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26. Calcareous Nannofossils from Leg 178, Antarctic Peninsula, Pacific Continental Margin: Sites 1096 and 1101[1]

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ABSTRACT

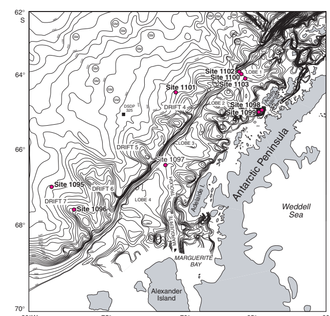
Sites 1096 and 1101, two hemipelagic sediment drift sites on the continental rise off the northwestern Pacific margin of the Antarctic Peninsula, contained calcareous nannofossils in the upper intervals of each site (downhole to 168.37 meters below seafloor [mbsf] in Hole 1096B and 121.1 mbsf in Hole 1101A). The occurrences were sporadic and observed to be confined to fine-grained intervals. These intervals were interpreted on board to be interglacial and often contained foraminifers as well. Calcareous nannofossils exhibited a reliable stratigraphy during an interval when other fossils groups were absent, quite rare, or reworked.

In total, nine events and three zones were recognized in this study. The base of the Pleistocene was not recorded with calcareous nannofossils, the oldest datum being the first occurrence of medium *Gephyrocapsa* spp. at 1.69 Ma. All events have been correlated to the paleomagnetic record for each site.

INTRODUCTION

Sites 1096 and 1101 are located on the continental rise of the northwest Pacific margin of the Antarctic Peninsula at 67°34.0′S, 76°57.8′W (3152 m water depth), and 64°22.3′S, 70°15.7′W (3279 m water depth), respectively (Fig. F1). Both are situated on hemipelagic sediment drifts,

F1. Location map of Sites 1096 and 1101, p. 11.



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providing extended sections with increased possibility for biostratigraphic resolution. Three holes were drilled at Site 1096, with a total depth of 607.7 meters below seafloor (mbsf) cored. The age of this site extended from the Holocene to the early Pliocene. At Site 1101, a single hole was cored to 217.7 mbsf with 99.1% recovery. The age at the bottom of the hole was late Pliocene, slightly younger than Site 1096, extending up to the Holocene at the top. These continental rise sites were the only ones that contained a calcareous nannofossil biostratigraphy, in addition to those produced by other fossil groups. Both sites had well-defined paleomagnetic ages, giving good age control to the observed biostratigraphic events.

Calcareous nannofossils from the Antarctic Pliocene–Pleistocene have been previously reported from Ocean Drilling Program (ODP) Legs 113, 114, and 120 (Barker, Kennett, et al., 1988; Barron, Larson, et al., 1989; Barron et al., 1991; Wei and Wise, 1990, 1992a, 1992b). Burckle and Pokras (1991) observed Holocene nannofossils from near the western side of the Antarctic Peninsula. Villa and Wise (1998) noted *Thoracosphaera* spp. from the Cape Roberts Project hole CRP-1. They also report calcareous nannofossils from various other sites around Antarctica. These will be discussed in greater detail in **"General Discussion,"** p. 6.

METHODS

Preparation Techniques and Examination

Standard nannofossil smear slide techniques were used to prepare the samples. Norland optical adhesive was used as a mounting medium. Slides were examined using a Zeiss and/or Olympus polarizing compound microscope at 1000×. All core catchers were examined, along with selected samples from within the cores, which were picked from finer-grained, more calcareous material.

Abundance and Preservation

Etching and overgrowth are the most important features of nannofossil preservation. To establish a ranking of preservation, the code system adopted by the Leg 172 Shipboard Scientific Party (1998) was used:

- G = good (little or no evidence of dissolution and/or secondary overgrowth of calcite; diagnostic characters fully preserved).
- M = moderate (dissolution and/or secondary overgrowth; partially altered primary morphological characteristics [however, nearly all specimens can be identified at the species level]).
- P = poor (severe dissolution, fragmentation, and/or secondary overgrowth with primary features largely destroyed; many specimens cannot be identified at the species level and/or generic level).

The total abundance of calcareous nannofossils, at 1000×, for each sample was estimated as follows:

- A = abundant (>10–100 nannoliths per field of view).
- C = common (1–10 nannoliths per field of view).
- F = few (1 nannolith per 3–5 fields of view).

R = rare (<1 nannolith per 10 fields of view).
X = scarce (<3 nannoliths per traverse).
B = barren.

Calcareous Nannofossil Zonation

The nannofossil zonation schemes proposed by Okada and Bukry (1980) and Martini (1971) were used as the basic zonal reference for Leg 178. Ages of most calcareous nannofossil datums that are employed to construct the Leg 178 age model used for the Pliocene–Pleistocene interval are drawn from the work of Raffi et al. (1993) and Wei (1993). These are summarized in the Leg 172 *Initial Reports* volume "Explanatory Notes" chapter (Shipboard Scientific Party, 1998). The zonal scheme is illustrated in the Leg 178 *Initial Reports* volume "Explanatory Notes" chapter (Shipboard Scientific Party, 1999a); please refer to these for a complete discussion. All ages of the species events are correlated to the geomagnetic polarity timescales of Berggren et al. (1995). Reworked species were nearly nonexistent. One *Braarudosphaera* spp. (very dissolved) was observed in Core 178-1101A-5H, and a broken *Sphenolithus* spp. was noted in Section 178-1101A-10H-CC.

Table T1 lists the nannofossils considered in this study. Because of often poor preservation, the *Gephyrocapsa* spp. were utilized for the datums correlated with distinctive sizes, that is, the first occurrence (FO) and last occurrence (LO) of large *Gephyrocapsa* spp. (>6 µm) and the reentrance of medium-sized *Gephyrocapsa* spp. (>4 to <6 µm). *Gephyocapsa oceanica* and *Gephyrocapsa caribbeanica,* included in these size-based groupings, are included in the table of species but not in the data tables. Elsewhere in the world in the Pleistocene, episodes of temporary disappearances of medium *Gephyrocapsa* spp. are observed, leaving only the small form. This small variety was noted in this study to see if these episodes were present in sediments from this part of the Southern Ocean. As can be seen, the overall paucity of nannofossil intervals distributed throughout the holes did not allow this distinction. The small variety was never broken down into species level; this topic is further discussed in Raffi et al. (1993).

T1. Calcareous nannofossil species in this study, p. 14.

SITE SUMMARIES

Site 1096

Site 1096 is located on a sedimentary drift on the continental rise off the northwestern Pacific margin of the Antarctic Peninsula (Fig. F1). Three holes were cored at this site in 3152 m water depth. Hole 1096A was piston cored to 140.7 mbsf, with 84.2% recovery. Hole 1096B was also piston cored to a depth of 260.6 mbsf, with 80.5% total recovery. Hole 1096C was both piston cored (409.9 m) and drilled (197.8 m) to a combined depth of 607.7 mbsf, with 84.2% recovery for both.

Sediments recovered are mainly fine-grained and terrigenous material, consistent with drift deposition, and divided into three depositional units. The detailed lithology is discussed in the "Site 1096" chapter of the Leg 178 *Initial Reports* volume (Shipboard Scientific Party, 1999b). The age of the sediments extend from the Holocene to early Pliocene at the base of Hole 1096C. Fossil preservation and abundance varies throughout Holes 1096A and 1096B (Table T2).

T2. Calcareous nannofossil distribution, Site 1096, p. 15.

Site 1101

Site 1101 is located northeast of Site 1096, also on a hemipelagic sedimentary drift, in 3291.2 m water depth. One hole was attempted and cored at this site. Twenty-four cores were recovered (99.1% recovery), with a total depth of 217.7 mbsf. The sediments from Site 1101 contain a nearly continuous distal glacial record of the past 3.1 m.y. and can be divided into three lithostratigraphic units (Shipboard Scientific Party, 1999c). Calcareous nannofossils are observed in the upper two units, in laminated as well as massive sediments. Foraminifers are noted to be present below 53.3 mbsf, but nannofossils occur sporadically from the top of the hole to 121.1 mbsf. Hole 1101A extends to the late Pliocene, but nannofossils provide age correlation only within the Pleistocene. Preservation and abundance vary, with the majority of samples being poorly preserved with rare occurrences of species (Table T3).

T3. Calcareous nannofossil distribution, Site 1101, p. 19.

Site 1098

Samples from Hole 1098C were also examined for calcareous nannofossils. We looked only at Hole 1098C, due to an almost total lack of calcareous nannofossils in this material.

Because of an observed increasing dissolution problem with sediment in storage over time (Osterman et al., Chap. 7, this volume), the samples examined were ones prepared aboard ship for a diatom study. Even with this precaution, there were only very rare sightings of nannofossils in the sediment. An *Emiliana huxleyi* specimen was observed in Section 178-1098C-1H-2, 20 cm, and a *Calcidiscus leptoporus* specimen in 178-1098C-4H-2, 100 cm. *Thoracosphaera* spp. fragments were the most common taxa observed, yet these were seen only rarely, at best. The possibility of examining original slides taken on cruises, as opposed to subsequent, later sampling of cores, should be strongly considered when reexamining older material from the higher southern latitudes for calcareous biogenic information.

BIOSTRATIGRAPHIC DISCUSSION

Biocalcareous Stratigraphic Events

The biostratigraphy afforded by calcareous nannofossils in material from Leg 178 continental rise sites is discontinuous and incomplete. Nevertheless, they allow biostratigraphic age control when there would otherwise be only paleomagnetic data, as diatoms, radiolarians, and foraminifers are rare and reworked in the upper intervals of these sites. Overall abundance and diversity is often low, with several samples having abundant or common placoliths (Tables T2, T3). Table T4 lists the biostratigraphic events observed during this study.

T4. Calcareous nannofossil events, p. 21.

The acme of *E. huxleyi* in the uppermost Holocene is not observed in any of the samples examined from these three holes (1096A, 1096B, and 1101A). The base of *E. huxleyi* is noted in Hole 1101A (interval 178-1101A-2H-5, 90 cm, to 2H-CC [15.6–18.2 mbsf]), allowing the CN15/NN21a biozone boundary to be assigned in this hole. In all three sites the next 10–15 m of sediment below this interval is barren of any nannofossils. Holes 1101A and 1096B have samples with only scarce or rare occurrences down through 72 and 78 mbsf, respectively. Hole 1096A contained two samples with higher abundances at 28 and 53 mbsf, the first of which contained the youngest sample, with common to abundant numbers of *Coccolithus pelagicus*. The samples containing greater numbers (≥1 per field of view) are indicated with a dot on Figures F2 and F3. The gray bars on these two figures illustrate the periodic nature of the samples containing calcareous nannofossils. The overall abundance of nannofossils is also indicated with the graph on the right side of the figures.

The next biostratigraphic event observed is the LO of *Pseudoemiliania lacunosa* (interval 178-1096A-3H-CC to 4H-2, 40 cm [25.23–28.6 mbsf]). The large barren interval in Hole 1101A makes it unwise to place this event in this hole. The LO of *P. lacunosa* indicates the base of Biozones CN14b/NN20. Hole 1096B contains the next two stratigraphically older events, the LO of *Reticulofenestra asanoi* and the reentrant of medium-sized *Gephyrocapsa* spp. These two events are contained in one sample at 78.41 mbsf (Section 178-1096B-9H-6, 61 cm), with the ranges for each extending to the samples on either side (up- and downcore). The LO of *R. asanoi* ranges between 76.76 and 78.41 mbsf (interval 178-1096B-9H-5, 46 cm, to 9H-6, 61 cm) and the reentrant of medium-sized *Gephyrocapsa* spp. between 78.41 and 79.72 mbsf (interval 178-1096B-9H-6, 61 cm, to 9H-7, 42–44 cm). Raffi et al. (1993) observed the reentrant event to occur at 0.96 Ma. Both of these events occur between 1.03 and 1.05 Ma in Hole 1096B (based on paleomagnetics and sedimentary rates at this site). The difference in the event(s) age and the fact that there are barren and low-abundance samples upcore from Sample 178-1096B-9H-6, 61 cm, indicate that neither of these are likely to be the actual LO and reentrant events. They are both included in the table of calcareous nannofossil events despite this possibility, due to the uncertainty of how calcareous nannofossil events occurred in the Southern Ocean and the fact that Hole 1101A also contained the reentrant event of medium-sized *Gephyrocapsa* spp. between 1.05 and 1.15 Ma (Table T4).

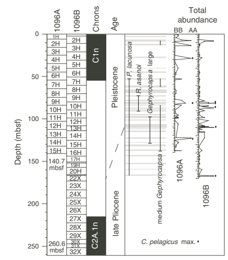
The FO of *R. asanoi* was noted at both sites, occurring at 90.4–91.5 mbsf (interval 178-1096B-11H-1, 11 cm, to 11H-2, 70 cm) and 84.77–84.94 mbsf (interval 178-1101A 10H-6, 107 cm, to 10H-CC). The total range of the large variety of *Gephyrocapsa* spp. was observed at both sites: from 91.5–97.42 to 128.84–131.49 mbsf at Site 1096 and from 84.94–90.9 to 94.19–98.88 mbsf at Site 1101 (see Tables T2 and T3 for samples). Neither *Gephyrocapsa oceanica* or *Gephyrocapsa caribbeanica* (large varieties) occurred in great numbers in either hole, yet these species were distinctive in both their appearance and in the intervals in which they did occur, with very little reworking indicated.

The LO of *Helicosphaera selli* was observed only at Site 1101 at 90.9–93.87 mbsf (interval 178-1101A-11H-4, 70 cm, to 11H-6, 67 cm). The base of Biozone CN13b is defined by the FO of medium-sized *Gephyrocapsa* spp., noted in Site 1096 at 138.37–138.45 mbsf (interval 178-1096B-15H-5, 11 cm, to 15H-CC). Calcareous nannofossils were not observed (downhole) at 168.37 and 121.1 mbsf in Holes 1096B and 1101A, respectively.

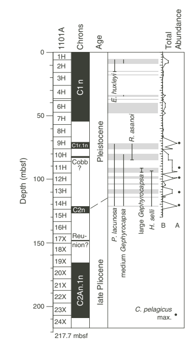
C. pelagicus "Blooms"

As can be seen in Figures F2 and F3, the total abundance and frequency of occurrence of calcareous nannofossils increase toward the lower part of their range at each site. Many of the samples with high total abundance contain large numbers of *C. pelagicus* (these samples are illustrated by black dots in the aforementioned figures). It is worthy of

F2. Biostratigraphic ranges of calcareous nannofossil species, Site 1096, p. 12.



F3. Biostratigraphic ranges of calcareous nannofossil species, Site 1101, p. 13.



note that in Hole 1096B, maximum abundances of *C. pelagicus* are associated with lower numbers of medium-sized *Gephyrocapsa* spp. Sato et al. (1998) studied *C. pelagicus* from middle and high northern latitudes in relation to its significance as a cold-water current indicator. Presently, this species occurs only in high-latitude regions but has a fossil distribution as far south as the equatorial Pacific (>4.5, 4.5–3.66, and 2.75–1.65 Ma). This southerly distribution was associated with the elevation of the Isthmus of Panama, causing the cold northern currents to flow into the equatorial Pacific. Wei and Wise (1992b) noted *C. pelagicus* to mark the warmer end of the spectrum when compared with an even colder water species, *Reticulofenestra perplexa,* from the Antarctic during the Miocene.

General Discussion

Pliocene and Pleistocene occurrences of calcareous nannofossils in ODP cores were noted previously from the Southern Ocean during Legs 113, 119, and 120 (Barker and Kennett, 1988; Barron, Larson, et al., 1989; Barron et al., 1991; Wei and Wise, 1990, 1992a, 1992b). Hole 693A (Leg 113) contains rare occurrences of *G. oceanica* in Section 113-693A-1H-CC, which were believed at the time to be a contaminant (Wei and Wise, 1990). This site is situated in a hemipelagic setting in the eastern Weddell Sea. Site 690 (also Leg 113) contained rare occurrences of *C. pelagicus* and *P. lacunosa*. Wei and Wise (1990) also concluded that the presence of *C. pelagicus* at Site 690, in the middle Pliocene to upper Pleistocene, suggests that interglacial conditions during this time were sufficiently warm to allow this species to exist at this site. Hole 747A (Leg 120) contained abundant to common *E. huxleyi* in the upper two samples. Several samples within the Pliocene–Pleistocene interval had rare to abundant occurrences of small *Gephyrocapsa* spp., with one sample (120-747A-1H-4, 10–11 cm) containing abundant *G. oceanica*. *C. pelagicus* is rare to very abundant throughout the Pliocene–Pleistocene interval of this Hole, with a somewhat discontinuous range (Wei and Wise, 1992a). Wei and Thierstein (1991) (Leg 119) observed an early to middle Pleistocene assemblage in Sample 119-738A-1H-CC (*C. leptoporus, C. pelagicus, G. caribbeanica, Helicosphaera kamptneri,* and *P. lacunosa*). They suggested that the presence of these species might indicate surface waters that were significantly warmer during this period than they are today.

Villa and Wise (1998) observed *Thoracosphaera* spp. in the CRP-1 hole of the Cape Roberts Project in the Ross Sea. This is interpreted to mean several possible things. Either the ability of this genus to form cysts allowed them to survive in the Antarctic environment, or there were warmer conditions in the Ross Sea during the time of production and deposition (or a bit of both). In addition to this core, they also examined others from various sites around Antarctica. Several Deep Freeze cores, also from the Ross Sea, were examined and found to contain rare occurrences of *C. pelagicus, Reticulofenestra producta, Gephyrocapsa* spp., and *Thoracosphaera* spp. A SEDANO (Sediment Drifts of the Antarctic Offshore) core nearer to the area of Leg 178, the Pacific margin of the Antarctic Peninsula, contained *Gephyrocapsa ericsonii, C. leptoporus, C. pelagicus, Helicosphaera* spp., and *E. huxleyi.*

Burckle and Pokras (1991) report finding early Holocene calcareous nannofossils in cores near the western side of the Antarctic Peninsula. In this same paper, however, they conclude that average surface-water temperatures have to be above 3°C during the growing season to produce and preserve calcareous nannofossils. Following this approach, Kennett and Hodell (1993, 1995) argue that the absence of Pliocene calcareous nannofossils in Antarctic waters can be used as a paleotemperature index; the absence of calcareous nannofossils must indicate temperatures below 5°C. Under such warming, they surmise, biosiliceous sedimentation in Antarctic waters would be replaced by biocalcareous sedimentation, such as that seen north of the Polar Front today. An obvious problem with generalizations is that in some instances they do not completely apply. At this time, there is no easy explanation why calcareous nannofossils were living and subsequently being deposited in the hemipelagic drifts on the western Pacific margin of the Antarctic Peninsula during the Pleistocene. There were no concrete conclusions reached in previous investigations that observed Pleistocene and Pliocene nannofossils in the studies mentioned earlier from several points in the Southern Ocean. That they were either not growing or not being deposited in large numbers is quite evident. The most common species observed is not always the most dissolution resistant (i.e., *C. pelagicus*), yet there are intervals where this species is abundant. Many of the samples are poorly preserved, but not completely.

These biocalcareous components of the sediment in close proximity to the continent can not and should not be ignored or considered to be random mistakes; they occur in too high a frequency and diversity to be such.

CONCLUSIONS

The stratigraphic usefulness of calcareous nannofossils proved itself again during Leg 178. This group provides reliable age constraints for the Pleistocene at Sites 1096 and 1101, correlating well with the paleomagnetic record from each site. Considering that the reference ages for the biostratigraphic events were drawn from studies well to the north of the locale of this leg, this is quite an interesting phenomenon. Although species diversity and total abundance were often low, the reliability of the biostratigraphic ages produced was not grossly affected. The many previous studies that included similar observations of nannofossils (general abundance and specific species) in the Southern Ocean from the Pleistocene allow us to conclude that they had a circumpolar distribution for at least several periods of time in this interval. The periodic nature of the occurrences of nannofossils in the sediment, and their often low abundance, seems to indicate that conditions were perhaps not optimal but were consistently present to allow production and subsequent preservation in the sediment. The fact that calcareous nannofossils occur in an interval that contains rare, fragmented, and reworked biosiliceous species begs further study from numerous sites around the Antarctic continent.

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Figure F1. Location map of Leg 178 Sites 1096 and 1101.

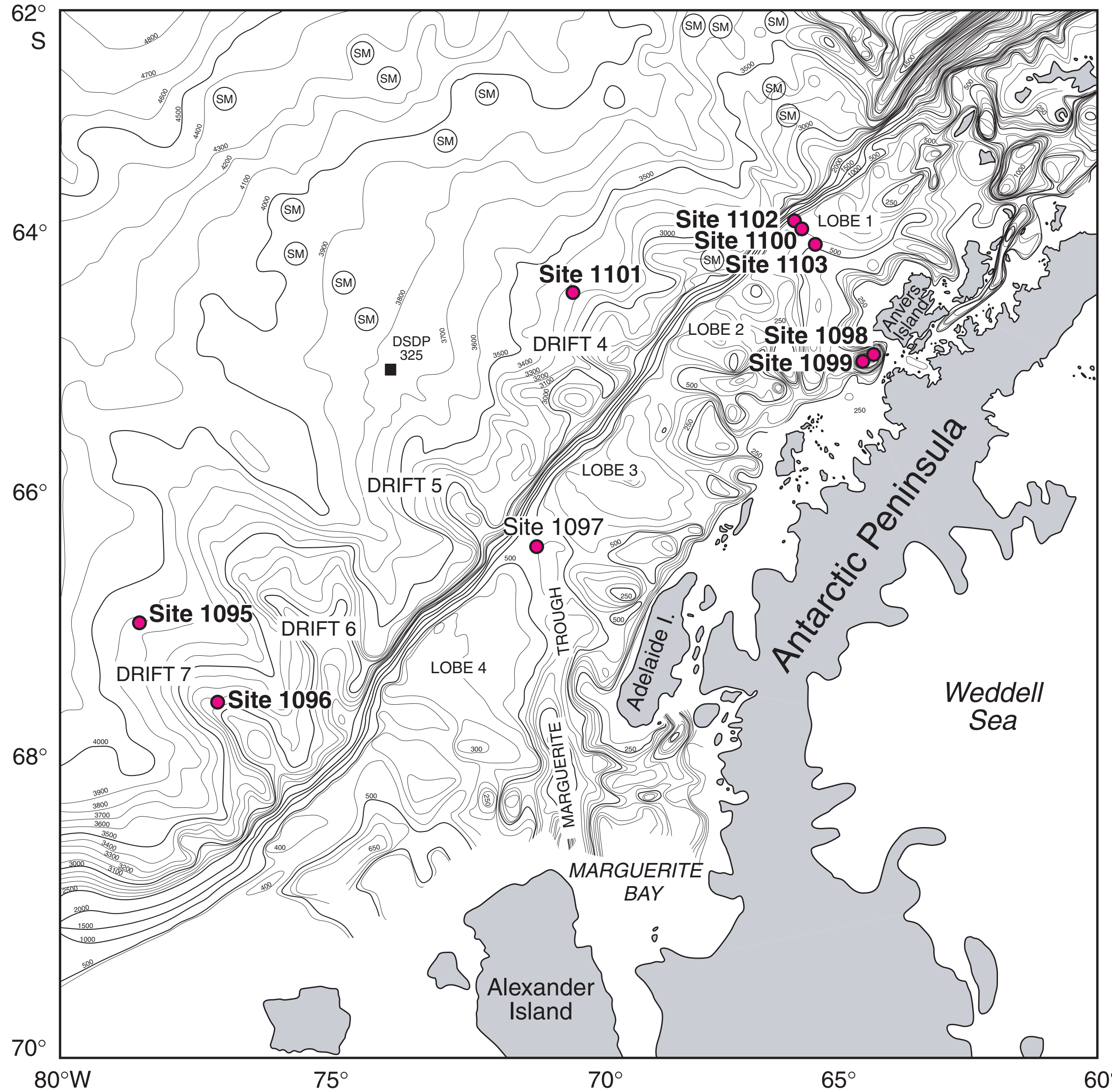

Figure F2. Illustration of biostratigraphic ranges of calcareous nannofossil species from Holes 1096A and 1096B. Black bars = normal polarity chrons. Gray horizontal bars = intervals in which nannofossils were observed. The graphs to the right show total abundance of assemblage: left = barren, right = abundant. Black dots indicate samples with maximum abundances of *C. pelagicus*.

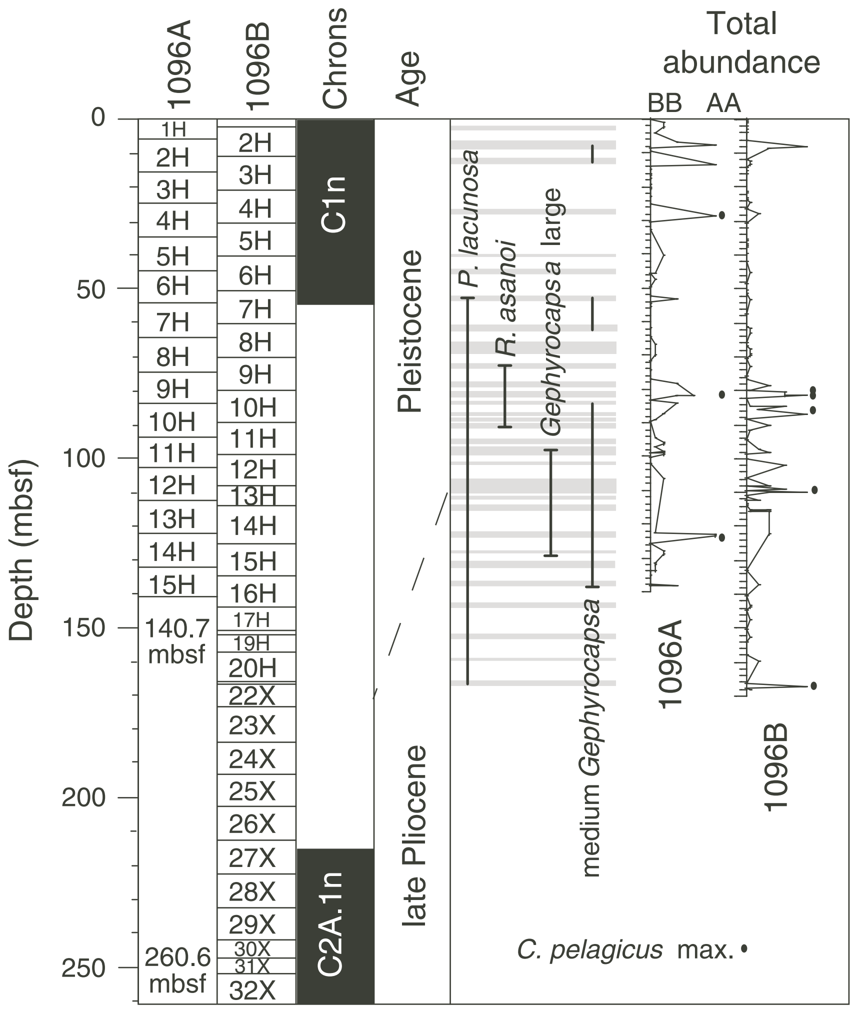

Figure F3. Illustration of biostratigraphic ranges of calcareous nannofossil species from Hole 1101A. Black bars = normal polarity chrons. Gray horizontal bars = intervals in which nannofossils were observed. The graph to right shows total abundance of assemblage: left = barren, right = abundant. Black dots indicate samples with maximum abundances of *C. pelagicus*.

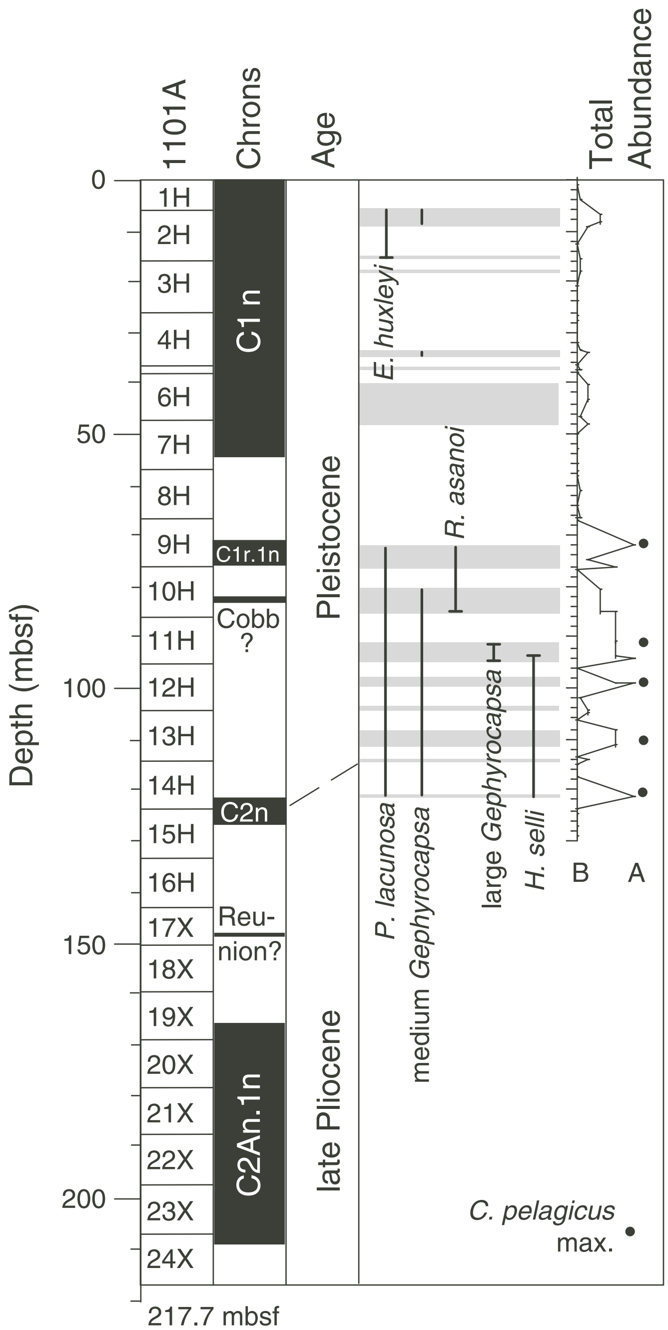

Table T1. List of calcareous nannofossil species considered in this study.

Calcidiscus leptoporus (Murray and Blackman, 1898) Loeblich and Tappan, 1978
Calcidiscus macintyrei (Bukry and Bramlette, 1969) Loeblich and Tappan, 1978
Coccolithus pelagicus (Wallich, 1877) Schiller, 1930
Emiliana huxleyi (Lohmann, 1902) Hay and Mohler in Hay et al., 1967
Gephyrocapsa caribbeanica Boudreaux and Hay, 1967
Gephyrocapsa oceanica Kamptner, 1943
Helicosphaera selli Bukry and Bramlette, 1969
Pseudoemiliana lacunosa (Kamptner, 1963) Gartner, 1969
Reticulofenestra spp.
Reticulofenestra asanoi Sato and Takayama, 1992

Table T2. Distribution of Pleistocene calcareous nannofossils, Site 1096. (**See table notes.** Continued on next three pages.)

Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*Calcidiscus leptopus*	*Calcidiscus macintyrei*	*Coccolithus pelagicus*	*Emiliana huxleyi*	*Gephyrocapsa* spp. (large)	*Gephyrocapsa* spp. (medium)	*Gephyrocapsa* spp. (small)	*Helicosphaera kamptneri*	*Helicosphaera selli*	*Pseudoemiliana lacunosa*	*Reticulofenestra* spp.	*Reticulofenestra asanoi*	NN Zone	CN Zone
178-1096A-																	
1H-1, 5-7	0.05	B															
1H-1, 87	0.87	R	P														
1H-2, 70	2.20	R	P														
1H-3, 95	3.95	X	P													NN21a	CN15
1H-5, 71	6.71	F	P														
1H-CC	7.58	A	M	R		F	F		C	F							
2H-1, 82-84	8.52	B														NN20	CN14b
2H-2, 16-18	9.36	B															
2H-4, 127	13.47	A	M	C		F			F	R	R			VR			
2H-5, 17-19	13.87	B															
2H-5, 120	14.90	B															
2H-6, 73-75	15.93	B															
2H-6, 80	16.00	B															
2H-7, 10-12	16.80	B															
2H-7, 62	17.32	B															
2H-CC	17.41	B															
3H-2, 50	19.20	B															
3H-2, 125-127	19.95	B															
3H-3, 32-34	20.52	B															
3H-4, 115-117	22.85	B															
3H-6, 17-19	24.87	B															
3H-CC	25.23	B															
4H-2, 40	28.60	A	P	F		C			C	C			F			NN19	CN14a(?)
4H-3, 69-71	30.39	B															
4H-CC	32.71	B															
5H-3, 97-99	40.17	R	P			VR							R				
5H-7, 33	45.53	VR	P			VR				VR							
5H-CC	45.75	B															
6H-2, 34	47.54	VR	P							VR							
6H-3, 90	49.60	B															
6H-5, 80	52.50	B															
6H-6, 27	53.47	F	P	VR		VR			R	VR	VR		R				
6H-6, 108-110	54.28	B															
6H-CC	54.71	B															
7H-1, 31-33	55.51	B															
7H-1, 50	55.70	B															
7H-5, 50	61.70	B															
7H-CC	64.44	B															
8H-2, 45	66.65	VR	P										VR				
8H-4, 45	69.65	VR	P										VR				
8H-5, 69-71	71.39	B															
8H-CC	74.08	B															
9H-2, 116-118	76.86	B															
9H-3, 110	78.30	F	P	R		R							F				
9H-6, 130	81.78	C	P	R		C							R	R?			
9H-7, 10	82.05	F	P			F							F				CN13b
9H-CC	83.45	B															
10H-1, 50	84.20	F	P	R		F		?	VR				R	?			
10H-3, 72	87.42	R	P			R											
10H-4, 73	88.99	VR	P			VR											
10H-4, 79-81	89.05	VR	P			VR											
10H-CC	89.51	B															
11H-1, 138	94.58	VR	P										VR	?			
11H-2, 105-107	95.75	R	P			VR		R	VR				VR				
11H-2, 136	96.06	R	P											R?			
11H-3, 80-82	97.00	VR	P			VR		VR									
11H-4, 54	98.24	R	P	VR		VR		R					VR				
11H-4, 109-111	98.79	B															

Table T2 (continued).

Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*Calcidiscus leptopus*	*Calcidiscus macintyrei*	*Coccolithus pelagicus*	*Emiliana huxleyi*	*Gephyrocapsa* spp. (large)	*Gephyrocapsa* spp. (medium)	*Gephyrocapsa* spp. (small)	*Helicosphaera kamptneri*	*Helicosphaera selli*	*Pseudoemiliana lacunosa*	*Reticulofenestra* spp.	*Reticulofenestra asanoi*	NN Zone	CN Zone
11H-4, 119	98.89	R	P			R											
11H-5, 32	99.52	R	P			VR		VR	\				VR	?			
11H-5, 105	100.25	B															
11H-5, 107-109	100.27	B															
11H-CC	102.17	B															
12H-CC	106.49	R	P			VR		VR	VR				VR	VR			
14H-1, 69-71	122.39	VR	P			VR											
14H-1, 132	123.02	A	M	R		A		\	F	F			R				
14H-2, 29-31	123.49	A	M	R		A		\	C	C	VR		C	R			
14H-2, 44	123.64	A	P	R		A		VR	F	F			R	R			
14H-3, 114-116	125.54	B															
14H-5, 39-41	128.09	R	P			R			R				R				
14H-5, 114	128.84	R	P			R		VR									
14H-CC	131.49	VR	P			VR											
15H-1, 86	132.06	VR	P			VR											
15H-2, 96	133.66	VR	P											VR			
15H-2, 110	133.80	B															
15H-3, 84-86	135.04	B															
15H-3, 94	135.14	B															
15H-5, 81	138.01	B															
15H-5, 117	138.37	F	P	VR		R		\	VR	VR			R	F			
15H-CC	138.45	B															
178-1096B-																	
1H-1, 12-13	0.12	B															
1H-1, 64-66	0.64	B															
1H-1, 116-118	1.16	B															
1H-2, 66-68	2.16	B															
1H-2, 124-126	2.74	B															
1H-CC	3.64	B															
2H-1, 8-10	3.88	B															
2H-2, 80	4.60	B															
2H-3, 136-138	8.16	A	P	X		F			F	C	R		X				
2H-4, 35	8.65	F	P			R				F							
2H-6, 80	12.04	B															
2H-6, 86-88	12.10	X	P						X								
2H-CC	13.31	X	P			X											
3H-1, 100	14.30	B															
3H-2, 18-20	14.98	B															
3H-2, 23	15.03	B															
3H-2, 120	16.00	B															
3H-6, 20-22	21.00	B														NN20	CN14b
3H-6, 70	21.50	B															
3H-CC	23.01	B															
4H-1, 90-92	23.70	B															
4H-2, 14-16	24.44	X	P			X										NN19	CN14a
4H-4, 39	26.34	B															
4H-5, 26-28	27.71	R	P							R							
4H-7, 10-12	30.55	B															
4H-8, 36-38	31.81	B															
4H-CC	32.15	B															
5H-2, 130-132	35.10	B															
5H-3, 48-50	35.78	B															
5H-4, 7	36.87	B															
5H-4, 54-56	37.34	B															
5H-4, 74-76	37.54	B															
5H-5, 102-104	39.32	B															
5H-7, 60	41.90	B															
5H-CC	42.03	B															
6H-3, 52-54	45.32	X	P			X											
6H-5, 54-56	48.34	B															

Table T2 (continued).

Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*Calcidiscus leptopus*	*Calcidiscus macintyrei*	*Coccolithus pelagicus*	*Emiliana huxleyi*	*Gephyrocapsa* spp. (large)	*Gephyrocapsa* spp. (medium)	*Gephyrocapsa* spp. (small)	*Helicosphaera kamptneri*	*Helicosphaera selli*	*Pseudoemiliana lacunosa*	*Reticulofenestra* spp.	*Reticulofenestra asanoi*	NN Zone	CN Zone
6H-6, 120-122	50.50	B															
6H-7, 35-37	51.15	B															
6H-CC	51.53	B															
7H-2, 46-48	53.20	X	P						X	X							
7H-5, 32-34	57.56	B															
7H-CC	61.21	B															
8H-1, 92-94	61.72	X	P							X							
8H-2, 56	62.87	X	P						X	X							
8H-4, 70	66.00	B															
8H-5, 10-12	66.90	B															
8H-5, 110-112	67.90	X	P						X	X							
8H-6, 85	69.15	X	P			X				X			X	X			
8H-6, 114-116	69.44	X	P										X				
8H-CC	70.76	B															
9H-2, 119	72.99	X	P	X													
9H-3, 66	73.96	R	P										R				
9H-4, 94	75.74	B															
9H-5, 46-48	76.76	B															
9H-6, 61	78.41	F	P	R		F			R	X			R	R	X		
9H-7, 42-44	79.72	X	P											X			CN13b
9H-CC	79.98	B															
10H-1, 68	80.48	C	P	R		C			X	R	R		X	R			
10H-1, 140-142	81.20	C	M	R		C				X	X		R	R	R		
10H-2, 16	81.46	A	M	C		A				R	R		R	F	R		
10H-2, 94-96	82.24	B															
10H-4, 18-20	84.48	X	P			X											
10H-4, 104	85.34	C	M	R		C				R			R	R	F		
10H-4, 106-108	85.36	R	P			R							X		R		
10H-5, 93	86.73	A	M	F						X			F	R			
10H-CC	88.45	B															
11H-1, 110-112	90.40	F	P	X		F							X	X	X		
11H-2, 70	91.50	X	P			X											
11H-4, 73	94.53	B															
11H-6, 62	97.42	R	P			R		R					R				
11H-6, 128	98.08	F	P			R		R	R	X			R	X	?		
11H-bottom of core	98.67	B															
12H-1, 123	100.03	B															
12H-3, 14	101.94	C	P	F		R		R	F	F			R	R	?		
12H-5, 94	105.74	B															
12H-7, 14	107.94	F	P	F		R		R	F	F			R				
12H-CC	108.05	B															
13H-1, 51-53	108.81	C	M	F	?	R		X	F	C			X	R			
13H-1, 57	108.87	C	M	R	?	R		X	F	A			R	R			
13H-1, 58	108.88	C	P	R		R		X	F	C			R	X			
13H-1, 104	109.34	B															
13H-2, 10-12	109.90	A	P			A			X	R			X				
13H-2, 25	110.05	F	P	R				?	F	F			R	R			
13H-2, 130	111.10	B															
13H-2, 131-133	111.11	B															
13H-3, 2	111.32	B															
13H-3, 90-92	112.20	R	P	X		X				X	?		X				
13H-3, 94	112.24	B															
13H-4, 36	113.16	B															
13H-4, 100	113.80	B															
13H-5, 59	114.89	X	P			X											
13H-5, 103-105	115.33	F	P			R				F							
13H-5, 119	115.49	*															
13H-CC	115.75	F	M	X		F			R	F							
14H-CC	122.00	F	P			F			R	R							
15H-CC	133.00	B															
16H-2, 70	137.40	F	M	X		R				X			X	F			CN13a

Table T2 (continued).

Core, section, interval (cm)	Depth (mbsf)	Abundance	Preservation	*Calcidiscus leptopus*	*Calcidiscus macintyrei*	*Coccolithus pelagicus*	*Emiliana huxleyi*	*Gephyrocapsa* spp. (large)	*Gephyrocapsa* spp. (medium)	*Gephyrocapsa* spp. (small)	*Helicosphaera kamptneri*	*Helicosphaera selli*	*Pseudoemiliana lacunosa*	*Reticulofenestra* spp.	*Reticulofenestra asanoi*	NN Zone	CN Zone
16H-4, 70	140.40	B															
16H-6, 70	143.40	X	P	X													
16H-CC	143.94	X	P						?	X							
17H-1, 60	144.70	B															
17H-3, 60	147.70	X	P										X	X			
18H-CC	150.57	B															
19H-2, 39-41	152.59	X	P									X					
19H-2, 70	152.90	B															
19H-3, 22-24	153.92	B															
19H-4, 70	155.90	B															
19H-CC	157.62	B															
20H-2, 49-51	159.69	R	P			R											
20H-4, 49-51	162.69	B															
20H-CC	166.50	B															
21H-2, 136	167.40	A		F	?	C			?			R	F				
21H-CC	167.90	B															
22H-CC	168.37	VR	M			R						?	X				

Notes: * = very dissolved and overgrown. Abundance: A = abundant, C = common, F = few, R = rare, X = scarce, B = barren. Preservation: P = poor, M = moderate.

Table T3. Distribution of Pleistocene calcareous nannofossils, Site 1101. (See table notes. Continued on next page.)

Core, section, interval(cm)	Depth (mbsf)	Abundance	Preservation	*Calcidiscus leptopus*	*Calcidiscus macintyrei*	*Coccolithus pelagicus*	*Emiliana huxleyi*	*Gephyrocapsa* spp. (large)	*Gephyrocapsa* spp. (medium)	*Gephyrocapsa* spp. (small)	*Helicosphaera* spp.	*Helicosphaera selli*	*Pseudoemiliana lacunosa*	*Reticulofenestra* spp.	*Reticulofenestra asanoi*	NN Zone	CN Zone
178-1101A-																	
1H-1, 80	0.80	B															
1H-3, 80	3.80	X	P			X											
1H-5, 80	6.80	F	M	R		R	X			R	X			R		NN21a	CN15
1H-CC	8.32	F	M	X		R	R		X	F	X		X	R			
2H-1, 70	9.40	R	P			X	R			R							
2H-3, 90	12.60	B															
2H-5, 90	15.60	X	P			X	X		X								
2H-CC	18.20	X	M			X								X		NN20	?
3H-2, 110	20.80	B															
3H-4, 110	23.80	B															
3H-6, 110	26.80	B															
3H-CC	27.67	B															
4H-3, 130	32.00	B															
4H-4, 130	33.50	X	P	X													
4H-5, 50	34.20	R	M	R		R				R							
4H-6, 130	36.50	B															
4H-7, 85	37.55	X	P			X	?							X			
4H-CC	37.59	B															
5H-CC	37.69	B															
6H-2, 70	40.40	R	P			R				X							
6H-4, 70	43.40	R	P			R											
6H-6, 70	46.40	X	P	X		X											
6H-CC	48.04	R	P			R											
7H-2, 75	49.95	B															
7H-4, 75	52.95	B															
7H-6, 75	55.95	B															
7H-CC	57.41	B															
8H-1, 105	58.25	B															
8H-3, 91	61.21	X	P	X		X								X			
8H-5, 96	64.16	B															
8H-7, 14	66.34	X	P	X													
8H-CC	66.72	B															
9H-2, 87	67.07	B															
9H-4, 87	72.07	A	P	R		A				X	X		R	X	R		CN14a
9H-6, 46	74.66	R	P	R		R							X	X	R		
9H-CC	76.01	C	P	R	?	F							F	X	R		
10H-1, 46	76.66	B															
10H-3, 118	80.38	F	P	F		X			R	R			F	X	F		
10H-6, 107	84.77	F	P	R		R		?	X		X		F	X	X		
10H-CC	84.94	C	P	F		X		X	R				C	R	?		
11H-4, 70	90.90	C	P	F		C		F	R				R	R			
11H-6, 67	93.87	C	P	R		R		R	F		X	R	R	X			
11-CC	94.19	A	P	R	?	F		F	A	R	X		X				
12H-1, 87	96.07	B															
12H-3, 63	98.88	C	P	R		C			R				X				
12H-3, 90	99.10	A	P	F		F			C	X	X	X	R	X			
12H-5, 77	101.97	X	P			X			X				X				
12H-7, 36	104.56	R	P			R			R				X				
12H-CC	104.60	R	P			R			R	R				X			
13H-1, 138	106.08	B															
13H-3, 48	108.18	C	P	R		F			F	C	R	R					
13H-5, 52	111.22	C	P	R	X	C			R	R	F	X	X	X			
13H-7, 34	113.54	B															
13H-CC	114.00	R	P		X	R				X				X			
14H-1, 97	115.17	B															
14H-3, 44	117.64	B															
14H-5, 90	121.10	A	P	F	X	C			R	F	R		R	A			
14H-7, 52	123.72	B															

Table T3 (continued).

Core, section, interval(cm)	Depth (mbsf)	Abundance	Preservation	*Calcidiscus leptopus*	*Calcidiscus macintyrei*	*Coccolithus pelagicus*	*Emiliana huxleyi*	*Gephyrocapsa* spp. (large)	*Gephyrocapsa* spp. (medium)	*Gephyrocapsa* spp. (small)	*Helicosphaera* spp.	*Helicosphaera selli*	*Pseudoemiliana lacunosa*	*Reticulofenestra* spp.	*Reticulofenestra asanoi*	NN Zone	CN Zone
14H-CC	123.80	B															
15H-1, 81	124.51	B															
15H-3, 20	126.90	B															
15H-5, 70	129.00	B															

Notes: Abundance: A = abundant, C = common, F = few, R = rare, X = scarce, B = barren. Preservation: P = poor, M = moderate.

Table T4. Position of Pleistocene calcareous nannofossil events, Sites 1096 and 1101.

Core, section, interval (cm)	Depth (mbsf)	Estimated age (Ma)	Event
178-1096A-			
3H-CC to 4H-2, 40	25.23-28.60	0.36-0.40	T *Pseudoemiliania lacunosa*
178-1096B-			
9H-5, 46 to 9H-6, 61	76.76-78.41	1.03-1.04	T *Reticulofenestra asanoi*
9H-6, 61 to 9H-7, 42	78.41-79.72	1.04-1.05	Reentrance medium *Gephyrocapsa* spp.
11H-1, 110 to 11H-2, 70	90.40-91.50	1.17-1.18	B *Reticulofenestra asanoi*
11H-2, 70 to 11H-6, 62	91.50-97.42	1.18-1.25	T large *Gephyrocapsa* spp.
178-1096A-			
14H-5, 114 to 14H-CC	128.84-131.49	1.58-1.61	B large *Gephyrocapsa* spp.
15H-5, 117 to 15H-CC	138.37-138.45	1.71-1.72	B medium *Gephyrocapsa* spp.
178-1101A-			
2H-5, 90 to 2H-CC	15.60-18.20	0.24-0.26	B *Emiliania huxleyi*
9H-CC to 10H-3, 118	76.01-80.38	1.05-1.15	Reentrance medium *Gephyrocapsa* spp.
10H-6, 107 to 10H-CC	84.77-84.94	1.19-1.20	B *Reticulofenestra asanoi*
10H-CC to 11H-4, 70	84.94-90.90	1.21-1.28	T large *Gephyrocapsa* spp.
11H-4, 70 to 11H-6, 67	90.90-93.87	1.28-1.35	T *Helicosphaera selli*
11H-CC to 12H-3, 63	94.19-98.88	1.36-1.42	B large *Gephyrocapsa* spp.

Note: T = top, B = bottom.