

31. PALEOGENE PLANKTONIC FORAMINIFER MAGNETOBIOSTRATIGRAPHY OF THE SOUTHERN KERGUELEN PLATEAU (SITES 747-749)¹

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ABSTRACT

An essentially complete Paleogene record was recovered on the Central and Southern Kerguelen plateaus (55°–59°S) in a calcareous biofacies. Recovery deteriorated in the middle Eocene and down to the upper Paleocene because of the presence of interbedded cherts and chinks. The stratigraphic distribution of about 70 taxa of planktonic foraminifers recovered at Sites 747–749 is reported in this paper. Faunas exhibited fairly high diversity (approximately 20–25 species) in the early Eocene, followed by a gradual reduction in diversity in the middle Eocene. A brief incursion of tropical keeled morozovellids occurred near the Paleocene/Eocene boundary, similar to that recorded on the Maud Rise (ODP Sites 689 and 690).

The high-latitude Paleogene zonal scheme developed for ODP Leg 113 sites has been adopted (with minor modifications) for the lower Eocene–Oligocene part of the Kerguelen Plateau record. A representative Oligocene (polarity chronozones 7–13) and late Eocene–late middle Eocene (questionably polarity chronozones 16–18) magnetostratigraphic record has allowed the calibration of several biostratigraphic datum levels to the standard Global Polarity Time Scale (GPTS) and established their essential synchrony between low and high latitudes.

INTRODUCTION

Ocean Drilling Program (ODP) Legs 119 and 120 drilled a latitudinal transect spanning some 10° of latitude (approximately 52°–62°S) from which Paleogene sediments were recovered. Leg 120 drilled five sites on the central and southern part of the Kerguelen Plateau. Four of these, Sites 747–750, spanning about 4° of latitude (55°–59°S), recovered Paleogene sediments, and the planktonic foraminifer record of three of those sites is discussed here (Sites 747–749; Table 1). When the results of these two legs are synthesized, together with those from earlier high-latitude legs (113, 114, and 119), it should be possible to obtain a more thorough understanding of the Paleogene biostratigraphy and biogeography of planktonic foraminifers of this region.

Until the drilling undertaken during Legs 119 and 120, the Kerguelen Plateau remained one of the least explored areas of the world. Our understanding of the faunal history of this region came from only a few scattered piston cores. The Paleogene record of the Kerguelen Plateau is now known to be essentially complete and to contain a faunal succession that reflects a gradual reduction in diversity in the middle Eocene, following a period of high diversity in the latest Paleocene and early Eocene. Although some of the low-latitude Paleogene markers are present in the Kerguelen sites, including several keeled morozovellids during the extratropical incursion of the early Eocene, the general faunal succession is similar to that described from the mid-latitudes of the Austral region (Jenkins, 1971), the South Atlantic, and, more recently, the Weddell Sea of the Antarctic region (~65°S, Stott and Kennett, 1990). I have adopted the zonal scheme of the latter authors (for the most part) for the Kerguelen Plateau in an attempt to provide a framework for interregional correlation.

The direct correlation of several biostratigraphic events to a fairly complete Oligocene magnetostratigraphy has provided

a precise means for correlation between the Kerguelen Plateau and low- to mid-latitude magnetobiostratigraphies. The depths of Paleogene magnetic polarity chronozones (MPC) identified in Sites 747, 748, and 749 are listed in Table 2; the stratigraphic positions of various biostratigraphic datum levels and chronostratigraphic boundaries are presented in a series of tables accompanying the site discussions.

MATERIAL AND METHODS

The samples discussed here were collected and processed aboard the *JOIDES Resolution*. Approximately one (20 cm³) sample per section (less frequently, one sample every second section) plus the core catcher (CC) sample were examined. Samples were prepared by washing in warm water, wet-sieving over a 63- μ m mesh screen, and drying in an oven at <50°C. The faunal composition is reported here in nonquantitative terms, based on an assessment of forms observed in a random sample of 200–400 specimens from the >63- μ m size fraction. Relative abundances are recorded on the range charts (Appendixes A–F, in back pocket) as follows: abundant (A) = >25%, common (C) = 16%–24%, frequent (F) = 6%–15%, and rare (R) = 1%–5%.

The generic classification used in this study follows to a large extent that of Loeblich and Tappan (1988). Taxonomic notes are provided to clarify usage in cases of taxa with identification and/or classification schemes that are more controversial.

SITE AND RECOVERY DATA

Four of the five sites drilled on Leg 120 recovered Paleogene sediments (Sites 747, 748, 749, and 750). Site locations and depth are shown in Figure 1 and Table 1. The sites are located over 4° of latitude between 54°48.68' (Site 747) and 58°43.03' (Site 749). An essentially complete Paleogene sequence was recovered among the four sites, although recovery was better in the Oligocene, upper Eocene, and lower Paleocene (Danian) than in the remainder of the section, where the presence of cherts inhibited core recovery of the interbedded nannofossil chinks. Relevant data on preservation and recovery are provided under each site in the discussion below and are presented in more detail in Schlich, Wise, et al.

¹ Wise, S. W., Jr., Schlich, R., et al., 1992. *Proc. ODP, Sci. Results*, 120: College Station, TX (Ocean Drilling Program).

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Table 1. Location data for Leg 120 sites that recovered Paleogene sediments.

Site	Latitude (S)	Longitude (E)	Water depth (mbsf)	Remarks on recovery
747	54°48.68'	76°47.64'	1695	Relatively complete Danian, condensed lower Eocene, incomplete upper Eocene and lower Oligocene, essentially complete upper Oligocene.
748	58°26.45'	78°58.89'	1290	Essentially complete sequence from lower part of middle Eocene through upper Oligocene
749	58°43.03'	76°24.45'	1069.5	Relatively complete middle lower Eocene to lower upper Oligocene with upper Eocene/lower Oligocene disconformity spanning about 6 m.y. Poor recovery in lower and middle Eocene.
750	57°35.54'	81°14.42'	2030.5	Relatively thick (~45 m) and complete Danian section and lower upper Paleocene; washed cores in the section above indicate the presence of middle Eocene.

(1989). Discussion here is limited to the first three sites. Hole 750A was wash- and interval-cored using a rotary core barrel (RCB) and recovered only scraps of middle and lower Eocene cherts and chalks before recovering a ~40–50 m thick section of Danian (Zones P1–P2) chalks. The Danian of Site 750 will form the subject of a separate study.

Magnetic polarity chronozones (MPC) 6C–13 were identified in these three sites and MPC 16–18 were questionably identified at Site 748 (Heider, this volume; Inokuchi, this volume). Polarity chronozones 27 and 28 were identified in the Danian of Hole 750. The depth of Paleogene polarity chronozones identified at Sites 747–749 is shown in Table 2.

BIOSTRATIGRAPHY

Paleogene planktonic foraminifer occurrences are presented in a series of charts (Appendix), and the ranges of stratigraphically useful or otherwise distinctive forms are presented in a series of range charts, which accompany the text below.

Planktonic foraminifer faunas exhibit a trend to decreasing diversity over the course of the Paleogene. Paleocene and lower Eocene faunas are similar to those occurring at low latitudes, and the P-zonation of Berggren and Miller (1988) may be applicable over (at least part of) this interval. For instance, morozovellids appear abruptly at the Paleocene/Eocene boundary (Site 747), but the section is so condensed that meaningful separation between distinct bioevents is not possible. A similar extratropical excursion of morozovellids over a very short stratigraphic interval at the Paleocene/Eocene boundary has been recorded at ODP Sites 689 and 690 on the Maud Rise (Stott and Kennett, 1990). Recovery in other parts of the section (i.e., the upper Paleocene) was inadequate to allow evaluation of the applicability of the P-zonation scheme at the Kerguelen Plateau sites.

For the middle Eocene, faunas exhibit a marked difference from contemporaneous low-latitude faunas. Acariniids, globigerinathekids, catapsydracids, and subbotinids dominate the faunas, and morozovellids, clavigerinelids, hantkeninids, and other characteristic warm-water elements are notably absent. Subbotinids, catapsydracids, chiloguembelinids, and

Table 2. Depth of Paleogene magnetic polarity chronozones identified at Sites 747–749 (Kerguelen Plateau).

Magnetic polarity chronozone	Depth (mbsf)				
	Top	Base	Hole 747A	Hole 748B	Holes 749A and 749B
1. 6C	X		125.70	63.7	
2. 7	X	X	129.65	68.2	
3. 7A	X	X	133.30		
4. 8	X	X	137.50	71.0	
5. 9	X	X	138.35	72.4	
6. 10	X	X	138.70	74.9	
7. 11	X	X	140.45	78.3	
8. 12	X	X	151.70	78.6	3.35
9. 13	X	X	154.60		
				88.6	
				90.6	10.30
				98.9	13.75
				101.7	
				105.0	
				117.4	
				119.3	

Note: Data from Heider et al. (this volume) and Inokuchi and Heider (this volume).

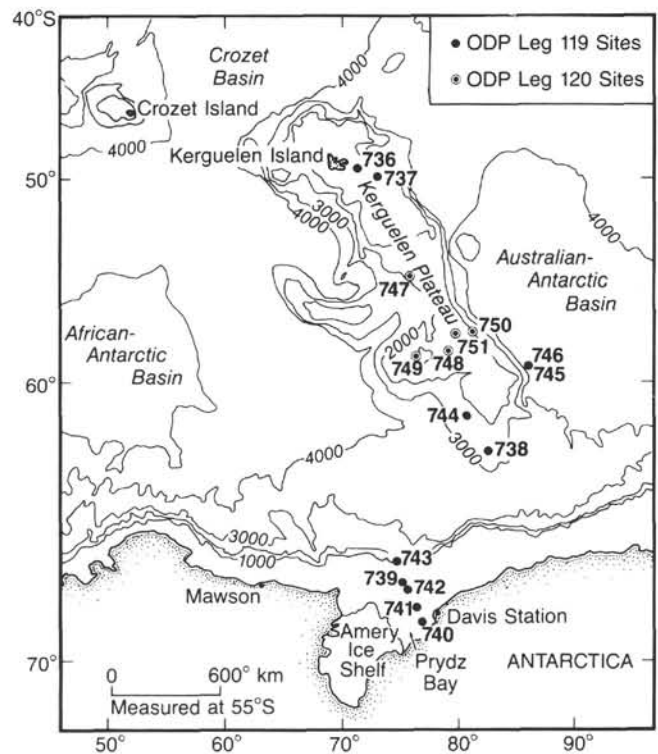


Figure 1. Map showing location of sites drilled on Leg 120, southern Kerguelen Plateau.

monospecific globigerinathekids (*G. index*) dominated late Eocene faunas.

Faunal diversity continued to decrease in the Oligocene, and faunas exhibited the characteristic features of high-latitude, cool-water assemblages: low diversity and high dominance. Chiloguembelinids, globigerinids, and subbotinids (usually one or two species of each) alternated as the dominant forms in most Oligocene samples.

Jenkins (1971) developed an Austral Paleogene zonation for these types of faunas, and I was at least partially success-

ful in adapting his zonal scheme during drilling on the Kerguelen Plateau. Using 16 distinct datum events, Stott and Kennett (1990) have proposed a 14-fold zonal subdivision of the "Antarctic" Paleogene (exclusive of the upper part of the upper Oligocene) based on Leg 113 drilling on Maud Rise in the Weddell Sea at about 65°S latitude. Huber (1991) has since redefined one of these (middle Eocene) zones based on Leg 119 drilling on the Southern Kerguelen Plateau.

To provide continuity and a means for biostratigraphic correlations among the Paleogene sites drilled in the circumantarctic region on ODP Legs 113, 119, and 120, I have used the zonal scheme of Stott and Kennett (1990) for the Eocene and Oligocene to the extent possible. The reader is referred to their paper for zonal definitions and characterizations (see also Huber, 1991).

The only modification to the zonal scheme of Stott and Kennett (1990) concerns the middle Oligocene *Globigerina labiacrassata* (AP14) Zone. They subdivided Zone AP14 into two subzones: AP14a = *Chiloguembelina cubensis* (the interval between the last appearance datum [LAD] of *S. angiporoides* and the LAD of *C. cubensis*); and AP14b = *Globigerina euapertura* Zone (partial range of nominate taxon between the LAD of *C. cubensis* and LAD of *G. labiacrassata*). The LAD of *G. labiacrassata* was shown to correlate approximately with the upper part of Chron C9N (~28–28.5 Ma), which I have verified at Sites 747 and 748 on the Kerguelen Plateau. There is, however, a significant (bio)stratigraphic interval that spans about 5 m.y. between the LAD of *G. labiacrassata* (Chron C9N) and the Oligocene/Miocene boundary (Chron C6CN2), which was not treated by Stott and Kennett (1990) or Huber (1991), but was recovered at Sites 747 and 748. Planktonic foraminifer biostratigraphic events within this interval are rare, if not nonexistent. I have found, however, that the LAD of *G. euapertura* closely approximates the Oligocene/Miocene boundary as calibrated (and correlated) paleomagnetically. For this reason, I would suggest modification of the *G. labiacrassata* (AP14) Zone and the addition of two zones to the upper Oligocene zonal format.

**Zone AP14: *Chiloguembelina cubensis* Interval Zone
(= Subzone AP14a of Stott and Kennett, 1990)**

Definition: Interval from the LAD of *S. angiporoides* to the LAD of the nominate taxon.

Remarks: This zone represents a rather brief (2 m.y.) time span, and denotes the uppermost part of the range of the nominate taxon, a distinctive element in lower Oligocene faunas. *Globigerina labiacrassata* is a distinctive and common element in faunas of this zone. The definition of the zone is the same as that of Stott and Kennett (1990) for their Subzone AP14a.

**Zone AP15: *Globigerina labiacrassata* Interval Zone
(= Subzone AP14b of Stott and Kennett, 1990)**

Definition: Interval from the last occurrence (LO) of *Chiloguembelina cubensis* (base) to the LAD of the nominate taxon (top).

Remarks: This biozone corresponds exactly to Subzone AP14b (*Globigerina euapertura* Zone) of Stott and Kennett (1990), but the nominate form has been changed to allow the use of *G. euapertura* as the nominate form for the upper Oligocene (bio)stratigraphic interval above the LAD of *G. labiacrassata*.

Zone AP16: *Globigerina euapertura* Interval Zone

Definition: Interval between the LO of *G. labiacrassata* (base) and the LO of the nominate taxon (top).

Remarks: *Globigerina euapertura* is a characteristic, if sporadic, element in upper Oligocene assemblages on the Kerguelen Plateau. Faunas of this zonal interval are characterized by catapsydracids (*C. dissimilis*-*C. unicavus* group), *Globorotaloides suteri*, and tenuitellids (*T. gemma*, *T. munda*). This zone corresponds, in part, to the Austral zone of the same name defined by Jenkins (1971) for the upper Oligocene; his zone was more extensive, however, extending from the LAD of *S. angiporoides* to the first appearance datum (FAD) of *Globoquadrina dehiscens*.

SITE 747

Site 747 (proposed site SKP-1) is located in the central part of the Kerguelen Plateau (54°48.68'S, 76°47.64'E), about 500 km south of the present-day Polar Front (Antarctic Convergence), at a water depth of 1695 m. Three holes were drilled at this site (see further discussion in Berggren, this volume). Discussion here is restricted to the Paleogene recovered in Holes 747A and 747C (Fig. 2).

The Paleocene at Site 747 is about 54 m thick (~128–mbsf) and consists of calcareous nannofossil and foraminifer oozes and chalks. At least three unconformities punctuate the stratigraphic sequences: (1) an intra-lower Oligocene unconformity at 170 mbsf (spanning about 4 m.y. between 31 and 35 Ma); (2) an intra-Eocene (upper Eocene/lower Eocene) unconformity at 173 mbsf (spanning about 15 m.y. from 38 to 53 Ma); and (3) an intra-Paleocene unconformity (upper Paleocene/upper Danian) at 174.5 mbsf (spanning 6 m.y. from 58 to 64 Ma). An extremely condensed but essentially complete section of strongly bioturbated lower Eocene sediments occurs within a 1.5-m interval bounded by the two unconformities at 173 and 174.5 mbsf, respectively. The Paleogene section ends in a lower Danian volcanoclastic debris flow, which was the subject of a special study (Aubry and Berggren, 1989).

Hole 747A

The Paleogene of Hole 747A is represented by Core 120-747A-14H to Section 120-747A-20X-CC (~128 to ~182.5 mbsf) and spans the upper Oligocene to lower Danian (Table 3). At least three disconformities (see above) occur in this interval.

Hole 747C

Hole 747A overlaps the stratigraphic sequence of Hole 747C at 159 mbsf (upper Oligocene). There is an offset of about 2.4 m between Holes 747A and 747C, which is the result of the ODP convention of adjusting upward all incompletely recovered cores. This is discussed below more fully (see Fig. 3).

Paleogene

Despite the disconformities and extremely condensed lower Eocene section, Paleogene faunas yield valuable information on both biostratigraphy and biogeography. Diverse early Eocene faunas include morozovellids (*M. aequa formosa*, *M. subbotinae*, *M. marginodentata*), acariniids (*A. angulosa*, *A. appressocamerata*, *A. pentacamerata*, *wilcoxensis*, among others), subbotinids, (*S. patagonica*, *S. inaequispira*), and *Globanomalina australiformis*, and attest to the penetration into high latitudes of low-latitude, tropical-subtropical faunas near the Paleocene/Eocene boundary. Upper Eocene faunas are decidedly less diverse and are dominated by *Globigerinatheka index*, *Subbotina angiporoides*, and *Chiloguembelina cubensis*.

The LAD of *G. index* is interpreted to occur in Sample 120-747C-2R-2, 89–91 cm (170.9 mbsf), though relatively common (predominantly fragmented) specimens occur in

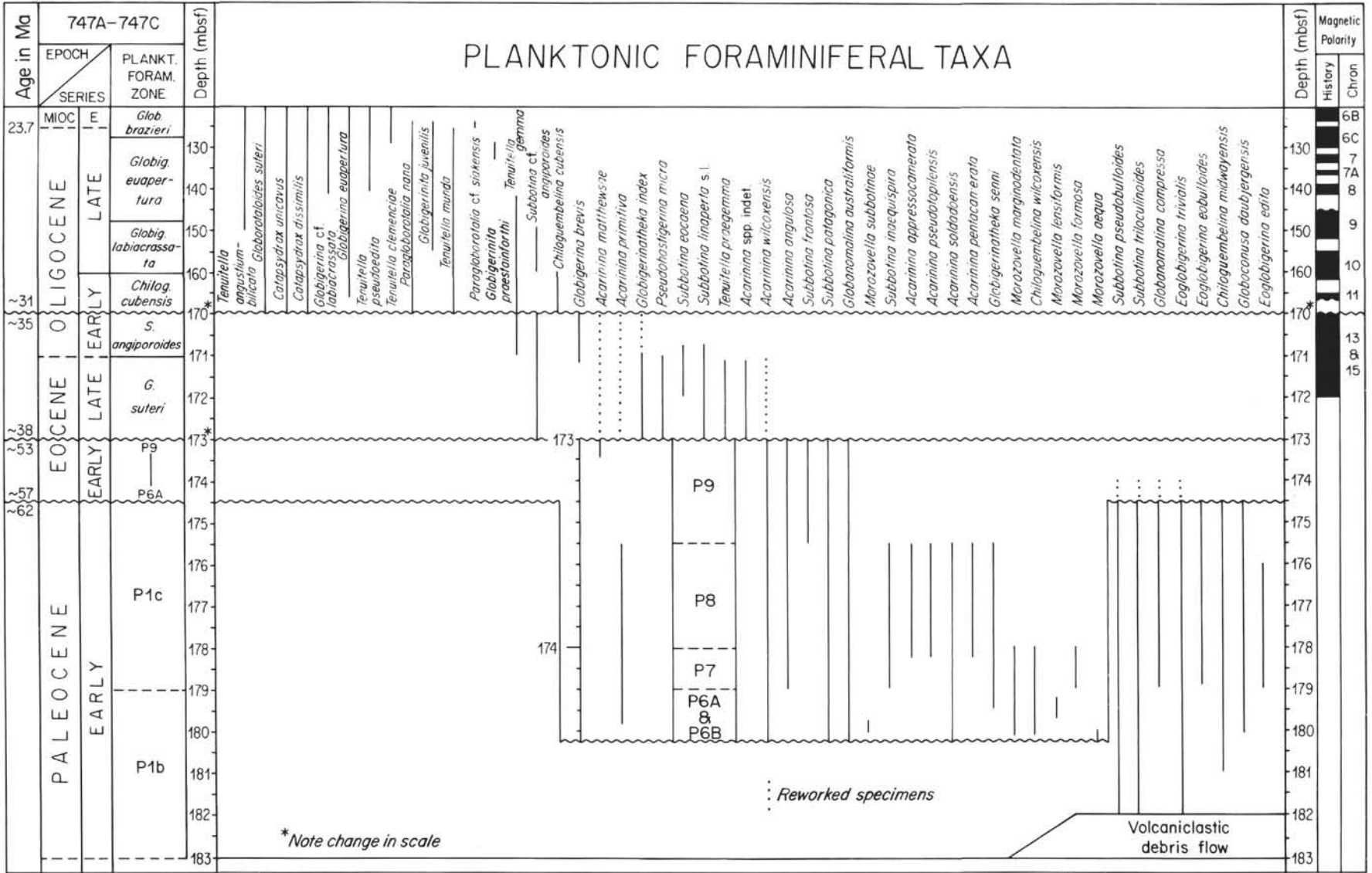


Figure 2. Stratigraphic distribution of Paleogene planktonic foraminifers in Holes 747A and 747C.

Table 3. Magnetobiostratigraphic calibration and stratigraphic level of five Paleogene planktonic foraminifer events, Site 747 (Kerguelen Plateau).

Biostratigraphic event	Core, section, interval (cm)	Depth (mbsf)	Paleomagnetic calibration
1. LAD <i>Globigerina euapertura</i>	747A-14H-4, 40–44 to 14H-6, 40–44	127.9–130.9	Base C6C
2. LAD <i>Globigerina labiacrassata</i>	747A-15H-7, 40–44 to 15H-CC	141.9–142.0	C9N (base)
3. LAD <i>Chiloguembelina cubensis</i>	747C-1R-1, 41–45 to 1R-2, 41–45	159.4–160.9	C10N (base)
4. LAD <i>Subbotina linaperta</i> s.l.	747C-2R-2, 69–71 to 2R-2, 79–81	170.7–170.8	—
5. LAD <i>Globigerinatheka index</i>	747C-2R-2, 79–81 to 2R-2, 89–91	170.8–170.9	—

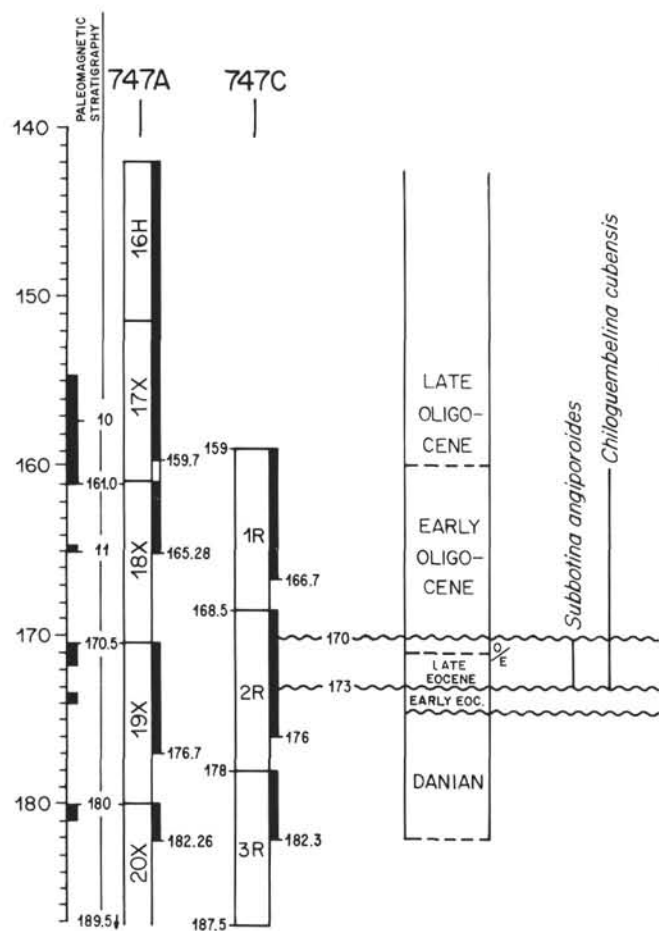


Figure 3. Correlation between Holes 747A and 747C.

Samples 120-747C-2R-2, 79–81 and 69–71 cm (170.8 and 170.7 mbsf), respectively. Accordingly, the Eocene/Oligocene boundary was drawn at 170.9 m.

Only about 2 m of lower Oligocene is present at Site 747 (between ~169 and 171 mbsf). Basal Oligocene faunas are similar to upper Eocene ones, but lack *G. index* and *S. linaperta*.

Above the disconformity at ~169 mbsf, an upper lower Oligocene fauna is dominated by *Globigerina labiacrassata*, catapsydracids (*C. dissimilis*, *C. unicavus*) and *Chiloguembelina cubensis*. *Subbotina angiporoides* does not occur above the disconformity at 169 mbsf, whereas *C. cubensis* has its LAD at about 160 mbsf, supporting the determination that the oldest sediments above the disconformity are between the

LAD of *S. angiporoides* and the LAD of *C. cubensis* (i.e., middle Oligocene, ~31 Ma).

Upper Oligocene faunas are characterized by catapsydracids and small tenuitellids.

Reworking

Reworked specimens are a common component of the total faunal assemblage observed in the Paleogene of Site 747. The reworking takes several forms:

1. Danian planktonic foraminifers (*S. pseudobulloides*, *S. triloculinoide*s, *G. compressa*, and others) are commonly reworked into the uppermost Paleocene–basal Eocene sediments at about 173 mbsf. They exhibit little discoloration and are probably the result of intense bioturbation in the basal Eocene interval above 174 mbsf.

2. Lower Eocene acariniids (predominantly *A. primitiva* and *A. bullbrookii*) are commonly reworked in the upper Eocene and Oligocene sediments (above 171 mbsf). These reworked elements are easily recognized by their brownish yellowish color; specimens are often preserved as internal molds and have a dull to slightly shiny surface “patina.”

3. Essentially penecontemporaneous reworking of lower upper Oligocene faunal elements (globigerinids, catapsydracids, and others) occurs in Core 120-747C-1R. These specimens are also brownish yellow in color and preserved (predominantly) as internal molds. For example, a few individuals of *S. angiporoides* were found in Sample 120-747C-1R-2, 41–45 cm (160.0 mbsf). Over 50% of the specimens are estimated to consist of reworked elements in these lower upper Oligocene sediments. Reworking was observed to occur commonly up to about 152 mbsf (Core 120-747A-17X), above which specimens are virtually 95% or more white (i.e., no evidence of discoloration or alteration).

Offset between Holes 747A and 747C

Hole 747C was begun at 159 mbsf and overlaps with the lower part of Core 120-747A-17X (which was cored to a depth of 159.7 mbsf but recovered only 5½ sections (i.e., to 159.7 mbsf, see Fig. 3).

During an examination of samples from Cores 120-747A-17X and -18X and Cores 120-747C-1R and -2R, I observed that biostratigraphic events and the intra-Oligocene and intra-Eocene disconformities do not align themselves between the two holes. For instance, the disconformity (as determined biostratigraphically) between Samples 120-747A-18X-CC and -19X-1, 11–13 cm (between 165.0 and 170.6 mbsf), separates lower Oligocene and lower Eocene sediments. The upper Eocene/lower Eocene disconformity can be precisely located in Hole 747C in Sample 120-747C-2R-3 between 139–141 and 146–148 cm (172.9–173.04 mbsf). At the corresponding level in Hole 747A (Sample 120-747A-19X-3, 19–21 cm; 173.2 mbsf), the fauna consists of a mixed assemblage of early to late Paleocene forms similar to those observed in Sections 120-747C-2R-4 and -5 (~174 mbsf).

Sample 120-747A-19X-1, 11–13 cm (~170.6 m), contains a lower Eocene fauna, whereas Samples 120-747C-2R-2, 40–42 and 69–71 cm (170.4 and 170.7 mbsf), respectively, contain basal Oligocene faunas, just 2+ m above the disconformity at 173 mbsf that separates upper Eocene from lower Eocene sediments.

Core 120-747A-19X was drilled between 170.5 and 180.00 mbsf, but 6.2 m was recovered. This 6.2 m was credited to the upper part of the cored interval (i.e., from 170.5 to 176.7 mbsf), according to standard ODP procedures. If Core 120-747C-19X, however, is “lowered” 2.4 m, the disconformity at 173 mbsf in Hole 747C will align itself precisely with the top of Core 120-747A-19X, and correlation between the two holes is possible.

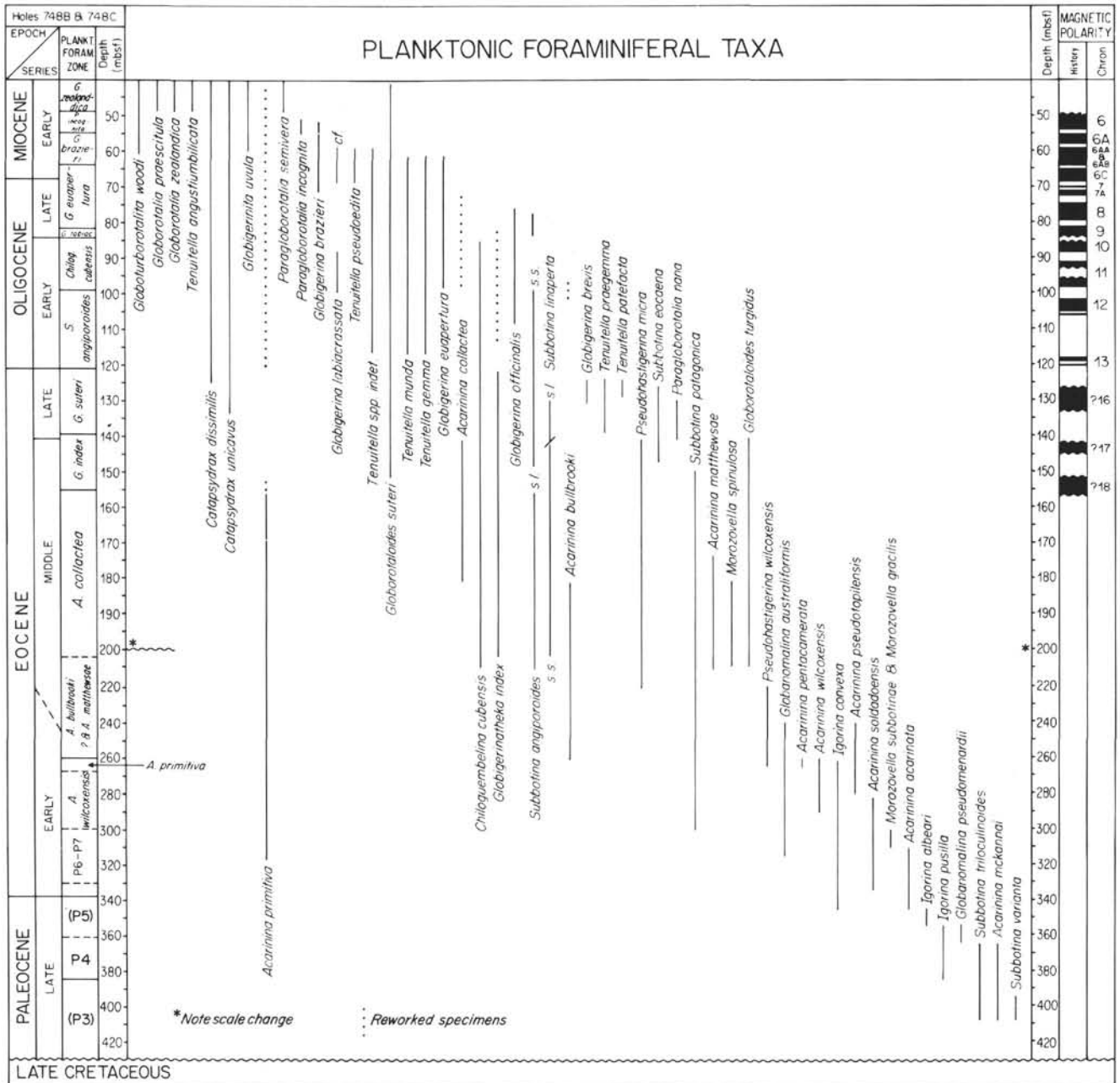


Figure 4. Stratigraphic distribution of Paleogene planktonic foraminifers in Holes 748B and 748C.

Magnetobiostratigraphy

Part or all of magnetic polarity chronozones 6C-10 were recognized at Site 747. In addition, a short, incomplete normal interval at ~165 mbsf (within the *Chiloguembelina cubensis* Zone) probably represents MPC 11, and another short, incomplete, normal interval at ~171 mbsf (within the *Globorotaloides suteri* Zone) may represent MPC 13 and/or 15. The correlation of five planktonic foraminifer events to the paleomagnetic stratigraphy is shown in Table 3.

SITE 748

Site 748 (proposed site SKP-3C) is a reentry site located on the Southern Kerguelen Plateau in the western part of the Raggatt Basin, east of Banzare Bank (58°26.45'S, 78°58.89'E), at a water depth of about 1290 m. Additional background data on this site may be found in the companion paper on the Neogene planktonic foraminifers (Berggren, this volume).

Paleogene

The Paleogene is represented by approximately 343 m of sediment between 67 and 410 mbsf (Samples 120-748B-9H-1, 40-44 cm, and 120-748C-26R-CC). Lower upper Paleocene nanofossil oozes, calcareous grainstones, and cherts lie unconformably on upper Maestrichtian glauconitic bioclastic packstones at about 410 mbsf (between Sections 120-748C-26R-CC and -27R-CC).

The Oligocene is apparently represented by a continuous, approximately 55-m-thick stratigraphic section extending from Samples 120-748B-8H-CC to -14H-6, 80-84 cm (~67-121.5 mbsf). Late Oligocene faunas are characterized by globigerinids (*Globigerina brazieri*, *G. euapertura*, *G. labiacrassata*), catapsydracids (*C. unicavus-dissimilis* group, *G. suteri*) and tenuitellids (*Tenuitella gemma*, *T. munda*, and others) (Fig. 4).

Lower Oligocene faunas contain, in addition to the above elements, *Subbotina angiporoides* (to Sample 120-748B-

Table 4. Magnetobiostratigraphic calibration of nine Paleogene planktonic foraminifer events, Hole 748B.

Biostratigraphic event	Core, section, interval (cm)	Depth (mbsf)	Paleomagnetic calibration	Remarks
1. LAD <i>Globigerina euapertura</i>	8H-2, 40–44 to 8H-6, 40–44	63.5–65.0	C6CN	
2. LAD <i>Tenuitella gemma</i>	9H-1, 40–44 to 9H-2, 40–44	67.0–68.5	C6CN	
3. LAD <i>Globigerina labiacrassata</i>	10H-4, 40–44 to 10H-5, 40–44	81.0–82.5	C9N	
4. LAD <i>Chiloguembelina cubensis</i>	10H-6, 34–38 to 10-CC	83.9–85.6	midpoint of concatenated C9N and C10N	
5. LAD <i>Subbotina angiporoides</i>	12H-2, 80–84 to 12H-3, 40–44	97.4–98.5	C11N	
6. LAD <i>Globigerinatheka index</i>	14H-5, 40–44 to 14H-6, 80–84	120.5–122.4	C13R (upper third)	
7. LAD <i>Acarinina collactea</i>	16H-6, 40–44 to 16H-7, 80–84	141.4–142	?C17N	In interval of uninterpretable paleomagnetism data and just above level identified as possibly C17N (see Item 8 below).
8. LAD <i>Subbotina linaperta</i> s.s.	17H-1, 80–84 to 17H-2, 80–84	143.4–144.9	?C17N	Probable normal polarity interval interpreted as C17N on biostratigraphic evidence
9. LAD <i>Acarinina primitiva</i>	18H-1, 40–44 to 18H-2, 80–84	152.5–154.4	?C18N	In interval of uninterpretable paleomagnetism data just above level interpreted (on less reliable data) as possibly C18N

12H-3, 40–44 cm; ~89 mbsf) and *Chiloguembelina cubensis* (to Sample 120-748B-10H-CC; ~85 mbsf).

A distinctive feature of the Oligocene is the persistent reworking (in about 75% of the samples examined) of middle to upper Eocene forms (*Acarinina primitiva*, *A. collactea*, *Globigerinatheka index*, among others).

The Eocene is apparently represented by a continuous, approximately 88–89 m thick section extending from Samples 120-748B-14R-6, 80–84 cm, to 120-748C-15R-CC (~121.5–310 mbsf). Recovery was rather poor in the cherty interval below ~180 mbsf, although elements of most of the lower and lower-middle Eocene zonal biostratigraphy were recognizable in core catchers and a few samples from partially recovered intervals.

Upper Eocene faunas are dominated by *Globigerinatheka index* with subsidiary numbers of subbotinids (*S. eoacaena*, *S. aff. linaperta*, *S. angiporoides*) and catapsydracids (*C. unica-vus-dissimilis* group, *G. suteri*).

Middle Eocene faunas exhibit greater diversity than upper Eocene ones, with the addition of acarininids (*A. collactea* to Sample 120-748C-16H-7, 80–84 cm [~142 mbsf]; *A. primitiva* to Sample 120-748C-18H-2, 80–84 cm [~153.5 mbsf]; and *A. bullbrooki* to Section 120-748C-18H-CC [~161 mbsf]) to the fauna. The *G. unica-vus-dissimilis* group and *G. suteri* are replaced (downhole) in the middle Eocene by *Globorotaloides turgidus*. *Subbotina linaperta* s.s. is a common element of middle Eocene faunas (up to Sample 120-748C-17H-2, 80–84 cm; ~144 mbsf) and *S. patagonica* is a rare to frequent component of lower middle Eocene faunas (up to Section 120-748C-18H-CC; ~161 mbsf).

Morozovella spinulosa, a distinctive element of middle Eocene, low-latitude faunas occurs over an approximately 25-m stratigraphic interval in the middle part of the *A. collactea* Zone (Sections 120-748B-21X-CC and -23X-CC and 120-748C-1R-CC [~176–203 mbsf]), equivalent approximately to Zone P12 (Berggren and Miller, 1988).

The lower Eocene extends from about 310 mbsf to within the stratigraphic interval between 220.5 mbsf (Section 120-748C-6R-CC) and 258.7 mbsf (Sample 120-748C-10R-1, 19–21 cm). Thus, the estimated thickness of the lower Eocene is thus about 60–80 m. Lower Eocene faunas are characterized by high-diversity acarininid and igorinid faunas; subbotinids, planorotaliids, pseudohastigerinids, and chiloguembelinids, and rare morozovellids are also distinctive of this interval. A characteristic se-

quence of faunal events suggests that a complete lower Eocene section is represented. The presence of *Morozovella subbotinae* and *M. gracilis* in Section 120-748C-14R-CC (~298 mbsf); of *Acarinina pentacamerata*, *M. lensiformis*, *Subbotina inaequispira*, common *Subbotina patagonica*, and forms morphologically transitional between *M. aragonensis* and *M. caucasica* in Sections 120-748C-10R-1 to -3 and -CC (~258.7–262.3 mbsf); and of *Acarinina bullbrooki* in Sample 120-748C-10R-1, 19–21 cm (~258.7 mbsf) supports the contention that the lower Eocene is essentially complete at this site and that it corresponds stratigraphically to the Zones P6–P9 interval in tropical environments. *Acarinina wilcoxensis*, *A. pseudotopilensis*, *A. angulosa*, *A. soldadoensis*, and *A. primitiva* are characteristic components of the lower Eocene faunas.

Globanomalina australiformis is a distinctive element of lower Eocene faunas and occurs as high as Sample 120-748C-10R-1, 19–21 cm (~258.7 mbsf), associated with the lowest occurrence of *A. bullbrooki*. *Igorina convexa*, a characteristic component of northeast Caucasus lower Eocene planktonic faunas in the "Zone of conical globorotaliids" (Subbotina, 1953) occurs here up to Sample 120-748C-10R-2, 97–99 cm (~261 mbsf).

The Paleocene is represented by a ~100-m section (Sections 120-748C-16R-CC to -26R-CC [~315.5 to ~409.1 mbsf]). Recovery was poor over this interval, and semiquantitative estimates of faunal elements were not possible because of the poor preservation and small specimen sizes. Acarininids (*A. soldadoensis*, *A. acarinata*) and subbotinids (*S. triangularis*, *S. velascoensis*) characterize the interval above 340 mbsf, whereas *Subbotina triloculinoides*, *Igorina pusilla*, and *I. albeari* occur below this level. The presence of *S. triloculinoides*, *S. varianta*, and small acarininids suggest that the lowest Paleocene sample recovered (Section 120-748C-26R-CC; ~409 mbsf) is of early late Paleocene (Selandian) age, approximately equivalent to Zones P3 or P4 of the tropical environment.

Magnetobiostratigraphy

Polarity chronozones 6A and 7A through 13 were recognized in part or completely at Site 748. In addition, MPCs 16 through 18 are questionably identified (see also Inokuchi and Heider, this volume). Nine planktonic foraminifer biostratigraphic events have been correlated to the magnetostratigraphy (Table 4). The relationship of chronostratigraphic boundaries to magnetostratigraphy is shown in Table 5.

Table 5. Stratigraphic position and magnetobiostratigraphic calibration of main Paleogene chronostratigraphic boundaries at Site 748.

Chronostratigraphic boundary	Biostratigraphic event	Core, section, interval (cm)	Depth (mbsf)	Paleomagnetic calibration
Oligocene/Miocene	Close to LAD <i>Globigerina euapertura</i>	8H-CC to 9H-1, 40–44	66.6–67.0	Midpoint Chron C6C-N2
early/middle Oligocene	LAD <i>Chiloguembelina cubensis</i>	10H-6, 34–38 and 10H-CC	83.9–85.6	Middle part of combined Chrons C9-10N
Eocene/Oligocene	LAD <i>Globigerinatheka index</i>	14H-5, 40–44 to 14H-6, 80–84	120.5–122.4	Upper part Chron C13R
middle/late Eocene	LAD <i>Subbotina linaperta</i> s.s.	17H-1, 80–84 to 17H-2, 80–84	143.4–144.9	Probable normal polarity interval interpreted as C17N on biostratigraphic evidence

Site 749

Site 749 (proposed site SKP-4) is a reentry site situated on the western flank of the Banzare Bank, on the southern part of the Kerguelen Plateau (58°43.03'S, 76°24.45'E) at a water depth of 1069.5 m.

About 44 m of Oligocene to middle Eocene nannofossil ooze was recovered with the advanced hydraulic piston corer (APC), at which point (middle Eocene) chert was encountered. Coring continued with the extended core barrel (XCB), but with limited success. Hole 749B ended at a depth of 123.8 m in upper lower Eocene nannofossil ooze and chert. Hole 749C was cored with the rotary core barrel (RCB) with only limited success through lower Eocene nannofossil oozes and chert to basement at 202 mbsf.

Except for a superficial interval (<0.5 m thick) of Pliocene-Pleistocene foraminiferal and diatomaceous sands and oozes with ice-rafted detritus ranging in size from gravel to sand-silt size, the stratigraphic succession recovered at Site 749 is wholly Paleogene.

Paleogene

Approximately 190 m of Paleogene (upper Oligocene to lower Eocene) nannofossil chalks and oozes were recorded at Site 749 (Fig. 5). With the exception of a distinct unconformity at ~15.5 mbsf, which separates upper lower Oligocene from lower upper Eocene chalks, the section appears to be complete. Phosphatic fragments are prevalent in Sample 120-749B-3H-1, 40–44 cm (15.7 mbsf), at which level typical Eocene faunal elements disappear abruptly, among others, *Globigerinatheka index*, *Pseudohastigerina micra*, and *Subbotina linaperta* s.l. The duration of the hiatus is estimated here at about 5 m.y. (from >32.5–33 Ma to >38 Ma); the basis for this estimate is discussed more fully below under the "Magnetostatigraphy" section.

Hole 749B

Upper Oligocene faunas are characterized by *Globigerina praebulloides* and *G. euapertura*. Tenuitellids (*T. gemma* and *T. munda*) and *Globigerina juvenilis* are common accessory forms. A superficial (30–40 cm) veneer of Holocene sediments occurs on the seafloor and *Neogloboquadrina pachyderma* occurs in the uppermost sample (120-749B-1H-1, 40–44 cm; 0.40 mbsf) mixed (downward) into the highest Oligocene level. The LAD of *Chiloguembelina cubensis* (120-749B-2H-2, 40–44 cm; 7.7 mbsf) serves to delineate the upper/lower Oligocene boundary and the LAD of *Subbotina angiporoides* (120-749B-2H-6, 40–44 cm; 13.7 mbsf). Furthermore, the characteristic development of *Globigerina labiacrassata* above this level allows the determination of the two Oligocene zones based on these taxa.

Upper Eocene faunas are characterized by *Globigerinatheka index*, *Globorotaloides suteri*, *Chiloguembelina cubensis*, and *Subbotina angiporoides*. I have observed here (as at Site 748) that forms referable to *Subbotina linaperta* s.s. have their LAD well below the Eocene/Oligocene boundary (see also Stott and Kennett, 1990). The LAD of *S. linaperta* s.s. is in Sample 120-749B-4H-7, 40–44 cm (34.2 mbsf)—and

about 6 m below the LAD of *Acarinina collectea*—and occurs nearly 20 m below the unconformity (at ~15.5 mbsf) that separates upper Eocene and lower Oligocene calcareous oozes and chalks. Forms referable to *S. linaperta* s.l. occur, in generally lower relative abundances, in the stratigraphic interval above the disappearance of typical forms of *S. linaperta*. Middle Eocene faunas are characterized by the occurrence of acarininids (*A. collectea*, *A. primitiva*, *A. matthewsae*, *A. bullbrooki*, and others), globigerinathekids (*G. index*) subbotinids (*S. linaperta*, *S. eocaena*, *S. patagonica*). Forms typical of the larger and more robust *Subbotina angiporoides* occur down to about Sample 120-749B-3H-6, 40–44 cm (23.2 mbsf) (late Eocene); whereas between Samples 120-749B-44H-5, 40–44 cm, and 120-749B-9X-CC (31.2–78.3 mbsf), individuals are consistently smaller and less markedly cancellate than typical *S. angiporoides*. These forms have been denominated *S. angiporoides minima* by Jenkins (1966); they are referred here to *S. angiporoides* s.l.

An estimation of the thickness of the middle Eocene *A. collectea* and *G. index* zones is difficult, as the discussion below will show. The lowest occurrence of *Globigerinatheka index* (base of the *A. collectea* Zone) occurs in Sample 120-749B-9X-1, 40–44 cm (72.3 mbsf). It is not present in Sample 120-749B-9X-CC (78.7 mbsf), giving an approximate FAD at 75.5 mbsf. The base of the *G. index* (AP11) Zone is based upon the LAD of *A. primitiva*. Core 120-749B-6X was drilled between 43.8 and 53.3 mbsf. However, only the core-catcher sample was retrieved from Core 120-749B-6X, because of the difficulty of recovering interbedded calcareous ooze and chert. The core-catcher sampler was placed, according to ODP conventions, in the upper part of the core, at ~44 mbsf (Section 120-749B-6X-CC). The LAD of *A. primitiva* occurs in Sample 120-749B-6X-CC (44 mbsf). It is not present in Sample 120-749B-5H-CC (43.8 mbsf). In actual fact, the LAD can lie anywhere between 44 and 53.3 mbsf (the actual bottom depth of the cored interval). The LAD of *A. primitiva* normally occurs well above the FAD of *G. index*; thus, under normal circumstances, the *A. collectea* (AP10) Zone is considerably thicker (i.e., of longer duration) than the *G. index* (AP11) Zone (see Stott and Kennett, 1990).

Therefore, in Hole 749B, I arbitrarily placed the LAD of *A. primitiva* (in Sample 120-749B-6X-CC) at the top of the cored interval of Core 120-749B-6X at 44 mbsf. As such, the *A. collectea* Zone is 30 m thick, and the *G. index* Zone, 14 m thick. Dominant elements in the *G. index* Zone include *S. linaperta* s.s. (with typical quadrate test outline) and *G. index*. Other common elements include *S. eocaena*, *A. collectea*, *Chiloguembelina cubensis*, and *S. angiporoides* s.l. Faunal assemblages of the *A. collectea* Zone are essentially the same.

The *Acarinina matthewsae* (AP9) Zone (as redefined by Huber, 1991) is defined as the biostratigraphic interval between the LAD of *A. matthewsae* and the FAD of *G. index*. The latter event occurs in Sample 120-749B-9X-1, 40–44 cm (72.7 mbsf), with an estimated FAD at ~75.5 mbsf, which means that the *A. matthewsae* (AP9) Zone is rather thin (~5 m) in Hole 749B; this also appears to be the case at Site 738,

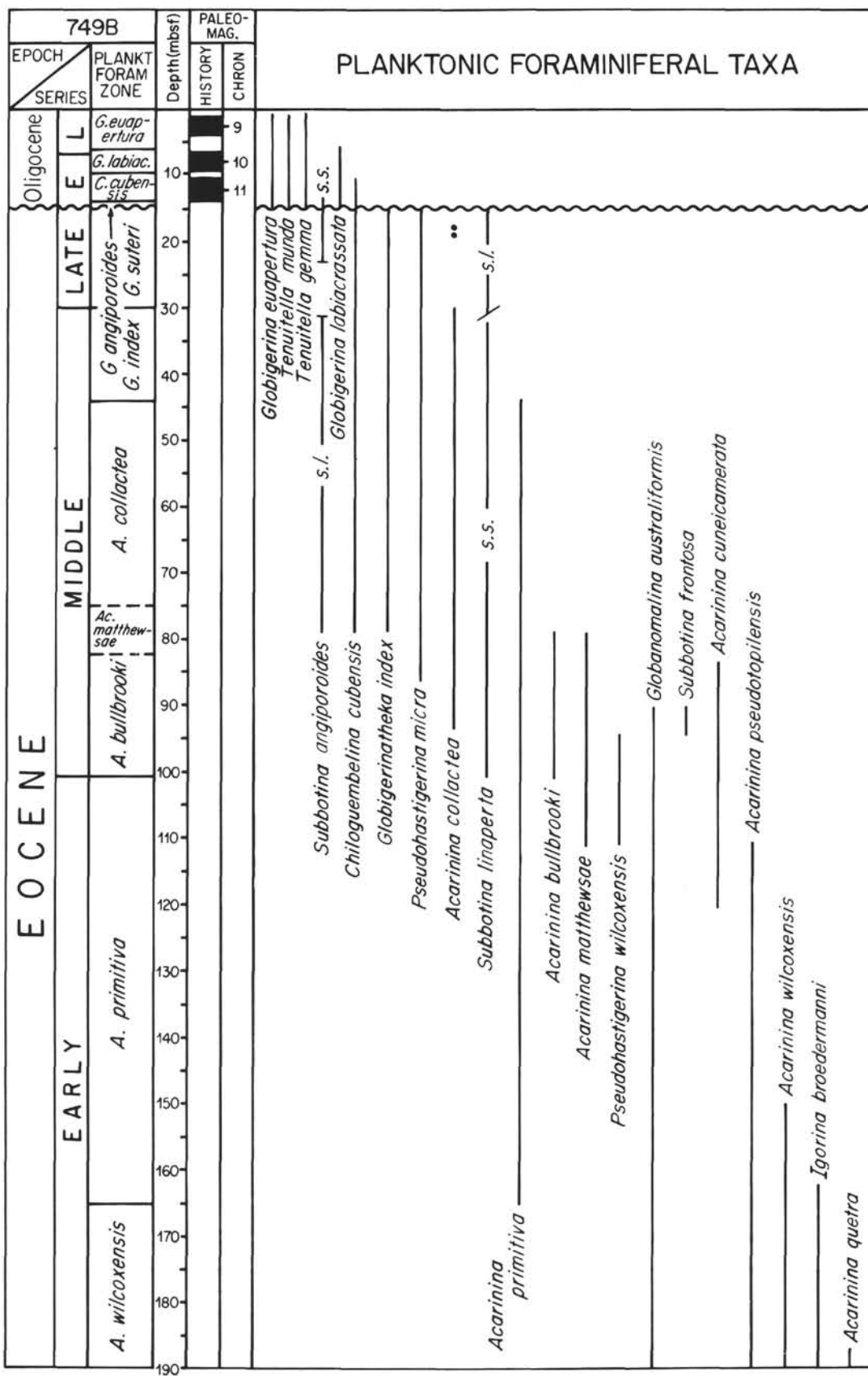


Figure 5. Stratigraphic distribution of some planktonic foraminifers in Hole 749B: Paleogene.

Table 6. Magnetobiostratigraphic calibration of some Paleogene planktonic foraminifer events, Holes 749B and 749C.

Biostratigraphic event	Core, section, interval (cm)	Depth (mbsf)	Paleomagnetic calibration	Remarks
1. LAD <i>Chiloguembelina cubensis</i>	2H-1, 40–44 to 2H-2, 40–44	6.2–7.7	C10N (upper part)	
2. LAD <i>Subbotina angiporoides</i>	2H-5, 40–44 to 2H-6, 40–44	12.2–13.7	C11N (lower part)	
3. LAD <i>Acarinina collactea</i>	4H-3, 40–44 to 4H-4, 40–44	28.2–29.7		Correlated to an interval of uninterpretable paleomagnetic data just above level identified as possibly C17N in Hole 748B.
4. LAD <i>Subbotina linaperta</i> s.s.	4H-5, 40–44 to 4H-7, 40–44	31.2–34.2		Correlated to probably normal polarity interval interpreted as C17N in Hole 748B
5. LAD <i>Acarinina primitiva</i>	5H-CC to 6H-CC	43.8–44.1		Correlated to an interval of uninterpretable paleomagnetic data just above level interpreted (on less reliable data) as possibly C18N in Hole 748B
6. LAD <i>Globanomalina australiformis</i>	10-CC to 11H-1, 40–44	89.0–91.7		

located on the southern edge of the Kerguelen Plateau at 62°S (Huber, 1991).

The *Acarinina bullbrooki* (AP8) Zone extends from about 102 to 80 mbsf and contains a diverse acarininid fauna (*A. bullbrooki*, *A. collactea*, *A. primitiva*, *A. cuneicamerata*, *A. camerata*, and the distinctively angulate, cuneate *A. matthewsae*), together with subbotinids (*S. patagonica*) and the small *G. pseudomenardii* homeomorph, *Globanomalina australiformis*, which has its LAD within this zone. *Pseudohastigerina micra* ranges from at least Sample 120-749B-11X-CC (93.5 mbsf) in the lower part of the *A. bullbrooki* Zone. The larger, somewhat more inflated *P. wilcoxensis* is present in at least Sample 120-749B-13X-1, 40–44 cm (110.7 mbsf) in the upper part of the *A. primitiva* Zone.

The basal 20 m of interbedded chalk and chert belongs to the lower Eocene *Acarinina primitiva* (AP7) Zone. Faunas are similar to those of the overlying *A. bullbrooki* Zone but lack typical *S. linaperta*, *A. bullbrooki*, and *A. collactea*.

Hole 749C

Hole 749C was drilled with the rotary core barrel (RCB) between 102.0 and 249.5 mbsf and ended in basement basalts (below 202 mbsf). Recovery was generally very poor in the interbedded chalk and chert between 102 and 202 mbsf, but a biostratigraphy is possible because of the good state of preservation of the foraminifer faunas.

The upper 20 m recovered in Hole 749B overlaps with the lower 20 m of Hole 749B (upper part of *A. primitiva* [AP7] Zone), but there was no recovery in this interval. Samples from Sections 120-749B-6R-CC (150.0 mbsf) to -7R-CC (164.0 mbsf) belong to the *A. primitiva* Zone as well, attesting to the extensive thickness (~65 m) of this zone at Site 749. The *A. primitiva* Zone is characterized by a diverse acarininid assemblage (*A. pseudotopilensis*, *A. camerata*, *A. soldadoensis*, *A. pentacamerata*, *A. primitiva*, *A. wilcoxensis*, among others) subbotinids (*S. patagonica*, and less commonly, *S. inaequispira*), and *Globanomalina australiformis*. A distinct component of these lower Eocene faunas is the minute, low trochospiral form with asymmetrically placed aperture, *Globanomalina planoconica*. *Igorina broedermanni* occurs sporadically within the lower part of the *A. primitiva* Zone.

The boundary between the *A. primitiva* (AP7) and *A. wilcoxensis* (AP6) zones is within the interval from 164.9 mbsf (Section 120-749C-7R-CC), the lowest sample in which *A. primitiva* occurs, and 169.0 mbsf (Section 120-749C-8R-CC), in which it is absent. Faunal assemblages of the *A. wilcoxensis* Zone contain most of the acarininids of the *A. primitiva* Zone. *Acarinina wilcoxensis* is characterized by its typical morphology, and the distinctively angulate-cuneate *A. quetra* and the large, robust tripartite, strongly muricate *A. coalingensis* are distinctive elements of the *A. wilcoxensis* Zone, as they are of correlative levels in the North Caucasus, that is, the "Zone of conical globorotaliids" (Subbotina, 1953).

The lower/middle Eocene boundary is placed at about 100 mbsf, near the base of the *A. bullbrooki* Zone. Thus, the lower Eocene is seen to be in excess of 100 m thick at Site 749. The abnormally thick section of lower middle and lower Eocene interbedded chert and nannofossil chalk has been ascribed to the action of synsedimentary scouring and redeposition of nannofossil oozes from nearly exposed basement outcrops, resulting in a type of sediment "drift" at this location (Schlich, Wise, et al., 1989).

Magnetobiostratigraphic calibration of several biostratigraphic events in Holes 749B and 749C is shown in Table 6, and the estimated position of several chronostratigraphic boundaries is given in Table 7.

MAGNETOSTRATIGRAPHY

Magnetic polarity chronozones 9 through 11 were identified at Site 749. Two planktonic foraminifer events have been correlated with the magnetostratigraphy (Table 6). An unconformity is inferred to occur at ~15.5 mbsf, which separates upper lower Oligocene from lower upper Eocene chalks. Polarity chronozones 11 is recognized between ~10.3 and 13.7 mbsf and was identified based on the LAD of *S. angiporoides* between 12.2 and 13.7 mbsf, consistent with determinations elsewhere (Berggren et al., 1985, p. 191). Late Eocene elements, including *G. index*, *S. linaperta* s.l., and *Pseudohastigerina micra*, disappear abruptly at 15.7 mbsf at a level where phosphate fragments are common. The age of the base of MPC 11 is estimated at 32.06 Ma (Berggren et al., 1985, p. 146). An age vs. depth plot using the upper and lower age

Table 7. Magnetobiostratigraphic calibration of some chronostratigraphic boundaries at Site 749, Kerguelen Plateau.

Chronostratigraphic boundary	Planktonic foraminifer event	Core, section, interval (cm)	Depth (mbsf)	Paleomagnetic calibration
1. early/late Oligocene (Rupelian/Chattian)	LAD <i>Chiloguembelina cubensis</i>	2H-1, 40-44 to 2H-2, 40-44	6.2-7.7	C10N (upper part)
2. middle/late Eocene (Bartonian/Priabonian)	LAD <i>Subbotina linaperta</i> s.s.	4H-5, 40-44 to 4H-7, 40-44	31.2-34.2	Correlated to probably normal polarity interval interpreted as C17N in Hole 748B
3. early/middle Eocene (Ypresian/Lutetian)	FAD <i>A. bullbrooki</i>	12X-1, 40-44 to 12X-CC	101.2-103.0	

estimate for MPC 11 suggests that the younger age of the unconformity would be slightly more than 32.5 Ma. Calcareous nannoplankton just below the disconformity (top of 120-749B-3H-1) indicate a zonal assignment close to the NP18/NP19 boundary (M.-P. Aubry, pers. comm., 1990), which indicates an age of about 38 Ma (Berggren et al., 1985, p. 162). The hiatus at 15.7 mbsf is estimated to span about 5 m.y.

CHRONOSTRATIGRAPHY

Chronostratigraphy is that part of stratigraphy that deals with the age of rock strata and their temporal relationships. Boundaries between successive chronostratigraphic events are, by definition, synchronous and the rocks formed during successive chronostratigraphic units are isochronous. The definition of chronostratigraphic units and their recognition (i.e., correlative) elsewhere presents distinctly separate and unique problems (see Schoch, 1988, for further discussion). The integrated use of magnetobiostratigraphy provides the most powerful method of long distance chronocorrelation, and I have adapted this methodology in attempting to establish a chronostratigraphic framework for the Kerguelen Plateau Cenozoic record. Where magnetostratigraphy is lacking, I relied on the classical biostratigraphic approach whereby one independent biostratigraphy (planktonic foraminifers) is linked as much as possible to another independent biostratigraphy (calcareous nannoplankton, as a rule), which may, or may not, be linked elsewhere to paleomagnetic stratigraphy.

A Paleogene magnetobiostratigraphic framework has recently been established (Berggren et al., 1985; Aubry et al., 1988), and a revised and updated tropical zonal scheme has been calibrated as much as possible to the Global Polarity Time Scale (GPTS) of Berggren and Miller (1988). More recently, an Austral Paleogene scheme has been developed by Stott and Kennett (1990) and modified, in small part, by Huber (1991), and I have used that scheme in this study.

It should be noted here that the Paleogene planktonic foraminifer record of the Kerguelen Plateau exhibits a pattern of decreasing diversity, particularly from the early middle Eocene on, and a gradual replacement of subtropical faunas in the late Paleocene, early Eocene by temperate elements, starting in the middle Eocene. Despite the difficulties presented by the need for independent biostratigraphies in subtropical and temperate regions during the Paleogene, the occurrences of several biostratigraphic events that denote standard chronostratigraphic boundaries at low latitudes can be shown to occur essentially synchronously at high southern latitudes (Kerguelen Plateau) when calibrated to magnetic polarity stratigraphy. Some of these are discussed below.

Paleocene/Eocene Boundary

The Paleocene/Eocene boundary has been recognized as correlative with the LAD of *Morozovella velascoensis*, which occurs essentially simultaneously with the FAD of *Pseudohasti-*

gerina wilcoxensis at low latitudes (Berggren and Miller, 1988), and is correlated with the middle part of Chron C24R.

The Paleocene/Eocene boundary interval was recovered only at Site 747 and in an extremely condensed, highly bioturbated sequence. The sequential association of *Morozovella acuta*, *M. subbotinae*, *M. marginodentata*, and *M. lensiformis*, and *M. formosa* and the LADs of the benthic foraminifer taxa *Stensioina beccariiiformis*, *Bolivina delicatulus*, *Neoflabellina semireticulata*, *Gavelinella velascoensis*, *Neoeponides hillebrandti*, *Nuttallides florealis*, *Anomalinoidea rubiginosus*, among others, within the lower part of Section 120-747C-2R-4 (see also Mackensen and Berggren, this volume) indicate that the Paleocene/Eocene boundary interval falls at ~174-174.5 mbsf. *Morozovella velascoensis* was not observed at Site 747.

Early/Middle Eocene Boundary

The early/middle Eocene boundary in tropical and subtropical latitudes is denoted by the FAD of *Hantkenina* spp. (Toumarkine and Luterbacher, 1985; Berggren et al., 1985; Berggren and Miller, 1988) and is associated with the top of Chron C22N. However, these forms are not found at Kerguelen Plateau sites (Stott and Kennett, 1990; also, this paper). The early/middle Eocene boundary interval was apparently recovered only at Site 749 in the interval from 90 to 100 mbsf; no magnetic stratigraphy is associated with this level. Placement of the boundary is made on the basis of calcareous nannoplankton biostratigraphy (Aubry, this volume) and would appear to correlate closely with the FAD of *Acarinina densa*.

Middle/Late Eocene Boundary

The biostratigraphic denotation of the middle/late Eocene remains equivocal (Berggren et al., 1985), although it has been approximately associated with the LAD of muricate acarininids (*A. collectea*) and morozovellids (*M. spinulosa*) at low latitudes (Berggren et al., 1985). At Site 748 the LAD of *A. collectea* is associated with an interval of uninterpretable paleomagnetic data and just above an interval identified as possibly C17N.

In Hole 690B, Stott and Kennett (1990) have correlated the LAD of *A. collectea* with Chron C18N2 and the LAD of *Subbotina linaperta* s.s. with the top of Chron C17N1; they equate the middle/late Eocene boundary with this latter event. At Site 748 the LAD of *S. linaperta* s.s. occurs in association with a probable normal polarity interval interpreted here as C17N also, and these records are seen to be consistent. I note, however, the reverse order (although fairly minor in terms of stratigraphic extension) in the LADs of *A. collectea* (later) and *S. linaperta* (earlier) at Sites 748 and 749 on the Kerguelen Plateau, as opposed to those recorded by Stott and Kennett (1990) in the Weddell Sea. Placement of the middle/late Eocene boundary at the LAD of *S. linaperta* s.s. in Holes 748 and 749 facilitates correlation between the Kerguelen Plateau and the Weddell Sea (Hole 689B).

Eocene/Oligocene Boundary

The Eocene/Oligocene boundary interval is generally associated at low latitudes with a number of biostratigraphic events, among others, the LADs of hantkeninids and *Turbotalia cerroazulensis*, associated with the younger part of Chron C13R (Nocchi et al., 1986; Berggren and Miller, 1988). In Austral regions, Jenkins (1971) suggested that the LAD of *Globigerinatheka index* served to approximate the position of the Eocene/Oligocene boundary, although the actual boundary level was, as subsequently recognized by him and most other New Zealand investigators, placed within the brief *Globigerina brevis* Zone, which succeeds the LAD of *G. index* (see, however, a recent synthesis by Edwards et al. (1988) that equates the Eocene/Oligocene boundary of New Zealand with the LAD of *G. index* and the Whangaroan/Runangan Stage boundary).

At Site 748 the Eocene/Oligocene boundary is present in an expanded stratigraphic section; it is delineated by the LAD of *G. index*, which occurs at 121 mbsf and in the upper third of a reversed magnetic interval identified here as C13R. This correlation suggests that the LAD of *G. index* is a globally synchronous event between low (Nocchi et al., 1986) and high (this work) latitudes and is useful in denoting the position of the Eocene/Oligocene boundary.

In the Weddell Sea, Stott and Kennett (1990) record the LAD of *G. index* in Hole 689B at a level identified as C16N (upper part), nearly 2 m.y. older than the age estimated by correlation between the Kerguelen and northern Italian records. However, an alternative interpretation of the paleomagnetic stratigraphy of Hole 689B (Spieß, 1990) suggests that this level may be Chron C15N, in which case the (apparent) temporal latitudinal diachrony of the LAD of *G. index* would be significantly reduced, if not eliminated.

Early/Late Oligocene Boundary

The LAD of biserial chiloguembelinids (*C. cubensis*), associated with Chron C10N, has been suggested as useful in denoting the early/late Oligocene boundary in low and middle latitudes (Berggren et al., 1985). This event occurs at Sites 747 (~160 mbsf) and 749 (~7 mbsf) in association with Chron C10N. At Site 748 it occurs at ~84–85 mbsf at the midpoint of a concatenated Chron C9N and C10N. The usefulness of the LAD of the biserial chiloguembelinids as an (essentially) globally synchronous bioevent would appear to be verified.

Oligocene/Miocene Boundary

The Paleogene/Neogene boundary has been correlated biostratigraphically (FAD *Globorotalia kugleri*) with Chron C6CN2 (Berggren et al., 1985) at low and middle latitudes. Whether this correlation is accurate in terms of present-day boundary stratotype concepts remains controversial; nevertheless, the distinctive signature of Chron C6CN is useful in global correlation, and I have used this level (C6CN2) in determining the Paleogene/Neogene boundary on the Kerguelen Plateau.

At Sites 747 and 748, I have recognized a close association between the LAD of *Globigerina euapertura* and Chron C6CN (occurring near the base of C6CN at Site 747 and near the top of C6CN at Site 748).

SUMMARY

A fairly complete Paleogene stratigraphic record of calcareous oozes and chalks has been recovered at Kerguelen Plateau Sites 747–749. Despite the poor recovery in the upper Paleocene to middle Eocene, and the poor preservation in the upper Paleocene, a biostratigraphic framework for the Ker-

guelen Plateau has been established that essentially mirrors, and extends, the one developed in the Weddell Sea by Stott and Kennett (1990). In conjunction with the good magnetostratigraphic record (magnetic polarity chronozones 6C through 13 have been recognized, and 16–18 are questionable), a bio- and chronostratigraphic framework has been established that will allow precise interregional chronocorrelations (sensu Schoch, 1988, p. 236).

The lower middle Eocene through Oligocene appears to be complete at Site 748, although recovery is poor in the middle Eocene part of the section because of the presence of interbedded chalk and chert. However, the essentially continuous recovery of an approximately 78-m-thick, apparently continuous upper Eocene and Oligocene section with a fairly complete Oligocene magnetostratigraphic record suggests that this site may serve as a standard for delimiting and monitoring late Paleogene oceanographic changes in this region (see Zachos et al., this volume). A complementary upper Paleogene magnetostratigraphic record was retrieved at Site 747, although most of the lower Oligocene is missing because of an unconformity spanning ~4 m.y.. A late Eocene–early Oligocene hiatus, that spans about 5 m.y. occurs at Site 749 as well.

Planktonic foraminifer faunas exhibit a gradual decrease in diversity through the Paleogene, following a brief incursion of tropical-subtropical morozovellids and acarininids near the Paleocene/Eocene boundary (Site 747). A diverse acarininid fauna characterizes early Eocene time, together with pseudohastigerinids and globanomalinids (identified elsewhere as planorotalitids) at Sites 747 and 749.

Middle Eocene faunas are dominated by acarininids, subbotinids, and *Globigerinatheka index*. In the late Eocene, chiloguembelinids achieved numerical dominance and continued to be abundant into the early Oligocene, displaying fluctuating frequencies in the later part of their range.

Planktonic foraminifer faunas exhibited continued reduction in diversity in the early Oligocene, reflecting the cooling trend seen in the oxygen isotope record (Zachos et al., this volume). Subbotinids, globigerinids, and chiloguembelinids were the dominant forms. Diversity decreased further in the late Oligocene, mirroring the increase in biosiliceous (particularly diatoms) forms; faunas were dominated by globigerinids and tenuitellids.

Integration of magnetostratigraphy, Sr isotopes, and the $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ records with the biostratigraphic record of calcareous and siliceous microplankton should provide an integrated magnetobiostratigraphic framework for (at least) part of the Paleogene record of the Kerguelen Plateau, which will allow regional correlations with the southern Kerguelen record of Leg 119 and the Weddell Sea record of Leg 113 (see Berggren et al., this volume).

SPECIES LIST AND TAXONOMIC NOTES

Paleogene taxa identified in this study are listed below. Comments are made on some taxa to record and clarify morphologic features used in identification and to interpret possible phylogenetic relationships and synonymies. Because of restrictions on the number of plates, I have chosen to illustrate taxa of stratigraphic importance or characteristic of particular assemblages. These are illustrated on Plates 1–4.

Chiloguembelina cubensis (Palmer) 1934 (Plate 4, Figs. 9 and 10).

Chiloguembelina midwayensis (Cushman)

Chiloguembelina wilcoxensis (Cushman and Ponton) 1932

Chiloguembelina spp.

Eoglobigerina edita (Subbotina) 1953 (Plate 1, Figs. 5 and 6). This weakly cancellate spinose form is characterized by an elevated spiral side. It is the stem form of the igorinid lineage and ancestral to *I. spiralis* (Bolli).

- Eoglobigerina fringa* (Subbotina) 1953 (Plate 1, Fig. 2). Moderately cancellate, (probably) spinose form that is interpreted as the stem form of the subbotinid (*S. triloculinooides*) group and as a senior synonym of *Eoglobigerina eobulloides* (Morozova) (see also Toumarkine and Luterbacher, 1985, p. 106).
- Eoglobigerina trivialis* (Subbotina) 1953 (Plate 1, Fig. 1). Distinctly cancellate, spinose form; relatively common in Danian faunas on Kerguelen Plateau.
- Globanomalina* spp.
Paleocene to early Eocene trochospiral, microperforate, nonspinose forms have been (re)assigned to *Globanomalina* Haque 1956 by Banner (1989), whereas *Planorotalites* is reserved for early-middle Eocene macroperforate, and distinctly muricate forms typified by *P. pseudoscutula* (Glaessner).
- Globanomalina australiformis* (Jenkins) 1966. This small and distinct form was a characteristic element of early Eocene faunas (although it appeared in the late Paleocene); its LAD appears to occur at a level that, by cross-correlation with calcareous nannoplankton biostratigraphy, closely approximates the early/middle Eocene boundary at Site 749.
- Globanomalina chapmani* (Parr) 1938
- Globanomalina compressa* (Plummer) 1926 (Plate 1, Figs. 14–16)
- Globanomalina planoconica* (Subbotina) 1953
- Globanomalina pseudomenardii* (Bolli) 1957
- Pseudohastigerina micra* (Cole) 1927 (Plate 3, Fig. 16)
- Pseudohastigerina wilcoxensis* (Cushman and Ponton) 1932. The earliest occurrence of this taxon at the Kerguelen Plateau sites is within the lower Eocene *A. primitiva* Zone at a level approximately equivalent to Zone P8, somewhat later than its FAD in Zone P6 in lower latitudes.
- Globoconusa daubjergensis* (Brönnimann), 1953 (Plate 1, Fig. 4)
- Subbotina* spp.
Subbotina is reserved for those forms exhibiting a distinctly cancellate and spinose test. Taxonomy and phylogeny within this group remains controversial and inadequately documented. I have documented here only those forms with relatively distinctive morphologies.
- Subbotina angiporoides* (Hornibrook), 1965 (Plate 4, Figs. 5–8). Typical forms with a strongly cancellate test and bulla-like final chamber are characteristic of late Eocene and early Oligocene assemblages on Kerguelen Plateau. I have not been able to consistently distinguish between *S. angiporoides* and forms referable to *S. utilisindex* (Jenkins and Orr), which was said to differ from *S. angiporoides* in lacking an enveloping final chamber (Jenkins and Orr, 1973: 135). Such differences are considered of degree rather than kind, the two forms have essentially the same (recorded) stratigraphic range, same surficial morphology and texture and are treated as synonymous here. Somewhat smaller, less distinctly cancellate forms of the middle Eocene have been identified as *S. angiporoides minima* Jenkins; they are assigned here to *S. angiporoides* s.l. Forms exhibiting a marked similarity to *S. angiporoides* occurred sporadically in the late Oligocene at Sites 747, 748, and 749 (particularly during the time represented by AC9) and are referred to here as *S. cf. angiporoides* in the range charts that accompany the text. These forms may actually be referable to *Catapsydrax*.
- Subbotina angiporoides* has recently been recorded in lower Oligocene glaciomarine sediments (the so-called *Chlamys*-bearing conglomerate) of the Polonez Cove Formation of King George Island, South Shetland Islands, West Antarctica, at about 61°S Latitude (Gadzicki, 1989).
- Subbotina brevis* (Jenkins) 1966 (Plate 3, Figs. 13–15). This robust, quadrilobate, strongly cancellate, and (apparently) spinose form appears more appropriately placed in *Subbotina* than in *Globigerina* (cf. Jenkins, 1971; Kennett and Stott, 1990). It occurs sporadically in the upper Eocene to lower Oligocene of the Kerguelen Plateau.
- Subbotina eocaena* (Gümbel) 1968 (Plate 3, Fig. 12)
- Subbotina inaequispira* (Subbotina) 1953
- Subbotina linaperta* (Finlay) 1939 (Plate 3, Figs. 1–4). I follow Jenkins (1971) in assigning to *S. linaperta* those forms in which the final chamber is compressed and flattened at the periphery. Forms exhibiting this character disappear abruptly in Kerguelen Plateau sites close to the disappearance of the muricate acarininids (*col- lactea*), that is, near the middle/upper Eocene boundary (see also Stott and Kennett, 1990). In the upper Eocene, forms with rounded terminal chamber(s) occur; these are assigned here to *S. linaperta* s.l. In some cases they are difficult to distinguish from *S. brevis* (Jenkins).
- Subbotina patagonica* (Todd and Kniker) 1952 (Plate 2, Fig. 16). This form is a common to abundant element in early Eocene faunas on the Kerguelen Plateau as it is in Northern Hemisphere middle to high latitudes.
- Subbotina pseudobulloides* (Plummer) 1926 (Plate 1, Figs. 7 and 8). Our studies have revealed that *S. pseudobulloides* is a spinose form, which would appear to eliminate it from direct ancestry to the morozovella lineage (see comments under *Morozovella taurica* (Morozova)).
- Subbotina quadrata* (White) 1928
- Subbotina triangularis* (White) 1928
- Subbotina triloculinooides* (Plummer) 1926
- Subbotina varianta* (Subbotina) 1953 (Plate 1, Fig. 3)
- Subbotina velascoensis* (White) 1928
- Globigerina euapertura* (Jenkins) 1960 (Plate 4, Fig. 16). This form is sporadically distributed in middle to late Oligocene assemblages on the Kerguelen Plateau.
- Globigerina labiacrassata* (Jenkins) 1966 (Plate 4, Figs. 13–15). The highly arched aperture and thick apertural rim are distinct characters of this middle to late Oligocene taxon. A similar form has been observed in lower Miocene assemblages on the Kerguelen Plateau and identified as *G. cf. labiacrassata* (see accompanying paper on the Neogene by Berggren, this volume).
- Globigerina officinalis* (Subbotina) 1953
- Igorina albeari* (Cushman and Bermudez) 1949
- Igorina broedermanni* (Cushman and Bermudez) 1949 (Plate 2, Figs. 11 and 12)
- Igorina convexa* (Subbotina) 1953. This taxon, although rare and sporadic on the Kerguelen Plateau, is characteristic of the early Eocene, as it is in the North Caucasus (Subbotina, 1953).
- Igorina pusilla* (Bolli) 1953
- Acarinina angulosa* (Blow) 1979
- Acarinina appressocamerata* (Blow) 1979
- Acarinina bullbrookii* (Bolli) 1957 (Plate 2, Figs. 9 and 10)
- Acarinina coalingensis* (Cushman and Hanna) 1927 (Plate 2, Fig. 3). This distinctly trilobate, strongly muricate form is restricted to the lower Eocene on the Kerguelen Plateau.
- Acarinina collectea* (Finlay) 1939 (Plate 2, Figs. 13–15). Dominant acarininid in middle Eocene assemblages on the Kerguelen Plateau.
- Acarinina cuneicamerata* (Blow) 1979
- Acarinina matthewsae* (Blow) 1979. There is a wide variety of acarininid morphotypes in late early to early middle Eocene assemblages that are difficult to distinguish consistently. The *A. matthewsae* morphotype is characterized by tangentially elongate chambers, each of which occupies a quadrant of the (essentially) quadrate, tightly coiled test. This morphotype is distributed over a distinct stratigraphic range which corresponds essentially to Zones P10 and P11 of the lower latitudes. As such it is a useful biostratigraphic marker on the Kerguelen Plateau. (See also Huber, 1991).
- Acarinina mckannai* (White) 1928
- Acarinina nitida* (Martin) 1943
- Acarinina pentacamerata* (Subbotina) 1947
- Acarinina primitiva* (Finlay) 1947 (Plate 2, Figs. 4 and 5). I distinguish this form from the similar *A. coalingensis* (see above) on the basis of its quadrate rather than trilobate (*coalingensis*) test. The latter form has a more restricted stratigraphic range. I have not found *A. primitiva* below the Eocene (cf. Jenkins, 1966) on the Kerguelen Plateau. In the middle Eocene, *A. primitiva* and *A. collectea* are the dominant acarininids.
- Acarinina pseudotopilensis* (Subbotina) 1953 (Plate 2, Fig. 2)
- Acarinina soldadoensis* (Brönnimann) 1953. This form has an acme occurrence across the Kerguelen Plateau that may prove to be of biostratigraphic value in regional correlation.
- Acarinina wilcoxensis* (Cushman and Ponton) 1932 (Plate 2, Fig. 1). This form exhibits a wide range of morphologic variability, but it is primarily characterized by a subacute periphery and dorsal (spiral) flattening of the test. It appears near the Paleocene/Eocene

boundary (i.e., in association with the influx of morozovellids of the *A. subbotinae-marginodentata* group).

Morozovella acuta (Toulmin) 1941

Morozovella aequa (Cushman and Renz) 1942

Morozovella formosa (Bolli) 1957

Morozovella marginodentata (Subbotina) 1953

Morozovella lensiformis (Subbotina) 1953

Morozovella aragonensis (Nuttall) 1930

Morozovella tadjikistanensis (Bykova) 1953

Morozovella inconstans (Subbotina) 1953 (Plate 1, Figs. 12 and 13).

Rather common in the Danian of the Kerguelen Plateau, this form would appear to be within the direct ancestral lineage leading to the early (keeled) morozovellids (see remarks under *M. taurica* below).

Morozovella taurica (Morozova, 1961 (Plate 1, Figs. 9–11). *S. pseudobulloides* is a spinose, cancellate form and, as such, probably does not lie in the direct line of ancestry to the nonspinose morozovellids (as typified by *M. velascoensis*). Blow (1979) suggested that the morozovellid lineage may have stemmed from forms he identified as *Globorotalia* (*Turborotalia*) cf. *pseudobulloides* in Zone Pa through *G. (T) pseudoinconstans* Blow in Zone P1. I believe this latter form is a junior synonym of *M. taurica*, a relatively common form, and zonal taxon of the lower Danian in the Crimea. The wall structure of *M. taurica* is currently under investigation.

Paragloborotalia nana (Bolli) 1957

Tenuitella augustumbilicata (Bolli) 1952

Tenuitella gemma (Jenkins) 1966 (Plate 4, Fig. 12)

Tenuitella impariapertura (Li) 1987

Tenuitella insolita (Jenkins) 1966

Tenuitella minutissima (Bolli) 1957

Tenuitella munda (Jenkins) 1966

Tenuitella patefacta (Li) 1987

Globigerinita juvenilis (Bolli) 1957

Catapsydrax dissimilis (Cushman and Bermudez) 1937

Catapsydrax unicavus (Bolli, Loeblich and Tappan) 1957. I have tried to use the criteria of single (*unicavus*) vs. multiple (*dissimilis*) infralaminar accessory aperture(s) in distinguishing these two taxa (see also Kennett and Srinivasan, 1983; cf. Bolli and Saunders, 1985, p. 186, who have recently combined these forms). These forms are illustrated in the accompanying paper on the Neogene (Berggren, this volume).

Globorotaloides suteri (Bolli) 1957

Globorotaloides turgidus (Finlay) 1939

Globigerinatheka index (Finlay) 1939 (Plate 3, Figs 5–11). This strongly muricate and cancellate form is common to abundant in middle to upper Eocene assemblages in the Kerguelen Plateau. The supplementary aperture on the spiral side appears to be a highly variable character, present on some tests (Plate 3, Fig. 6), absent on others (Plate 3, Fig. 7).

Globigerinatheka senni (Beckmann) 1953

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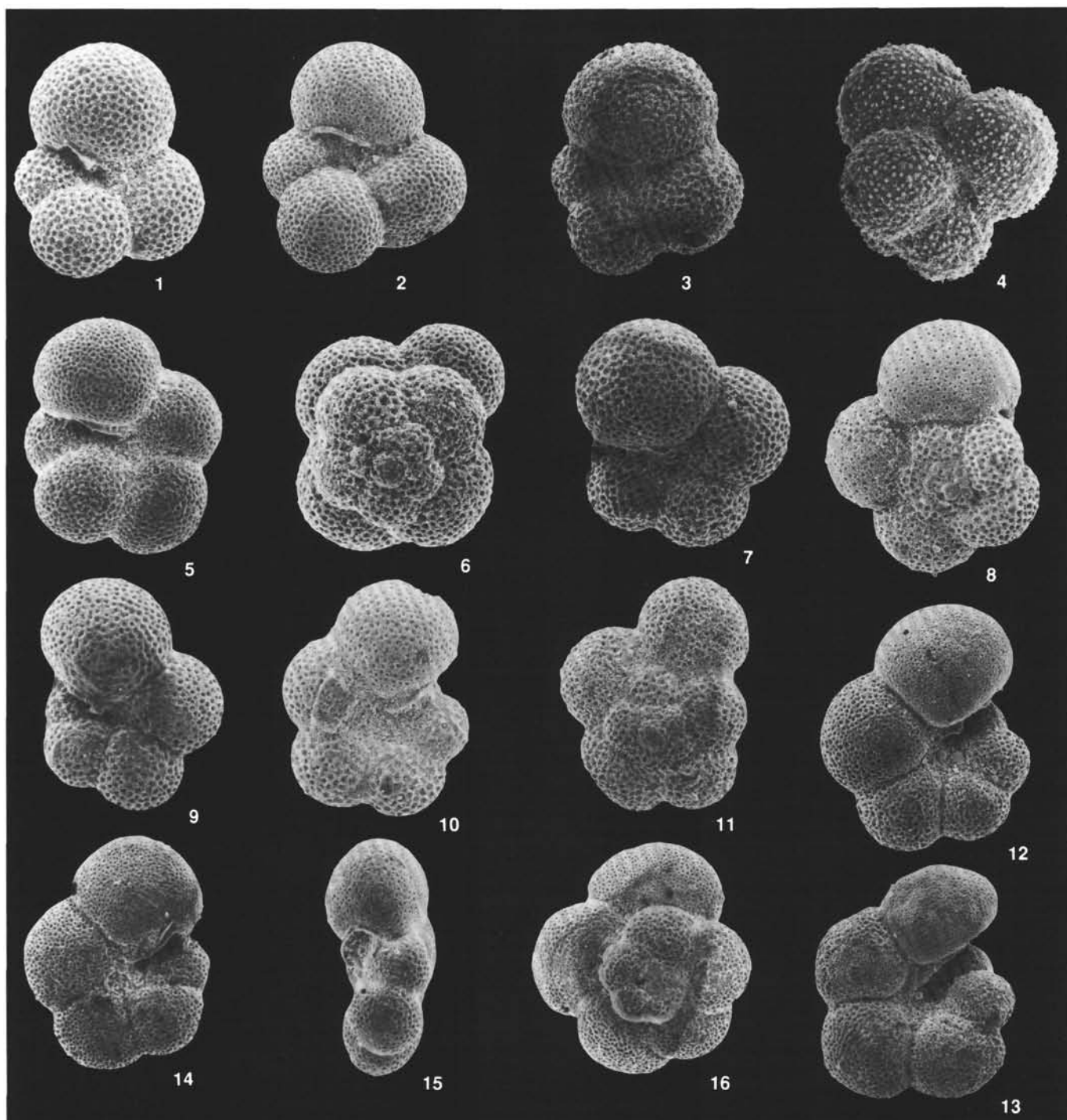


Plate 1. Lower Paleocene (Danian). 1. *Eoglobigerina trivialis* (Subbotina), Sample 120-747A-19H-CC; $\times 175$. 2. *Eoglobigerina fringa* (Subbotina), Sample 120-747C-3H-2, 22–24 cm; $\times 135$. 3. *Subbotina varianta* (Subbotina), Sample 120-747A-19H-CC; $\times 140$. 4. *Globoconusa daubjergensis* (Brönnimann), Sample 120-747A-19H-CC; $\times 185$. 5, 6. *Eoglobigerina edita* (Subbotina), Sample 120-747A-19H-CC; (5) $\times 155$; (6) $\times 185$. 7, 8. *Subbotina pseudobulloides* (Plummer), Sample 120-747A-19H-CC; (7) $\times 185$; (8) $\times 135$. 9–11. *Morozovella taurica* (Morozova), Sample 120-747C-3H-2, 22–24 cm; $\times 155$. 12, 13. *Morozovella inconstans* (Subbotina), Sample 120-747A-19H-CC; (12) $\times 155$; (13) $\times 135$. 14–16. *Globanomalina compressa* (Plummer), Sample 120-747A-19H-CC; (14, 16) $\times 135$; (15) $\times 155$.

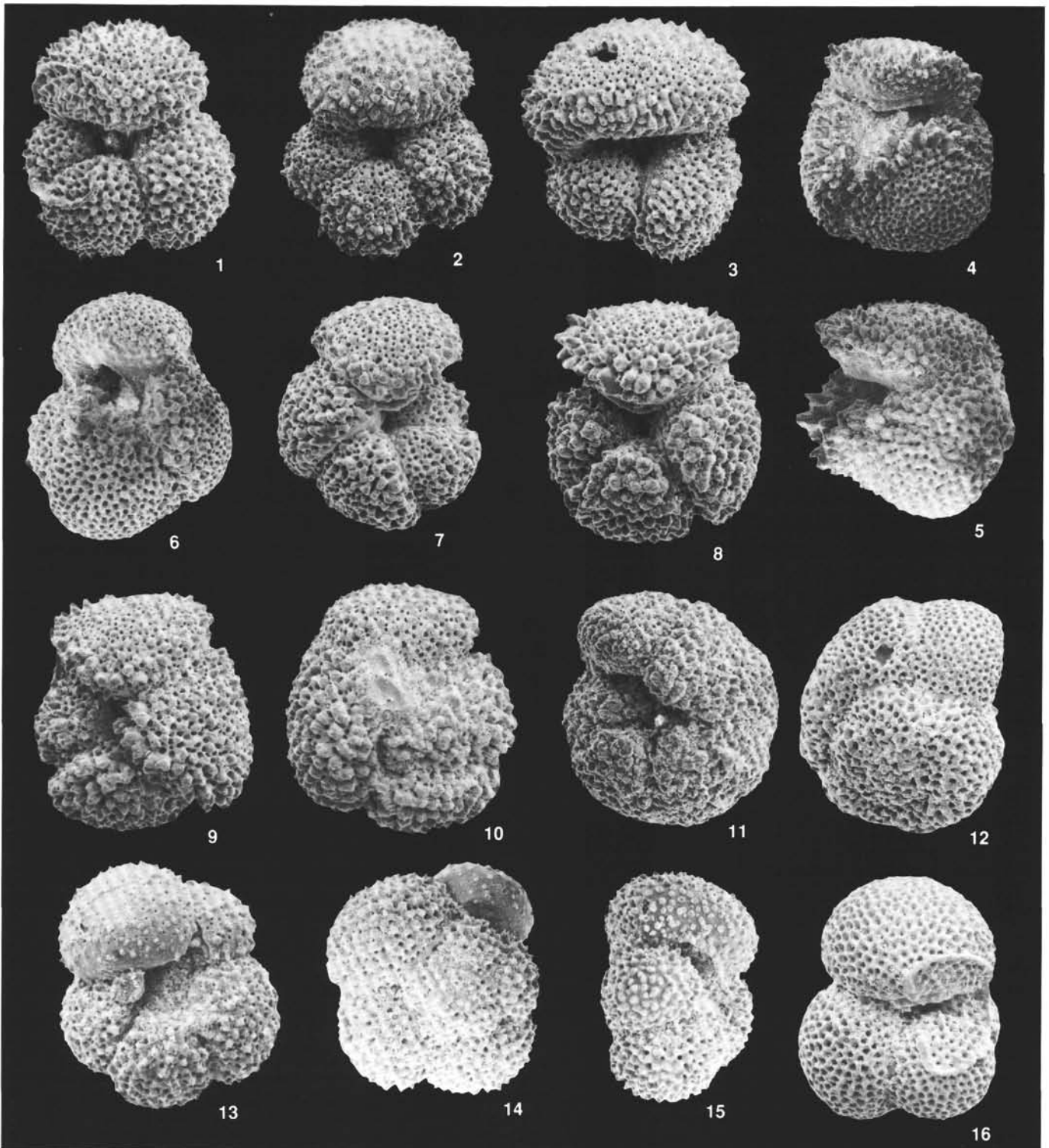


Plate 2. Lower-middle Eocene. 1. *Acarinina wilcoxensis* (Cushman and Ponton), Sample 120-749C-10R-1, 40–44 cm; $\times 60$. 2. *Acarinina pseudotopilensis* (Subbotina), Sample 120-749C-10R-1, 40–44 cm; $\times 100$. 3. *Acarinina coalingensis* (Cushman and Hanna), Sample 120-749C-10R-1, 40–44 cm; $\times 135$. 4, 5. *Acarinina primitiva* (Jenkins), Sample 120-748B-18H-3, 80–84 cm; (4) $\times 100$; (5) $\times 110$. 6. *Acarinina angulosa* (Bolli), Sample 120-748C-10R-1, 19–21 cm; $\times 115$. 7, 8. *Acarinina matthewsae* (Blow), Sample 120-749B-10H-2, 40–44 cm; $\times 115$. 9, 10. *Acarinina bullbrookii* (Bolli), Sample 120-748B-22X-CC, 24–28 cm; $\times 20$. 11, 12. *Igorina broedermanni* (Cushman and Bermudez), Sample 120-749C-10R-1, 40–44 cm; $\times 135$. 13, 14. *Acarinina collactea* (Finlay), Sample 120-748C-10R-1, 19–21 cm; (13) $\times 140$; (14) $\times 115$. 15. *Acarinina collactea* (Finlay), Sample 120-748B-18H-3, 80–84 cm; $\times 155$. 16. *Subbotina patagonica* (Todd and Kniker), Sample 120-748C-10R-1, 17–19 cm; $\times 110$.

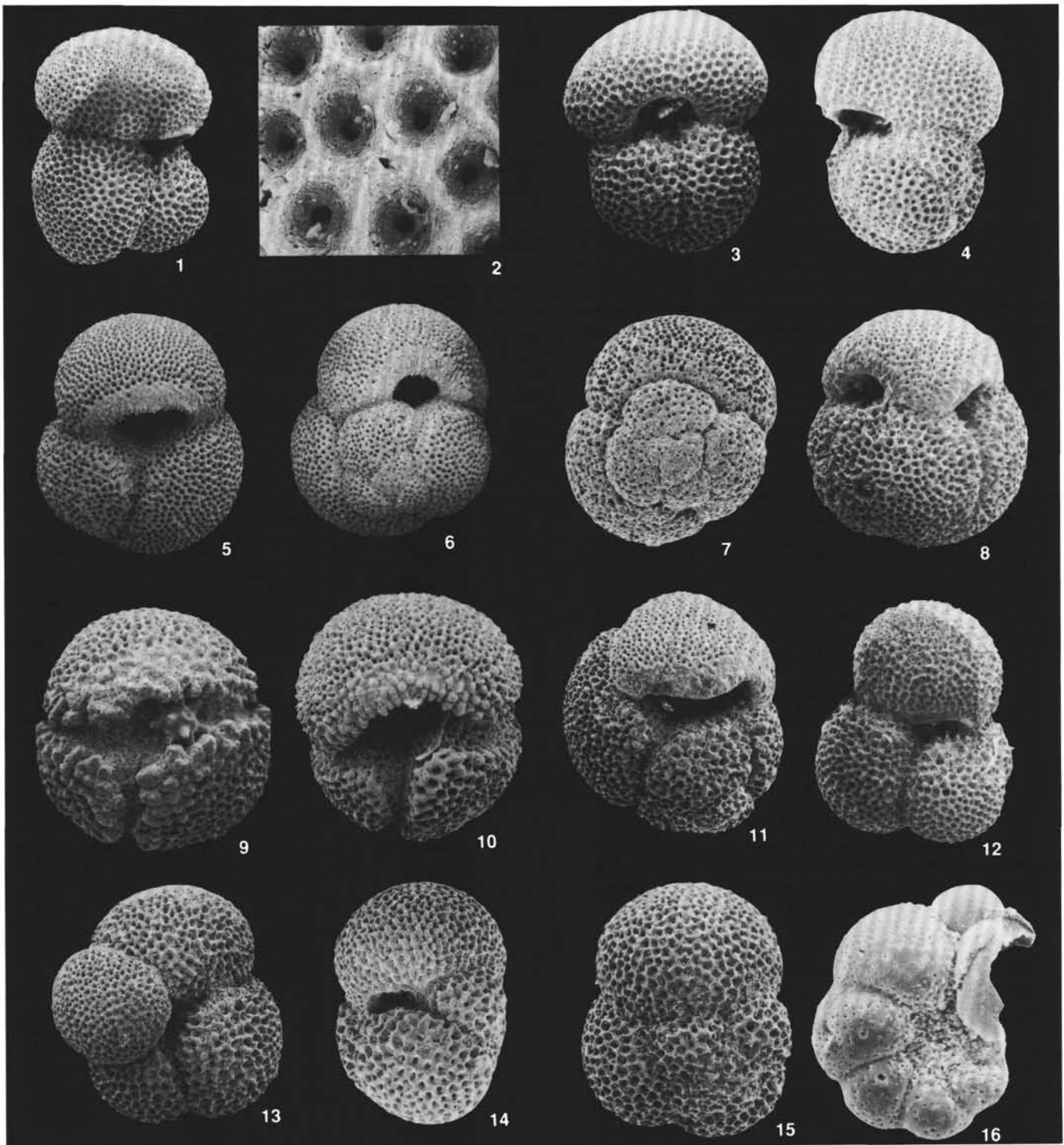


Plate 3. Middle-upper Eocene. 1-4. *Subbotina linaperta* s.s., Sample 120-748B-17H-5, 80-84 cm; (1) $\times 90$; (2) $\times 750$; (3) $\times 105$; (4) $\times 100$; note spine base hole at junction of interpore ridges in Figure 2 (= detail of last chamber of Fig. 1). 5-7. *Globigerinatheka index* (Finlay), Sample 120-748B-15H-4, 40-44 cm; (5, 6) $\times 105$; (7) $\times 125$. 8. *Globigerinatheka index* (Finlay), Sample 120-748B-16H-5, 40-44 cm; $\times 95$. 9-11. *Globigerinatheka index* (Finlay), Sample 120-748B-17H-5, 80-84 cm; (9) $\times 135$; (10, 11) $\times 95$. 12. *Subbotina eocaena* (Gümbel), Sample 120-748B-16H-5, 40-44 cm; $\times 85$. 13-15. *Subbotina brevis* (Jenkins), Sample 120-748B-15H-4, 40-44 cm; (13) $\times 95$; (14) $\times 195$; (15) $\times 140$. 16. *Pseudohastigerina micra* (Cole), Sample 120-748B-15H-4, 40-44 cm; $\times 220$.

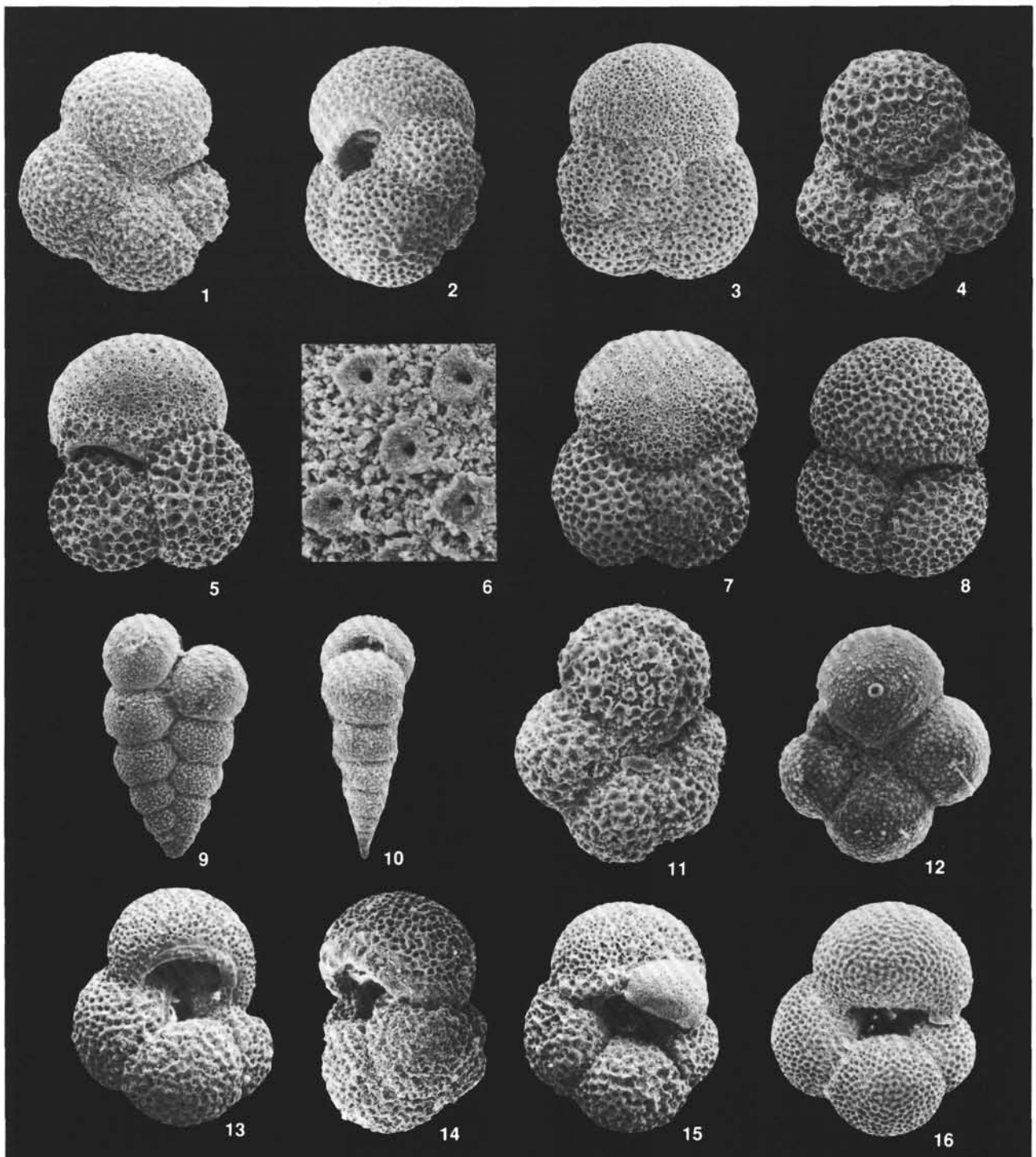


Plate 4. Oligocene. 1-3. *Paragloborotalia nana* (Bolli), Sample 120-748B-16H-5, 40-44 cm; (1, 2) $\times 125$; (3) $\times 135$. 4. *Globorotaloides suteri* (Bolli), Sample 120-748B-15H-4, 40-44 cm; $\times 155$. 5-7. *Subbotina angiporoides* (Finlay), Sample 120-748B-15H-4, 40-44 cm; (5) $\times 115$; (6) $\times 750$; (7) $\times 100$; note the effect of differential dissolution on last chamber. 8. *Subbotina angiporoides* (Finlay), Sample 120-748B-14H-5, 40-44 cm; $\times 110$. 9, 10. *Chiloguembelina cubensis* (Palmer), Sample 120-748B-14H-5, 40-44 cm; (9) $\times 150$; (10) $\times 135$. 11. *Globorotaloides* sp. 1., Sample 120-748B-15H-4, 40-44 cm; $\times 220$; note etching effect of dissolution on test surface. 12. *Tenuitella gemma* (Jenkins), Sample 120-748B-14H-5, 40-44 cm; $\times 210$. 13-15. *Globoturborotalita labiacrassata* (Jenkins), Sample 120-749B-2H-5, 40-44 cm; (13, 15) $\times 90$; (14) $\times 105$. 16. *Globigerina euapertura* (Jenkins). Sample 120-748B-8H-5, 125-129 cm; $\times 90$.