of stomata and polygonal ordinary cells with less sinuous cell walls. **f**; a fold between upper and lower cuticles. **oc**; an occasional abortive stoma. **5d**, Lower cuticle, showing scattered stomata and the vein-course cells (Vc) with thickly cutinized anticlinal and end walls. **5e**, Lower cuticle, showing the scattered stomata and the ordinary cells with rather delicate and indistinct anticlinal and end walls. The stomatal apertures are usually oblique or occasionally transverse in direction. **5f**, A stoma in surface view. **Gc**; sunken guard cell, **Sc**; thickly cutinized subsidiary cell, **P**; a thickly cutinized papilla originated from the central region of each subsidiary cell to face oppositely with the other, at the general surface of lower cuticle.





ble those of the present specimens, but are distinguished from the latter by their markedly developed basal acroscopic and basiscopic auricles as shown by Vakhrameev (1962) and Zheng and Zhang (1983), instead of having slightly cordate base as in the latter. Therefore, we (Nakazawa, Ohana and Kimura) here propose *Neozamites intermedius* as a new species to accommodate the present leaves.

The bennettitalean leaves had been considered to be simply pinnate (except for *Nils-soniopteris* leaves which have been considered to be not pinnate) until the discoveries of bipinnate bennettitalean leaves represented by *Coreanophyllum variisegmentum* Kimura et Kim (Kimura and Kim, 1982, 1988), *Nipponoptilophyllum bipinnatum* Kimura et Tsujii (Kimura and Tsujii, 1984), *N. ryosekiense* Ohana, Kimura et Kawazoë (Ohana et al., 1989) and *Neozamites lebedevii* Vakhrameev (Zheng and Zhang, 1983).

Diagnosis.—Leaf pinnate, medium-sized. (Whole leaf unknown.) Petiole rather thick. An axis sending off alternate or subopposite pinnae. Pinnae attached by a small region near the middle of pinna base on the upper sides of axis, typically oblong or short rectangular in form with blunt apex and slightly cordate base. Proximal pinnae reduced in size, becoming triangular. Pinna margins of typical pinnae markedly toothed but margins of the proximal pinnae nearly entire. The teeth directed forward and each often further divided into two lobes by a shallow sinus; distal one larger in size than proximal one. Veins numerous and radiated from the small region of pinna attachment and forked dichotomously at all levels. (Cuticle and reproductive organs not known.)

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← **Figure 6.** *Neozamites elongatus* Kimura et Sekido (SEM micrographs of cuticle). **6a**, Upper cuticle, showing the ordinary cells with faintly preserved sinuous anticlinal and end walls (surface view). **6b**, A broken stoma, showing a pair of oppositely disposed and thickly cutinized papillae. The lower papilla is broken and the guard cells are missing in the course of maceration (surface view). **6c**, Lower cuticle, showing scattered stomata (inner view). **6d**, Lower cuticle, showing a stoma enlarged (inner view). Gc, guard cell; Sc, thickly cutinized flange of subsidiary cell.

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Geographical and stratigraphical names: Japan: Akaiwa 赤岩, Mekkodani 目付谷, Oguchi 尾口, Okamigo 尾上郷, Okurodani 大黒谷, Ryoseki 領石, Tetori 手取, China: Antu 安図, Bacheligou 八車力溝, Beipiao 北票, Boli 勃利, Chengzihe 城子河, Dalazi 大拉子, Dongshan 東山, Fuxin 阜新, Har-Zuo 喀左, Hegan 鶴崗, Heihe 黑河, Heilongjiang 黑龍江, Houshigou 候石溝, Jilin 吉林, Jiutai 九台, Jixi 雞西, Liangjiang 兩江, Liaoning 遼寧, Menjia 孟家, Mudanjiang 牡丹江, Qitaihe 七台河, Shantai 沙海, Shitouhe 石頭河, Sunjiawan 孫家灣, Tongfosi 銅佛寺, Yimin 伊敏, Yingcheng 營城, Zalainor 扎賚諾爾.

中国東北部および日本内帯の下部白亜系から得られた *Neozamites* 属 (ベネチテス目) 化石 2 種: *Neozamites* 属はベネチテス目に属する葉を対象とした器官属で、1962 年, Vakhrameev により創設・記載された。本属の特徴は、羽片の葉縁に著しい粗鋸歯があること、およびその産出が、シベリア東部、中国東北部の大部分および日本内帯の下部白亜系に限られることにある。なお南沿海州の下部白亜系からも、本属に属すると考えられる種が産出する。

本属に属する種は、いままでに 4 種が知られ、うち 1 種 (*N. elongatus*) は、1971 年, 手取果層群尾口層から記載されたが、残念ながら、その cuticle は保存されていなかった。今回、中国東北部の鶴崗炭田から、cuticle がよく保存された *N. elongatus* が得られたので、ここにその詳細を報告する。また、岐阜県大黒谷に分布する下部白亜系から得られた標本は、明らかに本属に属し、かつ新種として認められるので、ここにこれらの葉標本に対して *N. intermedius*, sp. nov. を提唱した。

孫革・仲沢隆・大花民子・木村達明

961. MIDDLE PERMIAN FORAMINIFERS FROM BAN NAM SUAI THA SA-AT, CHANGWAT LOEI, NORTHEAST THAILAND*

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Abstract. Middle Permian foraminifers including such fusulinaceans as *Verbeekina verbeeki* (Geinitz), *Pseudodoliolina* cf. *pseudolepida* (Deprat), and *Presumatrina* cf. *neoschwagerinoides* (Deprat) are found from a small limestone outcrop exposed at about 2 km northwest of Ban Nam Suai Tha Sa-at, east of Loei, northeast Thailand. The present fusulinacean fauna has a close resemblance with those of the *Neoschwagerina simplex* (B6) and *Presumatrina schellwieni* (B7) Zones of the Ratburi (or Saraburi) Limestone in the Sara Buri area, central Thailand, and the lower Murgabian (*Neoschwagerina simplex* Zone) of the Pamirs, Central Asia. It is referable to early Murgabian (late Middle Permian) of the Permian standard stratigraphic scheme in the Tethyan Province in age. This is the first discovery of the late Middle Permian foraminiferal fauna characterized by the verbeekiniid and neoschwageriniid fusulinaceans in the Loei area.

Key words. Foraminifers, Loei, Middle Permian, Murgabian, Ratburi (or Saraburi) Limestone, Thailand.

Introduction

In the Loei and Wang Saphung areas of northeast Thailand where the Ratburi (or Saraburi) Limestone is widely distributed, the Middle Carboniferous to Lower Permian fusulinaceans were reported and their biostratigraphy and zonation were examined in detail (Igo, 1972). Very recently, two additional contributions concerning the Upper Carboniferous Gzhelian foraminifers (Ueno and Igo, 1993) and the upper Lower Permian

Yakhtashian fusulinaceans (Igo *et al.*, 1993) were published. However, the Middle Permian fossils as well as their biostratigraphy and faunal characteristics in these areas are too poorly known for a detailed discussion, as yet covered only by some preliminary reports (Pitakpaivan, 1965; Borax and Stewart, 1966; Toriyama, 1967).

In 1988, we visited the Loei area for the geologic and paleontologic investigations of the Upper Paleozoic strata in Thailand. We collected a limestone rock sample from a small outcrop near Ban Nam Suai Tha Sa-at, about 20 km east of Loei, and discriminated a Middle Permian foraminiferal fauna which is

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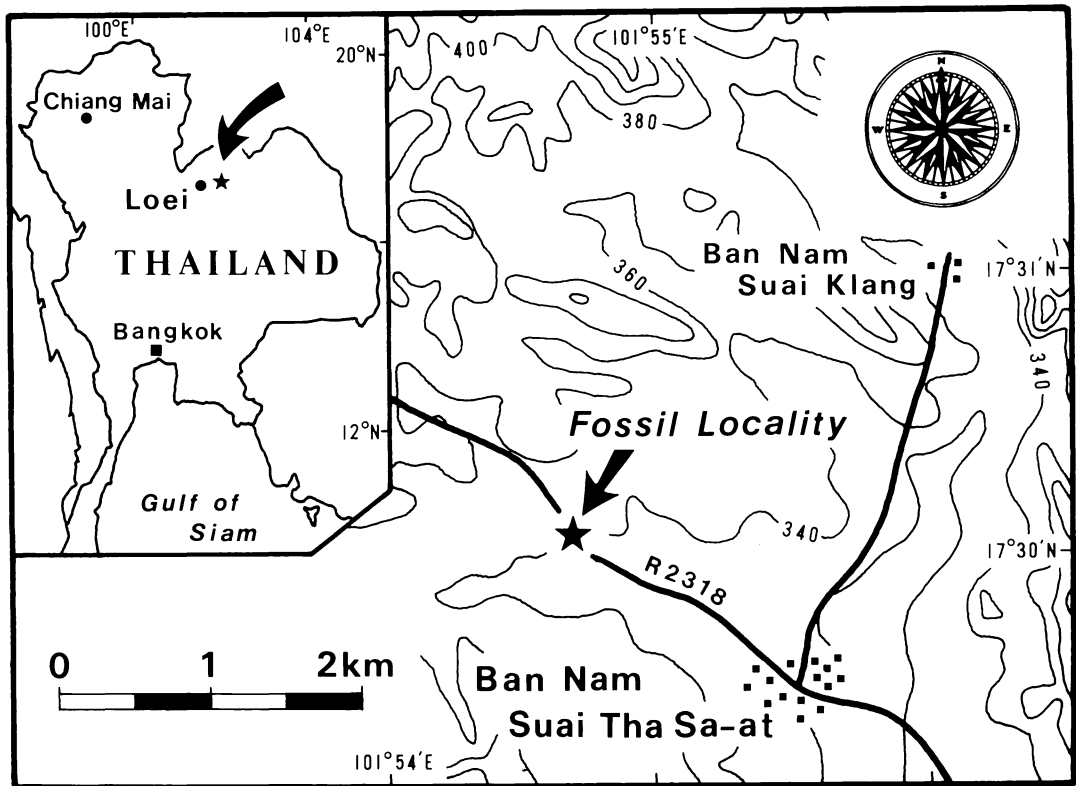


Figure 1. Index map showing the fossil locality near Ban Nam Suai Tha Sa-at, east of Loei, northeast Thailand.

poorly understood in this area.

In the present paper, we discuss the character and geologic age of this foraminiferal fauna. Moreover, we illustrate most of the foraminifers and describe all the fusulinaceans.

Fossil locality and foraminiferal fauna

The fossil locality studied herein is situated at the roadside of Route 2318, about 2 km northwest of Ban Nam Suai Tha Sa-at, east of Loei, northeast Thailand (Figure 1), where a

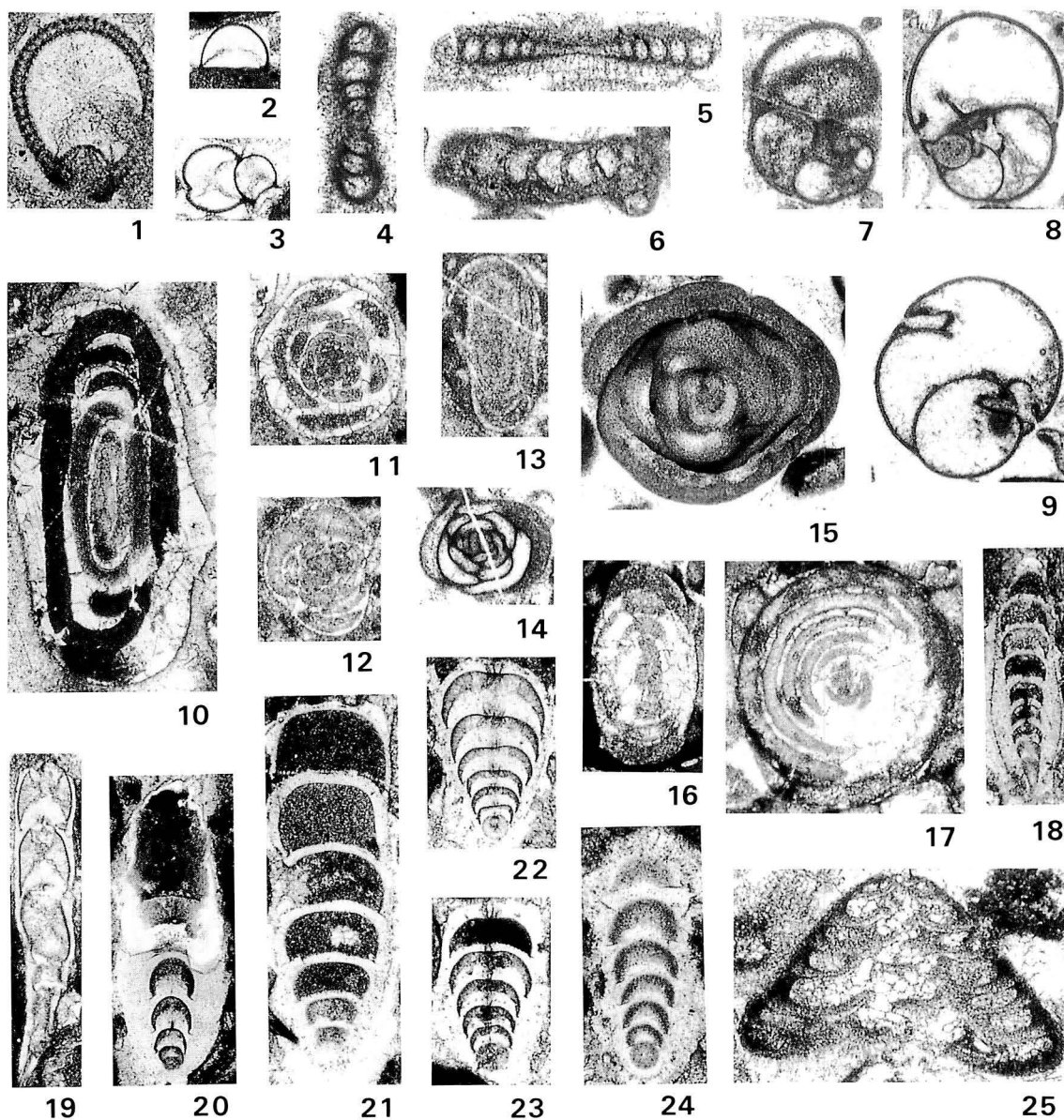
→ **Figure 2.** 1: *Eotuberitina* sp., longitudinal section, IGUT-KU0794. 2: *Eotuberitina reitlingerae* Miklukho-Maklay, longitudinal section, IGUT-KU0795. 3: *Tuberitina* sp., longitudinal section, IGUT-KU0796. 4: *Pseudoammodiscus* ? sp., axial section, IGUT-KU0797. 5: *Eolasiodiscus* sp., tangential section, IGUT-KU0798. 6: *Spiroplectammina* sp., longitudinal section, IGUT-KU0799. 7: *Globivalvulina* sp., lateral section, IGUT-KU0800. 8, 9: *Paraglobivalvulina* ? sp., lateral sections, IGUT-KU0801, IGUT-KU0802. 10, 11: *Agathammina* sp., 10: longitudinal section, IGUT-KU0803, 11: transverse section, IGUT-KU0804. 12, 13: *Agathammina pusilla* (Geinitz), 12: transverse section, IGUT-KU0805, 13: longitudinal section, IGUT-KU0806. 14: *Pseudoglomospira* sp., horizontal section, IGUT-KU0807. 15: *Glomospira* ? sp., horizontal section, IGUT-KU0808. 16, 17: *Multidiscus* sp. A., 16: axial section, IGUT-KU0809, 17: sagittal section, IGUT-KU0810. 18: *Pachyphloia* sp. A, lateral section, IGUT-KU0811. 19: *Nodosaria* sp., longitudinal section, IGUT-KU0812. 20: *Pachyphloia* sp. B, longitudinal section, IGUT-KU0813. 21: *Fronidina* ? sp., longitudinal section, IGUT-KU0814. 22–24: *Lunucammina* sp., 22, 23: longitudinal sections, IGUT-KU0815, IGUT-KU0816, 24: lateral section, IGUT-KU0817. 25: *Tetrataxis* sp., axial section, IGUT-KU0818. 8, 9: $\times 20$, 15, 20: $\times 30$, 2, 3, 6, 7, 10–14, 16–19, 21–25: $\times 40$, 1, 4, 5: $\times 100$.

massive limestone bed crops out. Limestone microfacies in this locality is black, impure algae-foraminiferal grainstone. According to the geologic map of Changwat Loei (scale 1:250,000) compiled by Vimuktanandana (1988), the Permian Nam Mahoran Formation composed mainly of a limestone, sandstone, shale, and chert is distributed here.

We identified the following smaller for-

aminifers and fusulinaceans from the sample collected at the fossil locality studied herein. Smaller foraminifers are illustrated on Figures 2 and 3.

Smaller foraminifers: *Eotuberitina reitlingerae* Miklukho-Maklay, *Eotuberitina* spp., *Tuberitina* sp., *Spiroplectammina* sp., *Pseudoammodiscus* ? sp., *Eolasiodiscus* sp., *Pseudoglomospira* sp.,



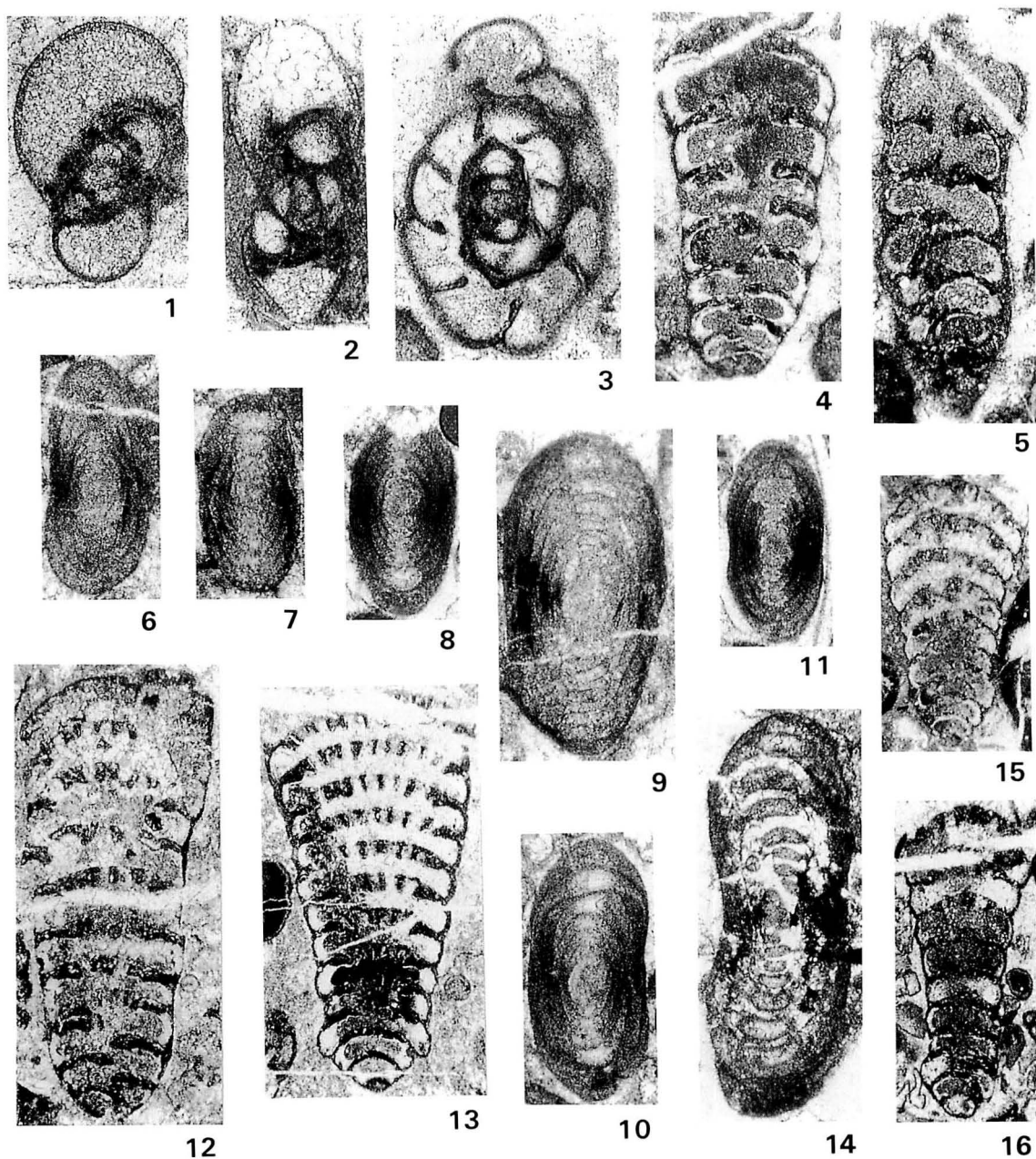


Figure 3. 1: *Endothyra* sp., axial section, IGUT-KU0819. 2, 3: *Neoendothyra* sp., 2: axial section, IGUT-KU0820, 3: sagittal section, IGUT-KU0821. 4, 5: *Climacammina* sp., longitudinal sections, IGUT-KU0822, IGUT-KU0823. 6–11: *Multidiscus* sp. B, axial sections, IGUT-KU0824, IGUT-KU0825, IGUT-KU0826, IGUT-KU0827, IGUT-KU0828, IGUT-KU0829. 12, 13: *Climacammina gigas* Suleimanov, 12: longitudinal section, IGUT-KU0830, 13: lateral section, IGUT-KU0831. 14: *Neodiscus* cf. *permicus* (Grozdilova), axial section, IGUT-KU0832. 15, 16: *Climacammina valvulinoides* Lange, longitudinal sections, IGUT-KU0833, IGUT-KU0834. 13: $\times 15$, 12, 15, 16: $\times 20$, 4–11, 14: $\times 40$, 2, 3: $\times 75$, 1: $\times 100$.

Glomospira? sp., *Globivalvulina* spp., *Paraglobivalvulina*? sp., *Tetrataxis* sp., *Endothyra* sp., *Neoendothyra* sp., *Climacammina* *gigas* Suleimanov, *C. valvulinoides* Lange, *Climacammina* sp., *Lunucammina* spp., *Pachyphloia* sp. A, *Pachyphloia* sp. B, *Pachyphloia* spp., *Nodosaria* sp., *Fronchina*? sp., *Neodiscus* cf. *permicus* (Grozdilova), *Multidiscus* sp. A, *Multidiscus* sp. B, *Agathammina* cf. *pusilla* (Geinitz), *Agathammina* sp.

Fusulinaceans: *Neofusulinella*? *pseudogiraudi* (Sheng), *Neofusulinella* sp., *Yangchenia* sp., *Minojapanella* (*Russiella*)? sp., *Dunbarula*? sp., *Parafusulina* sp., *Nankinella* sp., *Staffella* sp., *Pisolina* cf. *subspherica* Sheng, *Presumatrina* cf. *neoschwagerinoides* (Deprat), *Pseudodoliolina* cf. *pseudolepida* (Deprat), *Verbeekina* *verbeeki* (Geinitz).

Among the foraminifers, fusulinaceans are important for the discussion of the geologic age of this foraminiferal fauna. The most characteristic species of this foraminiferal fauna is *Verbeekina verbeeki* (Geinitz). This species is known to flourish in the late Middle Permian (Murgabian and Midian) in the Tethyan Province (Ozawa, 1970 and others). In the Ratburi Limestone of the Sara Buri area, central Thailand, it occurs in the *Presumatrina schellwieni* Zone (B7) which is correlated with the lower Murgabian (Toriyama, 1975; Ingavat *et al.*, 1980).

Pseudodoliolina cf. *pseudolepida* (Deprat) is also abundant in our foraminiferal fauna. *Pseudodoliolina pseudolepida* (Deprat) is a well known species in the Tethyan Province and widely distributed in its upper Middle Permian deposits (Ozawa, 1970 and others).

A species closely related to *Presumatrina neoschwagerinoides* (Deprat) discriminated from our foraminiferal fauna is worthy of note because it is characteristic in the *Neoschwagerina simplex* Zone (lower Murgabian) of the Pamirs, Central Asia, where the Permian standard stratigraphic scheme in the Tethyan Province was established (Leven, 1965, 1967, 1980). *Presumatrina neoschwagerinoides* (Deprat) was also reported from the *Neoschwagerina simplex* (B6) and *Presumatrina schellwieni* (B7) Zones of the

Ratburi Limestone distributed in the Khao Phrong Phrab area, Sara Buri, central Thailand (Toriyama, 1975). These zones are correlated with the lower Murgabian (Ingavat, 1984).

Neofusulinella pseudogiraudi (Sheng) was reported from the Qixia (Chihsia) and Maokou Limestones (*Misellina* and *Cancellina* Subzones) of Guizhou (Kueichow), South China (Sheng, 1963). In Southeast Asia, it is known to occur from the limestone distributed in the Sungei Sedili area, Johore, Malaysia (Igo *et al.*, 1979).

Pisolina subspherica Sheng was originally described from the *Nankinella orbicularia* Zone of southern Shanxi (Sensi) which is correlated with the lower Qixia Limestone (Sheng, 1956). Later, this species was reported from the upper part of the *Cancellina neoschwagerinoides*-*Parafusulina multiseptata* Zone of Zhejiang, where *Parafusulina multiseptata* (Schellwien) and *Cancellina danneri* Skinner and Wilde are associated (Wang and Tang, 1986).

Judging mainly from the joint occurrence of *Verbeekina verbeeki* (Geinitz), *Pseudodoliolina* cf. *pseudolepida* (Deprat), and *Presumatrina* cf. *neoschwagerinoides* (Deprat), the geologic age of this foraminiferal fauna is considered to be early Murgabian (late Middle Permian) of the Permian standard stratigraphic scheme in the Tethyan Province proposed by Leven (1980). As well, other coexisting fusulinacean and smaller foraminiferal genera and species are almost concordant with this age determination. Biogeographically, this foraminiferal fauna is a typical one in the Tethyan Province.

Systematic description

All specimens treated in this paper are deposited in the paleontological collection of the Institute of Geoscience, University of Tsukuba. The abbreviation IGUT is the prefix for repository numbers of specimens.

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

Yangchenia sp.

Figures 5-8-9

Remarks.—Two poorly oriented sections were prepared for this study. Massive chomata and a *Fusulinella*-type four-layered spirotheca in this form possibly suggest it to be referable to the genus *Yangchenia*, in spite of its poor orientation.

Materials.—Diagonal sections; IGUT-KU0853, IGUT-KU0854.

Subfamily Schubertellinae Skinner, 1931
 Genus *Neofusulinella* Deprat, 1912

Neofusulinella ? *pseudogiraudi*
 (Sheng, 1963)

Figures 5-11-13

Schubertella pseudogiraudi Sheng (MS), 1962, p. 427-428, pl. 1, figs. 8-9.

Schubertella pseudogiraudi Sheng, 1963, p. 35, 159, pl. 4, figs. 14-19; Han, 1976, p. 26, pl. 8, fig. 8; Lin *et al.*, 1977, p. 34, pl. 6, fig. 20; Chen and Yang, 1978, p. 26, pl. 3, figs. 36-37; Igo *et al.*, 1979, p. 100, pl. 17, figs. 9-10, pl. 18, figs. 11-14; Xie, 1982, p. 15, pl. 6, fig. 7; Sun *et al.*, 1983, p. 17, pl. 3, fig. 2.

Remarks.—This species was originally referred to the genus *Schubertella*, and most fusulinacean students have followed this genus assignation. However, it is more advisable to include it in the genus *Neofusulinella* rather than in *Schubertella*, in its spirothecal composition and well developed septal pores, although keriothecal structure, which is a diagnostic shell character in the former genus, is hardly discernible in the spirotheca of this species.

The present specimens are quite identical with the original ones by Sheng (1963) from

the Qixia and Maokou Limestones of Guizhou, South China.

Materials.—Axial section; IGUT-KU0856. Oblique section; IGUT-KU0857. Sagittal section; IGUT-KU0858.

Neofusulinella sp.

Figure 5-10

Remarks.—Keriothecal structure is barely discernible in some part of spirotheca in this species. This species can be distinguished from *Neofusulinella* ? *pseudogiraudi* (Sheng) by its larger shell. It is somewhat similar to *Neofusulinella saraburiensis* originally described by Toriyama *et al.* (1969) from the Khao Phrong Phrab area of Sara Buri, central Thailand, in the shell size. The specific identification is, however, postponed because only one sagittal section is available for examination.

Material.—Sagittal section, IGUT-KU0855.

Family Boultoniidae Skinner
 and Wilde, 1954

Genus *Minojapanella* Fujimoto
 and Kanuma, 1953

Subgenus *Russiella* Miklukho-Maklay, 1957

Minojapanella (*Russiella*) ? sp.

Figures 5-1-3

Remarks.—This unidentified species is questionably assigned to the subgenus *Russiella* because of its highly elongate shell shape, regularly and intensely fluted septa, and weakly developed axial fillings. It can be distinguished from *Minojapanella* (*Russiella*) *pulchra* Miklukho-Maklay in having a smaller shell and less developed axial fillings.

Materials.—Axial sections; IGUT-KU0846, IGUT-KU0847. Sagittal section; IGUT-KU0848.

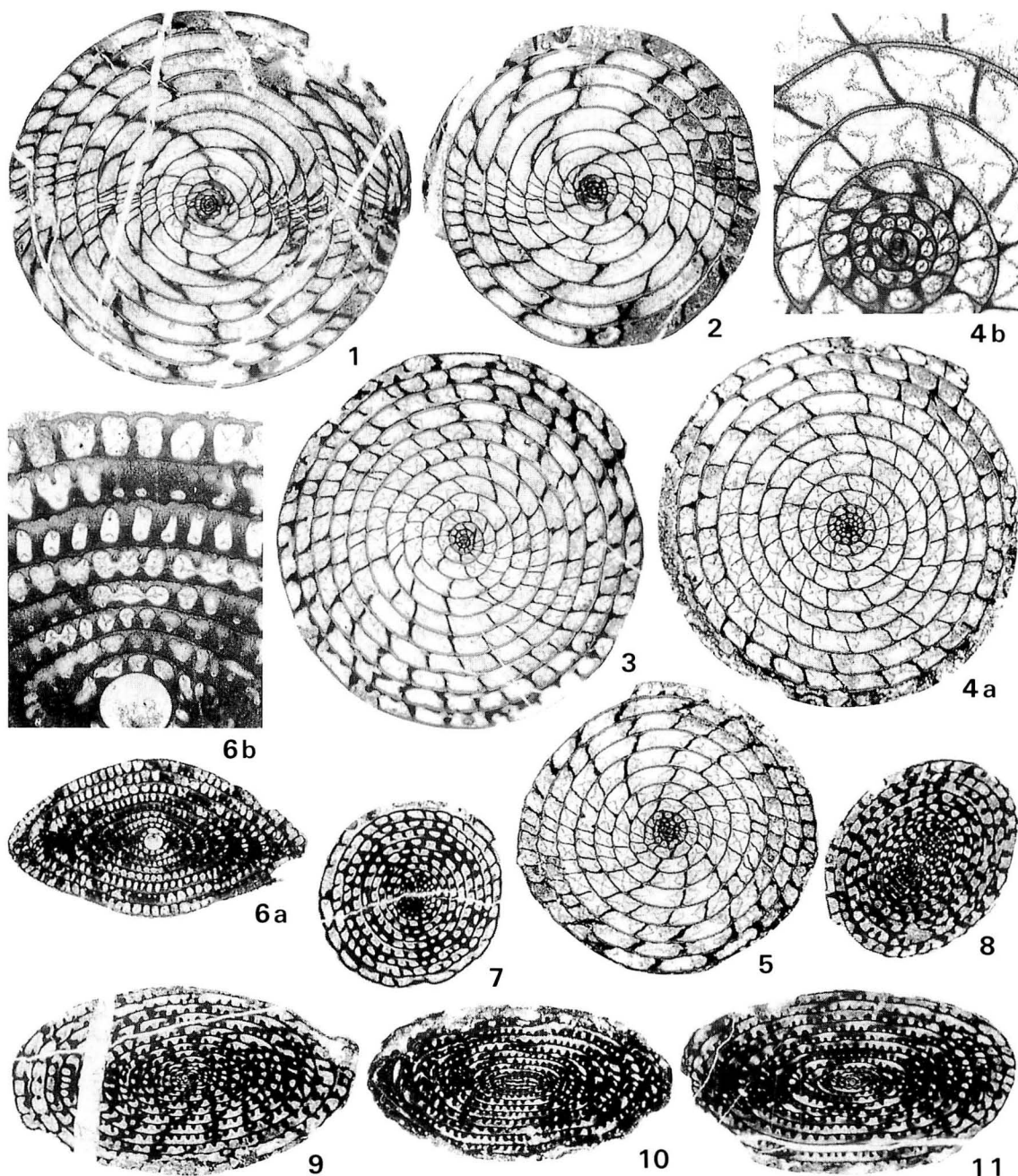


Figure 4. 1-5. *Verbeekina verbeeki* (Geinitz), 1, 2: slightly oblique axial sections, IGUT-KU0835, IGUT-KU0836, 3, 4a, 5: sagittal sections, IGUT-KU0837, IGUT-KU0838, IGUT-KU0839, 4b: enlarged part of 4a, showing tightly and skew-coiled inner volutions, and minute proloculus. 6. *Presumatrina* cf. *neoschwagerinoides* (Deprat), 6a: axial section, IGUT-KU0840, 6b: enlarged part of 6a. 7-11. *Pseudodoliolina* cf. *pseudolepida* (Deprat), 7: parallel section, IGUT-KU0841, 8: sagittal section, IGUT-KU0842, 9, 11: axial sections, IGUT-KU0843, IGUT-KU0845, 10: tangential section, IGUT-KU0844. 1-3, 4a, 5, 6a, 7-11: $\times 10$, 4b, 6b: $\times 40$.

Genus *Dunbarula* Ciry, 1948

Dunbarula ? sp.

Figure 5-14

Remarks.—The present form has a fusiform shell, rather loosely coiled volutions, fluted septa in polar regions, and slightly recrystallized spirotheca. These shell characters are suggestive of an assignment to the genus *Dunbarula*. The genus assignment is, however, tentative owing to the poor material.

Material.—Axial section ; IGUT-KU0859.

Family Schwagerinidae Dunbar
and Henbest, 1930

Subfamily Schwagerininae Dunbar
and Henbest, 1930

Genus *Parafusulina* Dunbar
and Skinner, 1931

Parafusulina sp.

Figures 5-4—5

Remarks.—This unidentified species somewhat resembles *Parafusulina quasigruperaensis* originally described by Sheng (1963) from the Maokou Limestone of Guizhou, South China. It is also recorded from the *Presumatrina schellwieni* Zone (B7) of the Ratburi Limestone in the Khao Phrong Phrab area, central Thailand. The specific identification is postponed until sufficient materials are available.

Materials.—Axial section ; IGUT-KU0849. Parallel section ; IGUT-KU0850.

Family Staffellidae Miklukho-Maklay, 1949

Genus *Nankinella* Lee, 1934

Nankinella sp.

Figures 5-6—7

Remarks.—*Nankinella akiyoshiensis* originally described by Toriyama (1958) from the *Neoschwagerina craticulifera* Zone (Pm₉) of the Akiyoshi Limestone Group, southwest Japan, is the closest to this unidentified species except for having a less angular periphery of shell.

Materials.—Tangential sections ; IGUT-KU0851, IGUT-KU0852.

Genus *Staffella* Ozawa, 1925

Staffella sp.

Figure 5-15

Remarks.—Morphological characters of this species are not examined precisely because the material is completely replaced by secondary mineralization.

Material.—Axial section ; IGUT-KU0860.

Genus *Pisolina* Lee, 1933

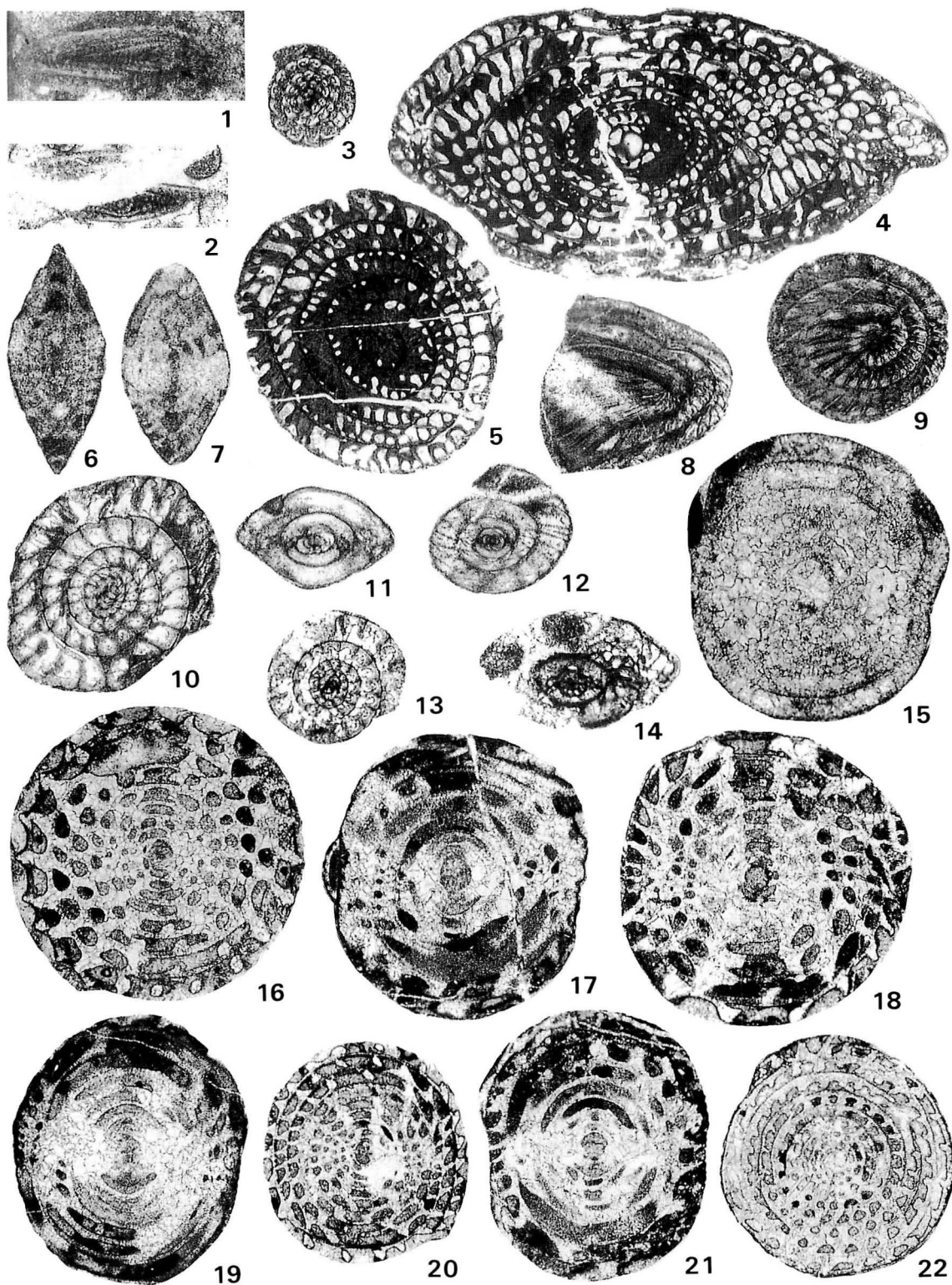
Pisolina cf. *subspherica* Sheng, 1956

Figures 5-16—22

Compare.—

Pisolina subspherica Sheng, 1956, p. 183, 205-206, pl. 2, fig. 6 ; Sheng, 1966, p. 23, pl. 2, fig. 13 (same as pl. 2, fig. 6 of Sheng, 1956, p. 183, 205-206) ; Lin

→ **Figure 5.** 1-3. *Minojapanella (Russiella)* ? sp., 1, 2: axial sections, IGUT-KU0846, IGUT-KU0847, 3: sagittal section, IGUT-KU0848. 4, 5. *Parafusulina* sp., 4: axial section, IGUT-KU0849, 5: parallel section, IGUT-KU0850. 6, 7: *Nankinella* sp., tangential sections, IGUT-KU0851, IGUT-KU0852. 8, 9: *Yangchenia* sp., diagonal sections, IGUT-KU0853, IGUT-KU0854. 10: *Neofusulinella* sp., sagittal section, IGUT-KU0855. 11-13. *Neofusulinella ? pseudogiraudi* (Sheng), 11: axial section, IGUT-KU0856, 12: oblique section, IGUT-KU0857, 13: sagittal section, IGUT-KU0858. 14: *Dunbarula* ? sp., axial section, IGUT-KU0859. 15: *Staffella* sp., axial section, IGUT-KU0860. 16-22: *Pisolina* cf. *subspherica* Sheng, 16, 22: sagittal sections, IGUT-KU0861, IGUT-KU0867, 17, 19, 21: axial sections, IGUT-KU0862, IGUT-KU0864, IGUT-KU0866, 18, 20: oblique sections, IGUT-KU0863, IGUT-KU0865. 4, 5, 20, 22: ×10, 16-19, 21: ×15, 6, 7, 15: ×20, 8, 9: ×30, 1-3, 10-14: ×40.



et al., 1977, p. 16, pl. 2, fig. 20; Ding, 1978, p. 280, pl. 96, fig. 14; Lin *et al.*, 1979, pl. 1, fig. 7; Wang *et al.*, 1982, p. 97, pl. 24, fig. 7; Xie, 1982, p. 8, pl. 3, figs. 1–2; Lin, 1984, p. 174–175, pl. 15, fig. 21; Chen, 1984, p. 59, pl. 14, fig. 13; Zhou and Zhang, 1984, pl. 3, figs. 6–7.

Description.—Shell medium for genus with a broadly rounded periphery and slightly shorter axis of coiling. Mature shell of 7 to 9 volutions 2.33 to 3.30 mm in length and 2.87 to 3.90 mm in width. Form ratio ranging from 0.80 to 0.91, averaging 0.84 for 4 specimens. Shell expanded gradually through growth. Proloculus large for shell size. Its outside diameter ranging from 0.220 to 0.370 mm, averaging 0.295 mm for 6 specimens. Spirotheca replaced by secondary mineralization. Keriothecal structure partly observed in spirotheca of some specimens. Septa short, numerous and unfluted. Low and broad chomata developed in all volutions. Tunnel path straight and narrow.

Remarks.—Our specimens almost agree with the original one described by Sheng (1956) from the *Nankinella orbicularia* Zone (upper part of the Qixia Limestone) of southern Shanxi except for having a slightly larger shell and smaller form ratio. *Pisolina* cf. *subspherica* Sheng can be easily distinguished from *P. excessa* Lee by a different shell shape.

Materials.—Axial sections; IGUT-KU0862, IGUT-KU0864, IGUT-KU0866. Sagittal sections; IGUT-KU0861, IGUT-KU0867. Oblique sections; IGUT-KU0863, IGUT-KU0865.

Family Verbeekinidae Staff
and Wedekind, 1910
Subfamily Verbeekininae Staff
and Wedekind, 1910
Genus *Verbeekina* Staff, 1909

Verbeekina verbeeki (Geinitz, 1876)

Figures 4–1–5

Descriptive remarks.—Shell large and almost spherical. Illustrated specimens 4.40

to 6.00 mm in length and 4.95 to 5.80 mm in width, giving form ratio of about 1.00. Mature shell attained a maximum of 10 volutions. Inner few volutions tightly and skew coiled. Outer volutions uniformly expanded. Proloculus minute and 0.040 mm in outside diameter. Spirotheca thin and composed of a tectum and fibrous keriotheca. Parachomata numerous but developed only adjacent to septa.

In Thailand, *Verbeekina verbeeki* (Geinitz) was recorded from the Maoteetang Limestone of Sara Buri, central Thailand (Pitakpaivan, 1965), from Wat Kirinakratanaram, central Thailand (Toriyama and Pitakpaivan, 1973), and from the *Presumatrina sehellwieni* Zone (B7) and the overlying limestone conglomerate formation (Upper C Formation) in the Khao Phrong Phrab area of Sara Buri, central Thailand (Toriyama, 1975; Toriyama and Kanmera, 1977). The following synonymy can supplement Ueno (1992).

Verbeekina verbeeki, Nie and Song, 1983, pl. 1, fig. 3;
Kahler, 1988, fig. 77; Vachard, 1990, pl. 5, fig. 3.
? *Verbeekina* ex gr. *verbeeki*, Vachard and Miconnet,
1989, pl. 3, fig. 2.

Materials.—Slightly oblique axial sections; IGUT-KU0835, IGUT-KU0836. Sagittal sections; IGUT-KU0837, IGUT-KU0838, IGUT-KU0839.

Subfamily Pseudodoliolininae Leven, 1963
Genus *Pseudodoliolina* Yabe
and Hanzawa, 1932

Pseudodoliolina cf. *pseudolepida*
(Deprat, 1912)

Figures 4–7–11

Descriptive remarks.—Shell cylindrical with a broadly rounded periphery. Mature specimens having 12 to 15 volutions, about 5.00 mm in length and 2.55 to 2.83 mm in width, giving form ratios of 1.77 to 1.96. Proloculus small and measuring from 0.095 to 0.125 mm in outside diameter. Spirotheca

thin and composed of a tectum and lower less dense layer. Parachomata well developed.

The compared synonymies are followed by Ueno (1992). The present form almost agrees with Deprat's original. However, the specific identification is tentative because the former has a smaller proloculus than the latter.

Materials.—Axial sections; IGUT-KU0843, IGUT-KU0845. Sagittal section; IGUT-KU0842. Tangential section; IGUT-KU0844. Parallel section; IGUT-KU0841.

Family Neoschwagerinidae Dunbar
and Condra, 1927

Subfamily Sumatrininae Silvestri, 1933
Genus *Presumatrina* Tumanskaya, 1950

Presumatrina cf. *neoschwagerinoides*
(Deprat, 1913)

Figure 4-6

Compare.—

Doliolina neoschwagerinoides Deprat, 1913, p. 52-53,
pl. 10, figs. 1-5, 7 (not pl. 10, fig. 6).

Cancellina primigena, Ozawa, 1925, pl. 2, figs. 3-7
(same as pl. 10, figs. 1-4, 7 of Deprat, 1913, p. 52-53).

Cancellina schellwieni, Chen, 1934, p. 105-106, pl. 16,
figs. 5-12.

Cancellina neoschwagerinoides, Sheng, 1963, p. 99-
100, 232, pl. 34, figs. 7, 8, 10-12; Sheng, 1966, p.
144-145, pl. 25, fig. 2 (same as pl. 16, fig. 5 of
Chen, 1934, p. 105-106); Toriyama, 1975, 87-90,
pl. 17, figs. 14-23; Lin *et al.*, 1977, p. 89-90, pl.
30, fig. 11; Wang *et al.*, 1982, p. 104, pl. 29, fig.
3; Sun *et al.*, 1983, p. 37-38, pl. 10, fig. 9.

Praesumatrina neoschwagerinoides, Leven, 1965, p.
143, pl. 4, fig. 2; Leven, 1967, p. 196-197, pl. 34,
figs. 2, 3, 5, 7; Chediya *et al.*, 1986, pl. 3, fig. 15;
Wei *et al.*, 1987, pl. 3, fig. 10.

Presumatrina neoschwagerinoides, Ozawa, 1970, pl. 6,
figs. 3-5 (3, 4: same as pl. 10, figs. 1, 2 of Deprat,
1913, p. 52-53, 5: same as pl. 34, fig. 3 of Leven,
1967, p. 196-197); Chen and Yang, 1978, p. 120-
121, pl. 31, fig. 3.

Praesumatrina schellwieni, Liu *et al.*, 1978, p. 97, pl.
23, fig. 1.

Presumatrina ex gr. *neoschwagerinoides*, Leven, 1982,
pl. 3, fig. 8.

? *Doliolina* cf. *neoschwagerinoides*(?), Colani, 1924, p.
115, pl. 20, fig. 4.

? *Cancellina neoschwagerinoides*, Kahler and Kahler,
1979, p. 248-249, pl. 9, fig. 5; Chen, 1984, p. 68,
pl. 22, figs. 5-7; Yang, 1985, pl. 3, fig. 14; Wang
and Tang, 1986, pl. 2, fig. 8.

? *Cancellina* cf. *neoschwagerinoides*, Sun and Zhang,
1988, pl. 4, fig. 24; Zhu, 1990, p. 58, pl. 7, figs.
12-13.

not *Cancellina neoschwagerinoides*, Zhang and Wang,
1974, p. 291, pl. 151, fig. 4.

not *Praesumatrina neoschwagerinoides*, Liu *et al.*,
1978, p. 97-98, pl. 23, fig. 5.

Description.—Shell fairly large for genus
and fusiform with bluntly pointed polar ends
and slightly convex lateral slopes. Well
oriented axial section having $8\frac{1}{2}$ volutions,
4.34 mm in length and 2.30 mm in width,
giving a form ratio of 1.88. Shell expanded
gradually through growth. Radius vectors of
the first to eighth volution 0.21, 0.29, 0.38,
0.48, 0.61, 0.77, 0.92, and 1.09 mm, and form
ratios 1.11, 1.40, 1.59, 1.68, 1.62, 1.63, 1.64 and
1.62, respectively. Proloculus large for shell
size and measuring 0.270 mm in outside diam-
eter. Spirotheca thin and composed of a
tectum and keriotheca. Thickness of spiro-
theca of the first to eighth volution 0.020,
0.020, 0.015, 0.025, 0.030, 0.035, 0.030, and
0.020 mm. Primary transverse septula thin
and well developed in all volutions. Tips of
primary transverse septula coated by dark
microgranular calcite materials and slightly
swollen, and in contact with tops of para-
chomata adjacent to septa. One secondary
transverse septulum occasionally inserted
between 2 adjacent primary transverse septula
in outer volutions. Parachomata narrow
and high, and well developed in all volutions.

Remarks.—Some fusulinacean students
have referred this species to the genus *Cancel-
lina*. However, *Presumatrina* is most suit-
able for genus assignment of this species as in
it the transverse septula have slightly
solidified and swollen tips. Our specimen is
quite similar to the original ones of
Presumatrina neoschwagerinoides described
by Deprat (1913) from Laos in the shell

shape, and nature of chomata and transverse septula. However, the Loei specimen has a slightly larger shell and proloculus than Deprat's original. At any rate, the exact identification is postponed until additional specimens are available.

In Thailand, *Presumatrina neoschwagerinoides* (Deprat) is reported from the *Neoschwagerina simplex* (B6) and *Presumatrina schellwieni* (B7) Zones of the Ratburi Limestone in the Khao Phrong Phrab area, Sara Buri, central Thailand, where *Neofusulinella praecursor* Deprat, *Yangchenia haydeni* Thompson, *Parafusulina granumavenae* (Roemer), *Chusenella tenuis* Toriyama and Kanmera, *Armenina sphaera* (Ozawa), *Verbeekina verbeeki* (Geinitz), *Pseudodoliolina ozawai* Yabe and Hanzawa, *Metadoliolina pinguis* Toriyama and Kanmera, *Neoschwagerina simplex* Ozawa, *Presumatrina schellwieni* (Deprat), and *Neothailandina komalarjuni* Toriyama and Kanmera are associated (Toriyama, 1975).

This species can be distinguished from *Presumatrina schellwieni* (Deprat) in having a larger shell and smaller form ratio, and from *P. rossica* and *P. primitiva*, both described by Miklukho-Maklay (1957) from the Crimea, in having a larger shell.

Material.—Axial section ; IGUT-KU0840.

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Akiyoshi 秋吉, Guizhou (Kueichow) 貴州, Maokou 茅口, Qixia (Chihhsia) 栖霞, Shanxi (Sensi) 陝西, Zhejiang 浙江.

タイ国北東部, ロエイ県ナムスワイターサート村から産出した中期ペルム紀有孔虫類:
タイ国北東部, ロエイ県のナムスワイターサート村近傍に露出する黒色不純石灰岩から
Verbeekina verbeeki (Geinitz), *Pseudodoliolina* cf. *pseudolepida* (Deprat), *Presumatrina* cf.
neoschwagerinoides (Deprat) を含む有孔虫群集が新たに見つかった。この有孔虫群集は上
述の紡錘虫を含んでいることから、その時代は中期ペルム紀の前期ムールガビアンと考え
られる。これはロエイ地域における、フェルビキナ科およびネオシュワゲリナ科紡錘虫
類を特徴とする中期ペルム紀後期の有孔虫群集の初めての報告である。

上野勝美・坂上澄夫

962. LATE CRETACEOUS CRABS FROM JAPAN*

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Abstract. Seven species in six genera of crabs are recorded from the Upper Cretaceous Yezo Supergroup of Hokkaido and Izumi Group of Osaka and Hyogo Prefectures, Japan. The following three species are new: *Metahomola brevis*, *Diaulax yokoi*, *Eodorippe binodosa*. The existence of *Archaeopus* shows that the Japanese Late Cretaceous fauna is closely related to the fauna from the Pacific slope of North America.

Key words. Crustacea, Decapoda, Brachyura, Upper Cretaceous, Yezo Supergroup, Izumi Group.

Introduction

Since Jimbô (1894) described *Eucorystes japonicus*, the first crab known from the Cretaceous of Hokkaido, a further eight decapod species in eight genera have been made known through studies of Nagao (1931; 1932; 1941), Takeda and Fujiyama (1983), and Collins and Karasawa (1993), these are *Callianassa ezoensis* Nagao, 1932, *Linuparus japonicus* Nagao, 1931, *Paragalathea miyakoensis* Takeda and Fujiyama, 1983, *Homolopsis hachiyai* Takeda and Fujiyama, 1983, *Notopocorystes* (*Eucorystes*) *intermedius* Nagao, 1931, *Necrocarcinus undecimtuberculatus* Takeda and Fujiyama,

1983, *Plagiolophus ezoensis* Nagao, 1941, and *Pithonoton inflatum* Collins and Karasawa, 1993.

In this paper, we describe three new species, *Metahomola brevis*, *Diaulax yokoi* and *Eodorippe binodosa*, from the Upper Cretaceous Yezo Supergroup of Hokkaido and new descriptions are given of *Notopocorystes* (*Notopocorystes*) *japonicus* (Jimbô, 1894) and *Archaeopus ezoensis* (Nagao, 1941) from the Upper Cretaceous deposits of Japan. In addition, the palaeobiogeography of the Japanese Late Cretaceous decapod fauna is discussed.

Specimens used in the paper are housed in the Yokosuka City Museum (YCM), Kanagawa Prefecture; Mizunami Fossil Museum (MFM), Gifu Prefecture; Mikasa City Museum (MCM), Hokkaido; Toyohashi

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Localities

1. Hokkaido (Fig. 1).

Locality YEZ-1: Kitazawa, Pinneshiridake, Nakatonbetsu-cho, Esashi-gun, Hokkaido. Pebble nodule from the U3 Formation of the Upper Yezo Group (Santonian by Igi, 1959). *Notopocorystes* (*N.*) *japonicus* collected by Mizuno.

Locality YEZ-2: Kasekizawa, Nakagawa-cho, Nakagawa-gun, Hokkaido. Calcareous nodule from the Nigorisawa Formation of the Upper Yezo Group (Santonian; *Inoceramus amakusensis* Zone by Osanai *et al.*, 1960). *Diaulax yokoi* sp. nov. collected by Yokoi.

Locality YEZ-3: Sankebetsugawa, Haboro-cho, Tomamae-gun, Hokkaido. Pebble nodule from the Upper Yezo Group (Santonian; *Inoceramus amakusensis* Zone

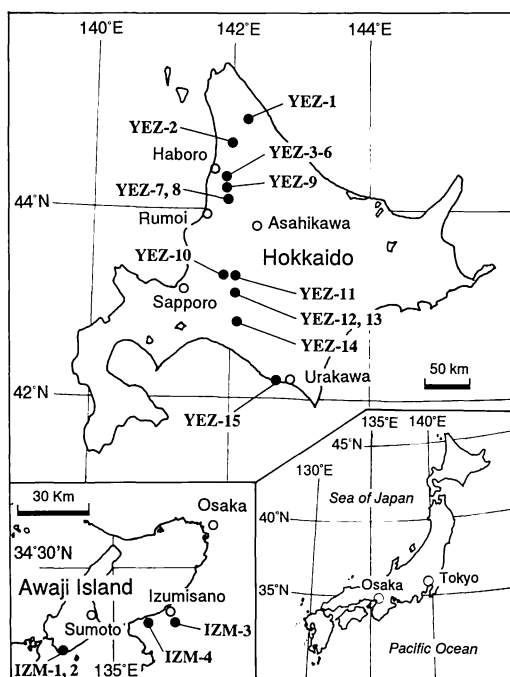


Figure 1. Index map showing the Late Cretaceous decapod localities from Japan.

by Toshimitsu, 1988). *Notopocorystes* (*N.*) *japonicus* collected by Hachiya.

Locality YEZ-4: Sakasagawa, Kamihaboro, Haboro-cho, Tomamae-gun, Hokkaido. Pebble nodule from the Upper Yezo Group (Santonian; *Inoceramus amakusensis* zone by Toshimitsu, 1988). *Metahomola brevis* sp. nov. collected by Mizuno.

Locality YEZ-5: Horotatezawa, Haboro-cho, Tomamae-gun, Hokkaido. Pebble nodule from the Middle Haborogawa Formation of the Upper Yezo Group (Santonian; *Inoceramus amakusensis* Zone by Toshimitsu, 1988). *Metahomola brevis* sp. nov. collected by Hachiya.

Locality YEZ-6: Detofutamatazawa, Kamihaboro, Haboro-cho, Tomamae-gun, Hokkaido. Nodule from the Upper Yezo Group (Santonian; *Inoceramus amakusensis* Zone by Ueda *et al.*, 1961). *Notopocorystes* (*Eucorystes*) *intermedius* collected by Hachiya.

Locality YEZ-7: Junction of the Kanajiri-sawa and the Obirashibe-gawa, Tappu, Obira-cho, Rumoi-gun, Hokkaido. Pebble nodule from the M1? Member of the Middle Yezo Group (Turonian; *Inoceramus hobetsuensis* Zone by Tanaka, 1963). *Meta-homola brevis*, *Notopocorystes* (*N.*) *japonicus*, *N.* (*Eucorystes*) *intermedius*, *Archaeopus ezoensis* collected by Hayashi.

Locality YEZ-8: Satoh-zawa, Kami-kinenbetsu-gawa, Tappu, Obira-cho, Rumoi-gun, Hokkaido. Pebble nodule from the Mj Member of the Middle Yezo Group (Turonian; *Inoceramus hobetsuensis* Zone by Tanaka, 1963). *Notopocorystes* (*Eucorystes*) *intermedius* collected by Mizuno.

Locality YEZ-9: Kiritachi, Tomamae-cho, Tomamae-gun, Hokkaido. Pebble nodule from the Upper Yezo Group (Santonian; *Inoceramus amakusensis* Zone). *Archaeopus ezoensis* collected by Mizuno.

Locality YEZ-10: Katsurazawa, Ikushunbetsu, Mikasa City, Hokkaido. Nodule of the Mikasa Formation of the Middle Yezo Group (Cenomanian; *Inoceramus nipponicus*-*I. pennatulus* Zone by Matsumoto, 1965). *Eodorippe binodosa* sp. nov. collected by Yokoi.

Locality YEZ-11: Kumaoizawa, Ikushunbetsu, Mikasa City, Hokkaido. Pebble nodule from the lower part of the Upper Yezo Group (Santonian; *Inoceramus amakusensis* Zone by Matsumoto, 1965). *Diaulax yokoi* sp. nov., *Notopocorystes* (*N.*) *japonicus* collected by Kera.

Locality YEZ-12: Hakkinzawa, Oyubari, Yubari City, Hokkaido. Pebble nodule from the upper part of the Middle Yezo Group (Cenomanian-Middle Turonian by Hirano *et al.*, 1977). *Notopocorystes* (*Eucorystes*) *intermedius* collected by Kera.

Locality YEZ-13: Kaneobetsu, Oyubari, Yubari City, Hokkaido. Pebble nodule from the upper part of the Middle Yezo Group (lower Cenomanian-middle Turonian by Iizawa *et al.*, 1980; middle Turonian by Matsumoto and Suekane, 1987). *Notopoco-*

rystes (*N.*) *japonicus* collected by Kera.

Locality YEZ-14: Sanushibe, Hobetsu-cho, Yufutsu-gun, Hokkaido. Pebble nodule from the upper part of the Upper Yezo Group (Santonian; *Inoceramus amakusensis* Zone by Kito *et al.*, 1986). *Notopocorystes* (*N.*) *japonicus* collected by Kera.

Locality YEZ-15: Ikandai, Urakawa-cho, Urakawa-gun, Hokkaido. Pebble nodule from the U1 Member of the Upper Yezo Group (Santonian; *Inoceramus amakusensis* Zone by Kanie, 1966). *Notopocorystes* (*N.*) *japonicus* collected by Yoshikawa.

2. Hyogo and Osaka Prefectures (Fig. 1).

Locality IZM-1: Nadachino, Nantan-cho, Mihara-gun, Hyogo Prefecture. Nodule from the Shimonada Formation, Izumi Group (Lower Maastrichtian; *Pachydiscus* aff. *subcompressus* Zone by Morozumi, 1985). *Archaeopus ezoensis* collected by Sato and Miyamoto.

Locality IZM-2: Okawa, Nantan-cho, Mihara-gun, Hyogo Prefecture. Pebbly conglomerate from the Shimonada Formation, Izumi Group (lower Maastrichtian; *Pachydiscus* aff. *subcompressus* Zone by Morozumi, 1985). *Archaeopus ezoensis* collected by Sato and Miyamoto.

Locality IZM-3: Takinoike, Izumisano City, Osaka Prefecture. Nodule from the Matsuo Formation from the Izumi Group (Campanian/Maastrichtian by Matsumoto and Morozumi, 1980). *Archaeopus ezoensis* collected by Miyamoto.

Locality IZM-4: Hakosaku, Han-nan-cho, Sen-nan-gun, Osaka Prefecture. Nodule from the Shindachi Formation of the Izumi Group (Maastrichtian by Kase, 1990). *Archaeopus ezoensis* collected by Miyamoto.

Systematic descriptions

Section Podotremata Guinot, 1977
 Subsection Dromioidea de Haan, 1833
 Superfamily Homolodoromioidea
 Alcock, 1899

Family Prosopidae von Meyer, 1860
 Subfamily Pithonotinae Glaessner, 1933

Genus *Pithonoton* von Meyer, 1842

Type species.—By subsequent designation of Beurlen, 1928; *Pithonoton marginatum* von Meyer, 1842.

Geologic range.—Middle Jurassic-Late Cretaceous.

Pithonoton inflatum Collins and
 Karasawa, 1993

Figures 2-1a-c

Pithonoton inflatum Collins and Karasawa, 1993, p. 17, figs. 1a-c.

Material.—TMNH01530 (holotype).

Diagnosis.—A *Pithonoton* with a rounded pentagonal carapace, a strongly inflated dorsal surface, an obsolete median course of the cervical furrow and a low ridge on a poorly delimited cardiac region (Collins and Karasawa, 1993).

Occurrence.—Hokkaido (detail of locality is uncertain). Middle or Upper Yezo Group.

Geologic range.—? Cenomanian-Campanian.

Superfamily Dromioidea de Haan, 1833
 Family Diaulacidae Wright and Collins, 1972

Genus *Diaulax* Bell, 1863

Type species.—By monotypy *Diaulax carteriana* Bell, 1863; = *Platypodia oweni* Bell, 1850.

Geologic range.—Albian-Campanian.

Diaulax yokoi sp. nov.

Figures 2-4, 5a-c

Material.—MFM247,001 (holotype), MCM A373 (paratype).

Type locality.—Loc. YEZ-2 (Nigorisawa Formation, Upper Yezo Group; Santonian).

Derivation of name.—From Mr. T. Yokoi who collected the type specimen.

Diagnosis.—Carapace hexagonal in outline, with regions more or less distinct and a well defined cervical furrow.

Description.—The carapace is hexagonal in outline, a little broader than long, widest immediately before the cervical notch about one-third distant from the front. In longitudinal section, the carapace is strongly downturned from the point of greatest carapace width and the hind part is flat. In transverse section, the part in front of the cervical furrow is flatly arched medially and behind that it is nearly flat. The orbitofrontal margin occupies about four-fifths of the total width. The front is downturned; the rostrum is obscured by matrix, but appears to be weakly sulcate, the narrowly raised margins leading back to the inclined upper orbital margin, terminating in a broadly triangular outer orbital spine. The upper orbital margin is irregularly beaded and there is a scattering of fine granules anteriorly on the dorsal surface. The orbits are broadly ovate. The lateral margins are distinct with a thickened edge continuing as far as the base of the cardiac region. The anterolateral margins are short with a weak spine nearer to the outer orbital spine than to a stronger one before the cervical notch. There is a similarly strong spine behind the notch and the posterolateral margins converge to the posterior margin which is narrower than the orbitofrontal margin and bounded by a thin ridge. A minute node either side of the midline interrupts the cervical furrow which is broadly V-shaped, deep and distinct to the outer angles of the mesogastric lobe where it broadens and, passing round the protogastric lobe in a shallow

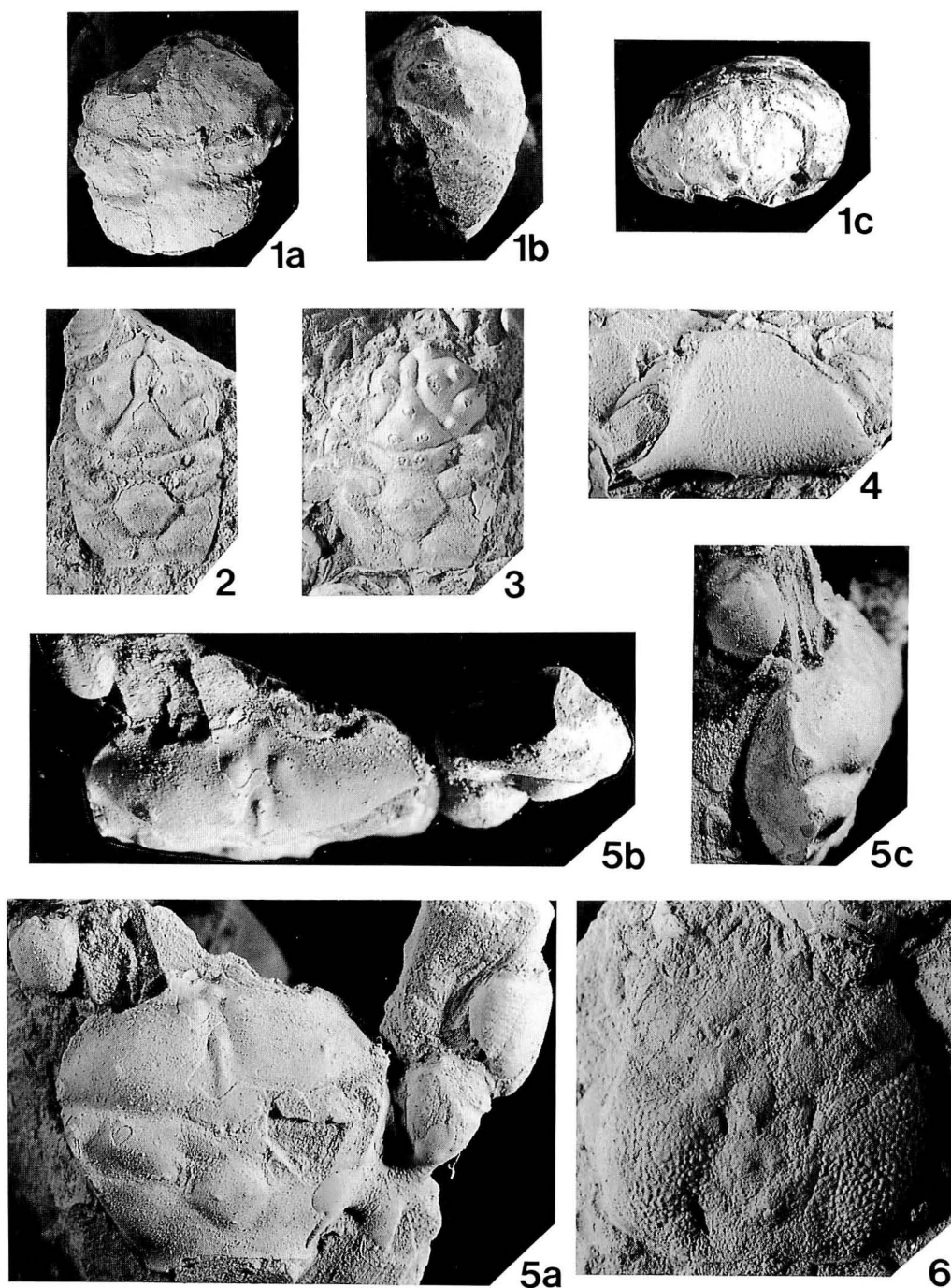


Figure 2. 1a-c. *Pithonoton inflatum* Collins and Karasawa, 1993, $\times 2.8$. a, dorsal; b, lateral; c, frontal view of carapace. 2, 3. *Metahomola brevis* sp. nov., dorsal view of carapace, $\times 3.3$. 2, YCM-GP854 (holotype), Loc. YEZ-7. 3, MFM247, 002 (paratype), Loc. YEZ-4. 4, 5a-c. *Diaulax yokoi* sp. nov. $\times 3.5$. 4, MCM A373 (paratype), Loc. YEZ-11, lateral view of right cheliped. 5, MFM247,001 (holotype), Loc. YEZ-2, a, dorsal; b, frontal; c, lateral view. 6. *Eodorippe binodosa* sp. nov., MFM247,003 (holotype), Loc. YEZ-10, $\times 3.5$, dorsal view of carapace.

curve, runs almost transversely to the margin. A thin furrow branching from the cervical runs obliquely back and defines a small triangular epibranchial lobe. The otherwise indistinct branchiocardiac furrow is bounded laterally by a low ridge which continues obliquely along the side of the carapace. The regions are mostly well defined: a weak depression separates the hepatic region from the protogastric lobes; there is a weak node on the anterior mesogastric process a little anterior to rather more prominent frontal lobes and a rounded ridge extends almost to the base of the mesogastric lobe. The urogastric lobe is divided into lozenge-shaped portions by a median furrow and laterally confluent with reniform mesobranchial lobes. A transverse groove separates the urogastric from the pentagonal cardiac region which has a weak median depression anteriorly. There is a node on each protogastric lobe opposite the cervical notch and a granule at the base of the cardiac region.

The propodus of the cheliped is trapezoidal in lateral view, with the basal margin about one-third longer than the dorsal and interdigital margins. There is a wide convexity in the basal margin at the base of the stout, moderately deflexed, slightly inturned fixed finger. The interdigital margin is nearly straight and bounded by a shallow groove and a wide, deep groove bounds the carpal articulation which is rather more oblique in the left chela, the right and left propodi have the finely granulated lateral surface smoothly rounded and have an incipient furrow extending parallel to the dorsal margin, but it is closer to the midline in the right chela. The slender dactylus is about as long as the fixed finger. The carpus is a little shorter than the propodus, rounded triangular in section and the strongly convex lateral surface is smooth with a median furrow.

Discussion.—The carapace of *Diaulax oweni* (Bell, 1850) (lower Albian-lower Cenomanian) of England is rather more pentagonal in outline and may be further distin-

guished from *D. yokoi* sp. nov. in having poorly differentiated regions and a less conspicuous cervical furrow. The dorsal regions may be vaguely tumid in some specimens of *D. feliceps* Wright and Collins, 1972 from the Gault (Albian) of England and its carapace is more or less similar in outline to *D. yokoi* sp. nov., but it lacks the anterolateral spine and an epibranchial boss replaces the spine behind the cervical notch; the cervical furrow of *D. feliceps* is weaker and more sinuous in its course to the margin. The carapace length of *Diaulax roddai* Bishop, 1983a from the Glen Rose Limestone (Albian) of Texas and *Diaulax millerae* Bishop, 1992 from the Merchantville Formation (Campanian) of Delaware exceeds the breadth and this character serves immediately to distinguish those species from *D. yokoi* sp. nov. The median furrow on the carpus is common to both *D. oweni* and *D. feliceps*, but only *D. feliceps* has a groove on the propodus, that of *D. oweni* being ornamented by longitudinal rows of granules continued onto the carpus.

Occurrence.—Loc. YEZ-2, 11.

Geologic range.—Santonian.

Subsection Archaeobrachyura Guinot, 1977

Superfamily Homoloidea de Haan, 1839

Family Homolidae de Haan, 1839

Genus *Metahomola* Collins and Rasmussen, 1992

Type species.—By original designation of Collins and Rasmussen, 1992; *Homolopsis punctata* Rathbun, 1917.

Geologic range.—Late Cretaceous.

Metahomola brevis sp. nov.

Figures 2-2, 3

Material.—YCM-GP854 (holotype), MFM247,002 (paratype).

Type locality.—Loc. YEZ-7 (Middle Yezo Group; Turonian).

Derivation of name.—Referring the rela-

tively short metabranchial ridges.

Diagnosis.—A *Metahomola* with short metabranchial ridges, three cardiac tubercles and intestinal nodes on either side of the midline close to the cardiac region.

Description.—The carapace is subquadrate in outline, about one-fourth longer than wide between the *linea homolicae* at about mid-carapace length; in longitudinal section it rises steeply from the front, becomes depressed at mid-length, rises and curves gently to the posterior margin, being moderately arched transversely. Convex anterolateral margins are weakly constricted before the orbital angle. The orbits are oblique and occupy half of the carapace width. The rostrum is produced, narrowly triangular and continues the downward curve of the carapace; its raised sides lead back to thin upper orbital margins. Almost straight posterolateral margins without spines lead to sharp posterior angles; the posterior margin is about as wide as the front and bounded by a fine ridge. Crossing the carapace about mid-length, the prominent cervical furrow is almost straight at the base of the mesogastric lobe, turns before the lobe's outer angle and, curving gently round the hepatic region, runs forward and outward to the margin. Equally prominent branchiocardiac furrows run more or less parallel to the cervical and terminate in a deep depression behind ovate, rather tumid mesobranchial lobes. The tip of the anterior mesogastric process extends between low epigastric lobes and a small tubercle about mid-length has a sulcus just behind it. Of the tubercles on the protogastric lobes, the inner pair flank that on the mesogastric process, another lays slightly forward and outward while a third occupies the space between the hepatic and mesogastric

lobes. There is a median tubercle and two basal ones on the mesogastric lobe and two on the clearly delimited hepatic region which is subcircular in outline. The narrow urogastric lobe has a transverse pair of small nodes. The shield-shaped cardiac region has three small tubercles in an inverted triangle and opposite its widest part a short, narrow ridge extends onto the metabranchial region. Each mesobranchial region has one tubercle behind the cervical furrow and a smaller one near the urogastric lobe. Flattened, circular intestinal nodes lay close to the midline on either side of the cardiac region.

Discussion.—*Metahomola* was proposed by Collins and Rasmussen, 1992 to contain homolids with an entire rostrum and a ridge extending from the widest part of the cardiac region onto the metabranchial lobe. A second genus, *Eohomola* Collins and Rasmussen, 1992, was described to contain species also with a metabranchial ridge, but further distinguished by the presence of a bifurcate rostrum, thereby leaving those species with an entire rostrum and lacking a metabranchial ridge in *Homolopsis* Bell, 1863.

Absence of a metabranchial ridge and juxtaposition of tubercular ornament immediately distinguishes *Homolopsis hachiyai* Takeda and Fujiyama, 1983, from the Miyako Group (lower Aptian) of Iwate Prefecture, from *Metahomola brevis* sp. nov. The urogastric lobe of *M. punctata* is divided at the midline, there are no nodes on the cardiac region and the intestinal nodes are set further apart. *Metahomola gibbosa* (Schlüter, 1879) from the Senonian of Germany lacks the tubercle at the median base of the protogastric lobe and the metabranchial ridges extend further towards the lateral margin.

M. brevis sp. nov. closely resembles the

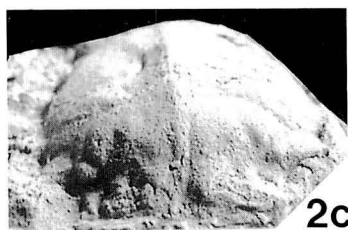
→ **Figure 3.** 1-6. *Notopocorystes (Notopocorystes) japonicus* (Jimbô, 1894). 1, MCM A374, Loc. YEZ-14, $\times 1.5$, dorsal view of carapace. 2a-c, ESN83007P, Loc. YEZ-3, $\times 2.5$, a, dorsal; b, lateral; c, frontal view of carapace. 3, YCM-GP856, Loc. YEZ-7, $\times 2.5$, dorsal view of carapace. 4, ESN83008P, Loc. YEZ-1, $\times 1.5$, dorsal view of carapace. 5a-c, YCM-GP849, Loc. YEZ-8, $\times 1.5$, a, dorsal; b, lateral; c, frontal view of carapace. 6a-c, YCM-GP850, Loc. YEZ-8, $\times 2.5$, a, dorsal; b, lateral; c, frontal view of carapace.



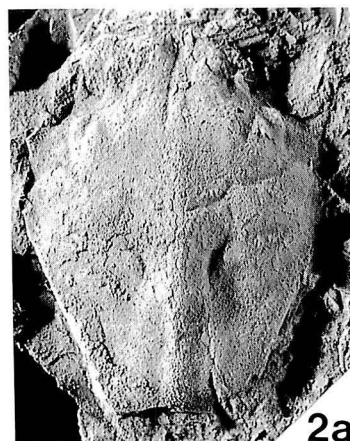
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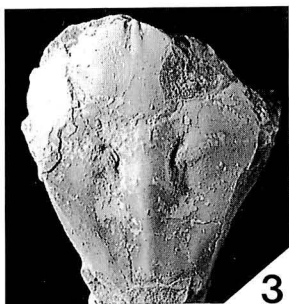
2b



2c



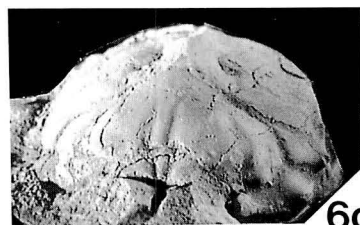
2a



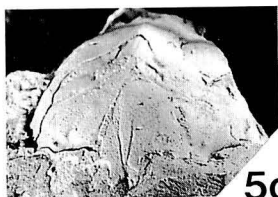
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4



6c



5c



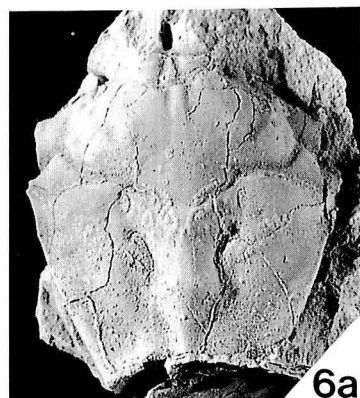
5a



5b



6b



6a

Middle Eocene species *Prohomola japonica* (Yokoyama, 1911) from the Manda Group of Fukuoka Prefecture (Karasawa, 1992) and could well be ancestral to it. *P. japonica* differs largely in having a flatter carapace with rather more rounded lateral margins; the rostrum is well developed, directed straight forward and there is a pair of large postrostral spines.

Occurrence.—Loc. YEZ-4, 5, 7,

Geologic range.—Turonian-Santonian.

Superfamily Raninoidea de Haan, 1841

Family Raninidae de Haan, 1841

Genus *Notopocorystes* McCoy, 1849

Type species.—Subsequently designated by Withers (1928), *Notopocorystes mantelli* McCoy, 1849 = *Corystes stokesii* Mantell, 1844.

Geologic range.—Early Albian-Santonian.

Subgenus *Notopocorystes* McCoy, 1849

Notopocorystes (*Notopocorystes*)
japonicus (Jimbô, 1894)

Figures 3-1—6

Eucorystes japonicus Jimbô, 1894, p. 101, pl. 9, fig. 7.
Notopocorystes ? *japonicus* (Jimbô). Glaessner, 1929, p. 277.

Notopocorystes (*Eucorystes*) *japonicus* (Jimbô). Nagao, 1931, p. 207.

Notopocorystes japonicus (Jimbô). Imaizumi, 1978, p. 32.

Material.—MA7483 (GT. I-159) (Holotype). YCM-GP849, 850, 852, 853, 856, 858; MCM A372, A375; ESN83007P, 83008P (new material).

Diagnosis.—Carapace with a weakly devel-

oped median carina without tubercles on the midline and protogastric and hepatic tubercles.

Description.—The carapace is truncated oval in outline, moderately arched longitudinally, reaching its highest point about mid-length where it becomes flattened before curving to the posterior margin, and moderately arched transversely. The orbitofrontal width is a little more than half the carapace width measured between the cervical notches. The rostrum projects slightly in front of the orbital spines, is widely bifurcate with two blunt terminal spines and is shallowly to moderately grooved; its sides are raised and lead to a small inner orbital spine. The orbits are wide and spines separate two evenly spaced fissures in the upper orbital margin. Two forwardly directed slender anterolateral spines are slightly upturned and there is a small one behind the cervical notch. The posterolateral margins are sharp anteriorly, becoming rounded and slightly concave to the posterior margin. The cervical furrow is shallow and fairly broad; it runs forward from the margin and curves back behind the mesogastric lobe in a shallow curve. An equally prominent groove, not quite uniting with the cervical, delimits the epibranchial lobe. An incipient ridge borders the lateral parts of feeble branchiocardiac furrows which become obsolete before the cardiac region. A median carina starting as a low, broad ridge on the urogastric lobe tapers on the cardiac region and continues parallel to the posterior margin where it is flanked by two, short ridges. The tip of the narrow anterior mesogastric process extends into the base of the rostrum and the feebly demarcated mesogastric lobe is smooth. The weakly

→ **Figure 4. 1a, b, 2.** *Notopocorystes* (*Eucorystes*) *intermedius* Nagao, 1931, $\times 2.5$. **1a, b**, ESN83006P, Loc. YEZ-6, a, dorsal; b, lateral view of carapace. **2**, ESN83009P, Loc. YEZ-8, dorsal view of carapace. **3-7.** *Archaeopus ezoensis* (Nagao, 1941). **3**, YCM-GP855, Loc. YEZ-7, $\times 3.0$, dorsal view of carapace. **4**, ESN83010P, Loc. IZM-4, $\times 1.8$, male thoracic sterna. **5**, ESN83011P, Loc. YEZ-9, $\times 3.0$, dorsal view of carapace. **6a-d**, ESN83012P, Loc. IZM-2, $\times 1.8$, a, frontal; b, dorsal; c, ventral; d, lateral view of carapace of female. **7a-c**, ESN83013P, Loc. IZM-2, $\times 1.8$, a, dorsal; b, ventral; c, lateral view of carapace of male.



1a



1b



2



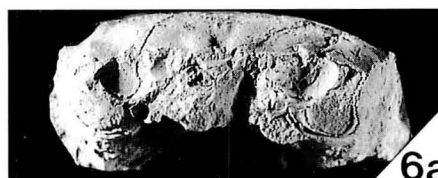
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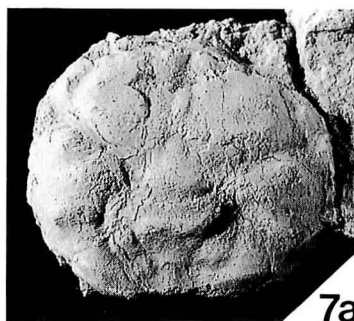
4



5



6a



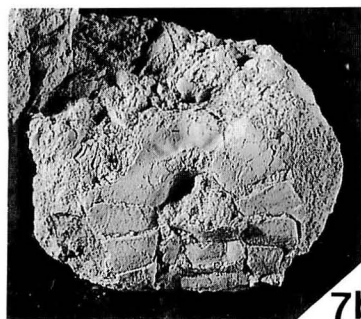
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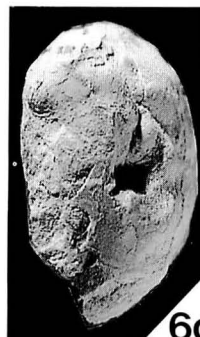
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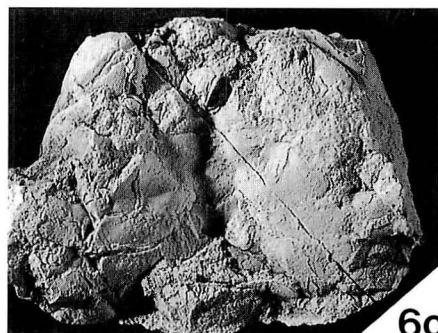
6b



7b



6d



6c

scabrous urogastric lobe is confluent with the cardiac region which has a prominent transverse pair of tubercles. There is a tubercle on the hepatic lobe and a row of minute tubercles from a crescentic ridge by the inner part of the hepatic region and within the curve is a larger tubercle on the protogastric lobe.

Discussion.—*Notopocorystes* (*N.*) *japonicus* lacks all trace of the 'strap' ornament of furrows and lobes which are diagnostic requirements for *Eucorystes*. Individuals of this species reach among the largest known of the genus. The longitudinal curvature becomes more evenly rounded as growth advances and the dorsal tubercles are much less in evidence.

Wright and Collins (1972) recognized a phylogenetic progression in the Albian species *Notopocorystes stokesii* (Mantell, 1844) and erected three subspecies of which the nominate form, *N. stokesii stokesii*, occupies the middle part of the progression. The earliest known (*Douvilleiceras mammillatum* Zone) form, *N. stokesii praecox* Wright and Collins, 1972 passes into *N. stokesii stokesii* (*Hoplites spathi-Dipoloceras cristatum* Subzone) which gives rise to *N. stokesii serotinus* Wright and Collins, 1972, which was well established in the *D. cristatum* Subzone, where it existed alongside *N. stokesii stokesii* and continued to the Cambridge Greensand (Albian). *N. stokesii praecox* has an almost continuous carina, notched into weak tubercles only just in front of and just behind the cervical furrow, there is a single, rarely two, tubercle on the hepatic region and the crescentic ridges and protogastric tubercles are indistinct; the orbitofrontal width/carapace width ratio averages 58.

N. (N.) japonicus would appear to be a regressive form of *N. stokesii praecox* for not only does it have a comparable orbitofrontal/carapace width ratio of 56.5, but retains some of the characters of that species, while the median carina is developed only on the branchial region. Characters not possessed by *N. stokesii praecox* are the ridges at the base of

the median carina and the transverse pair of cardiac tubercles, which is unique to the species discussed.

Occurrence.—Pankemoyubari River, a left-hand tributary of the Yubari, Ishikari Province; *Scaphites* beds (Turonian-Coniacian) (type locality). Loc. YEZ-1, 3, 7, 9, 11, 13, 14, 15.

Geologic range.—Cenomanian-Santonian.

Subgenus *Eucorystes* Bell, 1863

Type species.—By monotypy *Notopocorystes carteri* McCoy, 1854.

Geologic range.—Early Albian-Campanian.

Notopocorystes (Eucorystes)
intermedius Nagao, 1931

Figures 4-1, 2

Notopocorystes (Eucorystes) intermedius Nagao, 1931, p. 207, pl. 14, figs. 4, 4a.

Notopocorystes intermedius Nagao. Imaizumi, 1978, p. 27, fig. 38.

Material.—UHR3184 (Nagao's type specimen). YCM-GP851, 857; MCM A374; ESN83006P, 83009P (new material).

Diagnosis.—Carapace without a dorsal median carina.

Discussion.—This species differs from *Notopocorystes (N.) japonicus* (Jimbô, 1894) in having the carapace relatively longer than wide and the dorsal surface without the median carination. Young individuals of *N. (N.) japonicus* have tubercles on the protogastric and hepatic lobes, whereas the dorsal surface of *N. (E.) intermedius* is marked only by weak 'straps' on the gastric region.

Occurrence.—Southeast of Ikushunbetsu (Horonai) colliery and along the tributary of Ikushunbetsu, Province of Ishikari, Hokkaido (Horonai, Mikasa City); Mikasa Formation, Middle Yezo Group (Cenomanian-Turonian) (type locality). Loc. YEZ-6, 7, 8, 12.

Geologic range.—Cenomanian-Santonian.

Superfamily Cyclodorippoidea

Ortmann, 1892

(= Superfamily Tymolidae Alcock, 1896)

Family Torynommatidae Glaessner, 1980

(Rectae ICZN, Art, 20 (4), (b) (i))

Genus *Eodorippe* Glaessner, 1980

Type species.—By monotypy *Eodorippe spedeni* Glaessner, 1980.

Geologic range.—Late Cretaceous.

Eodorippe binodosa sp. nov.

Figure 2-6

Material.—MFM247,003 (holotype).

Type locality.—Loc. YEZ-10 (Mikasa Formation, Middle Yezo Group; Cenomanian).

Derivation of name.—With reference to the node on each protogastric lobe.

Diagnosis.—Carapace subrectangular, slightly longer than wide; lateral margin without hepatic spine, gently convergent anteriorly; one node on each protogastric lobe.

Description.—The carapace excluding the rostrum, is subrectangular in outline, slightly longer than wide with the greatest width across the mesobranchial and cardiac lobes in the posterior third. The dorsal surface is gently convex in both longitudinal and transverse sections. The wide orbitofrontal margin occupies about 0.8 of the greatest carapace width; a long, spatulate rostrum with a shallow median sulcus protrudes straight forwards and there is a small, broadly triangular postrostral spine on either side. The upper orbital margin is concave, slightly upturned and bears a sharp outer orbital spine. The lateral margins, with cervical and branchiocardiac notches, are slightly sinuous and convergent anteriorly; they form a sharp edge in the anterior half and there is a basal scar indicating a small spine before the cervical notch. The posterior margin is slightly convex and bounded by a narrow rim. The dorsal regions are reasonably well defined by

shallow, broad grooves. Large, tumid protogastric lobes are shallowly separated from the narrow anterior mesogastric process and each has a node close to the small, depressed, triangular mesogastric lobe. The cervical furrow, interrupted at the midline, is broadly V-shaped medially and curves sharply forward and outward to reach the margin about one-fourth distant from the front. The outer course of the branchiocardiac furrow runs almost parallel to the cervical and encloses a narrow epibranchial lobe, while a faint oblique groove defines a chordate metabranchial lobe and turns back to form deeper grooves bordering the urogastric lobe. The dorsal surface is coarsely granulated, with the granules tending to form spinules at the lateral margins.

Discussion.—The present new species differs from *Eodorippe spedeni* Glaessner, 1980 from the Campanian-Maastrichtian of New Zealand in having a subrectangular carapace, less obviously narrowing towards the front. The intermediate oblique grooves between the cervical and branchiocardiac furrows are weaker than in *E. spedeni* and of the three pairs of protogastric nodes developed in that species only the inner pair is present in *E. binodosa* sp. nov.

There appears to be a certain amount of damage about the rostrum of *E. spedeni* and the postrostral spines are not in evidence. Glaessner (1980) said that a significant difference between *Dorippe* and *Eodorippe* was the apparent absence of the prominent infraorbital teeth of *Dorippe* and the shape of the rostrum. The postrostral spines noted in *E. binodosa* sp. nov. would seem to foreshadow the infraorbital teeth of *Dorippe* and the reduction of the rostrum of *Eodorippe* and further development of the postorbital spines would undoubtedly produce a front in keeping with that of *Dorippe*.

Geologic range.—Cenomanian.

Table 1. Stratigraphic and geographic distribution of the Late Cretaceous decapods of Japan (compiled from Bishop, 1986, Collins and Karasawa, 1993, Collins and Rasmussen, 1992, Feldmann *et al.*, 1993, Glaessner, 1969; 1980; Nagao, 1931; 1932; 1941, Tshudy and Feldmann, 1988 and Wright and Collins, 1972). L, *Linuparus*; C, *Callianassa*; P, *Pithonotus*; D, *Diulax*; M, *Metahomola*; E, *Eodorippe*; N, *Notopocorystes* s. l.; A, *Archaeopus*.

Geologic age		Japan	Mada- gascar & India	New Zealand	Antarc- tica	Australia	North America		Europe	Green- land
		LCPDMENA	LCPDMENA	LCPDMENA	LCPDMENA	LCPDMENA	Pacific Slope	Western Interior & Atlantic Coastal Plain	LCPDMENA	LCPDMENA
Late Cretaceous	Maastrichtian									
	Campanian									
	Santonian									
	Coniacian									
	Turonian									
	Cenomanian									
Early Cretaceous										

Section Thoracotremata Guinot, 1977
Superfamily Ocypodoidea Rafinesque, 1815
Family Retroplumidae Gill, 1894

Genus *Archaeopus* Rathbun, 1908

Type species.—By monotypy *Archaeopus antennatus* Rathbun, 1908.

Geologic range.—Early ?-Late Cretaceous.

Archaeopus ezoensis (Nagao, 1941)

Figures 4-3-7; 5-1-5

Plagiolophus ezoensis Nagao, 1941, p. 97, pl. 26, figs. 1, 2; Imaizumi, 1978, p. 45.

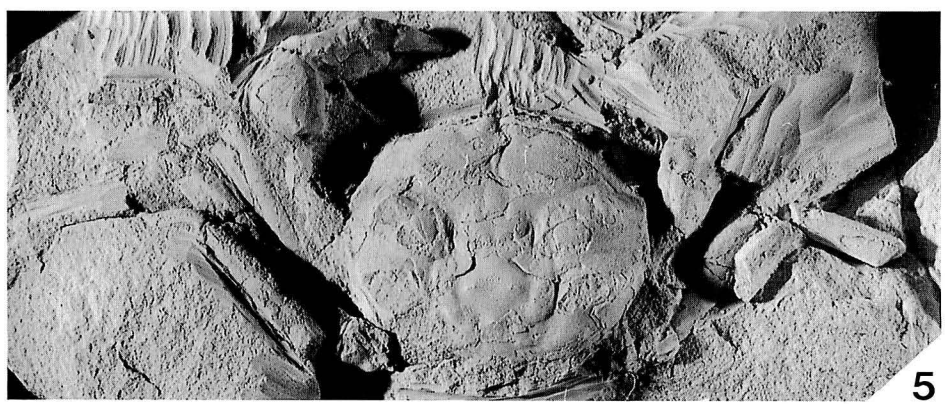
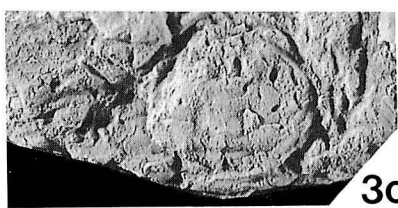
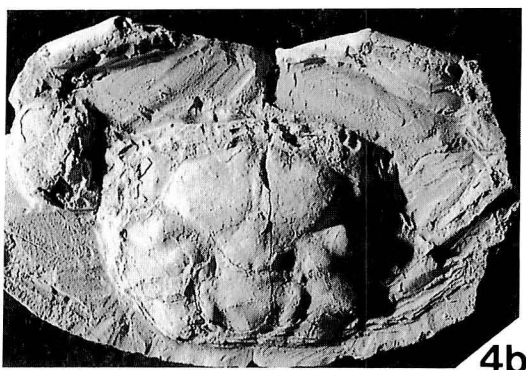
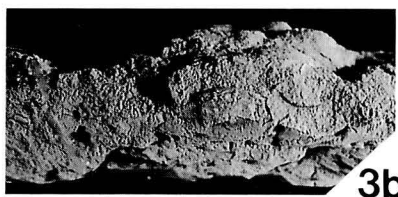
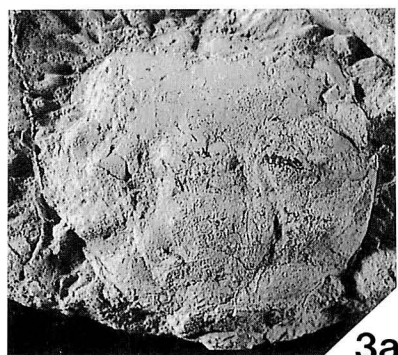
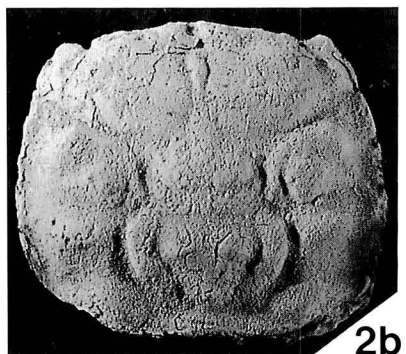
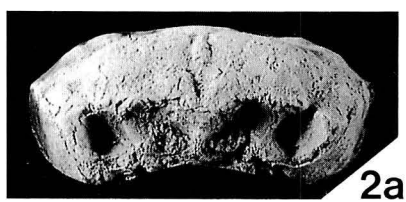
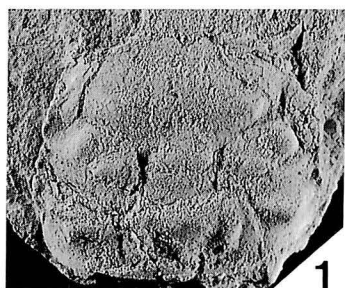
Material.—Nagao's type specimen.

YCM-GP855; ESN83010-83018P (new material).

Diagnosis.—*Archaeopus* with weak transverse protogastric ridges.

Description.—The carapace is subquadrate in outline, almost as long as wide, widest at the posterior third, moderately arched in transverse section, vaulted and more steeply downturned in front in longitudinal section. Straight anterolateral margins converge anteriorly and the posterior margins round into a slightly concave posterior margin which is thickened, bounded by a depression and, laterally, by a low ridge. The orbitofrontal margin takes up about four-fifths of the greatest carapace width, with ovate orbits taking up the outer thirds. The front, exten-

→ **Figure 5.** 1-5. *Archaeopus ezoensis* (Nagao, 1941). 1, ESN83014P, Loc. IZM-4, ×1.8, dorsal view of carapace. 2a, b ESN83015P, Loc. IZM-3, ×2.5, a, frontal; b, dorsal view of carapace. 3a-c, ESN83016P, Loc. IZM-1, ×1.8, a, dorsal; b, posterior; c, ventral view of carapace of female. 4a, b, ESN83017P, ×1.5, a lateral view of chelipeds; b, dorsal view. 5, ESN83018P, ×1.5, dorsal view.



ding a little beyond the upper orbital margin, is rounded acuminate, its sides are thickened and raised, a short median sulcus extends back between small, elongate epigastric lobes. The cervical furrow runs almost straight and oblique back from the margin to the mesogastric lobe before turning sharply back and passing across the midline in a broad curve. The branchiocardiac furrow is nearly transverse and separates a short urogastric lobe from the heart-shaped cardiac region. Four small, evenly spaced tubercles line the margin between the furrows. A prominent ridge extending across the base of the protogastric lobes is interrupted by the tip of the mesogastric lobe; a second ridge normally associated with retroplumids is represented by a large tubercle on each epibranchial lobe with a similar one stepped inward and backward on the metabranchial lobes in line with two smaller nodes at the base of the mesogastric lobe, while a third ridge bound by the branchiocardiac furrows is carried across the midline and the median part limited to the anterior pair of three tubercles on the cardiac region. There is a small tubercle on each hepatic region and a narrow, lingulate lobe runs between the cardiac and mesobranchial lobes.

Evidently the transverse ridges are a feature of ontogeny, for on a carapace with a width of 8.0 mm, only the hindmost of the ridges is to any extent developed, although the metabranchial prominence is circular rather than linear; of the middle ridge, only the epi- and mesobranchial tubercles with the latter the larger as in adults are present; and smooth, tumid protogastric lobes give no indication of the ridge later developed.

The abdominal sternites are very wide and shallow; the 1st-2nd appear to be broadly triangular in outline and have a shallow median depression; The 3rd with a deep circular median depression is separated from the 1st-2nd by a shallow groove; a groove separates them from the 4th sternites which are trapezoidal in outline with the latero-

posterior angle partly embracing the 5th sternites; the 5th-7th pairs are subrectangular. The 3rd sternites have a tumidity either side of the median trough while on the 4th two larger tumid areas line the trough and a low ridge bounds the cheliped margin. The 5th and 6th sternites each have a short ridge opposite the articulation boss of the corresponding limbs.

The chelipeds are subequal with the right slightly larger, extended their length would equal about twice the carapace width; the dactylus, having finely serrated occludent margins, is slender, deflexed and about half of the length; a row of pits lining a shallow groove runs the length of the fixed finger; the propodus height is equal to about half its length. The carpus is about half the length of the propodus, its subquadrate lateral surface is weakly rounded and smooth. The line of inclination of the 1st pereopods to the chelipeds suggests the presence of a similar gap between those limbs as discerned by Rathbun (1908, p. 348) on *A. antennatus*. The 2nd-4th pereopods are reduced in length posteriorly, but the ischia retain much the same proximal width and taper distally. The proximal width of the 4th pair is about one-third as long as the ischium. The ischial base of the 4th pereopods extends to, or slightly beyond, the posterior angle of the carapace, thus, the 5th pair of limbs, not preserved, would probably occupy much the same (subdorsal) position envisaged by Rathbun (1908) for those limbs of *A. antennatus*.

Discussion.—There is, in the general outline of the carapace and juxtaposition of dorsal characters considerable similarity between *A. ezoensis* and *A. vancouverensis* (Woodward, 1896) from the Campanian-Maastrichtian of British Columbia and Vancouver Island. The anterior transverse ridge of *A. vancouverensis* is stronger than that of *A. ezoensis*. The carapace of *A. antennatus* Rathbun, 1908 from the Upper Cretaceous Chico Formation of California is comparatively wider, its mesobranchial lobe is larger and ovate in

outline, and the cardiac part of the posterior ridge is continuous rather than limited to a pair of tubercles. The sternites of *A. anten-natus*, seen in detail (Rathbun, 1908, pls. 47, 58), are essentially similar to those of *A. ezoensis* except that in the former species the circular pit occupying the 1st-3rd sternites is more prominent in the male. The lateral angle is more attenuated on the 4th pair sternites and the tumid areas are linear, the one bordering the cheliped is reduced to a sharp edge.

Via (1982, fig. 2) put forward an acceptable scheme for the phylogeny and evolution for the Retroplumidae. Vega and Feldmann (1992) revised Via's scheme on the basis of the then known species, *Cristipluma mississippiensis* Bishop, 1893b from the Maastrichtian Coon Creek Formation of Union County, Mississippi, *Costacopluma mexicana* Vega and Perrilliat, 1989 from the upper Maastrichtian Potreillos Formation of Mexico, *Costacopluma bishopi* Vega and Feldmann, 1992 from the Maastrichtian Mexcala Formation of Mexico and the new locality recording for *Costacopluma concava* Collins and Morris, 1975 from the Maastrichtian of north India (Gaetani *et al.*, 1983). Two species, *Costacopluma* sp. from the Upper Eocene (Priabonian) of Hungary (Müller and Collins, 1991) and *Costacopluma binodosa* Collins and Rasmussen, 1992 from the lower Campanian of Greenland have since been described. It appears that *Costacopluma* was confined to the Tethyan and that *Archaeopus* except for the earliest member, *Archaeopus rathbunae* Beurlen, 1965 from the Albion of Brazil, is characteristic of the North Pacific seas.

Occurrence.—Sanushibezawa, Hobetsucho, Yufutsu-gun, Province of Iburi, Hokkaido; Hakobuchi Group (Campanian-Maastrichtian) (type locality). Loc. YEZ-7, 9, IZM-1-4.

Geologic range.—Turonian-Maastrichtian.

Discussion

The Upper Cretaceous decapod fauna from the Yezo Supergroup of Hokkaido and the Izumi Group of Hyogo and Osaka Prefectures is represented by nine species in eight genera. Their stratigraphic range is shown in Table 1. *Pithonoton*, a predominantly Jurassic genus, ranges into the Cretaceous; *Diaulax*, *Metahomola*, *Eodorippe*, *Notopocorystes* s.l., and *Archaeopus* are confined to the Cretaceous, while *Callianassa* and *Linuparus* have living species.

Among eight genera, *Linuparus*, *Callianassa* and *Notopocorystes* are cosmopolitan; *Pithonoton*, *Diaulax* and *Metahomola* are characteristic of the Tethyan realm, while *Archaeopus* was recorded from the Upper Cretaceous deposits of Japan and the Pacific slope of North America (Vancouver Island, British Columbia, and California), and namely, it is characteristic of the North Pacific realm. Considering the occurrences of *Pithonoton*, *Diaulax* and *Metahomola*, the Japanese decapod fauna seems to be related to the Tethyan fauna from the Cenomanian to the Santonian, whilst the existence of *Archaeopus* shows that it is closely related to the fauna from the Pacific slope of North America. *Eodorippe*, on the other hand, is known outside Japan only by its possible derivative, *Eodorippe spedeni* Glaessner, 1980 from the Campanian/Maastrichtian of New Zealand.

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日本産後期白亜紀短尾類 (十脚甲殻目): 北海道の上部白亜系蝦夷累層群および大阪府・兵庫県淡路島の上部白亜系和泉層群より産した 6 属 7 種の短尾類 (十脚甲殻目) 化石を報告する。北海道の蝦夷累層群より産した足孔群 3 種, *Diaulax yokoi*, *Metahomola brevis*, *Eodorippe binodosa* を新種として記載する。古生物地理学的に, 後期白亜紀の日本の十脚甲殻類相は, 北アメリカ太平洋岸の十脚甲殻類相との関連が強い。

Joe S.H. Collins ・ 蟹江康光 ・ 柄沢宏明

963. MOLLUSCAN FAUNA FROM THE MIOCENE MESHIKUNI FORMATION ON REBUN ISLAND, NORTHERN HOKKAIDO*

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Abstract. The Meshikuni Formation occurs in the northern part of Rebun Island and is composed of sandstone and siltstone in which many molluscan fossils occur. The Meshikuni molluscan fauna consists of three assemblages; the first one is represented by *Mytilus tichanovitchi* Makiyama, the second by “*Crassostrea*” *gravitesta* (Yokoyama) and *Glycymeris* species, and the third by deep-water mollusks. *Mytilus tichanovitchi* is one of the representative species of the Asahi fauna of central Hokkaido, and is reported from the Lower to lower Middle Miocene strata of Sakhalin and Kamchatka as well as Japan. The discovery of *Mytilus tichanovitchi* suggests that the Meshikuni Formation is correlative with the Asahi Formation of central Hokkaido.

Key words. Molluscan fauna, Neogene, *Mytilus*, Rebun Island, Hokkaido

Introduction

Rebun Island, located off the northwest coast of Hokkaido (Figure 1), consists mainly of Mesozoic strata of the Rebun Group. Neogene strata occurring on the island have been divided into the Motochi, Meshikuni, Hamanaka and Kusuko Formations, in ascending order, by Nagao *et al.* (1963) (Figure 2). Among these, the Meshikuni Formation includes the Meshikuni facies (main-part) composed of siltstone and sandstone, and the Kabuka facies composed of volcanic conglomerates and hyaloclastites. On the basis of molluscan fossils, Nagao *et al.* (1963)

correlated the Motochi Formation with the Middle Miocene Chikubetsu Formation of northwestern Hokkaido, and also correlated the Meshikuni Formation (including the Kabuka facies) with the Middle to Upper Miocene Togeshita Formation of northwestern Hokkaido. They also suggested that the Hamanaka Formation is correlative with the Upper Miocene Wakkanai stage on the basis of lithofacies characteristics of the so-called “black hard shale.” Noda and Hoyanagi (1987) pointed out that the Meshikuni Formation may contain both Chikubetsu and Togeshita molluscan elements and that the part of the Meshikuni yielding mytilid fossils may be equivalent to the Motochi Formation, although detailed geological and paleontological studies were not done.

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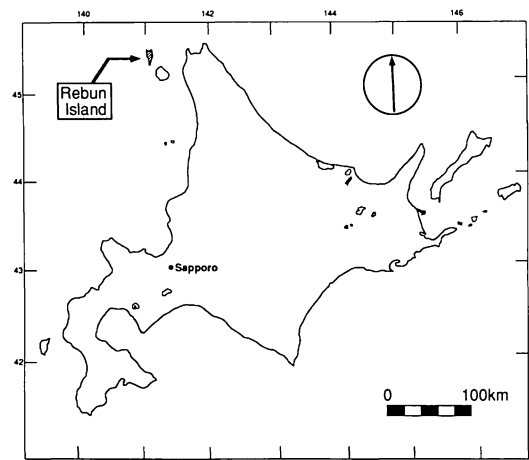


Figure 1. Map showing Hokkaido and location of Rebun Island.

Age	Nagao <i>et al.</i> , 1963		This study	
	Northern region	Southern region	Northern region	Southern region
Quaternary-Tertiary	Kusuko Formation		Kusuko Formation	
Miocene	Hamanaka Formation	Hamanaka Formation	Hamanaka Formation	Hamanaka Formation
	Meshikuni Formation	Meshikuni Formation (Kabuka facies)		Kabuka Formation
		Motochi Formation	Meshikuni Formation	Motochi Formation
Cretaceous	Rebun Group	Rebun Group	Rebun Group	Rebun Group

Figure 2. Stratigraphic sequences on Rebun Island.

The first author recently investigated Neogene strata in the northern part of Rebun Island, including the type locality of the Meshikuni Formation. Subsequently, the authors concluded that the Meshikuni Formation, which yields mytilid mollusks, is correlative with the Asahi Formation (which includes the Asahi fauna) in central Hokkaido.

The authors verify the presence of *Mytilus tichanovitchi* Makiyama in the Meshikuni Formation, which has already been noted by Noda and Hoyanagi (1987) and Uozumi and Akamatsu (1988). Since *Mytilus tichanovitchi* has been reported from various Miocene

marine strata in Hokkaido, Honshu, Kamchatka and Sakhalin, this species is very important for correlation.

The described and figured molluscan specimens are deposited at the Institute of Geology and Paleontology, Faculty of Science, Tohoku University, Sendai, Japan (IGPS collection catalog numbers 102493–102502).

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Geological setting

Neogene strata are well exposed on Rebun Island except for the cliffs along the western coast. They are subdivided, in ascending order, into the Meshikuni, Hamanaka and Kusuko Formations in the northern part and the Motochi, Kabuka and Hamanaka Formations in the southern part, and unconformably overlie the Nairo and Anama Formations of the Mesozoic Rebun Group (Figures 2 and 3). In this article, the authors deal mainly with the Motochi and Meshikuni Formations.

The Motochi Formation is restricted in distribution to the southern part of the island,

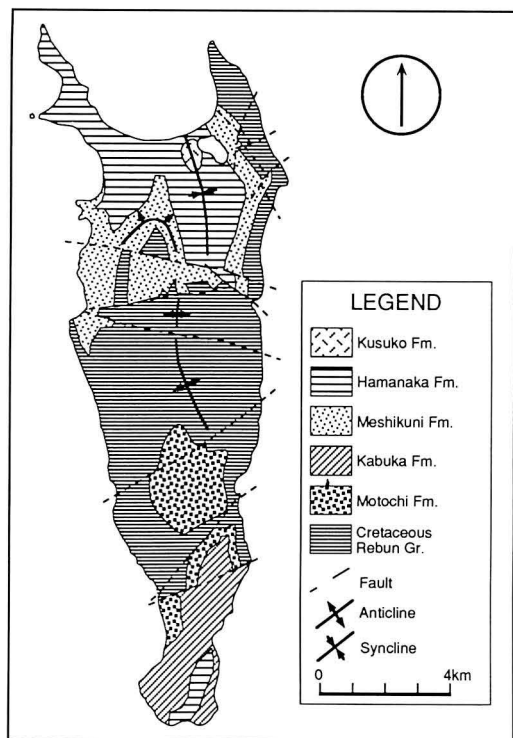


Figure 3. Geological sketch map of Rebutama Island, mainly based on Nagao *et al.* (1963). Volcanic dyke rocks are not shown.

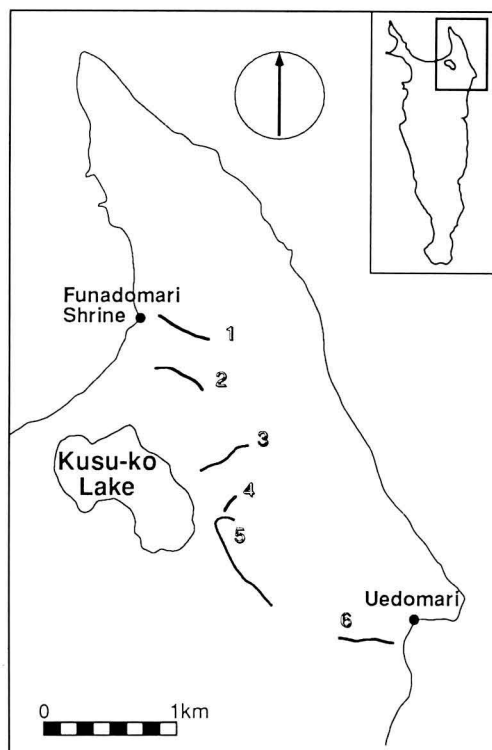


Figure 4. Map showing routes of examined sections indicated in Figure 5.

and consists of green-colored tuff and sandstone in association with coal and siltstone layers. Some molluscan fossils are obtained from pebbly sandstone in the lower part of the formation (Loc. Mo-1).

The Meshikuni Formation crops out in the northern part of the island, dips SE, mostly 10–30°, and is composed mainly of conglomerate, sandstone, pebbly mudstone and pebbly sandstone. Many molluscan fossils occur from sandstone of this formation.

Along the road connecting the towns of Uedomari and Funadomari, six geologic columnar sections were measured and examined (Figures 4 and 5). They all show a similar lithologic succession, beginning with pebbly to cobbly conglomerates at the basal part of the Meshikuni Formation (which unconformably overlies the basaltic lava or

consolidated tuff layers of the Mesozoic Nairo Formation), which are overlain by pebbly sandstone, pebbly mudstone and/or medium- to coarse-grained sandstone of the main part of the Meshikuni Formation. The pebbly sandstone and pebbly mudstone might have been formed by transgressive shoreface erosion. The sandstones (Loc. UF-1 to 5) are considered to be deposited in nearshore environments, such as upper to lower shoreface. Molluscan fossils occur in sandstones of the roadcuts (Loc. UF-1, 2, and 3) and from nodules in pebbly mudstone that is typically exposed along the Funadomari Shrine route (Loc. Fd-2).

In the Teppu district of the west coast, the Meshikuni Formation consists mainly of alternating beds of siltstone and sandstone, partly associated with slumping structures in places. The sediments were deposited in

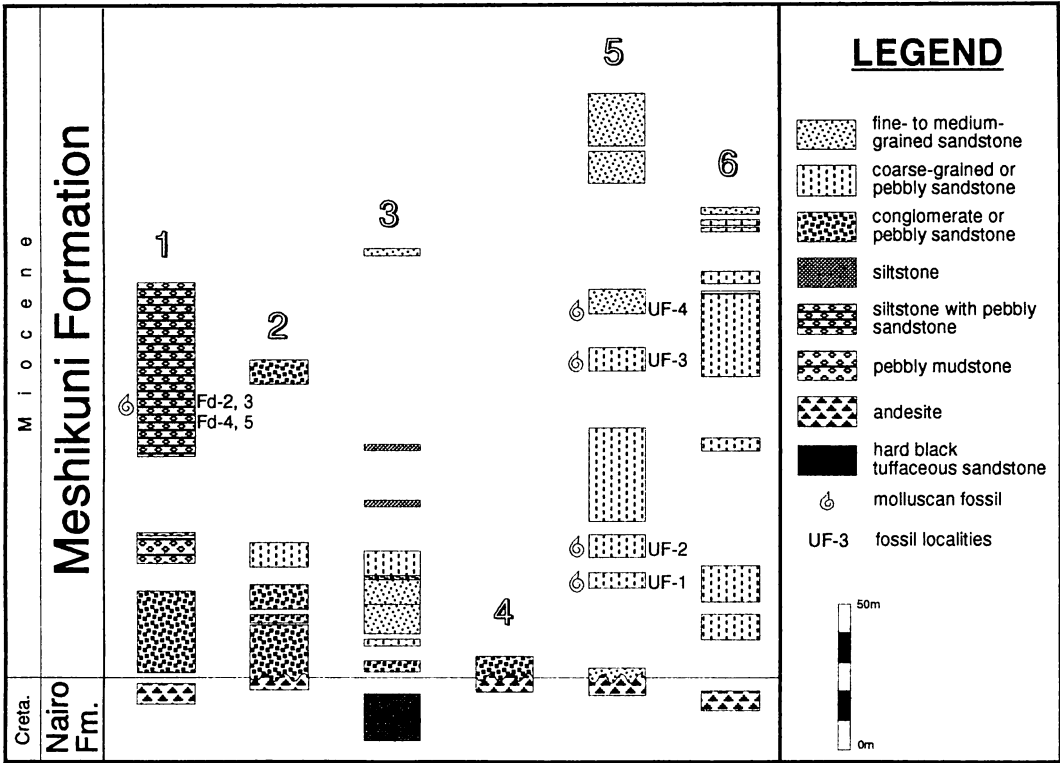


Figure 5. Columnar sections of the Meshikuni Formation. Localities are shown in Figure 4.

shelf to slope environments.

At the Meshikuni coast, the type locality of the Meshikuni Formation, a light-green-colored, very coarse-grained tuffaceous sandstone of this formation crops out along the beach. At its base, it becomes platy, hard, very coarse-grained sandstone and overlies hard tuff layers of the Mesozoic Anama Formation. The hard Mesozoic rocks form a cliff-like hill just behind the beach, and it seems that the Neogene rocks filled valley-like basins in the older rocks. The Mesozoic rocks occur topographically higher than the Neogene beds that crop out almost at sea level ; strata of the latter dip only slightly and are almost horizontal in attitude. This situation suggests that the Mesozoic rocks had cropped out of the sea and controlled the sedimentation of Neogene strata. The mytilid fossils occur from coarse-grained sandstone of the Meshikuni Formation along

the beach (Loc. Ms-1 and 2), and indicate a shallow to intertidal environment.

Figure 6 shows the geologic map of the northeastern part of the island. The Mesozoic Nairo Formation occurs in the northeastern part of the mapped region, and controls the orientation of the peninsula. The Tertiary Meshikuni Formation occurs in the neighboring southwest area against the Nairo Formation. The Hamanaka Formation, which overlies the Meshikuni Formation, is not shown in the map, because the boundary between the two formations is concealed. It occurs in the western area of the mapped region (Nagao *et al.*, 1963). There are some faults striking NW-SE and NE-SW. They are inferred from lineations in aerial photographs and from the distribution of the boundary between the Nairo Formation and the Meshikuni Formation.

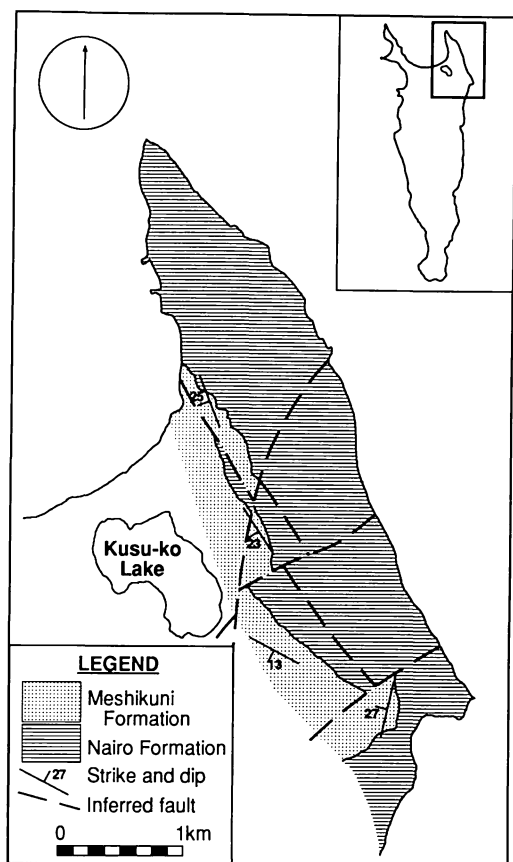


Figure 6. Geologic map of the northeastern part of Rebun Island.

Molluscan fauna from the Meshikuni Formation

Molluscan fossils obtained from the Meshikuni Formation are shown in Table 1, and their localities in Figure 7. Although the molluscan material is insufficient for statistic analysis, three types of molluscan assemblages corresponding to lithofacies can be recognized.

The first assemblage occurs with medium- to coarse-grained sandstone, and is represented by *Mytilus tichanovitchi* in association with pectinids and many fragments of "*Balanus*" species. These fossils occur sporadically and are not deformed (Loc. UF-1-5, Ms-1, 2).

The second assemblage is represented by "*Crassostrea*" *gravitesta* (Yokoyama) and *Glycymeris* species in association with *Turritella* species and *Laevicardium* cf. *shiobarense* (Yokoyama). These mollusks occur in siltstone with calcareous nodules and occasionally in pebbly sandstones. This assemblage is well exposed along the stream behind the Funadomari Shrine (Loc. Fd-1-5). "*Crassostrea*" *gravitesta* occasionally forms a shell bed like an oyster bank.

The last assemblage is observed at localities Tp-1 and 2, where fossils also occur in siltstone without pebbly sandstone. Fossil mollusks of this assemblage are represented by rather deep, muddy bottom dwellers such as *Lucinoma acutilineata* (Conrad) and *Macoma* species. This assemblage is very different from the other two in having no sandy-bottom dwellers.

On *Mytilus tichanovitchi* Makiyama

Specimens of *Mytilus tichanovitchi* from the Rebun were collected from coarse-grained sandstone at localities UF-3 and MS-2, the latter of which is near the type locality of the Meshikuni Formation. *Mytilus tichanovitchi* is one of the characteristic species of Early to early Middle Miocene faunas of the northwestern Pacific region. It is known from the Asahi, Fukuroji and Tokomuro Formations in Hokkaido (Uozumi, 1953; Uozumi, 1966; Uozumi and Akamatsu, 1988; Matsuno *et al.*, 1964; Ohara, 1966; Kanno *et al.*, 1968; Mizuno *et al.*, 1969), the Goyasu Formation in the Joban coal-field (O'Hara and Nemoto, 1982), the Kuluven and Ilyin Formations in Kamchatka and the Chekhov Formation in Sakhalin (Gladenkov *et al.*, 1984). Recently, *M. aff. tichanovitchi* was reported from the Lower Miocene Hota Group of the Boso Peninsula, central Japan (Sanada *et al.*, 1983). Radiolarians from the Hota Group have been assigned to the *Calocyclella costata* Zone of Riedel and Sanfillippo (1978) (Saito, 1992; S. Saito, personal communica-

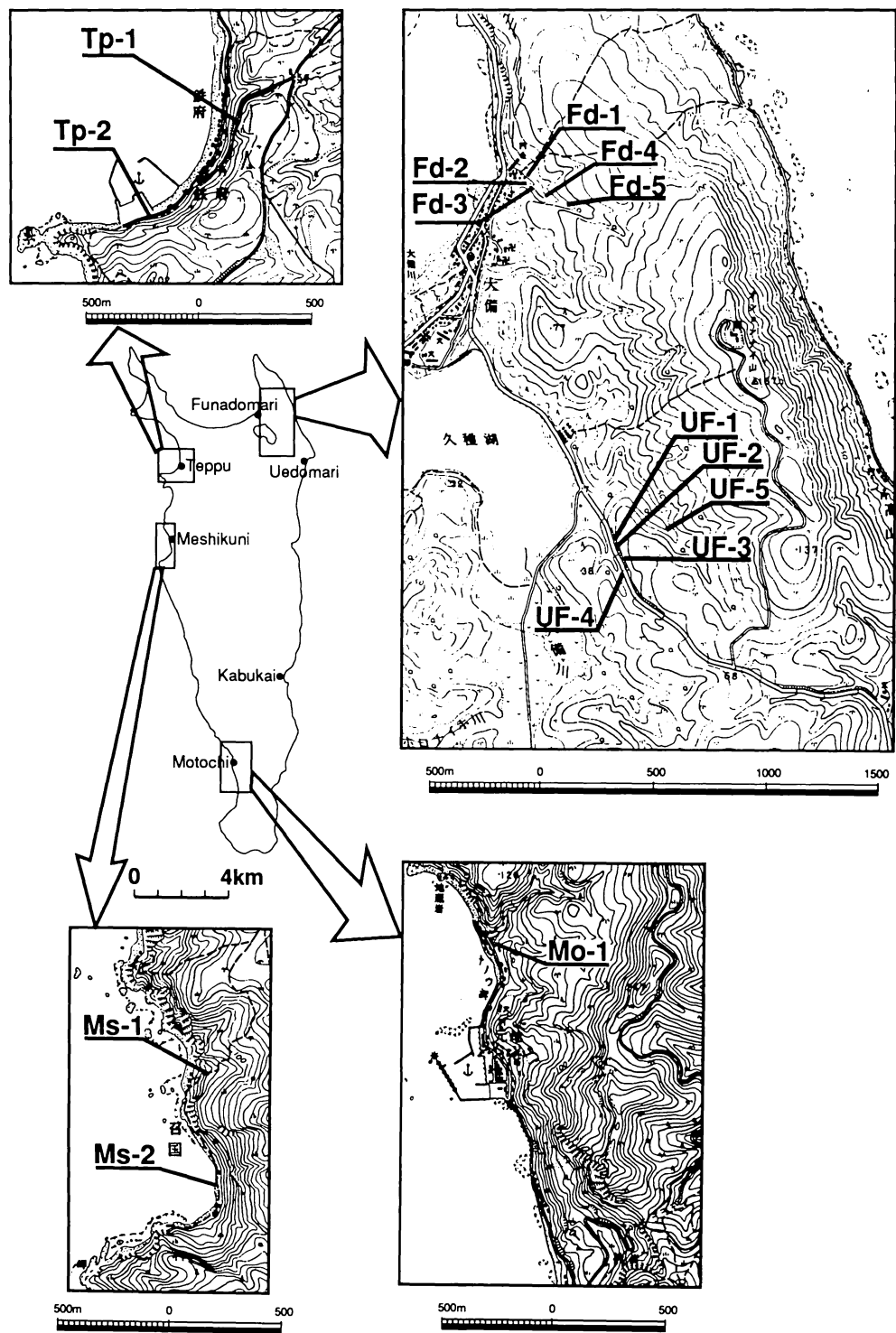


Figure 7. Maps showing localities of megafossils. Mo-1 is from the Motochi Formation. All remaining localities are of the Meshikuni Formation.

Table 1. List of megafossils collected from the Meshikuni and Motochi Formations. UF-, Fd-, Tp- and Ms-series are from the Meshikuni Formation. Mo-1 is from the Motochi Formation. Localities are shown in Figure 7.

Specific name	Localities	UF-1	UF-2	UF-3	UF-4	UF-5	Fd-1	Fd-2	Fd-3	Fd-4	Fd-5	Tp-1	Tp-2	Ms-1	Ms-2	Mo-1
Bivalvia																
<i>Acharax</i> sp.												+				
<i>Glycymeris cisshuensis</i> Makiyama						+										
<i>Glycymeris idensis</i> Kanno							+	+								
<i>Glycymeris</i> sp.									+							
<i>Mytilus tichanovitchi</i> Makiyama			+			+								+	+	
<i>Mytilus</i> ? sp.	+															
<i>Chlamys</i> aff. <i>ingeniosa</i> (Yokoyama)	+															
Pectinid gen. et sp. indet.	+		+			+										
" <i>Crassostrea</i> " <i>gravitesta</i> (Yokoyama)							+									
" <i>Ostrea</i> " sp.								+	+	+	+					
<i>Lucinoma acutilineata</i> (Conrad)												+				
<i>Laevicardium</i> cf. <i>shiobarensis</i> (Yokoyama)									+							
<i>Clinocardium shinjiense</i> (Yokoyama)																+
<i>Serripes</i> aff. <i>laperousii</i> (Deshayes)							+									
<i>Spisula</i> sp.			+													
<i>Megangulus imatsumotoi</i> (Otuka)	+															
<i>Macoma izurensis</i> (Yokoyama)													+			
<i>Macoma optiva</i> (Yokoyama)												+				
<i>Macoma</i> sp.	+	+										+				
<i>Macoma</i> ? sp.	+															
<i>Mya</i> sp.												+				
Bivalvia gen. et sp. indet.	+		+													
Gastropoda																
<i>Turritella</i> (<i>Hataiella</i>) cf. <i>sagai</i> Kotaka							+									
<i>Turritella</i> sp.												+				
" <i>Natica</i> " sp.	+		+										+			
<i>Nassarius</i> ? sp.			+													
<i>Neptunea</i> sp.																+
Barnacle																
" <i>Balanus</i> " sp.	+		+	+												

tion), which is Early Miocene in age.

The presence of *Mytilus tichanovitchi* in the Meshikuni Formation is important for paleobiogeographic reconstruction of the Early Miocene of the northwestern Pacific. Early Miocene marine strata, such as the Asahi Formation in the Yubari coal-field and the Sankebetsu Formation in the Haboro coal-field in Hokkaido, are characterized by mytilid bivalves. In Kamchatka and Sakhalin, several mytilid mollusks have been recorded from Miocene strata, and they seem to be consistent key markers for use in biostratigraphic correlation. The Kamchatkan mytilid assemblages are consistent in species composition, and the authors consider them to be arranged in ascending order as follows: the Early Miocene *Mytilus tichanovitchi*-*M. ochotensis*-*Modiolus wajampolkensis* assem-

blage, the early Middle Miocene *Mytilus chejsleveemensis*-*M. (Plicatomytilus) kaker-tensis*-*M. (P.) kavranensis* assemblage, and the Middle Miocene *Mytilus expansus*-*M. kawi*-*M. coalingensis* assemblage. *Plicatomytilus* species are also preserved in the so-called Middle Miocene in Hokkaido; the Kamikineusu and Furanui Formations in the Hidaka area, central southern Hokkaido. During the late Middle Miocene to Pliocene, mytilids such as *M. coruscus* Gould and/or *M. grayanus* Dunker, both of which are extant species, dwelled in Japan. In summary, the Japanese Neogene mytilid assemblages are represented, in ascending order, by the Early Miocene *Mytilus tichanovitchi*, by Middle Miocene *Plicatomytilus* species, and by Late Miocene-Recent species.

Discussion

The Meshikuni molluscan fauna is correlative with the Early Miocene Asahi fauna of central Hokkaido on the basis of the presence of *Mytilus tichanovitchi*. On the other hand, *Megangulus tmatumotoi*, *Macoma optiva* and *M. izurensis* are common in the Early Miocene Sankebetsu and Middle Miocene Chikubetsu faunas of northwestern Hokkaido, and the Chikubetsu fauna also includes *Clinocardium shinjiense* and *Lucinoma acutilineata* (Noda, 1992). Most Meshikuni faunal elements indicate a cool-temperate water condition, based on ecologic data of comparable living species of the same genera. However, "*Crassostrea*" *gravitesta* and *Glycymeris cisshuensis* suggest that relatively warm water influenced this area, and indicate a possibility of correlation with the Takinoue fauna of central Hokkaido, although typical warm species of the Takinoue fauna are not present in the Meshikuni fauna.

The Early Miocene Goyasu Formation in the Joban coal-field, Northeast Honshu, yields molluscan fossils from sandstone, and is correlative with the Meshikuni Formation on the basis of some distinctive species; *Mytilus tichanovitchi*, "*Crassostrea*" *gravitesta*, *Clinocardium shinjiense* and *Lucinoma acutilineata* (O'Hara and Nemoto, 1982, 1984).

No microfossils were obtained from the Meshikuni Formation. A K-Ar age of 18.2 ± 1.2 Ma from a dolerite outcrop beside Kusu Lake was reported by Goto and Wada (1991). The volcanism that produced the dolerite is thought to have been in activity at almost the same time as the deposition of the Meshikuni Formation, because the dolerite crops out as a dyke and a lava sheet within the Meshikuni Formation, although Goto and Wada (1991) stated that the volcanic rocks are unconformably overlain by the Meshikuni Formation. This information suggests that the Meshikuni Formation is

Early to Middle Miocene in age.

A few molluscan fossils of the Motochi Formation occur from a very coarse-grained sandstone (Loc. Mo-1), cropping out at the sea side cliff just behind the hotel near the Menou Coast on the southern part of the island (Figure 7). Nagao *et al.* (1963) reported *Chlamys* sp., *Patinopecten* sp., *Japellion* sp., *Neptunea oomurai* Otuka and *Psephaea* sp. from the same locality. This assemblage seems to be equivalent to the early Middle Miocene Chikubetsu fauna. Although there are no species in common between the Meshikuni and Motochi Formations, these two formations are considered tentatively to be of the same age.

The volcanoclastic Kabuka Formation was considered to be a local facies of the Meshikuni Formation by Nagao *et al.* (1963). It consists of conglomeratic and hyaloclastic sediments, and is quite different from the Meshikuni Formation. It unconformably overlies the Motochi Formation and underlies the Hamanaka Formation. As mentioned above, the Motochi Formation is considered to be the same age as the Meshikuni Formation, which suggests that the Kabuka Formation should be treated as a separate stratigraphic unit.

Conclusion

The Meshikuni molluscan fauna may be divided into three assemblages, two of which have shallow marine elements and one of which has rather deep-water elements. The first assemblage is characterized by *Mytilus tichanovitchi*, which indicates that it is suitable to correlate the Meshikuni Formation with the Early Miocene Asahi fauna of central Hokkaido. The Meshikuni fauna is a cool-temperate water fauna and is also correlative with the Sankebetsu and Chikubetsu faunas of the Haboro coal-field, northwestern Hokkaido.

The presence of *Mytilus tichanovitchi* in the Meshikuni Formation is important for

understanding phylogenic and systematic problems of mytilid mollusks and understanding the origin and migration of Miocene mollusks in the North Pacific.

The Motochi Formation seems to be a southern equivalent of the Meshikuni Formation, although it contains very few fossils.

Description

Turritella (Hataiella) cf. sagai Kotaka, 1951

Figures 8-1a-b

Compared with.—

Turritella s-hataii sagai Kotaka, 1951, p. 87-88, pl. 12, figs. 13-17

Description.—Shell large, turreted, with more than eight whorls. Whorl profile a little convex, with rounded shoulder developed at abapical part (J-type of Ida, 1952). Suture impressed. Whorls sculptured with seven to eight spiral cords, and growth lines near aperture; spiral cords distinct in notations (u C t6 B s4 A3 r5 r1) in adult; in young stage, spiral u obsolete and the area abapical to spiral C rather excavated; primary spirals flat-topped, and rather quadrate in section; secondary spiral t narrower than interspaces. Base ornamented by two spiral cords of which adapical one is primary spiral D. Growth line of double-arched type; antispirally directed sinus medium in depth and at the point of spiral s; spirally directed sinus at the point of spiral D or sutural; growth-line angle almost zero degree or minus. Apex and protoconch unknown. Aperture oval in shape, not angulated. Apical angle about 16 degrees.

Remarks.—Only one specimen was examined. This *Turritella* species is the first discovered from Rebun Island. The shell has a rather large size compared with hitherto reported Miocene *Turritella* in Hokkaido.

This specimen is closely related to *Turritella (Hataiella) sagai* Kotaka in having similar strength of spiral cords, spiral notation and

growth lines, but the shortage of the number of specimens prevents a firm determination. It is similar to *T. shataii* Nomura, *T. inflariata* Nagao and *T. tighilana* Ilyina, but is distinguished by different notation and larger shell. *Turritella kadosawaensis* Otuka is also similar to the present specimen in regard to the growth lines, but differs in having different spiral notation.

Turritella (Hataiella) sagai was originally described from the Miocene Togari Formation of central Japan (Kotaka, 1951); subsequently, it has been reported mainly from various strata of central Japan and also from the Bear Lake Formation of Alaska Peninsula (Marincovich and Kase, 1986).

Dimensions.—Height 72.4 mm. Width of body whorl 24.5 mm (IGPS coll. cat. no. 102493).

Glycymeris cisshuensis Makiyama, 1926

Figures 8-2a-c, -3, -4

Glycymeris cisshuensis [sic] Makiyama, 1926, p. 155-156, pl. 13, figs. 2-3; Nagao, 1928, p. 29-30, pl. 2, figs. 1-3, pl. 3, figs. 1-3, pl. 4, figs. 22-25.

Glycymeris cisshuensis Makiyama. Nomura and Hatai, 1937, p. 125, pl. 17, fig. 7. Itoigawa, 1956, pl. 2, fig. 1; Araki, 1960, p. 79-80, pl. 5, figs. 7a-c, 8; Kanno, 1960, p. 207-208, pl. 31, figs. 34-35; Hashimoto, 1961, p. 81-82, pl. 9, figs. 3-6; Kamada, 1962, p. 62-63, pl. 3, figs. 1-3; Okamoto and Nakano, 1963, p. 532-536, pl. 57, figs. 1-3, text-figs. 2-4; Iwasaki, 1970, p. 393-394, pl. 4, figs. 6-7; Itoigawa in Itoigawa *et al.*, 1974, p. 57-58, pl. 5, figs. 1-5; Takahashi and Nishida, 1974, p. 18, pl. 1, figs. 1-10; Itoigawa *et al.*, 1981, pl. 3, figs. 3a-b, 1982, p. 25-26; Tsuru, 1983, p. 53-54, pl. 8, figs. 13-16, pl. 9, figs. 1-2; Fuse and Kotaka, 1986, pl. 17, figs. 18-19.

Glycymeris vestitoides Nomura, 1935, p. 33-34, pl. 5(4), figs. 4-7; Nomura and Onisi, 1940, p. 182, pl. 18, fig. 7; Otuka, 1940, p. 92-93, pl. 11, fig. 4; Mizuno, 1964, pl. 3, fig. 12; Mizuno, 1965, p. 331, pl. 1, figs. 9-11; Ogasawara, 1973, p. 148, pl. 12, fig. 14; Suzuki *et al.*, 1983, pl. 2, fig. 5.

Glycymeris cisshuensis var. *compressa* [sic] Nagao, 1928, p. 30, pl. 3, figs. 25, 25a-c.

Glycymeris (Veletuceta) cisshuensis Makiyama. Matsukuma, 1986, p. 90, pl. 5, figs. 7-8.

Description.—Shell medium to large in size,

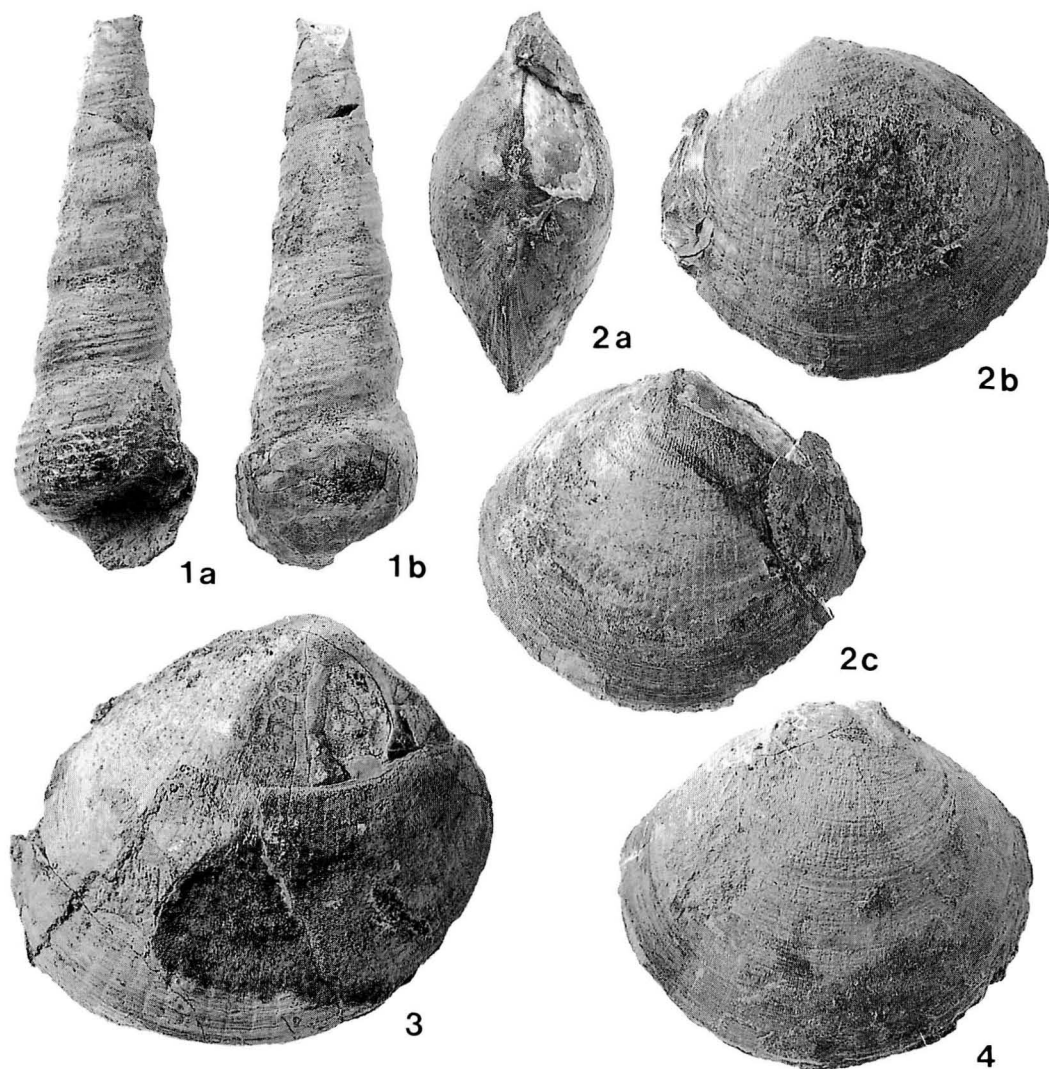


Figure 8. 1a-b. *Turritella* (*Hataiella*) cf. *sagai* Kotaka, $\times 1$, IGPS coll. cat. no. 102493, Loc. Fd-1, Meshikuni Formation. 2-4. *Glycymeris cisshuensis* Makiyama, $\times 1$, IGPS coll. cat. nos. 102494-4, -1 and -2, Loc. Fd-1, Meshikuni Formation, 2a: Dorsal view of intact valves, 2b: Left valve, 2c: Right valve, 3: Right valve of intact valves, 4: Right valve of intact valves.

ventricose, transversely oval in outline, longer than high, slightly inequilateral, equivalve, and with thick test; posterior part a little longer than anterior. Beak orthogyrate. Anterodorsal margin slightly convex and passing into regularly rounded anterior margin; posterodorsal margin a little convex and more descending than anterodorsal or equal;

ventral margin smoothly rounded with both anterior and posterior margins. Surface of shell sculptured with more than 30 radial ribs and incremental growth lines, which sometimes making cancellate ornamentations; radials flat-topped, much wider than interspatial grooves, becoming obscure near both anterior and posterior margins, and with four

or more numbers of fine threads on the top of themselves of well-preserved surfaces. Inner structure and hinge unknown.

Remarks.—Seven specimens occurred from a calcareous nodulous hard block of siltstone containing the bank-forming "*Crassostrea*" *gravitesta* (Yokoyama). All valves are intact, and inner characters are not observed. However, such characters as their thick tests, ventricose shells, surface sculptures of ribs and fine threads on ribs are identical with those of *Glycymeris cisshuensis* Makiyama. Two of the specimens show very inequilateral shells, but this is considered to be intra-specific variation.

Glycymeris cisshuensis was originally described by Makiyama (1926) from the Miocene of Korea (Mankodo Formation), and has been reported from various localities in Japan. But some of these occurrences may be of species other than *G. cisshuensis*, as already stated by Itoigawa *et al.* (1982). Matsukuma (1986) thought that *G. vestitoides* Nomura, reported from Miocene strata in Northeast Honshu and Hokkaido, is synonymous with the present species, and the authors agree with him.

This species can be distinguished from the Recent species *G. yessoensis* (Sowerby) and *G. vestita* (Dunker) and the fossil species *G. idensis* Kanno by having a thicker test and more convex shells. Gladenkov *et al.* (1984) stated that *Glycymeris slodkewitschi* Sinelnikova differs from *G. cisshuensis* in the presence of chevrons on the cardinal area. Adding to that, this species has a more shouldered shell shape than *G. slodkewitschi*.

Glycymeris cisshuensis is known from the Oligocene of Kyushu and from the Miocene of Japan and Korea.

Dimensions (in mm.).—

IGPS coll. cat. no.	Length	Height	Thickness	
102494-1	64.3	52.2	11.6	Right valve (Loc. Fd-1)
102494-1	65.5	57.0	18.3	Left valve (Loc. Fd-1)
102494-2	56.4	49.3	28.8	Both valves (Loc. Fd-1)
102494-3	39.8	33.8	19.6	Both valves (Loc. Fd-1)
102494-4	51.8	46.0	26.0	Both valves (Loc. Fd-1)

Distribution.—Oligocene: Yamaga, Sakamizu and Wakita Fms. (Formations), Ashiya G. (Group), Chikuhō Coal-field; Yukiaino Sandstone, Kishima G. and Kyoragi and Yoshinotani Fms., Ouchi G., Karatsu Coal-field; Funatsu Fm., Takashima Coal-field; Tochinoura and Kakinoura Fms. (Maze Fm.), Nishisonogi G., Sakito-Matsushima Coal-field. All in Kyushu Island. Miocene: Mankodo Fm., North Korea (type locality); Yamato (Chikubetsu) Fm., northern Hokkaido; Kamikineusu Fm., central southern Hokkaido; Tanosawa and Nagane Fms., Aomori Pref.; Nishikurosawa and Senosawa Fms., Akita Pref.; Moniwa and Nanakita Fms., Miyagi Pref.; Taira and Kubota Fms., Fukushima Pref.; Itahana Fm., Gunma Pref.; Ushikubitoge Fm., Saitama Pref.; Mizunami G., Gifu Pref.; Shiodani Sandstone, Tsuzuki G., Kyoto Pref.; Kaisekizan Fm., Mie Pref.; Togane Fm., Shimane Pref.; Kiwado and Taoyama Fms., Yamaguchi Pref.; Lower Fm., Taishu G., Tsushima Is., Nagasaki Pref.; Kadogawa Fm., Miyazaki Pref.

Glycymeris idensis Kanno, 1956

Figures 9-2, -3, -6

Glycymeris idensis Kanno, 1956, p. 267-268, pl. 38, figs. 1-5; Masuda and Takegawa, 1965, pl. 1, figs. 2-3; Mizuno *et al.*, 1969, pl. 28, fig. 10.

Glycymeris (*Glycymeris*) *idensis* Kanno. Amano, 1983, p. 41, pl. 2, fig. 7; Amano, 1986, p. 193-195, pl. 1, figs. 1a-b, 2a-b, 4.

Glycymeris i-idensis [*sic*] Kanno. Gladenkov *et al.*, 1984, p. 177-178, pl. 31, figs. 9-10.

Description.—Shell small to medium in size, equivalve, subequilateral to inequilateral, moderately convex; length almost equal to height, ratio of shell height to length is 0.84 to 1.12, average is 0.97; test rather thick. Beak situated almost center of shell length, not pointed and rounded. Both antero- and posterodorsal margins almost straight or a little convex; ventral margin regularly rounded. Surface ornamented by 27 to more

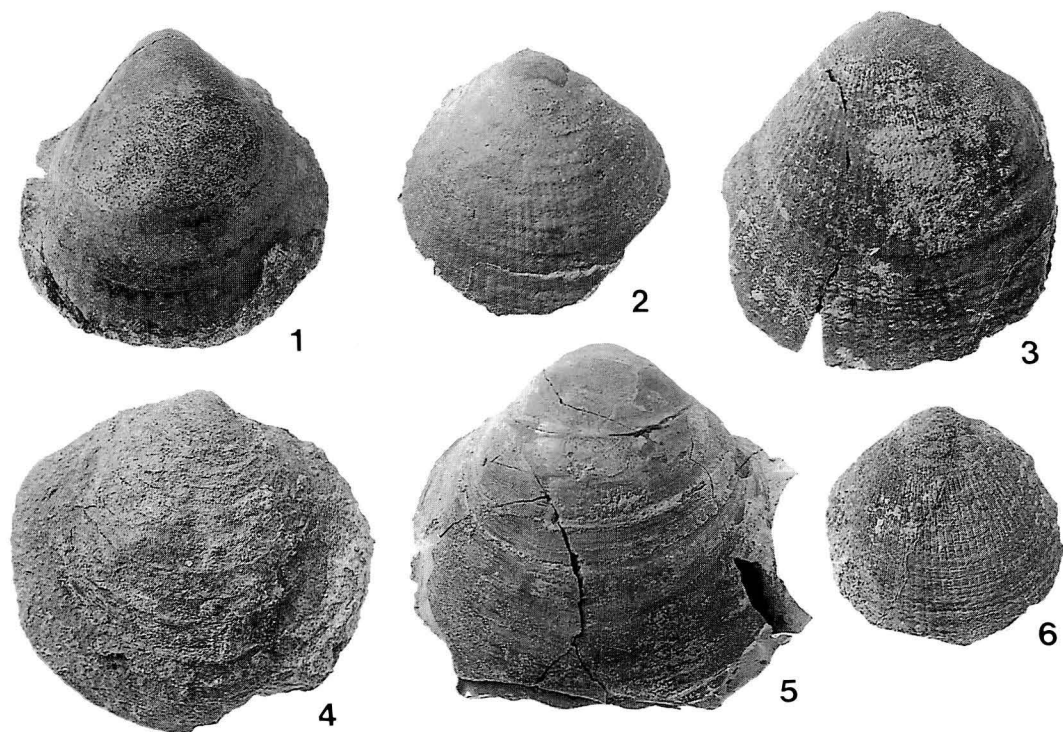


Figure 9. 1. *Clinocardium shinjiense* (Yokoyama), $\times 1.2$, right valve inner mold, IGPS coll. cat no. 102499, Loc. Mo-1, Motochi Formation. 2, 3, 6. *Glycymeris idensis* Kanno, $\times 1.2$, IGPS coll. cat. nos. 102495-1, -2 and -3, Loc. Fd-2, Meshikuni Formation. 4. *Lucinoma acutilineata* (Conrad), $\times 1$, right valve of intact valves, IGPS coll. cat. no. 102500, Loc. Tp-1, Meshikuni Formation. 5. *Serripes* aff. *laperousii* (Deshayes), $\times 1$, right valve, IGPS coll. cat. no. 102501, Loc. Fd-2, Meshikuni Formation.

than 35 radial ribs and crossing growth lines; ribs wider than interspatial shallow grooves, sometimes obsolete and invisible; concentric growth lines ventrally becoming dense and making more or less undulations. Interior margin crenulated. Ligamental area sculptured with 6 to 7 chevron shaped grooves.

Remarks.—About 20 specimens from the Meshikuni Formation were examined. Some of the Meshikuni specimens have a greater number of radial ribs than the type specimen, but they are included in the species variation. Amano (1986) studied the specimens from the Upper Miocene Ishiizawa Formation of eastern Hokkaido, and subdivided them into two morphological types according to shell shape. Type 1 is a com-

mon shape with a rather inflated and suborbicular shell, and type 2 has a moderately inflated and longitudinally ovate shell shape. There exist both types 1 and 2 in the specimens at hand.

Glycymeris chitanii Yokoyama (Yokoyama, 1929; as *Glycimeris chitanii*) from the Bor Formation of Sakhalin is similar to the present species in its shape, but is distinguished from the present species in having a more rounded and equilateral shell, and more numerous radials (about 50 in number). *Glycymeris yessoensis* (Sowerby) greatly resembles the present species, but has a thinner shell and more numerous radial ribs (about 40 in number).

Dimensions (in mm).—

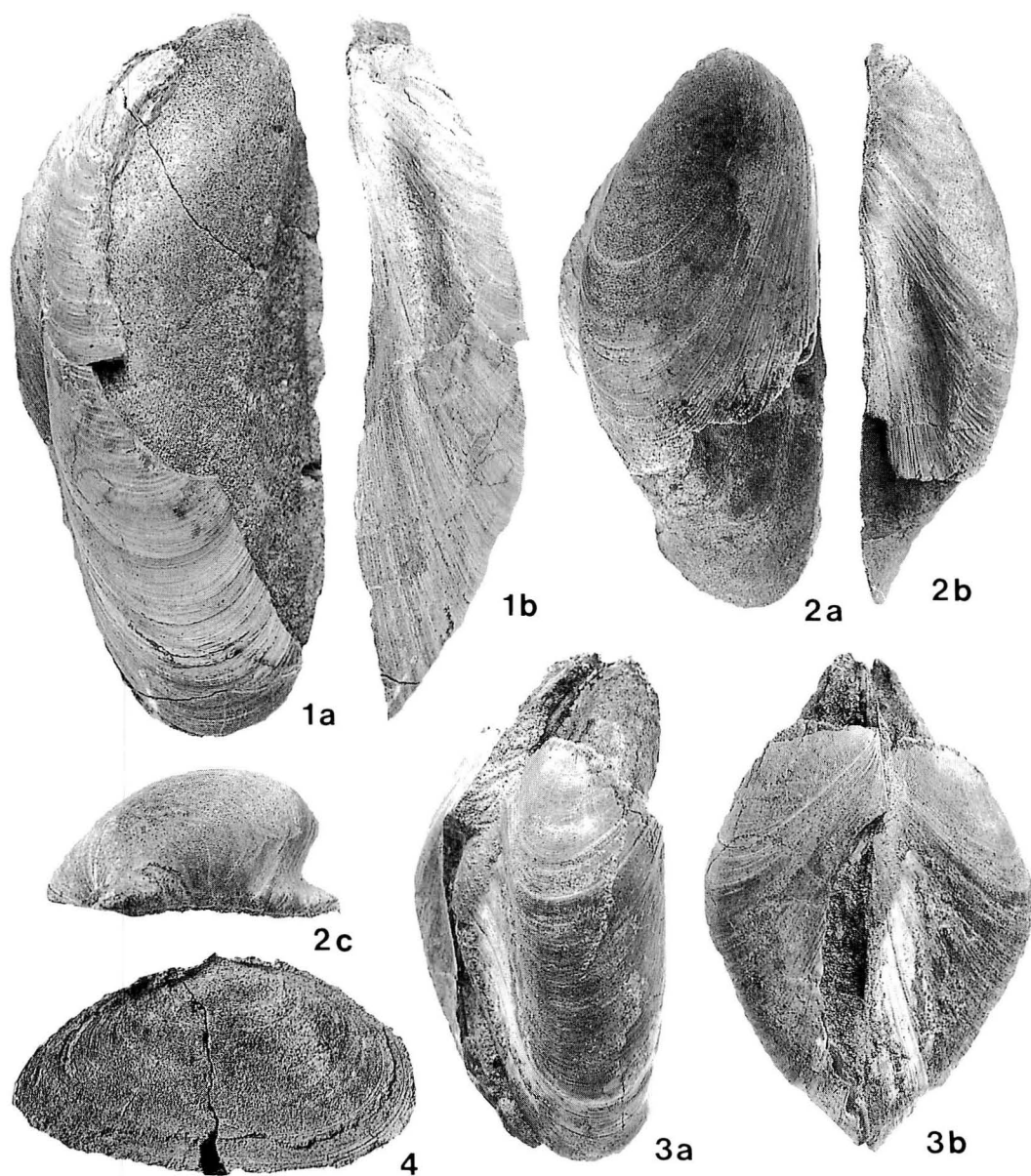


Figure 10. 1-3. *Mytilus tichanovitchi* Makiyama, $\times 1$, IGPS coll. cat. nos. 102497-3, -2 and -1, Loc. UF-3, Meshikuni Formation, **1**: Right valve; **a**: Side view; **b**: Dorsal view, **2**: Right valve; **a**: Side view; **b**: Dorsal view; **c**: View from beak, **3a**: Side view of intact valves, **3b**: Dorsal view of intact valves. **4**: *Megangulus imatsumotoi* (Otuka), $\times 1$, Left valve, outer mold, IGPS coll. cat.no.102502, Loc. UF-1, Meshikuni Formation.

IGPS coll. cat. no.	Length	Height	Thickness	
102495-1	30.5	29.2	6.0	Left valve (Loc. Fd-2)
102495-2	ca.40	39.0	6.9	Right valve (Loc. Fd-2)
102495-3	27.3	25.3	6.2	Right valve (Loc. Fd-2)
102496	43.4	41.8	9.8	Left valve (Loc. Fd-3)

Distribution.—Miocene: Yoshigasawa Fm., Miyagi Pref. (type locality); Togeshita and Atsunai (Ishiizawa) Fms., Hokkaido; Kanagase Fm., Miyagi Pref.; Kakert Fm., western Kamchatka.

Mytilus tichanovitchi Makiyama, 1934

Figures 10-1a-b, -2a-c, -3a-b

Mytilus tichanovitchi Makiyama, 1934, p. 134-135, pl. 4, figs. 11-12; Uozumi, 1953, p. 25, pl. 22, figs. 175a-b; Matsuno *et al.*, 1964, pl. 11, figs. 5-6; Uozumi, 1966, p. 129-130, pl. 9, figs. 2-4, 8; Kanno *et al.*, 1968, p. 8-9, pl. 1, figs. 4-6; O'Hara and Nemoto, 1982, pl. 1, figs. 5-8; Uozumi and Akamatsu, 1988, p. 332-333, pl. 3, figs. 2, 5, 7, pl. 5, figs. 1-5.

Mytilus tichanovitchi [sic] Makiyama. Gladenkov *et al.*, 1984, p. 181, pl. 33, fig. 4, pl. 54, fig. 11.

Description.—Shell medium to large in size, equivalve, very inequilateral, very elongate trigonal in outline, thick tested, and with distinct dorsal wing. Beak terminal and blunt. Anterodorsal margin narrowly rounded, making a gentle angle with ventral margin; ventral margin nearly straight or slightly concave; anterodorsal slightly convex; posterior margin rounded. Dorsal wing long but not wide, situated from the corner of anterodorsal and dorsal margins to the point about 3/5 posterior of shell length, making a deep groove-like concavity with overhanging dorsal slope. The peak of the umbonal ridge at about the middle of shell length or a little anteriorly. Ventral slope smooth or slightly depressed. Surface ornamented with distinct concentric lines of growth and stair-like undulations. Margin smooth. Inner surface with radial striations along margins. Two anterior byssal retractors, small, situated along the umbonal ridge. Muscle scars unknown.

Remarks.—Three well-preserved specimens

and several inner and outer molds were examined. One of them (Figures 10-2a-b) is identical with the specimens of Uozumi (1966) from the Asahi Formation in central Hokkaido.

Subgenus *Tumidimytilus* Kafanov, 1984 was proposed on the basis of *M. tichanovitchi* as the type species, but there are no descriptions of inner structures except the dental area and ligaments. The two small anterior byssal retractors of this species have not been observed before; they remind us of the inner structure of subgenus *Plicatomytilus* Allison and Addicott, 1976, which apparently has anterior byssal retractors. These retractors suggest that *Tumidimytilus* is closely related to *Plicatomytilus*.

This species is easily distinguished from *Mytilus* (*Plicatomytilus*) species from Miocene strata of the North Pacific region by not having plicate folds on the ventral and/or posterior part of the valve or a wavy plane of commissure, and it also differs from the recent *Mytilus* species by its remarkably hunch-backed shell shape and overhanging dorsal slope of shell.

Mytilus ochotensis (Slodkewitsch) from the Kuluven and Ilyin Formations of western Kamchatka and the Chekhov Formation of Sakhalin is very similar to this species in the general outline of the shell and its hunch-backed shell form, but differs in having a more posteriorly situated dorsal wing and less overhanging dorsal area than the latter. *Mytilus chejsleveemensis* Slodkewitsch from the Kakert Formation of Kamchatka (Slodkewitsch, 1938) is another related species, but has a shorter and much more inflated shell with a smaller dorsal wing than *M. tichanovitchi*. *Mytilus tichanovitchi* is also related to *M. furanuiensis* Uozumi and Akamatsu from the Furanui Formation and *M. shunbetsuensis* Suzuki and Uozumi (Suzuki *et al.*, 1983) from the Kamikineusu Formation, both in Hokkaido, but *M. furanuiensis* has a dorsal plication between the dorsal wing and dorsal slope and *M. shunbetsuensis*

has a more elongate and less inflated shell.

M. ksakurai Nomura and Hatai from the Isomatsu Formation of the Tsugaru Peninsula, northern Honshu (Nomura and Hatai, 1936) was once considered to be a synonym of the present species (Kanno *et al.*, 1968), but the former has a rather small shell and co-occurs with *M. (Plicatomytilus) hidakensis* Suzuki and Uozumi (Noda and Motoyama, 1991) originally described from the Kamikineusu Formation (Suzuki *et al.*, 1983), and the authors are inclined to identify *M. ksakurai* as a juvenile form of *hidakensis*.

Dimensions (in mm.).—

IGPS coll. cat. no.	Length	Height	Thickness	
102497-1	67.4	ca.29	45.4	Both valves (Loc. UF-3)
102497-2	76.1	37.0	19.8	Right valve (Loc. UF-3)
102497-3	97.6	45.9	26.3+	Right valve (Loc. UF-3)
102498-1	67.0	ca.33	15.2	Left valve (Loc. Ms-2)
102498-2	50.8	28.0	ca.12.5	Left valve (Loc. Ms-2)

Distribution.—?Oligocene: Machigar Fm. (?), North Sakhalin (type locality). Miocene: Kuluven and Ilyin Fms., western Kamchatka; Chekhov Fm., South Sakhalin; Asahi (Horomui) and Tokomuro Fms., Hokkaido; "Goyasu" Fm., Fukushima Pref.

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Anama アナマ, Funadomari 船泊, Furanui フラヌイ, Hamanaka 浜中, Kabuka 香深, Kamikineusu 上杵臼, Kusu 久種, Kusuko 久種湖, Meshikuni 召国, Meshikuni Formation メシクニ層, Motochi 元地, Nairo 内路, Rebun 礼文, Uedomari 上泊, Teppu 鉄府.

北海道北部, 礼文島の中新統メシクニ層の貝化石群: 礼文島北部に分布する中新統メシクニ層から産出した貝化石群には, 三つの群集が認められた。一つは *Mytilus tichanovitchi* に代表される群集で, 二つめは "*Crassostrea*" *gravitesta* と *Glycymeris* spp. の群集であり, ともに浅海であり, ともに浅海の砂底群集である。第三の群集は *Lucinoma* 等のやや深い泥底群集である。*Mytilus tichanovitchi* は北海道をはじめサハリンやカムチャッカでも報告されており, メシクニ層からの産出は北太平洋地域の *Mytilus* の時空分布を考える上で重要である。メシクニ層は *Mytilus tichanovitchi* の産出によって北海道中央部の朝日層と対比できるとともに, その化石内容からは, 羽幌地域の築別・三毛別動物群に対比可能である。

野田芳和・保柳康一

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◎1994 年例会(第 143 回例会)は、熊本大学理学部で 6 月後半に開催の予定です。講演申込は 4 月 30 日(必着)です。講演申込と予講集原稿の書き方については、「化石」54 号をご覧ください。

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