Journal of South American Earth Sciences, Vol. 2, No. 1, pp. 73–108, 1989
Printed in Great Britain

0895-9811/89 $3.00 + 0.00

Late Neogene history of the Pacific-Caribbean gateway

G. KELLER,[1] C. E. ZENKER,[2] and S. M. STONE[3]

[1]Department of Geological and Geophysical Sciences, Princeton University, Princeton, NJ 08544
[2]408 Darwin Street, Santa Cruz, CA 95062
[3]U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025

(Received for publication October 1988)

Abstract—Planktic foraminiferal provinces of Caribbean DSDP Hole 502A and East Pacific DSDP Hole 503A have been analyzed and compared with benthic and planktic isotope records, carbonate, hiatus events, and sea level changes. Four major events are evident in the closure history of the Pacific-Caribbean gateway, at 6.2, 4.2, 2.4 and 1.8 Ma. The faunal change at 6.2 Ma coincides with the $\delta^{13}C$ shift and is primarily caused by upwelling in the western Caribbean. This suggests restricted circulation of intermediate water and deflection northeastward, strengthening the Gulf Stream as reflected in the first major erosion on Blake Plateau. The second faunal change, at 4.2 Ma, coincides with increased surface water salinity evident in $\delta^{18}O$ data and indicates increasingly restricted surface water exchange. Divergence of faunal provinces beginning at 2.4 Ma is marked by increasing abundance of high salinity tolerant species (*Globigerinoides ruber*) in the Caribbean. This suggests that initial closure of the Pacific-Caribbean gateway and cessation of sustained surface current flow between the Pacific and Caribbean occurred as late as 2.4 Ma. Maximum divergence of faunal provinces begins at 1.8 Ma and continues to the present. This implies that at least incipient littoral-neritic leakage occurred across the Pacific-Caribbean gateway between 2.4 and 1.8 Ma, with final closure by 1.8 Ma.

Resumen—Se han estudiado las provincias de foraminíferos planctónicos de los sondeos del DSDP 502A, en el Caribe, y 503A en el Pacífico. Estas se compararon con los registros isotópicos de los foraminíferos planctónicos y bentónicos, con el contenido de carbonato, con las brechas y con los cambios en el nivel del mar. Cuatro eventos faunísticos importantes son evidentes en la historia del cierre del pasaje Pacífico-Caribeño. Estos acontecieron hace 6.2, 4.2, 2.4, y 1.8 Ma. El primer cambio faunístico (6.2 Ma) coincide con una variación de $\delta^{13}C$, fue causado principalmente por "upwelling" en el Caribe Occidental. Esto provocaría una circulación restringida de agua intermedia, que se desviaría hacia el Noreste, reforzando la Corriente del Golfo, como puede observarse en la primera gran erosión de la Plataforma de Blake. El segundo cambio de fauna (4.2 Ma) coincide con un incremento en la salinidad de las aguas superficiales, encontrada en los datos de $\delta^{18}O$, e indica una creciente disminución en el intercambio de las aguas. La separación de las provincias faunísticas que comienza hace 2.4 Ma se caracteriza en el Caribe por un aumento de especies tolerantes de alta salinidad (*Globigerinoides ruber*). Esto sugiere, que el cierre inicial del pasaje Pacífico-Caribeño y el fin de la corriente superficial entre el Pacífico y el Caribe se produjo, como maximo, hace 2.4 Ma. Las mayores divergencias de las provincias faunísticas comenzaron hace 1.8 Ma y continúan hasta el presente. Esto implica que, al menos, los condiciones nerítico-litorales se mantuvieron en el pasaje Pacífico-Caribeño desde los 2.4 Ma hasta hace 1.8 Ma.

INTRODUCTION

THE PACIFIC-CARIBBEAN gateway has served a fundamental role in global circulation and climate since the late Mesozoic. Disruption of this gateway in the late Neogene has resulted in major differences in circulation patterns, water chemistry, and faunal provinces.

In the northern Pacific Ocean, restriction and eventual closure of the Caribbean gateway resulted in increased gyral circulation and thermal gradients. In the Caribbean Ocean, divergence of water northward intensified the Gulf Stream and increased the volume of warm, saline waters into high latitudes. Evaporation of this water led to increased precipitation over eastern Canada and Greenland which resulted in cooler temperatures, the development of a polar ice cap, and the initiation of northern hemisphere glaciation by about 3.2-2.5 Ma (Shackleton and Kennett, 1975; Shackleton and Opdyke, 1977, Shackleton and Hall, 1984).

Divergence of Atlantic and Pacific low-latitude water masses can largely be traced to the development of a sill across Central America in early to middle Miocene time (Mullins and Neumann, 1979) that restricted Antarctic Bottom Water (AABW) flow into the Caribbean (Keller and Barron, 1983). Shoaling and constriction of the Pacific-Caribbean gateway in middle to late Miocene time resulted in weakening and restriction of deep and intermediate water flow into the eastern Pacific and strengthened the Gulf Stream system (Kaneps, 1979; Keigwin, 1982a,b). During the late Miocene, production of North Atlantic Deep Water (NADW) further differentiated Pacific and Atlantic water masses (Blanc *et al.*, 1980; Kroopnick, 1980). By early to middle Pliocene time, onset of northern hemisphere glaciation, coupled with severely restricted flow through the Pacific-Caribbean gateway, led to major salinity changes in the Caribbean (Keigwin, 1982a,b; Prell, 1982; Oberhansli and Hemleben, 1984; Shackleton and Hall, 1984). Emergence of the Panama isthmus

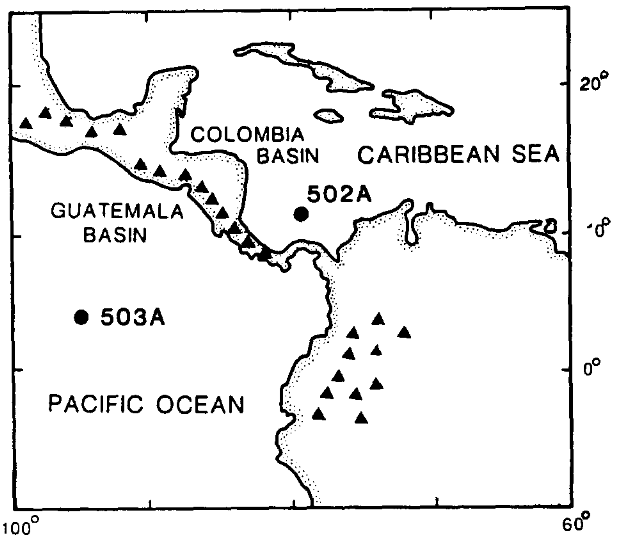

Fig. 1. Location map of DSDP Sites 502A and 503A, and schematic illustration of Pleistocene explosive volcanic centers.

is estimated to have occurred between middle and late Pliocene time (Keigwin, 1979, 1982a,b; Kaneps, 1979; Gartner *et al.*, 1987).

Major changes in circulation between the Caribbean and eastern Pacific — particularly changes in salinity, temperature, and nutrients — are recognizable in carbon and oxygen isotope data from analysis of benthic and planktic foraminifers as well as fluctuating populations of foraminifers and nannofossils. Benthic foraminifers at DSDP Sites 502 and 503 show faunal associations indicative of changing water masses influenced by the uplift of the Isthmus of Panama (McDougall, pers. commun., 1987). In a study of the Pacific-Caribbean distribution of the benthic foraminifer *Amphistegina gibbosa*, Crouch and Poag (1979) estimated that the initial closure of the Isthmus of Panama began at about 2.5 Ma, with complete closure occurring as late as 1.8 Ma. A qualitative study of planktic foraminifers of DSDP Sites 502 and 503 by Keigwin (1982c) showed diachroneity of species extinctions as well as gradual divergence of faunal patterns through the Pliocene. A more comprehensive study by Gartner *et al.* (1987), based on nannofossils from the eastern Pacific (Site 577), Caribbean (502), and Gulf of Mexico (Core E67), revealed divergent faunal provinces during early to late Pliocene, with emergence of the Panama isthmus possibly as late as 2.3 Ma.

The purpose of this paper is to elucidate the oceanographic changes induced by shoaling and subsequent emergence of the Panama isthmus during the last 8 million years. This study is primarily based on quantitative investigation of planktic foraminifers of the western Caribbean Hole 502A and eastern equatorial Pacific Hole 503A (Fig. 1). Our premise is that planktic foraminifers that live primarily in the upper 300 meters of the water column should show progressive changes as the isthmus rose, restricting and eventually eliminating communication between the Caribbean and the Pacific. Our faunal analysis is based on population abundance changes in abundance of dominant species groupings of surface (0-100 m) and intermediate (100-300 m) water dwellers based on oxygen isotope ranking of individual species (Keller, 1985). These results are compared and correlated with carbon and oxygen isotope data, carbonate in sediments, erosion patterns, sea level changes, and volcanic activity. These data elucidate the history and final closure of the Caribbean gateway during the past 8 million years.

METHODS

Foraminiferal samples were processed by standard techniques (Stone and Keller, 1985). Quantitative analysis was based on splits of 300-500 individuals from the >150mm size fraction using a modified Otto microsplitter. All specimens were picked, mounted on microslides, and identified. Species abundance data are listed in Tables 1-7.

BIOSTRATIGRAPHY

Pelagic and hemipelagic sediments recovered from DSDP Holes 502A and 503A represent an essentially continuous late Neogene record as indicated by paleomagnetic and biostratigraphic studies (Kent and Spariosu, 1982a,b; Keigwin, 1982c; Baldauf, 1985; Zenker, 1986). Preservation of foraminiferal assemblages is generally good, but intermittent carbonate dissolution is apparent — particularly in the eastern Pacific Hole 503A. In these intervals, abundance of dissolution-prone species (surface dwellers) is generally reduced, biasing the assemblage toward more solution-resistant (deeper dwelling) species. These dissolution intervals account for some of the abundance variability but do not affect overall trends.

Planktic foraminiferal biostratigraphy of Holes 502A and 503A was originally reported by Keigwin (1982c), and our results are in essential agreement (Zenker, 1986). Therefore, our discussion here is restricted to major faunal differences between the Caribbean and eastern Pacific which may be related to closure of the Pacific-Caribbean gateway. Because excellent paleomagnetic and biostratigraphic studies are available for Holes 502A and 503A (Kent and Spariosu, 1982 a,b; Keigwin, 1982c; Baldauf, 1985; Zenker, 1986), absolute ages were calculated for all samples based on the paleomagnetic stratigraphy of Kent and Spariosu (1982), the integration of calcareous and siliceous microfossil datum events, and extrapolation of sample ages from sediment accumulation rates.

FAUNAL PROVINCES

Planktic foraminifera live primarily in the upper 300m of the water column with some species preferring surface waters (0-100m) and other intermediate waters (100-300m). Depth stratification can be determined from oxygen isotope ranking of species; isotopically light species live closest to the surface, isotopically heavier species live in deeper waters near or below the thermocline (Fairbanks *et al.*, 1979, 1982; Oberhansli and Hemleben, 1984; Keller, 1985). Keller (1985) has applied oxygen isotope ranking of species to trace oceanographic changes reflected in changing watermass stratification in the Pacific through the Miocene. We apply this method here to show that population differences between surface and intermediate dwelling species reflect changes in oceanographic conditions such as climate, temperature, salinity or circulation. We hope to determine which effect(s) is(are) present with the aid of stable isotope data, sea level changes, and hiatuses.

Intermediate Dwellers

Relative abundances of dominant intermediate-dwelling species are illustrated in Fig. 2. These species populations would be affected first by a rising isthmus and restricted flow through the Pacific-Caribbean gateway. Significant differences between the Caribbean and eastern Pacific are apparent in all dominant species populations of intermediate-depth dwellers (*Neogloboquadrina humerosa* and *N. dutertrei*, *N. pachyderma*, *Globorotalia menardii*) except for *Neogloboquadrina acostaensis*, beginning at or just before 6.2 Ma. The most dramatic change occurred in the *Neogloboquadrina pachyderma* population. This species is nearly absent in the eastern equatorial Pacific but dominates in the Caribbean, reaching 40-60% between 6.2 and 4.3 Ma. *Neogloboquadrina pachyderma* is known to be a cold-water, high-latitude species (Ingle, 1963; Be and Hamlin, 1967; Kennett, 1968; Prell and Hays, 1976; Keller, 1978; Reynolds and Thunell, 1986); its presence in a tropical Caribbean assemblage is anomalous. It is likely that this *N. pachyderma* population thrived in upwelling currents (Keigwin, 1982c) that may have been caused by deflection of intermediate water northeastward by a rising Panama isthmus.

Upwelling appears to have continued in the western Caribbean until about 3.2 Ma. This is implied by the abundance of *N. pachyderma* between 6.2 and 4.3 Ma and by a significant increase in the upwelling species *Globigerina bulloides* between 4.3 and 3.2 Ma. Thereafter, upwelling species are an insignificant component among Caribbean foraminiferal assemblages (Fig. 2).

Throughout the late Neogene there are major differences among globorotalid species. *Globorotalia tumida* and *G. menardii* are common to abundant in the eastern Pacific. In contrast, *G. tumida* is nearly absent in the Caribbean and *G. menardii* is only intermittently common (Fig. 2). These population

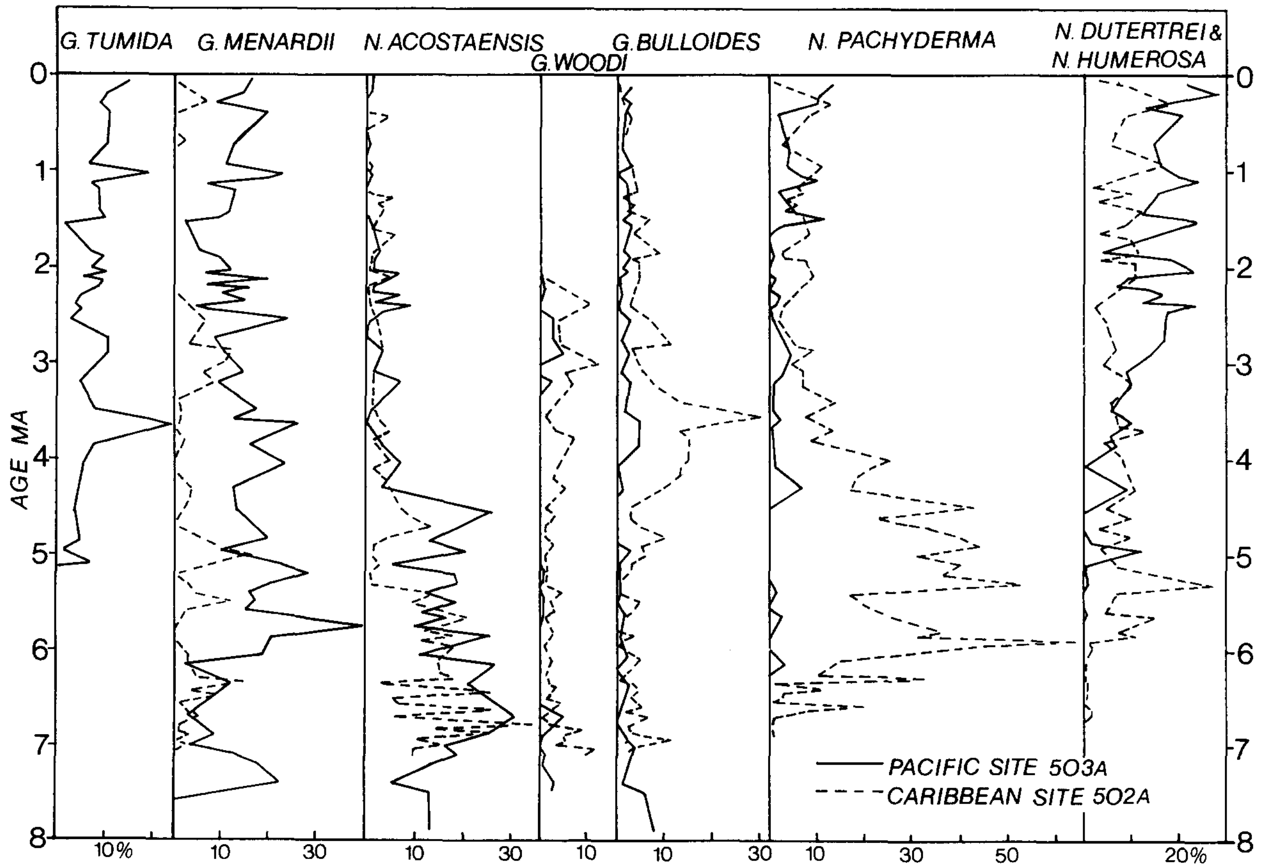

Fig. 2. DSDP Sites 502A and 503A: Relative abundance of dominant planktic foraminiferal species living at intermediate depths between about 100-300 m as interpreted from relatively heavy $\delta^{18}O$ values.

Table 1. Relative percent abundance of planktic foraminifers, Pacific Hole 503A, Cores 1-20.

Core: Sample No: Depth in Meters:	1 1-1 0.8	2 2-1 2.6	3 2-2 4.3	4 2-3 5.4	5 4-1 11.1	6 4-2 13.1	7 4-3 14.4	8 5-1 15.8	9 5-2 17.3	10 5-3 18.5	11 7-1 25.1	12 7-2 26.3	13 7-3 27.6	14 9-1 35.4	15 9-2 35.0	16 10-1 38.0	17 10-2 39.4	18 10-3 40.6	19 11-1 42.4	20 11-2 43.7
Candeina nitida	-	-	-	-	-	-	-	-	-	-	0.3	0.2	-	-	-	-	0.7	-	0.3	-
Catapsydrax sp.	-	-	-	-	0.3	-	0.3	-	-	0.3	-	-	-	-	-	-	-	-	-	-
C. cf. *unicavus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Globigerinella aequilateralis	2.4	0.7	1.5	2.1	0.6	1.1	0.9	1.4	1.0	0.3	0.6	0.6	0.7	-	-	0.6	1.0	-	1.2	1.2
Globigerina apertura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. bulloides	3.3	1.3	2.4	1.9	0.6	3.0	-	1.1	2.2	2.3	3.3	1.7	2.9	1.9	2.5	1.5	2.3	0.6	1.2	1.4
G. calida	-	1.0	-	-	0.6	-	-	-	-	-	-	-	-	-	-	-	-	1.2	1.2	-
G. decoraperta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. digitata	0.3	-	0.6	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. druryi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. falconensis	-	-	-	-	-	1.1	-	-	0.3	0.6	0.3	-	1.1	0.6	-	-	-	0.3	0.3	-
G. foliata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. incisa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-
G. nepenthes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. obesa	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.4	0.6	-	-	0.6	-
G. praecalida	-	-	-	-	-	-	-	-	-	-	-	-	-	1.0	-	-	-	-	-	-
G. praedigitata	-	0.3	0.3	-	-	-	-	-	-	-	-	0.2	-	-	-	-	-	-	-	-
G. pseudobesa	0.3	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. quadrilatera	-	1.0	0.9	-	0.3	0.8	-	1.1	1.3	0.9	1.5	-	0.2	-	-	-	-	-	-	-
G. rubescens	0.6	-	-	1.1	0.6	1.1	-	0.3	2.9	-	-	0.4	17.3	0.3	-	-	-	-	-	-
G. sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.6	-	-
G. umbilicata	0.6	-	-	-	-	0.3	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-
G. woodi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	1.2	0.9

Globigerinita glutinata	3.3	4.0	10.2	5.8	19.0	14.2	5.0	5.4	17.5	23.1	10.5	5.7	16.4	18.1	7.9	8.0	7.9	7.9	7.7	5.6
G. iota	0.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. uvula	1.2	0.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Globigerinoides bolli	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. bulloideus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. conglobatus	0.3	0.7	0.3	0.8	1.2	0.8	0.9	–	0.6	1.7	2.4		0.7	1.9	1.1	1.2	0.7	0.9	1.2	0.2
G. extremus	–	–	–	–	0.3	–	–	–	–	0.9	0.9	–	0.7	–	–	0.6	–	0.3	0.9	0.5
G. fistulosus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0	–	–	0.3	–	0.2
G. obliquus	0.3	–	0.3	–	0.3	0.3	–	–	–	0.9	0.9	1.9	0.4	1.3	0.7	1.5	0.7	1.2	0.6	0.5
G. pyramidalis	–	–	1.5	1.1	0.6	0.8	–	0.6	1.0	0.3	–	–	0.2	–	–	0.9	1.0	–	0.9	0.5
G. quadrilobatus	–	–	1.5	2.1	2.3	1.9	1.3	0.6	2.2	0.6	0.9	–	0.9	3.9	2.2	0.9	–	1.2	1.2	0.9
G. ruber	5.9	8.8	13.2	13.5	11.5	20.2	7.2	5.9	12.4	14.3	20.5	14.6	14.6	25.2	23.0	22.2	22.8	21.4	28.7	18.6
G. sacculifer	1.5	1.7	3.0	1.6	0.9	2.7	1.6	2.5	0.6	0.3	0.6	1.5	1.6	1.9	1.1	5.0	0.7	2.3	2.8	3.5
G. seiglei	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. tenellus	–	–	1.8	1.6	–	–	–	–	–	0.3	–	–	–	–	–	–	–	–	–	–
G. trilobus	–	1.0	2.7	3.7	1.4	2.5	1.6	1.1	1.6	1.4	3.6	1.9	1.8	4.9	7.9	6.5	2.3	3.8	7.4	3.5
Globoquadrina altispira	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. conglomerata	–	0.7	1.5	1.3	–	–	0.3	–	–	–	–	–	0.4	–	0.4	–	1.0	0.9	–	0.2
G. dehiscens	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. pseudofoliata	–	–	–	0.5	1.4	0.5	0.3	0.3	0.6	–	0.3	0.6	–	–	–	–	–	0.6	–	0.2
G. venezuelana		–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Globorotalia cibaoensis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. continuosa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. conoidea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. conomiozea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

(continued)

Table 1 (continued)

Core: / Sample No: / Depth in Meters:	1 / 1-1 / 0.8	2 / 2-1 / 2.6	3 / 2-2 / 4.3	4 / 2-3 / 5.4	5 / 4-1 / 11.1	6 / 4-2 / 13.1	7 / 4-3 / 14.4	8 / 5-1 / 15.8	9 / 5-2 / 17.3	10 / 5-3 / 18.5	11 / 7-1 / 25.1	12 / 7-2 / 26.3	13 / 7-3 / 27.6	14 / 9-1 / 35.4	15 / 9-2 / 35.0	16 / 10-1 / 38.0	17 / 10-2 / 39.4	18 / 10-3 / 40.6	19 / 11-1 / 42.4	20 / 11-2 / 43.7
G. crassaformis	-	-	0.6	-	-	-	-	-	-	-	-	-	0.2	-	-	-	-	0.3	0.9	-
G. crassula	-	-	1.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. exilis	0.6	-	3.3	0.8	0.9	1.9	0.3	0.3	0.6	-	-	-	-	-	-	-	-	1.5	4.6	6.5
G. fimbriata	-	-	0.9	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-
G. flexuosus	-	-	-	-	-	-	-	1.1	-	0.6	-	-	-	-	0.4	-	-	0.3	0.6	-
G. limbata	-	-	-	-	-	-	-	-	-	-	-	-	0.2	-	-	-	-	0.6	-	-
G. menardii	18.1	15.2	8.7	20.2	13.0	11.7	23.3	19.7	7.3	13.1	12.0	10.1	2.7	5.8	9.7	11.8	6.3	19.9	6.5	18.1
G. merotumida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. miocenica	-	-	-	0.8	-	-	-	-	-	0.6	-	-	-	-	-	-	-	0.3	-	-
G. miozea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. multicamerata	-	-	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
G. pleisiotumida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. puncticulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. scitula	-	-	-	-	-	-	0.3	0.3	-	-	0.3	0.4		-	-	-	-	0.3	-	0.7
G. sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. theyeri	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. tosaensis	-	-	-	-	-	-	-	-	-	-	1.5	1.1	1.1	2.3	-	-	-	-	-	-
G. tumida	15.7	10.4	9.3	10.3	10.4	6.3	19.2	12.4	7.6	8.3	9.0	9.7	1.6	6.8	9.4	7.1	10.6	5.3	9.0	8.4
G. ungulata	3.6	2.4	1.8	0.8	1.7	2.7	0.3	-	22.2	0.6	0.9	0.4	0.2	0.6	-	0.9	1.3	2.9	0.9	-
Globorotaloides hexagonus	1.5	1.0	2.7	0.8	2.9	0.5	0.6	0.8	0.6	1.1	2.1	1.3	0.9	2.3	-	0.3	0.7	0.6	-	0.9
Neogloboquadrina acostaensis s.l.	-	-	-	-	-	-	-	-	-	-	-	-	1.1	1.3	1.8	1.2	3.3	2.6	1.5	0.7
N. acostaensis s.s.	0.9	0.3	-	-	0.6	-	1.3	-	-	-	-	-	-	1.0	-	-	3.6	0.9	0.3	-
N. atlantica	1.5	5.1	-	1.3	-	-	1.9	0.6	-	0.3	0.3	0.6	0.7	-	-	-	0.3	-	-	-

N. dutertrei	16.6	25.3	9.0	12.5	12.4	9.8	10.7	10.4	14.0	7.7	5.7	16.1	13.7	2.9	12.6	10.7	3.6	2.1	-	-
N. humerosus	-	-	-	1.1	0.9	1.9	1.9	3.4	0.6	2.3	3.6	3.2	3.6	1.3	2.5	7.4	9.6	5.9	3.7	10.7
N. pachyderma f2	2.4	2.4	3.9	-	2.6	1.1	2.5	4.2	2.2	0.3	1.8	2.5	2.9	-	1.1	-	0.7	1.2	0.3	0.2
N. pachyderma (left)	-	-	-	-	-	0.3	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-
N. pachyderma (right)	9.8	7.7	6.0	2.1	1.7	2.5	4.7	5.4	4.8	1.4	3.3	9.9	0.2	-	-	-	-	-	-	-
N. pachyderma/dutertrei	5.0	3.4	4.5	6.9	2.3	4.6	7.2	10.4	6.1	6.3	2.7	5.1	5.4	-	3.2	5.3	-	-	-	-
N. pachyderma/humerosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.0	3.2	2.8	3.2
N. sp.	-	-	-	-	0.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N. sp A	-	0.7	0.3	-	-	-	-	0.3	-	-	-	0.2	0.2	0.6	2.2	-	-	-	-	-
Orbulina bilobata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2
O. suturalis	-	-	0.3	-	-	0.3	-	0.8	0.3	-	0.6	-	-	1.6	0.4	0.3	-	-	-	-
O. universa	0.6	-	0.6	0.8	1.4	0.3	0.3	1.7	1.0	0.9	0.3	1.5	0.9	1.0	1.8	1.8	0.3	0.9	0.6	1.4
Pulleniatina finalis	0.3	0.3	0.6	0.5	1.4	-	-	0.6	0.6	-	-	-	-	-	-	-	-	-	-	-
P. obliquiloculata	2.4	3.7	4.8	2.9	4.9	4.4	3.8	3.1	6.4	7.1	6.3	2.7	3.4	4.2	3.6	1.8	3.0	3.2	4.3	6.5
P. praecursor	-	-	-	-	-	-	-	-	-	0.3	-		-	0.6	-	0.6	-	0.3	1.2	0.5
P. primalis	-	-	-	-	-	-	-	-	-	-	-	-	-	2.9	-	-	2.6	-	1.5	0.9
Sphaeroidinella dehiscens	0.6	0.7	-	0.5	-	0.3	2.2	1.4	1.3	0.6	2.4	4.0	0.7	1.3	4.3	1.2	5.6	3.5	2.5	2.6
S. excavata	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	0.7
Sphaeroidinellopsis seminulina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. subdehiscens	-	-	-	0.3	-	-	-	0.8	-	-	-	0.6	-	-	-	-	0.3	0.6	-	-
Turborotalita humilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-
Total Counts:	337	297	334	337	347	366	318	355	314	350	332	473	446	309	278	338	302	341	324	431
Diversity:	29	26	32	30	32	30	26	31	28	33	31	29	34	30	23	26	29	37	34	31

Table 2. Relative percent abundance of planktic foraminifers, Pacific Hole 503A, Cores 21-40.

Core: Sample No: Depth in Meters:	21 11-3 45.4	22 12-1 46.8	23 12-2 48.2	24 12-3 49.2	25 13-1 51.3	26 14-1 55.2	27 15-1 59.9	28 16-1 63.7	29 17-1 68.3	30 19-1 77.7	31 20-1 82.0	32 21-1 86.7	33 23-1 95.2	34 24-1 99.6	35 27-1 112.4	36 29-1 121.6	37 30-1 125.9	38 31-1 130.3	39 32-1 134.4	40 33-1 139.2
Candeina nitida	-	-	-	-	0.8	-	-	-	-	-	-	-	-	-	-	0.4	0.7	-	-	-
Catapsydrax sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-
C. cf. *unicavus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.8	-	-	0.5	-
Globigerinella aequilateralis	1.2	0.6	2.4	0.6	0.8	0.5	0.6	1.8	1.6	0.8	1.5	0.3	0.7	0.3	1.5	2.3	2.0	3.4	1.1	0.8
Globigerina apertura	2.0	1.2	0.3	0.8	-	-	0.3	-	0.3	-	-	-	-	-	-	-	-	-	-	0.3
G. bulloides	1.2	-	0.6	1.1	3.0	1.3	2.2	1.2	3.1	2.0	4.6	4.7	4.6	1.0	1.5	-	-	2.9	0.5	0.8
G. calida	-	-	-	-	-	-	-	-	-	-	-	-	0.7	-	-	-	-	-	-	-
G. decoraperta	-	0.3	0.9	-	3.0	2.6	1.4	1.8	2.2	1.6	4.6	0.8	1.3	5.8	5.2	-	2.7	0.6	2.7	1.1
G. digitata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. druryi	-	-	-	-	-	-	0.6	-	0.3	-	0.5	0.3	-	-	-	-	-	0.6	1.6	0.6
G. falconensis	0.5	-	-	0.6	-	-	-	0.3	0.6	2.4	-	-	-	-	-	-	-	-	-	-
G. foliata	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-
G. incisa	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. nepenthes	-	-	-	-	-	-	-	0.3	-	-	-	-	-	1.6	-	0.4	1.7	-	0.5	-
G. obesa	0.2	0.3	-	-	-	-	-	-	-	-	-	0.3	-	0.6	-	-	0.2	1.1	-	-
G. praecalida	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-
G. praedigitata	0.7	-	0.3	-	-	-	-	0.3	0.3	-	-	-	-	-	-	-	-	-	-	-
G. pseudobesa	-	-	-	-	-	-	0.6	-	-	-	0.5	-	-	-	0.3	-	-	-	-	-
G. quadrilatera	-	-	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. rubescens	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. umbilicata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. woodi	0.2	-	-	-	2.3	2.6	5.0	-	2.5	-	-	0.3	-	-	-	0.4	-	-	-	0.8

Globigerinita glutinata	9.4	4.6	4.6	3.6	4.5	4.9	5.0	6.6	10.6	7.9	6.2	4.7	14.7	4.9	14.3	3.1	2.2	1.4	1.6	2.2
G. iota	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. uvula	0.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.3
Globigerinoides bolli	–	0.3	–	–	–	–	1.4	0.9	0.9	0.8	1.0	0.8	1.3	2.9	2.9	0.4	0.5	0.3	2.1	0.3
G. bulloideus	–	–	–	–	–	0.3	–	–	–	–	–	–	0.7	0.6	–	–	0.2	–	–	–
G. conglobatus	0.7	2.8	0.3	0.6	3.0	0.3	0.3	–	0.9	–	–	0.6	–	–	–	–	0.2	–	–	–
G. extremus	0.5	4.0	0.6	4.2	–	1.6	0.8	2.4	1.3	0.4	1.5	1.1	1.3	–	2.0	–	1.2	–	1.6	0.3
G. fistulosus	1.0	0.6	1.2	–	3.8	1.0	0.6	–	–	–	–	–	–	–	–	–	–	–	–	–
G. obliquus	2.2	7.7	10.1	5.8	3.8	6.2	3.6	10.0	8.1	12.7	7.2	11.1	9.4	7.5	8.2	11.5	6.8	6.3	10.7	16.7
G. pyramidalis	0.2	–	–	0.8	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. quadrilobatus	2.7	0.6	1.8	3.6	–	–	1.9	0.9	0.9	1.2	0.5	0.8	2.3	1.9	–	–	1.7	–	2.1	–
G. ruber	11.1	14.8	11.9	15.5	8.3	12.4	15.7	9.1	7.8	0.4	–	–	–	–	–	–	–	–	–	0.3
G. sacculifer	2.7	3.4	3.0	5.0	9.8	6.5	1.7	6.9	2.5	4.0	4.6	–	1.6	3.2	0.3	1.9	8.8	7.2	3.7	3.9
G. seiglei	–	–	–	–	–	–	–	–	0.3	–	–	–	–	–	–	–	–	–	–	–
G. sp.	–	–	0.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. tenellus	–	–	–	–	–	–	0.6	–	–	–	–	–	–	–	–	–	–	–	–	–
G. trilobus	4.7	7.7	5.5	6.9	3.0	7.5	5.2	7.3	5.9	9.9	5.2	4.5	4.9	5.8	6.4	5.0	8.3	11.8	5.3	7.2
Globoquadrina altispira	–	–	–	–	–	–	–	0.6	1.6	2.0	2.6	2.5	1.3	7.8	3.5	6.5	3.4	5.2	–	–
G. conglomerata	0.2	0.3	0.3	0.6	1.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. dehiscens	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. pseudofoliata	0.7	–	0.9	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. venezuelana	–	–	–	–	–	–	–	–	–	–	0.5	0.3	0.3	0.6	0.6	0.4	1.5	0.9	2.1	0.3
Globorotalia cibaoensis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. continuosa	–	–	–	–	–	–	1.4	1.8	0.6	0.4	–	0.6	–	1.0	–	–	–	–	2.7	–
G. conoidea	–	–	–	–	–	–	0.3	–	–	–	0.5	–	–	–	–	–	–	–	–	–
G. conomiozea	–	–	–	–	–	0.3	–	0.9	–	–	–	0.6	–	–	–	1.9	–	0.9	0.5	1.9

(continued)

Table 2 (continued)

Core: Sample No: Depth in Meters:	21 11-3 45.4	22 12-1 46.8	23 12-2 48.2	24 12-3 49.2	25 13-1 51.3	26 14-1 55.2	27 15-1 59.9	28 16-1 63.7	29 17-1 68.3	30 19-1 77.7	31 20-1 82.0	32 21-1 86.7	33 23-1 95.2	34 24-1 99.6	35 27-1 112.4	36 29-1 121.6	37 30-1 125.9	38 31-1 130.3	39 32-1 134.4	40 33-1 139.2
G. crassaformis	-	-	-	0.6	-	0.3	0.3	-	-	0.4	-	-	-	-	-	-	-	-	-	-
G. crassula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. exilis	-	-	-	-	0.8	1.0	0.3	2.1	-	3.2	1.5	2.2	-	-	-	3.1	0.2	0.3	0.5	1.4
G. fimbriata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. flexuosus	-	-	-	-	0.8	4.7	-	3.0	0.3	6.7	7.2	5.8	1.3	-	0.6	-	2.0	-	-	-
G. limbata	3.0	-	-	3.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. menardii	9.9	15.7	4.3	7.2	24.2	8.3	11.3	14.5	9.4	17.9	12.4	20.6	16.0	24.0	13.4	13.8	20.8	10.1	23.0	28.4
G. merotumida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. miocenica	-	0.3	-	1.1	-	-	-	-	-	-	-	0.3	-	0.6	-	-	0.2	-	-	-
G. miozea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. multicamerata	1.0	0.6	0.9	3.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. pleisiotumida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.8	3.2	2.0	5.3	4.2
G. puncticulata	0.7	-	0.3	-	0.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. scitula	-	0.6	-	-	0.8	-	-	0.3	-	0.4	0.5	0.3	0.3	0.6	-	0.8	-	-	0.5	0.8
G. sp.	-	-	-	-	-	-	0.3	-	0.3	-	-	-	0.3	-	-	-	-	-	-	-
G. theyeri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. tosaensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. tumida	5.7	4.6	4.0	5.5	2.3	5.9	10.5	3.6	4.7	1.2	11.9	18.1	6.8	5.8	4.4	3.8	3.4	0.9	7.0	-
G. ungulata	1.2	4.9	0.9	-	-	0.8	0.3	0.3	0.3	0.4	1.0	1.1	-	-	1.5	-	1.7	0.9	2.7	-
Globorotaloides hexagonus	1.0	0.6	0.3	-	2.3	2.3	-	0.3	0.6	0.4	-	0.8	2.0	0.6	0.3	0.8	1.0	0.6	1.6	1.7
Neogloboquadrina acostaensis s.l.	4.7	1.8	9.1	1.4	-	-	3.9	1.5	7.5	0.8	-	-	2.9	-	3.2	6.2	2.2	2.6	-	5.8
N. acostaensis s.s.	2.2	-	-	2.2	-	-	-	-	-	-	-	-	-	7.5	-	20.0	10.5	18.4	5.3	12.5
N. atlantica	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

N. dutertrei	–	1.2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
N. humerosus	16.0	6.5	15.5	14.7	10.6	7.5	4.1	3.0	3.4	0.4	2.6	0.6	2.9	–	3.2	–	1.2	9.8	–	–
N. pachyderma f2	1.7	1.2	–	–	–	2.6	0.8	2.1	0.9	0.8	1.0	0.8	0.3	–	–	–	–	–	–	–
N. pachyderma (left)	–	–	–	–	–	–	3.9	–	–	–	–	–	–	1.6	3.8	–	–	–	0.5	–
N. pachyderma (right)	0.7	–	0.6	0.3	1.5	–	–	1.5	0.6	0.8	1.5	–	1.3	–	3.5	–	–	–	–	–
N. pachyderma/dutertrei	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
N. pachyderma/humerosa	2.5	4.9	9.5	3.3	6.8	9.6	9.9	6.0	6.9	5.6	7.2	3.6	3.9	–	5.8	–	–	3.7	–	–
N. sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
N. sp A	–	–	0.3	–	–	0.3	0.6	–	–	–	–	–	–	–	–	–	–	–	–	–
Orbulina bilobata	–	–	–	–	–	–	–	–	–	–	–	–	0.7	–	–	0.4	0.2	–	–	–
O. suturalis	0.5	0.3	–	0.3	–	–	–	–	–	0.4	–	–	1.0	–	–	0.4	1.2	0.9	1.6	0.3
O. universa	1.5	1.5	2.1	0.3	–	–	–	–	–	1.2	1.0	0.6	3.6	0.3	0.3	3.1	3.7	1.1	1.6	1.4
Pulleniatina finalis	–	–	0.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P. obliquiloculata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P. praecursor	0.7	–	0.6	–	1.5	2.6	0.8	2.1	5.0	4.0	1.5	2.2	4.6	–	0.6	0.8	1.0	–	–	–
P. primalis	2.7	2.5	1.8	2.2	–	2.3	2.2	2.1	3.8	2.4	4.6	3.6	2.3	10.4	1.7	0.8	1.0	1.1	–	–
Sphaeroidinella dehiscens	1.5	3.1	2.7	2.5	–	1.8	1.9	1.2	0.9	0.4	–	–	–	0.3	–	–	–	–	–	–
S. excavata	–	–	–	1.1	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sphaeroidinellopsis seminulina	–	–	–	–	–	–	–	0.6	0.6	2.4	2.1	1.4	0.7	–	2.3	3.8	1.2	2.3	4.8	1.7
S. subdehiscens	–	–	0.6	–	–	1.8	0.3	2.1	1.9	4.0	2.1	3.6	4.2	2.3	8.5	3.5	2.9	2.9	5.9	3.9
Turborotalita humilis	–	–	–	–	–	0.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total Counts:	405	325	328	361	132	387	363	331	320	252	194	359	307	308	343	260	409	348	187	359
Diversity:	38	32	36	30	24	31	36	35	37	34	30	33	32	26	28	28	34	28	29	27

Table 3. Relative percent abundance of planktic foraminifers, Pacific Hole 503A, Cores 41-58.

Core: Sample No: Depth in Meters:	41 34-1 143.0	42 35-1 147.3	43 36-1 152.4	44 37-1 156.8	45 49-1 165.3	46 40-1 170.0	47 41-1 173.4	48 42-2 180.4	49 43-1 183.3	50 44-1 187.6	51 47-1 201.0	52 48-1 205.1	53 49-1 209.6	54 50-1 213.9	55 51-1 218.2	56 52-1 222.6	57 53-1 227.1	58 54-1 231.4
Candeina nitida	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Catapsydrax sp.	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
C. cf. *unicavus*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Globigerinella aequilateralis	1.3	-	-	0.3	0.5	1.1	0.4	0.4	0.3	2.4	-	-	-	0.5	0.8	0.4	-	-
Globigerina apertura	-	-	-	-	1.1	-	-	-	0.3	-	-	-	-	-	-	-	0.3	-
G. bulloides	0.4	0.9	0.3	1.9	2.1	0.9	2.1	2.9	-	2.4	-	2.0	3.1	2.6	2.4	1.5	6.1	8.1
G. calida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. decoraperta	1.3	1.4	6.5	2.8	1.6	0.2	3.9	0.4	4.4	3.3	-	0.3	0.3	-	1.3	0.4	2.4	2.7
G. digitata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. druryi	0.4	2.3	1.4	1.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. falconensis	1.3	-	-	0.3	0.7	-	1.8	0.4	1.1	-	-	-	-	-	-	-	-	2.7
G. foliata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. incisa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. nepenthes	-	-	-	0.3	0.9	-	0.4	-	0.6	1.6	1.9	-	-	-	-	0.4	0.3	-
G. obesa	-	0.5	-	-	-	-	0.2	0.8	0.3	0.8	-	-	-	-	-	-	-	-
G. praecalida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. praedigitata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. pseudobesa	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	0.7	-
G. quadrilatera	-	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-
G. rubescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. umbilicata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. woodi	0.9	-	0.6	0.8	0.2	0.3	-	-	-	-	5.8	0.9	-	1.0	0.5	2.9	2.7	-

Globigerinita glutinata	3.9	4.6	8.0	6.4	7.2	3.2	10.1	14.0	26.4	10.6	30.8	1.2	2.5	3.1	1.9	0.4	8.8	10.8
G. iota	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. uvula	-	0.9	1.1	-	1.3	0.8	0.4	-	0.3	8.1	-	-	-	-	-	-	-	-
Globigerinoides bolli	2.2	3.7	1.7	2.2	1.9	0.9	1.4	-	0.6	-	-	0.6	0.6	-	0.5	0.7	1.0	-
G. bulloideus	-	-	-	-	0.1	-	1.1	1.2	7.8	-	-	1.8	-	0.8	0.3	1.8	4.1	13.5
G. conglobatus	-	-	-	-	-	-	-	-	-	0.8	-	0.3	-	-	-	0.4	-	2.7
G. extremus	-	-	-	-	0.4	0.9	0.5	0.4	0.3	-	-	2.3	0.8	-	1.3	2.6	1.4	-
G. fistulosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. obliquus	13.9	13.8	18.2	9.1	9.0	8.2	2.7	2.5	3.9	-	7.7	14.9	9.3	9.9	8.9	33.9	30.8	13.5
G. pyramidalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. quadrilobatus	-	-	-	-	1.5	-	0.7	8.2	-	4.1	-	0.3	1.7	4.7	4.9	-	0.7	5.4
G. ruber	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. sacculifer	2.2	6.4	2.8	2.2	2.5	2.6	2.0	0.8	-	-	1.9	1.2	4.8	5.5	3.2	2.9	3.1	-
G. seiglei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. sp.	-	-	-	-	-	-	-	-	1.1	-	-	-	-	-	0.3	-	-	-
G. tenellus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. trilobus	8.2	12.8	2.6	3.6	3.4	4.8	3.4	14.0	4.2	1.6	3.8	2.9	9.9	12.0	18.9	5.1	5.1	16.2
Globoquadrina altispira	-	1.4	1.7	-	2.1	2.0	1.6	2.9	1.1	8.1	-	5.0	23.5	14.7	1.1	4.0	2.0	2.7
G. conglomerata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. dehiscens	-	-	-	-	-	-	-	-	-	-	3.8	1.5	1.7	1.6	1.6	1.5	1.4	-
G. pseudofoliata	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-
G. venezuelana	1.7	2.8	2.3	3.6	0.9	1.4	1.2	0.4	0.6	1.6	-	4.1	4.0	1.8	-	0.4	1.4	5.4
Globorotalia cibaoensis	-	-	-	0.6	0.6	-	-	-	-	-	-	-	-	-	-	-	-	-
G. continuosa	1.3	-	1.7	-	3.4	3.1	2.0	3.3	3.6	1.6	-	-	-	-	-	-	-	-
G. conoidea	-	-	0.3	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. conomiozea	1.3	1.4	1.7	0.8	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-

(continued)

Table 3 (continued)

Core: Sample No: Depth in Meters:	41 34-1 143.0	42 35-1 147.3	43 36-1 152.4	44 37-1 156.8	45 49-1 165.3	46 40-1 170.0	47 41-1 173.4	48 42-2 180.4	49 43-1 183.3	50 44-1 187.6	51 47-1 201.0	52 48-1 205.1	53 49-1 209.6	54 50-1 213.9	55 51-1 218.2	56 52-1 222.6	57 53-1 227.1	58 54-1 231.4
G. crassaformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. crassula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. exilis	3.5	0.5	0.6	0.8	0.6	5.7	1.8	1.6	-	2.4	-	3.5	0.8	3.7	7.5	3.3	0.7	-
G. fimbriata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. flexuosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. limbata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. menardii	21.6	16.1	17.0	15.5	27.3	42.4	20.8	18.9	2.5	12.2	3.8	8.2	3.7	12.3	18.6	22.3	9.5	-
G. merotumida	2.6	1.4	-	1.1	1.8	-	-	-	0.8	1.6	1.9	-	0.3	0.8	2.2	2.9	0.3	-
G. miocenica	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. miozea	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. multicamerata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. pleisiotumida	-	1.8	3.4	2.5	4.2	3.2	1.2	1.2	1.4	-	-	1.2	-	-	1.1	0.7	-	-
G. puncticulata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. scitula	-	0.9	0.3	0.3	0.6	0.3	0.9	-	1.7	0.8	-	0.6	1.4	0.3	0.3	0.7	1.0	-
G. sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. theyeri	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. tosaensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. tumida	-		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. ungulata	-	-	-	3.3	-	-	3.2	2.5	2.5	4.1	-	0.6	-	-	0.8	0.4	1.4	-
Globorotaloides hexagonus	0.9	0.5	0.3	2.8	1.2	1.4	0.2	-	1.1	-	1.9	2.3	1.7	0.8	0.5	1.5	0.3	-
Neogloboquadrina acostaensis s.l.	8.7	-	5.4	1.7	-	-	-	-	-	-	9.6	12.0	10.8	13.4	9.2	2.9	6.4	8.1
N. acostaensis s.s.	10.8	11.9	13.4	9.4	16.8	9.7	26.3	10.3	27.2	21.1	21.2	12.3	5.7	5.0	3.5	2.2	6.8	5.4
N. atlantica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

N. dutertrei	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
N. humerosus	0.4	–	–	0.3	–	–	–	–	–	–	–	–	–	0.3	–	–	–	–
N. pachyderma f2	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
N. pachyderma (left)	–	1.4	–	0.6	–	1.1	–	0.8	1.7	–	–	–	–	–	–	–	–	–
N. pachyderma (right)	0.9	0.9	–	0.3	–	1.5	–	–	1.9	–	–	–	–	–	–	–	–	–
N. pachyderma/dutertrei	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
N. pachyderma/humerosa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
N. sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
N. sp A	–	–	0.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Orbulina bilobata	0.9	1.4	1.1	–	0.2	–	–	–	–	–	–	–	0.3	0.3	0.5	–	–	–
O. suturalis	0.9	–	0.3	0.8	–	–	–	–	–	–	–	0.3	1.1	0.5	2.2	1.1	0.7	2.7
O. universa	1.3	1.8	1.4	1.7	1.1	1.2	3.6	2.9	1.4	1.6	3.8	1.8	2.3	0.8	1.1	0.4	–	–
Pulleniatina finalis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P. obliquiloculata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P. praecursor	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P. primalis	1.3	–	–	15.5	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sphaeroidinella dehiscens	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.3	–	–	–
S. excavata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sphaeroidinellopsis seminulina	1.3	2.8	1.1	2.2	1.2	0.8	2.1	2.5	0.6	3.3	–	5.6	3.1	0.8	1.9	0.7	–	–
S. subdehiscens	4.8	6.0	4.3	3.9	3.2	2.3	4.3	6.6	0.6	5.7	1.9	12.3	6.5	2.4	2.4	1.8	0.7	–
Turborotalita humilis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total Counts:	231	218	352	361	853	649	563	243	360	123	52	342	353	382	371	274	295	37
Diversity:	28	26	29	36	32	25	28	24	29	22	14	28	24	27	30	29	27	14

Table 4. Relative percent abundance of planktic foraminifers, Caribbean Hole 502A, Cores 1-18.

Core: Sample No: Depth in Meters:	1 1-1 0.7	2 2-1 2.6	3 3-2 8.4	4 4-1 11.4	5 5-2 17.3	6 6-1 20.2	7 7-3 27.6	8 8-1 29.4	9 8-2 30.4	10 8-3 31.2	11 9-1 32.9	12 10-1 38.2	13 10-2 39.3	14 10-3 40.8	15 12-1 46.4	16 12-2 48.3	17 12-3 49.3	18 13-1 50.4
Candeina nitida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Catapsydrax sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.1	-
Globigerinella aequilateralis	4.6	2.8	-	0.9	0.7	1.6	0.8	1.3	0.5	-	0.4	0.9	0.8	1.0	-	0.6	1.1	-
G. praesiphonifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Globigerina apertura	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.3	-	-	0.8
G. bulloides	0.3	0.3	1.3	3.4	1.3	2.9	3.9	4.1	1.8	2.8	2.5	6.9	4.0	5.2	8.3	3.4	4.2	4.7
G. calida	2.7	1.5	1.3	2.1	0.7	0.6	-	1.0	1.3	-	-	0.6	0.5	0.3	-	1.3	-	-
G. cariacoensis	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. decoraperta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.4	1.1	1.6
G. digitata	0.8	-	0.6	-	0.7	1.6	-	0.8	-	-	0.4	-	-	-	-	-	-	-
G. druryi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. falconensis	1.4	-	-	0.6	0.7	-	1.3	1.5	0.5	0.9	1.1	0.6	1.8	1.4	0.8	2.2	0.5	-
G. foliata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. incisa	-	-	-	-	-	-	-	0.5	1.3	0.6	1.1	0.9	3.0	-	-	1.3	-	0.5
G. nepenthes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. obesa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-
G. praecalida	1.9	1.5	-	0.9	2.6	1.0	0.5	2.3	1.8	0.9	-	0.9	0.3	-	-	1.6	0.3	0.3
G. praedigitata	-	-	-	-	-	0.3	-	-	-	0.6	-	-	-	-	0.5	0.3	-	0.5
G. pseudobesa	-	-	-	-	-	-	-	-	-	-	-	-	0.5	-	-	-	-	-
G. quadrilatera	-	0.6	1.0	0.9	0.7	0.6	0.8	1.0	1.0	1.5	2.5	0.6	0.5	3.1	2.7	1.6	1.3	0.8
G. rubescens	1.1	1.2	0.3	0.9	1.0	-	5.7	2.3	0.8	1.5	1.1	2.7	5.0	6.5	7.2	1.9	-	-
G. cf. *seiglei*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. sp.	0.3	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-
G. woodi	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.5	-

Globigerinita glutinata	14.7	12.8	8.1	10.1	4.2	7.3	46.4	12.1	11.6	12.5	9.5	9.3	21.6	13.7	23.1	16.6	10.3	5.8
G. iota	–	–	–	–	–	–	0.5	–	–	–	–	–	–	–	–	–	–	–
G. parkerae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. uvula	–	0.3	–	–	–	–	–	0.5	–	1.2	1.1	–	0.8	1.4	–	–	–	–
Globigerinoides bollii	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.3	–	–
G. bulloideus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. conglobatus	1.1	3.1	–	0.3	1.6	0.6	0.5	2.3	0.8	0.3	1.4	0.6	–	0.3	0.8	0.3	3.4	–
G. extremus	2.4	0.6	1.0	1.5	2.0	0.3	1.0	0.8	0.5	0.9	1.4	3.3	–	1.0	0.8	2.5	1.3	–
G. fistulosus	–	0.3	–	–	–	–	–	–	–	–	–	–	–	–	0.5	–	0.5	–
G. kennetti	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. obliquus	–	–	–	–	–	–	1.5	1.8	1.5	1.8	0.7	0.6	3.5	–	1.1	–	0.5	1.3
G. pyramidalis	1.1	0.3	0.3	0.6	0.7	0.3	0.3	1.0	1.3	0.3	–	1.5	–	–	0.8	–	0.8	1.3
G. quadrilobatus	–	3.1	1.3	0.6	0.3	0.6	1.3	4.4	7.1	2.1	3.2	–	1.5	–	–	0.9	3.2	0.8
G. ruber	43.5	40.4	21.7	22.3	43.0	27.5	21.4	24.2	30.4	29.4	27.4	33.0	24.1	35.4	25.5	28.4	17.9	34.1
G. sacculifer	3.5	4.9	4.9	3.1	5.5	4.2	–	5.4	10.4	11.0	9.1	4.8	2.5	2.1	1.6	5.0	11.6	4.2
G. seiglei	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. tenellus	3.0	–	–	2.1	1.0	–	–	–	–	–	–	0.9	–	1.7	0.5	0.6	2.9	–
G. trilobus	4.3	2.1	5.5	5.5	8.5	6.1	1.5	4.1	6.8	6.1	6.0	3.9	6.8	2.4	0.5	7.8	6.9	5.8
Globoquadrina altispira	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. conglomerata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. pseudofoliata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. venezuelana	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Globorotalia continuosa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. conoidea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. conomiozea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

(continued)

Table 4 (continued)

Core: Sample No: Depth in Meters:	1 1-1 0.7	2 2-1 2.6	3 3-2 8.4	4 4-1 11.4	5 5-2 17.3	6 6-1 20.2	7 7-3 27.6	8 8-1 29.4	9 8-2 30.4	10 8-3 31.2	11 9-1 32.9	12 10-1 38.2	13 10-2 39.3	14 10-3 40.8	15 12-1 46.4	16 12-2 48.3	17 12-3 49.3	18 13-1 50.4
G. crassaformis oceanica	–	–	–	0.9	–	0.3	–	–	0.8	1.2	1.4	–	–	0.7	–	0.6	–	0.8
G. crassaformis ronda	–	–	–	1.2	0.7	0.6	–	–	0.8	0.3	0.4	–	–	–	–	–	–	0.5
G. crassaformis	–	0.3	0.6	0.3	1.3	–	–	–	0.8	1.8	2.1	–	–	0.7	1.6	1.9	1.1	–
G. crassula	–	–	–	–	–	–	–	–	–	–	–	–	–	1.0	0.8	0.9	–	0.3
G. exilis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.5	0.6	–	–
G. flexuosus	–	0.6	0.6	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. inflata	3.3	–	1.3	7.6	–	0.6	–	3.6	–	–	–	–	–	1.4	–	–	–	–
G. juanai	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. limbata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. margaritae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. menardii	–	–	6.5	–	2.9	–	–	–	–	–	–	3.0	–	–	0.8	0.9	–	–
G. merotumida	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. miocenica	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. miozea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. pleisiotumida	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. scitula	2.2	0.3	–	0.6	1.3	–	0.8	1.0	–	–	–	0.9	–	0.3	1.6	0.9	0.5	1.0
G. sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.3	–	–	–
G. tosaensis	0.8	–	0.6	–	–	0.3	–	–	2.8	0.9	2.1	–	–	–	–	–	–	0.3
G. truncatulinoides	1.4	1.8	0.6	2.8	1.0	2.6	0.5	0.8	–	1.2	0.7	–	–	–	–	–	–	–
G. tumida	–	0.9	1.6	–	–	–	–	–	–	–	–	0.9	–	–	1.3	0.9	–	–
G. ungulata	–	4.0	1.0	–	1.3	–	–	–	–	–	–	2.1	–	–	–	0.6	–	–
Globorotaloides hexagonus	–	–	–	–	–	3.5	–	0.3	–	–	–	–	–	–	–	–	–	0.3
Hastigerina pelagica	–	–	–	–	0.3	–	–	–	–	–	–	–	–	–	–	–	–	–
Neogloboquadrina acostaensis s.l.	–	–	–	–	–	–	–	–	–	–	–	1.2	5.5	–	–	–	5.3	2.1

N. acostaensis s.s.	-	-	-	4.9	-	1.6	-	0.3	5.3	2.1	3.9	-	0.5	-	1.1	-	-	2.6
N. atlantica	0.3	-	5.2	2.8	1.3	2.9	-	1.3	-	0.3	0.4	0.9	2.0	-	1.1	-	3.4	2.9
N. dutertrei	2.7	6.1	12.6	6.1	3.9	11.2	0.8	8.5	2.0	4.6	7.7	4.2	2.5	5.8	7.5	1.9	4.2	4.2
N. humerosus	-	0.9	-	-	-	-	-	-	-	-	-	1.2	-	-	-	-	1.3	1.0
N. pachyderma f2	-	-	4.2	0.6	0.7	3.5	1.0	2.8	1.0	0.6	1.8	1.8	-	1.4	1.3	0.3	2.9	2.9
N. pachyderma (left)	-	-	4.5	-	-	-	0.8	-	0.3	-	0.4	-	-	-	-	-	0.3	-
N. pachyderma (right)	0.8	4.3	3.9	8.3	2.6	7.7	4.4	4.4	2.8	5.5	2.5	5.4	8.3	6.2	1.1	3.1	4.5	6.0
N. pachyderma/dutertrei	0.5	2.8	5.5	3.1	2.6	5.8	0.8	2.1	1.3	2.1	5.6	3.9	1.0	4.1	3.2	1.6	3.4	4.2
N. pachyderma/humerosa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N. sp.	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
N. sp A	-	-	-	-	-	-	-	-	1.3	0.6	-	0.3	2.3	-	0.3	0.3	0.8	2.9
N. sp.	-	0.3	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-
Orbulina bilobata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
O. suturalis	-	-	0.6	0.3	-	0.3	-	0.3	-	-	-	-	-	0.3	0.5	-	0.5	1.6
O. universa	1.4	0.9	0.3	4.0	2.3	1.0	1.0	1.0	0.8	1.8	0.7	1.5	0.3	0.3	1.1	2.8	1.3	1.8
Pulleniatina finalis	-	-	0.6	-	-	0.3	-	0.3	-	0.3	-	-	-	-	-	-	-	-
P. obliquiloculata	-	0.6	2.3	0.6	1.3	1.3	1.8	1.5	0.5	0.9	1.4	-	0.5	0.3	0.3	-	-	0.8
P. praecursor	-	-	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-
P. primalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphaeroidinella dehiscens	-	-	-	-	1.6	0.3	0.3	0.5	0.5	0.9	0.7	0.3	0.3	0.7	0.3	0.6	1.1	1.0
S. excavata	-	-	-	-	-	0.6	0.3	-	-	-	-	-	-	0.7	-	-	-	0.3
Sphaeroidinellopsis seminulina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
S. subdehiscens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Turborotalita humilis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Counts:	368	327	309	327	307	313	388	399	395	327	285	333	399	291	373	320	379	381
Diversity:	25	30	30	31	32	33	27	34	31	33	31	32	26	29	35	34	33	34

Table 5. Relative percent abundance of planktic foraminifers, Caribbean Hole 502A, Cores 19-34.

Core: Sample No: Depth in Meters:	19 16-1 64.1	20 17-1 68.5	21 18cc 76.7	22 19-1 77.3	23 20-1 81.7	24 21-1 86.4	25 22-1 90.5	26 23-1 94.9	27 24-1 99.3	28 25-1 104.0	29 26-1 108.1	30 27-1 112.5	31 28-1 116.9	32 29-1 119.6	33 30-1 123.5	34 32-1 129.2
Candeina nitida	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-
Catapsydrax sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Globigerinella aequilateralis	0.3	0.6	-	-	-	0.6	-	0.7	0.6	0.4	0.3	0.5	-	-	0.4	0.3
G. praesiphonifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Globigerina apertura	1.8	2.5	0.3	0.6	2.7	0.6	0.7	1.0	-	0.4	4.1	0.8	0.6	1.2	2.9	-
G. bulloides	3.3	6.6	12.8	3.1	4.5	6.4	7.3	12.4	31.4	13.7	15.4	15.8	13.7	13.1	10.6	3.7
G. calida	-	-	-	-	-	0.3	-	0.3	-	-	-	-	-	-	-	-
G. cariacoensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. decoraperta	3.0	4.1	5.3	3.8	4.0	2.6	2.1	3.7	1.0	1.4	4.7	4.3	2.7	1.2	1.5	4.3
G. digitata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. druryi	-	-	-	-	0.3	-	-	-	-	-	-	-	0.6	0.9	0.4	-
G. falconensis	0.6	2.2	2.1	-	0.8	2.0	1.0	5.7	1.0	1.4	1.6	1.3	1.5	1.6	1.5	-
G. foliata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. incisa	-	-	-	-	-	-	0.3	0.3	-	-	-	-	-	-	-	-
G. nepenthes	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	0.4	-
G. obesa	1.8	1.3	-	0.3	0.5	-	-	0.3	-	-	-	0.5	0.9	0.6	0.4	-
G. praecalida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
G. praedigitata	-	-	0.3	0.3	-	-	0.7	0.3	-	-	-	-	-	-	-	-
G. pseudobesa	-	-	-	-	-	-	0.3	0.3	-	-	0.3	-	-	-	-	-
G. quadrilatera	0.6	0.3	0.5	0.9	2.1	0.9	0.7	0.7	1.9	1.1	0.6	1.3	-	0.3	1.1	0.9
G. rubescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. cf. *seiglei*	0.6	0.3	0.3	-	-	-	-	0.7	-	-	-	-	-	-	-	-
G. sp.	-	-	-	-	-	0.3	-	-	-	0.4	-	-	-	-	-	-
G. woodi	10.7	4.1	4.0	5.0	11.9	5.2	6.6	4.0	1.3	3.5	6.9	4.5	3.6	3.4	5.8	1.4

Globigerinita glutinata	6.5	9.7	12.6	6.6	6.1	9.6	9.0	13.0	10.8	14.8	8.2	9.8	18.2	9.0	15.3	9.4
G. iota	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. parkerae	–	–	–	0.3	–	–	–	–	1.0	0.4	–	0.3	–	–	–	–
G. uvula	–	0.6	–	–	–	0.3	–	–	0.3	–	–	–	–	–	–	0.9
Globigerinoides bollii	0.6	0.6	1.3	–	0.3	0.9	1.4	1.3	0.3	–	0.9	–	–	–	–	0.6
G. bulloideus	–	–	–	–	1.1	2.3	2.1	0.3	1.9	0.4	–	0.5	–	–	–	–
G. conglobatus	0.3	2.5	–	–	0.5	1.5	0.7	–	–	–	–	–	–	–	–	–
G. extremus	1.5	0.3	1.6	0.9	2.4	3.8	1.7	2.3	1.9	0.7	1.6	2.3	0.6	1.6	1.1	1.4
G. fistulosus	0.3	1.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. kennetti	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. obliquus	0.9	3.8	3.2	4.1	6.9	7.0	2.8	12.0	6.7	9.9	10.7	4.3	6.1	8.1	6.9	8.9
G. pyramidalis	–	0.3	–	0.6	–	–	–	–	–	–	–	–	–	–	–	–
G. quadrilobatus	1.2	0.3	0.5	0.6	1.6	1.5	1.0	–	–	–	1.6	1.3	2.1	1.6	–	0.3
G. ruber	33.1	23.5	11.2	10.1	4.0	7.9	6.6	1.0	–	–	0.6	–	–	–	–	–
G. sacculifer	2.4	2.5	5.3	5.3	5.3	5.5	5.6	3.3	1.3	2.1	5.6	2.0	3.0	1.2	1.8	2.0
G. seiglei	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.3
G. tenellus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. trilobus	3.8	1.9	4.0	4.1	4.5	3.8	5.9	3.0	1.9	3.5	2.8	2.3	4.6	5.0	5.1	0.9
Globoquadrina altispira	–	–	–	–	2.1	3.5	3.1	1.0	2.5	2.8	0.6	1.5	1.2	3.4	1.1	0.9
G. conglomerata	–	–	–	–	0.8	0.6	0.3	–	–	–	–	–	–	–	–	–
G. pseudofoliata	–	–	–	–	–	–	–	–	–	–	0.3	–	–	–	–	–
G. sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. venezuelana	–	–	–	–	–	–	–	–	–	–	–	0.3	–	–	–	0.3
Globorotalia continuosa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. conoidea	–	0.3	–	–	1.1	–	0.7	–	–	–	–	–	–	–	–	–
G. conomiozea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–

(continued)

Table 5 (continued)

Core: Sample No: Depth in Meters:	19 16-1 64.1	20 17-1 68.5	21 18cc 76.7	22 19-1 77.3	23 20-1 81.7	24 21-1 86.4	25 22-1 90.5	26 23-1 94.9	27 24-1 99.3	28 25-1 104.0	29 26-1 108.1	30 27-1 112.5	31 28-1 116.9	32 29-1 119.6	33 30-1 123.5	34 32-1 129.2
G. crassaformis oceanica	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. crassaformis ronda	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. crassaformis	1.8	1.9	2.4	1.9	0.5	0.3	1.0	–	1.9	0.7	0.9	1.5	0.3	–	–	–
G. crassula	0.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. exilis	–	–	0.3	1.3	0.3	0.6	0.3	0.3	–	–	–	–	–	–	–	–
G. flexuosus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. inflata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. juanai	–	–	–	–	–	–	–	–	–	–	–	–	0.3	–	–	–
G. limbata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. margaritae	–	–	–	–	–	–	–	–	1.9	1.8	–	–	0.3	0.3	1.8	–
G. menardii	3.6	7.2	3.7	11.3	10.9	6.7	9.4	1.7	2.9	1.8	2.5	0.8	0.6	2.8	4.0	2.6
G. merotumida	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. miocenica	0.3	0.3	–	0.3	–	0.3	–	1.0	–	–	–	–	–	–	–	–
G. miozea	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. pleisiotumida	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. scitula	0.3	–	0.3	0.3	–	0.3	–	1.0	0.3	–	–	–	1.2	–	–	–
G. sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. tosaensis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. truncatulinoides	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. tumida	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. ungulata	0.9	0.6	0.5	1.9	–	0.6	1.0	–	1.0	1.1	–	–	–	0.6	–	–
Globorotaloides hexagonus	–	0.6	–	–	1.3	1.2	–	–	1.3	0.4	1.3	–	–	–	–	–
Hastigerina pelagica	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Neogloboquadrina acostaensis s.l.	–	–	–	–	–	–	–	1.0	–	4.6	1.6	5.3	1.8	3.4	5.5	–

N. acostaensis s.s.	-	2.2	2.7	3.1	2.1	1.7	1.0	-	2.2	-	-	-	-	0.9	-	6.9
N. atlantica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7	-
N. dutertrei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N. humerosus	9.2	3.4	9.1	13.5	5.3	4.4	5.2	5.0	3.2	4.6	0.3	3.5	3.3	5.6	3.6	2.3
N. pachyderma f2	2.7	2.2	1.9	4.4	3.2	3.8	1.4	3.3	2.5	1.1	5.6	9.3	12.5	6.9	2.2	2.6
N. pachyderma (left)	-	-	-	-	0.5	0.6	-	6.4	2.5	5.6	2.5	15.3	7.3	10.9	14.2	20.0
N. pachyderma (right)	0.3	-	3.7	4.7	1.3	3.8	5.9	4.3	2.9	6.3	1.3	1.8	1.2	0.9	0.7	20.6
N. pachyderma/dutertrei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N. pachyderma/humerosa	2.7	5.0	6.7	6.9	4.2	7.9	10.4	6.4	8.6	13.0	4.4	8.3	8.8	10.3	10.2	4.9
N. sp.	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	0.9
N. sp A	-	1.3	-	0.3	-	-	-	1.0	-	0.4	-	-	-	-	-	-
N. sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orbulina bilobata	-	-	-	-	0.3	-	-	-	-	-	0.3	0.3	0.3	0.3	-	-
O. suturalis	1.5	-	0.5	0.6	0.3	-	-	0.3	-	-	1.6	0.3	0.3	1.9	-	0.3
O. universa	3.3	5.6	2.4	1.3	0.3	0.6	0.7	-	0.6	0.4	1.3	-	0.6	-	-	0.3
Pulleniatina finalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. obliquiloculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. praecursor	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-
P. primalis	-	-	-	-	-	-	-	-	1.6	-	2.2	-	1.2	0.3	-	-
P. sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphaeroidinella dehiscens	0.3	-	-	0.3	3.7	-	0.3	-	-	-	-	-	-	-	-	-
S. excavata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphaeroidinellopsis seminulina		-	-	-	-	-	0.3	-	-	0.7	1.9	0.5	-	1.2	0.4	0.6
S. subdehiscens	-	-	-	0.9	2.1	-	2.1	-	0.3	1.1	5.3	-	-	0.6	0.4	1.4
Turborotalita humilis	-	-	0.3	-	0.3	0.3	-	-	0.3	-	-	-	-	0.3	-	0.6
Total Counts:	338	319	374	318	377	343	288	299	315	284	319	398	329	321	274	350
Diversity:	32	33	29	32	37	37	35	35	33	31	34	29	29	32	27	29

Table 6. Relative percent abundance of planktic foraminifers, Caribbean Hole 502A, Cores 35-50.

Core: Sample No: Depth in Meters:	35 33-1 131.9	36 34-1 134.9	37 35-1 138.0	38 36-1 141.5	39 37-1 144.5	40 38-1 146.4	41 39-1 147.9	42 40-1 150.9	43 41-1 153.8	44 42-1 156.7	45 43-1 158.9	46 44-1 162.0	47 45-1 164.4	48 46-1 166.9	49 47-1 168.9	50 48-1 171.9
Candeina nitida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Catapsydrax sp.	-	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-	-
Globigerinella aequilateralis	1.4	-	0.5	0.5	0.3	-	-	-	0.9	0.6	0.9	0.6	1.6	0.3	-	0.6
G. praesiphonifera	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Globigerina apertura	0.3	-	0.3	-	1.7	0.3	2.0	-	2.9	-	2.7	1.8	2.0	1.6	0.7	1.8
G. bulloides	2.7	5.6	10.4	4.9	6.2	3.4	2.7	0.3	0.6	4.2	3.8	2.1	0.7	4.1	1.1	0.3
G. calida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. cariacoensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. decoraperta	2.7	2.0	1.8	1.1	2.5	0.9	0.7	1.9	7.5	2.4	2.4	4.5	4.6	3.5	1.4	0.9
G. digitata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. druryi	0.7	0.5	-	0.5	0.3	0.3	0.7	-	-	-	-	-	-	-	0.4	-
G. falconensis	-	0.7	0.5	3.0	0.6	2.8	1.0	-	0.3	0.9	0.3	0.6	0.3	0.9	-	0.9
G. foliata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. incisa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. nepenthes	0.3	-	-	1.1	1.1	-	-	-	0.9	-	-	-	-	-	-	0.6
G. obesa	1.7	-	-	0.3	0.3	-	-	-	1.4	-	0.9	-	0.3	0.3	0.4	-
G. praecalida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. praedigitata	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. pseudobesa	-	-	-	-	-	-	-	-	-	0.3	-	-	-	0.3	-	-
G. quadrilatera	0.3	1.2	1.0	0.5	0.8	0.6	1.0	-	1.1	1.2	1.5	1.2	0.3	1.6	0.4	0.3
G. rubescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. cf. *seiglei*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. sp.	-	-	-	-	-	0.3	-	-	-	-	-	0.6	-	-	-	-
G. woodi	3.1	1.2	1.0	2.5	1.4	1.5	1.3	1.0	4.3	2.1	3.6	1.5	2.6	2.5	1.8	1.5

Globigerinita glutinata	11.0	19.3	8.1	10.7	5.9	6.5	3.7	1.6	2.9	1.8	4.7	1.8	4.2	6.6	0.7	3.4
G. iota	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. parkerae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. uvula	0.7	–	0.3	–	–	–	–	–	0.3	–	0.6	–	–	–	–	–
Globigerinoides bollii	0.3	0.2	0.3	1.6	0.3	0.3	0.7	–	–	–	–	1.2	–	0.3	–	–
G. bulloideus	–	0.2	–	–	–	–	0.3	–	0.3	–	0.9	1.2	1.0	0.9	–	0.6
G. conglobatus	–	–	–	–	–	–	–	–	0.6	–	–	0.3	–	–	–	0.3
G. extremus	1.4	1.0	3.0	–	0.3	–	2.0	–	3.7	1.5	1.2	2.1	2.3	2.2	–	0.9
G. fistulosus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. kennetti	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. obliquus	11.6	9.0	2.3	3.3	8.2	7.1	4.0	1.3	13.2	13.7	6.2	5.1	4.9	4.7	4.3	4.0
G. pyramidalis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. quadrilobatus	–	0.2	–	–	–	–	–	–	–	1.2	0.6	–	–	0.3	–	0.3
G. ruber	–	–	–	–	–	–	–	–	–	0.3	–	–	–	–	–	–
G. sacculifer	1.4	1.2	1.5	0.5	1.4	–	1.3	–	1.1	4.2	0.9	0.6	2.0	0.9	1.4	2.4
G. seiglei	–	0.2	–	–	–	–	–	–	0.6	–	–	–	–	–	–	–
G. sp.	–	–	–	–	–	–	–	–	0.3	–	–	–	0.3	0.3	–	0.3
G. tenellus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. trilobus	8.2	2.4	3.0	0.5	5.1	4.6	1.3	2.5	2.9	5.4	3.0	1.5	2.9	3.1	2.5	4.6
Globoquadrina altispira	–	1.0	0.5	–	–	0.6	1.0	–	0.6	0.9	1.8	3.9	6.5	0.9	0.7	1.2
G. conglomerata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. pseudofoliata	–	–	0.5	–	–	–	–	–	–	–	–	–	–	–	–	–
G. sp.	–	–	–	–	0.3	0.6	–	–	–	–	–	0.9	–	–	–	
G. venezuelana	–	–	–	1.1	–	–	1.7	–	–	–	–	0.9	–	–	–	–
Globorotalia continuosa	–	–	–	–	0.6	–	–	–	–	–	–	–	–	–	–	–
G. conoidea	–	–	–	–	–	0.3	–	1.0	–	–	–	–	–	–	–	–
G. conomiozea	–	–	–	–	0.3	0.6	1.0	–	0.9	0.9	–	–	–	0.9	0.7	0.6

(continued)

Table 6 (continued)

Core:	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
Sample No:	33-1	34-1	35-1	36-1	37-1	38-1	39-1	40-1	41-1	42-1	43-1	44-1	45-1	46-1	47-1	48-1
Depth in Meters:	131.9	134.9	138.0	141.5	144.5	146.4	147.9	150.9	153.8	156.7	158.9	162.0	164.4	166.9	168.9	171.9
G. crassaformis oceanica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. crassaformis ronda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. crassaformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. crassula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. exilis	-	-	-	0.5	2.5	1.2	1.3	-	-	0.9	-	-	0.3	-	-	0.3
G. flexuosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. inflata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. juanai	-	-	-	-	-	-	-	-	-	-	-	-	0.7	-	1.1	-
G. limbata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. margaritae	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. menardii	1.7	-	5.6	11.0	16.1	9.6	8.1	2.5	4.3	12.2	3.8	-	0.3	-	0.4	1.8
G. merotumida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. miocenica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. miozea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. pleisiotumida	-	-	-	0.3	0.8	2.2	1.0	0.3	0.9	0.9	3.3	0.9	1.0	-	0.4	-
G. scitula	-	0.5	-	0.3	0.3	-	-	-	0.9	-	0.9	2.1	0.7	0.3	-	-
G. sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. tosaensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. truncatulinoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. tumida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. ungulata	-	-	0.5	0.5	1.1	0.9	1.0	0.6	-	-	-	-	-	-	-	-
Globorotaloides hexagonus	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-
Hastigerina pelagica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Neogloboquadrina acostaensis s.l.	4.8	0.2	2.8	-	-	2.5	-	-	6.3	4.5	8.9	8.1	6.8	6.3	-	9.5

N. acostaensis s.s.	4.5	13.4	2.3	1.9	1.7	-	0.7	1.0	6.6	5.1	7.1	13.4	5.2	11.9	10.4	8.9
N. atlantica	-	-	1.3	-	-	-	-	-	-	-	-	-	-	-	-	-
N. dutertrei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N. humerosus	3.4	0.5	3.5	0.3	2.8	2.2	3.0	3.5	8.9	7.2	7.1	7.8	2.6	5.7	-	0.9
N. pachyderma f2	7.5	20.5	23.5	28.3	17.5	17.6	19.9	19.4	5.7	9.3	6.5	8.7	11.1	7.9	0.4	8.6
N. pachyderma (left)	3.4	7.1	11.9	12.9	11.9	20.7	17.5	32.4	10.1	10.4	16.0	16.1	26.1	23.0	58.6	34.9
N. pachyderma (right)	12.3	5.6	5.3	2.2	1.7	2.8	0.3	1.9	1.7	0.6	1.8	1.5	0.3	0.3	6.5	1.8
N. pachyderma/dutertrei	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N. pachyderma/humerosa	10.3	3.7	6.3	4.1	4.8	6.8	16.2	27.9	5.7	6.0	5.6	7.8	4.9	5.7	1.1	1.2
N. sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.4	-
N. sp A	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N. sp.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Orbulina bilobata	-	-	-	-	-	-	-	-	-	-	-	-	1.0	-	-	-
O. suturalis	0.3	-	-	-	-	0.3	1.0	-	0.3	-	1.5	0.3	1.3	0.9	-	0.6
O. universa	-	1.0	0.8	0.5	-	0.3	1.0	-	0.6	-	1.2	0.3	1.0	1.6	2.2	0.6
Pulleniatina finalis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. obliquiloculata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. praecursor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
P. primalis	-	-	0.5	-	-	-	0.6	1.0	0.3	-	-	-	-	-	1.1	1.2
P. sp.	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-
Sphaeroidinella dehiscens	-	-	-	-	-	-	-	-	-	0.6	-	-	-	-	-	-
S. excavata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sphaeroidinellopsis seminulina	1.4	0.5	0.8	1.4	0.6	0.3	-	-	-	-	-	0.3	-	-	0.7	-
S. subdehiscens	1.0	-	0.5	3.0	-	0.9	1.3	0.6	0.9	0.9	0.6	0.6	0.3	-	0.4	4.0
Turborotalita humilis	1.0	0.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total Counts:	292	409	395	364	354	324	297	315	348	335	338	335	307	318	278	327
Diversity:	29	28	29	30	32	32	31	18	34	28	30	32	32	30	26	32

Table 7. Relative percent abundance of planktic foraminifers, Caribbean Hole 502A, Cores 51-68.

Core: Sample No: Depth in Meters:	51 50-1 175.9	52 51-1 179.0	53 52-1 181.4	54 53-1 183.4	55 54-1 185.4	56 55-1 187.9	57 56-1 190.0	58 57-1 191.9	59 58-1 194.0	60 59-1 195.4	61 60-1 197.9	62 61-1 200.2	63 62-1 201.5	64 63-1 204.0	65 65-1 207.9	66 66-1 210.0	67 67-1 211.8	68 68-1 213.6
Candeina nitida	0.3	-	-	-	-	0.3	-	-	-	-	-	-	-	0.3	0.3	-	-	-
Catapsydrax sp.	0.6	-	-	-	-	-	-	-	0.4	-	-	-	-	-	-	-	-	-
Globigerinella aequilateralis	-	-	0.3	-	0.3	-	-	-	0.4	-	-	-	-	0.6	0.3	-	-	-
G. praesiphonifera	-	-	-	-	-	-	0.9	-	-	-	-	-	-	-	-	-	-	-
Globigerina apertura	0.8	1.0	-	0.3	2.3	1.5	0.6	0.3	-	0.3	-	-	-	-	2.2	0.3	-	-
G. bulloides	4.8	2.1	0.6	3.3	4.1	4.1	3.4	4.2	5.0	2.3	6.5	2.7	3.4	4.7	11.4	4.7	3.8	-
G. calida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. cariacoensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. decoraperta	2.8	0.8	1.1	3.0	0.9	1.8	0.9	1.2	-	0.3	-	1.3	-	0.3	0.3	1.5	0.7	3.8
G. digitata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. druryi	-	0.5	0.6	-	-	0.6	1.5	-	-	-	-	-	-	2.5	0.6	0.9	-	-
G. falconensis	-	-	-	-	-	0.6	-	0.9	-	-	-	-	-	0.3	0.3	-	0.7	5.8
G. foliata	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	-	-	-	-
G. incisa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. nepenthes	-	-	0.3	3.3	0.6	2.1	4.0	3.3	1.1	4.0	6.5	1.3	2.4	2.5	1.2	1.5	10.3	1.9
G. obesa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. praecalida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. praedigitata	-	-	-	0.3	-	0.6	-	-	-	-	-	-	-	-	-	-	0.3	-
G. pseudobesa	-	0.3	-	0.3	-	-	-	-	0.4	-	-	0.7	0.7	0.3	0.6	-	-	-
G. quadrilatera	2.8	1.8	0.3	-	0.3	-	1.2	-	0.7	1.2	1.6	-	-	-	-	0.3	-	-
G. rubescens	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. cf. *seiglei*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. sp.	0.3	-	0.7	-	-	-	-	-	0.7	-	4.8	-	-	-	-	0.3	1.4	-
G. woodi	2.3	1.8	2.0	2.0	3.2	2.4	1.9	4.5	1.4	2.3	-	2.0	9.0	5.4	5.2	3.8	11.0	9.6

Globigerinita glutinata	6.8	13.3	1.7	5.6	5.5	1.2	0.9	5.7	1.8	2.9	1.6	2.7	2.4	7.9	12.3	9.4	7.6	3.8
G. iota	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. parkerae	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. uvula	–	–	–	–	–	–	–	–	–	–	–	–	–	0.3	–	1.2	0.3	–
Globigerinoides bollii	0.3	1.3	1.7	1.3	1.2	0.6	–	0.9	1.4	–	–	–	–	–	–	0.3	–	–
G. bulloideus	0.3	0.5	0.8	0.7	1.7	2.1	1.9	2.4	2.9	5.2	3.2	2.7	8.6	6.6	5.2	3.5	5.9	13.5
G. conglobatus	–	0.5	–	–	–	–	–	0.6	–	–	–	–	–	–	–	0.3	–	–
G. extremus	1.7	1.8	2.0	4.0	1.7	1.5	1.5	1.8	1.4	0.6	–	–	–	1.9	0.6	1.2	1.7	–
G. fistulosus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. kennetti	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1.9
G. obliquus	13.5	8.3	8.7	11.6	10.5	11.5	10.8	25.8	11.2	14.2	25.8	6.7	15.5	11.4	17.8	15.2	23.8	28.8
G. pyramidalis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. quadrilobatus	1.1	1.0	0.3	1.0	0.9	1.8	–	1.2	1.8	0.6	–	–	0.3	1.6	3.7	0.3	–	–
G. ruber	–	–	–	–	0.6	–	–	–	–	–	–	–	–	–	–	–	–	–
G. sacculifer	4.8	1.6	2.0	4.0	1.2	5.3	1.2	5.7	4.3	1.7	3.2	4.0	1.0	3.8	2.2	5.3	3.4	1.9
G. seiglei	–	–	–	–	0.3	0.3	0.3	0.6	0.4	–	–	–	0.7	1.3	0.3	–	–	–
G. sp.	–	0.3	0.3	–	–	–	–	–	–	0.6	–	–	–	–	–	0.3	–	–
G. tenellus	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. trilobus	4.5	4.2	3.6	11.9	5.0	5.9	5.9	8.7	5.4	5.2	8.1	5.4	6.9	4.7	7.1	5.9	5.2	3.8
Globoquadrina altispira	2.8	7.0	0.3	1.3	2.6	4.4	1.2	0.9	1.1	1.4	1.6	3.4	3.4	1.6	8.3	5.6	2.1	–
G. conglomerata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. pseudofoliata	–	0.3	–	–	0.3	–	–	–	–	–	–	–	–	–	–	–	–	–
G. sp.	–	1.0	0.6	–	–	0.3	–	–	–	–	–	–	–	0.3	–	–	0.3	7.7
G. venezuelana	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0.6	–	–	3.8
Globorotalia continuosa	–	0.3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
G. conoidea	–	–	–	0.3	–	–	–	–	0.4	0.9	–	–	0.7	–	–	–	–	–
G. conomiozea	2.3	7.8	5.0	2.0	2.6	3.2	3.4	2.1	0.4	–	–	–	–	–	–	–	–	–

(continued)

Table 7 (continued)

Core:	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68
Sample No:	50-1	51-1	52-1	53-1	54-1	55-1	56-1	57-1	58-1	59-1	60-1	61-1	62-1	63-1	65-1	66-1	67-1	68-1
Depth in Meters:	175.9	179.0	181.4	183.4	185.4	187.9	190.0	191.9	194.0	195.4	197.9	200.2	201.5	204.0	207.9	210.0	211.8	213.6
G. crassaformis oceanica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. crassaformis ronda	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. crassaformis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. crassula	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. exilis	-	-	-	1.7	1.2	0.3	0.6	-	-	-	-	-	-	-	-	-	-	-
G. flexuosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. inflata	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. juanai	1.4	6.0	2.0	1.0	1.5	-	-	0.9	-	-	-	-	-	0.9	-	0.9	-	-
G. limbata	-	-	-	-	0.9	-	0.9	-	-	-	-	-	-	-	-	-	-	-
G. margaritae	-	-	-	-	-	-	-	0.6	-	-	-	-	-	-	-	-	-	-
G. menardii	3.4	3.4	5.3	16.8	8.2	3.2	9.9	1.8	-	2.6	4.8	1.3	1.7	3.8	0.9	2.6	-	-
G. merotumida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.2	-	-
G. miocenica	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. miozea	-	-	1.1	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-
G. pleisiotumida	5.9	-	2.0	2.6	0.3	0.6	1.5	0.9	0.4	2.6	8.1	5.4	11.7	0.9	0.3	11.4	2.4	1.9
G. scitula	-	1.6	-	0.7	-	0.6	-	1.8	-	0.9	-	-	0.3	0.3	0.9	0.6	0.7	-
G. sp.	-	-	-	-	0.3	-	-	-	-	-	-	-	-	-	-	-	-	-
G. tosaensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. truncatulinoides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. tumida	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
G. ungulata	-	-	-	-	1.2	-	0.6	-	-	-	-	-	-	-	-	-	-	-
Globorotaloides hexagonus	-	-	-	-	0.3	0.3	0.3	-	-	-	-	-	-	-	-	-	-	-
Hastigerina pelagica	-	-	-	-	-		-	-	-	-	-	-	-	-	-	-	-	-
Neogloboquadrina acostaensis s.l.	4.8	3.4	2.5	-	9.6	9.4	2.5	2.1	9.4	10.1	-	26.8	5.5	7.3	2.8	6.2	6.6	3.8

N. acostaensis s.s.	9.9	11.2	14.8	2.6	11.1	16.8	2.5	3.9	11.2	15.3	4.8	8.7	8.6	18.4	7.4	9.1	3.1	5.8
N. atlantica	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
N. dutertrei	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
N. humerosus	–	–	–	–	–	0.9	–	–	–	–	–	–	–	–	–	–	–	–
N. pachyderma f2	–	–	1.4	–	–	–	–	–	4.7	3.2	–	–	–	–	–	–	–	–
N. pachyderma (left)	15.5	0.8	2.5	0.7	10.2	3.2	1.2	1.5	15.1	4.6	1.6	1.3	0.3	1.3	–	–	–	–
N. pachyderma (right)	–	10.4	30.5	0.7	0.9	–	1.5	–	–	0.6	–	–	0.3	–	–	–	–	–
N. pachyderma/dutertrei	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
N. pachyderma/humerosa	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
N. sp.	0.6	–	1.1	–	–	–	–	–	2.2	2.6	–	–	–	–	–	–	–	–
N. sp A	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
N. sp.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Orbulina bilobata	0.3	0.3	–	0.7	0.6	0.6	0.3	1.2	0.7	0.3	–	–	–	–	0.3	0.3	–	–
O. suturalis	0.6	1.0	0.8	3.0	0.9	1.2	0.9	1.2	0.7	0.3	–	1.3	2.8	1.6	1.5	1.8	–	–
O. universa	0.3	2.9	2.0	4.0	2.6	3.8	2.8	6.0	2.5	0.9	–	0.7	4.1	3.2	1.5	0.9	0.3	–
Pulleniatina finalis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P. obliquiloculata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P. praecursor	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
P. primalis	–	–	–	–	–	–	–	–	0.4	2.3	–	–	1.7	0.9	–	–	–	–
P. sp.	–	–	–	–	–	1.8	–	–	–	–	–	0.7	–	–	–	0.9	–	–
Sphaeroidinella dehiscens	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
S. excavata	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Sphaeroidinellopsis seminulina	0.6	0.3	0.3	1.3	0.6	0.9	4.6	1.8	0.7	1.4	1.6	–	1.0	0.3	2.5	2.6	3.4	–
S. subdehiscens	4.2	1.3	1.7	7.6	4.1	4.4	28.1	5.1	9.7	8.4	16.1	20.8	6.6	2.5	1.2	–	4.6	1.9
Turborotalita humilis	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Total Counts:	355	384	357	303	343	339	324	333	278	346	62	149	290	316	325	341	290	52
Diversity:	30	34	33	32	37	36	32	32	32	32	16	20	25	32	30	32	23	16

differences most likely reflect changes in water temperature and salinity (Keller, 1985). An abundance peak of *G. tumida* in Pacific Hole 503A between 7 and 7.5 Ma appears to indicate a warm event, as similar abundance peaks are present in the warm surface water *Globigerinoides* group (Fig. 3). No data for this interval are available for Caribbean Hole 502A. Differences in faunal provinces are also seen in reduced abundances of *Neogloboquadrina dutertrei* and *N. humerosa* in the Caribbean prior to 5.2 Ma and during the last 3 million years. These species population changes imply that, among intermediate-water dwellers, faunal provinces diverged significantly as early as 6.2 million years ago and again between 2 and 3 million years ago.

Surface Dwellers

Relative abundance changes of dominant surface dwellers of Holes 502A and 503A are illustrated in Fig. 3. These species would be affected last by closure of the Pacific-Caribbean gateway. All *Globigerinoides* species show high-frequency abundance fluctuations. Some of the lower peaks, however, are partly caused by intervals of carbonate dissolution and climatic cooling. We ignore, therefore, single-peak abundance changes in favor of overall trends. With these constraints, the only significant change between the western Caribbean and eastern Pacific faunal provinces is an overall greater abundance of *G. triloba* in the Pacific between 5.4 and 2.4 Ma. In fact, the first major and permanent change among surface dwellers begins at 2.4 Ma (Fig. 3). From this time on, *Globigerinoides* species — in particular *G. ruber* — dominate the Caribbean faunal province, whereas in the eastern equatorial Pacific this group declines sharply beginning at 2 Ma.

Abundances of *Globigerinodes ruber* and *G. sacculifer* are controlled by salinity changes, with *G. ruber* generally tolerating a high-salinity, low-nutrient environment better than *G. sacculifer* (Be and Tolderlund, 1971; Thunell *et al.*, 1983). Our data suggest that, beginning at 2.4 Ma, Caribbean surface waters became significantly more saline — similar to the present. This implies that mixing of saline Atlantic surface water with equatorial Pacific water ceased at this time, leading to increased salinity in the Caribbean. It also suggests that the Pacific-Caribbean gateway closed by about 2.4 Ma. Our date is significantly later than the mid-Pliocene closure previously estimated by Kaneps (1979) and Keigwin (1979, 1982a,b), but it is in substantial agreement with a recent study by Gartner *et al.* (1987) based on nannofossil provinces, and by Crouch and Prell (1979) based on the distribution of the benthic foraminifer *Amphistegina gibbosa*.

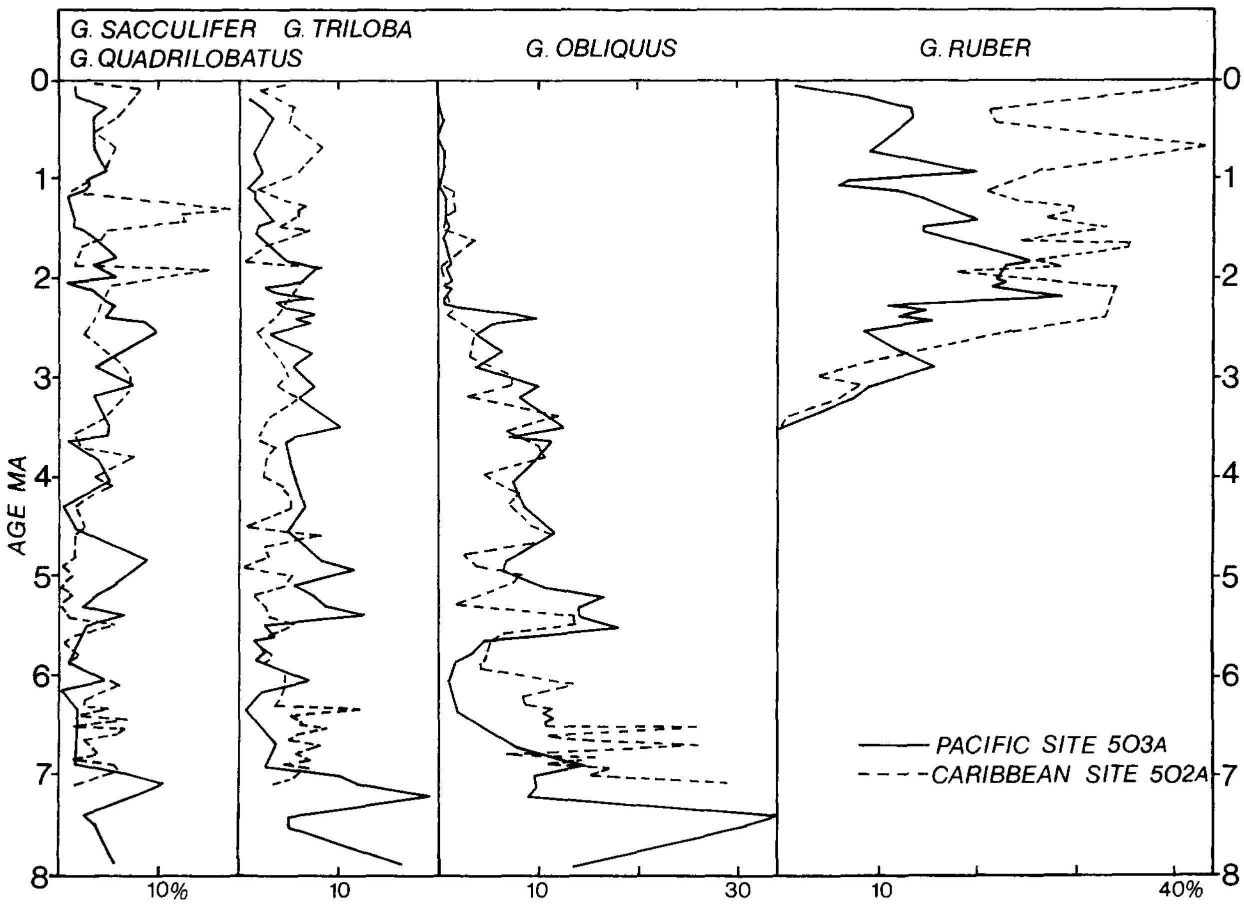

Fig. 3. DSDP Sites 502A and 503A: Relative abundance of dominant planktic foraminiferal species living in surface waters above 100 m depth as interpreted from relatively light $\delta^{18}O$ values.

CLOSURE OF THE PACIFIC-CARIBBEAN GATEWAY

Differences between Caribbean and eastern Pacific faunal provinces are best illustrated by cumulative percent abundances of intermediate and surface dwellers as shown in Fig. 4. The oxygen isotope record of *Globigerinoides sacculifer* based on data from Keigwin (1982b) and Prell (1982) is also shown. Additional non-faunal parameters that bear on closure of the Pacific-Caribbean gateway are illustrated in Fig. 5. Three major events that affected the closure of the Pacific-Caribbean gateway can be identified in the faunal provinces during the past 8 million years, at 6.2, 4.2, 2.4, and 1.8 Ma.

Prior to 6.2 Ma, faunal provinces were similar in the Caribbean and eastern Pacific, implying unrestricted flow of surface and intermediate waters. Essentially similar benthic oxygen isotope values at Holes 502A and 503A support this conclusion (Fig. 5). Two episodes of major volcanic activity occurred in Central America between 7-7.4 Ma and 5.4-6.1 Ma (Ledbetter, 1982). Caribbean carbonate values were an average of 20% lower than in the Pacific, but they gradually increased after 6.2 Ma and approached Pacific values after 3.8 Ma (Fig. 5). This increase may be due to a decreasing influx of old corrosive Antarctic bottom water (AABW) and an increase of North Atlantic deep water (NADW) in the Caribbean, as also suggested by upwelling. At 6.2 Ma, major upwelling (*N. pachyderma*) began in the western Caribbean, indicating restricted flow of intermediate water across the Pacific-Caribbean gateway and deflection northeastward strengthening the Gulf Stream (Fig. 4). Evidence for this is seen in the first intensive erosion on the Blake Plateau (Kaneps, 1979). Further evidence for a change is seen in benthic isotope data (Fig. 5).

Caribbean benthic $\delta^{13}C$ values were significantly enriched relative to the Pacific (Keigwin, 1982a,b). This is believed to be due to NADW production (Blanc *et al.*, 1980). At 6.2 Ma, eastern Pacific bottom water temperature cooled relative to the Caribbean, and there was a permanent shift in the $\delta^{13}C$ of both regions. The $\delta^{13}C$ shift is explained by increased production of NADW (Bender and Keigwin, 1979) and/or by termination of deep to intermediate water exchange through the Pacific-Caribbean gateway (Keigwin, 1982a). The latter explanation is favored by our faunal data. Benthic isotope trends were essentially parallel after 6.2 Ma, indicating no further major changes in bottom-water circulation (Fig. 5).

Figure 4 illustrates that, among surface dwellers, there was an overall decrease in the Caribbean relative to the Pacific beginning at 5.4 Ma, coincident with a global cool event and widespread hiatus (NH7, Fig. 5). Planktic $\delta^{18}O$ values were similar in the Caribbean and eastern Pacific prior to 4.2 Ma, but

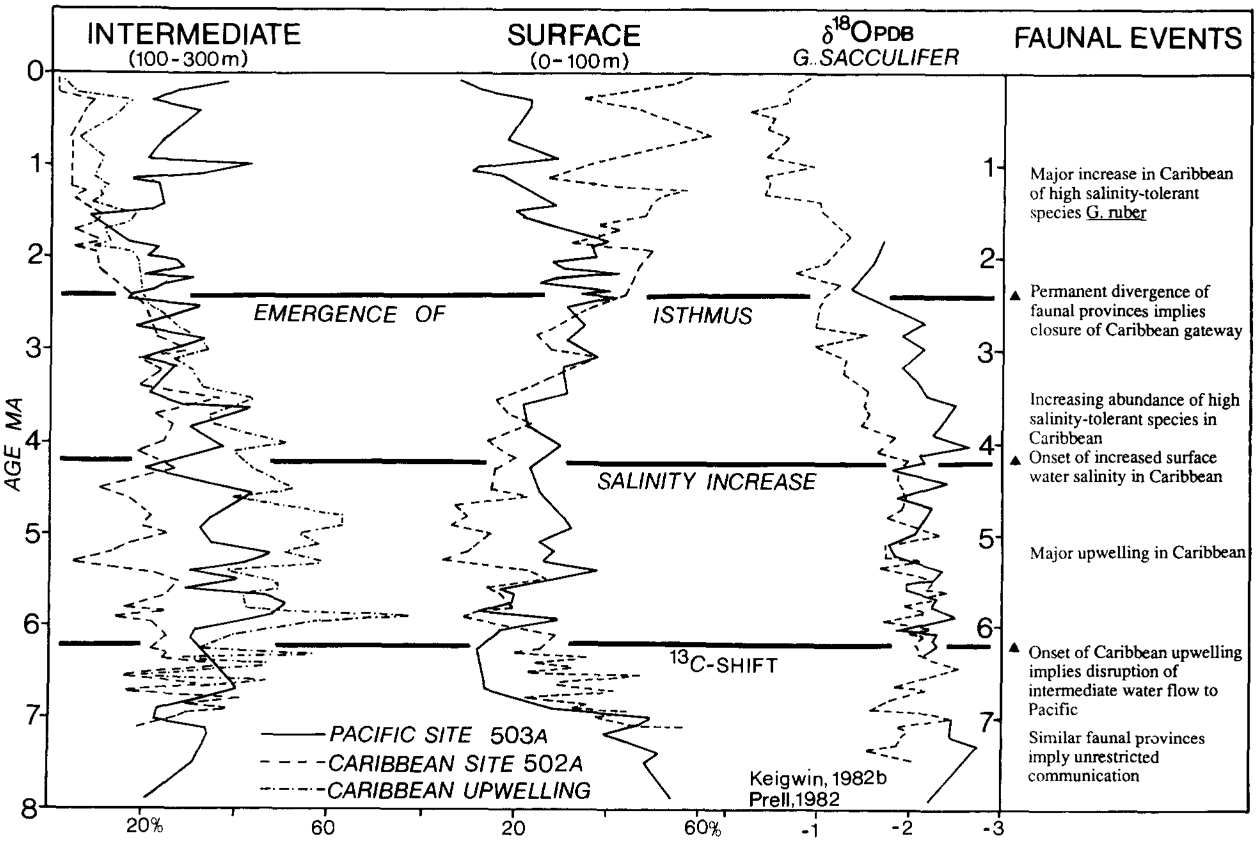

Fig. 4. Variations in faunal provinces of DSDP Sites 502A and 503A as observed in cumulative abundance curves of intermediate (100-300 m) and surface (0-100 m) water-dwelling planktic foraminifers, with major faunal events indicated. The planktic oxygen isotope record of *G. sacculifer* from Keigwin (1982b) and Prell (1982) is given for comparison. Prell's high-resolution data were adjusted to our wider sample spacing by selecting one interval per core and averaging three samples.

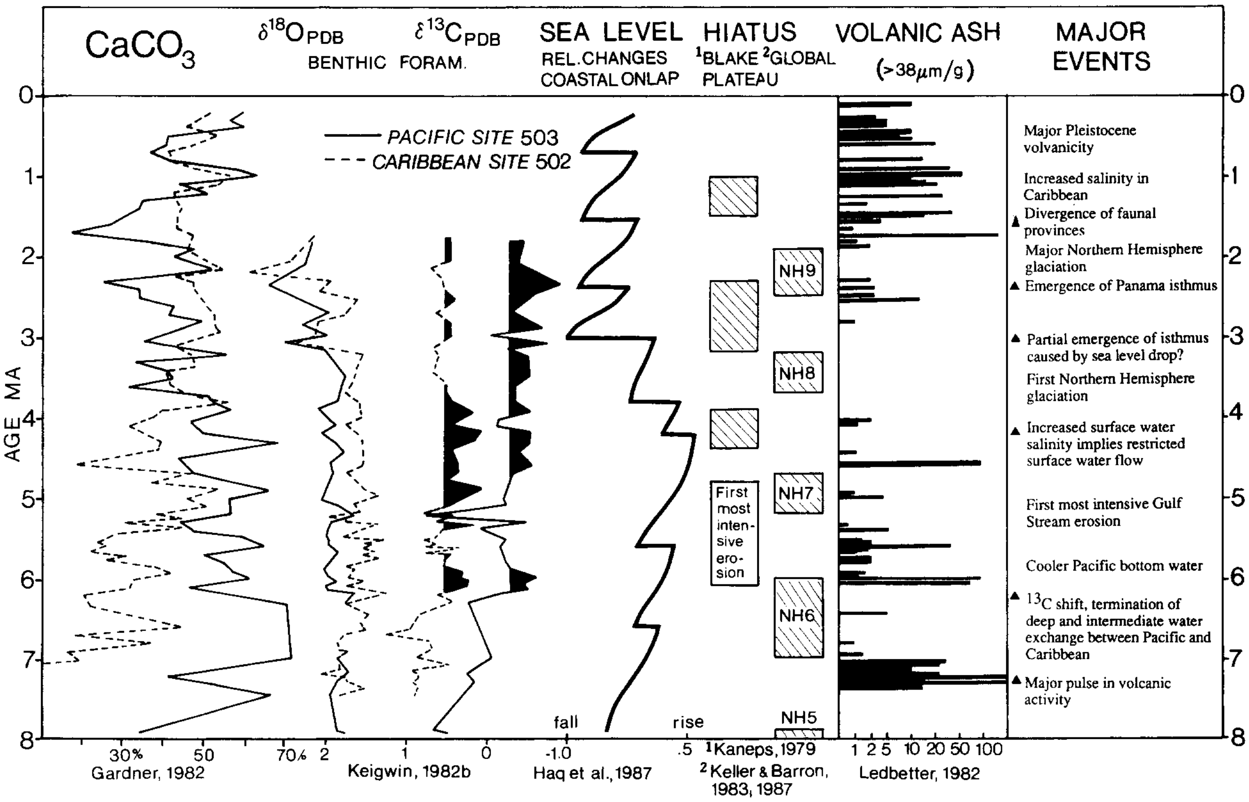

Fig. 5. Late Neogene record of volcanic ash, percent carbonate, and benthic foraminifers of DSDP Sites 502A and 503A compared with sea level changes, widespread hiatus events, and erosion on the Blake Plateau. Major events in the closure history of the Pacific-Caribbean gateway are indicated. Carbonate data from Gardner (1982) based on three sample values averaged at approximately 100,000 year intervals.

were slightly heavier in the Caribbean between 5.4 and 4.2 Ma (Fig. 4) and suggest either cooler surface-water temperatures or increased salinity. By 3.8 Ma, carbonate reached its present average values in the Caribbean and decreased in the eastern equatorial Pacific. Carbon-13 data suggest that this carbonate switch may be related to higher productivity in the Caribbean (Fig. 5).

Beginning at 4.2 Ma, planktic $\delta^{18}O$ values in the Caribbean became significantly heavier than in the eastern Pacific (Fig. 4, Keigwin, 1982a). A similar trend was observed by Oberhansli and Hemleben (1984) in eastern Caribbean DSDP Sites 541 and 543. Both authors interpreted this isotopic shift as an increase in surface-water salinity rather than decreased temperature. The presence of tropical faunal assemblages supports their interpretation. Among surface dwellers in the Caribbean, there was a gradual increase — particularly in the high salinity-tolerant *Globigerinoides sacculifer* — between 4.2 and 2.4 Ma. At the same time, the upwelling species *G. pachyderma* declined. There was little change among eastern Pacific faunas (Hole 503A) during this interval. These data suggest increasingly restricted communication through the Pacific-Caribbean gateway between 4.2 and 2.4 Ma and a strengthened Gulf Stream. This interpretation is supported by erosion on the Blake Plateau between 3.9-4.4 Ma and 2.3-3.2 Ma, which does not correlate with more widespread deep-sea hiatus (NH) events. The latter hiatus was associated with a major drop in sea level (Fig. 5; Haq *et al.*, 1987) and polar cooling that marked the onset of northern hemisphere glaciation by 3 Ma (Shackleton and Kennett, 1975; Shackleton and Opdyke, 1977). On the basis of stable isotope data, Keigwin (1982a) argued that emergence of the Panama isthmus occurred at this time. However, our faunal province data suggest that some surface water communication existed until 2.4 Ma. It appears likely that, coupled with a major sea level drop, the emergence of islands temporarily restricted surface water communication through the Caribbean gateway 3 million years ago.

A major divergence in the faunal provinces of the Caribbean and eastern Pacific began at 2.4 Ma and accelerated after 1.8 Ma (Fig. 4). Between 2.4 and 1.8 Ma, intermediate dwellers began to decrease in the Caribbean and surface dwellers increased, whereas Pacific values remained essentially unchanged. Maximum divergence between Pacific and Caribbean surface and intermediate dwellers began at 1.8 and continues to the present. The sharp increase in surface dwellers at this time is primarily due to the high salinity-tolerant species *Globigerinoides ruber*. Higher surface salinity during the Pleistocene has also been observed in the oxygen isotope and faunal data by Prell and Hays (1976) and Prell (1982).

Our data strongly suggest that the divergence of eastern Pacific and Caribbean faunal provinces beginning at 2.4 Ma reflects initial emergence of the Isthmus of Panama and cessation of sustained surface current flow between the Pacific and Caribbean.

However, the slow divergence of faunal provinces between 2.4 and 1.8 Ma implies at least incipient littoral-neritic leakage across the isthmus until the latest Pliocene-Pleistocene uplift of the Isthmus of Panama. This interpretation is in substantial agreement with Crouch and Poag (1979) who concluded, based on the distribution of the benthic foraminifer *Amphistegina gibbosa*, that closure of the Isthmus of Panama began about 2.5 Ma, with final closure occurring at 1.8 Ma.

Initial closure of the Pacific-Caribbean gateway coincided with a major global cool event, onset of northern hemisphere glaciation dated at 2.5 to 2.4 Ma, (Shackleton and Hall, 1984), increased temperature gradients in the mid- to high-latitude Atlantic (Stein, 1984), a drop in sea level, and a widespread hiatus (NH9, Fig. 5). Subsequently, major volcanic activity occurred during Pleistocene time in Central America (Ledbetter, 1982).

CONCLUSIONS

Planktic foraminiferal faunal provinces of the eastern equatorial Pacific (Hole 503A) and western Caribbean (Hole 502A) indicate the first significant divergence of faunas at 6.2 Ma, coincident with a permanent shift in $\delta^{13}C$. Between 6.2 and 4.2 Ma, a high abundance of the generally cool, high-latitude species *N. pachyderma* in the western Caribbean implies upwelling of cooler intermediate water resulting from a restricted flow path caused by a rising isthmus.

The first significant change among surface water assemblages occurred at 4.2 Ma, coincident with an increased surface water-salinity in the Caribbean implied by $\delta^{18}O$ data. Between 4.2 and 2.4 Ma, a gradual increase in the salinity-tolerant species *Globigerinoides sacculifer* implies an increasingly restricted surface water exchange through the Caribbean gateway.

The most dramatic faunal change began at about 2.4 Ma. Beginning at this time, Caribbean assemblages were increasingly dominated by the high salinity-tolerant species *Globigerinoides ruber*, reflecting higher Atlantic surface-water salinity. This suggests that initial closure of the Pacific-Caribbean gateway and cessation of sustained surface current flow between the Pacific and Caribbean occurred as late as 2.4 Ma.

Maximum divergence of both intermediate and surface dwellers began at about 1.8 Ma and continues to the present. This implies that at least incipient littoral-neritic leakage occurred across the Pacific-Caribbean gateway between 2.4 and 1.8 Ma, with final closure by 1.8 Ma.

Acknowledgements—We wish to thank J. C. Ingle, S. Gartner, K. McDougall, B. MacDonald, J. Barron, and M. L. Gamero for review, discussions, and insightful comments. DSDP samples were provided by the National Science Foundation through the Deep Sea Drilling Project.

REFERENCES

Baldauf, J., 1985. A high resolution late Miocene-Pliocene diatom biostratigraphy for the eastern equatorial Pacific. *Initial Reports of the Deep Sea Drilling Project* **85**, 457-475.

Be, A. W. H., and Hamlin, W. H., 1967. Ecology of Recent planktonic foraminifera, Part 3: Distribution in the North Atlantic during the summer of 1962. *Micropaleontology* **13** (1), 87-106.

Be, A. W. H., and Tolderlund, D. S., 1971. Distribution and ecology of living planktic foraminifera in surface waters of the Atlantic and Indian Oceans. In: *Micropaleontology of the Oceans* (Edited by Funnel, B. M., and Riedel, W. R.), pp. 105-149. Cambridge University Press, London.

Bender, M. L., and Keigwin, L. D., Jr., 1979. Speculations about the upper Miocene change in abyssal Pacific dissolved bicarbonate $\delta^{13}C$. *Earth and Planetary Science Letters* **45**, 383-393.

Blanc, P., Rabussier, D., Vergnand-Grazini, C., and Duplessy, J. C., 1980. North Atlantic Deep Water formed by the later middle Miocene. *Nature* **283**, 553-555.

Crouch, R. W., and Poag, W. C., 1979. *Amphistegina gibbosa* D'Orbigny from the California borderlands: The Caribbean connection. *Journal of Foraminiferal Research* **9** (2), 85-105.

Fairbanks, R. G., Wiebe, P.H., and Be, A. W. H., 1979. Vertical distribution of isotopic composition of living planktonic foraminifera in the western North Atlantic. *Science* **207**, 61-63.

Fairbanks, R. G., Sverdloue, M., Free, R., Wiebe, P. H., and Be, A. W. H., 1982. Vertical distribution and isotopic fractionation of living planktonic foraminifera from the Panama Basin. *Nature* **298**, 847-844.

Gardner, J. V., 1982. High-resolution carbonate and Quaternary organic-carbon stratigraphies for the late Neogene and Quaternary from the western Caribbean and eastern equatorial Pacific. *Initial Reports of the Deep Sea Drilling Project* **68**, 347-364.

Gartner, S., Chow, J., and Stanton, R. J., Jr., 1987. Late Neogene paleoceanography of the eastern Caribbean, the Gulf of Mexico and the eastern equatorial Pacific. *Marine Micropaleontology* **12**, 255-304.

Haq, B. U., Hardenbol, J., and Vail, P. R., 1987. Chronology of fluctuating sea level since the Triassic (250 million years ago to present). *Science* **235**, 1158-1167.

Ingle, J., 1963. Neogene foraminifera from the northeastern Pacific Ocean, Leg 18, DSDP. *Initial Reports of the Deep Sea Drilling Project* **18**, 517-567.

Kaneps, A. G., 1979. Gulf Stream: Velocity fluctuations during the late Cenozoic. *Science* **204**, 297-301.

Keigwin, L. D., Jr., 1979. Pliocene closing of the Isthmus of Panama based on biostratigraphic evidence from nearby Pacific Ocean and Caribbean Sea cores. *Geology* **6**, 630-634.

Keigwin, L. D., Jr., 1982a. Isotopic paleoceanography of the Caribbean and east Pacific: Role of Panama uplift in late Neogene time. *Science* **217**, 350-353.

Keigwin, L. D., Jr., 1982b. Stable isotope stratigraphy and paleoceanography of Sites 502 and 503. *Initial Reports of the Deep Sea Drilling Project* **68**, 445-453.

Keigwin, L. D., Jr., 1982c. Neogene planktonic foraminifera from Deep Sea Drilling Project Sites 502 and 503. *Initial Reports of the Deep Sea Drilling Project* **68**, 269-288.

Keller, G., 1978. Morphologic variation of *Neogloboquadrina pachyderma* (Ehrenberg) in sediments of the marginal and central northeast Pacific Ocean and paleoclimatic interpretation. *Journal of Foraminiferal Research* **8** (3), 208-224.

Keller, G., 1985. Depth stratification of planktonic foraminifera. In: *The Miocene Ocean: Paleoceanography and Biogeography* (Edited by Kennett, J. P.). Geological Society of America, Memoir **163**, 177-193.

Keller, G., and Barron, J. A., 1983. Paleoceanographic implications of Miocene deep-sea hiatuses. *Bulletin of the Geological Society of America* **94**, 590-613.

Keller, G., and Barron, J. A., 1987. Paleodepth distribution of Neogene hiatuses. *Paleoceanography* 2(6), 697-713.

Kennett, J. P., 1968. Latitudinal variation in *Globigerina pachyderma* (Ehrenberg) in surface sediments of the southwest Pacific Ocean. *Micropaleontology* 14(3), 305-318.

Kent, D. V., and Spariosu, D.J., 1982a. Magnetostratigraphy of Caribbean Site 502 Hydraulic piston cores. *Initial Reports of the Deep Sea Drilling Project* 68, 419-434.

Kent, D.V., and Spariosu, D.J., 1982b. Magnetostratigraphy of Caribbean Site 503 Hydraulic piston cores. *Initial Reports of the Deep Sea Drilling Project* 68, 435-440.

Kroopnick, P., 1980. The distribution of ^{13}C in the Atlantic Ocean. *Earth and Planetary Science Letters* 49, 469-484.

Ledbetter, M. T., 1982. Tephrochronology at Sites 502 and 503. *Initial Reports of the Deep Sea Drilling Project* 68, 403-408.

Mullins, H. T., and Neumann, A. C., 1979. Geology of the Miami Terrace and its paleoceanographic implications. *Marine Geology* 30, 205-232.

Oberhansli, H., and Hemleben, C., 1984. Stable isotope record of the Pliocene and Pleistocene planktonic foraminifers from Leg 78A, Sites 541 and 543, on the Barbados Ridge Complex. *Initial Reports of the Deep Sea Drilling Project* 78A, 499-508.

Prell, W., 1982. Oxygen and carbon isotope stratigraphy for the Quaternary of Hole 502B: Evidence for two modes of isotopic variability. *Initial Reports of the Deep Sea Drilling Project* 68, 455-466.

Prell, W., and Hays, J. D., 1976. Late Pleistocene faunal and temperature patterns of the Colombia Basin, Caribbean Sea. *Geological Society of America, Memoir* 145, 201-220.

Reynolds, L. A., and Thunnell, R. C., 1986. Seasonal production and morphologic variation of *Neogloboquadrina pachyderma* (Ehrenberg) in the northeast Pacific. *Micropaleontology* 32(1), 1-18.

Shackleton, N. J., and Kennett, J. P., 1975. Late Cenozoic oxygen and carbon isotope changes at Deep Sea Drilling Project Site 284: Implication for glacial history of the northern hemisphere and Antarctica. *Initial Reports of the Deep Sea Drilling Project* 29, 801-807.

Shackleton, N. J., and Opdyke, N. D., 1977. Oxygen isotope and paleomagnetic evidence for early Pliocene northern hemisphere glaciation. *Nature* 270, 216-219.

Shackleton, N. J., and Hall, M. A., 1984. Oxygen and carbon isotope stratigraphy of Deep Sea Drilling Project Hole 552A: Plio-Pleistocene glacial history. *Initial Reports of the Deep Sea Drilling Project* 81, 599-610.

Stein, R., 1984. *Zur Neogenen Klimaentwicklung in Nordwest-Afrika und Paläo-Ozeanographie in Nordost-Atlantik: Ergebnisse von DSDP Sites 141, 366, 397 und 544B.* Geologisch-Paläontologisches Institut der Universitat Kiel, NR4, 210 p.

Stone, S. M., and Keller, G., 1985. Planktonic foraminiferal biostratigraphy of the Middle America Trench region, DSDP Leg 84. *Initial Reports of the Deep Sea Drilling Project* 84, 419-471.

Thunell, R.C., Curry, W. B., and Honjo, S., 1983. Seasonal variation in the flux of planktonic foraminifera —Time series sediment trap: Results from the Panama Basin. *Earth and Planetary Science Letters* 64, 44-56.

Zenker, C. E., 1986. *The Emergence of the Isthmus of Panama in the Late Neogene and Associated Paleoclimatic and Paleoceanographic Changes.* MS thesis, University of California at Santa Cruz, 80 p.