

26. SHALLOW-WATER FORAMINIFERAL TAPHOCOENOSSES AT SITE 821: IMPLICATIONS FOR THE PLEISTOCENE EVOLUTION OF THE CENTRAL GREAT BARRIER REEF SHELF, NORTHEASTERN AUSTRALIA¹

Lucien F. Montaggioni² and Marie-Thérèse Vénec-Peyré³

ABSTRACT

Reworked shallow-water foraminifers that settled on the upper slope of the central Great Barrier Reef at Site 821 (water depth, 212.6 m) were used as indicators of the paleoclimatic and paleoenvironmental conditions that have controlled the Pleistocene evolution of the adjacent platform. Throughout the 400-m-thick sequence drilled, the nature, composition, and distribution of the shallow-water foraminiferal assemblages studied indicate that (1) all the species recorded are at present living in diverse tropical, reef-related areas of the Indo-Pacific and Atlantic provinces; (2) the composition of the microfaunal taphocoenoses is almost identical between the different stratigraphic intervals studied and the modern Great Barrier Reef environments; (3) inner-neritic, tropical environments have continued to develop since the middle Pleistocene; (4) high- to moderate-energy platform edges occurred repeatedly throughout Pleistocene time. These factors may suggest that, since the beginning of the Pleistocene, several reef-like tracts have grown successively on the central area of the northeastern Australian shelf edge. These tracts probably had a sufficiently evolved morphological zonation to act as shelters for foraminiferal biocoenoses of high species diversity.

INTRODUCTION

One of the main objectives of Leg 133 of the Ocean Drilling Program, during which the carbonate platforms of northeastern Australia were drilled, was to determine the timing and factors controlling the development of the central region of the Great Barrier Reef (GBR). For years, much attention has been devoted to defining the nature, geometry, and age of the modern reefs and subreef deposits. Most work in the region has been largely geophysical (Davies et al., 1987; Symonds et al., 1983; Feary et al., 1991) and has shown that, on the outer continental shelf of the central GBR, 250- to 300-m-thick reef complexes occur in the form of a series of reef bodies separated by low-sea-level-generated unconformities. The reef complex constitutes only the uppermost part of a thick sequence that has been dominated by fluviodeltaic sediments. In addition, a borehole drilled in 1926 at Michaelmas Cay, off Cairns, shows about 100 m of presumably Pliocene–Pleistocene reef facies overlying siliciclastic sediments (Lloyd, 1973). Davies et al. (1987, 1989) showed that the GBR was diachronous in its development (i.e., Miocene in the north and Pliocene–Pleistocene in the south). In the central region, the reef system that developed upon progradational fluvioclastic packages must be a young feature. Reef growth was thought to have begun in the late Pliocene to Pleistocene or later. Preliminary results obtained from shipboard investigations suggested a very young age for the central GBR area (less than 1 Ma). Moreover, the modern GBR environments and surface sediments are well documented, mainly from the central region (Maxwell, 1968; Scoffin and Tudhope, 1985; Tudhope and Scoffin, 1988).

Based on the biosedimentological analysis of Site 821, this chapter is a contribution to elucidate the geological evolution of the central GBR region and, more particularly, the platform growth history. Basically, close inspection of platform-derived organisms deposited onto the upper slope of the GBR would provide relevant information about possible reef occurrences. However, detritus resulting from disintegration of typical reef-dwelling organisms (i.e., scleractinian

corals, various calcareous algal species, and mollusks, etc.) lose diagnostic characteristics when reaching the pebble (6 mm) to very coarse sand (1–2 mm) size ranges. Given that the mean sizes of the sediments at Site 821 are generally smaller than 0.15 mm, confusion with fragments produced by deeper- or colder-water organisms (i.e., ahermatypic corals, calcareous algae, mollusks, etc.) is highly possible. Moreover, the original platform-generated signal was disturbed by post-mortem displacement of bioclasts, because only a minor part of the reef-derived detritus reaches the fore-reef aprons (Davies, McKenzie, Palmer-Julson, et al., 1991). Foraminifers remain the only identifiable taxa on species or genera levels, even in the fine sand size; therefore, they have been selected to be used as paleobathymetric and paleoclimatologic markers.

MATERIAL AND METHODS

Site 821 is one of three sites (with Sites 819 and 820) located on the upper slope of the Great Barrier Reef system and in the most proximal position with respect to the latter, at 16°38.793'S and 146°17.376'E (Fig. 1). Water depth is 212.6 m below sea level. Hydraulic piston coring was continuous from 0.0 to 145.9 m below seafloor (mbsf) (Cores 133-821A-1H to -16H), with 102.4% recovery. The extended core barrel system was used from Cores 133-821A-17X to -43X, reaching 400 mbsf, with 91.88% recovery.

The series to 400 mbsf is an expanded Pleistocene sequence; nannofossils indicate that the bottom of Hole 821A has an age of 1.27 to 1.48 Ma. (Davies, McKenzie, Palmer-Julson, et al., 1991). Lithostratigraphy was divided into five units, based on sharp facies changes, that displayed alternations between siliciclastic-rich, terrestrial and carbonate-rich, marine skeletal sediments (Fig. 2). Lithologic evidence suggests an unconformity between lithologic Units II and I.

The material investigated comes from Cores 133-821A-43X through -1H, by collecting one 10 cm³ sample from each section. In the shore-based laboratory, the samples were dried at 60°C and then weighed before being washed through a series of sieves having mesh sizes of 500, 150, and 125 µm, respectively. A total of 271 samples was qualitatively examined to retrieve information about the richness of the benthic microfauna and the preservational state of the shells. Throughout the hole, rich and well-preserved assemblages appear to alternate with poorly diversified and preserved ones. The samples containing the richest and best-preserved taphocoenoses are the fol-

¹ McKenzie, J.A., Davies, P.J., Palmer-Julson, A., et al., 1993. *Proc. ODP, Sci. Results*, 133: College Station, TX (Ocean Drilling Program).

² URA-CNRS 1208, Université de Provence, 13331 Marseille cedex 3, France.

³ URA-CNRS 12, Institut de Paléontologie, Muséum National d'Histoire Naturelle, 75005, Paris, France.

lowing, from base to top: 133-821A-38X-5, 30–32 cm; 133-821A-35X-1, 30–32 cm; all samples from Core 133-821A-34X, Sections 133-821A-24X-1, -24X-2, -23X-3, -22X-1, -17X-3, -15H-7, -11H-4 to -11H-1, -2H-2, -2H-3, and Core 133-821A-1H. The taphocoenoses from Core 133-821A-18X are relatively poor and severely altered as are those from Sections 133-821A-17X-6 to -17X-4.

Three types of analysis were performed to assess the benthic foraminiferal content. First, qualitative analysis of the benthic microfauna restricted to the neritic zone was performed for the fraction larger than 125 μm on seven samples regarded as accurately representative of foraminiferal assemblages through Pleistocene time in the region considered. The intervals studied were as follows: 133-821A-1H-1, 30–32 cm (0.30 mbsf); 133-821A-11H-1, 30–32 cm (90.20 mbsf); 133-821A-17X-3, 30–32 cm (149.20 mbsf); 133-821A-24X-1, 131–133 cm (214.10 mbsf); 133-821A-35X-1, 30–32 cm (219.30 mbsf); 133-821A-42X-1, 21–23 cm (386.59 mbsf) and 133-821A-43X-3, 30–32 cm (399.40 mbsf). Second, semiquantitative estimates of the abundance of larger foraminifers were done for the whole 271 samples in the fraction coarser than 500 μm , because most are considered to be symbiont-bearing forms (i.e., platform-dwelling foraminifers; Leutenegger, 1984). Finally, three representative samples (133-821A-1H-1, 30–32 cm; 133-821A-17X-3, 30–32 cm; 133-821A-35X-1, 30–32 cm) were selected for quantitative analysis of the total benthic foraminiferal content, with each count including 200 to 300 individuals.

As a taxonomic framework, the foraminiferal classification proposed by Loeblich and Tappan (1974) has been adopted here.

STRATIGRAPHIC DISTRIBUTION OF THE SHALLOW-WATER FORAMINIFERAL ASSEMBLAGES

Inspection of the sediment fractions coarser than 500 μm throughout the cores reveals the distributional pattern of larger foraminifers as detritus. Amphisteginids are relatively scarce in the lower part of the hole, below Core 133-821A-30X (280 mbsf). These occur commonly within Sections 133-521A-18X-4, 22X-1, 27X-4 and 29X-1. Their amount increases in the upper part of the hole, in Sections 133-821A-16H-4, -14H-1, -13H-7 to -13H-3, -12H-6, -11H-4, -11H-2, -11H-1, -10H-7, -8H-5, -8H-3, -7H-2, -5H-4, -5H-3, -5H-1, -3H-3, -2H-5 and -2H-4. The most common form belongs to the species *Amphistegina papillosa*. Fragments of heterosteginid tests (*Heterostegina* cf. *depressa*) are markedly less common; these were encountered in Sections 133-821A-2H-1, -2H-4, -5H-3, -10H-7, -11H-1 and -24X-1. Pieces of *Operculina* cf. *ammonoides* seem to be restricted in Sections 133-821A-2H-5, -4H-4, -5H-3, -5H-4, -7H-3, -8H-5, -11H-2, -24X-1, -29X-1, and -35X-1. The species *Alveolinella quoyi* was recorded to Sections 133-821A-2H-4, -5H-4 and -11H-1 only. By way of contrast, the anomalinids *Heterolepa praecincta* and *H. margaritifera* as well as the rotaliid *Asterorotalia gaimardii* are widespread. As a whole, larger foraminifers tend to decrease markedly in amount downhole, below Section 133-821A-16H-4. However, this is not of general value. Indeed, within the upper part of the hole, these larger foraminifers are absent in numerous sections, particularly in Core 133-821A-1H. This suggests that the dearth of symbiont-bearing foraminifers in the sediments deposited along the outer margin does not indicate drastic environmental changes on the adjacent platform. Moreover, when present, these organisms are not more abundant in the upper one-half of the hole than in the lower part and rarely exceed 5% of the whole foraminiferal population.

Table 1 gives the list of shallow-water foraminifers present within the sediment fractions coarser than 125 μm , in the seven intervals selected from Sections 133-821A-1H-1, -11H-1, -17X-3, -24X-1, -35X-1, -42X-1, and -43X-3. There were 104 species encountered, distributed as follows: suborder *Textulariina* (8 species), suborder *Miliolina* (29 species), and suborder *Rotaliina* (67 species). The species number varies between 64 and 54, from 0.30 to 319 mbsf. The

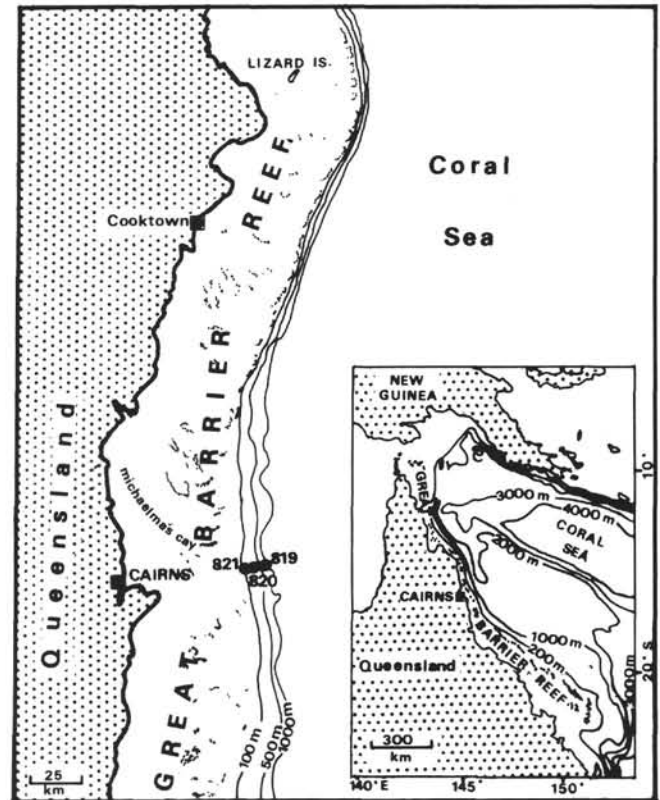


Figure 1. Map showing the situation and general physiographies of the Great Barrier Reef system of Australia (northwestern margin), with location of Sites 819, 820, and 821.

apparent specific diversity diminishes markedly downhole, with the number of species ranging from 17 to 21, at depths of 306.59 and 399.40 mbsf respectively. Such a decrease is probably due to poor preservation of initially deposited foraminiferal tests as a consequence of increasing-downward diagenetic alteration (Davies, McKenzie, Palmer-Julson, et al., 1991). About 75% of the species recorded at Site 821 had already been reported by Collins (1958) and Baccaert (1987) from the modern-reef environments of the northern Australian margin. The remaining percentage corresponds to forms described from other Indo-Pacific and/or Atlantic tropical reef areas (Chapman, 1900; Cushman, 1921a, 1921b; Cushman et al., 1954; Todd and Post, 1954; Graham and Militante, 1959; Todd and Low, 1960; Guilcher et al., 1965; Hirshfield et al., 1968; Brazier, 1975; Le Calvez and Salvat, 1980; Poag and Tresslar, 1981; Montaggioni, 1981; Véneć-Peyré, 1985, 1991; Montaggioni et al., 1986; Murray, 1991).

The relative percentages of the three foraminiferal suborders (*Textulariina*, *Miliolina*, and *Rotaliina*) in the samples studied are plotted in Figure 3, according to the method of Murray (1973). For comparison, the summary data compiled by Baccaert (1987) from the Lizard Island Reef area are plotted simultaneously. All the samples are concentrated along the *Miliolina-Rotaliina* side of the diagram, thereby indicating a life environment of normal marine lagoons. Our results thus appear to be consistent with Baccaert's study. At Site 821, percentages of *Textulariina* are generally low (less than 9%), showing a same order of magnitude as in the Lizard reef area (less than 10% except for some perireefal areas). The concentration of *Miliolina* varies from 9% to 35%; these values are similar to those obtained from the Lizard back-reef zones. Concerning *Rotaliina*, the abundance is high (61% to 100% of the total benthic foraminiferal assemblage) at Site 821 as it occurs in the samples from the reef flats around Lizard Island. However, attention must be paid to the samples from

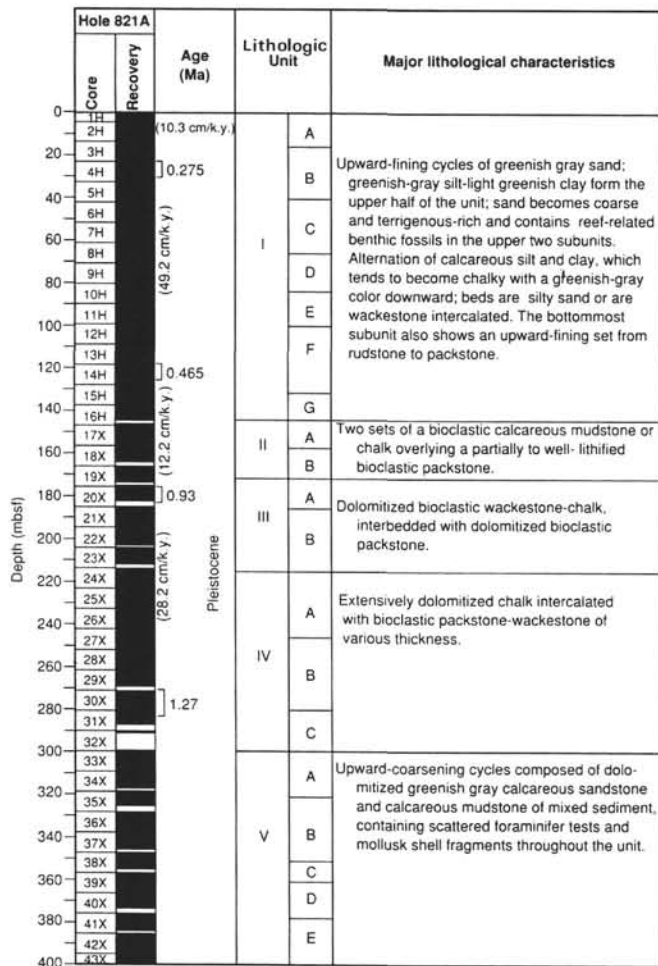


Figure 2. Summary chart indicating the lithostratigraphy and lithologic characteristics for each unit at Site 821. Age assignment provided by nanofossil biostratigraphy (from Davies, McKenzie, Palmer-Julson, et al., 1991, p. 577).

intervals 133-821A-42X-1, 21–23 cm, and -43X-3, 30–32 cm, that give a distorted picture of the originally deposited shallow-water foraminifers because of poor preservation.

Considering its time of deposition (about 1 k.y.), the uppermost interval taken into account here (133-821A-H1-1, 30–32 cm) can be regarded as a reference for the distributional pattern of Holocene foraminiferal thanatocoenoses derived from the GBR platform. The species representative of the three suborders *Textulariina*, *Miliolina*, and *Rotaliina* are 3, 20, and 38 respectively. These numbers comprise the boundary values obtained for the three suborders (0–22, 22–83, 30–104 species, respectively) from the various reef zones in the Lizard Island area (Baccaert, 1987). The percentages of species shared by both the reference sample and the lower ones have been estimated. Among the forms present at interval 133-821A-11H-1, 30–32 cm, 54.7% are identical to those of the reference sample, 55% at interval 133-821A-17X-3, 30–32 cm, 62% at interval 133-821A-24X-1, 131–133 cm, 68% at interval 133-821A-35X-1, 30–32 cm, 76% at interval 133-821A-42X-1, 21–33 cm, and 80% at interval 133-821A-43X-3, 30–32 cm. Thus, the foraminiferal composition of the samples analyzed appears to be closely related throughout the hole.

Results of quantitative analysis of three representative assemblages on the family level are given in Table 2. For each family, only individuals belonging to species recorded from the modern inner-neritic, euphotic (0–120 m) environments and, particularly, from reef provinces were taken into account. The percentages refer to the

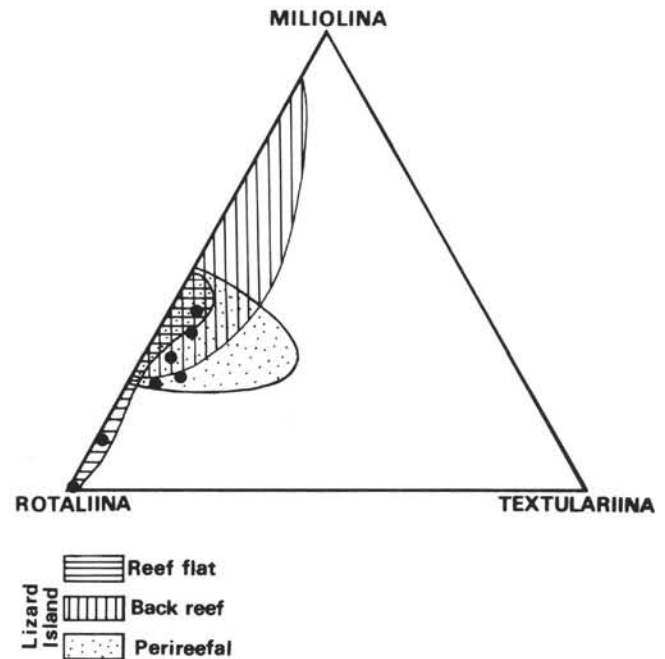


Figure 3. Triangular diagram showing the distribution of foraminiferal species in Samples 133-821A-1H-1, 30–32 cm; -11H-1, 30–32 cm; -17X-3, 30–32 cm; -24X-1, 131–133 cm; -35X-1, 30–32 cm; -42X-1, 21–23 cm; and -43X-3, 30–32 cm, according to the method of Murray (1973). For comparison, the summary triangular plot constructed by Baccaert (1987), showing the main reef environments from Lizard Island area, is also reproduced.

abundance of these shallower individuals relative to the total benthic population (including outer-neritic and deeper microfauna). The inner-neritic foraminifers largely dominate, representing 79.5%, 79.1%, and 76.6% in Samples 133-821A-1H-1 (30–32 cm), -17X-1 (30–32 cm) and -35X-1 (30–35 cm), respectively. So, more than three quarters of the individuals came from the adjoining platform. Frequency is similar from sample to sample. The bulk of the assemblages is composed of individuals belonging to nine main families (*Bolivinitidae*, *Rotaliidae*, *Uvigerinidae*, *Cymbaloporidae*, *Discorbidae*, *Miliolidae*, *Anomalinidae*, *Cibicides*, *Amphisteginidae*). Abundance of *Bolivinitidae* ranges between 4.1% and 17.8% of the total benthic foraminiferal assemblage; the most common species is *Bolivina compacta* (1.9%–14.9%), which mainly inhabits the modern perireefal GBR areas, as epiphyte of cyanobacterial coats. Among *Rotaliidae*, the species *Asterorotalia gaimardii* predominate, reaching 15.8% of the total benthic individuals; this contrasts sharply with their dearth in the modern GBR taphocoenoses, which may be partly explained by their preferential occurrence in perireefal to off-reef shelf environments (Collins, 1958; Baccaert, 1987). Concentrations of *Uvigerinidae* decrease markedly from the upper to the lower samples (18.5% to 2.2%); *Siphouvigerina ampullacea* and *Trifarina bradyi* show high frequencies in the upper sample (14.4% to 3.8%, respectively) in contrast to their scarcity in modern biocoenoses (Baccaert, 1987); this is probably caused by transporting effect rather than local environmental changes. Abundances of *Cymbaloporidae* vary widely (3.2%–10.5%); these values appear to partly reflect the relative high frequency of living individuals in the modern GBR biocoenoses. Concerning *Discorbidae*, the amount ranges between 3.9% and 8.3%; the species *Gavelinopsis lobatulus*, which lives in perireefal zones, is one of the most common, averaging 2% of the total benthic population. The content of *Miliolidae* varies from 6.1% to 11.2%. No specific form is clearly dominant: 11 to 14 species exhibit amounts varying between 0.4% and 1.9%. The *Quinqueloculina* species present in the samples (see Table 1) are regarded as characteristic proximal back-

Table 1. Checklist of the shallow-water foraminifers present in Hole 821A.

SPECIES	S A M P L E N U M B E R						
	1H-1 30-32	11H-1 30-32	17X-3 30-32	24X-1 131-133	35X-1 30-32	42X-1 21-23	43X-3 30-32
SUBORDER TEXTULARIINA							
Family Textulariidae							
<i>Textularia candeiana</i> d'Orbigny *	+		+	+	+		
<i>Textularia cf. pseudogramen</i> Chapman-Parr *	+						
<i>Textularia agglutinans</i> d'Orbigny *				+			
<i>Textularia fistulosa</i> Brady *		+	+	+	+		
<i>Textularia conica</i> d'Orbigny *						+	
<i>Textularia saggitula</i> Delrance °		+	+	+			
<i>Siphotextularia</i> sp.	+				+		
Ataxophragmidae							
<i>Gaudryina siphonifera</i> (Brady) *		+		+			
SUBORDER MILIOLINA							
Fischeriidae							
<i>Cyclogyra involvens</i> Reuss °	+					+	
<i>Planispirinella exigua</i> (Brady) *	+					+	
Nubeculariidae							
<i>Wiesnerella auriculata</i> (Egger) *	+	+	+	+	+		
<i>Vertebralina striata</i> d'Orbigny *	+	+				+	
<i>Spiroloculina communis</i> Cushman-Todd *		+	+	+		+	
Miliolidae							
<i>Quinqueloculina crassicarinata</i> Collins *	+					+	
<i>Quinqueloculina curta</i> Cushman *			+				
<i>Quinqueloculina granulocostata</i> Germeraad *	+	+	+	+	+		
<i>Quinqueloculina lamarciana</i> d'Orbigny *	+	+	+	+	+		+
<i>Quinqueloculina oblonga</i> (Montagu) *	+		+	+	+		
<i>Quinqueloculina poyeana carinata</i> Albani *	+						
<i>Quinqueloculina pseudoreticulata</i> Parr °		+					
<i>Quinqueloculina distorta</i> Cushman °						+	
<i>Quinqueloculina bosciana</i> d'Orbigny °							
<i>Quinqueloculina</i> sp.			+				
<i>Triloculina eburnea</i> d'Orbigny *	+						
<i>Triloculina trigonula</i> (Lamarck) *		+	+	+	+		
<i>Triloculina tricarinata</i> d'Orbigny *	+	+	+	+	+		+
<i>Pyrgo denticulata</i> (Brady) *	+			+			
<i>Pyrgo oblonga</i> d'Orbigny °	+		+	+			
<i>Spirosigmolina parri</i> Collins *	+	+		+	+		
<i>Miliolinella australis</i> (Parr) *	+	+	+	+	+		
<i>Miliolinella baragwanathi</i> (Parr) *	+						
<i>Hauerina occidentalis</i> Cushman *	+	+	+	+	+		
<i>Articulina pacifica</i> Cushman *						+	
Soritidae							
<i>Monalysidium politum</i> Chapman *	+						
<i>Peneroplis pertusus</i> (Forsk.) *	+					+	
<i>Sorites</i> (juvéniles) *	+	+					
Alveolinidae							
<i>Alveolinella quoyi</i> (d'Orbigny) *		+					
SUBORDER ROTALIINA							
Nodosariidae							
<i>Lagena cf. strumosa</i> Reuss *	+					+	
<i>Bolivinella elegans</i> Parr *		+				+	
Glandulinidae							
<i>Fissurina marginato-perforata</i> (Seguenza) *	+						
<i>Fissurina orbignyana</i> Seguenza *			+		+	+	+
<i>Oolina spiralis</i> (Brady) *							
Spirillinidae							
<i>Spirillina vivipara</i> Ehrenberg *	+						
<i>Patellina carinata</i> Collins *	+		+	+	+		
Ceratobuliminidae							
<i>Lamarckina scabra</i> (Brady) *		+	+	+	+	+	+
<i>Lamarckina ventricosa</i> (Brady) °		+		+			

Table 1 (continued).

SPECIES	S A M P L E N U M B E R						
	1H-1 30-32	11H-1 30-32	17X-3 30-32	24X-1 131-133	35X-1 30-32	42X-1 21-23	43X-3 30-32
Turrilliniidae							
<i>Buliminella latissima</i> Collins *	+						
<i>Buliminella</i> sp.			+				
Buliminoididae							
<i>Buliminoides williamsonianus</i> Cushman *		+		+	+		
<i>Buliminoides madagascariensis</i> (d'Orbigny) var. <i>spicatus</i> (Cushman & Parker) *	+	+	+	+	+		+
Bolivinitidae							
<i>Bolivina compacta</i> Sidebottom *	+	+	+	+	+	+	+
<i>Bolivina rhomboidalis</i> (Millet) *			+		+		
<i>Bolivina semicostata</i> Cushman °		+					
<i>Bolivina subangularis</i> Brady °		+	+		+		
<i>Bolivina subreticulata</i> Parr °		+	+	+			
<i>Bolivina amygdalaeformis</i> Brady °	+		+	+			
<i>Bolivina hantkeniana</i> Brady °			+	+	+		
<i>Brizalina pacifica</i> (Cushman & Mc Culloch) *	+	+					
<i>Brizalina striatula</i> (Cushman) *	+	+	+	+	+	+	+
<i>Brizalina convallaria</i> (Millet) *	+						+
<i>Rectobolivina raphana</i> (Parker & Jones) *		+	+	+			
Buliminidae							
<i>Reussella simplex</i> (Cushman) *	+	+	+	+	+	+	+
Uvigerinidae							
<i>Siphogenerina virgula</i> (Brady) *	+				+		
<i>Uvigerina porrecta</i> Cushman *	+	+	+	+			
<i>Siphouvigerina ampullacea</i> (Brady) *	+	+	+	+	+	+	+
<i>Trifarina bradyi</i> Cushman *	+	+	+	+	+	+	+
<i>Bifarina limbriata</i> (Millet) °	+		+	+			
Discorbidae							
<i>Neoconorbina terquemi</i> (Rhezak) *	+		+	+		+	
<i>Neoconorbina tuberculata</i> (Chapman) °			+	+			
<i>Discorbis mira</i> Cushman *	+		+	+			
<i>Gavelinopsis cf. lobatulus</i> (Parr) *	+		+	+	+	+	+
Eponididae							
<i>Neoeponides berthelotianus</i> (d'Orbigny) *		+	+	+			
<i>Poroeponides lateralis</i> (Terquem) *			+				
Glabratiellidae							
<i>Glabratiella earlandi</i> Collins *	+			+			
<i>Glabratiella opercularis</i> (d'Orbigny) °	+	+			+		
Epistomariidae							
<i>Epistomariella milletti</i> Collins *	+						
Siphoninidae							
<i>Siphonina tubulosa</i> Cushman *	+	+	+	+	+	+	+
Amphisteginidae							
<i>Amphistegina lessonii</i> d'Orbigny *	+	+	+	+	+	+	+
<i>Amphistegina lobifera</i> Larson *	+		+	+	+		
<i>Amphistegina radiata</i> (Fichtel-Moll.) °		+					
<i>Amphistegina papillosa</i> Said *		+					
Cibicididae							
<i>Cibicides lobatulus</i> (Walker-Jacob) *	+	+	+	+	+		+
<i>Cibicides mayori</i> (Cushman) °			+	+			
Planorbulinidae							
<i>Planorbulinella larvata</i> (Parker-Jones) *		+		+			
Cymbaloporidae							
<i>Cymbaloporella taballaeformis</i> (Brady) *	+		+	+			
<i>Tretomphalus-Cymbaloporetta</i> group *	+	+	+	+	+	+	+
Rotaliidae							
<i>Asterotalia gaimardii</i> (d'Orbigny) *		+	+	+	+		
<i>Ammonia beccarii</i> s.l. (Linné) °	+	+	+	+	+	+	+
Calcarinidae							
<i>Calcarina spengleri</i> (Gmelin) *		+	+				
<i>Calcarina calcar</i> d'Orbigny *	+	+	+	+			
<i>Baculogypsina sphaerulata</i> (Parker-Jones) *			+				

Table 1 (continued).

SPECIES	S A M P L E N U M B E R						
	1H-1 30-32	11H-1 30-32	17X-3 30-32	24X-3 131-133	35X-3 30-32	42X-1 21-23	43X-3 30-32
Elphidiidae							
<i>Elphidium advenum</i> (Cushman) *	+	+	+	+	+	+	+
<i>Elphidium crispum</i> (Linne) *		+		+			
<i>Parrellina milletti</i> (Heron-Allen & Earland) *			+				
Nummulitidae							
<i>Operculina</i> cf. <i>ammonoides</i> (Gronovius) *	+	+	+	+	+		
<i>Heterostegina</i> cf. <i>depressa</i> (d'Orbigny) *		+		+			
Caucasinidae							
<i>Fursenkoina pauciloculata</i> (Brady) *	+	+	+	+	+		+
<i>Sigmavirgulina tortuosa</i> (Brady) *	+	+	+	+	+		
Loxostomatidae							
<i>Loxostomum lobatum</i> (Brady)		+	+	+	+	+	+
Nonionidae							
<i>Nonion suburgidum</i> (Cushman) *	+				+		+
<i>Svratkina tuberculata</i> (Balkwill-Wright) *	+		+	+	+		
Anomalinidae							
<i>Anomalina glabrata</i> Cushman *	+	+	+	+	+	+	
<i>Heterolepa praecincta</i> (Karrer) *			+	+	+	+	
<i>Heterolepa margaritifera</i> (Brady) *			+	+	+	+	

Notes: Only sediment fractions coarser than 125 μm are included. Crosses indicate the occurrence of a given species in a given sample. The specific names indexed by stars refer to the faunas reported from the Great Barrier Reef environments by Collins (1958) and/or Baccaert (1987). The specific names indexed by open circles refer to the faunas not recorded by the previous authors, but present in other Indo-Pacific reef environments.

reef taxa in the GBR system, according to Baccaert (1987). *Anomalinidae* locally are very common (8.3%); *Heterolepa margaritifera* and *Anomalina glabrata*, generally linked to the presence of *Halimeda* substrate, can exceed 3%. Abundances of *Cibicides* range from 0.8% to 5.7%; *Cibicides lobatulus*, which is ubiquitous in the perireefal GBR areas, is the more typical form of this family. Concentrations of *Amphistegina* reach maximum values of 3.5%; as indicated previously, *Amphistegina papillosa* is the most common species. Concentrations of the other families mentioned do not exceed 4% of the total benthic foraminiferal population within each sample. Similarities in the origin, taxonomic property, and frequency of the foraminiferal shells among the three samples considered strongly suggest that the nature of the successive microfaunal biocoenoses and derived taphocoenoses, which have developed throughout the platform, has remained relatively constant, as have processes of displacement and deposition during margin development.

One of the most striking features is the absence or scarceness of several larger foraminiferal species that are particularly common on modern reef environments and are considered to be typical reef-dwelling GBR forms. These include arborescent foraminifers (*Homotrematines*, *Victoriellines*) occurring as active reef-binders on the present-day outer shelf-reef flats of the GBR (L.F. Montaggioni, pers. observ.), most agglutinated foraminifers, most soritids (soritines *Marginozouma vertebralis* and *Amphisorus hemprichii*) and, to a lesser extent, calcarinids (*Calcarina spengleri* and *Baculogypsina sphaerulata*). Note that all these microfaunal types are even absent in the reference sample (133-821A-1H-1, 30-32 cm). This indicates that the platform-derived foraminiferal taphocoenoses that were deposited along the outer slope incompletely reflect the composition of the original biocoenoses, which were partially distorted by reworking, transport, and redeposition toward the slope. The most realistic explanation for such a discrepancy comes under the basic hydrodynamic behavior of the relevant shells. Laboratory experiments conducted by Maiklem (1968) and Song (1991) demonstrated that shape, angularity, size, structure, and bulk density are major factors controlling the mode of displacement and deposition of larger foraminiferal shells.

Four grain shapes (blocks, rods, plates, and spheres) can be recognized. Arenaceous foraminifers and homotrematids produce block-shaped particles or irregularly surfaced rods that range in size from 0.5–2 mm to 1–5 mm, respectively. *Amphistegina lobifera* (1–3 mm), *A. lessonii* (1–1.5 mm), and *Asterorotalia gaimardii* form spheroidal grains. *Baculogypsina* and *Calcarina* tests, 0.5 to 1.5 mm in diameter, have spines on their surfaces, which make them deviate from true spheres, but their spines have been rapidly broken off or rounded by abrasion. As for soritines, these contribute to plate-shaped grains and vary from 0.5 to 8 mm in diameter. These different grain types differ from each other in their settling velocity and hydrodynamic stability. Plate-shaped grains settle slower than any of the other grain types. In contrast, blocks are the fastest settling particles. In the 1- to 2-mm size range, blocks and rods settle about 100% faster than do plates; the rate increases to more than 200% greater in the 3- to 5-mm range. This may explain the scarcity of agglutinated foraminifers and the absence of arborescent forms downslope, because the relevant fragments were hydrodynamically unable to be moved by suspension far from their production area. Note that, in addition, agglutinates can be rapidly disintegrated by collision and abrasion before possible long-distance transport. Among plates, soritine tests are the slowest to settle, because of their higher buoyancy and porous nature (low bulk density); when deposited, they are more stable and more resistant to the entraining shear stress associated with bottom flow than are dynamically equivalent spheric grains. The specific response of soritine shells to current energy accounts for their extreme dearth in the upper-slope deposits of the platform margin. These organisms were encountered only as juveniles in two samples. Subspheric shells, which are markedly less resistant to entrainment forces, are relatively abundant, compared with other foraminiferal types. Thus, the rotaliid *Asterorotalia gaimardii* represents up to 15% of Sample 133-821A-17X-3, 30–32 cm, whereas amphisteginids (mainly *Amphistegina lobifera* and *A. lessonii*) reach 2% to 3% in numerous core sections.

Nevertheless, it appears that—beyond the distortion effects from reworking, differential sorting, and deposition—a relatively close similarity in the composition of the foraminiferal taphocoenoses can

Table 2. Relative abundance of shallower (inner-neritic) vs. deeper (outer-neritic) benthic foraminifers in three representative samples from Hole 821A.

	SAMPLE		NUMBER
	1H-1 30-32cm	17X-3 30-32cm	35X-1 30-32cm
SHALLOW-WATER FORAMINIFERS			
<i>Bolivinitidae</i>	4.1	4.4	17.8
<i>Rotaliidae</i>	0.3	17.1	8.4
<i>Uvigerinidae</i>	18.5	4.4	2.2
<i>Cymbaloporidae</i>	4.8	10.5	3.2
<i>Discorbidae</i>	8.3	3.9	6.1
<i>Miliolidae</i>	11.2	6.1	9.0
<i>Anomaliniidae</i>	1.6	8.3	0.6
<i>Cibicididae</i>	5.7	0.8	3.2
<i>Amphisteginidae</i>	3.5	2.2	1.6
<i>Elphidiidae</i>	1.6	1.3	4.2
<i>Buliminidae</i>	2.2	0.8	3.8
<i>Textulariidae</i>	0.9	3.0	1.9
<i>Nonionidae</i>	0.9	2.2	1.9
<i>Nubeculariidae</i>	2.8	0.8	1.2
<i>Caucasinidae</i>	0.9	3.0	0.6
<i>Glandulinidae</i>	2.5	0.4	1.6
<i>Ceratobuliminidae</i>	0.6	3.0	0.6
<i>Nummulitidae</i>	0.6	0.8	2.9
<i>Fischeriidae</i>	2.5	--	1.2
<i>Siphoninidae</i>	0.3	2.6	0.6
<i>Nodosariidae</i>	1.2	--	2.5
<i>Spirillinidae</i>	1.2	0.4	0.9
<i>Calcarinidae</i>	0.6	1.3	--
<i>Loxostomatidae</i>	0.9	0.4	0.6
<i>Turritinidae</i>	0.6	0.8	--
<i>Soritidae</i>	0.9	--	--
<i>Eponididae</i>	--	0.8	--
<i>Epistomariidae</i>	0.3	--	--
	79.5	79.1	76.6
DEEPER FORAMINIFERS			
	20.5	20.9	23.4

Note: The family names are arranged in decreasing order of abundance.

be seen among the various stratigraphic intervals considered and the modern GBR environments.

SIGNIFICANCE OF SHALLOW-WATER FORAMINIFERAL ASSEMBLAGES

Climatic Significance

Based on previous studies of modern distribution of benthic foraminifers (Chapman, 1900; Heron-Allen and Earland, 1915; Cushman, 1911, 1921a, 1921b, 1922, 1924, 1931, 1937, 1942; Cushman et al., 1954; Todd and Post, 1954; Graham and Militante, 1959; Todd and Low, 1960; Guilcher et al., 1965; Blanc-Vernet, 1969; Murray, 1973; Brazier, 1975; Le Calvez, 1977; Montaggioni, 1981; Vénec-Peyré, 1985, 1991; Baccaert, 1987; Hayward, 1990; Murray, 1991), we present a geographic classification of the species identified at Site 821; four reference categories were defined for convenience: (1) cosmopolitan, adapted to tropical and temperate seas; (2) cosmopolitan, exclusively tropical (Atlantic to Indo-Pacific provinces); (3) exclusively Indo-Pacific, adapted to tropical and temperate seas; (4) exclusively Indo-Pacific, exclusively tropical (Table 3). Attention must be paid to the fact that these results are not of absolute value, because they were established from literature data available at present; some forms considered to be exclusively tropical may have a wider latitudinal distribution area. However that may be, except for possible misinterpretations of geographic distribution, the foraminiferal assemblages studied are clearly dominated by tropical affinity forms (Table 4); about two-thirds of the species may be related to tropical shelves. Moreover, the relative abundance of exclusive tropical forms is practically similar from sample to sample. This may suggest that, on the margin, (1) climatic conditions were almost similar at the time of life of the relevant biocoenoses; and (2) tropical conditions presumably have continued through time.

Table 3. Geographic and climatic distributions of the shallow-water benthic foraminifers recorded in Hole 821A.

C O S M O P O L I T A N		
TROPICAL TO TEMPERATE	EXCLUSIVELY TROPICAL	
<i>Textularia pseudogramen</i>	<i>Textularia candeiiana</i>	
<i>Textularia agglutinans</i>	<i>Textularia conica</i>	
<i>Textularia sagittula</i>	<i>Planispirinella exigua</i>	
<i>Vertebrulina striata</i>	<i>Spiroloculina communis</i>	
<i>Cyclogyra involvens</i>	<i>Wiesnerella auriculata</i>	
<i>Quinqueloculina oblonga</i>	<i>Triloculina eburnea</i>	
<i>Quinqueloculina bosciiana</i>	<i>Hauerina occidentalis</i>	
<i>Triloculina trigonula</i>	<i>Reussella simplex</i>	
<i>Triloculina tricarinata</i>	<i>Bolivina compacta</i>	
<i>Pyrgo oblonga</i>	<i>Rectobolivina raphana</i>	
<i>Sorites</i> sp.	<i>Neoconorbina tuberculata</i>	
<i>Spirillina vivipara</i>	<i>Siphonina tubulosa</i>	
<i>Lamarckina scabra</i>	<i>Amphistegina lessonii</i>	
<i>Lamarckina ventricosa</i>	<i>Cibicides mayori</i>	
<i>Bolivina rhomboidalis</i>	<i>Svatkina tuberculata</i>	
<i>Brizalina pacifica</i>		
<i>Brizalina striatula</i>		
<i>Bulminoides williamsonianus</i>		
<i>Trifarina bradyi</i>		
<i>Neoconorbina terquemii</i>		
<i>Discorbis mira</i>		
<i>Poroeponides lateralis</i>		
<i>Amphistegina lobifera</i>		
<i>Cibicides lobatulus</i>		
<i>Ammonia beccani</i>		
<i>Elphidium crispum</i>		
<i>Elphidium advenum</i>		
I N D O - P A C I F I C		
TROPICAL TO TEMPERATE	EXCLUSIVELY TROPICAL	
<i>Quinqueloculina curta</i>	<i>Textularia listulosa</i>	<i>Brizalina convallaria</i>
<i>Quinqueloculina lamarckiana</i>	<i>Gaudryina siphonifera</i>	<i>Siphonina virgula</i>
<i>Miliolinella australis</i>	<i>Quinqueloculina crassicarinata</i>	<i>Uvigerina porrecta</i>
<i>Miliolinella baragwanathi</i>	<i>Quinqueloculina granulocostata</i>	<i>Siphonoglypta ampullacea</i>
<i>Fissurina orbignyana</i>	<i>Quinqueloculina poyeana carinata</i>	<i>Bifurca limbatata</i>
<i>Oolina spiralis</i>	<i>Quinqueloculina pseudoreticulata</i>	<i>Neosponides berthelotianus</i>
<i>Gavelinopsis lobatulus</i>	<i>Quinqueloculina distorquata</i>	<i>Glabrata eardi</i>
<i>Sigmavirgulina tortuosa</i>	<i>Pyrgo denticulata</i>	<i>Glabrata operculina</i>
<i>Heterolepa margaritifera</i>	<i>Spirosigmilloina parri</i>	<i>Epistomaria milleti</i>
	<i>Articulina pacifica</i>	<i>Amphistegina radiata</i>
	<i>Monalysidium politum</i>	<i>Amphistegina papillosa</i>
	<i>Peneroplus pertusus</i>	<i>Planorbiculina larvata</i>
	<i>Alveolinella quoyi</i>	<i>Cymbaloporella tabulaeformis</i>
	<i>Lagena cf. strumosa</i>	<i>Cymbaloporella-tretomphalus</i>
	<i>Bolivina elegans</i>	<i>Asterorotalia gaimardii</i>
	<i>Fissurina marginato-perforata</i>	<i>Calcarina spengleri</i>
	<i>Patellina cannata</i>	<i>Calcarina calcar</i>
	<i>Bulminella latissima</i>	<i>Baculogypsina sphaerulata</i>
	<i>Bulminoides madagascariensis</i>	<i>Operculina ammonoides</i>
	<i>var. spicalus</i>	<i>Heterostegina depressa</i>
	<i>Bolivina semicostata</i>	<i>Fursenkoina pauciloculata</i>
	<i>Bolivina subangularis</i>	<i>Loxostomum lobatum</i>
	<i>Bolivina subreticulata</i>	<i>Nonion suburgidum</i>
	<i>Bolivina amygdalaeformis</i>	<i>Anomala glabrata</i>
	<i>Bolivina harikeniana</i>	<i>Heterolepa praecincta</i>

Environmental Significance

Hottinger (1983) and Hallock & Glenn (1986) proposed models of distributions of larger foraminifers by depth and substrate types for Cenozoic tropical shelf areas on the basis of modern analogs. Baccaert (1987) provided a summary of the succession of the foraminiferal species living in the various reef environments around the Lizard Island area; species have been regarded as characteristic of a given environment on the basis of their persistent occurrence and/or abundance in the relevant taphocoenosis. Previously, Collins (1958) indicated broad zones where the species collected from the northern GBR province occur, as well as their abundances. These distributional schemes have been used here as reference categories for characterization of neritic, platform-related environments. Three main types of environments have been recognized: high- to medium-energy, open environments (outer platform area, platform edge) vs. low-energy, and restricted ones (inner platform area) (Table 5).

In the Indo-Pacific Province, extensive outer platform areas and fore-slopes within the euphotic zone (30 to about 130 m deep) are typified by agglutinates (diverse textulariids), large flattened rotaliines (*Amphistegina radiata*, *A. papillosa*, *Heterostegina*, and *Operculina*), and some large, very flat soritids. Shallower areas (less than 30–40 m) are dominated by intermediate rotaliines (*Amphistegina lessonii*), alveolinids (*Alveolinella quoyi*), soritids (*Monalysidium*, *Peneroplus pertusus*, *Sorites*) and nummulitids. Smaller foraminifers include some textulariids, nubeculariids (*Spiroloculina communis*), numerous miliolids (*Quinqueloculina crassicarinata*, *Q. granulocostata*, *Q. lamarckiana*; *Triloculina*; *Spirosigmilloina parri*), buliminids (*Reussella sim-*

Table 4. Species number and relative abundance of the various climate-related categories of shallow-water benthic foraminifers recorded in Hole 821A.

		SAMPLE NUMBER							
		1H-1 30-32 cm	11H-1 30-32 cm	17X-3 30-32 cm	24X-1 131-133 cm	35X-1 30-32 cm	42X-1 21-23 cm	43X-3 30-32 cm	
Cosmopolitan	tropical to temperate	14 (22.6)	13 (24.5)	15 (24.2)	14 (24.2)	13 (22.4)	3 (16.1)	5 (23.8)	
	exclusively tropical	15 (24.2)	10 (18.9)	16 (25.8)	16 (27.6)	14 (24.2)	8 (44.5)	7 (33.4)	
Exclusively Indo-Pacific	tropical to temperate	5 (8.0)	3 (5.7)	5 (8.1)	4 (6.9)	4 (6.9)	1 (5.5)	1 (4.7)	
	exclusively tropical	28 (45.2)	27 (50.9)	26 (41.9)	24 (41.3)	27 (46.5)	6 (33.4)	8 (38.1)	
% exclusively tropical		69.4	69.8	67.7	68.9	70.7	77.9	71.5	

Notes: The numbers without brackets refer to the number of species recorded in each sample; the numbers in brackets refer to the percentage of species belonging to each climate-related category in each sample.

plex), uvigerinids (*Siphovigerina ampullacea*), discorbids (*Neocorbina terquemi*, *Gavelinopsis lobatulus*), eponidids (*Neoeponides*, *Poroeponides*), siphoninids (*Siphonina tubulosa*), cibicides (*Cibicides lobatulus*), rotaliids (*Ammonia beccarii*), elphidiids (*Elphidium advenum*), caucasinids (*Fursenkoina pauciloculata*), loxostomids (*Loxostomum lobatum*), Nonionids (*Nonion subturgidum*), and anomalinids (*Heterolepa praecincta*).

The foraminiferal fauna of the platform edge represents a variety of forms mainly living in intertidal to slightly subtidal, high-energy environments. These assemblages are dominated by robust ovoids to subspheric rotaliines (*Amphistegina lobifera*, *Calcarina*, *Baculogypsina*). Miliolines and small rotaliines also are common: nubeculariids (*Vertebralina striata*), miliolids (*Quinqueloculina curta*, *Miliolinella baragwanathi*), bolivinids (*Bolivina compacta*, *B. rhomboidalis*), buliminoidids (*Buliminoides madagascariensis spicatus*), uvigerinids (*Rectobolivina raphana*), discorbids (*Discorbis mira*), cymbaloporids (*Cymbaloporella*, *Cymbaloporetta*), rotaliids (*Asterorotalia gaimardii*), and elphidiids (*Elphidium crispum*, *Parrellina milletti*).

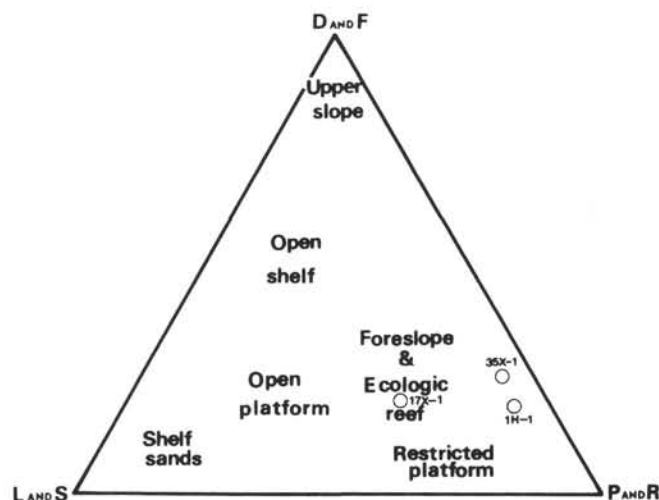


Figure 4. Triangular diagram showing the distribution of foraminiferal assemblages from each of Wilson's standard facies, according to the method of Hallock and Glenn (1986, modified): D and F = deeper benthics and flat rotaliines; L and S = lenticular and subspheroidal large rotaliines (including *Amphistegina*, *Asterorotalia*, *Heterolepa*); P and R = porcelaneous forms (including miliolines) and smaller rotaliines.

The inner platform areas having depths of less than 30 m exhibit diverse foraminiferal faunas. Miliolines, intermediate to small rotaliines, dominate as epiphytal forms dwelling in cyanobacterial film and macroalgal coat substrata. Among rotaliines, the most frequent species belong to the glandulinids (*Fissurina orbignyana*), buliminids (*Reusella simplex*), bolivinids (*Brizalina striatula*, *B. convallaria*), uvigerinids (*Siphovigerina ampullacea*), discorbids (*Neocorbina terquemi*, *Gavelinopsis* cf. *lobatulus*), siphoninids (*Siphonina tubulosa*), cymbaloporids, rotaliids (*Ammonia beccarii*, *Asterorotalia gaimardii*), elphidiids (*Elphidium advenum*), caucasinids (*Fursenkoina pauciloculata*), loxostomids, and anomalinids (*Heterolepa praecincta*). Miliolines are mainly represented by *Quinqueloculina granulocostata*, *Q. oblonga*, *Triloculina trigonula*, and *Hauerina occidentalis*. Larger foraminifers (soritids, *Amphistegina lessonii*, *A. radiata*) are locally prolific.

In modern Indo-Pacific tropical platforms, the most diagnostic foraminiferal species of reef environment are those possessing robust and thick tests and that have, thus, adapted to high light intensity and high water turbulence (Hallock and Glenn, 1986). Among the species listed by Baccaert (1987) in the taphocoenoses from the Lizard Island area, 31% are typical of platform edge areas (reef flats, proximal shallow back-reef zones). This value is close to that (36%) obtained from the whole species collected at Site 821. The reference sample (133-821A-1H-1, 30-32 cm), which presents 34% of turbulence-tolerating species, gives a faithful picture of the composition of the Holocene foraminiferal accumulations on the GBR. The relative abundance of these species in the other samples studied varies as follows: 18.5% at interval 133-821A-11H-1, 30-32 cm; 34% at interval -17X-3, 30-32 cm; 30.5% at interval -24X-1, 131-133 cm; 27.0% at interval -35X-1, 30-32 cm; 12% at interval -42X-1, 21-23 cm, and 23.8% at interval -43X-3, 30-32 cm. Two hypotheses emerge from these results: (1) the frequency of the high-energy adapted species may be virtually equivalent throughout the upper two-thirds of the cored sedimentary series; (2) even in the lowermost, intensively altered beds, the amounts of the characteristic species are significant. This indicates that at Site 821 during the last 1.4 m.y. the margin slope was regularly supplied from high-energy microfaunal communities, thereby demonstrating the persistence of platform edges through time along the northern Australian shelf. This contention is supported by the triangular plotting of the quantitative foraminiferal data obtained from the intervals 133-821A-1H-1, 30-32 cm; -17X-3, 30-32 cm; and -35X-1, 30-32 cm. According to Hallock and Glenn (1986), the triangular diagram (Fig. 4) shows where the microfaunal assemblages from each of Wilson's standard facies (1974) are plotted. The plot of the samples denotes reef flat to proximal lagoonal environments (i.e., high- to moderate-energy conditions on platform edges).

Table 5. Distribution of the shallow-water foraminiferal species in Hole 821A in their main environments of life (outer platform, platform edge, and inner platform).

	Outer (> 30 m)	Platform (< 30 m)	Platform Edge	Inner Platform
SUBORDER TEXTULARIINA				
Family Textulariidae				
<i>Textularia candeiana</i> d'Orbigny *				
<i>Textularia</i> cf. <i>pseudogramen</i> Chapman-Parr. *				
<i>Textularia agglutinans</i> d'Orbigny *				
<i>Textularia fistulosa</i> Brady *				
<i>Textularia conica</i> d'Orbigny *				
<i>Textularia saggitula</i> DeFrance °				
Ataxophragmidae				
<i>Gaudryina siphonifera</i> (Brady) *				
SUBORDER MILIOLINA				
Fischeriidae				
<i>Cyclogyra involvens</i> Reuss °				
<i>Planispirinella exigua</i> (Brady) *				
Nubeculariidae				
<i>Wiesnerella auriculata</i> (Egger) *				
<i>Vertebralina striata</i> d'Orbigny *				
<i>Spiroloculina communis</i> Cushman-Todd *				
Miliolidae				
<i>Quinqueloculina crassicarinata</i> Collins *				
<i>Quinqueloculina curta</i> Cushman *				
<i>Quinqueloculina granulocostata</i> Germeraad *				
<i>Quinqueloculina lamarckiana</i> d'Orbigny *				
<i>Quinqueloculina oblonga</i> (Montagu) *				
<i>Quinqueloculina poyeana carinata</i> Albani. *				
<i>Quinqueloculina pseudoreticulata</i> Parr °				
<i>Quinqueloculina distorquata</i> Cushman °				
<i>Quinqueloculina bosciiana</i> d'Orbigny °				
<i>Triloculina eburnea</i> d'Orbigny. *				
<i>Triloculina trigonula</i> (Lamarck) *				
<i>Triloculina tricarinata</i> d'Orbigny *				
<i>Pyrgo denticulata</i> (Brady) *				
<i>Pyrgo oblonga</i> d'Orbigny *				
<i>Spirosigmolina parri</i> Collins *				
<i>Miliolinella australis</i> (Parr) *				
<i>Miliolinella baragwanathi</i> (Parr) *				
<i>Hauerina occidentalis</i> Cushman *				
<i>Articulina pacifica</i> Cushman *				
Soritidae				
<i>Monalysidium politum</i> Chapman *				
<i>Peneroplis pertusus</i> (Forskal) *				
<i>Sorites</i> (juveniles) *				
Alveolinidae				
<i>Alveolinella quoyi</i> (d'Orbigny) *				
SUBORDER ROTALIINA				
Nodosaridae				
<i>Lagena</i> cf. <i>strumosa</i> Reuss *				
<i>Bolivina elegans</i> Parr *				
Glandulinidae				
<i>Fissurina marginato-perforata</i> (Seguenza) *				
<i>Fissurina orbignyana</i> Seguenza *				
<i>Oolina spiralis</i> (Brady) *				
Spirillinidae				
<i>Spirillina vivipara</i> Ehrenberg *				
<i>Patellina carinata</i> Collins *				

Notes: Solid lines refer to species characteristic of a given environment. Dashed line refers to species present, but not regarded as characteristic. Data from Collins (1958), Hallock and Glenn (1986), and Baccaert (1987).

Table 5 (continued).

	Outer (> 30 m)	Platform (< 30 m)	Platform Edge	Inner Platform
Ceratobuliminidae				
<i>Lamarckina scabra</i> (Brady) *				
<i>Lamarckina ventricosa</i> (Brady) °				
Turrilinae				
<i>Buliminella latissima</i> Collins *				
Buliminoididae				
<i>Buliminoides williamsonianus</i> Cushman *				
<i>Buliminoides madagascariensis</i> (d'Orbigny) var. <i>spicatus</i> (Cushman & Parker) *				
Bolivinitidae				
<i>Bolivina compacta</i> Sidebottom *				
<i>Bolivina rhomboidalis</i> (Millet) *				
<i>Bolivina semicostata</i> Cushman °				
<i>Bolivina subangularis</i> Brady °				
<i>Bolivina subreticulata</i> Parr °				
<i>Bolivina amygdalaeformis</i> Brady °				
<i>Bolivina hantkeniana</i> Brady °				
<i>Brizalina pacifica</i> (Cushman & Mc Culloch) *				
<i>Brizalina striatula</i> (Cushman) *				
<i>Brizalina convallaria</i> (Millet) *				
Buliminidae				
<i>Reussella simplex</i> (Cushman) *				
Uvigerinidae				
<i>Siphogenerina virgula</i> (Brady) *				
<i>Uvigerina porrecta</i> Cushman *				
<i>Siphouvigerina ampullacea</i> (Brady) *				
<i>Trifarina bradyi</i> Cushman *				
<i>Bifarina fimbriata</i> (Millet) °				
Discorbidae				
<i>Neoconorbina ferquemi</i> (Rhezak) *				
<i>Neoconorbina tubero-capitata</i> (Chapman) °				
<i>Discorbis mira</i> Cushman *				
<i>Gavelinopsis cf. lobatulus</i> (Parr) *				
Eponididae				
<i>Neoeponides berthelotianus</i> (d'Orbigny) *				
<i>Poroeponides lateralis</i> (Terquem) *				
Glabratellidae				
<i>Glabratella earlandi</i> Collins *				
<i>Glabratella opercularis</i> (d'Orbigny) °				
Epistomariidae				
<i>Epistomariella milletti</i> Collins *				
Siphoninidae				
<i>Siphonina tubulosa</i> Cushman *				
Amphisteginidae				
<i>Amphistegina lessonii</i> d'Orbigny *				
<i>Amphistegina lobifera</i> Larsen *				
<i>Amphistegina radiata</i> (Fichtel-Moll.) °				
<i>Amphistegina papillosa</i> Said *				
Cibicididae				
<i>Cibicides lobatulus</i> (Walker-Jacob) *				
<i>Cibicides mayori</i> (Cushman) °				
Planorbulinidae				
<i>Planorbulinella larvata</i> (Parkes-Jones) *				
Cymbaloporidae				
<i>Cymbaloporella taballaeformis</i> (Brady) *				
<i>Tretomphalus-Cymbaloporella</i> group *				

Table 5 (continued).

	Outer (> 30 m)	Platform (< 30 m)	Platform edge	Inner Platform
Rotaliidae				
<i>Asterorotalia gaimardii</i> (d'Orbigny) *				
<i>Ammonia beccarii</i> s.l. (Linne) °				
Calcarinidae				
<i>Calcarina spengleri</i> (Gmelin) *				
<i>Calcarina calcar</i> d'Orbigny *				
<i>Baculogypsina sphaerulata</i> (Parker-Jones) *				
<i>Parrellina milleti</i> (Heron-Allen & Earland) *				
Elphidiidae				
<i>Elphidium advenum</i> (Cushman) *				
<i>Elphidium crispum</i> (Linne) *				
Nummulitidae				
<i>Operculina</i> cf. <i>ammonoides</i> *				
<i>Heterostegina</i> cf. <i>depressa</i> *				
Caucasinidae				
<i>Fursenkoina pauciloculata</i> (Brady) *				
<i>Sigmavirgulina tortuosa</i> (Brady) *				
Loxostomatidae				
<i>Loxostomum lobatum</i> (Brady) *				
Nonionidae				
<i>Nonion suburgidum</i> (Cushman) *				
<i>Svratkina tuberculata</i> (Balkwill-Wright) *				
Anomalinidae				
<i>Anomalina glabra</i> Cushman *				
<i>Heterolepa praecincta</i> (Karrer) *				
<i>Heterolepa margaritifera</i> (Brady) *				

DISCUSSION: IMPLICATIONS FOR THE GROWTH HISTORY OF THE CENTRAL GREAT BARRIER REEF

Several lines of evidence emerge after the analysis of the composition and distribution of shallow-water foraminiferal assemblages at Site 821:

1. The whole species recorded throughout Hole 821A are living in various reef sites throughout the Indo-Pacific and Caribbean provinces.
2. A relatively close similarity is seen in the nature and composition of the taphocoenoses among the different stratigraphic intervals studied and the modern GBR environments.
3. Environmental and climatic conditions were relatively stable during deposition of the successive microfaunal assemblages studied; inner-neritic, tropical environments developed repeatedly throughout Pleistocene time.
4. High- to moderate-energy platform edges formed repeatedly during the last 1.4 m.y.

From the foregoing, one can see that environmental factors favorable to reef development may have occurred several times at least, if not maintained constantly, since the beginning of the Quaternary along the northern Australian margin. Davies, McKenzie, Palmer-Julson, et al., (1991, p. 485), postulated that, in this region, reef growth was inhibited from the early Pliocene until the initiation of the GBR system; no major barrier reef would have existed along the Queensland margin for about 2 m.y. Similarly, based on lithological and geophysical surveys on the GBR shelf edge and adjacent slope at Sites 819 to 821, Feary et al. (this volume) point out that the most likely period for reef growth initiation in the central GBR area corresponds to the time of deposition of Units II and III, and more accurately, of the top of Unit II (age range: 0.5–1 m.y.). If this is correct, the factors responsible for inhibition of reef growth, especially during basically favorable periods, should have operated on a regional scale only (i.e., restricted to the central part of the Queensland shelf). Indeed, during the early Pleistocene, reef sys-

tems flourished in various areas of the West Pacific Ocean. Seismic data (Davies et al., 1988) from the northern GBR area and the outer Papuan shelf indicate the presence of buried relict Pliocene–Pleistocene shelf-edge reefs of varying thickness. Coudray (1976) reported the occurrence of a 120-m-thick reef tract, dated 1 to 1.5 Ma., beneath the modern New Caledonian reef province. Carney et al. (1985) also stated that successive regressive fringing reef complexes developed around the flanks of various uplifted Vanuatu islands throughout late Pliocene–Pleistocene time. The foraminiferal data presented here indicate that (1) climatic and environmental reef growth-inhibiting conditions cannot have operated throughout the early and intermediate Pleistocene; (2) reef-like bodies may have formed repeatedly on the platform as the slope was prograding. The bodies that may have developed at the time of deposition of interval 133-821A-24X-1, 131–133 cm (age: older than 1 m.y.), would be coeval with small reefal mounds seismically discovered on the GBR shelf edge in Unit IV, within the progradational package, by Feary et al. (this volume). The hypothesis conflicts with the previously advanced contention by Davies, McKenzie, Palmer-Julson, et al. (1991, p. 405). Reef development was probably not inhibited during the early Pleistocene. In fact, the most important questions to be raised are: (1) what geometry and size do former reef systems from the Queensland margin require to be regarded as the incipient GBR system? (2) Must the GBR concept be exclusively restricted to wider and semicontinuous lines of build-ups able to induce dramatic changes in the style of sedimentation on the adjacent slope? If the term GBR refers to the history of a major reef system having channelled major low-sea-level deposition and thus controlled the transition from progradational to aggradational sedimentary regime onto the northwestern Australian margin, the reefs that may have grown during the early Pleistocene cannot probably be regarded as the direct precursors of the present-day GBR tract. In contrast, if the GBR concept can be applied to the history of all reefs that have developed and evolved in-situ along the edge of the Queensland margin, such reefs were the actual cradle of the GBR complex. We suggest that since early Pleistocene time, scattered but morphologically well

differentiated reef systems grew successively on the central north Australian shelf edge; these exhibited sufficiently various environments (reef flat to back-reef zones) to serve as habitats for foraminiferal biocoenoses of high specific diversity. The modern GBR system might be only the final evolution of successive reef tracts that have developed since the beginning of the Quaternary.

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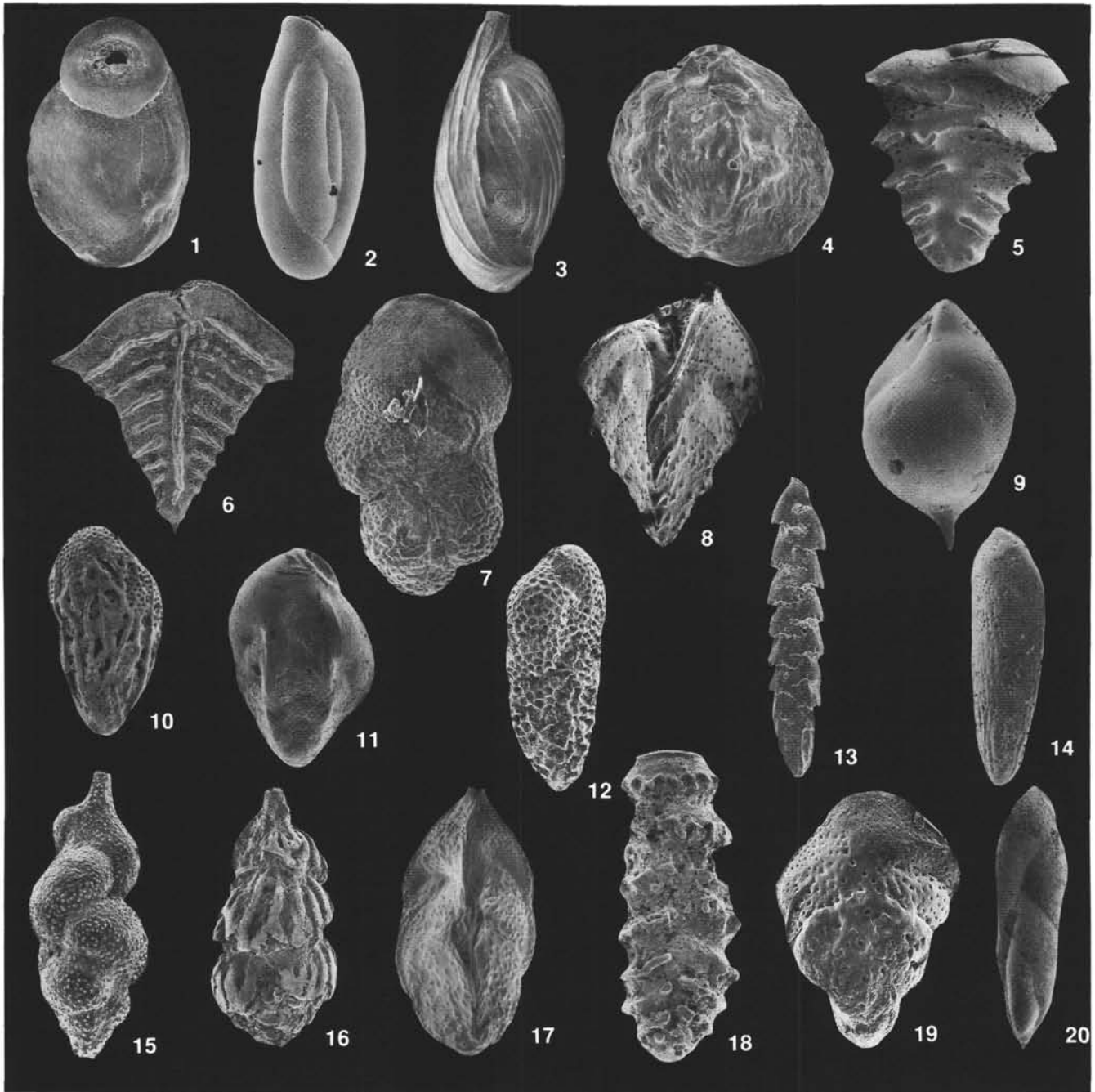


Plate 1. 1. *Wiesnerella auriculata* (Egger). Sample 133-821A-1H-1, 30–32 cm (124 \times). 2. *Quinqueloculina oblonga* (Montagu). Sample 133-821A-1H-1, 30–32 cm (124 \times). 3. *Quinqueloculina poyeana* carinata Albani. Sample 133-821A-1H-1, 30–32 cm (100 \times). 4. *Hauerina occidentalis* Cushman. Sample 133-821A-1H-1, 30–32 cm (200 \times). 5. *Patellinella carinata* Collins. Sample 133-821A-1H-1, 30–32 cm (150 \times). 6. *Bolivina elegans* Parr. Sample 133-821A-1H-1, 30–32 cm (128 \times). 7. *Buliminella latissima* Collins. Sample 133-821A-1H-1, 30–32 cm (200 \times). 8. *Reussella simplex* (Cushman). Sample 133-821A-29X-1, 74–76 cm (118 \times). 9. *Buliminoides madagascariensis* (d'O.) var. *spicta* (C. & P.). Sample 133-821A-24X-1, 131–133 cm (150 \times). 10. *Bolivina amygdalaeformis* Brady. Sample 133-821A-24X-1, 131–133 cm (70 \times). 11. *Bolivina subangularis* Brady. Sample 133-821A-35X-1, 30–32 cm (70 \times). 12. *Bolivina compacta* Sidebottom, Sample 133-821A-35X-1, 30–32 cm (100 \times). 13. *Brizalina convallaria* (Millett) Sample 133-821A-1H-1, 30–32 cm (100 \times). 14. *Brizalina striatula* (Cushman). Sample 133-821A-24X-1, 131–133 cm (138 \times). 15. *Siphovigerina ampullacea* (Brady). Sample 133-821A-35X-1, 30–32 cm (150 \times). 16. *Uvigerina porrecta* (Brady). Sample 133-821A-24X-1, 131–133 cm (100 \times). 17. *Trifarina bradyi* Cushman. Sample 133-821A-1H-1, 30–32 cm (150 \times). 18. *Bifarina fimbriata* (Millett). Sample 133-821A-35X-1, 30–32 cm (150 \times). 19. *Sigmavirgulina tortuosa* (Brady). Sample 133-821A-17X-3, 30–32 cm (118 \times). 20. *Fursenkoina pauciloculata* (Brady). Sample 133-821A-1H-1, 30–32 cm (106 \times).

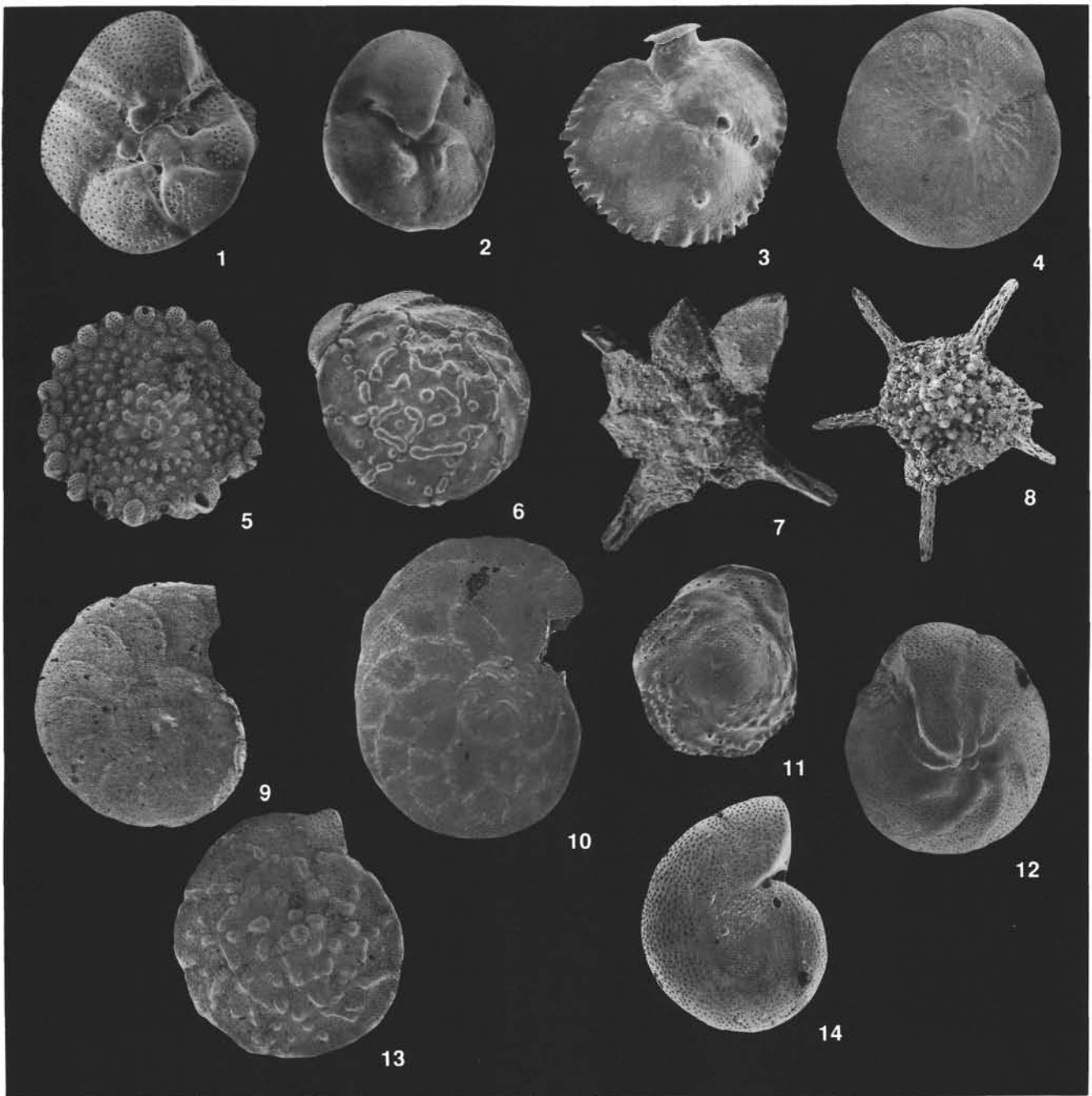


Plate 2. **1.** *Gavelinopsis* cf. *lobatulus* (Parr). Sample 133-821A-1H-1, 30–32 cm (150×). **2.** *Neoeponides berthelotianus* (d'Orbigny). Sample 133-821A-29X-1, 74–76 cm (70×). **3.** *Siphonina tubulosa* Cushman. Sample 133-821A-1H-1, 30–32 cm (100×). **4.** *Amphistegina papillosa* Said. Sample 133-821A-29X-1, 74–76 cm (30×). **5.** *Planorbulinella larvata* (P. & J.). Sample 133-821A-29X-1, 74–76 cm (30×). **6.** *Asterorotalia gaimardii* (d'Orbigny). Sample 133-821A-29X-1, 74–76 cm (45×). **7.** *Calcarina calcar* d'Orbigny, young specimen. Sample 133-821A-1H-1, 30–32 cm (200×). **8.** *Calcarina spengleri* (Gmelin). Sample 133-821A-2H-1, 30–32 cm (40×). **9.** *Operculina* cf. *ammonoides* (Gronovius). Sample 133-821A-29X-1, 74–76 cm (62×). **10.** *Heterostegina depressa* d'Orbigny. Sample 133-821A-2H-1, 30–32 cm (90×). **11.** *Svratkina tuberculata* (B. & W.). Sample 133-821A-35X-1, 30–32 cm (100×). **12.** *Heterolepa praecincta* (Karrer). Sample 133-821A-29X-1, 74–76 cm (45×). **13.** *Heterolepa margaritifera* (Brady). Sample 133-821A-29X-1, 74–76 cm (45×). **14.** *Anomalina glabrata* Cushman. Sample 133-821A-35X-1, 30–32 cm (150×).