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Neogene and Quaternary Foraminifera and Paleoenvironments
of a Corehole from Horn Island, Mississippi

By Thomas G. Gibson

Prepared in cooperation with the U.S. National Park Service, Gulf Islands National Seashore



This report is preliminary and has not been reviewed for conformity with U. S. Geological Survey editorial standards or with the North American Stratigraphic Code

Table of Contents

Abstract	3
Introduction	3
Horn Island Corehole Stratigraphy	4
Location and Methods	4
Foraminifera	5
Pliocene Foraminiferal Assemblages	6
Biostratigraphy	7
Paleosalinity	7
Paleotemperature	8
Holocene Foraminiferal Assemblages	9
Biostratigraphy	14
Paleosalinity/paleobathymetry	15
Paleotemperature	18
Acknowledgments	19
References	19

Table 1. Foraminiferal values of selected samples.

Figure 1. Map of Coastal Mississippi.

Figure 2. Map of Horn Island showing corehole location.

Figure 3. Neogene and Quaternary units in corehole.

**NEOGENE AND QUATERNARY FORAMINIFERA AND PALEOENVIRONMENTS
OF A COREHOLE FROM HORN ISLAND, MISSISSIPPI**

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ABSTRACT

A 510 ft deep continuously cored stratigraphic test hole on Horn Island penetrated three late Cenozoic stratigraphic units (Gohn and others, 1994). The oldest unit, of Pliocene age, contains low diversity calcareous benthic foraminiferal assemblages that are characteristic of estuarine environments having salinities of 10 to 20 o/oo and paleotemperatures comparable to those existing today. The middle unit, of Pliocene (?) age, does not contain calcareous fossils.

The upper unit, of Holocene age with a maximum radiocarbon date of 9,470 years, contains abundant and diverse calcareous foraminiferal assemblages. The middle beds of the Holocene section contain foraminiferal assemblages that suggest deposition in shallow open-marine or near open-marine environments such as those found in channels between barrier islands. These assemblages have species that are characteristic of subtropical environments as well as species that are more characteristic of cool to warm temperate environments. These assemblages suggest that water temperatures were cooler than those found here at the present time. Foraminiferal assemblages in the upper part of the Holocene section suggest that the depositional environments were of slightly greater water depths and the water temperature subtropical, similar to modern ones in the area, and warmer than those present earlier in the Holocene.

INTRODUCTION

The U.S. Geological Survey (USGS) continuously cored a stratigraphic test hole to a depth of 510 ft on Horn Island, a barrier island located six miles off the Mississippi mainland, to study the Neogene and Quaternary geologic history of the Mississippi coastal area (figs. 1, 2). Samples were examined for foraminifers from the most promising of the relatively limited number of calcareous intervals in the cores.

This report provides complete foraminiferal species lists, including the species frequencies within assemblages, for samples from the Neogene and Quaternary deposits of the Horn Island corehole. The foraminiferal assemblages provide very limited biostratigraphic information, but they are useful for a paleoenvironmental interpretation of the Neogene and Holocene deposits. Fairly detailed paleoenvironmental interpretations are possible for these upper Cenozoic deposits because the distribution of living foraminiferal assemblages, in terms of bathymetry and salinity, are well known from various studies of Mobile Bay, Mississippi Sound, and the more offshore barrier-island and open-Gulf areas off Mississippi and Alabama.

HORN ISLAND COREHOLE STRATIGRAPHY

Gohn and others (1994) described the lithology of the Horn Island corehole for its entire 510 ft depth. On the basis of lithology, palynomorph assemblages, and isotopic dates, Gregory Gohn (written commun., 1994) divided the strata in the Horn Island corehole into three stratigraphic units (fig. 3).

Pliocene unit HI-1, extends from a depth of 173 ft to the total depth of the corehole at 510 ft. This unit consists of sand, silt, and clay beds that contain several intervals with abundant molluscan shells and shell fragments. The foraminiferal assemblages are from shelly sand and clay strata that are in the approximate middle of this unit (fig. 3). Unit HI-1 is considered Pliocene in age on the basis of overlapping biostratigraphic ranges of pollen and dinoflagellate taxa (Lucy Edwards and Debra Willard, USGS, personal commun., 1994).

The overlying unit HI-2, questionably referred to the Pliocene, extends from a depth of 81.8 to 173 ft. This unit consists of clay and sand units that commonly contain fine gravel or plant fragments. No foraminifera were recovered from this unit. An unconformity separates the overlying Holocene strata of unit HI-3 from unit HI-2. Although the Biloxi Formation and other Pleistocene units are present in Mississippi and Alabama coastal areas (Otvos, 1975; 1976), they are not present in the Horn Island corehole.

Holocene deposits of unit HI-3 extend from the top of the corehole to a depth of 81.8 ft. The lower part of the Holocene deposits consists of a considerable thickness of peat and organic-rich clay from 62.0 to 81.8 ft. A radiocarbon date of $9,470 \pm 90$ years was obtained from peaty material at 76.7 ft (Gregory Gohn, personal commun., 1994). No foraminifera were recovered from this organic-rich interval.

The middle part of the Holocene deposits, from about 40 ft to 62 ft, contains some sand beds as well as silty clay and clayey silt beds. Foraminifers were recovered from sandy, clayey silt, and silty clay intervals, all of which also contained sparse to common molluscan shell fragments.

The upper part of the Holocene deposits, above 35 ft, are coarser grained, being largely composed of sand. Foraminifers were recovered from a shelly sand bed in this section.

LOCATION AND METHODS

The Horn Island corehole is located in the central part of Horn Island, about 50 yards north of the National Park Service Ranger Station. The corehole is located in Section 22 (SE/4, SE/4), Township 9 S, Range 7 W, and is in the Horn Island West 7.5-minute quadrangle. Ground elevation at the drill site is about +5 ft. The coring procedure utilized a ten-foot core barrel that was run inside the drill pipe with a wire-line retrieval system.

About two- to three-inch-long sections of the core were processed for foraminifers. The outside rind of the core, which could contain contaminated drilling mud, was removed from the samples before processing. The samples were washed over a 63 micrometer screen. The foraminiferal assemblages were concentrated by soap flotation from the greater than 63-micrometer fraction.

Foraminiferal assemblages were obtained from three samples in the middle part of

Pliocene unit 1 and from eight samples in the middle and upper parts of the Holocene deposits. Five of the Holocene foraminiferal-rich concentrations were split by a small microsplitter into an aliquot of greater than 300 specimens.

FORAMINIFERA

The next section lists the benthic species in the Pliocene samples; it is followed by a section that lists the Holocene assemblages. An interpretation of the paleoenvironment by use of the foraminiferal assemblages, including estimates of both paleosalinity/paleobathymetry and paleotemperature, accompanies each list.

Identifications of benthic foraminiferal species from the Horn Island corehole were based upon numerous publications that document the modern species of the Gulf of Mexico as well as other publications that treat the cosmopolitan species occurring there. Phleger and Parker (1951), Parker (1954), and Phleger (1954) provide particularly important taxonomic treatments of the modern Gulf of Mexico fauna. The Horn Island specimens also were compared with primary and secondary type specimens of the species that are in the Cushman Collection at the U.S. National Museum (USNM). Culver and Buzas (1981) and Poag (1981) summarized taxonomic and geographic distributional data on foraminiferal species and genera in the Gulf of Mexico. The taxonomy used herein largely follows that of Culver and Buzas (1981) as they examined modern foraminifers from all three U.S. continental margins and thus reduced the regional application of species names.

Phleger (1951, 1954), Bandy (1954, 1956), Parker (1954), and Walton (1964) are important sources of information on the environmental distribution of benthic foraminiferal species in the open marine areas of the Gulf of Mexico that are beyond the Mississippi and Alabama barrier islands. Culver and Buzas (1981) also present a summary of the distributional data from these papers along with data from 71 other studies on the modern Gulf of Mexico foraminifera. In addition, Culver and Buzas (1980, 1982) summarized the distribution of benthic foraminiferal species along the North American Atlantic Coast and those in the Caribbean region. These summaries are very helpful in determining the latitudinal distribution of species that occur in the Horn Island corehole assemblages.

Anderson (1968), Lamb (1972), and Puckett (1992) supply valuable distributional data for foraminiferal faunas of the low and moderate salinity environments of Mobile Bay and the eastern part of Mississippi Sound just to the east of Horn Island (fig. 1). They also give limited data on assemblages from very shallow, open marine environments on the seaward side of the Alabama barrier islands.

Information on biostratigraphic ranges of the species was derived from numerous publications on Cenozoic foraminifera, from specimens deposited in the USNM collections, and from the USNM foraminiferal card catalog that contains species occurrence records.

Calcareous specimens highly dominate (> 99%) both the Pliocene and Holocene assemblages. Only two agglutinated taxa, *Bigenerina irregularis* and *Textularia agglutinans* are present, and they both occur only in the highest Holocene sample. Agglutinated specimens reach their greatest abundances in brackish water and in deep marine environments. Numerous agglutinated species, particularly *Ammotium salsus* and *Miliammina fusca*, are very abundant in

brackish water environments in the northeastern Gulf of Mexico (Puckett, 1992). Agglutinated species of the genera *Reophax*, *Haplophragmoides*, and *Trochammina*, among others, occur in low to moderate abundances in inner and middle neritic environments of the Gulf of Mexico (Parker, 1954). The absence of most agglutinated species in the Holocene deposits and the complete absence of agglutinated species in the Pliocene deposits suggest that diagenetic processes have removed most or all of whatever agglutinated specimens were present originally. Poag (1978) noted the general difficulty of preserving fragile estuarine agglutinated species as fossils, and Gibson (unpubl. data) has found agglutinated species to be poorly represented in Neogene and Quaternary neritic deposits of the eastern U.S. The sandy nature of the Horn Island deposits possibly facilitated the diagenetic removal of the agglutinated specimens.

Pliocene foraminiferal assemblages

Calcareous foraminifers were obtained only from three shell-bearing samples in the approximate middle of Gohn's Pliocene unit 1. Other sparingly to moderately shelly Pliocene samples examined both above and below these samples are barren of foraminifers (Gregory Gohn, personal commun., 1994). Organic inner linings of benthic foraminifera were observed in palynomorph slides from other Pliocene samples in this corehole (Lucy Edwards, personal commun., 1993). Their presence indicates that some calcareous foraminiferal specimens originally were present in these samples but that early or late diagenetic processes removed the calcareous portions of the tests and left only the organic linings that are present in some calcareous benthic species. *Ammonia beccarii* and some species of *Elphidium* have organic linings to their calcareous tests; thus the samples that now only have organic linings could have contained an assemblage that is similar to the Pliocene samples that do contain calcareous specimens. Both types of preservation could represent similar depositional environments but differing diagenetic histories. Calcareous foraminifers also were not observed in Neogene samples from three other USGS coreholes that were drilled onshore in southern Mississippi (fig. 1), although organic linings of foraminifera also were present in some of the palynomorph samples from these coreholes (Lucy Edwards, personal commun., 1994).

Pliocene foraminiferal assemblages in the Horn Island corehole have very low diversity. All three Pliocene assemblages are similar in their species composition and proportions, but the highest sample differs slightly from the lower two samples. The assemblage lists are ordered from the most abundant to the least abundant species.

<u>Species</u>	<u>Number of individuals</u>	<u>Frequency (%)</u>
<u>380.2 ft</u> 2 species		
<i>Ammonia beccarii</i>	413	98.6
<i>Elphidium gunteri</i>	<u>6</u>	<u>1.4</u>
TOTAL	419	100.0

376.1 ft 3 species

<i>Ammonia beccarii</i>	522	98.9
<i>Elphidium mexicanum</i>	4	0.7
<i>Elphidium gunteri</i>	<u>2</u>	<u>0.4</u>
TOTAL	528	100.0

357.5 ft 5 species

<i>Ammonia beccarii</i>	46	86.8
<i>Elphidium gunteri</i>	4	7.5
<i>Elphidium discoideale</i>	1	1.9
<i>Elphidium</i> sp.	1	1.9
<i>Lenticulina</i> sp.	<u>1</u>	<u>1.9</u>
TOTAL	53	100.0

Biostratigraphy

The benthic species in these assemblages are found in the southeastern U.S. in strata ranging in age from at least middle Miocene to Holocene. Therefore, they offer little biostratigraphic resolution.

Paleosalinity

The benthic assemblages, however, do provide important paleoenvironmental information. Paleosalinity will be discussed first, followed by a discussion of paleotemperature.

Salinities are highly variable in estuarine, bay, and sound environments in this area because of possibly large influxes of fresh water (Eleuterius and Beaugez, 1979). Anderson (1968) and Schroeder and Lysinger (1979) noted salinity variations of approximately 30 o/oo in Mobile Bay within a period of a few days. What is probably critical to foraminiferal species distributions is the duration of the extreme salinities rather than just the absolute range in salinity over a period of time. Possibly the rapidity of the salinity changes is also an important factor. No studies of the above two conditions exist at the present time. However, similar foraminiferal distribution patterns in relation to salinity gradients were found in several studies on various brackish water areas in the northeastern Gulf of Mexico, and these modern patterns are used as the basis for paleosalinity interpretations of the Horn Island Neogene assemblages.

In a study of foraminifera in brackish water and marine environments on the west coast of Florida, Bandy (1956) found a minimum salinity of between 1 and 9 o/oo for the occurrence of *Ammonia*. Bandy found that various species having an agglutinated wall structure usually occur along with *Ammonia* in the modern low-salinity environments. As discussed earlier, these agglutinated species usually are not preserved in fossil assemblages. Bandy noted that a second

calcareous genus, *Elphidium*, appeared in the *Ammonia* dominated assemblages in higher salinities between 9-27 o/oo in river, inner channel, and bay areas. At salinities greater than 27 o/oo, he found more diversified calcareous assemblages including miliolids and other marine species occurring along with *Ammonia* and *Elphidium*.

Anderson (1968) studied foraminiferal distributions in the eastern part of Mississippi Sound and in Mobile Bay. He found that *A. beccarii* and *E. gunteri* are indicative of fluctuating salinity areas, with *A. beccarii* apparently able to withstand greater fluctuation and lower salinity than *E. gunteri*. Anderson found a minimum salinity of 9 o/oo for *A. beccarii* and *E. gunteri* in the estuarine environments of Mobile Bay. Mobile Bay assemblages that have high dominances of these two species usually contain several agglutinated species and commonly contain a small proportion of *E. mexicanum*. This calcareous faunal composition closely compares with that found in the three Neogene samples from the Horn Island corehole. Lamb (1972) also found that the foraminiferal assemblages highly dominated (> 80%) by *A. beccarii* and *E. gunteri* occur in Mobile Bay waters with salinities slightly above 10 o/oo and higher.

Puckett (1992) studied modern foraminiferal assemblages in Mobile Bay, the eastern part of Mississippi Sound, and the shallow, open marine environments on the seaward side of several barrier islands off Alabama. This area is immediately to the east of Horn Island. Puckett's more extensive quantitative study of the foraminiferal distribution in different salinity environments supports the results of the previous studies of Anderson (1968) and Lamb (1972) in this area. Puckett found that calcareous assemblages composed almost entirely of *A. parkinsoniana* (= *A. beccarii* of this report) and *E. gunteri* (his APEG assemblage) are in environments characterized by a salinity range of approximately 10 to 20 o/oo. His APEG assemblages usually have from 2 to 6 calcareous species. Those calcareous assemblages that contain only *A. beccarii*, or those that have proportions of 90 percent or higher of this species, occur in areas that have an even lower salinity range of about 2 to 17 o/oo.

The modern assemblages, which contain species compositions and proportions similar to those found in the Pliocene assemblages in the Horn Island cores, suggest that the Pliocene foraminifera-bearing intervals were deposited in estuarine waters having a salinity range between 10 and 20 o/oo. The lowest two Pliocene assemblages, which have very high dominances of *A. beccarii* (> 98%) and only contain 2 to 3 calcareous species, probably represent environments with salinities of 10 to 15 o/oo. The highest Pliocene sample has a slight increase in the number of calcareous species (5) and also a slight decrease in the proportion of *A. beccarii* (87%). This sample may reflect a slight increase in salinity to possibly approaching 20 o/oo during the time of deposition.

Paleotemperature

Although *Ammonia beccarii* occurs along the U.S. Atlantic Coast from Florida northward to Nova Scotia (Culver and Buzas, 1980), its most common occurrences and its greatest abundances are in the warmer, more southern parts of this range. Similarly, *Elphidium gunteri* has been reported as far north as Cape Cod, but its most frequent occurrences and greatest relative abundances are found south of Cape Hatteras. The great predominance of recordings of *E. discoidale* and *E. mexicanum* are in Atlantic coastal waters south of Cape Hatteras (Culver

and Buzas, 1980). The co-occurrence and the dominance of these species in the Pliocene deposits in the Horn Island corehole, as well as the absence of any species characteristic of cooler waters, suggest that warm waters, similar to the subtropical environments found today south of Cape Hatteras, and very likely as warm as those found in the northeastern Gulf of Mexico area today, existed in this area during this part of the Pliocene.

Holocene Foraminiferal Assemblages

The Holocene assemblages have a much higher species diversity than do the Pliocene ones. Assemblages in five samples were split into aliquots and the species abundances are given in percent of the total benthics. The species are listed in decreasing order of abundance. Planktonic specimens are given in percent of the total foraminifers (planktonics plus benthics). Three intervening samples were qualitatively picked and the species are reported on a presence/absence basis only. The species composition of these three samples is very similar to that present in the other five samples.

	<u>Species</u>	<u>Number of individuals</u>	<u>Frequency</u>
<u>61.9 ft</u>	29 benthic species		
	<i>Haynesina germanica</i>	177	31.7
	<i>Buliminella elegantissima</i>	79	14.1
	<i>Elphidium excavatum</i>	67	12.0
	<i>Ammonia beccarii</i>	54	9.7
	<i>Quinqueloculina seminula</i>	37	6.6
	<i>Rosalina</i> n. sp.	36	6.4
	<i>Elphidium</i> n. sp.	19	3.4
	<i>Elphidium mexicanum</i>	12	2.1
	<i>Cibicides</i> sp.	11	2.0
	<i>Bolivina striatula</i>	10	1.8
	<i>Rosalina subaraucana</i>	10	1.8
	<i>Buccella hannai</i>	9	1.6
	<i>Nonionella basiloba</i>	7	1.3
	<i>Triloculina schreiberiana</i>	5	0.9
	<i>Stetsonia minuta</i>	4	0.7
	<i>Asterigerina carinata</i>	3	0.5
	<i>Bolivina lowmani</i>	3	0.5
	<i>Eponidella gardenislandensis</i>	3	0.5
	<i>Elphidium</i> sp. B	2	0.4
	<i>Sagrina pulchella</i>	2	0.4
	<i>Elphidium discoideale</i>	1	0.2
	<i>Elphidium</i> sp. A	1	0.2

<i>Fissurina</i> sp.	1	0.2
<i>Gavelinopsis umbonata</i>	1	0.2
<i>Globulina gibba</i>	1	0.2
<i>Hanzawaia concentrica</i>	1	0.2
<i>Pseudononion atlantica</i>	1	0.2
<i>Quinqueloculina</i> sp.	1	0.2
<i>Reusella atlantica</i>	<u>1</u>	<u>0.2</u>
TOTAL	559	100.2
planktonics	1	0.2

61.4 ft 19 benthic species

<i>Ammonia beccarii</i>	presence only
<i>Asterigerina carinata</i>	
<i>Buccella hannai</i>	
<i>Cibicides</i> sp.	
<i>Elphidium excavatum</i>	
<i>E. fimbriatulum</i>	
<i>E. gunteri</i>	
<i>E. mexicanum</i>	
<i>E. poeyanum</i>	
<i>E. n. sp.</i>	
<i>E. sp.</i>	
<i>Eponidella gardenislandensis</i>	
<i>Eponides</i> sp.	
<i>Haynesina germanica</i>	
<i>Nonionina</i> sp.	
<i>Quinqueloculina auberiana</i>	
<i>Q. compta</i>	
<i>Q. seminula</i>	
<i>Rosalina subaraucana</i>	

55.3 ft 22 benthic species

<i>Ammonia beccarii</i>	presence only
<i>Asterigerina carinata</i>	
<i>Buccella hannai</i>	
<i>Cibicides</i> sp.	
<i>Elphidium excavatum</i>	
<i>E. galvestonense</i>	
<i>E. gunteri</i>	
<i>E. mexicanum</i>	
<i>E. poeyanum</i>	
<i>E. n. sp.</i>	

E. sp.
Eponidella gardenislandensis
Guttulina australis
Hanzawaia concentrica
Haynesina germanica
Nonionella basiloba
Nonionina sp.
Quinqueloculina auberiana
Q. compta
Q. seminula
Q. sp.
Sagrina pulchella

54.8 ft	24 benthic species		
	<i>Haynesina germanica</i>	225	37.1
	<i>Elphidium excavatum</i>	86	14.2
	<i>Buliminella elegantissima</i>	80	13.2
	<i>Ammonia beccarii</i>	74	12.2
	<i>Elphidium n. sp.</i>	33	5.4
	<i>Quinqueloculina seminula</i>	24	4.0
	<i>Rosalina n. sp.</i>	22	3.6
	<i>Buccella hannai</i>	16	2.6
	<i>Elphidium mexicanum</i>	7	1.2
	<i>Rosalina subaraucana</i>	7	1.2
	<i>Bolivina striatula</i>	5	0.8
	<i>Cibicides sp.</i>	5	0.8
	<i>Nonionella basiloba</i>	5	0.8
	<i>Bolivina lowmani</i>	3	0.5
	<i>Sagrina pulchella</i>	3	0.5
	<i>Eoeponidella delicatulum</i>	2	0.3
	<i>Quinqueloculina laevigata</i>	2	0.3
	<i>Bolivina sp.</i>	1	0.2
	<i>Cassidulina reniforme</i>	1	0.2
	<i>Fissurina sp. A</i>	1	0.2
	<i>Fissurina sp. B</i>	1	0.2
	<i>Gavelinopsis umbonata</i>	1	0.2
	<i>Pseudononion atlantica</i>	1	0.2
	<i>Spiroloculina antillarum</i>	<u>1</u>	<u>0.2</u>
	TOTAL	606	100.1
	planktonics	2	0.3

52.3 ft 26 benthic species

<i>Ammonia beccarii</i>		presence only
<i>Asterigerina carinata</i>		
<i>Bolivina striatula</i>		
<i>Buccella hannai</i>		
<i>Buliminella elegantissima</i>		
<i>Elphidium discoidale</i>		
<i>Elphidium excavatum</i>		
<i>Elphidium fimbriatulum</i>		
<i>Elphidium gunteri</i>		
<i>Elphidium mexicanum</i>		
<i>Elphidium poeyanum</i>		
<i>Elphidium</i> sp. A		
<i>Elphidium</i> n. sp.		
<i>Hanzawaia concentrica</i>		
<i>Haynesina germanica</i>		
<i>Nonionella basiloba</i>		
<i>Nonionina</i> sp.		
<i>Pseudononion atlantica</i>		
<i>Quinqueloculina auberiana</i>		
<i>Quinqueloculina compta</i>		
<i>Quinqueloculina poeyana</i>		
<i>Quinqueloculina seminula</i>		
<i>Rosalina subaraucana</i>		
<i>Rosalina</i> n. sp.		
<i>Sagrina pulchella</i>		
<i>Triloculina</i> sp.		
planktonics		

51.7 ft 20 benthic species

<i>Elphidium excavatum</i>	262	47.5
<i>Ammonia beccarii</i>	112	20.3
<i>Buliminella elegantissima</i>	64	11.6
<i>Elphidium</i> n. sp.	40	7.2
<i>Haynesina germanica</i>	27	4.9
<i>Buccella hannai</i>	12	2.2
<i>Elphidium gunteri</i>	9	1.6
<i>Bolivina striatula</i>	7	1.3
<i>Quinqueloculina seminula</i>	7	1.3
<i>Bolivina lowmani</i>	2	0.4
<i>Cassidulina reniforme</i>	1	0.2
<i>Cibicides</i> sp.	1	0.2
<i>Elphidium mexicanum</i>	1	0.2

<i>Fissurina</i> sp. A	1	0.2
<i>Fissurina</i> sp. B	1	0.2
<i>Fursenkoina mexicana</i>	1	0.2
<i>Quinqueloculina laevigata</i>	1	0.2
<i>Rosalina subaraucana</i>	1	0.2
<i>Sagrina pulchella</i>	1	0.2
<i>Stetsonia minuta</i>	<u>1</u>	<u>0.2</u>
TOTAL	552	100.3
planktonics	0	0.0

40.8 ft 28 benthic species

<i>Elphidium gunteri</i>	80	20.3
<i>Ammonia beccarii</i>	46	11.6
<i>Quinqueloculina seminula</i>	42	10.6
<i>Elphidium mexicanum</i>	34	8.6
<i>Rosalina subaraucana</i>	27	6.8
<i>Hanzawaia concentrica</i>	25	6.3
<i>Rosalina</i> n. sp.	23	5.8
<i>Haynesina germanica</i>	19	4.8
<i>Cibicides</i> sp.	17	4.3
<i>Buliminella elegantissima</i>	14	3.5
<i>Quinqueloculina</i> sp.	12	3.0
<i>Elphidium discoideale</i>	10	2.5
<i>Pseudononion atlantica</i>	8	2.0
<i>Asterigerina carinata</i>	6	1.5
<i>Nonionina</i> sp.	6	1.5
<i>Buccella hannai</i>	5	1.3
<i>Nonionella basiloba</i>	4	1.0
<i>Elphidium fimbriatulum</i>	3	0.8
<i>Sagrina pulchella</i>	3	0.8
<i>Bolivina paula</i>	2	0.5
<i>Elphidium</i> sp. A	2	0.5
<i>Elphidium</i> sp. B	1	0.3
<i>Eponidella gardenislandensis</i>	1	0.3
<i>Glabratella</i> sp.	1	0.3
<i>Globulina gibba</i>	1	0.3
<i>Guttulina australis</i>	1	0.3
<i>Guttulina</i> sp.	1	0.3
<i>Stetsonia minuta</i>	<u>1</u>	<u>0.3</u>
TOTAL	395	100.1
planktonics	1	0.3

26.3 ft 31 benthic species

<i>Hanzawaia concentrica</i>	222	40.1
<i>Quinqueloculina seminula</i>	87	15.7
<i>Elphidium gunteri</i>	73	13.2
<i>Elphidium mexicanum</i>	28	5.1
<i>Guttulina australis</i>	25	4.5
<i>Quinqueloculina compta</i>	16	2.9
<i>Ammonia beccarii</i>	15	2.7
<i>Elphidium discoidale</i>	15	2.7
<i>Quinqueloculina auberiana</i>	15	2.7
<i>Rosalina subaraucana</i>	8	1.4
<i>Asterigerina carinata</i>	5	0.9
<i>Cibicides</i> sp.	5	0.9
<i>Pseudononion atlantica</i>	5	0.9
<i>Triloculina linneiana</i>	5	0.9
<i>Buccella hannai</i>	4	0.7
<i>Buliminella elegantissima</i>	4	0.7
<i>Triloculina</i> sp. A	3	0.5
<i>Archais angulatus</i>	2	0.4
<i>Elphidium fimbriatum</i>	2	0.4
<i>Rosalina</i> n. sp.	2	0.4
<i>Textularia agglutinans</i>	2	0.4
<i>Bigenerina irregularis</i>	1	0.2
<i>Elphidium poeyanum</i>	1	0.2
<i>Elphidium</i> n. sp.	1	0.2
<i>Fursenkoina pontoni</i>	1	0.2
<i>Globulina gibba</i>	1	0.2
<i>Haynesina germanica</i>	1	0.2
<i>Quinqueloculina agglutinans</i>	1	0.2
<i>Quinqueloculina poeyana</i>	1	0.2
<i>Quinqueloculina</i> sp.	1	0.2
<i>Reusella atlantica</i>	<u>1</u>	<u>0.2</u>
TOTAL	553	100.1
planktonics	2	0.4

Biostratigraphy

Most benthic species in the assemblages have biostratigraphic ranges that extend back into the Miocene or Pliocene. Few studies have been made of shallow-water Pleistocene foraminiferal faunas in warm-water areas of eastern North America, and the stratigraphic ranges of those benthic species that extend back only into the Pleistocene are not known at this time.

Paleosalinity/paleobathymetry

Both the species composition and the relatively high species diversity of the Holocene benthic assemblages suggest that these deposits represent shallow marine environments of normal, or near normal salinity. The following discussion first examines the open marine species in the assemblages and then the benthic diversity of the assemblages. This is followed by a brief discussion of the planktonic foraminiferal component of the samples, and finally by a discussion of possible paleobathymetric changes.

Several benthic species occur in the Holocene assemblages of the Horn Island cores that are known only from open marine environments of the Gulf of Mexico. Other species in the Holocene assemblages have most of their recordings in open marine environments, but they also have some records from channels between barrier islands off the Alabama and Mississippi coasts and lower ends of bays or estuaries that have almost open marine conditions.

Species in the Holocene assemblages that have almost all recordings in open marine conditions include *Asterigerina carinata*, *Bigenerina irregularis*, *Sagrina pulchella*, *Stetsonia minuta*, and *Textularia agglutinans*. The presence of at least some of these species in all of the Holocene samples suggests similar near-open to open marine environments for these deposits.

Phleger (1951) and Culver and Buzas (1981) found a number of benthic species that have modern bathymetric ranges in shallow open marine environments with a maximum water depth of 164 ft (50 m) or less. A number of these species occur in the Holocene assemblages in the Horn Island cores, including *Asterigerina carinata*, *Bigenerina irregularis*, *Bolivina striatula*, *Buccella hannai*, *Elphidium discoidale*, *E. mexicanum*, *Hanzawaia concentrica*, and *Quinqueloculina seminula*. Therefore, this group of species suggests water depths less than 164 ft during Holocene deposition. This shallow depth range is supported by all the other studied foraminiferal factors.

Changes in the proportions of several benthic species through parts of the Holocene section suggest that some changes in paleobathymetry, salinity, currents, position of barrier islands, paleoclimate, or other factors took place during its deposition.

Hanzawaia concentrica occurs in several assemblages in the middle and lower parts of the Holocene section in abundances of six percent or less (Table 1). However, this species composes 40.1 percent of the assemblage at 26.3 ft. Bandy (1954), Walton (1964), and Bock (1976) found that the proportion of *H. concentrica* is usually five percent or less in waters less than 60 ft deep, although it may be as much as ten percent. However, the proportion of this species increases considerably at depths greater than 60 ft, reaching 30 percent or greater. The high proportion of this species in the assemblage at 26.3 ft suggests that water depths as great as 60 ft or slightly more were present. The probability that the high proportion of *H. concentrica* represents slightly deeper waters is supported by the occurrence in this sample of both the highest species diversity and lowest proportion of *Ammonia beccarii* in any of the Holocene samples, as discussed below.

Puckett (1992) found that the highest dominance of *Ammonia beccarii* in the calcareous assemblage occurs in low salinity waters of around 3 to 17 o/oo, and that the dominance of this

species decreased as the salinity increased. He found that the proportion of this species was approximately 15 percent or less in the shallow open marine environments. Two trends are seen for this species in the Horn Island assemblages (Table 1). There is a gradual upward increase in the proportion of this species in the lower three samples from slightly less than 10 percent in the lowest sample to slightly greater than 20 percent in the highest sample of the three. This upward increase could suggest a slight upward decrease in the paleobathymetry or the salinity, or it could represent just a change in currents or bottom topography around a barrier island or channel. As discussed below, the species diversity also decreases upward through these three samples, and there is also a small upward decrease in the planktonic percentage. Both of these decreases also could suggest a slight upward change in some environmental aspect.

The other trend seen in the *Ammonia beccarii* distribution is the smaller proportion of this species in the sample at 40.8 ft than at 51.7 ft, followed by a considerable decrease to only 2.7 percent of this species in the uppermost sample at 26.3 ft. The small proportion of this species at 26.3 ft would support the depth increase suggested by the increase in *H. concentrica* and by the increase in species diversity.

Another general environmental trend in species distributions that is parallel to the distribution of *A. beccarii* is the dominance of the benthic assemblage by the two species, *A. beccarii* and *Elphidium gunteri*. Lamb (1972) and Puckett (1992) found that the highest combined frequency of these two species is in brackish waters with salinities of around 20 to 25 o/oo. Although the combined frequencies of these two taxa usually was greater than 40 percent in the lower part of Mobile Bay and in the inner half of Mississippi Sound, the combined percentages were usually between 13 to 37 percent in the channels between the barrier islands and in open marine areas. Bandy (1956) also found that in the northeastern Gulf of Mexico both *Ammonia* spp. and *E. gunteri* are much more abundant in waters of less than 40 ft depth than in deeper waters. *Elphidium gunteri* is replaced in the lower three Holocene samples by the cooler water species *E. excavatum* and this measure cannot be applied to these samples. However, in the upper two samples the proportion of these two species decreases from 31.9 percent in the sample at 40.8 ft to 15.9 percent in the sample at 26.3 ft (Table 1). The decrease in these two species supports other information suggesting a slight depth increase over this interval.

A foraminiferal assemblage characteristic that can be applied to paleoenvironmental analysis is the number of benthic species in the assemblage. The number of benthic species in continental shelf assemblages generally increases as water depth and distance from shore increases. This increase in species numbers has been documented in the Gulf of Mexico (Bandy, 1954; 1956; Walton, 1964; Gibson and Buzas, 1973).

Puckett (1992) found that Mobile Bay benthic foraminiferal assemblages vary from around three species in the upper, less saline parts of the bay to six to seven species in the lower, more saline parts. A maximum of 11 species was found in the channel between the barrier islands at its mouth. His assemblages from inner parts of eastern Mississippi Sound also had eight species or fewer. Assemblages from channel areas between barrier islands at the outer part of Mississippi Sound and in shallow open ocean areas just seaward of the barrier islands have 14 to 21 species. Walton (1964) found about 20 benthic species in the middle of Mississippi Sound and an increase to about 30 species in the shallow open-marine areas just seaward of the Mississippi-Alabama barrier islands.

The diversity ranges from 20 to 31 species in the Holocene samples (Table 1). All of these values suggest depositional environments from near channel inlets between the barrier islands to shallow open-marine environments of the inner shelf. The upward decrease from 29 species in the lowest sample at 61.9 ft to 20 species in the sample at 51.7 ft may suggest a shallowing, a decrease in the salinity of the environment, or some other change as other measures show change over this same interval. That the highest diversity of 31 species occurs in the sample at 26.3 ft follows the trends of other measures that suggest that this sample was deposited in a slightly deeper water environment.

Grimsdale and Van Morkhoven (1955) and Gibson (1989) documented that the proportion of planktonic specimens in foraminiferal assemblages increases as the water depth and distance from shore increases. Oceanographic conditions of reduced salinity and increased turbidity, such as commonly found in nearshore environments, seemingly are the cause of the decrease in density of planktonic specimens (Funnell, 1967). Therefore, the total foraminiferal assemblages in the lower salinity, high turbidity environments of Mobile Bay and Mississippi Sound would be expected to have few planktonic specimens. Even the shallow open marine environments around the Mississippi-Alabama barrier islands should have relatively small proportions of planktonic specimens in the assemblages.

Although Puckett (1992) found planktonic specimens in most assemblages in the channels between the Alabama barrier islands and on the seaward side of the barrier islands, they composed less than one percent of the total foraminiferal assemblage. He found planktonic foraminifers in only one sample in Mobile Bay and that consisted of a single specimen.

A low proportion of planktonic specimens occurs in the Holocene samples in the Horn Island corehole. Four of the five samples contain planktonic specimens, but they compose only 0.2 to 0.4 percent of the assemblage. However, their occurrence in most samples would confirm a nearly open-marine to shallow open-marine depositional environment. The one sample that does not contain any planktonic specimens also is considered as representing the shallowest water or most restricted environment.

Thus, the foraminiferal assemblages would suggest that there was an upward environmental change through the Holocene section in the Horn Island corehole from 61.9 to 51.7 ft. This change could be the result of a modest shallowing of the environment, a slight decrease in the salinity, a difference in current directions, or some other relatively small change. The environmental differences could represent a change in the position of this corehole in relation to a barrier island or to the channel between barrier islands so that the degree of open ocean access was slightly hindered.

A second environment change is present in the upper two samples at 40.8 and 26.3 ft, as compared to the sample at 51.7 ft and to each other. The foraminiferal constituents suggest that these two samples were deposited in slightly more open marine or slightly deeper water environments than those present during deposition of the sample at 51.7 ft. Additionally, the sample at 26.3 ft appears to represent a slightly deeper water depositional environment than any of the other Holocene samples. These changes also could be a result of changes in the configuration of a barrier island and channel, but the differences in the uppermost sample more strongly suggest that there was a higher sea level at this time.

Paleotemperature.

A change in the paleotemperature during Holocene deposition at Horn Island is suggested by compositional changes in the benthic foraminiferal assemblages between the lower three assemblages and the upper two. The lower three Holocene samples at 61.9, 54.8, and 51.7 ft contain some species, such as *Asterigerina carinata*, *Bolivina striatula*, *Elphidium mexicanum*, *Nonionella basiloba*, *Reusella atlantica*, *Rosalina subaraucana*, *Sagrina pulchella*, and *Stetsonia minuta* that are characteristic of warm, subtropical waters such as those found today to the south of Cape Hatteras, North Carolina, and in the northeastern Gulf of Mexico (Culver and Buzas, 1980; 1981). But some cooler water species also are present in these samples. *Elphidium excavatum* is among the three most dominant species in these three assemblages. This species is most commonly found and is most abundant in temperate waters north of Cape Hatteras, although there are some occurrences of this species just to the south of Cape Hatteras (Culver and Buzas, 1981). *Elphidium gunteri*, a species most characteristic and most abundant in the Atlantic margin south of Cape Hatteras and in the northeastern Gulf of Mexico, is found only in the uppermost of these three samples, and there it occurs only in a low proportion.

However, the uppermost two Holocene samples at 40.8 and 26.3 ft contain large proportions of *E. gunteri* and no specimens of *E. excavatum*. The upper two samples, particularly the uppermost one, contain additional warm water species *Archais angulatus*, *E. fimbriatulum*, *E. poeyanum*, *Quinqueloculina auberiana*, and *Q. compta* that are not present in the lower three samples.

The species occurrences suggest that the interval from 61.9 to 51.7 ft was deposited under climatic conditions that allowed both cool and warm water species to commingle, such as occurs today in the Cape Hatteras area. The upper interval from 40.8 to 26.3 ft more closely reflects subtropical temperatures such as those found today to the south of Cape Hatteras and in the northeastern Gulf of Mexico.

There may be a connection between the warmer sea temperatures suggested for the upper part of the Holocene deposits in the Horn Island corehole and the higher sea levels suggested for this interval. Conversely, the cooler sea temperatures suggested for the lower part of the Holocene deposits may be correlated with slightly lower sea levels. As the radiocarbon age for the peaty sediments immediately underlying the 61.9 to 51.7 interval is $9,470 \pm 90$ years, it is possible that the foraminiferal faunas in this interval reflect cooler temperatures that were present during the relatively early stages of post-glaciation warming and sea level rise. The warmer sea temperatures suggested for the higher Holocene interval may reflect the upper part of a warming cycle that started with the lower samples, but there also is the possibility that the relatively sudden entrance of the warmer water assemblage at 40.8 ft reflects a hiatus in the section somewhere between this depth and the sample at 51.7 ft.

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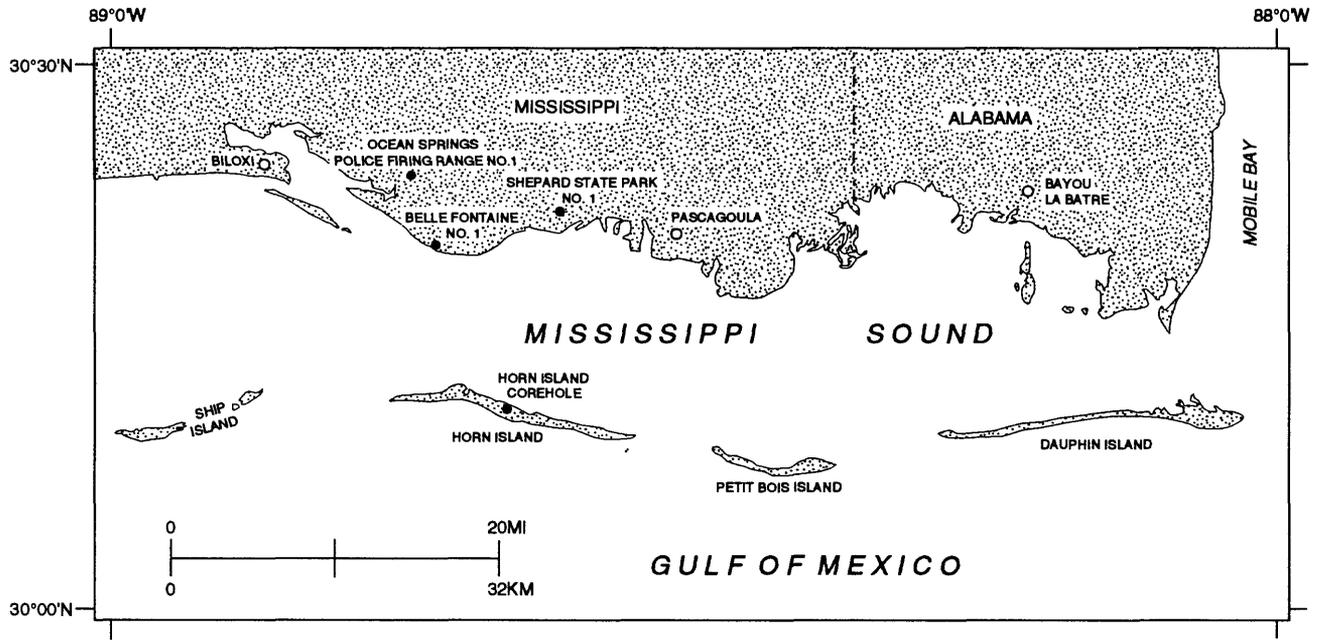


Figure 1. Map of coastal Mississippi and Alabama with filled circles showing location of Horn Island corehole and three USGS coreholes in southern Mississippi.

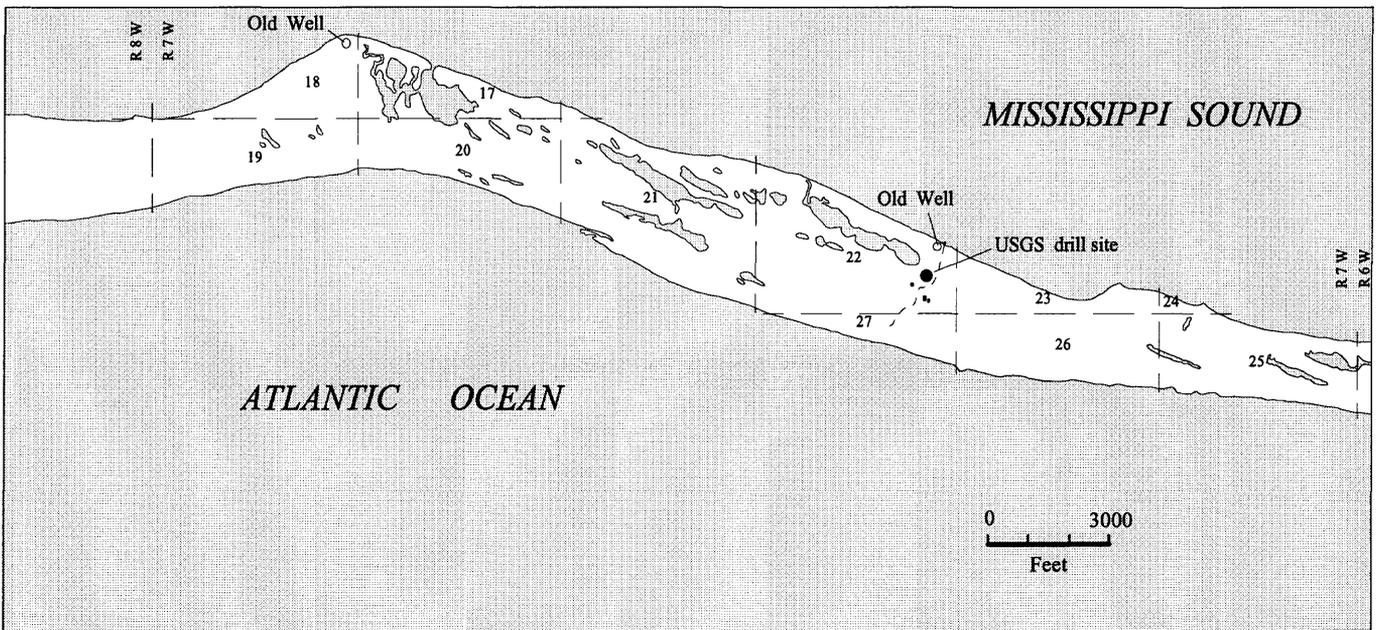


Figure 2. Map of the central part of Horn Island showing the location of the USGS drill site. Sections within Township 9 South, Range 7 West, are indicated.

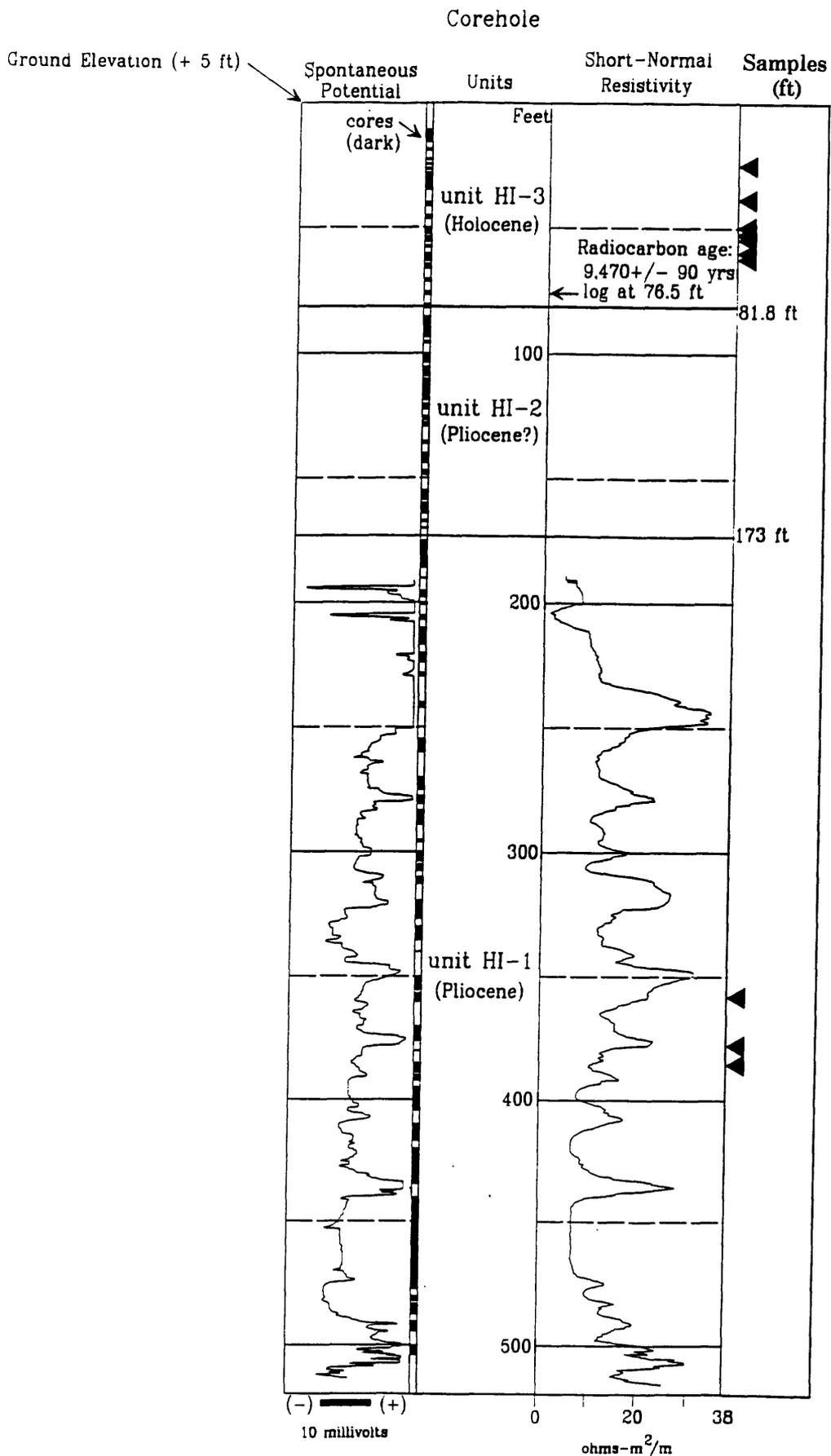


Figure 3. Neogene and Quaternary units and electric logs in Horn Island corehole (from Gregory Gohn, written comm., 1994). Triangles show locations of foraminiferal samples.

Table 1. Foraminiferal values in Horn Island corehole Pliocene and Holocene samples.

Sample depth (ft)	Number of Benthic species	Planktonic percentage	<i>Ammonia beccarii</i> percentage	<i>Elphidium gunteri</i> percentage	<i>Hanzawaia concentrica</i> percentage
26.3	31	0.4	2.7	13.2	40.1
40.8	28	0.3	11.6	20.3	6.3
51.7	20	0.0	20.3	1.6	0.0
54.8	24	0.3	12.2	0.0	0.0
61.9	29	0.2	9.7	0.0	0.2
357.5	5	0.0	86.8	7.5	0.0
376.1	3	0.0	98.9	0.4	0.0
380.2	2	0.0	98.6	1.4	0.0