26. QUATERNARY CALCAREOUS BENTHIC FORAMINIFERS, LEG 80[1]

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ABSTRACT

Calcareous benthic foraminifers were recovered from Quaternary sediments from three sites in the northeast Atlantic, more specifically on the slope of the Goban Spur and the neighboring abyssal plain (Leg 80, Holes 548, 549A, and 550. Hole 548, at a water depth of 1256 m, presents a complete Quaternary series 110 m thick from which 139 samples were studied. The autochthonous benthic foraminifers belong to two biologic units. One is at the upper part of the Quaternary between bioclimatic Stages I to XII, shows evidence of glaciation, and has a usually poor microfauna; the other, at the lower part of the Quaternary between bioclimatic Stages XXIII and XIII, is characterized by a richer and more homogeneous microfauna. This site is today overlain by water masses low in oxygen, a mixture of water from the Mediterranean and the upper part of the North Atlantic Deep Water (NADW). Quaternary paleohydrologic variations were observed. During bioclimatic Stage V and the lower Quaternary, normally oxygenated waters similar to the present-day NADW overlay this site. Less oxygenated waters (in comparison to modern ones) existed during the Quaternary close to the Brunhes/Matuyama reversal. Displaced faunas from the neighboring continental shelf appear to be quite abundant throughout the Quaternary. Coastal displaced faunas were found at points corresponding to periods of deglaciation—the transitions from bioclimatic Stages XII to XI and from Stages VI to V. The occurrence of these faunas suggests the existence of two episodes of low sea levels on the neighboring continental shelf.

Hole 549A, which is at a water depth of 2535.5 m, yielded 27 m of Quaternary sediments belonging to the upper 20 bioclimatic stages. Eighty samples were studied. The degree of glaciation determined benthic foraminiferal abundance. The benthic foraminifers in the upper part of the sequence (bioclimatic Stages I to XII), where there were numerous fossil-poor levels corresponding to glacial maxima, vary widely in number, whereas the benthic foraminifers in the lower part of the sequence (bioclimatic Stages XIII to XX) do not vary greatly in number. As shown by Holocene benthic microfauna, the site is overlain today by the well oxygenated North Atlantic Deep Water. Almost the same type of water mass characterized this site during the Quaternary, when *Planulina wuellerstorfi* and *Hoeglundina elegans* prevailed. Indications of less oxygenated waters were, however, observed in bioclimatic Stages XIII to XII and VI to V, where a spectacular development of *Uvigerina peregrina* (90% of faunal assemblage) was noted, often in association with pyrite. The oxygenation decrease could have been the result of the influx of organic matter.

Hole 550, located at a water depth of 4432 m, yielded only 6 m of Quaternary sediments, which correspond to the last 125,000 yr. (bioclimatic Stages I–V). Its benthic microfauna is presently living in the lower North Atlantic Deep Water environment; the water mass also contains a small Antarctic Bottom Water component. An episode marked by water low in oxygen was recognized.

From a biostratigraphic point of view, certain species within the benthic assemblages became extinct at the Brunhes/Matuyama reversal, and this change in assemblage appears to be in step with observations made about similar paleoenvironments on the African margin.

INTRODUCTION

The Quaternary period in the northeast Atlantic has for the past 15 yr. been the subject of diverse (both surface and core material) micropaleontological studies. The primary objective of these studies, especially those concerning the Bay of Biscay and the closely related zones south of the Goban Spur, has been to solve biostratigraphic (Caralp, 1971; Pujol, 1980) or paleoecological problems (Peypouquet, 1977) associated with late Quaternary sediments (isotopic Stages 1–5). In the temperate northeast Atlantic, the late Quaternary sediments are practically the only sediments known. As a result of the research in this region, depth zonation schemes for the benthic foraminifers have been established (Schnitker, 1969; Caralp et al., 1970; Pujos-Lamy, 1973b; Pujos, 1976). Although dealt with, the Quaternary period has not been discussed in great depth by previous DSDP papers (Legs 12 and 48: Berggren, 1972; Murray, 1979; Schnitker, 1979a).

A complete sequence of Quaternary deposits acquired from three sites during Leg 80 permitted the entire Pleistocene sequence to be studied, in particular Pleistocene calcareous benthic foraminiferal faunas (Sites 548, 549, and 550).

In some previous studies correlations have been developed between the distribution of certain bathyal and abyssal calcareous benthic foraminifers and certain deep water masses (Schnitker, 1974, 1979b, 1980; Lohmann, 1978; Gofas, 1978); in others, the development of certain species has been correlated with one or several physico-chemical properties, such as temperature, salinity, water oxygenation (Streeter, 1973; Streeter and Shackleton, 1979), the oxygenation of the underlying sediment (Miller and Lohmann, 1982), or hydrostatic pressure in relation to bottom water temperature (Belanger and Streeter, 1980). These research surveys, which are based on recent or late Pleistocene deposits, were made in marine domains like the northwest Atlantic (Schnitker, 1979b),

[1] Graciansky, P. C. de, Poag, C. W., et al., *Init. Repts. DSDP*, 80: Washington (U.S. Govt. Printing Office).

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South Atlantic (Lohmann, 1978), Arctic Sea (Lagoe, 1979; O'Neill, 1981), and Norwegian Sea (Belanger and Streeter, 1980).

All these survey data were used in this study, and when they were applied to the Quaternary Leg 80 sediments, they helped to explain the Quaternary ecological and hydrological conditions and the subsequent paleoclimatic and paleohydrological changes. Similar DSDP studies have been carried out by Lutze (1979) on the western African margin (Site 397, Leg 47, at a 2900 m water depth) and by Keller (1980) in the Japan Trough (Leg 57), both studies dealing with Tertiary as well as Quaternary deposits.

The three Leg 80 sites form an ENE-WSW transect from the Goban Spur to the abyssal plain across the Pendragon scarp (Fig. 1). Site 548 is on the upper slope at a water depth of 1256 m, and it yielded a thick sequence of Quaternary sediments. Site 549 is on the uppermost part of a ridge at a water depth of 2535.5 m and yielded a more condensed 27 m-thick sediment sequence. Site 550 is on the abyssal plain near the lower part of the slope, at a water depth of 4432 m. It yielded only one core (6 m) of late Quaternary sediment.

The continental shelf is situated northeast of the sites studied: it is very wide, perhaps at its widest in the northeast Atlantic. During periods of high and low sea level, this continental shelf became, therefore, a region where there was considerable change in shoreline position. Next to the continental shelf, the broad, smooth Goban Spur slopes gently southwest to depths of 2500 m; there it steepens abruptly to depths of 4000 to 4500 m, as shown in Figure 2.

As a result of this topography, the region near Site 548, which is about halfway down the slope, is an area that receives detrital input from the neighboring continental shelf; partly as a result, the Quaternary sedimentation rates are relatively high. At Site 549, which is nearer the foot of the slope, the detrital input is less abundant than at Site 548, and sedimentation rates are low. Site 550, which is located on the abyssal plain, is in an area practically free of detrital input; sedimentation rates during the late Quaternary were very low.

The Goban Spur and adjacent slopes belong (from a hydrological point of view) to the domain of the North Atlantic Deep Water (NADW). This complex water mass forms near the North Atlantic straits by the mixing of three water masses (Broecker and Takahashi, 1980): (1) the part of the Norwegian Sea that passes the Denmark Strait and later flows into the western abyssal basin; (2) the part of the Norwegian Sea that passes over the Faroe Island shelf and flows into the eastern basin; and (3) the Labrador Sea, which flows toward the south.

Above the NADW lies the Mediterranean water mass, a countercurrent issuing from the Gibraltar Strait (Worthington, 1976), part of which flows north. This water mass, which is at depths between 800 and 1200 m within the Bay of Biscay (Le Floch 1968, 1969), may flow far north (Reid, 1979; D. A. Johnson, 1982). In the northeast Atlantic, the Mediterranean, Labrador, and Antarctic water masses mix at depths between 1200 and 3500 m, forming, according to the Lee and Ellet (1965) definition, the "Merlin complex."

The bottom water temperatures are 7.6°C at Site 548 (1256 m depth), 3.4°C at Site 549 (2535.5 m depth), and 2.6°C at Site 550 (4432 m depth).

The diagrams published by Reid (1979), which are for a N-S hydrological transect in the northeast Atlantic close to the Goban Spur, provide the following general information about the three sites.

Near Site 548, at depths from 1250 to 1300 m, the bottom water masses display an 8°C temperature, a salinity of 35.4‰, and an oxygen content between 4.8 and

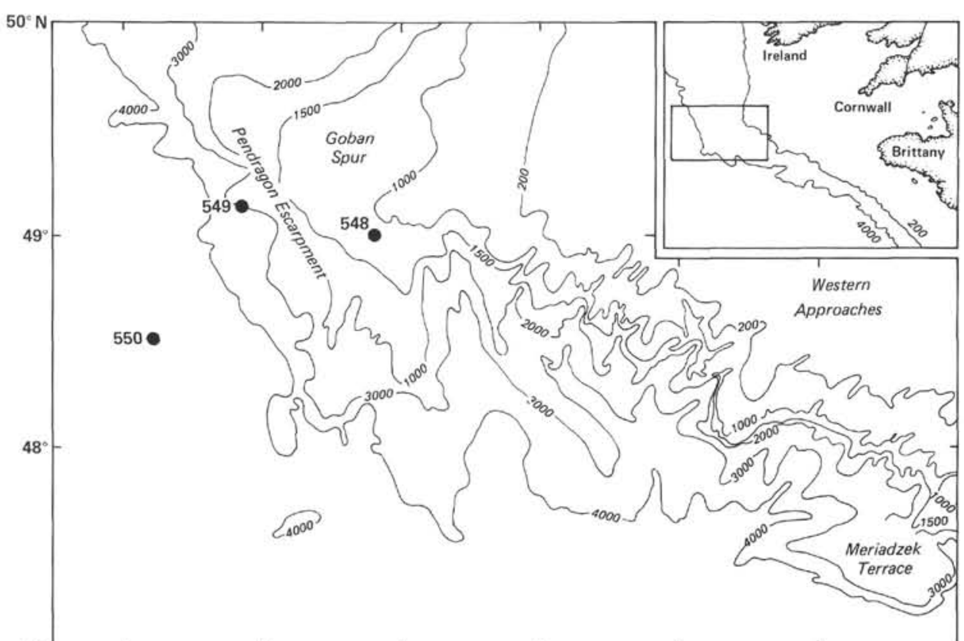

Figure 1. Location of Sites 548, 549, and 550 northwest of the Bay of Biscay. Water depths in m.

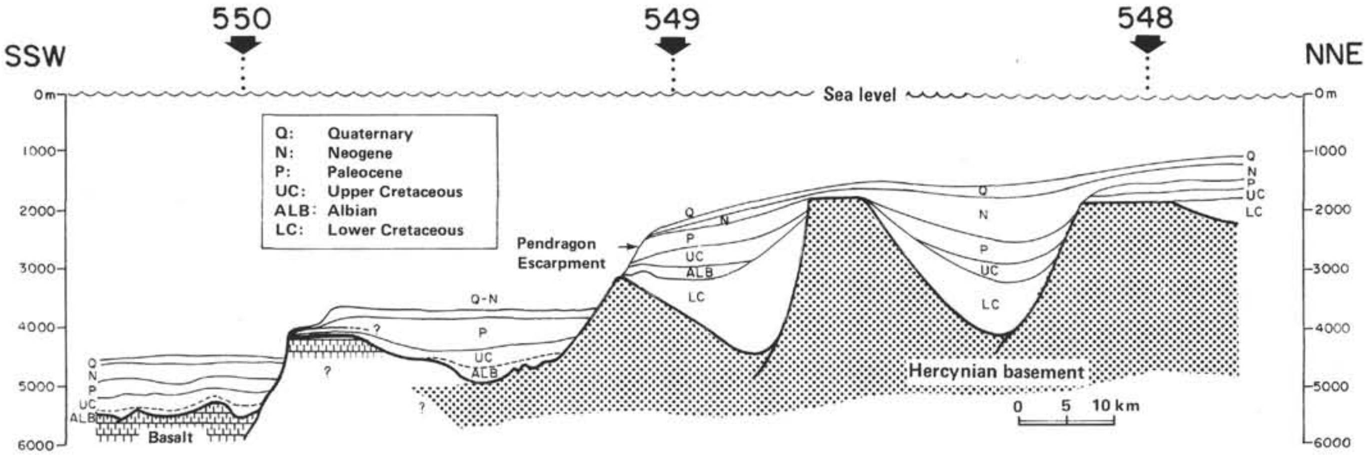

Figure 2. Schematic cross section of the Goban Spur along seismic line CM 10. Sites 548 and 550 are projected northward onto the line; Site 549 is drilled on the line (after de Graciansky et al., 1982).

5.2 ml/l. These values are intermediate between those of the Mediterranean water mass and the NADW.

Near Site 549, at a depth of 2500 m, the bottom water masses display approximately a 3°C temperature, a salinity range between 34.95 and 35‰, and an oxygen content between 5.4 and 5.6 ml/l. These estimates agree with those obtained by Schnitker (1979a) from the Worthington and Wright (1970) data.

Near Site 550, at a depth of 4432 m, the present water mass is the lower NADW, which is characterized by a small Antarctic contribution (issued from Antarctic Bottom Water, AABW). According to Schnitker (1979a), the water mass temperatures reach approximately 2°C, and salinity ranges between 34.91 and 34.92‰.

The bottom water temperatures of all three sites correspond very well to the values estimated from Reid's diagrams.

METHODS

Two hundred thirty samples from the three sites were analyzed to determine the characteristics of the calcareous benthic foraminifers. The samples were distributed as follows: 139 samples were from Cores 1 to 15, Site 548; 80 samples were from Cores 1 to 3, Hole 549A; and 11 samples were from Core 1, Site 550. Each sample was washed and sieved after the calcimetric analysis and weighing of the bulk sediment and of three granulometric fractions (>150 μm, 150–63 μm, <63 μm). Renewed sieving of the coarse fraction revealed foraminifers larger than 250 μm; these were sorted, identified, and counted. The sieving residue permitted us to define the relative proportions of organic and inorganic material (quartz, volcanic ash, pyrite, etc.). So the results would be comparable, the benthic foraminifer counts were brought down to 10 g of washed bulk sediment weight for all samples. The results are given in Tables 1 to 3. Species that might be considered environmental indicators were especially carefully examined. The benthic foraminifer counts were very low (fewer than 20 specimens) at many levels at Site 548, a fact that would tend to invalidate species abundances expressed as percentages of faunal assemblage. Therefore the results for this site are given as the number of specimens per 10 g of bulk sediment. Conversely, the results for Hole 549A may be expressed in terms of faunal assemblage percentage; the species considered do not figure at levels that contain very few foraminifers.

Since the publication of Lohmann's work (1978), the advantages of studying benthic foraminiferal specimens larger than 250 μm have become well known, namely (1) better observation of faunal assemblage variations because of the smaller number of species and (2) the elimination of several small, rare, or insignificant forms, which are more easily displaced than larger forms. Given the geomorphological location of the three sites, the ability to ameliorate the problem of microfaunal displacement is extremely important. The size selection also has a great disadvantage, however, because it eliminates certain small frequently occurring forms that are of considerable hydrological significance. An obvious example is *Epistominella exigua,* which according to Schnitker (1979b) is an Arctic Bottom Water (ABW) marker.

Although counteracted by the 250 μm sieving, the faunal displacement problem is acute at Site 548 and to a lesser extent in Hole 549A. Previous studies on benthic foraminiferal assemblages based both on Bay of Biscay surface samples (Schnitker, 1969; Pujos-Lamy, 1973a and b; Pujos, 1976) and core sampling from recent Quaternary deposits (Caralp et al., 1970) were used to establish the original bathymetric position of the benthic foraminifers (Fig. 3). Other similar studies outside the Bay of Biscay were also used for reference, namely the survey work by Phleger (1960); Phleger et al. (1953); Parker (1958); Pflum and Frerichs (1976); Lohmann (1978); and Belanger and Streeter (1980).

The biostratigraphic scale adopted here is the scale established for the planktonic foraminifers by Pujol and Duprat (this volume); the results are given in relation to both bioclimatic stages and the paleomagnetism results of Townsend (this volume).

SITE 548

The physiographic and structural settings of Site 548 are shown in Figures 1 and 2. The stratigraphy established by Pujol and Duprat (this volume) shows 110 m of Quaternary sediments deposited during continuous sedimentation starting 1.8 m.y. ago (Olduvai Event). The sediments were recovered in 15 cores, and 139 samples were studied.

The epibathyal domain within which Site 548 is found is a difficult zone to define, because the existing data are less detailed than the data for the neighboring sectors (continental shelf and mesobathyal zone). Because the habitat limits of certain species are not clear, certain forms are perhaps unjustifiably thought to be autochthonous.

Because of its position on a gentle slope (Fig. 2), this site is likely to be a place of sediment redeposition from the neighboring continental shelf. The displaced sediments may affect the faunal assemblages; it is therefore reasonable to consider these assemblages carefully.

Analytical Data

The total number of calcareous benthic foraminifers recovered at Site 548 ranges from 0 to more than 400 per 10 g of bulk sediment. The occurrence of levels with few

Table 1. Number of foraminifers, by species, in each Quaternary sample at Site 548.

Core	Section	Interval (cm)	Preservation[a]	*Sigmoilopsis schlumbergeri*	*Melonis barleeanum*	*Uvigerina peregrina*	*Gyroidinoides orbicularis*	*Bulimina mexicana*	*Pullenia quinqueloba*	*Planulina ariminensis*	*Discopirina* sp.	*Pyrgo lucernula*	*Oridorsalis tener*	*Cibicidoides robertsonianus*	*Globobulimina affinis*	*Globobulimina* sp.	*Pyrgo murrhina*	*Spiroloculina canaliculata*	*Lagena* div. sp.	*Bolivina quadrilatera*	*Planulina wuellerstorfi*	*Pyrgo oblonga*	*Miliolinella irregularis*	*Hoeglundina elegans*	*Bulimina aculeata*	*Pullenia bulloides*	*Triloculina tricarinata*	*Cibicidoides kullenbergi*	*Gyroidinoides soldanii*
1	1	0-3	M	48	9	46	3	8	1	5	1																		
1	1	4-5	M	36	15	33	12	6	3			3		9					1										
1	1	14-17	M	30	3	33	6	7	1	2	1		1		8		2	1	2										
1	1	70-71	M	2	8		6	2																					
1	2	40-43																											
1	2	70-71	M	4			1	1							2	2													
1	2	90-93	G	1		1														2									
1	3	20-23	M	2											3														
2	1	20-23	G	2											1	1							2						
2	1	41-42	G	6							5					2			4		2	3							
2	2	20-23	G	12			1								1				1		2		1						
2	3	20-23	M	6	3	1	2								1						2		1			1			
2	4	33-36	M	5	3		4								2				1		3								
2	4	53-54	M	5	4										5						5								
2	5	2-3	M	2	6		1	2							3	1										1			
2	5	33-36	G	7	7	18	1	2	1						3						10								
2	6	70-71	G	7	7			1							2						1		1						
2	6	33-36	G	12	8	5	1	12			1				3	3	1	1			4		1		3				
2	7	33-36	M	6	8	5		7	1												6			3					
3	1	34-35	G				3										3		9	2			3				3		2
3	1	56-57	G	56	7	4	7	6									4				4			6					
3	1	76-79	G	24	3	4	3	9	1								3	5	2		8								
3	1	113-120	G	31	36	2	10	34	1				1	8			4		4		42								
3	2	76-79	M	2												2	1		2										
3	3	76-79	G	11	3		2	4						1	1		3				3			2					
3	4	76-79	M		1			3								1			3		1								
3	5	76-79	M					1																	1				
3	6	76-79	M	5				3																					1
3	7	29-32	M	2			1																		2			2	
4	1	61-65	G	14	2	3	4	6	2				2				4	2			1		1		7				
4	2	61-65	G	8	2	4	2	3					3				1	1				1							
4	3	61-65	G	4	4	1	1								1			2								1			
4	4	61-65	G	10	9		4	4							12	4		1	1						1				
4	5	61-65	G	10	3		3	2																	1				
4	6	20-23	M	2	2			2							2										4				
4	7	10-13	G	7				3			1														1			8	
5	1	73-74	M	23	9	2	8	9					2															5	
5	2	21-24	M	10	8	8	8		1						2													2	
5	2	77-78	M	15		3	2	2					1				1												
5	3	21-26	G						1																				
5	4	21-24	P	2		1																			1				
5	5	21-24	M	17	2		2	4							2										11				
5	6	21-24	M	1				1																	1				
5	7	21-24	M												3											1			
6	1	57-60	P	17	1			3							1				1				1		1				
6	2	16-18	M	2	4		2	2									1									1			
6	2	95-98	M	3		1		3																					
6	3	16-18	P			2		2																					
6	4	16-18	M		1	1		1																					
6	5	28-29	M	2												2													
6	6	16-19	M	3	1																				7				
6	7	13-16	M	2															1										
7	1	76-79	M	1				3							1						1								
7	2	84-85	M				1																		2				
7	3	40-43	P																										
7	3	104-111	M																						9				
7	4	40-43	G	39	15	1	5								4				2	1					60				1
7	4	103-110	M	15	1		3	4							2		1								22				
7	5	19-22	G	11	2	2	2	3									1			1			2		6				
7	5	71-72	M	3																									
7	5	111-116	G	44	3		5	6	1					1			2	5	1					6					
7	5	140-141	G	44	15		2	22									7								4	1			
7	6	40-43	M	4	5		2	1									1						1						
7	6	100-117	G	3	2		2	7							2		2												
7	7	10-13	M	9	4		5								1		3												
8	1	69-70	M	10	15			8																		1			
8	1	123-130	G	8	1	1	2	3									1									1			
8	2	40-47	M	6	2			2																		1			
8	2	90-91	M	3	2			4																					
8	2	140-147	M	8	1		1	5									1												
8	3	69-70	M	5	2			2																					
8	4	20-27	G	12	4		2	10							3		2		1							2			
8	4	90-91	M	4	2										1														
8	5	20-27	G	33	2		2	5									2	1								1			
8	5	69-70	M	6	6			1	1								1		1						1				
8	5	103-110	G	8	1	3	2	9							2		4	4	1							1			
8	6	69-70	G	14	9		6	6									2	5	1		2			2		4			
8	6	124-125	G	14	1		1	1	1																	1			

Table 1. (Continued).

Virgulina exilis	*Rupertia stabilis*	*Frondicularia inaequalis*	*Chilostomella oolina*	*Globocassidulina subglobosa*	*Sphaeroidina bulloides*	*Carpenteria* sp.	*Laticarinina pauperata*	*Uvigerina* sp. cf. *U. auberiana*	*Melonis pompilioides*	*Pleurostomella* sp.	*Gyroidinoides* sp.	*Cibicides* div. sp.	*Cibicidoides* sp. 2	*Nodosaria* sp. 1	*Nodosaria* sp. 2	*Dentalina* sp. 3	*Orthomorphina* sp. 1	*Orthomorphina* sp. 2	*Orthomorphina challengeriana*	*Stilostomella* sp.	*Ellipsoglandulina* sp.	*Cribrononion lidoense*	*Gavelinopsis praegeri*	*Quinqueloculina* sp.	*Lenticulina* sp.	*Cibicides* cf. *lobatulus*	*Nonion labradoricum*	*Cassidulina laevigata*	*Cibicides pseudoungerianus*
																									1	2			25
																										6			21
																									1	3			53
																										8			4
																													9
																						3			1				1
																								5					2
																								9				3	13
																								1		1			10
																									1				4
																													8
																													26
																						2							118
																						1				1		1	2
			1																					19	1	4			92
																								1					149
					2																		3	29					9
																										12			9
																										2			
																										12			1
																						4					1		1
				1																					1			1	2
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				4																						1			
																													1
				1																		1		2					9
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																						171							5
1																						4							3
	-																					1							2
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	1																					3		3					18
					1																			1					14
																							1			2			32
																							1		1				6
2					2																	5							2
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		1												1										2					
				1																		4							
	1				3																	1				3		1	5
					1																					1			7

Table 1. (Continued).

Core	Section	Interval (cm)	Preservation[a]	*Sigmoilopsis schlumbergeri*	*Melonis barleeanum*	*Uvigerina peregrina*	*Gyroidinoides orbicularis*	*Bulimina mexicana*	*Pullenia quinqueloba*	*Planulina ariminensis*	*Discopirina* sp.	*Pyrgo lucernula*	*Oridorsalis tener*	*Cibicidoides robertsonianus*	*Globobulimina affinis*	*Globobulimina* sp.	*Pyrgo murrhina*	*Spiroloculina canaliculata*	*Lagena* div. sp.	*Bolivina quadrilatera*	*Planulina wuellerstorfi*	*Pyrgo oblonga*	*Miliolinella irregularis*	*Hoeglundina elegans*	*Bulimina aculeata*	*Pullenia bulloides*	*Triloculina tricarinata*	*Cibicidoides kullenbergi*	*Gyroidinoides soldanii*
9	1	20-23	M	30	8		3	5			3	1					1	2	4		2			1					
9	1	100-107	M	35	4	1	2	14	1						3		2		4		4	1		3					
9	2	20-23	M	11	11	1	3	24					4	2			10	1	3		22			5					3
9	2	43-44	M	26	26	5	3	8	3					1			15		3		22			3		1			3
9	2	108-109	M	19	32	4	13	44					4	5	3		14	1	4		69			4				3	1
9	3	20-23	M	23	3	1	2	8	2				1				1	3			34								
10	4	43-44	G	137	11	21	8	42	3				4	15	2		2	3			60			130	15	3			3
10	4	96-99	M	9	2		2	12													2			2					2
10	4	114-116	M	36	1		4	3									1	2	2		32			8	2	2			4
10	5	43-44	G	61	1	3	3	20	1				7	28			1	4	3		23			29	3				
10	5	120-122	M	8	1		2		2												2			4	3	1			
10	6	54-58	G	28	2				1				8	5			3	2			13			16				30	1
10	6	88-90	M	3	4	1		2						4	6						12								
11	1	50-53	M	13	7			11					1	1	2		1	1			11			7				2	1
11	1	73-74	M	29				15	2					2	2				4		6					2		4	2
11	1	140-147	G	147	40	4	8	34	5	4			39	28	1		4		20		23			15		4		17	5
11	2	50-53	M		1			1							3														
11	2	140-147	G	12	3	5		5					2		11		2		2			5						4	1
11	3	50-53	M	9		21		5													1				2			4	2
11	3	139-146	G	133	2	5	8	35	1				25		2		1		4					2				41	12
11	4	50-53	M	6		1		3					1		1														
11	4	140-147	M	30		1	3	19	2						9		1		1					1				8	1
11	5	17-24	G	24	8		1	23							1		10		7		4			61				12	3
11	5	50-53	G	8	55		1	3					1		9						8			4	15				
11	5	92-97	G	38	17	36	4	10	1						20		11		4		17			52		2		77	
11	5	143-150	G	35	3	10	8	34	1				1		4		1		4		16			8		1		27	3
11	6	8-15	G	33	2	6	6	15							1		2		2		2			23		1		38	6
12	1	129-130	M	35	5		7	1					2						1					2					
12	2	36-37	M	4	1	3	1	9																					
13	1	130-137	G	31	8	24	2	26	2								2	4	4		16	2				2		26	
13	2	35-38	G	5	5	11		5								1					4			3		4		8	
13	2	120-121	M	44	6			32					2						9									9	
13	3	22-29	G	16	3	21	3	9	2				1					7	2		11					1		42	
13	3	105-106	M	34	3			3					6																
13	3	120-121	M	166	20	25	41	79					10				5	20	5		23					5		10	
13	3	130-131	M	303	13	47	6	63									4	4	4		15					6		34	6
13	4	35-38	M	25	4	2	7	7										2			13			1				52	
13	4	95-96	M	30	14	12															3			1				1	6
13	5	35-38	M	90	3	9	5	5					7				1	3	1		24			2		2		2	
13	5	130-132	G	59	12	20	2	16	2				7		6		2	5	1		1			4		2		1	2
13	6	27-34	G	23	1	16	2	18					2		2			2	1		3			2					2
13	6	81-82	M					3									2		2										
14	1	4-7	M	11	2	6		3					1		1									1					
14	1	40-47	M	31	5	3	1	12					3		1		1											6	2
14	2	84-91	G	29	9	5	1	13					1		1		1	1			5			4				12	1
15	1	44-45	M	14	2			2	2				2								4								6
15	1	112-119	G	73	12	16	8	30	1				1		1				2		11			13		2			2
15	2	30-33	G	18	8	15	7	10					2		1			3			41			6				10	
15	2	112-119	G	53	13	44	21	24	1				4		10		6	6	1		27			2		1		6	2
15	3	30-33	G	66	4	12	1	15	1				10						1		1			1				9	2
15	3	110-117	G	55	8	6	1	28	1						7			3			3							10	2
15	4	3-4	M	9		2	2	4	2																				
15	4	12-13	M	155	26	12	10	65	2				2								18							44	
15	4	27-28	M	7	1	1							1															1	
15	4	110-117	G	18	7	7	5	20	2				3	10	1		2	1	1		8			6				2	1
15	5	30-33	M	69	1	16	7	15	1				4	4			9				30			37		1		28	2
15	5	63-68	G	61	1	2	8	24	1				3	23	2		3		2		8			57				23	3
15	5	82-87	M	26	4	3	6	17	1				4	3					1		4			10		1		4	3
15	5	130-137	G	27	1	3	2	12					2		1		1	1	2		5			2				21	1
15	6	30-33	M	15	1	1	1	5					3		1						15			1				11	3
15	6	120-123	G	6		1	1	1									1							1		1		12	1

[a] P = poor, M = moderate, G = good, D = dissolved.

Table 1. (Continued).

Virgulina exilis	*Rupertia stabilis*	*Frondicularia inaequalis*	*Chilostomella oolina*	*Globocassidulina subglobosa*	*Sphaeroidina bulloides*	*Carpenteria* sp.	*Laticarinina pauperata*	*Uvigerina* sp. cf. *U. auberiana*	*Melonis pompilioides*	*Pleurostomella* sp.	*Gyroidinoides* sp.	*Cibicides* div. sp.	*Cibicidoides* sp. 2	*Nodosaria* sp. 1	*Nodosaria* sp. 2	*Dentalina* sp. 3	*Orthomorphina* sp. 1	*Orthomorphina* sp. 2	*Orthomorphina challengeriana*	*Stilostomella* sp.	*Ellipsoglandulina* sp.	*Cribrononion lidoense*	*Gavelinopsis praegeri*	*Quinqueloculina* sp.	*Lenticulina* sp.	*Cibicides* cf. *lobatulus*	*Nonion labradoricum*	*Cassidulina laevigata*	*Cibicides pseudoungerianus*
					1		1																						5
	1				2		1	1						1								1		4				1	10
					5		4															9							17
					5		1																						32
	1				22																	20					1		49
					2																	7							37
	3				12																	4		2		3			122
					1													1							1				54
					2									1				1					3			1			59
				3	1															1			5		1				
																				1			1						
				1	3		1	9								4		1					4						23
				4	2														1	1									20
																1					2							2	22
	1				2															1								4	90
				4	6	6	5		1	4		23								1	1			7		8			270
																													3
		2			2					1		1								1				2					30
																						10							22
					3	3	1									2										6			248
																				1									16
					1					3								1	1						1				34
					2		2			7		1		1									2		2				35
					9				3							1	1	1											28
		1			7					1						1									8	5			35
		1			14						58	1							2						3	3			72
		1			7					1	67				4										1	1			11
										2																			58
							1																						28
				6	14						20								1						2			1	98
				1	5																				3				11
										6										1									35
					7					2			5					3		1									5
										3								1											51
					20					2							1					9			2	20			325
					4		4			8						3										8			554
				1	2					1															2				81
													7							1									63
				5	3		21			1						1	1	1		1									30
					5		5		1							4	1			1						4			2
				2	2		3								2	1													8
		1					4								1														15
					2		2																						14
		2		1	1		7			1				1		1				1									60
				1	2		2							1		1							4		1				8
				2						2										2									16
					2		1					9			2		3	2		6					3				66
				2	4		2					4		1						2									2
				1	24		6					12		2	1	2				2		3			1				57
										2		2				1							1						67
					13		2			1		1		1															27
							4					2								2									17
				8	6		2			4		16				10													149
															1					1									6
				3	4		2					3						1		1		4							23
					4		6					1		3		1		1					5		2	10			34
				5	5		1							1		3							3						42
				3	2									1															4
				2	1		4	2								1		1		2									19
					2		1					2		1															19
					1		2					2		1			1												17

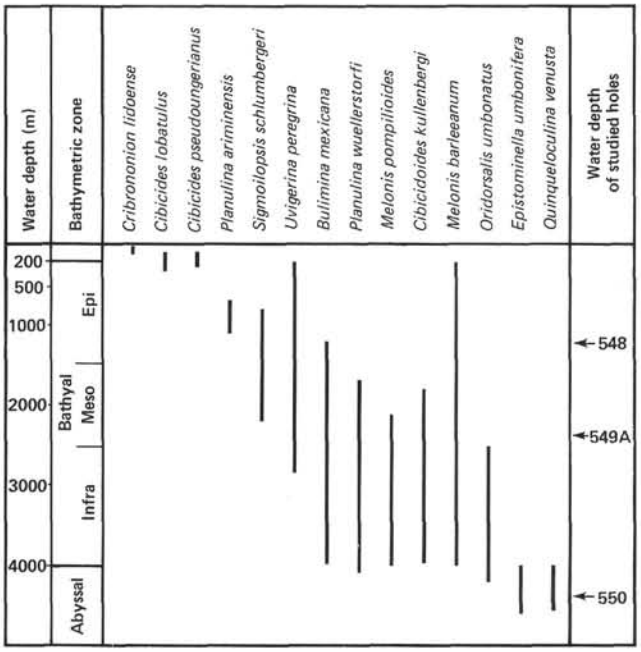

Figure 3. Schematic bathymetric range of some calcareous benthic foraminifer species in the Bay of Biscay (from Pujos-Lamy, 1973b; Pujos, 1976).

benthic foraminifers (≤20 individuals) is noteworthy. A comparison between the abundance of benthic foraminifers and lithologic data shows that there is a close relationship between levels with an abundant fauna, a $CaCO_3$ content higher than 30%, and an increased proportion of grain size elements larger than 63 μm (Fig. 4). It is, therefore, inferred that the residual elements larger than 63 μm after washing represent detrital carbonates.

Displaced Faunas

The definition of Quaternary displaced faunas is based upon data obtained from the regions neighboring Site 548 (Fig. 3). We therefore consider to be displaced those faunas that are dominated by *Cribononion lidoense* and include some rare *Elphidium* specimens; this fauna is typically coastal (Pujos, 1976). We also consider to be displaced faunas those dominated by (often broken) specimens of *Cibicides pseudoungerianus,* which originated on the continental shelf (Pujos-Lamy, 1973b; Pujos, 1976); to this species may be added *Gavelinopsis praegeri, Cibides lobatulus,* various species of *Lenticulina* and *Quinqueloculina* (Pujos, 1976), *Nonion labradoricum*, which is from the border of the continental shelf (Caralp et al., 1967), and finally *Cassidulina laevigata,* for which no sufficiently precise bathymetric information exists.

This list is not complete, especially insofar as species of *Buliminidae* are concerned, which may well be associated with turbidites (Phleger et al., 1953; Lutze, 1977). Likewise, it is difficult to recognize epibathyal forms that are displaced within their own bathymetric zone (that is, from the upper part of the continental slope to the position of the site, about 1000 m deeper). For instance, the specimens of *Bulimina* and *Uvigerina* may be divided into two groups. In some intervals they are broken, worn out, and not numerous (probably displaced); in others they are well preserved, and the individuals may therefore be autochthonous.

As indicated by Figure 4, compared with the fauna as a whole, the percentage of displaced faunas seems high (occasionally >50%), but this is not exceptional when only littoral and continental shelf faunas are considered (Ingle et al., 1980). Displaced faunas appear to be more abundant, although irregularly distributed, in the upper Quaternary (Cores 548-1 to 548-8) than in the lower Quaternary (Cores 548-9 to 548-15).

One of the highest percentages of displaced faunas appears to correspond to a turbidite sequence identified on board ship (see site chapters, this volume). The turbidite sequence occurs between Sections 548-2-4 and 548-2-7. The maximum percentage of displaced faunas occurs at the base of the turbidite sequence (Section 548-2-7); it decreases gradually to Section 548-2-4, where the displaced faunas disappear completely.

Washed Residue (Fraction >250 μm)

Association between Quartz Sands and Displaced Microfauna

In levels where the percentage of displaced faunas is high, the detrital fraction greater than 250 μm displays an important quantity of quartz sands or of various other detrital elements which most likely became displaced at the same time as the faunal elements. These levels may correspond to turbiditic displacements and contain most of the faunas displaced from the continental shelf (lower part of Core 548-2; see Fig. 4).

There are two levels at which these quartz sands are associated with displaced coastal fossils, which are marked by numerous specimens of *Cribononion lidoense:* Sample 548-4-3 (61–65 cm), which is about 250,000 yr. old and comes from the base of bioclimatic Stage VII; and Sample 548-6-5 (28–29 cm), which is about 380,000 yr. old and comes from the base of bioclimatic Stage XI. This fauna is less common than faunas displaced from the continental shelf, and it rarely occurs intensively. Its very existence has bathymetric and hydrological implications for the site and the surrounding region.

Quartz Sands Not Associated with Displaced Microfauna

Quartz sands occur at some levels not associated with displaced microfauna. These quartz sands are located in the upper part of the Quaternary between Section 548-7-3 and the top of Section 548-7-2 (corresponding to bioclimatic Stage XII), from the base of Core 548-6 to Section 548-3-5 (bioclimatic Stage VI), and from Sections 548-1-3 to 548-1-2 (bioclimatic Stage II). The sand is rounded, quartzlike, irregular in size, and appears in sections that contain very few benthic foraminifers but do contain polar planktonic microfaunas (Pujol and Duprat, this volume). These quartz sands originate in ice-rafting and not in an influx of detritus from a neighboring continent.

Other Inorganic Elements

Pyrite

Pyrite occurs sporadically throughout the section. It is more characteristic of some zones than others (Pl. 7, Fig. 10: Sample 548-11-4, 140–147 cm), and it is often found in faunal assemblages that contain *Uvigerina peregrina*.

Volcanic Ash

In the >250 μm grain size fraction, no ash bedding was recorded in the samples examined, but simply some bubbled elements.

Autochthonous Benthic Foraminifers

The quantitative changes in the calcareous benthic foraminifers throughout the Quaternary at Site 548 (Fig. 4) permit us to divide this time interval into two parts. From the base of Core 548-15 to the top of Core 548-9, the fossil benthic foraminifers are numerous despite the occurrence of very localized samples with fewer than 20 specimens. From the base of Core 548-8 to the top of Core 548-1, the microfauna is generally less abundant. The numerical variations from one sample to another are considerable, and samples free of microfauna occur frequently. Samples with many benthic foraminifers correspond, throughout the section, to high percentages of $CaCO_3$.

The numerical distribution of the benthic foraminifers is closely associated with the climatic variations that accompany glaciation (Pujol and Duprat, this volume). There is a distinct relationship between faunas characterized by numerous specimens and interglacial Holocene periods and very poor faunas and times of maximum glaciation.

It is interesting that the samples with the highest percentages of displaced faunas are not the samples with the highest number of specimens.

Distribution of Certain Species

Some 60 species covering the entire Quaternary period were recognized at Site 548. Only 20 of them are well represented (Table 1). Figure 5 shows the distribution of some of the species that are most indicative of environmental conditions.

Two species, *Bulimina mexicana* and *Melonis barleeanum,* occur throughout the Quaternary. Present-day data (Fig. 3) locate the two species within epibathyal and mesobathyal environments. The species are represented throughout the section at Site 548, except during periods when climatic conditions are too unfavorable, when they disappear. They are well represented in bioclimatic Stage V and in the lower part of the Quaternary. The two species are also present at the top of Core 548-1 in the Holocene.

Sigmoïlopsis schlumbergeri, which is not included in Figure 5, has a distribution similar to that of the previous two species. This species belongs to the Miliolidae group but has a partly agglutinant shell; it is well represented throughout the Quaternary and has undergone few variations within the entire faunal assemblage.

Three species, *Planulina wuellerstorfi, Hoeglundina elegans,* and *Cibicidoides kullenbergi,* show a more irregular distribution. Present-day data (Fig. 3) (Schnitker, 1974; Lohmann, 1978) show that these three mesobathyal and infrabathyal species are linked to the North Atlantic Deep Water. Figure 5 shows that from the base of Core 548-15 to Core 548-9, these species are present in all the samples studied. From Cores 548-8 to 548-1 (top), however, the three species occur sporadically: at the top of Core 548-5 (bioclimatic Stage IX) for *Cibicidoides kullenbergi;* in Core 548-3 (bioclimatic Stage V) for *Planulina wuellerstorfi* and *Hoeglundina elegans;* and in Core 548-2 (bioclimatic Stage III) for *Planulina wuellerstorfi* alone. None of these three species is presently represented in the faunal assemblage (Core 1, Holocene).

The last species is *Uvigerina peregrina,* which prevails throughout the bathyal domain (Fig. 3); it is known for its tolerance of low oxygen conditions (Streeter and Shackleton, 1979; Miller and Lohmann, 1982). Although present in all samples except those deposited during periods of cold climatic conditions, the distribution of this species differs from that of other species; its abundance changes suddenly from one sample to another. The abundance of this species peaks at the top of the Quaternary (Core 548-1) and in Samples 548-11-3 (50–53 cm) and 548-11-5 (50–53 cm), near the Brunhes/Matuyama reversal, where *Uvigerina peregrina* represents 30% of the faunal assemblage. A comparison between the distribution of the three previous NADW species and *Uvigerina peregrina* shows that the differences are particularly pronounced in the lower part of the Quaternary and the upper part of Holocene.

Interpretation and Discussion

Biostratigraphic Results

The faunal assemblage variations observed throughout the Quaternary at Site 548 are essentially related to climatic change. The faunal assemblages do not show any major qualitative modifications between the base and the top of the Quaternary. The lower part of the Quaternary (Section 548-10-6 to Core 548-15) does however contain various genera (*Dentalina, Orthomorphina, Stilostomella,* and *Ellipsoglandulina;* Table 1) that are absent above Section 548-10-5. Lutze (1979) located these same forms in synchronous biozones at the base of the Quaternary at Site 397, which is at a depth of 2900 m off the western coast of Africa. The level at which these genera cease to exist could represent the top of a biozone for the deep temperate northeast Atlantic.

Bathymetric Results

The faunal assemblages at two levels, Samples 548-4-3 (61–65 cm) and 548-6-3 (28–29 cm), are marked by the presence of a considerable number of specimens of *Cribrononion lidoense*, which originate in coastal or littoral zones. Because of the physiography of the region, a marine regression of about 150 to 200 m (compared to the present 0) would cause the very long continental shelf that stretches to the east of the Goban Spur to emerge. The coastal zone would then be very close to

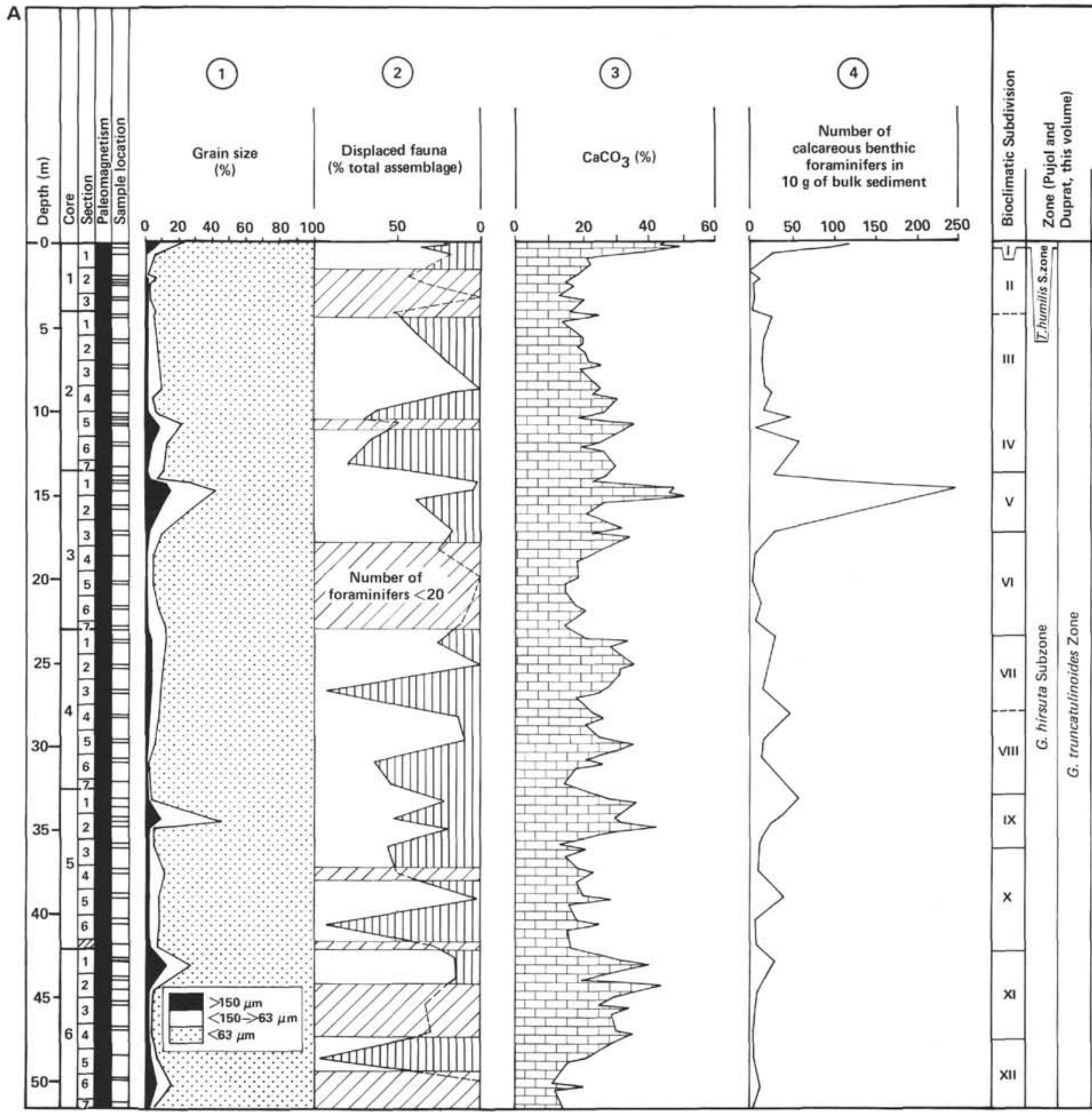

Figure 4. General characteristics of Quaternary Site 548 sediments. A. Cores 1 to 6. B. Cores 7 to 15. 1—Grain size. 2—Percentage of benthic assemblage that is displaced fauna. 3—$CaCO_3$ percentages. 4—Number of autochthonous benthic foraminifer specimens in 10 g of bulk sediment.

Site 548, and no domain similar to that of the present continental shelf would exist; the break in slope would be close to the shoreline. These assumptions, if true, could explain the presence of considerable numbers of specimens of solely coastal faunas. Two periods of low sea level would be indicated, one corresponding to the base of bioclimatic Stage VII (about 250,000 yr. ago); this is the period of deposition for Sample 548-4-3 (61–65 cm).

The second would correspond to the base of bioclimatic Stage XI (about 380,000 yr. ago), the period of deposition for Sample 548-6-5 (28–29 cm).

Because the coastal faunas are restricted to depths of only a few centimeters (appearing and then disappearing again within the depth of single samples), the duration of inputs from coastal zones was short lived; consequently, the low sea level was fleeting. A more condensed sampling from Site 548 might permit us to see evidence of the other periods of low sea level. Furthermore, the presence of various sandy levels between Cores 548-7 and 548-1 indicates ice-rafting. It is likely that in the levels corresponding to the coldest glacial periods (Pujol and Duprat, this volume), the deposition of continental shelf and coastal faunas ceased completely, for no evidence of displaced faunas has been found. Consequently, during these cold periods the existence of low sea levels cannot be determined by the study of benthic foraminifers.

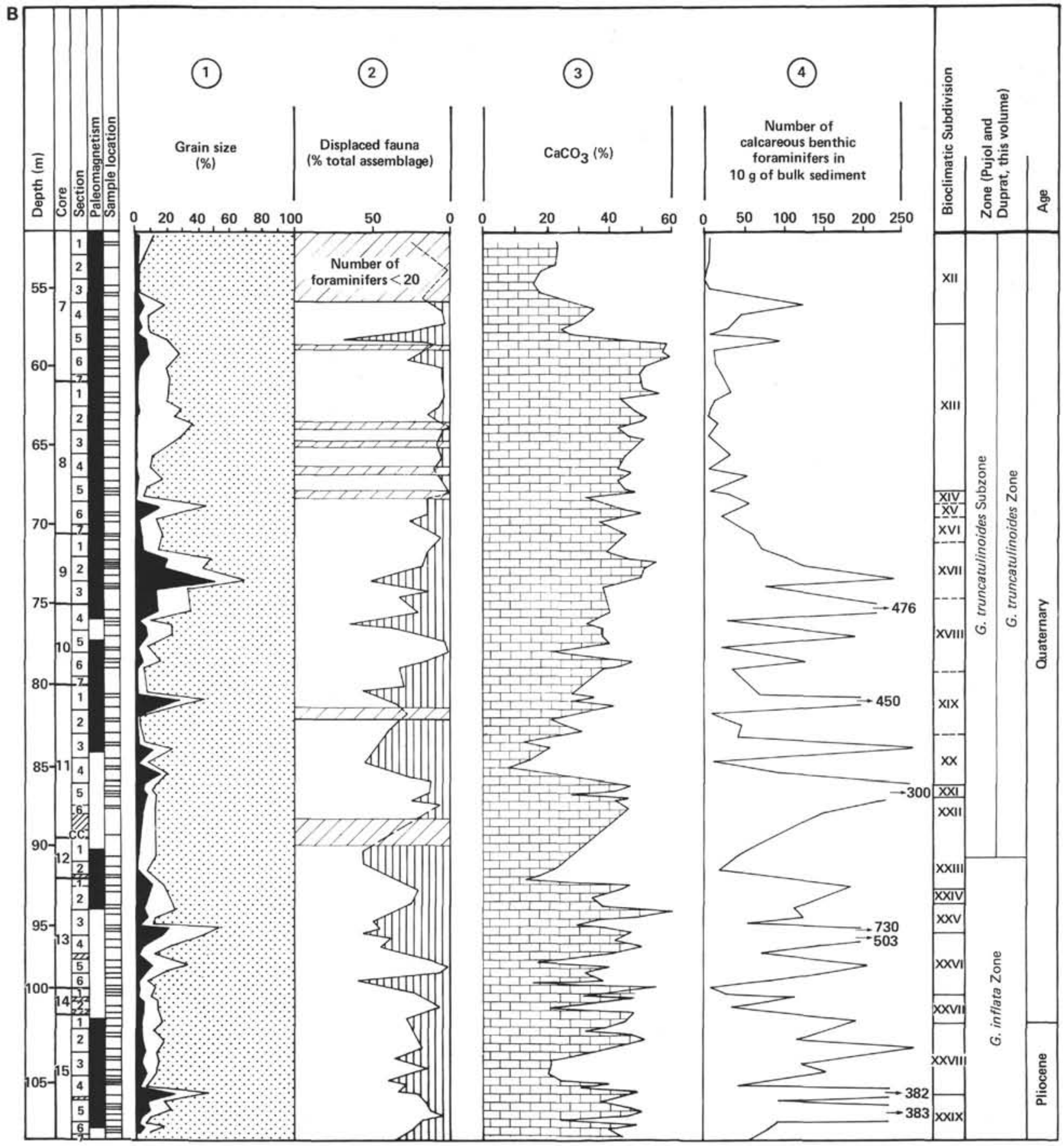

Figure 4. (Continued).

Hydrological Bottom Water Results

The most common species—because of their capacity to inhabit North Atlantic Deep Water (NADW)—in the Quaternary Site 548 sediments are *Planulina wuellerstorfi, Cibicidoides kullenbergi,* and *Hoeglundina elegans.* From the distribution of these species (Fig. 5), it appears that the water mass that existed at the base of the Quaternary (between Cores 548-9 and 548-15) may be comparable to that of the present NADW; the physico-chemical characteristics of the water masses are similar, and so are the species that inhabit them. A comparable water mass probably also appeared for a while during bioclimatic Stage V (Core 548-3).

An important observation must however be made: today Site 548 is free of NADW species. This suggests that the present water mass at 1256 m is not the North Atlantic Deep Water and that the last bioclimatic stage during which the NADW drained Site 548 was bioclimatic Stage V. Therefore, this benthic foraminiferal analysis indicates that a NADWlike water mass occupied the site twice, during the early and late Quaternary. From these assumptions, one may infer that the depth of the top of the NADWlike water mass changed from one time to

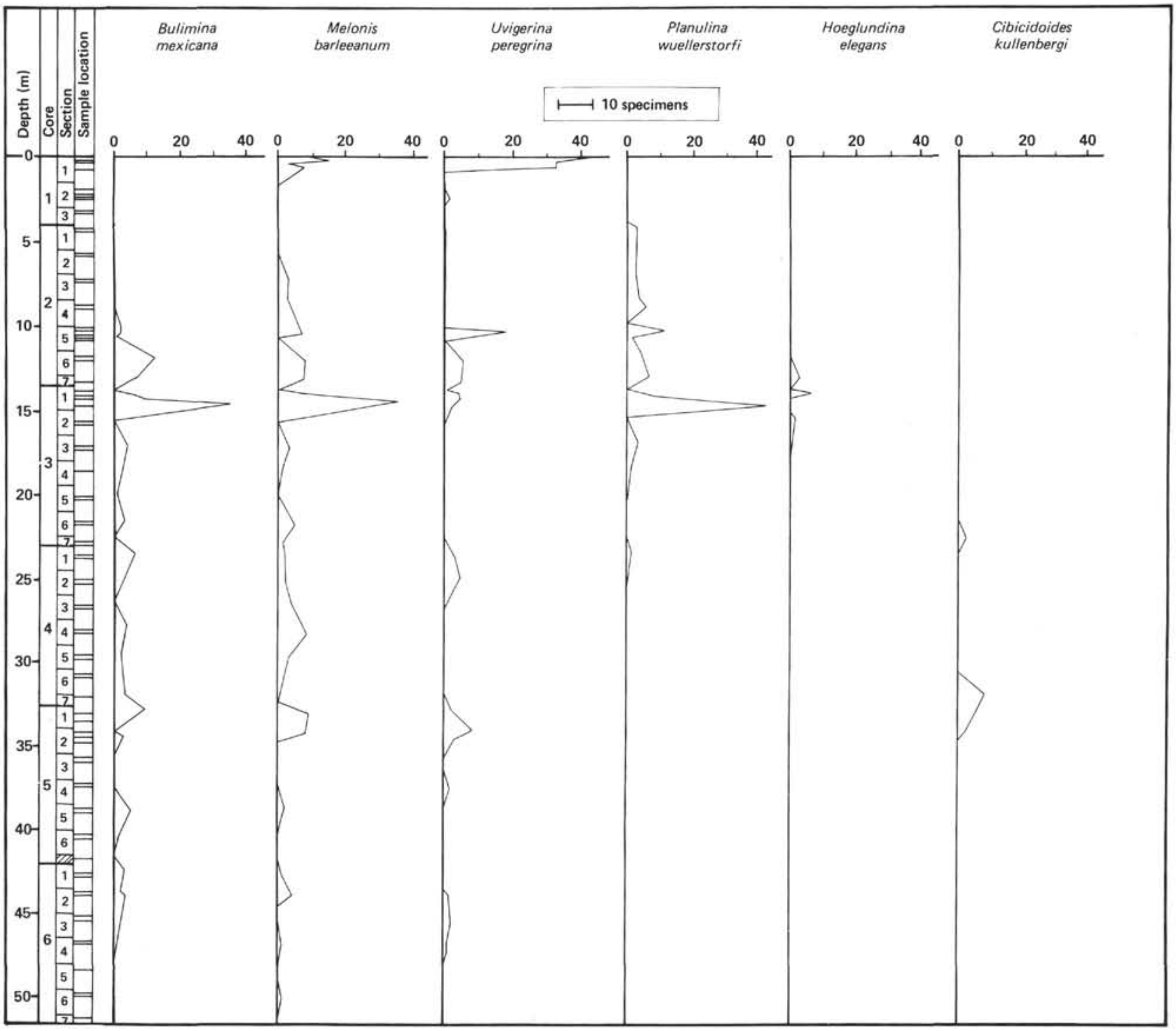

Figure 5. Numerical faunal data of some important species throughout Quaternary cores (Site 548).

another; the top of this water mass is above 1256 m during warm climatic stages (periods of high sea level); it is lower than 1256 m during the Holocene (see Hole 549A results).

Throughout the Quaternary Site 548 sediments there have also been found, in addition to the species associated with the NADW, a certain number of samples in which the faunal assemblage is characterized by *Uvigerina peregrina* (Fig. 5 and Table 1). This species occurs in the upper part of Section 548-1-1 (in Holocene horizons) and near the Brunhes/Matuyama reversal (Sections 548-11-3 and 548-11-5).

According to Reid's diagrams (1979), the water masses that today overlie Site 548 are a mixture of water from the Norwegian and Mediterranean seas, which have a low oxygen content (between 4.6 and 5.2 ml/l). Higher numbers of *Uvigerina peregrina* could be seen as an indicator of this slightly lower oxygen content (Streeter and Shackelton, 1979). The underlying reason for variations in the *Uvigerina peregrina* population at Site 548 is not easy to determine. As shown by Lutze (1980) for the continental margins off northwestern Africa and by Miller and Lohmann (1982) for the northeast Atlantic slope, lower levels of dissolved oxygen at the bottom may parallel a high rate of deposition of organic detritus. This high organic input could be the true limiting factor for the population of *Uvigerina peregrina.* The highest values of organic carbon and highest abundances of *Uvigerina peregrina* do not seem to correlate at Site 548. Indeed, the highest percentages of organic carbon (>0.6%) are found between Cores 548-2 and 548-6 and between Cores 548-7 and 549-9 (see site chapters, this volume), intervals in which *Uvigerina peregrina* is almost absent (Table 1). However, only limited conclusions can be drawn from the Site 548 sediments, in which the percentages of *Uvigerina peregrina* are never as high as in Hole 549A (see below).

The paleohydrology of the Quaternary bottom waters at Site 548 indicates the existence of two types of bottom waters. One resembles the present-day NADW and characterizes bioclimatic Stage V and most of lower Quaternary levels. The other resembles modern site con-

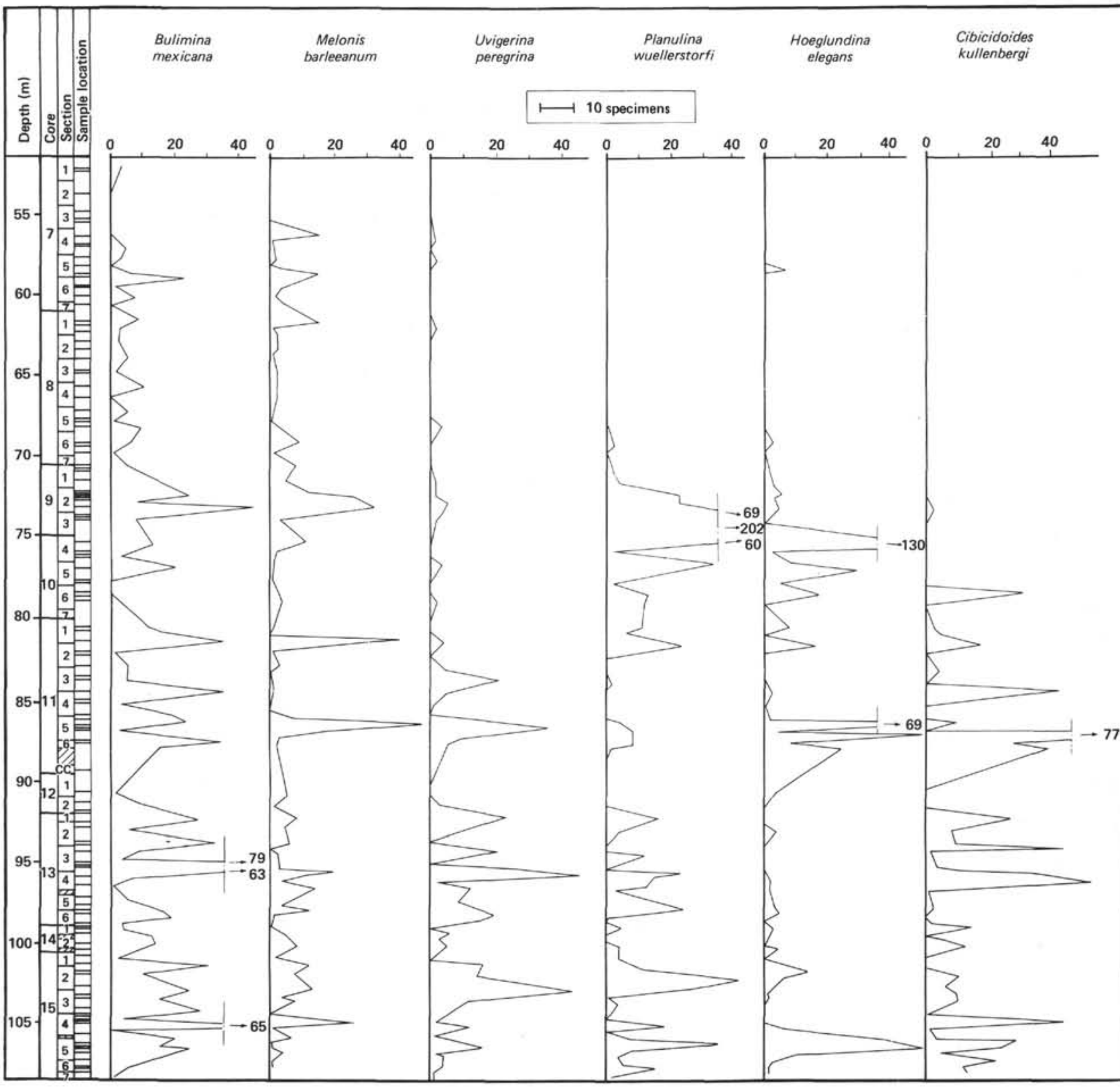

Figure 5. (Continued).

ditions and characterizes more precisely the Holocene and certain lower Quaternary levels.

HOLE 549A

Hole 549A is 2535.5 m deep and is located near the Pendragon scarp. The stratigraphy established by Pujol and Duprat (this volume) shows continuous Quaternary sedimentation. Twenty-seven m of sediment (three cores) were recovered; 80 samples were studied. Over the interval from the upper part of the Matuyama to the Holocene, the sedimentation rate is lower in the lower part of the Quaternary (bioclimatic Stages XII–XX) than in the upper part of the Quaternary (bioclimatic Stages I–XII).

Analytical Results

Benthic foraminifers are present in all samples analyzed, but the number of specimens at each level is highly variable (Fig. 6); it may lie between 400 and 20. An examination of the calcimetry results shows that the number of benthic foraminifers is high whenever the $CaCO_3$ percentage in the sediment is $>40\%$ and low whenever this percentage is $<20\%$. Certain levels are inconsistent with this pattern (especially at the base of Sections 549A-1-4 and 549A-3-2); at these levels the number of specimens is high even though the $CaCO_3$ percentage is relatively low. These levels correspond to the proliferation of certain species (namely *Uvigerina*). The grain size results (Fig. 6) show a close relationship between coarse grain size and high $CaCO_3$ content, which suggests the presence of numerous carbonate elements in the washed residue. With a few exceptions between Sections 549A-2-2 and 549A-2-5, the microfauna sampled is on the whole quite well preserved (Table 2).

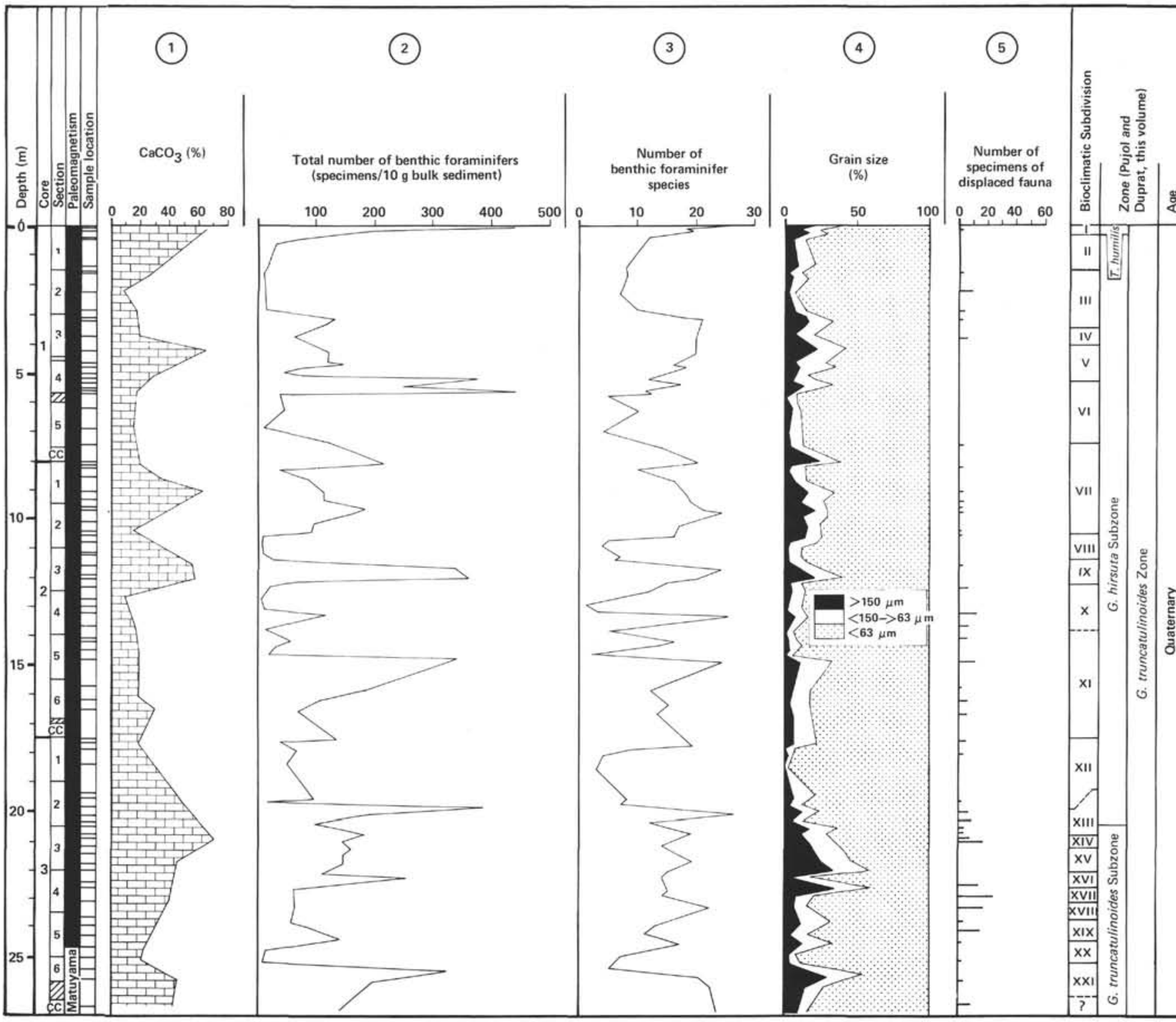

Figure 6. General characteristics of Quaternary Hole 549A sediments. 1—$CaCO_3$ percentages. 2—Number of benthic foraminifer specimens in 10 g of bulk sediment. 3—Number of benthic foraminifer species. 4—Grain size distribution. 5—Number of specimens of displaced fauna.

Displaced Faunas

If previous data (Phleger et al., 1953), especially those concerning the Bay of Biscay (Pujos-Lamy, 1973b) were taken into consideration, the percentage of displaced forms in Hole 549A would seem very low (Fig. 6). It is lower at the top of the Quaternary (between Sections 549A-1-1 and 549A-2-4) than at the base. There is no clear relationship between displaced specimens and a type of facies; the forms are scarce and are encountered not only in marly foraminifer-nannofossil ooze but also in mudstone. Most of the elements displaced from the neighboring continental shelf seem to have settled on the upper part of the Goban Spur slope. Indeed, most of these displaced faunas are such light forms as *Cassidulina laevigata*. The following forms may also be considered displaced: *Elphidium* spp., *Gavelinopsis praegeri, Cibicides pseudoungerianus,* and *Islandiella norcrossi.*

Other Quaternary species may also be displaced, but the displacement is difficult to detect, especially if the species live in the epibathyal domain. As suggested by Lutze (1979), only detailed and recent surface sediment studies can determine displacement in these species. The irregular numerical distribution of ***Bolivina quadrilatera*** throughout the section suggests displacement, for example. Specimens of this species are more numerous in levels of the lower Quaternary (below Section 549A-2-3) in which some displaced faunas from the continental shelf domain are present; it is therefore supposed that ***Bolivina quadrilatera*** is a displaced form at Site 549.

Autochthonous Faunas

In all the Quaternary samples studied at Site 549, only 54 species have been recorded, and a single sample rarely shows more than 25 species. The average number of species is between 15 and 20, sometimes even less. Figure 7 indicates that there is a relationship between the abundance of specimens and the abundance of species in a sample. The faunal assemblages may be divided into four groups, as follows.

Unit 1 groups microfaunas that are rich in both species and specimens. These microfaunas appear at levels that represent warm intervals during the Quaternary. The levels also show the highest $CaCO_3$ percentages (Fig. 6).

Unit 2, like the previous unit, groups microfaunas characterized by varied species but two or three times fewer specimens. The unit includes levels that correspond to interglacial periods and periods of deglaciation (Pujol and Duprat, this volume).

Unit 3 consists of microfaunas with few species (fewer than 10) and few specimens (fewer than 30). These microfaunas characterize the coldest periods of glaciation and have the lowest $CaCO_3$ percentages.

Unit 4 consists of faunal assemblages that have slightly more varied species (fewer than 15) but are very rich in specimens. The occurrence of these microfaunas, unlike the occurrence of those in the other three units, is not directly governed by a climatic factor (temperature) but by physico-chemical conditions at the bottom, as discussed below.

The benthic foraminiferal assemblage from the surface (Sample 549A-1-1, 1–4 cm) is typical of Holocene deposits. It clearly corresponds to the benthic foraminiferal assemblages that live today at a depth of 2500 m (Fig. 3; Pujos-Lamy, 1973b).

A fossil count (Table 2) shows that the Quaternary faunal assemblage differed in species abundance and composition from the Holocene assemblage at the surface. In terms of the number of specimens and species, the Quaternary assemblage is impoverished in comparison to the Holocene assemblage. The impoverishment is at a maximum at levels that correspond to the hardest climatic conditions (according to the planktonic microfaunal results).

In terms of species diversity, the Quaternary sediments carry two types of assemblages. The first is dominated by *Uvigerina peregrina,* which alone may represent 50% and sometimes even 90% of the assemblage. The rest of the assemblage is made up of a few specimens of the most frequently occurring Holocene species. This fauna belongs to Unit 4 (Fig. 7). The second type of assemblage is found down core (below Sample 549A-3-6, 46–49 cm), where various genera like *Pleurostomella, Stilostomella,* and *Orthomorphina* are added to the faunal assemblages. These species occur throughout the remainder of the Quaternary.

Distribution of Certain Species

The distribution of the most important species in the Hole 549A faunal assemblage was analyzed in more detail (Fig. 8). The first species worthy of particular mention is *Planulina wuellerstorfi,* which is common nowadays and is found at depths of 2500 m in temperate and subarctic zones. It inhabits young, well oxygenated waters (NADW) (Belanger and Streeter, 1980) between 1.5 and 3.5°C in temperature (Lohmann, 1978); it belongs to Lutze's (1979) "cold water" category of species.

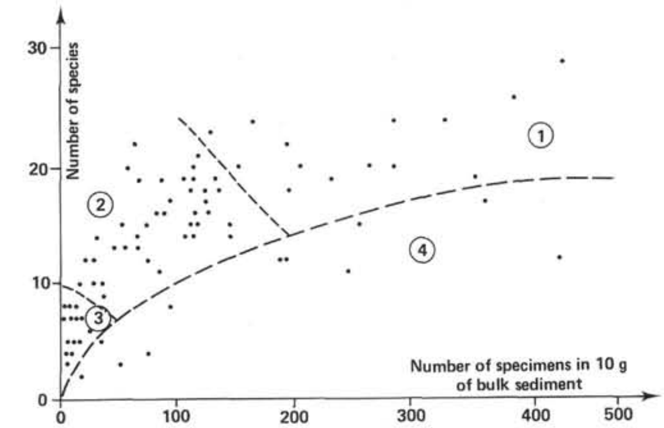

Figure 7. Number of Quaternary species and specimens of benthic foraminifers in Hole 549A samples. Faunal assemblage groups are described in text.

Hoeglundina elegans, Cibicidoides kullenbergi, and *C. robertsonianus* occur throughout the Quaternary. These species live in the NADW where the temperature lies between 2.5 and 3°C according to Lohmann (1978) and between 2 and 4°C according to Schnitker (1974). Because of its aragonitic test, the distribution of *Hoeglundina elegans* is confined further, to the upper part of NADW. These so-called "warm species" (Lutze, 1979) are quite numerous throughout the Quaternary Hole 549A sediments and characterize the NADW mass.

The most frequently occurring species, however, is *Uvigerina peregrina.* It makes up very high percentages (90–95%) of the faunal assemblage in certain levels of the Hole 549A Quaternary section (Fig. 8). As at Site 548, this species proliferates in environments low in dissolved oxygen, either in water masses where the oxygen content is less than 5 ml/l (as indicated by Streeter and Shackleton, 1979) or at sediment levels rich in organic carbon that may result in interstitial waters poor in oxygen (Lutze, 1980; Miller and Lohmann, 1982).

Interpretation and Discussion

Biostratigraphic Results

The calcareous benthic foraminifers in the Quaternary cores in Hole 549A are not suitable for providing biostratigraphic information. The faunal variations observed are essentially due to climatic conditions and cannot be used for biostratigraphic purposes outside the study area. Nevertheless, because of the presence of the genera *Stilostomella, Pleurostomella,* and *Orthomorphina,* the faunal assemblage observed at the base of the section (Sample 549A-3-6, 80–84 cm and Section 549A-3,CC) is similar to that at the base of the Quaternary Site 548 section (Cores 549-13 to 549-15), although the assemblage is not as rich or varied. These forms disappear at the Brunhes/Matuyama reversal, or about 790,000 yr. ago (R. G. Johnson, 1982). These genera were also observed at comparable stratigraphic levels at Site 397 (Lutze, 1979). The level at which these genera disappear completely may,

Table 2. Number of foraminifers, by species, in each Quaternary sample at Hole 549A.

Core	Section	Interval (cm)	Preservation[a]	*Hoeglundina elegans*	*Melonis pompilioides*	*Sphaeroidina bulloides*	*Gyroidinoides orbicularis*	*Uvigerina peregrina*	*Planulina wuellerstorfi*	*Cibicidoides kullenbergi*	*Pyrgo murrhina*	*Melonis barleeanum*	*Gyroidinoides soldanii*	*Gyroidinoides neosoldanii*	*Pullenia quinqueloba*	*Lagena* spp.	*Globobulimina affinis*	*Globobulimina* sp.	*Pullenia bulloides*	*Cibicidoides robertsonianus*	*Sigmoilopsis schlumbergeri*	*Oridorsalis tener*	*Quinqueloculina* spp.	*Bulimina mexicana*	*Chilostomella oolina*	*Chilostomella ovoidea*	*Cibicides* spp.
1	1	1-4	G	16	19	1	9	106	80	32	10	16	15	6	11	3	1		1	17	42	7	1	29			
		8-11	G	6	12	2	4	52	42	34	2	8	2	4	2	2				6	18			2			
		39-42	G	2	6	2	1	4	16		1	3		3	2	1	2			5	7			7	2	2	3
		42-45	G		2	1			6	1	1	1		1						10	2	1					
		137-140	M					5				1					1		1		1			1			1
1	2	2-5	M						2				1		1		1			1				1			
		5-8	M						1				1				1		1	3							
		70-77	M														1	1		2							
		130-137	G	1	2	1		3	1		1								1	2							
1	3	10-13	M		20	14		14	19		7	3	2		2	1	2			27	7		2				
		20-23	G		4	6		7	17		7	16			1	1	1		1	29	6		1				
		70-77	G			1		2	10		1		3		1	1	2	8		14	4	1					
		125-131	M	2	2				35	1	8	13	2		1	1	1	4		10	25	2					
1	4	10-13	M		8	4	1	14	38	1		5	8		2		1		6	13	10						
		20-23	G	5	12		2	5	27	7	6	7	7			5			16	12	22						
		40-43	M		2	2		11	29						2				3	8	8						
		54-57	M		3	2		8	8	1	2		3		2	2			3	8	4						
		72-78	G		4			219	19	1	12	18			2		3		18	41	11	2			1		
		88-93	G					157	4		18	2			4	3			8	36	4						
		100-103	G		11			316	15		6	1		1					4	41	3	12					
		105-109	M					24	2		3						1			3							
1	5	20-23	M		1			7	1		2	1				1			2	9	3						
		90-97	M									1								2	1						
		144-147	G		1			65	7		11	1	3		1		1		1	13	7	1					
2	1	3-6	M	6	9				70	1	15	10	5			9			7	21	24	4			1		
		10-16	G	2	2			56	10		6	3	1		1				5	11	9	2					
		20-23	M					1	15		5	1							1	6	6						
		55-58	M		3	3		19	6		6	5		1		1	5		2	13	11	1			1		
		102-108	G		12	2	1	5	49	1	1	3	4		2				4	7	8	5		1			
		135-138	M		4	21		8	18	13	1	6	6		1	3			1	2	5	8			1		1
2	2	10-13	G		10	16		27	52	6	4	6	6	4	1	1			1	11	18	6					1
		20-23	G	3	7	1	1	53	29	12	4		3	3	4	3	1		3	7	18	5		1	1		2
		56-63	G		9	8	1	11	35			10	1						3		7	4					
		95-98	M	1	9			6	28	1	6	1	1			1			4	6	12	5					
		100-107	M		1			2	2										3								
		130-133	P			1			3										1								
2	3	15-18	M			2			1				1		1						2	1					
		20-23	M			4		13	1				3		1							3					
		58-65	G	16	15	5	4	89	80		4	5	7		2	2	2		19	16	33	21			1		
		95-96	M		15			80	67	5	20	6		4	2	2			12	11	29	3		3			1
		107-113	M		1			8	38	1		1	4		3		1			11	4	1	1				
		132-135	M	1		1		6	3				2	1			3				2						6
2	4	23-30	P												1												
		50-53	P						1								1										
		74-77	M	12	1	4		10	19	7				1	3	3	1		13	6	15	1		3			3
		120-127	M										2						2	3	1						
2	5	10-13	M		2			17	3			1			1	2	8		1	6	3	2	2				
		20-23	M	1	1			14	1			3		1			4		3	1	1	1		1			
		50-57	P					16																			
		80-83	G	3				62	103		13	22	2			8			6	32	28	5		1			
2	6	20-23	M			1		89	26				5			2			9	13	6	1		21			
		64-71	M	4	3	6	2	20	20		8						2		12	14	15						
		103-110	G	1	1			15	12		4	1	3						2	20	5			2			
3	1	2-5	G		3	4		23	45		7	4	2		7	7	1			7	11			3			1
		7-14	M				1	30	1		1	1				1			1								
		40-41	M					64											5	2				2			
		89-92	M					45	2										3								
3	2	40-41	G	1				56	16		5								5	5	5						
		51-54	M	1				3					1								3			1			1
		89-96	G	1	11		2	198	58	7	21	19	1		2	3	1		4	19	21	3		7			
		115-118	M		4	1		112	23	9	1	5	5						7	9	20			2			
		138-139	M		4			8	35		12	5	7	2	2	2				16	16	2		2			
		147-150	M		1	4	2	5	27		4	1	5			1				12	9	1	1	2			
3	3	29-30	M	12				36	6		5	12	13			2			1	44	18			9			
		41-48	G	13				54	10		9	5	2		3					37	7		1				
		70-71	G	32		4	10	13	13		17	2	4		2					14	10	10					
		99-102	G	3	7			3	27		15	7	3		4	10			1	12	15	7			1		
		132-139	G		14	2			48		30	11	2		3	6				8	11	4					
3	4	1-4	M		3	3		9	47	3			1	1	3					12	12	2					6
		47-48	G		29			5	136		20				2	9				14	16	2					
		64-67	M		2	1		12	5		1	1			2		1			3	9			1			
		105-110	G	4	3			10	17		3	3	2		3	1	1			18	6	2		5			
3	5	16-19	M	3	2				12		1	5	5				1			3	12			1			3
		47-48	M	1				19	21	8	3		3							3	5	3					
		80-83	M		1	1	1	2	39	34	7	3	5		1					7	18	4		1			
		120-127	M		1				1				1		1		2				2						
3	6	0-7	M						1												1						
		46-49	G		10	2		17	71	3	12	27			3	4			3	19	50	17	2				
		80-84	G	1	23			26	68		13	3	3		2	1			1	8	25	5		9			
3	CC	15-22	G	2	14	2		13	47		6	4	6		2	7	3		1	5	14	3		8			

[a] P = poor, M = moderate, G = good.

Table 2. (Continued).

Pyrgo oblonga	*Bolivinita quadrilatera*	*Miliolinella irregularis*	*Cassidulina laevigata*	*Lenticulina* spp.	*Osangularia culter*	*Bulimina buchiana*	Lagenidae div. sp.	*Pyrgo* sp.	*Elphidium* spp.	*Epistominella exigua*	*Pyrgo lucernula*	*Bulimina aculeata*	*Triloculina tricarinata*	*Cibicidoides* sp. 1	*Globocassidulina subglobosa*	*Quinqueloculina venusta*	*Islandiella norcrossi*	*Ruperria stabilis*	*Uvigerina* sp.	*Ehrenbergina* sp.	*Gavelinopsis praegeri*	*Laticarinina pauperata*	*Cibicides pseudoungerianus*	*Nodosaria* sp. 2	*Pleurostomella* sp.	*Stilostomella* sp.	*Orthomorphina* sp. 1	*Siphonaptera* sp.
							2																					
								2																				
1																												
	1																											
	1																											
	1	1	1	1																								
	7		1						1																			
	2								1																			
	2								1	7																		
3	3				7							1	1															
	1		5		1	1			1				1	2														
						1					1	8	1	2														
	1												1															
												1			1													
						2		1		2	3																	
	2																											
2					1		1					8	3															
												12	1															
										3		17																
							1																					
	4																											
			2									2		1														
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	1											3				1												
	1								1								1											
												1																
	1											5		1	1													
			1													1												
								6				1		1														
											1	4																
	1				1							1		1														
							2					2		1														
	1								1																			
					1																							
2	2				7						1			3														
												10		4		2		1										
														1				1										
					1			1								1												
	1																											
1	9						1	1								1												
	4																											
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	1		13		1			3		1		1		3					1									
1			2																									
	6		6		1							1	1															
					1							1																
	1		3	1			1					3	1															
	1																											
	2																											
	8			1																								
1	10		4		2				1				1	1	1					1								
			1																		1							
					2																							
			1								1			3								1						
			2					3						2		1												
	1		8		1														4									
	4		6					8	1					6			1											
								1			1			3								1						
					1									1								1						
							2	6						2														
2	5		6	2				11	1				1	9														
	24							1						1														
	2		11					1	2			1										1						
1	1		3																									
	11		3											5														
	2				1																							
					1																							
				1																								
	2				2									2	2				12	1								
	1		3					1			3			2										1	3			1
3			6	1							2												1	5		1	2	2

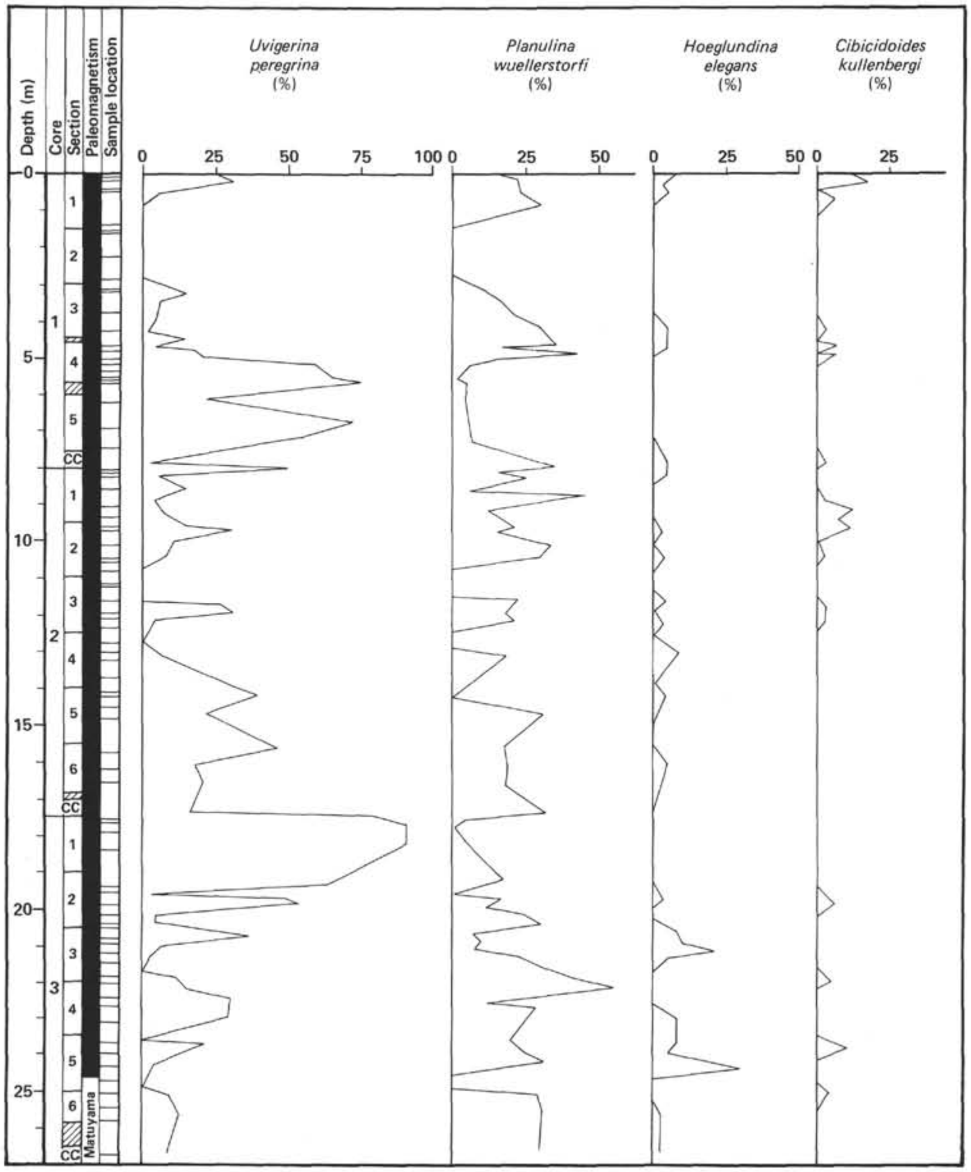

Figure 8. Distribution (in percent of faunal assemblage) of some important species in Quaternary Hole 549A cores.

therefore, represent the top of a biozone known today in the northeast Atlantic within the bathyal domain.

Climatic Results

The impact of climatic factors, especially temperature, on the calcareous benthic foraminiferal assemblages has frequently been alluded to in the previous analysis and coincides with the planktonic foraminifer results. Previous surveys (Pujol, 1980) have shown that sediments at temperate latitudes, specifically the Bay of Biscay and elsewhere in the northeast Atlantic, undergo the most important climatic variations in the late Quaternary (which is associated with glacial phenomena).

The Quaternary deposits in Hole 549A yielded an accurate record of the climatic variations due to glaciation at the ocean floor. According to the data gathered, the Quaternary sediments at Hole 549A may be divided in two. The base levels (Sections 549A-3-1 to 549A-3,CC) generally contain homogeneous fauna, suggesting quite stable environmental conditions. The upper levels (Sections 549A-1-1 to 549A-3-1) contain benthic assemblages that rapidly become more impoverished from one level to another in number and type of species.

The contrast in the behavior of the benthic foraminifers during these two periods is obvious from an examination of the number of benthic foraminifer specimens (Fig. 6). The clay mineralogy (Chennaux et al., this volume) shows the same two parts in the Quaternary, with a homogeneous lower part (Core 549A-3) and swift variations in the upper part (Cores 549A-1 and 549A-2).

Hydrological Bottom Water Results

The most abundant benthic foraminifer in all three of the Quaternary Hole 549A cores is *Planulina wuellerstorfi* (Fig. 8), a species known for its adaptability in the bottom waters of the NADW. *Planulina wuellerstorfi* is associated throughout the section with other species known for their occurrence in these waters. These species are *Pyrgo murrhina, Cibicidoides robertsonianus, C. kullenbergi, Hoeglundina elegans,* and occasionally *Bulimina aculeata* and *Laticarinina pauperata.* Some of these NADW species (*Planulina wuellerstorfi* and *Pyrgo murrhina*) can live in even colder bottom water temperatures ("cold species" by Lutze, 1979). This is deduced from their current habitat in the Norwegian Sea (Belanger and Streeter, 1980). The socalled "warm species" (*Cibicidoides robertsonianus, C. kullenbergi,* and *Hoeglundina elegans*) disappear during periods of glaciation.

According to the biostratigraphy of the Quaternary Hole 549A sediments (Pujol and Duprat, this volume), the samples corresponding to periods of glaciation (Stages II, III, VI, VIII, and parts of X, XII, and XX) end up by containing only "cold benthic species". It is inferred that during these glacial periods the water mass near Site 549 was similar to the present NADW, with only "cold species assemblages". The "warm species" absent at Hole 549A continue to exist at Site 397 west of Bojador Cape (Lutze, 1979), and they display a far more constant distribution; these forms are referred to by Schnitker (1974) as being species that drifted south to 40° N latitude during cold periods. These results illustrate the way in which certain benthic foraminifers may be used to detect minor temperature variations (or even other factors, if they are associated with temperature) within water masses like the NADW.

The distribution of fossil benthic foraminifers (Table 2 and Fig. 8) shows quite clearly the exceptional development of *Uvigerina peregrina* in certain samples. It is interesting to note in Figure 8 the opposing behavior of *Planulina wuellerstorfi,* which is associated with the well oxygenated NADW, and *Uvigerina peregrina,* which is tolerant of low levels of dissolved oxygen.

The dominance of *Uvigerina peregrina* is clear in (1) the section between Samples 549A-3-1 (40–41 cm) and 549A-3-2 (40–41 cm) and (2) the section between Samples 549A-1-4 (100–103 cm) and 549A-1-5 (144–147 cm) (interrupted locally at Sample 549A-1-5, 90–97 cm). This section is characterized by a quartz residue that has yielded probably displaced forms, namely *Bolivina quadrilatera.*

The first of these zones corresponds to the transition from bioclimatic Stage XIII to Stage XII, the second to the transition from bioclimatic Stage VI to Stage V. Both transition periods occurred during deglaciation periods that preceded the last interglacial period. Between Samples 549A-1-5 (144–147 cm) and 549A-2-2 (53–63 cm) (Stage VII), the populations of *Planulina wuellerstorfi* and *Uvigerina peregrina* fluctuate rapidly in alternation.

Two hypotheses can be proposed to explain the occurrence of high populations of *Uvigerina peregrina.* Its distribution may be influenced directly by the low oxygen content of the overlying waters, as proposed by Streeter and Shackleton (1979), or the species may respond to low oxygen levels in the sediments that are caused by high levels of organic carbon, as proposed by Lutze (1980) and Miller and Lohmann (1982).

The Quaternary Hole 549A sediments were analyzed for organic carbon content (see site chapters, this volume). In Sample 549A-3-2 (43–44 cm), the total organic carbon content is 0.66%, the highest value found in these Quaternary sediments. Furthermore, an examination of the washed residue from the same core (549A-3) revealed the presence of pyrite in several samples (e.g., Sample 549A-3-1, 40–41 cm). Therefore, the results obtained seem to fit well with the Lutze (1980) and Miller and Lohmann (1982) hypotheses.

The sudden and repeated faunal variations during bioclimatic Stage VII could be the result of the sporadic arrival of limited amounts of organic material in a bottom water environment that tends to be low in oxygen. During periods when the numbers of *Uvigerina peregrina* are high and consequently the oxygen at the bottom is low, species associated with the NADW (water rich in dissolved oxygen) occur very little. Other similar episodes may exist throughout this section, but their recognition would require more detailed sampling.

Bathymetric Results

Throughout the Quaternary the Hole 549A faunal assemblages are those that inhabit the existing site depth of approximately 2500 m. Variations in the shoreline are more difficult to detect than at Site 548. The scarce displaced faunas are only continental shelf derived; their numbers in comparison to the autochthonous faunas are always low. Environmental conditions at a 2500 m depth appear to have been generally stable throughout the Quaternary. This stability is marked by the consistency of the faunal assemblage and the fairly constant rate of sedimentation. The bottom hydrology resembles, on the whole, that of the present-day NADW. The Quaternary variations observed are the result of either very severe climatic conditions as a result of glaciation, in which case the faunal associations become impoverished because of insufficient nutrients rather than changes in the physico-chemical conditions, or very low oxygen levels at the bottom, which affects the faunal assemblage.

SITE 550

Site 550 is 4432 m deep. It is located on the abyssal plain southwest of the Pendragon scarp (Figs. 1 and 2). The Quaternary is represented by a single core (6 m); 11 samples were analyzed.

General Characteristics of Benthic Microfauna

The calcareous benthic foraminifers from Core 1 at Site 550 are few and little diversified. They belong to 17 species typical of the abyssal domain. Two samples are relatively rich in fauna, for they contain more than 50 specimens: Samples 550-1-1 (7–14 cm) and 550-1-2 (130–137 cm). Most of the samples contain approximately 20 specimens, others many fewer. Despite a few broken specimens, the fossils are, on the whole, well preserved. Traces of dissolution were observed in Sample 550-1-3 (93–100 cm). Some rare specimens (belonging to five species) appear among the autochthonous fossils; they issued from the neighboring continental shelf (Fig. 9 and Table 3).

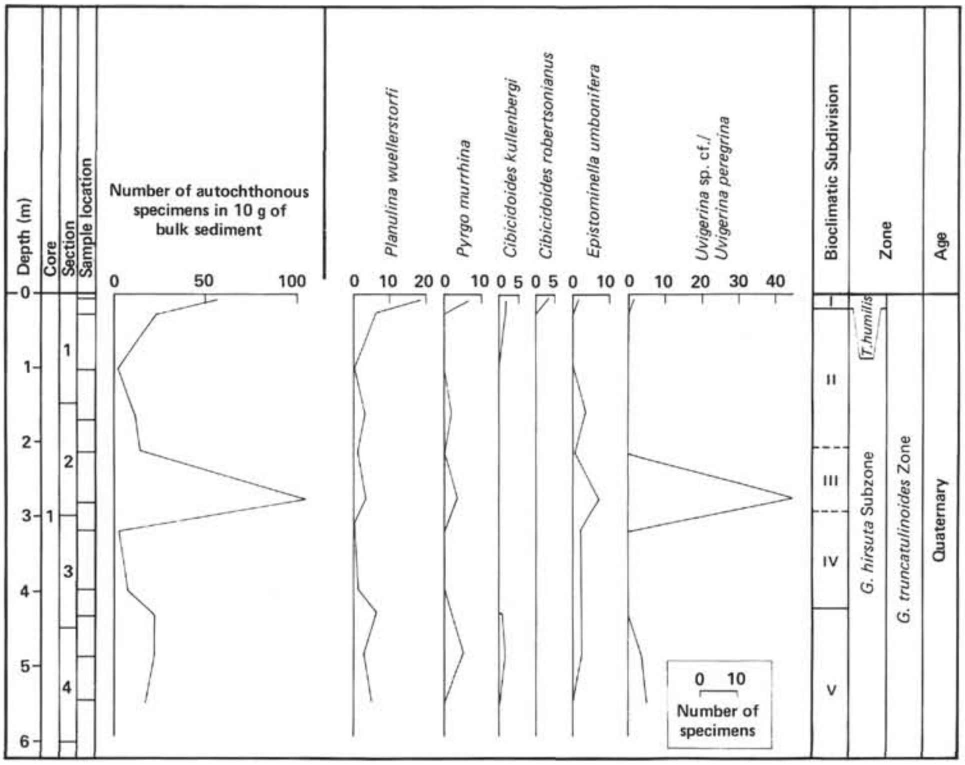

Figure 9. Analytical results of benthic foraminiferal study throughout Quaternary Core 1 (Site 550).

Table 3. Number of foraminifers, by species, in each Quaternary sample at Site 550.

																					Displaced fauna				
Core	Section	Interval (cm)	Preservation[a]	*Melonis barleeanum*	*Uvigerina* sp. cf. *U. peregrina*	*Gyroidinoides soldanii*	*Melonis pompilioides*	*Epistominella umbonifera*	*Planulina wuellerstorfi*	*Cibicidoides robertsonianus*	*Cibicidoides kullenbergi*	*Quinqueloculina venusta*	*Pyrgo murrhina*	*Sphaeroidina bulloides*	*Oridorsalis umbonatus*	*Pullenia bulloides*	*Chilostomella oolina*	*Lagena* div. sp.	*Uvigerina* sp.	*Pyrgo* sp.	*Cibicides lobatulus*	*Cibicides* sp.	*Cribononion lidoense*	Miliolidae	Lagenidae
1	1	7-14	M	11	1		5	1	20	3	1	5	6	2	2	1					2				
1	1	30-33	G	3			2		6		1				2		2	5	1						
1	1	100-107	P												1								2		
1	2	23-30	M					3	3				1			5		1			1				
1	2	60-62	M			2			1						3	6									
1	2	130-137	G	1	45	9	2	7	3				3	1	3	5		1			1	3			
1	3	18-21	M					2							1										
1	3	93-100	D				1	2	1						1	1		1							
1	3	130-137	G	7			1	2	6				1		3			1		1					1
1	4	34-38	M	2	4			2	3		1		5	2	1				1						
1	4	80-87	M	2	5	1	1		5						3				1	1		1		3	1

[a] P = poor, M = moderate, G = good, D = dissolved.

Assemblage Types

Seventeen species were identified. Special attention was paid to the species that were adapted to particular water mass environments or certain physico-chemical parameters. The species associated with the NADW (Lohmann, 1978) were divided into two groups, as follows.

Planulina wuellerstorfi and *Pyrgo murrhina,* which are common in the Norwegian Sea (Belanger and Streeter, 1980), occur throughout the core except at certain levels that correspond to the last stage of glaciation (Pujol and Duprat, this volume). Both species are well represented at the top of the Holocene (Sample 550-1-1, 7–14 cm) and near the base of the Quaternary (between Samples 550-1-3, 130–137 cm and 550-1-4, 80–87 cm), in an interval that corresponds to the last interglacial period (isotopic Stage V).

Cibicidoides kullenbergi and *C. robertsonianus,* which are associated with the NADW (Lohmann, 1978), do not seem to be as tolerant of low temperatures as the previous two species (Lutze, 1979). They occur only at the top of the Holocene (Sample 550-1-1, 7–14 cm) and toward the base of the Quaternary (Sample 550-1-4, 34–38 cm); that is, only during warm periods.

Species associated with an AABW component, such as *Epistominella umbonifera,* (Lohmann, 1978; Schnitker, 1979b), are present almost throughout the core, the number of specimens varying between 1 and 7. *Epistominella umbonifera* represents the majority of the fossils at levels marked by dissolution (Samples 550-1-3, 18–21 cm and 550-1-3, 93–100 cm). Finally, the sporadic occurrence of *Uvigerina* sp. cf. *U. peregrina* is noteworthy. This species is particularly abundant in Sample 550-1-2 (130–137 cm), where it represents 45% of a quite varied faunal assemblage. The environmental requirements for this species were discussed above with regard to Sites 548 and 549.

Interpretation and Discussion

Biostratigraphic Results

The abundance and composition of the benthic microfauna at Site 550 reflect three climatic episodes that were first determined from the planktonic microfauna (Pujol and Duprat, this volume). From the base to the top, these episodes are as follows.

Between Samples 550-1-4 (80–87 cm) and 550-1-3 (130–137 cm), the microfauna is quite varied, containing both "cold" and "warm" species (Lutze, 1979) associated with the NADW during bioclimatic Stage V, which is equivalent to the interglacial (Riss-Würm) period on the neighboring continent (Caralp et al., 1974).

Between Samples 550-1-3 (93–100 cm) and 550-1-1 (100–107 cm), the microfauna is poor, containing only those species able to tolerate cold climatic conditions. This episode corresponds to glacial climatic conditions (bioclimatic Stages IV to II), an interval equivalent to the Würm glacial period.

From Sample 550-1-1 (30–33 cm) to the top, the assemblages are richer, containing rather diverse species that are associated with the NADW and represent Holocene deposits (bioclimatic Stage I).

Hydrological Results

The late Quaternary hydrological evolution of Site 550 occurs in three stages that correspond to the three biostratigraphic episodes discussed above. The top and base episodes are marked by the occurrence of fossils that live in water masses that resemble the lower NADW. This water mass may also have a small component from the AABW, a component that does not go much farther north. In the middle of the core similar types of water masses must exist, but only "cold species" are represented. It is difficult to say whether this is the result of a reduction in primary productivity or a slight temperature drop. During this median episode, the fossil assemblage (Sample 550-1-2, 130–137 cm) suggests an environment lower in dissolved oxygen and a temporary slowing in the bottom water circulation. These conditions could be related to comparable phenomena that took place in the Bay of Biscay between 32,000 and 28,000 yr. ago (Caralp et al., 1982).

At a depth of 4432 m, the mixing of the NADW and the AABW, is difficult to detect in the fossil record because the depth is too great for the NADW and the source is too distant for the AABW. Therefore, the hydrological significance of the Quaternary fossils at Site 550 is very limited.

CONCLUSIONS AND SUMMARY

The following remarks are derived from the study of Quaternary benthic foraminifers at Sites 548, 549, and 550. The comments immediately below apply to both Site 548 and Hole 549A.

The benthic foraminifer faunal assemblages is made up of the same species throughout the Quaternary. Only a few of these species disappeared, an event that occurred roughly between 790,000 and 750,000 yr. ago, near the Brunhes/Matuyama reversal. Their disappearance at this time permits the recognition of a biozone observed in several parts of the northeast Atlantic, a biozone that extends from western Africa (Lutze, 1979) to the Goban Spur.

Species abundance varies with changes in the degree of glaciation. The coldest glacial stages are always associated with sharp reductions in the abundance and sometimes the extinction of benthic faunas. The subsequent appearance of detrital elements is ice-rafting derived. Thus, climate appears to regulate benthic foraminiferal abundance within this temperate sector of the northeast Atlantic.

Within the Quaternary two faunal subunits may be distinguished. From the base of the Quaternary up to and including bioclimatic Stage XIII, the faunal assemblages are uniform. Climatically and paleohydrologically, the environmental conditions may be considered (despite some momentary changes) relatively stable. From the base of bioclimatic Stage XII to the present, the faunal assemblages vary from one level to another in both abundance and species composition. This suggests frequent environmental changes caused above all by changes in the degree of glaciation and to a lesser extent by changes in bottom hydrological conditions.

The Quaternary faunas at Site 548 revealed that the impact of intervals of glaciation on the distribution of benthic faunas was enormous. The extreme scarcity of specimens at levels that correspond to the glacial maxima does not allow of any paleohydrological explanation.

The deposition of material most likely derived from the continental shelf ceased during glacial stages. The detrital elements collected do not contain any displaced faunas, which would mean that these elements are ice-rafting derived.

There were variations in the Quaternary water masses that lay over Site 548. From the available data, it is evident that this site presently lies beneath mixed waters that contain a Mediterranean component slightly low in oxygen. Throughout the Quaternary and more often during early Quaternary and bioclimatic Stage V, well oxygenated waters similar to the NADW covered the site. Low oxygen conditions, however, prevailed during the period between 850,000 and 750,000 yr. ago (Brunhes/Matuyama transition) and the late Holocene.

Displaced faunas usually issued from the neighboring continental shelf. These faunas, which are presumed to occur at the same time as the detrital turbidite deposits, are present throughout the section, but they are more abundant in the interval between Cores 548-7 and 548-1.

At two levels in the section, the displaced faunas issued from a coastal zone. The massive but very localized occurrence of these faunas is indicative of low sea levels close to the edge of the continental shelf. The lows in sea level should have occurred near the base of bioclimatic Stage XI and the base of bioclimatic Stage VII. The detection of other lows in sea level (which must have occurred throughout the Quaternary) would require a closer and more adequate sampling than the present one.

The Quaternary succession of faunas at Hole 549A gave the following results.

There is a relationship between the degree of glaciation and the abundance and composition of the benthic fauna. The levels corresponding to the coldest climatic conditions are largely free of fauna, probably more as a result of low nutrient levels than low temperatures.

Bottom waters similar to the present-day NADW occur frequently during the Quaternary at Hole 549A. Indeed, as the benthic foraminiferal assemblage shows, the site is presently overlain by the well oxygenated NADW, and the most frequently occurring faunal assemblages are those associated with well oxygenated waters similar to the NADW. However, during glacial episodes the number of specimens and species decrease to such an extent that it is impossible to estimate the water's oxygen content or quality with any accuracy. Twice in the section, the abundance of *Uvigerina peregrina* indicates low oxygen conditions. These conditions occur during the transitions from bioclimatic Stage XIII to XII (475,000–425,000 yr. ago) and Stage VI to V (130,000–120,000 yr. ago). As has been suggested by Lutze (1980) and Miller and Lohmann (1982), this low oxygen level is due to the deposition of larger amounts of organic matter on the bottom.

A good correlation exists between the Quaternary succession in Hole 549A and that at Site 397, which is in a comparable bathymetric position on the west African slope (Lutze, 1979). At this latitude the same benthic faunal assemblage and comparable climatic conditions (in spite of greater variations below temperate latitudes) prevailed.

Displaced faunas from upper bathymetric zones (namely the continental shelf) are few, and there was no evidence of the changes in sea level observed at Site 548.

The Quaternary sediments at Site 550 represent only the last 125,000 yr. The distribution of the benthic foraminifers is directly affected by recent glacial events. The diversity of the faunas suggests the existence of a mixed water mass resembling the lower NADW with an Antarctic component.

The sections from Site 548 and Hole 549A represent the first complete Quaternary faunal successions for the temperate latitudes of the northeast Atlantic. The detailed analysis of the benthic foraminifers has provided valuable information not only on faunal assemblages but also on Quaternary climatic and paleohydrological conditions. This study has also revealed bottom environmental changes caused by glacial phenomena or physico-chemical conditions at two depths in the bathymetric domain.

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APPENDIX
Species List

Seventy-seven species have been identified out of the calcareous benthic foraminifers recovered in three Quaternary Leg 80 sections (those from Site 548, Hole 549A, and Site 550). Most of these species exist all over the world's oceans (Loeblich and Tappan, 1964). Each is given an explanatory bibliographic reference, whenever possible one from the Atlantic Ocean.

Bolivina quadrilatera (Schwager); Lutze, 1979, pl. 3, fig. 3.
Bulimina aculeata d'Orbigny; Pflum and Frerichs, 1976, pl. 1, fig. 8.
Bulimina bucchiana d'Orbigny; Pujos, 1976, pl. IX, fig. 1.
Bulimina mexicana (Cushman); Phleger et al., 1953, pl. 6, fig. 1. This species seems to correspond to that established by Brady (1884) and defined by Barker (1960) as *Bulimina striata* d'Orbigny var. *mexicana* Cushman. It is also believed that this species, insofar as the Bay of Biscay is concerned, was attributed to *Bulimina striata* Seguenza by Pujos-Lamy (1973b).

Carpenteria sp. This species is most likely *Carpenteria monticularis* Carter, which is discussed by Barker (1960, p. 202, pl. 98, figs. 13, 15, 16), but we have at our disposal only young individuals.

Cassidulina laevigata d'Orbigny; Rosset-Moulinier, 1972, pl. 11, fig. 18. This very light species is associated with displaced faunas in the studied cores, especially in Hole 549A.

Chilostomella oolina Schwager; Barker, 1960, p. 112, pl. 55, figs. 14–17.

Chilostomella ovoidea Reuss; Barker, 1960, p. 112, pl. 55, figs. 15, 16, 20.

Cibicides lobatulus (Walker and Jacob); Phleger et al., 1953, pl. 11, figs. 9, 14. This species is associated with displaced faunas in the studied cores.

Cibicides pseudoungerianus (Cushman); Barker, 1960, p. 194, pl. 94, fig. 9; Pujos, 1976, pl. XI, fig. 7. This species, which is well represented in the Bay of Biscay, has a bathymetric range of 100 to 300 m. It is largely displaced throughout the cores studied, especially at Site 548.

Cibicides div. sp. The grouped individuals of this genus may be compared to *Cibicides* cf. *ungerianus* (d'Orbigny); Pujos, 1976, p. 257, pl. V, figs. 3 a–c.

Cibicidoides kullenbergi (Parker); Lohmann, 1978, pl. 2, figs. 5–7.

Cibicidoides robertsonianus (Brady); Phleger et al., 1953, pl. 11, figs. 15–17. Like Phleger et al. (1953), we have distinguished two groups within this species, one small in size and displaying few chambers on the spiral side and some or no keel (figs. 15 and 16), the other large and displaying more chambers and a more apparent keel (fig. 17). The large-sized individuals may also be compared to *C. robertsonianus* (Brady) determined by Lutze, 1979, pl. 2, figs. 4a, b.

Cibicidoides sp. 1 Lutze, 1979, pl. 2, figs. 3a, b.

Cibicidoides sp. 2.

Cribrononion lidoense (Cushman); Pujos, 1976, p. 254, pl. VIII, fig. 13. This infralittoral species is very abundant at two levels of Site 548, where it represents a displaced form.

Dentalina sp. 3.

Discopirina sp.

Ehrenbergina sp.

Ellipsoglandulina sp.

Elphidium div. sp. This group of species starts to scatter away from the continental shelf.

Epistominella exigua (Brady); Barker, 1960, p. 212, pl. 103, figs. 13, 14. With a diameter generally lower than 250 μm, this species seems to be rare in washed residues.

Epistominella umbonifera (Cushman); Corliss and Honjo, 1981, pp. 364–365, pl. 3.

Gavelinopsis praegeri (Heron-Allen and Earland); Murray, 1971, p. 133, pl. 55, figs. 1–5.

Glandulina sp.

Globobulimina affinis (d'Orbigny); Parker, 1958, p. 262, pl. 2, fig. 25. Established by Parker (1958), this species is encountered in the Mediterranean by Mullineaux and Lohmann (1981). Lutze (1979) indicates the existence of *G. hoeglundi* Uchio (1960) in the Atlantic near West Africa, which appeared to correspond to the same form.

Globobulimina sp. This species differs from the previous one in that it shows a sharp apical portion; only a detailed study of its forms could determine whether one or two species exist.

Globocassidulina subglobosa (Brady); Corliss, 1979, p. 8, pl. 3, figs. 12, 13.

Gyroidinoides neosoldanii (Brotzen); Herb, 1971, pl. 4, fig. 13, pl. 15, fig. 5; and Lohmann, 1978, pl. 1, figs. 4–9.

Gyroidinoides orbicularis (d'Orbigny); Corliss and Honjo, 1981, pp. 359–360, pl. 4.

Gyroidinoides soldanii (d'Orbigny); Lohmann, 1978, p. 29, pl. 1, figs. 1–3 and Corliss, 1979, p. 9, pl. 5, figs. 4–6.

Gyroidinoides sp.

Hoeglundina elegans (d'Orbigny); Corliss, 1979, p. 12, pl. 5, figs. 11–13.

Islandiella norcrossi (Cushmann); Feyling-Hanssen, 1964, p. 325, pl. 16, fig. 20, pl. 17, fig. 1.

Lagena div. sp.

Lagenidae div. sp. Here there are grouped scarce unidentified morphs, sporadically present in Hole 549A.

Laticarinina pauperata (Parker and Jones); Lutze, 1977, p. 428, pl. 2, fig. 6.

Lenticulina sp.

Melonis barleeanum (Williamson); Corliss, 1979, p. 10, pl. 5, figs. 7, 8.

Melonis pompilioides (Fichtel and Moll); Lohmann, 1978, pl. 1, figs. 12, 13.

Miliolinella irregularis (d'Orbigny); Mullineaux and Lohmann, 1981, p. 30, pl. 1, figs. 3, 4.

Nodosaria sp. 1.

Nodosaria sp. 2.

Nonion labradoricum (Dawson); Caralp et al., 1967, pl. XIV, fig. 5.

Oridorsalis tener (Brady); Lohmann, 1978, p. 26, pl. 4, figs. 5–7.

Oridorsalis umbonatus (Reuss); Lohmann, 1978, p. 26, pl. 4, figs. 1–3.

Orthomorphina challengeriana (Thalmann); Barker, 1960, p. 136, pl. 64, fig. 26.

Orthomorphina sp. 1, Lutze, 1979, p. 431, pl. 3, figs. 6a, b.

Orthomorphina sp. 2.

Osangularia culter (Parker and Jones); Lohmann, 1978, pl. 3, figs. 7–9.

Parafrondicularia advena (Cushman); Barker, 1960, p. 138, pl. 66, figs. 8–12 and Lutze, 1979, pl. 3, fig. 5.

Planulina ariminensis d'Orbigny; Pujos-Lamy, 1973b, pl. II, fig. 8.

Planulina wuellerstorfi (Schwager); Corliss and Honjo, 1981, p. 374, pl. 8, figs. 1–3.

Pleurostomella sp.

Polymorphinidae. A group of scarce genera and species of this family.

Pullenia bulloides (d'Orbigny); Lohmann, 1978, p. 26, pl. 1, figs. 10, 11.

Pullenia quinqueloba (Reuss); Phleger et al., 1953, p. 47, pl. 10, fig. 20.

Pyrgo lucernula (Schwager); Mullineaux and Lohmann, 1981, pp. 30–31, pl. 1, figs. 14, 15.

Pyrgo murrhina (Schwager); Corliss and Honjo, 1981, p. 376.

Pyrgo oblonga (d'Orbigny), Phleger et al., 1953, p. 29, pl. 5, figs. 25, 26.

Pyrgo sp.

Quinqueloculina venusta Karrer; Lohmann, 1978, p. 32, pl. 4, figs. 8, 9.

Quinqueloculina sp. A group of species that starts to scatter away from the continental shelf comprising *Q. auberiana* d'Orbigny and *Q. seminulum* (Linne).

Rupertia stabilis Wallich; Herb, 1971, pp. 296–297, pl. 15, figs. 7–9.

Sigmoilopsis schlumbergeri (Silvestri); Lutze, 1979, pl. 3, fig. 1.

Siphonaptera sp. This genus is characterized by grumous form and has five chambers in the final whorl, like *Quinqueloculina*. These specimens display the same characteristics as *Pyrgo lucernula* (Schwager) presented by Pflum and Frerichs, 1976, pl. 1, figs. 3, 4. They may be the same form.

Sphaeroidina bulloides d'Orbigny; Barker, 1960, p. 174, pl. 84, figs. 1, 2.

Spiroloculina canaliculata d'Orbigny; Pujos, 1976, p. 225, pl. X, fig. 14.

Stilostomella sp. This genus consists of two forms differing by the position of spines (see pl. 2, figs. 7–9). Those forms with spines laid out in a regular coronalike manner may be assimilated with the form in the unnumbered figure in pl. 3 by Lutze, 1979 and *Stilostomella lepidula* (Schwager), Keller, 1980, pl. 1, fig. 7. The other forms display scattered spines on the chambers.

Triloculina tricarinata (d'Orbigny); Barker, 1960, p. 6, pl. 3, fig. 17.

Uvigerina sp. cf. *U. auberiana* d'Orbigny; Phleger et al., 1953, pl. 7, figs. 30, 32.

Uvigerina peregrina Cushman; Lutze, 1979, pl. 1, figs. 3a, b. This polymorphic species has been studied as a whole, as Lohmann, 1978, and Lutze, 1979 have done. It is a group comprising all the costate subspecies.

Uvigerina sp. cf. *U. peregrina* Cushman. Although this morph resembles *Uvigerina peregrina,* it differs by a much finer shell construction and a lighter ornamentation formed of a series of small pustules rather than a series of costae, as in the case of *Uvigerina peregrina.*

Uvigerina sp.

Virgulina exilis (Brady); Barker, 1960, p. 102, pl. 50, figs. 5, 6.

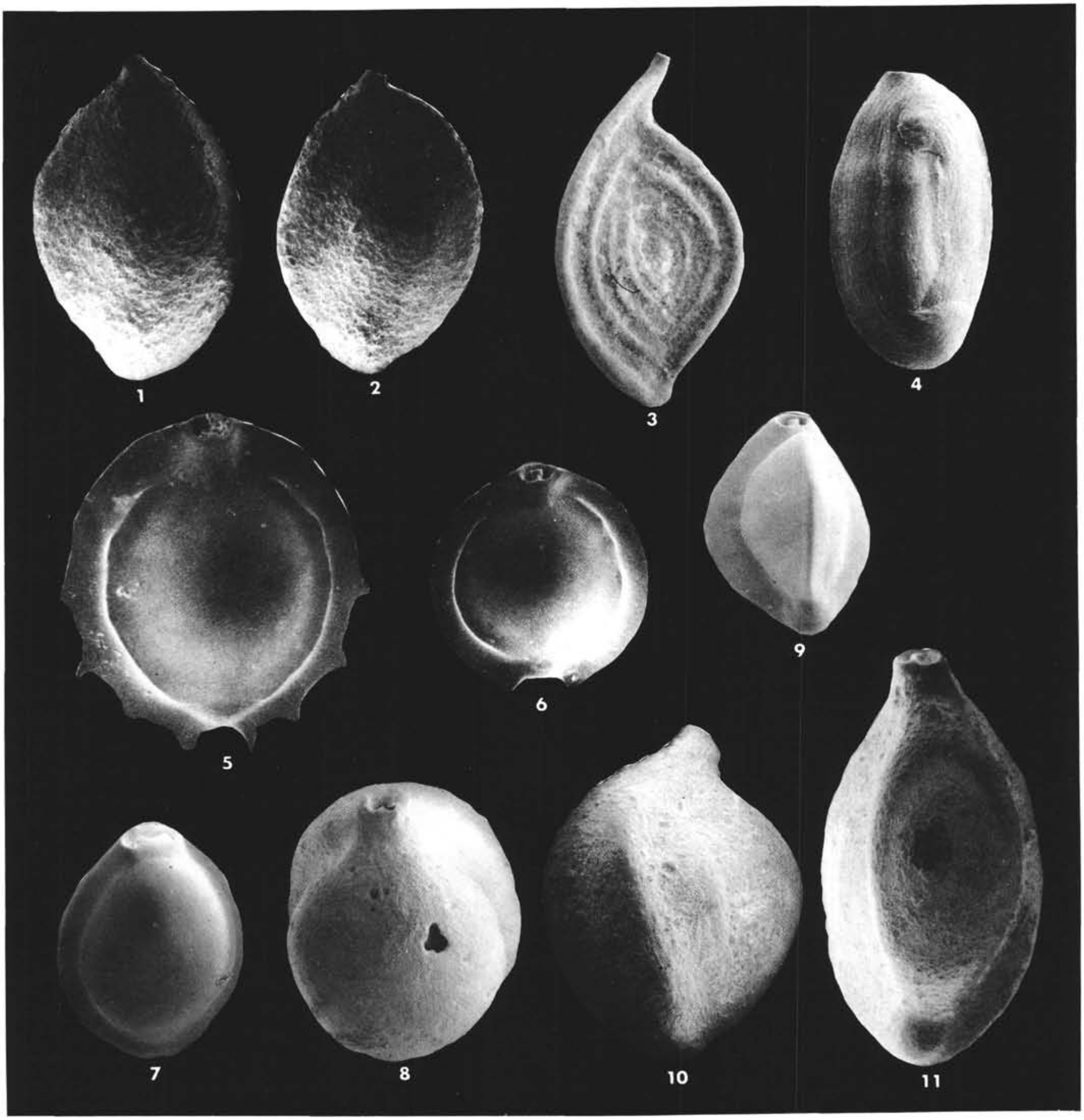

Plate 1. **1, 2.** *Sigmoilopsis schlumbergeri* (Silvestri), opposite sides, ×100, Sample 548-15-1 (117–119 cm). **3.** *Spiroloculina canaliculata* d'Orbigny, ×150, Sample 548-3-1 (76–79 cm). **4.** *Quinqueloculina venusta* Karrer, ×110, Sample 551-1-1 (7–14 cm). **5–6.** *Pyrgo murrhina* (Schwager), ×67.5, Sample 549A-1-3 (125–131 cm). **7.** *Pyrgo oblonga* (d'Orbigny), ×100, Sample 549A-3,CC (15–22 cm). **8.** *Pyrgo lucernula* (Schwager), ×50, Sample 549A-1-4 (40–43 cm). **9.** *Triloculina tricarinata* (d'Orbigny), ×100, Sample 549A-1-4 (72–78 cm). **10, 11.** *Siphonaptera* sp., ×60, Sample 549A-3,CC (15–22 cm).

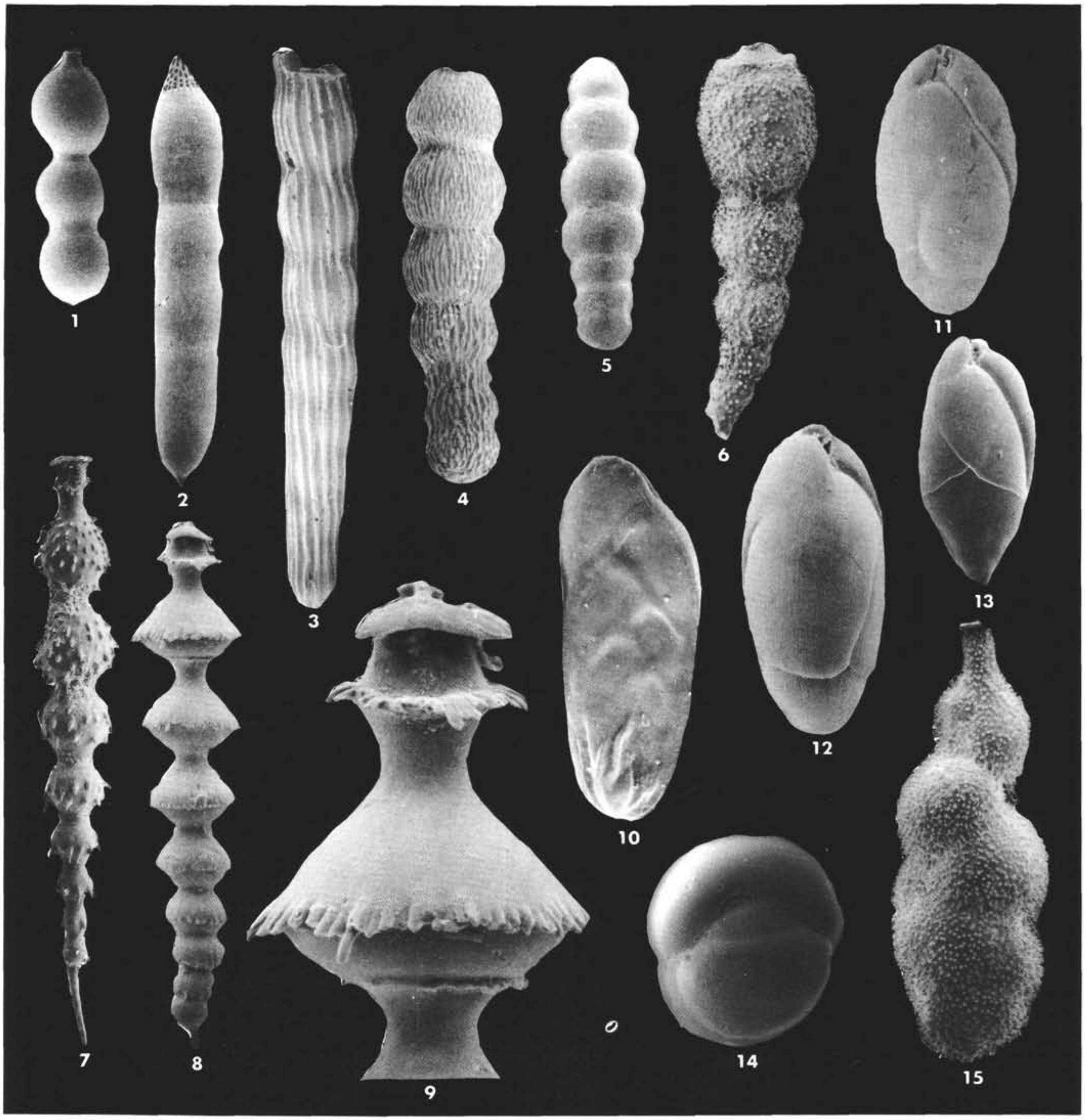

Plate 2. **1.** *Nodosaria* sp. 1, ×60, Sample 548-11-1 (73–74 cm). **2.** *Nodosaria* sp. 2, ×50, Sample 548-11-6 (8–15 cm). **3.** *Dentalina* sp. 3, ×50, Sample 548-11-5 (92–97 cm). **4.** *Orthomorphina challengeriana* (Thalmann), ×70, Sample 548-11-5 (143–150 cm). **5.** *Orthomorphina* sp. 2, ×80, Sample 548-10-4 (96–99 cm). **6.** *Orthomorphina* sp. 1, ×50, Sample 548-13-5 (35–38 cm). **7–9.** *Stilostomella* sp., Sample 548-15-1 (117–119 cm). (7) ×70, (8) ×110, (9) ×300. **10.** *Bolivina quadrilatera* (Schwager), ×150, Sample 549A-2-1 (135–138 cm). **11, 12.** *Globobulimina affinis* (d'Orbigny), ×100, Sample 548-11-5 (92–97 cm). **13.** *Globobulimina* sp., ×100, Sample 548-4-4 (61–65 cm). **14.** *Sphaeroidina bulloides* d'Orbigny, ×150, Sample 549A-1-3 (10–13 cm). **15.** *Uvigerina* sp., ×150, Sample 549A-3-6 (46–49 cm).

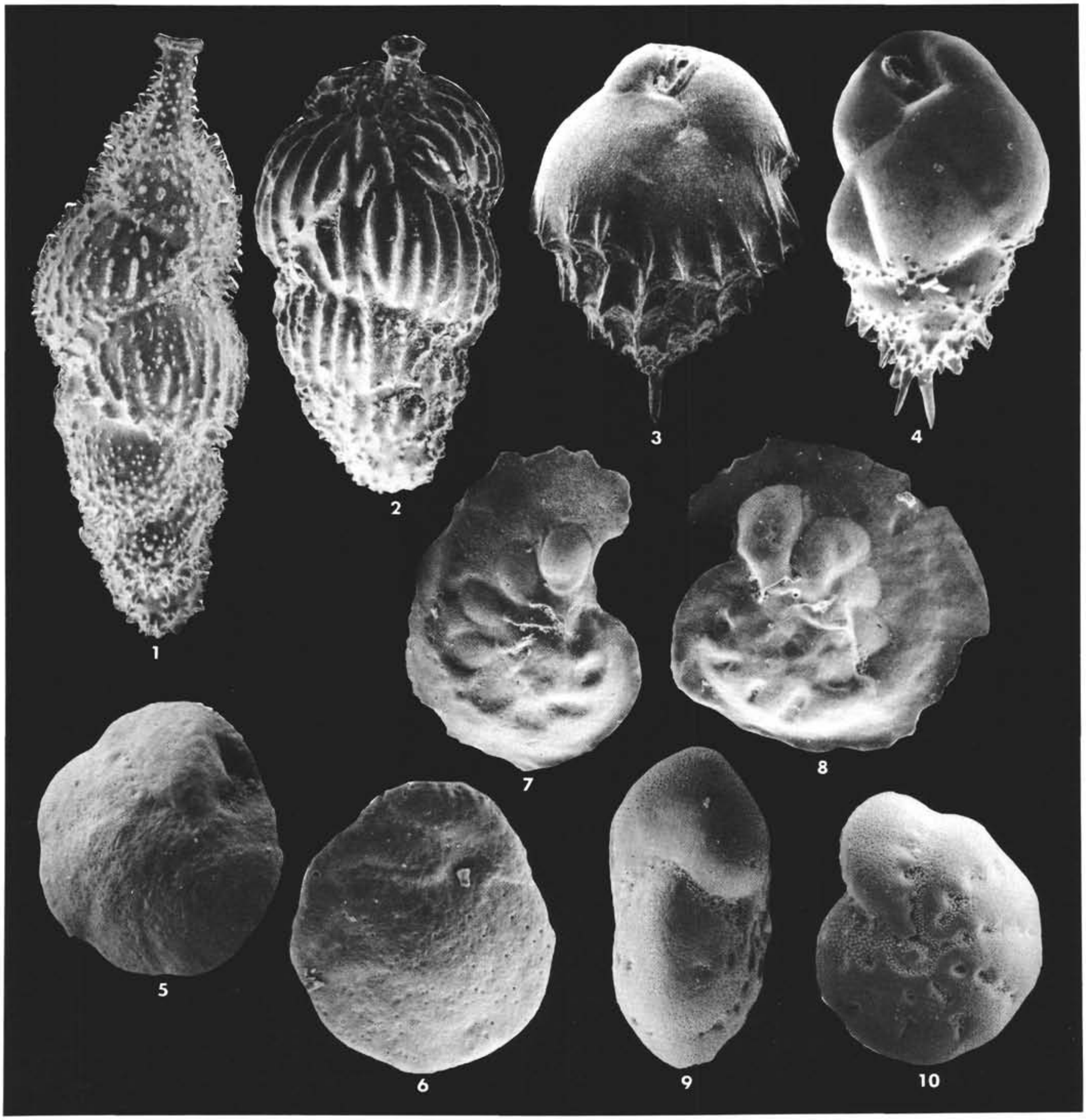

Plate 3. **1.** *Uvigerina* sp. cf. *U. peregrina* Cushman, ×200, Sample 550-1-2 (130–133 cm). **2.** *Uvigerina peregrina* Cushman, ×100, Sample 549A-1-4 (72–78 cm). **3.** *Bulimina mexicana* (Cushman), ×120, Sample 549A-1-1 (1–4 cm). **4.** *Bulimina aculeata* d'Orbigny, ×100, Sample 549A-1-4 (100–103 cm). **5, 6.** *Epistominella umbonifera* (Cushman), dorsal and ventral sides, ×150, Sample 550-1-2 (130–133 cm). **7, 8.** *Laticarinina pauperata* (Parker and Jones), dorsal and ventral sides, ×120, Sample 548-13-5 (35–38 cm). **9, 10.** *Cribrononion lidoense* (Cushman), side and edge views, ×120, Sample 548-4-3 (61–65 cm).

Plate 4. **1, 2.** *Planulina wuellerstorfi* (Schwager), ventral and dorsal sides, ×80, Sample 549A-2-1 (102–108 cm). **3, 4.** *Planulina ariminensis* d'Orbigny, ventral and dorsal sides, ×100, Sample 548-1-1 (0–3 cm). **5.** *Rupertia stabilis* Wallich, ×50, Sample 549A-2-3 (93–96 cm). **6.** *Pleurostomella* sp., ×100, Sample 548-11-5 (17–24 cm). **7.** *Pleurostomella* sp., ×100, Sample 548-13-2 (137–138 cm). **8, 9.** *Carpenteria* sp., ×100, dorsal side and edge view, Sample 548-11-3 (139–146 cm). **10.** *Ellipsoglandulina* sp., ×100, Sample 548-11-1 (50–53 cm). **11.** *Globocassidulina subglobosa* (Brady), ×150, Sample 548-13-5 (35–38 cm). **12, 13.** *Cibicides pseudoungerianus* (Cushman), dorsal and ventral sides, ×100, Sample 548-2-5 (33–36 cm).

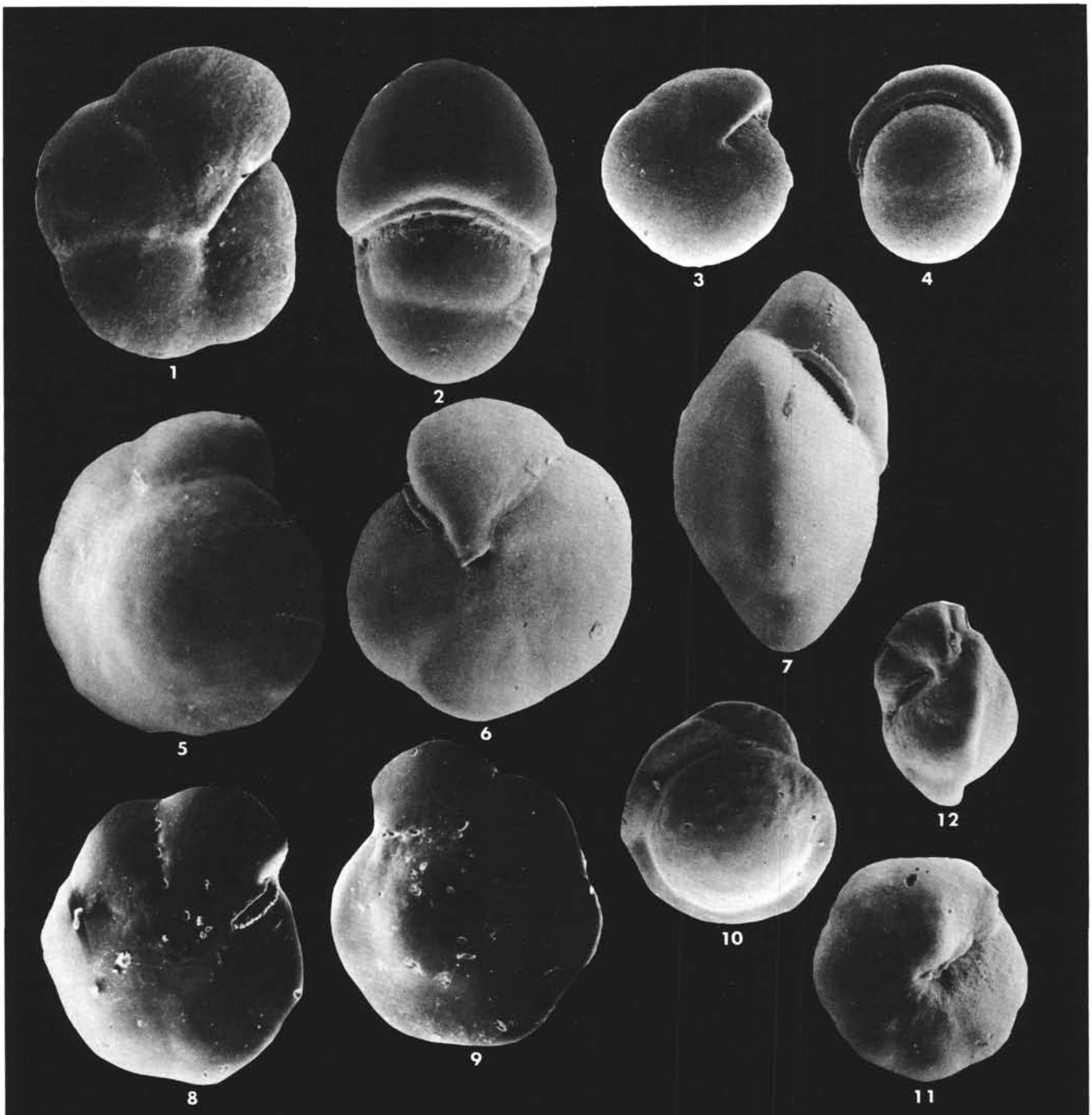

Plate 5. **1, 2.** *Pullenia quinqueloba* (Reuss), side and edge views, ×180, Sample 549A-1-1 (1–4 cm). **3, 4.** *Pullenia bulloides* (d'Orbigny), side and edge views, ×190, Sample 549A-1-4 (72–78 cm). **5–7.** *Oridorsalis umbonatus* (Reuss), opposite sides, edge view, ×120, Sample 550-1-3 (130–137 cm). **8, 9.** *Oridorsalis tener* (Brady), ventral and dorsal sides, ×60, Sample 549A-1-4 (100–103 cm). **10–12.** *Gyroidinoides* sp., dorsal, ventral sides, edge views, ×100, Sample 548-11-5 (143–150 cm).

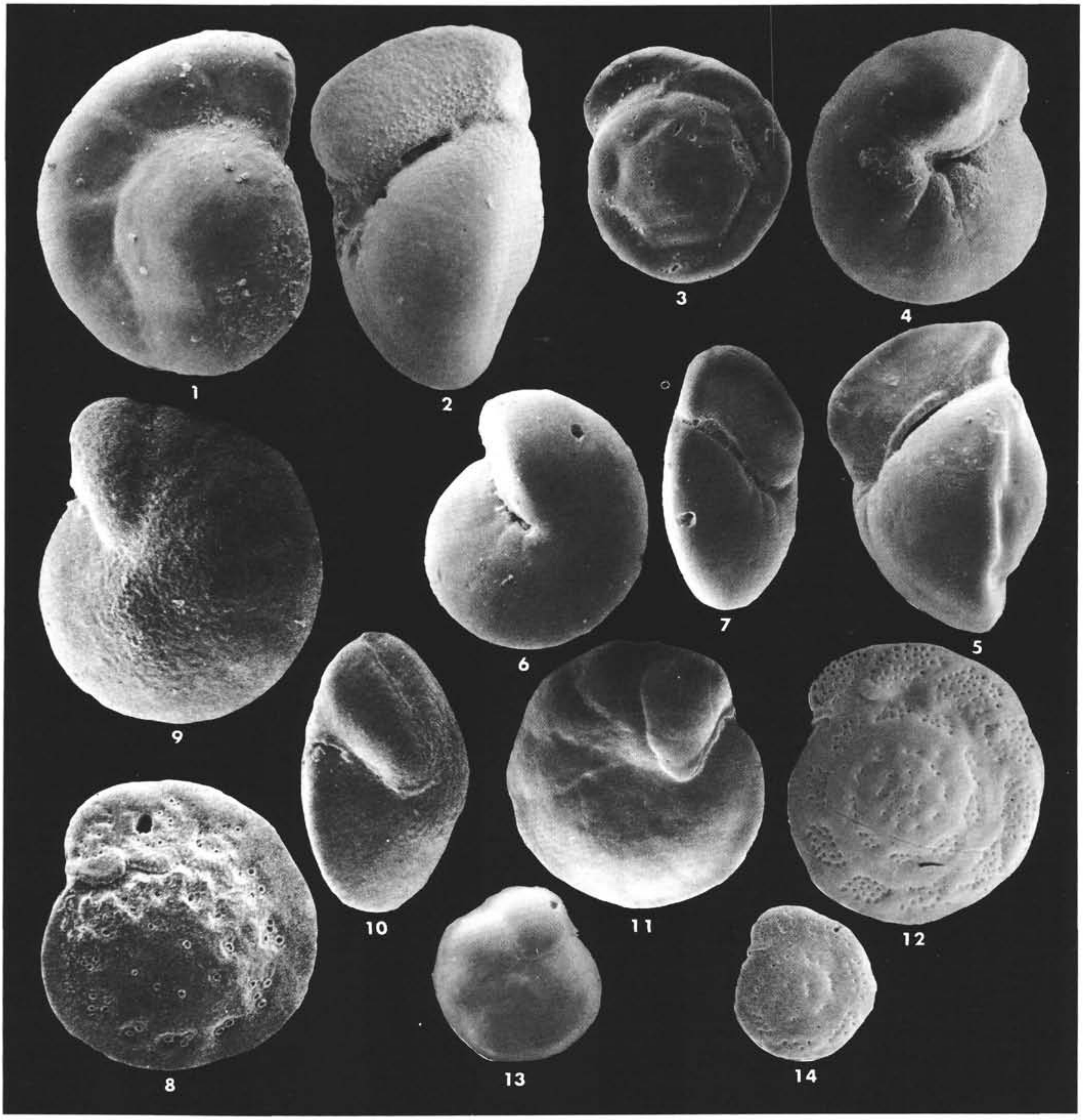

Plate 6. **1, 2.** *Gyroidinoides neosoldanii* (Brotzen), dorsal side, edge view, ×100, Sample 549A-11-5 (143–150 cm). **3–5.** *Gyroidinoides soldanii* (d'Orbigny), dorsal and ventral sides, edge view, ×150, Sample 549A-3-3 (29–32 cm). **6, 7.** *Gyroidinoides orbicularis* (d'Orbigny), edge view, ventral side, ×100, Sample 548-9-2 (108–109 cm). **8–10.** *Cibicidoides kullenbergi* (Parker), ventral and dorsal sides, edge view, ×110, Sample 549A-3-5 (80–83 cm). **11–14.** *Cibicidoides robertsonianus* (Brady), large and small specimens, ventral and dorsal sides, ×100, Sample 548-15-5 (63–68 cm).

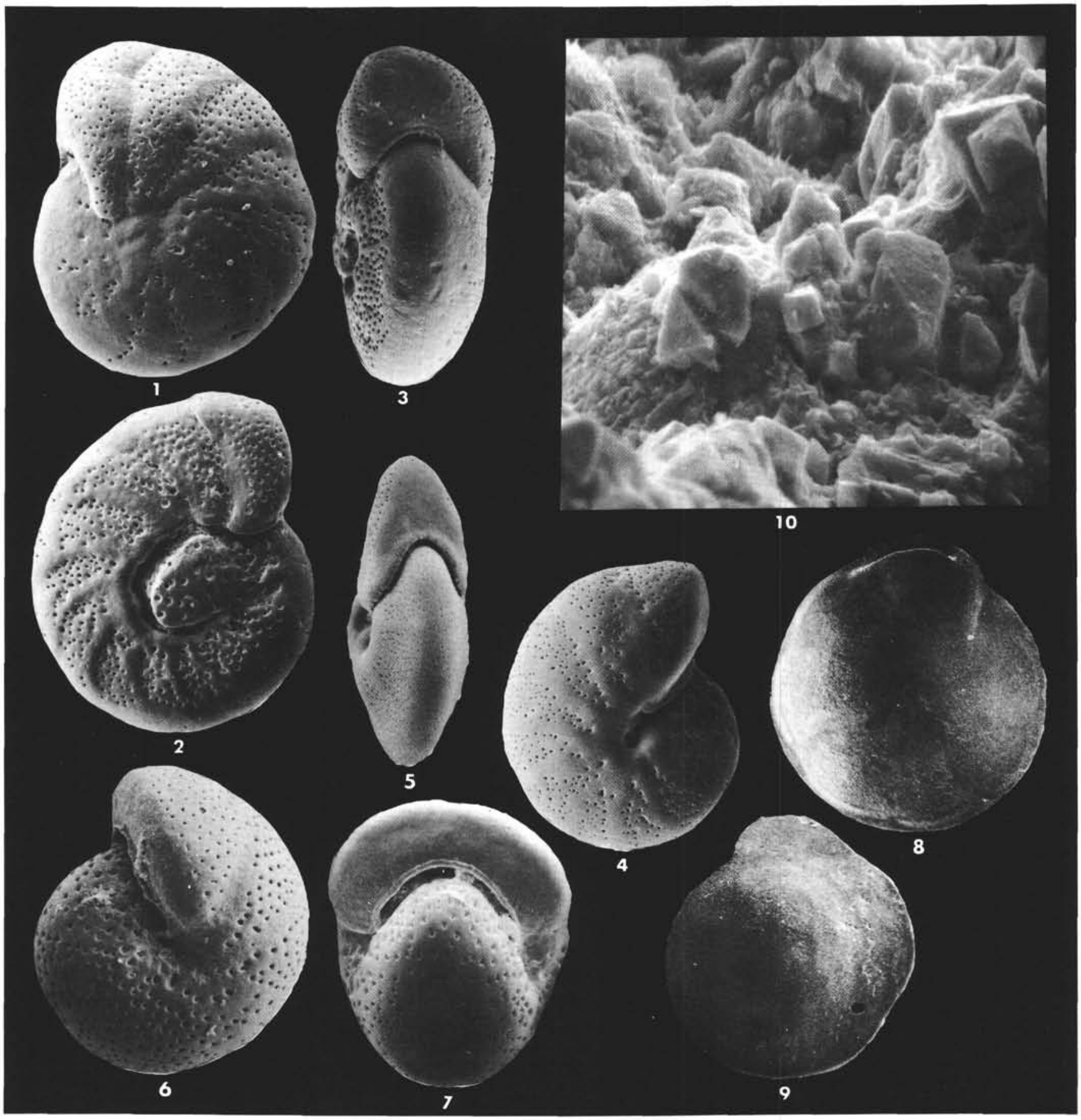

Plate 7. **1-3.** *Cibicidoides* sp., ventral and dorsal sides, edge view, ×100, Sample 548-13-3 (22–29 cm). **4, 5.** *Melonis barleeanum* (Williamson), side, edge views, ×120, Sample 549A-1-4 (72–75 cm). **6, 7.** *Melonis pompilioides* (Fichtel and Moll), side, edge views, ×120, Sample 549A-2-2 (10–13 cm). **8, 9.** *Hoeglundina elegans* (d'Orbigny), ventral and dorsal sides, ×100, Sample 548-15-5 (63–68 cm). **10.** Pyrite crystals on the upper part of a foraminiferal wall, ×1500, Sample 548-11-4 (140–147 cm).