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## **Paleobathymetric Interpretation of Pleistocene Sediments in the South Padre Island Area, Northwestern Gulf of Mexico, Using Benthic Foraminiferal Morphology**

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PALEOBATHYMETRIC INTERPRETATION OF PLEISTOCENE  
SEDIMENTS IN THE SOUTH PADRE ISLAND AREA,  
NORTHWESTERN GULF OF MEXICO,  
USING BENTHIC FORAMINIFERAL MORPHOLOGY

By

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B.S. August 1988, University of New Orleans

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Approved by

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## ABSTRACT

PALEOBATHYMETRIC INTERPRETATION OF PLEISTOCENE  
SEDIMENTS IN THE SOUTH PADRE ISLAND AREA,  
NORTHWESTERN GULF OF MEXICO,  
USING BENTHIC FORAMINIFERAL MORPHOLOGY

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Old Dominion University, 1993

Director: Dr. Randall S. Spencer

This study tested the validity of using intraspecific variation in benthic foraminifera as a means for determining Pleistocene paleobathymetry. Canonical variate analysis was used as a means for determining visually undetectable but statistically significant differences in the morphology of selected species. Two species, Cassidulina subglobosa and Uvigerina peregrina, were collected from Pleistocene well cuttings from the northwest Gulf of Mexico. The canonical analysis involved comparing the intraspecific variation of these Pleistocene species to their counterparts occurring in the modern Gulf of Mexico, where intraspecific variation was previously analyzed and found to be sufficient to allow detection of bathymetric differences of 200 meters or less.

In order to validate this statistical comparison of intraspecific variation between Pleistocene and modern individuals of the same species and their implied bathymetry,

a taxonomic analysis of these same Pleistocene samples was conducted in order to construct paleobathymetric estimates. In addition, a Q-mode cluster analysis of species abundances was performed in order to detect any possible paleoenvironmental or paleobathymetric subgroups occurring in the Pleistocene section studied.

The canonical analysis for Cassidulina subglobosa in the top eight samples in the well indicated a paleobathymetric range of 50-100 meters, while that for Uvigerina peregrina indicated a paleobathymetric range of 50-200 meters.

The Q-mode cluster analysis revealed two major groupings and hence changes in biofacies. The first major group contains three samples, the top three samples in the well, and represents a shallow water environment. The second major group contains twenty samples and can be separated into two subgroups, one with fourteen samples, representing deeper water. The other subgroup contains six samples, five of which are immediately below the top three well samples, and represents a transitional environment between the shallower and deeper water groups. These five samples plus the the top three samples in the well are those which were used for canonical analysis.

The species assemblage data indicated a paleobathymetric range of 100-200, and possibly extending to 500 meters, a shallow water environment, for the three samples in the first major cluster group, which correspond to the top three samples in the well. A paleobathymetric range of 100-500, and

possibly extending to 1000 meters was indicated for the smaller cluster subgroup with six samples, five of which are immediately below the top three well samples. A paleobathymetric range of 100-1000 meters for the twenty samples in larger cluster subgroup.

Considering the different strategies involved between these two methods of determining paleobathymetry, the results indicate that further investigation of intraspecific variation as it relates to bathymetry is warranted.

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## INTRODUCTION

Ecology is the study of the relationships between organisms and their environments. One focus of ecologic studies involves the analysis of environmental factors which control the distribution, diversity and abundance of living marine organisms (Pinet et al., 1988). In the study of marine environments these environmental factors include such physical and chemical characteristics as temperature, hydrostatic pressure, salinity, alkalinity and dissolved oxygen. Ecologic studies of extant marine organisms which are also found in the stratigraphic record allow us to infer similar environmental conditions for the past (Lipps, 1979).

One aspect of paleoenvironmental reconstruction essential for an accurate picture of the geologic history of an area is paleobathymetry. "Ancient water depth is important to know because it defines the configuration of marine basins and contributes to our picture of paleogeography for particular intervals of geologic time... Although it is one of the most useful parameters for reconstruction of past environments, water depth is very difficult to determine" (Raup and Stanley, 1978, p.255).



Attempts to determine paleobathymetry traditionally rely on various benthic fossils. Benthic foraminifera are particularly useful because they are small in size, are easily preserved whole, and are abundant enough to make these fossils invaluable stratigraphic markers in drilling (Cushman, 1946). Furthermore, the use of benthic foraminifera as paleoenvironmental indicators is frequently employed in the petroleum industry (e.g., Albers et al., 1966; Tipsword et al., 1966; Lipps, 1979) to better understand basinal history. Utilization of fossils as paleoenvironmental indicators requires the direct comparison of fossil assemblages with analogous modern assemblages. Similar environments and the organisms' response to those environments are thus inferred (Lipps, 1979).

#### Foraminifera as paleoenvironmental indicators

Three general approaches can be used to reconstruct paleoenvironments. These tactics, in order of increasing informational input, involve analysis of assemblages for faunal trends, use of taxonomic data, and use of form and structure, or morphology, of benthic foraminifera (Douglas, 1979).

The analysis of faunal trends within assemblages entails studying changes in abundance and species diversity, planktic to benthic ratios, and ratios or relative abundances of test types, for example, porcelaneous, agglutinated and hyaline

tests. Faunal trends such as those of species diversity patterns, can be useful in determining increasing depth and latitudinal changes (Buzas and Gibson, 1969; Gibson and Buzas, 1973). The advantage of using faunal trends to study paleoenvironments is that the data are readily available and that no taxonomic identification is required, therefore making the study relatively simple. The limitation of employing faunal trends in the study of paleoenvironments is that such trends and patterns vary widely and can be imprecise if taken as more than a generalization (Douglas, 1979).

A taxonomic approach to paleoecologic studies and paleoenvironmental interpretations requires taxonomic identification of the fauna, either at the family, generic or specific level. The sensitivity of organisms to the interaction of multiple environmental factors leads to varying distributional patterns, which can generally be related to water depth (Smith, 1965). Paleodepths can thus be inferred based on the known distributions of modern foraminiferal taxa. The advantages of the taxonomic method are that it can be applied at the family, generic or specific level, and can be used in reconstructing the depositional history of a basin with more precision than simple faunal trends. Limitations of a taxonomic approach are that most Recent species evolved in the early-middle Miocene (Berggren, 1972; Schnitker, 1979) and therefore pre-Neogene benthic foraminiferal species have only distant affinities to modern species (Douglas, 1979). The use

of the taxonomic method in dealing with pre-Neogene species requires one to establish ecologic relationships between higher taxa or to use analogous or homeomorphic species (Sliter, 1971; Sliter and Baker, 1972). Since most Recent genera originated in the late Cretaceous or early Tertiary (Douglas, 1979), and many more common benthic foraminiferal genera in modern oceans appear in the Eocene (Douglas, 1979), generic level data can only be applied back to the late Cretaceous or the early Tertiary (Douglas, 1979). Affinities at the family level for modern taxa can be traced from the early and early-mid-Cretaceous (Douglas, 1979).

Paleoenvironmental studies based on form and structure of benthic foraminifera were first suggested by Bandy (1960) with the observation that foraminiferal form is related to its function. Because it is assumed that similar morphologies between fossil and modern species indicate similar morphologic adaptations, fossil species with modern morphologic analogues can be used to interpret paleoenvironments. Indeed, Douglas (1979, p.46) stated "The relationship of form, structure and environment in benthic foraminifera is potentially the most powerful tool available for paleoecologic interpretation". Although Albers et al., (1966, p.345) were referring to entire assemblages with the statement "...projection of Recent ecologic zones into older sediments is dependent upon the degree to which the fossil assemblages reflect the same environments as their modern counterparts", the statement can

be extended to singular species considered in morphologic studies. Therefore, paleoecologic interpretations utilizing morphology of one or more species can be based on modern ecologic relationships if the investigator assumes that the species' physiological adaptations and depth distributions do not change with time (Douglas, 1979). A restriction beyond the investigator's control for the morphologic approach is that depth limits of morphologic forms can vary with geographic location (Bandy and Arnal, 1960). The morphologic approach then may not be applicable from one geographic region or major water body to another. The advantage of this approach, although there are geographically varying depth limits for some morphologic forms, is that the evolutionary sequence of these morphologic forms, as well as their relative bathymetry, is known from the early Tertiary (Bandy and Arnal, 1960). This advantage is confirmed by morphogroup and intraspecific variation studies (Spencer, 1988; Gary et al., 1989; Collins, 1989).

#### Statement of problem

The problem which this study addresses is whether the statistically significant and depth-relatable intraspecific variation detected by Spencer (1985, 1987, 1988, 1992) for some foraminiferal species from the Gulf of Mexico can be used to establish the paleobathymetry of geologically older Gulf of Mexico material.

## Purpose

The purpose of this study is to test the hypothesis of Spencer (1985, 1987, 1988) which proposes that statistically significant morphometric differences found in modern, commonly occurring benthic foraminifera can be related to paleobathymetry. Spencer (1985, 1987, 1988, 1992) has developed a morphometric data base for twelve commonly occurring, modern benthic foraminifera from the northwestern Gulf of Mexico. The morphometries of two species, Cassidulina subglobosa and Uvigerina peregrina, from this data base will be utilized as a standard of comparison in my study. The present study, using the same two species collected from a Pleistocene stratigraphic sequence, obtained from a well drilled in the northwestern Gulf of Mexico, will attempt to determine the paleobathymetry of that sequence.

The morphometric approach will be tested for its validity by using a taxonomic approach on the Pleistocene samples. This traditional method, using a full faunal assemblage, shall either qualify or disqualify the morphometric utility of one or both species used in this study.

Although faunal trends vary widely (Douglas, 1979), species diversity and planktic-benthic ratios will be evaluated also in this study. The advantage of using trends or other aspects of the assemblage is to hopefully, and more objectively, constrain the paleobathymetric interpretation (Murray, 1973).

## PREVIOUS WORK

### Initial studies

Bandy and Arnal (1960) proposed a relationship between foraminiferal structure and form in their study of Tertiary foraminifera. Since the pioneering efforts of Bandy (Bandy and Arnal, 1960; Bandy and Chierici, 1966), many approaches have been tried and reported with varying degrees of success.

It has been suggested (Douglas, 1979) that foraminiferal test morphology is related to environment and that it may prove to be a most valuable tool in paleoenvironmental interpretations. A quantitative and qualitative study by Smith (1963) considered morphology of the family Bolivinidae in relation to paleodepths and found that the intraspecific variation of some species could be related to depth while other species showed no such relationship.

Pflum and Frerichs (1976) used a taxonomic approach to modern species, but they also suggested relationships between foraminiferal test morphology and bathymetry in the Gulf of Mexico. In their study, Pflum and Frerichs (1976) specifically discovered that, for many different modern species, the size and length to width ratio of the foraminiferal tests change with increasing water depth. An increase in size with water depth was noted for six species, Hoeglundina elegans, Laticarinina pauperata, Sphaeroidina bulloides, Chilostomella oolina, Haplophragmoides bradyi, and

Cyclammina cancellata. They also noted a change in the ratio of length to width for Bolivina albatrossi, with the ratio being more pronounced in the microspheric generation.

#### Recent morphologic studies

Gary (1984) used Fourier-shape analysis to study the relationship of depth to morphologic changes within three modern bolivinid species from the northwestern Gulf of Mexico. Gary (1984, 1985) found that triangularity and lobateness of Bolivina albatrossi decreases with increasing water depth, while Gary (1984) found that Bolivina subspinescens has a more elongate test and Bolivina lowmani a more symmetric test in neritic depths than in deeper waters. A more recent study by Gary et al. (1989) correlated intraspecific morphologic variability of Bolivina albatrossi with factors related to water column properties in the northwestern Gulf of Mexico. They found that the change from a triangular to a spindle-shaped test was not constrained totally by water mass boundaries. Instead, the depth range over which the triangular form predominates coincides with the dissolved oxygen-minimum zone, while the depth range over which the spindle-shaped form predominates coincides with bottom waters of a higher concentration of dissolved oxygen in the Gulf of Mexico. They also found a relationship between test lobateness, dissolved oxygen concentration, temperatures, and water density.

Another line of paleobathymetric investigation is illustrated by Culver et al. (1985), relating morphologic form, within an assemblage, to bathymetry in the northern Gulf of Mexico. This was done by cluster analysis to find the distribution of sets of morphological features. Culver et al. (1985) found that some of their "morphologic biofacies" were depth relatable and some were not.

Canonical variate analysis was used by Collins (1989), for the Gulf of Maine area, in determining the relationship of environmental gradients to morphologic variations within and between modern foraminiferal populations of Bulimina aculeata and Bulimina marginata. Statistically significant differences in foraminiferal test morphology with respect to bathymetry were found. In Collins' (1989) study, the variation in the ratio of length to width is found to be significantly related to changes in carbonate, salinity and oxygen, which affect environmental preferences of the species Bulimina aculeata. The canonical variate analyses thus used morphology to discriminate environments. Collins (1989) also was able to relate morphologic changes to nutritive organics and grain size.

The current study is based on the recent work of Spencer (1985, 1987, 1988, 1992), which uses canonical variate analysis of morphometric measurements of twelve commonly occurring Recent benthic foraminifera and relates these intraspecific variations to bathymetry. The twelve taxa used



in Spencer's (1988, 1992) studies are the following : Bolivina albatrossi, Bolivina lowmani, Bolivina subspinescens, Cassidulina subglobosa, Cibicidoides pachyderma, Cibicidoides robertsonianus, Epistominella exigua, Oridorsalis umbonatus, Gavelinopsis translucens, Hoeglundina elegans, Pullenia quinqueloba, and Uvigerina peregrina. Canonical variate analysis of morphologic measurements of these twelve benthic foraminifera can detect intraspecific variations which are relatable to bathymetry. It was also found that morphologic differences within species can represent differences in bathymetry with a resolution as fine as 100-200 meters for both the shelf and slope. As a result of these observations, Spencer (1987) hypothesized that because intraspecific morphologic differences are difficult to detect visually, canonical variate analysis performed on foraminiferal parameter measurements can more readily detect such differences and thus relate these differences to the depths from which the foraminifera were obtained.

## CHAPTER 3

### GENERAL GEOLOGY OF THE GULF OF MEXICO

#### Tectonic setting

The Gulf of Mexico, considered by some to be a miniplate (Poag, 1981), originated at approximately the Permian-Triassic boundary (Tanner, 1965). This miniplate is located between a large right lateral megashear extending from under the eastern Gulf of Mexico to the east end of the Ouachita Mountains, and a left lateral megashear paralleling the Mexican coastline and extending to the Marathon Uplift (Beall, 1973). According to Pindell (1985), the initial basin was completely closed.

Formation of the Gulf of Mexico began during a Precambrian-Paleozoic compressional regime, when the Gulf basin miniplate moved approximately 400 miles to the northwest. Rebound, in conjunction with the cessation of compression, induced tension faults along zones of crustal weakness (Beall, 1973). Following this compressional cycle, the Mesozoic Gulf basin formed with the separation of the North and South American plates, the opening of the Mississippi Embayment, and contemporaneous development of the aforementioned megashears (Walper and Rowett, 1972).

Mesozoic tensional stresses promoted rifting and faulting in the Triassic to initiate subsidence. Block faulting was

typical of the region with many horst and graben structures developing (Beall, 1973).

#### Sedimentation and stratigraphy

Fault-bound depressions were filled with Triassic-Jurassic redbeds, which were intruded by basalts (Curtis, 1987). Following partial erosion of these redbeds, restricted circulation resulted in deposition of Middle Jurassic evaporites. By Late Jurassic time, open marine circulation produced marine and paralic sedimentation. During the overall advance and retreat of the sea from Late Jurassic to earliest Cretaceous, terrigenous clastics and carbonates were deposited. A period of erosion and nondeposition followed, spanning approximately 10my, with subsequent deposition of fluviodeltaic and marine sediments signaling another period of transgression (Murray, 1961). Sedimentation rates equalled subsidence rates such that a broad shelf prograded over attenuated and subsiding continental crust, to develop a series of banks and reefs, known as the "Lower Cretaceous Reef Trend", extending along the shelf margin from south Texas to Florida (Curtis, 1987).

In Late Cretaceous time, an increase in terrigenous clastic deposition allowed thick sediment accumulation in the landward basins. The weight of these overlying terrigenous sediments promoted deformation of the underlying salts to create salt domes and other deformational structures

(McGookey, 1975). Intrusive and extrusive volcanism occurred throughout the area (Curtis, 1987).

Starting in late Paleocene time, subsidence increased, but sediment supply from the Rocky Mountains, as a result of the Laramide Orogeny, exceeded subsidence rates. This resulted in progradation of deltaic sequences beginning in southern Texas, and then advancing toward the deeper Gulf, to produce a series of shifting depocenters from Paleocene to mid-Miocene time (Curtis, 1987).

By mid-Miocene, the principle drainage shifted from the Rio Grande to the Mississippi Embayment. Subsidence increased overall in the Cenozoic, with deltaic sequences continuing to prograde into the deeper Gulf (Murray, 1961). Throughout the Pliocene and Pleistocene, another progradational pulse continued to build sedimentation Gulfward and subsidence increased due to sediment loading (Curtis, 1987).

The samples used in this study are derived from an area, where Cenozoic sediments loaded oceanic crust in the northwestern Gulf of Mexico, which is not underlain by Middle-Late Jurassic salts (McGookey, 1975). According to seismic data, this area is underlain by shale (McGookey, 1975), such that the structural and sedimentation style in this area is dominated by shale tectonics. The shale tectonic regime resulted from Tertiary progradation of shallow water sand-clay sequences over the slope and abyssal mud deposits. Loading of high specific gravity sand-clay sequence over lower specific

gravity muds, the inability of the muds to efficiently expel connate water and hydrocarbons, and continued hydrocarbon generation in the deep-water muds, promoted flowage of these muds (McGookey, 1975). The muds tended to flow into a series of ridges and troughs. The troughs then became self-perpetuating, as the shelf edge prograded seaward so that sedimentation in the troughs caused flowage of the overpressurized mud into adjacent ridges. This pattern continued until an isostatic balance was acquired and troughs were filled with sediment. Subsequent deposition over these filled troughs was nearly flat (McGookey, 1975).

#### Sea-level changes

Quaternary global and regional fluctuations in sea level can be interpreted in terms of Quaternary sedimentation (Morton and Price, 1987). The Quaternary depositional regimes are controlled by at least eight major glacioeustatic cycles within the Gulf of Mexico (Beard et al., 1982). These cycles are characterized by paleotemperature changes, sea level highstands and lowstands, and are partially related to volumetric changes in continental ice sheets. In general, during glacial periods, there was a gradual fall in sea level, increased precipitation, and increased sediment yield, producing thick progradational facies and thin aggradational facies. Interglacial periods were characterized by rapid sealevel rises, inundation of entrenched valleys to form

estuaries, and a submerged coastal plain which was partially truncated by shoreface retreat (Morton and Price, 1987).

Approximately 1.7my ago, during the early Pleistocene, there was a regressive depositional episode which ended with a relative sea level rise (Angulogerina E transgression) and landward shift in the shoreline (Morton et al., 1991).

The middle Pleistocene began following the Angulogerina E transgression, and base level was lowered along with a basinward shift in nearshore sedimentation. After this, there was a subsequent brief sea level rise and landward shift of the shoreline, coincident with the Hyalinea baltica extinction horizon. The middle Pleistocene ended with a subsequent regression and the Trimosina denticulata transgression (Morton et al., 1991).

The late Pleistocene began with a sea level fall. Eventually, sediment supply exceeded subsidence in the south Texas offshore area (Morton et al., 1991).

Pleistocene sea levels were not only influenced by glacial and interglacial episodes, but also by local diapirism or crustal warping. The influence of unknown amounts of basinal subsidence and isostatic adjustment can lead to complications in the interpretation of Pleistocene sea levels for the Gulf of Mexico (Poag and Sidner, 1976). Because the aforementioned Gulf of Mexico sea level curves have been constructed with no regard to other geologic processes, such as tectonic and isostatic deformation (Morton and Price,

1987), it is questionable that the sea level curves for the northwestern Gulf of Mexico are accurate.

## CHAPTER 4

### MATERIALS AND METHODS

#### A. Field Area

Samples used in this study were collected from well cuttings in a Mobil Oil well, located on Block A-57 in the northwestern Gulf of Mexico at 26.2 N, 96.4 W (Figures 1, 2). The well is located within the South Padre Island East area, specifically, within Mobil Oil's leased block A-57. It was a wildcat drilled on June 13, 1978, to a total depth of 8607 feet, with the oldest sediment penetrated being Miocene in age. The status of the well is D & A (dry and abandoned). A total of 24 samples were analyzed in the current study, from 1560'MD (measured depth from the rotary table) at the Globorotalia inflata last occurrence datum (LAD), to 3300'MD in the well. Figure 3 shows the sampling range within this well. A faunal analysis was done on all 24 samples.

#### B. Sampling Methods

The samples from the Mobil well were obtained using standard offshore vertical drilling techniques, rotary drilling with a conventional rock drill bit. As there was a constant stream of fluid rising, the mud logger cleaned



FIGURE 1. REGIONAL MAP OF THE STUDY AREA  
(box indicates area covered by Figure 2).

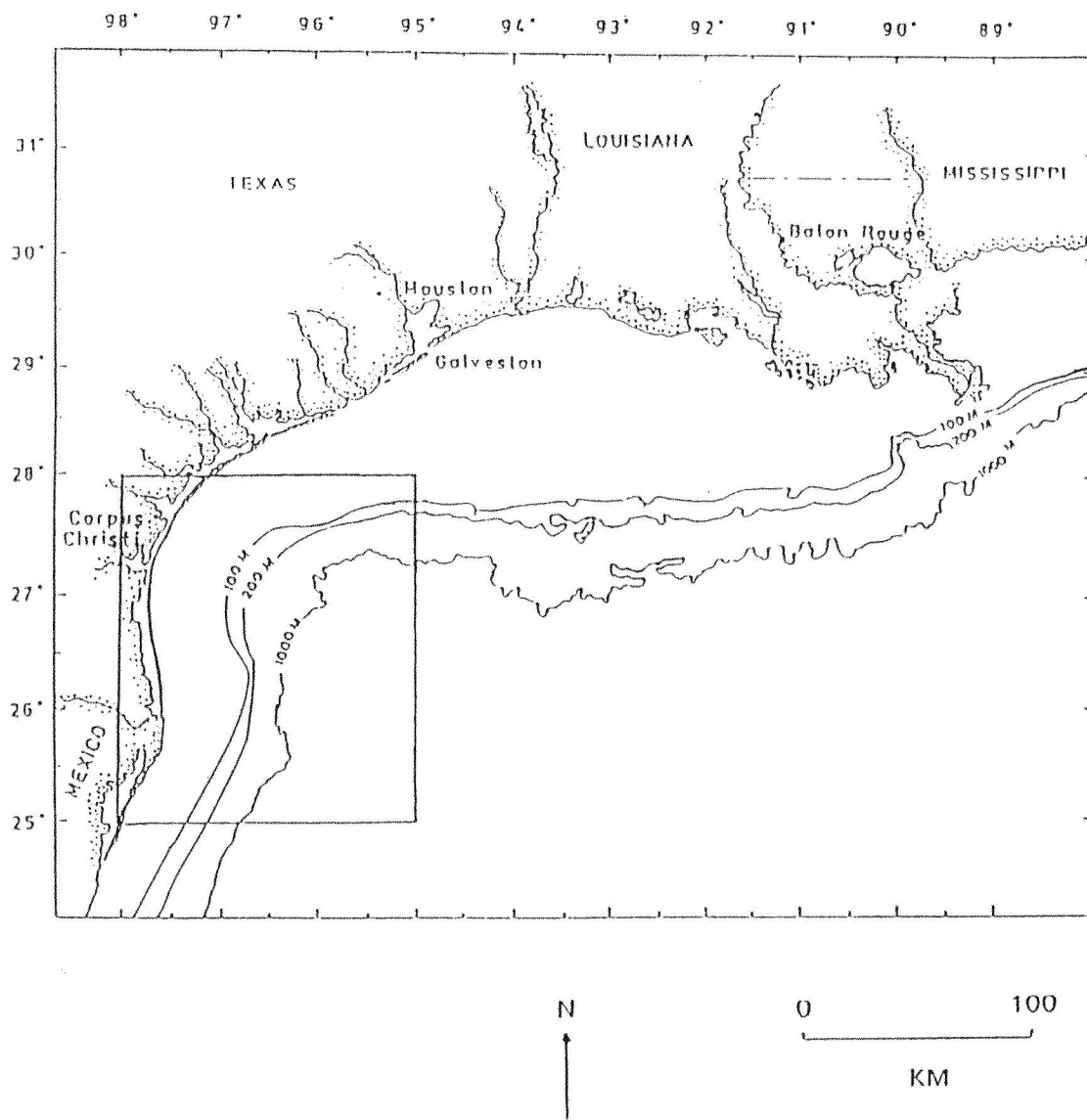


FIGURE 2. LOCATION OF THE MOBIL WELL, BLOCK A-57  
NORTHWESTERN GULF OF MEXICO  
(map taken from Uchupi, 1967).

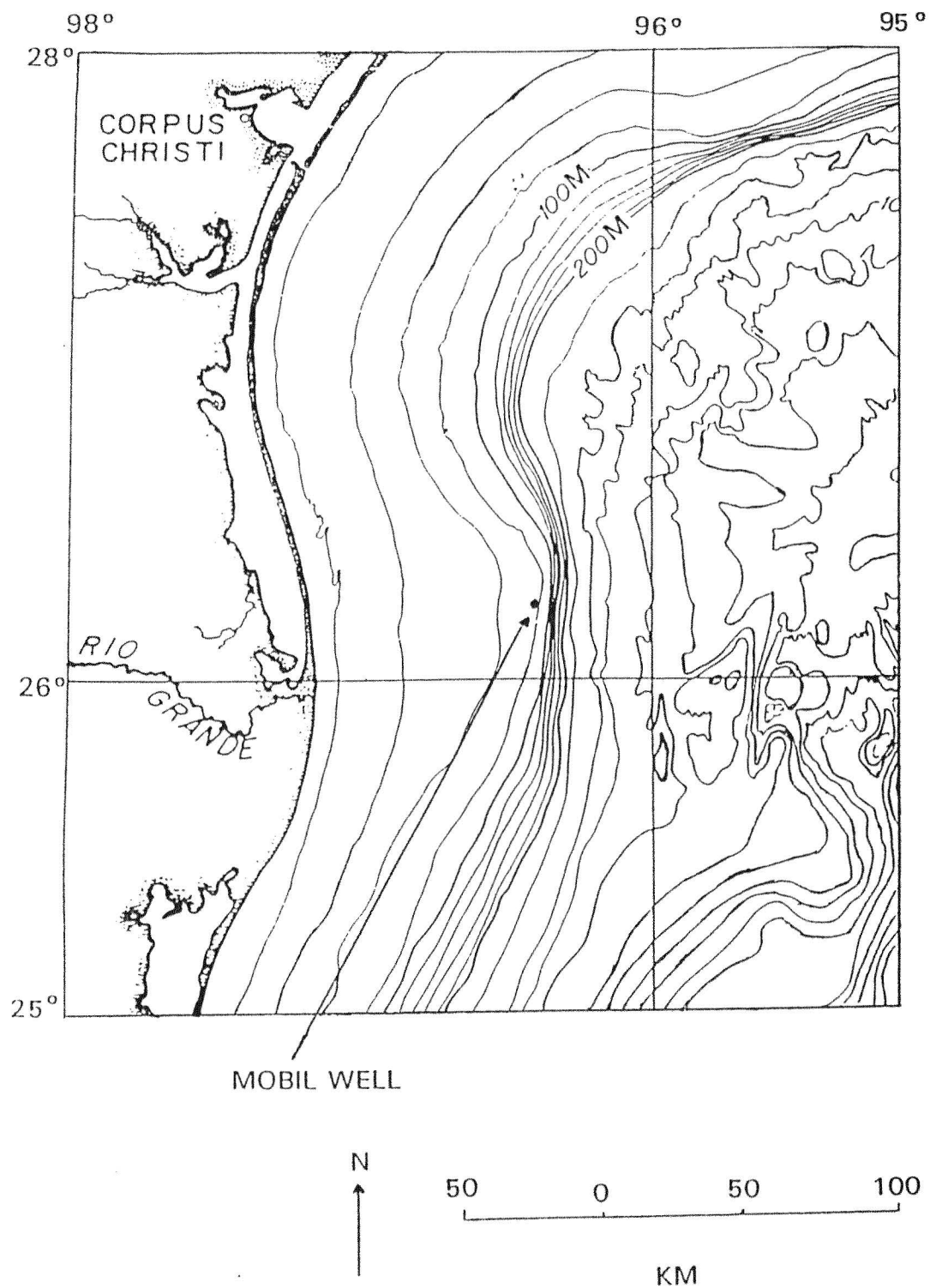


FIGURE 3. ENVIRONMENTAL INTERPRETATION  
AND BIOSTRATIGRAPHY ACCORDING  
TO MOBIL OIL FOR MOBIL WELL  
ON SOUTH PADRE ISLAND EAST, BLOCK A-57  
(LADS=last occurrence datums,  
\*=samples used in morphometric analyses  
\*\*=index species placed next to the  
last sample in which they occur).

EPOCH	AGE IN MY	WELL DEPTH	INDEX SPECIES LADS**	DEPTH ZONES NOTED BY MOBIL OIL	WORLDWIDE PLANKTIC FORAMINIFERAL ZONES		
					STAINFORTH ET AL., 1976	BLOW, 1969	
P L E I S T O C E N E	.25	1560*	<u>Globorotalia inflata I</u>	OUTER NERITIC	<u>Globorotalia truncatulinoides</u>	N23	
		1950*					
		2100*					
		2430*					
		2520*					
	.45	2550*		UPPER BATHYAL			N22
	.55	2640*	<u>Trifarina denticulata</u>				
		.85	2760*				
		2790					
		2820					
		2850					
		2880					
		2910					
	1.4	2940	<u>Angulogerina (E)</u>				
		2970					
		3000					
		3030					
		3060					
		3120					
		3150					
		3180					
		3210					
		3240					
		3270					

the shaker at each 30 feet, so that 30 foot cuttings could be collected, logged and bagged, and sent to Paleo-Data, Inc.

The lithology of all cuttings is dominantly composed of quartz with some clay aggregates and a few opaque minerals (see Appendix E).

## C. Laboratory Techniques

### I. Micropaleontology Sample Preparation

Paleo-Data, Inc. processed the entire amount of sample received, so that the foraminiferal assemblage found in the well was accurately represented. First, the cuttings were rinsed over a 150 mesh size screen and then soaked in Varsol, followed by water rinsing to break down the shale. These samples were then returned to Mobil Oil micropaleontologists for faunal and paleobathymetric interpretation. This study is based on these samples.

### II. Picking of foraminifera for morphometric analysis

In order to expedite foraminiferal picking, a soap-floating technique was used to concentrate foraminiferal specimens, because the samples contained a large amount of arenaceous and argillaceous sediments mixed with the foraminifera. This float procedure expedites the recovery of foraminifera from the sand-size fraction of the sample. A

brief discussion of this soap-float method was given by Harris and Sweet (1989).

The method adapted for this study was the following. Each whole sample was placed in a large evaporating dish and covered with an inch of water. A soap lather of "Dove" soap was made with the hands and rinsed into the dish with a small amount of water. The sample was then gently swirled with the hand to mix the soapy water into the clean water and sample. Foraminiferal tests, having air-filled chambers, floated to the top of the water surface in a soapy scum, which was decanted from the dish onto a 63 micron sieve. The process was repeated until there were presumably no longer any foraminifera remaining in the dish. The floated portion was washed repeatedly with tap water over the sieve to remove the remaining soap. Both portions were then dried in an oven at 100 degrees Fahrenheit for a few hours. Next the material that did not float was examined to see if any foraminifera remained. The float procedure was repeated on that material which still contained foraminifera.

Foraminifera were picked using a lightly moistened 00000 brush. Specimens were placed onto cardboard microfossil slides covered with a thin layer of gum tragacanth to insure the specimens would remain in place.

Because this study involved measuring dimensions of foraminifera to ascertain relationships of morphology to paleodepths, ontogenetic size variations must be eliminated.



To exclude the effects of ontogeny, only adult specimens were picked. In the case of Cassidulina subglobosa, which is a biserial enrolled species, only specimens between the length of .10 and .25 millimeters were chosen. In the case of Uvigerina peregrina, a triserial elongate species, specimens were determined to be adults if they were between the length of .20 and .50 millimeters, and possessed greater than seven chambers.

### III. Picking foraminifera for taxonomic analysis

The bulk samples were first weighed using a Mettler scale. Each sample was then split with a microsplitter until the final split was of sufficient size to cover a gridded picking tray. Each split was then weighed on the Mettler scale. The final split was gradually and carefully emptied onto a gridded metal picking tray, divided into 100 numbered grids. All specimens from each square grid were picked with a minimum of 300 specimens picked per tray. A random numbers table was used to insure unbiased picking.

### IV. SEM preparation

Representatives of the two species to be used in morphometric analyses, Cassidulina subglobosa and Uvigerina peregrina, were illustrated in both side and apertural view (Appendix A), using a Cambridge S100 Stereoscan. Specimens were first placed onto an aluminum stub covered with double-

sided tape. The stub was then placed into an E5200 SEM Autocoating unit/vacuum and sputter-coated to a thickness of one Angstrom, using a gold-paladium target. The specimens were then photographed on polaroid NP55 film.

## CHAPTER 5

### PLANKTONIC FORAMINIFERAL BIOSTRATIGRAPHY

Mobil Oil Company provided the biostratigraphic framework for the well section studied. The stratigraphic range is from the early Pleistocene (1.8 Ma), to late Pleistocene (.25 Ma) (Figure 3). The biostratigraphic interpretation given by Mobil Oil for this well section was based on the last occurrence datums (LADS) of key benthic and planktic foraminiferal species. These key species were sought using The Systematic Index of Recent and Pleistocene Planktonic Foraminifera by Saito, Thompson, and Breger (1981), and Neogene Planktonic Foraminifera by Kennett and Srinivasan (1983). None of the biostratigraphic indicator species, however, could be found in the samples with the exception of Hyalinea baltica, last encountered for this study at 2790'MD in the well, whereas Mobil Oil micropaleontologists noted the last occurrence of Hyalinea baltica at 2760'MD in the well (see Figure 3). The samples were checked in this study for Stainforth et al. (1975) planktonic zonal indicator, Globorotalia truncatulinoides (see Figure 3). This species, based on its limited stratigraphic distribution of early Pleistocene-Recent (Kennett and Srinivasan, 1983), confirmed that the studied well section was Pleistocene in age, as it was found in the majority of samples examined.

## CHAPTER 6

### METHODS OF PALEOBATHYMETRIC ANALYSIS

#### A. Introduction

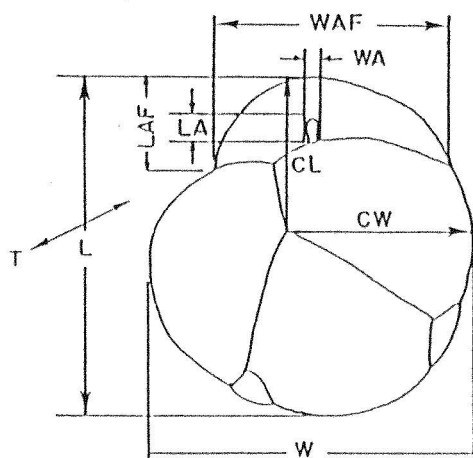
In this study, paleobathymetry was interpreted based on canonical variate analysis of morphometric measurements of the benthic foraminifera in the sampled interval of the Mobil well.

#### B. Morphologic Approach

The morphology of two species, nine characters of Cassidulina subglobosa and fifteen characters of Uvigerina peregrina, was measured using a Leitz-Wetzlar binocular microscope at 100x power, and optical micrometer and goniometer. The measured characters for each species are diagrammed in Figure 4 and were chosen because Spencer's analysis of the same species found them to be significant in distinguishing intraspecific morphologic variation.

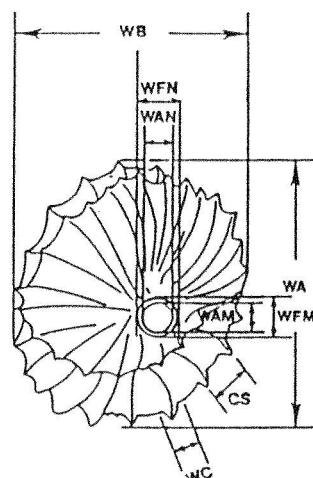
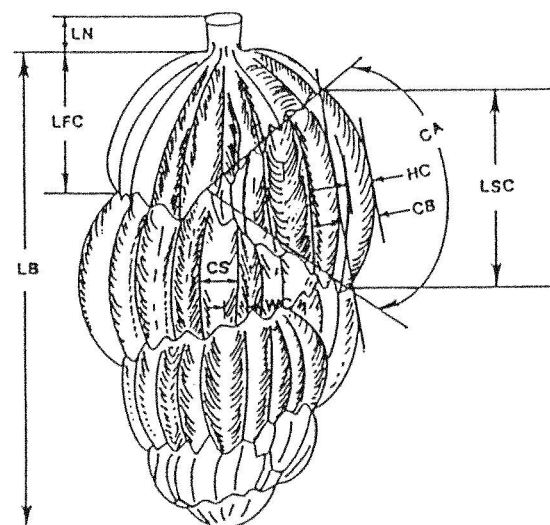
Table 1 displays the number of foraminifera collected in the individual samples/30 foot cuttings for morphometric analyses. Only eight samples contained well preserved adult specimens of the desired species for measuring purposes.

FIGURE 4. MEASURED PARAMETERS OF  
CASSIDULINA SUBGLOBOSA AND  
UVIGERINA PEREGRINA.



L=length, W=width, T=thickness,  
LAF=length of apertural face,  
WAF=width of apertural face,  
LA=aperture length, WA=aperture  
width, CL=center height, CW=center  
width

Cassidulina subglobosa



Uvigerina peregrina

LB=length excluding neck, LN=length of neck,  
LFC=length of final chamber,  
LSC=length of second to last chamber,  
HC=height of costae, CB=chamber bulge of  
second to last chamber, WC=width of costae,  
CS=costae spacing, CA=chamber angle radius on  
second to last chamber, WB=minimum width,  
WA=maximum width, WAN=minimum width of  
aperture, WAM=maximum width of aperture,  
WFM=maximum flange width, WFN=minimum flange  
width

TABLE 1. NUMBER OF FORAMINIFERA  
COLLECTED IN MOBIL WELL SAMPLES  
FOR MORPHOMETRIC ANALYSES.

WELL DEPTH FROM ROTARY TABLE	1560	1950	2100	2430	2520	2550	2640	2760
SPECIES	NUMBER OF SPECIMENS FOUND							
<u>CASSIDULINA</u> <u>SUBGLOBOSA</u>	13	0	3	20	0	25	0	26
<u>UVIGERINA</u> <u>PEREGRINA</u>	10	4	4	23	16	11	18	30



Appendix B provides the measurements for each species.

### C. Statistical Procedures

Once the measurements for each species were made, they were subjected to canonical discriminant analysis using a SAS (statistical analysis system) program. Canonical discriminant analysis can be thought of as a dimension-reduction technique. Given a classification variable (the sample groups), and several quantitative variables (the morphologic measurements), the statistical analysis derives canonical functions. These functions are axes in n-dimensional space that express linear combinations of the quantitative variables. These canonical functions summarize the variation between sample groups in a manner similar to the way principle component analysis summarizes the total variation (SAS, 1985). Given several groups of observations, in this case, the Mobil well samples and the modern day database, with measurements on several quantitative variables (morphologic measurements), canonical discriminant analysis derives a linear combination of variables with the highest possible multiple correlation of the groups along each particular canonical function. The linear combination possesses linear coefficients called canonical coefficients or canonical weights. The variable defined by the coefficients is the first canonical variable, otherwise known as the canonical component (Rock, 1988).

Because it is desirable for the pooled within group variance of the canonical variable to be equal to one, the data need to be normalized. In SAS, normalization of the data is incorporated into the program (SAS, 1985; Rock, 1988).

SAS determines the percentage of variance which each canonical function contributes to discriminating the samples, that is, these programs delineate what percentage the first, second, third, et cetera, canonical functions contribute to the total variance (SAS, 1985).

SAS was also used to obtain variance-covariance matrices, with which one can construct confidence ellipses, at a 95% confidence interval. These ellipses are graphical representations of the bivariate normal frequency distributions of the sample groups in three-dimensional space, allowing one to visualize how distinct one sample group is from another by the relative proximity of the ellipses (Buzas, 1979).

#### D. Faunal Approach

##### Taxonomy

Taxonomic identification of 24 samples in the Pleistocene section was performed to the species level for benthic foraminifera. As the taxonomic approach to paleoecology relies on the direct comparison between fossil and analogous modern day assemblages (Lipps, 1979), these fossil assemblages

encountered in the Pleistocene section were compared to modern-day depth related specific assemblages. The assemblages encountered within the Pleistocene samples were compared to modern-day depth related specific assemblages outlined by Phleger and Parker (1951), Parker (1954), Albers et al., (1966), Poag and Valentine (1976), Culver and Buzas (1981), Poag (1981), and Culver (1988).

#### Cluster analysis

##### Species abundances

Cluster analysis was utilized to determine similarity of all twenty-four samples, based on abundances of the one hundred fifteen species present within these samples, within the Pleistocene stratigraphic section. A data matrix consisting of relative abundances of each species in each sample was constructed. The Bray-Curtis similarity coefficient was used to evaluate this data matrix. This coefficient compares samples based on the species proportions within each sample. Data for this matrix were transformed from raw counts of species to percentages, and then from percentages to arcsines. Therefore, species with unequally distributed proportions can be compared (Hazel, 1970). The unweighted pair group method was utilized in this cluster analysis to minimize distortion of the original data matrices.

### Planktic-Benthic ratios

It has been generally observed that the percentage of planktic foraminifera increases with increasing distance offshore (Phleger and Parker, 1951). This study evaluates, in terms of percent planktonics for each Pleistocene sample, the planktic to benthic ratio, in hopes of corroborating evidence for morphometrically and taxonomically determined paleodepths.

### Species diversity

Variations in species diversity have been related to changes in water depth (Gibson and Buzas, 1973). Species diversity is the "relationship of the number of species to the number of individuals" (Murray, 1973). Although sample sizes are quite constant (three hundred to three hundred thirty specimens), this study utilizes the Shannon-Wiener information function to determine species diversity. The equation for this function is :

$$\text{eq. 1 : } H(S) = -\sum p_i \ln p_i$$

where  $H(S)$  is the Shannon-Wiener measure of diversity, and  $p_i$  is the proportion of the  $i$ th species. Species equitability,  $E$ , also referred to as dominance, was then calculated by the equation :

$$\text{eq. 2 : } E = H(S) / \ln S$$

where  $S$  is the number of species per sample (Hazel, 1970). Equitability represents the percent of the assemblage composed of the single most abundant species. Species equitability is

equal to one when all species are equally distributed, representing a higher dominance of a species. Higher values of equitability or dominance, in general, indicate shallow-marine environments or areas of restricted circulation, whereas values tend to decrease offshore into deeper marine waters. Studies in the Gulf of Mexico, however, show little change in the range of equitability values from shallow into deep marine waters (Gibson and Hill, 1992).

## CHAPTER 7

### RESULTS AND INTERPRETATIONS

#### A. Organization of Original Pleistocene Data

Small sample size in some original samples made it necessary to either eliminate these samples or combine them with other samples to create a sample size sufficiently large for statistical analyses. The reorganization of original samples was necessary in order to obtain greater precision by minimizing the variance of measured values within each group. Statistical analyses should, whenever possible, be based upon samples of similar size. In the case of multivariate analyses, the number of observations within a sample group should at least equal the number of variables measured per observation (Rock, 1988).

The eight original Pleistocene samples were regrouped separately for Cassidulina subglobosa and Uvigerina peregrina. These new groups for Cassidulina subglobosa are the following : group 81 representing 1560' and 2100', group 84 representing 2430', group 83 representing 2550', and group 86 representing 2760' (well depths from the rotary table). The new groups for Uvigerina peregrina are the following : group 81 representing 1560'-2100', group 84 representing 2430', and group 83 representing 2520' and 2550', group 85 representing 2640', and

group 86 representing 2760' (well depths from the rotary table). These new sample groups are displayed in Table 2.

B. Samples of the modern day  
database

Once regrouped, the Pleistocene samples were separately incorporated into Spencer's (1992) modern day database and canonical variate analyses, using SAS, were performed on ODU's mainframe for each new sample group. The modern day database (Spencer, 1992) represents samples which display depth-relatable morphologic measurements for Cassidulina subglobosa and Uvigerina peregrina along a shelf-slope transect (50-1950m) within the Gulf of Mexico. The modern day database includes sample group numbers 28 (50-100m) with twenty-three specimens, 63 (101-200m) with thirty specimens, 447 (201-450m) with twenty-three specimens, 60 (451-700m) with thirteen specimens, 37 (701-950m) with thirty-five specimens, 42 (951-1200m) with thirty-four specimens, 481 (1201-1450m) with forty-two specimens, and 129 (1701-1950m) with forty-eight specimens for Cassidulina subglobosa, and 28 (50-200m) with two hundred fifty-eight specimens, 34 (201-450m) with one hundred forty-five specimens, 122 (451-700m) with ninety-five specimens, 50 (701-950m) with two hundred twenty-nine specimens, 42 (951-1200m) with one hundred sixty-seven specimens, 126 (1201-1450m) with one hundred twenty-nine

TABLE 2. NEW PLEISTOCENE SAMPLE GROUPS  
FOR CASSIDULINA SUBGLOBOSA  
AND UVIGERINA PEREGRINA.



NEW SAMPLE GROUPS FOR <u>CASSIDULINA SUBGLOBOSA</u>		
NEW SAMPLE NUMBER	WELL DEPTHS (feet)	NUMBER OF SPECIMENS
81	1560, 2100	16
84	2430	20
83	2550	25
86	2760	26

NEW SAMPLE GROUPS FOR <u>UVIGERINA PEREGRINA</u>		
NEW SAMPLE NUMBER	WELL DEPTHS (feet)	NUMBER OF SPECIMENS
81	1560, 1950, 2100	18
84	2430	23
83	2520, 2550	27
85	2640	18
86	2760	30

specimens, and 343 (1701-1950m) with eighty-three specimens for Uvigerina peregrina. These modern day sample groups are displayed in Table 3.

C. Canonical discriminant analysis  
of the regrouped Pleistocene samples

Analysis of group 81 for Cassidulina subglobosa

Group 81 had sixteen specimens of Cassidulina subglobosa available for analysis. Employing SAS, canonical analysis was performed in order to obtain the variance-covariance matrices needed to construct the 95% confidence ellipses. The group centroids and their respective confidence ellipses are plotted in Figures 5 and 6. Along the first two canonical functions, which account for 73% of the variance, the 95% confidence ellipses of groups 81 and 28 (50-100m) completely overlap. In addition, the 95% confidence ellipse of group 81 intersects, to a lesser degree, those of samples 63 (101-200m) and 37 (701-950m). Along the third function, which contains 11% of the variance, the same three samples continue to have overlapping 95% confidence ellipses with the ellipse of group 81.

Due to the complete overlap of Pleistocene group 81 with group 28 (50-100m) along all three canonical functions, the interpretation for Pleistocene group 81 can be expressed as a probable depth range of 50-100m. The intersection of

TABLE 3. MODERN DAY DATABASE SAMPLE  
GROUPS FOR  
CASSIDULINA SUBGLOBOSA  
AND UVIGERINA PEREGRINA  
(data from Spencer, 1992).

MODERN DAY DATABASE SAMPLE GROUPS- <u>CASSIDULINA SUBGLOBOSA</u>		
SAMPLE NUMBER	DEPTH RANGE	NUMBER OF SPECIMENS
28	50-100m	23
63	101-200m	30
447	201-450m	23
60	451-700m	13
37	701-950m	35
42	951-1200m	34
481	1201-1450m	42
129	1701-1950m	48

MODERN DAY DATABASE SAMPLE GROUPS- <u>UVIGERINA PEREGRINA</u>		
SAMPLE NUMBER	DEPTH RANGE	NUMBER OF SPECIMENS
28	50-200m	258
34	201-450m	145
122	451-700m	95
50	701-950m	229
42	951-1200m	167
126	1201-1450m	129
343	1701-1950m	83

FIGURE 5. SAS CONFIDENCE ELLIPSE PLOT  
FOR CASSIDULINA SUBGLOBOSA FOR GROUP 81  
(CSCF1=Cassidulina subglobosa canonical function 1,  
CSCF2=Cassidulina subglobosa canonical function 2).

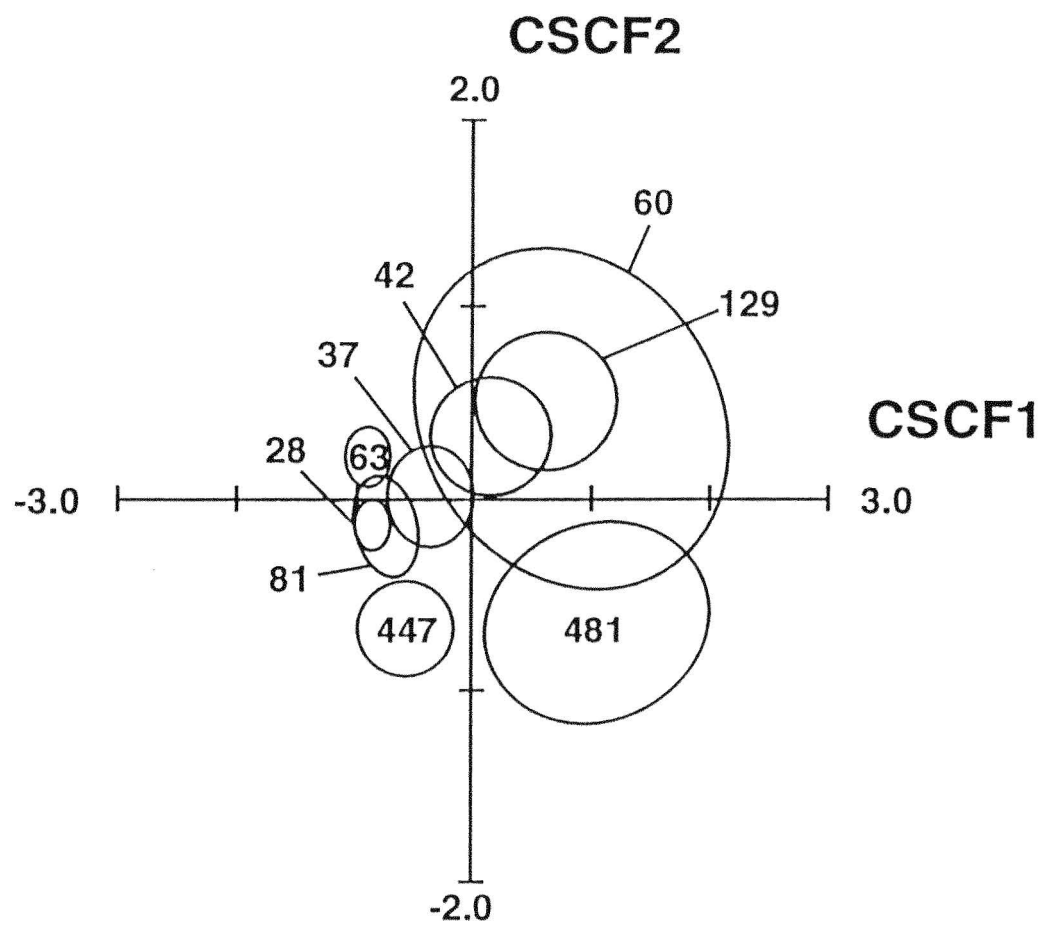
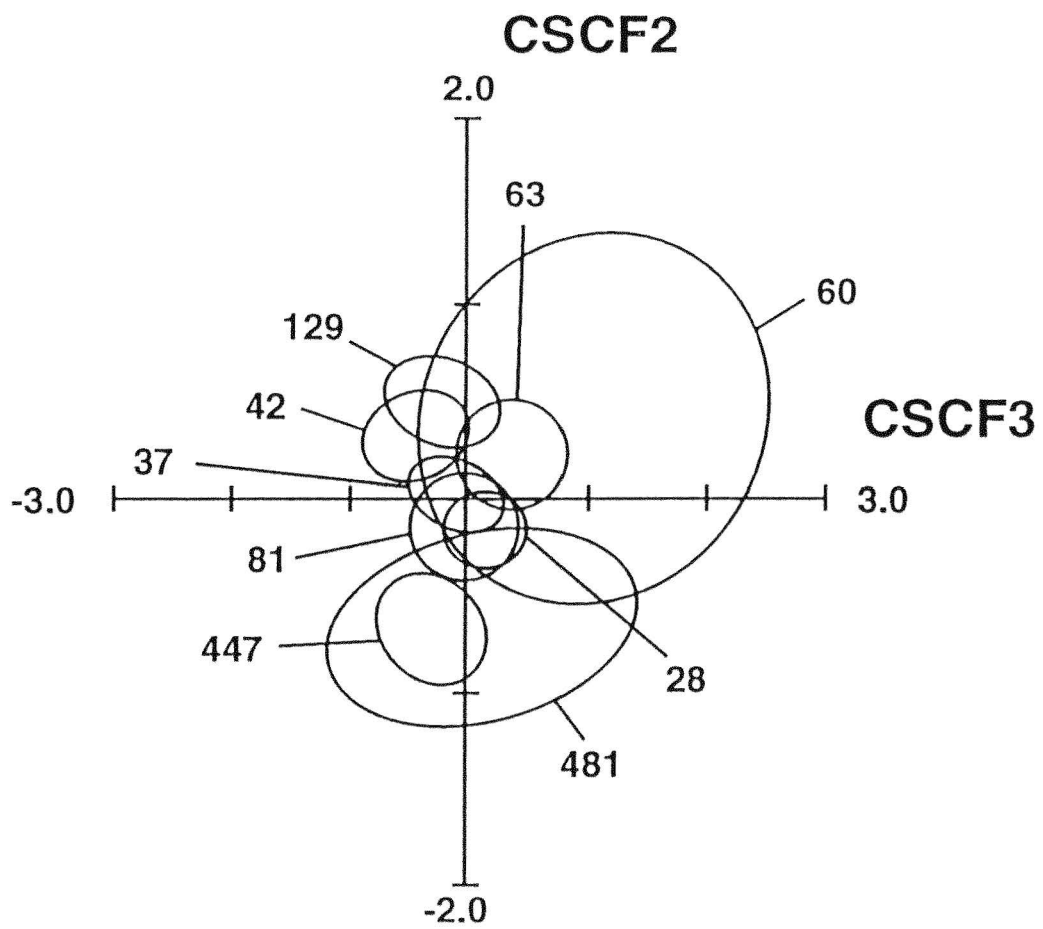


FIGURE 6. SAS CONFIDENCE ELLIPSE PLOT  
FOR CASSIDULINA SUBGLOBOSA FOR GROUP 81  
(CSCF2=Cassidulina subglobosa canonical function 2,  
CSCF3=Cassidulina subglobosa canonical function 3).





confidence ellipses of group 81 with those of groups 63, 37, 60, and 481 is not as pronounced as the strong overlap of groups 81 and 28. The intersection of group 81 with 60 and 481 along the third function only is a result of viewing along a third dimension.

Although the probable depth range for group 81 is thought to be 50-100m, the previously mentioned intersection of groups 81, 63, and 37 along all three functions may be indicative of a possible range of 50-950m.

#### Analysis of group 84 for Cassidulina subglobosa

Group 84 had twenty specimens of Cassidulina subglobosa available for analysis. The group centroids and their respective 95% confidence ellipses are plotted in Figures 7 and 8. Along the first two canonical functions, which contain 75% of the variance, the confidence ellipse of group 84 strongly overlaps only that of group 28 (50-100m). Along the third canonical function, which contains 11% of the variance, the 95% confidence ellipses of groups 84 and 28 are statistically discrete, while the confidence ellipse of group 84 overlaps those of groups 37 (701-950m) and 60 (451-700m). The fact that group 84 did not intersect groups 37 and 60 along the first two canonical functions, accounting for the majority of the variance, represents an association of these two groups due to changing representation of the axes in three-dimensional space.

FIGURE 7. SAS CONFIDENCE ELLIPSE PLOT  
FOR CASSIDULINA SUBGLOBOSA FOR GROUP 84  
(CSCF1=Cassidulina subglobosa canonical function 1,  
CSCF2=Cassidulina subglobosa canonical function 2).

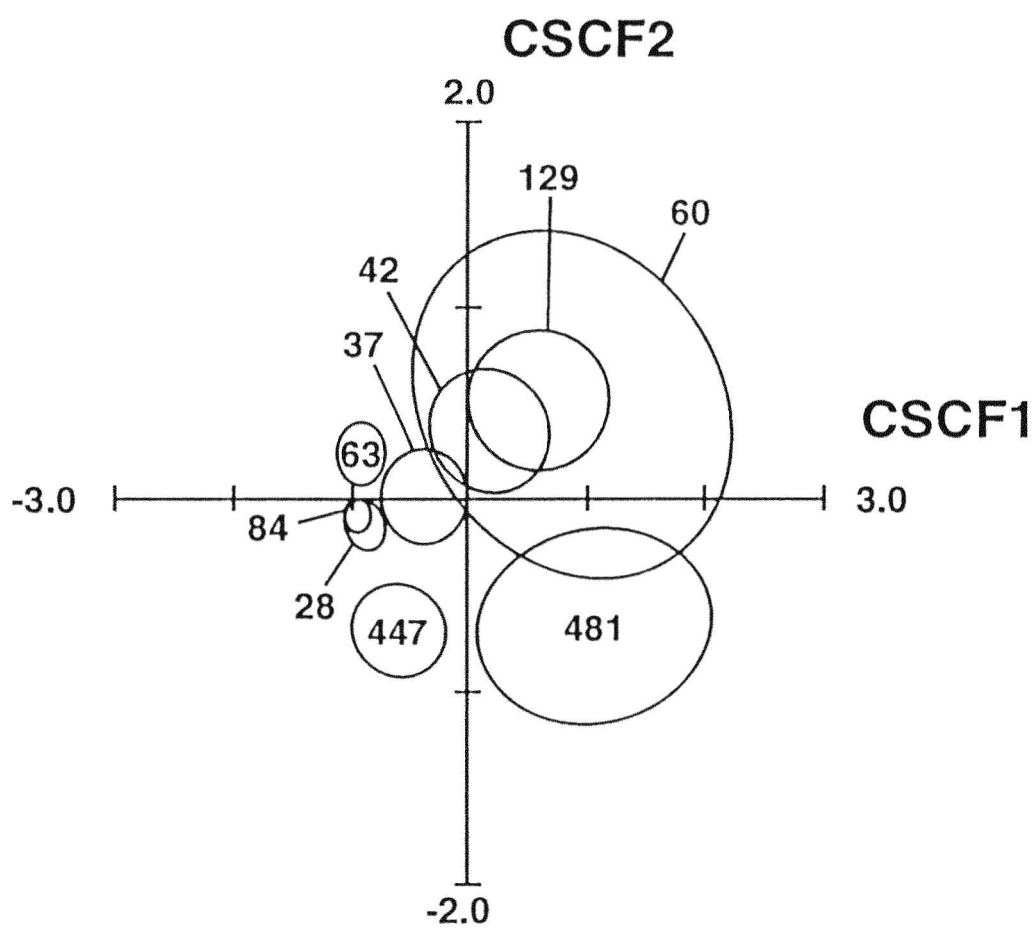
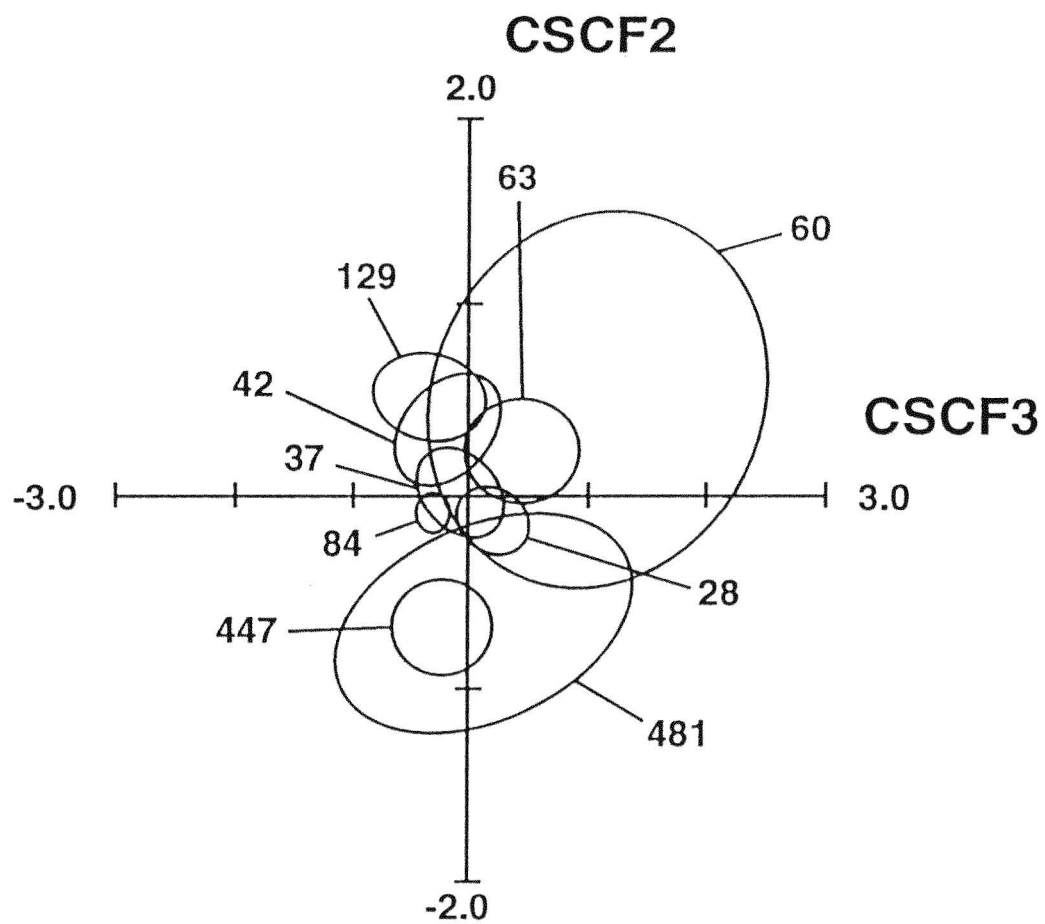


FIGURE 8. SAS CONFIDENCE ELLIPSE PLOT  
FOR CASSIDULINA SUBGLOBOSA FOR GROUP 84  
(CSCF2=Cassidulina subglobosa canonical function 2,  
CSCF3=Cassidulina subglobosa canonical function 3).



The interpretation for Pleistocene group 84 is expressed as a probable depth of 50-100m.

#### Analysis of group 83 for Cassidulina subglobosa

Group 83 had twenty-five specimens of Cassidulina subglobosa available for analysis. Figures 9 and 10 depict the plots of this canonical analysis along with 95% confidence ellipses. Along the first two canonical functions, which account for 72% of the variance, groups 83 and 28 (50-100m) have intersecting confidence ellipses. Along the third function, containing an additional 12% of the variance, groups 83 and 28 form discrete plots, while group 81 slightly intersects group 481 (1201-1450m). As group 81 did not intersect group 481 along the plot of the first two canonical functions, the intersection of these groups along the third function is simply due to the view along the third dimension.

The interpretation for the Pleistocene group 83 is expressed as a probable depth range of 50-100m.

#### Analysis of group 86 for Cassidulina subglobosa

Group 86 had twenty-six specimens of Cassidulina subglobosa available for analysis. The plots for this canonical analysis are shown in Figures 11 and 12. Along the first two canonical functions, which account for 72% of the variance, groups 86 and 28 (50-100m) have strongly overlapping confidence ellipses.

FIGURE 9. SAS CONFIDENCE ELLIPSE PLOT  
FOR CASSIDULINA SUBGLOBOSA FOR GROUP 83  
(CSCF1=Cassidulina subglobosa canonical function 1,  
CSCF2=Cassidulina subglobosa canonical function 2).

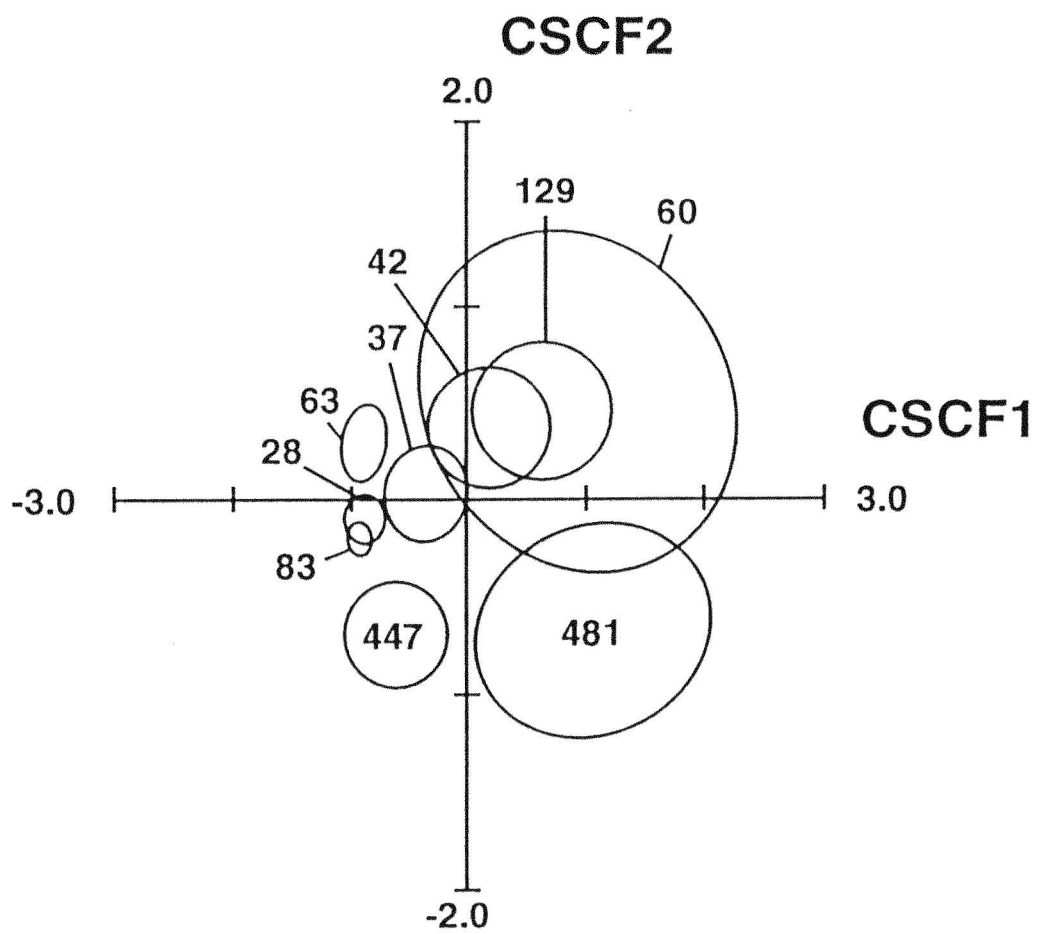




FIGURE 10. SAS CONFIDENCE ELLIPSE PLOT  
FOR CASSIDULINA SUBGLOBOSA FOR GROUP 83  
(CSCF2=Cassidulina subglobosa canonical function 2,  
CSCF3=Cassidulina subglobosa canonical function 3).

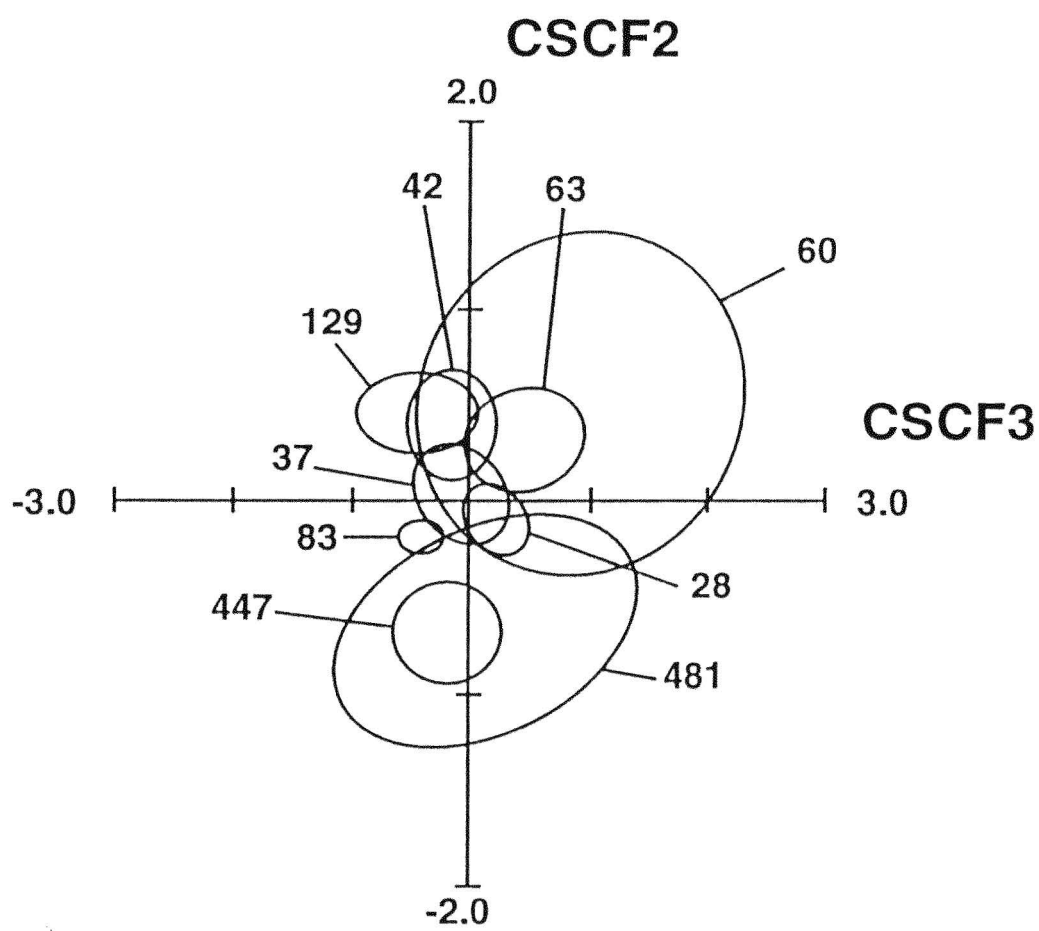


FIGURE 11. SAS CONFIDENCE ELLIPSE PLOT  
FOR CASSIDULINA SUBGLOBOSA FOR GROUP 86  
(CSCF1=Cassidulina subglobosa canonical function 1,  
CSCF2=Cassidulina subglobosa canonical function 2).

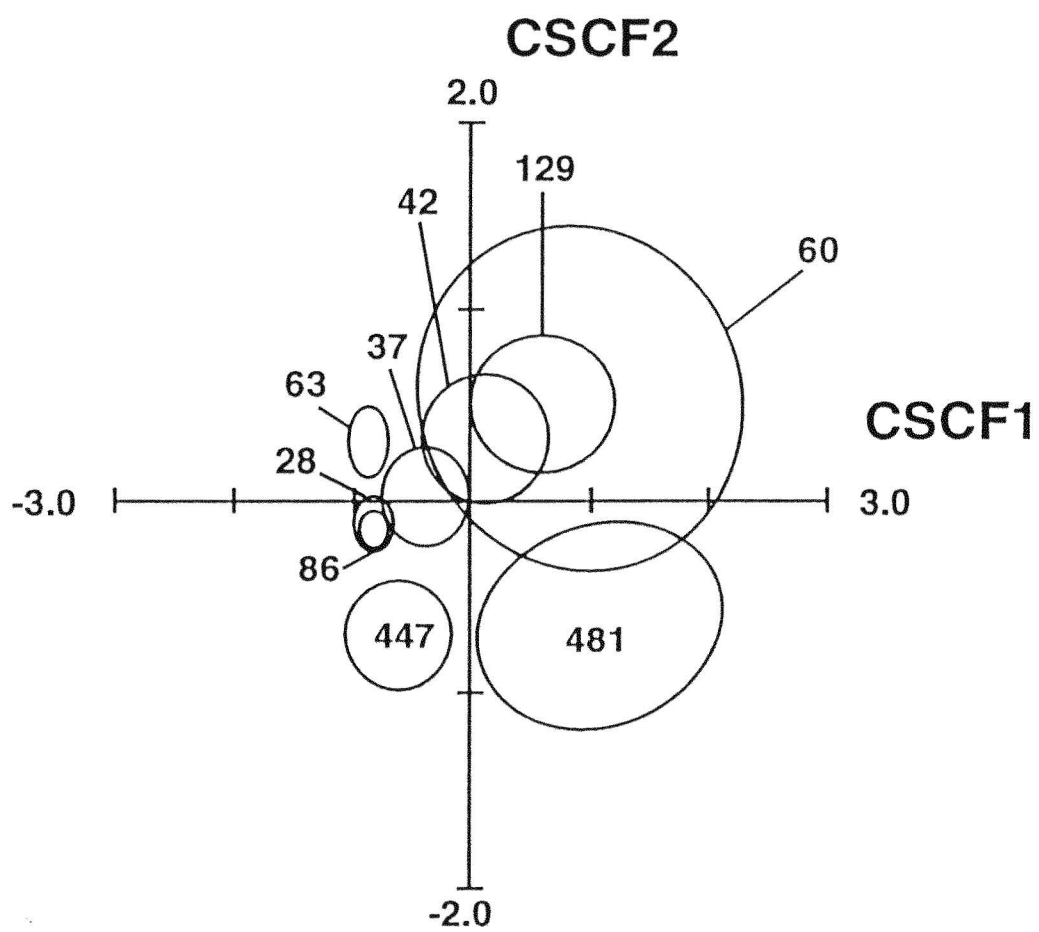
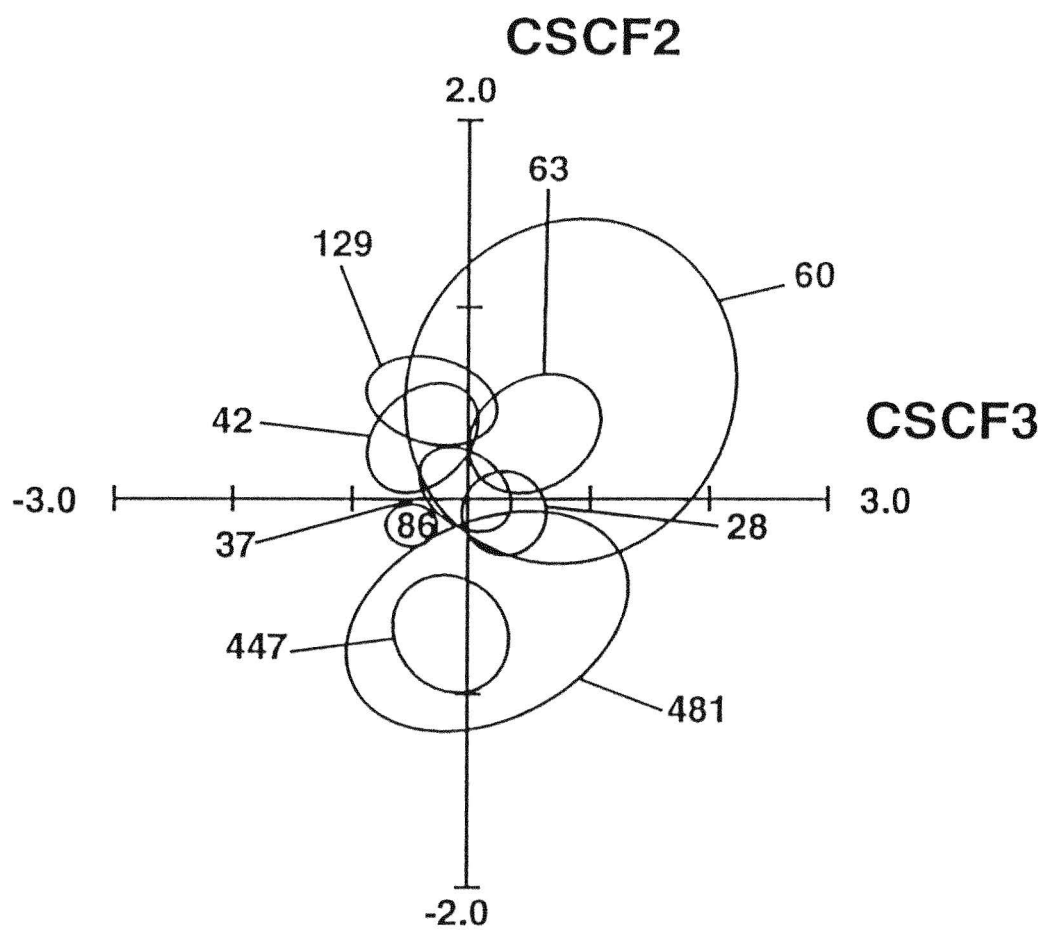


FIGURE 12. SAS CONFIDENCE ELLIPSE PLOT  
FOR CASSIDULINA SUBGLOBOSA FOR GROUP 86  
(CSCF2=Cassidulina subglobosa canonical function 2,  
CSCF3=Cassidulina subglobosa canonical function 3).



Along the third function, which accounts for an additional 13% of the variance, the confidence ellipse of group 86 plots distinctly away from the confidence ellipse representing group 28.

Based on the plot of canonical functions (see Figures 11 and 12), a probable bathymetric range of 50-100m may be indicated for group 86.

Table 4 summarizes the canonical analysis results for Pleistocene Cassidulina subglobosa groups.

#### Analysis of group 81 for Uvigerina peregrina

Group 81 had eighteen specimens of Uvigerina peregrina available for analysis. Figures 13 and 14 display the SAS plots of this analysis and the 95% confidence ellipses. The first two canonical functions, which account for 89% of the variance, shows group 81, although closest to group 28 (50-200m), as a discrete entity. Along the third function, which accounts for an additional 6% of the variance, the ellipse of group 81 is also a discrete entity. This would seem to indicate that, while the intraspecific variation exhibited by specimens of group 81 is somewhat similar to that exhibited by specimens of group 28, it is distinct from any of the bathymetric variation found in the modern day database for Uvigerina peregrina.

The bathymetric interpretation for group 81 is possibly 50-200m. The complete separation of the confidence ellipse

TABLE 4. SUMMARY OF SAS RESULTS  
FOR CASSIDULINA SUBGLOBOSA.



WELL GROUPS	CF1 vs. CF2	CF3 vs. CF2	INFERRED DEPTH RANGE OF WELL GROUPS
	modern day correlative samples		
81 (1560'-2100')	28 (50-100m) 63 (101-200m) 37 (701-950m)	28 (50-100m) 63 (101-200m) 37 (701-950m)	50-100m
84 (2430')	28 (50-100m)	none	50-100m
83 (2550')	28 (50-100m)	none	50-100m
86 (2760')	28 (50-100m)	none	50-100m

FIGURE 13. SAS CONFIDENCE ELLIPSE PLOT  
FOR UVIGERINA PEREGRINA FOR GROUP 81  
(UPCF1=Uvigerina peregrina canonical function 1,  
UPCF2=Uvigerina peregrina canonical function 2).

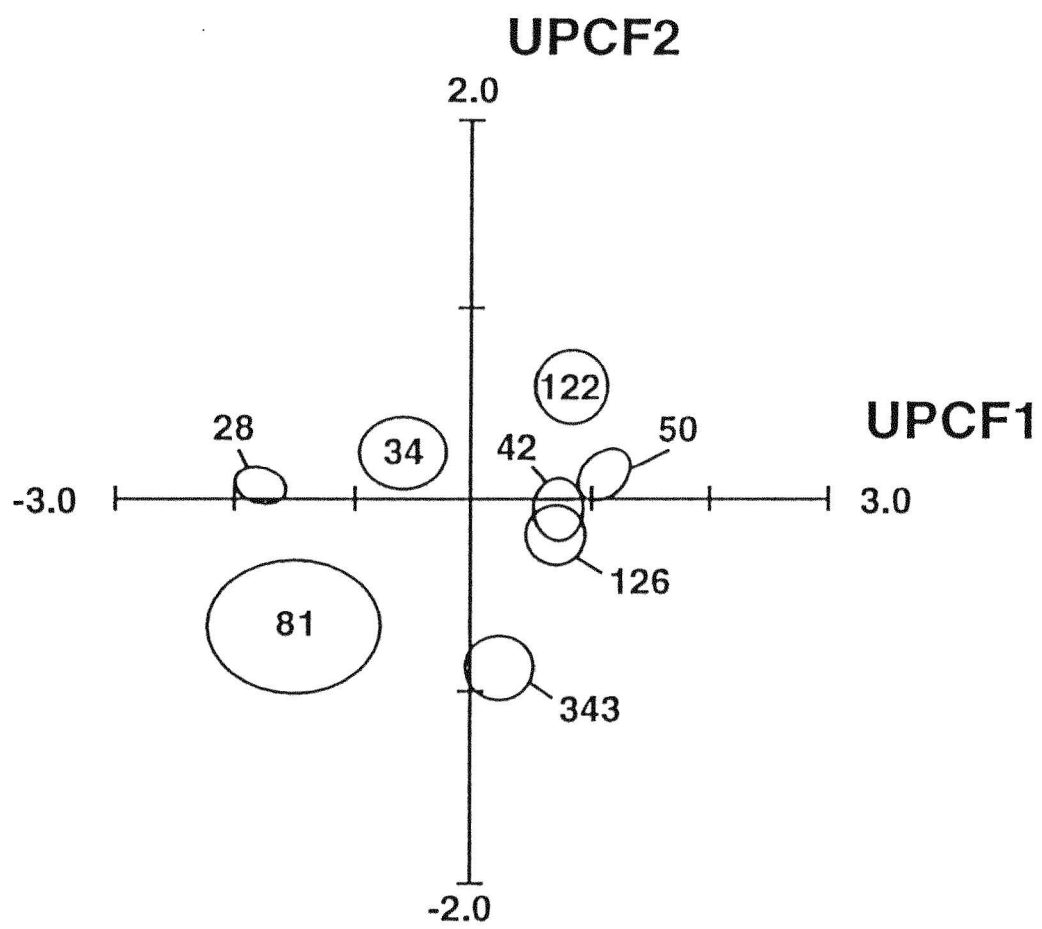
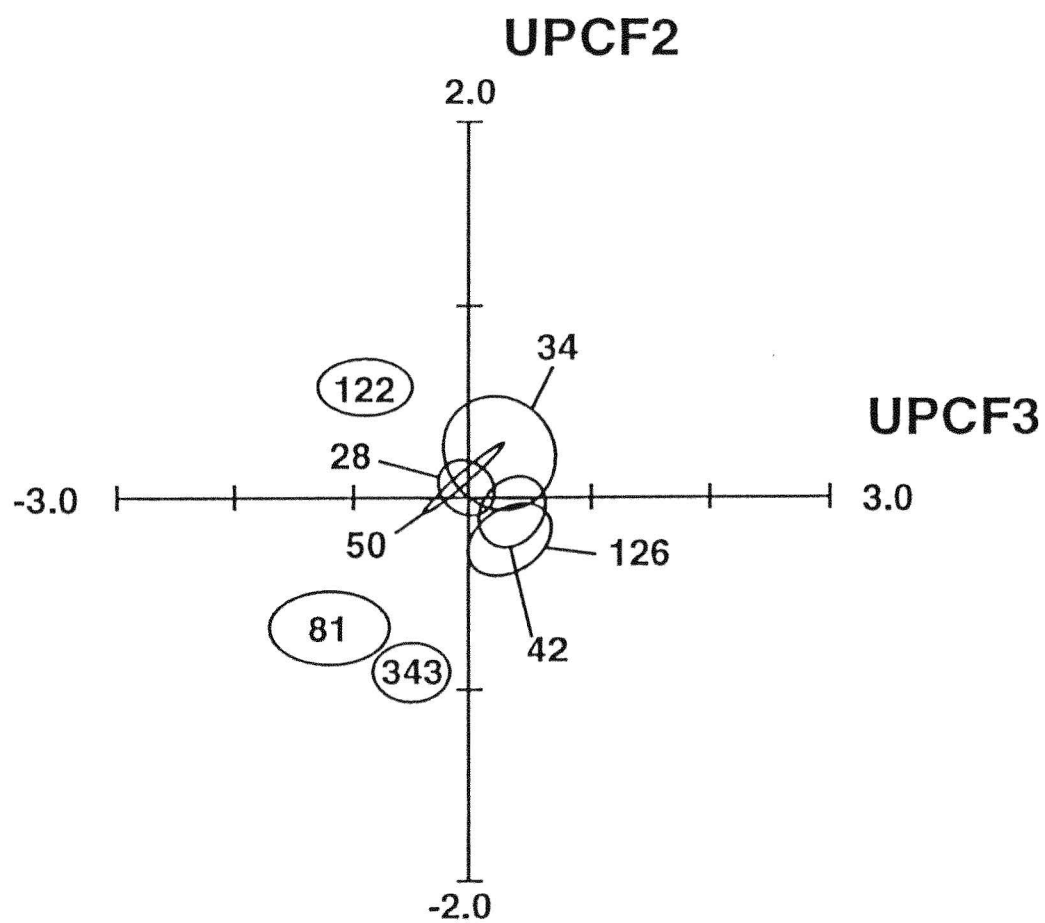


FIGURE 14. SAS CONFIDENCE ELLIPSE PLOT  
FOR UVIGERINA PEREGRINA FOR GROUP 81  
(UPCF2=Uvigerina peregrina canonical function 2,  
UPCF3=Uvigerina peregrina canonical function 3).



representing group 81 from those of the modern day database, however, could imply that the intraspecific variation of specimens represented by group 81 has no direct correlation with the modern day database of Uvigerina peregrina.

#### Analysis of group 84 for Uvigerina peregrina

Group 84 had twenty-three specimens of Uvigerina peregrina available for analysis. Figures 15 and 16 show the plots and 95% confidence ellipses for this analysis. Along the first two canonical functions, containing 90% of the variance, the confidence ellipse of group 84 intersects that of group 28 (50-200m). Along the third function, with an additional 6% of the variance, the confidence ellipse of group 84 is separate from all other ellipses.

The interpretation for group 84 is a bathymetric range of 50-200m.

#### Analysis of group 83 for Uvigerina peregrina

Group 83 had twenty-seven specimens of Uvigerina peregrina available for analysis. The plots and their 95% confidence ellipse for this analysis are depicted in Figures 17 and 18. Along the first two canonical functions, with 90% of the variance, the ellipse for group 83, completely overlaps that of group 28 (50-200m). Along the third function, with an additional 6% of the variance, the ellipse of group 83 is a discrete entity.

FIGURE 15. SAS CONFIDENCE ELLIPSE PLOT  
FOR UVIGERINA PEREGRINA FOR GROUP 84  
(UPCF1=Uvigerina peregrina canonical function 1,  
UPCF2=Uvigerina peregrina canonical function 2).

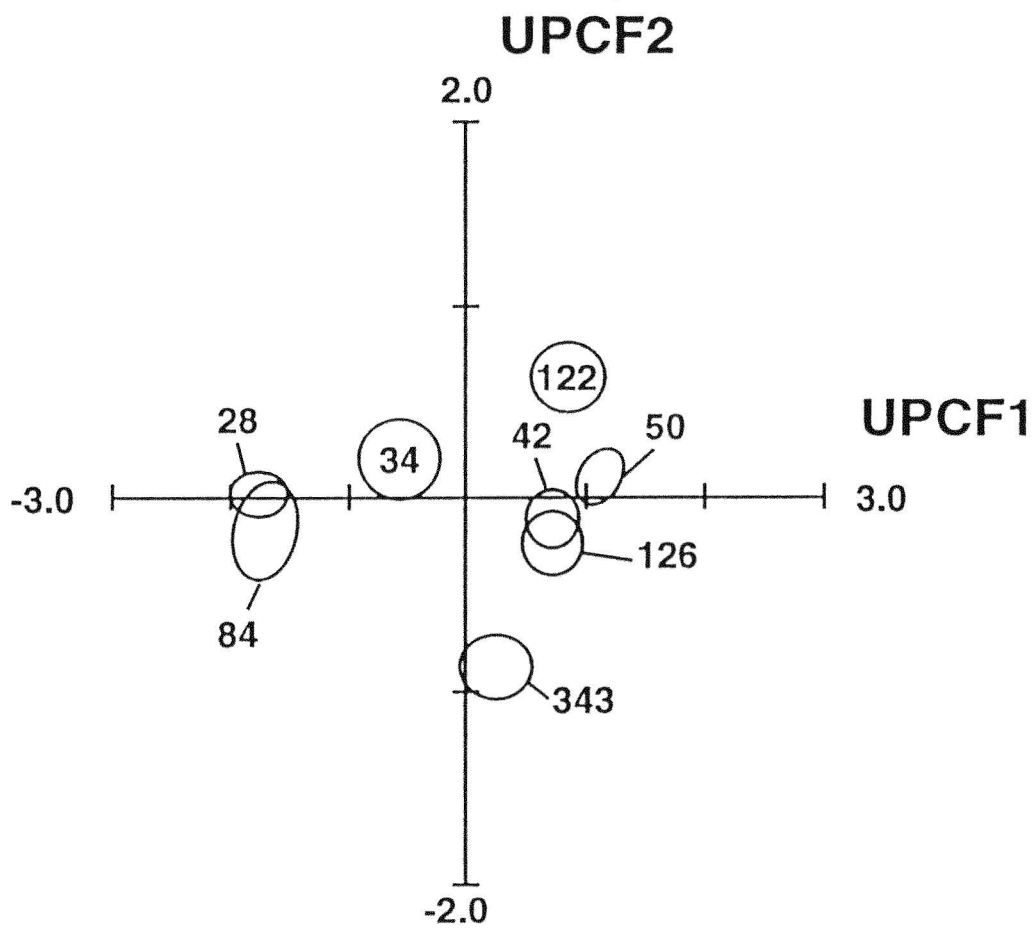




FIGURE 16. SAS CONFIDENCE ELLIPSE PLOT  
FOR UVIGERINA PEREGRINA FOR GROUP 84  
(UPCF2=Uvigerina peregrina canonical function 2,  
UPCF3=Uvigerina peregrina canonical function 3).

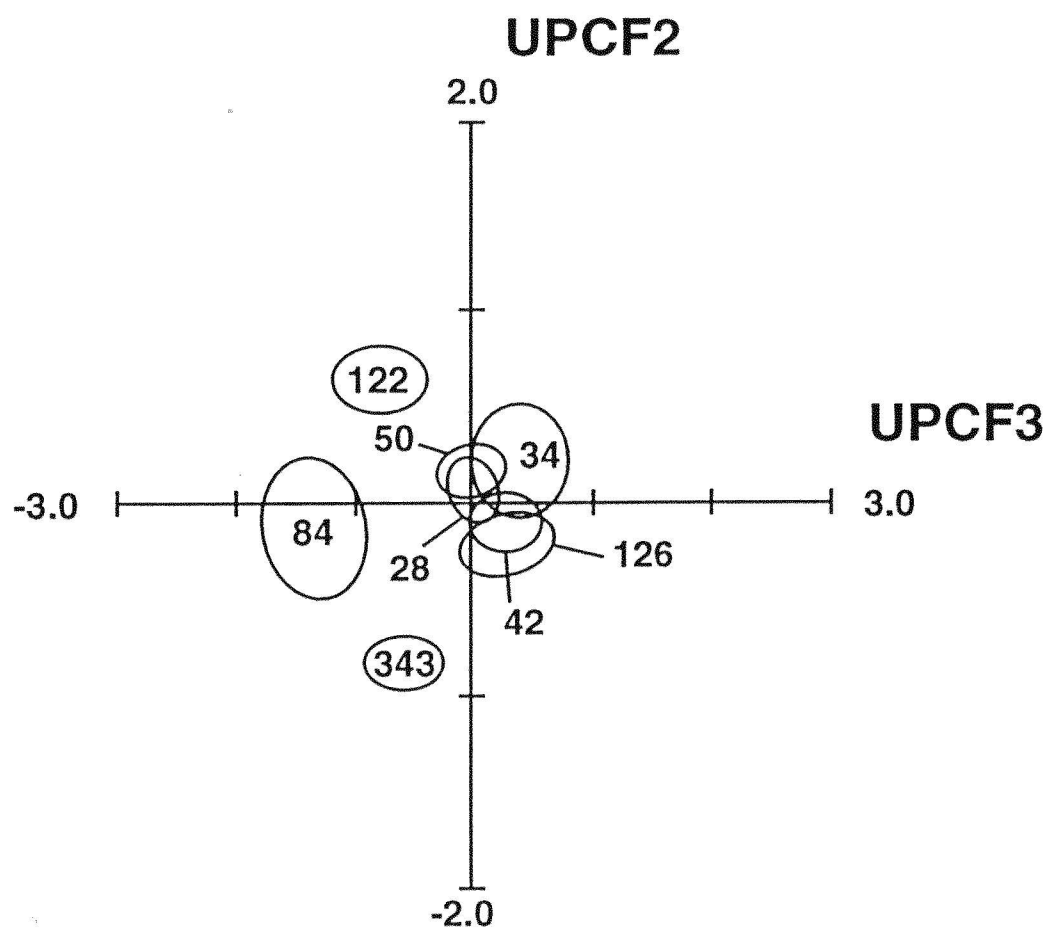


FIGURE 17. SAS CONFIDENCE ELLIPSE PLOT  
FOR UVIGERINA PEREGRINA FOR GROUP 83  
(UPCF1=Uvigerina peregrina canonical function 1,  
UPCF2=Uvigerina peregrina canonical function 2).

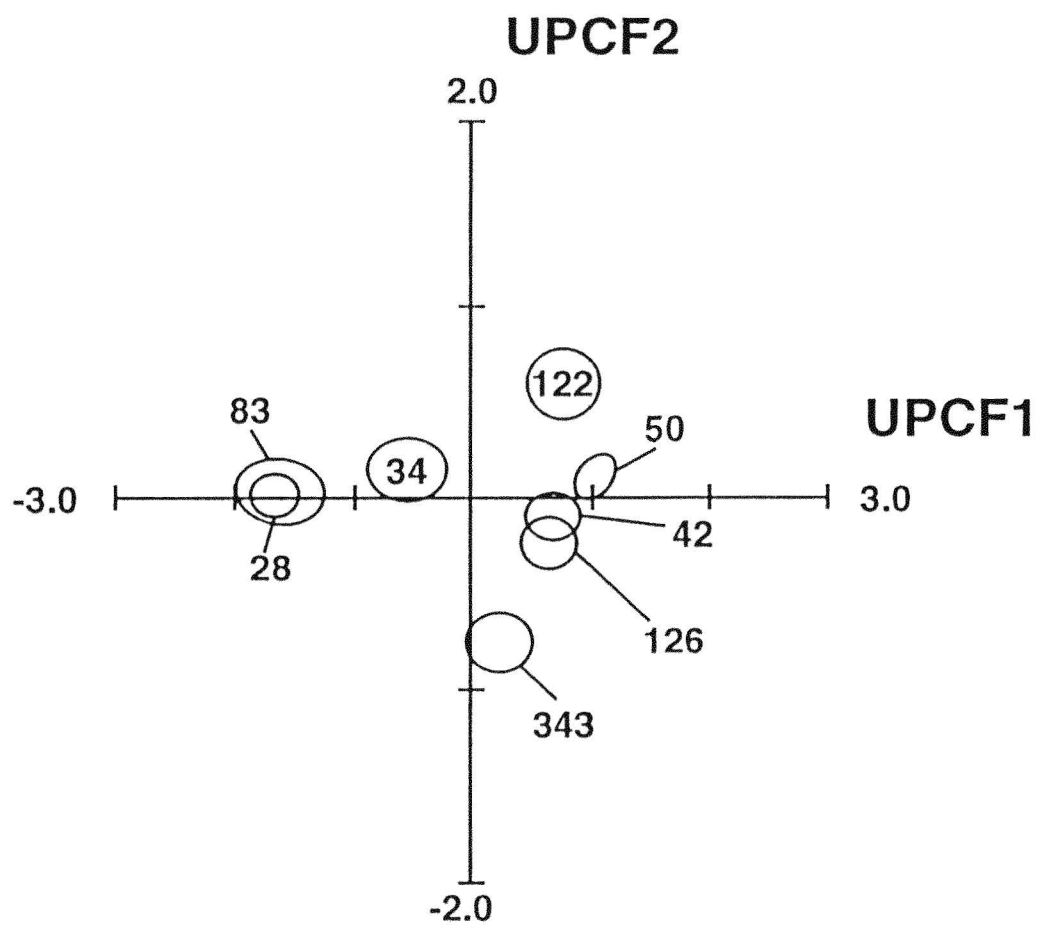
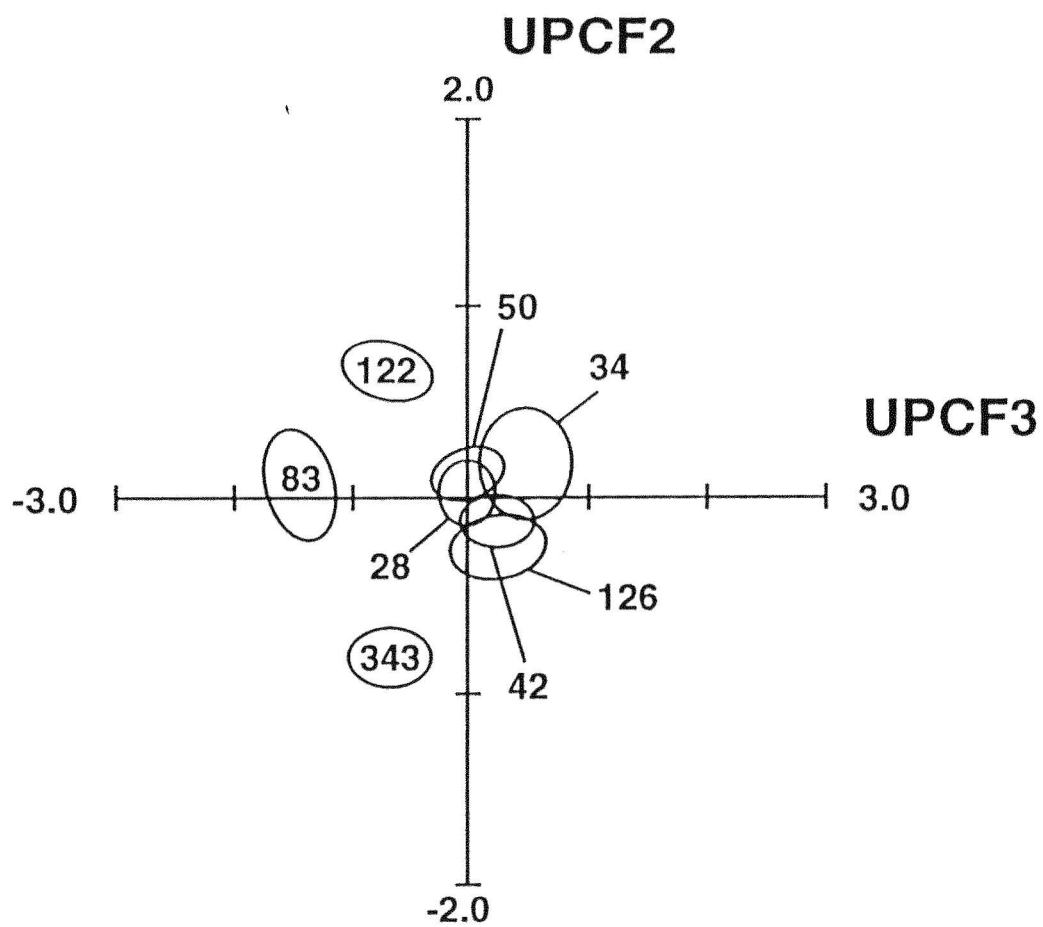


FIGURE 18. SAS CONFIDENCE ELLIPSE PLOT  
FOR UVIGERINA PEREGRINA FOR GROUP 83  
(UPCF2=Uvigerina peregrina canonical function 2,  
UPCF3=Uvigerina peregrina canonical function 3).



A possible bathymetric interpretation for group 83 could be expressed as a range of 50-200m.

#### Analysis of group 85 for Uvigerina peregrina

Group 85 contained eighteen specimens for analysis. The plots and their 95% confidence ellipse plots for this analysis are depicted in Figures 19 and 20. Along the first two canonical functions, containing 90% of the variance, the ellipse of group 85, intersects that of group 28 (50-200m). Along the third canonical function, which contains an additional 6% of the variance, the ellipse of group 85 is separate from all other ellipses.

The interpretation for group 85, based on the SAS plots, is a bathymetric range of 50-200m.

#### Analysis of group 86 for Uvigerina peregrina

Group 86 had thirty specimens of Uvigerina peregrina available for analysis. The plots and their 95% confidence ellipses for this analysis are shown in Figures 21 and 22. Along the first two canonical functions, which account for 90% of the variance, the confidence ellipse of group 86, while separate from all other ellipses, is closest in space to that of group 28 (50-200m). Along the third canonical function, which accounts for an additional 6% of the variance, the confidence ellipse of group 86 is also a discrete entity.

A possible bathymetric interpretation for group 86 is

FIGURE 19. SAS CONFIDENCE ELLIPSE PLOT  
FOR UVIGERINA PEREGRINA FOR GROUP 85  
(UPCF1=Uvigerina peregrina canonical function 1,  
UPCF2=Uvigerina peregrina canonical function 2).



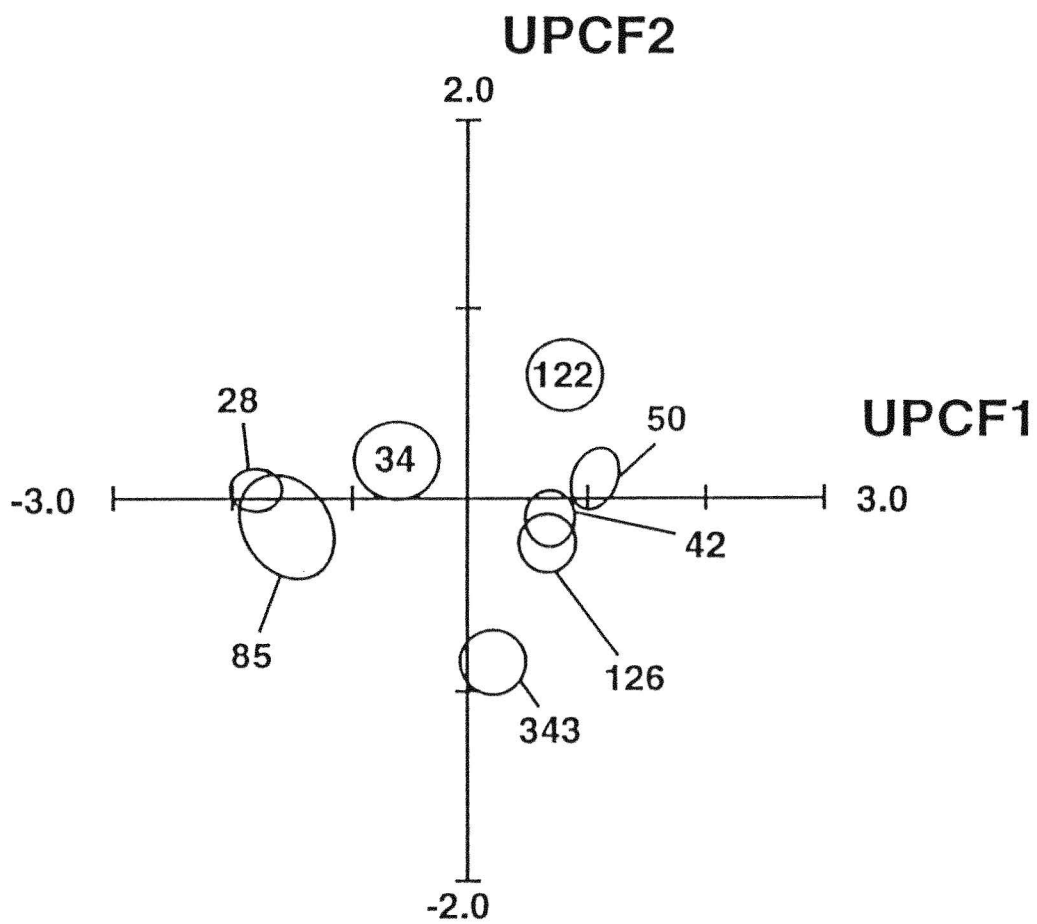


FIGURE 20. SAS CONFIDENCE ELLIPSE PLOT  
FOR UVIGERINA PEREGRINA FOR GROUP 85  
(UPCF2=Uvigerina peregrina canonical function 2,  
UPCF3=Uvigerina peregrina canonical function 3).

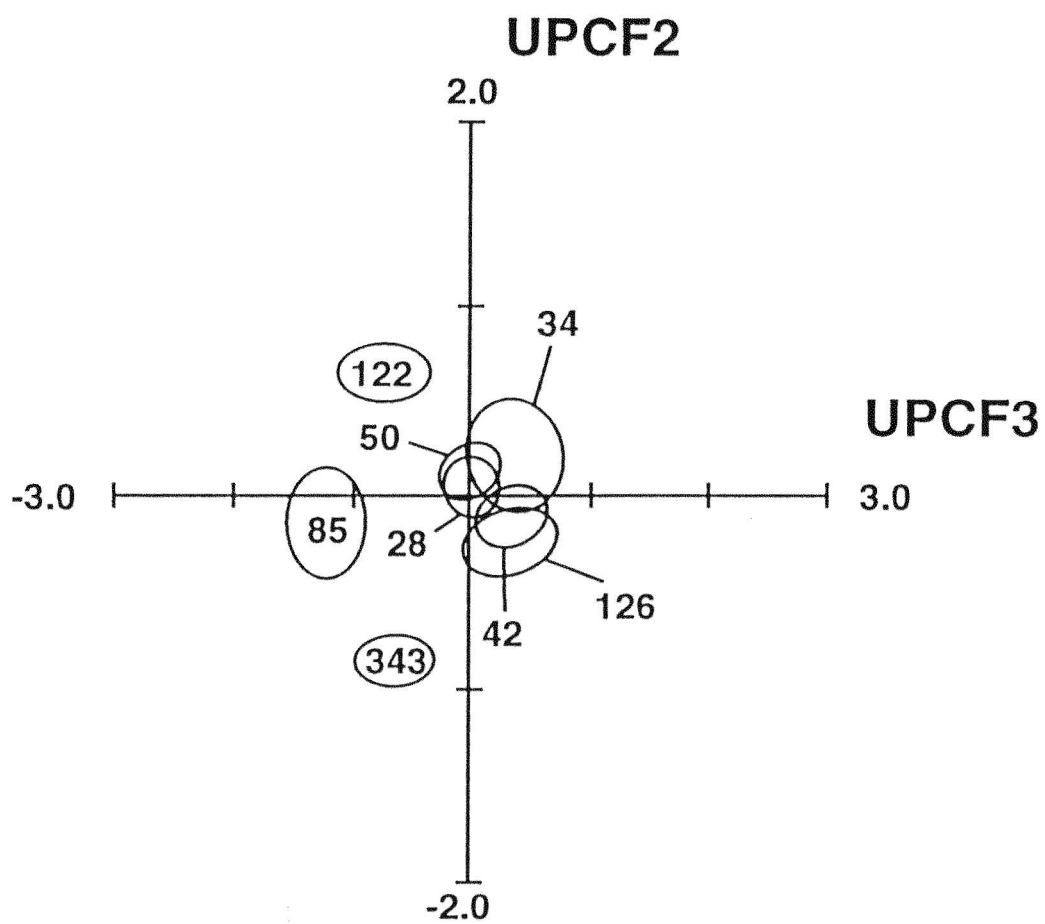


FIGURE 21. SAS CONFIDENCE ELLIPSE PLOT  
FOR UVIGERINA PEREGRINA FOR GROUP 86  
(UPCF1=Uvigerina peregrina canonical function 1,  
UPCF2=Uvigerina peregrina canonical function 2).

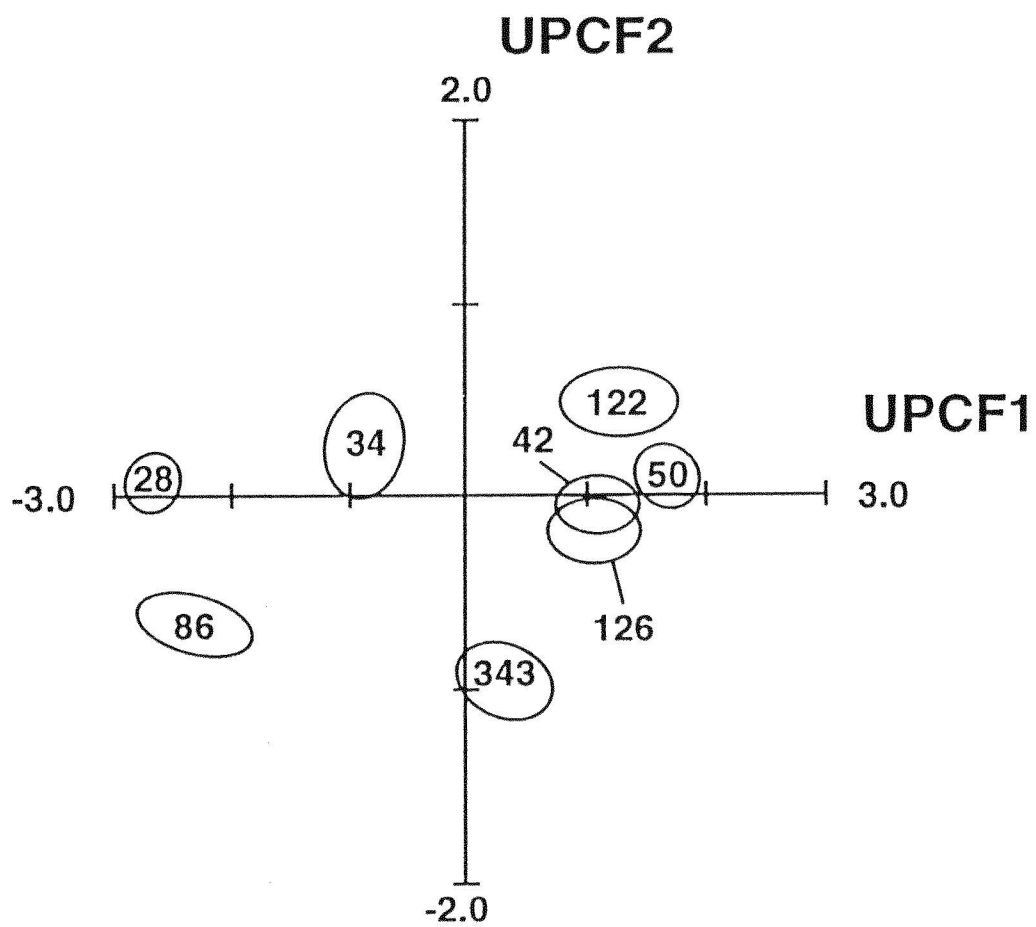
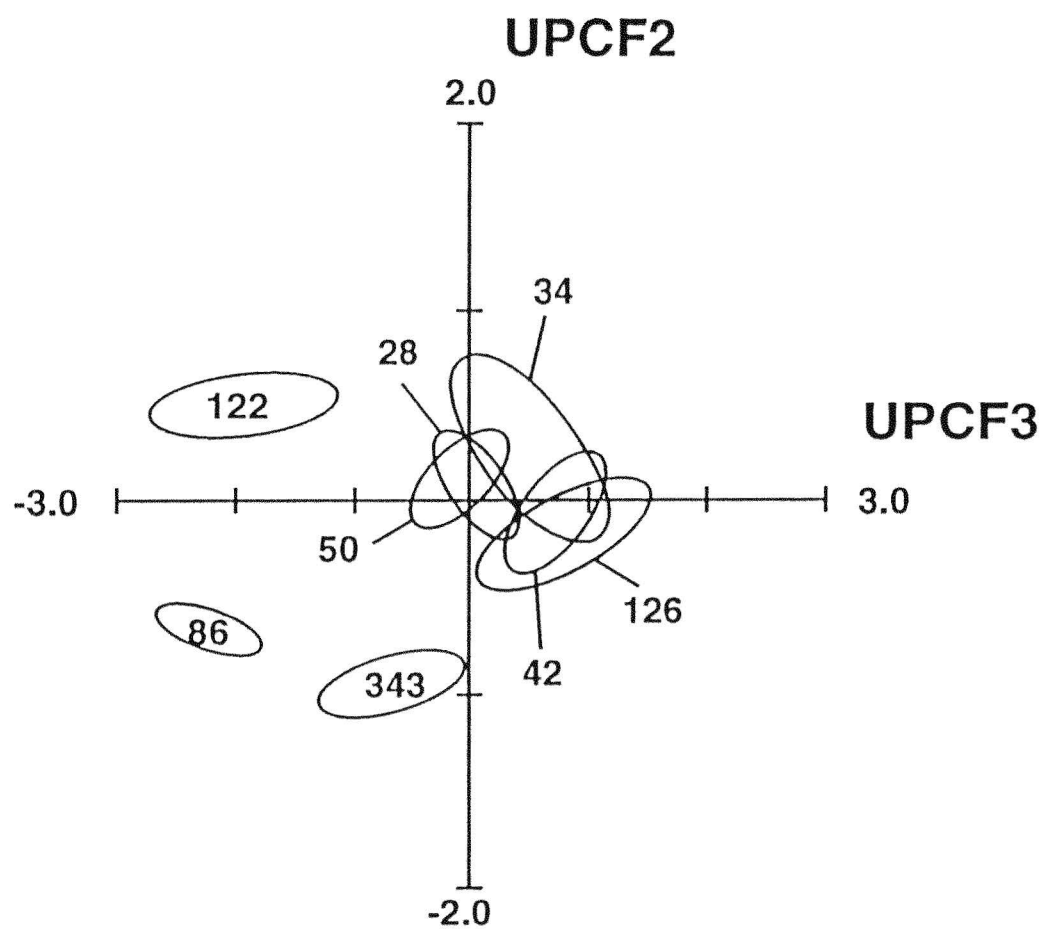


FIGURE 22. SAS CONFIDENCE ELLIPSE PLOT  
FOR UVIGERINA PEREGRINA FOR GROUP 86  
(UPCF2=Uvigerina peregrina canonical function 2,  
UPCF3=Uvigerina peregrina canonical function 3).



50-200m. The complete separation of the confidence ellipse representing group 86 from those of the modern day database, however, could imply that the intraspecific variation of specimens represented by group 86 has no direct correlation with the modern day database of Uvigerina peregrina.

Table 5 summarizes the canonical analysis results for Pleistocene Uvigerina peregrina groups.

#### D. Taxonomic analysis and faunal trends

##### Q mode cluster analysis

The cluster analysis (Figure 23) showed two clusters. The first is composed of three samples (1560, 1950, and 2100), while the second is composed of twenty samples, excluding sample 2850, an outlier. The cluster composed of twenty samples shows the samples are arranged in a step-wise pattern implying a continuum of abundances from sample to sample. This large cluster can be broken into subgroups, at a similarity coefficient of approximately 65%. These subgroups, as well as the distinctly separate cluster containing three samples are labelled with alphabetic characters beside them in Figure 23.

As most species are rare and the true distribution of rare species is difficult to characterize, (Koch, 1991), an assemblage cannot be defined by those species which occur in



TABLE 5. SUMMARY OF SAS RESULTS  
FOR UVIGERINA PEREGRINA.

WELL GROUPS	CF1 vs. CF2	CF3 vs. CF2	INFERRED DEPTH RANGE OF WELL GROUPS
	modern day correlative samples		
81(1560'-2100')	closest to 28(50-200m)	none	50-200m
84(2430')	28(50-200m)	none	50-200m
83(2520'-2550')	28(50-200m)	none	50-200m
85(2640')	28(50-200m)	none	50-200m
86(2760')	closest to 28(50-200m)	none	50-200m

FIGURE 23. DENDROGRAM SHOWING RESULTS  
OF AN UNWEIGHTED PAIR-GROUP METHOD  
CLUSTER ANALYSIS USING THE  
BRAY-CURTIS SIMILARITY COEFFICIENT  
ON ABUNDANCE DATA FROM ALL PLEISTOCENE  
WELL SAMPLES

(well samples are numbered to the left  
of the dendrogram, a and b represent small subgroups,  
c represents a major group, \* represents outliers,  
. represents samples used in canonical analysis).

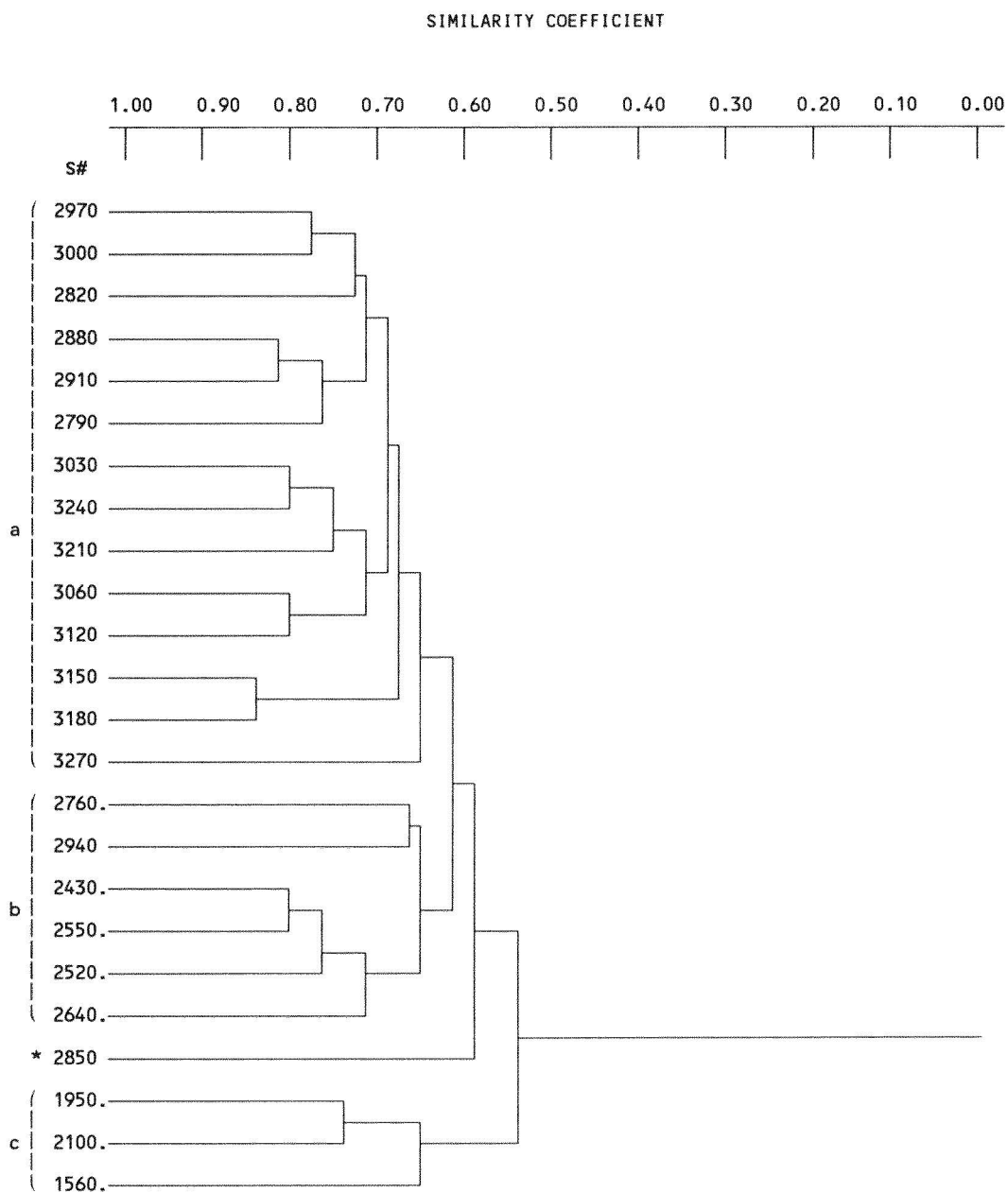


TABLE 6. SPECIES PERCENTAGES (2% OR >) IMPORTANT  
IN SEPARATING ABUNDANCE CLUSTER GROUPS AND SUBGROUPS  
(samples are ordered as they occur in cluster,  
SC#=species code number, S#=sample number,  
2=Bolivina albatrossi, 4=Bolivina fragilis,  
8=Bolivina minima, 9=Bolivina ordinaria,  
12=Bolivina subaenariensis mexicana,  
14=Bolivina translucens, 19=Bulimina marginata,  
42=Elphidium discoidale, 65= Hanzawaia strattoni,  
112=Uvigerina auberiana).

C L U S T E R	SC#\S#	2	4	8	9	12	14	19	42	65	112
a	2970			7.8	2.0	20.1	2.5	6.1			7.4
	3000	2.6	2.6	3.9	2.2	9.2	2.2	5.7	2.2		10.9
	2820	2.9		5.7	2.9	13.2	5.7	8.6			5.7
	2880			3.9		14.1		6.8			3.9
	2910	3.0		5.0		11.4		8.4	3.5		7.9
	2790	4.9	3.3	8.2	2.5	9.4		4.1			5.7
	3030	5.9		7.1		10.6		5.9			18.2
	3240			2.6		16.2		5.7			18.3
	3210		2.0	2.9		23.0		15.7			15.7
	3060	6.0		3.0		8.9					16.7
	3120	3.4		3.9		11.7		7.3			26.3
	3150	3.8		3.8	2.2	5.9		3.8			32.8
	3180	3.0		5.1		13.6	6.0	2.6			29.4
	3270		4.3	3.9		21.0		4.3	5.1		12.9
b	2760			2.8		5.1		6.5		3.3	4.2
	2940	2.9				5.7		6.3		3.2	13.9
	2430					4.8		4.8	4.8		5.7
	2550					9.6		3.6	4.4	5.2	2.8
	2520					4.2		3.3	5.9	5.0	
	2640					6.0		6.0	6.0	3.4	
c	1950					6.7		4.2	18.1	18.9	
	2100					11.4		10.4	14.2	9.0	
	1560					9.9		14.7	24.6	5.5	

small amounts. Therefore, the cluster analysis of species abundances (Figure 23) was based on species which occurred at 2% or greater for any sample. A chart of the species' percentages which appeared important in forming the cluster groups and subgroups, is shown in Table 6, in order of sample appearance in the cluster.

a) Abundance data analysis

Subgroup "a" samples are the following : 2970, 3000, 2820, 2880, 2910, 2790, 3030, 3240, 3210, 3060, 3120, 3150, 3180, and 3270' measured depths from the rotary table. These samples consist dominantly of the genera Bolivina, Cibicides, and Uvigerina. According to Poag (1981), when these genera predominate, the environment represented is outer shelf to upper slope. Subgroup "b" samples are the following : 2760, 2940, 2430, 2550, 2520, and 2640' (except for sample 2940, five of the eight samples used in morphometric analyses) measured depths from the rotary table. Subgroup "b" consists dominantly of the genera Bolivina, Cibicides, and Uvigerina, which signifies an outer shelf-upper slope environment (Poag, 1981). Group "c" samples are the following : 1950, 2100, and 1560' (three of the eight samples used in morphometric analyses) measured depths from the rotary table. The dominant genera are Elphidium and Hanzawaia, composing an assemblage which is representative of a middle-shelf environment. The abundance data cluster shows a paleobathymetric deepening with increasing depth in the well for the Pleistocene samples.

TABLE 7. OCCURRENCE (O), CONSTANCY (C), AND  
BIOFACIES FIDELITY (BF) VALUES FOR ABUNDANCE  
CLUSTER GROUPS AND SUBGROUPS A-C, IN ORDER  
OF DECREASING BIOFACIES FIDELITY FOR  
CLUSTER SUBGROUP A.



SPECIES\SUBGROUP	"a"			"b"			"c"		
	<u>O</u>	<u>C</u>	<u>BF</u>	<u>O</u>	<u>C</u>	<u>BF</u>	<u>O</u>	<u>C</u>	<u>BF</u>
<u>Bolivina barbata</u>	1	1	10	0	0	0	0	0	0
<u>Bolivina fragilis</u>	4	3	10	0	0	0	0	0	0
<u>Bolivina hastata</u>	2	1	10	0	0	0	0	0	0
<u>Bolivina ordinaria</u>	5	4	10	0	0	0	0	0	0
<u>Bolivina translucens</u>	4	3	10	0	0	0	0	0	0
<u>Bolivina inflata mexicana</u>	1	1	10	0	0	0	0	0	0
<u>Cibicides robertsonianus</u>	1	1	10	0	0	0	0	0	0
<u>Fursenkoina loeblichii</u>	1	1	10	0	0	0	0	0	0
<u>Fursenkoina squamosa</u>	3	2	10	0	0	0	0	0	0
<u>Oridorsalis umbonatus</u>	1	1	10	0	0	0	0	0	0
<u>Planulina exorna</u>	2	1	10	0	0	0	0	0	0
<u>Sigmoilina distorta</u>	1	1	10	0	0	0	0	0	0
<u>Bolivina minima</u>	14	10	8	1	2	2	0	0	0
<u>Bolivina albatrossi</u>	9	6	7	1	2	3	0	0	0
<u>Dentalina sp.</u>	6	4	7	1	2	3	0	0	0
<u>Cassidulina crassa</u>	6	4	6	2	3	4	0	0	0
<u>Cassidulina curvata</u>	4	3	6	1	2	4	0	0	0
<u>Cibicides umbonatus</u>	4	3	6	1	2	4	0	0	0
<u>Uvigerina auferiana</u>	14	10	6	4	7	4	0	0	0
<u>Cassidulina laevigata</u>	10	7	5	4	7	5	0	0	0
<u>Fursenkoina compressa</u>	3	2	4	0	0	0	1	3	6
<u>Uvigerina peregrina</u>	14	10	4	6	10	4	2	7	2
<u>Bolivina subaenariensis mexicana</u>	14	10	3	6	10	3	3	10	4
<u>Bulimina marginata</u>	13	9	3	6	10	3	3	10	4
<u>Bulimina spicata</u>	2	1	3	1	2	7	0	0	0
<u>Cassidulina subglobosa</u>	5	4	3	4	7	5	1	3	2
<u>Cibicides pachyderma</u>	13	9	3	6	10	4	2	7	3
<u>Cibicides sp. A</u>	2	1	3	1	2	7	0	0	0
<u>Quinqueloculina sp. A</u>	1	1	3	1	2	7	0	0	0
<u>Trifarina bella</u>	1	1	3	2	3	7	0	0	0
<u>Eponides regularis</u>	1	1	2	1	2	3	1	3	5
<u>Hanzawaia concentrica</u>	1	1	2	2	3	4	1	3	4
<u>Elphidium discoideale</u>	3	2	1	4	7	4	3	10	5
<u>Islandiella norcrossi</u>	1	1	1	0	0	0	2	7	9
<u>Nonionella atlantica</u>	2	1	1	1	2	2	2	7	7
<u>Planulina ariminensis</u>	2	1	1	3	5	6	1	3	3
<u>Ammonia beccarii</u>	0	0	0	0	0	0	1	3	10
<u>Bulimina aculeata</u>	0	0	0	2	3	10	0	0	0
<u>Bulimina striata mexicana</u>	0	0	0	1	2	10	0	0	0
<u>Cribrolenticulina akersi</u>	0	0	0	2	3	10	0	0	0
<u>Elphidium gunteri</u>	0	0	0	1	2	10	0	0	0
<u>Globocassidulina globosa</u>	0	0	0	1	2	10	0	0	0
<u>Hanzawaia strattoni</u>	0	0	0	5	8	4	3	10	6
<u>Lenticulina rotulata</u>	0	0	0	2	3	5	1	3	5
<u>Planulina foveolata</u>	0	0	0	2	3	10	0	0	0
<u>Quinqueloculina bicostata</u>	0	0	0	1	2	10	0	0	0
<u>Quinqueloculina compta</u>	0	0	0	1	2	10	0	0	0
<u>Rectobolivina advena</u>	0	0	0	0	0	0	1	3	10
<u>Reussella atlantica</u>	0	0	0	1	2	4	1	3	6
<u>Siphonina bradyana</u>	0	0	0	1	2	10	0	0	0

## b) Biofacies fidelity analysis

In order to compile depth ranges from the abundance data cluster group and subgroups, the occurrence, constancy, and biofacies fidelity were calculated to determine which species would be good indicator or key species for each cluster. Tables 7, 8, and 9 show the occurrence (O), constancy (C), and biofacies fidelity (BF) values for all three clusters.

Table 7, in order of decreasing BF values for subgroup "a", shows that Bolivina barbata, Bolivina hastata, Bulimina inflata mexicana, Cibicides robertsonianus, Fursenkoina loeblichii, Oridorsalis umbonatus, Planulina exorna, and Sigmoilina distorta occurred only in subgroup "a", but each occurred in only 10% of the samples in that subgroup. Fursenkoina squamosa also occurred only in subgroup "a", yet only in 20% of the samples. Bolivina fragilis and Bolivina translucens occurred only in subgroup "a" and in 30% of the samples. Bolivina ordinaria also occurred only in subgroup "a" and in 40% of the samples. Examination of other values (see Table 6) for subgroup "a" shows that Bolivina minima (found in 100% of the samples, BF is 8), Bolivina albatrossi (found in 60% of the samples, BF is 7), Uvigerina auberiana (found in 10 % of the samples, BF is 6), and Cassidulina laevigata (found in 70% of the samples, BF is 5), are also good indicator species for that subgroup.

Table 8, in order of decreasing BF values for cluster subgroup "b" shows that Bulimina striata mexicana, Elphidium

TABLE 8. OCCURRENCE (O), CONSTANCY (C), AND  
BIOFACIES FIDELITY (BF) VALUES FOR ABUNDANCE  
CLUSTER GROUPS AND SUBGROUPS A-C, IN ORDER  
OF DECREASING BIOFACIES FIDELITY FOR  
CLUSTER SUBGROUP B.

SPECIES\SUBGROUP	"a"			"b"			"c"		
	<u>Q</u>	<u>C</u>	<u>BF</u>	<u>Q</u>	<u>C</u>	<u>BF</u>	<u>Q</u>	<u>C</u>	<u>BF</u>
<u>Bulimina aculeata</u>	0	0	0	2	3	10	0	0	0
<u>Bulimina striata mexicana</u>	0	0	0	1	2	10	0	0	0
<u>Cribrilenticulina akersi</u>	0	0	0	2	3	10	0	0	0
<u>Elphidium gunteri</u>	0	0	0	1	2	10	0	0	0
<u>Globocassidulina globosa</u>	0	0	0	1	2	10	0	0	0
<u>Planulina foveolata</u>	0	0	0	2	3	10	0	0	0
<u>Quinqueloculina bicostata</u>	0	0	0	1	2	10	0	0	0
<u>Quinqueloculina compta</u>	0	0	0	1	2	10	0	0	0
<u>Siphonina bradyana</u>	0	0	0	1	2	10	0	0	0
<u>Bulimina spicata</u>	2	1	3	1	2	7	0	0	0
<u>Cibicides sp. A</u>	2	1	3	1	2	7	0	0	0
<u>Quinqueloculina sp. A</u>	1	1	3	1	2	7	0	0	0
<u>Trifarina bella</u>	1	1	3	2	3	7	0	0	0
<u>Planulina ariminensis</u>	2	1	1	3	5	6	1	3	3
<u>Cassidulina laevigata</u>	10	7	5	4	7	5	0	0	0
<u>Cassidulina subglobosa</u>	5	4	3	4	7	5	1	3	2
<u>Lenticulina rotulata</u>	0	0	0	2	3	5	1	3	5
<u>Cassidulina curvata</u>	4	3	6	1	2	4	0	0	0
<u>Cassidulina crassa</u>	6	4	6	2	3	4	0	0	0
<u>Cibicides pachyderma</u>	13	9	3	6	10	4	2	7	3
<u>Cibicides umbonatus</u>	4	3	6	1	2	4	0	0	0
<u>Elphidium discoidale</u>	3	2	1	4	7	4	3	10	5
<u>Hanzawaia concentrica</u>	1	1	2	2	3	4	1	3	4
<u>Hanzawaia strattoni</u>	0	0	0	5	8	4	3	10	6
<u>Reussella atlantica</u>	0	0	0	1	2	4	1	3	6
<u>Uvigerina auferiana</u>	14	10	6	4	7	4	0	0	0
<u>Uvigerina peregrina</u>	14	10	4	6	10	4	2	7	2
<u>Bolivina albatrossi</u>	9	6	7	1	2	3	0	0	0
<u>Bolivina subaenariensis mexicana</u>	14	10	3	6	10	3	3	10	4
<u>Bulimina marginata</u>	13	9	3	6	10	3	3	10	4
<u>Dentalina sp.</u>	6	4	7	1	2	3	0	0	0
<u>Eponides regularis</u>	1	1	2	1	2	3	1	3	5
<u>Bolivina minima</u>	14	10	8	1	2	2	0	0	0
<u>Nonionella atlantica</u>	2	1	1	1	2	2	2	7	7
<u>Ammonia beccarii</u>	0	0	0	0	0	0	1	3	10
<u>Bolivina barbata</u>	1	1	10	0	0	0	0	0	0
<u>Bolivina fragilis</u>	4	3	10	0	0	0	0	0	0
<u>Bolivina hastata</u>	2	1	10	0	0	0	0	0	0
<u>Bolivina ordinaria</u>	5	4	10	0	0	0	0	0	0
<u>Bolivina translucens</u>	4	3	10	0	0	0	0	0	0
<u>Bulimina inflata mexicana</u>	1	1	10	0	0	0	0	0	0
<u>Cibicides robertsonianus</u>	1	1	10	0	0	0	0	0	0
<u>Fursenkoina compressa</u>	3	2	4	0	0	0	1	3	6
<u>Fursenkoina loeblichii</u>	1	1	10	0	0	0	0	0	0
<u>Fursenkoina squamosa</u>	3	2	10	0	0	0	0	0	0
<u>Islandiella norcrossi</u>	1	1	1	0	0	0	2	7	9
<u>Oridorsalis umbonatus</u>	1	1	10	0	0	0	0	0	0
<u>Planulina exorna</u>	2	1	10	0	0	0	0	0	0
<u>Rectobolivina advena</u>	0	0	0	0	0	0	1	3	10
<u>Sigmoilina distorta</u>	1	1	10	0	0	0	0	0	0

gunteri, Globocassidulina globosa, Quinqueloculina bicostata, Quinqueloculina compta, and Siphonina bradyana occurred only in subgroup "b", but occurred in only 20% of the samples. Bulimina aculeata, Cribrolenticulina akersi, and Planulina foveolata also occurred only in subgroup "b", yet only in 30% of the samples. Further inspection of the values (see Table 8) for subgroup "b" reveals that Cassidulina laevigata and Cassidulina subglobosa (both found in 70% of the samples and having a BF of 5), Cibicides pachyderma (found in 100% of the samples, BF is 4), and Hanzawaia strattoni (found in 80% of the samples, BF is 4) can also be used as key species for that subgroup, although BF values are notably low.

Table 9, in order of decreasing BF values for cluster group "c", shows that Ammonia beccarii and Rectobolivina advena occurred only in group "c", and only in 30% of the samples. Other diagnostic indicator species for group "c" are Islandiella norcrossi (found in 70% of the samples, BF is 9), Nonionella atlantica (found in 70% of the samples, BF is 7), Hanzawaia strattoni (found in 100% of the samples, BF is 6), and Elphidium discoidale (found in 100% of the samples, BF is 5).

#### Planktic-benthic ratios

The planktic percentages range from 10% to 52% in the observed well section (see Table 10). The percent of planktic foraminifera is low to moderate (10%-35%) in the majority of

TABLE 9. OCCURRENCE (O), CONSTANCY (C), AND  
BIOFACIES FIDELITY (BF) VALUES FOR ABUNDANCE  
CLUSTER GROUPS AND SUBGROUPS A-C, IN ORDER  
OF DECREASING BIOFACIES FIDELITY FOR  
CLUSTER GROUP C.

SPECIES\SUBGROUP	"a"			"b"			"c"		
	<u>O</u>	<u>C</u>	<u>BF</u>	<u>O</u>	<u>C</u>	<u>BF</u>	<u>O</u>	<u>C</u>	<u>BF</u>
<u>Ammonia beccarii</u>	0	0	0	0	0	0	1	3	10
<u>Rectobolivina advena</u>	0	0	0	0	0	0	1	3	10
<u>Islandiella norcrossi</u>	1	1	1	0	0	0	2	7	9
<u>Nonionella atlantica</u>	2	1	1	1	2	2	2	7	7
<u>Fursenkoina compressa</u>	3	2	4	0	0	0	1	3	6
<u>Hanzawaia strattoni</u>	0	0	0	5	8	4	3	10	6
<u>Reussella atlantica</u>	0	0	0	1	2	4	1	3	6
<u>Elphidium discoidale</u>	3	2	1	4	7	4	3	10	5
<u>Eponides regularis</u>	1	1	2	1	2	3	1	3	5
<u>Lenticulina rotulata</u>	0	0	0	2	3	5	1	3	5
<u>Bolivina subaenariensis mexicana</u>	14	10	3	6	10	3	3	10	4
<u>Bulimina marginata</u>	13	9	3	6	10	3	3	10	4
<u>Hanzawaia concentrica</u>	1	1	2	2	3	4	1	3	4
<u>Cibicides pachyderma</u>	13	9	3	6	10	4	2	7	3
<u>Planulina ariminensis</u>	2	1	1	3	5	6	1	3	3
<u>Cassidulina subglobosa</u>	5	4	3	4	7	5	1	3	2
<u>Uvigerina peregrina</u>	14	10	4	6	10	4	2	7	2
<u>Bolivina albatrossi</u>	9	6	7	1	2	3	0	0	0
<u>Bolivina barbata</u>	1	1	10	0	0	0	0	0	0
<u>Bolivina fragilis</u>	4	3	10	0	0	0	0	0	0
<u>Bolivina hastata</u>	2	1	10	0	0	0	0	0	0
<u>Bolivina minima</u>	14	10	8	1	2	2	0	0	0
<u>Bolivina ordinaria</u>	5	4	10	0	0	0	0	0	0
<u>Bolivina translucens</u>	4	3	10	0	0	0	0	0	0
<u>Bulimina aculeata</u>	0	0	0	2	3	10	0	0	0
<u>Bulimina inflata mexicana</u>	1	1	10	0	0	0	0	0	0
<u>Bulimina spicata</u>	2	1	3	1	2	7	0	0	0
<u>Bulimina striata mexicana</u>	0	0	0	1	2	10	0	0	0
<u>Cassidulina crassa</u>	6	4	6	2	3	4	0	0	0
<u>Cassidulina curvata</u>	4	3	6	1	2	4	0	0	0
<u>Cassidulina laevigata</u>	10	7	5	4	7	5	0	0	0
<u>Cibicides robertsonianus</u>	1	1	10	0	0	0	0	0	0
<u>Cibicides umbonatus</u>	4	3	6	1	2	4	0	0	0
<u>Cibicides sp. A</u>	2	1	3	1	2	7	0	0	0
<u>Cribrolenticulina akersi</u>	0	0	0	2	3	10	0	0	0
<u>Dentalina sp.</u>	6	4	7	1	2	3	0	0	0
<u>Elphidium gunteri</u>	0	0	0	1	2	10	0	0	0
<u>Fursenkoina loeblichii</u>	1	1	10	0	0	0	0	0	0
<u>Fursenkoina squamosa</u>	3	2	10	0	0	0	0	0	0
<u>Globocassidulina globosa</u>	0	0	0	1	2	10	0	0	0
<u>Oridorsalis umbonatus</u>	1	1	10	0	0	0	0	0	0
<u>Planulina exorna</u>	2	1	10	0	0	0	0	0	0
<u>Planulina foveolata</u>	0	0	0	2	3	10	0	0	0
<u>Quinqueloculina bicostata</u>	0	0	0	1	2	10	0	0	0
<u>Quinqueloculina compta</u>	0	0	0	1	2	10	0	0	0
<u>Quinqueloculina sp. A</u>	1	1	3	1	2	7	0	0	0
<u>Sigmoilina distorta</u>	1	1	10	0	0	0	0	0	0
<u>Siphonina bradyana</u>	0	0	0	1	2	10	0	0	0
<u>Trifarina bella</u>	1	1	3	2	3	7	0	0	0
<u>Uvigerina auferiana</u>	14	10	6	4	7	4	0	0	0

samples. This would seem to indicate rather shallow depths of 0-200m (Tipsword et al., 1966). In the cases where the percent of planktics increases from a low to moderate percentage, e.g., from 19% in sample 2790 to 43% in sample 2820, it would be expected that the water may be deepening with depth in the well. There are, however, no increased planktic percentages over any considerable, i.e., greater than 30 feet, stratigraphic intervals within the samples. The sudden increase from 19% in sample 2790 to 43% in sample 2820 may be due to a planktic bloom or vagaries of currents.

#### Species diversity

Species diversity values range from 2.48 to 3.37 (see Table 10), with an average diversity of 2.99. These values are considered to be normal for neritic to upper bathyal depths in the Gulf of Mexico. According to Gibson and Buzas (1973), an average value of species diversity for 0-100m is 2.58, and for 100-1000m is 2.74 in the northwestern Gulf of Mexico. Species diversity values in the Pleistocene well section for the uppermost well depths (samples numbered 1560-2430), considered to be neritic by Mobil Oil and neritic to upper bathyal by assemblage data from this study, are below 3.00. The remainder of samples are reported by Mobil Oil to be upper bathyal. Samples numbered 2520-3060, with the exception of two samples, numbered 2640 and 3030, are above 3.00, and samples numbered 3120-3270 are below 3.00.

Equitability values range from 0.40 to 0.67 (see Table



10), averaging 0.52 and show no noticeable trends. Gibson and Buzas (1973) note that equitability values average from 0.52-0.54 for the northwestern Gulf of Mexico.

#### Assemblage analysis

As a test for the validity of the canonical analyses based on the morphometric intraspecific variability of the species Cassidulina subglobosa and Uvigerina peregrina, a taxonomic analysis of the eight individual Pleistocene well samples in question was performed. In addition, a taxonomic analysis was performed on the remaining sixteen Pleistocene well samples obtained for this study.

The interpreted assemblage depth ranges for all sample groups was based on modern day specific depth-relatable assemblages outlined by Phleger and Parker (1951), Parker (1954), Albers et al., (1966), Poag and Valentine (1976), Culver and Buzas (1981), Poag (1981), and Culver (1988).

The assemblage depth ranges were interpreted for the abundance cluster groups and subgroups "a" through "c", using depth ranges of good indicator species based upon biofacies fidelity values (see Tables 7, 8, and 9), and upon species whose abundances were important (occurring in at least half of all samples within the cluster) in forming abundance clusters (see Table 6). Data upon which the interpreted assemblage depth ranges are based are presented in Figures 24-26.

The assemblage of abundance cluster subgroup "a" contains

Assemblage of cluster subgroup a (14 samples)

S# 2970, 3000, 2820, 2880, 2910, 2790, 3030, 3240, 3210, 3060, 3120, 3150, 3180, 3270

#B 244, 229, 174, 206, 202, 244, 170, 229, 204, 168, 179, 186, 235, 233

%P 19, 24, 43, 31, 33, 19, 44, 27, 32, 45, 41, 39, 22, 23

	IN	MN	ON	UB	MB	LB	A
<u>Bolivina albatrossi</u>							
<u>Bolivina barbata</u>							
<u>Bolivina fragilis</u>							
<u>Bolivina hastata</u>							
<u>Bolivina minima</u>							
<u>Bolivina ordinaria</u>							
<u>Bolivina subaenariensis mexicana*</u>							
<u>Bolivina translucens</u>							
<u>Bulimina inflata mexicana</u>							
<u>Bulimina marginata*</u>							
<u>Cassidulina laevigata</u>							
<u>Cibicides robertsonianus</u>							
<u>Fursenkoina loeblichii</u>							
<u>Fursenkoina squamosa</u>							
<u>Oridorsalis umbonatus</u>							
<u>Planulina exorna</u>							
<u>Sigmoilina distorta</u>							
<u>Uvigerina auferiana</u>							

FIGURE 25. ENVIRONMENTAL RANGES OF  
CHARACTERISTIC TAXA IN ABUNDANCE CLUSTER  
SUBGROUP B

[bars indicate depth range of the majority of  
records, others may be shallower or deeper,  
S#=sample group number, #B=number of benthics,  
%P=percent planktics, IN=inner neritic(0-20m),  
MN=middle neritic(20-100m), ON=outer neritic(100-200m),  
UB=upper bathyal(200-500m), MB=middle bathyal(500-1000m),  
LB=lower bathyal(1000-2000m), A=abyssal(>2000m),  
\*=species found important with respect  
to abundance only (see Table 6)].

Assemblage of cluster subgroup b (6 samples)

S# 2760, 2940, 2430, 2550, 2520, 2640

#B 215, 158, 228, 251, 239, 234

%P 29, 52, 31, 19, 21, 23

	IN	MN	ON	UB	MB	LB	A
<u>Bolivina subaenariensis mexicana</u> *							
<u>Bulimina aculeata</u>							
<u>Bulimina marginata</u> *							
<u>Bulimina striata mexicana</u>							
<u>Cassidulina laevigata</u>							
<u>Cassidulina subglobosa</u>							
<u>Cibicides pachyderma</u>							
<u>Cribrolenticulina akersi</u>							
<u>Elphidium discoidale</u> *							
<u>Elphidium gunteri</u>							
<u>Globocassidulina globosa</u>							
<u>Hanzawaia strattoni</u> *							
<u>Planulina foveolata</u>							
<u>Quinqueloculina bicostata</u>							
<u>Quinqueloculina compta</u>							
<u>Uvigerina auberiana</u>							

FIGURE 26. ENVIRONMENTAL RANGES OF  
CHARACTERISTIC TAXA IN ABUNDANCE CLUSTER  
GROUP C

[bars indicate depth range of the majority of  
records, others may be shallower or deeper,  
S#=sample group number, #B=number of benthics,  
%P=percent planktics, IN=inner neritic(0-20m),  
MN=middle neritic(20-100m), ON=outer neritic(100-200m),  
UB=upper bathyal(200-500m), MB=middle bathyal(500-1000m),  
LB=lower bathyal(1000-2000m), A=abyssal(>2000m),  
\*=species found important with respect  
to abundance only (see Table 6)].

Assemblage of cluster group c (3 samples)

S# 1950, 2100, 1560

#B 238, 211, 272

%P 23, 30, 10

	IN	MN	ON	UB	MB	LB	A
<u>Ammonia beccarii</u>							
<u>Bolivina subaenariensis mexicana*</u>							
<u>Bulimina marginata*</u>							
<u>Elphidium discoideale</u>							
<u>Hanzawaia strattoni</u>							
<u>Islandiella norcrossi</u>							
<u>Nonionella atlantica</u>							
<u>Rectobolivina advena</u>							

fourteen samples with eighteen characteristic indicator species. Based upon biofacies fidelity and constancy values, two of these species (Bolivina subaenariensis mexicana and Bulimina marginata) are good indicator species. These species were also found to occur in at least half of all samples within the subgroup and had abundances which were important in forming the cluster (see Table 6). Also, Bolivina hastata and Planulina exorna had high biofacies fidelity values, however, the environmental ranges of these taxa suggest a shallower lower depth limit (approximately 500m) than most of the characteristic species of subgroup "a" (see Figure 24). The combined depth ranges of all eighteen species suggest a possible depth range of 100-1000m, even though Bolivina hastata and Planulina exorna might argue for a somewhat shallower lower depth limit.

The assemblage of abundance cluster subgroup "b" contains six samples with sixteen characteristic species. Four of these species (Bolivina subaenariensis mexicana, Bulimina marginata, Elphidium discoidale, and Hanzawaia strattoni) were found to be good indicator species based upon biofacies fidelity values and constancy values. These four species occurred in at least half of the samples within the subgroup and had abundances which were important in forming the cluster (see Table 6). The combined depth ranges of all sixteen species suggest a depth range of 100-1000m for cluster subgroup "b". There are some species, Elphidium discoidale,

Elphidium gunteri, Hanzawaia strattoni, and Quinqueloculina bcostata, which would suggest a narrower depth range of 100-500m for subgroup "b".

The assemblage of abundance cluster group "c" contains three samples with eight characteristic species. Two of these species (Bolivina subaenariensis mexicana and Bulimina marginata) were found to be good indicator species based upon biofacies fidelity and constancy values, and were found to occur in at least half of all the samples within the cluster and had abundances which were important in forming this cluster (see Table 6). Because there are some species (Hanzawaia strattoni, Elphidium discoidale and Islandiella norcrossi) which suggest a shallower lower depth limit, and because of lower diversity in cluster group "c" than in subgroups "a" and "b", the interpreted range of this assemblage is 100-200(500)m.

The abundance and biofacies fidelity analyses indicate that cluster "c" represents shallow water, 100-200(500)m, or extending to 500m, possibly a middle-shelf environment; cluster "a" represents deeper water, 100-1000m, possibly an outer shelf-middle slope environment; and cluster "b" represents an environment, possibly middle shelf to upper slope, that is transitional between the shallow water of cluster "c" and the deeper water of cluster "a".

A complete listing of samples by species is shown in Appendix D. A listing of the percentages of species within



each sample is shown in Appendix E. Lithology of each group is shown in Appendix F.

## CHAPTER 8

### DISCUSSION

Morphometric analysis showed that groups 81, 84, 83, and 86 corresponded to a modern day bathymetry of 50-100m, for Cassidulina subglobosa. Assemblage analyses of the samples forming these same groups showed the bathymetry to range from 100-500m, while the bathymetric analysis of Mobil Oil is outer neritic (100-200m) for groups 81 (samples 1560 and 2100), and 84 (2430), and upper bathyal (200-600m) for groups 83 (sample 2550) and 86 (sample 2760). The morphometric analysis of Cassidulina subglobosa indicate shallower paleobathymetries than were indicated by either the assemblage study or Mobil Oil's interpretations, although there is agreement with their neritic interpretations.

Morphometric analysis showed that groups 81, 84, 83, 85, and 86 possibly corresponded to a modern day bathymetry of 50-200m for Uvigerina peregrina. Assemblage analysis of the samples forming these same groups showed a bathymetric range from 100-200 (500)m, and is in general agreement with the bathymetric interpretation by Mobil Oil. Their interpretation is outer neritic (100-200m) for groups 81 (samples 1560, 1950, and 2100), and 84 (sample 2430), and upper bathyal (200-600m) for groups 83 (samples 2520 and 2550), 85 (sample 2640), and 86 (sample 2760). The morphometric analysis of Uvigerina

peregrina shows a degree of overlap between its paleobathymetric range and that determined by the assemblage analysis. The morphometric analysis also indicates similar depth interpretations with Mobil Oil's analysis for the samples of groups 81 and 84.

Part of the differences found between the three paleobathymetric analyses may lie in the different strategies used to determine paleobathymetry and in the use of the terms "neritic" and "bathyal". The paleobathymetric interpretation made by Mobil Oil is based on both a faunal analysis of assemblages using their own bathymetric scheme for those assemblages, and upon the presence of what they consider key bathymetric indicators (Ford, 1992). The assemblage analysis conducted herein is based on the bathymetric ranges of species as published by Phleger and Parker (1951), Parker (1954), Albers et al. (1966), Poag and Valentine (1976), Culver and Buzas (1981), Poag (1981), and Culver (1988). An assemblage analysis using a different scheme also would give different paleobathymetric results. For example, using Tipsword et al., (1966), the assemblage of cluster subgroup "b" most closely resembles inner-outer neritic depth (0-200m) assemblages, while the interpretation based on the depth ranges in this study show subgroup "b" to have a depth range of 100-500(1000)m or outer neritic-upper bathyal. The terms "neritic" and "bathyal" are defined differently by different authors. For example, the term "neritic" is generally defined

as extending from low tide level to the edge of the continental shelf (200m). In the Gulf of Mexico, however, the edge of the continental shelf is at an average depth of 150m (Curtis, 1987). Also, Albers et al., (1966) and Tipsword et al., (1966), subdivide the bathyal into upper bathyal (200-500m) and lower bathyal (500-2000m), whereas Culver (1988) subdivides the bathyal into upper bathyal (200-500m), middle bathyal (500-1000m), and lower bathyal (1000-2000m); and, Spencer (1985, 1987) subdivides the bathyal into upper bathyal (200-600m), middle bathyal (600-1000m), and lower bathyal (1000-2000m).

In addition, a paleobathymetric analysis based upon species' depth distributional patterns have some internal inconsistencies. First, some species change their depth distribution around the Gulf of Mexico (Culver and Buzas, 1981); second, depth ranges for species are constructed using the majority of records, while other records may indicate a shallower or deeper occurrence for a species; third, boundaries between bathymetric zones are imprecise even though absolute numbers are applied to these boundaries (Nybakken, 1988). For example, Bulimina marginata, which is considered to have a bathymetric range of outer neritic to middle bathyal (100-1000m), has reported occurrences of living individuals as shallow as 38m (Phleger and Parker, 1951). Similarly other species such as Planulina exorna, Nonionella atlantica, and Reussella atlantica have reported shallower depths than their

most commonly reported bathymetric ranges (Phleger and Parker, 1951). Consequently, a morphometric depth range of 50-100m for Cassidulina subglobosa and an assemblage depth range of 100-500m may not be as inconsistent as it first appears.

An analysis of the faunal assemblage indicates that while a few species occur at inner neritic depths, most first occur at middle neritic depths and both kinds continue into deeper waters. No species confined to inner neritic waters were found in the samples. If the Mobil Oil samples represent environments that were developed in the Pleistocene but are no longer present in the modern Gulf of Mexico or environments that the modern day database did not sample, then the statistical analysis, depending on the degree of morphologic similarity that developed in these environments, could plot the unknowns (Mobil Oil samples) with the closest similar samples. If a greater morphologic dissimilarity is present, the unknowns could be plotted in close proximity to a known sample group, but with non-intersecting confidence ellipses.

Sample groups 81 and 86 for Uvigerina peregrina, which represents material from well depths of 1560'-2100' and 2760' respectively, have a statistical plot that is isolated from, but in close proximity to a known modern sample group (sample group 28, 50-200m). In contrast, samples 84, 83, and 85, which represent material taken from intervening well depths of 2430', 2520'-2550', and 2640', respectively, have intersecting 95% confidence ellipses with the modern sample group 28. It

is thought that these isolated plots, occurring at the bottom and top of the sampled stratigraphic interval, represent intraspecific variation from an environment not represented in the modern day database.

Lastly, the abundance cluster analysis indicates two major biofacies. The first biofacies is composed of three samples and, based upon analyses of the faunal assemblages, represents a shallower water, middle-shelf environment. The second biofacies cluster is composed of twenty samples and is arranged in a step-wise cluster pattern. This cluster pattern, implying a gradation, can be divided into two subgroups. Based upon analyses of the faunal assemblages, one subgroup represents a deeper water environment, possibly outer shelf-middle slope, while the second subgroup represents an environment that is transitional between the shallower and deeper water biofacies, possibly a middle shelf to upper slope environment. These interpretations are generally consistent with those developed by Mobil Oil.

Table 10 summarizes the results of the three paleobathymetric analyses as well as presenting information on the percentage of planktic foraminifera, species diversity, equitability, and abundance subgroups for each Pleistocene well sample.

The time interval presented in Table 10 is expressed in millions of years before present (MYBP), and was supplied by Mobil Oil Company micropaleontologists for this well section.

TABLE 10. SUMMARY OF MORPHOMETRIC AND  
TAXONOMIC ANALYSES VERSUS MOBIL OIL'S  
BATHYMETRIC INTERPRETATION

(Cs=Cassidulina subglobosa, Up=Uvigerina peregrina,

s=sample numbers, \*=outliers,

ON=outer neritic/100-200m, UB=upper bathyal/200-600m,

%P=percent planktics, H(S)=species diversity,

E=equitability, A=abundance cluster subgroups).

TIME MYBP	WELL DEPTH (ft)	SAMPLE GROUPS	MORPHOMETRIC DEPTH RANGES		ASSEMBLAGE DEPTH RANGES	BATHYMETRY ACCORDING TO MOBIL OIL	%P	H(S)	E	A
			Cs	Up						
.25	1560	81	50-100m	50-200m	100-200(500)m	ON(100-200m)	10	2.75	0.42	c
	1950				100-200(500)m	ON(100-200m)	23	2.49	0.42	c
	2100		50-100m		100-200(500)m	ON(100-200m)	30	2.89	0.52	c
	2430	84	50-100m	50-200m	100-500(1000)m	ON(100-200m)	31	2.94	0.57	b
	2520	83		50-200m	100-500(1000)m	UB(200-600m)	21	3.37	0.60	b
.45	2550		50-100m		100-500(1000)m	UB(200-600m)	19	3.06	0.51	b
.55	2640	85		50-200m	100-500(1000)m	UB(200-600m)	23	2.96	0.49	b
.85	2760	86	50-100m	50-200m	100-500(1000)m	UB(200-600m)	29	3.20	0.57	b
	2790				100-1000m	UB(200-600m)	19	3.26	0.61	a
	2820				100-1000m	UB(200-600m)	43	3.20	0.62	a
	2850				*	UB(200-600m)	39	3.36	0.67	*
	2880				100-1000m	UB(200-600m)	31	3.16	0.55	a
	2910				100-1000m	UB(200-600m)	33	3.14	0.55	a
1.4	2940				100-500m	UB(200-600m)	52	3.14	0.55	b
	2970				100-1000m	UB(200-600m)	19	3.01	0.51	a
	3000				100-1000m	UB(200-600m)	24	3.26	0.61	a
	3030				100-1000m	UB(200-600m)	44	2.92	0.49	a
	3060				100-1000m	UB(200-600m)	45	3.09	0.54	a
	3120				100-1000m	UB(200-600m)	41	2.71	0.49	a
	3150				100-1000m	UB(200-600m)	39	2.84	0.43	a
	3180				100-1000m	UB(200-600m)	22	2.48	0.40	a
	3210				100-1000m	UB(200-600m)	32	2.78	0.40	a
	3240				100-1000m	UB(200-600m)	27	2.82	0.44	a
	3270				100-1000m	UB(200-600m)	23	2.91	0.52	a



The well in this study was drilled on the shelf at approximately 76m/250ft through Pleistocene sediments. Consequently, it is important to know approximate glacial and interglacial intervals, in order to evaluate the comparison of modern day morphometric data to Pleistocene morphometric data. Ruddiman (1971, p. 299) states that "none of the long-term Pleistocene climatic curves can be considered definitive". Ruddiman (1971) also pointed out that there is no regionally unified interpretation or exact chronology of Pleistocene glacial episodes available. Also, because of the few dates given by Mobil Oil to constrain the Pleistocene samples in the well studied, it would be difficult to assign glacial and interglacial ages. However, considering more recent literature, such as Berggren and van Couvering (1974), and Poag and Valentine (1976), generalized age assignments can be made. From 1.7-1.6 MYBP, there is a cool interval as presented by Berggren and van Couvering (1974); 1.6-1.3 MYBP is referred to as a glacial interval by Poag and Valentine (1976); 1.3-1.0 MYBP is referred to as an interglacial interval by Poag and Valentine (1976); 1.0-0.7 MYBP is referred to as a glacial interval by Poag and Valentine (1976); 0.7-0.5 MYBP is referred to as an interglacial interval by Poag and Valentine (1976); 0.5-0.13 MYBP is referred to as a glacial interval by Poag and Valentine (1976). Although these dates would seem to indicate that the Pleistocene well samples 1560, 1950, 2100, 2430,

2520, 2550, and 2640 were taken from a glacial interval, which possibly lowered sea level and influenced the environment and thus possibly the morphology of the foraminifera of these samples, there is evidence to the contrary for some of these samples. Because samples 1560 and 2640 have noted extinction horizons and associated sea level rises (for example, the Globorotalia inflata I transgression and the Trimosina denticulata transgression) as referenced in Morton et al., (1991), they possibly represent either interstadial or interglacial episodes.

Considering the dynamic nature of the Gulf of Mexico which includes sea level changes related to glacioeustasy, subsidence, tectonism, and diapirism, the problem of delineating paleobathymetry in this area becomes very complex and adds to the discrepancies between various methods of paleobathymetric interpretations. Because a new method using intraspecific morphologic variation to determine paleobathymetry is being tested in this study, there must be some other procedure by which the validity of this new method can be judged. Based upon such work as Poag and Sidner (1976), Poag and Valentine (1976) and Culver and Buzas (1981), a taxonomic analysis using the depth distributions of modern day species occurring in the Gulf of Mexico compared to those same species of Pleistocene age was selected as the measure against which this new method can be tested.

In spite of the fact that a paleobathymetric analysis

using species assemblages tends to give a broad paleobathymetric range, while the morphometric approach is designed to give much narrower paleobathymetric ranges, a comparison between the two methods indicates a general agreement, especially for the paleobathymetric interpretation of Uvigerina peregrina.

## CHAPTER 9

### CONCLUSIONS

The purpose of this study was to test the validity of statistically defined intraspecific variation to determine paleobathymetry. This validation process involved comparison of Pleistocene paleobathymetric estimates obtained through a species assemblage analysis to that obtained from the canonical analysis of intraspecific variation of two species, Cassidulina subglobosa and Uvigerina peregrina, using the morphometries of modern forms of these same two species as a bathymetric standard of reference. The results of these comparisons are listed below :

1. The morphometric interpretation of paleobathymetry using Cassidulina subglobosa indicates a shallower depth (50-100m) than that obtained from the species assemblage analysis.
2. The morphometric interpretation of paleobathymetry using Uvigerina peregrina indicates a depth of 50-200m, and is within the 100-200 (500)m depth interpretation using assemblage data.

3. When comparing the paleobathymetric interpretations obtained by morphometric analysis to that provided by Mobil Oil, the morphometric data is in general agreement with Mobil Oil's analysis for those samples identified as "outer neritic", but they provide shallower interpretations than those samples identified as "upper bathyal" in Mobil's analysis.
4. While the assemblage analysis indicates depth ranges extending from 100 to 1000m, the dominant genera and species abundances found within the cluster analysis argue for narrower paleobathymetric ranges. The cluster analysis clearly defined two major groups, the smaller of which represents a shallow water, middle shelf environment. The larger cluster group represents a transitional to deeper water environment that extends from the outer shelf to the middle slope. The paleobathymetric estimates are in agreement with that presented by Mobil Oil.

The paleobathymetric discrepancies encountered between the morphometric approach and that presented for species assemblage interpretations may lie in the different strategies and methods each technique employed. The fact that some species change their depth distribution around the Gulf of

Mexico, depth ranges for species are constructed using a majority of records while other records may indicate a shallower or deeper occurrence for a species, and boundaries between bathymetric zones are imprecise even though absolute numbers are applied to those boundaries, all contribute to the disparity found in determining paleobathymetry of the Pleistocene samples studied.

Two sample groups of Uvigerina peregrina, one occurring at the bottom and the other occurring at the top of the studied Pleistocene stratigraphic sequence, have statistical plots that are distinct from but close to a modern day sample from the Gulf of Mexico, that represents a bathymetry of 50-200m. The statistical plots for the intervening samples from this same Pleistocene stratigraphic sequence all have intersecting 95% confidence ellipses with their modern day counterpart representing a water depth of 50-200m. It is thought that these isolated plots represent intraspecific variation from an environment not recorded in the modern day database.

In summary, the results of using quantified intraspecific variation to interpret paleobathymetry appears to be in general agreement with that obtained through standard paleobathymetric analysis using species depth distribution information.

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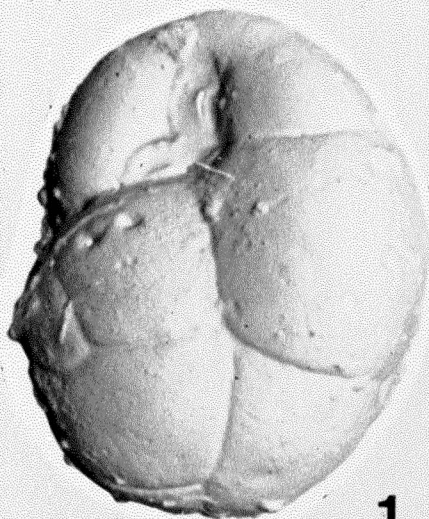


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APPENDIX A  
SCANNING ELECTRON MICROGRAPHS  
OF CASSIDULINA SUBGLOBOSA AND  
UVIGERINA PEREGRINA

(1=apertural view of Cassidulina subglobosa,  
2=side view of Cassidulina subglobosa,  
3=side view of Uvigerina peregrina,  
4=apertural view of Uvigerina peregrina).



1

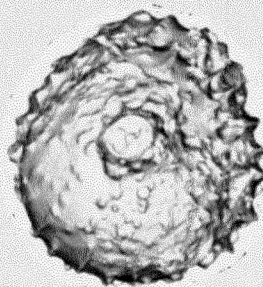


2

100 $\mu$ m



3



4

200 $\mu$ m

APPENDIX B

MORPHOLOGIC MEASUREMENTS FOR

CASSIDULINA SUBGLOBOSA AND

UVIGERINA PEREGRINA FROM

PLEISTOCENE SAMPLES

(obs=observation, cn=case number,

id=identification, tra=traverse,

dn=depth number, sta=station or group,

l-cw=Cassidulina subglobosa measurements

in millimeters, nc=new computer code,

lb-wan=Uvigerina peregrina measurements

in millimeters).

OBS	CN	ID	TRA	DN	STA	L	W	WA	LA	WAF	LAF	T	CH	CW	NC
1	1	1	8	1560	81	0.21	0.17	0.02	0.05	0.14	0.07	0.17	0.08	0.09	0
2	2	1	8	1560	81	0.11	0.10	0.01	0.02	0.08	0.04	0.08	0.05	0.06	0
3	3	1	8	1560	81	0.12	0.10	0.01	0.02	0.08	0.03	0.07	0.06	0.07	0
4	4	1	8	1560	81	0.13	0.11	0.01	0.02	0.08	0.04	0.08	0.06	0.07	0
5	5	1	8	1560	81	0.17	0.14	0.01	0.03	0.09	0.05	0.11	0.07	0.08	0
6	6	1	8	1560	81	0.12	0.10	0.01	0.03	0.07	0.05	0.08	0.04	0.05	0
7	7	1	8	1560	81	0.11	0.09	0.01	0.02	0.07	0.03	0.07	0.07	0.06	0
8	8	1	8	1560	81	0.12	0.09	0.01	0.02	0.09	0.04	0.07	0.05	0.07	0
9	9	1	8	1560	81	0.16	0.13	0.01	0.03	0.12	0.08	0.11	0.08	0.09	0
10	10	1	8	1560	81	0.12	0.10	0.01	0.02	0.06	0.03	0.08	0.06	0.08	0
11	11	1	8	1560	81	0.12	0.10	0.01	0.02	0.07	0.03	0.08	0.06	0.06	0
12	12	1	8	1560	81	0.12	0.09	0.01	0.02	0.06	0.03	0.08	0.07	0.06	0
13	13	1	8	1560	81	0.14	0.12	0.02	0.02	0.09	0.04	0.10	0.06	0.08	0
14	14	2	8	2100	81	0.22	0.20	0.01	0.03	0.10	0.07	0.14	0.11	0.10	0
15	15	2	8	2100	81	0.22	0.18	0.01	0.03	0.15	0.08	0.12	0.10	0.07	0
16	16	2	8	2100	81	0.15	0.13	0.01	0.02	0.11	0.05	0.10	0.10	0.06	0
17	15	3	8	2430	84	0.11	0.10	0.01	0.01	0.07	0.03	0.06	0.08	0.06	0
18	16	3	8	2430	84	0.13	0.10	0.01	0.02	0.08	0.03	0.07	0.09	0.06	0
19	17	3	8	2430	84	0.11	0.10	0.02	0.01	0.05	0.02	0.07	0.05	0.06	0
20	18	3	8	2430	84	0.13	0.10	0.01	0.02	0.08	0.03	0.06	0.07	0.08	0
21	19	3	8	2430	84	0.11	0.09	0.02	0.01	0.07	0.03	0.07	0.07	0.05	0
22	20	3	8	2430	84	0.13	0.11	0.02	0.02	0.08	0.03	0.06	0.07	0.06	0
23	21	3	8	2430	84	0.12	0.11	0.01	0.02	0.08	0.03	0.06	0.06	0.05	0
24	22	3	8	2430	84	0.12	0.10	0.02	0.01	0.06	0.02	0.07	0.08	0.07	0
25	24	3	8	2430	84	0.13	0.10	0.03	0.01	0.08	0.04	0.07	0.07	0.06	0
26	25	3	8	2430	84	0.14	0.12	0.02	0.02	0.10	0.05	0.07	0.08	0.06	0
27	26	3	8	2430	84	0.12	0.10	0.02	0.01	0.07	0.03	0.06	0.07	0.06	0
28	27	3	8	2430	84	0.14	0.11	0.02	0.01	0.08	0.03	0.08	0.07	0.06	0
29	28	3	8	2430	84	0.11	0.10	0.01	0.02	0.08	0.03	0.06	0.07	0.05	0
30	3	3	8	2430	84	0.12	0.11	0.01	0.02	0.08	0.03	0.07	0.08	0.06	0
31	4	3	8	2430	84	0.14	0.11	0.01	0.02	0.09	0.03	0.08	0.07	0.07	0
32	5	3	8	2430	84	0.11	0.09	0.01	0.02	0.07	0.03	0.06	0.07	0.05	0
33	6	3	8	2430	84	0.12	0.10	0.01	0.02	0.08	0.03	0.08	0.06	0.05	0
34	7	3	8	2430	84	0.12	0.10	0.01	0.02	0.07	0.03	0.05	0.06	0.05	0
35	8	3	8	2430	84	0.12	0.10	0.01	0.02	0.07	0.03	0.06	0.07	0.06	0
36	9	3	8	2430	84	0.12	0.10	0.01	0.02	0.06	0.03	0.06	0.07	0.05	0
37	31	4	8	2550	83	0.14	0.13	0.03	0.02	0.09	0.04	0.09	0.08	0.07	0
38	32	4	8	2550	83	0.13	0.12	0.02	0.02	0.09	0.03	0.08	0.06	0.07	0
39	33	4	8	2550	83	0.13	0.11	0.02	0.01	0.07	0.03	0.07	0.08	0.06	0
40	34	4	8	2550	83	0.13	0.11	0.02	0.02	0.08	0.03	0.08	0.08	0.07	0
41	35	4	8	2550	83	0.13	0.11	0.03	0.01	0.09	0.03	0.07	0.08	0.06	0
42	36	4	8	2550	83	0.12	0.10	0.01	0.02	0.07	0.04	0.05	0.07	0.06	0
43	37	4	8	2550	83	0.12	0.10	0.01	0.02	0.07	0.03	0.07	0.06	0.05	0
44	38	4	8	2550	83	0.12	0.11	0.01	0.02	0.07	0.03	0.07	0.06	0.06	0
45	39	4	8	2550	83	0.13	0.10	0.01	0.02	0.07	0.03	0.06	0.06	0.05	0
46	40	4	8	2550	83	0.14	0.12	0.01	0.02	0.10	0.04	0.07	0.09	0.07	0
47	41	4	8	2550	83	0.12	0.11	0.01	0.02	0.07	0.03	0.07	0.08	0.06	0
48	42	4	8	2550	83	0.12	0.10	0.01	0.02	0.07	0.03	0.06	0.07	0.06	0
49	43	4	8	2550	83	0.14	0.12	0.03	0.01	0.09	0.03	0.07	0.08	0.07	0
50	44	4	8	2550	83	0.13	0.11	0.03	0.02	0.08	0.03	0.08	0.07	0.06	0
51	45	4	8	2550	83	0.13	0.11	0.01	0.02	0.08	0.03	0.08	0.09	0.05	0
52	46	4	8	2550	83	0.15	0.13	0.01	0.02	0.10	0.04	0.09	0.10	0.07	0
53	47	4	8	2550	83	0.13	0.11	0.01	0.02	0.08	0.03	0.07	0.09	0.05	0
54	48	4	8	2550	83	0.17	0.13	0.01	0.02	0.11	0.05	0.07	0.10	0.07	0
55	49	4	8	2550	83	0.12	0.10	0.01	0.02	0.07	0.03	0.05	0.05	0.06	0
56	50	4	8	2550	83	0.15	0.13	0.01	0.02	0.08	0.03	0.09	0.09	0.06	0

Cassidulina subglobosa

Cassidulina subglobosa

OBS	CN	ID	TRA	DN	STA	L	W	WA	LA	WAF	LAF	T	CH	CW	NC
57	51	4	8	2550	83	0.13	0.10	0.01	0.02	0.08	0.03	0.06	0.07	0.05	0
58	52	4	8	2550	83	0.13	0.10	0.01	0.02	0.08	0.03	0.07	0.07	0.06	0
59	53	4	8	2550	83	0.15	0.13	0.01	0.02	0.08	0.03	0.07	0.08	0.07	0
60	54	4	8	2550	83	0.12	0.10	0.01	0.02	0.08	0.03	0.06	0.06	0.05	0
61	55	4	8	2550	83	0.12	0.10	0.02	0.01	0.07	0.03	0.06	0.07	0.05	0
62	56	5	8	2760	86	0.15	0.12	0.02	0.03	0.10	0.04	0.08	0.10	0.05	0
63	58	5	8	2760	86	0.16	0.14	0.01	0.02	0.10	0.04	0.10	0.10	0.09	0
64	61	5	8	2760	86	0.14	0.12	0.01	0.02	0.09	0.03	0.08	0.09	0.08	0
65	62	5	8	2760	86	0.15	0.13	0.01	0.02	0.10	0.04	0.08	0.09	0.08	0
66	63	5	8	2760	86	0.13	0.11	0.01	0.02	0.08	0.03	0.07	0.08	0.07	0
67	64	5	8	2760	86	0.18	0.16	0.01	0.03	0.10	0.04	0.10	0.11	0.09	0
68	65	5	8	2760	86	0.11	0.10	0.02	0.02	0.08	0.04	0.06	0.07	0.05	0
69	66	5	8	2760	86	0.13	0.11	0.01	0.02	0.08	0.03	0.08	0.08	0.07	0
70	67	5	8	2760	86	0.12	0.10	0.01	0.02	0.07	0.03	0.07	0.08	0.07	0
71	68	5	8	2760	86	0.13	0.12	0.01	0.02	0.09	0.04	0.06	0.08	0.07	0
72	69	5	8	2760	86	0.12	0.10	0.01	0.02	0.08	0.03	0.07	0.08	0.06	0
73	70	5	8	2760	86	0.11	0.10	0.01	0.02	0.08	0.03	0.05	0.07	0.05	0
74	71	5	8	2760	86	0.13	0.11	0.01	0.02	0.09	0.04	0.09	0.09	0.07	0
75	72	5	8	2760	86	0.12	0.10	0.01	0.02	0.08	0.04	0.06	0.08	0.05	0
76	73	5	8	2760	86	0.13	0.11	0.01	0.02	0.09	0.04	0.07	0.09	0.07	0
77	74	5	8	2760	86	0.12	0.11	0.01	0.02	0.07	0.03	0.07	0.07	0.05	0
78	75	5	8	2760	86	0.18	0.15	0.01	0.02	0.10	0.04	0.10	0.11	0.08	0
79	76	5	8	2760	86	0.13	0.10	0.01	0.02	0.08	0.03	0.08	0.08	0.06	0
80	77	5	8	2760	86	0.17	0.15	0.02	0.01	0.10	0.03	0.08	0.11	0.09	0
81	78	5	8	2760	86	0.18	0.15	0.01	0.02	0.11	0.05	0.11	0.11	0.07	0
82	79	5	8	2760	86	0.13	0.11	0.01	0.02	0.08	0.03	0.07	0.08	0.07	0
83	81	5	8	2760	86	0.13	0.10	0.01	0.02	0.08	0.04	0.07	0.09	0.06	0
84	82	5	8	2760	86	0.12	0.10	0.01	0.02	0.07	0.03	0.07	0.07	0.06	0
85	83	5	8	2760	86	0.17	0.15	0.01	0.02	0.12	0.04	0.10	0.11	0.08	0
86	84	5	8	2760	86	0.14	0.13	0.01	0.02	0.10	0.04	0.09	0.10	0.08	0
87	85	5	8	2760	86	0.14	0.12	0.01	0.02	0.09	0.03	0.08	0.08	0.07	0

Uyigerina peregrina

OBS	CN	ID	TRA	DN	STA	LB	LN	LFC	LSC	HC	WC	CS	CA	CB	NC	WA	WB	WFM	WFN	WAM	WAN
1	1	1	8	1560	81	0.41	0.03	0.13	0.13	0.01	0.01	0.02	1.05	0.02	0	0.20	0.18	0.04	0.03	0.02	0.01
2	2	1	8	1560	81	0.33	0.04	0.12	0.10	0.01	0.01	0.02	1.22	0.02	0	0.18	0.17	0.03	0.02	0.02	0.01
3	3	1	8	1560	81	0.28	0.03	0.09	0.08	0.02	0.01	0.03	1.05	0.03	0	0.18	0.15	0.03	0.02	0.02	0.01
4	4	1	8	1560	81	0.35	0.05	0.11	0.10	0.02	0.01	0.02	1.05	0.03	0	0.22	0.21	0.04	0.03	0.02	0.01
5	5	1	8	1560	81	0.41	0.04	0.11	0.10	0.01	0.01	0.02	1.13	0.02	0	0.20	0.18	0.03	0.02	0.01	0.01
6	6	1	8	1560	81	0.36	0.04	0.11	0.12	0.02	0.01	0.02	1.05	0.03	0	0.22	0.20	0.04	0.03	0.02	0.01
7	7	1	8	1560	81	0.27	0.04	0.08	0.11	0.01	0.01	0.02	0.87	0.04	0	0.20	0.16	0.03	0.02	0.02	0.01
8	8	1	8	1560	81	0.35	0.04	0.10	0.09	0.01	0.01	0.02	1.05	0.02	0	0.18	0.16	0.04	0.02	0.02	0.01
9	9	1	8	1560	81	0.28	0.02	0.11	0.07	0.01	0.01	0.02	1.05	0.02	0	0.20	0.19	0.04	0.03	0.02	0.01
10	1	1	8	1560	81	0.22	0.00	0.08	0.06	0.01	0.01	0.02	1.31	0.03	0	0.18	0.16	0.00	0.00	0.00	0.00
11	10	2	8	1950	81	0.33	0.04	0.10	0.09	0.01	0.01	0.02	1.13	0.02	0	0.18	0.16	0.03	0.02	0.01	0.01
12	11	2	8	1950	81	0.36	0.03	0.10	0.11	0.01	0.01	0.02	1.05	0.03	0	0.23	0.21	0.03	0.02	0.01	0.01
13	12	2	8	1950	81	0.36	0.03	0.12	0.15	0.01	0.01	0.02	1.05	0.03	0	0.21	0.20	0.05	0.03	0.02	0.01
14	13	2	8	1950	81	0.29	0.03	0.12	0.13	0.01	0.01	0.02	1.05	0.03	0	0.21	0.20	0.04	0.03	0.02	0.01
15	14	3	8	2100	81	0.37	0.03	0.10	0.10	0.01	0.01	0.02	0.87	0.02	0	0.23	0.20	0.03	0.02	0.02	0.01
16	15	3	8	2100	81	0.34	0.03	0.10	0.14	0.01	0.01	0.02	0.87	0.02	0	0.24	0.22	0.04	0.03	0.02	0.01
17	16	3	8	2100	81	0.37	0.06	0.10	0.12	0.01	0.01	0.02	1.05	0.02	0	0.20	0.18	0.04	0.03	0.02	0.01
18	17	3	8	2100	81	0.38	0.02	0.10	0.14	0.02	0.01	0.02	1.05	0.03	0	0.22	0.20	0.04	0.03	0.01	0.01
19	18	4	8	2430	84	0.35	0.02	0.12	0.10	0.01	0.01	0.02	1.13	0.02	0	0.20	0.19	0.04	0.03	0.02	0.02
20	19	4	8	2430	84	0.31	0.02	0.11	0.08	0.01	0.01	0.02	1.05	0.02	0	0.16	0.15	0.03	0.02	0.02	0.01
21	20	4	8	2430	84	0.32	0.02	0.10	0.11	0.01	0.01	0.02	1.05	0.03	0	0.19	0.18	0.04	0.03	0.03	0.02
22	21	4	8	2430	84	0.30	0.03	0.12	0.11	0.01	0.01	0.02	1.05	0.03	0	0.17	0.16	0.03	0.02	0.01	0.01
23	22	4	8	2430	84	0.32	0.03	0.09	0.10	0.01	0.01	0.02	1.05	0.02	0	0.18	0.17	0.05	0.04	0.03	0.02
24	23	4	8	2430	84	0.34	0.04	0.10	0.09	0.01	0.01	0.02	1.05	0.02	0	0.21	0.19	0.03	0.02	0.02	0.01
25	24	4	8	2430	84	0.40	0.03	0.09	0.10	0.01	0.01	0.02	1.13	0.02	0	0.16	0.15	0.03	0.02	0.02	0.01
26	25	4	8	2430	84	0.33	0.04	0.10	0.12	0.01	0.01	0.01	0.87	0.03	0	0.18	0.17	0.04	0.03	0.02	0.01
27	26	4	8	2430	84	0.27	0.02	0.08	0.09	0.01	0.01	0.02	0.87	0.02	0	0.16	0.14	0.04	0.03	0.03	0.02
28	27	4	8	2430	84	0.26	0.03	0.12	0.13	0.01	0.01	0.02	0.87	0.02	0	0.15	0.14	0.05	0.03	0.03	0.02
29	28	4	8	2430	84	0.33	0.04	0.10	0.09	0.02	0.01	0.02	1.22	0.03	0	0.21	0.20	0.05	0.04	0.02	0.01
30	29	4	8	2430	84	0.29	0.03	0.08	0.11	0.01	0.01	0.02	0.96	0.02	0	0.16	0.15	0.03	0.02	0.01	0.01
31	30	4	8	2430	84	0.29	0.04	0.11	0.10	0.02	0.01	0.02	1.05	0.03	0	0.20	0.17	0.04	0.03	0.02	0.01
32	31	4	8	2430	84	0.28	0.02	0.09	0.08	0.02	0.01	0.02	1.05	0.03	0	0.17	0.15	0.03	0.02	0.01	0.01
33	32	4	8	2430	84	0.27	0.04	0.07	0.10	0.01	0.01	0.01	0.87	0.02	0	0.17	0.14	0.03	0.02	0.01	0.01
34	2	4	8	2430	84	0.31	0.00	0.11	0.08	0.01	0.01	0.02	1.22	0.02	0	0.21	0.19	0.00	0.00	0.00	0.00
35	3	4	8	2430	84	0.25	0.00	0.12	0.09	0.01	0.02	0.03	1.13	0.02	0	0.17	0.15	0.00	0.00	0.00	0.00
36	4	4	8	2430	84	0.24	0.00	0.12	0.10	0.01	0.02	0.03	1.05	0.03	0	0.16	0.15	0.00	0.00	0.00	0.00
37	5	4	8	2430	84	0.28	0.00	0.12	0.10	0.01	0.02	0.03	1.05	0.03	0	0.20	0.18	0.00	0.00	0.00	0.00
38	6	4	8	2430	84	0.24	0.00	0.11	0.09	0.01	0.01	0.02	1.22	0.03	0	0.16	0.14	0.00	0.00	0.00	0.00
39	7	4	8	2430	84	0.26	0.00	0.11	0.10	0.01	0.03	0.04	1.05	0.03	0	0.17	0.14	0.00	0.00	0.00	0.00
40	8	4	8	2430	84	0.26	0.00	0.12	0.10	0.01	0.02	0.03	1.22	0.03	0	0.16	0.15	0.00	0.00	0.00	0.00
41	9	4	8	2430	84	0.30	0.00	0.13	0.12	0.01	0.02	0.03	1.22	0.03	0	0.17	0.14	0.00	0.00	0.00	0.00
42	33	5	8	2520	83	0.31	0.02	0.08	0.10	0.02	0.01	0.02	1.13	0.03	0	0.18	0.16	0.04	0.02	0.03	0.01
43	34	5	8	2520	83	0.26	0.02	0.10	0.08	0.01	0.01	0.02	1.05	0.02	0	0.12	0.10	0.03	0.02	0.02	0.01
44	35	5	8	2520	83	0.45	0.03	0.16	0.11	0.02	0.01	0.02	1.22	0.03	0	0.24	0.22	0.04	0.03	0.02	0.01
45	36	5	8	2520	83	0.36	0.03	0.10	0.11	0.01	0.01	0.02	1.05	0.02	0	0.22	0.20	0.05	0.04	0.02	0.01
46	37	5	8	2520	83	0.36	0.03	0.12	0.10	0.02	0.01	0.03	1.22	0.03	0	0.21	0.19	0.03	0.02	0.01	0.01
47	38	5	8	2520	83	0.32	0.03	0.12	0.11	0.01	0.01	0.02	0.87	0.03	0	0.21	0.20	0.04	0.03	0.02	0.01
48	39	5	8	2520	83	0.26	0.02	0.08	0.10	0.01	0.01	0.02	1.22	0.02	0	0.16	0.15	0.03	0.02	0.02	0.01
49	1	5	8	2520	83	0.24	0.00	0.09	0.08	0.01	0.02	0.03	1.22	0.03	0	0.15	0.13	0.00	0.00	0.00	0.00
50	2	5	8	2520	83	0.29	0.00	0.10	0.08	0.01	0.02	0.03	1.22	0.03	0	0.16	0.14	0.00	0.00	0.00	0.00
51	3	5	8	2520	83	0.24	0.00	0.09	0.09	0.01	0.02	0.03	1.05	0.02	0	0.17	0.15	0.00	0.00	0.00	0.00
52	4	5	8	2520	83	0.26	0.00	0.10	0.09	0.01	0.01	0.02	1.22	0.02	0	0.15	0.13	0.00	0.00	0.00	0.00
53	5	5	8	2520	83	0.28	0.00	0.10	0.09	0.01	0.02	0.03	0.78	0.03	0	0.18	0.16	0.00	0.00	0.00	0.00
54	6	5	8	2520	83	0.27	0.00	0.12	0.09	0.01	0.02	0.03	1.05	0.03	0	0.15	0.13	0.00	0.00	0.00	0.00
55	7	5	8	2520	83	0.30	0.00	0.11	0.09	0.01	0.01	0.02	1.13	0.03	0	0.17	0.15	0.00	0.00	0.00	0.00
56	8	5	8	2520	83	0.25	0.00	0.12	0.10	0.01	0.02	0.03	1.05	0.03	0	0.16	0.14	0.00	0.00	0.00	0.00



OBS	CN	ID	TRA	DN	STA	LB	LN	LFC	LSC	HC	WC	CS	CA	CB	NC	WA	WB	WFM	WFN	WAM	WAN
57	9	5	8	2520	83	0.31	0.00	0.13	0.12	0.01	0.020	0.030	1.22	0.04	0	0.20	0.17	0.00	0.00	0.000	0.00
58	40	6	8	2550	83	0.27	0.03	0.10	0.10	0.01	0.010	0.020	1.05	0.02	0	0.15	0.14	0.03	0.02	0.020	0.01
59	41	6	8	2550	83	0.29	0.03	0.10	0.10	0.01	0.020	0.030	1.05	0.02	0	0.19	0.17	0.03	0.02	0.020	0.01
60	42	6	8	2550	83	0.27	0.03	0.09	0.10	0.01	0.010	0.020	1.05	0.02	0	0.17	0.15	0.04	0.03	0.020	0.01
61	43	6	8	2550	83	0.29	0.02	0.09	0.10	0.01	0.010	0.020	1.05	0.03	0	0.18	0.16	0.03	0.02	0.010	0.01
62	44	6	8	2550	83	0.30	0.03	0.12	0.10	0.01	0.010	0.020	0.96	0.03	0	0.17	0.14	0.04	0.02	0.020	0.01
63	45	6	8	2550	83	0.40	0.03	0.12	0.11	0.01	0.020	0.030	0.96	0.02	0	0.22	0.20	0.03	0.02	0.020	0.01
64	46	6	8	2550	83	0.36	0.05	0.12	0.14	0.01	0.010	0.020	0.87	0.03	0	0.21	0.19	0.05	0.04	0.020	0.01
65	47	6	8	2550	83	0.27	0.02	0.07	0.10	0.01	0.010	0.020	1.05	0.02	0	0.16	0.15	0.03	0.02	0.020	0.01
66	48	6	8	2550	83	0.28	0.03	0.09	0.07	0.01	0.010	0.020	1.13	0.03	0	0.15	0.13	0.03	0.02	0.020	0.01
67	1	6	8	2550	83	0.26	0.00	0.08	0.08	0.01	0.010	0.020	1.13	0.02	0	0.15	0.13	0.00	0.00	0.000	0.00
68	2	6	8	2550	83	0.28	0.00	0.12	0.11	0.01	0.030	0.040	1.22	0.03	0	0.19	0.17	0.00	0.00	0.000	0.00
69	49	7	8	2640	85	0.28	0.03	0.08	0.07	0.01	0.010	0.020	1.05	0.02	0	0.15	0.14	0.03	0.02	0.020	0.01
70	50	7	8	2640	85	0.32	0.03	0.12	0.10	0.01	0.010	0.020	1.05	0.02	0	0.19	0.17	0.03	0.02	0.010	0.01
71	51	7	8	2640	85	0.34	0.03	0.12	0.13	0.01	0.010	0.030	1.05	0.03	0	0.20	0.18	0.03	0.02	0.010	0.01
72	52	7	8	2640	85	0.30	0.02	0.14	0.14	0.01	0.010	0.020	1.05	0.02	0	0.18	0.16	0.03	0.02	0.020	0.01
73	53	7	8	2640	85	0.27	0.03	0.10	0.09	0.01	0.010	0.020	1.05	0.02	0	0.18	0.16	0.03	0.02	0.020	0.01
74	54	7	8	2640	85	0.37	0.03	0.14	0.15	0.01	0.010	0.020	0.87	0.03	0	0.23	0.21	0.03	0.02	0.020	0.01
75	55	7	8	2640	85	0.32	0.05	0.12	0.12	0.01	0.010	0.020	0.87	0.03	0	0.20	0.19	0.04	0.03	0.020	0.01
76	56	7	8	2640	85	0.27	0.02	0.08	0.09	0.01	0.010	0.020	1.05	0.03	0	0.15	0.13	0.03	0.02	0.020	0.01
77	57	7	8	2640	85	0.25	0.03	0.09	0.08	0.01	0.010	0.020	1.05	0.02	0	0.17	0.15	0.03	0.02	0.020	0.01
78	58	7	8	2640	85	0.30	0.03	0.13	0.12	0.01	0.010	0.020	1.13	0.02	0	0.20	0.18	0.03	0.02	0.020	0.01
79	59	7	8	2640	85	0.33	0.02	0.10	0.10	0.01	0.010	0.030	0.87	0.03	0	0.21	0.20	0.04	0.03	0.020	0.01
80	60	7	8	2640	85	0.26	0.02	0.09	0.07	0.01	0.010	0.020	1.22	0.02	0	0.16	0.14	0.03	0.02	0.020	0.01
81	3	7	8	2640	85	0.31	0.00	0.10	0.08	0.01	0.020	0.030	1.22	0.02	0	0.17	0.15	0.00	0.00	0.000	0.00
82	4	7	8	2640	85	0.30	0.00	0.11	0.10	0.01	0.020	0.030	1.22	0.02	0	0.17	0.15	0.00	0.00	0.000	0.00
83	5	7	8	2640	85	0.30	0.00	0.10	0.10	0.01	0.010	0.020	1.13	0.02	0	0.18	0.16	0.00	0.00	0.000	0.00
84	6	7	8	2640	85	0.32	0.00	0.13	0.10	0.01	0.020	0.030	1.22	0.03	0	0.22	0.20	0.00	0.00	0.000	0.00
85	7	7	8	2640	85	0.33	0.00	0.15	0.12	0.01	0.020	0.030	1.22	0.04	0	0.25	0.22	0.00	0.00	0.000	0.00
86	8	7	8	2640	85	0.25	0.00	0.12	0.11	0.01	0.020	0.030	1.13	0.04	0	0.19	0.16	0.00	0.00	0.000	0.00
87	61	8	8	2760	86	0.33	0.03	0.13	0.15	0.02	0.010	0.020	0.96	0.03	0	0.20	0.17	0.03	0.02	0.020	0.01
88	62	8	8	2760	86	0.31	0.03	0.08	0.09	0.01	0.010	0.020	0.87	0.03	0	0.20	0.19	0.03	0.02	0.020	0.01
89	63	8	8	2760	86	0.24	0.03	0.11	0.11	0.01	0.010	0.020	0.87	0.03	0	0.15	0.14	0.03	0.02	0.020	0.01
90	64	8	8	2760	86	0.35	0.03	0.13	0.09	0.01	0.010	0.020	1.05	0.02	0	0.20	0.19	0.04	0.03	0.020	0.01
91	65	8	8	2760	86	0.30	0.03	0.08	0.08	0.01	0.010	0.020	1.05	0.02	0	0.18	0.16	0.04	0.03	0.020	0.01
92	66	8	8	2760	86	0.32	0.03	0.13	0.13	0.01	0.010	0.020	0.96	0.03	0	0.20	0.18	0.03	0.02	0.020	0.01
93	67	8	8	2760	86	0.60	0.07	0.18	0.16	0.01	0.010	0.020	1.13	0.04	0	0.35	0.33	0.05	0.03	0.030	0.01
94	68	8	8	2760	86	0.25	0.02	0.11	0.11	0.01	0.010	0.020	0.96	0.02	0	0.15	0.14	0.03	0.02	0.020	0.01
95	69	8	8	2760	86	0.32	0.03	0.11	0.09	0.01	0.010	0.020	1.13	0.02	0	0.15	0.14	0.03	0.02	0.010	0.01
96	70	8	8	2760	86	0.34	0.03	0.16	0.16	0.01	0.010	0.020	0.96	0.04	0	0.24	0.23	0.03	0.02	0.020	0.01
97	71	8	8	2760	86	0.31	0.03	0.15	0.13	0.01	0.010	0.020	0.87	0.03	0	0.19	0.17	0.04	0.03	0.020	0.01
98	72	8	8	2760	86	0.24	0.03	0.09	0.10	0.01	0.010	0.015	0.87	0.03	0	0.15	0.13	0.03	0.02	0.010	0.01
99	73	8	8	2760	86	0.26	0.02	0.09	0.09	0.01	0.010	0.020	1.05	0.02	0	0.13	0.12	0.04	0.03	0.020	0.01
100	74	8	8	2760	86	0.27	0.03	0.09	0.08	0.01	0.010	0.020	0.87	0.02	0	0.16	0.14	0.03	0.03	0.020	0.01
101	75	8	8	2760	86	0.28	0.05	0.11	0.10	0.01	0.015	0.020	1.05	0.03	0	0.18	0.17	0.04	0.03	0.020	0.01
102	76	8	8	2760	86	0.26	0.04	0.12	0.10	0.01	0.010	0.020	0.87	0.02	0	0.17	0.16	0.03	0.02	0.020	0.01
103	77	8	8	2760	86	0.40	0.04	0.12	0.11	0.01	0.010	0.020	1.05	0.04	0	0.23	0.22	0.04	0.03	0.020	0.01
104	78	8	8	2760	86	0.44	0.05	0.15	0.16	0.01	0.010	0.020	0.87	0.02	0	0.26	0.25	0.04	0.03	0.020	0.01
105	79	8	8	2760	86	0.27	0.02	0.10	0.09	0.01	0.010	0.020	1.05	0.02	0	0.17	0.15	0.03	0.02	0.020	0.01
106	80	8	8	2760	86	0.35	0.03	0.10	0.10	0.01	0.010	0.020	1.05	0.03	0	0.21	0.20	0.04	0.03	0.015	0.01
107	81	8	8	2760	86	0.30	0.03	0.11	0.12	0.01	0.010	0.020	1.05	0.02	0	0.21	0.19	0.04	0.03	0.020	0.01
108	82	8	8	2760	86	0.27	0.03	0.10	0.09	0.01	0.010	0.020	0.87	0.02	0	0.15	0.13	0.03	0.02	0.020	0.01
109	83	8	8	2760	86	0.27	0.03	0.10	0.12	0.01	0.010	0.015	1.05	0.02	0	0.14	0.13	0.03	0.02	0.010	0.01
110	84	8	8	2760	86	0.27	0.02	0.12	0.11	0.01	0.010	0.020	1.05	0.03	0	0.17	0.15	0.03	0.02	0.020	0.01
111	85	8	8	2760	86	0.30	0.02	0.09	0.10	0.01	0.010	0.010	1.05	0.02	0	0.15	0.14	0.03	0.02	0.010	0.01
112	86	8	8	2760	86	0.31	0.03	0.10	0.09	0.01	0.010	0.020	1.22	0.02	0	0.19	0.18	0.03	0.02	0.020	0.01

Uvigerina peregrina

OBS	CN	ID	TRA	DN	STA	LB	LN	LFC	LSC	HC	WC	CS	CA	CS	NC	WA	WE	WFM	WFN	WAM	WAN
113	87	8	8	2760	86	0.37	0.03	0.13	0.14	0.01	0.01	0.020	1.13	0.02	0	0.26	0.25	0.03	0.02	0.02	0.01
114	88	8	8	2760	86	0.34	0.03	0.12	0.14	0.01	0.01	0.020	1.05	0.03	0	0.22	0.21	0.03	0.02	0.02	0.01
115	89	8	8	2760	86	0.36	0.04	0.11	0.10	0.01	0.01	0.020	1.13	0.02	0	0.23	0.22	0.03	0.02	0.02	0.01
116	90	8	8	2760	86	0.34	0.05	0.12	0.10	0.01	0.01	0.015	1.05	0.03	0	0.17	0.16	0.03	0.02	0.01	0.01

Uyigerina peregrina

## APPENDIX C

### SYSTEMATIC PALEONTOLOGY

The species referred to in this section are presented according to the classification systems of Loeblich and Tappan (1988). Each synonymy is structured to include the original reference of the species and all references used in identification of the species. Species references are followed by a description and an occurrence section. The "occurrence" section includes the geologic occurrence of the species in the study area. The description contains the basic characters of each species. Following the occurrence section is a discussion of the taxa relevant to identification for this study.

Specimens in this study were compared, where applicable, to primary and secondary type specimens, as well as to figured and unfigured specimens, lodged in the Cushman Collection, National Museum of Natural History, Washington, D.C., and to figures from the type references (Ellis and Messina, 1940 et seq.).

Family CASSIDULINIDAE d'Orbigny, 1839  
Subfamily CASSIDULININAE d'Orbigny, 1839  
Genus Cassidulina d'Orbigny, 1826

Cassidulina subglobosa Brady, 1884

Appendix A, figures 1, 2

Cassidulina subglobosa BRADY, 1884 p. 430, pl. 54, figs.

17a-c.

CUSHMAN, 1929, p. 100, pl. 14,  
figs. 11a,b.

GALLOWAY AND MORREY, 1929 p. 40,  
pl. 6, fig. 6.

Description : Test subglobular, very slightly compressed laterally, with four to six chambers in final whorl, test enrolled; chambers biserially arranged; wall finely perforate, optically granular; sutures slightly depressed, aperture an oblique or nearly vertical loop-like slit. Length range : .10-.25 millimeters.

Occurrence : Open marine in the Gulf of Mexico, present in all well samples except 3060' and 3120'.

Discussion : The genus Cassidulina is similar in appearance to the genus Islandiella. However, Cassidulina is optically granular, whereas Islandiella is optically radial and has no internal tooth. Cassidulina is very similar to Globocassidulina, as Cassidulina has an apertural plate, which is similar in appearance to the cristate tooth of Globocassidulina (Nomura, 1983).

Family BULIMINELLIDAE    Hofker, 1951  
Subfamily UVIGERININAE    Haekel, 1894  
Genus Uvigerina    d'Orbigny, 1826

Uvigerina peregrina    Cushman, 1923

Appendix A, figures 3, 4

Uvigerina pygmaea, FLINT, 1899, p. 320, pl. 68, fig.2.

Uvigerina peregrina, CUSHMAN, 1923, p. 166, pl. 42, figs.7-10.

Description : Test elongate, one and a half to two and  
a half times as long as broad, chambers  
are inflated and triserially arranged;  
distinct, depressed sutures; wall calcareous,  
perforate, ornamented with longitudinal costae  
or striae, aperture terminal and circular,  
located at the end of a neck, with a phialine  
lip and hemicylindrical toothplate. Length  
range : .20-.50 millimeters.

Occurrence : Open marine in the Gulf of Mexico, present in all  
well samples.

Discussion : The species Uvigerina peregrina has been called U. pygmaea. The latter species, however, has not been identified above the Pliocene (Boersma, 1984). As used in this study, U. peregrina is costate on all chambers, with occasional hisps or spines in the intercostal spaces.

APPENDIX D  
ABUNDANCE DATA FOR  
PLEISTOCENE SAMPLES  
- NUMBER OF BENTHIC SPECIMENS  
PER SAMPLE.



Species\Sample	1560	1950	2100	2430	2520	2550	2640	2760	2790	2820	2850	2880
<i>Ammonia beccarii</i>	7	3	1	1	4	3	1	0	1	2	0	1
<i>Bolivina albatrossi</i>	0	0	0	0	4	2	4	4	12	5	8	4
<i>Bolivina barbata</i>	1	3	3	0	1	3	1	0	5	2	0	1
<i>Bolivina fragilis</i>	1	0	0	0	0	0	1	0	8	1	4	0
<i>Bolivina goesii</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bolivina hastata</i>	0	0	0	1	0	0	0	0	0	0	0	0
<i>Bolivina lowmani</i>	1	0	0	0	0	0	0	2	1	0	4	0
<i>Bolivina minima</i>	2	0	1	1	1	0	0	6	20	10	2	8
<i>Bolivina ordinaria</i>	0	0	0	0	1	3	0	2	6	5	4	1
<i>Bolivina pulchella</i>	2	0	0	0	1	1	0	1	2	0	1	1
<i>Bolivina striatula spinata</i>	0	0	0	0	0	0	0	1	0	1	2	1
<i>Bolivina subaenariensis mexicana</i>	27	16	24	11	10	24	14	11	23	23	13	29
<i>Bolivina subspinescens</i>	0	2	0	3	1	2	2	0	2	0	1	0
<i>Bolivina translucens</i>	0	0	0	0	0	0	2	0	0	10	0	4
<i>Bulimina aculeata</i>	0	0	0	3	9	0	0	5	2	3	3	0
<i>Bulimina affinis</i>	0	0	0	0	0	0	1	0	0	0	0	0
<i>Bulimina alazanensis</i>	0	0	0	0	2	2	0	0	0	0	0	0
<i>Bulimina inflata mexicana</i>	0	0	0	0	0	0	3	2	0	0	0	0
<i>Bulimina marginata</i>	40	10	22	11	8	9	14	14	10	15	16	14
<i>Bulimina ovata</i>	0	0	0	1	0	0	0	0	0	0	0	0
<i>Bulimina spicata</i>	0	0	1	0	0	4	7	0	4	1	0	9
<i>Bulimina tenuis</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bulimina striata mexicana</i>	0	0	1	0	0	0	0	0	1	3	0	1
<i>Buliminella bassendorfensis</i>	5	0	0	0	0	0	0	0	0	0	0	1
<i>Cancris oblonga</i>	0	0	0	1	0	4	0	0	0	0	0	0
<i>Cassidulina crassa</i>	1	0	0	0	12	0	0	6	3	0	2	5
<i>Cassidulina curvata</i>	0	0	0	2	1	2	2	2	9	3	2	6
<i>Cassidulina laevigata</i>	0	0	0	3	5	12	5	1	7	3	11	3
<i>Cassidulina subglobosa</i>	2	3	8	14	14	6	3	11	7	6	4	1
<i>Cassidulinoides tenuis</i>	0	0	0	0	0	0	0	0	0	0	1	0
<i>Cibicides io</i>	0	1	0	0	3	0	1	0	0	0	1	0
<i>Cibicides mollis</i>	0	2	2	0	0	3	0	0	3	0	0	0
<i>Cibicides pachyderma</i>	4	50	16	40	28	52	57	34	24	18	11	11
<i>Cibicides robertsonianus</i>	1	0	0	3	3	3	0	0	0	0	7	0
<i>Cibicides robustus</i>	0	0	0	0	0	2	0	0	0	0	0	1
<i>Cibicides umbonatus</i>	0	0	0	0	2	3	2	10	4	0	4	8
<i>Cibicides sp. A</i>	0	0	2	1	9	1	0	1	5	2	2	1
<i>Criboilenticulina akersi</i>	1	3	2	2	7	2	3	5	1	0	0	0
<i>Discorbis floridana</i>	0	0	0	0	0	1	0	0	0	0	0	0
<i>Dentalina sp.</i>	0	0	0	0	0	0	0	8	4	4	2	6
<i>Elphidium delicatulum</i>	0	0	0	0	0	1	0	0	0	0	1	0
<i>Elphidium discoidale</i>	67	43	30	11	14	11	14	2	3	2	5	2
<i>Elphidium excavatum</i>	1	0	0	0	0	0	0	0	0	2	0	0
<i>Elphidium fimbriatum</i>	0	1	2	0	0	0	0	0	0	0	0	0
<i>Elphidium galvestonense</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium gunteri</i>	0	1	0	0	1	3	0	8	0	0	0	0
<i>Elphidium incertum</i>	0	0	0	0	0	0	0	0	0	0	4	0
<i>Elphidium koeboeense</i>	1	0	0	0	0	0	0	0	0	0	0	0
<i>Epistominella decorata</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Epistominella exigua</i>	4	0	0	0	1	0	0	1	1	0	0	0
<i>Eponides hannai</i>	0	0	0	2	0	0	0	0	0	0	0	0
<i>Eponides regularis</i>	1	0	8	5	2	3	2	1	2	1	0	2
<i>Eponides tumidulus</i>	1	0	0	0	0	0	0	0	0	0	1	0
<i>Eponides turgidus</i>	0	0	1	0	0	0	0	0	1	0	4	0
<i>Fursenkoina compressa</i>	6	0	2	0	2	0	0	1	3	2	0	0
<i>Fursenkoina loeblichii</i>	1	0	0	0	0	0	0	0	0	0	0	0

Species\Sample	2910	2940	2970	3000	3030	3060	3120	3150	3180	3210	3240	3270
<i>Ammonia beccarii</i>	0	0	0	1	0	1	0	2	0	0	1	1
<i>Bolivina albatrossi</i>	6	4	3	6	10	10	6	7	7	3	1	2
<i>Bolivina barbata</i>	0	1	2	2	1	0	0	0	1	1	2	1
<i>Bolivina fragilis</i>	0	0	0	6	0	0	0	1	1	4	0	10
<i>Bolivina goesii</i>	0	0	0	0	0	0	0	0	0	1	0	0
<i>Bolivina hastata</i>	5	3	0	0	1	1	0	0	0	0	6	1
<i>Bolivina lowmani</i>	2	0	1	2	0	0	0	1	1	0	1	2
<i>Bolivina minima</i>	10	1	19	9	12	5	7	7	12	6	6	9
<i>Bolivina ordinaria</i>	1	0	5	5	1	1	0	4	4	1	4	4
<i>Bolivina pulchella</i>	1	0	0	0	0	0	0	0	0	0	0	2
<i>Bolivina striatula spinata</i>	1	0	0	1	0	0	0	0	0	0	0	0
<i>Bolivina subaenariensis mexicana</i>	23	9	49	21	18	15	21	11	32	47	37	49
<i>Bolivina subspinescens</i>	0	0	0	2	2	0	1	0	1	0	0	0
<i>Bolivina translucens</i>	0	0	6	5	1	2	0	3	14	0	0	1
<i>Bulimina aculeata</i>	0	3	0	1	0	0	0	2	0	0	1	2
<i>Bulimina affinis</i>	0	0	0	0	0	0	0	0	0	0	0	2
<i>Bulimina alazanensis</i>	0	1	0	0	0	0	0	0	0	0	0	0
<i>Bulimina inflata mexicana</i>	2	0	1	3	3	2	4	0	0	0	0	2
<i>Bulimina marginata</i>	5	10	15	13	10	1	13	7	6	32	13	10
<i>Bulimina ovata</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Bulimina spicata</i>	7	2	0	2	2	0	0	2	0	1	0	0
<i>Bulimina tenuis</i>	0	0	0	0	1	0	0	0	0	0	0	0
<i>Bulimina striata mexicana</i>	2	4	0	0	0	0	0	2	0	0	1	2
<i>Buliminella bassendorffensis</i>	0	0	0	0	0	0	0	0	0	1	0	0
<i>Cancris oblonga</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cassidulina crassa</i>	5	0	7	18	1	1	2	3	6	3	5	0
<i>Cassidulina curvata</i>	12	9	3	3	2	4	1	0	0	1	0	1
<i>Cassidulina laevigata</i>	5	4	8	7	7	5	7	9	4	14	3	10
<i>Cassidulina subglobosa</i>	3	3	6	11	1	0	0	3	3	2	2	8
<i>Cassidulinoides tenuis</i>	0	0	0	0	0	0	1	0	0	0	0	0
<i>Cibicides io</i>	0	0	0	0	0	0	1	0	0	0	0	0
<i>Cibicides mollis</i>	0	1	0	0	0	0	0	1	4	2	0	0
<i>Cibicides pachyderma</i>	19	22	16	5	16	12	8	6	10	18	18	2
<i>Cibicides robertsonianus</i>	0	2	0	0	0	1	0	0	0	0	0	5
<i>Cibicides robustus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Cibicides umbonatus</i>	2	1	5	0	1	9	5	0	1	3	2	0
<i>Cibicides sp. A</i>	3	1	1	6	0	0	3	0	1	2	0	0
<i>Criboilenticulina akersii</i>	0	1	0	0	0	1	1	0	0	2	1	0
<i>Discorbis floridana</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Dentalina sp.</i>	2	2	1	0	4	4	4	6	3	2	3	0
<i>Elphidium delicatulum</i>	0	0	0	1	0	0	0	0	0	0	0	0
<i>Elphidium discoidale</i>	7	0	4	5	0	2	2	0	0	2	1	12
<i>Elphidium excavatum</i>	1	1	0	0	0	0	0	0	0	0	0	0
<i>Elphidium fimbriatulum</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Elphidium galvestonense</i>	0	1	0	0	0	0	0	0	0	0	0	0
<i>Elphidium gunteri</i>	0	0	0	3	2	2	0	2	0	1	3	1
<i>Elphidium incertum</i>	0	1	0	0	0	0	0	1	0	1	0	0
<i>Elphidium koeboeense</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Epistominella decorata</i>	0	0	0	1	0	0	0	0	0	0	2	0
<i>Epistominella exigua</i>	2	0	1	3	0	0	0	1	0	1	1	0
<i>Eponides hannai</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Eponides regularis</i>	2	2	0	0	1	0	0	2	2	1	4	8
<i>Eponides tumidulus</i>	0	1	0	0	0	0	0	0	0	0	0	0
<i>Eponides turgidus</i>	0	0	0	0	0	0	0	0	0	0	0	0
<i>Fursenkoina compressa</i>	0	1	3	6	0	3	3	2	3	5	4	5
<i>Fursenkoina loeblichii</i>	2	0	0	1	0	0	0	0	0	2	1	5

Species\Sample	1560	1950	2100	2430	2520	2550	2640	2760	2790	2820	2850	2880
Fursenkoina squamosa	2	1	0	0	0	3	3	0	0	5	0	5
Globobulimina affinis	0	0	0	0	0	0	0	0	0	0	0	0
Globobulimina pyrula spinescens	0	0	0	0	2	0	0	0	0	0	0	0
Globocassidulina globosa	0	0	0	0	0	0	0	0	0	1	0	0
Guttulina spicaeformis	0	0	1	0	0	0	0	0	0	0	0	0
Gyroidina neosoldanii	0	0	0	0	0	0	2	0	0	0	0	0
Gyroidina orbicularis	0	0	0	0	0	0	2	0	0	0	0	0
Hanzawaia concentrica	10	4	1	7	3	4	3	5	0	5	0	2
Hanzawaia strattoni	15	45	19	3	12	13	8	7	2	0	0	4
Hoeglundina elegans	0	0	0	0	0	0	0	0	0	0	0	0
Hyalinea baltica	0	0	0	0	0	0	0	0	2	0	0	0
Islandiella norcrossi	13	2	7	2	2	1	1	3	2	1	2	3
Lagena clavata	0	0	0	0	0	0	0	0	0	0	1	0
Lagena gracilis	0	0	0	0	0	0	0	0	0	0	0	0
Lenticulina aculeata	0	0	0	0	0	0	0	1	0	1	1	1
Lenticulina orbicularis	0	0	0	0	0	0	2	0	0	0	0	0
Lenticulina peregrina	1	0	0	0	0	0	0	0	0	0	0	0
Lenticulina rotulata	2	6	3	0	5	0	8	4	3	0	1	0
Lenticulina sp. A	0	0	0	0	0	0	0	1	0	0	1	0
Marginulina planata	0	0	0	0	2	0	0	1	0	0	0	0
Marginulinopsis subaculeata glabrata	0	0	0	0	1	0	0	0	0	0	0	0
Martinottiella communis	0	0	0	0	1	0	0	0	0	0	0	0
Melonis barleeanus	1	0	0	0	0	0	0	0	0	0	0	0
Nodosaria comatula	0	0	0	0	0	0	0	0	0	0	0	0
Nonionella atlantica	14	2	11	4	5	2	4	1	4	0	5	0
Nonionella grateolupi	0	0	0	0	0	0	0	0	0	1	0	0
Nonionella opima	0	0	0	0	0	2	0	0	0	0	0	0
Oolina longispina	0	0	0	0	0	0	0	0	0	0	0	0
Oridorsalis umbonatus	0	3	0	0	4	1	0	2	2	1	3	5
Planulina ariminensis	8	3	2	7	2	8	5	0	0	3	0	1
Planulina exorna	0	1	0	0	0	0	0	4	2	2	3	4
Planulina foveolata	0	0	0	0	0	0	6	7	3	0	4	1
Pseudoclavina mexicana	0	0	0	0	1	0	0	0	0	0	0	1
Pullenia bulloides	0	0	0	0	0	1	0	0	0	0	1	0
Pullenia quinqueloba	0	0	0	0	1	0	0	0	0	2	0	0
Pyrgo murrhina	0	0	2	0	0	0	0	0	0	0	0	0
Pyrgo nasuta	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina bicostata	0	0	0	4	2	3	6	1	0	0	2	1
Quinqueloculina compta	0	0	2	0	5	1	0	1	0	1	4	0
Quinqueloculina horrida	0	4	1	0	2	0	0	1	1	1	1	0
Quinqueloculina lamarckiana	0	0	1	0	0	0	0	0	0	0	0	1
Quinqueloculina poeyana	0	0	1	0	0	0	0	0	0	0	0	0
Quinqueloculina seminula	0	0	0	1	1	0	0	1	0	0	2	0
Quinqueloculina sp. A	2	2	0	5	0	0	0	0	0	1	0	0
Rectobolivina advena	7	0	2	2	3	1	0	0	1	2	1	0
Reussella atlantica	12	2	2	2	3	6	0	0	2	2	2	2
Saracenaria mexicana	0	0	0	0	0	0	1	0	0	0	0	0
Sigmoilina distorta	0	0	0	0	0	0	0	0	0	0	5	5
Siphonina bradyana	0	2	2	0	1	0	8	1	0	0	0	0
Siphonina pulchra	0	0	0	0	0	0	0	1	0	0	0	0
Textularia candeiana	0	0	0	0	0	0	0	0	0	0	0	0
Textularia parvula	0	0	0	0	0	0	1	0	0	0	0	0
Textularia sp. A	0	0	0	0	0	0	0	0	0	0	0	0
Trifarina bella	5	1	1	10	1	5	1	0	2	0	3	1
Trifarina bradyi	0	0	0	2	0	0	2	0	0	0	1	1
Uvigerina auferiana	1	2	4	13	4	7	2	9	14	10	8	8
Uvigerina peregrina	11	19	22	26	27	31	28	25	28	13	21	33
Uvigerina parvula	0	0	0	0	0	0	0	0	0	0	1	3
total per sample	272	238	211	228	239	251	234	215	244	174	190	206

Species\Sample	2910	2940	2970	3000	3030	3060	3120	3150	3180	3210	3240	3270
Fursenkoina squamosa	1	0	0	0	1	0	0	0	1	0	3	6
Globobulimina affinis	1	0	2	0	0	0	0	0	0	0	2	0
Globobulimina pyrula spinescens	0	0	0	0	0	0	0	0	0	0	0	0
Globocassidulina globosa	0	4	1	1	0	0	0	2	0	0	0	0
Guttulina spicaeformis	0	0	0	0	0	0	0	0	0	0	0	0
Gyroidina neosoldanii	0	0	0	0	0	0	0	0	0	0	0	0
Gyroidina orbicularis	0	0	0	0	0	0	0	0	0	0	0	0
Hanzawaia concentrica	1	2	1	1	1	3	0	1	0	2	0	2
Hanzawaia strattoni	3	5	2	2	3	1	3	1	1	0	2	4
Hoeglundina elegans	0	1	0	1	0	0	0	0	0	0	1	0
Hyalinea baltica	0	1	0	0	0	0	0	1	0	0	0	0
Islandiella norcrossi	2	0	5	3	2	1	2	0	0	1	3	0
Lagenia clavata	0	0	0	0	0	0	0	0	0	0	0	0
Lagenia gracilis	0	0	0	0	0	1	0	0	0	0	0	0
Lenticulina aculeata	0	0	0	0	0	0	0	0	0	0	0	0
Lenticulina orbicularis	0	0	0	0	1	1	0	0	0	0	2	0
Lenticulina peregrina	0	0	0	0	0	0	0	0	0	0	0	0
Lenticulina rotulata	0	2	2	1	0	3	2	0	0	3	0	0
Lenticulina sp. A	0	0	0	0	0	0	0	0	0	0	0	0
Marginulina planata	0	0	0	0	0	0	0	0	0	0	0	0
Marginulinopsis subaculeata glabrata	0	0	0	0	0	0	0	0	0	0	0	0
Martinottiella communis	0	0	0	0	0	0	0	0	0	0	0	0
Melonis barleanus	0	0	0	0	0	0	0	0	0	0	0	0
Nodosaria comatula	0	0	0	0	1	0	0	0	0	0	0	0
Nonionella atlantica	0	1	3	2	3	2	1	4	2	1	6	4
Nonionella grateloupi	1	0	0	0	0	0	0	0	0	0	0	0
Nonionella opima	0	0	0	0	0	0	2	0	0	0	0	0
Oolina longispina	0	0	0	0	1	0	0	0	0	0	0	0
Oridorsalis umbonatus	1	1	1	0	2	3	2	3	1	1	3	1
Planulina ariminensis	0	1	2	5	1	4	0	2	2	3	2	2
Planulina exorna	4	0	8	0	0	3	3	1	0	0	0	0
Planulina foveolata	2	1	0	0	1	0	0	0	0	0	0	0
Pseudoclavina mexicana	0	0	0	1	0	2	0	0	0	0	0	0
Pullenia bulloides	0	0	0	1	0	2	0	0	0	0	0	0
Pullenia quinqueloba	0	0	1	0	0	0	0	0	0	0	0	0
Pyrgo murrhina	0	0	1	1	1	1	1	0	0	0	0	0
Pyrgo nasuta	0	0	1	0	0	0	0	0	0	0	0	0
Quinqueloculina bicostata	0	0	1	2	0	1	0	0	0	1	0	2
Quinqueloculina compta	0	1	4	0	0	2	0	1	0	0	1	0
Quinqueloculina horrida	0	1	4	1	2	0	0	1	0	0	0	0
Quinqueloculina lamarckiana	0	0	0	0	0	0	1	1	0	0	0	0
Quinqueloculina poeyana	0	0	0	0	0	0	0	0	0	0	0	0
Quinqueloculina seminula	1	0	3	0	0	0	0	0	0	0	0	2
Quinqueloculina sp. A	0	3	0	5	1	0	0	0	0	2	2	0
Rectobolivina advena	1	1	0	0	0	0	0	1	1	0	0	1
Reussella atlantica	1	0	0	1	1	1	1	0	0	0	0	2
Saracenaria mexicana	0	0	0	0	0	0	0	0	0	0	0	0
Sigmoilina distorta	0	0	0	0	0	2	0	0	0	0	0	0
Siphonina bradyana	2	0	0	0	0	0	0	2	1	0	0	0
Siphonina pulchra	0	0	0	0	0	0	0	0	0	0	0	0
Textularia candeiana	0	0	0	0	0	1	0	0	0	0	0	0
Textularia parvula	0	0	0	0	0	0	0	0	0	0	0	0
Textularia sp. A	0	0	0	0	0	0	0	0	0	1	0	0
Trifarina bella	1	0	1	8	0	1	2	1	2	0	0	0
Trifarina bradyi	0	1	0	1	0	0	0	1	0	1	0	0
Uvigerina auberiana	16	22	18	25	31	28	47	61	69	32	42	30
Uvigerina peregrina	31	19	28	18	20	24	21	14	33	19	37	19
Uvigerina parvula	2	1	0	0	0	0	0	0	0	1	0	0
total per sample	202	158	244	229	170	168	179	186	235	204	229	233

APPENDIX E  
ABUNDANCE DATA FOR  
PLEISTOCENE SAMPLES  
- PERCENT OF BENTHIC SPECIMENS  
PER SAMPLE.



Species\Sample	1560	1950	2100	2430	2520	2550	2640	2760	2790	2820	2850	2880
<i>Ammonia beccarii</i>	2.6	1.3	0.5	0.4	1.7	1.2	0.4		0.4	1.1		0.5
<i>Bolivina albatrossi</i>					1.7	0.8	1.7	1.9	4.9	2.9	4.2	1.9
<i>Bolivina barbata</i>	0.4	1.3	1.4		0.4	1.2	0.4		2	1.1		0.5
<i>Bolivina fragilis</i>	0.4						0.4		3.3	0.6	2.1	
<i>Bolivina goesii</i>												
<i>Bolivina hastata</i>				0.4								
<i>Bolivina lowmani</i>	0.4							0.9	0.4		2.1	
<i>Bolivina minima</i>	0.7		0.5	0.4	0.4			2.8	8.2	5.7	1.1	3.9
<i>Bolivina ordinaria</i>					0.4	1.2		0.9	2.5	2.9	2.1	0.5
<i>Bolivina pulchella</i>	0.7				0.4	0.4		0.5	0.8		0.5	0.5
<i>Bolivina striatula spinata</i>								0.5		0.6	1.1	
<i>Bolivina subaenariensis mexicana</i>	9.9	6.7	11	4.8	4.2	9.6	6	5.1	9.4	13	6.8	14
<i>Bolivina subspinescens</i>		0.8		1.3	0.4	0.8	0.9		0.8		0.5	
<i>Bolivina translucens</i>							0.9			5.7		1.9
<i>Bulimina aculeata</i>				1.3	3.8			2.3	0.8	1.7	1.6	
<i>Bulimina affinis</i>							0.4					
<i>Bulimina alazanensis</i>					0.8	0.8						
<i>Bulimina inflata mexicana</i>							1.3	0.9				
<i>Bulimina marginata</i>	15	4.2	10	4.8	3.3	3.6	6	6.5	4.1	8.6	8.4	6.8
<i>Bulimina ovata</i>				0.4								
<i>Bulimina spicata</i>			0.5			1.6	3		1.6	0.6		4.4
<i>Bulimina tenuis</i>												
<i>Bulimina striata mexicana</i>			0.5						0.4	1		0.5
<i>Buliminella bassendorffensis</i>	1.8											0.5
<i>Cancris oblonga</i>				0.4		1.6						
<i>Cassidulina crassa</i>	0.4				5			2.8	1.2		1.1	2.4
<i>Cassidulina curvata</i>				0.9	0.4	0.8	0.9	0.9	3.7	1.7	1.1	2.9
<i>Cassidulina laevigata</i>				1.3	2.1	4.8	2.1	0.5	2.9	1.7	5.8	1.5
<i>Cassidulina subglobosa</i>	0.7	1.3	3.8	6.1	5.9	2.4	1.3	5.1	2.9	3.4	2.1	0.5
<i>Cassidulinoides tenuis</i>											0.5	
<i>Cibicides io</i>		0.4			1.3		0.4				0.5	
<i>Cibicides mollis</i>		0.8	0.9			1.2			1.2			
<i>Cibicides pachyderma</i>	1.5	21	7.6	18	12	21	24	16	9.8	10	5.8	5.3
<i>Cibicides robertsonianus</i>	0.4			1.3	1.3	1.2					3.7	
<i>Cibicides robustus</i>						0.8						0.5
<i>Cibicides umbonatus</i>					0.8	1.2	0.9	4.7	1.6		2.1	3.9
<i>Cibicides sp. A</i>			0.9	0.4	3.8	0.4		0.5	2.1	1.1	1.1	0.5
<i>Cribrolenticulina akersi</i>	0.4	1.3	0.9	0.9	2.9	0.8	1.3	2.3	0.4			
<i>Discorbis floridana</i>						0.4						
<i>Dentalina sp.</i>								3.7	1.6	2.3	1.1	2.9
<i>Elphidium delicatulum</i>						0.4					0.5	
<i>Elphidium discoidale</i>	25	18	14	4.8	5.9	4.4	6	0.9	1.2	1.1	2.6	1
<i>Elphidium excavatum</i>	0.4									1.1		
<i>Elphidium fimbriatulum</i>		0.4	0.9									
<i>Elphidium galvestonense</i>												
<i>Elphidium gunteri</i>		0.4			0.4	1.2		3.7				
<i>Elphidium incertum</i>											2.1	
<i>Elphidium koeboeense</i>	0.4											
<i>Epistominella decorata</i>												
<i>Epistominella exigua</i>	1.5				0.4			0.5	0.4			
<i>Eponides hannai</i>				0.9								
<i>Eponides regularis</i>	0.4		3.8	2.2	0.8	1.2	0.9	0.5	0.8	1.2		1
<i>Eponides tumidulus</i>	0.4										0.5	
<i>Eponides turgidus</i>			0.5						0.4		2.1	
<i>Fursenkoina compressa</i>	2.4		0.9		0.8			0.5	1.2	1.1		
<i>Fursenkoina loeblichii</i>	0.4											

Species\Sample	2910	2940	2970	3000	3030	3060	3120	3150	3180	3210	3240	3270
Ammonia beccarii				0.4		0.6		0.5			0.4	0.4
Bolivina albatrossi	3	2.5	1.2	2.6	5.9	6	3.4	3.8	3	1.5	1.4	0.9
Bolivina barbata		0.6	0.8	0.9	0.6				0.4	0.5	0.9	0.4
Bolivina fragilis				2.6				0.5	0.4	2		4.3
Bolivina goesii										0.5		
Bolivina hastata	2.5	1.9			0.6	0.6					2.6	0.4
Bolivina lowmani	1		0.4	0.9				0.5	0.4		0.4	0.9
Bolivina minima	5	0.6	7.8	3.9	7.1	3	3.9	3.8	5.1	2.9	2.6	3.9
Bolivina ordinaria	0.5		2	2.2	0.6	0.6		2.2	1.7	0.5	1.7	1.7
Bolivina pulchella	0.5											0.9
Bolivina striatula spinata				0.4								
Bolivina subaenariensis mexicana	11	5.7	20	9.2	11	8.9	12	5.9	14	23	16	21
Bolivina subspinescens				0.9	1.2		0.6		0.4			
Bolivina translucens			2.5	2.2	0.6	1.2		1.6	6			0.4
Bulimina aculeata		1.9		0.4				1.1			0.4	0.9
Bulimina affinis												0.9
Bulimina alazanensis		0.6										
Bulimina inflata mexicana	1		0.4	1.3	1.8	1.2	2.2					0.9
Bulimina marginata	2.5	6.3	6.1	5.7	5.9	0.6	7.3	3.8	2.6	16	5.7	4.3
Bulimina ovata												
Bulimina spicata	3.5	1.3		0.9	1.2			1.1		0.5		
Bulimina tenuis					0.6							
Bulimina striata mexicana	1	2.5						1.1			0.4	0.9
Buliminella bassendorffensis										0.5		
Cancris oblonga												
Cassidulina crassa	2.5		2.9	7.9	0.6	0.6	1.1	1.6	2.6	1.5	2.2	
Cassidulina curvata	5.9	5.7	1.2	1.3	1.2	2.4				0.5		0.4
Cassidulina laevigata	2.5	2.5	3.3	3.1	4.1	3	3.9	4.8	1.7	6.9	1.3	4.3
Cassidulina subglobosa	1.5	1.9	2.5	4.8	0.6			1.6	1.3	1	0.9	3.4
Cassidulinoides tenuis							0.6					
Cibicides io							0.6					
Cibicides mollis		0.6						0.5	1.7	1		
Cibicides pachyderma	9.4	14	6.6	2.2	9.4	7.1	4.5	3.2	4.3	8.8	7.9	0.9
Cibicides robertsonianus		1.3				0.6						2.1
Cibicides robustus												
Cibicides umbonatus	1	0.6	2		0.6	5.4	2.8		0.4	1.5	0.9	
Cibicides sp. A	1.5	0.6	0.4	2.6			1.7		0.4	1		
Cribrolenticulina akersi		0.6				0.6	0.6			1	0.4	
Discorbis floridana												
Dentalina sp.	1	1.3	0.4		2.4	2.4	2.2	3.2	1.3	1	1.3	
Elphidium delicatulum				0.4								
Elphidium discoidale	3.5		1.6	2.2		1.2	1.1			1	0.4	5.1
Elphidium excavatum	0.5	0.6										
Elphidium fimbriatulum												
Elphidium galvestonense		0.6										
Elphidium gunteri				1.3	1.2	1.2		1.1		0.5	1.3	0.4
Elphidium incertum		0.6						0.5		0.5		
Elphidium koeboeense												
Epistominella decorata				0.4							0.9	
Epistominella exigua	1		0.4	1.3				0.5		0.5	0.4	
Eponides hannai												
Eponides regularis	1	1.3			0.6			1.1	0.9	0.5	1.7	3.4
Eponides tumidulus		0.6										
Eponides turgidus												
Fursenkoina compressa		0.6	1.2	2.6		1.8	1.7	1.1	1.3	2.5	1.7	2.1
Fursenkoina loeblichii	1			0.4						1	0.4	2.1

Species\Sample	1560	1950	2100	2430	2520	2550	2640	2760	2790	2820	2850	2880
Fursenkoina squamosa	0.7	0.4				1.2	1.3			2.9		2.4
Globobulimina affinis												
Globobulimina pyrula spinescens					0.8							
Globocassidulina globosa										0.6		
Guttulina spicaeformis			0.5									
Gyroidina neosoldanii							0.9					
Gyroidina orbicularis							0.9					
Hanzawaia concentrica	3.7	1.7	0.5	3.1	1.3	1.6	1.3	2.3		2.9		1
Hanzawaia strattoni	5.5	19	9	1.3	5	5.2	3.4	3.3	0.8			1.9
Hoeglundina elegans												
Hyalinea baltica									0.8			
Islandiella norcrossi	4.8	0.8	3.3	0.9	0.8	0.4	0.4	1.4	0.8	0.6	1.1	1.5
Lagena clavata											0.5	
Lagena gracilis												
Lenticulina aculeata								0.5		0.6	0.5	0.5
Lenticulina orbicularis							0.9					
Lenticulina peregrina	0.4											
Lenticulina rotulata	0.7	2.5	1.4		2.1		3.4	1.9	1.2		0.5	
Lenticulina sp. A								0.5			0.5	
Marginulina planata					0.8			0.5				
Marginulinopsis subaculeata glabrata					0.4							
Martinottiella communis					0.4							
Melonis barleeanus	0.4											
Nodosaria comatula												
Nonionella atlantica	5.1	0.8	5.2	1.8	2.1	0.8	1.7	0.5	1.6		2.6	
Nonionella grateloupi										0.6		
Nonionella opima						0.8						
Oolina longispina												
Oridorsalis umbonatus		1.3			1.7	0.4		0.9	0.8	0.6	1.6	2.4
Planulina ariminensis	2.9	1.3	0.9	3.1	0.8	3.2	2.1			1.7		0.5
Planulina exorna		0.4						1.9	0.8	1.1	1.6	1.9
Planulina foveolata							2.6	3.3	1.2		2.1	0.5
Pseudoclavina mexicana					0.4							0.5
Pullenia bulloides						0.4					0.5	
Pullenia quinqueloba					0.4					1.1		
Pyrgo murrhina			0.9									
Pyrgo nasuta												
Quinqueloculina bicostata				1.8	0.8	1.2	2.6	0.5			1.1	0.5
Quinqueloculina compta			0.9		2.1	0.4		0.5		0.6	2.5	
Quinqueloculina horrida		1.7	0.5		0.8			0.5	0.4	0.6	0.5	
Quinqueloculina lamarckiana			0.5									0.5
Quinqueloculina poeyana			0.5									
Quinqueloculina seminula				0.4	0.4			0.5			1.1	
Quinqueloculina sp. A	0.8	0.8		2.2						0.7		
Rectobolivina advena	2.6		0.9	0.9	1.3	0.4			0.4	1.1	0.5	
Reussella atlantica	4.4	0.8	0.9	0.9	1.3	2.4			0.8	1.1	1.1	1
Saracenaria mexicana							0.4					
Sigmolilina distorta											2.6	2.4
Siphonina bradyana		0.8	0.9		0.5		3.4	0.5				
Siphonina pulchra								0.5				
Textularia candeiana												
Textularia parvula							0.4					
Textularia sp. A												
Trifarina bella	1.8	0.4	0.5	4.4	0.4	2	0.4		0.8		1.6	0.5
Trifarina bradyi				0.9			0.9				0.5	0.5
Uvigerina auberiana	0.4	0.6	1.9	5.7	1.7	2.8	0.9	4.2	5.7	5.7	4.2	3.9
Uvigerina peregrina	4	6.9	8.1	9.6	9.9	11	10	9.2	12	7.5	11	16
Uvigerina parvula											0.5	1.5



Species\Sample	2910	2940	2970	3000	3030	3060	3120	3150	3180	3210	3240	3270
Fursenkoina squamosa	0.5				0.6				0.4		1.3	2.6
Globobulimina affinis	0.5		0.8								0.9	
Globobulimina pyrula spinescens												
Globocassidulina globosa		2.5	0.4	0.4				1.1				
Guttulina spicaeformis												
Gyroidina neosoldanii												
Gyroidina orbicularis												
Hanzawaia concentrica	0.5	1.3	0.4	0.4	0.6	1.8		0.5		1		0.9
Hanzawaia strattoni	1.5	3.2	0.8	0.9	1.8	0.6	1.7	0.5	0.4		0.9	1.7
Hoeglundina elegans		0.6		0.4							0.4	
Hyalinea baltica		0.6						0.5				
Islandiella norcrossi	1		2	1.3	1.2	0.6	1.1			0.5	1.3	
Lagena clavata												
Lagena gracilis						0.6						
Lenticulina aculeata												
Lenticulina orbicularis					0.6	0.6					0.9	
Lenticulina peregrina												
Lenticulina rotulata		1.3	0.8	0.4		1.8	1.1			1.5		
Lenticulina sp. A												
Marginulina planata												
Marginulinopsis subaculeata glabrata												
Martinottiella communis												
Melonis barleeanus												
Nodosaria comatula					0.6							
Nonionella atlantica		0.6	1.2	0.9	1.8	1.2	0.6	2.2	0.9	0.5	2.6	1.7
Nonionella grateloupi	0.5											
Nonionella opima							1.1					
Oolina longispina					0.6							
Oridorsalis umbonatus	0.5	0.6	0.4		1.2	1.8	1.1	1.6	0.4	0.5	1.3	0.4
Planulina ariminensis		0.6	0.8	2.2	0.6	2.4		1.1	0.9	1.5	0.9	0.9
Planulina exorna	2		3.3			1.8	1.7	0.5				
Planulina foveolata	1	0.6			0.6							
Pseudoclavina mexicana				0.4		1.2						
Pullenia bulloides				0.4		1.2						
Pullenia quinqueloba			0.4									
Pyrgo murrhina			0.4	0.4	0.6	0.6	0.6					
Pyrgo nasuta			0.4									
Quinqueloculina bicostata			0.4	0.9		0.6				0.5		0.9
Quinqueloculina compta		0.6	1.6			1.2		0.5			0.4	
Quinqueloculina horrida		0.6	1.6	0.4	1.2			0.5				
Quinqueloculina lamarckiana							0.6	0.5				
Quinqueloculina poeyana												
Quinqueloculina seminula	0.5		1.2									0.9
Quinqueloculina sp. A		1.9		2.2	0.6					1	0.7	
Rectobolivina advena	0.5	0.6						0.5	0.4			0.4
Reussella atlantica	0.5			0.4	0.6	0.6	0.6					0.9
Saracenaria mexicana												
Sigmoilina distorta						1.2						
Siphonina bradyana	1							1.1	0.4			
Siphonina pulchra												
Textularia candeiana						0.6						
Textularia parvula												
Textularia sp. A										0.5		
Trifarina bella	0.5		0.4	3.5		0.6	1.1	0.5	0.9			
Trifarina bradyi		0.5		0.6				0.5		0.5		
Uvigerina auberiana	7.9	14	7.4	11	18	17	26	33	29	16	18	13
Uvigerina peregrina	15	12	12	7.9	12	14	12	7.5	14	9.3	16	8.2
Uvigerina parvula	1	0.6								0.5		

APPENDIX F  
LITHOLOGY OF ALL PLEISTOCENE  
SAMPLE GROUPS/WELL DEPTHS

(gr=gray color, gr-b=gray to brown color,  
b=brown color, sa-sr=subangular to subrounded,  
sr=subrounded, vfs=very fine sand, fs=fine sand,  
cqz=clear quartz, c&Fe-qz=clear and iron stained quartz,  
ca=clay aggregates, lg-ca=large clay aggregates,  
↑ca=increased clay aggregates, o=opaques,  
↑o=increased opaques).

WELL DEPTH	LITHOLOGY
1560'	gr, sa-sr, vfs-clay, cqz, ca
1950'	gr, sa-sr, vfs-clay, cqz, ca
2100'	gr, sa-sr, vfs-clay, cqz, ca
2430'	gr, sa-sr, vfs-clay, c&Fe-qz, ca, o
2520'	gr, sa-sr, vfs-clay, c&Fe-qz, ca, o
2550'	gr, sa-sr, vfs-clay, c&Fe-qz, ca, o
2640'	gr, sa-sr, vfs-clay, c&Fe-qz, ca, †o
2760'	gr, sa-sr, vfs-clay, c&Fe-qz, ca, †o
2790'	gr-b, sr, vfs, c&Fe-qz, lg-ca, o
2820'	gr-b, sr, vfs, c&Fe-qz, lg-ca, o
2850'	gr-b, sr, fs-clay, cqz, ca, o
2880'	gr, sa-sr, fs-clay, c&Fe-qz
2910'	gr, sa-sr, fs-clay, c&Fe-qz
2940'	gr, sa-sr, fs-clay, c&Fe-qz
2970'	gr, sa-sr, vfs-clay, c&Fe-qz, ca
3000'	gr-b, sr, fs-clay, c&Fe-qz, †ca, †o
3030'	gr-b, sa-sr, fs-clay, c&Fe-qz, ca, o
3060'	gr-b, sa-sr, fs-clay, c&Fe-qz, †ca, †o
3120'	gr-b, sa-sr, fs-clay, c&Fe-qz, ca, o
3150'	gr-b, sa-sr, fs-clay, c&Fe-qz, †ca, o
3180'	gr-b, sa-sr, fs-clay, c&Fe-qz, ca, o
3210'	gr-b, sa-sr, vfs-clay, c&Fe-qz, ca, o
3240'	gr-b, sa-sr, vfs-clay, c&Fe-qz, †ca, o
3270'	b, sa-sr, fs-clay, c&Fe-qz, ca, o