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15. HIGH-RESOLUTION BIOSTRATIGRAPHY AT THE MIOCENE/PLIOCENE BOUNDARY IN HOLES 974B AND 975B, WESTERN MEDITERRANEAN[1]

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ABSTRACT

Extended sedimentary sequences encompassing the Miocene/Pliocene boundary were continuously cored in the Tyrrhenian Sea (Hole 974B) and Balearic Basin (Hole 975B) during Ocean Drilling Program Leg 161, and investigated in terms of foraminifer (planktonic and benthic) high-resolution biostratigraphy.

The interval studied includes the earliest part of the Zanclean (Zone MP11) and the Miocene/Pliocene boundary. The lower Zanclean (*Sphaeroidinellopsis* Acme Zone or MP11) is characterized by pelagic sediments in both holes.

Within the lower part of MP11 Zone, cyclically repeated changes in abundance of *Globigerinoides* population have been recognized at both sites and interpreted as caused by astronomical forcing precession cycles. The calibration of these cycles with bioevents like the acme interval of *Sphaeroidinellopsis,* two intervals of *Neogloboquadrina acostaensis* sinistrally coiled, and the first common occurrence (FCO) of *Globorotalia margaritae* led to the identification of five cycles in Hole 974B and six cycles in Hole 975B. Such data indicate that the Hole 975B sequence is more complete than that recorded in Hole 974B, where the first cycle is missing.

The MP11/MP12 boundary, which is based on the FCO of *Globorotalia margaritae* at 5.07 Ma, represents the top of the sequence investigated.

The repopulation of the Mediterranean basin floor by benthic foraminifers is stepwise. The first immigrants were small in size (*Eponides pusillus* and bolivinids) and were found only in Hole 975B. They were followed by *Oridorsalis stellatus, Cassidulina subglobosa,* and *Uvigerina peregrina,* which occur at both sites. Such assemblages suggest water masses partially depleted of oxygen at the very base of the Pliocene sequence.

INTRODUCTION

Our knowledge of the high-resolution biostratigraphy at the Miocene/Pliocene boundary is based mainly on land sections of southern Italy (Sicily and Calabria; Langereis and Hilgen, 1991; Sprovieri, 1992, 1993; Di Stefano et al., 1996) and on Site 653 in the Tyrrhenian Sea (Sprovieri, 1993; McKenzie and Sprovieri, 1990). According to the most recent calibration, the Miocene/Pliocene boundary as defined in the Capo Rossello composite section (Hilgen, 1991), falls at 5.33 Ma, five cycles below the Thvera Subchron and two cycles below the base of the *Sphaeroidinellopsis* acme range.

It is well known and documented (Ryan, Hsü, et al., 1973; Hsü et al., 1978; Cita et al., 1978) that the Mediterranean salinity crisis abruptly ended by the influx of Atlantic water, which invaded the different parts of the Mediterranean Basin at the beginning of the Pliocene. This sudden change from continental to marine sediments is clearly recognizable both in land and deep-marine sections where open-marine deposits lie on Lago Mare facies, testifying that this event occurred under subaqueous conditions.

High-resolution stratigraphic studies of this interval revealed a series of paleoceanographic events between the termination of the salinity crisis and the re-establishment of a fully open marine connection with the Atlantic Ocean, which until now were not clearly understood. McKenzie and Sprovieri (1990) recognized three stages, each one indicative of an evolutionary phase of the earliest Mediterranean paleoceanography.

Holes 974B and 975B from Ocean Drilling Program (ODP) Leg 161 were investigated through foraminifer high-resolution biostratigraphy to test the completeness of the Pliocene sequence in the two western Mediterranean basins and provide new evidence of the paleoceanographic conditions at the Miocene/Pliocene (M/P) boundary in the central Tyrrhenian Sea (Site 974) and in the South Balearic Basin (Site 975).

Site 978, located in the Eastern Alboran Basin, should have been important to further knowledge of the M/P boundary in the eastern part of the western Mediterranean, but it was not analyzed because the recovery in the boundary interval was very poor (found in only the core-catcher of Core 45R, and there was no recovery of Core 46R). Regardless, the lowermost Pliocene recognized at 161-978A-45R-CC at 630 meters below seafloor (mbsf), belongs to Zone MP11.

MATERIAL AND METHODS

High-resolution sampling encompassing the Miocene/Pliocene boundary was conducted on board the *JOIDES Resolution* at closely spaced intervals of 10 to 20 cm throughout the latest Messinian and lower part of MP11, and 50 to 70 cm through the upper part of MP11 up to the base of MP12. Subsequently, additional samples were taken from Leg 161 cores at the Bremen Repository.

For the shore-based study, the 10-cm^3 samples were washed on 63-µm sieves and the residues larger than 125 µm were used for a quantitative study of the planktonic foraminifers. Approximately 300 specimens were counted to achieve a statistically meaningful distribution pattern. The benthic foraminiferal analysis is based on the total number of specimens (fraction >125 µm) and on semiquantitative analysis (<125-µm fraction). Where not specified, the benthic foraminiferal distribution discussed in this chapter is the fraction >125 µm.

The planktonic foraminiferal biostratigraphic scheme proposed for the Mediterranean by Cita (1973, 1975) and amended by Rio et al. (1984) and Sprovieri (1992, 1993) was adopted.

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BIOSTRATIGRAPHIC RESULTS

Hole 974B

Hole 974B is located in the central Tyrrhenian Sea (40° 21.362′N, 12°8.516′E) (Shipboard Scientific Party, 1996a) very close to Site 652 (ODP, Leg 107) at 3454 m depth (Fig. 1). The sedimentary sequence cored (late Messinian to Pleistocene) is 203 m thick. In the interval investigated, extending from 183.06 mbsf (161-974B-20X-6, 66–68 cm) down to 203.7 mbsf (bottom of the hole), 53 samples were analyzed (Table 1). Samples 974B-22X-6, 66–68 cm, to 22X-4, 93–95 cm (2.73 m thick) are referred to the latest Messinian "non-distinctive" Zone (Iaccarino, 1985); Samples 974B-22X-4, 70–72 cm, to 20X-CC belong to MP11 Zone (15 m thick); Sample 974B-20X-6, 66–68 cm, belongs to MP12 Zone on the basis of the first common occurrence (FCO) of *Globorotalia margaritae*. The Miocene/Pliocene

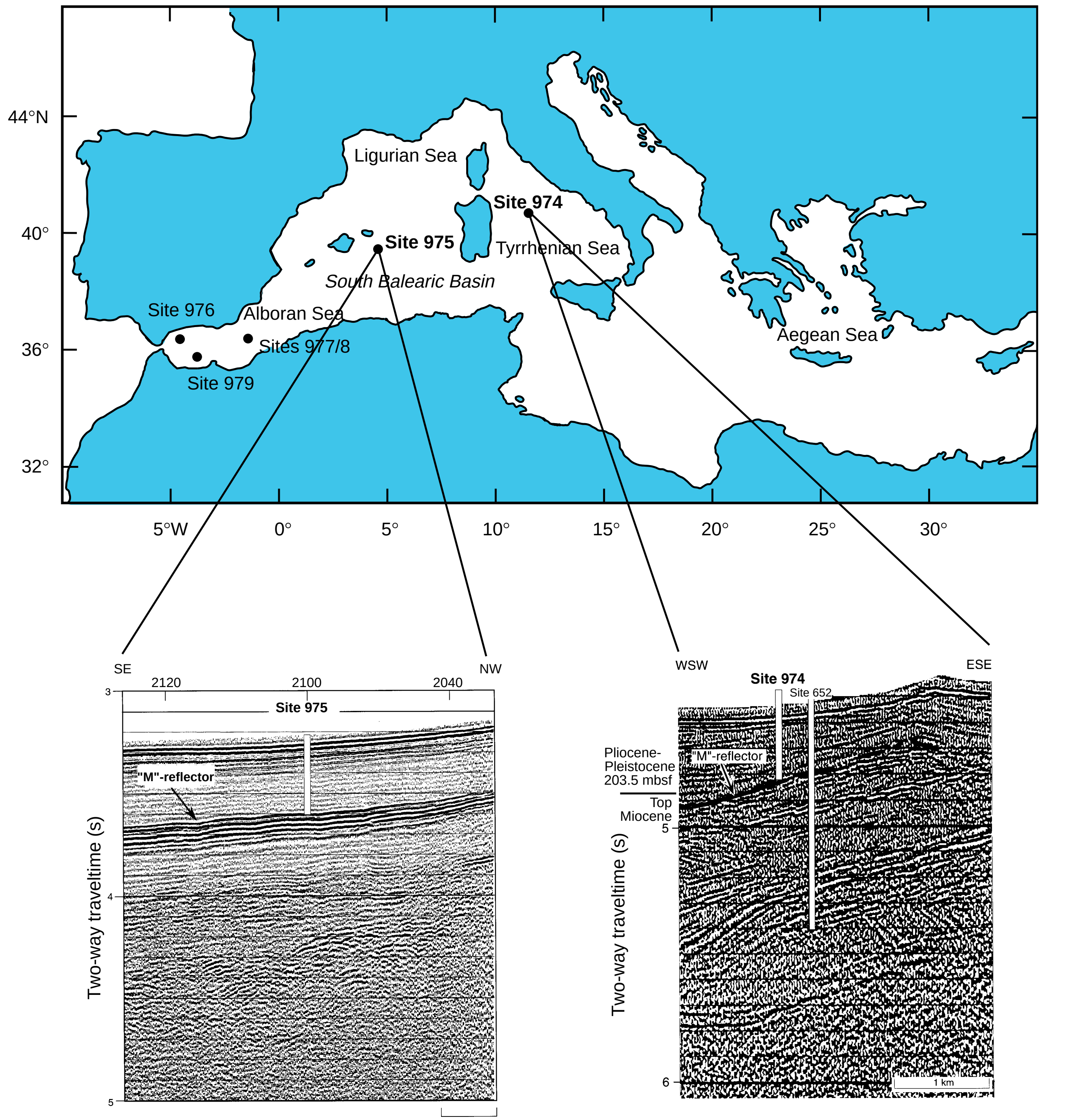

Figure 1. Location map of Sites 974 and 975, and seismic profiles of Site 974 and Site 975.

Table 1. Investigated samples of Hole 974B: depth, weight of dried sample and washed residue fractions, and sediment color.

Core, section, interval (cm)	Depth (mbsf)	Sample weight (g)	Residue weight (g) >125 µm	Residue weight (g) >63–<125 µm	Sediment color
161-974B-					
20X-6, 66-68	183.06	10.47	0.19	0.21	Light gray (N 7)
20X-CC	184.30	10.47	0.20	0.30	Yellowish gray (5Y 7/2)
21X-2, 67-69	186.67	10.47	0.27	0.20	Yellowish gray (5Y 7/2)
21X-2, 108-110	187.08	12.36	0.39	0.86	Yellowish gray (5Y 7/2)
21X-4, 130-132	190.30	10.47	0.26	0.27	Yellowish gray (5Y 7/2)
21X-5, 53-55	191.03	11.88	0.28	0.30	Pale yellowish orange (10YR 8/6)
21X-6, 99-101	192.99	7.19	0.11	0.46	Grayish yellow (5Y 8/4) very pale orange (10YR 8/2)
21X-6, 103-105	193.03	9.85	0.21	0.85	Grayish yellow (5Y 8/4) very pale orange (10YR 8/2)
21X-6, 122-125	193.23	11.34	0.28	0.59	Grayish orange (10 YR 7/4) very pale orange (10YR 8/2)
21X-6, 140-142	193.40	10.63	0.22	0.56	Light brown (5YR 5/6)
21X-7, 17-19	193.67	10.84	0.24	0.27	Moderate reddish brown (10R 4/6) very pale orange (10YR 8/2)
21X-7, 35-37	193.85	9.99	0.25	0.42	Moderate reddish brown (10R 4/6) very pale orange (10YR 8/2)
21X-CC	194.00	10.47	0.42	0.23	Moderate reddish brown (10R 4/6) very pale orange (10YR 8/2)
22X-1, 20-22	194.30	10.32	0.34	0.26	Moderate reddish brown (10R 4/6) very pale orange (10YR 8/2)
22X-1, 37-39	194.47	10.30	0.29	0.22	Moderate reddish brown (10R 4/6) very pale orange (10YR 8/2)
22X-1, 57-59	194.67	10.20	0.21	0.24	Moderate reddish brown (10R 4/6) very pale orange (10YR 8/2)
22X-1, 80-82	194.90	11.21	0.27	0.29	Moderate reddish brown (10R 4/6) very pale orange (10YR 8/2)
22X-1, 100-102	195.10	9.41	0.23	0.18	Moderate reddish brown (10R 4/6) very pale orange (10YR 8/2)
22X-1, 120-122	195.30	9.66	0.32	0.26	Light brown (5YR 6/4) very pale orange (10YR 8/2)
22X-1, 140-142	195.50	9.83	0.34	0.29	Light brown (5YR 6/4) very pale orange (10YR 8/2)
22X-2, 10-12	195.70	9.78	0.30	0.84	Very pale orange (10YR 8/2) grayish orange (10YR 7/4) light brown (5YR 5/6)
22X-2, 34-36	195.94	8.52	0.23	0.25	Very pale orange (10YR 8/2) grayish orange (10YR 7/4) light brown (5YR 5/6)
22X-2, 56-58	196.16	8.95	0.31	0.51	Light brown (5YR 5/6) grayish orange (10YR 7/4)
22X-2, 77-79	196.37	9.60	0.27	1.16	Light brown (5YR 5/6) grayish orange (10YR 7/4)
22X-2, 98-100	196.58	9.08	0.26	0.86	Light brown (5YR 5/6) grayish orange (10YR 7/4)
22X-2, 115-117	196.75	10.56	0.33	1.25	Grayish orange (10YR 7/4)
22X-2, 136-138	196.96	9.89	0.20	0.23	Grayish orange (10YR 7/4)
22X-3, 10-12	197.20	6.31	0.16	0.23	Grayish orange (10YR 7/4)
22X-3, 28-30	197.38	6.95	0.17	0.31	Pale reddish brown (10YR 5/4) moderate reddish brown (10R 4/6)
22X-3, 42-44	197.54	7.53	0.20	0.74	Moderate reddish brown (10R 4/6)
22X-3, 62-64	197.72	9.25	0.27	0.49	Light brown (5YR 5/6) very pale orange (10YR 8/2)
22X-3, 81-82	197.90	8.86	0.26	1.21	Moderate yellowish brown (10YR 5/4) moderate brown (5YR 4/4)
22X-3, 102-104	198.12	8.58	0.23	0.48	Moderate yellowish brown (10YR 5/4) vary pale orange (10YR 8/2)
22X-3, 115-117	198.25	8.97	0.26	0.46	Grayish orange (10YR 7/4) very pale orange (10YR 8/2)
22X-3, 130-132	198.40	10.02	0.11	1.26	Moderate yellowish brown (10YR 5/4)
22X-3, 145-147	198.55	11.26	3.86	4.32	Light olive gray (5Y 6/1) brownish gray (5YR 4/1)
22X-4, 14-16	198.74	8.37	0.30	0.19	Very pale orange (10YR 8/2) dark yellowish orange (10YR 6/6)
22X-4, 34-36	198.94	8.15	0.11	0.34	Moderate yellowish brown (10YR 5/4) very pale orange (10YR 8/2)
22X-4, 52-54	199.12	8.35	0.38	0.53	Light bluish gray (5B 7/1) yellowish orange (10YR 6/6)
22X-4, 70-72	199.30	9.62	0.16	0.27	Moderate yellowish brown (10YR 5/4) light olive gray (5Y 6/1)
22X-4, 93-95	199.53	9.94	0.05	0.60	Pale brown (5YR 5/2) moderate brown (5YR 4/4) light olive gray (5Y 6/1)
22X-4, 114-116	199.74	9.05	0.18	1.13	Pale brown (5YR 5/2) moderate brown (5YR 4/4) light olive gray (5Y 6/1)
22X-4, 133-135	199.93	13.15	0.06	0.08	Light olive gray (5Y 6/1)
22X-5, 32-34	200.42	12.29	0.02	0.41	Light olive gray (5Y 6/1)
22X-5, 48-49	200.57	15.14	0.00	0.01	Light olive gray (5Y 6/1)
22X-5, 70-72	200.80	12.71	0.00	(one fract.)	Light olive gray (5Y 6/1)
22X-5, 90-92	201.00	14.26	0.00	0.01	Light olive gray (5Y 6/1)
22X-5, 110-112	201.20	15.33	0.00	(one fract.)	Light olive gray (5Y 6/1)
22X-5, 125-127	201.35	14.90	0.03	0.02	Light olive gray (5Y 6/1)
22X-5, 143-145	201.53	9.74	0.04	0.18	Light olive gray (5Y 6/1)
22X-6, 16-18	201.76	13.60	0.10	0.47	Light olive gray (5Y 6/1)
22X-6, 50-52	202.10	14.61	0.27	2.27	Light olive gray (5Y 6/1)
22X-6, 66-68	202.26	14.32	0.38	3.11	Light olive gray (5Y 6/1)

boundary is easily recognized through the abrupt change from barren to highly fossiliferous sediments and the strong variation of the $CaCO_3$ content (Fig. 2). The color changes upward from brown to reddish (Fig. 3). Drilling disturbances make the lithologic change difficult to see.

Planktonic foraminifers are very abundant from the base of the Pliocene upward, but they are absent in the Messinian sediments (Table 2 and Appendix A). The major events recognized within this interval are the following:

1. The FCO of *Globorotalia margaritae* in the uppermost sample of the investigated interval (161-974B-20X-6, 66–68 cm) at 183.06 mbsf;
2. Within the range of predominantly dextrally coiled *Neogloboquadrina acostaensis*, two short shifts of *N. acostaensis* sinistral occur; the lower one from Sample 161-974B- 22X-4, 70–72 cm, to Sample 22X-4, 14–16 cm, and the higher from Sample 974B-22X-3, 81–83 cm, to Sample 22X-3, 10–12 cm, for a thickness of 0.75 m and 0.70 m, respectively;
3. The CO of *Globorotalia scitula* dextral is considered, as *Gr. margaritae*, a "delayed invasion event" after the Pliocene flooding, at 197.20 mbsf (Sample 161-974B-22X-3, 10–12 cm);
4. The acme interval of *Sphaeroidinellopsis* (7.2 m thick) from Sample 161-974B-22X-3, 115–117 cm, through Sample 21X-5, 53–55 cm; and
5. A peak of abundance (14.1%) of *Globigerina nepenthes* occurs at 198.40 mbsf (Sample 161-974B-22X-3, 130–132 cm). This acme, recognized by Zachariasse and Spaak (1983), precedes the base of the *Sphaeroidinellopsis* acme.

Benthic foraminifers are rare at this site and therefore the quantitative study was not useful. Most taxa show scattered distribution; only few taxa are "dominant" and show a quite continuous distribution (Appendix B).

From the base of the Pliocene up to 198.55 mbsf (Samples 161-974B-22X-6, 66–68 cm, to 22X-3, 145–147 cm) benthic foraminifers are almost completely absent in the fraction >125 µm and only very rare specimens of *Brizalina-Bolivina* gr., *Astrononion stelligerum*, and *Fursenkoina* spp. are present at 198.94 mbsf (Sample 974B-22X-4, 34–36 cm) and 198.74 mbsf (Sample 974B-22X-4, 14–16 cm) in the fraction <125 µm.

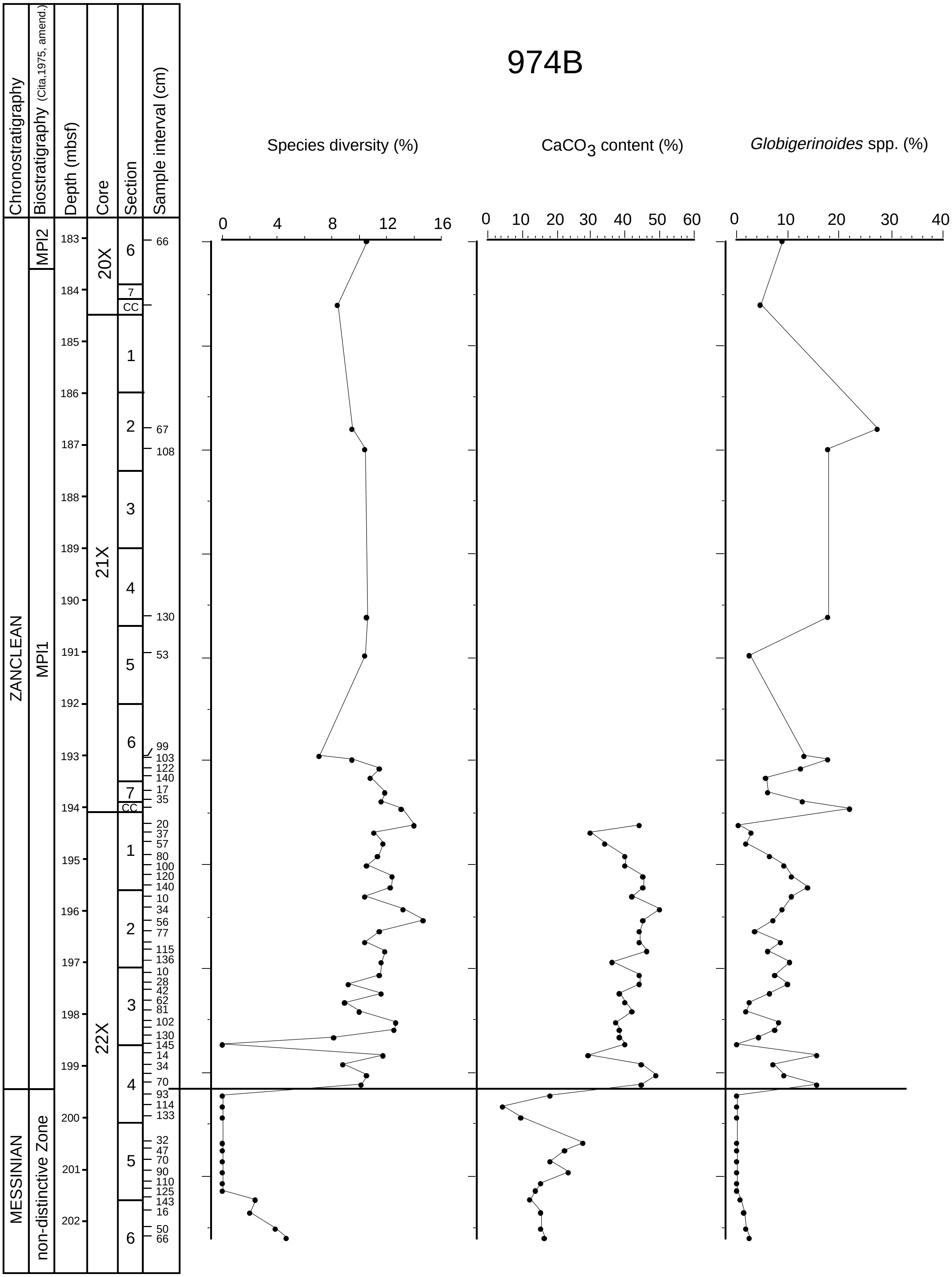

Figure 2. Specific diversity of planktonic foraminifers, $CaCO_3$, and *Globigerinoides* spp. curves in Hole 974B.

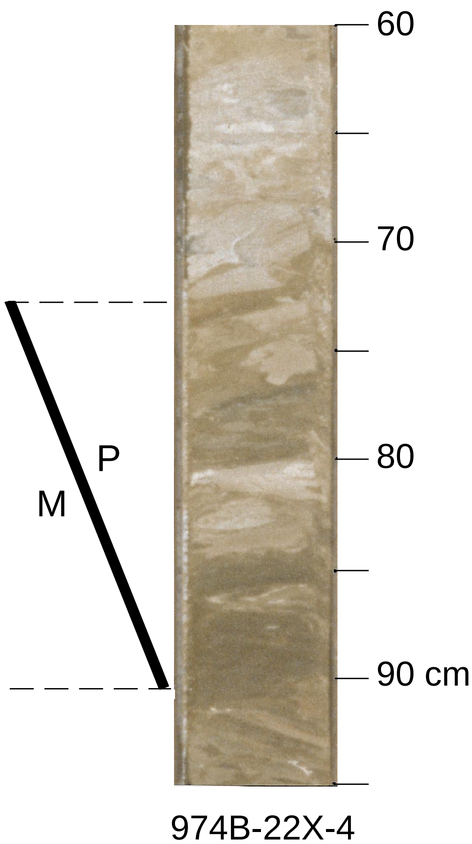

Figure 3. Lithologic variation at the Miocene/Pliocene boundary in Hole 974B. The boundary falls between Samples 161-974B-22X-4, 73 cm, and 22X-4, 91 cm.

Some benthic "events" were recognized:

1. The consistent occurrence of benthic foraminifers from Sample 161-974B-22X-3, 130–132 cm (198.4 mbsf) upward;
2. In the first samples where it is present, the benthic assemblage is dominated by *Oridorsalis* spp. and *Gyroidinoides* spp.;
3. At 197.72 mbsf (Sample 161-974B-22X-3, 62–64 cm) arenaceous foraminifers (represented mainly by *Karreriella bradyi*) first occur;
4. At 195.94 mbsf (Sample 161-974B-22X-2, 34–36 cm) the first increase of the total abundance of benthic foraminifers is recorded. *Oridorsalis stellatus, Gyroidinoides laevigatus,* and *Karreriella bradyi* increase and dominate the assemblage;
5. Between 195.94 and 195.70 mbsf (Samples 161-974B-22X-2, 34–36 cm, and 22X-2, 10–12 cm), the increase in abundance of *Globocassidulina subglobosa, Nonion* spp., and *Dentalina* spp. first occurs; and
6. From 193.23 mbsf (Sample 161-974B-22X-6, 122–125 cm) upwards, a sharp increase in abundance of benthic foraminifers is observed; only *Dentalina* gr. and *Gyroidinoides* gr. *soldanii* decrease.

Hole 975B

Hole 975B is located on the South Balearic Margin (38° 53.786′N, 4°30.596′E) (Shipboard Scientific Party, 1996b), not too far from Site 372 (Deep Sea Drilling Project, Leg 42) at 2200 m depth (Fig. 1). The entire sedimentary sequence (late Messinian to Pleistocene) is 307 m thick. The investigated interval is 11 m thick, extending from Sample 161-975B-32X-3, 116–118 cm (at 296.70 mbsf), to Sample 161-975B-33X-CC, 10 cm, below which the evaporites occur. Samples 975B-33X-2, 132–134 cm, to 33X-3, 137–139 cm, belong to the "non-distinctive" Zone of Iaccarino (1985). Samples 975B-32X-4, 40–42 cm, to 33X-2, 130–132 cm, are referred to MP11. Sample 975B-32X-3, 116–118 cm, belongs to MP12.

The quantitative study, carried out on 57 samples, was mostly concentrated on the interval between Sample 161-975B-33X-3, 137–139 cm, and Sample 32X-6, 116–118 cm (Table 3). The Miocene/Pliocene boundary falls between Sample 975B-33X-2, 132–134 cm, and Sample 33X-2, 130–132 cm, at 305.23 mbsf, corresponding to a lithologic and color change (Fig. 4). The $CaCO_3$ curve shows a strange pattern; in fact, the uppermost Messinian sediments are richer in $CaCO_3$ than the lowermost Pliocene sediments (Fig. 5). Small clasts dispersed in the pelagic ooze characterize the very base of the Pliocene sediments (Fig. 6). Planktonic foraminifers are abundant, well preserved, and well diversified from the base of the Pliocene sediments (Table 4 and Appendix C).

The major events recognized within Zone MP11 are the following:

1. The FCO of *Gr. margaritae* marking the base of MP12, at Sample 161-975B-32X-3, 116–118 cm (at 296.81 mbsf);
2. The acme interval of *Sphaeroidinellopsis* (2.6 m thick) between Sample 161-975B-33X-2, 0–2 cm, and Sample 32X-6, 116–118 cm;
3. Two sinistral shifts of *N. acostaensis,* the lower one from Sample 161-975B-33X-2, 50–52 cm (at 304.41 mbsf) up to 33X-2, 30–32 cm (at 304.21 mbsf) and the higher one from Sample 975B-33X-1, 143–145 cm (at 303. 84 mbsf) up to 33X-1, 117–119 cm (at 303.58 mbsf) for a thickness of 0.20 m and 0.26 m respectively;
4. The CO of *Gr. scitula* dextral occurs from Sample 161-975B-33X-1, 125–127 cm, at 303.66 mbsf, which is 1.5 m above the Miocene/Pliocene boundary; and
5. A peak of abundance (9.2%) of *Gg. nepenthes* at Sample 161-975B-33X-2, 10–12 cm, at 304.01 mbsf just below the base of the *Sphaeroidinellopsis* acme interval.

Total benthic foraminifers from the fraction >125 µm is shown in Appendix D; only semi-quantitative analyses were conducted for the fraction <125 µm.

The interval studied is characterized by the following benthic "events":

1. The uppermost Messinian is characterized by the abundance of *Bolivina* cf. *paralica*, *Rosalina* spp., and small *Ammonia tepida* (Iaccarino and Bossio, Chap. 42, this volume);
2. At the base of MP11 Zone, *Brizalina-Bolivina* gr. and *Trifarina bradyi* are present and *G.* gr. *soldanii* and *Oridorsalis umbonatus* show the highest abundances. At the very base (Samples 161-975B-33X-2, 130–132 cm, to 33X-2, 116–118 cm) *Eponides pusillus* and *Epistominella exigua* are common in the fraction <125 µm;
3. At 304.41 mbsf (Sample 161-975B-33X-2, 50–52 cm) *G. subglobosa* becomes one of the dominant taxa;
4. At about 304 mbsf (Samples 161-975B-33X-2, 20–22 cm, and 33X-2, 10–12 cm) *O. stellatus* and the agglutinants (mainly represented by *K. bradyi, Martinottiella* spp., and *Bigenerina nodosaria*) first occur and/or become more abundant;
5. From 303.16 mbsf (Sample 161-975B-33X-1, 75–77 cm) a high benthic abundance is recorded; *G. subglobosa* shows increasing percentages, and *Uvigerina* spp. becomes continuously present with low percentages; and
6. At 302.39 mbsf (Sample 161-975B-32X-CC, 37–39 cm) *Uvigerina pygmaea-peregrina* increases, and a sharp decrease of *G. subglobosa* occurs.

Table 2. Percentages of selected planktonic foraminifers in Hole 974B.

Core, section, interval (cm)	*Gr. margaritae*	*Ss. seminulina*	*N. acostaensis* (sx)	*N. acostaensis* (dx)	*Gr. scitula* (dx)	*Gr. scitula* (sx)	*Gg. nepenthes*
161-974B-							
20X-6, 66-68	3.3	0.7	0.7	16.7	9.2		1.7
20X-CC					6.6	3.3	1.3
21X-2, 67-69		0.4	0.7	24.4	3.6	0.4	2.2
21X-2, 108-110		0.3	0.6	20.4	0.3		9.1
21X-4, 130-132				8.4	1.0		1.3
21X-5, 53-55	0.3	1.0	0.3	15.3	5.8		3.0
21X-6, 99-101		1.3		11.4	0.3		1.0
21X-6, 103-105			0.3	14.7	1.0		1.6
21X-6, 122-125		0.8	0.3	13.2	4.6		3.0
21X-6, 140-142		0.6	0.6	13.6	5.7		9.6
21X-7, 17-19		1.1		12.1	6.8		5.1
21X-7, 35-37		1.2		10.1	3.6		2.4
21X-CC			1.3	11.0	2.9	0.3	2.6
22X-1, 20-22		0.9	0.3	8.2	6.6		5.7
22X-1, 37-39		2.3	0.3	9.2	2.9		2.3
22X-1, 57-59		2.5	0.6	15.6	6.6		0.9
22X-1, 80-82		0.7		15.2	8.3		2.3
22X-1, 100-102		1.0		12.2	5.5		2.6
22X-1, 120-122		0.6		12.5	5.0		5.6
22X-1, 140-142		0.3	0.7	8.7	2.8		9.1
22X-2, 10-12		1.6	0.3	14.4	0.7		9.2
22X-2, 34-36		1.5	0.7	15.7	1.7		4.7
22X-2, 56-58			0.3	9.1			5.8
22X-2, 77-79		1.9	1.4	17.4	3.6		3.6
22X-2, 98-100			0.8	11.6	3.9		3.9
22X-2, 115-117		1.3	1.0	11.1	5.3		11.1
22X-2, 136-138		0.9		9.8	4.4		10.0
22X-3, 10-12		1.1	8.8	2.0	3.4		10.5
22X-3, 28-30		1.2	13.7	0.6			1.6
22X-3, 42-44		2.1	9.9				6.3
22X-3, 62-64		0.6	8.8	1.9			8.5
22X-3, 81-82		1.0	10.9	1.9			3.5
22X-3, 102-104		0.2	0.5	11.2	0.7		4.1
22X-3, 115-117		0.4		12.8	0.9		5.8
22X-3, 130-132			0.5	15.7	0.5		14.1
22X-3, 145-147							
22X-4, 14-16			14.3	0.9	0.6		9.9
22X-4, 34-36			17.3	1.2	0.6		7.9
22X-4, 52-54			10.4	0.3	0.8		6.5
22X-4, 70-72			10.3	4.7			4.0
22X-4, 93-95							
22X-4, 114-116							
22X-4, 133-135							
22X-5, 32-34							
22X-5, 48-49							
22X-5, 70-72							
22X-5, 90-92							
22X-5, 110-112							
22X-5, 125-127							
22X-5, 143-145			2.0	1.4		1.1	
22X-6, 16-18			2.2	0.9		0.2	0.2
22X-6, 50-52			6.8	4.4	1.6	0.5	0.7
22X-6, 66-68			7.2	3.7	1.3	0.7	0.4

Note: Blank space = planktonic foraminifers absent.

Cyclicity

According to Hilgen (1991), sedimentary cyclicity is driven by astronomical parameters (precession, obliquity, and eccentricity). In Trubi sections exposed in Sicily, the cyclicity is clearly visible; Hilgen (1991) and Langereis and Hilgen (1991) demonstrated that these cycles are driven by precession periodicity. Sprovieri (1992, 1993), counting total *Globigerinoides*, found that abundance fluctuation shows a cyclicity that correlates well with the precession-driven sedimentary cycles. Therefore, we adopted this method to recognize the cyclicity at Sites 974 and 975, because the Pliocene sediments cored at these sites do not show any visible cyclicity.

Counting the fluctuations of the relative abundance of *Globigerinoides* spp., Sprovieri (1993) and Sprovieri et al. (1996) recognized ten cycles within MP11. The two sinistral shifts of *N. acostaensis* fall within Cycles 2 and 3 respectively, the acme interval of *Sphaeroidinellopsis* ranges from Cycle 2 to Cycle 6, and the FCO of *Gr. margaritae* occurs within Cycle 10. Based on these events in Holes 974B and 975B, several cycles were clearly identified in Zone MP11 (Tables 5, 6). However, sampling in the upper part of the zone was inadequate for the recognition of all cycles.

In Hole 974B, five cycles were recorded (Fig. 7): we suggest that the first cycle is missing, because here the base of the Pliocene is characterized by *N. acostaensis* sinistrally coiled, which correlates with the second cycle.

In Hole 975B, six cycles were recognized (Fig. 8): Cycle 1 is recognizable below the first sinistral shift of *N. acostaensis*. Evidence of a more complete sequence in Hole 975B is the presence of a transitional interval in the underlying latest Messinian, which yielded a benthic assemblage missing in Hole 974B (Iaccarino and Bossio, this volume).

BENTHIC FORAMINIFERS AND CYCLES

Hole 974B

E. pusillus and *E. exigua*, which were found in Cycle 1 by Sgarrella et al. (1997), are missing in the lowermost part of the Pliocene of Hole 974B (Fig. 9), which is in agreement with the absence of Cycle 1 recorded by planktonic foraminifers.

In Cycle 2, benthic foraminifers are almost absent up to 198.55 mbsf (Sample 161-974B-22X-3, 145–147 cm). In the upper part of this cycle, the benthic assemblage is dominated by *O. stellatus* (indicative of slightly low oxygen content, according to Sprovieri and Hasegawa, 1990) and *Gyroidinoides* spp., which indicates epibathyal depth (Caralp et al., 1970).

In Cycle 3, *K. bradyi* first occurs, indicating well-oxygenated waters and bathyal depths (Van der Zwaan, 1982).

In Cycle 4, the total abundance of benthic foraminifers increases in both >125 µm and <125 µm fractions, and *G. subglobosa, Nonion* spp., and *Dentalina* group first occur.

In Cycle 6, a further increase in the abundance of benthic foraminifers is recorded; all the taxa proportionally increase except for *Dentalina* group and *G.* gr. *soldanii*.

Hole 975B

In Hole 975B (Fig. 10), the distribution of benthic foraminifers in the earliest MP11 correlates well with the cyclicity identified by planktonic foraminifers.

In Cycle 1, the presence of *Brizalina-Bolivina* gr., *T. bradyi, E. exigua,* and *E. pusillus* (the last one in the fraction <125 µm) indicates disaerobic bottom-water conditions (van der Zwaan, 1982). Moreover, the high abundance of *G.* gr. *soldanii* and *O. umbonatus* suggests epibathyal water depth.

A similar distribution is reported by Sgarrella et al. (1997) in the basal part of the Trubi formation at Capo Rossello (Sicily) in Cycle 1; *E. pusillus* and *E. exigua*, are present, and *G. soldanii* and *O. umbonatus* are the best represented species in the assemblage >125 µm. Nevertheless, *G. subglobosa,* as reported by Sgarrella et al. (1997) is not present in Cycle 1 in Hole 975B. The presence of *E. pusillus* and *E. exigua* at the very base of Cycle 1 in Hole 975B confirm the opportunistic character of these species as reported by Smart et al. (1994) and Sgarrella et al. (1997). The occurrence of *E. pusillus* and

Table 3. Investigated samples of Hole 975B: depth, weight of dried sample and washed residue fractions, and sediment color.

Core, section, interval (cm)	Depth (mbsf)	Total weight (g)	Residue weight (g) >125 µm	Residue weight (g) >63–<125 µm	Sediment color
161-975B-					
32X-3, 116-118	296.81	10.00	1.48	0.53	Yellowish gray (5Y 8/1)
32X-4, 40-42	297.55	12.00	0.76	0.41	Yellowish gray (5Y 8/1)
32X-4, 116-118	298.31	16.00	0.93	1.09	Yellowish gray (5Y 8/1)
32X-5, 41-43	299.06	16.00	1.36	1.43	Yellowish gray (5Y 8/1)
32X-5, 116-118	299.81	20.00	1.45	1.25	Yellowish gray (5Y 8/1)
32X-6, 40-42	300.55	16.00	1.48	1.07	Yellowish gray (5Y 8/1)
32X-6, 116-118	301.31	16.00	2.14	1.87	Yellowish gray (5Y 8/1)
32X-6, 126-128	301.41	14.69	2.24	1.71	Yellowish gray (5Y 8/1)
32X-6, 144-146	301.59	13.90	2.35	2.02	Yellowish gray (5Y 8/1)
32X-7, 15-17	301.80	13.84	0.96	0.54	Yellowish gray (5Y 8/1)
32X-7, 35-37	302.00	15.01	1.29	1.00	Yellowish gray (5Y 8/1)
32X-7, 40-42	302.05	16.00	1.26	1.06	Yellowish gray (5Y 8/1)
32X-CC, 16-18	302.18	14.86	0.76	0.56	Yellowish gray (5Y 8/1)
32X-CC, 37-39	302.39	13.87	1.47	0.92	Yellowish gray (5Y 8/1)
33X-1, 5-7	302.46	9.43	1.05	0.82	Yellowish gray (5Y 8/1)
33X-1, 14-16	302.55	7.26	0.64	0.57	Yellowish gray (5Y 8/1)
33X-1, 25-27	302.66	13.51	0.67	0.74	Yellowish gray (5Y 8/1)
33X-1, 35-37	302.76	11.40	0.83	0.82	Yellowish gray (5Y 8/1)
33X-1, 40-42	302.81	8.13	1.03	0.80	Yellowish gray (5Y 8/1)
33X-1, 55-57	302.96	11.23	1.03	0.66	Yellowish gray (5Y 8/1)
33X-1, 63-65	303.04	7.79	0.48	0.54	Yellowish gray (5Y 8/1)
33X-1, 75-77	303.16	8.81	2.17	0.91	Yellowish gray (5Y 8/1)
33X-1, 83-85	303.24	8.44	0.46	0.67	Yellowish gray (5Y 8/1)
33X-1, 95-97	303.36	11.61	0.64	0.58	Yellowish gray (5Y 8/1)
33X-1, 100-102	303.41	8.50	0.32	0.51	Yellowish gray (5Y 8/1)
33X-1, 117-119	303.58	9.75	0.53	0.63	Yellowish gray (5Y 8/1)
33X-1, 125-127	303.66	11.62	0.54	0.66	Yellowish gray (5Y 8/1)
33X-1, 143-145	303.84	8.77	1.03	0.95	Yellowish gray (5Y 8/1)
33X-2, 0-2	303.91	8.24	1.38	0.82	Yellowish gray (5Y 8/1)
33X-2, 10-12	304.01	14.39	0.98	0.86	Yellowish gray (5Y 8/1)
33X-2, 20-22	304.11	11.84	0.35	0.50	Yellowish gray (5Y 8/1)
33X-2, 30-32	304.21	9.17	1.35	0.72	Yellowish gray (5Y 8/1)
33X-2, 40-42	304.31	10.87	1.53	0.99	Yellowish gray (5Y 8/1)
33X-2, 46-48	304.37	8.95	2.31	1.21	Yellowish gray (5Y 8/1)
33X-2, 50-52	304.41	10.80	2.24	1.51	Yellowish gray (5Y 8/1)
33X-2, 62-64	304.53	17.22	1.18	1.22	Yellowish gray (5Y 8/1)
33X-2, 70-72	304.61	9.52	0.38	0.49	Yellowish gray (5Y 8/1)
33X-2, 80-82	304.71	12.71	0.39	0.39	Yellowish gray (5Y 8/1)
33X-2, 85-87	304.76	7.54	0.42	0.56	Yellowish gray (5Y 8/1)
33X-2, 90-92	304.81	12.39	0.42	0.41	Yellowish gray (5Y 8/1)
33X-2, 98-100	304.89	14.75	0.16	0.21	Yellowish gray (5Y 8/1)
33X-2, 100-102	304.91	9.97	0.02	0.09	Yellowish gray (5Y 8/1)
33X-2, 105-107	304.96	15.45	0.63	0.73	Yellowish gray (5Y 8/1)
33X-2, 114-116	305.05	11.84	0.44	0.56	Yellowish gray (5Y 8/1)
33X-2, 116-118	305.07	15.20	0.35	0.37	Yellowish gray (5Y 8/1)
33X-2, 120-122	305.11	16.12	0.34	0.32	Yellowish gray (5Y 8/1)
33X-2, 129-131	305.20	5.78	0.14	0.04	Yellowish gray (5Y 8/1)
33X-2, 130-132	305.21	16.52	0.85	0.09	Yellowish gray (5Y 8/1)
33X-2, 132-134	305.23	7.19	0.01	0.01	Light greenish gray (5GY 8/1)
33X-3, 6-8	305.47	11.65	0.02	(one fract.)	Light greenish gray (5GY 8/1)
33X-3, 33-35	305.74	12.48	0.15	0.04	Light olive gray (5Y 6/1)
33X-3, 35-37	305.76	12.05	0.06	0.06	Yellowish gray (5Y 8/1)
33X-3, 47-49	305.88	13.04	0.04	0.07	White (N9) light greenish gray (5GY 8/1)
33X-3, 83-85	306.24	13.21	0.02	0.03	White (N9)
33X-3, 112-114	306.53	11.29	0.02	0.07	Yellowish gray (5Y 8/1) white (N9)
33X-3, 125-127	306.66	13.30	0.08	0.08	Very light gray (N8)
33X-3, 137-139	306.78	13.46	0.10	0.11	Light greenish gray (5GY 8/1)

G. gr. *soldanii*, at the very base of the Pliocene in Hole 975B, indicates a transition from poorly oxygenated to more normal environments (Vismara Schilling, 1986; Mullineaux and Lohman, 1981).

The appearance of *G. subglobosa* and agglutinants (mainly *K. bradyi*, *Martinottiella* spp., and *B. nodosaria*) marks the base of Cycle 2.

The decrease of benthic specimens and the replacement of *O. umbonatus* by *O. stellatus* in Cycle 3 suggest less oxygenated water masses.

As in Hole 974B, the abundance of the total assemblage of benthic foraminifers in Cycle 4 increases. The distribution of *Uvigerina* spp. (mainly *U. pygmaea-peregrina*) from Cycle 4 upward and the increase in abundance of this taxon from Cycle 5 indicate a new depletion of oxygen bottom content (Lohman, 1978).

In general, the recorded benthic assemblages in Holes 974B and 975B are quite similar to those reported by Sprovieri and Hasegawa (1990) and McKenzie and Sprovieri (1990) at Sites 652, 653, and 654 of ODP Leg 107 (Tyrrhenian Sea), but the benthic foraminifers are even rarer. In fact, the above-mentioned authors reported that the MP11 biozone is mainly characterized by the presence of *Dentalina filiformis*, *G. soldanii*, *G. laevigata*, *G. subglobosa*, *O. stellatus*, and *U. pygmaea*, and that the assemblage is not well diversified. Moreover, at the same sites, Hasegawa et al. (1990) recognized four zones in the Pliocene–Pleistocene interval; the lowest one (Zone I) is characterized by the dominance of *Globocassidulina* spp. (mainly *G. subglobosa*), as in most samples in Hole 975B.

The distribution of *U. pygamea-peregrina* in Holes 974B and 975B correlates well with the *U. pygamea-peregrina* Event reported by Sgarrella et al. (1997) in the Mediterranean. In Hole 974B, the first occurrence of *Uvigerina* is immediately above the top of Cycle 6. It has a similar distribution to that indicated by the above-mentioned authors for the Sicilian sections and the Tyrrhenian Basin, in which the event starts from Cycle 6. In Hole 975B, the presence of *U. pygmaea-peregrina* starts from Cycle 3, but only at Cycle 4 does it be-

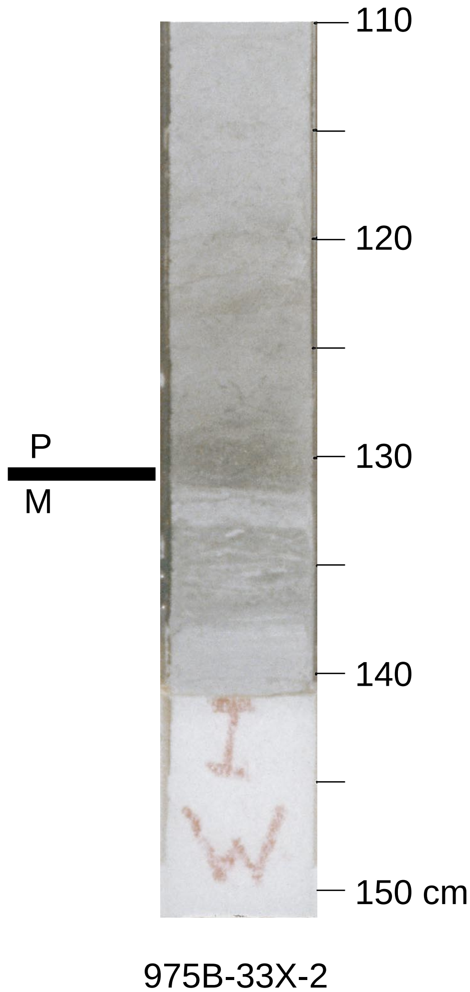

Figure 4. Lithologic variation at Miocene/Pliocene boundary in Hole 975B. The boundary falls at Sample 161-975B-33X-2, 132 cm, between gray and whitish color change.

come continuous. Sgarrella et al. (1997) recognized this event in the Jonian Basin starting from Cycle 4.

According to McKenzie and Sprovieri (1990) and Sprovieri and Hasegawa (1990), a low oxygen content characterizes the bottom waters of the Mediterranean Basin in the basal part of Zone MP11. However, the distribution of the benthic foraminifers sensitive to oxygen content shows variations that are not simultaneous in the Tyrrhenian and Balearic Basins, probably because of the different depths and physiographies of the two basins.

CONCLUSIONS

The basal Pliocene sediments are typical pelagic oozes composed mainly of planktonic foraminifers. At Site 975, however, in the first 2–3 cm of the Pliocene sediments, small clasts are present within the pelagic ooze, indicating terrigenous input. The benthic population indicates that at the beginning of the Pliocene, circulation was restricted in Hole 974B and was disaerobic in Hole 975B. Only later, when the connection with the Atlantic Ocean was well established, did the benthic fauna increase and become more diversified.

The paleoenvironmental change at the Miocene/Pliocene boundary is also recognizable through the lithology (mainly in Hole 975B) and carbonate content (mainly in Hole 974B).

The sedimentation rate was higher in Hole 974B than in Hole 975B and was constant for the entire Zone MP11 (Fig. 11). The Miocene/Pliocene boundary is identifiable at both sites (no more than 0.2 k.y. are missing in Hole 974B) and correlates with that of the Capo Rossello composite section, which is five cycles below the Thvera Subchron. In fact, even if the paleomagnetic data are not available for these sequences, the position of the polarity change may be inferred through the biostratigraphic events and the *Globigerinoides* fluctuations related to the precession periodicity (Fig.12).

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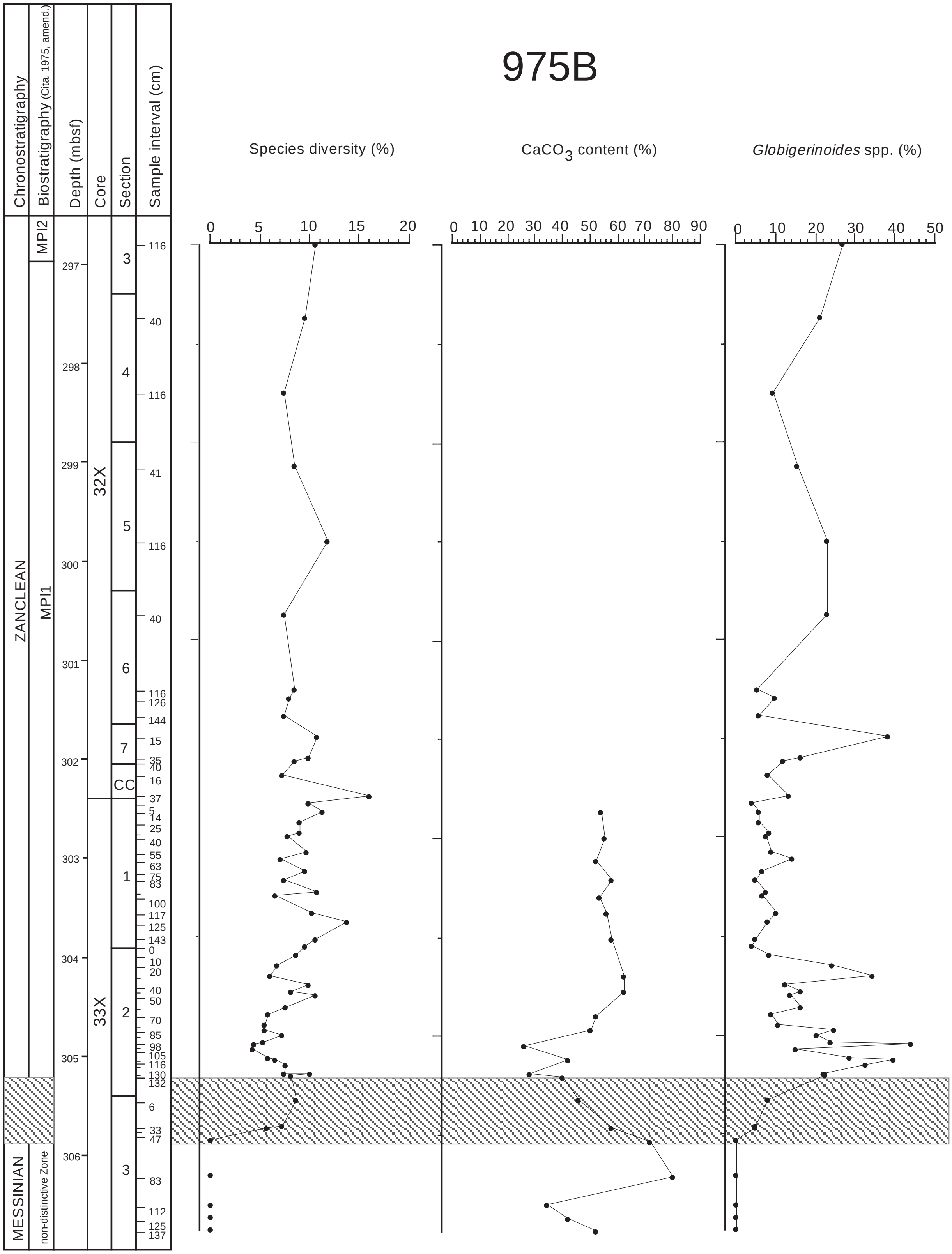

Figure 5. Specific diversity of planktonic foraminifers, $CaCO_3$, and *Globigerinoides* spp. curves in Hole 975B. The shadow area below the M/P boundary corresponds to a transitional unit at the top of the Messinian sequence. The $CaCO_3$ curve is based on a minor number of samples in respect to the *Globigerinoides* curve.

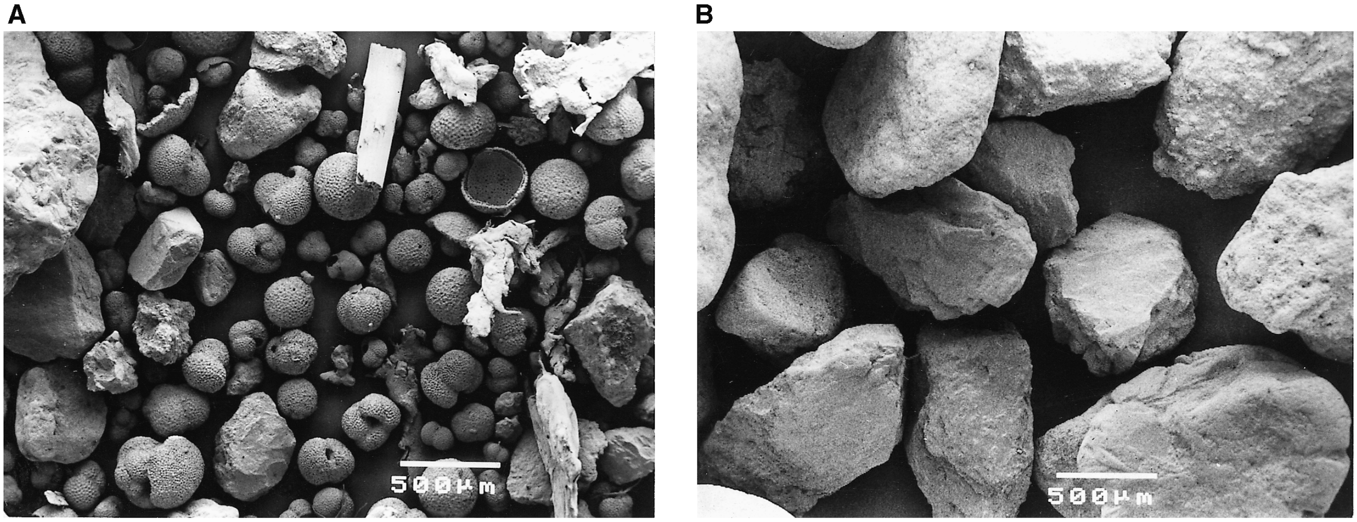

Figure 6. Residue composition in Sample 161-975B-33X-2, 129–131 cm, in two different fractions. **A.** Fraction > 125 µm: planktonic foraminifers are associated with clasts. **B.** Fraction > 300 µm.

Table 4. Percentages of selected planktonic foraminifers in Hole 975B.

Core, section, interval (cm)	*Gr. margaritae*	*Ss. seminulina*	*N. acostaensis* (sx)	*N. acostaensis* (dx)	*Gr. scitula* (dx)	*Gr. scitula* (sx)	*Gg. nepenthes*
161-975B-							
32X-3, 116-118	8.5		0.4	12.0			
32X-4, 40-42			0.7	9.9	0.7		0.3
32X-4, 116-118		1.2	0.6	23.3	1.5	0.3	0.9
32X-5, 41-43		0.5		16.4	0.3		1.6
32X-5, 116-118				16.4	8.5		0.3
32X-6, 40-42			0.7	14.7			2.4
32X-6, 116-118		0.6	0.3	16.6	7.2	1.6	1.6
32X-6, 126-128		0.5	0.5	13.8	9.2	0.2	1.6
32X-6, 144-146		1.9	0.5	12.0	1.6		2.2
32X-7, 15-17		1.4		13.1	1.8	0.7	2.5
32X-7, 35-37		0.3	0.9	16.3	0.6		0.3
32X-7, 40-42		1.7	1.1	16.9	2.9		4.0
32X-CC, 16-18		0.9	2.1	30.3	0.9	0.3	4.0
32X-CC, 37-39		1.8		10.8	4.8	0.6	2.7
33X-1, 5-7				17.6	2.2	0.9	2.8
33X-1, 14-16		1.2	0.9	13.2	6.1	0.6	0.9
33X-1, 25-27		2.9	1.0	9.6			3.8
33X-1, 35-37		0.7	1.0	7.8			7.8
33X-1, 40-42		0.6	1.8	16.7	0.9		2.3
33X-1, 55-57		1.0	1.0	17.3	1.0		5.9
33X-1, 63-65		0.8	1.9	21.7	1.4	0.3	0.5
33X-1, 75-77		0.9	0.6	22.2	0.3	0.3	1.5
33X-1, 83-85		0.9	0.9	12.8	0.3		0.6
33X-1, 95-97		0.5	2.4	17.3	3.2		4.4
33X-1, 100-102		0.9	1.2	12.2	1.5		4.5
33X-1, 117-119		1.1	5.2	10.6	2.6		3.2
33X-1, 125-127		2.3	6.8	6.0	3.7		3.7
33X-1, 143-145		3.4	12.7	5.2	0.3		1.2
33X-2, 0-2		1.9	4.1	22.5	0.6		4.4
33X-2, 10-12			2.0	19.6	0.3		9.2
33X-2, 20-22			0.3	15.4	0.9		4.2
33X-2, 30-32		0.3	2.4	12.7			1.2
33X-2, 40-42		0.9	14.2	3.6	0.3		7.4
33X-2, 46-48		0.3	17.9	3.5			1.9
33X-2, 50-52			14.3	3.7	2.2		6.8
33X-2, 62-64		0.5		26.1	0.3	0.3	4.0
33X-2, 70-72			0.3	20.5	1.0		2.9
33X-2, 80-82			1.3	15.8	2.3		3.9
33X-2, 85-87				13.9		0.3	2.2
33X-2, 90-92			1.2	16.4			6.1
33X-2, 98-100			0.6	17.0			5.0
33X-2, 100-102			1.3	6.9	0.3		1.6
33X-2, 105-107				16.8		0.3	1.6
33X-2, 114-116			0.6	7.1			7.3
33X-2, 116-118				6.8			5.6
33X-2, 120-122		0.5	0.3	2.9		0.3	5.5
33X-2, 129-131			0.3	11.0	0.3	0.3	0.9
33X-2, 130-132			0.8	4.8	0.8	0.8	2.7
33X-2, 132-134		0.6	0.6	7.0		0.6	1.3
33X-3, 6-8	c	0.3	1.2	18.1	2.3		2.9
33X-3, 33-35	c		0.8	12.8	1.0	0.5	4.8
33X-3, 35-37	c	0.2	1.3	13.2	0.6		5.0
33X-3, 47-49							
33X-3, 83-85							
33X-3, 112-114							
33X-3, 125-127							
33X-3, 137-139							

Note: c = downhole contamination; blank space = planktonic foraminifers absent.

Table 5. Depth and age of the events and cycles in Hole 974B.

Events	Depth (mbsf)	Age (Ma)
FCO *Gr. margaritae*	296.8	5.07
Top *Sphaeroidinellopsis* acme	301.6	5.20
Top Cycle 6	301.41	
Top Cycle 5	302.18	
Top Cycle 4	302.5	
Top Cycle 3	303.3	
Base *Sphaeroidinellopsis* acme	303.9	5.29
Top Cycle 2	303.9	
Top Cycle 1	304.5	
Base Pliocene	305.21	5.33

Table 6. Depth and age of the events and cycles in Hole 975B.

Events	Depth (mbsf)	Age (Ma)
FCO *Gr. margaritae*	183.06	5.07
Top *Sphaeroidinellopsis* acme	190.80	5.20
Top Cycle 6	191.03	
Top Cycle 5	193.40	
Top Cycle 4	194.30	
Top Cycle 3	196.37	
Top Cycle 2	197.90	
Base *Sphaeroidinellopsis* acme	198.00	5.29

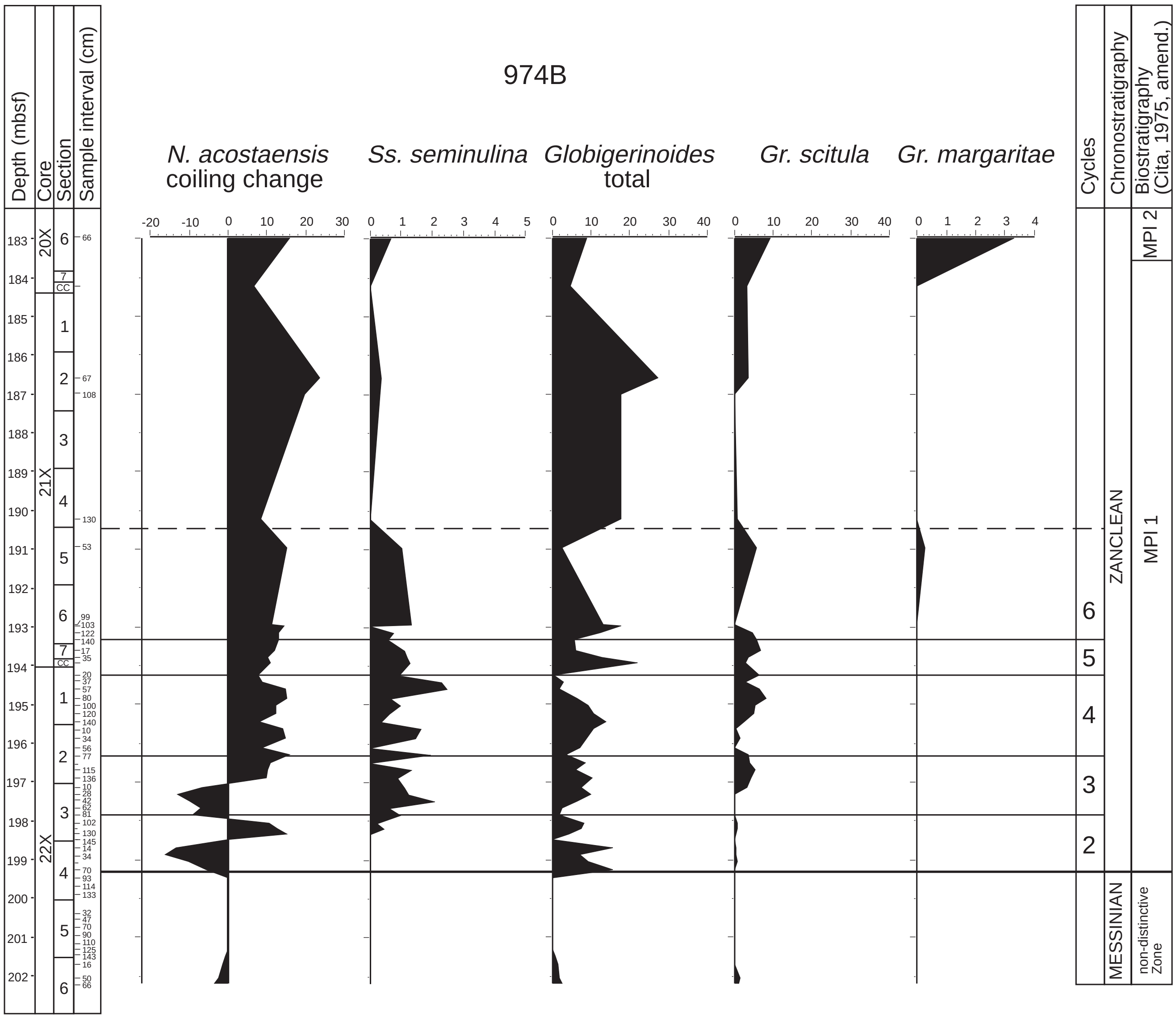

Figure 7. Events and abundance curves (%) of the most significant planktonic foraminifers in Hole 974B. Precession cycles listed on the right are well recognizable from Cycle 2 to Cycle 6. The upper boundary of Cycle 6 is dashed because the sampling is too loose in this interval and the boundary could be located above. Cycle 1 is missing.

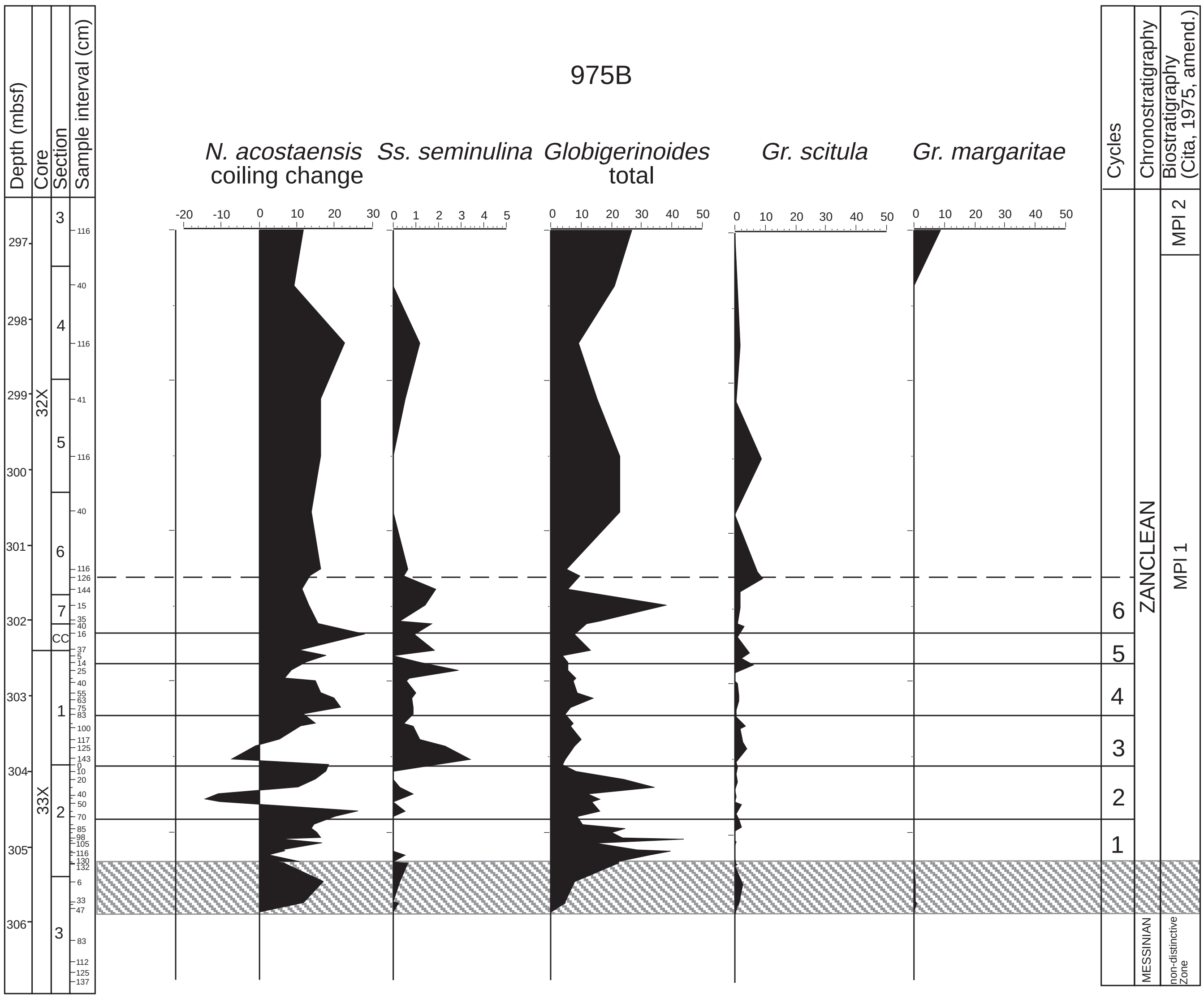

Figure 8. Events and abundance curves (%) of the most significant planktonic foraminifers in Hole 975B. Precession cycles listed on the right are well recognizable from Cycle 1 to Cycle 6. The upper boundary of Cycle 6 is dashed because the sampling is too loose in this interval and the boundary could be located above. The shadow area below the M/P boundary corresponds to a transitional unit at the top of the Messinian sequence.

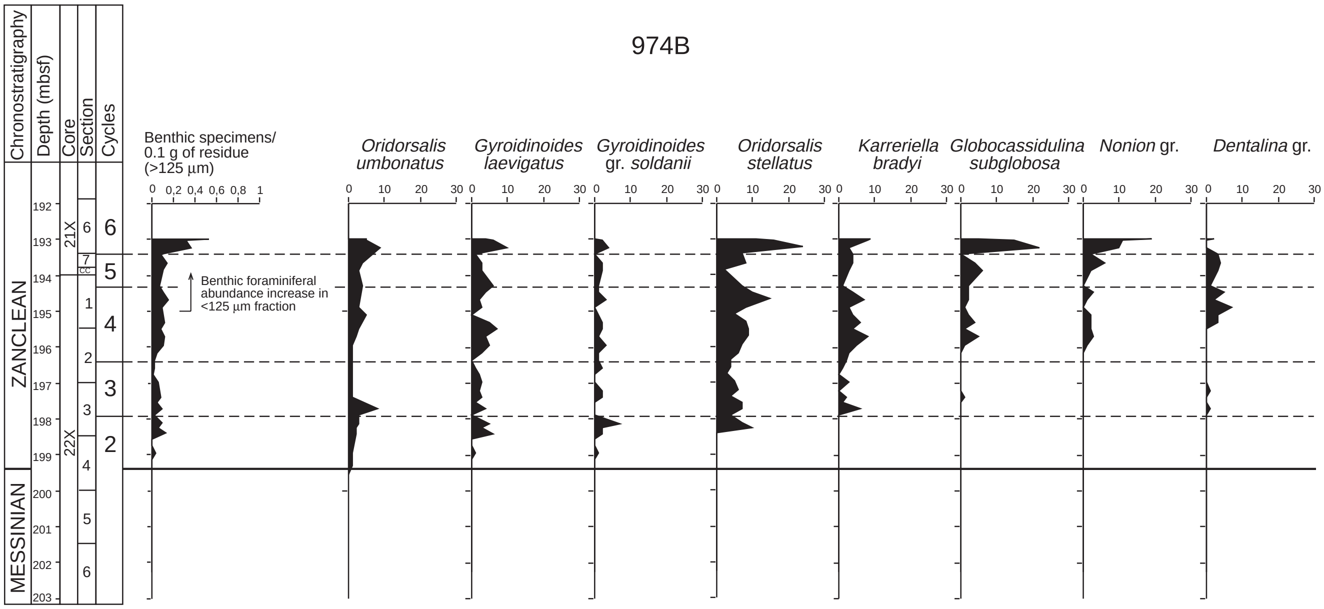

Figure 9. Quantitative distribution curves of benthic foraminifers vs. cycles in Hole 974B (see Appendix E).

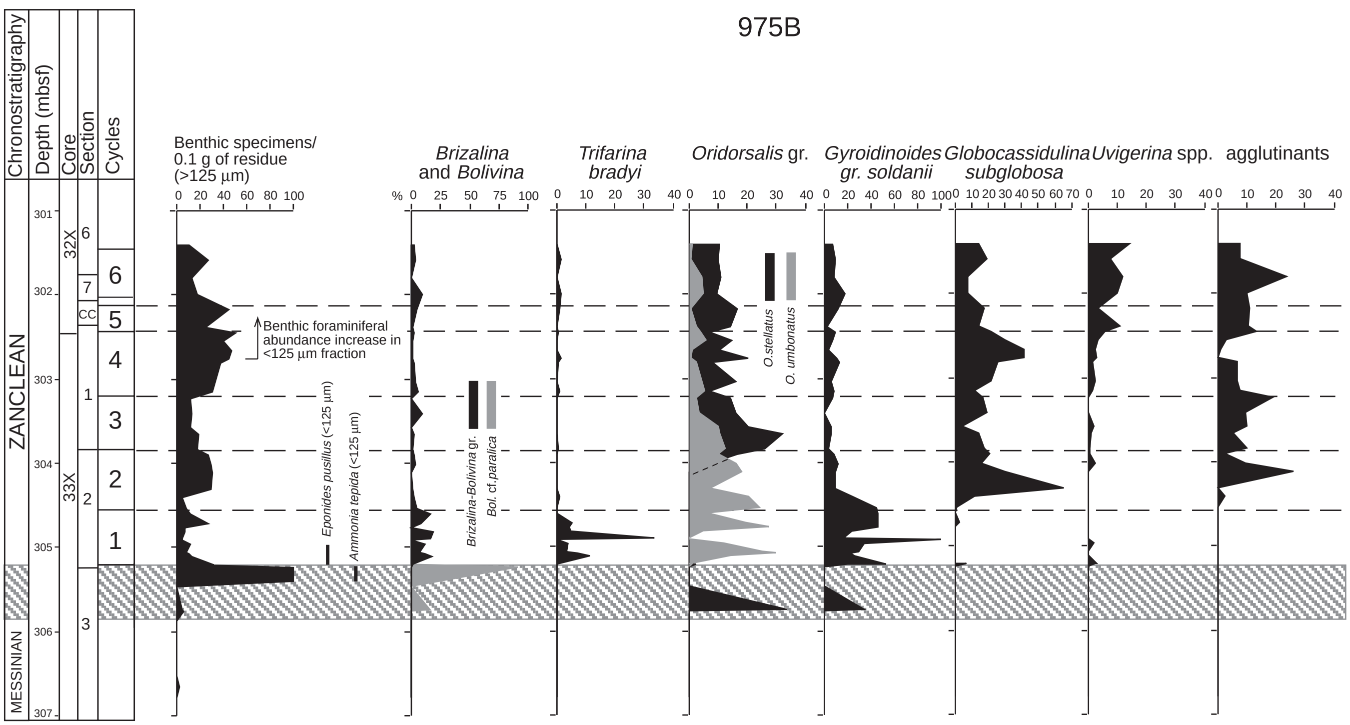

Figure 10. Frequency curves (%) of benthic foraminifers vs. cycles in Hole 975B (see Appendix E). The shaded area below the M/P boundary corresponds to a transitional unit at the top of the Messinian sequence.

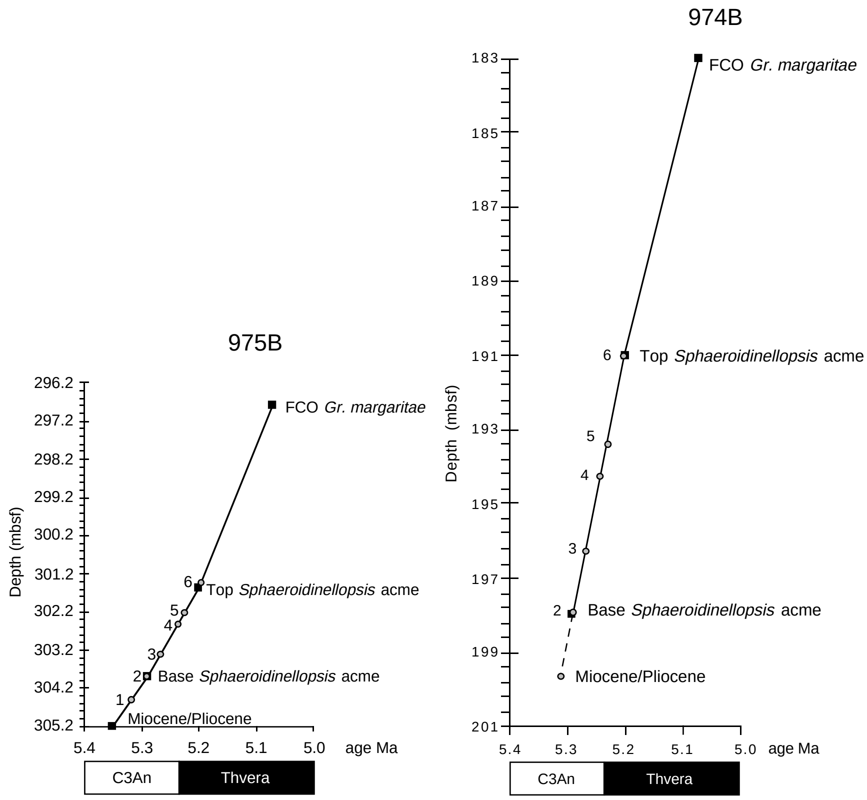

Figure 11. Age (Hilgen, 1991; Berggren et al., 1995) vs. depth of the cycles and biostratigraphic events in Zone MP11. The sedimentation rate is higher in Hole 974B than in Hole 975B, but the difference remains constant through the entire interval. Circles indicate the top depths of the cycles; squares indicate the bio-events.

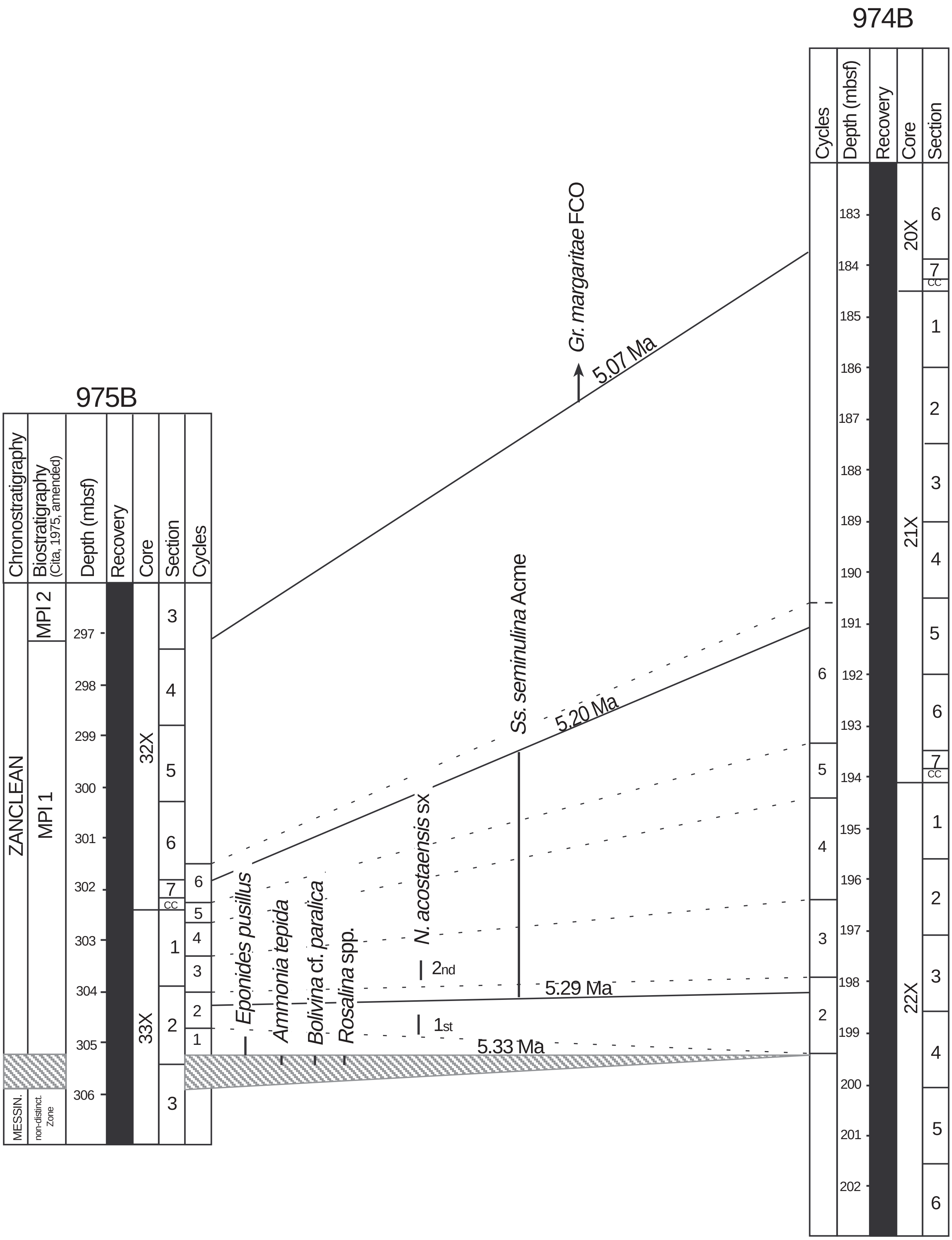

Figure 12. Comparison between the major biostratigraphic events and cycles within the two holes. The shaded area below the M/P boundary corresponds to a transitional unit at the top of the Messinian sequence.

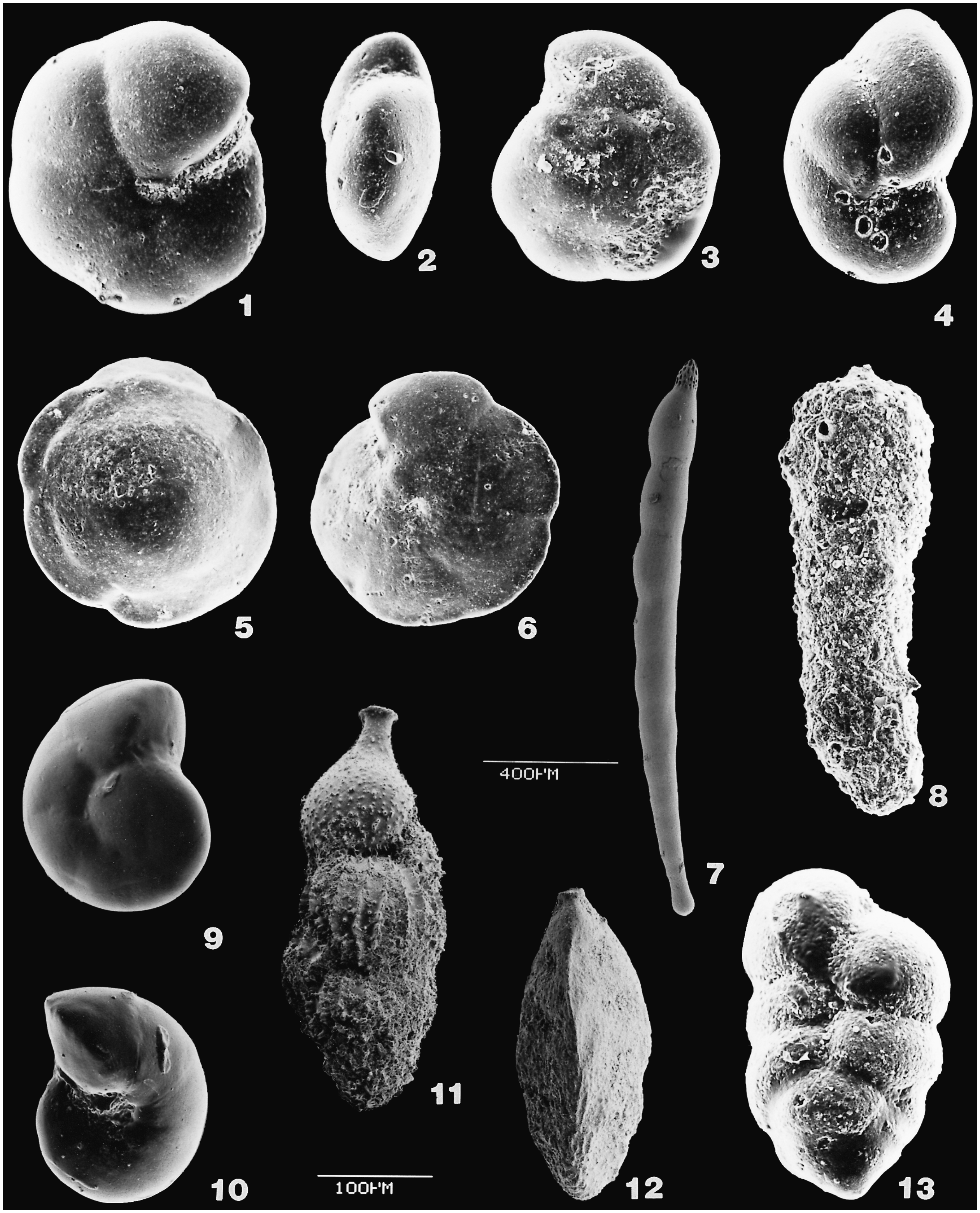

Plate 1. **1–3.** *Oridorsalis umbonatus* (Reuss). Sample 161-975B-33X-2, 0–2 cm. **4**. *Nonion* sp. Sample 161-974B-21X-2, 108–110 cm. **5, 6.** *Oridorsalis stellatus* (Silvestri). Sample 161-975B-33X-2, 0–2 cm. **7.** *Dentalina filiformis* (d'Orbigny). Sample 161-974B-22X-1, 37–39 cm. **8.** *Martinottiella communis* (d'Orbigny). Sample 161-975B-33X-2, 0–2 cm. **9, 10.** *Gyroidinoides laevigatus* (d'Orbigny). Sample 161-974B-22X-1, 80–82 cm. **11.** *Uvigerina pygmaea* d'Orbigny. Sample 161-974B-21X-5, 53–55 cm. **12**. *Trifarina bradyi* Cushman. Sample 161-975B-33X-2, 120–122 cm. **13.** *Karreriella bradyi* (Cushman). Sample 161-974B-22X-1, 80–82 cm. The larger magnification (400 µm) refers to figure 7 only.

Appendix A. Range chart of planktonic foraminifers through the Miocene/Pliocene boundary and MP11 Zone.

Core, section, interval (cm)	*Gg. apertura*	*Gg. bulloides*	*Gg. decoraperta*	*Gg. falconensis*	*Gg. foliata*	*Gg. multiloba*	*Gg. nepenthes*	*Gg. quinqueloba*	*Gg.* cf. *woodi*	*Ga. glutinata*	*Ga. uvula*	*B. praedigitata*	*Gs. bulloideus*	*Gs. conglobatus*	*Gs. trilobus* s.l.	*Gs. obliquus obliquus*	*Gs. obliquus extremus*	*Gs. quadrilobatus*	*Gs. ruber*	*Gs. trilobus*	*Gs. sacculifer*	*Gr. margaritae*	*Gr. menardii* group	*Gr. scitula* (dx)	*Gr. scitula* (sx)	*N. acostaensis* (sx)	*N. acostaensis* (dx)	*N. incompta* (sx)	*N. incompta* (dx)	*N. pachyderma*	*N. praehumerosa*	*Gl. obesa*	*Gl. praecalida*	*Gl. pseudobesa*	*H. siphonifera*	*O. bilobata*	*O. universa*	*O. suturalis*	*Turborotalita* sp.	*Ss. seminulina*	*Globoquadrina* spp.	*Globorotaloides* spp.	*Globigerinids* sp.
974B-20X-6, 66-68	F	A	C	C	R		F	F	R			R			R	F		F			F	F		C		R	A	R	R		R	R	R	F	R			R		R			C
20X-CC		C	C	F	R		F	F		A		F				F	F	R						F			C		R			F		F	F	F	C	F				R	C
21X-2, 67-69	R	C	C	F	R		F			C		R			F	C		C		R	C			F	R	R	A		F			R		R			F	F		R		R	F
21X-2, 108-110		C	C	C	R		C	R		C		R			C	C		R			F			R		R	A		F	F		R		F	R		F	F		R		F	F
21X-4, 130-132	R	C	C	F	R		F			A		F				A	R		R					F			C		F			F		F	R	F	C	F				R	C
21X-5, 53-55	R	C	A	F	F		F	F		A		R				F						R		C		R	A		F	F	R	F	R	F	R		C	F		F		R	F
21X-6, 99-101		F	A	R	R		R	R		A		F			C	C		R			R			R			C		F	F	R	R		F	R		F	F		F	R		F
21X-6, 103-105		C	C	F	R		F	F		A		R			C	C	R	F		R	F			R		R	C		C	R				F	F		F	F					F
21X-6, 122-125	R	C	C	F	F		F	F	R	A		F	R		R	C								F		R	C		F	R		R		F	F		F	F		R		R	F
21X-6, 140-142		F	A	C	F		C	F	R	A		F				C								C		R	C	R	F		R	F		R	F		F	R		R		F	F
21X-7, 17-19	R	C	C	F			C	F		A		C	R			C				R				C			C		F	R	R	F		F	F		F	F		F		R	F
21X-7, 35-37	R	C	C	C	F		F	F	R	A	R	F				C	R			R				F			C		F	R		R		F	F		F	R		F		R	F
21X-CC	R	C	C	F	R		F	R		C	R	F			F	C	R	C	R		F			F	R		C		R		R	R		F		R	C	F		F		R	C
22X-1, 20-22	R	A	C	C	F		C	F	R	C		R					R							C		R	C		C	R	F	R		F	F		F	F	R	R		F	C
22X-1, 37-39		A	C	C	F		F	F		C	R	R				F				R				F		R	C		F		R	R		F	R		F	F		F		F	F
22X-1, 57-59		C	C	C	C		R	F		C	R	R				F				R				C		R	A		F	R		F		F	R	R	F		F	F	R	R	C
22X-1, 80-82	F	C	C	C	C		F	R		C		F				C								C			A	R	F	R				R	R		R			R		F	F
22X-1, 100-102	R	A	C	C	R		F	F	R	C		R				C	R							C			C	R	F	R		R		F	F		R			R		F	C
22X-1, 120-122	F	A	C	C	F		C	F		C		F			R	C		R						F			C		F	R		R		F	F		F	F		R	R	F	F
22X-1, 140-142	R	C	A	C	F		C	R		C				R	F	C	R	R			F			F		R	C		F	F	R	F	R	F			R	F		R		F	F
22X-2, 10-12	R	C	C	C	F		C	F		C				R	R	C								R		R	C		C	R	R			F	R		R	F		F		R	F
22X-2, 34-36	R	C	C	C	F		F	F		C		F			R	C	R	R						F		R	A	R	C			F		F	R		F	F		F		F	C
22X-2, 56-58	R	C	C	C	F		C	F		C	R	F			R	C										R	C		F	R	R		R	F	R		C	F				F	C
22X-2, 77-79		C	C	C	F		F	F		C			R			F		R		R				F		F	A	R	F	R		R		F	F		F	F	R	F		F	C
22X-2, 98-100		C	C	C			F	F	R	A		F	R			C								F		R	C	R	F	R		R		F			F	F				F	F
22X-2, 115-117	R	C	C	F	F		C	R		A	R	R				C				R				C		R	C	R	C	R			R	F	R	R	F	F		F		R	F
22X-2, 136-138	R	C	C	C	F		C	F		A		R				C	R			R				F			C	R	C	R		R		F	R		F	F	R	R		R	F
22X-3, 10-12		C	A	C	F		C	F		C					R	C		R						F		C	F	F	R	R			R	R		R	F	F		F			F
22X-3, 28-30	F	A	C	A			F	R		F	R	F			R	C	F									C	R	F	R					F	R	F	C	F		F		F	F
22X-3, 42-44	R	C	C	C	F		C	F		C	R	F	F			F										C		C	F			R		R			F	F		F		R	F
22X-3, 62-64	R	C	A	C	R		C	F	R	C						F										C	F	F	R	R	R			F			F	R		R		R	F
22X-3, 81-82		C	A	C	F		F	R		C						F				R						C	F	C			R		R	F	R		F	F		R		R	F
22X-3, 102-104	F	C	C	C	R		F	F		C	R		F			C	R							R		R	C	R	C		R	R		F	R	R	F	F		R	R	R	F
22X-3, 115-117	F	C	C	C	R		C	R	R	C		R	R			C	R							R			C	R	C	R	R	R		F	R		C	F		R	R	R	F
22X-3, 130-132	F	F	A	F			C	R		C	R		R			F				R				R		R	A	R	C		R			F	R		F	F			R	R	F
22X-3, 145-147																																											
22X-4, 14-16	R	C	C	R	R		C	R		C		F			R	C	C							R		C	R	C	R	R	R		R	F			F	F					F
22X-4, 34-36		C	A	F	R		C	R		C	R	F				C				R				R		A	F	F		R	R	R		F		R	R	R				R	R
22X-4, 52-54	R	C	A	F	F		C	C		A	R	F	R			C	R		R					R		C	R	C	R		R			F		R	F	F			R	R	F
22X-4, 70-72	F	C	C	F	R		F	C	R	A		F	R			C	F									C	F	F				R		F	R		C	F				R	F
22X-4, 93-95																																											
22X-4, 114-116																																											
22X-4, 133-135																																											
22X-5, 32-34																																											
22X-5, 48-49																																											
22X-5, 70-72																																											
22X-5, 90-92																																											
22X-5, 110-112																																											
22X-5, 125-127																																											
22X-5, 143-145		F	F	R		R		A		A		R				R									F	F	F	F	F									R				R	F
22X-6, 16-18		R	R	F			R	A		A		R	R			R							R		R	F	R	F	F					R									
22X-6, 50-52		F	F	F	F		R	A		C	R	F	R		R	R							F	F	R	C	F	F	F	R	R		R	F				R				R	F
22X-6, 66-68		F	F	F	R	R	R	A	R	A	R	F	R		R	F							F	F	R	C	F	F	F		R		R	F			R	R			R	F	F

Note: A = Abundant (>15%); C = Common (5-15%); F = Few (1-5%); R = Rare (<1%); blank space = planktonic foraminifers absent.

Appendix B. Quantitative range chart of benthic foraminifers (>125 µm) through the Miocene/Pliocene boundary and MP11 Zone in Hole 974B.

Core, section, interval (cm)	Total benthic foraminifers	*Oridorsalis umbonatus*	*Gyroidinoides* gr. *soldanii* *	*Gyroidinoides laevigatus*	*Pullenia salisbury*	*Stilostomella* spp. *	*Cibicidoides ungerianus*	*Glomospira charoides*	*Oridorsalis stellatus*	*Dentalina filiformis*	*Karreriella bradyi*	*Martinottiella communis*	*Globocassidulina subglobosa*	*Quinqueloculina* spp.	*Cibicidoides pseudoungerianus*	*Eggerella bradyi*	*Uvigerina* spp. *	*Cibicides refulgens*	*Nonion* gr. *	*Nodosaria* spp. *	*Dentalina* sp.	*Fursenkoina squammosa*	*Brizalina-Bolivina* gr. *	*Cibicides lobatulus*	*Elphidium complanatum*	*Marginulina subbullata*	*Pleurostomella alternans*	*Triloculina* sp.	*Globobulimina saubriguensis*	*Lagena* spp. *	*Sigmoilinita tenuis*	*Dimorphina tuberosa*	*Chrysalogonium lanceolum*	*Astrononion stelligerum*	*Quadrimorphina allomorphinoides*	*Uvigerina pygmaea-peregrina*	*Anomalinoides alazanensis*	*Globocassidulina oblonga*	*Ortomorphina* cf. *tenuicostata*	*Globulina gibba*	Indet. specimens
161-974B-																																									
21X-2, 108-110	87		4	1			1		14		7		14			12	1		15					2		3			2	1			1		1	5		1	1	1	
21X-5, 53-55	43		3	3					5				19	2										1			1									6		3			
21X-5, 99-101	58	5		4		1			11	2	9		5						19	1													1								
21X-6, 103-105	67	5	2	6		1			16		8		15						11														2								1
21X-6, 122-125	106	9	4	10					24		3		22	1					10					3									1		19						
21X-6, 140-142	18			1					7	3	4								2								1														
21X-7, 17-19	36	4	2	3					8	4	4		4						6							1															
21X-7, 35-37	30	3	2	3			1		2	3	3		6	1					2					1											2						1
22X-1, 20-22	28	4	1	6					7	1	1		2																1		1		2	1							1
22X-1, 37-39	30		1	4					10	5	4		2						3												1										
22X-1, 57-59	34		3	2					15	2	7		2						1										2												
22X-1, 80-82	28	3		3					8	7	3		1										1								1	1									
22X-1, 100-102	27	5	1					1	5	3	4	1	2						2			2	1																		
22X-1, 120-122	37		2	5					8	3	6		4	1					2								1	2	1	1											1
22X-1, 140-142	33	3	2	7					9		4		1						2				1	1	1	1	1														
22X-2, 10-12	36	2	1	4					9		8	1	5					1	3		1	1																			
22X-2, 34-36	25	1	3	5				1	7		5		1						1	1																					
22X-2, 56-58	16	1	1	3					6		3						1	1																							
22X-2, 77-79	8	1	1						4		2																														
22X-2, 98-100	8		2	1					4		1																														
22X-2, 115-117	5			2					3																																
22X-2, 136-138	13			3					5		3					1																									
22X-3, 10-12	13		2	2					6	1				1	1																										
22X-3, 28-30	15	1	2	3					4		2	2	1																												
22X-3, 42-44	10			1					7		1	1																													
22X-3, 62-64	26	8		4					7	1	6																														
22X-3, 81-82	7	3							4																																
22X-3, 102-104	23	3	7	5					7																																
22X-3, 115-117	17	2	2	3					10																																
22X-3, 130-132	15	2	2	6		2	1	2																																	
22X-3, 145-147																																									
22X-4, 14-16																																									
22X-4, 34-36	4	1	1	1	1																																				
22X-4, 52-54																																									
22X-4, 70-72	1	1																																							
22X-4, 93-95																																									
22X-4, 114-116																																									
22X-4, 133-135																																									
22X-5, 32-34																																									
22X-5, 48-49																																									
22X-5, 70-72																																									
22X-5, 90-92																																									
22X-5, 110-112																																									
22X-5, 125-127																																									
22X-5, 143-145																																									
22X-6, 16-18																																									
22X-6, 50-52																																									
22X-6, 66-68																																									

Note: * = groupings of species (see Appendix E); blank space = benthic foraminifers absent.

Appendix C. Range chart of planktonic foraminifers through the Miocene/Pliocene boundary and MP11 Zone.

Core, section, interval (cm)	*Gg. apertura*	*Gg. bulloides*	*Gg.d ecoraperta*	*Gg. falconensis*	*Gg. foliata*	*Gg. nepenthes*	*Gg. quinqueloba*	*Gg.* cf. *woodi*	*Ga. glutinata*	*Ga. uvula*	*B. praedigitata*	*Gs. bulloideus*	*Gs. trilobus* s.l.	*Gs. obliquus obliquus*	*Gs. obliquus extremus*	*Gs. quadrilobatus*	*Gs. trilobus*	*Gs.ruber*	*Gs. sacculifer*	*Gr. margaritae*	*Gr.menardii* group	*Gr. scitula* (dx)	*Gr. scitula* (sx)	*N. acostaensis* (sx)	*N. acostaensis* (dx)	*N. humerosa*	*N. incompta* (sx)	*N. incompta* (dx)	*N.* cf. *pachyderma*	*N. praehumerosa*	*Gl. obesa*	*Gl. praecalida*	*Gl. pseudobesa*	*H. siphonifera*	*O. bilobata*	*O. universa*	*O. suturalis*	*Turborotalita* spp.	*Ss. seminulina*	*Globoquadrina* spp.	*Globorotaloides* spp.	*Globigerinids* sp.
161-975B-																																									
32X-3, 116-118		A	F	C			F		C		R		C	C		F			F	C				R	C		R	F			F		R			R	R					F
32X-4, 40-42	R	A	C	C		R	F		A		F		F	A	R	F	R		F			R		R	C			F			R		R			R	R			R		C
32X-4, 116-118		C	C	C		R	R		A				R	C	R			R				F	F	R	A		R	F			R		F			F	F	R	F		R	C
32X-5, 41-043	R	C	C	F		F	F	F	A		R		F	C	R	F	R	F	R			R			A		R	C		R							F		R			F
32X-5, 116-118		C	C	F		R	F		C				F	C	R	C	F		F			C			A			F		R	F		F	R		F	F				F	F
32X-6, 40-042		C	C			F	F		A	R				A	R									R	C			F		F	F		F	F		F	F				R	F
32X-6, 116-118		C	C	F	R	F	F		A	R			R	F			R					C	R	R	A			F		R	R		F		R	F	F		R		F	C
32X-6, 126-128	R	C	C	F		F	F		A					C		R					R	C	R	R	C			R		R	R		R	R	R	F	R		R			C
32X-6, 144-146	R	C	C	R	R	F	F		A		R		R	F		R						F		R	C			F		R	F					C	F		F		F	C
32X-7, 15-17		C	C	F		F	R		C				C	A		C			F			F	R		C			F		R				F	R	F	F		F		R	F
32X-7, 35-37		C	C	F	R	R	F		A				F	C	R	F			F		R	R		R	A			F		R	C		R	F	R	C	F		R			C
32X-7, 40-42		C	F	F		F	F		A	R			F	C				R				F		F	A			F		F	F	R		R		F	F		F		R	C
32X-CC, 16-18		F	C	R	F	F	F		C				R	C			R					R	R	F	A		F	R		R	R			R		C	F		R		R	C
32X-CC, 37-39		C	C	F	R	F	F	R	C	R	F		F	F	R	F			R			F	R		C		R	F	R	R	F		R	F	R	F	R		F		F	C
33X-1, 5-7	R	A	A	C	R	F	F		C	R	F			F								F	R		A	R	R	F		F	F		R			F	F				F	F
33X-1, 14-16		A	C	F		R	R		C		R			F		R			R			C	R	R	C			F		R	F		F	R		F	F		F		F	C
33X-1, 25-27	R	A	C	C	R	F	R	R	C				R	C			R							R	C		R	R		F	R		F	R		F			F		F	C
33X-1, 35-37		A	C	C		C	R		A		F			C		R					R			F	C		R	F		F	F			R		F	F		R		F	F
33X-1, 40-42		C	C	F		F	F		A					C			R				R	R		F	A			F		R	R		F	F	R	F	F		R			C
33X-1, 55-57		C	C	C		C	F		A				F	F		F	R					R		R	A			F	R	R	R			R		F	R		R		R	C
33X-1, 63-65		C	C	F		R	R		A				F	C		R	R					F	R	F	A			F			R				R	R	F		R		R	C
33X-1, 75-77		C	C	C	R	F	F		C	R	R			C			R					R	R	R	A			F	R	F	F			R		F	F		R	R	F	C
33X-1, 83-85		C	C	F	R	R	F		A					F		R	R					R		R	C			F			R		R	R		F	F		R			A
33X-1, 95-97		C	C	C	R	F	R		A		R	R	F	F		R	R				R	F		F	A		R	F	R	R			R	R		F	F		R	R	F	C
33X-1, 100-102		C	C	F		F	F		A	R				C		R						F		F	C			R		R			R	R		F	R		R		R	C
33X-1, 117-119		C	C	F		F	F		A		R			C	R	F			F			F		C	C		R	R			R		R	R		F	F		F		R	A
33X-1, 125-127		C	C	F	R	F	F	R	C	R	R			C	R	R					R	F		C	C		F	R		R	R			R	R	F	F		F	R	F	C
33X-1, 143-145		C	C	F		F	C		C					F		R						R		C	C		F	R		R	F		R	R		C	R		F		R	C
33X-2, 0-2	R	C	C	F	R	F	F		C			R		F		R						R		F	A		R	F		F	F		R	R		C	F	R	F	R	R	C
33X-2, 10-12	R	C	A	F	F	C	F	R	C		R	R	F	F		F			F			R		F	A		R	F	R	R	R			R		F	F				R	F
33X-2, 20-22		F	A	R	R	F	R	F	A			R	F	A				R				R		R	A			F	R		R		R	R		F	R				R	F
33X-2, 30-32		F	F		R	F	F		A				F	A	F	F			R					F	C			R		R					R	C	F		R	R		F
33X-2, 40-42	R	C	C	F	R	C	F	R	A	R		R	R	C								R		C	F		F	R		F	R		R	R		F	F		R	R	R	F
33X-2, 46-48		C	C			F	F		A					C	F									A	F		F				F					F	F		R		R	C
33X-2, 50-52		C	C			C	F		C		R			C	R	R						F		C	F		F	R			F		R	R		F	F					C
33X-2, 62-64		C	C	F	R	F	F		C			R	R	C		F			R			R	R		A		R	F	R	R			R	R	R	C	R		R	R	R	F
33X-2, 70-72		F	C	R		F	F		A	R			R	C					R			R		R	A	R		F	R				R	R		F	F				R	F
33X-2, 80-82		F	C		R	F	F		A					C								F		F	A	R	R	F		R			R		R	F					F	F
33X-2, 85-87		F	C			F	F		A					A	F								R		F			F								F	F				R	C
33X-2, 90-92		F	C	R	R	C	F		A			R		A	F									F	A			F	R				R	F		F	R				R	F
33X-2, 98-100		F	F	R		F	F		A		R			A	F									R	A			R						R		F	F				R	F
33X-2, 100-102		R	C		R	F			A				F	A		R			R			R		F	F		R	R						R		F	F				R	C
33X-2, 105-107		F	C	R	R	F	F	R	A		R			C	R	F			R				R		A			R	R				R	R		F	F				R	F
33X-2, 114-116	R	F	C		F	C	F		A		R		C	A		F			F					R	C			F		R				R		F	R				R	F
33X-2, 116-118		F	C		R	C	F		A		R		F	A	R	C			F						C			R					R			F	F				F	R
33X-2, 120-122		F	A	R	R	C	F	R	A		R		F	A	R	C	R	R	F				R	R	F									R		F	F		R		R	F
33X-2, 129-131		C	A	R		R	F		C		R		R	A	F	R			R			R	R	R	C			F	R	R			R	R	R	C	F				F	F
33X-2, 130-132		C	C	R	R	F	F		C		F	R	F	A	R	F					F	F	R	R	F		R			R				R	F	A	C					F
33X-2, 132-134		F	A	F	R	F	C		C		R		F	A			F						R	R	C		F									A	F		R			F
33X-3, 6-8	R	C	C	F	R	F	F		A		F			C				R		c		F		F	A		R	F			R		F			R			R	R	F	C
33X-3, 33-35		F	C	F	F	F	A	R	A					F			R			c		F	R	R	C		F	C		R		R		R		R	R				R	F
33X-3, 35-37		F	C	F	R	F	A		A				R	F						c		R		R	C		R	F	R							R	R		R		F	F
33X-3, 47-49																																										
33X-3, 83-85																																										
33X-3, 112-114																																										
33X-3, 125-127																																										
33X-3, 137-139																																										

Note: A = Abundant (>15%); C = Common (5–15%); F = Few (1–5%); R = Rare (<1%); c = downhole contamination; blank space = planktonic foraminifers absent.

Appendix D. Range chart of benthic foraminifer percentages (>125 µm) through the Miocene/Pliocene boundary and MP11 Zone in Hole 975B.

Core, section, interval (cm)	Total benthic foraminifers	*Siphonina reticulata*	*Ortomorphina jedlitskai*	**Pleurostomella* spp.	**Pullenia* spp.	**Oridorsalis stellatus*	*Cibicides* spp.	*Brizalina* cf. *paralica*	*Gyroidinoides* gr. *soldanii*	**Gyroidinoides laevigatus*	*Melonis* spp.	**Rosalina* spp.	*Ammonia tepida*	*Epistominella exigua*	*Brizalina-Bolivina* gr.	**Oridorsalis umbonatus*	*Cibicidoides pseudoungerianus*	*Cibicidoides ungerianus*	*Globocassidulina subglobosa*	*Oridorsalis* spp.	*Planulina ariminensis*	*Uvigerina pygmaea-peregrina*	*Uvigerina* spp.	**Cibicidoides italicus*	*Pyramidulina stainforthi*	*Astacolus* cf. *ovatus*
161-975B-																										
32X-6, 126-128	170		0.6	1.2	1.8	10.6	10.0		7.1	5.3					2.4	1.2		1.2	14.1	0.6		14.1				1.2
32X-6, 144-146	480		2.9	5.2	0.4	10.2	6.3		8.8	2.1	0.2				2.9	0.6	0.8	1.3	19.6	0.6		7.5	0.2			
32X-7, 15-17	93		1.1	5.4		10.8	2.2		7.5	5.4						5.4		1.1	7.5			12.9				
32X-8, 35-37	163		2.5	1.8		8.6	4.3		16.0						8.6	4.3		3.1	7.4				9.2			
32X-CC, 16-18	252	0.4	4.4	2.4	1.6	16.7	2.8		11.1	2.4		0.4			4.8	2.8		1.2	17.9	0.4		3.2	0.4	0.8		0.8
32X-CC, 37-39	271		8.5	2.6	0.7	14.4	2.2		1.8	8.5	0.4				1.5	2.6		0.7	14.4	2.2		11.1	0.4	0.4		
33X-1, 5-7	393		5.6	6.1	1.3	7.4	2.3		8.7	0.8					1.8	4.3		1.0	21.6			5.6	0.8			1.0
33X-1, 14-16	192		3.6	5.7	0.5	14.6	3.1		7.3	3.6					0.5	5.7		0.5	29.7	1.6		2.6	1.0			0.5
33X-1, 25-27	235		0.9	5.5	0.4	10.6			3.8	9.4					1.3	1.3	0.9	2.6	41.7	0.4	0.4	3.0	0.9	1.3		
33X-1, 35-37	276		0.7	1.1		20.3	1.1		9.8	1.4					1.4	0.7	1.4	1.4	41.3	1.8	0.7	2.2	1.1	1.1		0.4
33X-1, 40-42	286		3.8	7.3		8.0	3.5		12.2	2.1					2.4	2.4		2.4	25.9	2.8		1.4		0.3		
33X-1, 63-65	118		1.7	4.2	1.7	16.1	2.5		5.9	3.4					3.4	4.2	2.5		22.0			2.5				
33X-1, 75-77	495		3.2	19.8	1.4	7.3	1.4	0.4	7.7	5.1	0.2	0.4			5.3	7.5	0.2	1.4	11.5		0.2		1.4			0.4
33X-1, 83-85	42		2.4	4.8		14.3			7.1	9.5						2.4			16.7							
33X-1, 100-102	31			12.9		16.1				6.5					9.7	3.2			19.4					6.5		
33X-1, 117-119	49	2.0		8.2		20.4			6.1	8.2						10.2			4.1			2.0				
33X-1, 125-127	78		5.1	2.6		32.1	1.3		5.1	6.4					2.6	10.3		2.6	14.1		1.3		1.3	1.3		1.3
33X-1, 143-145	130		9.2	2.3	0.8	26.2	3.1		3.8	3.8					0.8	12.3			17.7	1.5		0.8		1.5		
33X-2, 0-2	276		8.3	5.4		16.7	2.2		8.3	1.4	1.1				2.2	10.1	1.1		20.7	0.4	0.7	0.4	0.4			0.4
33X-2, 10-12	211		8.5	1.4		6.6	0.9		11.8	2.8					3.8	16.1	0.9	1.4	16.1	0.9		2.4		0.9		
33X-2, 20-22	77		7.8						9.1	7.8						18.2			29.9	1.3						
33X-2, 40-42	337		0.3	1.5			0.6		9.5	3.0	0.3	0.6			0.6	7.1		0.9	65.3				0.3	0.6		1.5
33X-2, 50-52	88	1.1	5.7	2.3			3.4		23.9						2.3	20.5	1.1		11.4							
33X-2, 62-64	75		2.7	5.3	1.3		2.7		44.0	2.7		2.7			4.0	24.0		1.3	1.3							
33X-2, 70-72	31						3.2		45.2	3.2					16.1	6.5										
33X-2, 80-82	77		3.9	3.9	1.3				45.5			1.3			7.8	19.5		1.3	2.6							
33X-2, 85-87	22								45.5			13.6				27.3		4.5								
33X-2, 90-92	21		4.8	4.8					23.8	9.5	4.8				19.0	4.8										
33X-2, 98-100	6						16.7		16.7						16.7											
33X-2, 100-102	1								100.0											16.7						
33X-2, 105-107	50		6.0	6.0			2.0		34.0			8.0			12.0	12.0						2.0				
33X-2, 114-116	28		10.7	3.6					28.6		3.6	3.6			7.1	25.0	3.6									3.6
33X-2, 116-118	27								22.2						11.1	29.6		3.7		18.5						
33X-2, 120-122	35						2.9		25.7	5.7	2.9				17.1	14.3										5.7
33X-2, 129-131	34								52.9		5.9			2.9	2.9			5.9		14.7		2.9		5.9	2.9	
33X-2, 130-132	113	3.5			0.9	2.7	1.8		19.5		0.9	31.9	8.9	1.8	0.9	0.9	9.7	1.8	7.1	0.9	2.7	0.9	1.8			
33X-2, 132-134	78							91.0		1.3	1.3	3.8	2.4													
33X-3, 6-8	0																									
33X-3, 33-35	6					33.3	16.7	16.7	33.3																	
33X-3, 35-37	3		33.3	33.3	33.3																					
33X-3, 47-49	0																									
33X-3, 83-85	0																									
33X-3, 112-114	0																									
33X-3, 125-127	1	100.0																								
33X-3, 137-139	0																									

Note: * Indicates groupings of species (see Appendix E); blank space = benthic foraminifers absent.

Appendix D (continued).

Core, section, interval (cm)	*Chrysalogonium* spp.	**Dentalina filiformis*	*Fissurina* spp.	**Lenticulina* spp.	**Trifarina bradyi*	*Bulimina* spp.	*Marginulina* spp.	**Anomalinoides* sp.	*Lenticulina inornata*	*Stilostomella* spp.	**Hanzawaia boueana*	*Astrononion stelligerum*	*Amphicoryna* spp.	*Anomalinoides alazanensis*	**Fursenkoina squammosa*	*Dimorphina tuberosa*	*Nodosaria* spp.	**Pandaglandulina dinapolii*	*Martinottiella* spp.	**Ortomorphina* spp.	**Rectuvigerina gaudryinoides*	*Sigmoilinita tenuis*	*Alliatinella* sp.	*Gyroidinoides* spp.	**Lenticulina rotulata*
161-975B-																									
32X-6, 126-128			0.6			1.8				0.6		3.5	1.2	1.8								3.5			1.2
32X-6, 144-146	1.0	0.6	0.4			0.4			0.8	0.4		1.7	0.4	6.0					0.2			0.2		0.8	0.8
32X-7, 15-17	1.1	1.1										1.1		1.1					4.3			1.1			1.1
32X-8, 35-37			1.8	1.8	1.2		0.6	2.5		1.8		4.9							1.8			1.2			
32X-CC, 16-18		0.4	0.8		1.2	0.8				0.4		2.0	0.4	1.6					0.8			2.4			0.4
32X-CC, 37-39	0.4	0.7	0.4		0.4	0.4						2.2		2.2					4.4			3.3			1.1
33X-1, 5-7	2.5	1.0	0.5	0.3	0.8		1.0			0.5		0.5	0.3	2.5			0.3		1.3			0.8			0.8
33X-1, 14-16	0.5	0.5								0.5		1.6		4.7					1.0						1.6
33X-1, 25-27		0.4		0.4		0.4	0.4					0.9		8.5											3.4
33X-1, 35-37			0.4		1.4	1.1			0.7	0.4				5.4					0.4						1.8
33X-1, 40-42		0.7	0.3	1.0	0.7	0.7						2.8		4.5					1.0	0.3		0.3			1.0
33X-1, 63-65				1.7	0.8	0.8						5.9		0.8					1.7						1.7
33X-1, 75-77	0.4	1.6		1.6	1.0	0.6	0.2			1.0	0.2	1.8	0.2						1.0			1.2		0.4	0.8
33X-1, 83-85			2.4	4.8								7.1							7.1			2.4			2.4
33X-1, 100-102										3.2		6.5							3.2						3.2
33X-1, 117-119	4.1									6.1	2.0	8.2							2.0			2.0			4.1
33X-1, 125-127		1.3							1.3										1.3					1.3	1.3
33X-1, 143-145					0.8							0.8							4.6			2.3			
33X-2, 0-2	2.5	1.8			0.4	1.4				0.4		4.0							1.4	2.5		0.4		0.4	1.1
33X-2, 10-12	0.5	1.4	0.5			0.5	0.9			1.4		5.2		0.5					3.3	0.5		0.9			0.9
33X-2, 20-22																			6.5						
33X-2, 40-42	3.0			0.9	0.3	0.3	1.5									0.3	0.3		0.3				0.3	0.6	0.3
33X-2, 50-52	9.1				1.1		1.1		1.1	1.1			1.1		3.4				1.1	1.1	6.8	1.1			
33X-2, 62-64	0.0	1.3				1.3								1.3		1.3	1.3	1.3							
33X-2, 70-72	6.5	3.2										6.5			6.5										
33X-2, 80-82	1.3			1.3	5.2		1.3						1.3	2.6											
33X-2, 85-87					4.5							4.5													
33X-2, 90-92	4.8		4.8		4.8					9.5	4.8														
33X-2, 98-100					33.3																				
33X-2, 100-102																									
33X-2, 105-107	4.0	6.0			4.0			4.0	2.0																
33X-2, 114-116					3.6	3.6	3.6																		
33X-2, 116-118	7.4				7.4																				
33X-2, 120-122	5.7	2.9	2.9	2.9	11.4																				
33X-2, 129-131																									
33X-2, 130-132																									
33X-2, 132-134																									
33X-3, 6-8																									
33X-3, 33-35																									
33X-3, 35-37																									
33X-3, 47-49																									
33X-3, 83-85																									
33X-3, 112-114																									
33X-3, 125-127																									
33X-3, 137-139																									

Appendix D (continued).

Core, section, interval (cm)	*Bigenerina nodosaria*	*Karreriella bradyi*	*Dentalina leguminiformis*	*Eggerella bradyi*	*Ellipsoidina ellipsoides*	*Oolina* spp.	**Spiroplectammina* spp.	**Dentalina* spp.	*Quadrimorphina allomorphinoides*	*Nonion* gr.	**Cassidulina* spp.	**Cibicidoides* spp.	*Discorbinoides bertheloti*	*Elphidium* spp.	*Lagena* spp.	**Saracenaria italica*	*Sphaeroidina bulloides*	*Sigmoilopsis* spp.	**Alabamina wilcoxensis*	*Valvulineria* cf. *bradyiana*	*Asterigerinata planorbis*	*Textularia* sp.	*Plectofrondicularia tenuissima*	Indet. specimens
161-975B-																								
32X-6, 126-128	0.6	3.5				0.6	0.6	0.6	1.8	4.1				0.6						0.6	1.8			
32X-6, 144-146	0.8	6.3			0.2	0.8	1.3	0.2	1.0	2.9							0.4	0.6					0.2	0.2
32X-7, 15-17	10.8	7.5					1.1	2.2	2.2	1.1								1.1						4.3
32X-8, 35-37	1.2	4.9						2.5		4.3								3.1				0.6		
32X-CC, 16-18	1.6	6.3	0.4				0.4		2.4	1.6	1.6										0.4			
32X-CC, 37-39		2.6				1.8	0.7		1.1	4.1	0.4				0.7				0.4	0.4				
33X-1, 5-7	2.3	8.9	0.3		0.3	0.8		0.3	1.5	2.5	0.5	0.3							0.3					0.5
33X-1, 14-16	0.5	1.6		0.5		0.5			2.1	2.6					0.5			0.5						
33X-1, 25-27		0.9							0.4															
33X-1, 35-37										0.4														
33X-1, 40-42	1.4	3.8			0.3	0.3	1.4			2.8					0.3									1.0
33X-1, 63-65		5.1				0.8			2.5	5.1					1.7									0.8
33X-1, 75-77	1.2	4.0	0.2				0.8	0.2	1.6	3.4	0.2	0.2	0.2	0.2	0.4	0.2	0.2							
33X-1, 83-85		9.5	2.4				2.4			2.4														
33X-1, 100-102		6.5					3.2																	
33X-1, 117-119		6.1							2.0															
33X-1, 125-127	2.6	1.3	1.3			1.3																		
33X-1, 143-145	0.8	2.3	0.8		2.3					0.8														0.8
33X-2, 0-2		0.7		0.7			0.4	0.4	0.4															1.4
33X-2, 10-12	1.9	3.3	0.9	0.5	0.5	0.5	0.9																	
33X-2, 20-22	2.6	16.9																						
33X-2, 40-42																								
33X-2, 50-52																								
33X-2, 62-64																								
33X-2, 70-72																								3.2
33X-2, 80-82																								
33X-2, 85-87																								
33X-2, 90-92																								
33X-2, 98-100																								
33X-2, 100-102																								
33X-2, 105-107																								
33X-2, 114-116																								
33X-2, 116-118																								
33X-2, 120-122																								
33X-2, 129-131																								2.9
33X-2, 130-132																								1.8
33X-2, 132-134																								
33X-3, 6-8																								
33X-3, 33-35																								
33X-3, 35-37																								
33X-3, 47-49																								
33X-3, 83-85																								
33X-3, 112-114																								
33X-3, 125-127																								
33X-3, 137-139																								

Appendix E

In Appendixes B and D some species of benthic foraminifers were grouped because of their very rare and scattered presence:

Anomalinoides alazanensis: comprises also *A. alazanensis spissiformis.*

Amphicoryna spp.: includes *A. scalaris, A. semicostata,* and *A. sublineata*.

Brizalina and *Bolivina*: in Hole 975B, *Brizalina-Bolivina* gr. includes many species having a generally scattered distribution: *Bolivina alazanensis, B.* cf. *suteri, B. cistina, B. fastigia, B. lanceolata, B. leonardii, B. punctata, B. reticulata, Bolivinita quadrilatera, Brizalina arta, Br. catanensis, Br. dilatata, Br. spathulata, Br. dinapolii, Br. lanceolata, Brizalina* spp. In Hole 974B, *B. leonardii, Br. dinapolii,* and *Brizalina* sp. were found in Cycle 4.

Cassidulina spp.: this genus is represented mainly by *C. neocarinata* and, rarely, by *C. laevigata*.

Chrysalogonium spp.: includes *C. lanceolum, C. tenuicostatum* and *C.* cf. *obliquatum*.

Dentalina spp.: comprises *D. aciculata, D. cuvieri, D. inornata,* and some unidentified specimens; the most common species *D. filiformis* and *D. leguminiformis* were not grouped.

Elphidium spp.: includes *E. advenum* and *E. complanatum*.

Fissurina spp.: comprises *F. apiculata, F. bradyiana, F. marginata, F. orbignyana, F. pseudorbignyana,* and some unidentified specimens.

Gyroidinoides gr. *soldanii*: this group includes *G. soldanii* and *G. neosoldanii* in both holes.

Gyroidinoides spp.: groups *G. girardanus, G. umbonatus,* and some unidentified forms.

Lagena spp.: in Hole 975B it includes *L. sulcata interrupta, L. tenuistriatiformis,* and some unidentified specimens; in Hole 974B, includes two unidentified specimens.

Lenticulina spp.: groups *L.* cf. *brevispinosa, L. gibba, L. peregrina, L. stellata,* and some unidentified specimens.

Marginulina spp.: includes *M. glabra, M. subbullata,* and some unidentified specimens.

Martinottiella spp.: includes *M. perparva* and *M. communis*.

Melonis spp.: represented by *M. padanum, M. soldanii,* and *M.* cf. *pompilioides*.

Nodosaria spp.: includes *N. longiscata* and *N. pentecostata* in Hole 975B, and *N. radicula* and *N. pentecostata* in Hole 974B.

Nonion gr.: groups the genera *Nonion* and *Nonionella* in both holes.

Oolina spp.: groups *O. heteromorpha, O. hexagona, O. intercalata,* and *O. squammosa*.

Ortomorphina spp.: comprises rare specimens of *O. havanensis* and *O. tenuicostata* in Hole 975B; *O. jedlitskai*, being more common, is plotted separately.

Pleurostomella spp.: includes an unnamed species, *P. alternans,* and *P. brevis*.

Pullenia spp.: comprises *P. bulloides, P. quinqueloba, P. quadriloba,* and *P. salisbury*.

Sigmoilopsis spp.: includes *S. schlumbergeri* and *S. celata*.

Spiroplectammina spp.: includes *S. carinata, S. deperdita,* and *S. depressa.*

Stilostomella spp.: represented in Hole 975B by *S. adolphina, S. annulifera, S. antillea, S. consobrina emaciata, S. fistuca, S. modesta, S. monilis, S. pyrula* and some unidentified specimens; in Hole 974B this genus is represented by *S. consobrina, S. modesta,* and *S. monilis.*

Uvigerina spp.: in Hole 975B, groups *U. bononiensis, U.* cf. *hispida, U. cylindrica, U. rutila* and some unidentified specimens; in Hole 974B, only *U. bononiensis* and *U. proboscidea* are included.