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27. LATE MIOCENE–HOLOCENE PALEOCEANOGRAPHY OF THE WESTERN EQUATORIAL ATLANTIC: EVIDENCE FROM DEEP-SEA BENTHIC FORAMINIFERS[1]

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ABSTRACT

Changes in deep-water environments of the western Atlantic over the past six million years were investigated by studying benthic foraminiferal abundance changes in 335 samples from Sites 926 (3598 m), 928 (4010 m), and 929 (4358 m) on the Ceara Rise. The location of these sites on a transect at lower abyssal depths provides a unique opportunity to evaluate changes in water mass properties as well as in the supply of organic matter from the surface waters, especially because other Leg 154 studies provided a precise time scale for correlations between the sites.

Relative abundances and fluxes of the most abundant species were calculated, with emphasis on the four most common species—*Nuttallides umbonifera, Globocassidulina subglobosa, Epistominella exigua,* and *Alabaminella weddellensis.* There are two patterns in relative abundance of these species with time: the first group of species (*N. umbonifera* and *G. subglobosa*) shows abundance variations that differ from site to site (i.e., with depth). The other group (*E. exigua* and *A. weddellensis*) shows variations in relative abundance that are similar at all three sites and thus independent of depth.

In the first group, *G. subglobosa* increased in relative abundance at the shallowest Site 926 from 2.4 to 1 Ma, but decreased at the two deeper sites. In contrast, *N. umbonifera,* a marker species for corrosive bottom waters and specifically for Antarctic Bottom Water (AABW), shows large fluctuations in relative abundance, but overall increased in relative abundance at the two deeper sites and decreased at the shallower site from 2.1 Ma to the present. Its relative abundance shows three peaks during the last 0.9 m.y., which were coeval at the two deeper sites. These large fluctuations in abundance of *N. umbonifera* suggest that production of AABW fluctuated in intensity, with increases during interglacial periods. AABW formation increased overall from about 3 Ma, and the amplitude of the fluctuations increased from 0.9 Ma to present. The differences between sites are interpreted as showing that the deeper Sites 928 and 929 were commonly within AABW, whereas the shallower site was not.

The species in the second group, *E. exigua* and *A. weddellensis,* occur in the recent oceans commonly in oceanic regions where spring blooms lead to seasonal deposition of phytodetrital material. At the Ceara Rise sites, they show variations in relative abundance that are similar at all three sites from 4.5 to 1.2 Ma, confirming that these species react to environmental factors that are not depth related, and thus possibly to surface productivity. The two species, however, do not covary exactly: at 2.6 Ma, for example, *E. exigua* decreased in relative abundance whereas *A. weddellensis* increased.

INTRODUCTION

Stratigraphic changes in deep-sea benthic foraminiferal faunas have been commonly associated with changes in North Atlantic deep-water circulation during the Pleistocene glacial-interglacial cycles (Streeter, 1973; Streeter and Shackleton, 1979; Schnitker, 1974, 1979, 1980; Peterson and Lohmann, 1982). Studies on recent benthic foraminiferal assemblages likewise revealed a relation between faunal composition and hydrographic parameters such as temperature, salinity, oxygen content, and carbonate saturation (Murray, 1973; Lohmann, 1978; Corliss, 1979; Corliss and Honjo, 1981; Peterson, 1984; Mead, 1985). Many different authors have attempted to correlate the distribution of deep-water benthic foraminifers with changes in water mass circulation patterns in the deep oceans, and benthic foraminiferal faunal changes have been linked to changes in stable isotope records (e.g., Woodruff and Savin, 1989; Boersma, 1990; Hermelin, 1991; Thomas, 1992).

On the other hand, several authors reported that the abundance of several species of benthic foraminifers is correlated to surface primary productivity and thus the availability of food on the seafloor. Much data on faunas along continental margins suggest that faunas rich in genera such as *Melonis, Uvigerina,* and *Bolivina* reflect a high food supply rather than oxygen concentration in the bottom waters (e.g., Lutze and Coulbourn, 1984; Mackensen et al., 1985; Altenbach and Sarnthein, 1989; Schnitker, 1993; Rathburn and Corliss, 1994; Corliss, 1983; Miao and Thunell, 1993; Hermelin and Shimmield, 1990; Thomas et al., 1995).

Other species of benthic foraminifers have been observed to respond opportunistically to a seasonal supply of phytodetritus under overall oligotrophic circumstances in the open ocean (Gooday, 1988, 1993; Gooday and Lambshead, 1989). High rates of phytodetritus deposition can not be linked in a simple way to high surface productivity, but reflect hydrographic conditions in the upper layers of the oceans (particularly, a deep layer of winter mixing), that lead to a strong phytoplankton bloom (Campbell and Aarup, 1992). The opportunistic, phytodetritus-exploiting species have been used to reconstruct the occurrence of episodes with common phytodetritus deposition in down-core investigations (Smart et al., 1994; Thomas et al., 1995; Thomas and Gooday, in press).

Benthic foraminiferal faunas thus can play an important role in the investigation of deep-water circulation patterns as well as paleoproductivity (e.g., Mackensen et al., 1995). The purpose of this study is to examine the long-term changes in deep-water environments as based on benthic foraminiferal faunal and abundance changes during the past 6 m.y.

MATERIAL AND METHODS

Samples were taken from three sites drilled on Leg 154 on the Ceara Rise (equatorial Atlantic Ocean) on a depth transect between 3000 and 4300 m, at lower abyssal depths (Fig. 1). Hole 926A (3°43.146′ N, 43°44.884′W, 3598.4 m) is presently in the lower part of North Atlantic Deep Water (NADW). Hole 928A (5°27.320′N,

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Previous Chapter Table of Contents Next Chapter

42°54.489′W, 4010.7 m) is under the mixing zone of NADW and Antarctic Bottom Water (AABW), and is near the lysocline. Hole 929A (5°58.573′N, 43°44.396′W, 4357.6 m) is presently under AABW.

Samples were taken at 1.5-m intervals (one sample per section) over a sediment section corresponding to the last 6–7 m.y.; 114 samples from Hole 926A, 107 samples from 928A, and 114 samples from Hole 929A were examined (Tables 1–3). Samples of about 10 cm^3 were treated with a 1%–3% hydrogen peroxide solution for 1–12 hr, and wet-sieved over a 63-µm screen. The coarse fraction was dried and split into aliquots containing approximately 200–300 specimens. More than 200 specimens were identified and counted. Some samples at Site 929 did not contain enough specimens or carbonate fragments at all. Some miliolid and unilocular species were not identified to the generic and specific level because of their rarity and extremely high diversity. The preservation of specimens was almost good, except for several samples at Site 929 that had completely dissolved.

The age models in this paper are based on the correlation between magnetic susceptibility records and previously published isotope records (Curry, Shackleton, Richter, et al., 1995). Benthic foraminiferal accumulation rates were estimated by using gamma-ray attenuation porosity evaluator (GRAPE) density data and sedimentation rates as derived from these age models (Tables 4–6, back pocket). The benthic foraminiferal accumulation rate (BFAR, the number of foraminifers per cm^2 per 1000 yr) is defined as follows:

$$\text{BFAR} = \text{\#BF/g} \times \text{GRD (g/cm}^3) \times \text{SDR (cm/ky)},$$

in which #BF is the number of benthic foraminifers, GRD is the GRAPE density, and SDR is the sedimentation rate. The BFAR has been used as a proxy for deposition rate of organic matter to the sea floor, and of primary productivity (Berger and Diester-Haass, 1988; Herguera and Berger, 1991; Herguera, 1992).

To observe long-term trends of benthic foraminiferal abundances, 3-point moving averages were calculated for the relative abundances and accumulation rates of the four most abundant species, the phytodetritus species, and the total number of individuals.

RESULTS

Relative Abundances

The relative abundances of the most common species at all three sites were plotted vs. numerical age in Figures 2–4. The four most abundant species (*Alabaminella weddellensis, Epistominella exigua, Globocassidulina subglobosa,* and *Nuttallides umbonifera*) together account for about 60% of the fauna in most samples. These species are the most common and cosmopolitan lower abyssal species in the present world oceans since the early–middle Miocene (Woodruff and Savin, 1989), and the fluctuations in their relative and absolute abundance can thus give information on changes in the abyssal paleoenvironment. The relative abundances of these four species for each sites are shown versus numerical age in Figure 5, with superimposed 3-point moving averages; data for all sites together are shown in Figure 6.

Globocassidulina subglobosa shows different fluctuations in relative abundance at all sites, although the records for the two deeper sites show some similarities—at both these sites the relative abundance decreases overall since about 4.5 Ma. At the shallower site it fluctuates, but appears to have high values between 2.5 and 1.0 Ma, and during the last 0.5 m.y.

The relative abundance of *N. umbonifera* also shows different patterns by depth, especially during the last 3 m.y. At the shallowest site, Site 926, it shows generally weak fluctuations throughout the last 6 m.y., possibly with a peak abundance at 4.5 Ma. At the two deeper sites, the relative abundance of this species shows similar patterns, with the lowest values between 3 and 4.5 Ma, and very strong fluctuations superimposed on a relative increase over the last 3 m.y. The species shows peaks in abundance at both deeper sites at about 2.5 Ma, 1.5 Ma, and three peaks during the last 1 m.y.

Alabaminella weddellensis is a very small species, and its taxonomy has been rather confused. The species has commonly been identified as *Eponides pusillus* or *Eilohedra weddellensis* in samples from the Pacific Ocean (Loeblich and Tappan, 1994). Specimens from both the Atlantic and the Pacific were studied, and a conclusion was reached that they belong to the same species. Because *A. weddellensis* is a commonly used name in studies of Atlantic foraminifers, it has also been applied to this specimen. The patterns of fluctuation in relative abundance of this species are very similar at all three sites, especially during the last 3.5 m.y. The species shows peak abundances at about 3.5–3.2 Ma, then a decline followed by a rapid increase to peak values at 2.6–2.0 Ma, then another decrease followed by a peak at 1.2–0.9 Ma, and a final increase from 0.7 Ma on.

Epistominella exigua also has similar patterns of fluctuations in relative abundance at all three sites. Low values occurred at about 5.5, 4.8 and 4.2 Ma, but stronger fluctuations occurred after about 3.5 Ma. High values occurred between about 3.2 and 2.6 Ma (when *A. weddellensis* had low abundances), followed by an abrupt decline at about 2.6 Ma, when *A. weddellensis* increased. After 2.6 Ma the species fluctuated in relative abundance, with on overall increase at all sites since about 0.7 Ma.

Epistominella exigua, *A. weddellensis* and a few other species have been observed to inhabit phytodetrital aggregates, and the distribution and abundance of these species has been said to be controlled by the occurrence of strongly seasonal fluxes of this material (Gooday, 1988, 1993). Summed relative abundances of these two taxa at all three sites are shown in Figure 7A. In addition, the summed relative abundance of these two species is shown together with that of two other species that resemble them morphologically; i.e., they are small, trochospiral, and have thin and translucent walls. The two additional species are *Epistominella* sp. A (an obese variant of *E. exigua*) and *Ioanella tumidula* (Figure 7B). Figures 7A and 7B are similar because *E. exigua* and *A. weddellensis* are much more common than the other two taxa, although the resemblance between the curves for the different sites is largest in Figure 7B.

The phytodetritus species show a low in relative abundance at about 5.4 Ma and another at around 4.1–4.2 Ma. These show increased amplitude fluctuations from about 3 Ma on, and even more extreme after 1.5 Ma. A sharp drop occurred at around 0.7 Ma. During the last 0.3 m.y., their abundances decreased at the shallowest and the deepest sites, but increased at the middle Site 928.

Several species show first or last appearances at all three sites during the studied interval (Figure 8). *Pleurostomella* spp. decreased in relative abundance after about 3 Ma and had their last occurrence at 2 Ma at the deepest Site 929, at 1.6 Ma at the middle Site 928, and at 1.3 Ma at Site 926. *Stainforthia fusiformis* first appeared at about 4.0 Ma at the deeper two sites. *Pullenia osloensis* had a peak in abundance at about 3 Ma, and abruptly decreased in abundance at about 2.6 Ma at Sites 926 and 928. *Ioanella tumidula* shows similar fluctuations in abundance at all three sites, but was more common at the shallower Site 926.

Benthic Foraminiferal Accumulation Rates

Accumulation rates of benthic foraminifers are caused by complex multiple factors, which include changes in the deposition rate of particulate organic matter to the seafloor (which in turn may be caused by changes in productivity of organic matter in the surface waters, changes in export productivity, changes in the rate of oxidation of organic matter in the water column, and other factors, as well as the water depth at the site). In addition, physicochemical parameters of sea water in the region may be a factor. Furthermore, dissolution may influence the preservation of specimens.

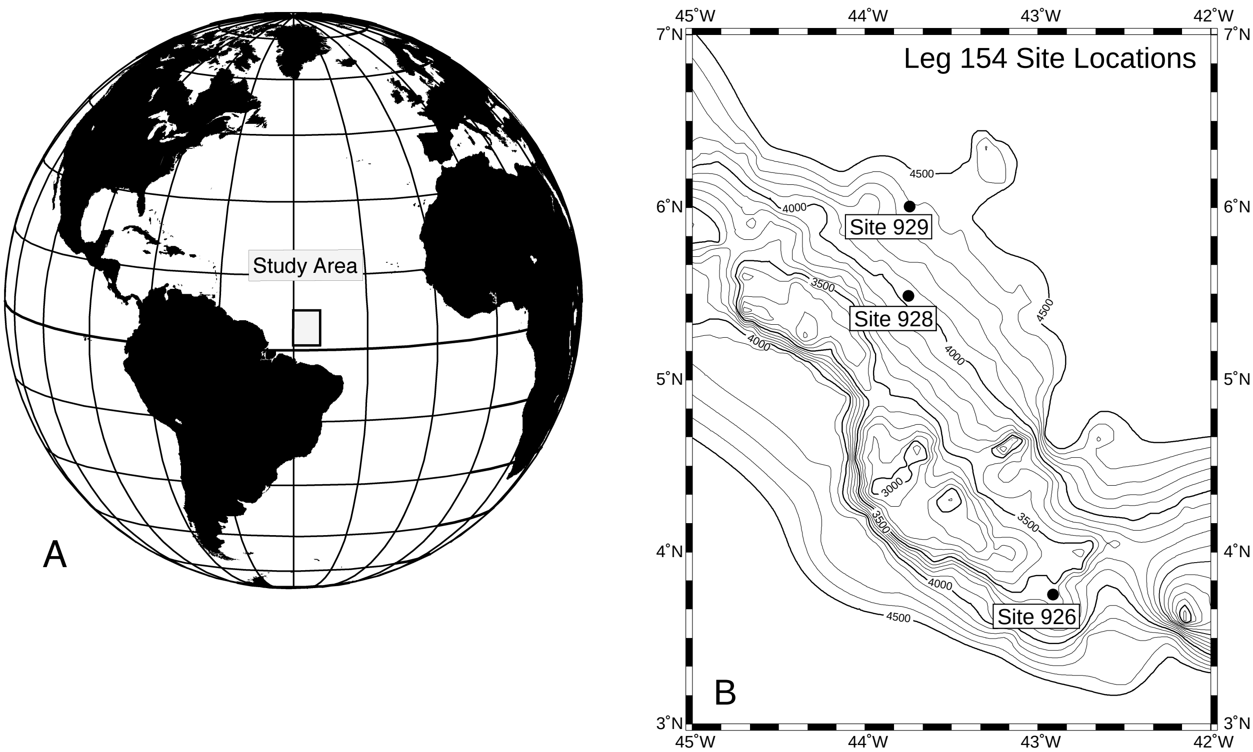

Figure 1. **A.** Location map of the Ceara Rise in the equatorial Atlantic Ocean. **B.** Position of Sites 926, 928, and 929 on the Ceara Rise.

Fluctuations in the accumulation rates of *E. exigua* and *N. umbonifera* are of greater amplitude than those of *G. subglobosa* and *A. weddellensis* (Figs. 9, 10). All species show a resemblance between the curves for relative abundance and accumulation rate (Figs. 6, 10). The fluctuations in accumulation rates of *N. umbonifera* were largest during the last 3 m.y. Before that time, the accumulation rate of this species was similar at all three sites, and afterwards it was more abundant, with larger fluctuations at the two deepest sites. Three peaks in abundance occurred in the last 1 m.y.

Accumulation rates of *A. weddellensis* increased at about 3.5 Ma, with very similar patterns of fluctuation at all three sites. *Epistominella exigua* shows strong fluctuations in accumulation rates after about 3.2 Ma, especially at Site 929. *Globocassidulina subglobosa* shows similar rates of accumulation at Sites 926 and 928 before about 4.4 Ma. After about 3.0 Ma, the species generally decreased in accumulation rate at the two deeper sites, with a maximum at the shallower site at about 2.2 Ma.

The phytodetritus group of species shows very strong fluctuations in accumulation rates over time, with the largest amplitude at the two deepest sites. Fluctuations have a larger amplitude than those in relative abundance (Figs. 7, 11). Before 4 Ma the accumulation rates were very low at Site 929, with higher, co-varying values at the two shallower sites. Overall, accumulation rates increased from 4 Ma, but there was a large decrease at all three sites at about 2 Ma, until about 1.6 Ma. The fluctuations in accumulation rate occur at similar times at all three sites, and there is no obvious relation between the depths of the sites and the accumulation rates at any point in time.

Accumulation rates of the total fauna are shown in Figures 12 and 13. There is a strong correlation between the accumulation rate of the total fauna and that of the phytodetritus species (Figs. 11, 14).

Before 3.4 Ma, the accumulation rates were very low at the deepest Site 929, at the time when carbonate accumulation rates were also low (Curry, Shackleton, Richter, et al., 1995). Accumulation rates at both shallower sites were very similar, with a high at about 5.2 Ma, and a low at 4.2 Ma. At about 3.2 Ma the accumulation rates increased strongly, as did the amplitude of their fluctuations. The lower values of the last 3.2 m.y. are similar to the average values before 3.2 Ma. Peaks occurred synchronously at all three sites, with the highest peak at about 2.1 Ma. Accumulation rates would be expected to be higher at the shallower site (Herguera and Berger, 1991), but this is not observed consistently.

DISCUSSION

The observed changes in deep-sea benthic foraminiferal faunas have been caused by a combination of changes in deep-water circulation, deep-water chemical properties, and productivity, as described for the modern ocean by Mackensen et al. (1995). The four most common species have very similar abundances at the three sites between 3 and 3.4 Ma, suggesting that the deep-water environments at all sites were similar at these times, and thus that waters at these depths were not strongly stratified.

The benthic foraminiferal accumulation rate (BFAR) is controlled mostly by a limited food supply, and additionally due to local chemical conditions plus differences of preservation due to carbonate saturation. Accordingly, the BFAR are possibly a recorder of surface paleo-productivity, if carbonate dissolution and water mass changes are also taken into account through the interval. Herguera (1992) researched a relation between the BFAR and the decay of organic carbon with depth, and concluded that the BFAR is directly linked to the flux of organic matter to the seafloor.

Comparison of the BFAR at Sites 926, 928, and 929 (Figs. 12, 13) clearly shows a major difference between faunas before and after ~3.2 Ma (with a short exception from 3.8 to 4.0 Ma). Before 3.2 Ma, the BFAR was much lower at the deepest site than at the two shallower ones, and there was much less difference than predicted by Herguera's equation between the BFAR at the two shallower sites. However, the BFAR at Site 929 was obviously not equal, which indicates that there was a big contrast in carbonate dissolution between water depths of 4000 and 4300 m before and after ~3.2 Ma. At the deepest site (4300 m), most of the species have low accumulation rates. This

Table 1. Census data for the benthic foraminifer species from Hole 926A in the 63-µm fraction.

Core, section, interval (cm)	Depth (m)	Depth (mcd)	Age (Ma)	*Abditodentrix pseudothalmanni*	*Alabaminella weddellensis*	*Anomalinoides globosus*	*Astrononion echolsi*	*Bolivina pacifica*	*Bolivina* spp.	*Bulimina alazanensis*	*Bulimina* sp. A	*Cassidulina* spp.	*Cibicidoides bradyi*	*Cibicidoides kullenbergi*	*Cibicidoides mundulus*	*Cibicidoides robertsonianus*	*Cibicidoides wuellerstorfi*	*Discorbinella bertheloti*	*Ehrenbergina* sp.	*Epistominella exigua*	*Epistominella* sp. A	*Globocassidulina subglobosa*	*Gyroidina lamarckiana*	*Gyroidina regularis*	*Gyroidina* spp.	*Gyroidina umbonata*	*Gyroidinoides neosoldanii*	*Gyroidinoides orbicularis*	*Ioanella tumidula*	*Laticarinina pauperata*	*Melonis barleeanus*	*Melonis pompilioides*	*Nonionella* sp.
154-926A-																																	
1H-1, 80–82	0.8	0.86	0.027		68						13	1			1		6			8		58											
1H-2, 80–82	2.3	2.36	0.073		47						8	5	1		4		7			10		41	1			1		2	6			1	
1H-3, 29–31	3.29	3.35	0.104	1	35			1	2		7	5			9		2			12		48					1	6			1		
2H-1, 80–82	4.8	7.1	0.219		80						7	1			6	1				29	16	49				3			7			1	
2H-2, 80–82	6.3	8.6	0.265		32				4		6	2			6			5		19	5	34		3		2	1		4				
2H-3, 80–82	7.8	10.1	0.311		46						12				2		1			27	6	19	18				1		3		1	1	
2H-4, 80–82	9.3	11.6	0.357		56	1					9	1			2					125	5	27	4				2		1			1	
2H-5, 80–82	10.8	13.1	0.403		112					2	11				2		1			4		13	3				1		7				
2H-6, 80–82	12.3	14.6	0.448		58						16				3		2			9	1	16	9					1	9				
2H-7, 20–22	13.2	15.5	0.476		48				8		4	1		4	7		3			3	6	34	3	3	2	1	2		13				1
3H-1, 80–82	14.3	15.39	0.473		62	1					6	3			1		3			8	1	18	7					1	7		1		
3H-2, 80–82	15.8	16.89	0.518		71						5	1			5		3			37	12	2	5			2	1		7				
3H-3, 80–82	17.3	18.39	0.564		10				1		6		1	6	15		2				9	52					1		21		1		
3H-4, 80–82	18.8	19.89	0.61		59	1			1		7	4					5			32	7	14	13			3	3		9				
3H-5, 80–82	20.3	21.39	0.655		32						12	3		1	17		3			39	12	18	8			1	2		17				
3H-6, 80–82	21.8	22.89	0.701		55			1	1		7	1			25		1			26	2	15	6			2	2	1	1		1		
4H-1, 80–82	23.8	26.38	0.807		64	1	1	1	1		4			5	23		1			27	5	40	2		1	2	3		8		1		
4H-2, 80–82	25.3	27.88	0.853		45				1					6	4		1			68	6	6	10		2	7	5		8		1	3	
4H-3, 80–82	26.8	29.38	0.899		50				1		6			3	4				1	29	2	7	4		2	3		1	16				
4H-4, 80–82	28.3	30.88	0.944		81						5	10		1	10		3			3	6	18	8		2	4			1				
4H-5, 80–82	29.8	32.38	0.99		80						10	9		2	2		5			19	8	19	11			4	1						
4H-6, 80–82	31.3	33.88	1.036		64		1		2		4		5	10	6		2			4	3	31	8			3			9				
4H-7, 50–52	32.5	35.08	1.072		57	1			1		5	3			15		1			21	5	41					2		2			1	1
5H-1, 80–82	33.3	36.71	1.122		59	1	1				6	3	3	9	8		4			19	4	53	8				1		7	1		1	
5H-2, 80–82	34.8	38.21	1.168		42		1		1			5			8					32	10	30	8			1	1		12				1
5H-3, 80–82	36.3	39.71	1.214		69						10	13			8		5			33	6	30	8			1			2		1	1	
5H-4, 80–82	37.8	41.21	1.26	1	42	1	6				4	13			22	2	1			26	15	20				3			19				
5H-5, 80–82	39.3	42.71	1.305		17		5			1	14	29			12					14	2	48	3				1		22				3
5H-6, 80–82	40.8	44.21	1.351		48				2			9			4		2			47		32	3				1		6				1
5H-7, 50–52	42	45.41	1.388		34		4				9	17			3		8	1		7	5	49	2		1	4	2	1	6		2		
6H-1, 80–82	42.8	46.87	1.433		7						12	19	2		20		2	2		10	3	52		2			1		19	1			
6H-2, 80–82	44.3	48.37	1.479		54				2		5	7			10		3			77		25	8						4				
6H-3, 80–82	45.8	49.87	1.526		47				1		7	5			12		1			13	3	59				5	3		14		1		1
6H-4, 80–82	47.3	51.37	1.572		47		5				4	7	3		7		1			7	1	45	1				3		4		1	2	
6H-5, 80–82	48.8	52.87	1.618		47				7		3	12			7		1			51	7	50		1		2			10				
6H-6, 80–82	50.3	54.37	1.665	1	11		7		9		2	19	4		19			3		3	1	39							30		2		1
7H-1, 80–82	52.3	58.83	1.804	2	47		3		20		3	4		1	9		1			11	4	31	3			3			14				
7H-2, 80–82	53.8	60.33	1.851		55		1		2		3	14	1		1					15	3	34	1				1		14		2		
7H-3, 80–82	55.3	61.83	1.898		5	1	4		2		5	11			12		1	3		25	7	53	4				1		4	3			
7H-4, 80–82	56.8	63.33	1.945		14				4		4	8			12					16	6	62	4			1	2		23				1
7H-5, 80–82	58.3	64.83	1.992		69				1		11	21					2			15	8	55	10			2			12				
7H-6, 80–82	59.8	66.33	2.04		41	1			8		4	5			8		3			9	5	62	1		1	6	3		13		2		
7H-7, 50–52	61	67.53	2.078		37		1		1		8	15					2	2		31	11	67	2		1	6	1		13	1	1	1	3
8H-1, 80–82	61.8	69.89	2.153		47				2		4	5		2	7					25	6	33	1						17		1		
8H-2, 80–82	63.3	71.39	2.201		29		1				6	14			3		1			29	12	45	4						2				
8H-3, 82–84	64.82	72.91	2.249		51		4	1	1		5	13					4	1		23		38	1		1	4			5		1	1	
8H-4, 78–80	66.28	74.37	2.296		30		1				3	5			17		1	1		8	4	48	1			3	2		22				1
8H-5, 77–79	67.77	75.86	2.344		39			1	2		2	15								30	6	57							17				
8H-6, 78–80	69.28	77.37	2.393		67						7	15			4		2			30	6	37	4						10				
8H-7, 50–52	70.5	78.59	2.433		36							9			2		7			24	7	31	6		1	4			3				1
9H-1, 80–82	71.3	80.84	2.506	1	37						7	11	2	7	4			1		22	11	25	6				3	1	1		1		
9H-2, 78–80	72.78	82.32	2.555	2	28				9		9	6			5		1	1		29	1	37	3	1		8	3	3	14				8
9H-3, 80–82	74.3	83.84	2.605	2	13				9		2	7			6			5		51	2	36	3	1			4	2	2				2
9H-4, 80–82	75.8	85.34	2.654	2	107			1	3		14	11			3		1			49	14	60	3		2	4			4		1	1	
10H-1, 77–79	80.77	91.28	2.853	1	33	1			3		5	5			15					33	10	22	2			2	2	2	11		4		2
10H-2, 77–79	82.27	92.78	2.903		5		4		12		3	8	1		5			4		53	10	34	3			6		1	11		3	1	5
10H-3, 77–79	83.77	94.28	2.954	2	36			2	8		4	6					2			61	5	54	4				4		10		2		
10H-4, 77–79	85.27	95.78	3.005	3	51				3		3	2					6	1		36	9	25				4	1	1	11		3		1
10H-5, 77–79	86.77	97.28	3.057	2	35		1		3		4	4	1		1		4			11	10	33	6	2			4	2	10				1
10H-6, 77–79	88.27	98.78	3.108	1	32				5			4		2			4			42	14	25	1		2		2	2	5		1		1
10H-7, 49–51	89.49	100	3.15	9	12			1	4			4					2	2		55	7	25	3	2		3	3		5	1	5		
11H-1, 80–82	90.3	102.35	3.232	1	38							10			6		3	1		23	5	25	7	1		4		13	6				2
11H-2, 80–82	91.8	103.85	3.284	2	47				8			4	2		2		3	2		26	2	27	5	1	1	1	1	3	8		1		1
11H-3, 80–82	93.3	105.35	3.337		54							6	1		5					26	3	27	3				1	8	7				1
11H-4, 80–82	94.8	106.85	3.39	2	20		1		5			9	2		6		2	3		27	7	45	4	1	2	1	1	1	3		2		2
11H-5, 80–82	96.3	108.35	3.443	1	36				1	1		3	1				1			47	4	31	3	2		6	1		3		5		
11H-6, 80–82	97.8	109.85	3.497		27	1						8			1		3			16	8	44	3			1	3	5	9			1	
11H-7, 35–37	98.85	110.9	3.534		47	1			2			7	2		15					41	11	55	5			2	2		8				2
12H-1, 80–82	99.8	112.16	3.58	1	35		1		2			7			7			1		49	7	17	1	5	2	6	2	3	2				
12H-2, 80–82	101.3	113.66	3.634		28		6		1		2	8	2	2	12					38	12	32	1	2		2	2	1	9		2		
12H-3, 80–82	102.8	115.16	3.688		17		7		3			3	6	3	12		1	1		33	17	22	2			2		3	18				
12H-4, 80–82	104.3	116.66	3.743		8	2	2				3	7	1		18					36	13	33	7			1	4	5	12				2
12H-5, 80–82	105.8	118.16	3.798		3		2	1	5			10		1	5					38	11	30	1	1	1	3	2		5		1		
12H-6, 80–82	107.3	119.66	3.854		3	2	14		6			9	2		18					36	10	45	1			2	1		7	1			
12H-7, 35–37	108.35	120.71	3.893	1	11		7		5			8	1		2			2		34	8	34	8	2	5	5	1	1	5				1
13H-1, 80–82	109.3	122.95	3.977		6		6		2			15	1		5		1	1		48	6	30	3	3		5	5	3	9				
13H-2, 80–82	110.8	124.45	4.033		8		3					7	1				1	1		38	6	56	7	1				2	8				1
13H-3, 90–92	112.4	126.05	4.094		18	1	3		3	1		10			1		2			20	8	25	8	4	1	5	3		12				2
13H-4, 80–82	113.8	127.45	4.147	1	10	1	1	1	5		4	4	1					2		15	5	46	5	2		9	2		6	1			3

Table 1 (continued).

Core, section, interval (cm)	Depth (m)	Depth (mcd)	Age (Ma)	*Nuttallides umbonifera*	*Oridorsalis* sp.	*Oridorsalis tener*	*Oridorsalis umbonatus*	*Pleurostomella* sp.	*Pseudoparrella* sp.	*Pullenia bulloides*	*Pullenia osloensis*	*Pullenia quinqueloba*	*Pullenia zaandamae*	*Pullenia* spp.	*Pyrgo murrhina*	*Pyrgo* spp.	*Schackoinella* sp.	*Siphotextularia catenata*	*Sphaeroidina bulloides*	*Stainforthia fusiformis*	*Tosaia hanzawai*	*Uvigerina hispida*	*Uvigerina peregrina*	*Uvigerina proboscidea*	*Uvigerina* spp.	Miliolids	Thin wall miliolids	Unilocular species	Others	Total	Division
154-926A-																															
1H-1, 80–82	0.8	0.86	0.027		3	4	11		1		3			9	1			4		2	3					2	6	19	9	234	1/4
1H-2, 80–82	2.3	2.36	0.073	3		5	15		2		14	6		15	1	2		2		2						3	1	14	6	225	5/32
1H-3, 29–31	3.29	3.35	0.104		3	6	3				6	9		6							1					4	10	34	2	230	1/16
2H-1, 80–82	4.8	7.1	0.219	9		6	17				2	6		3	3	2	2			2	1		2			2	1	14	14	286	3/32
2H-2, 80–82	6.3	8.6	0.265	19			2				2	2		2		1	3	3			1	1				9	3	19	14	245	3/32
2H-3, 80–82	7.8	10.1	0.311	4		3	3				5	1		12				2			1					3	4	17	13	222	5/64
2H-4, 80–82	9.3	11.6	0.357	5		2	14		8	1	7	11		7		3		1		2	1					4	3	38	6	348	1/8
2H-5, 80–82	10.8	13.1	0.403	8		5	2		5		2	2		3				4		1			2			4	14	19	5	232	1/8
2H-6, 80–82	12.3	14.6	0.448	13		4	9				4	6		8	2	1		2	1	2	3		3			3	2	14	13	214	1/8
2H-7, 20–22	13.2	15.5	0.476	4		8	2				11	16		4			2									4	3	28	10	237	1/16
3H-1, 80–82	14.3	15.39	0.473	20		13					8	5	1	5				3		1	5		2			5	3	16	17	223	1/16
3H-2, 80–82	15.8	16.89	0.518	6		4	9				2	4		3				1					4				1	9	6	200	5/64
3H-3, 80–82	17.3	18.39	0.564	6		5	1				10	3		8	1					1						16	2	30		254	1/8
3H-4, 80–82	18.8	19.89	0.61	38		2	6				2	9		2	1			1		3	1		18			1	1	7	6	348	3/32
3H-5, 80–82	20.3	21.39	0.655	19		9	6				6	14		3	2			3	1		2		3			7		16	4	297	3/32
3H-6, 80–82	21.8	22.89	0.701	27		10	16				1	8		3				4	1		3		1			3		5	4	233	1/16
4H-1, 80–82	23.8	26.38	0.807	8		6	8				3	5	2	9		1		5			2		6			10		15	5	438	7/64
4H-2, 80–82	25.3	27.88	0.853	40		2	7		9		4	8		4	2	1		5		1	3		1			2		17	3	282	1/8
4H-3, 80–82	26.8	29.38	0.899	20		2	7				5	6		5			1	2		3			3			3	2	18	4	219	3/32
4H-4, 80–82	28.3	30.88	0.944	6		10	18				7	7		3	3			3		6	1					3		13	7	239	3/32
4H-5, 80–82	29.8	32.38	0.99	2		9	7			2	2	4		7		1				1			5			1		13	7	232	3/64
4H-6, 80–82	31.3	33.88	1.036	4		5	4			3		3		2				2		2	4		10					10	9	210	1/16
4H-7, 50–52	32.5	35.08	1.072			1	14			1	1			5	1	1			1	1	3		5			4		17	2	213	5/64
5H-1, 80–82	33.3	36.71	1.122	10		8	9			1	5	7	1	2		4	2	1		1	1		3			5	1	17	5	283	5/32
5H-2, 80–82	34.8	38.21	1.168	3		2	10			2	6	10		4	3			2			4		10			3		8	5	224	1/16
5H-3, 80–82	36.3	39.71	1.214			4	10				5	3		1	1	1	1	1		2	4		2			1		14	6	243	3/32
5H-4, 80–82	37.8	41.21	1.26	7		7	7				10	6	2	4				2			6							8	3	238	5/128
5H-5, 80–82	39.3	42.71	1.305			7	3	2		1	8	3	1	6		1	1	1				1				2		15	4	352	5/64
5H-6, 80–82	40.8	44.21	1.351	6		4	5				7	4						1			3		3					4	8	202	1/16
5H-7, 50–52	42	45.41	1.388	4		4	18				11	13	4	4				3			1	16	1			1		8	8	346	5/64
6H-1, 80–82	42.8	46.87	1.433	12		2	4	1			5	5	1	1	2			4								3		13	4	403	3/32
6H-2, 80–82	44.3	48.37	1.479			8	31				4	1		3		1		1		1	1							7	8	263	3/64
6H-3, 80–82	45.8	49.87	1.526	8		3	7				7	4		3	1	2					3				1	1		13	9	362	3/32
6H-4, 80–82	47.3	51.37	1.572	8		10	5				5		1	1	1			6		1	3		5			2		11	10	251	1/16
6H-5, 80–82	48.8	52.87	1.618	9		3	14				3	2	1	4		3		2		1					1			12	2	326	7/64
6H-6, 80–82	50.3	54.37	1.665	11		10	6				4	1		3				1			4					7		20	9	462	7/64
7H-1, 80–82	52.3	58.83	1.804	20		6	10	3			2	5	3	1		3		3				1			3	5		17	3	488	5/64
7H-2, 80–82	53.8	60.33	1.851			10	1				3	11		2	3			2		2			5			3		12	9	210	7/128
7H-3, 80–82	55.3	61.83	1.898	24		5	6	1		2	4	1		4		1		2			3							14	4	231	3/32
7H-4, 80–82	56.8	63.33	1.945	10		11	6							3	1	1		2			2					2		13	4	273	5/64
7H-5, 80–82	58.3	64.83	1.992	4		2	14			1		4		6	1			3		2	5	2				5		13	15	285	3/32
7H-6, 80–82	59.8	66.33	2.04	36		3	7	5			2			3				1			1	1				9		18	5	330	33/512
7H-7, 50–52	61	67.53	2.078	11		2	7	2		1	2	6		2	1			3			2		1		1	1		22	11	348	1/16
8H-1, 80–82	61.8	69.89	2.153	36		1	4	2			2	5		1				2	1		1					1		9	4	717	5/128
8H-2, 80–82	63.3	71.39	2.201	28			9				1			1							3				1	1		16	3	209	1/32
8H-3, 82–84	64.82	72.91	2.249	26		2	5			2	6	1		1	1	2		2	1				1		1	3		7	2	221	3/64
8H-4, 78–80	66.28	74.37	2.296	15		1	13	1			2			2				1			3					2		21	6	281	9/128
8H-5, 77–79	67.77	75.86	2.344	10		1	18				1	2		1	1		1	1			1				1	5		15	9	236	3/64
8H-6, 78–80	69.28	77.37	2.393	12		7	14				3	2			2			3		2	2				1	1		19	4	287	1/16
8H-7, 50–52	70.5	78.59	2.433	18		1	16			3	2			8	1	1	1	3			2					4		24	3	218	7/128
9H-1, 80–82	71.3	80.84	2.506	26		5	2	1			2				1		1	1			1					5	1	14	9	261	9/256
9H-2, 78–80	72.78	82.32	2.555	24		2	6	3		2	11	1	1	3		2		4			2					2		18	6	343	3/32
9H-3, 80–82	74.3	83.84	2.605	57		3	4	4			11			5			1				1					2		21	5	321	3/16
9H-4, 80–82	75.8	85.34	2.654	7		1	20	3	1		10			7				1		1	2					9		25	9	470	9/128
10H-1, 77–79	80.77	91.28	2.853	18		6	5	5		1	5	9	2			1		1		2	4					5		13	2	445	3/32
10H-2, 77–79	82.27	92.78	2.903	15		4	8	6		1	13	2	2	5		3	1	1	1		1					4		21	11	312	1/16
10H-3, 77–79	83.77	94.28	2.954	9		4	10	3			4	3	1			1	1	3		1	4				2	6		19	7	296	5/64
10H-4, 77–79	85.27	95.78	3.005	8		5	8	10			7	5		5	1						2	1					1	12	6	365	41/512
10H-5, 77–79	86.77	97.28	3.057	14		8	11	9			9	4	1	4		1			1	1	4				1	1		17	11	362	9/128
10H-6, 77–79	88.27	98.78	3.108	14		3		6		1	10	2		3	2						4					3		16	7	214	9/128
10H-7, 49–51	89.49	100	3.15	18		4	3	4			12	4	1	5	1			1		4	1			1		6		7	10	388	9/128
11H-1, 80–82	90.3	102.35	3.232	13			9	4			2	4	4	7				2	1		3					1		25	15	321	13/128
11H-2, 80–82	91.8	103.85	3.284	12		9	16	8			15	5	2	5				1	2		5							17	8	309	1/16
11H-3, 80–82	93.3	105.35	3.337	9		4	13				6	8		2						1	2				1	3		22	8	265	5/64
11H-4, 80–82	94.8	106.85	3.39	16		4	5	6		1	11		1	7				2	1		4				1	3		14	7	255	7/128
11H-5, 80–82	96.3	108.35	3.443	20			3	13			10		2	4	2	1	1	1		2	3				1	4		16	13	411	9/128
11H-6, 80–82	97.8	109.85	3.497	20		4	4	4			12	5	2	7		2			1		4				1	3		16	9	246	3/32
11H-7, 35–37	98.85	110.9	3.534	18		1	5	7		1	4	6		9			1	1			5				1	3		15	11	325	17/256
12H-1, 80–82	99.8	112.16	3.58	26		1	8	6		1	9			2				1			1					3		10	7	317	9/128
12H-2, 80–82	101.3	113.66	3.634	6		5	7	3			11			2		1				1	4					1		14	13	342	9/128
12H-3, 80–82	102.8	115.16	3.688	7		2	5	6		1	7	3	5	6		3					1				1	4		8	13	233	1/16
12H-4, 80–82	104.3	116.66	3.743	1		7	6	9			1	2	1	7		1		4			4							15	10	570	5/64
12H-5, 80–82	105.8	118.16	3.798	22		7	8	10			3	4	3	6	1			1		1	2				1	2		13	6	232	1/16
12H-6, 80–82	107.3	119.66	3.854	12		3	4	6			6	3	4	4		1		1			6					2		18	3	334	9/128
12H-7, 35–37	108.35	120.71	3.893	32			13	11		2	11	8		13		2		1		1	6	1				1		18	15	354	3/32
13H-1, 80–82	109.3	122.95	3.977	19			9	5			6		2	10		5	1	1				1				3		8	7	560	49/512
13H-2, 80–82	110.8	124.45	4.033	14		1	9	8			7	1	7	6					1		5		1		1	4		15	9	570	49/512
13H-3, 90–92	112.4	126.05	4.094	21		2	10	5			6		4	4				2	1	2	4							13	6	500	17/256
13H-4, 80–82	113.8	127.45	4.147	22		1	22	6			7		1	6			2	4			1					3		16	11	277	53/512
13H-5, 80–82	115.3	128.95	4.205	16		1	19	7			10	5		5		1	2			1	3							24	13	381	57/512

Table 1 (continued).

Core, section, interval (cm)	Depth (m)	Depth (mcd)	Age (Ma)	*Abditodentrix pseudothalmanni*	*Alabaminella weddellensis*	*Anomalinoides globosus*	*Astrononion echolsi*	*Bolivina pacifica*	*Bolivina* spp.	*Bulimina alazanensis*	*Bulimina* sp. A	*Cassidulina* spp.	*Cibicidoides bradyi*	*Cibicidoides kullenbergi*	*Cibicidoides mundulus*	*Cibicidoides robertsonianus*	*Cibicidoides wuellerstorfi*	*Discorbinella bertheloti*	*Ehrenbergina* sp.	*Epistominella exigua*	*Epistominella* sp. A	*Globocassidulina subglobosa*	*Gyroidina lamarckiana*	*Gyroidina regularis*	*Gyroidina* spp.	*Gyroidina umbonata*	*Gyroidinoides neosoldanii*	*Gyroidinoides orbicularis*	*Ioanella tumidula*	*Laticarinina pauperata*	*Melonis barleeanus*	*Melonis pompilioides*	*Nonionella* sp.
13H-5, 80–82	115.3	128.95	4.205		13	1			6			9	3							16	5	58	1	1	4	5		1	4		1		4
13H-6, 80–82	116.8	130.45	4.263	1	26	1			4		1	9		1			3			40	4	30	3	3	1	2		2	6				2
13H-7, 50–52	117.5	131.15	4.29		26		2		17		4	8	3	3			1	2		31	3	25	4	3		2	2	1	4			1	4
14H-1, 80–82	118.8	134.61	4.425		18		2		15			12	1							22	5	44	1	2		1	2		7		1		1
14H-2, 80–82	120.3	136.11	4.484		24		5		4	1	1	3	2	1				1		49	3	27	3	4		8			2				
14H-3, 80–82	121.8	137.61	4.544		12		2		3			8					1			19	7	23	9			6			9			1	
14H-4, 80–82	123.3	139.11	4.604		25		1					3		1	2		1	4		34	4	33	5		1		2		5				
14H-5, 80–82	124.8	140.61	4.664		12	2	2		11			19		1				3		28	6	40	4	3		3	5		7		1		2
14H-7, 80–82	126.78	142.59	4.745		21		3		4			18	1		2		1			19	6	41	3	3	1	5	4		12				1
15H-1, 80–82	128.3	145.11	4.848	1	15		5		7			14		2	11			1		13	5	58	5	1		7			6				2
15H-2, 80–82	129.8	146.61	4.91	1	25		2		11	1		6		1	13		1	3		13	2	51	4	2					2		3		
15H-3, 80–82	131.3	148.11	4.972		23				4			5	1		14			1		39	2	44	3	6			1		1		4		2
15H-4, 80–82	132.8	149.61	5.035	1	27		3				1	5			10					41	2	32	8			1	1	1	5		2		1
15H-5, 100–102	134.5	151.31	5.107		23				3		3	4	1		16					36	4	49	5	2		1	2		4		1	1	
15H-6, 80–82	135.8	152.61	5.162		18		2		5			9			1					38	2	47	6	4	3	3			4				2
15H-7, 50–52	136.5	153.31	5.192	1	11	1			5			16		1	7					16	6	40	6	2	1	4	1		1				1
16H-1, 80–82	137.8	155.76	5.297	2	21				4			5	1		2		3			31	6	34	5	3		3	1		3		1		
16H-2, 90–92	139.4	157.36	5.367	5	31				19	1		14			8		5	1		10	7	114	3	4	1	8		2	5		1		
16H-3, 80–82	140.8	158.76	5.428	2	15				9		3	14	2		4			1		24	2	55	7			4	1		5				
16H-4, 75–77	142.25	160.21	5.491		14				8			14			12					13	2	113	6	4		6	1	3	2	1			1
16H-5, 80–82	143.8	161.76	5.56		10	1			28			17			15		2			15	3	108	13	2		11	1		9		1		
16H-6, 80–82	145.3	163.26	5.627	1	6				27			15	1	2						12		82	5		1	5	3		11				
16H-7, 50–52	146.5	164.46	5.681	1	5				1			1	1		4					8	1	80	7	1		2	1		7	1			
17H-1, 80–82	147.3	166.28	5.763		18	1						3			7					55	4	56	12	4	3	2	4		7		1		1
17H-2, 80–82	148.8	167.78	5.831	1	27		1		1			5		4	10		1	1		53	3	44	7	1	3	2		2	7				
17H-3, 80–82	150.3	169.28	5.9	1	20		2		3			9		2	1			1		14	3	65	1	2		1	1	2	10		2		2
17H-4, 80–82	151.8	170.78	5.969	2	8				4	1		13	1	1	7					23	5	70	2	1	2	1		1	11				
17H-5, 80–82	153.3	172.28	6.039	4	30	1	1		11			2			4		1			61	4	75	5			8	3	1	10		1	1	2
17H-6, 80–82	154.8	173.78	6.109	10	23	1	1		11			3			12					28	5	47	6			3			3				1
18H-1, 81–83	156.81	176.46	6.236	5	5		1		8			2						1		27	2	44	13			13	5		17				1
18H-2, 81–83	158.31	177.96	6.308	1	25		2		1				2		10					15	3	61	13			6	2		10	1	2		
18H-3, 81–83	159.81	179.46	6.38	1	31							7			8	1	1			99	6	62	7			8	2		14				
18H-4, 81–83	161.31	180.96	6.453		17				3			1	1		12		1			38	4	51	7			3	2		10				1
18H-5, 81–83	162.81	182.46	6.526		22	1	1		1			1	1	2	1		1			62	3	58	6	3		6	3	2	6				2
18H-6, 77–79	164.27	183.92	6.598	3	45				1			4			22					64	9	36	8	3	1	4			3		2		1

Note: Numbers are expressed as number of specimens in the subdivided samples. Division is expressed as a fraction, which means the subdivided material to the whole sample used in this report.

anomalously low productivity is interpreted to mean that the corrosive water mass has been expanded below the depth 4000 m. Between 3.2 and 0 Ma, the BFAR at the two deepest sites was for the most part relatively similar; at the shallower site BFAR was slightly higher, though with many exceptions.

These results may negate the depth effect of benthic foraminifer productivity or indicate that changes in not only organic matter flux, but also deep-water chemistry and circulation patterns have played a role in controlling benthic foraminifer abundances and faunal associations.

Globocassidulina subglobosa is widely distributed in the present deep ocean. Corliss (1979) reported that this species dominates the faunal assemblage where relatively warm (0.6°–0.8°C) AABW is present. Boersma (1990) investigated environmental variations in the size of *G. subglobosa* and found a direct relationship between estimates of good carbonate preservation and higher abundances of large size *G. subglobosa* in the Oligocene and Miocene sections. Mackensen et al. (1995) suggested that this species is more common on steep flanks of ridges. A geographical difference, however, does not explain the historical change of *G. subglobosa* flux at three sites on the Ceara Rise (Figs. 9, 10).

However, the exact physicochemical factors controlling the distribution of this species are not well known. Considering the distribution patterns and depth stratification, *G. subglobosa* prefers the relatively fresh and less cold deep water such as NADW, or Circumpolar Deep Water. Accordingly, the difference in accumulation rates may indicate the vertical differentiation of water masses. After 3 Ma, AABW gradually intensified and the stratification of water masses began to be distinct. As a result, *G. subglobosa* gradually decreased in the deep sites.

Epistominella exigua and *Alabaminella weddellensis* are generally recognized as phytodetritus species. In this paper, two other species, *Epistominella* sp. A and *Ioanella tumidula*, are included in the phytodetritus species group. Their total accumulation rates are shown in Figures 11A and 11B.

As these species are considered to opportunistically respond to fresh organic matter produced by phytoplankton blooming (Gooday, 1988), the change in total absolute abundances of these species closely relates to a strength of seasonality, and is an index for surface paleo-productivity. The accumulation rates of phytodetritus species have a high coefficient of correlation with those of total individuals despite the fact that phytodetritus species account for only one third of the total (Fig. 14). This suggests that the changes in paleo-productivity of total benthic foraminifers are controlled mainly by food supply.

N. umbonifera and *G. subglobosa* are less correlative with total individuals, especially *N. umbonifera* at the shallow site, and *G. subglobosa* at the deep site. These two species are controlled by not only food supply but also other complex ecological factors.

Although *E. exigua* and *A. weddellensis* have similar fluctuation patterns in relative abundances at every site, these species have partly different trends in accumulation rates even though both are phytodetritus species. The amplitude fluctuations of *E. exigua* are different at each depth site especially during the last 3.2 m.y., and the flux of *E. exigua* is more correlative with *N. umbonifera* than *A. weddellensis.* If the productivity of *E. exigua* and *A. weddellensis* is controlled by

Table 1 (continued).

Core, section, interval (cm)	Depth (m)	Depth (mcd)	Age (Ma)	*Nuttallides umbonifera*	*Oridorsalis* sp.	*Oridorsalis tener*	*Oridorsalis umbonatus*	*Pleurostomella* sp.	*Pseudoparrella* sp.	*Pullenia bulloides*	*Pullenia osloensis*	*Pullenia quinqueloba*	*Pullenia zaandamae*	*Pullenia* spp.	*Pyrgo murrhina*	*Pyrgo* spp.	*Schackoinella* sp.	*Siphotextularia catenata*	*Sphaeroidina bulloides*	*Stainforthia fusiformis*	*Tosaia hanzawai*	*Uvigerina hispida*	*Uvigerina peregrina*	*Uvigerina proboscidea*	*Uvigerina* spp.	Miliolids	Thin wall miliolids	Unilocular species	Others	Total	Division
13H-6, 80–82	116.8	130.45	4.263	17		3	4	5		1	4		1	13			1	2			2		1			3		13	3	383	5/64
13H-7, 50–52	117.5	131.15	4.29	26		3	11	6		1	10	4	2	9				1			2							6	9	345	5/64
14H-1, 80–82	118.8	134.61	4.425	22		4	5	19		2	8	1		8	1		1	1	2		1					2		16	13	469	49/512
14H-2, 80–82	120.3	136.11	4.484	47			3	10			11	4	3	4							1					5		11	5	462	33/512
14H-3, 80–82	121.8	137.61	4.544	59		1	3	7			15	3	3	10				3	2		1					1		9	9	388	33/512
14H-4, 80–82	123.3	139.11	4.604	26			8	7			4	4	3	11	1			1			3					3		14	8	634	35/512
14H-5, 80–82	124.8	140.61	4.664	41		3	7	7			8	2	2	4		1		3			3				1	1		14	5	388	129/2048
14H-7, 80–82	126.78	142.59	4.745	35		1	3	7			10		2	9				1	1		2					4		6	10	736	65/1024
15H-1, 80–82	128.3	145.11	4.848	26				15			9	1	2	4				1			4					1		16	3	541	9/128
15H-2, 80–82	129.8	146.61	4.91	28		6	15	8			12	1	5	6			1	1							2	3		17	9	316	41/512
15H-3, 80–82	131.3	148.11	4.972	26		2	4	4		1	13		1	4		1		1			10	3			3	1		14	3	371	33/512
15H-4, 80–82	132.8	149.61	5.035	14		4	8	3			6	5	1					3			1	5	2					15	7	228	1/16
15H-5, 100–102	134.5	151.31	5.107	13		2	7	8			9	4	3		1		1	6			7	6				2		9	10	247	3/64
15H-6, 80–82	135.8	152.61	5.162	22		10	8	5			4	4	1	2		1		2			2				4	2		13	7	239	1/16
15H-7, 50–52	136.5	153.31	5.192	46		3	9	7			11	2	2	3		1					2		1		1	5		10	3	290	5/64
16H-1, 80–82	137.8	155.76	5.297	23		3	9	5			7	1	2	1		1		3			3				1	1		15	8	210	1/32
16H-2, 90–92	139.4	157.36	5.367	23		3	9	8		1	4	2	3	10					1		4		1		1			11	4	368	9/128
16H-3, 80–82	140.8	158.76	5.428	20			5	6				3	1	10				1			1				1	2		17	8	729	5/64
16H-4, 75–77	142.25	160.21	5.491	16		4	7	12			3	2	1	4							5					1		11	5	534	9/128
16H-5, 80–82	143.8	161.76	5.56	19		6	8	13			13	2	1	8	1			4			5					2		13	8	464	1/16
16H-6, 80–82	145.3	163.26	5.627	10		9	3	7			9	2		4				6		1	7					2		12	11	413	9/128
16H-7, 50–52	146.5	164.46	5.681	17		16	6	10			1	2	2	6				4			8							15	6	215	1/16
17H-1, 80–82	147.3	166.28	5.763	20		2	1	9			2	4	1	4				2			7					1		11	15	258	1/16
17H-2, 80–82	148.8	167.78	5.831	18		9	20	6			6	1		7				4			3					5		13	6	274	1/16
17H-3, 80–82	150.3	169.28	5.9	17		12	20	9			6	2		4	1			6			3					4		12	2	240	3/32
17H-4, 80–82	151.8	170.78	5.969	16		4	17	8			2	2	2	2			1	2			3		1		1	3		8	4	229	3/64
17H-5, 80–82	153.3	172.28	6.039	29		14	16	8			2	3	1	6	1	2		6	1		15				3	2		20	12	366	1/16
17H-6, 80–82	154.8	173.78	6.109	7		7	7	10			7	2	2	6				5			5					7		18	7	245	1/16
18H-1, 81–83	156.81	176.46	6.236	44		7	11	11			10	5		4		1		2			6					1		11	14	277	3/32
18H-2, 81–83	158.31	177.96	6.308	19		14	12	6			9	4	1	2				1							6			12	7	250	1/16
18H-3, 81–83	159.81	179.46	6.38	34		13	12	1			4		1	5				1			6				5			11	19	359	1/16
18H-4, 81–83	161.31	180.96	6.453	10		5	7	3			5		1	3	1	1		3			3				3	2		12	3	213	1/16
18H-5, 81–83	162.81	182.46	6.526	19		6	10	4			8			4			1	1			4				6	3		12	13	273	3/64
18H-6, 77–79	164.27	183.92	6.598	12		8	6	2			3	3	1	3				1			7				3	3		8	11	277	3/64

just organic matter alone, the abundance changes should not be so different at each site.

The recent depth distribution pattern of *E. exigua* follows the relatively high oxygen condition of the North Atlantic (Poag and Low, 1985), Indian (Peterson, 1984), and Pacific oceans (Burke, 1981). This means that this species responds to the presence of fresh deep water such as the Norwegian Over Flow Water, Antarctic Circumpolar Deep Water, and AABW. Hermelin and Shimmield (1995) reported an abundance change of this species with a 100-k.y. cyclicity in the Arabian Sea, which they interpreted as reflecting long-term changes in wind intensity, resulting in increased upwelling, and hence high surface water productivity and accumulation of phytodetritus on the seafloor. Accordingly, these facts suggest that *E. exigua* is influenced not only by complex ecological factors such as phytodetritus, but also by other physicochemical factors such as the oxygen content of deep water.

A. weddellensis has similar fluctuation patterns in accumulation rates at every site, with an exception prior to 4.4 Ma at Site 928. The similarity of fluctuations at every depth means that this species is controlled mainly by organic flux from the ocean's surface. Some other factor must account for the pattern at Site 928 before 4.4 Ma. The ecological difference of this species from *E. exigua* is not well known, but *A. weddellensis* is more sensitive to phytodetritus than *E. exigua.*

The accumulation rates of *N. umbonifera* began to increase at about 3 Ma at Site 929. At the two deep sites, this species has exhibited high-amplitude fluctuations during the last 1 m.y. (Fig. 9). Living and downcore studies in benthic foraminifers have revealed that *N. umbonifera* typically associates with carbonate undersaturated bottom water (Corliss, 1979; Bremer and Lohmann, 1982), and dominates below the lysocline and above the carbonate compensation depth (Mackensen et al., 1993). The abundant occurrence of *N. umbonifera* directly indicates the presence of AABW (Corliss, 1979; Bremer and Lohmann, 1982; Peterson, 1984; Mackensen et al., 1995). Additionally, this species is widely distributed in the postglacial and interglacial periods (Schnitker, 1974, 1979). On the other hand, some authors consider this species as an indicator of extreme oligotrophy (Gooday, 1993; Loubere, 1994). Correlation between *N. umbonifera* and *Alabaminella weddellensis* fluxes, and phytodetritus species flux suggests that there is no relation or partly negative correlation of productivity between these two species (Fig. 15A) and total phytodetritus species (Fig. 15B). These results support that *N. umbonifera* was abundant in oligotrophy condition.

A comparison of magnetic susceptibility records with benthic foraminifer flux at Site 929 shows that the high accumulation peaks of *N. umbonifera* correlate with the lower and lowest peaks of susceptibility (Fig. 16). The fluctuation pattern of magnetic susceptibility is correlative with $\delta^{18}O$ curve (Tiedemann et al.,1994), and lowest peaks of magnetic susceptibility correspond with interglacial times. A low value of magnetic susceptibility means generally high accumulation of carbonate, which is interpreted as weak carbonate dissolution or high surface productivity. As ocean paleo-productivity has been much higher in glacial than in interglacial periods (Sarnthein et al., 1988), low accumulation rates of carbonate in glacials indicate stronger dissolution than accumulation of carbonate. This suggests that this species increased during warm periods, and is an indication that the optimum environment of this species expanded in interglacial periods. This relationship is concordant with the recent distribution of this species and water mass structures (Schnitker, 1974, 1979).

As the high accumulation rates of *N. umbonifera* strongly suggest the presence of AABW (not glacial AABW) and less organic matter flux, and the BFAR at Site 929 before 3.2 Ma are similar to the lower

Table 2. Census data for the benthic foraminifer species from Hole 928A in the 63-µm fraction.

Core, section, interval (cm)	Depth (m)	Depth (mcd)	Age (Ma)	*Abditodentrix pseudothalmanni*	*Alabaminella weddellensis*	*Anomalinoides globosus*	*Astrononion echolsi*	*Bolivina pacifica*	*Bolivina* spp.	*Bulimina alazanensis*	*Bulimina* sp. A	*Cassidulina* spp.	*Chilostomella oolina*	*Cibicides lobertulus*	*Cibicidoides bradyi*	*Cibicidoides kullenbergi*	*Cibicidoides mundulus*	*Cibicidoides robertsonianus*	*Cibicidoides* sp.	*Cibicidoides wuellerstorfi*	*Discorbinella bertheloti*	*Ehrenbergina* sp.	*Epistominella exigua*	*Epistominella* sp. A	*Globocassidulina subglobosa*	*Gyroidina lamarckiana*	*Gyroidina regularis*	*Gyroidina* spp.	*Gyroidina umbonata*	*Gyroidinoides neosoldanii*	*Gyroidinoides orbicularis*	*Ioanella tumidula*	*Laticarinina pauperata*
154-928A-																																	
1H-1, 60–62	0.6	0.78	0.022	1	52						3						6			4			22		24	6						26	
1H-2, 60–62	2.09	2.27	0.067		45		1	1	1			1		1	1		1			6			42	2	9	5						9	
1H-3, 60–62	3.58	3.76	0.111		50						7	1		2		2	2						34	1	4	10						2	
1H-4, 60–62	5.07	5.25	0.155	1	22				2		2									5			49	2	12	3			2	2			6
1H-5, 60–62	6.56	6.74	0.198		67						4									5			25	2	15	8			3			15	
1H-6, 30–32	7.75	7.93	0.231		68						3						4			3			12	1	17	11					2	14	
2H-1, 60–62	9.1	9.48	0.275		86						2	2								5			10		7	6			1			3	
2H-2, 60–62	10.59	10.97	0.32		55							0					4			5			37		10	3			1	1		6	
2H-3, 60–62	12.08	12.46	0.362		40				1		2	1					3			3			35		5	5						14	
2H-4, 60–62	13.57	13.95	0.411		21						2						1			1			23		17	3				2		1	
2H-5, 60–62	15.06	15.44	0.455		35						2												45		7	6				1	1	8	
2H-6, 60–62	16.55	16.93	0.498		19			2				4	1				7						52	2	4	4				4	2	3	
2H-7, 30–32	17.74	18.12	0.533		63												9		4	2			19		4	1			1	1		5	
3H-1, 60–62	18.6	20.76	0.604		35						2	4					3		1	3			15	4	13	9				2	2	9	
3H-2, 60–62	20.09	22.25	0.642		33						6	1					9			4			14	7	16	4	3		2	1		12	
3H-3, 60–62	21.58	23.74	0.681		21						1	1					6						30	4	5	4						2	
3H-4, 60–62	23.07	25.23	0.719		34												30			2			74	3		5	0	1	3		0	1	
3H-5, 60–62	24.56	26.72	0.761		29												10			4			19	2	2					4		1	
3H-6, 60–62	26.05	28.21	0.804		44			1	9								3			7			29	2	2					1		3	
3H-7, 30–32	27.24	29.4	0.839		19												4						47	1	12	2					1		
4H-1, 60–62	28.1	30.71	0.878		34												1			1			40	2	12	4			2		1	4	
4H-2, 60–62	29.59	32.2	0.925		53				1		5				3	3	13						4	2	20	5						3	
4H-3, 60–62	31.08	33.69	0.973		65			1									2			4			27	2	14	6			5	1		2	
4H-4, 60–62	32.57	35.18	1.021		57						4	2				6	4			3			35	6	16	3						10	
4H-5, 60–62	34.06	36.67	1.068		27		2									2	13			6	1		36	2	19		1	1		1		5	1
4H-6, 60–62	35.55	38.16	1.107		81		2	1			3	2				2	1			4			43	2	23	10			3	1		2	
4H-7, 30–32	36.74	39.35	1.138		50	1	2				5	1			1	3				1			25	1	35	19			4	1		17	
5H-1, 60–62	37.6	40.62	1.171		63							1				7	5			3	1		27	2	18	2			1			3	
5H-2, 60–62	39.09	42.11	1.213		70							2					27			5			21	2	43	6			11			6	
5H-3, 60–62	40.58	43.6	1.258		36		3				2	3				8	4			5			31	3	21	10						7	
5H-4, 60–62	42.07	45.09	1.304		20		2		1		4					4	9			4			19	7	18	1			1			3	
5H-5, 60–62	43.56	46.58	1.351		51		1				3	2			3	4	15						45	5	10	6				4	3	11	
5H-6, 60–62	45.05	48.07	1.398		29						2						7			3			12	2	17	11						9	
5H-7, 60–62	46.54	49.56	1.445		53		1				5	1					9			2			19	5	40	14						10	
6H-1, 60–61	47.1	51.07	1.494	1	22					1	5	2				6	9	1		1			22	2	26	2				2	1	11	
6H-2, 60–62	48.59	52.56	1.543		30						6	1			1	5	8		0	2			11	3	20	13				2		12	
6H-3, 60–62	50.08	54.05	1.591		78				4		5						12			3			41	1	12	10		2				4	
6H-4, 60–62	51.57	55.54	1.64		44						1						10			2			22		37	11						6	
6H-5, 60–62	53.06	57.03	1.688		52		4		1		1	4			1		2			2			14	3	20	15		5			2	10	
6H-6, 60–62	54.55	58.52	1.731		59			1				2					13			2			14	2	26	5			3			11	
6H-7, 30–32	55.74	59.71	1.766		76						15	6			1		8			9			8	3	58	7	4		1	1	2	11	
7H-1, 60–62	56.6	61.34	1.814	1	12		2				7	4				7	15			9			19	3	27	7			5	3		14	2
7H-2, 60–62	58.09	62.83	1.858		37		1				4	2				3	5			4			8	19	21	5	3		1	2	2	19	
7H-3, 60–62	59.58	64.32	1.905		47		1					2					16						12	11	25	9				3	1	7	
7H-4, 60–62	61.07	65.81	1.95		36		1				2	3								5			37	11	36	8	3		3	1	1	7	1
7H-5, 60–62	62.56	67.3	1.995		65							3					12			1			16	5	40	9			1	2	3	4	
7H-6, 60–62	64.05	68.79	2.039		52						1	4				1	8			4			27	3	22	4				4	3	12	
7H-7, 30–32	65.24	69.98	2.075		52		3		1		1	4				3	10			2			14	5	31	8						8	
8H-3, 60–62	69.08	74.54	2.212		58		4				12	6				3	9			1			9	1	29	4			1		1	4	
8H-4, 60–62	69.79	75.25	2.234		59		5		1		13	6			1		4			2			37	14	22	3				2		4	
8H-5, 60–62	71.28	76.74	2.279		48		4				1	5				2	8			2			104	15	59	4				3		10	
8H-6, 60–62	72.77	78.23	2.325		18		2				4	5			1		1			1			45	6	24	4						11	1
8H-7, 30–32	73.67	79.13	2.353		52							5					11						86	10	36	12			1			13	
9H-1, 60–62	75.6	81.58	2.429		81						3	2					12			3			25	2	31	7			3			12	
9H-2, 60–62	77.09	83.07	2.478		64						10	5					15						6	9	26	4					1	6	
9H-3, 60–62	78.58	84.56	2.533		55							4					1			2			27	6	23	5						3	
9H-4, 60–62	80.07	86.05	2.587		22						5	2			1		12			4			19	4	41	1	1					2	
9H-5, 62–64	81.58	87.56	2.643		36						5	3				10	11						39	4	25	10	3			1		7	1
9H-6, 60–62	83.05	89.03	2.698	1	22					2	13	1					5				2		36	6	16	5				5		2	
9H-7, 30–32	84.24	90.22	2.734		24				4		6	4					7			1			76	7	42	8				1	2	3	
10H-1, 63–65	85.13	91.36	2.768		6		2		5	3	16	1				2	5			10			18	6	36	6			3	1		5	
10H-2, 60–62	86.59	92.82	2.813		23				5		2	1				3	4			1			38	7	34	6	1					6	
10H-3, 60–62	88.08	94.31	2.859		24						2	2			2		7			3			45	5	24	8	2	4	4	2		6	
10H-4, 60–62	89.57	95.8	2.906		16				1		4	2					2						57	8	18	9	2		1	2		4	
10H-5, 61–63	91.07	97.3	2.955		32						2	2					2						55	10	18	6			1			8	
10H-6, 60–62	92.55	98.78	3.006		50						10	2			3		5			6			44	7	29	3	4		5	2	1	10	1
10H-7, 30–32	93.74	99.97	3.044		32				1		4	4					9			2			55	1	22	4			2		2	5	1
11H-1, 60–62	94.6	102.53	3.123		38						1						1			6	1		23	5	19	6	3		4	3		14	
11H-2, 60–62	96.09	104.02	3.17		48							3					13			2			41	2	35	4	2			2		11	
11H-3, 60–62	97.58	105.51	3.216		20	1						1			1		2			2			24		24	6	4		2		3	9	
11H-4, 60–62	99.07	107	3.262		57				1			2					5			2			45	2	31	10			2			8	
11H-5, 60–62	100.56	108.49	3.308		42			2				3			2	1	2						14	3	38	7				1	2	7	
11H-6, 60–62	102.05	109.98	3.353		46							2					5			4			23		45	4		2	6		3	7	
11H-7, 30–32	103.24	111.17	3.389		30							1				1	4			2			23	3	54				4	3		4	
12H-1, 60–62	104.1	112.52	3.43	1	23		1				3	2			1		2			3			45	5	28	4	2		3			7	
12H-2, 60–62	105.59	114.01	3.49		23				1			5			1		3			3	1		25	3	36	4	2		4		2	4	
12H-3, 60–62	107.08	115.5	3.552		26							7			1		4						25	1	40	9			4	2		4	
12H-4, 60–62	108.57	116.99	3.615		25							1				2	5				1		24	3	50	8			6	1		2	
12H-5, 60–62	110.06	118.48	3.677		13		3				3					3	4					1	25	2	53	8			6			3	
12H-6, 58–60	111.53	119.95	3.739		18						1	3			1		4			2			65	2	35	12	1	2	6	1	1	3	

Table 2 (continued).

Core, section, interval (cm)	Depth (m)	Depth (mcd)	Age (Ma)	*Melonis barleeanus*	*Melonis pompilioides*	*Nonionella* sp.	*Nuttallides umbonifera*	*Oridorsalis tener*	*Oridorsalis umbonatus*	*Planulina* sp.	*Pleurostomella* sp.	*Pseudoparrella* sp.	*Pullenia bulloides*	*Pullenia osloensis*	*Pullenia quinqueloba*	*Pullenia zaandamae*	*Pullenia* spp.	*Pyrgo murrhina*	*Pyrgo* spp.	*Shackoinella* sp.	*Siphotextularia catenata*	*Sphaeroidina bulloides*	*Stainforthia fusiformis*	*Tosaia hanzawai*	*Uvigerina hispida*	*Uvigerina peregrina*	*Uvigerina* spp.	Miliolids	Thin wall miliolids	Unilocular species	Others	Total	Division
154-928A-																																	
1H-1, 60–62	0.6	0.78	0.022		1		26	1	11				3	4	7		2	1			7		1					2		10	3	223	3/16
1H-2, 60–62	2.09	2.27	0.067	5			17	4	10				1	8	5		2	1	1	4	2	2		1				2		14	5	209	11/64
1H-3, 60–62	3.58	3.76	0.111				63	2	4					1		2	2	1					2	4				1		9	3	209	1/4
1H-4, 60–62	5.07	5.25	0.155			2	69		5					7	1		1	2	1	4			1	1				7		14	4	233	3/64
1H-5, 60–62	6.56	6.74	0.198	3			46		5					5	11	1	1				7		1	2						5	8	239	1/4
1H-6, 30–32	7.75	7.93	0.231	1		3	24	3	19					9	18			2	1		7		2	2				5		20	10	261	5/16
2H-1, 60–62	9.1	9.48	0.275			2	11	6	11					13	8	2			1		6									12	8	203	1/4
2H-2, 60–62	10.59	10.97	0.32	3			39	5	3					9	5	3		1		1	3		2			1		5		5	6	213	5/64
2H-3, 60–62	12.08	12.46	0.362				21	7	5					14	9				2		10		1	1				3		16	8	206	1/4
2H-4, 60–62	13.57	13.95	0.411	1	1		82	1	7					3	4		1				3		2	2		1		2		6	9	196	1/8
2H-5, 60–62	15.06	15.44	0.455				63	3	2				1	1	4		1		1	2	3			1						8	4	199	1/8
2H-6, 60–62	16.55	16.93	0.498	1			55	5	3					9	14			0	2		3		1	1				4		10	7	220	1/4
2H-7, 30–32	17.74	18.12	0.533		2		15	6	16				1	6	17	1	2				4		3	6	2	1		5	2	5	11	214	5/16
3H-1, 60–62	18.6	20.76	0.604	1			29	5	18			0		1	8				2		3	2		7				2		11	11	202	3/16
3H-2, 60–62	20.09	22.25	0.642		1	1	68	6	4					13	10	1	2	1		18	2		2	4				5		11	6	374	1/8
3H-3, 60–62	21.58	23.74	0.681	2	1		47	7	2			26		9	9		3				1		1	1				2		15	6	208	1/8
3H-4, 60–62	23.07	25.23	0.719				99		4					6	8		4			1	2		6	2			1	1		4	5	296	1/4
3H-5, 60–62	24.56	26.72	0.761		2		79		8				1	5	13		2				3		1	4		1		1		10	6	208	3/16
3H-6, 60–62	26.05	28.21	0.804	2	1		44	3	20					6	11		2		1		2		1	2			3	1		10	8	218	1/8
3H-7, 30–32	27.24	29.4	0.839				93		4						2		1		1		1		2	2	3					7	1	203	1/16
4H-1, 60–62	28.1	30.71	0.878				67	6	9					7	9		2	1	1	3	1	1	1	1				1		14	3	246	7/128
4H-2, 60–62	29.59	32.2	0.925	4	1		31	7	8					8	7	1	2				3		1	3				1		4	11	204	3/2
4H-3, 60–62	31.08	33.69	0.973		5		1	4	15					10	5	1	2	1	2				1	4				4		12	13	209	1/16
4H-4, 60–62	32.57	35.18	1.021		2		28		9					5	7		3	1			3			7				1		5	6	223	1/8
4H-5, 60–62	34.06	36.67	1.068			3	30	7	13					7	4		2	1		2				3			3	5		13	3	232	5/64
4H-6, 60–62	35.55	38.16	1.107			1	5	5	16					3	5		2		1		1		3	2			1	2		5	8	240	1/16
4H-7, 30–32	36.74	39.35	1.138	5			1	7	5			2		9	5			1	1	1	2					1		3		16	9	238	5/64
5H-1, 60–62	37.6	40.62	1.171				11	4	12					5	5		7			2			1	2		2		2		9	7	203	1/8
5H-2, 60–62	39.09	42.11	1.213		1		7		32					8	13	3	5	3	1		4	1	2	2			2	4		13	4	298	1/8
5H-3, 60–62	40.58	43.6	1.258		4		9	8	15					2	18	1	4		5		9			4	4					12	9	237	1/16
5H-4, 60–62	42.07	45.09	1.304	1			50	15	13					9	1	1	1	1		3			2	2				1		7	5	218	5/128
5H-5, 60–62	43.56	46.58	1.351	1	1		28	4	14					10	6		2	6		2	3			6		1		1		13	7	269	3/16
5H-6, 60–62	45.05	48.07	1.398		1		95		3					7	4	2	4				3						2			4	9	228	3/32
5H-7, 60–62	46.54	49.56	1.445		1		9	6	14					8	5		3	3	3		1			2				2		11	2	231	1/8
6H-1, 60–61	47.1	51.07	1.494	1			56		5					6	2		1	1		4			1	4				4		16	2	235	9/128
6H-2, 60–62	48.59	52.56	1.543	1			23	3	8			1	1	4	3	1	1		2	2	5			3			5	1		18	9	217	1/8
6H-3, 60–62	50.08	54.05	1.591				2	10	23					8	8		5	2	1	1	1		2	6			2	3		9	10	278	3/32
6H-4, 60–62	51.57	55.54	1.64				21		13				2	3	4	1	1						1	4				4		9	7	208	1/8
6H-5, 60–62	53.06	57.03	1.688	2	1		21	3	16		1			7	11	1	4		2		4	1	1	3		1		3		14	7	273	3/16
6H-6, 60–62	54.55	58.52	1.731		1		13	4	9					5	14			1		1	5			3				2		6	7	209	1/8
6H-7, 30–32	55.74	59.71	1.766				18	4	21					3	4		2	2			6		2	6			1	5		11	5	311	1/8
7H-1, 60–62	56.6	61.34	1.814	2			30	3	10					10		3	2				5				3			2		13	2	233	13/64
7H-2, 60–62	58.09	62.83	1.858	1		1	20	3	10		4		2	11	4		1				1		1	4		3		3		13	6	224	7/32
7H-3, 60–62	59.58	64.32	1.905				25	3	11					4	13	5	1						1	1						5	5	208	1/8
7H-4, 60–62	61.07	65.81	1.95	2		1	26	4	12		4		1	2				1			2		1	4				3		14	7	240	3/32
7H-5, 60–62	62.56	67.3	1.995		1		6	4	8		1			5	6		1				4		1	1				3		11	8	221	3/32
7H-6, 60–62	64.05	68.79	2.039				26	4	1					7	3		1											4		7	4	383	7/64
7H-7, 30–32	65.24	69.98	2.075	2			12	2	10		2			3	10		1			1	1		1	3				3		23	1	222	1/8
8H-3, 60–62	69.08	74.54	2.212	3			16	4	7		1		1		1	1				1	1			1				4		20	5	210	5/64
8H-4, 60–62	69.79	75.25	2.234	4			2	3	12					2	2	3	2			1	4			3			1	5		7	1	225	3/32
8H-5, 60–62	71.28	76.74	2.279	5			41	1	9		3			5	10		1	1		1	1	1	2	2		1		5		12	11	378	1/8
8H-6, 60–62	72.77	78.23	2.325	2			62	4	12					2		2	1			5	3			2				3		19	4	244	5/64
8H-7, 30–32	73.67	79.13	2.353	1		3	50	3	34					7	5		2	2		3	11	1		9				7		10	6	380	1/8
9H-1, 60–62	75.6	81.58	2.429				25	6	30		1		1	12	2		8		2	1	4		1	1				1		14	16	306	1/16
9H-2, 60–62	77.09	83.07	2.478	2			2	5	11		1			12	6	1	1				1		1	2				2		14	5	212	5/64
9H-3, 60–62	78.58	84.56	2.533		2		21	5	20					19	7				1		3		4	6				5		20	10	249	3/32
9H-4, 60–62	80.07	86.05	2.587	3			9	2	12		4			17	3	3			1	1	1		1	2				4		24	9	210	13/128
9H-5, 62–64	81.58	87.56	2.643				14	2	8		3			6	4	2					1			1				2		7	4	217	1/16
9H-6, 60–62	83.05	89.03	2.698	1			24	2	8		5			8	7	1	2	1		12		1		1				10		13	7	223	17/256
9H-7, 30–32	84.24	90.22	2.734		1	2	21	3	6		1		2	10	4		2			8				1				1		16	6	273	9/128
10H-1, 63–65	85.13	91.36	2.768			2	15	4	3		3			23	8	3	3	1		3	1			8				6		9	10	311	1/16
10H-2, 60–62	86.59	92.82	2.813	6	1	2	20	3	4		1			12	9		5	1		6				1			1	5		6	6	224	9/128
10H-3, 60–62	88.08	94.31	2.859	2	1	1	17	1	7		2			14	5	1			1					5				2		13	4	281	9/128
10H-4, 60–62	89.57	95.8	2.906	3		1	21	1	6					8	2	2				10		1		3	1			8		7	5	218	1/16
10H-5, 61–63	91.07	97.3	2.955			2	24		7		3			11	3								1	3				2		10	5	218	1/16
10H-6, 60–62	92.55	98.78	3.006	3	1	2	18	2	9		6			14	1	1	3		1	4	1		2	2				5		13	9	314	9/128
10H-7, 30–32	93.74	99.97	3.044	1		2	9	2	7		3			17	3	2	1			1	2	1		4				6		15	7	234	9/128
11H-1, 60–62	94.6	102.53	3.123				31		4		3			7	5		2		1	3				1				10		15	12	226	1/16
11H-2, 60–62	96.09	104.02	3.17			3	16	2	7		5			14	7	2	2		1	1				3				1		14	7	265	33/512
11H-3, 60–62	97.58	105.51	3.216	3		2	15	4	14		10			12	5		2	3	5					3				4		17	7	208	9/64
11H-4, 60–62	99.07	107	3.262		1		15	3	16		4			17	10		7	4						5				8		4	9	270	1/16
11H-5, 60–62	100.56	108.49	3.308				12	2	10		4			14	5	3	5	1			1		1	9				4		10	8	230	3/32
11H-6, 60–62	102.05	109.98	3.353	2		1	2	4	8		4			10	6	1	7				1		1	9				3		17	6	232	3/32
11H-7, 30–32	103.24	111.17	3.389				11	2	4		5			9	2			2		4	3		1	6				5	1	16	4	204	1/16
12H-1, 60–62	104.1	112.52	3.43				28	2	4		3			14	3		2	2			1		1	1				1		14	5	211	3/64
12H-2, 60–62	105.59	114.01	3.49	5	2		8	7	3		6			7	4		3	3	7	3	1			1				3		21	6	226	5/64
12H-3, 60–62	107.08	115.5	3.552	3			13		3		8			7	4		5		1	1	1	2		8				7		19	10	297	5/64
12H-4, 60–62	108.57	116.99	3.615	2		1	14	3	7		3			13	8		3			1	1			9				4		12	3	219	9/128
12H-5, 60–62	110.06	118.48	3.677	2		2	3	3	3		7			7	1		3	1	1				1	3				3	1	27	13	208	9/128
12H-6, 58–60	111.53	119.95	3.739				3	2	3		4			12	1		2	5					3	3				3		8	14	224	1/16

Table 2 (continued).

Core, section, interval (cm)	Depth (m)	Depth (mcd)	Age (Ma)	*Abditodentrix pseudothalmanni*	*Alabaminella weddellensis*	*Anomalinoides globosus*	*Astrononion echolsi*	*Bolivina pacifica*	*Bolivina* spp.	*Bulimina alazanensis*	*Bulimina* sp. A	*Cassidulina* spp.	*Chilostomella oolina*	*Cibicides lobertulus*	*Cibicidoides bradyi*	*Cibicidoides kullenbergi*	*Cibicidoides mundulus*	*Cibicidoides robertsonianus*
13H-1, 63−65	113.63	122.85	3.861	1	36	1										4	10	
13H-2, 60−62	115.1	124.32	3.929		32							3			2		3	
13H-3, 60−62	116.6	125.82	4.001		23		1										3	
13H-4, 60−62	118.1	127.32	4.076		33		7					3			1		4	
13H-5, 60−62	119.6	128.82	4.151		42						3	1					1	
13H-6, 60−62	121.1	130.32	4.227		34							2					4	
13H-7, 30−32	122.3	131.52	4.289		24		1					3			1		6	
14H-1, 60−62	123.1	132.01	4.314		11						2	3			2		1	
14H-2, 60−62	124.6	133.51	4.392		16	1	1					1						
14H-3, 65−67	126.15	135.06	4.497		39		4				7	4			2			
14H-4, 60−62	127.6	136.51	4.574		16		1		1			3			3		4	
14H-5, 60−62	129.1	138.01	4.652		39		2					6				2	3	
14H-6, 60−62	130.6	139.51	4.731	2	37		1				2	1			1	4	7	
14H-7, 14–16	131.64	140.55	4.778	1	48		5		1			3			1		4	
15H-1, 60−62	132.6	145.6	5.001		49				1			5				1	12	
15H-2, 60−62	134.1	147.1	5.068		44		1										15	
15H-3, 60−62	135.6	148.6	5.14		34						1	1			1	5	11	
15H-4, 60−62	137.1	150.1	5.212		31							5			2		11	
15H-5, 60−62	138.6	151.6	5.299		30							3				3	6	
15H-6, 60−62	140.1	153.1	5.387		27							3				1		
16H-1, 60−62	142.1	155.9	5.563		55							2					7	
16H-2, 60−62	143.6	157.4	5.65		47		2										7	
16H-3, 60−62	145.1	158.9	5.728		60							1					5	
16H-4, 60−62	146.6	160.4	5.821		43										3		9	
16H-5, 60−62	148.1	161.9	5.92		116												2	
16H-6, 60−62	149.6	163.4	6.023		48			1				2			1		4	
16H-7, 30−32	150.8	164.6	6.108		70												7	

Core, section, interval (cm)	*Cibicidoides* sp.	*Cibicidoides wuellerstorfi*	*Discorbinella bertheloti*	*Ehrenbergina* sp.	*Epistominella exigua*	*Epistominella* sp. A	*Globocassidulina subglobosa*	*Gyroidina lamarckiana*	*Gyroidina regularis*	*Gyroidina* spp.	*Gyroidina umbonata*	*Gyroidinoides neosoldanii*	*Gyroidinoides orbicularis*	*Ioanella tumidula*	*Laticarinina pauperata*
13H-1, 63−65		1	1		42	2	73	6	3		10	2	3	4	
13H-2, 60−62		1		1	26		39	7			10	4	1	9	
13H-3, 60−62					33		43	4			7	2	1	3	
13H-4, 60−62		2			30	4	42	3			8	4		2	
13H-5, 60−62		1	3		22	2	48	7		3	2	1		6	
13H-6, 60−62		3			16	8	33	5			3	2		2	1
13H-7, 30−32		4			23	5	45	4				1		6	
14H-1, 60−62		1			7	6	47	11			2	3		9	
14H-2, 60−62		1	1		30	3	52	4	1		4	2		9	1
14H-3, 65−67		1	1		40	4	113	4			9	4		6	
14H-4, 60−62		3			39	4	52	5	2					11	
14H-5, 60−62		2	1		31	4	78	7	1		6	2		4	
14H-6, 60−62		1			38	2	41	7			6	1	2	9	
14H-7, 14–16		3			37	9	46	7			4	2	2	17	
15H-1, 60−62			1		79	5	54	6			5			3	
15H-2, 60−62				1	41	12	56	6			7		3	14	
15H-3, 60−62					35	7	35	4			4			2	
15H-4, 60−62			1		27	10	75	5			11	1		5	
15H-5, 60−62					26	4	79	4	3		3		1	3	
15H-6, 60−62		1	2		23	2	61	7	1					4	
16H-1, 60−62					39	2	61	4	1		5			3	
16H-2, 60−62			1	1	36	8	51	4	5		6	2		2	
16H-3, 60−62		1			28	6	50	3	2		5			4	
16H-4, 60−62					39	1	33	2	7		10	3		2	1
16H-5, 60−62					41	6	21	2		2	9				
16H-6, 60−62				2	26		33	6		1	10			4	
16H-7, 30−32		1			19	4	54	2		2	5			4	

Note: Numbers are expressed as number of specimens in the subdivided in the subdivided samples. Division is expressed as a fraction, which means the subdivided material to the whole sample used in this report.

or lowest values during the last 3 m.y., the conditions of the water mass before 3.2 Ma at 4300 m depth is considered to be basically the same as glacial conditions after 3 Ma. It is noted that in the oxygen isotope results, the average ice volume before 3.2 Ma is the same as that of interglacial periods since the initiation of northern hemisphere glaciation (Tiedemann et al., 1994). However, accumulation rates of total individuals at Sites 926 and 928, with the exception of the last 0.8 m.y. at Site 928, indicate that paleo-productivity had not changed so much during the last 6 m.y.

It has been observed for the last glacial that NADW formation decreased relative to formation of AABW (Oppo and Fairbanks, 1987; Boyle and Keigwin, 1982, 1987), and the bottom ocean was occupied by an Antarctic source of water. Benthic foraminiferal faunas, especially *N. umbonifera* abundance, indicate that the characteristics of modern bottom water (AABW) is different from that of glacial southern source bottom water. Before 3.2 Ma, the deepest site (Site 929) is clearly influenced by corrosive bottom water. In other words, the present type of AABW circulation had not existed in or had not reached the deep equatorial Atlantic between 6 and 3.2 Ma. After 3.2 Ma, the deep-water circulation and bottom-water production, especially during interglacial times, were enhanced by the increased amplitude of glacial-interglacial contrast.

It is evident that *N. umbonifera* evolved to exploit the bottom-water environment of AABW and, expanding its niche, kept in step with the enlargement of bottom-water production in the Antarctic area.

SUMMARY

The ODP Leg 154 depth transect indicates drastic changes in deep-water environments during the past 6 m.y.

1. At 3.2 Ma, benthic foraminiferal accumulation rates below 4000 m changed drastically. Prior to 3.2 Ma, the accumulation rates of both total specimens and *Nuttallides umbonifera* are low, which indicates that the bottom-water mass was different from the present.
2. Prior to 3.2 Ma, deep-water circulation patterns, especially AABW, are similar to those of glacial periods after 3 Ma.
3. High relative abundances and accumulation rates of *N. umbonifera* are correlative with low peaks in the susceptibility records. This suggests that this species was widely distributed in the interglacial periods.
4. Phytodetritus species abundance changes indicate the same fluctuation pattern as total benthic foraminiferal accumulation rates.

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Table 2 (continued).

Core, section, interval (cm)	Depth (m)	Depth (mcd)	Age (Ma)	*Melonis barleeanus*	*Melonis pompilioides*	*Nonionella* sp.	*Nuttallides umbonifera*	*Oridorsalis tener*	*Oridorsalis umbonatus*	*Planulina* sp.	*Pleurostomella* sp.	*Pseudoparrella* sp.	*Pullenia bulloides*	*Pullenia osloensis*	*Pullenia quinqueloba*	*Pullenia zaandamae*	*Pullenia* spp.	*Pyrgo murrhina*	*Pyrgo* spp.	*Shackoinella* sp.	*Siphotextularia catenata*	*Sphaeroidina bulloides*	*Stainforthia fusiformis*	*Tosaia hanzawai*	*Uvigerina hispida*	*Uvigerina peregrina*	*Uvigerina* spp.	Miliolids	Thin wall miliolids	Unilocular species	Others	Total	Division
13H-1, 63–65	113.63	122.85	3.861		1	4	19	3	7		4			11	5	3		1		3	1		1	2				2	1	20	13	393	65/512
13H-2, 60–62	115.1	124.32	3.929	3			5	2	10	1	10			3	3	1	2					2	2	6				4		26	17	252	9/64
13H-3, 60–62	116.6	125.82	4.001				25	4	8		6			9		1	6			3	2	1		3				2		9	6	337	81/1024
13H-4, 60–62	118.1	127.32	4.076			1	17	3	7		3			3	4	2	1	1	1	1				2				2		11	4	406	29/512
13H-5, 60–62	119.6	128.82	4.151	2			26	4	6		8			12	4	2	2			4	2			3			1	4		27	5	363	9/128
13H-6, 60–62	121.1	130.32	4.227	1			20	4	3		8			17	5	1	6			2				2						15	9	226	21/256
13H-7, 30–32	122.3	131.52	4.289		2	2	23	1	6		4			9	8	1	1			5	4			5				1		15	11	231	9/128
14H-1, 60–62	123.1	132.01	4.314	5		1	12	4	7		11			11	2	1	3		1		3	1		4			1	5		21	9	235	15/128
14H-2, 60–62	124.6	133.51	4.392	4			12	4	2		12			5	6		3		1	1	1	1		7				3		13	10	302	9/128
14H-3, 65–67	126.15	135.06	4.497	2			34		3		10			7	6	1	5			1	1	2		6				4		18	11	522	17/256
14H-4, 60–62	127.6	136.51	4.574	2		2	22	5	4		5			5	2	1	1				1			2			1	2		7	3	683	3/64
14H-5, 60–62	129.1	138.01	4.652	1	1	1	34	2			14			17	10	2	5		1	1	2			3			3	2		15	17	422	65/512
14H-6, 60–62	130.6	139.51	4.731	2		1	16	2	9		6			12	5		6			3				4				9		21	11	308	1/16
14H-7, 14–16	131.64	140.55	4.778	3	3	1	28	5	12		9			13	7	2	4	1	1	5				5			1	5		26	8	372	1/8
15H-1, 60–62	132.6	145.6	5.001				24	7	6		2			9	5	1	5	1		5	1			1			3	4		21	5	430	5/128
15H-2, 60–62	134.1	147.1	5.068	2	1	1	20	7	4		7			3	2		5	1			4						1	4		16	12	290	1/16
15H-3, 60–62	135.6	148.6	5.14				17		13		4			5	1	1	4				5			2						11	10	213	3/64
15H-4, 60–62	137.1	150.1	5.212	3			32	10	9		11			9	3		6							4			1	4		16	7	305	1/16
15H-5, 60–62	138.6	151.6	5.299			1	20	4	9		5				3		3			3	3			4				1	1	15	12	262	1/16
15H-6, 60–62	140.1	153.1	5.387				16	5	9		4			5			4							4				1		16	7	203	1/32
16H-1, 60–62	142.1	155.9	5.563	1		3	4	2	11		3			6	3		1			3		2		2				3		19	9	251	5/64
16H-2, 60–62	143.6	157.4	5.65	6			12		5					9	3			2				1		7				3		11	8	239	1/32
16H-3, 60–62	145.1	158.9	5.728	2			18	7	4		3			12	2		10	1		1				4						11	8	248	1/16
16H-4, 60–62	146.6	160.4	5.821				36	9	6		2			3	4			2		1	3							1		15	5	240	1/16
16H-5, 60–62	148.1	161.9	5.92			2	25	3	10		7			5	3		4		1		1			3				4		12	3	282	1/16
16H-6, 60–62	149.6	163.4	6.023	2		1	19	6	10		4			14		1	7			2	3	1		2				2		11	11	234	1/16
16H-7, 30–32	150.8	164.6	6.108	1	1	2	21	8	16		4			9		2	6				5			4			3	1		7	6	264	1/16

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Table 3. Census data for the benthic foraminifer species from Holes 929A and 929B in the 63-µm fraction.

Core, section, interval (cm)	Depth (m)	Depth (mcd)	Age (Ma)	*Abditodentrix pseudothalmanni*	*Alabaminella wddellensis*	*Anomalinoides globosus*	*Astrononion echolsi*	*Bolivina pacifica*	*Bolivina* spp.	*Bulimina* sp. A	*Cassidulina* spp.	*Cibicidoides bradyi*	*Cibicidoides kullenbergi*	*Cibicidoides lobertulus*	*Cibicidoides mundulus*	*Cibicidoides robertsonianus*	*Cibicidoides wuellerstorfi*	*Discorbinella bertheloti*	*Epistominella exigua*	*Epistominella* sp. A	*Globocassidulina subglobosa*	*Gyroidina lamarckiana*	*Gyroidina regularis*	*Gyroidina* spp.	*Gyroidina umbonata*	*Gyroidinoides neosoldanii*	*Gyroidinoides orbicularis*	*Ioanella tumidula*	*Laticarinina pauperata*	*Melonis barleeanus*	*Melonis pompilioides*	*Nodogenerina* sp.
154-929A-																																
1H-1, 60–62	0.6	0.6	0.0139		45												9		36		24	9			1		1	7				
1H-2, 60–62	2.1	2.1	0.0509		57						1				9		6		36		12	6			2			14		3		
1H-3, 60–62	3.6	3.6	0.0879																													
2H-1, 60–62	5.1	6.15	0.1508		25										5	2		1	30		6	3			2			7		1		
2H-2, 60–62	6.6	7.65	0.1931		40										5				26		2	1			5		2	3		2		
2H-3, 60–62	8.1	9.15	0.2354		49										11		2		22			2			12			15			1	
2H-4, 60–62	9.6	10.65	0.2776		16												1		94		5				3			9				
2H-5, 60–62	11.1	12.15	0.3201		36										4		2		34		7	5			6			9		1	1	
2H-6, 60–62	12.6	13.65	0.3625		15										8		2		12		3				3					1		
3H-1, 54–56	14.54	16.16	0.4367		13										7	1	5		126		21	2			1			8				
3H-2, 60–62	16.1	17.72	0.4846		51										4		6		24									6				
3H-3, 60–62	17.6	19.22	0.5307		18										6													1				
3H-4, 60–62	19.1	20.72	0.5714		12							1			7		6		44		5	2						7				
3H-4, 93–95	19.43	21.05	0.579		30										12		11		17	2	29	11			6			1			2	
3H-5, 60–62	20.6	22.22	0.6061		10							1			11		6		24		3							6			5	
3H-6, 60–62	22.1	23.72	0.6409		51										5		6		63		3	4			1		4	10		6	3	
3H-6, 111–113	22.61	24.23	0.653		16										4		9		69			9					1	7			4	
4H-1, 60–62	24.1	26.19	0.6981	1	11				1				1		14		2		36	8	10						8	8			1	
4H-1, 141–143	24.91	27	0.717																													
4H-2, 60–62	25.6	27.69	0.7328		21										10		2		19	2	7	1					3	3		1	3	
4H-2, 75–77	25.75	27.84	0.736		8										2		4		42		7	4	1		1			1			1	
4H-3, 60–62	27.1	29.19	0.7754		17										4		1		26	2	2			4			12	6			1	
4H-4, 12–14	28.12	30.21	0.805		65										12		3		15		13	7						10				
4H-4, 60–62	28.6	30.69	0.819		22										14		2		44		7	1				1	2	10			2	
4H-5, 14–16	29.64	31.73	0.849		27										2		2		42		3				1		1	1				
4H-5, 60–62	30.1	32.19	0.8626		26										5				16									39			4	
4H-5, 142–144	30.97	33.01	0.887														9		21		2											
4H-6, 60–62	31.6	33.69	0.9068		46										11		3		4	4	21	2						7			1	
154-929B-																																
4H-4, 7–9	33.07	35.67	0.966		44						1	1			10		4		22	3	12	12	1		4		1	1			1	
5H-1, 60–62	33.6	36.7	0.9971		47		1								9		8		25		33	6				1		16			3	
5H-1, 130–132	34.3	37.4	1.018		52						5				22		5		27	2	22	10			3	3		4			1	
5H-2, 60–62	35.1	38.2	1.0421		54					1	5				8				17	7	31	11			3		1	14		1	4	
5H-2, 134–136	35.84	38.94	1.064		16										3		4		84	2	24	2						3				
5H-3, 60–62	36.6	39.7	1.084		46						7				6		2		22		25							1			4	
5H-4, 60–62	38.1	41.2	1.1226		78										14		6		37	1	3	1	1		2			4				
5H-5, 60–62	39.6	42.7	1.1612		38						4				10				41	2	10	5						9		2	3	
5H-6, 60–62	41.1	44.2	1.2008		35		2		1	1	2				12		2		63	3	13				2		1	3				
6H-1, 60–62	43.1	47.71	1.3081		30	1	3			2					11		8		13	3	11				1			2				
6H-2, 60–62	44.6	49.21	1.3536		36					4	3	5			17		3		9	1	4	6			2			8		1	1	
6H-3, 60–62	46.1	50.71	1.3992		30							1			16		3		1		5	7			1		1	20			13	
6H-4, 60–62	47.6	52.21	1.4466		39		1			3	2				10		5		7		12	3				3	2	13				
6H-5, 60–62	48.98	53.59	1.4908		62							1			2		5		40		20	22				5		5			2	
6H-6, 60–62	50.48	55.09	1.5389		16					6					14		2		10	2	5	7				2	3	13		2	2	
7H-1, 60–62	52.6	58.56	1.6505		42										6		3		26	3	12	4					2	16				
7H-2, 60–62	54.1	60.06	1.6973		20		1			4	2	1			13		2		26		8	1					1	5		2	1	1
7H-3, 60–62	55.6	61.56	1.7421		28		2			3	1				13				49		8	2				1		2			1	
7H-4, 60–62	57.1	63.06	1.787		44		2			2	3	1			23		4		1	2	19	10				4	2	6		3	1	
7H-5, 60–62	58.6	64.56	1.8321		42						2				6		4			3	32	12			4		1	7				
7H-6, 60–62	60.1	66.06	1.8788		39						2				8		2		64	2	22	10			3	2		10				
8H-1, 60–62	62.1	70.06	2.0068		82						4				4		4		2		22	11						9			3	
8H-2, 60–62	63.6	71.56	2.0551		38					5			5		8		3		35		17	6		1	1			7	1	1		
8H-3, 60–62	65.1	73.06	2.1035		46		1				2		1		14				46		25	2				1	2	5		3		
8H-4, 60–62	66.6	74.56	2.1517		47								3		10		4	1	30		31	6				1		7		1	1	
8H-5, 60–62	68.1	76.06	2.2		54						9	1		2	3		3			3	12	2						21			1	
8H-6, 60–62	69.6	77.56	2.2484		82						2	2			25		3		25	1	16	5						5		2	1	
9H-1, 60–62	71.6	80.37	2.339		85			1			1				17		3				20	3			3			8				
9H-2, 57–59	73.07	81.84	2.3866		50										4		6		7	1	15	4						22				
9H-3, 60–62	74.6	83.37	2.4362		74										5		6		3	3	14	17						10		1		
9H-4, 60–62	76.1	84.87	2.4895		55			2		8		1			14		7		10	7	31	4				3		5		1	5	
9H-4, 94–96	76.44	85.21	2.502		28					3					10		2		30	3	40	6			3			1				
9H-5, 4–6	77.04	85.81	2.525		117					1					8		1		4		26	9		1	2						1	
9H-5, 60–62	77.6	86.37	2.5463		6					1					10		3		44		15	2						4	1		1	
9H-6, 27–29	78.77	87.54	2.591		15					4	2				4		1		50	2	16	2	2			1	2	3				
9H-6, 60–62	79.1	87.87	2.6034		12			1		2			3		7				38	1	19	4	1					5			1	
9H-7, 20–22	80.2	88.97	2.6454		68							1			11		3		18	2	28	13						7			2	
154-929B-																																
9H-6, 70–72	84.2	89.82	2.678		10					2	1				6		2		70	3	16	6			3	1		4	2			
10H-1, 24–26	80.74	90.21	2.693		15					2					7		1		73	2	15		1		3	1		4			3	
10H-1, 60–62	81.1	90.57	2.7079		14				1	2					11		4		76	2	12	2						1		2		
10H-2, 19–21	82.19	91.66	2.755		12					4	1				7		2	1	18	2	31	12			4	1		10	1	1	2	
10H-2, 60–62	82.6	92.07	2.7726		13					4					6		4		26	16	45	8						3		1		
10H-3, 60–62	84.1	93.57	2.8376		4				9	4					7				60	3	39	7				1	1	2			1	
10H-4, 11–13	85.11	94.58	2.876		12					3							2		30	2	47	6	2		2			3		1		
10H-4, 60–62	85.6	95.07	2.8942		11					4		1			8				43	4	11	7					1	6		4		
10H-4, 145–147	86.45	95.92	2.926		23				1	3	3				3		2		63	2	12	3					2	12			1	
10H-5, 60–62	87.1	96.57	2.9509		25			1				1	2		7		3		31	9	17	12						4			1	

Table 3 (continued).

Core, section, interval (cm)	Depth (m)	Depth (mcd)	Age (Ma)	*Nonionella* sp.	*Nuttallides umbonifera*	*Oridorsalis tener*	*Oridorsalis umbonatus*	*Oridorsalis* sp.	*Orthomorphina* sp.	*Pleurostomella* spp.	*Pseudoparrella* sp.	*Pullenia bulloides*	*Pullenia osloensis*	*Pullenia quinqueloba*	*Pullenia zaandamae*	*Pullenia* spp.	*Pyrgo murrhina*	*Pyrgo* spp.	*Schackoinella* sp.	*Siphotextularia catenata*	*Sphaeroidina bulloides*	*Stainforthia fusiformis*	*Tosaia hanzawai*	*Uvigerina hispida*	*Uvigerina peregrina*	*Uvigerina* spp.	Miliolids	Thin wall miliolids	Unilocular species	Others	Total	Division
154-929A-																																
1H-1, 60–62	0.6	0.6	0.0139		7		6						5	16						9		2	4				3		11	12	207	1/4
1H-2, 60–62	2.1	2.1	0.0509		13		18						5	11		6	1			4		1	5				3		5	4	222	5/16
1H-3, 60–62	3.6	3.6	0.0879																												0	1/1
2H-1, 60–62	5.1	6.15	0.1508		49		4						2	9		1	1	1	4	3			6				5	2	11	13	193	17/256
2H-2, 60–62	6.6	7.65	0.1931		60		13						3	13		1				5			4						3	4	192	5/16
2H-3, 60–62	8.1	9.15	0.2354		14		23						3	53		7		1				1	6						11	1	234	5/8
2H-4, 60–62	9.6	10.65	0.2776		28	1	3						11	3		1	2		2	2							4	1	10	4	202	5/128
2H-5, 60–62	11.1	12.15	0.3201		10	6	14						5	7	3	5				5			1				4		20	2	188	1/8
2H-6, 60–62	12.6	13.65	0.3625		62	3	9				1		4	11	1			1	1	9		1	3		1		2		16	14	183	3/32
3H-1, 54–56	14.54	16.16	0.4367		93	4	40				1		3	4		1			2				2	2			4	1	6	7	354	1/1
3H-2, 60–62	16.1	17.72	0.4846		54	4	11						10	4		1	1				1						2		5	13	197	3/128
3H-3, 60–62	17.6	19.22	0.5307		8		4						1	3			1			1		1	1				2		4	2	53	1/1
3H-4, 60–62	19.1	20.72	0.5714		47	5	14						7	12	1					3		2	1				4		13	2	205	5/64
3H-4, 93–95	19.43	21.05	0.579		27	2	6					1	13	14	1	2				4			1						9	18	219	1/8
3H-5, 60–62	20.6	22.22	0.6061		63	10	28						3	11	1	2				3		2	4						8	10	211	1/16
3H-6, 60–62	22.1	23.72	0.6409		13	5	16						12	23		2				6		1	4					1	14	10	265	1/8
3H-6, 111–113	22.61	24.23	0.653		34		10						14	6	2					3			4						1	8	201	3/8
4H-1, 60–62	24.1	26.19	0.6981		44	5	9						5	10	1	1				2		3	3						14	15	220	1/4
4H-1, 141–143	24.91	27	0.717																												0	1/1
4H-2, 60–62	25.6	27.69	0.7328		85	12	21	10					9	17	1	3			3	4			4				1		11	4	260	1/8
4H-2, 75–77	25.75	27.84	0.736		140	1	2						7	8		1			4	2			1				1		8	7	253	1/32
4H-3, 60–62	27.1	29.19	0.7754		41	2	11						3	11						10		1	3				3		9	6	176	1/4
4H-4, 12–14	28.12	30.21	0.805	1	11	2	13						16	11	1	1	1		1	4			10				5		11	13	232	3/32
4H-4, 60–62	28.6	30.69	0.819		184	1	3						12			1				4			4		3		1		3	4	325	1/8
4H-5, 14–16	29.64	31.73	0.849	1	76	3	11						12	11					5	5	1						3		16	8	232	1/8
4H-5, 60–62	30.1	32.19	0.8626		109								6	12						2		1	1						2	6	229	1/1
4H-5, 142–144	30.97	33.01	0.887		171											1															204	1/2
4H-6, 60–62	31.6	33.69	0.9068		60	1	19					1	8	20		1		1	1	4		1	3				2		13	11	245	3/32
154-929B-																																
4H-4, 7–9	33.07	35.67	0.966		61	2	12						7	6	1				2	4			1				3		7	5	229	1/16
5H-1, 60–62	33.6	36.7	0.9971		34		13	10				7	11	14		4	1			6			6				3		14	9	281	1/4
5H-1, 130–132	34.3	37.4	1.018		26	1	31						9	11	3		1			6	2		4				7		17	12	286	3/16
5H-2, 60–62	35.1	38.2	1.0421		9		32	4				4	9	12		2		2		4	3		4		1		3		20	6	272	5/32
5H-2, 134–136	35.84	38.94	1.064	3	42	3	22						9	3					1	1	1		1						8	8	242	1/32
5H-3, 60–62	36.6	39.7	1.084		40		17	2					7	4		7	1		3	3			4				1		11	5	219	3/32
5H-4, 60–62	38.1	41.2	1.1226		41	5	16	3								1				3			6				3		7	12	244	3/16
5H-5, 60–62	39.6	42.7	1.1612		41		24	2				3	6	8	1			1	2	2		2	4		2		7		13	10	255	3/32
5H-6, 60–62	41.1	44.2	1.2008		18		22						7	1	1		1		3	3			3				4		6	6	215	5/128
6H-1, 60–62	43.1	47.71	1.3081		67		4						11	3	2				1	3		1	2				1		11	3	196	5/64
6H-2, 60–62	44.6	49.21	1.3536		56	1	6					1	4	3				1	2	3			3		3		5		11	6	210	7/128
6H-3, 60–62	46.1	50.71	1.3992		4		38					2	5	55		4				3			6				5		6	3	251	3/16
6H-4, 60–62	47.6	52.21	1.4466		67	1	1						11	4	2	1	1		1		2		2						12	4	284	5/64
6H-5, 60–62	48.98	53.59	1.4908	2	38	3	15						8	10		1	4		2	8		1	6				4		8	5	279	1/8
6H-6, 60–62	50.48	55.09	1.5389		81	1	4					2	15	4			1		4	7	1	1	2						15	1	225	3/32
7H-1, 60–62	52.6	58.56	1.6505		19	2	33						3	8		2	1			5		3	7				2		15	11	235	1/8
7H-2, 60–62	54.1	60.06	1.6973		48	3	4					1	17	9	2	1	2	3	6	5			7			2	4		8	4	218	7/64
7H-3, 60–62	55.6	61.56	1.7421		30	5	14					1	7	8				1	8	4		1	3				3		11	2	213	3/64
7H-4, 60–62	57.1	63.06	1.787		9	4	9					1	20	12						5		1	5				2		11	5	211	1/8
7H-5, 60–62	58.6	64.56	1.8321		21	3	25						7	13		8				6		20	7				1		18	7	251	1/8
7H-6, 60–62	60.1	66.06	1.8788		90	4	12					6	24	9		4				2			1						14	10	340	1/1
8H-1, 60–62	62.1	70.06	2.0068		11	2	18						6	9		5				6			5						13	6	222	3/16
8H-2, 60–62	63.6	71.56	2.0551		34	6	3						9	8			1		3				4				6		12	4	299	5/128
8H-3, 60–62	65.1	73.06	2.1035		13	1	11			2			2	7		1	2		2	3			1				4		9	10	217	5/128
8H-4, 60–62	66.6	74.56	2.1517	1	42	2	10				2		6	9					6	4	1		2				2		7	3	250	1/16
8H-5, 60–62	68.1	76.06	2.2		53	2	13					1	19	6		2		1		8		9	6				2		14	17	264	1/8
8H-6, 60–62	69.6	77.56	2.2484		49	2	12			2	1	2	20	8						6		1	2						7	6	287	1/8
9H-1, 60–62	71.6	80.37	2.339		19	3	24					1	6	6	1	3	2			4			5				2		8	6	231	1/16
9H-2, 57–59	73.07	81.84	2.3866		64	5	7						13	1		1			2	6		1	4				3		7	15	238	5/64
9H-3, 60–62	74.6	83.37	2.4362		6	6	36				1		21	2		2	1	2		8		3	8				2		11	8	250	1/8
9H-4, 60–62	76.1	84.87	2.4895		18		17			3			21	2						4	3	1	5				1		25	12	265	3/16
9H-4, 94–96	76.44	85.21	2.502		37	2	7			2			8	1			1		11	1			2				3		9	7	217	3/64
9H-5, 4–6	77.04	85.81	2.525		10	3	14						19	11		5						2	4				1		11	5	255	1/8
9H-5, 60–62	77.6	86.37	2.5463		70	4	1						12	3			1		1	4	1	2	2				3		11	2	204	1/16
9H-6, 27–29	78.77	87.54	2.591		66		7			1			12	3		1	1		11	2			2				4		12	6	232	3/64
9H-6, 60–62	79.1	87.87	2.6034		83	1							9	4					6	2		1	1				3		11	4	219	3/64
9H-7, 20–22	80.2	88.97	2.6454		9	1	12			1			9	1						1	2	5	6				5		8	7	220	3/64
154-929B-																																
9H-6, 70–72	84.2	89.82	2.678		54	3	8			2			8	9		4			5	3			3				4		8	7	244	1/16
10H-1, 24–26	80.74	90.21	2.693		45	2	6						9	3		2			13			2	3						14	8	234	3/64
10H-1, 60–62	81.1	90.57	2.7079		33	5	11						9			4			5	2			4				6		11	4	221	3/64
10H-2, 19–21	82.19	91.66	2.755		32	3	8			3			24	5		2			3	2			1				5		13	6	217	1/16
10H-2, 60–62	82.6	92.07	2.7726		42	3	19			3			15	7		10			1	6		1	3				7		12	7	262	1/16
10H-3, 60–62	84.1	93.57	2.8376	1	46	1							9	2					7	2			6				3		7	3	225	3/128
10H-4, 11–13	85.11	94.58	2.876		44	1	18			1			21	9		1				4		2	3						10	5	235	1/16
10H-4, 60–62	85.6	95.07	2.8942	1	41	7	3			2			16	3		1	1		7	4	1	2	3				3		11	5	211	1/16
10H-4, 145–147	86.45	95.92	2.926	1	35	1	14			2			7	4		2	1			3			2				6		9	2	220	3/64
10H-5, 60–62	87.1	96.57	2.9509	5	17	2	11			2			17	6		4				2	2	1	3				7		16	4	213	1/32

Table 3 (continued).

Core, section, interval (cm)	Depth (m)	Depth (mcd)	Age (Ma)	*Abditodentrix pseudothalmanni*	*Alabaminella wddellensis*	*Anomalinoides globosus*	*Astrononion echolsi*	*Bolivina pacifica*	*Bolivina* spp.	*Bulimina* sp. A	*Cassidulina* spp.	*Cibicidoides bradyi*	*Cibicidoides kullenbergi*	*Cibicidoides lobertulus*	*Cibicidoides mundulus*	*Cibicidoides robertsonianus*	*Cibicidoides wuellerstorfi*	*Discorbinella bertheloti*	*Epistominella exigua*	*Epistominella* sp. A	*Globocassidulina subglobosa*	*Gyroidina lamarckiana*	*Gyroidina regularis*	*Gyroidina* spp.	*Gyroidina umbonata*	*Gyroidinoides neosoldamni*	*Gyroidinoides orbicularis*	*Ioanella tumidula*	*Laticarinina pauperata*	*Melonis barleeanus*	*Melonis pompilioides*	*Nodogenerina* sp.
10H-6, 60–62	88.6	98.07	3.0077		31			1		2					4		2		22	2	52	6				3	1	2				
10H-6, 89–91	88.89	98.36	3.019		39					3	2				3		1		30	1	37	8	3				2	3	1			
10H-7, 20–22	89.2	98.67	3.0298		24					2					3				42	3	29	10	3					1	1			
154-929B-																																
10H-6, 148–150	94.48	99.56	3.06		13					13	11	1			13		4		34	1	42	4			3		2	2	3	1	2	
11H-1, 60–62	90.6	100.67	3.098		25										1		5		22	3	47	5					1	5		1	1	
11H-2, 60–62	92.1	102.17	3.1495		19				1			1			2			1	70	3	27	8						4		2	2	
11H-3, 26–28	93.26	103.33	3.19		10								1		1				88	3	24	7	3		3			3	1	1		
11H-3, 60–62	93.6	103.67	3.2034		11								2		2		2		22	3	36	12				1		6				
11H-4, 60–62	95.1	105.17	3.2653		69							1			9		4		11		17	8			1			2			1	
11H-4, 69–71	95.19	105.26	3.269		41			5			2						4		9		46	13	1		5	1		2		1	2	
11H-5, 60–62	96.6	106.67	3.3262		45						1	1							9	6	46	10	7		3	3		5				
11H-5, 110–112	97.1	107.17	3.346		81						1				1		3		11		29	7			4		1	11			1	
11H-6, 35–37	97.85	107.92	3.375		42				1		1				5			1	27		42	13	5		4		2	2		1		
11H-6, 60–62	98.1	108.17	3.3849		36							2			5		2	1	19	2	40	11	1		2			5				
11H-7, 20–22	99.2	109.27	3.4281		18										3		1		41	1	29	10	2		2		1	8		1		
12H-1, 32–34	99.82	110.68	3.4929		34			1	1				1		2		1	1	39	4	28	3	1		2		1	6		4	3	
12H-2, 134–136	102.34	113.2	3.6176		11				1		2				3		1	3	23	3	40	12	3		7			5		1		
12H-3, 72–74	103.22	114.08	3.6609		19		3	1				1			4		6		25	1	59		6			1	3	4				
12H-4, 19–21	104.19	115.05	3.7138		32		3								3		3	1	56	2	45	1			1	1		3				
12H-5, 132–134	106.82	117.68	3.86		27							1			8		1	1	30	1	40	7		1	6	1		5	1	2	1	
12H-6, 132–134	108.32	119.18	3.936		31		1								24		3		24	2	47	9	3		2	4		3			1	
12H-7, 18–20	108.68	119.54	3.9543		34				1		3				6		7		68	2	19					1		2		1		
13H-1, 99–101	109.99	121.85	4.0587		26	1	1					1			10		3		12	4	52	11			2	2	1			2	1	
13H-2, 105–107	111.55	123.41	4.149		20		1	1			1				12		4		19	1	74	6			3		1	7	1	1		
13H-3, 44–46	112.44	124.3	4.2048		37	1		1			4	2	2		12		3	2	26	2	63	3		2	3	3	1	1				
13H-4, 102–104	114.52	126.38	4.3381		28										14			1	27	5	51	3	1	2	2	2		3		1		
13H-5, 49–51	115.49	127.35	4.4011		37		2					1			6		1	1	13	1	71	3			3			4		4		
13H-6, 67–69	117.17	129.03	4.5171		35							1					3		34	3	46	3			3	1		1		1		
154-929B-																																
13H-6, 30–32	121.8	130.11	4.605	1	26		4								1		2		51	3	22	2	1		2	3		5		3		
14H-2, 46–48	121.29	133.45	4.882		25		3	1	1		2				7				52		56	5	2			1		3		2		
14H-4, 60–62	122.93	135.09	5.0177		36							2			5		1		47	2	34	7	2		2	1		1		2		
14H-6, 61–63	124.75	136.91	5.1705		29			1				1			7		1		52	2	24	5			7	1		2				
14H-7, 61–63	126.16	138.32	5.2957		46			1		1					5			1	44	3	44	1			2	4		2				
15H-1, 60–62	128.6	140.03	5.455		32					1		3			8				58	2	44	4			1		2	6				
15H-2, 60–62	130.1	141.53	5.6014		30			1							6		2	1	46	4	24	1			1			4	2		1	
15H-3, 60–62	131.6	143.03	5.7318		33										18		3		39	3	42	2			3	2	1					
15H-4, 60–62	133.1	144.53	5.8557		50										13		1		32	1	59	8			2	7		6				
15H-5, 60–62	134.6	146.03	5.9799		25							4			6			3	15		67	5			2	5		3				
15H-6, 20–22	135.7	147.13	6.0582		46							2			8				41	1	28	3				2		3				

Notes: Numbers are expressed as number of specimens in the subdivided samples. Division is expressed as a fraction, which means the subdivided material to the whole sample used in this report.

Table 3 (continued).

Core, section, interval (cm)	Depth (m)	Depth (mcd)	Age (Ma)	*Nonionella* sp.	*Nuttallides umbonifera*	*Oridorsalis tener*	*Oridorsalis umbonatus*	*Oridorsalis* sp.	*Orthomorphina* sp.	*Pleurostomella* spp.	*Pseudoparrella* sp.	*Pullenia bulloides*	*Pullenia osloensis*	*Pullenia quinqueloba*	*Pullenia zaandamae*	*Pullenia* spp.	*Pyrgo murrhina*	*Pyrgo* spp.	*Schackoinella* sp.	*Siphotextularia catenata*	*Sphaeroidina bulloides*	*Stainforthia fusiformis*	*Tosaia hanzawai*	*Uvigerina hispida*	*Uvigerina peregrina*	*Uvigerina* spp.	Miliolids	Thin wall miliolids	Unilocular species	Others	Total	Division
10H-6, 60–62	88.6	98.07	3.0077		29		9			1			7			4		1	1	3	1		3				2		9	2	249	1/32
10H-6, 89–91	88.89	98.36	3.019	3	18	1	10			4			7	4	1	4	1		2	4		1	2				4		5	2	206	3/64
10H-7, 20–22	89.2	98.67	3.0298	2	18	1	8			1			11	1		4			5	1		1	4				3		13	8	209	5/128
154-929B-																																
10H-6, 148–150	94.48	99.56	3.06	3	14	4	8			6		1	20	6			1	1	3	2	1		4				3		15	6	248	3/32
11H-1, 60–62	90.6	100.67	3.098	2	12	1	9			1			21	2		1	1		1	4	1	4	3				2		13	4	201	1/16
11H-2, 60–62	92.1	102.17	3.1495	1	36	5				1			5	2		1	1		7	5			1				4		8	7	226	3/64
11H-3, 26–28	93.26	103.33	3.19		15	1	6			2			5	2		6			6	1		3	2				4		11	2	221	1/32
11H-3, 60–62	93.6	103.67	3.2034		24	2	10			1			22	8		3		1	1	1		1	8				3		13	6	201	1/16
11H-4, 60–62	95.1	105.17	3.2653		14	4	12			2			14	2		3	1			4	1	1	1				2		12	3	199	1/32
11H-4, 69–71	95.19	105.26	3.269		9	4	20			3			19	6		3				7		1	5						14	7	230	3/32
11H-5, 60–62	96.6	106.67	3.3262	1	11	16	2			4			10	2					3				4				3		11	7	215	3/64
11H-5, 110–112	97.1	107.17	3.346		5	1	5						7	6	1	5						3	4				3		10	6	206	1/16
11H-6, 35–37	97.85	107.92	3.375		8	5	4			3			8	1		2	2		4								6		13	5	207	1/16
11H-6, 60–62	98.1	108.17	3.3849		16	2	6			3			17	2					2			1	2				5		9	3	194	3/32
11H-7, 20–22	99.2	109.27	3.4281		56		17			2		1	9			1	1					2	4				2		13	8	233	3/32
12H-1, 32–34	99.82	110.68	3.4929		12	3	8			3			17		2	4			4	1	1		2				4		14	1	215	3/32
12H-2, 134–136	102.34	113.2	3.6176		12	3	10			3			20	8	3	3			2								5		10	5	215	7/64
12H-3, 72–74	103.22	114.08	3.6609		23		7			3			10	3		1			2			1	1				3		10	4	204	5/64
12H-4, 19–21	104.19	115.05	3.7138		27	2	7			3			8	1	2	3		1			3						1		5	5	219	5/64
12H-5, 132–134	106.82	117.68	3.86	2	11	2	12			5			7	3	3	4			2	2		1					4		11	1	346	7/64
12H-6, 132–134	108.32	119.18	3.936		10	1	12		2			1	8	2	1	4		1	2	1		1	5	1					11	7	225	1/16
12H-7, 18–20	108.68	119.54	3.9543	2	20		4			1		2	6	2			2			1	1		4	6					9	3	207	1/16
13H-1, 99–101	109.99	121.85	4.0587	3	9	7	8			3			7	3	1	4			1	3		1	3				7		14	4	313	7/64
13H-2, 105–107	111.55	123.41	4.149		17	4	10			5			11	8		5		1	6				2				2		19	5	247	1/8
13H-3, 44–46	112.44	124.3	4.2048	1	18	3	12			4			4	2		6		1	2	3			5				1		16	6	252	3/32
13H-4, 102–104	114.52	126.38	4.3381		12	2	6			1			4	2		7				2			5				1		9	3	199	5/64
13H-5, 49–51	115.49	127.35	4.4011	2	14	1	10			3			8	7		3			1	3	1		3				4		13	10	234	3/32
13H-6, 67–69	117.17	129.03	4.5171	2	34	2	6			4			5	2		2							2				1		12	7	296	7/128
154-929B-																																
13H-6, 30–32	121.8	130.11	4.605	1	35	7	1			1			4		1	3	1			2			3				4		10	7	367	3/64
14H-2, 46–48	121.29	133.45	4.882		45	2	11			2			16			3			1	1			2				1	3	13	9	269	3/32
14H-4, 60–62	122.93	135.09	5.0177		38	2	3			1			2	1		1				1			5						4	4	204	3/32
14H-6, 61–63	124.75	136.91	5.1705		15	5	10			2			6	5		6	1		5				1	3			1		6	4	204	5/64
14H-7, 61–63	126.16	138.32	5.2957		48	6	12			1			13	14	1		1		1				5				1		13	8	278	1/8
15H-1, 60–62	128.6	140.03	5.455		100	6	10			3			8	6					3	4			1				1		10	8	321	1/8
15H-2, 60–62	130.1	141.53	5.6014		67		10			1			3	4		1													8	2	219	1/8
15H-3, 60–62	131.6	143.03	5.7318		55	5	11			2			10	5	2		1			3	1		1						4	7	253	1/8
15H-4, 60–62	133.1	144.53	5.8557		17	2	10			5			8	6	2	2				3	2		5						11	6	258	1/8
15H-5, 60–62	134.6	146.03	5.9799		15	6	6			4			1		1	2				2	2		4						7	3	188	1/16
15H-6, 20–22	135.7	147.13	6.0582		35	3	12			1			1	2	2	3				2			1						11	3	211	7/64

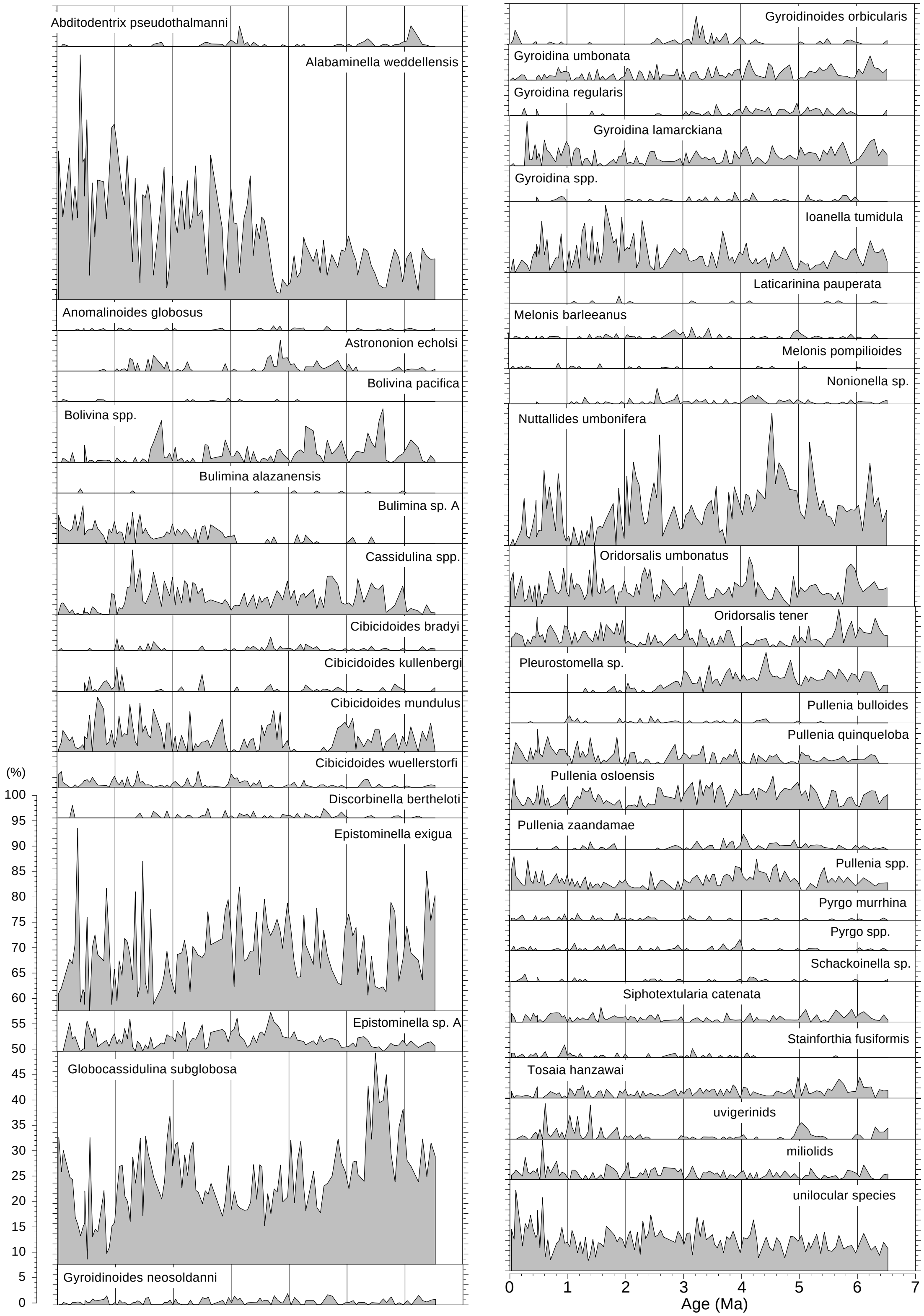

Figure 2. Relative abundances of selected benthic foraminiferal species in Hole 926A.

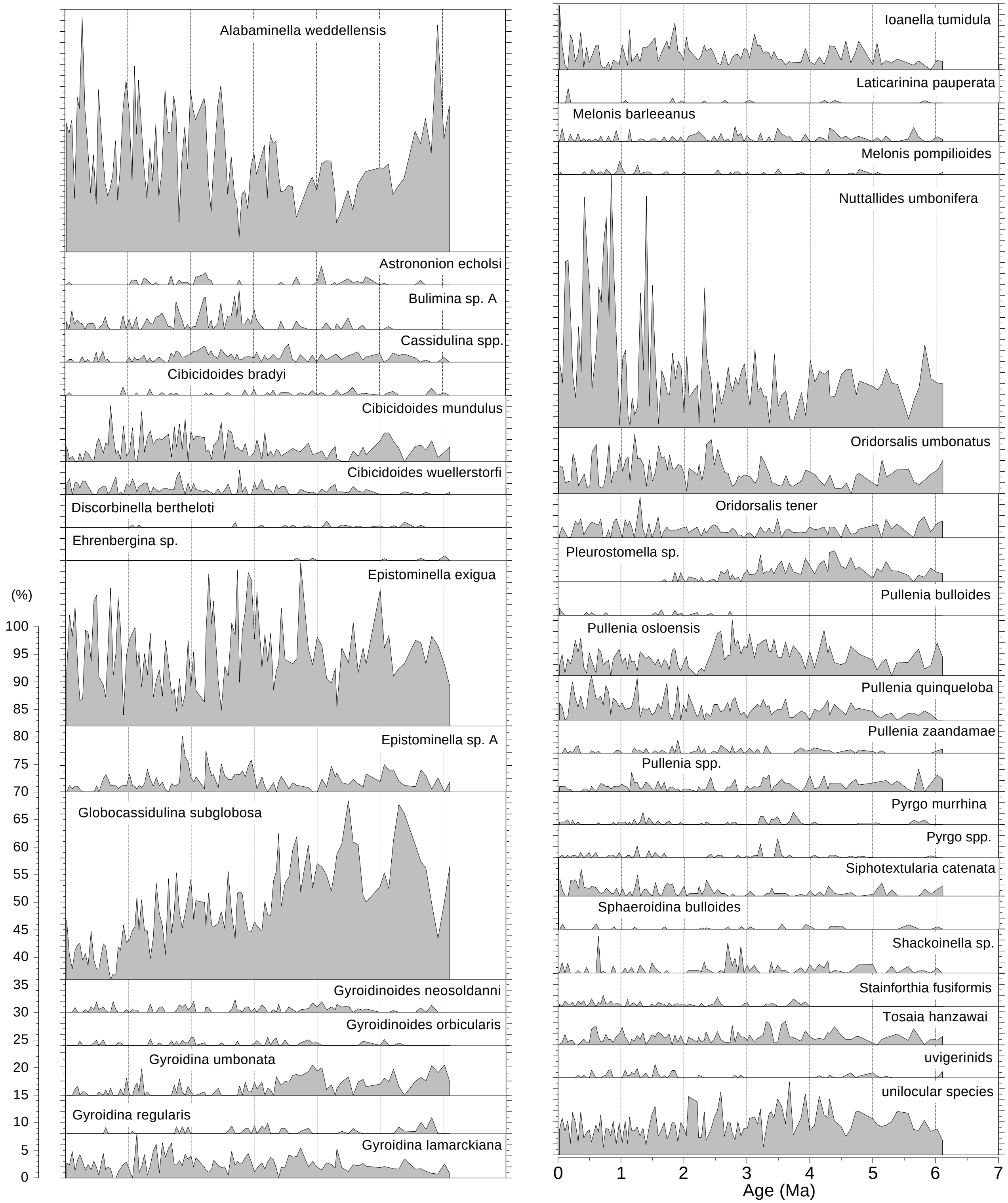

Figure 3. Relative abundances of selected benthic foraminiferal species in Hole 928A.

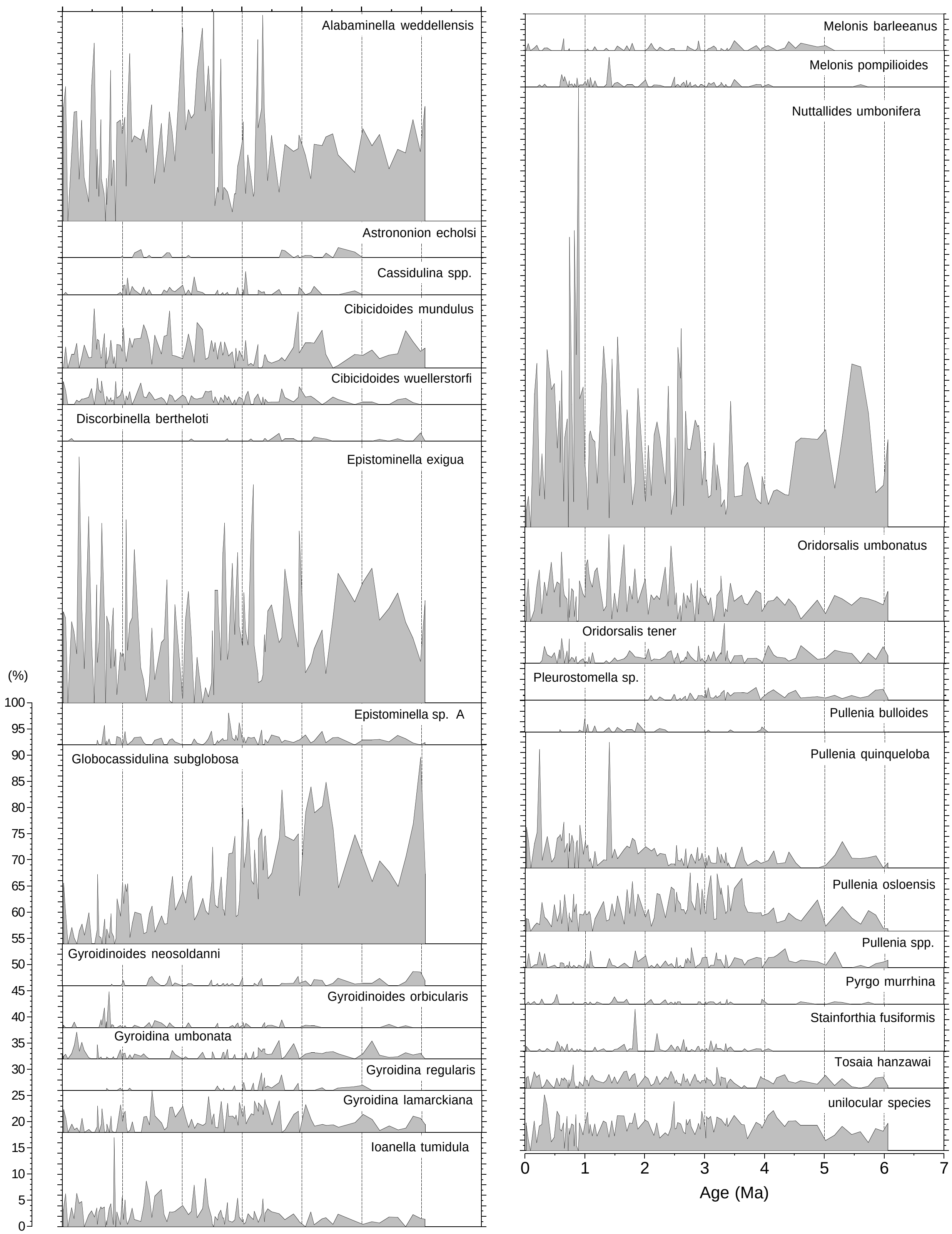

Figure 4. Relative abundances of selected benthic foraminiferal species in Hole 929A.

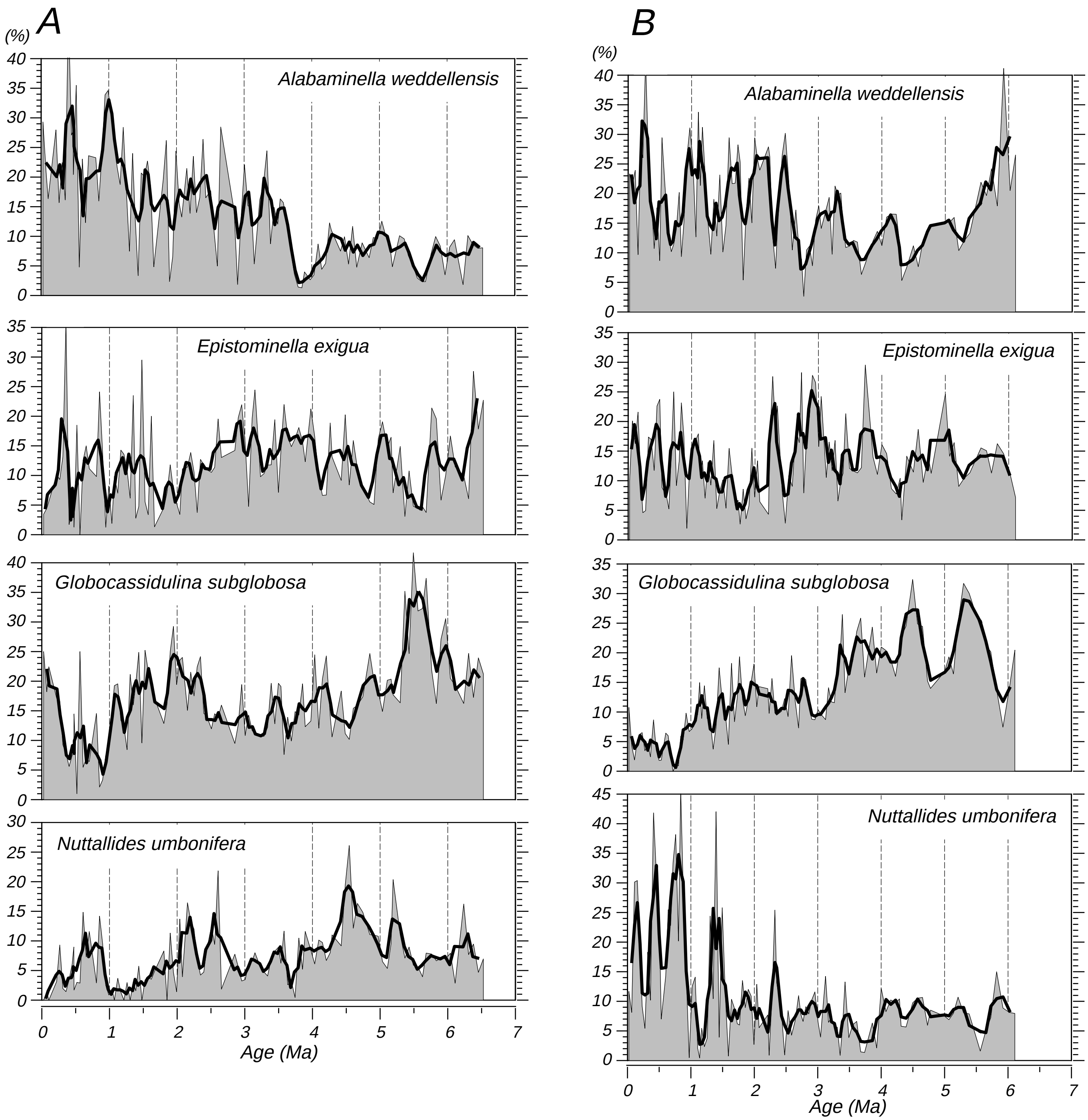

Figure 5. Relative abundance area graphs for four abundant species with superimposed curves of three-point moving averages for Holes (**A**) 926A, (**B**) 928A, and (**C**) 929A.

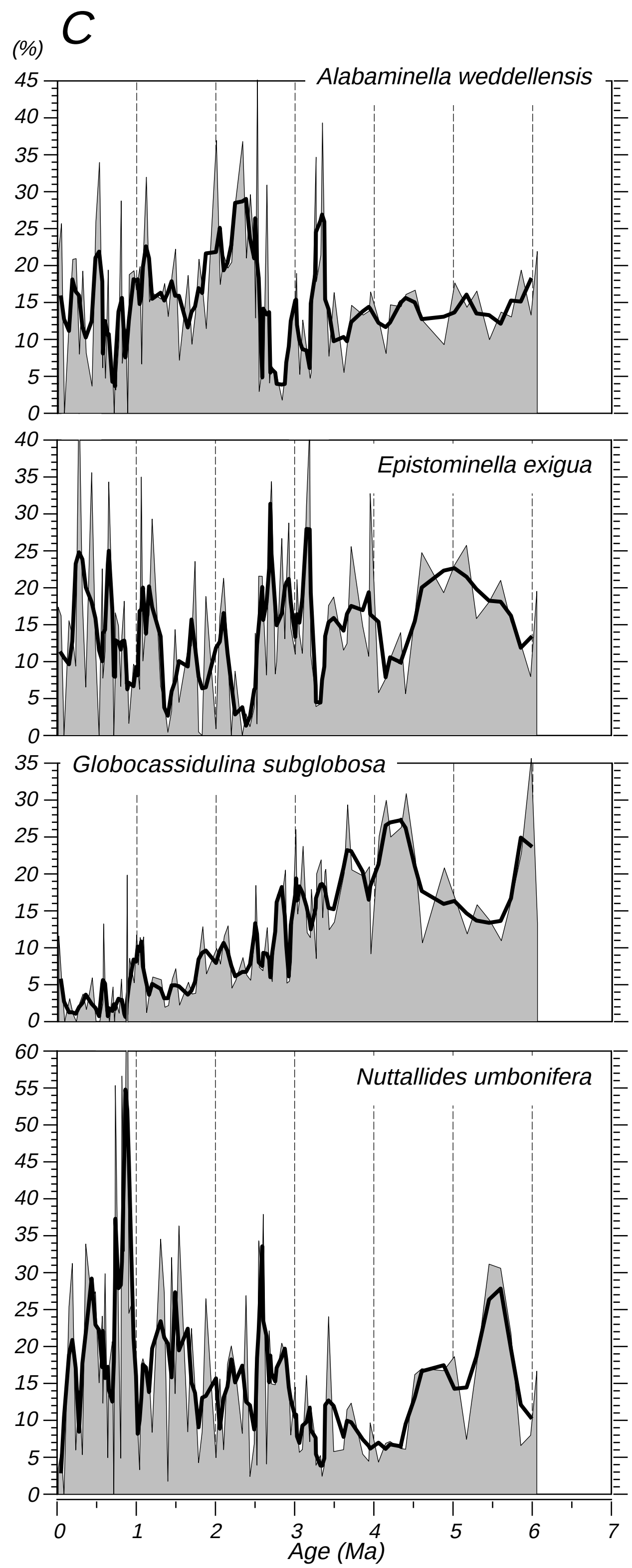

Figure 5 (continued).

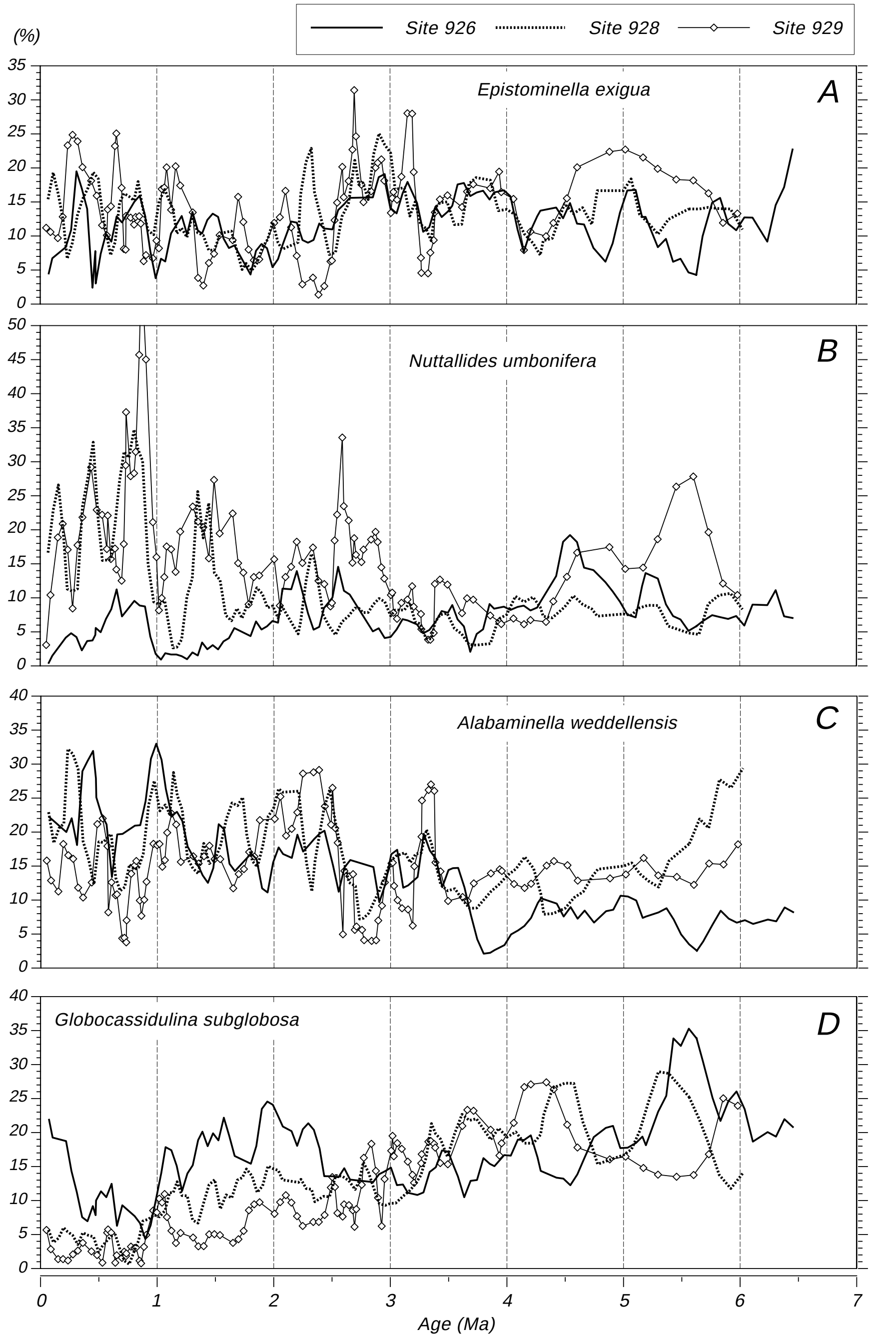

Figure 6. Three-point moving average curves of relative abundances for four species in Holes 926A, 928A, and 929A. **A.** *Epistominella exigua.* **B.** *Nuttallides umbonifera.* **C.** *Alabaminella weddellensis.* **D.** *Globocassidulina subglobosa.*

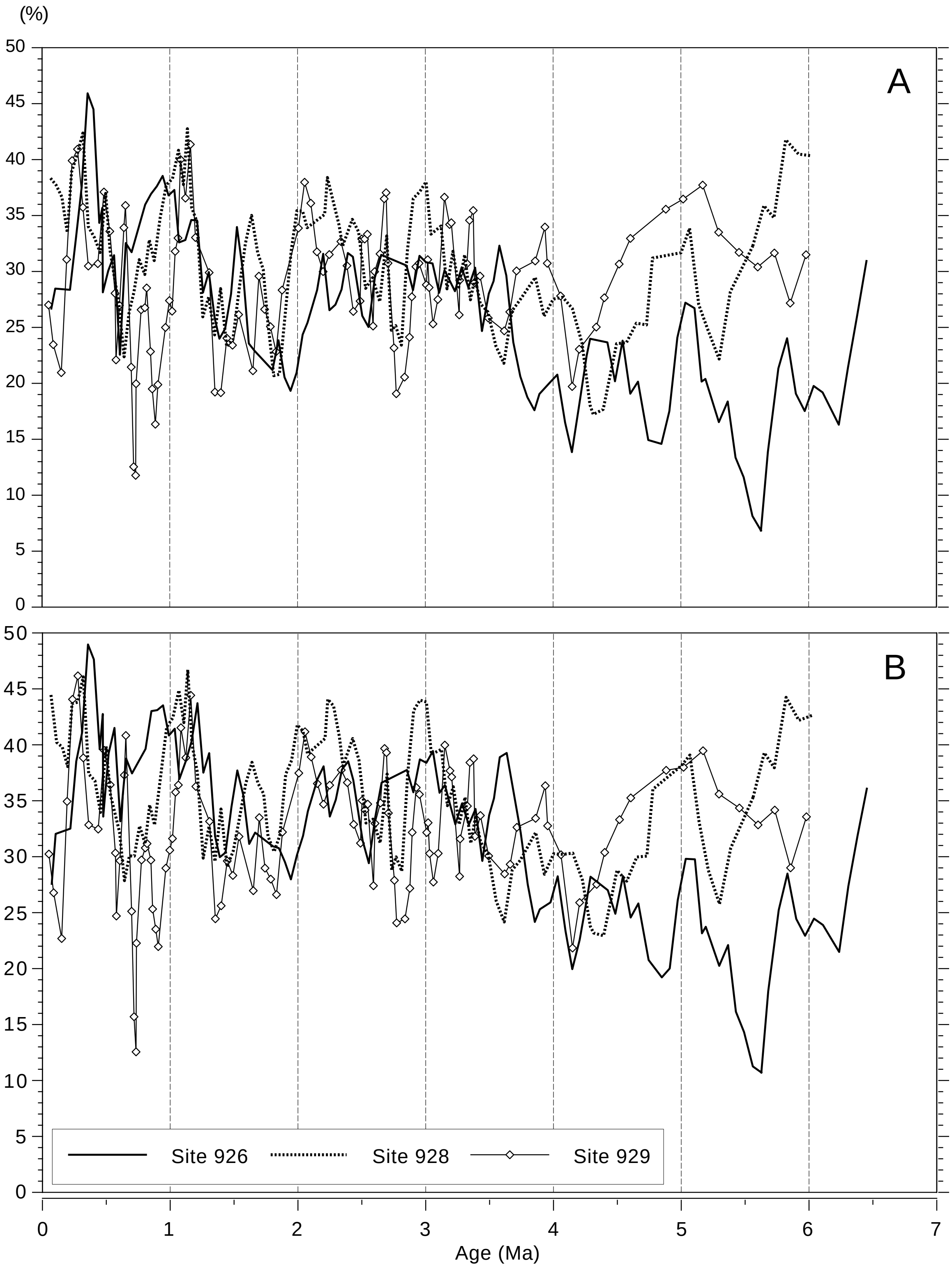

Figure 7. Relative abundance curves for phytodetritus species. **A.** *Epistominella exigua* and *Alabaminella weddellensis.* **B.** *Epistominella* sp. A and *Ioanella tumidula* are added to above two species.

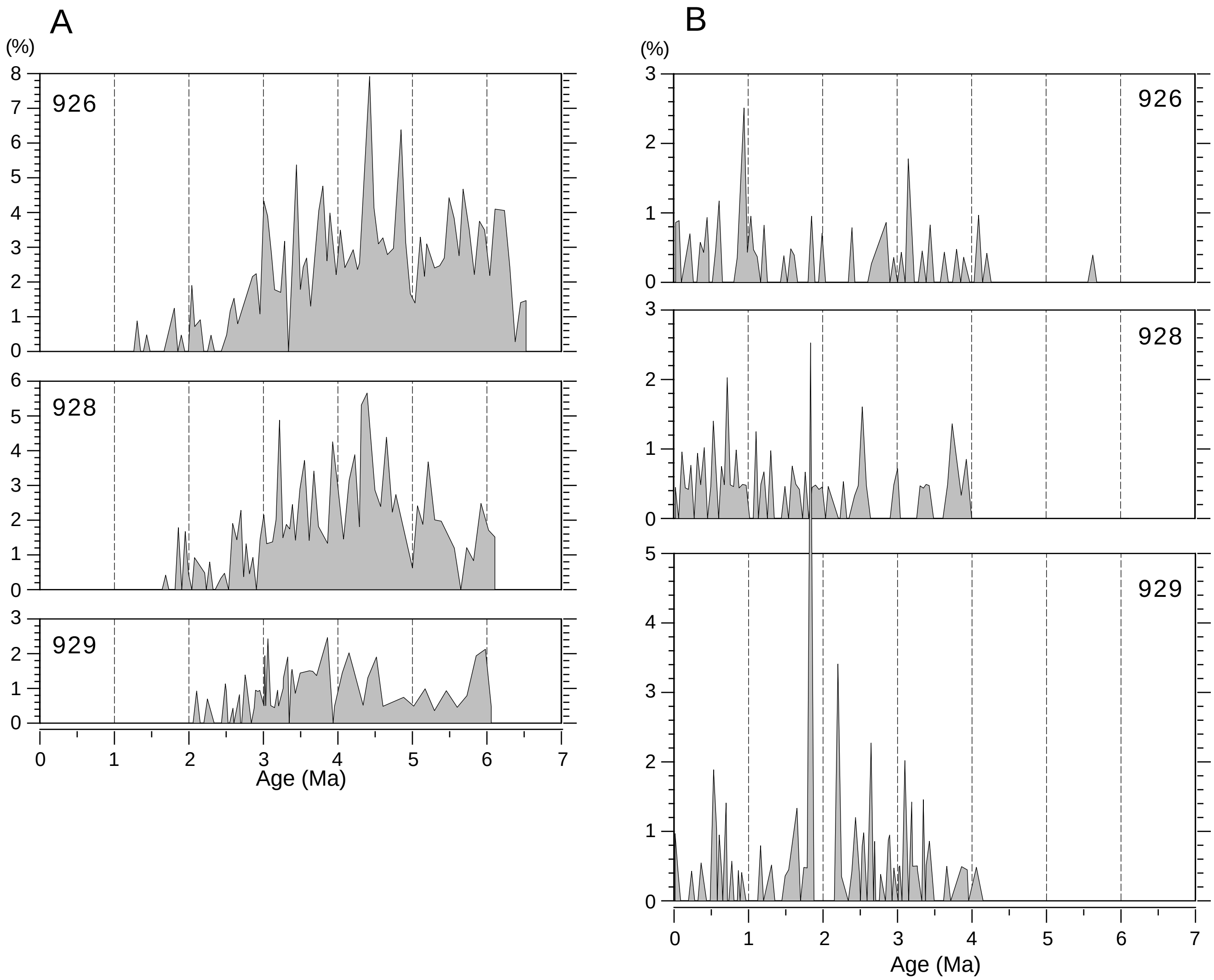

Figure 8. Relative abundance graphs for selected benthic foraminiferal species, which have stratigraphically characteristic occurrences in Holes 926A, 928A, and 929A. **A.** *Pleurostomella* spp. **B.** *Stainforthia fusiformis.* **C.** *Pullenia osloensis.* **D.** *Ioanella tumidula.*

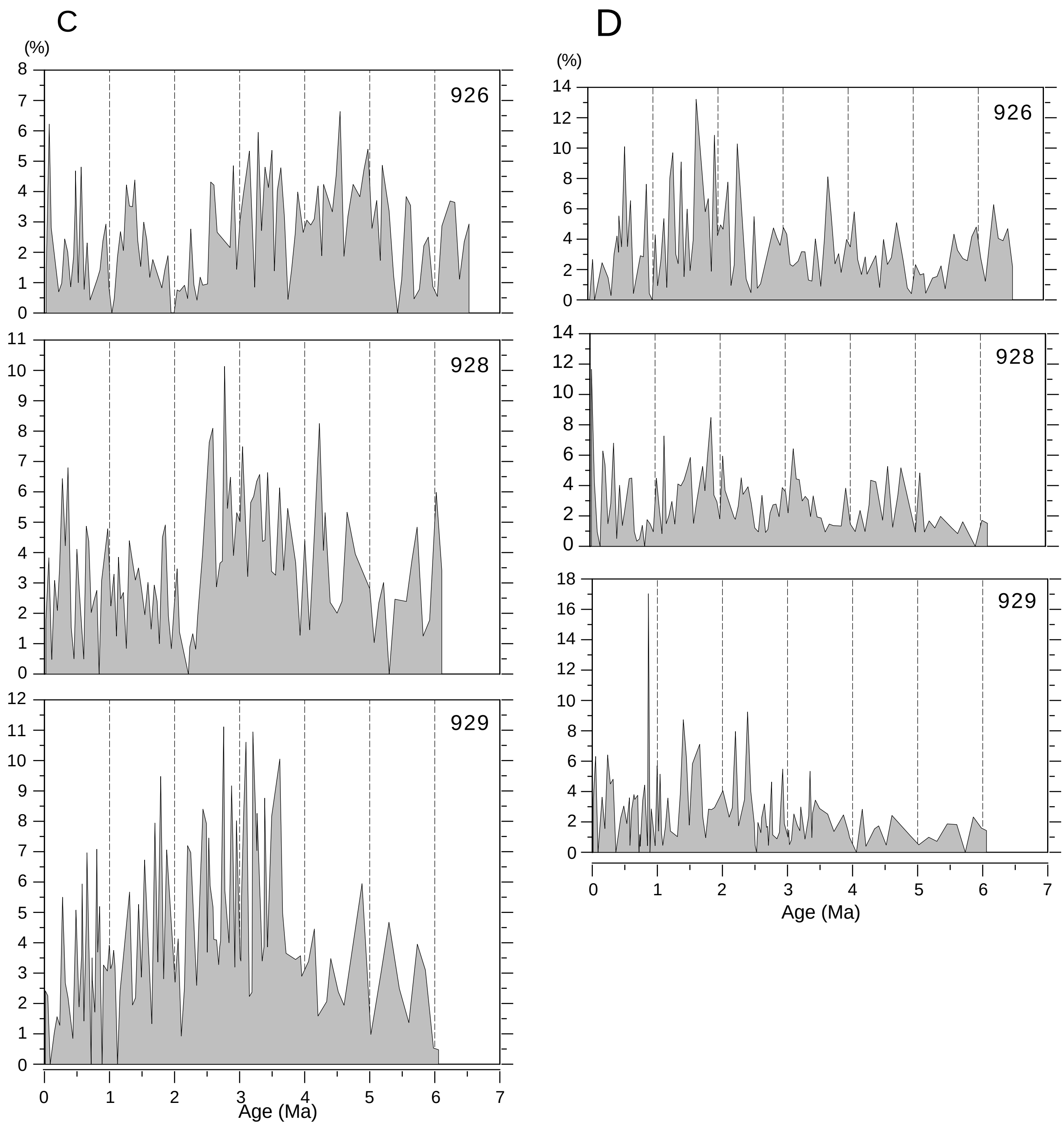

Figure 8 (continued).

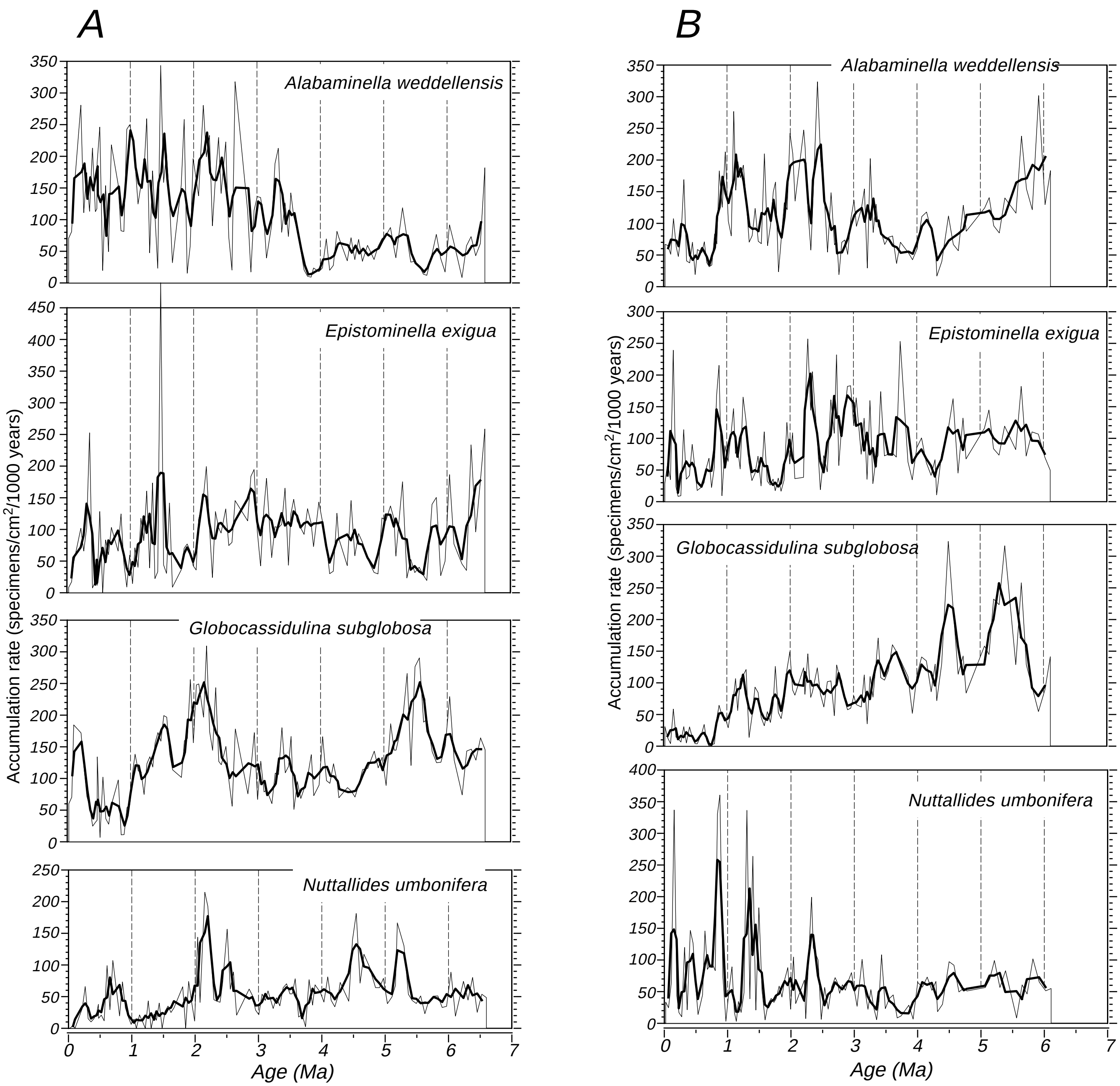

Figure 9. Accumulation rate area graphs for four species in Holes (**A**) 926A, (**B**) 928A, and (**C**) 929A, with the curves of three-point moving averages superimposed.

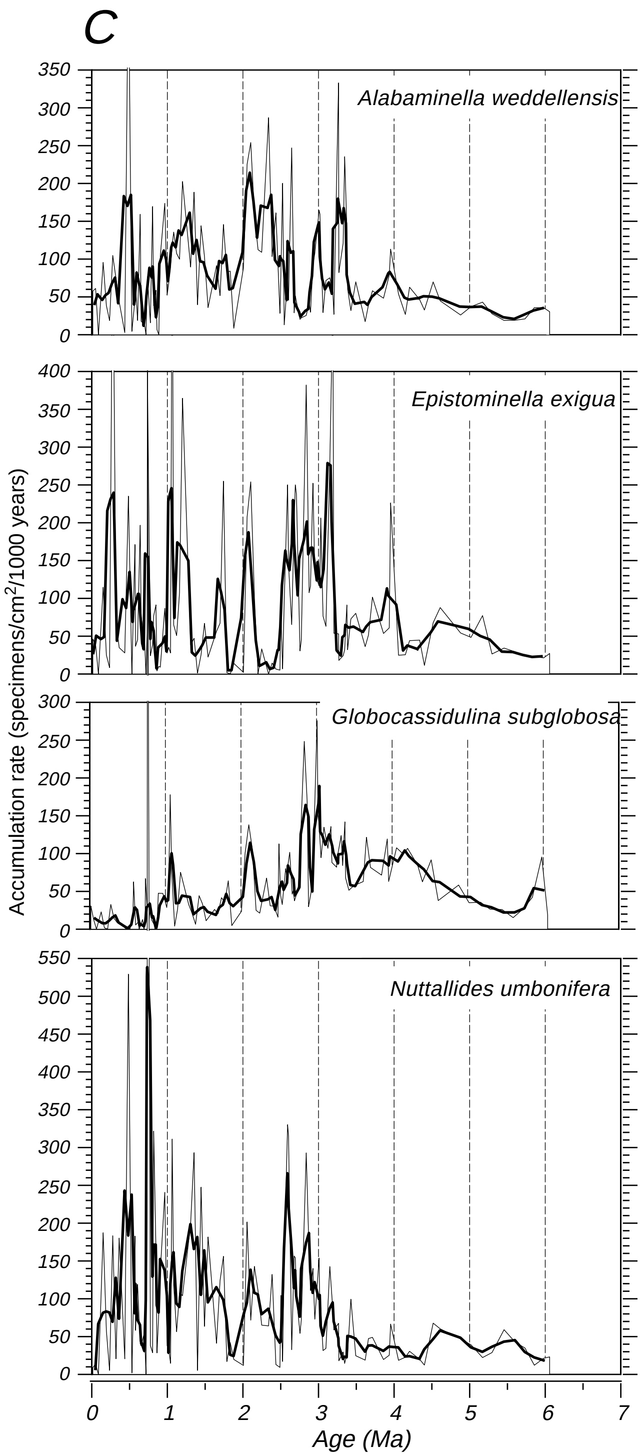

Figure 9 (continued).

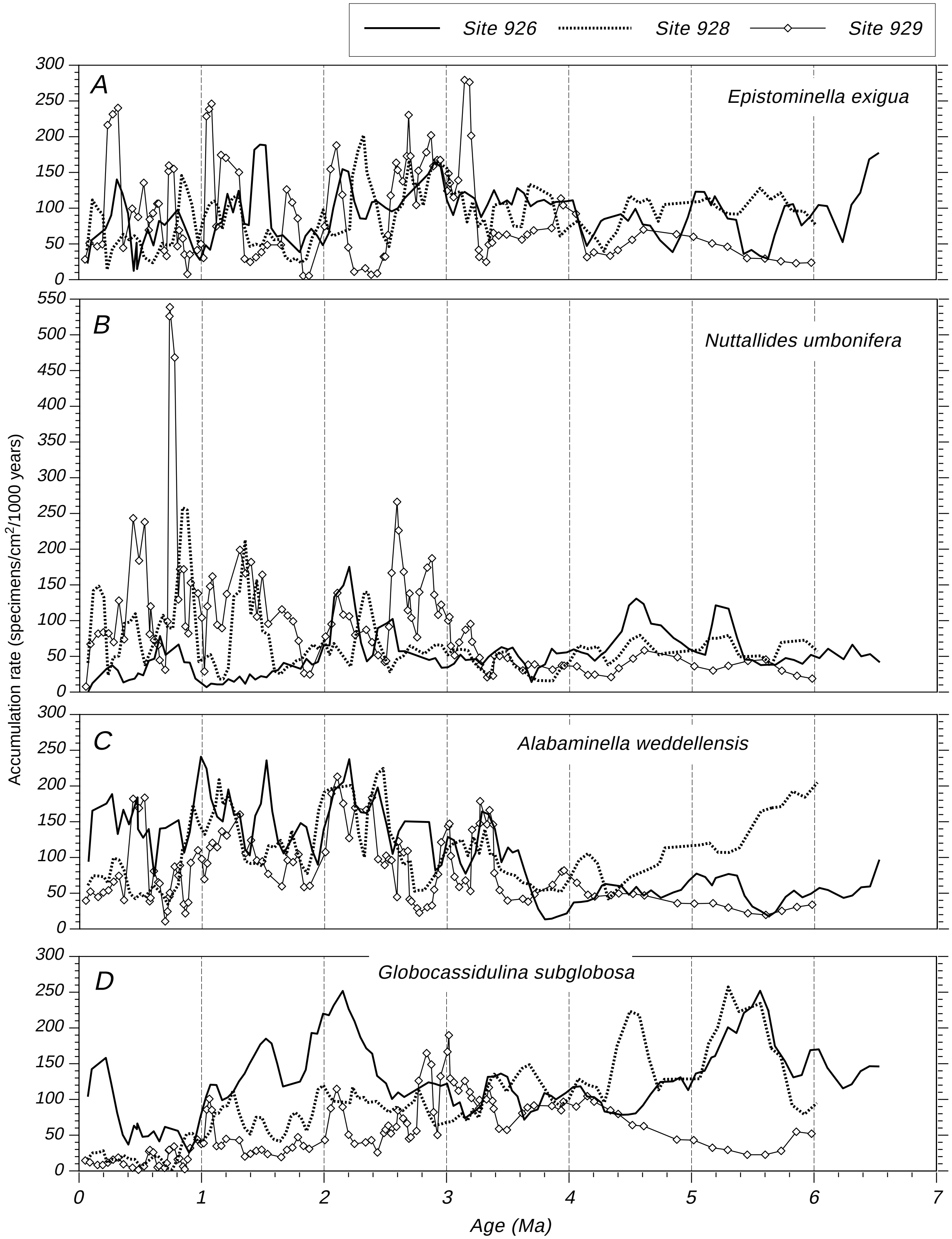

Figure 10. Three-point moving average curves of accumulation rates for four species in Holes 926A, 928A, and 929A. **A.** *Epistominella exigua.* **B.** *Nuttallides umbonifera.* **C.** *Alabaminella weddellensis.* **D.** *Globocassidulina subglobosa.*

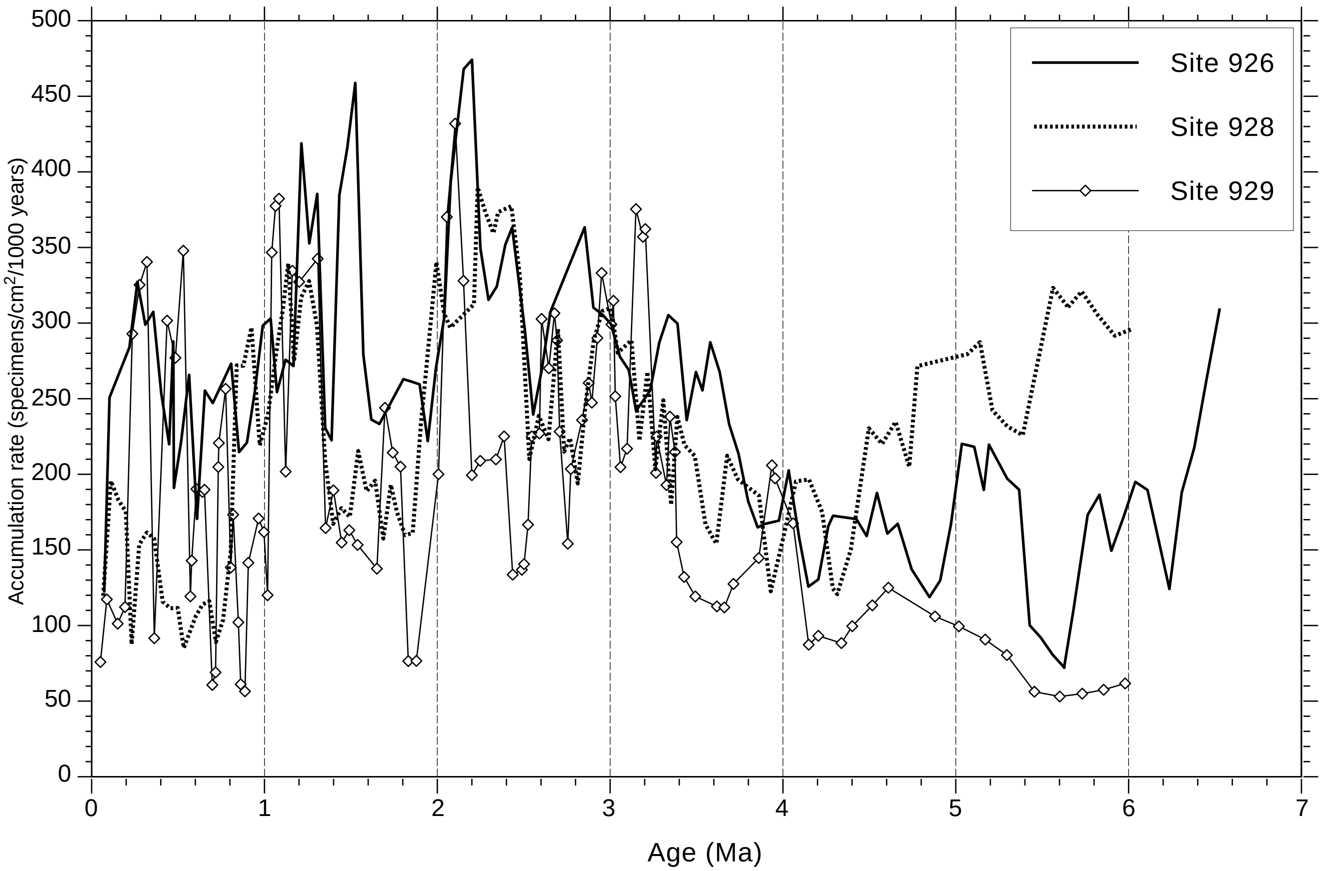

Figure 11. Accumulation rates of phytodetritus species (the sum of *Epistominella exigua, Alabaminella weddellensis, Epistominella* sp. A, and *Ioanella tumidula*) in Holes 926A, 928A, and 929A.

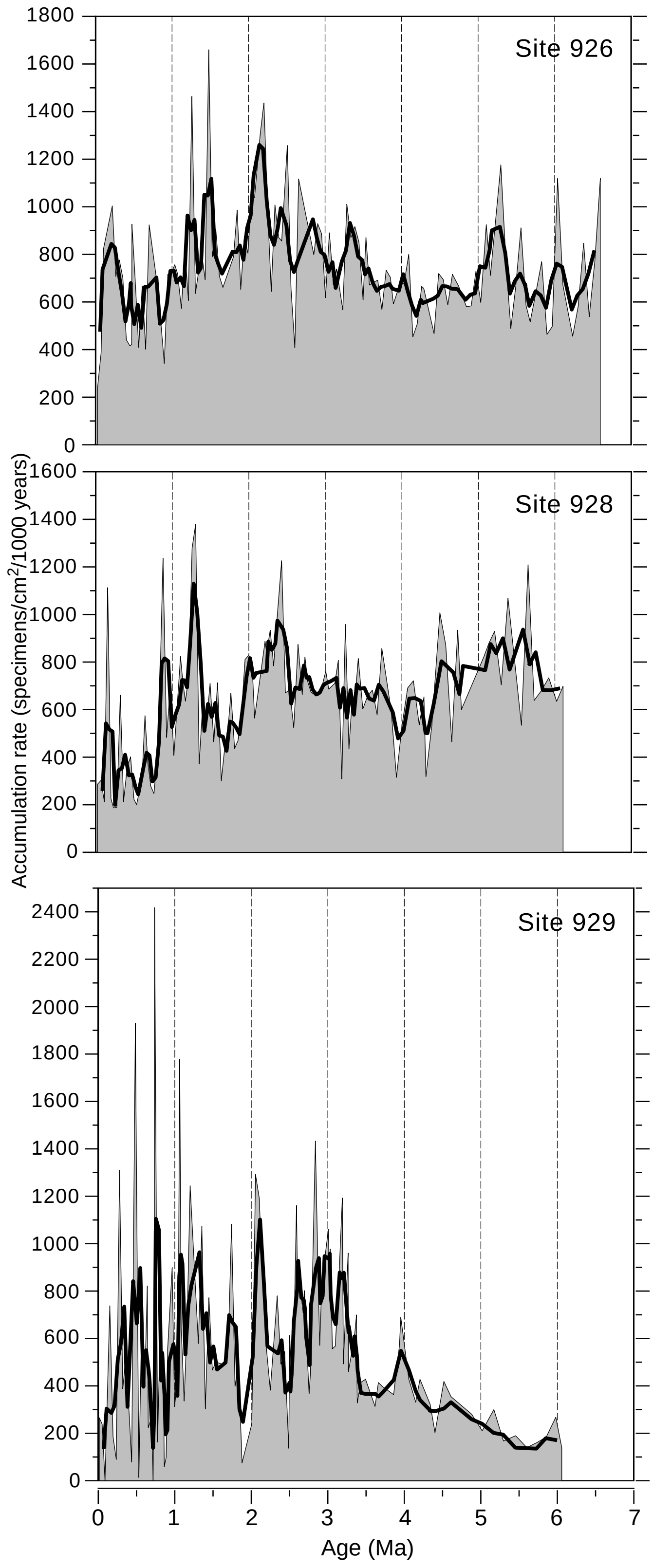

Figure 12. Accumulation rates of total individuals in Holes 926A, 928A, and 929A, with the curves of three-point moving averages superimposed.

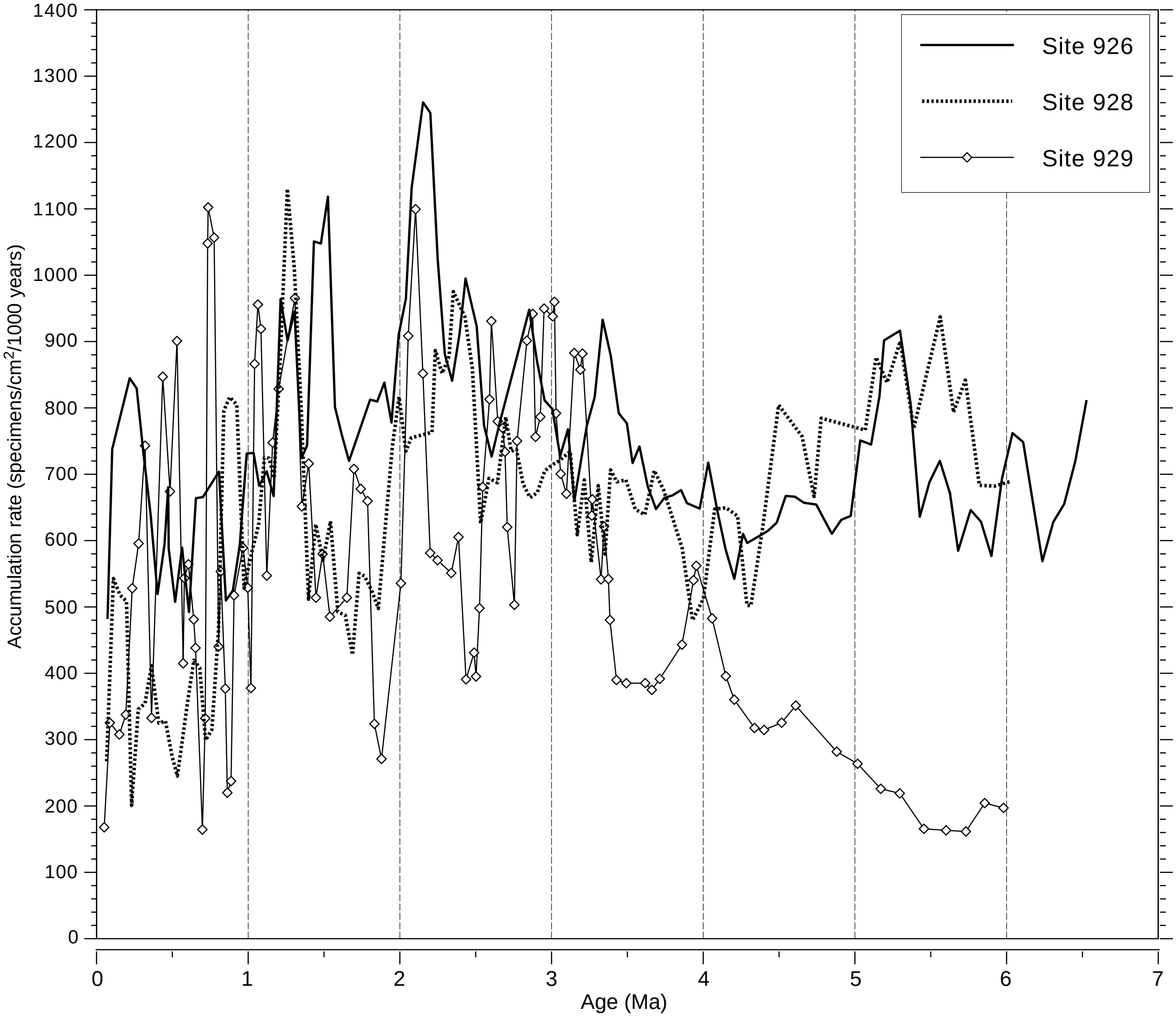

Figure 13. Accumulation rates of total individuals in Holes 926A, 928A, and 929A.

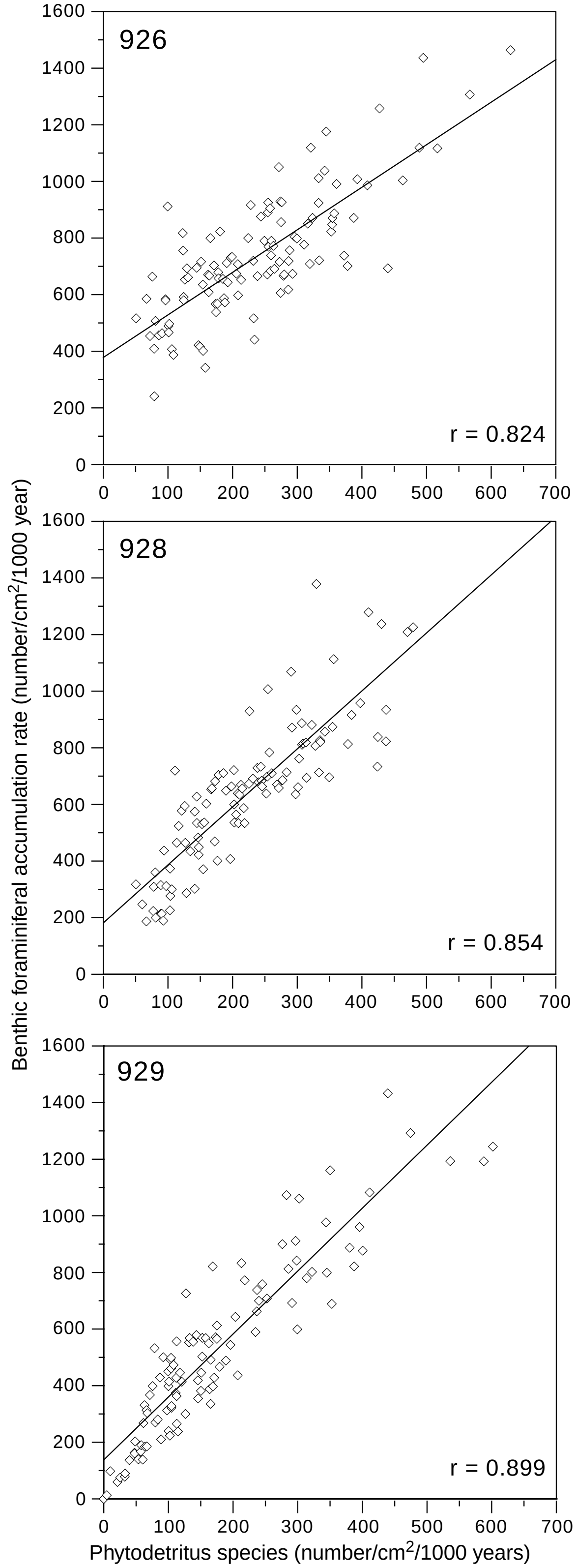

Figure 14. Correlation of accumulation rates between total benthic foraminifers and phytodetritus species in Holes 926A, 928A, and 929A.

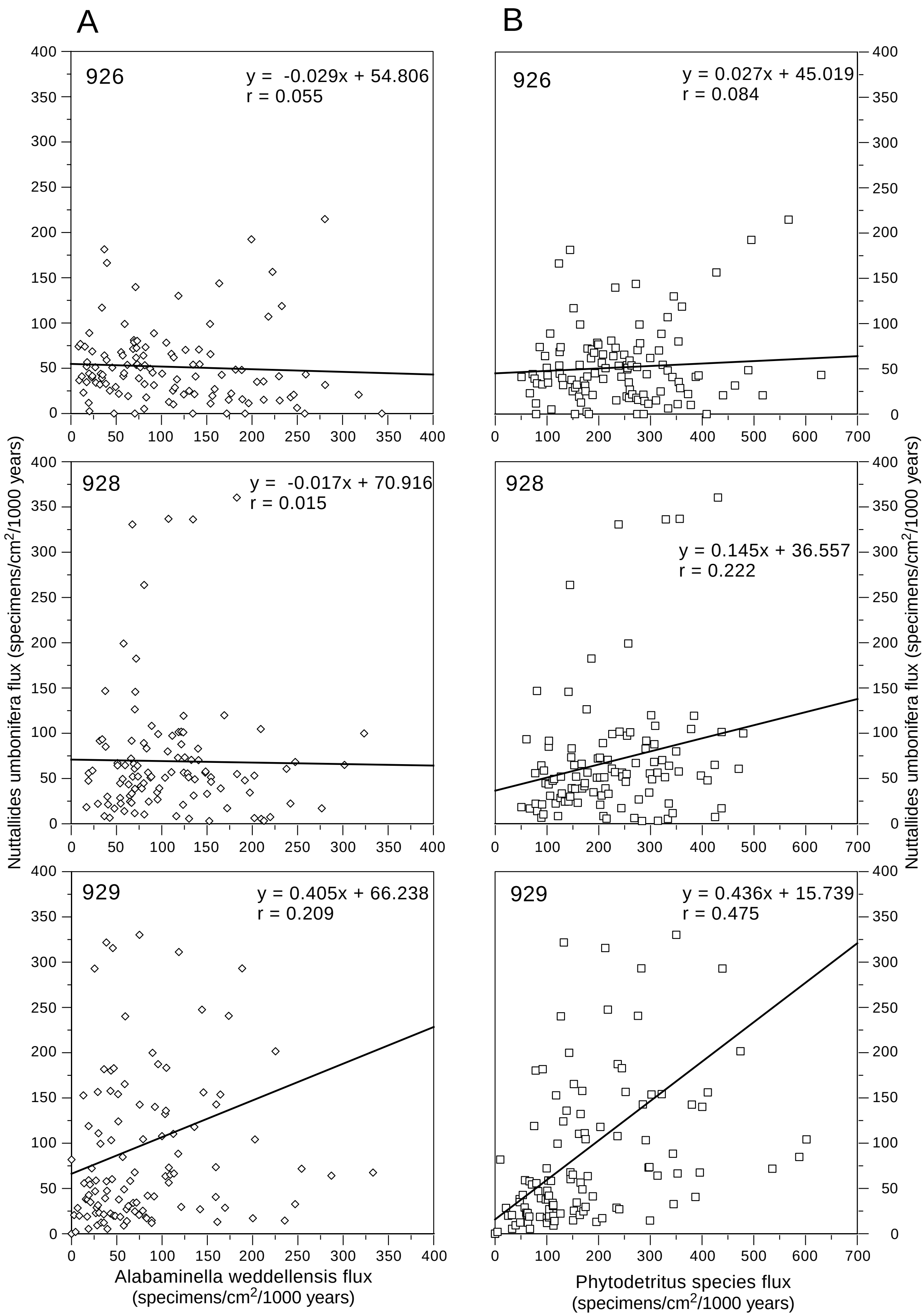

Figure 15. Correlation of accumulation rates between (**A**) *Nuttallides umbonifera* and *Alabaminella weddellensis*, and (**B**) *Nuttallides umbonifera* and phytodetritus species in Holes 926A, 928A, and 929A.

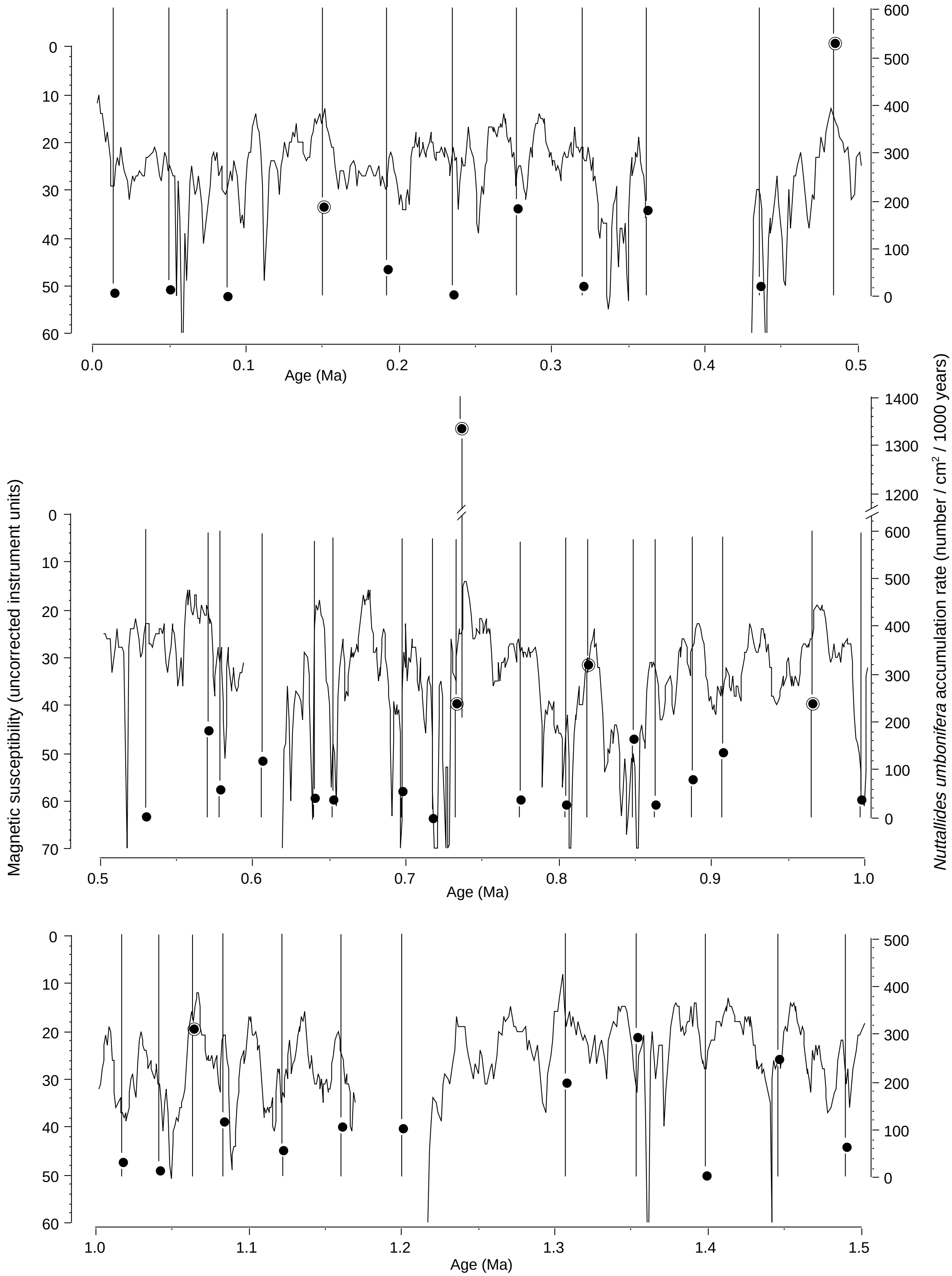

Figure 16. Correlation between magnetic susceptibility records and accumulation rates of *Nuttallides umbonifera* in Hole 929A during the last 1.5 m.y. Closed circles represent *Nuttallides umbonifera* accumulation rate values, and closed circles with open circle represent relatively high fluxes of *N. umbonifera* corresponding to low or lowest peaks of magnetic susceptibility.

APPENDIX

Faunal Reference List

Abditodetrix pseudothalmanni (Boltovskoy and Guissani de Khan). *Bolivinita pseudothalmanni* Boltovskoy and Guissani de Khan, 1981 (*fide* Loeblich and Tappan, 1988), p. 503, pl. 554, figs. 1–5.

Alabaminella weddellensis (Ealand). *Eponides weddellensis* Erland, 1936, *Discovery Repts.,* v. 13, p. 57, pl. 1, figs. 65–67.

Anomalinoides globulosus (Chapman and Parr). *Anomalina globulosus* Chapman and Parr, 1937, *Rep. Australasian Antarctic Exped.,* C, v.1, p. 119, pl. 9, fig. 27.

Astrononion echolsi Kennett, 1967, *Contrib. Cushman Lab. Foraminiferal Res.,* v. 8, p. 408, pl. 11, figs. 14, 15.

Bolivina pacifica Cushman and McCulloch. *Bolivina acerosa* Cushman var. *pacifica* Cushman and McCulloch, 1942, *Allan Hancock Pacific Exped.,* v. 6, p. 185, pl. 21, figs. 2, 3.

Bulimina alazanensis Cushman, 1927, *J. Paleontol.,* v. 1, p. 161, pl. 25, fig. 4.

Chilostomella oolina Schwager, 1878, *Boll. della Reale Comit. Geol. Italiana,* v. 9, p. 527, pl. 1, fig. 16.

Cibicidoides bradyi (Trauth). *Truncatulina bradyi* Trauth, 1884, *Denkschr. K. Akad. Wiss. Wien, Math. Naturwiss. Kl.,* v. 95, p. 235, pl. 4, figs. 7–9.

Cibicidoides kullenbergi (Phleger, Parker and Peirson). *Cibicides kullenbergi* Phleger, Parker and Peirson, 1953, *Rep. Swed. Deep Sea Exped.,* 1947–1948, v. 7, pl. 11, figs. 7, 8.

Cibicidoides mundulus (Brady, Parker and Jones). *Truncatulina mundulus* Brady, Parker and Jones, 1888, *Trans. Zool. Soc. London,* v. 12, p. 228, pl. 45, fig. 25a–c.

Cibicidoides robertsonianus (Brady). *Planorbulina* (*Truncatulina*) *robertsoniana* Brady, 1881, *Q. J. Microsc. Sci.,* new ser., v. 21, p. 65.

Cibicidoides wuellerstorfi (Schwager). *Anomalina wuellerstorfi* Schwager, 1866, *Novara Exp. Geol. Theil.,* v. 2, p. 258, pl. 7, figs. 105, 107.

Discorbinella bertheloti (d'Orbigny). *Rosalina bertheloti* d'Orbigny, 1839, *Historie naturelle des iles Canaries,* v. 2, p. 135, pl. 1, figs. 28–30.

Epistominella exigua (Brady). *Pulvinulina exigua* Brady, 1884, *Rep. Voy. Challenger, Zool.,* v. 9, p. 696, pl. 103, figs. 13, 14.

Globocassidulina subglobosa (Brady). *Cassidulina subglobosa* Brady, 1884, *Rep. Voy. Challenger, Zool.,* v. 9, p. 430, pl. 54, figs. 17a–c.

Gyroidina lamarckianus (d'Orbigny). *Rotalina lamarckiana* d'Orbigny, 1839, *Hist. Nat. Iles Canaries,* v. 2, p. 131, pl. 2, figs. 13–15.

Gyroidina regularis (Phleger and Parker). *Eponides regularis* Phleger and Parker, 1951, *Mem. Geol. Soc. Am.,* v. 46, pt. 2, p. 21, pl. 11, figs. 3a, b, 4a–c.

Gyroidina umbonata (Silvestri). *Rotalia soldanii* d'Orbigny var. *umbonata* Silvestri, 1898, *Accad. Pont. Nuovi Lincei, Mem.,* vol. 15, p. 329, pl. 6, figs. 14a–c.

Gyroidinoides neosoldanii (Brotzen). *Gyroidina neosoldanii* Brotzen, 1936, *Sweden, Sver. Geol. Unders. Avh.,* Ser. C, no. 396, p. 158.

Gyroidinoides orbicularis (d'Orbigny). *Gyroidina orbicularis* d'Orbigny, 1826, *Ann. Sci. Nat.,* ser. 1, p. 278.

Ioanella tumidula (Brady). *Truncatulina tumidula* Brady, 1884, *Rep. Voy. Challenger, Zool.,* v. 9, p. 666, pl. 95, figs. 8a–c.

Laticarinina pauperata (Perker and Jones). *Pulvinulina repanda* Fichtel and Moll, var. *menardii* d'Orbigny, subvar. *pauperata* Perker and Jones, 1865, *Philos. Trans. R. Soc. London,* v. 155, p. 395, pl. 16, figs. 50, 51a–c.

Melonis barleeanus (Williamson). *Nonionina barleeana* Williamson, 1858, *Recent Foraminifera of Great Britain,* p. 32, pl. 3, figs. 68, 69.

Melonis pompilioides (Fichtel and Moll). *Nautilus pompilioides* Fichtel and Moll, 1798, *Test. Microsc.,* p. 31, pl. 2, figs. a–c.

Nuttallides umbonifera (Cushman). *Pulvinulina umbonifera* Cushman, 1933, *Contrib. Cushman Lab. Foraminiferal Res.,* v. 9, pt. 4, p. 90, pl. 9, figs. 9a–c.

Oridorsalis tener (Brady). *Truncatulina tenera* Brady, 1884, *Rep. Voy. Challenger, Zool.,* v. 9, p. 665, pl. 95, figs. 11a–c.

Oridorsalis umbonatus (Reuss). *Rotalina umbonata* Reuss, 1851, *Z. Dtsch. Geol. Ges.,* v. 3, pl. 5, figs. 35a–c.

Pullenia bulloides (d'Orbigny). *Nonionina bulloides* d'Orbigny, 1846, *Foraminifères fossiles du Bassin Tertiaire de Vienne,* p. 107, pl. 5, figs. 9, 10.

Pullenia osloensis Feyling-Hanssen, 1954, *Norsk Geol. Tidskrift,* v. 33, no. 1–2, p. 133, pl. 2, fig. 3a, b.

Pullenia quinqueloba (Reuss). *Nonionina quinqueloba* Reuss, 1851, *Z. Dtsch. Geol. Ges.,* v. 3, p. 47, pl. 5, fig. 31.

Pullenia zaandamae (van Voorthuysen). *Anomalinoides barleeanum* (Williamson) var. *zaandamae* van Voorthuysen, 1952, *J. Paleontol.,* v. 26, no. 4, p. 680–681.

Pyrgo murrhina (Schwager). *Biloculina murrhina* Schwager, 1866, *Novara Exp. Geol. Theil.,* v. 2, p. 203, pl. 4, figs. 15a–c.

Siphotextularia catenata (Cushman). *Textularia catenata* Cushman, 1911, *Bull. U. S. Nat. Mus.,* v. 71, p. 23, figs. 39–40.

Sphaeroidina bulloides d'Orbigny, 1826, *Ann. Sci. Nat.,* v. 7, p. 267, modèles no. 65.

Stainforthia fusiformis (Williamson). *Bulimina pupoides* d'Orbigny var. *fusiformis* Williamson, 1858, *Roy. Soc., London,* p. 63, pl. 5, figs. 129, 130.

Tosaia hanzawai Takayanagi, 1953, *Tohoku Univ. Inst. Geol. Paleont., Short Papers,* no. 5, p. 30, pl. 4, figs. 7a, b.

Uvigerina hispida Schwager, 1866, *Geol. Teil,* v. 2, pt. 2, p. 249, pl. 7, fig. 95.

Uvigerina peregrina Cushman, 1923, *Bull. U. S. Nat. Mus.,* v. 104, pt. 4, p. 166, pl. 42, figs. 7–10.

Uvigerina proboscidea Schwager, 1866, *Geol. Teil,* v. 2, pt. 2, p. 250, pl. 7, fig. 96.

Previous Chapter Table of Contents Next Chapter