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## Variation and distribution of *Globigerinoides ruber* in the Gulf of Mexico

### ABSTRACT

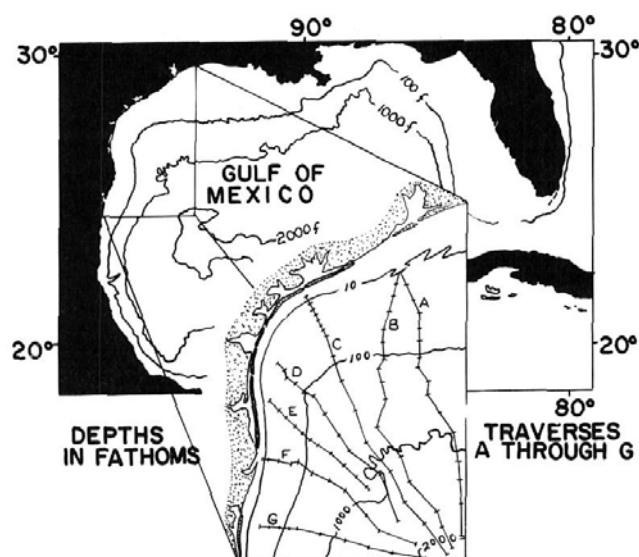
The population of the planktonic foraminiferal species *Globigerinoides ruber* from sediments in the northwest Gulf of Mexico changes considerably in character in basinward traverses. One variety of *G. ruber* may belong to a group of planktonic foraminifera which are allochthonous to the Gulf. Some of the delicate structures of *G. ruber* which are rare in fossil specimens may imply rapid biologic sedimentation, where they are prevalent in populations from marine sediments.

### INTRODUCTION

Population studies of Recent planktonic foraminifera from sediments in the northwest Gulf of Mexico have revealed some interesting distribution patterns with respect to the assemblage occupying the overlying water mass there. Specimens of *Globigerinoides ruber* (d'Orbigny) from this assemblage exhibit considerable morphological variation. The multiple varieties of this species are distributed in zonal patterns in the sediments which reflect a number of predepositional and postdepositional factors in the northwest Gulf. The samples used in this study were provided by a number of universities and petroleum companies, and consist of the uppermost portions of shallow Phleger-type cores. Out of a large suite of available samples, seven linear traverses normal to the coastline were assembled from ninety-two individual sediment samples (text-figure 1). The area in the northwest Gulf covered by these traverses includes the continental shelf and slope, the Sigsbee Scarp and the continental rise. Because the results obtained from the separate traverses were highly homogeneous, the distribution of the several varieties of *G. ruber* is depicted in profiles, rather than in areal contour maps, for ease of presentation.

### POPULATIONS

Phleger (1960) has shown that the fauna of planktonic foraminifera in the Gulf of Mexico is composed of assemblages from middle-latitude and low-latitude water masses. A number of authors have demonstrated that the greatest portion of the standing crop of planktonic foraminifera occupies the near-surface waters in the bathymetric column. Surface currents in the Gulf (Leipper, 1954) enter through the Yucatan Channel and the Caribbean Sea from the tropical Atlantic. The northwest part of the Gulf is characterized by converging surface currents through most of the year. This area of converging currents concentrates the planktonic foraminifera and inevitably causes the occurrence of a planktonic fauna in the sediments with an abnormally high species diversity. Twenty-three species of planktonic foraminifera were recorded in the present study (table 1). Phleger (1951) has recorded a much lower diversity figure for the same area. This disparity may be attributed to the very low frequencies of about one-fourth of the fauna. The rare species, including *Globigerinella adamsi*, *Globigerina rubescens*, *Globigerinita uvula*, *Globigerina digitata*, *Globigerinita humilis* and *Globigerinita glutinata*, are almost invariably represented by juvenile specimens and are unreported from plankton hauls in this part of the Gulf. In the past, these small rare specimens, which are undoubtedly allochthonous to the northwest Gulf, may have been overlooked or misidentified.



TEXT-FIGURE 1  
Locality map of study area in northwest Gulf of Mexico, showing positions of seven traverses.

The multiplicity of varieties and the complete range of specimen sizes attest to the autochthonous character of *Globigerinoides ruber*. Moreover, living specimens of this species are seasonally predominant in the upper portion of the water column in the northwest Gulf (Phleger, 1951). One of the varieties of *G. ruber* may be allochthonous to the northwest Gulf. Parker (1962) has been able to divide the species *G. ruber* in the Pacific into three varieties with respect to both morphology and distribution. Over ninety-five per cent of the specimens of *G. ruber* in the northwest Gulf correspond with Parker's group 1. This group (text-figure 2) is characterized by a low width-height ratio, large apertures, inflated chambers and a tropical distribution. Members of this group correspond closely with the lectotype selected by Banner and Blow (1960) for *G. ruber*. The remaining specimens of *G. ruber* in the northwest Gulf correspond with Parker's group 2, which is characterized by greater height than width, smaller apertures than those of the specimens in group 1, flattened chambers, and a subtropical to temperate distribution. A plot of the width-height measurements from northwest Gulf specimens of *G. ruber* shows both of these varieties (text-figure 2). Although these varieties may be members of a cline elsewhere, the points plotted from northwest Gulf specimens are concentrated around the varieties rather than being continuous. It seems likely that the subtropical to temperate group of *G. ruber* indicated to be present here may be part of the allochthonous assemblage of planktonic foraminifera entering the Gulf from the Caribbean Sea.

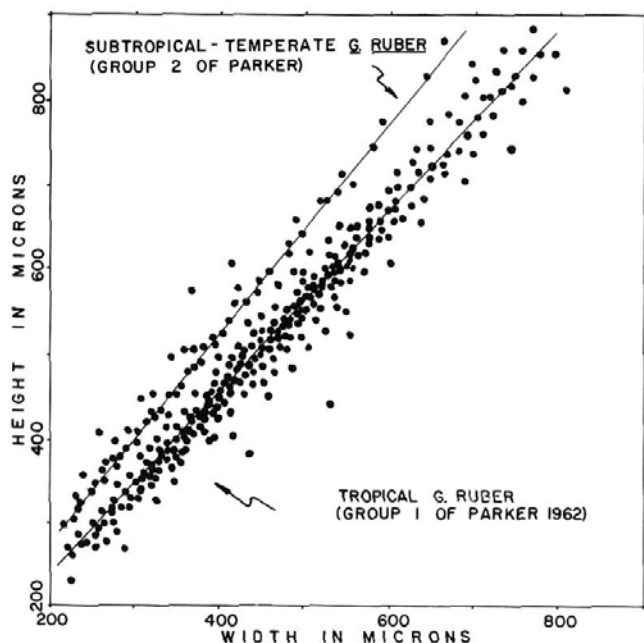
TABLE 1

Incidence of planktonic foraminiferal species from sediments in the northwest Gulf of Mexico

Species	Per cent of total planktonic fauna
<i>Candeina nitida</i> d'Orbigny	<1
<i>Globigerina bulloides</i> d'Orbigny	10
<i>Globigerina digitata</i> Brady	<0.5
<i>Globigerina pachyderma</i> (Ehrenberg)	<1
<i>Globigerina rubescens</i> Hofker	<0.5
<i>Globigerinella adamsi</i> (Banner and Blow)	<0.5
<i>Globigerinella siphonifera</i> (d'Orbigny)	3
<i>Globigerinita glutinata</i> (Egger)	<0.5
<i>Globigerinita humilis</i> (Brady)	<0.5
<i>Globigerinita uvula</i> (Ehrenberg)	<0.5
<i>Globigerinoides conglobatus</i> (Brady)	2
<i>Globigerinoides ruber</i> (d'Orbigny)	29
<i>Globigerinoides sacculifer</i> (Brady)	5
<i>Globobulimina dutertrei</i> (d'Orbigny)	6
<i>Globobulimina crassaformis</i> (Galloway and Wissler)	<1
<i>Globobulimina cultrata</i> (d'Orbigny)	6
<i>Globobulimina inflata</i> (d'Orbigny)	2
<i>Globobulimina scitula</i> (Brady)	<1
<i>Globobulimina truncatulinoides</i> (d'Orbigny)	7
<i>Globobulimina tumida</i> (Brady)	2
<i>Hastigerina pelagica</i> (d'Orbigny)	<1
<i>Orbulina universa</i> (d'Orbigny)	7
<i>Pulleniatina obliquiloculata</i> (Parker and Jones)	18

#### SIZE DISTRIBUTION

The basinward increase in average specimen size of planktonic foraminifera from sediments has been noted by a number of authors. Text-figure 3 is a composite of average specimen sizes for *G. ruber* from the northwest Gulf traverses. "Juvenile" here refers to specimens in the 200–400 micron (maximum diameter) size range. Because *G. ruber* has not been successfully cultured through a complete reproductive cycle, the meaning of reproductive maturity is unclear with respect to specimen size. Specimens less than 200 microns in maximum diameter are exceedingly difficult to distinguish from juveniles of a number of other species, unless they are pigmented. The inner continental shelf population of *G. ruber* may be characterized in this area by a juvenile/adult ratio of around twenty to one. Outer shelf and slope populations exhibit a juvenile/adult ratio of around eight to one consequent to a gradual decrease from the high juvenile concentrations on the shelf. Populations from sediments at and below 1000 meters have a juvenile/adult ratio from around three to one to as low as one to one. Bé (1960) has reported an increase in average specimen size in living specimens with successive depth in the bathymetric column. He has related this vertical size gradation of living specimens to the size succession of empty tests in sediments on the bathymetric profile. The paucity of juveniles below 1000 meters may be in part due to the destructive solution of these thin-walled specimens at that depth.

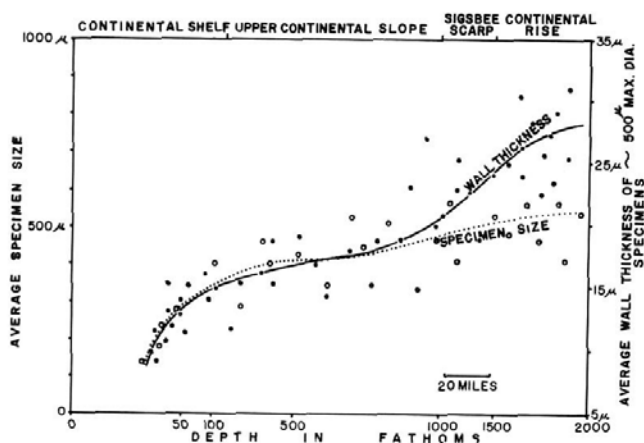


TEXT-FIGURE 2

Size distribution (height and width) of specimens of *Globigerinoides ruber* (d'Orbigny) from sediments in the northwest Gulf of Mexico.

#### SECONDARY CALCIFICATION

Almost all planktonic foraminifera exhibit some degree of secondary acquisition of calcium carbonate as a layer or crust on the outer portion of the test. Unlike many planktonics, particularly the globorotaliids, the secondary layer in *G. ruber* is frequently not apparent on visual inspection of the outer surface. To examine the secondary calcification in *G. ruber*, twenty specimens of a standard maximum diameter (500 microns) were selected from each sample and sectioned. Because the ultimate chamber exhibits secondary calcification infrequently, only the penultimate chamber was measured for thickness variation. The test wall itself varies in thickness and is markedly thinner near the sutures. Only that portion of the wall farthest from the sutures on the chamber hemisphere was measured for thickness (text-figure 4). Bé and Ericson (1963) have recorded a clear demarcation between the inner foundation wall and outer secondary cortex in specimens of *Globorotalia truncatulinoides* (d'Orbigny). This demarcation between the inner and outer walls is visible only occasionally in specimens of *G. ruber*. Where it can be distinguished, the inner wall is around eight to ten microns in thickness. Since the demarcation between these walls is usually not visible, the entire wall thickness was measured in the course of this study. The thickness of the wall was measured from the inside surface to the base of the spines on the exterior surface because of the variation in the length of the terminations of the calcite



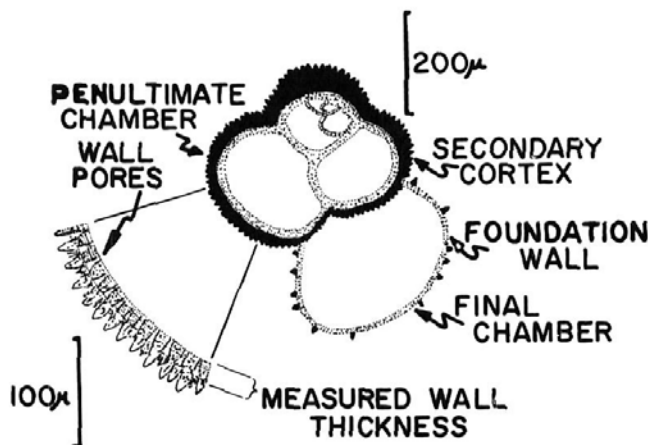
TEXT-FIGURE 3

Average size distribution (maximum diameter) and wall thickness of penultimate chamber of specimens of *Globigerinoides ruber* (d'Orbigny) from the northwest Gulf of Mexico. Solid dots represent average specimen size from each sample. Circles represent average wall thickness of specimens from each sample. Composite of specimens from all seven traverses.

crystals where they elongate on the C-axis normal to the test wall. Populations of *G. ruber* exhibit an increase in average wall thickness of eight to ten microns across the continental shelf. Average wall thickness is twenty microns in continental slope specimens. Below the continental slope the wall thickness increases to a maximum of twenty-eight microns in specimens from continental rise sediments. The pattern of two successive increases in wall thickness, apparent in text-figure 3, resembles the secondary thickening in species of *Globorotalia* (Orr, 1967). In four species of the latter genus, the initial increase in wall thickness is far more pronounced than the second increase. Ontogenetic series of *G. ruber* from each sample were sectioned to examine wall thickness. In most of the samples, twenty to twenty-five specimens were sectioned (text-figure 6D), and evaluation of the data from this process indicates that secondary acquisition of calcite in *G. ruber* is primarily an adult character. About half of any given population of *G. ruber* from continental shelf or deeper sediments exhibits thickening. By contrast, fully three-quarters or more of the specimens in populations of *Globorotalia* exhibit thickening in deep-water sediments. Because the apparent increase in average wall thickness across the continental shelf (text-figure 3) is based on populations of *G. ruber* of a standard size, the juvenile/adult size succession in these sediments may be ruled out as a related factor.

#### PIGMENTATION

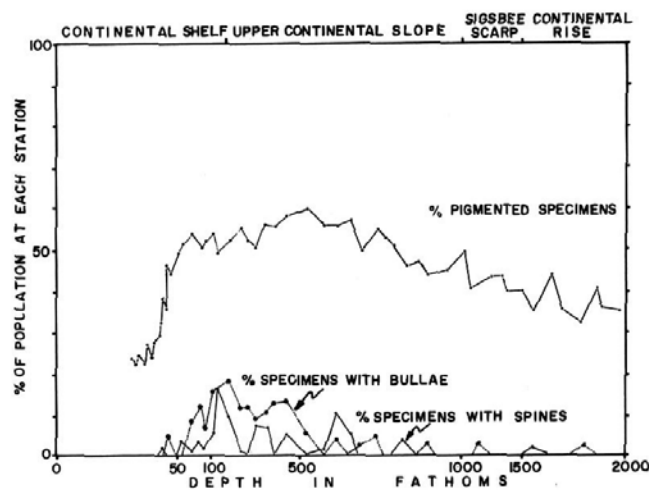
Two species of planktonic foraminifera from the marine sediments in the northwest Gulf were recorded as



TEXT-FIGURE 4

Vertical section through *Globigerinoides ruber* (d'Orbigny) showing secondary calcite cortex and wall detail.

including pigmented specimens in their populations. All of the specimens of *G. rubescens* encountered in the present study possess a light orange hue to the test, while a little less than two-thirds of the tests of specimens of *G. ruber* are colored. Bé and Hamlin (1967) have identified the pigment in the test of *G. ruber* as pheophytin. The significance of this organic pigment with respect to the life processes of the foraminifer is not yet clearly understood, but it may be related to the large symbiotic flora of zooxanthellae within the cytoplasm of *G. ruber*. Adult specimens of *G. ruber* from sediments in the northwest Gulf assume three basic color variations. Specimens may 1) possess pigmentation in the test wall of all chambers of an equal shade of deep red, 2) be pigmented in the test wall of all chambers with a light pink hue of equal shade, or 3) have a deep red pigmentation in the test wall of the proloculus and first or second whorls of the test becoming progressively lighter until the ultimate and penultimate chambers may be colorless. The latter type is numerically dominant in the pigmented population by a ratio of three to one. Pigmented specimens are concentrated in the juvenile size range (text-figure 6C). After the death of the organism and after a period of time lapses during which the test is buried in the marine sediments, the pigmentation alters successively to light tan, then colorless. No data have been presented in this study with respect to the length of time required to alter the test pigmentation, but the successive discolorations of the test may be utilized as a qualitative indication of the rate of pelagic biologic sedimentation. The highest percentages of colored specimens occur in outer shelf and upper slope sediments (text-figure 5). Pigmented specimens from the lower slope and continental rise which have been



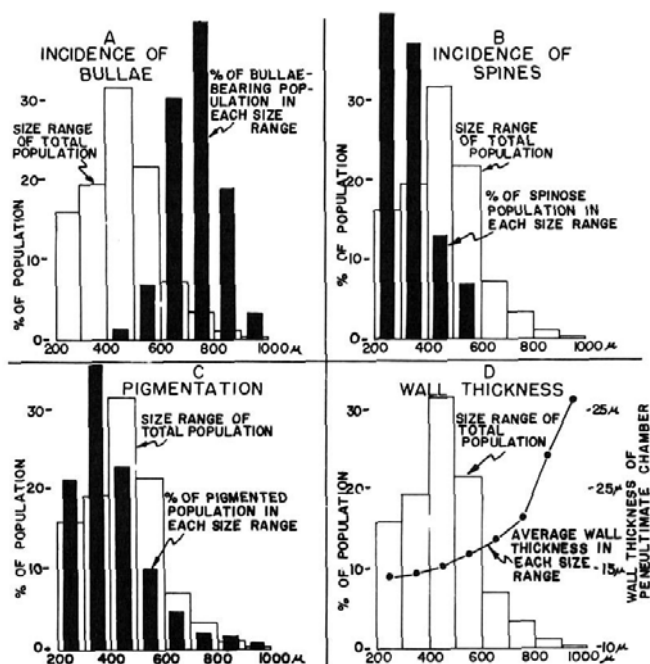
TEXT-FIGURE 5

Distribution of pigmented specimens of *Globigerinoides ruber* and specimens bearing bullae and spines from sediments in the northwest Gulf of Mexico. Composite of specimens from all seven traverses.

subject to solution exhibit a cloudy pink coloration. In shelf sediments shallower than sixty meters, non-pigmented specimens are dominant by a ratio of three to one. Between sixty and eighty meters the number of pigmented specimens sharply increases to a maximum of 50% on the upper continental slope. In lower slope and continental rise sediments the ratio of pigmented to non-pigmented specimens is highly variable but averages 40% pigmented specimens. The low percentage of colored specimens in coastal sediments may be related to some areal distribution or vertical stratification of pigmented/non-pigmented specimens in the overlying water mass. It seems likely, however, that the rapid clastic sedimentation in this area dilutes the planktonic fauna, reducing the probability of encountering the less common pigmented specimens.

#### BULLAE AND RELATED STRUCTURES

Considerable variation exists in populations of *G. ruber* with respect to the incidence and geometry of bullae and related apertural structures. Two types of these structures occur in specimens of *G. ruber* from the northwest Gulf, apertural flanges and bullae (plate 1, figures 3 and 4). In rare specimens the umbilical aperture, as well as all of the accessory apertures on the ultimate and penultimate whorls, bear bullae (plate 1, figure 3). The largest of these structures in a single specimen is the bulla situated over the umbilical aperture. The umbilical bulla frequently equals the ultimate chamber in size but may be readily distinguished by the thinner wall and lower pore frequency on the bulla. Specimens with bullae developed on two or more apertures are rare.



TEXT-FIGURE 6

Incidence of bullae, spines, pigmentation and secondary wall thickening with respect to size in the population of *Globigerinoides ruber* in the northwest Gulf of Mexico.

Even less common are apertural flanges (plate 1, figure 4). The flange structures appear to represent an intermediate stage in the development of the bullae. The frequency of bullae and apertural flanges with respect to specimen size indicates that, like secondary thickening, these structures are primarily adult features (text-figure 6A). The incidence of specimens bearing these structures from sediments on the bathymetric profile is highest in the outer continental shelf and upper slope (text-figure 5). The low percentage of bulla-bearing specimens in shallow sediments is related to the average size distribution of specimens from those sediments. The paucity of bullae on specimens from lower continental slope and deeper sediments may be attributed to the solution of these delicate structures at the lower depths. Like coloration, bullae and flange structures may be utilized as a qualitative indicator of rapid biologic sedimentation where they are abundant in sediments.

#### SPINES

Spines in the foraminifera are a highly ephemeral character with respect to specimens in the sediments. Spinose individuals of *G. ruber* from sediments are concentrated in the juvenile size range (text-figure 6B). Because spines are primarily a juvenile character, spinose individuals should be concentrated where the juvenile specimens occur in high frequency in the bathy-

metric profile, namely, in inner to middle continental shelf sediments. Contrary to expectation, the frequency of spinose individuals in inner shelf populations is relatively low (text-figure 5), while the highest incidence of spinose individuals is in the outer continental shelf and upper slope sediments. In lower continental slope and deeper sediments the delicate spines are destroyed by solution. Spines may thus, like other ephemeral characters mentioned here, indicate active biologic sedimentation where they occur in high frequencies in populations from marine sediments.

#### COILING

Coiling in populations of *G. ruber* from the northwest Gulf of Mexico averages forty per cent right and sixty per cent left. This ratio appears to be completely random with respect to size, pigmentation, species variants, and distribution of specimens on the bathymetric profile.

#### SUMMARY AND CONCLUSIONS

Far from being homogeneous, populations of *G. ruber* from successively deeper sediments on the bathymetric profile differ considerably. Populations from marine sediments are complicated by a number of variables including areal and vertical distributions of the organisms in the water mass, rate of biologic sedimentation, and secondary chemical processes acting at and below the water-sediment interface. Three differing populations of *G. ruber* may be distinguished in the northwest Gulf of Mexico in respect to depth.

- 1) Inner and middle continental shelf population. This group is characterized by a predominance of juvenile specimens and a low incidence of spinose, bullate and pigmented specimens.
- 2) Outer continental shelf and upper continental slope population. This group has approximately eight juveniles for each adult specimen. Juvenile specimens are frequently spinose and/or pigmented. Adult specimens are also frequently pigmented and/or bear bullae, but are rarely spinose.
- 3) Lower continental slope and continental rise population. In this group adult forms may occur in frequencies equal to those of the juveniles. Many of the specimens exhibit secondary calcification, and few individuals bear spines or bullae. Pigmented specimens occur in percentages equal to or somewhat lower than percentages of non-pigmented specimens, and frequently have a cloudy pink appearance due to solution.

The high frequency of specimens with bright red pigmentation, spines and bullae, as well as the appearance of numerous thin-walled juveniles, may indicate rapid



sedimentation capable of the preservation of these features. The northwest Gulf of Mexico, as an area of converging surface currents, is an area of accumulation for many allochthonous species from low-latitude and middle-latitude water masses. Twenty-six per cent of the planktonic foraminiferal species from sediments in the northwest Gulf are undoubtedly allochthonous, and at least one species (*G. ruber*) is represented by two varieties in the northwest Gulf, one of which may be allochthonous.

#### ACKNOWLEDGMENTS

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#### REFERENCES

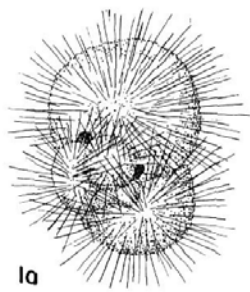
- BANNER, F. T., and BLOW, W. H.  
1960 *Some primary types of species belonging to the superfamily Globigerinaceae*. Cushman Found. Foram. Res., Contr., vol. 11, pt. 1, pp. 1–41, pls. 1–8.
- BÉ, A. W. H.  
1960 *Ecology of Recent planktonic foraminifera. Part 2 – Bathymetric and seasonal distributions in the Sargasso Sea off Bermuda*. Micropaleontology, vol. 6, no. 4, pp. 373–392, text-figs. 1–19.

- BÉ, A. W. H., and ERICKSON, D. B.  
1963 *Aspects of calcification in planktonic foraminifera (Sarcodina)*. New York Acad. Sci., Ann., vol. 109, art. 1, pp. 65–81, text-figs. 1–10.
- BÉ, A. W. H., and HAMLIN, W. H.  
1967 *Ecology of Recent planktonic foraminifera. Part 3 – Distribution in the North Atlantic during the summer of 1962*. Micropaleontology, vol. 13, no. 1, pp. 87–106, text-figs. 1–41.
- LEIPPER, D. F.  
1954 *Physical oceanography of the Gulf of Mexico*. U.S. Fish and Wildlife Service, Fishery Bull., vol. 55, no. 89, pp. 119–137, text-figs. 34–43.
- ORR, W. N.  
1967 *Secondary calcification in the foraminiferal genus Globorotalia*. Science, vol. 157, no. 3796, pp. 1554–1555, text-figs. 1–2.
- PARKER, FRANCES L.  
1962 *Planktonic foraminiferal species in Pacific sediments*. Micropaleontology, vol. 8, no. 2, pp. 219–254, pls. 1–10.
- PHLEGER, F. B.  
1951 *Part I. Foraminifera distribution*. In: Phleger, F. B., and Parker, Frances L., *Ecology of foraminifera, northwest Gulf of Mexico*. Geol. Soc. Amer., Mem., no. 46, pp. 1–88, text-figs. 1–33.
- 1960 *Ecology and distribution of Recent foraminifera*. Baltimore: Johns Hopkins Press, pp. 1–297, pls. 1–11, text-figs. 1–83.

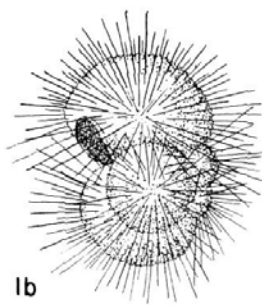
#### PLATE 1

a, spiral view; b, edge view; c, umbilical view

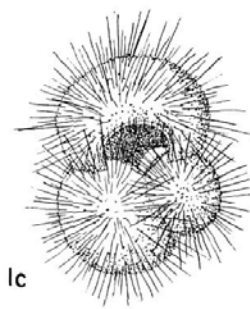
- 1–4 *Globigerinoides ruber* (d'Orbigny)  
1, spinose juvenile specimen showing supplementary apertures. Univ. Oregon, Mus. Nat. Hist., hypotype no. 27493, Locality no. 2572. 2, specimen belonging to Parker's subtropical-temperate group 2 with a large height to width ratio, small apertures and flattened chambers. Univ. Oregon, Mus. Nat. Hist., hypotype no. 27494, Locality no. 2573. 3, adult specimen with well-developed bullae over most of the apertures. This specimen belongs to Parker's tropical group 1 characterized by a small height to width ratio, large apertures and inflated chambers. Univ. Oregon, Mus. Nat. Hist., hypotype no. 27495, Locality no. 2574. 4, adult specimen showing considerable development of the incipient bullae or flanges. One supplementary aperture has a complete bulla developed (figure 4a). Specimen belongs to Parker's group 1. Univ. Oregon, Mus. Nat. Hist., hypotype no. 27496, Locality no. 2575.



1a



1b



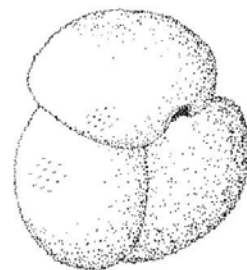
1c



2a



2b



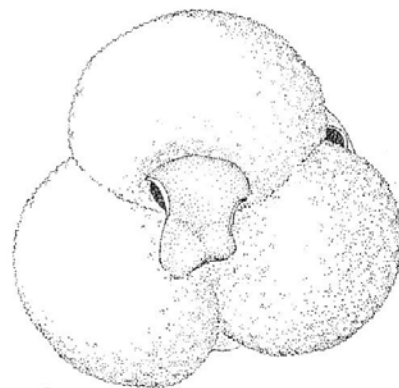
2c



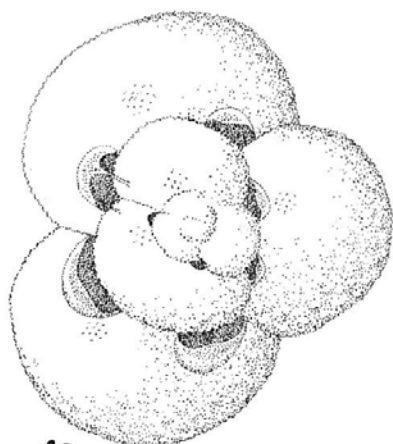
3a



3b



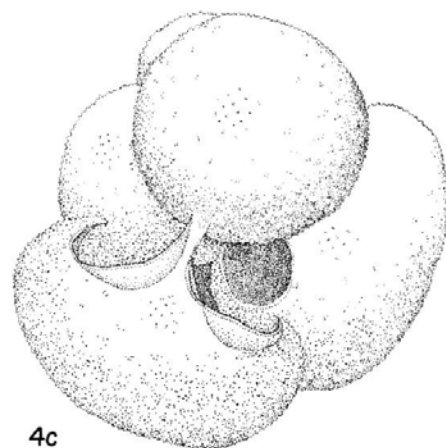
3c



4a



4b



4c