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THE DISAPPEARANCE OF THE *COSCINODISCUS YABEI* ZONE IN THE SUBARCTIC HOKKAIDO REGION

by

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(with 4 text-figures, 1 table and 1 plate)

Abstract

The overlapped ranges of *Denticulopsis praedimorpha* and *Denticulopsis dimorpha*, which belong to the same evolutionary lineage, were firstly recognized in the subarctic section of Hokkaido. The stratigraphic distribution of some diatom species around the boundary between the middle and late Miocene reveals diachronous distribution across the subarctic front by the effect of a "climatic wedge."

Introduction

Both *Denticulopsis praedimorpha* and *Denticulopsis dimorpha* belong to the same evolutionary lineage (e. g. Maruyama, 1984). These two cool-water diatoms have the overlapped ranges at DSDP's Site 468 (32°37.41′N) and Site 469 (32°37′N) off southern California, but their ranges are separate at more southern Site 470 (28°54.46′N) and Site 472 (23°00.35′N) off Baja Clifornia (Barron, 1981). On the other hand, the stratigraphic levels of the last occurrence of *D. praedimorpha* and the first occurrence of *D. dimorpha* have been isolated in the northwestern Pacific region, and so *Coscinodiscus yabei* Zone is defined as the interval zone between these two datum levels (Koizumi, 1985).

It has been discussed that the stratigraphic distribution of some diatom datum levels reveals diachronic distribution across the subarctic boundary by the effect of "climatic wedge" (Koizumi, 1985, 1990). Critical examination of paleo-oceanographic history is also necessary for evaluation of biostratigraphic datum levels, because diatom provincialism is largely related to the distinct latitudinal zonality of surface water masses (Koizumi, 1986b).

This paper presents some diachronic datum levels and overlapped ranges of *D. praedimorpha* and *D. dimorpha* at the north-to-south transect of sections in the northwestern Pacific region.

Materials and Methods

Middle and late Miocene diatom assemblages have been quantitatively

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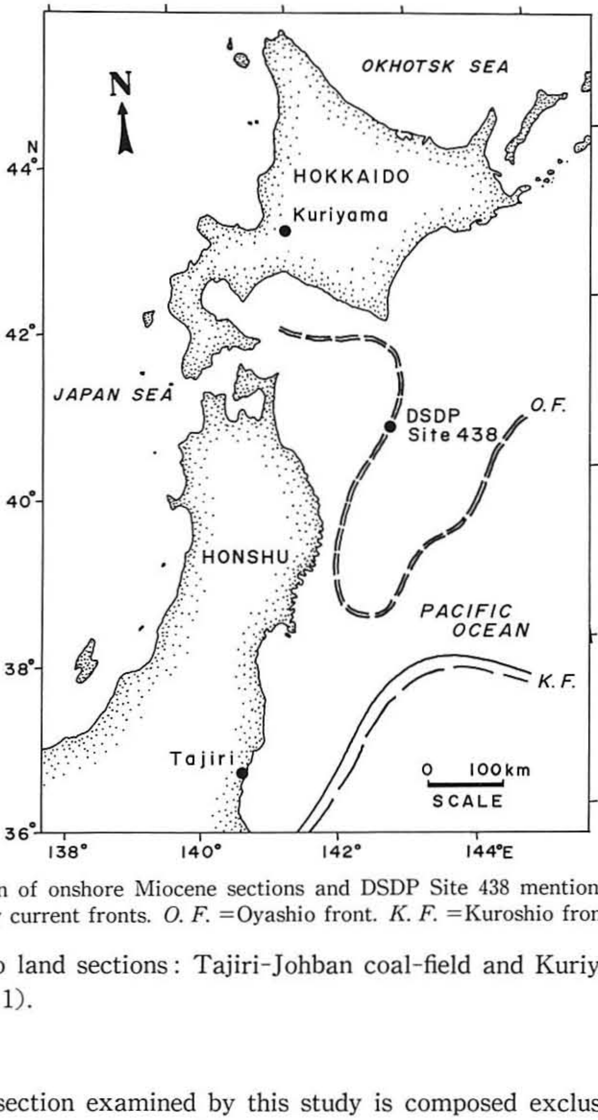


Txet-fig. 1 Location of onshore Miocene sections and DSDP Site 438 mentioned in the text, and the present day current fronts. *O. F.* =Oyashio front. *K. F.* =Kuroshio front.

examined in two land sections: Tajiri-Johban coal-field and Kuriyama-south Hokkaido (Text-fig. 1).

Tajiri section

The Tajiri section examined by this study is composed exclusively of the Kushigata Formation (Eguchi and Suzuki, 1953) in the road side cliff between Tajiri and Tajiri-hama. The Kushigata Formation consists mostly of massive, olive-green tuffaceous siltstone and mudstone, but intercalates some thin pumiceous tuff and sandstone. The mudstone in lower horizon includes some calcareous concretions and layers (Text-fig. 2).

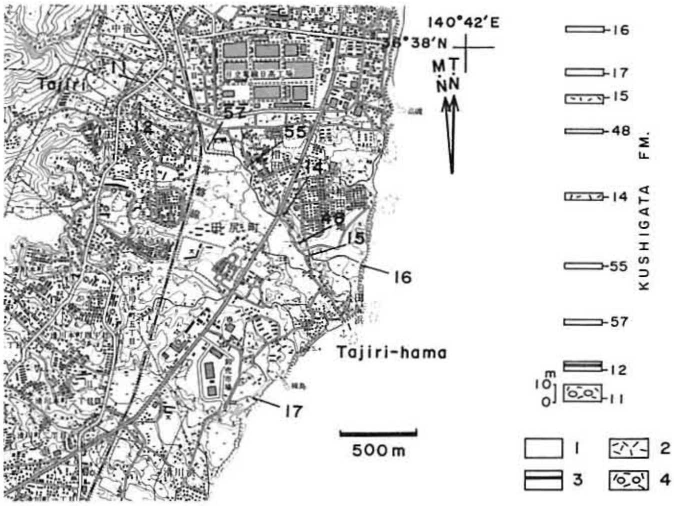
Kuriyama section

The Oiwake Formation (Sasa et al., 1964), which crops out along the Kurioka-gawa east of Kurioka, Kuriyama-cho, was examined by this study. The Oiwake Formation in the Kuriyama section consists mostly of massive, olive-green diatomaceous mudstone, but intercalates some thin sandstone (Text-fig. 3).

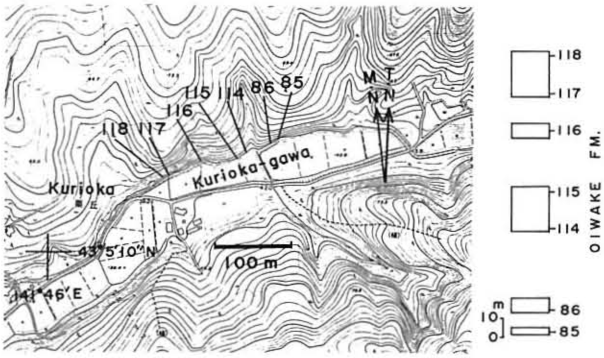
DSDP Site 438

The stratigraphic distribution of middle-late Miocene diatoms in DSDP Site 438 off northern Honshu, Japan is drawn from Maruyama (1984).

Original material was treated by hydrogen peroxide and hydro-chloric acid.



Text-fig. 2 Location and stratigraphic position of samples from the Tajiri section, Johban coal-section. A part of the 1 : 25,000 scale map of " Hitachi " published from Geological Survey Institute of Japan. 1=siltstone. 2=tuffaceous siltstone. 3=mudstone including calcareous layer. 4=tuffaceous mudstone including calcareous concretions.



Text-fig. 3 Location and stratigraphic position of samples from the Kuriyama section, South Hokkaido. A part of the reduction of the 1 : 2,500 scale map published from the town office of Kuriyama-cho, Hokkaido. Lithologic symbol is shown in Text-fig. 2.

Pleurax was used as a mounting medium. All diatoms were identified and counted until the number of individual reached 200 in each count at 1250× (Table 1).

Results

Tajiri section

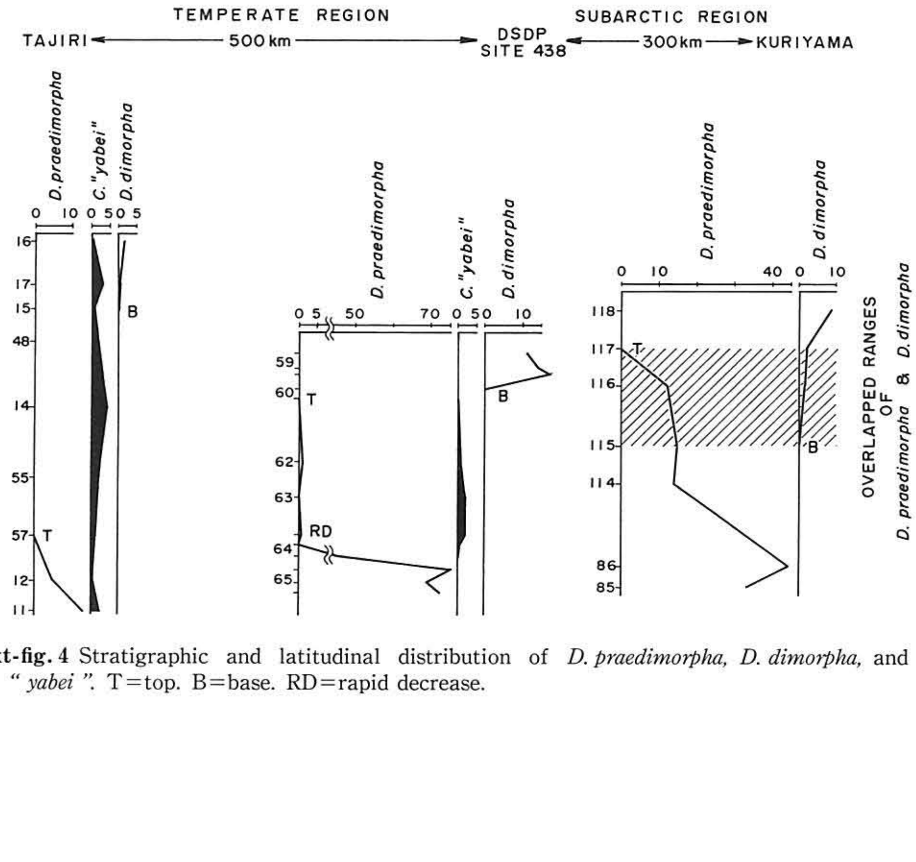
The Tajiri section is located in the southern part of the Johban coal-field facing the mixed water region between the Kuroshio and Oyashio front (Text-fig. 1).

The rapidly decreased last occurrence of *D. praedimorpha* is recognized at the interval between samples 12 and 57 in the lower part of the Kushigata Formation. On the other hand, the first occurrence of *D. dimorpha* is in the upper part of this formation (Text-fig. 4). As these two datum levels are separated, the interval is defined as the *Coscinodiscus yabei* Zone (Koizumi, 1985), which is characterized by the presence of abundant *Denticulopsis hustedtii,* few to rare *Actinocyclus ingens, Goniothecium tenue* and *Rouxia californica* (Table 1). *C. " yabei "* occurs in few to rare abundances throughout the interval (Text-fig. 4)

DSDP Site 438

DSDP Site 438 is located in the northern part of the mixed water region adjacent to the Oyashio front off northern Japan (Text-fig. 1).

The rapid decrease datum of *D. praedimorpha* occurs between samples 64-3 (10-14cm) and 63-1 (10-14cm). The last occurrence of *D. praedimorpha* is recognized in the interval between samples 62-1 (20-24cm) and 60-3 (27-29cm). The



Text-fig. 4 Stratigraphic and latitudinal distribution of *D. praedimorpha, D. dimorpha,* and *C. " yabei ".* T=top. B=base. RD=rapid decrease.

D. praedimorpha Zone occupies exclusively the occurrence of *C. " yabei "*. As the first occurrence of *D. dimorpha* is recognized in samle 59-5 (17-21cm), the interval between samples 60-3 (16-20cm) and 60-1 (34-38cm) is assigned to the *C. yabei* Zone. This zone is characterized by the occurrences of abundant *D. hustedtii,* common *A. ingens* and *G. tenue,* few to rare *R. californica,* and rare *C. " yabei "* by Barron (1980).

Kuriyama section

The Kuriyama section is situated about 40km east of Sapporo, Hokkaido and located in the subarctic region north of the Oyashio front (Text-fig. 1).

The overlapped occurrences of *D. praedimorpha* and *D. dimorpha* are recognized in sample 116 of the Oiwake Formation (Table 1 and Text-fig. 4). The last occurrence of *D. praedimorpha* is noticed with a rapid decrease level. Not only *C. " yabei "* but also such subtropic-temperate species as *Actinocyclus ellipticus, Hemidiscus cuneiformis* and *Thalassiosira leptopus* are not recognized throughout the section (Table 1). Their abundances are gradually decreasing into northern areas. On the other hand, such cool-water species as *A. ingens, Coscinodiscus marginatus, D. hustedtii, D. praedimorpha* and *G. tenue* occur abundantly throughout the Kuriyama section than southern sections.

Summary and discussion

The overlapped ranges of *D. praedimorpha* and *D. dimorpha,* which belong to a single evolutionary lineage (Maruyama, 1984), are recognized in the subarctic Kuriyama section of Hokkaido as well as in the northern area of the northeastern Pacific region by Barron (1981). Therefore, the *C. yabei* Zone, defined by these two cool-water diatom datum levels; namely the last occurrence of *D. praedimorpha* at its base and the first occurrence *D. dimorpha* at its top, disappears because of a later occurrence than 9.6Ma of *D. praedimorpha* and/or an earlier occurrence than 8.9Ma of *D. dimorpha* in the subarctic region. *C. " yabei "* and other temperate diatom species are decreasing in abundances into northern areas and they finally disappear throughout the Kuriyama section.

The effect of a " climatic wedge " (Gladenkov, 1988) has resulted in their diachronic distribution across the subarctic boundary as well as a decline of *Crucidenticula nicobarica* and an earlier occurrence of *D. praedimorpha* in the middle Miocene of the northern areas (Koizumi, 1990).

The diachronous nature of microfossils have been recognized not only in diatoms but also in planktonic foraminifera (Ingle, 1973: Keller and Barron, 1981) and molluscs (Gladenkov, 1987).

During the interval between middle and late Miocene, corresponding to *C. yabei* Zone, the pronounced abundances in both the cool-water diatom *D. hustedtii* and the upwelling-related diatom *Thalassionema nitzschioides* are recognized in the northeast Japan (Koizumi, 1990). These increases are associated with the in-

Table 1 Stratigraphic occurrences of the marine diatoms in the Tajiri section and Kuriyama section.

Samples	TAIJRI									KURIYAMA						
	Kushigata Fm.									Oiwake Fm.						
Species	11	12	57	55	14	48	15	17	16	85	86	114	115	116	117	118
Actinocyclus curvatulus								1	1							
A. ellipticus	1	1	1	1	2			1	5							
A. ingens	7	7	4	4	3	5	3	10	7	18	14	11	22	24	3	6
A. octonarius	1	3		1			1					1				
Actinoptychus senarius		8	4	10	1	12	1			2	5	8	7	11	8	10
Azpeitia endoi	1	2	1	2	1		1	6	2						3	1
A. nodulifer	1		1	1	1	3	2	1	9						3	2
A. vetustissima		1	2	3	4	1	2								1	1
Cladogramma californicum		1			1		1								1	
Cocconeis costata										1						1
C. disculus			1													
C. scutellum			1		1	1										
Coscinodiscus elegans	2	2	2		1	4	1	3		2	1	13	10	6	2	1
C. flexuosus	2		1	1	4	1		2								
C. marginatus	2	9	2	3	4	3	1	3	10	9	3	12	26	15	1	3
C. obscurus	1					1										
C. plicatus	2	1	1	3	2	2	1	4	2							
C. symbolophorus				1	1	1	1			1	1	2	2		1	1
C. temperei		1			2	1	1									
Crucidenticula punctata		1														
Denticulopsis dimorpha								1	3					3	4	17
D. hustedtii	17	2	48	56	47	52	31	36	49	50	45	45	29	21	53	52
D. hyalina					1			1		5	5	6	10	7	1	3
D. katayamae															4	15
D. miocenica	1											2	2			
D. praedimorpha	26	10								67	89	28	30	25		
D. sp. 1															6	3
Diploneis smithii							1									
Goniothecium tenue	4	9	2	8	7	5	2	3	1	13	7	8	10	6	19	4
Grammatophora spp.		2		2	1		1				1	1	2	1	1	
Hemiaulus polymorphus	1	1					1	1				1				1
Hemidiscus cuneiformis				1	1	1	1	2	2							
Hyolodiscus scoticus		1														
Kisseleviella carina											1	2	2	1		
Lithodesmium undulatum																1
Mediaria splendida	1									1	1	4	1	1		
Nitzschia challengeri				1	1									1	1	
N. heteropolica			1													
N. umaoiensis												1	1	1	3	
Odontella aurita		1														
Paralia sulcata		8	2	7	1		1			2	1	4				
Pseudodimerogramma elegans	1		1								2					
Pseudopodosira elegans									1							
Rhizosolenia alata					1											
R. barboi	1	1		1	1	1	1	1	2	1						2
R. hebetata f.		1		1	1											
R. miocenica		5	1		1			1					1			
R. styliformis		3	1	3	1		2		1			7	3	7	4	3
R. spp.				2	1	2				8	7			5		
Rouxia californica	1	1	2	8		2	1	2						9	2	
R. diploneis			3	1										6	3	
R. naviculoides								2								
R. yabei			2	1	1	1	1							3		
Stephanogonia hanzawae		3	1						1		1	4	2	1		
Stephanopyxis megapora		1	1													
S. schenckii		1											1			
S. turris		15	8	9	3	15	7	1	1	6	5	8	15	21	14	26
S. spp.										1	2		1	4		1
Synedra jouseana		1	3	3	3		2	1	1		1			3	1	1
Thalassionema hirosakiensis				12	6	13	3	21	12						6	6
T. nitzschioides	124	91	105	54	79	69	124	97	81	10	5	28	21	34	31	29
Thalassiosira leptopus	1				1	1	1	1	3							
T. manifesta		1	1		2	1					1	2	1	1	5	1
T. marujamica			1		1	1									4	1
T. sp. 1															1	
Thalassiothrix longissima	1	5	1	3	1	3	3			1	1	1	1	1	1	2
Triceratium condecorum	1		1		1					2	1	1				1
Total number of valves	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200

creased oceanic circulation and upwelling which was caused by polar cooling. In the equatorial Pacific Ocean, however, *D. hustedtii* disappeared by 11.0Ma and *Tn. nitzschioides* replaced *D. hustedtii* after 9.0Ma (Barron, 1985, 1986). These events coincide with a spike of climatic optimum; a rising of sea-level in the interval from 10.5Ma to 8.6Ma (Haq et al., 1987) and a decreasing in oxygen isotope values of the benthic foraminifers between 9.2Ma and 9.0Ma in DSDP Site 588 (Kennett, 1986). After 8.2Ma, the latitudinal provincialism in all planktonic groups and the latitudinal thermal gradient increased (Keller and Barron, 1983; Barron, 1986).

Acknowledgments

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Taxonomic notes and floral references

Actinocyclus curvatulus Janisch: Koizumi, 1973b, p. 831, pl. 1, figs. 1-6; Sancetta, 1982, p. 222, pl. 1, figs. 1-3.

Actinocyclus ellipticus Grunow: Hustedt, 1929, p. 533, fig. 303; Koizumi, 1975b, pl. 3, figs. 2, 3 (not fig. 1).

Actinocyclus ingens Rattray: Kanaya, 1959, p. 97, pl. 7, figs. 6-9; Koizumi, 1986a, pl. 1, fig. 20. **Synonym:** *Actinocyclus tsugaruensis* Kanaya, 1959, p. 99, pl. 8, figs. 5-8. [pl. 1, fig. 17]

Actinocyclus octonarius Ehrenberg: Andrews, 1980, p. 23, pl. 1, fig. 1, pl. 4, fig. 1. **Synonym:** *Actinocyclus ehrenbergi* Ralfs, Koizumi, 1973a, pl. 20, fig. 11.

Actinoptychus senarius (Ehrenberg) Ehrenberg: Sancetta, 1982, p. 225, pl. 1, fig. 7. **Synonym:** *Actinoptychus undulatus* (Baily) Ralfs, Koizumi, 1973a, pl. 20, figs. 1-3.

Azpeitia endoi (Kanaya) Sims and Fryxell in Fryxell et al., 1986, p. 16. **Synonym:** *Coscinodiscus endoi* Kanaya, Koizumi, 1986a, pl. 2, fig. 1.

Azpeitia nodulifer (Schmidt) Fryxell and Sims in Fryxell et al., 1986, p. 19, figs. 17, 18-1, 2, 4, 5, 30-3, 4. **Synonym:** *Coscinodiscus nodulifer* Schmidt, Koizumi and Tanimura, 1985, pl. 3, fig. 8.

Azpeitia vetustissima (Pantocsek) Sims in Fryxell et al., 1986, p. 16. **Synonym:** *Coscinodiscus vetustissimus* Pantocsek, Koizumi, 1986a, pl. 2, figs. 4, 5.

Cladogramma californicum Ehrenberg: Kanaya, 1959, p. 87, pl. 6, fig. 1; Koizumi, 1968, pl. 32, fig. 19.

Cocconeis costata Gregory: Hustedt, 1933, p. 332, fig. 785; Akiba, 1985, pl. 30, fig. 1.

Cocconeis disculus Schumann: Hustedt, 1933, p. 345, fig. 799.

Cocconeis scutellum Ehenberg: Hustedt, 1933, p. 337, fig. 790; Akiba, 1985, pl. 30, figs. 3, 11.

Coscinodiscus elegans Greville: Kanaya, 1959, p. 75, pl. 3, figs. 6, 7; Koizumi, 1986a, pl. 1, figs. 18, 19. [pl. 1, fig. 12]

Coscinodiscus flexuosus Brun: Schrader, 1973, p. 702, pl. 7, figs. 6, 7, 10-13, 15, 16. **Remarks:** Margin is flat and clearly defined. Marginal structure is separated from the valve structure by a hyaline area. [pl. 1, fig. 11]

Coscinodiscus marginatus Ehranberg: Hustedt, 1928, p. 416, fig. 223; Koizumi, 1968, pl. 33, figs. 3a-b. [pl. 1, fig. 14]

Coscinodiscus obscurus Schmidt: Hustedt, 1928, p. 418, fig. 224; Sheshukova-Poretzkaya, 1967, p. 164, pl. 23, fig. 1.

Coscinodiscus plicatus Grunow: Kanaya, 1971, p. 555, pl. 40.4, figs. 4-6; Koizumi and Tanimura, 1985, pl. 3, figs. 3, 4. **Remarks:** Margin is not separated from the valve structure. Small spines present between the marginal striae. [pl. 1, fig. 13]

Coscinodiscus symbolophorus Grunow: Schrader, 1973, p. 703, pl. 22, figs. 8, 9; Koizumi, 1986a, pl.

1, fig. 12.

Coscinodiscus temperei Brun: Kanaya, 1959, p. 84, pl. 4, fig. 8; Koizumi, 1968, pl. 32, fig. 28.

Crucidenticula punctata (Schrader) Akiba and Yanagisawa, 1985, p. 487, pl. 2, figs. 8-14.

Denticulopsis dimorpha (Schrader) Simonsen: Akiba and Yanagisawa, 1985, p. 448, pl. 15, figs. 1-25, pl. 16, figs. 1-11; Koizumi and Tanimura, 1985, pl. 1, fig. 1. [pl. 1, figs. 4, 5]

Denticulopsis hustedtii (Kanaya and Simonsen) Simonsen: Akiba and Yanagisawa, 1985, p. 488, pl. 17, figs. 4, 5, 7-23, pl. 18, figs. 1-10, pl. 19, figs. 1-5; Koizumi and Tanimura, 1985, pl. 1, figs. 7, 8. [pl. 1, fig. 6]

Denticulopsis hyalina (Schrader) Simonsen: Akiba and Yanagisawa, 1985, p. 488, pl. 10, figs. 1-16, pl. 12, figs. 1-5; Koizumi and Tanimura, 1985, pl. 1, fig. 3. [pl. 1, fig. 1]

Denticulopsis katayamae Maruyama, 1984, p. 158, pl. 12, figs. 1-6, pl. 17, figs. 1-23; Koizumi and Tanimura, 1989, pl. 1, fig. 12. [pl. 1, fig. 8]

Denticulopsis miocenica (Schrader) Simonsen: Akiba and Yanagisawa, 1985, p. 489, pl. 10, figs. 17-23, pl. 12, figs. 6-9; Tanimura, 1989, fig. 3. 18, 19.

Denticulopsis praedimorpha (Akiba) Barron, 1981, p. 529, pl. 4, figs. 8-10; Akiba and Yanagisawa, 1985, p. 489, pl. 13, figs. 1-28, pl. 14, figs. 1-12; Koizumi and Tanimura, 1985, pl. 1, fig. 2. [pl. 1, figs. 2, 3]

Denticulopsis sp. 1: **Synonym:** Koizumi and Matoba, 1989, pl. 1, fig. 13 an *Denticulopsis* sp. **Remarks:** This species has transitional features from *D. hustedtii* to *D. katayamae* which belong to a single evolutionary lineage. This species is similar to *D. katayamae* but differs from it by having sporadical areolation on valve face. [pl. 1, fig. 7]

Diploneis smithii (Brebisson) Cleve: Hustedt, 1937, p. 647, fig. 1051.

Goniothecium tenue Brun: Koizumi, 1973b, p. 833, pl. 7, figs. 7-9. [pl. fig. 9]

Grammatophora spp. **Remarks:** At least the following species are represented but their occurrences are not specifically tabulated; *G. angulosa* Ehrenberg (Hustedt, 1937, p. 39, fig. 564), *G. arcuata* Ehrenberg (Hustedt, 1937, p. 42, fig. 567) and *G. oceanica* (Ehrenberg) Grunow (Hustedt, 1937, p. 45, fig. 573).

Hemiaulus polymorphus Grunow: Hustedt, 1930, p. 880, fig. 525; Schrader, 1937, pl. 13, figs. 4-7.

Hemidiscus cuneiformis Wallich: Kanaya, 1971, pl. 40.3, figs. 5, 6; Koizumi and Tanimura, 1985, pl. 5, fig. 12.

Hyalodiscus scoticus (Kutzing) Grunow: Hustedt, 1928, p. 293, fig. 133.

Kisseleviella carina Sheshukova-Poretzkaya, 1962, p. 207, figs. 1, 2; Koizumi, 1973b, pl. 7, figs. 3,4.

Lithodesmium undulatum Ehrenberg: Hustedt, 1930, p. 789, fig. 461; Hendey, 1964, p. 111, pl. 6, fig. 6.

Mediaria splendida Sheshukova-Poretzkaya, 1962, p. 210, figs. 2, 5; Koizumi, 1973b, pl. 7, figs. 5, 6.

Nitzschia challengeri Schrader, 1973, p. 707, pl. 5, figs. 10-14, 34; Barron, 1980, pl. 2, fig. 10.

Nitzschia heteropolica Schrader, 1973, p. 707, pl. 26, figs. 1, 2; Akiba, 1985, pl. 23, fig. 3.

Nitzschia umaoiensis Akiba, 1985, p. 440, pl. 23, figs. 1, 2.

Odontella aurita (Lyngbye) Agardh: Sancetta, 1982, p. 234, pl. 3, fig9. 11, 12; Koizumi, 1989, fig. 23.

Paralia sulcata (Ehrenberg) Cleve: Sancetta, 1982, p. 235, pl. 3, figs. 13-15; Koizumi, 1989, fig. 15.

Pseudodimerogramma elegans Schrader in Schrader and Fenner, 1976, p. 993, pl. 3, fig. 14.

Pseudopodosira elegans Sheshukova-Poretzkaya, 1964, p. 75, pl. 2, figs. 4, 5; Koizumi and Tanimura, 1985, pl. 4, fig. 10.

Rhizosolenia alata Brightwell: Hustedt, 1929, p. 600, fig. 345; Koizumi, 1975a, pl. 1, fig. 38.

Rhizosolenia barboi (Brun) Tempere and Peragallo: Schrader, 1973, pl. 24, figs. 4, 7. **Synonym:** *Rhizosolenia curvirostris* v. *inermis* Jouse, Koizumi, 1973b, pl. 5, figs. 32-33; *Rhizosolenia curvirostris* Jouse, Koizumi, 1975a, pl. 1, figs. 35-37.

Rhizosolenia hebetata (Bailey) Gran f. *hiemalis* Gran: Hustedt, 1929, p. 590, fig. 337; Koizumi, 1973b, pl. 5, figs. 34, 35.

Rhizosolenia miocenica Schrader, 1973, p. 709, pl. 10, figs. 2-6, 9-11; Koizumi and Tanimura, 1989, pl. 1, fig. 9.

Rhizosolenia styliformis Brightwell: Hustedt, 1929, p. 584, fig. 334; Koizumi, 1975a, pl. 1, fig. 33.

Rhizosolenia spp. **Remarks:** Some species of *Rhizosolenia* are difficult to identify precisely at present.

Rouxia californica Peragallo: Schrader, 1973, pl. 3, figs. 18-20, 22, 26; Koizumi and Tanimura, 1985, pl. 1, fig. 21.

Rouxia diploneis Schrader, 1973, p. 710, pl. 3, figs. 24, 25.

Rouxia naviculoides Schrader, 1973, p. 710, pl. 3, figs. 27-32; Koizumi and Matoba, 1989, pl. 1, fig. 6.

Rouxia yabei Hanna: Schrader, 1973, pl. 3, figs. 21, 23: Koizumi and Tanimura, 1985, pl. 1, fig. 20.

Stephanogonia hanzawae Kanaya, 1959, p. 118, pl. 11, figs. 3-7; Koizumi, 1968, pl. 35, figs. 3a-4.

Stephanopyxis megapora Grunow, Hustedt, 1928, p. 307, fig. 146.

Stephanopyxis schenckii Kanaya, 1959, p. 67, pl. 2, figs. 2-4; Koizumi, 1968, pl. 35, figs. 5a-6b.

Stephanopyxis turris (Greville and Arnott) Ralfs: Koizumi, 1973b, pl. 6, figs. 13-16. [pl. 1, fig. 15]

Stephanopyxis spp. **Remarks:** Specific identification is not possible at present.

Synedra jouseana Sheshukova-Poretzkaya, 1962, p. 208, fig. 4; Koizumi, 1973b, pl. 6, fig. 17.

Thalassionema hirosakiensis (Kanaya) Schrader, 1973, p. 711, pl. 23, figs. 31-33; Koizumi and Matoba, 1989, pl. 1, fig. 8. [pl. 1, fig. 10]

Thalassionema nitzschioides (Grunow) H. and M. Peragallo: Sancetta 1982, p. 239, pl. 4, figs. 11-13; Koizumi and Tanimura, 1985, pl. 6, fig. 10 as *T. nitzschioides* Grunow. **Remarks:** No attempt was made to separate several varieties of this species (see Koizumi 1973b, p. 833). [pl. 1, fig. 16]

Thalassiosira leptopus (Grunow) Hasle and Fryxell, 1977, p. 20, figs. 1-14; Koizumi, 1989, fig. 10.

Thalassiosira manifesta Sheshukova-Poretzkaya, 1964, p. 72, pl. 1, figs. 6, 7; Koizumi, 1968, p. 218, pl. 35, figs. 16, 17.

Thalassiosira marujamica Sheshukova-Poretzkaya, 1959, p. 41, pl. 1, fig. 7; Akiba, 1985, p. 446, pl. 13, figs. 1-7.

Thalassiosira sp. 1 Barron, 1980, p. 673, pl. 5, figs. 6, 7; Koizumi and Tanimura, 1985, pl. 4, figs. 1-3.

Thalassiothrix longissima (Cleve) Cleve and Grunow: Hasle and Mendiola, 1967, p. 114, fig. 20; Koizumi, 1968, pl. 35, fig. 29, Sancetta, 1982, p. 245, pl. 6, figs. 3,4.

Triceratium condecorum Brightwell: Hanna, 1932, p. 221, pl. 17, figs. 1, 3; Schrader, 1973, pl. 12, fig. 9.

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Explanation of Plate 1

Magnifications are x1500

Fig. 1 *Denticulopsis hyalina* (Schrader) Simonsen, Sample 116 of the Oiwake Formation, Kuriyama.

Fig. 2 *Denticulopsis praedimorpha* (Akiba) Barron, Sample 115 of the Oiwake Formation, Kuriyama.

Fig. 3 *Denticulopsis praedimorpha* (Akiba) Barron, Sample 85 of the Oiwake Formation, Kuriyama.

Fig. 4 *Denticulopsis dimorpha* (Schrader) Simonsen, Sample 118 of the Oiwake Formation, Kuriyama.

Fig. 5 *Denticulopsis dimorpha* (Schrader) Simonsen, Sample 117 of the Oiwake Formation, Kuriyama.

Fig. 6 *Denticulopsis hustedtii* (Simonsen and Kanaya) Simonsen, Sample 85 of the Oiwake Formation, Kuriyama.

Fig. 7 *Denticulopsis* sp. 1, Sample 117 of the Oiwake Formation, Kuriyama.

Fig. 8 *Denticulopsis katayamae* Maruyama, Sample 117 of the Oiwake Formation, Kuriyama.

Fig. 9 *Goniothecium tenue* Brun, Sample 117 of the Oiwake Formation, Kuriyama.

Fig. 10 *Thalassionema hirosakiensis* (Kanaya) Schrader, Sample 118 of the Oiwake Formation, Kuriyama.

Fig. 11 *Coscinodiscus flexuosus* Brun, Sample 14 of the Kushigata Formation, Tajiri.

Fig. 12 *Coscinodiscus elegans* Greville, Sample 117 of the Oiwake Formation, Kuriyama.

Fig. 13 *Coscinodiscus plicatus* Grunow, Sample 15 of the Kushigata Formation, Tajiri.

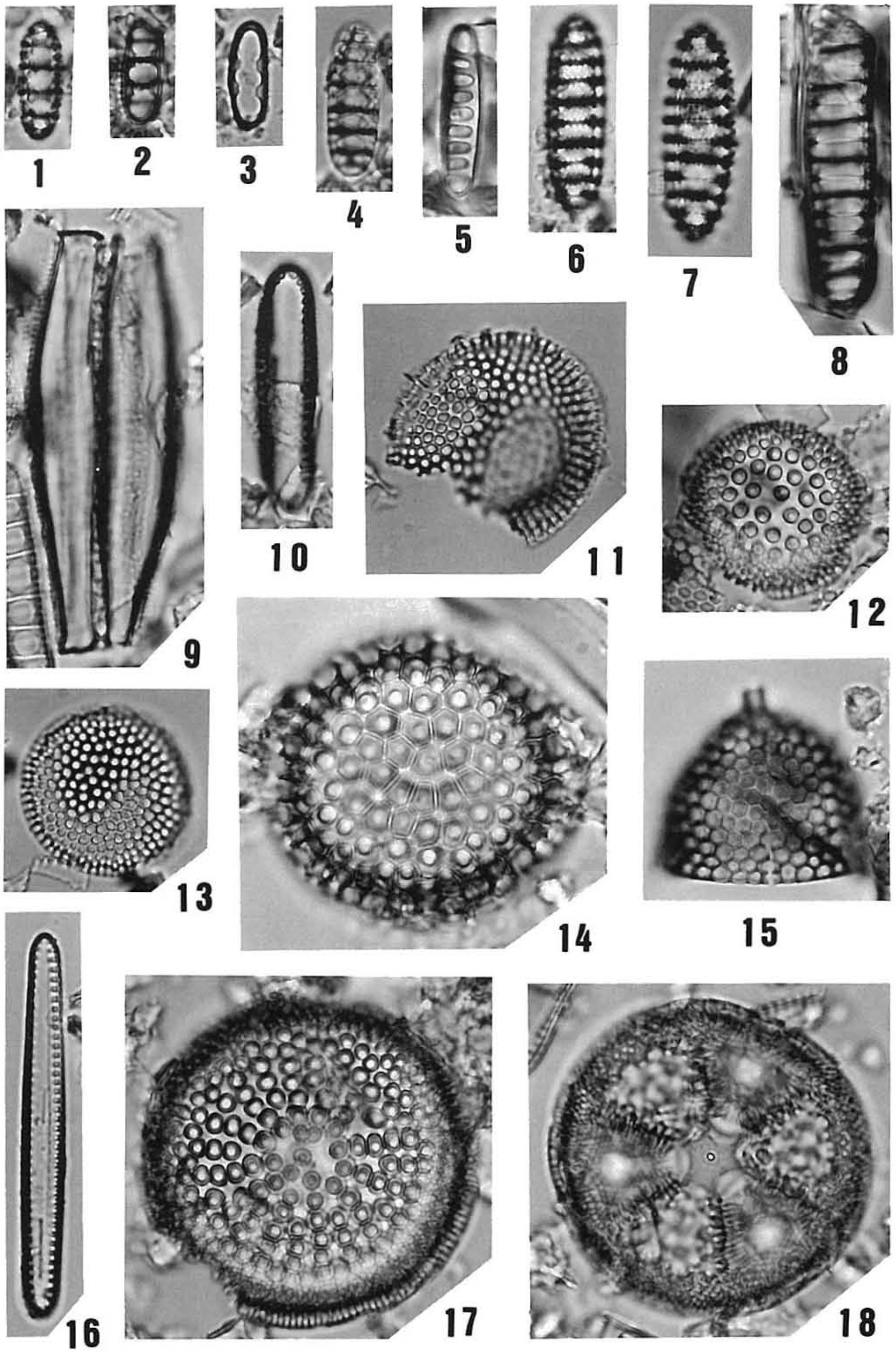
Fig. 14 *Coscinodiscus marginatus* Ehrenberg, Sample 85 of the Oiwake Formation, Kuriyama.

Fig. 15 *Stephanophyxis turris* (Greville and Arnott) Ralfs, Sample 117 of the Oiwake Formation, Kuriyama.

Fig. 16 *Thalassionema nitzschioides* (Grunow) H. and M. Peragallo, Sample 16 of the Kushigata Formation, Tajiri.

Fig. 17 *Actinocyclus ingens* Rattray, Sample 116 of the Oiwake Formation, Kuriyama.

Fig. 18 *Actinoptychus senarius* (Ehrenberg) Ehrenberg, Sample 85 of the Oiwake Formation, Kuriyama.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