36. LATE QUATERNARY PLANKTONIC FORAMINIFERS FROM THE PIGMY BASIN, GULF OF MEXICO, SITE 619, DEEP SEA DRILLING PROJECT LEG 96[1]

Barry Kohl, Chevron U.S.A. Inc.[2]

ABSTRACT

Site 619, located in the Pigmy Basin off the coast of Louisiana, penetrated the late Quaternary Ericson Zones X, Y, and Z. The penetrated section can be divided into four intervals. The lower interval (below 157 m sub-bottom) comprises 51 m of displaced sediments which probably originated from the Louisiana continental shelf. The upper three intervals (above 157 m) are dominated by pelagic/hemipelagic sedimentation associated with a closed basin. These are divided on the basis of planktonic foraminifers into Zones X, Y, and Z.

These warm–cool water intervals are identified mainly by using the *Globorotalia menardii* complex (warm) and *G. inflata* (cool). The intervals correlate with published curves taken from piston core samples in the western Gulf of Mexico.

INTRODUCTION

Site 619 was drilled to investigate the Quaternary climatic history of the Pigmy Basin, a blocked canyon–intraslope basin on the middle continental slope off Louisiana in the Gulf of Mexico (Fig. 1). This basin ranges from 3.8 to 7.5 km wide and 20 km long and has a maximum water depth of 2400 m (Bouma, Stelting, et al., this volume).

Site 619 is located toward the center of the basin at 27° 11.61′N; 91°24.54′W, in a water depth of 2274 m. The site was drilled using a hydraulic piston corer (HPC) to 208.7 m sub-bottom and Holocene and late Pleistocene sediments were collected. Twenty-five cores comprising 111.88 m of sediments were recovered from Hole 619. In addition, Hole 619A was cored at the same location and recovered an additional mudline core. Sediments at Site 619 are predominantly clays with some intercalated sands and silts (Site 619 chapter, this volume).

Originally the site drilled in the Orca Basin (Site 618) had been intended as the primary site for investigation of Quaternary biostratigraphy. However, because extensive slumping was encountered at Site 618, the *Glomar Challenger* moved its focus to the alternate Site 619, in the Pigmy Basin. Seismic reflectors indicated a well-stratified section (Bouma, Stelting, et al., this volume).

This study investigates the distribution of Quaternary planktonic and benthic foraminifers at Site 619. The objective is to identify warm and cool intervals penetrated and relate these to the established Quaternary zonation of Ericson and Wollin (1968). Benthic foraminifers are used to recognize displaced sediments derived from shallow-water (neritic) environments.

METHODS

A total of 100 samples from Site 619 were used for quantitative analysis. Planktonic foraminifers from at least one sample from each section of the cores were investigated in detail. Additional samples were checked for possible faunal changes within specific cores.

Volumes used in this study ranged from 10 to 68 cm^3 (9–56 g dry weight) depending on the foraminiferal abundance. Each sample was washed with a fine water spray over a U.S. standard 63-μm sieve and the resultant residue dried. The volume of this residue was calculated as a percentage of the original volume, which was used to calculate foraminiferal abundance per unit volume.

For quantitative analysis, the dry sample was sieved on a 149-μm sieve and the fraction >149 μm split until an aliquot included 300 or more planktonic foraminifers. All of the planktonic foraminifers were identified, counted, and each species abundance calculated as the percentage of the total planktonic foraminiferal assemblage for each sample. Benthic species were also identified and their total number was calculated for each sample to determine a planktonic/benthic ratio. Some samples contained a sparse foraminiferal fauna; in that case the entire assemblage was counted.

The abundances of 34 planktonic species identified are shown in Appendix Table 1. Relative abundances are indicated in the table as follows: A, abundant ($>10\%$); C, common (5–10%); F, few (2–5%); R, rare ($<2\%$), /, present (for samples with planktonic counts <30 specimens). Abundance data for other microfossils are given as relative values.

BIOSTRATIGRAPHY

Because of sedimentation rates as high as 194 cm/1000 yr. (Site 619 chapter, this volume) and shallow penetration of 208 m, the oldest sediments reached at Site 619 were of late Pleistocene age. The foraminiferal biostratigraphic framework proposed by Ericson and Wollin (1968) and expanded for the Gulf of Mexico by Kennett and Huddlestun (1972) is used to subdivide the Quaternary (Fig. 2). In addition to foraminifers, subdivision and dating of the section penetrated at Site 619 was achieved through the use of tephrochronology, calcareous nannoplankton, magnetic stratigraphy, and oxygen-isotope stratigraphy (see other chronostratigraphy chapters, this volume).

Site 619 was chosen for a quantitative analysis of planktonic foraminifers because it has a nearly undisturbed sedimentary record for the late Quaternary. It was cored specifically to determine the climatic history of the Gulf of Mexico through an interdisciplinary approach.

There have been several previous studies of the late Quaternary of the Gulf of Mexico, including those of Kennett and Huddlestun (1972), Thunell (1976, 1984), Beard (1973), and Brunner and Keigwin (1981). A study

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[2] Address: Chevron U.S.A. Inc., 935 Gravier St., New Orleans, LA 70112.

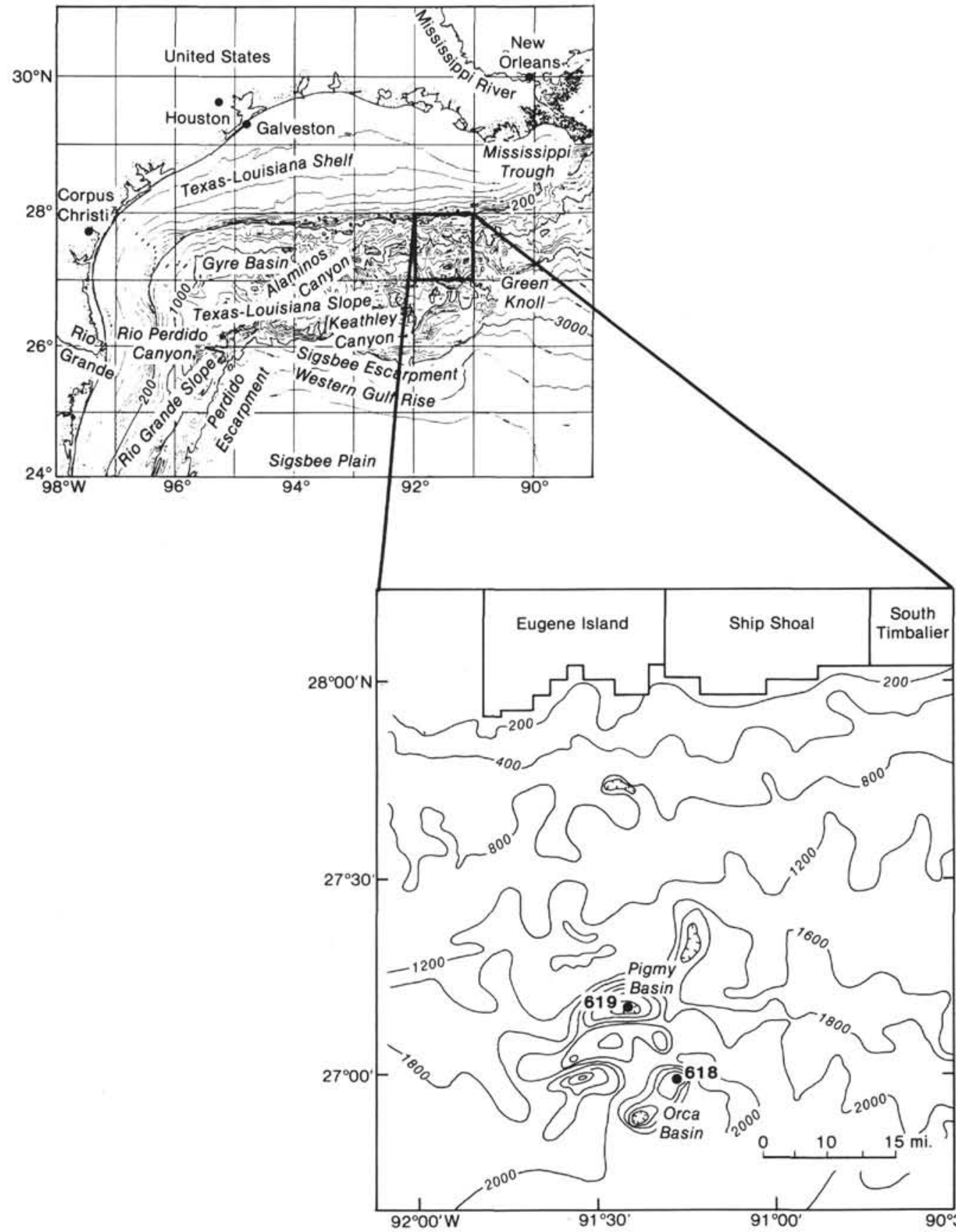

Figure 1. Bathymetric map showing the location of Site 618 in Orca Basin and Site 619 in Pigmy Basin. Contour intervals in meters. After Martin and Bouma (1978) and U.S.G.S. data.

of the late Quaternary of the Caribbean by Rögl and Bolli (1973) is also applicable to the Gulf of Mexico sediments.

Quaternary Zonation at Site 619

Zones X through Z of Ericson and Wollin (1968) as well as a few subzones of Kennett and Huddlestun (1972) can be recognized at Site 619. Correlation with oxygen-isotope stratigraphy is presented in Williams and Kohl (this volume).

Ericson Zone Z (Holocene, isotope Stage 1 of Emiliani, 1971) was recovered from 0 to 5.0 m sub-bottom. The top of the Holocene is defined by the sediment/water interface and is characterized by a planktonic foraminiferal ooze near the top containing abundant *Globorotalia menardii* and *G. tumida*. The sample from the sediment/water interface in Hole 619A was stained using Rose Bengal but no benthic foraminifers took the stain, indicating that the upper few centimeters of the Holocene are missing. The base of Zone Z is usually recognized in the Gulf of Mexico by a downward reduction of the *G. menardii* complex and a coincident last appearance datum (LAD) of *G. inflata* (Beard, 1973). The base of Zone Z at Site 619 is not well defined be-

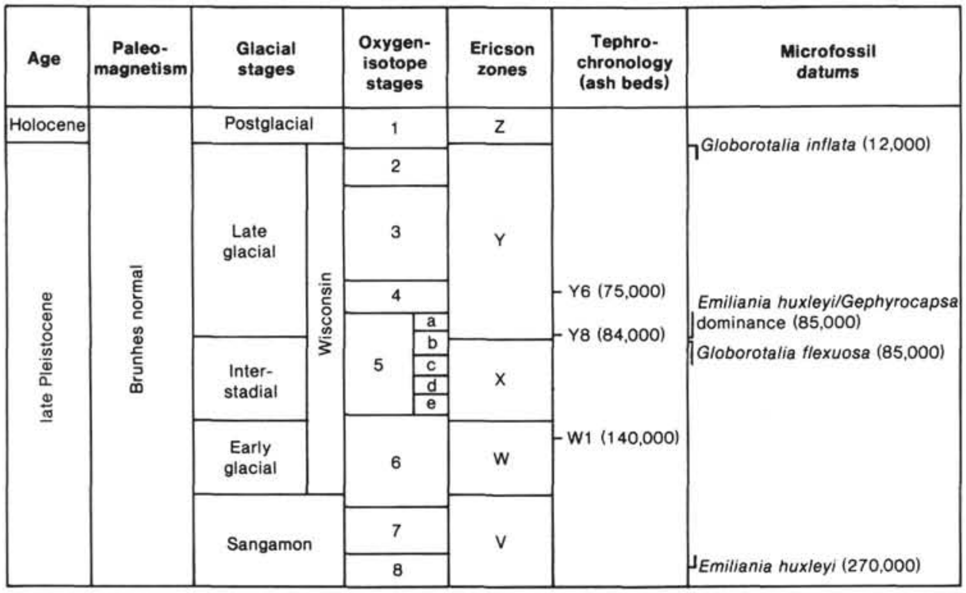

Figure 2. Late Quaternary zonation of the Gulf of Mexico. After Rabek et al. (1985), Williams (1984), and others. The dates used in the two right-hand columns are in years.

cause of a transitional zone below the common occurrence of *G. menardii*. This interval contains sparse foraminifers and continues from 5.0 to 8.75 m sub-bottom, which is the uppermost occurrence of *G. inflata*.

Sediments from Ericson Zone Y (late Wisconsin glacial, isotope Stages 2–4 and 5a–b [part]) were recovered from 5.0 to 147 m sub-bottom. The top of this Zone Y is characterized by a poorly developed foraminiferal fauna. The LAD of *G. inflata* occurs at 8.75 m sub-bottom, marking the beginning of a warming trend at the end of the Pleistocene. *G. inflata* is generally common to abundant in Zone Y below 25 m sub-bottom. The base of Zone Y is marked by the disappearance (LAD) of *G. flexuosa* and the coincident dominance of *Emiliana huxleyi* over *Gephyrocapsa* spp. above the boundary (Constans and Parker, this, volume). The Y8 ash, which occurs in the Y8 subzone of Kennett and Huddlestun (1972), occurs as a 3- to 4-cm-thick layer at 142 m sub-bottom depth at Site 619. The Y8 ash is dated at 84,000 yr. ago (Ledbetter, this volume).

Sediments from Ericson Zone X (Wisconsin interstadial isotope Stages 5b [part] to 5c) were recovered from 147 to 157 m sub-bottom. The top of Zone X is defined by the disappearance (LAD) of *Globorotalia flexuosa*. It is characterized by an abundance of *G. menardii s.l.* and an occurrence of *Globorotaloides hexagona*. The cool-water planktonic foraminifer *Globorotalia inflata* is rare to absent.

It is questionable whether or not the interval from 157 to 208 m sub-bottom also belongs to Ericson Zone X. Below 157 m there is a rapid reduction in foraminiferal fauna and in the recovery percentages of cores, resulting in a questionable data base for determination of oxygen-isotope stages (Williams and Kohl, this volume). Normally in the Gulf of Mexico, the base of Zone X is marked by a change from dominant warm-water planktonic foraminifers above to dominant cool-water planktonic foraminifers with abundant *G. inflata* below the X/W boundary. A zone of dominant *G. inflata* was not observed below 157 m, suggesting that Zone W of Ericson and Wollin was probably not reached.

PALEOCLIMATOLOGY

The distribution of Holocene planktonic foraminifers in the Gulf of Mexico has been documented by Snyder (1978) and Brunner (1979). Bé and Tolderlund (1971) and Boltovskoy (1969), among others, have charted planktonic foraminifer distribution in the Atlantic Ocean. Rögl and Bolli (1973) summarized the ecologic distribution of selected planktonic foraminifers based on temperature and utilized these data to interpret the Quaternary paleoclimate at DSDP Site 147, in the Cariaco Basin, Caribbean Sea (Fig. 3). In the modern Gulf of Mexico, the most frequent planktonic foraminifers are those that live in the transitional, subtropical, and tropical zoogeographic zones.

Studies by Ericson and Wollin (1970) indicated that the *Globorotalia menardii* complex is the most sensitive climatic indicator for the Quaternary. The *G. menardii* complex includes *G. menardii, G. tumida* and *G. flexuosa*. An inverse relationship between *G. menardii* and *G. inflata* in Gulf of Mexico cores is well established (Kennett and Huddlestun, 1972; Beard, 1973). The *G. menardii* complex is dominant in the warm intervals (interglacials and interstadials) whereas *G. inflata* is dominant in the glacials. Within the Ericson zones, subtle temperature changes can be determined by comparing frequency curves of transitional–tropical species.

At Site 619, the frequency curves of many temperature-sensitive species in Ericson Zone Y correlate closely with the curves of Beard (1973) and Kennett and Huddlestun (1972) for the western Gulf of Mexico.

A detailed analysis of these curves is beyond the scope of this chapter. However, the inverse relationship of the *G, menardii* complex and *G. inflata* was used successfully to subdivide the section encountered at Site 619.

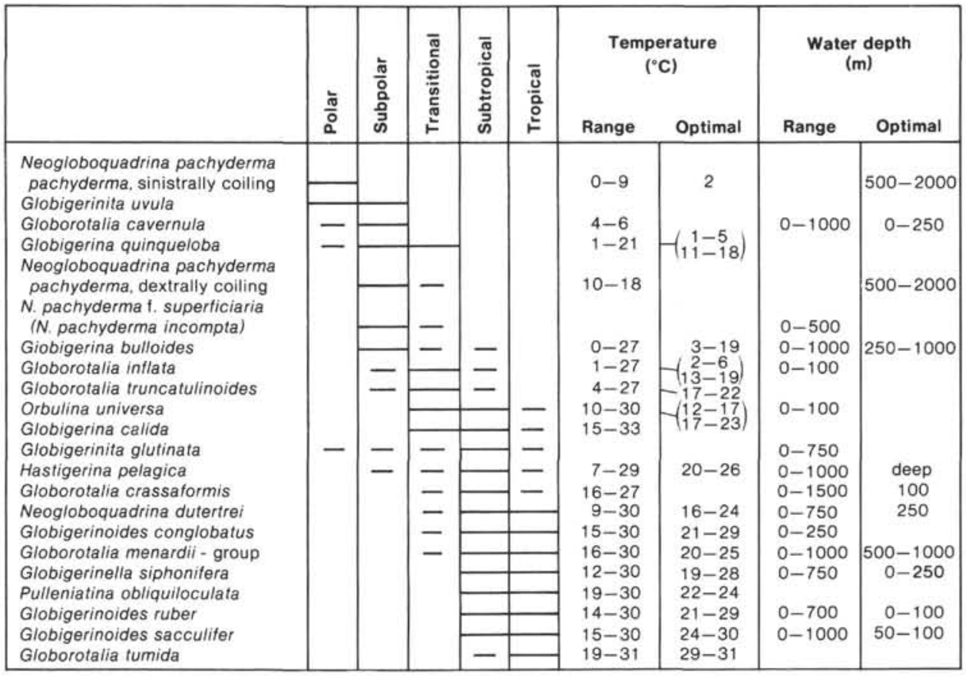

Figure 3. Chart of temperature-sensitive planktonic foraminifers. From Rögl and Bolli (1973), after Bé and Tolderlund (1971), and others.

DEPOSITIONAL HISTORY

Changes in volume of the washed residue >63 μm and intervals of sparse foraminiferal faunas are indicators of sedimentary changes (Fig. 4). In most cases, the increase in volume of residues >63 μm indicates an increase in the abundance of planktonic foraminifers per unit volume and a subsequent decrease of terrigenous clastic input into the Pigmy Basin.

However, the interval from 157 to 208 m sub-bottom has large residues containing abundant quartz sand and low abundances of biogenic carbonate. This indicates rapid deposition. The residues also contain common to abundant benthic foraminifers from a neritic environment (Fig. 4). *Ammonia, Brizalina, Bulimina, Elphidium*, and *Hanzawaia* are genera that live on the continental shelf of the Recent Gulf of Mexico (Phleger, 1951; Poag, 1981). The occurrence of these taxa in association with the quartz sand supports a shallow-water origin for these sediments.

Above 157 m, the volume percentage changes are more a direct indicator of the sedimentation rate; that is, low values indicate a greater contribution of silt and clay and high values indicate lower sedimentation and/or higher productivity of planktonic foraminifers. The sparse faunal intervals numbered 1 through 6 (Fig. 4) have very small residues. The sparsity of planktonic foraminifers in these intervals may represent meltwater episodes related to deglaciation, which would have decreased salinity and contributed large volumes of pelagic clay and silt to the Gulf of Mexico during the late Pleistocene (Williams and Kohl, this volume).

The interval from 100 to 157 m sub-bottom shows an increase in the number of planktonic foraminifers per unit volume and thus a lower sedimentation rate of terrigenous clastics. Conversely, the interval from 35 to 100 m shows a reduction of biogenic carbonate which indicates an increase in the sedimentation rate (Fig. 4).

Reworked Pleistocene planktonic foraminifers occur in Samples 619-10-3, 103-108 cm, 619-13-2, 25-30 cm, and 619-13-3, 25-30 cm. Pliocene planktonic foraminifers are rare, occurring usually as single specimens of several species in the following samples: 619-3-2, 25-30 cm, 619-6-2, 103-108 cm, 619-13-2, 25-30 cm, 619-13-3, 25-30 cm, 619-22,CC, and 619-23,CC. The following species are representative of the early and late Pliocene:

Globigerina nepenthes Todd
Globigerinoides extremus Bolli and Bermudez
Globoquadrina altispira (Cushman and Jarvis)
Globorotalia cf. *Gl. margaritae* Bolli and Bermudez
Globorotalia miocenica Palmer
Globorotalia multicamerata Cushman and Jarvis
Sphaeroidinellopsis seminulina (Schwager)
Sphaeroidinellopsis subdehiscens Blow

Most reworked Pleistocene and Pliocene foraminifers at Site 619 are interpreted to be either slumps derived from the flanks of surrounding salt diapirs or erosion of Pliocene–Pleistocene strata exposed around the Pigmy Basin.

There are rare occurrences of Upper Cretaceous planktonic foraminifers and radiolarians for the interval 619-20,CC through 619-25,CC (Appendix Table 1). The Cretaceous radiolarians are represented by the genus *Dictyomitra* and the Cretaceous planktonic foraminifers are dominated by *Heterohelix* spp. These reworked Cretaceous taxa occur in a sandy interval that also has a high percentage of neritic benthic foraminifers. Cretaceous foraminifers and radiolarians are the same genera as those occurring in the sandy intervals in the Mississippi Fan sites (Kohl et al., 1985; Morley and Kohl, this volume).

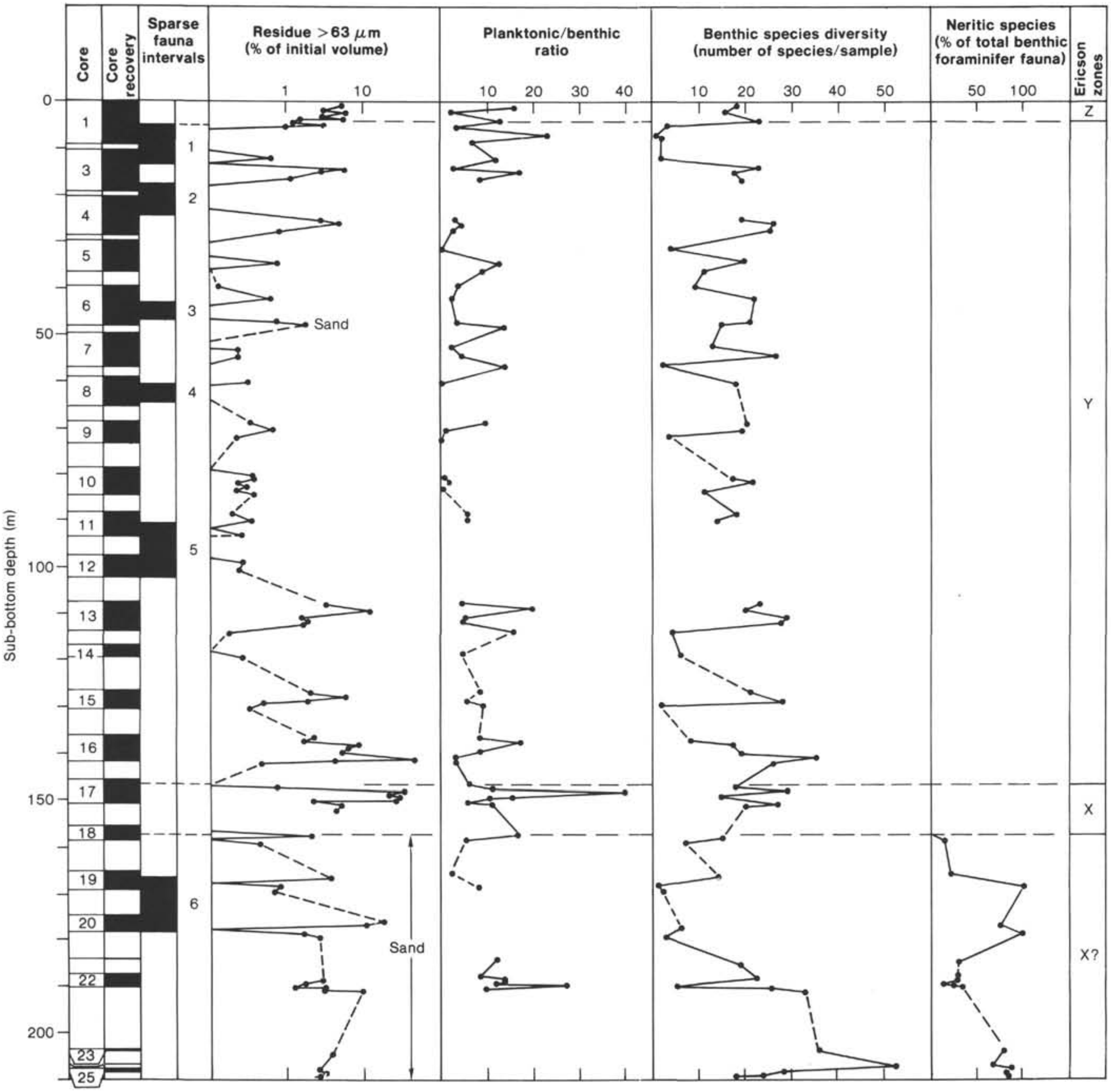

Figure 4. Factors depicting the depositional history at Site 619. Planktonic/benthic ratio, benthic species diversity, and neritic species refer to >149-μm fraction.

The microfaunal evidence suggests that Pigmy Basin was open to bottom sediment transport during deposition of the sediments between 157 and 208 m sub-bottom. These sediments were derived from the Louisiana continental shelf and probably transported as a density flow.

Above 157 m sub-bottom, no shallow-water (neritic) benthic foraminifers, reworked Cretaceous foraminifers, or persistent siliciclastics were found in the samples used for this study. This indicates that the Pigmy Basin was closed as it is today, preventing density flows from entering the basin. The sedimentation above 157 m sub-bottom is composed almost entirely of pelagic/hemipelagic silt and mud. Intervals of increased hemipelagic sedimentation can be recognized by the decrease in the percentage of calcareous bioclastic constituents in the washed residue (Fig. 4).

CONCLUSIONS

The section penetrated in Site 619 can be divided into four intervals on the basis of planktonic foraminiferal faunas (Fig. 5).

0–5 m	Zone Z (Holocene)
5–147 m	Zone Y (late Wisconsin glacial)
147–157 m	Zone X (Wisconsin interstadial)
157–208 m	Zone X? (zone of faunal mixing)

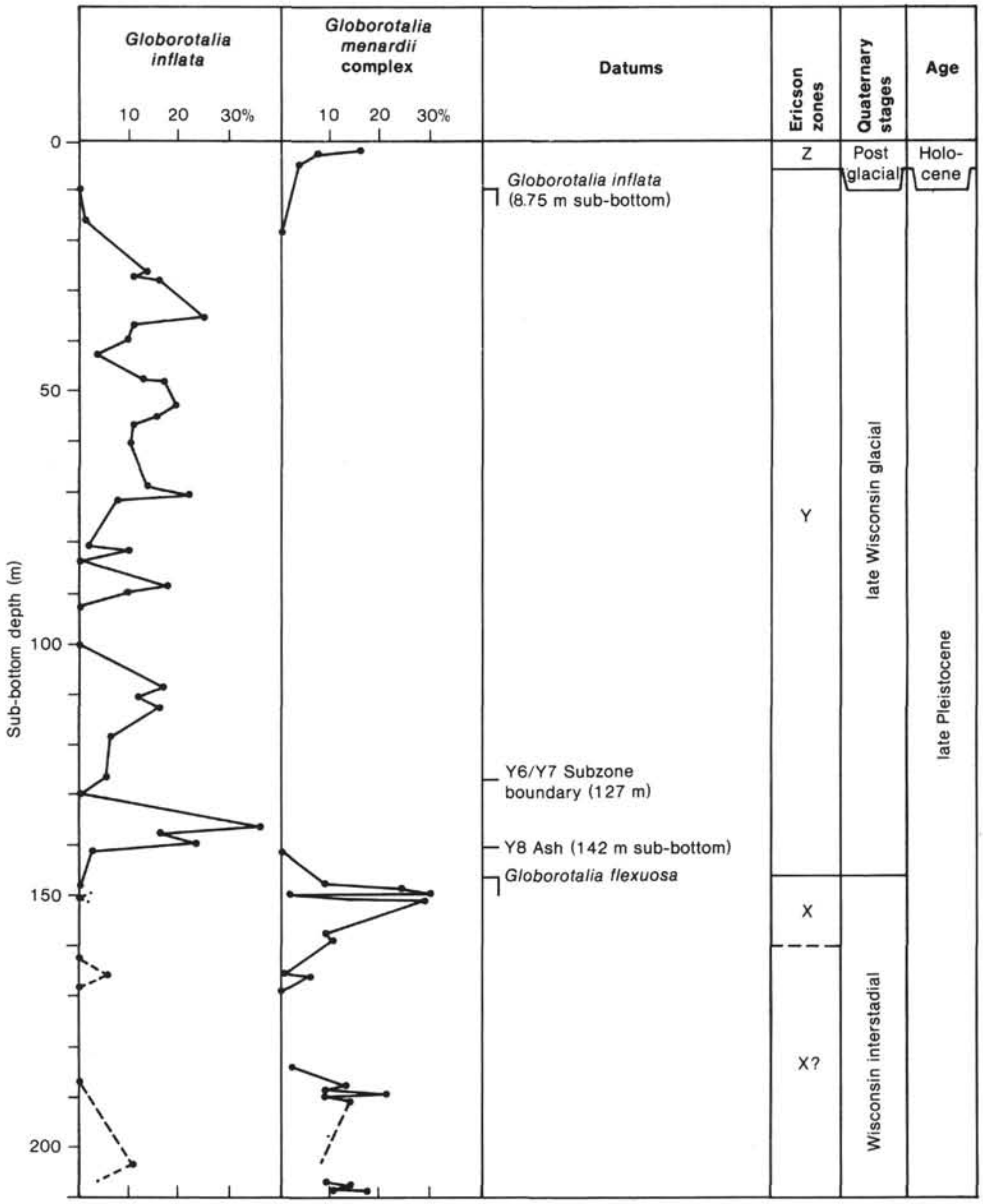

Figure 5. Summary of relationship of *Globorotalia inflata* (cool-water indicator) and *Globorotalia menardii* complex (warm-water indicator) to Ericson zones and various datums at Site 619.

The age and paleoenvironment of the deepest interval (157–208 m) is unclear. Although occurrences of *Globorotalia menardii* are generally greater than *G. inflata*, in some cases the percentages are almost equal. The planktonic assemblage is mostly tropical–subtropical with *Pulleniatina obliquiloculata, Sphaeroidinella dehiscens*, and rare *G. flexuosa*. Oxygen-isotope values for this interval (Williams and Kohl, this volume) are more typical of isotope Stage 5.

The poor core recovery between 157 and 208 m (Fig. 4) as well as the dilution of the cores by siliciclastics of probable displaced origin further complicates the interpretation of that interval. Reworked Cretaceous foraminifers and radiolarians, and shallow-water (neritic) benthic foraminifers also occur throughout this interval. These relationships indicate mass movement of terrigenous sediment into the Pigmy Basin; the resultant mix of planktonic assemblages probably represents different temperature regimes. For these reasons, the interval from 157 to 208 m is tentatively placed in Zone X (Wisconsin interstadial).

The upper three intervals were picked on the dominance of either *G. inflata* or *G. menardii*. In addition to the definite change at 147 m sub-bottom marking the top of Zone X, one other datum is worth noting: the downcore increase of *P. obliquiloculata* that has been observed by many workers. Kennett and Huddlestun (1972) used this datum to pick their Y6/Y7 subzone boundary. This datum occurs at 127 m at Site 619.

Reworking or local slumping appears to have played a minor role in deposition of the sediments above 157 m. Some slumping was observed in Core 619-13 with a mix of reworked Pleistocene and Pliocene planktonic foraminifers.

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APPENDIX

Distribution and Relative Abundance of Planktonic Foraminifers at Site 619

Beella digitata (Brady). This species is generally rare, making up less than 1% of the planktonic assemblage. It occurs throughout the warm- and cool-water intervals. One abundant occurrence in Sample 619-3-3, 103–108 cm made up 58% of the planktonic assemblage.

Candeina nitida d'Orbigny. Typical forms occur sporadically at Site 619 with values less than 1%, except for Core 619-13 where this species increases up to 4% of the planktonic assemblage (Appendix Fig. 1).

Globigerina bulloides d'Orbigny. Occurrence of this species is generally restricted to the glacial (cool) intervals, with values less than 1%.

Globigerina falconensis Blow. This species is not common at Site 619. Juvenile forms of *G. calida* are difficult to distinguish from *G. falconensis.* Only the more typical forms are shown in Appendix Table 1 and are restricted to the cooler intervals with frequencies of <1–3%.

Globigerina quinqueloba Natland. This species occurs infrequently at Site 619. Three occurrences are noted: Samples 619-7-5, 103–108 cm, 619-13-3, 25–30 cm, and 619-18,CC, all in the cooler intervals.

Globigerina rubescens Hofker. This species occurs in the warm- and cool-water intervals at Site 619 although the values in Zones Z and X are generally less than 1%. Occurrences in Zone Y range from <1% to 8% in Sample 619-9-3, 25–30 cm. Most specimens possess the characteristic pink color.

Globigerinella calida (Parker). Occurrences of this species are found throughout Site 619 with lower frequencies, <2%, in Zones X and Z whereas values as high as 8% occur in Sample 619-10-4, 25–30 cm, Zone Y (Appendix Fig. 2).

Globigerinella siphonifera (d'Orbigny). Occurrences of *G. siphonifera* correlate with those of *G. calida* but *G. siphonifera* generally has higher percentage values.

Globigerinita glutinata (Egger). This small species occurs in most samples, with a wide range of values from <1–23%.

Globigerinoides conglobatus (Brady). This species is poorly represented at Site 619. Generally it is found in abundances of less than 1% in Zones Y and Z. It is more persistent below Section 619-17-1, where occurrences are commonly greater than 1%.

Globigerinoides fistulosus (Schubert). This species occurs only in Sample 619-1-2, 122–127 cm in Zone Z.

Globigerinoides ruber (d'Orbigny). This is the most abundant planktonic species at Site 619. Combined values of pink and white varieties range from 11 to 75% with the higher values generally occurring in Zone Y. The pink variety occurs in most samples with percentage values one-half or less than the values of the white variety (Appendix Fig. 1).

Globigerinoides sacculifer (Brady). Typical forms with a saclike last chamber are separated from *G. trilobus* and occur with values ranging from <1 to 4%, with the higher values in Sections 619-7-3 and 619-7-5.

Globigerinoides trilobus (Reuss). Forms without the saclike last chamber are included here. This species varies in abundance from <1 to 23%, the higher values occurring in Zone Z (Appendix Fig. 1).

Globorotalia bermudezi Rögl and Bolli. This species occurs in most samples at Site 619. Its percentage values range from <1 to 20% with the higher values occurring in Zone Y.

Globorotalia crassaformis (Galloway and Wissler). This species is absent in the uppermost part of Zone Z. It ranges throughout the X and Y Zones with values of <1 to 16%, and is most abundant in Core 619-5 (Appendix Fig. 2).

Globorotalia fimbriata (Brady). This species is very rare at Site 619, being found only in Sample 619-17-2, 87–89 cm in Zone Y.

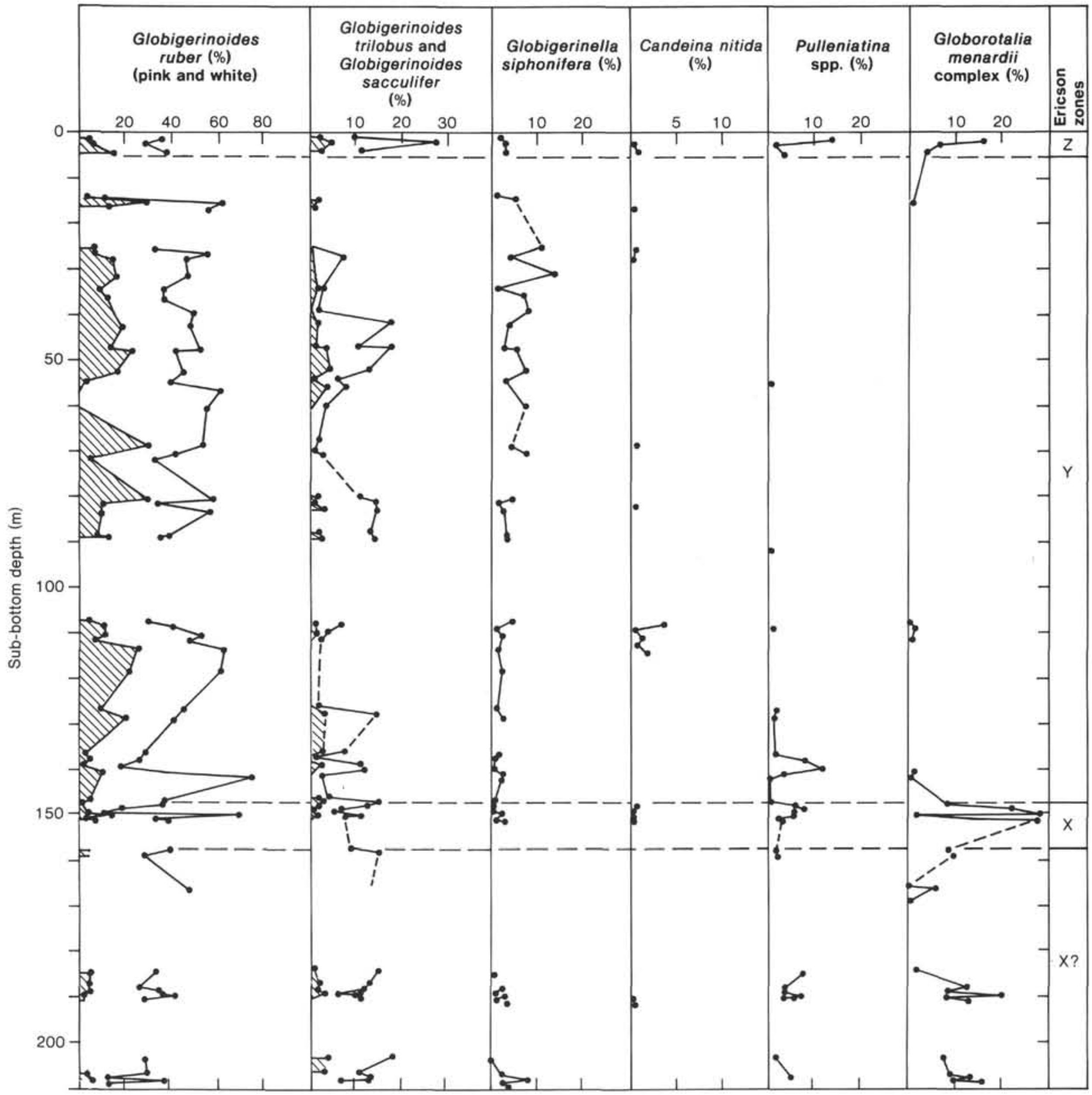

Figure 1. Selected tropical-subtropical planktonic species as percentages of total planktonic foraminiferal assemblage >149 μm. *Globigerinoides ruber* hachured curve includes pink specimens only; hachured curve in second column includes percentage of *G. sacculifer* only; *Globorotalia menardii* complex curve includes total percentage of *G. menardii, G. tumida, G. flexuosa*, and *G.* cf. *flexuosa.*

Globorotalia flexuosa (Koch). *Globorotalia flexuosa* is the major marker defining the upper boundary of Ericson Zone X. Its disappearance (LAD) at Site 619 occurs in Sample 619-17-2, 87–89 cm (148.08 sub-bottom). Occurrences of this species below are usually less than 2%. Forms assigned to *G.* cf. *flexuosa* also occur in the same samples.

Globorotalia hirsuta (d'Orbigny). This species has sporadic occurrences throughout the section penetrated in Site 619. Generally it has abundances less than 2%.

Globorotalia inflata (d'Orbigny). An indicator of cooler water in the late Pleistocene Gulf of Mexico, this species is common to abundant in the glacial stages. At Site 619, *G. inflata* is absent in Zone Z and disappears (LAD) at 8.75 sub-bottom in Sample 619-1-6, 22–26 cm. There is generally an inverse relationship between the abundances of *G. inflata* and *G. menardii* at Site 619, with only rare occurrences of *G. inflata* in Zone X (Fig. 5). The highest percentage of *G. inflata* occurs in Sample 619-16-1, 25–28 cm where it comprises 35% of the planktonic assemblage. This species averages approximately 10% of the planktonic fauna in Zone Y.

Globorotalia menardii (Parker, Jones, and Brady). This species is abundant in Zones Z and X, representing the warmer-water intervals at Site 619. Rare occurrences of less than 1% are present sporadically in Zone Y. Below 157 m sub-bottom, *G. menardii* is generally dominant over *G. inflata* but the relationship is complicated by probable faunal mixing. Above 157 m the typical inverse relationship with *G. inflata* is apparent (Fig. 5). Coiling direction is dominantly sinistral but rare dextral forms do occur within a population.

Globrotalia scitula (Brady). Infrequent. Rare occurrences (generally <1%) are found in Zone Y. This species is absent from Zone Z and very rare in Zone X.

Globorotalia truncatulinoides (d'Orbigny). The distribution of this species is shown in Appendix Fig. 2. Peaks in the sinistral coiling of *G. truncatulinoides* do not correlate with increases in the abundance of *G. inflata*, and there does not appear to be any relationship in abundance of dextral or sinistral *G. truncatulinoides* to other cool-water planktonics. Dextral coiling is generally dominant.

Globorotalia tumida (Brady). This species is restricted to Zones Z and X. Higher percentages (2–3%), occur in Zone Z.

Globorotalia ungulata Bermudez. Rare occurrences (<1%) are restricted to Zone Z (Holocene).

Globorotaloides hexagona (Natland). This species is considered to be distinctive of Zone X according to Kennett and Huddlestun (1972). At Site 619, it occurs consistently below 140 m sub-bottom but is rare in Zone X. It increases in abundance to <3% below 165 m sub-bottom.

Neogloboquadrina humerosa (Takayanagi and Saito). Low-spired forms related to *N. dutertrei* are included here. This species occurs throughout Site 619 but is more common in Zones X and Z.

Neogloboquadrina dutertrei (d'Orbigny). High-spired forms are included within this species. The occurrences are very similar to those of *N. humerosa* and are combined for the frequency curve shown in Appendix Fig. 2.

Orbulina bilobata (d'Orbigny). This species is very rare, only occurring in Samples 619-6,CC, 619-10-1, 25–30 cm and 619-10-4, 25–30 cm with abundances of <1% of the total planktonic assemblage.

Orbulina universa (d'Orbigny). This species occurs throughout Site 619 (Appendix Fig. 2). Higher frequencies of *O. universa* occur in Zone Y, where they correlate very closely with the percentage increases of *G. inflata.*

Pulleniatina finalis Banner and Blow. This species has one rare occurrence in Zone Z but is almost continuous below Section 619-15-2, coinciding with the general increase in *P. obliquiloculata.*

Pulleniatina obliquiloculata Parker and Jones. Sinistral forms are rare with sporadic occurrences below Section 619-16-2. Dextral forms are more common, with continuous occurrences from Samples 619-15-1, 25–30 cm through 619-24,CC. This species is common to abundant in the Holocene (Zone Z) but is absent in the upper part of Zone Y (Appendix Fig. 1). This relationship was noted by Kennett and Huddlestun (1972) as a significant event and they picked their Y6/Y7 subzone boundary on the downcore reoccurrence of *P. obliquiloculata.* At Site 619, this level is picked in Section 619-15-1 at 127 m sub-bottom.

Sphaeroidinella dehiscens Parker and Jones. Occurrences of this tropical species are generally restricted to Zones X and Z, where it comprises <1% of the planktonic assemblage.

Turborotalita humilis (Brady). The apparent distribution and abundance at Site 619 of this small species is probably governed by the sieve size used >149 μm). A spot check of size fractions <149 μm indicated that *T. humilis* was common in many samples.

Distribution of Other Microfossils

Echinoids. Most remains are fragments of plates and spines. Occurrences are usually rare throughout Site 619 except for Cores 619-24 and 619-25 where fragments are common to abundant.

Ostracodes. Single valves are rare to common in most cores and are usually unbroken.

Pteropods. Fragments are common in some Holocene samples but rather sparse throughout the remainder of the cores.

Radiolarians. Quaternary radiolarians are rare and poorly represented in Site 619 (Morley and Kohl, this volume). They are absent below Core 619-15. Cretaceous radiolarians occur below 157 m sub-bottom and are rare.

Tasmanitids. These cysts of pelagic chlorophyllous algae from a low-salinity littoral environment (Williams, 1978) are present below Section 619-3-5. In several intervals, there are common to abundant occurrences which may represent glacial meltwater events.

Table 1. Occurrence of selected planktonic foraminifers, other microfossils, and lithologic components at Site 619.[a]

Sub-bottom depth (m)	Core-Section (interval in cm)	*Beella digitata*	*Candeina nitida*	*Globigerina bulloides*	*Globigerina falconensis*	*Globigerina quinqueloba*	*Globigerina rubescens*	*Globigerinella calida*	*Globigerinella siphonifera*	*Globigerinita glutinata*	*Globigerinoides conglobatus*	*Globigerinoides fistulosus*	*Globigerinoides ruber* (pink)	*Globigerinoides ruber* (white)	*Globigerinoides sacculifer*	*Globigerinoides trilobus*	*Globorotalia bermudezi*	*Globorotalia crassaformis*	*Globorotalia fimbriata*	*Globorotalia flexuosa*	*Globorotalia* cf. *G. flexuosa*	*Globorotalia hirsuta*	*Globorotalia inflata*	*Globorotalia menardii* (sinistral)	*Globorotalia menardii* (dextral)	*Globorotalia scitula*	*Globorotalia truncatulinoides* (dextral)	*Globorotalia truncatulinoides* (sinistral)
0	1-1, 0-5	R	R				R	R	R	F	R	R	C	A	F	C	F	R				R		A	R		C	R
	1-1, 22-26	R					R	R	R		R		C	A	R	C								A	R		C	R
	1-2, 122-127	R	R				R	F	F	F		R	C	A	F	A		R				R		F	R		F	F
5	1-3, 22-26	R	R				R	R	F	F			A	A	F	C	F	A				R		R			C	R
	1-4, 22-26						/			/			/	/		/												
	1-5, 22-26								/	/				/		/	/											
10	1-6, 22-26						/		/	/			/	/		/		/					/					/
	3-1, 25-30													/													/	
	3-2, 25-30									/				/		/		/					/		/			
	3-3, 103-108	A			R		R	F	R	A			F	C				R				R	R			R	R	R
15																												
	3-4, 25-30			R				R	C	R	R		A	A		R	R	C					R	R			R	R
	3-5, 25-30	R	R	R				F	C	F			A	A	R	R	F	C				R					C	F
20	3-6, 25-30													/														
	4-1, 25-30				/									/														
	4-2, 25-30																											
25	4-3, 25-30												/															
	4-4, 103-108	F	R		R		C	C	A	C	R		C	A		R	F	F				R	A			R	F	R
	4-5, 25-30			R			R	R	C	R			A	A	R	F	R	F				R	A	R			R	
30	4-6, 25-30	R	R					R	F	F	R		A	A	R	C	F	C				R	A	R		R	C	R
	5-1, 25-30												/															
	5-2, 25-30						F	F	A	C			A	A			C	A									C	
	5-3, 25-30						/						/				/	/					/					
35	5-4, 25-30			R			R		R	R	R		C	A	R	R	C	A				R	A				R	
	5-5, 25-30						R	R	C	R			A	A			C	A				R	A				F	
	6-1, 25-30			R				C	C	C			A	A		R	C	F					C				R	
40																												
	6-2, 103-108	R						R	F	F			A	A	R	A	F	A					F				F	
45	6-3, 103-108																											
	6-4, 103-108																											
	6-5, 103-108																											
	6-6, 25-30	R		R				R ·	F	C			A	A	R	C	F	F					A			R	F	R
	6,CC							R	C	R	R		A	A	F	A	R	F					A	R			F	
50	7-1, 25-30																											
	7-2, 25-30																											
	7-3, 25-30	R						F	C	R			A	A	F	C	F						A				F	
	7-4, 103-108	R			R		F	F	F	C	R		F	A	R	C	R	C				R	A	R		R	F	R
55																												
	7-5, 103-108				/	/	/			/				/	/	/							/					
60	8-1, 103-108						F	R	C	F	R		R	A	R	F	F	R					A	R		R	F	
	8-2, 25-30												/	/														
	8-3, 25-30																											
	8-4, 25-30													/														
70	9-1, 25-30	R	R	R			F	R	F	R	R		A	A		R	R	F				R	A	R	F			
	9-2, 25-30	R					R	R	C	F	F		A	A	R	R	R	F				R	A			R	R	R
	9-3, 25-30				F		C	C		A			C	A		F		C				F	C			C	F	
80	10-1, 25-30																											
	10-2, 103-108						R	C	F	F			A	A	R	C	F	F				R	F			R	F	R
	10-3, 103-108	R	R				R	F	R	C	R		A	A	R	A	F	C		R		R	C			R	C	R
	10-4, 25-30						F	C	F	F			A	A	F	A	R	R					R			R		
	11-1, 25-30	R						F	F	F			C	A	R	A	R	F					A	R			F	
90	11-2, 25-30	R		R			R	F	F	C	R		A	A	R	A	F	C				R	A			R	F	
	11-3, 25-30																											

[a] Letter codes for abundance defined in text. Abundance based on actual counts apply only to planktonic foraminifers. Other abundance data are approximations (uncounted).

Table 1 (continued).

												Other microfossils							Foraminifer counts				Lithology					
Globorotalia tumida	*Globorotalia ungulata*	*Globorotaloides hexagona*	*Neogloboquadrina humerosa*	*Neogloboquadrina dutertrei*	*Orbulina universa*	*Orbulina bilobata*	*Pulleniatina finalis*	*Pulleniatina obliquiloculata* (dextral)	*Pulleniatina obliquiloculata* (sinistral)	*Sphaeroidinella dehiscens*	*Turborotalita humilis*	Echinodermata	Ostracoda	Pteropoda	Radiolarians (Quaternary)	Radiolarians (Cretaceous)	Tasmanitids	Reworked foraminifers	Total planktonic	Total benthic	Planktonic/benthic ratio	Benthic species	Pyrite	Quartz sand	Ericson zone	Blow zone (1969)	Quaternary stages	Age
C	R		R	C	C		R	A		R		F	C		R				500	50	10	65		/	Z	N23	Post glacial	Holocene
F	R		R	F	C		R	A		R									605	40	15.1	18						
R	R		F	C	C			R		R			R	C	R				456	180	2.5	16						
R	R		R	R	F			F											336	25	12.	23						
																			11	3	3.7	3						
			/		/					/									23	1	23	1			Y		late Wisconsin glacial	late Pleistocene
			/	/							/								28	4	7	2						
				/	/														9	0		0						
			/												/			/	24	2	12	2						
					F						R		C	/	C				222	70	3.2	23						
			R		A			R											571	30	17	18						
			R	R	F														369	42	8.8	19						
																	C		1	0								
																	C		2	0								
																	C		0	0								
																	R		3	0								
				R	R							R	C	R			R		191	61	3.1	19						
			R	R	F							R	C	F			R		474	96	5.0	26						
			R	R	F							/	C				F		424	152	2.8	25						
																	A		1	0								
			F														F		36	65	0.5	4						
																	R		6	0								
			R		A								C		R		F		756	60	12.5	20						
				R	A						R				R		F		135	15	9	11						
					F														170	47	3.6	9						
					F							F	C		R		C	/	403	166	2.4	22						
																	A		0	0								
																	A		1	0								
																	A		3	1								
		R	R	R	F							/	F				R		354	103	3.4	21	C					
		R			C	R											R		257	19	13.5	15		C				
																	C		0	0								
																			0	0								
					F							/	/		R		A		256	95	2.7	13						
		R		R	C			R			R		F				C		296	63	4.7	27						
																	F		28	2	14	2						
R			R	R	C							/	F				F		183	280	0.7	18						
																	C		3	0								
																	F		0	0								
																	C		1	0								
			R	R	C							/	C		R		/		687	69	10	20						
					R								C				R		551	557	0.9	19						
			C		C												R		39	338	0.1	4						
																	R		0	0								
				R	R	R							C				R		394	393	1.0	17						
			R	R	F										/		F	/	396	263	1.5	22						
					C	R							F				F		222	229	0.9	11	C					
			R	R	F							/	/		R		R		335	63	5.3	18						
			R	R	F														377	72	5.2	14						
								/									R		2	0								

Table 1 (continued).

Sub-bottom depth (m)	Core-Section (interval in cm)	*Beella digitata*	*Candeina nitida*	*Globigerina bulloides*	*Globigerina falconensis*	*Globigerina quinqueloba*	*Globigerina rubescens*	*Globigerinella calida*	*Globigerinella siphonifera*	*Globigerinita glutinata*	*Globigerinoides conglobatus*	*Globigerinoides fistulosus*	*Globigerinoides ruber* (pink)	*Globigerinoides ruber* (white)	*Globigerinoides sacculifer*	*Globigerinoides trilobus*	*Globorotalia bermudezi*	*Globorotalia crassaformis*	*Globorotalia fimbriata*	*Globorotalia flexuosa*	*Globorotalia* cf. *G. flexuosa*	*Globorotalia hirsuta*	*Globorotalia inflata*	*Globorotalia menardii* (sinistral)	*Globorotalia menardii* (dextral)	*Globorotalia scitula*	*Globorotalia truncatulinoides* (dextral)	*Globorotalia truncatulinoides* (sinistral)
	11-4, 25-30	/			/		/			/			/	/		/							/					
	12-1, 25-30																											
100	12-2, 103-108									/				/									/					
	12-3, 25-30																											
	13-1, 25-30	R	F	R			R	F	F	A			C	A			A						A	R		F	F	F
110	13-2, 25-30		R						R		R		A	A	R	C		F			R		A	R	R		C	F
	13-3, 25-30	R	R			R		R	F	F	R		A	A	R	F	R	F					A				F	R
	13-4, 25-30	R	R				R	R	F	F	R		C	A	R	F	R	F					A	R		R	F	R
115	13,CC		R		R		R		R	R			A	A			F	R									R	F
	14-1, 25-30																											
125	14-2, 25-30			F					F	C			A	A			A	F					C				F	
	15-1, 25-30	R			R		R	R	R	C			A	A	R	R	R	F					C	R			A	
	15-2, 25-30	R			R		R	R	F	F			A	A	F	A	R	C				R	F			R	F	
130	15-3, 25-30			/			/		/					/				/					/					
	15,CC																											
	16-1, 25-28							R	R	F	R		F	A	F	C							A				F	C
	16-2, 25-28	R			R		R	R	R	F	R		F	A	R	R	R	R					A				C	C
140	16-3, 25-28	R						R	R	R	R		R	A	F	C	R	F					A			R	F	R
	16-4, 29-31	R					R	R	F	R	R		A	A	R	A	R	C			R		A	R			F	R
	16,CC	R					R	R	F	R	R		C	A	R	F	R	R					F	R			F	R
	17-1, 103-108						F	R	R	A			C	A	R	F	F	R						C		R	F	F
	17-2, 25-30	R	R	R				R	R	R	F		R	A	F	A	R	R			R	R	R	C			A	R
	17-2, 87-89		R					R	R	R	F		F	A	R	A		F	R	R	R	R	R	A			A	R
	17-3, 51-54							R		R	R		F	A	R	C		F		R	R		F	A			A	R
150	17-3, 84-88	R	R				R	R	F	F	R		A	A	R	F		R			R			R			R	
	17-4, 25-30	R					R	R	R	F	R		F	A	R	C		F		R	R		R	A		R	A	R
	17,CC	R	R					R	F	F	R		C	A	R	C	R	F		R	R	R	R	A			A	R
	18-1, 46-51													/														
	18-1, 121-124						R	R	R	C	R		F	A	R	C	F	R		R	R			C	R		A	
	18-2, 43-45													/														
160	18,CC				F	F	F			F			F	A		A	F							C			A	
	19-1, 30-35												/	/		/	/	/						/			/	
	19-1, 84-89									A				A		A	F						C	C			C	
	19-2, 84-89												/	/														
170	19-3, 30-35			/										/		/	/			/	/						/	
	20-1, 38-42							/		/			/	/														
	20-2, 97-99																											
	20-3, 9-11															/	/											
180	20,CC									/			/	/			/										/	
	21,CC						R	R	R	F	F		F	A	R	A		R		R	R		R	C			A	R
	22-1, 40-45	R					R	R	F	F	R		F	A	R	A	F	C		R	R		R	C			A	
	22-1, 118-121						R	F	R	F	F		C	A	R	A	R	F				R	R	C			C	R
	22-2, 32-37							R	F	C	R		F	A	F	F	F	R		R			R	A			C	R
	22-2, 62-67		R	R	R		R	R	R	C	R		F	A	R	C	R	F		R	R		R	A	R	R	C	R
	22,CC (7-13)						R		R	C	R		F	A	R	C	R	F			R	R	R	C	R		A	R
190	22,CC		R				R	R	F	C	R		F	A	R	A	F	F		R	R		F	A	R		A	R
	23,CC							R	R	F	R			A	F	A	R	R					A	C			A	F
	24,CC							R	F	F	R		F	A	F	C		R			R	R	F	C			A	R
	25-1, 5-8								C					A		A	F	C						A			A	
	25-1, 44-47							F	F	C			C	A		A								C			C	
208	25,CC (7-10)								F				F	A		C								A			A	

Table 1 (continued).

												Other microfossils							Foraminifer counts				Lithology					
Globorotalia tumida	*Globorotalia ungulata*	*Globorotaloides hexagona*	*Neogloboquadrina humerosa*	*Neogloboquadrina dutertrei*	*Orbulina universa*	*Orbulina bilobata*	*Pulleniatina finalis*	*Pulleniatina obliquiloculata* (dextral)	*Pulleniatina obliquiloculata* (sinistral)	*Sphaeroidinella dehiscens*	*Turborotalita humilis*	Echinodermata	Ostracoda	Pteropoda	Radiolarians (Quaternary)	Radiolarians (Cretaceous)	Tasmanitids	Reworked foraminifers	Total planktonic	Total benthic	Planktonic/benthic ratio	Benthic species	Pyrite	Quartz sand	Ericson zone	Blow zone (1969)	Quaternary stages	Age
																			8	0								
																	F		2	1								
																			7	1								
																			1	0								
					F						R	/	C	C	R		/		197	43	4.6	23						
			F	F	C			R				/	/	/			/	/	497	26	19	20		/				
			F	F	C							/	C	/			R	/	473	93	5.1	29						
		R	F	F	C			R										/	389	78	4.9	28						
			R	F	A												R		62	4	15.5	4						
																	R		1	1							late Wisconsin glacial	
					F								R				R		47	10	4.7	6			Y			
			F	A	F			R				/	F				R		244	29	8.4	21		/				
			C	C	R		R	R					F	/	R				540	97	5.6	28						
			/		/														18	2	9	2						
																	/		2	1								
			R	R	C			R											134	16	8.4	8		/				
			F	C	A		R	C	R										756	45	16.8	17						
			A	C	F		R	C		R		/	/				/		504	60	8.4	19						
		R	F	F	C		R	F				R	R						592	180	3.3	35						
		R	R	R	F			R		R	R	/	/				R		618	160	3.8	26						
R		F	R	R	R			R					/				/		130	21	6.2	18						
R		R	R	R	C		R	C					R	R					659	61	11	29						
R		R	R	F	F		R	C		R			/						701	18	39	15						
			C	F	R		R	F	R	R			/	/			/		508	32	16	15					Wisconsin Interstadial	
R					C		R	C											309	30	10	16			X			
		R	C	F	F		R	R		R			R	R					270	46	5.9	27						late Pleistocene
			C	R	F		R	F		R		R	R	R					463	42	11	20				N23		
													/				/		4	0		0						
			C	R	C		R	R					R	F					527	31	17	15						
																			1	0								
			F	C				F											41	7	5.9	7		C				
			/														F		14	0		0		C				
		F	F	F										/			F		38	15	2.5	14						
												/					/		2	1		1		A				
				/				/				/					/		16	2	8.0	2		A				
												/					R		6	8		6						
																	R		0	0				R				
																	R		2	0				VR				
																/	/	/	5	3		3		C				
		R	F	F	C		F	F	R	R			/						306	27	11.3	19		C				
R		R	C	F	F			F	R	R			/						336	39	8.6	23		A	X?		Interstadial?	
		R	F	F	F			F				/	/				/		195	14	13.9	12		C				
		R	F	R	R			C					/						109	8	13.6	5		R				
R		R	C	R	F		R	C	R	R			F					/	638	54	11.8	26		C				
		R	R	R	F		R	F					/	/			F	/	389	38	10.2	27		C				
		R	F	R	F		R	F					/					/	510	51	10	33		A				
		R	R		F		R	R				/	/				/	/	131	233	0.6	36		A				
		R	C	R	C			F		R		C	/	/				/	201	299	0.7	53		A				
			A	F	F							/	/				/		23	265	0.1	28		/				
			C	F	C							C	/			/	R	/	30	261	0.1	24		A				
												A	/			/		/	25	122	0.2	18		C				

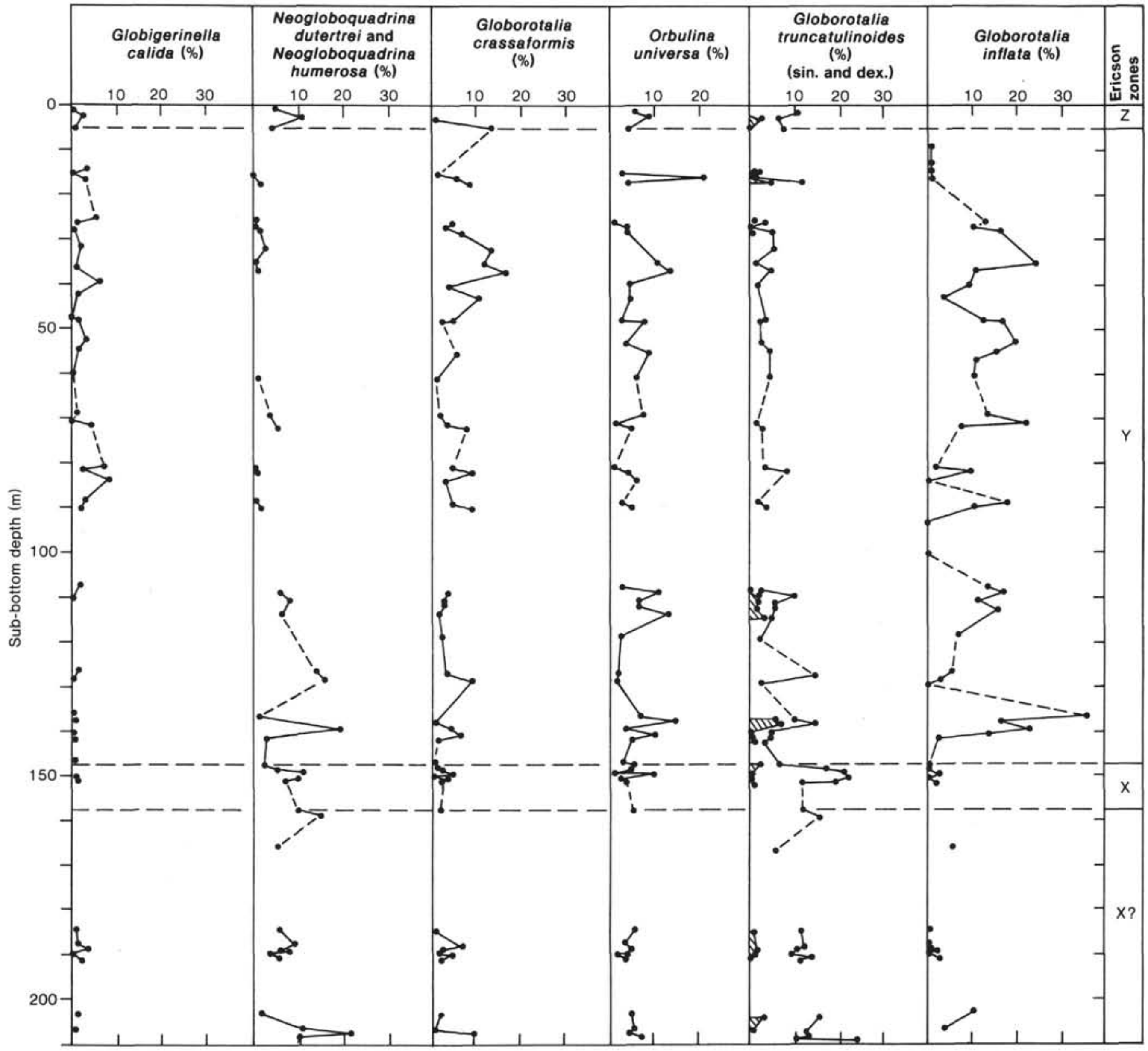

Figure 2. Selected subtropical-transitional planktonic species as percentages of total planktonic foraminiferal fauna. Hatchured curve in *Globorotalia truncatulinoides* column includes percentage of sinistral ones only.