Dinoflagellate cysts during the Middle Miocene Climatic Optimum (MMCO) from the Namiishi-zawa section of the Kamagui Formation, northern Niigata, central Japan

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Abstract

Dinoflagellate cysts during the Middle Miocene Climatic Optimum (MMCO) are described from the Kamagui Formation along the Namiishi-zawa section, Tainai City, northern part of the Niigata sedimentary basin. Eleven samples yielded dinoflagellate cyst assemblages of generally high diversity, being composed of 32 taxa. They are indicative of the lower part of the Subzone b of the *Diphyes latiusculum* Zone (16.3 - 15.9 Ma). This confirms the timing of the rift propagation in this area during the backarc spreading. Comparison with the coeval data from eastern South Korea suggests possible paleoenvironmental control on the paleogeographic distribution of dinoflagellate cysts in this interval.

Key words: dinoflagellate cysts, Kamagui Formation, Middle Miocene Climatic Optimum (MMCO), Namiishi, Niigata sedimentary basin.

Introduction

This study aims to describe dinoflagellate cysts from the oldest Miocene sediments at the Namiishi-zawa section, Tainai City, in the northern part of the Niigata sedimentary basin. From the section, tropical-subtropical pollen assemblages during the Middle Miocene Climatic Optimum (MMCO; Zachos et al., 2001) were reported by Yamanoi (1976).

Fossil organic-walled dinoflagellate cysts have been studied in terms of biostratigraphy

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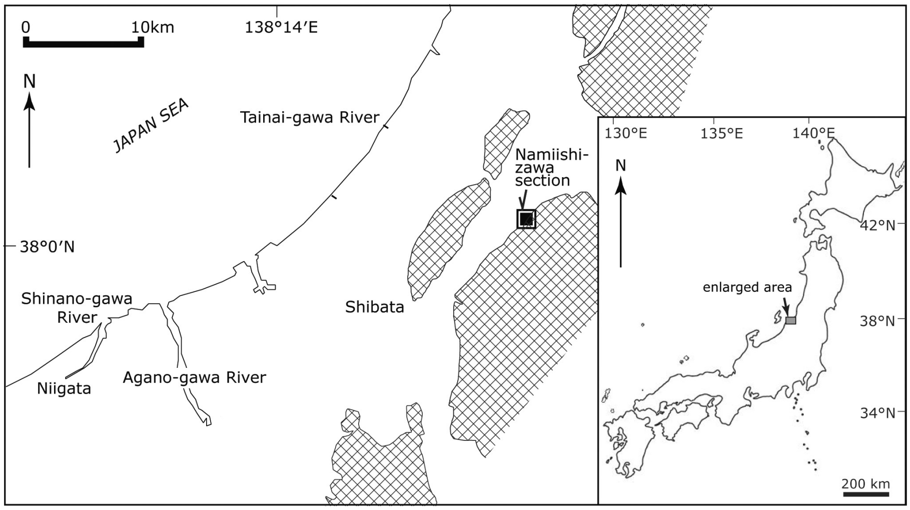

Fig. 1. Index map showing the location of the Namiishi-zawa section. Solid lines denote coastlines. Hatched areas indicate exposed areas of the pre-Neogene basement rocks (after Niigata Prefecture, 2000).

and paleoecology essentially in shallow marine sediments through the Mesozoic and Cenozoic (e.g., Edwards, 1992; Powell, 1992). For understanding of their diversity and significance through geologic time, further detailed documenting of their fossil records is needed particularly for the Neogene on which relatively scarce studies have been conducted.

In the Niigata sedimentary basin, extensive siliciclastic sediments up to 6,000 m thick were deposited since the Early Miocene (Takano, 2002). The sediments have been subject to various micropaleontological/palynological studies that include the pioneering work on Neogene terrestrial palynology by Yamanoi (1968, 1976, 1979). Yamanoi (1976) reported a pollen assemblage from the basal Neogene sediments at the Namiishi-zawa section (Fig. 1) and the assemblage is characterized by tropical conifer tree *Dacrydium* and other evergreen tree taxa. Subsequently, Yamanoi (1990) compiled his work on Neogene sediments in Japan which led to a recognition of pollen assemblages of tropical - subtropical forests widespread during the late Early - early Middle Miocene. This comprises one of the paleontological evidence of the MMCO in Japan.

The present study provides new data to the inventory of dinoflagellate cysts from the MMCO interval in Japan and surrounding areas which include Matsuoka (1974, 1983; Japan), Matsuoka et al. (1987; Japan), Yun (1988; onshore Korea), Obuse and Kurita (1999; northeast Japan), Kurita and Obuse (2003; off Sanriku Coast) and Yun et al. (2007; offshore Korea).

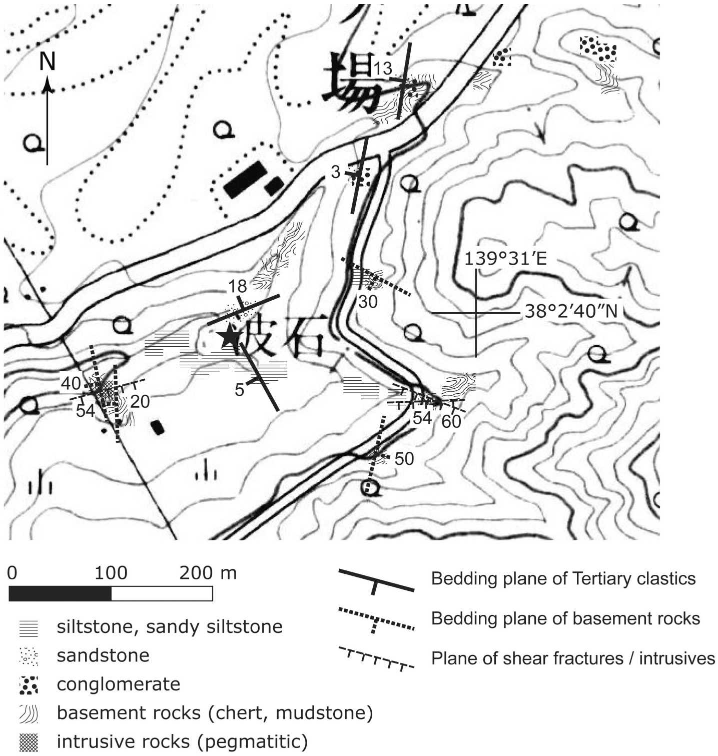

Fig. 2. Distribution of exposures and their lithology along the Namiishi-zawa section, Tainai City. Asterisk (★) indicates the location of the largest known float of "Namiishi". Topographic map is after 1/25,000 scale "Azumi" by the Geographical Survey Institute.

Geology

Exposure map, geologic map and columnar section for the Namiishi-zawa section are illustrated on Figs. 2, 3 and 4.

The Tertiary geology and stratigraphy in the northern part of the Niigata sedimentary basin was first established by Nishida and Tsuda (1961). Their framework has been followed by subsequent researches (e.g., Yamanoi, 1976; Shiroi et al., 1999; Takano et al., 2001). Along the Namiishi-zawa section within the Tainai-gawa River tributaries, the Kamagui Formation, the basal part of the Neogene strata in this area (Nishida and Tsuda, 1961), is exposed with its basement.

The basement rocks are composed of bedded and massive chert and siliceous mudstone (Plate 1, fig. 1). They are intruded by a small body of pegmatitic rocks. The basement rocks in this area are regarded as part of a Jurassic accretionary complex assignable to the Ashio Belt (Komatsu et al., 1985). In addition, the "Namiishi" (wavy rock) is a local name for the bedded chert that is frequently found as large, boulder-sized floats in streams and hill slopes in the northern Niigata area. Those rocks are derived from the pre-Neogene basement. The Namiishi-zawa is named after the occurrence of numerous “Namiishi” floats within the stream and particularly after the largest known float settled on the bank of the stream that has been designated as one of the natural monuments of Tainai City (Plate 1, fig. 1).

The Kamagui Formation (Nishida and Tsuda, 1961) in this section is here informaly subdivided into the lower part (5 m thick) and the upper part (15 m thick). The lower part begins with a cobble - boulder conglomerate layer of 1 - 2 m thick that is poorly-sorted and apparently reversely-graded (Plate 1, fig. 2). This is overlain by fine-grained, well-sorted sandstone layers that are parallel-bedded or intensely bioturbated (Plate 1, figs. 3 and 4). This basal section grades upward into massive, sandy siltstone. The upper part is composed of massive siltstone only that is occasionally very weakly bedded or sometimes becomes tuffaceous (Plate 1, fig. 5).

This Neogene section has homoclinal internal structure that gently dips westward. The irregular contact with the basement should be the result of an inclined, incised surface prior to the deposition against which the sediments abutted. In addition, this section is interpreted to be displaced by a WNW-ESE trending fault on the basis of lithological discontinuity as well as a shear zone of the same trend within the basement. By this faulting, the southern block is downthrown.

These lithostratigraphic and structural characteristics show that the Kamagui Formation in this section was deposited along the basin margin, filling the relief of the basement, under the decreasing energy condition that made up the overall upward-fining succession. After the deposition, gentle westward tilting as well as faulting in a WNW-ESE trend deformed the sediments slightly.

Samples and methods

Fourteen samples, NMI-01 to 14 from the Namiishi-zawa section were analyzed by this study (Figs. 4 and 5). NMI-01 to 04 from the lower part of the section are fine- to very fine-grained sandstone, whereas NMI-05 to 14 from the upper part are siltstone and occasionally tuffaceous or sandy.

The samples were treated with HCl and HF under room condition to eliminate carbonate and siliceous minerals. The organic residues were then concentrated using zinc bromide heavy liquid (specific gravity = 2.0), screened on a 20μ m sieve, and mounted on slide with polyvinylalchohol and polyester resin. No oxidation was carried out in the sample processing.

A Carl Zeiss Axioplan microscope was used for microscopic analysis. Each microscope slide was traversed at 160× along the shorter side of the coverslip. Identification was conducted at 600× using interference contrast. Each raw count of a given taxon in a sample is

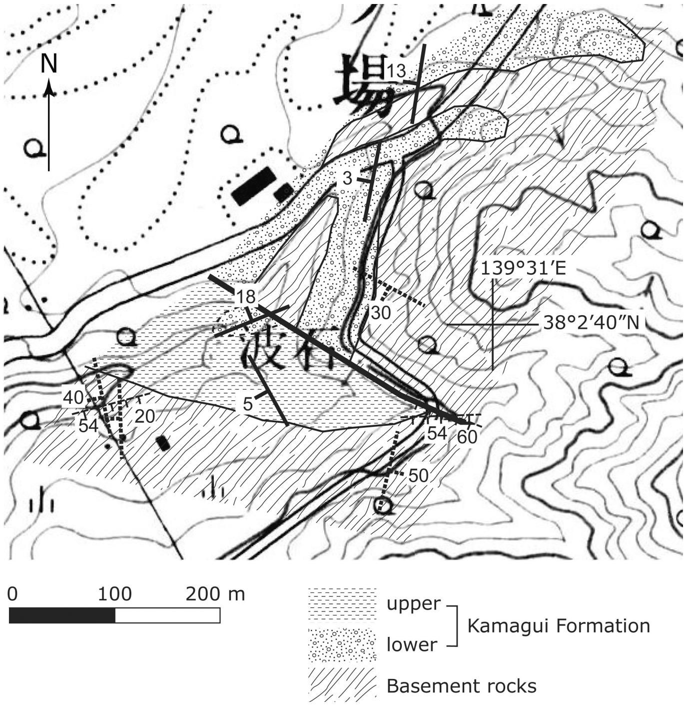

Fig. 3. Geologic map along the Namiishi-zawa section, Tainai City. Bold line applies to a fault, solid lines to unconformity and dashed line to the contact between the lower and upper parts of the Kamagui Formation. For the legend of planer structures, see Fig. 2.

shown in Table 1. Relative abundance of cysts in each sample was calculated by the cyst counts per microscope traverse. In Table 1, abundance is expressed as R (rare, less than an average of one specimen per microscope traverse), C (common, 1 - 10), A (abundant, 10 - 30), and VA (very abundant, 30 or more). The density of residue strewn on the slide is not constant for all the samples, thus the abundance is only approximately true in this case. The cyst nomenclature used in this study generally follows Williams et al. (1998). All the material discussed in this paper is housed in the palynological collection at the Department of Geology, Faculty of Science, Niigata University.

Dinoflagellate cysts from the Namiishi-zawa section

The results are shown in Table 1. Selected specimens are illustrated on Plates 2 and 3. Three samples (NMI-01, 10, 12) out of 14 were barren of dinoflagellate cysts. In other samples, abundance varies between rare to very abundant. Preservation is generally good, although slight diagenetic corrosion of specimens was found in some samples. List of identified taxa is in Table 2.

The dinoflagellate cyst assemblages are generally diverse and characterized by frequent occurrences of *Cribroperidinium*? *granomembranaceum*, *Lingulodinium machaerophorum*, *Operculodinium centrocarpum*, *Spiniferites* spp. and *Systematophora placacantha*. Other relatively minor taxa include *Batiacasphaera minuta*, *Brigantedinium* spp., *Diphyes*

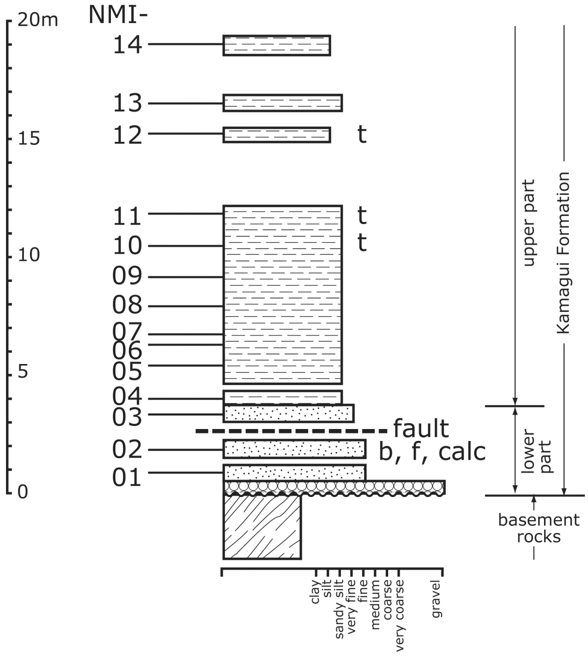

Fig. 4. Geologic columnar section and sampled horizons along the Namiishi-zawa section, Tainai City. t=taffaceous, b=bioturbated, f=observation of a float, calc=calcareous.

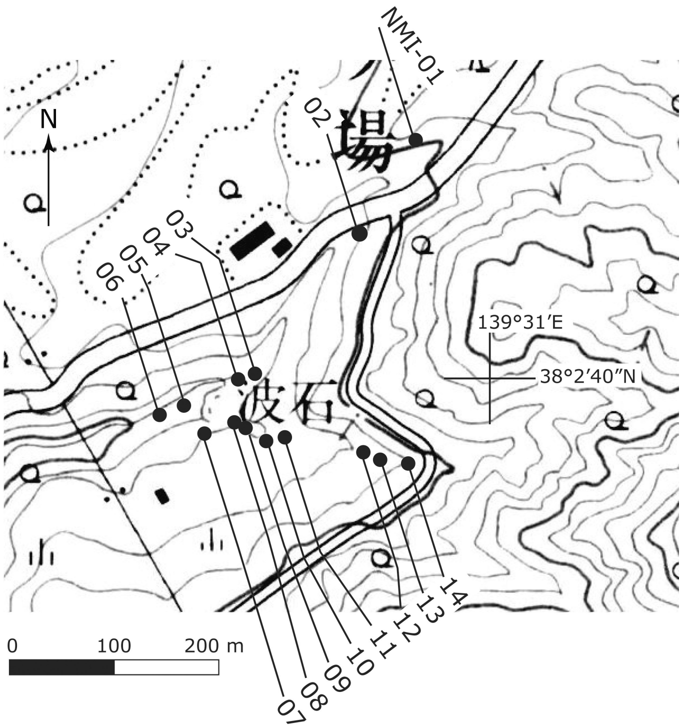

Fig. 5. Sample localities along the Namiishi-zawa section, Tainai City.

Table 1. Dinoflagellate cysts and other associated organic microfossils from the Namiishi-zawa section, Tainai City.

	←upsection													
rock unit	Kamagui Formation													
	Upper part (massive siltstone)										Lower (Cgl & Sst)			
sample number	NMI-													
	14	13	12	11	10	09	08	07	06	05	04	03	02	01
number of traverses on slide	10	3	15	19	22	10	10	10	30	3	23	3	39	29
cysts counted	139	102	0	59	0	206	326	208	111	93	48	129	11	0
averaged cyst count per traverse	14	34	0	3.1	0	21	33	21	3.7	31	2.1	43	0.3	0
abundance	A	VA	-	C	-	A	VA	A	C	VA	C	VA	R	-
Dinoflagellate cysts														
Achomosphaera ramulifera		2						1		3		3	1	
Achomosphaera spongiosa		2				1	2			1				
Achomosphaera spp.		1								1		3		
Batiacasphaera minuta							1			2		1		
Brigantedinium grande						1		3	1					
Brigantedinium spp.	1							3	2					
Cleistosphaeridium ancyreum	1													
Cribroperidinium ? *granomembranaceum*	72	19		1		3	5	2		1	7	2	2	
Dapsilidinium pastielsii												1		
Diphyes latiusculum	3	1		2		1			1	1		2		
Hystrichokolpoma denticulata		2		3		2	4	1				3		
Impagidinium manumii								1						
Lejeunecysta spp.						3		1						
Lingulodinium machaerophorum	11	7				4	1	14	7	3	12	2		
Lingulodinium multivirgatum												1		
Lingulodinium sp. A	3													
Operculodinium centrocarpum	6	3		3		81	250	57	52	22	3	17		
Operculodinium sp. cf. *O. israelianum*		1												
Operculodinium longispinigerum								1		1		1		
Operculodinium giganteum		1		2			1	2	2	3		4		
Operculodinium ? *eirikianum*						1								
Reticulatosphaera actinocoronata				1								1		
Spiniferites ellipsoideus				1										
Spiniferites membranaceus												2		
Spiniferites mirabilis												2	1	
Spiniferites pseudofurcatus	1	3		5		3			1	1		5		
Spiniferites ramosus		14		1		1	1	1		6		2		
Spiniferites sp. cf. *S. ramosus*						2								
Spiniferites solidago				1		2		2		1		2	1	
Spiniferites spp.	32	23		15		44	8	39	15	24	23	57	1	
Systematophora placacantha	9	23		24		57	53	80	30	22	3	18	4	
"cyst A" of Kurita (2004)										1			1	
Other palynomorphs														
Dacrydium (tropical conifer pollen)	2	7		5				5	1	6		3		
chitinous foraminifera linings						3	2		2	3				
Cyclopsiella granosa (acritarch)	1					2		5			1		3	
Tasmanites sp. (prasinophycean alga)	1	1		1	4	1		1						
Pterospermella sp. (prasinophycean alga)					1									

latiusculum, *Hystrichokolpoma denticulata* and *Spiniferites pseudofurcatus*. Stratigraphic changes in the species composition are not distinctive, although abundance peak of *O. centrocarpum* is in the middle of the section and that of *C.*? *granomembranaceum* at the top. Most of the identified taxa belong to gonyaulacaceans, while protoperidiniacean taxa were represented by only minor occurrences of *Brigantedinium* spp. and *Lejeunecysta* spp. The assemblages were occasionally accompanied with an acritarch species *Cyclopsiella granosa*. Pollen of *Dacrydium* were frequently encountered during the study, which supports the results by Yamanoi (1976).

Table 2. List of dinoflagelate cysts and acritarch taxa identified from the Namiishi-zawa section , Tainai City.

Dinoflagellate cysts

Achomosphaera ramulifera (Deflandre, 1937) Evitt, 1963
Achomosphaera spongiosa Matsuoka and Bujak, 1988
Achomosphaera spp.
Batiacasphaera minuta (Matsuoka, 1983) Matsuoka and Head, 1992
*Brigantedinium grand*e Matsuoka, 1987
Brigantedinium sp.
Cleistosphaeridium ancyreum (Cookson and Eisenack, 1965) Eaton et al., 2001
Cribroperidinium? *granomembranaceum* (Matsuoka, 1983) Lentin and Williams, 1985
Dapsilidinium pastielsii (Davey and Williams, 1966) Bujak et al., 1980
Diphyes latiusculum Matsuoka, 1974
Hystrichokolpoma denticulata Matsuoka, 1974
Impagidinium manumii Matsuoka and Bujak, 1988
Lejeunecysta spp.
Lingulodinium machaerophorum (Deflandre and Cookson, 1955) Wall, 1967
Lingulodinium multivirgatum de Verteuil and Norris, 1996
Lingulodinium sp. A
Operculodinium centrocarpum (Deflandre and Cookson, 1955) Wall, 1967
Operculodinium sp. cf. *O. israelianum* (Rossignol, 1962) Wall, 1967
Operculodinium longispinigerum Matsuoka, 1983
Operculodinium giganteum Wall, 1967
Operculodinium? *eirikianum* Head et al., 1989
Reticulatosphaera actinocoronata (Benedeck, 1972) Bujak and Matsuoka, 1986
Spiniferites ellipsoideus Matsuoka, 1983
Spiniferites membranaceus (Rossignol, 1964) Sarjeant, 1970
Spiniferites mirabilis (Rossignol, 1964) Sarjeant, 1970
Spiniferites pseudofurcatus (Klumpp, 1953) Sarjeant, 1970
Spiniferites ramosus (Ehrenberg, 1838) Mantell, 1854
Spiniferites sp. cf. *S. ramosus* (Ehrenberg, 1838) Mantell, 1854
Spiniferites solidago de Verteuil and Norris, 1996
Spiniferites spp.
Systematophora placacantha (Deflandre and Cookson, 1955) Davey et al., 1969
"cyst A" of Kurita, 2004

Acritarch

Cyclopsiella granosa (Matsuoka, 1983) Head et al., 1992

The dinoflagellate cyst assemblages from the Namiishi-zawa section indicate the correlation to the lower part of the Subzone b of the *Diphyes latiusculum* Zone. The *D. latiusculum* Zone was originally established by Matsuoka et al. (1987) and subsequently redefined, subdivided and age-calibrated by Obuse and Kurita (1999). According to Obuse and Kurita (1999), the lower part of the Subzone b of the *D. latiusculum* Zone is coeval with the diatom *Denticulopsis praelauta* Zone (16.3 - 15.9 Ma, earliest Middle Miocene; Yanagisawa and Akiba, 1998). This age range correlates well with the Middle Miocene Climatic Optimum (MMCO; Zachos et al., 2001) interval.

This age assignment indicates that the earliest transgression during the Miocene in the Namiishi-zawa area should be located within the range of 16.3 - 15.9 Ma. This confirms the previous age assignment of the Kamagui Formation (e.g., Kobayashi and Tateishi, 1992).

This also indicates that the rifting around the Namiishi-zawa occurred during the latest stage of the rifting of the Japan Sea region that initiated at around 26 Ma (Jolivet and Tamaki, 1992). This supports the rift propagation concept during the backarc spreading by Sato et al. (2004).

Comparison of the present assemblages with the data from the Pohang Basin, eastern South Korea (Yun et al., 2007), suggests that the Subzone b of the *Diphyes latiusculum* Zone in northern Japan is correlated to the *Distatodinium craterum* Zone of Yun et al. (2007) on the basis of the consistent occurrences of *Cribroperidinium* spp., *Diphyes* spp. , *Hystrichokolpoma* spp., *Lingulodinium machaerophorum*, *Operculodinium centrocarpum*, *Spiniferites pseudofurcatus* and *Systematophora placacantha*. This shows that the correlation of the Miocene strata between northern Japan and eastern South Korea can be well constrained by dinoflagellate cyst biostratigraphy. The species composition in the coeval Pohang assemblages, however, is slightly different. This difference may be attributable to variation of depositional environments. For example, *Distatodinium craterum*, which is abundant in the Pohang assemblages, is absent in the present study. In addition, Obuse and Kurita (1999) and Kurita and Obuse (2003) did not record this species from the latest Early to earliest Middle Miocene sediments in northern Japan and off Sanriku Coast. These suggest that the distribution of *D. craterum* in the northwest Pacific region would be affected by paleoenvironmental control.

Conclusion

On the basis of abundant occurrences of dinoflagellate cysts, the earliest transgression during the Miocene in the Namiishi-zawa area is located within the range of 16.3 - 15.9 Ma. This confirms the timing of the rift propagation in this area. Comparison with the coeval data from eastern South Korea shows the feasibility of biostratigraphic usage of Miocene dinoflagellate cysts, and also suggests the possible paleoenvironmental control on the paleogeographic distribution of dinoflagellate cysts.

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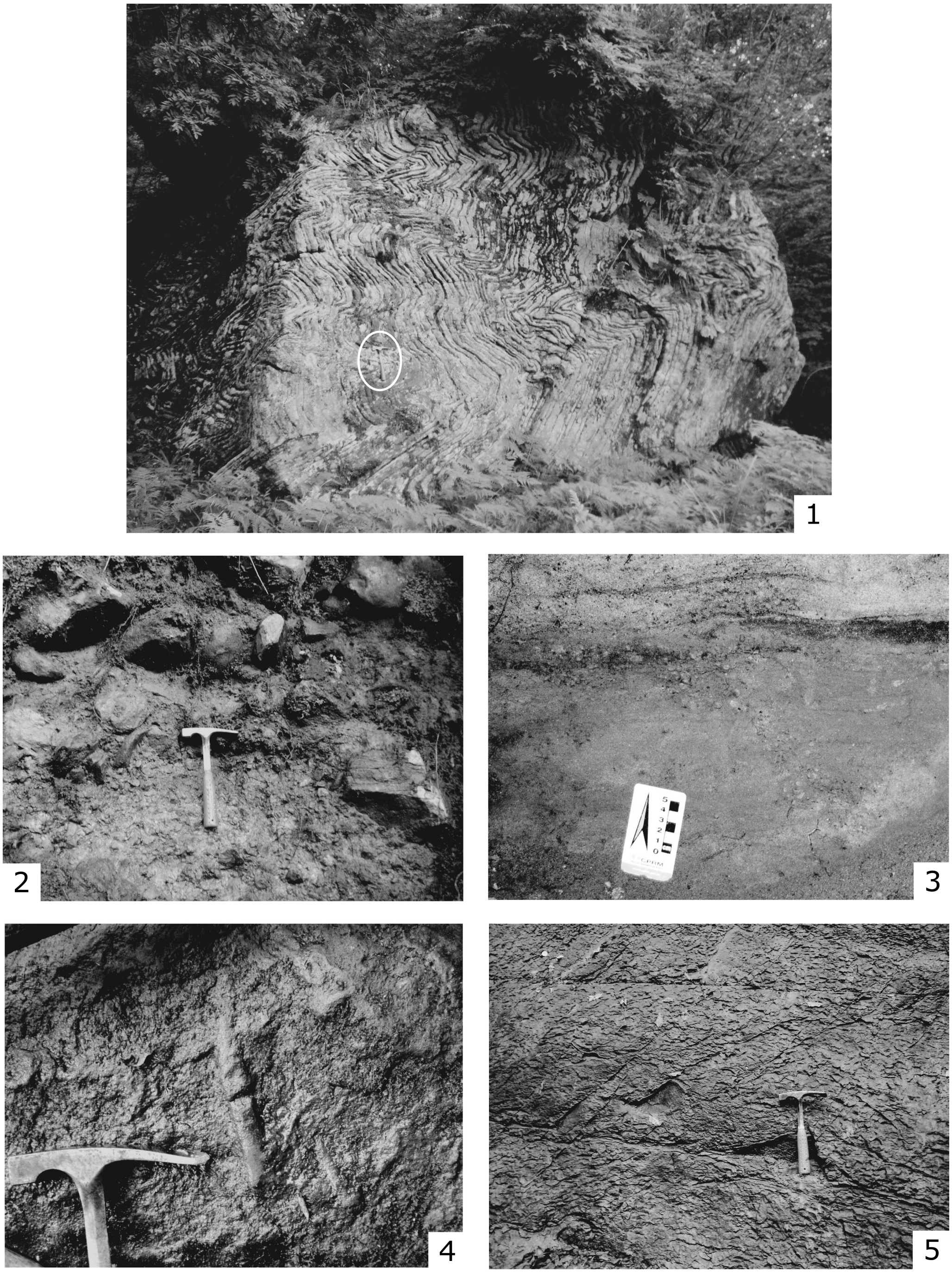
Explanation of Plate 1

Outcrops in the Namiishi-zawa section, Tainai City, northern part of the Niigata sedimentary basin. Hammer (16 cm × 28 cm) for scale.

1. The largest known float of bedded chert, the “Namiishi” (wavy rock), derived from the basement and settled on the bank of the Namiishi-zawa stream. Location is indicated by an asterisk in Fig. 2 in the text. This rock has been designated as one of the natural monuments of Tainai City.
2. Poorly-sorted conglomerate, showing apparent reverse-grading at the base of the Kamagui Formation. Location is close to the sample site NMI-02.
3. Fine-grained sandstone irregularly containing granules, right above the basal conglomerate. Sample NMI-01 was taken from this layer.
4. A float of fine-grained sandstone presumably locatable right above the basal conglomerate and sandstone, containing shell fragments, being extensively bioturbated, well-sorted, and calcareous. Sample NMI-02 was taken from this block.
5. Massive siltstone of the upper part of the Kamagui Formation. Location: sample site NMI-08.

Plate 1

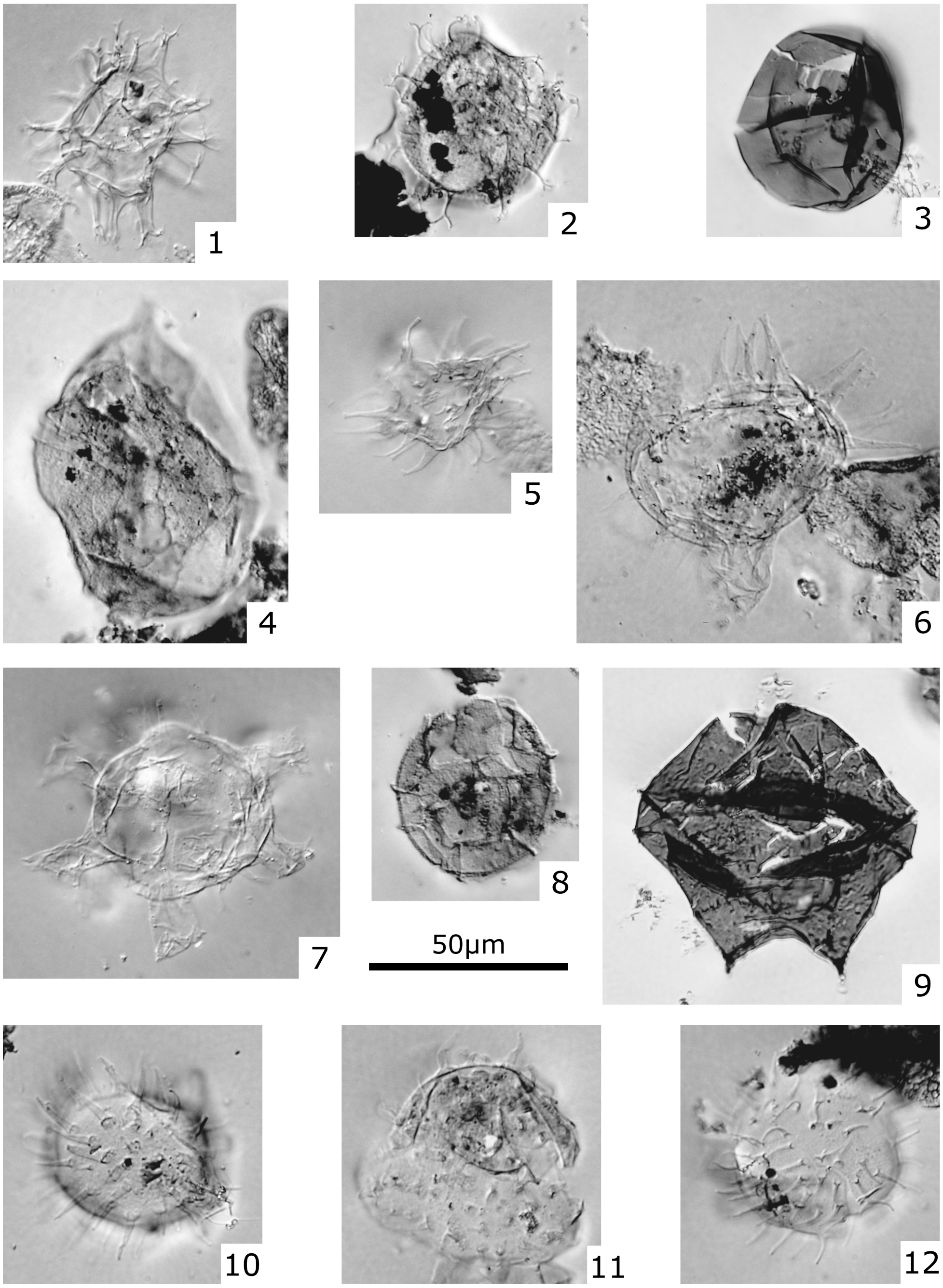


Explanation of Plate 2

Photomicrographs of selected dinoflagellate cysts from the Namiishi-zawa section, under interference contrast. Scale bar is 50 μm. Each species name is followed by sample ID, slide number and X-Y stage coordinates at a Carl Zeiss 45-35-02 stage for Axioplan microscope.

1. *Achomosphaera ramulifera*. NMI-03, #2, 84.0×7.3
2. *Achomosphaera spongiosa*. NMI-08, #2, 86.2×15.4
3. *Brigantedinium* sp. NMI-14, #2, 91.7×9.7
4. *Cribroperidinium*? *granomembranaceum*. NMI-08, #2, 93.6×4.6
5. *Dapsilidinium pastielsii*. NMI-03, #2, 84.6×19.3
6. *Diphyes latiusculum*. NMI-11, #2, 90.7×5.0
7. *Hystrichokolpoma denticulata*. NMI-11, #2, 103.2×17.7
8. *Impagidinium manumii*. NMI-07, #2, 85.3×8.0
9. *Lejeunecysta* sp. NMI-09, #2, 89.8×7.9
10. *Lingulodinium machaerophorum*. NMI-04, #1, 104.0×5.5
11. *Lingulodinium multivirgatum*. NMI-03, #2, 85.5×7.0
12. *Lingulodinium* sp. A. NMI-14, #2, 83.9×11.3

Plate 2



Explanation of Plate 3

Photomicrographs of selected dinoflagellate cysts and associated organic- walled microfossils from the Namiishi-zawa section, under interference contrast unless otherwise noted. Scale bar is 50 µm except for Figs. 9 and 10 where it is 100 µm. Each species name is followed by sample ID, slide number and X-Y stage coordinates at a Carl Zeiss 45-35-02 stage for Axioplan microscope.

1. *Operculodinium giganteum*. NMI-07, #2, 89.8×21.8
2. *Operculodinium centrocarpum*. NMI-07, #2, 96.9×21.2
3. *Spiniferites ellipsoideus*. NMI-11, #2, 100.5×21.5, Phase contrast
4. *Reticulatosphaera actinocoronata*. NMI-03, #2, 86.6×15.2
5. *Operculodinium*? *eirikianum*. NMI-09, #2, 98.2×6.0
6. *Spiniferites pseudofurcatus*. NMI-03, #2, 84.6×17.7
7. *Spiniferites solidago*. NMI-03, #2, 87.2×18.5
8. *Spiniferites* sp. NMI-03, #2, 84.0×19.2
9. *Spiniferites membranaceus*. NMI-03, #2, 84.2×11.5
10. *Spiniferites* sp. NMI-03, #2, 87.7×19.0
11. *Systematophora placacantha*. NMI-06, #1, 88.7×10.6
12. *Systematophora placacantha*. NMI-03, #2, 85.6×15.3. Operculum attached.
13. *Cyclopsiella granosa*, an acritarch. NMI-14, #2, 88.2×9.1
14. *Dacrydium*, tropical conifer pollen. NMI-13, #2, 87.0×14.0

Plate 3