

Teresa L. Moore. FORAMINIFERAL BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE MIOCENE PUNGO RIVER FORMATION, CENTRAL ONSLOW EMBAYMENT, NORTH CAROLINA CONTINENTAL MARGIN. (Under the direction of Dr. Scott W. Snyder) East Carolina University, Department of Geology, March, 1986.

The Pungo River Formation in Central Onslow Embayment consists of three third-order seismic sequences (FPF, AF, and BBF), which comprise smaller, fourth-order seismic sequences bounded by unconformities. Biostratigraphic analyses indicate a Burdigalian (late early Miocene) age for the FPF sequences. FPF-1 through FPF-3 and the lower portion of FPF-6 are assigned to planktonic foraminiferal Zone N6 (Blow, 1969, 1979) based on the concurrent ranges of secondary indicator species such as Globigerinoides quadrilobatus altiapertura, Catapsydrax unicavus, Globorotalia birnageae, Globigerinoides quadrilobatus praeimmaturus and Globigerinoides subquadratus. The middle and upper portion of the FPF-6 sequence lies within the early portion of Zone N7 (based on the first appearance of Globigerinoides sicanus praesicanus). The AF sequence is Langhian (early middle Miocene) in age and is assigned to planktonic foraminiferal Zone N9 (characterized by the appearance of Orbulina universa and the disappearance of early Miocene taxa). The age of the BBF sequence in Central Onslow Bay cannot be as accurately estimated due to the long stratigraphic ranges of species present. However, in Northern Onslow Bay the disappearance of the



Globigerinoides sicanus complex, along with the co-occurrence of Globigerinoides bollii and Globorotalia siakensis (Snyder, pers. comm., 1985), suggests a Serravallian (middle Miocene) age corresponding to Zones N11-N14. When compared to coastal offlap/onlap curves, the FPF, AF and BBF sequences fall within the third-order Miocene TM 1.4, 2.1 and 2.2 transgressions, respectively (Vail et al., 1977; Vail and Mitchum, 1979).

Moderate species diversity and faunal predominance in benthic assemblages indicate deposition on the middle to outer continental shelf. Three distinct benthic foraminiferal associations in Central Onslow Bay are each associated with a particular sediment type throughout the sequences. Change in species composition of benthic assemblages reflects variations in water mass properties and sediment type, rather than paleobathymetry. The FPF-1, FPF-2 and FPF-3 sequences are slightly predominated by Bolivina paula and other species associated with high-nutrient, low-oxygen conditions characteristic of upwelling zones. Increased abundance of Valvulineria floridana and Cibicides americanus in the FPF-6 sequence suggests transition from conditions of modest nutrient supply to more highly oxygenated, normal marine conditions. The strong predominance of Cibicides americanus in the AF-3 sequence suggests a well oxygenated, open marine environment. Bolivina paula predominates in the BBF-1 and BBF-2 sequences. In BBF-1, the abundance of this species, in association with diatoms and high phosphate content suggests strong upwelling conditions. The predominance of Bolivina paula in BBF-2 is probably related to its



preferential preservation involving mechanical destruction of other species that may have been present.

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OF THE MIOCENE PUNGO RIVER FORMATION,  
CENTRAL ONSLOW EMBAYMENT,  
NORTH CAROLINA CONTINENTAL MARGIN

A Thesis

Presented to  
the Faculty of the Department of Geology

East Carolina University

In Partial Fulfillment  
of the Requirements for the Degree  
Master of Science in Geology

by

Teresa L. Moore

March 6, 1986

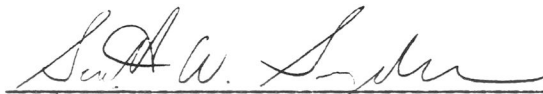
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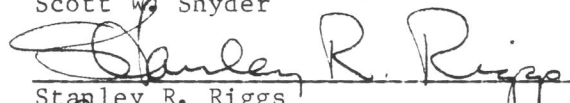
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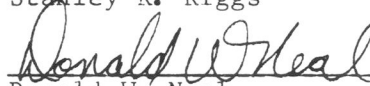
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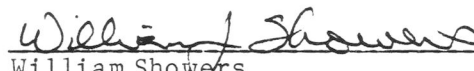
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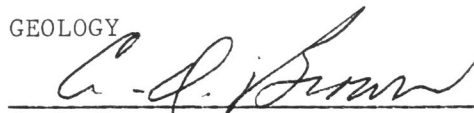
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THE END

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## INTRODUCTION

Onslow Bay is located on the southeastern continental margin of North Carolina (Fig. 1). The Miocene Pungo River Formation, which underlies the northeastern portion of the North Carolina Coastal Plain, extends across Onslow Bay to form a seaward-thickening wedge of sediments.

The Pungo River Formation is equivalent to the Calvert Formation of the early Miocene to late Pliocene Chesapeake Group, which occurs along the Atlantic Coastal Plain from North Carolina to Delaware (Bailey, 1973). Pungo River strata unconformably overly sediments of Eocene to Oligocene age, and are unconformably overlain by the Pliocene Yorktown Formation (Akers, 1972; Snyder et al., 1983) or Quaternary sediments. Miocene sediments along some portions of the southeastern Atlantic Coastal Plain and Continental Shelf contain high concentrations of phosphate. Although economically important phosphate deposits do not occur in the Calvert, Choptank and St. Marys Formations of Maryland and Virginia (lower through middle Miocene), Pungo River sediments in North Carolina are generally phosphate-rich. The most concentrated deposits occur in the Aurora mining district and in Southern Onslow Bay (Riggs et al., 1985) (Fig. 1). Pungo River sediments are also correlative with the Miocene Hawthorn Formation, which contains abundant phosphate in Florida, Georgia and South Carolina (Riggs et al., 1982a; Riggs, 1984).

Research on phosphate genesis and accumulation, funded by the

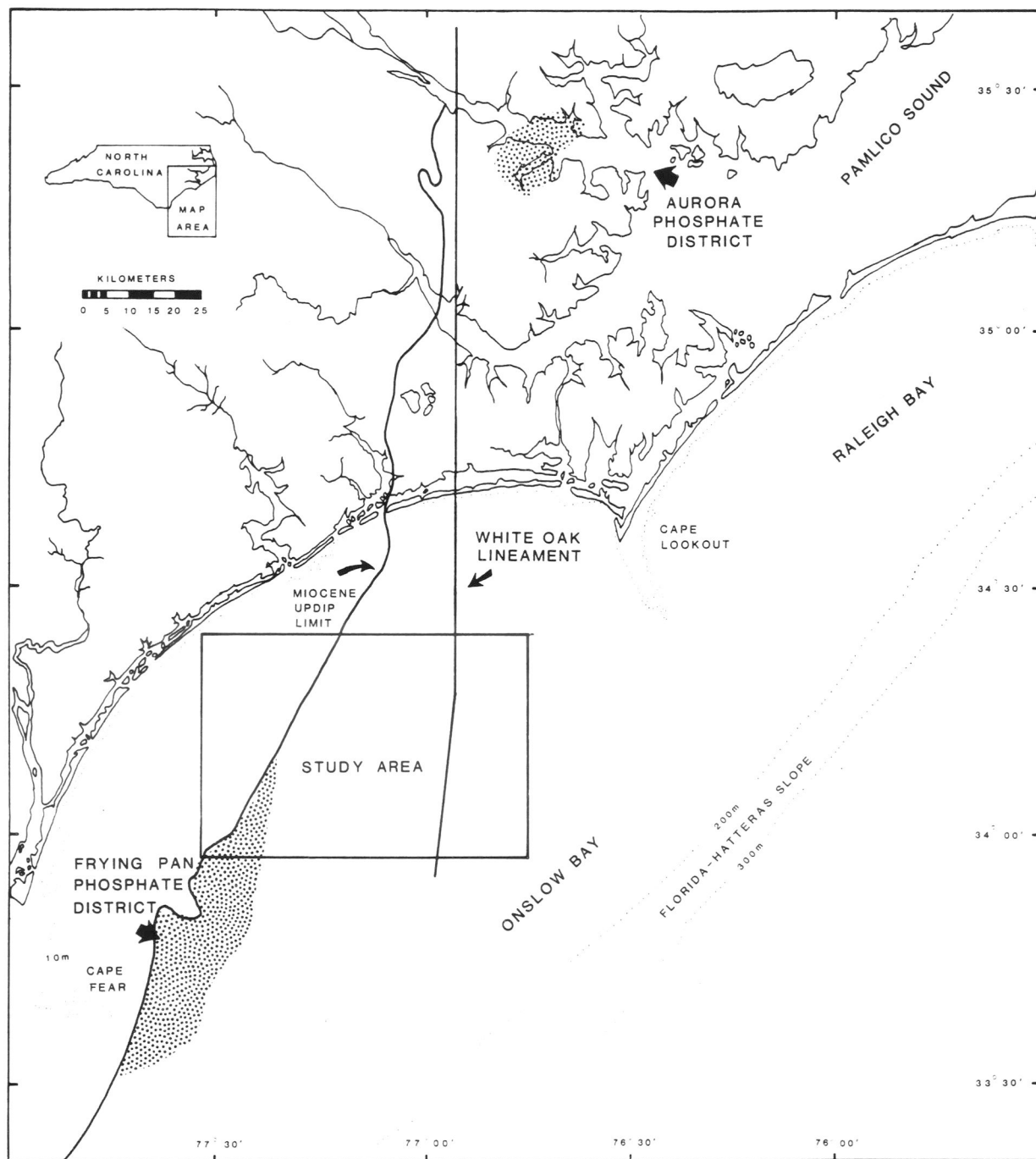


Fig. 1. Location of study area of Central Onslow Bay to major geographic features and phosphate districts (after Riggs et al., 1985).

National Science Foundation and coordinated by Dr. Stanley R. Riggs of East Carolina University and Dr. Albert C. Hine of the University of South Florida, has demonstrated that Pungo River sediments crop out across the continental shelf of Onslow Bay, North Carolina (Fig. 2) (Lewis, 1981; S.W.P. Snyder et al., 1982; Riggs et al., 1982a). Vibracore data and high-resolution seismic profiles of Pungo River strata in Onslow Bay indicate a belt of phosphatic sediments extending for 150 km across the continental shelf from Northern Onslow Bay southwestward to the Frying Pan Area (Fig. 2). Studies of Pungo River sedimentary sequences from Aurora and Onslow Bay have led to a model of cyclic transgressive/regressive deposition controlled largely by global eustatic sea-level fluctuations (Riggs et al., 1982b; Riggs, 1984).

Portions of the Pungo River Formation have been interpreted by way of seismic stratigraphy, lithostratigraphy, geochemistry, foraminiferal paleoecology and biostratigraphy, sedimentology and petrology. My study, as part of this larger phosphate research project, uses foraminiferal assemblages to interpret paleoenvironments and biostratigraphic age assignments of Pungo River sedimentary sequences in Central Onslow Bay. The results, integrated with seismic, lithologic and similar paleoecological studies (Waters, 1983; Snyder et al., 1982; Katrosh and Snyder, 1982; Riggs et al., 1982a; S.W.P. Snyder, 1982; Lewis, 1981) provide more complete understanding of the genesis, deposition and diagenesis of the Pungo River Formation. Biostratigraphic age assignments permit depositional sequences to be related to global eustatic sea-level fluctuations (Vail and Mitchum,

1979; Vail et al, 1977).

## REGIONAL GEOLOGIC AND GEOGRAPHIC SETTING

Onslow Bay is a broad embayment along the southeastern continental margin off North Carolina. The embayment is bordered by the elongate sand bodies associated with the Cape Lookout High to the northeast and Cape Fear to the southwest (Fig. 1). The shelf edge marks its eastern boundary. Water depths grade from 6 m at the base of the lower forebeach to about 50 m at the shelf edge. Average water depths in Onslow Bay are approximately 20-30 m.

In Onslow Bay, Miocene Pungo River sediments unconformably overlie light green, calcareous quartz sands of the lower Miocene/upper Oligocene Silverdale Formation. Pleistocene carbonates or Holocene surface sands, in turn, unconformably overlie the Pungo River Formation (Lewis, 1981; Lewis et al., 1982).

The terrain of the adjacent North Carolina Coastal Plain has low relief and elevation (0-15 m), and is predominantly swamps and pocosin highlands. Mesozoic and Cenozoic subsurface sediments overlie a pre-Cretaceous crystalline basement (Brown et al., 1972). These sediments form a seaward thickening wedge which extends beneath the continental shelf, grading eastward from 600 m to more than 3 km. Erosional truncation has produced a series of subparallel Tertiary bands that become younger in a seaward direction (Riggs et al., 1982a). Deposition and erosion of the sediments have been controlled by recurrent movement along the basement structures according to Miller

(1971), Brown et al. (1972) and Harris et al. (1979). Throughout Neogene time, however, deposition and erosion of sediments have been controlled by marine transgressive/regressive cycles, and seismic data suggest minimal structural movement (S. W. P. Snyder, 1982; Riggs et al., 1982a).

## METHODS OF STUDY

At present, 135 vibracores have been collected from Onslow Bay. Twenty-eight cores (9 m maximum length) from Central Onslow Bay were examined in detail (Fig. 2). Cores were selected by using lithologic logs and seismic profiles of Onslow Bay (Lewis, 1981; Riggs et al., 1982b; S.W.P. Snyder, 1982; S.W.P. Snyder et al., 1982) to ensure complete sample coverage of seismic/stratigraphic sequences within the study area.

Foraminiferal samples collected from cores at half meter intervals were soaked in a weak Calgon solution for approximately 24 hours. Each sample was boiled for 20-30 minutes in a very dilute solution of Quaternary "O" (alkyl imidazolinium chloride) to deflocculate the residual clays, which were then removed by wet sieving. The sediment was washed through U. S. Standard Sieves No. 14 (1.41 mm openings) and No. 230 (63  $\mu$  openings) in order to concentrate the sand-sized fraction. Washed samples were reduced to a workable size by using a microsplitter. The entire split was used to describe both the mineralogy and microfaunal assemblages.

After examining washed sediments from 28 cores, 41 samples from 15 cores were selected for detailed study of microfossils. Selection was based on the presence of sufficient numbers of foraminifers to yield statistically reliable interpretations. Table 1 summarizes selected samples and specifies types of analysis applied to each.

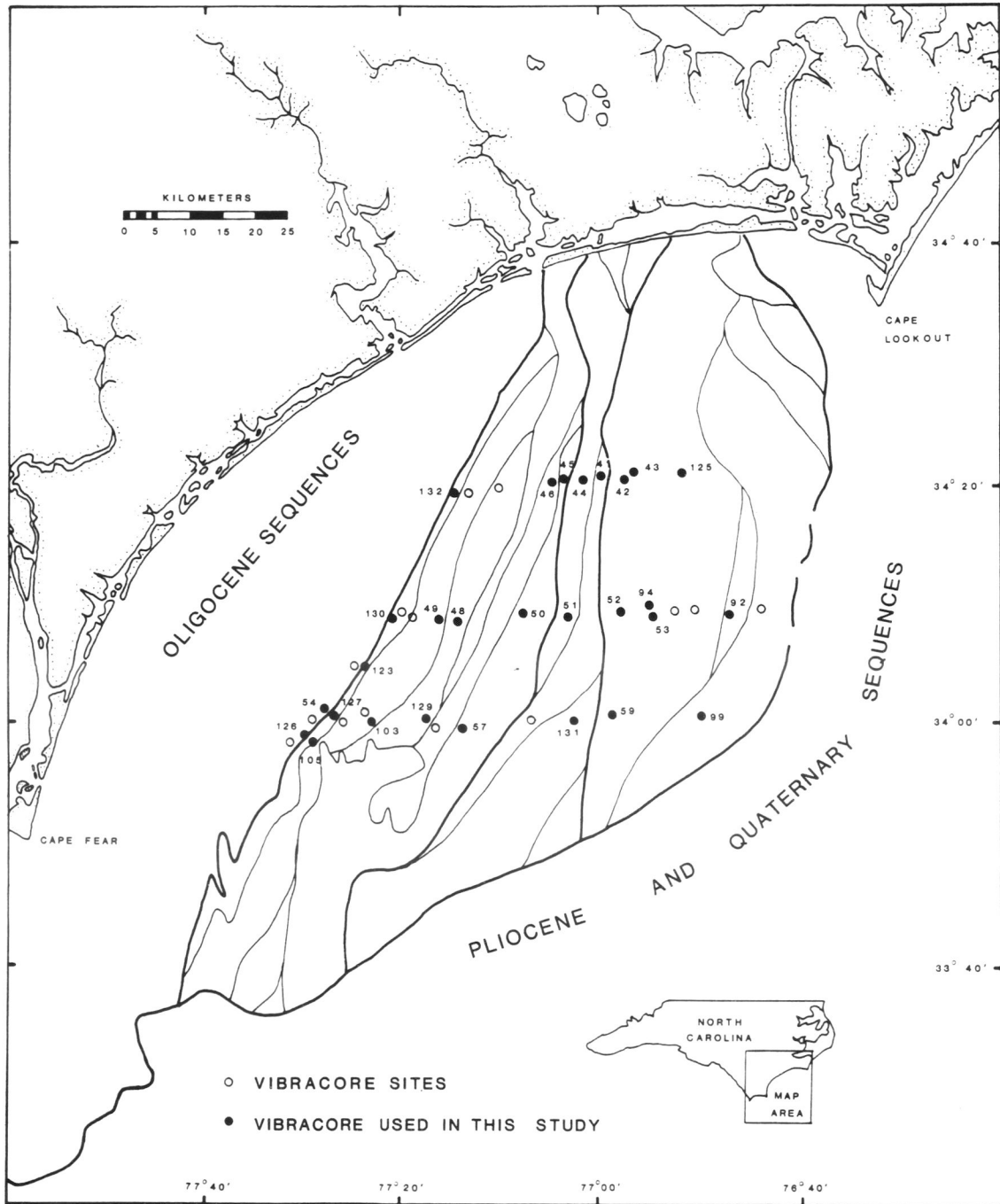


Fig. 2. Central Onslow Bay vibracore sites (after Riggs et al., 1985).



TABLE 1  
SUMMARIZATION OF SAMPLE ANALYSES

| CORE  | DEPTH (m) | PLANKTONIC FORAMINIFERS | BENTHIC FORAMINIFERS | COMPOSITION OF SAND FRACTION | SEISMIC SEQUENCE | CORE                                                                                               | DEPTH (m) | PLANKTONIC FORAMINIFERS | BENTHIC FORAMINIFERS | COMPOSITION OF SAND FRACTION | SEISMIC SEQUENCE         |
|-------|-----------|-------------------------|----------------------|------------------------------|------------------|----------------------------------------------------------------------------------------------------|-----------|-------------------------|----------------------|------------------------------|--------------------------|
| OB-41 | 3.50-3.75 |                         |                      | x                            | AF-1             | OB-92                                                                                              | 4.00      |                         |                      | x                            | BBF-2                    |
|       | 5.00-5.25 |                         |                      | x                            | AF-1             |                                                                                                    | 5.50      |                         | x                    | x                            | BBF-2                    |
|       | 7.00-7.25 |                         |                      | x                            | AF-1             |                                                                                                    | 6.00      |                         | x                    | x                            | BBF-2                    |
| OB-42 | 1.25-1.50 |                         |                      | x                            | BBF-1            | OB-94                                                                                              | 1.00      |                         | x                    | x                            | BBF-1                    |
|       | 3.00-3.25 |                         |                      | x                            | BBF-1            | OB-99                                                                                              | 5.00      |                         |                      | x                            | Y                        |
|       | 4.50-4.75 |                         |                      | x                            | BBF-1            | OB-103                                                                                             | 1.00      |                         |                      | x                            | FPF-2                    |
|       | 6.00-6.25 |                         |                      | x                            | BBF-1            |                                                                                                    | 2.00      |                         |                      | x                            | FPF-2                    |
|       | 6.50-6.75 |                         |                      | x                            | BBF-1            |                                                                                                    | 3.00      |                         |                      | x                            | FPF-2                    |
| OB-43 | 1.00-1.25 |                         | x                    | x                            | BBF-1            |                                                                                                    | 4.00      |                         |                      | x                            | FPF-2                    |
|       | 2.00-2.25 |                         |                      | x                            | BBF-1            |                                                                                                    | 5.00      |                         | x                    | x                            | FPF-2                    |
|       | 3.00-3.25 |                         |                      | x                            | BBF-1            |                                                                                                    | 5.90      |                         | x                    | x                            | FPF-2                    |
|       | 4.00-4.25 |                         |                      | x                            | BBF-1            | OB-105                                                                                             | 1.50      | x                       | x                    | x                            | FPF-1                    |
| OB-44 | 1.75-2.00 |                         |                      | x                            | AF-1             |                                                                                                    | 4.50      | x                       | x                    | x                            | FPF-1                    |
|       | 3.75-4.00 |                         |                      | x                            | AF-1             |                                                                                                    | 7.50      | x                       | x                    | x                            | FPF-1                    |
|       | 5.50-5.75 |                         |                      | x                            | AF-1             |                                                                                                    | 9.10      | x                       | x                    | x                            | FPF-1                    |
| OB-45 | 0.75-1.00 | x                       | x                    | x                            | FPF-6            | OB-123                                                                                             | 1.00      | x                       |                      | x                            | P                        |
|       | 3.00-3.25 | x                       | x                    | x                            | FPF-6            |                                                                                                    | 3.00      |                         |                      | x                            | FPF-2                    |
|       | 4.75-5.00 | x                       | x                    | x                            | FPF-6            |                                                                                                    | 4.50      |                         |                      | x                            | FPF-2                    |
| OB-46 | 2.75-3.00 |                         |                      | x                            | FPF-5            |                                                                                                    | 6.70      |                         |                      | x                            | FPF-2                    |
|       | 5.00-5.25 |                         |                      | x                            | FPF-5            | OB-125                                                                                             | 1.50      |                         |                      | x                            | Y                        |
|       | 7.00-7.25 |                         |                      | x                            | FPF-5            |                                                                                                    | 4.50      |                         |                      | x                            | Y                        |
| OB-48 | 1.25-1.50 |                         |                      | x                            | FPF-3            | OB-126                                                                                             | 1.00      | x                       | x                    | x                            | S                        |
|       | 2.25-2.50 | x                       | x                    | x                            | FPF-3            |                                                                                                    | 3.50      | x                       | x                    | x                            | S                        |
|       | 4.75-5.00 | x                       | x                    | x                            | FPF-3            |                                                                                                    | 5.00      | x                       | x                    | x                            | S                        |
|       | 6.25-6.50 |                         |                      | x                            | FPF-3            |                                                                                                    | 7.00      | x                       | x                    | x                            | S                        |
|       | 7.50-8.00 |                         |                      | x                            | FPF-3            | OB-127                                                                                             | 3.50      |                         |                      | x                            | FPF-1                    |
| OB-49 | 1.50-1.75 |                         |                      | x                            | FPF-2            |                                                                                                    | 4.50      |                         | x                    | x                            | FPF-1                    |
|       | 3.50-3.75 |                         |                      | x                            | FPF-2            |                                                                                                    | 5.50      |                         | x                    | x                            | FPF-1                    |
|       | 6.00-6.25 |                         |                      | x                            | FPF-2            |                                                                                                    | 7.00      |                         | x                    | x                            | FPF-1                    |
|       | 7.50-8.00 |                         |                      | x                            | FPF-2            |                                                                                                    | 8.00      |                         | x                    | x                            | FPF-1                    |
| OB-50 | 3.25-3.60 | x                       | x                    | x                            | FPF-6            | OB-129                                                                                             | 2.50      | x                       | x                    | x                            | FPF-3                    |
|       | 4.43-4.75 |                         |                      | x                            | FPF-6            |                                                                                                    | 4.00      | x                       | x                    | x                            | FPF-3                    |
|       | 5.75-6.00 |                         |                      | x                            | FPF-6            |                                                                                                    | 5.50      |                         | x                    | x                            | FPF-3                    |
| OB-51 | 3.00      |                         |                      | x                            | AF-1             |                                                                                                    | 7.00      |                         |                      | x                            | FPF-3                    |
|       | 6.00      |                         |                      | x                            | AF-1             | OB-130                                                                                             | 1.00      |                         |                      | x                            | FPF-1                    |
| OB-52 | 1.25-1.50 |                         |                      | x                            | P                |                                                                                                    | 3.00      |                         |                      | x                            | FPF-1                    |
|       | 2.70-3.00 |                         |                      | x                            | P                | OB-131                                                                                             | 3.00      | x                       | x                    | x                            | AF-3                     |
|       | 3.75-4.00 |                         |                      | x                            | BBF-1            |                                                                                                    | 4.50      |                         |                      | x                            | AF-3                     |
| OB-53 | 1.25-1.50 |                         | x                    | x                            | BBF-1            |                                                                                                    | 6.59      | x                       | x                    | x                            | AF-3                     |
|       | 2.75-3.00 |                         | x                    | x                            | BBF-1            | OB-132                                                                                             | 1.50      | x                       | x                    | x                            | FPF-1                    |
|       | 3.30-3.50 |                         | x                    | x                            | BBF-1            |                                                                                                    | 2.00      | x                       | x                    | x                            | FPF-1                    |
|       | 4.75-5.00 |                         | x                    | x                            | BBF-1            |                                                                                                    | 2.50      | x                       | x                    | x                            | FPF-1                    |
|       | 5.25-5.50 |                         | x                    | x                            | BBF-1            |                                                                                                    | 3.50      | x                       | x                    | x                            | FPF-1                    |
|       | 6.25-6.50 |                         | x                    | x                            | BBF-1            |                                                                                                    | 4.10      | x                       | x                    | x                            | FPF-1                    |
| OB-54 | 2.25      |                         |                      | x                            | S                |                                                                                                    |           |                         |                      |                              |                          |
|       | 3.00      |                         |                      | x                            | S                |                                                                                                    |           |                         |                      |                              |                          |
|       | 3.50      |                         |                      | x                            | S                |                                                                                                    |           |                         |                      |                              |                          |
| OB-57 | 0.75-1.00 |                         |                      | x                            | FPF-6            | LEGEND<br>Pungo River Formation<br>FPF-1 AF-1<br>FPF-2 AF-3<br>FPF-3 BBF-1<br>FPF-5 BBF-2<br>FPF-6 |           |                         |                      |                              | P = Pleistocene/Holocene |
|       | 3.25-3.50 |                         |                      | x                            | FPF-6            |                                                                                                    |           |                         |                      |                              | S = Silverdale Formation |
|       | 5.25-5.50 |                         |                      | x                            | FPF-5            |                                                                                                    |           |                         |                      |                              | Y = Yorktown Formation   |
|       | 8.25-8.50 |                         |                      | x                            | FPF-5            |                                                                                                    |           |                         |                      |                              |                          |
| OB-59 | 4.75-5.00 |                         | x                    | x                            | BBF-1            |                                                                                                    |           |                         |                      |                              |                          |
|       | 5.89-6.00 | x                       | x                    | x                            | BBF-1            |                                                                                                    |           |                         |                      |                              |                          |
|       | 6.75-7.00 |                         | x                    | x                            | BBF-1            |                                                                                                    |           |                         |                      |                              |                          |
|       | 7.80-8.20 | x                       | x                    | x                            | BBF-1            |                                                                                                    |           |                         |                      |                              |                          |

A picking tray divided into a systematic grid pattern was used to count 100 randomly distributed sand-sized grains which were classified according to biologic or mineralogic affinities. A basic compositional description of the sand fraction in each sample is given in Appendix B. The abundance of each grain type is expressed as a percentage of the total washed sample. Detailed mineralogical analyses were not performed because other studies (Lewis, 1981; Lewis et al., 1982; Riggs et al., 1982a; Ellington, 1984; Mallette, in progress) provide a more complete sedimentary framework of reference.

Benthic foraminifers (a minimum of 300 specimens/sample) were selected at random, identified to species level and statistically analyzed. Identification of 300 specimens from a larger assemblage provides accuracy of  $\pm 5\%$  for the estimated abundance of any given species in a sample (Chang, 1967). In samples where 300 specimens could not be retrieved, as many specimens as possible were identified, but no statistical analyses were attempted.

Five faunal characteristics were determined for each statistically reliable sample. All but the first one listed below were computed using only the benthic foraminiferal assemblage.

1. P/B ratio (ratio of planktonic to benthic tests).
2. Relative abundance

The relative abundance of each species is expressed as a percentage of the total benthic foraminiferal assemblage.

### 3. Species diversity

Diversity is expressed using the Shannon-Wiener Information Function, which is largely independent of sample size and occurrences of rare species (Gibson and Buzas, 1973; Sanders, 1968). The function is defined as:  $H(S) = -\sum p_i \ln p_i$  where  $p_i$  is the portion of the total population represented by species  $i$ , and  $H(S)$  is the index of information which statistically characterizes the assemblage.  $H(S)$  will equal zero where specimens belong to one species. A low  $H(S)$  value suggests stressed conditions to which few species can adapt. A high  $H(S)$  value characterizes more stable environments that are favorable to many species.

### 4. Equitability (the apportionment of individuals among taxa).

The ratio is defined by Buzas and Gibson (1969) as:  $E = e^{H(S)}/S$  where  $S$  is the number of species in a sample and  $e$  is the base of the natural logarithms.  $E$  equals 1 when all species are equally distributed; a value less than 1 measures how far the sample departs from equitability.

### 5. Faunal predominance (the percentage of the most abundant species in a given sample or assemblage).

This characteristic is directly proportional to environmental variability and inversely proportional to the variability of the fauna. An assemblage with high

predominance and low diversity values indicates stressed conditions (e.g., marginal marine), while an assemblage with low predominance and greater diversity values suggests more environmentally stable conditions (e.g., offshore).

Summaries of benthic data obtained from each sample are presented in Appendix A. P/B ratios for each sample are included in Appendix B.

Samples were also examined for planktonic species to be used for biostratigraphic interpretation. Where possible, 100-200 specimens were examined, which usually required larger volumes of sediment than the splits used for benthic analysis. Relative abundance of each species was estimated and results were placed into four categories: 1) rare, <3%; 2) few, 3-15%; 3) common, 15-30%; 4) abundant, >30%.

World-wide studies of Neogene foraminifers (Banner and Blow, 1965; Blow, 1969 and 1979; Berggren and Van Couvering, 1974; Stainforth et al., 1975; numerous Deep Sea Drilling Project reports) led to the establishment of biostratigraphic zonations that can be correlated with European type sections. This allows for dependable correlation of strata that are widely separated from type localities. Age assignments of Central Onslow Bay sediments are expressed in the standard planktonic zonations of Blow (1969 and 1979).

## PREVIOUS WORK

Phosphatic Miocene sediments of eastern North Carolina were originally described by Brown (1958), who correlated them with the middle Miocene Calvert Formation of Maryland. These sediments were named the Pungo River Formation by Kimrey (1964) based on a type-section well near Belhaven, North Carolina.

Numerous lithologic, paleoenvironmental and stratigraphic studies have been conducted on coastal plain Pungo River sequences. Gibson (1967) correlated the upper calcareous beds of the Pungo River Formation with the Calvert Formation based on key foraminiferal and molluscan species found at the mine of Texasgulf, Inc. near Aurora, North Carolina. Gibson suggested that Pungo River sediments were deposited in a northeast-southwest trending oceanic embayment between the Norfolk Arch in southern Virginia and a positive feature in the vicinity of New Bern, North Carolina. The latter is the same feature mentioned by Riggs (1979), called the Castle Hayne Arch by Miller (1971), and termed the Cape Lookout High by S.W.P. Snyder et al. (1982). Gibson stated that foraminiferal evidence indicated the lower phosphatic strata near Aurora accumulated in cool-temperate waters at depths from 100-200 m, while the upper calcareous units were deposited in waters less than 70 m. Leutze (1968) argued that the water depths were shallower than those proposed by Gibson.

Miller (1971) studied the subsurface Pungo River Formation by analyzing core data from the eastern North Carolina Coastal Plain.

Based on diagnostic foraminiferal species in down-basin phosphorites and calcareous sands, he interpreted the entire formation as middle Miocene. On the basis of the benthic foraminiferal fauna, he suggested an open marine, normal salinity, shallow shelf environment of deposition. Gibson (1982) refined the age assignments of the Calvert and Pungo River Formations using planktonic and key benthic foraminiferal species to extend portions of the ages of both formations downward into late early Miocene time. Miller (1982) agreed with Gibson and revised his original description of the depositional environment from open marine to slightly restricted. Biostratigraphic age assignments by Gibson (1983) indicate that Pungo River strata from the vicinity of Norfolk, Virginia, to south of the Neuse River in North Carolina correlate with planktonic foraminiferal Zone N8 (Blow, 1969, 1979). Planktonic assemblages indicating Zone N11 were reported only from northeastern North Carolina. According to Gibson, strata belonging to planktonic foraminiferal Zones N9 and N10 have not yet been recognized. He suggested that strata of this age may have been deposited and subsequently eroded, but he did not formally propose that a major unconformity exists within the formation.

Pungo River strata in the Aurora phosphate district comprise four lithostratigraphic units (A through D) and their associated lateral facies (Scarborough, 1981; Scarborough et al., 1982). Phosphate content increases upward from units A through C, which appear to have been deposited during a marine transgression. Unit D caps the sequence, has a negligible amount of phosphate and is interpreted to

represent the initial phase of a marine regression. Lithostratigraphic units A-C contain a similar vertical sequence of sediments (siliciclastics, followed by phosphate, capped by carbonate), and each is separated from adjacent beds by a minor unconformity (Riggs et al., 1982a). Katrosh and Snyder (1982) recognized two benthic foraminiferal assemblage zones within Pungo River strata of the North Carolina Coastal Plain. Their assemblage zones 1 and 2 correspond respectively with the lower (units A and B) and upper (units C and D) portions of the Pungo River section in the Aurora phosphate district, and they suggested a depositional environment that progressed from inner to outer shelf conditions. The lower units (A and B) are nearly devoid of planktonic foraminifera and a biostratigraphic age assignment was not possible. However, diatom assemblages described by Abbott and Ernisee (1983) indicate chronostratigraphic equivalence to Blow Zones N8/N9. Unit C contains planktonic foraminifera and was assigned to planktonic Zone N8/N9 (Katrosh and Snyder, 1982).

Pungo River phosphatic sediment-faunal relationships within the Aurora Embayment were analyzed by Snyder et al. (1982). Distinct types of phosphate accumulation characterized the lower (A and B) and upper (C) units. Foraminiferal assemblages within units A and B suggest upwelling-induced, high-nutrient conditions with phosphorite sediments forming in the same area in which they are preserved. Unit C records a marine transgression during which nutrient-rich marine waters were replaced by more normal marine waters. Faunal assemblages suggest that

the phosphorites of unit C represent material reworked and transported from more shoreward areas.

The Pungo River Formation has been traced offshore into Onslow Bay (Lewis et al., 1982). Studies of Pungo River sediments near Aurora and in Onslow Bay have led to a proposed model of cyclic transgressive/regressive deposition controlled by global eustatic sea-level fluctuations (Riggs et al., 1982b; Riggs, 1984). Based on seismic stratigraphy, S. W. P. Snyder et al. (1982) related the Pungo River depositional control to regional paleotopography, high frequency sea-level cyclicity and changes in Gulf Stream flow dynamics. Waters (1983) stated that Pungo River strata from Southern Onslow Bay accumulated in environments from middle shelf to upper slope. Biostratigraphic analyses indicated an age of late early Miocene for Pungo River sediments in Southern Onslow Bay (Zones N6 through early N7) (Waters, 1983; Waters and Snyder, 1986). Based on planktonic foraminiferal species, Snyder (per. comm., 1985) assigned a biostratigraphic age of late early through middle Miocene to Pungo River sequences in Northern Onslow Bay. Figure 3 demonstrates the relationship of seismic sequences in Onslow Bay to planktonic foraminiferal zones and to relative global sea-level.



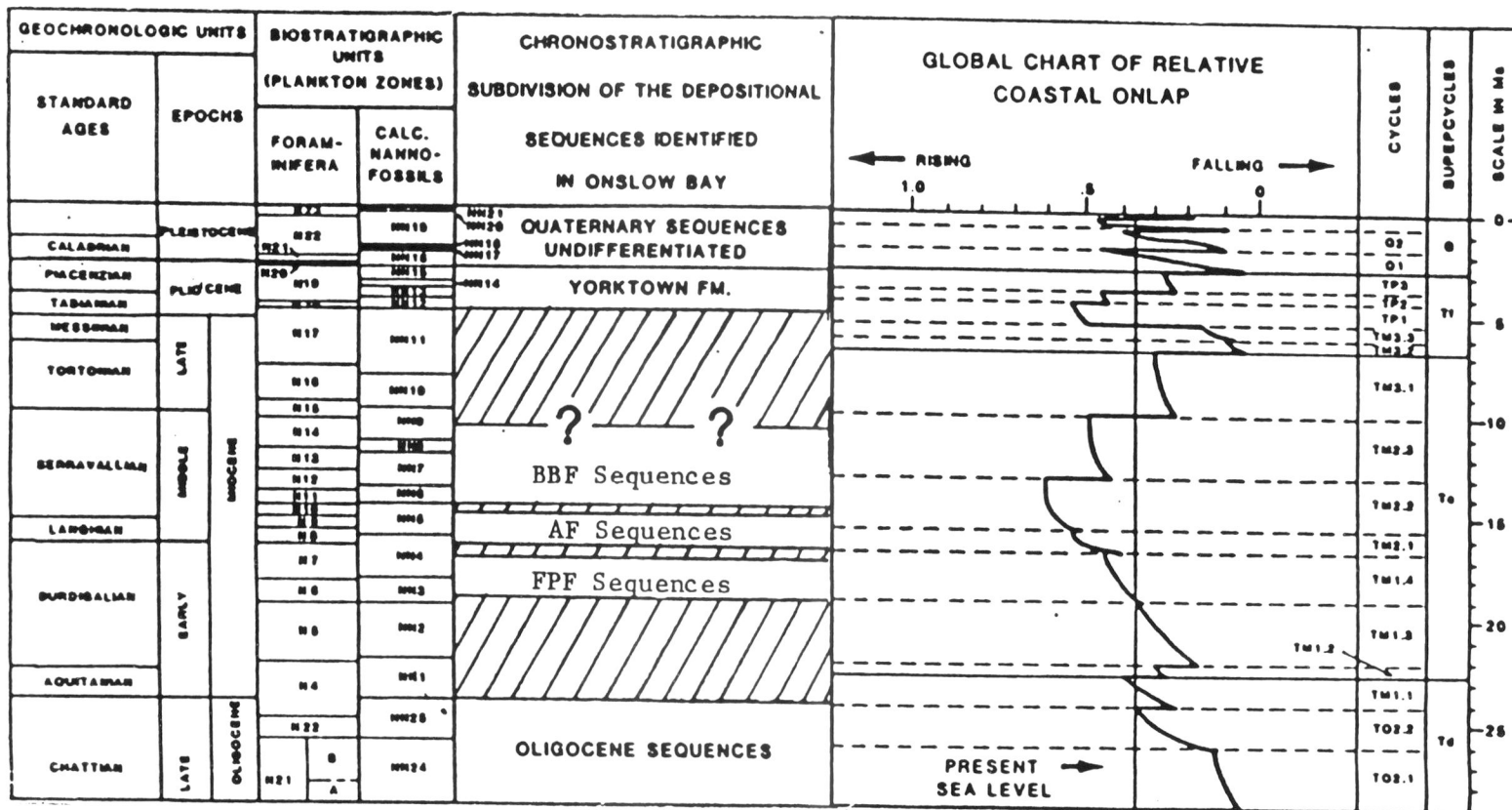


Fig. 3. Chart showing relationship of seismic sequences of Onslow Bay (modified from S.W.P. Snyder, 1982) to planktonic foraminiferal zones and relative global sea-level (From Vail and Mitchum, 1979).

## LITHOLOGIC AND SEISMIC FRAMEWORK

Miocene Pungo River strata underlie the northeastern coastal plain and southeastern continental shelf of North Carolina. Along this continental margin, the Mid-Carolina Platform High (a broad, first-order structural feature) controlled the regional distribution of Miocene sediments. Interbedded sequences of nonphosphatic, phosphatic and phosphorite sediments thicken eastward and southeastward toward the shelf edge (Popenoe, 1985) where they are abruptly truncated (Riggs et al., 1985). Riggs (1979, 1980, 1981 and 1984) pointed out that phosphate deposition and distribution along the southeastern U. S. continental margin is not continuous or uniform, either laterally or vertically. A strong correlation exists between phosphate accumulations and proximity to major structural and paleotopographic features. Maximum accumulations of phosphate occurred in shelf environments around the noses and flanks of paleotopographic highs. According to Riggs (1984), phosphogenic episodes correspond to three third-order sea level cycles on the Miocene second-order transgressive cycle (Vail and Mitchum, 1979). During these third-order episodes, smaller-scale fourth-order transgressive oscillations caused topographically induced upwelling and phosphate production as the Gulf Stream migrated westward onto paleobathymetric features. Regressions corresponded to erosional events which separate depositional sequences.

Pungo River phosphatic sediments were deposited in two major depocenters, the Aurora and Onslow Embayments (Fig. 1). The embayments

are separated by an east-west oriented, pre-Miocene, second-order topographic feature designated the Cape Lookout High (S.W.P. Snyder, 1982; S.W.P. Snyder et al., 1982) (Fig. 1). The erosional updip limit of the Pungo River Formation coincides with a north-striking hingeline (Brown et al., 1972) which marks the Aurora Embayment's western boundary. The hingeline extends into northern and central Onslow Bay where it forms a prominent scarp known as the White Oak Lineament (S.W.P. Snyder, 1982). Sediments thicken abruptly to more than 25 m at the scarp and dip eastward forming a complex series of erosionally altered, clinoform depositional sequences. Local variations in thickness are due to the combined effects of erosion and underlying paleotopographic irregularities (S.W.P. Snyder, 1982).

Based on high-resolution seismic stratigraphic analyses, S.W.P. Snyder (1982) divided Pungo River strata in Onslow Bay into three third-order seismic sequences which can be subdivided into at least 17 smaller, fourth-order sequences. The three third-order seismic sequences are informally designated as the Frying Pan (FPF), Aurora (AF) and Bogue Banks (BBF) sequences (Fig. 4).

The FPF sequence is of late early Miocene age (Burdigalian) (Waters and Snyder, 1986). In the Frying Pan Area of Southern Onslow Bay the FPF sequence unconformably overlies muddy, calcareous, fine-grained quartz sands of Oligocene age (S.W.P. Snyder et al., 1982; Waters, 1983). Studies of lithostratigraphy and biostratigraphy have focused on the Miocene of the Frying Pan area due to the presence of phosphate-rich sediments (Lewis, 1981; Riggs et al., 1982a, 1982b;

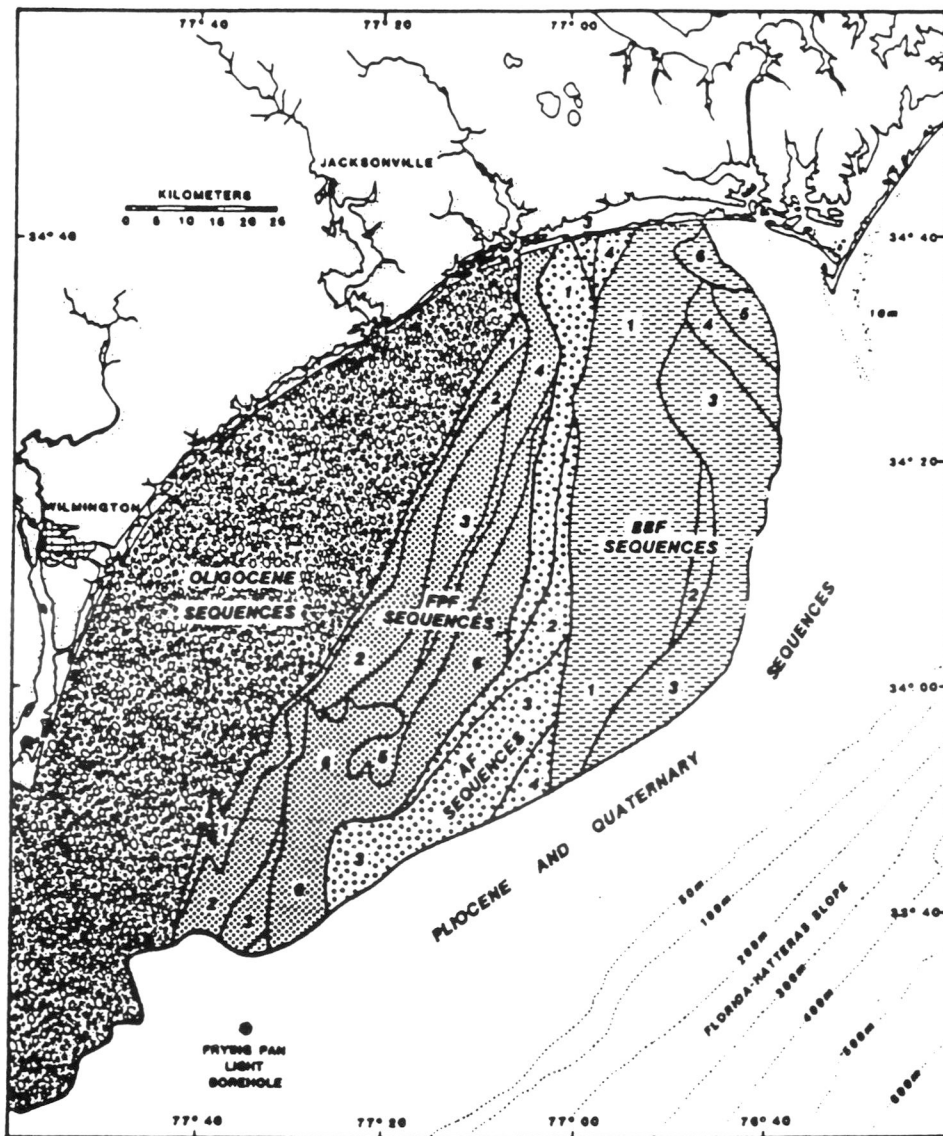


Fig. 4. Outcrop distribution of Miocene Pungo River Formation in Onslow Bay (from Riggs et al., 1985).

Riggs, 1984; Waters, 1983). Sediments occur in outcrop and shallow subcrop throughout the area and dip towards the east and southeast. S.W.P. Snyder (1982) divided the FPF sequence into six fourth-order seismic sequences and designated them FPF-1 (oldest) through FPF-6 (youngest) (Fig. 4).

Maximum phosphate concentration in Onslow Bay occurs in the FPF sequences, particularly in the Frying Pan Area. The lowermost FPF sequences (FPF-1, FPF-2 and FPF-3) comprise muddy, foraminiferal, phosphorite sands with varying amounts of quartz. Phosphatic sediment content decreases upward through the FPF sequences. The FPF-2 and FPF-3 sequences are slightly phosphatic, quartz-bearing foraminiferal muds. The upper sequences (FPF-4, FPF-5 and FPF-6) are muddy quartz sands with minor phosphate. The uppermost sequence (FPF-6) contains an exceptionally rich and diverse foraminiferal fauna. The AF sequence, which forms a north-south trending outcrop belt across Onslow Bay (Fig. 4), has been separated into four fourth-order seismic stratigraphic sequences (AF-1 through AF-4) by S.W.P. Snyder (1982). The AF sequence thickens abruptly across a prominent erosional scarp, infilling the basin to the east and southeast. The sediments thin and pinch out across the Cape Lookout High to the north (S.W.P. Snyder, 1982). The AF sequence comprises calcareous, slightly phosphatic muds and quartz sands with horizons of bioclastic hash. The BBF sequence has been divided into six fourth-order seismic sequences (BBF-1 through BBF-6) by S.W.P. Snyder (1982). BBF sequences crop out in the eastern portion of Onslow Bay (Fig. 4) where they form a wide north-south striking

outcrop belt (S.W.P. Snyder, 1982). Sediments of the BBF sequence are lithologically variable: portions contain abundant phosphate and diatomaceous intervals, while intervening strata are largely clean quartz sands. This area has not been as extensively studied as the FPF sequence due to its lower concentrations of phosphate.

## PLANKTONIC FORAMINIFERA

Planktonic foraminifera occur throughout the Pungo River section in Central Onslow Bay. Standard planktonic foraminiferal zonations (Blow, 1969, 1979; Berggren and Van Couvering, 1974; Stainforth et al., 1975) are based on the first and last appearances of stratigraphically restricted species that characterize tropical-subtropical, low latitude faunas. Few of these stratigraphically restricted species occur in Pungo River sediments of Central Onslow Bay, where most taxa are cool-temperate, cosmopolitan species. Where primary indicator species are not present, standard zonal boundaries can be approximated using the first and last appearances of secondary indicator species. In this report, planktonic foraminiferal assemblages are related to the zonal scheme of Blow (1969, 1979), with modifications based on Stainforth et al. (1975). Accepted ranges for biostratigraphically useful species found in Central Onslow Bay are illustrated in Figure 5. Occurrences of all planktonic species in each sample are presented in Appendix C.

FPF Sequence

The FPF sequence is assigned to planktonic Zones N6 through early N7 (late Burdigalian) based on the first or last appearance data (FAD or LAD) of several secondary indicator species. The base of N6 is approximated by the FAD (Stainforth et al., 1975) of Globigerinoides quadrilobatus triloba (Reuss), Globorotalia fohsi peripheroronda Blow

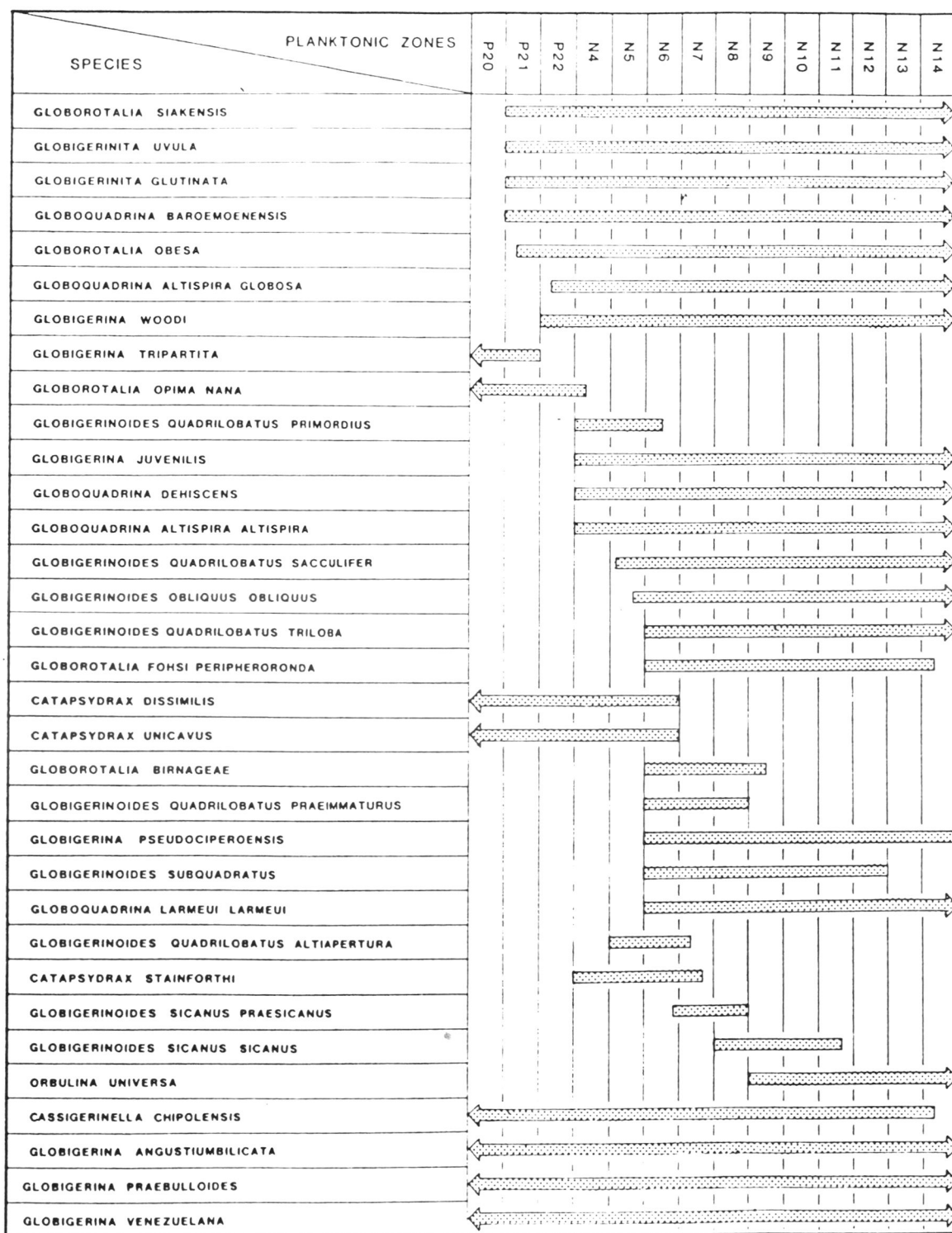


Fig. 5. Stratigraphic ranges of planktonic foraminiferal species from Central Onslow Bay (data from Blow, 1969, 1979; Brönnimann and Resig, 1971; Stainforth et al., 1975; Poore, 1978).



and Banner, Globorotalia birnageae Blow, Globigerinoides quadrilobatus praeimmaturus Brönnimann and Resig, Globigerinoides subquadratus Brönnimann, and Globoquadrina larmeui larmeui Akers. Keller (1981) suggested that G. subquadratus evolved as early as Zone N4. Globigerina pseudociperoensis Blow, thought to first appear within Zone N7, appears first with Zone N6 faunal elements in Central Onslow Bay. According to Blow (1969, 1979), the stratigraphic range of G. pseudociperoensis has not been fully evaluated.

The N6/N7 zonal boundary is approximated by the LAD of Globigerinoides quadrilobatus altiapertura Bolli and Catapsydrax unicavus Bolli, Loeblich, and Tappan (Stainforth et al., 1975). The LAD of Catapsydrax stainforthi Bolli, Loeblich, and Tappan and Catapsydrax dissimilis (Cushman and Bermudez) also coincide with this boundary, but specimens of these species are rare in Pungo River sediments. The FAD of Globigerinoides sicanus praesicanus Brönnimann and Resig (affine form) approximates the base of Zone N7. This species was first described from sediments in the southwestern Pacific and ranges from Zone N7 through N8 (Brönnimann and Resig, 1971).

Globigerina tripartita Koch and Globigerina opima nana Bolli, both rare in the FPF sequence, suggest reworking of older sediments. The occurrence of these species is typical of Oligocene age material, but they have occasionally been reported from the early Miocene (Stainforth et al., 1975; Blow, 1969, 1979). Globigerinoides quadrilobatus primordius Blow and Banner occurs with Zone N6 faunal elements in central Onslow Bay. According to Blow (1969, 1979), the stratigraphic

range of G. q. primordius extends upward from the base of Zone N4 to early N5. In the Atlantic and Gulf of Mexico, this species first appears near the base of Zone N3. Stainforth et al. (1975) suggest the FAD cannot be rigidly defined. Apparently, the LAD is also of questionable biostratigraphic significance.

Figure 6 illustrates the abundance of diagnostic planktonic species along with associated longer ranging forms within Pungo River depositional sequences. Table 2 summarizes the biostratigraphic age assignments of Central Onslow Bay. Units FPF-1 through FPF-3 are assigned to Zone N6. The N6/N7 zonal boundary is placed within the lower portion of the FPF-6 sequence based on the first appearance of Globigerinoides sicanus praesicanus, and its co-occurrence with rare specimens of Catapsydrax dissimilis and Catapsydrax unicavus. Seismic sequences FPF-4 and FPF-5 were devoid of foraminifera and a biostratigraphic age assignment was not possible. If the FPF sequences are compared to coastal offlap/onlap curves (Vail et al., 1977; Vail and Mitchum, 1979), individual depositional sequences correspond to fourth- or higher order cycles within the third-order TM 1.4 Miocene transgression (Fig. 3).

#### AF Sequence

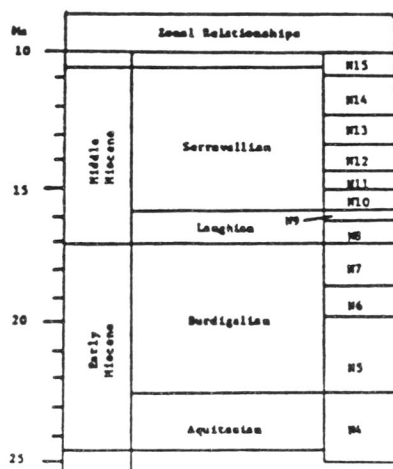
The N8/N9 zonal boundary is recognized by the LAD of Globigerinoides sicanus praesicanus and the FAD of Orbulina universa d'Orbigny, a primary indicator species of Zone N9. The first appearance of O. universa defines a worldwide datum which coincides with the beginning of the middle Miocene (Stainforth et al., 1975).

| SEISMIC SEQUENCE                           | FPF-1 | FPF-2 | FPF-3 | FPF-6 | AF-3  | BBF-1   | BBF-2 |
|--------------------------------------------|-------|-------|-------|-------|-------|---------|-------|
| SPECIES                                    |       |       |       |       |       |         |       |
| CASSIGERINELLA CHIPOLENSIS                 | F     |       |       |       |       |         |       |
| CATAPSYDRAX DISSIMILIS                     |       |       |       | R     |       |         |       |
| CATAPSYDRAX STAINFORTHII                   | R     |       |       |       |       |         |       |
| CATAPSYDRAX UNICAVUS                       | R     |       | R     | R     |       |         |       |
| GLOBIGERINA ANGUSTIUMBILICATA              | R     |       |       |       |       |         |       |
| GLOBIGERINA JUVENILIS                      | R     |       |       |       |       |         |       |
| GLOBIGERINA PRAEBULLOIDES                  | C     |       | F     | F     | F     | C       |       |
| GLOBIGERINA PSEUDOCIPEROENSIS              |       |       |       | R     | R     |         |       |
| GLOBIGERINA TRIPARTITA                     | R     |       | R     | R     |       |         |       |
| GLOBIGERINA VENEZUELANA                    | C     |       | F     | F     | R     | F       |       |
| GLOBIGERINA WOODI                          | R     |       | R     | R     |       |         |       |
| GLOBIGERINITA GLUTINATA                    | F     |       | R     | R     |       |         |       |
| GLOBIGERINITA UVULA                        | F     |       | R     | R     |       |         |       |
| GLOBIGERINOIDES OBLIQUUS OBLIQUUS          |       |       | F     | F     |       |         |       |
| GLOBIGERINOIDES QUADRILOBATUS ALTIAPERTURA | F     |       | F     | F     |       |         |       |
| GLOBIGERINOIDES QUADRILOBATUS PRAEIMMATUS  | R     |       | R     | R     | R     |         |       |
| GLOBIGERINOIDES QUADRILOBATUS PRIMORDIUS   | F     |       | F     | R     |       |         |       |
| GLOBIGERINOIDES QUADRILOBATUS SACCULIFER   | F     |       | F     | F     | F     |         |       |
| GLOBIGERINOIDES QUADRILOBATUS TRILOBA      | C     |       | A     | C     | A     | C       |       |
| GLOBIGERINOIDES SICANUS PRAESICANUS        |       |       | R     | F     | R     |         |       |
| GLOBIGERINOIDES SICANUS SICANUS            |       |       |       |       | R     |         |       |
| GLOBIGERINOIDES SUBQUADRATUS               | R     |       | F     | R     | C     | C       |       |
| GLOBOQUADRINA ALTISPIRA ALTISPIRA          | R     |       |       |       |       |         |       |
| GLOBOQUADRINA ALTISPIRA GLOBOSA            | F     |       | F     | F     | F     | F       |       |
| GLOBOQUADRINA BAROEMOENENSIS               | F     |       | F     | R     | R     | R       |       |
| GLOBOQUADRINA DEHISCENS                    | F     |       | F     | R     | R     |         |       |
| GLOBOQUADRINA LARMEUI LARMEUI              | R     |       | F     | R     | R     | R       |       |
| GLOBOROTALIA BIRNAGEAE                     | R     |       |       |       |       |         |       |
| GLOBOROTALIA FOHSI PERIPHERORONDA          | C     |       | F     | F     | F     | R       |       |
| GLOBOROTALIA OBESA                         | F     |       | F     | F     |       | R       |       |
| GLOBOROTALIA OPIMA NANA                    | R     |       |       | R     |       |         |       |
| GLOBOROTALIA SIAKENESIS                    | F     |       | F     | F     | F     | R       |       |
| ORBULINA UNIVERSA                          |       |       |       |       | R     |         |       |
| PLANKTONIC ZONE ASSIGNMENT                 | N6    |       |       | N7    | N8/N9 | N11-N14 |       |

Fig. 6. Occurrences of planktonic foraminiferal species and biostratigraphic age assignments, Pungo River Formation, Central Onslow Bay. Average abundance of species: R= less than 3%, F= 3 to 10%, C= 11 to 30%, and A= more than 30% of the total planktonic foraminiferal assemblage.

TABLE 2  
SUMMARY OF BIOSTRATIGRAPHIC AGE ASSIGNMENTS

| CORE  | DEPTH (m) | SEISMIC SEQUENCE | PLANKTONIC FORAMINIFERAL ZONE (BLM, 1969, 1979) | CORE   | DEPTH (m) | SEISMIC SEQUENCE | PLANKTONIC FORAMINIFERAL ZONE (BLM, 1969, 1979) |
|-------|-----------|------------------|-------------------------------------------------|--------|-----------|------------------|-------------------------------------------------|
| OB-41 | 3.50-3.75 | AF-1             |                                                 | OB-59  | 4.75-5.00 | BBF-1            |                                                 |
|       | 5.00-5.25 | AF-1             |                                                 |        | 5.89-6.00 | BBF-1            | N11-N14                                         |
|       | 7.00-7.25 | AF-1             |                                                 |        | 6.75-7.00 | BBF-1            | N11-N14                                         |
| OB-42 | 1.25-1.50 | BBF-1            |                                                 |        | 7.80-8.20 | BBF-1            |                                                 |
|       | 3.00-3.25 | BBF-1            |                                                 | OB-92  | 4.00      | BBF-2            |                                                 |
|       | 4.50-4.75 | BBF-1            |                                                 |        | 5.50      | BBF-2            |                                                 |
|       | 6.00-6.25 | BBF-1            |                                                 |        | 6.00      | BBF-2            |                                                 |
|       | 6.50-6.75 | BBF-1            |                                                 | OB-94  | 1.00      | BBF-1            |                                                 |
| OB-43 | 1.00-1.25 | BBF-1            |                                                 | OB-99  | 5.00      | Y                |                                                 |
|       | 2.00-2.25 | BBF-1            |                                                 | OB-103 | 1.00      | FFF-2            |                                                 |
|       | 3.00-3.25 | BBF-1            |                                                 |        | 2.00      | FFF-2            |                                                 |
|       | 4.00-4.25 | BBF-1            |                                                 |        | 3.00      | FFF-2            |                                                 |
| OB-44 | 1.75-2.00 | AF-1             |                                                 |        | 4.00      | FFF-2            |                                                 |
|       | 3.75-4.00 | AF-1             |                                                 |        | 5.00      | FFF-2            |                                                 |
|       | 5.50-5.75 | AF-1             |                                                 |        | 5.90      | FFF-2            |                                                 |
| OB-45 | 0.75-1.00 | FFF-6            | N6/N7                                           | OB-105 | 1.50      | FFF-1            | N6*                                             |
|       | 3.00-3.25 | FFF-6            | N6/N7                                           |        | 4.50      | FFF-1            | N6*                                             |
|       | 4.75-5.00 | FFF-6            | N6/N7                                           |        | 7.50      | FFF-1            | N6*                                             |
| OB-46 | 2.75-3.00 | FFF-5            |                                                 |        | 9.10      | FFF-1            | N6*                                             |
|       | 5.00-5.25 | FFF-5            |                                                 | OB-123 | 1.00      | P                |                                                 |
|       | 7.00-7.25 | FFF-5            |                                                 |        | 3.00      | FFF-2            |                                                 |
| OB-48 | 1.25-1.50 | FFF-3            |                                                 |        | 4.50      | FFF-2            |                                                 |
|       | 2.25-2.50 | FFF-3            | N6                                              |        | 6.70      | FFF-2            |                                                 |
|       | 4.75-5.00 | FFF-3            | N6                                              | OB-125 | 1.50      | Y                |                                                 |
|       | 6.25-6.50 | FFF-3            |                                                 |        | 4.50      | Y                |                                                 |
|       | 7.50-8.00 | FFF-3            |                                                 | OB-126 | 1.00      | S                |                                                 |
| OB-49 | 1.50-1.75 | FFF-2            |                                                 |        | 3.50      | S                |                                                 |
|       | 3.50-3.75 | FFF-2            |                                                 |        | 5.00      | S                |                                                 |
|       | 6.00-6.25 | FFF-2            |                                                 |        | 7.00      | S                |                                                 |
|       | 7.50-8.00 | FFF-2            |                                                 | OB-127 | 3.50      | FFF-1            |                                                 |
| OB-50 | 3.25-3.60 | FFF-6            | N6*                                             |        | 4.50      | FFF-1            |                                                 |
|       | 4.3-4.75  | FFF-6            |                                                 |        | 5.50      | FFF-1            |                                                 |
|       | 5.75-6.00 | FFF-6            |                                                 |        | 7.00      | FFF-1            |                                                 |
| OB-51 | 3.00      | AF-1             |                                                 |        | 8.00      | FFF-1            |                                                 |
|       | 6.00      | AF-1             |                                                 | OB-129 | 2.50      | FFF-3            | N6                                              |
| OB-52 | 1.25-1.50 | P                |                                                 |        | 4.00      | FFF-3            | N6                                              |
|       | 2.70-3.00 | P                |                                                 |        | 5.50      | FFF-3            |                                                 |
|       | 3.75-4.00 | BBF-1            |                                                 |        | 7.00      | FFF-3            |                                                 |
| OB-53 | 1.25-1.50 | BBF-1            |                                                 | OB-130 | 1.00      | FFF-1            |                                                 |
|       | 2.75-3.00 | BBF-1            |                                                 |        | 3.00      | FFF-1            |                                                 |
|       | 3.30-3.50 | BBF-1            |                                                 | OB-131 | 3.00      | AF-3             | N8/N9                                           |
|       | 4.75-5.00 | BBF-1            |                                                 |        | 4.50      | AF-3             |                                                 |
|       | 5.25-5.50 | BBF-1            |                                                 |        | 6.50      | AF-3             | N8/N9                                           |
|       | 6.25-6.50 | BBF-1            |                                                 | OB-132 | 1.50      | FFF-1            | N6*                                             |
| OB-54 | 2.25      | S                |                                                 |        | 2.00      | FFF-1            | N6                                              |
|       | 3.00      | S                |                                                 |        | 2.50      | FFF-1            | N6                                              |
|       | 3.50      | S                |                                                 |        | 3.30      | FFF-1            | N6                                              |
| OB-57 | 0.75-1.00 | FFF-6            |                                                 |        | 4.10      | FFF-1            | N6                                              |
|       | 3.25-3.50 | FFF-6            |                                                 |        |           |                  |                                                 |
|       | 5.25-5.50 | FFF-5            |                                                 |        |           |                  |                                                 |
|       | 8.25-8.50 | FFF-5            |                                                 |        |           |                  |                                                 |



LEGEND

- S= Silverdale Formation  
 Y= Yorktown Formation  
 P= Pleistocene  
 \* = Presence of older materials  
 (late Oligocene-earliest Miocene)

Only the AF-3 sequence contained sufficient planktonic foraminifera to permit an age assignment. It is assigned to planktonic foraminiferal Zone N9 (Langhian) based on: 1) the disappearance of diagnostic early Miocene taxa such as Globigerinoides quadrilobatus altiapertura, Globigerinoides quadrilobatus primordius, Catapsydrax dissimilis, Catapsydrax stainforthi, Catapsydrax unicavus; 2) the transition from Globigerinoides sicanus praesicanus to Globigerinoides sicanus sicanus de Stephani; 3) and the appearance of rare specimens of Orbulina universa. Zone N8 may be represented by sequences AF-1 and AF-2, but planktonic foraminiferal evidence is inconclusive. The AF sequences appear to correlate to the fourth-order TM 2.1 Miocene transgression of coastal offlap/onlap curves (Fig. 3) (Vail et al., 1977; Vail and Mitchum, 1979).

#### BBF Sequence

The zonal assignment of the BBF sequence cannot be as accurately approximated as the previous sequences. Stratigraphic ranges of the planktonic foraminiferal species in the BBF sequence in Central Onslow Bay are too long to be biostratigraphically diagnostic (Fig. 5). Data from northern Onslow Bay suggest an age of Zone N11-N14 (Serravallian) (Snyder, pers. comm., 1985). This age assignment is based on the co-occurrence of Globigerinoides bollii Blow and Globorotalia siakensis Leroy. The Globigerinoides sicanus complex, seen previously in the AF sequence, is no longer present in the BBF sequence. The BBF sequences are presumed to correlate with the fourth-order TM 2.2 Miocene

transgression of the coastal offlap/onlap curves of Vail et al. (1977) and Vail and Mitchum (1979) (Fig. 3).

## BENTHIC FORAMINIFERA

Pungo River seismic sequences in Central Onslow Bay contain moderately diverse benthic foraminiferal assemblages (Fig. 7). Mean values of species diversity, expressed as  $H(S)$ , within individual sequences range from 0.34 to 2.37; the average relative abundance of predominant species ranges from 19% to 93% of the fauna. Mean equitability values range from 0.20 to 0.46. Relative abundances of all benthic species in each sample are presented in Appendix C.

FPF-1 Sequence

Buliminella elegantissima d'Orbigny predominates in 62% of samples from this sequence. The most abundant secondary species include Bolivina paula Cushman and Cahill, Valvulineria floridana Cushman and Epistominella danvillensis Howe and Wallace, each of which predominates in a few samples (Fig. 7). Species of lesser abundance and frequency of occurrence include Bulimina elongata d'Orbigny, Bolivina calvertensis Dorsey, Florilus grateloupi (d'Orbigny), Florilus pizzarensis (Berry), Hanzawaia concentrica (Cushman) and Cibicides americanus (Cushman) (Fig. 8). Buliminella cf. B. brevior Cushman, which generally occurs sporadically and in minor amounts, increases and becomes prominent in one sample from this sequence. These species are present throughout the Central Onslow Bay Pungo River section; and most have been reported from Southern Onslow Bay (Waters, 1983) and the

| SEISMIC<br>SEQUENCE                                                                                                                                                                                                                                                                                             | SPECIES<br>COUNT |       | SPECIES<br>DIVERSITY<br>H(S) |                    | EQUITABILITY<br>E |                    | P/B<br>RATIO |                      | RELATIVE ABUNDANCE<br>OF<br>PREDOMINANT SPECIES |                    | PREDOMINANT<br>SPECIES | PERCENTAGE OF SAMPLES<br>IN WHICH THIS SPECIES<br>PREDOMINATES | PREDOMINANT SPECIES<br>IN<br>REMAINING SAMPLES |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|-------|------------------------------|--------------------|-------------------|--------------------|--------------|----------------------|-------------------------------------------------|--------------------|------------------------|----------------------------------------------------------------|------------------------------------------------|
|                                                                                                                                                                                                                                                                                                                 | Mean             | Range | Mean                         | Range              | Mean              | Range              | Mean         | Range                | Mean                                            | Range              |                        |                                                                |                                                |
| BBF-2                                                                                                                                                                                                                                                                                                           | 7.5              | 6-9   | 0.34                         | 0.21<br>to<br>0.47 | 0.20              | 0.18<br>to<br>0.21 | 1/204        | 1/101<br>to<br>1/307 | 93.0                                            | 90.8<br>to<br>96.1 | ①                      | 100                                                            |                                                |
| BBF-1                                                                                                                                                                                                                                                                                                           | 13.6             | 11-22 | 1.38                         | 0.79<br>to<br>2.15 | 0.29              | 0.21<br>to<br>0.39 | 1/70.6       | 1/4<br>to<br>1/306   | 42.6                                            | 0.3<br>to<br>71.5  | ①                      | 77                                                             | ⑤ and ③                                        |
| AF-3                                                                                                                                                                                                                                                                                                            | 17.5             | 16-19 | 1.80                         | 1.60<br>to<br>1.99 | 0.35              | 0.31<br>to<br>0.38 | 1/7          | 1/4<br>to<br>1/10    | 48.7                                            | 40.0<br>to<br>57.3 | ④                      | 100                                                            |                                                |
| FPF-6                                                                                                                                                                                                                                                                                                           | 19.6             | 15-23 | 2.01                         | 1.99<br>to<br>2.04 | 0.39              | 0.33<br>to<br>0.49 | 1/7.5        | 1/2<br>to<br>1/20    | 26.9                                            | 11.0<br>to<br>32.8 | ①                      | 75                                                             | ③                                              |
| FPF-3                                                                                                                                                                                                                                                                                                           | 20.1             | 19-24 | 2.22                         | 2.13<br>to<br>2.38 | 0.46              | 0.44<br>to<br>0.48 | 1/3.6        | 1/1<br>to<br>1/6     | 21.4                                            | 11.0<br>to<br>28.7 | ①                      | 60                                                             | ④ and ③                                        |
| FPF-2                                                                                                                                                                                                                                                                                                           | 16.5             | 16-17 | 1.81                         | 1.76<br>to<br>1.85 | 0.37              | 0.34<br>to<br>0.40 | 1/28         | 1/17<br>to<br>1/77   | 33.8                                            | 22.0<br>to<br>45.6 | ① and ③                | 50 and 50                                                      |                                                |
| FPF-1                                                                                                                                                                                                                                                                                                           | 25.3             | 21-30 | 2.37                         | 2.08<br>to<br>2.66 | 0.44              | 0.41<br>to<br>0.49 | 1/2.3        | 1/1<br>to<br>1/9     | 18.6                                            | 2.0<br>to<br>32.6  | ②                      | 62                                                             | ①, ③<br>and<br>⑥                               |
| <div> <div>① - <i>Bolivina paula</i></div> <div>② - <i>Buliminella elegantissima</i></div> </div> <div> <div>③ - <i>Valvulineria floridana</i></div> <div>④ - <i>Cibicides americanus</i></div> </div> <div> <div>⑤ - <i>Cibicides floridanus</i></div> <div>⑥ - <i>Epistominella danvillensis</i></div> </div> |                  |       |                              |                    |                   |                    |              |                      |                                                 |                    |                        |                                                                |                                                |

Fig. 7. Benthic foraminiferal faunal characteristics, Pungo River Formation, Central Onslow Bay.



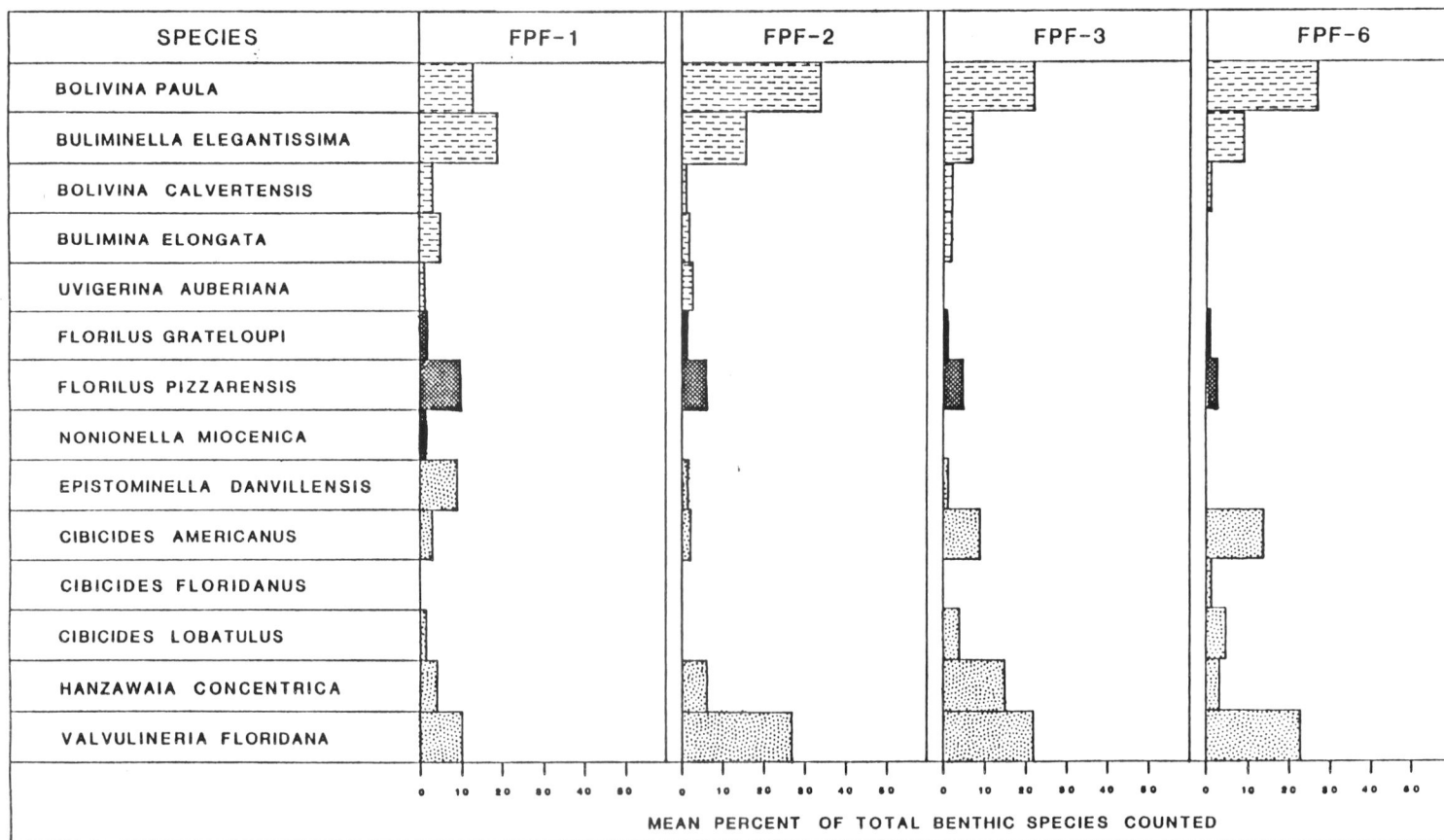


Fig. 8. Mean relative abundance of the most important benthic foraminiferal species, Pungo River Formation, Central Onslow Bay.

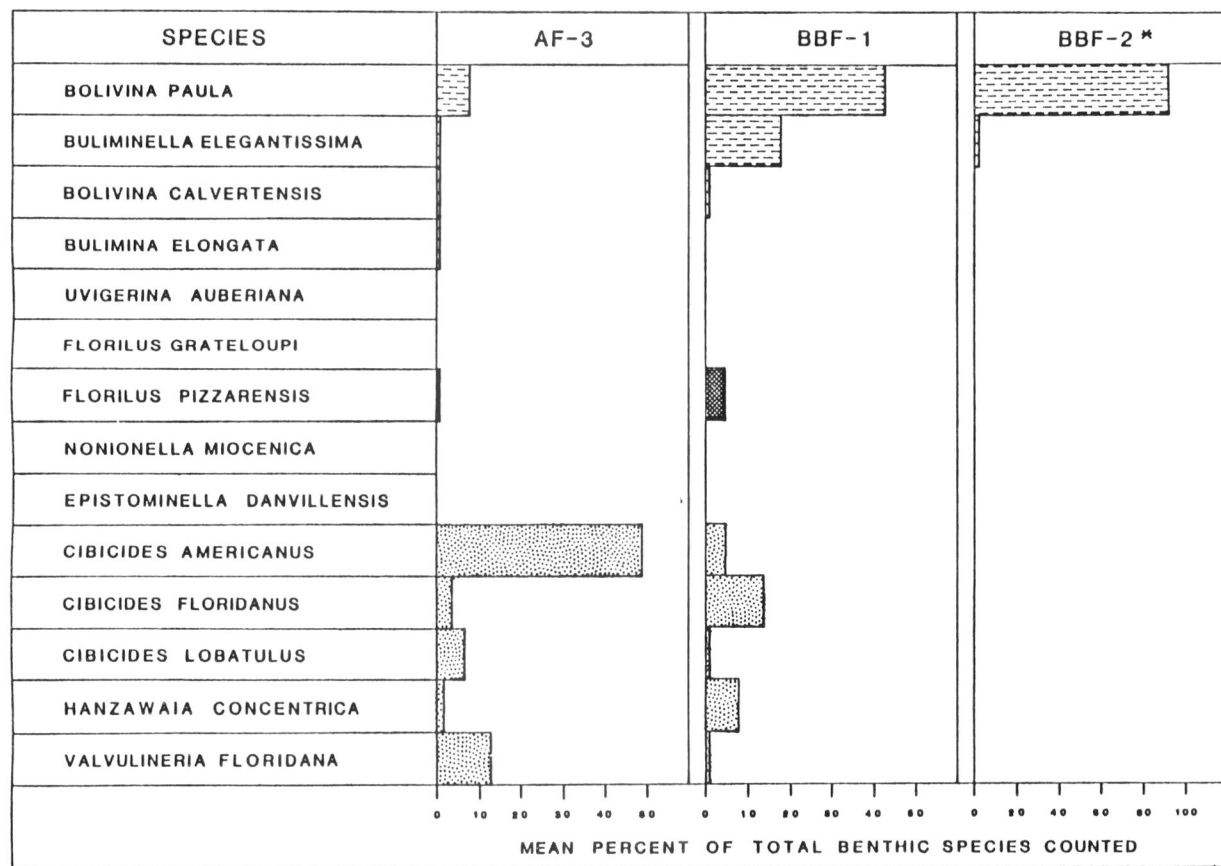


Fig. 8. (cont.) Mean relative abundance of the most important benthic foraminiferal species, Pungo River Formation, Central Onslow Bay.

Aurora district (Katrosh, 1981; Katrosh and Snyder, 1982; Miller, 1982; Gibson, 1983).

Rare species which are restricted to FPF-1 include Baggina sp., Fissurina lucida (Williamson), Globulina gibba d'Orbigny, Lagena cf. L. palmerae McLean, Lagena pseudosulcata McLean, Melonis sp., Oolina hexagona (Williamson), Pseudopolymorphina rutila (Cushman), Spiroplectammina mississippiensis (Cushman) and Stilostomella recta (Palmer and Burmudez). Waters (1983) reported most of these species from FPF-1 in southern Onslow Bay.

Benthic foraminifers are generally abundant and moderately well preserved in sequence FPF-1. Minor recrystallization and dissolution that produces pitting of test walls are common. Sequence FPF-1 has high species diversity values, averaging 2.37 and ranging from 2.08 to 2.66. The relative abundance of the predominant species averages 18.6%. Planktonic foraminifers are frequent, with a mean P/B ratio of 1/2.3.

#### FPF-2 Sequence

Only one core from this sequence yielded a sufficient number of specimens for analyses. The following general characteristics should therefore be considered tentative. Predominant species include Bolivina paula and Valvulineria floridana (Fig. 7). Buliminella elegantissima is the most common secondary species (Fig. 8). Faunal assemblages of FPF-2 have markedly fewer species than those of FPF-1, largely because many rare species and some secondary species found in

FPF-1 are not present in FPF-2. There are no species that are restricted to sequence FPF-2.

Foraminifers are generally less abundant in FPF-2. Preservation is poor and many specimens have been altered by recrystallization and/or partial dissolution. Species diversity values average 1.81 and range from 1.76 to 1.85. The mean relative abundance of the predominant species is 33.8%. The average P/B ratio is 1/28.

#### FPF-3 Sequence

Bolivina paula predominates in 60% of samples from this sequence. Cibicides americanus (Cushman) and Valvulineria floridana predominate in the remainder of the samples (Fig. 7). Faunal assemblages of sequence FPF-3 are in some ways similar to those of FPF-1 and FPF-2. Many of the rare species found in FPF-1 are also present in FPF-3. Relative abundance patterns of predominant species are more similar to those of FPF-2. Some secondary species, such as Buliminella elegantissima, Florilus pizzarensis, Bulimina elongata and Bolivina calvertensis (Fig. 8), decrease in relative abundance. Other secondary species, such as Cibicides lobatulus (Walker and Jacob) and Hanzawaia concentrica, become more prominent in this sequence than in FPF-2 (Fig. 8). Only one rare form, Astacolus sp., is restricted to this sequence.

Foraminiferal preservation is poor to moderate and recrystallization of test walls is common. Species diversity values, averaging 2.22 and ranging up to 2.38, are slightly higher than those

of unit FPF-2. Planktonic foraminifers are more abundant in sequence FPF-3, with a mean P/B ratio of 1/3.6.

#### FPF-6 Sequence

The association of predominant species in FPF-6 is similar to that in FPF-2. Bolivina paula predominates in 75% of the samples and Valvulineria floridana predominates in the remainder (Fig. 7). Abundant secondary species include Buliminella elegantissima, Cibicides americanus, Florilus pizzarensis and Cibicides lobatulus. Two forms which occur only in this sequence are Rosalina globularis d'Orbigny and Guttulina sp. Many of the rare forms found in FPF-1 and FPF-3 are absent in FPF-6.

Benthic foraminifers are generally abundant and well preserved. The mean relative abundance of the predominant species is 27%. Species diversity values average 2.01 and range from 1.99 to 2.04. P/B ratios range from 1/20 to 1/2 and average 1/7.5.

#### AF-3 Sequence

Only one core from sequence AF-3 contained a sufficient number of specimens for analyses, so general statements must be considered tentative. Cibicides americanus predominates in all samples from this sequence (Fig. 7). With the exception of Valvulineria floridana and Cibicides lobatulus, secondary species decrease in relative abundance (Fig. 8). No species are restricted to this sequence.

Preservation of benthic foraminifers is generally poor; most specimens are altered by recrystallization. Species diversity averages 1.80 and ranges up to 1.99. The mean relative abundance of the predominant species is 49%. Planktonic foraminifers are frequent, with P/B ratios averaging 1/7.

#### BBF-1 Sequence

Bolivina paula predominates in 77% of samples from this sequence. Cibicides floridanus and Valvulineria floridana predominate in the remaining samples (Fig. 7). Many secondary species that were important in previous sequences decrease abruptly in relative abundance in sequence BBF-1. Cibicides americanus, Cibicides lobatulus and Valvulineria floridana decrease in abundance, whereas Buliminella elegantissima and Florilus pizzarensis increase in abundance (Fig. 8). Faunal assemblages in portions of BBF-1 are very similar to those found in FPF-1 and FPF-3. Only two rare forms, Lagena cf. L. laevis (Montagu) and Nodosaria sp. are restricted to this sequence.

Benthic foraminifers are generally abundant and well preserved in sequence BBF-1. Species diversity values average 1.38 and range from 0.79 to 2.15. The mean relative abundance of the predominant species is 43%. Planktonic foraminifers are scarce, with P/B ratios averaging 1/70.6.

#### BBF-2 Sequence

The foraminiferal assemblages in sequence BBF-2 are distinguished

from those of previous sequences by the predominance of Bolivina paula in all samples (Fig. 7). The abundance of many secondary species declines sharply and many are absent from this sequence. No species is restricted to BBF-2. However, only one core was available from this sequence, so general statements are tentative.

Although foraminifers are not very abundant, they are moderately well preserved. Species diversity values are lower in this unit than in previous units. The mean diversity value is 0.34 and it ranges only up to 0.47. The mean relative abundance of the predominant species is 93%. Planktonic foraminifers are rare, with P/B ratios averaging 1/204.

## PALEOECOLOGY

Three benthic foraminiferal associations can be distinguished within the Miocene Pungo River sediments of Central Onslow Bay. The foraminiferal assemblages vary with sediment type through each seismic sequence. Fauna 1, an assemblage associated with phosphate-enriched sands, is predominated by species of Buliminella and Bolivina, while species of Bulimina and Uvigerina are consistently present but less abundant. Fauna 2 characterizes clean, quartzitic sands and contains abundant Valvulineria floridana, Hanzawaia concentrica, and Cibicides spp. Fauna 3, associated with muddy sands, contains increased numbers of Florilus spp., Siphogenerina spp., and Nonionella miocenica. It remains secondary in abundance and is usually most important where Fauna 1 is predominant.

The ratio of Fauna 1 specimens to those of Fauna 2 is informative when compared to the percent of phosphate found in the sediment. A low ratio generally corresponds to a low percentage of phosphate, whereas a high ratio corresponds to a high percentage of phosphate in the sediment. Figure 9 summarizes Fauna 1/Fauna 2 ratios to percentage of phosphate in samples from Central Onslow Bay.

## Environmental Characteristics of Key Benthic Foraminifera

Buliminella elegantissima, the most abundant species in FPF-1, is



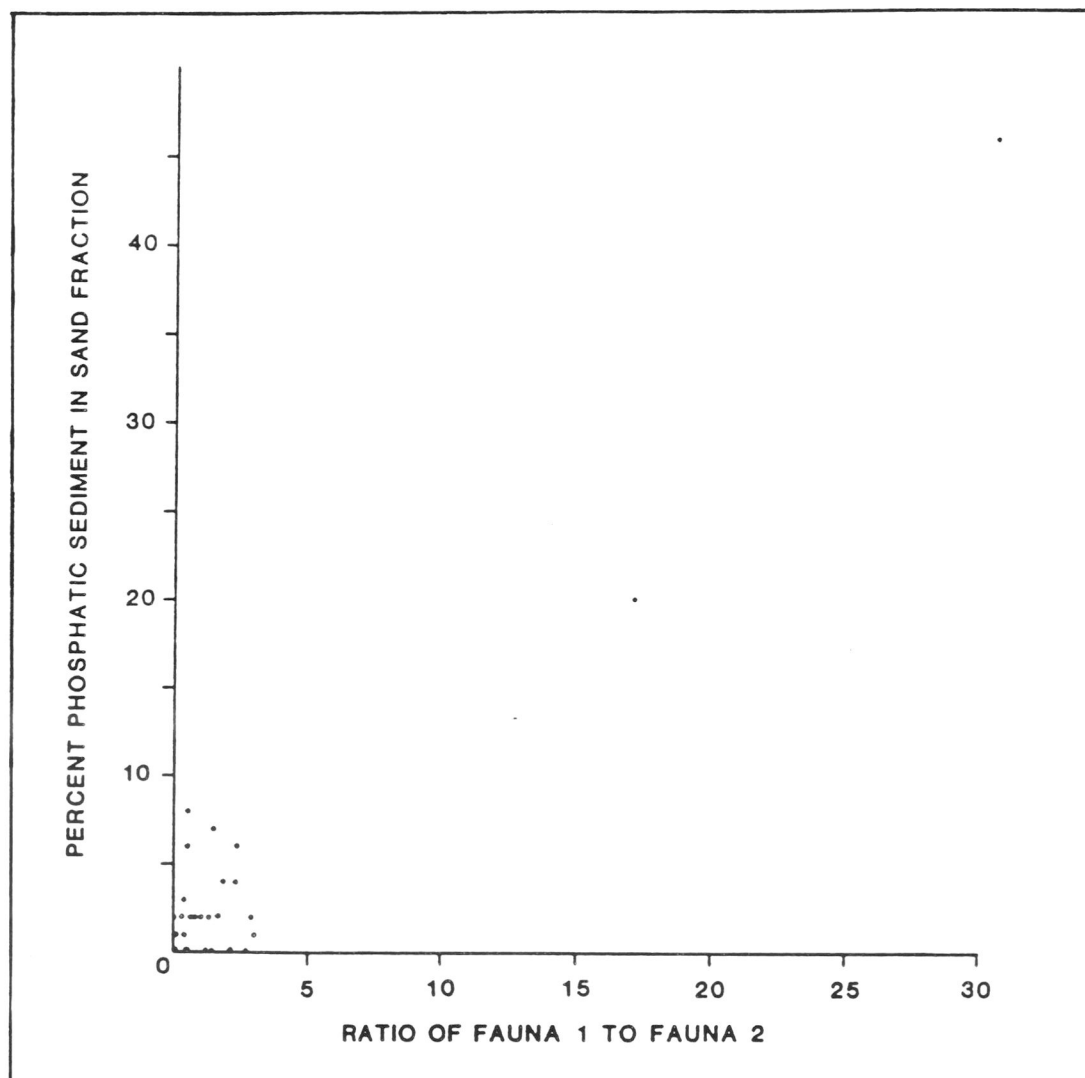


Fig. 9. Summarization of Fauna 1 to Fauna 2 ratios vs. percentage of phosphatic sediment, Pungo River Formation, Central Onslow Bay.

most common along the modern inner and middle shelf of the Atlantic and Gulf of Mexico, where it is limited to depths less than 200 m (Culver and Buzas, 1980, 1981). According to Poag (1981), B. elegantissima is common along the inner and middle shelf of the western and southern Gulf of Mexico. On the inner continental shelf along the eastern side of the Mississippi Delta, B. elegantissima comprises more than 20 percent of the modern benthic population in water depths of 12 to 60 m (Walton, 1964). Schnitker (1971) recorded small numbers of this species from nearshore environments of the Atlantic continental shelf. Although it occurs in small numbers along many modern continental shelves, B. elegantissima becomes abundant in sediments that are high in organic carbon, such as those along portions the Caribbean shelf (Seiglie, 1968) and in sewage outfall areas along the California coast (Bandy et al., 1964a, 1964b, 1965). Buliminella elegantissima is predominant in the lower Pungo River section of the North Carolina Coastal Plain (Katrosh, 1981; Katrosh and Snyder, 1982).

Bolivina paula predominates in a many samples in Central Onslow Bay and species of Bolivina are present throughout the Pungo River section. Bolivina paula is common in Southern Onslow Bay (Waters, 1983) and in the Aurora area (Katrosh, 1981; Katrosh and Snyder, 1982). Culver and Buzas (1980) recorded B. paula across the Atlantic continental shelf from Cape Hatteras to Florida at depths less than 200 m. Bolivinid enrichment in modern environments has been associated with high-nutrient, low-oxygen conditions. Large populations of bolivinids have been reported from oxygen minimum zones in the Pacific

Ocean (Phleger and Soutar, 1973). In the Gulf of Mexico, there is a Bolivina predominance facies encircling the Gulf along the outer shelf and upper slope, which is also circumscribed by an oxygen minimum zone (Poag, 1983). Within the Bolivina predominance facies, increasing bolivinid enrichment is attributed to high organic productivity and reduction of dissolved oxygen. A modern assemblage predominated by bolivinids was described by Sen Gupta et al. (1981) and Sen Gupta and Strickert (1982) in sediments with a high clay-silt, organic carbon and hydrocarbon content from the northern Florida continental shelf. Anomalously high formaminiferal densities in this area were attributed to periodic upwelling produced by meandering of the Gulf Stream onto the continental shelf.

Bulimina elongata, though never predominant, is an important accessory species in FPF-1. A Bulimina generic predominance facies characterizes the continental slope of the Gulf of Mexico (Walton, 1964; Poag, 1981). According to Schnitker (1971), Bulimina spp. attain their greatest abundance at depths below 80 m on the continental slope off the coast of North Carolina. Bulimina is also abundant in low-oxygen, nearshore continental shelf areas. Phleger and Soutar (1973) reported an abundance of Bulimina spp. in shallow oxygen minimum zones in the Santa Barbara Basin and off the continental shelf of Baja, California.

Florilus pizzarensis and Florilus grateloupi are most characteristic of the Fauna 3 assemblage. The genus Florilus is rare along the modern Atlantic continental shelf (Culver and Buzas, 1980),

though Schnitker (1971) found it to be a common faunal constituent across the shelf and upper slope of North Carolina. Florilus spp. are recorded from slope and abyssal depths in the Gulf of Mexico (Culver and Buzas, 1981). The association of bolivinids and Florilus has been related with high percentages of organic carbon in modern sediments (Seiglie, 1968; Phleger and Soutar, 1973).

An important species of the Fauna 2 assemblage is Valvulineria floridana, an extinct form that occurs in Neogene deposits of the Atlantic and Gulf Coastal Plains. According to Smith (1968), Valvulineria spp. indicate bathyal depths of 300-600 m. Valvulineria spp. occur across the continental shelf from Cape Hatteras to Cape Cod and are most typical of depths greater than 200 m (Culver and Buzas, 1980). Schnitker (1971) recorded species of Valvulineria in mid-shelf to shelf-edge environments. In the Gulf of Mexico, Valvulineria spp. occur at depths of 50-2000 m (Culver and Buzas, 1981).

Another important species in the Fauna 2 assemblage is Hanzawaia concentrica. Though not a predominant species, H. concentrica occurs in modest numbers throughout the Pungo River sequences. In modern environments, this species occurs across the Atlantic continental shelf from Florida to Cape Cod at depths reaching 200 m (Culver and Buzas, 1980). Hanzawaia concentrica reaches its greatest abundance (>15%) on the middle continental shelf off the coast of North Carolina. According to Schnitker (1971), frequencies of greater than 10% are indicative of middle shelf environments. Walton (1964) reported similar abundances of H. concentrica at depths less than 60 m in the

northeastern Gulf of Mexico. This species extends down to depths of 1000 m in the Gulf of Mexico, but most occurrences lie on the shelf (Culver and Buzas, 1981). Throughout the Gulf of Mexico, H. concentrica is common in moderate to large numbers on the inner and middle shelf (Poag, 1981).

Epistominella danvillensis, though generally rare, occurs in modest numbers in the FPF sequence. Epistominella danvillensis has been recorded from Miocene and Pliocene strata of the Central Atlantic Coastal Plain (Gibson, 1983). Katrosh (1981) described E. danvillensis as rare but persistent throughout the Pungo River and Yorktown sections from the North Carolina Coastal Plain. In Southern Onslow Bay, Waters (1983) reported E. danvillensis as rare in Pungo River sediments. An Epistominella generic predominance facies occurs in the Gulf of Mexico adjacent to the Mississippi Delta (Poag, 1981; Walton, 1964).

Cibicides americanus, an extinct form and Cibicides lobatulus, which is extant are important components of the Fauna 2 assemblage. Cibicides lobatulus is common across the modern central and northern Atlantic continental shelf. It occurs from Cape Hatteras to Newfoundland at depths less than 200 m, but occasionally is reported at slope depths (Culver and Buzas, 1980). The distribution of C. lobatulus may be more strongly influenced by sediment type than by water depth. Cibicides lobatulus is a wide-spread attaching form which is generally restricted to firm substrates (Beem, 1973).

## Paleoecological Interpretations

### FPP-1 Sequence

The FPP-1 sequence is generally predominated by the Fauna 1 benthic foraminiferal assemblage (Fig. 10), particularly by Buliminella elegantissima, the most abundant species in FPP-1. Bolivina paula predominates in a few samples from FPP-1 and species of Bolivina are present throughout the Pungo River section. Bulimina elongata is an important accessory species in the FPP-1 sequence. Species of Fauna 2 (Valvulineria floridana and Hanzawaia concentrica), while not predominant, are common. Epistominella danvillensis, though generally rare, predominates in two samples from FPP-1. The association of these foraminifers, along with common occurrences of Florilus pizzarensis and Florilus grateloupi in slightly phosphatic sediments suggests an environment of modest nutrient enrichment, perhaps not far removed from upwelling conditions. Moderate diversity values, moderate values of faunal predominance, the abundance of planktonic specimens (Fig. 7) and the modern distributional patterns of key species indicate deposition on the middle to outer continental shelf. In FPP-1, the percentage of phosphate in the sediment is rather low (Fig. 10) and the ratio of Fauna 1 to Fauna 2 is correspondingly low.

### FPP-2 Sequence

As stated previously, the interpretation of this sequence is tentative due to the paucity of available samples. Overall, the Fauna

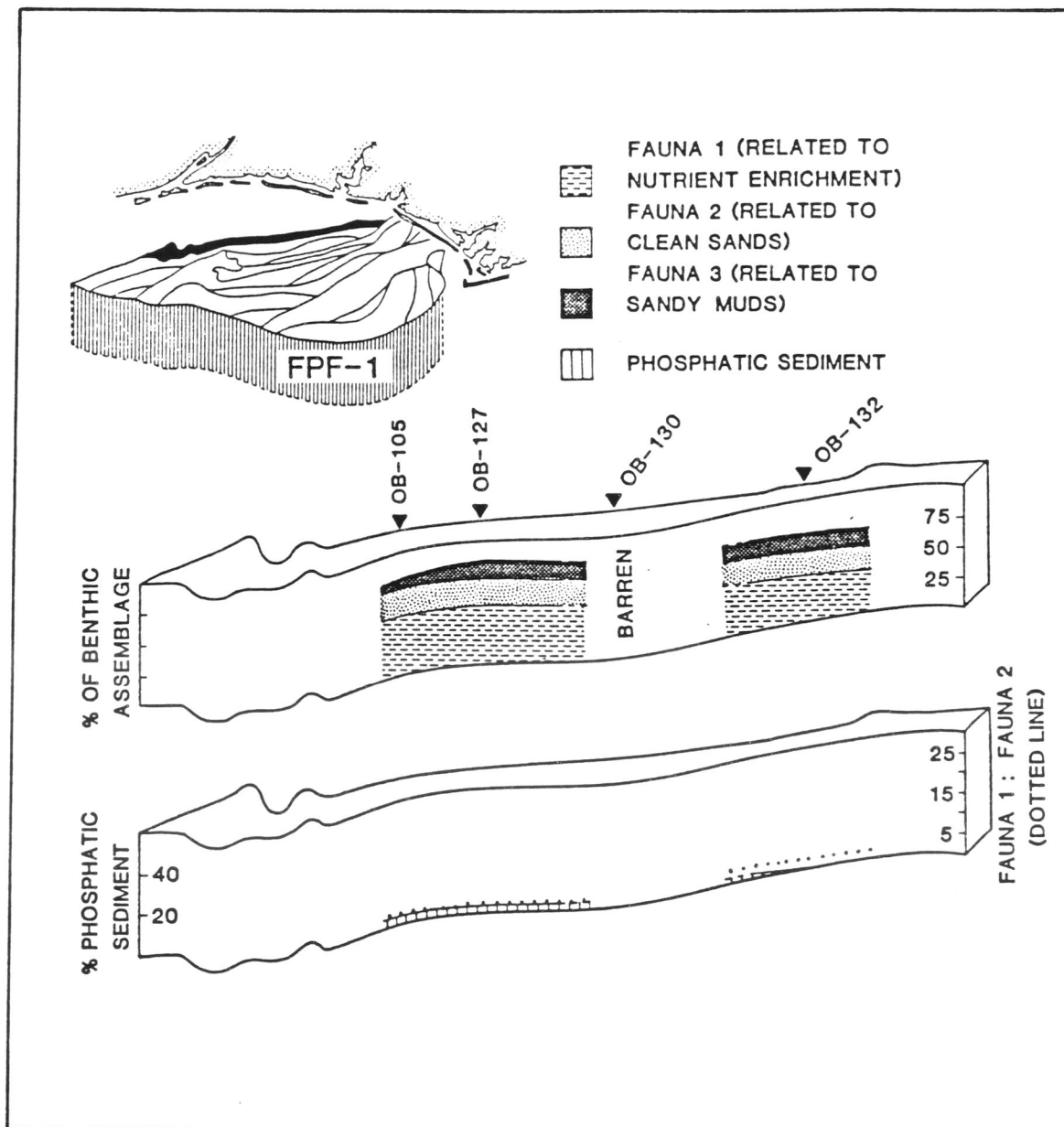


Fig. 10. Faunal-sediment relationships in sequence FPF-1, Pungo River Formation, Central Onslow Bay.

1 assemblage predominates this slightly phosphatic, sandy mud sequence, with Bolivina paula being the most numerically abundant species. However, other species associated with Fauna 1, such as Buliminella elegantissima and Bulimina elongata, decrease in abundance relative to their levels in FPF-1. Florilus pizzarensis, typical of the Fauna 3 assemblage, is again present as a secondary species. Valvulineria floridana and Hanzawaia concentrica are the most abundant species associated with Fauna 2 in FPF-2. Valvulineria floridana predominates in one sample of this sequence. Collectively, species of Fauna 2 are nearly as abundant as those of Fauna 1 (Fig. 11).

The slight predominance of species that typify Fauna 1, along with the common occurrence of species of Fauna 3, indicates environmental conditions related to modest nutrient supply. Deposition on the middle continental shelf is indicated by moderate diversity values, moderate faunal predominance, low P/B ratios (Fig. 7), and modern distributional patterns of key species. Occasional increases in relative abundance of V. floridana and H. concentrica probably indicate that the area was periodically exposed to highly oxygenated, normal marine conditions. The phosphate content is low in this sequence and the ratio of Fauna 1 to Fauna 2 is correspondingly low (Fig. 11).

### FPF-3 Sequence

Sequence FPF-3 differs slightly from FPF-1 and FPF-2 in terms of species composition and relative abundance of predominant species. Species that characterize Fauna 2 collectively predominate this



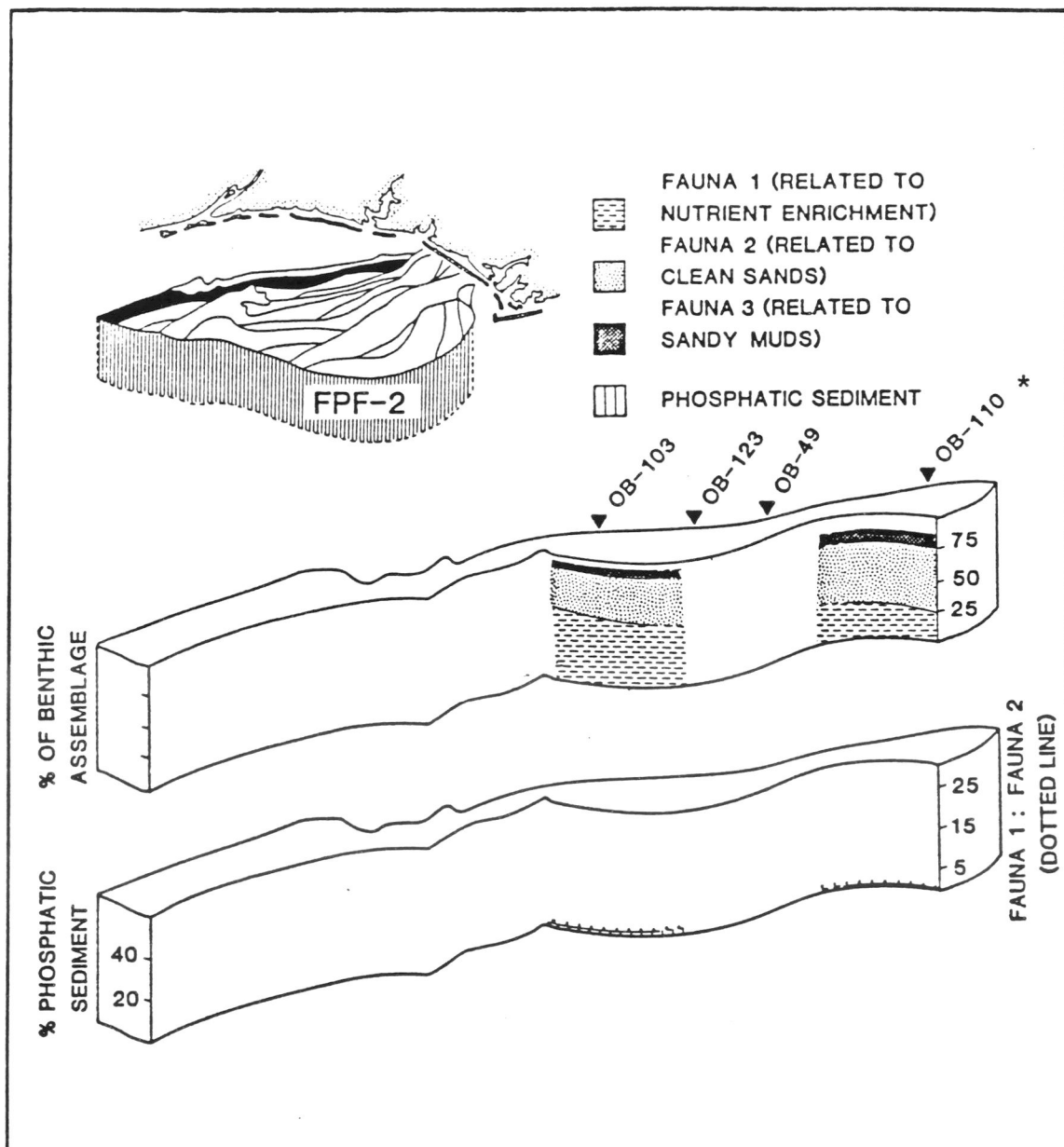


Fig. 11. Faunal-sediment relationships in sequence FPF-2, Pungo River Formation, Central Onslow Bay. (\* unpublished data from S. W. Snyder for Northern Onslow Bay)

sequence (Fig. 12), but Bolivina paula is still the most abundant single species. Many secondary species in the Fauna 1 assemblage, such as Buliminella elegantissima and Bulimina elongata, decrease in abundance relative to older sequences. The occurrence of Florilus pizzarensis and Florilus grateloupi, major elements of the Fauna 3 assemblage, is expected in this slightly phosphatic, sandy mud sequence. Valvulineria floridana predominates in one sample from FPF-3 and is numerically the most abundant species among those that typify the Fauna 2 benthic foraminiferal assemblage. Hanzawaia concentrica is common in this sequence, where it averages approximately 15 percent of the fauna (Fig. 8). Cibicides americanus and Cibicides lobatulus are common species in FPF-3. Moderate diversity values, moderate faunal predominance, moderate P/B ratios (Fig. 7), and the distributional pattern of important species, such as Hanzawaia concentrica, suggest deposition on the middle continental shelf. The predominance of Bolivina paula suggests some nutrient enrichment, but the abundance of the Fauna 2 benthic assemblage implies frequent periods of highly oxygenated, open marine conditions. The low Fauna 1 to Fauna 2 ratio, along with the low percentage of phosphate in the sediment (Fig. 12) supports this interpretation.

#### FPF-6 Sequence

The FPF-6 sequence is a muddy, foraminiferal quartz sand with minor amounts of phosphate. Bolivina paula is the most abundant species in this sequence, but the Fauna 2 foraminiferal association

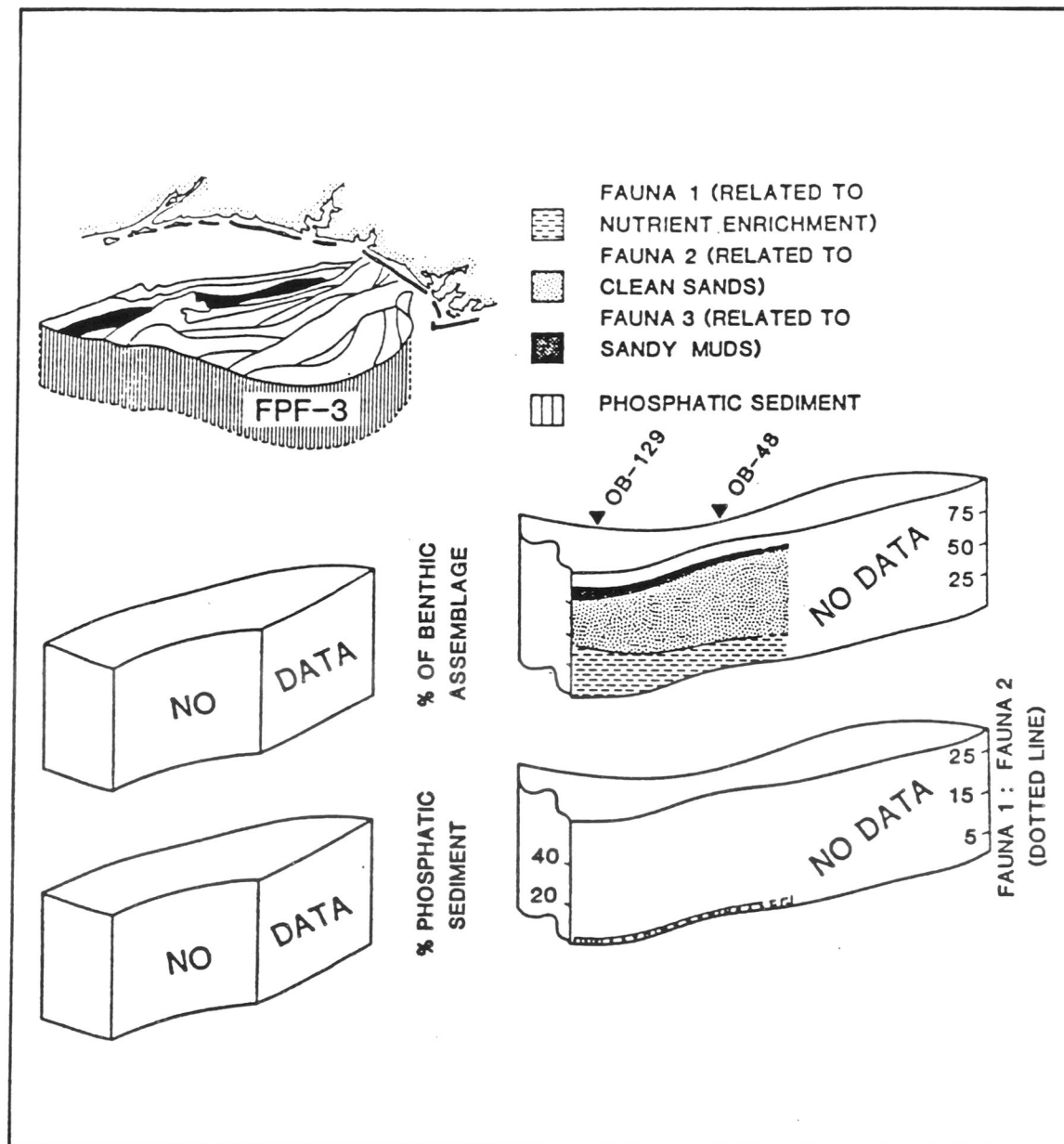


Fig. 12. Faunal-sediment relationships in sequence FPF-3, Pungo River Formation, Central Onslow Bay.

collectively predominates the benthic foraminiferal assemblages (Fig. 13). A few secondary species from Fauna 1 and Fauna 3, such as Buliminella elegantissima and Florilus pizzarensis, are still present, but other important secondary species noted from previous sequences are absent. Valvulineria floridana and Cibicides americanus are the most abundant species of the Fauna 2 assemblage.

The abundance of Bolivina paula in the FPF-6 sequence is overshadowed by the collective predominance of the Fauna 2 assemblage, which is typical of well oxygenated, open marine environments. This faunal association indicates a transition from conditions of modest nutrient supply to more highly oxygenated, normal marine conditions, probably related to the influx of warmer Gulf Stream waters onto the continental shelf in response to rising sea level (Riggs, 1984). Moderate diversity values, moderate faunal predominance, the abundance of planktonic foraminifers (Fig. 7) and modern species distributional patterns suggest deposition on the middle to outer continental shelf. The decrease in phosphate content corresponds to a decrease in the Fauna 1 to Fauna 2 ratio (Fig. 13).

### AF-3 Sequence

The interpretation of this sequence is tentative because of the insufficient number of available samples. The AF-3 sequence is carbonate-rich and generally devoid of phosphate. The Fauna 2 benthic foraminiferal assemblage predominates this sequence (Fig. 14). Cibicides americanus, the most abundant species, composes approximately

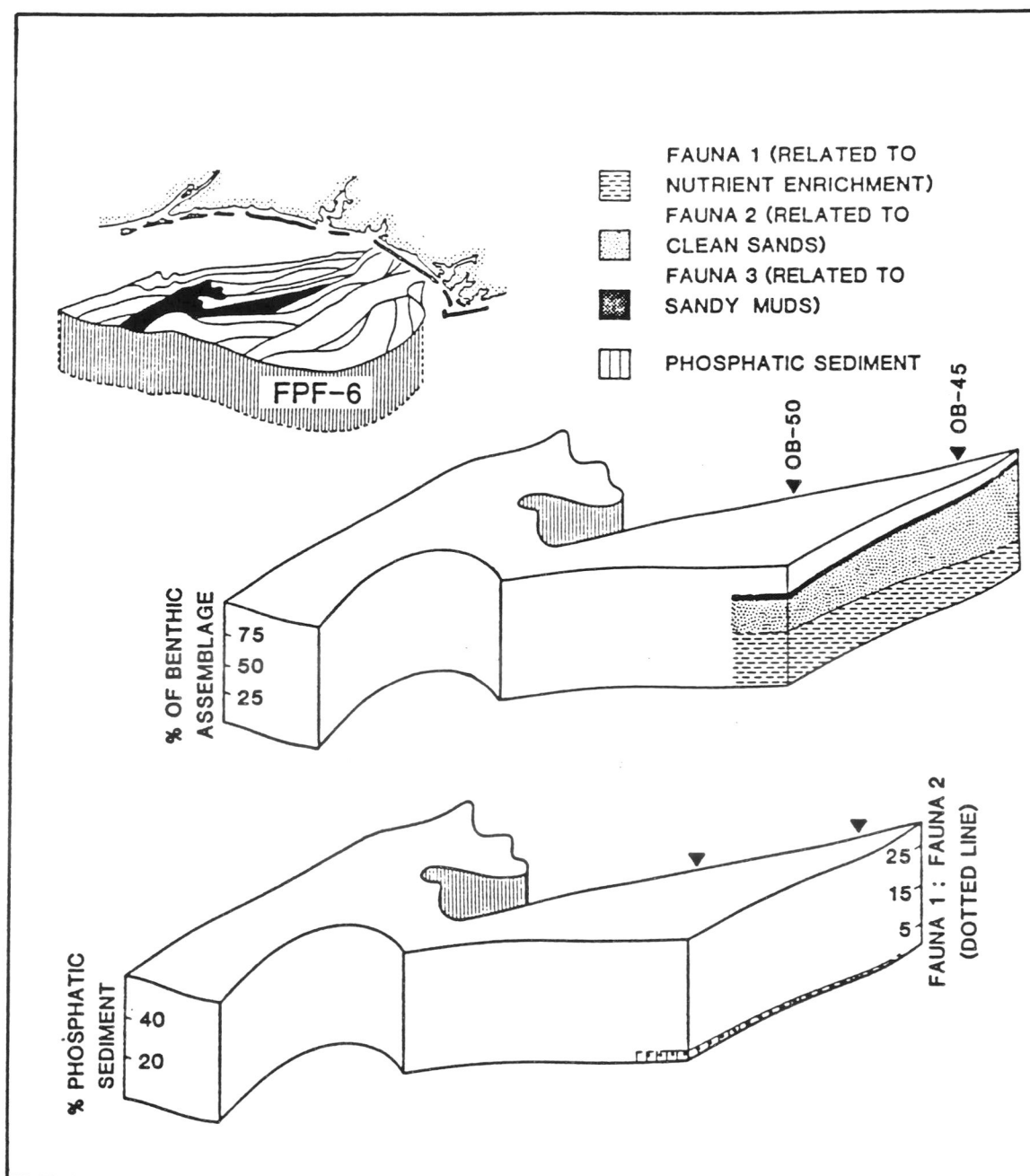


Fig. 13. Faunal-sediment relationships in sequence FPF-6, Pungo River Formation, Central Onslow Bay.

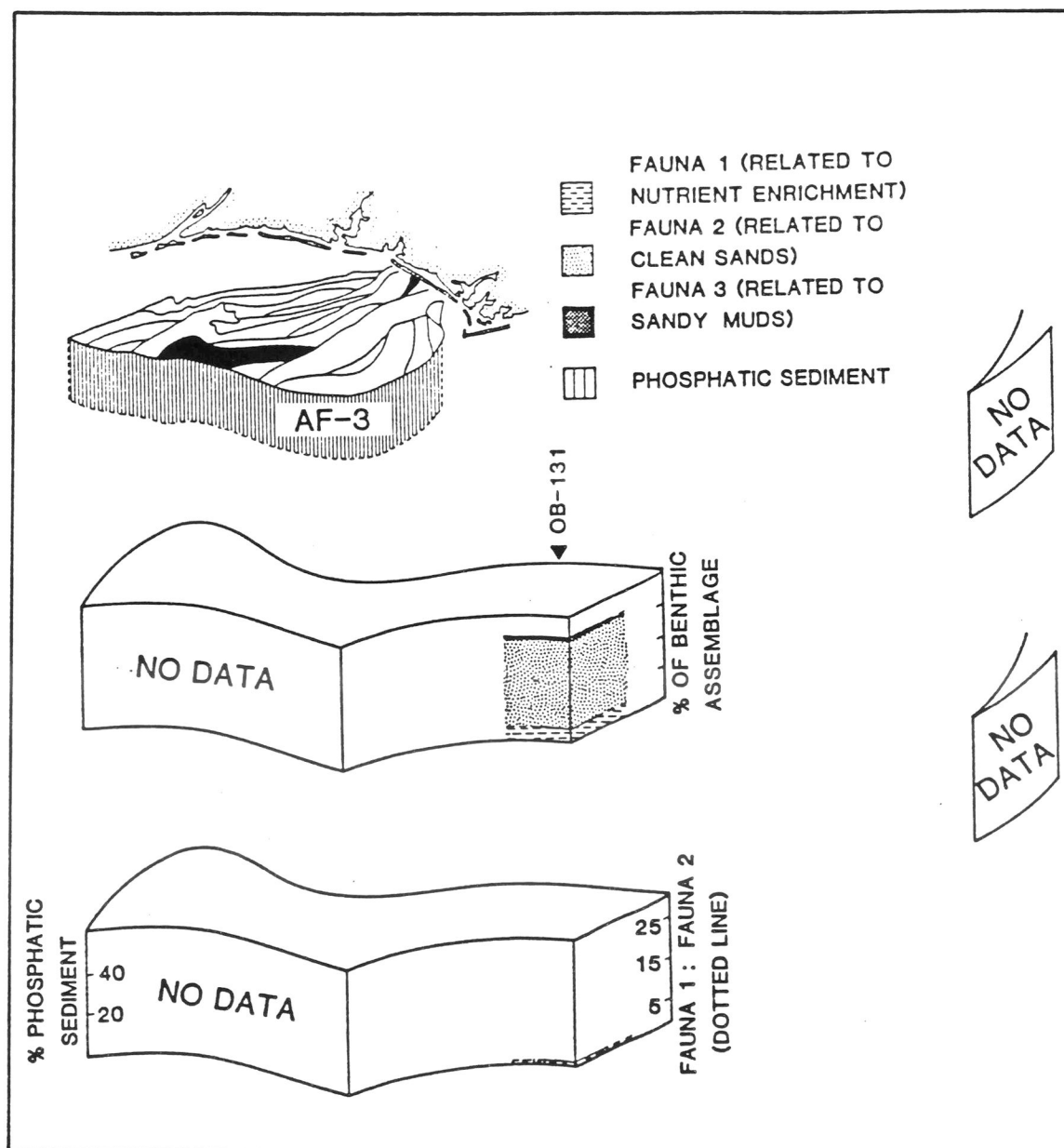


Fig. 14. Faunal-sediment relationships in sequence AF-3, Pungo River Formation, Central Onslow Bay.

49 percent of the total benthic population (Fig. 8). Species typical of the Fauna 1 assemblage are present in small numbers. The predominance of Cibicides americanus, along with the common occurrence of Valvulineria floridana and Hanzawaia concentrica, indicates a well oxygenated, open marine environment of deposition. Moderate diversity values and the abundance of planktonic foraminifers (Fig. 7) suggest deposition on the middle to outer continental shelf. The very low percentage of phosphate in the sediment is associated with a correspondingly low ratio of Fauna 1 to Fauna 2 (Fig. 14).

#### BBF-1 Sequence

Sequence BBF-1 contains abundantly phosphatic and diatomaceous intervals. The Fauna 1 benthic foraminiferal assemblage predominates in this sequence, and Bolivina paula predominates by a large margin in phosphatic and diatomaceous intervals in the middle portion of BBF-1. Valvulineria floridana and Cibicides americanus predominate in the non-phosphatic and non-diatomaceous zones of the lower portion of BBF-1. Florilus pizzarensis, a major element of the Fauna 3 assemblage, occurs in small numbers, mostly in association with the more phosphatic intervals. The Fauna 1 to Fauna 2 ratio closely parallels the percentage of phosphate found in the sediments of the lower and middle portions within the BBF-1 sequence (Figs. 15, 16). No cores were available from upper BBF-1 in Central Onslow Bay.

The predominance of Bolivina paula, in association with Buliminella elegantissima and Florilus pizzarensis, suggests that

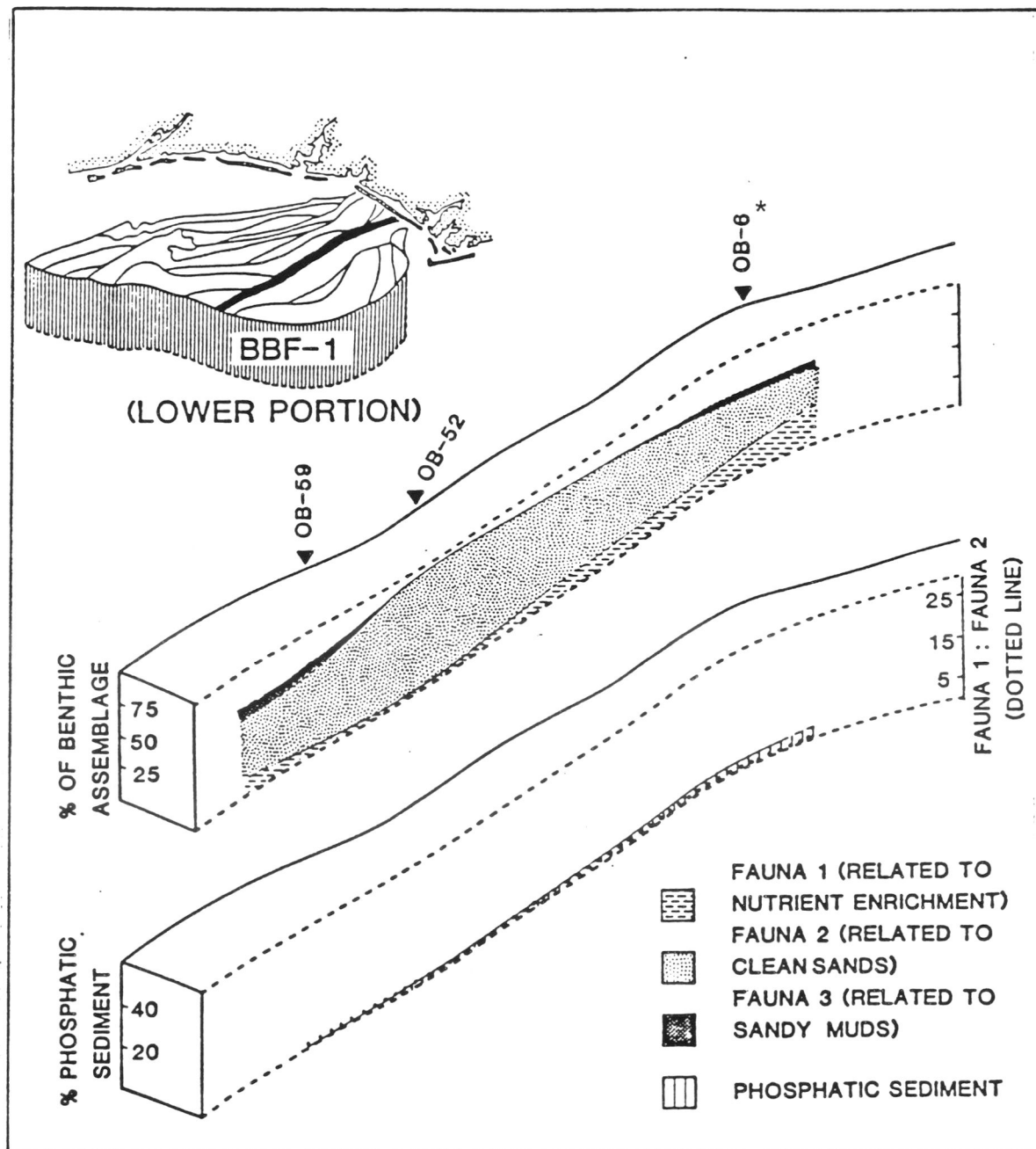


Fig. 15. Faunal-sediment relationships in sequence BBF-1 (lower portion), Pungo River Formation, Central Onslow Bay. (\* unpublished data from S. W. Snyder for Northern Onslow Bay)



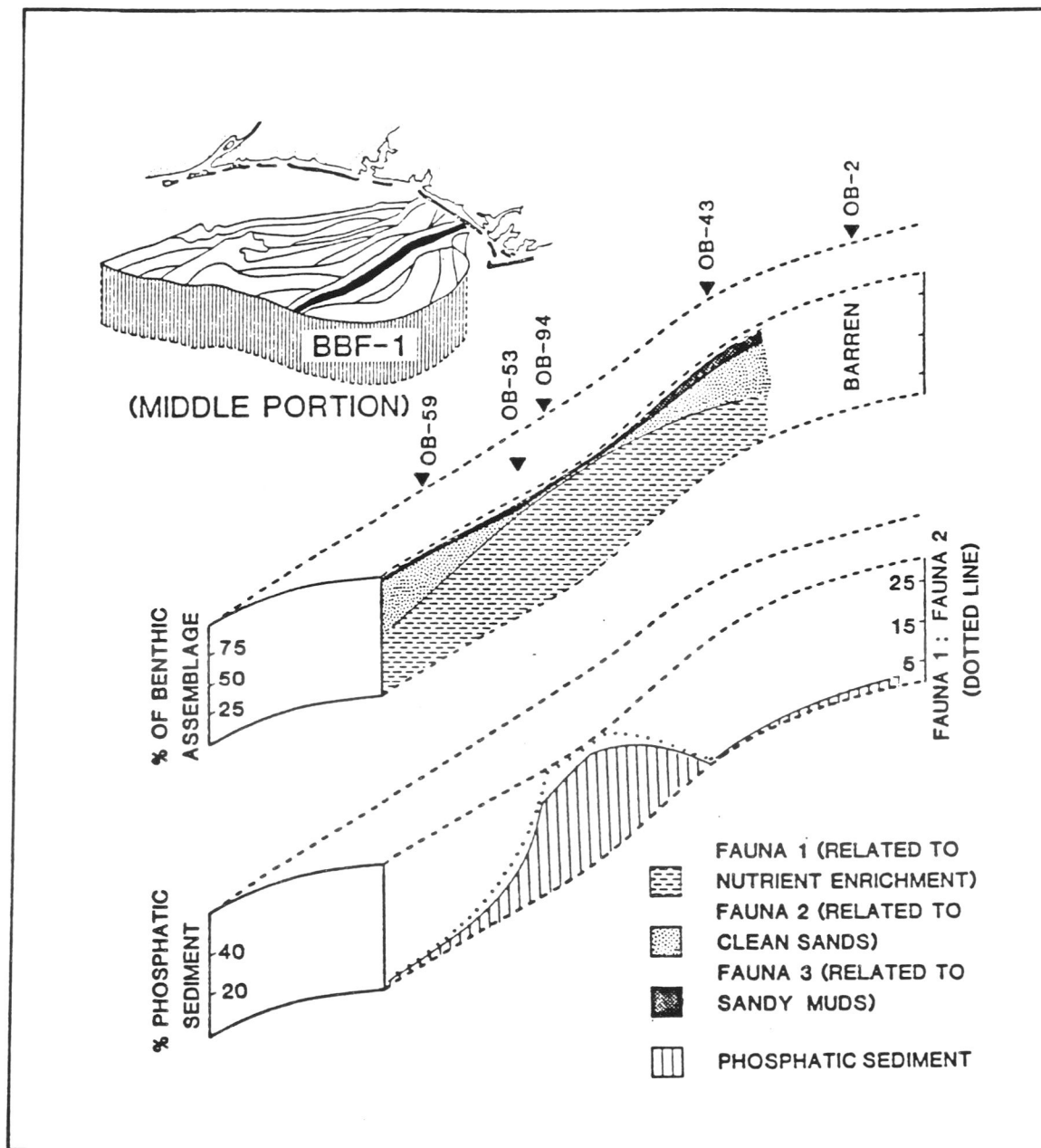


Fig. 16. Faunal-sediment relationships in sequence BBF-1 (middle portion), Pungo River Formation, Central Onslow Bay.

phosphatic intervals accumulated in oxygen-poor conditions related to high nutrient levels. Lower diversity values, high faunal predominance, and the rarity of planktonic specimens suggest (Fig. 7) deposition in a stressed middle continental shelf environment.

#### BBF-2 Sequence

The BBF-2 sequence is generally a coarse, clean, quartzitic sand with minor amounts of phosphate. The Fauna 1 benthic foraminiferal assemblage totally predominates this sequence. Bolivina paula, numerically the most abundant species, averages 93 percent of the foraminiferal fauna.

The predominance of Bolivina paula in BBF-2 does not appear to be associated with nutrient-rich conditions. The coarse sediment, low phosphate percentages, and absence of diatoms all suggest a moderate energy, highly oxygenated bottom. The high concentrations of B. paula may be related to mechanical abrasion/destruction of other foraminifera. Many specimens of B. paula are worn or broken to varying degrees. Due to their small size and tapering shape, it is possible for them to be protected in the interstitial spaces of the quartz sand, thus reducing their chance of being destroyed. Larger species might, under the same conditions, be crushed against and between mobile grains of this substrate. This interpretation is speculative due to the small number of samples available from sequence BBF-2.

## SUMMARY AND CONCLUSIONS

The Pungo River Formation in Central Onslow Bay consists of three third-order seismic sequences (FPF, AF, and BBF), which comprise smaller, fourth-order seismic sequences, each bounded by unconformities. Phosphate content, though generally low throughout the sequences in Central Onslow Bay, does increase dramatically in the middle portion of sequence BBF-1.

Biostratigraphic analyses indicate a late Burdigalian (late early Miocene) age for the FPF sequence. The FPF-1, FPF-2, FPF-3 and lower FPF-6 sequences lie within planktonic foraminiferal Zone N6; middle and upper FPF-6, in the early portion of Zone N7. The AF-3 sequence is Langhian (early middle Miocene) in age and is assigned to planktonic foraminiferal Zone N9. The BBF sequences in Central Onslow Bay cannot be evaluated as accurately as the previous sequences; but based on data from Northern Onslow Bay (Snyder, unpub. data), it is presumed to be Serravallian (middle Miocene) in age (Zone N11-N14). When compared to coastal offlap/onlap curves (Vail et al., 1977; Vail and Mitchum, 1979), the FPF, AF, and BBF sequences correspond to the third-order Miocene TM 1.4, TM 2.1, and TM 2.2 transgressions, respectively.

Moderate values of species diversity and faunal predominance characterize most benthic assemblages of the Pungo River Formation in Central Onslow Bay. Three benthic foraminiferal associations (Fauna 1, Fauna 2 and Fauna 3) are recognized and each is associated with a

specific sediment type through individual seismic sequences. Fauna 1, associated with phosphate-enriched sands, is comprised of species of Bolivina, Buliminella, Bulimina and Uvigerina. Fauna 2 characterizes clean, quartzitic sands and contains species of Valvulineria, Hanzawaia and Cibicides. Fauna 3, associated with muddy sands, contains species of Florilus, Siphogenerina and Nonionella. Changes in species composition reflect variations in water mass properties and substrate type rather than paleobathymetry. Deposition of the seismic sequences in this study area occurred on the middle to outer continental shelf. Bolivina paula, Buliminella elegantissima and other species associated with high nutrient conditions are slightly predominant in sequences FPF-1, FPF-2 and FPF-3. Such abundances of these species indicate moderately low-oxygen conditions, associated with zones of upwelling. The predominance of Valvulineria floridana in a few samples in each of these sequences suggests periods of highly oxygenated conditions. The slight predominance of Valvulineria floridana and Cibicides americanus in the FPF-6 sequence suggests a transition from conditions of modest nutrient supply to more highly oxygenated, normal marine conditions. Attaching forms, such as Cibicides americanus and Cibicides spp., predominate in the AF-3 sequence. The strong predominance of Cibicides americanus in AF-3, in association with Valvulineria floridana and Hanzawaia concentrica, indicates a well-oxygenated, open marine environment. In highly phosphatic portions of the BBF-1 sequence, the abundance of Bolivina paula increases (up to 71% of the total benthic foraminiferal assemblage) and this species strongly predominates. This

association indicates that the phosphatic zone in the middle portion of BBF-1 was deposited during strong upwelling conditions. The predominance of Bolivina paula in BBF-2 is probably related more to mechanical abrasion/destruction of other benthic species than to high-nutrient conditions.

## ANNOTATED FAUNAL LIST

Planktonic foraminifera from Central Onslow Bay appear in the first portion of this section; benthic foraminifera, in the second part. Species are grouped within genera that are arranged alphabetically. Generic concepts follow the Treatise on Invertebrate Paleontology (1964). No suprageneric classification is given and only original descriptions are cited. Diagnostic morphological characteristics are briefly summarized for each species along with a statement on stratigraphic occurrence and geographical distribution within the study area. The relative abundance of benthic species within individual samples is presented in Appendix C.

Planktonic Foraminifera

Genus: Cassigerinella Porkorny, 1955

Cassigerinella chipolensis (Cushman and Ponton)

Pl. 5, fig. a-b

Cassidulina chipolensis CUSHMAN AND PONTON, 1932, Florida Geol. Soc. Survey Bull. 9, p. 98, pl. 15, fig. 2.

Test a small, robust, smooth, biserial coil; usually 8-10 chambers, gradually enlarging and becoming progressively more inflated; aperture a U-shaped arch on inward facing portion of ultimate chamber. Range: Early Zone Pl8 to later Zone N13 (Blow, 1969, 1979).

Earliest Oligocene to end of middle Miocene; Pseudohasterigerina micra to Globorotalia siakensis Zone (Stainforth et al., 1975).

Occurrence: Few in FPF-1 sequence.

Genus: Catapsydrax Bolli, Loeblich, and Tappan, 1957

Catapsydrax dissimilis (Cushman and Bermudez)

Pl. 3, fig. f-g

Globigerina dissimilis CUSHMAN AND BERMUDEZ, 1937, Cushman Lab. Foram. Research, Contr., v. 13, p. 25, pl. 3, fig. 4-6.

Test compact with 4 chambers in final whorl; surface texture coarsely cancellate; umbilicus covered by bulla with at least 2 and up to 4 arched supplementary apertures over sutural depressions.

Range: Within Zone Pl3 through Zone N6 (Blow, 1969, 1979).

Middle Eocene to early Miocene; Orbulinoides beckmanni to

Catapsydrax stainforthi Zone (Stainforth et al., 1975). Zone

N2 through N6 (Poore, 1978).

Occurrence: Rare in FPF-6 sequence.

Catapsydrax stainforthi Bolli, Loeblich, and Tappan

Pl. 3, fig. h-i

Catapsydrax stainforthi BOLLI, LOEBLICH, AND TAPPAN, 1957, U. S. Natl.

Museum Bull. 215, p. 37, pl. 7, fig. 11.

Test small; 4 chambers in final whorl; surface texture not as coarse as C. dissimilis or C. unicavus; primary aperture completely covered by single bulla with small, arched openings over intercameral sutures.

Range: Latest Zone N4 to later part of Zone N7 (Blow, 1969, 1979).

Early Miocene; Catapsydrax dissimilis to Globigerinatella insueta Zone (Stainforth et al., 1975).

Occurrence: Rare in FPF-1 sequence.

Catapsydrax unicavus Bolli, Loeblich, and Tappan

Pl. 3, fig. j-k

Catapsydrax unicavus BOLLI, LOEBLICH, AND TAPPAN, 1957, U. S. Natl.

Museum Bull. 215, p. 37, pl. 7, fig. 9.

Test small, low-spined; commonly 4 chambers in final whorl; primary aperture covered by bulla attached to chambers on 3 sides, leaving a low, arched opening on fourth.

Range: Within Zone P20 to N6 (Blow, 1969, 1979).



Late middle Eocene to early Miocene; Truncorotaloides rohri to Catapsydrax stainforthi Zone (Stainforth et al., 1975); recorded as high as Zone N8 (Poore, 1978).

Occurrence: Rare in FPF-1, FPF-3, and FPF-6 sequences.

Genus: Globigerina d'Orbigny, 1826

Globigerina angustiumbilocata Bolli

Pl. 1, fig. k-1

Globigerina ciperensis angustiumbilocata BOLLI, 1957, U. S. Natl. Museum Bull. 215, p. 109, pl. 22, fig. 12-13.

Test small, low trochospire; uniformly 5 chambers in final whorl; surface texture perforate; aperture small, arched opening.

Range: Upper Zone Pl6 to Zone N22 (Blow, 1969, 1979).

Late Eocene to Pleistocene or Holocene; Globorotalia cerroazulensis s.l. to Globorotalia truncatulinoides Zone (Stainforth et al., 1975).

Occurrence: Rare in FPF-1 sequence.

Globigerina juvenilis Bolli

Pl. 1, fig. m

Globigerina juvenilis BOLLI, 1957, U. S. Natl. Museum Bull. 215, p. 110, pl. 24, fig. 5a-c, 6.

Test small with 4 chambers in final whorl; umbilicus small; aperture a low, elongate slit with a slight lip.

Range: Base of Zone N4 to Zone N23 (Blow, 1969, 1979).

Late Oligocene through Pleistocene.

Occurrence: Rare in FPF-1 sequence.

Globigerina praebulloides Blow

Pl. 1, fig. a-b

Globigerina praebulloides BLOW, 1959, Bull. Amer. Paleontology, v. 39, p. 180, pl. 8, fig. 47, pl. 9, fig. 48.

Test with 4 loosely coiled chambers in final whorl; umbilicus wide; aperture partially extraumbilical.

Range: Zone Pl6 to within N17 (Blow, 1969, 1979).

Late Eocene through late Miocene.

Occurrence: Few in FPF-3, FPF-6, AF-3 sequences; common in FPF-1 and BBF-1 sequences.

Globigerina pseudociperoensis Blow

Pl. 1, fig. c-d

Globigerina praebulloides pseudociperoensis BLOW, 1969, Proc. First Internatl. Conf. Planktonic Microfossils, p. 381-382, pl. 17 fig. 8, 9.

Test moderate sized with 5 loosely embracing chambers in final whorl; surface texture finely perforate; umbilicus open and aperture tends to be somewhat extraumbilical.

Range: At least Zone N7 to within Zone N12 (Blow, 1969, 1979).

Zone N6 to Zone N14 (Poore, 1978).

Early to middle Miocene.

Occurrence: Rare in FPF-6 and FPF-3 sequences.

Globigerina tripartita Koch

Pl. 1, fig. e-f

Globigerina bulloides d'Orbigny var. tripartita KOCH, 1926, Ecologue Geol. Helvetiae, v. 19, p. 746, fig. 21 a-b.

Test moderate sized, globose; generally 3 chambers in final whorl; umbilicus triangular; aperture intraumbilical.

Range: Zone P14 to Zone N3 (Blow, 1969, 1979).

Middle Eocene to Late Oligocene and recognized in early Miocene, but not rigidly defined (Stainforth et al., 1975).

Occurrence: Rare in FPF-1, FPF-3, and FPF-6 sequences.

Globigerina woodi Jenkins

Pl. 1, fig. i-j

Globigerina woodi JENKINS, 1960, Micropaleontology, v. 6, n. 4, p. 252, pl.2, fig. 2.

Test small, coarsely textured with 4 chambers in final whorl; aperture interiomarginal, centered over antepenultimate chamber, semicircular.

Range: Zone P22 to middle Zone N21 (Poore, 1978).

Late Oligocene to Pliocene.

Occurrence: Rare in FPF-1, FPF-3, and FPF-6 sequences.

Globigerina venezuelana Hedberg

Pl. 1, fig. g-h

Globigerina venezuelana HEDBERG, 1937, Jour. Paleontology, v. 11, p. 681, pl. 92, fig. 7.

Test large with finely cancellate surface texture; generally 4 and 1/2 chambers in final whorl; ultimate chamber is usually small and irregular, embracing and partially covering rectangular umbilicus.

Range: Within Zone P22 to within Zone N19 (Blow, 1969, 1979).

Middle Eocene through Miocene, with some Pliocene occurrences (Stainforth et al., 1975).

Occurrences: Common in FPF-1; few in FPF-3, FPF-6, and BBF-1; rare in AF-3.

Genus: Globigerinita Bronnimann, 1951

Globigerinita glutinata (Egger)

Pl. 4, fig. k-l

Globigerinita glutinata EGGER, 1893, Abh. K. Bayer. Akad. Wiss. Munchen, Cl. II, v. 18, p. 371, pl. 13, fig. 19, 20.

Test small, finely perforate; usually 3-4 chambers in final whorl; umbilicus covered by bulla that may be simple and inflated (as illustrated) or appressed and bordered by small, multiple openings.

Range: Zone P21 to Zone N22 (Poore, 1978).

In synonymy with G. naparimaensis, middle Miocene to Holocene (Stainforth et al., 1975).

Occurrence: Few in FPF-1; rare in FPF-3 and FPF-6 sequences.

Globigerinita uvula (Ehrenberg)

Pl. 4, fig. m

Pyloedexia uvula EHRENBURG, 1861, K. Preuss, Akad. Wiss. Berlin, Monatsber., p. 276-277, 308.

Test small, high-spined with 4 chambers in final whorl; aperture interiomarginal, umbilical, low arch with delicate lip.

Range: Zone P21 to Zone N22 (Poore, 1978).

Late Oligocene to Holocene.

Occurrence: Few in FPF-1; rare in FPF-3 and FPF-6 sequences.

Genus: Globigerinoides Cushman, 1927

Globigerinoides obliquus obliquus Bolli

Pl. 2, fig. a-b

Globigerinoides obliqua BOLLI, 1957, U. S. Natl. Museum Bull. 215, p. 113, pl. 25, fig. 9, 10.

Test moderate sized with 4 chambers compressed in lateral oblique manner in final whorl; aperture interiomarginal high arch; one or more supplementary sutural apertures on spiral side.

Range: Latest Zone N5 into Zone N22 (Blow, 1969, 1979).

Zone N8 into Zone N22 (Poore, 1978).

Early Miocene into Pleistocene.

Occurrence: Rare in FPF-1 and BBF-1; few in FPF-3 and FPF-6 sequences.

Globigerinoides quadrilobatus altiapertura Bolli

Pl. 2, fig. c-d

Globigerinoides triloba altiapertura BOLLI, 1957, U. S. Natl. Museum Bull. 215, p. 113, pl. 25, fig. 7-8.

Test ovoid, low-spined with 3 and 1/2 to 4 appressed globular chambers in final whorl; aperture a circular arch extending over umbilical area and completely embracing antepenultimate chamber; large, lunate supplementary apertures on spiral side.

Range: Base of Zone N5 to early Zone N7 (Blow, 1969, 1979).

Early Miocene; Catapsydrax dissimilis and Catapsydrax stainforthi Zones (Stainforth et al., 1975).

Occurrence: Few in FPF-1, FPF-3, and FPF-6 sequences.

Globigerinoides quadrilobatus praeimmaturus Brönnimann and Resig

Pl. 2, fig. e-f

Globigerinoides quadrilobatus praeimmaturus BRÖNNIMANN AND RESIG, 1971, Initial Reports of the Deep Sea Drilling Project, v. VII, p. 1272, pl. 9, fig. 1-4.

Test a low trochospire with 4 subglobular chambers slowly increasing in size through final whorl; strongly pustulose surface texture; aperture umbilical, interiomarginal, narrow slit; secondary slit visible on spiral side.

Range: Zone N6 to Zones N7/N8, common in Zones N7/N8 (Brönnimann and Resig, 1971).

Early Miocene to middle Miocene.

Occurrence: Rare in FPF-1, FPF-3, FPF-6, and AF-3 sequences.

Globigerinoides quadrilobatus primordius Blow and Banner

Pl. 2, fig. g-h

Globigerinoides quadrilobatus primordius BLOW AND BANNER, 1962, In Eames, F. E. et al., Fundamentals of mid-Tertiary stratigraphical correlation, p. 115, pl. 9, fig. Dd-Ff.

Test low trochospire with 3 and 1/2 to 4 chambers in final whorl doubling in size as added; primary aperture arched; primary and supplementary apertures align so that one sees through them.

Range: Base Zone N4 to early Zone N5 (Blow, 1969, 1979).

Early Miocene; Globorotalia kugleri Zone (Stainforth et al., 1975).

Occurrence: Few in FPF-1 and FPF-3; rare in FPF-6.

Globigerinoides quadrilobatus sacculifer (Brady)

Pl. 2, fig. i-j

Globigerina sacculifera BRADY, 1877, Geol. Mag., dec. 2, v. 4, p. 535.

Test low trochospire; generally 4 appressed and globular chambers in final whorl; ultimate chamber becoming almond-shaped or sack-like in adult specimens; similar to G. q. triloba in early stages; conspicuous primary and supplementary apertures.

Range: Within Zone N5 to Zone N23 (Blow, 1969, 1979).

Early Miocene to Holocene (Stainforth et al., 1975).

Occurrence: Few in FPF-1, FPF-3, FPF-6, and AF-3 sequences.

Globigerinoides quadrilobatus triloba (Reuss)

Pl. 2, fig. k-1

Globigerina triloba REUSS, 1850, Akad. Wiss. Wien Denkschr., Math. Nat. Kl., v. 1, p. 347, pl. 47, fig. 11.

Test moderate sized with 3 appressed chambers in final whorl; surface texture coarsely cancellate; conspicuous median suture separates quadrate coil from ultimate chamber; primary aperture a low arch encompassing earlier portion of test; irregular or lunate supplementary apertures on spiral side.

Range: Within early portion of Zone N6 to N23 (Blow, 1969, 1979).

Early Miocene to Holocene; Catapsydrax dissimilis to Globorotalia truncatulinoides zones (Stainforth et al., 1975).

Occurrence: Common in FPF-1, FPF-6, and BBF-1; abundant in FPF-3 and AF-3 sequences.

Globigerinoides sicanus praesicanus Brönnimann and Resig

Pl. 3, fig. a-b

Globigerinoides sicanus praesicanus BRÖNNIMANN AND RESIG, 1971, Initial Reports of the Deep Sea Drilling Project, v. VII, p. 1273, pl. 10, fig. 5, 6, 8.

Test with 3 to 3 and 1/2 subglobular chambers in final whorl; ultimate chamber comprises approximately 1/2 of test, showing a



tendency to envelope preceding chambers; large, arched, interiomarginal primary aperture; small supplementary apertures on spiral side (2 in typical form, 1 in affine form).

Range: Zone N4 to N6 (typical)

Zone N7/N8 (affine) (Brönnimann and Resig, 1971).

Occurrence: Rare in AF-3 sequence.

Globigerinoides sicanus sicanus de Stefani

Pl. 3, fig. c

Globigerinoides sicanus DE STEFANI, 1950, *Plinia*, v. 3, note 4, p. 9.

Test finely cancellate with 3 subglobular chambers in final whorl; differs from G. s. praesicanus in having a larger, more embracing final chamber and slit-like primary aperture.

Range: Base of Zone N8 to within early Zone N9 (Blow, 1969, 1979).

Early middle Miocene.

Occurrence: Rare in AF-3.

Globigerinoides subquadratus Brönnimann

Pl. 3, fig. d-e

Globigerinoides subquadratus BRÖNNIMANN, 1954, *In* Todd, Cloud, Low, and Schmidt, *Amer. Jour. Science*, v. 252, p. 680, pl. 1, fig. 5.

Test coarsely cancellate with 3 subglobular chambers in final whorl, lightly embracing in adult specimens; primary aperture large, nearly circular, located symmetrically above intercameral suture

between penultimate and antepenultimate chambers; generally 2 supplementary apertures on spiral side.

Range: Middle to late Zone N5 to top of Zone N13 (Blow, 1969, 1979).

Early Miocene to Middle Miocene; Catapsydrax stainforthi Zone to Globorotalia fohsi/robusta Zone (Stainforth et al., 1975).

Occurrence: Rare in FPF-1 and FPF-6; few in FPF-3; common in AF-3 and BBF-1 sequences.

Genus: Globoquadrina Finlay, 1947

Globoquadrina altispira altispira (Cushman and Jarvis)

Pl. 4, fig. a-b

Globigerina altispira CUSHMAN AND JARVIS, 1936, Cushman Lab. Foram. Research, Contr. v. 12, pt. 1, p. 5, pl. 1, fig. 13, 14.

Test high trochospire with 4 to 5 chambers in final whorl; initial chambers globose and rapidly enlarging, later becoming appressed; surface texture finely cancellate; aperture umbilical, partially concealed by triangular apertural teeth of previous chambers.

Range: Zone N4 to early Zone N20 (Blow, 1969, 1979).

Early Miocene to late Pliocene; Catapsydrax stainforthi to Globorotalia margaritae zones (Stainforth et al, 1975).

Zone N7 to base of Zone N21 (Poore, 1978).

Occurrence: Rare in FPF-1 sequence.

Globoquadrina altispira globosa Bolli

Pl. 4, fig. c-d

Globoquadrina altispira globosa BOLLI, 1957, U. S. Natl. Museum Bull. 215, p. 111, pl. 24, fig. 9, 10.

Test somewhat elevated but not as high spired as G. a. altispira; usually 5 slowly enlarging chambers in final whorl; umbilicus wide, deep, partially concealed by triangular apertural teeth.

Range: Within Zone P22 to earliest Zone N20 (Blow, 1969, 1979).

Latest Oligocene to Pliocene; Globigerina ciperoensis Zone to Pulleniatina obliquiloculata Zone (Stainforth et al., 1975).

Occurrence: Few in FPF-1, FPF-3, FPF-6, AF-3, and BBF-1 sequences.

Globoquadrina baroemoenensis (LeRoy)

Pl. 4, fig. e-f

Globigerina baroemoenensis LEROY, 1939, Natuurk. Tijdschr. Nederl.-Indie, Batavia, Java, p. 263, pl. 6, fig. 1, 2.

Test flattened on spiral side; 3 and 1/2 to 4 rapidly enlarging chambers in final whorl; aperture a large opening with a distinct, protruding plate-like tooth.

Range: Zone N2 to Zone N16 (Blow, 1969, 1979).

Base of Zone P21 to top of Zone N12 (Poore, 1978).

Late Oligocene to middle Miocene.

Occurrence: Few in FPF-1 and FPF-3; rare in FPF-6, AF-3, and BBF-1 sequences.

Globoquadrina dehiscens (Chapman, Parr, and Collins)

Pl. 4, fig. g-h

Globorotalia dehiscens CHAPMAN, PARR, AND COLLINS, 1934, Linn. Soc.

London Jour. Zoology, v. 38, n. 262, p. 569, pl. 11, fig. 36.

Test a quadrate coil with 4 chambers in final whorl; spiral side flattened; aperture an elongate slit partially concealed by toothlike projection.

Range: Latest Zone N4 to within Zone N19 (Blow, 1969, 1979).

Largely confined to Miocene (Stainforth et al., 1975).

Occurrence: Few in FPF-1 and FPF-3; rare in FPF-6 and AF-3 sequences.

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Globoquadrina larmeyi larmeyi Akers

Pl. 4, fig. i-j

Globoquadrina larmeyi AKERS, 1955, Jour. Paleontology, v. 29, n. 4, p.

661, pl. 65, fig. 4.

Test flattened on spiral side; generally 3 and 1/2 chambers in final whorl; aperture interiomarginal, umbilical-extraumbilical with distinct teeth.

Range: Zone N6-N18 (Blow, 1969, 1979)

Base of Zone N6-N16 (Poore, 1978)

Early to Late Miocene, possibly early Pliocene.

Occurrence: Rare in FPF-1, FPF-6, AF-3, and BBF-1; Few in FPF-3 sequences.

Genus: Globorotalia Cushman, 1927

Globorotalia birnageae Blow

Pl. 5, fig. a-b

Globorotalia birnageae BLOW, 1959, Bull. Amer. Paleontology, v. 39, n. 178, p.210-211, pl. 17, fig. 108.

Test small with 4 to 5 tightly coiled inflated chambers in final whorl; aperture interiomarginal, umbilical-extraumbilical slit with developed lip; lack of peripheral keel.

Range: Within Zone N7 to within Zone N9 (Blow, 1969, 1979).

Zone N6 to Zone N7 (Poore, 1978).

Reported as low as Zone N6 (Brönnimann and Resig, 1971).

Late early Miocene to middle Miocene.

Occurrence: Rare in FPF-1 sequence.

Globorotalia fohsi peripheroronda Blow and Banner

Pl. 5, fig. c-d

Globorotalia (Turborotalia) peripheroronda BLOW AND BANNER, 1966, Micropaleontology, v. 12, n. 3, p. 294, pl. 1, fig. 1, pl. 2, fig. 1-3.

Test coarsely textured with 6 to 7 inflated chambers in final whorl; aperture interiomarginal, umbilical-extraumbilical slit with distinct lip; periphery rounded and without keel.

Range: Zone N6 to Zone N11 (Blow 1969, 1979).

Early to middle Miocene; Catapsydrax dissimilis Zone to within

Globorotalia fohsi lobata/robusta Zone (Stainforth et al.,

1975).

Zone N8 to Zone N14 (Poore, 1971).

Occurrence: Common in FPF-1; few in FPF-3, FPF-6, and AF-3; rare in BBF-1 sequence.

Globorotalia obesa Bolli

Pl. 5, fig. g-h

Globorotalia obesa BOLLI, 1957, U. S. Natl. Museum Bull. 215, p. 119, pl. 29, fig. 2-3.

Test a low, quadrate trochospire; 4 to 4 and 1/2 globose chambers increasing rapidly in size through final whorl; umbilicus wide and deep; aperture a high arch extending from umbilical pit to periphery.

Range: Within Zone P21 to Zone N23 (Blow, 1969, 1979).

Late Oligocene to Holocene; Globigerina ciperoensis Zone to Globorotalia truncatulinoides Zone (Stainforth et al., 1975).

Zone P21 to Zone N14 (Poore, 1978).

Occurrence: Few in FPF-1, FPF-3, and FPF-6; rare in BBF-1 sequences.

Globorotalia opima nana Bolli

Pl. 5, fig. i-j

Globorotalia opima nana BOLLI, 1957, U. S. Natl. Museum Bull. 215, p. 118, pl. 28, fig. 3.

Test a small, tightly coiled trochospire; 4 chambers in final

whorl; spiral outline somewhat quadrangular; aperture interiomarginal, umbilical-extratumbilical slit with a slight rim or lip.

Range: Within Zone P15 to within early Zone N3(P22) (Blow, 1969, 1979).

Late Eocene and Oligocene; Globigerinatheka seminvoluta to within Globigerina ciproensis zones (Stainforth et al., 1975).  
Zone N4 (Poore, 1978).

Occurrence: Rare in FPF-1 and FPF-6 sequences.

Globorotalia siakensis Leroy

Pl. 5, fig. 1-m

Globorotalia siakensis LEROY, 1939, Natuurk. Tijdschr. Nederl.-Indie., v. 99, n. 6, p. 262, pl. 4, fig. 20-22.

Test a discoidal trochospire with 5 to 6 chambers in final whorl; umbilicus narrow and deep; rounded periphery; aperture crescentic to comma-shaped extending from umbilicus to periphery.

Range: Latest Zone P21 to top of Zone N14 (Blow, 1969, 1979).

Late Oligocene to middle Miocene; within Globorotalia opima opima to Globorotalia siakensis Zone (Stainforth et al., 1975).  
Zone P21 to Zone N16 (Poore, 1978).

Occurrence: Few in FPF-1, FPF-3, FPF-6, and AF-3; rare in BBF-1 sequences.

Genus: Orbulina d'Orbigny

Orbulina universa d'Orbigny

Pl. 5, fig. k

Orbulina universa D'ORBIGNY, 1839, In R. de la Sagra, Histoire  
Physique, Politique et Naturelle de l'Ille de Cuba, Paris, p. 2,  
pl. 1, fig. 1.

Test a spherical chamber with scattered large pores as  
apertures; surface texture cancellate, often finely hispid.

Range: Within early to middle Zone N9 to Zone N23 (Blow, 1969, 1979).

Middle Miocene to Holocene (Stainforth et al., 1975).

Occurrence: Rare in AF-3 sequence.



Benthic Foraminifera

Genus: Astacolus de Montfort, 1808

Astacolus cf. A. dubius (Neugeboren)

Pl. 6, fig. f

Marginulina dubia NEUGEBOREN, 1851, Siebenberg. Ver. Naturwiss. Verh.  
u. Mitt., v. 2, p. 120, pl. 4, fig. 1.

Test elongate, slightly arcuate, compressed; early stage coiled, later chambers become uniserial; aperture terminal, radiate.

Occurrence: Rare in FPF-6 sequence.

Astacolus sp.

Pl. 6, fig. g

Test arcuate, compressed, slightly keeled; early chambers enrolled, becoming uniserial, and increasingly elongate.

Occurrence: Rare in FPF-3 sequence.

Genus: Baggina Cushman, 1926

Baggina sp.

Pl. 10, fig. c-d

Test perforate, trochospiral; few subglobular chambers rapidly enlarging and somewhat overlapping on spiral side; aperture broad umbilical opening without lip.

Occurrence: Present in FPF-1 sequence.

Genus: Bolivina d'Orbigny

Bolivina advena Cushman

Pl. 8, fig. c

Bolivina advena CUSHMAN, 1925, Cushman Lab. Foram. Research, Contr.,  
v. 1, pt. 2, p. 29, pl. 5, fig. 1a, b.

Test coarsely porous, biserial; early chambers somewhat compressed; sutures limbate, slightly raised, sinuate, forming an irregular, prominent ridge along median of test.

Occurrence: Rare in FPF-6, AF-3, BBF-1, and BBF-2 sequences.

Bolivina calvertensis Dorsey

Pl. 8, fig. d

Bolivina calvertensis DORSEY, 1948, Maryland Dept. Geology, Mines,  
Water Resources Bull. 2, p. 306, pl. 36, fig. 17.

Test elongate, biserial, gently tapering; chambers somewhat inflated; numerous longitudinal costae covering all but last few chambers.

Occurrence: Rare to few in FPF-1 and FPF-3; rare in FPF-2, FPF-6, AF-3, BBF-1, and BBF-2 sequences.

Bolivina floridana Cushman

Pl. 8, fig. e

Bolivina floridana CUSHMAN, 1918, U. S. Geol. Survey Bull. 676, p. 49,  
pl. 10, fig. 4.

Test elongate, gradually tapering, slightly rounded apertural end; sutures undulate with numerous excavated re-entrants.

Occurrence: Rare in FPF-1 and BBF-1 sequences.

Bolivina marginata multicostata Cushman

Pl. 8, fig. f

Bolivina marginata Cushman var. multicostata CUSHMAN, 1930, Fla. Geol.

Survey Bull. 4, p. 46, pl. 8, fig. 13-14.

Test elongate, gradually tapering; periphery acute to subacute; numerous longitudinal costae on early chambers.

Occurrence: Rare in FPF-1, FPF-2, FPF-3, AF-3, and BBF-1 sequences.

Bolivina paula Cushman and Cahill

Pl. 8, fig. g

Bolivina paula CUSHMAN AND CAHILL, 1932, In Cushman and Ponton, Fla.

Geol. Survey Bull. 9, p. 84, pl. 12, fig. 6.

Test elongate, compressed; sides nearly parallel, slightly tapering at initial end; 8-10 chamber pairs; periphery subacute.

Occurrence: Rare to abundant throughout the Pungo River sequences.

Bolivina cf. B. subdillatata Pishvanova

Pl. 8, fig. h

Bolivina subdillatata PISHVANOVA, 1960, Leningrad Vses. Neft. Nauchno-

Issled. Geol.-Razved Inst., vypusk 153, sbornik 11, p. 109, 110.

Test wedge-shaped, tapering rapidly from initial end; periphery subacute; chambers somewhat inflated.

Occurrence: Rare in FPF-1, FPF-2, FPF-3, FPF-6, BBF-1, and BBF-2 sequences.

Genus: Bolivinopsis Yakovlev, 1891

Bolivinopsis fairhavenensis Gibson

Pl. 6, fig. e

Bolivinopsis fairhavenensis GIBSON, 1983, Smithsonian Contr. Paleobiology, n.53, p. 379, pl. 20, fig. 1-4.

Test small, elongate, compressed; early stage planispiral, later becoming biserial; rounded periphery; sides of test nearly parallel.

Occurrence: Rare in FPF-1, FPF-2, and FPF-6 sequences.

Genus: Bulimina d'Orbigny, 1826

Bulimina elongata d'Orbigny

Pl. 8, fig. i

Bulimina elongata D'ORBIGNY, 1846, Foraminifères fossiles du Bassin

Tertiaire de Vienne (Autriche), Paris, p. 187, pl. 11, fig. 19, 20.

Test elongate, smooth, slightly twisted; chambers inflated; early stage triserial, later becoming biserial.

Occurrence: Rare to common throughout the Pungo River sequences.

Bulimina striata mexicana Cushman

Pl. 8, fig. j

Bulimina striata d'Orbigny var. mexicana CUSHMAN, 1922, U. S. Natl. Museum Bull. 104, pt. 3, p. 95, pl. 21, fig. 2.

Test triserial, conical in outline; chambers inflated and overhanging with prominent longitudinal costae ending with short spine; final chambers have smooth upper surface.

Occurrence: Rare in FPF-1 and FPF-2 sequences.

Genus; Buliminella Cushman, 1911

Buliminella cf. B. brevior Cushman

Pl. 8, fig. a

Buliminella brevior CUSHMAN, 1925, Cushman Lab. Foram. Research, Contr., v. 1, n. 8, p. 33, pl. 5, fig. 14.

Test small, broad, elongate; initial end somewhat pointed; slightly flattened apertural face.

Note: Pungo River specimens tend to be smaller and have a more pointed apical end than typical representatives of this species.

Occurrence: Rare to common in FPF-1 through FPF-6, BBF-1, and BBF-2 sequences.

Buliminella elegantissima (d'Orbigny)

Pl. 8, fig. b

Buliminella elegantissima D'ORBIGNY, 1839, Voy. Amer. Merid., v. 5,

pt. 5, "Foraminiferes", p. 51, pl. 7, fig. 13-14.

Test elongate, fusiform; numerous tall, narrow, slightly inflated chambers arranged in high spire; aperture an elongate opening in apertural face.

Occurrence: Rare to abundant throughout the Pungo River sequences.

Genus: Cancris de Montfort, 1808

Cancris sagra (d'Orbigny)

pl. 10, fig. e-f

Rotalina (Rotalina) sagra D'ORBIGNY, 1839, In de la Sagra, Histoire...de l'Ille de Cuba, "Foraminiferes", p. 77, Tab. 5, fig. 13-15.

Test biconvex, trochospiral, with acute periphery; keeled; aperture umbilical-extraumbilical, bearing faint lip.

Occurrence: Rare in FPF-3 and BBF-1 sequences.

Genus: Cassidella Hofker, 1951

? Cassidella sp.

Pl. 11, fig. e

Test elongate, slightly twisted; early chambers triserial, later becoming biserial; chambers somewhat inflated.

Occurrence: Rare in FPF-1, FPF-3, and FPF-6 sequences.

Genus: Cassidulinoides Cushman, 1927

Cassidulinoides bradyi (Norman)

Pl. 8, fig. k

Cassidulina bradyi NORMAN, 1881, In Brady, Quart. Jour. Micro. Sci.,  
n. s., v. 21, p. 59, pl. 5, fig. 2.

Test biserial; early stage subglobular and enrolled, later  
uncoiling; aperture recessed in face of final chamber and having  
prominent tooth.

Occurrence: Rare in BBF-1 sequence.

Genus: Cibicides de Montfort, 1808

Cibicides americanus (Cushman)

Pl. 10, fig. k-1

Truncatulina americana CUSHMAN, 1918, U. S. Geol. Survey Bull. 676,  
p. 63, pl. 20, fig. 2, 3, pl. 21, fig. 1.

Test planoconvex, periphery subacute, umbilical side nearly  
flat; 8 to 10 chambers in final whorl; aperture extending slightly on  
spiral side bearing faint lip.

Occurrence: Rare to common in FPF-1 through FPF-6, BBF-1 and BBF-2;  
abundant in AF-3 sequences.

Cibicides floridanus (Cushman)

Pl. 11, fig. a-b

Truncatulina floridana CUSHMAN, 1918, U. S. Geol. Survey Bull. 676, p. 62, pl. 19, fig. 2.

Test biconvex; periphery acute, slightly lobate, keeled; wall coarsely punctate.

Occurrence: Rare in FPF-1, FPF-3, FPF-6, and AF-3; rare to abundant in BBF-1 sequences.

Cibicides lobatulus (Walker and Jacob)

Pl. 11, fig. c-d

Nautilus lobatulus WALKER AND JACOB, 1798, In Kanmacher, Adam's Essays on the Microscope, ed. 2, p. 642, pl. 14, fig. 36.

Variable morphology due to attaching mode of life; lobate periphery; spiral side planar to concave, umbilical side convex; test coarsely punctate.

Occurrence: Rare to common in FPF-1, FPF-3, FPF-6, AF-3, and BBF-1 sequences.

Genus: Discorbis Lamarck, 1804

Discorbis bassleri (Cushman and Cahill)

Pl. 9, fig. g

Rotalia bassleri CUSHMAN AND CAHILL, 1933, U. S. Geol. Survey Prof. Paper 175-A, p. 30, pl. 10, fig. 7.

Test small, trochospiral, biconvex to planoconvex; slightly keeled; subacute periphery; prominent umbilical plug.

Occurrence: Rare to common in FPF-1, FPF-3, FPF-6, AF-3, BBF-1, and



BBF-2 sequences.

Genus: Elphidium de Montfort, 1808

Elphidium excavatum (Terquem)

Pl. 10, fig. i

Polystomella excavatum TERQUEM, 1875, Essai sur le classement des animaux qui vivent sur la plage et dans les environs de Dunkerque, pt. 1, p. 25, pl. 2, fig. 2 a-f.

Test planispiral, biumbonate; central umbonal boss; periphery rounded to subacute; sutures depressed with single row of sutural pores.

Note: Pungo River specimens encountered are placed into forma clavatum.

Occurrence: Rare in FPF-1 through FPF-6, and BBF-1 sequences.

Genus: Epistominella Husezima and Maruhasi, 1944

Epistominella danvillensis Howe and Wallace

Pl. 9, fig. h

Epistominella danvillensis HOWE AND WALLACE, 1932, Louisiana Dept. Conserv. Bull. 2, p. 71, pl. 13, fig. 7.

Test small, trochospiral, biconvex; circular in outline; periphery slightly lobate; 8-10 chambers in final whorl; aperture narrow opening parallel to periphery of test; surface texture finely

perforate.

Occurrence: Rare to abundant in FPF-1, FPF-2, and FPF-3 sequences.

Genus: Eponides de Montfort, 1808

Eponides cf. E. repandus (Fichtel and Moll)

Pl. 10, fig. j

Nautilus repandus FICHTEL AND MOLL, 1798, Test. Micr., p. 35, pl. 3,  
fig. a-d.

Test large, nearly circular on outline; spiral side flattened adjacent to periphery; aperture an interiomarginal, umbilical-extraumbilical arch extending nearly to periphery.

Occurrence: Rare in FPF-1 sequence.

Genus: Estorffina Kleinpell and Tipton, 1980

Estorffina mayi (Cushman and Parker)

Pl. 7, fig. g

Siphogenerina mayi CUSHMAN AND PARKER, 1931, Cushman Lab. Foram. Research, Contr., v. 7, p. 10-11, pl. 2, fig. 7.

Test elongate, finely perforate; early stage triserial, rapidly becoming uniserial; chambers inflated with numerous, delicate, longitudinal costae; aperture circular, terminal with short neck and slight lip.

Occurrence: Rare in FPF-1 and FPF-6 sequences.

Genus: Fissurina Reuss, 1850

Fissurina lucida (Williamson)

Pl. 7, fig. i

Entosolenia marginata (Montagu) var. lucida WILLIAMSON, 1848, Ann.

Mag. Nat. Hist., v. 1, ser. 2, p. 17, pl. 2, fig. 17.

Test small, smooth, ovate; aperture a slit at end of test; short apical spines.

Occurrence: Rare in FPF-1 sequence.

Genus: Florilus de Montfort, 1808

Florilus grateloupi (d'Orbigny)

Pl. 12, fig. b-c

Nonionina grateloupi D'ORBIGNY, 1826, Annales Sci. Nat. Hist., v. 7,

n. 12, p. 294, modele 19.

Test smooth, finely perforate, trochospiral; chambers compressed and rapidly increase in height, slightly flaring.

Occurrence: Rare to few in FPF-1, FPF-2, FPF-3, FPF-6, and BBF-1 sequences.

Florilus pizzarensis (Berry)

Pl. 12, fig. d-e

Nonion pizzarensis BERRY, 1928, Jour. Paleontology, v. 1, n. 2, p.

269, fig. 1.

Test large, trochospiral, moderately flaring; surface texture smooth; granular material commonly developed on one side of umbilicus.

Occurrence: Rare to common in FPF-1 through FPF-6, BBF-1, and BBF-2 sequences.

Genus: Fursenkoina Loeblich and Tappan, 1961

Fursenkoina fusiformis (Williamson)

Pl. 11, fig. g

Bulimina pupoides d'Orbigny var. fusiformis WILLIAMSON, 1858, On the Recent Foraminifera of Great Britain, p. 63, pl. 5, fig. 129, 130.

Test small, elongate fusiform, sigmoid to biserial; surface texture finely perforate; aperture an elongate slit extending up base in final chamber.

Occurrence: Rare in FPF-1 and BBF-1 sequences.

Fursenkoina sp.

Pl. 11, fig. h

Test elongate, somewhat compressed; slightly twisted in early stage; chambers somewhat inflated, sutures distinct; aperture elongate slit.

Occurrence: Rare in FPF-1, FPF-3, and BBF-1 sequences.

Genus: Globocassidulina Voloshina, 1960

Globocassidulina crassa (d'Orbigny)

Pl. 11, fig. j

Cassidulina crassa D'ORBIGNY, 1839, Voy. l'Amer. Meridionale,

"Foraminifera", v. 5, pt. 5, p. 56, pl. 7, fig. 18-20.

Test small, smooth, biserially coiled, subcircular in outline; chambers inflated; aperture a narrow slit extending up face of final chamber.

Occurrence: Rare in FPF-1, FPF-3, FPF-6, and BBF-1 sequences.

Genus: Globulina d'Orbigny, 1826

Globulina gibba d'Orbigny

Pl. 7, fig. c

Globulina gibba D'ORBIGNY, 1826, Annales Sci. Nat., v. 7, n. 10, p. 266, modele 63.

Test smooth, ovate; globular chambers strongly overlapping; aperture radiate.

Occurrence: Present in FPF-1.

Globulina inaequalis Reuss

Pl. 7, fig. d

Globulina inaequalis REUSS, 1850, Denkschr. Kais. Akad. Wiss. Wien., v. 1, p. 377, p. 48, fig. 9.

Test smooth, slightly compressed; chambers few, strongly overlapping; sutures slightly depressed; aperture radiate.

Occurrence: Present in FPF-1, FPF-3, FPF-6, and BBF-1 sequences.

Genus: Guttulina d'Orbigny, 1826

Guttulina sp.

Pl. 7, fig. f

Test ovate, chambers inflated, strongly overlapping chambers; sutures depressed; aperture radiate.

Occurrence: Rare in FPF-6 sequence.

Genus: Hanzawaia Asano, 1944

Hanzawaia concentrica (Cushman)

Pl. 12, fig. g-h

Truncatulina concentrica CUSHMAN, 1918, U. S. Geol. Survey Bull. 676, p.64, pl. 21, fig. 3.

Test planoconvex, periphery subacute and partially keeled; spiral side highly inflated; umbilical side nearly flat and showing supplementary apertures beneath chamber flaps; chamber flaps becoming increasingly fused with growth of test; aperture a peripheral arch extending slightly onto convex side.

Occurrence: Rare to common in FPF-1 through FPF-6, AF-3, and BBF-1 sequences.

Genus: Islandiella Norvang, 1958

Islandiella sp.

Pl. 8, fig. 1

Test smooth, biserially enrolled, slightly compressed with rounded periphery; aperture an elongate slit extending up face of final chamber, partially concealed by tooth plate.

Occurrence: Rare in FPF-1 and BBF-1 sequences.

Genus: Lagena Walker and Jacob, 1798

Lagena cf. L. laevis (Montagu)

Pl. 6, fig. h

Vermiculum laeve MONTAGU, 1803, Testacea Britannica, p. 524.

Test small, smooth, ovate; very finely hispid surface texture.

Occurrence: Rare in BBF-1 sequence.

Lagena cf. L. palmerae McLean

Pl. 6, fig. i

Lagena palmerae MCLEAN, 1956, Bull. Amer. Paleontology, v. 36, n. 160,  
p. 332, pl. 39, fig. 5, 6.

Test subspherical with an elongate, fluted neck; basal costae not restricted to lower half of test but extend its entire length.

Occurrence: Rare in FPF-1 sequence.

Lagena pseudosulcata McLean

Pl. 6, fig. j

Lagena pseudosulcata MCLEAN, 1956, Bull. Amer. Paleontology, v. 36, n. 160, p. 332-333, pl. 39, fig. 11.

Test small, sparsely but coarsely costate; neck ornamented with thick rugose collar.

Occurrence: Rare in FPF-1 sequence.

Lagena substriata Williamson

Pl. 6, fig. k

Lagena substriata WILLIAMSON, 1848, Annals and Mag. Nat. History, ser. 2, v. 1, p. 15, pl. 1, fig. 12.

Test small, oval; surface covered with numerous, fine striations extending entire length onto neck.

Occurrence: Rare in FPF-1 and FPF-2 sequences.

Genus: Lenticulina Lamarck, 1804

Lenticulina americana americana (Cushman)

Pl. 6, fig. 1

Cristellaria americana CUSHMAN, 1918, U. S. Geol. Survey Bull. 676, p. 50, pl. 10, fig. 5, 6.

Test lenticular, biumbonate, planispiral; periphery acute, slightly keeled; aperture radiate; sutures raised ending in a raised umbonal area.

Occurrence: Rare to common in FPF-1 through FPF-6, AF-3, and BBF-1 sequences.

Genus: Loxostomum Ehrenberg, 1854

Loxostomum gunteri Cushman

Pl. 11, fig. i

Loxostomum gunteri CUSHMAN, 1930, Fla. Geol. Survey Bull. 4, 47, pl. 8, fig. 11.

Test small, elongate, biserial, tapering, slightly compressed;



surface ornamented with fine longitudinal costae.

Occurrence: Rare in FPF-1 through FPF-6 sequences.

Genus: Melonis de Montfort, 1808

Melonis sp.

Pl. 12, fig. f

Test planispiral, involute, biumbilicate; periphery rounded; aperture an elongate interiomarginal, equatorial slit extending laterally to umbilicae.

Occurrence: Rare in FPF-1 sequence.

Genus: Nonionella Cushman, 1926

Nonionella miocenica Cushman

Pl. 12, fig. a

Nonionella miocenica CUSHMAN, 1926, Cushman Lab. Foram., Research, Contr., v. 2, pt. 3, p. 64.

Test trochospiral, somewhat compressed; 9-10 chambers in final whorl; final chamber overhangs the umbilicus forming a bulbous flap.

Occurrence: Rare to few in FPF-1, FPF-3, FPF-6, AF-3, and BBF-1 sequences.

Genus: Oolina d'Orbigny, 1839

Oolina hexagona (Williamson)

Pl. 7, fig. h

Entosolenia squamosa Montagu var. hexagona WILLIAMSON, 1848, Annals and Mag. Nat. History, ser. 2, v. 1, p. 20, pl. 2, fig. 3.

Test small with single ovate, globular chamber; surface ornamented with coarse, irregularly arranged reticulations; aperture slightly produced.

Occurrence: Rare in FPF-1 sequence.

Genus: Planularia DeFrance, 1826

Planularia cf. P. clara Cushman and Jarvis

Pl. 7, fig. a

Planularia clara CUSHMAN AND JARVIS, 1929, Cushman Lab. Foram. Research, Contr., v. 5, pt. 1, p. 7, pl. 2, fig. 14-15.

Test highly compressed; periphery keeled; early stage planispiral coil, later tending to uncoil; aperture terminal, radiate, at peripheral angle, with short slit extending down into face of final chamber.

Occurrence: Rare in FPF-1 and AF-3 sequences.

Genus: Plectofrondicularia Liebus, 1902

Plectofrondicularia floridana Cushman

Pl. 7, fig. b

Plectofrondicularia floridana CUSHMAN, 1930, Fla. Geol. Survey Bull. n. 4, p. 41, pl. 8, fig. 1.

Test elongate, tapering, compressed, tricarinate; chambers uniserial with broad inverted U-shape; aperture terminal, radiate.

Occurrence: Rare in FPF-3 sequence.

Genus: Pseudopolymorphina Cushman and Ozawa, 1928

Pseudopolymorphina rutila (Cushman)

Pl. 7, fig. e

Polymorphina regina Brady, Parker, and Jones var. rutila CUSHMAN, 1923, U. S. Geol. Survey Prof. Paper 133, p. 34, pl. 5, fig. 7, 8.

Test compressed, elongate, fusiform; short spine at base; chambers elongate somewhat overlapping; surface ornamented with longitudinal costae; aperture radiate.

Occurrence: Rare in FPF-1 sequence.

Genus: Rosalina d'Orbigny, 1826

Rosalina cavernata (Dorsey)

Pl. 9, fig. i-j

Discorbis cavernata DORSEY, 1948, Maryland Dept. Geology, Mines, Water Resources Bull. 2, p. 311, pl. 37, fig. 2.

Test planoconvex, nearly circular in outline; somewhat compressed; periphery subacute; umbilicus deeply excavated, stellate, partially covered by surrounding chamber flaps.

Occurrence: Rare to few in FPF-1 through FPF-6, AF-3, and BBF-1 sequences.

Rosalina cf. R. floridana (Cushman)

Pl. 9, fig. k-l

Discorbis floridanus CUSHMAN, 1922, Carnegie Inst. Washington Bull. 311, p. 39, pl. 5, fig. 11, 12.

Test rotaliform; periphery rounded, somewhat lobate; sutures incised on umbilical side.

Note: Diagnostic apertural features often obscured by recrystallization in Pungo River specimens.

Occurrence: Rare in FPF-1, FPF-3, FPF-6, AF-3, and BBF-1 sequences.

Rosalina globularis d'Orbigny

Pl. 10, fig. a-b

Rosalina globularis D'ORBIGNY, 1826, Annales Sci. Nat. History, ser. 1, v. 7, p. 271, pl. 13, fig. 1-4.

Test planoconvex, somewhat compressed; peripheral margin rounded; chambers few, usually 5 in last formed whorl.

Occurrence: Rare to common in FPF-6 sequence.

Genus: Siphogenerina Schlumberger, 1882

Siphogenerina transversa Cushman

Pl. 9, fig. c

Siphogenerina raphanus (Parker and Jones) var. transversa CUSHMAN, 1918, U. S. Natl. Museum Bull. 103, p. 64, pl. 22, fig. 8.

Test elongate, early stage triserial, later becoming uniserial;

Pungo River specimens have a blunt base (indicating megalospheric generation); chambers slightly inflated, sutures indented with an inverted U-shape; generally 10-12 longitudinal costae; aperture terminal, on a short neck with phialine lip.

Occurrence: Rare in FPF-1, FPF-2, FPF-3, and BBF-1 sequences.

Genus: Siphonodosaria Silvestri, 1924

Siphonodosaria sp.

Pl. 9, fig. a

Test narrow, smooth, uniserial, arcuate, chambers becoming more inflated in adult stage; basal spine on proloculus; aperture rounded, produced on neck bordered by phialine lip; sutures horizontal and slightly constricted.

Occurrence: Rare in BBF-1 sequence.

Genus: Sphaeroidina d'Orbigny

Sphaeroidina bulloides d'Orbigny

Pl. 7, fig. j

Sphaeroidina bulloides D'ORBIGNY, 1826, Ann. Sci. Nat., v. 7, p. 267, modele 65.

Test smooth, nearly spherical; chambers few, arranged in streptospiral coil, each centrally placed over previous aperture, strongly embracing; aperture semicircular or crescentic, bordered by a delicate lip, located near sutural contact between 3 previous chambers.

Occurrence: Rare in FPF-1 sequence.

Genus: Spiroplectammina Cushman, 1927

Spiroplectammina mississippiensis (Cushman)

Pl. 6, fig. a

Textularia mississippiensis CUSHMAN, 1922, U. S. Geol. Survey Prof.

Paper 129-E, p. 90, pl. 14, fig. 4.

Test elongate, fairly broad, compressed, finely arenaceous; periphery acute; initial stage planispirally coiled, later becoming biserial.

Occurrence: Rare in FPF-1 sequence.

Genus: Stilostomella Guppy, 1894

Stilostomella recta (Palmer and Bermudez)

Pl. 9, fig. b

Ellipsonodosaria recta PALMER AND BERMUDEZ, 1936, Mem. Soc. Cubana

Hist. Nat., v. 10, p. 297, pl. 18, fig. 6, 7.

Test elongate, rectilinear, uniserial; gradually enlarging subglobular chambers; adult chambers ornamented with short spines along base; aperture terminal, on a short neck with phialine lip.

Occurrence: Rare in FPF-1 sequence.

Genus: Textularia DeFrance, in de Blainville, 1824

Textularia agglutinans d'Orbigny

Pl. 6, fig. b

Textularia agglutinans D'ORBIGNY, 1839, In de la Sagra Histoire... de l'Ille de Cuba, "Foraminiferes", p. 136, pl. 1, fig. 17, 18, 32-34.

Test elongate, coarsely arenaceous, chambers biserially arranged, inflated, slightly tapering; periphery rounded.

Occurrence: Rare in FPF-1, FPF-3, AF-3, and BBF-1 sequences.

Textularia articulata d'Orbigny

Pl. 6, fig. c

Textularia articulata D'ORBIGNY, 1846, Foraminiferes fossiles du Bassin Tertiaire de Vienne, p. 250, pl. 15, fig. 16-18.

Test elongate, compressed, finely arenaceous; periphery acute, slightly keeled.

Occurrence: Rare in FPF-1 and FPF-3.

Textularia candeiana d'Orbigny

Pl. 6, fig. d

Textularia candeiana D'ORBIGNY, 1839, In de la Sagra Histoire... de l'Ille de Cuba, "Foraminiferes", p. 143, Tab. 1, fig. 19, 20.

Test elongate, rapidly flaring; chambers inflated; coarsely arenaceous; periphery rounded.

Occurrence: Rare in FPF-1, FPF-3, AF-3, and BBF-1 sequences,

Genus: Trifarina Cushman, 1923

Trifarina occidentalis (Cushman)

Pl. 9, fig. d

Uvigerina occidentalis CUSHMAN, 1923, U. S. Natl. Museum Bull. 104, pt. 4, p. 169.

Test small, elongate, triserial, somewhat triangular in section; early chambers strongly inflated; longitudinal costae cover early chambers; aperture terminal, on a short neck with a thickened rim or lip.

Occurrence: Rare in FPF-1 and BBF-1 sequences.

Genus: Uvigerina d'Orbigny

Uvigerina auberiana d'Orbigny

Pl. 9, fig. e

Uvigerina auberiana D'ORBIGNY, 1839, In de la Sagra Histoire...de l'Ille de Cuba, "Foraminiferes", p. 106, pl. 2, fig. 23, 24.

Test elongate, triserial; chambers strongly inflated, sutures depressed; characterized by fine, hispid ornamentation; aperture terminal, produced on neck with phialine lip.

Occurrence: Rare to common in FPF-1 through FPF-6 sequences.

Uvigerina subperegrina Cushman and Kleinpell

Pl. 9, fig. f

Uvigerina subperegrina CUSHMAN AND KLEINPELL, 1934, Cushman Lab. Foram. Research, Contr., v. 10, pt. 1, p. 12, pl. 2, fig. 9, 11.

Test fusiform; chambers inflated, ornamented by numerous fine, longitudinal costae independent from those of previous chambers;



aperture terminal, on a short neck with phialine lip; sutures distinct.

Occurrence: Rare in FPF-1 sequence.

Genus: Valvulineria Cushman, 1926

Valvulineria floridana Cushman

Pl. 10, fig. g-h

Valvulineria floridana CUSHMAN, 1930, Fla. Geol. Survey Bull. 4, p. 54, pl. 10, fig. 6.

Test biconvex, trochospiral, smooth, compressed; periphery subacute, partially keeled; aperture interiomarginal, umbilical-extraumbilical with broad thin flap extending over umbilicus.

Occurrence: Rare to common on FPF-1, BBF-1, and BBF-2; common to abundant in FPF-2, FPF-3, FPF-6, and AF-3 sequences.

Genus: Virgulinella Cushman, 1932

Virgulinella miocenica (Cushman and Ponton)

Pl. 11, fig. f

Virgulina miocenica CUSHMAN AND PONTON, 1931, Cushman Lab. Foram. Research, Contr., v. 7, p. 32, pl. 4, fig. 14-16.

Test elongate, slender, gradually tapering towards both ends; chambers somewhat inflated, marked by strongly developed retral processes extending across sutures; aperture an elongate, narrow slit extending down face of final chamber.

Occurrence: Rare in FPF-1, BBF-1, and BBF-2 sequences.

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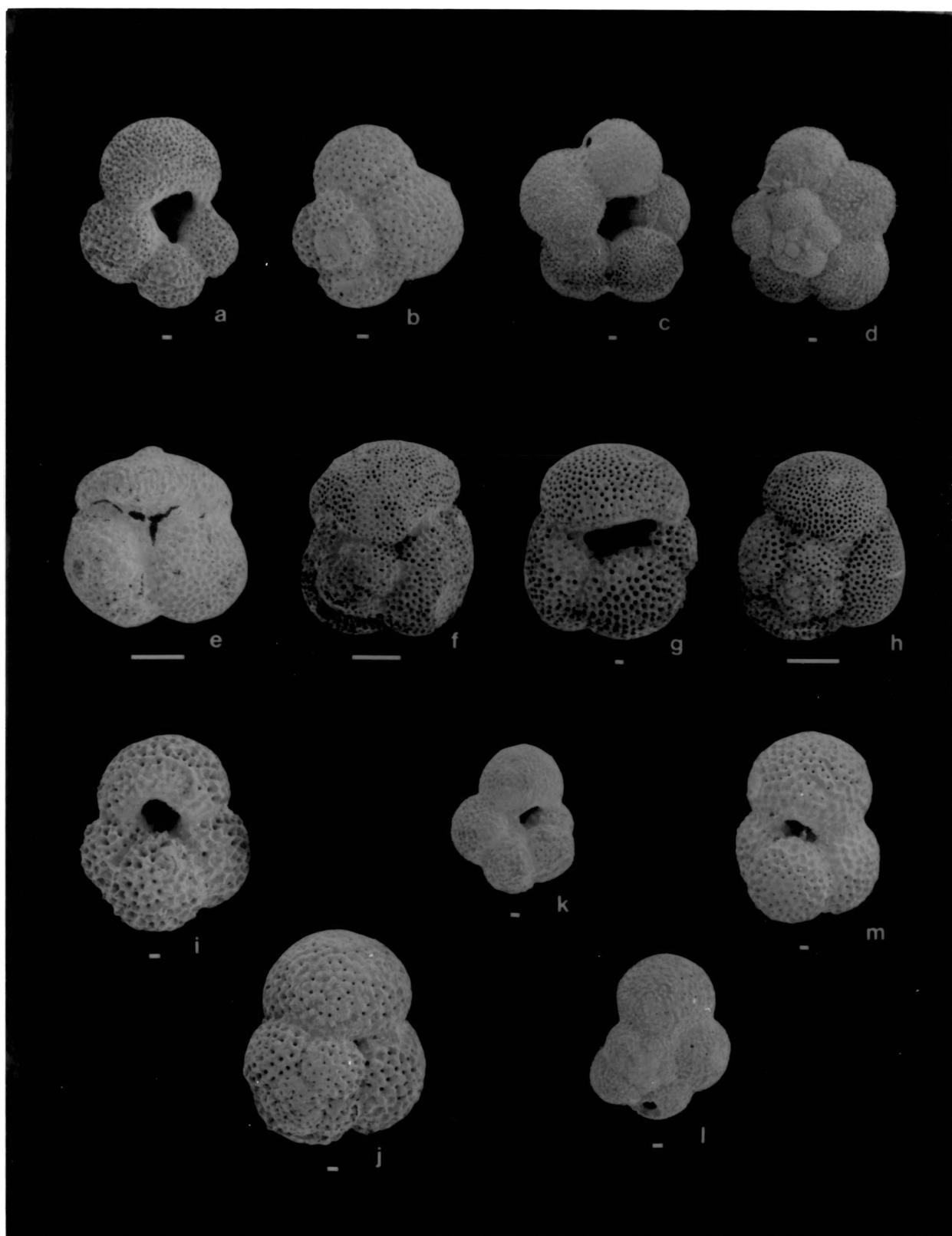
## PLATE 1

## Figure

- a-b. Globigerina praebulloides Blow  
a. Umbilical view (Core OB-105, 7.50 m)  
b. Spiral view (Core OB-105, 1.50 m)
- c-d. Globigerina pseudociperoensis Blow  
c. Umbilical view (Core OB-105, 4.50 m)  
d. Spiral view (Core OB-105, 1.50 m)
- e-f. Globigerina tripartita Koch  
e. Umbilical view (Core OB-50, 3.25-3.60 m)  
f. Spiral view (core OB-50, 3.25-3.60 m)
- g-h. Globigerina venezuelana Hedberg  
g. Umbilical view (Core 105, 1.50 m)  
h. Spiral view (Core 105, 1.50 m)
- i-j. Globigerina woodi Jenkins  
i. Umbilical view (Core OB-50, 3.25-3.60 m)  
j. Spiral view (Core OB-105, 1.50 m)
- k-l. Globigerina angustiumbilitata Bolli  
k. Umbilical view (Core OB-105, 1.50 m)  
l. Spiral view (Core OB-105, 1.50 m)
- m. Globigerina juvenilis Bolli  
Umbilical view (Core OB-105, 4.50 m)

each scale line = 100 microns

## PLATE 1



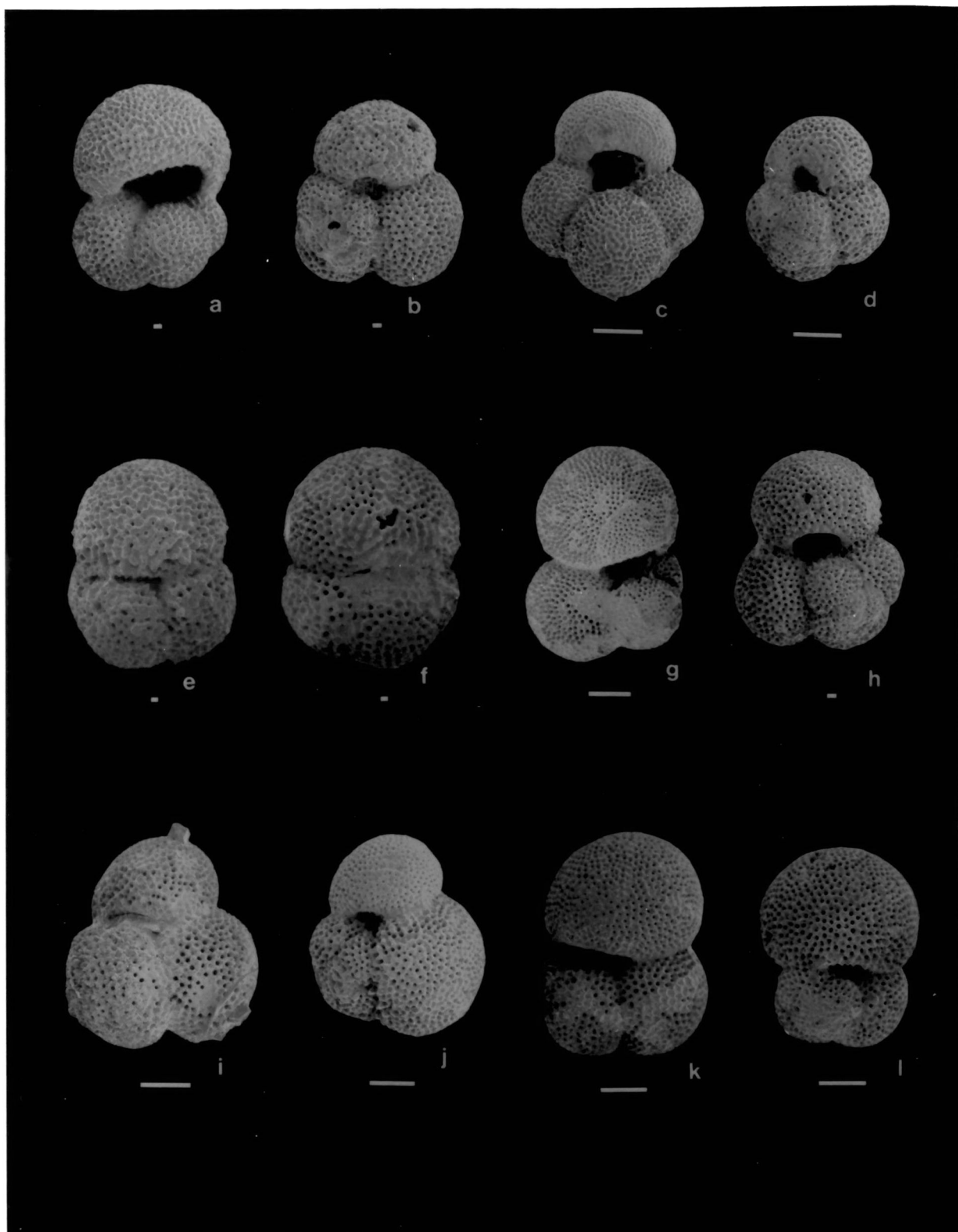
## PLATE 2

## Figure

- a-b. Globigerinoides obliquus obliquus Bolli  
 a. Umbilical view (Core OB-105, 7.50 m)  
 b. Spiral view (Core OB-50, 3.25-3.60 m)
- c-d. Globigerinoides quadrilobatus altiapertura Bolli  
 c. Umbilical view (Core OB-50, 3.25-3.60 m)  
 d. Spiral view (Core OB-50, 3.25-3.60 m)
- e-f. Globigerinoides quadrilobatus praeimmaturus Brönnimann and Resig  
 e. Umbilical view (Core OB-105, 4.50 m)  
 f. Spiral view (Core OB-50, 3.25-3.60 m)
- g-h. Globigerinoides quadrilobatus primordius Blow and Banner  
 g. Umbilical view (Core OB-105, 7.50 m)  
 h. Spiral view (Core OB-105, 7.50 m)
- i-j. Globigerinoides quadrilobatus sacculifer (Brady)  
 i. Umbilical view (Core OB-50, 3.25-3.60 m)  
 j. Spiral view (Core OB-50, 3.25-3.60 m)
- k-l. Globigerinoides quadrilobatus triloba (Reuss)  
 k. Umbilical view (Core OB-50, 3.25-3.60 m)  
 l. Spiral view (Core OB-50, 3.25-3.60 m)

each scale line = 100 microns

## PLATE 2



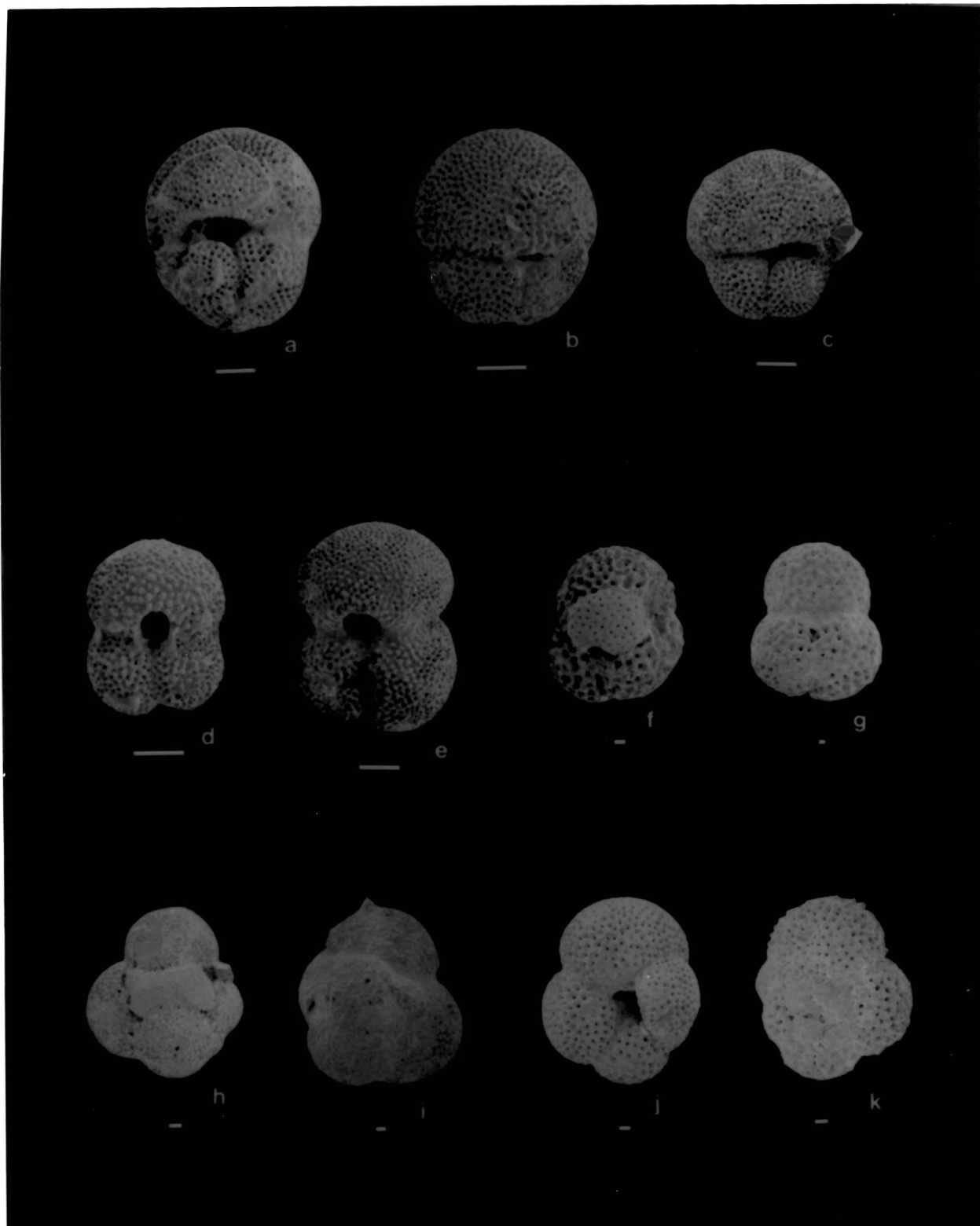
## PLATE 3

## Figure

- a-b. Globigerinoides sicanus praesicanus Brönnimann and Resig  
 a. Umbilical view (Core OB-131, 3.00 m)  
 b. Spiral view (Core OB-131, 6.59 m)
- c. Globigerinoides sicanus sicanus de Stephani  
 Umbilical view (Core OB-131, 3.00 m)
- d-e. Globigerinoides subquadratus Brönnimann  
 d. Umbilical view (Core OB-50, 3.25-3.60 m)  
 e. Spiral view (Core OB-50, 3.25-3.60 m)
- f-g. Catapsydrax dissimilis (Cushman and Bermudez)  
 f. Umbilical view (Core OB-50, 3.25-3.60 m)  
 g. Spiral view (Core OB-105, 7.50 m)
- h-i. Catapsydrax stainforthi Bolli, Loeblich, and Tappan  
 h. Umbilical view (Core OB-105, 1.50 m)  
 i. Spiral view (Core OB-105, 1.50 m)
- j-k. Catapsydrax unicavus Bolli, Loeblich, and Tappan  
 j. Umbilical view (Core OB-105, 4.50 m)  
 k. Spiral view (Core OB-50, 3.25-3.60 m)

each scale line = 100 microns

## PLATE 3



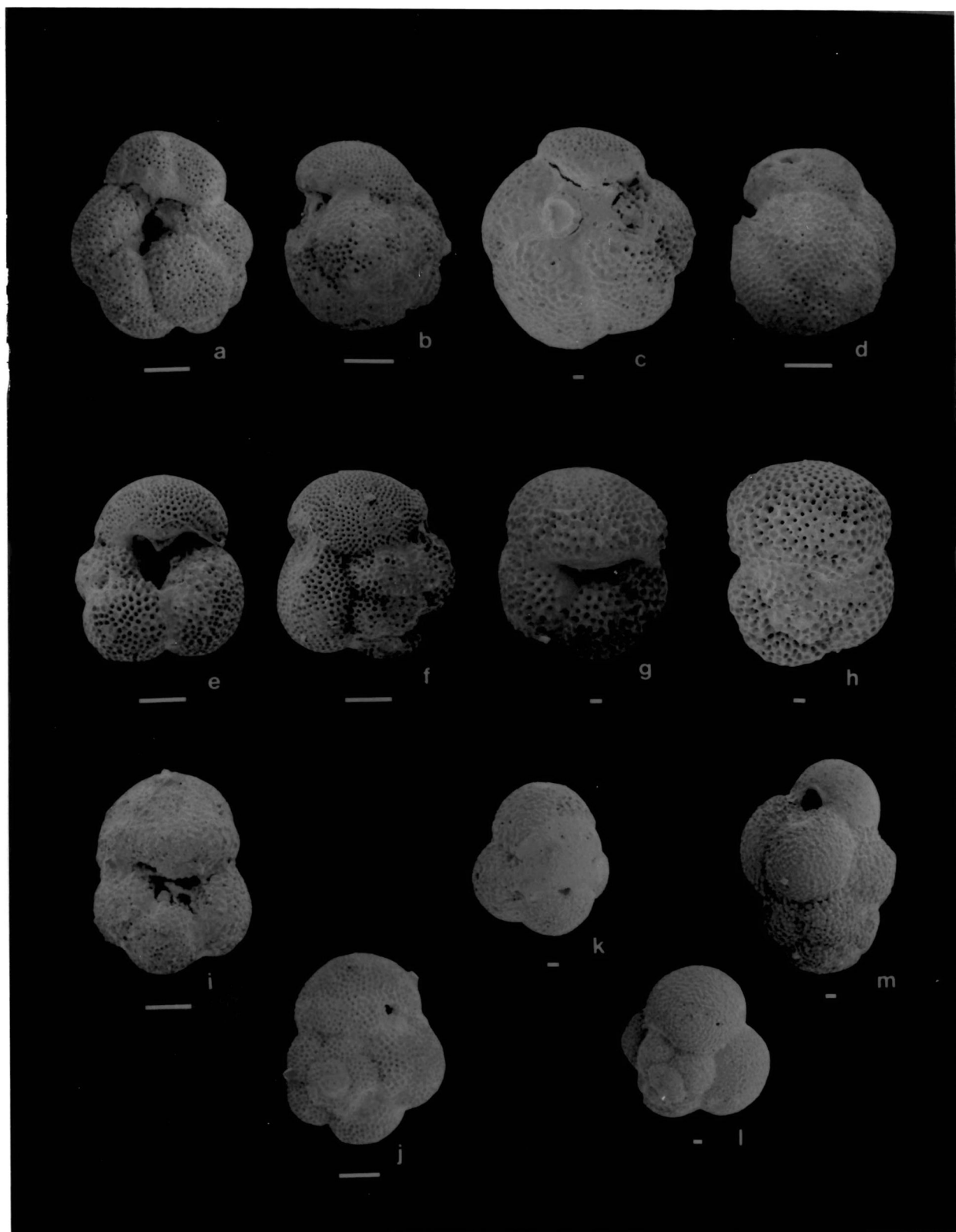
## PLATE 4

## Figure

- a-b. Globoquadrina altispira altispira (Cushman and Jarvis)  
 a. Umbilical view (Core OB-105, 1.50 m)  
 b. Edge view (Core OB-105, 1.50 m)
- c-d. Globoquadrina altispira globosa Bolli  
 c. Umbilical view (Core OB-59, 7.80-8.20 m)  
 d. Edge view (Core OB-59, 5.89-6.00 m)
- e-f. Globoquadrina baroemoenensis (LeRoy)  
 e. Umbilical view (Core OB-50, 3.25-3.60 m)  
 f. Spiral view (Core OB-50, 3.25-3.60 m)
- g-h. Globoquadrina dehiscens (Chapmann, Parr, and Collins)  
 g. Umbilical view (Core OB-132, 2.50 m)  
 h. Spiral view (Core OB-105, 1.50 m)
- i-j. Globoquadrina larmeui larmeui Akers  
 i. Umbilical view (Core OB-48, 4.75-5.00 m)  
 j. Spiral view (Core OB-48, 2.25-2.50 m)
- k-l. Globigerinita glutinata (Egger)  
 k. Umbilical view (Core OB-105, 1.50 m)  
 l. Spiral view (Core OB-105, 1.50 m)
- m. Globigerinita uvula (Ehrenberg)  
 Edge view (Core OB-105, 1.50 m)

each scale line = 100 microns

## PLATE 4





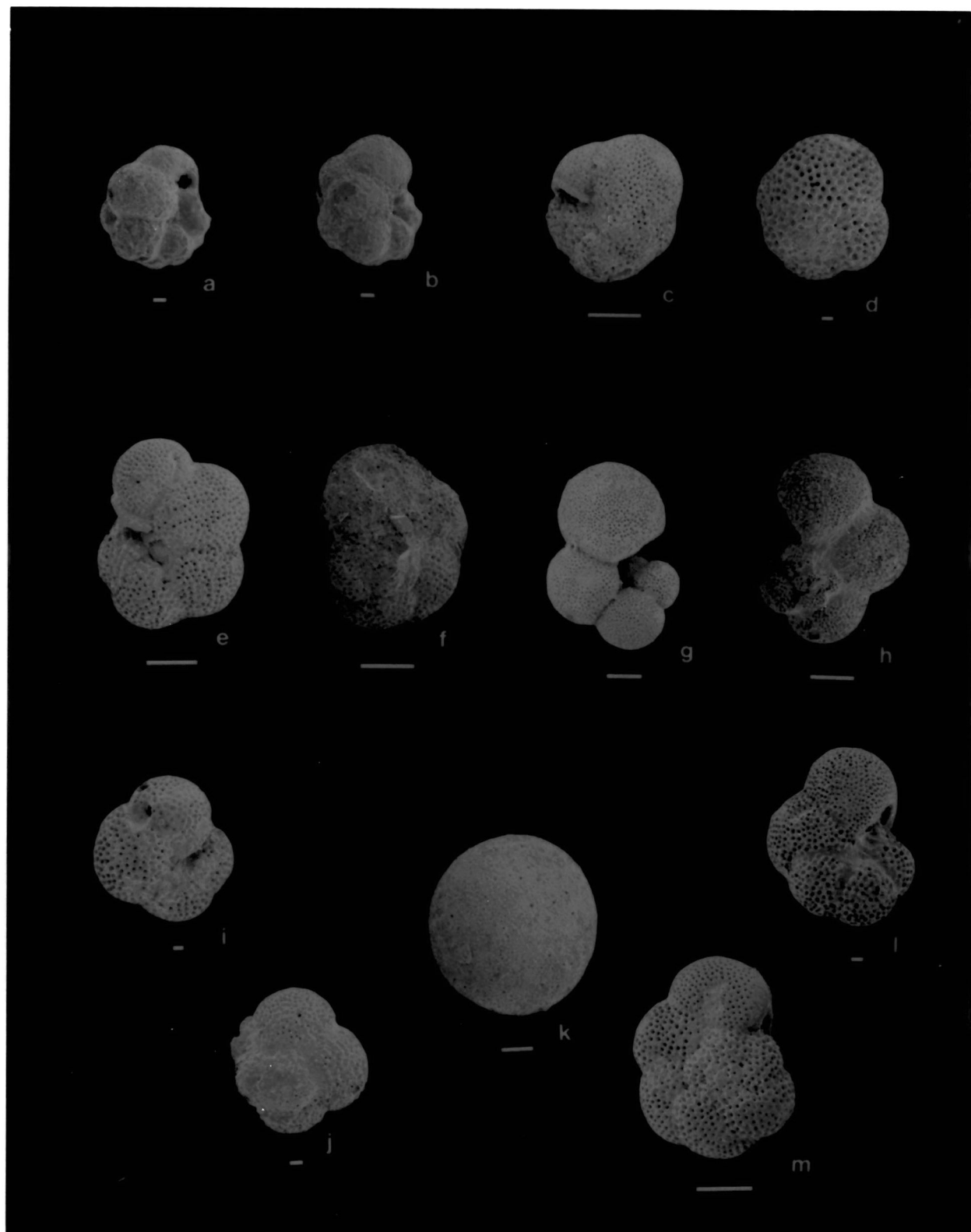
## PLATE 5

## Figure

- a-b. Cassigerinella chipolensis (Cushman and Ponton)
  - a. Side view (Core OB-105, 9.10 m)
  - b. Side view (Core OB-105, 9.10 m)
- c-d. Globorotalia birnageae Blow
  - c. Umbilical view (Core OB-105, 1.50 m)
  - d. Spiral view (Core OB-105, 1.50 m)
- e-f. Globorotalia fohsi peripheroronda Blow and Banner
  - e. Umbilical view (Core OB-105, 7.50 m)
  - f. Spiral view (Core OB-129, 4.00 m)
- g-h. Globorotalia obesa Bolli
  - g. Umbilical view (Core OB-50, 3.25-3.60 m)
  - h. Spiral view (Core OB-50, 3.25-3.60 m)
- i-j. Globorotalia opima nana Bolli
  - i. Umbilical view (Core OB-105, 1.50 m)
  - j. Spiral view (Core OB-105, 1.50 m)
- k. Orbulina universa d'Orbigny
  - Side view (Core OB-131, 3.00m)
- l-m. Globorotalia siakensis Leroy
  - l. Umbilical view (Core OB-50, 3.25-3.60 m)
  - m. Spiral view (Core OB-50, 3.25-3.60 m)

each scale line = 100 microns

## PLATE 5



## PLATE 6

## Figure

- a. Spiroplectammina mississippiensis (Cushman)  
Side view (Core OB-132, 3.50 m)
- b. Textularia agglutinans d'Orbigny  
Side view (Core OB-132, 2.50 m)
- c. Textularia articulata d'Orbigny  
Side View (Core OB-132, 4.10 m)
- d. Textularia candeiana d'Orbigny  
Side view (Core OB-132, 2.50 m)
- e. Bolivinosia fairhavenensis Gibson  
Side view (Core OB-50, 3.25-3.60 m)
- f. Astacolus cf. A. dubius (Neugeboren)  
Side view (Core OB-50, 3.25-3.60 m)
- g. Astacolus sp.  
Side view (Core OB-129, 2.50 m)
- h. Lagena cf. L. laevis (Montagu)  
Side view (Core OB-53, 1.25-1.50 m)
- i. Lagena cf. L. palmerae McLean  
Side view (Core OB-53, 1.25-1.50 m)
- j. Lagena pseudosulcata McLean  
Side view (Core OB-105, 1.50 m)
- k. Lagena substriata Williamson  
Side view (Core OB-103, 5.90 m)
- l. Lenticulina americana americana (Cushman)  
Side view (Core OB-50, 3.25-3.60 m)

each scale line = 100 microns

PLATE 6



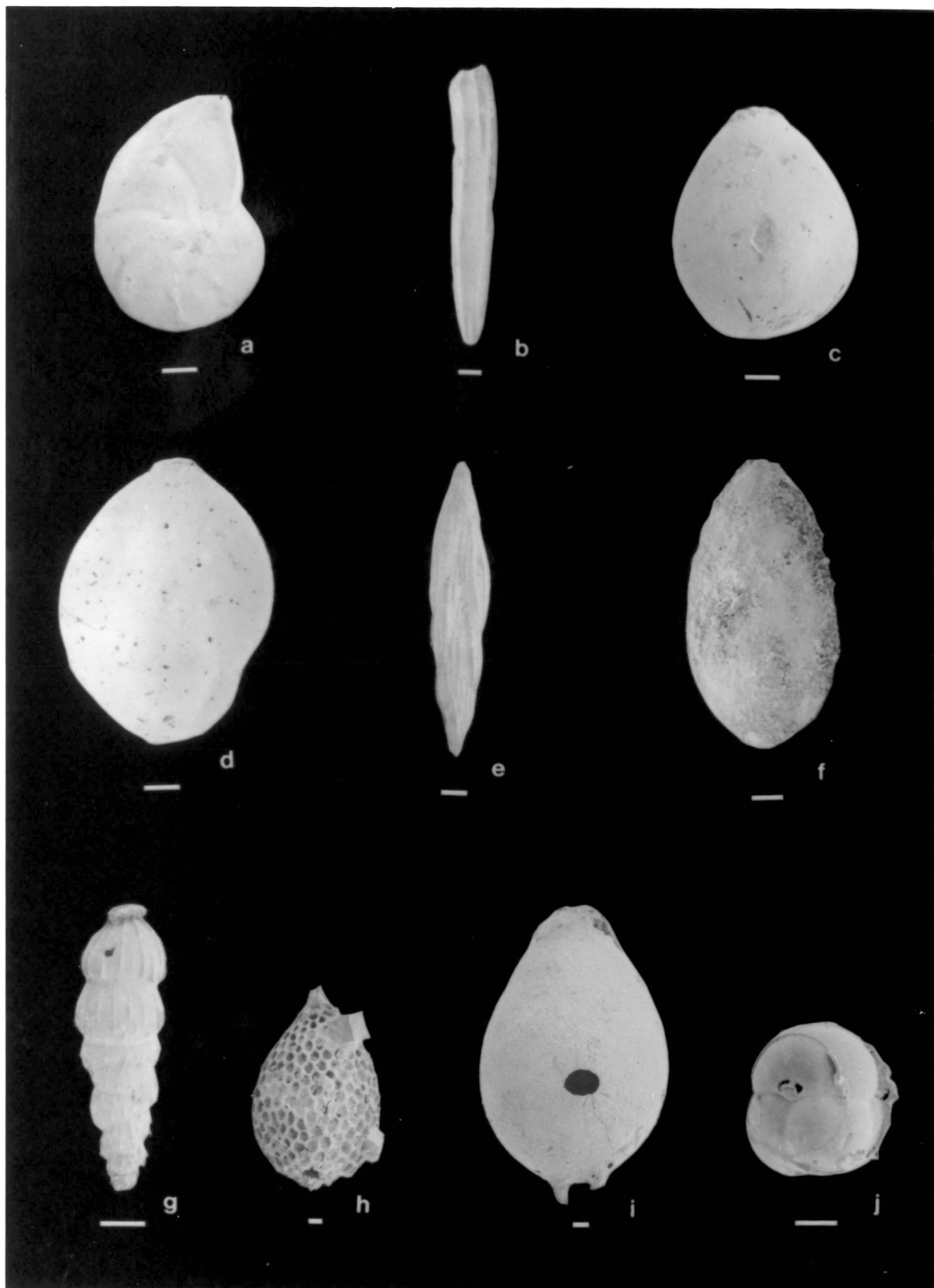
## PLATE 7

## Figure

- a. Planularia cf. P. clara Cushman and Jarvis  
Side view (Core OB-127, 8.00 m)
- b. Plectofrondicularia floridana Cushman  
Side view (Core OB-129, 4.00 m)
- c. Globulina gibba d'Orbigny  
Side view (Core OB-50, 3.25-3.60 m)
- d. Globulina inaequalis Reuss  
Side view (Core OB-50, 3.25-3.60 m)
- e. Pseudopolymorphina rutila (Cushman)  
Side view (Core OB-105, 7.50 m)
- f. Guttulina sp.  
Side view (Core OB-45, 3.00-3.25 m)
- g. Estorffina mayi (Cushman and Parker)  
Side view (Core OB-104, 4.50 m)
- h. Oolina hexagona (Williamson)  
Side view (Core OB-105, 1.50 m)
- i. Fissurina lucida (Williamson)  
Side view (Core OB-127, 4.00 m)
- j. Sphaeroidina bulloides d'Orbigny  
Apertural view (Core OB-59, 7.80-8.20 m)

each scale line = 100 microns

## PLATE 7



## PLATE 8

## Figure

- a. Buliminella cf. B. brevior Cushman  
Side view (Core OB-127, 7.00 m)
- b. Buliminella elegantissima (d'Orbigny)  
Side view (Core OB-45, 3.00-3.25 m)
- c. Bolivina advena Cushman  
Side view (Core OB-132, 3.50 m)
- d. Bolivina calvertensis Dorsey  
Side view (Core OB-105, 4.50 m)
- e. Bolivina floridana Cushman  
Side view (Core OB-127, 7.00 m)
- f. Bolivina marginata multicostata Cushman  
Side view (Core OB-45, 0.75-1.00 m)
- g. Bolivina paula Cushman and Cahill  
Side view (Core OB-50, 3.25-3.60 m)
- f. Bolivina cf. B. subdilatata Pishvanova  
Side view (Core OB-105, 4.50 m)
- i. Bulimina elongata d'Orbigny  
Side view (Core OB-50, 3.25-3.60 m)
- j. Bulimina striata mexicana Cushman  
Side view (Core OB-105, 4.50 m)
- k. Cassidulinoides bradyi (Norman)  
Side view (Core OB-127, 7.00 m)
- l. Islandiella sp.  
Side view (Core OB-105, 7.50 m)

each scale line = 100 microns

## PLATE 8





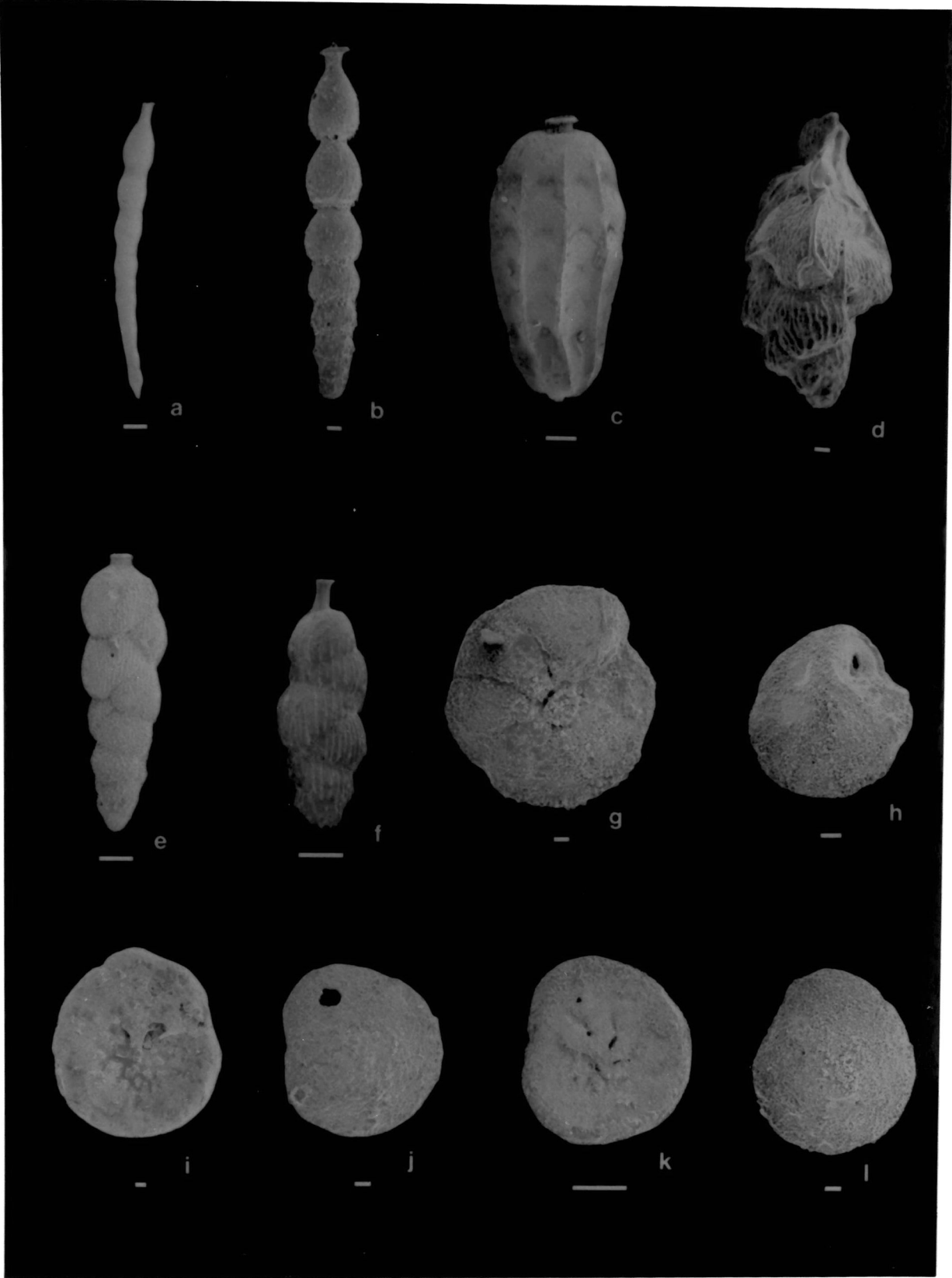
## PLATE 9

## Figure

- a. Siphonodosaria sp.  
Side view (Core OB-45, 0.75-1.00 m)
- b. Stilostomella recta (Palmer and Bremudez)  
Side view (Core OB-105, 1.50 m)
- c. Siphogenerina transversa Cushman  
Side view (Core OB-105, 4.50 m)
- d. Trifarina occidentalis (Cushman)  
Side view (Core OB-131, 3.00 m)
- e. Uvigerina auberiana d'Orbigny  
Side view (Core OB-105, 1.50 m)
- f. Uvigerina subperegrina Cushman and Kleinpell  
Side view (Core OB-105, 1.50 m)
- g. Discorbis bassleri (Cushman and Cahill)  
Umbilical view (Core OB-132, 1.50 m)
- h. Epistominella danvillensis Howe and Wallace  
Umbilical view (Core OB-105, 4.50 m)
- i-j. Rosalina cavernata (Dorsey)
  - i. Umbilical view (Core OB-105, 1.50 m)
  - j. Spiral view (Core OB-105, 4.50 m)
- k-l. Rosalina cf. R. floridana (Cushman)
  - k. Umbilical view (Core OB-45, 4.75-5.00 m)
  - l. Spiral view (Core )B-45, 4.75-5.00 m)

each scale line = 100 microns

PLATE 9



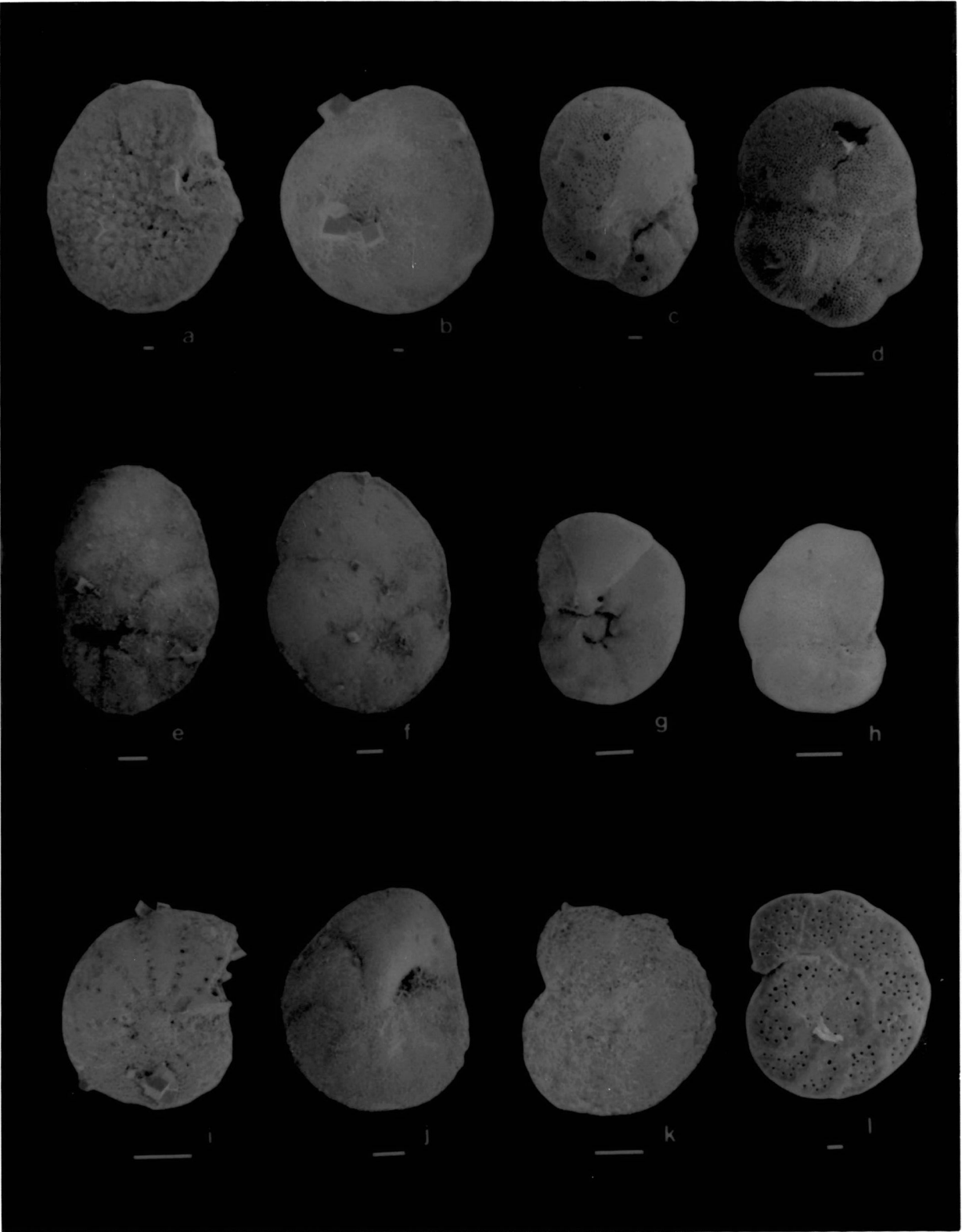
## PLATE 10

## Figure

- a-b. Rosalina globularis d'Orbigny
  - a. Umbilical view (Core OB-45, 0.75-1.00 m)
  - b. Spiral view (Core OB-45, 0.75-1.00 m)
- c-d. Baggina sp.
  - c. Umbilical view (Core OB-105, 1.50 m)
  - d. Spiral view (Core OB-105, 1.50 m)
- e-f. Cancris sagra (d'Orbigny)
  - e. Umbilical view (Core OB-129, 4.00 m)
  - f. Spiral view (Core OB-129, 2.50 m)
- g-h. Valvulineria floridana Cushman
  - g. Umbilical view (Core OB-50, 3.25-3.60 m)
  - h. Spiral view (Core OB-50, 3.25-3.60 m)
- i. Elphidium excavatum (Terquem)
  - Side view (Core OB-45, 0.75-1.00 m)
- j. Eponides cf. E. repandus (Fichtel and Moll)
  - Umbilical view (Core OB-59, 4.75-5.00 m)
- k-l. Cibicides americanus (Cushman)
  - k. Umbilical view (Core OB-45, 3.00-3.25 m)
  - l. Spiral view (Core OB-45, 3.00-3.25 m)

each scale line = 100 microns

PLATE 10



## PLATE 11

## Figure

- a-b. Cibicides floridanus (Cushman)
  - a. Umbilical view (Core OB-45, 3.00-3.25 m)
  - b. Spiral view (Core OB-45, 3.00-3.25 m)
- c-d. Cibicides lobatulus (Walker and Jacob)
  - c. Umbilical view (Core OB-50, 3.25-3.60 m)
  - d. Spiral view (Core OB-48, 2.25-2.50 m)
- e. Cassidella sp.
  - Side view (Core OB-132, 1.50 m)
- f. Virgulinea miocenica (Cushman and Ponton)
  - Side view (Core OB-53, 2.75-3.00 m)
- g. Fursenkoina fusiformis (Williamson)
  - Side view (Core OB-105, 1.50 m)
- h. Fursenkoina sp.
  - Side view (Core OB-132, 2.00 m)
- i. Loxostomum gunteri Cushman
  - Side view (Core OB-105, 1.50 m)
- j. Globocassulina crassa (d'Orbigny)
  - Side view (Core OB-127, 7.00 m)

each scale line = 100 microns

## PLATE 11



## PLATE 12

## Figure

- a. Nonionella miocenica Cushman  
Side view (Core OB-50, 3.25-3.60 m)
- b-c. Florilus grateloupi (d'Orbigny)  
b. Umbilical view (Core OB-132, 1.50 m)  
c. Spiral view (Core OB-129, 5.50 m)
- d-e. Florilus pizzarensis (Berry)  
d. Umbilical view (Core OB-50, 3.25-3.60 m)  
e. Spiral view (Core OB-50, 3.25-3.60 m)
- f. Melonis sp.  
Side view (Core OB-127, 8.00 m)
- g-h. Hanzawaia concentrica (Cushman)  
g. Umbilical view (Core OB-50, 3.25-3.60 m)  
h. Spiral view (Core OB-50, 3.25-3.60 m)

each scale line = 100 microns

## PLATE 12





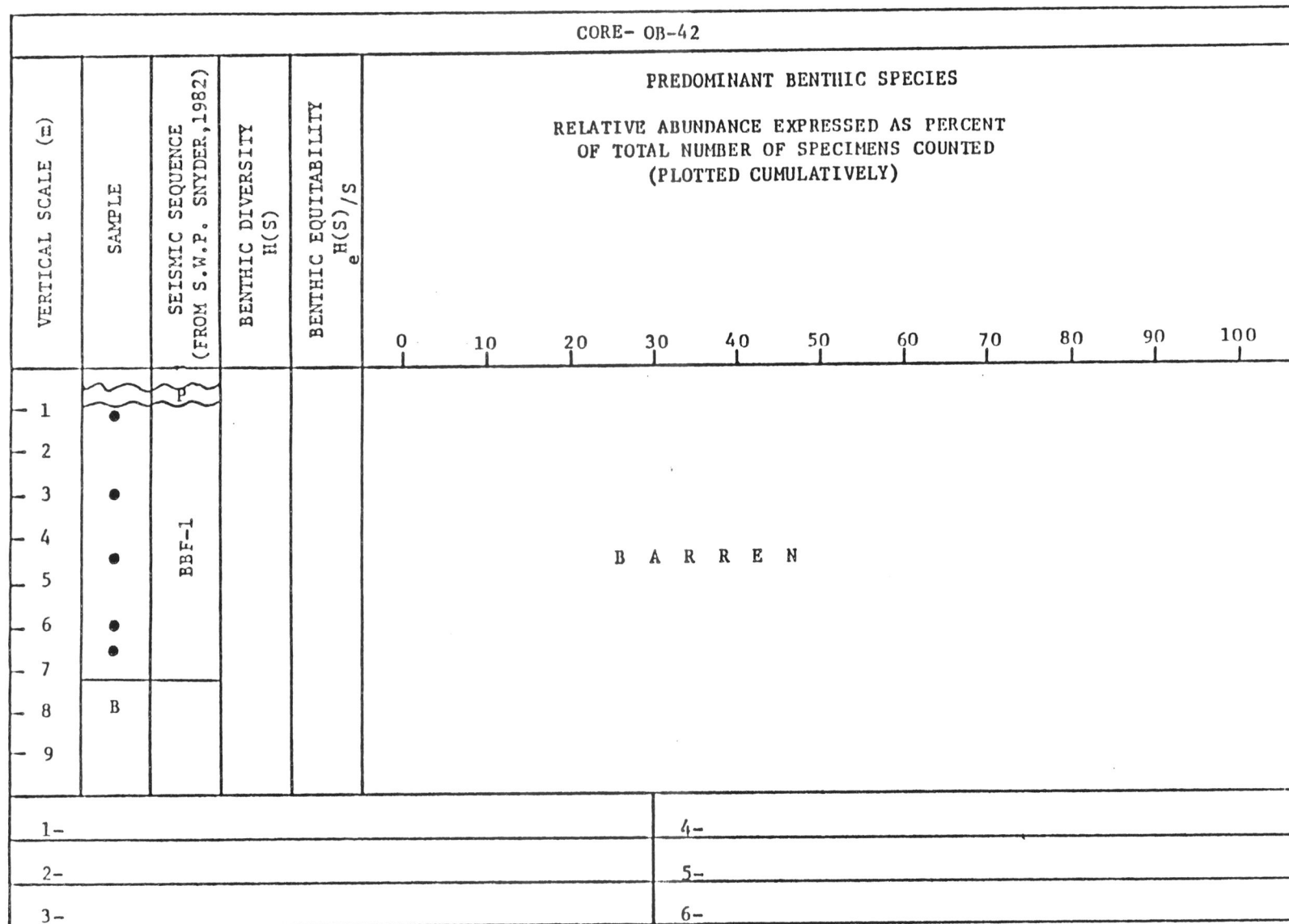
## Appendix A

### Summary of Benthic Foraminiferal Data Obtained from Core Samples

| CORE- OB-41        |        |                                                |                           |                                      |                                                                                                                                              |
|--------------------|--------|------------------------------------------------|---------------------------|--------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| VERTICAL SCALE (m) | SAMPLE | SEISMIC SEQUENCE<br>(FROM S.W.P. SNYDER, 1982) | BENTHIC DIVERSITY<br>H(S) | BENTHIC EQUITABILITY<br>$H_e(S) / S$ | PREDOMINANT BENTHIC SPECIES<br><br>RELATIVE ABUNDANCE EXPRESSED AS PERCENT<br>OF TOTAL NUMBER OF SPECIMENS COUNTED<br>(PLOTTED CUMULATIVELY) |
|                    |        |                                                |                           |                                      | 0      10      20      30      40      50      60      70      80      90      100                                                           |
| - 1                |        | II                                             |                           |                                      | B A R R E N                                                                                                                                  |
| - 2                |        |                                                |                           |                                      |                                                                                                                                              |
| - 3                |        |                                                |                           |                                      |                                                                                                                                              |
| - 4                | •      |                                                |                           |                                      |                                                                                                                                              |
| - 5                | •      | AF-1                                           |                           |                                      |                                                                                                                                              |
| - 6                |        |                                                |                           |                                      |                                                                                                                                              |
| - 7                | •      |                                                |                           |                                      |                                                                                                                                              |
| - 8                |        |                                                |                           |                                      |                                                                                                                                              |
| - 9                | B      |                                                |                           |                                      |                                                                                                                                              |
| 1-                 |        |                                                |                           |                                      | 4-                                                                                                                                           |
| 2-                 |        |                                                |                           |                                      | 5-                                                                                                                                           |
| 3-                 |        |                                                |                           |                                      | 6-                                                                                                                                           |

II= Holocene

B= Bottom of core



P= Pleistocene

B= Bottom of core

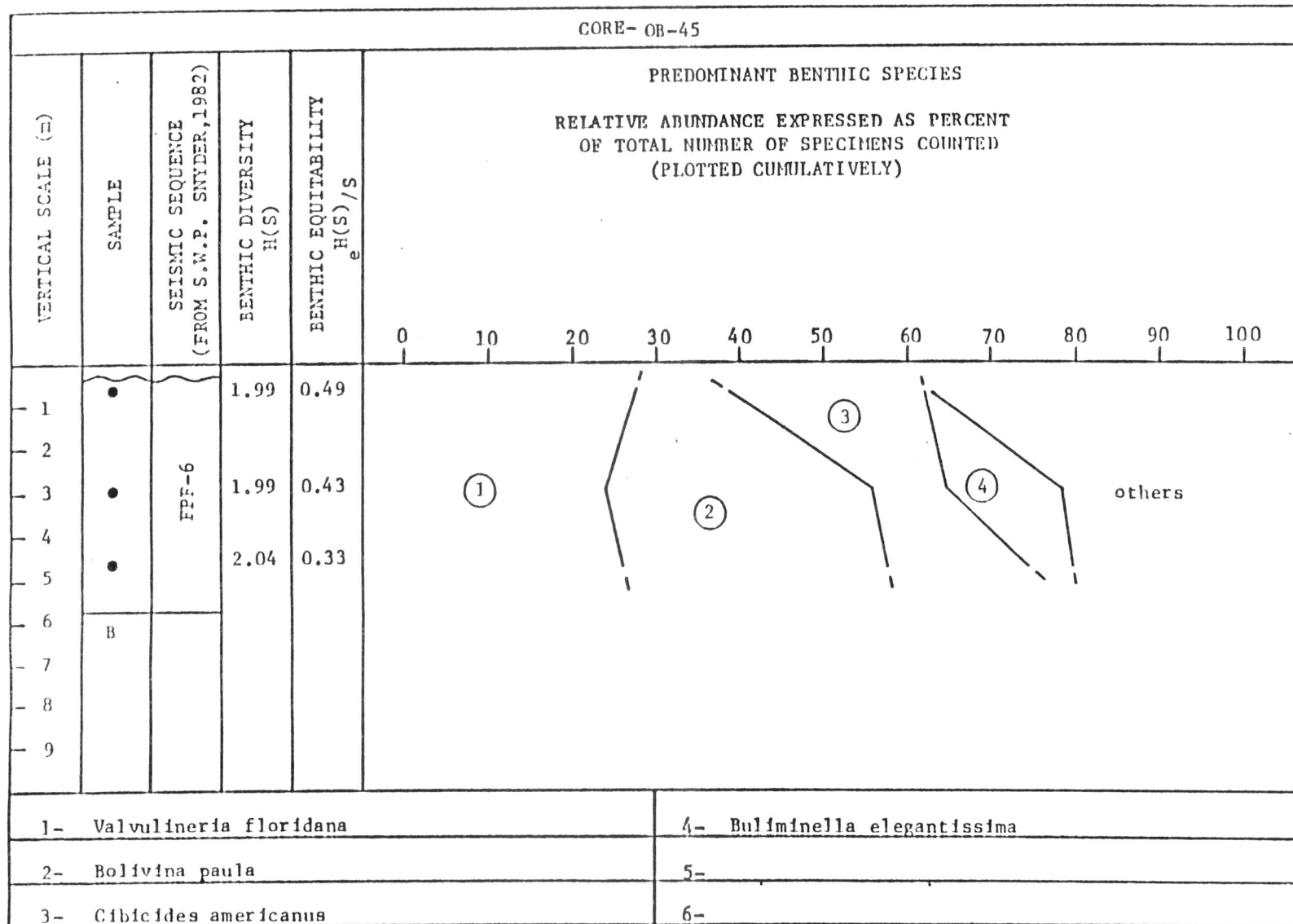
| CORE- OB-43                  |        |                                                |                           |                                    |                                                                                                           |    |    |    |    |    |    |    |    |    |     |
|------------------------------|--------|------------------------------------------------|---------------------------|------------------------------------|-----------------------------------------------------------------------------------------------------------|----|----|----|----|----|----|----|----|----|-----|
| VERTICAL SCALE (m)           | SAMPLE | SEISMIC SEQUENCE<br>(FROM S.W.P. SNYDER, 1982) | BENTHIC DIVERSITY<br>H(S) | BENTHIC EQUITABILITY<br>$H_e(S)/S$ | PREDOMINANT BENTHIC SPECIES                                                                               |    |    |    |    |    |    |    |    |    |     |
|                              |        |                                                |                           |                                    | RELATIVE ABUNDANCE EXPRESSED AS PERCENT<br>OF TOTAL NUMBER OF SPECIMENS COUNTED<br>(PLOTTED CUMULATIVELY) |    |    |    |    |    |    |    |    |    |     |
|                              |        |                                                |                           |                                    | 0                                                                                                         | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
| 1                            | •      | H                                              | 1.70                      | 0.39                               | ①                                                                                                         |    |    |    |    |    |    |    |    |    |     |
| 2                            | •      | BBF-1                                          |                           |                                    |                                                                                                           |    |    |    |    |    |    |    |    |    |     |
| 3                            | •      |                                                |                           |                                    |                                                                                                           |    |    |    |    |    |    |    |    |    |     |
| 4                            | •      |                                                |                           |                                    |                                                                                                           |    |    |    |    |    |    |    |    |    |     |
| 5                            | B      |                                                |                           |                                    | ②                                                                                                         |    |    |    |    |    |    |    |    |    |     |
| 6                            |        |                                                |                           |                                    |                                                                                                           |    |    |    |    |    |    |    |    |    |     |
| 7                            |        |                                                |                           |                                    |                                                                                                           |    |    |    |    |    |    |    |    |    |     |
| 8                            |        |                                                |                           |                                    |                                                                                                           |    |    |    |    |    |    |    |    |    |     |
| 9                            |        |                                                |                           |                                    |                                                                                                           |    |    |    |    |    |    |    |    |    |     |
| 1- Bolivina paula            |        |                                                |                           |                                    | 4- Valvulineria floridana                                                                                 |    |    |    |    |    |    |    |    |    |     |
| 2- Florilus pizzarensis      |        |                                                |                           |                                    | 5-                                                                                                        |    |    |    |    |    |    |    |    |    |     |
| 3- Buliminella elegantissima |        |                                                |                           |                                    | 6-                                                                                                        |    |    |    |    |    |    |    |    |    |     |

H= Holocene    B= Bottom of core

| CORE- OB-44        |        |                                                |                           |                                    |                                                                                                                                              |
|--------------------|--------|------------------------------------------------|---------------------------|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| VERTICAL SCALE (m) | SAMPLE | SEISMIC SEQUENCE<br>(FROM S.W.P. SNYDER, 1982) | BENTHIC DIVERSITY<br>H(S) | BENTHIC EQUITABILITY<br>$H_e(S)/S$ | PREDOMINANT BENTHIC SPECIES<br><br>RELATIVE ABUNDANCE EXPRESSED AS PERCENT<br>OF TOTAL NUMBER OF SPECIMENS COUNTED<br>(PLOTTED CUMULATIVELY) |
| 1                  |        |                                                |                           |                                    | 0                                                                                                                                            |
| 2                  | •      |                                                |                           |                                    | 10                                                                                                                                           |
| 3                  |        |                                                |                           |                                    | 20                                                                                                                                           |
| 4                  | •      | AF-1                                           |                           |                                    | 30                                                                                                                                           |
| 5                  |        |                                                |                           |                                    | 40                                                                                                                                           |
| 6                  | •      |                                                |                           |                                    | 50                                                                                                                                           |
| 7                  | B      |                                                |                           |                                    | 60                                                                                                                                           |
| 8                  |        |                                                |                           |                                    | 70                                                                                                                                           |
| 9                  |        |                                                |                           |                                    | 80                                                                                                                                           |
|                    |        |                                                |                           |                                    | 90                                                                                                                                           |
|                    |        |                                                |                           |                                    | 100                                                                                                                                          |
| 1-                 |        |                                                |                           |                                    | 4-                                                                                                                                           |
| 2-                 |        |                                                |                           |                                    | 5-                                                                                                                                           |
| 3-                 |        |                                                |                           |                                    | 6-                                                                                                                                           |

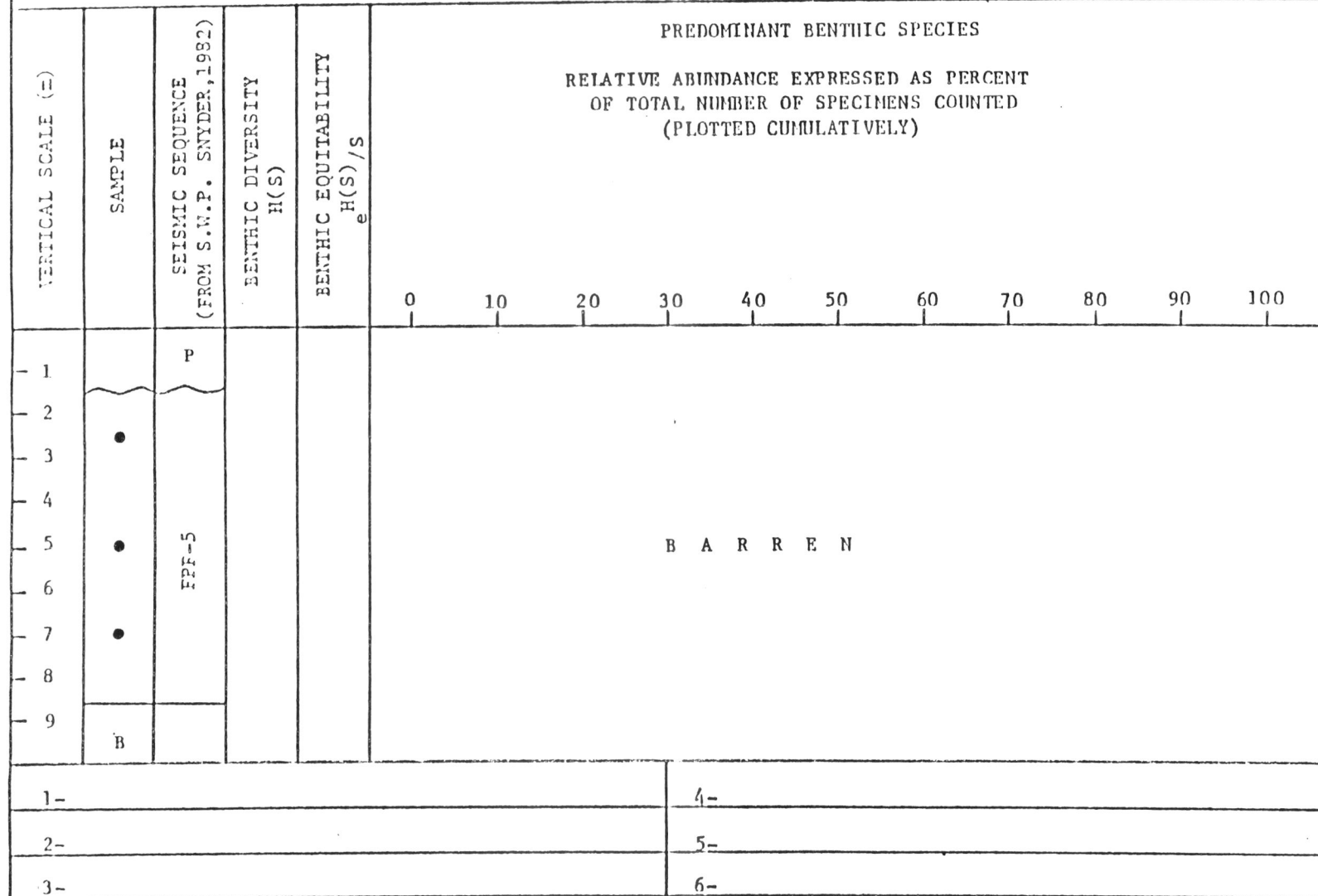
B= Bottom of core

B A R R E N

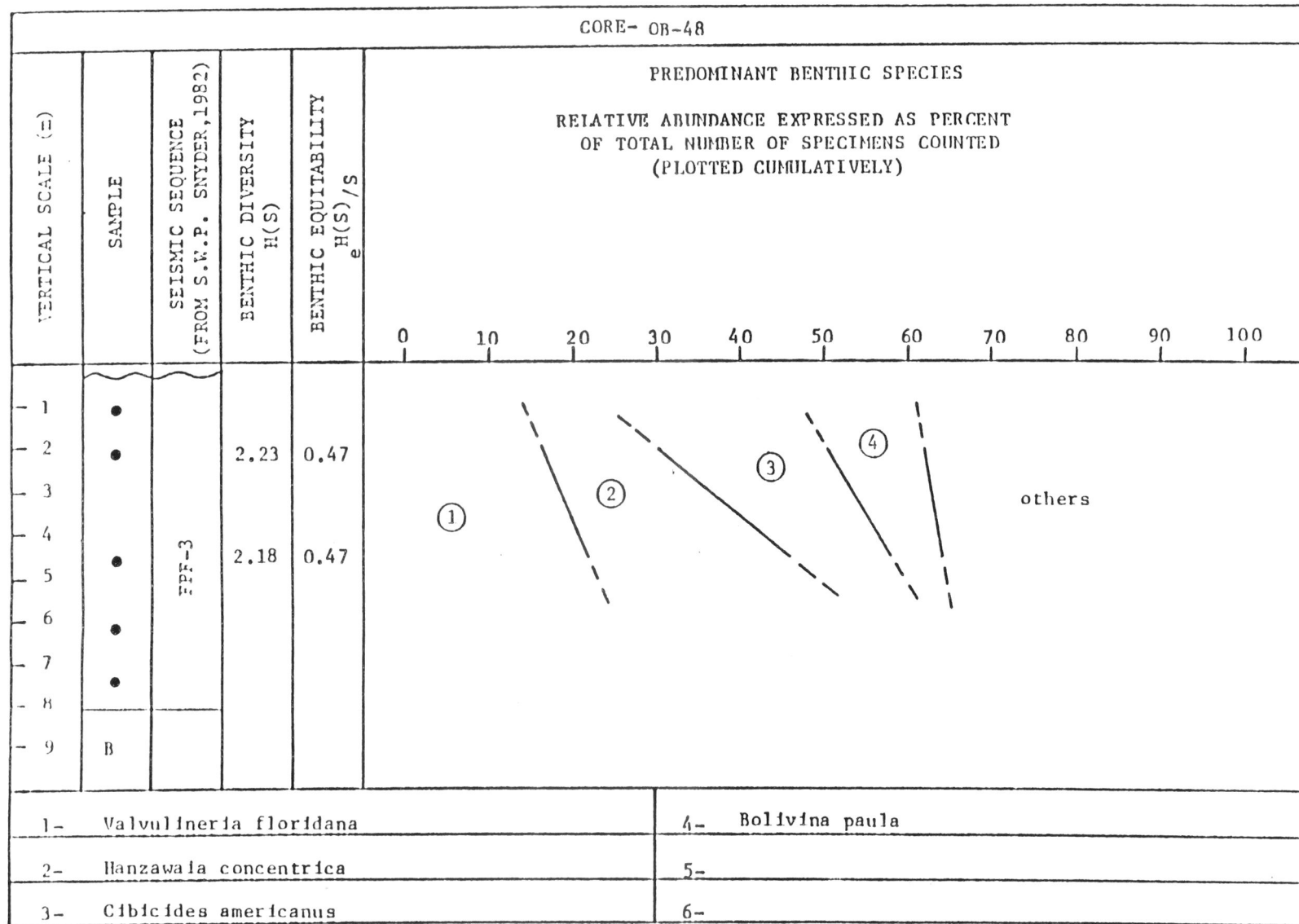


B= Bottom of core

CORE- OB-46



P= Pleistocene B= Bottom of core

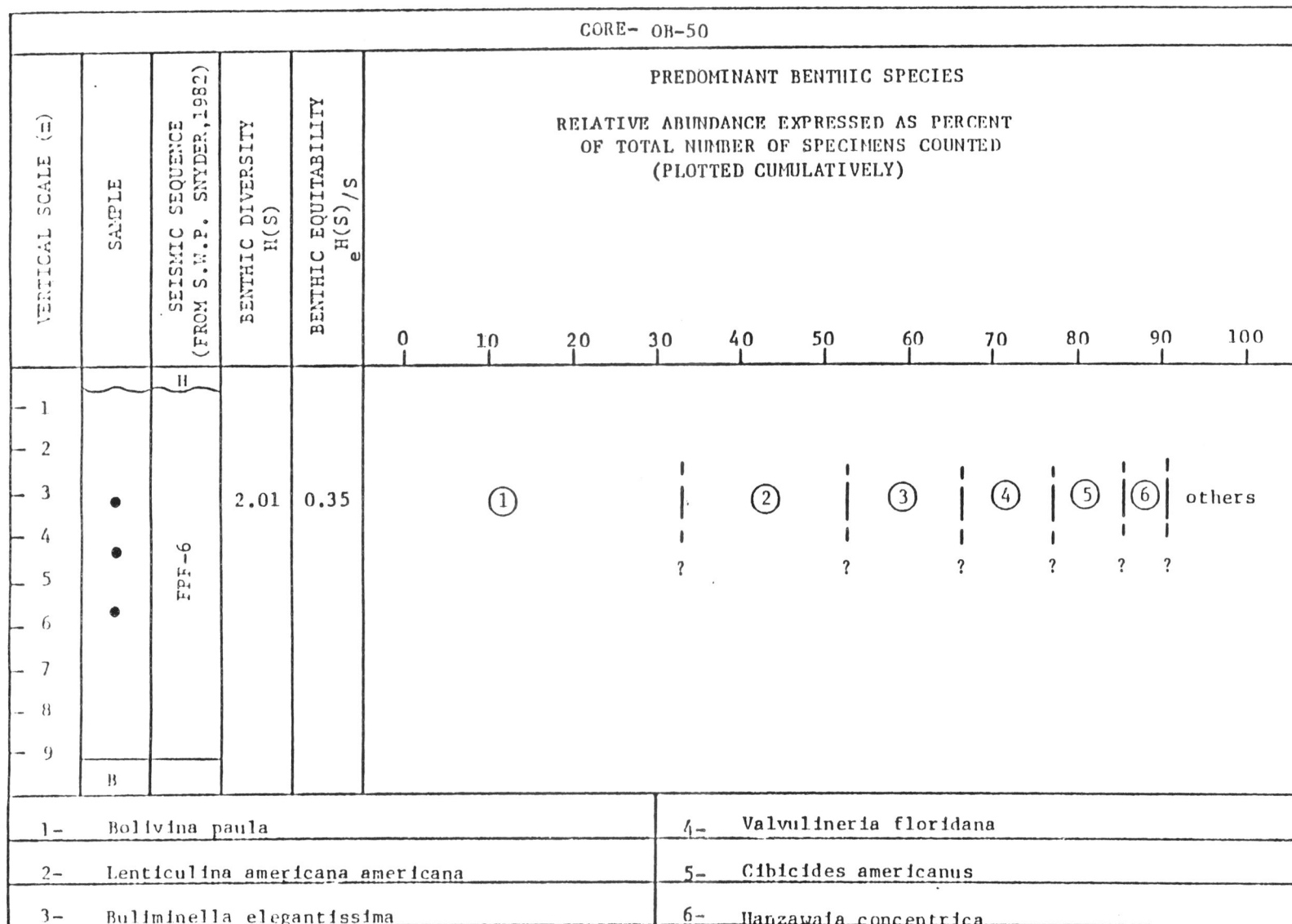


B= Bottom of core

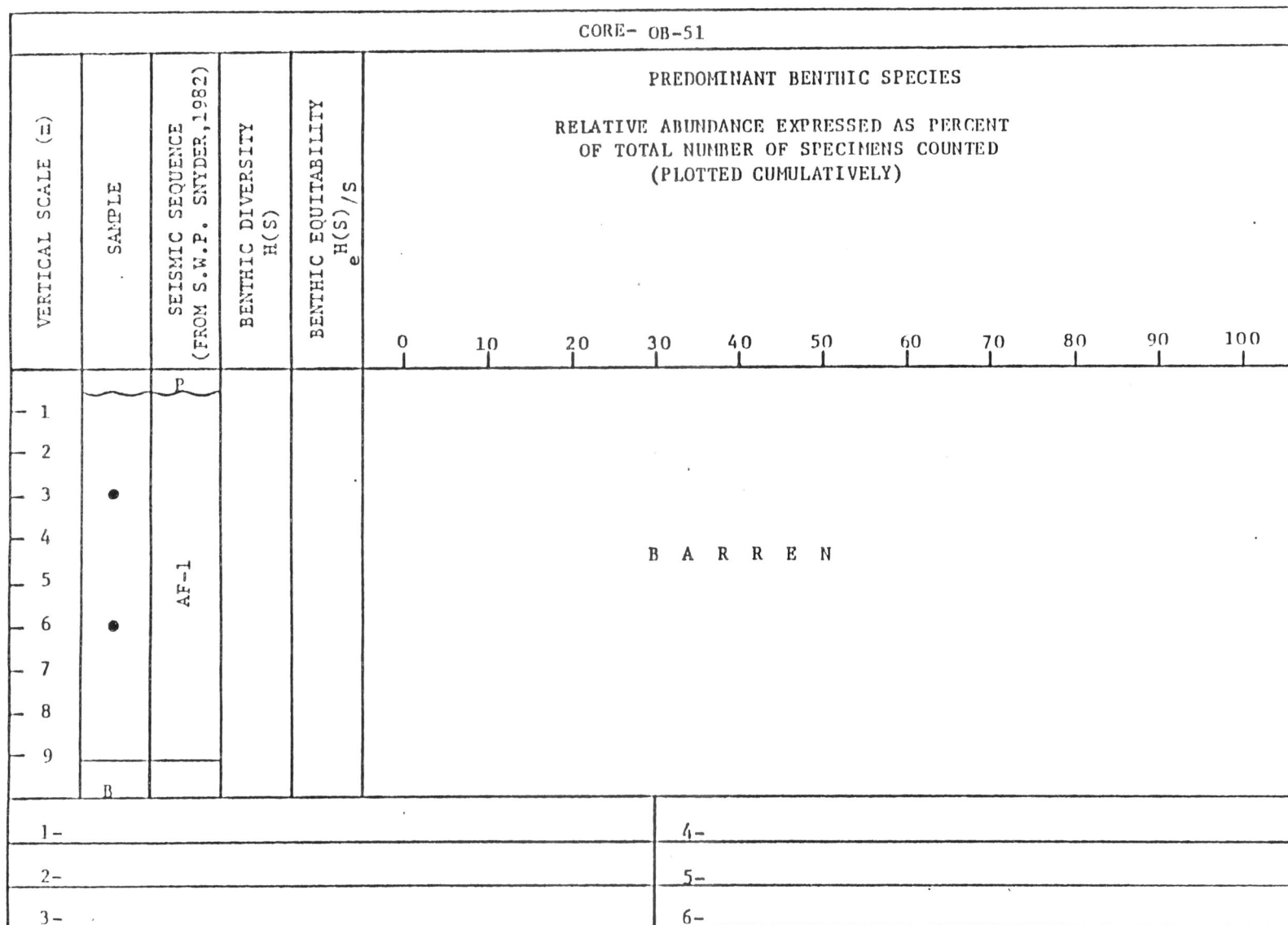


| CORE- OB-49        |        |                                                |                             |                                    |                                                                                                                                              |
|--------------------|--------|------------------------------------------------|-----------------------------|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| VERTICAL SCALE (m) | SAMPLE | SEISMIC SEQUENCE<br>(FROM S.W.P. SNYDER, 1982) | BENTHIC DIVERSITY<br>$H(S)$ | BENTHIC EQUITABILITY<br>$H_e(S)/S$ | PREDOMINANT BENTHIC SPECIES<br><br>RELATIVE ABUNDANCE EXPRESSED AS PERCENT<br>OF TOTAL NUMBER OF SPECIMENS COUNTED<br>(PLOTTED CUMULATIVELY) |
|                    |        |                                                |                             |                                    |                                                                                                                                              |
| 1                  | •      | H<br><br>FPF-2                                 |                             |                                    | 0 10 20 30 40 50 60 70 80 90 100<br><br>B A R R E N                                                                                          |
| 2                  |        |                                                |                             |                                    |                                                                                                                                              |
| 3                  | •      |                                                |                             |                                    |                                                                                                                                              |
| 4                  |        |                                                |                             |                                    |                                                                                                                                              |
| 5                  |        |                                                |                             |                                    |                                                                                                                                              |
| 6                  | •      |                                                |                             |                                    |                                                                                                                                              |
| 7                  |        |                                                |                             |                                    |                                                                                                                                              |
| 8                  |        |                                                |                             |                                    |                                                                                                                                              |
| 9                  | •      |                                                |                             |                                    |                                                                                                                                              |
| 1-                 | B      |                                                |                             |                                    |                                                                                                                                              |
| 2-                 |        |                                                |                             |                                    | 4-                                                                                                                                           |
| 3-                 |        |                                                |                             |                                    | 5-                                                                                                                                           |
|                    |        |                                                |                             |                                    | 6-                                                                                                                                           |

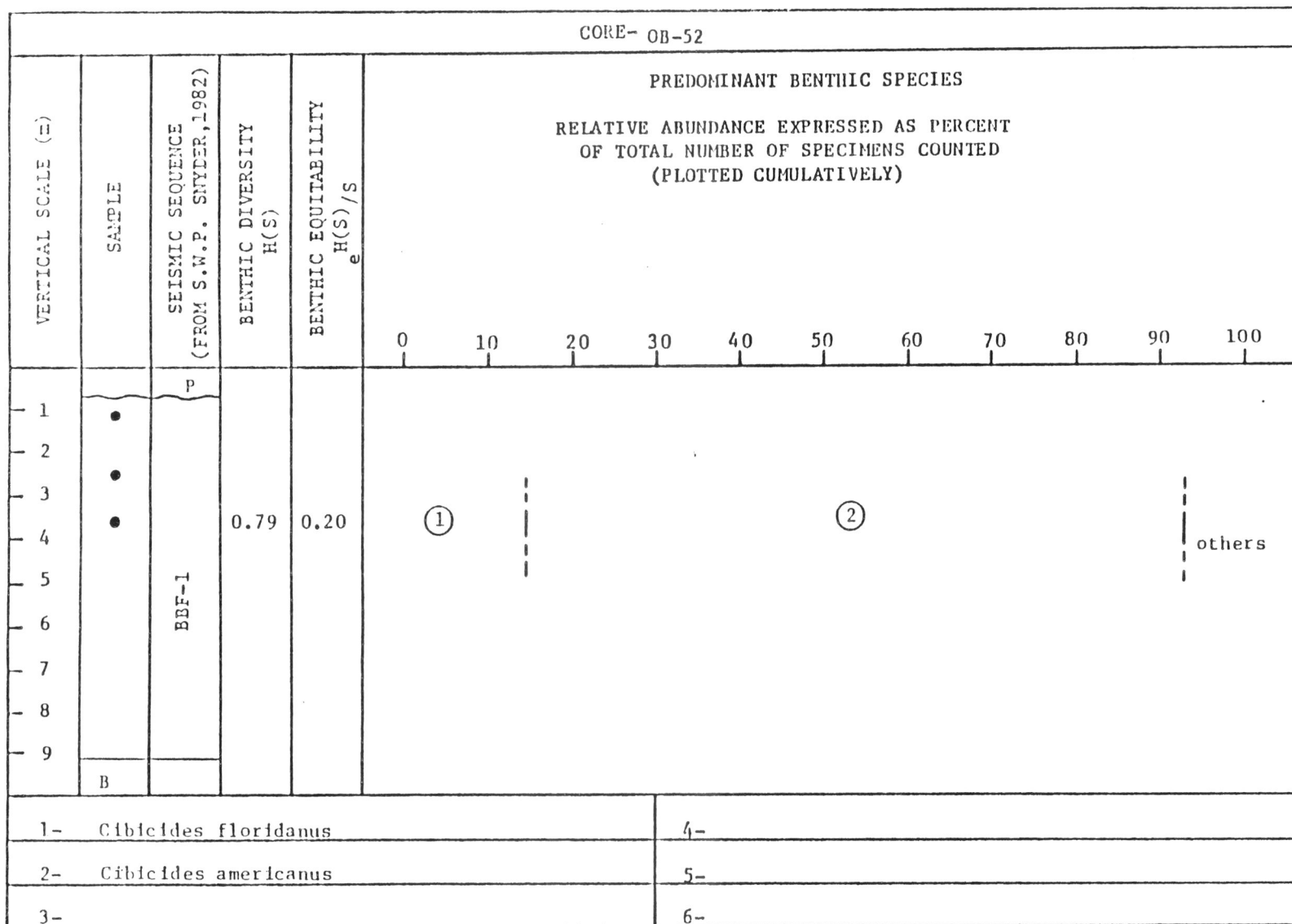
H= Holocene B= Bottom of core



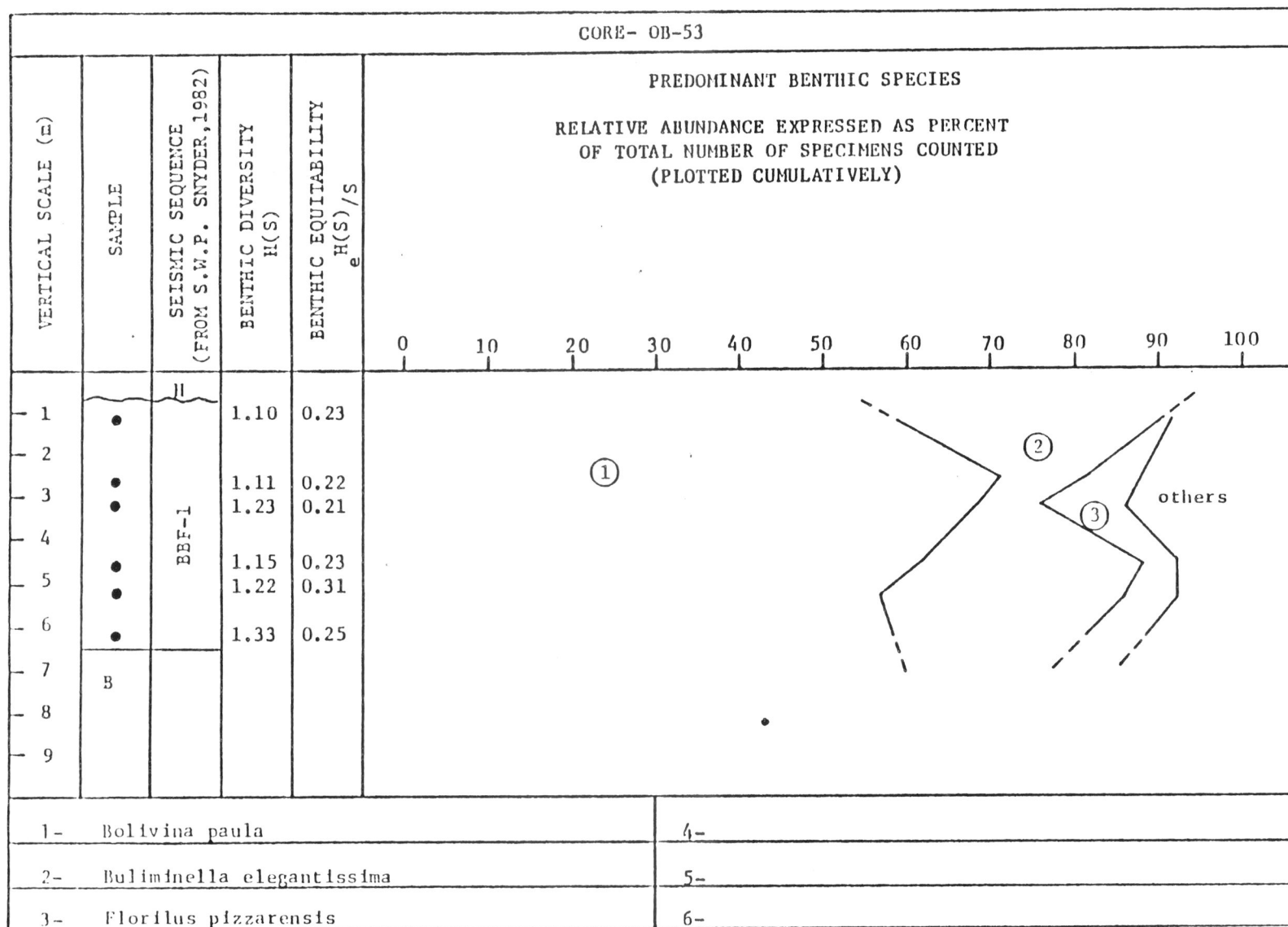
H= Holocene B= Bottom of core



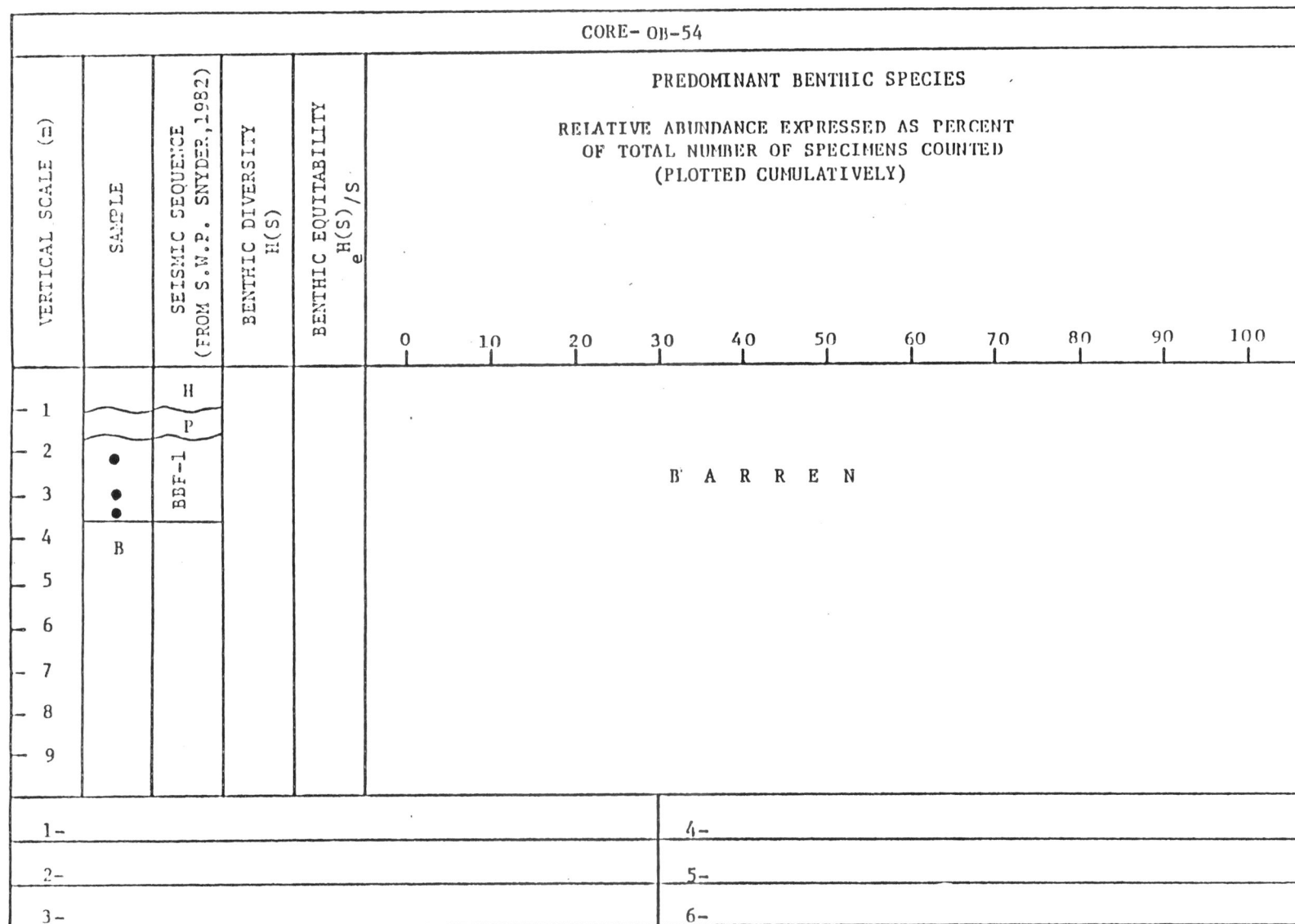
P= Pleistocene    B= Bottom of core



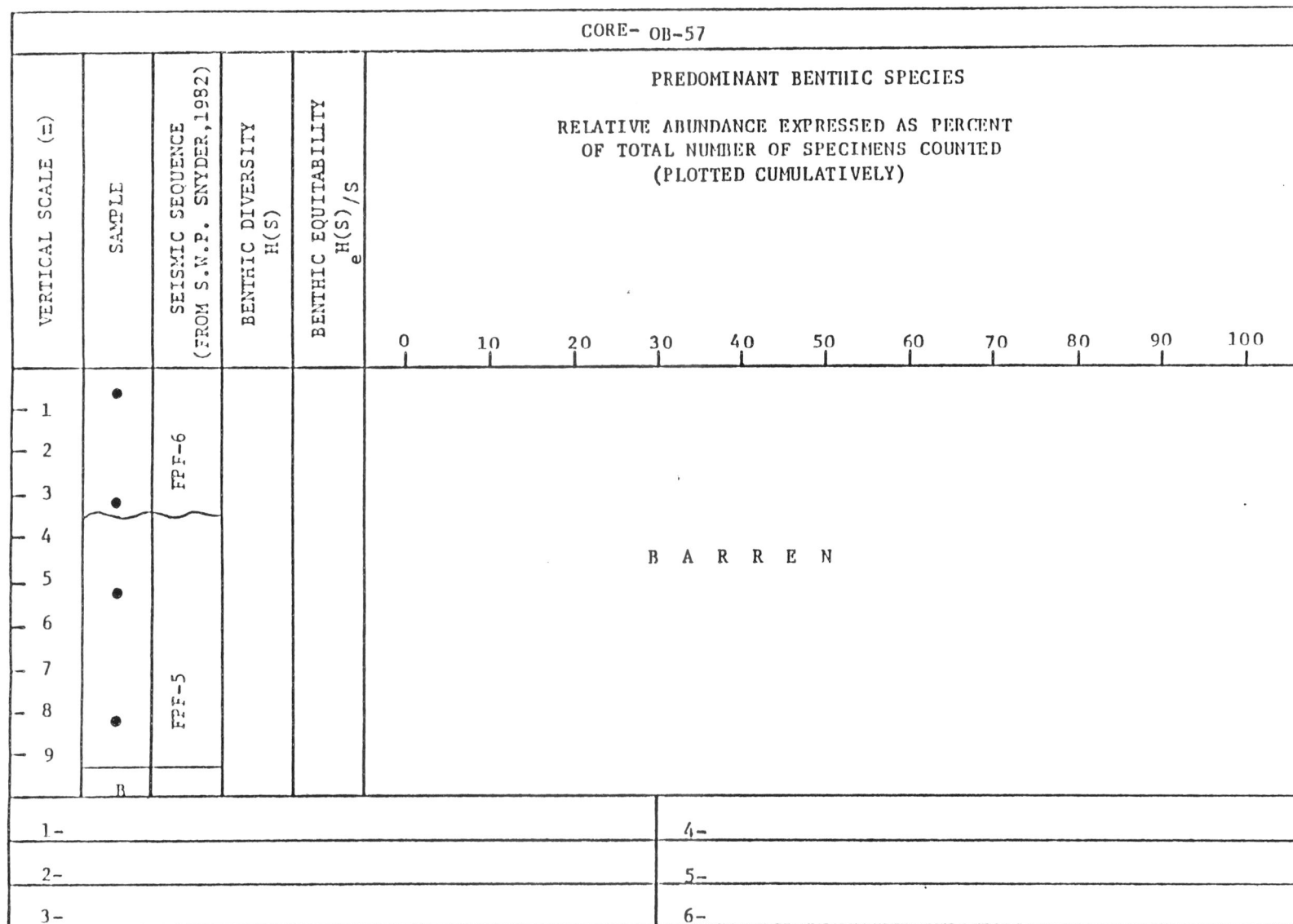
P= Pleistocene B= Bottom of core



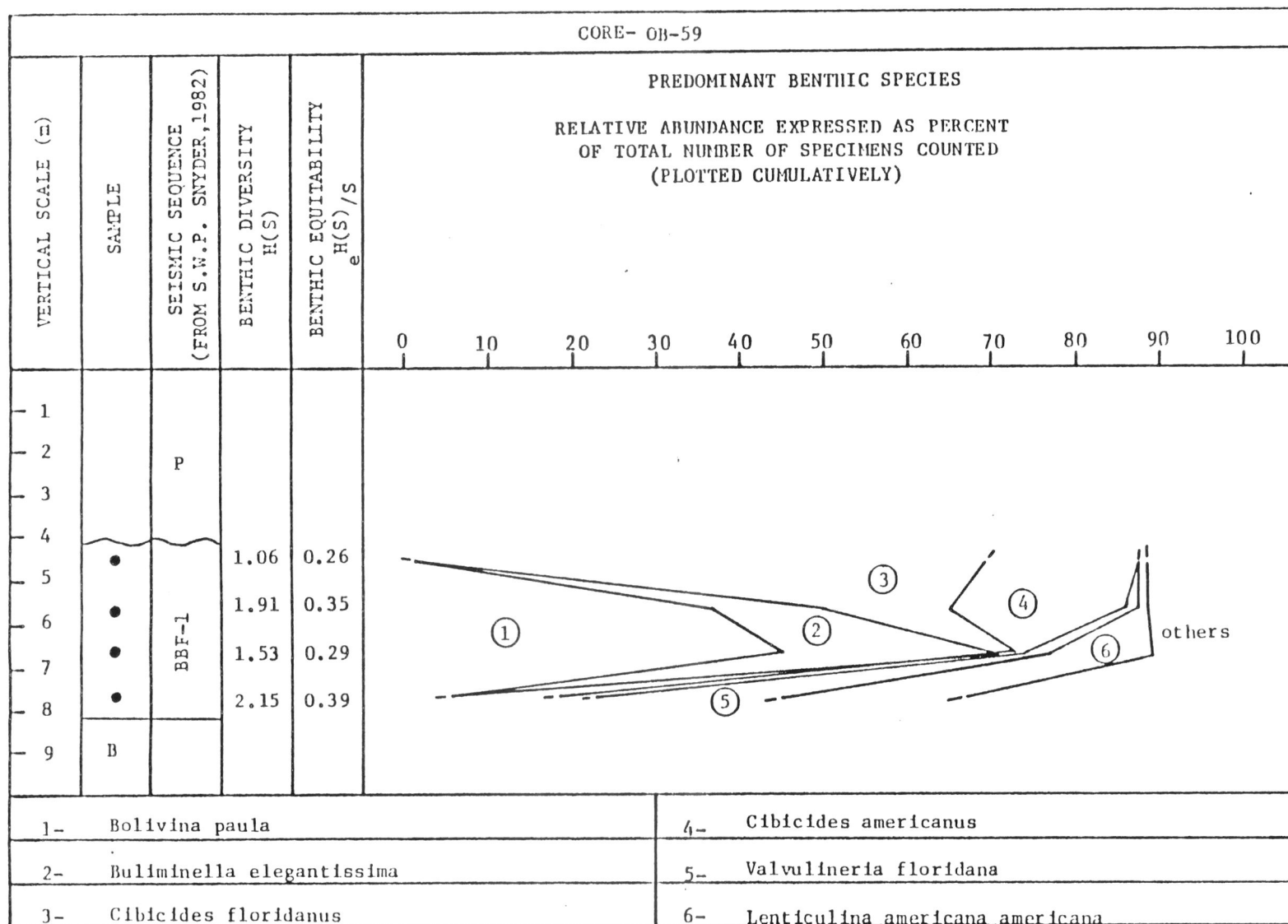
H= Holocene B= Bottom of core



H= Holocene    P= Pleistocene    B= Bottom of core

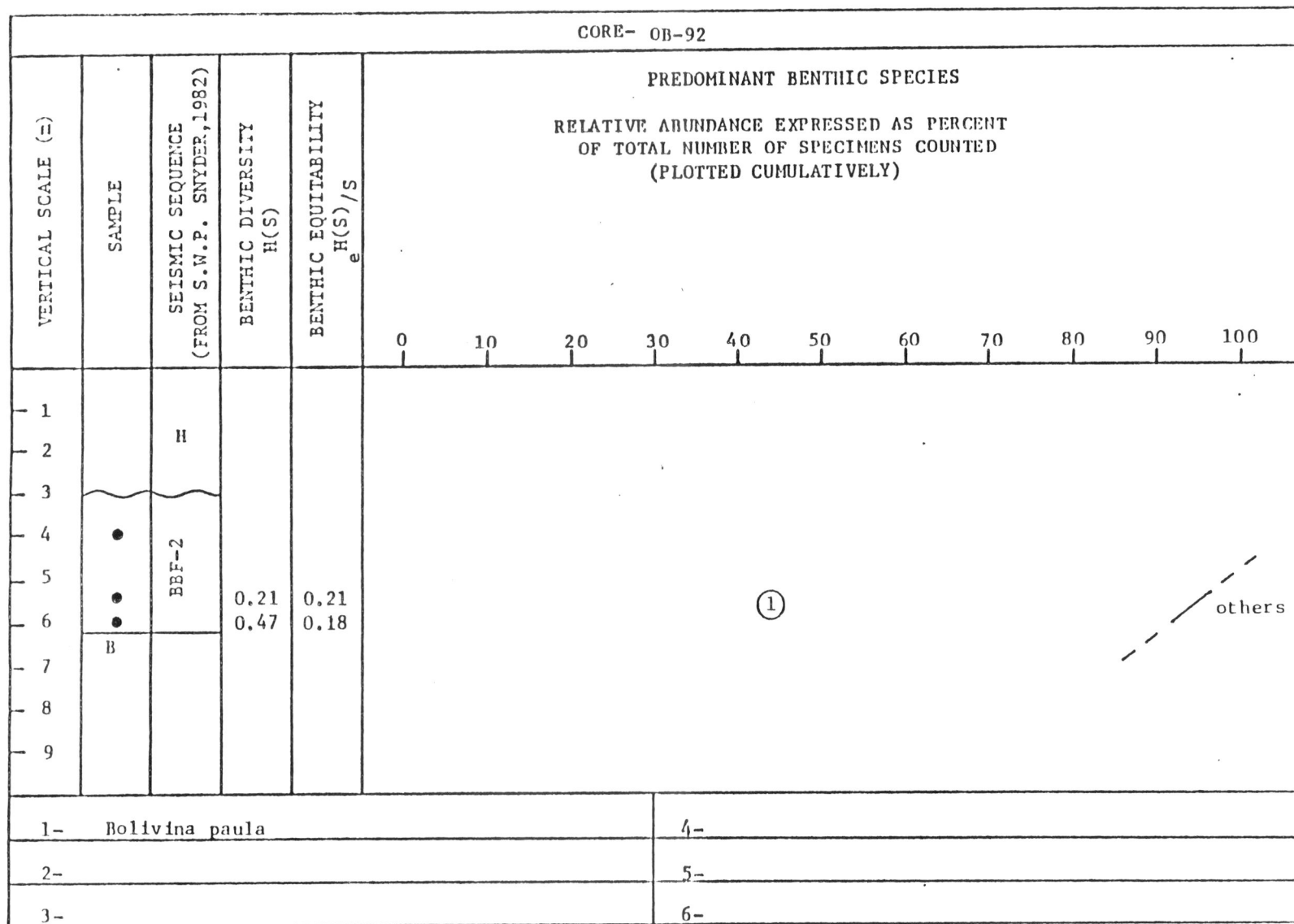


B= Bottom of core

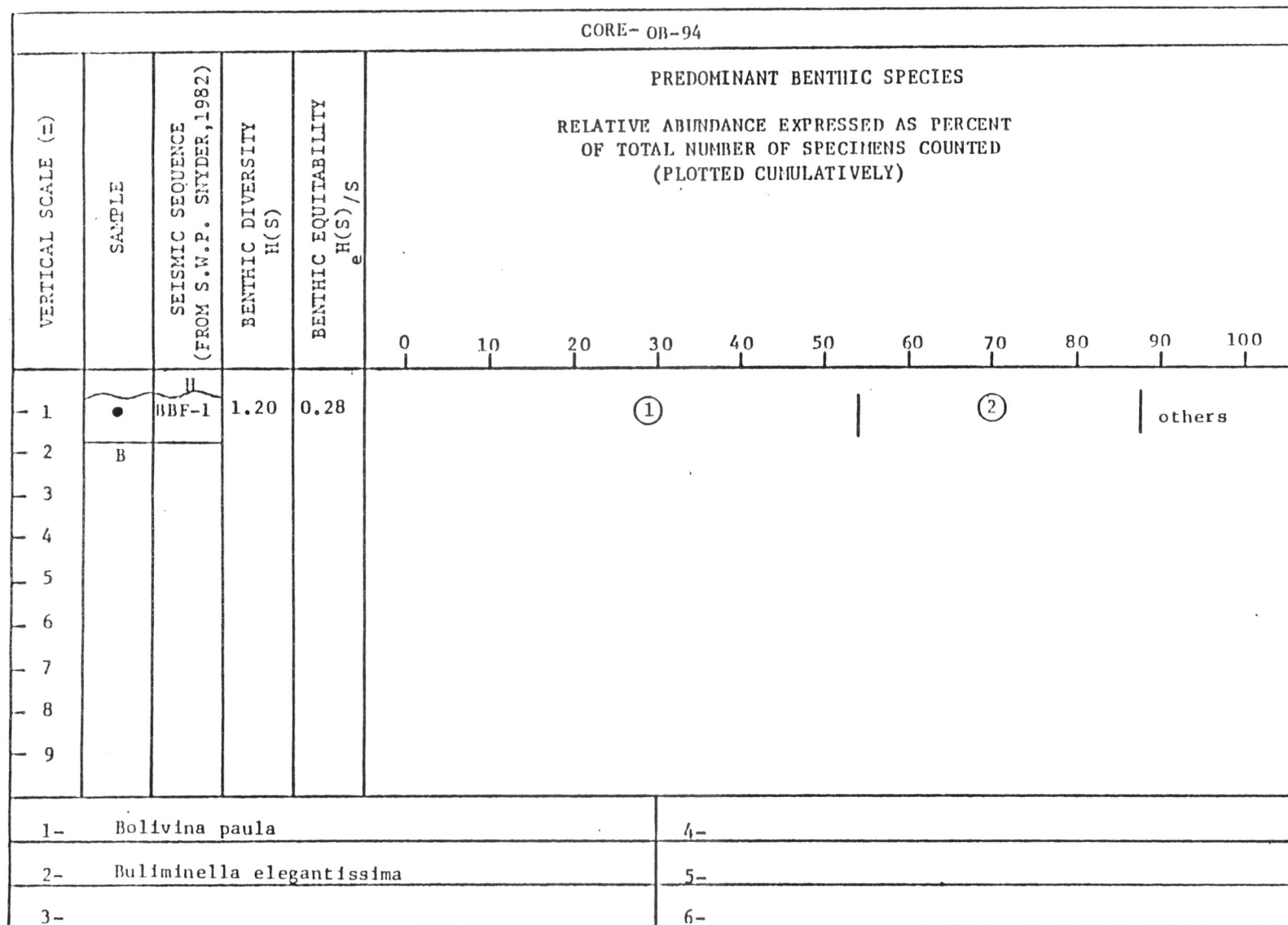


P= Pleistocene    B= Bottom of core

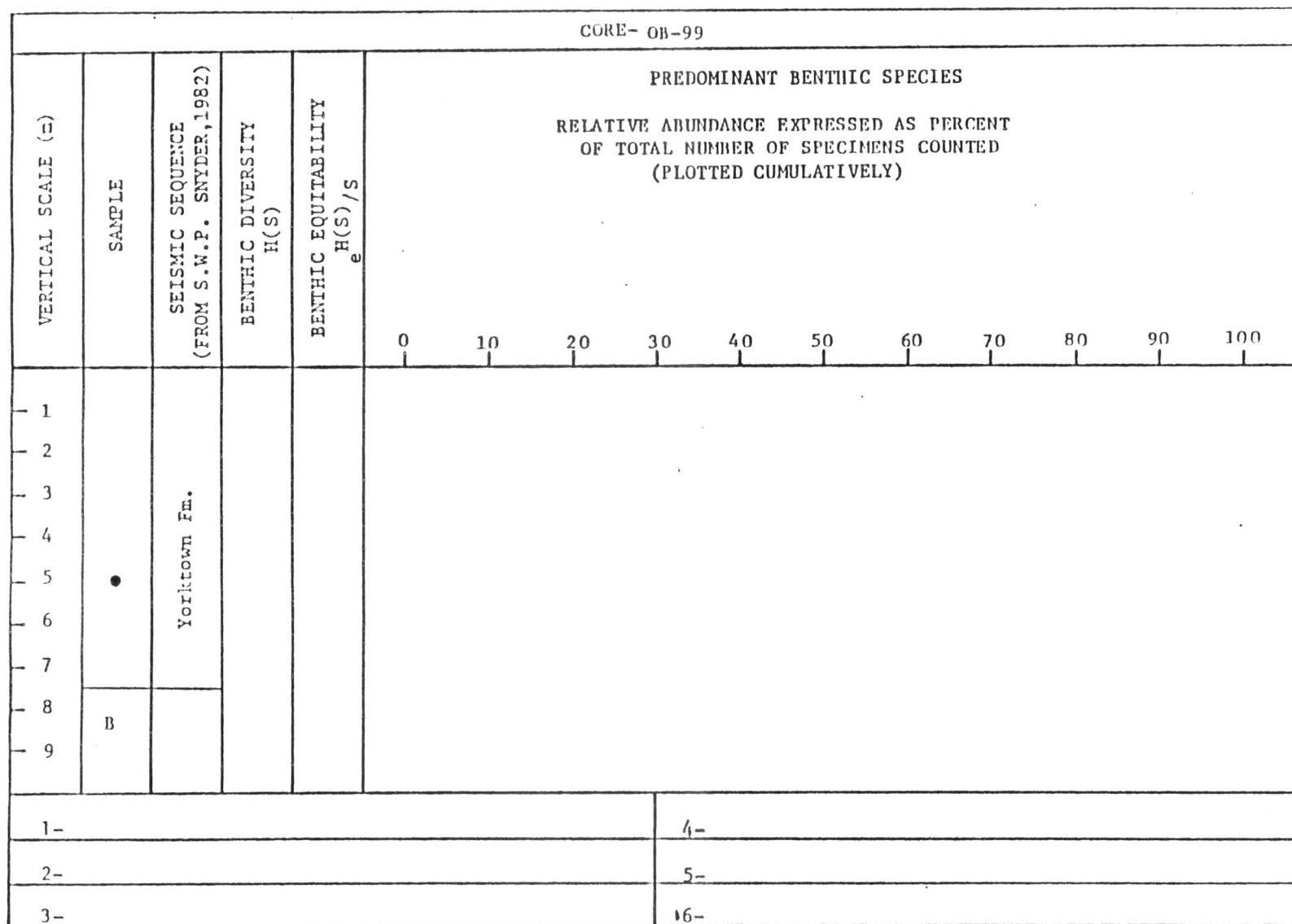




H= Holocene B= Bottom of core

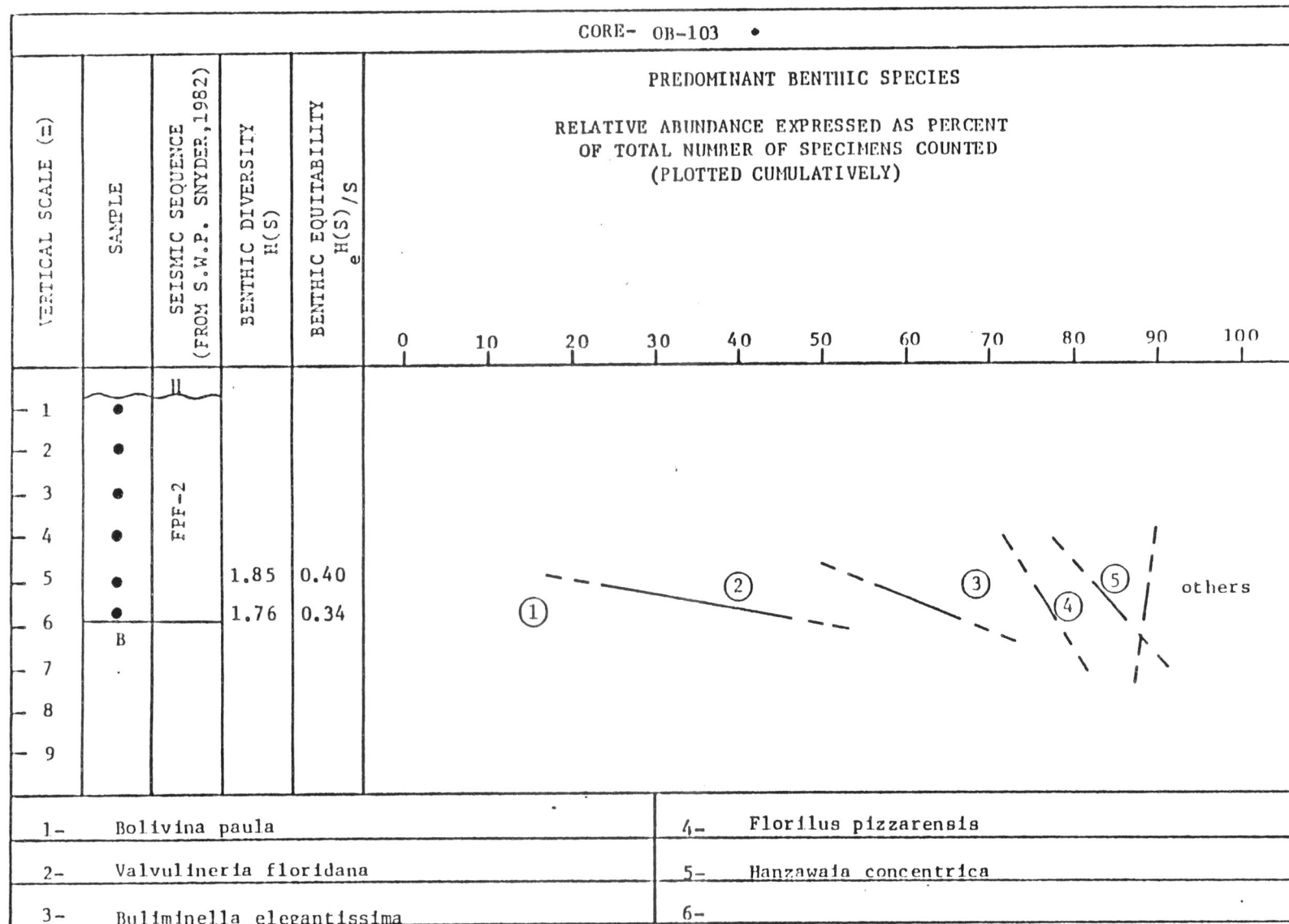


H= Holocene    B= Bottom of core

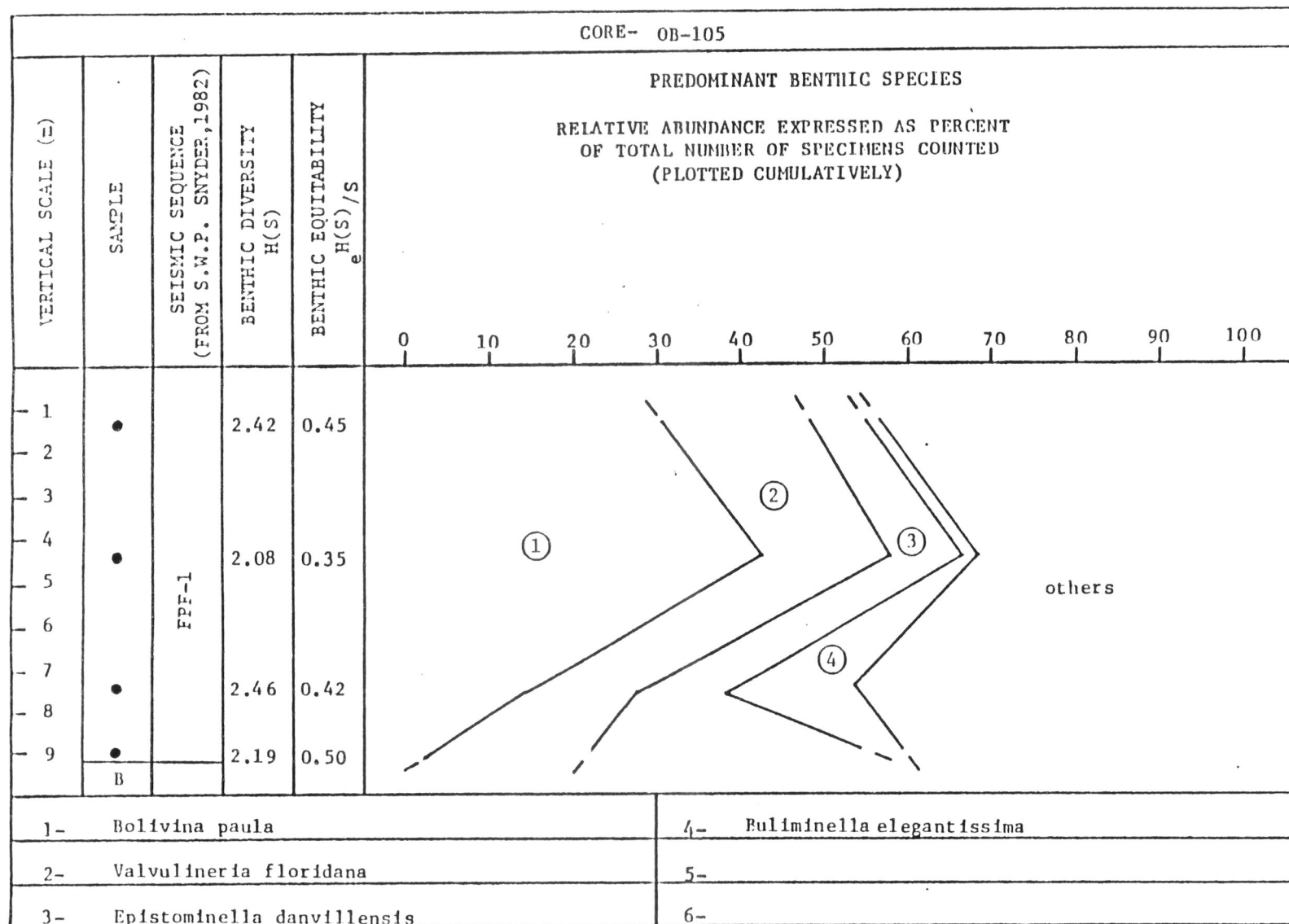


B= Bottom of core

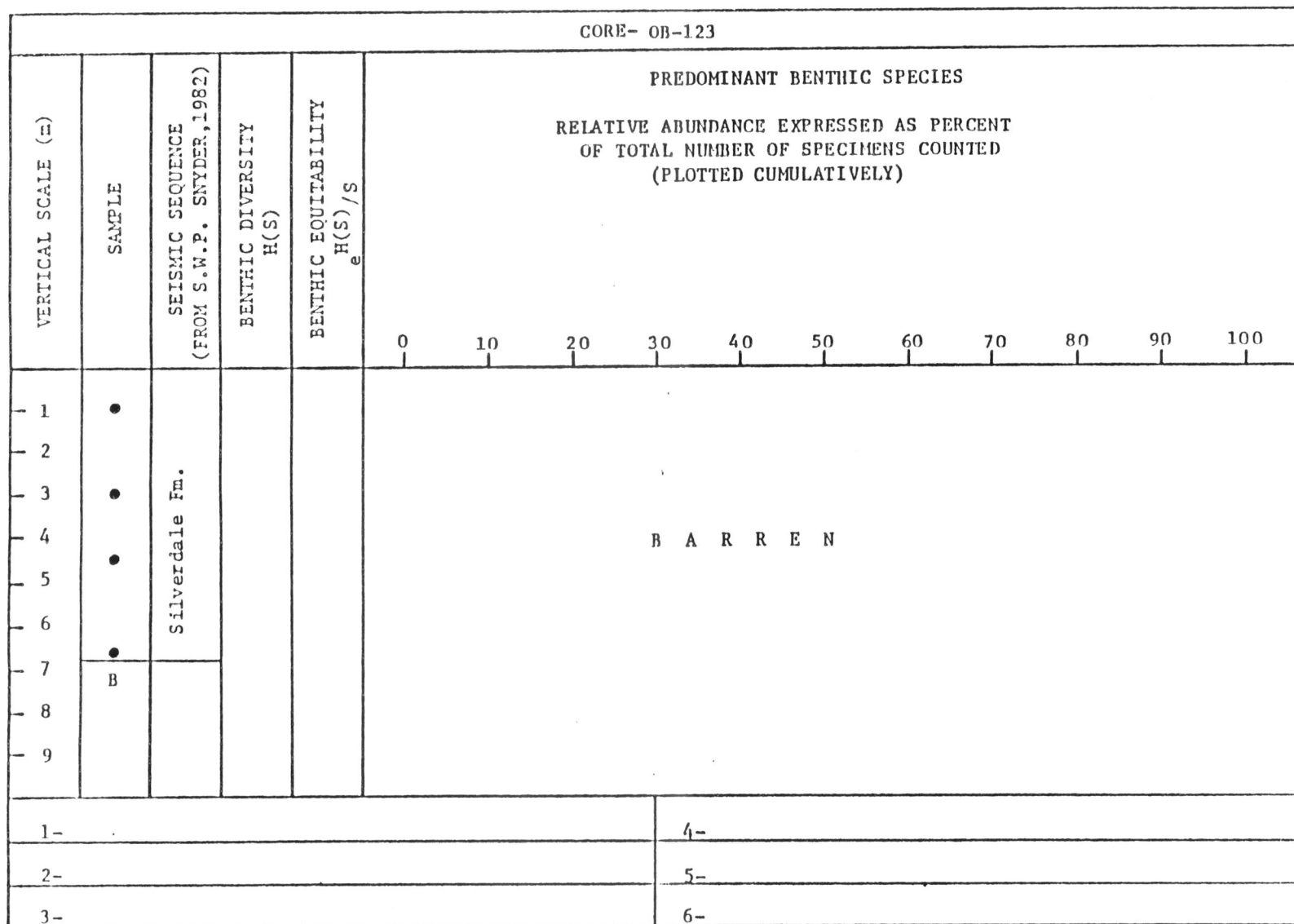
CORE- OB-103 •



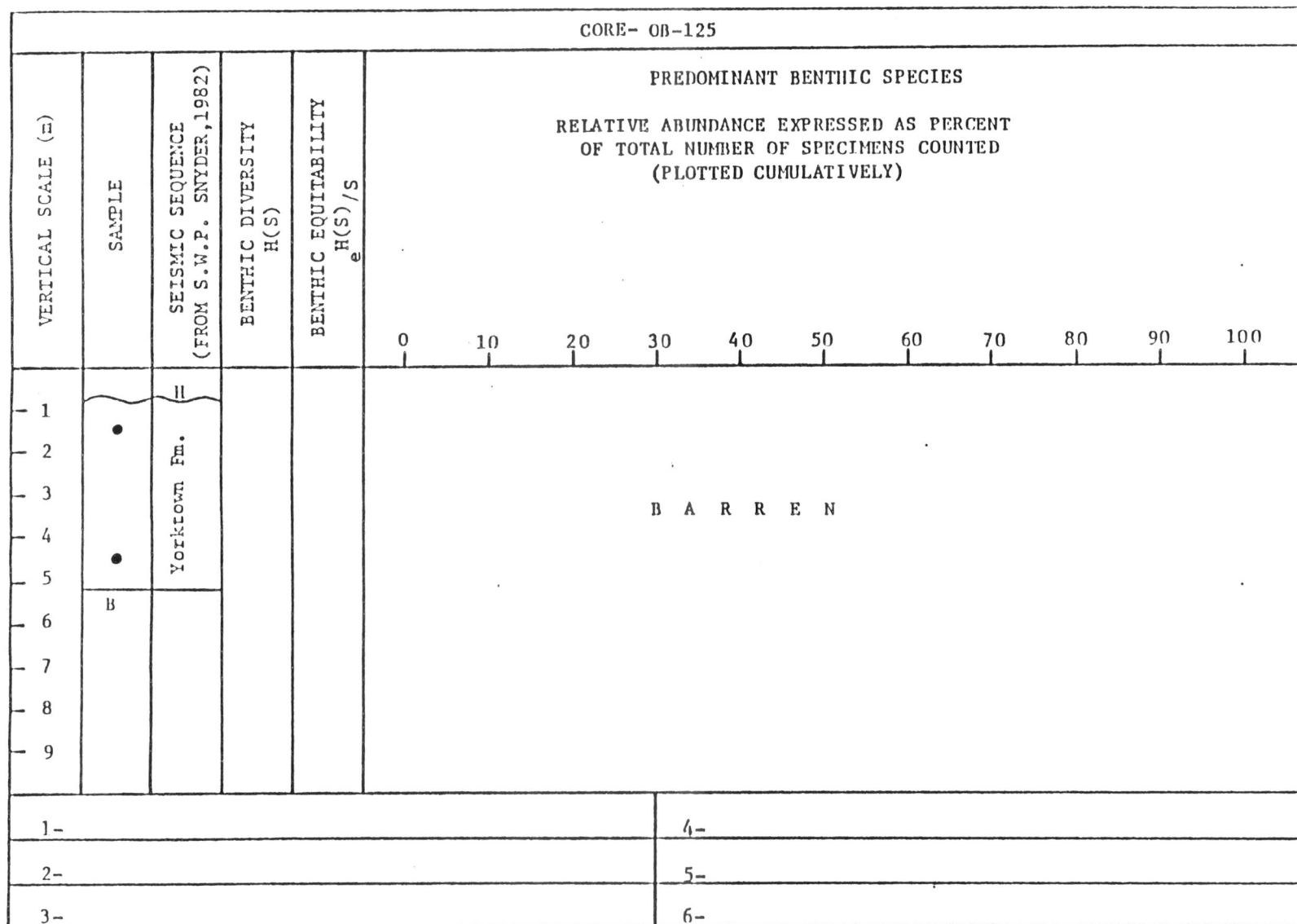
H= Holocene B= Bottom of core



B= Bottom of core



B= Bottom of core

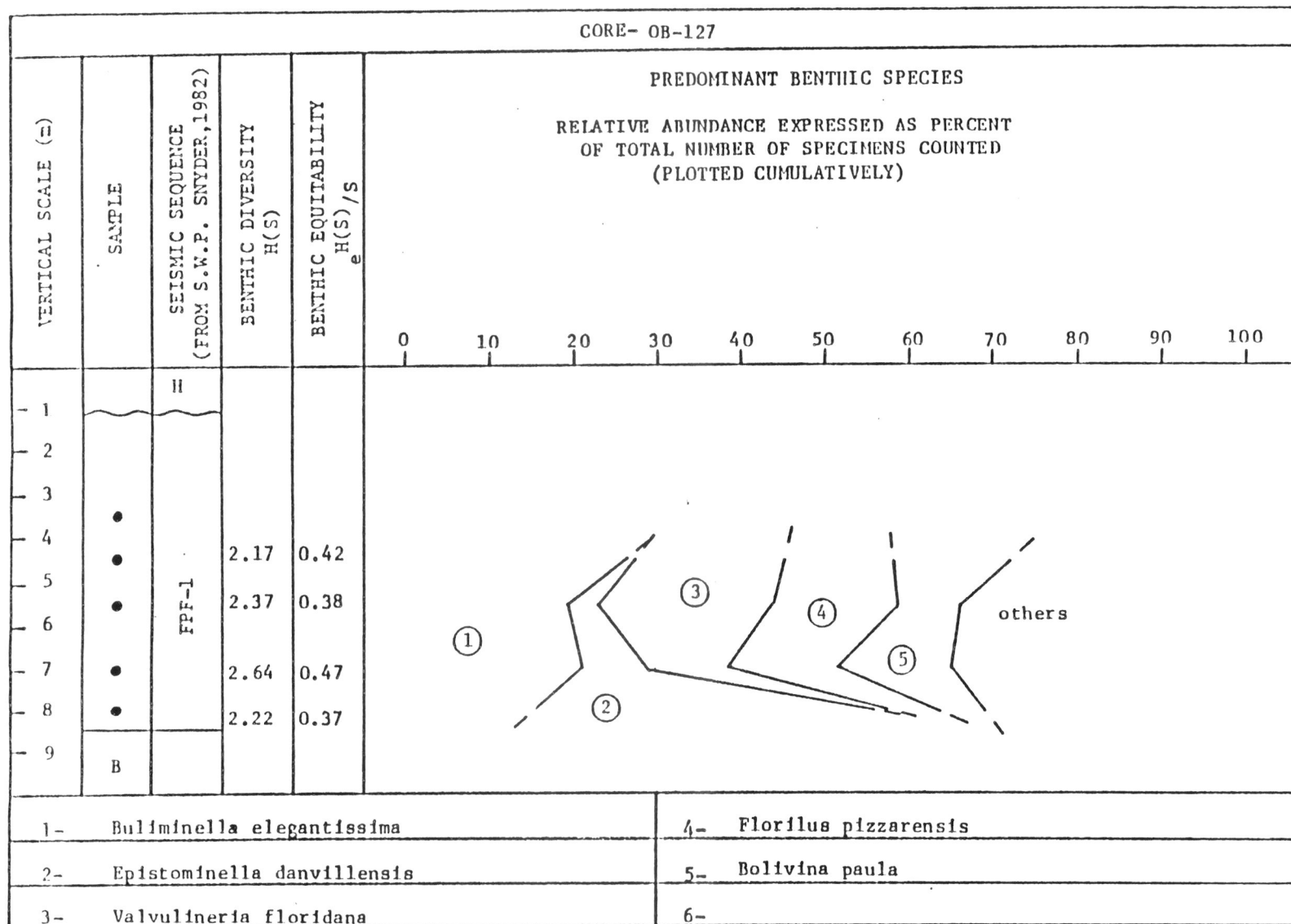


B= Bottom of core II= Holocene

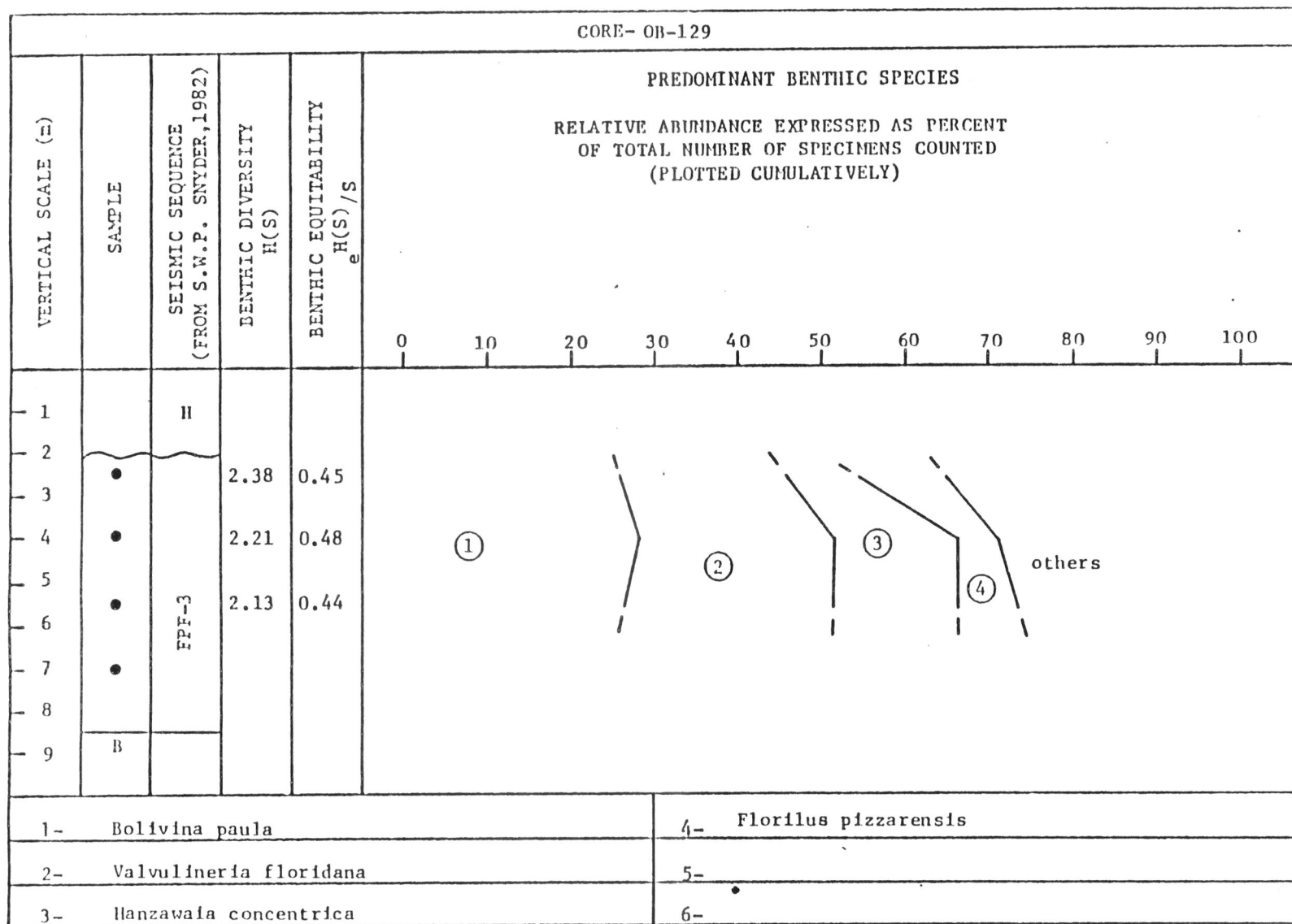
| CORE-OB-126         |        |                                                |                             |                                    |                                                                                                                                              |
|---------------------|--------|------------------------------------------------|-----------------------------|------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|
| VERTICAL SCALE (ft) | SAMPLE | SEISMIC SEQUENCE<br>(FROM S.W.P. SNYDER, 1982) | BENTHIC DIVERSITY<br>$H(S)$ | BENTHIC EQUITABILITY<br>$H_e(S)/S$ | PREDOMINANT BENTHIC SPECIES<br><br>RELATIVE ABUNDANCE EXPRESSED AS PERCENT<br>OF TOTAL NUMBER OF SPECIMENS COUNTED<br>(PLOTTED CUMULATIVELY) |
|                     |        |                                                |                             |                                    |                                                                                                                                              |
| 1                   | •      | Silverdale Fm.                                 |                             |                                    | <div> 0102030405060708090100 </div>                                                                                                          |
| 2                   |        |                                                |                             |                                    |                                                                                                                                              |
| 3                   |        |                                                |                             |                                    |                                                                                                                                              |
| 4                   | •      |                                                |                             |                                    |                                                                                                                                              |
| 5                   | •      |                                                |                             |                                    |                                                                                                                                              |
| 6                   |        |                                                |                             |                                    |                                                                                                                                              |
| 7                   | •      |                                                |                             |                                    |                                                                                                                                              |
| 8                   |        |                                                |                             |                                    |                                                                                                                                              |
| 9                   | B      |                                                |                             |                                    |                                                                                                                                              |
| 1-                  | 4-     |                                                |                             |                                    |                                                                                                                                              |
| 2-                  | 5-     |                                                |                             |                                    |                                                                                                                                              |
| 3-                  | 6-     |                                                |                             |                                    |                                                                                                                                              |

B= Bottom of core

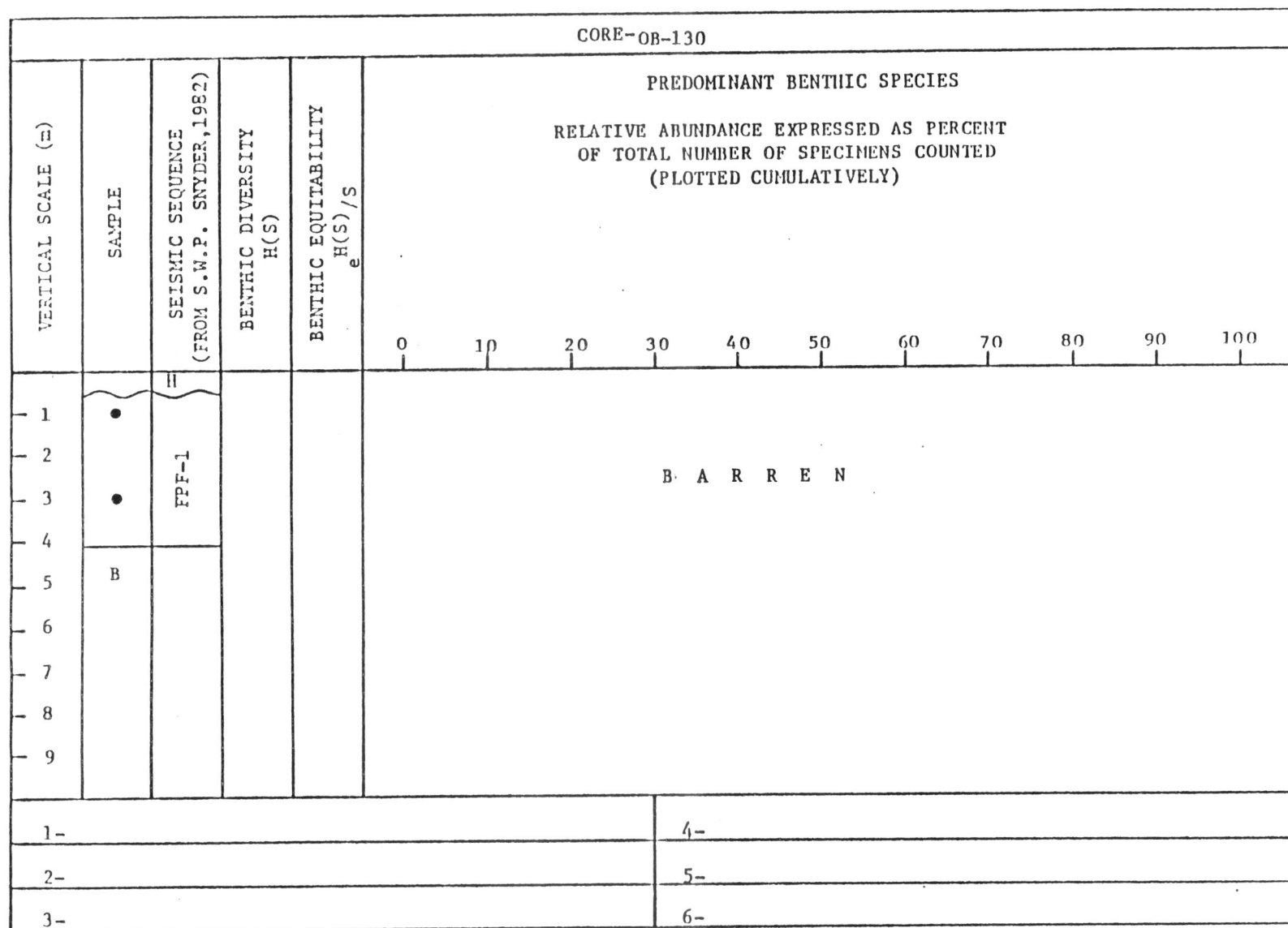




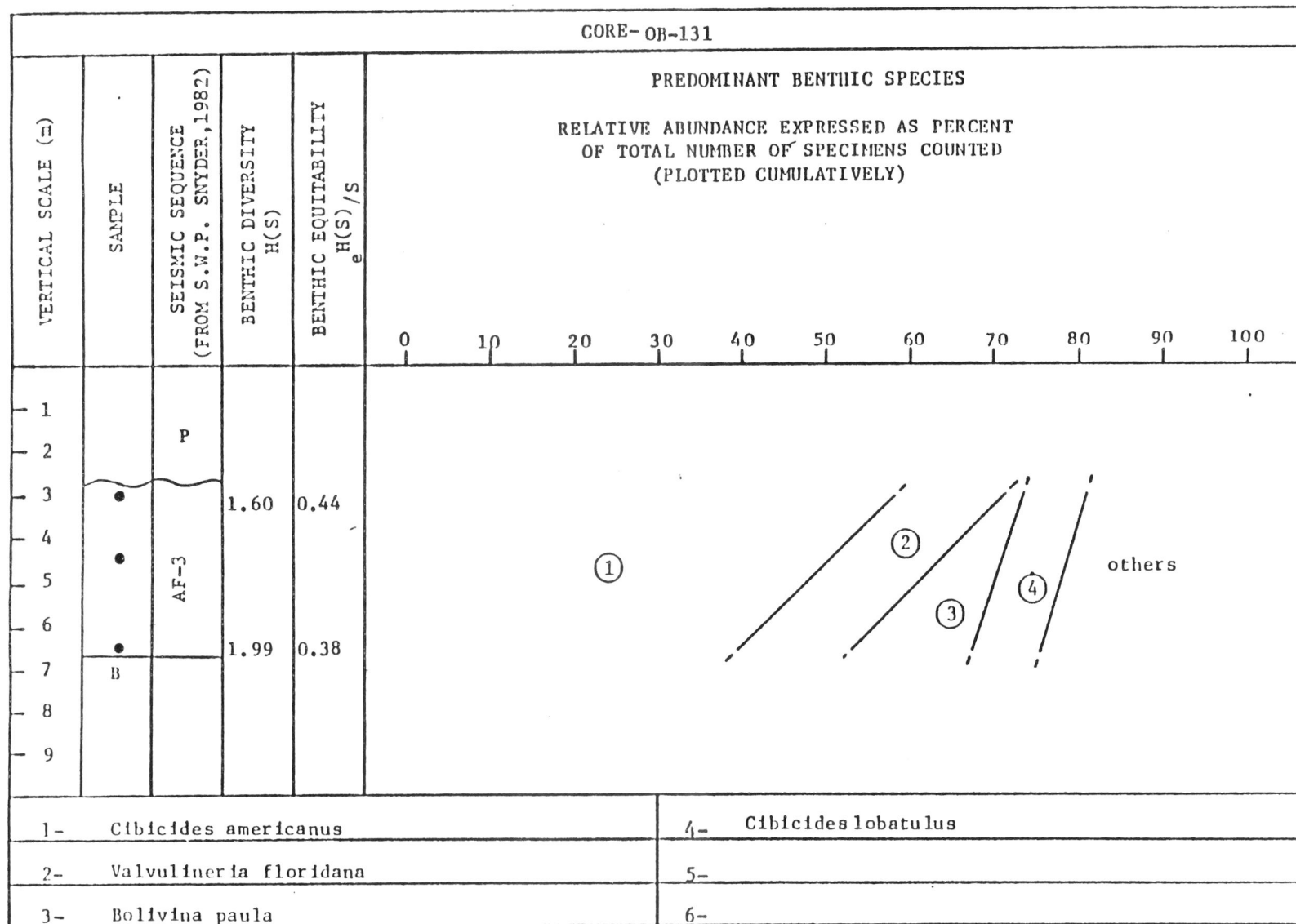
II= Holocene B= Bottom of core



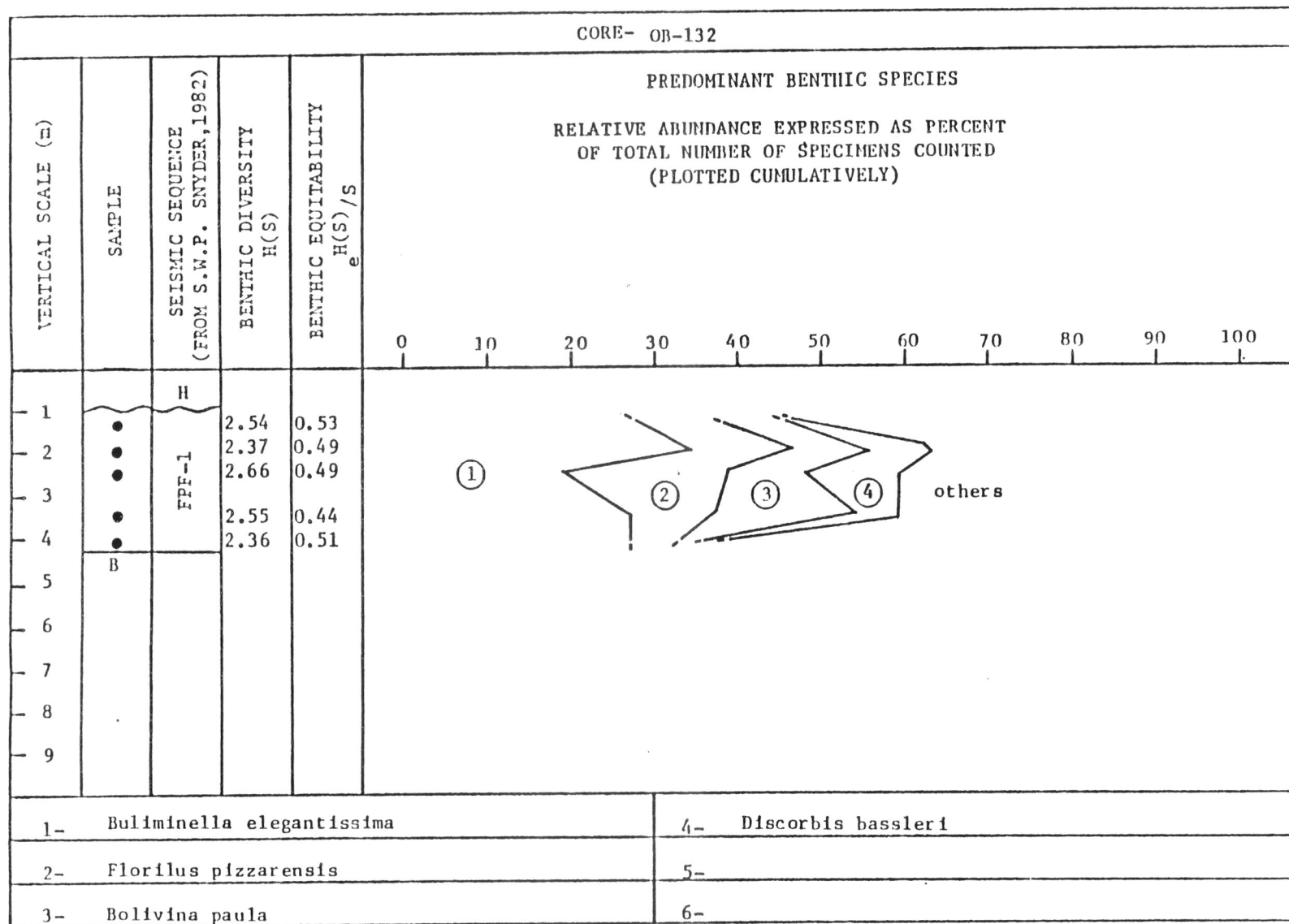
II= Holocene B= Bottom of core



H= Holocene    B= Bottom of core



P= Pleistocene    B= Bottom of core



H= Holocene B= Bottom of core

Appendix B  
Sedimentary Description of Sand Fraction  
in Core Samples

Appendix B. Sedimentary description of sand fraction in core samples.

The following data is expressed as percentage of 100 randomly counted grains in the sand-sized fraction. P/B ratios are also presented. The headings are abbreviated as follows:

Biotic

FOR= Foraminifers  
OST= Ostracods  
RAD= Radiolarians  
DIA= Diatoms  
SPIC= Spicules  
ECH= Echinoid fragments  
MOL= Mollusk fragments  
BRY= Bryozoan fragments  
BAR= Barnacle fragments

Lithic

PHOS= Phosphate  
QTZ= Quartz  
C/D= Calcite/dolomite  
GLAU= Glauconite  
MICA= Mica  
OTH= Other  
  
\*= Sample barren of foraminifera  
Y= Yorktown Formation  
S= Silverdale Formation

| CORE  | DEPTH<br>(m) | SEISMIC<br>SEQUENCE | P/B<br>RATIO | BIOTIC<br>FOR | OST | RAD | DIA | SPIC | ECI | MOL | BRY | BAR | OTH | LITHIC<br>PHOS | QTZ | C/D | GLAU | MICA | OTH |
|-------|--------------|---------------------|--------------|---------------|-----|-----|-----|------|-----|-----|-----|-----|-----|----------------|-----|-----|------|------|-----|
| OB-41 | 3.50-3.75    | AF-2                | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 1              | 97  | 0   | 0    | 0    | 2   |
| OB-41 | 5.00-5.25    | AF-2                | *            | 0             | 0   | 0   | 0   | 0    | 0   | 2   | 0   | 0   | 0   | 0              | 97  | 0   | 0    | 0    | 1   |
| OB-41 | 7.00-7.25    | AF-2                | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 0              | 90  | 0   | 0    | 0    | 10  |
| OB-42 | 1.25-1.50    | BBF-1               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 0              | 27  | 1   | 0    | 0    | 72  |
| OB-42 | 3.00-3.25    | BBF-1               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 1              | 78  | 0   | 3    | 2    | 16  |
| OB-42 | 4.50-4.75    | BBF-1               | *            | 0             | 0   | 0   | 2   | 0    | 0   | 0   | 0   | 0   | 0   | 2              | 78  | 0   | 4    | 0    | 14  |
| OB-42 | 6.00-6.25    | BBF-1               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 1   | 0   | 0   | 0   | 1              | 73  | 0   | 3    | 0    | 23  |
| OB-42 | 6.50-6.75    | BBF-1               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 5              | 50  | 0   | 2    | 3    | 40  |
| OB-43 | 1.00-1.25    | BBF-1               | 1:306        | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 0              | 50  | 0   | 0    | 2    | 48  |
| OB-43 | 2.00-2.25    | BBF-1               | *            | 0             | 0   | 0   | 0   | 0    | 1   | 0   | 0   | 0   | 0   | 1              | 54  | 0   | 1    | 0    | 43  |
| OB-43 | 3.00-3.25    | BBF-1               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 1              | 64  | 0   | 1    | 4    | 30  |
| OB-43 | 4.00-4.25    | BBF-1               | *            | 0             | 0   | 1   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 0              | 57  | 0   | 1    | 5    | 37  |
| OB-44 | 1.75-2.00    | AF-1                | *            | 0             | 0   | 0   | 0   | 0    | 0   | 17  | 0   | 0   | 0   | 1              | 80  | 0   | 0    | 1    | 1   |
| OB-44 | 3.75-4.00    | AF-1                | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 0              | 25  | 0   | 0    | 0    | 75  |
| OB-44 | 5.50-5.75    | AF-1                | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 3              | 96  | 1   | 0    | 0    | 0   |
| OB-45 | 0.75-1.00    | FPP-6               | 1:20         | 4             | 0   | 0   | 0   | 0    | 1   | 2   | 2   | 63  | 0   | 0              | 26  | 2   | 0    | 0    | 0   |
| OB-45 | 3.00-3.25    | FPP-6               | 1:2          | 1             | 0   | 0   | 0   | 0    | 1   | 2   | 0   | 0   | 0   | 1              | 95  | 0   | 0    | 0    | 0   |
| OB-45 | 4.75-5.00    | FPP-6               | 1:6          | 1             | 0   | 0   | 0   | 0    | 0   | 4   | 0   | 0   | 0   | 0              | 95  | 0   | 0    | 0    | 0   |
| OB-46 | 2.75-3.00    | FPP-5               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 0              | 100 | 0   | 0    | 0    | 0   |
| OB-46 | 5.00-5.25    | FPP-5               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 2              | 98  | 0   | 0    | 0    | 0   |
| OB-46 | 7.00-7.25    | FPP-5               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 4              | 96  | 0   | 0    | 0    | 0   |
| OB-48 | 1.25-1.50    | FPP-3               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 1   | 0   | 0   | 0   | 4              | 93  | 0   | 0    | 0    | 2   |
| OB-48 | 2.25-2.50    | FPP-3               | 1:5          | 1             | 0   | 0   | 0   | 0    | 0   | 5   | 0   | 0   | 0   | 2              | 91  | 0   | 0    | 0    | 1   |
| OB-48 | 4.75-5.00    | FPP-3               | 1:5          | 2             | 0   | 0   | 0   | 0    | 0   | 4   | 0   | 0   | 0   | 4              | 90  | 0   | 0    | 0    | 0   |
| OB-48 | 6.25-6.50    | FPP-3               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 1              | 99  | 0   | 0    | 0    | 0   |
| OB-48 | 7.50-8.00    | FPP-3               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 1   | 0   | 0   | 0   | 0              | 97  | 2   | 0    | 0    | 0   |
| OB-49 | 1.50-1.75    | FPP-2               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 2              | 95  | 0   | 0    | 1    | 2   |
| OB-49 | 3.50-3.75    | FPP-2               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 0              | 100 | 0   | 0    | 0    | 0   |
| OB-49 | 6.00-6.25    | FPP-2               | *            | 0             | 0   | 0   | 1   | 0    | 0   | 0   | 0   | 0   | 0   | 1              | 97  | 0   | 0    | 1    | 0   |
| OB-49 | 8.90-9.12    | FPP-2               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 2              | 96  | 2   | 0    | 0    | 0   |
| OB-50 | 3.25-3.60    | FPP-6               | 1:2          | 3             | 0   | 0   | 0   | 0    | 1   | 3   | 1   | 0   | 0   | 4              | 88  | 0   | 0    | 0    | 0   |
| OB-50 | 4.43-4.75    | FPP-6               | *            | 0             | 0   | 0   | 4   | 0    | 0   | 2   | 0   | 0   | 0   | 2              | 92  | 0   | 0    | 0    | 0   |
| OB-50 | 5.75-6.00    | FPP-6               | *            | 0             | 0   | 0   | 47  | 0    | 0   | 0   | 0   | 0   | 0   | 3              | 32  | 0   | 0    | 2    | 20  |
| OB-51 | 3.00         | AF-1                | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 8              | 91  | 0   | 0    | 0    | 1   |
| OB-51 | 6.00         | AF-1                | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 9              | 80  | 0   | 0    | 0    | 11  |
| OB-52 | 1.25-1.50    | BBF-1               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 56  | 0   | 3   | 0   | 2              | 39  | 1   | 0    | 2    | 0   |
| OB-52 | 2.70-3.00    | BBF-1               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 2              | 97  | 0   | 0    | 0    | 1   |
| OB-52 | 3.75-4.00    | BBF-1               | 1:25         | 8             | 0   | 0   | 0   | 0    | 1   | 7   | 0   | 0   | 0   | 2              | 82  | 0   | 0    | 1    | 0   |
| OB-53 | 1.25-1.50    | BBF-1               | 1:89         | 0             | 0   | 0   | 35  | 0    | 0   | 0   | 0   | 0   | 0   | 4              | 64  | 0   | 0    | 0    | 0   |
| OB-53 | 2.75-3.00    | BBF-1               | 1:69         | 1             | 0   | 0   | 1   | 0    | 0   | 0   | 0   | 0   | 0   | 14             | 83  | 0   | 0    | 0    | 0   |
| OB-53 | 3.30-3.50    | BBF-1               | 1:64         | 0             | 0   | 0   | 2   | 1    | 0   | 1   | 0   | 0   | 0   | 20             | 76  | 0   | 0    | 0    | 0   |
| OB-53 | 4.75-5.00    | BBF-1               | 1:78         | 1             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 27             | 72  | 0   | 0    | 0    | 0   |
| OB-53 | 5.25-5.50    | BBF-1               | 1:100        | 1             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 24             | 74  | 0   | 0    | 0    | 1   |
| OB-53 | 6.25-6.50    | BBF-1               | 1:103        | 2             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 28             | 70  | 0   | 0    | 0    | 0   |
| OB-54 | 2.25         | FPP-1               | *            | 0             | 0   | 0   | 1   | 0    | 1   | 4   | 0   | 1   | 0   | 0              | 91  | 0   | 1    | 0    | 1   |
| OB-54 | 3.00         | FPP-1               | *            | 0             | 0   | 1   | 0   | 0    | 0   | 7   | 0   | 0   | 0   | 0              | 92  | 0   | 0    | 0    | 0   |
| OB-54 | 3.50         | FPP-1               | *            | 0             | 0   | 0   | 0   | 1    | 0   | 6   | 0   | 0   | 0   | 0              | 93  | 0   | 0    | 0    | 0   |
| OB-57 | 0.75-1.00    | FPP-6               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 1              | 97  | 0   | 0    | 0    | 2   |
| OB-57 | 3.25-3.50    | FPP-6               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 1              | 96  | 0   | 0    | 0    | 3   |
| OB-57 | 5.25-5.50    | FPP-5               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 2              | 97  | 0   | 0    | 1    | 0   |
| OB-57 | 8.25-8.50    | FPP-5               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 2              | 92  | 0   | 0    | 6    | 0   |



| CORE   | DEPTH<br>(m) | SEISMIC<br>SEQUENCE | P/B<br>RATIO | BIOTIC<br>FOR | OST | RAD | DIA | SPIC | ECH | MOL | BRY | BAR | OTH | LITHIC<br>PHOS | QTZ | C/D | GLAU | MICA | OTH |
|--------|--------------|---------------------|--------------|---------------|-----|-----|-----|------|-----|-----|-----|-----|-----|----------------|-----|-----|------|------|-----|
| OB-59  | 4.75-5.00    | BBF-1               | 1:9          | 9             | 0   | 0   | 0   | 0    | 3   | 54  | 7   | 5   | 0   | 0              | 22  | 0   | 0    | 0    | 0   |
| OB-59  | 5.89-6.00    | BBF-1               | 1:4          | 1             | 0   | 0   | 0   | 0    | 0   | 4   | 0   | 0   | 0   | 0              | 94  | 0   | 0    | 1    | 0   |
| OB-59  | 6.75-7.00    | BBF-1               | 1:6          | 4             | 0   | 0   | 0   | 0    | 0   | 35  | 0   | 0   | 0   | 0              | 58  | 0   | 0    | 3    | 0   |
| OB-59  | 7.80-8.20    | BBF-1               | 1:10         | 4             | 0   | 0   | 0   | 0    | 0   | 9   | 1   | 0   | 0   | 2              | 82  | 0   | 2    | 0    | 0   |
| OB-92  | 4.00         | BBF-2               | *            | 0             | 0   | 0   | 2   | 0    | 0   | 1   | 0   | 0   | 0   | 3              | 94  | 0   | 0    | 0    | 0   |
| OB-92  | 5.50         | BBF-2               | 1:307        | 1             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 1              | 98  | 0   | 0    | 0    | 0   |
| OB-92  | 6.00         | BBF-2               | 1:101        | 1             | 0   | 0   | 0   | 0    | 0   | 2   | 0   | 0   | 0   | 1              | 97  | 0   | 0    | 0    | 0   |
| OB-94  | 1.00         | BBF-1               | 1:55         | 1             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 46             | 56  | 0   | 0    | 0    | 0   |
| OB-99  | 5.00         | Y?                  | *            | 0             | 0   | 0   | 0   | 0    | 0   | 2   | 0   | 0   | 0   | 0              | 98  | 0   | 0    | 0    | 0   |
| OB-103 | 1.00         | FPF-2               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 1              | 96  | 1   | 0    | 0    | 2   |
| OB-103 | 2.00         | FPF-2               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 1              | 95  | 2   | 0    | 0    | 2   |
| OB-103 | 3.00         | FPF-2               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 2              | 97  | 0   | 0    | 0    | 1   |
| OB-103 | 4.00         | FPF-2               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 2              | 96  | 1   | 0    | 0    | 1   |
| OB-103 | 5.00         | FPF-2               | 1:77         | 1             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 2              | 97  | 0   | 0    | 0    | 0   |
| OB-103 | 5.90         | FPF-2               | 1:17         | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 3              | 97  | 0   | 0    | 0    | 0   |
| OB-105 | 1.50         | FPF-1               | 1:2          | 9             | 0   | 0   | 0   | 0    | 3   | 0   | 0   | 0   | 0   | 2              | 85  | 0   | 1    | 0    | 0   |
| OB-105 | 4.50         | FPF-1               | 1:2          | 3             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 5              | 90  | 0   | 0    | 0    | 2   |
| OB-105 | 7.50         | FPF-1               | 1:1          | 2             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 3              | 92  | 0   | 0    | 1    | 1   |
| OB-105 | 9.10         | FPF-1               | 1:2          | 7             | 0   | 0   | 0   | 0    | 0   | 7   | 0   | 0   | 0   | 2              | 87  | 0   | 0    | 1    | 0   |
| OB-123 | 1.00         | S                   | *            | 1             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 0              | 98  | 0   | 0    | 1    | 0   |
| OB-123 | 3.00         | S                   | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 0              | 100 | 0   | 0    | 0    | 0   |
| OB-123 | 4.50         | S                   | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 0              | 96  | 0   | 1    | 2    | 1   |
| OB-123 | 6.70         | S                   | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 0              | 98  | 0   | 0    | 1    | 0   |
| OB-125 | 1.50         | Y?                  | *            | 0             | 0   | 0   | 0   | 0    | 1   | 3   | 0   | 0   | 0   | 3              | 93  | 0   | 0    | 0    | 0   |
| OB-125 | 4.50         | Y?                  | *            | 0             | 0   | 0   | 0   | 0    | 1   | 29  | 0   | 0   | 0   | 2              | 68  | 0   | 0    | 0    | 0   |
| OB-126 | 1.00         | S                   | *            | 2             | 0   | 0   | 0   | 0    | 0   | 2   | 0   | 0   | 0   | 0              | 95  | 0   | 0    | 1    | 0   |
| OB-126 | 3.50         | S                   | *            | 1             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 1   | 1              | 95  | 0   | 0    | 1    | 1   |
| OB-126 | 5.00         | S                   | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 1              | 99  | 0   | 0    | 0    | 0   |
| OB-126 | 7.00         | S                   | *            | 2             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 2              | 96  | 0   | 0    | 0    | 0   |
| OB-127 | 3.50         | FPF-1               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 16             | 84  | 0   | 0    | 0    | 0   |
| OB-127 | 4.50         | FPF-1               | 1:9          | 2             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 9              | 89  | 0   | 0    | 0    | 0   |
| OB-127 | 5.50         | FPF-1               | 1:5          | 1             | 0   | 0   | 0   | 0    | 2   | 0   | 0   | 0   | 0   | 6              | 90  | 0   | 0    | 1    | 0   |
| OB-127 | 7.00         | FPF-1               | 1:1          | 2             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 1              | 97  | 0   | 0    | 0    | 0   |
| OB-127 | 8.00         | FPF-1               | 1:1          | 5             | 0   | 0   | 0   | 0    | 1   | 0   | 0   | 0   | 0   | 3              | 91  | 0   | 0    | 0    | 0   |
| OB-129 | 2.50         | FPF-3               | 1:1          | 3             | 0   | 0   | 0   | 0    | 4   | 0   | 0   | 0   | 0   | 0              | 92  | 0   | 0    | 0    | 1   |
| OB-129 | 4.00         | FPF-3               | 1:1          | 4             | 1   | 0   | 0   | 0    | 1   | 0   | 0   | 0   | 0   | 2              | 92  | 0   | 0    | 0    | 0   |
| OB-129 | 5.50         | FPF-3               | 1:6          | 2             | 0   | 0   | 0   | 0    | 1   | 0   | 0   | 0   | 0   | 5              | 91  | 0   | 0    | 0    | 1   |
| OB-129 | 7.00         | FPF-3               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 4              | 95  | 1   | 0    | 0    | 0   |
| OB-130 | 1.00         | FPF-1               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 0              | 98  | 0   | 0    | 2    | 0   |
| OB-130 | 3.00         | FPF-1               | *            | 0             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 0              | 100 | 0   | 0    | 0    | 0   |
| OB-131 | 3.00         | AF-3                | 1:4          | 8             | 0   | 0   | 0   | 0    | 0   | 23  | 1   | 3   | 0   | 0              | 64  | 0   | 0    | 0    | 1   |
| OB-131 | 4.50         | AF-3                | *            | 1             | 0   | 0   | 0   | 0    | 0   | 10  | 0   | 0   | 0   | 1              | 18  | 0   | 0    | 0    | 70  |
| OB-131 | 6.59         | AF-3                | 1:10         | 0             | 0   | 0   | 0   | 0    | 0   | 15  | 0   | 0   | 0   | 1              | 84  | 0   | 0    | 0    | 0   |
| OB-132 | 1.50         | FPF-1               | 1:1          | 1             | 0   | 0   | 0   | 0    | 0   | 0   | 0   | 0   | 0   | 0              | 99  | 0   | 0    | 0    | 0   |
| OB-132 | 2.00         | FPF-1               | 1:1          | 2             | 0   | 0   | 0   | 0    | 1   | 1   | 0   | 0   | 0   | 0              | 96  | 0   | 0    | 0    | 0   |
| OB-132 | 2.50         | FPF-1               | 1:1          | 3             | 0   | 0   | 0   | 0    | 1   | 0   | 0   | 0   | 0   | 0              | 94  | 0   | 0    | 2    | 1   |
| OB-132 | 3.50         | FPF-1               | 1:1          | 2             | 0   | 0   | 0   | 0    | 2   | 0   | 0   | 0   | 0   | 0              | 94  | 0   | 0    | 0    | 2   |
| OB-132 | 4.10         | FPF-1               | 1:3          | 1             | 0   | 0   | 0   | 0    | 0   | 2   | 0   | 0   | 0   | 0              | 95  | 0   | 0    | 2    | 0   |

## Appendix C

Species Range Chart

Central Onslow Bay

Appendix C. Species range chart, Central Onslow Bay.

Planktonic foraminifera are presented in the first part, benthic foraminifera in the second part. Species are grouped by genera that are arranged alphabetically. Abbreviations are as follows:

Planktonic foraminifera

R= Rare, <3%  
F= Few, 3-15%  
C= Common, 15-30%  
A= Abundant, >30%

Benthic foraminifera

Expressed as percentage of total foraminiferal assemblage.

| PLANKTONIC SPECIES |           |                                   |                               |                                |                           |                                     |                              |                                  |                                      |                               |                                |
|--------------------|-----------|-----------------------------------|-------------------------------|--------------------------------|---------------------------|-------------------------------------|------------------------------|----------------------------------|--------------------------------------|-------------------------------|--------------------------------|
|                    |           | <i>Cassigerinella chipolensis</i> | <i>Catapsydrax dissimilis</i> | <i>Catapsydrax stainforthi</i> | <i>Catapsydrax unicus</i> | <i>Globigerina angustumbilicata</i> | <i>Globigerina juvenilis</i> | <i>Globigerina praebulloides</i> | <i>Globigerina pseudociperoensis</i> | <i>Globigerina tripartita</i> | <i>Globigerina venezuelana</i> |
| CORE               | DEPTH (m) |                                   |                               |                                |                           |                                     |                              |                                  |                                      |                               |                                |
| OB-43              | 1.00-1.25 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ..                               | ....                                 | ....                          | ....                           |
| OB-45              | 0.75-1.00 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | F                                | ....                                 | ....                          | F                              |
| OB-45              | 3.00-3.25 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | F                                | ....                                 | ....                          | F                              |
| OB-45              | 4.75-5.00 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | F                                | ....                                 | ....                          | F                              |
| OB-48              | 2.25-2.50 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | F                                | ....                                 | R                             | ....                           |
| OB-48              | 4.75-5.00 | ....                              | ....                          | ....                           | R                         | ....                                | ....                         | F                                | ....                                 | R                             | ....                           |
| OB-50              | 3.25-3.60 | ....                              | R                             | ....                           | R                         | ....                                | ....                         | F                                | ....                                 | R                             | ....                           |
| OB-52              | 3.75-4.00 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-53              | 1.25-1.50 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-53              | 2.75-3.00 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-53              | 3.30-3.50 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-53              | 4.75-5.00 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-53              | 5.25-5.50 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-53              | 6.25-6.50 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-59              | 4.75-5.00 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-59              | 5.89-6.00 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | C                                | ....                                 | ....                          | ....                           |
| OB-59              | 6.75-7.00 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | C                                | ....                                 | ....                          | F                              |
| OB-59              | 7.80-8.20 | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | C                                | ....                                 | ....                          | ....                           |
| OB-92              | 5.50      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-92              | 6.00      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-94              | 1.00      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-103             | 5.00      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-103             | 5.90      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-105             | 1.50      | F                                 | ....                          | R                              | ....                      | ....                                | R                            | F                                | ....                                 | R                             | C                              |
| OB-105             | 4.50      | F                                 | ....                          | ....                           | R                         | F                                   | R                            | F                                | ....                                 | ....                          | C                              |
| OB-105             | 7.50      | F                                 | ....                          | ....                           | ....                      | R                                   | ....                         | C                                | ....                                 | R                             | C                              |
| OB-105             | 9.10      | F                                 | ....                          | ....                           | ....                      | R                                   | ....                         | F                                | ....                                 | ....                          | ....                           |
| OB-127             | 4.50      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-127             | 5.50      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-127             | 7.00      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-127             | 8.00      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-129             | 2.50      | ....                              | ....                          | ....                           | R                         | ....                                | ....                         | F                                | ....                                 | R                             | R                              |
| OB-129             | 4.00      | ....                              | ....                          | ....                           | R                         | ....                                | ....                         | F                                | ....                                 | R                             | F                              |
| OB-129             | 5.50      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-131             | 3.00      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | F                                | R                                    | ....                          | R                              |
| OB-131             | 6.59      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | F                                | R                                    | ....                          | R                              |
| OB-132             | 1.50      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | R                             | F                              |
| OB-132             | 2.00      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | ....                             | ....                                 | ....                          | ....                           |
| OB-132             | 2.50      | ....                              | ....                          | ....                           | ....                      | ....                                | ....                         | F                                | ....                                 | ....                          | F                              |
| OB-132             | 3.50      | ....                              | ....                          | ....                           | ....                      | R                                   | R                            | C                                | ....                                 | ....                          | F                              |
| OB-132             | 4.10      | ....                              | ....                          | ....                           | R                         | ....                                | ....                         | C                                | ....                                 | ....                          | ....                           |

| PLANKTONIC SPECIES |           |                          |                                |                            |                                          |                                                   |                                                    |                                                 |                                                 |                                              |                                        |                                            |                                     |
|--------------------|-----------|--------------------------|--------------------------------|----------------------------|------------------------------------------|---------------------------------------------------|----------------------------------------------------|-------------------------------------------------|-------------------------------------------------|----------------------------------------------|----------------------------------------|--------------------------------------------|-------------------------------------|
|                    |           | <i>Globigerina woodi</i> | <i>Globigerinita glutinata</i> | <i>Globigerinita uvula</i> | <i>Globigerinoides obliquus obliquus</i> | <i>Globigerinoides quadrilobatus altiapertura</i> | <i>Globigerinoides quadrilobatus praeimmaturus</i> | <i>Globigerinoides quadrilobatus primordius</i> | <i>Globigerinoides quadrilobatus sacculifer</i> | <i>Globigerinoides quadrilobatus triloba</i> | <i>Globigerinoides sicanus sicanus</i> | <i>Globigerinoides sicanus praesicanus</i> | <i>Globigerinoides subquadratus</i> |
| CORE               | DEPTH (m) |                          |                                |                            |                                          |                                                   |                                                    |                                                 |                                                 |                                              |                                        |                                            |                                     |
| OB-43              | 1.00-1.25 | ....                     | ....                           | ....                       | ....                                     | ..                                                | ..                                                 | ..                                              | ..                                              | ..                                           | ..                                     | ..                                         | ..                                  |
| OB-45              | 0.75-1.00 | ....                     | ....                           | ....                       | ....                                     | F                                                 | R                                                  | ....                                            | F                                               | C                                            | ....                                   | F                                          | R                                   |
| OB-45              | 3.00-3.25 | ....                     | R                              | ....                       | ....                                     | F                                                 | R                                                  | ....                                            | F                                               | C                                            | ....                                   | F                                          | ....                                |
| OB-45              | 4.75-5.00 | ....                     | ....                           | R                          | ....                                     | F                                                 | ....                                               | ....                                            | F                                               | C                                            | ....                                   | F                                          | ....                                |
| OB-48              | 2.25-2.50 | R                        | ....                           | ....                       | ....                                     | F                                                 | R                                                  | R                                               | F                                               | A                                            | ....                                   | ....                                       | ....                                |
| OB-48              | 4.75-5.00 | ....                     | R                              | ....                       | R                                        | F                                                 | R                                                  | F                                               | F                                               | A                                            | ....                                   | ....                                       | ....                                |
| OB-50              | 3.25-3.60 | R                        | ....                           | ....                       | F                                        | F                                                 | R                                                  | R                                               | F                                               | C                                            | ....                                   | R                                          | R                                   |
| OB-52              | 3.75-4.00 | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-53              | 1.25-2.50 | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-53              | 2.75-3.00 | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-53              | 3.30-3.50 | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-53              | 4.75-5.00 | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-53              | 5.25-5.50 | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-53              | 6.25-6.50 | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-59              | 4.75-5.00 | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-59              | 5.89-6.00 | ....                     | ....                           | ....                       | R                                        | ....                                              | ....                                               | ....                                            | F                                               | C                                            | ....                                   | ....                                       | A                                   |
| OB-59              | 6.75-7.00 | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | C                                   |
| OB-59              | 7.80-8.20 | ....                     | ....                           | ....                       | R                                        | ....                                              | ....                                               | ....                                            | R                                               | C                                            | ....                                   | ....                                       | ....                                |
| OB-92              | 5.50      | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-92              | 6.00      | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-94              | 1.00      | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-103             | 5.00      | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-103             | 5.90      | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-105             | 1.50      | R                        | R                              | F                          | R                                        | R                                                 | R                                                  | F                                               | R                                               | F                                            | ....                                   | ....                                       | R                                   |
| OB-105             | 4.50      | R                        | F                              | F                          | ....                                     | R                                                 | R                                                  | F                                               | R                                               | F                                            | ....                                   | ....                                       | R                                   |
| OB-105             | 7.50      | R                        | F                              | F                          | R                                        | R                                                 | ....                                               | F                                               | R                                               | F                                            | ....                                   | ....                                       | ....                                |
| OB-105             | 9.10      | R                        | R                              | R                          | ....                                     | R                                                 | ....                                               | F                                               | R                                               | F                                            | ....                                   | ....                                       | R                                   |
| OB-127             | 4.50      | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-127             | 5.50      | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-127             | 7.00      | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-127             | 8.00      | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-129             | 2.50      | ....                     | R                              | ....                       | R                                        | F                                                 | R                                                  | R                                               | F                                               | A                                            | ....                                   | ....                                       | F                                   |
| OB-129             | 4.00      | ....                     | R                              | ....                       | F                                        | F                                                 | R                                                  | R                                               | F                                               | A                                            | ....                                   | ....                                       | F                                   |
| OB-129             | 5.50      | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | R                                      | ....                                       | ....                                |
| OB-131             | 3.00      | R                        | ....                           | ....                       | R                                        | ....                                              | R                                                  | ....                                            | F                                               | A                                            | R                                      | R                                          | C                                   |
| OB-131             | 6.59      | ....                     | ....                           | ....                       | R                                        | ....                                              | R                                                  | F                                               | F                                               | C                                            | ....                                   | R                                          | C                                   |
| OB-132             | 1.50      | R                        | ....                           | R                          | R                                        | F                                                 | ....                                               | ....                                            | F                                               | F                                            | ....                                   | ....                                       | R                                   |
| OB-132             | 2.00      | ....                     | ....                           | ....                       | ....                                     | ....                                              | ....                                               | ....                                            | ....                                            | ....                                         | ....                                   | ....                                       | ....                                |
| OB-132             | 2.50      | R                        | R                              | ....                       | ....                                     | F                                                 | R                                                  | F                                               | F                                               | C                                            | ....                                   | ....                                       | R                                   |

| PLANKTONIC SPECIES                |           |      |      |      |      |      |      |      |      |      |      |      |
|-----------------------------------|-----------|------|------|------|------|------|------|------|------|------|------|------|
| Globoquadrina altispira altispira |           |      |      |      |      |      |      |      |      |      |      |      |
| Globoquadrina altispira globosa   |           |      |      |      |      |      |      |      |      |      |      |      |
| Globoquadrina baroemensis         |           |      |      |      |      |      |      |      |      |      |      |      |
| Globoquadrina dehiscens           |           |      |      |      |      |      |      |      |      |      |      |      |
| Globoquadrina larmei larmei       |           |      |      |      |      |      |      |      |      |      |      |      |
| Globorotalia birnagae             |           |      |      |      |      |      |      |      |      |      |      |      |
| Globorotalia fohsi peripheroronda |           |      |      |      |      |      |      |      |      |      |      |      |
| Globorotalia obesa                |           |      |      |      |      |      |      |      |      |      |      |      |
| Globorotalia opima nana           |           |      |      |      |      |      |      |      |      |      |      |      |
| Globorotalia siakensis            |           |      |      |      |      |      |      |      |      |      |      |      |
| Orbulina universa                 |           |      |      |      |      |      |      |      |      |      |      |      |
| CORE                              | DEPTH (m) |      |      |      |      |      |      |      |      |      |      |      |
| OB-43                             | 1.00-1.25 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-45                             | 0.75-1.00 | .... | F    | .... | .... | R    | .... | F    | .... | .... | F    | .... |
| OB-45                             | 3.00-3.25 | .... | F    | .... | R    | R    | .... | C    | F    | .... | F    | .... |
| OB-45                             | 4.75-5.00 | .... | .... | .... | .... | .... | .... | F    | F    | .... | F    | .... |
| OB-48                             | 2.25-2.50 | .... | F    | F    | .... | R    | .... | F    | R    | .... | F    | .... |
| OB-48                             | 4.75-5.00 | .... | F    | R    | F    | .... | .... | R    | F    | .... | F    | .... |
| OB-50                             | 3.25-3.60 | .... | .... | .... | .... | .... | .... | .... | R    | R    | F    | .... |
| OB-52                             | 3.75-4.00 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-53                             | 1.25-1.50 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-53                             | 2.75-3.00 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-53                             | 3.30-3.50 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-53                             | 4.75-5.00 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-53                             | 5.25-5.50 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-53                             | 6.25-6.50 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-53                             | 7.80-8.20 | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-59                             | 4.75-5.00 | .... | .... | .... | .... | .... | .... | .... | .... | .... | P    | .... |
| OB-59                             | 5.89-6.00 | .... | R    | R    | .... | R    | .... | R    | .... | .... | .... | .... |
| OB-59                             | 6.75-7.00 | .... | .... | .... | .... | .... | .... | .... | .... | .... | R    | .... |
| OB-59                             | 7.80-8.20 | .... | F    | .... | .... | R    | .... | R    | R    | .... | .... | .... |
| OB-92                             | 5.50      | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-92                             | 6.00      | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-94                             | 1.00      | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-103                            | 5.00      | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-103                            | 5.90      | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-105                            | 1.50      | R    | F    | .... | F    | .... | .... | R    | R    | R    | F    | .... |
| OB-105                            | 4.50      | .... | .... | .... | F    | .... | .... | R    | F    | R    | R    | .... |
| OB-105                            | 7.50      | .... | F    | R    | .... | R    | R    | F    | F    | F    | F    | .... |
| OB-105                            | 9.10      | .... | F    | .... | R    | .... | R    | F    | F    | R    | F    | .... |
| OB-127                            | 4.50      | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-127                            | 5.50      | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-127                            | 7.00      | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-127                            | 8.00      | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-129                            | 2.50      | .... | R    | R    | R    | F    | .... | F    | F    | .... | R    | .... |
| OB-129                            | 4.00      | .... | R    | F    | R    | F    | .... | F    | R    | .... | R    | .... |
| OB-129                            | 5.50      | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-131                            | 3.00      | .... | R    | R    | .... | R    | .... | F    | .... | .... | R    | .... |
| OB-131                            | 6.59      | .... | F    | .... | .... | R    | .... | R    | .... | .... | F    | .... |
| OB-132                            | 1.50      | .... | R    | F    | R    | .... | .... | C    | F    | .... | R    | .... |
| OB-132                            | 2.00      | .... | .... | .... | F    | .... | .... | .... | .... | .... | .... | .... |
| OB-132                            | 2.50      | .... | .... | .... | .... | R    | .... | C    | F    | .... | F    | .... |
| OB-132                            | 3.50      | .... | .... | F    | F    | R    | .... | C    | R    | .... | F    | .... |
| OB-132                            | 4.10      | .... | .... | R    | F    | R    | .... | C    | R    | .... | F    | .... |

| BENTHIC SPECIES                  |           |      |      |      |      |      |      |      |      |      |      |      |
|----------------------------------|-----------|------|------|------|------|------|------|------|------|------|------|------|
| Astacolus cf. A. dubius          |           |      |      |      |      |      |      |      |      |      |      |      |
| Astacolus sp.                    |           |      |      |      |      |      |      |      |      |      |      |      |
| Baggina sp.                      |           |      |      |      |      |      |      |      |      |      |      |      |
| Bolivina advena                  |           |      |      |      |      |      |      |      |      |      |      |      |
| Bolivina calvertensis            |           |      |      |      |      |      |      |      |      |      |      |      |
| Bolivina floridana               |           |      |      |      |      |      |      |      |      |      |      |      |
| Bolivina marginata multicostrata |           |      |      |      |      |      |      |      |      |      |      |      |
| Bolivina paula                   |           |      |      |      |      |      |      |      |      |      |      |      |
| Bolivina cf. B. subdilatata      |           |      |      |      |      |      |      |      |      |      |      |      |
| Bolivinopsis fairhavenensis      |           |      |      |      |      |      |      |      |      |      |      |      |
| Bulimina elongata                |           |      |      |      |      |      |      |      |      |      |      |      |
| Bulimina striata mexicana        |           |      |      |      |      |      |      |      |      |      |      |      |
| CORE                             | DEPTH (m) |      |      |      |      |      |      |      |      |      |      |      |
| OB-43                            | 1.00-1.25 | .... | .... | .... | .... | 2.9  | .... | .... | 39.2 | .... | .... | 1.0  |
| OB-45                            | 0.75-1.00 | .... | .... | .... | .... | .... | .... | .... | 11.0 | .... | .... | 0.3  |
| OB-45                            | 3.00-3.25 | .... | .... | .... | .... | 0.7  | .... | .... | 32.6 | .... | 0.7  | 0.3  |
| OB-45                            | 4.75-5.00 | .... | .... | .... | 0.3  | 1.7  | .... | .... | 31.0 | .... | 0.3  | 0.3  |
| OB-48                            | 2.25-2.50 | .... | .... | .... | .... | 0.3  | .... | .... | 11.0 | .... | .... | 0.3  |
| OB-48                            | 4.75-5.00 | .... | .... | .... | .... | 1.0  | .... | .... | 15.0 | 0.7  | .... | 0.7  |
| OB-50                            | 3.25-3.60 | 0.3  | .... | .... | .... | .... | .... | .... | 32.8 | 0.3  | 0.7  | 0.3  |
| OB-52                            | 3.75-4.00 | .... | .... | .... | .... | .... | .... | .... | 1.0  | .... | .... | .... |
| OB-53                            | 1.25-1.50 | .... | .... | .... | .... | 3.7  | .... | .... | 59.2 | 0.8  | .... | 0.6  |
| OB-53                            | 2.75-3.00 | .... | .... | .... | 1.2  | .... | 0.6  | .... | 71.5 | .... | .... | 0.6  |
| OB-53                            | 3.30-3.50 | .... | .... | .... | .... | .... | 0.6  | 0.3  | 69.0 | .... | .... | 0.3  |
| OB-53                            | 4.75-5.00 | .... | .... | .... | .... | 2.2  | .... | .... | 61.2 | 0.3  | .... | .... |
| OB-53                            | 5.25-5.50 | .... | .... | .... | 1.7  | 1.3  | .... | .... | 56.7 | 0.3  | .... | .... |
| OB-53                            | 6.25-6.50 | .... | .... | .... | .... | 2.6  | 0.3  | .... | 57.3 | 0.3  | .... | 0.3  |
| OB-59                            | 4.75-5.00 | .... | .... | .... | .... | .... | .... | .... | 0.3  | .... | .... | .... |
| OB-59                            | 5.89-6.00 | .... | .... | .... | .... | 0.3  | .... | 0.3  | 34.7 | 1.0  | .... | .... |
| OB-59                            | 6.75-7.00 | .... | .... | .... | .... | 1.6  | .... | .... | 44.6 | 0.3  | .... | .... |
| OB-59                            | 7.80-8.20 | .... | .... | .... | .... | .... | .... | .... | 6.3  | .... | .... | 0.3  |
| OB-92                            | 5.50      | .... | .... | .... | .... | 0.3  | .... | .... | 96.1 | 0.3  | .... | .... |
| OB-92                            | 6.00      | .... | .... | .... | .... | 1.3  | .... | .... | 90.8 | .... | .... | 2.3  |
| OB-94                            | 1.00      | .... | .... | .... | 0.9  | 3.0  | .... | .... | 53.3 | .... | .... | 1.2  |
| OB-103                           | 5.00      | .... | .... | .... | .... | 1.0  | .... | .... | 22.0 | 0.6  | 0.6  | 1.6  |
| OB-103                           | 5.90      | .... | .... | .... | .... | 0.6  | .... | 0.6  | 45.6 | .... | .... | 1.3  |
| OB-105                           | 1.50      | .... | .... | 1.3  | .... | 3.6  | 0.3  | .... | 30.0 | 0.3  | .... | 1.7  |
| OB-105                           | 4.50      | .... | .... | .... | .... | 1.3  | .... | 0.3  | 41.8 | .... | .... | 0.3  |
| OB-105                           | 7.50      | .... | .... | .... | .... | 2.2  | .... | 0.6  | 12.3 | .... | 0.6  | 15.4 |
| OB-105                           | 9.10      | .... | .... | .... | .... | 13.4 | .... | 2.6  | 2.6  | .... | 3.3  | 1.6  |
| OB-127                           | 4.50      | .... | .... | .... | .... | .... | .... | 0.3  | 13.0 | 0.3  | .... | 12.3 |
| OB-127                           | 5.50      | .... | .... | .... | .... | 0.6  | 0.3  | .... | 7.1  | .... | .... | 13.7 |
| OB-127                           | 7.00      | .... | .... | .... | .... | 4.2  | 0.3  | 0.3  | 13.0 | .... | 1.3  | 5.8  |
| OB-127                           | 8.00      | .... | .... | .... | .... | 5.1  | 0.3  | 1.0  | 6.4  | .... | 1.0  | 4.2  |
| OB-129                           | 2.50      | .... | 0.3  | .... | .... | 5.2  | .... | 1.2  | 25.8 | .... | .... | 4.5  |
| OB-129                           | 4.00      | .... | .... | .... | .... | 2.0  | .... | 0.7  | 28.7 | .... | .... | 2.6  |
| OB-129                           | 5.50      | .... | .... | .... | .... | 0.7  | .... | 0.7  | 26.3 | .... | .... | 0.7  |
| OB-131                           | 3.00      | .... | .... | .... | 0.7  | 0.3  | .... | .... | 1.6  | .... | .... | 1.0  |
| OB-131                           | 6.59      | .... | .... | .... | 0.6  | 0.9  | .... | 0.6  | 15.2 | .... | .... | .... |
| OB-132                           | 1.50      | .... | .... | .... | .... | 5.2  | .... | 1.0  | 7.5  | .... | .... | 3.6  |
| OB-132                           | 2.00      | .... | .... | .... | .... | 2.7  | .... | .... | 8.3  | .... | .... | 2.3  |
| OB-132                           | 2.50      | .... | .... | .... | .... | 2.7  | .... | 1.0  | 9.3  | .... | 0.3  | 1.7  |
| OB-132                           | 3.50      | .... | .... | .... | .... | 0.3  | .... | 1.0  | 15.8 | .... | .... | 2.0  |
| OB-132                           | 4.10      | .... | .... | .... | .... | .... | .... | 0.3  | 4.2  | .... | 0.3  | 2.3  |

| BENTHIC SPECIES            |           |      |      |      |      |      |      |      |      |      |      |      |
|----------------------------|-----------|------|------|------|------|------|------|------|------|------|------|------|
| Bulminella cf. B. brevior  |           |      |      |      |      |      |      |      |      |      |      |      |
| Bulminella elegantissima   |           |      |      |      |      |      |      |      |      |      |      |      |
| Canceris sagra             |           |      |      |      |      |      |      |      |      |      |      |      |
| Cassidella sp.             |           |      |      |      |      |      |      |      |      |      |      |      |
| Cassidulinoides bradyi     |           |      |      |      |      |      |      |      |      |      |      |      |
| Cibicides americanus       |           |      |      |      |      |      |      |      |      |      |      |      |
| Cibicides floridanus       |           |      |      |      |      |      |      |      |      |      |      |      |
| Cibicides lobatulus        |           |      |      |      |      |      |      |      |      |      |      |      |
| Discorbis bassleri         |           |      |      |      |      |      |      |      |      |      |      |      |
| Elphidium excavatum        |           |      |      |      |      |      |      |      |      |      |      |      |
| Epistominella danvillensis |           |      |      |      |      |      |      |      |      |      |      |      |
| Eponides cf. E. repandus   |           |      |      |      |      |      |      |      |      |      |      |      |
| CORE                       | DEPTH (m) |      |      |      |      |      |      |      |      |      |      |      |
| OB-43                      | 1.00-1.25 | 1.6  | 14.7 | .... | .... | .... | 1.6  | .... | .... | .... | 0.3  | .... |
| OB-45                      | 0.75-1.00 | .... | 0.9  | .... | .... | .... | 22.7 | .... | 12.2 | 2.1  | 0.6  | .... |
| OB-45                      | 3.00-3.25 | .... | 14.0 | .... | .... | .... | 9.0  | 3.0  | 3.3  | .... | .... | .... |
| OB-45                      | 4.75-5.00 | 0.3  | 6.9  | .... | .... | .... | 14.9 | 1.0  | 4.3  | 1.3  | 0.3  | .... |
| OB-48                      | 2.25-2.50 | .... | 14.6 | 0.7  | 0.3  | .... | 19.3 | .... | 9.6  | 1.3  | 3.7  | 0.3  |
| OB-48                      | 4.75-5.00 | .... | 1.6  | .... | .... | .... | 14.1 | 1.6  | 7.2  | 2.9  | .... | 0.3  |
| OB-50                      | 3.25-3.60 | .... | 13.8 | .... | 0.3  | .... | 7.5  | 1.0  | .... | .... | 0.3  | .... |
| OB-52                      | 3.75-4.00 | .... | 0.3  | .... | .... | .... | 14.0 | 79.1 | .... | 1.7  | .... | .... |
| OB-53                      | 1.25-1.50 | .... | 31.0 | .... | .... | .... | 0.8  | 0.3  | 0.6  | 1.4  | .... | .... |
| OB-53                      | 2.75-3.00 | 0.3  | 10.4 | .... | .... | .... | 0.3  | 0.9  | .... | .... | .... | .... |
| OB-53                      | 3.30-3.50 | .... | 6.9  | 0.3  | .... | 0.9  | 0.3  | .... | 0.9  | 0.3  | .... | .... |
| OB-53                      | 4.75-5.00 | 0.3  | 27.2 | .... | 0.6  | .... | .... | 0.6  | 0.3  | .... | .... | .... |
| OB-53                      | 5.25-5.50 | 1.0  | 29.0 | .... | .... | .... | .... | .... | .... | .... | .... | .... |
| OB-53                      | 6.25-6.50 | 0.3  | 24.3 | .... | .... | 0.6  | 1.0  | .... | .... | .... | .... | .... |
| OB-59                      | 4.75-5.00 | .... | .... | .... | .... | .... | 18.2 | 68.7 | 3.9  | 1.3  | .... | 0.3  |
| OB-59                      | 5.89-6.00 | .... | 14.3 | .... | .... | .... | 21.3 | 14.7 | 1.0  | 2.0  | 0.3  | .... |
| OB-59                      | 6.75-7.00 | .... | 35.7 | .... | .... | .... | 2.3  | 2.3  | .... | 1.0  | .... | .... |
| OB-59                      | 7.80-8.20 | .... | 0.3  | 0.3  | .... | 0.3  | 5.4  | 10.8 | 2.2  | .... | .... | .... |
| OB-92                      | 5.50      | .... | 2.3  | .... | .... | .... | 0.7  | .... | .... | .... | .... | .... |
| OB-92                      | 6.00      | 3.0  | 0.7  | .... | .... | .... | 0.7  | .... | .... | 0.7  | .... | .... |
| OB-94                      | 1.00      | .... | 34.5 | .... | .... | .... | 2.1  | 0.3  | .... | .... | .... | .... |
| OB-103                     | 5.00      | .... | 19.1 | .... | .... | .... | 1.6  | .... | .... | .... | 0.3  | 0.3  |
| OB-103                     | 5.90      | 0.3  | 12.3 | .... | .... | .... | 1.3  | .... | .... | .... | .... | 0.6  |
| OB-105                     | 1.50      | .... | 2.0  | .... | .... | .... | 2.6  | .... | .... | .... | .... | 6.3  |
| OB-105                     | 4.50      | 0.3  | 2.6  | .... | .... | .... | 1.0  | .... | .... | .... | .... | 8.6  |
| OB-105                     | 7.50      | 0.9  | 18.5 | .... | .... | .... | 2.2  | .... | .... | 0.3  | 0.9  | 7.1  |
| OB-105                     | 9.10      | .... | 8.5  | .... | .... | .... | 3.9  | .... | 0.3  | .... | 4.2  | 32.2 |
| OB-127                     | 4.50      | 1.3  | 25.6 | .... | .... | .... | 1.0  | .... | .... | 0.3  | .... | 1.0  |
| OB-127                     | 5.50      | 0.3  | 19.6 | .... | .... | .... | 0.9  | .... | .... | 0.3  | 0.3  | 2.2  |
| OB-127                     | 7.00      | 1.0  | 20.5 | .... | .... | .... | 2.6  | .... | .... | .... | 0.3  | 9.7  |
| OB-127                     | 8.00      | 0.3  | 14.1 | .... | .... | .... | .... | .... | 1.0  | .... | 1.0  | 40.9 |
| OB-129                     | 2.50      | 0.3  | 6.7  | 0.9  | .... | .... | 2.4  | .... | 0.3  | 1.2  | .... | 1.5  |
| OB-129                     | 4.00      | .... | 5.2  | 3.9  | .... | .... | 2.6  | .... | 1.0  | 1.3  | .... | 0.3  |
| OB-129                     | 5.50      | .... | 7.7  | 1.0  | .... | .... | 6.3  | .... | 3.0  | .... | .... | 2.3  |
| OB-131                     | 3.00      | .... | .... | .... | .... | .... | 57.3 | .... | 7.5  | 3.6  | .... | .... |
| OB-131                     | 6.59      | .... | 2.1  | .... | .... | .... | 40.0 | 7.6  | 7.3  | 6.1  | .... | .... |
| OB-132                     | 1.50      | .... | 27.8 | .... | 0.3  | .... | 4.2  | .... | 2.3  | 10.1 | 0.3  | 0.3  |
| OB-132                     | 2.00      | .... | 32.6 | .... | .... | .... | 5.3  | .... | 0.7  | 8.3  | 0.3  | 0.7  |
| OB-132                     | 2.50      | .... | 19.9 | .... | .... | .... | 7.0  | 1.0  | 0.7  | 9.6  | 1.0  | 2.0  |
| OB-132                     | 3.50      | 1.7  | 26.4 | .... | .... | .... | 6.6  | 0.3  | 3.6  | 4.6  | 0.3  | 1.0  |
| OB-132                     | 4.10      | 23.8 | 26.4 | .... | .... | .... | 5.9  | .... | 2.3  | 2.0  | .... | 3.3  |



| BENTHIC SPECIES |           | <i>Estorffina mayi</i> | <i>Fissurina lucida</i> | <i>Florilus grateloupi</i> | <i>Florilus pizzarensis</i> | <i>Fursenkoina fusiformis</i> | <i>Fursenkoina</i> sp. | <i>Globocassidulina crassa</i> | <i>Globulina gibba</i> | <i>Globulina inaequalis</i> | <i>Guttulina</i> sp. | <i>Hanzawaia concentrica</i> | <i>Islandiella</i> sp. |
|-----------------|-----------|------------------------|-------------------------|----------------------------|-----------------------------|-------------------------------|------------------------|--------------------------------|------------------------|-----------------------------|----------------------|------------------------------|------------------------|
| CORE            | DEPTH (m) |                        |                         |                            |                             |                               |                        |                                |                        |                             |                      |                              |                        |
| OB-43           | 1.00-1.25 | ....                   | ....                    | 1.6                        | 24.8                        | 0.3                           | ....                   | ....                           | ....                   | ....                        | ....                 | 0.3                          | ....                   |
| OB-45           | 0.75-1.00 | ....                   | ....                    | ....                       | 3.9                         | ....                          | ....                   | ....                           | ....                   | 0.3                         | ....                 | 1.2                          | ....                   |
| OB-45           | 3.00-3.25 | ....                   | ....                    | ....                       | 3.7                         | ....                          | ....                   | 0.3                            | ....                   | 0.3                         | 0.7                  | 4.7                          | ....                   |
| OB-45           | 4.75-5.00 | ....                   | ....                    | 0.3                        | 1.7                         | ....                          | ....                   | 0.3                            | ....                   | ....                        | 0.3                  | 2.6                          | ....                   |
| OB-48           | 2.25-2.50 | ....                   | ....                    | 0.3                        | 1.3                         | ....                          | 0.3                    | ....                           | ....                   | ....                        | ....                 | 16.6                         | ....                   |
| OB-48           | 4.75-5.00 | ....                   | ....                    | 2.0                        | 3.3                         | ....                          | ....                   | ....                           | ....                   | 0.3                         | ....                 | 21.9                         | ....                   |
| OB-50           | 3.25-3.60 | 0.3                    | ....                    | 2.0                        | 1.3                         | ....                          | ....                   | ....                           | ....                   | ....                        | ....                 | 5.2                          | ....                   |
| OB-52           | 3.75-4.00 | ....                   | ....                    | ....                       | ....                        | ....                          | ....                   | 0.7                            | ....                   | ....                        | ....                 | ....                         | 0.3                    |
| OB-53           | 1.25-1.50 | ....                   | ....                    | ....                       | 0.6                         | ....                          | ....                   | ....                           | ....                   | ....                        | ....                 | ....                         | ....                   |
| OB-53           | 2.75-3.00 | ....                   | ....                    | ....                       | 2.9                         | ....                          | ....                   | ....                           | ....                   | 0.3                         | ....                 | 0.3                          | ....                   |
| OB-53           | 3.30-3.50 | ....                   | ....                    | ....                       | 10.7                        | 0.9                           | ....                   | ....                           | ....                   | ....                        | ....                 | ....                         | ....                   |
| OB-53           | 4.75-5.00 | ....                   | ....                    | ....                       | 2.6                         | ....                          | 0.3                    | ....                           | ....                   | ....                        | ....                 | ....                         | ....                   |
| OB-53           | 5.25-5.50 | ....                   | ....                    | 0.3                        | 5.3                         | ....                          | ....                   | ....                           | ....                   | ....                        | ....                 | ....                         | ....                   |
| OB-53           | 6.25-6.50 | ....                   | ....                    | ....                       | 6.8                         | ....                          | 0.6                    | ....                           | ....                   | ....                        | ....                 | ....                         | ....                   |
| OB-59           | 4.75-5.00 | ....                   | ....                    | ....                       | ....                        | ....                          | ....                   | ....                           | ....                   | 0.3                         | ....                 | 0.3                          | ....                   |
| OB-59           | 5.89-6.00 | ....                   | ....                    | ....                       | 1.7                         | ....                          | ....                   | ....                           | ....                   | ....                        | ....                 | 1.0                          | ....                   |
| OB-59           | 6.75-7.00 | ....                   | ....                    | 2.0                        | 2.0                         | ....                          | ....                   | 0.3                            | ....                   | ....                        | ....                 | 1.0                          | ....                   |
| OB-59           | 7.80-8.20 | ....                   | ....                    | 3.2                        | 3.8                         | ....                          | ....                   | 0.6                            | ....                   | 0.3                         | ....                 | 19.0                         | ....                   |
| OB-92           | 5.50      | ....                   | ....                    | ....                       | 0.3                         | ....                          | ....                   | ....                           | ....                   | ....                        | ....                 | ....                         | ....                   |
| OB-92           | 6.00      | ....                   | ....                    | ....                       | ....                        | ....                          | ....                   | ....                           | ....                   | ....                        | ....                 | ....                         | ....                   |
| OB-94           | 1.00      | ....                   | ....                    | ....                       | 2.4                         | ....                          | 0.3                    | ....                           | ....                   | ....                        | ....                 | ....                         | ....                   |
| OB-103          | 5.00      | ....                   | ....                    | 1.0                        | 5.5                         | ....                          | ....                   | ....                           | ....                   | ....                        | ....                 | 7.8                          | ....                   |
| OB-103          | 5.90      | ....                   | ....                    | 0.6                        | 6.8                         | ....                          | ....                   | ....                           | ....                   | ....                        | ....                 | 4.5                          | ....                   |
| OB-105          | 1.50      | ....                   | ....                    | 0.7                        | 3.6                         | ....                          | ....                   | 1.7                            | 0.7                    | 0.7                         | ....                 | 3.3                          | 0.7                    |
| OB-105          | 4.50      | ....                   | ....                    | 0.7                        | 7.2                         | 1.3                           | ....                   | 3.6                            | ....                   | ....                        | ....                 | 2.6                          | 0.3                    |
| OB-105          | 7.50      | ....                   | ....                    | 0.6                        | 10.2                        | 0.3                           | ....                   | 3.4                            | 0.3                    | 0.9                         | ....                 | 1.5                          | ....                   |
| OB-105          | 9.10      | ....                   | ....                    | ....                       | 1.6                         | ....                          | ....                   | ....                           | ....                   | ....                        | ....                 | 2.3                          | ....                   |
| OB-127          | 4.50      | ....                   | ....                    | 1.7                        | 13.3                        | ....                          | ....                   | ....                           | ....                   | 0.3                         | ....                 | 5.0                          | ....                   |
| OB-127          | 5.50      | ....                   | ....                    | 0.6                        | 15.5                        | 2.2                           | ....                   | 3.4                            | 0.6                    | 0.6                         | ....                 | 3.1                          | ....                   |
| OB-127          | 7.00      | ....                   | 0.3                     | 1.9                        | 14.3                        | 0.6                           | ....                   | 2.9                            | ....                   | 1.0                         | ....                 | 4.2                          | ....                   |
| OB-127          | 8.00      | ....                   | ....                    | 1.3                        | 4.2                         | 0.6                           | ....                   | ....                           | ....                   | 1.6                         | ....                 | 5.1                          | ....                   |
| OB-129          | 2.50      | ....                   | ....                    | 0.6                        | 10.3                        | ....                          | ....                   | 0.9                            | ....                   | ....                        | ....                 | 8.8                          | ....                   |
| OB-129          | 4.00      | ....                   | ....                    | 1.3                        | 5.2                         | ....                          | ....                   | 2.6                            | ....                   | ....                        | ....                 | 13.7                         | ....                   |
| OB-129          | 5.50      | ....                   | ....                    | 1.3                        | 6.3                         | ....                          | ....                   | 0.3                            | ....                   | 0.3                         | ....                 | 14.7                         | ....                   |
| OB-131          | 3.00      | ....                   | ....                    | ....                       | 1.3                         | ....                          | ....                   | ....                           | ....                   | ....                        | ....                 | 3.6                          | ....                   |
| OB-131          | 6.59      | ....                   | ....                    | ....                       | ....                        | ....                          | ....                   | ....                           | ....                   | ....                        | ....                 | 0.6                          | ....                   |
| OB-132          | 1.50      | 0.3                    | ....                    | 4.9                        | 10.5                        | 1.3                           | 1.0                    | 0.3                            | ....                   | 3.3                         | ....                 | 5.2                          | ....                   |
| OB-132          | 2.00      | 0.3                    | ....                    | 4.3                        | 14.3                        | ....                          | 0.7                    | ....                           | ....                   | 3.7                         | ....                 | 4.0                          | ....                   |
| OB-132          | 2.50      | ....                   | ....                    | 3.7                        | 19.3                        | 0.3                           | 1.0                    | ....                           | ....                   | 1.3                         | ....                 | 5.3                          | ....                   |
| OB-132          | 3.50      | ....                   | ....                    | 4.0                        | 11.2                        | 1.0                           | 1.0                    | ....                           | ....                   | 2.0                         | ....                 | 5.0                          | ....                   |
| OB-132          | 4.10      | ....                   | ....                    | 4.6                        | 6.8                         | 4.9                           | 3.6                    | ....                           | ....                   | 0.7                         | ....                 | 3.3                          | ....                   |



| BENTHIC SPECIES |           |                           |                                         |                            |                                   |                           |                               |                                         |                            |                               |                              |                             |                               |
|-----------------|-----------|---------------------------|-----------------------------------------|----------------------------|-----------------------------------|---------------------------|-------------------------------|-----------------------------------------|----------------------------|-------------------------------|------------------------------|-----------------------------|-------------------------------|
| CORE            | DEPTH (m) | <i>Rosalina cavernata</i> | <i>Rosalina</i> cf. <i>R. floridana</i> | <i>Rosalina globularis</i> | <i>Siphonogenerina transversa</i> | <i>Siphonodosaria</i> sp. | <i>Sphaeroidina bulloides</i> | <i>Spiroplectamina mississippiensis</i> | <i>Stilostomella recta</i> | <i>Textularia agglutinans</i> | <i>Textularia articulata</i> | <i>Textularia candelana</i> | <i>Trifarina occidentalis</i> |
| OB-43           | 1.00-1.25 | ....                      | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | 0.3                         | ....                          |
| OB-45           | 0.75-1.00 | ....                      | 2.7                                     | 12.5                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-45           | 3.00-3.25 | 2.3                       | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-45           | 4.75-5.00 | 2.6                       | 0.3                                     | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-48           | 2.25-2.50 | 4.3                       | 0.7                                     | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | 0.3                           | ....                         | ....                        | ....                          |
| OB-48           | 4.75-5.00 | 2.0                       | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | 1.0                          | 0.3                         | ....                          |
| OB-50           | 3.25-3.60 | 0.3                       | 0.3                                     | 0.7                        | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-52           | 3.75-4.00 | 1.3                       | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | 0.3                         | 1.0                           |
| OB-53           | 1.25-1.50 | ....                      | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-53           | 2.75-3.00 | ....                      | ....                                    | ....                       | ....                              | 0.3                       | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-53           | 3.30-3.50 | ....                      | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | 0.3                           | ....                         | ....                        | ....                          |
| OB-53           | 4.75-5.00 | ....                      | 0.3                                     | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-53           | 5.25-5.50 | ....                      | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-53           | 6.25-6.50 | ....                      | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | 0.3                           |
| OB-59           | 4.75-5.00 | 1.0                       | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | 4.6                         | ....                          |
| OB-59           | 5.89-6.00 | 1.3                       | 0.3                                     | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | 2.7                         | 0.3                           |
| OB-59           | 6.75-7.00 | ....                      | 0.7                                     | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | 0.7                         | ....                          |
| OB-59           | 7.80-8.20 | 0.6                       | ....                                    | ....                       | 0.3                               | ....                      | 0.3                           | ....                                    | 0.3                        | ....                          | ....                         | ....                        | 0.3                           |
| OB-92           | 5.50      | ....                      | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-92           | 6.00      | ....                      | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-94           | 1.00      | ....                      | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-103          | 5.00      | ....                      | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-103          | 5.90      | 0.3                       | ....                                    | ....                       | 1.3                               | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-103          | 1.50      | 2.0                       | ....                                    | ....                       | 1.0                               | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-105          | 4.50      | 1.6                       | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | 0.3                           |
| OB-105          | 7.50      | 0.9                       | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | 0.9                        | ....                          | ....                         | ....                        | 0.3                           |
| OB-105          | 9.10      | 3.3                       | 0.3                                     | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-127          | 4.50      | 0.7                       | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-127          | 5.50      | ....                      | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | 0.9                        | ....                          | ....                         | ....                        | ....                          |
| OB-127          | 7.00      | 0.6                       | 0.3                                     | ....                       | 0.3                               | ....                      | ....                          | ....                                    | 0.6                        | ....                          | ....                         | ....                        | 0.3                           |
| OB-127          | 8.00      | 1.6                       | 0.3                                     | ....                       | ....                              | ....                      | ....                          | ....                                    | 0.3                        | ....                          | ....                         | ....                        | ....                          |
| OB-129          | 2.50      | 0.3                       | ....                                    | ....                       | 3.6                               | ....                      | ....                          | ....                                    | ....                       | 0.3                           | ....                         | ....                        | ....                          |
| OB-129          | 4.00      | ....                      | ....                                    | ....                       | 3.6                               | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-129          | 5.50      | 0.7                       | ....                                    | ....                       | 2.3                               | ....                      | ....                          | ....                                    | ....                       | 0.7                           | 0.7                          | ....                        | ....                          |
| OB-131          | 3.00      | 2.9                       | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | 1.6                         | ....                          |
| OB-131          | 6.59      | 2.1                       | 1.2                                     | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | 0.6                         | ....                          |
| OB-132          | 1.50      | 1.6                       | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | ....                          | ....                         | ....                        | ....                          |
| OB-132          | 2.00      | 4.0                       | ....                                    | ....                       | ....                              | ....                      | ....                          | ....                                    | ....                       | 0.7                           | ....                         | 1.3                         | ....                          |
| OB-132          | 2.50      | 2.3                       | ....                                    | ....                       | ....                              | ....                      | ....                          | 0.7                                     | ....                       | 0.7                           | ....                         | 2.0                         | 0.3                           |
| OB-132          | 3.50      | 1.3                       | 0.3                                     | ....                       | ....                              | ....                      | ....                          | 0.3                                     | ....                       | 0.3                           | ....                         | ....                        | ....                          |
| OB-132          | 4.10      | 1.0                       | ....                                    | ....                       | ....                              | ....                      | ....                          | 0.3                                     | ....                       | ....                          | ....                         | ....                        | ....                          |

| BENTHIC SPECIES |           | <i>Uvigerina auberiana</i> | <i>Uvigerina subperegina</i> | <i>Valvulineria floridana</i> | <i>Virgulinerella miocenica</i> |
|-----------------|-----------|----------------------------|------------------------------|-------------------------------|---------------------------------|
| CORE            | DEPTH (m) |                            |                              |                               |                                 |
| OB-43           | 1.00-1.25 | ....                       | ....                         | 10.1                          | ....                            |
| OB-45           | 0.75-1.00 | ....                       | ....                         | 28.4                          | ....                            |
| OB-45           | 3.00-3.25 | ....                       | 0.3                          | 23.3                          | ....                            |
| OB-45           | 4.75-5.00 | ....                       | 0.3                          | 26.4                          | ....                            |
| OB-48           | 2.25-2.50 | ....                       | ....                         | 14.3                          | ....                            |
| OB-48           | 4.75-5.00 | ....                       | ....                         | 23.2                          | ....                            |
| OB-50           | 3.25-3.60 | ....                       | ....                         | 11.8                          | ....                            |
| OB-52           | 3.75-4.00 | ....                       | ....                         | ....                          | ....                            |
| OB-53           | 1.25-1.50 | ....                       | ....                         | 0.6                           | ....                            |
| OB-53           | 2.75-3.00 | ....                       | ....                         | 7.5                           | 3.5                             |
| OB-53           | 3.30-3.50 | ....                       | ....                         | 3.8                           | 3.8                             |
| OB-53           | 4.75-5.00 | ....                       | ....                         | 2.6                           | 1.0                             |
| OB-53           | 5.25-5.50 | ....                       | ....                         | 2.7                           | 0.7                             |
| OB-53           | 6.25-6.50 | ....                       | ....                         | 3.9                           | 0.6                             |
| OB-59           | 4.75-5.00 | ....                       | ....                         | ....                          | ....                            |
| OB-59           | 5.89-6.00 | ....                       | ....                         | 2.0                           | ....                            |
| OB-59           | 6.75-7.00 | ....                       | ....                         | 3.0                           | 0.3                             |
| OB-59           | 7.80-8.20 | ....                       | ....                         | 21.9                          | ....                            |
| OB-92           | 5.50      | ....                       | ....                         | ....                          | ....                            |
| OB-92           | 6.00      | ....                       | ....                         | 0.3                           | 0.3                             |
| OB-94           | 1.00      | ....                       | ....                         | 0.3                           | 0.9                             |
| OB-103          | 5.00      | 2.9                        | ....                         | 34.6                          | ....                            |
| OB-103          | 5.90      | 2.3                        | ....                         | 19.4                          | ....                            |
| OB-105          | 1.50      | 11.9                       | 1.7                          | 18.2                          | ....                            |
| OB-105          | 4.50      | 1.3                        | ....                         | 15.5                          | ....                            |
| OB-105          | 7.50      | 0.9                        | 0.6                          | 16.6                          | 0.3                             |
| OB-105          | 9.10      | ....                       | 0.3                          | 17.6                          | ....                            |
| OB-127          | 4.50      | 1.3                        | 3.0                          | 18.3                          | 0.3                             |
| OB-127          | 5.50      | 1.2                        | 1.2                          | 21.4                          | 0.3                             |
| OB-127          | 7.00      | 1.3                        | 1.6                          | 6.8                           | ....                            |
| OB-127          | 8.00      | ....                       | ....                         | 4.2                           | ....                            |
| OB-129          | 2.50      | 0.3                        | ....                         | 19.7                          | ....                            |
| OB-129          | 4.00      | 0.7                        | ....                         | 22.8                          | ....                            |
| OB-129          | 5.50      | ....                       | ....                         | 24.3                          | ....                            |
| OB-131          | 3.00      | ....                       | ....                         | 14.3                          | ....                            |
| OB-131          | 6.59      | ....                       | ....                         | 12.4                          | ....                            |
| OB-132          | 1.50      | ....                       | ....                         | 2.6                           | ....                            |
| OB-132          | 2.00      | ....                       | ....                         | 2.0                           | ....                            |
| OB-132          | 2.50      | ....                       | 0.3                          | 1.3                           | ....                            |
| OB-132          | 3.50      | ....                       | 0.7                          | 5.0                           | ....                            |
| OB-132          | 4.10      | ....                       | ....                         | 2.3                           | ....                            |