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Data report: calcareous nannofossil biostratigraphy of the lower Pleistocene in Holes C0002K and C0002L, IODP Expedition 338, Nankai Trough Seismogenic Zone Experiment[1]

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Keywords: Integrated Ocean Drilling Program, IODP, *Chikyu*, Expedition 338, Site C0002, Kumano Basin, Nankai Trough Seismogenic Zone Experiment, NanTroSEIZE, calcareous nannofossils, middle Pleistocene

Contents

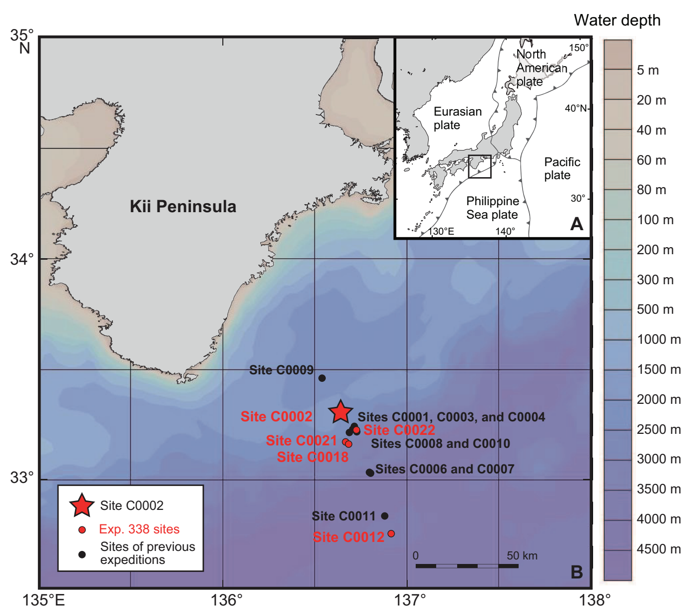
Abstract

Integrated Ocean Drilling Program Site C0002 is a key site in the Nankai Trough Seismogenic Zone Experiment for obtaining fundamental geologic information on the Kumano forearc basin and revealing tectonic activity around the Nankai Trough subduction zone. Many scientific drilling programs have been performed at this site. During Expedition 338, deep-sea cores, cuttings, and logging-while-drilling data were collected. This paper provides counting results for calcareous nannofossils in lower Pleistocene sediments from Holes C0002K and C0002L and revises nannofossil biohorizons previously recognized. Four calcareous nannofossil biohorizons in the Quaternary were detected in sediments from the two holes, and the investigated sequences can be assigned to about 1.24–1.04 Ma. Counts of subordinate calcareous nannofossil taxa were also performed to examine sea-surface environmental changes. Subtropical taxa including a Kuroshio water species were dominant throughout the section and occurred with irregular fluctuations in abundance.

Introduction

In 2012, Integrated Ocean Drilling Program Expedition 338, as part of the Nankai Trough Seismogenic Zone Experiment (NanTroSEIZE), conducted a scientific drilling program at five sites around the edge of the Kumano Basin off Kii Peninsula in the middle part of the Pacific side of the Japanese islands (Figure **F1**). The sites drilled during this expedition were situated on the outer-arc high and the trench-slope basins near the Kumano forearc basin (**Strasser et al.**, 2014). Among these, Site C0002 is a key site for clarifying the lithostratigraphy and chronostratigraphy of the sediments deposited in the Kumano forearc basin and for revealing the tectonic activity of

Figure F1. Location map of sites drilled during Nankai Trough Seismogenic Zone Experiment expeditions (modified after Ashi et al., 2009; Strasser et al., 2014; and Tatsumi et al., 2016). Bathymetry was illustrated using Ocean Data View software (Schlitzer, 2020).



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the outer-arc high related to the movement of the megasplay fault beneath the basin (**Strasser et al.**, 2014). Six holes (Holes C0002F, C0002H, C0002I, C0002J, C0002K, and C0002L) were drilled at Site C0002, and both riser drilling with logging-while-drilling (LWD) measurements and riserless coring were performed in these holes (**Strasser et al.**, 2014). This paper reports fundamental counting results for calcareous nannofossil assemblages with the aim of constructing an age model for Holes C0002K and C0002L, which correspond to the middle part of the sequences at Site C0002. Sediments from these two holes were extracted from between Holes C0002B and C0002D (**Strasser et al.**, 2014), which were cored during Integrated Ocean Drilling Program Expedition 315 in 2007 (Expedition 315 Scientists, 2009). Preliminary results of calcareous nannofossil biostratigraphy from two holes were provided by **Strasser et al.** (2014). In this study, based on the stratigraphic occurrence of index nannofossil species, we demonstrate revised calcareous nannofossil biohorizons. We also provide stratigraphic distributions of subordinate taxa, which are related to sea-surface environmental changes around the Pacific side of Japan during the early Pleistocene.

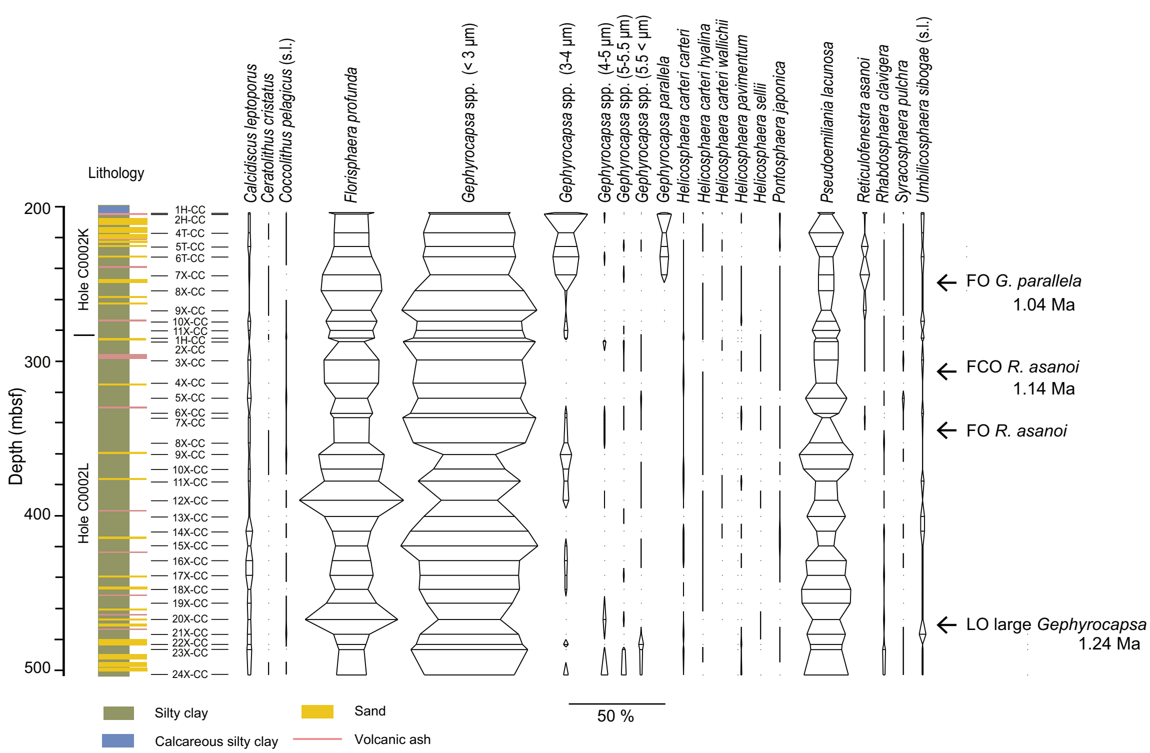
Materials and methods

We investigated 34 core catcher samples from Holes C0002K and C0002L at 204.48–502.74 meters below seafloor (mbsf) (Figure **F2**). Most samples were mainly composed of mudstones, and they contained abundant calcareous nannofossil specimens. Standard smear slides were made and were examined using an Olympus BX51 optical microscope with simple polarizing lenses at 1500× magnification. Two different counting techniques were applied. First, 200 nannofossil specimens were counted to investigate the overall calcareous nannofossil assemblages in both holes. Taxonomic divisions of nannofossils basically followed Young (1998) and Young et al. (2017).

The genus *Gephyrocapsa* is the main constituent taxon in the Quaternary calcareous nannofossil assemblages. Because occurrences of medium- to large-sized *Gephyrocapsa* are considered to be stratigraphically useful (Rio, 1982; Matsuoka and Okada, 1990), *Gephyrocapsa* specimens were divided into the following groups based on the maximum length of the specimen measured using an eyepiece graticule: small *Gephyrocapsa* (<3 and 3–4 µm), medium *Gephyrocapsa* (4–5 and 5–5.5 µm), and large *Gephyrocapsa* (>5.5 µm). *Gephyrocapsa* specimens were divided into two types based on visual observation of the bridge angle (bar orientation in the central part of a specimen): those almost parallel to a minor axis and those at other oblique angles to a minor axis.

Subordinate nannofossil taxa, except *Gephyrocapsa, Reticulofenestra, Florisphaera*, and *Pseudoemiliania*, were counted to reveal stratigraphic distributions of environmental proxy species in both holes. A separate count of subordinate taxa of 100 specimens in each sample was conducted. Based on the recent distribution of calcareous nannoplankton thanatocoenosis around the Japanese islands reported by Tanaka (1991), the spatial distributions of *Umbilicosphaera sibogae* (s.l.), *Calcidiscus leptoporus*, *Helicosphaera* spp., and other minor taxa are generally related to major sea-surface currents and/or water masses. In this study, *U. sibogae* (s.l.) includes *U. sibogae* and *Umbilicosphaera foliosa*.

Figure F2. Stratigraphic occurrence of main calcareous nannofossil taxa, Holes C0002K and C0002L. The lithology of both holes is based on Strasser et al. (2014). Detected Quaternary biohorizons are also indicated. LO = last occurrence, FCO = first common occurrence, FO = first occurrence. Numerical ages are from Gradstein et al. (2012).



The preservation state of the nannofossil assemblage in each sample was visually evaluated employing a modified version of the classification used during Expedition 338 (**Strasser et al.**, 2014):

- G (good) = little or no dissolution and no overgrowth.
- M (moderate) = slight evidence of etching and/or overgrowth.
- P (poor) = severe dissolution, fragmentation, or overgrowth.

Results

At least 18 genera and 30 species were found in samples from Holes C0002L and C0002K. The obtained sediments generally contained abundant and well-preserved calcareous nannofossils (Figure **F2**; Tables **T1**, **T2**, **T3**, **T4**). Calcareous nannofossils from both holes correspond to Quaternary assemblages, and *Gephyrocapsa, Florisphaera*, and *Pseudoemiliania* were dominant throughout the investigated sequences. In addition, *Calcidiscus* and *Umbilicosphaera* commonly occurred, and other minor taxa were sporadically observed (Figure **F2**). Reworked specimens that appeared to have originated in the lower part of the sequences were often found in sediment from Hole C0002L (Table **T2**). These specimens were mainly large *Gephyrocapsa, Reticulofenestra pseudoumbilicus, Discoaster* spp., and *Sphenolithus* spp. Specimens of large *Gephyrocapsa* were sporadically observed above their consistent occurrences, and others are apparently from specimens of the Pliocene and older sequences. In particular, the uppermost samples, 338-C0002L-1X-CC, 36.0–41.0 cm (285.41 mbsf), and 2X-CC, 20.5–25.5 cm (287.7 mbsf), contained a large number of reworked specimens. Their presence sometimes made it difficult to determine the geologic ages of samples.

Based on our counting data, however, the occurrence of stratigraphically important species in the two holes enabled us to detect important biohorizons (Table **T5**). *Gephyrocapsa* specimens of different size and morphology were abundant throughout the section. This taxon represented approximately 30%–70% of the total flora, and small forms of *Gephyrocapsa* (<3 µm in diameter) were among the most dominant taxa throughout the sections in both holes. Another small form (3–4 µm in diameter) was abundantly observed in the middle part of Hole C0002L and the upper part of Hole C0002K.

On the other hand, medium-sized specimens of *Gephyrocapsa* (>4 µm in diameter) occurred sporadically (except in the lower part of Hole C0002L) but abundantly in the upper part of Hole C0002K. Bridge angles of these small to medium *Gephyrocapsa* specimens were mostly less than 45° from the long axis. At the same time, however, *Gephyrocapsa* specimens with a bridge nearly parallel to the minor axis were occasionally observed in the upper part of Hole C0002K (Figure **F2**). These specimens correspond to *Gephyrocapsa parallela* (Hay and Beaudry, 1973), *Gephyrocapsa omega* (Bukry, 1973), or *Gephyrocapsa* sp. 3 (Rio, 1982). The first occurrence of this species is placed between Samples 338-C0002K-7X-CC, 30.5–35.5 cm (244.58 mbsf), and 8X-CC, 34.0–39.0 cm (254.83 mbsf). A numerical age of 1.04 Ma (Gradstein et al., 2012) was proposed for the biohorizon.

Large *Gephyrocapsa* (>5.5 µm in diameter) were consistently abundant in the lowest part of Hole C0002L and continuously occurred below Sample 338-C0002L-20X-CC, 60.5–65.5 cm (466.98 mbsf). The last occurrence (LO) of large *Gephyrocapsa* was between Samples 20X-CC, 60.5–65.5 cm (466.98 mbsf), and 21X-CC, 35.5–40.5 cm (476.48 mbsf). Because of their sporadic occurrences, large *Gephyrocapsa* specimens from Samples 16X-CC, 85.0–90.0 cm (428.98 mbsf), to 1X-CC, 36.00–41.00 cm (285.41 mbsf), should be interpreted as reworked specimens from the lower part of the section. The LO of large *Gephyrocapsa* corresponds to 1.24 Ma (Gradstein et al., 2012). A biostratigraphic datum, the last occurrence of *Helicosphaera sellii*, was not detected because sporadic occurrences of this species in Hole C0002L were also considered to be reworked specimens.

Table T1. Total counts of calcareous nannofossils, Hole C0002K. **Download table in CSV format.**

Table T2. Total counts of calcareous nannofossils, Hole C0002L. **Download table in CSV format.**

Table T3. Counts of subordinate taxa of calcareous nannofossils, Hole C0002K. **Download table in CSV format.**

Table T4. Counts of subordinate taxa of calcareous nannofossils, Hole C0002L. **Download table in CSV format.**

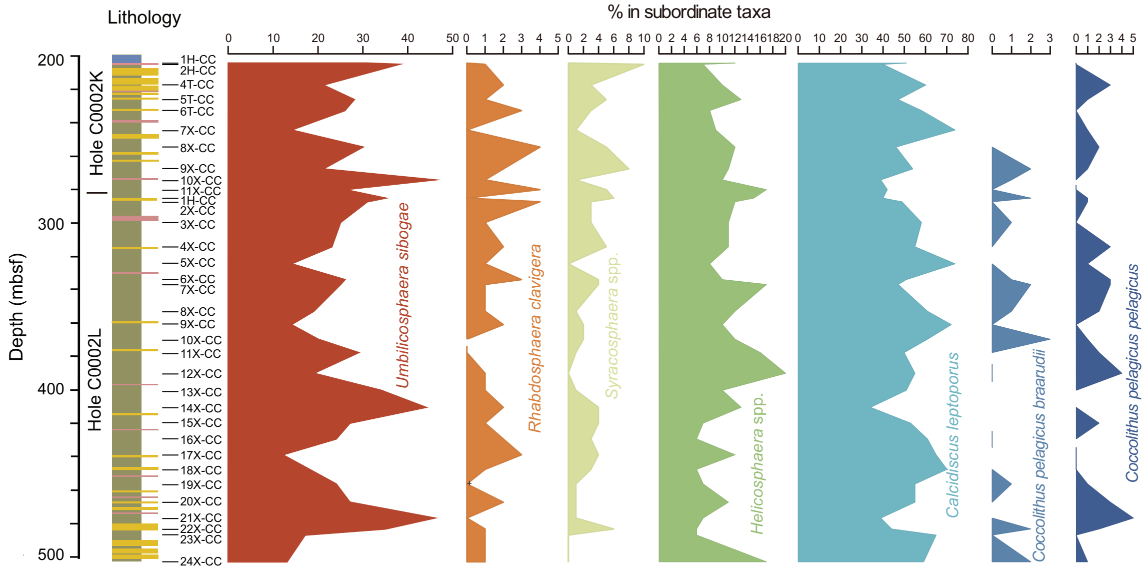
Table T5. Calcareous nannofossil events, Holes C0002K and C0002L. **Download table in CSV format.**

Although a small number of *Reticulofenestra* specimens occurred in the studied section, a stratigraphically important taxon, *Reticulofenestra asanoi*, was found above Samples 338-C0002L-7X-CC, 25.0–30.0 cm (336.75 mbsf), and the first occurrence of this species was at this horizon. This species occurred continuously above Sample 4X-CC, 50.5–55.5 cm (314.49 mbsf), and thus the first common occurrence (FCO) can be placed at this horizon. The numerical age of this FCO is considered to be 1.14 Ma (Gradstein et al., 2012).

Other abundant taxa in Holes C0002L and C0002K are *Florisphaera profunda* and *Pseudoemiliania lacunosa* (Figure **F2**). The average abundance of *F. profunda,* a warm-water taxon (e.g., Tanaka, 1991) found around the southwestern Pacific side of the Japanese islands, was approximately 23%, and it is abundant in Samples 338-C0002L-20X-CC, 60.5–65.5 cm (466.98 mbsf), 12X-CC, 67.0–72.0 cm (390.04 mbsf), and 338-C0002K-8X-CC, 34.0–39.0 cm (254.84 mbsf).

Separate counts indicated that the subordinate taxa *Calcidiscus, Umbilicosphaera, Helicosphaera, Coccolithus*, and other minor species characteristically occurred following sea-surface environmental changes (Figure **F3**; Tables **T3**, **T4**). *C. leptoporus, Helicosphaera* spp., and *U. sibogae* occupied approximately 90% of the subordinate taxa assemblage throughout the section. In particular, *C. leptoporus* was the most abundant of all subordinate taxa, and its relative abundance was from about 35% to 75% with an average of 54%. *U. sibogae*, a Kuroshio Current indicator around the Japanese islands (Tanaka, 1991), also occurred abundantly, and there were three characteristically abundant horizons in Samples 338-C0002L-21X-CC, 35.5–40.5 cm (476.48 mbsf), 14X-CC, 35.0–40.0 cm (409.98 mbsf), and 338-C0002K-10X-CC, 31.0–36.0 cm (274.56 mbsf). The relative abundance of *Helicosphaera* spp., except possibly reworked *H. sellii*, ranged from 6% to 20% in all subordinate taxa. A cool and upwelling water subspecies (e.g., Ziveri et al., 2004), *Coccolithus pelagicus braarudii*, occupied a few percent of subordinate taxa and was recognized below Sample 338-C0002K-9X-CC, 30.0–35.0 cm (267.48 mbsf). A colder water subspecies (e.g., Ziveri et al., 2004), *Coccolithus pelagicus pelagicus*, was found throughout the examined section even though its occurrence was sporadic. A small number of *Rhabdosphaera clavigera* and *Syracosphaera* spp., which are comparatively warmer water species, were continuously present,

Figure F3. Stratigraphic occurrences of subordinate calcareous nannofossil taxa, Holes C0002K and C0002L. The lithology of both holes (Strasser et al., 2014) is shown in Figure F2.



and other rare species, *Pontosphaera* spp., *Braarudosphaera bigelowii*, *Calciosolenia murrayi*, and *Ceratolithus cristatus,* were also observed. Environmental proxy taxa that depend on the sea-surface water, *F. profunda*, *U. sibogae*, *C. leptoporus*, and *Coccolithus pelagicus,* should be studied with a higher chronological resolution in the near future to reveal orbital-, millennial-, and centennial-scale paleoceanographic changes.

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