9. CRETACEOUS-TERTIARY PLANKTONIC FORAMINIFERS FROM THE SOUTHEASTERN ATLANTIC, WALVIS RIDGE AREA, DEEP SEA DRILLING PROJECT LEG 74[1]

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ABSTRACT

Planktonic foraminifers were studied from the > 149 μm fractions of Cretaceous and Cenozoic sediments at DSDP Sites 525, 526, 527, 528, and 529, all clustered in the southernmost Angola Basin and central Walvis Ridge area of the southeastern Atlantic. Faunas were commonly mixed by consistent slumping in the Maestrichtian and, to a lesser degree, in the Paleocene. Contamination that is presumed to be due to downhole coring emplacement of coarse-fraction drilling sands was common in the Miocene of Sites 525 and 528, particularly in the mid-Miocene (Zones N11-N13). Species ranges presumed to be anomalous in these intervals, therefore, are frequent.

Cretaceous sediments were interlayered with basalt and/or altered by contact with basalt at all but Site 529. Inconsistency between foraminiferal and nannofossil zonations and paleomagnetic results through most of the Maestrichtian at all sites is attributed to consistent slumping of sediment coarse fractions, which include most of the foraminifers.

Paleocene sediments are moderately well preserved at Sites 525, 527, 528, and 529, but the sections are incomplete. Only shallow-water carbonates with some larger foraminifers were attributed to the Paleocene (Manivit, this volume) in Hole 526C. At three sites, 525, 527, and 528, good, apparently continuous Paleocene/Eocene boundary sections were recovered.

The Eocene was recovered at all sites, but is incomplete because of dissolution near the CCD at Sites 528 and 527, typical South Atlantic mid to late Eocene dissolution and recrystallization at Sites 525 and 529, and lack of index fossils in the shallow-water carbonates at Site 526. Eocene/Oligocene boundary sections are present in Hole 526A and at Site 529, though marked by an erosional hiatus from Zones P16-P20 at Site 526. This boundary at Site 529 is marked by dissolution pulses and the disappearance of typical Eocene globigerinathekids, turborotalids, and hantkeninids, followed by a fauna rich in globigerinids, *Globorotaloides* sp. and *Catapsydrax* spp.

A relatively complete Oligocene section at Site 529 and a section from Zone P20-P22 at Site 526 contain well-preserved, typical, middle-latitude faunas; the preservation is better at the shallower Site 526. The biserial genus, *Streptochilus*, first appeared in Zone P21B. A small, angular globoquadrinid that is considered the predecessor to *Globoquadrina dehiscens* first appeared in Zone P22 here, as at other Walvis Ridge sites previously drilled.

Relatively well preserved Miocene faunas found at all but Site 527, which lay below the foraminiferal CCD throughout this time, are difficult to zone because of contamination by the drilling process, lack of index taxa such as *Catapsydrax* spp. and most lower-latitude index species, and premature disappearance of indices such as *G. dehiscens*. The major change in faunal composition occurred in Zone P16, where *G. dehiscens* disappeared and subtropical and some tropical species increased in abundance.

Pliocene sediments from all sites are well preserved, even at Site 527, which rose above the CCD at the beginning of the Pliocene. The *Globorotalia conoidea-G. conomiozea* group ranges higher here than reported at other DSDP sites, overlapping with the evolutionary transition to *G. inflata* at the beginning of the late Pliocene.

Well-preserved Pleistocene faunas recovered in one or two cores at all sites contain a higher percentage of subtropical species than do Pliocene faunas below.

INTRODUCTION

On Leg 74, five sites were drilled along a traverse from the Walvis Ridge crest into the southern Angola Basin to the north (Fig. 1). The sections recovered at Sites 525, 527, 529, and 528 range in age from Maestrichtian through Pleistocene; Site 526 recovered only Cenozoic sediments (Fig. 2).

Planktonic foraminifers from the > 149 μm fraction of sediments in core-catcher samples and one additional sample per core were analyzed from all cores recovered. Because of the close proximity of the core sites, the foraminiferal faunas are extremely similar. Species lists, therefore, were made for each epoch or series in the one or two best-preserved sections and occurrences are listed in Tables 2-5 and 7-12, later; the resultant biostratigraphic subdivisions of all sites are shown in Table 1.

In Pliocene samples from Sites 525 and 527, planktonic foraminiferal species were counted and the percentages of the most abundant species were plotted in order to examine, at least cursorily, the effect of the Pliocene glacials on the faunal contents of planktonic foraminifers in this region.

CRETACEOUS

Maestrichtian

Maestrichtian sediments were recovered in Hole 525A (Cores 40-60, Hole 527 (Cores 32-42), Hole 528 (Cores 32-46) and Hole 529 (Cores 41-44). At Sites 525-528 basal sediments are interbedded with and sometimes altered by basalt. Most of the Maestrichtian section at all sites contains evidence of continuous turbiditic flow and slumping into thin, *in situ* planktonic ooze layers. In ad-

[1] Moore, T. C., Jr., Rabinowitz, P. D., et al., *Init. Repts. DSDP*, 74: Washington, D.C. (U.S. Govt. Printing Office).

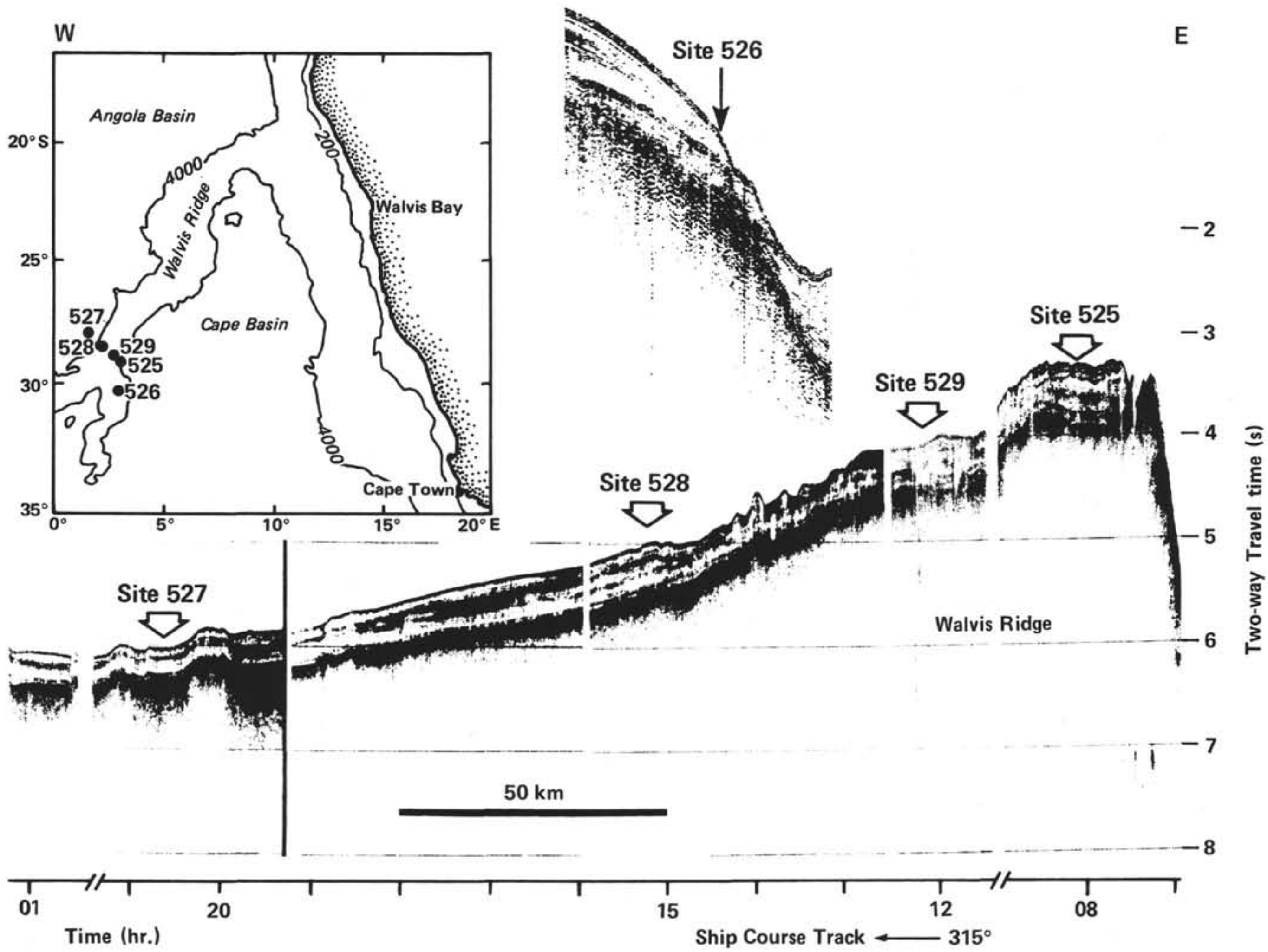


Figure 1. Location of Leg 74 sites in the eastern South Atlantic.

dition, volcanic sediments were deposited episodically during the Maestrichtian and are concentrated in levels around the Cretaceous/Tertiary boundary. As a result, little of the Maestrichtian section is well preserved; nevertheless, moderately well preserved sediments were found at the deepest Site 527. No foraminiferal faunas are well preserved across the Cretaceous/Tertiary boundary.

Site 527

Planktonic foraminiferal faunas from Site 527 are listed in Table 2, and biostratigraphic subdivision of the Cretaceous at this site is shown in Figure 2 and Table 1. Faunas dominated by *Globotruncana stuartiformis, G. arca*, and various heterohelicids resemble those reported by Caron (1978) at nearby Site 363, but are better preserved. These faunas have a nontropical character which may have resulted both from the poor preservation as well as the latitudinal position of the site. At some levels there are unusual concentrations of small-sized *G. conica* (e.g., at 527-37-3, 116 cm) and *Racemiguembelina fructicosa* (527-36-3, 26 cm). It is uncertain whether these concentrations represent proliferation of the species or size-sorting during sediment slumping.

The section contains several biostratigraphic anomalies including, *inter alia*, the overlap of *Abathomphalus mayaroensis* and *G. fornicata* and the simultaneous appearances of *G. contusa* and *R. fructicosa*. These anomalies appear to be the direct result of erosion and slumping of Maestrichtian sediments.

Site 525

In Hole 525A we drilled the oldest sediments of Leg 74, belonging to the basal Maestrichtian *Globotruncana tricarinata* Zone (Fig. 2, Tables 1, 3). These sediments are moderately to poorly preserved throughout the section and are particularly altered within the basalt complex and when interbedded with volcanogenic sediment layers (Cores 60–53).

Various sedimentologic and chemical processes have dissolved or otherwise altered the planktonic faunas at this site. Lower Maestrichtian assemblages are dominated by *G. arca*, the heterohelicids, and *Rugoglobigerina rugosa*. The apparent resistance of these taxa to *in situ* dissolution is illustrated in Sample 525A-47-5, 138 cm from which all other species have been removed or exist only as fragments. Upper Maestrichtian faunas are

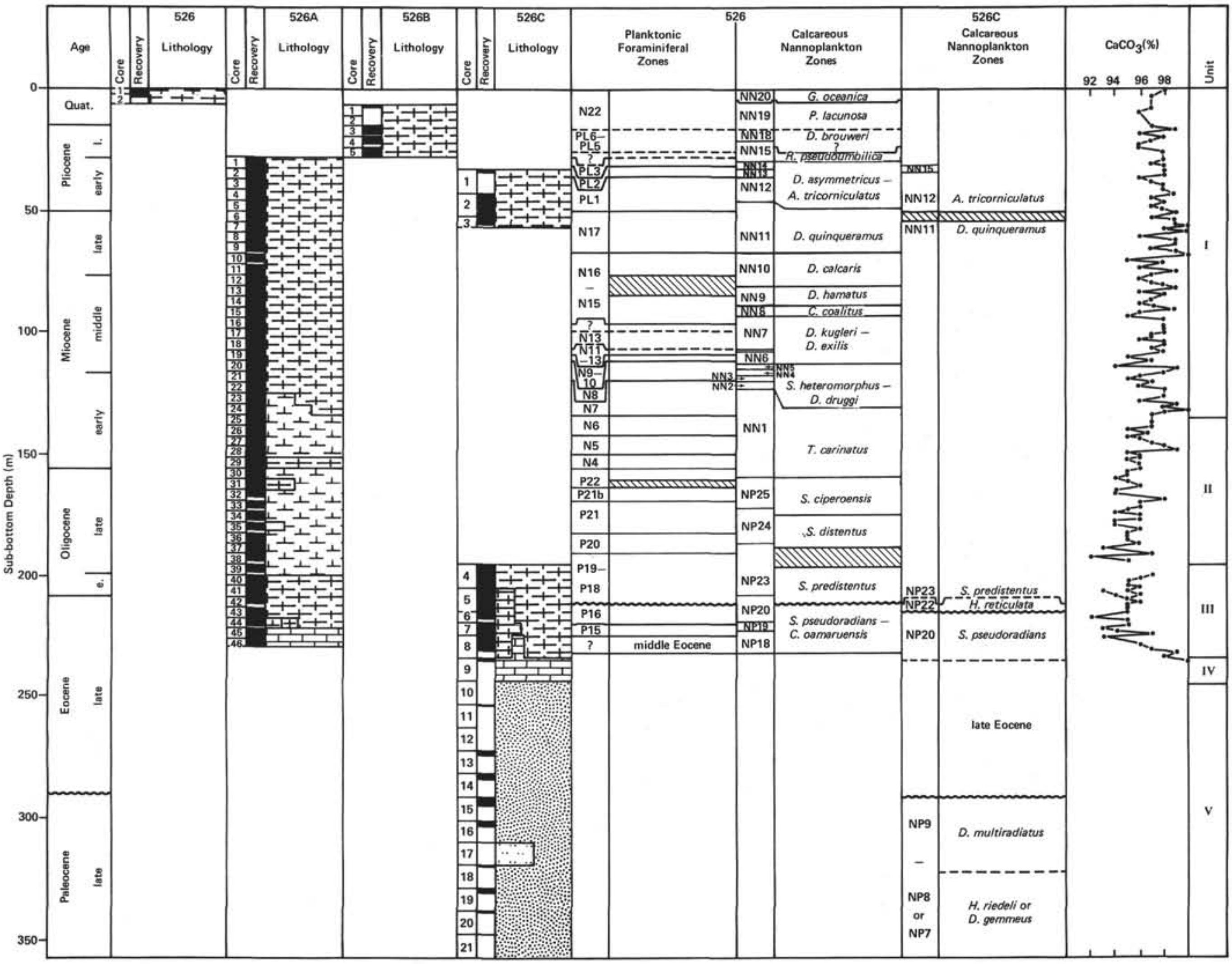


Figure 2. Biostratigraphic summary diagrams of Sites 525–529; zonations from Premoli Silva and Boersma (1977), Hardenbol and Berggren (1978), and Berggren (1972, 1973).

slightly better preserved and resemble those from Site 527.

Site 528

Basal sediments at this site are interbedded with basalt (Cores 39–46) and penetrate the basal Maestrichtian *Globotruncana tricarinata* Zone. Planktonic fossils are few and the preservation is very poor. Some levels (528-39-1, 64 cm; 528-39,CC) contain large amounts of *Inoceramus* prisms. The most consistently occurring fossils are *Globotruncana stuartiformis* and *G. arca*; the few more diverse faunas resemble those from Site 525. Above Core 39, *G. fornicata* is accompanied by the characteristically upper Maestrichtian forms *Abathomphalus mayaroensis* and, above Core 38, *Racemiguembelina fructicosa*. The overlapping ranges of *G. fornicata, G. contusa, A. mayaroensis*, and *G. tricarinata* are considered an artifact of sediment erosion and redeposition.

Site 529

Upper Maestrichtian sediments were recovered in Cores 41–44; sediments contained significant amounts of volcanogenic sediments, mollusk particles, and only moderately well preserved planktonic foraminiferal faunas. Faunas closely resembled those from the upper Maestrichtian of the three other sites; *Abathomphalus mayaroensis* and the *Globotruncana stuartiformis* group were the most frequent forms in these faunas.

Maestrichtian Foraminiferal-Magnetic Correlations and Sediment Disturbance

Comparison of the biostratigraphic datums at Sites 525 and 527 with the interpreted paleomagnetic anomaly boundaries (Chave, this volume) shown in Figure 3 would suggest that *Globotruncana tricarinata* and *G. fornicata* disappeared during the reversed episode between Anomalies 31 and 32; *Abathomphalus mayaroensis* appeared at the base of Anomaly 31; *Racemiguembelina fructicosa* and *Pseudoguembelina excolata* appeared simultaneously at the base of Anomaly 30; and *G. contusa* appeared within Anomaly 30. These correlations are anomalous relative to those established in the Pacific for Sites 207–208 by Keating et al. (1975) or in

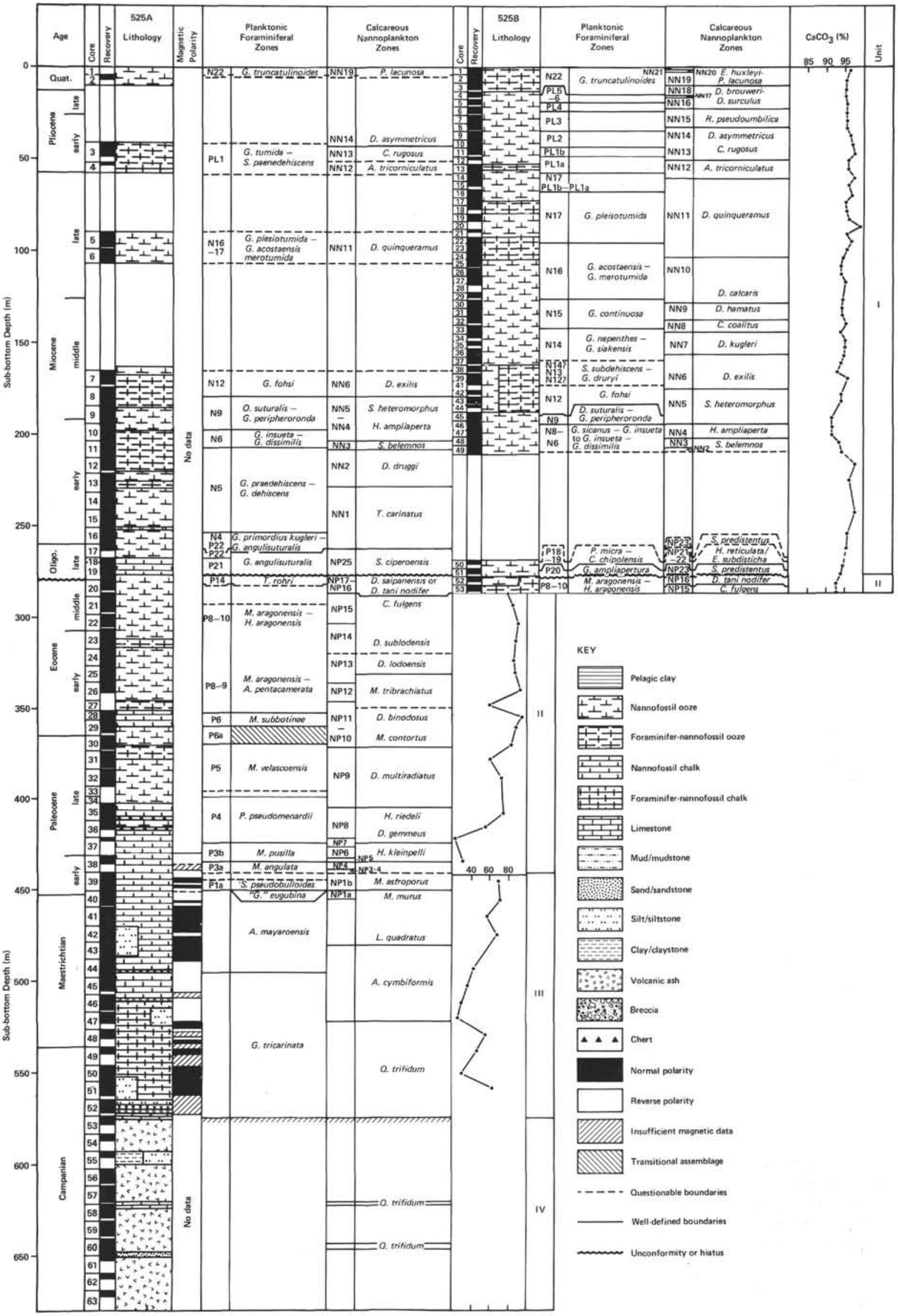


Figure 2. (Continued).

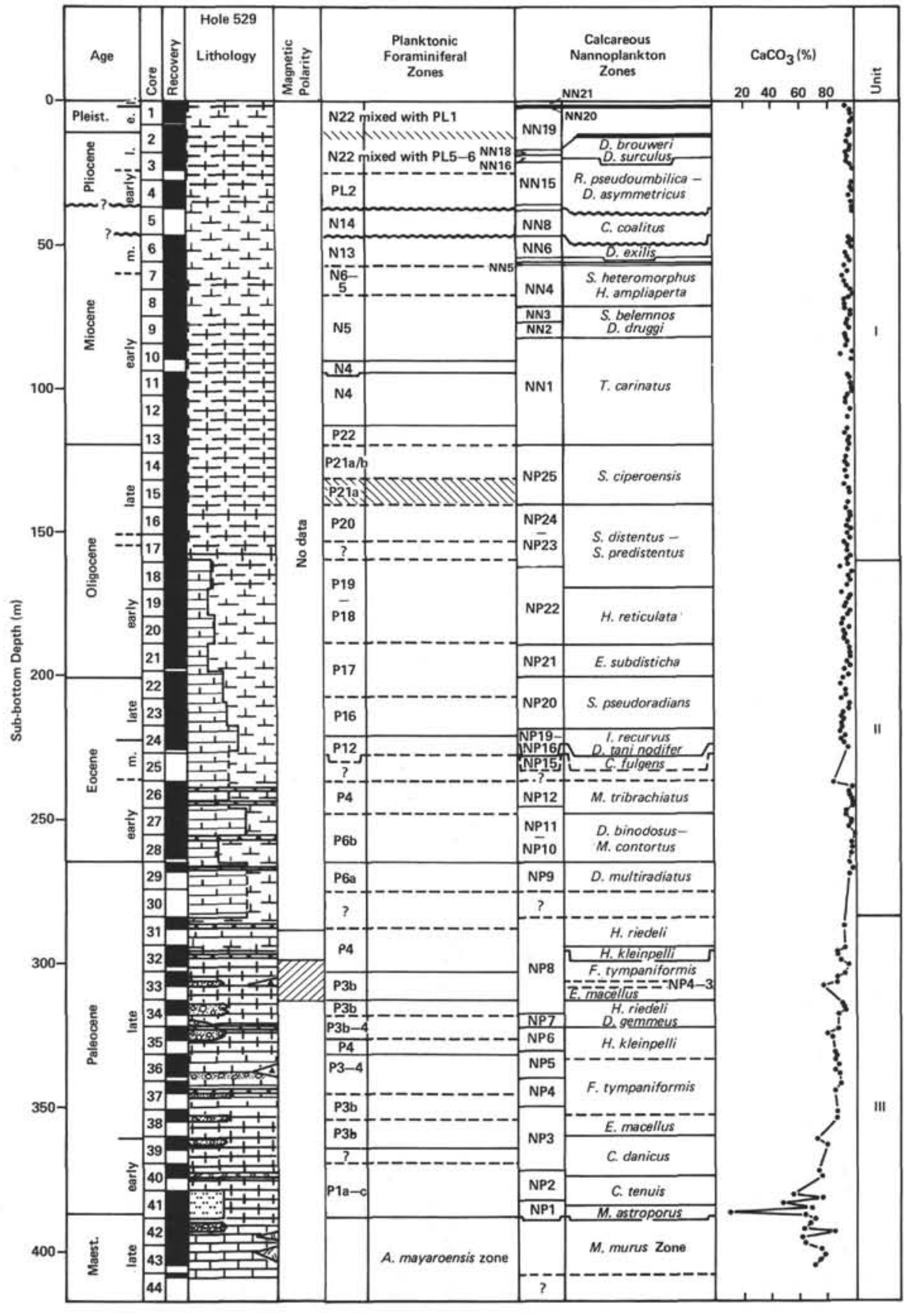


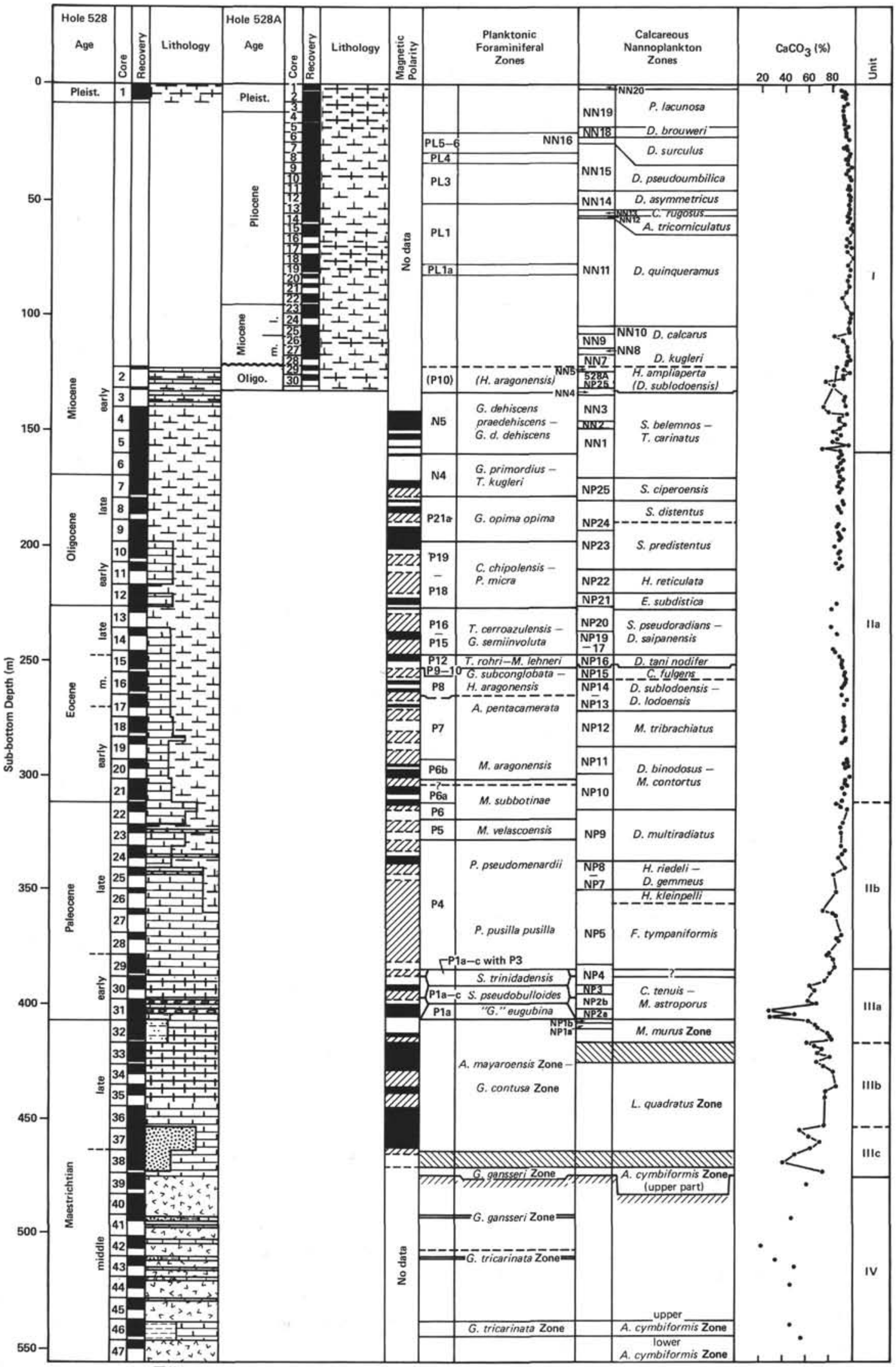
Figure 2. (Continued).

the standard section at Gubbio (Premoli Silva, 1977; Alvarez et al., 1977).

Comparison of nannofossil and foraminiferal zones and anomalies from Leg 74 sites with other South Atlantic sites (Fig. 4) demonstrates the uncertainties in the correlation of both the foraminiferal and nannofossil data, at least in these South Atlantic sections. Nevertheless, the several co-occurring endpoints, the anomalous relation of *A. mayaroensis* to *R. fructicosa* and *G. contusa*, and the lack of correlations with the Pacific and Gubbio sections all suggest that the correlations at the Leg 74 sites are an artifact of sediment disturbances.

THE CRETACEOUS/TERTIARY BOUNDARY

The Cretaceous/Tertiary boundary was recovered at Sites 525, 527, 528, and 529. At all sites the sediments are semilithified and the foraminiferal faunas are not well preserved. The very top of the Maestrichtian section at all sites has a thin (0.5–1.0 cm), blue-tinged, fine-grained sediment layer containing a unique foraminiferal fauna. At Site 528 (528-32-1, 1 cm), the blue-white chalk layer contains small-sized individuals typical of the *Abathomphalus mayaroensis* zone, with the addition of *Hedbergella monmouthensis* and morphotypes



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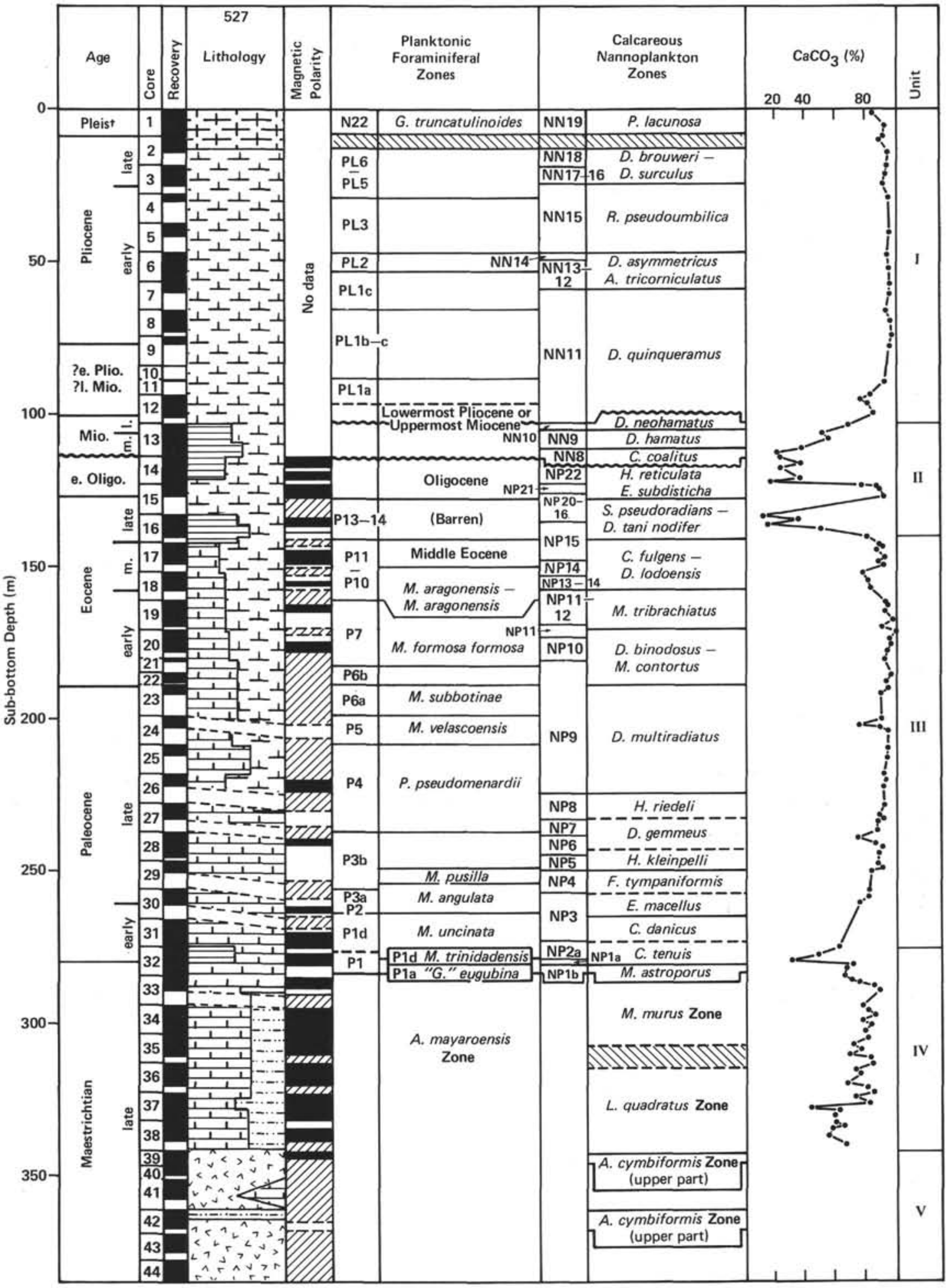

Figure 2. (Continued).

of *Pseudoguembelina excolata* displaying noticeably heavier costation. Substantial amounts of pyrite are embedded in the foraminiferal tests here, as at Site 527, where this fauna is less well preserved. The immediately overlying Paleocene samples (528-31,CC) have volcanic glass and other minerals, less pyrite, and are moderately well-preserved. *Chiloguembelina morsei* comprises over 75% of the fauna, which also contains *Guembelitria cretacea, Planorotalites eugubinus*, and an unnamed species of *Chiloguembelina*. The *P. eugubinus* Zone ranges from Sample 528-31,CC to 528-31-7, 24 cm.

At Site 527 the blue-white chalk layer is found from 527-32-4, 50 cm to 527-32-4, 52 cm and contains a fauna similar to that at Site 528, but less well preserved. The *P. eugubinus* Zone extends from 527-32-4, 50 cm to 527-32-4, 26 cm and contains faunas similar to those at Site

Table 1. Biozonation of planktonic foraminifers at Sites 525–529.

Age	Zone	Site 525 Hole 525A	Site 525 Hole 525B	Site 526 Hole 526A	Site 526 Hole 526B,C		Site 527 Hole 526	Site 528 Hole 528	Site 528 Hole 528A	Site 529
Pleistocene	N23	1	1–2		1–3,CC		1	1	1–5,CC	1-2-6
Pliocene	Pl6		3–4		4,CC	1,CC	2–3,CC		6–7,CC	2-6-3-2
	Pl5									
	Pl4		5		5,CC				8	
	Pl3		6–8	1-1			4–5,CC		9–12,CC	
	Pl2		9–10	1,CC						3-2–4,CC
	Pl1	2-3	11–13	2-2-5-3			6–11,CC		13–19,CC	
Miocene	N17	4-6	14-2–16	5,CC–9,CC		2–3,CC			20	
	N16		17-2–26	10–11,CC						
	N15		27-2–30							
	N14		31-1–36							5
	N13			12						
	N12	7		13-1–15,CC						
	N11		39-2	16–18						
	N10		41–39							
	N9	8-1–9		19-3–20,CC						6-2–6,CC
	N8		42-2–48-2							
	N7	10-1–10,CC		21-2–21,CC						
	N6		48-2–49	22-1–23,CC						
	N5	11-2–15,CC		24-1–26-1				3		7-3–10-2
	N4	16-1–16,CC		26-2–31-3				4–6,CC		10-2–13-4
Oligocene	P22	17-1–17,CC		31-3–31,CC						13-4–14-6
	P21	18		32–35,CC				7–9,CC		14,CC–16-2
	P20		50–51	36–37,CC						16-4–17-4
	P19			38-1–40,CC		4–5,CC		10–12,CC		17-4–20-3
	P18									
	P17			42						20-3–20,CC
Eocene	P16			43		7–9,CC				21–23,CC
	P15			44			16,CC	13–14,CC		
	P14	19								
	P13						17?			
	P12							15-2–15-5		24
	P11									
	P10	20–22	52–53				18?	15-5–15,CC		
	P9									
	P8	23–25						16		
	P7	26–27					19–20,CC	17–19,CC		25–28,CC
	P6	32-1–28-2					21-1–24-2	20–22-2		29–30,CC–
Paleocene	P5	32-1–32,CC					26–27	23-2–27-2		
	P4	36–33-1						27-2–28-2		31–38,CC mixed
	P3	37-1–38,CC					28–30-3	28-2–29		
	P2						30-3–30-4			
	P1d						30-4–31-5			
	P1c	39-4–39-2								
	P1b	39-4–39,CC					31-5–32-4	30-2–31-7		39–40
	P1a									
	Planorotalites eugubinus	39-4–110					32-4-50–32-3-95	32-1		41-6
Maestrichtian	*Abathomphalus mayaroensis*	39,CC–44,CC					32-4–43,CC	32-1–42,CC		41–44,CC
	Globorotalia tricarinata	45-5–60						43–54,CC		

Note: Zonal boundaries are located to core and section level.

528. At Site 525, however, the sediments are more mixed both above and below the boundary; the result is a mixed transition at this site.

TERTIARY

Paleocene

Incomplete Paleocene sections were recovered from Sites 525, 527, 528, and 529 (Fig. 2). Hole 526C bottomed in shallow-water carbonate sands and limestone which, according to nannofossil data (Manivit, this volume), may have been late Paleocene in age. These sediments, however, contain no planktonic foraminifers.

Paleocene sediments have been subdivided according to the biostratigraphic zonation of Hardenbol and Berggren (1978). The most complete section, at Site 527, includes small thicknesses of all Paleocene zones. At the other sites Zones P1d and P2 are missing; Zone P3a is only found slumped into Zone P1 levels at Site 528. Site 529 (and to a lesser degree, Site 528) contains several slumps in the mid and upper Paleocene.

Site 527

The moderate to good preservation through the Paleocene at this site is interrupted only by two short episodes of dissolution in Zone P3b and Zone P5 (Table 4). Planktonic foraminiferal faunas are temperate in character. In the basal *Planorotalites eugubinus* Zone the biserial heterohelicids dominate the faunas. By the upper *P. eugubinus* Zone the nominate taxon and an unusual hedbergellid, *Hedbergella monmouthensis*, found only in middle to higher latitude Paleocene sediments

Table 2. Stratigraphic ranges and relative abundances of most common planktonic foraminifers (fraction > 149 μm) through the Maestrichtian of Hole 527.

Stage	Planktonic Foram. Zone	Core/Section (level in cm)	Preservation	*Globotruncana stuartiformis*	*Globotruncana arca*	*Globotruncana* trans. *stuarti*	*Globotruncana* cf. *coronata*	*Globotruncana conica*	*Globotruncana* spp.	*Globotruncana fornicata*	*Rugoglobigerina rugosa*	*Pseudoguembelina excolata*	*Pseudotextularia elegans*	*Planoglobulina glabrata*	*Gublerina* spp.	*Heterohelix pulchra*	*Heterohelix globulosa*	*Heterohelix striata*	*Planoglobulina multicamerata*	*Globigerinelloides asper*	*Abathomphalus mayaroensis*	*Globotruncanella havanensis*	*Globotruncana calciformis*	*Racemiguembelina* trans. *fructicosa*	*Globotruncana* cf. *contusa*	*Abathomphalus intermedia*	*Rugoglobigerina rotundata*	*Globotruncana contusa*	*Racemiguembelina fructicosa*	*Globotruncana stuarti*
Maestrichtian	*Abathomphalus mayaroensis*	32-6, 21	P	F	F						F	F	I	I	F	I	C	F	I	F	F	F	F					F	F	C
		33-3, 133	M	F	F						F	F	I	I	F	I	C	F	I	F	F	F	I					F	F	
		34-3, 29	P	F	F		R				F	I	I	I	I		F	F	R	F	F	F	I					I	F	
		35-3, 101	M	A	C	R	R				F	F	I	I	F		C	I		F	F	F	F					C	I	
		36-3, 26	M		A						F			F	I		C	C	I		C	F	R					R	A	
		37-3, 116	P	C	C			C				I		F	C		C				F		C	C	C					
		38-3, 104	M	C	C	R		F			C	I	I	P	I	I	C	F	F		F	F	F	F	I	R	I			
		42-2, 16	M–P	C	C			F	R	I	C	F	I		C	I	C	F				F	I							
		42-3, 45	P	C	C	I	R	I	R	I	F	F	I	F	C	I	C	C	I	C	I	I								

Note: Foraminiferal abundances estimated as A = abundant, C = common, F = frequent, I = infrequent, and R = rare. For preservation, P = poor, M = moderate, G = good.

Table 3. Stratigraphic ranges and relative abundances of most common planktonic foraminifers through the Maestrichtian of Hole 525A.

Stage	Zone	Core/Section (level in cm)	Preservation	*Globotruncana tricarinata*	*Globotruncana fornicata*	*Globotruncana arca*	*Planoglobulina glabrata*	*Pseudotextularia elegans*	*Rugoglobigerina rugosa*	*Globigerinelloides asper*	*Heterohelix globulosa*	*Heterohelix pulchra*	*Globotruncanella havanensis*	*Rugoglobigerina rotundata*	*Globotruncana* cf. *coronata*	*Rugotruncana* spp.	*Globotruncana* cf. *stuarti*	*Pseudoguembelina costulata*	*Globotruncana calciformis*	*Globotruncana* spp.	*Globotruncana stuartiformis*	*Abathomphalus mayaroensis*	*Globotruncana conica*	*Globotruncana fundiculosa*	*Planoglobulina multicamerata*	*Racemiguembelina fructicosa*	*Pseudoguembelina excolata*	*Globotruncana contusa*
Maestrichtian	*Abathomphalus mayaroensis*	40-2, 50	P				F	F	F		F	F		I							F	F	F		I	F	F	F
		40-5, 68	P				F	C	F		F	P		I							F	F	F			F	I	F
		41-3, 33	VP				R		I	I	I	I									I	I	I				I	I
		41-3, 100	M–P			I	F	I	F		C	F	F	R							I	I	F	I		F	I	I
		42-2, 107	P				I	I	F		F	F		R							I			I	I	C	F	I
		42-5, 53	M			F		I	C	F	C	C	I				I		F		C	R	I	R		R	I	
		43-5, 92	P				C	I	C		C	F		F			R		I		I	R	R	I				
		43-6, 114	P			R	F	I	C		C	C	I	I				I	I		I	F	I					
		44-1, 125	M–P			R	C	F	C		C	C		I			R		R		C	I						
		44-6, 70	P		I	C	I	F	I	C	C							R	R	R								
		45-3, 104	VP			R					C	C					R	R										
	Globorotalia tricarinata	45-5, 85	P			C	F		C		C	C			R		R											
		46-1, 102	P	I		C	C	R	I	C	C	C			R													
		46-3, 103	P	R	R	F			C	I	C	F	I	I	R													
		47-5, 138	P		R	C			A		A			I														
		48-1, 89	P	F	F	F			I	I	I	I			I	I												
		49-2, 31	P	C	I	C	F		F	F	F	F		I	R	F												
		50-6, 52	P	R	R	F	R	R	A		F	F		F														
		51-6, 23	P	R	R	I	R	R	C	I	F	I	I	F														
		52-1, 6	P	I	F	F	R	I	C	I	F	I	I															

Note: Symbols as in Table 2.

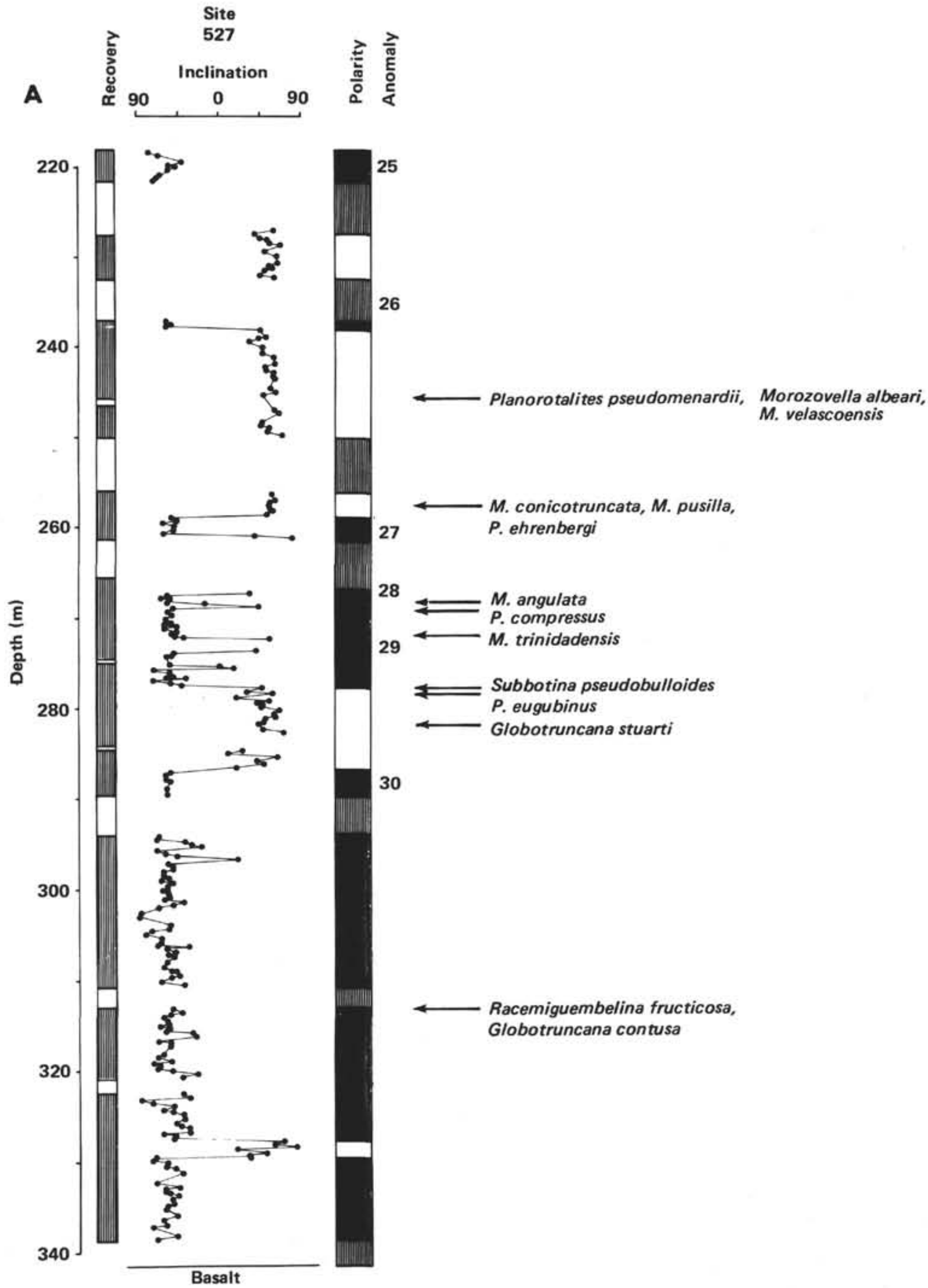

Figure 3. Maestrichtian and Paleocene foraminiferal datums plotted against interpreted paleomagnetic anomalies (Chave, this volume) for Holes 527 and 525A. Datum levels in meters downcore for the Paleocene at this site are listed in Table 6. The consistent slumping through this section in Hole 527 (A) is considered responsible for the anomalous foraminiferal-magnetic correlations. In Hole 525A (B), such slumping was consistent through the Maestrichtian, in particular.

(Boersma and Premoli Silva, in press), predominate in the faunas, with heterohelicids lesser in abundance. In Zone P1 the common appearance of *Subbotina pseudobulloides* and *P. compressus* and lesser abundances of heterohelicids are typical of middle-latitude sites, as are the joint high abundances of *S. triloculinoides*, small biconvex morozovellids (such as *Morozovella albeari*) and the acarininids in Zones P3 and P4. The unusual fauna of Zone P5, including many large, flat forms of the *M. velascoensis* plexus and *M. tadjikistanensis djanensis*, closely resembles that of Site 329 near 55° S paleolatitude on the Falkland Plateau (Tjalsma, 1978). The only other such fauna was found in the Caucasus where the *M. tadjikistanensis* plexus was named.

Site 525

Preservation of faunas in Hole 525A is generally moderate (Table 5). The section, less complete than that

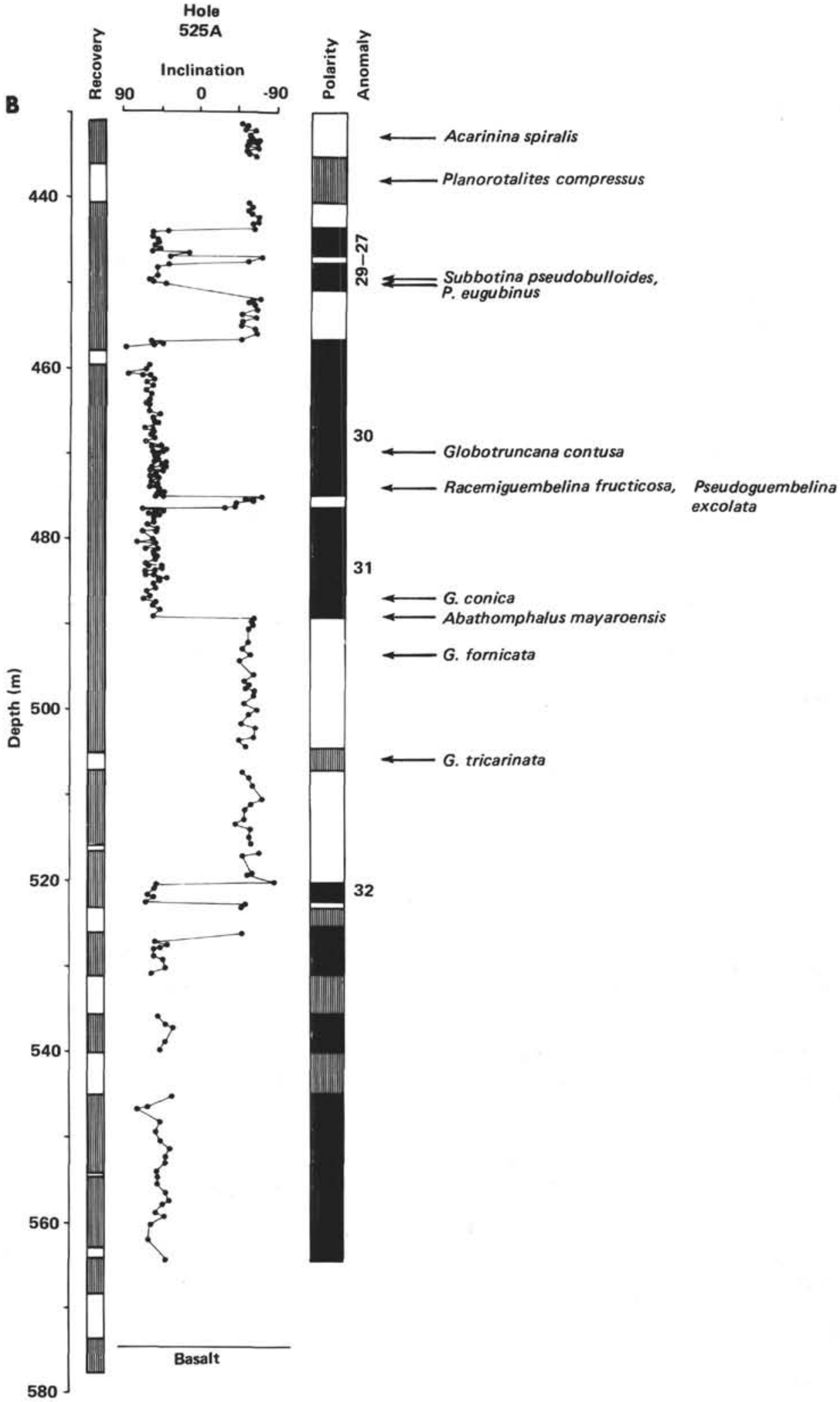

Figure 3. (Continued).

at Site 527 (Fig. 2) lacks Zones P1d and P2, but contains slightly longer sections of the other zones, and of Zone P4 in particular. The character of the faunas, slightly different from those at Site 527 to the south, suggests the presence of a biogeographic boundary between the two sites. In the lower Paleocene the larger numbers of heterohelicids and in the upper Paleocene the lack of *Morozovella djanensis* and *Planorotalites australiformis* indicate less connection between Site 525 and the higher middle latitudes than is indicated at Site 527.

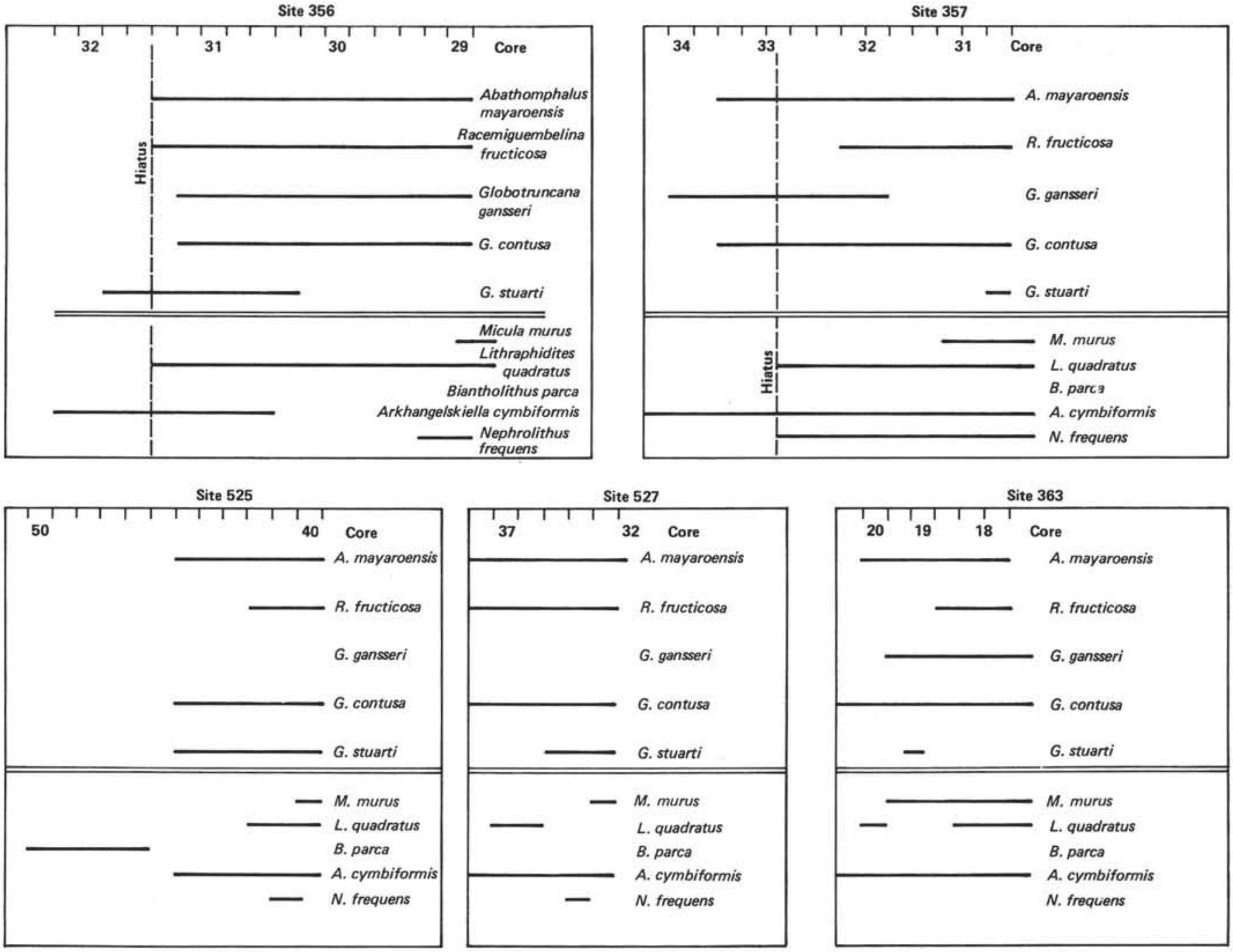

Figure 4. Summary of the ranges of planktonic foraminiferal and nannofossil index species through the Maestrichtian at five South Atlantic DSDP sites. Data from Premoli Silva and Boersma (1977), Caron (1978) Perch-Nielsen (1977) and Proto Decima et al. (1978).

Table 4. Stratigraphic ranges and relative abundances of most common planktonic foraminifers through the Paleocene of Hole 527.

Epoch	Zone	Core/Section (level in cm)	Preservation	*Woodringina hornerstownensis*	*Chiloguembelina midwayensis*	*Planorotalites eugubinus*	*Hedbergella monmouthensis*	*Globoconusa daubjergensis*	*Subbotina fringa*	*Subbotina minutula*	*Guembelitria cretacea*	*Subbotina pseudobulloides*	*Planorotalites* aff. *compressus*	*Planorotalites compressus*	*Morozovella inconstans*	*Subbotina triloculinoides*	*Morozovella angulata*	*Morozovella conicotruncata*	*Planorotalites ehrenbergi*	*Morozovella pusilla pusilla*	*Morozovella occlusa*	*Morozovella acutispira*	*Morozovella marginodentata*	*Morozovella velascoensis*	*Planorotalites pseudomenardii*	*Subbotina patagonica*	*Morozovella albeari*	*Acarinina nitida*	*Acarinina spiralis*	*Acarinina coalingensis*	*Subbotina varianta*	*Subbotina trilocularis*	*Acarinina pseudotopilensis*	*Acarinina wilcoxensis*	*Acarinina soldadoensis*	*Morozovella acuta*	*Planorotalites reissi*	*Morozovella subbotinae*	*Planorotalites* cf. *australiformis*	*Morozovella* cf. *djanensis*	*Acarinina* cf. *nicoli*	*Acarinina mckannai*	*Chiloguembelina midwayensis*	*Subbotina eocaena*	*Pseudohastigerina wilcoxensis*
Eocene		20-3, 88	G																							C	I	I		F		I	I	C	I	C	I	F	R			R		F	R
		21-1, 50	M																		R		I			A	I	I	I	I		I		C	F	F	I	F			I	I	C		
		22,CC	M																							A	I	I		F		I	F	F	F	F	I	F			R				
	P6	23-1, 30	P																		F					A	I	I	I	I				C		I	I	C	R	R					
		·24-1, 30	P																		F			R																					
		24-4, 90	P																		F			F		C	F	F	F	F	I	I		R		I									
		25-2, 61	M																					F		C	C	C	C	C	I	I		I	I	I									
		26-3, 35	M																		F			C	I	A	A	A	I			F													
	P5	27-1, 78	G																		F			F	C	C	C	C	C		R	I	R	R											
Paleocene		27-4, 9	G																							R		R																	
		28-4, 89	G									I									C	I	F	A	I	F	C	I	I	R	I														
	P3	29-1, 100	P		R							I				C				I																									
		29-2, 100	G		R							I				A	I	I	F	C	C																								
	P2	30-3, 77	M		F							A		R	C	A	R																												
	P1	30-4, 41	P		F							F	C	F	F	A																													
	Planorotalites eugubinus	32-3, 95	G		F			I				C	C	C	C	F																													
		32-4, 50	G	R	I	C	C	F	I	I	R																																		

Note: Symbols as in Table 2.

Table 5. Stratigraphic ranges and relative abundances of most common planktonic foraminifers through the Paleocene of Hole 525A.

Epoch	Zone	Core/Section (level in cm)	Preservation	*Woodringina hornerstownensis*	*Chiloguembelina morsei*	*Planorotalites eugubinus*	*Globoconus daubjergensis*	*Guembelitria cretacea*	*Subbotina minutula*	*Hedbergella monmouthensis*	*Subbotina fringa*	*Chiloguembelina midwayensis*	*Planorotalites* aff. *compressus*	*Subbotina pseudobulloides*	*Subbotina triloculinoides*	*Planorotalites compressus*	*Acarinina spiralis*	*Acarinina chasconona*	*Morozovella acutispira*	*Morozovella conicotruncata*	*Morozovella* trans. *velascoensis*	*Morozovella albeari*	*Planorotalites pseudomenardii*	*Acarinina nitida*	*Subbotina patagonica*	*Acarinina* cf. *nicoli*	*Morozovella velascoensis*	*Chiloguembelina wilcoxensis*	*Acarinina pseudotopilensis*	*Planorotalites reissi*	*Acarinina soldadoensis*	*Morozovella apanthesma*	*Morozovella acuta*	*Subbotina varianta*	*Subbotina* cf. *eocaena*	*Planorotalites chapmani*	*Morozovella subbotinae*	*Acarinina coalingensis*	*Subbotina trilocularis*	*Morozovella marginodentata*	*Pseudohastigerina wilcoxensis*
Eocene	P6	29-2, 60	G																					C	F			C	F	R	I		F			R	I	A		I	R
Paleocene		30-4, 30	M									F					C							C	A			C		R	I		F	I	C		I	C		I	
		30-6, 30	M														C							C	P	R		A	I	I	I		I	I		I	I	C		I	
		31-7, 60	G									C					F							F	A		I	A	I		F		I			F	I	C	F		
		31-4, 60	G														F							I	A		I	C		I	I	I	I			R	I	C		I	
		31-2, 60	M														I							I	A		I	C		I	I		I	I		F	I	A			
	P5	32-1, 70	M														I							I	A		I	C		I			F	I			F	C	I	F	
		32-4, 70	VG														I							I	A	R	I	F	F			R	I	I		R	F	C	I		
		32-5, 70	P																				R	I	A	I	F	F			I		I	I	I	R					
	P4	35-1, 74	P														I						F	F	A	I	F	I	I	I	I	R	I	I							
		35-3, 24	P														C						I	I	A			I	R	I	I										
		35-7, 30	G														C					F	F	C	C		R	I	R	I	I	R									
		36-1, 70	G														C		F			F	F	C	A		C	I													
		36-3, 24	G														C		P			I	I	C	C		R														
	P3	37-1, 140	M											I			A	A	C	I	R	C																			
		38-1, 15	G									R				R																									
		38-3, 15	VP									I			C	C																									
	P1	39-2, 8	M	I	I	I	I	I		I	F	F	F	C																											
		39-4, 110	M	F	F	C	F	F	C	C	C	F																											

Note: Symbols as in Table 2.

Sites 528 and 529

Biostratigraphic subdivision of Holes 528 and 529 is shown in Figure 2 and Table 1. The preservation of these faunas and their contents closely resemble those of Site 525. Slumping, however, caused substantial disturbance of the upper Paleocene, which is so extreme at Site 529 as to produce seven cores in which layers of sediments of Zones P3b and P4 age alternate.

Foraminiferal–Paleomagnetic Correlations

Successful measurement of paleomagnetics at Holes 525A and 527 (Chave, this volume) allows correlation of foraminiferal biostratigraphic datums and the chronostratigraphy. Foraminiferal datums, listed in Table 6 and plotted against magnetics in Figure 3, indicate the following correlations:

1) LAD *Planorotalites eugubinus* and FAD *Subbotina pseudobulloides* in the top of the reversed interval between Anomalies 30 and 29;

2) FAD *Morozovella angulata* in Anomaly 27;

3) FAD *M. pusilla* and *P. ehrenbergi* near the bottom of the reversed interval between Anomalies 27 and 26; and

4) FAD *P. pseudomenardii* near the top of the reversed interval between Anomalies 26 and 27.

My interpretation differs from that of Chave (this volume) for Site 527. I suggest that Anomalies 29 through 27 are compressed within the normal event between 278 and 268 m, that Anomaly 28 is located near 272 m, and Anomaly 27 closer to 269 m.

Table 6. Location of first appearance datums of Paleocene planktonic foraminifers in Holes 527 and 525A.

Species	Sub-bottom Depth (m)
Hole 525A	
Planorotalites eugubinus	451.7
Subbotina pseudobulloides	450
P. compressus	440.6
Acarinina spiralis	431.1
Morozovella conicotruncata	422.3
M. pusilla pusilla	422.3
M. albeari	422.3
P. pseudomenardii	412.1
M. velascoensis	412.1
S. patagonica	412.1
Hole 527	
P. eugubinus	279.9
S. pseudobulloides	279
P. compressus	269.8
M. trinidadensis	272
M. angulata	269.3
M. conicotruncata	258.5
M. pusilla pusilla	258.5
P. pseudomenardii	246.5
M. albeari	246.5
M. velascoensis	246.5

Note: Limits of the *Planorotalites eugubinus* Zone located by examination at 10 cm intervals. One sample per section was examined in all other cores to locate the datum levels.

Eocene

Short, incomplete Eocene sections were recovered at all sites on Leg 74. Their biostratigraphies, according to the zonation of Hardenbol and Berggren (1978), are shown in Figure 2 and Table 1. In general preservation is good in the lower Eocene of all sites except in Hole 526C, which contains a carbonate sand/limestone in this interval. Preservation deteriorates in the middle Eocene and hiatuses and/or dissolution disrupt the sections at all sites. In Zones P15 and P16 preservation improves, and upper Eocene sediments were recovered at all but the deepest Site 527, which sank below the foraminiferal CCD after Zone P14.

Site 528

Lower and middle Eocene planktonic foraminiferal species are listed in Table 7. As at other sites, their preservation is good into Zone P7 (Cores 20–17), above which it becomes moderate to poor, so that only small faunas of solution-resistant species such as *Globigerina senni* are preserved. By Cores 14–13 of the upper Eocene, faunas are nearly unispecific.

Lower Eocene faunas are typical of middle latitudes, where acarininids predominate over morozovellids. By the middle Eocene *Globigerapsis* spp. dominate the acarininids and the only common morozovellids are a small, dense form of *Morozovella aragonensis* and, in higher samples, *M. spinulosa* and *Acarinina bullbrooki*. The upper Eocene samples contain large proportions of *Globigerapsis index*. The site probably lay below the foraminiferal lysocline after Zone P12 (Section 528-15-2) time.

Site 529

Above a thick lower Eocene section similar to that at Site 528, most of the middle Eocene is missing, but upper Eocene sediments are also thick. The most common species from this interval is *Globigerapsis index*; faunas contain subsidiary amounts of *Catapsydrax unicavus*, *Globigerina corpulenta*, and the *Turborotalia cerroazulensis* group. There is a significant amount of inmixed middle Eocene material throughout the upper Eocene interval until the Eocene/Oligocene boundary, which at this site is marked by an episode of dissolution.

Site 525

Lower and middle Eocene sediments were recovered in Cores 525A-29 to 19, but no upper Eocene was found at this site. Basal Eocene sediments are well preserved; however, fossils become cemented and barely recognizable by Core 27 and remain poorly preserved up to Core 20, which contains a diverse planktonic foraminiferal population that is moderately well preserved.

Lower Eocene faunas are diverse and contain large numbers of morozovellids, which predominate in most samples. *Morozovella marginodentata* is usually the most common species; *M. acuta* and *M. subbotinae* are also commonly present. Acarininids are less frequent than in the upper Paleocene, but the *Subbotina eocaenica/patagonica* plexus is frequent throughout. At some levels *Chiloguembelina* is both common and diversified into several several species, including *C. midwayensis*, *C. triangularis*, and *C. wilcoxensis*. In Sample 525A-28,CC *C. wilcoxensis* becomes both huge in size and very common in the population.

At the top of the lower Eocene, faunas change markedly; acarininids and subbotinids become the most common forms. In these poorly preserved samples only two main morozovellids continue, *M. aragonensis* and *M. lensiformis*. By Core 525A-25 only solution-resistant species such as *Globigerina senni*, *Acarinina densa*, and *M. aragonensis* are preserved.

The two cores with well-preserved middle Eocene faunas contain several new species, including *M. spinulosa*, *Catapsydrax unicavus*, *S. linaperta*, and *Hant-*

Table 7. Stratigraphic ranges and relative abundances of most common planktonic foraminifers from the lower middle Eocene of Hole 528.

Epoch	Zone	Core/Section (level in cm)	Preservation	*Planorotalites elongatus*	*Morozovella aequa*	*Morozovella marginodentata*	*Acarinina soldadoensis*	*Acarinina angulosa*	*Morozovella lensiformis*	*Morozovella formosa*	*Morozovella aragonensis*	*Acarinina coalingensis*	*Chiloguembelina wilcoxensis*	*Subbotina linaperta*	*Subbotina eocenica*	*Turborotalia praecentralis*	*Acarinina* cf. *broedermanni*	*Morozovella taroubaensis*	*Planorotalites pseudoimitata*	*Pseudohastigerina wilcoxensis*	*Acarinina pseudotopilensis*	*Globigerina senni*	*Morozovella acuta*	*Subbotina compacta*	*Subbotina frontosa*	*Morozovella* cf. *spinulosa*	*Acarinina bullbrooki*	*Hantkenina aragonensis*	*Globigerapsis index*	*Acarinina mathewsae*	*Hantkenina mexicana*
Eocene	P6	20-2, 20	VP	I	I	C	C	C	I	F		I	F	I	I	R	R														
	P7	19,CC	VP	F	I	I	C	C		F		F	R	I	I	F		R	R	R	F										
		18-4, 20	VP				F	F	F			I									I										
		17,CC	P				F	I	F	R	R	F			R	R		I			I	I	I								
		17-3, 71	M				F	I	I		I	C									F	I	I								
	P8	16,CC	P–M				C	F			C	F					R				F	I	I								
		16-4, 22	M				F	I	I		C	F					F	R						R							
	P9–10	15,CC	P	R			F	I	R		F	F	R	R				R		R	C	I		R	R	I	I				
	P12	15-3, 100	P–M															R			C	I			I		C	R	I	R	R
		14-2, 20	P																			I							I		
	P15–16	13,CC	M																										A		
		13-2, 4	G																										A		

Note: Symbols as in Table 2.

kenina aragonensis; acarininids and globigerinid-form species are the most common components of the samples. In Sample 525A-20,CC only a few specimens of the middle Eocene species of *Guembelitria* were found.

Zone P14 is represented in Core 19 by specimens of *Globigerapsis semiinvoluta, G. index, Turborotalia cocoaensis, H. alabamensis*, and *S. angiporoides*. As is typical of temperate faunas, *Globigerapsis* species dominate samples and the only morozovellid is *M. spinulosa*.

Site 526

Although older sediments were identified by nannofossils in Hole 526C, no planktonic foraminifers of Eocene age were found until Core 44 in Hole 526A. Benthic foraminifers (Boersma, in press) in Cores 44 and 43 indicate that the site had sunk rapidly to upper slope depths by the late Eocene, when planktonic foraminiferal faunas began to be preserved. They are not particularly well preserved, but contain large numbers of *Globigerapsis index*, with significantly less common *Catapsydrax unicavus, Turborotalia cerroazulensis* and several globigerinids resembling *Globigerina corpulenta* and *G. eocaena*.

The Eocene terminates with a hiatus at this site.

Oligocene

Incomplete Oligocene sections were recovered at Sites 525, 526, and 528; Site 529 is nearly complete. The biozonation of Hardenbol and Berggren (1978) was applied to these sections (Fig. 2, Table 1). At this time, Site 527 lay below the foraminiferal CCD, so that no foraminiferal faunas were preserved. Site 528 lay below the lysocline and its sediments are very badly dissolved; as a result, there are several unispecific faunas. Preservation is good throughout the Oligocene at the other sites, particularly at the shallowest Site 526, where more diverse faunas and several dissolution-susceptible species are better preserved. This difference in preservation between Sites 526 and Site 529 also results in slight variations in the biozonation of the upper Oligocene between the two sites.

Site 529

As shown in Table 8, preservation through this section is generally good except for two episodes of dissolution and the emplacement of Eocene sediments in portions of Zone P17. Although most of the biostratigraphic indices for the lower-latitude zonation of Hardenbol and Berggren (1978) are present and could be used to subdivide the Oligocene at Site 529 (Fig. 2, Table 1), these zones are not strictly time-equivalent to their lower-latitude counterparts because of the diachronous ranges of planktonic foraminifers through latitude and longitude.

Oligocene faunas of Site 529 contain elements described from New Zealand and resemble those from nearby Site 363 on the Walvis Ridge (Jenkins, 1978). The temperate character of the faunas is indicated by a number of criteria:

1) lack of true *Globigerina tripartita*;

2) abundance of the *G. tapuriensis–G. euapertura* plexus and generalized forms related to *G. tripartita*;

Table 8. Stratigraphic ranges and relative abundances of most common planktonic foraminifers through the Oligocene of Hole 529.

Epoch	Zone	Core/Section (level in cm)	Preservation	*Tenuitella gemma*	*Catapsydrax unicavus*	*Globorotaloides suteri*	*Globoquadrina tripartita*	*Chiloguembelina cubensis*	*Turborotalia opima nana*	*Subbotina linaperta*	*Globigerina corpulenta*	*Subbotina angiporoides*	*Globigerina gortanii*	*Globigerina pseudoampliapertura*	*Pseudohastigerina micra*	*Turborotalia increbescens*	*Globoquadrina tapuriensis*	*Tenuitella munda*	*Globigerina decepta*	*Globoquadrina winkleri*	*Globigerina ampliapertura*	*Globoquadrina rohri*	*Globigerina brazieri*	*Globoquadrina praedehiscens*	*Turborotalia siakensis*	*Turborotalia acrostoma*	*Turborotalia bella*	*Turborotalia opima opima*	*Globoquadrina sellii*	*Catapsydrax dissimilis*	*Globigerina angulisuturalis*	*Streptochilus* sp.	*Globigerinoides praeprimordius*	*Globigerina ciperoensis*	*Globoquadrina tripartita*	*Turborotalia mendacis*	*Globigerinoides primordius*	*Globigerinita glutinata*	*Catapsydrax stainforthi*	*Globoquadrina trans. dehiscens*	*Globoquadrina binaiensis*	*Globigerina ouachitaensis*	*Turborotalia kugleri*
Miocene	N4	12,CC	M		F	I	F		I		I						I					I		I	I						I						R	I	R	C	I	R	F
Oligocene	P22	13-4, 10	M		F		C				I						I					I		F	I				R						R	R	R	R					
		14-2, 120	G		F	I	C				I						I					I			I				R	R		A			R	R							
		14-4, 104	G		I		C				F		I				I					I			I				I		R		R	R									
		14-5, 104	M-P		I	I	C		I		F						I					I	I		I				I		F	C											
	P21	14-6, 10	G		I	I	C		I		F						I					I	I		I				I		F												
		15-5, 60	G		I	I	C	I	I		F						I	C		I		I	I	I					I	R	F												
		15-6, 37	G		F	I	F		I		F		I				I	C		I		I	I	R				R	R	R													
		16-3, 30	G		F	I	C	C	F		F		I				I	C				I	R		R		R	I															
	P20	16-6, 115	G		F	F	C	C	I				F				I	C				F		I	I	R	R																
	P18–P19	17-4, 20	M-P	C	C		C	C	I		I	I					I	C				I		I	F	F	R																
		17-7, 20	M	C	F		C	C		I	F	F	F		R		F	C			I	I	R																				
		18-3, 60	G	C	A		F	C	I						F		I	C			R		R																				
		19-2, 40	G	F	F		C	C	F		I		I				I	C				F																					
		19-6, 20	M	I	A	I	F	C	I	I							I	C		I	I	I																					
	P17	20-2, 141	M-P	I	C	I	F	C	C	I	I	I	I		I		C	I				C																					
		20-3, 90	M-P	F	A	I	I	C	I		I	I	I	R			I	C				I	R																				
		20-5, 117	M-P	F	A	I	F	F	F		I		I		R		I	F		I		F																					
		21-2, 74	M-P	R	C		C	I	R						I		F	F			R	F																					
		21-3, 129	G	C	F	I	F	C	I		I		R	I	C	I	C		I	I	I																						
		21-4, 104	M-P	I	C	I	F	F	I	I		I		I	I			I		R																							
		21-5, 56	M	R	F	I	F	F	F	I		I	R	I	F	R	I	I	I																								
		21-5, 136	G	I	F	I	I	F	F	I				I	F	I																											
		21-6, 73	M-P	F	I	I	F	F	I	I				F	F	I																											
		22-1, 40	M	I	C	I	I	C	I	I	I	I	R	I	I																												

Note: Symbols as in Table 2.

3) presence of large globigerinids such as *G. corpulenta*;

4) rarity of *G. ampliapertura*;

5) abundance of *G. pseudoampliapertura* and *Catapsydrax* at the beginning of the Oligocene;

6) rarity and presumed premature disappearance of *Turborotalia opima opima*;

7) incidence of the turborotalids *T. siakensis* and *T. acrostoma* in the mid-Oligocene;

8) appearance in the upper Oligocene of small forms transitional to *Globoquadrina dehiscens*;

9) absence of the flat globoquadrinids of the *G. globosa* group; and

10) presence of several higher-latitude species such as *G. brazieri* and *G. angiporoides*.

The Neogene biserial heterohelicid genus *Streptochilus* appears one core above the extinction of *Chiloguembelina cubensis* at the top of Zone P21. This is before its appearance in the middle-latitude western South Atlantic (Boersma, 1977). In the equatorial Pacific, the transition from *Chiloguembelina* to *Streptochilus* can be observed at the P21a/b boundary. The appearance of the new genus is apparently delayed at middle latitudes.

Uppermost Oligocene faunas reflect the warming of the oceans and the reintroduction of subtropical elements into middle-latitude faunas. *Globigerinoides primordius, Globigerina ciperoensis*, and true *G. tripartita* all occur at Site 529 in Zone P22.

Site 526

Faunas from Hole 526A are generally well preserved throughout the Oligocene section, which extends from high in Zone P19 through Zone P22. A large hiatus spans the Eocene/Oligocene boundary and most of Zones P17 through P19. Analysis of benthic foraminifers (Boersma, in press) suggests that the site lay at upper bathyal depths by the end of the Eocene and again in the sediments overlying the hiatus in Zone P19.

Faunas in Hole 526A closely resemble those from Site 529. The *Globigerina tripartita–G. tapuriensis–G. euapertura* plexus dominates most samples along with the large globigerinids like *G. corpulenta*. In the uppermost Oligocene, however, solution-susceptible species such as *Globoquadrina baroemoenensis* are present at the shallower Site 526, but not at Site 529. Other solution-susceptible species such as *Globigerinoides primordius* are present at both sites, but persist longer and appear earlier in the shallower site.

Site 528

Intense dissolution in Cores 12–6 has left severely depleted foraminiferal faunas at most levels through the Oligocene. These faunas contain *Catapsydrax unicavus, Globorotaloides suteri*, some members of the *Globigerina tripartita–G. tapuriensis–G. euapertura* plexus, and some unispecific faunas of *G. angiporoides*. The resulting biozonation is uncertain and sketchy (Fig. 2, Table 1).

Site 525

Small sections of Zones P21–P22 were recovered at Hole 525A overlying a hiatus to the middle Eocene. At adjacent Hole 525B, a small section of the mid-Oligocene Zones P19–P20 is bracketed by hiatuses spanning the upper Eocene–lower Oligocene and the remainder of the upper Oligocene. The few faunas that were recovered are well preserved and identical to those at Site 529.

Miocene

Incomplete Miocene sections were recovered at all but Site 527, which lay below the foraminiferal CCD throughout the epoch (Fig. 2, Table 1). Most samples contain well-preserved foraminiferal oozes with only occasional levels of dissolution adjacent to the hiatuses of the middle Miocene and in the upper Miocene (for example, at 526A-14-2, 60 cm).

The drilling process emplaced large amounts of coarse, size-sorted debris of Miocene through Pleistocene age into the topmost sections and core catchers of many Miocene and Pliocene cores, particularly in the HPC holes at Sites 525 and 528. This process has confused the biostratigraphy of the middle Miocene, in particular, by downhole contamination, especially in the soupy sediments at the lower/middle Miocene transition.

Ranges of key lower–middle Miocene biostratigraphic index species are shown in Figure 5. Biostratigraphic subdivision of the Miocene according to standard zonations is, however, complicated by the absence or unusual ranges of key taxa such as *Catapsydrax dissimilis, C. stainforthi, Globigerinatella insueta*, members of the *Globorotalia fohsi* group, and even by the premature disappearance of *Globoquadrina dehiscens*.

The subtropical-transitional zones of Srinivasan and Kennett (1982) also could not be applied since the lower–middle Miocene species in this area do not meet the criteria for zones in the southwestern Pacific.

Middle and upper Miocene sequences of Leg 74 are less complete than those of the lower Miocene, but demonstrate a similar paucity of the usual, useful, biostratigraphic index species.

Site 526

Ranges of planktonic foraminiferal species in Hole 526A are shown in Figure 5A and Tables 9–10. Preservation is generally good throughout the section. Faunas of the lower Miocene contain several large globigerinid-form species including a generalized morphotype of *Globigerina tripartita, G. tapuriensis*, frequent *G. dehiscens* (including the small form which first occurs in the upper Oligocene), rare specimens of *Catapsydrax* spp., and several higher-latitude species such as *Turborotalia bella, G. brazieri*, and *G. labiacrassata*. The *G. woodi* group is present, but not common.

Middle Miocene faunas (Table 10) include the only members of the *Globorotalia fohsi* plexus which range through middle latitudes, *G. peripheroronda* and *G. fohsi lobata*, along with *G. miozea, G. conomiozea* and *G. conoidea* in abundance, and levels occasionally rich in *G. menardii. Sphaeroidinellopsis seminulina* and *S. subdehiscens* are not frequently found; the lower-latitude form *Globoquadrina altispira* is found in only one or two samples. *Globigerina nepenthes* is common throughout.

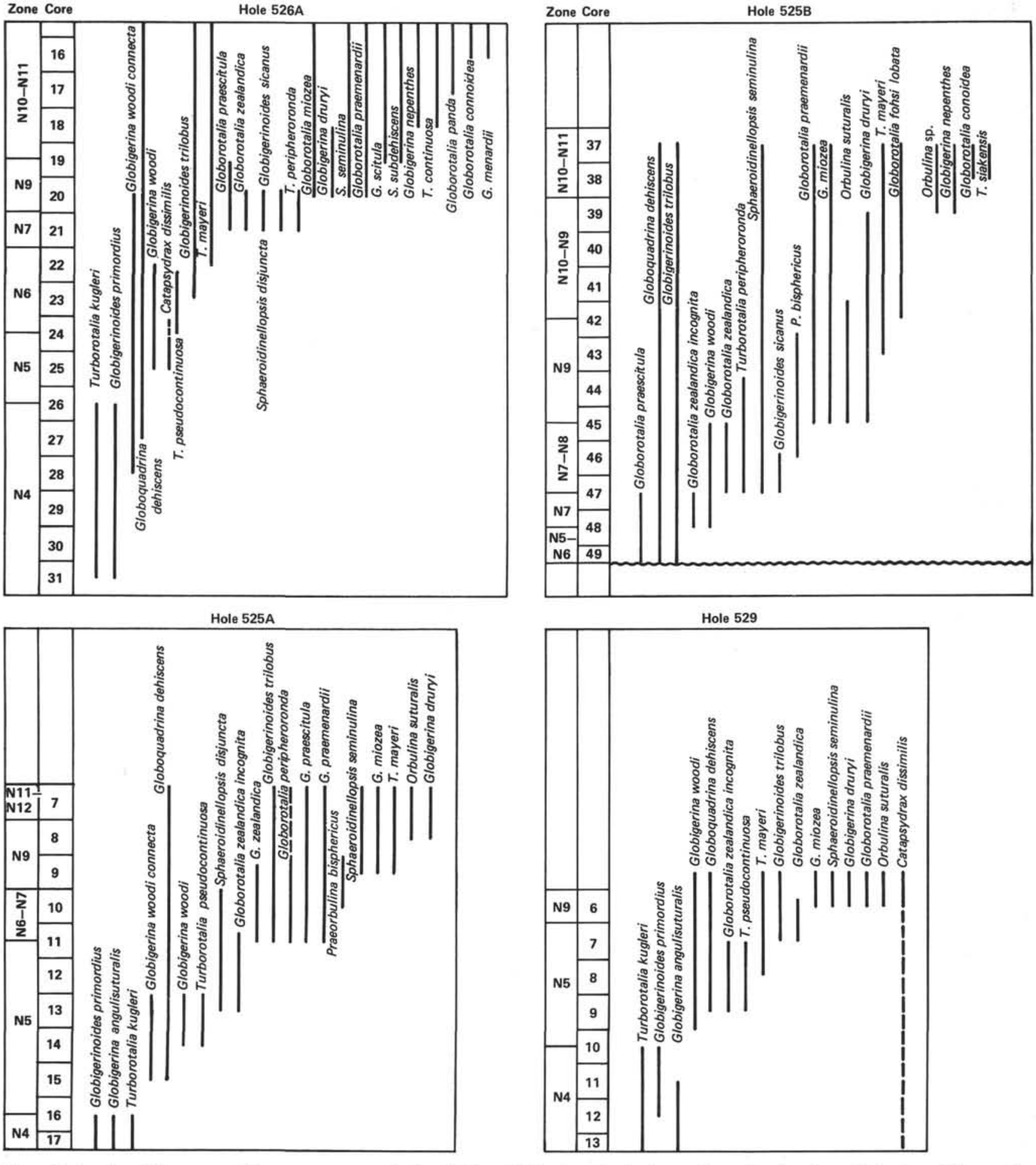

Figure 5. Stratigraphic ranges of the most common planktonic foraminiferal species in the >149 μm fraction through the lower Miocene in Holes 526A, 525B, 525A, and 529.

Upper Miocene faunas are dominated by *G. bulloides* and *G. nepenthes*, accompanied by large numbers of *Globorotalia conoidea* and/or *G. conomiozea*. Turborotalids, *Turborotalia continuosa* and *T. acostaensis*, are uncommon in these faunas, and *Globoquadina dehiscens* disappears from the faunas several cores below the Miocene/Pliocene boundary. *Sphaeroidinellopsis* spp. become frequent only at the top of the Miocene.

Site 525

Addition of the sequences at Holes 525A and 525B results in a nearly complete Miocene section at this site. Since the *Globorotalia fohsi* group is largely absent, it is difficult to assess how much, if any, of the middle Miocene is missing. Downhole contamination is particularly bothersome at the lower/middle Miocene transition in

Table 9. Stratigraphic ranges and relative abundances of most common planktonic foraminifers from the upper Oligocene to lower Miocene of Hole 526A.

Epoch	Zone	Core/Section (level in cm)	*Globoquadrina tripartita*	*Catapsydrax unicavus*	*Globigerina brazieri*	*Globigerinita glutinata*	*Globigerina ciperoensis*	*Globigerina euapertura*	*Globoquadrina venezuelana*	*Globigerina corpulenta*	*Globigerina ouachitaensis*	*Globoquadrina tapuriensis*	*Turborotalia bella*	*Turborotalia opima nana*	*Turborotalia continuosa*	*Turborotalia pseudocontinuosa*	*Turborotalia semivera*	*Catapsydrax martinii*	*Tenuitella gemma*	*Turborotalia pseudokugleri*	*Globoquadrina trans. dehiscens*	*Globoquadrina sellii*	*Globigerinoides primordius*	*Turborotalia kugleri*	*Turborotalia mendacis*	*Turborotalia mayeri*	*Globoquadrina praedehiscens*	*Globoquadrina baroemoensis*	*Turborotalia siakensis*	*Globigerina woodi connecta*	*Globoquadrina dehiscens*	*Globigerina labiacrassata*	*Catapsydrax dissimilis*	*Globigerina woodi woodi*	*Globigerinoides trilobus*
Miocene	N6	22-2, 105	R		F	R			I				I	I	I	I					F	R				I			I	I	F	I		I	R
		23-7, 60	I	I	I	I			I				I	I		I					F					R				R	F			R	
	N5	24-2, 70	I	I	F	R			I			R	R								C	R				R	R			R	C	R			
		25-2, 80	F	I	I	I		R	F		R	R	I	I	I	R					F	R					I			R	I		R		
		26-2, 70	I	I	I	I			I		I		R	R	I		I				C		I	R			R			R	F	R			
	N4	27-2, 65	I	R	R	R			R		F	R						R			F		R	R			R				F	I			
		28-3, 75	F	I	R	I	R	I	I		F			R	R		R	I	I		I		R	R			R	R	R	R					
		29-3, 70	F	F	R	I		I			I			R	I		I	I	F	F	I	R	R	I	I	R									
Oligocene	P22	30-3, 63	C	I	I	F	R	I	I	I	I	I	I	I	I	I	I	I																	

Note: Symbols as in Table 2.

Table 10. Stratigraphic ranges and relative abundances of most common planktonic foraminifers from the middle upper Miocene of Hole 526A.

Epoch	Zone	Core/Section (level in cm)	*Globoquadrina dehiscens*	*Globorotalia peripheroronda*	*Sphaeroidinellopsis disjuncta*	*Globoquadrina dehiscens advena*	*Globorotalia praemenardii*	*Globorotalia miozea*	*Sphaeroidinellopsis seminulina*	*Globigerina druryi*	*Globorotalia miotumida*	*Globorotalia lobata*	*Globorotalia praescitula*	*Orbulina universa*	*Globigerina bulloides*	*Globorotalia peripheroacuta*	*Globoquadrina altispira*	*Globigerinoides trilobus*	*Globoquadrina venezuelana*	*Globigerina woodi woodi*	*Globigerina nepenthes*	*Turborotalia mayeri*	*Globorotalia conoidea*	*Globorotalia conomiozea*	*Globigerinoides sacculifer*	*Sphaeroidinellopsis subdehiscens*	*Globigerinellopsis aguasayensis*	*Globorotalia menardii*	*Globorotalia scitula*	*Globorotalia* cf. *suterae*	*Orbulina bilobata*	*Turborotalia acrostoma*	*Neogloboquadrina* cf. *acostaensis*	*Turborotalia continuosa*	*Globigerinellopsis mitra*	*Globorotalia cibaoensis*
Miocene	N17	7-2, 100						R	F					I	F			R			I		I	I		I			I	I	R					F
		8-2, 60						R	F					F	F			I					F	F	I	I			I	I						I
		9-2, 65						R	F		I			F	F			R			C		F	I	R	R		F	R	R					R	
	N16	11-2, 17	R			I		R	I					F	I			R	R		C		R	F	R	R		F	I	I				R		
	N13	12-2, 60	I			I		R	R		R			I	I			C			F	I	I	F	R	R	R	F	I	I		I	R	R		
	N12–N13	13-2, 60	R					R	R		R	R		I	I			I			C	I	I	F	I	R		F	R	R		F				
		14-2, 60	I			I		I	I		R	R		I	I			R	R		C	R	F	F	I	I		F	R	R						
		15-2, 110	F			F		I	I					I	I			I	I		C	I	F	F	R	R			R	R	R					
	N10–N11	16-2, 47	I	R		R	F	I	R		R	R		I	F			R	R	I	F	I	F	F	I	R	R	I	I	F	R					
		17-2, 60	F			F		R	R		R	R		R	F		R	I			F	R	F	I	F	R	R									
		19-2, 50	F	F		F	I	I	I		I	F		I	I			I	I	I	I	I														
		20-3, 50	I	I	I	C	F	F	I	I	I	C	I	F	I	R	R	R	I	I																

Note: Symbols as in Table 2.

these holes. Nearly all of the faunas reflect good preservation.

A long upper Miocene section was recovered from Hole 525B; faunas from this hole are listed in Table 11. Preservation is good to moderately good throughout the sequence. The planktonic foraminiferal populations are dominated by *Globigerina nepenthes*, the *Globorotalia conomiozea–G. conoidea* group, and at some levels, by *G. scitula*. A major change in faunal constitution occurs from Cores 26–25; *Globoquadrina dehiscens* and *G. dehiscens advena* disappear permanently from the section and *Globigerina nepenthes* decreases in importance, whereas *Sphaeroidinellopsis* spp., the *G. miozea* plexus, and *G. menardii* become more abundant.

At several levels (525B-18-1, 53 cm, 525B-17-2, 20 cm, for example) *G. nepenthes* increases markedly in size. *G. bulloides* exhibits a similar size increase just below the Miocene/Pliocene boundary (525B-14-2, 45 cm).

Site 529

Only short sections of the Miocene were recovered at this site (See Fig. 2, Table 1). The ranges of key species through the lower Miocene are shown in Figure 5D.

Table 11. Stratigraphic ranges and relative abundances of most common planktonic foraminifers from the upper Miocene of Hole 525B.

Epoch	Zone	Core/Section (level in cm)	Preservation	*Globigerina nepenthes*	*Globorotalia miozea*	*Globorotalia connoidea*	*Globoquadrina dehiscens advena*	*Sphaeroidinellopsis seminulina*	*Globigerinita glutinata*	*Globorotalia scitula*	*Globoquadrina dehiscens*	*Globorotalia* cf. *suterae*	*Sphaeroidinellopsis subdehiscens*	*Turborotalia mayeri*	*Turborotalia siakensis*	*Globigerinoides ruber*	*Turborotalia continuosa*	*Globorotalia peripheroronda*	*Orbulina universa*	*Globigerinellopsis mitra*	*Globigerina bulloides*	*Globorotalia conomiozea*	*Neogloboquadrina* trans. *acostaensis*	*Globorotalia panda*	*Globorotalia menardii*	*Orbulina bilobata*	*Globigerinoides trilobus*	*Globigerinoides sacculifer*	*Globoquadrina altispira*	*Globigerinoides obliquus*	*Neogloboquadrina pachyderma*	*Globorotalia miotumida*	*Globigerinellopsis aguasayensis*	*Globorotalia cibaoensis*	*Globigerinoides conglobatus*	*Globorotalia* sp.	*Globorotalia* trans. *crassaformis*	*Globorotalia sphericomiozea*	*Neogloboquadrina acostaensis*
		19-2, 95	G	I		I				R	R			I					I		I	I								R		R		I		F	F	F	R
	N17	15-2, 90	M	I		I				I									I		I	F		R								R		I		I			
		16-2, 100	G	I	F	C		I	R	F			I			R			I		I	C								R				F	R				
		17-2, 20	M	I	R	F		R	R	F			I			R			I		I	C								R		I							
		18-1, 53	M	I	R	F			R	F			F			R			F	R	I	I			F	R	R			R		R	R						
		19-2, 66	G	I	R	F		R	R	F			F			R			I		I	F	R							R	R	R							
		20-1, 8	M	I	I	I			R										R		R	I					R												
	N16	21-1, 40	M	I	I	I			R	I									R		I	I				R	R												
		22-2, 57	M	R	I	F		I	I	F		R	R				R		I	R	I	F	R				R				R								
		23-2, 64	M	I	F	C		I	I	F		I	I			R			F	I	I	C		R	R	R		R	R	R									
		24-2, 51	G	I	F	F		I	R	I		R	I						I		I	F			R		I												
Miocene		25-2, 55	G	F	F	F		F	R	R			R		I	R			F	R	F	F			I		I	I											
		26-2, 120	G	I	F	F		I	R	R					I	R			I		F	F			I		I	F											
		27-2. 66	G	F	F	F	I	C	R	I	R		R		I	R			I		F	F			F	I	F	I											
	N15	29-2, 73	G	F	F	F	I	F	R	R	R				I	R			F		I	F			F		R												
		30-2, 55	M	C	I	F	I	I	R	R	I		R		F	R			F	R	I	F			F		R												
		31-2, 50	G	F	F	F	I	I	R	R	I		R		F	R			F	R	I	F		R	F		R												
		32-2, 55	G	F	F	F	F	I	R	I	F	R	R		F	R			I	R	I	F			I		I												
	N14	33-2, 70	G	F	F	F	I	F	R	I	I		R		F	R			I		I	F		R	F		I												
		34-2, 55	G	F	C	C	R	I	R	R	F		R		R	R	R		I		I	F	R	R	F														
		35-2, 55	G	C	I	F	I	I	R		I		R			R			I		I	I		R	R	I													
		36-2, 55	G	F	F	C	A	F	I	I	R		R	R	R	R	R		I	R	I	R	I	R															
	N10–11	37-2, 101	G	A	F	F	F	R	I	F	I	R	R	R	R	R	R	R	F																				

Note: Symbols as in Table 2.

Preservation is good at the base of the Miocene (Cores 10–13) but only moderate in other Miocene samples. Faunas resemble those of Site 525.

Pliocene–Pleistocene

Pliocene sections were recovered at all sites (Fig. 2, Table 1); the longest and most complete were cored at Holes 525B (Cores 3–13) and 528A (Cores 6–19). Pliocene samples are generally well preserved except at Site 527, which was elevated above the foraminiferal CCD near the beginning of the Pliocene, but apparently lay below the foraminiferal lysocline through the course of the Pliocene. Preservation at Site 527 grades upward from poor to moderate through the Pliocene and most samples contain large numbers of fragments and broken fossils.

Pliocene faunas contain enough index species to be assigned to the lower-latitude zonation of Berggren (1973). In Leg 74 sites *Globorotalia connoidea* and *G. conomiozea* range through the lower Pliocene and disappear simultaneously with the transition from *G. puncticulata* to *G. inflata* at the top of the lower Pliocene. The ranges of these two species are appreciably higher than reported elsewhere (Kennett, 1973; Srinivasan and Kennett, 1982). In a current study of the Pliocene from DSDP Leg 75 sites in the southern Angola Basin, both species were found to range through the lower Pliocene and disappear synchronously with the transition from *G. puncticulata* to *G. inflata* (Boersma, in press). Apparently this plexus survived longer in the southeastern Atlantic and the Benguela Current than elsewhere in the world ocean.

Site 525

Table 12 lists planktonic foraminiferal species through the Pliocene in Hole 525B. All samples are well preserved and contain diverse planktonic foraminiferal faunas. Lower Pliocene faunas are dominated by *Globigerina bulloides*, the *Globorotalia conomiozea–G. conoidea* plexus, and *G. puncticulata*. *Globigerina nepenthes* and species of *Globigerinoides*, except for *G. obliquus*, are rare. *Globoquadrina altispira* occurs in only three samples and is very rare therein. Species of *Sphaeroidinellopsis* are infrequent lower in the section, but more frequent in the mid-Pliocene prior to their final extinctions. These species both appear to lose their cortices just before they disappear.

A major change in faunal composition occurs in the mid-Pliocene synchronous with the evolutionary transition from *Globorotalia puncticulata* to *G. inflata* (Figure 6). Austral faunal elements except for *G. inflata* disappear from all sites, and *G. crassaformis* dominates faunas which also contain large numbers of *Globigerina bulloides*. By the top of the Pliocene at this site and at Site 527, *Globorotalia inflata* becomes more prominent in the faunas, *Globigerinoides obliquus* increases in importance and *G. ruber* is more frequent than in older samples. *Globorotalia tosaensis* was not found.

Table 12. Stratigraphic ranges and relative abundances of most common planktonic foraminifers through the Pliocene of Hole 525B.

Epoch	Zone	Core/section (level in cm)	*Orbulina universa*	*Orbulina biolobata*	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis subdehiscens*	*Globorotalia panda*	*Globorotalia margaritae*	*Globorotalia menardii*	*Globorotalia conoidea*	*Globorotalia cibaoensis*	*Globorotalia scitula*	*Globorotalia* cf. *miozea*	*Globorotalia miotumida*	*Globorotalia conomiozea*	*Globorotalia puncticulata*	*Globigerinoides conglobatus*	*Globigerinoides trilobus*	*Globigerinoides ruber*	*Globigerinoides obliquus*	*Globigerina bulloides*	*Globigerina nepenthes*	*Hastigerinella aequilateralis*	*Globoquadrina altispira*	*Globorotalia cultrata*	*Globorotalia crassaformis*	*Globorotalia sphericomiozea*	*Globorotalia inflata*	*Globigerinoides sacculifer*	*Sphaeroidinella dehiscens*	*Globorotalia tumida*	*Globorotalia truncatulinoides*
Pliocene	Pl5–6	3-2, 65	I						R			R						R	I	I	F		I			A		C		I	I	VR
		4-2, 87	I									I					R		I	F	F		I			F		F				
	Pl4	5-1, 97	F									R				I		I	I	F	F		I			C		I	R			
	Pl3	6-2, 64	I		I	F										C	R		R	I	F		I			C	R	I				
		7-2, 56	I		F	F						R			R	C		I		R	I		I	R		C	R	R				
	Pl2	8-2, 65	I		I	I				I		R	I		I	C		R	R	R	I		I			C	F					
		9-2, 40	I	R	F	F	R	R	R						F	F	R		R	I	I	I	I	I		F	F					
		10-2, 40	I		R	R				R	R				F	F	R		I	I	I					I	F					
	Pl1	11-2, 40	F		R	I				R	R		R		R	A		R	R	R	F	R	R		F							
		12-1, 30	I	I	I	I			R	F	I	F			F	C				R	I	R	R	R								
		13-2, 44	I	I	I	I	F	I	I	F	I	I	I	I	F	F	R	R	R	R	C	R										

Note: Symbols as in Table 2. VR = very rare.

Globorotalia truncatulinoides first occurs in Core 3 along with new, subtropical species such as *G. tumida* and *Sphaeroidinella dehiscens*. Faunas are still dominated, however, by *G. crassaformis, G. inflata*, and *Globigerina bulloides* through the few Pleistocene samples.

Sites 526–529

Faunas at Sites 526, 527, 528 and 529 are identical to those at Site 525 and show the same faunal transitions in the mid Pliocene (see Fig. 7).

SUMMARY

Planktonic foraminiferal faunas were recovered at five sites, Sites 525–529, on Leg 74. The following results were produced by analysis of foraminifers in the >149 μm fraction from core catchers and one additional sample in each core:

1) Cretaceous sediments were recovered at four sites; lower Maestrichtian material was found at Sites 525 and 528, upper Maestrichtian at Sites 527 and 529. Sediments were not very well preserved; all but Site 529 bottomed in basalt and were altered at the bottom. Extreme sediment disturbance and erosion were evidenced at all sites, resulting in altered species ranges and making biozonation problematic and correlations with paleomagnetics difficult.

2) The Cretaceous/Tertiary boundary was identified at four sites, none of which contained well-preserved microfossils across this interval. Boundaries at all four sites were typified by an uppermost Cretaceous blue-gray chalk layer containing small individuals of typical Maestrichtian foraminiferal species, unusually ornamented pseudoguembelinids, and *Hedbergella monmouthensis*. Basal Paleocene samples contained faunas typical of the *Planorotalites eugubinus* Zone at other middle-latitude sites; heterohelicids are strongly dominant, with accessory amounts of *P. eugubinus* also present.

3) Paleocene sediments were recovered at Sites 525, 527, 528, and 529. Faunas are typical of middle latitudes and contain predominantly subbotinids and planorotalitids, with accessory amounts of the small biconvex morozovellids. Faunas suggest a distinct biogeographic boundary between Sites 527 and 525; more higher-latitude species occur at Site 527.

4) A distinct Paleocene fauna including *Morozovella tadjikistanensis djanensis* occurs at Site 527, relating it to Site 329 on the Falkland Plateau and the Caucasus region where the species was named.

5) Paleocene sections are relatively complete and the foraminiferal datums could be correlated with paleomagnetic stratigraphy of Chave (this volume). However, the foraminifers suggest a slightly different interpretation of Anomalies 29–27 at Site 527.

6) Site 526 was apparently a carbonate bank through the Paleocene and until the upper Eocene when planktonic foraminifers first begin to accumulate there.

7) The Eocene is incomplete and/or much truncated at all sites. The lower Eocene is well represented, but the middle part contains badly preserved sediments and/or hiatuses at Leg 74 sites and all other South Atlantic sites. Small portions of the upper Eocene were found at all sites except Site 527, which sank below the CCD in Zone P14, and Site 528, which sank below the foraminiferal lysocline in the middle Eocene. Eocene faunas are dominated by the morozovellids and acarininids in the lower Eocene; in the few moderately well preserved middle Eocene samples there is a major shift to a predominance of acarininids and globigerinid-form species, and later to the globigerapsids. Some boreal elements such as *Globigerina angiporoides* first appear in this area in the middle Eocene.

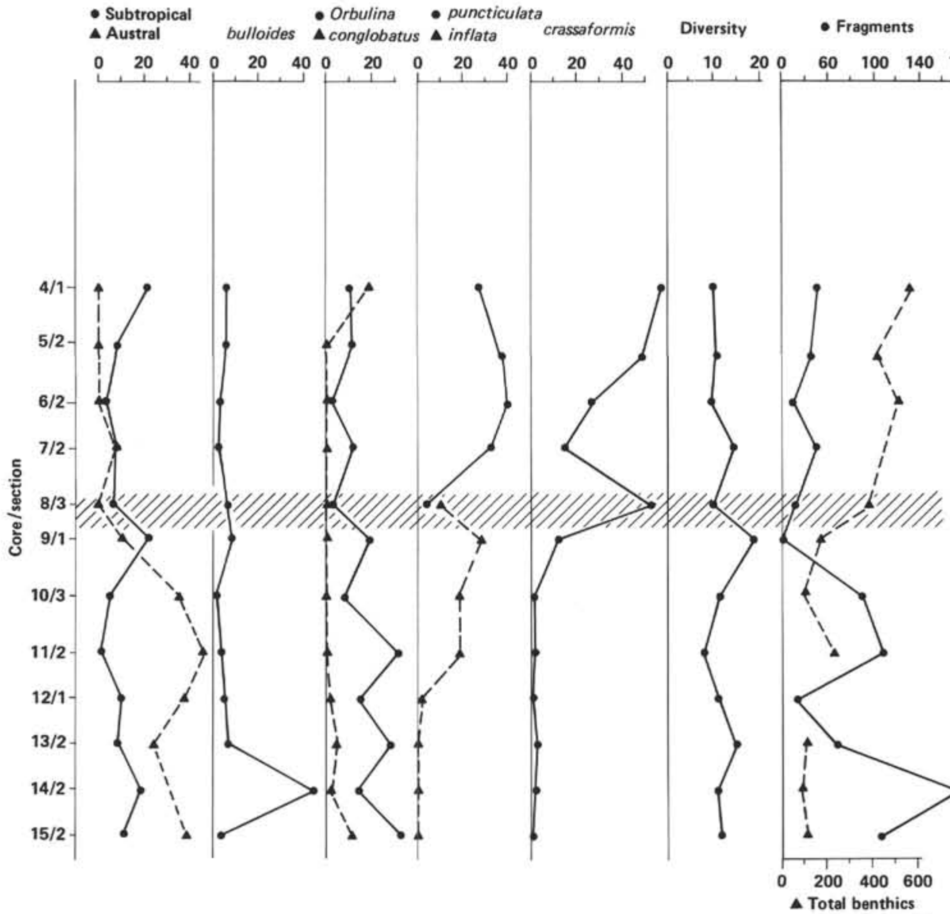

Figure 6. Percentages of planktonic foraminiferal species, total benthics, diversity, numbers of fragments, and boreal versus subtropical species in counts of 350 specimens in the > 149 μm fraction of Pliocene cores from Hole 525B. Diagram demonstrates the major change in planktonic foraminiferal faunas from Section 525B-9-1 to 525B-8-3 that is associated with the evolutionary transition from *Globorotalia puncticulata* to *G. inflata* at the top of the lower Pliocene. Planktonic species include *Globigerina bulloides, Orbulina universa, Globigerinoides conglobatus, Globorotalia puncticulata, G. inflata*, and *Globorotalia crassaformis*. The combined percentage figure for subtropical index species included *G. menardii, Globigerinoides* spp., *G. altispira*, and *Globorotalia* cf. *miocenica*. Boreal species include *G. conomiozea, G. conoidea*, and *Globigerina falconensis*. Diversity is a simple species richness estimation of the total number of species in each count. Fragments, taken as a measure of dissolution, are estimated by counting 350 particles. "Total benthics" is the number of benthic specimens in 0.5 g sediment.

8) The Eocene/Oligocene boundary is represented in a nearly continuous section at Site 529; there is a dissolution pulse just above the boundary, as is indicated by the disappearance of *Hantkentina* and *Globigerapsis* spp. Basal Oligocene faunas are characterized by large globigerinids, *Catapsydrax* spp., and significant numbers of *Globigerina pseudoampliapertura*.

9) The Oligocene is nearly complete at Site 529; a long upper Oligocene section is found at Site 526, but only small segments of the epoch were recovered at Site 525 and Site 528, which is very badly dissolved. Faunas are dominated by large globoquadrinids of the *G. tripartita* group and small globigerinids. Several unique turborotaliids characterize the mid-Oligocene; they are *T. siakensis* and *T. acrostoma*. The biserial genus *Streptochilus* first appears in Zone P21b; this is after its evolutionary first appearance at the P21a/b boundary in the Pacific, but before its arrival in the Rio Grande area of the western South Atlantic.

9) A small, angular globoquadrinid which may be the predecessor of *Globoquadrina dehiscens* occurs in Zone P22 in Leg 74 sites. Several solution-susceptible species appear earlier or last longer at the shallower Site 526 than at Site 529, which is deeper.

10) Miocene sediments containing foraminifers were recovered from all but Site 527, which remained below the CCD through the course of the epoch. The Miocene is difficult to subdivide biostratigraphically because the ranges of *Catapsydrax* and *Globoquadrina* spp. are anomalous and the subtropical globorotaliids are missing. Downhole contamination by the drilling process in the HPC sites added confusion to the biostratigraphy. Foraminiferal faunas are dominated by *Globigerina nepenthes* and the boreal globorotaliids. *Globigerinoides* spp. were rarely found. A large faunal change occurs in Zone P16, involving the loss of *Globigerina dehiscens* and a decrease in the import of *G. nepenthes*, but increased abundances of *Globorotalia menardii,*

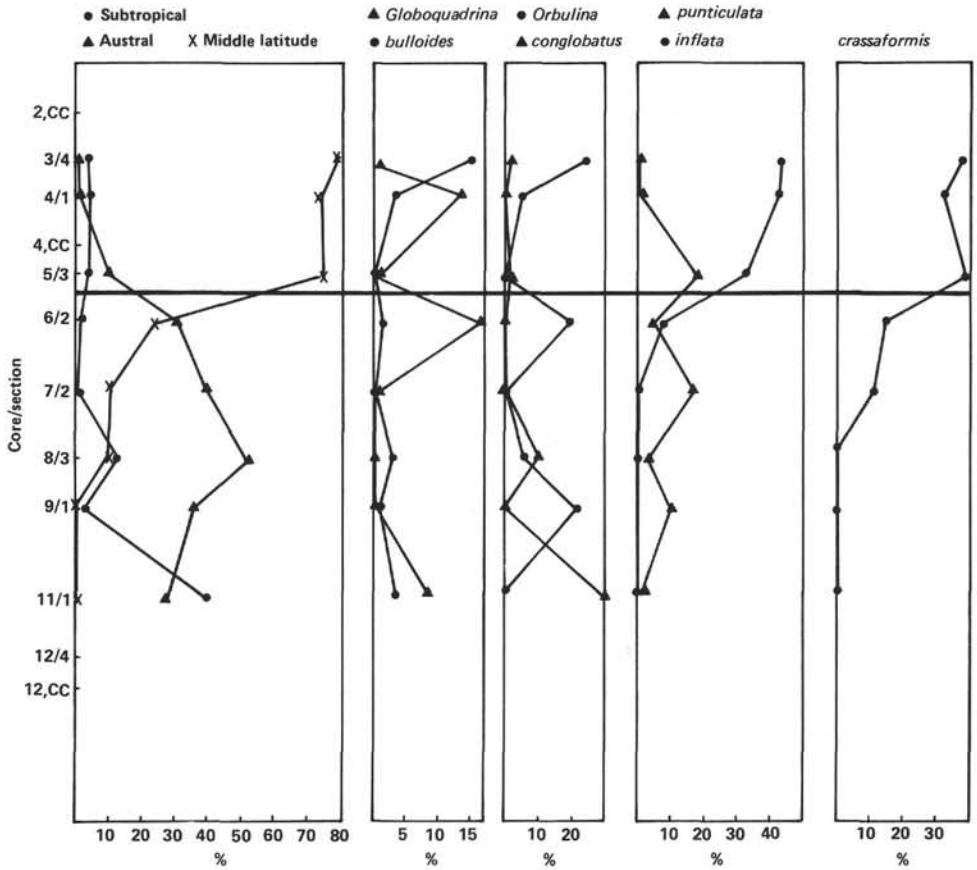

Figure 7. Percentages of planktonic foraminiferal species, total benthics, diversity, numbers of fragments, and boreal versus subtropical species in counts of 350 specimens in the > 149 μm fraction of Pliocene cores from Site 527. See explanation for Figure 6.

Sphaeroidinellopsis species, and the *G. miozea* plexus. Both *Globigerina nepenthes* and *G. bulloides* increase markedly in size near the top of the Miocene.

11) Pliocene sediments were recovered at all sites, including Site 527, which apparently rose above the CCD near the base of the Pliocene. Preservation at that site improved steadily through the course of the epoch. Sediments at all other sites are relatively well preserved. In the lower Pliocene faunas are dominated by *Globigerina bulloides, Globorotalia puncticulata*, and the *G. conomiozea–connoidea* group. There is a large faunal change synchronous with the transition from *G. puncticulata* to *G. inflata*; after this, *G. crassaformis, Globigerina bulloides*, and/or *Globorotalia inflata* dominate the faunas. Austral elements (except *G. inflata*) disappear from most faunas above this level.

12) *Globorotalia conomiozea* and *G. connoidea* range through the lower Pliocene at Sites 525, 527 and other Leg 74 and Leg 75 sites analyzed by this author. Their ranges here are apparently higher than elsewhere in the world ocean.

13) Pleistocene faunas were recovered in one or two cores at all sites. Subtropical elements such as *Globorotalia tumida* and *Globigerinoides conglobatus* join faunas dominated by *Globorotalia inflata* and *G. crassaformis* at the base of the Pleistocene. The *G. tosaensis–G. truncatulinoides* transition was not observed at the Leg 74 sites.

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