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Data report: calcareous nannofossils from upper Pliocene and Pleistocene, Expedition 306 Sites U1313 and U1314[1]

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Chapter contents

Abstract

Integrated Ocean Drilling Program Expedition 306 recovered expanded Pliocene–Pleistocene sections at two sites in the North Atlantic. Site U1313 was drilled on the western flank of the Mid-Atlantic Ridge northwest of the Azores, whereas Site U1314 was drilled on the southern Gardar Drift. Calcareous nannofossils from both sites are abundant and moderately to well preserved in the upper Pliocene and Pleistocene. The assemblages are dominated by gephyrocapsids and reticulofenestrids. Biostratigraphic analysis of the upper 158 meters composite depth (mcd) of Site U1313 yields a complete succession of nannofossil datums spanning the last 3 m.y. Site U1314, which had higher sedimentation rates during the Pleistocene, spans the last 1 m.y. in the upper 96 mcd.

Introduction

During Integrated Ocean Drilling Program (IODP) Expedition 306, three sites were drilled in the North Atlantic (Fig. F1) to obtain expanded Pliocene–Pleistocene sections for generation of integrated millennial-scale stratigraphies incorporating geomagnetic paleointensity, stable isotopes, and detrital carbonate layers (see the "Expedition 306 summary" chapter). Two sites, U1313 and U1314, yielded sections with suitably high sedimentation rates to achieve this objective.

Site U1313 represents a reoccupation of Deep Sea Drilling Project (DSDP) Site 607, a classic locality for studying changes in ocean circulation and ice sheet variability during the Pliocene and Pleistocene (see the "Site U1313" chapter). Four holes were drilled in ~3412 m of water at Site U1313 (41°0.0′N, 32°57.4′W), located at the base of the upper western flank of the Mid-Atlantic Ridge northwest of the Azores. These holes yielded two complete composite sections to 174 meters composite depth (mcd) (mid-Pliocene). Site U1313 includes a complete and relatively expanded Pliocene–Pleistocene section, with sedimentation rates based on shipboard biostratigraphy of 4.1–4.5 cm/k.y.

Site U1314 is located on the southern Gardar Drift in the North Atlantic (see the "Site U1314" chapter). This site is situated south of DSDP Sites 983 and 984, where high sedimentation rates (10–15 cm/k.y.) during the Pliocene and Pleistocene were recorded. However, Sites 983 and 984 are outside the main ice-rafted debris

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(IRD) belt and located at water depths too shallow to monitor North Atlantic Deep Water (NADW). Site U1314 was selected in a location more proximal to the IRD belt and at depths deep enough to record NADW (see the **"Site U1314"** chapter). Three holes were drilled in ~2800 m of water at Site U1314 (56°21.9′N, 27°53.3′W), recovering a section spanning the upper Pliocene and Pleistocene. Sedimentation rates based on shipboard biostratigraphy indicate higher rates than those found at Site U1313, with rates during the late Pliocene close to 11 cm/k.y., decreasing to 7.0–7.5 cm/k.y. during the Pleistocene.

Calcareous nannofossils are abundant and moderately to well preserved throughout the Pliocene and Pleistocene sections of Sites U1313 and U1314. Shipboard biostratigraphic analysis pinpointed datums to core catcher samples and more rarely to a section within a core based on a limited number of "toothpick" samples taken to refine the biostratigraphy. Because the primary objective of Expedition 306 was to produce a paleointensity-assisted chronology suitable for correlation at sub-Milankovitch scales, it is vital to further refine the biostratigraphy to fit into the chronologic framework. This study refines the shipboard calcareous nannofossil biostratigraphy by examining one sample per section (or one sample every ~1.5 mcd) spanning the last 3 m.y. at Site U1313 and 1 m.y. at Site U1314.

Methods and materials

A total of 111 samples from Site U1313 and 66 samples from Site U1314 were included in this study. The sampling interval between samples was ~1.5 mcd. The meters composite depth scale was constructed by correlating cores from multiple holes drilled at one site using closely spaced measurements of physical properties (see the **"Site U1312–U1315 methods"** chapter). Sediment samples were prepared using standard smear slide techniques (e.g., Bown and Young, 1998). Calcareous nannofossils were examined at 1500× magnification under a Nikon E600 polarizing light microscope or at 1250× magnification on a Zeiss Axioskop 2 polarizing light microscope. Preservation of nannofossils was recorded as follows:

- G = good: little or no evidence of dissolution and/or overgrowth, little or no alteration of primary morphological features, and specimens are identifiable to the species level;
- M = moderate: minor dissolution or crystal overgrowth observed, some alteration of primary morphological features, but most specimens are identifiable to the species level; and
- P = poor: strong dissolution or crystal overgrowth, significant alteration of primary morphological features, and many specimens are unidentifiable at the species and/or generic level.

Semiquantitative data were collected by identifying and counting at least 300 upper photic zone specimens in a varying number of fields of view per sample. These data are normalized to 100%; reworked species were not included in this calculation. Lower photic zone species *Florisphaera profunda* was counted separately in the same fields of view when encountered, and its relative abundance within the total coccolithophore flora was calculated. After completion of the initial examination, samples were scanned for rare taxa.

Results are correlated to the calcareous nannofossil biostratigraphic zonation of Martini (1971). Absolute ages for datums are assigned based on the astrobiochronology of Raffi et al. (2006) whenever possible. Calcareous nannofossil species considered in this paper are listed in the **"Appendix,"** where they are arranged alphabetically by generic epithets. Bibliographic references for these taxa can be found in Perch-Nielsen (1985), Bown (1998), and Sáez et al. (2003).

Pliocene and Pleistocene calcareous nannoflora contain abundant coccoliths of *Gephyrocapsa* and *Reticulofenestra*. Intensity of calcification of the central area of coccoliths produced by these genera varies greatly. Because taxonomic concepts differ among authors, particularly for gephyrocapsids (see Flores et al., 1999, or Raffi, 2002, for a synthesis), it is important to define species concepts; in this study, we generally follow the gephyrocapsid species concepts described in Flores et al., 1999. Coccoliths of *Gephyrocapsa* with well-calcified (mostly closed) central areas are identified as *Gephyrocapsa caribbeanica*. Coccoliths with less calcified (more open) central areas and a bridge angle >30° are identified as *Gephyrocapsa oceanica*. Coccoliths of *Gephyrocapsa* with a less calcified central area and with a low-angle bridge (<30°) are identified as *Gephyrocapsa muellerae*. Noelaerhabdaceae coccoliths without a bridge are identified as *Reticulofenestra*. Specimens with heavily calcified (closed) central areas are assigned to *Reticulofenestra productella*, and those with less calcified (open) central areas are identified as *Reticulofenestra* spp.

Coccoliths of *Gephyrocapsa* and *Reticulofenestra* from Pliocene and Pleistocene sediments show great size variation, and the size ranges of some have been used as biostratigraphic datums (e.g., Raffi et al., 1993; de Kaenel et al., 1999; Maiorano and Marino, 2004). To provide objective information of biostratigraphic size variation of *Gephyrocapsa* and *Reticu-*

lofenestra in the Pliocene and Pleistocene sediments of this study, the length of coccoliths of these two genera was estimated using an eyepiece micrometer at 1 µm intervals for most specimens between 2 and 7 µm in diameter. Under the light microscope, it is difficult to identify small specimens (<3 µm) to species level. Following Okada (2000) we separate small gephyrocapsids (<3 µm) into two size categories. All coccoliths <2 µm with a bridge are grouped as *Gephyrocapsa* spp. (<2 µm). Coccoliths 2–3 µm in length are divided into two groups: those with a closed central area as *G. caribbeanica* s.l. (2–3 µm) and those with a more open central area as *Gephyrocapsa* spp. (2–3 µm). López-Otálvaro et al. (2008) separated small placoliths (2.5–3 µm) with a closed central area as a small morphotype of *G. caribbeanica* for the purposes of coccolith carbonate calculations. We found we could reliably separate small (2–3 µm) gephyrocapsids with a closed central area from other specimens and so follow that definition. Small coccoliths without a bridge are separated into two size categories: very small placoliths (<2 µm) and *Reticulofenestra* spp. (2–3 µm).

The short-term occurrence of *Reticulofenestra asanoi* in the middle Pleistocene is a useful biostratigraphic event. In this study, specimens of *Reticulofenestra* >6.5 µm with a less calcified central area are assigned to *R. asanoi*, consistent with the definition used for the astrobiochronology of Raffi et al. (2006), which is based on Wei (1993) and Raffi (2002). The mid-Pliocene extinction of *Reticulofenestra pseudoumbilicus* is also an important biostratigraphic datum but is easily misidentified depending on the size definition used for this species. A recent study by Gibbs et al. (2005) found a synchronous extinction of R. *pseudoumbilicus* >7 µm at 3.82–3.81 Ma, which is used in the astrobiochronology of Raffi et al. (2006). Therefore, for the purposes of this study, *R. pseudoumbilicus* includes specimens >7 µm.

Results

Site U1313

All 111 sediment samples studied yielded sufficient numbers of calcareous nannofossils for biostratigraphy. Calcareous nannofossil preservation is moderate in upper Pliocene samples, moderate to good in lower Pleistocene samples, and good in middle Pleistocene samples (Table **T1**).

A total of 13 biostratigraphic datums are recognized in the Pleistocene section of Site U1313. The most recent nannofossil event, the base of *Emiliania huxleyi* acme (0.082–0.063 Ma) is found in Sample 306-U1313B-1H-3, 12–13 cm (3.29 mcd). This zone was first defined by Gartner and Emiliani (1976) and represents the change in dominance from gephyrocapsids to *E. huxleyi*. The last occurrence (LO) of *Helicosphaera inversa* occurs in Sample 306-U1313C-2H-2, 12–13 cm (4.75 mcd). The first occurrence (FO) of *E. huxleyi* (0.289 Ma), which marks the base of Zone NN21 of Martini (1971), is present in Sample 306-U1313B-2H-5, 2–3 cm (13.68 mcd). The LO of *Pseudoemiliania lacunosa* (0.440 Ma), which defines the top of Zone NN19, as well as the FO of *H. inversa*, is found in Sample 306-U1313C-3H-6, 15–16 cm (21.29 mcd). The LO of *R. asanoi* (0.905 Ma) occurs in Sample 306-U1313C-5H-5, 90–91 cm (42.64 mcd). This event represents the last consistent occurrence of this species, and occurrences above are attributed to reworking or the difficulty of accurately determining the >6.5 µm size distinction using an eyepiece micrometer. The recurrence of medium *Gephyrocapsa* (>4 µm; 1.007 Ma) occurs in Sample 306-U1313C-5H-7, 90–91 cm (45.64 mcd). The FO of *R. asanoi* (1.136 Ma) is found in Sample 306-U1313B-6H-2, 16–17 cm (51.91 mcd). The LO of large *Gephyrocapsa* spp. (1.255 Ma) occurs in Sample 306-U1313B-6H-6, 16–17 cm (57.91 mcd). The LO of *Helicosphaera sellii* (1.256 Ma) is found in Sample 306-U1313B-7H-3, 91–92 cm (65.20 mcd). The FO of large *Gephyrocapsa* spp. (1.560 Ma) occurs in Sample 306-U1313C-8H-4, 17–18 cm (72.70 mcd). The LO of *Calcidiscus macintyrei* (1.607 Ma) occurs in Sample 306-U1313B-9H-2, 17–18 cm (78.80 mcd). The FOs of medium (>3 µm) *G. oceanica* and *G. caribbeanica* (1.689 Ma) occur in Sample 306-U1313B-9H-5, 77–78 cm (89.24 mcd). This event is ~117 k.y. younger than the Pliocene/Pleistocene boundary.

Four Pliocene biostratigraphic datums are recognized in the studied section. *Discoaster brouweri* (1.926 Ma), the biostratigraphic datum for the latest Pliocene and ~112,000 k.y. older than the Pliocene/Pleistocene boundary, occurs in samples deeper than 306-U1313C-10H-4, 62–63 cm (93.83 mcd). It is difficult to define the true LO of *D. brouweri* because this species is quite rare in the upper Pliocene samples and some occurrences may be reworked. Rare specimens of medium *Gephyrocapsa* spp. (>4 µm) co-occur with *D. brouweri* in the three samples between 306-U1313C-11H-3, 62–63 cm, and 306-U1313B-10H-5, 62–63 cm (102.73–99.83 mcd). This pattern of very rare *Gephyrocapsa* spp. (>4 µm) occurrences below the Pliocene/Pleistocene boundary is consistent with results from Site U1312 (see the **"Site U1312"** chapter) and reports of similar occurrences from the Blake Ridge, northwest Atlantic (Okada, 2000). Thus the FOs of *G. oceanica* and *G. caribbeanica* are placed at the base of consistent occurrences of these species.

The LO of *Discoaster pentaradiatus* occurs in Sample 306-U1313C-12H-5, 27–28 cm (116.27 mcd). No reworked specimens were found above this horizon, and *D. pentaradiatus* was consistently present below. The LO of *Discoaster surculus* is questionably placed in Sample 306-U1313B-12H-5, 27–28 cm (120.21 mcd), based on a broken specimen. Consistent occurrences of *D. surculus* are present below this horizon. The last biostratigraphic datum in the examined section is the LO of *Discoaster tamalis*, which is found in Sample 306-U1313B-13H-6, 27–28 cm (131.78 mcd). *D. tamalis* is generally consistently present below this horizon, although it is not found in every sample. The next biostratigraphic datums are the LOs of *Sphenolithus* spp. and *R. pseudoumbilicus*. Both are sporadically reworked in the upper Pliocene and Pleistocene sediments of Site U1313, but the lack of consistent occurrences of *Sphenolithus* spp. in the last samples examined indicate that those sediments must be younger than the LO of *Sphenolithus* spp. (3.52–3.56 Ma).

Site U1314

All 60 samples examined contain abundant calcareous nannofossils (Table T2). Calcareous nannofossil preservation is moderate to good in middle Pleistocene samples and good in upper Pleistocene samples.

The youngest biostratigraphic event, the base of the *E. huxleyi* acme (0.082–0.063 Ma), occurs in Sample 306-U1314B-2H-2, 77–79 cm (7.53 mcd). The LO of *H. inversa* is found in Sample 306-U1314B-2H-5, 77–79 cm (12.03 mcd). The FO of *E. huxleyi* (0.289 Ma) occurs in Sample 306-U1314B-4H-3, 127–129 cm (28.58 mcd). This event defines the base of Zone NN21. The LO of *P. lacunosa* (0.440 Ma), which defines the top of Zone NN19, occurs in Sample 306-U1314C-4H-7, 24–25 cm (36.05 mcd). The rare, sporadic occurrences of *H. inversa* made it impossible to identify the FO of this species in this hole. The LO of *R. asanoi* (0.905 Ma) occurs in Sample 306-U1314C-8H-6, 24–25 cm (75.15 mcd), and is the last biostratigraphic event in the samples examined from this site.

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Figure F1. Location of sites drilled during Expedition 306. Contours = meters below sea level. (Modified from **iodp.tamu.edu/scienceops/maps/exp/303306/303306w_pr.jpg**).

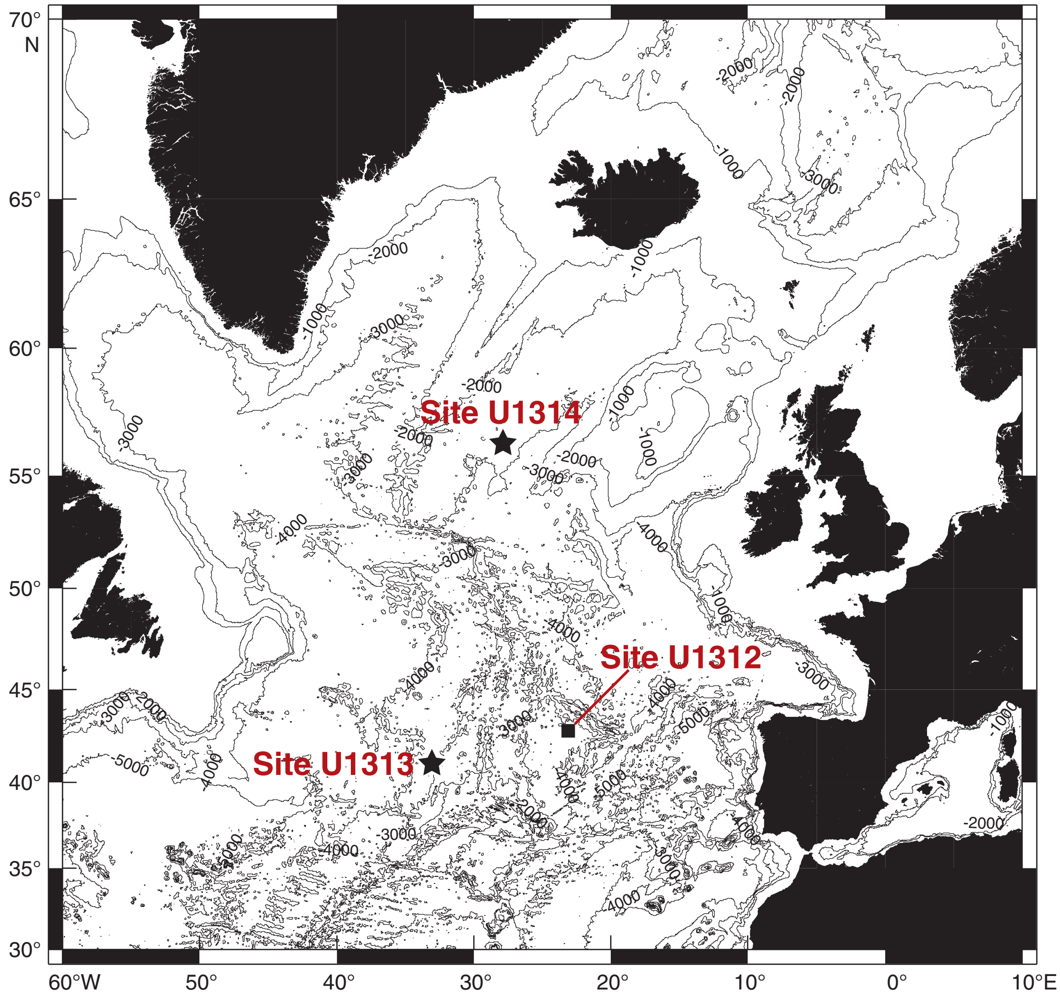

Table T1. Calcareous nannofossil distribution, Site U1313. This table is available in an **oversized format.**

Table T2. Calcareous nannofossil distribution, Site U1314. This table is available in an **oversized format.**

Appendix

Systematic paleontology

Bibliographic references for these taxa can be found in Perch-Nielsen (1985), Bown (1998), and Sáez et al. (2003).

Braarudosphaera bigelowii (Gran and Braarud, 1935) Deflandre, 1947
Calcidiscus leptoporus (Murray and Blackman, 1898) Loeblich and Tappan, 1978
Calcidiscus tropicus Kamptner, 1956 sensu Gartner, 1992
Calcidiscus macintyrei (Bukry and Bramlette, 1969) Loeblich and Tappan, 1978
Calciosolenia spp.
Ceratolithus spp.
Coccolithus pelagicus (Wallich, 1871) Schiller, 1930
Discoaster asymmetricus Gartner, 1969
Discoaster brouweri Tan, 1927
Discoaster deflandrei Bramlette and Riedel, 1954
Discoaster pentaradiatus Tan, 1927
Discoaster quadramus Bukry, 1973
Discoaster surculus Martini and Bramlette, 1963
Discoaster tamalis Kamptner, 1967
Discoaster triradiatus Tan, 1927
Discoaster variabilis Martini and Bramlette, 1963
Emiliania huxleyi (Lohmann, 1902) Hay and Mohler in Hay et al., 1967
Florisphaera profunda Okada and Honjo, 1973
Gephyrocapsa caribbeanica Boudreaux and Hay, 1967
Gephyrocapsa muellerae Bréhéret, 1978
Gephyrocapsa oceanica Kamptner, 1943
Hayaster perplexus (Bramlette and Riedel, 1954) Bukry, 1973
Helicosphaera carteri (Wallich, 1877) Kamptner, 1954
Helicosphaera intermedia Martini, 1965
Helicosphaera inversa (Gartner, 1980) Theodoridis, 1984
Helicosphaera neogranulata (Gartner, 1977) Haq and Berggren, 1978
Helicosphaera sellii (Bukry and Bramlette, 1969) Jafar and Martini, 1975
Holodiscolithus macroporus (Deflandre in Deflandre and Fert, 1954) Roth, 1970
Oolithotus antillarum (Cohen, 1964) Reinhardt in Cohen and Reinhardt, 1968
Oolithotus fragilis (Lohmann, 1912) Martini and Müller, 1972
Pontosphaera spp.
Pseudoemiliania lacunosa (Kamptner, 1963) Gartner, 1969
"*Pyrocyclus*" spp.
Reticulofenestra asanoi Sato and Takayama, 1992
Reticulofenestra pseudoumbilicus (Gartner, 1967) Gartner, 1969
Reticulofenestra productella (Bukry, 1975) Gallagher, 1989
Reticulofenestra spp.
Rhabdosphaera clavigera Murray and Blackman, 1898
Scyphosphaera spp.
Sphenolithus spp.
Syracosphaera spp.
Tetralithoides symeonidesii Theodoridis, 1984
Thoracosphaera spp.
Umbellosphaera irregularis Paasche in Markali and Paasche, 1955
Umbellosphaera tenuis (Kamptner, 1937) Paasche in Markali and Paasche, 1955
Umbilicosphaera foliosa (Kamptner, 1963) Geisen et al., 2002
Umbilicosphaera hulburtiana Gaarder, 1970
Umbilicosphaera jafari Müller, 1974
Umbilicosphaera sibogae (Weber-van Bosse, 1901) Gaarder, 1970