TULANE STUDIES IN GEOLOGY AND PALEONTOLOGY

Volume 14, Number 1 June 1, 1978

DISTRIBUTION OF PLANKTONIC FORAMINIFERA IN SURFACE SEDIMENTS OF THE GULF OF MEXICO

SCOTT W. SNYDER
EAST CAROLINA UNIVERSITY
GREENVILLE, NORTH CAROLINA

CONTENTS

ILLUSTRATIONS

I. ABSTRACT

Distributional patterns of 40 individual species and subspecies of planktonic Foraminifera are plotted on the basis of relative abundance at each of 90 stations located throughout the Gulf of Mexico. All species are illustrated with scanning electron photomicrographs.

There is only a poor relationship between the areal distribution of most species and the distribution of temperature and salinity values in the overlying water mass. Only nine species exhibit moderate correlation to trends of temperature and salinity in near surface waters. This results from factors that obscure such relationships during the process of incorporation into the sediments. Important factors in the Gulf of Mexico include the effects of surface currents and the absolute abundance of the particular species in question. Differential resistance to solution and downslope displacement are of lesser importance.

The concept of using "ideal" or key species as paleoecological indicators is rejected because no single species fulfills all of the requirements: sensitivity to temperature and salinity changes, high resistance to solution, and great absolute abundance. Plotting ratios between species indicative of different ecological conditions only compounds the problem. Dealing with larger faunal elements, such as tropical vs. non-tropical species, produces the most accurate reflection of conditions in the overlying water mass.

The relative ages of sediments exposed on the floor of the Gulf of Mexico were determined through the use of commonly accepted planktonic foraminiferal criteria. Except for the extreme southwestern portions of the study area, micropaleontological interpretations agree closely with those from the seismic profiler studies used to compile the preliminary map of the Gulf.

II. INTRODUCTION

The sensitivity of living planktonic foraminiferal species to variations in ecologic factors is now generally recognized. Although widely distributed, species are limited in the extent of their areal occurrence by these variations. This principle has been applied, although in only a few instances, to analyzing distributional patterns within surface sediments of ocean basins. Such studies have dealt with areas of the Pacific, Indian, and Atlantic oceans, but no definitive work of this nature has been attempted in the Gulf of Mexico. This study is an effort to provide analysis of distributional patterns within surface sediments of this previously unstudied area.

Although it is well known that planktonic foraminiferal species in living populations exhibit limited areal distributions, the preciseness with which these distributions are reflected by patterns within surface sediments is not well understood. Kennett (1969) and Boltovskoy (1971) have discussed the problem and offer somewhat conflicting viewpoints. Although no analysis of the distribution of living planktonic Foraminifera has ever been conducted throughout the entire Gulf of Mexico, large volumes of data are available on the physical oceanography of the area. These data were supplied to this writer by the National Oceanographic Data Center. By comparing the distribution of values for various factors with distributional patterns of planktonic foraminiferal tests in surface sediments, a means of indirectly correlating the living assemblage with the underlying thanatocoenose is provided. The dependability and accuracy of ecologic interpretations based on such thanatocoenoses can also be evaluated.

In addition to using planktonic species in ecological investigations, this study incorporates their usefulness as stratigraphic indicators. The exposure of ancient sediments over areas of the Gulf floor is indicated by the presence of characteristic faunal assemblages. Relative age determinations made in this manner can be compared to those made by the seismic profiler studies used to construct the preliminary geologic map of the Gulf of Mexico (Wilhelm and Ewing, 1972).

III. ACKNOWLEDGMENTS

The author wishes to express his gratitude to several people who were most helpful and

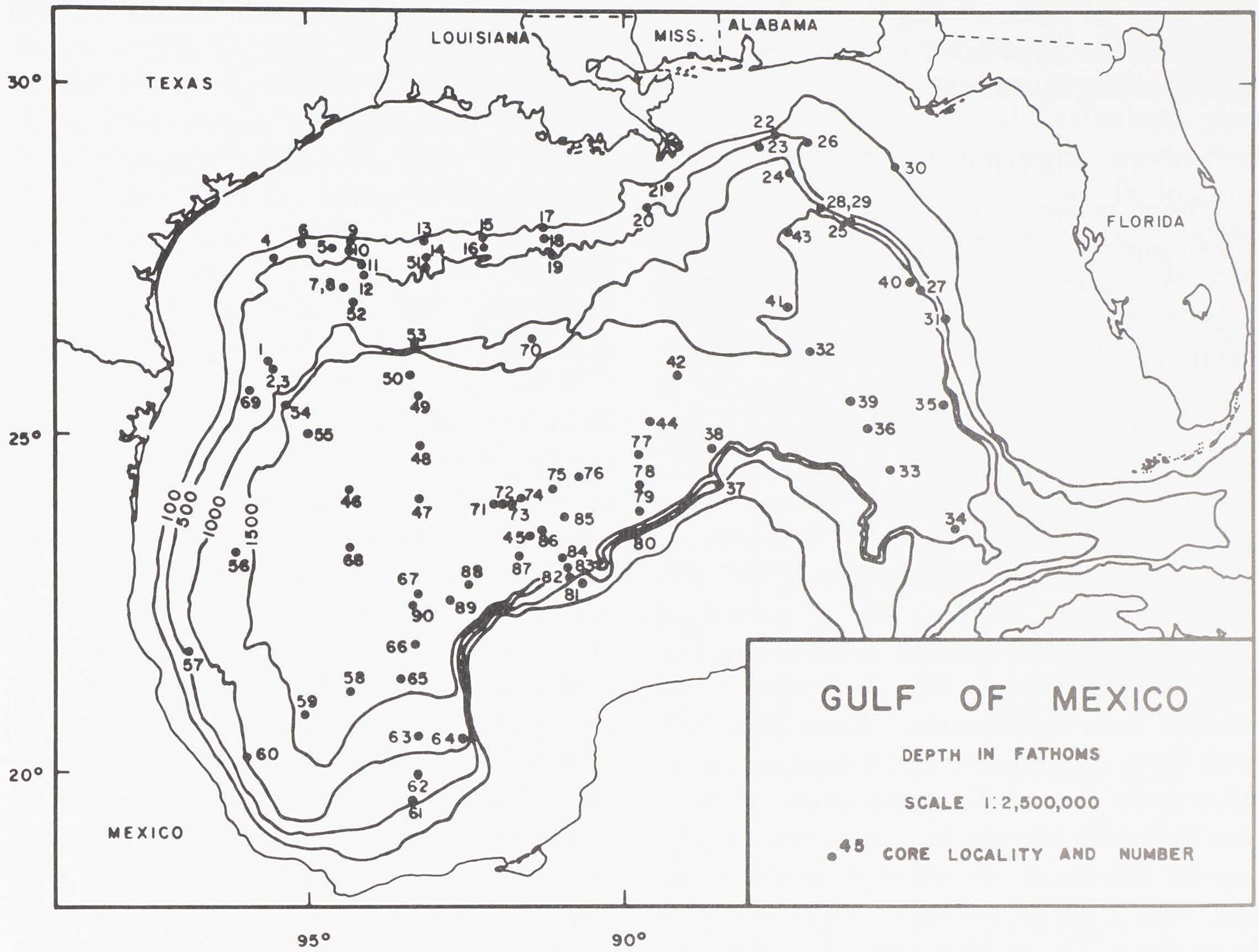

Figure 1. Index map (core locations and bathymetry).

instrumental in the completion of this project. Hubert C. Skinner has provided guidance and advice concerning numerous aspects of the project. W. H. Akers, of Chevron U S A , has assisted not only through discussions concerning taxonomy, but also by acting as an intermediary in securing the samples (from the Gulf of Mexico Slope Project) so kindly donated by Chevron. Herbert C. Eppert, Jr., of the U.S. Naval Oceanographic Office, supplied portions of all core materials recovered during Cruise 939014 of the USNS *Kane*. His time and effort in sampling those cores is greatly appreciated. The photographs presented here were taken with the Jelco scanning electron microscope (JSM-2) at Louisiana State University, Baton Rouge. The cooperation of Arthur Merkel, along with his instruction on the operation of the machine, made illustration with scanning electron photomicrographs possible. Part of the publication costs for this paper were provided by a grant from the Research Council of East Carolina University.

IV. SAMPLES

The samples utilized in this study were obtained from three independent sources. Materials recovered by the USNS *Kane* during Cruise 939014 were contributed by the U.S. Naval Oceanographic Office. Localities of these 39 samples are evenly dispersed throughout the Gulf of Mexico. Chevron Oil Company contributed materials from the continental slope area between eastern Texas and central Florida. These 31 samples were recovered through the joint effort of four major oil companies. Materials from a single traverse (64-A-9) of the RV *Alaminos*, operated by Texas A & M University, were available. These 20 samples are largely from the Sigsbee Deep but do include some material from the Campeche Slope. Coverage provided by combining samples from these three sources provides adequate control for the Gulf of Mexico (fig. 1). All samples represent the uppermost sediment recovered during coring operations.

V. METHOD OF STUDY

Those materials obtained from Chevron Oil Company (now Chevron USA) and Texas A & M University had been washed prior to receipt. Those from the U.S. Naval Oceanographic Office were washed in the following manner. Several grams of sediment, in most cases all that was available, were boiled in a dilute solution of Quaternary "O" (several drops of Quaternary "O" per 50 ml water). This product is a very active detergent that aids in disaggregating the clay sized particles. Boiling for a period of approximately 45 minutes produced sufficient deflocculation. Samples were then washed on a U.S. Standard Sieve (No. 200) with sieve openings of 0.074 mm; immature planktonic foraminiferal specimens of lesser size generally cannot be differentiated into species categories. In order to avoid breakage, only a gentle stream of water was used in washing. The residue trapped on the sieve was, in most cases, a nearly pure concentrate of planktonic foraminiferal tests.

Washed sample material was reduced to a workable size with a microsplitter. Samples were not split beyond the point that produces aliquots equalling 1/32 the original volume, as beyond this point rare specimens may be eliminated. The material was then placed in a rectangular plastic picking dish marked with a grid of systematically arranged divisions. For samples that still contained great numbers of specimens, a random sampling was obtained through the unbiased, *a priori* selection of particular divisions in the picking tray from which specimens were to be counted. Care was taken to examine and count every specimen in the randomly designated divisions.

This process was continued until 300 to 400 specimens had been examined. Chang (1967, p. 500-502) has charted the relationship of maximal variability in percentage estimation, expressed as maximized standard deviation, with the studied population number. Working at a confidence interval of 95.4%, a studied population number of 300 specimens yields an estimate that is within 5% of the actual percentage of the species involved. Increasing the population number studied to 1000 reduces the margin of error only to plus or minus 3%. Thus, only a minimal improvement in accuracy would be attained by increasing the count threefold. Examining 300 to 400 specimens yields reasonably accurate and consistent results.

After 300 to 400 specimens had been identified and counted, larger volumes of the sample were examined. This allowed the presence of very rare forms, which might have been missed, to be recorded. Seldom did such searching yield a species that had not already been encountered. The number of specimens within each species was recorded and computed as a percentage of the total planktonic foraminiferal assemblage.

Benthonic species were also counted and identified at each station. Depth ranges, as presented by Phleger (1951), were recorded for all species identified. The primary purpose of this procedure was to determine the presence or absence of faunal elements from shallower areas. In this manner the extent of mixing due to downslope movement, and hence the dependability of percentages computed, can be evaluated.

VI. PREVIOUS WORK

During recent years the ecological optima and limitations of living planktonic foraminiferal species have been extensively studied. Numerous studies dealing with their areal distribution indicate that temperature is a primary controlling factor. Effects of temperature are manifested through the latitudinal segregation of species. Recognizing the broad pattern of segregation, the earliest studies concerning distributional patterns of planktonic Foraminifera categorized species as warm-tolerant, cold-tolerant, or cosmopolitan. Of early publications, those by Bradshaw (1959) and Bé (1959, 1960) rank among the most important.

Throughout the 1960's and into the present decade many workers have studied distributional patterns in various geographic areas. As detailed knowledge of physical oceanography progressed so did the accuracy of estimates concerning ecological tolerances of planktonic foraminiferal species. Parameters other than temperature were measured and evaluated in terms of their controlling influence. Some of these factors, for example the concentration of inorganic nutrients, were found to influence total numbers of individuals, but temperature and salinity were established as the major limiting factors in the areal distribution of most species. Rather than describing species as merely warm-tolerant or cold-tolerant, precise optima were recorded for temperature (°C) and salinity (‰). Although estimates vary slightly from worker to worker, published data for most species are generally in close agreement (fig. 2). Among workers making contributions during this period, Bé and Cifelli, both publishing with various co-workers, and Boltovskoy have been the most active.

SPECIES	OPTIMUM TEMPERATURE RANGE (°C)	OPTIMUM SALINITY RANGE (‰)	OPTIMUM DEPTH RANGE (meters)	MAJOR FAUNAL GROUP	SOURCE
Globigerina					
bulloides	10-14	34-36	0-250	CT	1-6, 8-14
digitata	?	?	0-300	TR	2, 10
pachyderma	11-15	34.5-35	0-300	SP	1,2,4,6,8,10-14
quinqueloba	12-15	34.5-35	0-250	T	1,2,4,6,8-12,14
rubescens	?	?	0-250	ST	5,6,8-11
Globigerinella					
siphonifera	> 20	> 36	0-250	ST	1-6,8-11,13,14
Globigerinoides					
conglobatus	> 21	> 36	?	ST	1-4,6,8-11,13,14
elongatus	> 20	> 35.5	0-50	ST	4,9
quadrilobatus quadrilobatus	> 22	> 36	0-50	ST	4,5,7-9,13
quadrilobatus sacculifer	> 23	> 36	0-100	TR	1-11,13,14
ruber	> 20	> 35.5	0-50	ST	1-11,13,14
tenellus	?	?		?	5
Orbulina					
suturalis	?	?		ST	6,9
universa	> 18	> 36	0-300	ST	1-4,6,8-11,13,14
Hastigerina					
pelagica	> 23	> 36	0-300	ST	1-6,8-11,14
Sphaeroidinella					
dehiscens	16-20	?	200-300	TR	2,10,13
Candeina					
nitida	> 20	> 36	0-300	TR	1,2,4,6,8,10,11
Globigerinita					
glutinata	1·1-30	34-36	0-250	C	1-6,8-14
uvula	> 10	34-35.5	> 250	SP	8,12
Globoquadrina					
dutertrei	17-23	35.5-36+	0-150	WT	1-4,6-11,13,14
Pulleniatina					
obliquiloculata	19-25	> 36	0-150	ST	1-4,6-8,10,11,13
Globorotalia					
crassiformis	16-26	> 35.5	150-200	WT	1,3,4,6-10,13,14
hirsuta	18-21	> 35	100-250	T	1-6,8-11,13,14
inflata	13-17	34-36.6	100-150	CT	1-6,8-14
menardii	17-25	> 36	100-150	ST	1-11,13,14
scitula	15-17	?	200-300	T	2,5,6,8-10,12
truncatulinoides	15-22	35-37	100-225	ST	1-6,8-14
tumida	19-30	?	0-300	ST	2,8,10,11,13

Abbreviations: TR, tropical; ST, subtropical; WT, warm temperate; T, temperate; CT, cold temperate; SP, subpolar; C, cosmopolitan

Sources:
1. Bé, 1959
2. Bradshaw, 1959
3. Bé, 1960
4. Cifelli, 1965
5. Boltovskoy, 1966
6. Bé & Hamlin, 1967
7. Jones, 1967
8. Boltovskoy, 1969
9. Cifelli & Smith, 1970
10. Bé & Tolderlund, 1971
11. Bé, Vilks & Lott, 1971
12. Boltovskoy, 1971
13. Lynts, 1971
14. Tolderlund & Bé, 1971

Figure 2. Optimum ecological conditions for modern planktonic foraminiferal species.

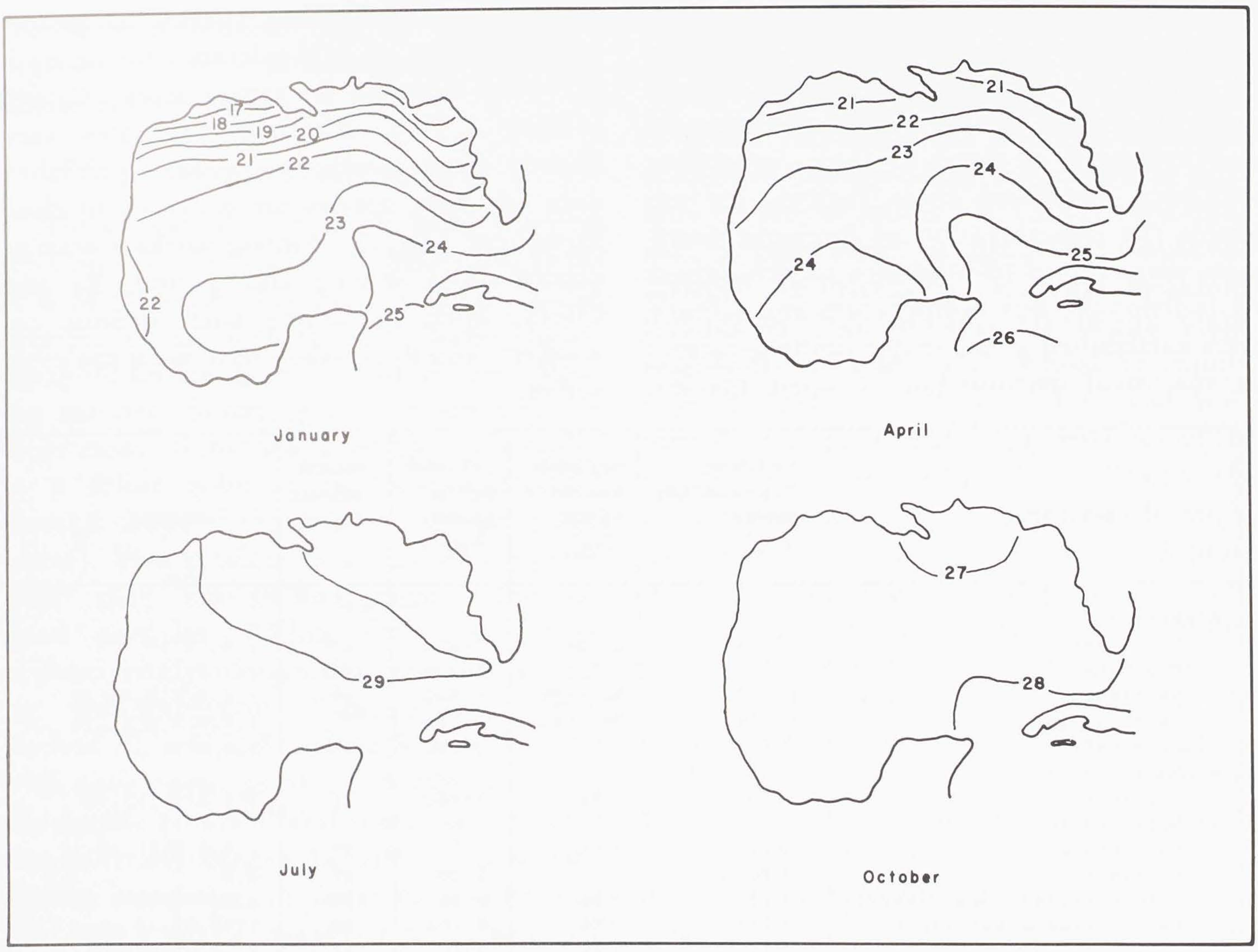

Figure 3. Mean surface water temperature (°C) during each of four months of the year in the Gulf of Mexico. (after Greiner, 1970 from charts supplied by the National Oceanographic Data Center, 1966)

One logical correlative of such studies is the more detailed examination of selected species. Jones (1966, 1968) conducted such studies of populations in the Caribbean Sea. He has demonstrated that some species regarded as reliable indicators of major water masses are also excellent indicators of minor changes in environmental conditions. Small changes in any one of several ecologic factors may influence the areal distribution of such species. Figure 2 summarizes the present knowledge concerning optimum ecologic conditions for the species encountered in this study.

Another approach is the analysis of distributional patterns in surface sediments. Papers by Parker (1962), Ruddiman (1969), Kennett (1969), and Riess *et al.* (1971) present studies dealing with planktonic foraminiferal species in surface sediments of various geographic areas. Thus far, all that can be said is that latitudinal segregation, although not precisely correlative with that exhibited by living populations, does exist in surface sediment distributions.

VII. CLASSIFICATION SYSTEM AND DISTRIBUTIONAL PATTERNS OF TEMPERATURE, SALINITY, AND SURFACE CURRENTS

The organization of this paper follows the system of classification proposed by Parker (1967). Her classification, including only those genera encountered during this project, is outlined below.

Family GLOBIGERINIDAE

Globigerina
Globigerinella
Globigerinoides
Orbulina
Hastigerina
Pseudohastigerina
Sphaeroidinella

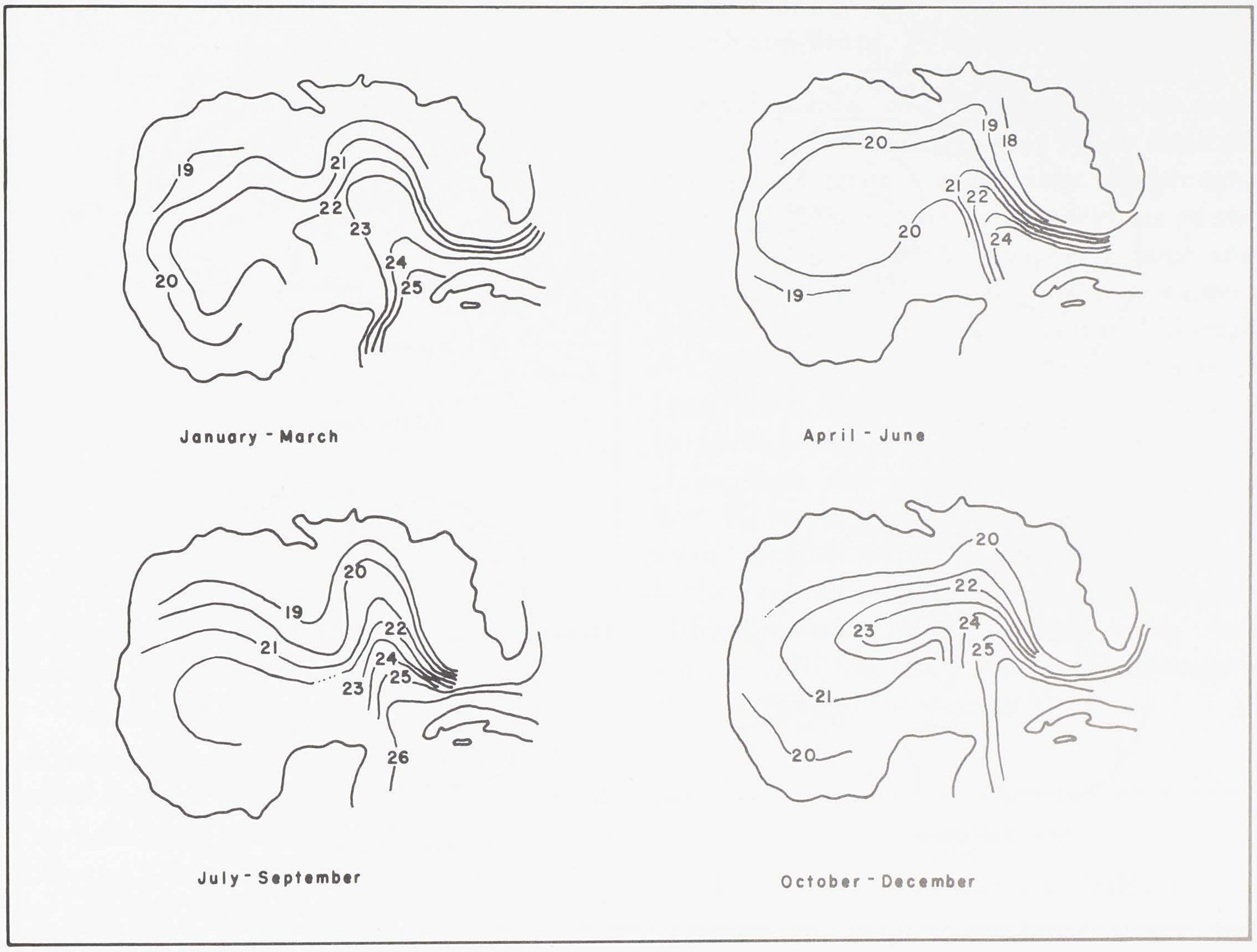

Figure 4. Mean water temperature (°C) for each of the four seasons of the year at a depth of approximately 100 meters in the Gulf of Mexico. (after Greiner, 1970 from charts supplied by the National Oceanographic Data Center, 1966)

Family CANDEINIDAE
Candeina
Globigerinita
Family CATAPSYDRACIDAE
Globoquadrina
Pulleniatina
Family GLOBOROTALIIDAE
Globorotalia

Parker's classification emphasizes the importance of true, elongate spines as a taxonomic character. Lipps (1966), utilizing microstructural characters, proposed a classification which agrees closely with that of Parker. Bé, Jongebloed, and McIntyre (1969) used point projection x-ray microscopy to examine internal morphology, variations in wall thickness from earliest to latest chambers, pore concentration, and pore diameter. Their classification is nearly identical to that of Parker. They differ only with respect to the placement of *Globigerinita.*

The basic organization of the above classifications differs from those of Bolli, Loeblich, and Tappan (1957) and Banner and Blow (1959). These workers emphasized the importance of mode of coiling, shape of chambers, position of apertures, number of chambers per whorl, presence or absence of keel, and ornamentation. Although arguments can be advanced for the use of each of these general systems of classification, that utilized by Parker has been selected for the present project.

The illustrations presented for each species represent an attempt to provide a nearly complete view of the range of variation within that species. They also summarize my interpretation of each species concept as it is presented by contemporary

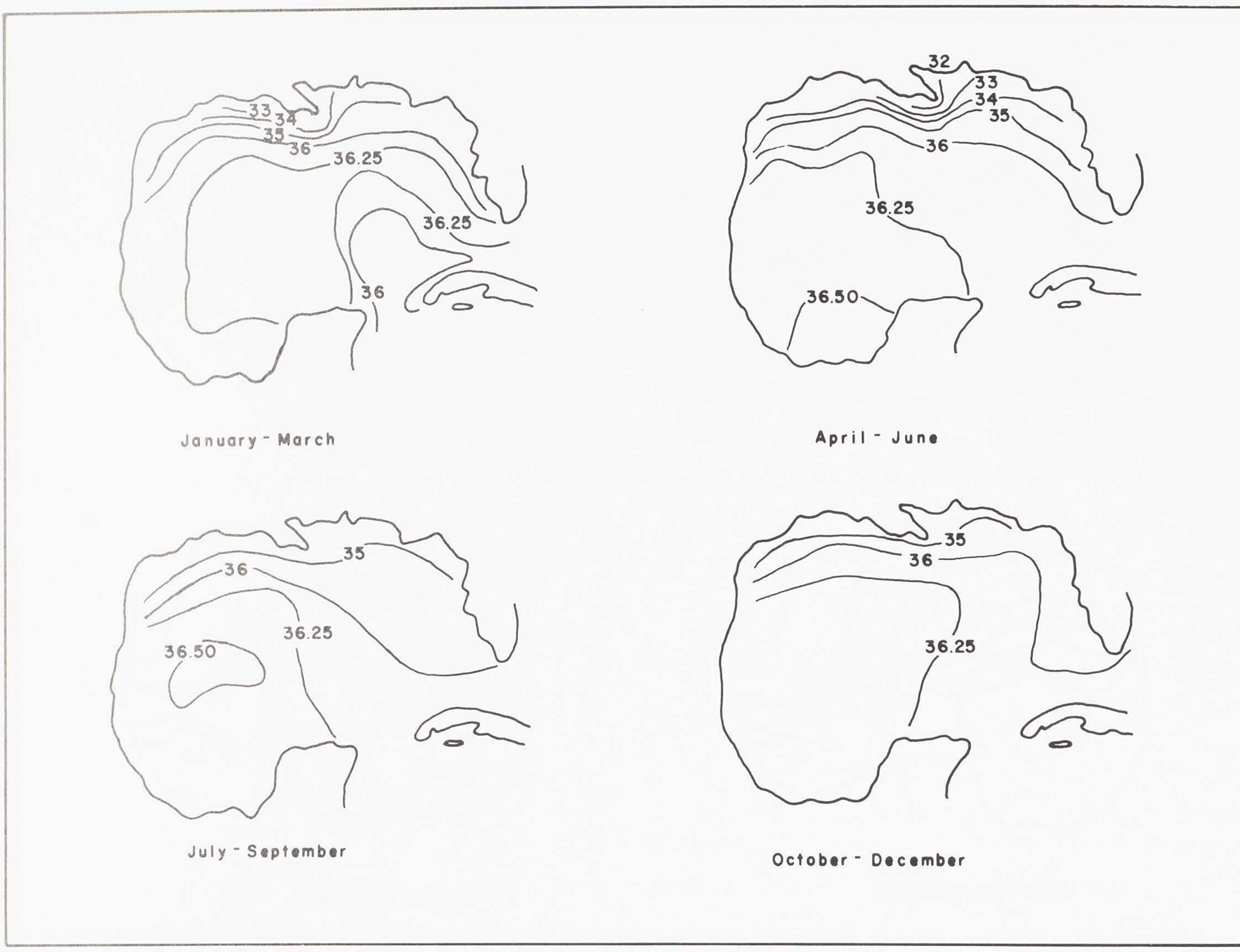

Figure 5. Mean surface water salinity (‰) during four seasons of the year for the Gulf of Mexico. (after Greiner, 1970 from charts supplied by the National Oceanographic Data Center, 1966)

workers. This approach serves to stress the populational aspect of these species. In addition, understanding each species concept as it is perceived by contemporary workers is necessary to utilize the ecological information that is provided almost exclusively by those same workers. The distributional pattern of each species is compared to charts on which are plotted the distribution of mean surface water temperature (fig. 3), mean water temperature at a depth of approximately 100 meters (fig. 4), and mean surface water salinity (fig. 5) during four seasons of the year in the Gulf of Mexico. The effects of surface water currents (fig. 6) are also considered.

Reference to Table I will supplement the discussions concerning the effects of solution. Those stations at which solution seriously distorts the estimates of relative abundance are relatively few. At stations 10 and 22 there is only moderate distortion but at stations 3, 5, 8, 20, and 32 the problem is serious. Samples from the latter five stations yield only those species most resistant to solution. Specimens are so few in number at these stations that percentage analyses are of little value.

VIII. AGE OF SEDIMENTS

The limited stratigraphic range of many planktonic foraminiferal species makes them useful for determining the relative age of sediments. Although distinguishing between late Pleistocene and early Holocene sediments is difficult, several criteria based upon planktonic Foraminifera are useful. Some species became extinct, or at least were excluded from the area of study, during the late Pleistocene. These include *Globorotalia flexuosa* and *Globorotalia inflata.* The presence of large numbers of either of these

Figure 6. Gulf of Mexico surface water currents. (from Greiner, 1970)

species suggests exposure of Pleistocene sediments. Several species are not encountered in sediments of the Gulf of Mexico until the Holocene. These include *Globorotalia ungulata* and the large, very tumescent forms of *Globorotalia tumida*. Other species, such as *Pulleniatina obliquiloculata finalis*, are encountered in the Holocene and uppermost Pleistocene. Large numbers of extinct and/or excluded species, combined with the absence of Holocene species, indicate the presence of pre-Holocene sediments. Small numbers of excluded species in samples where Holocene species are present in average concentrations are indicative of vertical mixing.

Differentiating between Pleistocene and Pliocene sediments is difficult because the definition of the Plio-Pleistocene boundary is still an unresolved issue. Without entering into a detailed evaluation of the various lines of evidence involved, the commonly used planktonic foraminiferal criteria are accepted for use in this study. These are the first abundant occurrence of *Globorotalia truncatulinoides* followed by the transition of populations of *Globorotalia menardii* to large and predominantly sinistral forms. Species considered characteristic of the late Pliocene, but which do not extend into the Pleistocene, include *Globoquadrina altispira*, *Globoquadrina venezuelana*, *Globorotalia multicamerata*, and *Globigerina nepenthes* (Lamb and Beard, 1972, p. 42).

Applications of these criteria to sediments examined during this study indicate that no sediments older than Pleistocene were encountered. All representatives of the *Globorotalia menardii* lineage are large and sinistrally coiled. *Globorotalia truncatulinoides* is present at all stations. Although the relative abundance is small at several localities, concentrations are generally between 3 and 10% of the planktonic fauna throughout the study area. Characteristic late Pliocene species were not identified from surface sediment samples anywhere within the study area. Finally, *Pulleniatina obliquiloculata finalis*, which does not appear until the late Pleistocene, is numerically important throughout the area.

Table I

Hierarchy of Resistance to Solution

(modified from Jenkins and Orr (1972) after Berger (1970)

Low resistance

1. *Globigerinoides ruber*
2. *Orbulina universa*
3. *Globigerinella siphonifera*
4. *Globigerina rubescens*
5. *Globigerinoides quadrilobatus sacculifer*
6. *Globigerinoides tenellus*
7. *Globigerinoides conglobatus*
8. *Globigerina bulloides*
9. *Globigerina quinqueloba*
10. *Globigerinita glutinata*
11. *Candeina nitida*
12. *Globorotalia hirsuta*
13. *Globorotalia truncatulinoides*
14. *Globorotalia inflata*
15. *Globorotalia menardii*
16. *Globoquadrina dutertrei*
17. *Globigerina pachyderma*
18. *Pulleniatina obliquiloculata*
19. *Globorotalia crassiformis*
20. *Sphaeroidinella dehiscens*
21. *Globorotalia tumida*

High resistance

Sediment samples that can be assigned confidently to the Pleistocene are limited to only eleven localities (fig. 7). The assemblages present at Stations 2, 13-16, 25-27, 40, 50 and 51 are interpreted as exposures of Pleistocene sediments. Those at Stations 22, 23, 28, 29, 30 and 31 indicate vertical mixing. Significant distortion of species percentage estimates probably does not occur at these latter stations.

The areal distribution of exposed Pleistocene sediments, as determined by using planktonic foraminiferal criteria, can be compared to the results of Wilhelm and Ewing (1972). Utilizing seismic profiler data, these authors have compiled a preliminary geologic map of the Gulf of Mexico. Except for the extreme southwestern portion of the Gulf, their findings, based solely upon geophysical data, are in close agreement with micropaleontological evidence. Abyssal portions of the Gulf are covered by Holocene sediments. The Mississippi cone, also covered by Holocene sediments, is flanked by continental slope areas to the west and east. Here, from southern Texas to eastern Louisiana, and again off the coast of eastern Mississippi and western Florida, Pleistocene sediments are exposed. Although not as continuous areally as is indicated by seismic profiler data, sediments here interpreted as Pleistocene occur only in these two general areas (fig. 7).

At this point, the similarity between the results from geophysical and paleontological analyses deteriorates. Surface sediments from continental slope areas adjacent to the Campeche Escarpment and the Western Florida Escarpment yield Holocene planktonic foraminiferal assemblages. However, based upon seismic profiler data, correlation with coastal formations indicates this area is covered by Miocene and Pliocene sediments. The same relationship exists over the much more gentle and geographically more extensive continental slope in Campeche Bay. Along steep escarpments the reason for this discrepancy may be related to downslope displacement of Quaternary sediments. The presence of small numbers of shallower water benthonic Foraminifera in abyssal sediments adjacent to steep slope areas supports this suggestion. Thicker deposits of the late Tertiary, as detected by seismic methods, may be overlain by a very thin veneer of Holocene sediments. This veneer, undetected because it is so thin, yields the assemblages described in this report. The mechanism for such transport of Quaternary materials is more difficult to visualize for the gentle slopes in Campeche Bay. Perhaps slow rates of deposition explain the presence of a thin veneer of Holocene sediments in this area.

IX. CONCLUSIONS

Distributional Patterns of Individual Species

Distributional patterns of the relative abundances for individual species (figs. 11-46) show varying degrees of correlation with the values of temperature and salinity in the overlying water mass. No single species has a pattern within the surface sediments that corresponds closely with the areal patterns displayed by either of these ecological parameters. The pattern of a number of species correlates moderately well with those of temperature values. These species include:

Globigerina bulloides
Globigerina digitata
Globigerina pachyderma
Globigerinella siphonifera
Globigerinoides quadrilobatus quadrilobatus
Globigerinoides quadrilobatus sacculifer
Globigerinoides ruber
Globorotalia tumida
Globorotalia ungulata

The remainder of the species present in surface sediments of the study area have distributions that show little or no correlation with those of temperature and salinity values. However, living specimens of many of these species are known to be highly sensitive to changes in those same parameters. During the process of incorporation into sediments, a number of factors evidently masks the record of this sensitivity.

One such disrupting factor is solution. As noted in Table 1, planktonic foraminiferal species exhibit different degrees of resistance to solution. As solution becomes progressive-

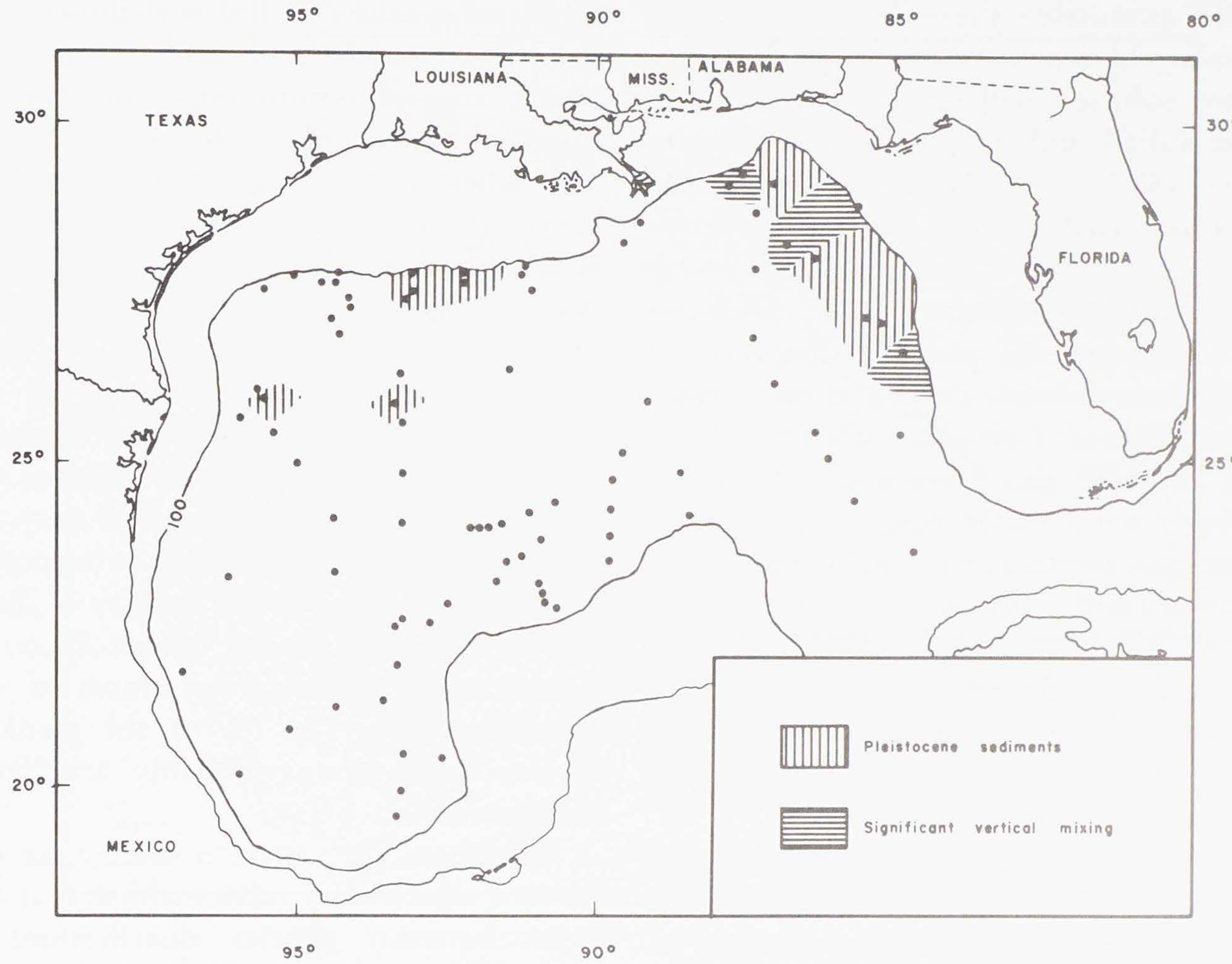

Figure 7. Areal distribution of Pleistocene sediments and sediments indicating significant vertical mixing.

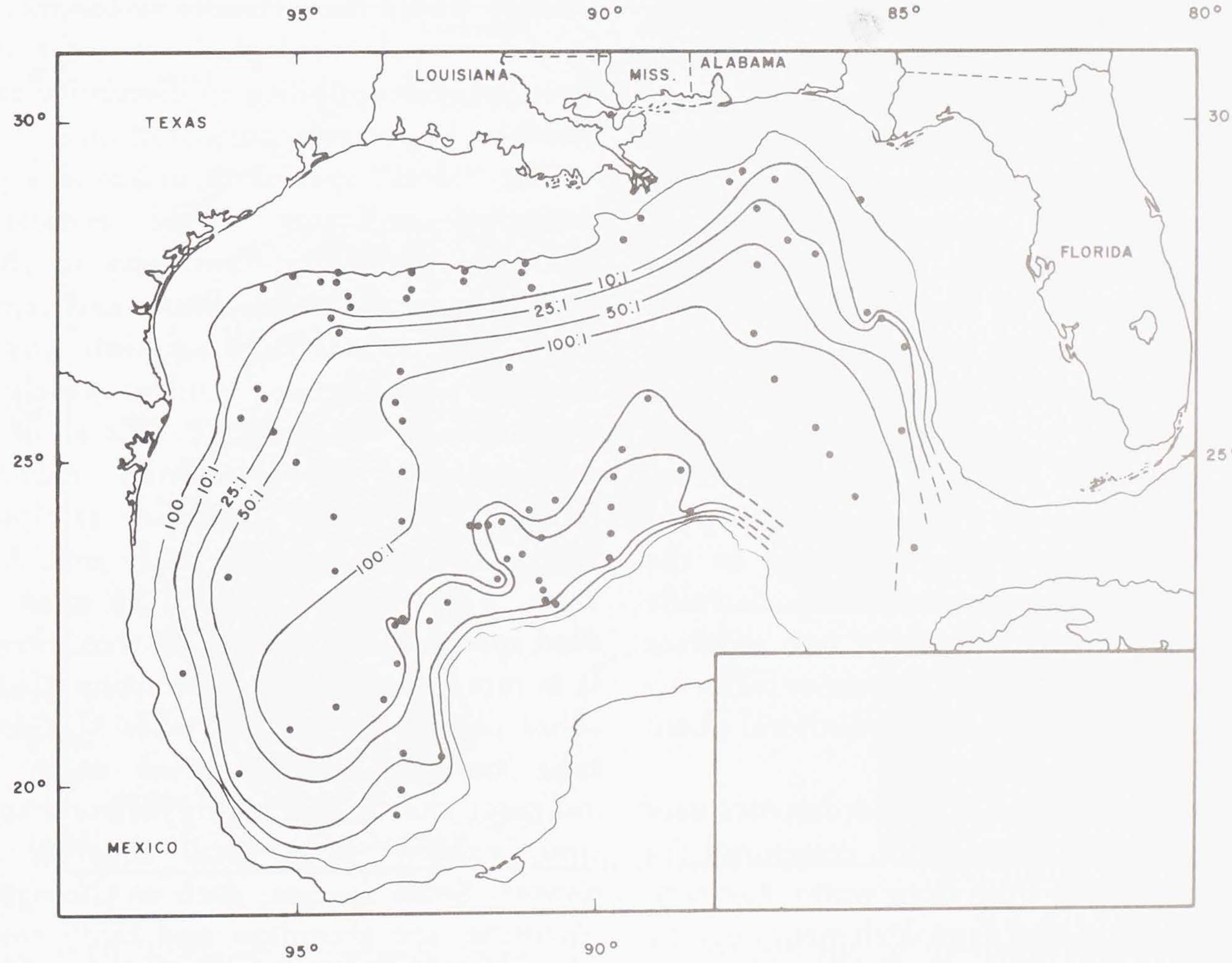

Figure 8. Areal distribution of planktonic to benthonic ratio values.

ly more extensive, there are concomitant changes in the aspect of the fauna. Relatively minor solution will result in the absence of thin-walled and fragile species (Jenkins and Orr, 1972, p. 1074). As with any attribute characterized by negative evidence, this stage of solution is often difficult to recognize. Intermediate solution, which eliminates immature forms and partially dissolves the tests of more resistant species, is much more easily recognized. Complete solution will, of course, result in the absence of all species. Solution is not a major modifying factor of distributions within surface sediments of the Gulf of Mexico. Evidence of intermediate solution is encountered at only seven stations (3, 5, 8, 10, 20, 22, and 32). Although difficult to assess, the error introduced by minor solution effects is probably negligible.

Surface currents may also be a disrupting factor. In many areas of the Gulf of Mexico these currents trend across changes in temperature and salinity values (compare figure 6 with figures 3, 4, and 5). Here their mixing effects may hinder recognition of the relationship between the distribution of a species and the ecological factor or factors operative in limiting that distribution. This is especially true when the tests of dead planktonic organisms are transported away from the area in which the organisms lived. Surface currents are important modifiers of planktonic foraminiferal distributions in surface sediments of the study area. Not only do they strongly influence the patterns of many individual species, but their effects are also evident in patterns involving larger faunal elements. Plots of tropical versus non-tropical elements (figs. 9 and 10) indicate a particularly strong influence in the western Gulf at approximately latitude 26°N. Here the convergence of two separate current systems (fig. 6) is the major influencing factor on planktonic foraminiferal distributions in surface sediments.

Downslope movement of sediments may alter the relative abundance computed for species in samples from deep water. Contamination by displaced faunal elements can be detected by the presence of benthonic foraminiferal species that live in shallower water. Significant numbers of shallow water forms would suggest serious error due to downslope movement. No such evidence exists in the samples from the Gulf of Mexico. Although minor amounts of displacement have been well documented, at no station does contamination seriously alter the values of relative abundances.

Finally, the absolute number of specimens representing a particular taxon may affect distributional patterns. Species represented by very few specimens may show marked percentage variations in response to minor fluctuations in the severity of disrupting factors. The patchy, discontinuous distributions of some species, most of which constitute less than 1% of the planktonic foraminiferal fauna, probably arise in just this manner.

The above discussion considers the major factors, which alter relationships, that might exist between species distributions and ecological parameters. Of course, living specimens of different species vary in sensitivity to changes in ecologic factors (fig. 2). Those species that are most sensitive to such changes would theoretically be the most useful for paleoecological interpretations. However, susceptibility to disruptive factors is also an important consideration.

The "ideal" species to utilize as a paleoecological indicator would possess the following characters: sensitivity to changes in ecological factors (salinity and temperature), high resistance to solution, and great absolute abundance. Unfortunately, no single species adequately fulfills all of these requirements. *Globigerinoides ruber* approaches this "ideal" condition as closely as any species present in the study area. A good warm water indicator, it is the most abundant species in the Gulf of Mexico. However, it is more susceptible to solution than any other planktonic species (table 1). *Globorotalia tumida,* another good warm water indicator that is also highly resistant to solution, exhibits only small absolute abundances. Some species, such as *Globigerinita glutinata,* are abundant and fairly resistant to solution but tolerate broad ranges of

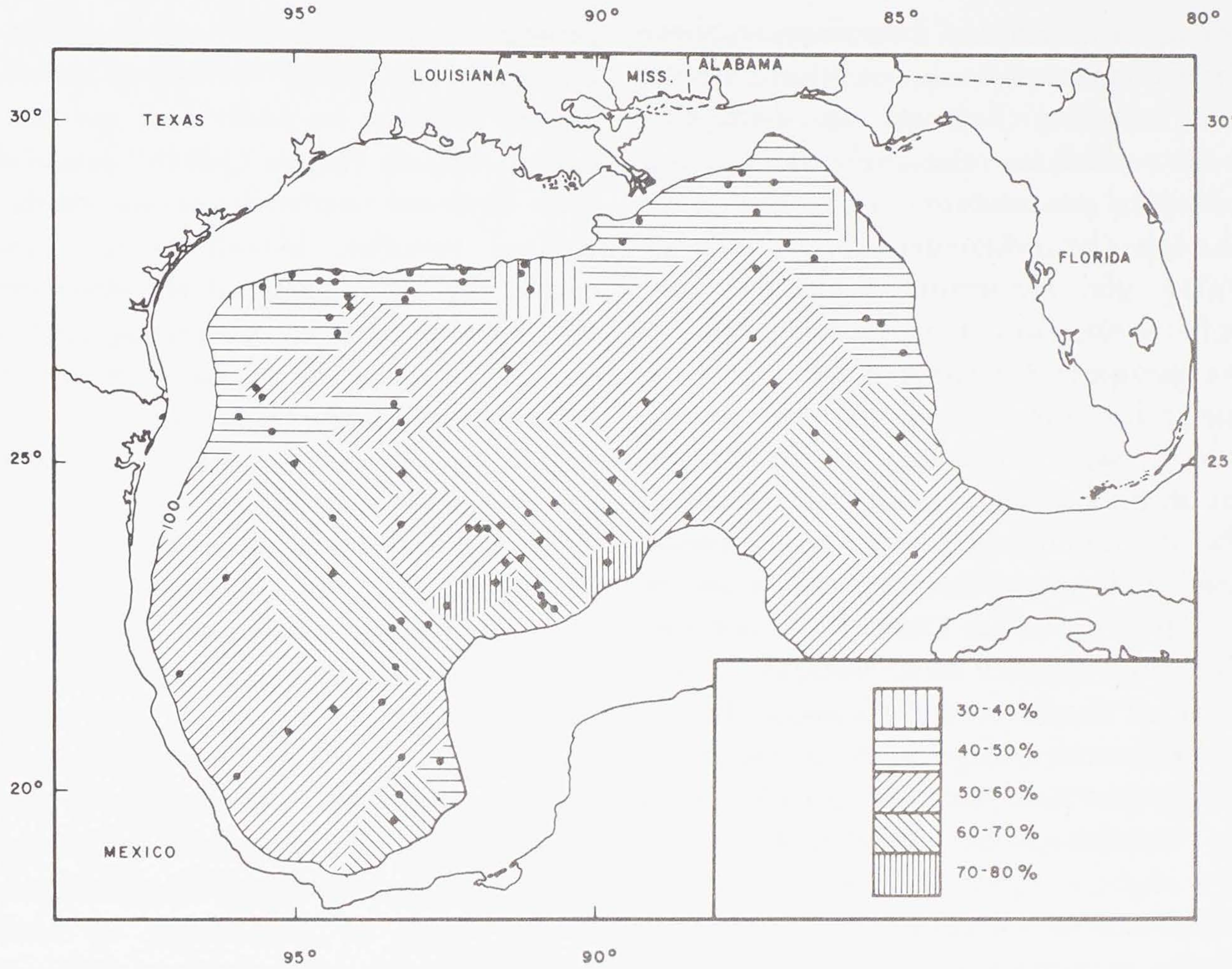

Figure 9. Relative abundance, computed as a percentage of the total planktonic foraminiferal assemblage, of the tropical faunal element.

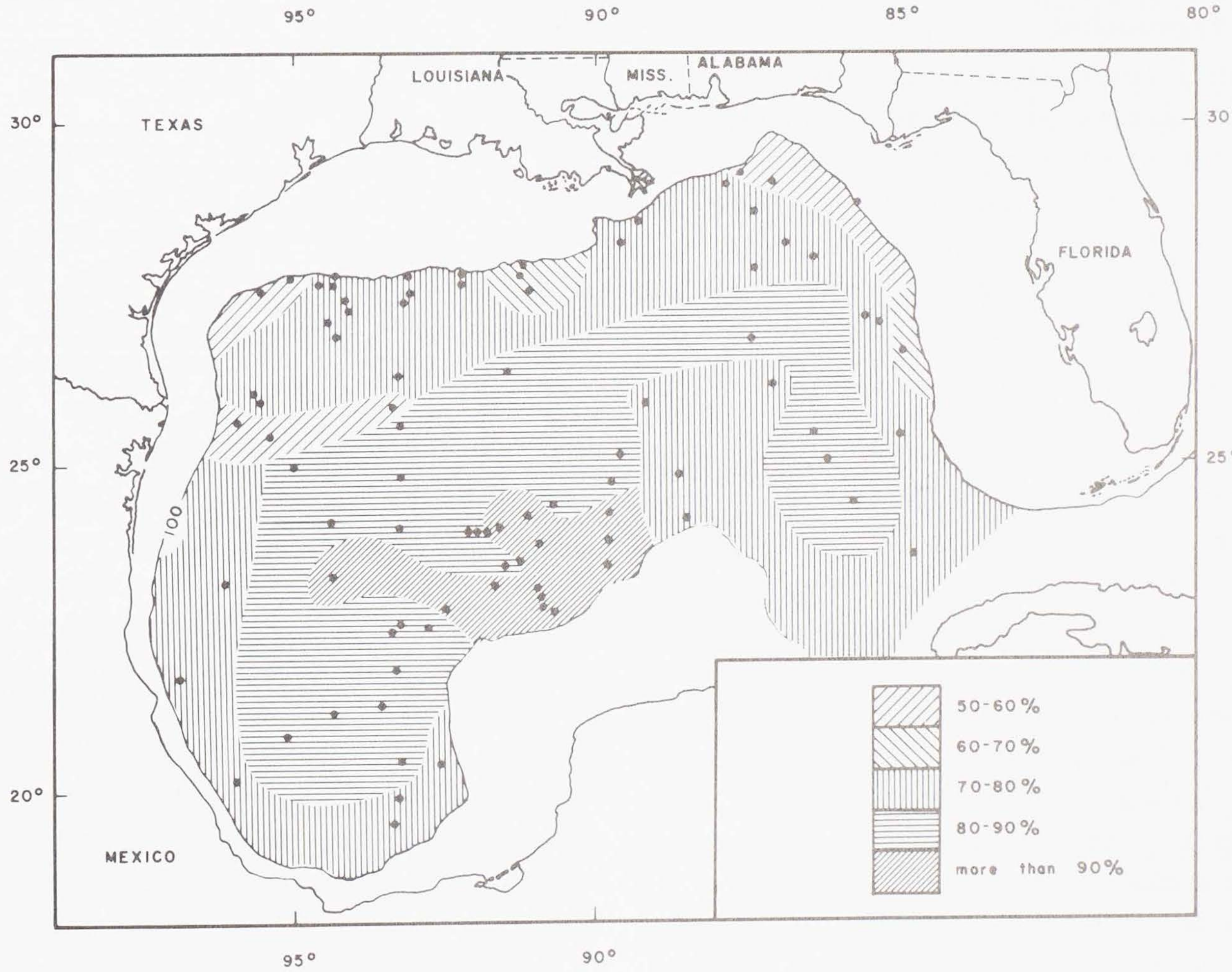

Figure 10. Relative abundance, computed as a percentage of the total assemblage minus cosmopolitan and poorly understood species, of the tropical faunal element.

temperature and salinity. In summary, there is no "ideal" species. Each one is susceptible, albeit in varying degrees, to disrupting factors that mask its relationship to measurable ecological parameters.

Although the refinement of knowledge concerning the optimum ecological conditions for living specimens is most interesting, the prospect of utilizing such detailed knowledge for interpreting thanatocoenoses is not favorable. Too many variables exist to attempt more than generalized estimates of past climatic conditions. In terms of broad latitudinal patterns, the thanatocoenoses of surface sediments of the Gulf of Mexico conform well with that which would be expected. That is, in terms of major faunal groups, these assemblages can be described as subtropical. Analysis of distributional patterns exhibited by individual species supports slightly more detailed interpretations. Generalized estimates of temperature and salinity maxima and minima, along with an appreciation for broad trends exhibited by values of these parameters, represent optimum attainable results.

Other Approaches

Several approaches, other than the relative abundances of individual species, have been utilized to interpret the paleoclimatic implications of thanatocoenoses. These include the planktonic number, the planktonic to benthonic ratio, ratios of various species to other selected species, and the species diversity index.

The planktonic number was not utilized during this investigation because samples from two of the three sources were washed through a sieve prior to receipt by the writer. Theoretically, this technique provides some basis for estimating the absolute abundance of planktonic Foraminifera. Unfortunately, values depend upon both the rate of sedimentation and primary productivity. Values cannot be correlated with ecological parameters unless detailed knowledge of sedimentation rates is available.

Another common procedure is plotting values of the ratio between two selected species. The species are selected because they are considered indicative of different ecological conditions, and because they approach the "ideal" indicator species condition. Because no individual species corresponds closely to this "ideal," establishing a ratio between two such species yields no increased benefits. Indeed, it may even increase the complexity of the situation. The two species used in computing such a ratio may not be reacting to the same factors. The resultant ratio may, therefore,be independent of the particular parameter or parameters being considered. In addition, the initially computed relative abundances are influenced by various disruptive factors. Errors inherent in these initial estimates will vary from species to species according to which disruptive processes are operative, the severity of these processes, and the susceptibility of individual species to them. The relationship of any such ratio to values of temperature and salinity becomes hopelessly obscured.

The ratio of planktonic to benthonic foraminiferal specimens is another commonly used measurement. Because it is strongly influenced by physiographic setting, the distribution of values of this ratio is closely related to regional bathymetry. This relationship would be disrupted by extensive downslope movement. Close correlation between the P/B ratio and bathymetry in the Gulf of Mexico (fig. 8) serves as substantive evidence that such displacement is of minor importance. Differential solution of foraminiferal tests might also seriously distort values of this ratio. Its close correlation with bathymetry lends support to other lines of evidence suggesting solution is a relatively minor modifier of foraminiferal assemblages.

Analysis of species diversity represents another approach to ecological studies. "The species diversity index is a measure of the relative concentration or variety of species within a biologic community" (Gibson, 1966, p. 117). There are a number of diversity indices, many of which do not follow parallel trends in the same developmental series. These indices incorporate more than a single component of diversity, usually variety and evenness in apportionment of individuals among species. The writer follows Tolderlund and Bé (1971) in using a modification of the index proposed by Simpson in 1949. It is calculated as follows:

$$I = \frac{\sum_{i=1}^{x} n_i\,(n-1)}{N\,(N-1)}$$

where n equals the number of individuals in species $n_1, n_2, \ldots n_x$, and N equals the number of individuals in the sample (Tolderlund and Bé, 1971, p. 318). In order to avoid confusion, the value of this index is subtracted from unity so that the index increases as diversity increases. The value of this index was computed for each station. A plot of values throughout the study area revealed absolutely no relationship to the distribution of temperature and salinity values within the Gulf of Mexico. However, the values are similar to those of seasonal peaks for living planktonic Foraminifera in subtropical areas (Tolderlund and Bé, 1971, p. 318).

Limitations of Analyses Based on Thanatocoenoses

Throughout this discussion, reference has been made to the difficulties in deriving precise ecological interpretations from assemblages within surface sediments. In this context, 'precise' simply means accuracy comparable to present knowledge about the ecology of living representatives from various species. Distortion by disrupting factors, such as solution and surface currents, makes precise interpretations based on the distributions of individual species impossible. Various other commonly used approaches are affected by the same factors. In addition, some of these introduce unfounded assumptions, which produce even greater complexities.

Grouping assemblages into larger elements, such as tropical and non-tropical, decreases the precision of interpretations. It also negates much of the distortion inherent in dealing with more limited groups. As the number of components within the system increases, statistical limitations imposed upon that system decrease. Figure 9 displays the distribution of tropical species computed as a percentage of the total planktonic foraminiferal fauna. Relative abundances correlate well with the distribution of temperature values, especially those at a depth of 100 meters (fig. 4). Correlation with temperature values is improved when the tropical species are computed as a percentage of the total assemblage minus ubiquitous and poorly understood species (fig. 10). Such species are readily recognizable in Figure 2. These distributions reflect prominent trends in temperature values of the overlying, near-surface water mass. Utilizing knowledge about the optimum ecological conditions for those species that are good temperature indicators, generalized estimates of temperature maxima and minima are discernible. Salinity does not appear to be an important influencing factor. Analysis based upon major faunal elements, such as that described above, represents the ultimate accuracy attainable in interpretation of thanatocoenoses.

X. DISTRIBUTION OF SPECIES

Family GLOBIGERINIDAE Carpenter, Parker, and Jones, 1862

Genus GLOBIGERINA d'Orbigny, 1826

GLOBIGERINA BULLOIDES d'Orbigny

Plate 1, figures 1-6

Globigerina bulloides D'ORBIGNY, 1826, Ann. Sci. Nat., (ser. 1), vol. 7, p. 277, nos. 17 and 76.

Globigerina bulloides is clearly distinguishable from other species, except for some specimens of *Globigerina falconensis;* however, the latter species tends to have slightly more elongate final chambers and a more constricted aperture with a more prominent lip. In surface sediments of the study area they are separable into distinct groups that are assigned species rank by this writer.

Globigerina bulloides constitutes 1 to 3% of planktonic foraminiferal assemblages in surface sediments over most of the Gulf of Mexico (fig. 11). Areas with relative abundances of less than 1% are located along the continental slope off Florida and in the south-central portion of the Gulf basin. Relative abundances ranging from 5 to 10% occur at several isolated stations. Percentages ranging from 3 to 5% are characteristic of the continental slope areas off the coast of

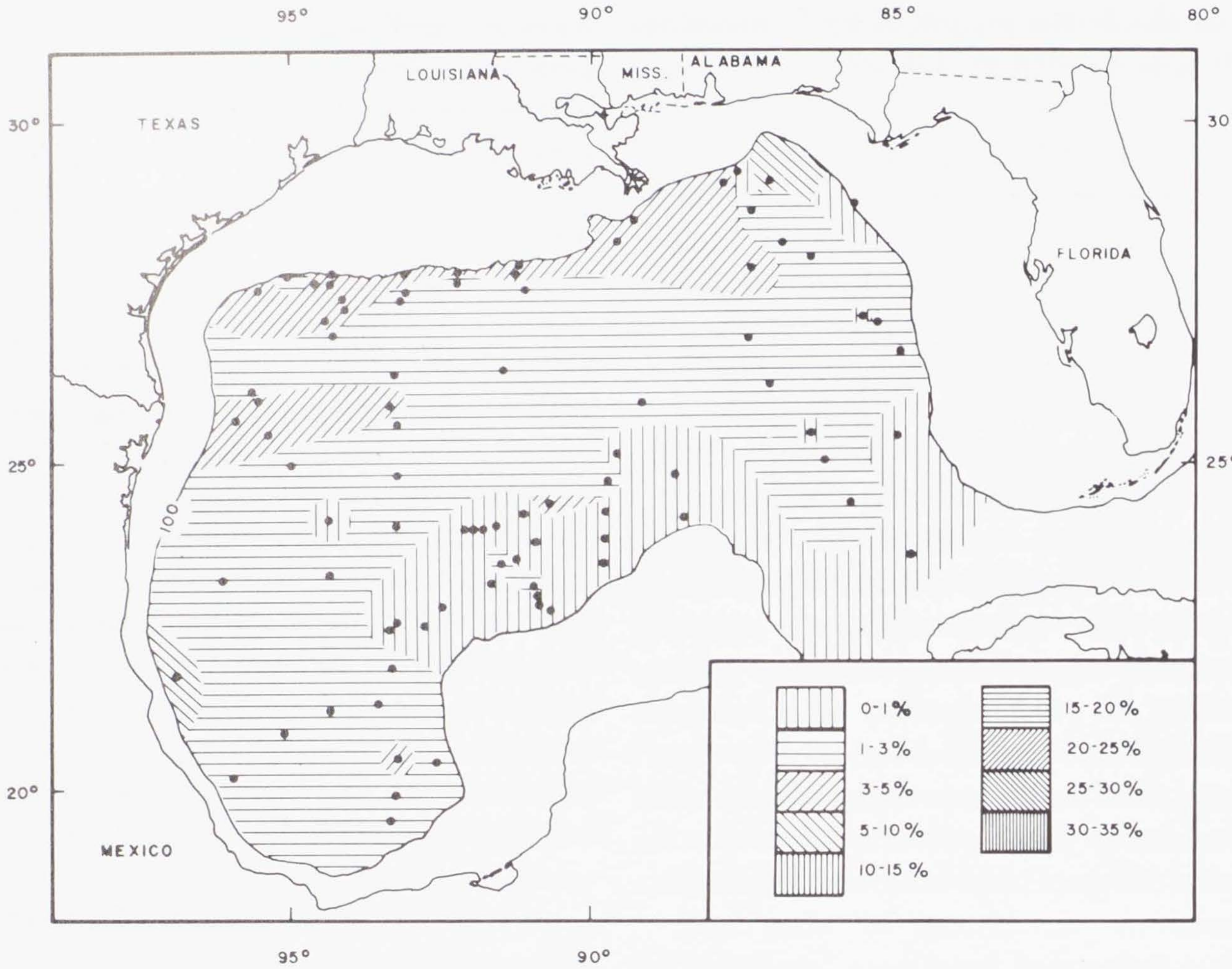

Figure 11. Relative abundance of *Globigerina bulloides*.

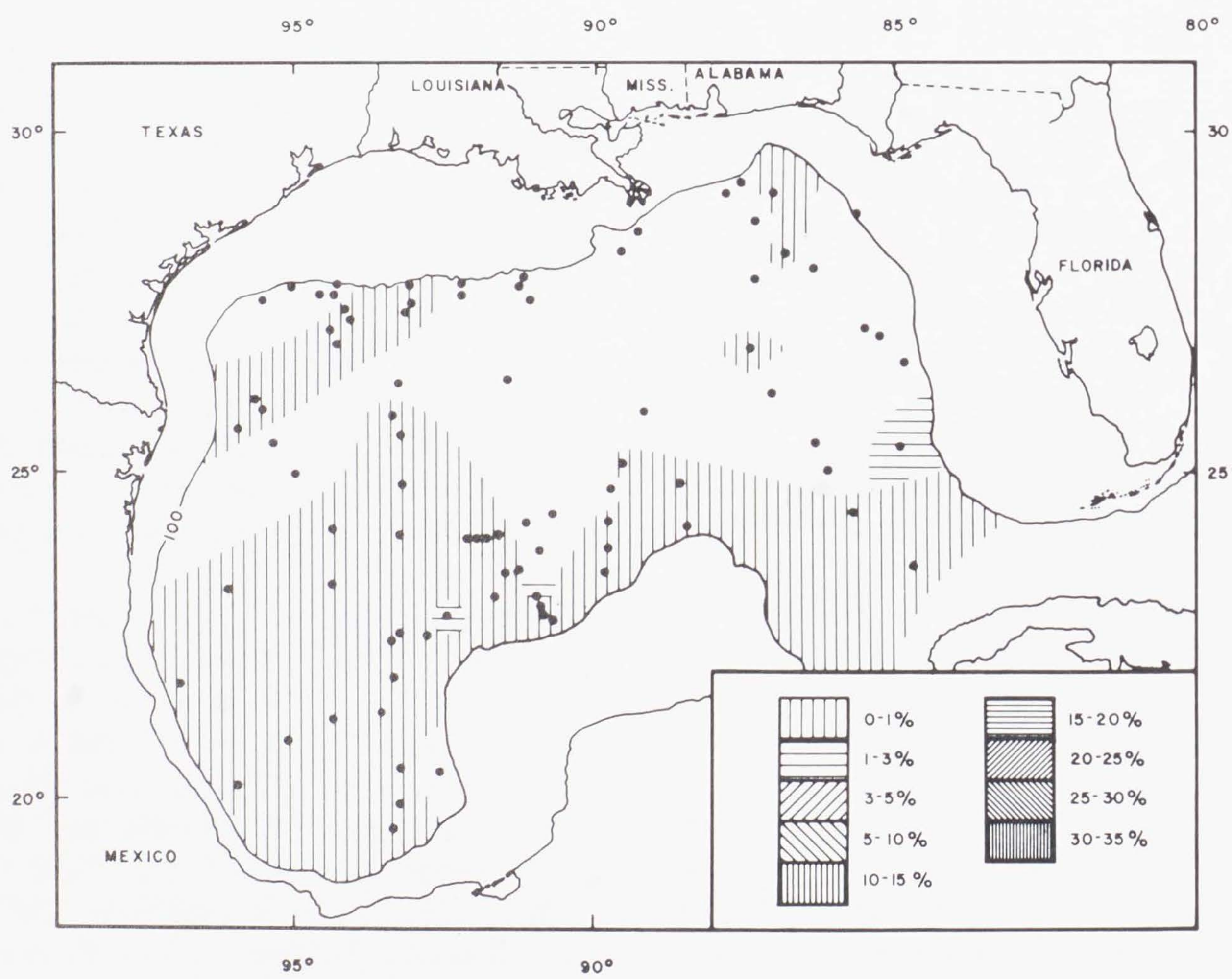

Figure 12. Relative abundance of *Globigerina calida*.

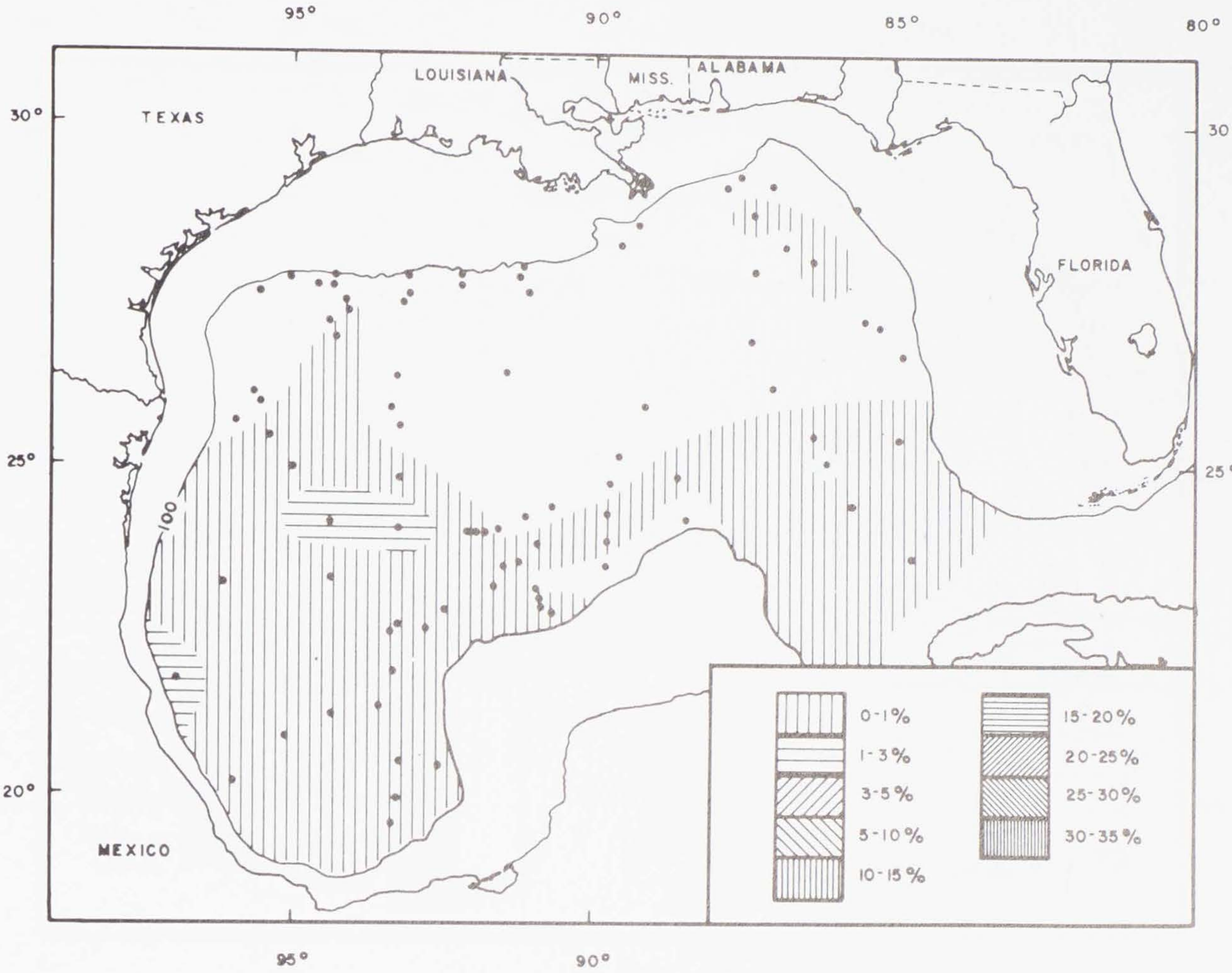

Figure 13. Relative abundance of *Globigerina digitata.*

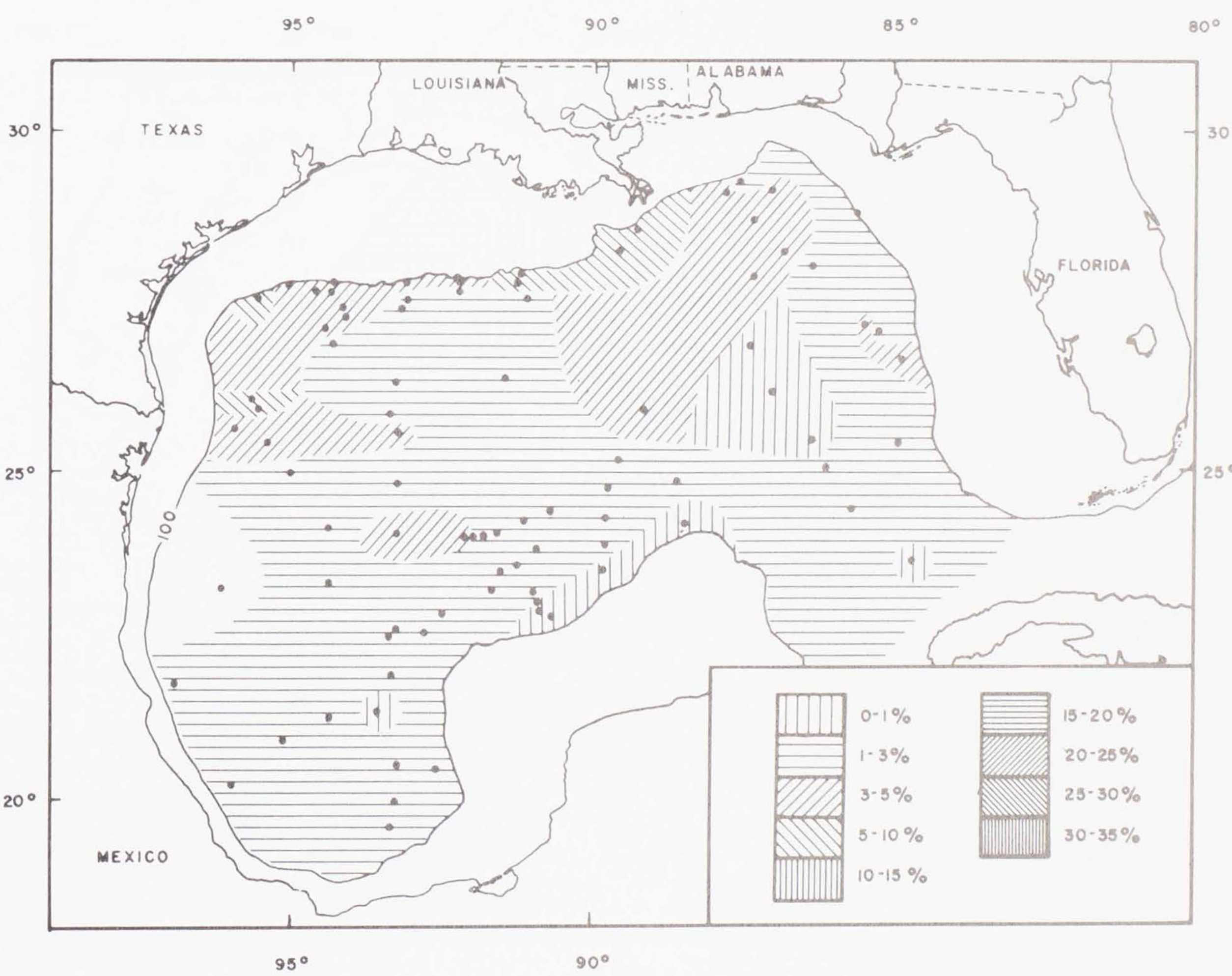

Figure 14. Relative abundance of *Globigerina falconensis.*

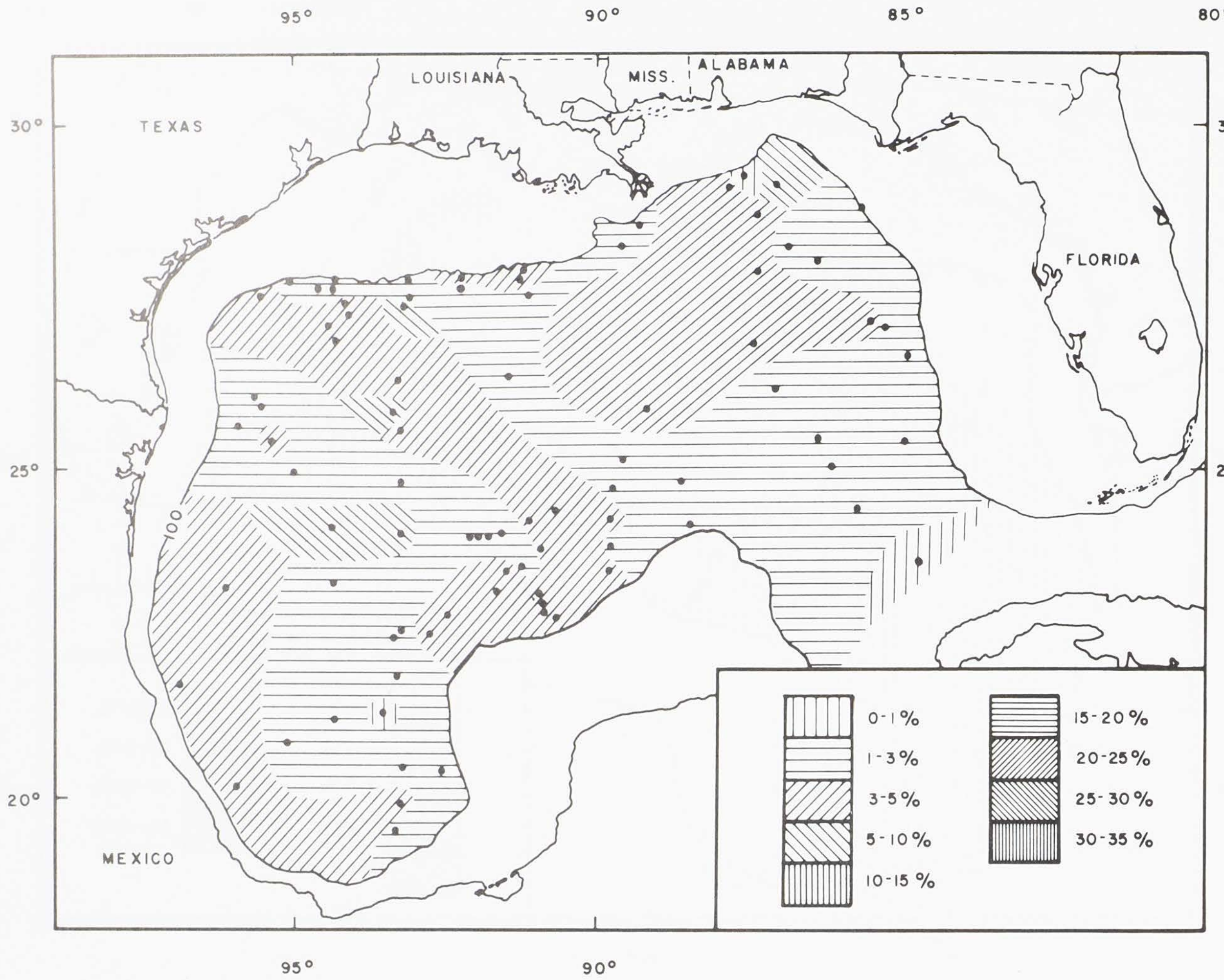

Figure 15. Relative abundance of the *Globigerina falconensis* morphological variant with reduced final chamber.

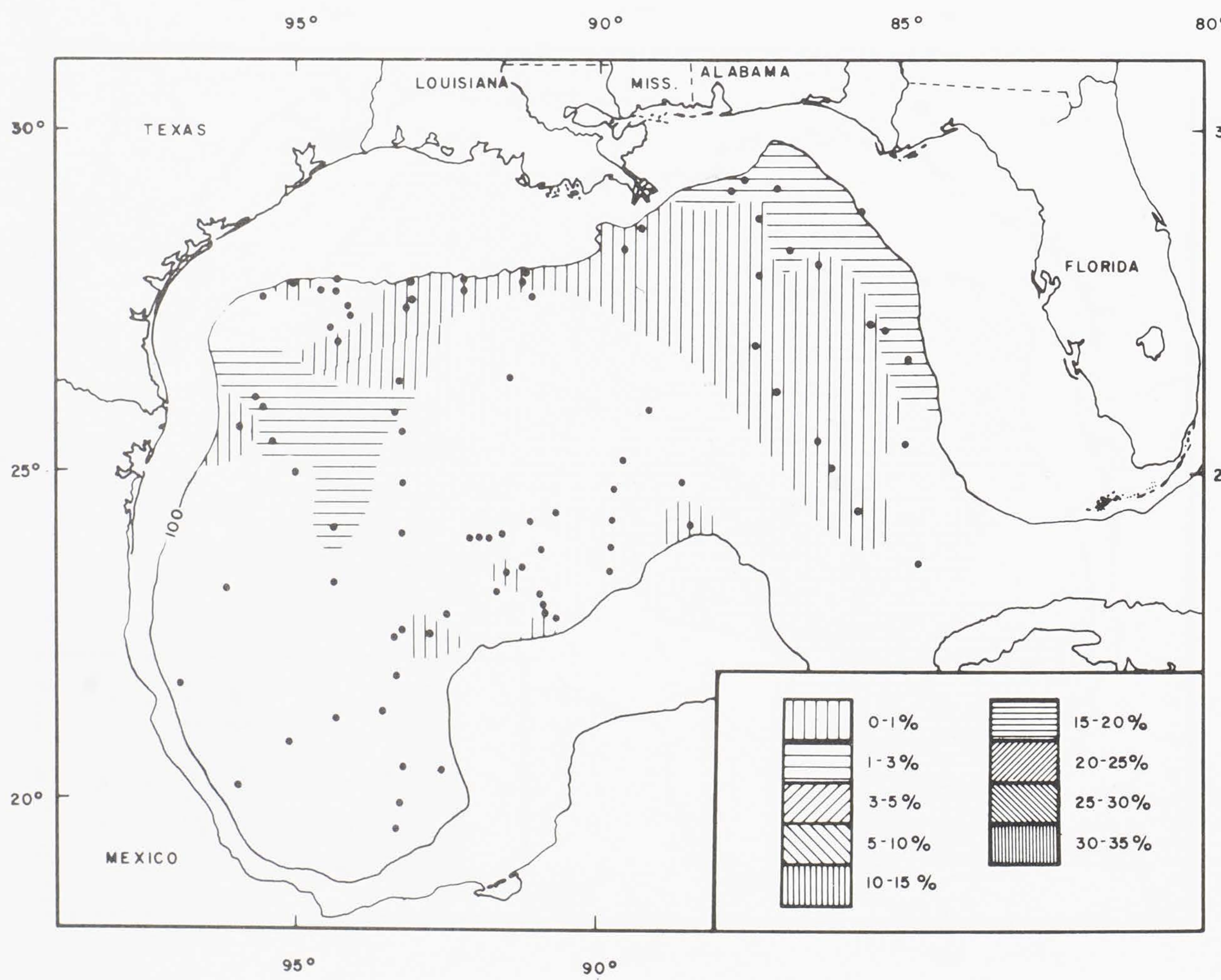

Figure 16. Relative abundance of *Globigerina pachyderma*.

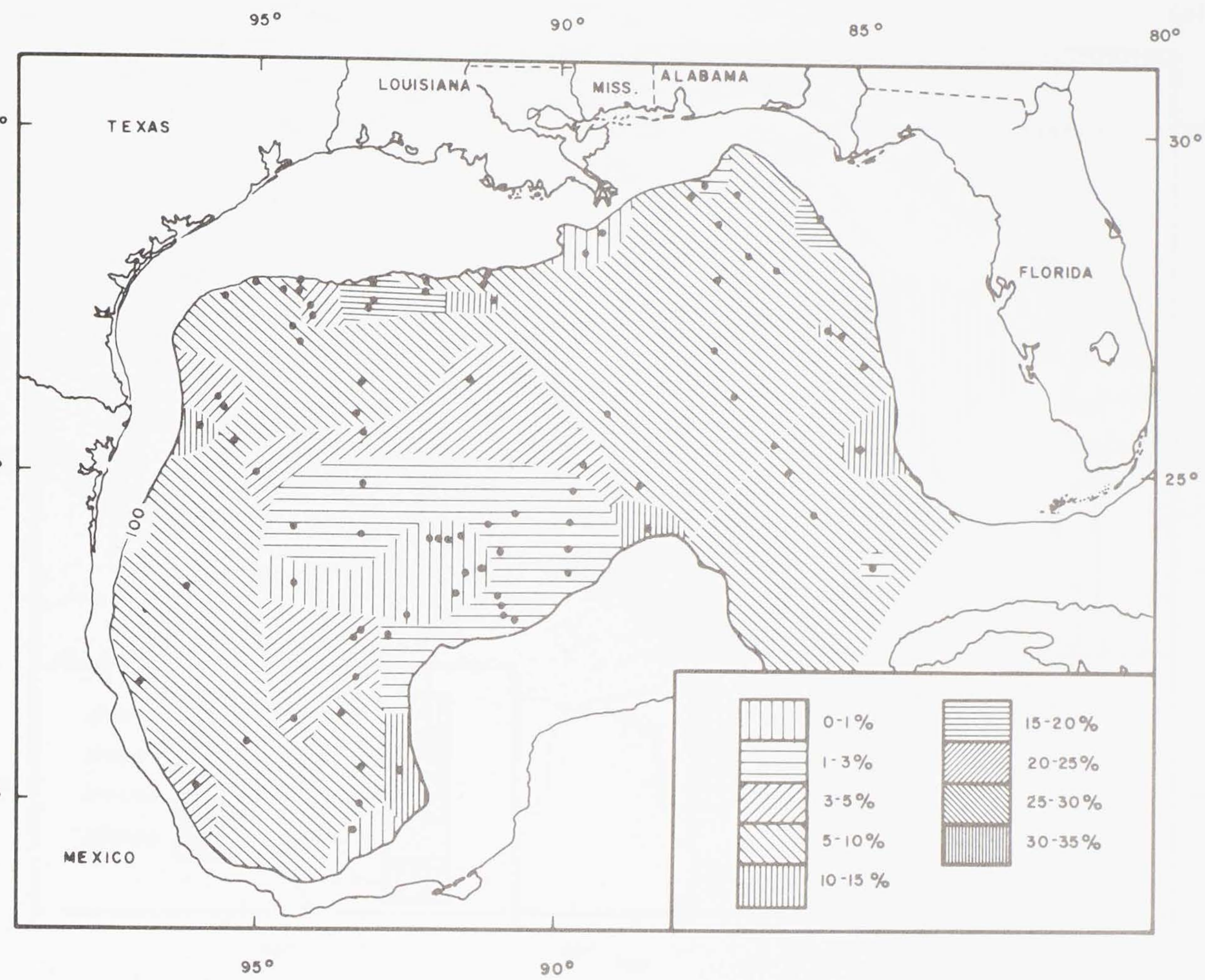

Figure 17. Relative abundance of *Globigerina quinqueloba.*

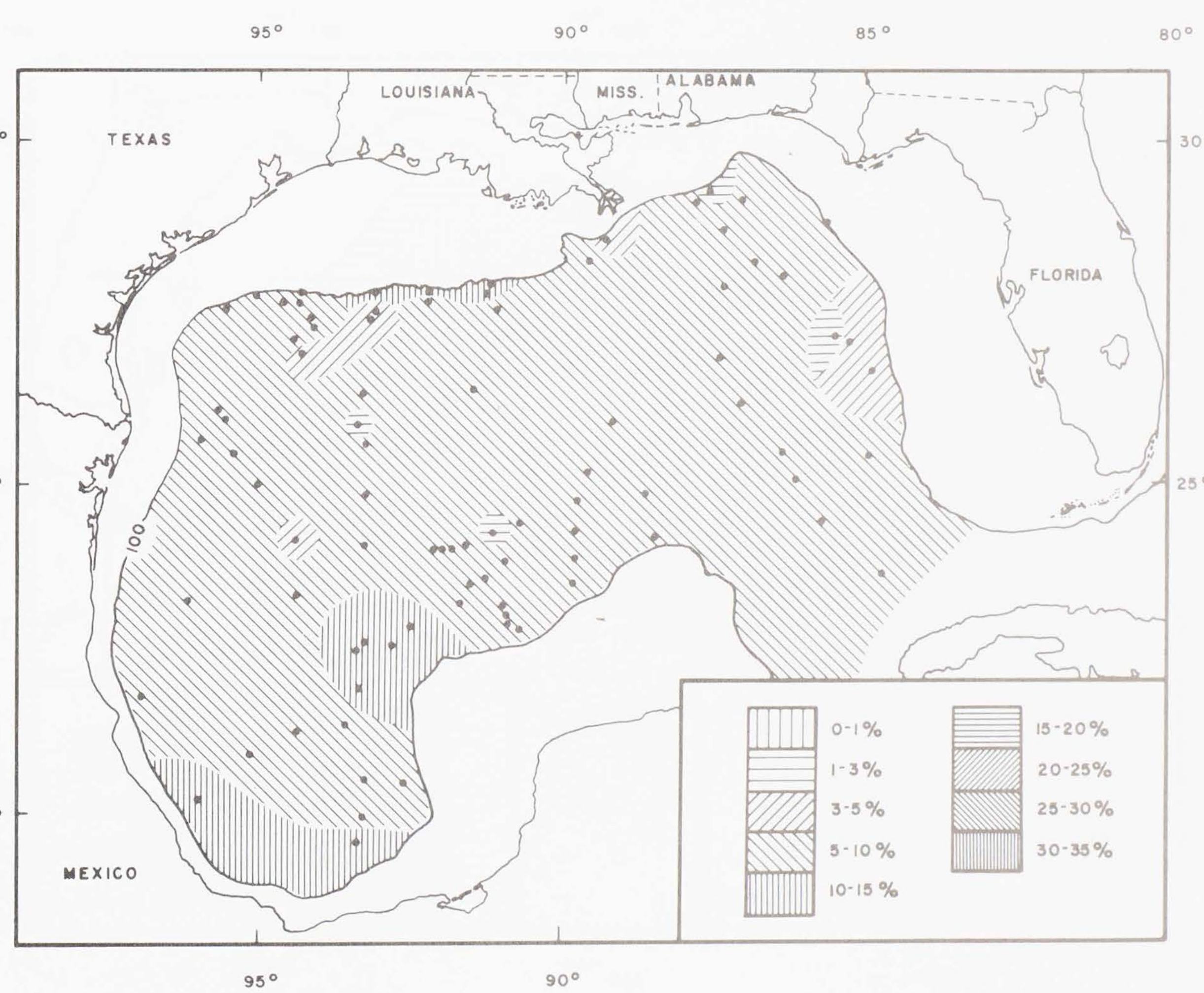

Figure 18. Relative abundance of *Globigerina rubescens.*

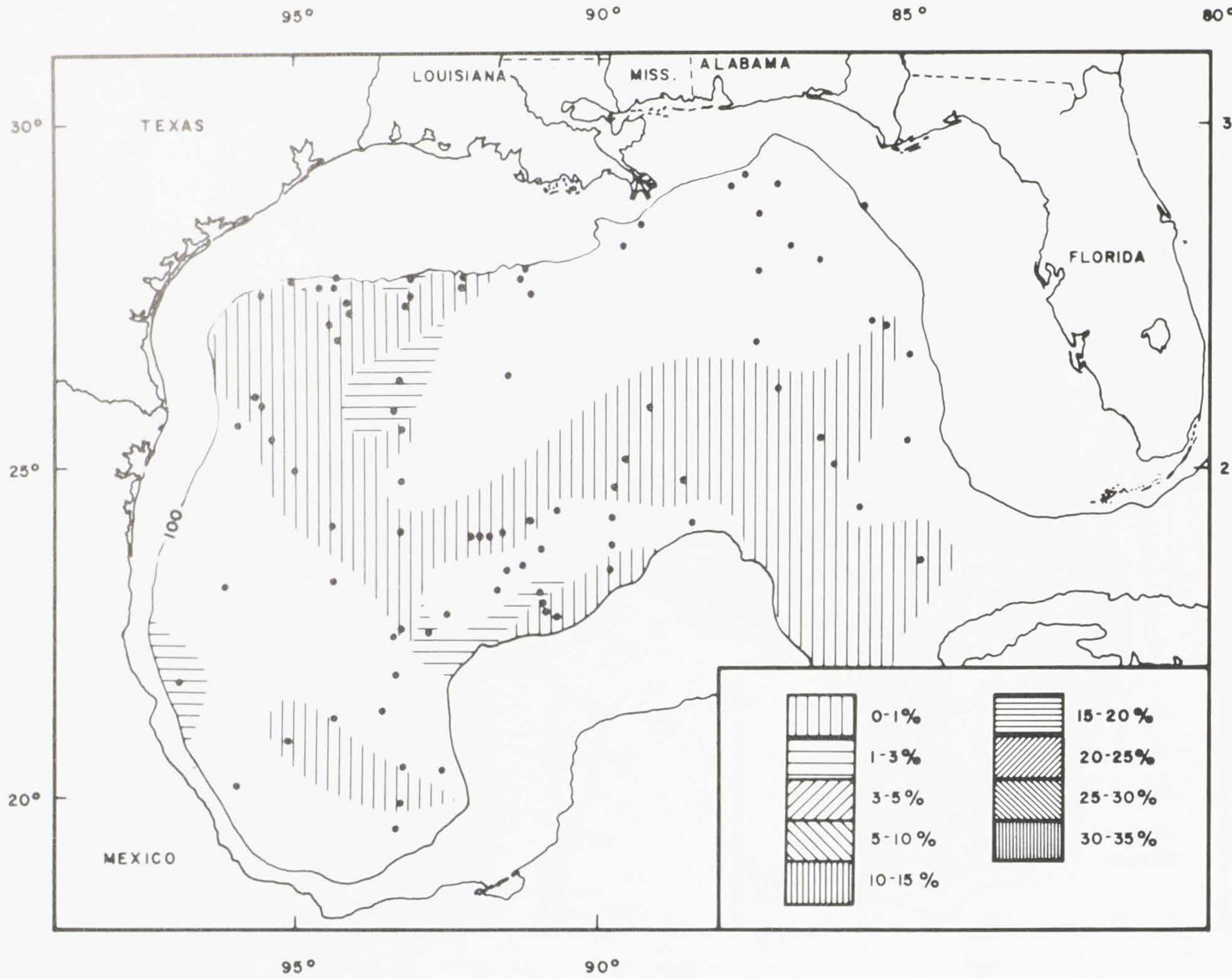

Figure 19. Relative abundance of *Globigerina* sp.

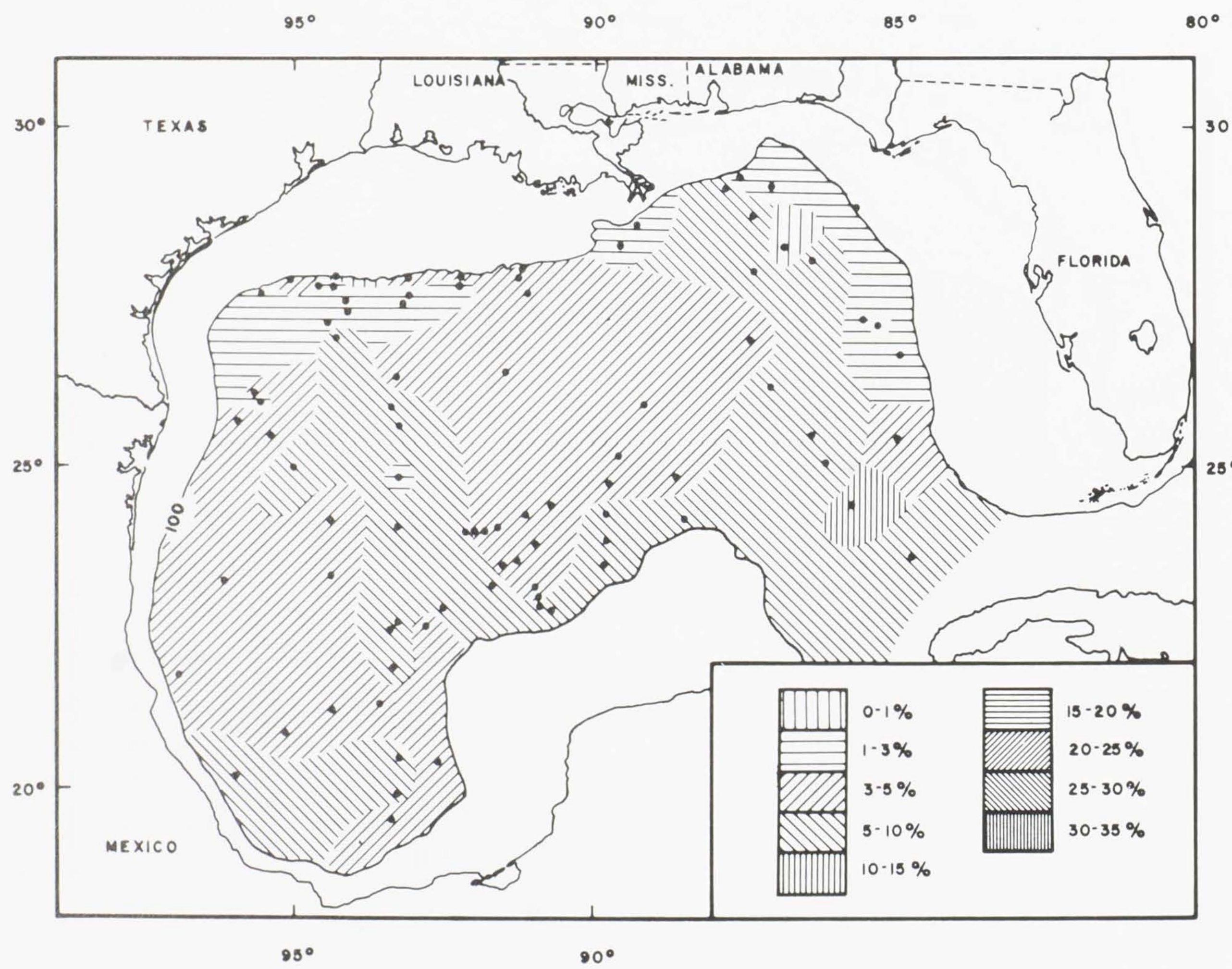

Figure 20. Relative abundance of *Globigerinella siphonifera*.

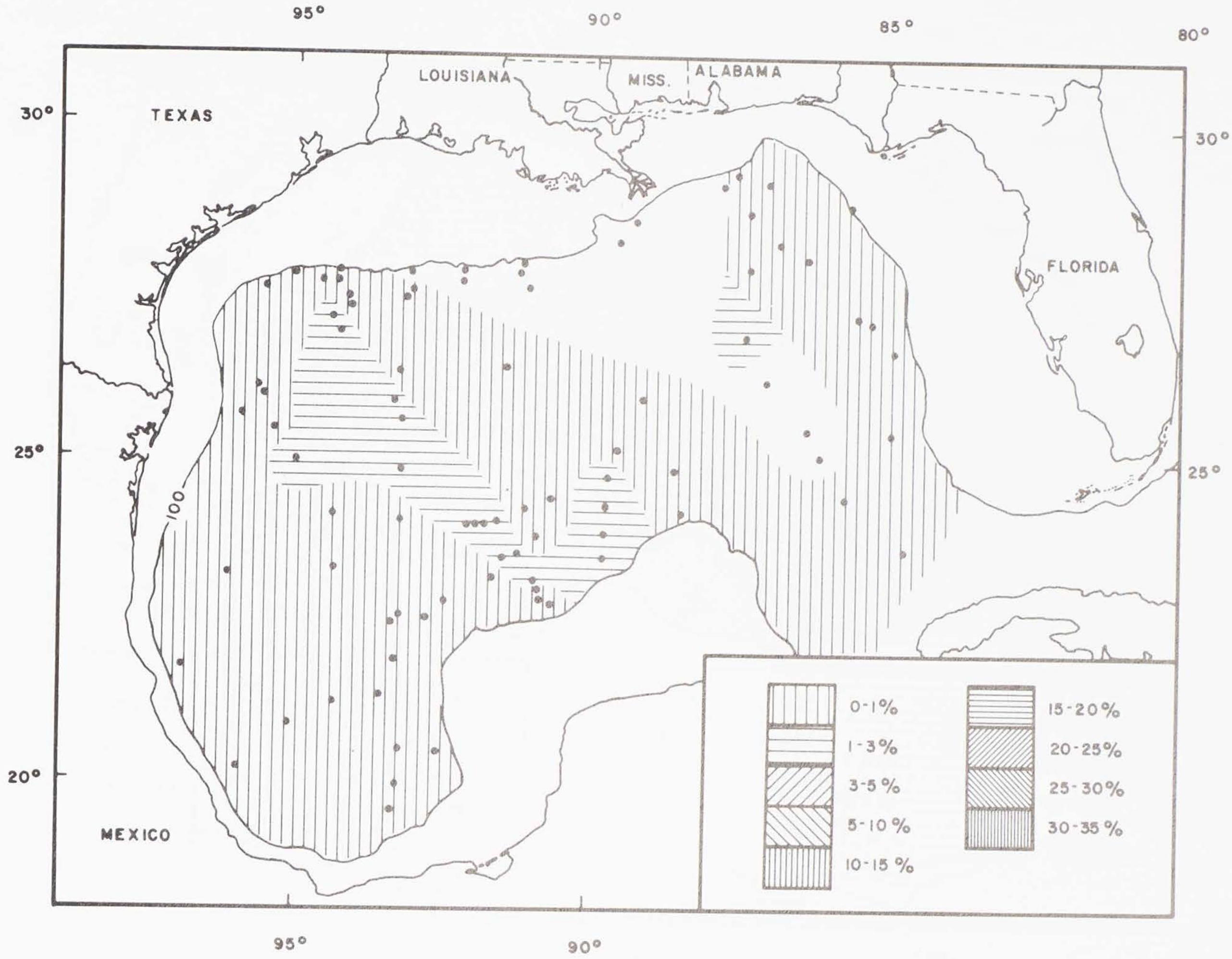

Figure 21. Relative abundance of *Globigerinoides conglobatus.*

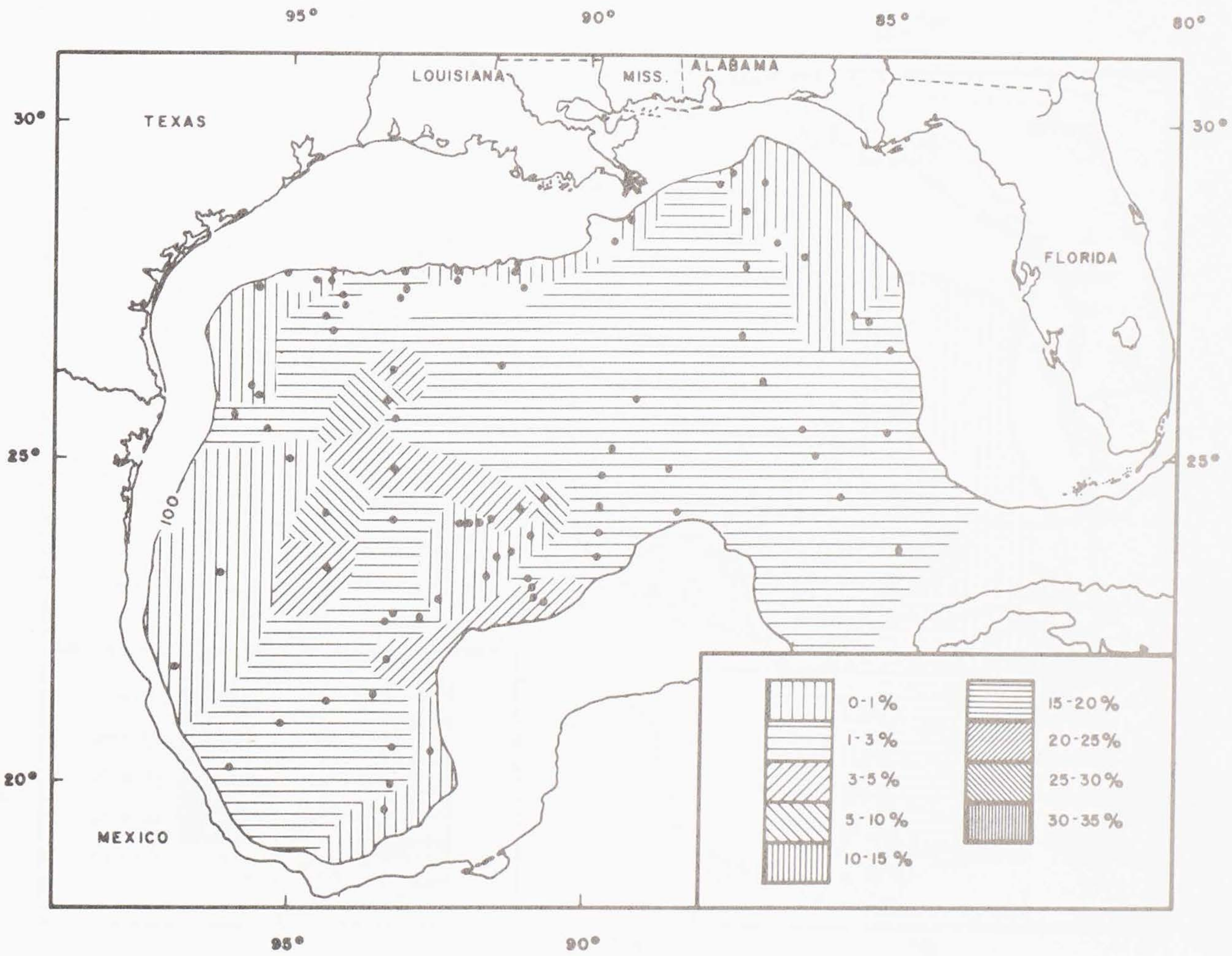

Figure 22. Relative abundance of *Globigerinoides elongatus.*

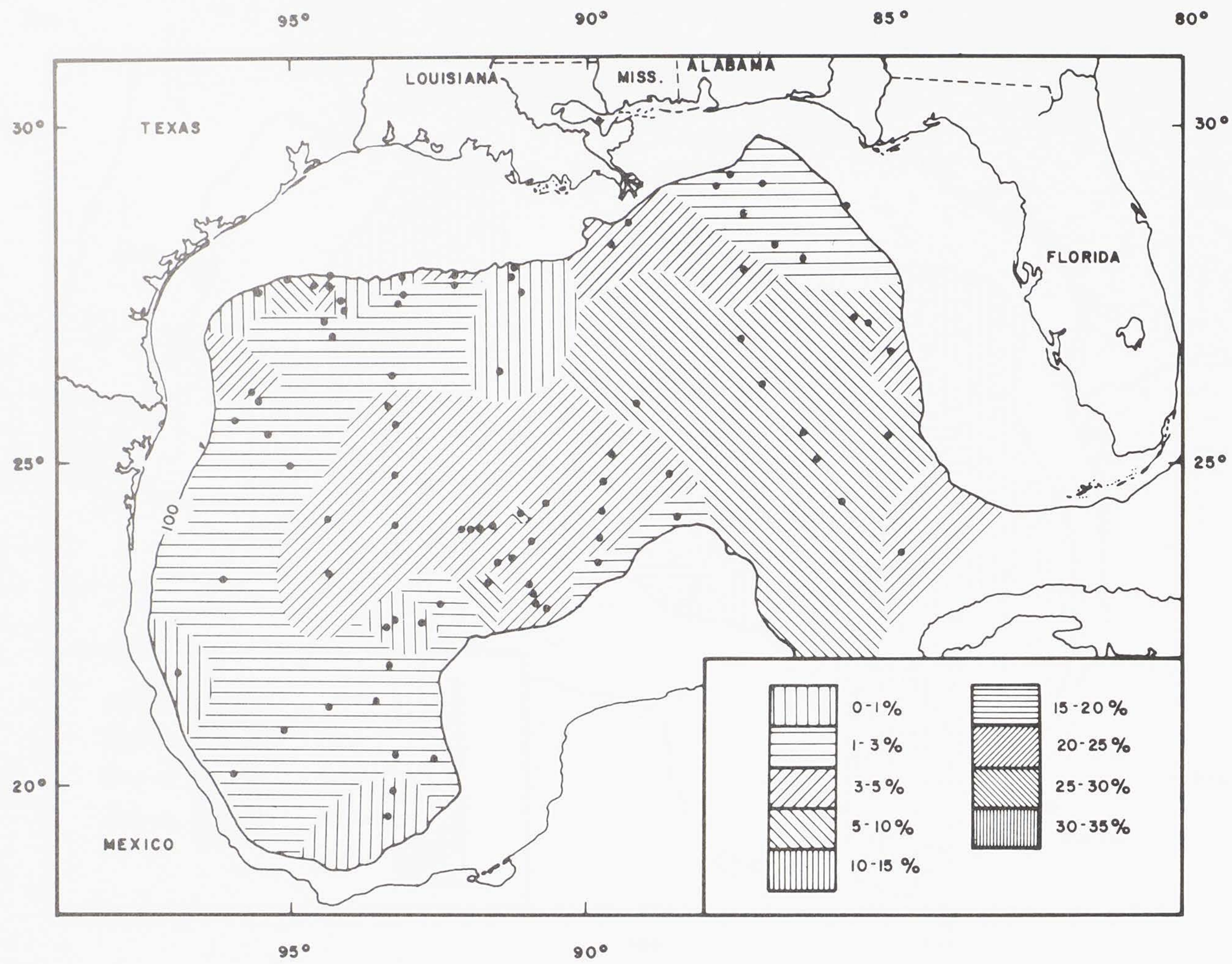

Figure 23. Relative abundance of *Globigerinoides quadrilobatus quadrilobatus*.

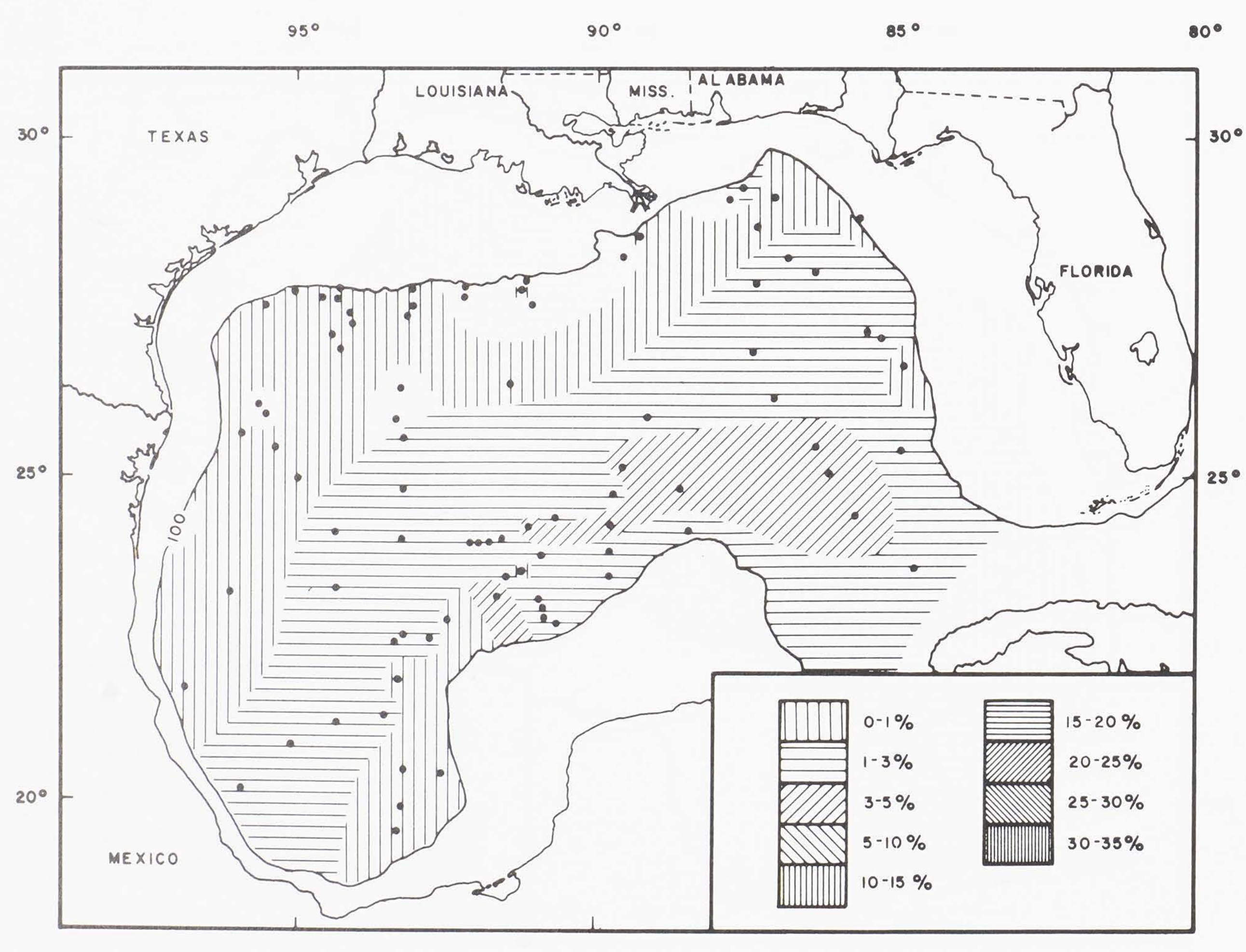

Figure 24. Relative abundance of *Globigerinoides quadrilobatus sacculifer*.

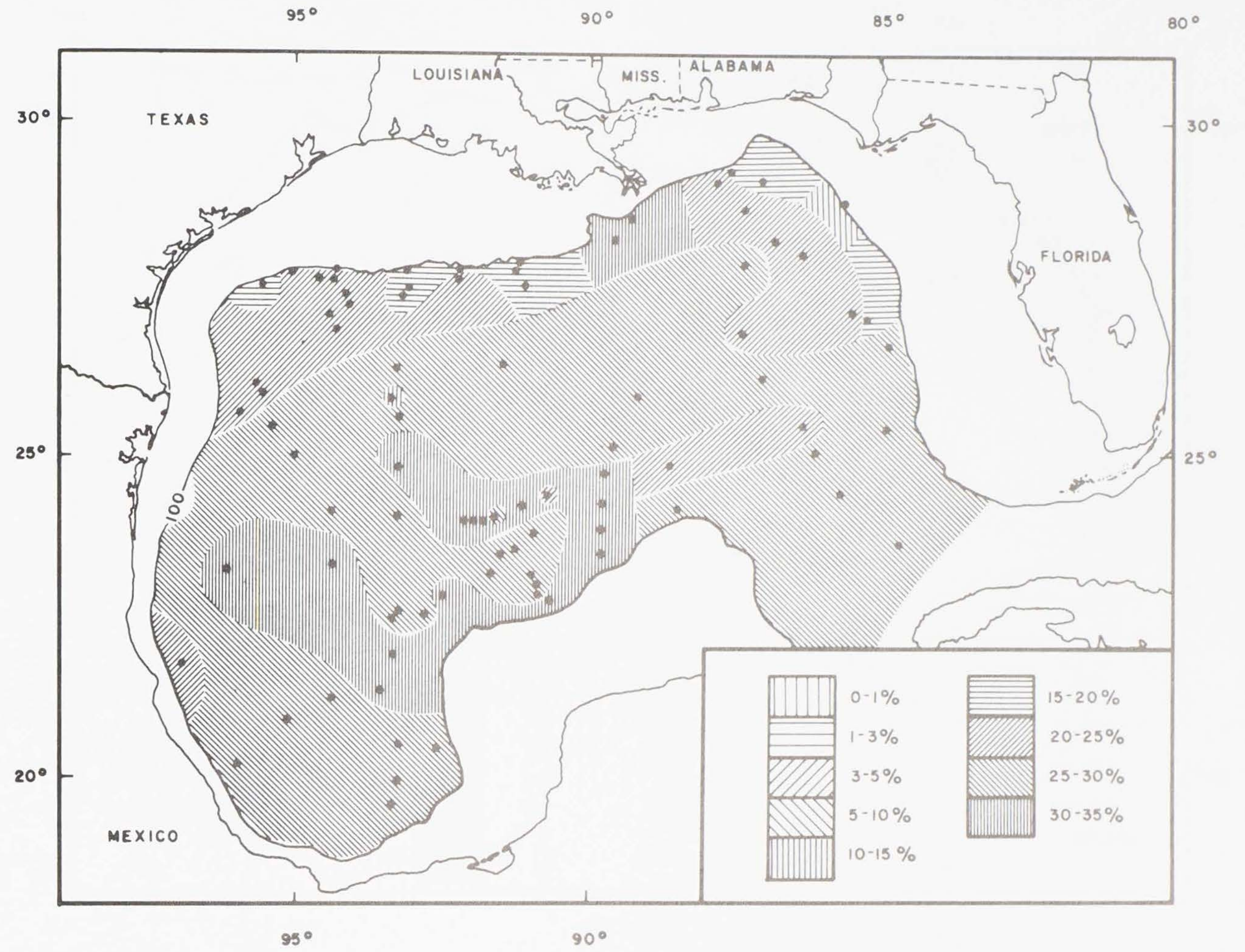

Figure 25. Relative abundance of *Globigerinoides ruber*.

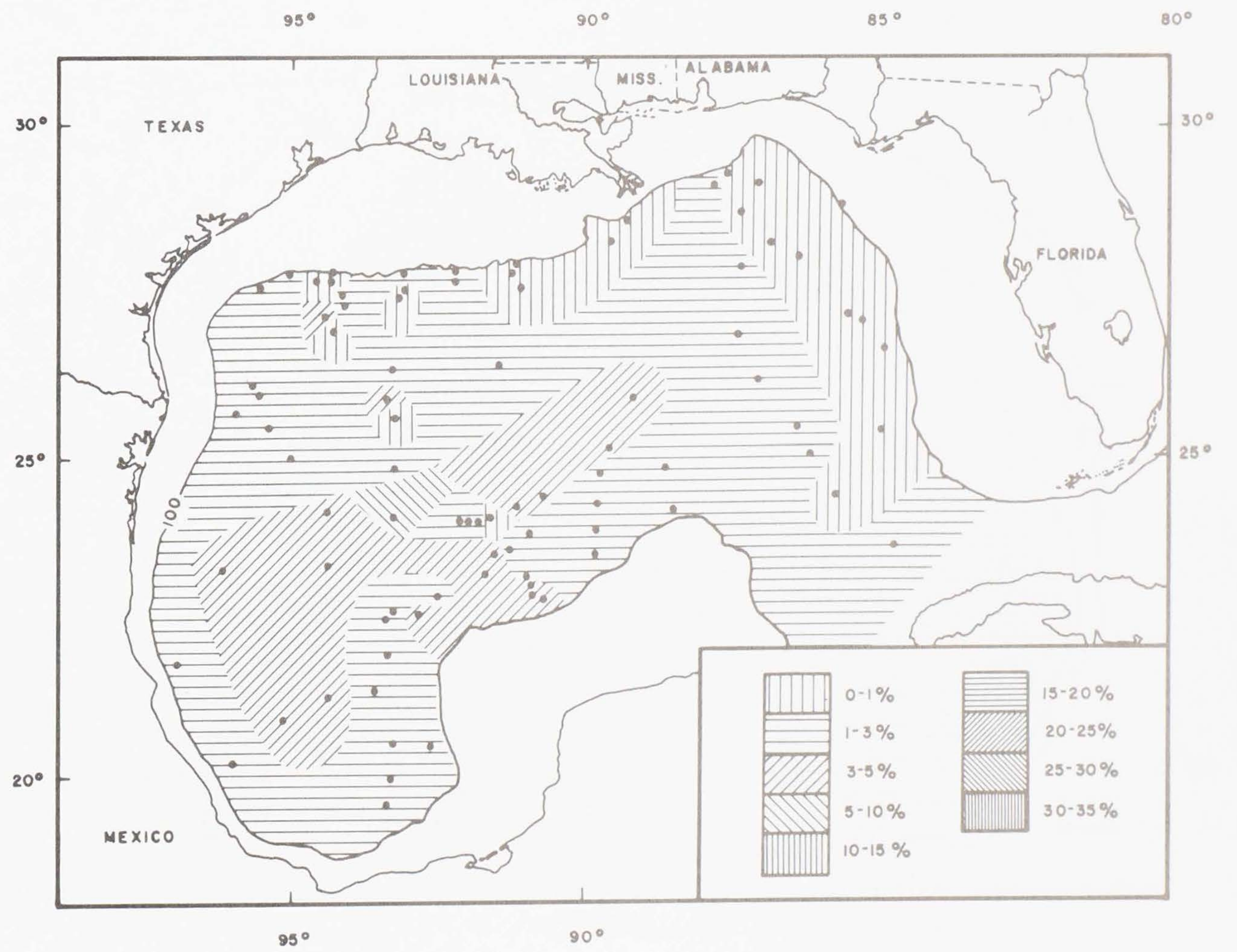

Figure 26. Relative abundance of *Globigerinoides tenellus*.

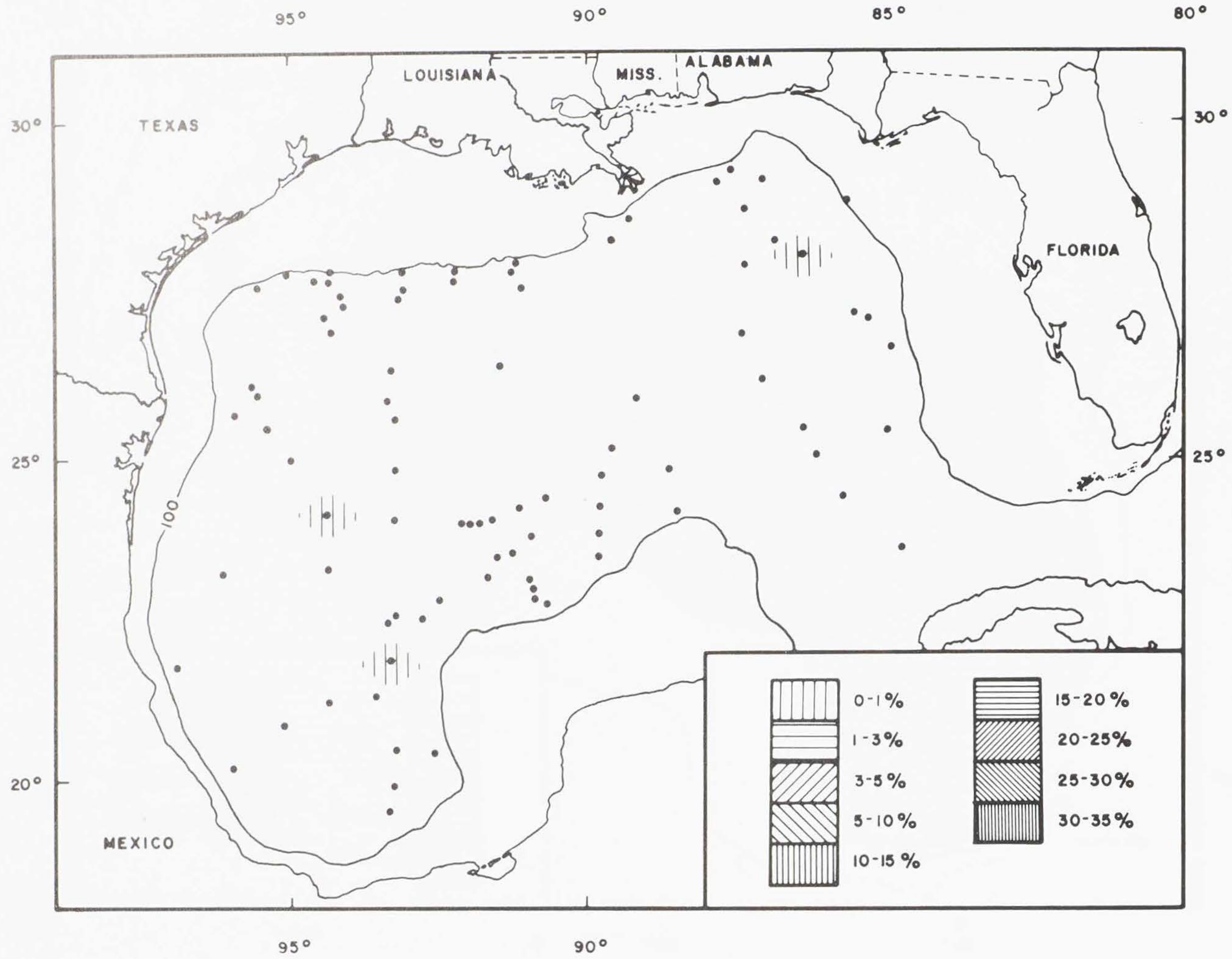

Figure 27. Relative abundance of *Orbulina bilobata.*

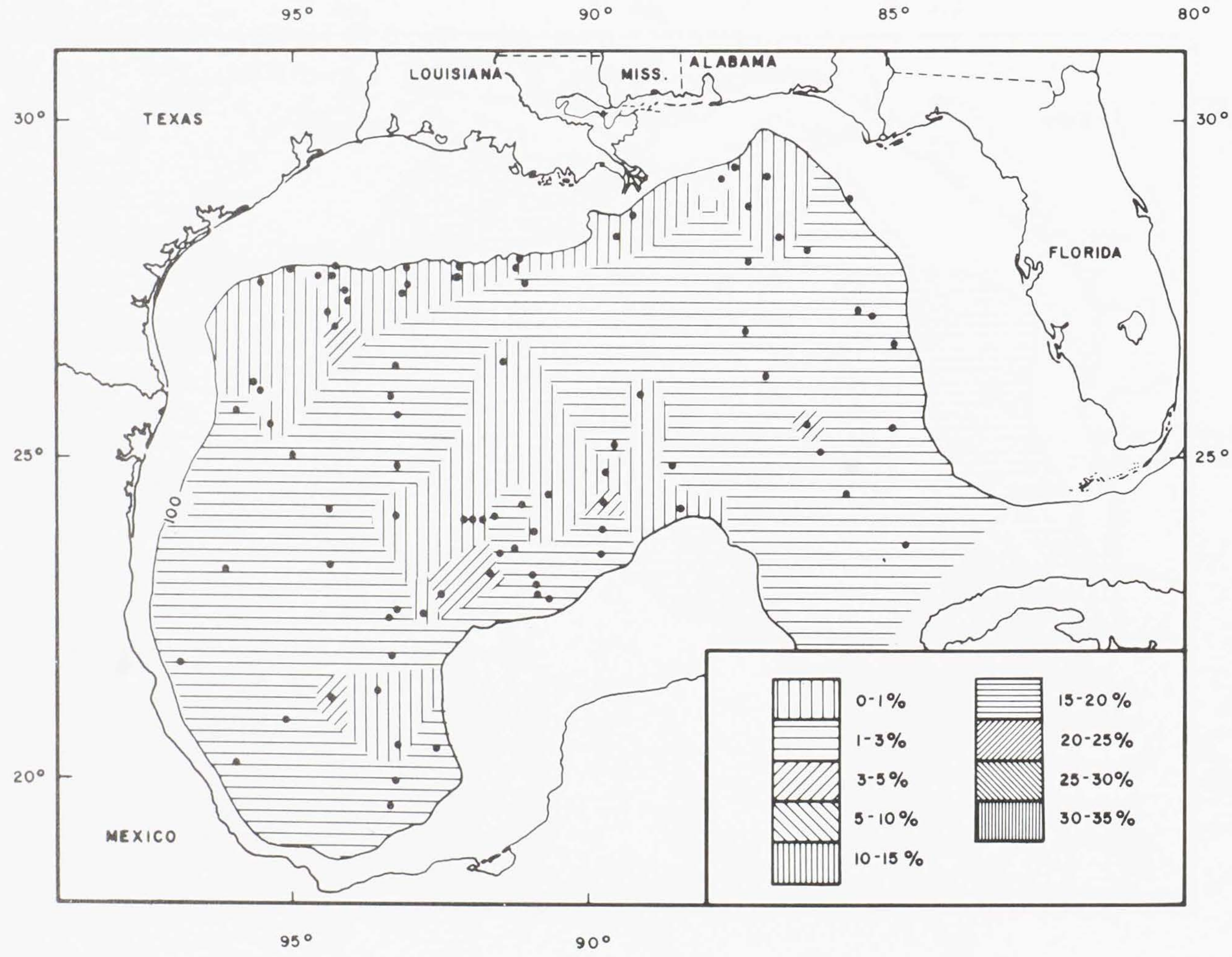

Figure 28. Relative abundance of *Orbulina universa.*

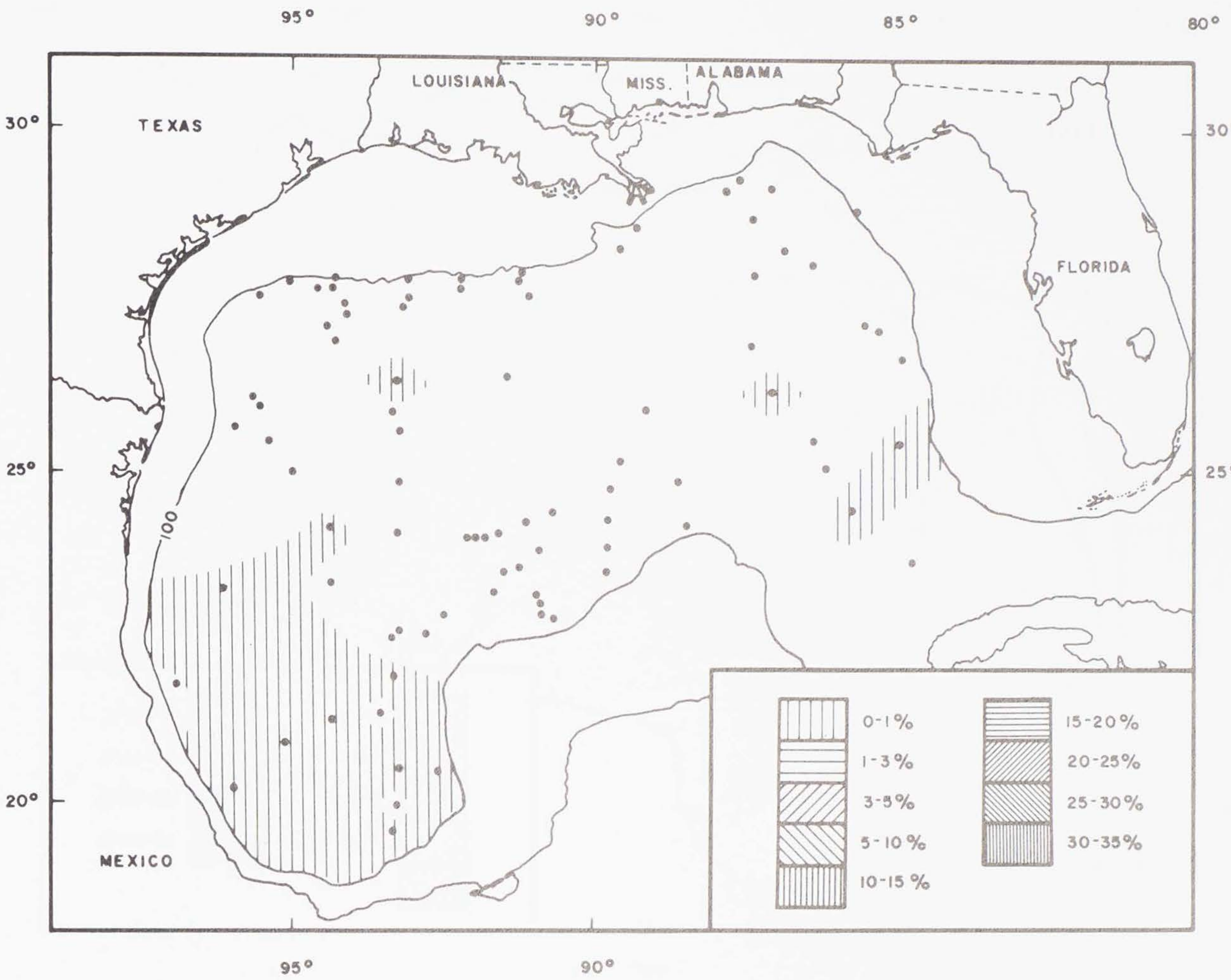

Figure 29. Relative abundance of *Hastigerina pelagica.*

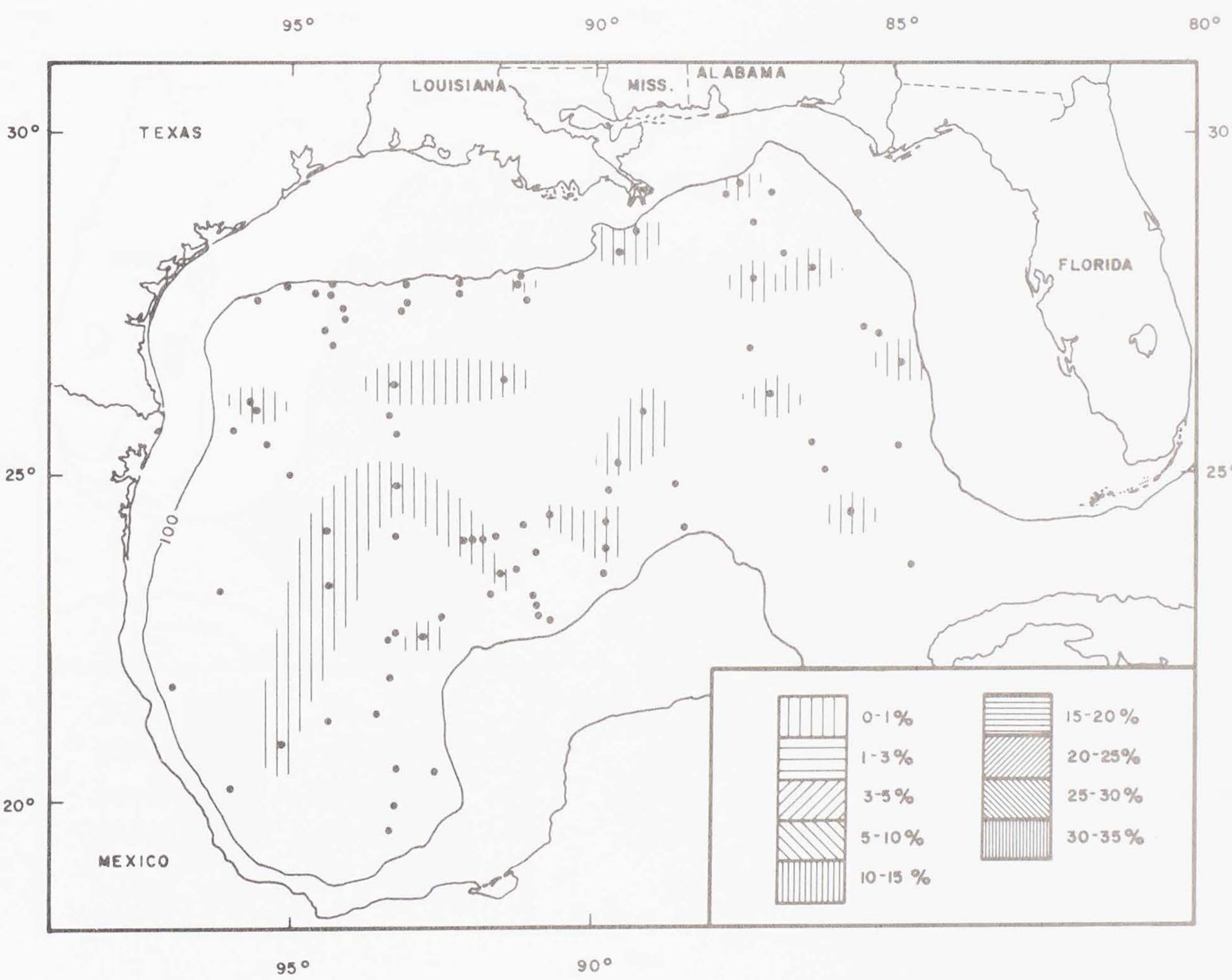

Figure 30. Relative abundance of *Sphaeroidinella dehiscens.*

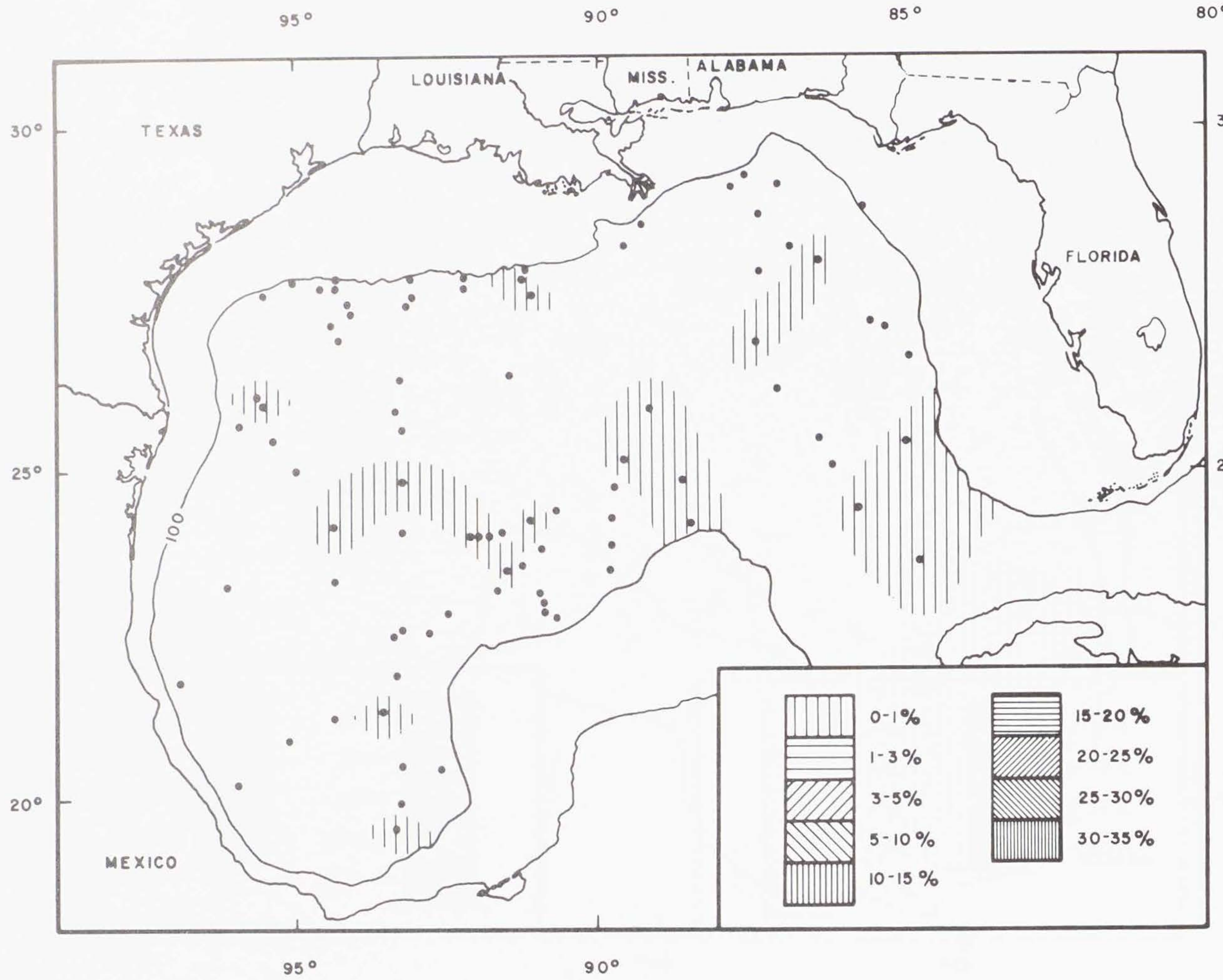

Figure 31. Relative abundance of *Candeina nitida.*

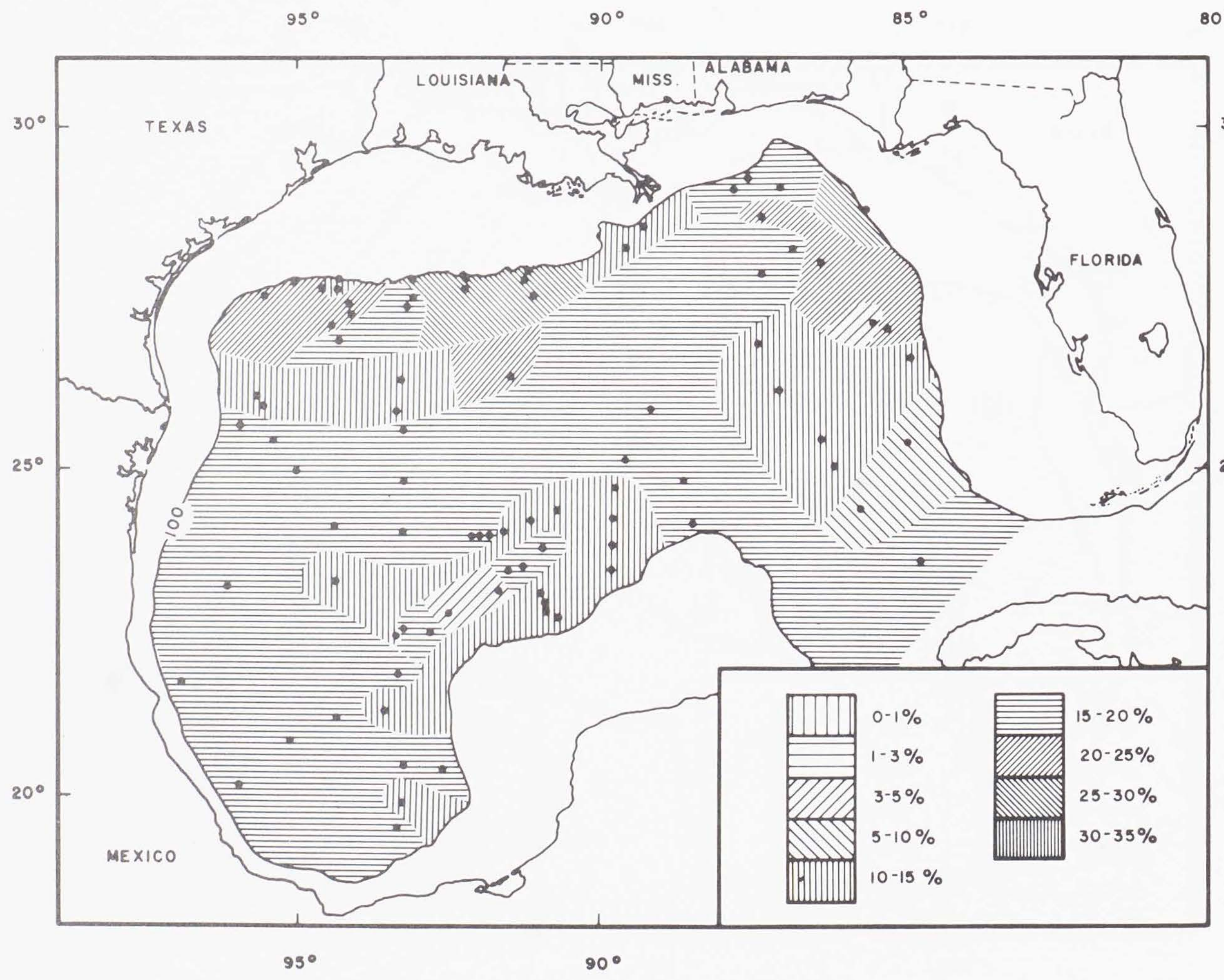

Figure 32. Relative abundance of *Globigerinita glutinata.*

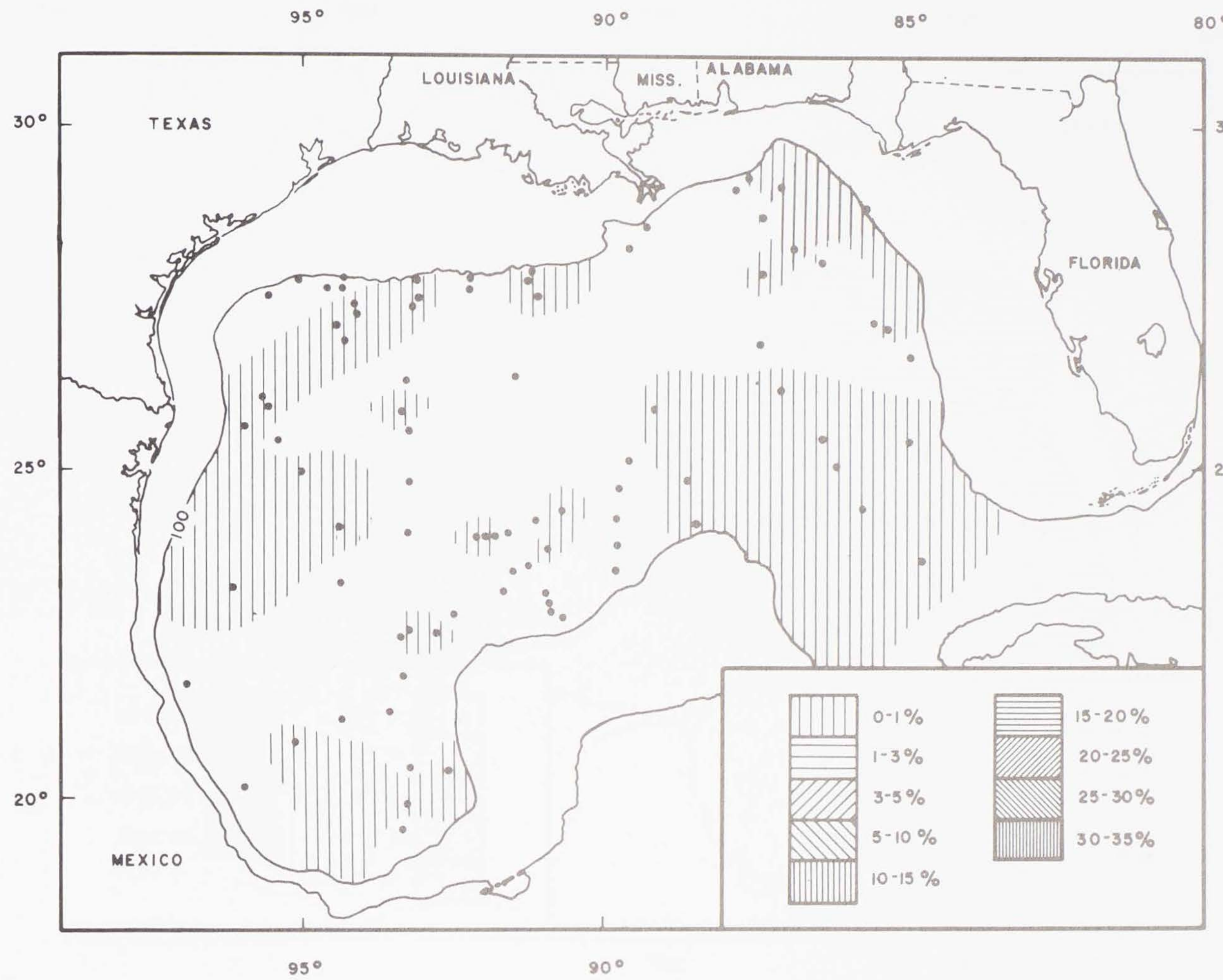

Figure 33. Relative abundance of *Globigerinita iota.*

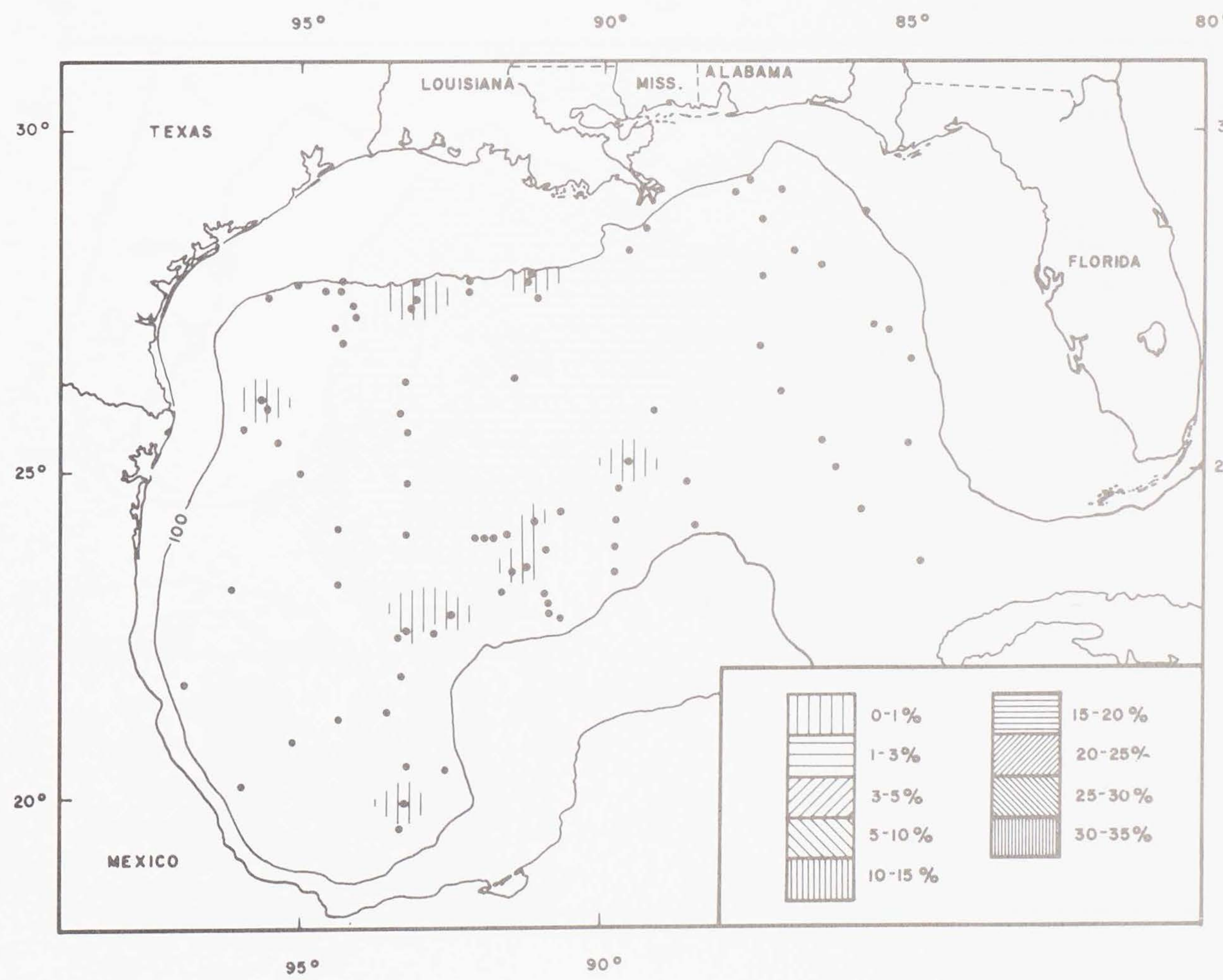

Figure 34. Relative abundance of *Globigerinita uvula.*

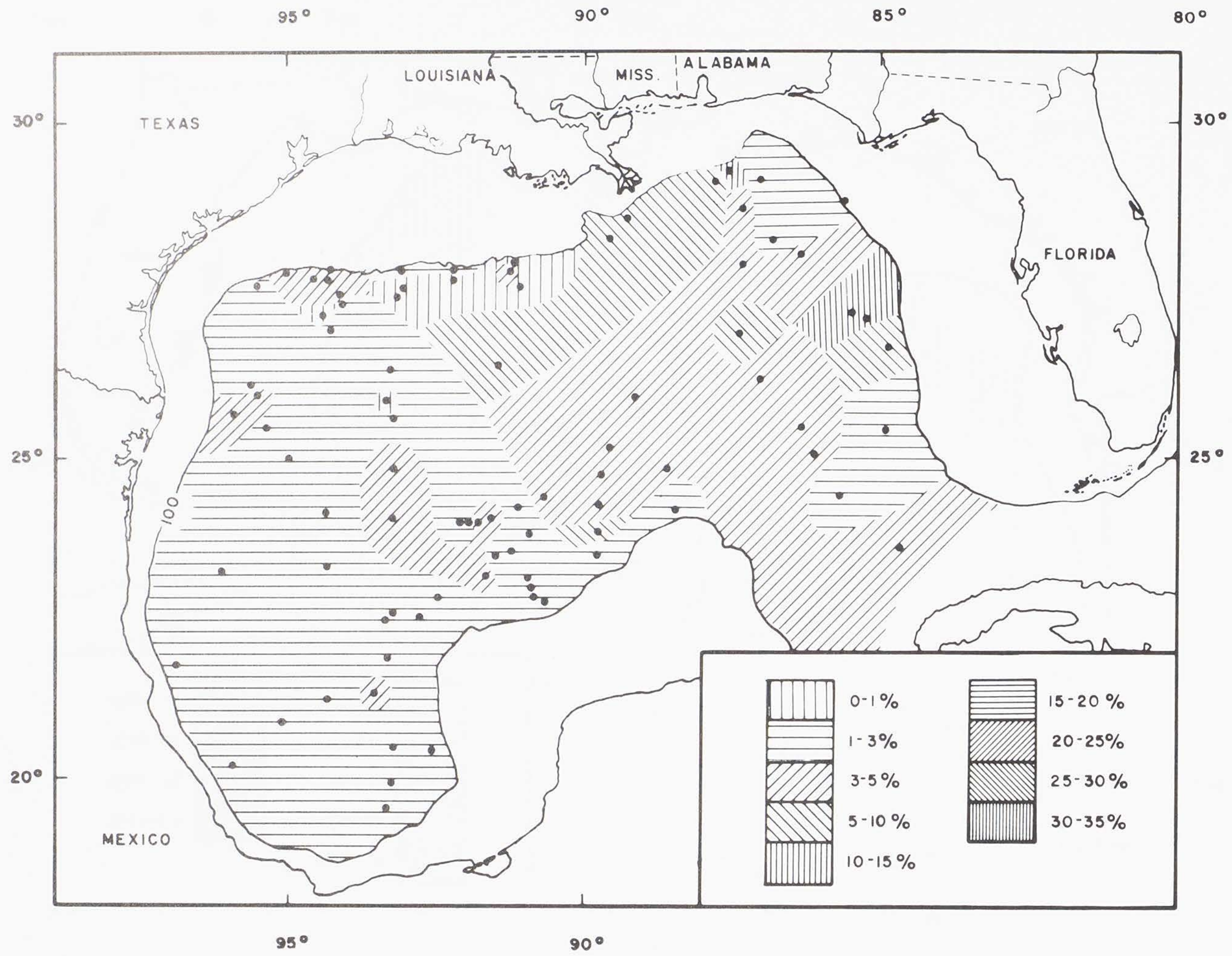

Figure 35. Relative abundance of *Globoquadrina dutertrei.*

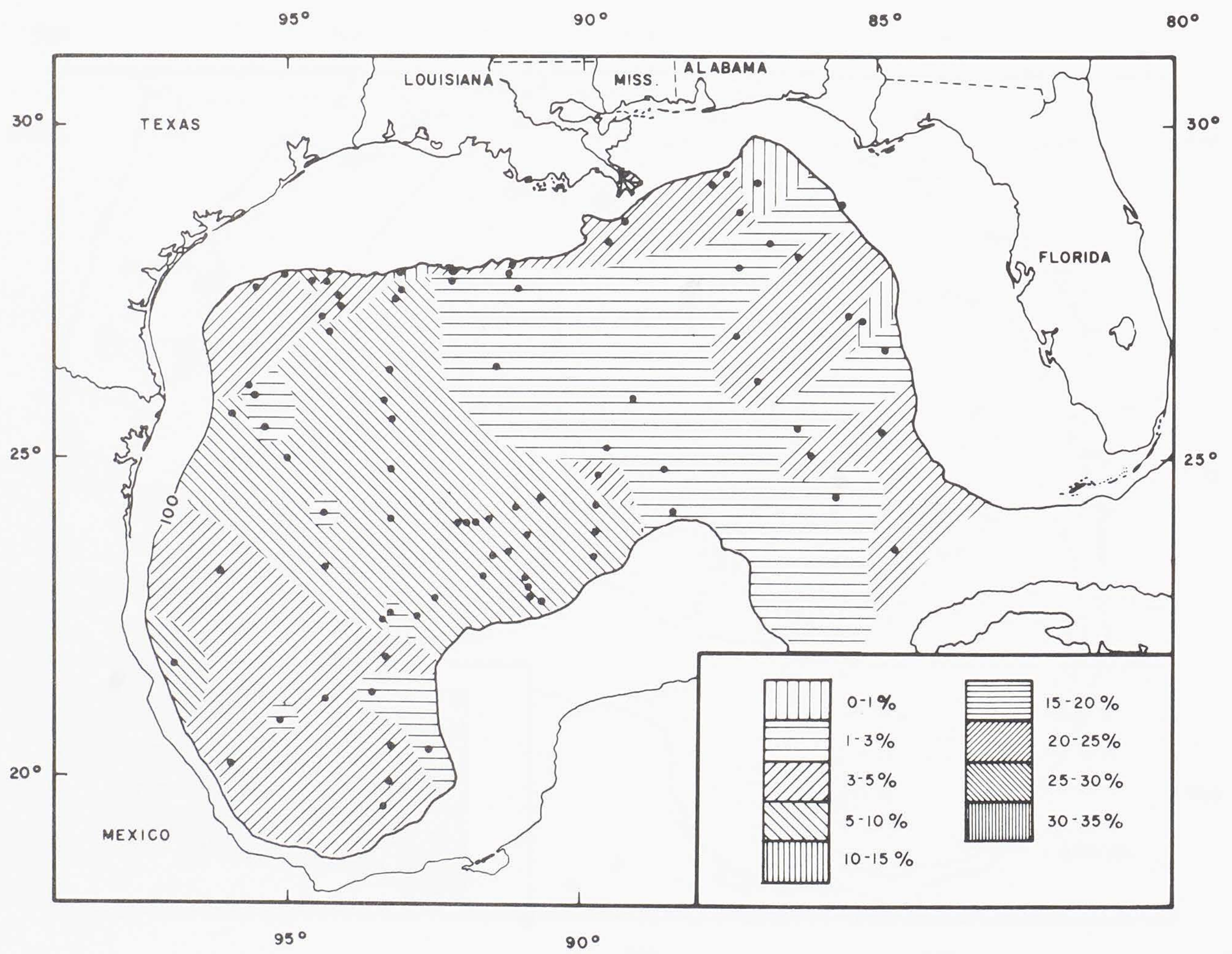

Figure 36. Relative abundance of the *Pulleniatina obliquiloculata* complex.

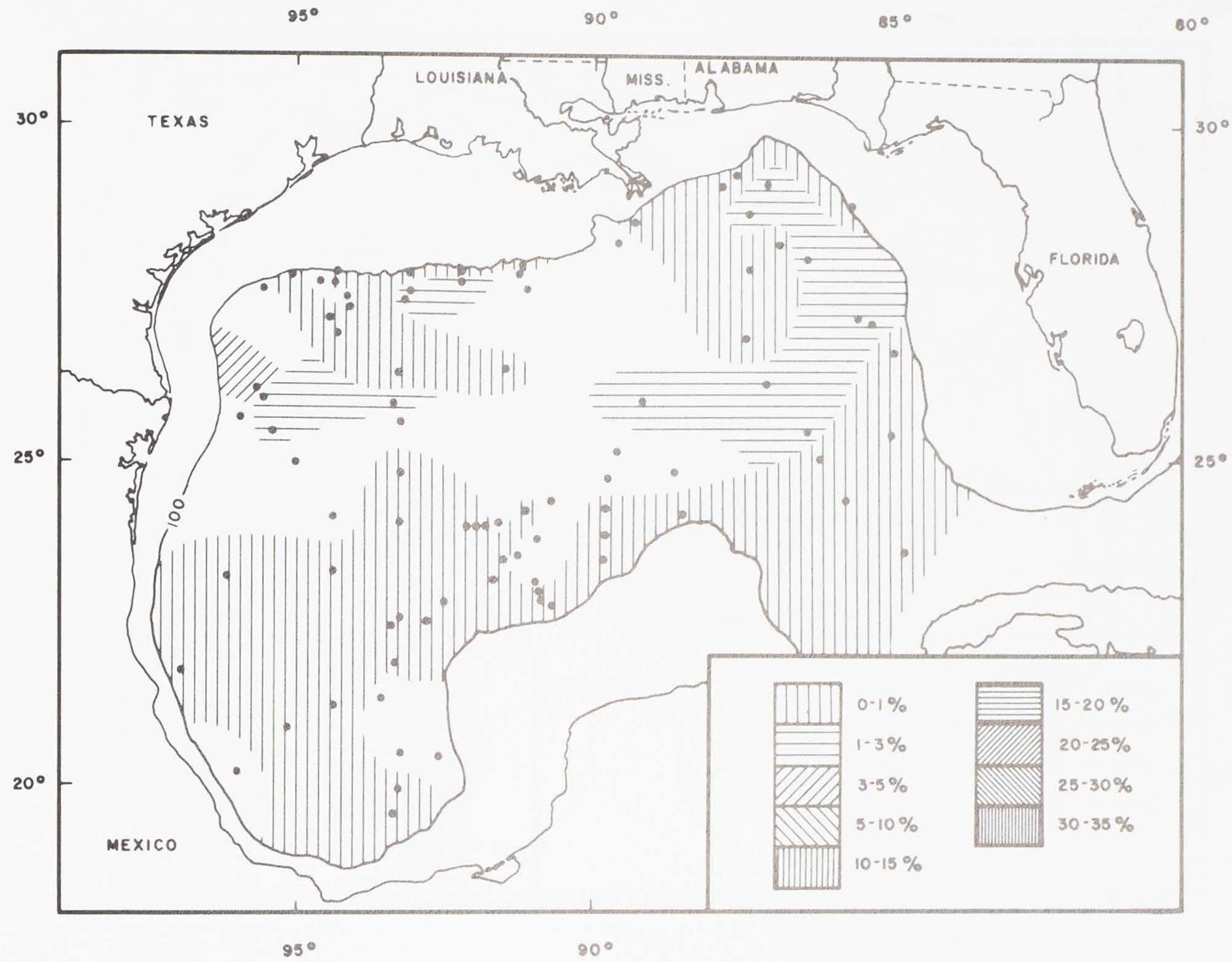

Figure 37. Relative abundance of *Globorotalia crassiformis*.

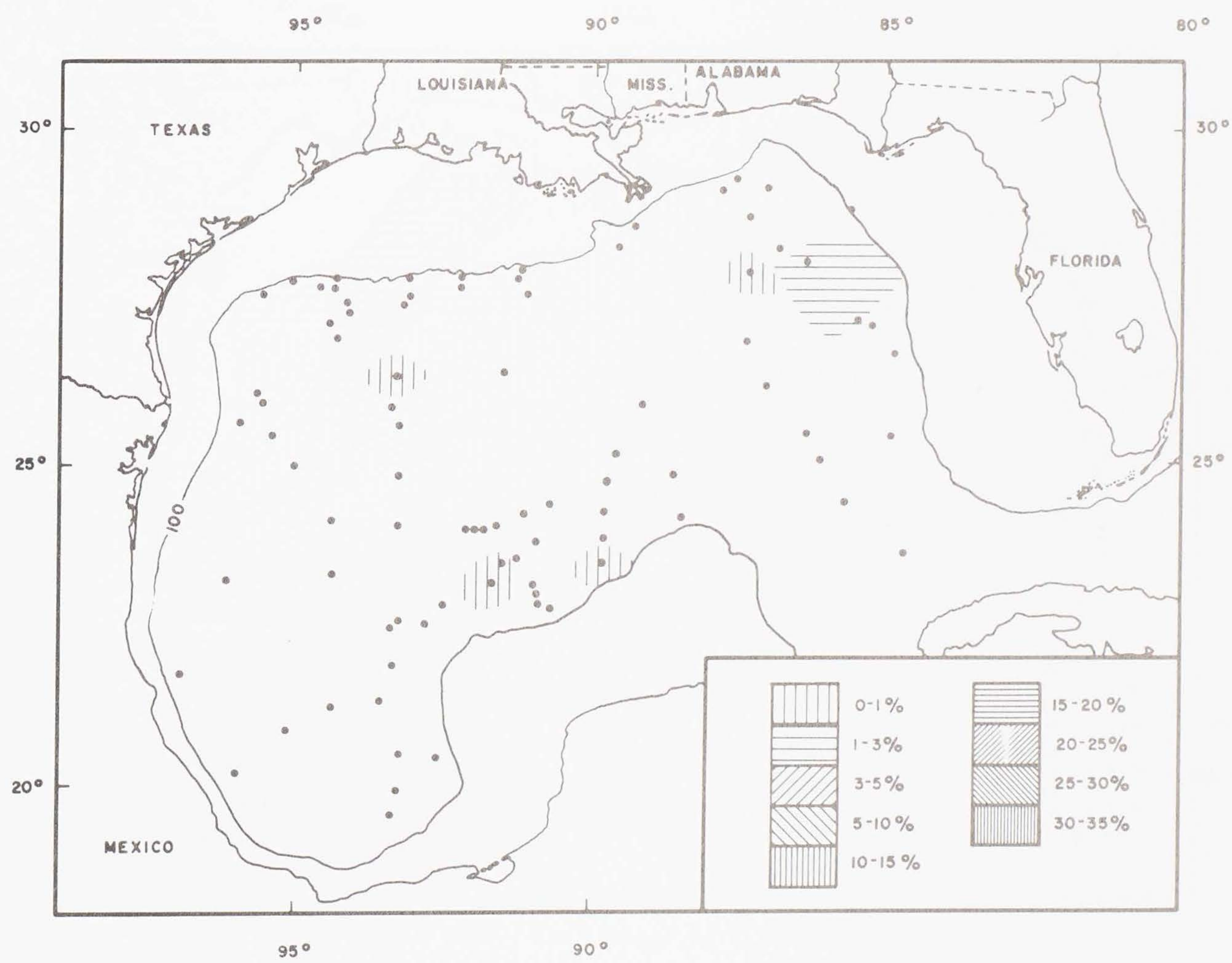

Figure 38. Relative abundance of *Globorotalia flexuosa*.

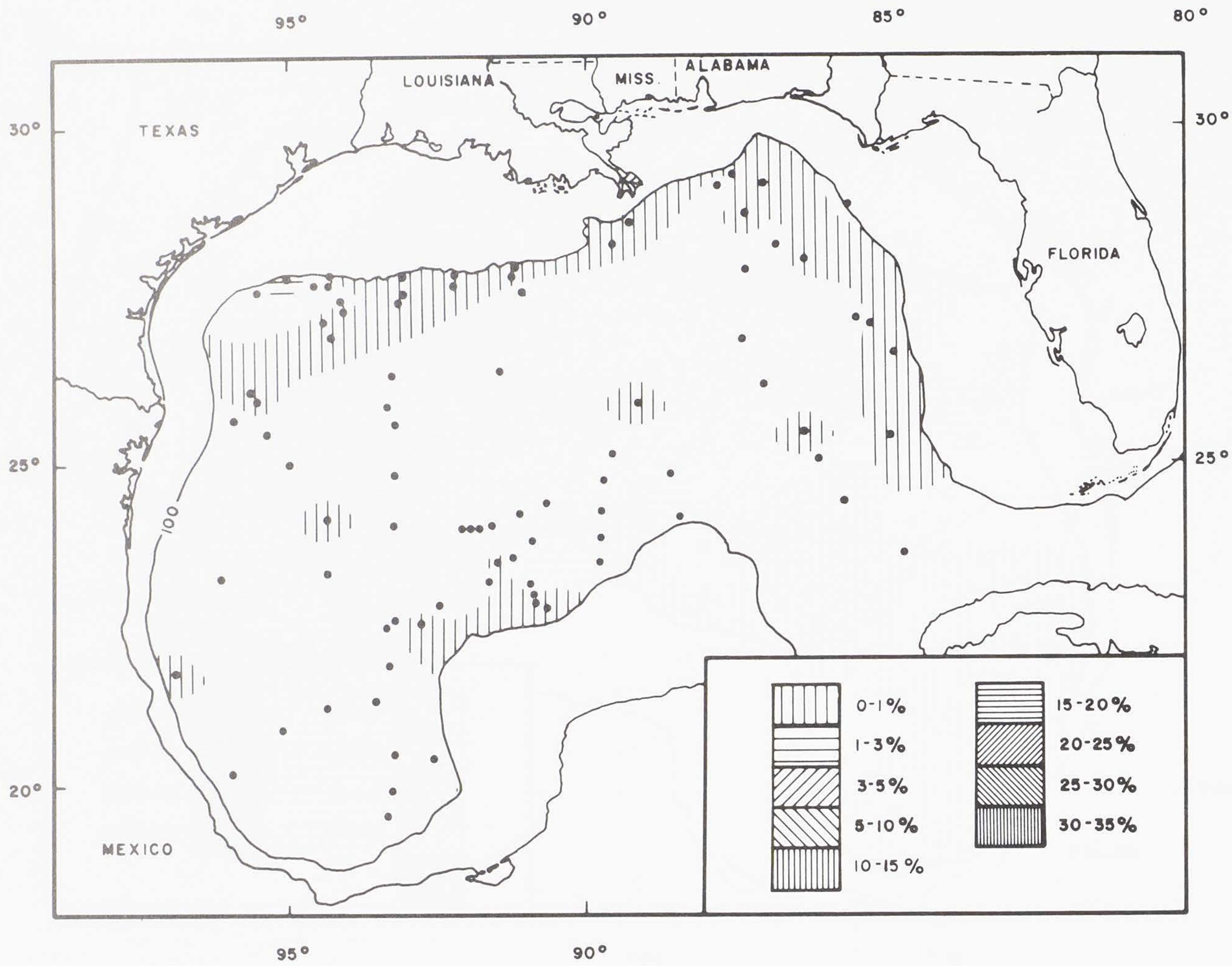

Figure 39. Relative abundance of *Globorotalia hirsuta.*

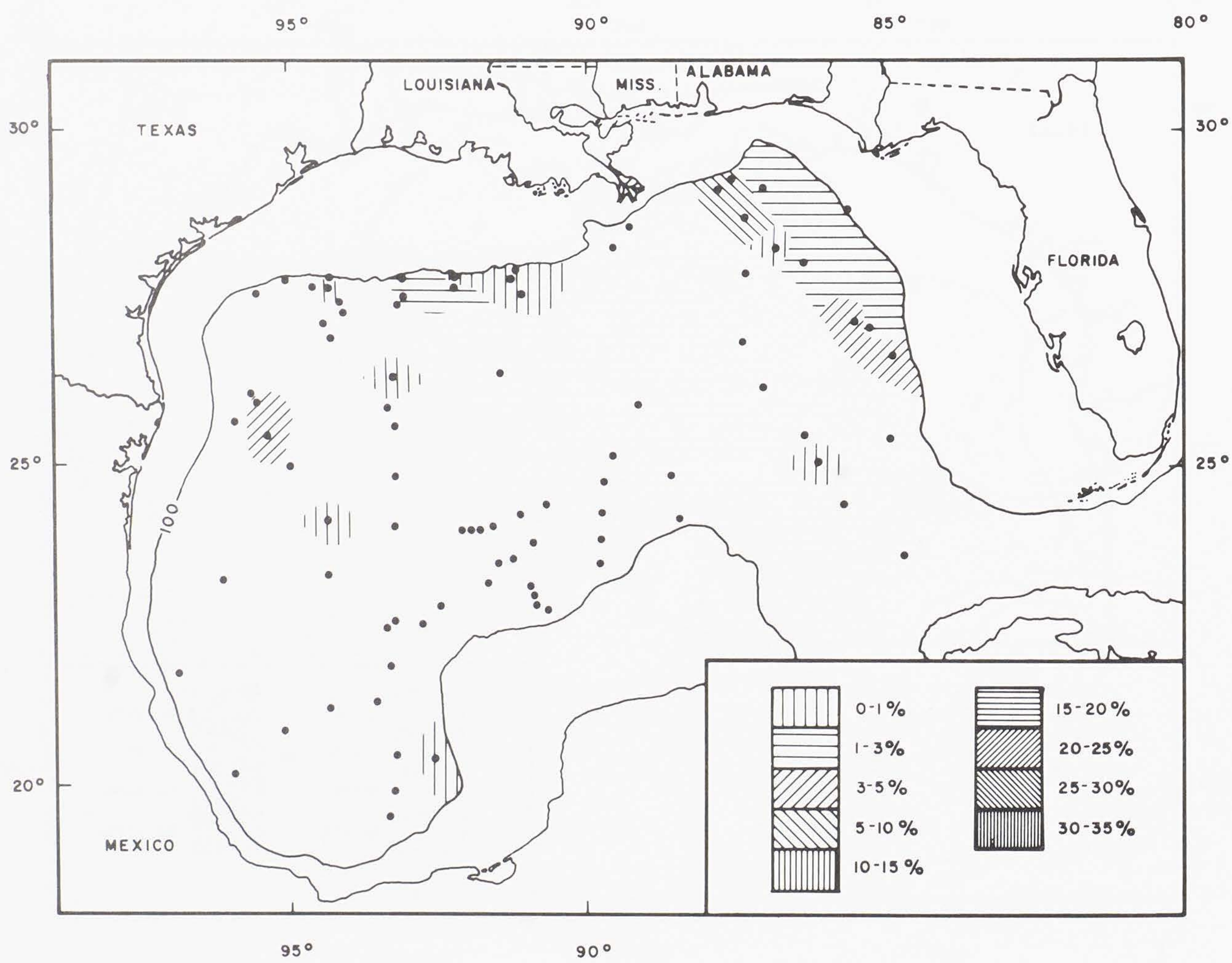

Figure 40. Relative abundance of *Globorotalia inflata.*

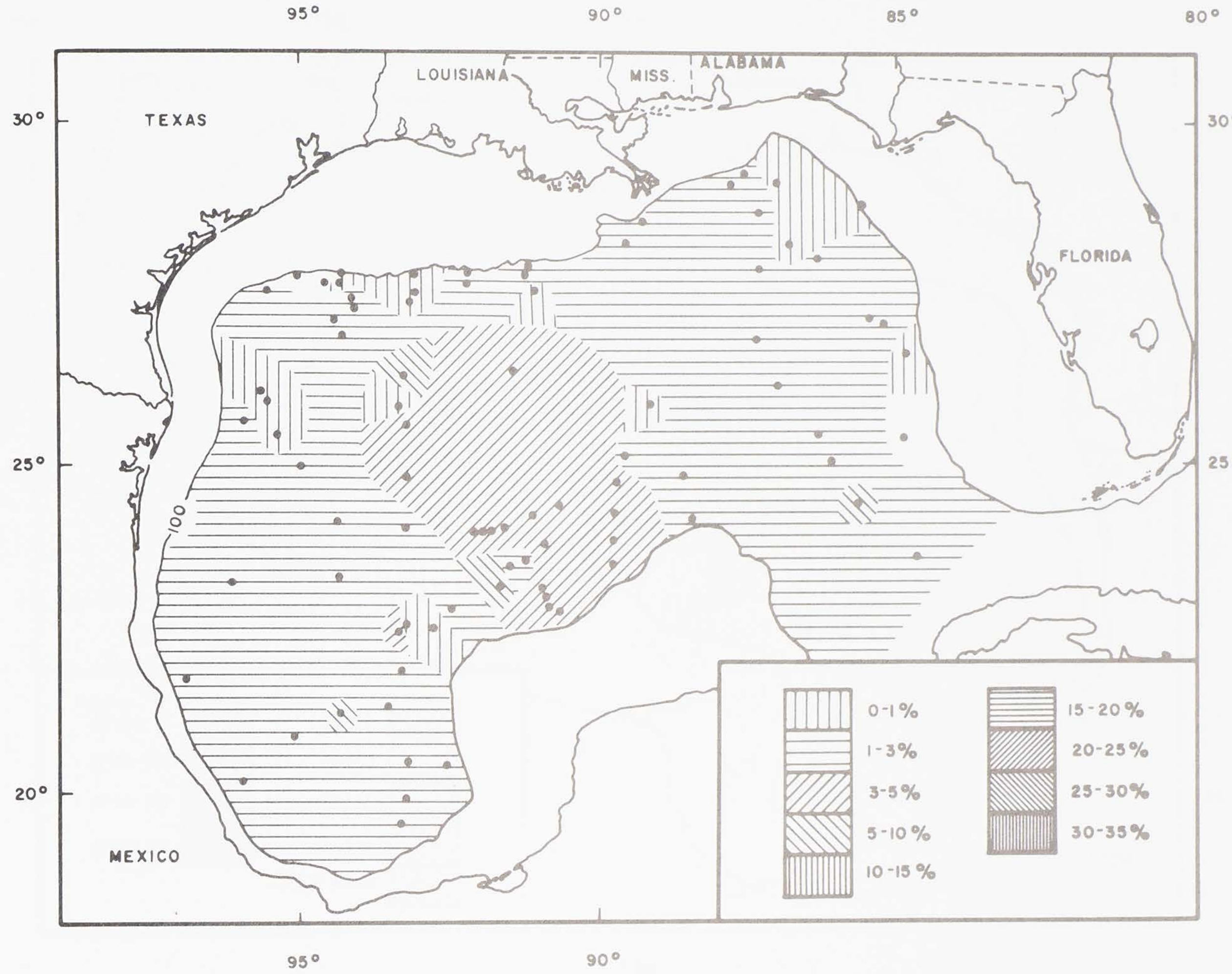

Figure 41. Relative abundance of *Globorotalia menardii.*

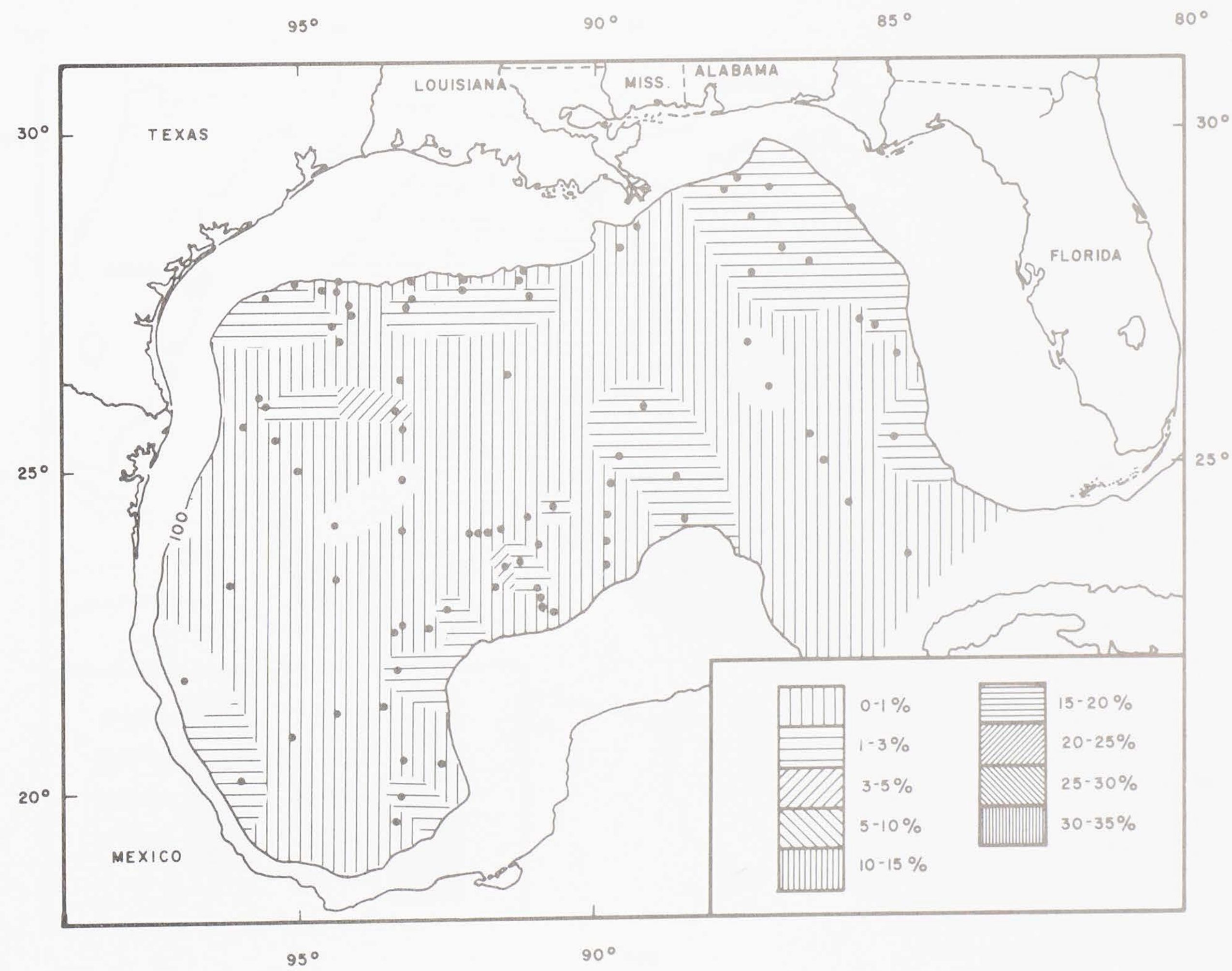

Figure 42. Relative abundance of *Globorotalia scitula.*

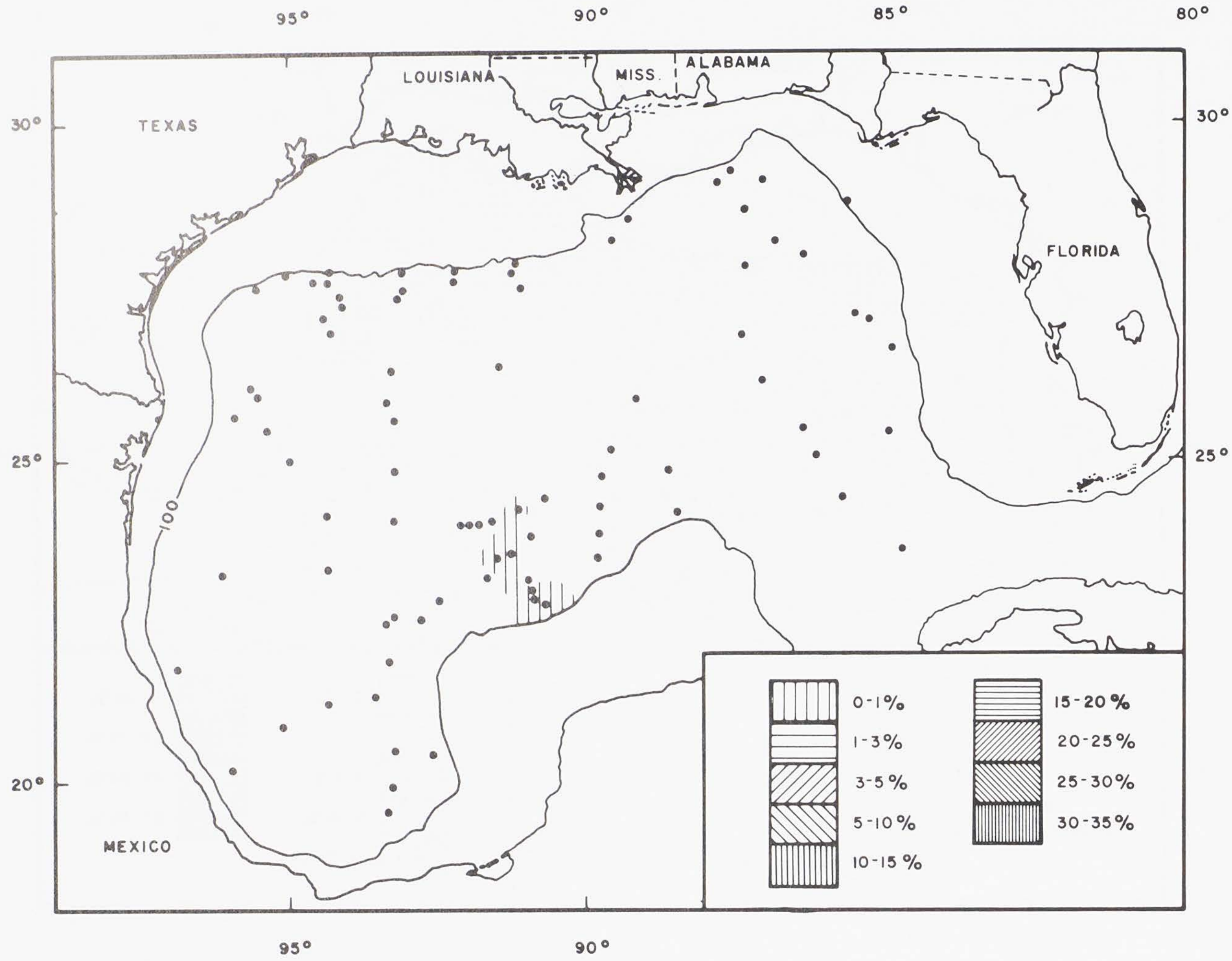

Figure 43. Relative abundance of *Globorotalia akersi.*

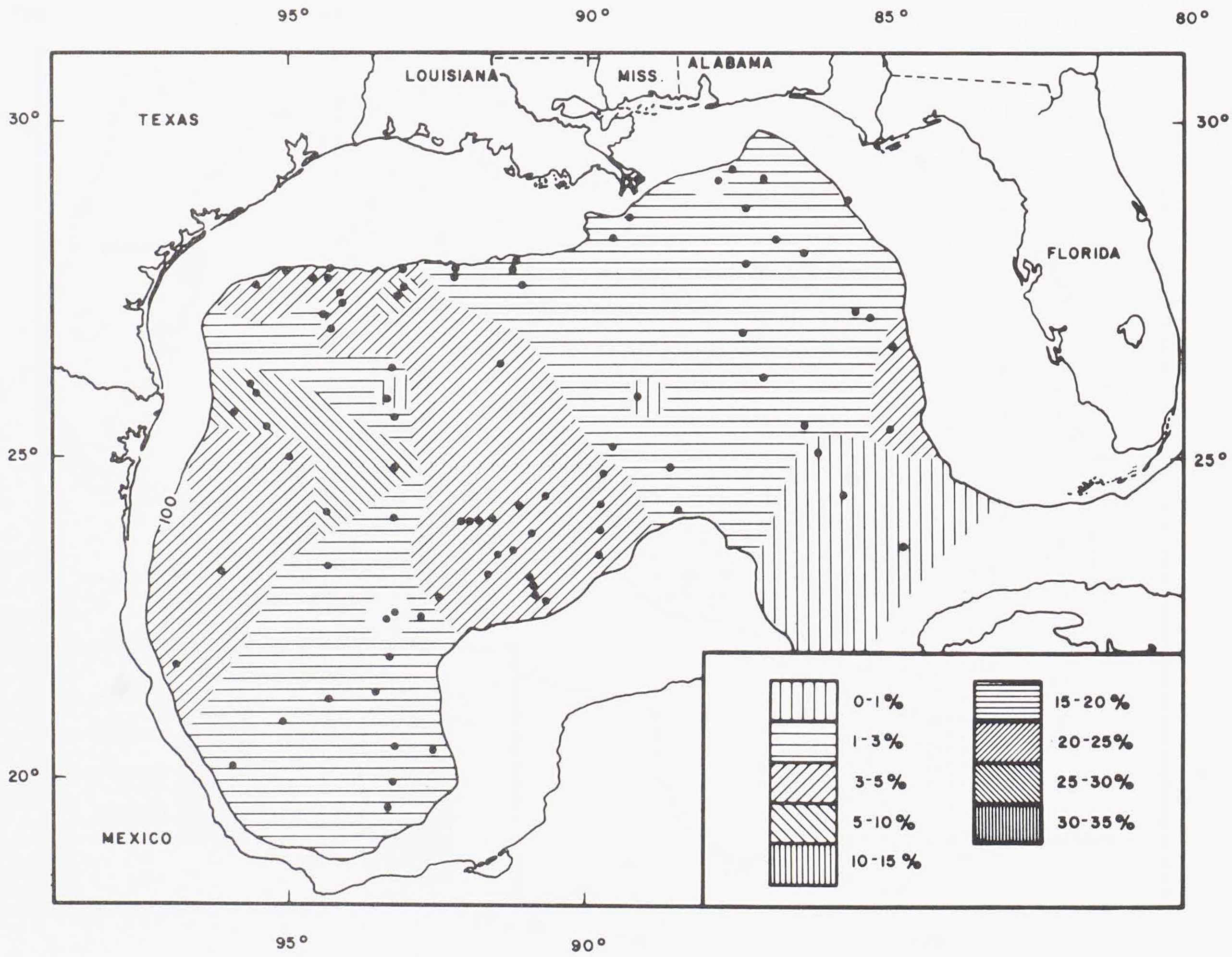

Figure 44. Relative abundance of *Globorotalia truncatulinoides.*

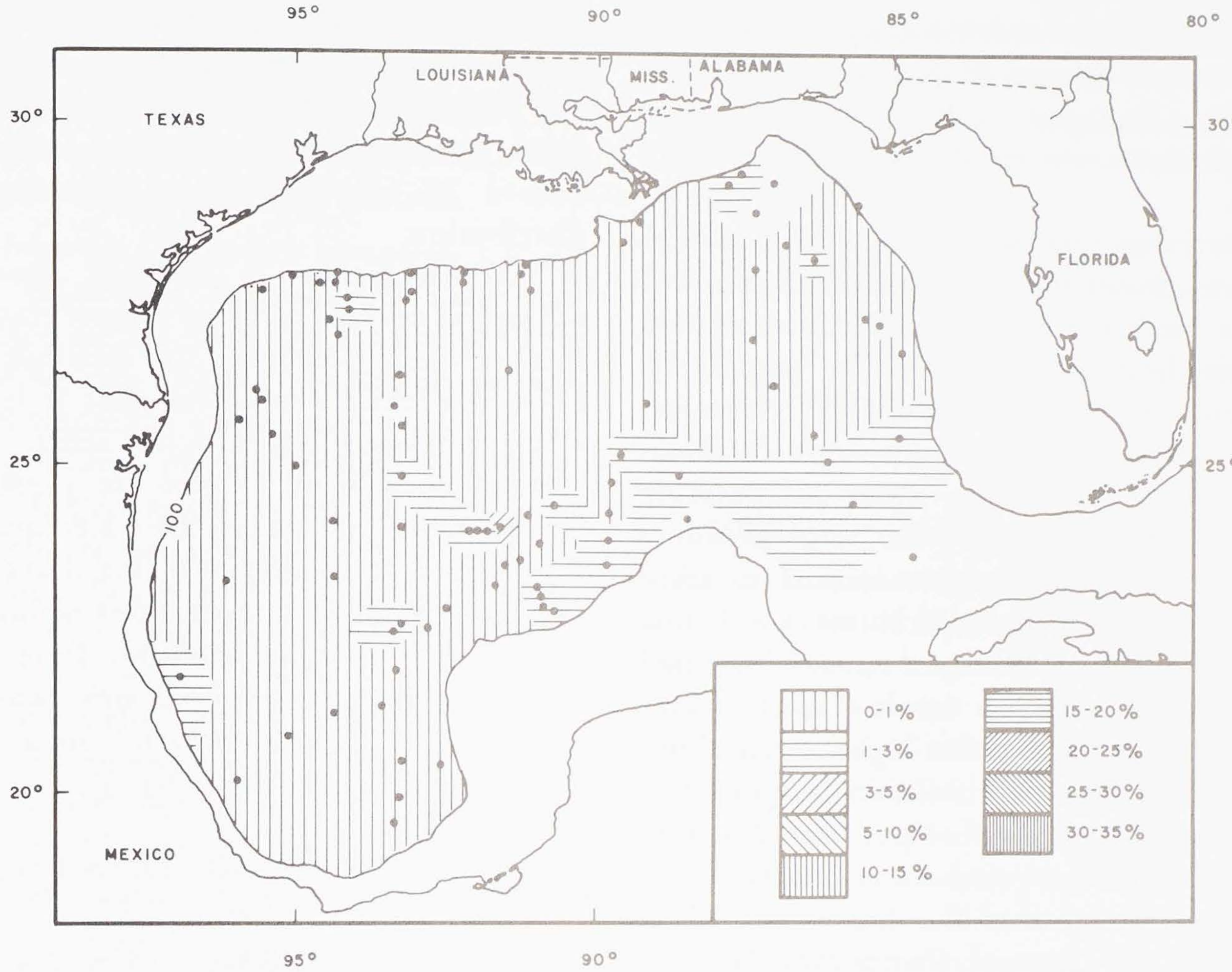

Figure 45. Relative abundance of *Globorotalia tumida.*

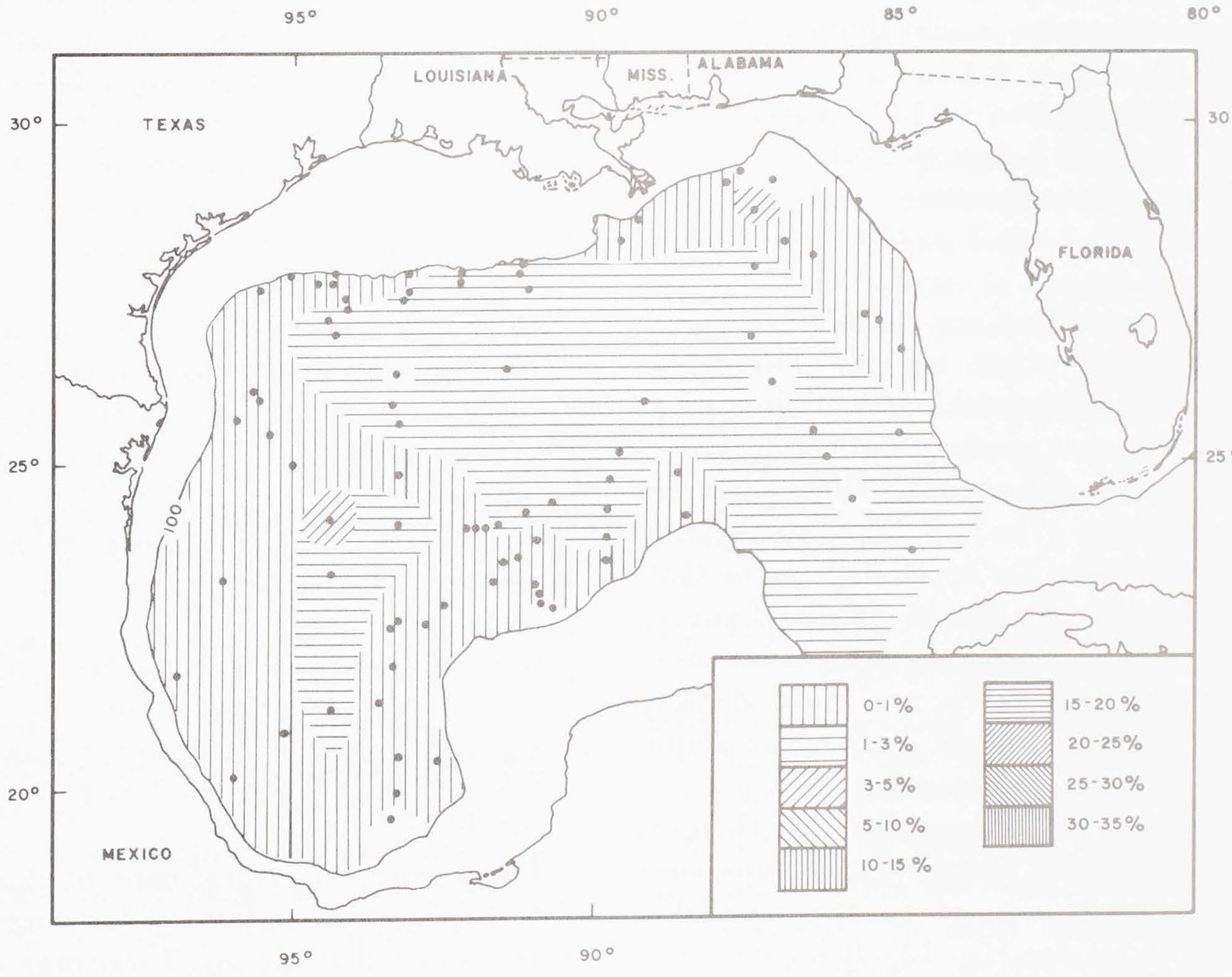

Figure 46. Relative abundance of *Globorotalia ungulata.*

Texas, Louisiana and Mississippi. Also, in a well defined tongue-shaped area extending eastward into the Gulf at approximately 26°N latitude, the relative abundances are 3 to 5%.

The living representatives of this species thrive in water temperatures of 10 to 14°C, depths from the surface to 250 meters, and salinities between 34 and 36 ‰ (fig. 2). Its distributional pattern in the Gulf of Mexico shows a moderate correlation with the distribution of near-surface water temperature values (figs. 3 and 4). Relative abundances greater than 3% are concentrated in areas where the winter temperatures are below 20°C. The tongue-shaped area described above is probably the result of surface currents crossing the areas of high relative abundance of *Globigerina bulloides* from east to west (fig. 6). After being diverted southward, this east to west current system encounters a northward flowing current coming from the Bay of Campeche. The net result is diversion of both currents toward the southeast at a point coincident with the tongue-shaped area of high relative frequencies. The lowest concentrations occur where winter temperatures remain above 23°C.

GLOBIGERINA CALIDA Parker
Plate 2, figures 1-13

Globigerina calida PARKER, 1962, Micropaleontology, vol. 8, no. 2, p. 221, pl. 1, figs. 9-13, 15.

Adult specimens are readily separable from those of other species. The major problem is distinguishing the immature specimens of this species from the young of *Globigerinella siphonifera.* Those features used by Parker (1962, p. 222) to separate these two species are applicable to the Gulf of Mexico material. The chambers of young, trochoid *Globigerinella siphonifera* are more involute and the walls are more densely hispid. The latter feature is the most prominent and is more consistently useful.

Globigerina calida comprises less than 1% of the planktonic foraminiferal fauna over nearly its entire area of occurrence within the Gulf of Mexico (fig. 12). It is consistently present only in the surface sediments of the southern part of the area with occurrences in the northern part few in number and widely scattered. There are several isolated patches where relative abundances exceed 1% in the southern portion of its distribution.

No information is available about the ecological optima of living representatives of this species. However, its distribution in Pacific sediments indicates that it is maximally developed in subtropical areas.

In the Gulf of Mexico its presence is limited to an area where the winter temperature of surface waters remains above 22°C (fig. 3). Summer temperatures would presumably offer no restrictions. It is consistently present only in those areas where the surface water salinity values remain above 36 ‰ during the entire year (fig. 5).

GLOBIGERINA DIGITATA Brady
Plate 1, figures 7-12

Globigerina digitata BRADY, 1879, Quart. Jour. Micro. Sci., (new ser.) vol. 19, p. 286.

Globigerina digitata has a distributional pattern very similar to that of *Globigerina calida* (fig. 13). It is consistently represented in surface sediments only in the southern portion of the Gulf of Mexico. Throughout most of the area it constitutes less than 1% of the planktonic foraminiferal assemblage, but several isolated patches with relative abundances greater than 1% are present in the southern Gulf.

Living specimens of *Globigerina digitata* are found only in the tropical latitudes. Its distribution in surface sediments of the Gulf of Mexico is limited to an area where temperatures remain above 22°C (fig. 3), and where surface water salinity values are always above 36 ‰ (fig. 5).

GLOBIGERINA FALCONENSIS Blow
Plate 3, figures 1-6

Globigerina falconensis BLOW, 1959, Bull. Amer. Paleontology, vol. 39, no. 178, p. 177, pl. 9, figs. 40-41.

The apparent intergradation of this form with *Globigerina bulloides* has been discussed under that species. There may also be a problem in distinguishing some specimens of *Globigerina falconensis* from *Globigerinita glutinata.* The smoother test surface, extraumbilical position of the aperture, and lack of an apertural lip in *Globigerinita glutinata* serve as distinguishing features.

Globigerina falconensis comprises 1 to 3% of the planktonic foraminiferal assemblage in surface sediments throughout most of the Gulf of Mexico (fig. 14). Scattered, isolated patches where the concentration is below 1% occur primarily in the southern part of the region. Concentrations ranging between 5 and 10% are present along the continental slope off Texas and Louisiana. Relative abundances of 3 to 5% occur most commonly in the northern portions, but isolated areas within this range of percentages occur in the western and central Gulf.

The optimum temperature and salinity ranges for living representatives of this species are similar to those of *Globigerina bulloides.* It thrives under conditions only slightly warmer than those that are optimum for the latter species.

High relative abundances of *Globigerina falconensis* (fig. 14) correspond to the area in which winter temperatures at the surface of the overlying water mass are below 20°C (fig. 3). Surface current systems modify this pattern in one isolated area, near 26°N latitude, where high relative abundances (those above 3%) occur. This area is elongated to the east and owes its existence to the current system described under *Globigerina bulloides.*

A variant of *Globigerina falconensis* with a reduced final chamber has high relative abundances (fig. 15) in the area in which winter and spring temperatures at a depth of 100 meters are below 20°C (fig. 4). A prominent zone with relative abundances below 3%, and extending from the southeastern extremity of the study area to the continental slope off western Louisiana, results from warmer water introduced by surface currents (fig. 6).

Both forms of this species are moderately susceptible to solution. However, effects are recognizable only at those stations characterized by high amounts of solution.

GLOBIGERINA PACHYDERMA (Ehrenberg)
Plate 4, figures 1-5

Aristerospira pachyderma EHRENBERG, 1861, K. Preuss. Akad. Wiss. Berlin, Monatsber., pp. 276, 277, 303.

The chambering makes this species easily distinguishable from other species of the genus, except for some particularly robust specimens of *Globigerina quinqueloba.* However, the surface texture of the latter species is much less densely and less coarsely hispid.

Globigerina pachyderma, except for a few widely scattered and rare occurrences in the southern Gulf of Mexico, is found only in the northern part of this region where it generally constitutes less than 1% of the planktonic foraminiferal fauna (fig. 16). Only in an area of the western Gulf, at approximately 26°N latitude, and an area along the continental slope off Alabama and Florida do relative abundances exceed 1%.

Only dextral specimens of *Globigerina pachyderma* are present in surface sediments of the Gulf of Mexico. Although they tolerate a wide range of temperatures, the optimum range of dextral forms is 11 to 15°C. The optimum salinity and depth ranges are 34.5 to 35 ‰ and 0 to 300 meters, respectively (fig. 2).

Distributional patterns in surface sediments can be correlated with the distribution of surface water temperature and salinity values. The species is present only where surface water temperatures are less than 19°C during winter (fig. 3). In this area, water temperature at a depth of 100 meters remains below 19°C during the entire year, and salinity values range only from 34 to 35 ‰ (figs. 4 and 5).

GLOBIGERINA QUINQUELOBA Natland
Plate 4, figures 6-12

Globigerina quinqueloba NATLAND, 1938, Calif. Univ., Scripps Inst. Oceanography, Tech. Ser., vol. 4, no. 5, p. 149, pl. 6, fig. 7.

Although the specimens of *Globigerina quinqueloba* from the Gulf of Mexico may not represent the most common phenon within the species (Parker, 1962, p. 225;

Boltovskoy, 1969, p. 250), it is distinct from other species within the study area. The less densely hispid test serves to distinguish it from *Globigerina pachyderma*, a species with which it may be confused in materials collected from higher latitudes.

Globigerina quinqueloba constitutes 5 to 10% of the planktonic foraminiferal assemblage in surface sediments throughout most of the Gulf of Mexico (fig. 17). In a large region in the south-central portion of the Gulf concentrations range from less than 1% up to 5%. In a few isolated areas (at or near the edge of the continental slope) off Florida, Louisiana, Texas, and Yucatan the relative abundance of this species reaches 10 to 15% of the total assemblage. In two areas along the upper continental slope, directly opposite of the Apalachicola and Sabine rivers, concentrations reach 15 to 20%.

Various authors estimate the temperature range within which *Globigerina quinqueloba* flourishes at 12 to 15°C. It thrives in salinities of 34.5 to 35 ‰ and occurs from the surface to a depth of 250 meters (fig. 2). This species lives mostly in cold-temperate waters, but occurs over a wide range of latitudes.

The distributional pattern of *Globigerina quinqueloba* does not correspond with the distribution of temperature and salinity values in surface waters of the Gulf of Mexico. Relative abundances of 15 to 20% occur in areas where water temperatures at a depth of 100 meters are below 20°C during most of the year (fig. 4). However, concentrations of 5 to 10% are present in areas where temperatures at this depth are quite variable.

Areas with low relative abundances may be largely the product of surface current systems (fig. 6). These areas have little circulation, and it may be that *Globigerina quinqueloba* is more severely limited by lack of circulation than by temperature requirements.

GLOBIGERINA RUBESCENS Hofker
Plate 4, figures 13-16

Globigerina rubescens HOFKER, 1956, Copenhagen Univ., Zool. Mus., Spolia, vol. 15, p. 234, pl. 35, figs. 18-21.

Globigerina rubescens is easily separated from other species, except for specimens of *Globigerinoides tenellus* in which the secondary aperture at the base of the final chamber is filled with sediment and cannot be discerned. The great similarity in chambering of these species makes determining the presence or absence of the secondary aperture critical. Additional cleaning is often necessary to make accurate species identification. Immature specimens of *Globigerinoides ruber* with four chambers in the peripheral whorl may resemble *Globigerina rubescens*, which has a more restricted aperture, a more finely hispid wall, and more spherical chambers than *Globigerinoides*

PLATE 1

Figures — Page

1-6. *Globigerina bulloides* d'Orbigny (X200) 15
- 1. Umbilical view; Station 55
- 2. Umbilical view; Station 55
- 3. Umbilical view; Station 55
- 4. Umbilical view; Station 53
- 5. Spiral view; Station 53
- 6. Umbilical view; Station 24

7-12. *Globigerina digitata* Brady (X100) 34
- 7. Umbilical view; Station 46
- 8. Spiral view; Station 46
- 9. Edge view; Station 46
- 10. Umbilical view; Station 46
- 11. Umbilical view; Station 46
- 12. Oblique view; Station 46

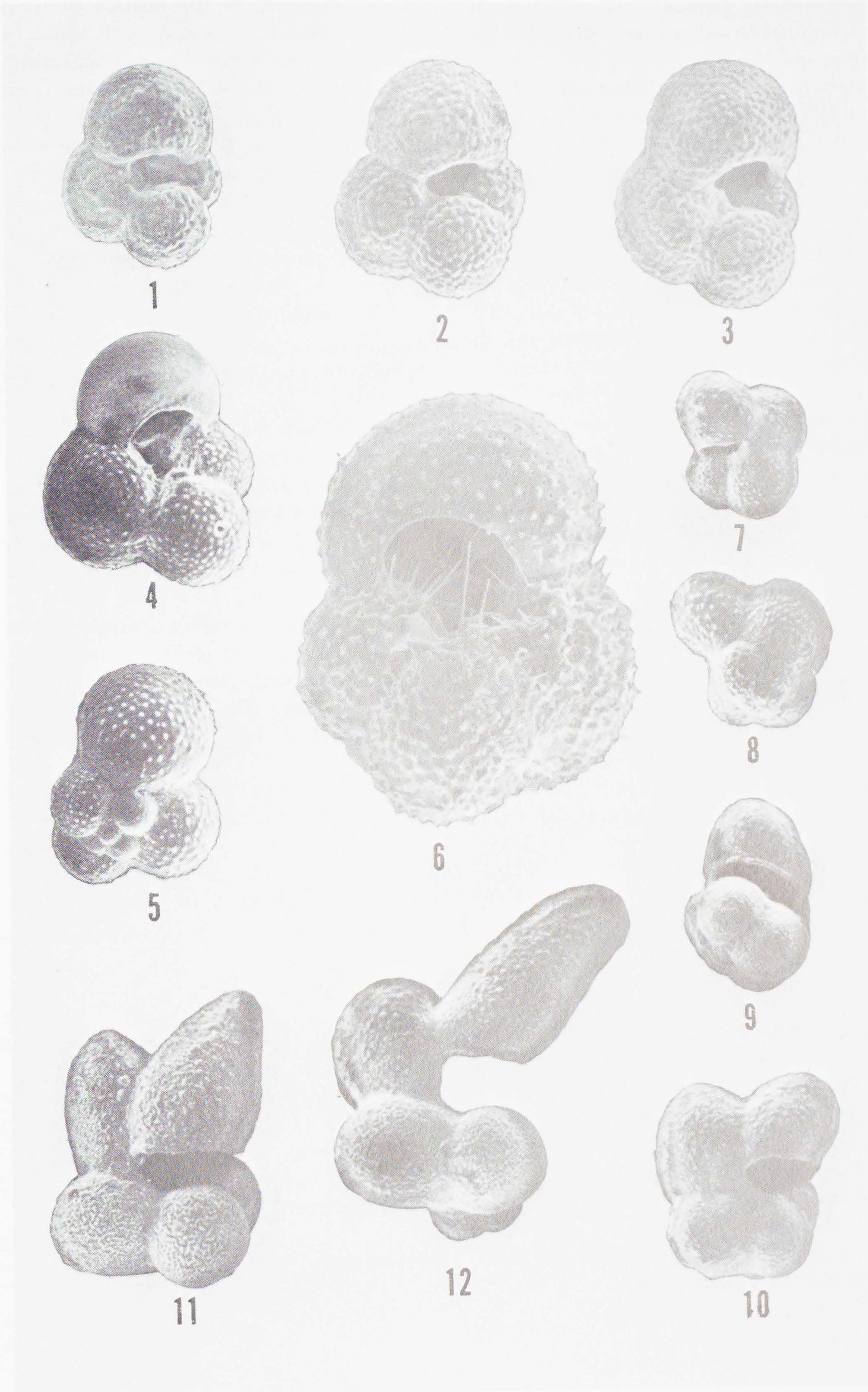

PLATE 1

ruber. The nearly diamond-shaped outline of *Globigerina rubescens* is useful in separating these two species.

Globigerina rubescens constitutes 5 to 10% of the planktonic foraminiferal assemblage throughout nearly the entire study area (fig. 18). In only a few isolated patches is the relative abundance below 5%. These patches are located along the continental slope in the northern Gulf of Mexico and in its west-central portions. Restricted areas with concentrations between 10 and 15% occur in the extreme southwestern and in the northwestern parts of the study area.

The distribution of this tropical-subtropical species does not correspond to the distribution of temperature and salinity values in surface and near-surface waters. Concentrations between 5 and 10% occur across all values of these parameters.

Globigerina rubescens has very little resistance to solution (table 1). The isolated areas with very low relative abundances may be caused by solution.

GLOBIGERINA sp.
Plate 3, figs. 7-8

Globigerina sp. may represent the immature stage of another form in the fauna; but it cannot be related to any of the other identified species by this writer.

This form occurs primarily in the central Gulf of Mexico (fig. 19). It usually constitutes less than 1% of the planktonic foraminiferal assemblage in surface sediments. In several isolated localities it comprises from 1 to 2% and, conversely, it is absent from sediments throughout much of the north-central, northeastern, and southwestern portions of the study area.

Genus GLOBIGERINELLA Cushman, 1927
GLOBIGERINELLA SIPHONIFERA (d'Orbigny)
Plate 5, figures 1-15

Globigerina siphonifera D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, p. 83, pl. 4, figs. 15-18.

It is difficult to distinguish immature specimens of this species from immature *Globigerina calida,* which has less involute chambers and a less hispid wall. The more coarsely hispid surface of *Globigerinella siphonifera* is the most useful criterion for very small specimens.

Globigerinella siphonifera constitutes 5 to 10% of the planktonic foraminiferal assemblage in surface sediments throughout most of the study area (fig. 20). Relative abundances between 3 and 5% are also present over a large area. The relative abundance of this species drops below 1% only at stations located in the most northern extremities of the study area. Areas where it constitutes less than 3% of the fauna are found only on the continental slope in the northern Gulf.

PLATE 2

Figures — Page

1-13. *Globigerina calida* Parker (X100) 34
1. Umbilical view; Station 46
2. Spiral view; Station 46
3. Spiral view; Station 46
4. Umbilical view; Station 46
5. Edge view; Station 46; dissected from adult specimen
6. Umbilical view; Station 46; dissected from adult specimen
7. Umbilical view; Station 46
8. Spiral view; Station 46; dissected from adult specimen
9. Spiral view; Station 46
10. Umbilical view; Station 46
11. Spiral view; Station 46
12. Umbilical view; Station 46
13. Edge view; Station 46

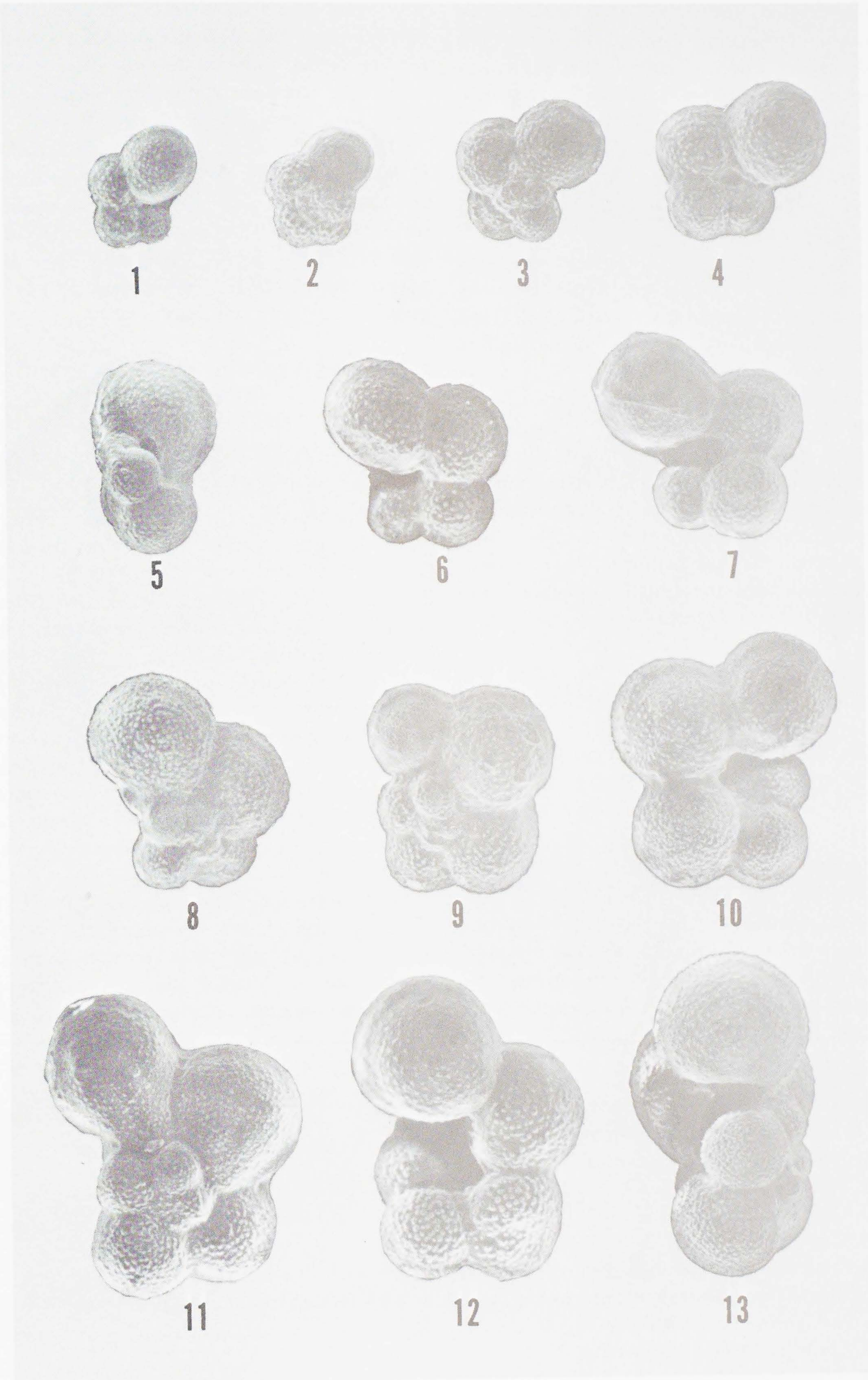

PLATE 2

Concentrations of 5 to 10% are present throughout the most southern regions of the study area. The pattern of this particular range of abundances extends north-northwest in two areas, one from both the eastern and western limits of the Campeche Slope. Relative abundances between 3 and 5% are found mainly in the western and north-central Gulf of Mexico.

This subtropical-tropical species tolerates a broad range of temperatures but flourishes only where temperatures exceed 20°C. Optimum ecological conditions also include salinities above 36 ‰ (fig. 2).

Concentrations above 3% of the assemblage are found only in an area approximating that defined by year-round near-surface (at a depth of 100 meters) water temperatures above 20°C. The configuration of temperature contours at this depth during late winter and late summer (fig. 4) help explain the aforementioned northward extensions of concentrations between 5 and 10%. It may be that this species is most abundant at about 100 meters below the surface.

Genus GLOBIGERINOIDES Cushman, 1927

GLOBIGERINOIDES CONGLOBATUS (Brady)

Plate 6, figures 1-4

Globigerina conglobata BRADY, 1879, Quart. Jour. Micr. Sci., (new ser.) vol. 19, p. 286.

Globigerinoides conglobatus comprises less than 1% of the planktonic foraminiferal assemblage in surface sediments throughout most of the Gulf of Mexico, with the exception of an area that corresponds to the Mississippi Cone (fig. 21). It comprises 1 to 2% of the fauna only in an area that trends northwest from the Campeche Slope to the continental slope off east-central Texas.

This tropical-subtropical species flourishes in temperatures above 21°C and salinities above 36 ‰ (fig. 2). However, its absence in the area of the Mississippi Cone indicates that turbidity may be the single most important factor limiting its distribution in this area.

GLOBIGERINOIDES ELONGATUS (d'Orbigny)

Plate 7, figures 1-7

Globigerina elongata D'ORBIGNY, 1826, Ann. Sci. Nat., (ser. 1) vol. 7, p. 277 (unfigured).

"*Globigerinoides elongatus* closely resembles and possibly is a variant form of *G. ruber*" (Cifelli and Smith, 1970, p. 37). It differs from *Globigerinoides ruber* sensu stricto in that the chambers are slightly less inflated, the final chamber is compressed and relatively small, and the primary aperture is more laterally restricted. Several other distinguishing characters are listed by Banner and Blow (1960, p. 21). However, differences in wall thickness and coarseness do not appear to be applicable to specimens representing these two species in the Gulf of Mexico.

Globigerinoides elongatus constitutes 1 to 3% of the planktonic foraminiferal assemblage in surface sediments throughout most of the Gulf of Mexico (fig. 22). Scattered areas with relative abundances below 1%

PLATE 3

Figures	Page
1-6. *Globigerina falconensis* Blow (X200)	34

1. Umbilical view; Station 53
2. Spiral view; Station 47
3. Umbilical view; Station 43
4. Umbilical view; Station 53
5. Umbilical view; Station 36; morphologic variant with reduced final chamber
6. Spiral view; Station 41; morphologic variant with reduced final chamber

Figures	Page
7-8. *Globigerina* sp. (X200)	38

7. Umbilical view; Station 72
8. Spiral view; Station 72

PLATE 3

occur near the northern, western, and south-central limits of the study area, and small areas with concentrations of 3 to 5% and 5 to 10% are present only in the south and central portions.

Cifelli and Smith (1970, p. 37) state that the distribution of this subtropical species in Atlantic populations is similar to but more restricted than that of *Globigerinoides ruber*. In the Gulf of Mexico its higher relative abundances occur where year-round water temperatures at a depth of 100 meters are above 20°C; but these scattered, isolated concentrations make it difficult to evaluate the importance of temperature as a limiting factor.

GLOBIGERINOIDES FISTULOSUS
(Schubert)
Plate 6, figure 5

Globigerina fistulosa SCHUBERT, 1910, Geol. Reichsanst. Verh., Vienna, p. 323, fig. 2.

In the Indo-Pacific region *Globigerinoides fistulosus* becomes extinct in the early Quaternary. Lamb and Beard (1972, p. 48) state that this species is encountered only in the late Pliocene and earliest Pleistocene in the Gulf of Mexico. Ericson and Wollin (1968, p. 1232) recognize its extinction level within the early Pleistocene. Its presence in surface sediments indicates either that pre-Pleistocene sediments are exposed or that there has been vertical mixing during sampling. At both stations where *Globigerinoides fistulosus* occurs, its presence is attributed to vertical mixing.

GLOBIGERINOIDES OBLIQUUS
OBLIQUUS Bolli

Globigerinoides obliqua BOLLI, 1957, U. S. Natl. Mus., Bull. 215, p. 113, pl. 25, figs. 9-10; text-fig. 21, no. 5.

Some specimens here included within the concept of *Globigerinoides elongatus* (pl. 7, fig. 5) closely resemble *Globigerinoides obliquus obliquus*. Bronnimann and Resig (1971, p. 1310) place *Globigerinoides obliquus obliquus* in synonymy with *Globigerinoides elongatus*. However, in the opinion of this writer these two species are separate.

Parker (1967, p. 155) states that *Globigerinoides obliquus obliquus* ranges into zone N. 21 (latest Pliocene) in Indo-Pacific cores. Blow (1969, p. 268) lists the range as extending into zone N. 22 (early Pleistocene). Lamb and Beard (1972, p. 48) state that the range extends through the lower

PLATE 4

Figures — Page

1-5. *Globigerina pachyderma* (Ehrenberg) (X150) 35
- 1. Umbilical view; Station 41
- 2. Umbilical view; Station 31
- 3. Spiral view; Station 1
- 4. Umbilical view; Station 32
- 5. Umbilical view; Station 28

6-12. *Globigerina quinqueloba* Natland (X200) 35
- 6. Umbilical view; Station 53
- 7. Umbilical view; Station 52
- 8. Umbilical view; Station 52
- 9. Spiral view; Station 52
- 10. Umbilical view; Station 52
- 11. Edge view; Station 52
- 12. Umbilical view; Station 70

13-16. *Globigerina rubescens* Hofker 36
- 13. Umbilical view, X 200; Station78
- 14. Umbilical view, X 300; Station 46
- 15. Spiral view, X 300; Station 46
- 16. Umbilical view, X 200; Station 78

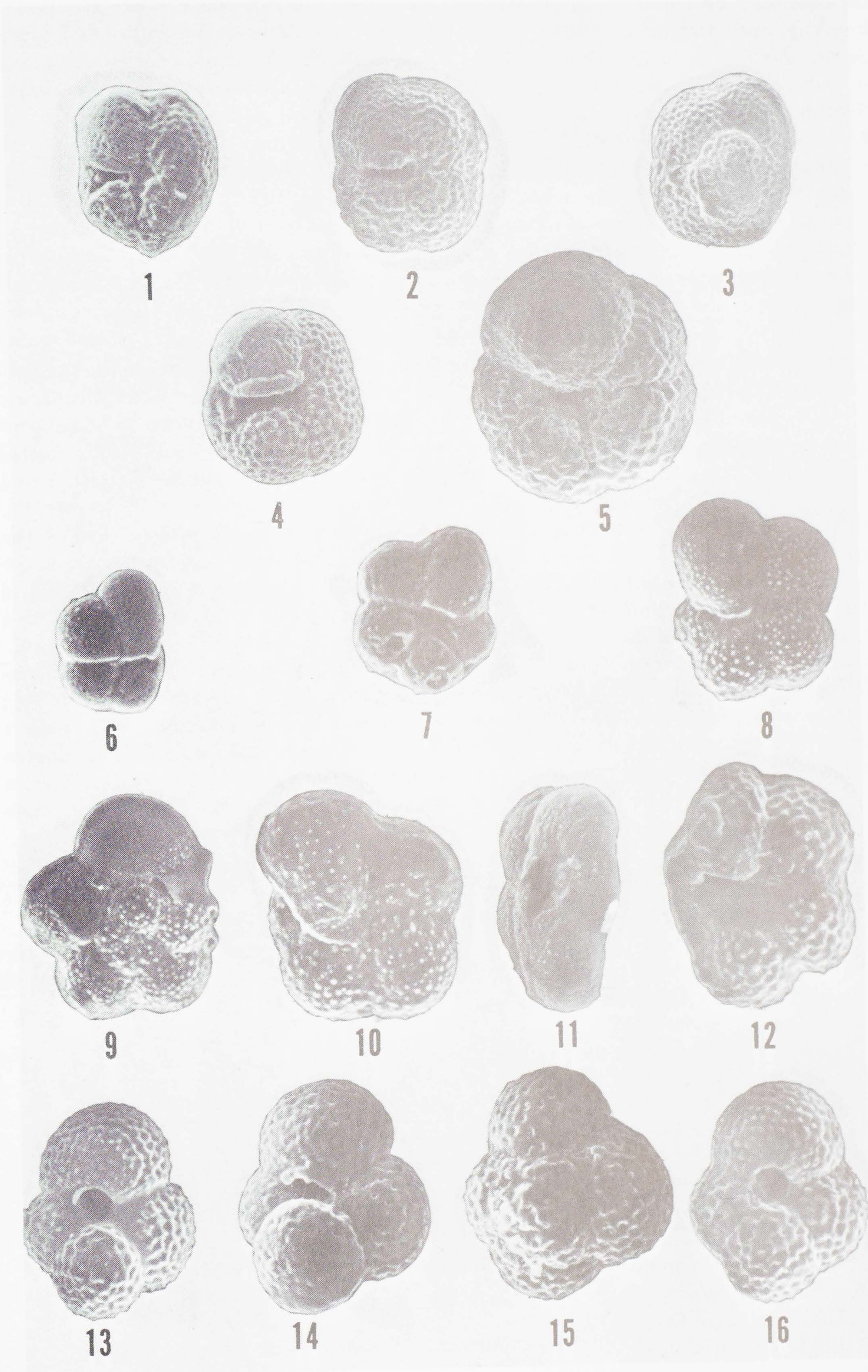

PLATE 4

Pleistocene sediments in the Gulf of Mexico. Boltovskoy and Watanabe (1975, p. 40) recognize this species in Recent assemblages from sediments of the South Pacific Ocean.

Specimens of *Globigerinoides obliquus obliquus* occur only at Station 1. Because its representatives constitute less than 1% of the planktonic foraminiferal fauna, and because there is no other faunal evidence to suggest exposure of pre-Holocene sediments, its presence is interpreted as indicating vertical mixing.

GLOBIGERINOIDES QUADRILOBATUS QUADRILOBATUS (d'Orbigny)
Plate 8, figures 1-7

Globigerina quadrilobata D'ORBIGNY, 1846, Foraminifères fossiles du bassin tertiaire de Vienne, p. 164, pl. 9, ? figs. 7-10.

While identification of mature specimens presents few difficulties, immature specimens may be confused with several other species, such as *Globigerinoides ruber*. The main distinguishing feature is that the aperture of *Globigerinoides quadrilobatus quadrilobatus* is more slit-like and restricted. Also, there are a greater number of chambers in the very early whorls than in *Globigerinoides ruber*. The growth series figured by Cifelli and Smith (1970, p. 38 and 39) for both of these species are most helpful for illustration of the differences mentioned above. In addition, immature *Globigerinoides quadrilobatus quadrilobatus* is chambered almost identically to some specimens of *Globigerinita glutinata*, causing difficulty if the characteristic umbilical bulla of the latter species is missing (compare pl. 8, fig. 1, with pl. 14, fig. 4). Identification is then made on the basis of the surface texture of *Globigerinoides quadrilobatus quadrilobatus* being much more coarsely cancellate and punctate. The problem of distinguishing *Globigerinoides quadrilobatus quadrilobatus* from *Globigerinoides quadrilobatus sacculifer* is discussed under the latter subspecies.

The relative abundances of *Globigerinoides quadrilobatus quadrilobatus* below 3% occur only in the northern, western, and southwestern portions of the study area (fig. 23). Concentrations from 3 to 5% of the planktonic assemblage are found only in the central Gulf of Mexico; those between 5 and 10%, almost entirely in the east-central and southeastern portions.

This subspecies thrives in water temperatures above 22°C, salinities above 36 ‰, and at depths from the surface to 50 meters (fig. 2). Areas with relative abundances above 3% occur where near-surface waters (at a depth of 100 meters) maintain year-round temperatures above 21°C.

PLATE 5

Figures	Page
1-15. *Globigerinella siphonifera* (d'Orbigny) (X100)	38

1. Umbilical view; Station 46
2. Spiral view; Station 46
3. Umbilical view; Station 46
4. Edge view; Station 46
5. Spiral view; Station 46
6. Edge view; Station 46
7. Edge view; Station 46
8. Oblique view; Station 46
9. Edge view; Station 46
10. Edge view; Station 46
11. Edge view; Station 46
12. Edge view; Station 46
13. Umbilical view; Station 72
14. Edge view; Station 72
15. Spiral view; Station 72

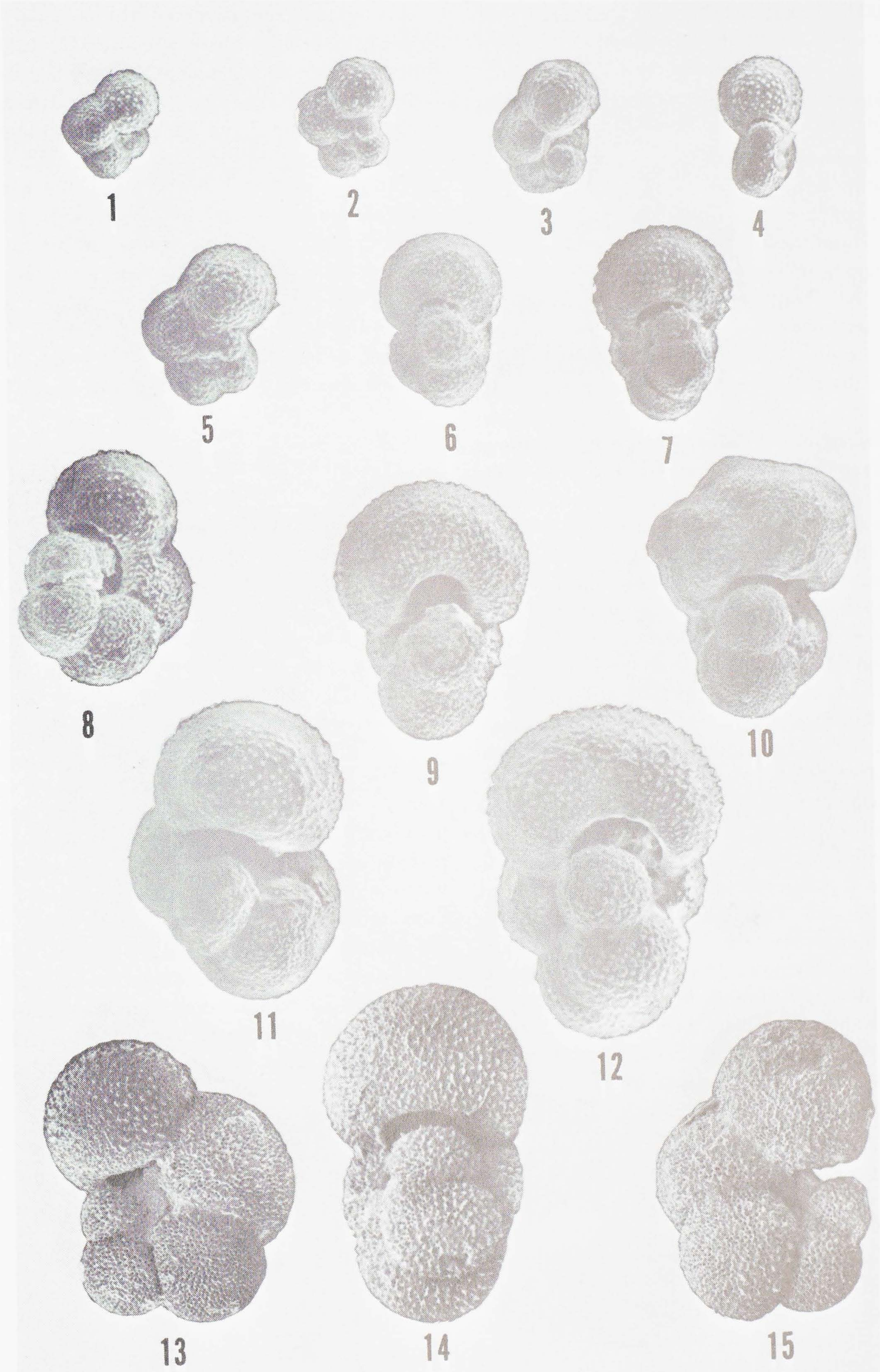

PLATE 5

GLOBIGERINOIDES QUADRILOBATUS SACCULIFER (Brady)
Plate 9, figures 1-7

Globigerina sacculifera BRADY, 1877, Geol. Mag., (new ser., dec. 2) vol. 4, no. 12, p. 535.

Specimens of *Globigerinoides quadrilobatus* with an irregular to sac-like final chamber are separated as the subspecies *Globigerinoides quadrilobatus sacculifer* (compare the figures of plate 9 with those of plate 8). Cifelli (1965, p. 27) combines both of these forms into one subspecies because he interprets them as a gradational series that does not represent an evolutionary sequence in time. Parker (1962, p. 229) also considers these two forms synonymous. Representing the other viewpoint is Jones (1967, p. 496), "... there is considerable evidence to indicate that the two forms of this species have different preferred environmental habitats, although with a wide degree of overlap, and that some fair degree of justification exists in considering them as true biologic subspecies." While treating the two forms as subspecies, this writer agrees with Cifelli (1965, p. 28) that the present arrangement of subspecies must be considered tentative and incomplete.

Globigerinoides quadrilobatus sacculifer constitutes less than 1% of the planktonic foraminiferal assemblage in surface sediments throughout the northwestern Gulf of Mexico and in a small area in its northeastern portion (fig. 24). Throughout most of the study area the relative abundances range between 1 and 3%. In some parts of the southern Gulf there are scattered stations with concentrations from 3 to 5%, representing the maximal development of the subspecies in this region.

Living representatives of this subspecies flourish in temperatures above 23°C, salinities above 36 ‰, and depths from the surface to 100 meters (fig. 2). Relative concentrations between 3 and 5% occur only where surface water temperatures remain above 23°C during the entire year (fig. 3). The only large area with relative abundances of 3 to 5% is located where year-round water temperatures at a depth of 100 meters are above 21°C. Like the more susceptible species, its distributional patterns may be altered by solution effects, which may explain its absence in certain parts of the area (fig. 24).

GLOBIGERINOIDES RUBER (d'Orbigny)
Plate 10, figures 1-9

Globigerina rubra D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, p. 82.

There is some variation in coiling in immature forms of *Globigerinoides ruber*. Most specimens have three chambers in the peripheral whorl (pl. 10, figs. 1-2, 4-6), however, one form has four (pl. 10, fig. 3). This form resembles a *Globigerina*. Resemblance is enhanced by the fact that supplementary apertures appear late in the ontogeny of *Globigerinoides ruber* and are seldom seen in small specimens. The only way to identify such specimens is to become thoroughly familiar with the growth series of the species (Cifelli and Smith, 1970, p. 38).

Adult specimens are distinctive and easily recognized but some immature forms may be confused with immature forms of *Globigerinoides quadrilobatus*. Distinguishing features are discussed under the latter species.

PLATE 6

Figures	Page
1-4. *Globigerinoides conglobatus* (Brady) (X100)	40
1. Umbilical view; Station 46	
2. Spiral view; Station 46	
3. Umbilical view; Station 46	
4. Spiral view; Station 46	
5. *Globigerinoides fistulosus* (Schubert) (X77)	42
Spiral view; Station 46	

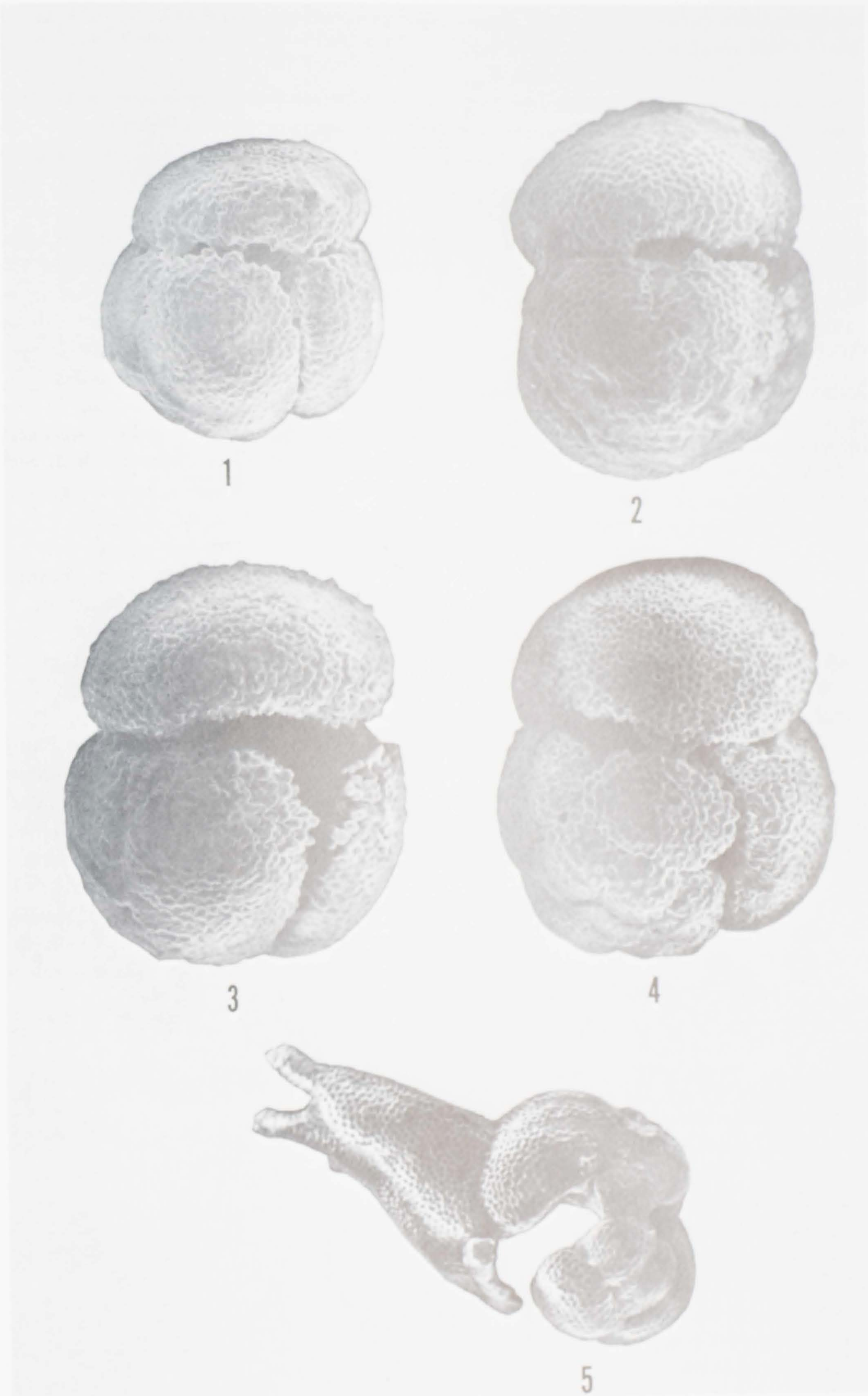

PLATE 6

Globigerinoides ruber is the most abundant planktonic foraminiferal species in surface sediments of the Gulf of Mexico (fig. 25). Over most of the area it constitutes 25% or more of the planktonic foraminiferal assemblage. Only the shoaler, most northern regions have relative abundances less than 25%; and, even here the relative abundance exceeds 10%. In the area of maximum development of the species, the south-central to central-western portion of the Gulf, relative abundances range between 30 and 35%.

Although *Globigerinoides ruber* has broad ecological tolerances, living specimens thrive in temperatures above 20°C and salinities above 35.5 ‰ . It is most abundant in the upper 50 meters of the water column but lives throughout the upper 250 meters (fig. 2).

Globigerinoides ruber constitutes 25% or more of the planktonic foraminiferal assemblage in areas where year-round surface water temperatures are above 22°C; and those at a depth of 100 meters, above 20°C (figs. 3 and 4). Concentrations of 30 to 35% occur only where winter temperatures of surface water are above 23°C. Because this species is most susceptible to solution, its relative abundances may be altered (table 1).

GLOBIGERINOIDES TENELLUS Parker
Plate 7, figures 8-10

Globigerinoides tenellus PARKER, 1958, Swedish Deep-Sea Exped., Rept., vol. 8, no. 4, p. 280, pl. 6, figs. 7-11.

Globigerinoides tenellus may be confused with specimens of *Globigerina rubescens* that lack pigmentation. The presence of the supplementary aperture (pl. 7, fig. 8) serves to distinguish the two, but this aperture may be difficult to see without tedious, time-consuming manual cleaning. Great care must be exercised in determining whether or not it is present. The slightly extraumbilical position of the primary aperture in most specimens of *Globigerinoides tenellus* (pl. 7, fig. 10) may aid in distinguishing it from *Globigerina rubescens*. However, the extent to which its position is extraumbilical varies and some specimens have a primary aperture that is nearly umbilical (pl. 7, fig. 9).

Globigerinoides tenellus constitutes 1 to 3% of the planktonic foraminiferal fauna in surface sediments throughout most of the study area (fig. 26). Concentrations below 1% occur along the continental slope off Texas, Louisiana, Alabama, and Florida. An area with relative abundances ranging from 3 to 10% trends northwest from the Bay of Campeche into the central Gulf of Mexico.

Globigerinoides tenellus is considered a poor indicator of temperature values because specimens are quantitatively too few in virtually every latitudinal area. The species' distribution in surface sediments of the Gulf of Mexico supports this statement because it bears little resemblance to the distribution of temperature values.

PLATE 7

Figures — Page

1-7. *Globigerinoides elongatus* (d'Orbigny) (X100) 40
1. Umbilical view; Station 49
2. Spiral view; Station 46
3. Spiral view; Station 46
4. Spiral view; Station 46
5. Umbilical view; Station 46
6. Spiral view; Station 48
7. Umbilical view; Station 46

8-10. *Globigerinoides tenellus* Parker (X200) 48
8. Spiral view; Station 46
9. Umbilical view; Station 46
10. Umbilical view; Station 46

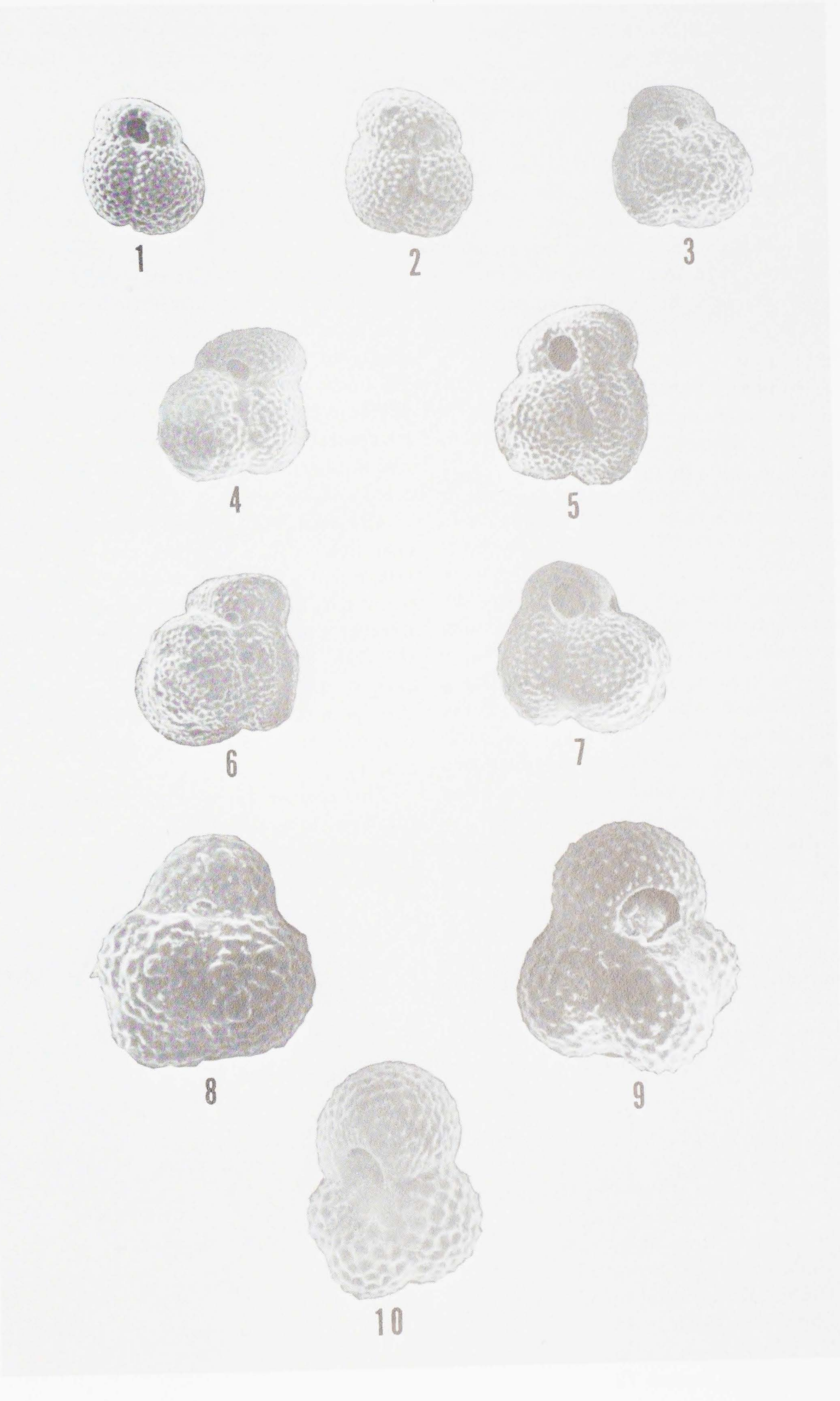

PLATE 7

Genus ORBULINA d'Orbigny, 1839
ORBULINA BILOBATA (d'Orbigny)
Plate 11, figure 1

Globigerina bilobata D'ORBIGNY, 1846, Foraminifères fossiles du bassin tertiaire de Vienne, p. 164, pl. 9, figs. 11-14.

Orbulina bilobata, which may be a morphologic variant of *Orbulina universa,* ranges into the Holocene but does not become abundant. This species was encountered at three localities in the Gulf of Mexico (fig. 27). In each instance it comprises less than 1% of the planktonic foraminiferal fauna.

ORBULINA SUTURALIS
Bronnimann, *emended* Blow
Plate 11, figure 4

Orbulina suturalis BRONNIMANN, 1951 (part), Cushman Found. Foram. Res., Contr., vol. 2, pt. 4, p. 135, text-fig. 2, nos. 1-2, 5-8, 10; text-fig. 3, nos. 3-8, 11, 13-16, 18, 20-22; text-fig. 4, nos. 2-4, 7-12, 15-16, 19-22.

Orbulina suturalis was originally described from the Oligo-Miocene of Trinidad (Bronnimann, 1951, p. 135). Blow (1956, p. 69), based upon his work in Trinidad, stated that *Orbulina suturalis* became extinct in the late Miocene or early Pliocene. However, this species has been recorded on at least two separate and independent occasions as living in the plankton. Bé and Hamlin (1967, p. 102) describe it as a tropical-subtropical member of the plankton in the North Atlantic where it is present in very small concentrations. Cifelli and Smith (1970, p. 42), also working in the North Atlantic, encountered four living specimens. Hence, the rare occurrence of this species in surface sediments of the Gulf of Mexico does not necessarily indicate either the exposure of earlier Neogene sediments or vertical mixing. This species occurs only at Station 46, where it comprises less than 1% of the planktonic foraminiferal assemblage.

ORBULINA UNIVERSA d'Orbigny
Plate 11, figures 2-3

Orbulina universa D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, vol. 8, no. 3, pl. 1, fig. 1.

Orbulina universa constitutes 1 to 3% of the planktonic foraminiferal fauna throughout most of the Gulf of Mexico (fig. 28). Scattered areas with concentrations below 1% occur along the continental slope in the northern extremities of the study area and in its central and southwestern portions. Relative abundances between 3 and 5% are scattered and isolated.

Orbulina universa is a subtropical species that flourishes in temperatures above 18°C, salinities of 36 ‰ or more, and depths from the surface to 300 meters (fig. 2). Because nearly all seasonal temperatures in the Gulf of Mexico are above 18°C (figs. 3 and 4) this species is widely distributed throughout the area, but with no clear relationship to changes in temperature or salinity.

This species has a very low resistance to solution. Irregularities in its distributional pattern are most likely associated with solution effects.

Genus HASTIGERINA Thompson, 1876
HASTIGERINA PELAGICA (d'Orbigny)
Plate 12, figures 1-2

Nonionina pelagica D'ORBIGNY, 1839, Voyage dans l'Amerique Meridionale, Foraminifères, p. 27, pl. 3, figs. 13-14.

PLATE 8

Figures — Page

1-7. *Globigerinoides quadrilobatus quadrilobatus* (d'Orbigny) (X100) 44
1. Umbilical view; Station 46
2. Spiral view; Station 46
3. Umbilical view; Station 72
4. Umbilical view; Station 46
5. Spiral view; Station 46
6. Umbilical view; Station 72
7. Spiral view; Station 72

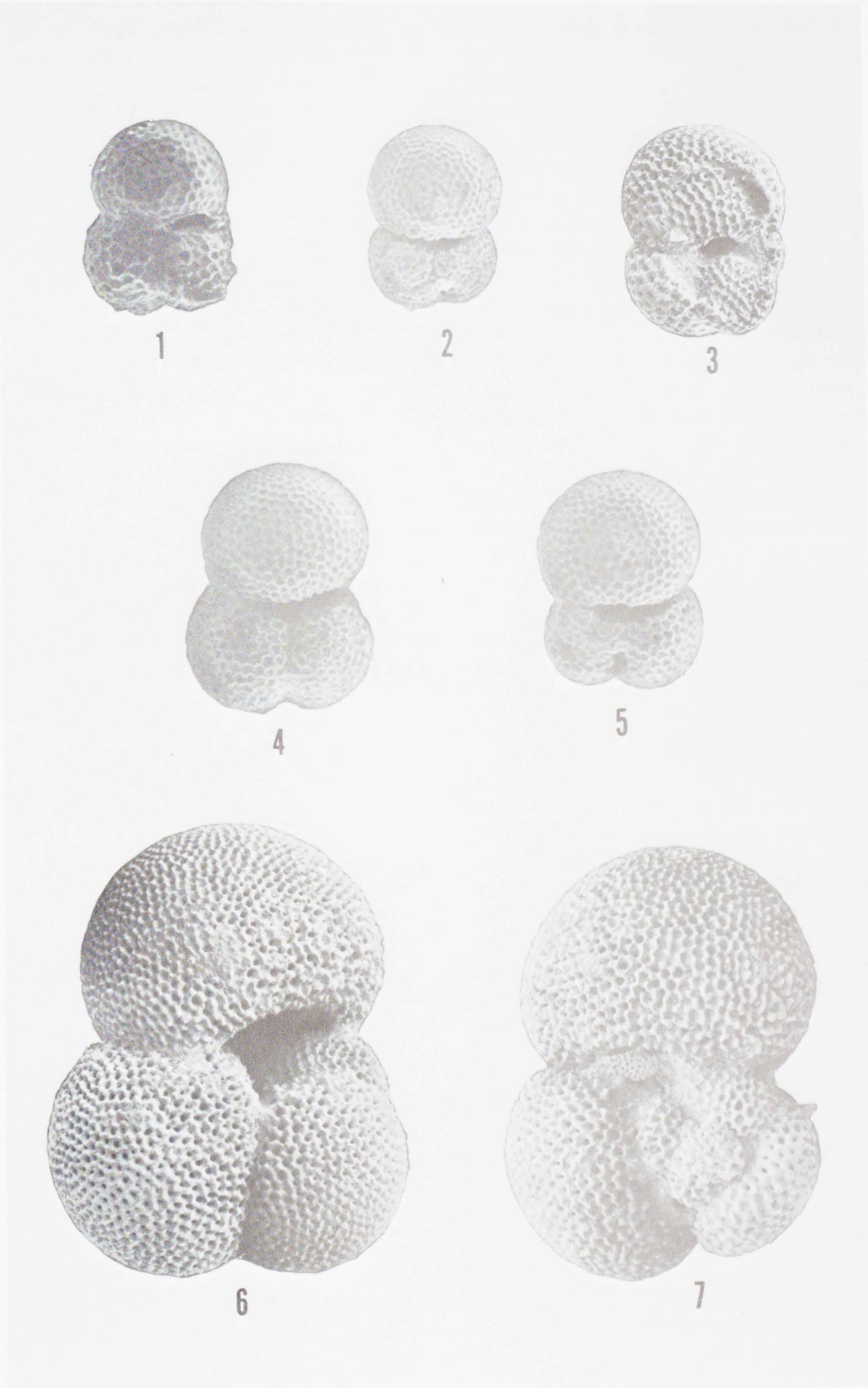

PLATE 8

The possibility of confusing *Hastigerina pelagica* with other species is remote. Only *Globigerinella siphonifera,* because of its tendency toward planispiral coiling, resembles it. The two can be easily distinguished by differences in the nature of the test surface. That of *Hastigerina pelagica* is finely perforate and bears a relatively few long triradiate spines and the surface of *Globigerinella siphonifera* is densely hispid and bears no triradiate spines.

Hastigerina pelagica occurs primarily in the southwestern portion of the Gulf of Mexico (fig. 29). Here surface sediments consistently yield specimens assignable to this species but the relative abundance at all localities is below 1% of the planktonic foraminiferal fauna. Scattered, isolated occurrences of this species are noted in the central and southeastern portions of the study area.

Hastigerina pelagica thrives in water temperatures above 23°C and salinities above 36 ‰ . Living specimens range to a depth of 1000 meters, but are in greater abundance in the upper 300 meters of the water column (fig. 2).

Hastigerina pelagica occurs only in the area where year-round surface water temperatures are above 22°C (fig. 3). It does not, however, occur consistently throughout this area of warm surface waters, but is found primarily where salinity values remain above 36.25 ‰ (fig. 5). The patchy distribution of this species may be caused by the fragility of the test coupled with its low relative abundance (below 5%) in living populations at the same latitude as the Gulf of Mexico (Bé, Vilks, and Lott, 1971).

Genus PSEUDOHASTIGERINA
Banner and Blow, 1959

PSEUDOHASTIGERINA PRAEPUMILIO
(Parker)
Plate 12, figures 3-6

Globanomalina praepumilio PARKER, 1967, Bull. Amer. Paleontology, vol. 52, no. 235, p. 148, pl. 18, figs. 1-4.

This form is distinctive but also quite small. The author is unaware of any previous record of its occurrence in the Gulf of Mexico. Parker (1967, p. 148) records a rather restricted range for this species in the Indo-Pacific region where it is found only in the upper part of Zone N. 20 and in N. 21 (late Pliocene).

Pseudohastigerina praepumilio occurs at only two stations in the entire study area. At Station 29 it constitutes less than 1% of the planktonic foraminiferal assemblage. This occurrence is interpreted as indicating vertical mixing. At Station 40 it constitutes 14% of the planktonic fauna, a high percentage which indicates a pre-Holocene age for sediments exposed at this locality.

Genus SPHAEROIDINELLA
Cushman, 1927

SPHAEROIDINELLA DEHISCENS
(Parker and Jones)
Plate 13, figures 1-3

Sphaeroidina bulloides d'Orbigny var. *dehiscens* PARKER and JONES, 1865, Roy. Soc. London, Philos. Trans., vol. 155, p. 369, pl. 19, fig. 5.

Specimens identified as *Sphaeroidinella dehiscens* include forms designated as *Sphaeroidinella dehiscens excavata* by Ban-

---

PLATE 9

Figures | Page
1-7. *Globigerinoides quadrilobatus sacculifer* (Brady) (X100) 46

1. Umbilical view; Station 46
2. Umbilical view; Station 46
3. Spiral view; Station 46
4. Umbilical view; Station 46
5. Spiral view; Station 46
6. Spiral view; Station 46
7. Spiral view; Station 46

PLATE 9

ner and Blow (see pl. 13, fig. 3). The writer does not recognize this subspecies because its diagnostic features appear to be related to size and, hence, to the maturity of the specimen. The form is interpreted as a developmental stage that is simply not attained by the majority of specimens.

Sphaeroidinella dehiscens occurs within surface sediments at scattered localities throughout the Gulf of Mexico (fig. 30). At no single locality does it account for more than 1% of the planktonic foraminiferal fauna.

Living specimens flourish in temperatures ranging from 16 to 20°C and at depths between 200 and 300 meters (fig. 2). Given the optimum depth range of this species, it is not surprising that its distributional patterns in surface sediments indicate no clear relationship to temperature changes in surface waters. As solution is not likely to alter the relative abundance of *Sphaeroidinella dehiscens* (see table 1), its patchy distribution is best explained by its low relative abundance (below 5%) in living planktonic foraminiferal populations (Bradshaw, 1959, p. 49).

Family CANDEINIDAE Cushman, 1927
Genus CANDEINA d'Orbigny, 1839
CANDEINA NITIDA d'Orbigny
Plate 13, figures 4-6

Candeina nitida D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, p. 108, pl. 2, figs. 27-28.

Like *Sphaeroidinella dehiscens, Candeina nitida* has an irregular distribution and is present only in relative abundance below 1% of the planktonic fauna (fig. 31). It flourishes in temperatures above 20°C, salinities above 36 ‰, and at depths from the surface to 300 meters (fig. 2). Its distributional pattern in surface sediments of the study area is too irregularly scattered to attempt correlation with temperature and salinity values in the overlying surface waters.

Genus GLOBIGERINITA
Bronnimann, 1951
GLOBIGERINITA GLUTINATA Egger
Plate 14, figures 1-5

Globigerinita glutinata EGGER, 1893, Abhandl. K. Bayer. Akad. Wiss. Munchen, CLII, vol. 18, p. 371, pl. 13, figs. 19-21.

Specimens with the umbilical bulla are readily recognizable as *Globigerinita glutinata.* Some specimens lacking the bulla are chambered much like immature *Globigerinoides quadrilobatus quadrilobatus;* however, the smooth to finely hispid surface of *Globigerinita glutinata* serves to distinguish such specimens from the coarsely cancellate *Globigerinoides quadrilobatus quadrilobatus.* Other specimens may resemble *Globigerina falconensis,* but are distinguished by their less hispid surface and the less prominent apertural lip. In some instances, identification of a particular specimen is arbitrary.

Globigerinita glutinata is the second most abundant planktonic species in surface sediments of the Gulf of Mexico (fig. 32). Over most of the area relative abundances range from 10 to 20% with concentrations of 15 to 20% in the western and central portions and of 10 to 15% in the south-central and eastern portions. Relative abundances of 5 to 10%

PLATE 10

Figures | Page
1-9. *Globigerinoides ruber* (d'Orbigny) (X100) 46
1. Umbilical view; Station 46
2. Umbilical view; Station 72
3. Umbilical view; Station 72, immature form with four peripheral chambers
4. Umbilical view; Station 46
5. Umbilical view; Station 46
6. Spiral view; Station 46
7. Umbilical view; Station 72
8. Spiral view; Station 72
9. Spiral view; Station 72

PLATE 10

are present only in the extreme southeastern portion of the study area. Concentrations between 20 and 25% occur locally through northern portions of the Gulf, but the highest concentrations (25 to 30%) are situated only along the continental slope off Louisiana and off the eastern Alabama-western Florida coast.

This species is the most cosmopolitan of modern planktonic foraminifers. It flourishes in temperatures ranging from 11 to 30°C, salinities from 34 to more than 36 ‰, and from the surface to depths of 250 meters (fig. 2).

Although the distributional pattern of *Globigerinita glutinata* generally does not reflect changes in temperature or salinity within the overlying surface waters, areas with concentrations above 20% occur only in the northern limits of the study area (fig. 32). Because this species thrives in such a wide range of temperatures and salinities, this pattern cannot be attributed to the presence of critical temperature and/or salinity thresholds. This area of maximal development does, however, correspond well with the area of minimal development exhibited by *Globigerinoides ruber.* The relative abundance of *Globigerinita glutinata* in this area may well be related to the decline of *Globigerinoides ruber,* rather than being directly dependent upon temperature and salinity values. This species may become numerically dominant under conditions where *Globigerinoides ruber* cannot.

GLOBIGERINITA IOTA Parker
Plate 14, figures 6-10

Globigerinita iota PARKER, 1962, Micropaleontology, vol. 8, no. 2, p. 250, pl. 10, figs. 26-30.

Globigerinita iota and immature specimens of *Globigerina quinqueloba* are similar but can be differentiated on the basis of the shell material covering the umbilicus. In *Globigerinita iota* this material is a bulla; in *Globigerina quinqueloba,* a modified final chamber. Also, *Globigerina quinqueloba* is more coarsely hispid.

Except for the southeastern portion of the Gulf of Mexico where it is consistently present, *Globigerinita iota* occurs in scattered, isolated patches throughout the study area (fig. 33). At no sampling station does the relative abundance of this species exceed 1% of the planktonic assemblage. There is no clear relationship between its distribution and that of temperature and salinity values.

GLOBIGERINITA UVULA (Ehrenberg)
Plate 14, figures 11-13

Pylodexia uvula EHRENBERG, 1861, K. Preuss. Akad. Wiss. Berlin, Monatsber., pp. 276, 277, 308.

Globigerinita uvula occurs in surface sediments at only a few stations in the study area (fig. 34). Its relative abundance in these isolated occurrences is less than 1% of the planktonic assemblage.

This subpolar species flourishes in temperatures below 10°C, salinities between 34 and 34.5 ‰, and at depths below 250 meters (fig. 2). The irregular distribution of the species is probably caused by its low optimum temperature range. Even at depth, water temperatures in the Gulf of Mexico would not support large numbers of living specimens. This scarcity of living specimens may produce the "spotty" distribution.

Family CATAPSYDRACIDAE Bolli, Loeblich, and Tappan, 1957

Genus GLOBOQUADRINA Finlay, 1947 (emended)

PLATE 11

Figures		Page
1. *Orbulina bilobata* (d'Orbigny) (X100)	Station 46	11
2-3. *Orbulina universa* d'Orbigny (X100)	2. Station 46; 3. Station 46	11
4. *Orbulina suturalis* Bronnimann (X100)	Station 46	50

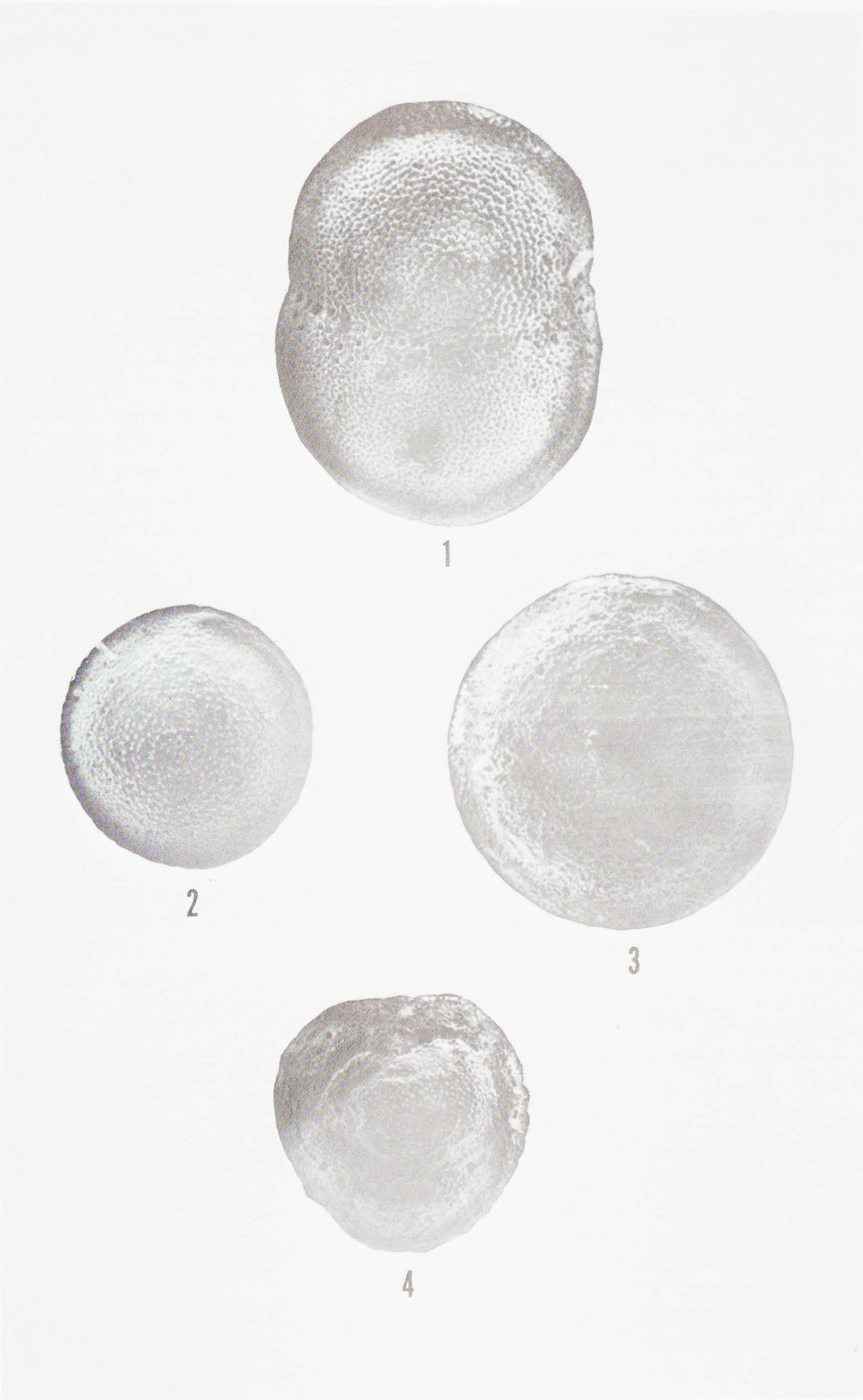

PLATE 11

GLOBOQUADRINA DUTERTREI (d'Orbigny)

Plate 15, figures 1-11

Globigerina dutertrei D'ORBIGNY, 1839, *in* DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, p. 84.

Although quite variable, *Globoquadrina dutertrei* is distinct from most other species. The practical separation of immature forms of this species, in which the aperture becomes umbilical early in ontogeny, from some specimens of *Globigerina pachyderma* is based upon the coarser surface texture and umbilical-extraumbilical aperture of the latter.

Globoquadrina dutertrei comprises 1 to 3% of the planktonic fauna in surface sediments of the western, southeastern, and extreme northwestern portions of the Gulf of Mexico (fig. 35). Concentrations between 3 and 5% occur over large regions in the eastern portion of the study area. Relative abundances above 5% occur in the north-central and northeastern Gulf of Mexico; those below 1%, only in the northwestern portion.

This warm-temperate species thrives in temperatures between 17 and 23°C, salinities above 35.5 ‰, and from the surface to depths of 150 meters (fig. 2). It tolerates such a wide range of temperatures that its distribution does not reflect changes in surface and near-surface water temperatures of the Gulf of Mexico. However, relative concentrations of *Globoquadrina dutertrei* are affected by the amount of post-depositional solution. It is among the planktonic species that are resistant to solution (table 1) and comprises more than 10% of the planktonic assemblage only at stations bearing evidence of solution.

Genus PULLENIATINA Cushman, 1927

PULLENIATINA OBLIQUILOCULATA OBLIQUILOCULATA (Parker and Jones)

Plate 12, figures 7-8

Pullenia obliquiloculata PARKER and JONES, 1862, *in* W. H. CARPENTER, Ray Soc., p. 183 (nomen nudum).

Pullenia sphaeroides obliquiloculata PARKER and JONES, 1865, Roy. Soc. London, Philos. Trans., vol. 155, p. 365, pl. 19, fig. 4.

Because this subspecies is rare and there is doubt about distinguishing immature specimens from the young of *Pulleniatina obliquiloculata finalis* (see discussion under this subspecies), percentages were not calculated for it. The two subspecies are lumped together in a category described as the "*Pulleniatina obliquiloculata* complex."

PULLENIATINA OBLIQUILOCULATA FINALIS Banner and Blow

Plates 16 and 17

Pulleniatina obliquiloculata finalis BANNER and BLOW, 1967, Micropaleontology, vol. 13, no. 2, p. 140, pl. 2, figs. 4-10; pl. 3, fig. 5; pl. 4, fig. 10.

The dissection of many specimens has revealed that *Pulleniatina obliquiloculata finalis* undergoes a marked change during its ontogenetic development (pl. 17, figs. 1-12). Initially the test is globigerinid in that it is trochospirally coiled, with an umbilicus, an umbilical aperture, and a hispid wall. Be-

PLATE 12

Figures — Page

1-2. *Hastigerina pelagica* (d'Orbigny) (X100) 50
   1. Edge view; Station 46
   2. Side view; Station 46

3-6. *Pseudohastigerina praepumilio* (Parker) (X200) 52
   3. Side view; Station 40
   4. Edge view; Station 40
   5. Edge view; Station 40
   6. Side view; Station 40

7-8. *Pulleniatina obliquiloculata obliquiloculata* (Parker and Jones) (X100) 58
   7. Dorsal view; Station 72
   8. Edge view; Station 72

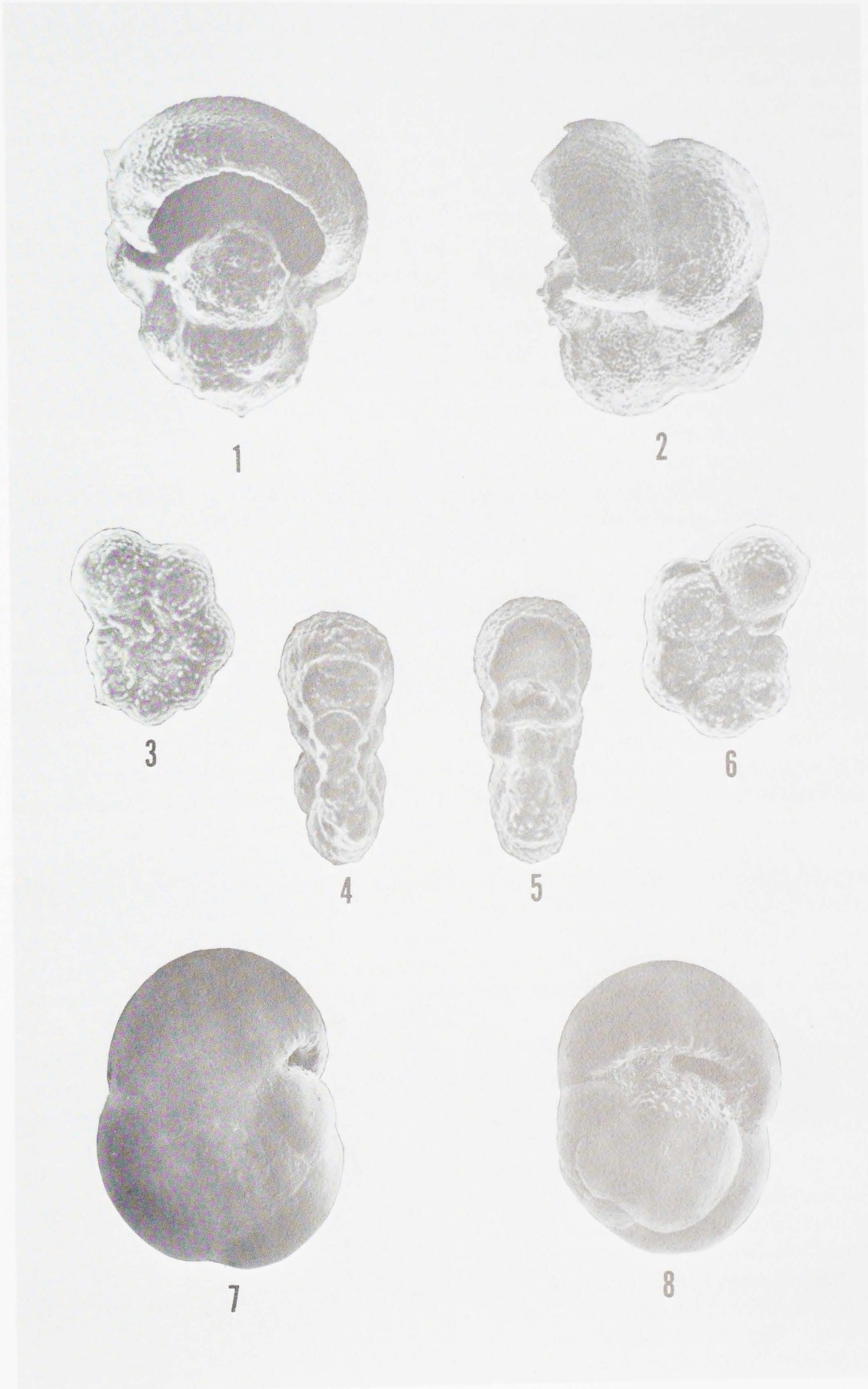

PLATE 12

cause of a transition toward streptospiral coiling (pl. 17, figs. 6-8) the umbilicus is lost and the aperture progresses toward its adult condition, described as "pseudoumbilical" by Banner and Blow (1967, p. 136). After the mode of coiling changes, the hispid nature of the surface is gradually lost. The rate at which this final step occurs seems to vary from specimen to specimen. The dissection series (pl. 17) is the evidence upon which the growth series (pl. 16, figs. 1-11) is based.

Although adult specimens of the two infraspecific taxa here discussed are distinguishable, the immature forms cause problems. As so few specimens of *Pulleniatina obliquiloculata* sensu stricto were available, extensive dissections were impossible. The precise ontogenetic development is unknown but it is apt to be quite similar to, if not indistinguishable from, that of *Pulleniatina obliquiloculata finalis.* Hence, the two are treated as a single taxon for the purpose of distributional analysis. This fact does not, however, cast doubt upon the growth series presented for *Pulleniatina obliquiloculata finalis.*

The two subspecies of *Pulleniatina obliquiloculata* constitute 5 to 10% of the planktonic assemblage in the west-central portion of the Gulf of Mexico (fig. 36). Areas with concentrations between 3 and 5% are situated in the southwestern, eastern, and extreme northwestern portions of the Gulf. Concentrations from 1 to 3% occur primarily in the central part of the study area; those below 1%, only along the continental slope in its northern portion.

Pulleniatina obliquiloculata is a subtropical species that flourishes in temperatures between 19 and 25°C, salinities above 36 ‰, and from the surface to depths of 150 meters (fig. 2). Because surface and near-surface water temperatures remain above 18°C (figs. 3 and 4) during the entire year, cool waters do not curtail its distribution in the Gulf of Mexico. However, summer temperatures are more than 29°C in a tongue-shaped area extending southeastward from the Louisiana coast (fig. 3). Such high temperatures may exclude the species from this area during the warmer seasons, thus reducing concentrations in the sediments below. This species is resistant to solution (table 1) and high relative concentrations may occur where solution rates are high.

Family GLOBOROTALIIDAE Cushman, 1927

Genus GLOBOROTALIA Cushman, 1927

GLOBOROTALIA CRASSIFORMIS (Galloway and Wissler)

Plate 18, figures 1-6

Globigerina crassiformis GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, p. 41, pl. 7, fig. 12.

It is sometimes difficult to separate this species from *Globorotalia hirsuta.* In adult specimens the chambers of *Globorotalia crassiformis* are more inflated, the spiral side of the test more flattened, and the wall more coarsely granular. However, these distinguishing features decrease in prominence in immature forms. When dealing with small specimens the inflation of the chambers seems to be the most consistent difference, but when the diameter of specimens is less than 0.15 mm the distinction between the two species becomes arbitrary.

PLATE 13

PLATE 13

Globorotalia crassiformis constitutes less than 1% of the planktonic assemblage over most of its area of occurrence (fig. 37). Distribution is rather irregular and the species is absent from sediments over large portions of the central and northern Gulf of Mexico. Scattered occurrences with concentrations between 1 and 5% occur in northern portions of the study area.

This warm-temperate to subtropical species thrives in temperatures between 16 and 26°C, salinities above 35.5 ‰, and at depths between 150 and 200 meters (fig. 2). Although temperature changes in overlying surface waters do not affect its distribution, this species is absent from sediments underlying areas where surface currents are absent. Hence, adequate circulation may be an important factor in limiting its distribution.

GLOBOROTALIA FLEXUOSA (Koch)
Plate 21, figures 8-9

Pulvinulina tumida flexuosa KOCH, 1923, Eclogae Geol. Helv., vol. 18, p. 357, figs. 9-10.

Lamb and Beard (1972) recognize the extinction level of *Globorotalia flexuosa* in the late Wisconsin glacial stage in the Gulf of Mexico. Ericson and Wollin (1968, p. 1232) and Emiliani (1969, p. 271) also record the extinction level in the last glacial period. Parker (1967, p. 182) states that flexuose forms occur intermittently throughout the section in Indo-Pacific cores. Adegoke, *et al.* (1971, p. 199) record the occurrence of a few specimens of this form in surface sediments of the Gulf of Guinea. These latter authors state that Boltovskoy (1968), in his study of living planktonic Foraminifera in the eastern equatorial Atlantic, recorded two specimens in the plankton. Bé and McIntyre (1970, p. 595) record living specimens from 47 plankton stations in the northern Indian Ocean.

Globorotalia flexuosa occurs only in a few, widely scattered localities in the Gulf of Mexico (fig. 38). Its relative abundance is generally less than 1% of the planktonic fauna.

Because of its close affinity to *Globorotalia tumida,* it is believed to have thrived in subtropical conditions. However, it became extinct in the Gulf of Mexico during the late Pleistocene (Lamb and Beard, 1972, p. 42). Its presence in surface sediments is evidence that either pre-Holocene sediments are exposed, or that vertical mixing has occurred. Sediments at stations 25 and 40 are interpreted as pre-Holocene, but other occurrences are considered to be the result of mixing.

GLOBOROTALIA HIRSUTA (d'Orbigny)
Plate 19, figures 1-5

Rotalina hirsuta D'ORBIGNY, 1839, *in* BARKER-WEBB and BERTHELOT, Hist. Nat. Iles

---

PLATE 14

Figures — Page

1-5. *Globigerinita glutinata* (Egger) (X200) 54
1. Umbilical view; Station 24
2. Spiral view; Station 52
3. Umbilical view; Station 52
4. Umbilical view; Station 46
5. Umbilical view; Station 68

6-10. *Globigerinita iota* Parker (X150) 56
6. Umbilical view; Station 46
7. Umbilical view; Station 28
8. Edge view; Station 31
9. Spiral view; Station 46
10. Umbilical view; Station 46

11-13. *Globigerinita uvula* (Ehrenberg) (X200) 56
11. Apertural view; Station 26
12. Spiral view; Station 28
13. Apertural view; Station 46

PLATE 14

Canaries, vol. 2, pt. 2, Zoology, p. 131, pl. 1, figs. 37-39.

As stated under the discussion of *Globorotalia crassiformis*, separating that species from *Globorotalia hirsuta* can be difficult, especially the immature forms. Distinguishing characters are the less inflated chambers, more acute periphery, and the convexity of the spiral side in *Globorotalia hirsuta*.

Globorotalia hirsuta constitutes less than 1% of the planktonic fauna in surface sediments of the Gulf of Mexico (fig. 39). This species is present along the continental slope from Texas to Florida. There are also isolated occurrences in the central and southern Gulf area. At only one station, on the continental slope off the coast of eastern Texas, does its relative abundance exceed 1%.

Globorotalia hirsuta is a temperate species that flourishes in temperatures between 18 and 21°C, salinities above 35 ‰, and at depths from 100 to 250 meters (fig. 2). Its distribution is influenced by surface current systems in the Gulf of Mexico (fig. 6). The species is present in areas of active mixing and generally absent from central portions of the study area where circulation is poor.

GLOBOROTALIA INFLATA (d'Orbigny)
Plate 19, figures 6-10

Globigerina inflata D'ORBIGNY, 1839, *in* BARKER-WEBB and BERTHELOT, Hist. Nat. Iles Canaries, vol. 2, pt. 2, Zoology, p. 134, pl. 2, figs. 7-9. ,

The closest morphologic affinities of *Globorotalia inflata* are to *Globorotalia crassiformis*. However, *Globorotalia inflata* has more inflated chambers, a more rounded periphery, and greater apertural height. These characters are quite consistent and useful, even in immature specimens.

Occurrences of *Globorotalia inflata* are primarily along the continental slope in northern portions of the Gulf of Mexico (fig. 40). Here concentrations of this species range from below 1% to nearly 10% of the planktonic assemblage. Isolated, widely scattered occurrences, only one of which has a relative abundance above 1%, are present farther to the south.

Globorotalia inflata is described as a cold-temperate species that thrives in temperatures between 13 and 17°C, salinities from 34 to 36 ‰ , and at depths from 100 to 150 meters (fig. 2). It is present in living populations from higher latitudes but has been excluded from the Gulf of Mexico since the earliest Holocene (Lamb and Beard, 1972, p. 42). Although its distribution is generally limited to the coolest, least saline portions of the Gulf, water temperatures are not low enough to provide optimum conditions. Hence, its presence in significant numbers in surface sediments from the study area indicates sediments deposited during the cooler Pleistocene climate. Smaller concentrations are evidence of vertical mixing.

GLOBOROTALIA MENARDII (d'Orbigny)
Plate 20, figures 1-3

PLATE 15

Figures Page

1-11. *Globoquadrina dutertrei* (d'Orbigny) (X100) 58
1. Umbilical view; Station 46
2. Umbilical view; Station 46; dissected from adult specimen
3. Umbilical view; Station 46
4. Umbilical view; Station 46; dissected from adult specimen
5. Umbilical view; Station 46
6. Umbilical view; Station 46
7. Edge view; Station 46
8. Spiral view; Station 46
9. Umbilical view; Station 46
10. Umbilical view; Station 46; morphologic variant
11. Umbilical view; Station 46; morphologic variant

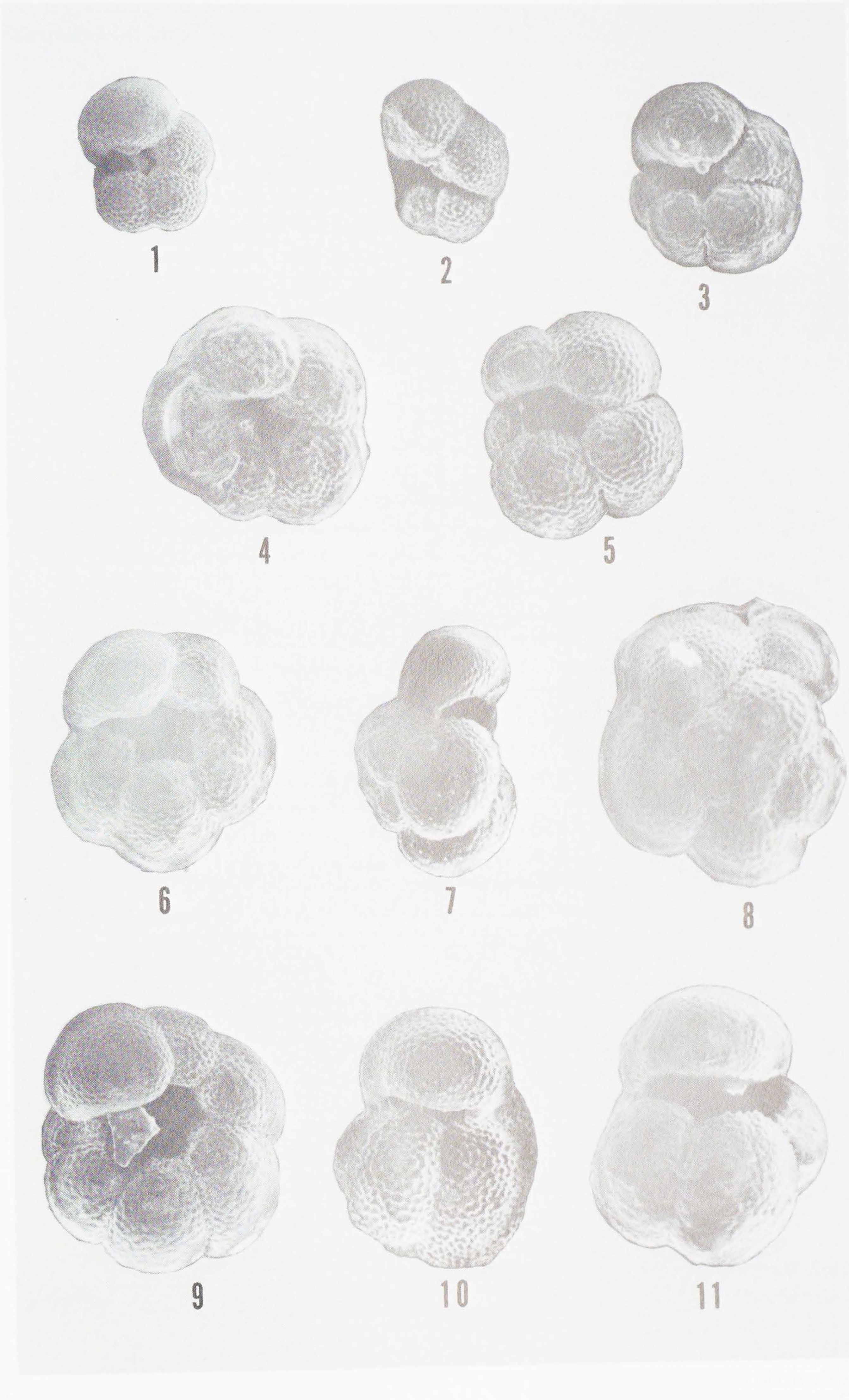

PLATE 15

Rotalia menardii D'ORBIGNY, 1826, Ann. Sci. Nat., (ser. 1) vol. 7, p. 273.

Globorotalia menardii is quite distinct and readily separated from other species encountered in the study area. However, immature specimens may be difficult to distinguish from immature *Globorotalia ungulata.* The latter species has more strongly inflated chambers, particularly the ultimate chamber of the final whorl.

Globorotalia menardii constitutes 1 to 3% of the planktonic foraminiferal assemblage over most of the Gulf of Mexico (fig. 41). Sediments in which the relative abundance of this species is below 1% are generally along the continental slope in the northern Gulf area. A large region in the central and south-central portions of the study area has concentrations ranging from 3 to 5%. Areas with relative abundances ranging from 5 to 10% are sparsely scattered through the central and southern portions of the region.

Globorotalia menardii is a subtropical species that flourishes in temperatures between 17 and 25°C, salinities above 36 ‰ , and at depths from 100 to 150 meters (fig. 2). Although its distributional pattern does not reflect changes in surface water temperatures and salinity, there is a relationship to surface current systems. The higher relative concentrations of this species (3-10%) occur in the central portion of the study area where circulation is poor (fig. 6). *Globorotalia menardii* is perhaps better adapted to such conditions than most other planktonic species.

GLOBOROTALIA SCITULA (Brady)
Plate 20, figures 4-5

Pulvinulina scitula BRADY, 1882, *in* TIZARD and MURRAY, Roy. Soc. Edinburgh, Proc., vol. 11, p. 716.

Globorotalia scitula constitutes less than 1% of the planktonic fauna in surface sediments over most of the Gulf of Mexico (fig. 42). Concentrations between 1 and 3% occur on or near the continental slope in the northern Gulf area and are widely scattered over its central and southern portions. Concentrations from 3 to 5% occur at only two localities, both in the central Gulf area.

Globorotalia scitula is a temperate species, which thrives in temperatures between 15 and 17°C (Boltovskoy, 1966). However, the species has been recorded in living populations where temperatures are as low as 3.5°C (Boltovskoy, 1971) and as high as 29°C (Bradshaw, 1959). It attains maximum abundances at depths of 200 to 300 meters (fig. 2). The ability of this species to tolerate a wide range of temperatures explains why its distribution does not reflect changes in surface water temperature in the Gulf of Mexico.

GLOBOROTALIA AKERSI Snyder
Plate 22, figures 8-9

Globorotalia akersi SNYDER, 1975, Tulane Stud. Geol. Paleont., vol. 11, no. 4, p. 302, pls. 1, 2.

Globorotalia akersi constitutes less than 1% of the planktonic fauna in one small area of the south-central Gulf of Mexico (fig. 43). The reasons for this limited distribution are not clear.

GLOBOROTALIA TRUNCATULINOIDES (d'Orbigny)
Plate 21, figures 1-4

Rotalina truncatulinoides D'ORBIGNY, 1839, *in* BARKER-WEBB and BERTHELOT, Hist. Nat. Iles Canaries, vol. 2, pt. 2, p. 132, pl. 2, figs. 25-27.

Globorotalia truncatulinoides constitutes between 1 and 3% of the planktonic fauna

PLATE 16

Figures — Page

1-11. *Pulleniatina obliquiloculata finalis* Banner and Blow, growth series, specimens from Station 72 and Station 73 (X100) 58
- 1-8. Umbilical view
- 9. Edge view
- 10. Dorsal view
- 11. Ventral view

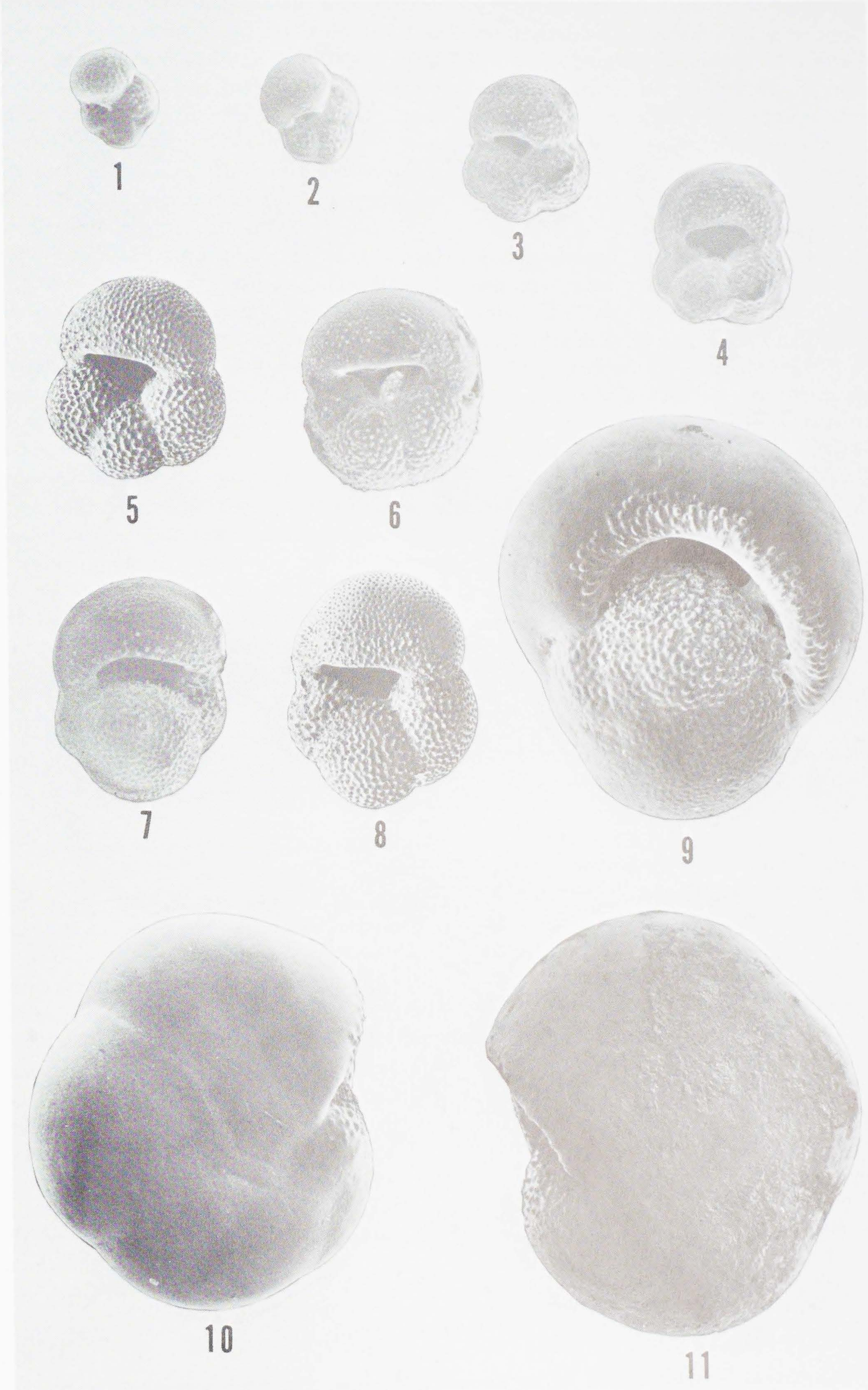

PLATE 16

throughout most of the Gulf of Mexico (fig. 44). Concentrations below 1% occur in the southeastern extremity of the study area and in isolated patches in its central portion. Relative abundances from 3 to 10% are present in the south-central, western, and northwestern regions of the Gulf. A small area off the coast of Florida has concentrations between 3 and 5%.

This species attains its maximum development in living communities with temperature conditions between 15 and 22°C, salinities from 35 to 37 ‰, and at depths from 100 to 225 meters (fig. 2). Its distributional pattern in surface sediments of the Gulf of Mexico does reflect changes in temperatures at a depth of 100 meters in the overlying waters. Concentrations above 3% occur only in areas where temperatures at this depth remain below 22°C during the entire year (fig. 4). In addition, relative abundances below 1% are encountered only where year-round temperatures at a depth of 100 meters are 24°C or more.

GLOBOROTALIA TUMIDA (Brady)
Plate 21, figures 5-7

Pulvinulina menardii var. *tumida* BRADY, 1877, Geol. Mag., (new ser., dec. 2) vol. 4, no. 12, p. 535.

Globorotalia tumida is distinguished from *Globorotalia menardii* by its greater elongation, greater thickness, and coarser surface texture. It is difficult to separate some specimens from *Globorotalia ungulata.* Most specimens of the latter species are less elongate, possess a finer surface texture, and have a much more acute umbilical shoulder than *Globorotalia tumida.* However, specimens with morphological similarities to both of these species do occur. The large, tumid forms of *Globorotalia tumida* are indicators of Holocene sediments.

Globorotalia tumida constitutes less than 1% of the planktonic foraminiferal fauna in surface sediments throughout the north-central and northeastern portions of the Gulf of Mexico (fig. 45). Except for one large area in the southeastern portion, concentrations between 1 and 3% occur only as small, isolated patches irregularly scattered over the study area. Only at one station, in the south-central Gulf of Mexico, does the relative abundance of this species exceed 3%.

Globorotalia tumida is a subtropical species that thrives in temperatures between 19 and 30°C and from the surface to depths of 300 meters (fig. 2). The distributional pattern of this species in surface sediments reflects temperature changes in overlying surface waters. Relative concentrations above 1% occur only in those areas with year-round surface water temperatures above 23°C (fig. 4). Isolated occurrences of concentrations above 1% may be related to solution phenomena. Because *Globorotalia tumida* is the planktonic foraminifer with the highest resistance to solution (table 1), local concentrations may be created by the preferential solution of less resistant species. The absence of the species at several localities in the southeastern Gulf is baffling. The author can offer no explanation for such absence in an area where concentrations above 1% would be expected.

GLOBOROTALIA UNGULATA Bermudez
Plate 22, figures 1-7

Globorotalia ungulata BERMUDEZ, 1961, Bol. Geologia (Venezuela), Spec. Pub. 3, p. 1304, pl. 15, fig. 6.

"Although the overall test shape is reminiscent of *Globorotalia tumida,* the very distinctive thin, delicate, finely perforate test wall enables this form to be recognized easily" (Lamb and Beard, 1972, p. 57). Indeed, the two species are quite similar in terms of chambering, peripheral outline, and apertural characters. Surface texture, the distinguishing feature mentioned above, is usually adequate to differentiate members of the two species. Lesser elongation of the cham-

PLATE 17

Figures		Page
1-12.	*Pulleniatina obliquiloculata finalis* Banner and Blow, dissection series; specimens from Station 72 and Station 73; all apertural views (X100)	58

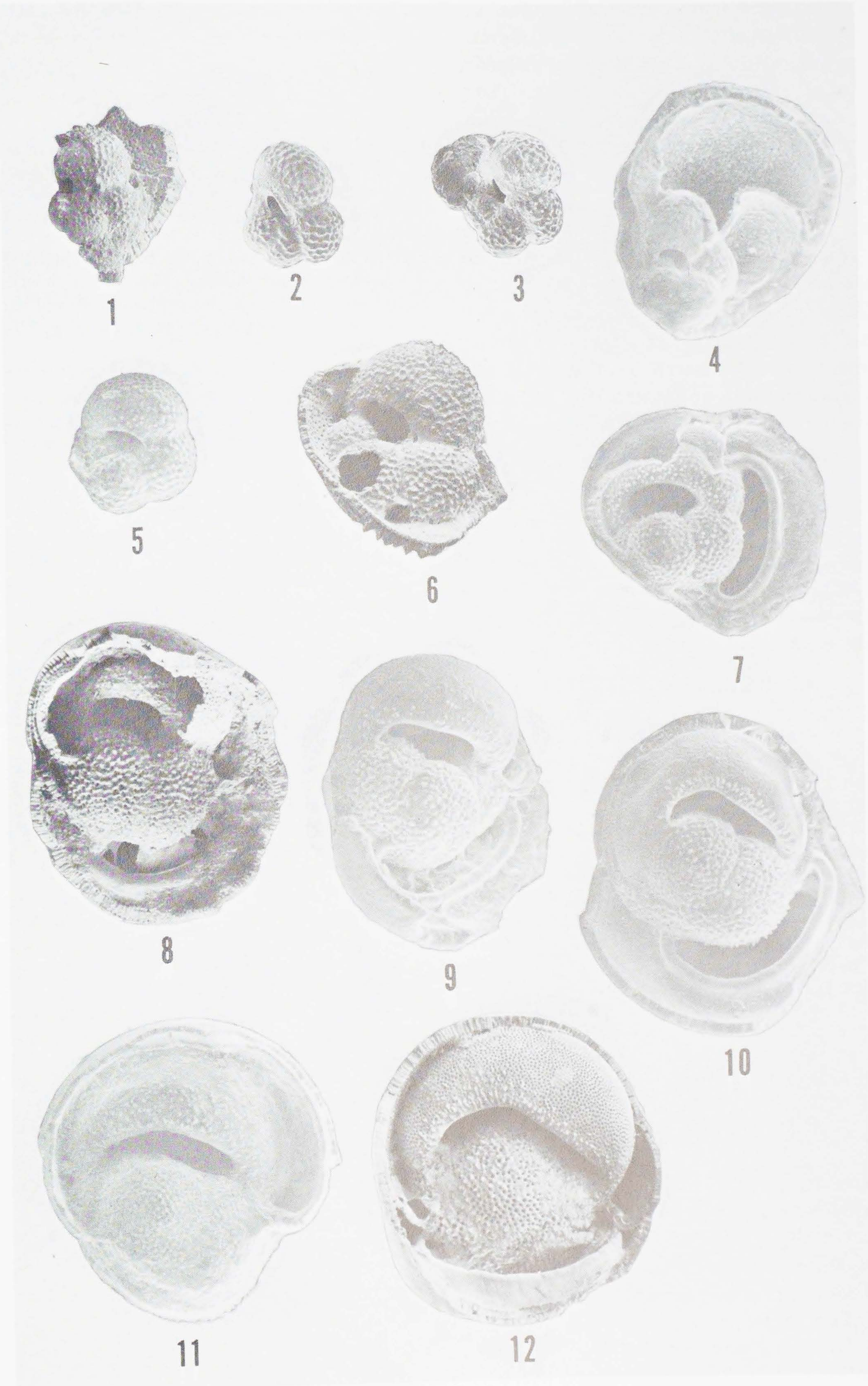

PLATE 17

bers and a more acute umbilical shoulder are other features of *Globorotalia ungulata* useful in differentiation. However, as mentioned earlier, transitional forms exist. These two "species" may be merely growth forms of the same species. Other than *Globorotalia tumida,* no species is likely to be confused with *Globorotalia ungulata.* According to Lamb and Beard (1972, p. 57) this species is not found in sediments older than earliest Holocene.

Globorotalia ungulata constitutes less than 1% of the planktonic fauna in surface sediments of the western, south-central, and northeastern Gulf of Mexico (fig. 46). Concentrations between 1 and 3% occur over the remainder of the study area.

The distribution of this subtropical-tropical species in surface sediments reflects changes in temperature at a depth of 100 meters in the overlying waters. Relative concentrations above 1% occur only in areas where year-round temperatures at this depth are above 20°C (fig. 4).

XI. REFERENCES CITED

ADEGOKE, O. S., T. F. J. DESSAUVAGIE, and C. A. KOGBE, 1971, Planktonic foraminifera in Gulf of Guinea sediments: Micropaleontology, vol. 17, no. 2, p. 197-213, tables 1-2, text-figs. 1-2, pls. 1-4.

AKERS, W. H., 1965, The Pliocene-Pleistocene boundary, northern Gulf of Mexico: Science, vol. 149, no. 3685, p. 741-742.

AKERS, W. H., 1972, Planktonic foraminifera and biostratigraphy of some Neogene formations, northern Florida and Atlantic Coastal Plain: Tulane Stud. Geol. Paleont., vol. 9, p. 1-140, figs. 1-3, pls. 1-60.

AKERS, W. H., and J. H. DORMAN, 1964, Pleistocene foraminifera of the Gulf Coast: Tulane Stud. Geol., vol. 3, no. 1, p. 1-93, pls. 1-15.

ANDERSEN, H. V., 1971, Key to Cenozoic foraminiferal families and genera of the Gulf Coastal Plain Province: Louisiana State Univ., School of Geoscience, Misc. Publ. 71-2, p. 1-33, tables 1-5.

BANDY, O. L., 1966, Restrictions of the "Orbulina" datum: Micropaleontology, vol. 12, no. 1, p. 79-86, text-figs. 1-4, pl. 1.

BANDY, O. L., 1971, Origin and development of *Globorotalia (Turborotalia) pachyderma* (Ehrenberg): Gulf Coast Assoc. Geol. Soc., Trans., vol. 21, p. 433-444, text-figs. 1-3, pls. 1-8.

BANNER, F. T., and W. H. BLOW, 1960a, The taxonomy, morphology, and affinities of the genera included in the subfamily Hastigerininae: Micropaleontology, vol. 6, no. 1, p. 19-31, text-figs. 1-11.

BANNER, F. T., and W. H. BLOW, 1960b, Some primary types of species belonging to the Superfamily Globigerinaceae: Cushman Found. Foram. Res., Contr., vol. 11, pt. 1, p. 1-45, text-fig. 1, pls. 1-8.

BANNER, F. T., and W. H. BLOW, 1962, The type specimens of *Globigerina quadrilobata* d'Orbigny, *Globigerina sacculifera* Brady, *Rotalina cultrata* d'Orbigny, and *Rotalia menardii* Parker, Jones, and Brady: Cushman Found. Foram. Res., Contr., vol. 13, pt. 3, p. 98-99; correction, pt. 4, p. 152.

BANNER, F. T., and W. H. BLOW, 1967, The origin, evolution, and taxonomy of the foraminiferal genus *Pulleniatina* Cushman, 1927: Micropaleontology, vol. 13, no. 2, p. 133-162, figs. 1-14, pls. 1-4.

BARKER, R. W., 1960, Taxonomic notes on the species figured by H. B. Brady in his report on the foraminifera dredged by H. M. S. *Challenger* during the years 1873-1876: Soc. Econ. Paleont. Min., Spec. Publ. 9, xxiv + 238 p., pls. 1-115.

BÉ, A. W. H., 1959, Ecology of Recent planktonic foraminifera. Part 1 – Areal distribution in the western North Atlantic: Micropaleontology, vol. 5, no. 1, p. 77-100, tables 1-2, text-figs. 1-52, pls. 1-2.

BÉ, A. W. H., 1960, Ecology of Recent planktonic foraminifera. Part 2 – Bathymetric and seasonal distributions in the Sargasso Sea off Bermuda: Micropaleontology, vol. 6, no. 4, p. 373-392, tables 1-6, text-figs. 1-19.

PLATE 18

Figures Page

1-6. *Globorotalia crassiformis* (Galloway and Wissler) (X150) 60

1. Umbilical view; Station 46
2. Umbilical view; Station 46
3. Umbilical view; Station 46
4. Edge view; Station 46
5. Umbilical view; Station 46
6. Spiral view; Station 46

PLATE 18

BERGER, WOLFGANG, 1968, Planktonic foraminifera: selective solution and paleoclimatic interpretation: Deep-Sea Research, vol. 15, p. 31-43.

BERGER, WOLFGANG, 1969, Ecologic patterns of living planktonic foraminifera: Deep-Sea Research, vol. 16, no. 1, p. 1-24, text-figs. 1-5, tables 1-6.

BERGER, WOLFGANG, 1969, Planktonic foraminifera: basic morphology and ecologic implications: Jour. Paleontology, vol. 43, no. 6, p. 1369-1383, text-figs. 1-9.

BERGER, WOLFGANG, and F. L. PARKER, 1970, Diversity of planktonic foraminifera in deep-sea sediments: Science, vol. 168, no. 3937, p. 1345-1347.

BERGGREN, W. A., R. K. OLSSON, and R. A. REYMENT, 1967, Origin and development of the foraminiferal genus *Pseudohastigerina* Banner and Blow, 1959: Micropaleontology, vol. 13, no. 3, p. 265-288, tables 1-14, text-figs. 1-12, pl. 1.

BLOW, W. H., 1956, Origin and evolution of the foraminiferal genus *Orbulina* d'Orbigny: Micropaleontology, vol. 2, no. 1, p. 57-70, text-figs. 1-4.

BLOW, W. H., 1969, Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy: First Internatl. Conf. Planktonic Microfossils, Proc., vol. 1, p. 199-422, text-figs. 1-49, pls. 1-54.

BOLLI, H. M., 1957, Planktonic foraminifera from the Oligocene-Miocene Cipero and Lengua formations of Trinidad, B. W. I.: U. S. Natl. Mus., Bull. 215, p. 97-123, text-figs. 17-21, pls. 22-29.

BOLLI, H. M., 1970, The foraminifera of Sites 23-31, Leg 4: Initial Repts. Deep Sea Drilling Project (JOIDES), vol. 4, p. 577-655, text-figs. 1-22, pls. 1-9.

BÉ, A. W. H., 1969, Microstructural evidence of the close affinity of *Globigerinella* Cushman to *Hastigerina* Thompson: First Internatl. Conf. Planktonic Microfossils, Proc., vol. 1, p. 89-91, pls. 1-4.

BÉ, A. W. H., and WILLIAM H. HAMLIN, 1967, Ecology of Recent planktonic foraminifera. Part 3 – Distribution in the North Atlantic during the summer of 1962: Micropaleontology, vol. 13, no. 1, p. 87-106, tables 1-3, text-figs. 1-41.

BÉ, A. W. H., W. J. JONGEBLOED, and ANDREW MCINTYRE, 1969, X-ray microscopy of Recent planktonic foraminifera: Jour. Paleontology, vol. 43, no. 6, p. 1382-1396, text-fig. 1, pls. 161-167.

BÉ, A. W. H. and ANDREW MCINTYRE, 1970, *Globorotalia menardii flexuosa* (Koch): An 'extinct' foraminiferal subspecies living in the northern Indian Ocean: Deep-Sea Research, vol. 17, no. 3, p. 595-601.

BÉ, A. W. H. and D. S. TOLDERLUND, 1971, Distribution and ecology of living planktonic foraminifera in surface waters of the Atlantic and Indian Oceans, *in* FUNNELL and RIEDEL, Micropaleontology of the Oceans, Cambridge Univ. Press, p. 105-149, tables 1-3, text-figs. 1-27.

BÉ, A. W. H., GUSTAV VILKS, and LEROY LOTT, 1971, Winter distribution of planktonic foraminifera between the Grand Banks and the Caribbean: Micropaleontology, vol. 17, no. 1, p. 31-42, text-figs. 1-9, pls. 1-2.

BEARD, J. H., and J. L. LAMB, 1968, The lower limit of the Pliocene and Pleistocene in the Caribbean and Gulf of Mexico: Gulf Coast Assoc. Geol. Soc., Trans., vol. 18, p. 174-186.

BERGER, WOLFGANG, 1967, Foraminiferal ooze: solution at depth: Science, vol. 156, no. 3773, p. 383-385, text-fig. 1.

PLATE 19

Figures — Page

1-5. *Globorotalia hirsuta* (d'Orbigny) (X150) 62
- 1. Spiral view; Station 7
- 2. Edge view; Station 28
- 3. Umbilical view; Station 2
- 4. Edge view; Station 46
- 5. Umbilical view; Station 46

6-10. *Globorotalia inflata* (d'Orbigny) (X150) 64
- 6. Edge view; Station 50
- 7. Umbilical view; Station 50
- 8. Spiral view; Station 50
- 9. Edge view; Station 50
- 10. Umbilical view; Station 50

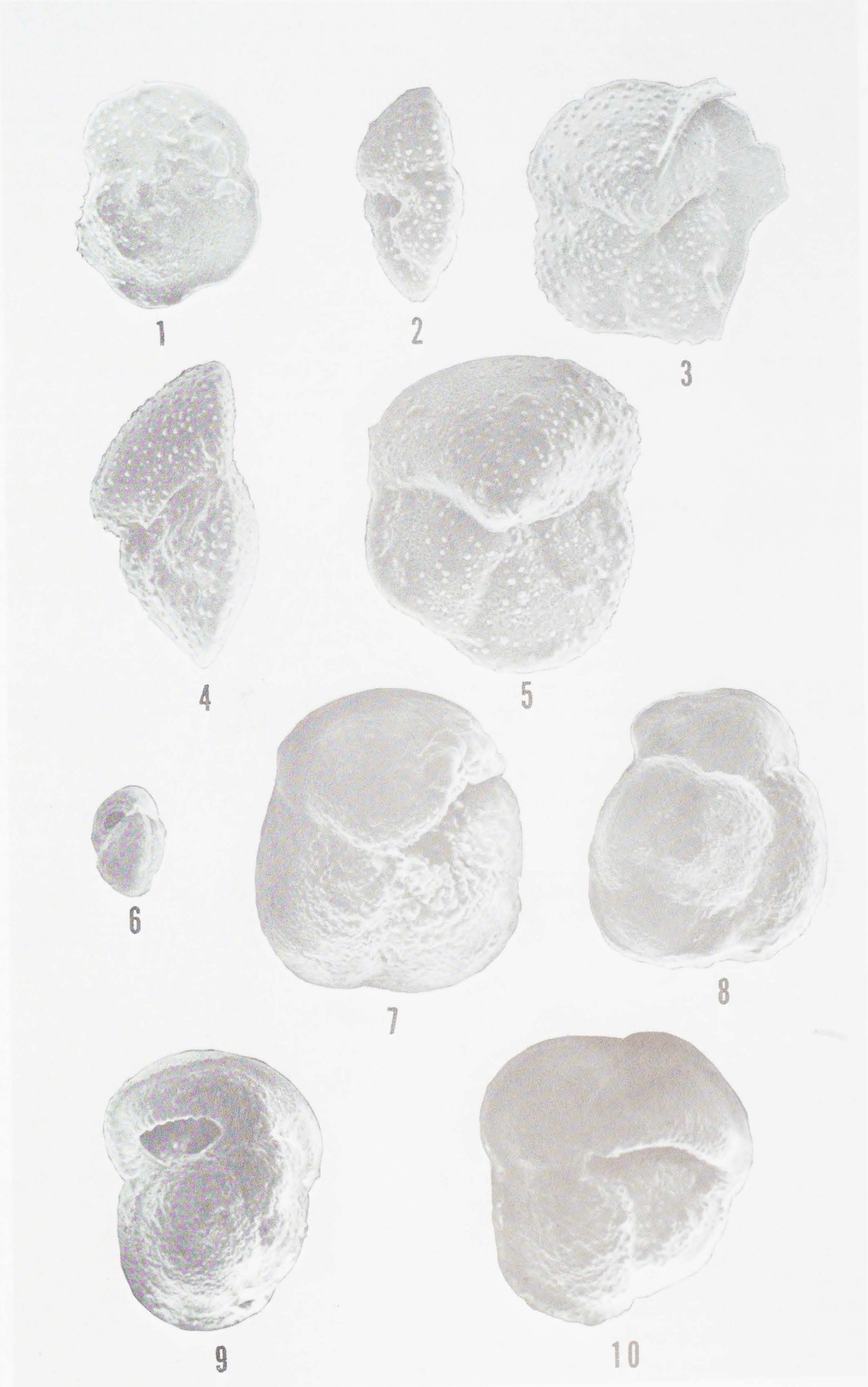

PLATE 19

BOLLI, H. M., J. E. BOUDREAUX, CESARE EMILIANI, W. W. HAY, R. J. HURLEY, and J. I. JONES, 1968, Biostratigraphy and paleotemperatures of a section cored on the Nicaragua Rise, Caribbean Sea: Geol. Soc. Amer., Bull., vol. 79, no. 4, p. 459-470.

BOLLI, H. M., A. R. LOEBLICH, JR., and HELEN TAPPAN, 1957, Planktonic foraminiferal families Hantkeninidae, Orbulinidae, Globorotaliidae, and Globotruncanidae: U. S. Natl. Mus., Bull. 215, p. 3-50, text-figs. 1-9, pls. 1-11.

BOLTOVSKOY, ESTEBAN, 1962, Planktonic foraminifera as indicators of different water masses in the South Atlantic: Micropaleontology, vol. 8, no. 3, p. 403-408.

BOLTOVSKOY, ESTEBAN, 1964, Distribution of living planktonic foraminifera in the equatorial Atlantic, western part ("Equalant" Exped.): Argentina Serv. Hidro. Naval, Publ. H639, p. 1-54, pls. 1-4, maps 1-5, text-figs. 1-4, tables 1-7.

BOLTOVSKOY, ESTEBAN, 1966, La zona de convergencia subtropical/subantarctica en el Oceano Atlantico (parte occidental): Argentina Serv. Hidro. Naval, Publ. H640, p. 1-69, maps 1-4, text-figs. 1-2, pl. 1.

BOLTOVSKOY, ESTEBAN, 1969, Living planktonic foraminifera at the 90°E. meridian from the equator to the antarctic: Micropaleontology, vol. 15, no. 2, p. 237-255, pls. 1-3.

BOLTOVSKOY, ESTEBAN, 1971a, Ecology of the planktonic foraminifera living in the surface layer of Drake Passage: Micropaleontology, vol. 17, no. 1, p. 53-68, text-fig. 1, tables 1-4, pl. 1.

BOLTOVSKOY, ESTEBAN, 1971b, Planktonic foraminiferal assemblages of the epipelagic zone and their thanatocoenoses, *in* FUNNELL and RIEDEL, Micropaleontology of the Oceans, Cambridge Univ. Press, p. 277-288, text-fig. 1.

BOLTOVSKOY, ESTEBAN, and S. WATANABE, 1975, First record of *Globigerinoides obliquus* Bolli in Recent bottom sediments: Journal Foram. Res., vol. 5, no. 1, p. 40-41.

BRADSHAW, J. S., 1959, Ecology of living planktonic foraminifera in the north and equatorial Pacific Ocean: Cushman Found. Foram. Res., Contr., vol. 10, pt. 2, p. 25-64, table 1, text-figs. 1-43, pls. 6-8.

BRONNIMANN, PAUL, 1951, The genus *Orbulina* d'Orbigny in the Oligocene-Miocene of Trinidad, B. W. I.: Cushman Found. Foram. Res., Contr., vol. 2, pt. 4, p. 132-138, text-figs. 1-5.

BRONNIMANN, PAUL, and JOHANNA RESIG, 1971, A Neogene Globigerinacean biochronologic time scale of the southwestern Pacific: Initial Repts. Deep Sea Drilling Project (JOIDES), vol. 7, pt. 2, p. 1235-1469, text-figs. 1-25, pls. 1-51.

CHANG, YI-MAW, 1967, Accuracy of fossil percentage estimation: Jour. Paleontology, vol. 41, no. 2, p. 500-502.

CHARMATZ, RICHARD, 1963, On "Hastigerina digitata" Rhumbler, 1911: Micropaleontology, vol. 9, no. 2, p. 228.

CIFELLI, RICHARD, 1961, *Globigerina incompta,* a new species of pelagic foraminifera from the North Atlantic: Cushman Found. Foram. Res., Contr., vol. 12, pt. 3, p. 83-86, table 1, pl. 4.

CIFELLI, RICHARD, 1962, Some dynamic aspects of the distribution of planktonic foraminifera in the western North Atlantic: Jour. Marine Research, vol. 20, no. 3, p. 201-213.

CIFELLI, RICHARD, 1965, Planktonic foraminifera from the western North Atlantic: Smithsonian Misc. Coll., vol. 148, no. 4, p. 1-36, text-figs. 1-4, pls. 1-9.

CIFELLI, RICHARD, 1967, Distributional analysis of North Atlantic foraminifera collected in 1961 during Cruises 17 and 21 of the R/V *Chain:* Cushman Found. Foram. Res., Contr., vol. 18, pt. 3, p. 118-127, text-figs. 1-4.

CIFELLI, RICHARD, and R. K. SMITH, 1969, Problems in the distribution of Recent planktonic foraminifera and their relationships with water mass boundaries in the North Atlantic: First Internatl. Conf. Planktonic Microfossils, Proc., vol. 1, p. 68-81, text-figs. 1-7.

CIFELLI, RICHARD, and R. K. SMITH, 1970, Distribution of planktonic foraminifera in the vicinity of the North Atlantic Current: Smithsonian Contr. Paleobiology, no. 4, p. 1-52, text-figs. 1-22, pls. 1-6.

D'ORBIGNY, ALCIDE, 1839, Foraminifères, *in* RAMON DE LA SAGRA, Histoire physique, politique, et naturelle de l'ile de Cuba: xlviii + 224 p., illus.

PLATE 20

Figures Page

1-3. *Globorotalia menardii* (d'Orbigny) (X100) 64
- 1. Umbilical view; Station 46
- 2. Umbilical view; Station 72
- 3. Spiral view; Station 72

4-5. *Globorotalia scitula* (Brady) (X200) 66
- 4. Umbilical view; Station 46
- 5. Spiral view; Station 46

PLATE 20

ELLIS, B. F., A. R. MESSINA, RICHARD CHARMATZ, and L. E. RONAI, 1969, Catalogue of index smaller foraminifera – vol. 2, Tertiary planktonic foraminifera: Amer. Mus. Nat. Hist., Spec. Publ., 538 p.

EMILIANI, CESARE, 1969, A new paleontology: Micropaleontology, vol. 15, no. 3, p. 265-300, text-figs. 1-7, pls. 1-22.

ERICSON, D. B., 1959, Coiling direction of *Globigerina pachyderma* as a climatic index: Science, vol. 130, p. 219-220, text-fig. 1.

ERICSON, D. B., MAURICE EWING, and GOESTA WOLLIN, 1963, Pliocene-Pleistocene boundary in deep-sea sediments: Science, vol. 139, no. 3556, p. 727-737, illus.

ERICSON, D. B., and GOESTA WOLLIN, 1968, Pleistocene climates and chronology in deep-sea sediments: Science, vol. 162, no. 3859, p. 1227-1234, text-figs. 1-6.

GALLOWAY, J. J., and S. G. WISSLER, 1927, Pleistocene foraminifera from the Lomita Quarry, Palos-Verdes Hills, California: Jour. Paleontology, vol. 1, p. 35-87, pls. 1-12, tables 1-3.

GIBSON, L. B., 1966, Some unifying characteristics of species diversity: Cushman Found. Foram. Res., Contr., vol. 17, pt. 4, p. 117-124.

GREINER, G. O. G., 1970, Distribution of major benthonic foraminiferal groups on the Gulf of Mexico continental shelf: Micropaleontology, vol. 16, no. 1, p. 83-101, text-figs. 1-15.

HOFKER, JAN, SR., 1969, Have the genera *Porticulasphaera, Orbulina (Candorbulina),* and *Biorbulina* a biologic meaning?: First Internatl. Conf. Planktonic Microfossils, Proc., vol. 1, p. 279-286, pls. 1-3.

JENKINS, D. G., 1967, Recent distribution, origin, and coiling ratio changes in *Globigerina pachyderma* (Ehrenberg): Micropaleontology, vol. 13, no. 2, p. 195-203, illus.

JENKINS, D. G., and W. N. ORR, 1972, Planktonic foraminiferal biostratigraphy of the eastern equatorial Pacific: Initial Repts. Deep Sea Drilling Project (JOIDES), vol. 9, p. 1059-1193, text-figs. 1-9, pls. 1-41.

JONES, J. I., 1966, The distribution and variation of living pelagic foraminifera in the Caribbean: Third Caribbean Geol. Conf., Trans. (Kingston, Jamaica), p. 178-183, text-figs. 1-3, tables 1-2.

JONES, J. I., 1967, Significance of distribution of planktonic foraminifera in the Equatorial Atlantic Undercurrent: Micropaleontology, vol. 13, no. 4, p. 489-501, table 1, text-figs. 1-36.

JONES, J. I., 1968, The relationship of planktonic foraminiferal populations to water masses in the western Caribbean and lower Gulf of Mexico: Bull. Marine Science, vol. 18, no. 4, p. 946-982, text-figs. 1-16.

KENNETT, J. P., 1968, Latitudinal variation in *Globigerina pachyderma* (Ehrenberg) in surface sediments of the northwest Pacific Ocean: Micropaleontology, vol. 14, no. 3, p. 305-318, table 1, text-figs. 1-9, pl. 1.

KENNETT, J. P., 1969, Distribution of planktonic foraminifera in surface sediments southeast of New Zealand: First Internatl. Conf. Planktonic Microfossils, Proc., vol. 2, p. 307-322, text-figs. 1-9.

LAMB, J. L., 1969, Planktonic foraminiferal datums and Late Neogene epoch boundaries in the Mediterranean, Caribbean, and Gulf of Mexico: Gulf Coast Assoc. Geol. Soc., Trans., vol. 19, p. 559-578, text-figs. 1-8, pls. 1-3.

LAMB, J. L. and J. H. BEARD, 1972, Late Neogene planktonic foraminifers in the Caribbean, Gulf of Mexico, and Italian stratotypes: Univ. Kansas Paleont. Contr., Protozoa, Art. 8, p. 1-67, text-figs. 1-25, pls. 1-36.

LOEBLICH, A. R., JR., and HELEN TAPPAN, 1964, Sarcodina – Chiefly "Thecamoebians" and Foraminiferida, *in* R. C. MOORE, Treatise on Invertebrate Paleontology, Part C, Protista 2, 900 p., 653 figs.

PLATE 21

Figures — Page

1-4. *Globorotalia truncatulinoides* (d'Orbigny) (X100) 66
- 1. Umbilical view; Station 46
- 2. Umbilical view; Station 46
- 3. Umbilical view; Station 72
- 4. Edge view; Station 72

5-7. *Globorotalia tumida* (Brady) (X100) 68
- 5. Umbilical view; Station 46
- 6. Edge view; Station 46
- 7. Spiral view; Station 46

8-9. *Globorotalia flexuosa* (Koch) 62
- 8. Umbilical view, X73; Station 46
- 9. Edge view, X65; Station 46

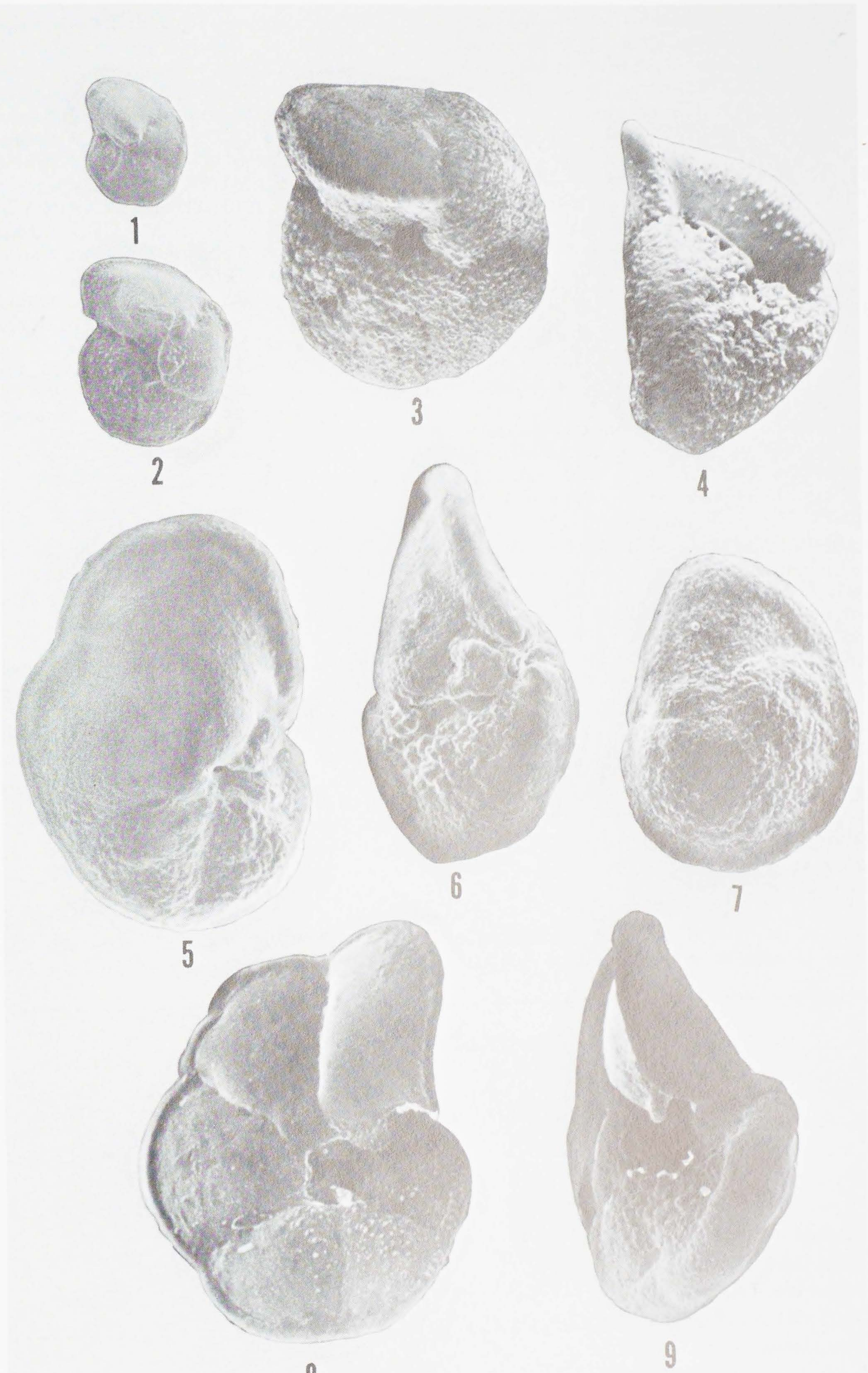

PLATE 21

LYNTS, G. W., 1971, Analysis of the planktonic foraminiferal fauna of Core 6275, Tongue of the Ocean, Bahamas: Micropaleontology, vol. 17, no. 2, p. 152-166, tables 1-8, text-figs. 1-4.

ODUM, E. P., 1969, The strategy of ecosystem development: Science, vol. 164, no. 3877, p. 262-270.

ODUM, H. T., J. E. CANTLON, and L. S. KORNICKER, 1960, An organizational hierarchy postulate for the interpretation of species – individual distributions, species entropy, ecosystem evolution, and the meaning of a species – variety index: Ecology, vol. 41, no. 2, p. 395-399.

ORR, W. N., 1969, Variation and distribution of *Globigerinoides ruber* in the Gulf of Mexico: Micropaleontology, vol. 15, no. 3, p. 373-379, text-figs. 1-6, pl. 1.

PARKER, F. L., 1954, Distribution of foraminifera in the northeastern Gulf of Mexico: Harvard Mus. Comp. Zoology, Bull., vol. 111, no. 10, p. 453-588, text-figs. 1-9, tables 1-30, pls. 1-13.

PARKER, F. L., 1955, Distribution of planktonic foraminifera in some Mediterranean sediments: Papers in Marine Biology and Oceanography, Deep-Sea Research, Suppl. to vol. 3, p. 204-211, table 1, fig. 1.

PARKER, F. L., 1958, Eastern Mediterranean foraminifera: Swedish Deep-Sea Exped., Rept., vol. 8, no. 4, p. 219-285, tables 1-20, text-figs. 1-6, pls. 1-6.

PARKER, F. L., 1960, Living planktonic foraminifera from the equatorial and southeast Pacific: Tohoku Univ., Sci. Repts., ser. 2 (Geol.), spec. vol., no. 4, p. 71-82, text-figs. 1-20.

PARKER, F. L., 1962, Planktonic foraminiferal species in Pacific sediments: Micropaleontology, vol. 8, no. 2, p. 219-254, tables 1-4, pls. 1-10.

PARKER, F. L., 1967, Late Tertiary biostratigraphy (planktonic foraminifera) of tropical Indo-Pacific deep-sea cores: Bull. Amer. Paleontology, vol. 52, no. 235, p. 115-208, 5 text-figs., pls. 17-32.

PARKER, F. L., 1971, Distribution of planktonic foraminifera in Recent deep-sea sediments, *in* FUNNELL and RIEDEL, Micropaleontology of the Oceans, Cambridge Univ. Press, p. 289-307, table 1, text-figs. 1-10.

PHLEGER, F. B, 1951, Ecology of foraminifera, northwest Gulf of Mexico: Geol. Soc. America, Mem. 46, pt. 1, Foraminifera Distribution, p. 1-88, text-figs. 1-33.

PHLEGER, F. B, 1960a, Ecology and distribution of Recent foraminifera: The Johns Hopkins Press, Baltimore, 297 p., illus.

PHLEGER, F. B, and F. L. PARKER, 1951, Ecology of foraminifera, northwest Gulf of Mexico: Geol. Soc. America, Mem. 46, pt. 2, Foraminifera Species, p. 1-64, pls. 1-20.

POAG, C. W., 1969, The Pliocene-Pleistocene boundary in the Gulf Coast region: Tulane Stud. Geol. Paleont., vol. 7, no. 2, p. 72-74 and 90.

POAG, C. W., 1971, A reevaluation of the Gulf Coast Pliocene-Pleistocene boundary: Gulf Coast Assoc. Geol. Soc., Trans., vol. 21, p. 291-308, illus.

PYLE, T. E., 1968, Late Tertiary history of Gulf of Mexico based on a core from Sigsbee Knolls: Amer. Assoc. Petr. Geol., Bull., vol. 52, no. 11, p. 2242-2262, text-figs. 1-8, tables 1-2.

RENZ, H. H., 1948, Stratigraphy and fauna of the Agua Salada Group, state of Falcón, Venezuela: Geol. Soc. Amer., Mem. 32, p. 1-219, text-figs. 1-15, tables 1-19, pls. 1-12.

RIEDEL, W. R., M. N. BRAMLETTE, and F. L. PARKER, 1963, "Pliocene-Pleistocene" boundary in deep-sea sediments: Science, vol. 140, no. 3572, p. 1238-1240.

RIESS, Z., P. MERLING-RIESS, and S. MOSHKOVITZ, 1971, Quaternary planktonic foraminiferida and nannoplankton from the Medi-

---

PLATE 22

Figures	Page
1-7. *Globorotalia ungulata* Bermudez (X100)	68
1. Umbilical view; Station 46
2. Umbilical view; Station 46
3. Umbilical view; Station 46
4. Umbilical view; Station 46
5. Umbilical view; Station 46
6. Edge view; Station 46
7. Spiral view; Station 46
8-9. *Globorotalia akersi* Snyder (X100)	66
8. Spiral view; Station 46
9. Umbilical view; Station 83

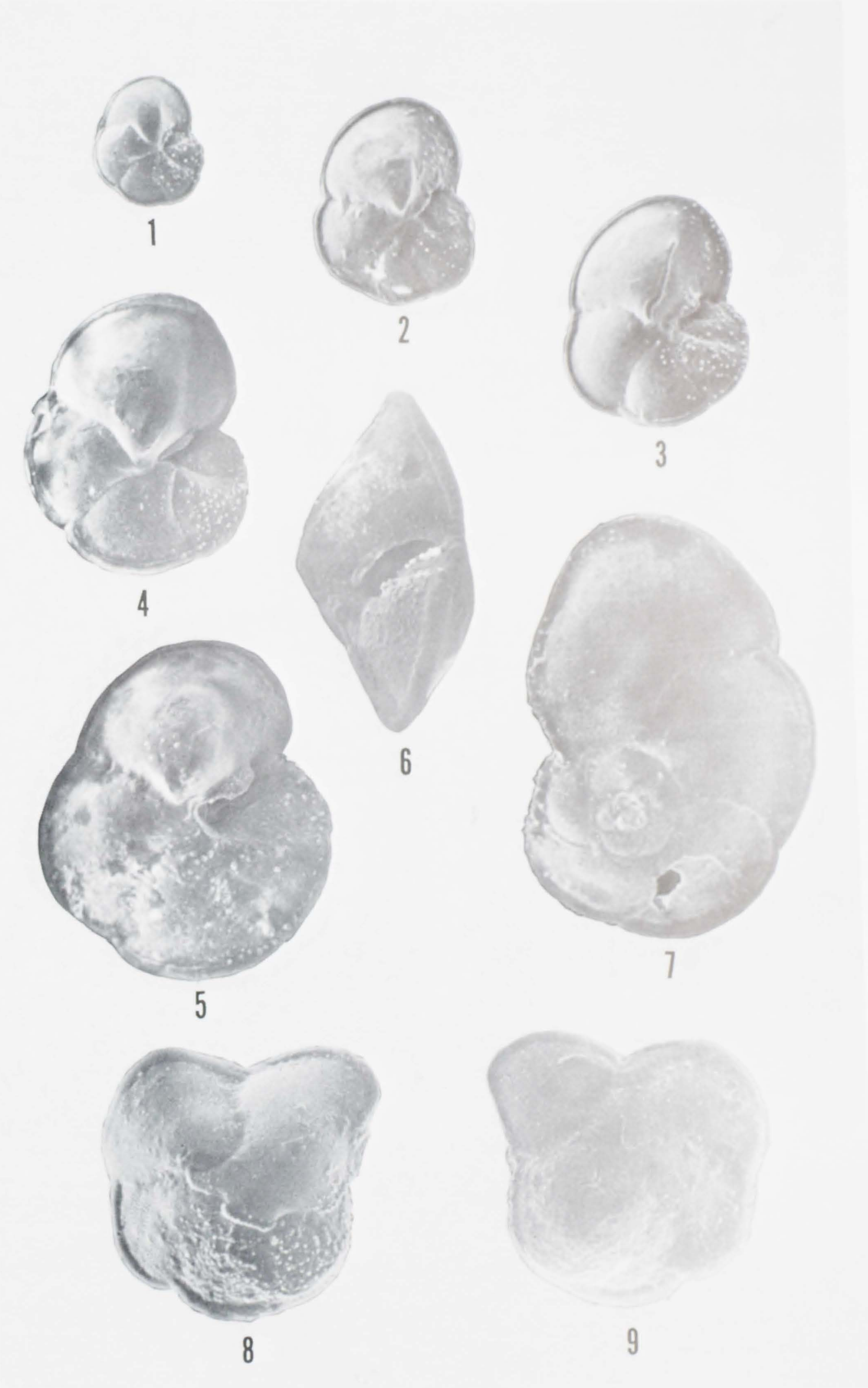

PLATE 22

terranean continental shelf and slope of Israel: Israel Jour. Earth Science, vol. 20, no. 4, p. 141-178, text-figs. 1-9, table 1, pls. 1-15.

RUDDIMAN, W. F., 1969, Recent planktonic foraminifera: dominance and diversity in North Atlantic surface sediments: Science, vol. 164, no. 3884, p. 1164-1167, illus.

RUDDIMAN, W. F., and B. C. Heezen, 1967, Differential solution of planktonic foraminifera: Deep-Sea Research, vol. 14, no. 6, p. 801-808, illus.

SAID, RUSHDI, 1950, The distribution of foraminifera in the northern Red Sea: Cushman Found. Foram. Res., Contr., vol. 1, pt. 2, p. 9-29.

SKINNER, H. C., and H. C. EPPERT, JR., 1966, A bibliography of foraminiferal ecology and paleoecology: Gulf Coast Assoc. Geol. Soc., Trans., vol. 16, p. 355-371.

SNYDER, S. W., 1975, A new Holocene species of *Globorotalia:* Tulane Stud. Geol. Paleont., vol. 11, no. 4, p. 302-305, pls. 1-2.

TOLDERLUND, D. S., and A. W. H. BÉ, 1971, Seasonal distribution of planktonic foraminifera in the western North Atlantic: Micropaleontology, vol. 17, no. 3, p. 297-329, tables 1-8, text-figs. 1-19.

UJÜE, HIROSHI, 1968, Distribution of living planktonic foraminifera in the southeast Indian Ocean: Nat. Sci. Mus. Tokyo, Bull., vol. 11, no. 1, p. 97-123, text-figs. 1-23, pls. 1-10.

WILHELM, OSCAR, and MAURICE EWING, 1972, Geology and history of the Gulf of Mexico: Geol. Soc. Amer., Bull., vol. 83, no. 3, p. 575-600, text-figs. 1-25, map.

ZOBEL, B., 1971, Foraminifera from plankton tows, Arabian Sea: areal distribution as influenced by ocean water masses: Second Internatl. Conf. Planktonic Microfossils, Proc., vol. 2, p. 1323-1333, text-figs. 1-8, pl. 1.

REVIEWS

FOSSIL ALGAE: Recent Results and Developments, edited by Erik Flügel. Published by Springer-Verlag, Berlin, Heidelberg and New York, 1977, xiii + 375 pp., 119 figures, 32 plates, $36.10

This book presents a review of recent progress in knowledge of algae and algal constructions and the role of algae as facies indicators and sedimentological factors in both Recent and ancient environments. It includes articles on the biology and morphology of blue-green algae, and on the ultrastructure of the calcareous algae. Twelve papers deal with algae and their sedimentary environments. The volume is the product of fifty-eight contributing authors from all parts of the world. The coverage of the subject is thorough and should prove to be of great value and interest to biologists as well as paleontologists and stratigraphers. The book is well illustrated and includes an index of generic and species names, as well as a subject index.

THE MEANING OF FOSSILS: Episodes in the History of Paleontology, second edition, by Martin J. S. Rudwick. Published by Science History Publications, USA, a division of Neale Watson Academic Publications, Inc., New York, 1977, xv + 287 pp., illus., cloth $15.00, paper $6.95

The first edition of this book appeared in 1972. It has been reissued with line corrections in the text and a new preface by Professor Rudwick at a reduced price and in paperback to encourage wider student use. The work is divided into five sections. *Fossil Objects* and *Natural Antiquities* treat the sixteenth and seventeenth centuries before paleontology, or even geology itself, had become codified and recognized as a distinct scientific discipline. The third chapter, *Life's Revolutions,* begins late in the eighteenth century with one of Cuvier's principal papers on extinction and continues to the year 1830. The fourth, *Uniformity and Progress,* treats the years between the appearance of Lyell's *Principles of Geology* and Darwin's *Origin of Species. Life's Ancestry,* the last chapter, deals with Bronn and Darwin and the later nineteenth century development of evolutionary theory.

In Martin Rudwick's own words, "this book makes no pretence at being an exhaustive or 'definitive' account of the history of paleontology," but presents his "own interpretation in a coherent and straightforward form, so that the non-specialist reader can at least see how the picture looks to *one* historian." This he has done ably and well.

--H.C.S.