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19. PALEOGENE PLANKTONIC FORAMINIFER BIOSTRATIGRAPHY AND PALEOENVIRONMENTAL REMARKS ON PALEOGENE SEDIMENTS FROM INDIAN OCEAN SITES, LEG 115[1]

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ABSTRACT

We drilled 13 holes on Ocean Drilling Program Leg 115 in the Indian Ocean and recovered Paleogene sediments that consisted primarily of pelagic components. Planktonic foraminifer assemblages displayed high diversity throughout the Paleogene from the late Paleocene to the Oligocene/Miocene boundary and consist of predominantly warm-water species. Faunas of middle Eocene age are remarkably well represented. Biostratigraphic assignment was, however, very difficult because of the turbiditic character of most of the Paleogene sediments. Reworking is a constant feature of the middle Eocene through early Oligocene planktonic faunas, with reworked faunas frequently overwhelming the younger ones. Preservation within turbidites ranges from excellent to very poor to total destruction of planktonic foraminifers.

A major dissolution episode is recorded in the interval that spans most of the late Eocene through the early Oligocene, especially at the deeper sites where the source area was probably well below the lysocline. Redeposition decreases markedly by the mid-Oligocene, but it is only by late Oligocene Zone P22 that normal sedimentation resumes and/or redeposition decreases even at the most affected sites (such as Hole 709C). Comparison with other sites drilled previously in the Indian Ocean reveals that mixed assemblages were already known for sediments from the Mascarene Plateau–Seychelles Bank and surrounding basins during that time span. Because of the disturbances that characterize Paleogene deposits, hiatuses are difficult to detect; nevertheless, a hiatus of less local importance, spanning Subzone P21b, was detected in three holes at different water depths.

INTRODUCTION

In this paper, we study planktonic foraminifers of Paleogene age recovered at 9 sites (706 through 714) and 13 holes drilled in the Indian Ocean during Ocean Drilling Program (ODP) Leg 115. As shown in Figure 1, a first set of sites (Sites 706–711) was drilled along an ideal north-south transect from the flank of the Nazareth Bank through the Madingley Rise to the abyssal plain north of the rise (see Table 1 for coordinates of sites and holes). A second set of sites (Sites 712–714) was drilled on the Chagos and Maldive ridges farther to the east and more northward close to the Maldives Islands (Fig. 1). A fourteenth hole (Hole 715A) recovered the transition from carbonate platform to pelagic facies of late early Eocene age; these data are reported in Nicora and Premoli Silva (this volume). The oldest sediments recovered during Leg 115 are aged to the late Paleocene (Hole 707C), but in most of the drill holes Paleogene sediments recovered were younger than the early to middle Eocene boundary.

In the Indian Ocean, Paleogene sediments were previously recovered from seven sites close to the latter locations during Leg 23A (Fleisher, 1974, described the planktonic foraminifer content in these sites) or from sites close to the Mascarene Plateau or generally located in the western Indian Ocean (Legs 24 and 25) (Fisher, Bunce, et al., 1974; Heiman et al., 1974; Sigal, 1974; Whitmarsh, Weser, et al., 1974). A summary of the biostratigraphic data obtained was reported by Fleisher (1977) and McGowran (1977), and a correlation with the previous sites is reported below.

METHODS

The present study is based, for the most part, on one sample per section. In a few cases, two samples per section were analyzed or, on the contrary, one sample per core, especially in the most dissolved sequences. Only a few core-catcher samples were included in this study. Sample volume was about 10 cm^3. In case some specimens proved to be suitable for isotope analyses, all samples were soaked only in water. Very rarely were samples soaked in a solution of 5% hydrogen peroxide. All samples were washed through >40-μm, >150-μm, and >250-μm sieves, and the three washed residues obtained were dried on a hot plate at 50°C. Each sample was dried and weighed before washing, as were as the three washed fractions. The latter operation was carried out for the purpose of quantitative analyses of total fossil components and, in the case of resedimented and/or dissolved assemblages, to prove sorting and/or degree of dissolution, respectively (Premoli Silva and Violanti, 1981). Abundances of single species, groups of species, and other components over total faunal content were estimated for each of the three fractions when possible. Eight categories are distinguished and plotted in the range charts. They are VR = a single specimen, R = rare (2–3 specimens), VF = very few (5–6 specimens), F = few (<10 specimens), C = common (10–30 specimens), A = abundant (more than 30%), VA = dominant, and X = simple occurrence when estimate was prevented.

Residue abundance and planktonic foraminifer preservation was graded with the following scale: 1 = very abundant, very good preservation; 2 = medium abundant, good preservation; 3 = medium scarce, medium preservation; 4 = scarce, poor preservation; and 5 = very scarce, very poor preservation.

PLANKTONIC FORAMINIFER BIOSTRATIGRAPHY

Preliminary biostratigraphic data from each Indian Ocean site are included in the *Proceedings of the Ocean Drilling Program, Initial Reports,* of Leg 115 (Backman, Duncan, et al., 1988). This chapter mainly deals with the major characteristics of planktonic foraminifer assemblages, their stratigraphic distribution, and the intensity of dissolution and/or displacement at each site.

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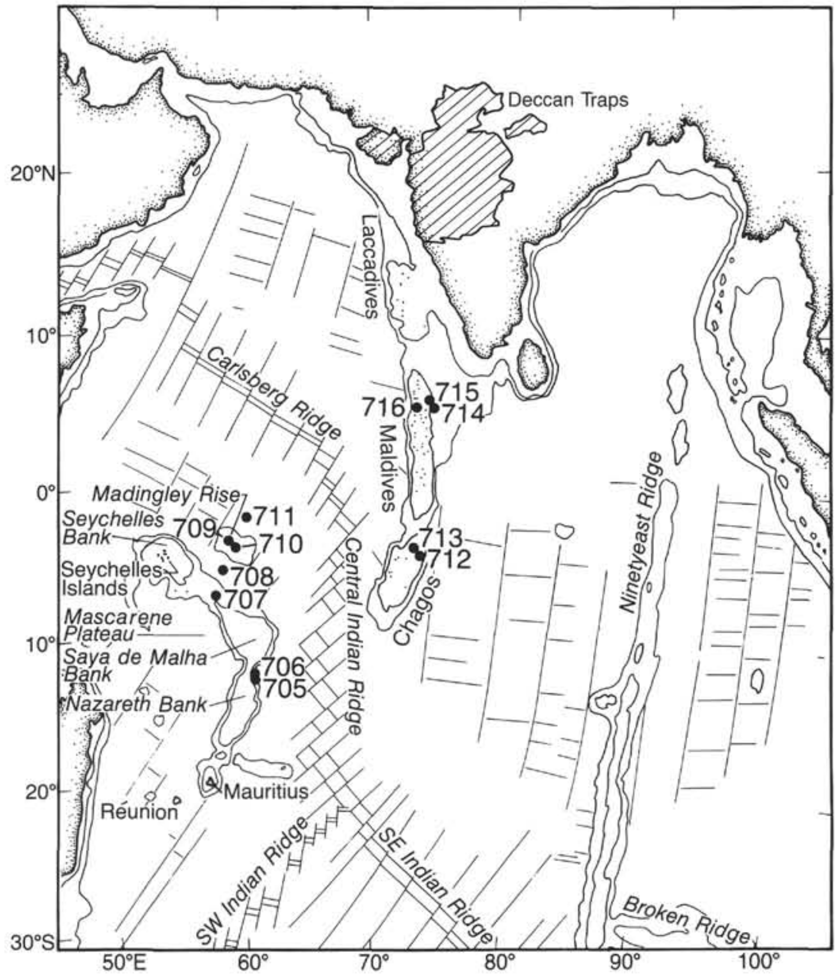

Figure 1. Location map for Leg 115 in the Indian Ocean.

Detailed study of planktonic foraminifer faunas revealed that most of the Eocene sediments were resedimented and planktonic faunas were largely affected by reworking. Preservation of planktonic foraminifers is very uneven from layer to layer and within the same residue, where the same taxon may be represented by well-preserved specimens or by minute fragments only. The amount of residue as well as the faunal components also change noticeably from layer to layer. These characteristics are further corroborated by mixing of benthic assemblages from different depth environments, which can range from outer shelf to abyssal and, more rarely, also from the shelf area.

Oligocene sediments are apparently less affected by such phenomena, at least at some sites, whereas in others displacement and reworking continued throughout. A typical case is represented by Hole 711A, where abyssal benthic foraminifers occur together with a large number of solution-susceptible planktonic and outer-shelf benthic foraminifers (see below). In such conditions, we had to rely on first evolutionary occurrences of taxa for biostratigraphic assignments rather than on extinction events. Moreover, heavy reworking also prevented a reliable reconstruction of distribution charts of planktonic foraminifer faunas from all the Eocene and some Oligocene sequences. Therefore, routine range charts have been replaced by synthetic logs for each site in which the most reliable biostratigraphic events, plotted vs. sub-bottom depths and recovery, were used for identifying the standard zones. Because planktonic foraminifer faunas from Indian Ocean sites are rich in tropical warm-water species, the low-latitude standard zonal schemes of Blow (1969), Berggren et al. (1985), and Toumarkine and Luterbacher (1985) apply to these sites.

The major events used for identifying the zonal boundaries or zones are (from old to young):

1. The co-occurrence of *Morozovella velascoensis, M. edgari, M. pasionensis,* and *M. gracilis,* equated to Zone P6a, latest Paleocene.
2. The first occurrence (FO) of *Morozovella aragonensis, M. formosa, Acarinina pentacamerata,* and "*Globigerinatheka*" *senni,* equated to Zone P7, early Eocene.
3. The FO of *Acarinina acceleratoria, Acarinina bullbrooki, Acarinina pseudotopilensis,* and *Morozovella caucasica,* equated to Zone P8, middle early Eocene.
4. The FO of *Planorotalites palmeri, Subbotina crociapertura, Turborotalia frontosa, Pseudohastigerina danvillensis,* and "*Turborotalia*" *griffinae,* equated to Zone P9, late early Eocene.
5. The FO of *Globigerinatheka subconglobata, Turborotalia possagnoensis,* and *Globorotaloides carcosellensis* along with *Hantkenina* spp., equated to Zone P11, early middle Eocene.
6. The FO of *Globigerinatheka index, Globigerinatheka rubriformis, Morozovella lehneri,* and *Subbotina angiporoides* gr., equated to late Zone P11, early middle Eocene.

Table 1. Geographic coordinates, water depth, and depth penetration of drill holes that recovered Paleogene sediments during Leg 115.

Hole	Coordinates	Water depth (m)	Penetration (m)
706A	13°06.85′S 61°22.26′E	25,043	475
706B	13°06.86′S 61°22.26′E	25,078	437
707A	07°32.72′S 59°01.01′E	15,523	2,133
707C	07°32.72′S 59°01.01′E	15,523	4,432
708A	05°27.35′S 59°56.62′E	41,093	2,362
709A	03°54.90′S 60°33.10′E	30,408	2,031
709B	03°54.90′S 60°33.10′E	30,408	2,548
709C	03°54.90′S 60°33.10′E	30,408	3,537
710A	04°18.70′S 60°58.80′E	38,243	2,097
711A	02°44.56′S 61°09.78′E	44,298	2,496
712A	04°12.99′S 73°24.38′E	29,043	1,153
713A	04°11.58′S 73°23.65′E	29,153	1,917
714A	05°03.60′N 73°47.20′E	20,383	2,330
715A	05°04.89′N 73°49.88′E	22,663	2,878

7. The FO of *Turborotalia pomeroli, Hantkenina alabamensis, Globorotaloides suteri,* and *Acarinina medizzai,* equated to Zone P12, middle middle Eocene.

8. The FO of *Globigerinatheka euganea, Globigerinatheka luterbacheri,* and the *Turborotalia possagnoensis/T. cerroazulensis* transition, equated to late Zone P12/Zone P13, late middle Eocene.

9. The FO of *Globigerinatheka tropicalis, Turborotalia cerroazulensis, Pseudohastigerina barbadoensis, Pseudohastigerina naguewichiensis, Subbotina praeturritillina, Tenuitella gemma,* and *Dentoglobigerina* sp. aff. *D. larmeui,* equated to Zone P14, late middle Eocene.

10. The FO of *Globigerinatheka semiinvoluta, Subbotina linaperta* s. str., *Turborotalia cocoaensis, Dentoglobigerina galavisi,* and the *Turborotalia pomeroli/Turborotalia pseudoampliapertura* transition, equated to Zone P15, late Eocene.

11. The FO of inflated *Hantkenina alabamensis, Globoquadrina tripartita,* and *Turborotalia pseudoampliapertura,* possibly indicating Zones P16/P17, late Eocene.

12. The FO of "*Globoquadrina*" *tapuriensis, Cassigerinella chipolensis,* "*Tenuitella* "*angustiumbilicata, Globigerina officinalis,* and *Globoquadrina rohri,* equated to Zone P18, early Oligocene.

13. The FO of *Cassigerinella globulosa, Dentoglobigerina baroemoenensis, Globoquadrina sellii,* and *Cassigerinella martinezpicoi,* equated to Zone P19, early Oligocene.

In the remaining Oligocene interval, beside the FO and LO of index species, on which the standard zonal scheme is based, the following events may be of some use in zonal assignment (from old to young) (see Fig. 2):

1. The FO of the "*Globigerina*" *ciperoensis*/"*Globigerina*" *anguliofficinalis* transition close to the base of Zone P21a, late Oligocene.

2. The successive FOs of the genus *Protentella* and *Paragloborotalia semivera,* "*G.*" *anguliofficinalis, Paragloborotalia siakensis* (>150 /m), *Globigerinita juvenilis,* "*Globigerina*" *angulisuturalis,* and the *Dentoglobigerina globularis/Dentoglobigerina altispira globosa* transition, which characterize the middle to late Zone P21a, late Oligocene.

3. An increase in abundance of large (>150 /m) *Cassigerinella* spp. at the top of Zone 21a.

4. The FO of *Globigerinoides primordius* and "*Globigerina*" *woodi* s. str., which marks the base of Zone P22.

5. A new acme of large (>150 /m) *Cassigerinella* spp. in the middle of Zone P22.

6. The successive Fos of *Globoquadrina binaiensis,* "*Globorotalia*" *pseudokugleri, Globorotaloides* sp. 2, the *Globoquadrina praedehiscens/G. dehiscens* transition, and the "*Globorotalia*" *pseudokugleri*/"*Globorotalia*" *kugleri* transition, which span almost the entire Zone P22, late Oligocene.

7. The FO of *Globoquadrina dehiscens,* just before the evolutionary appearance of "*Globorotalia*" *kugleri* in the very late Zone P22.

8. The FO of *Globigerinita uvula* and *Globigerinita glutinata,* within Zone N4, dated as latest Oligocene, just before Event 9.

9. The FO of other *Globigerinoides* species, which characterizes the middle of Zone N4, here aged as earliest Miocene (see below).

The Oligocene/Miocene Transition

The transition from the late Oligocene to the early Miocene deserves comment. In the Indian Ocean sites, typical *Globoquadrina dehiscens* is recorded just before the evolutionary appearance of "*Globorotalia*" *kugleri,* which according to the literature marks the beginning of Zone N4 (e.g., Bolli, 1957b; Blow, 1969, 1979; Berggren et al., 1985). However, the occurrence of *G. dehiscens,* at the beginning of its range, is discontinuous and, when missing, is replaced by its predecessor *Globoquadrina praedehiscens,* the latter occasionally associated with forms transitional to *G. dehiscens.* About in the middle of the "*G.*" *kugleri* range, thus well within Zone N4, the genus *Globigerinoides,* previously represented only by the species *G. primordius,* diversifies.

The new species recorded are *Globigerinoides immaturus, G. bollii,* and *G. trilobus.* Slightly after this diversification event, *Globigerinoides* shows a distinct increase in abundance. This succession of events differs from that previously reported by Srinivasan and Kennett (1983) from the equatorial to mid-latitude South Pacific and by Keller (1980) from the North Pacific. These authors recorded the FO of *G. dehiscens* much later than the appearance of "*Globorotalia*" *kugleri* and the major radiation of *Globigerinoides* almost at the end of the "*G.*" *kugleri* range. Moreover, the same authors used the FO of *G. dehiscens* for identifying the Oligocene/Miocene boundary.

Accordingly, because of the earlier appearance of *G. dehiscens* in the Indian Ocean sites, the Oligocene/Miocene boundary is here equated to the diversification level of the genus *Globigerinoides,* which is just preceded by the FO of *Globigerinita glutinata* and *G. uvula.*

SITE DESCRIPTIONS

Site 706

Site 706 lies on the eastern shoulder of the Mascarene Plateau at the northeastern margin of the Nazareth Bank at a water depth of 2506.5 m. Seven advanced hydraulic piston cores (APC) were raised from Hole 707A for a recovery rate of 82.7%. Coring was stopped at 47.5 mbsf upon the retrieval of a piece of basalt in the last core. Four APC cores were taken at Hole 706B. The

Figure 2. Calibration of second-order events with major biostratigraphic events among Oligocene planktonic foraminifers plotted vs. the low-latitude standard zonal scheme of Oligocene age (after Blow, 1969; Berggren et al., 1985; and this paper).

fourth core advanced only 1.80 m, and the extended core barrel (XCB) system was used for the remaining three cores, down to a final depth of 43.7 m, where basalt was encountered again. The recovery rate was 67.3%.

At Site 706, a 47.5-m-thick sedimentary sequence consisted of 3.8 m of Pleistocene foraminifer ooze unconformably overlying 44 m of Oligocene nannofossil ooze. The distribution of planktonic foraminifers from Hole 706A is plotted in Table 2. The faunal assemblages are rich in turborotaliids (*T. pseudoampliapertura* and *T. increbescens*), subbotinids, and *Globorotaloides* among others, suggesting that Sample 115-706A-6H-2, 86–91 cm, belongs to Zone P18. Sample 115-706A-6H-1, 86–91 cm, given the presence of *Globoquadrina sellii,* may be attributable to Zone P19, to which all the successive samples still belong. However, in the same sequence, few specimens are recorded that belong to much younger taxa, which appear in the stratigraphic succession until the top of the sequence. These taxa are reported in Figure 3. If one considers the latter taxa as the *in-situ* forms, then the zonal attribution might be changed to Zone P21 from the bottom up to Sample 115-706A-5H-5, 85–90 cm, whereas Sample 115-706A-5H-4, 85–90 cm, would belong to Zone P22 (Fig. 3). In Figure 4, the two interpretations for Hole 706B are plotted, which exhibits the same patterns as Hole 706A. The two holes perfectly correlate at the level of Samples 115-706A-3H-4, 85–92 cm, and 115-706B-3H-4, 86–91 cm, and at that of Samples 115-706A-2H-2, 86–91 cm, and 115-706B-1H-4, 50–55 cm, on the basis of two acmes of large cassigerinellids.

Site 707

Site 707 is located in the western tropical Indian Ocean on the northwestern part of the Mascarene Plateau about half way between the Seychelles and the Saya de Malha Banks. Three holes were drilled and two of them (Hole 707A and Hole 707C) penetrated Paleogene sediments. In Hole 707A, 19 APC and 5 XCB cores were drilled continuously to a terminal depth of 213.3 mbsf for a recovery rate of 75%. In Hole 707C, the upper 183.8 m of the sedimentary column was washed, followed by rotary core barrel (RCB) continuous coring. The recovery rate was 26% in the 20 sedimentary cores retrieved. Basalt was cored from Cores 115-707C-22R to -28R, with a recovery rate of 62%.

The 375.6-m-thick sedimentary sequence penetrated in the three holes consists (from top to bottom) of (1) 114 m of continuous Pleistocene to upper Miocene calcareous ooze (Holes 707A and 707B); (2) 28 m of condensed middle and lower Miocene calcareous ooze; and (3) 233 m of Paleogene calcareous ooze and chalk apparently continuous from Oligocene to upper Paleocene (lower part of Hole 707A and Hole 707C). The lower-

Table 2. Stratigraphic ranges of selected Oligocene planktonic foraminifers in Hole 706A.

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	Reworking	Contamination	Washed residues >40 μm	Washed residues >150 μm	Washed residues >250 μm	Preservation >40 μm	Preservation >150 μm	Preservation >250 μm	Volcanic glass >40 μm	Volcanic glass >150 μm	Volcanic glass >250 μm	Radiolarians >40 μm	Radiolarians >150 μm	Radiolarians >250 μm	Spicules >40 μm	Spicules >150 μm	Spicules >250 μm	"Globigerina" ampliapertura	Turborotalia pseudoampliapertura	Turborotalia increbescens	Turborotalia pseudoampliapertura/T. increbescens	Subbotina praeturritilina group	Dentoglobigerina aff. larmeui	Dentoglobigerina galavisi	Globorotaloides suteri	Catapsydrax martini	"Globigerina" euapertura	"Globigerina" venezuelana	"Globigerina" prasaepis	Subbotina gortanii	"Globoquadrina" tapuriensis	Globigerina officinalis	Subbotina utilisindex	Paragloborotalia sp.	Paragloborotalia opima nana
		2.5	2H-2, 86–91	—	C	3/2	4	4/3	2/3	3/2	3/2	F	F	F	—	—	—	—	—	—	X	X	X		X	X	X	X	X				X		X	X		X
			2H-3, 86–91	—	X	3/2	4	3/4	2/1	3/2	2	—	VF	—	—	—	—	—	—	—	X	X	X		X	X	X	X		X	X		X	X	X	X	X	X
			2H-4, 86–91	—	X	2	4	4	3	3	2	—	—	—	—	—	—	—	—	—	X	X	C		X	X	X		X			X		X	C	X	X	X
			2H-5, 86–91	—	X	2	3/2	3	3	3	3	—	—	—	—	—	—	—	—	—	X	X	X	X	X	X	X	X	X		X		X	X	X	X	X	X
			2H-6, 17–22	F	X	2	4/3	4/3	3	3/2	3/2	—	F	—	—	—	—	—	—	—	X	X	X		X	X	X	X	X				X	X	X	X	X	X
		12.2	3H-1, 86–91	—	F	3/2	4	4/3	2	2	3	F	F/C	F	—	—	—	—	—	—	X	X	X		X	X		X		X	X			X	X	X		X
			3H-2, 85–90	—	X	3/2	4	3/4	2/3	3/2	2/3	—	F	—	—	—	—	—	—	—	X	X	X		X	X	X	X	X	X		X	X	X	X	X	X	X
			3H-3, 85–90	—	X	3/2	4	4/3	2	4	3/2	—	—	—	—	—	—	—	—	—	X	X	X		X	X	X	X	X	X	X		X	X	X	X	X	X
			3H-4, 85–92	—	VF	2/1	3/4	3/4	3/2	3/4	3	R	VR	VF	—	—	—	—	—	—	X	X	R		X	X	X	X			X	X		X	X	R		X
			3H-5, 85–87	—	X	2/3	4	4/3	3/2	3	3	VF	—	—	—	—	—	—	—	—	X	X	X		X	X		X		X	X			X	F	X		X
	P19		3H-6, 30–32	—	F	3/2	4	4	2/3	3	3	—	F	—	—	—	—	—	—	—	X	X	X		X	X	X	X	X		X	X		X	X	X	X	X
Oligocene		21.9	4H-1, 90–95	—	F	4	3	4	3/2	3	3/2	VR	—	—	—	—	—	F	—	—	X	X	X		X	X	X	X	X	X	X		X	X	C	X	X	X
			4H-2, 90–95	—	—	1	3	3	3	3	3	F	F	—	—	—	—	—	—	—	X	X	X	X	X		X		X		X	X		X	C	X	X	X
			4H-3, 95–100	—	X	3	3	3	2	3	2/3	F	—	—	F	—	—	—	—	—	X	X	X		X			X	X	X	X		X	X	X	X	X	X
			4H-4, 95–100	—	X	2	3	3	3	3	2	—	F	—	—	—	—	—	—	—	R	X	X		X	X	X	X	X	X	X		X	X	X	X		X
			4H-5, 80–85	—	F	1	2	2	2	2	2	C	C	X	C	F	—	C	F	F	F	F	F		X	X		X		X	X	X		X	X	X	X	X
		31.5	5H-1, 85–90	—	—	3	3	3	3	4	2	F	F	F	—	—	—	—	—	—	X	X	X		X	X	X	X				X		X	X	X	X	X
			5H-2, 85–90	—	—	3	4	4	4	4	3	—	F	—	—	—	—	—	—	—	X	X	X				X		X	X				X	C	X		
			5H-3, 85–90	—	—	3	4	3	3	4	3	F	—	—	—	—	—	—	—	—	X	C	A		X	X	X		X	X	X	X	X	X	X	X	X	
			5H-4, 85–90	—	F	3	3	3	2	4	3	F	F	—	—	—	—	—	—	—	X	X	X		X	X	X	X	X	X	X			X	X	X	X	X
			5H-5, 85–90	—	F	3	4	4	2	4	3	VR	—	—	—	—	—	—	—	—	X	X	X		X	X	X	X		X	X	X		X	X	X		X
			5H-6, 85–90	—	X	3	5	4	2	4	2	—	—	—	—	—	—	—	—	—	X	A	A		X	X	X			X				X	X		X	
		41.1	6H-1, 86–91	—	X	3	4	3	2	4	2	—	—	—	—	—	—	—	—	—	C	X	X		X		X	X			X		X	X	X	X	X	CF
	P18	43.4	6H-2, 86–91	—	X	3/4	4	4	1	4	4	F	—	—	—	—	F	—	—	—	X	A	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	CF

Table 2 (continued).

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	*Catapsydrax* sp.	*Globigerina ouachitaensis*	*Subbotina angiporoides* group	*Subbotina angiporoides angiporoides*	*Paragloborotalia pseudocontinuosa*	*Globigerina praebulloides*	*Catapsydrax dissimilis dissimilis*	"*Globigerina*" aff. *ampliapertura*	Chiloguembelinids	*Tenuitella gemma*	*Tenuitella munda*	*Tenuitella clemenciae*	*Globigerina praebulloides occlusa*	*Cassigerinella chipolensis*	*Pseudohastigerina micra*	*Pseudohastigerina barbadoensis*	*Pseudohastigerina naguewichiensis*	*Globorotaloides variabilis*	*Globoquadrina tripartita*	*Globoquadrina sellii*	*Catapsydrax unicavus*	"*Tenuitella*" *angustiumbilicata*	*Dentoglobigerina globularis*	*Paragloborotalia siakensis*	*Tenuitella clemenciae/T. munda*	*Globorotaloides* sp. 1	"*Globigerina*" *ciperoensis*	*Cassigerinella globulosa*	*Dentoglobigerina larmeui*	*Tenuitella munda/Globigerinita juvenilis*	*Globoquadrina rohri*	*Dentoglobigerina galavisi/D. baroemoenensis*	*Dentoglobigerina baroemoenensis*	*Cassigerinella martinezpicoi*	*Globorotaloides permicrus*
		2.5	2H-2, 86–91	X	X				X			A	X	X	X		X	X	F	F	X				X	X		X						X				
			2H-3, 86–91		X	X	X		X		X	X	X	X	X	X	X		X	X	X	X			X	X		X	R	X				X				
			2H-4, 86–91		C	X			X		X	X	X		X	X		R	X	X	X	X			X	X				X						CF		
			2H-5, 86–91		X	X	X					X	X		X	X	R	X	X	X	X	X	X		X	X				X					X			X
			2H-6, 17–22		X	X	X	X	X		X	X	X	X	X		X	X	X	X		X	X		X	X		X		X		X		X		X		
		12.2	3H-1, 86–91		X		X	X	X		X	X	X		X		X	X	X	X			X		X								CF	X			X	
			3H-2, 85–90	X	X	X	X	X			X	A	X	X		X	X	X	A	A			X	X	X					R				X		CF		
			3H-3, 85–90		X	X	X	X			X	X	X	X	X	R	R		X	X	X	X	CF			X								X				
			3H-4, 85–92			X		X				X	X		X		C		X	C			CF		R	X											C	
			3H-5, 85–87		F	X			X			X	X	X	X	X		X	X	X		X	CF				X					X		X				
	P19		3H-6, 30–32		X	X	X	X	X		X	X	X	X	X		X	X	X	X		X		X		X								X			X	
Oligocene		21.9	4H-1, 90–95		C	R	X	X				X	X		X	X	R		X	X	X	X	X	X	R	X				X				X				
			4H-2, 90–95	X	C			X				X	X			X			X	X	X	X	CF	X						X				X				
			4H-3, 95–100		X	X		X			X	X	X		X	X	X	X	X	X		X	CF	X	R					X			CF	X			X	
			4H-4, 95–100		X	X	X		X		X	X	X	X	X	X		X	X	X	X	X	CF	X	X	X								X		X	X	
			4H-5, 80–85		X	X		X				X	X						X	X	X	X		X	X	X									C	X		
		31.5	5H-1, 85–90	X	X	X		X				X	X	X	X			X	X	X	X	X	CF	X	X	X	CF	X		X		X		X	X			
			5H-2, 85–90			X	X		X			X	X	X			F	X	X	X	X			X	X									CF				
			5H-3, 85–90	X	X	X	X	X				C	X	X				R	X	X		X	CF	X	X	X				R		X	CF					
			5H-4, 85–90		X	X	X	X				A	X	X	X	X		X	X	X		X		X	X	X			X	R								
			5H-5, 85–90		X	X	X					X	X	X					X	X	X	CF			X				X	R	X							
			5H-6, 85–90	X	X	X						X	X		X	X	VR	X	X	X	X		X	X		X	CF	X										
		41.1	6H-1, 86–91			X	X	X		X	X	A	X	X	X	X	VR		C	C	X	X	X	X	X													
	P18	43.4	6H-2, 86–91	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X																	

Note: VA = very abundant, A = abundant, C = common, F = few, VF = very few, R = rare, VR = very rare, X = present. 1 = very abundant, very good preservation; 2 = medium abundant, good preservation; 3 = medium scarce, medium preservation; 4 = scarce, poor preservation; 5 = very scarce, very poor preservation.

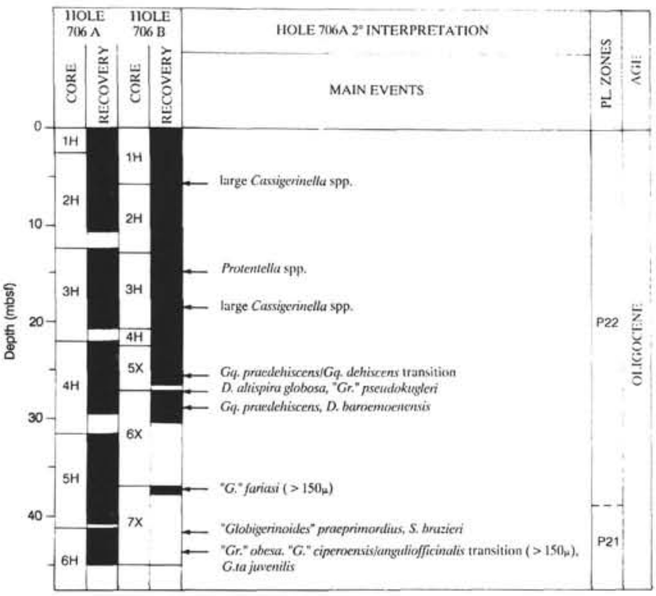

Figure 3. Main planktonic foraminifer events in Hole 706A plotted vs. biozone assignment according to the 2° interpretation. See text for explanation and Table 2 for the 1° interpretation.

most sediments overlying the basement, as well as inclusions 30 m below the top of basement, indicate a Paleocene age (Backman, Duncan, et al., 1988).

We studied 35 samples from Hole 707A and 25 from Hole 707C. Based on the planktonic foraminifer events, the two holes perfectly correlate, with Core 115-707A-22X corresponding to Core 115-707C-3R. The main bioevents are reported in Figure 5, and Table 3 shows the foraminifer distribution in the Oligocene portion from Cores 115-707A-21X to -15X.

Planktonic foraminifer faunas from sedimentary Sample 115-707C-21R-2, 68–70 cm, within the basalt contain very poorly preserved forms that belong to *Subbotina triloculinoides, Morozovella angulata, M. pusilla,* and rare "*Subbotina*" *pseudobulloides.* This assemblages may be attributable to late Paleocene Zone P3b. However, the occurrence of rare specimens of "*Morozovella*" *uncinata* suggests that some reworking from the older Zone P2 sediments is also present. Large amounts of crystalline rock-derived grains, large fragments of echinoids as well as pellets, common pyrite, and glauconite are also present. The next samples above basalt (Samples 115-707C-16R-2, 70–75 cm, and 115-707C-16R-1, 70–75 cm) yield poorly preserved, abundant planktonic foraminifers associated with common, mainly broken, large-sized benthic foraminifers and a few ornamented ostracods. The planktonic assemblage is rich in acarininids and morozovellids attributable to latest Paleocene Zone P6a. Identified species are *Morozovella velascoensis, M. pasionensis, M. edgari, M. gracilis,* and *M. aequa* along with *Acarinina soldadoensis, A. nitida, A. intermedia,* and *Planorotalites pseudoscitulus,* among others. Rare chiloguembelinids occur in the fraction >150 μm.

Sample 115-707C-15R-2, 69–72 cm, yielded poorly preserved but abundant planktonic foraminifers that seem to belong to the following early Eocene Zone P6b. Abundant large morozovellids and acarininids associated with less common low-spired subbotinids compose the faunal assemblage. Common species are *Morozovella subbotinae, M. gracilis, M. marginodentata, M. lensiformis, M. formosa, Acarinina soldadoensis,* and *A. esnaensis.* Large chiloguembelinids occur in the >250-μm fraction. Some reworking is present, possibly from Zone P6a, as indicated by the occurrence of *Morozovella edgari.* Sample 115-707C-15R-1, 69–72 cm, already belongs to Zone P7 on the basis of the occurrence of *Morozovella aragonensis, Acarinina solda-*

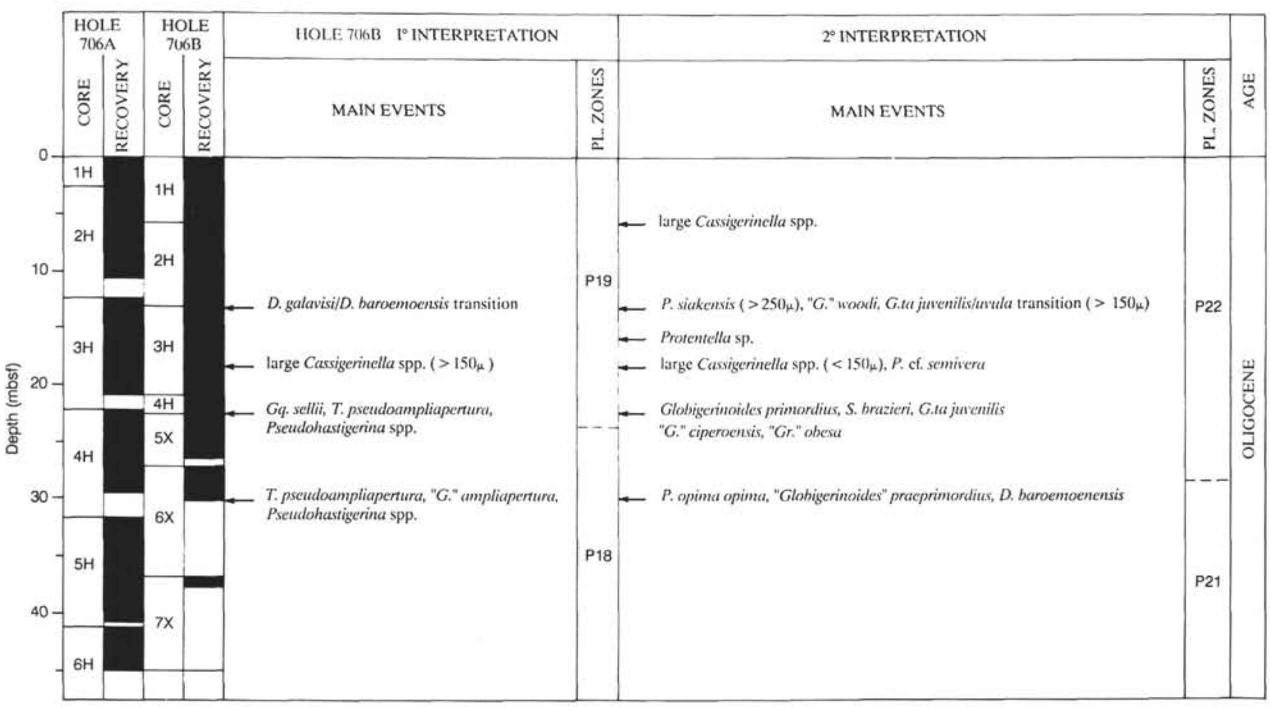

Figure 4. Main planktonic foraminifer events in Hole 706B plotted vs. biozone assignment according to the 1° and 2° interpretation. See text for explanation.

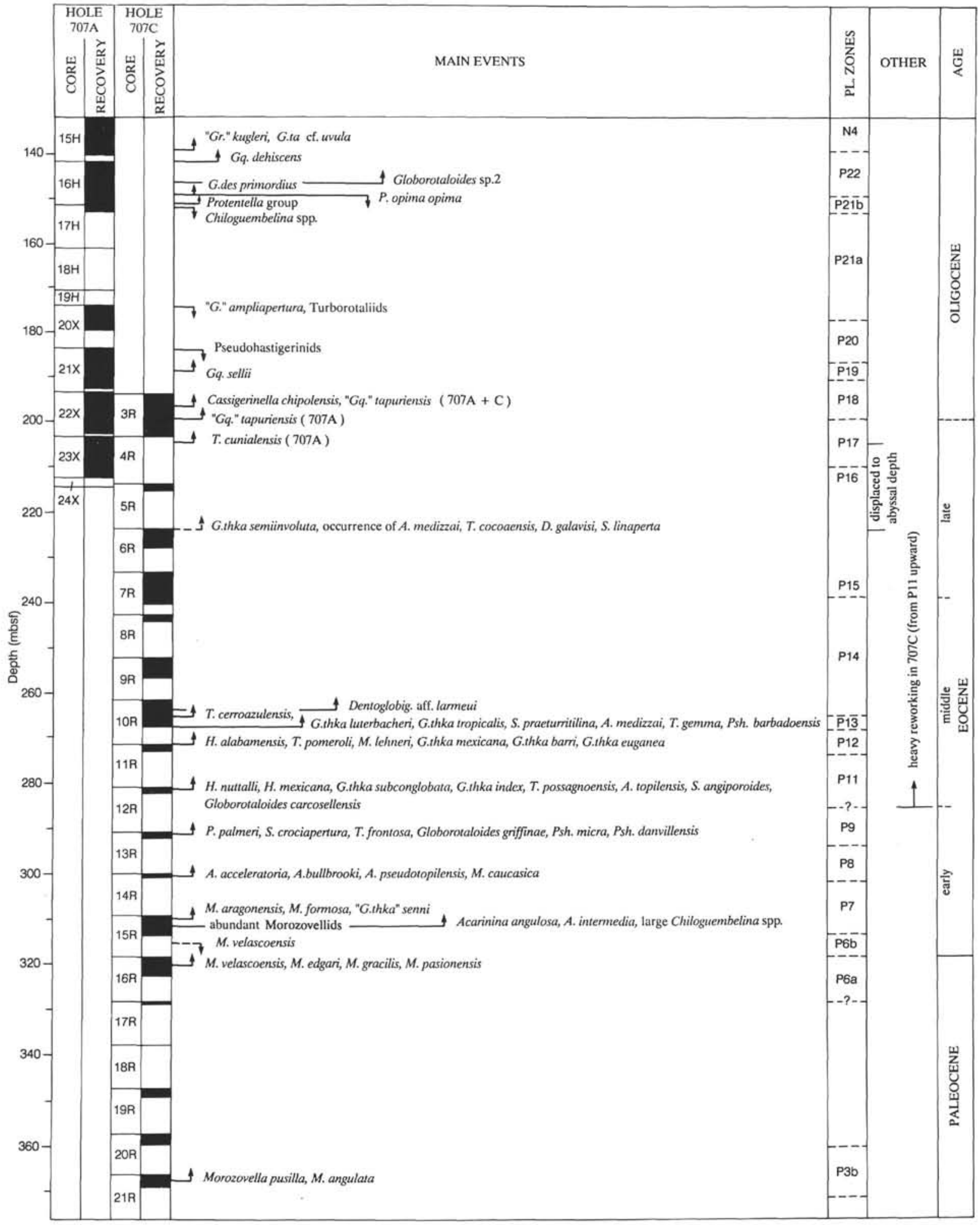

Figure 5. Main planktonic foraminifer events in Holes 707A and 707C plotted vs. biozone assignment.

doensis angulosa, and "*Globigerinatheka*" *senni.* Reworking from Zone P6b is still present. Sample 115-707C-14R-1, 38–40 cm, yielded an abundant, moderately preserved planktonic fauna attributable to Zone P8, given the occurrence of common *Acarinina pentacamerata, A. bullbrooki,* rare *Morozovella caucasica,* abundant *M. aragonensis,* and few *M. crassata.* Reworking increases in importance, although still limited, involving late Paleocene sediments possibly from Zone P4 along with those previously recorded from Zone P6b.

A major faunal change occurs in Sample 115-707C-13R-1, 50–53 cm. Large morozovellids are represented only by abundant *M. aragonensis* and rare *M. caucasica. Planorotalites palmeri,*

Table 3. Stratigraphic ranges of selected Oligocene planktonic foraminifers in Hole 707A.

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	Reworking	Contamination	Washed residues >40 µm	Washed residues >150 µm	Washed residues >250 µm	Preservation >40 µm	Preservation >150 µm	Preservation >250 µm	Volcanic glass >40 µm	Volcanic glass >150 µm	Volcanic glass >250 µm	Radiolarians >40 µm	Radiolarians >150 µm	Radiolarians >250 µm	Spicules >40 µm	Spicules >150 µm	Spicules >250 µm	*"Globigerina" ampliapertura*	*Subbotina praeturritilina*	*"Globoquadrina" tapuriensis*	*Globoquadrina tripartita*	*Turborotalia increbescens*	*Catapsydrax martini*	*Dentoglobigerina galavisi*	*Globorotaloides suteri*	*"Globigerina" euapertura*	*"Globigerina" venezuelana*	*Subbotina utilisindex*	*Subbotina angiporoides* group	*Turborotalia pseudoampliapertura*	*Subbotina angiporoides angiporoides*	*"Globigerina" aff. ampliapertura*	*Pseudohastigerina micra*	*Pseudohastigerina barbadoensis*	*Pseudohastigerina naguewichiensis*
	N4	137.9	15H-5, 38–43	X	C	1	1	2	2	3	2/3	—	—	—	—	—	—	—	—	—							CF	X										
			15H-6, 38–43	X	F	1	2	3/2	2	2	2/3	—	—	—	—	—	—	—	—	—			X	X			CF	X	X	X								
		141.3	16H-1, 38–43	X	X	1/2	3	4/3	2	3	4	—	—	—	—	—	—	—	—	—								X	X	X								
			16H-2, 38–43	X	—	1	3	3	1/2	3	3	—	—	—	—	—	—	—	—	—								X	X	X								
Oligocene	P22		16H-3, 38–43	X	—	1	3	4	2/1	3	4	—	—	—	—	—	—	—	—	—			X	X		X	X	X	X	X								
			16H-4, 38–43	X	X	1	4	4/5	3/2	4	4	—	F	—	—	—	—	—	—	—				X			R	X		X								
			16H-5, 38–43	C	X	1	4	4/5	3/2	4	4/5	—	—	—	—	—	—	—	—	—		X		X		X		X	X									
	P21b		16H-6, 38–43	X	X	1	2/3	3	2/3	3	3/2	—	—	—	—	—	—	—	—	—		X	X	X		X	X	X	X	X								
			16H-7, 38–43	X	X	1	3/2	3	2	3	2/3	—	—	—	VF	VF	—	C	VF	VR		X	X	X		X	X	X	X	X								
	P21a	151.0	17H-1, 38–43	F	F	1	3/2	3/2	3/2	3	3	—	—	—	F	F	—	F	F	—		X	X			X		C	X	X								
		173.7	20X-1, 38–43	VF	VF	2/3	3	4	2	4	3	—	—	—	A	C	VF	F	VF	—	X		X		X	X	X	X	X		X	X	X		X			
	P20		20X-2, 38–43	VF	—	2	4	4	2	5	4/5	—	F	—	VA	F	—	C	X	—	CF	X	X		X	X	X	X	X		X	X	X					
			20X-3, 38–43	—	—	2/3	4/5	4	3	4/5	4	—	—	—	VA	C	—	C	—	—			X			X	X	X			X	X	F	X	X			
		183.4	21X-1, 38–43	—	—	3/2	4/5	5	3/2	4	4/5	—	—	—	C	C/F	—	X	X	X				X		R		X	R		F	X	X	X	F		C	C
Oligocene	P19		21X-2, 38–43	—	—	3	4/3	4	2	4/5	3/4	—	—	—	VA	C	—	C/A	C	F	X	X		X		X		X		X	X	X	X	X	CF	X	C	C
			21X-3, 38–43	—	—	3	4/5	5	2	4/5	4	—	—	—	VA	C	—	X	X	—	X	X		X		X		X			X	X	F		R	X	X	X
		193.1	21X-4, 38–43	—	—	2	3/4	4/5	3	4	4	—	—	—	VA	A	—	C	C	X			X	X		F	X	X	X		C	X	F	X			F	F
	P18		21X-5, 38–43	—	—	3/2	5/4	5	3	5/4	4	—	—	—	VA	C/A	—	X	X	X						X	X	X		X	X	X	F	X		X	X	X
			21X-6, 38–43	VF	VF	3/2	4	4/5	3	4/5	4/5	—	—	—	VA	A	—	C	C	—	X	X	X	X	X	X	X	X	X	X	A	A	X	X	X	X	X	X

Table 3 (continued).

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	Chiloguembelinids	*Cassigerinella chipolensis*	*Tenuitella gemma*	*Paragloborotalia opima nana*	*Catapsydrax dissimilis dissimilis*	*Catapsydrax unicavus*	*"Globigerina" prasaepis*	*Dentoglobigerina larmeui*	*Dentoglobigerina* aff. *larmeui*	*Catapsydrax* sp.	*Paragloborotalia pseudocontinuosa*	*Globorotaloides* sp. 1	*Tenuitella clemenciae/T. munda*	*"Tenuitella" angustiumbilicata*	*Dentoglobigerina galavisi/D. baroemoenensis*	*Dentoglobigerina baroemoenensis*	*Tenuitella clemenciae*	*Globorotaloides variabilis*	*Globigerina ouachitaensis*	*Globigerina praebulloides occlusa*	*Globoquadrina sellii*	*Turborotalia pseudoampliapertura/T. increbescens*	*Paragloborotalia siakensis*	*Globigerina officinalis*	*Cassigerinella globulosa*	*Globoquadrina tripartita/G. sellii*	*Cassigerinella martinezpicoi*	*Tenuitella munda*	*Subbotina gortanii*	*Globoquadrina praedehiscens*	*Dentoglobigerina globularis*	*Globoquadrina rohri*	*Globorotaloides permicrus*	*Paragloborotalia opima opima*	*Catapsydrax dissimilis ciperoensis*
	N4	137.9	15H-5, 38–43		X	X		X			X	X			X		X		X	X	X		X			X	X						X	X	X	X		X
	P22		15H-6, 38–43		X	X	X	X	X			X		X	X		X	CF		X		X	X			X	X						X	X	X			
		141.3	16H-1, 38–43		X	X	X	X			X	X	X	X	X	X	X		X	X	X	X	X	X		X	X				CF		X	X	X	X		X
			16H-2, 38–43		X	X	X	X		X	X	X	X	X			A	X		X	X	X	X	X		X	X						X	X	X	X		X
Oligocene			16H-3, 38–43		X	X	X		X	X		X		X	X		A		X	X		X	X	X		X	X	X						X	X	CF		X
			16H-4, 38–43		X	X	X	X	X	X		X		X	X		X			X	X	X	X	X		X	X	X					X	X	X	X		X
			16H-5, 38–43		X	X	X	X			X	X		X	X		X		X	X	X	X	R			X	X	X		X	X			X				
	P21b		16H-6, 38–43		X	X	X	X		X		X		X	X		X			X	X		X	X			X	X						X	X	R	R	X
			16H-7, 38–43			X	X	X	X	X	X	X		X			X		X	X		X	X	X		X		X			X		CF	X	X		X	X
	P21a	151.0	17H-1, 38–43	A	X	A	X	X	X	X		X	X	X	X	X	A		X	X	X	X		X		X	R				X			X	X	CF	X	X
	P20	173.7	20X-1, 38–43	X	X	X	X		X	X		X		X	X		X	X	X	X		X		X	X	X	X	X	X	X	X				X	X		
			20X-2, 38–43	A	X	X	X		X		X	X	X	X	X				X	X		X		X	X	X	X	X		X					X			
			20X-3, 38–43	X	X	X			X	X		X		X	X				X	X							X	X	X	X	X	X	CF	X				
	P19	183.4	21X-1, 38–43	A	X	X			X			X	X		X		X			X				CF			X				X							
Oligocene			21X-2, 38–43	A	X	X	X		X	X		X		X	X		X			X									X	VR								
			21X-3, 38–43	X	X	X	X			X		X		X	X		X			X			R	VR	X	CFR	X	X	R									
	P18	193.1	21X-4, 38–43	X	R	X	X	F	X	X		X	X	X	X		X	X	CFR	X	X	X																
			21X-5, 38–43	F		X	X	X	X	X	X	X	X	X	X		X																					
			21X-6, 38–43	R	X	X	X																															

Table 3 (continued).

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	*Dentoglobigerina globularis/D. altispira globosa*	*Dentoglobigerina altispira globosa*	*Subbotina brazieri*	"*Globigerina*" *angulisuturalis*	"*Globigerina*" *anguliofficinalis*	*Paragloborotalia* sp.	"*Globorotalia*" *obesa*	*Globigerinita juvenilis*	*Protentella* sp. 1	"*Globigerina*" sp. 1	"*Globigerina*" sp. 2	*Globigerina praebulloides*	*Paragloborotalia semivera*	"*Globigerina*" *ciperoensis*	*Globigerinita juvenilis/G. uvula*	*Protentella* sp.	"*Globigerinoides*" *praeprimordius*	*Protentella clavaticamerata*	*Globigerinoides primordius*	*Globoquadrina binaiensis*	"*Globigerina*" *fariasi*	"*Globigerina*" *woodi*	"*Globorotalia*" *pseudokugleri*	*Globigerinella?* sp.	"*Globigerina*" *ciperoensis otrnangiensis*	"*Globorotalia*" *pseudokugleri* (ancestral form)	*Globorotaloides* sp. 2	"*Globorotalia*" *obesa/Globigerinella praesiphonifera*	*Globoquadrina praedehiscens/G. dehiscens*	*Globoquadrina dehiscens*	*Protentella navazuelensis*	"*Globorotalia*" *pseudokugleri*/"*G.*" *kugleri*	*Protentella* aff. *prolixa*	"*Globorotalia*" *kugleri*	*Globorotaloides* aff. *stainforthi*	*Globigerinita uvula*
Oligocene	N4	137.9	15H-5, 38–43	X	X		CF	CF		X	X	X		R		X	X	X			X	R	X		X	X	X	X	X	X		X		CF	X		X	X	CF
	P22		15H-6, 38–43	X	X	X	X	F	X	X	X	X			X	X	X	X	X		X	X	X		X	A	X	X	X	X	R	A	X	X	X	X			
		141.3	16H-1, 38–43	X	X	X	F	F	X	X	X	X			X		X				X	R	X		X	X	X	X	R	X	X	F	F	X					
			16H-2, 38–43	X	X		F	F		X	X	X	X					X			CF	X	X	X		X	X	X	X		X								
			16H-3, 38–43		X	X	F	X		X	X	X	C	C	X		X	X			X	X	X			X	X		X	X									
			16H-4, 38–43		X	X	C/F	X	X		X	X			X		X					X	X	X		X	X	X	X										
			16H-5, 38–43	X		X	C	X	X		X	X		X			X		X			X	X	X	CF	VR													
	P21b		16H-6, 38–43		X	X	C	X	X	X		X	X	X		X	X			X	CF	CF	CF																
			16H-7, 38–43	X	X	X	C	C			X	X	X	X	X	X	X	CFR	X																				
	P21a	151.0	17H-1, 38–43	X	R	X	X	X	X	X	R																												
	P20	173.7	20X-1, 38–43																																				
			20X-2, 38–43																																				
			20X-3, 38–43																																				
Oligocene	P19	183.4	21X-1, 38–43																																				
			21X-2, 38–43																																				
			21X-3, 38–43																																				
	P18	193.1	21X-4, 38–43																																				
			21X-5, 38–43																																				
			21X-6, 38–43																																				

Note: See note to Table 2 for legend.

Subbotina crociapertura, "Turborotalia" griffinae, Turborotalia frontosa, and large-size *Pseudohastigerina danvillensis* indicate that Zone P9, the youngest zone belonging to the early Eocene, is present there. Reworking apparently is absent. Poor recovery in this interval prevents the recognition of a hiatus between Cores 115-707C-13R and -12R. In fact, Sample 115-707C-12R-1, 21–25 cm, yielded a planktonic fauna already belonging to late Zone P11, given the presence of *Globigerinatheka rubriformis, G. index, Turborotalia possagnoensis, Acarinina topilensis, A. libyaensis, A. haynesi, A. spinuloinflata, Subbotina angiporoides* gr., and *Globorotaloides carcosellensis* along with a few hantkeninids and rare *Morozovella aragonensis.* The fauna appears homogeneous and without reworking, although large benthic foraminifers also occur.

A very different, much younger fauna occurs in Sample 115-707C-11R-1, 74–78 cm. Here, medium-large-sized globigerinathekids, including *G. euganea, G. subconglobata, G. barri,* and *G. rubriformis,* dominate the assemblages along with "*G.*" *senni* and "*G.*" *kiersteadae. Morozovella lehneri, M. spinulosa, Turborotalia pomeroli,* and *Hantkenina alabamensis* are also present. This assemblage may be attributable to late Zone P12. Reworking is important, as testified by the occurrence of common *Morozovella aragonensis* and strongly ornamented acarininids, which would indicate Zones P10 and early P11 according to Fleisher (1974). Large benthic foraminifers, ornamented ostracods, large fragments of echinoids, and one brachiopod (a pelagic one) also occur. Moreover, for the first time, large numbers of radiolarians are present in the medium and fine fractions. The occurrence of common larger-sized globigerinathekids, including *G. luterbacheri* and rare *G. tropicalis,* along with *Tenuitella gemma* and *Pseudohastigerina barbadoensis* in Sample 115-707C-10R-4, 106–110 cm, indicates that this assemblage may belong to Zone P13, although an attribution to early Zone P14 cannot be ruled out. The latter zone is definitively represented in Sample 115-707C-10R-3, 62–65 cm, on the basis of the occurrence of *Turborotalia cerroazulensis.* Radiolarians become more and more abundant in Core 115-707C-10R. Reworking becomes progressively more pronounced than in Core 115-707C-11R and increases upward. Large benthic foraminifers are heavily corroded, and echinoid fragments become more abundant along with the increased reworking. Reworked planktonic foraminifer assemblages apparently still belong to the same early middle Eocene zones as mentioned above. Sample 115-707C-9R-1, 25–28 cm, yielded a mixed fauna very similar to that from the top of Core 115-707C-10R.

Sample 115-707C-6R-1, 70–75 cm, belongs to the late Eocene. Except for a single specimen of *Acarinina medizzai,* all muricate forms are absent, whereas *Globigerinatheka semiinvoluta, Turborotalia cocoaensis,* and forms transitional between *T. pomeroli* and *T. pseudoampliapertura* are recorded. This assemblage is attributable at least to Zone P15. However, the occurrence of abyssal benthic foraminifers implies that all planktonic foraminifers are resedimented along with shallow-water pelecypod fragments. Therefore, a younger age cannot be ruled out. Radiolarians are very abundant in all fractions. The uppermost sample studied in this hole (Sample 115-707C-3R-2, 70–75 cm) yielded an earliest Oligocene fauna attributable to Zone P18 based on the occurrence of "*Globoquadrina*" *tapuriensis* and *Cassigerinella chipolensis,* among others. The assemblage, although resedimented, appears heavily dissolved and radiolarians dominate all fractions.

In Hole 707A, the occurrence of *Cassigerinella chipolensis* in Sample 115-707A-22X-2, 38–43 cm, allows us to correlate the two holes precisely. Although sediments in Hole 707A exhibit the same resedimented character described from the top of Hole 707C, Cores 115-707A-23X and -22X yielded planktonic foraminifer assemblages that represent the Eocene/Oligocene transition. *Turborotalia cunialensis* was recorded in Sample 115-707A-23X-1, 38–40 cm, and "*Globoquadrina*" *tapuriensis* in Sample 115-707A-22X-3, 38–43 cm. Therefore, the P17/P18 zonal boundary, equated to the Eocene/Oligocene boundary, is tentatively placed below the latter sample.

The interval from Core 115-707A-21X to -15H yielded an apparently undisturbed succession of planktonic foraminifer faunas that span the entire Oligocene up to the base of Zone N4, based on the presence of "*Globorotalia*" *kugleri* in the last sample studied (Sample 115-707A-15H-5, 38–43 cm). Poor recovery in the interval spanning Cores 115-707A-19H and -18H prevented the precise location of the P20/P21a zonal boundary. The distribution of planktonic foraminifers from the Oligocene portion is plotted in Table 3.

Site 708

Site 708 was drilled on the abyssal plain east of the Seychelles Bank at a water depth of 4109.3 m. Hole 708A was drilled to a total depth of 236.2 mbsf and yielded a recovery of 80.3%. Of the 25 cores taken, only the uppermost 8 were retrieved with the APC, the remaining with the XCB. The sedimentary sequence recovered at this site is characterized by numerous turbidites also in the Paleogene interval. We analyzed 19 samples from Core 115-708A-25X to -20X for their planktonic foraminifer content. The turbiditic characters of the sediments are also recorded in the distribution of planktonic foraminifers. Planktonic faunas occur with abyssal benthic foraminifers indicating that they are totally resedimented at abyssal depth. Reworking is heavy, and a routine range chart could not be constructed. The main events are plotted in Figure 6. Planktonic foraminifer faunas are generally scarce to absent in some samples, which occasionally yielded very abundant radiolarian faunas. The few species identified allowed us to recognize Zones P21a-P22 of late Oligocene age.

Site 709

Site 709 lies in a small basin perched near the summit of the Madingley Rise, a regional topographic high between the Carlsberg Ridge and the Northern Mascarene Plateau. We continuously cored 3 holes at Site 709. Hole 709A ended in nannofossil ooze of late Oligocene age at 203.1 mbsf. All 21 cores were taken with the APC and the recovery rate was 91%. Hole 709B yielded 27 cores and ended at 254.8 mbsf in early Oligocene oozes for a recovery rate of 92%. The 7 deepest cores were taken with the XCB, and the shallowest cores with the APC. Hole 709C, which ended in nannofossil chalks of middle Eocene age, was cored to 353.7 mbsf and yielded 20 APC and 17 XCB cores, for a total recovery rate of 93%. The sediments of Paleogene age are about 165 m thick. We analyzed a total of 127 samples for planktonic foraminifer content: 6 from Hole 709A, 39 from Hole 709B, and 82 from Hole 709C.

Paleogene sediments from Hole 709C yielded very mixed planktonic faunas from Cores 115-709C-37X through -26X. The remaining cores displayed less pronounced reworking, but downhole contamination was important. Abyssal benthic foraminifers were recorded throughout, even in small amounts, so all the planktonic faunas must be considered resedimented. Consequently, no routine range chart could be constructed for this hole; however, the main events are plotted in Figure 7. Based on these events, planktonic foraminifer assemblages representative of the interval from late Zone P11 to early Zone P15 could be documented, even though the younger late Eocene index species were missing. Consequently, the interval from Sample 115-709C-34X-3, 75–80 cm, to Sample 115-709C-32X-4, 75–80 cm, was attributed to an undifferentiated interval belonging to Zones P15 through P17. The P17/P18 zonal boundary (= Eocene/Oligocene boundary) was placed just below the FO of the cassi-

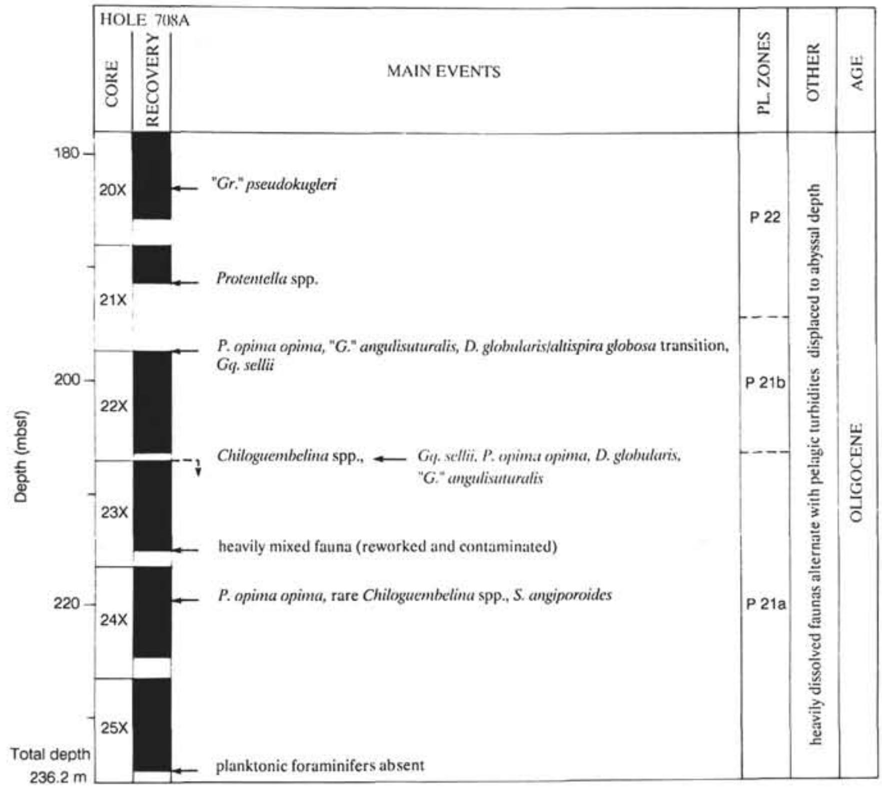

Figure 6. Main planktonic foraminifer events in Hole 708A plotted vs. biozone assignment.

gerinellids in Sample 115-709C-32X-4, 75–80 cm. The assemblages of this interval still contain a large number of muricate forms reworked from different levels of middle Eocene age. Some layers yielded well-preserved specimens even of very fragile taxa, such as several hantkeninids. Radiolarians are abundant throughout the entire sequence.

In the early Oligocene portion in Hole 709C, reworking of middle to late Eocene taxa is still very heavy, preventing the identification of the P19/P20 zonal boundary. The occurrence of the "*Globigerina*" *ciperoensis*/"*G.*" *anguliofficinalis* transition in Sample 115-709C-26X-2, 75–80 cm, associated with *Paragloborotalia opima opima* indicates Subzone P21a. The presence of this zone is corroborated by the successive occurrence of several new taxa higher in the sequence. Sample 115-709C-24X-1, 80–82 cm, yielded the last chiloguembelinids, whereas in Sample 115-709C-23X-4, 80–82 cm, *Globigerinoides primordius* is first recorded. The latter interval may be attributable to Subzone P21b. The remaining samples contain planktonic foraminifer faunas characteristic of late Oligocene Zone P22.

The Oligocene sequence recovered in Hole 709B and partially in Hole 709A apparently is less disturbed by displacement and mixing. It is worth mentioning that planktonic faunal reworking decreases in Hole 709C at about the same level where Hole 709B begins. Distributions of planktonic faunas in Holes 709A and 709B are tentatively reported in Tables 4 and 5, respectively. In particular, the succession of events from Hole 709B appeared the least disturbed in the Indian Ocean sites; therefore, on the basis of this sequence the minor bioevents among planktonic foraminifers were calibrated to the standard bioevents (Fig. 2). Correlation between Holes 709C and 709B presents some problems. The main events by which the standard zones were established, especially in the interval between the base of Subzone P21b up to Zone N4, apparently occur earlier in Hole 709B than in Hole 709C, and the zonal boundaries are offset by few meters.

In our material, the topmost core of Hole 709B contains the Oligocene/Miocene boundary, which is marked by the appearance of few new *Globigerinoides* species within Zone N4. Six samples were analyzed from Hole 709A. They belong to Zones P22 and N4, but in the topmost sample the representatives of *Globigerinoides* are missing.

Site 710

Site 710 lies on a fairly broad northeast-trending terrace in the central Madingley Rise in a water depth of 3824.3 m. Hole 710A was drilled continuously and ended in nannofossil ooze/chalk of early Oligocene age at 209.7 mbsf. We drilled 22 cores at this site, the uppermost 13 with the APC and the remaining 9 with the XCB. The total recovery rate was 88%.

Only seven samples, one per core, were analyzed for their planktonic foraminifer content. Planktonic foraminifers were generally sparse and poorly preserved except in Sample 115-710A-16X-3, 75–80 cm. A distribution chart was tentatively constructed (Table 6); however, zonal attributions were very uncertain because of the co-occurrence of species of different age in the same samples. Samples 115-710A-22X-3, 75–80 cm, and 115-710A-21X-3, 75–80 cm, yielded planktonic faunas attributable to Zone P20 based on the presence of *Turborotalia pseudoampliapertura*, *T. increbescens*, and *Paragloborotalia opima opima*. However, the chiloguembelinids were rare and few specimens of "*Globigerina*" *ciperoensis* >150 μm were recorded in Sample 115-710A-21X-3, 75–80 cm. The occurrence of the latter form is generally recorded in late Zone P21a (see Fig. 2). Sample 115-710A-20X-3, 75–80 cm, is difficult to assign to any zone because of the presence of *Globoquadrina binaiensis*, *Protentella* aff. *prolixa*, and *Paragloborotalia siakensis* (>250 μm)

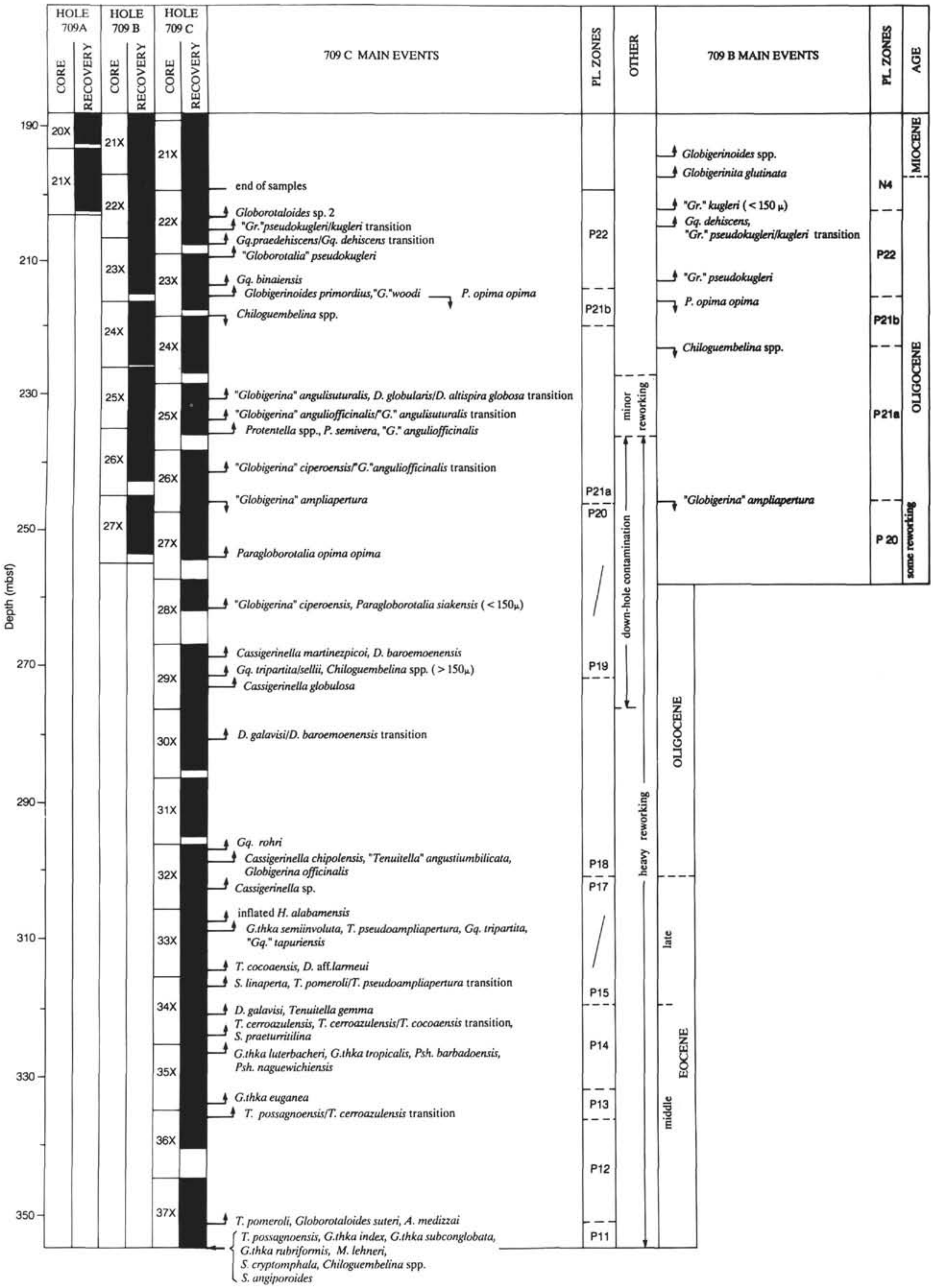

Figure 7. Main planktonic foraminifer events in Holes 709A and 709C plotted vs. biozone assignment.

along with *Paragloborotalia opima opima*. Two interpretations may be suggested: the first (reported in the range chart of Table 6) considers *P. opima opima* as *in situ* and the younger species as downhole contaminants; in the second interpretation, the younger forms are *in situ* and *P. opima opima* is reworked. The latter hypothesis implies that the younger faunas contained in the older cores are also *in situ*, whereas the bulk of planktonic foraminifers attributed to Zone P20 are in fact reworked. This second interpretation is reported in Figure 8. The interval from Cores 115-710A-19X to -16X yielded planktonic faunas characteristic of Zone P22, apparently without major mixing.

Site 711

Site 711 lies on the northern edge of the Madingley Rise just a few hundred meters above the abyssal plain at a water depth of 4429.8 m. An irregular relief characterizes the local topography, although the site was placed in a sheltered basin surrounded by two basement highs. Hole 711A was continuously cored and penetrated to 249.7 mbsf, yielding a total of 26 cores. The upper 11 of these were cored with the APC, and the remaining 15 with the XCB system. The total recovery rate was 81.7%. The 250-m-thick sediments are characterized by strong carbonate dissolution throughout the entire sequence.

We analyzed 40 samples for their planktonic foraminifer content. The association of planktonic foraminifers with abyssal benthic foraminifers suggests that all carbonate faunal components are resedimented at abyssal depths. Reworking is heavy throughout the entire sequence. Moreover, carbonate dissolution heavily affects the displaced faunas from Core 115-711A-22X uphole. Nevertheless, planktonic foraminifer assemblages attributable to all middle Eocene zones up to the base of late Eocene Zone P15 could be recognized, except for the base of Zone P10 (earliest middle Eocene) (see Fig. 9). Heavy dissolution affecting the planktonic faunas above Core 115-711A-21X prevented the recognition of any late Eocene events. The P17/P18 zonal boundary (= Eocene/Oligocene boundary) was tentatively placed below Sample 115-711A-16X-1, 60–65 cm, based on the presence of "*Globoquadrina*" *tapuriensis* in this sample. The occurrence of *Paragloborotalia opima opima* and *Globigerinita* cf. *juvenilis* in Samples 115-711A-15X-1, 60–65 cm, and 115-711A-14X-1, 60–65 cm, respectively, indicates that the latter assemblage may be attributable to Zone P21a. No planktonic foraminifers were found in Sample 115-711A-13X-1, 60–65 cm, whereas the uppermost sample (Sample 115-711A-12X-1, 60–65 cm) did not yield any younger elements indicative of the late Oligocene Zone P22 (see Fig. 9). The scarcity of planktonic foraminifers in the upper part of the sequence prevents identification of possible hiatuses.

Site 712

Site 712 is located on the northern margin of the Chagos Bank at a water depth of 2904.3 m. Hole 712A was rotary cored to a total depth of 115.3 mbsf and ended in middle Eocene nannofossil oozes and volcanic ashes. Recovery was 60% through the first 58.0 m of nannofossil oozes, and then fell abruptly to nearly nothing for the next 40 m.

We analyzed three samples from Core 115-712A-12R. All residues are rich in volcanic glass. Planktonic foraminifers exhibit a different preservation and abundance in the three samples, but they are generally broken and poorly preserved. Species diversity is high. The assemblages contain frequent *Subbotina cryptomphala, S. corpulenta,* and *S. praeturritilina* as well as common globigerinathekids, including *G. luterbacheri, G. mexicana, G. euganea,* and "*G.*" *senni*. The turborotaliids are represented by *T. pomeroli, T. possagnoensis, T. cerroazulensis,* and rare transitional forms to *T. cocoaensis*. The hantkeninids are mainly fragmented, but *H. alabamensis* could be identified. Rare *Dentoglobigerina galavisi, Pseudohastigerina barbadoensis, P. naguewichiensis,* and *Tenuitella gemma* are also recorded among others. This assemblage is attributable to late Zone P14 (latest middle Eocene). Reworking of early middle Eocene Zones P10-P11 planktonic faunas is heavy. Frequent to abundant radiolarians are also recorded along with rare sponge spicules.

Site 713

Site 713 was drilled close to Site 712 on the northern margin of the Chagos Bank at a water depth of 2915.3 m. Hole 713A was continuously cored to a total penetration of 192.0 m with the RCB. We retrieved 22 cores, for an average recovery rate of 60%. Hole 713A bottomed in basalt flows intercalated with nannofossil chalks of early middle Eocene age. The Paleogene sequence totally belongs to the Eocene. A major unconformity truncated the sequence in the late Eocene at the top of Core 115-713A-5R, which is overlain by Miocene sediments.

We analyzed 21 samples for their planktonic foraminifer content. Similar to the other sequences that span the middle to late Eocene interval from the westernmost sites previously described, planktonic foraminifer faunas from Hole 713A are strongly affected by reworking. Their abundance varies noticeably from layer to layer mainly because of dilution within volcanic material. Close to the lava flows, the preservation of planktonic foraminifers becomes very poor. Benthic foraminifers associated with planktonic faunas displayed a bathymetric range from upper to lower bathyal (*Aragonia* in Sample 115-713A-17R-1, 33–36 cm) to abyssal (Sample 115-713A-9R-2, 43–46 cm). Occasionally, a few shallow-water mollusc fragments were recorded.

Above the basalt, Samples 115-713A-17R-1, 33–36 cm, and 115-713A-16R-3, 8–12 cm, yielded planktonic faunas attributable to late Zone P11 based on the presence of *Turborotalia possagnoensis, Hantkenina mexicana, Morozovella lehneri, M. aragonensis,* and *Globigerinatheka index*. The planktonic foraminifer succession was interrupted by four cores with predominantly basalt flows. The next sample (115-713A-11R-3, 60–65 cm) yielded a planktonic fauna characteristic of Zone P12 (presence of *T. pomeroli*), which occurs up to Sample 115-713A-9R-2, 43–36 cm. The presence of *Globigerinatheka euganea* and *G. luterbacheri* associated with forms transitional between *Turborotalia possagnoensis* and *T. cerroazulensis* in Samples 115-713A-9R-1, 43–46 cm, and 115-713A-8R-3, 60–65 cm, suggests the presence of Zone P13. *Globigerinatheka tropicalis,* found in Sample 115-713A-8R-1, 60–65 cm, indicates that planktonic faunas from this level on are attributable to late middle Eocene Zone P14. The early late Eocene Zone P15 was identified in Sample 115-713A-3R-1, 60–65 cm, based on the occurrence of the *Turborotalia cerroazulensis*/*T. cocoaensis* transitional forms (Fig. 10). As at other sites mentioned above, reworked assemblages belong to late Paleocene faunas at the base of the sequence, and then mainly to early middle Eocene faunas. In some samples, the latter faunas overwhelm the younger planktonic foraminifers.

Site 714

Site 714 lies on the eastern shoulder of the Maldives Ridge. Two holes were drilled, but only Hole 714A recovered Paleogene sediments. Hole 714A was continuously cored in a water depth of 2038.3 m and ended in foraminifer-nannofossil chalk of late Oligocene age. Of the 25 cores recovered, 13 were retrieved with the APC and the remaining 12 with the XCB system. The total recovery rate was 83.5%. Paleogene sediments are represented by foraminifer-nannofossil chalk occasionally containing brecciated silicified limestone rich in redeposited shallow-water debris as in Core 115-714A-24X-CC (see Nicora and Premoli Silva, this volume). We analyzed 21 samples for their planktonic foraminifer

Table 4. Stratigraphic ranges of selected Oligocene planktonic foraminifers in Hole 709A.

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	Reworking	Contamination	Washed residues >40 µm	Washed residues >150 µm	Washed residues >250 µm	Preservation >40 µm	Preservation >150 µm	Preservation >250 µm	Volcanic glass >40 µm	Volcanic glass >150 µm	Volcanic glass >250 µm	Radiolarians >40 µm	Radiolarians >150 µm	Radiolarians >250 µm	Spicules >40 µm	Spicules >150 µm	Spicules >250 µm	*Dentoglobigerina globularis*	"*Globigerinoides*" *praeprimordius*	*Dentoglobigerina baroemoenensis*
Oligocene	N4	193.5	21H-1, 70–75	—	—	1	3/4	3/4	1/2	4/3	1/2	—	—	—	A/C	F/C	F	F	—	—	X		X
			21H-2, 70–75	—	—	2	3/2	2/3	2/1	3/2	2/3	—	—	—	C/A	C	VF	F	VF	VF	X		
	P22		21H-3, 70–75	—	—	1/2	3/2	2/1	1	3	2/3	—	VF	VF	A	C/F	F	X	—	—	X		X
			21H-4, 70–75	—	X	2	3/4	3	2/1	2	2	—	—	—	A	F	F	—	—	—	X		X
			21H-5, 70–75	X	—	2/1	3/2	3	2/1	2	2	F	VF	—	A	C/F	F	X	—	—	X	X	X
		203.1	21H-6, 70–75	—	—	2	3	3	1/2	2/1	2/1	—	—	—	C	C/F	C/F	X	—	—	X	X	X

Table 4 (continued).

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	*Globigerinita juvenilis*	"*Globigerina*" *angulisuturalis*	*Paragloborotalia opima nana*	"*Globorotalia*" *obesa*	"*Globigerina*" *ciperoensis ottnangiensis*	*Protentella* sp.	*Globorotaloides* sp. 1	*Cassigerinella chipolensis*	*Protentella clavaticamerata*	"*Globigerina*" *ciperoensis*/"*G.*" *angulioffcinalis*	*Paragloborotalia* sp.	*Paragloborotalia pseudocontinuosa*	"*Globorotalia*" *obesa*/*Globigerinella praesiphonifera*	*Tenuitella clemenciae*	*Tenuitella gemma*	*Globoquadrina tripartita*	"*Globoquadrina*" *tapuriensis*	*Globoquadrina sellii*	*Catapsydrax* sp.	*Globorotaloides variabilis*
Oligocene	N4	193.5	21H-1, 70–75	X		X	X	X	X	X	X	X		X	X		CF	X	CF	CF	X		X
			21H-2, 70–75	R		X	X	X		X	X	X		X	X	X	X	X	X		X		X
	P22		21H-3, 70–75	X		X	X	X		X	X	X		X		X	X	X	X	X		X	
			21H-4, 70–75	X	VR	X	X	X		X	X	X			X		X	X	X	X	X	X	X
			21H-5, 70–75	X	X	X	X	X		X	X	X				X	X	X	X	X	X	X	X
		203.1	21H-6, 70–75	X	VR	X	X	X	X	X	X	X	X	X	X	X	X	X					

Note: See note to Table 2 for legend.

content. Planktonic foraminifer distribution is reported in Table 7, and the main events are plotted in Figure 11.

The two lowermost samples (Samples 115-714A-25X-1, 125 cm, and 115-714A-25X-1, 110 cm) yielded the typical rich faunas of Zone P21 a, characterized by *Paragloborotalia opima opima,* chiloguembelinids, "*Globigerina*" *angulisuturalis, Globoquadrina praedehiscens,* and the *Dentoglobigerina globularis/ D. altispira globosa* transition, among others. The two samples from Core 115-714A-24X-1, 125 cm, and 115-714A-24X-1, 110 cm, contain *Globoquadrina binaiensis, Globigerinoides primordius,* protentellids, and *Globigerinita juvenilis,* among others, whereas *P. opima opima* is absent. This assemblage is attributable to Zone P22. Although the recovery of Core 115-714A-24X was only 1.5 m, a hiatus spanning Subzone P21b is hypothesized between the top of Core 115-714A-25X and the base of Core 115-714A-24X.

The remaining three cores contain a planktonic faunas representative of Zone P22. *Globoquadrina dehiscens* was recorded in Sample 115-714A-21X-CC, whereas "*Globorotalia*" *kugleri* is still missing, which prevents the identification of Zone N4.

SUMMARY AND CONCLUSIONS

The quality of the planktonic foraminifer assemblages examined from Paleogene Leg 115 was very uneven, from good to very good to total destruction. In the Eocene, well-preserved planktonic foraminifers are generally associated with mass-flow deposits that resulted in pelagic turbidites. In the Oligocene, well-preserved foraminifers apparently occur in undisturbed oozes.

Table 4 (continued).

Catapsydrax dissimilis ciperoensis	*Globoquadrina rohri*	*Dentoglobigerina altispira globosa*	*Globorotaloides* sp. 2	*Catapsydrax dissimilis dissimilis*	*Globoquadrina sellii/G. binaiensis*	*Globorotaloides suteri*	*Catapsydrax martini*	"*Globigerina*" *venezuelana*	*Globigerinoides primordius*	*Dentoglobigerina galavisi*	*Globoquadrina binaiensis*	*Globoquadrina praedehiscens*	*Dentoglobigerina* aff. *larmeui*	*Dentoglobigerina globularis/D. altispira globosa*	*Dentoglobigerina larmeui*	*Dentoglobigerina galavisi/D. baroemoenensis*	*Paragloborotalia siakensis*	"*Globorotalia*" *pseudokugleri* (ancestral form)	"*Globorotalia*" *pseudokugleri*	"*Globigerina*" *angulioffcinalis*	"*Tenuitella*" *angustiumbilicata*	"*Globigerina*" *ciperoensis*	*Globigerina praebulloides occlusa*	*Globigerina ouachitaensis*	*Subbotina brazieri*	"*Globigerina*" *angulioffcinalis*/"*G.*" *angulisuturalis*	*Paragloborotalia semivera*
	X	X	X	X		X	X		X		X	R	X	X	X		X		X	VR	X	X	X	X	X		X
	X	X	X	X		X		X	X		X	X	X		X		C	X	R		X	X		X	X	VR	X
X	X	X	X	X		X		X	X		X	X	X	X			X	X	X		X	X			X		X
	X	X	X	X		X	X	X	X		X	X	X	X	X	X	A	X	X		X	X		X	X		X
X	X	X		X		X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

Table 4 (continued).

Protentella aff. *prolixa*	*Catapsydrax unicavus*	*Globigerinella*? sp.	*Globorotaloides* aff. *stainforthi*	*Globigerinita juvenilis/G. uvula*	*Globorotaloides permicrus*	*Globoquadrina praedehiscens/G. dehiscens*	"*Globigerina*" sp. 2	*Globigerina officinalis*	"*Globigerina*" *fariasi*	*Protentella* sp. 1	*Tenuitella munda*	"*Globigerina*" *euapertura*	*Globoquadrina dehiscens*	"*Globorotalia*" *pseudokugleri*/"*G.*" *kugleri*	*Globigerina praebulloides*	"*Globorotalia*" *kugleri*	*Protentella navazuelensis*	"*Globigerina*" sp. 1	"*Globigerina*" *woodi*	*Globigerinita uvula*	*Globigerinita glutinata*
			R	X		X	X					X	C	X		C	X	X	X	X	X
X		X		RX		X	X	X				X	CF	X	X		X				
X		X	CF		X	X						X	CF	X	X	R					
X	X	X			CF	X	X	X	X	X	R										
X	X	X	CF	X																	

Poor preservation in planktonic foraminifers is particularly evident during the interval that spans the late Eocene through the early Oligocene, when heavily dissolved assemblages are recorded from the deepest holes, such as Holes 708A and 711A. There, the source area of turbidites was apparently well below the lysocline during that time.

Turbidite deposition was a constant characteristic of Paleogene sedimentation even at sites of actual intermediate depth. In fact, reworking also consistently affected planktonic foraminifer assemblages from all sites except for Holes 709B and 714A. In Site 714, however, Eocene shallow-water debris was redeposited in late Oligocene pelagic sediments, but apparently without involving any pelagic components. Constant redeposition and strong reworking began in the early middle Eocene and extended throughout the early Oligocene, even at Hole 709B. Reworking was also recorded in older (late Paleocene to middle early Eocene) sediments at Hole 707A, where volcaniclastic material was heavily mixed with pelagic sediments. The quietest sedimentation apparently occurred in late Oligocene Zone P22, when reworking markedly decreased, even at Hole 709C.

Despite these sedimentary disturbances, there was enough evidence to allow the biostratigraphic assignment of the sediments and to detect hiatuses. A summary of these zonal assignments for the Paleogene is given in Figure 12, where Leg 115 holes are plotted with sites previously drilled in nearby Indian Ocean locations. As at the Leg 115 holes from the Mascarene Plateau–Seychelles Bank and the surrounding basin, Holes 236 and 237 recovered highly mixed assemblages for most of the Eo-

Table 5. Stratigraphic ranges of selected Oligocene to earliest Miocene planktonic foraminifers in Hole 709B.

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	Reworking	Contamination	Washed residues			Preservation			Volcanic glass			Radiolarians			Spicules			*Dentoglobigerina larmeui*	*"Globigerina" prasaepis*	*Globorotaloides suteri*	*Dentoglobigerina baroemoenensis*	*Dentoglobigerina* aff. *larmeui*	*Globoquadrina tripartita*	*Globoquadrina rohri*	*"Globigerinoides" praeprimordius*	*Globoquadrina sellii*	*Dentoglobigerina galavisi*	*Dentoglobigerina globularis*	*Subbotina praeturritilina*	*Catapsydrax martini*	*Catapsydrax unicavus*	*Paragloborotalia opima nana*
						>40 μm	>150 μm	>250 μm	>40 μm	>150 μm	>250 μm	>40 μm	>150 μm	>250 μm	>40 μm	>150 μm	>250 μm	>40 μm	>150 μm	>250 μm															
Miocene	N4	187.2	21X-1, 80-85	—	—	2	3	4/3	3	2	3	—	—	—	C	C	F	—	—	—			X		X	X	X		X	CF					X
			21X-2, 80-85	X	—	1	3	4	1	2	3/2	—	—	—	C	F	—	—	—	—	X		X		X	X	X		X	X					X
			21X-3, 80-85	—	—	1	3	3	2	3	2	—	—	—	C	F	—	X	—	—	X	X	X		X	X	X		X	X			X		X
			21X-4, 80-85	X	—	1	3	3/2	1	3	2	—	—	—	C	F	C	—	—	—			X		X	CF	X		X	X	X		X		X
Oligocene			21X-5, 80-85	—	X	1	2	3	1	2/3	3/2	—	VF	—	C	F	C	—	—	—	X		X	X	X		X		X	X				X	X
			21X-6, 80-85	—	—	2	3	3	1	2	2	—	—	—	F	F	F	—	—	—	X	X	X	X	X	X	X		X	X	X		X	X	X
		196.8	22X-1, 80-85	—	—	2	4	4	1	4	3/2	—	—	—	C	C	F	—	—	—		X	X	CF	X	X	X	CF	X	X	X			X	X
			22X-2, 80-85	—	—	2	3	4	2	3	3	—	—	—	C	F	F	—	—	—	X		X		X	X	X	CF	X	X	X	CFR	X	X	
	P22		22X-3, 80-85	—	—	1	2	3	2	3	3	—	—	—	C	F	F	—	—	—		CF	X	X	X	CF	X				X	X		X	X
			22X-4, 80-85	—	—	1	3	4/3	1	2	2/3	VA	VA	C	A	F	F	—	—	—	X		X	X	X	X	X		X	X	X		X		X
			22X-5, 80-85	—	—	1	3	4/3	2	3	2	C	X	VR	A	C	F	—	—	—	X		X	X	X	X	X		X	X	X	X		X	X
			22X-6, 80-85	—	—	2	4	4	3	2	2/3	—	—	—	C	C	F	—	—	—	X		X	CF	X	X	X		X	X	X	X	X	X	X
		206.5	23X-1, 80-85	—	—	2	3	4/3	1	3	2	—	—	—	C/A	C	F	—	—	—			X		X	X	X	CF	X	X	X	CF	X	X	X
			23X-2, 80-85	—	—	1	3	4/3	1	3	2	—	—	—	C	F	F	—	—	—	X	X	X	CF	X	X	X		X	X	X	X	X		X
			23X-3, 80-85	—	—	1	3	4/3	1	2	2	F	—	—	F	F/C	F	—	—	—		X	X	CF	X	X	X	X	X	X	X	X	X		X
			23X-4, 80-85	—	—	1	3	3	2	3	4	—	—	—	C	C	—	—	—	—			C		X	X	X		X	X	X	X	X	X	X
			23X-5, 80-85	—	—	1/2	4	4	4	4	3	—	—	—	C	C	F	—	—	—		X	X		X	X	X	VR	X	X	X	X	X	X	X
	P21b	216.1	24X-1, 80-85	—	—	2	1	3/2	3	3	2	—	—	—	C	F	—	—	—	—			X		X	X	X		X		X	X	X	X	X
			24X-2, 80-85	—	—	1	2	2/1	2	2	2	—	—	—	C	C	F	VF	—	—		X	X	X	X	X	X		X	X	X	X	X	X	X
	P21a		24X-3, 80-85	—	—	1	1	3	2	2	2	C	F	—	A	F	F	X	—	—	X		X	X	X	X	X		X	X	X	CF	X	X	X
			24X-4, 80-85	F	—	1	1/2	3	3	3	2	—	—	—	A	F	—	—	—	—	X		X	CF	X	X	X	CF	X	X	X	X	X		X
			24X-5, 80-85	—	—	2	3	4/3	2	2	3	—	—	—	C	C	—	—	—	—	X	X	X		X	X	X	X	X		X	X	X	X	X
			24X-6, 80-85	—	—	1	2	3	4	3	3	—	—	—	C	F	—	—	—	—			X	R	X	X	X		X	X	X	X	X	X	X
		225.8	25X-1, 80-85	—	—	2	2	2	2	2	3	—	—	—	C	F	F	X	—	—	X	X	X	X	X	X	X		X	X	X	X	X	X	X
			25X-2, 80-85	—	—	2	1/2	1/2	2	3	1	—	F	F	C	C	F	X	—	—	X		X	X	X	X	X		X	X	X	X	X	X	X
			25X-3, 80-85	—	—	2	2/3	2/3	3	2	2	—	—	—	C	F	F	X	—	—		X	X	X	X	X	X	X	X	X	X	X	X	X	X
			25X-4, 80-85	—	—	3	3/2	2/3	3	2	3	F	X	X	C	C	—	C	—	—		X	X	X	X	X	X	CF	X	X	X	X	X	X	X
			25X-5, 80-85	—	—	3	4/3	4	4	2	3	F	X	—	A	C	—	A	—	—	CF		X	X	X	X	X	CF	X	X	X	X	X	X	X
			25X-6, 80-85	—	—	2	2	2	2	3	2	—	—	—	A	A	—	—	X	—	X		X	X	X	X	X		X	X	X	X	X	X	X
		235.5	26X-1, 80-85	—	—	2	2	2	2	4	2	—	F	—	A	C	F	—	—	—		X	X	X	X	X	X		X		X	X	X	X	X
			26X-2, 80-85	—	—	1	2	2	2	3	3	VA	A	C	A	A	F	X	—	—			X	X	X	X	X		X		X	X	X	X	X
			26X-3, 80-85	—	—	2	2/3	2	3	3	3	X	F	—	C	C	—	—	X	—		X	X	X	X	X	X		X	X	X	X	X	X	X
			26X-4, 80-85	—	—	2	2	3	2	3	3	—	X	—	A/C	C	F	—	—	—			X	X	X	X	X		X	X	X	X	X	X	X
	P20	245.1	27X-1, 80-85	—	—	2	4/3	4	3	4	3	X	F	—	C	F	F	—	—	—	X	X	X	X	X	X	X	X		X	CF	X	X	X	X
			27X-2, 80-85	—	—	3	2/3	3	3	3	3	X	X	—	C	C	F	—	—	—		X	X	X	X	X	X		X	X	X	C	X	X	X
			27X-3, 80-85	—	—	2	3/2	3	2	3	2/3	—	—	F	C	C	—	—	—	—	CF	X	X	X	X	X	X		X	X	X	X	X	X	X
			27X-4, 80-85	—	—	3	2/3	2/3	2	3	3	—	F	—	C	F	—	—	—	—		X	X	X	X	X			X	X	X	X	X	X	X
			27X-5, 80-85	—	—	2	4	4	2	4	2	—	—	—	C	F	—	—	—	—		X	A		X	X	X		X		X	X	X	X	X
		253.3	27X-6, 74-78	—	—	2	2/3	3/4	2	2	2	—	—	—	A	F	—	—	—	—	X	X	A	X	X	X	X	X	X	X	X	X	X	X	X

Note: See note to Table 2 for legend.

Table 5 (continued).

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	"Globoquadrina" tapuriensis	Paragloborotalia siakensis	Paragloborotalia pseudocontinuosa	"Globigerina" aff. ampliapertura	"Globigerina" venezuelana	Paragloborotalia opima opima	Globoquadrina praedehiscens	Catapsydrax dissimilis dissimilis	Globorotaloides variabilis	Subbotina angiporoides angiporoides	Subbotina angiporoides group	"Globigerina" ampliapertura	"Globigerina" euapertura	Globorotaloides sp. 1	Globigerina officinalis	Cassigerinella chipolensis	Chiloguembelinids	Globigerina praebulloides	Tenuitella gemma	"Tenuitella" angustiumbilicata	Tenuitella munda	Tenuitella clemenciae	Turborotalia pseudoampliapertura	Catapsydrax sp.	Subbotina gortanii	Turborotalia increbescens	Globigerina ouachitaensis	Turborotalia pseudoampliapertura/T. increbescens	Dentoglobigerina galavisi/D. baroemoenensis	Subbotina utilisindex	Paragloborotalia sp.
		187.2	21X-1, 80–85		X			X		X	X					X		X				X	X	CF			X			X				
			21X-2, 80–85		X	X		X		X		CF				X	X	X	X		X	X	X		X		X							
Miocene			21X-3, 80–85		X	X					X					X		X	X		X		X		X		X							
	N4		21X-4, 80–85		X	X		X		X	X							X	X		X	X	X		X		X			X				X
			21X-5, 80–85	X	X	X				X	X					X	X	X	X		X	X	X	CF			X			X				
			21X-6, 80–85	X	X	X		X		X	X	X					X	X	VR		X	X	X	CF	X					X				
		196.8	22X-1, 80–85	X	X	X				X	X	X						X	X			X	X		X					X				
			22X-2, 80–85	X	X	X				X	X	X				CF		X	X		X	X	X	CF	X		X			CF				
			22X-3, 80–85		X	X				X	X	X					X	X	X		X	X	X	X	X		X			X		X		
			22X-4, 80–85		X	X				X	X	X						X	X		X	X	X		X		X			X				
			22X-5, 80–85		X	X				X	X	X						X	X		X	X	X	X	X		X			X				
			22X-6, 80–85	X	X	X				X		X				X	X	X	X		X	X	X		X		X			X		X		
	P22	206.5	23X-1, 80–85		X	X		X		X	X	X						X	A		X	X	X		X		X			X		X		
			23X-2, 80–85	X	X	X		X		X	X	X				X		X	X			X	X	X						X				
			23X-3, 80–85		X	X		X		X	X	X				X		X	X		X	X	X		X		X			X				
			23X-4, 80–85	X	X	X				X	X	X					X	X	X		X	X	X	X	X		X			X				
			23X-5, 80–85	X	X	X		X		X	X	X				X	X	X	X		X	X	X	X	X		X			X				
		216.1	24X-1, 80–85	X	X	X		X	CFVR	X	X	X				X	X	X	X		R	X	X	X	X		X	X		X				X
	P21b		24X-2, 80–85	X	X	X		X	X	X	X	X						X	X		X	X	X	X	X		X	CF		X				
			24X-3, 80–85	X	X	X		X	X	X	X	X					X	X	X			X	X		X		X			X				
			24X-4, 80–85	X		X		X	X	X	X	X		CF		X	X	X	A	X	X	X	X	X	X		X	X		X		X		
			24X-5, 80–85	X	X	X		X	X	X	X	X		CF		X		X	X	C		X	X	X	X					CF				
Oligocene			24X-6, 80–85	X	X	X		X	X	X	X	X				X		X	X	X	R	X	X	X	X			R		X				
		225.8	25X-1, 80–85	X	X	X		X	X	X	X	X				X	X	X	X	C		X	X	X	X		X			X				X
	P21a		25X-2, 80–85	X	X	X		X	X	X	X	X				X	X	X	X	F	X	X	X	X	X			X		X		X		X
			25X-3, 80–85	X	X	X		X	X	X	X	X		X			X	X	X	X		X	X	X	X		X			X				
			25X-4, 80–85	X	X	X	CFVR	X	X			X		X		X	X	X	X	X	X	X	X	X	X					X				
			25X-5, 80–85	X	X	R		X	X		X	X						X	X	X		X	X	X	X					X			X	
			25X-6, 80–85	X	X	X		X	X	X	X	X	X			X	X	X	X	X		X	X	X	X		X	X		X		X		X
		235.5	26X-1, 80–85	X	X	X	R	X	X		X	X				X	X	X	X	X	X	X	X	X	X		X	X		X			X	
			26X-2, 80–85	X	X	X	R	X	X		X	X	X	X		X		X	X	X		X	X	X	X			X		X		X	X	
			26X-3, 80–85	X		X	R	X	X	X	X	X	X	X		X	X	R	X	X	X	X	X	X	X		X	X		X		X	X	X
			26X-4, 80–85	X	X	X	F	X	X	X	X	X	X	X		X	X	X	X	F		A	X	X	A		X	X		X			R	X
		245.1	27X-1, 80–85	X		X	X	X	X	X	X	X	X	X	CF	X	X	X		X		X	X	X	X	X	X	X	X			X		X
			27X-2, 80–85	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	A	X	C	X					
	P20		27X-3, 80–85	X		X	X		X	X			X	X	VR	X	X	X		X		X	X	X		A	X		X	X				X
			27X-4, 80–85		X	X	X	X	X	X	X	X			CF	X	X	X	X	A		X	X	X	X	X	X	X	X		X			X
			27X-5, 80–85	X		X	X	X	X		X	X	X	X	VR	X	X	X	X	A		X	X	R	X	X	X	X	F	X	X	X	X	X
		253.3	27X-6, 74–78	X	X	X	X	X	X	X	R	X	X	X	VR	X	X	X	X	A	R	A	X	X	X									

Note: See note to Table 2 for legend.

Table 5 (continued).

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	"Globorotalia" obesa	Globigerinita juvenilis	"Globigerina" ciperoensis	Tenuitella clemenciae/T. munda	"Globigerina" ciperoensis/"G." anguliofficinalis	Catapsydrax dissimilis ciperoensis	Subbotina brazieri	"Globigerina" sp. 1	"Globigerina" anguliofficinalis	Paragloborotalia semivera	Globigerinella? sp.	Protentella sp. 1	Protentella navazuelensis	Dentoglobigerina globularis/D. altispira globosa	Globigerina praebulloides occlusa	Dentoglobigerina altispira globosa	"Globigerina" anguliofficinalis/"G." angulisuturalis	"Globigerina" angulisuturalis	Globorotaloides permicrus	Cassigerinella martinezpicoi	Protentella sp.	Subbotina praeturritilina/S. gortanii	Globigerinita juvenilis/G. uvula	Globigerinita uvula	Cassigerinella globulosa	"Globigerina" sp. 2	"Globigerina" fariasi	"Globigerina" woodi	Globorotaloides sp. 2	Globoquadrina binaiensis	Globigerinoides primordius
Miocene	N4	187.2	21X-1, 80–85	X	X	CF			X	X		CF	X	X			X							X		X	X		X		X			X
			21X-2, 80–85	X	X				X	X	X		X					X	X							X	X		X		X	X	X	
			21X-3, 80–85	X	X				X	X	X	CF	X					X	X								X		X		X	X	X	X
			21X-4, 80–85	X	X				X	X	X			X	R		X		X			X				X	X		X		X	X	X	X
			21X-5, 80–85	X	X	X	X		X	X					X		X	X	X					X		X	R	X	X		X			X
Oligocene			21X-6, 80–85	X	X	CF			X	X			X	X	X	X	X		X							X				X	CF	C	X	X
		196.8	22X-1, 80–85	X	X		X		X	X			X	X	X	X	X	X	X									X			CF	X	X	
	P22		22X-2, 80–85	X	X	X	X		X	X				X		X	X	X	X					X							X	X	X	X
			22X-3, 80–85	X	X	X			X	X		X	X		X		X	X	X	X	X			X		X	X	X		X	X	X	X	X
			22X-4, 80–85	X	X	X			X	X		X	X	X	X		X	X	X		VR			X		X			X	X	X	X	X	X
			22X-5, 80–85		X	X			X	X	X	X		X		X	X	X	X			X		X				X	X		X		X	X
			22X-6, 80–85	X	X	X			X			X	X				X		X					X		CF			X	X				
		206.5	23X-1, 80–85	X	X	X			X	X	X	X	X						X		X			X		X		X	X	X	X		X	X
			23X-2, 80–85	X	X	X			X	X	A	X		X					X		X			X				X	X		X		X	X
			23X-3, 80–85	X	X	X			X	X	X	X			X			X	X		R	X		X				X	X	X			X	X
			23X-4, 80–85	X	X	X			X	X		X	X	X	X		X		X		X							X	X	X			CF	X
			23X-5, 80–85	X	X	X			X	X	X	X		X			X				X								X	X			X	
	P21b	216.1	24X-1, 80–85		X	X	X		X	X	X	X	X				X	X	X		R	X						X	X			CF		
			24X-2, 80–85	X	X	X			X	X	X	X					X	X	X		X	X		X		X		X	X		X			
	P21a		24X-3, 80–85		X	X	X	X	X	C		X	CF				X	X	X		X	X							X	X				
			24X-4, 80–85		X		X		X	X	X	X					X		X		X	X						X	X					
			24X-5, 80–85			X	X		X	X	X	X	X				X	X	X		X	X		X				X	X					
			24X-6, 80–85	X	X	X		X		X		X					X		X		X						CFR	R						
		225.8	25X-1, 80–85	X		X			X			X	CF				X		X		C	X					CF							
			25X-2, 80–85	X		X			X	X		X					X			X	X	X				X								
			25X-3, 80–85	X	X	X	X			X		X									X	X												
			25X-4, 80–85		X	X			X	C		X					X				X	X		X	X									
			25X-5, 80–85	R		X			X	X											X	X			X									
			25X-6, 80–85	X		X		X	X	X	R	X	X		X		X				R			X										
		235.5	26X-1, 80–85		F	X			X	X	R	X					X	X	X		X	X	X											
			26X-2, 80–85	X	F	X	X		X	X		X			X		X		X	X														
			26X-3, 80–85	X		X				X	R	X			X		X	X																
			26X-4, 80–85		F	X		X	X	X	R		CF	VR	VR	VR																		
	P20	245.1	27X-1, 80–85		CF				X		R																							
			27X-2, 80–85				X		X	X	R	X																						
			27X-3, 80–85						X																									
			27X-4, 80–85				X	CF																										
			27X-5, 80–85	CF	CF	CF																												
		253.3	27X-6, 74–78																															

Table 5 (continued).

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	"*Globorotalia*" *pseudokugleri*	"*Globigerina*" *ciperoensis ottnangiensis*	"*Globorotalia*" *pseudokugleri* (ancestral form)	*Protentella* aff. *prolixa*	"*Globorotalia*" *obesa*/*Globigerinella praesiphonifera*	*Globoquadrina praedehiscens*/*G. dehiscens*	*Globoquadrina dehiscens*	*Protentella clavaticamerata*	"*Globorotalia*" *pseudokugleri*/"*G.*" *kugleri*	*Globorotaloides* aff. *stainforthi*	"*Globorotalia*" *kugleri*	*Globorotaloides stainforthi*	*Globigerinita glutinata*	*Globigerinoides bollii*	*Globigerinoides immaturus*	*Globigerinoides trilobus*	*Streptochilus* sp.
		187.2	21X-1, 80–85	X	X	X			X					A	X	X	CF	X		VR
			21X-2, 80–85	X	X									X	X	X	CF	X	CF	VR
Miocene			21X-3, 80–85	X	X	X	X	X						C	X	X	CF	X	CF	
	N4		21X-4, 80–85	X				X					X	X	X	X	CF	X		
			21X-5, 80–85	X	X	X		X	C	A	X	X	X	R	CF	X	CF	X	CF	R
			21X-6, 80–85	X	X	X	X	X	X			C	X	R	X	X				
		196.8	22X-1, 80–85	X		X		X	C	F		X	X							
			22X-2, 80–85	X	X	X	X		X	X		X	X	R						
			22X-3, 80–85	X		X						X								
			22X-4, 80–85	X		X	X	X	X	X	X									
			22X-5, 80–85	C		X	X	X	X											
			22X-6, 80–85	X		X														
	P22	206.5	23X-1, 80–85	X		X														
			23X-2, 80–85	X		X		X												
			23X-3, 80–85	VR		X	X													
			23X-4, 80–85	X	X	X	X													
			23X-5, 80–85																	
		216.1	24X-1, 80–85																	
	P21b		24X-2, 80–85																	
			24X-3, 80–85																	
			24X-4, 80–85																	
			24X-5, 80–85																	
Oligocene			24X-6, 80–85																	
		225.8	25X-1, 80–85																	
	P21a		25X-2, 80–85																	
			25X-3, 80–85																	
			25X-4, 80–85																	
			25X-5, 80–85																	
			25X-6, 80–85																	
		235.5	26X-1, 80–85																	
			26X-2, 80–85																	
			26X-3, 80–85																	
			26X-4, 80–85																	
		245.1	27X-1, 80–85																	
			27X-2, 80–85																	
	P20		27X-3, 80–85																	
			27X-4, 80–85																	
			27X-5, 80–85																	
		253.3	27X-6, 74–78																	

Note: See note to Table 2 for legend.

Table 6. Stratigraphic ranges of selected Oligocene planktonic foraminifers in Hole 710A.

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	Reworking	Contamination	Washed residues >40 μm	Washed residues >150 μm	Washed residues >250 μm	Preservation >40 μm	Preservation >150 μm	Preservation >250 μm	Volcanic glass >40 μm	Volcanic glass >150 μm	Volcanic glass >250 μm	Radiolarians >40 μm	Radiolarians >150 μm	Radiolarians >250 μm	Spicules >40 μm	Spicules >150 μm	Spicules >250 μm	*Turborotalia pseudoampliapertura*	*Turborotalia increbescens*	*Catapsydrax unicavus*
Oligocene	P22	145.8	16X-3, 75–80	—	—	1	2/3	3	2	3/2	1	—	—	—	A	A/C	F	X	F	VF			X
	P22	155.5	17X-3, 75–80	—	—	1	3	3	3/4	4	4	—	—	—	C	C/F	C/F	X	—	—			
	P22	165.1	18X-3, 75–80	X	—	2/1	2/1	2/3	4	3/4	2/3	—	—	—	C	C/F	F	—	—	—			X
	P22	174.8	19X-3, 75–80	—	—	2/3	3/2	3	4	3/4	3/2	—	—	—	C	C/A	F	C	—	—			
	P21b?	184.5	20X-3, 75–80	X	X	1	3/2	3	4/3	3/4	4	VA	VA	A	VA	VA	F	X	X	—			
	P20	194.1	21X-3, 75–80	—	VF	2	3	3	4	3/4	3/2	X	F	—	A	C	F	C	—	—	X	X	X
	P20	203.8	22X-3, 75–80	F	F	3/2	4	4/5	3/4	2	3/4	X	—	—	A	C/A	F	VF	—	—	R	R	X

Table 6 (continued).

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	*Catapsydrax martini*	*"Globigerina" aff. ampliapertura*	*Dentoglobigerina globularis*	*"Globigerina" prasaepis*	*"Globigerina" sp. 1*	*"Globigerina" ampliapertura*	*Paragloborotalia sp.*	*"Globigerina" ciperoensis*	*Globorotaloides sp. 1*	*Paragloborotalia siakensis*	*"Globorotalia" obesa*	*Cassigerinella chipolensis*	*Catapsydrax dissimilis ciperoensis*	*Globorotaloides permicrus*	*Globigerina officinalis*	*Dentoglobigerina globularis/D. altispira globosa*	*Globigerina praebulloides*	*Subbotina brazieri*	*Globorotaloides sp. 2*	*Dentoglobigerina altispira globosa*
Oligocene	P22	145.8	16X-3, 75–80			X		X			X		X			X			X		X	R	X
	P22	155.5	17X-3, 75–80					X			X		X							X			
	P22	165.1	18X-3, 75–80	X		X		X			X		X		X	X					X	X	X
	P22	174.8	19X-3, 75–80	X									X	X		X		X	X	X	R		
	P21b?	184.5	20X-3, 75–80	X			X						X			X	X	X					
	P20	194.1	21X-3, 75–80	X	X	X	X	R	X	X	X	X	R	X	R								
	P20	203.8	22X-3, 75–80																				

Note: See note to Table 2 for legend.

cene, whereas quiet pelagic sedimentation was recorded in late Oligocene times. Moreover, at Hole 237 an important hiatus spans the interval from late Eocene Zone P17 to late Oligocene Zone P21a. This hiatus corresponds to the upper portion of the major dissolution interval (late Eocene) associated with reworking recorded at Hole 711A. The only other event that has a less local significance is a hiatus eliminating Subzone P21b, which occurs at such intermediate depth locations as Hole 714A on the Maldives Ridge, the deeper Hole 710A, and Site 223 much farther to the north in 3633-m water depth. If this hiatus at the shallowest site is related to the major fall in sea level that occurred globally at this time (see Nicora and Premoli Silva, this volume), it is not clear why it also occurs at a depth close to 4000 m, as in Hole 710A.

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Table 6 (continued).

"Globoquadrina" tapuriensis	Globorotaloides suteri	Catapsydrax sp.	Dentoglobigerina baroemoenensis	Globoquadrina tripartita	Globorotaloides variabilis	Globoquadrina sellii	Globoquadrina rohri	Dentoglobigerina aff. larmeui	Globoquadrina praedehiscens	Dentoglobigerina galavisi	Catapsydrax dissimilis dissimilis	Paragloborotalia pseudocontinuosa	Subbotina utilisindex	Subbotina angiporoides angiporoides	Paragloborotalia opima nana	Subbotina angiporoides group	Turborotalia pseudoampliapertura/T. increbescens	Paragloborotalia opima opima	Chiloguembelinids	Tenuitella gemma	Tenuitella clemenciae	Tenuitella munda	"Tenuitella" angustiumbilicata	Subbotina praeturritilina	"Globigerina" venezuelana	Dentoglobigerina larmeui
X	X	X	X			X	X	X	X			X			X					X	X		X		X	X
CF	X		CF	X	X	X	X	X	X		X	X			X					X	X		X			
X	X			X		X	X	X	X		X	X			X					X	X			X	X	X
X	X				X	X	X	X	X		X	X			X					X	X		X	X		
X	X	X		X	X	X	X	X							X			X		X	X			X	X	
X	X	X		X	X	X	X	X	CF			X	X		X			X	VR	X	X		X	X	X	X
X	X	X	X	X	X	R	X	X	CF	X	X	X	C	X	X	X	VR	X	X	X	X	X	X			

Table 6 (continued).

Paragloborotalia semivera	Protentella sp.	Globigerinita juvenilis	"Globorotalia" pseudokugleri (ancestral form)	Protentella clavaticamerata	Globigerina ouachitaensis	Protentella aff. prolixa	"Globorotalia" pseudokugleri	"Globigerina" ciperoensis ottnangiensis	"Globigerina" angulioffcinalis	"Globorotalia" obesa/Globigerinella praesiphonifera	Globigerinella? sp.	Globoquadrina binaiensis	Globoquadrina praedehiscens/G. dehiscens	Globoquadrina dehiscens	"Globigerina" woodi	"Globigerina" angulioffcinalis/"G." angulisuturalis
X		X	X	X		X	X	X				X	X	CF	X	X
		X	X	X	X	X	X	X	X	X	X					
X	X	X	CFVR													

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SPECIES LIST AND TAXONOMIC NOTES

The list of species is particularly rich. This signifies the abundance and high diversity of planktonic foraminifer faunas encountered in the Paleogene sediments recovered in the Indian Ocean during Leg 115. Species are listed in alphabetical order by genus. In the list are included all the species identified, although some of them were not specifically mentioned either in the text or in the range charts.

The generic and specific concepts and the species groups used by Boersma and Premoli Silva (1983); Boersma et al. (1987); and Premoli Silva and Boersma (1988, 1989) are retained in this paper, whenever possible. Reference is made to the most reliable illustrations reported in the literature.

The species illustrated in this paper are those rarely given elsewhere or those of stratigraphic interest.

Acarinina acarinata Subbotina, 1953. See Subbotina (1953), Pl. XXII, Figs. 4a–c.

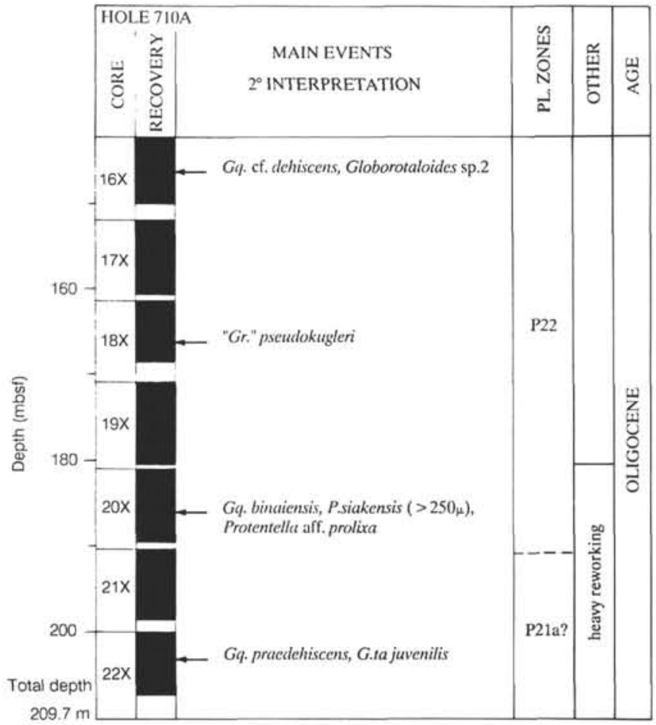

Figure 8. Main planktonic foraminifer events in Hole 710A plotted vs. biozone assignment.

"*Acarinina*" *aculeata* (Jenkins, 1971) (= *Globorotalia (Turborotalia) aculeata* Jenkins). See Jenkins (1971), Figs. 250–256.

"*Acarinina*" *aquiensis* (Loeblich and Tappan, 1957) (= *Globigerina aquiensis* Loeblich and Tappan). See Loeblich and Tappan (1957), Pl. 56, Figs. 4a–6c.

Acarinina boudreauxi Fleisher, 1974. See Fleisher (1974), Pl. 1, Figs. 2–5.

Acarinina bullbrooki (Bolli, 1957) (= *Globorotalia bullbrooki* Bolli). See Bolli (1957c), Pl. 38, Figs. 4–5.

"*Acarinina*" *chascanona* (Loeblich and Tappan, 1957) (= *Globigerina chascanona* Loeblich and Tappan). See Loeblich and Tappan (1957), Pl. 49, Figs. 4–5c.

Acarinina collactea (Finlay, 1939) (= *Globorotalia collactea* Finlay). See Jenkins (1965), Figs. 1–27.

Acarinina decepta (Martin, 1943) (= *Globigerina decepta* Martin). See Martin (1943), Pl. 7, Figs 2a–c.

"*Acarinina*" *echinata* (Bolli, 1957) (= *Catapsydrax echinatus* Bolli). See Bolli (1957c), Pl. 37, Figs. 2–5.

Acarinina esnaensis (Le Roy, 1953) (= *Globigerina esnaensis* Le Roy). See Le Roy (1953), Pl. 6, Figs. 8–10.

Acarinina gravelli (Brönnimann, 1952) (= *Globigerina gravelli* Brönnimann). See Brönnimann (1952), Pl. 1, Figs. 16–18.

Acarinina hainesi (Samanta, 1970) (= *Truncorotaloides hainesi* Samanta). See Toumarkine and Luterbacher (1985), Fig. 32 (2–3).

Acarinina intermedia Subbotina, 1953. See Subbotina (1953), Pl. XX, Figs. 14–16.

Acarinina libyaensis (El Khoudary, 1977) (= *Truncorotaloides libyaensis* El Khoudary). See Toumarkine and Luterbacher (1985), Fig. 32 (4–6).

Acarinina mckannai (White, 1928) (= *Globigerina mckannai* White). See Toumarkine and Luterbacher (1985), Fig. 18 (3–6).

Acarinina matthewsae (Blow, 1979) (= *Globorotalia (Acarinina) matthewsae* Blow). See Blow (1979), Pl. 170, Figs. 1–9.

Acarinina mattseensis alticonica Fleisher, 1974. See Fleisher (1974), Pl. 2, Figs. 1–5.

Acarinina medizzai (Toumarkine and Bolli, 1975) (= *Globigerina medizzai* Toumarkine and Bolli). See Toumarkine and Bolli (1975), Pl. 5, Fig. 16; Pl. 6, Figs. 1, 5, 7, and 8. This form seems closely related to *Acarinina rugosoaculeata*.

Acarinina nitida (Martin, 1943) (= *Globigerina nitida* Martin). See Martin (1943), Pl. 7, Fig. 1. We consider this species separate from *A. acarinata* because of its more subquadrate equatorial profile, less rounded axial periphery, more subrectangular chambers on the dorsal side of the last whorl, and more umbilical-extraumbilical aperture.

Acarinina pentacamerata Subbotina, 1953. See Subbotina (1953), Pl. XXIV, Figs. 1–6.

Acarinina pentacamerata acceleratoria Khalilov, 1956. See Khalilov (1956), Pl. 5, Figs. 7a–7c.

Acarinina pentacamerata camerata Khalilov, 1956. See Khalilov (1956), Pl. 5, Figs. 6a–c.

Acarinina planodorsalis Fleisher, 1974. See Fleisher (1974), Pl. 2, Figs. 6–9; Pl. 3, Figs. 1 and 2.

Acarinina praetopilensis (Blow, 1979) (= *Globorotalia (Truncorotaloides) topilensis praetopilensis* Blow). See Blow (1979), Pl. 169, Figs. 1–9. This species occurs in Zone P9 and is ancestral to *A. topilensis*, a characteristic form of the middle Eocene.

Acarinina primitiva (Finlay, 1939) (= *Globoquadrina primitiva* Finlay). See Jenkins (1971), Pl. 18, Figs. 555–561.

Acarinina pseudotopilensis Subbotina 1953. See Subbotina (1953), Pl. XXI, Figs. 8–9; Pl. XXII, Figs. 1–2.

Acarinina punctocarinata Fleisher, 1974. See Fleisher (1974), Pl. 3, Figs. 4–8.

Acarinina rohri (Brönnimann and Bermudez, 1953) (= *Truncorotaloides rohri* Brönnimann and Bermudez). See Toumarkine and Luterbacher (1985), Fig. 33 (12–18).

Acarinina rohri piparoensis (Brönnimann and Bermudez, 1953) (= *Truncorotaloides rohri* var. *piparoensis* Brönnimann and Bermudez). See Toumarkine and Luterbacher (1985), Fig. 32 (11).

Acarinina rotundimarginata Subbotina, 1953. See Subbotina (1953), Pl. XXV, Figs. 1–3.

Acarinina rugosoaculeata Subbotina, 1953. See Subbotina (1953), Pl. XXV, Figs. 4–5.

Acarinina soldadoensis (Brönnimann, 1952) (= *Globigerina soldadoensis* Brönnimann). See Sigal (1974), Pl. 6, Figs. 1a–c.

Acarinina soldadoensis angulosa (Bolli, 1957) (= *Globigerina soldadoensis* Brönnimann subsp. *angulosa* Bolli). See Bolli (1957a), Pl. 16, Figs. 4–6.

Acarinina spinuloinflata (Bandy, 1949) (= *Globigerina spinuloinflata* Bandy). See Cifelli (1972), Figs. 2a–c.

Acarinina topilensis (Cushman, 1925) (= *Globigerina topilensis* Cushman). See Toumarkine and Luterbacher (1985), Fig. 33 (1–7).

Acarinina velascoensis (Cushman, 1925) (= *Globigerina velascoensis* Cushman). See Sigal (1974), Pl. 6, Figs. 7a–c.

Cassigerinella chipolensis (Cushman and Ponton, 1932) (= *Cassidulina chipolensis* Cushman and Ponton). (Plate 1, Figs. 3a–c). See Bolli and Saunders (1985), Fig. 16 (1–2).

Cassigerinella globulosa (Egger, 1957) (= *Cassidulina globulosa* Egger). (Plate 1, Figs. 1a–c). See Rögl (1985), Fig. 5 (18–20).

Cassigerinella martinezpicoi (Bermudez and Seiglie, 1967) (= *Riveroinella martinezpicoi* Bermudez and Seiglie). (Plate 1, Figs. 2a–c). See Bermudez and Seiglie (1967), Pl. 1.

Catapsydrax dissimilis (Cushman and Bermudez, 1937) (= *Globigerina dissimilis* Cushman and Bermudez). See Blow and Banner (1962), Pl. XIV, Fig. d. Also included here are specimens that exhibit a lobulate periphery like typical *C. dissimilis* and possess, when present, a clear bulla with only two infralaminal accessory apertures. *Catapsydrax dissimilis*, considered to appear in the early Oligocene (Molina, 1979), is recorded since the early middle Eocene Zone P11 in the Indian Ocean material.

Catapsydrax dissimilis ciperoensis (Blow and Banner, 1962) (= *Globigerinita dissimilis ciperoensis* Blow and Banner). See Blow and Banner (1962), Pl. XIV, Figs. A–C.

Catapsydrax globiformis (Blow and Banner, 1962) (= *Globigerinita globiformis* Blow and Banner). See Blow and Banner (1962), Pl. XIV, Figs. S–U.

Catapsydrax taroubaensis (Brönnimann, 1952) (= *Globigerina taroubaensis* Brönnimann). See Bolli (1957a), Pl. 15, Figs. 1 and 2.

Catapsydrax unicavus Bolli, Loeblich and Tappan, 1957. See Bolli, Loeblich and Tappan (1957), Pl. 7, Figs. 9a–c. Only specimens very close to the holotype have been included in *C. unicavus*.

Chiloguembelina cubensis (Palmer, 1934) (= *Guembelina cubensis* Palmer). See Palmer (1934), Figs. 1–6.

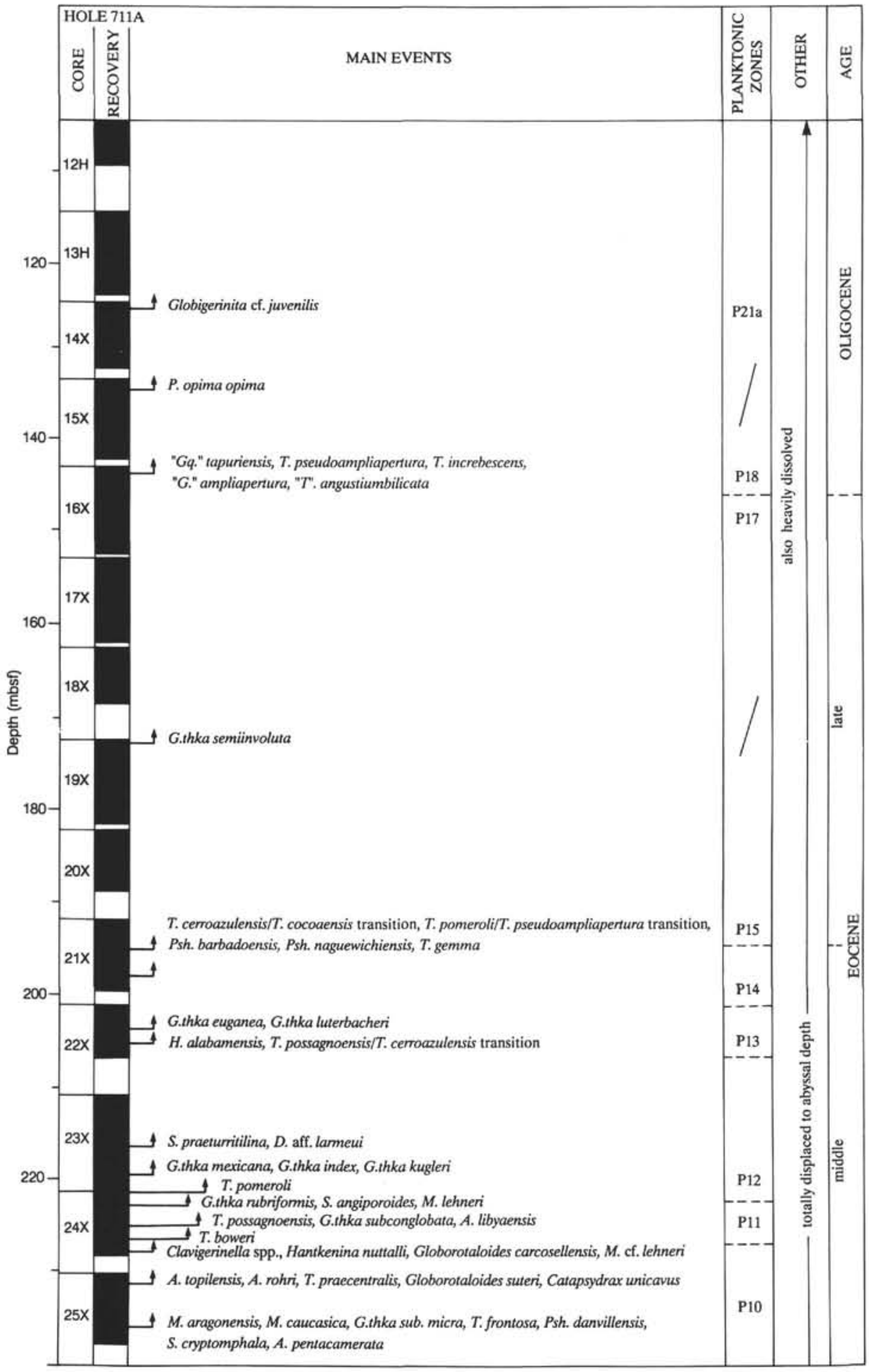

Figure 9. Main planktonic foraminifer events in Hole 711A plotted vs. biozone assignment.

Chiloguembelina midwayensis group Beckmann, 1957. See Beckmann (1957), Pl. 21, Figs. 1–3 and 6.

Chiloguembelina wilcoxensis (Cushman and Ponton, 1932) (= *Guembelina wilcoxensis* Cushman and Ponton). See Beckmann (1957), Pl. 21, Figs. 10a–b, and 12a–13.

Clavigerinella eocanica jarvisi (Cushman, 1930) (= *Hastigerina jarvisi* Cushman). See Toumarkine and Luterbacher (1985), Fig. 22 (7–9). Several specimens transitional to *Hantkenina nuttalli* occur in the same horizon along with typical *Clavigerinella jarvisi.*

Cribrohantkenina inflata (Howe, 1928) (= *Hantkenina inflata* Howe). (Plate 1, Figs. 7a–c). See Toumarkine and Luterbacher (1985), Fig. 26 (1–7). In the appropriate sedimentary interval, cribrohantkeninids are mainly recorded as fragments, which prevented the identification of *C. lazzarii* (Coccioni, 1988).

Dentoglobigerina altispira globosa (Bolli, 1957) (= *Globoquadrina altispira globosa* Bolli). See Bolli and Saunders (1985), Fig. 15 (1).

Dentoglobigerina baroemoenensis (Le Roy, 1939) (= *Globigerina baroemoenensis* Le Roy). See Molina (1979), Pl. 22, Figs. 2a–c.

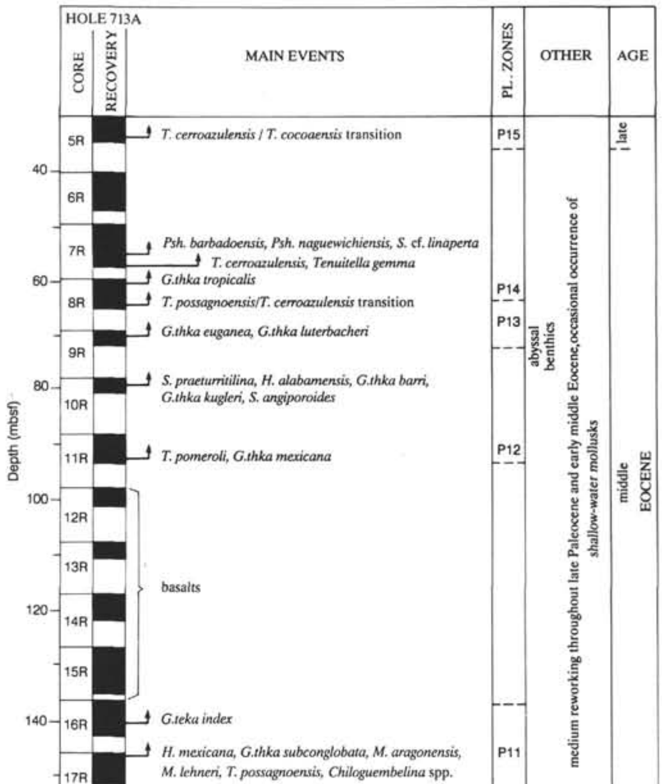

Figure 10. Main planktonic foraminifer events in Hole 713A plotted vs. biozone assignment.

Dentoglobigerina galavisi (Bermudez, 1961) (= *Globigerina galavisi* Bermudez). See Bermudez (1961), Pl. 4, Fig. 3. Transitional forms to *D. baroemoenensis* occur in Zone P20.

Dentoglobigerina globularis (Bermudez, 1961) (= *Globoquadrina globularis* Bermudez). See Molina (1979), Pl. 19, Figs. 1a–d. Transitional forms to *D. altispira* occur in Zones P21b-P22 (early).

"*Globigerina*" *ampliapertura* Bolli, 1957. (Plate 2, Figs. 1a–c). See Bolli (1957b), Pl. 22, Figs. 5–6.

"*Globigerina*" *anguliofficinalis* Blow, 1969. See Blow (1969), Pl. 11, Figs. 1–5. This species, associated with forms transitional to "*G.*" *angulisuturalis* increases its size (>150 μm) in Zone P21b.

"*Globigerina*" *angulisuturalis* Bolli, 1957. See Bolli (1957b), Pl. 22, Figs. 11a–c.

"*Globigerina*" *ciperoensis* Bolli, 1957. See Bolli (1957b), Pl. 22, Figs. 10a–b.

"*Globigerina*" *ciperoensis ottnangiensis* Rögl, 1969. See Rögl (1985), Fig. 5 (5).

"*Globigerina*" *euapertura* Jenkins, 1960. See Jenkins (1985), Fig. 6 (18a–c).

"*Globigerina*" *fariasi* Bermudez, 1961. See Bolli and Saunders (1985), Fig. 13 (9).

Globigerina officinalis Subbotina, 1953. See Subbotina (1953), Pl. 11, Figs. 1–7.

Globigerina ouchitaensis Howe and Wallace, 1932. See Blow and Banner (1962), Pl. IX, Figs. D and H–K.

Globigerina praebulloides Blow, 1959. See Blow and Banner (1962), Pl. IX, Figs. O–Q.

Globigerina praebulloides occlusa Blow and Banner, 1962. See Blow and Banner (1962), Pl. IX, Figs. U–W.

"*Globigerina*" *prasaepis* Blow, 1969. See Blow (1969), Pl. 10, Fig. 13; Pl. 18, Figs. 3–7.

"*Globigerina*" *venezuelana* Hedberg, 1937. See Bolli and Saunders (1985), Fig. 13 (20).

"*Globigerina*" *woodi* s. str. Jenkins, 1960. (Plate 3, Figs. 4a–c). See Chaproniere (1988), P1.1 and 2. In our material in addition to typical "*G.*" *woodi,* which has four chambers in the last whorl and a wide-arched aperture occasionally with a thin lip, there are two groups of forms informally named "*Globigerina*" sp. 1 and "*Globigerina*" sp. 2. "*Globigerina*" sp. 1 is characterized by three to three and a half chambers in the last whorl, a subrectagular profile, and a medium-sized, low-arched aperture. "*Globigerina*" sp. 2 is close to"*Globigerina*" sp. 1, but it possesses a rounder-arched aperture and three and a half to four chambers in the last whorl. They appear to be ancestral to "*G.*" *woodi* s. str.

Globigerinatheka barri Brönnimann, 1952. See Toumarkine and Luterbacher (1985), Fig. 37 (15), Fig. 39 (23–32).

Globigerinatheka euganea Proto Decima and Bolli, 1970. See Toumarkine and Luterbacher (1985), Fig. 40 (8–10).

Globigerinatheka index (Finlay, 1939) (= *Globigerinoides index* Finlay). (Plate 1, Figs. 8a–8b). See Toumarkine and Luterbacher (1985), Fig. 38 (20–24).

"*Globigerinatheka*" *kiersteadae* (Fleisher, 1974) (= *Subbotina kiersteadae* Fleisher). See Fleisher (1974), Pl. 16, Figs. 1–9.

Globigerinatheka kugleri (Bolli, Loeblich, and Tappan, 1957) (= *Globigerapsis kugleri* Bolli, Loeblich and Tappan). See Toumarkine and Luterbacher (1985), Fig. 37 (14); Fig. 39 (18–22).

Globigerinatheka luterbacheri Bolli, 1972. (Plate 2, Figs. 7a–b). See Toumarkine and Luterbacher (1985), Fig. 38 (1–13).

Globigerinatheka mexicana (Cushman, 1925) (= *Globigerina mexicana* Cushman). See Toumarkine and Luterbacher (1985), Fig. 37 (16–17), Fig. 39 (33–39).

Globigerinatheka rubriformis (Subbotina, 1953) (= *Globigerinoides rubriformis* Subbotina). See Toumarkine and Luterbacher (1985), Fig. 38 (18–19).

Globigerinatheka semiinvoluta (Keijzer, 1945) (= *Globigerinoides semiinvolutus* Keijzer). (Plate 2, Figs. 4a–b). See Toumarkine and Luterbacher (1985), Fig. 37 (11), Fig. 39 (1–17).

"*Globigerinatheka*" *senni* (Beckmann, 1953) (= *Sphaeroidinella senni* Beckmann). See Toumarkine (1978), Pl. 10, Figs. 10–14.

Globigerinatheka subconglobata (Shutskaya,1958) (= *Globigerinoides subconglobatus* var. *subconglobata* Khalilov (ms.) in Shutskaya, 1958). See Toumarkine and Luterbacher (1985), Fig. 40 (16–20).

Globigerinatheka subconglobata micra (Shutskaya, 1958) (= *Globigerinoides subconglobatus* var. *micra* Shutskaya). See Toumarkine and Luterbacher (1985), Fig. 37 (8–10).

Globigerinatheka tropicalis (Blow and Banner, 1962) (= *Globigerapsis tropicalis* Blow and Banner). (Plate 1, Figs. 9a–c). See Toumarkine and Luterbacher (1985), Fig. 37 (12), Fig. 38 (14–17).

Globigerinella sp. (Plate 4, Figs. 2a–c, 4a–c).

Globigerinita glutinata (Egger, 1893) (= *Globigerina glutinata* Egger). See Kennett and Srinivasan (1983), Pl. 56, Figs. 3–5.

Globigerinita juvenilis (Bolli, 1957) (= *Globigerina juvenilis* Bolli). See Bolli (1957b), Pl. 24, Figs. 5 and 6. In our material, there are specimens without a bulla or with a bulla but lacking sutural expansions; the spiral side can be more or less elevated with few high-spired forms tending to *Globigerinita uvula.* The first occurrence is within Zone P21a.

Globigerinita uvula (Ehrenberg, 1861) (= *Pylodexia uvula* Ehrenberg). See Kennett and Srinivasan (1983), Pl. 56, Figs. 6–8.

Globigerinoides bollii Blow, 1959. See Bolli and Saunders (1985), Fig. 20 (8). Specimens identical to *G. bollii* occur in Zone N4, the range of which, therefore, should be extended to the base of the Miocene.

Globigerinoides immaturus Le Roy, 1939. See Bolli and Saunders (1985), Fig. 20 (14).

Globigerinoides primordius Blow and Banner, 1962. See Bolli and Saunders (1985), Fig. 20 (16). Typical forms are preceded in Zone P21 by specimens displaying the same shape as *G. primordius* without supplementary apertures. The latter are plotted under the informal name of "*Globigerinoides*" *praeprimordius.*

Globigerinoides trilobus (Reuss, 1850) (= *Globigerina triloba* Reuss). See Bolli and Saunders (1985), Fig. 20 (15).

Globoquadrina binaiensis (Koch, 1935) (= *Globigerina binaiensis* Koch). See Bolli and Saunders (1985), Fig. 14 (6–10).

Globoquadrina dehiscens (Chapman, Parr and Collins, 1934) (= *Globorotalia dehiscens* Chapman, Parr and Collins). See Bolli and Saunders (1985), Fig. 15 (4–7).

Globoquadrina dehiscens praedehiscens Blow and Banner, 1962. See Blow and Banner (1962), Pl. 15, Figs. O–S. Transitional form to *G. dehiscens* is shown in Plate 4, Figs. 8a–c.

Globoquadrina sellii Borsetti, 1959. See Bolli and Saunders (1985), Fig. 14 (11).

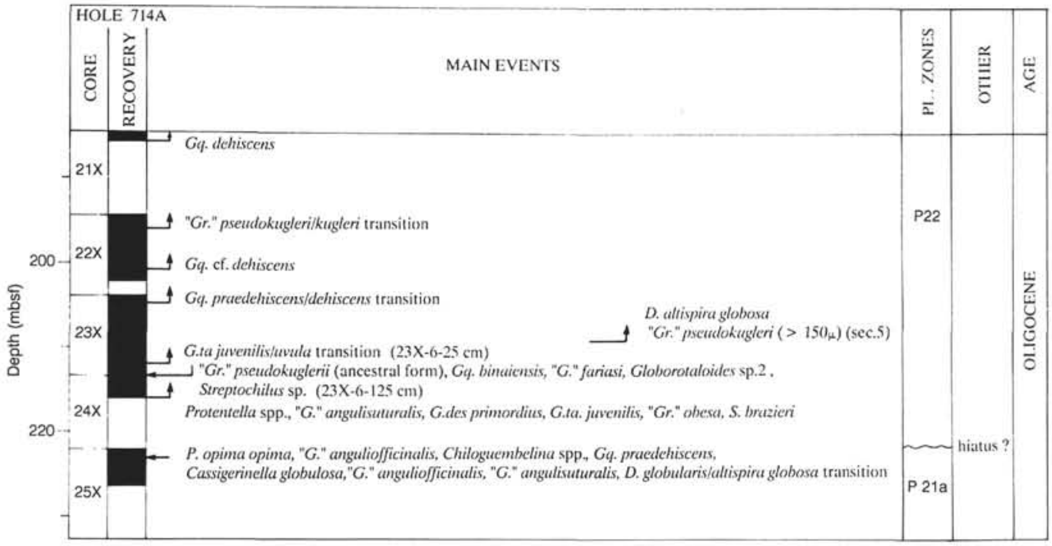

Figure 11. Main planktonic foraminifer events in Hole 714A plotted vs. biozone assignment.

"*Globoquadrina*" *tapuriensis* (Blow and Banner, 1962) (= *Globigerina tripartita tapuriensis* Blow and Banner). (Plate 2, Figs. 6a–c). See Blow and Banner (1962), Pl. 10, Figs. H–K. The genus *Globoquadrina* is kept in brackets because this species does not possess the typical tooth of the genus *Globoquadrina.*

Globoquadrina tripartita (Koch, 1926) (= *Globigerina bulloides* var. *tripartita* Koch). See Bolli and Saunders (1985), Fig. 14 (13).

"*Globorotalia*" *kugleri* Bolli, 1957. (Plate 3, Figs. 5a–c). See Bolli (1957b), Pl. 28, Figs. 5a–c.

"*Globorotalia*" *obesa* Bolli, 1957. See Bolli (1957b), Pl. 29, Figs. 2a–3. On the basis of the wall structure, this species should belong to the genus *Globigerina* s. str.; however, its taxonomic position is still uncertain. It seems that "*G.*" *obesa* evolves into *Globigerinella praesiphonifera* (see Plate 4, Figs. 1a–c).

"*Globorotalia*" *pseudokugleri* Blow, 1969. (Plate 3, Figs. 1a–c). See Blow (1969), Pl. 10, Figs. 4–6. A transitional form to "*G.*" *kugleri* is shown in Plate 3, Figs. 3a–c.

Globorotaloides carcosellensis Toumarkine and Bolli, 1975. See Toumarkine and Luterbacher (1985), Fig. 41 (9–16).

Globorotaloides stainforthi (Bolli, Loeblich and Tappan, 1957) (= *Catapsydrax stainforthi* Bolli, Loeblich and Tappan). See Molina (1979), Pl. 26, Figs. 1a–e.

Globorotaloides suteri Bolli, 1957. See Bolli (1957b), Pl. 27, Figs. 9–13. Herein this form appears much earlier than in Trinidad (probably in Zones P10-P11).

Globorotaloides turgida (Finlay, 1939) (= *Globigerina turgida* Finlay). See Jenkins (1971), Pl. 23, Figs. 656–658.

Globorotaloides sp. aff. *G. stainforthi* (Bolli, Loeblich and Tappan). Specimens included here seem to be ancestral of *G. stainforthi.* They possess fewer chambers and a smaller bulla than the typical form.

Globorotaloides sp. 1. (Plate 3, Figs. 2a–c). See Nocchi et al. (in press), Pl. 4, Figs. 6–9; Pl. 5, Figs. 19–22. This informal species was first identified in the subantarctic region and is recurrent in the Indian Ocean sites. It includes several small forms (< 150 μm) that possess (1) a globorotaliform inner-coiling mode resulting in a subacute lateral profile associated with subspherical outer chambers increasing rapidly in size as added, (2) a very coarsely honeycomb wall structure particularly evident in the last chambers, and (3) an umbilical-extraumbilical aperture bordered by a distinct rim. Sutures of the inner spire are curved, and depressed and radial to slightly curved in the last whorl. *Globorotaloides* sp. 1 shows some similarities with *Globorotaloides variabilis* Bolli, from which it can be distinguished by having (1) fewer chambers in the last whorl (no more than 4 in the Eocene, and 4–5 in the Oligocene), rapidly increasing in size, (2) more closed umbilicus, and (3) a much coarser wall structure in the last chambers. It occurs almost continuously from the late Paleocene through the Oligocene; it is particularly abundant in Zones P10-P11 and P18, when it also increases in size (> 150 μm). It seems a potential climatic index species.

Globorotaloides sp. 2. (Plate 3, Figs. 7a–c) (= *Catapsydrax dissimilis* subsp. 1 in Molina, 1979, Pl. 25, Figs. 3a–d). This form is very similar to *G. suteri,* but it possesses a very inflated bulla with five accessory apertures. Molina (1979) considered this form to be a subspecies of *Catapsydrax dissimilis;* however, the coiling mode is typical of the genus *Globorotaloides.* It has a very restricted range from late Zone P22 to Zone N4.

Hantkenina alabamensis Cushman, 1925. (Plate 1, Figs. 4a–c and 6a–c). See Toumarkine and Luterbacher (1985), Fig. 25 (1–10). In the upper part of its range, *H. alabamensis* exhibits more inflated chambers. This morphotype just precedes the *Cribrohantkenina* stage. A transitional form is shown in Plate 1, Fig. 5b.

Hantkenina dumblei Weinzierl and Applin, 1929. See Toumarkine and Luterbacher (1985), Fig. 24 (1–5).

Hantkenina mexicana Cushman, 1925. See Toumarkine and Luterbacher (1985), Fig. 23 (8–11).

Hantkenina nuttalli Toumarkine, 1981. See Toumarkine and Luterbacher (1985), Fig. 23 (1–5).

Morozovella acuta (Toulmin, 1941) (= *Globorotalia wilcoxensis* var. *acuta* Toulmin). See Toumarkine and Luterbacher (1985), Fig. 14 (7–8).

Morozovella aequa (Cushman and Renz, 1942) (= *Globorotalia crassata* (Cushman) var. *aequa* Cushman and Renz). See Toumarkine and Luterbacher (1985), Fig. 15 (1–3).

Morozovella angulata (White, 1928) (= *Globigerina angulata* White). See Luterbacher (1964), Figs. 37–39.

Morozovella aragonensis (Nuttall, 1930) (= *Globorotalia aragonenis* Nuttall). See Blow (1979), Pl. 141, Figs. 4–9.

Morozovella bandyi Fleisher, 1974. See Fleisher (1974), Pl. 14, Figs. 3–8.

"*Morozovella*" *broedermanni* (Cushman and Bermudez) (= *Globorotalia (Truncorotalia) broedermanni* Cushman and Bermudez). See Toumarkine and Luterbacher (1985), Fig. 29 (14–20).

"*Morozovella*" *broedermanni anapetes* (Blow, 1979) (= *Globorotalia (A.) broedermanni anapetes* Blow). See Toumarkine and Luterbacher (1985), Fig. 29 (21–22).

Morozovella caucasica (Glaessner, 1937) (= *Globorotalia caucasica* Glaessner). See Toumarkine and Luterbacher (1985), Fig. 16 (2–3).

"*Morozovella*" *convexa* (Subbotina, 1953) (= *Globorotalia convexa* Subbotina). See Subbotina (1953), Pl. XVII, Figs. 2–3.

Morozovella coronata Blow, 1979. See Blow (1979), Pl. 168, Figs. 1–8.

Morozovella crassata (Cushman, 1925) (= *Pulvinulina crassata* Cushman). See Toumarkine and Luterbacher (1985), Fig. 30 (9–10).

Morozovella crassata densa (Cushman, 1925) (= *Pulvinulina crassata* var. *densa* Cushman). See Toumarkine and Luterbacher (1985), Fig. 29 (1).

Table 7. Stratigraphic ranges of selected Oligocene planktonic foraminifers in Hole 714A.

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	Reworking	Contamination	Washed residues	Preservation	Volcanic glass	Radiolarians	Spicules	*Globoquadrina sellii*	*Globorotaloides permicrus*	*Globorotaloides suteri*	*Paragloborotalia opima opima*	*Globoquadrina rohri*	"*Globoquadrina*" *tapuriensis*	*Paragloborotalia opima nana*	"*Globigerina*" *angulisuturalis*	"*Globigerina*" *venezuelana*	"*Globigerina*" *ciperoensis*	*Paragloborotalia pseudocontinuosa*	*Subbotina praeturritilina*
Oligocene	P22		21X-CC	—	—	1	2/3	—	F	C/F	X		X		X		X		X	R	X	
		194.4	22X-1, 120	F	—	1	2/3	—	C	C	X		X		X		X		X		X	
			22X-2, 120	—	—	1	2	—	F	C	X		X		X		X		X	X		
			22X-3, 20	F	—	1	2/3	—	A/C	C	X		X		X		X	R	X	X	X	
			22X-3, 110	—	—	1	2	F	F	X	X		C/A		X	X	X		X	X	X	
			22X-3, 125	X	X	1	2/1	—	F	A	X		X		X		X		X	X		
			22X-4, 105	—	—	1	2/1	—	F	X	X		X		X	CF	X		X	X	X	CF
			22X-5, 65	F	—	1	3/2	—	F	A	X		X		X			VF	X	X		X
		204.1	23X-1, 110	—	—	1	3	—	F	A	X	X	X		X	X	X	R	X	X	X	X
			23X-1, 125	—	—	1	3	—	VF	A	X		X		X	X	X		X	X		
			23X-2, 125	—	—	2	2	—	F	A	X		X		X	X	X	X	X	X	X	X
			23X-3, 125	—	X	1	2/3	—	F	A	X		X		X	X	X	VR	X	X	X	X
			23X-4, 110	—	—	1	3/4	—	F/C	A	X		X		X	X	X		X	X	X	X
			23X-4, 125	—	—	1	1/2	F	F	X	X		X		X		X	X	X	X		
			23X-5, 125	—	—	1	3/2	—	F	X	X		X		X	X	X	X	X	X	X	X
			23X-6, 25	—	—	1	1	—	F	X	X		X		X		X	R	X	X	X	X
			23X-6, 125	—	—	1	3/4	—	F	X	X	R	X		X	X	X	X	X	X	X	X
		213.8	24X-1, 110	—	—	1	2/3	—	F	X	X		X		X		X	X		X	X	X
			24X-1, 125	—	—	2	3/2	X	F	X	X		X		X	X	X		X	X	X	
	P21a	223.3	25X-1, 110	—	—	1	2	X	F	X	X	X	X	X	X	X	X	F	X	X	X	X
		233.0	25X-1, 125	—	F	1	1/2	F	F	X	X	X	C	X	X	X	X	R	X	X	X	X

Morozovella edgari (Premoli Silva and Bolli, 1973) (= *Globorotalia edgari* Premoli Silva and Bolli). See Toumarkine and Luterbacher (1985), Fig. 15 (6).

Morozovella formosa (Bolli, 1957) (= *Globorotalia formosa formosa* Bolli). See Toumarkine and Luterbacher (1985), Fig 15 (13).

Morozovella gracilis (Bolli, 1957) (= *Globorotalia formosa gracilis* Bolli). See Bolli (1957a), Pl. 18, Figs. 4-6.

Morozovella lehneri (Cushman and Jarvis, 1929) (= *Globorotalia lehneri* Cushman and Jarvis). See Toumarkine and Luterbacher (1985), Fig. 31 (11-13).

Morozovella lensiformis (Subbotina, 1953) (= *Globorotalia lensiformis* Subbotina). See Subbotina (1953), Pl. XVIII, Figs. 4-5; Blow (1979), Pl. 126, Figs. 1-3, 5, and 6.

Morozovella marginodentata (Subbotina, 1953) (= *Globorotalia marginodentata* Subbotina). See Subbotina (1953), Pl. XVII, Figs. 1 4-1 6, Pl. XVIII, Figs. 3a-c.

"*Morozovella*" *nicoli* (Martin, 1943) (= *Globorotalia nicoli* Martin). See Martin (1943), P1.7, Fig. 3; Blow (1979), Pl. 97, Figs. 1, 2, and 6.

Morozovella pasionensis (Bermudez, 1961) (= *Pseudogloborotalia pasionensis* Bermudez). See Luterbacher (1964), Figs. 108-110.

Morozovella pusilla (Bolli, 1957) (= *Globorotalia pusilla pusilla* Bolli). See Toumarkine and Luterbacher (1985), Fig. 12 (13-14).

Morozovella quetra (Bolli, 1957) (= *Globorotalia quetra* Bolli). See Toumarkine and Luterbacher (1985), Fig. 15 (4-5).

Morozovella simulatilis (Schwager, 1883) (= *Discorbina simulatilis* Schwager). See Luterbacher (1964), Figs. 53-55.

Morozovella spinulosa (Cushman, 1927) (= *Globorotalia spinulosa* Cushman). See Toumarkine and Luterbacher (1985), Fig. 30 (1-2).

Morozovella subbotinae (Morozova, 1939) (= *Globorotalia subbotinae* Morozova). See Toumarkine and Luterbacher (1985), Fig. 15 (9-11).

"*Morozovella*" *uncinata* (Bolli, 1957) (= *Globorotalia uncinata* Bolli). See Bolli (1957a), Pl. 17, Figs. 13-15.

Morozovella velascoensis (Cushman, 1925) (= *Pulvinulina velascoensis* Cushman). See Toumarkine and Luterbacher (1985), Fig. 13 (11-12).

Morozovella wilcoxensis (Cushman and Ponton, 1932) (= *Globorotalia wilcoxensis* Cushman and Ponton). See Bolli (1957a), Pl. 19, Figs. 7-9.

Paragloborotalia opima nana (Bolli, 1957) (= *Globorotalia opima nana* Bolli). See Bolli (1957b), Pl. 28, Figs. 3a-c.

Paragloborotalia opima opima (Bolli, 1957) (= *Globorotalia opima opima* Bolli). See Bolli (1957b), Pl. 28, Figs. 1a-2.

Paragloborotalia pseudocontinuosa (Jenkins, 1967) (= *Globorotalia pseudocontinuosa* Jenkins. See Jenkins and Srinivasan (1986), Pl. 5, Figs. 2-4. In our material, transitional forms between *P. opima nana* and *P. pseudocontinuosa* are common when *P. opima nana* occurs either in the late Eocene or in the Oligocene. In the Oligocene, some specimens show a tendency to have five chambers in the last whorl.

Paragloborotalia semivera (Hornibrook, 1961) (= *Globigerina semivera* Hornibrook). (Plate 3, Figs. 8a-c). See Kennett and Srinivasan (1983), Pl. 42, Figs. 3-5.

Paragloborotalia siakensis (Le Roy, 1938) (= *Globigerina siakensis* Le Roy). See Molina (1979), Pl. 28, Figs. 1a-c; Kennett and Srinivasan (1983), Pl. 42, Figs. 1 and 6-8.

Planorotalites palmeri (Bolli, 1957) (= *Globorotalia palmerae* Bolli). See Toumarkine and Luterbacher (1985), Fig. 20 (14-29).

Planorotalites planoconicus (Subbotina,1953) (= *Globorotalia planoconica* Subbotina). See Blow (1979), Pl. 159, Figs 1-5; Pl. 161, Figs. 1, 8, and 9.

Planorotalites pseudoscitulus (Glaessner, 1937) (= *Globorotalia pseudoscitula* Glaessner). See Blow (1979), Pl. 173, Figs. 1-8.

Table 7 (continued).

Dentoglobigerina globularis	*Dentoglobigerina galavisi*	*Globigerina officinalis*	*Tenuitella clemenciae*	*Globoquadrina tripartita*	*Catapsydrax martini*	*Cassigerinella chipolensis*	"*Tenuitella*" *angustiumbilicata*	*Globorotaloides* sp. 1	"*Globigerina*" *euapertura*	*Paragloborotalia* sp.	*Catapsydrax* sp.	"*Globigerina*" *anguliofficinalis*	*Dentoglobigerina* aff. *larmeui*	"*Globigerina*" sp. 2	*Globoquadrina praedehiscens*	*Dentoglobigerina baroemoenensis*	"*Globigerina*" *prasaepis*	*Tenuitella clemenciae*/*T. munda*	*Paragloborotalia siakensis*	*Dentoglobigerina larmeui*	*Catapsydrax dissimilis ciperoensis*	Chiloguembelinids	"*Globigerina*" *anguliofficinalis*/"*G.*" *angulisuturalis*	*Paragloborotalia semivera*	*Globigerina praebulloides occlusa*	*Cassigerinella globulosa*
			X		X			X	X		X		X	X					X		X			X	X	
X			X	X	X	X	X	X					X	X	X	X	X	X	X		X		VR	X	X	
X			X		X	C	X	X	CF			X	X						X	X			X	X	X	R
X			X	X	X	X	X	X	X			F	X	X	X				X					X	X	
X			X		CF	X	X	X	X		X	X	X	X	R	X			X	X				X		
			X			X	X	X	X				X		R			X	X	X			VR	X		
		R			X	X	X	X	X			R	X		R	X	X		X		X			X		VR
X		X	X			X	X	X	X			F	X		R			X	X					X	X	
X		X				X	X	F				X	X	X		X	X	X	X						X	X
X			X	X	X	X	X	X	X	X					X		X		X	X				X	X	R
X			X		X	X	X		X		X	X	X		X				X					X		X
X			X		X	R	X	X	X				X	R	X	CF	X		X	X	X			X		
X			X	X		X	X	X					X	X				X	X					X	X	
X			X	X	X	X	X	X	X			X	X	X					X					X		
		X	X			C	X	X	X	X		X	X	X	X			X	X		X			X	X	
			X	X		X	X	X				X	X	X			X	X	X	X	X		X	X		
		X	X	X	X	X	X	X				X	X	X	X		X	X	X				X	X		R
X			X	X		X	X	X	X	X		X	X	X			X		X				X	X		X
X			X			X	X	X	X	X		X		X				X	X		X			X		X
X			X		X	VR	X	X	X	X			X	X	X	CF	X		X			X	X	X	X	VR
X	X	X	X	X	X	R	X	X	X	X	X	X	X	X	X	X	X	X	X	R	X	X				

Planorotalites pseudoscitulus elongatus (Glaessner, 1937) (= *Globorotalia pseudoscitula* var. *elongata* Glaessner). See Blow, 1979, Pl. 105, Figs. 1, 2, and 4-6.

Protentella clavaticamerata Jenkins, 1977. (Plate 4, Figs. 5a-c). See Molina (1979), Pl. 33, Figs. 2a-d. The specimen illustrated in Plate 4 is slightly trochospiral; however, the other characters are identical to those of Molina's species.

Protentella navazuelensis Molina, 1979. (Plate 4, Figs. 6a-c). See Molina (1979), Pl. 33, Figs. 1a-d; Pl. 34, Figs. 1a-d and 2a-e; Pl. 37, Fig. 3.

Protentella sp. aff. *P. prolixa* Lipps, 1964. (Plate 4, Figs. 7a-c). See Kennett and Srinivasan (1983), Pl. 55, Figs. 1 and 3-5. *P. prolixa* is described from middle Miocene. Our specimens, very similar to Lipps's species, occur in late Zone P22. For this reason, they are only tentatively attributed to this species.

Protentella sp. 1. (Plate 4, Figs. 3a-c). Under this informal species are grouped a number of protentellids, slightly trochoidal, that possess four to five chambers in the last whorl, with an extraumbilical aperture bordered by a rim.

Pseudohastigerina barbadoensis Blow, 1969. See Blow (1969), Pl. 53, Figs. 7-9.

Pseudohastigerina danvillensis (Howe and Wallace, 1932) (= *Nonion danvillensis* Howe and Wallace). See Blow (1979), Pl. 253, Figs. 10-12. This form appears in Zone P9 and becomes typical and increases in abundance in the early middle Eocene. Specimens larger than 150 μm are particularly frequent in the late Eocene. It becomes extinct at the Eocene/Oligocene boundary (Nocchi et al., 1986).

Pseudohastigerina micra (Cole, 1927) (= *Nonion micrus* Cole). See Blow (1979), Pl. 253, Figs. 1-9.

Pseudohastigerina wilcoxensis (Cushman and Ponton, 1932) (= *Nonion wilcoxensis* Cushman and Ponton). See Berggren et al. (1967), Fig. 2.

Subbotina angiporoides (Hornibrook, 1965) (= *Globigerina angiporoides* Hornibrook). See Hornibrook (1965), Pl. 1a-i and Pl. 2.

Subbotina angiporoides minima (Jenkins, 1966) (= *Globigerina angiporoides* Hornibrook subsp. *minima* Jenkins). See Jenkins (1966), Fig. 7 (52-57).

Subbotina brazieri (Jenkins, 1966) (= *Globigerina brazieri* Jenkins). (Plate 3, Figs. 6a-c). See Jenkins (1985), Fig. 6 (20a-c).

Subbotina corpulenta (Subbotina, 1953) (= *Globigerina corpulenta* Subbotina). See Subbotina (1953), Pl. 10, Figs. 1-4. The specimens attributed to this species tend to increase the height of the spire toward the *Subbotina praeturritilina* (Blow and Banner, 1962) stage.

Subbotina cryptomphala (Glaessner, 1937) (= *Globigerina bulloides* var. *cryptomphala* Glaessner). See Toumarkine and Luterbacher (1985), Fig. 42 (5-6).

Subbotina crociapertura Blow, 1979. See Blow (1979), Pl. 176, Figs. 1-9.

Subbotina eocaena (Guembel, 1868) (= *Globigerina eocaena* Guembel). See Toumarkine and Luterbacher (1985), Fig. 42 (1-4). This species is very rare.

Subbotina eocaenica (Terquem, 1882) (= *Globigerina eocaenica* Terquem). See Subbotina (1953), Pl. XI, Figs. 8-11. This form is not easily distinguishable from *Subbotina utilisindex,* with which it coexists in Zones P11-P12. The main difference between the two taxa consists in the nature of the aperture: *S. eocaenica* possesses a slightly arched, umbilical-extraumbilical aperture, with a moderately thin curved rim that never extends to the peripheral margin; *S. utilisindex,* on the other hand, has a slitlike aperture or an elongated low

Table 7 (continued).

Age	Zones	Depth (mbsf)	Core, section, interval (cm)	*Dentoglobigerina globularis/D. altispira globosa*	*Dentoglobigerina galavisi/D. baroemoenensis*	*Tenuitella gemma*	*Globoquadrina binaiensis*	*Globorotaloides variabilis*	"*Globorotalia*" *pseudokugleri* (ancestral form)	*Subbotina brazieri*	*Catapsydrax dissimilis dissimilis*	*Tenuitella munda*	*Globigerina ouachitaensis*	*Globigerinita juvenilis*	*Protentella* sp. 1	"*Globorotalia*" *obesa*	"*Globigerina*" sp. 1	"*Globigerinoides*" *praeprimordius*	*Globigerinoides primordius*	*Globigerinella*? sp.	"*Globigerina*" *woodi*	*Globigerina praebulloides*
Oligocene	P22		21X-CC	X					CF	X						X			R		X	
		194.4	22X-1, 120			X	X		X	X			X	X	X	X			X	X		
			22X-2, 120			X	X		X	R		X		X	R	X						
			22X-3, 20	X	X	X	X		X	X		X	X	X		X			VR			
			22X-3, 110	X			X	X		X						X	R			X	X	
			22X-3, 125			X	X		X	X	X		X	X		X						
			22X-4, 105	X		X	X		R	X		X	X	X	VR	X				VR	X	
			22X-5, 65	X		X	X		F	CF			X	X	X	X		X		X	CF	
		204.1	23X-1, 110			X	X		X		X		X	X				X				
			23X-1, 125	X		X	X		R		X		X	X		X				X		
			23X-2, 125			X	X		R			X	X	X	X	X	X			X		R
			23X-3, 125	X		X	X		VR	X	X	X	X	X		X						
			23X-4, 110			X	X	X	X	X	X			X		X						
			23X-4, 125	X		X	X	X	X	X	X	X	X	X		X		X				
			23X-5, 125			X	X		X	X	X	CF	X	X	X		X		X		X	
			23X-6, 25	X		X	X		X	X	X		X	X		X	X	X			CF	
			23X-6, 125			X	X	X	CF		X	X	X	X		X	X				VR	
		213.8	24X-1, 110			X	X	X	VR	X	X		X	X	X	X	X	X	X	CF	CF	X
			24X-1, 125			X	CF	X	VR	X	X	X	X	X	X							
	P21a	223.3	25X-1, 110	X	X	X																
		233.0	25X-1, 125																			

arch extended almost to the peripheral margin, with a straight and well-developed lip.

Subbotina gortanii (Borsetti, 1959) (= *Catapsydrax gortanii* Borsetti). See Borsetti (1959), Pl. 1, Figs. 1a–c.

Subbotina higginsi (Bolli, 1957) (= "*Globigerinoides*" *higginsi* Bolli). See Bolli (1957c), Pl. 36, Figs. 11–13.

Subbotina inaequispira (Subbotina, 1953) (= *Globigerina inaequispira* Subbotina). See Subbotina (1953), Pl. VI, Figs. 1–4.

Subbotina linaperta (Finlay, 1939) (= *Globigerina linaperta* Finlay). (Plate 2, Figs. 2a–c). See Hornibrook (1958), Pl. 1, Figs. 19–21; Nocchi et al. (in press), Pl. 6, Figs. 24–29. The main characteristics of this species are the flattening of the last chamber to assume a kidney-shaped form, ellipsoidal in cross-section, and a very coarse hexagonal wall texture. Specimens from Indian Ocean are typical. *Subbotina linaperta* s. str. appears in the late middle Eocene (Zone P14) and becomes extinct in the late Eocene.

Subbotina lozanoi (Colom, 1954) (= *Globigerina lozanoi* Colom). See Toumarkine and Luterbacher (1985), Fig. 28 (6–11).

Subbotina patagonica (Todd and Kniker, 1952) (= *Globigerina patagonica* Todd and Kniker). See Todd and Kniker (1972), Pl. 4, Fig. 32. Very rare.

"*Subbotina*" *pseudobulloides* (Plummer, 1926) (= *Globigerina pseudobulloides* Plummer). See Toumarkine and Luterbacher (1985), Fig. 14 (1–2).

Subbotina utilisindex (Jenkins and Orr, 1973) (= *Globigerina utilisindex* Jenkins and Orr). See Jenkins and Orr (1973), Pl. 1, Figs. 1–6; Pl. 2, Figs. 1–9; Pl. 3, Figs. 1–3. The main characteristics of this species are the round final chamber and the finer wall structure than *S. linaperta* s. str. In topotypic material, *S. utilisindex* constantly displays a slitlike aperture, located umbilically-extraumbilically, always bordered by a distinct imperforate lip, which allows us to link this species to *S. angiporoides*. *Subbotina utilisindex* has a longer range than *S. linaperta* s. str. and disappears in the mid-Oligocene together with *S. angiporoides* and *S. angiporoides minima*.

Tenuitella clemenciae (Bermudez, 1961) (= *Turborotalia clemenciae* Bermudez). See Bermudez (1961), Pl. 17, Fig. 10.

Tenuitella gemma (Jenkins, 1971) (= *Globorotalia (Turborotalia) gemma* Jenkins). See Jenkins (1971), Pl. 10, Figs. 263–269.

Tenuitella munda (Jenkins, 1966) (= *Globorotalia munda* Jenkins). See Jenkins (1966), Figs. 14 and 15.

Tenuitella reissi (Loeblich and Tappan, 1957) (= *Globorotalia reissi* Loeblich and Tappan). See Loeblich and Tappan (1957), Pl. 50, Fig. 3a–c; Pl. 58, Fig. 3a–c.

"*Tenuitella*" *angustiumbilicata* (Bolli, 1957) (= *Globigerina ciperoensis angustiumbilicata* Bolli). See Li Qianyu (1987), Pl. 2, Figs. 15 and 17–19.

Turborotalia cerroazulensis boweri (Bolli, 1957) (= *Globorotalia boweri* Bolli). See Toumarkine and Luterbacher (1985), Fig. 34 (12).

Turborotalia cerroazulensis cerroazulensis (Cole, 1928) (= *Globigerina cerroazulensis* Cole). See Toumarkine and Luterbacher (1985), Fig. 34 (3–4), Fig. 36 (16–18).

Turborotalia cerroazulensis cocoaensis (Cushman, 1928) (= *Globorotalia cocoaensis* Cushman). See Toumarkine and Luterbacher (1985), Fig. 34 (2), Fig. 36 (10–12).

Turborotalia cerroazulensis cunialensis (Toumarkine and Bolli, 1970) (= *Globorotalia cerroazulensis cunialensis* Toumarkine and Bolli). See Toumarkine and Luterbacher (1985), Fig. 34 (1), Fig. 36 (1–6).

Turborotalia cerroazulensis frontosa (Subbotina, 1953) (= *Globigerina frontosa* Subbotina). See Toumarkine and Luterbacher (1985), Fig. 35 (16–18).

Table 7 (continued).

"Globorotalia" obesa/Globigerinella praesiphonifera	*Protentella clavaticamerata*	*Globorotaloides* sp. 2	*"Globigerina" fariasi*	*Streptochilus* sp.	*Globigerinita juvenilis/G. uvula*	*Protentella* aff. *prolixa*	*Protentella* sp.	*"Globorotalia" pseudokugleri*	*"Globigerina" ciperoensis ottnangiensis*	*Dentoglobigerina altispira globosa*	*Catapsydrax unicavus*	*Globoquadrina praedehiscens/G. dehiscens*	*Globorotaloides* aff. *stainforthi*	*Globoquadrina dehiscens*	*Globorotaloides stainforthi*	*"Globorotalia" pseudokugleri/"G." kugleri*	*Protentella navazuelensis*	*Globigerinita uvula*
					X			X				C		C		X	CF	CF
		X			X	CF		X	X							CF	X	
X				VR	X	X	X	X			X		X		X	CF		
		X	X				X	X		X	X	RCF						
	CF		X		X		X	C		X								
		X	X		X			C			X		X					
								C/F		X		VRCF	X		X			
					X			F		X		X		CF				
	X	X			X			X		X		VR	X					
			X	VR				R			X	X						
	X		X					F		X								
		CF						R		X								
								R										
		CF						X	X	X								
X			X	CF	X			X	X	X	X							
	X		X	VR	X	X	X											
X	X	CF	X	CF														

Note: See note to Table 2 for legend.

Turborotalia cerroazulensis possagnoensis (Toumarkine and Bolli, 1970) (= *Globorotalia cerroazulensis possagnoensis* Toumarkine and Bolli). See Toumarkine and Luterbacher (1985), Fig. 34 (10), Fig. 35 (13–15). Frequent transitional forms to *T. cerroazulensis* s. str. occur in the Indian Ocean material.

"Turborotalia" griffinae Blow, 1979. See Toumarkine and Luterbacher (1985), Fig. 27 (13–23).

Turborotalia increbescens (Bandy, 1949) (= *Globigerina increbescens* Bandy). See Bolli and Saunders (1985), Fig. 14 (5).

Turborotalia pomeroli (Toumarkine and Bolli, 1970) (= *Globorotalia cerroazulensis pomeroli* Toumarkine and Bolli). See Toumarkine and Luterbacher (1985), Fig. 34 (9), Fig. 35 (4–9). According to Premoli Silva and Boersma (1988), this species belongs to a separate lineage evolving into *T. pseudoampliapertura* and *T. increbescens* in the late Eocene.

"Turborotalia" praecentralis Blow, 1979. See Blow (1979), Pl. 135, Figs. 7–9; Pl. 136, Figs. 1–6.

Turborotalia pseudoampliapertura (Blow and Banner, 1962) (= *Globigerina pseudoampliapertura* Blow and Banner). (Plate 2, Figs. 5a–c). See Bolli and Saunders (1985), Fig. 1 (4). A transitional form to *T. increbescens* is shown in Plate 2, Figs. 3a–c.

REFERENCES

Backman, J., Duncan, R. A., et al., 1988. *Proc. ODP, Init. Repts.*, 115: College Station, TX (Ocean Drilling Program).

Beckmann, J. P., 1957. *Chiloguembelina* Loeblich and Tappan and related foraminifera from the lower Tertiary of Trinidad, B.W.I. *Bull. U.S. Nat. Mus.*, 215:83–95.

Berggren, W. A., Kent, D. V., and Flynn, J. J., 1985. Jurassic to Paleogene: Part 2. Paleogene geochronology and chronostratigraphy. *In* Snelling, N. J. (Ed.), *The Chronology of the Geological Record.* Geol. Soc. Mem. (London), 10:141–195.

Berggren, W. A., Olsson, R. K., and Reyment, R. A., 1967. Origin and development of the foraminiferal genus *Pseudohastigerina* Banner and Blow. *Micropaleontology,* 13(3):265–288.

Bermudez, P. J., 1961. Contribuciön al estudio de las Globigerinidae de la regiön Caribe-Antillana (Paleocene-Recente). *Soc. Geol. Venez., Bol. Geol., Publ. Espec.* 3:1119–1393.

Bermudez, P. J., and Seiglie, B. S., 1967. A new genus and species of foraminifer from the early Miocene of Puerto Rico. *Tulane Stud. Geol.*, 5(3):177–179.

Bizon, G., and Müller, C., 1979. Remarks on the Oligocene/Miocene boundary based on results obtained from the Pacific and Indian Oceans. *Ann. Geol. Pays Hell.*, 1:101–111.

Blow, W. H., 1969. Late middle Eocene to Recent planktonic foraminiferal biostratigraphy. *In* Farinacci, A. (Ed.), *Proceedings of the First International Conference on Planktonic Microfossils, Geneva:* Leiden (E. J. Brill), 1:199–422.

_______, 1979. *The Cainozoic Globigerinida:* Leiden (E. J. Brill).

Blow, W. H., and Banner, F. T., 1962. The mid-Tertiary (upper Eocene to Aquitanian) Globigerinacea. *In* Eames, F. E., Banner, F. T., Blow, W. H., and Clarke, W. J. (Eds.), *Fundamentals of Mid-Tertiary Stratigraphical Correlation:* London (Cambridge Univ. Press), 61–151.

Boersma, A., and Premoli Silva, I., 1983. Paleocene planktonic foraminiferal biogeography and the paleoceanography of the Atlantic Ocean. *Micropaleontology,* 29(4):355–381.

Boersma, A., Premoli Silva, I., and Shackleton, N. J., 1987. Atlantic Eocene planktonic foraminiferal paleohydrographic indicators and stable isotope paleoceanography. *Paleoceanography,* 2(3):287-331.

Bolli, H. M., 1957a. The genera *Globigerina* and *Globorotalia* in the Paleocene-lower Eocene Lizard Springs Formation of Trinidad, B.W.I. *Bull. U.S. Nat. Mus.,* 215:61-82.

_______, 1957b. Planktonic foraminifera from the Oligocene-Miocene Cipero and Lengua formations of Trinidad, B.W.I. *Bull. U.S. Nat. Mus.,* 215:97-124.

_______, 1957c. Planktonic foraminifera from the Eocene Navet and San Fernando formations of Trinidad, B.W.I. *Bull. U.S. Nat. Mus.,* 215:155-172.

Bolli, H. M., and Saunders, J. B., 1985. Oligocene to Holocene low-latitude planktic foraminifera. *In* Bolli, H. M., Saunders, J. B., and Perch-Nielsen, K. (Eds.), *Plankton Stratigraphy:* Cambridge (Cambridge Univ. Press), 155-262.

Borsetti, A. M., 1959. Tre nuovi foraminiferi plantonici dell'Oligocene piacentino. *G. Geol.,* 27:205-212.

Brönnimann, P., 1952. Trinidad Paleocene and lower Eocene Globigerinidae. *Bull. Am. Paleontol.,* 34(143):1-34.

Brönnimann, P., and Bermudez, P. J., 1953. *Truncorotaloides,* a new foraminiferal genus from the Eocene of Trinidad, B.W.I. *J. Paleontol.,* 27(6):817-820.

Chaproniere, G.C.H., 1988. *Globigerina woodi* from the late Oligocene and early Miocene of southeastern Australia. *J. Foraminiferal Res.,* 18(2):124-129.

Cifelli, R., 1972. The holotypes of *Pulvinulina crassata* var. *densa* Cushman and *Globigerina spinuloinflata* Bandy. *J. Foraminiferal Res.,* 2(3):157-159.

Coccioni, R., 1988. The genera *Hantkenina* and *Cribrohantkenina* (Foraminifera) in the Massignano section (Ancona, Italy). *In* Premoli Silva, I., Coccioni, R., and Montanari, A. (Eds.), *The Eocene-Oligocene Boundary in the Marche-Umbria Basin (Italy).* Int. Subcomm. Paleog. Strat., Eocene/Oligocene Meeting, Ancona, Oct. 1987, Spec. Publ., Anniballi, 81-96.

Fisher, R. L., Bunce, E. T., et al., 1974. *Init. Repts. DSDP,* 24: Washington (U.S. Govt. Printing Office).

Fleisher, R. L., 1974. Cenozoic planktonic foraminifera and biostratigraphy, Arabian Sea Deep Sea Drilling Project, Leg 23A. *In* Whitmarsh, R. B., Weser, O. E., Ross, D. A., et al., *Init. Repts. DSDP,* 23: Washington (U.S. Govt. Printing Office), 1001-1072.

_______, 1975. Early Eocene to early Miocene planktonic foraminiferal biostratigraphy of the western Indian Ocean [PhD dissert.]. Los Angeles, Univ. Southern California.

_______, 1977. Oligocene planktonic foraminiferal assemblages from Deep Sea Drilling Project sites in the Indian Ocean. *In* Heirtzler, J. R., Bolli, H. M., Davies, T. A., Saunders, J. B., and Sclater, J. C. (Eds.), *Indian Ocean Geology and Biostratigraphy:* Washington (American Geophysical Union), 459-467.

Heiman, M. E., Frerich, W. E., and Vincent, E., 1974. Paleogene planktonic foraminifera from the western tropical Indian Ocean, Deep Sea Drilling Project Leg 24. *In* Fisher, R. L., Bunce, E. T., et al., *Init. Repts. DSDP,* 24: Washington (U.S. Govt. Printing Office), 651-766.

Hornibrook, N. de B., 1958. New Zealand foraminifera: key species in stratigraphy, no. 6. *N.Z.J. Geol. Geophys.,* 1(4):653-676.

_______, 1965. *Globigerina angiporoides* n. sp. from the upper Eocene and Lower Oligocene of New Zealand and the status of *Globigerina angipora* Stache, 1865. *N.Z.J. Geol. Geophys.,* 8(6):834-838.

Jenkins, D. G., 1960. Planktonic foraminifera from the Lakes Entrance oil shaft, Victoria, Australia. *Micropaleontology,* 6(4):345-371.

_______, 1965. A re-examination of *Globorotalia collactea* Finlay, 1939. *N.Z.J. Geol. Geophys.,* 8:844-848.

_______, 1966. Planktonic foraminiferal zones and new taxa from the Danian to lower Miocene of New Zealand. *N.Z.J. Geol. Geophys.,* 8:1088-1126.

_______, 1971. Cenozoic planktonic foraminifera of New Zealand. *N. Z. Geol. Surv. Paleontol. Bull.,* 42:1-278.

_______, 1977. Lower Miocene planktonic foraminifera from a borehole in the English Channel. *Micropaleontology,* 23:297-318.

_______, 1985. Southern mid-latitude Paleocene to Holocene planktic foraminifera. *In* Bolli, H. M., Saunders, J. B., and Perch-Nielsen, K. (Eds.), *Plankton Stratigraphy:* Cambridge (Cambridge Univ. Press), 263-282.

Jenkins, D. G., and Orr, W. N., 1973. *Globigerina utilisindex* n. sp. from the upper Eocene-Oligocene of the eastern equatorial Pacific. *J. Foraminiferal Res.,* 3(3):133-135.

Jenkins, D. G., and Srinivasan, M. S., 1986. Cenozoic planktonic foraminifers from the Equator to the Subantarctic of the southwest Pacific. *In* Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP,* 90: Washington (U.S. Govt. Printing Office), 795-834.

Keller, G., 1980. Early to middle Miocene planktonic foraminiferal datum levels of the equatorial and subtropical Pacific. *Micropaleontology,* 26:372-391.

Kennett, J. P., and Srinivasan, M. S., 1983. *Neogene Planktonic Foraminifera: A Phylogenetic Atlas:* Stroudsburg, PA (Hutchinson Ross).

Khalilov, D. M., 1956. On the pelagic foraminiferal fauna of the Paleogene of Azerbaijdzhan (in Russian). *Akad. Nauk Azerb. S. S. R., Inst. Geol.,* 17:1-255.

Le Roy, L. W., 1953. Biostratigraphy of the Maqfi section, Egypt. *Mem. Geol. Soc. Am.,* 54:1-73.

Li Qianyu, 1987. Origin, phylogenetic development and systematic taxonomy of the *Tenuitella plexus* (Globigerinitidae, Globigerinina). *J. Foraminiferal Res.,* 17(4):295-320.

Loeblich, A. R., Jr., and Tappan, H., 1957. Planktonic foraminifera of Paleocene and early Eocene age from the Gulf and Atlantic Coastal Plains. *Bull. U.S. Nat. Mus.,* 215:173-198.

Luterbacher, H. P., 1964. Studies in some *Globorotalia* from the Paleocene and lower Eocene of the central Apennines. *Eclogae Geol. Helv.,* 57(2):631-670.

McGowran, B., 1977. Maastrichtian to Eocene foraminiferal assemblages in the northern and eastern Indian Ocean region: correlations and historical patterns. *In* Heirtzler, J. R., Bolli, H. M., Davies, T. A., Saunders, J. B., and Sclater, J. C. (Eds.), *Indian Ocean Geology and Biostratigraphy:* Washington (American Geophysical Union), 417-458.

Martin, L. T., 1943. Eocene foraminifera from the type Lodo formation, Fresno County, California. *Stanford Univ., Publ. Geol. Sci.,* 3(3):93-125.

Molina, E., 1979. Oligoceno-Mioceno inferior por medio de foraminiferos planctonicos en el sector central de las Cordilleras Beticas (Espana) [PhD dissert.]. Publicacion Universidades de Granada y Zaragoza, Deposito Legal Z-804-80.

Nocchi, M., Amici, E., and Premoli Silva, I., in press. Planktonic foraminiferal biostratigraphy and paleoenvironmental interpretation of Paleogene sediments from Subantarctic Transect, ODP Leg 114. *In* Ciesielski, P. F., Kristoffersen, Y., et al., *Proc. ODP, Sci. Results,* 114: College Station, TX (Ocean Drilling Program).

Nocchi, M., Parisi, G., Monaco, P., Monechi, S., Madile, M., Napoleone, G., Ripepe, M., Orlando, M., Premoli Silva, I., and Bice, D. M., 1986. The Eocene-Oligocene boundary in the Umbrian pelagic sequences, Italy. *In* Pomerol, C., and Premoli Silva, I. (Eds.), *Terminal Eocene Events.* Develop. Palaeontol. Stratigr., 9:25-40.

Palmer, D. K., 1934. The foraminiferal genus *Guembelina* in the Tertiary of Cuba. *Mem. Soc. Cubana Hist. Nat.,* 8:73-76.

Premoli Silva, I., and Boersma, A., 1988. Atlantic Eocene planktonic foraminiferal historical biogeography and paleohydrographic indices. *Palaeogeogr., Palaeoclimatol., Palaeoecol.,* 67(3/4):315-356.

_______, 1989. Atlantic Paleogene planktonic foraminiferal bioprovincial indices. *Mar. Micropaleontol.,* 14:357-371.

Premoli Silva, I., and Violanti, D., 1981. Cenozoic planktonic foraminifer biostratigraphy of DSDP Hole 462, Nauru Basin (western equatorial Pacific) and distribution of the pelagic components. *In* Larson, R. L., Schlanger, S. O., et al., *Init. Repts. DSDP,* 61: Washington (U.S. Govt. Printing Office), 397-422.

Rögl, F., 1985. Late Oligocene and Miocene planktic foraminifera of the Central Paratethys. *In* Bolli, H. M., Saunders, J. B., and Perch-Nielsen, K. (Eds.), *Plankton Stratigraphy:* Cambridge (Cambridge Univ. Press): 315-328.

Sigal, J., 1974. Comments on Leg 25 sites in relation to the Cretaceous and Paleogene stratigraphy in the eastern and southeastern African and Madagascar regional setting. *In* Simpson, E.S.W., Schlich, R., et al., *Init. Repts. DSDP,* 25: Washington (U.S. Govt. Printing Office), 687-723.

Srinivasan, M. S., and Kennett, J. P., 1983. The Oligocene-Miocene boundary in the South Pacific. *Geol. Soc. Am. Bull.,* 94:789-812.

Subbotina, N. N., 1953. Fossil foraminifers of the USSR: Globigerinidae, Hantkeninidae, Globorotalidae. *Trudy VNIGRI,* new series, 76 (in Russian). Translated into English by E. Lees, *Fossil foraminifera of the USSR; Globigerinidae, Hantkeninidae and Globorotalidae:* London and Wellingborough (Collet's Ltd.).

Todd, R., and Kniker, H. T., 1952. An Eocene foraminiferal fauna from the Agua Fresca Shale of Magellanes Province, southernmost Chile. *Spec. Publ., Cushman Found. Foraminiferal Res.,* 1:1–28.

Toumarkine, M., 1978. Planktonic foraminiferal biostratigraphy of the Paleogene of Sites 360 to 364 and the Neogene Sites 362A, 363 and 364 Leg 40. *In* Bolli, H. M., Ryan, W.B.F., et al., *Init. Repts. DSDP,* 40: Washington (U.S. Govt. Printing Office), 679–721.

Toumarkine, M., and Bolli, H. M., 1975. Foraminifères planctoniques de l'Eocène moyen et supérieur de la coupe de Possagno. *Schweiz. Palaeontol. Abh.,* 97:69–185.

Toumarkine, M., and Luterbacher, H. P., 1985. Paleocene and Eocene planktic foraminifera. *In* Bolli, H. M., Saunders, J. B., and Perch-Nielsen, K. (Eds.), *Plankton Stratigraphy:* Cambridge (Cambridge Univ. Press), 87–154.

Whitmarsh, R. B., Weser, O. E., Ross, D. A., et al., 1974. *Init. Repts. DSDP,* 23: Washington (U.S. Govt. Printing Office).

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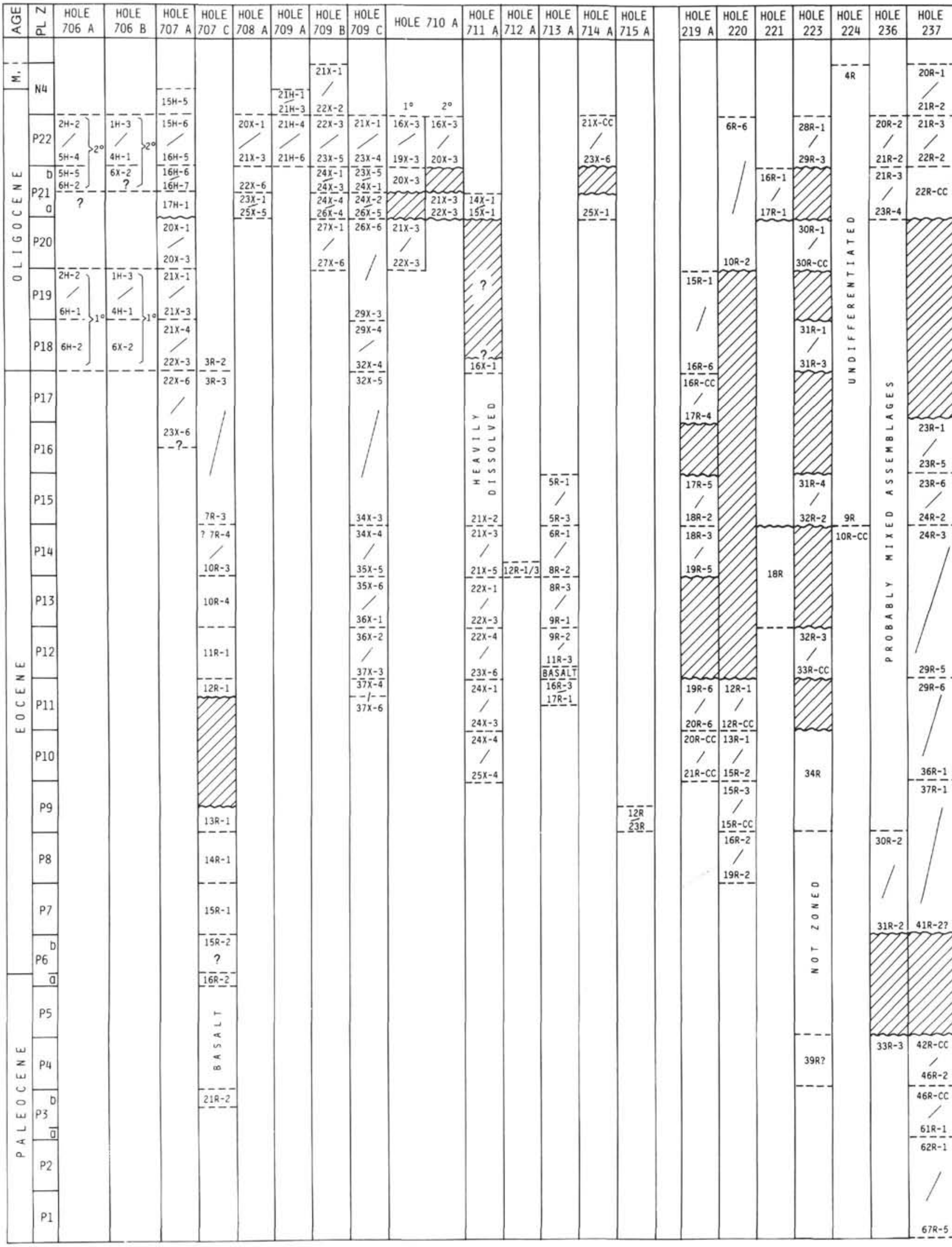

Figure 12. Summary of the planktonic foraminifer biostratigraphy for the Paleogene sediments from Leg 115 and from DSDP Legs 23A and 24 (after Fisher, Bunce, et al., 1974; Fleisher, 1974, 1975, 1977; Heiman et al., 1974; Whitmarsh, Weser, et al., 1974; McGowran, 1977; partially modified according to the present paper). For holes, the following values are represented: core numbers and section numbers. Undulated line marks hiatuses.

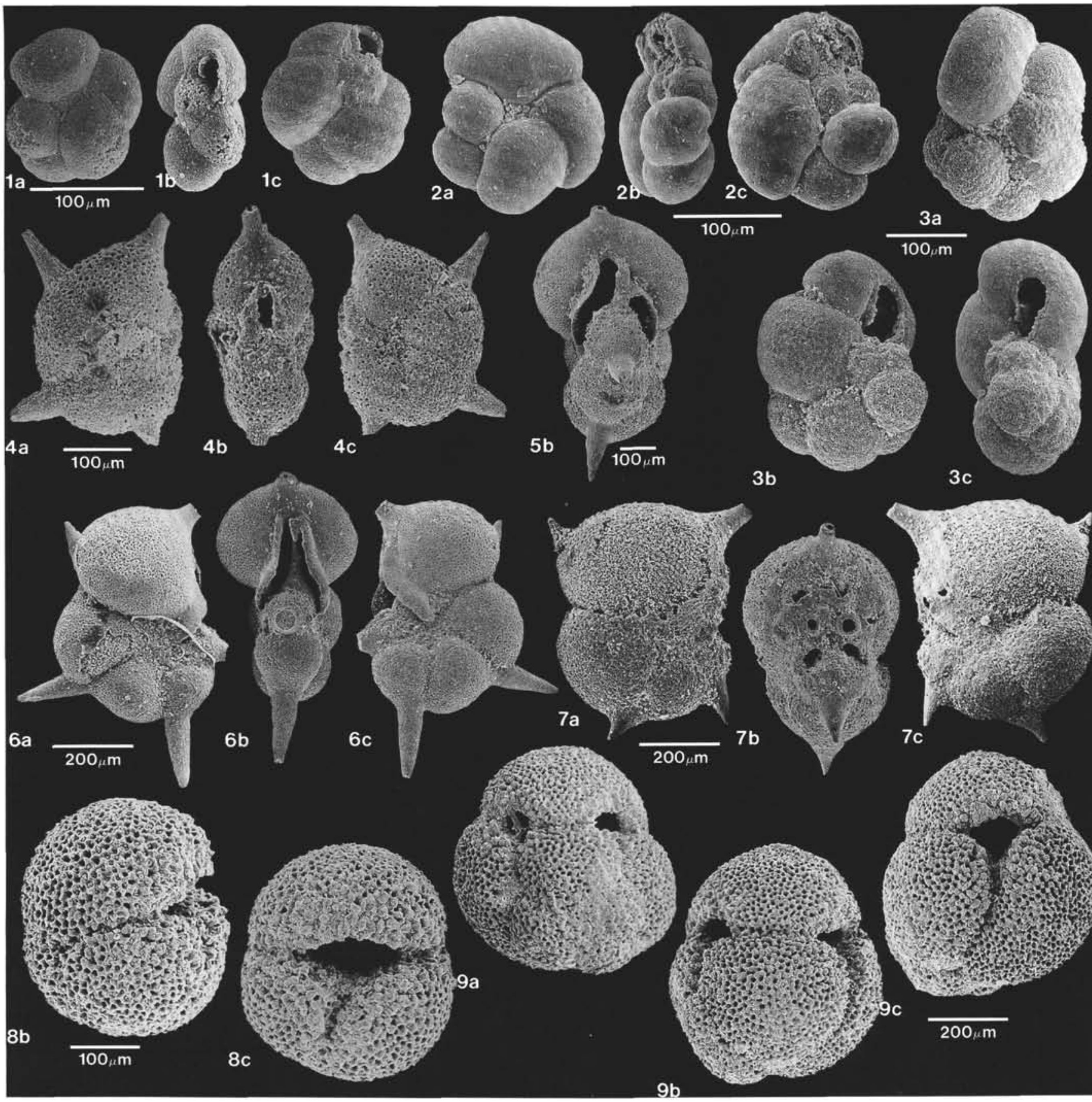

Plate 1. **1a–c.** *Cassigerinella globulosa* (Egger), Sample 115-707A-16H-5, 38–43 cm. **2a–c.** *Cassigerinella martinezpicoi* (Bermudez and Seiglie), Sample 115-706A-3H-6, 30–32 cm. **3a–c.** *Cassigerinella chipolensis* (Cushman and Ponton), Sample 115-709B-23X-1, 80–85 cm. **4a–c.** *Hantkenina alabamensis* Cushman, Sample 115-709C-31X-4, 75–80 cm. **5b.** *Hantkenina alabamensis* Cushman/*Cribrohatkenina inflata* (Howe) transition, Sample 115-709C-30X-3, 75–80 cm. **6a–c.** *Hantkenina alabamensis* Cushman, Sample 115-709C-33X-2, 75–80 cm. **7a–c.** *Cribrohantkenina inflata* (Howe), Sample 115-709C-30X-3, 75–80 cm. **8b–c.** *Globigerinatheka index* (Finlay), Sample 115-709C-33X-6, 10–15 cm. **9a–c.** *Globigerinatheka tropicalis* (Blow and Banner), Sample 115-709C-33X-3, 75–80 cm. (a) Spiral view, (b) side view, and (c) umbilical view.

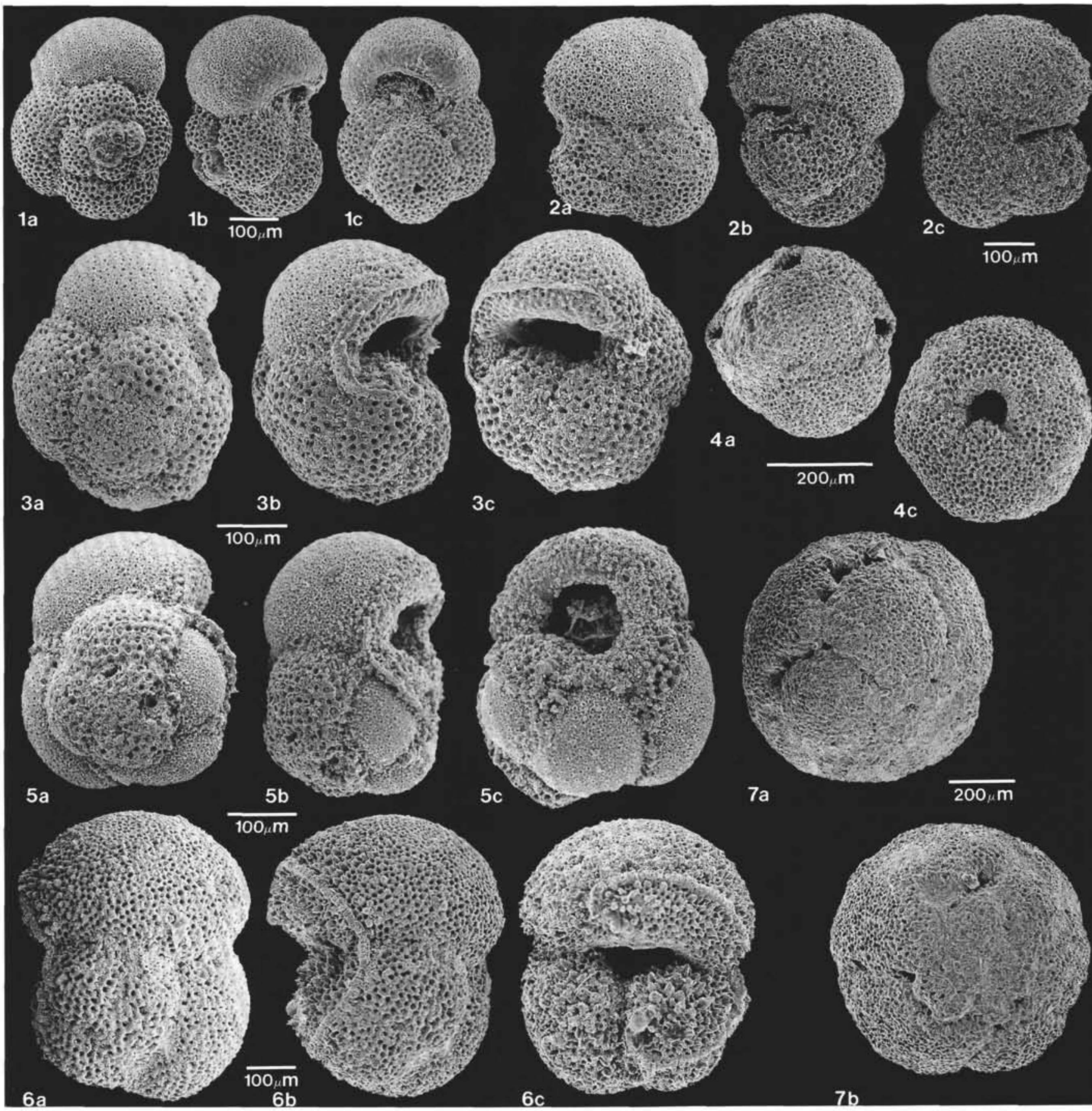

Plate 2. **1a–c.** "*Globigerina*" *ampliapertura* Bolli, Sample 115-706A-6H-2, 86–91 cm. **2a–c.** *Subbotina linaperta* (Finlay), Sample 115-709C-33X-1, 75–80 cm. **3a–c.** *Turborotalia pseudoampliapertura* (Blow and Banner)/*T. increbescens* (Bandy) transition, Sample 115-709B-27X-2, 80–85 cm. **4a, c.** *Globigerinatheka semiinvoluta* (Keijzer), Sample 115-709C-33X-3, 75–80 cm. **5a–c.** *Turborotalia pseudoampliapertura* (Blow and Banner), Sample 115-709B-27X-2, 80–85 cm. **6a–c.** "*Globoquadrina*" *tapuriensis* (Blow and Banner), Sample 115-709C-33X-3, 75–80 cm. **7a–b.** *Globigerinatheka luterbacheri* Bolli, Sample 115-709C-33X-6, 10–15 cm. (a) Spiral view, (b) side view, and (c) umbilical view.

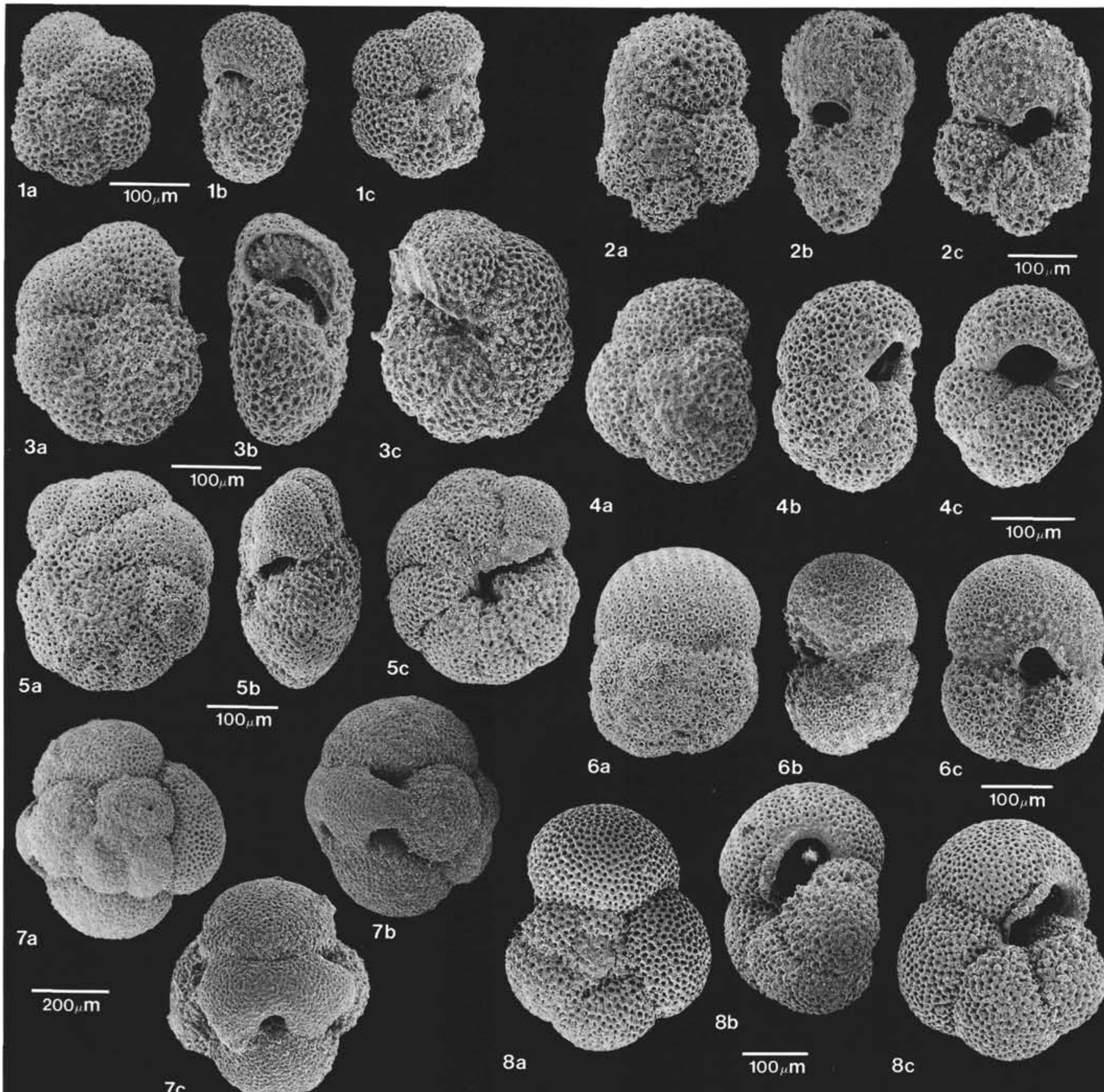

Plate 3. **1a–c.** "*Globorotalia*" *pseudokugleri* Blow, ancestral form, Sample 115-709B-22X-5, 80–85 cm. **2a–c.** *Globorotaloides* sp. 1, Sample 115-707A-16H-6, 38–43 cm. **3a–c.** "*Globorotalia*" *pseudokugleri* Blow/"*G.*" *kugleri* Bolli transition, Sample 115-709B-22X-2, 80–85 cm. **4a–c.** "*Globigerina*" *woodi* Jenkins, Sample 115-709B-24X-2, 80–85 cm. **5a–c.** "*Globorotalia*" *kugleri* Bolli, Sample 115-709B-21X-1, 80–85 cm. **6a–c.** *Subbotina brazieri* (Jenkins), Sample 115-709B-22X-3, 80–85 cm. **7a–c.** *Globorotaloides* sp. 2, Sample 115-709B-21X-6, 80–85 cm. **8a–c.** *Paragloborotalia semivera* (Hornibrook), Sample 115-709B-21 X-2, 80–85 cm. (a) Spiral view, (b) side view, and (c) umbilical view.

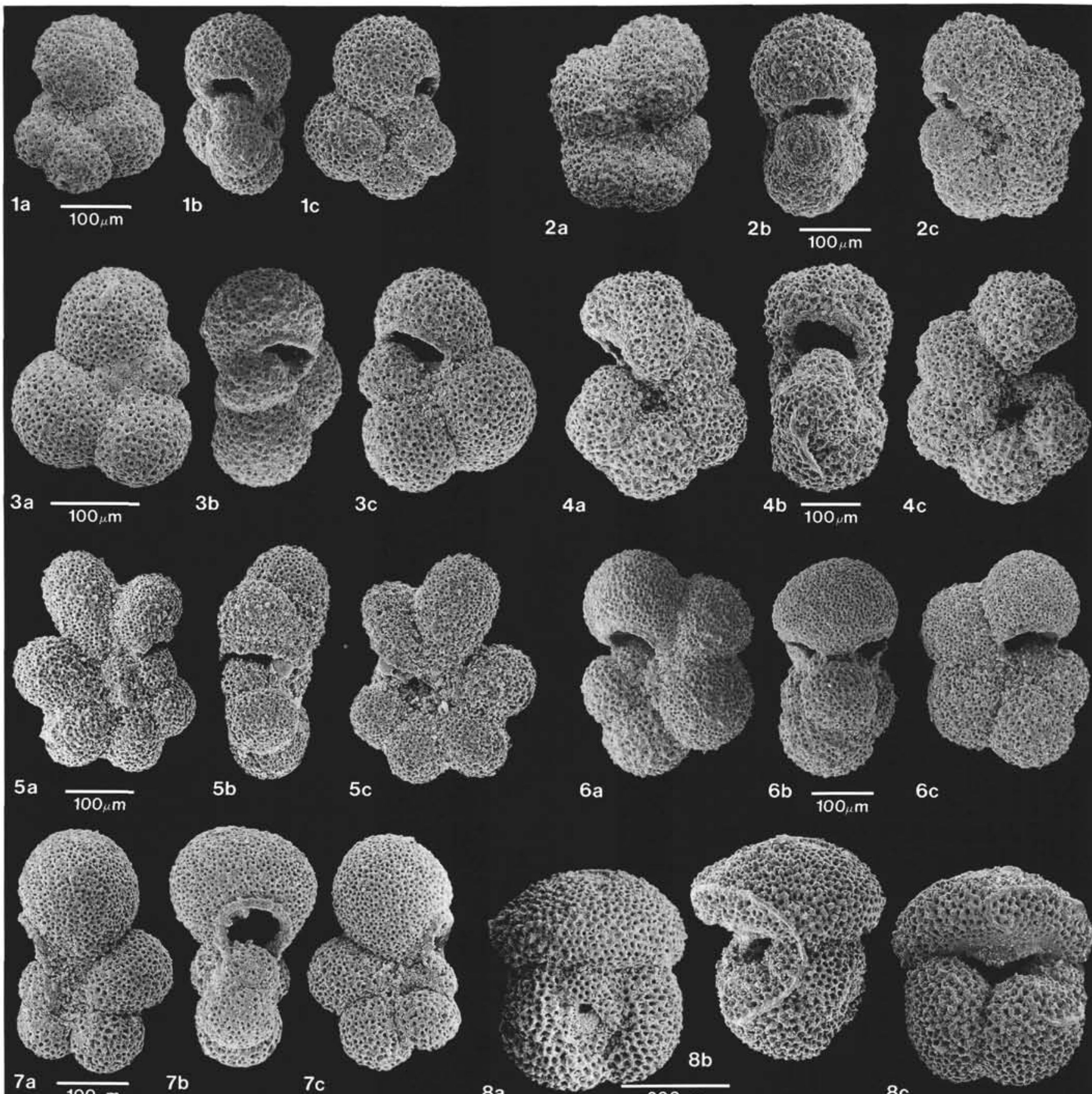

Plate 4. **1a–c.** "*Globorotalia*" *obesa* Bolli/*Globigerinella praesiphonifera* (Blow), Sample 115-709B-22X-1, 80–85 cm. **2a–c.** *Globigerinella*? sp., Sample 115-709B-22X-1, 80–85 cm. **3a–c.** *Protentella* sp. 1, Sample 115-709B-23X-4, 80–85 cm. **4a–c.** *Globigerinella*? sp., Sample 115-709B-22X-1, 80–85 cm. **5a–c.** *Protentella clavaticamerata* Jenkins, Sample 115-709B-22X-3, 80–85 cm. **6a–c.** *Protentella navazuelensis* Molina, Sample 115-709A-21 H-2, 70–75 cm. **7a–c.** *Protentella* sp. aff. *P. prolixa* Lipps, Sample 115-709B-22X-5, 80–85 cm. **8a–c.** *Globoquadrina praedehiscens* Blow and Banner/*G. dehiscens* (Chapman, Parr and Collins), Sample 115-707A-15H-6, 38–43 cm. (a) Spiral view, (b) side view, and (c) umbilical view.