25. QUATERNARY AND PLIOCENE PLANKTONIC FORAMINIFERS OF THE NORTHEASTERN ATLANTIC (GOBAN SPUR), DEEP SEA DRILLING PROJECT LEG 80[1]

Claude Pujol and Josette Duprat, Département de Géologie et Océanographie, Université de Bordeaux I[2]

ABSTRACT

Quaternary to Pliocene planktonic foraminifers of the Goban Spur, off the Irish coast, were investigated for their biostratigraphic and environmental significance.

Three biostratigraphic zones were recognized in the Pliocene. The uppermost of these (the *Globorotalia inflata* Zone) includes the transition between the Pliocene and the Quaternary. The Quaternary (the *G. truncatulinoides* Zone) is subdivided into three subzones; from the base, the *G. truncatulinoides, G. hirsuta,* and *Turborotalita humilis* subzones. The thorough study of ecological assemblages of planktonic foraminifers led to the division of the Pliocene-Quaternary sequence into some 30 bioclimatic subdivisions. Some of them are correlated with isotopic stages.

The Pliocene/Quaternary boundary does not appear to be well marked in the foraminiferal assemblages. The first indication of cooling appears at the base of the Olduvai Event. The first appearance datum (FAD) of *G. truncatulinoides*, which is usually used as a marker of the Quaternary base, occurs at the Jaramillo Event.

A significant biological event, the first appearance of *G. hirsuta*, is dated as occurring approximately 470,000 yr. ago and marks an environmental change. It occurs during bioclimatic Subdivision XIII.

The surficial Quaternary paleoenvironments in the North Atlantic were studied. The hydrological environment is illustrated by estimates of summer and winter surface water temperatures. During glacial periods, water temperatures are assumed to have averaged approximately 5.8°C in summer and 0°C in winter. All year long, there is a difference of about 10°C between the present and glacial periods that is also characteristic of the changes in geographic regions that are subject to intermittent glaciation. The general pattern of temperature estimates shows that a slight general cooling has taken place from 470,000 yr. ago to the present.

Twenty-four species of planktonic foraminifers were identified. Some of the most abundant of these are illustrated.

INTRODUCTION

Quaternary sediments were recovered from three holes (Holes 548, 549A, and 550) that were drilled during Leg 80 in the northeastern Atlantic Ocean (Table 1, Fig. 1).

These holes are located on a transect of the Goban Spur, a structural high in the Variscan basement that is blanketed by a relatively thin sedimentary cover (see site chapters, this volume) and follows an ENE-WSW trend on the northwest European Atlantic continental margin north of the Bay of Biscay.

The Quaternary sediments in Holes 550 and 549A are marly calcareous foraminifer nannofossil oozes (Lithologic Unit 1, site chapters, this volume). The upper Quaternary sediments in Hole 548 are of the same type, but the lower Pleistocene and Pliocene sediments are reddish to grayish clay and nannofossil oozes (Lithologic Units 2 and 3, site chapters, this volume). The planktonic foraminifers in the three holes are generally abundant and well preserved. They are seldom heavily damaged or broken, although they are affected to varying degrees by dissolution.

The purpose of this study is twofold. First, we wanted to recognize and define the biostratigraphic framework of the whole Quaternary sequence. We extended our observations several meters into Pliocene sediments in order to establish accurate biostratigraphic reference points for the correlation of the Pliocene/Quaternary boundary. Second, we wanted to determine within the Quaternary sequence the chief stages of climatic change and to estimate the temperature of surface water for summer and winter during these stages.

Table 1. Quaternary data for Leg 80 holes.

Hole	Latitude (N)	Longitude (W)	Water depth (m)	Depth of cored section (m)	Number of samples
548	48°54′95	12°09′84	1256	110 (210[a])	147 (217[b])
549A	49°05′29	13°05′89	2535.5	27	52
550	48°30′91	13°26′37	4432	5.5	10

[a] Includes Pliocene section.
[b] Includes samples from Pliocene section and samples used for biostratigraphic investigation.

MATERIAL AND METHODS

Sampling that was random (with regard to the lithology) was carried out in the Hole 548 and 549A sediments; however, at least one sample was acquired per section. Because of the relatively high accumulation rate in the late Quaternary sediments in Hole 548 and the low accumulation rate at the base of the Quaternary sequence in Hole 549A (site chapters, this volume), we chose to consider the holes as complementary and used both to reconstruct a continuous and complete record of the Quaternary. It was possible to observe the biostratigraphic evolution of planktonic microfauna from the Pliocene upward in Hole 548 (Cores 35-16). In Hole 550 the Quaternary sequence recovered was short; it consisted of one core only.

Each sample (initial volume: 5-10 cm^3) was used to evaluate carbonate content. The samples were washed through standard sieves and

[1] Graciansky, P. C. de, Poag, C. W., et al., *Init. Repts. DSDP*, 80: Washington (U.S. Govt. Printing Office).
[2] Address: Département de Géologie et Océanographie, Avenue des Facultés, 33405 Talence Cedex, France.

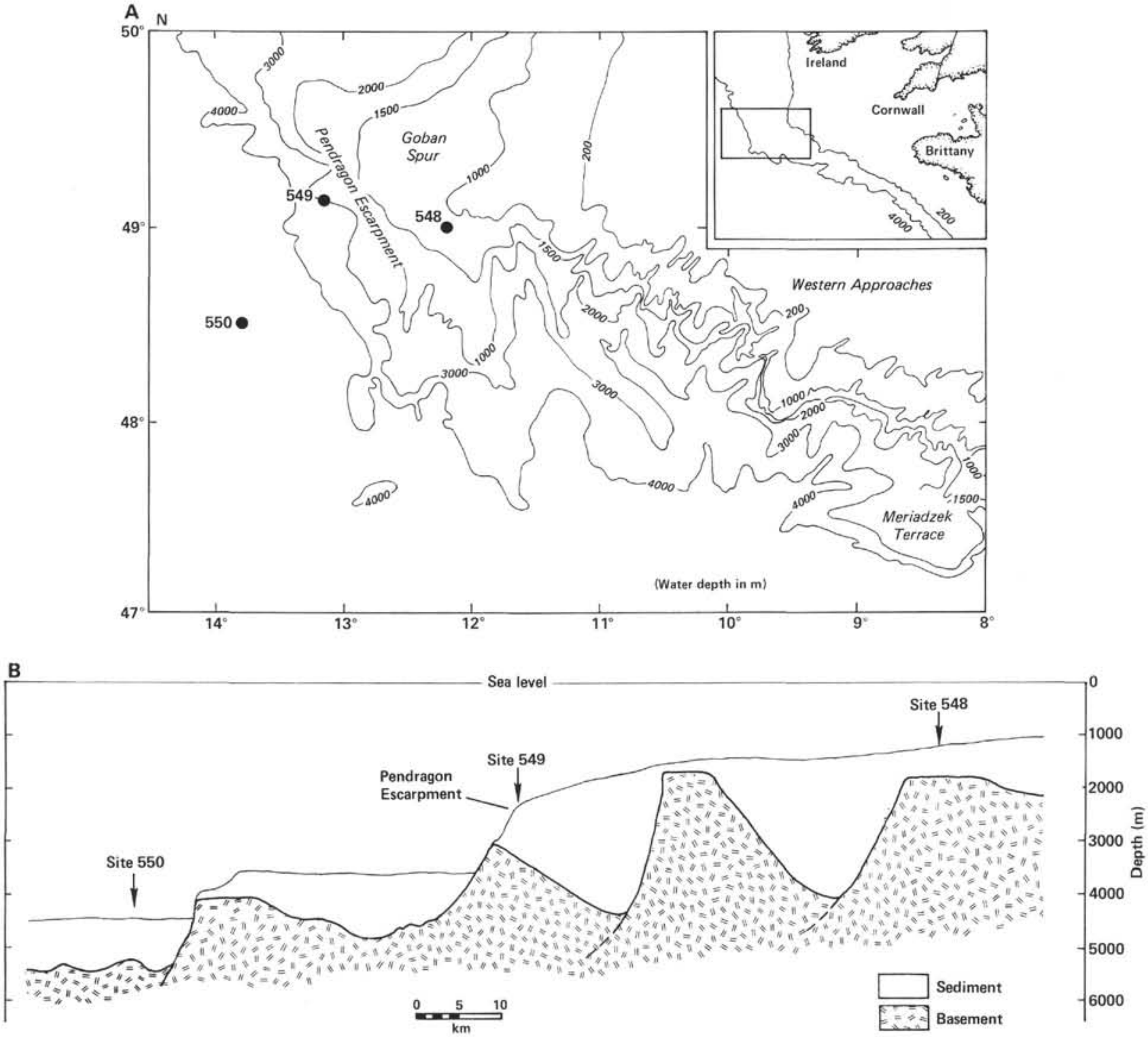


Figure 1. Location of Sites 548, 549, and 550. A. Position with respect to bathymetry. B. Position with respect to topography and sediment thickness. Quaternary sediment depths are 5.5 m at Site 550, 27 m at Site 549, and 101 m at Site 548.

weighed; the fraction sizes were >150 μm, 150 to 63 μm, and <63 μm.

Planktonic microfauna could be identified in the two larger size fractions. Abundances were established from the >150 μm size fraction; they are based on no fewer than about 300 specimens.

The distribution of the different species in each hole is summarized in Tables 2 to 4. The abundance, preservation, and dissolution of the planktonic microfauna are plotted for each sample.

REGIONAL FAUNAL ASSOCIATION

The present-day biocoenosis within the area investigated is an assemblage characteristic of temperate areas, and we have already determined the following specific proportions (Pujol, 1980); *Globigerina pachyderma* (left-coiling), 1.5%; *G. pachyderma* (right-coiling), 29%; *G. bulloides*, 36%; *G. quinqueloba*, 10%; *Globorotalia scitula*, 2%; *Globigerinita glutinata*, 13%; *Globorotalia inflata*, 7%; *Orbulina universa*, 1%; *Hastigerina siphonifera*, <1%. In addition, there are a few specimens of *Turborotalita humilis, G. hirsuta*, and *G. truncatulinoides*. The authors identified this microfauna as belonging to the biogeographic area of *Globigerina pachyderma* (right-coiling). It corresponds to a subdivision of the subarctic and transitional assemblages recognized by Bé (1977).

The faunal assemblage observed in surficial marine sediments (recent thanatocoenosis) is made up of the same species.

The Quaternary species recognized on the Goban Spur are as follows: arctic fauna—*G. pachyderma* (left-coiling); subarctic fauna—*G. pachyderma* (right-coiling), *G. bulloides, G. quinqueloba, Globigerinita uvula*; transitional or winter subtropical fauna—*Globorotalia scitula, G. inflata, Globigerinita glutinata, O. universa, H. siphonifera, Globorotalia truncatulinoides, G. hirsuta, T. humilis*; summer subtropical fauna—*Globigerinoides ruber, Globorotalia crassaformis* div. sp., *Globigerinoides conglobatus, Globigerina rubescens, G. falconensis, G. calida*; tropical fauna—*Globigerinoides trilobus, G. sacculiferus, Globorotalia menardii, Sphaeroidinella dehiscens, Globigerina digitata*.

Table 2A. Distribution of planktonic foraminifers in Hole 548 (Cores 1-5).

Depth below seafloor (m)	Core	Section	Interval (cm)	Abundance	Preservation	Dissolution	*Globigerina pachyderma* (left coiling)	*Globigerina pachyderma* (right coiling)	*Globigerina bulloides*	*Globigerina quinqueloba*	*Globorotalia scitula* (form 1)	*Globorotalia scitula* (form 2)	*Globigerinita glutinata*	*Globorotalia inflata*	*Hastigerina siphonifera*	*Orbulina universa*	*Globigerinoides ruber*	*Globorotalia crassaformis crassaformis*	*Globigerina cariacoensis*	*Globorotalia truncatulinoides*	*Globorotalia hirsuta*	*Globigerinoides conglobatus*	*Turborotalita humilis*
	1	1	0-3	A	G	2	T	C	P	P	R		R	P	R	R	R			R	R		P
			4-5	A	G	2	T	P	P	P	R		R	R	R	R	R			R	R		
			14-17	A	G	2	R	C	C	P	R		P	P	R	R	R			R	R		
			70-71	C	M		P	C	C	P	R		R	P		R				R	R		
		2	40-43	R	G	1	C		C	R	R			T									
			70-71	F	G	1	A		T														
			90-93	R	G	1	A	T		T													
4.		3	20-23	R	G	1	A	T	T														
	2	1	20-23	F	G	1	A	R	R	R	R		R										
			41-42	C	G	2	C	P	C	R	R		R	R		R							
		2	20-23	A	G	2	R	C	C	P	P		R	P		R							
		3	20-23	A	M	2	P	C	A	P	R		R	R									
		4	33-36	A	M	2	P	C	A	P	R		R	R									
			53-54	F	G	1	P	P	C	R	R		R	R									
		5	2-3	C	G	2	A	P	P	R	R		R	T									
			33-36	C	G	2		P	A	P	R		P	R					R				
			70-71	R	G	1	A	R	R														
		6	33-36	C	M	2	R	C	A	P	R		R	R		R					R		
13.5		7	33-36	C	G	2		A	C	P	R		R	R		R							
	3	1	34-35	C	G	3	C	P	C	P	R		R	R		P					R		
			56-57	A	G	2		C	C	P	R		P	P	T	R		T		R	R		
			76-79	A	G	2		A	A	P	R		P	P	R	R		R		R	R		
			113-120	A	G	2		A	C	P	R		P	P		R				R	R		
		2	76-79	A	G	2	P	C	C	R	R		R	P		R				R	R	R	
		3	76-79	A	G	1		C	C	R	R		R	P		R	R			R	R		
		4	76-79	C	G	2	R	C	C				R	P					R				
		5	76-79	F	G	1	A	R	P				R										
		6	76-79	C	G	1	A		R	R			R										
		7	29-32	C	G	1	A		R		T												
23.0	3	CC		A	G	1	R	C	C	R	R		R	P		R			T	R	T		
	4	1	61-65	A	G	2		C	C	P	R	T	R	P		R			T	R	R		
		2	61-65	A	G	2		A	C	R	R		R	R		R				R			
		3	61-65	C	G	2	P	C	C	P	R		R	P		R				T	T		
		4	61-65	A	G	2		C	A	P	R	T	P	P		R				R			
		5	61-65	C	G	1	C	P	P	P	R		R	P		R			T	T			
		6	20-23	C	G	1	R	C	C	P	R		R	P		R		R	R	R			
32.5		7	10-13	C	G	1	A	T						T									
	5	1	73-74	A	G	3		C	C	P	R		R	P		R		R		R	R		
		2	21-24	A	G	2		C	C	P	R	R	P	P		R	R	T	R				
			77-78	A	G	2		A	C	C	R	R	P	P		P	R		R	R			
		3	21-26	F	G	2	A	R	R							T			cf				
		4	21-24	A	G	1	P	C	C	P	R		P	C		P				T	T		
		5	21-24	C	G	1	R	A	C	R	R		R	P		R			T		T		
		6	21-24	F	G	1	A	R	R	R	R			R									
42.0		7	21-24	F	G	1	A		R														

Note: Species are plotted in order of appearance from the base of the hole. Species abundances are as follows: A = abundant (more than 30%); C = common (15–30%); P = present (3–15%); R = rare (< 3%); T = trace (isolated). For preservation, G = good, M = moderate, and B = bad. These conditions render the determination of species easy to difficult, very difficult, or impossible, respectively. For dissolution, blank = test not affected; 1 = slightly affected; 2 = damaged; 3 = severely damaged; 4 = partly destroyed; 5 = destroyed.

Within the Pliocene sequence there were recognized *Sphaeroidinellopsis seminulina, S. subdehiscens, Globorotalia margaritae, Globigerinoides obliquus, Globorotalia acostaensis, G. obesa, Globigerina atlantica, G. apertura, G. cariacoensis, Globorotalia crassula, G. triangula.*

Some of these are differentiated in morphotypes; others are grouped together.

FACTORS THAT DISTURB THE BIOSTRATIGRAPHIC RECORD

The transition of a planktonic foraminiferal biocoenosis to a thanatocoenosis and the preservation of the latter are subject to various factors that are related more or less directly to the submarine topography and the water depths of the different sites. Hole 548 was near the top of the continental slope that terminates the wide continental shelf (Fig. 1B). It was at 1256 m below sea level. Hole 549A was at the top of the Pendragon Escarpment, approximately halfway down the continental slope, at a water depth of 2535 m. Hole 550 was on the abyssal plain at 4432 m water depth.

Bathymetric position has effects with regard to both the reworking of displaced faunas and dissolution.

Reworked and Displaced Faunas

Reworked and displaced faunas occur in Hole 548 from Core 13 to Core 2, where a benthic microfauna that originated on the continental shelf was observed (Caralp,

Table 2B. Distribution of planktonic foraminifers in Hole 548 (Cores 6–9).

Depth below seafloor (m)	Core	Section	Interval (cm)	Abundance	Preservation	Dissolution	*Globigerina pachyderma* (left coiling)	*Globigerina pachyderma* (right coiling)	*Globigerina bulloides*	*Globigerina quinqueloba*	*Globorotalia scitula* (form 1)	*Globorotalia scitula* (form 2)	*Globigerinita glutinata*	*Globorotalia inflata*	*Globorotalia inflata* var.	*Hastigerina siphonifera*	*Orbulina universa*	*Globigerinoides ruber*	*Globorotalia crassaformis crassaformis*	*Globorotalia crassaformis ronda*	*Globigerina calida*	*Globorotalia crassaformis hessi*	*Globigerina cariacoensis*	*Globorotalia truncatulinoides*	*Globorotalia hirsuta*
	6	1	57-60	A	G	3	R	C	C	R	R		P	C		R	C								R
		2	16-19	A	G	3		C	C		R		P	C		P	P							R	
			95-98	C	M	3	T	C	P	P	R		R	P			P	T						R	
		3	16-19	C	M	2		C	P	P	R		R	P			T							T	
		4	16-19	C	G	2	T	P	P	R	P			C			R							R	
		5	28-29	F	G	2	A		R	R				T											
		6	16-19	F	G	1	A																		
51.5		7	13-19	F	G	1	A																		
	7	1	76-79	F	G	3	A	C	P			R													
		2	84-85	F	G	2	A	R	R														T		
		3	40-43	F	G	3	A	P	P	R	R	R	R	P			R								
			104-111	F	G	2	P	A	C				R	P		T	R						P		
		4	40-43	A	G	2		C	P	P	R	R	R	C	R		R						R		
			103-110	A	G	2		A	C	R	R	R	R	C	R		R								
		5	19-22	A	G	3	C	C	P		R	R	R	C			R								
			71-72	F	M	3		A	P	R			P	P		R	R							R	
			111-116	A	G	2		C	P	P	R	R	R	P			R						R	R	
			140-141	A	G	1	P	C	C	P	R		R	P									P		
		6	40-43	F	M	2		A	C	P	R	R	A	P			R							R	
			110-117	A	G	2		A	P	P		R	R	P		R	R	R			R		P	R	R
61.0		7	10-13	C	M	4		A	P	R	R	R	P	P			R	R	R		R			R	R
	8	1	69-70	A	M	3		A	R	R		R	R	P			R								
			120-122	A	G	2		C	P	P	R	R	R	P			R				R		P	R	
		2	40-47	A	G	2		C	C	P	R	R	P	P			R		R			R	P	R	
			90-91	C	M	2	R	C	P	R	R	R	R	P			R		R			R		R	
			140-147	A	G	1		A	P	R	R	R	P	P			R		R			R	R	P	
		3	69-70	C	M	1		A	P		R		R												
		4	20-27	A	G	1		A	P	R	R	R	R	P			R		P			P	R	R	
			90-91	F	M	1		A	P	R		P	P	P			R		R						
		5	20-22	A	G	1		A	C	R		R	R	C			A		R			R		R	
			69-70	C	M	2	R	A	C		C	P	R	C			R		R			T	R	T	
			103-110	A	G	2	A	A	C		R	R	R	P			R		T				R	T	
		6	69-70	A	G	1	A	A	C		R	R	R	P			R						P	T	
70.5			124-125	A	G	1	A	A	C		R	R	R	P			R						T		
	9	1	20-23	A	G	3	R	P	C		R	P	P	C								R		R	
			100-107	A	G	1	R	C	C	R	R	R		C					R	R		R	R		
		2	20-23	A	G	2	R	C	C	R	R		P	C		R	P	R	R	T		P		R	
			43-44	A	M	2	R	C	C		R		P	C			R		R	T	R	P	T	R	
			108-109	A	G	1	P	C	C		P	R	P	C		R	R	R	R	T			R	R	
75.		3	20-23	A	G	2		C	C		R	R	P	C		R	R						R	R	

this volume). Some planktonic microfauna have also been displaced. Redeposition and also grain size sorting by turbidite or contour currents are manifested by the frequent occurrence at some levels of small-sized microfauna and the relative abundance of shell fragments and resistant large forms at other levels. We disregarded samples from these levels in developing the biostratigraphy and reconstructing the paleoclimate.

Dissolution

In most of the samples examined the microfauna is quite well preserved and shows very few signs of dissolution. Although Hole 550 was at a water depth of 4432 m, dissolution was not particularly pronounced. Nevertheless, several levels, reflecting climatic conditions comparable to the present, show quite distinct evidence of dissolution, with foraminifers slightly affected to damaged. At Holes 549A and 548 the fauna is badly damaged at a few levels also.

The dissolution of planktonic foraminiferal calcitic tests may destroy the faunal association in whole or in part. It changes the nature of the association, which is usually interpreted as reflecting near-surface environmental conditions. An interpretation of environmental conditions must therefore be either disregarded or treated with particular care during biostratigraphic and paleoclimatic analyses. Other factors that can affect environmental reconstruction are drifts and bioturbation, which may mix or disturb original faunal associations. Environmental studies should, to the extent possible, avoid samples affected by any of these factors.

BIOSTRATIGRAPHIC ZONATION

The biostratigraphy established in this paper for the Quaternary sequences is based on planktonic foraminifers. We used the same faunal elements and criteria for this biostratigraphy as we did elsewhere in the northeast Atlantic (Pujol, 1980).

Table 2C. Distribution of planktonic foraminifers in Hole 548 (Cores 10–14).

Depth below seafloor (m)	Core	Section	Interval (cm)	Abundance	Preservation	Dissolution	*Globigerina pachyderma* (left coiling)	*Globigerina pachyderma* (right coiling)	*Globigerina bulloides*	*Globigerina quinqueloba*	*Globorotalia scitula* (form 1)	*Globorotalia scitula* (form 2)	*Globigerinita glutinata*	*Globorotalia inflata*	*Hastigerina siphonifera*	*Orbulina universa*	*Globigerinoides ruber*	*Globorotalia crassaformis crassaformis*	*Globorotalia crassaformis ronda*	*Globorotalia crassaformis oceanica*	*Sphaeroidinella dehiscens*	*Globigerina calida*	*Globorotalia crassaformis hessi*	*Globigerina cariacoensis*	*Globorotalia truncatulinoides*
	10	1	43-44	A	M	2		C	C	R	R	R	P	P	R	R	R	R							R
			121-122	A	M	3		A	C	R	T		P	C	T	R	R	R				R		R	R
		2	30-31	A	M	1	R	A	P	R	T	R	R	C	R	P	R	R				R			R
			126-129	F	G	1	P	P	P	P			P	P		P	R								T
		3	70-71	C	G	1	C				R	R	R	R		R									
			117-119	A	M	2	C	C	C		T		P	C	P	R		R	R						R
		4	43-44	A	M	2	P	A	C	R	T		R	C	R	R	R		R				T		T
			96-99	A	M	2	A	C	P	R			R	R	R	R									
			114-116	A	G	3	P	C	C	P	T	R	P	P	R	R									
		5	43-44	A	G	1	P	A	C	R		R	R	P	R							R	T		R
			120-122	C	M	2	P	A	P	R			R	P											T
		6	54-58	A	G	1	P	A	C	R		R	R	P	R	R	R	R	R						R
			88-90	C	M	2	R	A	C	R			R	P	R	R	R	R	R						T
80.0		CC		A	G	1		A	A	P	P	R	R	C	P	P	R	R	R	R			R		P
	11	1	52-53	A	G	1		A	C	R		R	R	P	R	R	R	P	P						R
			73-74	C	M	2		A	A	R			R	P	R	R	R	R	P						
			140-147	A	G	1	R	A			R	R	P	P	R	R	R	P	R				R		
		2	50-53	F	M	3		A	R			T	P						R						
			140-147	A	G	1		A	C	R		R	R	P	P	P	R	R	R			R			
		3	50-53	C	G	3		A	R				R	P		R		T	T			R			
			139-146	A	G	1		A	C	R			R	P	R	R	R	R	R				R		
		4	50-53	C	M	2		A	R				R	P		T		T							
			140-147	C	G	1		A	C			R	R	R		R		R	R				R		
		5	17-24	A	G	1		A	C	R	R	R	R	C	T	R	R	R	R				R		
			50-53	A	G	1		A	A	R	R		R	C	R	R	R	R	R				T		
			92-97	A	G	1		C	A	R		R	R	C	R	P	P	R	R	P	R	R	R		R
			143-150	A	G	1	R	C	A	R			R	C	R	P									R
		6	8-15	A	G	2		A	A	P		R	R	C	R	R	R								R
82.5		CC		A	G	1	R	A	A	P	R	R	R	C	P	P	R					R			T
	12	1	129-130	A	G	2	A	A	C	R	R	R	R	C	R	R	R								R
		2	36-37	F	G	3	C	C	C	R			R	C		R									
92		CC		A	G	2	P	A	A	P	R	R		C			P								
	13	1	130-137	A	G	1	R	A	C				R	C	R	I	R	R				R	R		
		2	35-38	C	G	2	P	C	P		R		R	C		P	T	R	R				R		
			120-121	A	G	3	A	A	P	R		R	R	P		R									
			137-138	A	M	3	C	C	P				R	P	R	R						R			
		3	22-29	A	G	2	C	C	A				R	C	R	P		R				R	R		
			105-106	C	M	3	C	C	P		R		T	P								R			
			120-121	A	G	2	C	C	P		R	R	R	P	R	R						R			
			130-131	A	G	2	A	C	P		R	R	R	P	R	R			T			R			
		4	35-38	A	G	3	C	A	P	R	R		R	C	R	R						R			
			95-96	A	G	3	C	C	C			R	R	C	R	R		T					R		
		5	35-38	A	G	2	C	C	C		R	R	R	C	R	R	R	R	R			R	P		
			130-132	A	G	2	C	C	A			R	R	C	R	P		T				R			
		6	27-34	A	G	2	P	C	C	R	R	R	R	C	R	R		R				R			
			81-82	A	G	2		C	C		R	R	R	C	R	R		R				R			
99.0		CC		A	G	2	R	C	C		R	R	R	C	P	P		P				R			
	14	1	4-7	A	M	3	R	R	C		T	R	R	C	R	R						R			
			40-47	A	G	2		C	C		R	R	R	C	P	R		R	R			R			
		2	84-91	A	G	1		C	A			R	R	C	P	P	R	P	R			R			
100.5		CC		A	G	2	R	A	A			P	R	C	P	P	R	P				R			

The Quaternary sequences at this midlatitude location in the North Atlantic have been given their character by the median position of the sites between the present and maximum (42°N) extent of glaciation (CLIMAP [Climate Long Range Investigation Mapping and Prediction] Project Members, 1976; Ruddiman and McIntyre, 1976). The biozonation must, therefore, take into account climatic fluctuations, which may be used to define bioclimatic subdivisions. These subdivisions are integrated with a biozonation that is defined by the following elements: species appearances and disappearances, the frequency and coiling ratio of *Globigerina pachyderma*, the presence and coiling ratio of *Globorotalia hirsuta* and *G. truncatulinoides*, and the presence of subtropical and tropical species (*G. crassaformis, Globigerinoides ruber, G. conglobatus*, and *Globorotalia menardii*).

Four zones, two of which were divided into three subzones each, were distinguished within the sedimentary Pliocene–Quaternary sequence at Holes 548, 549A, and 550. Figure 2 shows these zones and the species events used to define them. The base of the Quaternary was placed at the

Table 2D. Distribution of planktonic foraminifers in Hole 548 (Cores 15–18).

Depth below seafloor (m)	Core	Section	Interval (cm)	Abundance	Preservation	Dissolution	*Globigerina bulloides* var.	*Globorotalia puncticulata*	*Globorotalia atlantica*	*Globigerina pachyderma* (left coiling)	*Globigerina pachyderma* (right coiling)	*Globigerina bulloides*	*Globigerina quinqueloba*	*Globorotalia scitula* (form 1)	*Globorotalia scitula* (form 2)	*Globigerinita glutinata*	*Globorotalia inflata*	*Hastigerina siphonifera*	*Orbulina universa*	*Globigerinoides ruber*	*Globorotalia crassaformis crassaformis*	*Globorotalia crassaformis ronda*	*Globorotalia crassaformis oceanica*	*Sphaeroidinella dehiscens*	*Globorotalia crassula*	*Globorotalia* aff. *tosaensis*	*Globigerina calida*	*Globorotalia crassaformis hessi*	*Globigerina cariacoensis*
	15	1	44-45	C	M	3					C	C	R		R	R	C	P	R		P						R	R	
			112-119	A	G	1				P	C	C	R	R	R	P	C	P	P										T
		2	30-33	A	G	2				P	A	C	R	R	R	R	C	R	R										
			112-119	A	G	1				C	A	C	R	R	R	R	C	R	P										
		3	30-33	A	G	3				P	C	C	R	R		R	C		R										
			110-117	A	G	1				P	A	C		R	R	R	C	R	R		P	T					R	cf	
		4	3-4	C	M	3				P	C	C			R	R	C		R		P								
			12-13	A	G	1					A	C		R		R	C		R										
			27-28	C	M	3				P	A	C			R		C		R		R								
			110-117	A	G	1				R	A	C		P	P	R	C	R	R		R					T	R		
		5	30-33	A	M	2					A	C		P	R	R	C	R	R						R				
			63-68	A	G	1					A	C		P	P	R	C	R	R					T					
			92-97	A	G	1					A	C	R	R	P	R	C		R.										
			130-137	A	G	1					A	C			P	R	C	R	R						R				
		6	30-33	A	G	2					A	C	R	R	P	R	C	R	R										
			120-123	C	G	1					A	P		T	P	R	R		R		P	R	T						
108.5		CC		A	G	1					A	C	R	R	P	R	R			R	P	P	R	T					
	16	1	10-11	C	M	2					A	C		R	T				R		R	P							
			70-77	A	G	2					A	P		R	P	R			R		R	R		T					
			140-141	F	G	2					A	C			T				T		T								
		2	20-23	F	M	2					A	R						T											
			70-77	A	G	2					A	P		R	R			R	R		R	C	R						
			140-141	A	G	2					A	P		R	R			R	R		R	C	T						
		3	50-57	F	G	1					A	P		R	R				P		R	T							
			140-141	F	G	2					A	C						T											
		4	10-11	R	M						A	A																	
			70-77	A	G	3					A	C		R	P			R	P										
			140-141	F	M	3					A	R		T					T										
		5	10-11	F	G	2					A	P		T					R										
			70-77	A	G	2					A	C		R		R		R	P	T	P	R	R						
			140-141	A	G	3					C	C		R		R	R		R		P	P							
118.0		CC		A	M	3			R		A	A		R	P	R			R		P	P							
	17	1	53-57	C	G	2			R		C	A		T		R			P	T	P		R						
			113-120	A	G	2			P		A	C			P				R		P	R	R						
		2	50-57	A	G	3			P	R	R	P				P	R		R		P								
			105-112	C	M	2			C			P		R		P			R		R								
		3	51-58	A	G	2			A		R	C		R		P	R	R	R		C								
			103-110	A	G	1			C		C	A			C	P	C	R	R		C								
		4	53-56	F	G	3			C	R	P	C		R		P	R												
			100-107	A	G	1			P		C	C		R	R	P	C	R	P		P								
		5	50-57	A	G	2			C		C	A		R		P			R										
126.0		CC		A	G	1			C		A	C	P	R	R	P	P		R		C	R	R						
	18	1	45-47	C	G	2			C		C	C				P			R		C		R						
			102-109	A	G	1			C		A	A		R		P		R	R		P	R	R						
		2	45-47	F	M	3			C		P	C																	
			97-104	F	M	2			C		P	C				P			R										
		3	42-45	A	G	2		cf	C			C			R	P	P		R		R								
			99-106	C	G	2		cf	C	R	C	C		R		P			P		T								
		4	25-27	A	G	2	P		C	R	A	A				P	P		P										
131.0		CC		A	G	1		cf	A	R	A	C	P	R	R				P		A	P							

top of the Olduvai Event (1.72 m.y. ago) (Berggren et al., 1980). The Quaternary was divided into two zones, one of which had three subzones. Twenty-seven climatic subdivisions were recognized in the Quaternary, and three were recognized in the Pliocene.

Definition of Zones and Subzones

Zones are named after the taxon that appears at its base. Subzones are named after the most frequently occurring taxon. The zones are discussed below from the most recent to the oldest deposits. Zones that encompass a taxon's entire range are called taxon range zones (TRZs); zones that span only part of a taxon's range are called partial range zones (PRZs).

Globorotalia truncatulinoides Zone (TRZ)

Base: first appearance of *Globorotalia truncatulinoides*
Top: Recent (not defined)

This taxon appears suddenly, without any evident phylogenic transition from its presumed ancestor, *G. tosaensis*. The taxon appeared 880,000 to 900,000 yr. ago in the upper part of the Jaramillo Event. The zone is subdivided into three subzones, which are discussed below from top to bottom.

Turborotalita humilis Subzone (TRZ)

Base: first appearance of *Turborotalita humilis*
Top: Recent (not defined)

Table 2E. Distribution of planktonic foraminifers in Hole 548 (Cores 19–35).

Depth below seafloor (m)	Core	Section	Interval (cm)	Abundance	Preservation	Dissolution	*Sphaeroidinellopsis seminulina*	*Sphaeroidinellopsis subdehiscens*	*Globorotalia margaritae*	*Globorotalia acostaensis*	*Globigerina atlantica*	*Globigerinoides obliquus*	*Globigerinia pachyderma* (left coiling)	*Globigerinia pachyderma* (right coiling)	*Globigerina bulloides*	*Globorotalia scitula* (form 1)	*Orbulina universa*	*Hastigerina siphonifera*	*Globorotalia puncticulata*	*Globigerinita glutinata*	*Globorotalia obesa*	*Globigerina apertura*	*Globorotalia crassaformis crassaformis*	*Globigerinoides ruber*	*Globigerinoides sacculiferus*	*Globigerinoides trilobus*	*Globororotalia crassula*	*Globorotalia scitula* (form 2)	*Globigerina quinqueloba*	*Globorotalia inflata*	*Globigerina falconensis*	*Globorotalia crassaformis ronda*	*Globorotalia crassaformis oceanica*	*Globorotalia triangula*	*Globigerina bulloides* var.
	19	1	77-84	A	G	2					C			A	C	R	R	R					P					P		R		R			
			93-95	A	G	2					P			A	C	R	R	R		P			P					P		R	R	R			
		2	53-56	F	G	3					R				P		R			R			R												
			70-73	A	G	2					P			A	A	R	R	R	P	P			P					R		R		R	R		R
			94-101	A	G	2					P			C	A	P	R	R		P			C						R			R	R		T
		3	53-56	A	M	3								C	A	P	R			P			P									R			R
			104-111	F	G	1								A	C		R						R						R			R			
		4	2-8	A	G	1								C	C	P	R	R		P			P					R	R	P		P		R	
			45-48	F	G	2								C	C		R			P										R					
		5	53-56	A	G	2								C	C	P	R			P									R	R					
136.0		CC		A	G	1					R				C	P	R						C						R	R			R		
	20	1	33-36	A	G	1					R			A		R	R						P					R	R	R	R	R			
			100-107	A	G	2					P			A		P	R						P					P	R	P	R	P			
		2	33-36	A	G	2								A			P			P			P			R		P		R	R	R	R		
			100-107	A	G	2					P			A	A	R	R			P			C					R		R					
		3	33-36	C	G	3					A			A	A	P	P	R		P										P					
			100-107	A	G	3					A			A	A	P	R		T	P			R												
141.0		CC		A	G	1					A		R	A	C	P	R	R	R	C		P	C					P		R	R				
	21	2	120-123	A	G	1							R	A	C	P	R	R	P	C		R	R				R	C	R	R	R				
146.0		3	37-39	A	G	2					R		R	A	C	P	R	R	C	C			P			R	C	C		R					
152.0	22	CC		C	M	2					T			C	A		R		C				C					P		aff					
156.0	23	CC		A	G	1					P			P	A	P	P	R	C				C												
161.0	24	CC		A	G	1							R	C	A	P	P	P	P			P	C						R						
166.0	25	CC		A	G	2					C			P	C	P	R	R	C	P			C					P							
171.0	26	CC		A	G	1					A			P	C	P	P	R	P	P		P	C												
176.0	27	CC		A	G	2					A			R	C	P	R			R		P		R			C								
181.0	28	CC		A	G	1					A		R	P	C	P	R	R	P	R		P	R				R								
186.0	29	CC		A	G	1					P	R	R	P		P	P	R	C	P		R	P		R	R	C								
196.0	31	CC		A	G	1			C		P	R	T	C	A	R	R		C	P		P	cf	R											
201.0	32	CC		A	G	1			C	P	P	R	T	P	A	R	R		A	P		P													
206.0	33	CC		A	G	2			P	P	C	R	R	C	A	P	P		R			P													
209.0	34	CC		A	G	1			C	C	P	P	R	C	A	R	R		R	P		P													
211.0	35	CC		A	G	1	R	R	C	P	R	C	R	C	A	P	R	aff	T	R	R	P													

This small species, which is seen most often in size fractions between 150 and 63 μm, has a limited vertical distribution at the latitude of the Bay of Biscay. In the northeast Atlantic, *T. humilis* is present only in the upper part of the postglacial period, or Isotopic Stage 1 (Pujol, 1980).

Globorotalia hirsuta Subzone (PRZ)

Base: first appearance of *Globorotalia hirsuta*
Top: first appearance of *Turborotalita humilis*

G. hirsuta appears in the northeast Atlantic (Pujol, 1980) close to the *Pseudoemiliania lacunosa* last appearance datum, that is, approximately 470,000 yr. ago (Thierstein et al., 1977). This level is constant from the Azores Archipelago to Ireland in the regional distribution of the taxon.

Globorotalia truncatulinoides Subzone (PRZ)

Base: first appearance of *Globorotalia truncatulinoides*
Top: first appearance of *G. hirsuta*

Globorotalia inflata Zone (PRZ)

Base: disappearance of *Globigerina atlantica*
Top: first appearance of *Globoratalia truncatulinoides*

This zone includes the upper part of the Pliocene and the early Quaternary. The taxon begins to occur more frequently and attains its characteristic form in the middle of the zone, close to the base of the Olduvai Event. The first period of glaciation, which is reflected in a sudden and important increase in Arctic fauna (*Globigerina pachyderma*, left-coiling), also takes place during the Olduvai Event.

Globigerina atlantica Zone (PRZ)

Base: disappearance of *Globorotalia margaritae*
Top: disappearance of *Globigerina atlantica*

Globoratalia crassaformis and *G. crassula* develop within this zone. The first *G. inflata* individuals evolve gradually from *G. puncticulata*. This zone is part of the late Pliocene. Two subzones were distinguished. They are described below from top to bottom.

Globorotalia crassaformis ronda Subzone (PRZ)

Base: first appearance of *Globorotalia crassaformis* ronda
Top: disappearance of *G. atlantica*

The last specimens observed of the *G. puncticulata* species were at the base of this subzone. The *G. crassaformis* group begins to develop at this level.

Table 3. Distribution of planktonic foraminifers in Hole 549A (Cores 1–3).

Depth below seafloor (m)	Core	Section	Interval (cm)	Abundance	Preservation	Dissolution	*Globigerina pachyderma* (left coiling)	*Globigerina pachyderma* (right coiling)	*Globigerina bulloides*	*Globigerina quinqueloba*	*Globorotalia scitula* (form 1)	*Globorotalia scitula* (form 2)	*Globigerinita glutinata*	*Globorotalia inflata*	*Globorotalia inflata* var.	*Orbulina universa*	*Hastigerina siphonifera*	*Globorotalia truncatulinoides*	*Globigerinoides ruber*	*Globorotalia crassaformis* s.l.	*Globigerina calida*	*Globigerina rubescens*	*Globigerina digitata*	*Globigerina cariacoensis*	*Globorotalia inflata* var.	*Globorotalia hirsuta*	*Globorotalia menardii* group	*Globigerinoides conglobatus*	*Globigerinita uvula*	*Turborotalia humilis*
	1	1	1-4	A	G	2	R	A	C	R	R		C	C		R	R	R	R				T			R				R
			8-11	A	G	2	R	A	C	P	R		C	C		R		R	R			R				R				R
			39-42	A	G	1	A	P	P	R	R		P	P		R	R	R	R							R			T	R
			42-45	C	G	1	A	R	R	R			R	R		R		T	T			T				T				
			137-140	C	G	1	A	P	P	P	R		R	R		R		T								T				
		2	2-5	C	G	1	A	R	C	P	R		R	R		R		T												
			5-8	C	G	1	A	R	P	C	R		R	R																
			70-77	C	G	1	A		R	R			T	T		T														
			130-137	C	G		A	R	P	P	R		R	T																
		3	10-13	A	G	2	C	P	C	P	P		C	P				T								T				
			20-23	A	G	2	P	C	C	P	R		P	P		R		R								R				
			70-77	A	G	1	C	P	C	P	R		P	A		R										T				
			125-131	A	G	1	P	A	C	P	R		P	P		R	R	R	R	R		R				R				
		4	10-13	A	G	1	P	A	C	P	R		P	P		R	R	R	R	R						R		R		
			20-23	A	G	1	P	A	C	C	R		P	P		R		R	R			T				R		T		
			40-43	A	G	2	P	A	C	P	R	T	P	P		R	R	R	P	R		R				R		R		
			54-57	C	G	1	C	C	C	P	R		P	P		R		R	R				R			R				
			72-78	A	G	1	C	C	C	P	R		P	R		R				R		T				R				
			88-93	A	G	1	C	P	A	R	R		P	R		R						R				T				
			100-103	A	G	1	C	P	C	P'	R		P	R		R														
			105-109	A	G	1	A	C	C	P	R		P	R		R						R				T				
		5	20-23	C	G	1	A	C	C	P	R		P	P		R		R	R	T						R				
			90-97	C	G		A	R	T	R			R																	
7.47			144-147	A	G	1	C	A	C	P	R	T	P	R		R		R				T				R	R			
	2	1	3-6	A	G	2	P	A	C	P	R		P	P		R	R	R	R	R						R				
			10-16	A	G	1	C	A	C	P	R		P	P		R		R	R							R				
			20-23	C	G	1	C	A	C	P	R		P	P		R		R	R							R				
			55-58	A	G	2	C	A	C	C	P		P	P		R		R	R							R				
			102-108	A	G	1	P	A	P	P	P		P	C		R		R	R	R						R				
			135-138	A	G	1	P	C	C	R	P		P	P		R		R								R				
		2	10-13	A	G	1	P	A	C	P	P	R	P	C				R					T			R				
			20-23	A	G	1	R	A	P	P	P	R	P	P		R		R	R							R				
			56-63	A	G		P	A	C	P	R		R	R		R		R	R							R				
			95-98	A	G	1	R	A	P	R	P		R	P				R	R	R						R				
			100-107	C	G		A	P	R	R	R		R	R				R	R							R				
		3	15-18	C	G	1	A	P	R	R	R		R	R		R		T	T			T								
			20-23	C	G		P	C	P	P	R					R														
			58-65	A	G	1	R	A	P	P	R		R	R		R		R		R						R				
			93-96	A	G	1	P	A	C	C	R		R	P		R	R	R	R	R		R				R				
			107-113	A	G	2	R	A	P	P	R		R	P		R	R	R	R	R		P				R	T	R		
			132-135	C	G	1	A	C	P	P	R		P	P		R		R	R	R						R				
		4	23-30	F	G		A	P	R	R	R		R									T								
			50-53	F	G		A	C	P	P	R		P	R																
			74-77	A	G	1	A	C	P	P	P		R	R		R		R		T	R	R								
			120-127	F	G		A	R	R	R	R																			
		5	10-13	C	G		A	A	C	P	R		R	R		R		R		R						R				
			20-23	C	G		A	A	C	P	R	T	P	P		R	R	R	R	R		R								
			50-57	F	G		A	R	R	T			T					T												
			80-83	A	G	2	P	A	P	R	R		R	P		R	R	R		T		R				R				
		6	20-23	C	G	2	C	A	C	P	R·		R	P		R		T		T		R								
			64-71	C	G	3	A	A	P	P	R		R	R		R														
16.			103-110	C	G	1	P	A	C	P	R		P	P		R		R	R							R				
	3	1	2-5	A	G	3	P	A	C	P	R	T	P	P		R	T	R			R	R				R				
			7-14	F	G		A	R	R	T		T	T	R		T														
			40-41	F	G	3	A	P	P	R	R		R	R	R			R												
			89-92	R	G	1	C	C	P	R	R		R	R	T	R						R								
		2	40-41	C	G	1	C	A	P	P	R		R	P		R						R			P					
			51-54	C	G		A	R	T	R															T					
			89-96	A	G	1	C	A	P	R	R		R	P		R			T	T										
			115-118	A	G	1	R	A	P	R	R	T	R	P		R	R	R								R				
			138-139	A	G		R	A	C	R	R	R	R	C		R	R	R				R				R				
			147-150	A	G	1	R	A	C	P	R		P	C		R	T	R	R	R		R				R				
		3	29-32	A	G	1	R	A	C	P	R		P	C		R	T	R		R	R									
			41-48	A	G	1	P	A	P	P	R	T	R	P		R	R	R	R	R	T	R								
			70-71	A	G		P	C	C	C	R	T	P	C		R						R								
			99-102	A	G		P	A	C	P	R		P	A		P		R		R		R								
			132-134	A	G	1	P	A	C	P	R	R	P	A		R	R	R	R	R	R	R	T	P						
		4	1-4	C	M	2	C	C	P	R	R	R	R	R		R	R	R	R	R		R								
			47-48	A	G	1	P	P	C	P	R		R	C		R	R			R		R								
			64-67	A	G	1	A	P	P	P	R	R	R	P		R	R			R		R								
			105-110	A	G		C	C	C	P	R		P	C		R	R	R	R	R		R								
		5	16-19	A	G	1	A	C	P	P	R	R	R	P		R	R		R	R										
			47-48	C	G	1	C	C	C	C	R		P	P		R	R		R											
			80-83	A	G	1	R	A	P	P	R		R	P		R		R	R	R										
			120-127	A	G		A	R	R	R	R	R	R	R		R				R										
		6	0-7	A	G		A	R	R	R	R	R	R	R																
			46-49	A	G		A	C	C	P	P	R	R	P		R	R	R	R	R	R									
			80-84	A	G		C	C	C	P	R		P	P		R	R	R	R	R										
27.	3	CC		A	G		A	C	P	P	R		P	P		R	R	R	R	R										

Note: The order in which species appear and their abundance, preservation, and dissolution are as defined in Table 2.

Table 4. Distribution of planktonic foraminifers in Hole 550 (Core 1).

Depth below seafloor (m)	Core	Section	Interval (cm)	Abundance	Preservation	Dissolution	*Globigerina pachyderma* (left coiling)	*Globigerinia pachyderma* (right coiling)	*Globigerina bulloides*	*Globigerina quinqueloba*	*Globorotalia scitula* (form 1)	*Globigerinita glutinata*	*Globorotalia inflata*	*Orbulina universa*	*Hastigerina siphonifera*	*Globorotalia truncatulinoides*	*Globorotalia hirsuta*	*Turborotalita humilis*	*Globigerinoides ruber*	*Globorotalia crassaformis* s.l.	*Globigerinoides conglobatus*	*Globigerina digitata*
	1	1	7-14	A	G	2	P	A	A	C	C	C	C	C	P	C	C	P	P			R
			30-33	A	G	2	P	A	C	P	P	P	C	R	R	P	R	R	R			R
			100-107	F	G	1	A	P	R				T									
		2	23-30	C	G	1	A	C	C	R	R	R	R			T						
			60-62	F	G	1	A	C	C	R		R	P									
			130-137	C	G	1	A	C	C	R	R	P	P									
		3	18-21	F	G	1	A	C	C	R		R	R									
			93-100	F	G	1	A	C	R	R			R									
			130-137	C	G	2	R	A	C	P	P	C	C	P		P	C		R	T		
		4	34-38	A	G	1	R	A	C	C	P	C	C	P	P	P	P		R	R		R
5-37			80-87	C	G	2	C	P	C	C	P	C	P	P	P	P	P		P	R	P	R

Note: Species order, abundance, preservation, and dissolution as defined in Table 2.

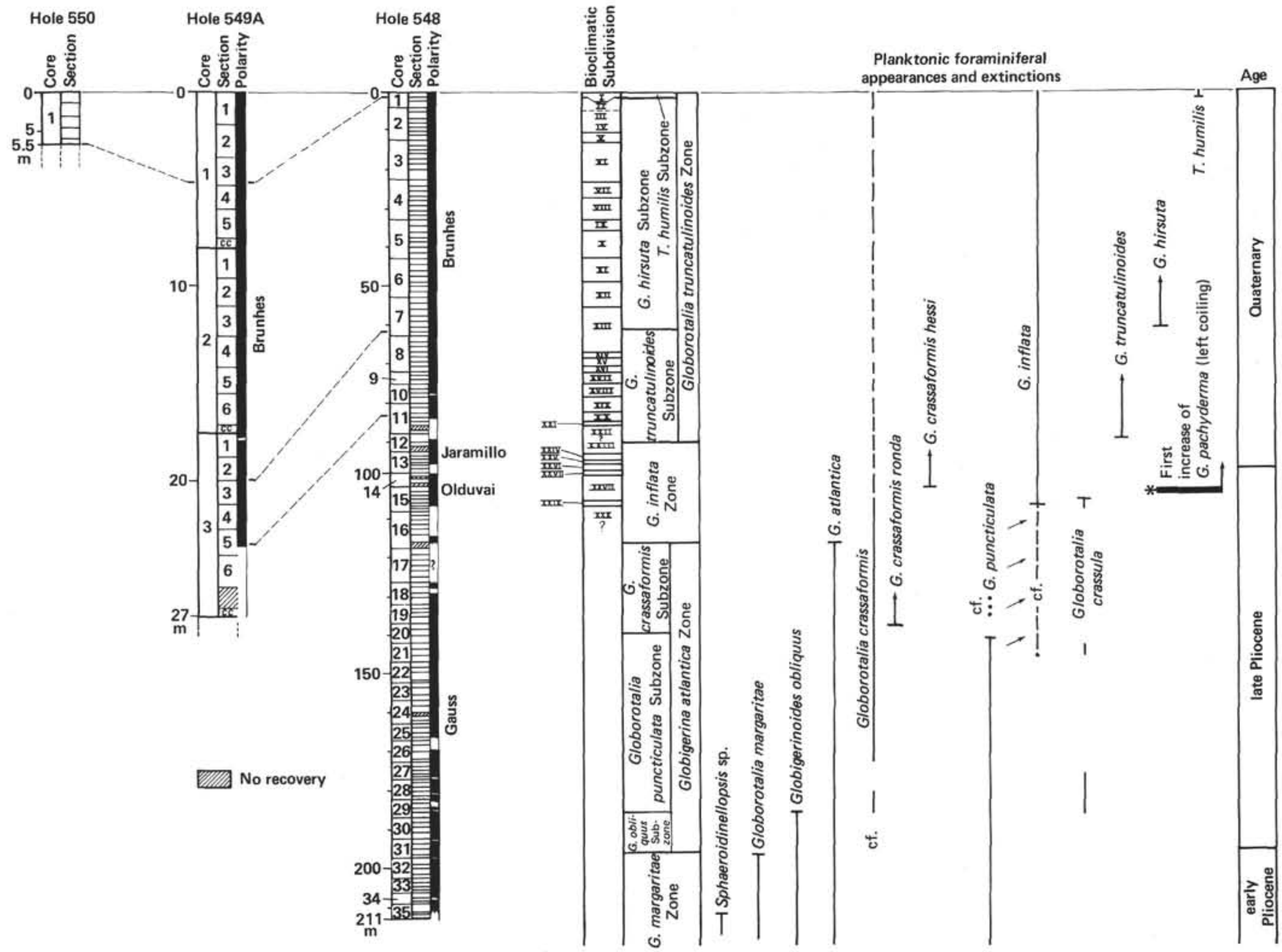


Figure 2. Biozonation of the Pliocene–Quaternary at Holes 548, 549A, and 550 with the planktonic foraminiferal datum levels.

Globorotalia puncticulata Subzone (PRZ)

Base: last appearance of *Globigerinoides obliquus*
Top: first appearance of *Globorotalia crassaformis ronda*

G. aff. *inflata* appears at the top of this subzone and *G. crassula* at the base.

Globigerinoides obliquus Subzone (PRZ)

Base: disappearance of *Globorotalia margaritae*
Top: disappearance of *Globigerinoides obliquus*

Globorotalia margaritae Zone (taxon range not defined)

Base: not observed
Top: disappearance of *Globorotalia margaritae*
This zone is assigned to the early Pliocene.

The characteristics of this biozonation are intimately related to the climatic conditions that prevailed over the North Atlantic during the Quaternary. The location of the sites near the center of the zone affected by the movement of the polar front makes the biozonation particularly interesting.

However, no satisfactory comparison can be made with the tropical and equatorial regions, where the hydrology was not influenced by the polar (cold) water. Equatorial zonations (Blow, 1969; Ericson and Wollin, 1956 and 1968; Bolli and Premoli Silva, 1973; Pujol and Duprat, 1984) cannot therefore be accurately correlated with the biozonation we have developed.

Bioclimatic Subdivisons of the Quaternary

Quaternary climatic variations correspond to variations in the volume of ice. In the North Atlantic, the building up and the spreading out of ice caused the movement of glaciers toward low latitudes, and consequently the displacement of Arctic microfauna. The farthest south the glaciers moved was about 42°N (CLIMAP Project Members, 1976).

The variations in climate are reflected on the Goban Spur in an increase in Arctic planktonic microfauna (*G. pachyderma*, left-coiling). A high proportion of this form (90–100% sinistral) suggests the proximity or presence of polar water near the Goban Spur. Conversely, a low proportion of this taxon and the simultaneous presence of subtropical microfauna reflect postglacial and/or interglacial conditions.

We used the microfauna at the Goban Spur to divide the Quaternary into 27 bioclimatic episodes or subdivisions. Episodes that resemble the climate of the present day (warm climatic stages) are marked by odd Roman numerals. Cold climatic stages are marked by even Roman numerals. All the episodes are essentially biologic subdivisions. Chronological correlations were made later on. Because of greater faunal variability, warm episodes proved easier to differentiate than cold episodes. Figure 2 and the figures presented for each site show the distribution of the bioclimatic subdivisions.

The following observations may be made about the bioclimatic subdivisions. First, from the pattern of recent deposits, it appears that the *T. humilis* Subzone corresponds or is equivalent to Subdivision I and that the *G. hirsuta* Subzone corresponds to Subdivisions II to XIII (upper part). Subdivisions II, III, and IV correspond to the last glacial stage. Caralp (1971) and Caralp et al. (1974) investigated the equivalent period in the Bay of Biscay, although they used the usual Alpine nomenclature. The available samples permit only a weak differentiation of these episodes, although Episode III can be recognized as an interstage.

The base of Subdivision V is characterized by the disappearance of *Globigerinoides conglobatus* and the presence of *Globorotalia crassaformis*. The disappearance of both taxa was detected during the last interglacial period (Isotopic Stage 5) throughout the northest Atlantic at latitudes above 42°N (Pujol, 1980).

Subdivision VII is distinguished by a temporary increase in the proportion of sinistral *G. truncatulinoides*. Pujol, Duprat, et al. (1974) designated this period in the Bay of Biscay Episode O.

Subdivision IX is characterized by the brief presence of the tropical species *G. menardii*. The presence of this species, which was also observed in the Bay of Biscay, is worthy of mention because this is the only time this tropical species invades such high latitudes during the Quaternary. A similar invasion takes place close to the Azores Archipelago during Isotopic Stage 9 (Pujol, 1980).

Subdivision XI is difficult to term a warm stage. There is a slight dominance of the sinistral population of *G. truncatulinoides*.

Some forms considered a variety of *G. inflata* occur in very limited amounts during Subdivision XII.

The middle part of Subdivision XIII is marked by the appearance of *Globorotalia hirsuta*.

The subdivisions above are correlated respectively to Isotopic Stages 1 to 13, which could be recognized in Hole 548 in Cores 1 to 8 and in Hole 549A in Core 1 to Core 3, Section 2 (Vergnaud Grazzini et al., this volume).

The *G. truncatulinoides* Subzone includes the lower part of Subdivision XIII to the upper part(?) of Subdivision XXIII.

Warm Episodes XV, XVII, XIX, and XXI (upper part) are normally characterized by a subtropical microfauna, the most significant species of which are *G. truncatulinoides* and *G. crassaformis*. The *G. crassaformis* species is represented by the subspecies *ronda* and *hessi*. Subdivision XIX is found at the Brunhes/Matuyama paleomagnetic reversal.

G. truncatulinoides appears in Subdivisions XXII to XXIII, which together may be considered synchronous to the base of the *G. truncatulinoides* Zone.

The base of the Quaternary (top of the Olduvai Event) is included in the upper part of the *G. inflata* Zone. Subdivisions XXIII(?) to XXVII are also part of the *G. inflata* Zone. Subdivision XXVIII, which is located within the Olduvai Event, corresponds to the first cold episode and is characterized by the frequent occurrence of Arctic microfauna. The first terrigenous evidence of ice-rafting was observed below this limit.

It was not possible to compare or correlate Subdivisions XIV to XXX with the isotopic stages recognized by Vergnaud Grazzini et al. (this volume).

HOLE 548

In Hole 548, continuous coring with the hydraulic piston corer resulted in the nearly complete recovery of an excellent Quaternary and Pliocene sequence 211 m thick (Fig. 3 and Table 2). Thirty-five cores were recovered. The top of the Olduvai Event was located at 101.1 m sub-bottom (Core 15, Section 1).

The Pliocene–Quaternary sequence consists of three lithologic units (site chapter, this volume). The first unit as one proceeds from top to bottom (Cores 1–8) is made up of alternating olive gray marly calcareous and nannofossil ooze. In Subunit 1a (from the surface to Core 7, Section 5), carbonate content varies widely (from 50 to 10%), with cyclical characteristics (Fig. 3A). In Subunit 1b (Core 7, Section 5 through Core 8), the range of the cyclical variation is lower.

Lithologic Unit 2 ranges from Core 9 through Core 15. The sediments consist of reddish or grayish clay and foraminifer–nannofossil oozes. The carbonate content is relatively constant in Cores 9 and 10 (Fig. 3B). Carbonate content decreases to a low value in Core 11, Section 4, close to the Brunhes/Matuyama paleomagnetic reversal. The underlying deposits undergo rather wide variations. Probably because of a decrease in accumulation rate, cycles are more difficult to identify than in the upper part of Unit I.

A third lithologic unit (Cores 16–35) consists of homogeneous greenish gray bioturbated nannofossil ooze. Variations in carbonate content are rapid down to Core 20 (Fig. 3C). Below Core 20 the more scattered sampling does not allow the documentation of such variations as those above. Nevertheless, it is possible that the lithology within Unit 3 is uniform.

The maximum values of carbonate content correspond to maxima in the coarse (sand) fraction, and minimum values of carbonate content correspond to maxima in the fine grain size fraction (Fig. 3). There is a significant change in grain size in the Pliocene–Quaternary sequence at the base of Core 15. Sediments of very fine grain size predominate from Core 15 to 35; the sediments are practically free of a coarse fraction, in contrast to the coarse sediments in the upper part of the hole (Cores 1–15).

All the biostratigraphic zones, subzones, and bioclimatic subdivisions described in the previous section were recognized in Hole 548. The lowest Quaternary sediments occur in Sample 548-15-1, 110–112 cm (the top of the Olduvai Event). The base of the *Globorotalia truncatulinoides* Zone, which is defined as the appearance of the taxon, occurs in Core 12, Section 1, 129–130 cm (during the Jaramillo Event). *G. hirsuta* occurs for the first time during the Brunhes Event (Core 7, Section 7, 10–13 cm, Fig. 3A). Finally, *Turborotalita humilis* appears only in Core 1, Section 1, 0–3 cm.

The thickness of the *G. hirsuta* Subzone indicates a rapid sedimentation rate that could be the result of supplementary supply from the continental shelf. The base of the subzone is marked by a sharp change in both lithology and carbonate content.

The disappearance of *Globigerinoides conglobatus* within Core 3, Section 2, 76–79 cm, occurs within climatic Subdivision V; *Globorotalia menardii* occurs only in climatic Subdivison IX (Core 5, Section 2, 77–78 cm), and *G. inflata* var. occurs only in climatic Subdivision XII (Core 7, Section 4).

The population of *G. hirsuta* is predominantly right-coiling, but at the top of the hole (climatic Subdivisions II, III, and IV) it becomes predominantly left-coiling. It is dextral from its appearance in Subdivision XIII to Subdivision V. The population of *G. truncatulinoides* is predominantly right-coiling, although some sinistral pulsations or coiling ratio changes were noted in climatic Subdivisions V, IX, XI, and XIII.

In the *G. truncatulinoides* Subzone (Fig. 3B) the sedimentation rate is lower than in the previous subzone. The planktonic foraminiferal assemblages during both warm and cold episodes are similar to the assemblages in the *G. hirsuta* Subzone. However, there is an important increase in the occurrence of *G. pachyderma* (right-coiling) in Cores 11 and 12, an increase that defines a separate assemblage. The cold climatic subdivisions in this interval (XX and XXII) are characterized not by the Arctic species *G. pachyderma* (left-coiling) but by the subarctic dextral population. This assemblage persists until the upper part of the *G. inflata* Zone (Jaramillo Event). The Quaternary base, which is included in the upper *G. inflata* Zone, is characterized by cyclical variations in fauna in which *G. pachyderma* (left-coiling) again marks the cold episodes (Figs. 3B and 4). The first incursion of a typical polar fauna occurs in Core 15, Section 4, that is, largely below the top of the Olduvai Event. The grain size of the sediment increases in Sample 548-15-6, 120–123 cm.

The transition between Pliocene and Quaternary sediments (*G. inflata* Zone) was observed between Core 16, Section 1, 140–141 cm and Core 16, Section 5, 10–11 cm. It is characterized by very fine-grained sediments containing very small microfossils. *G. inflata* becomes abundant and morphologically typical above Core 25, Section 6, 30–33 cm; below that level it is quite rare and noncharacteristic.

Only the core catchers were analyzed in the Pliocene sequence from Cores 16 to 20 (Fig. 3C). In this sequence the gradual evolution between *G. puncticulata* and *G. inflata* takes place.

G. crassula appears within the *G. puncticulata* Subzone. As shown in Figure 3D, the quite restricted range of this species is marked by a change from dominantly dextral at the bottom (Core 29) to dominantly sinistral at the top (Core 27). The opposite trend takes place during the Pliocene in the *G. crassaformis* population.

Finally, *G. margaritae* (always left-coiling) is found from the base of the hole to the core catcher for Core 31; it characterizes early Pliocene sediments.

HOLE 549A

The three cores examined from Hole 549A represent a Quaternary sequence 27 m long that corresponds to

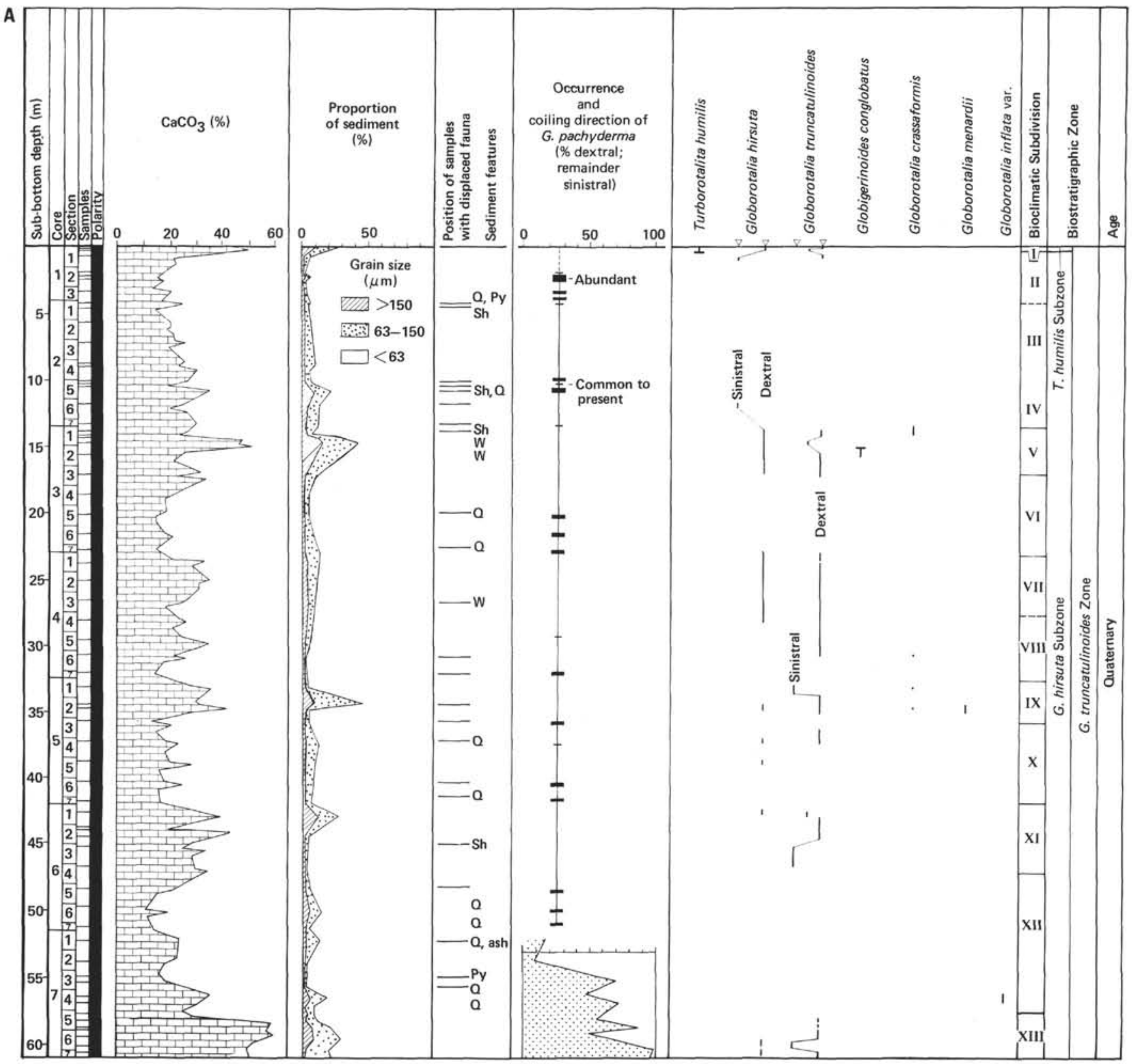


Figure 3. Analysis results for Hole 548. A. Cores 1 to 7. B. Cores 8 to 16. C. Cores 17 to 25. D. Cores 26 to 35. Py = pyrite, Q = quartz, Sh = shell fragments, W = winnowed. The occurrence of species that appear in both left- and right-coiling forms is shown by a line that moves left and right according to the proportion of individuals of these types within the population.

Lithologic Unit 1 (site chapter, this volume). The sequence comprises marly calcareous nannofossil and foraminifer-nannofossil oozes. The Brunhes/Matuyama paleomagnetic reversal is located betwen 24 and 24.79 m sub-bottom (in Core 3, Section 5, between 50–52 cm and 129–131 cm; Townsend, this volume). Carbonate content varies cyclically from 60 to 10%. The peaks in carbonate content are directly associated with peaks in the coarse sediment fraction, which in turn comprises mostly planktonic foraminiferal shells. A sudden lithlogic and microfaunal change between Cores 2 and 3 suggests the existence of a sedimentary gap. The *Globorotalia truncatulinoides* Zone and the *Turborotalita humilis, G. hirsuta*, and *G. truncatulinoides* subzones have been determined (Fig. 5, Table 3).

The *T. humilis* Subzone is limited to Sample 549A-1-1, 39–42 cm.

The first occurrence of *G. hirsuta* was observed in Core 3, Section 2, 147–150 cm. It was not possible to determine the first occurrence of *G. truncatulinoides*.

An examination of the coiling direction of *G. pachyderma* from the top of this site shows a succession of warm episodes (in which there is an abundance of right-coiling forms) and cold episodes (in which there is an

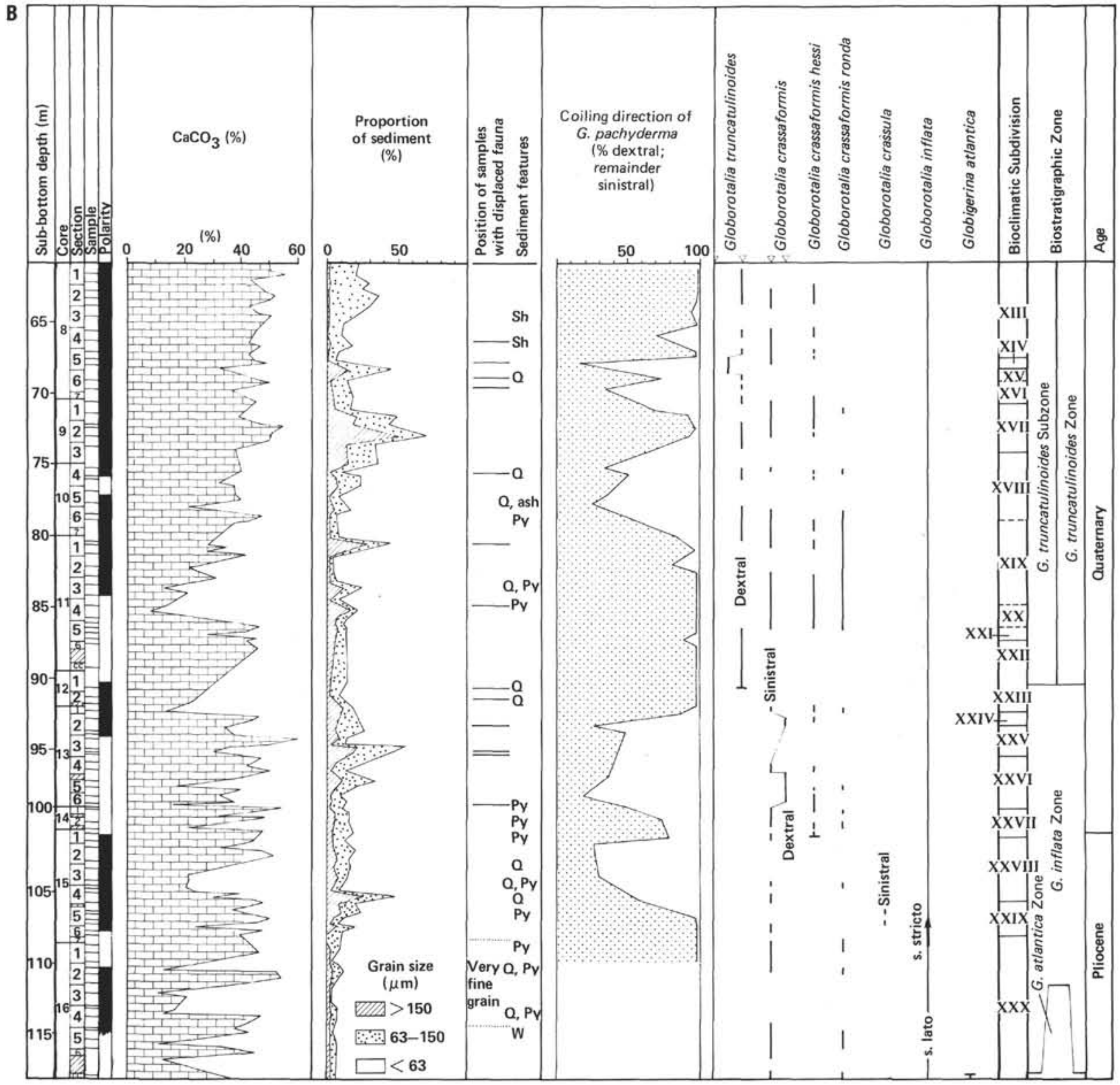


Figure 3. (Continued).

abundance of left-coiling forms). The warm episodes correspond perfectly to the peaks in carbonate content.

Thirteen bioclimatic subdivisions were distinguished within the *T. humilis* and *G. hirsuta* subzones. The hypothetical gap between Cores 2 and 3 mentioned above is reflected in a sudden change in faunal assemblage that takes place between Subdivisions XI and XII. It was difficult to determine the boundary between Subdivisions XII and XIII. The occurrence of *G. inflata* var. in Core 3, Section 2 from 40–41 cm to 51–54 cm led us to locate Subdivision XII at these levels.

The disappearance of *Globigerinoides conglobatus* was detected in Core 1, Section 4, 10–13 cm. *Globorotalia menardii* occurs punctually in Core 2, Section 3, 107–113 cm. *G. hirsuta* is right-coiling in climatic Subdivision I and throughout most of the rest of its range; it is dominantly sinistral only in Subdivisions II, III, and IV.

For the *G. truncatulinoides* species, three sinistral pulsations of the dominantly right-coiling population were observed in climatic Subdivisions VII, XI, and XIII.

The location of the Brunhes/Matuyama paleomagnetic reversal suggests that the sediment accumulation rate diminishes below the base of the *G. hirsuta* Subzone (Subdivision XIII), or approximately 470,000 yr. ago. The fluctuations in the coiling direction of *G. pachyderma* allow us to define Subdivisions XIV to XXI but without any accuracy.

HOLE 550

Only one surficial core 5.5 m long was recovered from Hole 550 (Fig. 6). The hole was at a water depth of 4432 m, and the sediments consist of Quaternary foraminifer–nannofossil oozes.

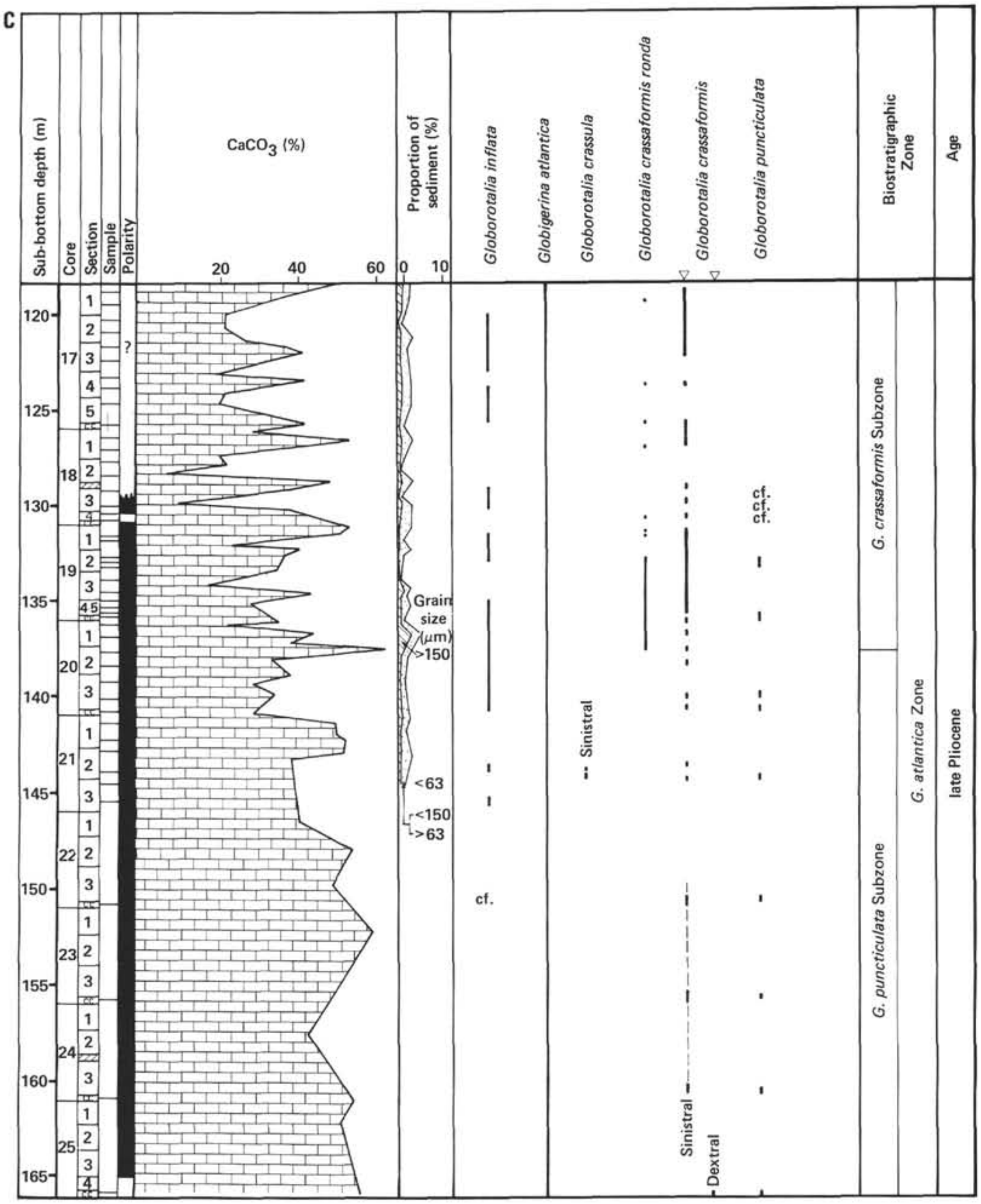


Figure 3. (Continued).

The *Turborotalita humilis* Subzone could be distinguished from the upper part of the *Globoratalia hirsuta* Subzone within the *G. truncatulinoides* Zone. In all, the first five climatic subdivisions could be recognized.

The *T. humilis* Subzone (climatic Subdivision I) extends into the uppermost sediments. The subzone corresponds to a peak in carbonate content.

Subdivision V is characterized by the occurrence within the faunal assemblage of *G. truncatulinoides, G. hirsuta, G. crassaformis*, and *Globigerinoides conglobatus*.

Subdivisions II, III, and IV were inferred from the observations above.

SEDIMENTATION RATES

Average sedimentation rates were calculated from the preliminary chronological framework shown in Figure 7. In Hole 548, important variations were observed between the late (Brunhes) and early Quaternary. A frequent and substantial displacement of sediments from the continent occurred during the late Quaternary (Caralp, this volume). The lower Quaternary sediments, on the other hand, are relatively condensed. The average sedimentation rate of 11.5 cm/10^3 yr. from the late Quaternary of Hole 548 corresponds to the fairly high rate of sedimentation observed elsewhere in the North Atlantic. In Hole 549A the average sedimentation rate of 3 cm/10^3 yr. reflects strong sediment condensation during the Brunhes period. The estimated sedimentation rates in Hole 549A since 470,000 yr. ago and in Hole 550 are similar (Fig. 8) and represent a pelagic sedimentation rate that is normal for this region. Thus, the sediments that record the climatic cycles most accurately belong

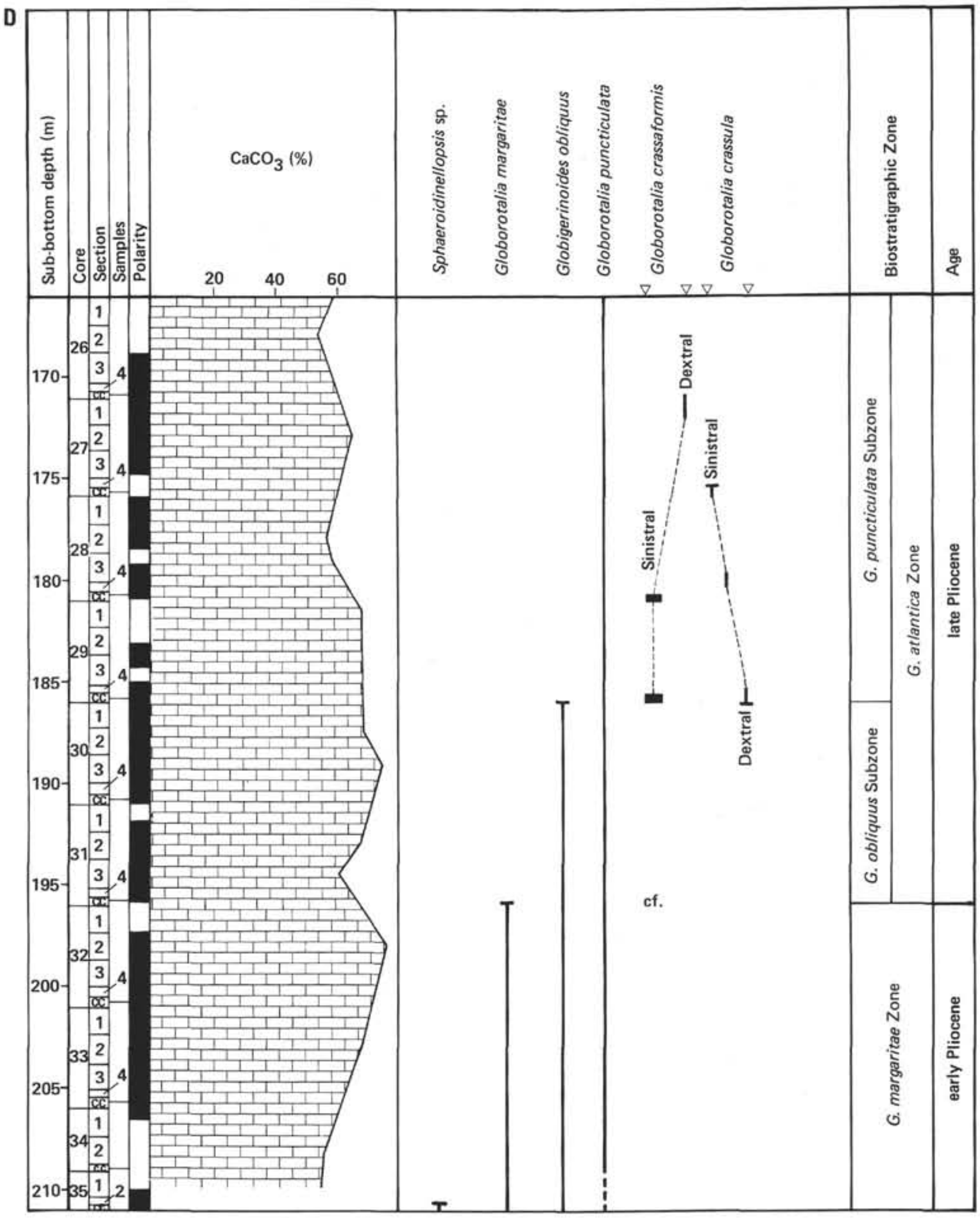


Figure 3. (Continued).

mainly to the late Quaternary between the Jaramillo period and the present. The recognition of the climatic cycles between the Olduvai and Jaramillo periods, an interval of fairly condensed sediments (1.6 cm/10^3 yr. in Hole 548) is problematic.

CORRELATION AND CHRONOLOGY OF LEG 80 SITES

Micropaleontological and lithologic data were used to develop the correlation between Holes 548, 549A, and 550 that is summarized below and in Figure 2.

Turborotalita humilis occurs in the uppermost part of the Quaternary sequence. This species defines an upper subzone within the *Globorotalia truncatulinoides* Zone. Climatic Subdivision I may be considered part of the postglacial period. A comparative study based on the surveys carried out in the Bay of Biscay (Caralp et al., 1974; Pujol, 1980) permitted the correlation of the *T. humilis* Subzone with Isotopic Stage I, in particular its upper part (down to the base of I_B), which is dated as being 8000 yr. old (Duplessy et al., 1981).

The disappearance of *Globigerinoides conglobatus* in Subdivision V was observed in the Bay of Biscay and the northeast Atlantic at the base of Isotopic Stage 5 (an interval of maximum deglaciation). This event was dated as occurring 125,000 yr. ago. It suggests that Subdivisions II, III, and IV are part of the last glacial period. The occurrence of a sinistral *Globorotalia hirsuta* population (Figs. 3A and 5) confirms this hypothesis (Pujol, 1975; Pujol and Duprat, 1977). Therefore, Subdivision V is correlated with Isotopic Stage 5. Further evidence of a warm interglacial period in Subdivision V is the brief occurrence of *G. crassaformis* and a pulsation toward a left-coiling *G. truncatulinoides* population in Hole

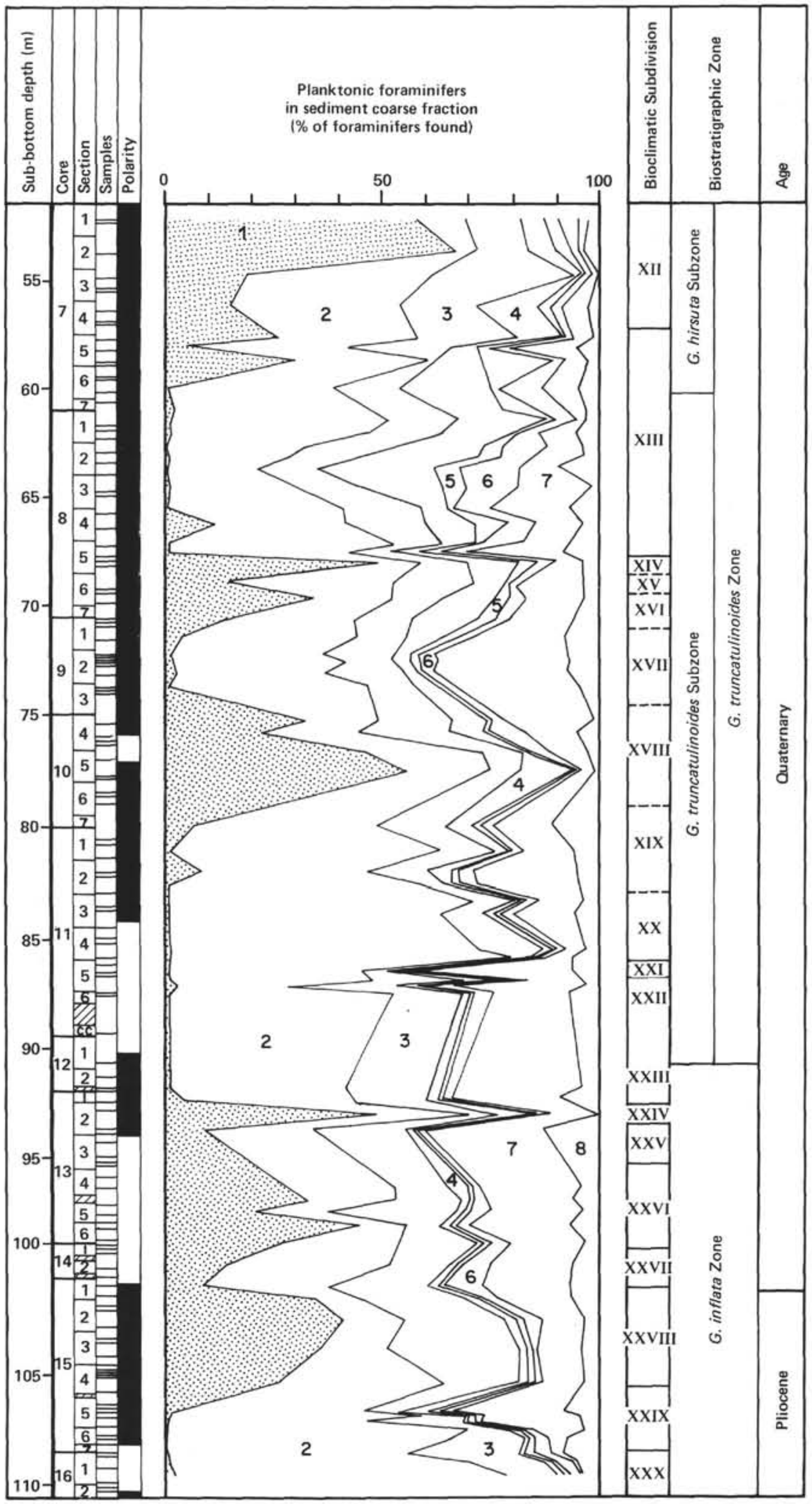


Figure 4. Cumulative percentage of planktonic foraminifers in sediment coarse fraction (> 150 μm). Hole 548, Cores 7 to 16 and comparison with biostratigraphy. 1 = *Globigerina pachyderma* (left-coiling); 2 = *G. pachyderma* (right-coiling); 3 = *G. bulloides*; 4 = *G. quinqueloba*; 5 = *Globorotalia scitula*; 6 = *Globigerinita glutinata*; 7 = *Globorotalia inflata*; 8 = other species. Note the first increase of left-coiling *Globigerina pachyderma* in Core 15, Section 4 and the development of right-coiling *G. pachyderma* in Cores 12 and 11.

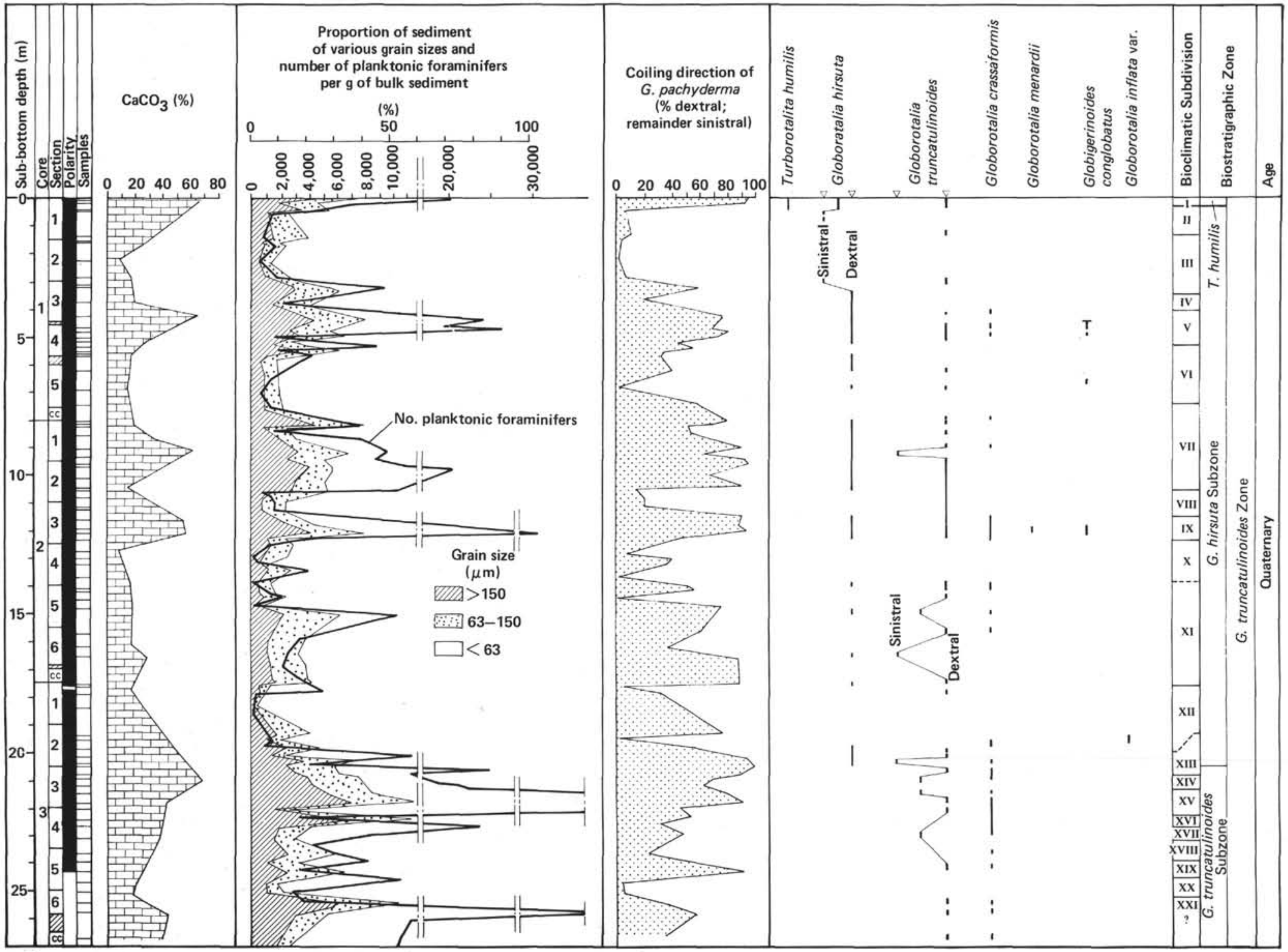


Figure 5. Analysis results for Hole 549A (Cores 1–3).

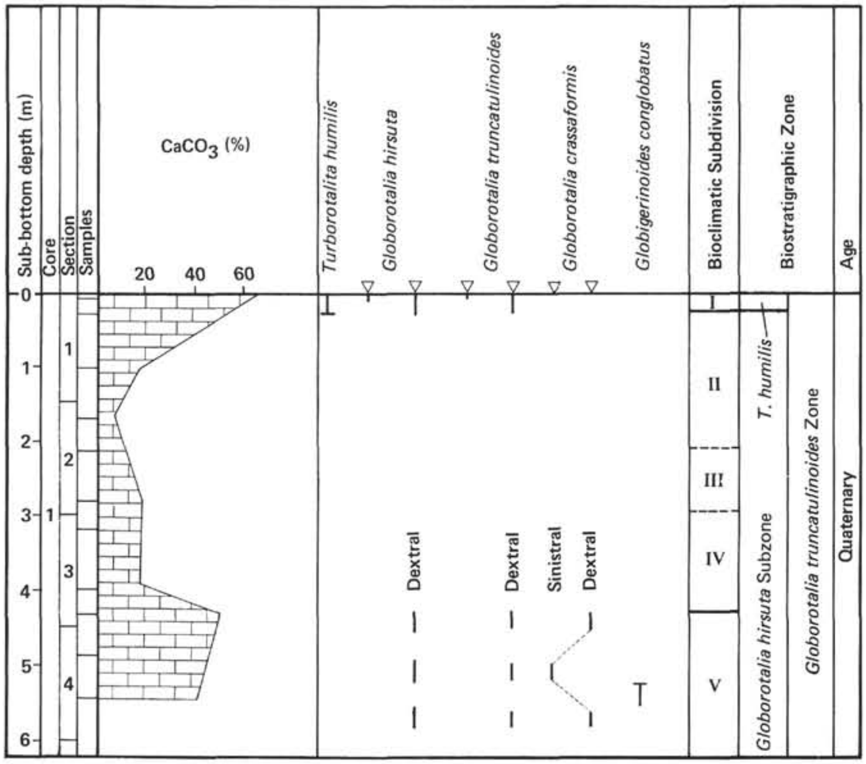


Figure 6. Analysis results for Hole 550 (Core 1).

548 (Fig. 3A). This pulsation was dated as occurring 105,000 to 110,000 yr. ago by extrapolating the sedimentation rate from an isotopic analysis of the Bay of Biscay and a region near Ireland (Pujol, 1980).

In Hole 549A, Subdivision VII is characterized by a sinistral pulsation of *G. truncatulinoides* (Fig. 5). Similar observations were made of numerous samples acquired between the Azores Archipelago and the coast of Ireland at Isotopic Stage 7 (Pujol, 1980).

At these latitudes, the presence of *G. menardii* appears to be characteristic of Isotopic Stage 9 (Pujol, 1980). This indicator could be given an age of about 300,000 yr.

The dominantly right-coiling *G. truncatulinoides* population in Subdivison XI has already been noted. Boundaries for this subzone can be defined only by using previously acquired data.

The first occurrence of *G. hirsuta* probably takes place in a subdivision equivalent to Isotopic Stage 13. The first occurrence of *G. hirsuta* was similar to this from the Azores to Ireland (Ruddiman and McIntyre, 1976; Pujol, 1980). This datum serves to emphasize the transition between two different environments within the Brunhes period (Caralp, this volume). The transition period is also characterized by the brief presence of *G. inflata* var.

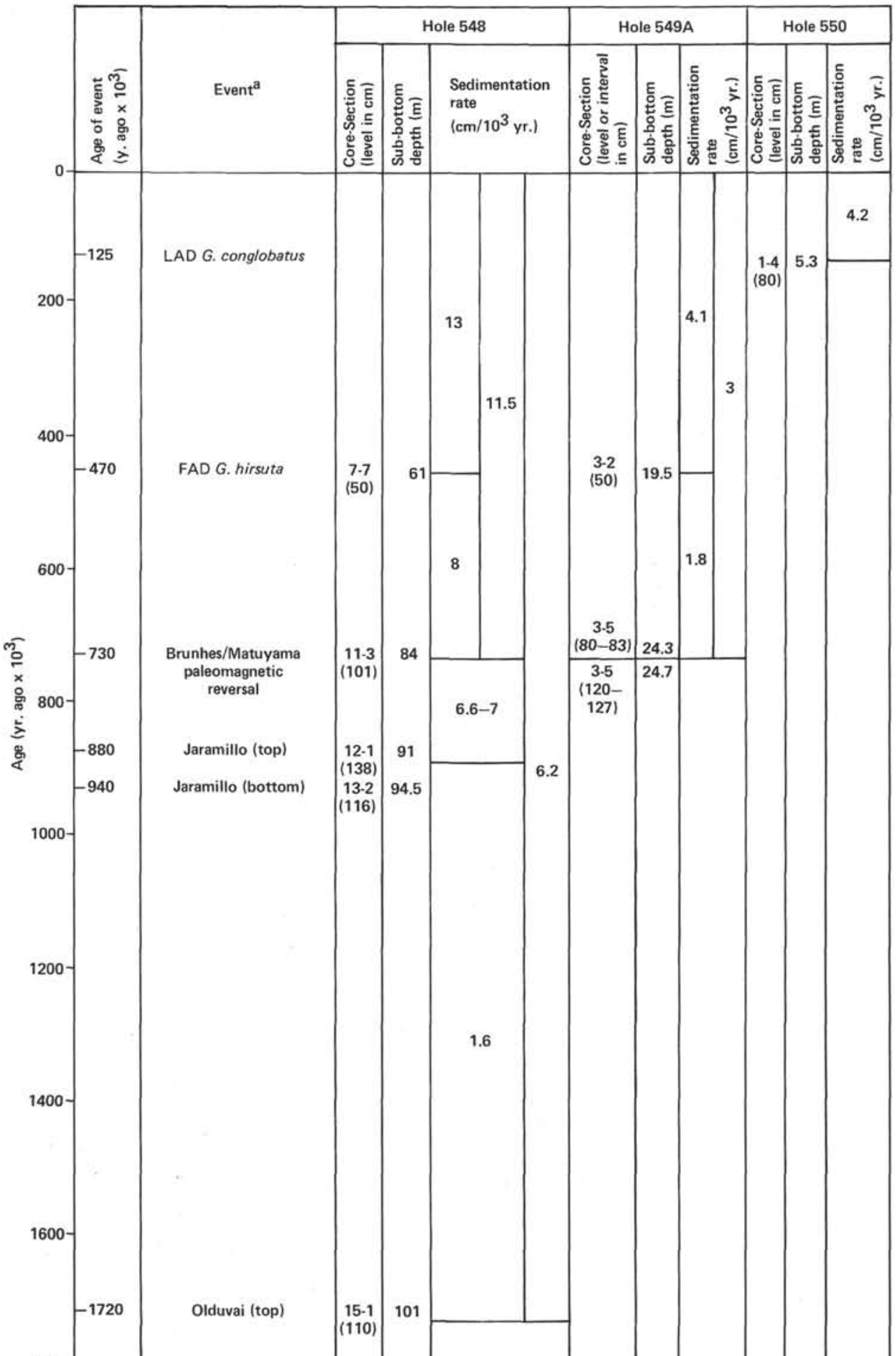
The Brunhes/Matuyama reversal, which was dated as occurring 730,000 yr. ago by Berggren et al. (1980), permitted the dating of Subdivision XIX and its probable correlation with Isotopic Stage 19. Between this reversal and the Jaramillo Event, climatic Subdivisions XIX, XX, and XXII to XXIII reflect a surficial hydrological environment distinguished by a high percentage of *Globigerina pachyderma* (right-coiling).

The first appearance of *Globorotalia truncatulinoides* occurs in Subdivision XXIII in the upper part of the Jaramillo Event, which is dated as occurring approximately 900,000 yr. ago. This estimate of age, which was proposed by Poore and Berggren (1975) after DSDP Leg 12 (Site 116; Hatton Rockall Basin) and used by Backman (1979) and Blanc (1981), needs to be reconsidered.

The first glaciation, which is reflected in the occurrence of the Arctic fauna (*Globigerina pachyderma*, left-coiling) takes place within the heart of the Olduvai Event. It reveals the existence of Subdivision XXVIII in the *Globorotalia inflata* Zone. The glaciation is, therefore, older than the base of the Quaternary (top of the Olduvai Event). The first evidence of an increase of the coarse terrigenous residue is detected at the base of the Olduvai Event (about 1,880,000 yr. ago).

At the base of the *G. inflata* Zone (Fig. 3B), which occurs within the Pliocene, an interval may be distinguished on the basis of the fine grain size of its sediments. According to the definition we have given to the *G. inflata* Zone, this interval may be considered a Pliocene/Quaternary transition zone. The microfaunal assemblage and its patterns (Fig. 4) look very much like those discussed by Poore and Berggren (1975) at Site 116 (DSDP Leg 12).

The Pliocene sediments were sampled less frequently than the Quaternary sediments, so our analysis of them is less detailed. The analysis was performed primarily to acquire information about the period immediately preceding the Quaternary so we could assess the character-



^a Dates for LAD of *G. conglobatus* and FAD of *G. hirsuta* are based on Leg 80 data; dates for Brunhes/Matuyama paleomagnetic reversal, Jaramillo epoch, and Olduvai event (the last of which ended 1,880,000 yr. ago) are based on Berggren et al. (1980).

Figure 7. Estimated average sedimentation rate of the different holes between some chronologic datums.

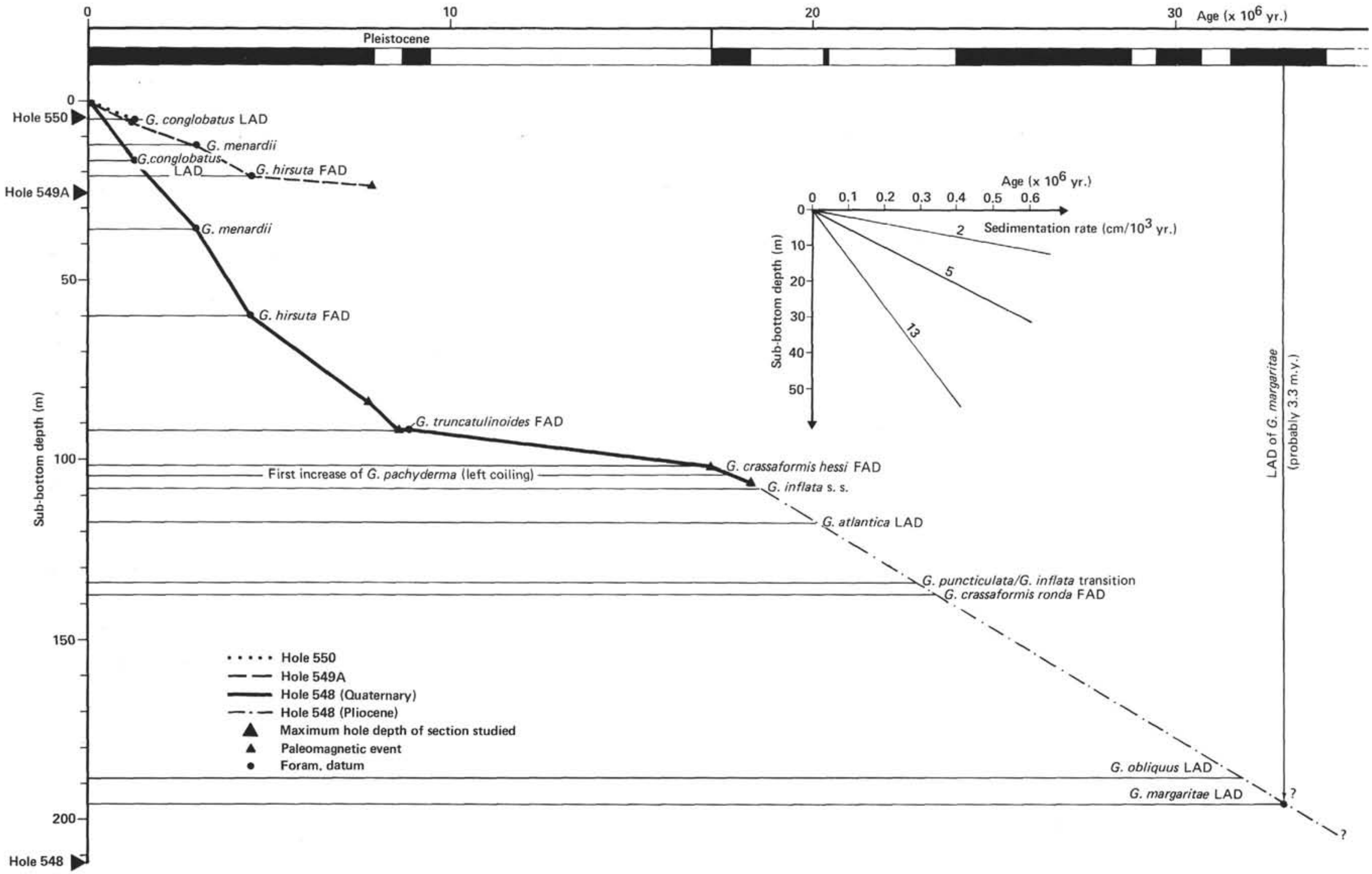


Figure 8. Estimate of average Pliocene–Quaternary sedimentation rates (Holes 548, 549A, and 550), with some planktonic foraminifer events.

istics and gauge the development of the Quaternary microfauna. Thus, the extinctions and appearances of the microfaunal species most often used to define zones and subzones are difficult to locate (date) with any accuracy. The disappearance of *Globigerina atlantica* clearly takes place in the upper Pliocene (below the Quaternary base). Its extinction cannot mark this base (Poore and Berggren, 1975; Berggren, 1972). Compared with the study by Poore and Berggren (1975), the interval between the FAD of *Globorotalia crassaformis* and the disappearance of *G. margaritae* (Fig. 3D) is too long (*G. crassaformis* appears too late). However, it is also true that it is difficult to date the disappearance of *G. margaritae*; the age proposed by Poore and Berggren of 3.3 m.y. appears rather old for this region, because it suggests a relatively low sedimentation rate, which seems to contradict the sedimentation rates for the underlying sediments. Estimates of chronological age should become more accurate as knowledge of the paleomagnetic scale improves.

PALEOCLIMATOLOGY

The recovery of a continuous Quaternary section permitted the paleoclimatology of these northern regions to be studied. The approach we adopted to reconstruct the climates was to assess the variations in physico-chemical parameters as revealed through the study of planktonic foraminifers.

Methodology

The method used was that developed by Imbrie and Kipp (1971) for the quantitative analysis of micropaleontological data. This method allows the quantitative estimation of the oceanographic variables that prevailed in the past. It is made up of three programs: CABFAC, REGRESS, and THREAD. The CABFAC program treats recent data (calculates percentages, performs standardization) and determines the chief components (performs a Q-mode factor analysis). In the REGRESS program, multiple regression analysis is used to define the relationships among factors and oceanographic variables. The regression analysis yields equations that are used in the THREAD program to estimate these oceanographic variables from factor loadings in samples for which these parameters are unknown.

Data and Material

Data are summarized in three matrices. The first covers the qualitative and quantitative analyses of recent thanatocoenosis and consists of regression equations. The samples used are those studied by Kipp (1976), Kellog (1973), Pujol (1980), and Duprat (1983). The matrix employed consists of 280 surface samples distributed throughout the North Atlantic from the Norwegian Sea to the Azores. The transfer function employed (FT 280) is that worked out by Duprat (1983).

The second matrix consists of the physico-chemical variables that correspond to the sampling locations for the first matrix. The summer and winter temperatures used were those established by the U.S. Naval Oceanographic Office (1958 and 1967).

The third matrix corresponds to faunal data for the sites investigated in this study. We used Cores 1 to 6 from Hole 549A and Cores 7 to 16 from Hole 548 for the biostratigraphic analysis. The matrix consists of 30 species and 146 samples.

Analytical Process

The CABFAC program distinguished six factors or assemblages. Each assemblage is defined according to its faunal content (Appendixes A and B). Their variance was as follows: 36.3% subarctic assemblage, 28.6% tropical assemblage, 16.2% arctic assemblage, 6.3% summer tropical assemblage, 4.9% winter tropical assemblage, and 2.3% gyre margin.

The distribution of these assemblages is approximately the same as described by Kipp (1976), Pujol (1980), and Thiede (1977); it corresponds to the pattern found by Duprat (1983).

The THREAD program, which dealt with the older levels of Holes 548 and 549A, responded fairly well at all the levels studied. The commonality observed was more than 0.90 at Hole 549A (Appendix B). Certain samples from Hole 548 showed commonalities of about 0.85. The commonalities for Hole 548, Core 8, Section 2, 90–91 cm; Core 8, Section 2, 140–147 cm; and Core 8, Section 3, 69–70 cm are respectively 0.71, 0.57, and 0.77.

Estimated Temperatures

The estimation of paleotemperatures for the Quaternary sequence has been the subject of numerous previous surveys, especially those performed by the CLIMAP Program. The first attempt to develop temperature estimates focused on 18,000 yr. ago, a reference age for conditions of maximum glaciation (CLIMAP Project Members, 1976).

Several studies in the North Atlantic went beyond this reference age to attempt to improve our understanding of glacial/interglacial changes. Recent data on paleotemperature estimates involve areas close to the investigation zone, that is, the eastern part of the North Atlantic gyre (Crowley, 1976); Ireland (Sancetta, Imbrie, Kipp, et al., 1972; Sancetta, Imbrie, and Kipp, 1973); the northeast Atlantic (Ruddiman and Glover, 1975; Ruddiman and McIntyre, 1976; McIntyre et al., 1976; Pujol, 1980); the Norwegian Sea (Kellog, 1977); and the Euroafrican margin and the Bay of Biscay (Molina-Cruz and Thiede, 1978; Pujol, 1980). However, these analyses usually concern only the last glacial cycle (0–127,000 yr. ago). The paleoclimatic analysis of the entire Quaternary sequence has rarely been studied in tropical zones (Briskin and Berggren, 1975). This is, therefore, the first time that such an investigation has taken place in the middle latitudes, where climatic variations due to the movement of glaciers are significant (Ruddiman and McIntyre, 1976, 1977, and 1981).

Our estimates of the fluctuations through time of the summer and winter temperatures of surface water are given in Appendixes C and D and are summarized in Figures 9 and 10, which show the whole Quaternary sequence and the Pliocene/Quaternary transition.

In Hole 549A, the estimates of present-day summer and winter surface water temperatures derived from a sample at the surface (1-4 cm m sub-bottom) are 16.9°C and 10.5°C. These temperatures correspond to the mean values given in the Atlas.

During periods of maximum glaciation (Isotopic Stage 2, 18,000 yr. ago), surface water temperatures are estimated to have averaged approximately 5.8°C in summer and 0°C in winter. These estimates correspond both to those found by the CLIMAP Project (CLIMAP Project Members, 1976) and to those found in more detailed studies of the North Atlantic by Pujol (1980) and Duprat (1983). There is a difference of about 10°C between the present and glacial periods that is characteristic of the changes in geographic regions that are subject to intermittent glaciation. The lower summer and winter temperatures can be recognized in Subdivisions II, VI, XII, and XX in Hole 549A and in Subdivison XXVI in Hole 548. The warmer temperatures were observed in Subdivisions V, VII, IX, XIII, and XV at Hole 549A and XVII, XIX, XXI, and XXIX in Hole 548 (Figs. 9 and 10). The difference between summer and winter temperatures within a single climatic period is on the order of 6°C (4.5°C to 8°C) and corresponds to present-day seasonal fluctuations.

The general pattern of temperature estimates shows that a slight general cooling takes place from Subdivision XIII to the present. In fact, a climatic deterioration occurred in the Quaternary sequence at Subdivision XIII, approximately 470,000 yr. ago.

CONCLUSIONS

The analysis of Quaternary planktonic microfauna acquired during Leg 80 from Holes 548, 549A, and 550 permitted various faunal assemblages or groupings of 24 species or varieties to be recognized. An investigation of the underlying Pliocene section revealed the presence of 11 of the most characteristic species. The biostratigraphic analysis covered 279 samples.

The biostratigraphy of the Quaternary sequence is based on the appearances and disappearances of specific taxa and on morphological variations (changes in coiling ratio) in several subtropical species. Bioclimatic differentiation of the sedimentary column in the Quaternary was made possible by observing faunal associations. The base of the Quaternary is located at the top of the Olduvai Event (1,720,000 yr. ago).

Three zones were recognized in the Pliocene. The upper zone (the *Globoratalia inflata* Zone) covers the Pliocene/Quaternary transition. The Quaternary (*G. truncatulinoides* taxonomic range Zone) is subdivided into three subzones: *G. truncatulinoides, G. hirsuta,* and *Turborotalia humilis*.

This biozonation applies to the northern part of the North Atlantic, which was subjected during the Quaternary to fluctuating climatic conditions and differs from conditions in tropical regions. Therefore a correlation of biozonations in these two domains does not yield satisfactory results. Climatic variations governed the microfaunal distribution, and about 30 bioclimatic subdivisions could be distinguished. A number of these subdivisions are comparable to the isotopic stages traditionally recognized in the Quaternary. The interpretation of these observations with respect to the paleomagnetic scale permits a chronological assessment to be made of the most important events.

The Pliocene/Quaternary boundary does not appear to be well marked in the planktonic foraminiferal assemblages. The first indication of cooling appears at the base of the Olduvai Event. The appearance of *G. truncatulinoides*, which is usually considered a marker of the Quaternary base, occurs at the Jaramillo Event.

The first appearance of *G. hirsuta* during Subdivision XIII accompanies an important lithologic and faunal change.

The distribution of most characteristic Pliocene taxa (such as *G. margaritae* and *Globigerina atlantica*) cannot be dated easily because of a lack of accurate paleomagnetic data.

Surficial Quaternary paleoenvironments in the North Atlantic were studied. Some 146 samples from Holes 549A and 548 yielded estimates of summer and winter surface water temperatures. Curves of these estimates corroborate the climatic subdivisions perceived on the basis of an examination of the microfauna.

During glacial stages the average summer water temperature was approximately 5.8°C; the average winter water temperature was approximately 0°C. For both seasons, the difference between the present and the glacial period is about 10°C. Within a given period (glacial or warm stage), the difference between summer and winter estimates is on the order of 6°C. Two climatic periods are distinguished in the Quaternary sequence; a change appears to occur approximately 470,000 yr. ago.

TAXONOMIC NOTES

This nonsystematic list consists only of the species and forms from the Goban Spur that are illustrated in the plates. The list of species and forms follows the order of the illustrations. For the Quaternary species, this order takes into account the species' present biogeographic distribution in the North Atlantic Ocean. The Pliocene species appear in alphabetical order after the Quaternary species. The specimens illustrated have been deposited in the paleotological collection of the Institut de Géologie du Bassin d'Aquitaine of the University of Bordeaux I (France).

Quaternary Fauna

*Globigerina pachyderma (*Ehrenberg) left-coiling (Pl. 1, Figs. 1-4). This is the only species from the Arctic assemblage. Because it lives in cold water, the frequency of its occurence is suggestive of the temperature of the water.

Globigerina pachyderma (Ehrenberg) right-coiling (Pl. 1, Figs. 5-9). This species is abundant throughout the Quaternary of the northeast Atlantic. Its occurrence reaches a climax at the base of the *Globorotalia truncatulinoides* Zone.

Globigerinita uvula (Ehrenberg) (Pl. 1, Fig. 10). Very scarce in the coarse fraction.

Globigerina quinqueloba Natland (Pl. 1, Figs. 11-14).

Globigerina bulloides d'Orbigny (Pl. 2, Figs. 1-4).

Globigerina cariacoensis Rögl and Bolli (Pl. 2, Figs. 5-12). This species appears to be part of the variability interval of *G. bulloides*. It differs, however, in its large size, higher spiral coiling, and greater number of chambers in the last whorl. This species probably reflects the ecological conditions special to the Caribbean region.

Globigerina bulloides d'Orbigny var. (Pl. 3, Figs. 1-6). This form, which is assumed to belong to the *G. bulloides* species, differs by a less lobate outline and a low arched aperture. It seems to disappear

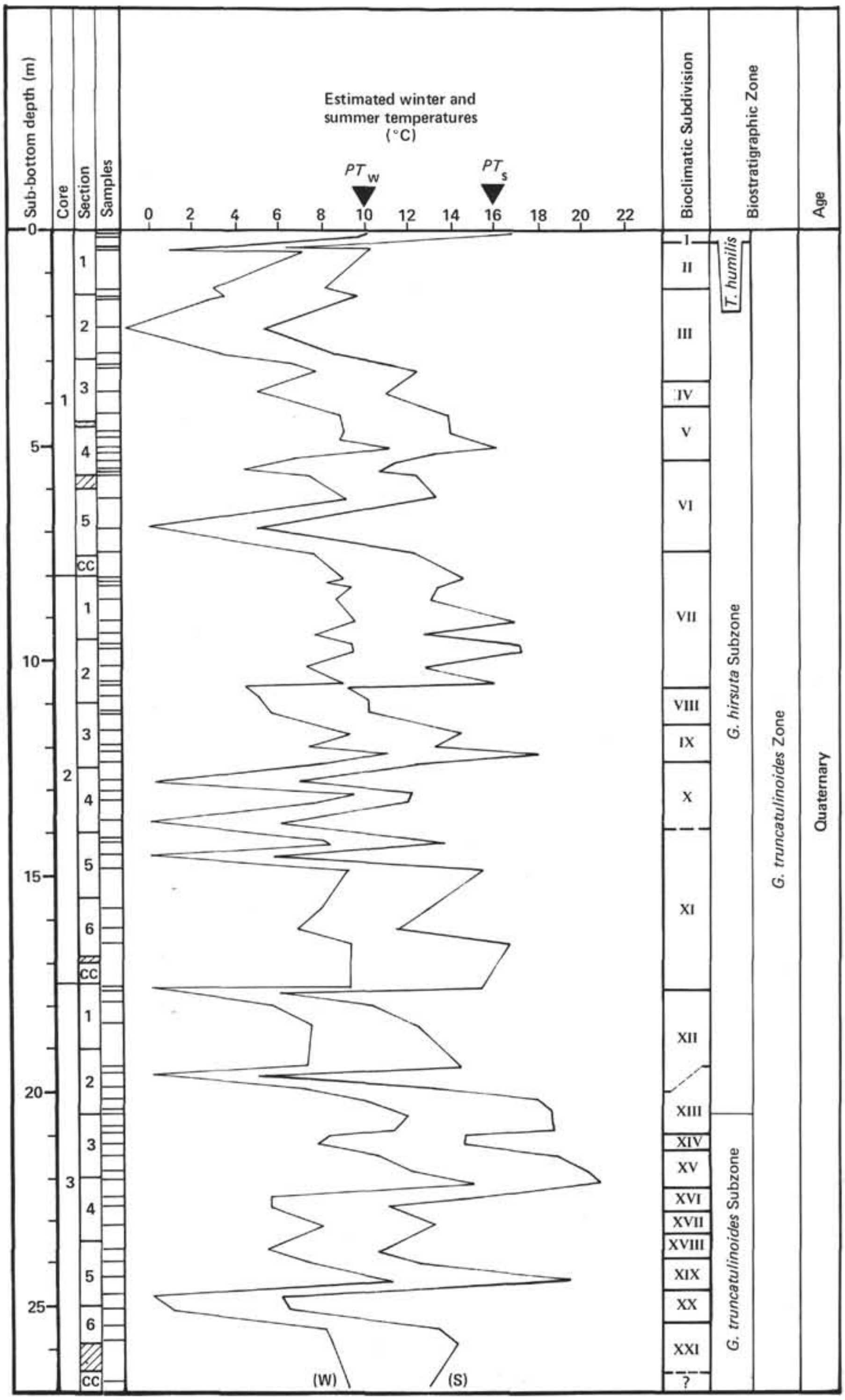


Figure 9. Estimated surficial temperature at Hole 549A (Cores 1-3) during winter (W) and summer (S) and comparison with biostratigraphic and bioclimatic subdivisons. PT_w = present winter temperature, PT_s = present summer temperature.

in the late Pliocene. Nevertheless, its characteristics lead us to illustrate this form near the recent subarctic species.

Globigerinita glutinata (Egger) (Pl. 3, Figs. 7–9).

Globorotalia scitula (Brady) form 1 (Pl. 3, Figs. 10, 13; Pl. 4, Figs. 3–6).

Globorotalia bermudezi (Rögl and Bolli) (Pl. 3, Figs. 11, 12). This species differs from the *G. scitula* form 1 mainly by its flat distal face and straight intercameral sutures. Inasmuch as its distribution resembles that of *G. scitula* form 1, both forms were analyzed under the name of the first for purposes of analysis.

Globorotalia scitula (Brady) form 2 (Pl. 3, Fig. 14; Pl. 4, Figs. 1–2). This form corresponds well to the species description. It differs, however, by its size and its coarse perforated test. Its stratigraphic range distribution is also appreciably different; it was observed chiefly in the early Quaternary (Matuyama Epoch and base of Brunhes Epoch).

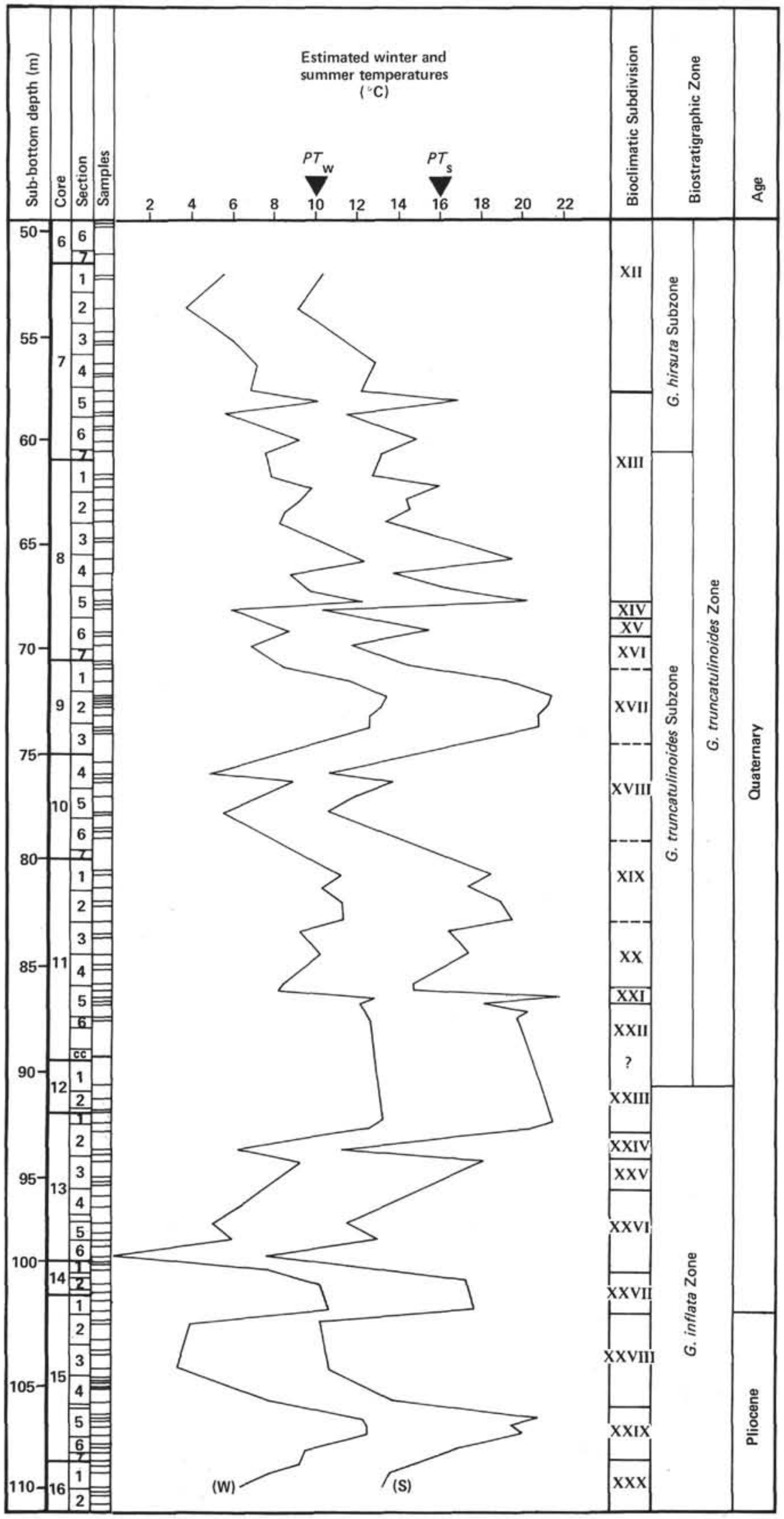


Figure 10. Estimated surficial temperature at Hole 548 (Cores 7–16) during winter (W) and summer (S) and comparison with biostratigraphic and bioclimatic subdivisions. PT_w = present winter temperature, PT_s = present summer temperature.

Orbulina universa d'Orbigny (Pl. 4, Fig. 7).

Hastigerina siphonifera (d'Orbigny) (Pl. 4, Figs. 8-10).

Globorotalia inflata (d'Orbigny) (Pl. 5, Figs. 1-2, 7-8, and 9-10). Figures 7 and 8 show transitional morphs of the *G. puncticulata* species. The forms illustrated in Figures 9 and 10 were defined as *G. inflata* aff; they are rare small-sized specimens that may be considered to be within the species variability.

Globorotalia inflata (d'Orbigny) var. (Pl. 5, Figs. 3-6). The distribution of this form is very limited on the stratigraphic scale. It was distinguished only in bioclimatic Subdivision XIII in Holes 548 and 549A. It differs from the characteristic form by a higher coil and a porcelaneous shell.

Globorotalia truncatulinoides (d'Orbigny) (Pl. 5, Figs. 11-14). This species is characteristic of Quaternary section and occurs at Goban Spur for the first time in the deposits of the Jaramillo Event.

Globorotalia hirsuta (d'Orbigny) (Pl. 6, Figs. 1-12). Morphological variations of this species have been described at length in a study by Pujol (1975) of the Bay of Biscay sediments

Turborotalita humilis (Brady) (Pl. 7, Figs. 1-3). This small species, characteristic of postglacial deposits, is almost nonexistent in the coarse fraction larger than 150 μm. Recognizing this species requires close observation of the fraction between 150 and 63 μm.

Globigerina calida Parker (Pl. 7, Fig. 4).

Globigerinoides ruber d'Orbigny (Pl. 7, Fig. 5).

Globorotalia crassaformis crassaformis (Galloway and Wissler) (Pl. 7, Figs. 6-8; Pl. 9, Figs. 4-6). Recent forms are largely different from the Pliocene forms (Pl. 9, Fig. 4-6). The profile of the latter is more angular. This species is still very badly differentiated within the Pliocene.

Globorotalia crassaformis hessi (Bolli and Premoli Silva) (Pl. 7, Figs. 9-11). This species occurs as early as at the base of the Quaternary. It is part of the *G. crassaformis* species distribution in Hole 549A.

Globorotalia crassaformis oceanica Cushman and Bermudez (Pl. 8, Figs. 1-5). This species is quite scarce. It is found in the range of diversification of the *G. crassaformis* species.

Globorotalia crassaformis ronda Blow (Pl. 8, Figs. 6-14; Pl. 9, Figs. 1-3). This subspecies appears in the Pliocene section and does not seem to develop after about 470,000 yr. ago.

Globorotalia crassula Cushman and Stewart (Pl. 9, Figs. 7-10; Pl. 10, Figs. 1-7). The Berggren and Amdurer (1973) description is employed for the Pliocene-Pleistocene deposits of the Rio Grande Rise (Berggren, 1977; Pujol and Duprat, 1984). This species occurs in the Pliocene but also at the lowest extremity of the Quaternary. At its appearance, the population is dominantly dextral, but it very quickly becomes sinistral. It is easy to differentiate this species from *G. margaritae* and *G. hirsuta*, with which it shares the same morphological characteristics, by the absence of a pronounced carina.

Globorotalia tumida (Brady) (Pl. 10, Fig. 8). This species has been grouped with *G. menardii.*

Globorotalia menardii (d'Orbigny) (Pl. 10, Fig. 9).

Globorotalia cf. flexuosa (Koch) (Pl. 10. Fig 10). Quite infrequent, this form is associated with the *G. menardii* group.

Globigerinoides conglobatus (Brady) (Pl. 10, Fig. 11). The disappearance of this species in the Goban Spur area takes place at the base of the last interglacial stage (Isotopic Stage 5).

Pliocene Fauna

Globigerina atlantica (Berggren) (Pl. 11, Figs. 1-9). This species disappears from the Goban Spur deposits before the first contemporary cooling of the Olduvai Event. Its last specimens show a decrease in the number of chambers of the last whorl (Pl. 11, Fig. 1).

Globorotalia puncticulata (Deshayes) (Pl. 12, Figs. 1-8). It is assumed that a phylogenic transition of this species with *G. inflata* takes place in the late Pliocene.

Globorotalia margaritae (Bolli and Bermudez) (Pl. 12, Figs. 9-11). This species characterizes the early Pliocene.

Globigerinoides obliquus (Bolli) (Pl. 12, Fig. 12).

Sphaerodinellopsis subdehiscens (Blow) (Pl. 12, Fig. 13).

ACKNOWLEDGMENTS

The writers wish to thank the Deep Sea Drilling Project for having made Quaternary samples from Leg 80 available for the present study. The Institut de Géologie du Bassin d'Aquitaine and the Laboratory of Oceanography (L.A. 197) of the University of Bordeaux I provided laboratory facilities and technical help. The authors wish to express their thanks to J. Sigal for making available the material of the Pliocene of Site 548. M. Caralp. J. P. Peypouquet, H. Townsend, and C. Vergnaud Grazzini have contributed to this study through discussions. We are also very grateful to W. A. Berggren, J. C. Duplessy, P. C. de Graciansky, and W. Ruddiman, who reviewed the manuscript.

The scanning electron micrographs were taken by M. Leblanc of the Centre de Microscopie Électronique of the University of Bordeaux I.

This investigation was supported in part by I.G.B.A. and in part by a grant from A.T.P. Geology and Geophysics of the Ocean (C.N.R.S., France).

REFERENCES

Backman, J., 1979. Pliocene biostratigraphy of DSDP Sites 111 and 116 from the North Atlantic Ocean and the age of Northern Hemisphere glaciation. *Stockholm Contrib. Geol.*, 32:115-137.

Bé, A. W. H., 1977. An ecological, zoogeographic and taxonomic review of Recent planktonic Foraminifera. *In* Ramsay, A. T. S. (Ed.), *Oceanic Micropaleontology* (Vol.1): London (Academic Press), pp. 1-100.

Berggren, W. A., 1972. Cenozoic biostratigraphy and paleobiogeography of the North Atlantic. *In* Laughton, A. S., Berggren W. A., et al., *Init. Repts. DSDP*, 12: Washington (U.S. Govt. Printing Office), 965-1000.

________, 1977. Late Neogene planktonic foraminiferal biostratigraphy of the Rio Grande Rise (South Atlantic). *Mar. Micropaleontol.*, 2:265-313.

Berggren, W. A., and Amdurer, M., 1973. Late Paleogene (Oligocene) and Neogene planktonic foraminiferal biostratigraphy of the Atlantic Ocean (lat. 30°N to lat. 30°S). *Riv. Ital. Paleontol.*, 79: 337-392.

Berggren, W. A., Burckle, L. H., Cita, M. B., Cooke, H. B. S., Funnell, B. M., Gartner, S., Hays, J. D., Kennett, J. P., Opdyke, N. D., Pastouret, L., Shackleton, N. J., and Takayanagi, Y., 1980. Towards a Quaternary time scale. *Quat. Res.*, 13:277-302.

Blanc, P. L., 1981. Paleoclimatologie isotopique et histoire de l'eau profonde atlantique depuis 15 millions d'années. Univ. Paris, Thesis No. 2474.

Blow, W. H., 1969. Late middle Eocene to Recent planktonic foraminiferal biostratigraphy. *In* Brönnimann, P., and Renz, H. H. (Eds.), *Proc. First Internat. Conf. Planktonic Microfossils*: Leiden (E. J. Brill), pp. 199-422.

Bolli, H. M., and Premoli Silva, I., 1973. Oligocene to Recent planktonic Foraminifera and stratigraphy of the Leg 15 sites in the Caribbean Sea. *In* Edgar, T. N., Saunders, J. B., et al., *Init. Repts. DSDP*, 15: Washington (U.S. Govt. Printing Office), 475-497.

Briskin, M., and Berggren, W. A., 1975. Pleistocene stratigraphy and quantitative paleooceanography of tropical North Atlantic Core V16-205. *In* Saito, T., and Burckle, L. (Eds.), *Late Neogene Epoch Boundaries*: New York (Micropaleontology Press), pp. 167-198.

Caralp M., 1971. Les foraminifères planctoniques du Pléistocène terminal dans le Golfe de Gascogne. Interprétation biostratigraphique et paléoclimatique. *Bull. Inst. Geol. Bassin Aquitaine*, 11: 1-191.

Caralp, M., Duprat, J., Moyes, J., and Pujol, C., 1974. La stratigraphie du Pléistocène supérieur et de l'Holocène dans le Golfe de Gascogne. Essai de synthèse des critères actuellement utilisables. *Boreas*, 3:35-40.

CLIMAP Project Members, 1976. The surface of the ice-age earth. *Science*, 191(4232):1131-1137.

Crowley, T., 1976. Fluctuations of the eastern North Atlantic gyre during the last 150,000 yr. [Ph. D. dissert.]. Brown Univ., Providence, R. I.

Duprat, J., 1983. Contribution à l'analyse biostratigraphique et des environnements du Quaternaire terminal dans l'Atlantique nord-est ibérique. *Bull. Inst. Geol. Bassin Aquitaine*, 33:71-150.

Ericson, D. B., and Wollin, G., 1956. Micropaleontological and isotopic determinations of Pleistocene climates. *Micropaleontology*, 2:257-270.

________, 1968. Pleistocene climates and chronology in deep sea sediments. *Science*, 1621227-1234.

Imbrie, J., and Kipp, N. G., 1971. A new micropaleontological method for quantitative paleoclimatology: application to a late Pleistocene Caribbean core. *In* Turekian, K. K. (Ed.), *The Late Cenozoic Glacial Ages*: New Haven (Yale Univ. Press), pp. 71–181.

Kellogg, T. B., 1973. Late Pleistocene climatic record in Norwegian and Greenland sea deep sea cores [Ph.D. dissert.]. Columbia Univ., N.Y.

________, 1977. Paleoclimatology and paleo-oceanography of the Norwegian and Greenland seas. The last 450,000 years. *Mar. Micropaleontol.*, 2:235–249.

Kipp, N. G., 1976. New transfer function for estimating past sea surface conditions from sea bed distribution of planktonic foraminiferal assemblages in the North Atlantic. *Geol. Soc. Am. Bull.*, 145: 3–41.

McIntyre, A., Kipp, N. G., Bé, A. W. H., Crowley, T., Kellogg, T., Gardner, J. V., Prell, W., and Ruddiman, W. F., 1976. Glacial North Atlantic 18,000 years ago. A climap reconstruction. *Geol. Soc. Am. Bull.*, 145:43–76.

Molina-Cruz, A., and Thiede, J., 1978. The glacial eastern boundary current along the Atlantic Eurafrican continental margin. *Deep Sea Res.*, 25:337–356.

Poore, R. Z., and Berggren, W. A., 1975. Late Cenozoic planktonic foraminiferal biostratigraphy and paleoclimatology of Hatton Rockall Basin: DSDP Site 116. *J. Foram. Res.*, 5:270–293.

Pujol, C., 1975. Intérêt des variations du sens d'enroulement de *G. truncatulinoides* et de *G. hirsuta* (Pleistocène supérieur et Holocène du Golfe de Gascogne). *Rev. Esp. Micropaleontol.*, Num. spec., pp. 107–116.

________, 1980. Les foraminifères planctoniques de l'Atlantique nord au Quaternaire. Ecologie—Stratigraphie—Environnement. *Mem. Inst. Geol. Bassin Aquitaine*, No. 10.

Pujol, C., and Caralp M., 1974. Variations du sens d'enroulement des foraminifères planctoniques dans l'interprétation stratigraphique du Quaternaire terminal de l'océan Atlantique nord. *Bull. Inst. Geol. Bassin Aquitaine*, 16:31–50.

Pujol, C., and Duprat, J., 1977. Intérêt de *Globorotalia hirsuta* dans le Quaternaire de l'Atlantique nord-oriental [paper presented at 5th annual meeting, Réun. Annu. Sci. Terre, Rennes, France, 19–22 April].

________, 1984. Quaternary planktonic foraminifers of the southwestern Atlantic (Rio Grande Rise) Deep Sea Drilling Project Leg 72. *In* Baker P., Johnson, D., et al., *Init. Repts. DSDP*, 72: Washington (U.S. Govt. Printing Office), 601–622.

Pujol, C., Duprat, J., Gonthier, E., Peypouquet, J. P., and Pujos-Lamy, A., 1974. Résultats préliminaires de l'étude effectuée par l'institut de géologie du Bassin d'Aquitaine concernant la mission FAEGAS (25 Juin–17 Juillet 1973) dans l'Atlantique nord-est. *Bull. Inst. Geol. Bassin Aquitaine*, 16:65–94.

Ruddiman, W. F., and Glover, L. K., 1975. Subpolar North Atlantic circulation at 9,300 years B.P. Faunal evidence. *Quat. Res.*, 5:361–389.

Ruddiman, W. F., and McIntyre, A., 1976. Northest Atlantic paleoclimatic change over the past 600,000 years. *Mem. Geol. Soc. Am.*, 145:111–146.

________, 1977. Late Quaternary surface ocean kinematics and climatic change in the high-latitude North Atlantic. *J. Geophys. Res.*, 82:3877–3887.

________, 1981. The North Atlantic Ocean during the last deglaciation. *Paleogeogr. Paleoclimatol. Paleoecol.*, 35:145–214.

Sancetta, C., Imbrie, J., and Kipp, N. G., 1973. Climatic record of the past 130,000 years in North Atlantic deep sea Core V23-83. Correlation with the terrestrial record. *Quat. Res.*, 3:110–116.

Sancetta, C., Imbrie, J., Kipp, G., McIntyre, A., and Ruddiman, W. F., 1972. Climatic record in north Atlantic deep sea core V23-82: comparison of the last and present interglacials based on quantitative time series. *Quat. Res.*, 2:363–367.

Thiede, J., 1977. Aspects of the variability of the glacial and interglacial North Atlantic eastern boundary current (last 150,000 years). *Meteor Forschungsergeb. Reihe C.*, 28:1–36.

Thierstein, H. R., Geitzenauer, K., Molfino, B., and Shackleton, N. J., 1977. Global synchroneity of late Quaternary coccolith datums: validation by oxygen isotopes. *Geology*, 5:400–404.

U.S. Naval Oceanographic Office, 1958. *Oceanographic Atlas of the Polar Seas. Part II: Arctic*. H.O. Pub. No. 705: Washington (U.S. Govt. Printing Office).

________, 1967. *Oceanographic Atlas of the North Atlantic Ocean. Section II: Physical Properties*. Pub. No. 700: Washington (U.S. Govt. Printing Office).

Date of Initial Receipt: April 12,1983
Date of Acceptance: July 8, 1983

APPENDIX A
Varimax Factor Matrix from Analysis of Hole 548 (Cores 7–16)

Sample	Core-Section (depth in cm)	Commonality	Factor assemblages 1	2	3	4	5	6
1	7.1,76.79	.9951	.2391	.0018	.9530	.0631	-.1603	-.0014
2	7.2,84.85	.9950	.1264	-.0038	.9770	.0582	-.1451	-.0015
3	7.3,104.111	.9464	.8626	.0077	.3333	.0209	-.3008	.0132
4	7.4,40.43	.8096	.5903	.0131	.6507	.0337	-.1909	-.0005
5	7.4,103.117	.9481	.8848	.0163	.3757	.0400	-.1490	.0095
6	7.5,19.22	.9834	.7702	.0107	.5653	.0470	-.2611	.0114
7	7.5,111.116	.9811	.9097	.0361	.1212	.2654	-.2534	.0529
8	7.5,140.141	.9513	.7043	.0001	.5959	.0755	-.3067	.0202
9	7.6,110.117	.8562	.9025	.0716	.0768	.0260	-.1729	-.0045
10	7.7,10.13	.9158	.9426	.0293	.1065	-.0290	-.1191	-.0111
11	8.1,69.70	.9096	.9400	.0226	.0694	-.0749	-.1224	-.0101
12	8.1,123.130	.9324	.9548	.0547	.0666	.0435	-.1060	.0120
13	8.2,40.47	.8849	.8632	.0506	.0552	.0800	-.3574	.0109
14	8.2,90.91	.7157	.7791	.0420	.1061	.1290	-.2802	.0221
15	8.2,140.147	.5776	.6738	.0612	.0971	.0446	-.3292	-.0090
16	8.3,69.70	.7792	.8092	.0687	.0857	.2376	-.2345	.0303
17	8.4,20.27	.9723	.9443	.0466	.0319	.2545	-.0974	.0565
18	8.4,90.91	.9429	.8576	.0412	.3368	.1849	-.2395	.0284
19	8.5,20.27	.9857	.9886	.0442	.0560	.0453	.0334	.0057
20	8.5,69.70	.9671	.9325	.0414	.0305	.2872	.0945	.0589
21	8.5,103.110	.9858	.2629	.0102	.9338	.1243	-.1707	.0086
22	8.6,69.70	.9736	.8918	.0278	.3391	.2215	-.1045	.0498
23	8.6,124.125	.9624	.5098	.0248	.7848	.2510	-.1456	.0406
24	9.1,20.23	.9114	.8300	.0340	.3906	.2275	-.1242	.0410
25	9.1,100.107	.9573	.9344	.0662	.1063	.2546	.0406	.0452
26	9.2,20.23	.9564	.8501	.0561	.0433	.4677	-.0160	.0990
27	9.2,43.44	.9612	.8759	.0729	.0473	.4158	.0851	.0792
28	9.2,108.109	.9573	.8435	.0767	.0529	.4745	-.0550	.0947
29	9.3,20.23	.9657	.9049	.0415	.0315	.3550	.1121	.0746
30	10.4,43.44	.9718	.5020	.0203	.7306	.3866	-.1751	.0741
31	10.4,114.116	.9812	.7173	.0590	.5384	.2483	-.3322	.0355
32	10.5,43.44	.9834	.5294	.0109	.8261	.1406	-.0208	.0196
33	10.5,120.122	.9974	.3284	-.0051	.9403	.0457	-.0577	.0021
34	11.1,52.53	.9724	.9525	.1021	.1804	.1416	-.0416	.0228
35	11.1,140.147	.9829	.9832	.0431	.0377	.0553	.0981	.0166
36	11.2,50.53	.9636	.8894	.0662	.1972	.3517	.0272	.0698
37	11.2,140.147	.9906	.9477	.0434	.0272	.1909	.2278	.0394
38	11.3,50.53	.9862	.9818	.0252	.0227	-.0008	.1451	.0063
39	11.3,139.146	.9904	.9815	.0248	.0263	.0642	.1455	.0206
40	11.4,140.147	.9779	.9823	.0150	.0305	-.0561	.0933	-.0015
41	11.5,17.24	.9803	.9623	.0240	.0227	-.0718	.2190	-.0083
42	11.5,50.53	.9593	.8249	.0533	.0100	.4615	.2304	.0990
43	11.5,92.97	.9424	.9410	.1976	.0792	-.0006	-.1077	-.0096
44	11.5,143.150	.9349	.7439	.0561	.0654	.5430	-.2570	.1145
45	11.6,8.15	.9912	.9773	.0577	.0151	.1726	.0295	.0439
46	13.1,130.137	.9695	.9055	.0419	.0162	.3744	-.0159	.0843
47	13.2,35.38	.9753	.9075	.0723	.1072	.3598	-.0041	.0746
48	13.2,120.121	.9963	.3832	.0139	.9075	.1581	-.0181	.0219
49	13.3,22.29	.9084	.7312	.0432	.2075	.5403	-.1435	.1277
50	13.4,95.98	.9711	.6397	.0371	.6115	.4229	-.0169	.0861
51	13.5,35.38	.9742	.5415	.0225	.7197	.3827	-.0996	.0779
52	13.5,130.132	.9446	.5927	.0409	.4547	.4731	-.3902	.0939
53	13.6,27.34	.9698	.3049	.0157	.8377	.4108	-.0218	.0753
54	14.1,40.47	.9761	.7180	.0276	.5765	.3261	-.1312	.0631
55	14.2,84.91	.9825	.9006	.0527	.3026	.2722	-.0152	.0517
56	15.1,112.119	.9645	.8547	.0595	.1918	.3675	-.2298	.0761
57	15.2,30.33	.9610	.4104	.0294	.7290	.3906	-.3198	.0734
58	15.3,110.117	.9408	.4576	.0034	.7044	.2706	-.3981	.0594
59	15.4,110.117	.9835	.8094	.0058	.5519	.1318	-.0735	.0293
60	15.5,63.68	.9517	.8853	.0442	.0414	.3679	.1535	.0736
61	15.5,92.97	.9910	.9631	.0216	.0093	.1930	.1533	.0472
62	15.5,130.137	.9715	.9355	.0190	.0212	.2963	-.0526	.0708
63	15.6,30.33	.9857	.9802	.0179	.0259	.0306	.1507	.0140
64	15.6,123.126	.9727	.9845	.0167	.0127	-.0431	.0357	-.0003
65	16.1,10.11	.9550	.9666	.0191	.0257	-.0157	-.1352	.0092
66	16.1,70.77	.9769	.9822	.0158	.0262	-.1020	.0269	-.0139
67	16.1,140.141	.9749	.9750	.0108	.0606	-.1096	.0904	-.0156

APPENDIX B
Varimax Factor Matrix from Analysis of Hole 549A (Cores 1-3)

Sample	Core-Section (depth in cm)	Commonality	Factor assemblages 1	2	3	4	5	6
1	1-1,1-4	.9937	.9823	.0614	.0838	.1063	-.0801	.0152
2	1-1,8-11	.9883	.9830	.0752	.1075	.0264	-.0639	-.0038
3	1-1,39-42	.9812	.3150	.0123	.9236	.1210	-.0698	.0067
4	1-1,42-45	.9848	.0517	-.0053	.9894	.0519	-.0226	-.0028
5	1-1,137-140	.9924	.1233	-.0031	.9842	.0737	-.0562	.0008
6	1-2,2-5	.9889	.1068	-.0042	.9420	.0813	-.2889	.0052
7	1-2,5-8	.9949	.0765	-.0081	.9753	.0461	-.1889	-.0009
8	1-2,70-77	.9831	-.0091	-.0121	.9903	.0463	-.0081	-.0029
9	1-2,130-137	.9948	.0860	-.0028	.9877	.0385	-.1019	-.0068
10	1-3,10-13	.9858	.4375	.0297	.7064	.1309	-.5265	.0106
11	1-3,20-23	.9591	.7473	.0547	.4192	.1743	-.4372	.0185
12	1-3,70-77	.9385	.3496	.0155	.7095	.0967	-.5944	.0114
13	1-3,125-131	.9559	.8910	.0764	.3274	.0433	-.2171	-.0100
14	1-4,10-13	.9967	.8835	.0487	.3835	.1540	-.2065	.0196
15	1-4,20-23	.9024	.8592	.0999	.2162	.1634	-.2822	.0098
16	1-4,40-43	.9811	.8964	.1400	.3183	.0630	-.2288	-.0176
17	1-4,54-57	.9944	.6704	.0445	.6762	.1034	-.2738	.0023
18	1-4,72-78	.9837	.7535	.0256	.5022	.0591	-.3994	.0075
19	1-4,86-93	.9354	.4829	.0179	.5297	.1412	-.6329	.0282
20	1-4,105-109	.9794	.4812	.0151	.8131	.0775	-.2836	.0062
21	1-5,20-23	.9970	.5900	.0334	.7749	.1239	-.1783	.0135
22	1-5,90-97	.9867	.0071	-.0121	.9924	.0389	.0082	-.0044
23	1-5,144-147	.9954	.8094	.0302	.4951	.0812	-.2960	.0086
24	2-1,3-6	.9933	.9190	.0610	.2187	.1288	-.2834	.0169
25	2-1,10-16	.9838	.8962	.0359	.3745	.1012	-.1692	.0178
26	2-1,20-23	.9909	.7427	.0370	.6318	.0858	-.1772	.0041
27	2-1,55-58	.9718	.7549	.0330	.5824	.0659	-.2395	.0039
28	2-1,102-108	.9851	.9652	.0593	.1369	.0595	.1665	.0071
29	2-1,135-138	.9775	.8301	.0277	.3884	.1942	-.3130	.0320
30	2-2,10-13	.9687	.9702	.0302	.1155	.1130	-.0047	.0182
31	2-2,20-23	.9653	.9702	.0451	.0980	.1071	-.0288	.0070
32	2-2,56-63	.9656	.6513	.0291	.3712	.0986	-.3037	.0206
33	2-2,95-98	.9708	.9668	.0463	.1227	.0455	.1297	.0019
34	2-2,100-107	.9835	.2015	.0003	.9684	.0534	-.0467	-.0043
35	2-2,130-133	.9948	.2745	-.0020	.9534	.0544	-.0863	-.0005
36	2-3,15-18	.9961	.2670	.0006	.9584	.0432	-.0661	-.0046
37	2-3,58-65	.9703	.9467	.0405	.1231	.0712	-.2282	.0087
38	2-3,93-96	.9355	.9192	.0217	.1547	.0322	-.2548	.0140
39	2-3,107-113	.9585	.9634	.0689	.0822	.1348	.0006	.0247
40	2-3,132-135	.9947	.6757	.0121	.7122	.0734	-.1592	.0080
41	2-4,23-30	.9830	.0773	-.0097	.9876	.0371	-.0090	-.0048
42	2-4,50-53	.9714	.5626	.0205	.8072	-.0207	-.0417	-.0270
43	2-4,74-77	.9913	.5198	.0043	.8446	.0450	-.0750	-.0002
44	2-4,120-177	.9880	.0225	-.0127	.9928	.0401	-.0066	-.0033
45	2-5,10-13	.9879	.7313	.0196	.6326	.0719	-.2174	.0073
46	2-5,20-23	.9946	.7710	.0238	.6081	.1133	-.1286	.0203
47	2-5,50-57	.9820	.0090	-.0121	.9898	.0442	-.0005	-.0033
48	2-5,80-83	.9859	.9135	.0319	.2803	.2391	-.1131	.0423
49	2-6,20-23	.9926	.8490	.0228	.4859	.0606	-.1774	.0079
50	2-6,64-71	.9947	.5177	-.0024	.8509	-.0061	.0512	-.0079
51	2-6,103-110	.9897	.9744	.0302	.1489	.1120	.0650	.0225
52	3-1,2-5	.9817	.9639	.0261	.1252	.1001	-.1597	.0270
53	3-1,7-14	.9822	.0534	-.0113	.9882	.0516	-.0016	-.0011
54	3-1,40-41	.9916	.3031	.0004	.9392	.0758	-.1088	.0031
55	3-1,89-92	.9810	.7046	.0107	.6775	.0071	-.1592	-.0030
56	3-2,40-41	.9938	.9350	.0175	.3206	.0410	.1212	.0083
57	3-2,51-54	.9851	.0160	-.0126	.9913	.0433	.0103	-.0031
58	3-2,89-96	.9844	.7966	.0053	.5882	.0487	.0356	.0124
59	3-2,115-118	.9828	.9581	.0257	.0904	.2305	.0051	.0535
60	3-2,138-139	.9763	.9628	.0214	.0384	.2103	-.0273	.0498
61	3-2,147-150	.9805	.9619	.0850	.0358	.1695	-.1316	.0268
62	3-3,29-32	.9665	.8757	.0357	.0893	.3786	-.1992	.0854
63	3-3,41-48	.9724	.9029	.0320	.3804	.0975	-.0409	.0181
64	3-3,70-71	.9017	.6596	.0498	.2711	.3997	-.4746	.0753
65	3-3,99-102	.9300	.7730	.0463	.1440	.5134	-.1845	.1093
66	3-3,132-139	.9281	.8475	.0742	.0921	.4298	-.0618	.0849
67	3-4,1-4	.9846	.6563	.1505	.7271	.0453	-.0116	-.0212
68	3-4,47-48	.8857	.5506	.0348	.2824	.5528	-.4276	.1149
69	3-4,64-67	.9941	.4630	.0114	.8500	.1681	-.1678	.0262
70	3-4,105-110	.9828	.6836	.0363	.6159	.3296	-.1501	.0604
71	3-5,16-19	.9965	.3399	.0078	.9260	.1349	-.0709	.0159
72	3-5,47-48	.9609	.6637	.0206	.6566	.2243	-.1918	.0413
73	3-5,60-63	.9786	.9276	.0353	.0973	.3126	.0712	.0682
74	3-5,120-127	.9836	.0405	-.0111	.9900	.0415	.0059	-.0041
75	3-6,0-7	.9834	.0693	-.0095	.9870	.0660	-.0035	.0008
76	3-6,46-49	.9827	.5782	.0443	.7247	.2471	-.2421	.0392
77	3-6,80-84	.9930	.8044	.0329	.5336	.1884	-.1530	.0352
78	3,CC	.9942	.5183	.0312	.8443	.1069	-.0159	.0066

APPENDIX C
Estimated Superficial Temperatures of Winter (T_w) and Summer (T_s) of Hole 548 (Cores 7–16)

Sample	Core-Section (depth in cm)	T_W	T_S
1	7.1,76.79	5.69142	10.38523
2	7.2,84.85	3.79310	9.21204
3	7.3,104.111	5.94442	11.60215
4	7.4,40.43	5.82644	11.20102
5	7.4,103.117	7.02678	12.86654
6	7.5,19.22	6.83638	12.15941
7	7.5,111.116	10.40561	16.80219
8	7.5,140.141	5.78023	11.40644
9	7.6,110.117	9.16255	14.83166
10	7.7,10.13	7.65740	13.10918
11	8.1,69.70	7.52721	12.69859
12	8.1,123.130	9.72078	15.91424
13	8.2,40.47	9.25829	14.35469
14	8.2,90.91	8.59829	14.71252
15	8.2,140.147	8.20912	13.43070
16	8.3,69.70	10.29852	16.84106
17	8.4,20.27	12.24509	19.40244
18	8.4,90.91	8.48901	13.95873
19	8.5,20.27	9.79616	16.45871
20	8.5,69.70	12.19739	20.19257
21	8.5,103.110	5.93822	10.40253
22	8.6,69.70	8.63992	15.48079
23	8.6,124.125	6.92304	11.82453
24	9.1,20.23	8.28621	14.41473
25	9.1,100.107	11.56480	19.09677
26	9.2,20.23	13.20607	21.32697
27	9.2,43.44	13.15438	21.27541
28	9.2,108.109	13.44143	21.33554
29	9.3,20.23	12.53332	20.79773
30	10.4,43.44	4.85902	10.60036
31	10.4,114.116	8.86646	13.58348
32	10.5,43.44	7.33961	11.93618
33	10.5,120.122	5.36447	10.64141
34	11.1,52.53	11.11315	18.20781
35	11.1,140.147	10.26527	17.35036
36	11.2,50.53	11.13970	18.87744
37	11.2,140.147	11.26942	19.38295
38	11.3,50.53	9.27703	16.13654
39	11.3,139.146	10.02721	17.34154
40	11.4,140.147	8.38645	14.66243
41	11.5,17.24	8.11130	14.65618
42	11.5,50.53	12.77940	21.53589
43	11.5,92.97	11.91446	18.03188
44	11.5,143.150	12.41459	20.28677
45	11.6,8.15	12.33532	19.65340
46	13.1,130.137	13.29044	21.21365
47	13.2,35.38	12.43903	20.26924
48	13.2,120.121	6.02148	11.18995
49	13.3,22.29	9.12361	17.92125
50	13.4,95.98	6.26625	13.03616
51	13.5,35.38	4.97555	11.45716
52	13.5,130.132	5.83240	12.79071
53	13.6,27.34	1.03121	7.08024
54	14.1,40.47	7.71039	13.31816
55	14.2,84.91	10.09026	17.03717
56	15.1,112.119	10.55655	17.62921
57	15.2,30.33	3.98540	10.66427
58	15.3,110.117	3.42316	10.62220
59	15.4,110.117	7.62483	13.55525
60	15.5,63.68	12.13752	20.51079
61	15.5,92.97	11.46741	19.42174
62	15.5,130.137	12.26885	19.85904
63	15.6,30.33	9.42861	16.55144
64	15.6,123.126	8.81152	14.82182
65	16.1,10.11	9.00142	14.43295
66	16.1,70.77	7.82703	13.33867
67	16.1,140.141	7.13746	13.03857

APPENDIX D
Estimated Superficial Temperatures of Winter (T_w) and Summer (T_s) of Hole 549A (Cores 1–3)

Sample	Core-Section (depth in cm)	T_W	T_S
1	1-1,1-4	10.49293	16.93039
2	1-1,8-11	9.66333	15.65680
3	1-1,39-42	6.43232	10.34690
4	1-1,42-45	1.47280	7.22030
5	1-1,137-140	3.01429	8.23057
6	1-2,2-5	3.55543	9.78546
7	1-2,5-8	2.89384	9.19319
8	1-2,70-77	-.14377	5.77677
9	1-2,130-137	3.32341	8.74736
10	1-3,10-13	6.62011	11.30172
11	1-3,20-23	7.86067	12.34632
12	1-3,70-77	5.04178	11.06653
13	1-3,125-131	8.94804	13.95925
14	1-4,10-13	9.17361	14.24243
15	1-4,20-23	9.84594	15.42049
16	1-4,40-43	10.92645	16.04713
17	1-4,54-57	9.71626	13.21944
18	1-4,72-78	6.70300	11.39479
19	1-4,88-93	4.36582	10.78611
20	1-4,105-109	7.43444	12.22343
21	1-5,20-23	9.16980	13.75793
22	1-5,90-97	.06705	5.85265
23	1-5,144-147	7.85087	12.35516
24	2-1,3-6	9.09218	14.57053
25	2-1,10-16	8.31856	14.10440
26	2-1,20-23	9.41603	13.57013
27	2-1,55-58	8.32694	12.92261
28	2-1,102-108	9.54056	16.95036
29	2-1,135-138	7.37357	12.78659
30	2-2,10-13	9.50096	16.26984
31	2-2,20-23	9.77334	16.20111
32	2-2,56-63	7.23302	12.81685
33	2-2,95-98	9.07492	16.12820
34	2-2,100-107	4.55593	9.20292
35	2-2,130-133	5.39832	10.22379
36	2-3,15-18	5.65379	10.24031
37	2-3,58-65	8.83380	14.32741
38	2-3,93-96	7.62442	13.25382
39	2-3,107-113	10.97058	18.04550
40	2-3,132-135	8.29077	12.62855
41	2-4,23-30	1.58949	7.09726
42	2-4,50-53	9.74671	12.14889
43	2-4,74-77	7.79979	12.02354
44	2-4,120-177	.37858	6.25343
45	2-5,10-13	8.17858	12.58294
46	2-5,20-23	8.43251	13.82544
47	2-5,50-57	.09756	5.89636
48	2-5,80-83	9.43759	15.53769
49	2-6,20-23	7.94250	12.97385
50	2-6,64-71	6.88890	11.64618
51	2-6,103-110	9.40552	16.60504
52	3-1,2-5	9.14360	15.45679
53	3-1,7-14	.72737	6.48319
54	3-1,40-41	5.83544	10.40769
55	3-1,89-92	7.79139	12.54321
56	3-2,40-41	7.62858	14.54194
57	3-2,51-54	.04773	5.85493
58	3-2,89-96	7.24803	13.42494
59	3-2,115-116	10.90964	18.47916
60	3-2,138-139	11.31800	18.64226
61	3-2,147-150	11.93296	18.39798
62	3-3,29-32	11.64555	18.99684
63	3-3,41-46	8.39251	14.74516
64	3-3,70-71	7.86002	14.63716
65	3-3,99-102	10.80454	18.67522
66	3-3,132-139	12.45177	20.26093
67	3-4,1-4	15.02878	21.42447
68	3-4,47-48	6.52559	14.68621
69	3-4,64-67	6.84652	11.76618
70	3-4,105-110	8.01063	13.32349
71	3-5,16-19	5.85319	10.70071
72	3-5,47-48	7.37600	12.62607
73	3-5,80-83	11.44243	19.47319
74	3-5,120-127	.70023	6.29286
75	3-6,0-7	1.08088	6.59861
76	3-6,46-49	8.25917	13.42511
77	3-6,30-34	8.65794	14.24666
78	3,CC	9.07235	13.44048

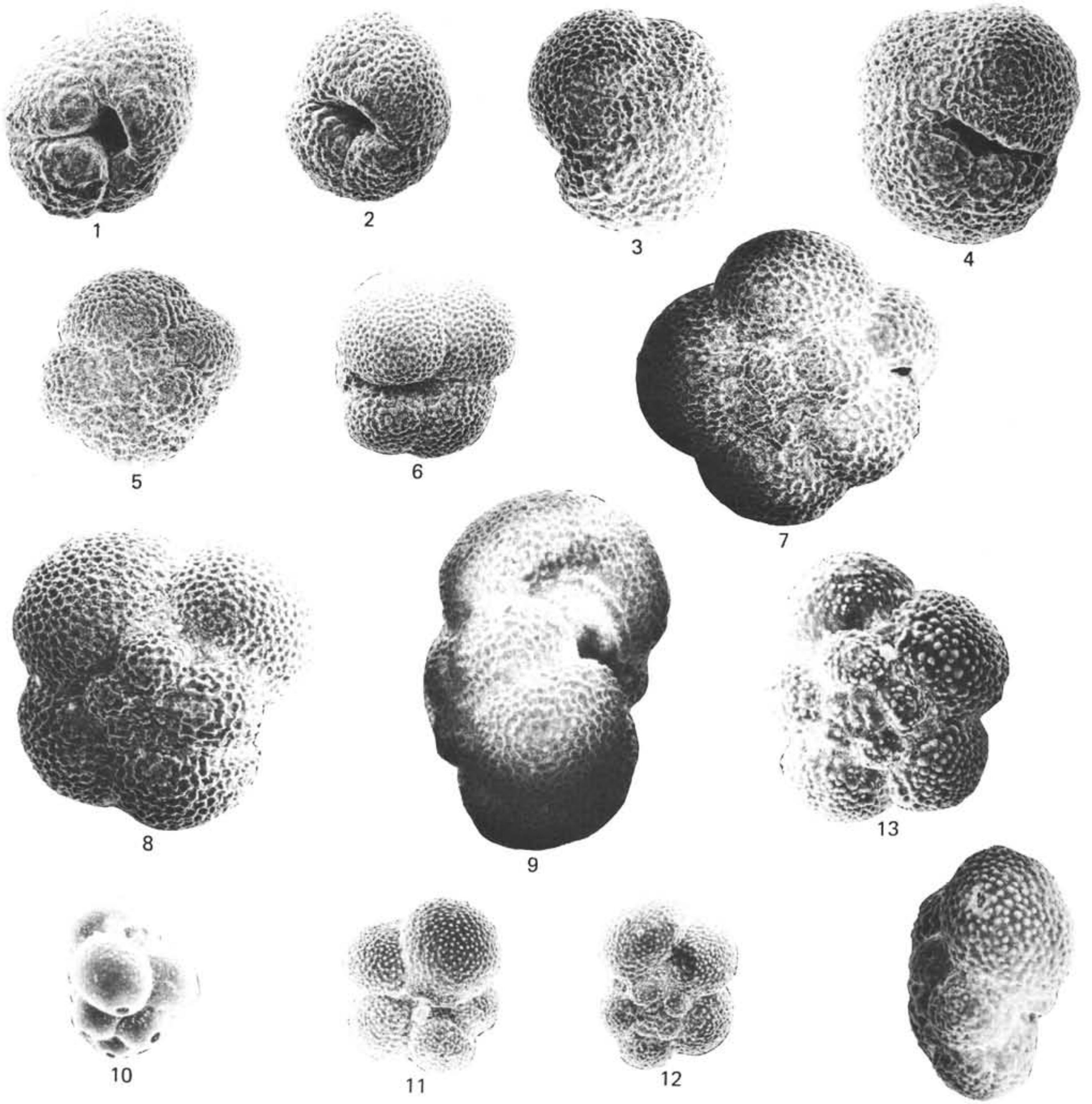


Plate 1. **1–4.** *Globigerina pachyderma* (Ehrenberg), left-coiling. (1, 2, 4) Sample 549A-1-2 (70–72 cm), ×120, umbilical view. (3) Sample 549A-1-2 (70–72 cm), ×120, spiral view. **5–9.** *Globigerina pachyderma* (Ehrenberg), right-coiling. (5) Sample 549A-1-1 (39–42 cm), ×120, spiral view. (6) Sample 549A-1-1 (39–42 cm), ×120, umbilical view. (7, 8) Sample 549A-1-1 (1–4 cm), ×140, spiral view. (9) Sample 549A-1-1 (1–4 cm), ×140, side view. **10.** *Globigerinita uvula* (Ehrenberg), Sample 549A-1-1 (39–42 cm), ×160, umbilical view. **11–14.** *Globigerina quinqueloba* Natland. (11) Sample 549A-1-1 (39–42 cm), ×120, umbilical view. (12) Sample 549A-1-1 (39–42 cm), ×120, spiral view. (13) Sample 549A-1-1 (1–4 cm), ×200, spiral view. (14) Sample 549A-1-1 (1–4 cm), ×200, side view.

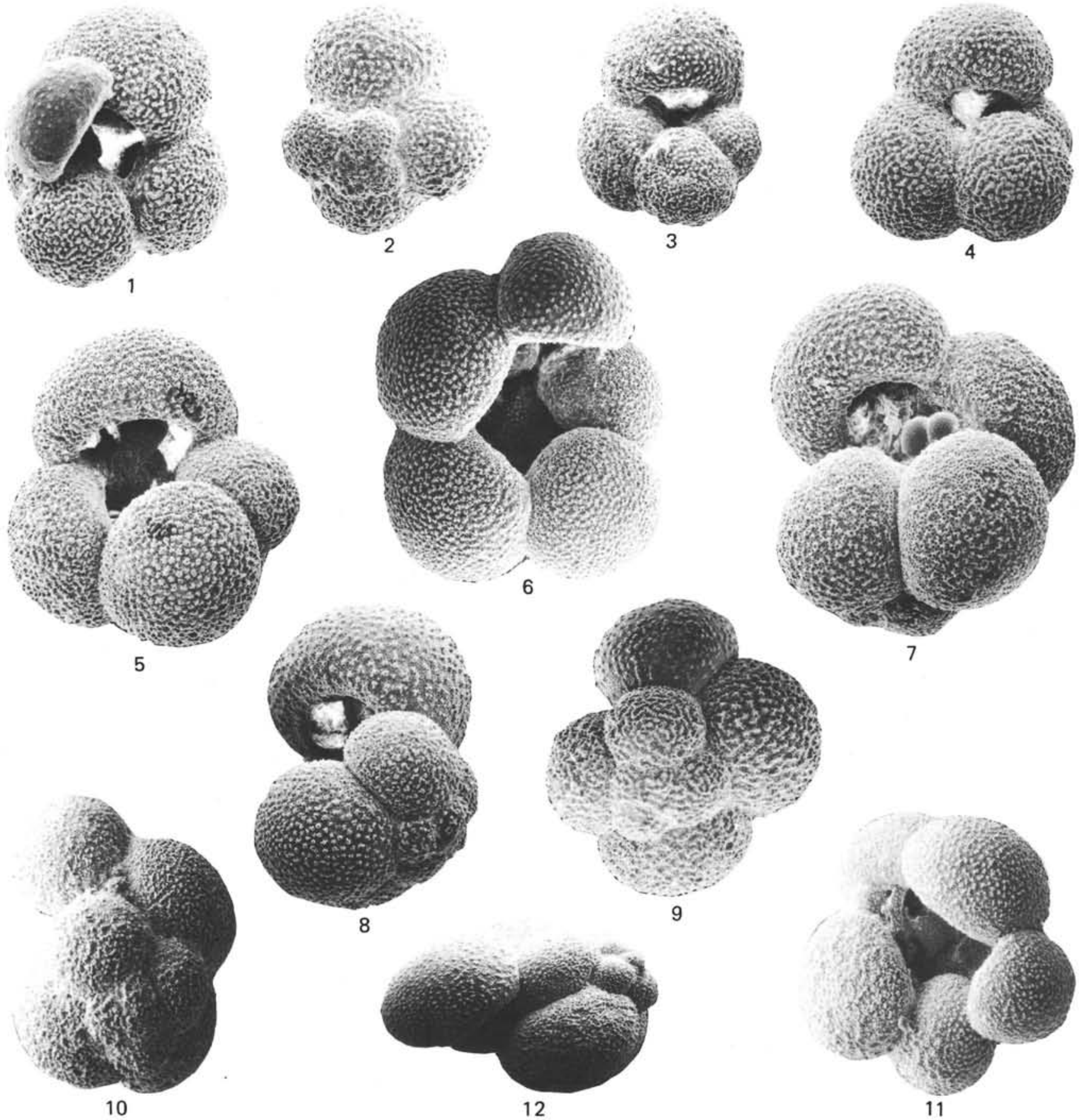


Plate 2. **1–4.** *Globigerina bulloides* d'Orbigny. (1) Sample 549A-1-1 (39–42 cm), × 120, umbilical view. (2) Sample 549A-1-1 (39–42 cm), × 120, spiral view. (3) Sample 549A-1-1 (39–42 cm), × 100, umbilical view. (4) Sample 549A-3-3 (132–134 cm), × 100, umbilical view. **5–12.** *Globigerina cariacoensis* Rögl and Bolli. (5–7) Sample 549A-3-3 (132–134 cm), × 120, umbilical view. (8) Sample 549A-3-3 (132–134 cm), × 100, side view. (9) Sample 549A-3-3 (132–134 cm), × 100, spiral view. (10) Sample 548-8-1 (120–122 cm), × 80, spiral view. (11) Sample 548-8-1 (120–122 cm), × 80, umbilical view. (12) Sample 548-8-5 (20–22 cm), side view.

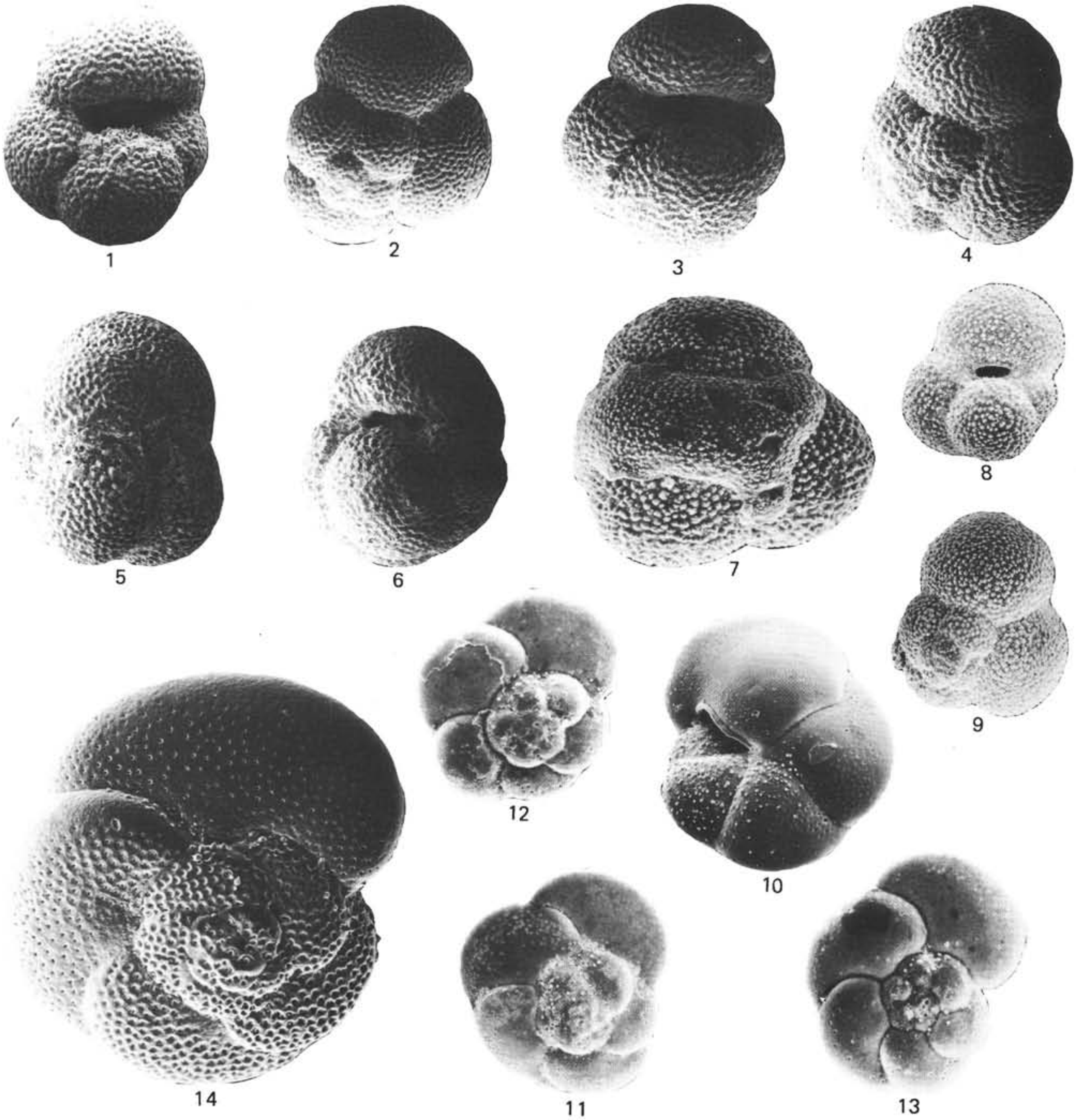


Plate 3. **1–6.** *Globigerina bulloides* d'Orbigny var. (1) Sample 548-18-4 (25–27 cm), ×100, umbilical view. (2) Sample 548-18-4 (25–27 cm), ×100, spiral view. (3) Sample 548-19-3 (53–56 cm), ×100, umbilical view. (4) Sample 548-29-3 (53–56 cm), ×100, spiral view. (5) Sample 548-18-4 (25–27 cm), ×100, umbilical view. (6) Sample 548-19-3 (53–56 cm), ×100, umbilical view. **7–9.** *Globigerinita glutinata* (Egger). (7) Sample 548-21-3 (37–39 cm), ×200, umbilical view. (8) Sample 549A-1-1 (39–42 cm), ×120, umbilical view. (9) Sample 549A-1-1 (39–42 cm), ×140, spiral view. **10, 13.** *Globorotalia scitula* (Brady) form 1. Sample 549A-1-1 (39–42 cm), ×100, umbilical view. (13) Sample 549A-1-1 (1–4 cm), ×150, spiral view. **11–12.** *Globorotalia bermudezi* Rögl and Bolli. (11) Sample 549A-1-1 (39–42 cm), ×100, spiral view. (12) Sample 549A-1-1 (1–4 cm), ×150, spiral view. **14.** *Globorotalia scitula* (Brady) form 2, Sample 549A-3-1 (7–14 cm), ×100, spiral view.

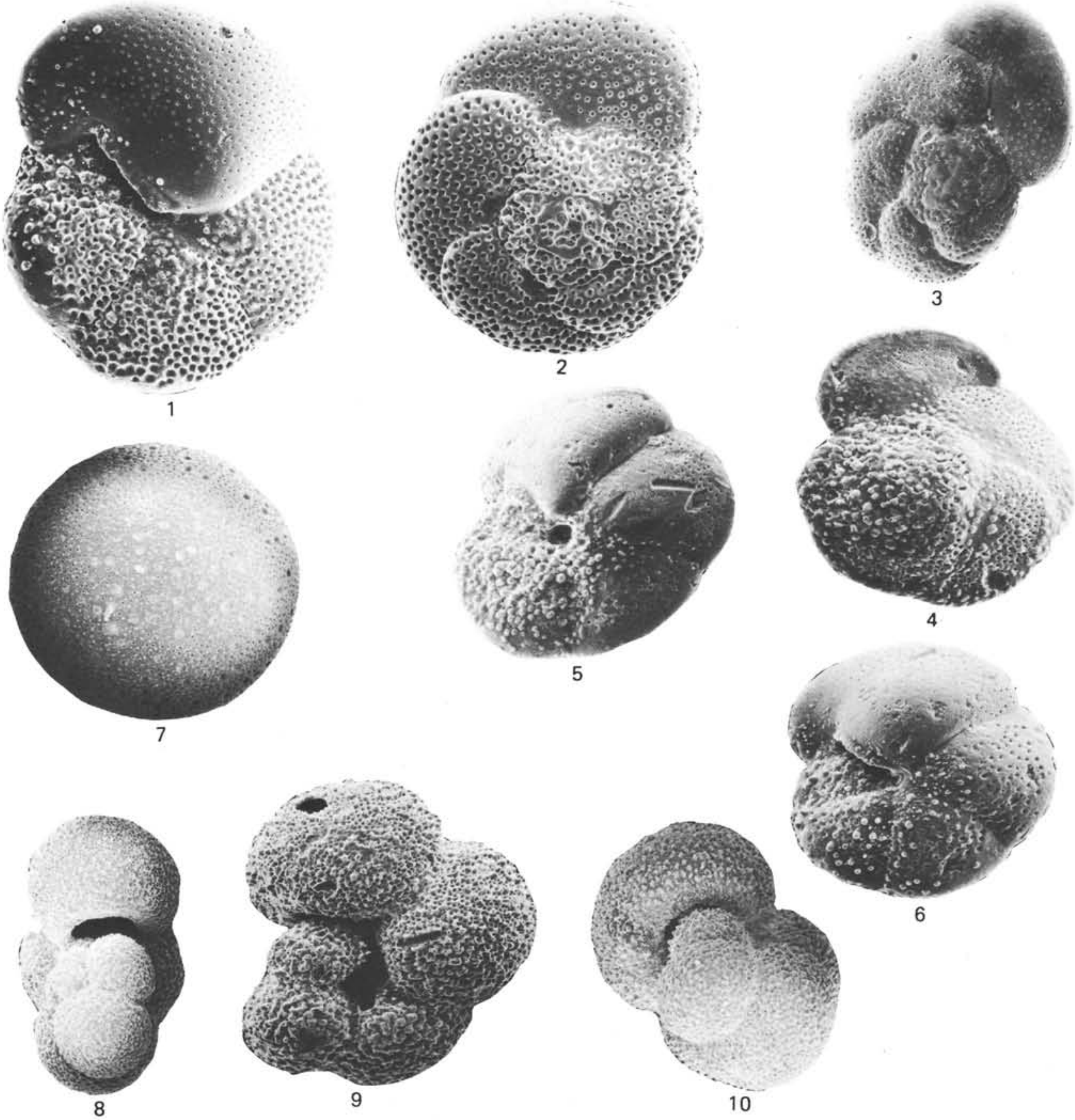


Plate 4. **1-2.** *Globorotalia scitula* (Brady) form 2. (1) Sample 549A-3-3 (132–134 cm), ×100, umbilical view. (2) Sample 549A-3-3 (132–134 cm), ×100, spiral view. **3–6.** *Globorotalia scitula* (Brady) form 1. (3) Sample 548-27,CC, ×100, spiral view. (4) Sample 548-35,CC, ×140, spiral view. (5) Sample 548-35,CC, ×140, umbilical view. (6) Sample 548-35,CC, ×140, umbilical view. **7.** *Orbulina universa* d'Orbigny, Sample 549A-1-1 (39–42 cm), ×80. **8–10.** *Hastigerina siphonifera* (d'Orbigny). (8) Sample 549A-2-1 (3–6 cm), ×80, peripheral view. (9) Sample 548-21-3 (37–39 cm), ×100, side view. (10) Sample 549A-1-4 (40–43 cm), ×80, peripheral view.

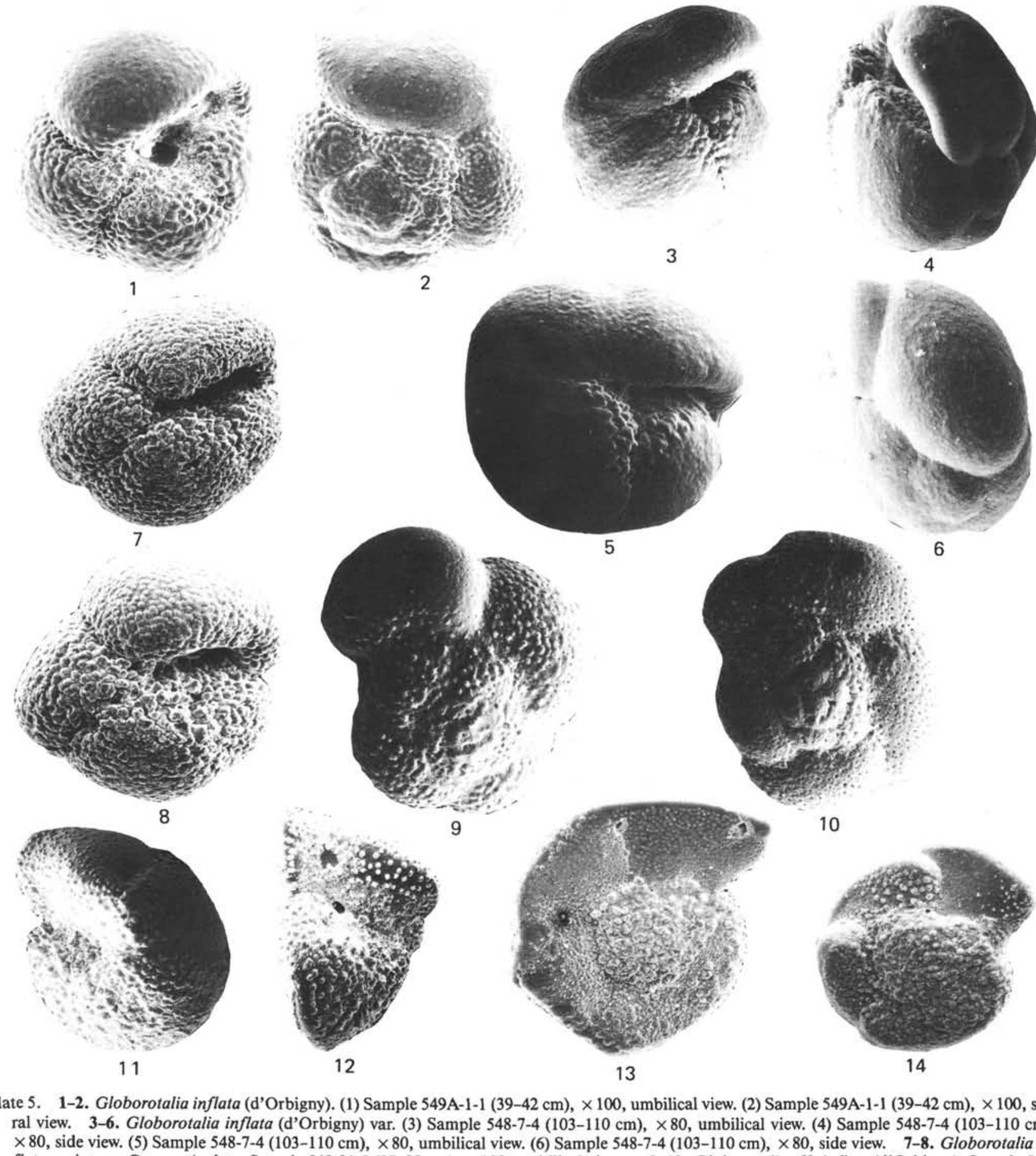


Plate 5. **1–2.** *Globorotalia inflata* (d'Orbigny). (1) Sample 549A-1-1 (39–42 cm), × 100, umbilical view. (2) Sample 549A-1-1 (39–42 cm), × 100, spiral view. **3–6.** *Globorotalia inflata* (d'Orbigny) var. (3) Sample 548-7-4 (103–110 cm), × 80, umbilical view. (4) Sample 548-7-4 (103–110 cm), × 80, side view. (5) Sample 548-7-4 (103–110 cm), × 80, umbilical view. (6) Sample 548-7-4 (103–110 cm), × 80, side view. **7–8.** *Globorotalia inflata* ex. interc. *G. puncticulata*, Sample 548-21-3 (37–39 cm), × 100, umbilical views. **9–10.** *Globorotalia* aff. *inflata* (d'Orbigny), Sample 548-18-3 (42–45 cm), × 160, spiral views. **11–13.** *Globorotalia truncatulinoides* (d'Orbigny). (11) Sample 548-12-1 (129–130 cm), × 100, umbilical view. (12) Sample 549A-1-4 (40–43 cm), × 80, side view. (13) Sample 549A-1-1 (39–42 cm), × 80, spiral view. **14.** *Globorotalia* aff. *truncatulinoides*, Sample 548-12-1 (123–130 cm), spiral view.

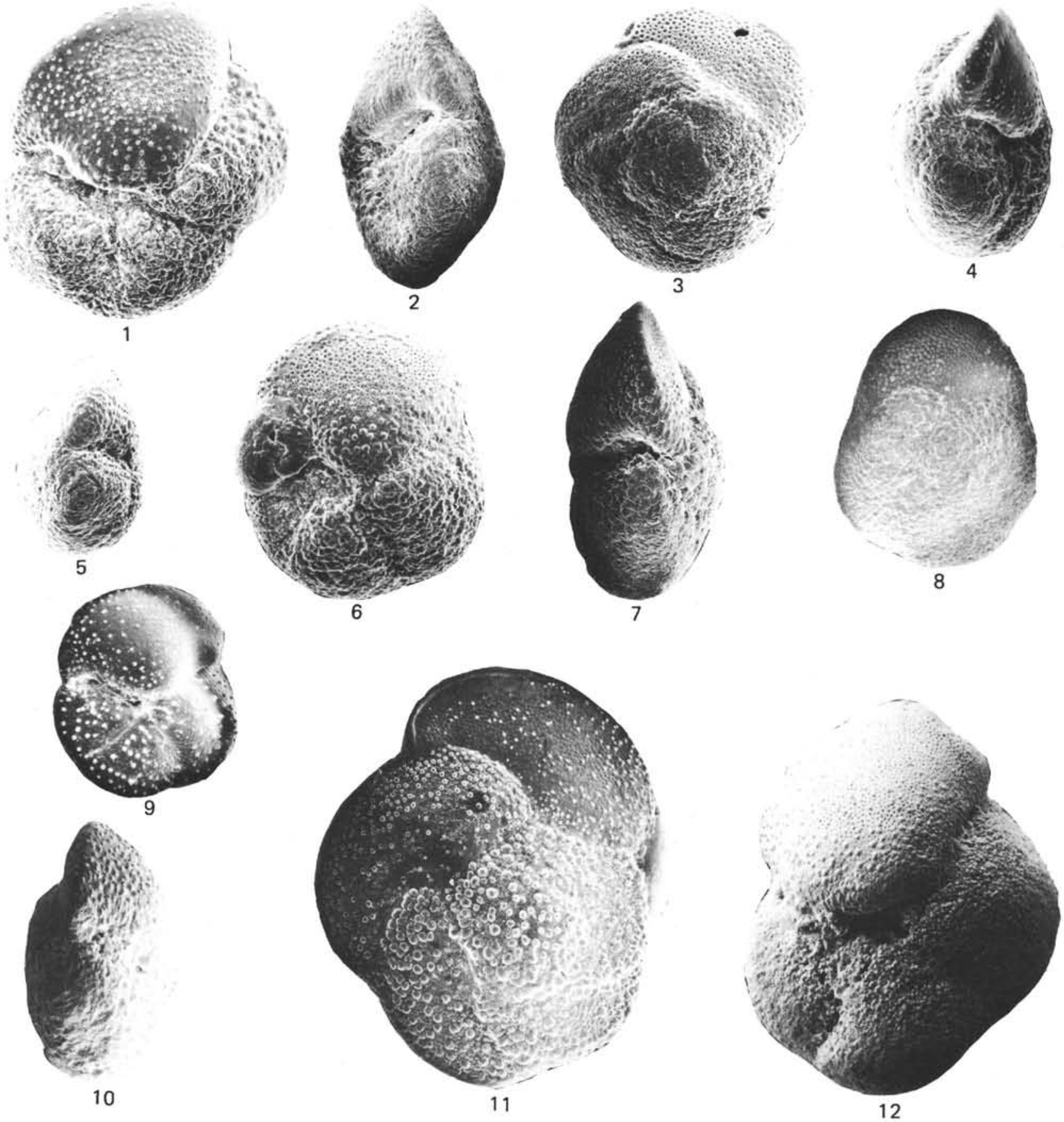


Plate 6. **1–12.** *Globorotalia hirsuta* (d'Orbigny). (1) Sample 549A-1-1 (39–42 cm), × 80, umbilical view. (2) Sample 549A-1-1 (39–42 cm), × 80, side view. (3) Sample 549A-1-4 (40–43 cm), × 80, spiral view. (4) Sample 549A-1-4 (40–43 cm), × 80, side view. (5) Sample 550-1-3 (130–137 cm), × 80, side view. (6) Sample 549A-1-4 (40–43 cm), × 80, umbilical view. (7) Sample 549A-1-1 (39–42 cm), × 80, side view. (8) Sample 550-1-3 (130–137 cm), × 80, spiral view. (9) Sample 549A-2-1 (3–6 cm), × 80, umbilical view. (10) Sample 548-7-7 (10–13 cm), × 80, side view. (11) Sample 549A-1-4 (40–43 cm), × 80, spiral view. (12) Sample 548-7-7 (10–13 cm), × 80, umbilical view.

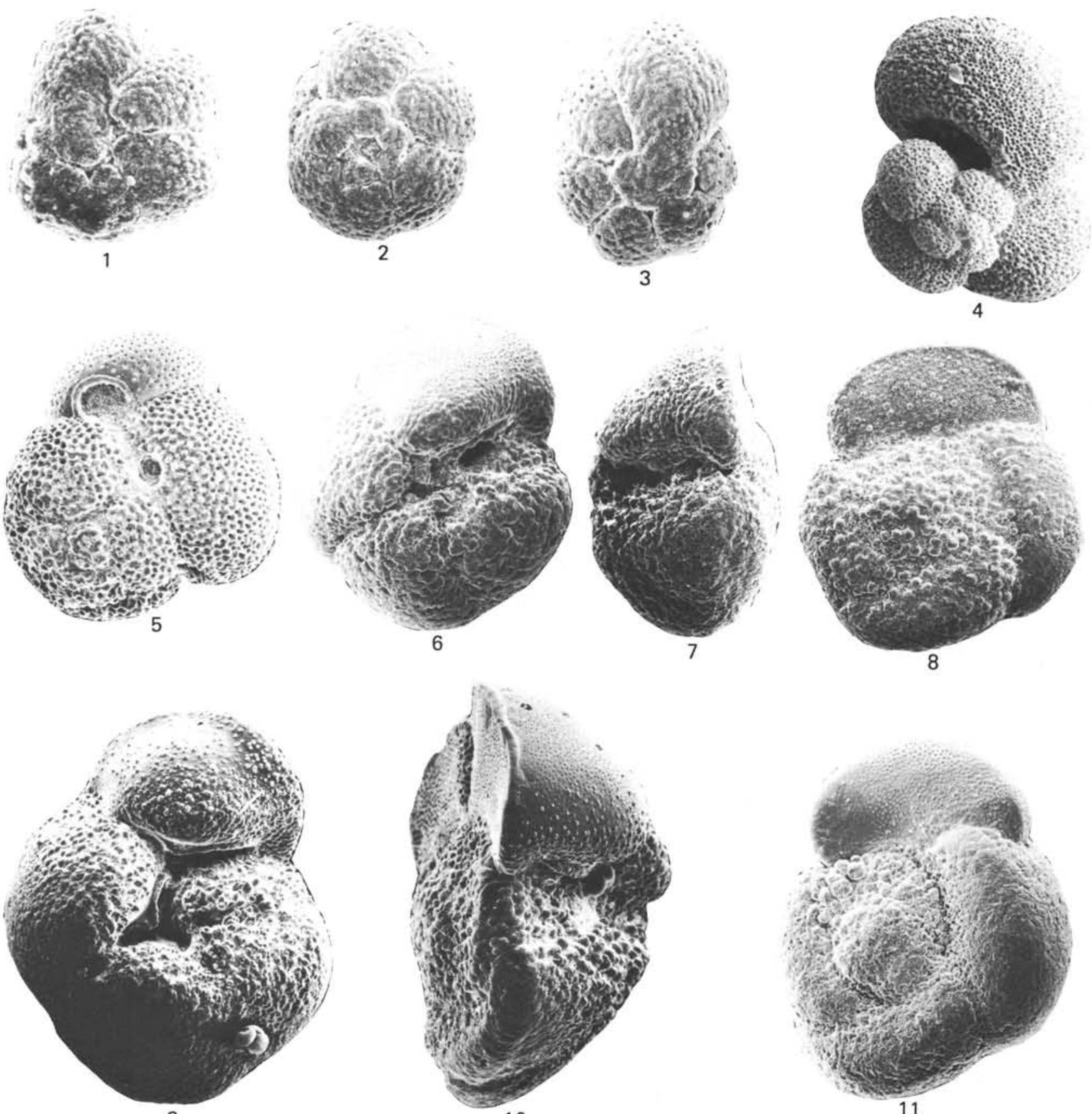


Plate 7. **1–3.** *Turborotalita humilis* (Brady). (1) Sample 549A-1-1 (1–4 cm), ×200, umbilical view. (2) Sample 549A-1-1 (1–4 cm), ×200, spiral view. (3) Sample 549A-1-1 (1–4 cm), ×200, umbilical view. **4.** *Globigerina calida* Parker, Sample 548-7-6 (110–117 cm), ×80, spiral view. **5.** *Globigerinoides ruber* (d'Orbigny), Sample 549-1-4 (40–43 cm), ×100, spiral view. **6–8.** *Globorotalia crassaformis crassaformis* (Galloway and Wissler). (6) Sample 549A-1-4 (10–13 cm), ×80, umbilical view. (7) Sample 549A-1-4 (10–13 cm), ×80, side view. (8) Sample 549A-1-4 (10–13 cm), ×80, spiral view. **9–11.** *Globorotalia crassaformis hessi* Bolli and Premoli Silva. (9) Sample 549A-2-3 (93–96 cm), ×80, umbilical view. (10) Sample 549A-2-3 (93–96 cm), ×80, side view. (11) Sample 549A-3-3 (132–134 cm), ×80, spiral view.

Plate 8. **1-5.** *Globorotalia crassaformis oceanica* Cushman and Bermudez. (1) Sample 548-10,CC, ×80, side view. (2) Sample 548-10,CC, ×60, umbilical view. (3) Sample 548-10,CC, ×80, spiral view. (4) Sample 548-10,CC, ×60, umbilical view. (5) Sample 548-10,CC, ×80, side view. **6-14.** *Globorotalia crassaformis ronda* Blow. (6) Sample 548-11-1 (140-147 cm), ×80, umbilical view. (7) Sample 548-9-2 (43-44 cm), ×80, side view. (8) Sample 548-11-3 (139-146 cm), ×80, spiral view. (9-10) Sample 548-9-2 (43-44 cm), ×80, spiral view. (11) Sample 548-11-3 (139-146 cm), ×80, spiral view. (12) Sample 548-16,CC, ×100, side view. (13) Sample 548-16,CC, ×100, umbilical view. (14) Sample 548-16,CC, ×100, spiral view.

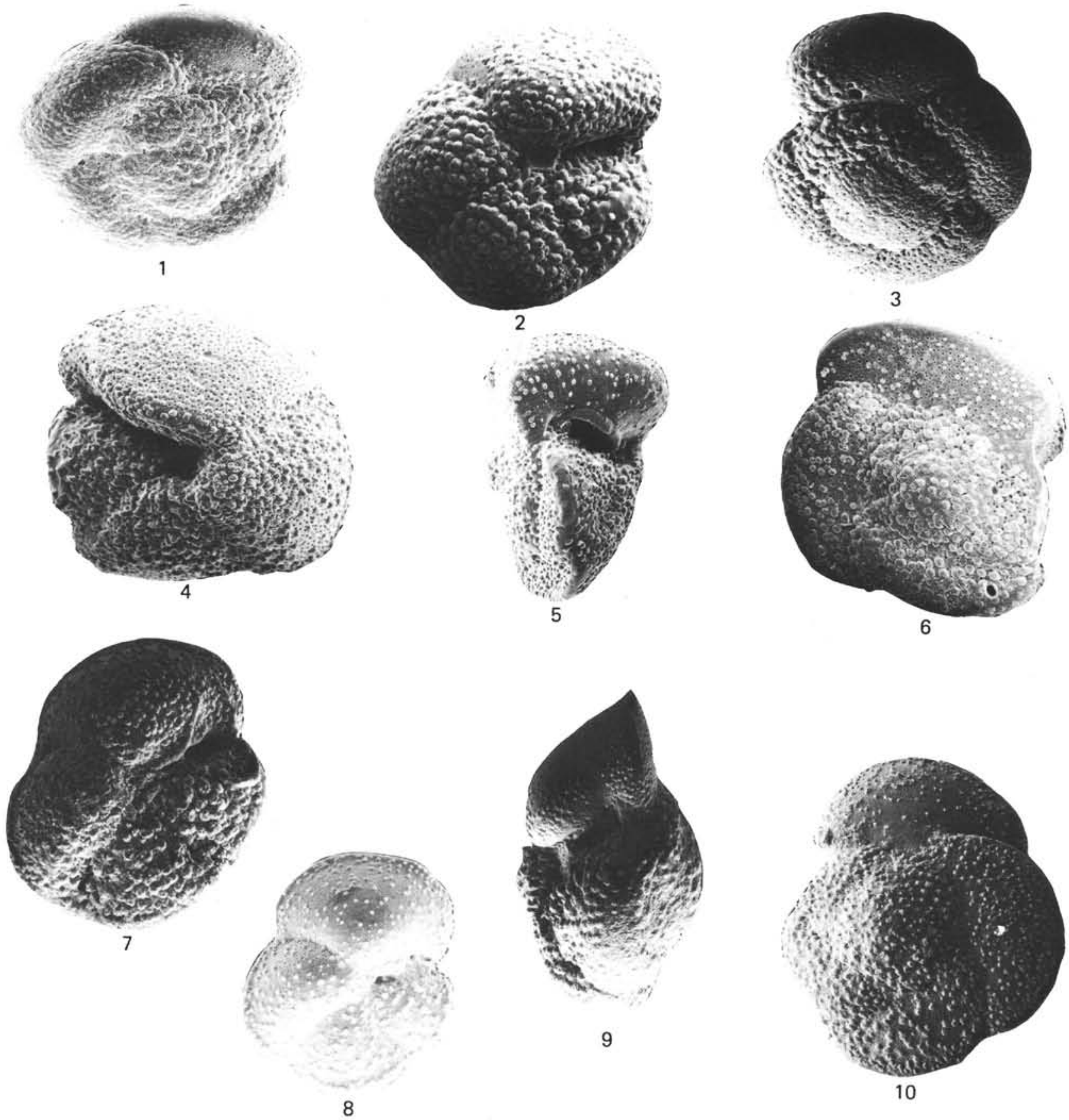


Plate 9. **1–3.** *Globorotalia crassaformis ronda* Blow. (1) Sample 548-18,CC, ×100, spiral view. (2) Sample 548-16-1 (70–77 cm), ×160, umbilical view. (3) Sample 548-16-1 (70–77 cm), ×160, spiral view. **4–6.** *Globorotalia crassaformis* (Galloway and Wissler). (4) Sample 548-25,CC, ×100, umbilical view. (5) Sample 548-25,CC, ×100, side view. (6) Sample 548-25,CC, ×100, spiral view. **7–10.** *Globorotalia crassula* Cushman and Stewart. (7) Sample 548-15-5 (30–33 cm), ×100, umbilical view. (8) Sample 548-15-5 (30–33 cm), ×100, umbilical view. (9) Sample 548-15-5 (30–33 cm), ×100, side view. (10) Sample 548-15-5 (30–33 cm), ×80, spiral view.

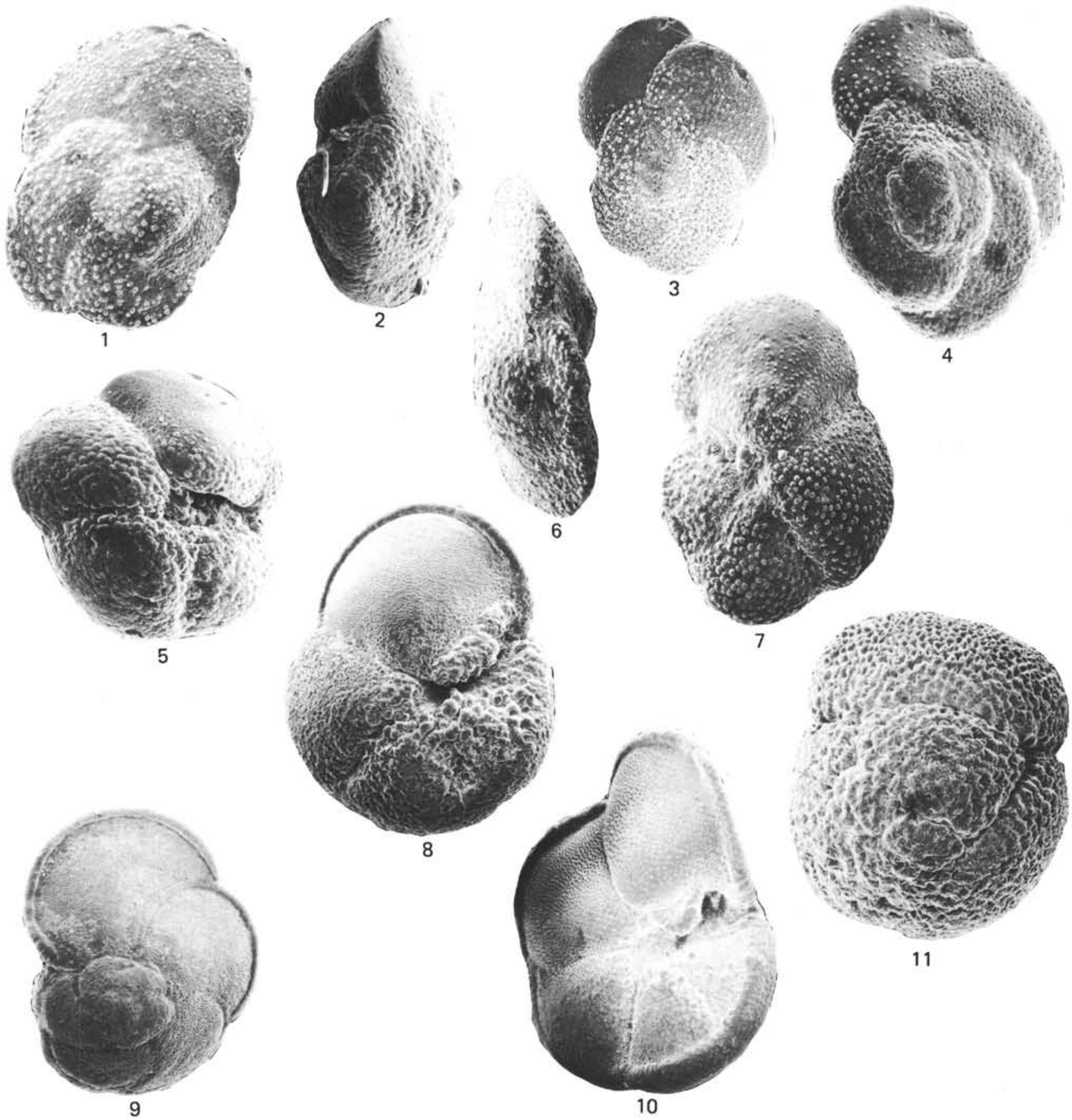


Plate 10. **1–7.** *Globorotalia crassula* Cushman and Stewart. (1) Sample 548-29,CC, ×80, spiral view. (2) Sample 548-21-3 (37–39 cm), ×80, side view. (3) Sample 548-21-3 (37–39 cm), ×80, spiral view. (4) Sample 548-21-3 (37–39 cm) ×80, spiral view. (5) Sample 548-21-3 (37–39 cm), ×80, umbilical view. (6) Sample 548-29,CC, ×100, side view. (7) Sample 548-29,CC, ×80, umbilical view. **8.** *Globorotalia tumida* (Brady), Sample 549A-2-3 (107–113 cm), ×60, umbilical view. **9.** *Globorotalia menardii* (d'Orbigny), Sample 549A-2-3 (107–113 cm), ×60, spiral view. **10.** *Globorotalia* cf. *flexuosa* (Koch), Sample 549A-2-3 (107–113 cm), ×60, umbilical view. **11.** *Globigerinoides conglobatus* (Brady), Sample 549A-1-4 (40–43 cm), ×80, spiral view.

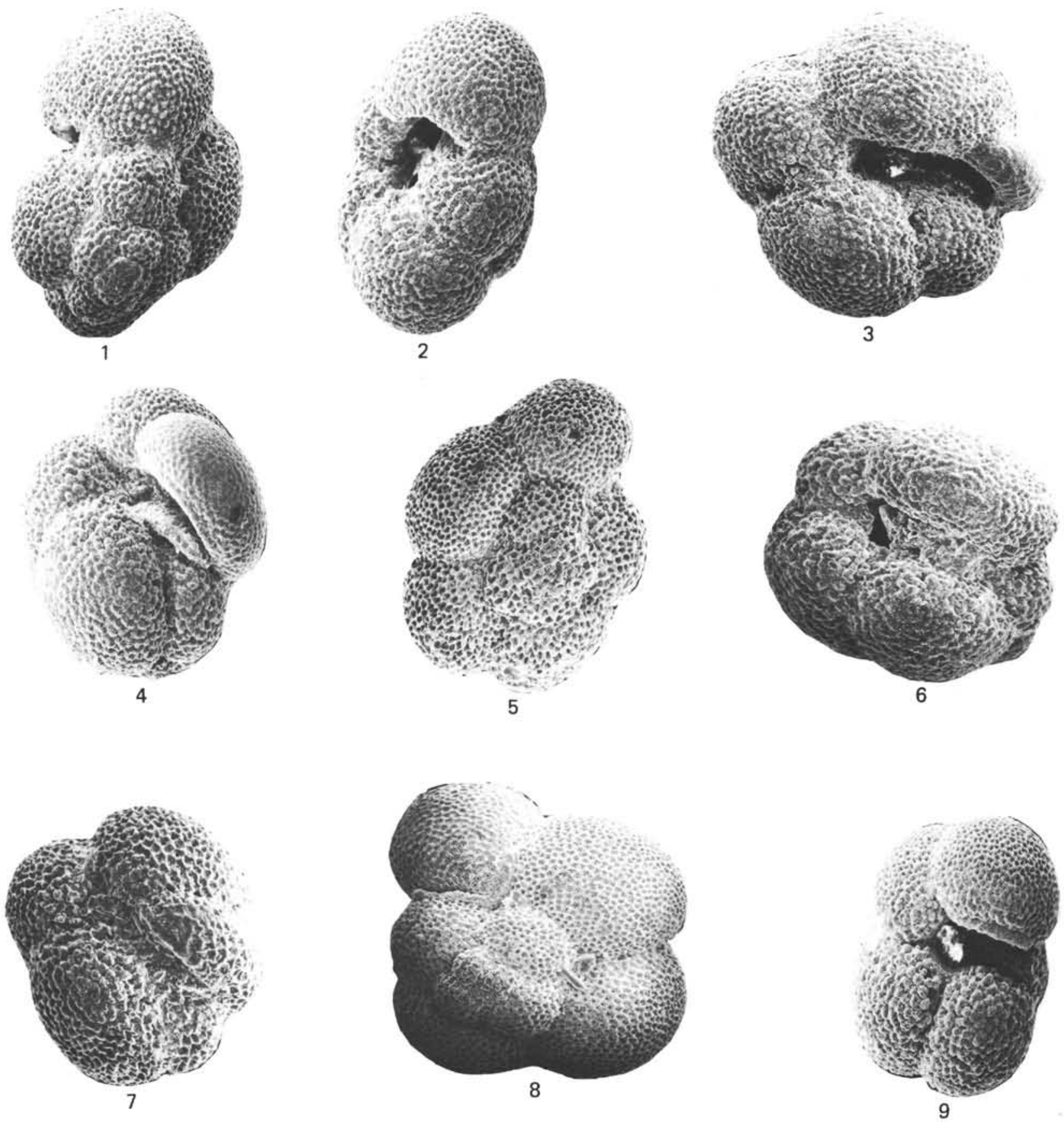


Plate 11. **1–9.** *Globigerina atlantica* (Berggren). (1) Sample 548-18,CC, ×100, spiral view. (2) Sample 548-28,CC, ×100, side view. (3) Sample 548-25,CC, ×100, umbilical view. (4) Sample 548-28,CC, ×100, umbilical view. (5) Sample 548-28,CC, ×100, spiral view. (6–7) Sample 548-18,CC, ×100, umbilical view. (8) Sample 548-25,CC, ×100, spiral view. (9) Sample 548-28,CC, ×100, umbilical view.

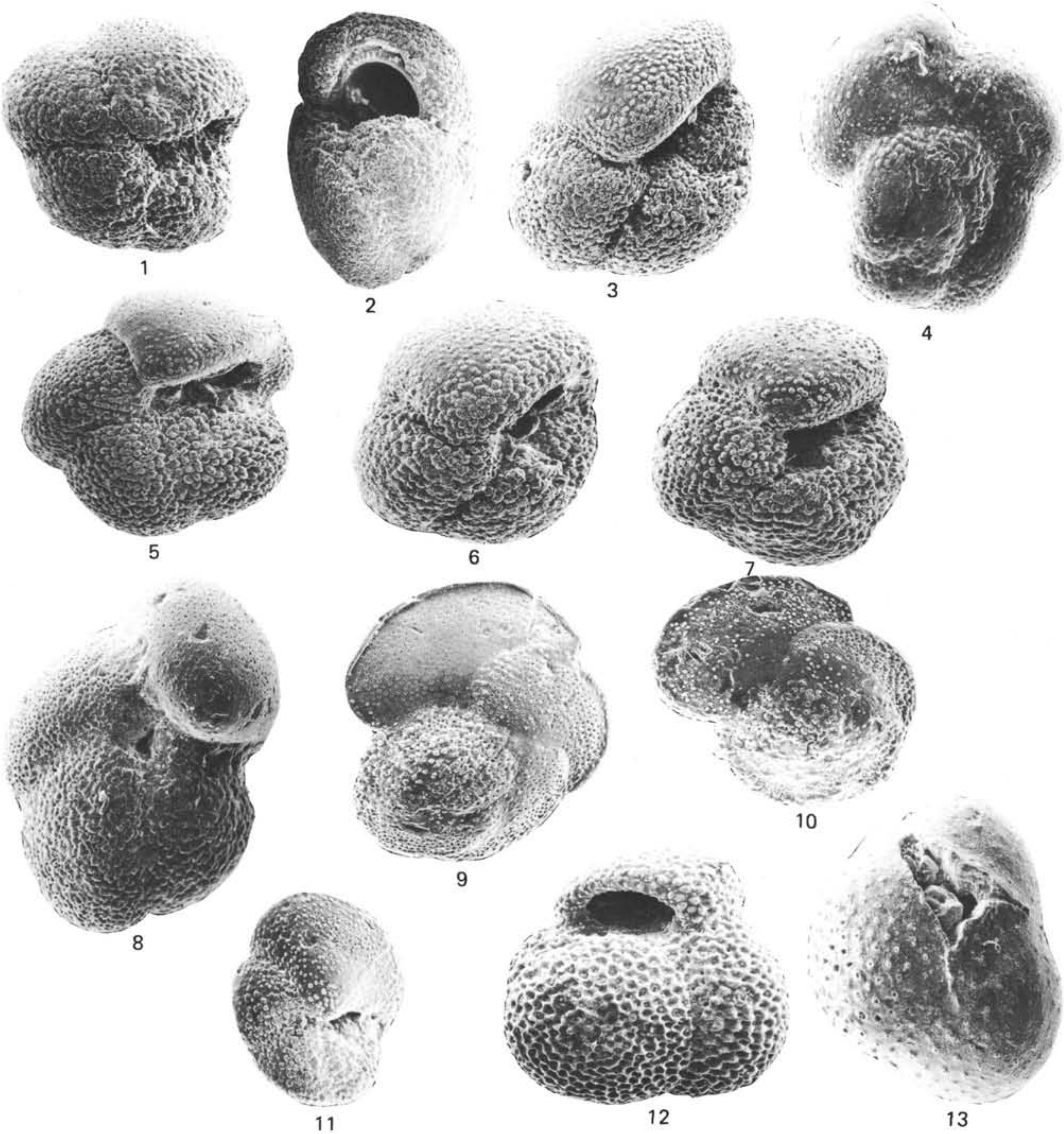


Plate 12. **1–8.** *Globorotalia puncticulata* (Deshayes). (1) Sample 548-25,CC, ×100, umbilical view. (2) Sample 548-25,CC, ×100, side view. (3) Sample 548-32,CC, ×100, umbilical view. (4) Sample 548-27,CC, ×100, spiral view. (5–7) Sample 548-32,CC, ×100, umbilical view. (8) Sample 548-29,CC, ×100, umbilical view. **9–11.** *Globorotalia margaritae* Bolli and Bermudez. (9–10) Sample 548-31,CC, ×100, spiral view. (11) Sample 548-31,CC, ×100, umbilical view. **12.** *Globigerinoides obliquus* Bolli, Sample 548-35,CC, ×140, umbilical view. **13.** *Sphaeroidinellopsis subdehiscens* (Blow), Sample 548-35,CC, ×100.