THE DISTRIBUTION OF PLANKTONIC FORAMINIFERA IN THE NORTHWEST GULF OF MEXICO

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THESIS

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ABSTRACT

THE DISTRIBUTION OF PLANKTONIC FORAMINIFERA IN THE NORTHWEST GULF OF MEXICO

By

William Norton Orr

Populations of twenty-two species of recent planktonic Foraminifera were studied from sediments in the northwest Gulf of Mexico. The distribution of the species and variants of the species in the marine sediments were found to be closely related to the relative abundance, life cycle, and depth preference of living populations. Many of the distribution patterns of variants of species particularly those with secondarily calcified tests are remarkably well-defined and constant with respect to depth in the northwest Gulf of Mexico. The distribution patterns of recent planktonics in sediments which have been outlined in this study may be of use as depth indices in fossil planktonic assemblages. Several planktonic species and variants previously unreported from the Gulf of Mexico are recorded with their distribution in the northwest Gulf.

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Introduction

It has been demonstrated by a number of authors (Bé, 1960, Jones, 1964, Bradshaw, 1959) that living planktonic Foraminifera are invariably vertically stratified to some degree in the bathymetric column. This vertical stratification of living specimens may involve entire populations or infraspecific variant groups within populations. Moreover, vertical stratification of species or variants of the species may change rapidly in cycles as short as twelve hours or in somewhat less ephemeral monthly or yearly cycles.

Authors (Phleger and Parker, 1951, Bandy, 1951) have also noted that the accumulations of empty tests of these organisms in marine sediments change considerably in their compositional character in traverses from shallow to deep water.

The purpose of the present study is two-fold: first to determine what, if any, relationship exists between the distribution of planktonic Foraminiferal tests in marine sediments and the vertical stratification of living specimens and, second, to establish which, if any, of the distributional patterns of empty tests in marine sediments may be utilized to make retrospections relative to the depth habitat and distribution of fossil populations.

In order to conduct this study, an area was selected in the Gulf of Mexico with a high frequency of available samples, a relatively simple bottom topography, an an absence of known strong subsurface currents. It was expected that in such an area with a minimum of extraneous operative variables the distribution patterns of living specimens might emerge as the primary factor controlling the distribution patterns of the empty tests in the sediments. Prior distribution studies of planktonic Foraminifera (Phleger and Parker, 1951, Parker, 1954) have been conducted in the Gulf of Mexico. These studies differ from the present study in three respects. First, the sample frequency of the present study was substantially higher than previous studies. Second, the present study considers only the planktonic Foraminifera while prior studies considered the benthonic as well as the planktonic Foraminifera. And third, the present study considers the distribution of infraspecific variants of species as well as populations of planktonic species; whereas, prior workers considered only population or interspecific distributions.

Intraspecific characters tabulated in this study included specimen size, wall thickness, color, incidence of spines and bullae, coiling, chamber, and aperture variation and pore size. Many of these intraspecific characters, when tabulated from specimens in the sediments, show a close relationship to the bathymetry, temperature, and salinity variations in the northwest Gulf as well as to the known vertical distribution of living planktonics in the bathymetric column. Other intraspecific characters in the above group are apparently random with respect to the physical or biological variables mentioned.

Previous Work

A great deal of descriptive work on the distribution of recent planktonic Foraminifera has been done in the last seventy-five years. Most of this work, however, has been on the areal distribution rather than on the vertical distribution of these organisms.

Of the few papers which did deal with vertical distribution, one of the earliest and most significant was that of Rhumbler, 1911, in which he described a nocturnal/diurnal vertical migration of pelagic Foraminiferal populations.

Lohman, 1920, considered the areal as well as vertical distribution of pelagic Foraminifers in a study conducted in the north and south Atlantic. He reported the highest percentages of plankton from the upper one hundred meters of the bathymetric column.

Schott, 1935, studied live plankton from the equatorial Atlantic and reported high percentages of plankton in the upper water column similar to Lohman's findings. He also reported a high concentration of plankton at one thousand meters. Emiliani, 1954, chemically analyzed the tests of a number of planktonic Foraminiferal species collected from sediments. Using isotope ratios as a guide to the temperature at which the tests were precipitated, Emiliani suggested the probable depth habitat of a number of species of planktonic Foraminifera.

Bé, 1959, 1960, has been and is conducting a thorough study of the areal and vertical distribution of planktonic Foraminifera from plankton hauls and marine sediments in the north and south

Atlantic. In these studies he has noted some vertical stratification of juvenile and adult populations and of certain variants of species.

Bradshaw, 1959, studied Foraminifera from plankton hauls in the Pacific and reported a temperature preference by certain species of planktonic Foraminifera. This temperature preference controls the organism's areal as well as vertical distribution.

Jones, 1965, studied live planktonics from the Caribbean area and was able to show temperature preference and vertical stratification of populations similar to those of Bradshaw, 1959. In addition, Jones, 1965, has shown the vertical and areal distribution of planktonic faunas to vary considerably over monthly and annual periods.

In summary, there is abundant evidence that planktonic faunas are vertically stratified in the water column by species and in some cases by variants of the species. This vertical stratification may change over very short periods (diurnal/nocturnal migration), and the faunal character of an area may change considerably over an annual period. The highest percentages of planktonic Foraminiferal faunas are to be found living in the upper one hundred meters of the water column. While other physical and chemical variables will have an effect on the distribution of plankton, the organisms seem to be most sensitive to temperature.

In the present study, many of these known distributions of live organisms in the water column were found to correspond closely to the distribution of the empty tests in the marine sediments. The living distributions, which are not manifest in sediments, were found to be those ephemeral distributions such as nocturnal/diurnal, vertical distributions or monthly/annual fluctuations in the standing crop.

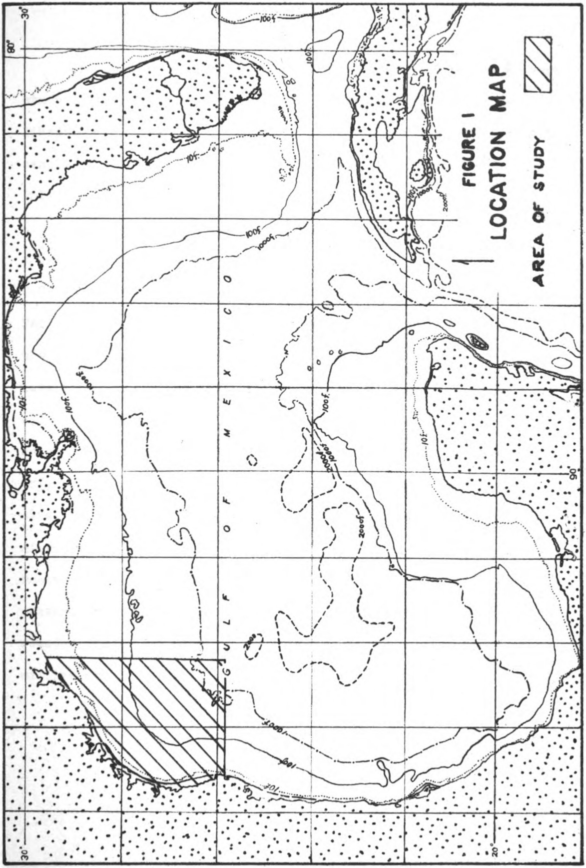


FIGURE I
LOCATION MAP

Sample Preparation and Counting Procedure

One hundred and twenty-seven samples were used in the present study (figure 2, page 7). These were obtained from the sample libraries of a number of petroleum companies and universities. All samples are from the upper one half inch of the sample taken in a Phleger-type coring device.

The samples were processed for counting by wet sieving through a two hundred and fifty mesh screen (Tyler standard screen scale: 0.062 mm openings), dried, and randomly split into five gram aliquots. The planktonic Foraminifera in the samples were tabulated by counting the first two hundred specimens encountered in a random strew. When less than two hundred specimens were present in a single sample, all specimens in the sample of five grams were counted. For this reason, areal distribution of species is plotted by percentage. The only variation which was recorded for all twenty-two species was size. Specimen size was measured in millimeters using an eyepiece micrometer and recording only the maximum diameter for each specimen. Because not every specimen in a random strew will lie flat enough to measure the maximum diameter accurately, the measurements were rounded off in the graphic presentation to the nearest tenth of a millimeter.

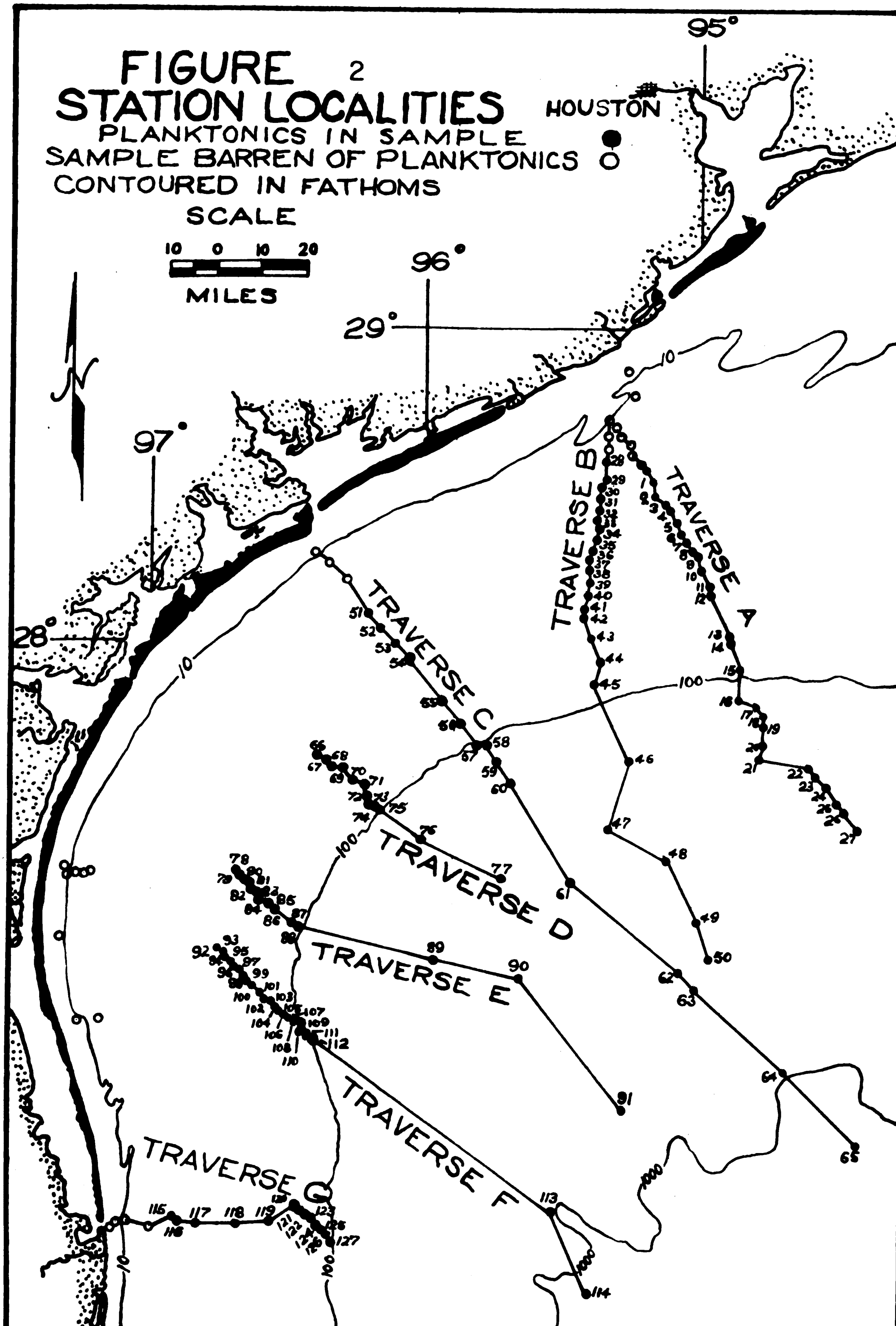


FIGURE 2
STATION LOCALITIES
PLANKTONICS IN SAMPLE
SAMPLE BARREN OF PLANKTONICS
CONTOURED IN FATHOMS
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
N
TRAVERSE A
TRAVERSE B
TRAVERSE C
TRAVERSE D
TRAVERSE E
TRAVERSE F
TRAVERSE G
10
100
1000

Physical Features of the Area of Study

The present study of recent planktonic Foraminifera was conducted in a roughly triangular-shaped area in the northwest Gulf of Mexico (figure 1, page 5). The area is bordered on the west and north by the Texas coast and on the south and east by latitude 25° N and longitude 94° W respectively. The arcuate coast line is characterized by lagoons and offshore barrier islands separated by passes at the mouths of the major rivers. The continental shelf in this area ranges in width from forty miles off Brownsville, Texas, to one hundred miles off Galveston, Texas, with an average gradient of two fathoms per mile. Topography of the continental shelf is smooth with few irregularities of greater relief than fifty feet (figure 3, page 9). No abrupt break in slope takes place between the continental shelf and slope. The limit of the shelf has been placed at one hundred fathoms where a gradual increase in gradient begins with a maximum gradient on the slope of ten fathoms per mile. The continental slope in this area ranges from sixty to one hundred miles in areal width. The upper part of the slope is characterized by rugged topography consisting of numerous high knolls and silled basins, many with closures of over one thousand feet. In the lower portion of the continental slope between one thousand fathoms and seventeen hundred fathoms, the gradient increases abruptly to a maximum of one hundred fathoms/mile. Below seventeen hundred fathoms the Sigsbee Deep extends down twenty-two hundred fathoms and is characterized by gentle slopes and subdued relief.

The northwest Gulf of Mexico is an area of converging surface

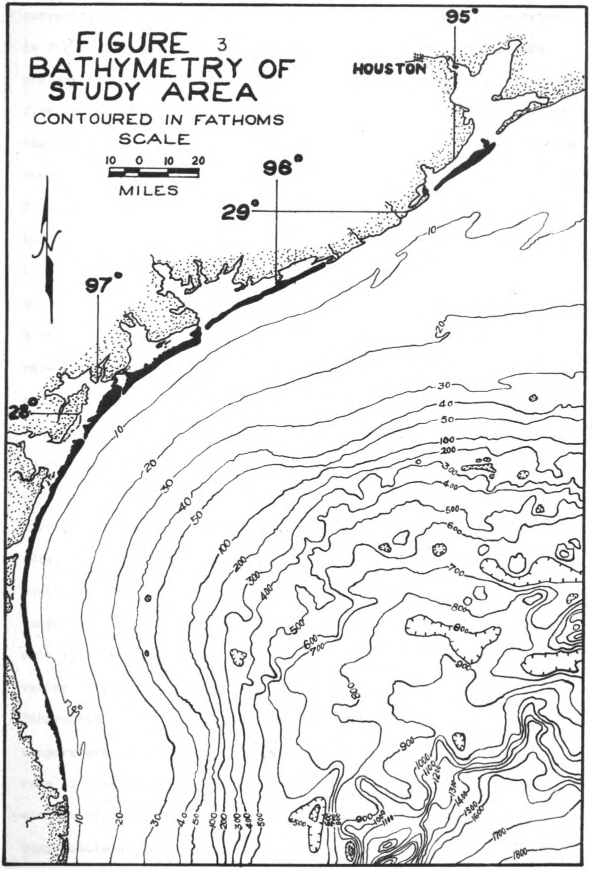
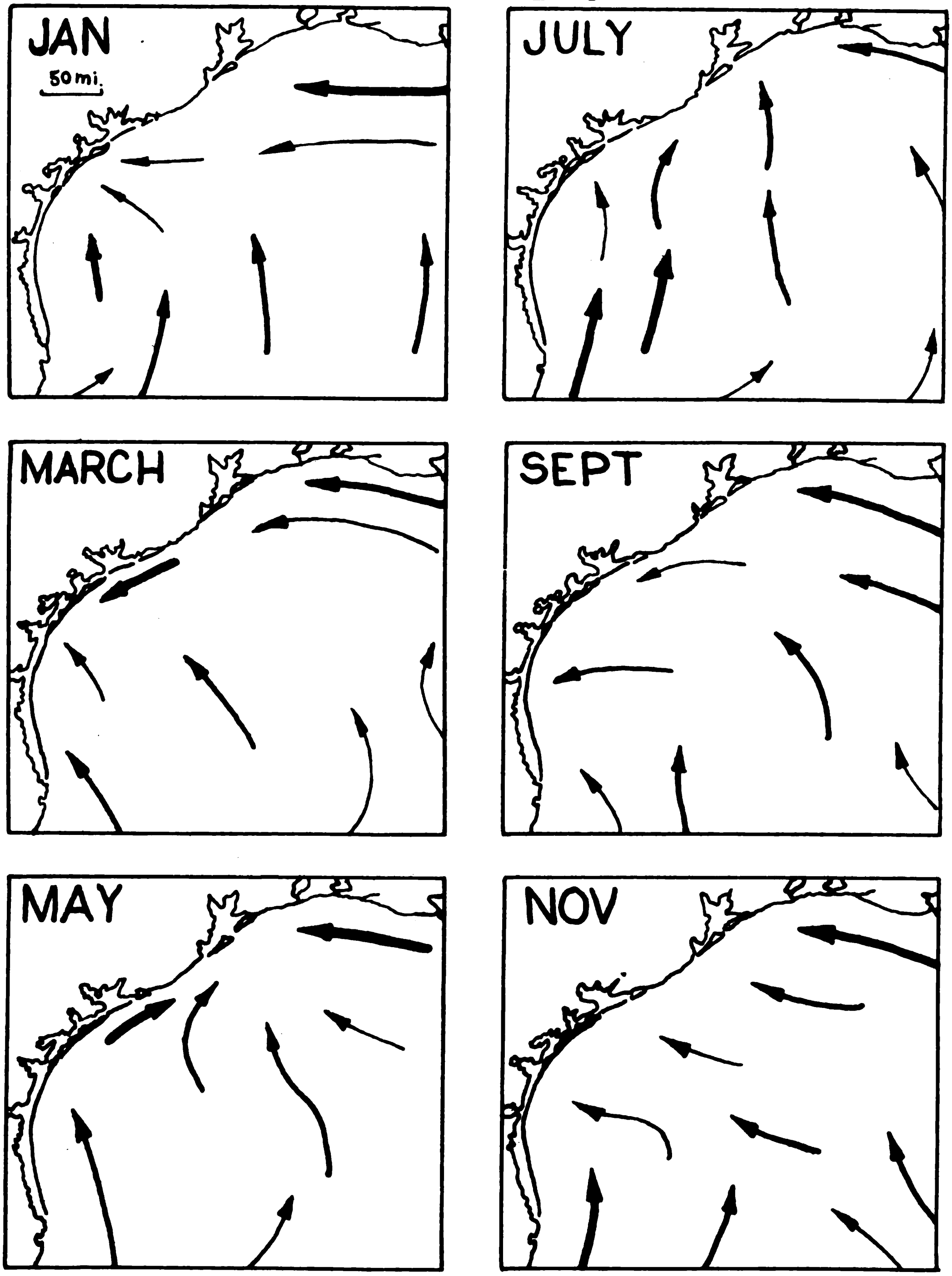


FIGURE 3
BATHYMETRY OF STUDY AREA
CONTOURED IN FATHOMS
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
10
20
30
40
50
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800

currents. Major marine surface currents in the Gulf are illustrated in figure 4, page 11. Surface currents for the northwest Gulf are presented in figure 5, page 12. From May through July surface currents flow in a predominantly northerly direction. During the remainder of the year currents flow predominantly in a westward direction. Surface currents in the Gulf of Mexico (Leipper, 1953) originate from the Yucatan Channel (figure 4, page 11). Upon passing through the Channel and entering the Gulf the current divides in three directions: east to the Florida Straits, north to the mouth of the Mississippi River, and west across the Campeche Bank. The northward current toward the Mississippi River divides south of the Mississippi into east and west currents. The Campeche current follows the coast of Mexico north and converges with the central current in the northwest Gulf of Mexico. The net predominance of these individual converging currents changes, as mentioned previously, from northward in the summer to westward in the winter months. No information was available on subsurface currents in the study area. Phleger and Parker, 1951, and Emiliani, 1954, have reported the temperature and salinity variation in the northwest Gulf of Mexico (figure 6, page 13). The open ocean temperature in the northwest Gulf above the upper boundary of the main thermocline at seventy to one hundred and twenty-five meters varies from sixty-six degrees Fahrenheit to seventy degress Fahrenheit. Below the thermocline, little annual variation in temperature takes place. Open ocean temperature drops at an average rate of five degrees Fahrenheit per three meters of depth to a minimum of forty degrees Fahrenheit at eight hundred meters. Average temperature of the surface water decreases shoreward from a maximum

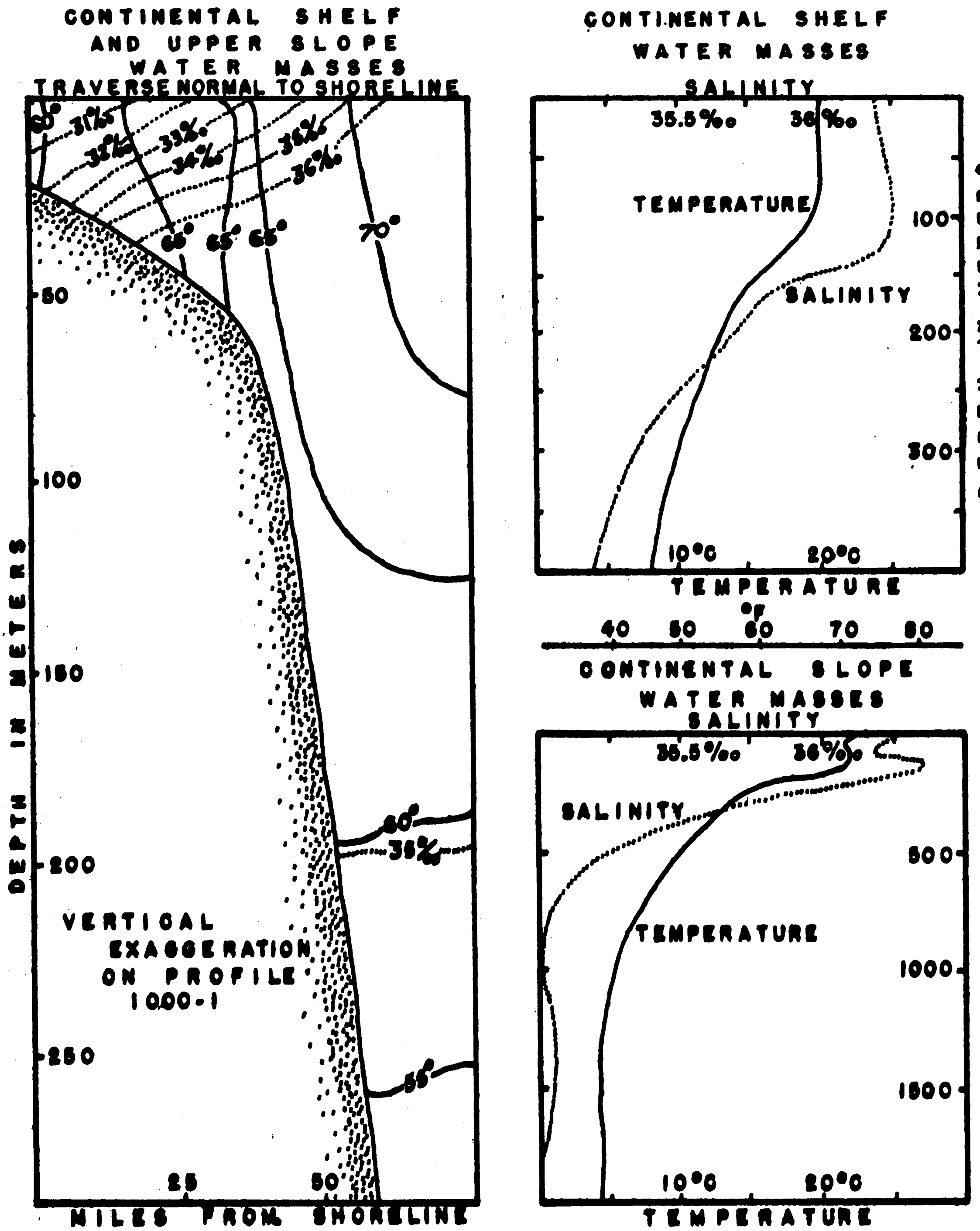
FIGURE 5



NORTHWEST GULF OF MEXICO SURFACE CURRENTS AFTER CURRAY 1960

CURRENT VECTOR VALUES → <5 NAUTICAL Mi./DAY
5-10
>10

FIGURE 6
VERTICAL DISTRIBUTION OF SALINITY AND TEMPERATURE IN THE NORTHWEST GULF OF MEXICO
AFTER PHLEGER 1951



of seventy-five degrees Fahrenheit to a minimum of fifty-four degrees Fahrenheit. Salinity of the offshore water in the northwest Gulf averages thirty-six and twenty-five hundreds parts per thousand to thirty-six and thirty-five hundreds parts per thousand. Variation in the salinity of offshore water in the uppermost one hundred and fifty meters of water is limited with salinity increasing slightly with depth accompanied by an increase in temperature. Below one hundred meters, salinity decreases to a minimum of less than thirty-five parts per thousand at six hundred to eight hundred meters (figure 6, page 13). Changes in temperature and salinity with depth in water masses overlying the middle and upper continental shelf are far more abrupt than in offshore water masses. Salinity of the shelf water masses increases with depth in some cases as much as one part per thousand per ten feet of depth. The temperature of shelf water masses, on the other hand, is relatively constant in vertical traverses but increases basinward at an average of one degree Fahrenheit with each succeeding ten miles from the shoreline up to twenty-five miles.

Distribution of Planktonics in Marine Sediments

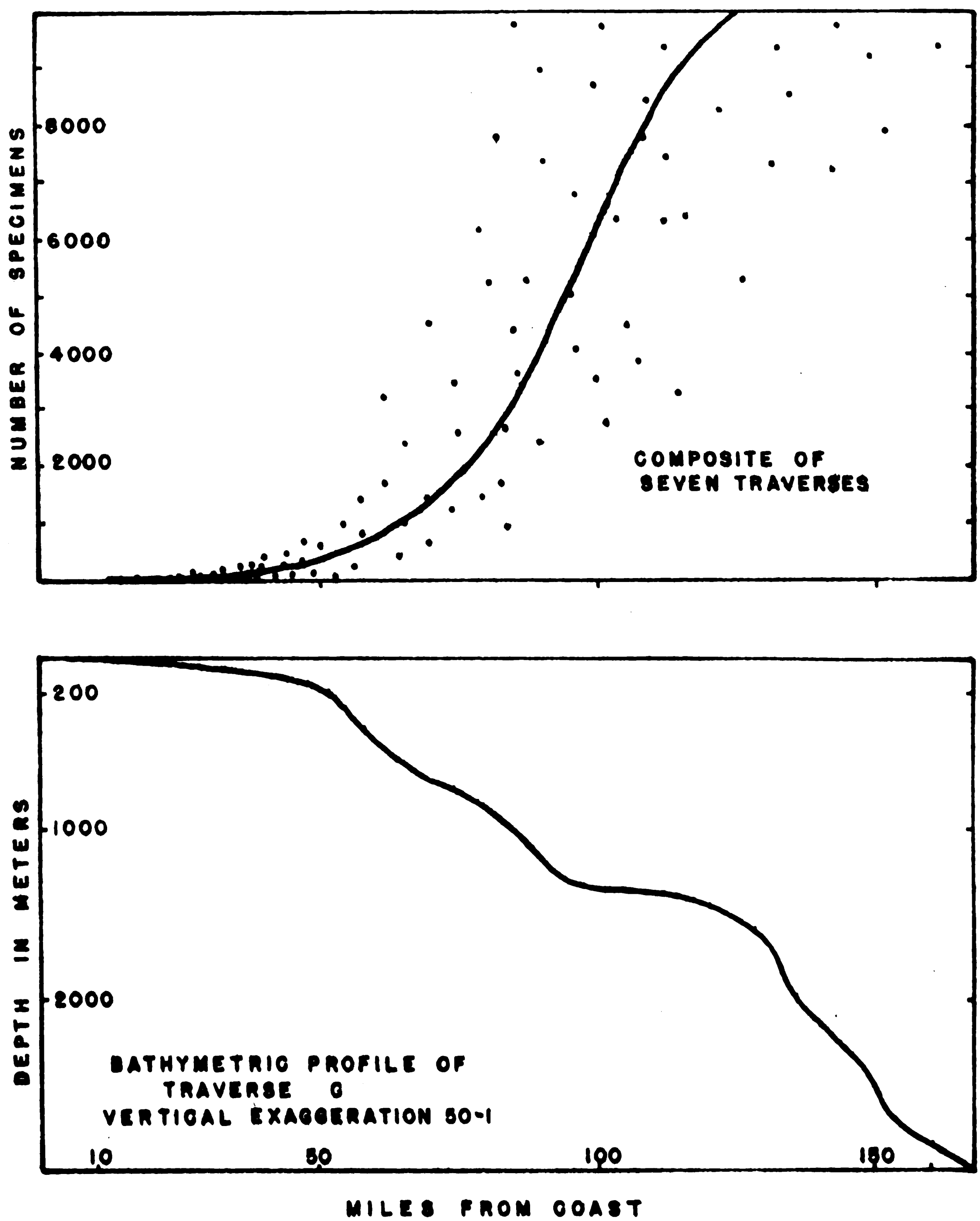
Part I: Interspecific distributions

Prior work on the distribution of species of planktonic Foraminifera from sediments in the northwest Gulf of Mexico differs only slightly in procedure from the present study. With respect to interspecific distributions, this study serves to sharpen somewhat the distribution patterns recorded by Phleger and Parker, 1951. Two characteristics of planktonic faunas in sediments are the lack of specimens in shallow water sediments and the basinward succession of increased species diversity.

The low incidence of planktonics in coastal marine sediments is well documented in fossil as well as recent assemblages. In the northwest Gulf of Mexico planktonics are found in sediments from depths greater than twenty-five to thirty meters. Even at thirty meters the incidence of planktonic tests in sediments is extremely low (figure 7, page 16). The number of tests per unit weight of sediment (five grams, unsieved, dry) increases gradually across the continental shelf, then rapidly to a maximum of as high as thirty thousand specimens on the lower continental slope in water depths greater than fifteen hundred meters. The low number of planktonics per unit weight of sediment on the continental shelf may be attributed in part to the diluting effect of the active sedimentation there (Curray, 1959). The primary factor, however, is the well documented, low frequency of the living organisms in the water masses overlying the continental shelf. Phleger, 1951, has suggested that this low planktonic frequency in shelf water

FIGURE 7

NUMBER OF PLANKTONIC SPECIMENS PER FIVE GRAM SAMPLE IN THE NORTHWEST GULF OF MEXICO

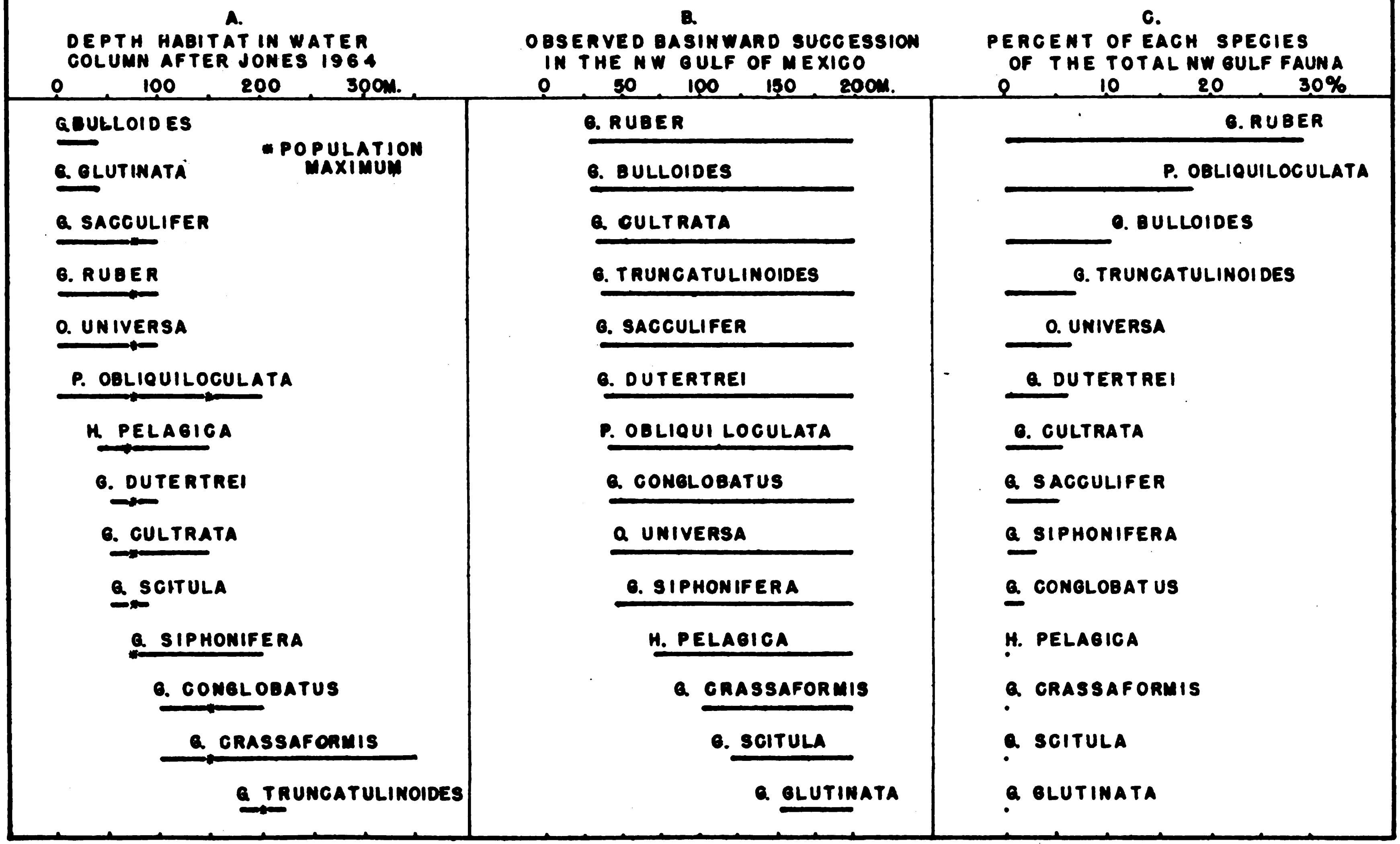


masses may be due to the physical and chemical differences between these water masses and the open ocean water masses where living planktonic Foraminifera reach their highest frequencies (figure 7, page 16). As additional evidence for his analysis Phleger, 1960, cites the high incidence of living planktonics in the near coastal water masses off southern California where, because of low runoff and a circulation factor, the near shore water masses have the physical and chemical characteristics of open ocean water.

The second characteristic distribution pattern which has been documented in studies is that of the basinward succession of increased species diversity. Assemblages of planktonic Foraminifera from successively deeper sediment samples in the northwest Gulf of Mexico display a fixed order of first appearance of the individual species (figure 8B, page 18). Although this successive basinward appearance of planktonic species has been recorded by a number of authors (Phleger and Parker, 1951, Bandy, 1951, Polski, 1959, and Wilcoxon, 1964), considerable difference of opinion exists in the interpretation of this phenomena. Phleger and Parker, 1951-1954, have interpreted the succession as a function of the relative abundance of the individual species with respect to the entire planktonic fauna. Abundant species such as Globigerinoides ruber (D'Orbigny) and Globigerina bulloides, D'Orbigny, would therefore be the only species encountered in shallow water sediments where, for reasons previously discussed, the planktonic fauna is poorly developed. Rare species, such as Globigerinita glutinata, Bronniman, would not appear in sediments except where the entire planktonic fauna is numerically well-developed.

FIGURE 8

DEPTH HABITAT, BASINWARD SUCCESSION AND PERCENT OF TOTAL FAUNA OF FOURTEEN PLANKTONIC SPECIES IN THE NW GULF OF MEX.



in deep water.

Bandy, 1956, Polski, 1959, and Wilcoxon, 1964, have interpreted the basinward succession as an expression of the vertical stratification of living species in the water column. According to Bandy and others, epipelagic species should be found in shallow as well as deep sediments, whereas mesopelagic and bathypelagic species would impinge on the bathymetric profile and thus be found only in deeper sediments.

In order to evaluate these two hypotheses, fourteen of the species for which the depth habitat is known (Jones, 1964) are illustrated with the order of successive basinward occurrence and percent of the fauna for each species recorded in the present study (figure 8, page 18). Using the depth habitat of species (figure 8 A) and species' percent (figure 8 C) as potential models for the succession (figure 8 B), it may be seen that neither model corresponds to the succession precisely. A satisfactory explanation of the succession of planktonics in sediments lies in a discussion of the intraspecific variants (part II of this section).

Distribution of Planktonics

Part II: Intraspecific Distributions

Section 1: General Discussion

In order to interpret effectively the distribution patterns of planktonics in sediments, it is necessary to tabulate the distribution of variants of the species as well as the distribution of the species as a whole. Intraspecific variations, which were counted and tabulated in the course of this study, included specimen size, secondary calcification, aberrant apertures and chambers, coiling, pore frequency and size, incidence of spines and bullae, and coloration. Many of these variations have been demonstrated by authors to be significant with respect to the distribution and ecology of living specimens. Some of the morphological characters which are significant in living specimens were found to be reflected in planktonic populations from sediments and may be of particular use in paleoecological studies.

Be, 1960, Bradshaw, 1959, Murray, 1895, and others have reported a basinward increase in average specimen size in assemblages of planktonics from sediments. Bé, 1960, has reported further that populations of live Foraminifera recovered from plankton hauls in the Atlantic exhibit an increase in average size with succeedingly greater depth. He attributes the size increase in planktonics from the sediments to the vertical stratification of the living organisms in the water column. Most of the planktonic populations examined in this study display an average size succession similar to those previously described. For the purpose of discussion, specimens which are in the smallest one-third of the population size range will be termed juveniles. Two exceptions to the size succession occur in populations of Pulleniatina obliquiloculata and Orbulina universa from the northwest Gulf of Mexico (figure 9, 10, page 22, 23). Orbulina universa has been shown by Bandy, 1966, to represent an ontogenetic stage of at least three separate species of planktonic Foraminifera. The fact that Orbulina universa is a polyspecific variant of intermediate and adult specimens may explain why no juveniles of this "species" are observed as well as why no succession of juveniles to adults occurs in shallow to deep water sediments in the northwest Gulf. Examination of size distribution graphs (figures 9, 10, 11, pages 22, 23, 24) reveals a paucity of juvenile specimens in the population of Pulleniatina obliquiloculata which parallels the failure of this species to conform to the size increase succession characteristic of the remainder of the planktonic fauna. The low ratio of juvenile specimens in populations of P. obliquiloculata and Orbulina universa may be due to extrinsic factors such as winnowing of specimens in the sediments or selective removal of living juvenile specimens in the water column by currents. Craig, 1967, has reported similar disparate population distributions in Bahaman pelecypod faunas in which certain species have a notably high or low ratio of juvenile specimens to adults. He has concluded that low or high ratios of juveniles to adults in death assemblages, which are manifest in only one or two species out of the entire fauna, must be attributed to either differential mortality or growth rates in those species. Two additional explanations for low juvenile-adult ratios in populations are the selective removal of the juveniles by diagenetic solution and the removal of live juveniles in the water

FIGURE 9

SIZE DISTRIBUTION OF PLANKTONICS FROM TRAVERSES IN THE NW GULF OF MEX.
1-10 SPECIMENS PER POINT

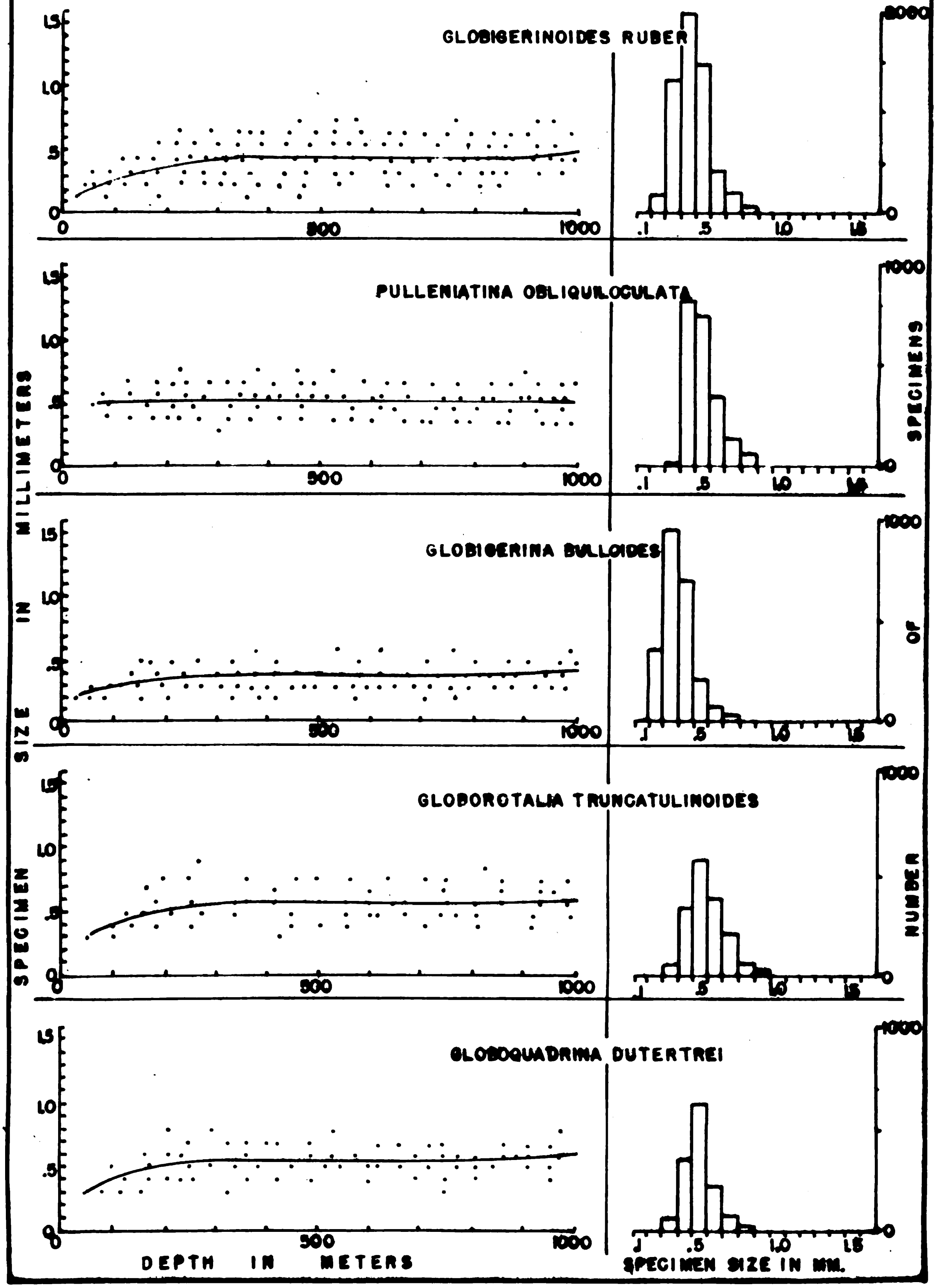


FIGURE 10

SIZE DISTRIBUTION OF PLANKTONICS FROM TRAVERSES IN THE NW GULF OF MEX.
1-10 SPECIMENS PER POINT

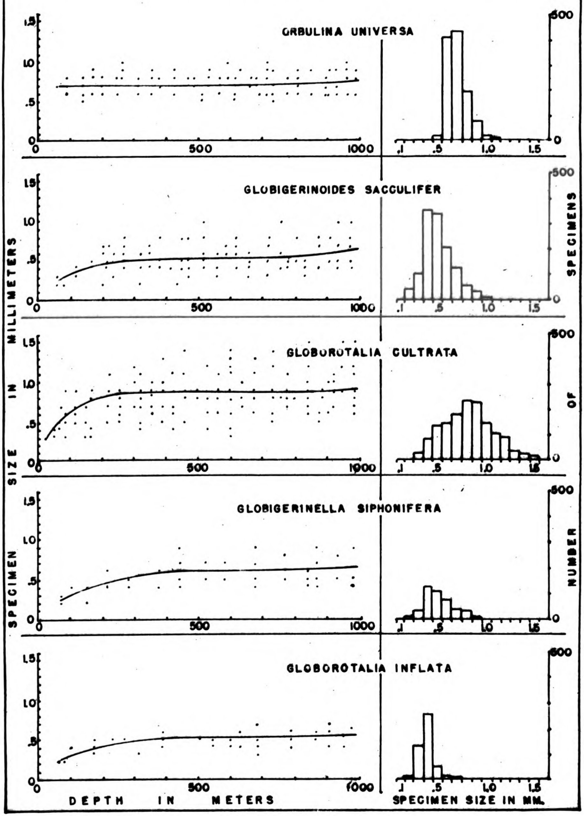
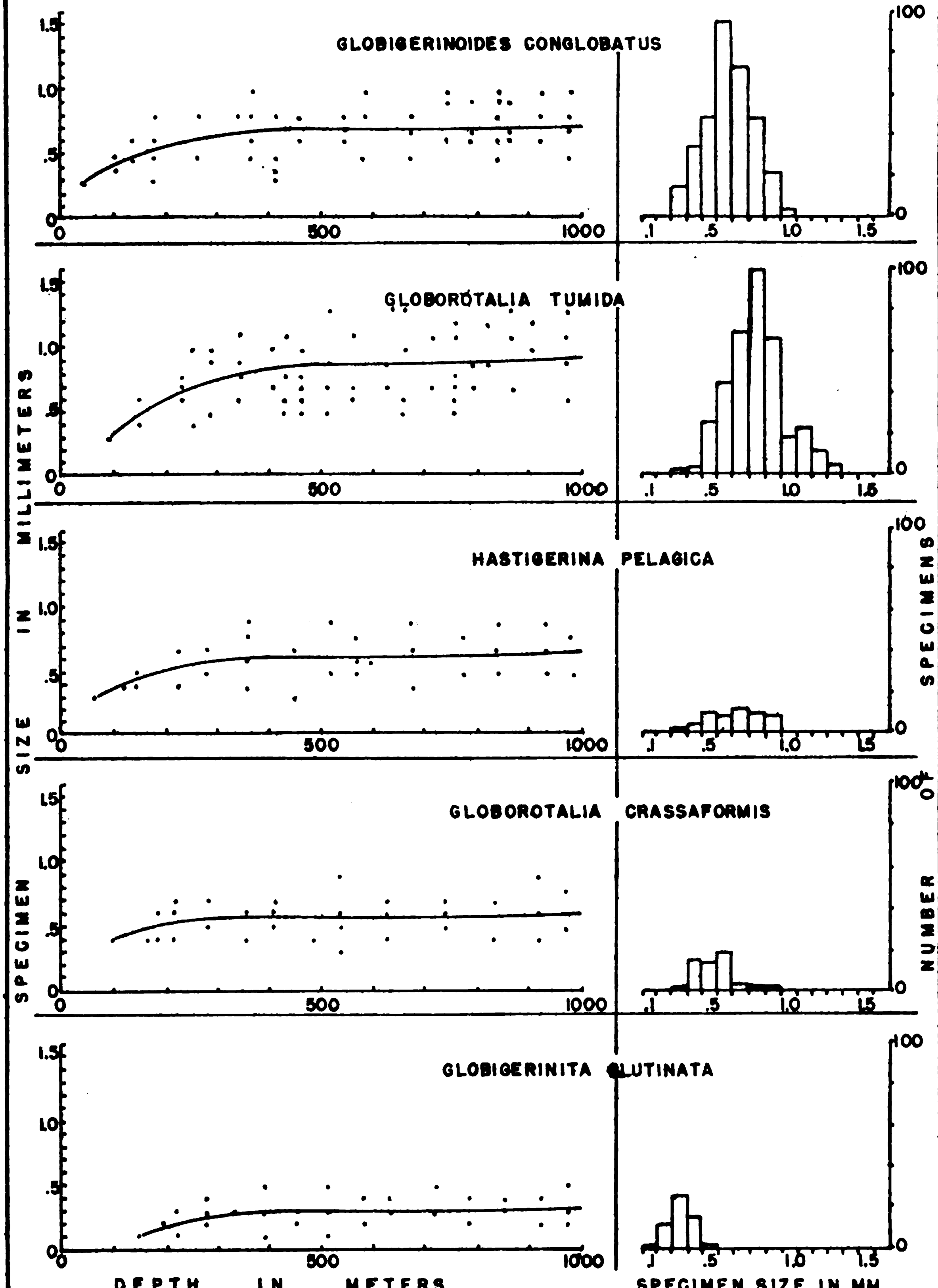


FIGURE 11

SIZE DISTRIBUTION OF PLANKTONICS FROM TRAVERSES IN THE NW GULF OF MEX.
1-10 SPECIMENS PER POINT



column by currents during limited time intervals. Solution does indeed affect juvenile specimens in sediments from depths greater than one thousand meters (Berger, 1967). There is, however, no evidence for extensive solution of juveniles in continental shelf and upper slope faunas. Removal of juveniles by marine currents during the reproductive period of Pulleniatina obliquiloculata is unlikely in as much as a number of planktonic species with high juvenile-adult ratios reproduce during the same period as P. obliquiloculata (Jones, 1964; Phleger, 1951).

Because the shallow water representatives of most of the planktonic species are juveniles, populations with a low proportion of juveniles in the depth assemblages may be poorly represented or absent in shallow water sediments. By excluding two such species, P. obliquiloculata and Orbulina universa, from the basinward succession (figure 8 B, page 18, it is apparent that the succession of planktonics in basinward traverses corresponds closely with the percent of each species (figure 8 C, page 18). From these considerations it is concluded that the basinward succession of planktonics (figure 8 B, page 18) is primarily an expression of the percent of the individual species rather than depth preference by species. Further, because the basinward succession of planktonic Foraminifera is a succession based on a basinward juvenile-adult series, any fluctuation in the ratio of juveniles to adults in a population will directly affect the uppermost occurrence of that species in continental shelf sediments.

Distribution of Planktonics

Part II: Intraspecific Distributions

Section 2: Secondary calcification of tests

The accretion of a secondary crust of calcite over the surface of the test of some species of planktonic Foraminifera has been reported by a number of authors (Ericson, 1964, Bé, 1964, 1965). The secondary crust, which may be as much as fifty microns thick as compared to an average of twenty microns for the underlying foundation wall, imparts a sucrosic, snow-white appearance to the outside of the test due to minute terminations of calcite crystals, the C axes of which are oriented normal to the test wall. (Plate 1, figures 3-12)

Ericson _et al._ (1961) have reported the occurrence of the secondary crust on eight separate species of planktonic Foraminifera from deep sea cores from the Atlantic Ocean. Bé and Ericson (1963) and Bé (1965) have considered in detail the structure of the secondary crust on selected species of Foraminifera and have reached two important conclusions:

1. The secondary thickening of the protozoan test is not an inorganic diagenetic process taking place after the death of the individual organism.

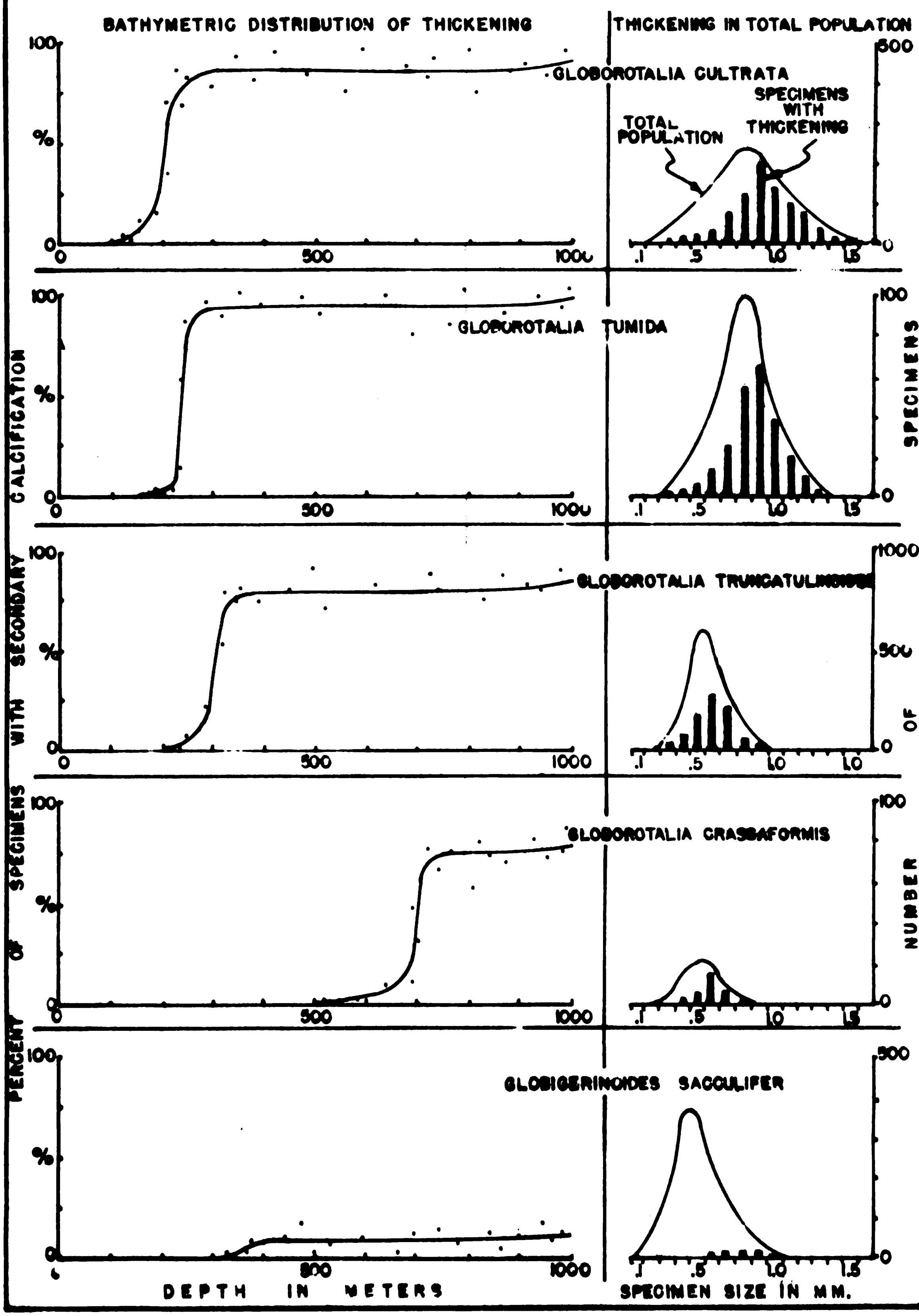
2. The acquisition of the secondary crust is a response by the protozoan to some extrinsic stimulus which prevails in deep waters below the epipelagic zone.

The present study offers some observations relative to the depth at which the thickening process begins in these organisms in the Gulf of Mexico. Planktonic Foraminifera from the marine sediments were counted as either having or not having the secondary crust. Bé and Ericson (1963) have reported live specimens from plankton hauls which had incipient thickening of the test in the form of short, blunt calcite crystals over the surface of the test. Most of the specimens counted from the Gulf of Mexico sediments either lacked the thickening completely or had a well-developed, sugary white crust (figure 12, page 28). The disparity between dead populations and the standing crop with respect to the number of individuals in the intermediate stage of thickening suggests that the thickening process itself may be rapid.

The basinward change from predominantly non-thickened to thick-walled populations is remarkably abrupt, taking place over a very short areal distance (figure 12, page 28). Each of the four species exhibits the change from thin to thick-walled populations at a different depth from the other species. For each species, the depth at which the secondary thickening takes place is constant over the entire area of the northwest Gulf of Mexico. Bé and Ericson (1963) have given three hundred to five hundred meters as the depth below which secondary thickening takes place in living specimens of <u>Globorotalia</u> <u>truncatulinoides</u> (D'Orbigny). The upper limit of this three hundred to five hundred meter zone is expressed in the distribution of populations of this species from sediments in the northwest Gulf. The depths recorded at which thickening takes place in the remaining three species in this study undoubtedly represent the upper limit of the thickening zone in the bathymetric column for living specimens: <u>G.</u> <u>crassaformis</u> (Galloway and Wissler), seven hundred meters; <u>G.</u> <u>cultrata</u> (D'Orbigny), one hundred and twenty meters;

FIGURE 12

SECONDARY CALCIFICATION IN POPULATIONS OF FIVE PLANKTONICS FROM THE NW GULF OF MEX.



G. tumida (Brady) two hundred meters. In addition to the Genus *Globorotalia*, secondary thickening is evident in the species *Globigerinoides quadrilobatus sacculifer* in the northwest Gulf beginning in the interval between three hundred and four hundred meters. No secondarily thickened specimens of *G. sacculifer* were counted from sediments shallower than three hundred meters (figure 12, page 28). Further consideration of secondary thickening in *G. sacculifer* appears in the discussion of variation of the species.

Distribution of Planktonics

Part II: Intraspecific Distributions

Section 3: Aberrant terminal chambers

Bé (1965) has described variations in the ultimate chamber in a number of north Atlantic planktonic Foraminifera. These variations may be classified into two groups where they occur in faunas from sediments in the northwest Gulf of Mexico. Populations of Globigerinella siphonifera, Globoquadrina dutertrei, Globorotalia cultrata and Globorotalia truncatulinoides all have a considerable percentage of specimens with a diminutive final chamber (figure 13, page 31). This terminal chamber, although reduced in size and bearing a comparatively thin wall, has the same shape as previous chambers. The second type of aberrant terminal chamber described by Bé (1965) is the sac structure of Globigerinoides sacculifer. This latter feature may be smaller or larger than the peniultimate chamber and has a wall similar to that of the remainder of the test, but it bears little resemblance in shape to previous chambers (figure 13, page 31). Bé (1965) has noted that both the sac structure and the diminutive terminal chamber on the previously mentioned species mark the termination of shell growth for the individual specimen.

Figure 14, page 32 shows the distribution in the northwest Gulf of specimens of these five species which bear either the sac structure or the diminutive terminal chamber. Specimens bearing these aberrant terminal chambers are all in the adult size range of each population curve. The distribution of specimens with aberrant terminal chambers is directly related to the average size distribution

FIGURE 13a
DIMINUTIVE FINAL CHAMBER ON FOUR PLANKTONIC SPECIES

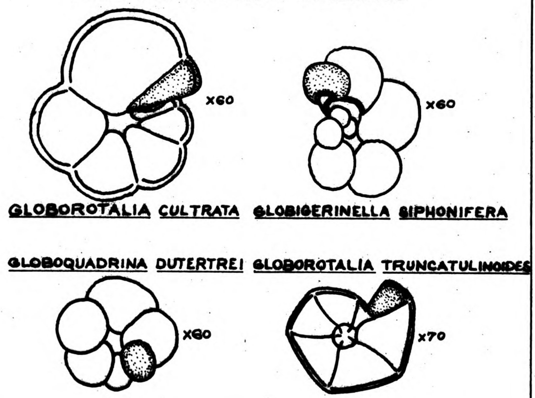


FIGURE 13b
SAC VARIATION IN
GLOBIGERINOIDES QUADRILOBATUS SACCULIFER

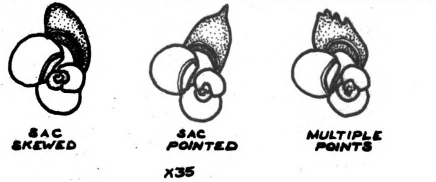
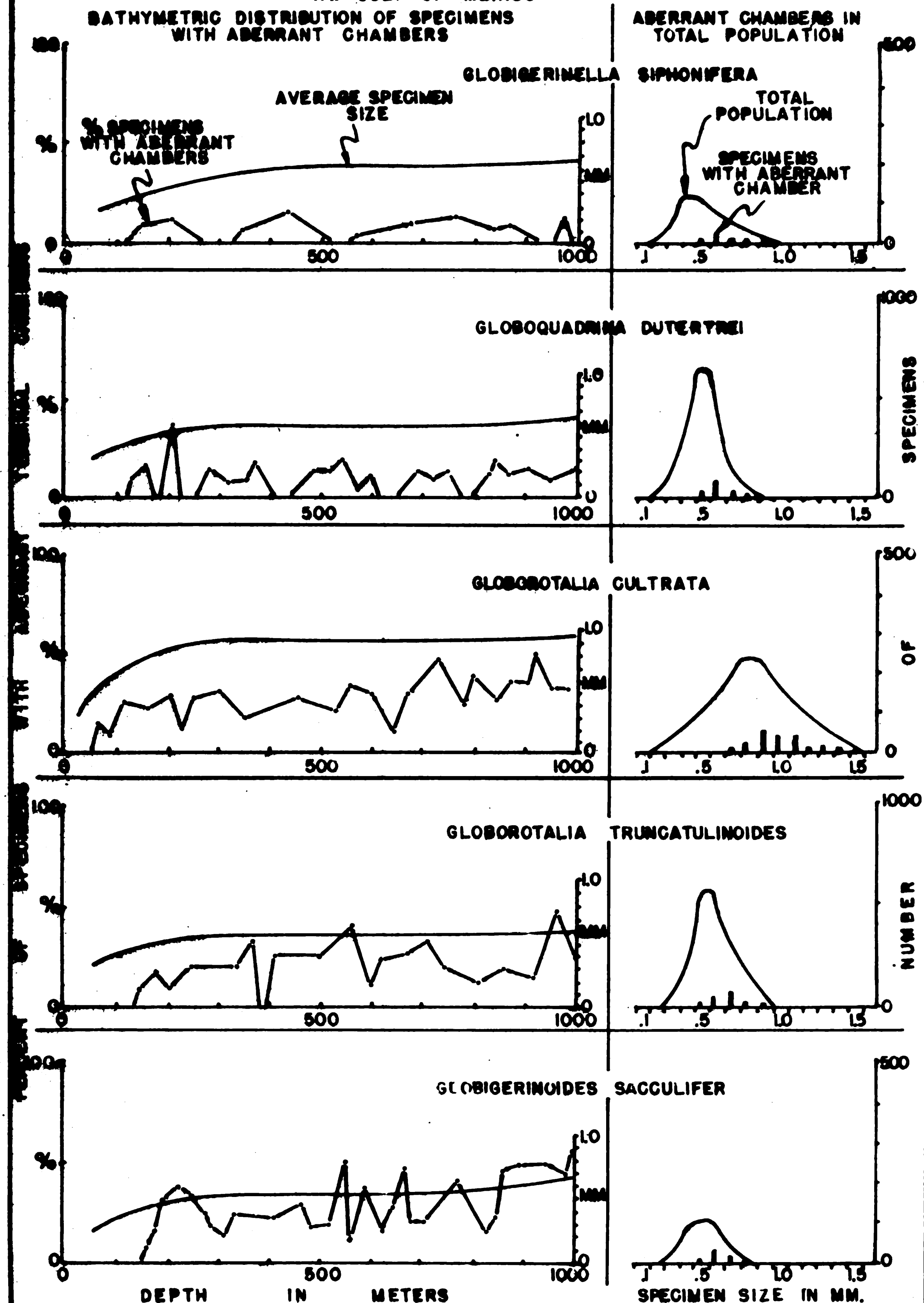


FIGURE 14
DISTRIBUTION OF PLANKTONICS BEARING ABERRANT FINAL CHAMBERS FROM THE NW GULF OF MEXICO



of each species in the sediments in that the appearance of specimens bearing the aberrant chambers corresponds to the initial occurrence of adult specimens on the bathymetric profile. Because aberrant terminal chambers are a function of the ontogenetic stage of an individual specimen and because the ontogenetic stages are vertically stratified in the water column, as shown in a previous discussion, the presence of these features is potentially of use in fossil assemblages as depth indicators.

Distribution of Planktonics

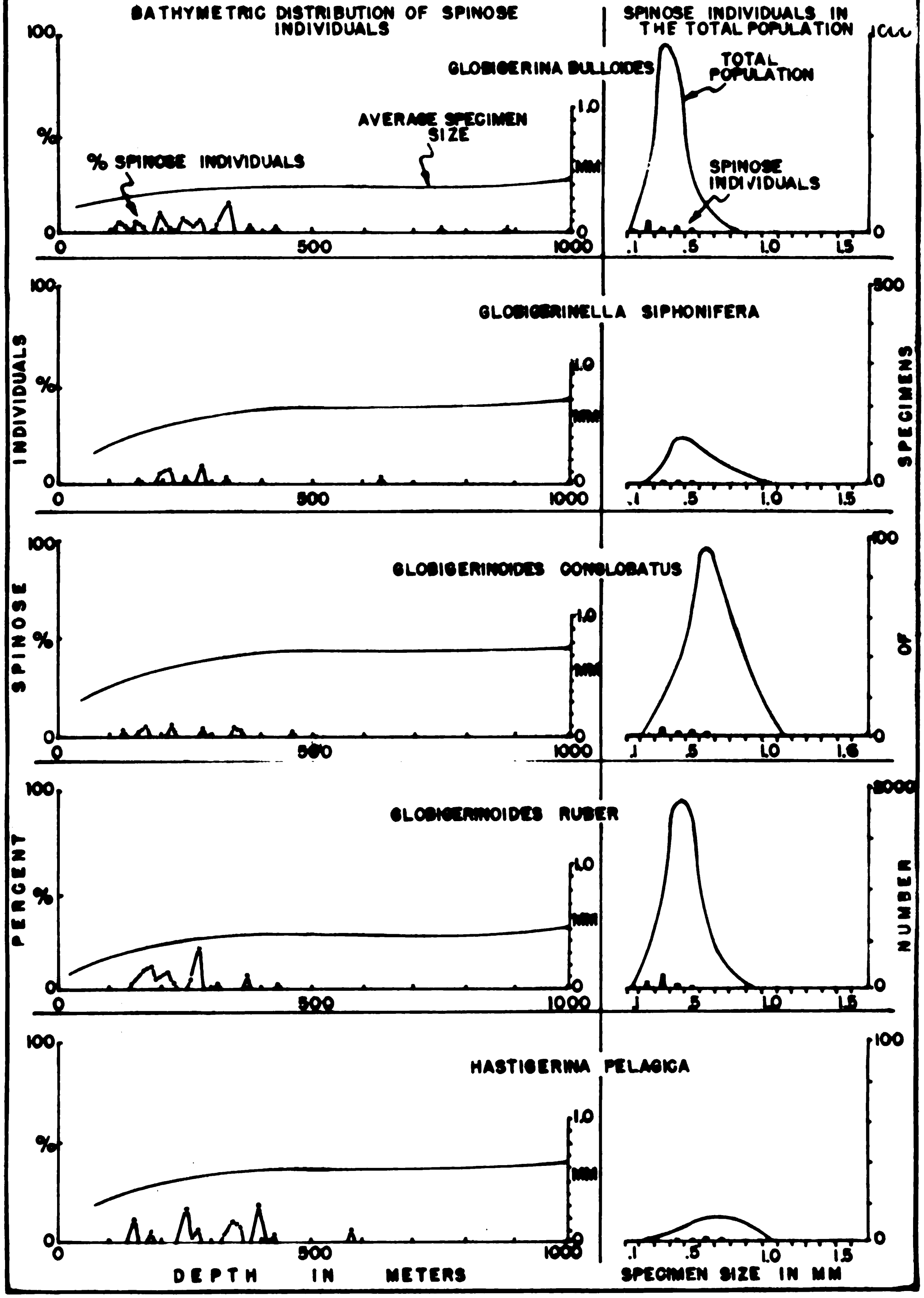
Part III: Intraspecific Distributions

Section 4: Spines

The presence or absence of spines was recorded for a number of planktonic species during the course of this study (figure 15, page 35). Species which have spinose individuals in their populations included: *Globigerina bulloides*, *Globigerinella siphonifera*, *Globigerinoides conglobatus*, *Globigerinoides ruber*, and *Hastigerina pelagica*. Individuals bearing spines were rare in sediments in the western Gulf of Mexico except in the outer shelf and upper slope areas. Live specimens from plankton tows (Bradshaw, 1959, Bé, 1958, etc.) commonly have spines. The ratio of spinose to nonspinose individuals in sediments is much smaller in the western Gulf of Mexico sediments than it is in the recorded ratio of spinose to nonspinose individuals from plankton tows (Bé, 1958). Spines are thus destroyed on many specimens after death by abrasion or solution. Further evidence of this secondary loss of spines in planktonics may be found in the fact that only the specimens from the uppermost portion of the sediments close to the water-sediment interface bear spines. Planktonic specimens from sediments more than five centimeters below the water-sediment interface typically have a dull tan to yellow test and frequently have very fine-grained sediments in the chambers. Fresh specimens are devoid of sediments in the chambers and have a whiter test. Spines were recorded only on the light colored specimens indicating that only the most recently deposited tests in the sediments have the spines and that spines are probably lost shortly

FIGURE 15

DISTRIBUTION OF PLANKTONIC FORAMINIFERA BEARING SPINES FROM SEDIMENTS IN THE NW GULF OF MEXICO



after the test is deposited. The distribution of spinose individuals in the sediments does not, therefore, reflect the distribution of spinose individuals in the overlying water mass. The distribution of spinose individuals (figure 15, page 35) shows a higher proportion of spinose individuals in the juvenile size range. Bé (1960) has commented on this loss of spines by mature specimens in his studies of live Foraminifera from the north Atlantic. The concentration of spinose individuals in the outer shelf and upper slope for these five species does not coincide with any concentration of juveniles at the same depth either in the sediments or in the overlying water mass. It is assumed that the concentration of individuals with the highly ephemeral spines is a function of active planktonic sedimentation in the outer shelf and upper slope areas.

Distribution of Planktonics

Part II: Intraspecific Distributions

Section 5: Bullae

Small chamberlets or bullae, which partially or wholly cover the openings of primary or secondary apertures on planktonic Foraminifera (figure 16, page 38), have been utilized by some authors (Blow, 1959; Loeblich, 1957) as taxonomic features in the description of new species and genera. Studies by Bradshaw (1959) and Parker (1962) have demonstrated that bullae may not be present throughout the life cycle of the individual. As a consequence of these latter studies, many of these genera and species, which were recognized on the presence or absence of bullae, have been placed in synonymy.

Five planktonic species from sediments in the northwest Gulf had bullae-bearing individuals in their populations. These species included Globigerina digitata, Globigerinoides conglobatus, Globigerinoides ruber, Globigerinita glutinata, and Globigerinita humilis. The bullae of both of the above species of Globigerinoides are small, inflated and cover secondary apertures. Bullae of Globigerina digitata and both species of Globigerinita are all broad, flap-like, and cover the umbilical aperture of the test (figure 16, page 38). Globigerinita uvula has been reported by Bé (1967) to have bullae in populations of the species in temperate water masses in the north Atlantic. The species was rare in the northwest Gulf of Mexico, and individuals with bullae were not recorded. Bullae from specimens of planktonics in the northwest Gulf typically

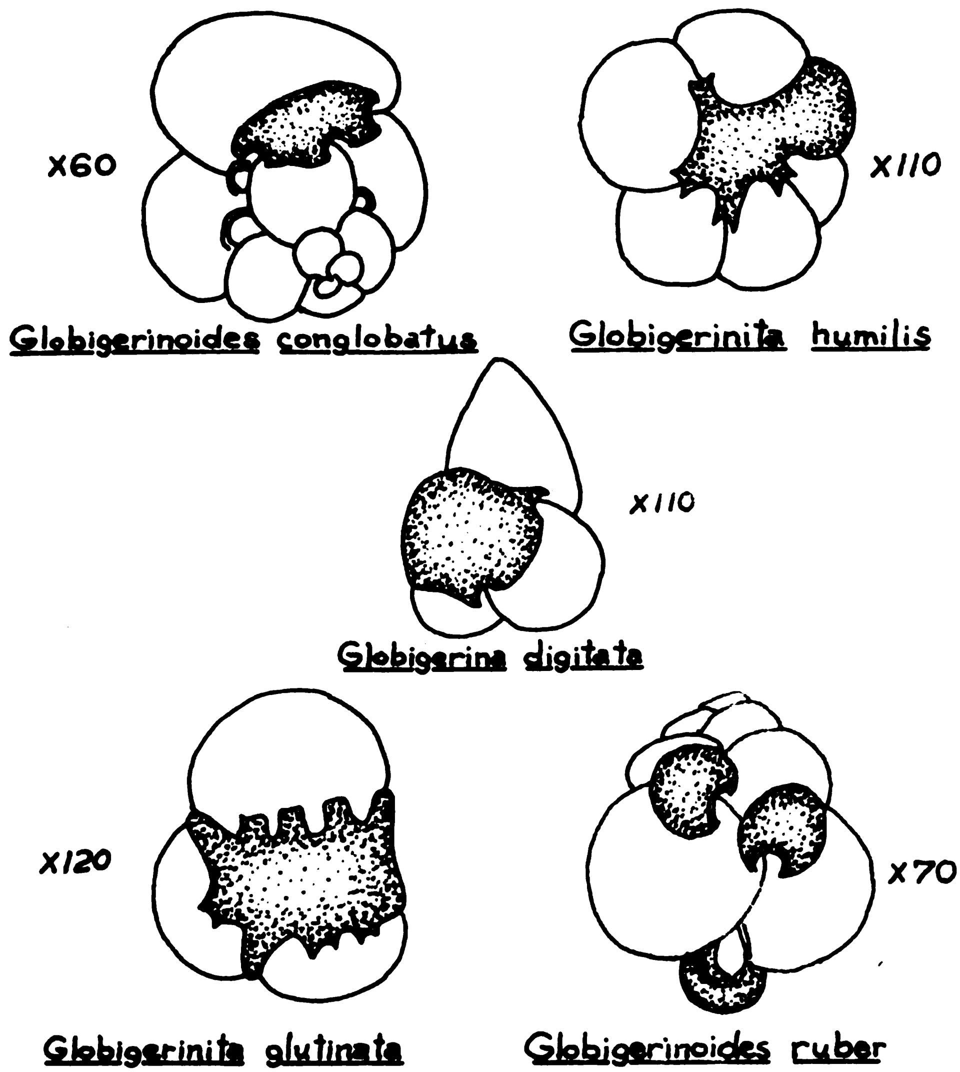
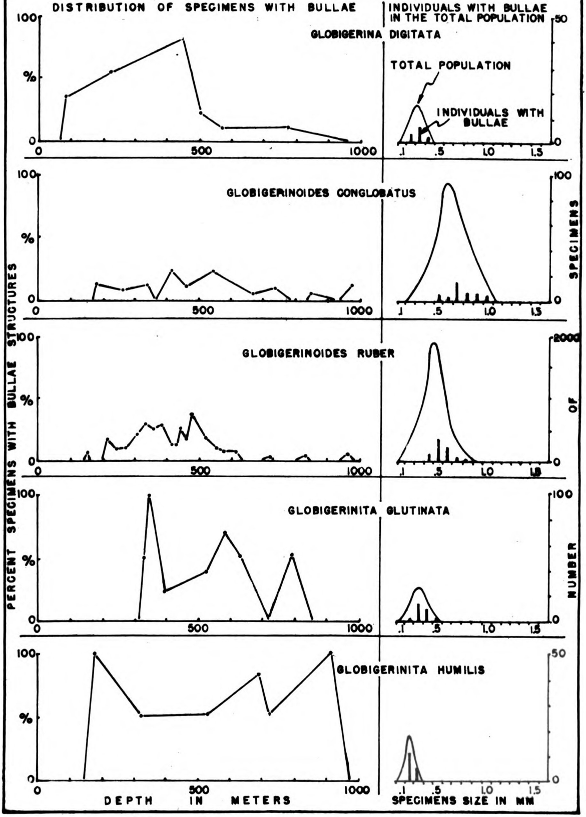


FIGURE 16
BULLAE STRUCTURES ON FIVE PLANKTONIC SPECIES

are thin to diaphanous and have a surface texture and pore distribution which differ considerably from the remainder of the test. The distribution of bullae is similar to the distribution of diminutive terminal chambers in populations of other species in that the structures are developed only in the adult portion of the population (figure 17, page 40). The distribution of individuals bearing bullae corresponds to the distribution of adult specimens of the five species in sediments in the northwest Gulf (figure 17, page 40). Populations from lower slope sediments show a reduction of individuals with the bulla structure. This decrease may be a reflection of the diagenetic solution of the thin bullae at that depth. Similar diagenetic solution of spines in lower slope sediments has been discussed in this study. As in the incidence of spinose individuals, the presence in the sediments of many individuals with thin bullae may reflect active pelagic sedimentation at that portion of the bathymetric profile.

FIGURE 17
DISTRIBUTION OF PLANKTONIC FORAMINIFERAL SPECIMENS WITH BULLAE STRUCTURES FROM SEDIMENTS IN THE NW GULF OF MEXICO



Distribution of Planktonics

Part II: Intraspecific Distributions

Section 6: Test pigmentation

Two species of planktonic Foraminifera in the northwest Gulf of Mexico include specimens in their populations which have pigmented tests. All of the specimens of Globigerina rubescens recorded in the present study have a light orange hue evenly distributed through the test. Populations of this small species have been reported elsewhere (Parker, 1962) with non-colored variants, but no similar variants were recorded in this study.

The other pigmented species, Globigerinoides ruber, exhibited considerable color variation in the Gulf of Mexico. This latter species varies from completely white specimens to specimens with a bright vermillion red color of an equal shade on all chambers in the test. Between these two extremes are individuals with a light pink coloration on all the chambers and specimens with bright red proloculus and initial whorl and succeedingly lighter red color on the younger chambers grading into pink. The ultimate and peniultimate chambers in this latter group are commonly white. Because of the complete intergradation of color variation specimens were counted as either colorless (white) or colored to some degree.

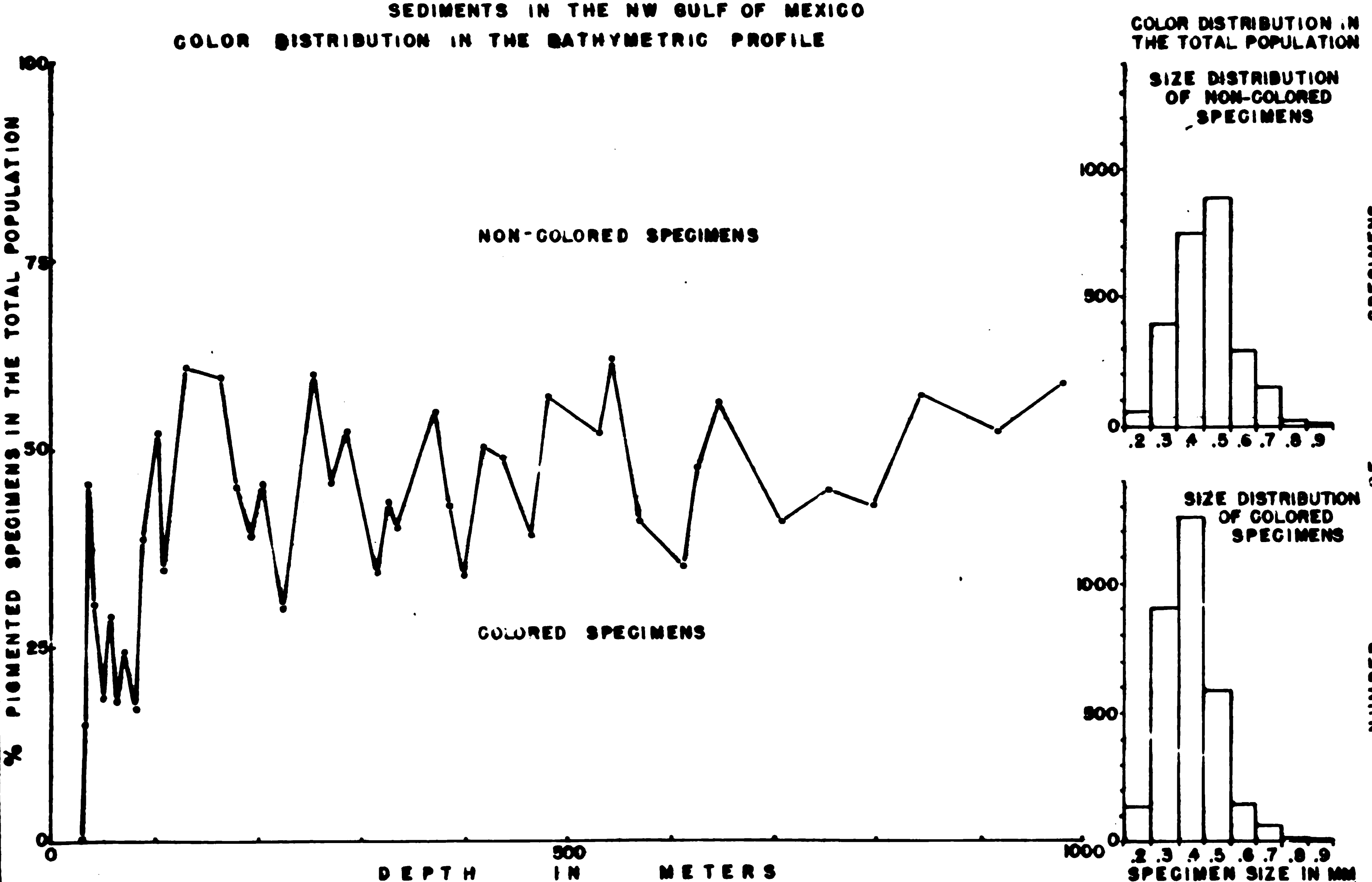
Colored and non-colored variants of Globigerinoides ruber may be separated into two populations by size as well as by color (figure 18, page 43). Both variants have the same size range (.2mm to .9mm), but colored specimens are numerically dominant in the size range from .2mm to .4mm by a ratio of almost two to one.

In the size range from .5mm to .9mm the non-colored variants are the numerically dominant form by a similar ratio.

In areal distribution (figure 18, page 43), non-colored specimens are the dominant form at the shallowest distribution of the species between twenty-six and one hundred meters on the continental shelf. In sediments deeper than one hundred meters, the ratio of colored to non-colored variants is approximately equal. The low percentage of pigmented specimens in the low temperature coastal water (16° C-18° C, figure 6, page 13) seems to agree with Bé's (1960) observation that living colored variants concentrate in water of a higher temperature range (18° C-28° C) than the remainder of the population. Living non-pigmented specimens coexist with the pigmented variety in the temperature 18°C-27° C and are the only variety present in the temperature range 16° C-18° C (Bé, 1967).

Although Bé (1967) has reported that some fossil specimens of G. ruber still bear pigmentation (phenophytin), the persistence of the pigmentation in fossils is infrequent. While the temperature significance of pigmented specimens of G. ruber may be unreliable in fossil assemblages, the feature may certainly be useful in the study of recent environments.

FIGURE 18
DISTRIBUTION OF PIGMENTED AND NON-PIGMENTED SPECIMENS OF GLOBIGERINOIDES RUBER FROM SEDIMENTS IN THE NW GULF OF MEXICO



Distribution of Planktonics

Part II: Intraspecific Distributions

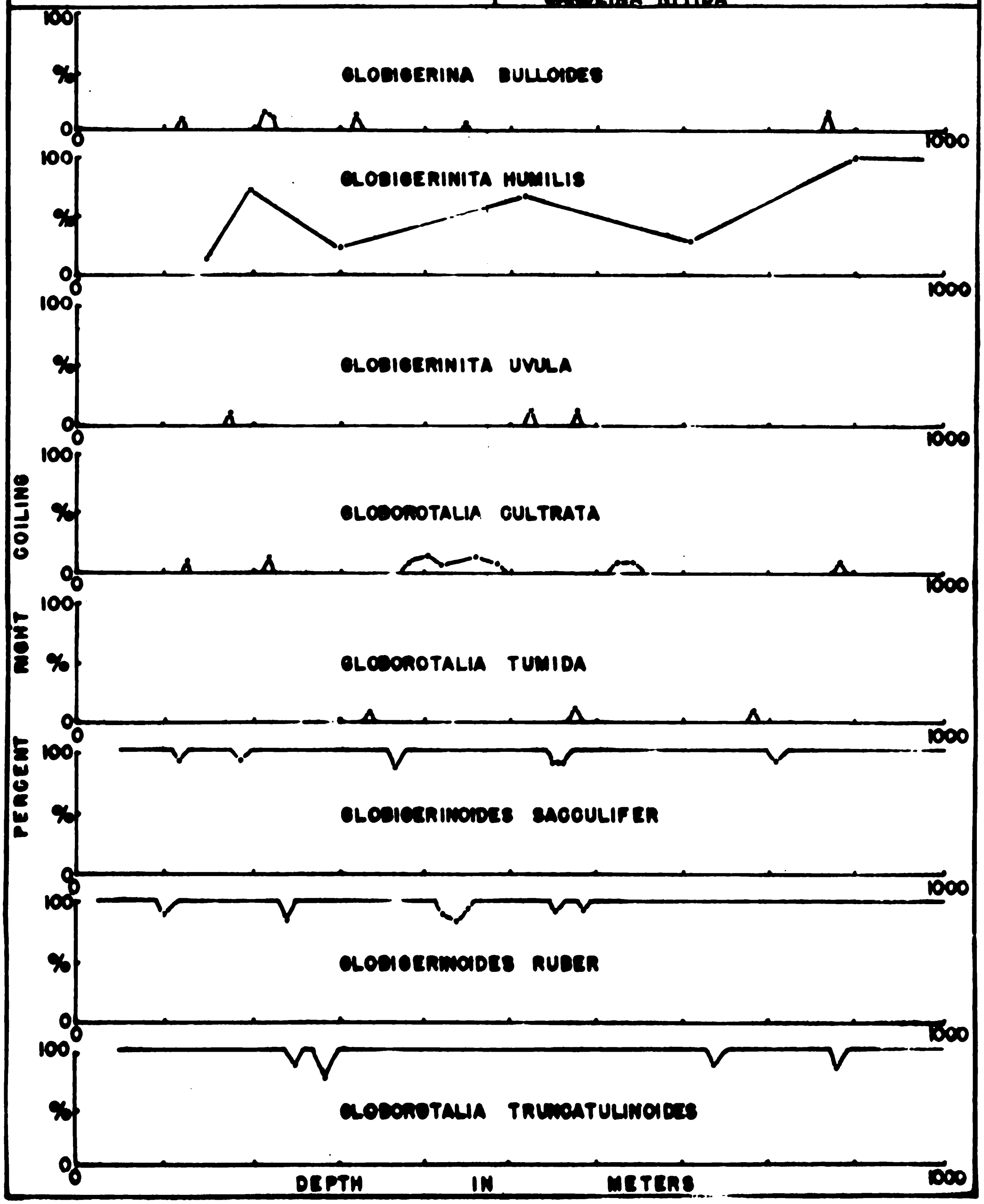
Section 7: Right and left coiling

Throughout their geographic distribution many species of recent planktonic Foraminifera may be divided into subpopulations on the basis of right or left coiling of the test. Studies by Ericson et al. (1954) and Bandy (1960) have shown that the direction of coiling in planktonic Foraminifera is apparently related to water temperature. Coiling direction of planktonic Foraminifera in the northwest Gulf of Mexico was recorded to test the possibility that right and left coiling subpopulations exist in the bathymetric column in response to the vertical temperature gradient. Mixtures of right and left coiling variants of single species or assemblages of species may also indicate the intersection of two water masses of varying temperatures. Coiling was tabulated for nineteen of the twenty-two species present in sediments of the northwest Gulf. Two of the remaining three species, Hastigerina pelagica and Globigerinella siphonifera, are planispiral while the third, Orbulina universa, is not coiled.

Coiling in most of the populations (figure 19, page 45) is generally homogeneous. The small percentage of aberrantly coiled specimens in the populations is scattered throughout the bathymetric profile. The lack of concentrations of one coiling type for any species of any particular depth seems to indicate that no vertical stratification of coiling in the bathymetric column exists in the northwest Gulf of Mexico. Phleger (1960) has suggested that many of the planktonic species in the Gulf of Mexico are allochothonous and

FIGURE 19
LEFT AND RIGHT COILING OF PLANKTONIC FORAMINIFERA FROM SEDIMENTS IN THE NW GULF OF MEXICO

100% RIGHT COILING	100% LEFT COILING
GLOBIGERINA DIGITATA	GLOBIGERINA RUBESCENS
GLOBIGERINA PACHYDERMA	GLOBIGERINITA GLUTINATA
GLOBOQUADRINA DUTERTREI	GLOBOROTALIA CRASSAFORMIS
PULLENIATINA OBLIQUILOCULATA	GLOBOROTALIA INFLATA
GLOBIGERINOIDES CONGLOBATUS	GLOBOROTALIA SCITULA
	CANDEINA NITIDA



that assemblages there are made up of mixed faunas of mid-latitude (20°-40° latitude) and low latitude (0°-20° latitude) species. Many of the planktonic species which are recorded in the northwest Gulf change in coiling direction where they occur in mid-latitude and low-latitude areas in the Atlantic (Ericson et al., 1954; Bé, 1967). If the Gulf faunas were mixed they should be heterogeneous with respect to coiling groups. Coiling, on the contrary, is generally homogeneous. Moreover, the trends in coiling of northwest Gulf faunas are markedly similar to those of low latitude assemblages. The homogeneity of coiling of faunas of planktonics in the northwest Gulf suggests that most of the species coexisting there are indigenous.

In fossil faunas where the species diversity is very low, a frequent characteristic of planktonic assemblages, the coiling direction of the individual species as well as the homogeneity or lack of homogeneity of coiling groups may provide a useful characteristic in identifying a particular fauna in a geographic as well as stratigraphic sense.

Distribution of Planktonics

Part II: Intraspecific Distributions

Section 8: Review and discussion

Although they have been separated here for purposes of discussion, intraspecific and interspecific distributions of planktonics are closely interrelated. For example, the basinward succession of planktonics in sediments is primarily a function of the relative abundance of each species. The shallow water representatives of a species are, however, juveniles. Thus fluctuations in the juvenile portion of a death assemblage may alter the basinward succession considerably.

The predominance of juvenile specimens in shallowwater populations of a species is directly related to the known living vertical stratification of planktonics in which juveniles occupy the shallowest portions of the bathymetric column. The low frequency of all planktonics in shallow water sediments has been attributed to the low frequency of living specimens in coastal waters. Low frequency of planktonics in shallow sediments is also due in part to dilution by the heavy sedimentation there. In opposition to the high frequency of juvenile specimens in shallow water sediments, there is a paucity of juveniles in marine sediments below one thousand meters. This is probably due to the diagenetic solution of the thin, fragile tests of juveniles at these depths. Because of their geometry, spines and bullae are two other structures on planktonic tests which are readily affected by solution. Both of the latter features are sufficiently delicate that they may be used as a qualitative indication of active planktonic sedimentation where they occur in abundance in assemblages from sediments.

Diminutive terminal chambers, bullae structures, and secondary calcification occur in higher frequency in adults than in juvenile specimens, and apparently they represent late stages in the ontogenetic development. Because the above features are associated with a particular specimen size, flucutations in the size distribution of populations bearing the stducture will directly affect the distribution of that feature in sediments. Secondary calcification occurs in four species of a single genus. Each of the four species changes from normal to predominantly secondarily calcified populations at separate and remarkably constant depths. The distribution of secondarily calcified individuals in sediments corresponds to the known distribution of living specimens in the bathymetric column.

Test pigmentation of the planktonic species, Globigerinoides ruber, has been reported as persistant in some fossil assemblages. The tendency for pigmentation to be lost in specimens after death of the individual, however, makes this character unreliable in most fossil assemblages. The living distribution as well as the distribution of pigmented specimens in recent sediments correspond closely to temperature. Thus the feature might be of use in identifying marine currents of varying temperatures. Another feature which is apparently a function of temperature is the direction of coiling (right or left) or the test. Unlike test pigmentation, the coiling direction cannot be destroyed after the organism's death unless, of course, the entire test is subject to solution. Coiling direction of an assemblage may be characteristic for water masses of even slight variations in temperature. This character has proven extremely useful in marine stratigraphy and in determining the paleogeography of water masses of particular temperatures.

It is interesting at this point to compare some of these features of planktonic Foraminifera to related features and known physical variables. Bullae structures, aberrant terminal chambers, and spines are all either directly or inversely related to the specimen size. Vertical stratification of sizes and secondary calcification of the test are in turn a funcation of some unknown depth-related stimulus. This latter stimulus may be temperature, but there is no experimental supporting evidence. Temperature is apparently the physical variable which controls the test pigmentation and coiling as well as the distribution of individual species (interspecific distributions). Direction of test coiling and distribution of individual species are the features most commonly used in marine stratigraphy. Authors employing these features are then in effect correlating temperature and not time. Analogs to this situation exist where some correlations based on floras are climate correlations instead of time.

Distribution of Planktonics

Part III: Variation and distribution of populations

In preceeding sections, morphological variations which may apply to all or a number of species have been discussed separately. From these discussions certain generalities were arrived at which may be applicable in fossil assemblages. In the present section the distribution and variation of individual species are considered. For each species the distribution is contoured for the northwest Gulf of Mexico. The contoured values for these distribution maps represent the percentage of the species with respect to the remainder of the planktonic fauna at each locality. As stated in the counting procedure section (page 6), where possible two hundred specimens were counted in each sample. The numerical maximum and the percentage maximum for a species may occur at different areas in the bathymetric profile. Globigerinoides ruber, for example, may be represented by five specimens in an entire sample from water shallower than thirty meters, but it may be one hundred percent of the fauna if it is the only species present in the sample. The lowest value would represent two specimens of a species in a maximum faunal count of two hundred specimens. This value contoured on the distribution maps is one percent. Rare species which are represented frequently by a single specimen, as, for example, Globigerina digitata and Globigerina rubescens, appear to have disjunct distributions for this reason.

Some of the very rare species discussed in this section may be allochothonous to the northwest Gulf of Mexico. Many of these species are abundant in the Caribbean and south Atlantic which are the source areas for surface marine currents in the Gulf of Mexico (figure 4, page 11). The rarer species, including *Globigerina digitata*, *Globigerina rubescens*, *Globigerinita humilis*, and *Globigerinita uvula*, are previously undescribed from the northwest Gulf. These rare species may have been overlooked because planktonics have been counted and studied by previous workers along with the benthonics. The species diversity of marine benthonic Foraminifera in the Gulf of Mexico is characteristically high (three hundred to five hundred species). Counting the benthonics with the planktonics will invariably statistically screen out many of the rarer planktonics.

Variation and Distribution of Populations

Globigerina bulloides D'Orbigny

Globigerina bulloides initially appears in the bathymetric profile between twenty-nine and thirty-one meters. This depth of first occurrence is consistent throughout the study area in the northwest Gulf of Mexico. Average size of the specimens of this species ranges from .2 mm. in populations collected at the shallow end of the traverses to .4mm. in slope populations. The largest specimens were recorded from the deepest samples in the traverses and measured up to .7mm. in maximum diameter.

Other variations counted for this species were spinosity and coiling. Less than ten percent of the specimens counted bear spines. These spinose individuals all occurred in continental shelf and upper slope samples. Ninety percent of the northwest Gulf specimens of *G. bulloides* coil to the right. Left coiling individuals are scattered throughout the bathymetric profile. Populations of *Globigerina bulloides* reach numerical maximums at the middle and outer continental shelf where they average fifteen to twenty percent of the total planktonic fauna. On the contiental slope, population percentages of the species drop off rapidly to averages of five to ten percent.

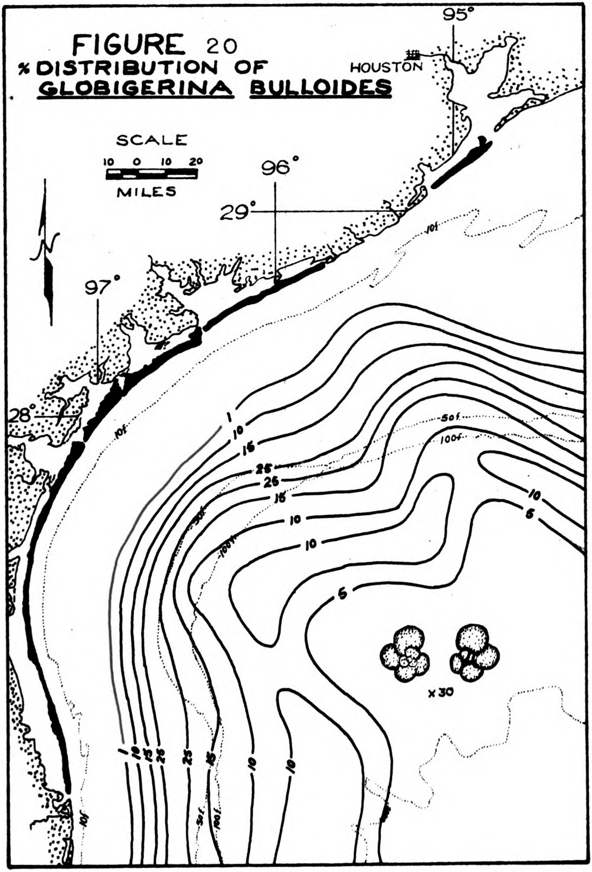


FIGURE 20
% DISTRIBUTION OF
GLOBIGERINA BULLOIDES
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
x 30

Globigerina digitata Brady

Although *Globigerina digitata* was rare in the western Gulf of Mexico, ninety percent of the specimens were in the shelf samples. A similar distribution was noted by Parker (1958) in her study of Mediterranean planktonics where she reported that, although *G. digitata* is less than one percent of the total planktonic fauna, it occurs consistantly high in the bathymetric profile in continental shelf sediments.

Specimens counted in this study averaged .2mm. Due to the rare occurrence of the species, however, no generalities can be made on size distribution with relation to the bathymetric profile. The increased abundance of live and dead specimens reported for this species in the Caribbean Sea and the equatorial Atlantic (Bé, 1966) seems to suggest that individuals of this species are being introduced into the Gulf of Mexico by marine currents flowing through the Yucatan Straits. All specimens of this species coil to the right in the northwest Gulf of Mexico. Approximately half of the northwest Gulf specimens of *G. digitata* bear a flap-like umbilical bulla. Most of these bullae-bearing individuals were counted from outer shelf and upper continental slope sediments.

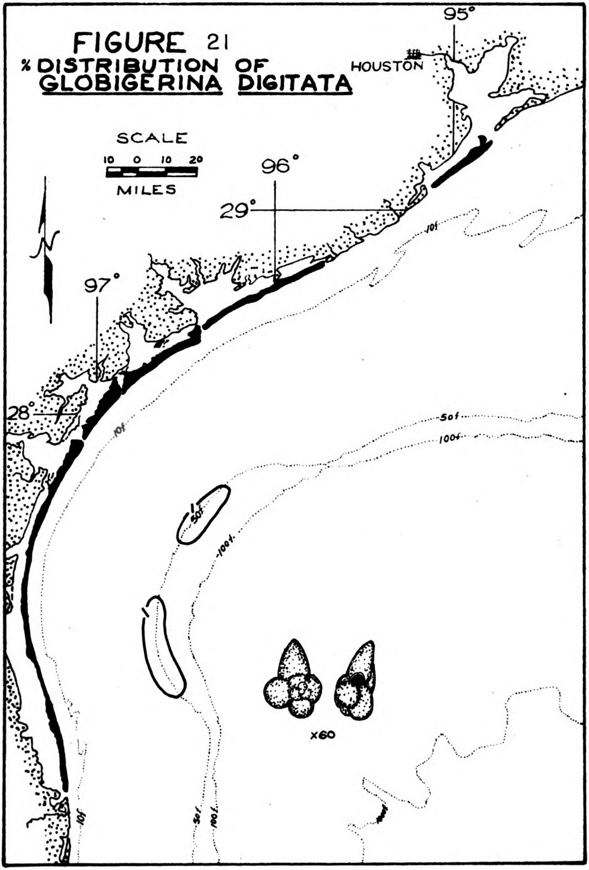


FIGURE 21
% DISTRIBUTION OF
GLOBIGERINA DIGITATA
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
10f
50f
100f
1
X60

Globigerina pachyderma (Ehrenberg)

This species was rare in the western Gulf of Mexico. The specimens averaged .4mm. in size and showed little size variation. Although the species is believed by some authors to live at depths of one hundred meters and greater in temperate and tropical regions, many of the specimens counted in the present study occurred in sediments from less than one hundred meters. Parker (1958) has stated that the species is a reliable cold water indicator in the Mediterranean Sea where it is rare in sediments shallower than three hundred and thirty-eight meters.

The absence of any appreciable percentages of *Globigerina pachyderma* in water masses or marine sediments adjacent to the Gulf of Mexico makes any suggestions as to the source of this foraminifer in the Gulf of Mexico at best speculatory. *G. pachyderma* is one hundred percent right-coiling in the northwest Gulf.

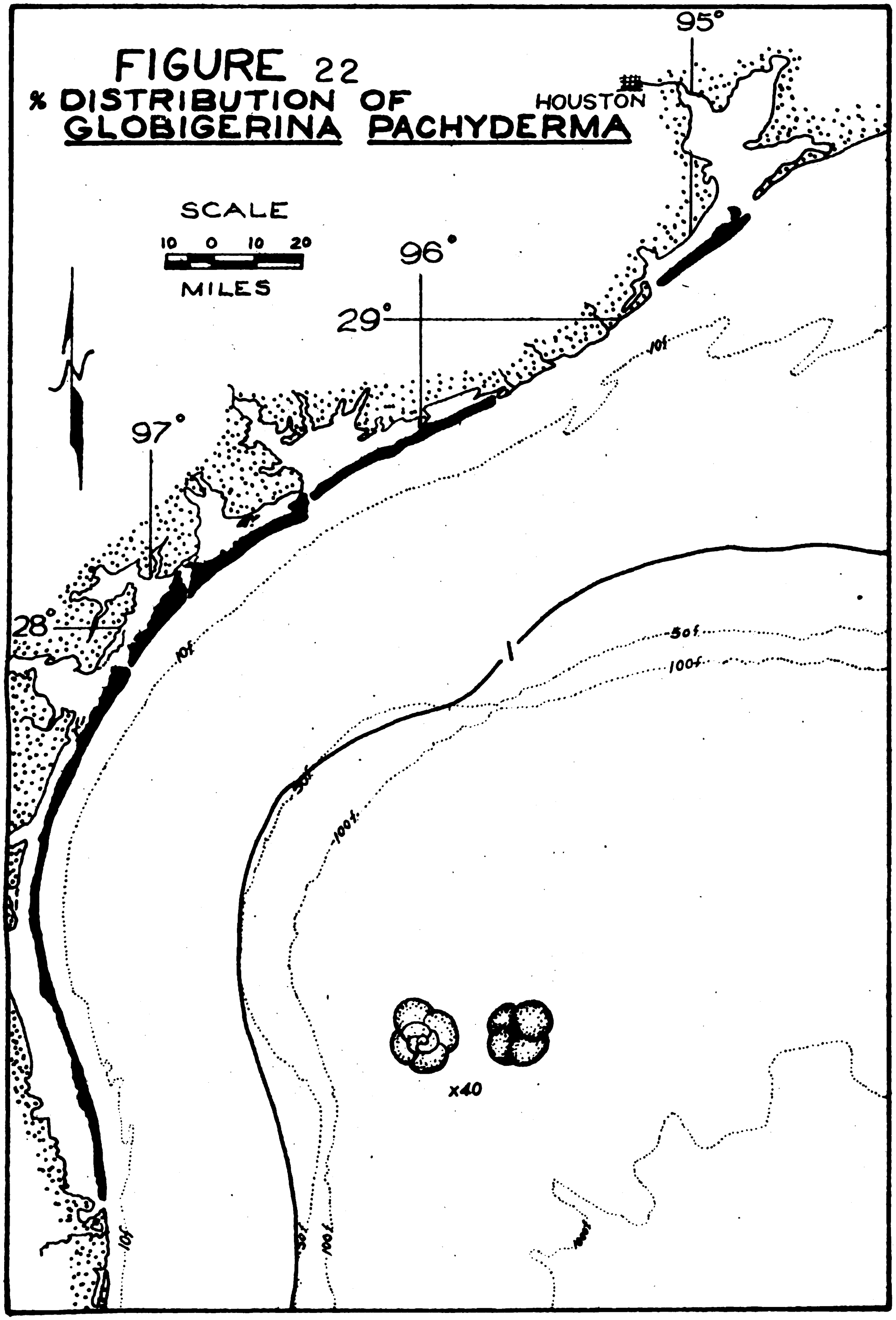


FIGURE 22
% DISTRIBUTION OF
GLOBIGERINA PACHYDERMA
HOUSTON
95°
96°
97°
29°
28°
SCALE
10 0 10 20
MILES
10f
50f
100f
x40

Globigerina rubescens Hofker

This small species is very rare and scattered in the area studied. All of the specimens counted were less than .2mm. maximum diameter. There was not a sufficient number of specimens counted to make any generalities on the distribution of size variants. The occurrence of *Globigerina rubescens* in the south Atlantic as reported by Bé (1966) suggests that, like *Globigerina digitata*, the species is being carried into the Gulf area by currents through the Yucatan Straits. All specimens of this species are left coiling in the northwest Gulf, and the test has a light orange hue.

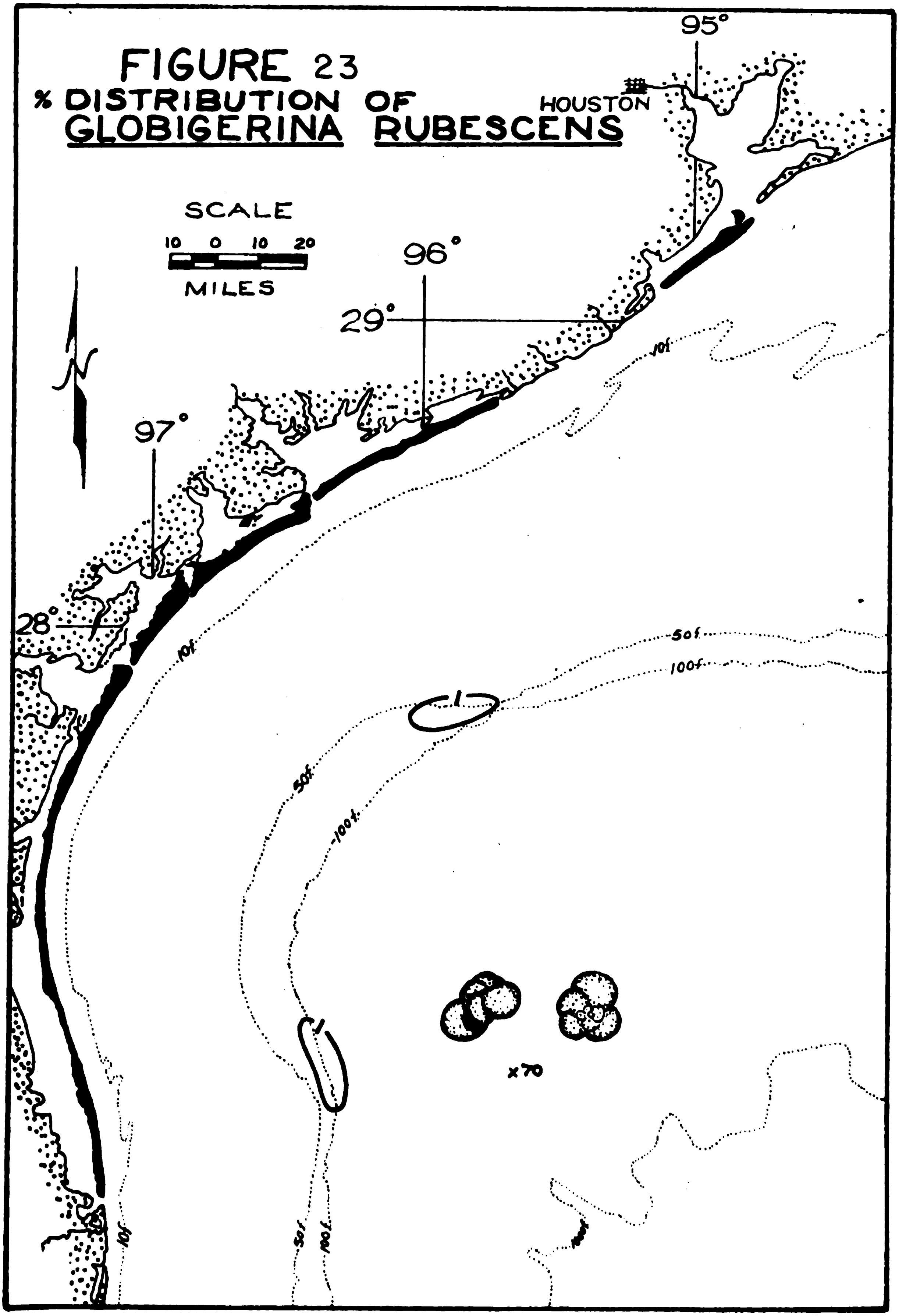


FIGURE 23
% DISTRIBUTION OF
GLOBIGERINA RUBESCENS
HOUSTON
95°
SCALE
10 0 10 20
MILES
96°
29°
97°
28°
10f
50f
100f
1
x70

Globigerinella siphonifera (D'Orbigny)

This species initially occurs in the bathymetric profile at around forty meters. Average size increases from .4mm. on shelf specimens to .6mm. on slope specimens. The largest specimens of Globigerinella siphonifera are not localized in their occurrence but are most common in shelf sediments. In addition to size variation, the presence or absence of a diminutive final chamber was counted. A diminutive final chamber was counted on about ten percent of the specimens, and individuals with the structure were scattered throughout the bathymetric profile. Highest numerical counts for the species occurred in the outer shelf sediments, but these did not exceed twelve percent of the total planktonic fauna in any of the traverses. Spinose juvenile individuals of G. siphonifera are up to fifteen percent of the population in shelf sediments but are rare elsewhere.

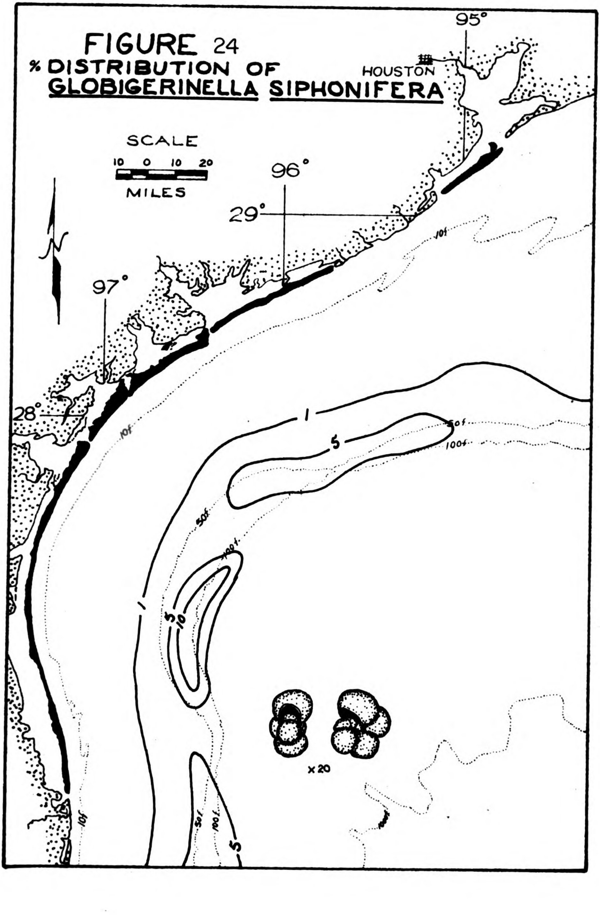


FIGURE 24
% DISTRIBUTION OF
GLOBIGERINELLA SIPHONIFERA
HOUSTON
95°
SCALE
10 0 10 20
MILES
96°
29°
97°
28°
1
5
10
x20

Globigerinita glutinata Bronniman

Specimens of *Globigerinita glutinata* were scattered in sediments in the northwestern Gulf of Mexico. Most of the specimens counted were from outer continental shelf and slope sediments. Size for the species was .3mm. (maximum diameter). The population is not sufficiently large to make any generalities on the distribution of size variants. Specimens bearing the bullae structure compose approximately half of the populations counted and are most common in sediments deeper than three hundred meters. The paucity of this species in the western and eastern Gulf of Mexico (Parker, 1954) and its increased abundance in the Orinoco and Caribbean areas (Drooger, 1958, Jones, 1966) indicates that the species is probably being introduced into the Gulf through the Yucatan Straits. All specimens of *G. glutinata* recorded in the northwest Gulf were left coiling.

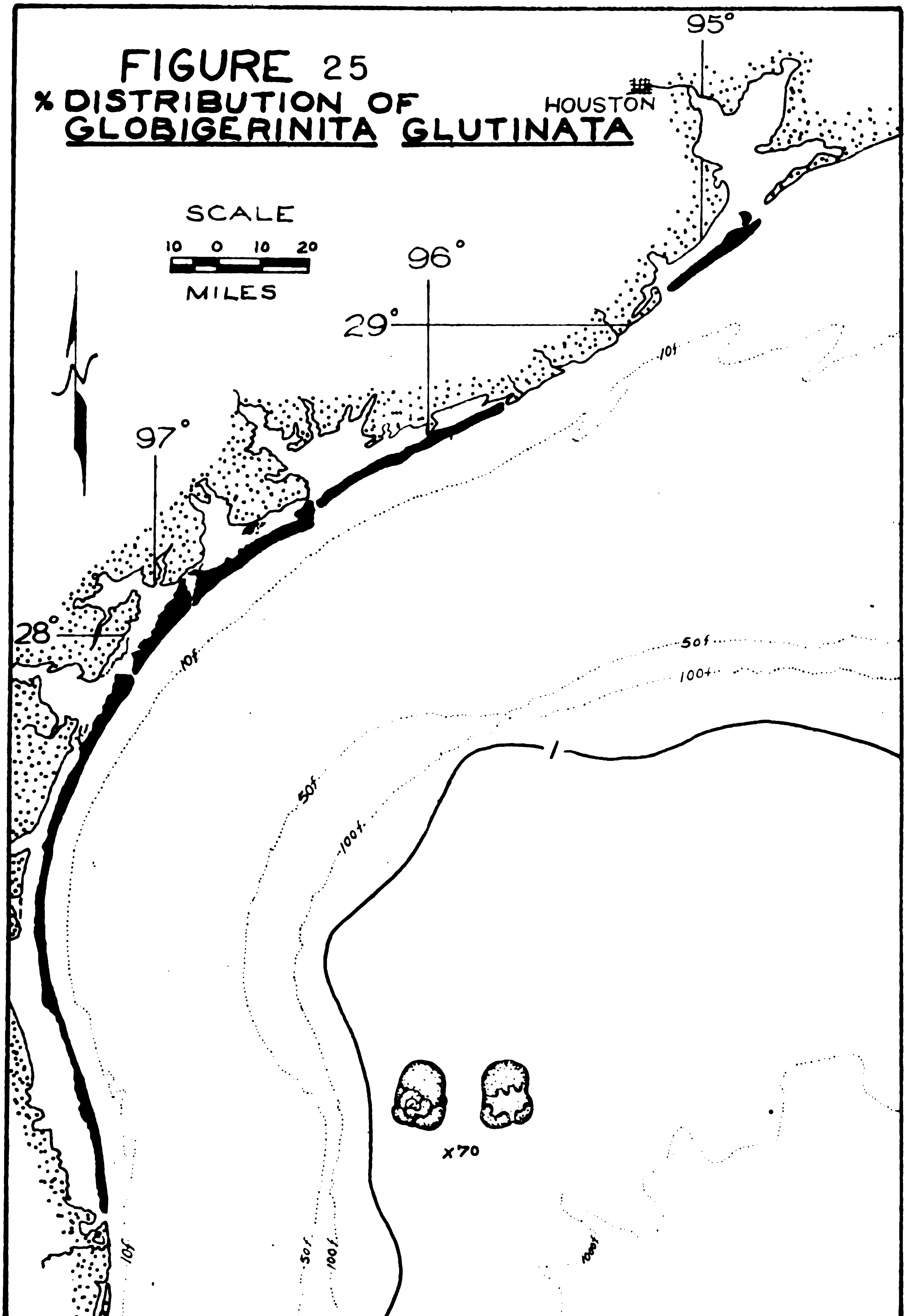


FIGURE 25
% DISTRIBUTION OF
GLOBIGERINITA GLUTINATA
HOUSTON
95°
96°
97°
29°
28°
SCALE
10 0 10 20
MILES
10f
50f
100f
1
x70

Globigerinita humilis (Brady)

Globigerinita humilis was rare in the western Gulf of Mexico. The species is unreported from water masses and marine sediments adjacent to the Gulf of Mexico, but the absence of the species in previous records may be due to the extremely small size of the specimens or to misidentification as benthonics, Parker (1951). The species was counted from outer shelf and continental slope sediments where it has a very scattered distribution. Populations of the species averaged .2mm. maximum diameter with little variation in size. Three quarters of the specimens bear a thin flap-like umbilical bulla which is a ventral extension of the final chamber. *G. humilis* was the most heterogeneous species tabulated with respect to coiling with a sixty to forty right-to-left coiling ratio.

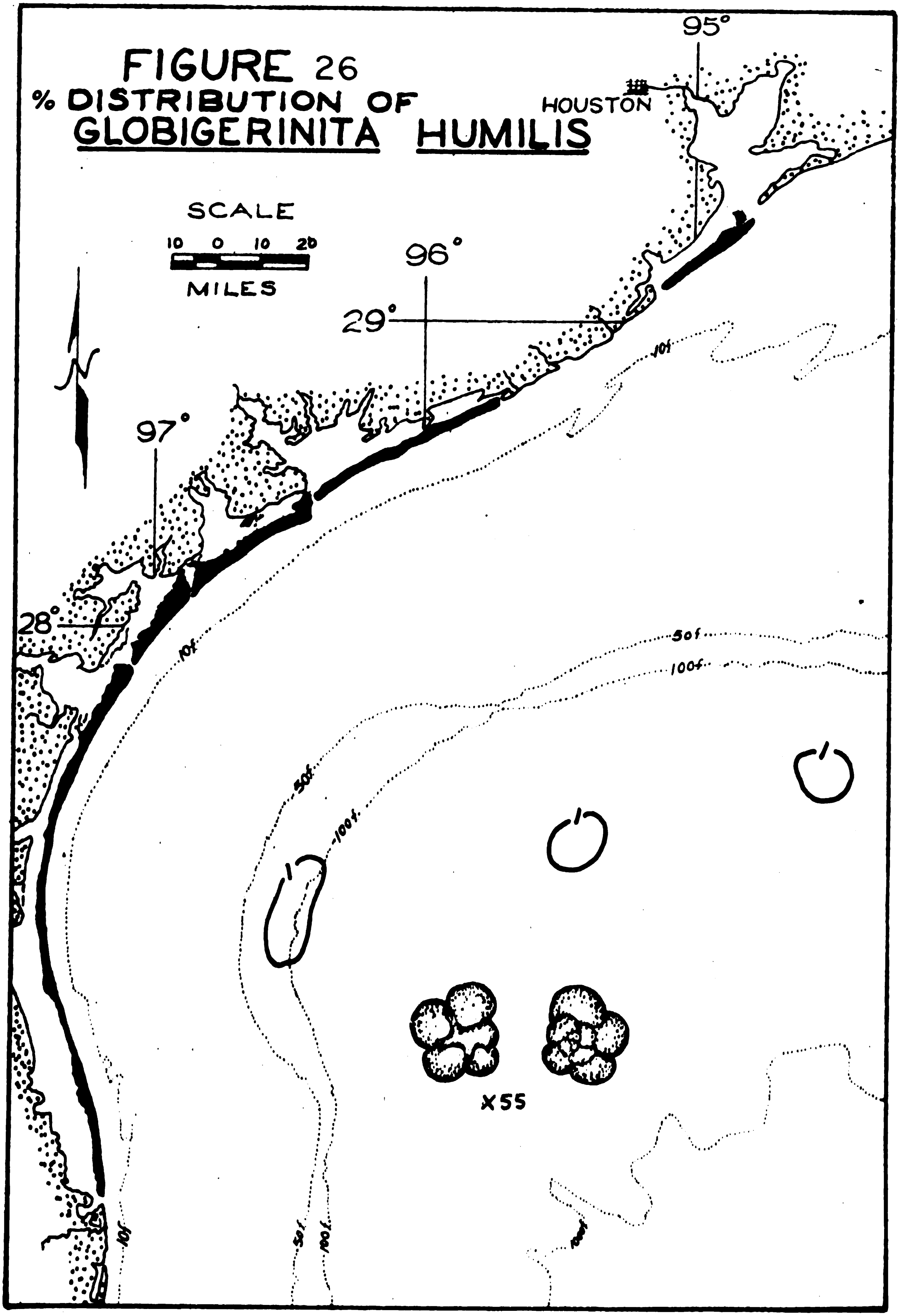


FIGURE 26
% DISTRIBUTION OF
GLOBIGERINITA HUMILIS
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
10f
50f
100f
X55

Globigerinita uvula (Ehrenberg)

This rare species was scattered in outer shelf and slope sediments in the northwestern Gulf of Mexico. Almost all of the specimens of this species measured .2mm. (maximum diameter). As with many of the smaller rare species encountered in the present study, the increased abundance in the Orinoco area (Drooger, 1958) indicates that the species is being introduced into the Gulf from the Yucatan Straits. Populations of *Globigerinita uvula* were more than ninety percent left coiling in the northwest Gulf.

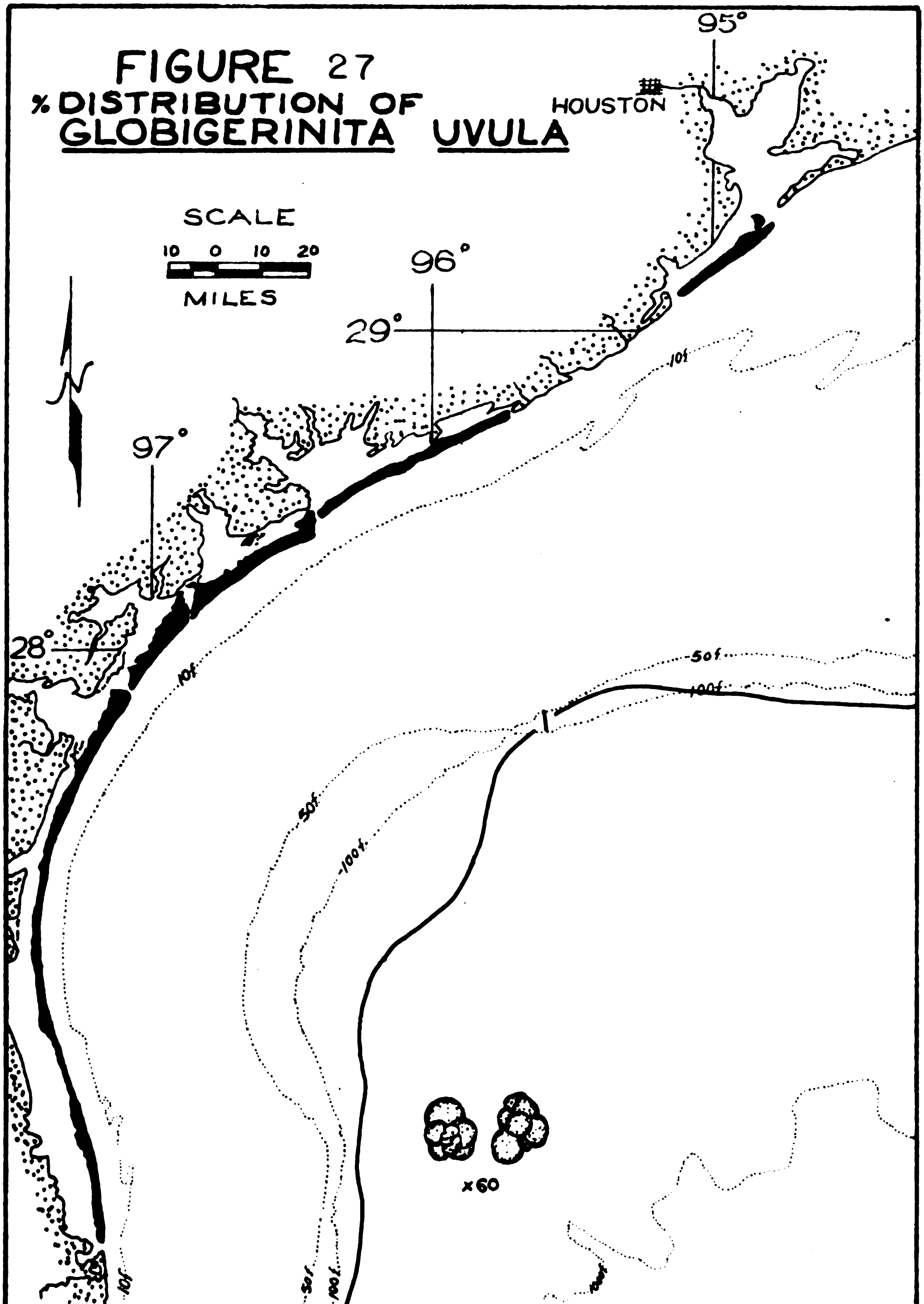


FIGURE 27
% DISTRIBUTION OF
GLOBIGERINITA UVULA
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
10f
50f
100f
x60

Globigerinoides conglobatus (Brady)

The first occurrence of Globigerinoides conglobatus is scattered in the western Gulf of Mexico between thirty and eighty meters. Specimens range in average size from .3mm. in the shallowest sediments to .7mm. in the deepest. Maximum size reached by the species is 1.0mm. in continental slope sediments. The highest numerical counts for the species were recorded in samples from the outermost continental shelf. In these sediments the species reaches a maximum of eight percent of the total planktonic fauna. In addition to size, the presence or absence of bullae structures and spines were tabulated for this species. Specimens having the bullae structure were primarily adults and were less than twelve percent of the total population. These bullae-bearing specimens were scattered through the bathymetric profile deeper than one hundred and fifty meters. Conversely, spinose individuals were predominantly juveniles and were restricted to middle and outer continental shelf sediments. One hundred percent of the populations of G. conglobatus in the northwest Gulf are right coiling.

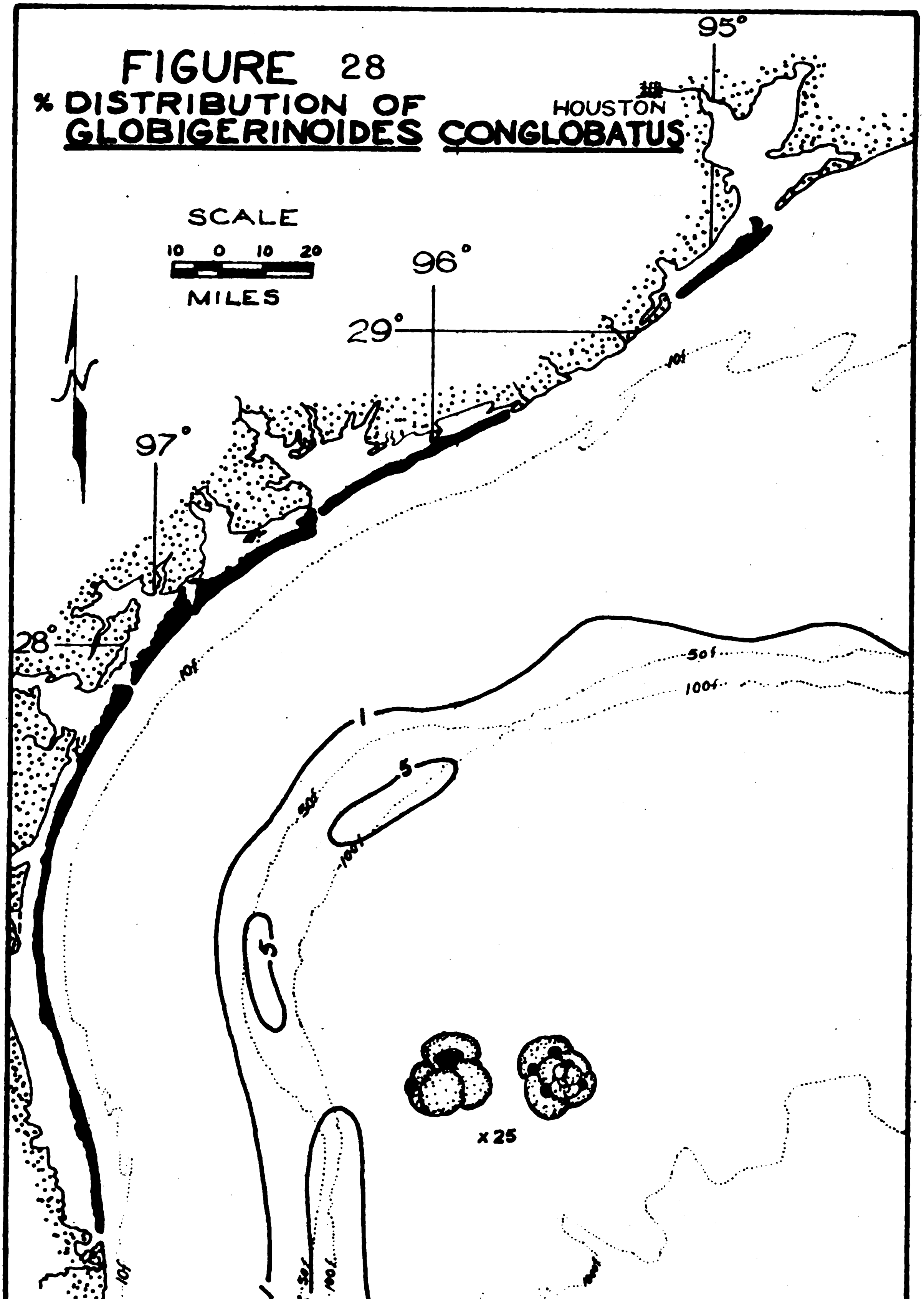


FIGURE 28
% DISTRIBUTION OF
GLOBIGERINOIDES CONGLOBATUS
HOUSTON
95°
96°
97°
29°
28°
SCALE
10 0 10 20
MILES
10f
50f
100f
1
5
x 25

Globigerinoides quadrilobatus sacculifer (Brady)

The first occurrence of *Globigerinoides quadrilobatus sacculifer* in the bathymetric profile takes place consistently at thirty to thirty-two meters. Average specimen size varies from .3mm. at the shallow end of the bathymetric profile to .5mm. in populations from slope sediments. Bé and Ericson (1963) have noted a similar range in sizes from live specimens taken in plankton tows. Their study of Atlantic planktonics demonstrated that higher proportions of smaller individuals inhabited the shallower epipelagic depths while larger specimens occupied respectively greater depths in the bathymetric column. The largest specimens of *G. quadrilobatus sacculifer* counted in this study measured up to 1.0mm. maximum diameter and were from lower slope sediments. In addition to size variation, test thickness, coiling, and the configuration of the final chamber were tabulated for northwest Gulf populations. Specimens of *G. quadrilobatus sacculifer* with a thickened test have been previously identified by authors (Bé, 1965) as *Sphaeroidinella dehiscens*. This morphological variant of *G. quadrilobatus sacculifer* was scattered in its occurrence in the northwestern Gulf of Mexico sediments but was not recorded from shallower than three hundred meters. This agrees with the known distribution of living specimens of the variant as recorded from plankton tows (Bé, 1965, Jones, 1965). Bé (1965) reports that the thickened variant occurs live in notable frequencies only at depths greater than five hundred meters in the north Atlantic. The "*Sphaeroidinella dehiscens*" variant ranges in size from .6mm. to 1.0mm. The configuration of the final chamber of non-thickened specimens of *G. quadrilobatus sacculifer* is frequently such that the chamber is sac-like and skewed away from the proloculus (figure 13, page 31). This aberrant chamber seems to be homologous to the diminutive terminal chamber of other planktonic species. Specimens with the sac-like final chamber were rare in the sediments shallower than one hundred and fifty meters. In sediments deeper than one hundred and fifty meters the percentage of the sac-bearing variants increases to a maximum of fifty percent of the population of the species from slope sediments.

The highest numerical counts of *G. quadrilobatus sacculifer* occur in lower slope sediments where the species is ten to fifteen percent of the total planktonic fauna. Phleger (1960) has reported a gradual increase of the percentage of *G. quadrilobatus sacculifer* from the western Gulf of Mexico toward the southeast Gulf of Mexico and the Caribbean Sea. This observed easterly increase of *G. quadrilobatus sacculifer* in the planktonic fauna indicates, according to Phleger (1960), that the species is being introduced into the Gulf of Mexico from the southeast. The complete spectra of juvenile to adult specimens in the western Gulf of Mexico seems to suggest the contrary. Ovey and Wiseman (1950) have stated that large accumulations of maximum size or adult tests in sediments would indicate an environment very suitable to the organism. Such accumulations of adult tests are the result of reproduction in which the adult test is evacuated during the process of asexual reproduction (Ovey and Wiseman, 1950). Ninety-five percent of the specimens of *G. quadrilobatus sacculifer* are right coiling in the northwest Gulf. Left coiled specimens are scattered through the bathymetric profile.

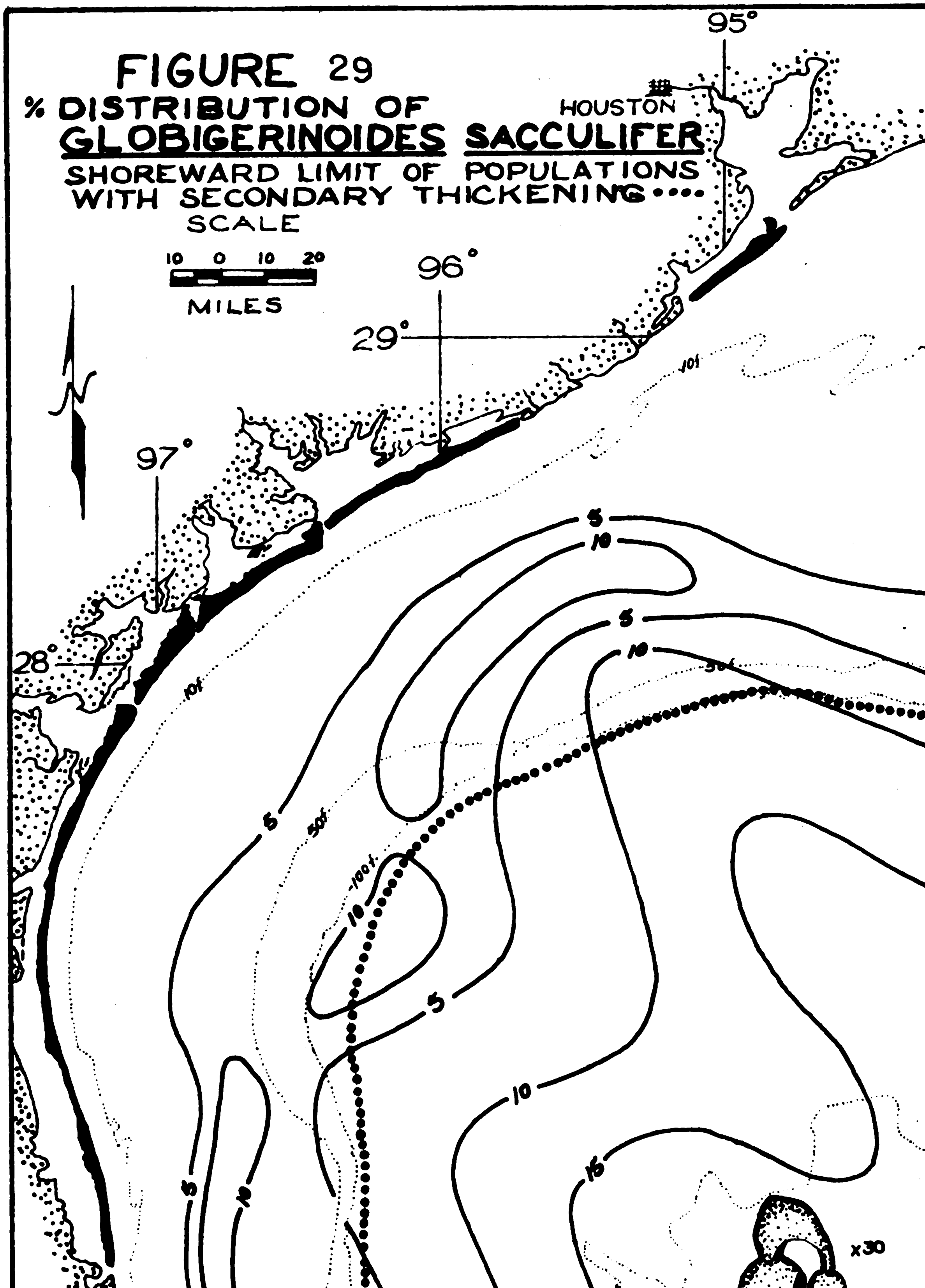


FIGURE 29
% DISTRIBUTION OF
GLOBIGERINOIDES SACCULIFER
SHOREWARD LIMIT OF POPULATIONS
WITH SECONDARY THICKENING ••••
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
x30

Globigerinoides ruber (D'Orbigny)

Globigerinoides ruber is the first planktonic Foraminifer to occur in the bathymetric profile of any of the traverses of the present study. The species first occurred between twenty-six and thirty-one meters and is seldom found in numbers greater than five specimens per sample until thirty-three to forty meters where twenty to sixty specimens occur per sample. Between forty and one hundred meters of depth the species is approximately forty percent to sixty percent of the planktonic fauna. Below one hundred meters on the continental slope, the population percentages decrease to twenty or twenty-five percent of the fauna.

Size range for the species varies from an average of .3mm. at the shallow end of the traverses to .5mm. on the outer shelf sediments. Largest specimens of the species measured .8mm. and were tabulated from outer shelf sediments.

Variation tabulated for the species included color, spines, coiling, bullae structures. The color varieties of the species were recorded as either non-colored, colored (red) throughout the test, or colored on the initial whorl. Because the "totally red" and "red on initial chamber" specimens completely intergrade, they are recorded as "colored". Colored specimens average .4mm. in size and make up approximately fifty percent of the populations of this species except in shallow sediments where they may be absent. Non-colored specimens average .5mm. in size. Specimens with spines and bullae structures are twenty to forty percent of the populations in outer shelf and upper slope sediments. Most of the spinose individuals are juveniles, whereas most of the bullae-bearing individuals are in the adult size range.

Studies of the cytology of this species by Freudenthal, Kossoy, and Bé (1965) indicate that the species has an abundant flora of zooaxonthellae symbionts. The presence of the chlorophyll synthesizing symbionts implies that the species is restricted to the euphotic zone. Studies by Emiliani (1954) on the chemistry of planktonic Foraminifers' tests showed that G. ruber lives in the upper forty-five meters of the bathymetric column. This data correlated well with the distribution of the species in the sediments of the northwest Gulf of Mexico. Ninety percent of the specimens in populations of G. ruber are right-coiling in the northwest Gulf. Left-coiling specimens are scattered in shelf and slope sediments.

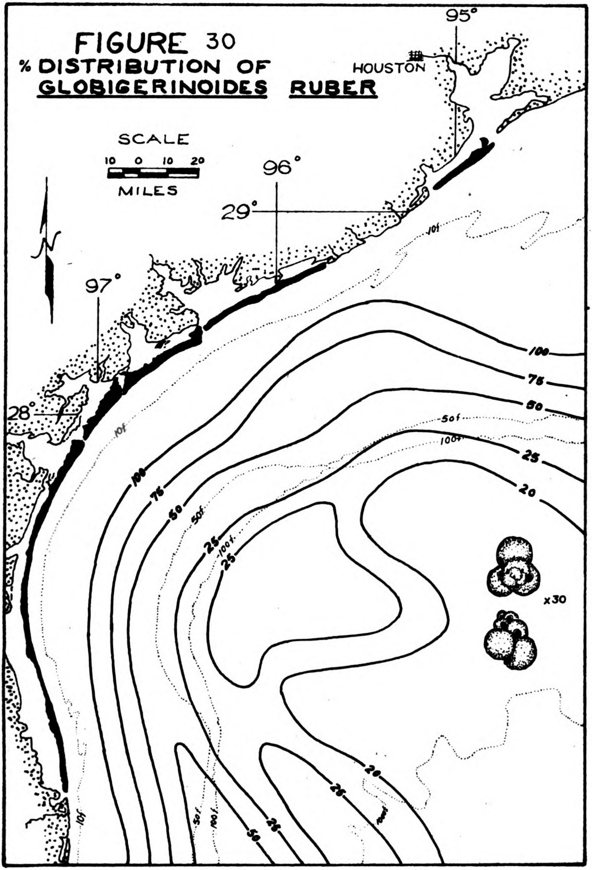


FIGURE 30
% DISTRIBUTION OF
GLOBIGERINOIDES RUBER
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
100
75
50
25
20
10f
50f
100f
x30

Globoquadrina dutertrei (D'Orbigny)

Globoquadrina dutertrei first occurs in the bathymetric profile between thirty-one and fifty meters. Average specimen size varies from .4mm. at the shallow ends of the traverses to .6mm. in the outer shelf and slope sediments. The largest specimens of this species occurred in the outer shelf and upper slope sediments and measured .8mm. (maximum diameter). In addition to size variation, the incidence of the diminutive final chamber and coiling were tabulated for this species. Specimens bearing the diminutive final chamber were evenly dispersed throughout the bathymetric profile except in sediments less than one hundred meters of water. Specimens bearing diminutive final chambers were invariably in the adult size range and were twenty to thirty percent of the population of the species in many samples. All specimens of G. dutertrei were right coiling in the northwest Gulf.

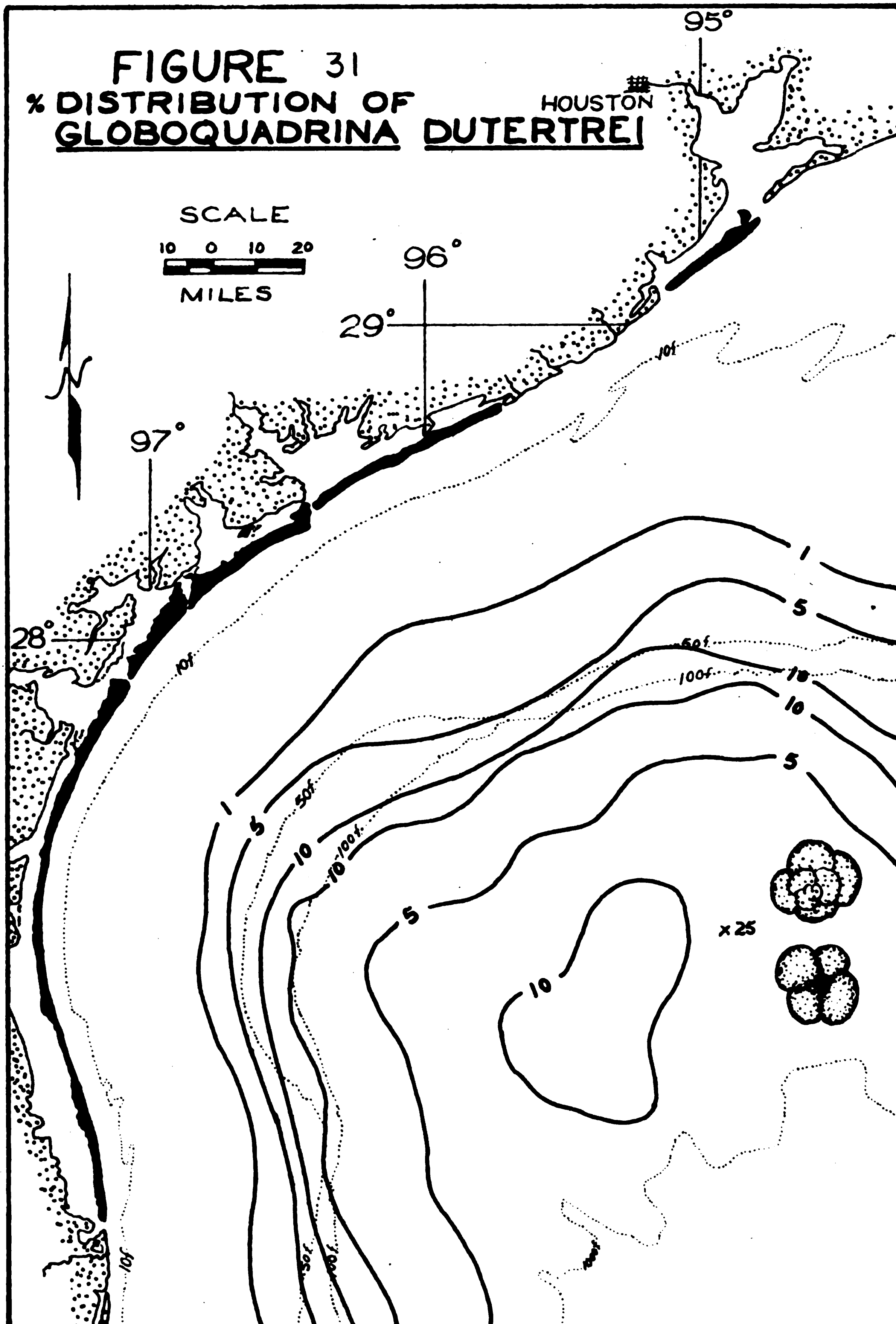


FIGURE 31
% DISTRIBUTION OF
GLOBOQUADRINA DUTERTREI
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
10f
50f
100f
1
5
10
x25

Globorotalia crassaformis Cushman

Globorotalia crassaformis is not a common species in the northwest Gulf, but its distribution in any of the samples in the seven traverses studied was consistent. First occurrence of the species in the bathymetric profile was scattered in the traverses between thirty-one and four hundred meters. Average size of specimens ranged from .4mm. in the shallowest samples up to .6mm. in the deepest samples. The largest specimens of this species measured .9mm. maximum diameter and occurred in the deepest samples on the continental slope. The highest percentages of the species were in faunas from the middle and outer shelf sediments where the species was four percent of the total planktonic fauna. Populations of Globorotalia crassaformis exhibited the secondary calcification of the test in deep water typical of the Globorotalid species. Secondarily thickened specimens of G. crassaformis are primarily in the adult size range and are limited to continental slope sediments deeper than seven hundred meters. The transition from thin-walled populations to thick-walled populations is, as in all of the Globorotalid species, abrupt. The range of sizes of this species in the sediments of the Gulf of Mexico suggests that, although the species is relatively low in its percentage of the total fauna, it is authochthonous to the Gulf. Populations of G. crassaformis are invariably one hundred percent left coiling in the northwest Gulf.

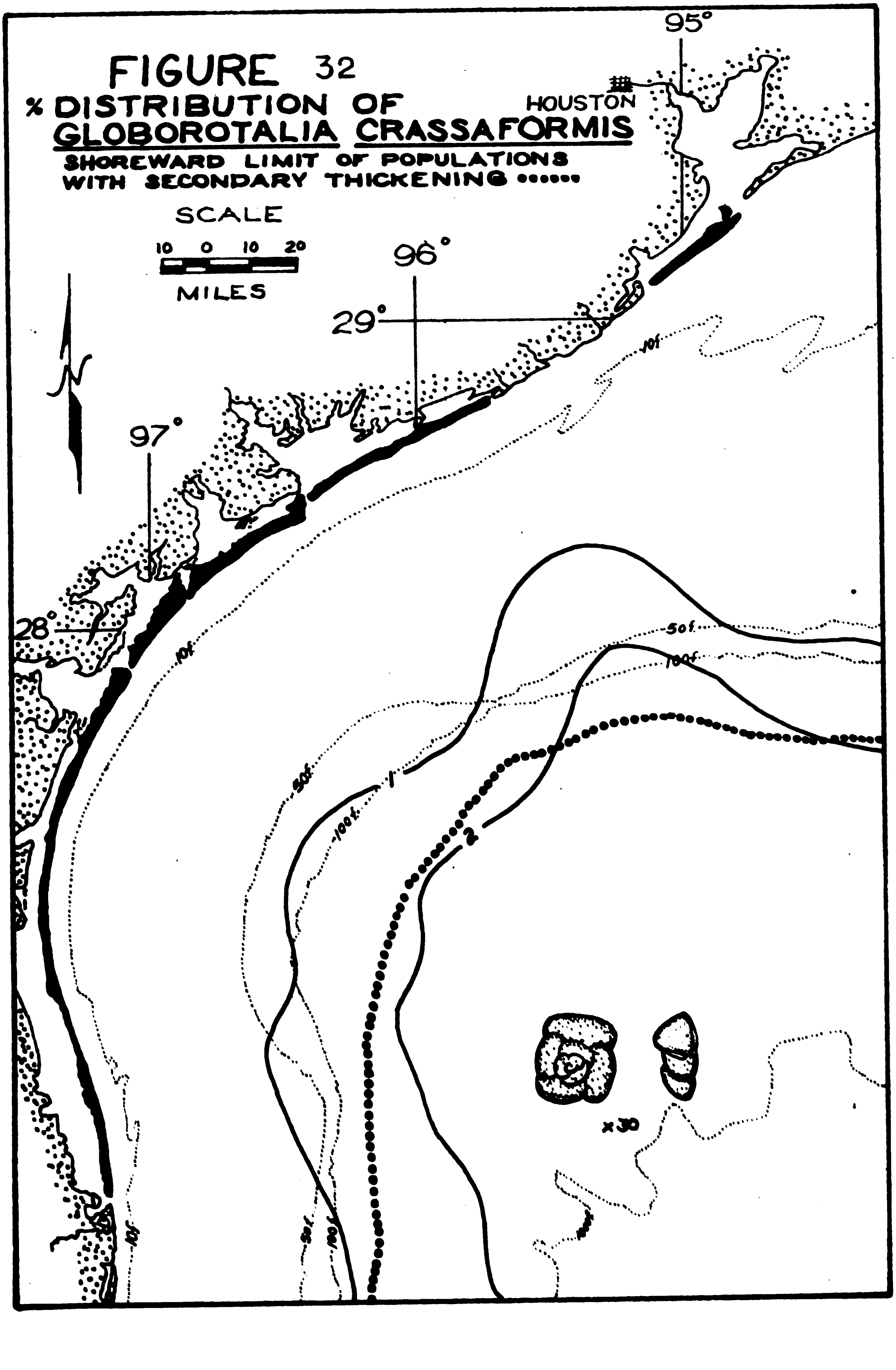


FIGURE 32
% DISTRIBUTION OF
GLOBOROTALIA CRASSAFORMIS
SHOREWARD LIMIT OF POPULATIONS
WITH SECONDARY THICKENING
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
10f
50f
100f
1
2
x30

Globorotalia cultrata (D'Orbigny)

This species occurs initially in depths between thirty-one and forty meters. Average specimen size varies from .4mm. at the shallow ends of the traverses up to .9mm. in samples from the outer shelf and continental slope. The largest specimens of this species measured 1.5mm. (maximum diameter) and occurred in continental slope sediments. The presence of a diminutive final chamber was relatively common in this species which was up to fifty percent of the population in some of the deeper samples. Most of the specimens bearing this structure are in the upper half of the size range (.7mm. to 1.5mm.) and are scattered through the bathymetric profile being only rare in shallow water. Populations of Globorotalia cultrata exhibited a profound change in wall thickness due to secondary calcification at approximately one hundred and twenty meters. Near this depth, populations changed from five percent thick-walled forms to more than eighty percent thick-walled forms. This change occurred in most cases in less than one mile linear distance. The highest percentages of this species in the total planktonic fauna are found in slope sediments where the species reaches highs of twenty percent. G. cultrata is more than ninety percent left coiling in the northwest Gulf of Mexico. Aberrant left coiling specimens are scattered at all levels of the bathymetric profile.

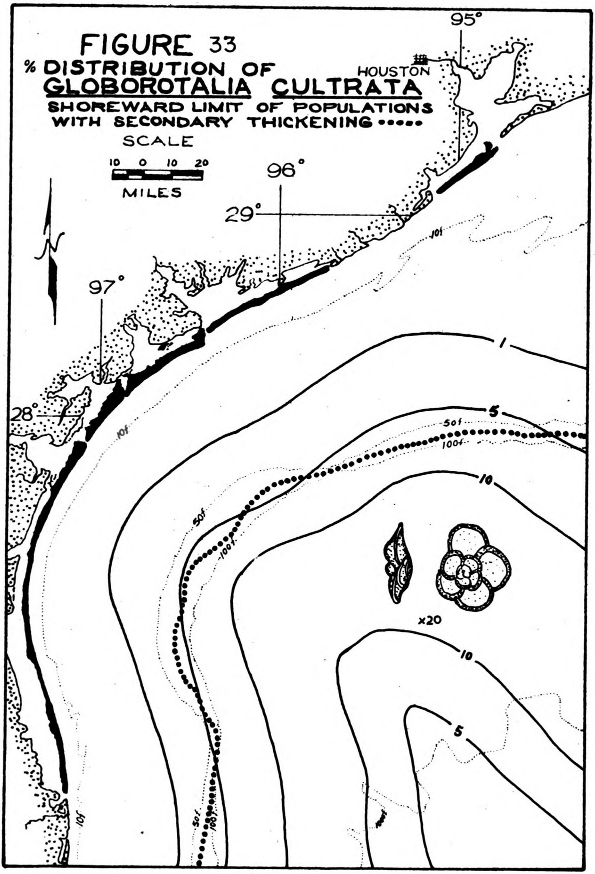


FIGURE 33
% DISTRIBUTION OF GLOBOROTALIA CULTRATA
SHOREWARD LIMIT OF POPULATIONS WITH SECONDARY THICKENING •••••
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
10f
50f
100f
1
5
10
x20

<u>Globorotalia inflata</u> (D'Orbigny)

This species first occurs in the bathymetric profile between forty-five and fifty meters. The first occurrence of the species is represented by very low percentages but is consistent throughout the area of the present study. The average size of the specimens ranges from .3mm. at the shallow ends of the traverses to .5mm. in continental slope sediments. The largest specimens of this species measured .7mm. and were from outer shelf and upper slope sediments. The highest percentage of the species occurs in outer shelf and slope sediments where it is up to six percent of the total planktonic fauna in isolated samples. All specimens of <u>G. inflata</u> tabulated coil to the left and none of the species exhibit the secondary calcification present in four other species of <u>Globorotalia</u> from the northwest Gulf.

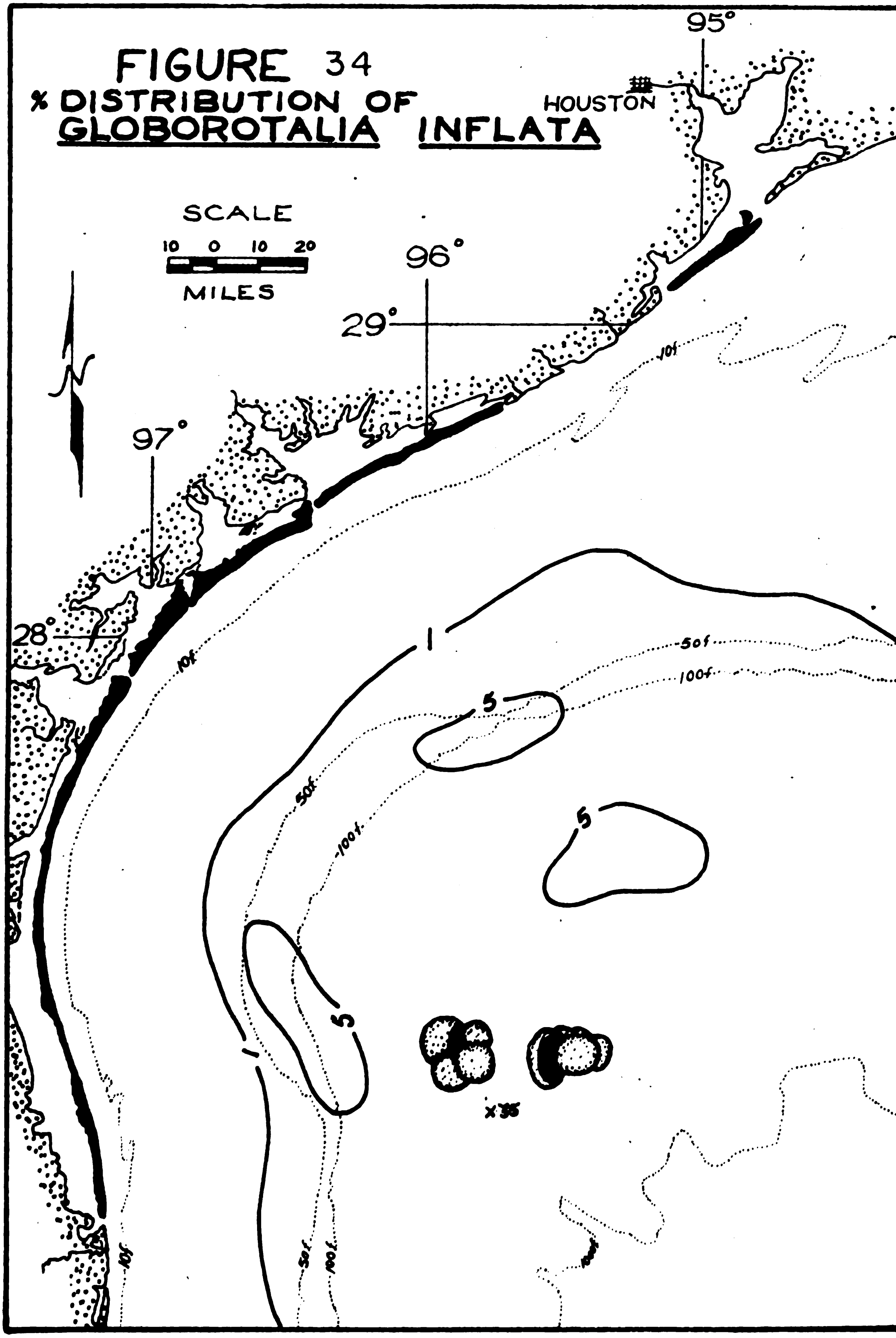


FIGURE 34
% DISTRIBUTION OF
GLOBOROTALIA INFLATA

Globorotalia scitula (Brady)

This species is rare in sediments from the northwest Gulf of Mexico seldom comprising more than two percent of the fauna in any sample. Specimens range in size from .5mm. to .8mm. Globorotalia scitula was one of two species of Globorotalia which did not show secondary calcification of the test wall. The rarity of the species in the northwest Gulf of Mexico and its scattered occurrence in the Caribbean (Jones, 1965) and equatorial Atlantic (Bé, 1958) indicates that the species is probably being supplied to the Gulf from Atlantic water masses. All specimens tabulated are left coiling in the northwest Gulf.

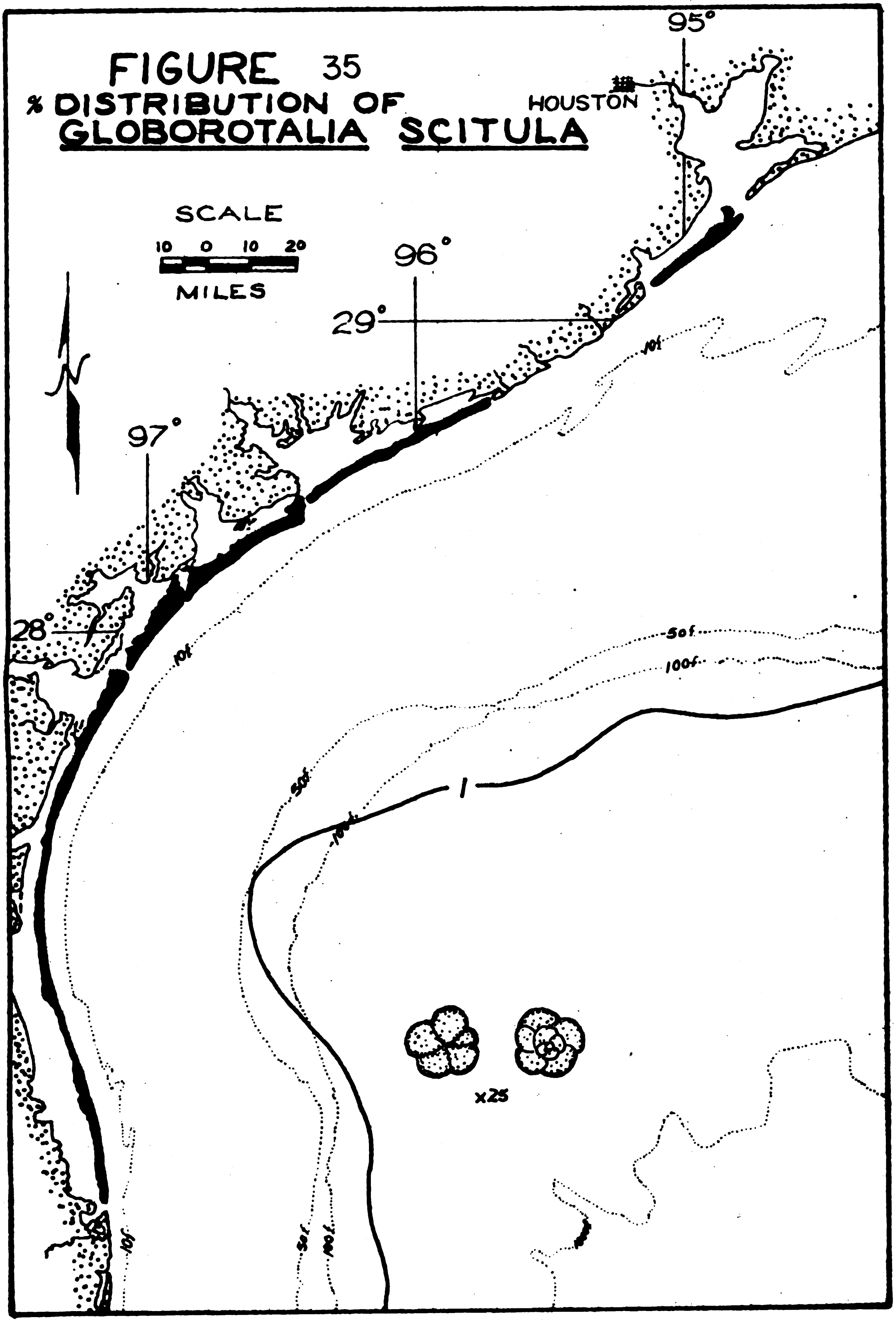


FIGURE 35
% DISTRIBUTION OF
GLOBOROTALIA SCITULA
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
10f
50f
100f
1
x25

Globorotalia truncatulinoides (D'Orbigny)

Globorotalia truncatulinoides occurs in the bathymetric profile initially at scattered intervals between thirty and forty meters. Average size of the specimens ranges from .4mm. at the shallow ends of the traverses to .6mm. in continental slope samples. The largest specimens of this species occurred in slope samples and measured .9mm. (maximum diameter). In addition to size of the test, variation in the test thickness as well as the presence or absence of a diminutive final chamber and coiling were tabulated for the species. At approximately three hundred meters, populations of *Globorotalia truncatulinoides* exhibit a basinward change from thin to thick tests. Above this depth, populations from sediments shallower than three hundred meters consist of more than ninety percent thin-walled individuals, whereas below that depth populations are made up of more than eighty percent thick-walled individuals. Bé and Ericson (1963) have noticed a similar distribution of live, secondarily calcified specimens of *G. truncatulinoides* from net tows in the north Atlantic. In their work they did not record notable percentages of these thick-walled variants of the species above three hundred meters. Between three hundred and five hundred meters in the north Atlantic they found living thick-walled forms to be relatively common in the bathymetric column. Most of the specimens of *G. truncatulinoides* which exhibited the diminutive final chamber are in the largest size range of the population (.5mm. to .9mm.) and occur throughout the bathymetric profile except in the shallowest sediments. The highest percentages of the species occurred on the continental slope between five hundred and one thousand meters where they were frequently fifteen to eighteen percent of the total planktonic fauna. G. truncatulinoides is more than ninety percent right coiling in the northwest Gulf. The aberrant left coiling specimens are scattered through the bathymetric profile.

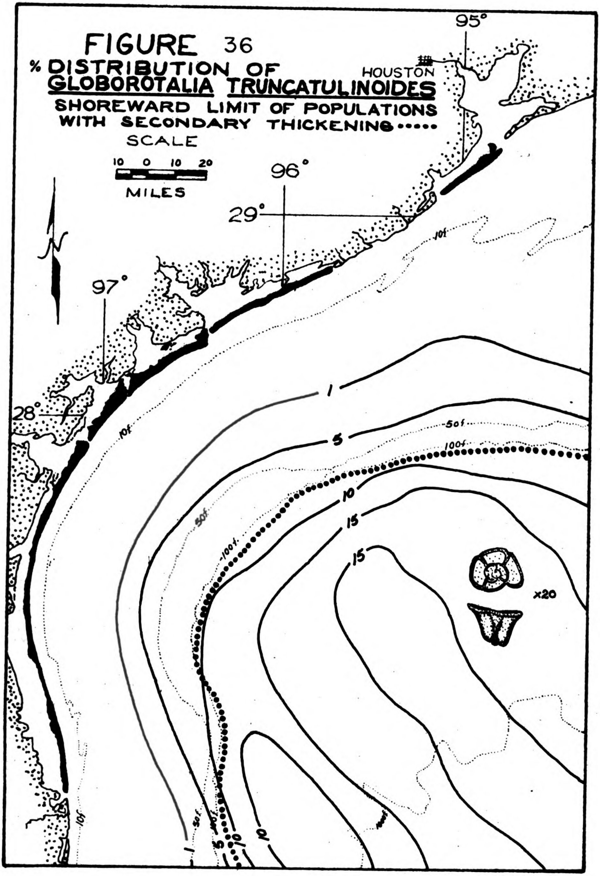


FIGURE 36
% DISTRIBUTION OF
GLOBOROTALIA TRUNCATULINOIDES
SHOREWARD LIMIT OF POPULATIONS
WITH SECONDARY THICKENING
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
10f
50f
100f
1
5
10
15
x20

Globorotalia tumida (Brady)

Globorotalia tumida has a very low initial occurrence in the northwest Gulf. In most of the traverses the species first appeared at eighty to one hundred and twenty meters. Average size of the individuals of this species ranged from .4mm. at the shallow ends of the traverse up to .9mm. in populations from slope samples. The largest specimens of the species measured 1.3mm. (maximum diameter) and occurred in slope sediments. This species, like most of the species of Globorotalia, exhibits the change from thin-walled populations to thick-walled populations in basinward traverses, which, in this case, occurs at approximately two hundred meters. Because the species has a relatively deep first occurrence in the bathymetric profile and because the population change from thin-walled to thick-walled forms takes place abruptly at two hundred meters, the majority of the specimens counted in this study were of the thick-walled variety. The highest percentages of this species occurred in slope sediments but seldom exceeded five percent of the total planktonic fauna. Populations of G. tumida are ninety-five percent left-coiling in the northwest Gulf and, moreover, aberrant left coiling individuals are evenly scattered areally.

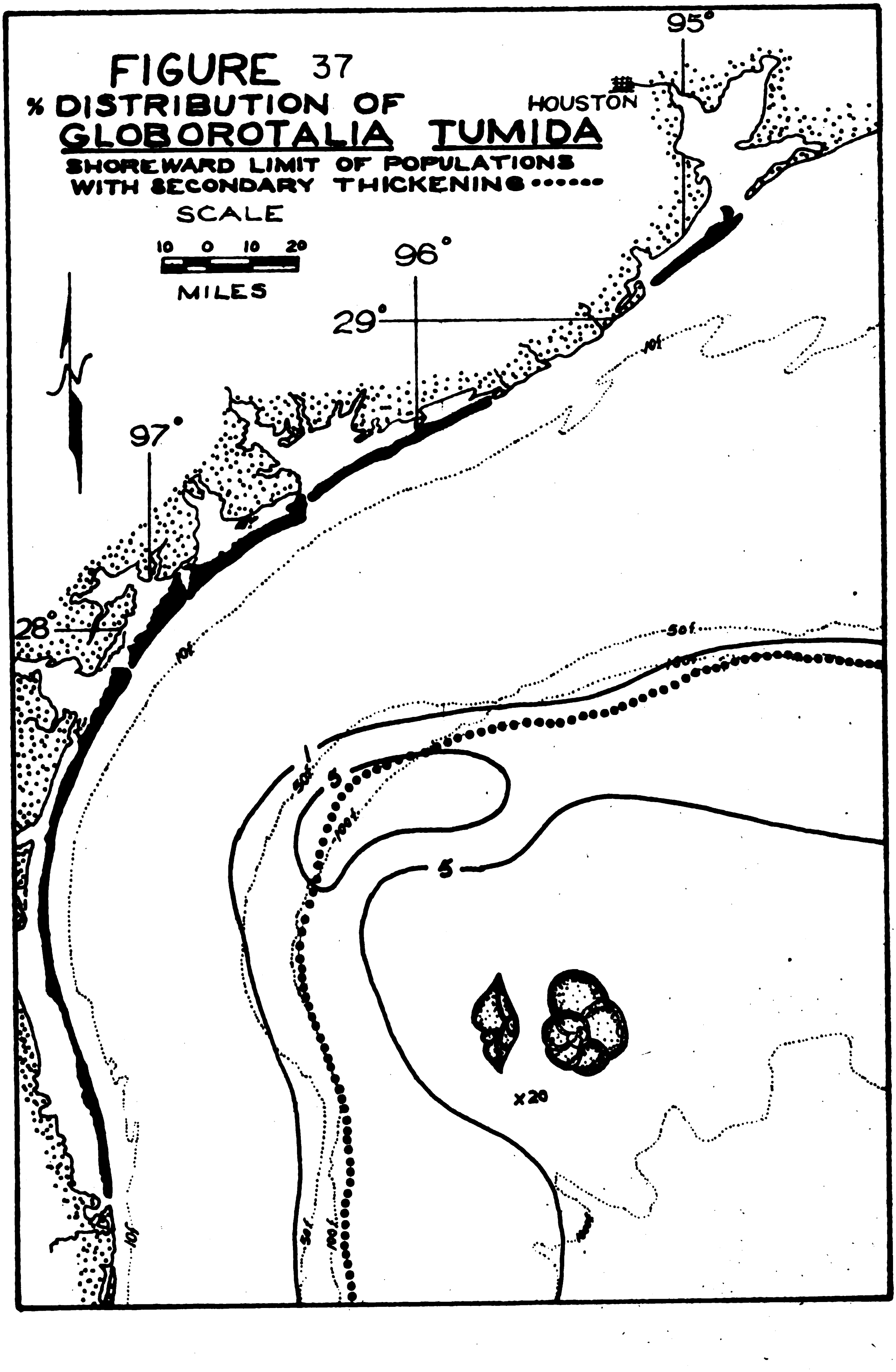


FIGURE 37
% DISTRIBUTION OF
GLOBOROTALIA TUMIDA
SHOREWARD LIMIT OF POPULATIONS
WITH SECONDARY THICKENING ••••••
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
N
5
5
x20

Hastigerina pelagica (D'Orbigny)

Hastigerina pelagica was the only species encountered in the present study which was more common in shelf sediments than in slope sediments. The first occurrence in the bathymetric profile of this species was scattered between seventy and one hundred and fifty meters. Average specimen size varies from .4mm. at the shallow ends of the traverses to .9mm. (maximum diameter) in the outer shelf samples. The highest percentages of the species occur in middle to outer shelf sediments, but populations from these sediments do not exceed four percent of the total planktonic fauna. Below two hundred meters on the continental shelf, the percentages of Hastigerina pelagica decrease. Occurrences of this species from slope sediments seldom exceed one percent of the planktonic fauna. Spinose individuals of H. pelagica are primarily in the lowest size range (.3mm. to .7mm.) and are rare in sediments deeper than four hundred meters.

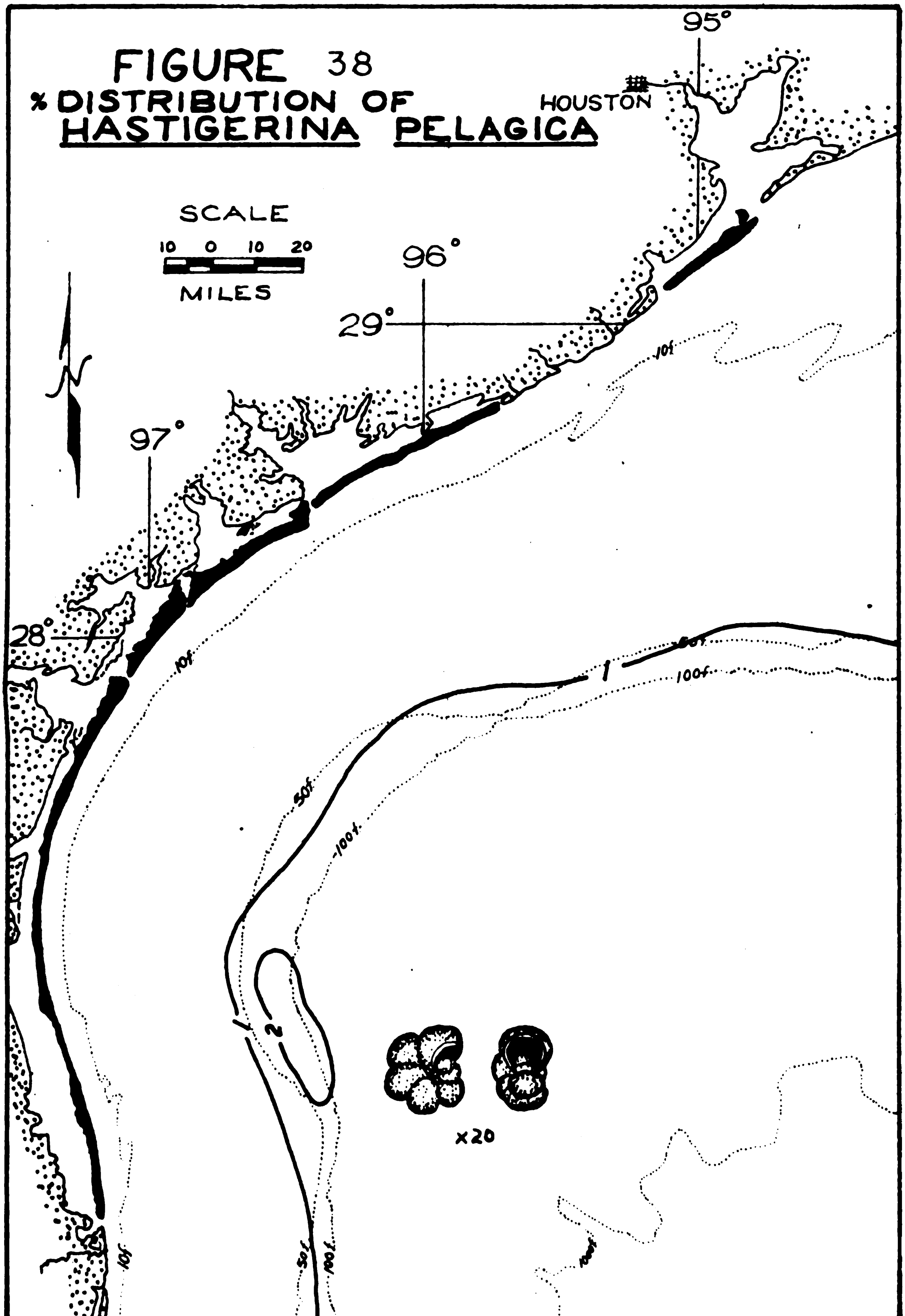


FIGURE 38
% DISTRIBUTION OF
HASTIGERINA PELAGICA
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
10f
50f
100f
1
2
x20

Orbulina universa (D'Orbigny)

Orbulina universa occurs for the first time in the bathymetric profile at scattered intervals between thirty and forty meters. Unlike other species encountered in the present study, populations of *Orbulina universa* do not increase in average specimen size from the shallow to the deep ends of the traverses. Throughout the bathymetric profiles the average specimen size for this form remains at approximately .7mm. This anomalous distribution is due to the lack of juveniles and probably relates to the polyphyly of the form which is discussed in the section on systematics. The highest percentages of the form occur at scattered intervals on the continental shelf where it reaches a high of fifteen percent to sixteen percent of the total planktonic fauna. An anomalous low, unlike that of any other species distribution, occurs in a large area on the continental shelf (distribution map).

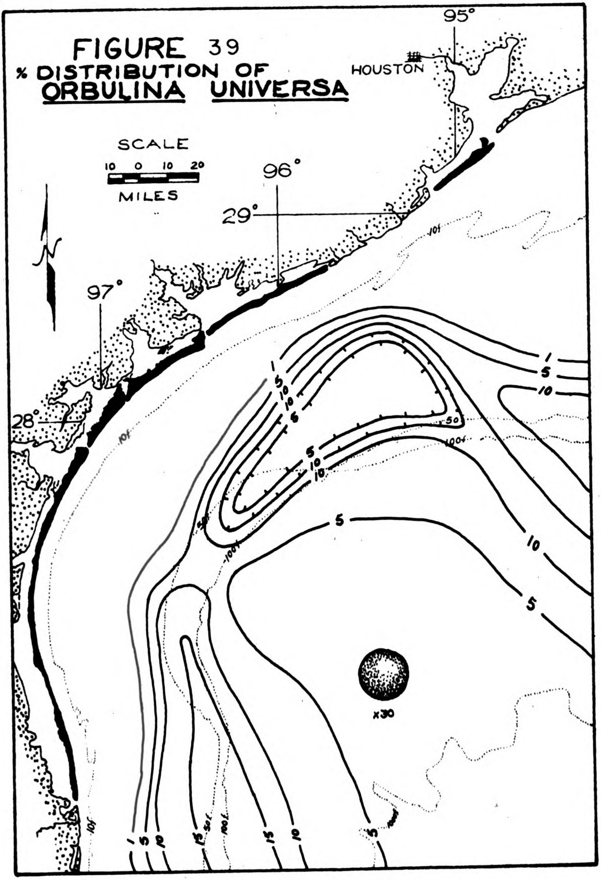


FIGURE 39
% DISTRIBUTION OF
ORBULINA UNIVERSA
HOUSTON
95°
96°
97°
29°
28°
SCALE
10 0 10 20
MILES
x30

Pulleniatina obliqueloculata (Parker and Jones)

Pulleniatina obliqueloculata is one of the most abundant planktonic Foraminifera in sediments in the northwestern Gulf of Mexico. The species first occurs in the bathymetric profile at scattered intervals between thirty and fifty-five meters. Like Orbulina universa, the species displays no increase in average size with depth, averaging .5mm. throughout its distribution. The highest numerical counts of this species were recorded from outer shelf and upper slope samples where the species reached percentages of twenty to twenty-five percent of the total planktonic fauna. Extremely low percentages of this species in sediments of the Orinoco and Caribbean areas have been reported by Jones (1965) and Drooger (1958). Jones has further reported that the species is very seasonal in its occurrence in the water column in the Caribbean appearing only during the month of January but periodically making up more than ninety percent of the fauna in plankton hauls. One hundred percent of the populations of the species in the northwest Gulf are right coiling.

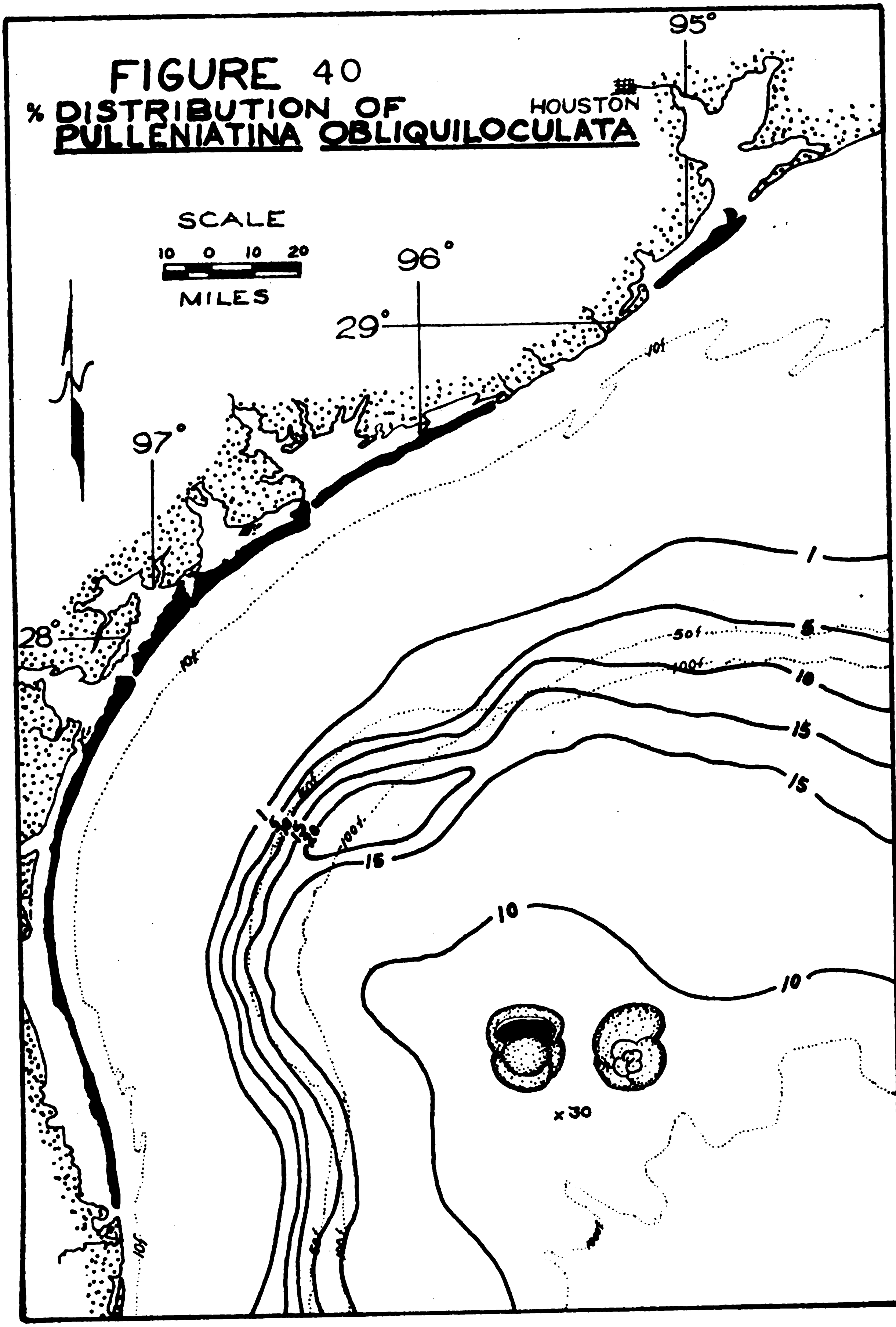


FIGURE 40
% DISTRIBUTION OF
PULLENIATINA OBLIQUILOCULATA
HOUSTON
95°
96°
97°
29°
28°
SCALE
10 0 10 20
MILES
10f
50f
100f
1
5
10
15
15
15
10
10
x30

Candeina nitida D'Orbigny

Candeina nitida is rare in sediments in the northwest Gulf of Mexico. The species occurred in scattered samples in the outer shelf and upper slope sediments. Average size of specimens of this species in the western Gulf was .4mm. with very little variation. Too few specimens of this species were counted to make any meaningful comments on the distribution. The very low percentages and limited size variations of this species suggest that it is allochthonous to the northwestern Gulf of Mexico. Both Jones (1965) and Drooger (1958) have reported *Candeina nitida* from the Caribbean and Orinoco areas respectively in percentages which are considerably higher than those recorded in the present study from the western Gulf of Mexico. The distributional gradient of the populations of the species from the northwest Gulf to the southeast Gulf suggests the species may be carried into the Gulf on the marine currents entering the Gulf from the south at the Yucatan Channel. Populations of the species in the northwest Gulf are one hundred percent left coiling.

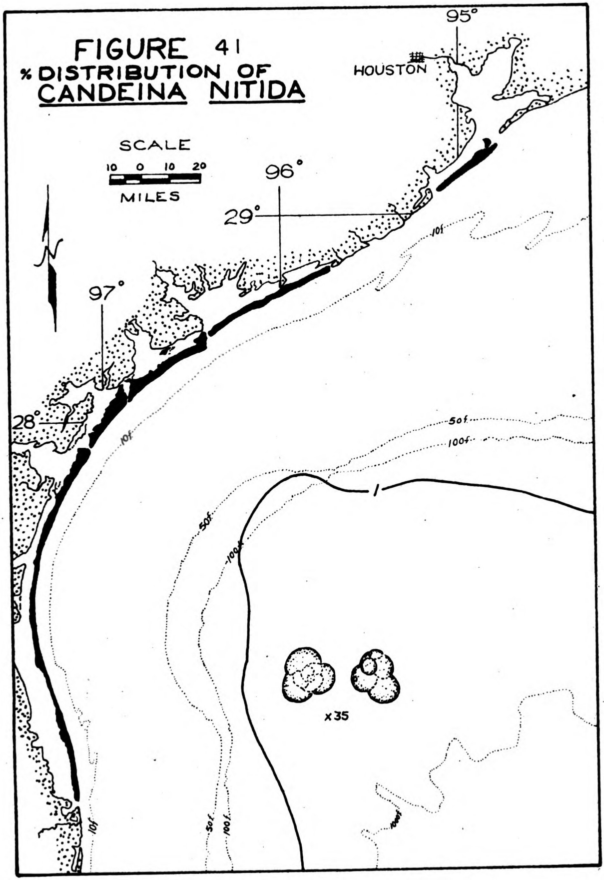


FIGURE 41
% DISTRIBUTION OF
CANDEINA NITIDA
SCALE
10 0 10 20
MILES
HOUSTON
95°
96°
97°
29°
28°
10f
50f
100f
1
x35

Part III: Variation and Distribution - Review and Discussion

The high species diversity of the recent planktonic Foraminiferal fauna in the northwest Gulf is due to the presence of an assemblage of allochthonous species. There is evidence that thirty-seven percent, or eight out of twenty-two species of planktonics in this area, are being introduced into the Gulf through the Yucatan Channel (see Distribution of Populations, page 50). These allochthonous species include *Globigerina pachyderma*, *Candeina nitida*, *Globorotalia scitula*, *Globigerinita glutinata*, *Globigerinita humilis*, *Globigerina digitata*, *Globigerinita uvula*, and *Globigerina rubescens*. Ovey and Wiseman (1950) have noted that the representation of a species by a limited or single size group such as juveniles may indicate that the species is allochthonous. All eight of the above planktonics from the northwest Gulf are represented elsewhere by a complete size spectrum. These eight species are distributed outside the Gulf of Mexico in low and middle latitude water masses. Average specimen size of all eight species in the northwest Gulf is invariably in the smallest or juvenile size range of the known size distribution elsewhere. In addition to this apparent sorting of juveniles, many of these species have a distributional gradient from a rare occurrence in the northwest Gulf to a common occurrence in the southeast Gulf or south Atlantic (Bé, 1966, Drooger, 1958). Phleger (1960) has suggested that some of the well-represented Foraminifera in the northwest Gulf may also be allochthonous because, like some of the rare species, they exhibit a distributional gradient increasing toward the eastern half of the Gulf. The abundance of these species, as well as their representation in the northwest Gulf by all of the size groups in their ontogeny, seems to indicate that they are indigeneous to the Gulf.

The variation in the first occurrence of a species in the sediments with respect to depth is well exemplified in the distribution maps of this section. This fluctuation in initial appareance is due to the extreme paucity of each species in shallow water sediments and precludes the use of first occurrence of a species as a precise depth indicator in fossil assemblages. The incidence of secondarily calcified tests is the only phenomenon which is relatively constant with respect to depth in the northwest Gulf. Even though the occurrence of this feature corresponds closely to depth, in all probability it is controlled by a variable such as temperature which must be considered before attempting to attach significance to secondarily calcified individuals in fossil assemblages.

Conclusions

1. The distribution of recent planktonic Foraminiferal species and species variants in sediments from the northwest Gulf of Mexico is directly related to the vertical and areal distribution of living species in the Gulf of Mexico.

2. Empty planktonic tests occur in very low frequencies in shallow water sediments. This low frequency corresponds to the low incidence of living specimens in the overlying coastal waters in which a combination of physical factors associated with fluvial runoff from the adjacent coast brings about conditions deleterious to the planktonic fauna.

3. Each species of planktonic Foraminifera in the northwest Gulf has a minimum depth at which it initially occurs in the marine sediments. At the minimum depth, species are represented by very few individuals all of which are in the juvenile size range for the population. The value of the minimum depth for each species fluctuates considerably because the specimens upon which it is based, being small and rare at that depth, are often overlooked. The minimum depths or initial appearance of the various species for the entire planktonic fauna may be expressed as a succession from shallow to deep water. This succession of species is itself an expression of the relative abundance of each species in the planktonic fauna. Abundant species such as Globigerinoides ruber will occur high in the bathymetric profile while rare species will occur in deeper sediments.

4. The average specimen size of planktonic populations increases in sediment samples taken from successively greater depths in the bathymetric profile. This average size increase may be attributed to the known vertical stratification of size groups of living planktonics in the marine water in which juvenile specimens occupy the shallowest portions of the water column. In sediments from water depths greater than one thousand meters a second increase in average size occurs because of the diagenetic removal by solution of the juvenile tests below this depth.

Because the shallowest specimens in the bathymetric profile are invariably juveniles, variation in the ratios of juveniles to adults in a death assemblage will affect the minimum depth at which a species occurs in sediments.

5. Thin, fragile structures on the foraminiferal test, including spines and bullae, are readily destroyed by abrasion or solution after the death of the individual bearing them. While these structures are of little use in interpreting fossil assemblages, their abundance in contemporary populations from marine sediments may be indicative of an area of active planktonic sedimentation. Such an area occurs in the northwest Gulf of Mexico on the outer continental shelf and upper continental slope.

6. The development of aberrant terminal chambers and secondary calcification of the test are regarded as terminal stages in the ontogeny of planktonics. The appearance of the latter feature in populations of <u>Globorotalia spp.</u> from sediments takes place with remarkable sharpness and consistency with respect to depth.

The areal distribution of secondarily calcified individuals in sediments is directly related to the level that living individuals occupy in the water column.

7. Temperature is apparently the physical variable controlling the distribution of pigmented specimens of *Globigerinoides ruber* as well as right or left coiling populations of planktonics. The latter feature may be useful in identifying mixed water masses in which planktonics should show considerable heterogeneity with respect to coiling if the water masses are of varying temperatures.

8. The Gulf of Mexico is reported (Phleger, 1961) to have a mixed assemblage of low and middle latitude planktonic Foraminifera. The allochthonous species which are part of this reported mixed assemblage include some of the more abundant planktonics in the Gulf. The homogeneity of the left-right coiling ratios of these well-represented planktonics, however, indicate that they are not a mixed middle and low latitude assemblage. There is good evidence that the Gulf of Mexico planktonic fauna is composed of allochthonous and autochthonous assemblages. The allochthonous species are, however, the poorly represented species instead of the abundant types and include many species which, because of their small size and low frequency, are previously undescribed from the Gulf of Mexico.

Systematics

Studies of the distribution of living Foraminifera conducted over the past ten years have had considerable effect on the taxonomy of these organisms. One of the major contributions of these studies has been the evidence that many previously recognized species are ecophenotypes of other species. Most of these ecophenotypes have been designated as separate species or even genera by authors because undue taxonomic significance was attached to a secondary feature of the test. Many of these features have been discussed in this study including color, coiling, bullae, spines, secondary calcification, aberrant chambers, and others. Because many of these ecophenotypes have since been placed in synonymy, the number of recognized species of living planktonic Foraminifera has been reduced from about fifty to thirty. While many of the planktonic species were placed in synonymy (Parker, 1962), some of the planktonic Foraminiferal genera have been subdivided. One example of this is the genus *Globigerina* which has been subdivided by authors into *Globigerina*, *Globigerinella*, *Globoquadrina*, *Globigerinita*, and *Globigerinoides* in recent assemblages. Some of the characters utilized to define these new genera include mode of coiling (planispiral, trochospiral), supplementary apertures, spines and bullae. Further studies on the ontogeny and distribution of planktonics may demonstrate deficiencies of these features as generic characters. With some exceptions, Foraminifera identified in the course of this study have been classified after the format given by Parker (1962).

Order Foraminifera

Family Globigerinidae Carpenter, Parker and Jones, 1862

Genus Globigerina D'Orbigny, 1826

Type species Globigerina bulloides D'Orbigny, 1826

Globigerina bulloides D'Orbigny
Plate 2, figure 10 a-c

1791. "Polymorphium tuberosa et Globuliderae" Soldani, A. (partim) Testaceographiae ac Zoophytographiae, vol.1, pt.2, p.117, pl.123, fig.10 only.

1826. Globigerina bulloides D'Orbigny, Ann. Sci. Nat., ser.1, vol.7, p.277.

1884. Globigerina bulloides D'Orbigny, Brady. Rept. Voyage Challenger, Zool., vol.9, p.593, pl.79, fig.7a-c.

1924. Globigerina bulloides D'Orbigny, Cushman. U.S. Natl. Mus. Bull. 104, p.7, pl.2, fig.1-4.

1941. Globigerina bulloides D'Orbigny, Cushman. Contr. Cushman Lab. Foram. Res., vol.17, pt.2, p.38-39, pl.10, fig.1-3.

1947. Globigerina bulloides D'Orbigny, Phleger, et al. Rept. Swedish Deep Sea Exped., vol.VII, no.1, p.11, pl.1, fig.3,4,7,8.

1950. Globigerina bulloides D'Orbigny, Natland. G.S.A. Memoir 43, p.36, pl.10, fig.2a-c.

1951. Globigerina bulloides D'Orbigny, Phleger. G.S.A. Memoir 46, p.34, pl.19, fig.6,7.

1957. Globigerina bulloides D'Orbigny, Bolli, Loeblich and Tappan. U.S. Natl. Mus. Bull. 215, p.31, pl.4, fig.1a-c.

1958. Globigerina bulloides D'Orbigny, Parker. Rept. Swedish Deep Sea Exped., vol.8, no.4, p.276, pl.5, fig.1,2,3,4.

1958. Globigerina bulloides D'Orbigny, Drooger and Kaasschieter. Verhandelungen der Koninklijke Nederlandse Akad. van Wetenschappen, eerste reeks, del XXII. Reports of the Orinoco Shelf Exped., vol.IV, p.84, pl.4, fig.16; pl.5, fig.3.

1959. Globigerina sp. Bradshaw. Contr. Cush. Found. Foram. Res. vol.10, pt.2, p.38, pl.6, fig.24,25.

1959. Globigerina bulloides D'Orbigny, Bé. Micropaleo., vol.5, no.1, pl.1, figs.15-17.

1959. Globigerina bulloides D'Orbigny, Blow. Bull. Amer. Paleo., vol.39, no.178, p.175, pl.9, fig.38a-c.

1959. Globigerina bulloides D'Orbigny, Bradshaw. Contr. Cush. Found. Foram. Res., vol.10, pt.2, p.33, pl.6, fig.1-5.

1960. Globigerina bulloides D'Orbigny, Phleger. Ecol. and Distr. of Recent Foram., p.223, pl.10.

1960. Globigerina bulloides D'Orbigny, Banner and Blow. Contr. Cushman Foram. Res., vol.11, pl.1, p.3; pl.1, fig.1,4.

1961. Globigerina bulloides D'Orbigny, Andersen. Louisiana Geol. Survey Geol. Bull. no.35, p.119, pl.27, fig.1a-b.

1962. Globigerina bulloides D'Orbigny, Parker. Micropaleo., vol.8, no.2, p.221, pl.1, fig.1-8.

1962. Globigerina calida Parker. Micropaleo., vol.8, no.2, p.221, pl.1, figs.9-3, 15.

1963. Globigerina bulloides Smith. Contr. Cush. Found. Foram. Res., vol.14, pt.1, p.2, pl.1, fig.1-4.

Globigerina bulloides was present in considerable percentages in all the samples examined in this study. Parker's (1962) Globigerina calida was included in synonymy here as was Bradshaw's (1959) Globigerina sp. Parker (1962) distinguishes G. calida from G. bulloides by the more radial elongation of the final chambers in G. calida and by the less hispid, thinner wall in G. calida. Both the chamber elongation and wall texture and thickness were found to be continuous in their variation in specimens from the western Gulf of Mexico study. As Bé (1959) has pointed out, juvenile specimens of G. bulloides smaller than .15 mm. in size are very difficult to distinguish from juvenile specimens of Globigerinella siphonifera (D'Orbigny). To circumvent the possible mixing of these species, juveniles smaller than .15mm. in the G. bulloides/Globigerinella siphonifera morphological series were not counted. Bé (1960) has reported a "Globigerina bulloides" juvenile stage in the ontogenetic development of Globigerina pachyderma from Arctic samples. The cumulation of the G. pachyderma development takes place, according to Be, as the addition of a thickened crust of calcite over the "Globigerina bulloides" stage. None of the specimens identified as G. bulloides in this study exhibited any secondary thickening of the test. Phleger (1960) has reported *G. bulloides* as abundant in mid latitudes. However, the species has been reported from all of the oceans of the world as a considerable percentage of the faunas therein.

Globigerina digitata Brady

Plate 2, figs. 7a-c, 8a-c; Plate 3, figs. 5a-c, 6a-c

1879. Globigerina digitata Brady. Quart. Jour. Micr. Sci., new ser. vol.19, p.286.

1884. Globigerina digitata Brady. Rept. Voyage Challenger, Zool. vol.9, p.599, pl.80, figs.6-10.

1957. Hastigerinella digitata (Brady) Loeblich, Tappan, and Bolli. U.S. Natl. Mus. Bull. 215, p.32, pl.5, fig.3a-b.

1958. Globigerina digitata Brady, Parker. Repts. Swedish Deep-Sea Exped., vol.VIII, no.4, p.276, pl.5, fig.8.

1959. Globorotalia (Hastigerinella) digitata (Brady), Banner and Blow. Paleontology, vol.2, p.16, fig.11.

1960. Globorotalia (Beella) digitata (Brady), Banner and Blow. Micropaleo., vol.6, no.1, p.26, fig.11.

1962. Globigerina digitata Brady, Parker. Micropaleo., vol.8, no.2, p.222, pl.1, fig.20-25.

This species was rare in the western Gulf of Mexico except in shelf samples. Jones (1965) did not report this species from the Caribbean area although it has been reported by Rhumbler (1911) and Brady (1897) from equatorial stations in the Atlantic. In the Pacific, the species has what appears to be a scattered and disjunct distribution which is probably due to its paucity in the samples examined. Parker (1958) has reported the species from the eastern Mediterranean in percentages as high as five percent of the total planktonic fauna. Many of the specimens counted have a previously unreported bulla on the umbilical side

Globigerina pachyderma (Ehrenberg)

Plate 2, figs. 5a-c

1861. Aristerospira pachyderma Ehrenberg. K. Preuss. Akad. Wiss. Berlin, Monatsber, p.276, 277, 303.

1872. Aristerospira pachyderma Ehrenberg. K. Preuss. Akad. Wiss. Abh. Jahrg. 1873, pl.1, fig.4.

1878. Globigerina bulloides D'Orbigny; var. borealis, Brady. Ann. Mag. Nat. Hist., ser.5, vol.1, p.435, pl.21, fig.10.

1881. Globigerina bulloides D'Orbigny; Arctic variety, Brady. Ann. Mag. Nat. Hist., ser.5, vol.1, no.48, p.412.

1953, Globigerina pachyderma Phleger et al. Rept. Swedish Deep-Sea Exped., vol.VII, no.1, p.13, pl.1, figs.17, 18, 19.

1959, Globigerina pachyderma (Ehrenberg), Bé. Micropaleo., vol.5, no.1, pl.1, fig.23-24.

1959. Globigerina pachyderma (Ehrenberg), Bradshaw. Contr. Cush. Found. Foram. Res., vol.10, pt.2, p.36, pl.6, figs.20-23.

1960. Globigerina pachyderma (Ehrenberg), Phleger. Ecol. and Distr. of Recent Foram., p.223, text plate 10.

1960. Globigerina pachyderma (Ehrenberg), Banner and Blow. Cushman Found. Foram. Res. Contr., vol.11, p.4, pl.3, fig.4.

1961. Globigerina incompta Cifelli. Cushman Found. Foram. Res. Contr., vol.12, p.84, pl.4, fig.1-7.

1962. Globigerina pachyderma (Ehrenberg), Parker. Micropaleo., vol.8, no.2, p.224, pl.1, fig.26-35; pl.2, fig.1-6.

1963. Globigerina pachyderma (Ehrenberg), Smith. Contr. Cushman Found. Foram. Res., vol.14, pt.1, p.2, figs.15-18.

Specimens of Globigerina pachyderma (Ehrenberg) counted in the course of the present study have a subcircular outline rather than the quadrate outline common in many Arctic specimens (Bé, 1960; Bandy, 1950). The species only occurred rarely in the samples examined. Jones (1965) has reported this species as rare in the Caribbean area. Phleger (1960) reports the species as characteristic at high and middle latitudes. Bradshaw (1959) reports the species in the Pacific north of latitude 40° N, and the species was reported by Parker (1953) as very rare south of latitude 20° N in the Atlantic.

A number of authors have suggested that G. pachyderma lives at depths greater than 100 m. in temperate latitudes on the basis of specimens studied from bottom sediments. At the present time, there is insufficient data from plankton tows at such depths to test this hypothesis effectively.

In a recent paper Be (1960) has suggested that reports of Globigerina bulloides from Arctic waters in reality concern juvenile specimens of G. pachyderma without the thickened test characteristic of G. pachyderma.

Globigerina rubescens Hofker

Plate 2, fig.3a-c

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

1962. *Globigerina rubescens* Hofker, Parker. Micropaleo., vol.8, no.2, p.226, pl.2, fig.17-18.

1966. *Globigerina rubescens* Hofker, Bé. Living planktonic foraminifera in the South Atlantic, paper delivered 51st Ann. Meeting, A.A.P.G.

This species is rare in the western Gulf of Mexico. It is easily distinguished by its light orange color. However, Parker (1962) reported some colorless specimens from colder areas in the Pacific. Because of its small size and similarity to juveniles of other species, the colorless specimens of this species have doubtless been frequently overlooked in plankton studies. The rare occurrence of this species was reported in the north and south Pacific by Parker (1962) and by Bé (1966) in his preliminary work on south Atlantic faunas. This species is previously unreported from the Caribbean area of the Gulf of Mexico.

Genus Globigerinella Cushman, 1927

Type species Globigerina siphonifera D'Orbigny, 1839

Globigerinella siphonifera (D'Orbigny)
Plate 2, figure 15a-c

1839. Globigerina siphonifera D'Orbigny. In de la Sagra Hist. Phys. Pol. Nat. Cuba "foraminifers", p.83, pl.4, fig.15-18.

1879. Globigerina aequilateralis Brady. Quart. Jour. Micr. Sci., New ser., vol.19, p.285.

1884. Globigerina aequilateralis Brady. Rept. Voyage Challenger, Zool., vol.9, p.605, pl.80, fig.18-21.

1917. Globigerina aequilateralis Brady; var. involuta, Cushman U.S. Natl. Mus. Proc., vol.15, no.2172, p.662.

1921. Globigerina aequilateralis Brady, Cushman. U.S. Natl. Mus. Bull., no.100, vol.4, p.293, fig.11.

1953. Globigerinella aequilateralis (Brady), Phleger et al. Repts. Swedish Deep-Sea Exped., vol.VII, no.1, p.16, pl.2, figs.,9, 10, 11.

1957. Hastigerina aequilateralis (Brady), Loeblich et al. U.S. Natl. Mus. Bull.215, p.29, pl.3, fig.4a,b.

1958. Globigerinella aequilateralis (Brady), Parker. Rept. Swedish Deep-Sea Exped., vol.VIII, no.4, p.278, pl.6, fig.5,6.

1959. Globigerinella aequilateralis (Brady), Bé. Micropaleo., vol.5, no.1, p.98, pl.1, figs.19, 20 and 27.

1960. Globigerinella aequilateralis (Brady), Phleger. Ecol. and Distr. of Recent Foram., p.223, pl.10.

1960. Hastigerina siphonifera (D'Orbigny), Parker. Micropaleo., vol.6, no.1, p.22, fig.2,3.

1962. Globigerinella siphonifera (D'Orbigny), Parker. Micropaleo., vol.8, no.2, p.228, pl.2, figs.22-28.

Parker (1962) has subdivided this species into two "groups" based on their morphology and occurrence in high and low latitudes. Specimens encountered in this study are predominantly of the "low latitude" type (Parker, 1962, pl.2, figs.22-26). A few of the "high latitude" types do occur in the western Gulf of Mexico. Because of the difficulty in separating juvenile specimens of G. siphonifera from juveniles of Globigerina bulloides (Bé, 1959), specimens of these two species smaller than .15mm. were not counted. Specimens of G. siphonifera frequently have an aberrant diminutive final chamber. This variant is common in the western Gulf of Mexico, occurring in most of the samples examined except those from shallow stations.

Bradshaw (1959) reports the species to be abundant in tropical and warm-temperate regions, with the highest frequencies in the equatorial regions. Brady (1884) reports the Atlantic distribution as between 50° N latitude and 35° S latitude. This species has been used by some authors as an indicator of warm intervals in marine core sections.

Genus *Globigerinita* Bronnimann, 1951

Type species *Globigerinita naparimaensis* Bronnimann, 1951

Parker (1962) includes the Genus *Globigerinita* along with *Candeina* in the Incertae Familiae. *Globigerinita* has been separated from the Family Globigerinidae by Parker because she believes the spines to be secondary in origin, although it is finely spinose to hispid. The genus is placed in the Family Globigerinidae here because smooth-walled specimens were not observed in this study and because of its typically globigerine architecture and accessory structures.

Globigerinita glutinata (Egger)

Plate 2, figure 1a-c; plate 2, figure 3a-c, 4a-c

1893. *Globigerina glutinata* Egger. Abhandl. K. Bayer, Akad. Wiss. Muenchen, CL II, vol.18, p.371, pl.13, figs.19-21.

1911. *Globigerina glutinata* Egger, Rhumbler. Plankton Exped. Humbolt Stift., vol.3, p.148, pl.29, figs.14-26; pl.33, fig.20; pl.34, fig.1.

1957. *Tinophodella ambitacrena* Loeblich and Tappan. Wash. Acad. Sci. Jour., vol.47, no.4, p.114, figs.2-3.

1953. *Globigerinita glutinata* (Egger), Phleger *et al*. Repts. Swedish Deep-Sea Exped., vol.VII, no.1, p.16, pl.2, figs.12, 13, 14, 15.

1957. Globigerinita naparimaensis Bronnimann, Loeblich et al. U.S. Natl. Mus. Bull. 215, p.37, pl.8, figs.1a-c, 2a-c.

1958. Globigerina glutinata Egger, Drooger et al. Verhandl. der Koninklijke Neder. Akad. van Wetenschappen, Afd. Naturkund., eerste reeks, deel XXII; Foraminifera of the Orinoco-Trinidad-Paria Shelf, Repts. of the Orinoco Shelf Exped., vol.IV, p.85, pl.4, fig.19; pl.5, fig.17.

1958. Globigerinita naparimaensis Bronnimann, Drooger et al. Verhandl. der Koninklije Neder. Akad. van Wetenschappen, Afd. Naturkund., eerste reeks, deel XXII; Repts. of the Orinoco Shelf Exped., vol.IV, p.85, pl.4, fig.18; plate 5, fig.18.

1962. Globigerinita glutinata (Egger), Parker, Micropaleo., vol.18, no.2, p.246, pl.9, figs.1-6.

In the literature various authors have subdivided Globigerinita glutinata on the presence or absence of the bulla structure. Parker (1962) has made a strong case for dropping the bulla as a specific character, and her illustrations of specimens of Globigerinita glutinata with and without the bullae support this argument. G. glutinata was common but never abundant in samples examined from the western Gulf of Mexico. Bradshaw (1959) has reported the species to be more abundant in tropical regions, with one small variety of the species ranging into subarctic water. These two varieties may account for the fact that Bé (1959) considers the species cold tolerant, whereas Bradshaw (1959), Boltovskoy (1962) and others have reported it to be indicative of warm water. Jones (1965) has determined that the species in the Caribbean area has a definate preference for warmer water. Although specimens with the bullae structure were common in the western Gulf of Mexico in sediments from deeper than one hundred and fifty meters, Jones (1965) reports that in the Caribbean area only forms without the bulla were observed. Drooger (1958) records both bullae and non bullae forms from the Orinoco Shelf area.

Globigerinita humilis (Brady)

Plate 2, figure 4a-c; plate 3, figure 7a-c

1884. Truncatulina humilis Brady. Rept. Voyage Challenger, Zool. vol.9, p.665, pl.94, fig.7.

1929. Globigerina cristata Heron-Allen, Earland. Jour. Royal Micr. Soc., ser.3, vol.49, pt.4, art.27, p.331, pl.4, figs. 33-39.

1957. Globigerinita parkerae Loeblich and Tappan. Wash. Acad. Sci. Jour., vol.47, p.113, pl.1, fig.1.

1960. Truncatulina humilis Brady, Banner and Blow. Cush. Found. Foram. Res. Contr., vol.11, p.36, pl.8, fig.1.

1960. Globigerina cristata Heron-Allen, Earland; Banner and Blow. Cush. Found. Foram. Res. Contr., vol.11, p.10, pl.7, fig.5.

1962. Globigerinita humilis (Brady), Parker. Micropaleo., vol.8, no.2, p.249, pl.10, figs.1-25.

Although Globigerinita humilis was present in many of the deeper samples from the western Gulf of Mexico, Jones (1965) did not report it from the Caribbean area. Similarly Parker (1954) does not record the species from the eastern Gulf of Mexico, nor does Drooger (1958) record it from the Orinoco Shelf area. Parker (1962) has reported the species to be widely distributed in the Pacific sediments but rare in the Atlantic. Her specimens almost invariably have the final chamber with the lobed extension covering the umbilical side. Many specimens from the western Gulf of Mexico have no covering on the umbilical side. However, the majority of the specimens from sediments deeper than two hundred meters have the lobed extension.

Globigerinita uvula (Ehrenberg)

Plate 2, figure 6a-c; plate 3, figure 2a-c

1861. Pylodexia uvula Ehrenberg. K. Preuss. Akad. Wiss. Berlin, Monaster, p.276, 308.

1872. Pylodexia uvula Ehrenberg. K. Akad. Wiss. Berlin, Abhl., pl.24-25.

1884. Globigerina sp. Brady. Rept. Voyage Challenger, Zool., vol.9, p.603, pl.82, fig.8,9.

1931. Globigerina bradyi Wiesner. "Die Foraminiferen der Deutschen Suedpolar-Expedition, 1901-1903" (in Drygalski, "Deutsche Sued-Polar Expedition, 1901-1903"), deGruyter, Berlin u. Leipzig, Bd.20; Zool., Bd.12, p.133.

1933. Globigerinoides minuta Natland. Calif., Scripps Inst. Oceanog., Tech. Ser., vol.3, no.10.

1938. Globigerinoides minuta Natland. Calif. Univ., Scripps Inst. Oceanog., Tech. ser., vol.4, no.5, p.150, pl.7, fig.2-3.

1957. Globigerina bradyi Wiesner, Bolli. U.S. Natl. Mus. Bull. 215, p.110-111, pl.23, fig.5a-c.

1958. Globigerina bradyi Wiesner, Drooger and Kaasschieter. Verhandl. der Koninklijke Neder. Akad. van Wetenschappen, Afd. Naturkunde, eerste reeks, deel XXII; Reports of the

Orinoco Shelf Exped., vol.IV, p.85, pl.4, fig.22a-c; pl.5, fig. 15a-c.

1959. Globigerina bradyi Wiesner, Blow. Bull. Amer. Paleo., vol.39, no.178, p.173-4, pl.7, fig.36.

1960. Globigerina bradyi Wiesner, Banner and Blow. Contr. Cush. Found. Res., vol.XI, pt.1, p.5, pl.3, fig.1,2.

1960. Pylodexia uvula Ehrenberg, Banner and Blow. Cush. Found. Foram. Res. Contr., vol.11, p.5, pl.3, fig.3.

1962. Globigerinita uvula (Ehrenberg), Parker. Micropaleo., vol.8, no.2, p.252, pl.8, fig.14-26.

Specimens of Globigerina uvula do not occur in any of the samples counted in frequencies greater than two percent. Although Jones (1965) does not report the species for the Caribbean, Drooger (1958) has reported the species from samples on the Orinoco Shelf but notes that it only attains notable frequencies in samples from colder water. Globigerinita uvula has been reported in the south Pacific by Parker (1962) between latitude 40° S and latitude 63° S. Specimens counted in this study were almost exclusively from very deep samples.

Although the species is small, it is easily distinguished from juveniles of other species by its characteristic conical architecture. Parker (1962) has illustrated specimens of G. uvula with a prominent umbilical bulla. Although none of the specimens encountered in this study have a bulla, they are identical to Parker's specimens without the bulla and are considered to be conspecific.

Genus *Globigerinoides* Cushman, 1927

Type species *Globigerina ruber* D'Orbigny, 1839

Globigerinoides conglobatus (Brady)
Plate 2, figure 11a-c

1879. *Globigerina conglobata* Brady. Quart. Jour. Micr. Sci., New ser., vol.19, p.286.

1884. *Globigerina conglobata* Brady. Rept. Voyage Challenger, Zool., vol.9, pl.80, fig.1-5, pl.82, fig.5.

1924. *Globigerina conglobata* Brady, Cushman. U.S. Natl. Mus. Bull. 104, p.18, pl.3, figs.8-13.

1950. *Globigerinoides conglobata* (Brady), Wiseman *et al.* Geol. Assoc. Proc., vol.61, pt.1, p.68, pl.3, figs.8a,b.

1951. *Globigerinoides conglobata* (Brady), Phleger and Parker. Geol. Soc. of America, Mem.46, p.35, pl.19, fig.15.

1953. *Globigerinoides conglobata* (Brady), Phleger *et al.* Rept. Swedish Deep-Sea Exped., vol.VII, no.1, p.15, pl.2, figs.1,2,3.

1958. *Globigerinoides conglobata* (Brady), Parker. Rept. Swedish Deep-Sea Exped., vol.VIII, no.4, p.279, pl.6, fig.16, 17.

1959. *Globigerinoides conglobata* (Brady), Bradshaw. Cushman Found. Foram. Res. Contr., vol.10, pt.2, p.40, pl.7, figs.5,6.

1959. Globigerinoides conglobatus (Brady) Bé. Micropaleo., vol.5, no.1, p.98, pl.2, figs.7-12.

1960. Globigerinoides conglobatus (Brady) Phleger. Ecol. and Distr. of Recent Foram., p.223, pl.10.

1960. Globigerina conglobata Brady, Banner and Blow. Cushman Found. Foram. Res. Contr., vol.11, p.6, pl.4, fig.4.

1961. Globigerinoides conglobatus (Brady), Andersen. La. Geol. Surv., Geol. Bull.35, pt.2, p.120, pl.27, fig.5.

1962. Globigerinoides conglobatus (Brady), Parker. Micropaleo., vol.8, no.2, p.229, pl.3, fig.1-5.

Jones (1965) reports that Caribbean specimens of this species do not have the bulla structure which Parker (1962) has reported from Pacific specimens. Specimens from the western Gulf of Mexico frequently have the bullae structures. Bradshaw's (1959) Globigerinoides sp. (p.42, pl.7, figs.16-17) has been included in synonymy with Globigerinoides conglobatus by Jones (1965). Bradshaw (1959) distinguishes his Globigerinoides sp. from Globigerinoides rubra by the presence of four chambers in the final whorl of Globigerinoides sp. and by the smaller accessory apertures in G. sp. Specimens identical to Bradshaw's G. sp. were counted as G. ruber in this study because of specimens found having four chambers in the final whorl as well as having small accessory apertures which had the typical red coloration of G. ruber on the initial chambers.

G. conglobatus has been reported in the Pacific by Bradshaw (1959) as limited to warm water with the greatest abundance in the equatorial area. Brady (1884) records the limits of the species in the Atlantic as 40° N latitude to 35° S latitude. Bé (1959) records the species in his "warm tolerant group."

Globigerinoides quadrilobatus sacculifer (Brady)

Plate 2, figure 16a-b

1877. *Globigerina sacculifer* Brady. Geol. Mag., new ser., sec.2, vol.4, no.12, p.535.

1879. *Globigerina sacculifera* Brady. Quart. Jour. Micr. Sci., new ser., vol.19, p.287.

1884. *Globigerina sacculifera* Brady. Rept. Voyage Challenger, Zool., vol.9, p.604, pl.80, figs.11-18; pl.82, fig.4.

1924. *Globigerina sacculifera* Brady, Cushman. U.S. Natl. Mus. Bull. 104, pl.2, p.21, figs.1-6.

1941. *Globigerinoides sacculifera* (Brady), Cushman. Am. Jour. Sci., vol.239, p.128, pl.3, fig.1.

1951. *Globigerinoides sacculifera* (Brady), Phleger and Parker, G.S.A. Mem.46, p.35, pl.19, figs.17,18.

1953. *Globigerinoides sacculifera* (Brady), Phleger *et al.* Rept. Swedish Deep-Sea Exped., vol.VII, no.1, p.16, pl.2, figs.5,6.

1960. *Globigerinoides sacculifera* (Brady), Phleger. Ecol. and Distr. of Recent Foram., p.223, pl.10.

1958. *Globigerinoides triloba* (Reuss), Drooger *et al.* Verhandl. der Koninklijke Neder. Akad. van Wetenschappen, Afd. Natuurkunde, eerste reeks, deel XXII; Repts. of the Orinoco Shelf Exped., vol.IV, p.83, pl.5, fig.8.

1958. Globigerinoides sacculifera (Brady), Drooger et al. Verhandl. der Koninklijke Neder. Akad. van Wetenschappen, Afd. Naturkunde, eerste reeks, deel XXII; Repts. of the Orinoco Shelf Exped., vol.IV, p.83, pl.5, fig.9.

1959. Globigerinoides sacculifera (Brady), Bé. Micropaleo., vol.5, no.1, p.98, figs.13-15.

1959. Globigerinoides sacculifera (Brady), Bradshaw. Contr. Cushman Found. Foram. Res., vol.10, pt.2, p.42, pl.7, figs.14, 15, 18.

1960. Globigerina sacculifera Brady, Banner and Blow. Cushman Lab. Foram. Res., Contr., vol.11, p.21, pl.4, figs.1,2.

1962. Globigerinoides quadrilobatus sacculifer (Brady), Parker. Micropaleo., vol.8, no.2, p.229, pl.3, figs.6-10.

1965. Sphaeroidinella dehiscens (Brady), Bé. Micropaleo., vol.11, no.1, p.81, figs.4-8.

Following Bé's (1965) conclusion that Sphaeroidinella dehiscens is a deep-water variant of Globigerinoides sacculifer, his figured specimens of S. dehiscens are placed in synonymy here. The process involving acetate peels and electron micrographs which Be uses to arrive at his conclusion about S. dehiscens is evidence that other specimens of S. dehiscens figured in the existing literature cannot now be placed in synonymy with Globigerinoides sacculifer. Just as "Orbulina universa" has been shown by Bandy (1966) to be a reproductive or resting stage for a number of species of planktonic foraminifera, "Sphaeroidinella dehiscens" may represent the deep-water, thickened stage of other species as well as Globigerinoides sacculifer. G. triloba of authors has been included in snyonymy here as Bé (1966) has shown this "species" to be a juvenile stage of Globigerinoides sacculifer without a sac.

Much variability was observed in G. sacculifer, particularly in the size and configuration of the sac. This variation will be considered in a later section.

G. sacculifer has been recorded from all of the world's oceans. Phleger (1960) reports that the species is common in middle latitudes with the highest frequencies in the Gulf of Mexico. Brady (1884) reports the Atlantic distribution to be from latitude 79° 20' N to latitude 46° 46' S. Bradshaw (1959) has reported the Pacific distribution of the species as most abundant between 40° N latitude and 20° N latitude. Coiling in this species is greater than 95 percent right in the western Gulf of Mexico.

Globigerinoides ruber (D'Orbigny)

Plate 2, figure 12a-c, 142-c.

1839. Globigerina rubra D'Orbigny. In de la Sagra, Hist. Phys. Pol. Nat. Cuba "Foraminiferes", p.82, vol.8, pl.4, figs.12-14.

1924. Globigerina rubra D'Orbigny, Cushman. U.S. Natl. Mus. Bull. 104, p.15, pl.3, figs.4-7.

1941. Globigerinoides rubra (D'Orbigny), Cushman. Amer. Jour. Sci., vol.239, p.128, pl.3, fig.3.

1950. Globigerinoides cyclostoma (Galloway and Wissler), Natland. G.S.A. Mem. 43, p.36, pl.10, figs.4a,b,c.

1951. Globigerinoides rubra (D'Orbigny), Phleger and Parker. G.S.A. Mem. 46, p.35, pl.19, fig.16.

1953. Globigerinoides rubra (D'Orbigny), Phleger et al. Repts. Swedish Deep-Sea Exped., vol.VII, no.1, p.15, pl.2, figs.4-7.

1957. Globigerinoides rubra (D'Orbigny), Loeblich et al. U.S. Natl. Mus. Bull.215, p.32, pl.4, fig.2a-c.

1958. Globigerinoides cyclostoma (Galloway and Wissler), Drooger et al. Verhandl. der Koninklijke Neder. Akad. van Wetenschappen, Afd., Natuurkunde, eerste reeks, Deel XXII; Repts. of the Orinoco Shelf Exped., vol.IV, p.82, pl.5, fig.7.

1958. Globigerinoides rubra (D'Orbigny), Drooger et al. Verhandl.

der Koninklijke Neder. Akad. van Wetenschappen Afd. Natuurkunde, eerste reeks, deel XXII; Repts. of the Orinoco Shelf Exped., vol.IV, p.83, pl.5, fig.10.

1958. Globigerinoides rubra (D'Orbigny), Parker. Repts. Swedish Deep-Sea Exped., Vol.VIII, no.4, p.279, pl.6, fig.12.

1959. Globigerinoides rubra (D'Orbigny), Bé. Micropaleo., vol.5, no.1, p.98, pl.2, fig.16-17.

1959. Globigerinoides rubra (D'Orbigny), Bradshaw. Contr. Cushman Found. Foram. Res., vol.10, pt.2, p.42, pl.7, figs.12,13.

1960. Globigerinoides rubra (D'Orbigny), Phleger. Ecol. and Distr. of Recent Foram., p.223, pl.10.

1960. Globigerina rubra D'Orbigny, Banner and Blow. Cushman Found. Foram. Res. Contr., vol.11, p.19, pl.3, fig.8.

1961. Globigerinoides rubra (D'Orbigny), Andersen. La. Geol. Surv., Geol. Bull.35, pt.2, p.120, pl.27, fig.4a,b.

1962. Globigerinoides ruber (D'Orbigny), Parker. Micropaleo., vol.8, no.2, p.230, pl.3, fig.11-14.

Specimens of Globigerinoides ruber encountered in this study correspond only to Parker's (1962) groups 1 and 2. The 3rd group of G. ruber recognized by Parker (1962) from Pacific samples corresponds to her Globigerinoides pyramidalis, van den Broeck, which Parker described from Mediterranean samples (Parker, 1958). The latter type is characterized by a high conical structure and by small supplementary apertures. Western Gulf of Mexico specimens of G. ruber are characterized by large apertural openings and a low spire. Jones (1965) reports the G. pyramidalis variety of this species from the Caribbean. Similarly, Drooger (1958) reports the same variety from the Orinoco area. Color variation was tabulated in this species as 1. "colorless", 2. Colored (red) throughout and 3. colored red on the initial chambers only. In addition, many specimens have bullae covering the umbilical as well as the supplementary apertures.

G. ruber was the most abundant species in the area studied. The species is reported by Brady (1884) between latitude 49° N and latitude 36° S in the Atlantic, with the highest concentration in the tropical area. Phleger (1953) reports the highest frequencies for the species in the Gulf of Mexico. Bradshaw (1959) and Parker (1960) report the species throughout the tropical and temperate Pacific, with the greatest concentration in the equatorial waters.

Genus *Globoquadrina* Finlay, 1947

Type species *Globorotalia dehiscens* Chapman, Parr and Collins, 1934

Globoquadrina dutertrei (D'Orbigny)

Plate 2, figure 9a-c

1826. *Globigerina rotundata* D'Orbigny. Ann. Sci., Nat. ser.1, vol.7, p.277, no.6.

1839. *Globigerina dutertrei* D'Orbigny. In de la Sagra, Hist. Phys. Pol. Nat. Cuba Foraminiferes, p.84, vol.8, pl.4, fig. 19-21.

1898. *Globigerina rotundata* D'Orbigny, Fornasini. Pal. Italica, vol.4, p.208, fig.3.

1901. *Globigerina eggeri* Rhumbler. In Brandt Nordisches Plankton, Lief. no.1, no.14, p.19, fig.20.

1901. *Globigerina suboretacea* Lomnicki. Naturf. Ver. Berlin, Bd.59 (1900), p.17, pl.82, fig.10.

1941. *Globigerina conglomerata* Schwager, Cushman. Amer. Jour. Sci. vol.239, p.128, pl.1, fig.3.

1951. *Globigerina eggeri* Rhumbler, Phleger, Parker. G.S.A. Mem.46, p.34, pl.19, fig.8,9.

1953. *Globigerina eggeri* Rhumbler, Phleger *et al.* Repts. Swedish Deep-Sea Exped., vol.VII, no.1, p.12, pl.1, figs.11,12.

1958. Globigerina eggeri Rhumbler, Drooger et al. Verhandl. der Koninklijke Neder. Akad. van Wetenschappen, Afd. Natuurkunde, eerste reeks, deel XXII; Repts. of the Orinoco Shelf Exped., vol.IV, p.84, pl.5, fig.1.

1958. Globigerina eggeri Rhumbler, Parker. Repts. Swedish Deep-Sea Exped., vol.VIII, no.4, p.277, pl.5, fig.7.

1959. Globigerina eggeri Rhumbler, Bé. Micropaleo., vol.5, no.1, p.98, pl.2, figs.1-3.

1959. Globigerina eggeri Rhumbler, Bradshaw. Contr. Cushman Found. Foram. Res., vol.10, pt.2, p.35, pl.6, figs.5,10.

1960. Globigerina eggeri Rhumbler, Phleger. Ecol. and Distr. of Recent Foram., p.223, pl.10.

1960. Globigerina rotundata D'Orbigny, Banner and Blow. Cushman Found. Foram. Res. Contr., vol.11, p.19, pl.2, fig.2.

1962. Globoquadrina dutertrei (D'Orbigny), Parker. Micropaleo., vol.8, no.2, p.242, pl.7, fig.1-13; pl.8, fig.1-4.

1963. Globigerina eggeri Rhumbler, Smith. Contr. Cushman Found. Foram. Res., vol.14, pt.1, p.1, pl.2, figs.8-11.

Globoquadrina dutertrei (D'Orbigny) was five to ten percent of most of the planktonic faunas examined in the course of this study. Twelve to thirty percent of the specimens of this species exhibited a considerable difference in size between the peniultimate and ultimate chambers so that the ultimate chamber was diminutive. Specimens with a diminutive final chamber were evenly dispersed throughout the bathymetric profile in sediments deeper than one hundred and ten meters. Phleger (1960) has reported this species to be most abundant in low latitudes. In the North Atlantic, Phleger (1953) reports the species between 0° latitude and 60° N latitude. Bradshaw (1959) reports the species in the Pacific between 0° latitude and 45° N latitude, with his highest concentrations around 40° N latitude. Parker (1960) reports the species as widespread in the southeast Pacific. The apparent disparity in the temperature preference of this form, as reported in the published literature, is largely due to the taxonomic confusion that has existed between this species and _Globigerina conglomerata_, _Globigerina eggeri_, and _Globigerina incompta_, as well as to the apparent morphological intergrade between this species and _Globigerina pachyderma_, Smith (1963).

Genus Globorotalia Cushman, 1927

Type species Pulvinulina menardii (D'Orbigny) var. tumida Brady, 1877

Globorotalia crassaformis (Galloway and Wissler)

Plate 1, figure 7a-c, 8a-c

1884. Pulvinulina crassa (D'Orbigny), Brady. (not Rotalia crassa, D'Orbigny). Rept. Voyage Challenger, Zool., vol.9, p.694, pl.103, figs.11-13.

1927. Globigerina crassaformis Galloway and Wissler. Jour. Paleo., vol.1, p.41, pl.7, fig.12.

1949. Globorotalia (Turborotalia) oceanica Cushman and Bermudez. Cushman Lab. Foram. Res. Contr., vol.25, p.43, pl.8, fig.13-15.

1951. Globorotalia punctulata (D'Orbigny), Phleger and Parker. G.S.A. Mem. 46, p.36, pl.20, fig.3-7.

1953. Globorotalia punctulata (Fornasini), Phleger, Parker and Pierson. Swedish Deep-Sea Exped., Repts. vol.VII, fasc.1, p.20, pl.4, figs.8-12.

1956. Globorotalia puncticulata (D'Orbigny), Bandy. U.S.G.S. Prof. Paper 274 G, p.194, pl.31, figs.1a-c.

1959. Globorotalia punctulata (D'Orbigny), Be. Micropaleo., vol.5, no.1, p.98, pl.1, figs.9-11.

1961. Globorotalia (Truncorotalia) cf. G. hirsuta (D'Orbigny), Andersen. La. Geol. Surv., Geol. Bull.35, pt.2, p.117, pl.26, figs.2a-c.

1962. Globorotalia crassaformis (Galloway and Wissler), Parker.

Globorotalia crassaformis was rare in the western Gulf of Mexico. Those specimens counted, however, did exhibit the typical secondary thickening of the test which is characteristic of the globorotalids. Jones (1965) records the rare occurrences of a closely related form, Globorotalia hirsuta (D'Orbigny), in the Caribbean area. Juvenile stages of G. hirsuta are in some cases nearly indistinguishable from Globorotalia crassaformis. However, no specimens, juvenile or adult, of G. hirsuta were encountered in this study.

G. crassaformis is reported in the North Atlantic from 0° latitude to 54° 53' N latitude with greatest concentrations near the equator. Parker (1960) reports the species in concentrations south of latitude 40° S in the South Pacific. Bradshaw (1959) does not report the species in the north and equatorial Pacific. Be (1959) records G. crassaformis as a warm tolerant species.

The species has been subdivided in the literature into variants based on the sharpness of the keel and the general outline of the test. These features are functions of the thickness of the secondary thickening of the test and are therefore not of taxonomic value.

Globorotalia cultrata (D'Orbigny)

Plate 1, figures 11a-c, 12a-c

1826. Rotalia (Rotalie) menardii D'Orbigny. Ann. Sci. Nat., ser.1, vol.7, p.273, no.26.

1826. Rotalia limbata D'Orbigny. Ann. Sci. Nat., ser.1, vol.7, p.274, no.30.

1826. Rotalia nitida D'Orbigny. Ann. Sci. Nat., ser.1, vol.7, p.274, no.31.

1839. Rotalia (Rotalina) cultrata D'Orbigny. In de la Sagra, Hist. Phys. Pol. Nat. Cuba "Foraminiferes", p.76, vol.8, pl.5, figs.7-9.

1865. Rotalia menardii Parker, Jones and Brady. Ann. Mag. Nat. Hist., vol.16, ser.3, p.20, pl.3, fig.81.

1902. Rotalia limbata D'Orbigny, Fornasini. R. Accad. Sci. Inst., Bologna, Mem. Sci. Nat., ser.5, vol.10, p.56, fig.55.

1906. Rotalia nitida D'Orbigny, Fornasini. R. Accad. Sci. Inst., Bologna, Mem. Sci. Nat., ser.6, vol.3, p.66, pl.3, fig.4.

1941. Globorotalia menardii (D'Orbigny), Cushman. Amer. Jour. Sci., vol.239, p.128, pl.3, fig.2.

1951. Globorotalia menardii (D'Orbigny), Phleger and Parker. G.S.A. Mem.46, p.36, pl.20, figs.1,2.

1953. Globorotalia menardii (D'Orbigny), Phleger et al. Swedish Deep-Sea Exped., vol.VII, no.1, p.19, pl.3, fig.1,2,4,5.

1959. Globorotalia menardii (D'Orbigny), Be. Micropaleo., vol.5, no.1, p.98, pl.1, fig.1-3.

1959. Globorotalia menardii (D'Orbigny), Bradshaw. Contr. Cushman Found. Foram. Res., vol.10, pt.2, p.44, pl.8, fig.3,4.

1960. Globorotalia menardii (D'Orbigny), Phleger. Ecol. and Distr. of Recent Foram., p.223, pl.10.

1960. Rotalia limbata D'Orbigny, Banner and Blow. Cushman Found. Foram. Res. Contr., vol.11, p.30, pl.5, fig.3.

1960. Rotalia nitida D'Orbigny, Banner and Blow. Cushman Found. Foram. Res. Contr., vol.11, p.33, pl.6, fig.3.

1960. Rotalia cultrata D'Orbigny, Banner and Blow. Cushman Found. Foram. Res. Contr., vol.11, p.34, pl.6, fig.1.

1960. Rotalia menardii Parker, Jones, Brady, Banner and Blow. Cushman Found. Foram. Res. Contr., vol.11, p.31, pl.6, fig.2.

1961. Globorotalia cultrata menardii (Parker, Jones, Brady), Andersen. La. Geol. Surv., Geol. Bull.35, pt.2, p.116, pl.25, figs.10a-c.

1961. Globorotalia cultrata fimbriata (Brady), Andersen. La. Geol. Surv., Bull.35, pt.2, p.116, pl.26, figs.5a-c.

1962. Globorotalia cultrata D'Orbigny, Parker. Micropaleo., vol.8, no.2, p.235, pl.5, fig.3-5.

Globorotalia cultrata has been subdivided by various authors by the presence or absence of the crystalline, secondary wall thickening. Evidence is presented in this study to show that this feature is a function of the individual specimen's habitat and thus has no place in taxonomic considerations. The presence of a diminutive last chamber was common in this species in samples deeper than sixty meters.

Globorotalia cultrata is generally regarded as a warm water, low latitude form. It is reported by Bradshaw (1959) and Parker (1960) between latitude 40° N and latitude 40° S in the Pacific, with concentrations in the equatorial regions. Brady (1884) gives the Atlantic distribution as latitude 55° 11' N to latitude 36° S. Phleger (1953) reports the highest percentages of the species in the Gulf of Mexico.

Globorotalia inflata (D'Orbigny)

Plate 1, figure 6a-c

1839. Globigerina inflata D'Orbigny. In Barker-Webb and Berthelot, Hist. Nat. Iles Canaries "Foraminiferes", vol.2, pt.2, Zool., p.134, pl.2, figs.7-9.

1924. Globigerina inflata D'Orbigny, Cushman. U.S. Natl. Mus. Bull. 104, p.12, pl.3, figs.1,2,3.

1951. Globigerina inflata D'Orbigny, Phleger and Parker. G.S.A. Mem.46, p.34, pl.19, figs.10,11.

1953. Globigerina inflata D'Orbigny, Phleger et al. Repts. Swedish Deep-Sea Exped., vol.VII, no.1, p.13, pl.1, figs.15,16.

1958. Globigerina inflata D'Orbigny, Drooger et al. Verhandl. der Koninklijke Neder. Akad. van Wetenschappen, Afd. Natuurkunde, eerste reeks, deel XXII; Repts. of the Orinoco Shelf Exped., vol.IV, p.84, pl.5, fig.2.

1958. Globigerina inflata D'Orbigny, Parker. Repts. Swedish Deep-Sea Exped., vol.VIII, no.4, p.277, pl.6, figs.3.

1959. Globigerina inflata D'Orbigny, Bé. Micropaleo., vol.5, no.1, p.98, pl.1, figs.12-14.

1959. Globigerina inflata D'Orbigny, Bradshaw. Contr., Cushman Found. Foram. Res., vol.10, pt.2, p.36, pl.6, fig.16,17,18.

1961. Globorotalia (Turborotalia) sp. Andersen. La. Geol. Surv., Geol. Bull.35, pt.2, p.118, pl.26, fig.1a-c.

1962. Globorotalia inflata D'Orbigny, Parker. Micropaleo. vol.8, no.2, p.236, pl.5, fig.6-9.

Parker (1962) has placed this species in the Genus Globorotalia because it lacks well-developed spines. The species has been similarly placed in the Genus Globorotalia in this study.

Specimens of Globorotalia inflata in the area studied are generally smaller in overall size (average .4mm.) than specimens of the same species from the Atlantic and Pacific (average .8mm.). Unlike most of the species of Globorotalia, G. inflata did not exhibit the secondary thickening of the test wall. The species is rare in the western Gulf of Mexico. Parker (1954) reports a similar scarcity of the species in the eastern Gulf of Mexico. Jones (1965) does not report the species from the Caribbean area. However, Phleger (1960) reports it as abundant in middle latitudes. Bé (1959) lists the species in his "cold tolerant" group. Parker (1960) and Bradshaw (1959) have reported scattered occurrences of the species in the north and south Pacific around latitude 40° S and latitude 40° N respectively with no reported occurrences in the equatorial region.

Globorotalia scitula (Brady)

Plate 1, figure 2a-c

1882. Pulvinulina scitula Brady. Roy. Soc. Edinburgh, Proc., vol.11, (1880-82), no.111, p.716.

1884. Pulvinulina patagonia D'Orbigny, Brady. Rept. Voyage Challenger Zool., vol.9, p.693, pl.103, fig.7.

1929. Pulvinulina patagonia (D'Orbigny), Rhumbler. Nordische Plankton-Foraminiferen Zool., teil 7, p.13, figs.4,5.

1950. Globorotalia scitula (Brady), Wiseman et al. Geol. Assoc. Proc., vol.61, pt.1, p.69, pl.3, fig.11a-c.

1951. Globorotalia scitula (Brady), Phleger and Parker. G.S.A. Mem.46, p.36, pl.20, figs.8,9.

1953. Globorotalia scitula (Brady), Phleger et al. Repts. Swedish Deep-Sea Exped., vol.VII, no.1, p.21, pl.4, fig.13,14.

1957. Globorotalia scitula (Brady), Loeblich et al. U.S. Natl. Mus. Bull. 215, p.120, pl.29, figs.11a-12c.

1959. Globorotalia scitula (Brady), Bradshaw. Contr. Cushman Found. Foram. Res., vol.10, pt.2, p.44, pl.8, figs.5,6.

1961. Pulvinulina scitula Brady, Banner and Blow. Cushman Found. Foram. Res. Contr., vol.11, p.27, pl.5, fig.5.

1962. Globorotalia scitula (Brady), Parker. Micropaleo., vol.8, no.2, p.238, pl.6, fig.4-6.

Parker (1962) has reported some specimens of Globorotalia scitula with spines from the Pacific. Only smooth-walled forms were encountered in this study. The species was rare in the area studied and did not exhibit the secondary thickening of the test wall common in other species of Globorotalia from the same area. Jones (1965) reported the species as rare in the Caribbean area. Brady (1884) has reported the Atlantic distribution as latitude 60° N to latitude 46° S. In the Pacific it is reported by Bradshaw (1959) in very scattered areas from the equatorial region to latitude 45° N and by Parker (1960) south of latitude 40° S.

Globorotalia truncatulinoides (D'Orbigny)

Plate 1, figures 3a-c, 4a-c

1839. Rotalina truncatulinoides D'Orbigny. In Barker-Webb and Berthelot, Hist. Nat. Iles Canaries "Foraminiferes", vol.2, pt.2, p.123, pl.2, fig.25, 26, 27.

1929. Pulvinulina truncatulinoides (D'Orbigny), Rhumbler Nordische Plankton-Foraminiferen Zool., teil 7, p.17, figs.16-18.

1941. Globorotalia truncatulinoides (D'Orbigny), Cushman. Amer. Jour. Sci., vol.239, p.128, pl.4, fig.1.

1950. Globorotalia truncatulinoides (D'Orbigny), Wiseman et al. Geol. Assoc. Proc., vol.61, pt.1, p.66, pl.2, fig.7a-c.

1951. Globorotalia truncatulinoides (D'Orbigny), Phleger, Parker. G.S.A. Mem.46, p.36, figs.10-13.

1953. Globorotalia truncatulinoides (D'Orbigny), Phleger et al. Swedish Deep-Sea Exped. Rept., vol.VII, pt.1, p.22, pl.4, figs.17,18.

1957. Globorotalia truncatulinoides (D'Orbigny), Loeblich et al. U.S. Natl. Mus. Bull.215, p.41, pl.10, figs.3a-c.

1959. Globorotalia truncatulinoides (D'Orbigny), Bé. Micropaleo. vol.5, no.1, p.98, pl.1, figs.5-7.

1959. *Globorotalia truncatulinoides* (D'Orbigny), Bradshaw. Contr. Cushman Found. Foram. Res., vol.10, pt.2, p.44, pl.8, fig.7,8.

1960. *Globorotalia truncatulinoides* (D'Orbigny), Phleger. Ecol. and Distr. of Recent Foram., p.243, pl.10.

1961. *Globorotalia (Truncorotalia) truncatulinoides* (D'Orbigny), Andersen. La. Geol. Surv., Geol. Bull.35, pt.2, p.117, pl.26, fig.3a-c.

1962. *Globorotalia truncatulinoides* (D'Orbigny), Parker. Micropaleo., vol.8, no.2, p.239, pl.6, fig.7.

In addition to the secondary thickening of the test, specimens of *Globorotalia truncatulinoides* exhibit variation in the size of the umbilical opening and the size of the final chamber. Populations of *G. truncatulinoides* counted in this study are over ninety percent right coiling.

Bradshaw (1959) and Parker (1960) have recorded the Pacific distribution of this species as two disjunct, narrow east-west belts at latitude 30° N and latitude 30° S. Bé (1959) records the highest Atlantic concentration of this species in the Sargasso Sea region. Brady (1884) reports the species in the Atlantic between latitude 79° N and 46° S. Phleger (1953) reports the highest frequencies of the species in the Gulf of Mexico.

Globorotalia tumida (Brady)

Plate 1, figures 9a-c, 10a-c

1877. *Pulvinulina menardii* (D'Orbigny) var. *tumida* Brady. Geol. Mag., ner ser. dec.2, vol.4, no.12, p.535.

1884. *Pulvinulina tumida* Brady. Rept. Voyage Challenger, Zool., vol.9, p.692, pl.103, figs.4-6.

1941. *Globorotalia tumida* (Brady), Cushman. Amer. Jour. Sci., vol.239, p.128, pl.3, fig.3.

1950. *Globorotalia tumida* (Brady), Wiseman *et al.* Geol. Assoc. Proc., vol.61, pt.1, p.69, pl.3, figs.2a-c.

1951. *Globorotalia tumida* (Brady), Phleger and Parker. G.S.A. Mem.46, p.36, pl.20, fig.14,15.

1953. *Globorotalia tumida* (Brady), Phleger *et al.* Repts. Swedish Deep-Sea Exped., vol.7, no.1, p.22, pl.3, fig.3, 6,7,8,10,11.

1957. *Globorotalia tumida* (Brady), Loeblich *et al.* U.S. Natl. Mus. Bull.215, p.41, pl.10, fig.2a-c.

1959. *Globorotalia tumida* (Brady), Bradshaw. Contr. Cushman Found. Foram. Res., vol.10, pt.2, p.47, pl.8, fig.9-13.

1960. *Globorotalia tumida* (Brady), Phleger. Ecol. and Distr. Recent Foram., p.223, pl.10.

1960. Pulvinulina menardii (D'Orbigny) var. tumida Banner and Blow. Cushman Found. Foram. Res. Contr., vol.11, p.26, pl.5, fig.1.

1961. Globorotalia tumida (Brady), Andersen. La. Geol. Surv., Geol. Bull.35, pt.2, p.116, pl.26, figs.4a-c.

1962. Globorotalia tumida (Brady), Parker. Micropaleo., vol.8, no.2, p.239, pl.6, fig.8-10.

Most of the specimens of Globorotalia tumida counted in the western Gulf of Mexico have a secondarily thickened test. Jones (1965) records this species as rare in the Caribbean area. In the present study the species was found to be in significant percentages only in some of the deeper samples. Bradshaw (1959) reports concentrations of this species in the equatorial Pacific, with smaller percentages up to latitude 25° N in the south Pacific. It is reported by Parker (1962) from latitude 20° N. Brady (1884) records the species from latitude 38° N to latitude 35° S in the Atlantic.

Genus Hastigerina Thomson, 1876

Type species Hastigerina murrayi Thomson, 1876

Hastigerina pelagica (D'Orbigny)

Plate 2, figure 17a,b

1839. Nonionina pelagica D'Orbigny. Voyage Amer. Merid. "Foraminiferes", vol.5, pt.5, p.27, pl.3, figs.13-14.

1876. Hastigerina murrayi Thomson. Roy. Soc. London, Proc., vol.24, p.534, pl.22,23.

1884. Hastigerina pelagica (D'Orbigny), Brady. Rept. Voyage Challenger, Zool., vol.9, p.613, pl.83, figs.1-8.

1924. Hastigerina pelagica (D'Orbigny), Cushman. U.S. Natl. Mus. Bull.104, p.33, pl.6, figs.1-8.

1929. Hastigerina pelagica (D'Orbigny), Rhumbler. Nordische Plankton-Foraminiferen Zool., teil 7, p.28, fig.31.

1957. Hastigerina murrayi Thomson, Loeblich et al. U.S. Natl. Mus. Bull.216, p.29, pl.3, figs.1-3.

1958. Hastigerina pelagica (D'Orbigny), Parker. Repts. Swedish Deep-Sea Exped., vol.VIII, no.4, p.280, pl.6, fig.15.

1959. Hastigerina pelagica (D'Orbigny), Bé. Micropaleo., vol.5, no.1, p.98, pl.2, fig.21,22.

1959. Hastigerinella rhumbleri Galloway, Bé. Micropaleo., vol.5, no.1, p.98, pl.2, fig.23.

1959. Hastigerina pelagica (D'Orbigny), Bradshaw. Contr. Cushman Found. Foram. Res., vol.10, pt.2, p.47, pl.8, figs.14,15.

1960. Hastigerina pelagica (D'Orbigny), Banner and Blow, Micropaleo., vol.6, no.1, p.20, fig.1.

1961. Hastigerina pelagica (D'Orbigny), Andersen. La. Geol. Surv., Geol. Bull.35, pt.2, pl.28, figs.3a,b.

1962. Hastigerina pelagica (D'Orbigny), Parker. Micropaleo., vol.8, no.2, p.228.

Jones (1965) and Parker (1962) both note the disparity between the high number of specimens of Hastigerina pelagica in the plankton tows and the low number found in the bottom sediments of the Caribbean and Pacific regions respectively. These authors have suggested that the specimens have been destroyed by abrasion and/or solution in bottom sediments due to the fragility of the test. Specimens encountered in this study were often broken, but no solution of the test was evident. Jones (1965) has included Bé's (1959) figure of Hastigerinella rhumbleri, Galloway, in synonymy with Globigerinella adamsi; however, the former species lacks the characteristic pointed, distal terminations on the ultimate and peniultimate chambers as illustrated by Parker (1962). A complete gradation was evident between the elongate chambered

"Hastigerinella rhumbleri" form and the compressed chambered "Hastigerina pelagica". Thus, H. rhumbleri is included in synonymy here with H. pelagica. Parker (1962) and Bradshaw (1959) report the species from the Pacific between latitude 40° N and latitude 50° S with the highest concentrations around latitude 40° S and latitude 30° N. It has been reported in the Atlantic by Be (1959) as a warm tolerant species with highest concentrations south of latitude 40° N.

Genus Orbulina D'Orbigny, 1839

Type species Orbulina universa D'Orbigny, 1839

Orbulina universa D'Orbigny

Plate 2, figure 13a,b

1839. "Orbulina universa" D'Orbigny. In de la Sagra Hist. Phys. Pol. Nat. Cuba, "Foraminiferes", p.3, vol.8, pl.1, fig.1.

Bandy (1966) has illustrated a number of broken specimens of "Orbulina universa" with juvenile specimens of Globigerinoides sacculifera, Globigerina bulloides and Globigerinoides conglobatus as internal ontogenetic stages. Because this seems to be conclusive evidence of polyphyly in Orbulina, no snyonymy is presented here for lack of a technique of distinguishing the various species of Orbulina without internal juvenile stages. Orbulina spp. has been considered in this study as a single species.

Only two percent of the specimens examined in this study contained an internal globigerine chamber (see plate 2, fig.13a). The thickness of the Orbulina test wall varied greatly, but the distribution of thick and thin-walled specimens appears to be random with respect to depth.

Genus Pulleniatina Cushman, 1927

Type species Pulleniatina obliquiloculata Parker and Jones, 1865

Pulleniatina obliquiloculata (Parker and Jones)

Plate 1, figure 5a-c

1862. Pullenia obliquiloculata Parker and Jones, In Carpenter, Introd. Foram., p.183.

1865. Pullenia sphaeroides (D'Orbigny) var. obliquiloculata Parker and Jones. Roy. Soc. London, Philos. Trans., vol. 155, p.365, pl.19, fig.4a-b.

1924. Pullenia obliquiloculata Parker and Jones, Cushman. U.S. Natl. Mus. Bull.104, p.43, pl.8, fig.10a,b.

1941. Pulleniatina obliquiloculata (Parker and Jones), Cushman. Amer. Jour. Sci., vol.239, p.128, pl.4, fig.3.

1950. Pulleniatina obliquiloculata (Parker and Jones), Wiseman et al. Geol. Assoc. Proc., vol.61, pt.1, p.69, pl.3, fig.7.

1951. Pulleniatina obliquiloculata (Parker and Jones), Phleger and Parker. G.S.A. Mem.46, p.35, pl.19, figs.19,20.

1953. Pulleniatina obliquiloculata (Parker and Jones), Phleger et al. Repts. Swedish Deep-Sea Exped., vol.VII, no.1, p.17, pl.2, fig.16-18.

1957. Pulleniatina obliqueloculata (Parker and Jones), Loeblich et al. U.S. Natl. Mus. Bull.215, p.33, pl.4, figs.3-5.

1959. Pulleniatina obliquiloculata (Parker and Jones), Bé. Micropaleo., vol.5, no.1, p.98, pl.2, fig.4-6.

1959. Pulleniatina obliquiloculata (Parker and Jones), Bradshaw. Contr. Cushman Found. Foram. Res., vol.10, pt.2, p.49, pl.8, fig.19, 20.

1960. Pulleniatina obliquiloculata (Parker and Jones), Phleger. Ecol. and Distr. Recent Foram., p.223, pl.10.

1960. Pullenia spaheroides (D'Orbigny), var. obliquiloculata Banner and Blow. Cushman Found. Foram. Res. Contr., vol.11, p.25, pl.7, fig.4.

1962. Pulleniatina obliquiloculata (Parker and Jones), Parker. Micropaleo., vol.8, no.2, p.234, pl.4, figs.13-16, 19, 22.

Parker (1962) has reported live specimens of Pulleniatina obliquiloculata from Pacific plankton tows with thin smooth tests, whereas specimens taken from Pacific sediments have a thick, highly polished test. Populations of the species in the area studied were very uniform in the foregoing respect being almost totally thick-walled and polished in appearance. Jones (1965) reports the species as rare in the Caribbean sediments and waters, whereas it composes a considerable percentage of the fauna in most of the samples taken from the eastern (Parker, 1954) and western Gulf of Mexico. Drooger (1958) reports Pulleniatina obliquiloculata as rare in sediments from the Orinoco Shelf area. The Atlantic distribution is reported by Phleger (1953) as highest east of Cuba and in the Gulf of Mexico. Bé reports the species as cold tolerant and scattered in the Atlantic, increasing toward the northern Gulf Stream off North America. Phleger (1960) has characterized the species as a low latitude form. In the Pacific Bradshaw (1959) and Parker (1960) report the species from latitude 40° N to latitude 10° S with highest concentrations in the equatorial region.

Incertae Familiae

Genus Candeina D'Orbigny, 1839

Type species Candeina nitida D'Orbigny, 1839

Candeina nitida D'Orbigny

1839. Candeina nitida D'Orbigny. In de la Sagra, Hist. Phys. Pol. Nat. Cuba Foraminiferes, p.108, pl.2, fig.27, 28.

1924. Candeina nitida D'Orbigny, Cushman. U.S. Natl. Mus. Bull. 104, p.34, pl.5, fig.1.

1929. Candeina nitida D'Orbigny, Rhumbler. Nordische Plankton-Foraminiferen, Zool., teil VII, p.35, fig.33a-c.

1941. Candeina nitida D'Orbigny, Cushman. Amer. Jour. Sci., vol.239, no.2, pl.2, fig.1.

1953. Candeina nitida D'Orbigny, Phleger, Parker and Pierson. Repts. Swedish Deep-Sea Exped., vol.VII, no.1, p.18, pl.2, fig.22, 23.

1957. Candeina nitida D'Orbigny, Bolli, Loeblich and Tappan. U.S. Natl. Mus. Bull.215, p.35, pl.6, fig.10a-11.

1959. Candeina nitida D'Orbigny, Bé. Micropaleo., vol.5, no.1, pl.2, fig.19,20.

1959. Candeina nitida D'Orbigny, Bradshaw. Contr. Cushman Found. Foram. Res., vol.X, p.32, pl.7, fig.19.

1961. Candeina nitida D'Orbigny, Andersen. La. Dept. of Conserv., Geol. Surv., Geol. Bull.35, pt.2, p.122, pl.27, fig.6.

1962. Candeina nitida D'Orbigny, Parker. Micropaleo., vol.8, no.2, p.253, pl.8, fig.27-30.

This easily recognized species was rare in the western Gulf of Mexico. Parker (1962) has placed the Genus Candeina in Incertae Familiae because it lacks the coarse perforations of spinose wall which is characteristic of the globigerines. Bolli, Loeblich and Tappan (1957) report that Candeina nitida passes through a "Globigerina" (single aperture) stage, followed by a "Globigerinoides" (multiple aperture) stage in its ontogenetic development. Specimens dissected in the present study were entirely smooth-walled at all stages of development. In view of the variability in the number of apertures in planktonic forms, classifications and phylogenies based on this character seem unwarrented.

Candeina nitida has been reported from the Pacific by Bradshaw (1959) between latitude 30° S and latitude 40° N. Cushman (1924) reports the species to be concentrated in the Caribbean area of the Atlantic; however, it has been reported in small percentages in the north Atlantic as far as latitude 55° N.

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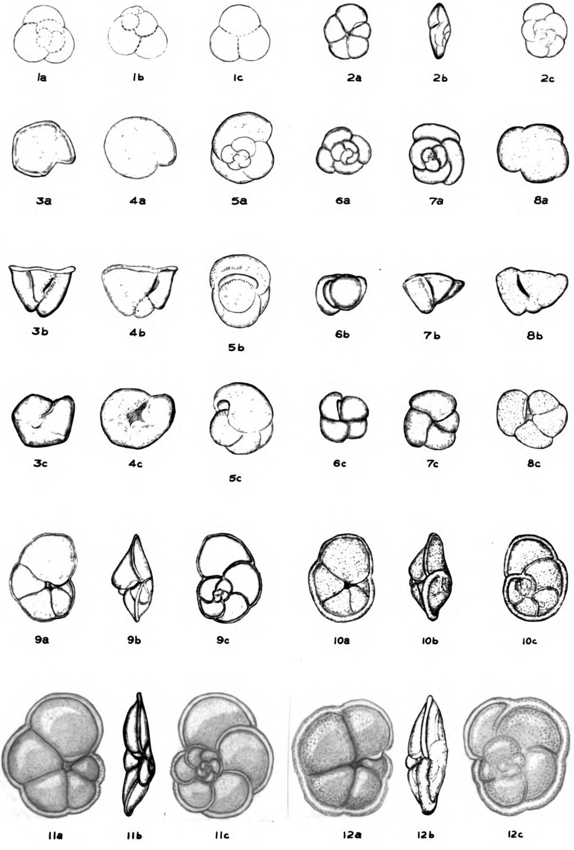
PLATE I



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10b
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11a
11b
11c
12a
12b
12c

Plate 1

All figures X35

All figures view (a,c) side view; view (b) edge view

1. Candeina nitida d'Orbigny

2. Globorotalia scitula (Brady)

3, 4. Globorotalia truncatulinoides (d'Orbigny)

fig.3. Normal specimen

fig.4. Specimen with secondary thickening

5. Pulleniatina obliquiloculata (Parker and Jones)

6. Globorotalia inflata (d'Orbigny)

7,8. Globorotalia crassaformis Cushman

fig.7, Normal specimen

fig.8. Specimen with secondary thickening

9,10. Globorotalia tumida (Brady)

fig.9. Normal specimen

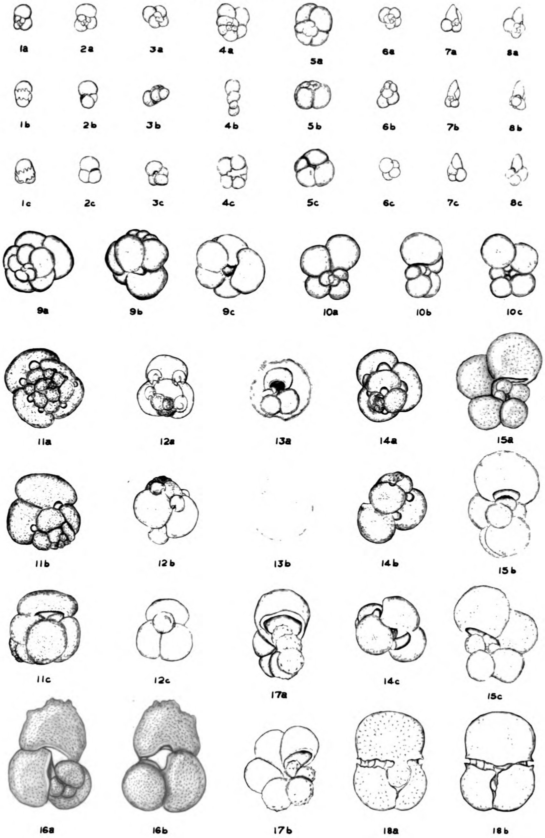
fig.10. Specimen with secondary thickening

11, 12. Globorotalia cultrata (d'Orbigny)

fig.11. Normal specimen

fig.12, Specimen with secondary thickening

PLATE 2



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1b 2b 3b 4b 5b 6b 7b 8b
1c 2c 3c 4c 5c 6c 7c 8c
9a 9b 9c 10a 10b 10c
11a 12a 13a 14a 15a
11b 12b 13b 14b 15b
11c 12c 17a 14c 15c
16a 16b 17b 18a 18b

Plate 2

All figures X35

All figures view (a,c) side view; view (b) edge view except figures 13, 16, 17, 18

1,2. Globigerinita glutinata Bronniman

fig.1. Specimen with umbilical bulla; fig.2. Specimen without bulla

3. Globigerina rubescens Hofker

4. Globigerinita humilis (Brady)

Figure showing modified final chamber

5. Globigerina pachyderma (Ehrenberg)

6. Globigerinita uvula (Ehrenberg)

7,8. Globigerina digitata Brady

fig.7. Specimen with umbilical bulla; fig.8. Specimen without bulla.

9. Globoquadrina dutertrei (D'Orbigny)

10. Globigerina bulloides (D'Orbigny)

11. Globigerinoides conglobatus (Brady)

12,14. Globigerinoides ruber (D'Orbigny)

fig.12. Specimen with bullae covering acessory apertures

fig.14. Specimen without bullae

13. Orbulina universa (D'Orbigny)

fig.13. A broken specimen showing internal "globigerine" juvenile stage

15. Globigerinella siphonifera (D'Orbigny)

16. Globigerinoides quadrilobatus sacculifer (Brady)

a,b edge views: Specimen with skewed multiple pointed sac

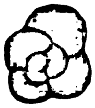
17. Hastigerina pelagica (D'Orbigny)

a. edge view; b. side view

18. "Sphaeroidinella dehiscens"

Views of G. sacculifer? showing thick secondary calcite crust

PLATE 3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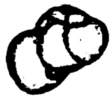
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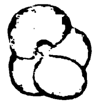
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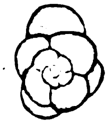
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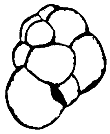
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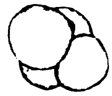
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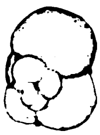
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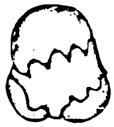
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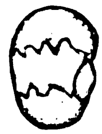
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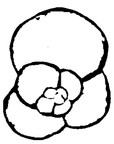
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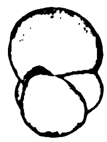
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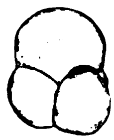
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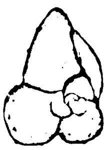
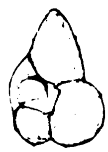

5a


5b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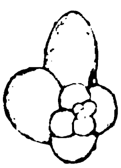
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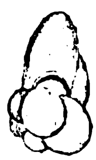
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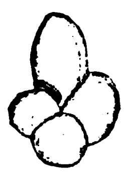
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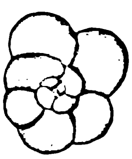
7a


7b

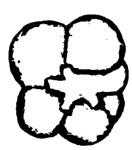
7c

Plate 3

All figures X55

All figures view (a,c) side views; view (b) edge view except fig.3

1. Globigerina rubescens Hofker

2. Globigerinita uvula (Ehrenberg)

3,4. Globigerinita glutinata Bronniman

3a,b side views; 3c edge view

fig.3 Specimen with umbilical bulla

fig.4 Specimen without bulla

5,6. Globigerina digitata Brady

fig.5. Specimen with umbilical bulla

fig.6. Specimen without bulla

7. Globigerinita humilis (Brady)

Specimen with modified final chamber