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2. Data Report: Dinoflagellate Cyst Analysis of Neogene Sediments from Sites 1095 and 1096, Antarctic Peninsula Continental Rise[1]

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ABSTRACT

Protoperidiniacean dinoflagellate cysts were identified in 19 of 28 samples from two sites on the Antarctic Peninsula continental rise. Cysts are most common in the lower Pliocene and upper Miocene and include species of *Brigantedinium, Lejeunecysta,* and *Selenopemphix.* Autotrophic gonyaulacacean dinoflagellate cysts are very rare in the samples. The dominance of taxa derived from assumed heterotrophic dinoflagellate motile forms may indicate high nutrient content in the surface waters, which sustained a considerable diatom population.

INTRODUCTION

The occurrence of dinoflagellate cysts in Neogene and Holocene sediments from the Southern Ocean is now becoming reasonably well documented. For some years it was thought that there were no post-Paleogene dinoflagellate cysts within Southern Ocean sediments (McMinn, 1995) because the geographical and thermal isolation of Antarctica had effectively prevented the migration of the dinoflagellates that produce hypnozygotic cysts. Recent research (Marret and de Vernal, 1997; Harland et al., 1998, 1999; Harland and Pudsey, 1999), however, has established the occurrence of dinoflagellate cysts, which were found in sediment traps and Quaternary sediments, within the waters of the Southern Ocean. In addition, Wrenn et al. have reported di-

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noflagellate cysts from the lower Miocene and Quaternary of East Antarctica by Wrenn et al. (1999). Our contribution aims to add to the knowledge of Southern Ocean Neogene dinoflagellate cysts by describing assemblages from the Miocene and Pliocene of the Antarctic Peninsula margin, recovered during Ocean Drilling Program (ODP) Leg 178, Sites 1095 and 1096.

MATERIALS AND METHODS

Twenty-eight samples were selected for dinoflagellate cyst analysis. The samples were taken from the Neogene and Quaternary of Holes 1095B, 1096B, and 1096C on the continental rise west of the Antarctic Peninsula (Fig. F1). Lithologies are mainly diatom-bearing silty clays and diatom silty clays, with muddy diatom oozes in the lower Pliocene and barren claystone at the base of Hole 1095B (Table T1) (Barker, Camerlenghi, Acton et al., 1999). Biogenic silica (in the form of diatoms, radiolarians, and rare silicoflagellates) was measured by point counting a smear slide made from each sample. The more expanded sequence at Site 1096 was sampled down to 513 meters below seafloor (mbsf) (~4.2 Ma), and Site 1095 was sampled from 122 mbsf (~4.2 Ma) to the base of the hole, which dates ~10 Ma. Lithologic cyclicity is evident in many of the sedimentary sequences, with fine-grained laminated sediments alternating with bioturbated, sandier lithologies on a scale of decimeters to meters. Several pairs of dinoflagellate samples were taken from these alternating lithologies. Sample depths were converted to age using the paleomagnetic timescale provided in Barker, Camerlenghi, Acton et al. (1999; tables T38, T34), with linear interpolation between magnetic reversal datum points.

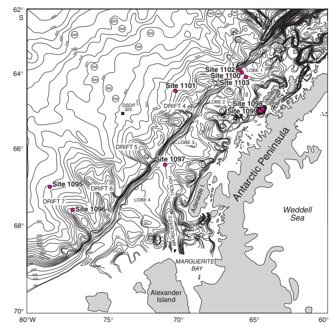
All the samples were prepared using the standard palynological preparation technique as outlined by Wood et al. (1996), except for the use of oxidizing reagents, which were avoided to prevent the loss of the protoperidiniacean dinoflagellate cysts (Dale, 1976). The samples were treated qualitatively, as the numbers of cysts recovered were low, and indeed, some of the samples proved to be entirely barren of cysts. The sample residues were stained with Safranin, made up onto strewn slides, and examined at 10× using a Zeiss Axiolab microscope.

RESULTS

Dinoflagellate cysts were recovered in 19 of the 28 samples, though some of the assemblages are very poorly preserved. Structured organic matter (STOM) or unstructured organic matter (USTOM) is present in almost all samples, and foraminiferal linings occur in most samples older than 6 Ma (Table T1). A few specimens of angiosperm pollen grains and spores were noted within the sample suite. The occurrence of the dinoflagellate cyst taxa is plotted against age in Figures F2 and F3, with the raw-count data given in Table T2.

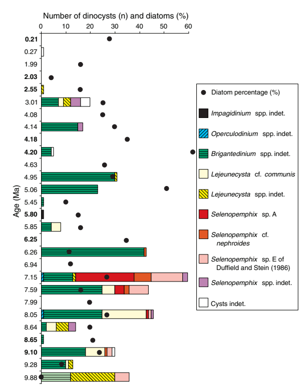
Samples 178-1096B-3H-1, 140–142 cm, 3H-4, 140–142 cm, 20H-4, 39–41 cm, and 20H-6, 39–41 cm (14.7, 19.2, 162.6 and 165.6 mbsf, RH313 to RH316 [laboratory-assigned numbers]), and samples 178-1095B-5H-1, 108–110 cm (122.1 mbsf, RH302),-5H-4, 94–96 cm (126.4 mbsf, RH303), and 26X-7, 4–6 cm (211.9 mbsf, RH403), which dated as Pleistocene isotope Stage 7 to early Pliocene in age, proved to be virtually barren of palynomorphs but do contain USTOM and STOM to-

F1. Location map of Sites 1095 and 1096, p. 6.

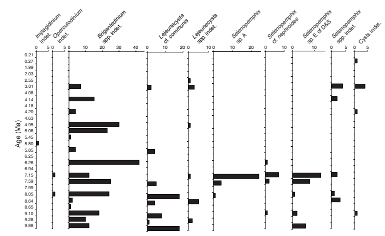


T1. Lithology and range of recovered palynomorphs, p. 9.

F2. Cumulative bar chart of the occurrence of dinoflagellate cysts, p. 7.



F3. Plots of the abundance of each cyst taxon, p. 8.



T2. Occurrence of dinoflagellate cyst taxa, p. 10.

gether with the occasional angiosperm pollen grain and bisaccate. In contrast, Samples 178-1096C-12X-3, 141–143 cm, 33X-2, 120–122 cm, and 34X-1, 115–117 cm (302.3, 503.7, and 512.55 mbsf; RH317 to RH319), which are late to early Pliocene in age, contain assemblages of dinoflagellate cysts mostly assignable to the genera *Brigantedinium, Lejeunecysta* and *Selenopemphix*. All these fossil cyst genera have been associated with the modern genus *Protoperidinium* and are therefore assumed to have a heterotrophic nutritional strategy. Their occurrence within these samples indicates the presence of water with a high nutrient content.

Samples 178-1095B-9H-3, 100–102 cm, and 9H-6, 91–93 cm (163.0 and 167.4 mbsf, RH304 and RH305), dated as early Pliocene in age, contained some dinoflagellate cysts that were identified to the genus *Brigantedinium.* These assemblages also contained rare angiosperm pollen grains and foraminiferal linings. Unfortunately, the palynomorph assemblages do not offer any biostratigraphic information on the age of the samples. Some angiosperm pollen was observed in Sample 178-1095B-12H-1, 81–83 cm (188.3 mbsf, RH395), together with the first foraminiferal linings downcore and some evidence of reworking from Upper Cretaceous sediments. A single specimen of *Brigantedinium* sp. indet. was also recovered from this sample.

Samples 178-1095B-14X-1, 19–21 cm, and 14X-2, 135–137 cm (205.2 and 207.8 mbsf; RH306 and RH307), which dated as late Miocene, are almost devoid of palynomorphs, but contain USTOM, STOM, the occasional spore, and angiosperm pollen together with limited numbers of dinoflagellate cysts. The cysts present mostly occur in 178-1095B-14X-2, 135–137 cm, and consist of *Brigantedinium* spp. indet. and *Lejeunecysta* cf. *communis* Biffi and Grignani, 1983.

Sample 178-1095B-17X-4, 17–19 cm (238.6 mbsf, RH397), yielded a reasonable dinoflagellate cyst assemblage consisting almost entirely of *Brigantedinium* spp. indet. and *Selenopemphix* cf. *nephroides* Benedek, 1972, together with foraminiferal linings, pollen, and spores. The samples above and below, 178-1095B-17X-2, 119–121 cm, and 23X-1, 100–102 cm (236.7 and 292.7 mbsf, RH396 and RH398), lack dinoflagellate cysts although some pollen and spores were observed.

The remaining upper Miocene samples, except for 178-1095B-29X-1, 126–128 cm, and 34X-6, 34–35 cm (350.8 and 405.1 mbsf, RH309 and RH401), which were almost barren, contained reasonable dinoflagellate cyst assemblages, including species of *Lejeunecysta* and *Selenopemphix* that have been associated with Miocene sediments. The assemblages consist entirely of cyst taxa attributable to the Protoperidiniaceae and are therefore thought to be heterotrophic in their nutritional strategy. Dinoflagellate cysts attributable to the Gonyaulacaceae are notably absent. Foraminiferal linings, pollen, and spores are also present. The dominance of taxa derived from assumed heterotrophic dinoflagellate motile forms may again indicate the presence of water with high nutrient content sustaining a considerable diatom population (but see later discussion).

DISCUSSION

The dinoflagellate cysts in these samples appear to be autochthonous, with minimal evidence of reworking from older material. The cysts were recovered mostly within the Miocene part of the sequence and were dominated by congruentidiacean, now protoperidiniacean, cysts. These are not well known in the published dinoflagellate literature; it is suspected that some may be new to science, and they are being studied further to provide detailed taxonomic descriptions. Virtually all the dinoflagellate cysts recovered can be assigned to or associated with the modern heterotrophic dinoflagellate *Protoperidinium.* By comparison with our knowledge of the modern cyst flora, which also is dominated by *Protoperidinium* cysts (Harland et al., 1998), a similar cold-water setting with high nutrient content can be interpreted for the sampled horizons. It is most probable that these dinoflagellates were feeding upon diatom populations that were taking advantage of seasonality and high supply of nutrients. The lack of autotrophic gonyaulacacean dinoflagellate cysts is noteworthy.

Similar situations, especially within the Miocene, have also been recognized elsewhere in the world, for example, at high latitudes in both the Labrador Sea and Baffin Bay (Head et al., 1989a, 1989b, 1989c), in the Gulf of Mexico (Duffield and Stein, 1986), and from the eastern seaboard of the United States (de Verteuil and Norris, 1992).

The relationship between diatom content and dinoflagellate cyst content of the samples, however, is not straightforward (Fig. F2). Many diatomaceous samples contain few or no dinoflagellate cysts. Diatoms were most abundant from 4 to 5.3 Ma (see Pudsey, Chap. 25, this volume), whereas dinoflagellate cysts attained highest abundance and diversity between 7 and 8 Ma. Dinoflagellate cysts persist at the base of the section where diatoms become less common because of silica dissolution. In the pairs of samples from bioturbated and laminated facies, the bioturbated sample tends to be the poorer in dinoflagellate cysts (e.g., samples at 4.20 Ma compared with 4.14 Ma, 5.80/5.85 Ma, 6.25/6.26 Ma, and 8.65/8.64 Ma). Foraminiferal linings are also less common in the bioturbated samples so this may simply be a preservational bias.

Finally, all the samples are almost barren of terrestrial palynomorphs such as angiosperm pollen, bisaccate grains, and spores, and only two of the samples contained any reworked material.

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Figure F1. Location map of Sites 1095 and 1096. Bathymetry is in meters.

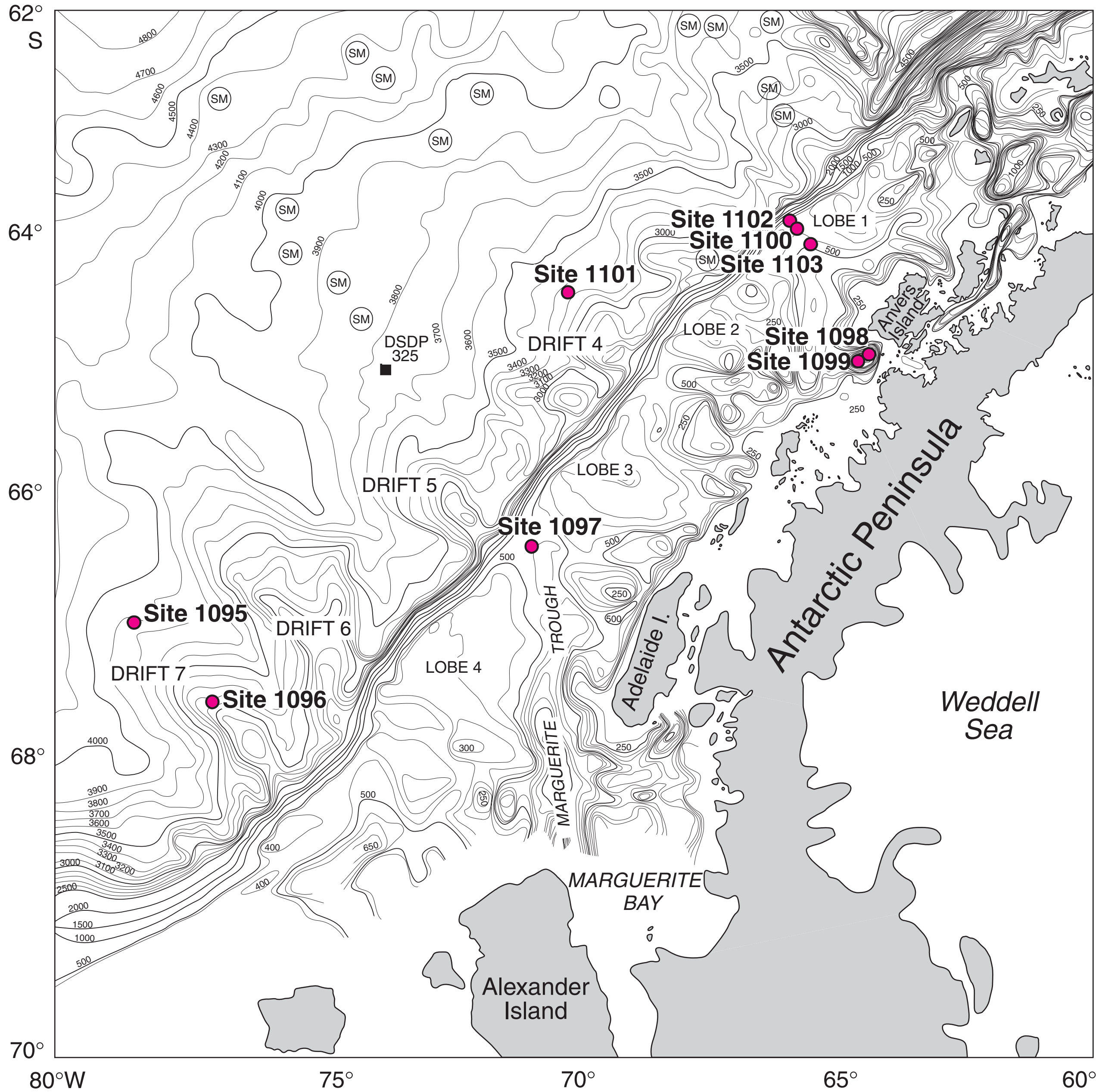

Figure F2. Cumulative bar chart of the occurrence of dinoflagellate cysts, plotted against age. Diatom percentage is also shown by black circles on the same scale. Samples from bioturbated intervals are shown in bold type on the age scale; samples from laminated intervals are in light type.

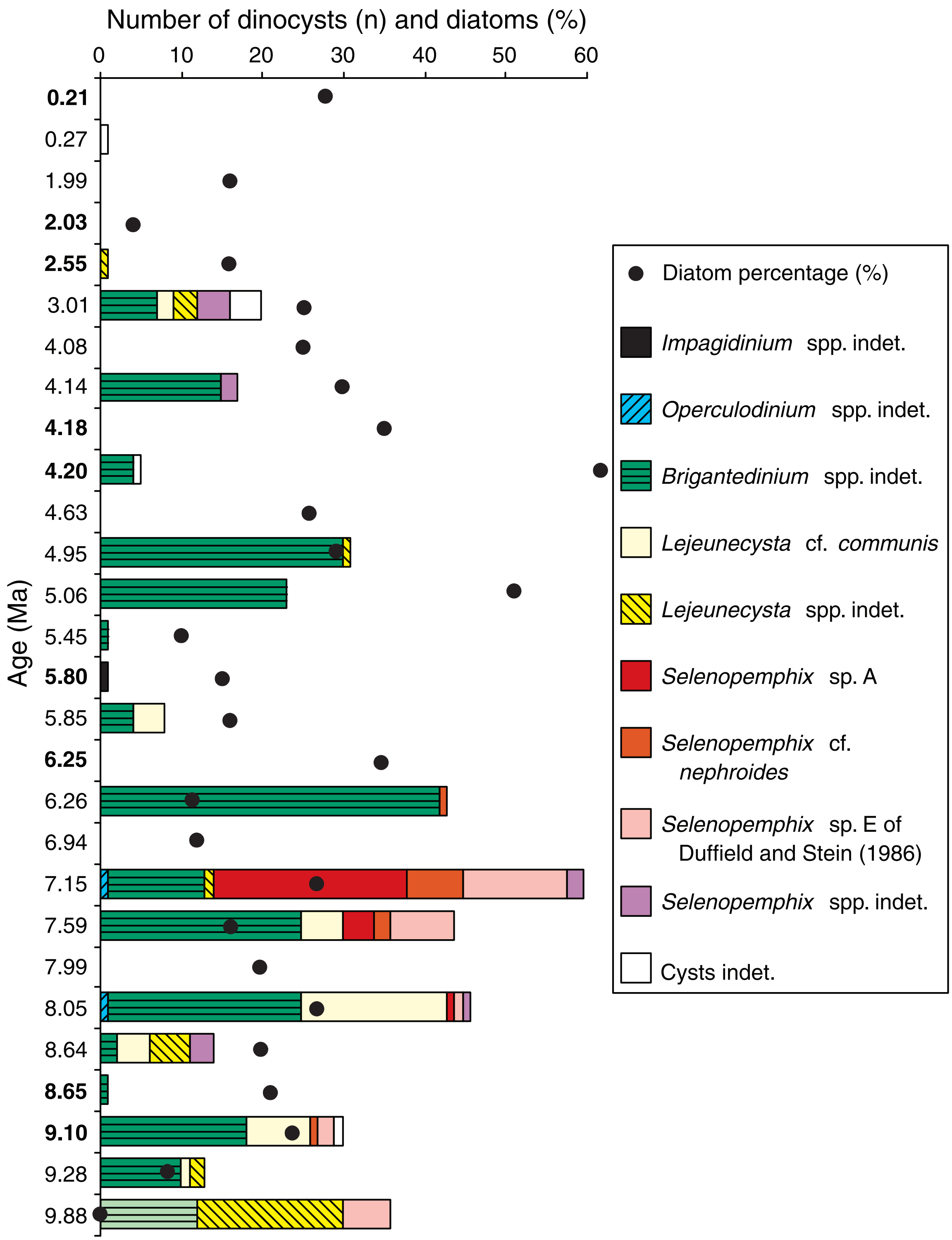

Figure F3. Plots of the abundance of each cyst taxon (numbers of cysts) against age. D&S = Duffield and Stein (1986).

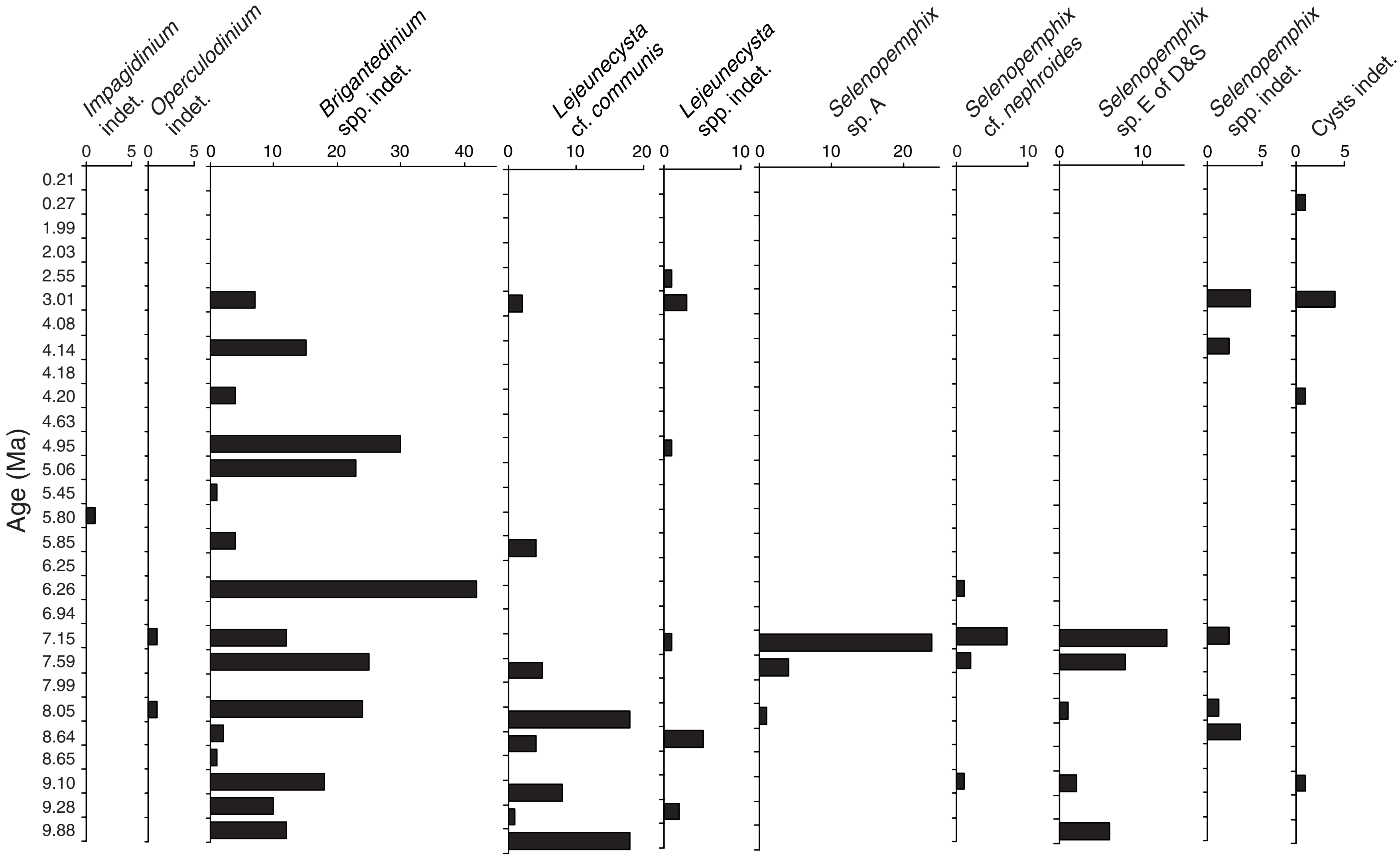

Table T1. Sample list of lithology and the range of recovered palynomorphs.

Sample	Core, section, interval (cm)	Depth (mbsf)	Age (Ma)	STOM	USTOM	Pollen	Spores	Foraminifer linings	Dinocysts	Lithology
RH313	1096B-3H-1, 140-142	14.70	0.21	x	x					Diatom silty clay, B
RH314	1096B-3H-4, 140-142	19.20	0.27	x	x	x			x	Silty clay
RH315	1096B-20H-4, 39-41	162.59	1.99	x	x					Diatom-bearing silty clay
RH316	1096B-20H-6, 39-41	165.59	2.03		x					Silty clay, B
RH403	1096B-26X-7, 4-6	211.94	2.55	x	x	x	x		x	Diatom-bearing silty clay, B
RH317	1096C-12X-3, 141-143	302.34	3.01		x				x	Diatom silty clay
RH302	1095B-5H-1, 108-110	122.08	4.08	x	x	x				Diatom silty clay
RH318	1096C-33X-2, 120-122	503.69	4.14		x				x	Diatom silty clay
RH303	1095B-5H-4, 94-96	126.44	4.18	x	x					Diatom silty clay, B
RH319	1096C-34X-1, 115-117	512.55	4.20		x	x	x		x	Muddy diatom ooze, B
RH394	1095B-7H-7, 10-12	149.07	4.63	x	x					Diatom clayey silt
RH304	1095B-9H-3, 100-102	163.00	4.95	x	x				x	Diatom silty clay, B
RH305	1095B-9H-6, 91-93	167.41	5.06		x	x			x	Muddy diatom ooze
RH395	1095B-12H-1, 81-83	188.31	5.45	x	x	x		x	x	Diatom-bearing silty clay
RH306	1095B-14X-1, 19-21	205.19	5.80		x		x		x	Diatom-bearing silty clay, B
RH307	1095B-14X-2, 135-137	207.80	5.85	x	x	x	x		x	Diatom-bearing silty clay
RH396	1095B-17X-2, 119-121	236.70	6.25	x	x					Diatom-bearing silty clay, B
RH397	1095B-17X-4, 17-19	238.57	6.26	x	x	x	x	x	x	Diatom-bearing silty clay
RH398	1095B-23X-1, 100-102	292.70	6.94	x	x	x	x			Diatom-bearing silty clay
RH308	1095B-24X-3, 101-103	305.31	7.15	x				x	x	Diatom silty clay
RH399	1095B-26X-5, 103-105	327.63	7.59	x	x	x		x	x	Diatom-bearing silty clay
RH309	1095B-29X-1, 126-128	350.76	7.99	x	x					Diatom-bearing silty clay
RH310	1095B-29X-4, 63-65	354.63	8.05	x	x			x	x	Diatom silty clay
RH400	1095B-34X-4, 53-54	402.33	8.64	x	x	x	x	x	x	Diatom-bearing silty clay
RH401	1095B-34X-6, 34-35	405.14	8.65	x	x	x	x		x	Diatom-bearing silty clay, B
RH311	1095B-39X-5, 50-52	451.60	9.10		x	x		x	x	Diatom-bearing silty clay, B
RH312	1095B-42X-3, 120-121	478.30	9.28		x	x		x	x	Silty clay
RH402	1095B-50X-1, 91-93	542.61	9.88	x	x	x	x	x	x	Silty clay

Notes: Samples are arranged in order of age. STOM = structured organic matter, USTOM = unstructured organic matter. B (in lithology column) = bioturbated sample; all others are laminated.

Table T2. Occurrence of dinoflagellate cyst taxa in each sample.

Sample	Depth (mbsf)	Age (Ma)	*Impagidinium* indet.	*Operculodinium* indet	*Brigantedinium* spp. indet.	*Lejeunecysta* cf. *communis*	*Lejeunecysta* indet.	*Selenopemphix* sp. A	*Selenopemphix* cf. *nephroides*	*Selenopemphix* sp. E of D&S	*Selenopemphix* indet	Cysts indet.	Total	Diatoms (%)
RH313	14.70	0.21											0	28
RH314	19.20	0.27										1	1	1
RH315	162.59	1.99											0	16
RH316	165.59	2.03											0	4
RH403	211.94	2.55					1						1	16
RH317	302.34	3.01			7	2	3				4	4	20	25
RH302	122.08	4.08											0	25
RH318	503.69	4.14			15						2		17	30
RH303	126.44	4.18											0	35
RH319	512.55	4.20			4							1	5	64
RH394	149.07	4.63											0	26
RH304	163.00	4.95			30		1						31	29
RH305	167.41	5.06			23								23	51
RH395	188.31	5.45			1								1	10
RH306	205.19	5.80	1										1	15
RH307	207.80	5.85			4	4							8	16
RH396	236.70	6.25											0	34
RH397	238.57	6.26			42				1				43	11
RH398	292.70	6.94											0	12
RH308	305.31	7.15		1	12		1	24	7	13	2		60	27
RH399	327.63	7.59			25	5		4	2	8			44	16
RH309	350.76	7.99											0	20
RH310	354.63	8.05		1	24	18		1		1	1		46	27
RH400	402.33	8.64			2	4	5				3		14	20
RH401	405.14	8.65			1								1	21
RH311	451.60	9.10			18	8			1	2		1	30	24
RH312	478.30	9.28			10	1	2						13	8
RH402	542.61	9.88			12	18				6			36	0

Note: Samples are arranged in order of age. D&S = Duffield and Stein (1986).