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

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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 chalks. 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 foraminiferal 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 Kehait, 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 magnetostratigraphic record has provided a precise means for correlation between the Kerguelen Plateau and low- to mid-latitude magnetostratigraphies. 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-µm 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-µm size fraction. Relative abundances are recorded on the range charts (Appendix 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 nanofossil chalk. 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.
Table 1. Location data for Leg 120 sites that recovered Paleogene sediments.

<table>
<thead>
<tr>
<th>Site</th>
<th>Latitude (S)</th>
<th>Longitude (E)</th>
<th>Water depth (mbsf)</th>
<th>Remarks on recovery</th>
</tr>
</thead>
<tbody>
<tr>
<td>747</td>
<td>54°48.68'</td>
<td>76°47.64'</td>
<td>1695</td>
<td>Relatively complete Danian, condensed lower Eocene, incomplete upper Eocene and lower Oligocene, essentially complete upper Oligocene.</td>
</tr>
<tr>
<td>748</td>
<td>58°26.45'</td>
<td>78°58.89'</td>
<td>1290</td>
<td>Essential complete sequence from lower part of middle Eocene through upper Oligocene.</td>
</tr>
<tr>
<td>749</td>
<td>58°43.03'</td>
<td>76°24.45'</td>
<td>1069.5</td>
<td>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.</td>
</tr>
<tr>
<td>750</td>
<td>57°35.54'</td>
<td>81°14.42'</td>
<td>2030.5</td>
<td>Relatively thick (~45 m) and complete Danian section and complete upper Paleocene; washed cores in the section above indicate the presence of middle Eocene.</td>
</tr>
</tbody>
</table>

(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.

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

<table>
<thead>
<tr>
<th>Magnetic polarity chronzone</th>
<th>Top depth (mbsf)</th>
<th>Base depth (mbsf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. 6C</td>
<td>X</td>
<td>Hole 747A (63.7)</td>
</tr>
<tr>
<td>2. 7</td>
<td>X</td>
<td>Hole 748B (68.2)</td>
</tr>
<tr>
<td>3. 7A</td>
<td>X</td>
<td>Holes 749A and 749B (3.35)</td>
</tr>
<tr>
<td>4. 8</td>
<td>X</td>
<td>151.70</td>
</tr>
<tr>
<td>5. 9</td>
<td>X</td>
<td>154.60</td>
</tr>
<tr>
<td>6. 10</td>
<td>X</td>
<td>164.65</td>
</tr>
<tr>
<td>7. 11</td>
<td>X</td>
<td>198.9</td>
</tr>
<tr>
<td>8. 12</td>
<td>X</td>
<td>207.0</td>
</tr>
<tr>
<td>9. 13</td>
<td>X</td>
<td>117.4</td>
</tr>
</tbody>
</table>

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.

BIOSSTRATIGRAPHY

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. Acarininids, globigerinathecids, catapsydracids, and subbotinids dominate the faunas, and morozovellids, clavigerinellids, hantkeninids, and other characteristic warm-water elements are notably absent. Subbotinids, catapsydracids, chiloguembelinids, and monospecific globigerinathecids (G. index) dominated late Eocene faunas.

Jaeger (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 circum-Antarctic 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 (API4) Zone. They subdivided Zone API4 into two subzones: API4a = Chilogeumebelia cubensis (the interval between the last appearance datum [LAD] of S. angiporoides and the LAD of C. cubensis); and API4b = 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 (API4) Zone and the addition of two zones to the upper Oligocene zonal format.

**Zone API4a: Chilogeumebelia cubensis Interval Zone (= Subzone API4a 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 API4a.

**Zone API5: Globigerina labiacrassata Interval Zone (= Subzone API4b of Stott and Kennett, 1990)**

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

**Remarks:** This biozone corresponds exactly to Subzone API4b (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 API6: 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. unicaucus group), Globorotaloides suturi, and tenuitellids (T. gemma, T. munda). This zone corresponds, in part, to the Austra 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 Globorotalia dehiscens.

**SITE 747**

Site 747 (proposed site SKP-1) is located in the central part of the Kerguelen Plateau (54°48'68"S, 76°47'65"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 Paleogene at Site 747 is about 34 m thick (~128-mbsf) and consists of calcareous nannofossil and foraminifere 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 volcaniclastic 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 unconformities (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 forma, M. subbotinae, M. marginodentata), acarininids (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 Globigerinatetha index, Subbotina angiporoides, and Chilogeumebelia 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>
<thead>
<tr>
<th>Age in Ma</th>
<th>Age in Ma</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eocene</td>
<td>Oligocene</td>
</tr>
<tr>
<td>Early</td>
<td>Early</td>
</tr>
<tr>
<td>Late</td>
<td>Late</td>
</tr>
<tr>
<td>P1b</td>
<td>P1c</td>
</tr>
<tr>
<td>P1a</td>
<td>P1d</td>
</tr>
<tr>
<td>P2a</td>
<td>P2b</td>
</tr>
<tr>
<td>P3a</td>
<td>P3b</td>
</tr>
<tr>
<td>P4a</td>
<td>P4b</td>
</tr>
<tr>
<td>P5a</td>
<td>P5b</td>
</tr>
<tr>
<td>Depth (mbsf)</td>
<td>Depth (mbsf)</td>
</tr>
</tbody>
</table>

**PLANKTONIC FORAMINIFERAL TAXA**

- *Retortella angustulobilica*
- *Globigerinoides rudolphi*
- *Catapsydrax arctics*
- *Catapsydrax dissimilis*
- *Globigerina cl. labradorica*
- *Globigerina neptuniana*
- *Tuphanella pseudobedria*
- *Tuphanella clementina*
- *Paraglobigerina azam*
- *Globigerinoides juvenilis*
- *Tuphanella macro*
- *Paraglobigerina cl. siamensis*
- *Globigerina pseudolitostorités*
- *Tuphanella gemma*
- *Subbotina o.ng.*
- *Chilostomella culebra*
- *Globigerina brevis*
- *Acarinina mitchelliae*
- *Acarinina primitiva*
- *Globigerinatocum index*
- *Pseudozamia micro*
- *Subbotina exocortex*
- *Subbotina inaperta s.l.*
- *Tuphanella prangemina*
- *Acarinina spp.*
- *Acarinina willcoxiensis*
- *Acarinina angulosa*
- *Subbotina frontosa*
- *Subbotina paragonica*
- *Globanomalina australiformis*
- *Moricovella subbotinae*
- *Subbotina moqui*
- *Azarinae compressidens*
- *Acarinina pseudolitostorités*
- *Acarinina solidospinosa*
- *Acarinina peroakens eraths*
- *Globigerinatocum senii*
- *Moricovella marginidentata*
- *Chilostomella willcoxiensis*
- *Moricovella transvers*
- *Moricovella formas*
- *Moricovella aequa*
- *Subbotina pseudobedria*
- *Subbotina tribuculina*
- *Globanomalina compressa*
- *Eoglabigerina trivialis*
- *Eoglabigerina echobridae*
- *Chilostomella mitoyensis*
- *Glabroconus duaspinifera*
- *Eoglabigerina elata*

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

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

**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 fauna 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 labiocrassata*, catapsydracids (*C. dissimilis*, *C. unicavus*) and *Chilopoguembelina cubensis*. *Subbotina angiporoides* does not occur above the unconformity 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. triloculinaedes*, *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 Oligocene acarininids (predominantly *A. primitiva* and *A. bullbrooki*) 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.
PLANKTONIC FORAMINIFERAL TAXA

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 nannofossil 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). Lower Oligocene faunas are characterized by globigerinids (Globigerina brazieri, G. euapertura, G. labiacrassata), catapsydracids (C. unicavus-dissimilis group, G. suteri) and tenuitellids (Tenuitella gemma, T. mundus, and others) (Fig. 4).

Lower Oligocene faunas contain, in addition to the above elements, Subbotina angiporoides (to Sample 120-748B-
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 approximately 88–89 m thick section extending from Samples 120-748C-17H-1, 80–84 to 120-748C-18H-1, 40–44 cm (-153.5 mbsf); and 120-748C-19H-2, 80–84 cm (-261 mbsf).

Upper Eocene faunas are dominated by Globigerinatheka index with subsidiary numbers of subbotinids (S. eocaena, S. aff. linaperta, S. angiporoides) and catapsydracids (C. unicus vus–dissimilis group and 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. unicus 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 spinodila, 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 chiloguembelids, and rare morozovellids are also distinctive of this interval. A characteristic sequence 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 inaequispina, 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 wilcoxonis, A. pseudotopilensis, A. angulosus, 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. Acaninids (A. soldadoensis, A. acarinate) and subbotinids (S. triangularis, S. velascoensis) characterize the interval above 340 mbsf, whereas Subbotina triloculinoides, I. pusilla, and I. albeari occur below this level. The presence of S. triloculinoides, S. varitata, and small acarinids 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.

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

<table>
<thead>
<tr>
<th>Biostratigraphic event</th>
<th>Core, section, interval (cm)</th>
<th>Depth (mbsf)</th>
<th>Paleomagnetic calibration</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. LAD Globigerina</td>
<td>9H-2, 40–44 to 9H-6, 40–44</td>
<td>63.5–65.0</td>
<td>C6CN</td>
<td>In interval of uninterpretable paleomagnetics data, and just above level identified as possibly C17N (see item 8 below).</td>
</tr>
<tr>
<td>2. LAD Tentaculites</td>
<td>9H-1, 40–44 to 9H-2, 40–44</td>
<td>67.0–68.5</td>
<td>C6CN</td>
<td>Probable normal polarity interval interpreted as C17N on biostratigraphic evidence</td>
</tr>
<tr>
<td>3. LAD Globigerina</td>
<td>10H-4, 40–44 to 10H-5, 40–44</td>
<td>81.0–82.5</td>
<td>C9N</td>
<td>In interval of uninterpretable paleomagnetics data just above level interpreted (on less reliable data) as possibly C18N</td>
</tr>
<tr>
<td>4. LAD Chiloguembelina</td>
<td>10H-6, 34–38 to 10H-CC</td>
<td>midpt of concatenated C9N and C10N</td>
<td>C11N</td>
<td></td>
</tr>
<tr>
<td>5. LAD Subbotina</td>
<td>12H-2, 80–84 to 12H-3, 40–44</td>
<td>97.4–98.5</td>
<td>C13R (upper third)</td>
<td></td>
</tr>
<tr>
<td>6. LAD Globigerinatheka</td>
<td>14H-1, 40–44</td>
<td>120.5–122.4</td>
<td>?C17N</td>
<td></td>
</tr>
<tr>
<td>7. LAD Acarinina</td>
<td>16H-6, 40–44 to 16H-7, 80–84</td>
<td>141.4–142</td>
<td>C12N</td>
<td></td>
</tr>
<tr>
<td>8. LAD Subbotina</td>
<td>17H-1, 80–84 to 17H-2, 80–84</td>
<td>143.4–144.9</td>
<td>C17N</td>
<td></td>
</tr>
<tr>
<td>9. LAD Acarinina</td>
<td>18H-1, 40–44 to 18H-2, 80–84</td>
<td>152.5–154.4</td>
<td>C18N</td>
<td></td>
</tr>
</tbody>
</table>

PLANKTONIC FORAMINIFER MAGNETOBIOS TRATIGRAPHY

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 chronozonal boundaries to magnetostratigraphy is shown in Table 5.
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 (AHC) that was encountered. Coring continued with the extended core barrel (XCB), but with limited success. Hole 749B reached a maximum depth of 202 mbsf. Except for a superficial interval (<0.5 m thick) of Pleistocene-Pliocene foraminiferal and diatomaceous sands and oozes with ice-rafter 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 disconformity 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, 44-44 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 8 m.y. (from >32.5 to 33 Ma to >38 Ma); the basis for this estimate is discussed more fully below under the "Magnetostratigraphy" 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 Chilougelumbelina cubensis (120-749B-2H-2, 40-44 cm; 7.7 mbsf) serves to delineate the upper 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, Chilougelumbelina 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-1H-7, 40-44 cm (34.2 mbsf) — and about 6 m below the LAD of Acarinina collactea — and occurs nearly 20 m below the disconformity (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. collactea, A. matthewseae, A. bulbrookii, 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-4H-1, 40-44 cm, and 120-749B-9X-CC (31.2-78.3 mbsf), individuals are consistently smaller and less markedly cancel late 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. collactea and G. index zones is difficult, as the discussion below will show. The lowest occurrence of Globigerinatheka index (base of the A. collactea Zone) occurs in Sample 120-749B-9X-1, 40-44 cm (72.3 mbsf). It is not present in Sample 120-749B-9X-CC (787 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-6H-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. collactea (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. collactea 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. collactea, Chilougelumbelina cubensis, and S. angiporoides s.l. Faunal assemblages of the A. collactea Zone are essentially the same.

The Acarinina matthewseae (AP9) Zone (as redefined by Huber, 1991) is defined as the biostратigraphic interval between the LAD of A. matthewseae and the FAD of G. index. The latter event occurs in Sample 120-749B-9X-1, 40-44 cm (72.3 mbsf), with an estimated FAD at ~75.3 mbsf, which means that the A. matthewseae (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.
The A. primitive (AP7) 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 distinctive angulate, cuneate A. matthewsae), together with subbotinids (S. patagonica) and the small G. pseudomonardii 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 (101.7 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. primitive, A. wilcoxensis, among others) subbotinids (S. patagonica, and less commonly, S. inaequalispira), and Globanomalina australiformis. A distinct component of these lower Eocene faunas is the minute, low trochospiral form with asymmetrically placed aperture, Globanomalina panoconica. Igorina brodermanni 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. primitive 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. primitive Zone. Acarinina wilcoxensis is characterized by its typical morphology, and the distinctly angulate-cuneate A. quetra and the large, robust tripartite, strongly muricate A. caulifera 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 nanofossil chalk has been ascribed to the action of synsedimentary scouring and redeposition of nanofossil ooze from nearly exposed basement outcrops, resulting in a type of sediment “drift” at this location (Schlich, Wise, et al., 1989).

Magnetobiostatigraphic 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.

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

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

The magnetic polarity chronozones defined in Table 7 extend from about 13.7 to 43.8 mbsf at Site 749. An unconformity is inferred to occur at ~15.5 mbsf, which separates upper lower Oligocene from lower upper Eocene chalks. The polarity chronozones 11 is recognized between ~10.3 and 13.7 mbsf and was identified based on the LAD of S. angigracilis 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.s., 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
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 unconformity (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 adopted this methodology in attempting to establish a chronostratigraphic framework for the Kerguelen Plateau Cenozoic record. Where magnetobiostratigraphy 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 (calcaceous nannoplankton, as a rule), which may, or may not, be linked elsewhere to paleomagnetic stratigraphy.

A Paleogene magnetostratigraphic 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 FAD of *Morozovella velascoensis*, which occurs essentially simultaneously with the FAD of *Pseudohastigerina wilcoxensis* at low latitudes (Berggren and Miller, 1988), and is correlated with the middle part of Chron C24R.

The Paleogene/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 beccariiformis*, *Bolvina delicatulus*, *Neoflabellina semirecuitula*, *Gavelinella velascoensis*, *Neoeponides hillebrandti*, *Nuttallides floreis*, *Anomalinoides rubiginosus*, among others, within the lower part of Section 120-74/7C-2R-4 (see also Mackensen and Berggren, this volume) indicate that the Paleogene/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 acarininds (*A. collactea*) and morozovelliids (*M. spinulosa*) at low latitudes (Berggren et al., 1985). At Site 748 the LAD of *A. collactea* is associated with an interval of uninterpretable paleomagnetic data and just above an interval identified as possibly C17N.

In Hole 698B, Stott and Kennett (1990) have correlated the LAD of *A. collactea* 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. collactea* (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 698B).

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

<table>
<thead>
<tr>
<th>Chronostratigraphic boundary</th>
<th>Planktonic foraminifer event</th>
<th>Core, section, interval (cm)</th>
<th>Depth (mbsf)</th>
<th>Paleomagnetic calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. early/late Oligocene (Rupelian/Chattian)</td>
<td>LAD Chilostomella cubensis</td>
<td>2H-1, 40-44 to 2H-2, 40-44</td>
<td>6.2-7.7</td>
<td>Correlated to probably normal polarity interval interpreted as C17N in Hole 748B</td>
</tr>
<tr>
<td>2. middle/late Eocene (Barremian/Paleocene)</td>
<td>LAD Subbotina linaperta s.s.</td>
<td>4H-5, 40-44 to 4H-7, 40-44</td>
<td>31.2-34.2</td>
<td>C18N (upper part)</td>
</tr>
<tr>
<td>3. early/middle Eocene (Ypresian/Lutetian)</td>
<td>FAD A. bullbrooki</td>
<td>12X-1, 40-44 to 12X-CC</td>
<td>101.2-103.0</td>
<td></td>
</tr>
</tbody>
</table>

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**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 *Turborotala 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 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 Whanganoo/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 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.

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**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. However, 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 Kerguelen 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, approximately 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 increase of global-subtropical planktonic foraminiferal faunas in 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 biosilicic (particularly diatoms) forms; faunas were dominated by globigerinids and tenuitellids.

Integration of magnetostratigraphy, Sr isotope, and the δ13C and δ18O records with the biostratigraphic record of calcareous and siliceous microplankton should provide an integrated magnetostratigraphic 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) 1932

*Chiloguembelina wilcoxensis* (Cushman) 1932

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

*Chiloguembelina midwayensis* (Cushman) 1932

*Chiloguembelina wilcoxensis* (Cushman and Ponton) 1932

*Chiloguembelina spp.*

*Eoglobigerina eummarginata* (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).
Eoglabigerina fringa (Subbotina) 1953 (Plate 1, Fig. 2). Moderately crenulate, (probably) spinose form that is interpreted as the stem form of the subbotinid (S. triloculinoides) group and as a senior synonym of Eoglabigerina eobulloides (Morozova) (see also Tompkins and Luterbacher, 1985, p. 106).

Subbotina inaequispira (Subbotina) 1953 (Plate 1, Fig. 1). Distinctly crenulate, spinose form; relatively common in Danian faunas on Kerguelen Plateau.

Globoanomalina spp.

Paleocene to early Eocene trochospiral, microperforate, nonspinose forms have been reassigned to Globoanomalina Haque 1956 by Bardseth (1998), whereas Planorotaliids are reserved for early-middle Eocene macroperforate, and distinctly muricate forms typified by P. pseudoscutula (Glaessner).

Globoanomalina 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 nanofossil biostratigraphy, closely approximates the early/middle Eocene boundary at Site 749.

Globoanomalina chapmani (Parr) 1938

Globoanomalina compressa (Plummer) 1926 (Plate 1, Figs. 14–16)

Globoanomalina planispiratica (Subbotina) 1953

Globoanomalina pseudomuriformis (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 site 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 daubjer根基 (Brönnimann), 1953 (Plate 1, Fig. 4)

Subbotina spp.

Subbotina is reserved for those forms exhibiting a distinctly crenulate and spinose test. Taxonomy and phylogeny within this group remains controversial and inadequately documented. I have documented here only those forms with relatively distinct morphologies.

Subbotina angiporoides (Horibooko), 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 a 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 textural differences and have a synonymous form. 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 here as S. cf. angiporoides in the range charts that accompany the test. 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, quadriborate, strongly cancellate, and (apparently) spinose form appears more appropriately placed in Subbotina than in Globigerina (cf. Jenkins, 1966; Kent; 1973). It occurs sporadically in the upper Eocene to lower Oligocene of the Kerguelen Plateau.

Subbotina eocaena (Günbel) 1968 (Plate 3, Fig. 12)

Subbotina inequiquina (Subbotina) 1953

Subbotina linaperta (Finlay) 1939 (Plate 3, Figs. 1–4). I follow Jenkins (1966) in referring S. linaperta to an inarticulate form 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-

laceae), 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 morozovellid lineage (see comments under Morozovella taurica (Morozova).

Subbotina quadrata (White) 1928

Subbotina triangulata (White) 1928

Subbotina triloculinoides (Plummer) 1926

Subbotina varians (Subbotina) 1953 (Plate 1, Fig. 3)

Subbotina velascoensis (White) 1928

Globigerina eocaena (Subbotina) 1953 (Plate 2, Fig. 2). This form has a more restricted stratigraphic range. I have not found a similar acarininid in middle Eocene assemblages on the Kerguelen Plateau.

Globigerina labracrassata (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. labracrassata (see accompanying paper on the Neogene by Berggren, this volume).

Globigerina officinalis (Subbotina) 1953

Igorina albeeri (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 appressocomaculata (Blow) 1979

Acarinina bulbochilis (Bolli) 1957 (Plate 2, Figs. 9 and 10)

Acarinina coalingensis (Cushman and Hanna) 1927 (Plate 2, Fig. 3).

This distinctly triborate, strongly muricate form is restricted to the lower Eocene on the Kerguelen Plateau.

Acarinina collactea (Finlay) 1939 (Plate 2, Figs. 13–15). Dominant acarininid in middle Eocene assemblages on the Kerguelen Plateau.

Acarinina conicamerata (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 meckanni (White) 1928

Acarinina nilida (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 triborate (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. collactea 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. subbotiniae-marginalinata group).

Morozovella acuta (Toulinon) 1941
Morozovella aqua (Bolli and Renz) 1942
Morozovella formosa (Bolli) 1957
Morozovella marginidonta (Subbotina) 1953
Morozovella lentiformis (Subbotina) 1953
Morozovella argonensis (Nuttall) 1930
Morozovella tadzikistanensis (Bykova) 1953

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

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 Fl. 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 augustiimbiculata (Bolli) 1952
Tenuitella gemma (Jenkins) 1966 (Plate 4, Fig. 12)
Tenuitella impatiens (Li) 1987
Tenuitella insolita (Jenkins) 1966
Tenuitella minutissima (Bolli) 1957
Tenuitella munda (Jenkins) 1966
Tenuitella paeuca (Li) 1987
Globigerinella juvetina (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 Kennedy and Shinava, 1983; cf. Bolli and Saunders, 1975, 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 turridus (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 semni (Beckmann) 1953

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Plate 2. Lower-middle Eocene. 1. *Acarinina wilcoxensis* (Cushman and Ponton), Sample 120-749C-10R-1, 40–44 cm; ×60. 2. *Acarinina pseudotopilensis* (Subbotina), Sample 120-749C-10R-1, 40–44 cm; ×100. 3. *Acarinina coalingensis* (Cushman and Hanna), Sample 120-749C-10R-1, 40–44 cm; ×135. 4, 5. *Acarinina primitiva* (Jenkins), Sample 120-748B-18H-3, 80–84 cm; (4) ×100; (5) ×110. 6. *Acarinina angulosa* (Bolli), Sample 120-748C-10R-1, 19–21 cm; ×115. 7, 8. *Acarinina mathewsonae* (Blow), Sample 120-749B-10H-2, 40–44 cm; ×115. 9, 10. *Acarinina bullbrooki* (Bolli), Sample 120-748B-22X-CC, 24–28 cm; ×20. 11, 12. *Igorina broedermanni* (Cushman and Bermudez), Sample 120-749C-10R-1, 40–44 cm; ×135. 13, 14. *Acarinina collactea* (Finlay), Sample 120-748C-10R-1, 19–21 cm; (13) ×140; (14) ×115. 15. *Acarinina collactea* (Finlay), Sample 120-748B-18H-3, 80–84 cm; ×155. 16. *Subbotina patagonica* (Todd and Kniker), Sample 120-748C-10R-1, 17–19 cm; ×110.
Plate 3. Middle-upper Eocene. 1-4. Subbotina linaperta s.s., Sample 120-748B-17H-5, 80–84 cm; (1) ×90; (2) ×750; (3) ×105; (4) ×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) ×105; (7) ×125. 8. Globigerinatheka index (Finlay), Sample 120-748B-16H-5, 40–44 cm; ×95. 9-11. Globigerinatheka index (Finlay), Sample 120-748B-17H-5, 80–84 cm; (9) ×135; (10, 11) ×95. 12. Subbotina eocaena (Gäumbei), Sample 120-748B-16H-5, 40–44 cm; ×85. 13-15. Subbotina brevis (Jenkins), Sample 120-748B-15H-4, 40–44 cm; (13) ×95; (14) ×195; (15) ×140. 16. Pseudohastigerina micro (Cole), Sample 120-748B-15H-44, 40–44 cm; ×220.
Plate 4. Oligocene. 1–3. Paragloborotalia nana (Bolli), Sample 120-748B-16H-5, 40–44 cm; (1, 2) ×125; (3) ×135. 4. Globorotaloides suteri (Bolli), Sample 120-748B-15H-4, 40–44 cm; ×155. 5–7. Subbotina angiporoides (Finlay), Sample 120-748B-15H-4, 40–44 cm; (5) ×115; (6) ×750; (7) ×100; note the effect of differential dissolution on last chamber. 8. Subbotina angiporoides (Finlay), Sample 120-748B-14H-5, 40–44 cm; ×110. 9, 10. Chiloguembelina cubensis (Palmer), Sample 120-748B-14H-5, 40–44 cm; (9) ×150; (10) ×135. 11. Globorotaloides sp. 1., Sample 120-748B-15H-4, 40–44 cm; ×220; note etching effect of dissolution on test surface. 12. Tenuitella gemma (Jenkins), Sample 120-748B-14H-5, 40–44 cm; ×210. 13–15. Globoturborotalita labiocrassata (Jenkins), Sample 120-749B-2H-5, 40–44 cm; (13, 15) ×90; (14) ×105. 16. Globigerina euapertura (Jenkins), Sample 120-748B-8H-5, 125–129 cm; ×90.