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8. OLIGOCENE–HOLOCENE CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY AND DIAGENETIC ETCH PATTERNS ON QUATERNARY PLACOLITHS AT ODP SITE 1139 ON SKIFF BANK, NORTHERN KERGUELEN PLATEAU[1]

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ABSTRACT

The distribution of calcareous nannofossils at Ocean Drilling Program Site 1139 on Skiff Bank off the western edge of the Northern Kerguelen Plateau has been used to delineate Quaternary, middle Miocene–middle Oligocene, and lower Oligocene sediments in an expanded 385-m rotary-cored section. Sedimentation rates through most of the Tertiary are high (average = 23 m/m.y.) as a result of clastic input and dilution by high siliceous productivity; chert, however, was encountered in only a single sample. These characteristics, plus the presence of multiple, reasonably well preserved siliceous and calcareous microfossil groups deposited well above the calcite compensation depth, make this site a potential candidate for more detailed coring for paleoceanographic objectives in the future.

A scanning electron microscope study revealed that diagenetic etching, apparently of gephyrocapsids, caused some of these placoliths to superficially resemble *Emiliania huxleyi* at levels in the Quaternary well below the evolutionary first occurrence of this taxon. Other larger specimens of etched gephyrocapsids and/or reticulofenestrids resembled *Pseudoemiliania lacunosa*. These observations suggest that caution should be exercised when age-dating Quaternary sediments not necessarily rich in carbonate.

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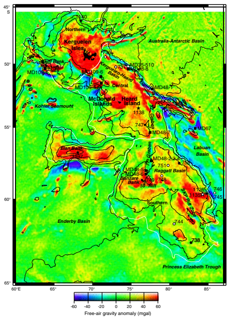
An unusual *Braarudosphaera* bloom recorded in upper Oligocene sediments on Skiff Bank is similar to that reported previously at Site 737 on the Northern Kerguelen Plateau and may correlate with other such occurrences of this age in the Atlantic and Indian Oceans. The base of the pelagic section is dated as earliest Oligocene by nannofossils and foraminifers (32.8–34.3 Ma; Subchron CP16a/b and basal AP13).

INTRODUCTION

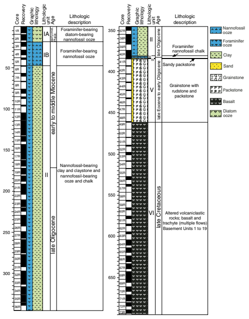
Ocean Drilling Program (ODP) Site 1139 was drilled in 1415 m of water at 50°11′S, 63°56′E on the isolated outlying Skiff Bank off the western edge of the Northern Kerguelen Plateau (Fig. **F1**). The drilling objectives included a determination of the facies of the seismic stratigraphic sequences, a definition of the ages of the seismic sequence boundaries, and a determination of the paleoceanographic history of the site. A detailed calcareous nannofossil stratigraphy, which is presented here, is necessary to help fulfill these objectives.

F1. Free-air gravity map of Kerguelen Plateau, p. 12.



At Site 1139, a thin (19 m) Quaternary section of foraminifer diatom-bearing nannofossil ooze (lithologic Subunit IA) is underlain by a greatly expanded 364-m middle Miocene to mid-Oligocene nannofossil ooze/chalk and clay/claystone sequence with generally well preserved siliceous and calcareous microfaunas and floras (lithologic Subunit IB–Unit III) (Fig. **F2**). There is no appreciable chert within this section, which was deposited well above the calcite compensation depth. This pelagic sequence overlies nearly 80 m of poorly dated reddish orange sandy packstones and grainstones, which, in turn, rest on basement units (Shipboard Scientific Party, 2000).

F2. Stratigraphic section, p. 13.

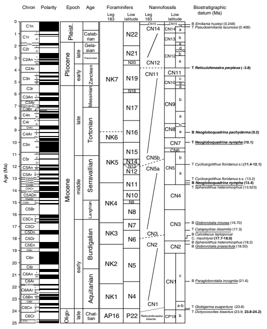


Minimum overall sedimentation rates are ~18 m/m.y. in the Miocene and 29 m/m.y. in the Oligocene or 23 m/m.y. for the entire Tertiary pelagic section (Shipboard Scientific Party, 2000; fig. F9). The high sedimentation rates have been attributed to high regional pelagic productivity plus the influx of fine terrigenous clastic sediments derived from the weathering of exposed portions of the volcanic edifice, Skiff Bank, on which the sediments were deposited (see "Lithostratigraphy" in Shipboard Scientific Party, 2000) (**Reusch,** this volume). The clastic input colored the normally white calcareous oozes and chalks gray to brownish gray. Only at the bottom of the section, where such input was minimal, are the sediments oxidized to a pinkish color.

ZONATIONS

The nannofossil biostratigraphic framework was provided by the zonal compilation schemes of Martini (1971), with modifications by Gartner (1977), Martini and Müller (1986), and Bukry (1973, 1975) as well as zonal code numbers added and modified by Okada and Bukry (1980). Pospichal et al. (1992), however, illustrated a significant decrease in biostratigraphic resolution in the Martini Cenozoic zonation from the low to high latitudes of the Southern Hemisphere. The greatest loss occurs in the Neogene scheme, where little stratigraphic control can be achieved between 51°S and 65°S.

F3. Holocene–Eocene timescale and biostratigraphic datums, p. 14.



Wei and Wise (1992) summarized and calibrated to the paleomagnetic timescale a few useful Neogene high-latitude nannofossil datums detectable on the Kerguelen Plateau and elsewhere in the Southern Ocean. These are indicated on Figure **F3** alongside the low-latitude zonation of Bukry for comparison. In this figure, the datums have been recalibrated for comparison with the Berggren et al. (1995) timescale (see discussion below). With so few datums at these latitudes, however, most Neogene nannofossil zones have had to be combined into a total of five zones.

High-latitude nannofossil zonations with moderate resolution have been developed for the Oligocene to mid–middle Eocene (Wise, 1983; Wei and Wise, 1990; Wei and Thierstein, 1991), and these have been inserted into Figure F3. Ages for key datum levels have been calibrated in the region of the Kerguelen Plateau against magnetostratigraphy by Wei (1992); these are indicated in bold type in Figure F3, where they have been recalibrated against the Berggren et al. (1995) timescale.

As noted by Wei (1992), biomagnetostratigraphic correlations at several Southern Ocean sites may show considerably different ages relative to those compiled from the mid-latitudes by Berggren et al. (1985, 1995). Where such differences exist, we have, in most instances, chosen to use ages derived from the high-latitude calibrations against the magnetostratigraphy.

As noted above, where such ages differ from those in the lower latitudes, the high-latitude ages are shown in bold type in Figure F3 following the corresponding datum level; similarly, high-latitude biostratigraphic datums are also indicated in bold type. For major differences in age assignment, arrows indicate where on the chart a datum has been repositioned for purposes of this study.

METHODS

Calcareous nannofossils were examined using standard light microscope techniques, under crossed polarizers, transmitted light, and phase contrast light at 1562× magnification. Preservation and abundance of calcareous nannofossil species may vary significantly because of etching, dissolution, or calcite overgrowth. It is not uncommon to find nearly pristine specimens present in the same sample as specimens exhibiting overgrowth or etching. Thus, a simple code system to characterize preservation has been adopted and is listed below:

VG = very good preservation; no evidence of dissolution and/or overgrowth; no alteration of primary morphological characteristics and specimens appear diaphanous; specimens are identifiable to the species level.
G = good preservation; little or no evidence of dissolution and/or overgrowth; primary morphological characteristics only slightly altered; specimens are identifiable to the species level.
M = moderate preservation; specimens exhibit some etching and/or overgrowth; primary morphological characteristics sometimes altered; however, most specimens are identifiable to the species level.
P = poor preservation; specimens are severely etched or exhibit overgrowth; primary morphological characteristics largely destroyed; fragmentation has occurred; specimens cannot be identified at the species and/or generic level.

Six calcareous nannofossil abundance levels are recorded as follows:

V = very abundant (11–100 specimens per field of view).
A = abundant (1–10 specimens per field of view).
C = common (1 specimen per 2–10 fields of view).
F = few (1 specimen per 11–100 fields of view).
R = rare (1 specimen per 101–1000 fields of view).
B = barren.

Calcareous nannofossil species considered in this paper are listed in "**Appendix,**" p. 11, where they are arranged alphabetically by generic epithet. Bibliographic references for these taxa can be found in Perch-Nielsen (1985) and Bown (1999).

PRESENCE AND DISTRIBUTION OF CALCAREOUS NANNOFOSSILS AT SITE 1139

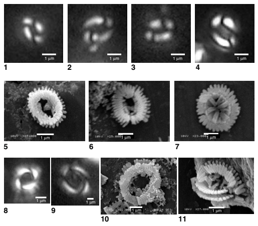
Calcareous nannofossils were generally well preserved and abundant in selected intervals of the Quaternary of lithologic Subunit IA and are consistently abundant and generally well preserved in the Miocene–Oligocene nannofossil oozes of Subunit IB and Unit II. They were abundant and moderately well preserved in the lowermost Oligocene of Unit III, where some taxa show overgrowths.

Quaternary

A relatively pure nannofossil ooze in the top of Section 183-1139A-1R-1 consists of few to very abundant *Gephyrocapsa* and very abundant *Emiliania huxleyi* (90% of the assemblage), which indicates the *E. huxleyi* acme of Gartner (1977) with an age of ~84 ka or less. The second section of the core contained few *E. huxleyi* but common *Gephyrocapsa* and is assigned to the lower portion of the *E. huxleyi* Zone (Zone CN15 or NN21). The remainder of the core, with the exception of the core catcher, yielded few to abundant nannoliths and is assigned to Zone NN20 of Martini.

The core catcher of the first core and all of the second core, except its core catcher, contain *Pseudoemiliania lacunosa* along with forms sometimes common in abundance that closely resemble *E. huxleyi* (Pl. **P1**; figs. 1–4). As *P. lacunosa* and *E. huxleyi* should not be present together in the same samples, these minute forms were further examined in the scanning electron microscope (SEM) (Pl. **P1**; figs. 5, 6). The micrographs reveal that they actually represent other taxa that have been etched in such a way as to mimic *E. huxleyi* (see further description below in "**Effects of Diagenetic Etching on Quaternary Placoliths,**" p. 7). These are indicated in Table **T1** by a lower case "m."

P1. Placoliths, p. 18.



The interval in question was assigned as Martini's Zone NN19. The carbonate content of this interval varies considerably, as the nannofossil content may be highly diluted by siliceous microfossils.

T1. Distribution of calcareous nannofossils, Site 1139, p. 17.

Tertiary

Core 183-1139A-3R contains common to very abundant *Cyclicargolithus abisectus, Cyclicargolithus floridanus, Coccolithus miopelagicus, Helicosphaera carteri, Helicosphaera granulosa,* common *Calcidiscus leptoporus/macintyrei,* and common *Discoaster variabilis,* which place it in the combined CN5a/CN3 Zone (middle Miocene). Diatoms are abundant with common *Actinocyclus ingens,* but no pennates were noted (see "Biostratigraphy" in Shipboard Scientific Party, 2000). This probably indicates that the sample can be assigned to the early part of the middle Miocene (between ~15 and 16 Ma). This age is consistent with the relatively large number of discoasters, which prefer warmer water conditions than would have prevailed at this site after the late–middle Miocene climatic optimum that ended at ~15 Ma (Zachos et al., 2001).

Discoasters are less common in Sample 183-1139A-4R-CC, which is dominated more by coccolithids, cyclicargolithids, and reticulofenestrids. These suggest cooler conditions than in the previous core catcher sample. Climate-induced alternations are common in this part of the section but are not described here in detail. The first evolutionary occurrence (FO) of the genus *Calcidiscus* in that same sample approximates the base of Zone CP3.

Samples 183-1139A-5R-CC through 8R-CC are mid–early Miocene in age and contain few to abundant *Discoaster deflandrei.* Samples 183-1139A-9R-CC through 18R-CC lack *C. leptoporus/macintyrei* and probably belong to the lower Miocene Zones CN2–CN1 in a section greatly expanded by the influx of clays derived from volcanic parent materials (**Reusch,** this volume). Discoasters are largely absent except for the middle portion of Core 183-1139A-16R; otherwise, the assemblages are overwhelmingly dominated by cool-water reticulofenestrids.

The downhole last occurrence (LO) of *Reticulofenestra bisecta* marks the nannofossil Miocene/Oligocene boundary at these latitudes and also marks the top of the zone of that name. Its placement is somewhat ambiguous in this section in that its last consistent common occurrence is in Sample 183-1139A-19R-4, 24–25 cm. A higher common occurrence of this taxon in Sample 183-1139A-17R-6, 25–26 cm, however, could be taken as the top of the zone if it is not reworked at that point. Reworking is entirely possible at this locality, as it is in the path of the Antarctic Circumpolar Current, which would have been active by this time (Lawver and Gahagan, 1998). For this reason, a rare occurrence of *R. bisecta* in Sample 183-1139A-17R-1, 25–26 cm, is considered reworked.

Regardless of where the top of the *R. bisecta* Zone is placed, this zone is considerably expanded here because of the input of fine clastic sediments as noted above. The base of the zone is placed at Sample 183-1139A-22R-2, 25–26 cm.

Samples 183-1139A-22R-CC through 40R-6, 22–24 cm, contain *Chiasmolithus altus* and *C. abisectus* in the virtual absence of *Reticulofenestra umbilica;* we assigned the samples to the mid-Oligocene *C. altus* Zone. This is somewhat interpretive because rare to few *R. umbilica* are sporadically present between Samples 183-1139A-29R-2, 26–27 cm, and 38R-3, 27–27 cm. These and related forms are considered reworked, again presumably under the influence of the then strengthening Antarctic Circumpolar Current. Support for this interpretation is provided by planktonic foraminiferal analysis, which suggests that Core 183-1139-33R can be assigned to the middle Oligocene Zone AP14 with "reasonable confidence" (Shipboard Scientific Party, 2000). Similar support is rendered by the presence of the middle Oligocene diatom *Azpetia oligocenica* in Sample 183-1139A-32-CC (Shipboard Scientific Party, 2000).

The last common occurrence of the holococcolith *Zygrhablithus bijugatus* is in Sample 183-1139A-22R-CC, which is also at the top of the *C. altus* Zone. *Helicosphaera bramlettei* occurs sporadically in this part of the zone, from Cores 183-1139A-25R to 31R, as do a number of pontosphaerids (particularly *Pontosphaera multipora* and *Pontosphaera* *versa*). A large high-rimmed *Pontosphaera* sp. was also noted in Sample 183-1139A-30R-CC. *D. deflandrei* is sporadic but sometimes abundant, whereas *Coronocyclus nitescens,* also sporadic, may be common.

An unusual presence is *Braarudosphaera bigelowii,* which is common to abundant as both whole and fragmented specimens in Samples 183-1139A-30R-CC and 31R-1, 26–27 cm. Wei and Thierstein (1991; table 3) recorded a similar presence of this normally neritic taxon in this part of the stratigraphic column in Hole 737B on the Northern Kerguelen Plateau. These presence of these might correspond to the mid-latitude Oligocene *Braarudosphaera* blooms in the Atlantic (e.g., Parker et al., 1985) and the Indian Ocean off northwest Australia (Siesser et al., 1992).

We noted a single reworked specimen of *Isthmolithus recurvus* near the bottom of the *C. altus* Zone in Sample 183-1139A-38R-CC. A few *Discoaster tanii* (five and six rayed) plus a high abundance of small reticulofenestrids are present in Sample 183-1139A-39R-CC, along with *Reticulofenestra daviesii,* which ranges to the top of the zone in this section. Few to common *D. deflandrei* and *Helicosphaera perch-nielseniae* accompany *Sphenolithus* in the first two sections of Core 183-1139A-40R, and small, delicate pontospherids that superficially resemble *Reticulofenestra oamaruensis* are found throughout much of this core; however, the overall assemblage is characteristic of the *C. altus* Zone. *Blackites spinosus* is common in Sample 183-1139A-40R-5, 25–27 cm, and in the core catcher of Core 40R.

The color of the sediment changes downhole in the lower part of Section 183-1139A-40R-5 from a greenish to a reddish orange color, but the nannoflora do not change until an apparent disconformity between Samples 183-1139A-40R-6, 20–22 cm, and 40R-6, 30–32 cm, well within the oxidized sediments (see figs. F2, F4, both in Shipboard Scientific Party, 2000). The latter sample and Sample 183-1139A-40R-CC are characterized by abundant *Reticulofenestra hillae;* common to abundant *I. recurvus* along with few to common *Coccolithus formosus, D. deflandrei,* and *D. tanii;* and common to abundant *Clausicoccus fenestratus, C. altus,* and *C. oamaruensis.* We observed no *C. abisectus, Discoaster saipanensis, R. oamaruensis,* or *Reticulofenestra reticulata.*

A broad age range for the assemblage described above is represented by the LO of *C. formosus* (32.8 Ma) and the LO of *R. reticulata* (35.4 Ma) or the FO of *I. recurvus* (35.7–36.3 Ma at these latitudes according to Wei, 1992). This assumes that *D. saipanensis* and *R. oamaruensis* are not present here because of truncated upper ranges resulting from ecological restriction in these higher latitudes (e.g., Wei, 1992). Nevertheless, this age range spans the Eocene/Oligocene boundary.

The relatively high number of *C. fenestratus* in Sample 183-1139A-40R-CC, however, suggests essentially an earliest Oligocene age (approximately Subzone CP16a/b) when compared with the Eocene/Oligocene sequence from Hole 511 of Deep Sea Drilling Project Leg 71 on the Falkland Plateau and Hole 737B of ODP Leg 119 on the Northern Kerguelen Plateau (table 1A of Wise, 1983; table 3 of Wei and Thierstein, 1991). At these localities, *C. fenestratus* is quite rare or absent below the Eocene/Oligocene boundary. An early Oligocene age for the base of Core 183-1139A-40R is also supported by the planktonic foraminiferal fauna, which lacks the definitive upper Eocene high-latitude index taxon *Globigerinatheka index* (Wise et al., 2002).

Nevertheless, the presence of both *C. formosus* and *I. recurvus* below the disconformity and the presence of both *C. abisectus* and *R. umbilica* above signals the absence of at least the *R. davesii* Zone and possibly more. The missing section would be equivalent to at least Subzone CP16, Zone CP17, and lower CP18 Zone.

EFFECTS OF DIAGENETIC ETCHING ON QUATERNARY PLACOLITHS

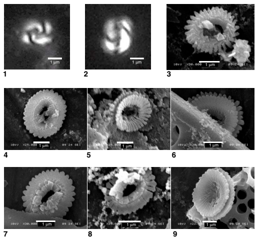
As mentioned previously, Quaternary placoliths in Sample 183-1139A-1CC as well as those in Samples 183-1139A-2R-3, 25–26 cm, and 2R-4, 25–26 cm, exhibited features that closely resemble *E. huxleyi,* although they lie stratigraphically well below the range of that taxon. Hence, the specimens in Sample 183-1139A-1-CC were examined with the SEM in order to resolve this apparent discrepancy.

The micrographs revealed small placoliths similar in construction to gephyrocapsids but etched so that their radial shield elements are well separated along their outer margins (Pl. **P1;** figs. 5, 6). As such, these elements superficially mimic the "I-bar" construction of *E. huxleyi* (cf., Malinverno et al. 2001, figs. 1 and 2, who also illustrate diagenetic modifications of this taxon). Etching, combined with the small size of our specimens, caused them to be confused with *E. huxleyi* during our initial light-microscope investigations. Identifications are particularly difficult if the centers of the specimens have also been enlarged by etching. This is not the case, however, in specimens where the central area has been thickened by secondary diagenetic overgrowth (e.g., Pl. **P1;** fig. 7).

The SEM micrographs further revealed larger placoliths in the assemblage attributable to *Reticulofenestra* and possibly *Gephyrocapsa* (Pl. **P1;** figs. 10, 11), with heavily etched centers and outer elements separated by etching. In the light microscope, these specimens might well mimic *P. lacunosa,* which displays a variable number of slits between its elements (e.g., Hine and Weaver, 1999; pl. 9.2, fig. 8).

Although the identifications of *Gephyrocapsa* in Plate **P1** (figs. 5, 6) are somewhat tentative, other specimens in the assemblage can be more positively attributed to that genus. A wide range of preservational states is displayed in Plate **P2.** The example in Plate **P2** (fig. 3) is unquestionably a gephyrocapsid, as the outer portions of its central area bar are clearly present. Its outer distal shield elements, however, are widely separated by etching, much like those in Plate **P1** (figs. 5, 6), thereby demonstrating that etched gephyrocapsids can indeed mimic *E. huxleyi*.

P2. Gephyrocapsids, p. 19.



CONCLUSIONS

The high sedimentation rates from the middle Miocene through the mid-Oligocene, the lack of appreciable chert within the section, and the presence of multiple groups of reasonably well preserved siliceous and calcareous microfossils deposited well above the calcite compensation depth give this site potential for more detailed paleoceanographic study in the future. Such study would require the coring of multiple holes using higher-quality core-recovery assemblies (such as the advanced piston corer and extended core barrel).

An SEM study revealed that diagenetic etching, apparently of gephyrocapsids, caused small members of this group to superficially resemble *E. huxleyi* at stratigraphic levels in the Quaternary well below the evolutionary FO of this taxon (i.e., in Zone NN19). Other larger specimens of etched gephyrocapsids and/or reticulofenestrids resembled *P. lacunosa*. These observations suggest that caution should be taken when age dating Quaternary sediments not necessarily rich in carbonate.

An unusual *Braarudosphaera* bloom recorded in the upper Oligocene sediments has been reported previously from the Northern Kerguelen Plateau (Wei and Thierstein, 1991) and may correlate with other such occurrences of this age in the Atlantic and Indian Oceans. We date a foraminiferal nannofossil chalk at the base of the pelagic section (Section 183-1139-40R-6) as earliest Oligocene in age by nannofossils and foraminifers (within the 32.8- to 34.3-Ma interval; Subzone CP16a/b and basal AP13).

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APPENDIX

Calcareous nannofossils considered in this paper in alphabetical order of generic epithets.

Bicolumnus ovatus Wei and Wise, 1990.
Blackites spinosus (Delandre and Fert) Hay and Towe, 1962.
Braarudosphaera bigelowii (Gran and Braarud) Deflandre, 1947.
Calcidiscus leptoporus (Murray and Blackman, 1898) Loeblich and Tappan, 1978.
Calcidiscus macintyrei (Bukry and Bramlette, 1969) Loeblich and Tappan, 1978.
Chiasmolithus altus Bukry and Percival, 1971.
Chiasmolithus oamaruensis (Deflandre) Hay, Mohler, and Wade, 1966.
Clausicoccus fenestratus (Deflandre and Fert) Prins, 1979.
Coccolithus formosus (Kampter) Wise, 1973.
Coccolithus miopelagicus Bukry, 1971.
Coccolithus pelagicus (Wallich) Schiller, 1930.
Coronocyclus nitescens (Kamptner) Bramlette and Wilcoxon, 1967.
Cyclicargolithus abisectus (Müller) Wise, 1973.
Cyclicargolithus floridanus (Roth and Hay in Hay et al.) Bukry, 1971.
Discoaster binodosus Martini, 1958.
Discoaster deflandrei Bramlette and Riedel, 1954.
Discoaster tanii Bramlette and Riedel, 1954.
Discoaster variabilis Martini and Bramlette, 1963.
Emiliania huxleyi (Lohmann) Hay and Mohler in Hay et al., 1967.
Gephyrocapsa carribeanica Boudreaux and Hay, 1969.
Gephyrocapsa oceanica Kamptner, 1943.
Gephyrocapsa sp. cf. *sinuosa* Hay and Beaudry, 1973.
Helicosphaera bramlettei Muller, 1970.
Helicosphaera carteri (Wallich, 1877) Kamptner, 1954.
Helicosphaera euphratis Haq, 1966.
Helicosphaera granulata Bukry and Percival, 1971.
Helicosphaera intermedia Martini, 1965.
Helicosphaera obliqua Bramlette and Wilcoxon, 1967.
Helicosphaera perch-nielseniae Haq, 1971.
Helicosphaera recta Haq, 1966.
Isthmolithus recurvus Deflandre, 1954.
Markalius inversus (Deflandre) Bramlette and Martini, 1964.
Pontosphaera callosa (Martini) Varol, 1998.
Pontosphaera multipora (Kamptner) Roth, 1970.
Pontosphaera plana (Bramlette and Sullivan) Haq, 1971.
Pontosphaera punctosa (Bramlette and Sullivan) Perch-Nielsen, 1984.
Pontosphaera versa (Bramlette and Sullivan) Sherwood, 1974.
Pseudoemiliania lacunosa (Kamptner) Gartner, 1969.
Reticulofenestra bisecta (Hay, Mohler, and Wade) Roth, 1970.
Reticulofenestra daviesii (Haq) Haq, 1971.
Reticulofenestra dictyoda (Deflandre and Fert) Stradner and Edwards, 1968.
Reticulofenestra hillae Bukry and Percival, 1971.
Reticulofenestra perplexa (Burns) Wise, 1983.
Reticulofenestra sp. cf. *R. reticulata* (Gartner and Smith) Roth and Thierstein, 1972.
Reticulofenestra samodurovii (Hay, Mohler, and Wade) Roth, 1970.
Reticulofenestra scrippsae (Bukry and Percival) Roth, 1973.
Rhabdosphaera tenuis Bramlette and Sullivan, 1961.
Sphenolithus dissimilis Bukry and Percival, 1971.
Sphenolithus moriformis (Brönnimann and Stradner) Bramlete and Wilcoxon, 1967.
Thoracosphaera saxea Stradner, 1961.
Triquetrorhabdulus carinatus Martini, 1965.
Zygrhablithus bijugatus (Deflandre) Deflandre, 1959.

Figure F1. Satellite-derived free-air gravity map of the Kerguelen Plateau (after Sandwell and Smith, 1997) showing ODP Site 1139 (black star) on Skiff Bank and other ODP and dredge localities. Leg 183 and previous ODP sites (Legs 119 and 120) are indicated by stars and circles, respectively (black = basement sites; white = sediment sites). Squares indicate dredge and piston core sites where igneous rock (black) and sediment (white) were recovered.

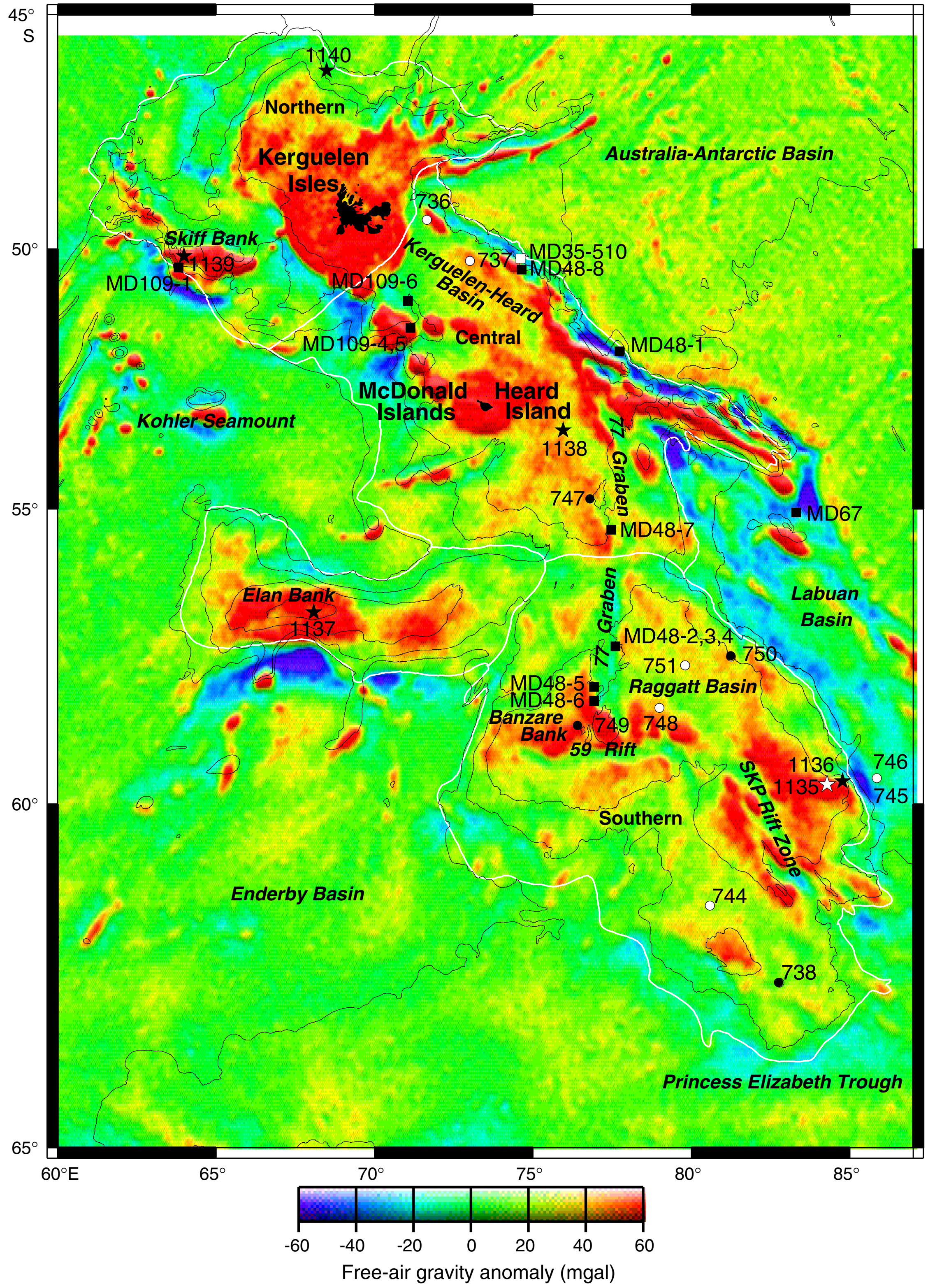


Figure F2. Composite stratigraphic section showing core recovery, a simplified summary of lithology, lithologic unit boundaries, ages of units, and names of lithologies from Hole 1139A.

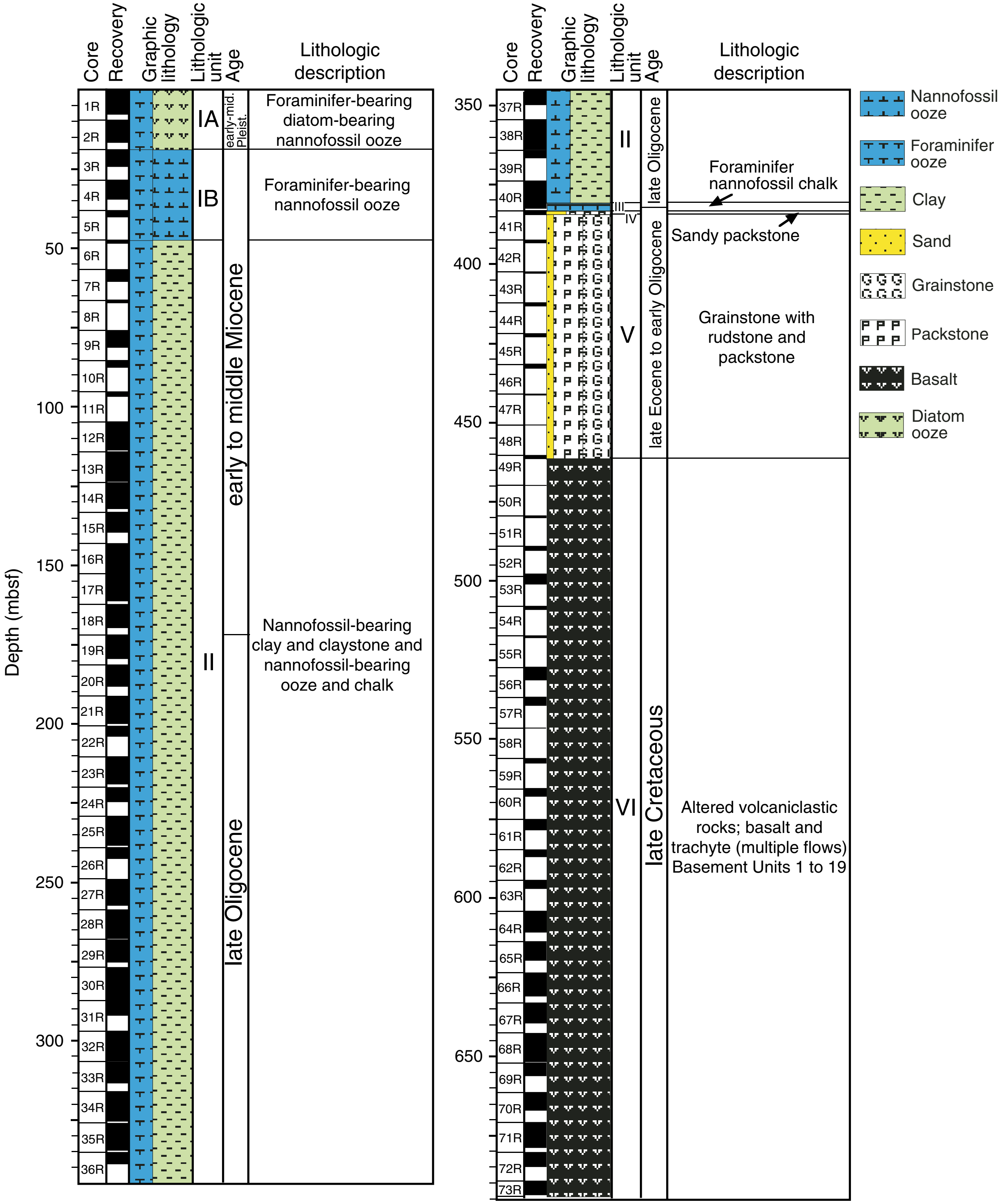


Figure F3. Holocene–Eocene timescale and biostratigraphic datums used for Leg 183 Kerguelen Plateau Site 1139 (modified from Berggren et al., 1995; Erba et al., 1995). High-latitude zonations used during Leg 183 vs. low-latitude zonations are indicated under "Leg 183" and "Low Latitude" respectively, for foraminifers and nannofossils. High-latitude biostratigraphic datum and age correlations are indicated in bold type under "Biostratigraphic Datums;" foraminiferal datums are underlined. Planktonic foraminifer zonations adopted from Berggren (1992: Neogene Kerguelen); Stott and Kennett (1990: Antarctic Paleogene; modified by Huber, 1991 and Berggren, 1992); Cita et al. (1997) (nannofossil zonations adopted from Wise, 1983; Antarctic Oligocene to mid–middle Eocene, modified by Wei and Wise, 1990, and Wei and Thierstein, 1991, and calibrated against magnetostratigraphy by Wei, 1992). Note that some of the high-latitude datums are only correlated to magnetic chrons in the literature. Dashed zonal boundaries indicate uncertain datum levels. T = top/last occurrence, B = base/first occurrence. Bold entries = see **"Zonations,"** p. 2, for explanation. (**Figure shown on next two pages.**)

Figure F3 (continued). (Caption shown on previous page.)

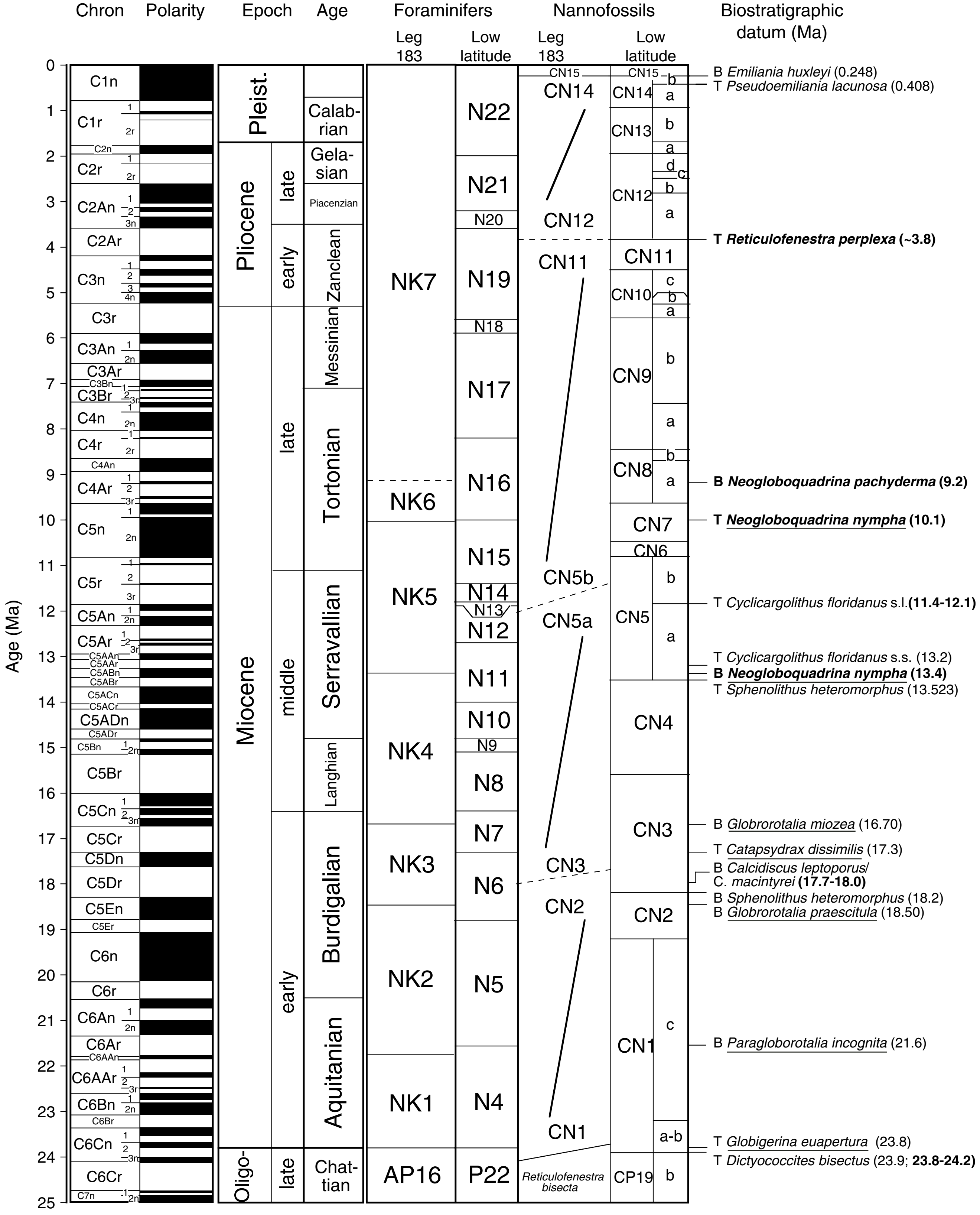


Figure F3 (continued).

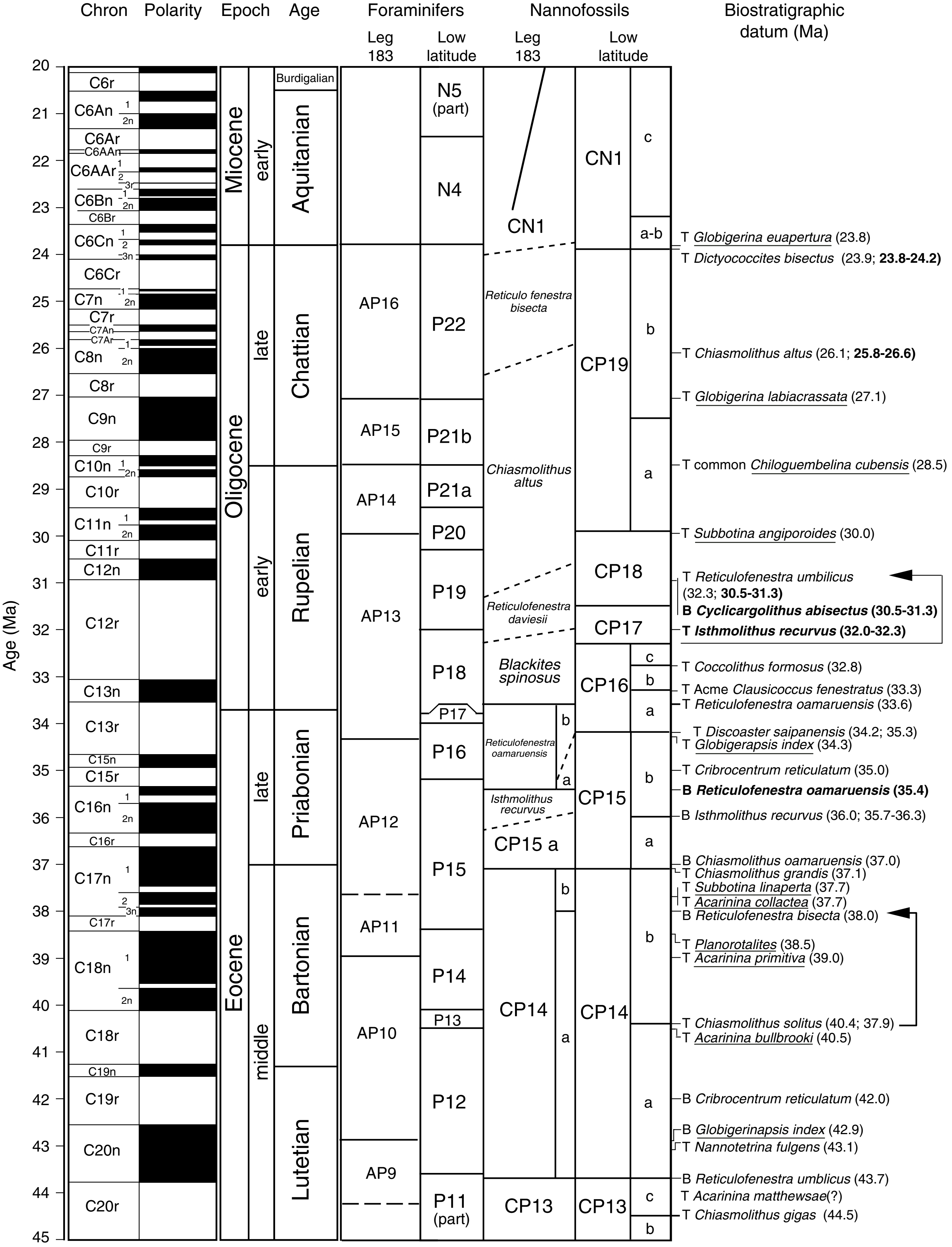
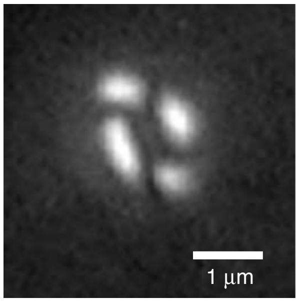


Table T1. Distribution of Quaternary, Miocene, and Oligocene calcareous nannofossils, Site 1139. (This table is available in an **oversized format.**)

Plate P1. Note: all micrographs of coccoliths are of the proximal view unless otherwise noted as distal (D). All micrographs are from Sample 183-1139A-1R-CC. Pol = polarized electron micrograph, SEM = scanning electron micrograph. **1–4.** Minute placoliths (of *Gephyrocapsa*?) that mimic *Emiliania huxleyi* as a result of etching during diagenesis that expands the central area and separates the outer shield elements (Pol). **5, 6.** SEMs that demonstrate how etching has separated the radial shield elements along their outer margins, causing them to superficially resemble the "I" bars of *Emiliania huxleyi*. **7.** Placolith (D) that exhibits overgrowth on the central area and, therefore, should not mimic *Emiliania huxleyi* in the light microscope. **8, 9.** *Pseudoemeliania lacunosa* (Pol). **10, 11.** Larger placoliths, possibly reticulofenestrids and/or gephyrocapsids, with heavily etched central areas and outer elements. These could mimic *Pseudoemeliania lacunosa* when viewed in the light microscope.



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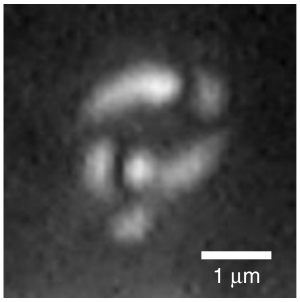

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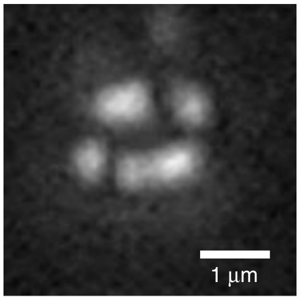

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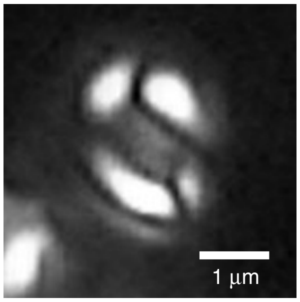

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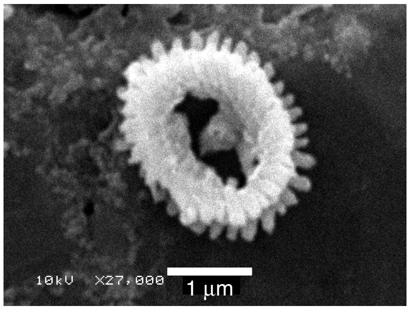

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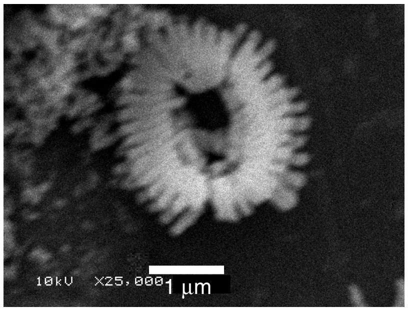

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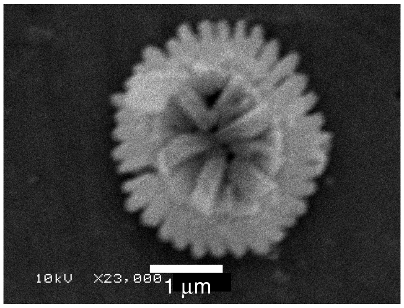

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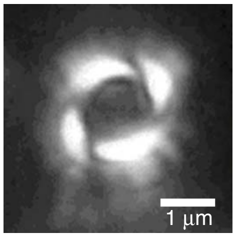

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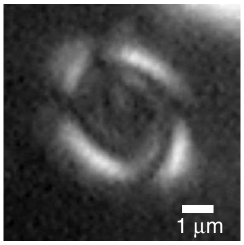

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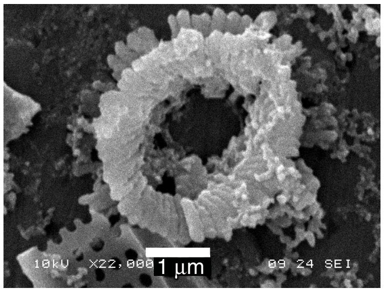

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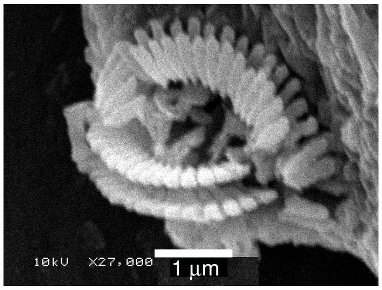

11

Plate P2. Note: all micrographs of coccoliths are of the proximal view unless otherwise noted as distal (D). All micrographs are from Sample 183-1139A-1R-CC. Pol = polarized electron micrograph, SEM = scanning electron micrograph. Gephyrocapsids in various states of preservation. **1, 2.** Characteristic gephyrocapsid interference patterns (Pol). **3.** Specimen showing the remnant of a central-area bridge but with elements around the outer periphery distinctly separated by etching (D). **4.** Well-preserved specimen with most bridge and shield elements intact (D). **5, 6.** Specimens with moderate separation of the proximal and distal shield elements, respectively. **7.** Specimen with moderate secondary calcite overgrowth along central area (D). **8.** Small specimen with selective separation of some shield elements (possibly a very small *Pseudoemeliania lacunosa*?) (D). **9.** Well-preserved specimen showing no signs of etching.