Planktonic Foraminifera From Deep-Sea Cores off Eniwetok Atoll

By RUTH TODD

BIKINI AND NEARBY ATOLLS, MARSHALL ISLANDS

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Age interpretations of samples of Globigerina *ooze from an adjoining guyot southwest of Eniwetok Atoll*

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PLANKTONIC FORAMINIFERA FROM DEEP-SEA CORES OFF ENIWETOK ATOLL

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ABSTRACT

Study of nine samples from a group of five cores taken on a guyot adjoining the southwest part of Eniwetok Atoll sheds some light on the slowly evolving planktonic population of Foraminifera that inhabited the oceanic water surrounding the Marshall Islands during the time between late Miocene and the present. The five cores sampled penetrate through a thin discontinuous and unindurated veneer of Quaternary organic debris currently being moved about over the shelf. This transitory cover, a *Globigerina* sand from which three samples were studied, overlies a slightly indurated *Globigerina*-coccolith ooze from which six more samples were studied as to their foraminiferal composition.

On the basis of species and subspecies recognized, as well as evolutionary changes within species, tentative ages of early Pliocene and late Miocene were assigned respectively to two and four of the samples of *Globigerina*-coccolith ooze. Early Pliocene is characterized by presence of *Globigerinoides sacculifer fistulosa* and absence of *Globorotalia truncatulinoides*. Late Miocene is characterized by presence of *Globoquadrina altispira*.

Approximate correlation of the *Globigerina*-coccolith ooze with an upper Miocene or lower Pliocene ooze from Sylvania Guyot off Bikini Atoll is possible by means of *Globoquadrina altispira*, *Sphaeroidinella disjuncta*, *Globorotalia menardii multicamerata*, *G. tumida flexuosa*, and *Globigerinoides sacculifer fistulosa*.

Correlation of the late Miocene parts of the cores with the West Indian section is possible by means of *Globorotalia fohsi robusta*, a zone marker in Trinidad, with the supporting evidence of *Globorotalia menardii praemenardii* and *Globoquadrina altispira*.

A total of 42 forms, classified in 32 species, were recognized from the composite of all the samples. Quantitatively the Recent and fossil assemblages are virtually the same. Their differences lie in (a) presence or absence of a very small proportion of the species, that is, those judged useful for age determination; (b) slight differences between more primitive or more advanced forms of a single species; and (c) changes in relative abundance of certain species or certain forms of a species.

The benthonic Foraminifera population, although constituting a negligible quantitative factor, shows a rough correlation between nearness to reef and proportion of total number of species. Number of benthonic species (as proportion of the total assemblage) increases with nearness to reef, which provides an additional tool for paleoecologic interpretation of fossil *Globigerina* ooze.

INTRODUCTION

The present study was undertaken as a search for species that might serve as age indicators in the uppermost part of the Tertiary and the Quaternary.

Because benthonic species have proved to have longer ranges than most planktonic species and because few benthonic species are reported to have ranges limited by age, not ecology, in the Late Tertiary, I have restricted to the planktonic population my search for additional species that might have limited ranges and thus be available to serve as age indicators.

The present study has yielded the following results: (a) Description of the present-day planktonic population now being or recently deposited on a deep shelf adjacent to Eniwetok atoll; (b) description of the Pliocene and upper Miocene planktonic population deposited over the same area; (c) description of some of the subtle changes in those species that are found throughout the cores as they evolve from the Miocene and Pliocene to the Pleistocene and Recent parts of the cores; (d) recognition of species restricted to either of these major divisions of the cores; and (e) worldwide correlation of the sediments penetrated by the cores.

Acknowledgments.—To M. N. Bramlette I owe my thanks for presenting me with this problem together with some clues for its solution. I am indebted for assistance of various kinds received from many colleagues, chiefly H. M. Bolli, Richard Cifelli, E. L. Hamilton, H. S. Ladd, Doris Low, and F. L. Parker. Helpful advice from and discussions with them are gratefully acknowledged. The fossil illustrations are the work of Elinor Stromberg.

GEOGRAPHIC BACKGROUND

Eleven deep-sea cores were obtained from the gently sloping surface of the guyot that adjoins Eniwetok Atoll on the south and southwest. Five of these cores penetrated through the thin veneer of Quaternary debris to the underlying sediment of Pliocene and late Miocene age. Selected samples from these five cores form the basis for the present study.

The cores were taken from depths between slightly more than 800 fathoms and somewhat deeper than 1,000 fathoms. The five cores that were studied range from 13 to 66 cm in length. The position of the cores studied approximates a circle about 4 miles in diameter (fig. 319).

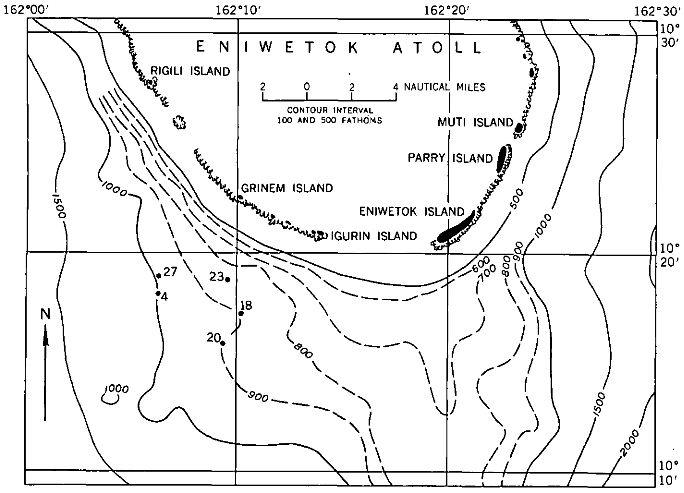

FIGURE 319.—Location of cores on the guyot southwest of Eniwetok Atoll, modified from Bramlette and others (1959).

All 11 cores were studied by Bramlette and others (1959, p. 1549–1551), who described the striking difference between the sediments interpreted as Quaternary (Recent or Pleistocene) and those of the late Tertiary and who specified, on a lithologic basis, the boundary between these two ages. The Quaternary sediments are distinguished from those of late Tertiary age by the following criteria: inclusion of coarse reef debris, particularly algal fragments; absence of fine-grained constituents such as coccoliths that form a significant part of the upper Tertiary pelagic deposits; absence of induration so that the Quaternary debris is now in process of being shifted across the sloping surface of the guyot into deeper water as a patchy thin veneer of ripple-marked loose debris; and presence of a brown crust or brown mottling decreasing downward that separates the overlying coarser and unindurated debris from the finer and slightly indurated pelagic deposit beneath.

Age assignments made by Bramlette and others were based largely on distinctive assemblages of coccoliths. Their statement (1959, p. 1550) that "differences between the pelagic assemblages of Quaternary and Pliocene Foraminifera are not great and seem to be of little age significance" is true in general. But a closer look reveals several restricted species and numerous recognizable, though subtle, evolutionary changes that are not obvious during a cursory examination. Their suggestion (Bramlette and others, 1959, p. 1550) that the common occurrence of *Globigerinoides sacculifer fistulosa* (Schubert) in the Pliocene may prove to be significant is borne out by this study and is endorsed here. (See discussion in the Systematic descriptions.)

Figure 320 shows graphically the lengths of the cores and the thickness of the veneer of shifting Recent and Pleistocene sand and debris that overlies the fossil (presumably Pliocene and Miocene) pelagic sediment. Table 1 provides a key to the sample numbers used in the present report.

CORE DESCRIPTIONS[1]

Core	Length (in cm)	Description
4	61	Slightly indurated *Globigerina*-coccolith ooze, with brown crust in top 3 cm and decreasing brown mottling down to 10 cm.
18	61	*Globigerina* sand with some reef debris of medium to coarse sand size down to 5 cm overlying slightly indurated *Globigerina*-coccolith ooze with faint brown mottling near 5 cm.
20	13	Slightly indurated *Globigerina*-coccolith ooze ($CaCO_3$=95 percent at 12 cm) with brown crust at top and brown mottling decreasing downward.
23	66	*Globigerina* sand with some reef debris of coarse sand size down to 12 cm overlying slightly indurated *Globigerina*-coccolith ooze ($CaCO_3$=96 percent at 30 cm) with decreasing brown mottling downward from 12 to 25 cm.
27	28	*Globigerina* sand with some reef debris down to 12 cm overlying slightly indurated *Globigerina*-coccolith ooze, with brown crust at 12 cm and brown mottling decreasing downward.

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[1] Adapted from Bramlette and others, 1959, p. 1551.

TABLE 1.—*Key to samples used in present report*

Core	Depth in core (in cm)	Designation of samples used in present report	Probable age
4	10	4–10	Early Pliocene.
18	3	18–3	Quaternary.
18	15	18–15	Early Pliocene.
20	13	20–13	Late Miocene.
23	6	23–6	Quaternary.
23	20	23–20	Late Miocene.
27	8	27–8	Quaternary.
27	15	27–15	Late Miocene.
27	25	27–25	Late Miocene.

BENTHONIC POPULATION

Although not an essential part of the present study, the benthonic population of Foraminifera found in the Eniwetok deep-sea core samples may shed additional light on the conditions of deposition.

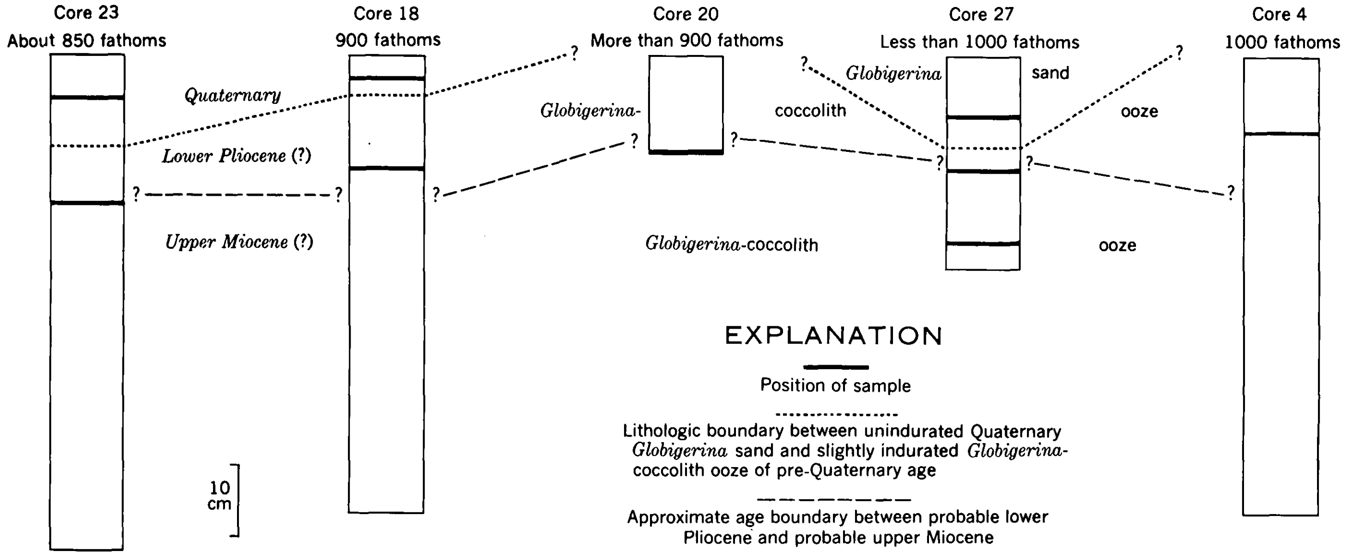

FIGURE 320.—Diagrammatic representation of core lengths, position of samples, and probable age of sediments penetrated.

In none of the samples studied was the benthonic population found to constitute more than a small fraction of 1 percent of the total number of specimens. However, as far as relative number of species is concerned, the picture is very different and is also different from one core to another. This difference from core to core is apparently a function of either or both distance from the actively building reef and steepness of slope from reef to deposition site. Depth of water also possibly influences the number of species making up the deep-water benthonic population, but that influence, if apparent between depths of 850 and 1,000 fathoms such as we are concerned with in these cores, is not evident.

Without making complete identifications of the benthonic species found as negligible constituents of the total assemblages, an estimate was made of the number of different species found in each core sample. The proportion of the total assemblage that was made up of benthonic species was then calculated for each sample (table 2).

TABLE 2.—*Proportion (estimated) of benthonic species to total number of species*

[Samples listed in order of nearness to reef]

Sample	Probable age	Proportion (in percentage of total assemblage)	Approximate distance from reef (in nautical miles)	Approximate depth (in fathoms)
23-6	Quaternary	78	3½	850
23-20	Late Miocene	67		
18-3	Quaternary	77	4½	900
18-15	Early Pliocene	54		
27-8	Quaternary	53	5	Nearly 1,000
27-15	Late Miocene	40		
27-25	Late Miocene	45		
4-10	Early Pliocene	40	5½	1,000
20-13	Late Miocene	36	6	900

Considering the three Quaternary samples together, their benthonic population, although negligible in numbers of specimens, composes 78, 77, and 53 percent of the total number of species, with percentage diminishing with increased distance from the reef. The two probably lower Pliocene samples are composed of relatively fewer benthonic species, 54 and 40 percent, respectively, at 4½ and 5½ miles from the reef edge. The four probably upper Miocene samples have relatively still fewer benthonic species, 67, 40, 45, and 36 percent at 3½, 5, and 6 miles from the reef edge.

In this group of samples there are no exceptions to the trends of (a) fewer benthonic species away from the reef, (b) fewer in lower Pliocene than in Quaternary, and (c) fewer in upper Miocene than in lower Pliocene. However, there is an exception in the unexpectedly higher proportion (45 percent) of benthonic species in sample 27–25 beneath the overlying younger sample (27–15) from the same core where a lower proportion (40 percent) was found.

In two of the three Quaternary samples, namely 23–6 and 18–3, that are nearer to the reef, more than 100 benthonic species were found. By contrast, in the third sample of presumably equivalent age, namely 27–8, that is at a greater distance from the reef and in a greater depth of water, only 24 benthonic species were found.

In all three of these samples the benthonic specimens have a fresh, lustrous appearance, with the pores clearly visible and the chamber cavities usually empty, unlike the dull often finely crystalline surface of the fossil specimens from all the other (older) samples.

In composition the benthonic population does not differ greatly from sample to sample. Even in the upper Miocene samples, the benthonic species are virtually the same as those in the Quaternary samples. Qualitatively, most of the species fall into the families Lagenidae, Buliminidae, Rotaliidae, Cassidulinidae, Anomalinidae and the aragonite genera *Robertina*, *Ceratobulimina*, and *Hoeglundina*. Rare representatives of the families Textulariidae, Miliolidae, and Elphidiidae are found in most of the samples. A few specimens of *Amphistegina*, but exclusively the flatter deep-water kinds, occur in some of the samples. There is a notable increase of miliolids in the two Quaternary samples from nearer the reef and a notable scarcity of them in the older samples and in the cores taken farthest from the reef.

To sum up, in studying the total assemblage of a deposit laid down chiefly by a planktonic population, the benthonic part, even though negligible in amount, may provide clues to some aspects of its paleoecology, particularly with respect to relative distance from a reef or shoreline where shallow-water sediments are being deposited.

ANALYSIS OF PLANKTONIC SPECIES

Analyses of samples of equivalent age showed no significant differences from core to core. Both faunas, that from the Quaternary veneer and that from the pre-Quaternary, are warm-water faunas.

There were 32 species, 8 subspecies, 1 transition form, and 1 variety identified from the composite fauna of both ages of sediments studied. Their occurrence and abundance are recorded, listed alphabetically, in table 3, with the core samples grouped in two groups: three Quaternary samples and six pre-Quaternary samples, the latter listed as they are interpreted in order from younger to older. Also included is an indication of the species whose occurrence as living plankton in the Pacific has been reported by Bradshaw (1959) and Parker (1960). That the older and younger faunas are virtually the same may be observed from the following two lists of species that are restricted or nearly restricted to the Quaternary and to the pre-Quaternary.

Five species and one variety were found only in the Quaternary. All are rare; only *Globorotalia truncatulinoides* occurs in any significant quantity.

Globigerina (*Beella*) *digitata* Brady
Globigerinella adamsi (Banner and Blow)
Globorotalia menardii (d'Orbigny) s.s.
  menardii var. *fimbriata* (Brady)
  (*Truncorotalia*) *truncatulinoides* (d'Orbigny)
Hastigerina pelagica (d'Orbigny)

Eight species and six subspecies were found only in the pre-Quaternary with exceptions as noted. Species marked with an asterisk were common in some samples; all other species were rare.

Globigerina obesa (Bolli) (rare in 23–6)
  sp. aff. *G. apertura* Cushman (rare in 23–6)
**Globigerinoides sacculifer fistulosa* (Schubert) (rare in 18–3)
**Globoquadrina altispira* (Cushman and Jarvis) (rare in 18–3)
  altispira globosa Bolli
Globorotalia fohsi robusta Bolli (rare in 18–3)
  menardii multicamerata Cushman and Jarvis
  menardii praemenardii Cushman and Stainforth
  tumida flexuosa (Koch)
  *(*Turborotalia*) *acostaensis* Blow (rare in 23–6)
Orbulina bilobata (d'Orbigny)
  suturalis Bronnimann (rare in 18–3)
**Sphaeroidinella disjuncta* Finlay
  kochi (Caudri)

TABLE 3.—*Distribution and abundance of planktonic Foraminifera in individual core samples*

[A=abundant; C=common; R=rare; ×=present]

Species	Quaternary			pre-Quaternary						Recorded from plankton (Bradshaw, 1959; Parker, 1960)
	23–6	27–8	18–3	4–10	18–15	27–15	27–25	20–13	23–20	
Candeina nitida d'Orbigny	C	C	C	R	C	R	R	C	C	×
Globigerina bulloides d'Orbigny	R	----	R	R	R	R	----	R	----	×
conglomerata Schwager	R	R	R	R	R	R	R	R	R	×
eggeri Rhumbler	C	R	A	R	----	R	----	----	----	×
obesa (Bolli)	R	----	----	R	R	R	R	R	R	----
rubescens Hofker	R	R	R	R	----	R	----	R	R	----
sp. aff. *G. apertura* Cushman	R	----	----	R	R	R	R	----	----	----
(*Globorotaloides*) *hexagona* Natland	R	R	R	R	R	R	R	R	R	×
(*Beella*) *digitata* Brady	R	----	----	----	----	----	----	----	----	×
Globigerinella adamsi (Banner and Blow)	R	R	R	----	----	----	----	----	----	×
aequilateralis (Brady)	A	C	R	R	R	R	C	C	C	×
Globigerinita glutinata (Egger)	C	R	R	R	C	C	R	R	C	×
humilis (Brady)	R	R	R	----	R	R	----	R	R	----
Globigerinoides conglobatus (Brady)	A	A	A	C	A	A	R	A	A	×
elongatus (d'Orbigny)	C	R	C	R	C	R	R	R	R	----
ruber (d'Orbigny)	A	C	A	C	----	R	R	----	R	×
sacculifer (Brady)	A	A	A	A	A	A	A	C	A	×
sacculifer fistulosa (Schubert)	----	----	R	C	R	R	----	----	----	----
Globoquadrina altispira (Cushman and Jarvis)	----	----	R	----	----	C	C	C	C	----
altispira globosa Bolli	----	----	----	R	R	R	R	R	R	----
Globorotalia (*Globorotalia*) *fohsi robusta* Bolli	----	----	R	----	R	R	----	R	R	----
(*Globorotalia*) *hirsuta* (d'Orbigny)	R	R	R	R	R	R	R	R	R	×
menardii (d'Orbigny)	R	----	R	----	----	----	----	----	----	×
var. *fimbriata* (Brady)	R	R	R	----	----	----	----	----	----	----
miocenica Palmer	R	----	R	----	R	R	----	----	----	----
multicamerata Cushman and Jarvis	----	----	----	----	R	----	R	R	----	----
praemenardii Cushman and Stainforth	----	----	----	----	----	----	R	----	R	----
ungulata Bermudez	C	----	R	R	C	R	R	R	C	×
menardii-tumida transition form	R	C	A	R	R	R	R	R	C	----
tumida (Brady)	R	R	A	R	R	C	----	C	----	×
tumida flexuosa (Koch)	----	----	----	R	R	R	R	R	R	----
(*Truncorotalia*) *punctulata* (d'Orbigny)	R	----	R	R	R	----	----	R	R	×
truncatulinoides (d'Orbigny)	R	R	R	----	----	----	----	----	----	×
(*Turborotalia*) *acostaensis* Blow	R	----	----	R	R	C	C	R	R	----
Hastigerina pelagica (d'Orbigny)	R	----	----	----	----	----	----	----	----	×
Orbulina bilobata (d'Orbigny)	----	----	----	----	----	----	R	R	R	×
suturalis Bronnimann	----	----	R	R	R	R	R	R	R	----
universa d'Orbigny	C	C	R	R	C	C	C	C	C	×
Pulleniatina obliquiloculata (Parker and Jones)	C	R	A	C	R	C	R	R	C	×
Sphaeroidinella dehiscens (Parker and Jones)	C	C	A	C	R	R	R	R	R	×
disjuncta Finlay	----	----	----	----	----	R	R	C	----	----
kochi (Caudri)	----	----	----	----	----	----	----	R	R	----

Thus there remain 19 species, 2 subspecies, and 1 transition form that occur in both Quaternary and pre-Quaternary sediments. None of the abundant constituents were found to be restricted to either the later or the earlier deposits.

Although no precise quantitative analyses were made of the individual samples studied, an estimate was made of the major constituents which compose the assemblages from the two different ages.

In the 3 samples representative of the Quaternary (23–6, 27–8, 18–3), 10 species constitute the major part of the population. They are listed in approximate order of their abundance:

Globigerinoides conglobatus (Brady)
  sacculifer (Brady)
Globigerinella aequilateralis (Brady)
Globigerinoides ruber (d'Orbigny)
Sphaeroidinella dehiscens (Parker and Jones)
Pulleniatina obliquiloculata (Parker and Jones)
Orbulina universa d'Orbigny
Globorotalia menardii-tumida transition form
  tumida (Brady)
Globigerina eggeri Rhumbler

In the pre-Quaternary (samples 4–10, 18–15, 27–15, 27–25, 20–13, and 23–20), nine species constitute the major part of the population. Six are the same as in the Quaternary population; three are different, of which two are restricted to the pre-Quaternary population. They are listed in approximate order of their abundance, but there are discrepancies as noted:

Globigerinoides sacculifer (Brady)
  conglobatus (Brady) (but rare in 27–25)
Globigerinella aequilateralis (Brady)
Globorotalia menardii ungulata Bermudez
  (*Turborotalia*) *acostaensis* Blow
Globoquadrina altispira (Cushman and Jarvis) (but not found in 4–10 and 18–15)
Pulleniatina obliquiloculata (Parker and Jones)
Orbulina universa d'Orbigny
Globorotalia menardii-tumida transition form

In general, the following trends of changes in abundance from older to younger were also noted: *Globigerinoides conglobatus* and *G. sacculifer* reverse their positions as the two predominant forms, *G. sacculifer* being the dominant form in the older (pre-Quaternary) deposits and *G. conglobatus* in the younger (Quaternary) deposits. *Globigerinoides ruber* and *Sphaeroidinella dehiscens* appear to be slightly more abundant in the younger than in the older deposits. No significant resemblances were noted between older and younger parts of a single core; instead the resemblances were between samples of equivalent age from different cores.

PROBLEMS RELATED TO USE OF PLANKTONICS FOR AGE DETERMINATION

The three samples representative of the Quaternary, as defined by Bramlette and others (1959), are 23–6, 27–8, and 18–3. In these samples were found representatives of 35 of the 42 species, subspecies, and variety identified. Studies of living planktonic Foraminifera from the North and Equatorial Pacific (Bradshaw, 1959) and from the Equatorial and Southeast Pacific (Parker, 1960) give excellent documentation of the planktonic species that are actually living in Pacific waters. Twenty-two of the thirty-five species found in these sediments can thereby be verified as undoubted Recent species. In addition, another species (or perhaps forma), *Orbulina bilobata*, was reported from the plankton under the name *Orbulina universa*. In the Eniwetok deep-sea core samples this bilocular form of *O. universa* was found only in the pre-Quaternary material.

Besides the 22 verified Recent species, *Globorotalia menardii* var. *fimbriata* may be regarded as probably Recent because of its presence exclusively in the Quaternary core samples. Remaining are 11 species found in the Quaternary parts of the cores whose existence as living animals during the time represented by those parts of the cores has not yet been verified from plankton.

Wholly on the basis of opinion, I have separated these species into two lists, those probably living in the Recent and those probably extinct before the Recent.

Species probably living in the Recent:
  Globigerina rubescens Hofker
  Globigerinita humilis (Brady)
  Globigerinoides elongatus (d'Orbigny)
Species probably extinct before the Recent:
  Globigerina obesa (Bolli)
    sp. aff. *G. apertura* Cushman
  Globigerinoides sacculifer fistulosa (Schubert)
  Globoquadrina altispira (Cushman and Jarvis)
  Globorotalia menardii miocenica Palmer
    menardii-tumida transition form
    (*Turborotalia*) *acostaensis* Blow
  Orbulina suturalis Bronnimann

THE PROBLEM OF SUBSPECIES

The problem of subspecies is best shown by the difficulty of representing the plexus of forms close to, evolving out of, or related to *Globorotalia menardii*. It is not yet clear what a subspecies is; that is, how it can be defined in fossil populations. Its definition as a geographically defined aggregate of local populations which differs taxonomically from other such subdivisions of the species—a species being an actually (or potentially) interbreeding natural population—fails to serve as a useful definition in studying and classifying such a group as planktonic Foraminifera. In this group almost nothing is known about the natural breeding of the animals, and even relatively little is known about the life cycle of the animals; that is, where their life is spent in relation to where their shells are eventually deposited.

Moreover, the difficulty of recognizing and evaluating the significance of the subtle differences between subspecies is multiplied in fossil sediments. Not only is there the natural mixing of faunas that lived in entirely different environments of the superjacent waters, there is the accidental mixing by postdepositional effects such as turbidity currents, activity of benthonic organisms, and other disturbances. In deep-water cores it is difficult to conceive of long-continued deposition without many such repeated disturbances of the natural sequence. Inasmuch as long periods of time are compressed into almost negligible thicknesses of sediment, the degree of disturbance and the amount of mixing is often extreme.

In these deep-water cores, therefore, we are faced with the necessity of trying to recognize the natural sequence that is hidden within (or obscured by) the disturbed sequence. We find specimens that are obviously (or probably) fossil together with other specimens whose Recent origin need not be doubted. We find a variety of morphologically related forms occurring together. We have no way of determining whether they lived together, or whether they came together following death of the animal.

From our general observations of evolution on a larger scale and in other animals, it seems reasonable to assume that each species of planktonic Foraminifera has evolutionary connections with a closely related ancestor. But, in addition, our observations on variation of physical features lead us to assume that nearly every species of planktonic Foraminifera has transitional relationships with several other closely similar or closely related species.

Thus there are both vertical and horizontal lines or trends that are to be looked for in almost all species of Foraminifera. In fact, among the planktonic species of the population under study, only two species can be said to stand alone without transitional forms toward, or connecting with, morphologically similar species. These are *Candeina nitida* and *Pulleniatina obliquiloculata.*

All the other species appear to show greater or lesser degrees of transition from one "species" to another. Examples are *Globigerina conglomerata-G. eggeri-Globorotalia acostaensis; Globigerina bulloides-G. obesa-Globigerinella aequilateralis-G. adamsi; Globigerinoides conglobatus-G. ruber-G. elongatus; Globorotalia truncatulinoides-G. punctulata-G. hirsuta; Sphaeroidinella dehiscens-S. kochi;* and *Globorotalia menardii-G. tumida* and their subspecies and variety.

The problem is how best to represent this transition, or looking at it from another point of view, how best to represent the variability of "species." Will recognition of similarities or recognition of differences serve us better? The answer depends on what we are seeking. If we are seeking correlation, especially worldwide correlation, then probably the recognition of similarities will serve our purpose better. If we are seeking a finer subdivision of a local sequence then probably the recognition of differences will serve us better. Thus for the solution of our present problem, that is, the search for forms available for zonation of the late Tertiary, we should attempt better recognition of subtle differences.

Why do some "species" appear to hold true to their conventional specific characters while others broaden out into vague transitional assemblages in which several "species" may be recognized? Is it because the species which hold true are not in the process of active evolution, whereas the transitional assemblages are? It is generally accepted (Henbest, 1952) that evolution is not a smoothly proceeding process but actually proceeds in bursts or explosively and that the "bursts" within different phylogenetic lines are not necessarily in phase.

Another possible explanation of the observation that some "species" appear to hold true, whereas others broaden out into transitional assemblages is that it is an artifact of our taxonomy.

The effect of taxonomy on our species concepts may be exemplified by the contrast between three individual species (*Globigerinella aequilateralis*, *Pulleniatina obliquiloculata*, and *Globigerinoides sacculifer*) on the one hand, and three groups of species (the *Globorotalia menardii-tumida* complex, the *Globigerinoides ruber-elongatus-conglobatus* complex, and the *Sphaeroidinella dehiscens-kochi* complex) on the other hand. These six species or groups of species are discussed individually.

VARIABILITY IN GLOBIGERINELLA AEQUILATERALIS

Among the specimens of *Globigerinella aequilateralis* some are more compact than the others; that is, proportionally broader and more tightly coiled, namely the form described as var. *involuta* (Cushman, 1917). Yet this distinction has not been widely accepted and the two forms are generally combined and regarded as but extremes of a single form. They are found occurring together and the fossil assemblages do not show any significantly different trends toward one form or of one form becoming predominant in the older or younger layers.

VARIABILITY IN PULLENIATINA OBLIQUILOCULATA

In *Pulleniatina obliquiloculata*, unlike *Globigerinella aequilateralis*, there are significant trends from the older (pre-Quaternary) specimens to the younger (Quaternary) specimens, as discussed in the Systematic descriptions. The older specimens are smaller and more evolute, and the sutures are slightly depressed (pl. 289, fig. 3). These specimens possibly could be described as a species distinct from the Recent specimens which are more involute and larger (pl. 289, fig. 2). Yet to do so would have posed more problems than it would have solved. If we have two very similar species, admittedly transitional to each other, we are forced into an arbitrary decision of when to stop calling the evolving form by one name and to begin calling it by another name. Moreover, by using the one name rather than the other, we tend to obscure or neglect their close relationship.

VARIABILITY IN GLOBIGERINOIDES SACCULIFER

Globigerinoides sacculifer presents yet another different kind of situation. In this species, the obvious unity that one sees is not so much morphology of the test as it is the honeycomb wall surface. As one looks at large assemblages where this species is common or abundant, as it is in the core samples studied, one is struck not so much by a change in the morphology of the adult test as by a change in the abundance of what might be considered full-fledged individuals. Starting with the Recent or Pleistocene assemblages, one sees that the typical forms have a single flattened final chamber. With them are many other specimens. The variation in these other specimens takes many different directions. Some have two flattened chambers; some have none. In some the flattened chamber is very small and abortive; in others it is abnormally large with its outer end extended into several fingers (regarded as the subspecies *fistulosa*). In some the apertural openings are abnormally small and almost obscured by adhering matrix. In some, almost all smaller than average size, the chambers are so nearly hemispherical, the apertures reduced in size, and the whole test so compact, that the resemblance is very close to *Globigerinoides trilobus* (Reuss), if indeed the specimens are not indistinguishable from it.

It would not be unreasonable, in view of the way such variants have been treated in other species, to give each variant a name so that they might be more easily discussed. As they all occur together they are probably not subspecies. Yet *fistulosa* apparently is a subspecies. Perhaps it floated at a different level, or perhaps it did not develop its fistulosity until it sank to the bottom. In any case, it appears first rarely in the upper Miocene, perhaps only as accidentals and then becomes a significant factor probably in the Pliocene. It has never been reported from plankton tows and is presumably extinct. If it were a variant it might be expected to persist as long as the true species persists, but it did not.

As for the other morphologic forms, those with abortive final chambers seem no more or less abundant or characteristic in one part of the geologic column or place in the world where the species occurs than another. Neither are those with broad (as opposed to narrow) flattened chambers, or those with incipient fistulose outgrowths on the final chambers, or those in which the flattened chamber is missing. However, it is observable that the *trilobus*-like form (that is, smaller, compact, with less widely open apertures) is more abundant in the older than in the Recent assemblages, and that the larger flatter more loosely coiled form is more abundant in the Quaternary than in the older fossil assemblages.

Let us now examine three similar situations that have been treated in a different way taxonomically.

VARIABILITY IN THE GLOBOROTALIA MENARDII-TUMIDA COMPLEX

The *Globorotalia menardii-tumida* complex is a vaguely defined group of forms out of which the two species that include the dominating globorotalid specimens in Recent seas appear to have evolved. In the later development of the complex, *G. menardii* and *G. tumida* are clearly distinct and present no problems in distinction of the two forms. But in the early development of the complex, there is a tendency of the two forms to fuse into each other and become one, a form that is morphologically about halfway between *menardii* and *tumida*. Schmid early recognized the existence of this transition and studied (Schmid, 1934) the biometrics of these two species as they occur in the Pliocene of Ceram, Indonesia. He regarded *G. menardii* as the microspheric form and *G. tumida* as the megalospheric form and concluded (1934, p. 103) that they should be combined as one species.

In deep-sea cores from the North Atlantic, this early (hybridlike) form was first recognized by Phleger and others (1953, p. 20) who also recognized (1953, p. 20, 22) that in the separation from this parent stock, *Globorotalia menardii* s. s. appeared well before *G. tumida* s. s. Ericson and others (1961, p. 263) also observed this same phenomenon in their study of North Atlantic cores, and they set up (1961, text fig. 24) six climatic zones: u to z—u, w, and y being glacial and v, x, and z being interglacial, interstadial, and postglacial, respectively. In these zones they found *menardii* and *tumida* existing without connecting transitional forms only in z, the uppermost zone. In the interstadial zone x, they found the flexuose subspecies to be dominant.

In the Atlantic, the flexuose subspecies apparently appeared briefly late in the Pleistocene and then ended its existence, giving rise to no descendants. In the Pacific, on the contrary, it apparently flourished at some time in the late Tertiary and became extinct before the Pleistocene.

As for the placement by Ericson and others (1961, p. 262) of the flexuose form as a subspecies of *Globorotalia menardii* instead of *G. tumida*, it is almost wholly (if not exclusively) the *tumida* form that is bent. Therefore it seems awkward to have to call them *G. menardii flexuosa*, but the difficulty is obvious. The only two ways this dilemma can be avoided is to call *menardii* and *tumida* separate species of *Globorotalia* or to call *flexuosa* a variety (which it obviously is not). I favor the first alternative. Actually, I believe some few specimens of *G. menardii* are flexuose to a degree that is perhaps not as great as in *G. tumida.*

In addition to these major and well-defined units in the *Globorotalia menardii-tumida* complex, there are additional variant units, of which it is not clear whether they are merely variant individuals (some immature) or actually distinct subspecies. They are *ungulata*, *miocenica*, *multicamerata*, and *fimbriata*.

The subspecies *ungulata* and *miocenica* are found equally in Quaternary and pre-Quaternary deposits. The subspecies *multicamerata* is found only in pre-Quaternary and *fimbriata* only in the Quaternary deposits. Because the fimbriate peripheral ornamentation is found on both *menardii* s. s. and the subspecies *ungulata*, it is believed to be not a subspecific character but a varietal one.

Now going back to the Eniwetok material being studied, *Globorotalia menardii* s. s. is not at all common, in fact it is hardly typical. The bulk of the specimens belong to the so-called *menardii-tumida* transition form (pl. 294, fig. 2) and to the subspecies *ungulata* (pl. 295, fig. 3). Yet, Bradshaw's (1959, p. 44, text fig. 25) records indicate that *menardii* is living in typical form in the area of Eniwetok. It is unexpectedly rare in the Eniwetok cores, even in the parts of them that are dated as Quaternary. Actually, when distinguished from its intergrades it is rarer than *tumida.* Yet Bradshaw (1959, text fig. 34) indicates that *menardii* is more abundant than *tumida.* This apparent discrepancy may be explained by the fact that my estimates of relative abundance are not comparable with Bradshaw's because he does include (1959, p. 44, pl. 8, figs. 10–12) the *ungulata* intergrade in his counts of *menardii* (J. S. Bradshaw, written communication, Oct. 2, 1961).

VARIABILITY IN THE GLOBIGERINOIDES ELONGATUS-RUBER-CONGLOBATUS COMPLEX

The *Globigerinoides elongatus-ruber-conglobatus* complex is less complicated than the *menardii-tumida* one. This complex appears to be a group of closely related individuals with greater or lesser degrees of height of spire, *elongatus* the greater and *conglobatus* the lesser. In the Eniwetok cores, specimens of *ruber* are least common and have the smallest average size; *elongatus* is next largest and next in abundance among these three; and *conglobatus* is the greatest in size and in abundance among these three. Taking typical examples of all three, no difficulty is experienced in distinguishing between them. The difficulty arises when one is forced to place intermediate forms in one or another of these three species. Then one is struck by the fact that such separation is an arbitrary one, namely that an individual having an intermediate form can be placed, with equal logic, in either *ruber* or *elongatus*, or perhaps in either *ruber* or *conglobatus.* However, the complex does not change strikingly from older to younger beds except that typical specimens of *ruber* become progressively more abundant in the younger beds.

VARIABILITY IN THE SPHAEROIDINELLA COMPLEX

The *Sphaeroidinella* complex is similar to the *Globigerinoides* complex in that it is a matter of morphology, that is, number of chambers per final whorl, *kochi* having the most (five or more) and *dehiscens* the least (three chambers in a globular unindented form). But unlike the absence of distinct trends in the *Globigerinoides* complex, this complex shows the progressive elimination of the many-chambered forms with the resulting predominance of the few-chambered forms in the Recent. However, the few-chambered forms are scarcely less abundant in the Miocene than in the Recent; the change comes in the decreasing abundance of the many-chambered forms in the younger layers and their extinction before the Recent.

In the planktonic facies (Donni Sandstone Member) of the Miocene Tagpochau Limestone of Saipan, this *Sphaeroidinella* complex was well represented (Todd, 1957, pl. 79, figs. 6–8), more completely so than in these deep-sea cores. On Saipan, the median forms, that is, *S. seminulina* (having four chambers or three arranged in an indented tripartite arrangment), are well represented. Only a very few from the Eniwetok cores fall into that median category, and even the many-chambered forms are not as lobulated as the corresponding ones from Saipan.

AGE OF FORAMINIFERA SPECIES

Determination of age of the six pre-Quaternary samples is made on the basis of relatively few of the species found, none of which are found abundantly. The following species seem to be useful for age determination:

Globigerina obesa (Bolli)
**Globigerinoides sacculifer fistulosa* (Schubert)
Globoquadrina altispira (Cushman and Jarvis)
    altispira globosa Bolli
Globorotalia fohsi robusta Bolli
    menardii multicamerata Cushman and Jarvis
        praemenardii Cushman and Stainforth
    tumida flexuosa (Koch)
    *(*Truncorotalia*) *truncatulinoides* (d'Orbigny)
    (*Turborotalia*) *acostaensis* Blow
Orbulina bilobata (d'Orbigny)
    suturalis Bronnimann
Sphaeroidinella disjuncta Finlay
    koohi (Caudri)

The two forms marked by an asterisk are probably post-Miocene in age. *Globigerinoides sacculifer fistulosa* is also probably pre-Recent because it has not been found in plankton. *Globorotalia truncatulinoides*, however, is abundant in the Recent. All the remaining species and subspecies are probably Miocene and (or) Pliocene in age, some with more or less limited ranges within the Miocene.

Among these species and subspecies, the narrowest range has been attributed to *Globorotalia fohsi robusta*, a form that has been used to designate one of the zones set up to subdivide the Miocene in the Oligocene-Miocene sequence in Trinidad (Bolli, 1957, p. 101, text fig. 18). The Trinidad zonation was subsequently used in Venezuela (Blow, 1959, chart 1) where the *G. fohsi robusta* zone was indicated to be approximately equivalent to the uppermost Burdigalian. This equivalence is also supported by Stainforth (1960, range chart) in his discussion of transatlantic correlation in the Oligocene and Miocene. An earlier discussion (Drooger, 1956, text fig. 1) of the same subject interpreted the entire *G. fohsi* zone (later to be subdivided into four zones of which the *G. fohsi robusta* zone is the uppermost) as extending from upper Helvetian through the Tortonian. Although the relative position of ranges of species does not differ significantly in these three papers, the interpretations of Blow and of Stainforth as to correlation with the European section seem more reasonable than that of Drooger when considered in the light of evidence from other organisms and from planktonic Foraminifera from other parts of the world.

Limited ranges within the Miocene have also been attributed (Bolli, 1957, text fig. 18) to *Globorotalia menardii praemenardii* and *Globoquadrina altispira*, both having ranges less narrowly limited than that of *G. fohsi robusta* but including the *G. fohsi robusta* zone within the upper parts of their ranges. Thus these three forms, in association with each other, provide a basis upon which age may be determined.

Therefore, sample 23–20 is correlated with the *G. fohsi robusta* zone of the West Indian Miocene sequence. Samples 27–15 and 20–13, in which *G. fohsi robusta* is found associated with *Globoquadrina altispira*, are also tentatively correlated with the *G. fohsi robusta* zone. Correlation of the other two samples in which specimens of *G. fohsi robusta* were found seems to be questionable. Because of the absence of *Globoquadrina altispira* in sample 18–15, it is probably not as old as 23–20 and 27–15. Sample 18–3, although it contains both *Globorotalia fohsi robusta* and *Globoquadrina altispira*, belongs, by virtue of its lack of consolidation, with the younger material of Quaternary age that is currently being moved about over the surface of the semiconsolidated deposits of pre-Quaternary age. The presence in sample 18–3 of obviously fossil forms is probably to be explained by redeposition or mixing.

By eliminating the five previously discussed forms, there remain nine whose reported ranges are in the Miocene and may or may not extend upward into the Pliocene or Pleistocene. They are:

Globigerina obesa (Bolli)
Globoquadrina altispira globosa Bolli
Globorotalia menardii multicamerata Cushman and Jarvis
    tumida flexuosa (Koch)
    (*Turborotalia*) *acostaensis* Blow
Orbulina bilobata (d'Orbigny)
    suturalis Bronnimann
Sphacroidinella disjuncta Finlay
    kochi (Caudri)

Specific information on the ranges of these species and subspecies is not easily deduced.

Blow (1959, p. 209–210) reported the range of *Globorotalia acostaensis* to be from the *Globorotalia menardii menardii*/*Globigerina nepenthes* zone to the *Globigerina bulloides* zone (or in terms of European equivalents, from within the Vindobonian into the Pliocene). The range of *Globigerina obesa* is indicated as approximately from the lowermost Miocene into the Pliocene by both Bolli (1957, text fig. 18) and Blow (1959, p. 218).

From recorded occurrences in the literature, the ranges of *Orbulina bilobata* and *O. suturalis* both probably extend up into the Pliocene, and the same is true of *Globorotalia menardii multicamerata* and *Globoquadrina altispira globosa*.

The range of *Globorotalia tumida flexuosa* is more speculative as most of its previously reported occurrences are indeterminate as to age. Its occurrence in all the pre-Quaternary samples at Eniwetok where it was found in association with several Miocene forms suggests that its range includes at least the upper Miocene as well as the Pliocene. Its absence from the Quaternary Eniwetok core samples suggests its age in the Pacific is not equivalent to its age in the Atlantic where it has been used as a marker for one of the six zones set up in the late Pleistocene.

AGE OF CORE SAMPLES

In table 3 the samples have been arranged in two groups, three core samples of Quaternary nonconsolidated sediments and six core samples of pre-Quaternary semiconsolidated sediments, with the nine samples listed in order (left to right) from youngest to oldest.

Samples 23–6 and 27–8 are composed of virtually Recent assemblages with few exceptions. The only possible exceptions, *Globorotalia acostaensis*, *Globigerina obesa*, and *G.* sp. aff. *apertura*, may be explained as accidentals from mixing in sample 23–6. Sample 18–3 contains the same assemblage but with the admixture of a few fossil species. The presence in 18–3 of brown masses of specimens cemented together confirms the supposition that this is a mixed assemblage. In addition these three samples contain several species not found in any of the pre-Quaternary samples.

The placement of sample 4–10 as next youngest was made because of the common occurrence of *Globigerinoides sacculifer fistulosa* and is supported by the absence of such Miocene species as *Globoquadrina altispira*, *Globorotalia fohsi robusta*, and the two fossil species of *Sphaeroidinella.* Sample 18–15 also lacks *Globoquadrina altispira*, so is presumably younger than those in which it is found. Because of the absence of *Globorotalia truncatulinoides*, these samples are interpreted as probably lower Pliocene.

Samples 27–15, 27–25, 20–13, and 23–20 all contain *Globoquadrina altispira* commonly. These four samples may be approximately the same age. The only faunal elements that suggest that 20–13, 23–20, and 27–25 might be of a slightly different age (probably older) than 27–15 are the presence of *Sphaeroidinella kochi* in samples 20–13 and 23–20 only and the presence of *Globorotalia menardii praemenardii* in 27–25 and 23–20 only. The presence of *Orbulina bilobata* in 27–25, 20–13, and 23–20 supports the probability of these three samples being approximately equivalent. Sample 27–15 is presumed, from its superjacent position and from the rare presence of *Globigerinoides sacculifer fistulosa* (a form that was not found with *Globoquadrina* in the older samples), to be slightly younger than 27–25. Yet by the presence of *Globoquadrina altispira*, sample 27–15 is allied more closely with sample 27–25 and the two other *Globoquadrina*-bearing ones, 20–13 and 23–20, than with any others.

The present Eniwetok material may, by means of association of species, throw some light on the local upper limits of some of these Miocene species. For example, *Globoquadrina altispira globosa* appears to range higher than *G. altispira* s. s. because it is found in samples 4–10 and 18–15, whereas *G. altispira* s. s. is not. In the present material, *Orbulina suturalis* appears to range higher than *O. bilobata* because it was found in all the pre-Quaternary samples, whereas *O. bilobata* was found only in the older ones. *Globigerinoides sacculifer fistulosa* seems to have appeared later than did *Globorotalia tumida flexuosa* because it is found only in the three presumably younger pre-Quaternary samples, whereas *Globorotalia tumida flexuosa* is found throughout them.

CORRELATION

By its faunal elements the Miocene assemblages present in the three cores (20, 23, and 27) where Miocene was recognized are closely allied to assemblages from equivalent facies from several remote areas, such as Trinidad, Venezuela, and the Mediterranean region, as discussed in the Systematic descriptions. In Victoria, Australia, a section of rich planktonic assemblages from the 1,200-foot Lakes Entrance oil shaft (Jenkins, 1960) includes in its upper part (zones 9, 10, and 11, extending to a depth of about 550 ft) a section containing several species present in the Miocene Eniwetok deep-sea cores. A tentative correlation can be made on the basis of several identical species and the intercontinental correlations suggested by Jenkins (1960, text fig. 10).

The closest affinity, however, is to a manganese-coated dredge haul sample (MP43DD) obtained from Sylvania Guyot off Bikini Atoll (Hamilton and Rex, 1959, p. 788, 789). In that sample, as in the present deep-sea cores off Eniwetok, the following species were associated: *Globoquadrina altispira*, *Globorotalia menardii multicamerata*, *Sphaeroidinella disjuncta*, *Globigerinoides sacculifer fistulosa*, and *Globorotalia tumida flexuosa.* On the basis of Foraminifera, Hamilton and Rex assigned a late Miocene age to their sample but noted (1959, p. 786, 789) that M. N. Bramlette preferred an early Pliocene dating on the basis of coccoliths. There seems to be no conclusive evidence now available to tip the scales one way or the other. Thus the problem of age must remain unsolved for the present. However, we may assume that this association of species, the first three mentioned probably near the upper extent of their stratigraphic ranges and the last two probably near the lower extent of theirs, indicates an age near (slightly above or slightly below) the Miocene-Pliocene boundary.

Besides this relatively nearby occurrence of Miocene and (or) Pliocene, there is another much nearer, within a distance of some 12–15 miles horizontally and more than a mile vertically—namely the Miocene found in the deep drilling of hole E–1 on Parry Island of Eniwetok Atoll (Todd and Low, 1960, p. 802–804). This occurrence, unlike that from Sylvania Guyot, has little in common with the occurrence in the deep-sea cores from the slope of Eniwetok Atoll. Because of their totally different environments, the one being an actively growing reef and the other a guyot in deep water adjoining the outer slope of the atoll, their faunal compositions are totally different and there is even little identity of species between the two deposits that, in some of their parts, must be equivalent in age.

The species of the reef assemblage found by the drilling on Parry Island have been recorded (Todd and Low, 1960, table 2) and the faunal composition discussed (1960, p. 800). Rare representatives of 10 of the species that are present in the deep-sea core samples were found in the Miocene drillings as follows:

- *Globigerina bulloides* d'Orbigny
  - *eggeri* Rhumbler
  - sp. B=*Sphaeroidinella disjuncta* Finlay
- *Globigerinoides conglobatus* (Brady)
  - *ruber* (d'Orbigny)
  - *sacculifer* (Brady)
- *Orbulina suturalis* Bronnimann
  - *universa* d'Orbigny
- *Pulleniatina obliquiloculata* (Parker and Jones)
- *Globorotalia menardii* (d'Orbigny)

The planktonic population in the drill hole, although nowhere more than negligible as compared with the benthonic reef population, is best represented around the presumed top of the Miocene at about 550 feet. However, a concentration at this level should not be interpreted as necessarily indicating age equivalence between the cores from the surface of the guyot and the sediments around 550 feet down in the drill hole on the reef. On the contrary, the conclusion might be that when the sediments now at 550 feet were being deposited the local oceanographic conditions (probably currents rather than depth) were such that more of the planktonic population accumulated with the debris being added to the reef at that time than at other times during the upbuilding of that particular part of the reef.

Of the group of species from the Miocene section of the Parry Island drilling only two (*Sphaeroidinella disjuncta* and *Orbulina suturalis*) are not represented in Recent as well as Miocene sediments. The rare planktonic specimens found in the reef assemblage are not well preserved and are poorly developed and smaller than normal. Altogether they make up a negligible proportion of the total population that accumulated on and around the growing reef. Nevertheless, these few species provide a tenuous bond between the two areas of deposition.

The faunal contrast between the Miocene sediments from 500 feet below the atoll surface and those from 5 or 6 inches below the surface of the guyot adjoining the atoll is identical with the faunal contrast between present-day contemporaneous sediments from reef and guyot environments shown at Bikini Atoll in the Marshall Islands (Cushman and others, 1954, p. 327, text figs. 117, 118, tables 1–5).

SYSTEMATIC DESCRIPTIONS

In the following pages are included partial synonymies, notes on ages and locations of other reported occurrences, descriptions of distinguishing characteristics and morphological trends, comments on frequency and restriction of occurrence in the present material, and discussions of specific and generic relationships of about 30 planktonic species recognized in the Eniwetok deep-sea cores. In this section I have followed conventional taxonomy for most, but not all, of the species. I have grouped together species that are clearly genetically related (such as *Globigerinoides conglobatus* and *G. ruber*) and others (such as *Globigerina bulloides* and *G. conglomerata*) between which the genetic relationship is less obvious or even subject to question and still others (such as *Globorotalia menardii* and *G. acostaensis*) in which the genetic relationship is virtually nonexistent, or, stated another way, is an artifact of classification.

I have followed convention in distinguishing as species what might more logically have been combined as three forma of one species: *Orbulina universa*, *O. bilobata*, and *O. suturalis*. I have diverged from convention in combining three or four species as synonyms of a single species, as in *Globigerina conglomerata* and *Globigerinita glutinata*.

I recognize that this organization into species is influenced by my familiarity or lack of familiarity with already existing taxonomy and that as a classification it is both incomplete and temporary and serves the immediate purpose of providing names by which groups of individuals may be discussed. It has flaws and inconsistencies because of the impossibility of representing what are gradational forms by specific names which are discrete entities.

The planktonic species discussed in this section fall into two families, Globigerinidae and Globorotaliidae, with some few species having characteristics of both these families, as discussed below. The order of treatment of the species is such that those placed at the end of the Globorotaliidae are closest in morphology to those at the beginning of the Globigerinidae. On the plates the arrangement of illustrations is reversed so that the *Globigerina*-like species of the Globorotaliidae are adjacent to the true species of *Globigerina* for easier comparison.

Family GLOBIGERINIDAE
Genus GLOBIGERINA d'Orbigny, 1826

Globigerina bulloides d'Orbigny

Globigerina bulloides d'Orbigny, 1826, Annales sci. nat., v. 7, p. 277; Modèles, nos. 17 (young) and 76 (adult). Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 33, pl. 6, figs. 1–4.

This well-known species, described from Rimini on the Adriatic Sea, has been widely recorded from all oceans. It is a temperate or cold-water form.

How far back it extends into geologic time is an open question because so many very similar species have been described and reported from fossil material. *Globigerina bulloides* undoubtedly existed in the Pleistocene and probably in the Pliocene, maybe even in the Miocene. I doubt that it occurred in the Oligocene. Some recorded occurrences of Miocene age that, from the figures, would appear to be authentic are those from the upper Miocene of Rumania (Iorgulescu, 1953, p. 192, pl. 7, fig. 1); the lower Aquitanian-upper Burdigalian of the Aquitaine Basin, France (Kaasschieter, 1955, p. 91, pl. 10, fig. 4); the Miocene of Aquitaine, France (Sacal and Debourle, 1957, p. 54, pl. 23, figs. 8, 9); the Pozón Formation of eastern Falcón, Venezuela (Blow, 1959, p. 175, pl. 9, fig. 38); and the Tortonian of Italy (Dieci, 1959, p. 89, pl. 7, fig. 21). On Saipan, *Globigerina bulloides* was reported (Todd, 1957, tables 2, 3) from both the Miocene and the upper Oligocene, the latter now regarded as probably not as old as Oligocene. I have reexamined these specimens and believe the recorded occurrence of the species in the Donni Sandstone Member of the Tagpochau Limestone should not be questioned, although the specimens are quite rare and poorly preserved. As for the Fina-sisu (upper Oligocene) record, it may well be doubted.

It seems, therefore, that *Globigerina bulloides* came into existence in the Miocene, perhaps the upper part, where it evolved out of a plexus of other related species that are almost indistinguishable from it. I doubt that any specimens of true *G. bulloides* have been found in upper Oligocene beds.

The strongest morphologic connections of the species seem to be with *Globigerina obesa* (Bolli) and, through it, to *Globigerinella aequilateralis* (Brady). In becoming lower spired, with its aperture lower and extending from umbilicus toward periphery, it is transformed into the first mentioned species. Its further transformation into *Globigerinella aequilateralis* is accomplished by its aperture becoming wholly peripheral, its spire nearly buried within the later coils, and its chambers becoming slightly elongate or bulging, which results in a less compact test.

In the present deep-sea cores, *Globigerina bulloides* is rare and not many typical ones were observed. Some forms have a tendency to be higher spired than typical specimens, and they may have a slightly less open aperture than usual. There is a good deal of range in compactness of the test. Some are nearly as compact as *G. eggeri* Rhumbler, but they are easily distinguished from that species by their fine spinosity instead of cancellated surface. The variation in *G. bulloides* does not extend to any change in number of chambers per final whorl; the number is uniformly four. No trends from older to younger were observed in these Eniwetok samples.

Globigerina sp. aff. G. apertura Cushman

Plate 292, figure 2

Test of average size for the genus, consisting of about 3 whorls in a flat coil, periphery lobulate; chambers few, rapidly increasing in size as added, 4½ making up the final whorl, flat dorsally but inflated ventrally and peripherally; sutures distinct and incised ventrally, indistinct and only slightly indented dorsally; wall densely covered by papillae; aperture large, high arched, extending from the umbilicus nearly to the periphery, rimmed with a narrow lip. Maximum dimension is 0.35–0.40 mm; thickness is 0.23–0.29 mm.

This species, only rarely represented in these Eniwetok cores, seems not to be described. It resembles *Globigerina apertura* Cushman (Cushman, 1918, p. 57, pl. 12, fig. 8), described from the upper Miocene, Yorktown Formation, at Suffolk, Va., in its large aperture but is not the same. It differs in the position of the aperture which in these specimens extends from the umbilicus to the periphery.

It also somewhat resembles *Globigerina bulloides*, but, even though in that species the aperture is equally large or larger, its opening faces into the umbilicus rather than into the plane of the ventral surface of the test. In the present species, on the other hand, the large aperture can be observed without tilting the specimen in order that its apertural opening can be looked into.

These Eniwetok specimens also resemble *Globigerina ampliapertura* Bolli (Bolli, 1957, p. 108, pl. 22, figs. 4–7), a species described from the upper Eocene and Oligocene of the Trinidad section, but the position of the aperture, which extends nearly from the umbilicus to the periphery, distinguishes it from that species.

Globigerina obesa (Bolli)

Plate 292, figure 4

Globorotalia obesa Bolli, 1957, U.S. Natl. Mus. Bull. 215, p. 119, pl. 29, figs. 2, 3.
Blow, 1959, Bull. Am. Paleontology, v. 39, no. 178, p. 218, pl. 19, fig. 124.
Hamilton and Rex, 1959, U.S. Geol. Survey Prof. Paper 260–W, p. 791 (footnote), pl. 253, fig. 14.
Jenkins, 1960, Micropaleontology, v. 6, p. 364, pl. 5, fig. 2.

This species was originally described from the Miocene, Cipero Formation of Trinidad. It was reported to range from the basal Miocene upward through the Lengua Formation in Trinidad. Blow (1959, p. 218) gives the range as beginning in the second zone above the basal Miocene and extending into the Pliocene in Venezuela. The third recorded occurrence is from Sylvania Guyot where it is reported from the *Globigerinatella insueta* zone which would be included within the ranges given by the other two recorded occurrences. The fourth recorded occurrence is from Miocene in the Lakes Entrance oil shaft in Victoria, Australia, where the species was reported to extend throughout the entire section.

From the coiled side, specimens of this species are easily mistaken for *Globigerina bulloides*, whereas from the involute side they look like *Globigerinella aequilateralis*. From the former they are distinguishable by the low curved slitlike aperture and from the latter by the aperture restricted to one side and not extending across the peripheral region. They also resemble *Globigerina hexagona* Natland, a species that is well illustrated from the North and Equatorial Pacific (Bradshaw, 1959, p. 36, pl. 6, figs. 11–15). But comparison with specimens of this species indicates that they differ in the type of wall surface as well as in lacking the fragile lip over the aperture.

Globigerina obesa is rare in the Eniwetok core samples but is found both in the younger and older parts of the cores.

Globigerina eggeri Rhumbler

Globigerina eggeri Rhumbler, 1901, Nordische Plankton, pt. 14, Foraminiferen, p. 19, fig. 20 (in text).
Bé, 1959, Micropaleontology, v. 5, p. 83 (list), pl. 2, figs. 1–3.
Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 35, pl. 6, figs. 5, 8–10.
Globigerina dubia Brady (not Egger), 1884, *Challenger* Rept., Zoology, v. 9, p. 595, pl. 79, fig. 17.
Glibigerina cretacea Brady (not d'Orbigny), 1884, *Challenger* Rept., Zoology, v. 9, p. 596, pl. 82, fig. 10.

This species has been recorded from both the Atlantic and Pacific; it is widely distributed and usually abundant. It has been usually regarded as a warm-water form, but in the western Mediterranean (Todd, 1958, p. 181, 208, table 20) it seemed to be indicative of cold water, judging by the fact that its abundance fluctuates in conformity with the abundance of known cold-water forms. In addition, Bradshaw's observations (1959, p. 36, text fig. 10) support its cold-water affinities. The lack of agreement as to interpretation of temperature affinity of this species may be resolved when a more precise distinction is possible between it and certain variants of the known cold-water species *Globigerina pachyderma* (Ehrenberg) (F. L. Parker, written communication, Oct. 2, 1961).

As a fossil form, *Globigerina eggeri* probably does not extend very far back into geologic time. The two oldest authentic verifiable recorded occurrences seem to be one from the Pleistocene under the name of *G. dubia* Egger (Phleger, 1939, p. 1404, pl. 1, figs. 14, 15) and another under the name of *Globigerina concinna* Reuss (Cushman and Todd, 1945, p. 65, pl. 11, fig. 10) from the Miocene of Buff Bay, Jamaica.

The question of how far back *G. eggeri* ranges is tied up with the question of its evolutionary relationships. Although there are resemblances with various species, such as *G. dubia* Egger, *G. concinna* Reuss, and *G. ciperoensis* Bolli, I believe these are morphologic resemblances, not genetic relationships.

In the present suite of cores being studied, the closest affinity is shown with *Globorotalia* (*Turborotalia*) *acostaensis* Blow, but there seems to be no transition between it and *Globigerina eggeri*, and thus there is probably no genetic relationship between them. There may be a genetic relationship to *Globoquadrina altispira* (Cushman and Jarvis), particularly through its subspecies *globosa*, but that also seems a rather remote possibility, and the similarity may be one of form only. These two species are easily distinguishable by means of their apertural characteristics.

Specimens of *Globigerina eggeri* exhibit considerable variation. Number of chambers per final whorl ranges from 5 to 7. The central part composed of the early coils may be either raised or flat. The final chamber is often, but not always, abnormally small.

The species is found in the three Quaternary samples, and only rare specimens are found in two of the older samples, 4–10 and 27–15.

Globigerina conglomerata Schwager

Plate 291, figures 8, 9

Globigerina conglomerata Schwager, 1866, *Novara*-Exped., Geol. Theil, v. 2, p. 255, pl. 7, fig. 113.
Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 33, pl. 6, figs. 6, 7.
Banner and Blow, 1960, Cushman Found. Foram. Research Contr., v. 11, p. 7, pl. 2, fig. 3.
Globigerina venezuelana Hedberg, 1937, Jour. Paleontology, v. 11, p. 681, pl. 92, fig. 7.
Globigerina eximia Todd, 1957, U.S. Geol. Survey Prof. Paper 280-H, p. 300, pl. 78, fig. 8.
Globigerina altispira Cushman and Todd (not Cushman and Jarvis), 1945, Cushman Lab. Foram. Research, Spec. Pub. 15, p. 66, pl. 11, figs. 11, 12.

Globigerina conglomerata was described from the Neogene (undoubtedly Pliocene) of Kar Nicobar. Under this name it has been recorded from the Pliocene to the Recent, but under other names (see above synonymy) its recorded occurrences extend its range back at least into the Oligocene. It is probably connected with, that is, descended from, even older species of closely similar shape.

Bradshaw (1959) obtained specimens in plankton tows in the Pacific, and it has been recorded from Recent bottom sediments from off Bikini and in the Philippines.

Some of its fossil occurrences are from the upper Miocene of North Atlantic deep-sea cores, Miocene of Trinidad and Saipan, and Oligocene of Venezuela and the Dominican Republic.

This species is characterized by its large size and compact form which is nearly as thick as broad. The wall is heavy and coarsely cancellated. The aperture is open, a deep elongate area in the center of the ventral side. In some specimens the chambers overhang the umbilicus, extending over it. In other specimens the umbilicus exists merely as the area between the chambers where they fail to meet. Surrounding the umbilicus the wall is coarsely spinose. Three or four chambers are about equally spaced around the umbilicus in adults. The umbilical parts of the chambers are either rounded and bulging or pinched together.

An attempt was made to distinguish between *Globigerina conglomerata* and *G. venezuelana*, but comparison of topotypes of the former with the holotype of the latter made it clear that the distinction is very slight, easily overlooked, and probably should not be regarded as of specific rank. More fundamental than number of chambers in the final whorl (three in *G. venezuelana* and four in *G. conglomerata*) is the kind of umbilicus and the shape of the chambers as they border it. In *G. venezuelana* the umbilicus is triangular or round and the chambers are pinched and overhang the opening. In *G. conglomerata* the umbilical opening is elongate and the chambers are bulging but not overhanging. Also, the sutures seem less incised and hence the periphery less indented in *G. venezuelana* than in *G. conglomerata*. These distinctions, however, do not seem to hold true, and thus the two species are combined as one.

Globigerina conglomerata was found in all the samples. It is best represented and best preserved in the three Quaternary samples, but specimens from the older samples are also typical.

Globigerina rubescens Hofker

Plate 292, figure 1

Globigerina rubescens Hofker, 1956, Skr. Univ. Zool. Mus., kobenhavn, XV, p. 234, pl. 35, figs. 18–21.

Test small for the genus, composed of about two whorls, coiled in a spire of moderate height, periphery distinctly lobulate; chambers few, inflated, four composing a single whorl; sutures distinct, incised; wall thin, rather coarsely papillate, most Recent specimens pink in color; aperture umbilical, large in proportion to the size of the test, high arched, surrounded by a thin lip. Maximum dimension about 0.25 mm; height about 0.20 mm.

This minute species was described from deep-water samples from the eastern part of the Malayan Archipelago and has also been found elsewhere in the Pacific (F. L. Parker, written communication, Oct. 2, 1961).

It is found in some numbers in the finer fractions of the Eniwetok material and is distinctive in its high arched and relatively large aperture and generally by its pink color. Even in the pre-Quaternary samples several pink specimens were found. It is probably not restricted to the Quaternary because identical but obviously fossil specimens occur in sample 4–10.

Globigerina (Globorotaloides) hexagona Natland

Plate 292, figure 3

Globigerina hexagona Natland, 1938, Scripps Inst. Oceanography Bull., Tech. Ser., v. 4, no. 5, p. 149, pl. 7, fig. 1.
Hamilton, 1953, Jour. Paleontology, v. 27, p. 222.
Phleger, Parker, and Peirson, 1953, Swedish Deep-Sea Exped. Repts., v. 7, Sediment Cores, no. 1, p. 12, pl. 1, figs. 13, 14.
Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 36, pl. 6, figs. 11–15.
Parker, 1960, Tōhoku Univ. Sci. Repts., 2d ser. (Geology), Spec. v. 4, p. 77, text fig. 7 (map).
Globorotaloides suteri Bolli, 1957, U.S. Natl. Mus. Bull. 215, p. 117, pl. 27, figs. 9–13; p. 166, pl. 37, figs. 10–12.

This species was originally described from 884 meters off southern California and from the lower Pliocene of the Los Angeles Basin. Other records include the modern fauna from the Mid-Pacific seamounts, Recent sediments from the North Atlantic, and plankton hauls from the Pacific. Under the name of *Globorotaloides suteri* Bolli, the species has been reported as a fossil ranging from the middle Eocene up through the *Globigerinatella insueta* zone of the Miocene in Trinidad. An additional record, under the name of *Globorotaloides variabilis* Bolli (Bolli, 1957, p. 117, pl. 27, figs. 15–20), may be included questionably. *G. variabilis* is reported higher in the Trinidad section, beginning where *G. suteri* leaves off and extending its range upward through the Miocene.

Comparison of types has led me to combine these species as synonyms, using the earlier name, *hexagona*. The best distinguishing character of the species seems to be the cancellated wall surface, somewhat like that of *Globigerinoides sacculifer*. Rare specimens exhibit the bullalike small final chamber described by Bolli as one of the generic characters of *Globorotaloides*. Looking at the species in its entire range from middle Eocene to Recent, its evolution seems to have proceeded from fewer chambers (4½) to more chambers (6), from a thicker to a flatter test, and from a more compact to a more attenuated shape.

Specimens were found in all the Eniwetok core samples but never more than rarely.

The question of whether or not to accept the genus *Globorotaloides* and if accepted whether to rank it as a genus or subgenus rests on whether there is a generic distinction between an aperture opening directly into the umbilicus and an aperture that extends from the umbilicus along the base of the final chamber to or toward the periphery.

As has been discussed above, no satisfactory answer to this question seems to have been found, apparently because of the transitional nature of virtually all morphologic characters in Foraminifera. Because of this transitional nature generic distinctions, as well as distinctions at other levels, must be arbitrarily made. It is chiefly a matter of convenience to have such a category as *Globorotaloides* for specimens which in effect start out like *Globorotalia* with an aperture extending from umbilicus to periphery and end up like *Globigerina* with a wholly umbilical aperture. Such a category stands in the gap between the genera *Globigerina* s. s. and *Globorotalia* s. s. and their respective families Globigerinidae and Globorotaliidae. It would seem the best solution, if only a temporary one, to regard *Globorotaloides* as a subgeneric category within the genus to which it seems most closely related. Hence, it is here placed as a subgenus under *Globigerina*.

Globigerina (Beella) digitata Brady

Globigerina digitata Brady (part), 1884, *Challenger* Rept., Zoology, v. 9, p. 599, pl. 80, figs. 6–10 (not pl. 82, figs. 6, 7).
Phleger, Parker, and Peirson, 1953, Swedish Deep-Sea Exped. Repts., v. 7, Sediment Cores, no. 1, p. 12, pl. 1, figs. 9, 10.
Parker, 1958, Swedish Deep-Sea Exped. Repts., 1947–48, v. 8, pt. 2, no. 4, p. 276, pl. 5, fig. 8.
Hastigerinella digitata (Brady). Bolli, Loeblich, and Tappan, 1957, U.S. Natl. Mus. Bull. 215, p. 32, pl. 5, fig. 3.
Globorotalia (*Hastigerinella*) *digitata* (Brady). Banner and Blow, 1959, Palaeontology, v. 2, pt. 1, p. 16, text fig. 4e.
Globorotalia (*Beella*) *digitata* (Brady). Banner and Blow, 1960, Micropaleontology, v. 6, no. 1, p. 26, text fig. 11.

This species, apparently not known as a fossil, was originally described from 1,990 fathoms in the South Atlantic (*Challenger* sta. 338). Its other recorded occurrences are from the South Pacific, North Atlantic, eastern Mediterranean, and the East Indies. Only three specimens were found in one of the younger core samples from Eniwetok.

Genus GLOBOQUADRINA Finlay, 1947

Globoquadrina altispira (Cushman and Jarvis)

Plate 291, figures 4, 5

Globigerina altispira Cushman and Jarvis, 1936, Cushman Lab. Foram. Research Contr., v. 12, p. 5, pl. 1, figs. 13, 14.
Phleger, Parker, and Peirson, 1953, Swedish Deep-Sea Exped. Repts., v. 7, Sediment Cores, no. 1, p. 11, pl. 1, figs. 1, 2, 6.
Globoquadrina altispira (Cushman and Jarvis). Bolli, Loeblich, and Tappan, 1957, U.S. Natl. Mus. Bull. 215, p. 31, pl. 5, fig. 4.
Hamilton and Rex, 1959, U.S. Geol. Survey Prof. Paper 260–W, p. 791 (footnote), pl. 254, figs. 1–3.
Globoquadrina altispira (Cushman and Jarvis) subsp. *altispira* (Cushman and Jarvis). Jenkins, 1960, Micropaleontology, v. 6, p. 355, pl. 3, fig. 5.

This species is characterized by rounded inflated chambers and a high spire. It has a deep widely open umbilicus and large valvelike flaps extending inward and covering the apertural area. The ventral part of each chamber tends to be flattened toward the axis of coiling, like the flattening of the final whorl of chambers in *Globigerinoides elongatus*. Variation in this species is chiefly in height of the spire and in the amount of flattening and inturning of the ventral parts of the chambers.

Globoquadrina altispira was originally described from the Miocene, Bowden marl, east of Port Antonio, Jamaica. Its other recorded occurrences are almost all from the Miocene, with the following localities being included: Haiti, Dominican Republic, Aruba, Trinidad, Venezuela, northern Colombia, northwestern Peru, Maryland, Balearic Islands, Italy, the Mediterranean region, 'Austria, Ukraine, Mid-Pacific mountains, Sylvania Guyot off Bikini, Saipan, Yap in the Caroline Islands, and Victoria, Australia. There are no Recent recorded occurrences for this species and it probably became extinct even before the Pliocene.

In the present Eniwetok core samples it occurs commonly in three of the five pre-Quaternary core sections, namely those from cores 20, 23, and 27 (samples at 15 and 25 cm), but it was not found in the other two, those from cores 4 and 18. On this basis the samples studied from the pre-Quaternary sections of cores 4 and 18 are interpreted as younger than the samples studied from the pre-Quaternary sections of cores 20, 23, and 27.

An exception to this restricted occurrence of *Globoquadrina altispira* was noted, a single small but typical specimen in the Quaternary material from 18–3. Its presence is regarded as accidental, possibly reworking of older material when the Quaternary deposit was laid down.

Globoquadrina altispira and *Globigerinoides sacculifer fistulosa* are nearly, with one rare exception, mutually exclusive in this series of samples. The conclusion that the samples with *Globoquadrina altispira* are older than those with *Globigerinoides sacculifer fistulosa* agrees with the Miocene age for the *altispira*-bearing samples that is indicated by the presence in all but one of them of *Globorotalia fohsi robusta.*

Globoquadrina altispira globosa Bolli

Plate 291, figure 7

Globoquadrina altispira globosa Bolli, 1957, U.S. Natl. Mus. Bull. 215, p. 111, pl. 24, figs. 9, 10.
Blow, 1959, Bull. Am. Paleontology, v. 39, no. 178, p. 183, pl. 11, fig. 52.
Ruggieri, 1960, Riv. Mineraria Siciliana, v. 11, no. 61, p. 14, text figs. 3, 4.

This subspecies was originally described from the Miocene of Trinidad. The range was indicated as extending both lower and higher than that of *G. altispira* s. s. but was shown as discontinuous in the middle part of its range. It has also been recorded from the Miocene of Venezuela and the lower Pliocene of Bonfornello, Palermo, Sicily.

The subspecies is separable from the typical form of the species on the basis of its more lobulate periphery, more open umbilicus, and the lack of pinched-together edges of the final chambers. Yet the umbilical teeth that are diagnostic of this genus are clearly visible in the subspecies *globosa.*

In the Eniwetok deep-sea core samples, specimens of *G. altispira globosa* are much fewer than those of *G. altispira* s. s. and apparently range somewhat higher than the typical form, but all are restricted to the pre-Quaternary sediments.

Genus GLOBIGERINOIDES Cushman, 1927

Globigerinoides conglobatus (Brady)

Plate 291, figures 3, 6

Globigerina conglobata Brady, 1884, *Challenger* Rept., Zoology, v. 9, p. 603, pl. 80, figs. 1–5; pl. 82, fig. 5.
Globigerinoides conglobatus (Brady). Bé, 1959, Micropaleontology, v. 5, p. 83 (list), pl. 2, figs. 7–12.
Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 40, pl. 7, figs. 5, 6.

This species was described from the North Atlantic. It is widely distributed and usually abundant in both oceans and is regarded as a warm-water form.

As a fossil the species has undoubtedly existed since the beginning of the Miocene but is probably not found in the Oligocene. Typical specimens, not even smaller than Recent ones, are recorded from the Miocene of the Dominican Republic and the Donni Sandstone Member of the Tagpochau Limestone of Saipan. In the present samples there seems to be no significant change from older to younger specimens, other than their increasing abundance in the younger samples. There is a considerable range of variation in size and in compactness of test and hence in size of apertures.

Globigerinoides elongatus (d'Orbigny)

Plate 291, figure 2

Globigerina elongata d'Orbigny, 1826, Annales sci. nat., v. 7, p. 277.
Fornasini, 1899, Accad. Sci. Ist. Bologna Mem., ser. 5, v. 7, p. 11, pl. 3, figs. 8–10.
Banner and Blow, 1960, Cushman Found. Foram. Research Contr., v. 11, p. 12, pl. 3, fig. 10.
Globigerinoides elongata (d'Orbigny). Cushman, 1941, Cushman Lab. Foram. Research Contr., v. 17, p. 40, pl. 10, figs. 20–23; pl. 11, fig. 3.
Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 368, pl. 91, fig. 5.
Todd, 1957, U.S. Geol. Survey Prof. Paper 280–H, p. 279 (table 3), pl. 78, fig. 9.
AGIP Mineraria, 1957, Foraminiferi Padani, Milan, pl. 46, fig. 2.

This species was described from the Adriatic near Rimini and as a fossil (probably Pliocene) from Castel Arquato, Italy. Its only Recent recorded occurrences are from the Adriatic and from off Bikini in the Marshall Islands. As a fossil it has been reported from the Pliocene and Pleistocene of Sicily, the Tortonian to Quaternary of Italy, and the Miocene of Saipan.

In the Eniwetok deep-sea core samples this species is better represented than is *Globigerinoides ruber* (d'Orbigny); that is, it is more abundant, and there are more typical specimens. There is a wide range of variation in the following features: size of test, size of apertures, height of spire, looseness of coiling in spire, and degree of flattening or inflation of later chambers.

The variable height of the spire or, stated another way, the sharpness or bluntness of the spire in *G. elongatus* is probably not of stratigraphic or taxonomic value. Banner and Blow (1960a, p. 13) stated that the important characters are "the high but equidimensional primary aperture, the shape and position of the supplementary apertures, the tightly coiled and relatively uninflated chambers and the characteristically thick and rough wall."

Globigerinoides elongatus seems to stand about midway between *G. conglobatus* and *G. ruber*. Even more than its high-spired coiling from which it takes its name, its distinguishing feature is the flattening of the final several chambers. This flattening suggests the flattened chambers of *G. conglobatus*, but in that species the plane of flattening is at right angles to a radius of the nearly spherical or boxlike shape of the whole test. In *G. elongatus*, on the other hand, the flattening is at an angle to the axis of coiling of the test. Moreover, when several of the final chambers are flattened, their several planes are all at the same angle to the axis as well as at angles to each other that correspond to the degree of revolution around the axis at which each succeeding chamber is built.

Another closely similar species, but one not found in the Eniwetok deep-sea core samples, is *Globigerinoides mitra* Todd. It is distinguished from *G. elongatus* in that its final chambers are globular, not flattened. Also, because there is no flattening in *G. mitra*, its initial spire sits neatly on the subsequent whorls, which results in the whole test being shaped like a cherry-topped dessert.

Globigerinoides ruber (d'Orbigny)

Plate 291, figure 1

Globigerina rubra d'Orbigny, 1839, *in* De la Sagra, Histoire physique, politique, et naturelle de l'Île de Cuba, Foraminifères, p. 82, pl. 4, figs. 12–14.

Globigerinoides ruber (d'Orbigny). Bé, 1959, Micropaleontology, v. 5, p. 83 (list), pl. 2, figs. 16, 17.

Globigerinoides rubra (d'Orbigny). Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 42, pl. 7, figs. 12, 13.

This species, described from off Cuba, has been recorded from both the Atlantic and Pacific and is widely distributed and usually abundant. It is regarded as a warm-water form. The red color from which the species takes its name is frequently but not invariably present in the earlier whorls but is found only in the Atlantic specimens and not in those from the Pacific. However, some specimens from sample 27–8 show a faint pink color.

As a fossil, *Globigerinoides ruber* probably does not extend as far back into the Miocene as most of the other common Recent planktonic species. Banner and Blow (1960a, p. 21) state its range to be Burdigalian to Recent. They regard its ancestral form to be *G. subquadratus* Bronnimann (now considered as a subspecies, *G. ruber subquadratus*) whose range is stated to be from middle Aquitanian to Burdigalian. In our collections we have typical specimens of *G. ruber* from the Miocene of Buff Bay, Jamaica, the Miocene of Spain, and the Burdigalian of the Balearic Islands. Specimens identified as such from the Miocene of Saipan are not good; although a few of them may be included in *G. ruber*, others belong in *G. elongatus* and *G. subquadratus*.

At Eniwetok this species is not well represented. Except in one Quaternary sample (27–8), specimens are hard to find and are not typical; that is, the spire is low and compact in this respect tending to be more like *G. subquadratus*.

The species is triangular in shape and has a distinct spire. The apertures are about equal in height and width. The range of variation is considerable in the following features: size of test, size of apertures, height of spire, looseness of coiling, and inflation of chambers. In some specimens the later chambers are slightly flattened, in this respect tending toward *G. elongatus*.

Globigerinoides sacculifer (Brady)

Plate 290, figures 7, 8

Globigerina sacculifera Brady, 1877, Geol. Mag. [Great Britain], dec. 2, v. 4, p. 535.

Brady, 1884, *Challenger* Rept., Zoology, v. 9, p. 604, pl. 80, figs. 11–17; pl. 82, fig. 4.

Globigerinoides sacculifer (Brady). Bé 1959, Micropaleontology, v. 5, p. 83 (list), pl. 2, figs. 13–15.

Globigerinoides sacculifera (Brady). Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 42, pl. 7, figs. 14, 15, 18.

This species was originally described from fossil material, a chalky deposit of the New Britain group in the Bismarck Archipelago, although at the time Brady recognized that the same form did exist commonly in many deep-sea dredgings. It has been recorded from both Atlantic and Pacific as widely distributed and usually abundant. It is a warm-water form.

Globigerinoides sacculifer extends back as a fossil into the Miocene, but I doubt that any typical specimens are to be found in the Oligocene. The species probably evolved from *G. trilobus* (Reuss) within the Miocene. Typical specimens of *G. sacculifer* occur in the Miocene of Buff Bay, Jamaica; the middle Miocene of Ecuador and of the Dominican Republic; and the Pliocene of Java. In the Miocene of Saipan, the Donni Sandstone Member of the Tagpochau Limestone, typical specimens are found, although those having the flattened final chamber are relatively fewer than those lacking it.

In the Eniwetok core samples the specimens are abundant and well developed except in 20–13 where they are less frequent than elsewhere but still typical.

Range of variation in this species is wide in the following features: (a) Size of entire test, (b) size of test before addition of the final flattened chamber, (c) size, shape, and position of the flattened chamber, (d) size of apertures, and (e) coarseness of cancellation of wall.

The proportion of specimens that have the characteristic flattened final chamber to those in which the final chamber is globular, as in *G. trilobus*, is greater in the younger samples. The size of the dorsal supplementary apertures also seems to increase in the younger samples.

Globigerinoides sacculifer fistulosa (Schubert)

Plate 290, figure 6

Globigerina fistulosa Schubert, 1910, K. k. geol. Reichsanstalt Verh., no. 14, p. 324, text fig. 2.
  Schubert, 1911, K. k. geol. Reichsanstalt Abh., v. 20, pt. 4, p. 100, text fig. 13.
Globigerinoides sacculifera (H. B. Brady) var. *fistulosa* (Schubert). Cushman, 1933, Cushman Lab. Foram. Research, Spec. Pub. 5, pl. 34, fig. 6.
  Boomgaart, 1949, Thesis, Univ. Utrecht, p. 141, pl. 10, fig. 7.
  Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 369, pl. 91 fig. 13.
  Hamilton and Rex, 1959, U.S. Geol. Survey Prof. Paper 260–W, p. 792, pl. 254, fig. 14.

Besides the above-listed illustrated references, the only other recorded occurrences of this form in the literature seem to be the following three: (1) *Globigerina* marl, Riukiu Island (Hanzawa, 1925, p. 42 [table]); (2) Pliocene, near Ngimbang, East Java (van der Sluis and de Vletter, 1942, p. 1014 [list]); and (3) "Plio-Pleistocene" of West Seran, island of Ceram, Indonesia (Valk, 1945, p. 27).

Of all the recorded occurrences, the only Recent ones are those in Cushman (1933) and Cushman and others (1954), all of which are suspect as to their Recent origin as discussed as follows.

The specimen illustrated by Cushman (1933, pl. 34, fig. 6) has recently been located in the U.S. National Museum collections, together with five others from nearby samples in the Tuamotu Island group in the South Pacific. Complete data for these six hitherto unpublished specimens are listed below, as quoted from the original dredging records (Townsend, 1901, p. 472–474):

Albatross H 3866, 17°17′00″ S., 145°45′30″ W., 804 fms., glob. oz. mang. (two specimens; one illustrated in Cushman, 1933, pl. 34, fig. 6)
Albatross H 3878 16°13′00″ S., 143°48′00″ W., 987 fms. glob. pter. vol. parts. (one specimen)
Albatross H 3881, 15°54′00″ S., 143°06′00″ W., 1,568 fms., glob. oz. mang. (two specimens)
Albatross H 3919, 19°45′30″ S., 139°54′00″ W., 1,494 fms., glob. oz. mang. (one specimen)

Because of the presence of manganese in three of these bottom samples of *Globigerina* ooze and of volcanic particles in the other, the strictly Recent origin of these specimens is to be doubted.

Because the specimens reported by Cushman and others (1954, p. 369, pl. 91, fig. 13, table 5) are all from short deep-sea cores on Sylvania Guyot, their strictly Recent origin is likewise to be doubted. Hence, there remain no verifiable Recent occurrences of this form, and the way is clear for postulating that it is a Pliocene or Pleistocene marker, and that it became extinct before the Recent.

This species was first mentioned and figured in a paper on a *Globigerina* marl of New Guinea. This first mention included the statement that the species was known from Siminis auf Djaul in the Bismarck Archipelago, where it was subsequently described the following year and reported to be common.

The recorded occurrences, none older than late Miocene if as old, include the following localities: Tuamotu island group; Sylvania Guyot off Bikini; Mid-Pacific mountains; New Guinea; Siminis auf Djaul in Bismarck Archipelago; Bodjonegoro in Java; occurrence near Ngimbang in East Java; West Seran, island of Ceram, Indonesia; and Riukiu Islands.

A specimen (Cushman colln. 14124) from the Miocene of Buff Bay, Jamaica, illustrated under the name of "*Globigerinoides sacculifera* (H. B. Brady)" (Cushman and Jarvis, 1930, pl. 34, fig. 4), is quite typical of the fistulose form of *G. sacculifer*. Despite the authors' statement that "the figured specimen * * * is a characteristic one," I found, in a further examination of about 500 specimens of *G. sacculifer* from this same sample, only 4 others with incipient fistulose extensions of the final chamber, none as well developed as the illustrated one.

Judging from its recorded occurrences, the subspecies *fistulosa* probably came into existence sporadically in the upper Miocene, blossomed out briefly in the Pliocene, especially around the Pacific, and died out rapidly, probably before the end of the Pliocene.

In the Eniwetok core samples, this subspecies was found commonly in only one sample, 4–10. Rare and less well developed specimens were found in three others, 18–3, 18–15, and 27–15. Its very limited occurrence in this series of samples, which, in most other respects seems almost homogeneous, supports the probability of a very short-lived existence for this form.

Individual variation seems to show a complete transition from the typical form of *sacculifer*, having a single elongate and flattened saclike chamber without any peripheral extensions, to the extreme development of fistulosity where as many as the final five chambers all show fistulose extensions at their outer ends.

It is curious that, so far as planktonic Foraminifera are concerned, the development of fistulosity seems to be strictly limited to this one species and has not been observed in any other. Amongst benthonic Foraminifera the fistulose character appears in many species, especially of the Polymorphinidae, yet at the same time seems to have no stratigraphic or taxonomic value as it does in *Globigerinoides sacculifer*.

Genus GLOBIGERINITA Bronnimann, 1951

Globigerinita glutinata (Egger)

Globigerina glutinata Egger, 1893, K. bayer. Akad. Wiss. Munchen, Math-naturh. Abt., Abh., Kl. 2, v. 18, p. 371, pl. 13, figs. 19–21.

Rhumbler, 1911, Ergebnisse Plankton-Exped. Humboldt-Stiftung, v. 3, p. 148–149, pl. 29, figs. 14–26.

Globigerinita glutinata (Egger). Phleger, Parker, and Peirson, 1953, Swedish Deep-Sea Exped. Repts., v. 7, Sediment Cores, no. 1, p. 16, pl. 2, figs. 12–15.

Bé, 1959, Micropaleontology, v. 5, p. 83 (list), pl. 1, figs. 25, 26.

Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 40, pl. 7, figs. 7, 8.

Globigerinita naparimaensis Bronnimann, 1951 Cushman Found. Foram. Research Contr., v. 2, p. 18, text figs. 1–14.

Conato, 1954, Riv. Italiana Paleont. Strat., v. 60, no. 1, p. 30, pl. 3, figs. 1–12.

Drooger, 1956, Micropaleontology, v. 2, p. 192, pl. 1, fig. 24.

Bolli, Lœblich, and Tappan, 1957, U.S. Natl. Mus. Bull. 215. p. 37, pl. 8, figs. 1, 2.

Drooger and Kaasschieter, 1958, Koninkl. Nederlandse Akad. Wetensch. Verh., Afd. Natuurk., ser. 1, v. 22, p. 85, pl. 4, fig. 18; pl. 5, fig. 18.

Bermudez, 1960, Soc. Ciencias Nat. La Salle Mem., v. 20, no. 55, p. 68, pl. 1, figs. 29, 30.

Globigerinita naparimaensis naparimaensis Bronnimann. Blow, 1959, Bull. Am. Paleontology, v. 39, no. 178, p. 206, pl. 15, fig. 99.

Globigerina (*Globigerinita*) *naparimaensis* (Bronnimann). Drooger, 1953, Cushman Found. Foram. Research Contr., v. 4, p. 142, pl. 24, fig. 20.

Globigerinita incrusta Akers, 1955, Jour. Paleontology, v. 29, no. 4, p. 655, pl. 65, fig. 2.

Globigerinita naparimaensis incrusta (Akers). Blow, 1959, Bull. Am. Paleontology, v. 39, no. 178, p. 206, pl. 15, figs. 100, 101.

Tinophodella ambitacrena Lœblich and Tappan, 1957, Washington Acad. Sci. Jour., v. 47, p. 114, text figs. 2, 3.

This species was originally described from deep-water samples taken by the *Gazelle* Expedition from off West Africa, Australia, and New Guinea. It has been widely recorded in both oceans.

Egger's original description of *Globigerina glutinata* includes no indication that he saw or recognized any bullae. However, the rest of the picture fits very well; three chambers of nearly equal size, small size of test (0.22 mm), delicate and dull glistening surface as compared with the coarse porous wall of *G. triloba.*

Bronnimann, in describing the genus *Globigerinita*, made no comparative or other reference to *Globigerina glutinata.* It was Parker in 1951 (reported by Hamilton, 1953, p. 226) who first transferred Egger's species into the genus *Globigerinita* on the basis of Rhumbler's good figures of *Globigerina glutinata* in which the presence of a bulla can be clearly seen.

I see no good specific distinctions between *Globigerinita naparimaensis* from the Miocene of Trinidad (the type species of *Globigerinita*) and *G. glutinata.* I would also combine *G. incrusta* from the Miocene of Louisiana with *G. glutinata.* Among the Eniwetok specimens I see examples of both these kinds: *naparimaensis* having multiple apertures all along the edges of the bulla and *incrusta* having apertures only at the ends of the extensions of the bulla along the sutural grooves. I doubt these are specific distinctions. In fact, they are much less easily recognized than the distinction between presence and absence of the bulla. In about half the specimens of *G. glutinata* the bulla is lacking.

As indicated by the preceding synonymy, I interpret *Globigerinita glutinata* as a species ranging from the Miocene with little if any evolutionary change between Miocene and Recent. Other reported fossil occurrences are the Pliocene of Italy and the Miocene of Venezuela, Aruba, and Morocco. Good specimens were found in all the Eniwetok samples.

Loeblich and Tappan (1957, p. 112) observed that among the type specimens of the type species of *Globigerinita* (namely *G. naparimaensis* Bronnimann) were some specimens in which the final chamber was modified to extend over the umbilicus as a bulla, whereas in other specimens the bulla consisted of a separate supplementary plate over the umbilicus. On this basis they emended *Globigerinita* to include only those having a modified final chamber and erected another genus for those having the separate supplementary plate. I repudiate this emendation as an unnatural and unnecessary subdivision of what is essentially a single species.

Globigerinita humilis (Brady)

Plate 290, figure 3

Truncatulina humilis Brady, 1884, *Challenger* Rept., Zoology, v. 9, p. 665, pl. 94, fig. 7.

Valvulineria cf. *humilis* (H. B. Brady). Phleger and Parker, 1951, Geol. Soc. America Mem. 46, pt. 2, p. 25, pl. 13, figs. 9, 10.

Valvulineria humilis (H. B. Brady). Phleger, Parker, and Peirson, 1953, Swedish Deep-Sea Exped. Repts., v. 7, Sediment Cores, no. 1, p. 40, pl. 8, figs. 31, 32.

Globigerina lamellosa Terquem. Rhumbler, 1911, Ergebnisse Plankton-Exped. Humboldt-Stiftung, v. 3, p. 149, pl. 30, figs. 1–6.

Globigerinita parkerae Loeblich and Tappan, 1957, Washington Acad. Sci. Jour., v. 47, no. 4, p. 113, text fig. 1.

This minute and distinctively shaped species was originally described from deep-water samples from the North Atlantic and South Pacific. It has also been recorded from the Gulf of Mexico. It is apparently widely distributed in both oceans but is often overlooked because of its small size. I know of no recorded fossil occurrences.

It seems not to have been taken in plankton hauls, and there may be some doubt that this species floats during life, or at least that it floats very much above the sea bottom.

In some specimens the final chamber has a simple lobe, in others a multifingered one. *Globigerinita humilis* seems to be related to *Globigerina quinqueloba* Natland, particularly in view of the fact that some specimens in that species have been found (Parker, 1958, pl. 6, fig. 2) possessing a bulla.

At Eniwetok, *G. humilis* has been found in all the younger and in all but two of the older samples.

Genus GLOBIGERINELLA Cushman, 1927

Globigerinella aequilateralis (Brady)

Plate 290, figure 5

Globigerina aequilateralis Brady, 1884, *Challenger* Rept., Zoology, v. 9, p. 605, pl. 80, figs. 18–21.

Globigerinella aequilateralis (Brady). Bé, 1959, Micropaleontology, v. 5, p. 83 (list), pl. 1, figs. 19, 20, 27.

Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 38, pl. 7, figs. 1, 2.

Globigerina aequilateralis Brady var. *involuta* Cushman, 1917, U.S. Natl. Mus. Proc., v. 51, p. 662; 1919, v. 56, p. 622.

Cushman, 1921, U.S. Natl. Mus. Bull. 100, v. 4, p. 294, text fig. 11.

Globigerina (*Globigerinella*) *involuta* Cushman. Hofker, 1956, Skr. Univ. Zool. Mus., Kobenhavn, XV, p. 224, pl. 33, figs. 33, 34.

Globigerinella aequilateralis (Brady) forma *involuta* (Cushman). Boltovskoy, 1959, Argentina Serv. Hidro. Naval, Pub. H1005, p. 112, pl. 19, fig. 7.

This species was described from the Atlantic and the Pacific, and the type is from the North Pacific. It has been recorded as widely distributed and is regarded as a warm-water form.

Fossil occurrences recorded in the literature indicate that it is well represented back through the Miocene with a worldwide distribution in the equatorial regions. Judging by the illustrations, its existence before the Miocene should be questioned. Foraminifera collections of the U.S. National Museum include specimens from the following ages and localities: Early Miocene of Ecuador; late Miocene of Buff Bay, Jamaica, and of the Dominican Republic; Miocene of Aruba; Miocene, Donni Sandstone Member of the Tagpochau Limestone of Saipan; and Pliocene of Java and Fiji.

It is of interest that Hofker (1956, p. 224) believes that the Indonesian species of *Globigerinella* are specifically different from the Atlantic ones, the Indonesian ones belonging in *G. involuta* (Cushman), and the Atlantic ones in *G. aequilateralis* (Brady). His reasons for distinction are as follows: *G. involuta* is of smaller size than *G. aequilateralis* (0.70 mm instead of 1.2 mm); finer pores in *G. involuta* and presence of distinct pustules between the pores in *involuta*, whereas the surface of *aequilateralis* is nearly smooth; last-formed chamber never uncoiling in *involuta;* and aperture in *involuta* more nearly closed and having an irregularly fringed border.

One might be more convinced of the reasonableness of such a separation if it could be observed to be actually a geographic separation. But instead, involute specimens are known in the Atlantic as well as in the Pacific. And the more evolute ones occur in the same region and in some of the same samples with those described as the involute variety (Cushman, 1921, p. 293–294), only less abundantly. Moreover, the bulging involute ones do not have the irregular fringe on the aperture, as Hofker specified that they do. A better interpretation of the involute specimens is that they are one end of a gradational series, a forma if it is necessary to distinguish them by name.

The combining of *Globigerinella* with *Hastigerina* (Bolli and others, 1957, p. 29) was done without a logical basis, overlooking the major difference in kind of spines as of no account. As far as shape of test, type of coiling, and position of aperture are concerned, there are no means of distinction between *Globigerinella* and *Hastigerina;* but the kind of spines is significant of distinction at a higher rank than merely specific. Thus *Globigerinella* is retained as a distinct genus.

Globigerinella adamsi (Banner and Blow)

Hastigerina (*Bolliella*) *adamsi* Banner and Blow, 1959, Palaeontology, v. 2, pt. 1, p. 13, text figs. 4a–d.

Banner and Blow, 1960, Micropaleontology, v. 6, no. 1, p. 24, text figs. 4a–c.

Globigerina digitata Brady (part), 1884, *Challenger* Rept., Zoology, v. 9, p. 599, pl. 82, figs. 6, 7 (not pl. 80, figs. 6–10).

Hastigerinella digitata (Brady). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 369, pl. 91, figs. 9, 10.

Globigerinella sp. Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, pt. 2, p. 38, pl. 7, figs. 3, 4.

This species was originally described from 580 fathoms off the Kei (Ewab) Islands in the East Indies (*Challenger* sta. 191A). It has been recorded from the South Atlantic, the South Pacific, off Bikini, and the Equatorial and west-central Pacific. It has not been reported as a fossil and in the present suite of cores, is found only in the three Quaternary samples.

Parker (1958, p. 277) seems to have been the first to recognize that this species (represented by Brady's pl. 82, figs. 6, 7) is in reality a species of *Globigerinella*, though she did not name it or even list or illustrate it as *Globigerinella*.

By its general appearance, coiling, and wall surface, this is related to, and in fact transitional into *Globigerinella aequilateralis*.

When originally named, this species was designated as type species of the subgenus *Bolliella* of the genus *Hastigerina*. Discussion under that genus presents my reason for excluding from *Hastigerina* species formerly placed in *Globigerinella*. Hence, this species must be transferred to *Globigerinella*. Possibly one might use *Bolliella* as a subgenus under *Globigerinella* to include species with radially elongate chambers, but I see no advantage in doing so.

Genus **ORBULINA** d'Orbigny, 1839

Orbulina universa d'Orbigny

Orbulina universa d'Orbigny, 1839, *in* Barker- Webb and Berthelot, Histoire naturelle des Îles Canaries, Paris, v. 2, pt. 2, Foraminifères, p. 123, pl. 1, fig. 1.
Brady, 1884, *Challenger* Rept., Zoology, v. 9, p. 608, pl. 78; pl. 81, figs. 8–26; pl. 82, figs. 1–3.

This cosmopolitan species was originally described from the Canary Islands. Its occurrence is widespread, even in colder areas, but the species is generally regarded as an indicator of warm temperature. As a fossil, the species extends back into the Miocene (but not to the Oligocene) and occurs chiefly in the equatorial regions. Its most northern recorded fossil occurrences are Georges Bank, Netherlands, and Japan, and its most southern are northwest Peru, Angola, Natal, and Victoria, Australia. The geographic range of the species extends both farther north and farther south in Recent seas.

In the Eniwetok deep-sea core samples, specimens are best developed and most abundant in the three Quaternary samples, although the species was not absent from any of the samples.

Orbulina bilobata (d'Orbigny)

Globigerina bilobata d'Orbigny, 1846, Foraminifères fossiles du Bassin tertiaire du Vienne, p. 164, pl. 9, figs. 11–14.
Orbulina universa d'Orbigny var. *bisphaerica* LeRoy, 1941, Colorado School of Mines Quart., v. 36, no. 1, pt. 1, p. 44, pl. 1, fig. 3.
Orbulina bisphaerica (LeRoy). LeRoy, 1944, Colorado School of Mines Quart., v. 39, no. 3, pt. 1, p. 41, pl. 3, fig. 46; pt. 2, p. 91, pl. 3, fig. 20.
Orbulina universa d'Orbigny (part). Fornasini, 1899, Accad. Sci. Ist. Bologna Mem., ser. 5, v. 7, p. 12, pl. 4, figs. 8–11.

This species was described from the Miocene of the Vienna Basin and most of its recorded occurrences have been as a fossil. It has been reported from the Miocene of Germany, Italy, Sicily, Sardinia, Spain, Trinidad, St. Martin in the West Indies, northwest Peru, California, Gulf Coast of the United States, Java, Sumatra, Saipan, and Sylvania Guyot in the Marshall Islands. There have been three recorded occurrences from the Oligocene as follows: upper Oligocene, Cojimar formation of Cuba; middle and upper Oligocene of the Dominican Republic; and the upper Oligocene of the Naparima area of Trinidad. It has been recorded from the Pliocene of Java and Italy and the Pleistocene of Sicily. In the Recent it is very rare, and its occurrences may be merely as bilocular forms of *Orbulina universa* and not as true individuals of *O. bilobata*. Its only Recent recorded occurrences are from the Adriatic, from off Dunkerque, off West Africa, the Atlantic off northwest Spain, and a few bilocular specimens obtained from plankton hauls in the North and Equatorial Pacific (Bradshaw, 1959, p. 49, pl. 8, fig. 17).

Its existence throughout the Miocene and possibly in the Oligocene seems established. It seems to have declined in abundance and areal distribution since the Miocene but is not yet extinct. Actually, it might be better interpreted as a forma, as some authors have done.

Only rare specimens from pre-Quaternary (probably upper Miocene) parts of the Eniwetok cores were found.

Orbulina suturalis Bronnimann

Plate 290, figure 1

Orbulina suturalis Bronnimann, 1951, Cushman Found. Foram. Research Contr., v. 2, p. 135, text fig. II, figs. 1–15; text fig. III, figs. 3–8, 11, 13–16, 18, 20–22; text fig. IV, figs. 2–4, 7–12, 15, 16, 19–22; text fig. V (part).
Candorbulina universa Jedlitschka, 1934, Naturf. Ver. Brünn Verh., v. 65 (1933), p. 21, text figs. 1–7, 19, 21–23.
Cushman and Dorsey (part), 1940, Cushman Lab. Foram. Research Contr., v. 16, p. 41, pl. 8, figs. 1–7 [not figs. 8, 9].
Jenkins, 1960, Micropaleontology, v. 6, p. 357, pl. 3, fig. 11.
Orbulina universa d'Orbigny (part). Fornasini, 1899, Accad. Sci. Ist. Bologna Mem., ser. 5, v. 7, p. 12, pl. 4, fig. 7.
Orbulina universa d'Orbigny. Bolli, Loeblich, and Tappan, 1957, U.S. Natl. Mus. Bull. 215, p. 35, pl. 7, figs. 2, 5.

This species was first described from the Miocene of Czechoslovakia by Jedlitschka, who recognized it as generically distinct from *Orbulina universa*. It was subsequently redescribed from the Miocene of Trinidad by Bronnimann, who regarded it as only specifically distinct from *O. universa.*

Its occurrence is worldwide in the equatorial regions and its existence later than the Miocene is open to doubt. Its reported Miocene occurrences include the following localities: Czechoslovakia, Austria, Rumania, Ukraine, Italy, Sicily, Spain, Mallorca, Egypt, Angola, Brazil, Trinidad, Venezuela, coastal Ecuador, northwest Peru, Gulf Coast of the United States, Maryland, Eniwetok, Saipan, Yap, Sumatra, Australia, and Taiwan.

From the published recorded occurrences it does not seem to occur in post-Miocene deposits, although there are a few exceptions. Surely it is not as likely to be found in the post-Miocene as *O. bilobata* is, and it fairly certainly does not occur in the Recent except as accidental occurrences. The statement that it perhaps "has maintained a tenuous continuity up to the present" (Todd, 1958, p. 183) was made regarding its occurrence in deep-sea cores judged to be Pleistocene in the western Mediterranean. This statement has not found any other supporting evidence. Hence, *O. suturalis* appears to be a good indicator of the Miocene.

In the Miocene, all three forms (*O. suturalis*, *O. bilobata*, and *O. universa*) occur together. Probably *O. suturalis* appeared first and died out first; *O. bilobata* appeared about the same time but declined later than did *O. suturalis*, and rare specimens are still found in plankton; *O. universa* probably appeared a little later than the other two and is not even yet declining. This group of species could, with equal logic, be regarded as a single species, *O. suturalis*, having three subspecies, *suturalis* s. s., *bilobata*, and *universa*, as has been done by Colom (1954, p. 210, pl. 18, figs. 1–22).

In the Eniwetok deep-sea core samples, only a few specimens of *O. suturalis* were found and most are not distinctive.

Genus SPHAEROIDINELLA Cushman, 1927

Sphaeroidinella dehiscens (Parker and Jones)

Plate 289, figure 4

Sphaeroidina dehiscens Parker and Jones, 1865, Philos. Trans., p. 369, pl. 19, fig. 5.

Brady, 1884, *Challenger* Rept., Zoology, v. 9, p. 621, pl. 84, figs. 8–11.

Sphaeroidinella dehiscens (Parker and Jones). Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 49, pl. 8, figs. 21–23.

Sphaeroidina bulloides d'Orbigny var. *dehiscens* Parker and Jones. Banner and Blow, 1960, Cushman Found. Foram. Research Contr., v. 11, p. 35, pl. 7, fig. 3.

Originally described from the tropical Atlantic and the Indian Ocean, the lectotype (Banner and Blow, 1960a, pl. 7, fig. 3) is from 1,080 fathoms in the Equatorial Atlantic. The species is widely recorded in the Pacific and Atlantic Oceans but not in the colder waters.

There have been numerous recorded occurrences of this species from the Miocene to the Recent. Some of them are as follows: Miocene of Jamaica, Haiti, Venezuela, and coastal Ecuador, early to middle Miocene of northwest Peru, middle Miocene of Dominican Republic, late Miocene of Italy, Miocene of Saipan, late Miocene or early Pliocene of Indonesia, Pliocene to Miocene of Java, Pliocene of Panama and Lower California, Pliocene and Pleistocene of West Seran, early Pleistocene and Tertiary of Louisiana, and Pleistocene of Boston Basin.

The emendation of *Sphaeroidinella* (Banner and Blow, 1959, p. 14) to exclude species lacking supplementary dorsal apertures and the erection of the genus *Sphaeroidinellopsis* to include them are ill advised. First, the basis of generic distinction of these two genera does not hold strictly true even along specific lines, and second, even if the few exceptions could be disregarded as accidentals, the separation into two genera of what is a single evolutionary series with complete transitional forms seems to be an unnecessary complication.

Based on observations of specimens from the Eniwetok deep-sea core samples, it is true that most specimens of *Sphaeroidinella dehiscens* show open fissures on both dorsal and ventral sides of the test. And it is likewise true that most specimens of *S. kochi* show open fissures on the ventral side only. But it is furthermore true that specimens otherwise indistinguishable from *S. dehiscens* are found without the open dorsal fissures, and that specimens otherwise indistinguishable from *S. kochi* are found with open dorsal fissures. The length and degree of opening of the fissures varies greatly. The larger specimens normally show the greater amount of fissuring, and the smaller ones often appear as if formerly open fissures had been sealed over by deposition of shell material along the protruding edges of the fissure.

Sphaeroidinella dehiscens was found in all the Eniwetok core samples but less abundant and less well preserved in the pre-Quaternary ones.

Sphaeroidinella kochi (Caudri)

Plate 289, figures 5, 6

Globigerina spec., Koch, 1923, Eclogae geol. Helvetiae, v. 18, p. 355, text fig. 8.

Globigerina kochi Caudri, 1934, Tertiary deposits of Soemba, Amsterdam, p. 144.

Sphaeroidinella kochi (Caudri). Glaessner, 1943, Royal Soc. Victoria Proc., v. 55 (new ser.), pt. 1, p. 69 (list).
Todd, 1957, U.S. Geol. Survey Prof. Paper 280–H, p. 279 (table 3), pl. 79, fig. 6.
Sphaeroidinella seminulina kochi (Caudri). Blow, 1959, Bull. Am. Paleontology, v. 39, no. 178, p. 198, pl. 12, figs. 78, 79.
Globigerina grimsdalei Keijzer, 1945, Geog. geol. Mededeel., Physiog.-Geol. Reeks, Utrecht, ser. 2, no. 6, p. 205, text fig. 33.
Sphaeroidinella grimsdalei (Keijzer). Bolli, 1957, U.S. Natl. Mus. Bull. 215, p. 114, pl. 26, figs. 8–12.

Sphaeroidinella kochi was described from the "Young-Tertiary" of Kabu, Java, and probably had a worldwide distribution in the equatorial regions. It has been reported from the Miocene of Trinidad, Venezuela, and Saipan, the "Oligomiocene" of Cuba, and the Tertiary of Soemba. It probably became extinct before the Pliocene or, stated another way, evolved into *S. seminulina* (Schwager) before the Pliocene.

As compared with the morphological changes observed in *Pulleniatina obliquiloculata*, the changes in the *Sphaeroidinella* series are even more marked. In this series, from older to younger, the number of chambers per final whorl is reduced from 5 or 6 to 3, the outline of the test loses its flattened and lobulate character and becomes more spherical, the amount of fissuring for apertural openings is increased and tends to appear consistently on both sides of the test, with the result that ventral and dorsal sides are difficult to tell apart. Thus, unlike *Pulleniatina obliquiloculata* where the specimens from the older end of the series carry the same name as those at the younger end, three names have been assigned respectively to the specimens at the older, middle, and younger parts of the *Sphaeroidinella* series, namely, *S. kochi*, *S. seminulina*, and *S. dehiscens*. *S. disjuncta* appears not to belong in this evolutionary series, although it is generically related.

Only rare specimens were found in two of the probably upper Miocene core samples, slightly less lobed than those found in the Miocene of Saipan. *S. seminulina* is very poorly represented in the present material and what few specimens were found have been included as transitional forms with *S. kochi*.

Sphaeroidinella disjuncta Finlay

Plate 290, figures 2, 4

Sphaeroidinella disjuncta Finlay, 1940, Royal Soc. New Zealand Trans., v. 69, p. 469, pl. 67, figs. 224–228.
Hornibrook, 1958, Micropaleontology, v. 4, p. 34, pl. 1, fig. 15.
Sphaeroidinella rutschi Cushman and Renz. Phleger, Parker, and Peirson, 1953, Swedish Deep-Sea Exped. Repts., v. 7, Sediment Cores, no. 1, p. 18, pl. 2, figs. 20, 21.
Sphaeroidinella multiloba LeRoy. Hamilton and Rex, 1959, U.S. Geol. Survey Prof. Paper 260–W, p. 792, pl. 254, fig. 7.
Globigerina sp. C, Todd, 1957, U.S. Geol. Survey Prof. Paper 280–H, p. 302, pl. 78, fig. 4.
Globigerina sp. B, Todd and Low, 1960, U.S. Geol. Survey Prof. Paper 260–X, p. 849, pl. 262, fig. 8.

The species was originally described from the lower to upper Miocene of New Zealand. Hornibrook (1958, p. 34) subsequently gave the type level as Altonian stage of the lower Miocene.

Under other names, this species has been recorded from the Miocene of deep-sea cores in the North Atlantic; the Miocene, Donni Sandstone Member of the Tagpochau Limestone, of Saipan; Miocene well material from Eniwetok Atoll; and the upper Miocene of Sylvania Guyot, Marshall Islands.

By its distinctive surface covered with a coarsely reticulate pattern, this species is unlike all other species of *Sphaeroidinella*. Normally in this genus the wall is composed of two parts, an inner coarsely porous primary wall and an outer secondary layer or layers of calcareous material called the cortex, through which the pores are constricted and which results in the smooth shiny surface of fresh and well-preserved individuals. The relationship between these two kinds of *Sphaeroidinella* is strikingly revealed by the presence of the honeycomb primary wall, identical with that of *S. disjuncta*, that can often be observed inside of broken specimens of *S. dehiscens*. Further confirmation of its affinity with *Sphaeroidinella*, rather than with *Globigerina*, is provided by the fissurelike, rather than arched apertural openings in this species.

Sphaeroidinella disjuncta may prove to be a useful Miocene indicator. Specimens were found in only three of the pre-Quaternary (probably upper Miocene) core samples at Eniwetok.

Genus PULLENIATINA Cushman, 1927

Pulleniatina obliquiloculata (Parker and Jones)

Plate 289, figures 2, 3

Pullenia obliquiloculata Parker and Jones, 1865, Philos. Trans., p. 368, pl. 19, fig. 4.
Pulleniatina obliquiloculata (Parker and Jones). Bé, 1959, Micropaleontology, v. 5, p. 83 (list), pl. 2, figs. 4–6.
Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 49, pl. 8, figs. 19, 20.

This species was originally described from three localities, as follows: Abrohlos Bank, 260 fathoms; tropical Atlantic, 1,080 fathoms; and Indian Ocean, 2,200 fathoms. It has a worldwide distribution and is a warm-water indicator.

Recorded fossil occurrences of this species are few, as follows: Pleistocene of Fiji, upper Tertiary of Java, Tertiary of New Guinea, fossil material from Bismarck Archipelago, lower Pleistocene and Tertiary of Louisiana, Pliocene of England and Italy, and Miocene of Saipan (where the specimens look primitive). The only fossil specimens in the U.S. National Museum collections are three from the Pliocene of Java and three from the upper Miocene of the Dominican Republic.

Pulleniatina obliquiloculata apparently ranges from the Miocene to the present but with considerable changes in morphology. From older to younger some of these changes are (a) increase in size of test, (b) surface changing from grainy or sugary to smooth and polished (however, this may be related to mode of preservation), (c) from more evolute to more involute, (d) from early whorl protruding and easily visible to becoming nearly hidden, and (e) from sutures slightly depressed to becoming indistinct and nearly flush. The most distinctive features of *P. obliquiloculata* are the low curved broad aperture with thick inward-curved lips and, in Recent forms only, the shiny surface.

This species is found in all the Eniwetok deep-sea core samples.

Genus **CANDEINA** d'Orbigny, 1839

Candeina nitida d'Orbigny

Plate 289, figure 1

Candeina nitida d'Orbigny, 1839, *in* De la Sagra, Histoire physique, politique, et naturelle de l'Île de Cuba, Foraminifères, p. 108, pl. 2, figs. 27, 28.
Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 32, pl. 7, fig. 19.

Candeina nitida was described from Cuba and Jamaica and has been recorded from both Atlantic and Pacific waters. It is a warm-water form extending back as a fossil at least into the Miocene. Typical specimens have been reported from the Donni Sandstone Member of the Tagpochau Limestone of Saipan and the Gurabo Formation of the Dominican Republic, both Miocene in age.

In the present material, it is well represented in the three Quaternary samples but is rare and less well preserved in the pre-Quaternary samples. I have not observed any trends of different size or any other feature distinguishing earlier from later forms. In the younger specimens, the interiors seem to be empty or partly empty. In some the spires are high, in others they are almost buried within the three final chambers that make up most of the test.

Upon examination of two specimens described as the holotype and a paratype of *Candeina nitida* var. *triloba* Cushman (1921, p. 296, pl. 57, fig. 1), it is clear they do not belong in this genus but are both three-chambered specimens of *Orbulina*, probably *O. suturalis* Bronnimann. In describing them, Cushman noted their "rougher, more punctate surface." Their presence in *Albatross* D 5191 from the Philippines suggests that that sample may prove to be older than Recent or even than Quaternary.

Genus **HASTIGERINA** Thomson, 1876

Hastigerina pelagica (d'Orbigny)

Nonionina pelagica d'Orbigny, 1839, Voyage dans l'Amérique Méridionale, v. 5, pt. 5, Foraminifères, p. 27, pl. 3, figs. 13, 14.
Hastigerina pelagica d'Orbigny, sp. Brady (part), 1884, *Challenger* Rept., Zoology, v. 9, p. 613, pl. 83, figs. 1–4, 6 (not figs. 5, 7, 8).
Parker, 1958, Swedish Deep-Sea Exped. Repts., 1947–48, v. 8, pt. 2, no. 4, p. 280, pl. 6, fig. 15.
Bé, 1959, Micropaleontology, v. 5, p. 83 (list), pl. 2, figs. 21, 22.
Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 47, pl. 8, figs. 14, 15.
Hastigerina (Hastigerina) pelagica (d'Orbigny) emended. Banner and Blow, 1960, Micropaleontology, v. 6, p. 20, text fig. 1.
Hastigerina murrayi Thomson, 1876, Royal Soc. London Proc., v. 24, p. 534, pls. 22, 23.
Bolli, Loeblich, and Tappan, 1957, U.S. Natl. Mus. Bull. 215, p. 29, pl. 3, figs. 1–3.

This appears to be a cosmopolitan, though rare, species in oceanic regions. Only a single fragmentary specimen was found in sample 23–6. Although there are several reports of its existence in Miocene beds, none seem to be verifiable and Banner and Blow (1960b, p. 21) regard its range as no older than Pliocene. I have reexamined the specimens reported from the Miocene of Saipan and now believe them to be merely unusually thick individuals of *Globigerinella aequilateralis* (Brady).

The inclusion of *Globigerinella* as a synonym of *Hastigerina* by Bolli and others (1957, p. 29) is without a natural basis. It was done chiefly on the premise that the kinds of spines found on the respective type species of these two genera are merely manifestations of the expectable variability of ornamentation in planktonic genera and therefore without generic significance. On the contrary, the type species of *Hastigerina* (*Nonionina*) *pelagica* d'Orbigny possesses trigonally prismatic spines (see illustrations and discussion by Banner and Blow, 1960b, p. 25–26, text figs. 1, 5–8, 10; especially fig. 10) which are not distributed evenly over the test, whereas in the type species of *Globigerinella* (*Globigerina aequilateralis* Brady) the wall is completely covered by a fine spinosity, resembling that of *Globigerina bulloides*.

There appears to be no transition between the large trigonally prismatic spines and the fine spines, and the two kinds of wall surface found in these two genera are significant of a natural separation at an even higher rank than generic. Therefore *Hastigerina* and *Globigerinella* are maintained as separate genera.

Family GLOBOROTALIIDAE

Genus GLOBOROTALIA Cushman, 1927

There are several distinctions between *Globorotalia* and *Globigerina*, such as hispidity of the wall, size of pores, globularity of chambers, flatness or height of spire on the dorsal surface, shape and position of the aperture, and presence or absence of a peripheral keel. None of these can serve alone as a single fundamental distinction between these two genera. Indeed, it seems unlikely that any single feature can serve as an infallible guide as to where any particular species should be placed in a natural classification. On the contrary, it is probably true that generic distinction should be based on a combination of characters, some characters having greater importance than others but none alone being of diagnostic value.

Greater weight in classification should undoubtedly be given to presence or absence of a peripheral keel, angle, or imperforate band than to position of the aperture; that is, whether it extends from umbilicus to periphery or is confined to the umbilicus. The recommendation (Bolli and others, 1957, p. 20, 31, 39) that, after wall composition and structure, the apertural position is of prime importance in the classification of planktonics serves more to enforce an unnatural classification than to facilitate a natural one.

On the other hand, the thesis that "There is no 'philosopher's stone' in taxonomy, no infallible means by which we can arrange specimens into a perfectly natural order," discussed (Cifelli, 1960, p. 557) in connection with variation in some Jurassic lagenids, is in harmony with the facts observed about the planktonic species that fall in the transitional zone between typical globigerinids and typical globorotaliids.

In this transitional zone, subgeneric groupings of species within the broad genus *Globorotalia* have been proposed (Cushman and Bermudez, 1949), and suggested as being phylogenetically distinct, as follows:

Globorotalia s. s. for the typical forms of the genus with biconvex test and angular periphery;
Truncorotalia for forms having a planoconvex test with angled periphery; and
Turborotalia for forms having a thick globular test with a rounded periphery.

But even with these subdivisions there are species whose morphology makes their placement an arbitrary choice of one of these subgenera.

Obviously the subgenus *Turborotalia* is morphologically closer than either of the other two to the genus *Globigerina* whose distinguishing generic characteristics are the lack of a peripheral keel, band, or angle, and the umbilical position of the aperture.

The question of whether or not to recognize position of the aperture as a generic characteristic in the planktonics necessitates inquiry as to whether it holds true strictly along species lines or whether as a feature it is transitional. Judging by the present material being studied, it is my opinion that it is not transitional, and that it holds true fairly consistently along species lines, although there is no dearth of exceptions. But this latter observation is true of almost any statement about Foraminifera, except possibly wall composition.

If position of aperture, that is, whether it is wholly umbilical or is elongate, can be utilized as a character of generic importance, then it is convenient to have such a genus as *Globorotaloides*. However, it would seem more logical to regard it as a subgenus of *Globigerina* s. l. It is primarily related to *Globigerina* by its globular adult chambers and umbilical aperture. It is secondarily related to *Globorotalia* by its flat initial coiling and to the subgenus *Turborotalia* by its globular final chambers which lack any peripheral band or angle.

The subgenus *Beella* was erected (Banner and Blow, 1960b, p. 26) for those species of *Globorotalia* s. l. in which the adult chambers become radially elongate. Because of lack of a peripheral keel or angle, this genus is more closely related to *Globigerina* than to *Globorotalia.*

Thus we have between *Globorotalia* s. s. and *Globigerina* s. s. species which may be grouped in the following subgenera:

Globorotalia s. s.
Truncorotalia
Turborotalia
Beella
Globorotaloides
Globigerina s. s.

In order from top to bottom they become more like *Globigerina* in shape of chambers. The first two are keeled or angled; the third and fourth bluntly angled or completely globular; the fifth and sixth completely globular. Also in order from top to bottom they progressively lose the elongate aperture of *Globorotalia* s. s. and assume the high-arched and wholly umbilical aperture of *Globigerina* s. s. Provisionally, the first three are placed in *Globorotalia* s. l. and the last three in *Globigerina* s. l.

Globorotalia menardii (d'Orbigny)

Plate 294, figure 1

Rotalia menardii d'Orbigny, 1826, Annales sci. nat., v. 7, p. 273, no. 6; Modèles, no. 10.

Pulvinulina menardii (d'Orbigny). Brady, 1884, *Challenger* Rept., Zoology, v. 9, p. 690, pl. 103, figs. 1, 2.

Globorotalia menardii (d'Orbigny). Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 44, pl. 8, figs. 3, 4.

Bé, 1959, Micropaleontology, v. 5, p. 83 (list), pl. 1, figs. 1–3.

Rotalia menardii Parker, Jones, and Brady, 1865. Banner and Blow, 1960, Cushman Found. Foram. Research Contr., v. 11, p. 31, pl. 6, fig. 2.

This species was originally described from the Adriatic near Rimini and was probably derived from redeposited fossil material as it is not present in Recent sediments of the Mediterranean. Parker, Jones, and Brady, the next to refer to the species, recorded it from the Isle of Man and the lectotype selected by Banner and Blow came from their material.

Globorotalia menardii is a widespread warm-water species, occurring in both oceans. As a fossil it undoubtedly extends back into the Miocene, in the process grading into several subspecies, some of them ancestral (such as *G. menardii praemenardii* Cushman and Stainforth and possibly *G. archaeomenardii* Bolli) and some of them homologous (such as *G. menardii miocenica, G. menardii multicamerata*, and *G. menardii ungulata*). In addition there are transitional forms connecting *G. menardii* with *G. tumida.* The latter species, in its typical form and with its subspecies *flexuosa*, is a rather late development out of what can be called the *menardii-tumida* transitional form. Finally, as probably the latest development of all, is the form having fimbriate ornamentation around the keel. As such ornamentation has been observed on *G. menardii ungulata* as well as on *G. menardii* s. s., the form is regarded as a variety, not a subspecies.

The general course of evolution from Miocene to Recent in this group proceeds from a thick test with curved dorsal surface to a thinner and flatter test with plane dorsal surface and toward progressively less incised ventral sutures and more heavily limbate and raised dorsal sutures.

In its typical form, *G. menardii* is not well developed in the Eniwetok deep-sea cores, and specimens are rare. On the other hand, specimens that can be called the *menardii-tumida* transition form, distinguished by their proportionally thicker and less elongate shape, are fairly well developed and more abundant, particularly in the Quaternary samples (pl. 294, fig. 2).

Globorotalia menardii praemenardii Cushman and Stainforth

Plate 295, figure 2

Globorotalia praemenardii Cushman and Stainforth, 1945, Cushman Lab. Foram. Research, Spec. Pub. 14, p. 70, pl. 13, fig. 14.

Cushman and Bermudez, 1949, Cushman Lab. Foram. Research Contr., v. 25, p. 31, pl. 5, figs. 17–19; pl. 6, figs. 1–3.

Bolli, 1957, U.S. Natl. Mus. Bull. 215, p. 120, pl. 29, fig. 4.

Globorotalia menardii praemenardii (Cushman and Stainforth). Blow, 1959, Bull. Am. Paleontology, v. 39, no. 178, p. 215, pl. 18, fig. 118.

This early form of *Globorotalia menardii* seems better regarded as a subspecies. It was described from zone III (the upper or *Globorotalia fohsi* zone) of the Cipero Formation of Trinidad, at that time regarded as probably of late Oligocene age. Subsequent upward revision of age of the Trinidad section now places this zone in the Miocene. Blow (1959, p. 215, chart 1) and Stainforth (1960, p. 223, range chart) regard the ranges of both *G. praemenardii* and *G. fohsi* to be Burdigalian, whereas Drooger (1956, text fig. 1) indicates the *G. fohsi* zone to be of Vindobonian (upper Helvetian and lower Tortonian) age.

The form undoubtedly has a worldwide distribution in the equatorial regions and has been recorded from Cuba, Venezuela, and several localities in the Mediterranean region.

Typical specimens were found in only two of the Eniwetok core samples, 23–20 and 27–25, where it is associated with *Globorotalia fohsi robusta* (sample 23–20 only) and *Globoquadrina altispira* (both samples).

Globorotalia menardii multicamerata Cushman and Jarvis

Plate 293, figure 3

Globorotalia menardii (d'Orbigny) var. *multicamerata* Cushman and Jarvis, 1930, Jour. Paleontology, v. 4, p. 367, pl. 34, fig. 8.

Cushman and Bermudez, 1949, Cushman Lab. Foram. Research Contr., v. 25, p. 30, pl. 5, figs. 8–13.

Graham and Militante, 1959, Stanford Univ. Pubs., Geol. Sci., v. 6, no. 2, p. 115, pl. 19, fig. 7.

Hamilton and Rex, 1959, U.S. Geol. Survey Prof. Paper 260–W, p. 793, pl. 254, fig. 12.

Globorotalia multicamerata Cushman and Jarvis. Phleger, Parker, and Peirson, 1953, Swedish Deep-Sea Exped. Repts., v. 7, Sediment Cores, no. 1, p. 20, pl. 3, figs. 9, 12.

This form was originally described as a variety from the Miocene of Buff Bay, Jamaica, and the following additional ages and localities have been reported for this many-chambered subspecies of *Globorotalia menardii:* Miocene of Cuba and of deep-sea cores in the North Atlantic; late Miocene or possibly Pliocene of Sylvania Guyot, Marshall Islands; and Recent of the Philippines and deep water off Cuba. If the two Recent recorded occurrences can be eliminated as redeposited sediments, this subspecies can be established as a suitable Miocene-Pliocene marker.

The Eniwetok specimens are very rare and not wholly typical, but they trend toward this many-chambered form of *G. menardii* which apparently developed late in the Miocene and is probably extinct in Recent seas.

Globorotalia menardii miocenica Palmer

Plate 295, figure 4

Globorotalia menardii (d'Orbigny) var. *miocenica* Palmer, 1945, Bull. Am. Paleontology, v. 29, no. 115, p. 70, pl. 1, fig. 10.

Globorotalia menardii miocenica Palmer. Blow, 1959, Bull. Am. Paleontology, v. 39, no. 178, p. 216, pl. 19, fig. 121.

This form was originally described as a variety from the Miocene, Bowden Marl of Jamaica. It has been recorded, as a subspecies, from the uppermost part of the Miocene section in Venezuela.

Through the courtesy of Mrs. Katherine V. W. Palmer I have examined the holotype, deposited at the Paleontological Research Institution at Ithaca, and compared the Eniwetok specimens with it. None of the Eniwetok specimens are strictly identical with the type from Jamaica, the chief point of difference being the gently bowed dorsal surface of those from Eniwetok instead of the plane dorsal surface of the type. Other distinctions are the more nearly circular outline and the presence of a broad flange projecting out above the aperture in the Eniwetok specimens.

Nevertheless, a few specimens have been picked out as probably best identified as the subspecies *miocenica.* They are transitional to the subspecies *ungulata* on the one hand (but less extremely swollen) and, on the other hand, to the *menardii-tumida* transitional form (but having a less elongate and more nearly plano-convex shape).

Globorotalia menardii ungulata Bermudez

Plate 295, figure 3

Globorotalia ungulata Bermudez, 1960, Venezuela Ministerio de Minas e Hidrocarburos, Bol. Geol., Pub. Especial 3, p. 1304, pl. 15, fig. 6.

Globorotalia cf. *G. menardii* (d'Orbigny). Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 44, pl. 8, figs. 10–12.

This was described from dredgings off Cuba, in 615 fathoms, as a species distinct from *Globorotalia tumida* in its more delicate construction, thinner wall, and the more inflated and angular ventral face of the final chamber. It seems, however, in its overall construction to be rather closely related to *G. menardii* and is here regarded as a subspecies of that species, differing from the typical form in the configuration of the chambers on the ventral side. Each chamber is conspicuously higher than the previous one, with each one having a peak at its inner umbilical end. In addition, the final one has a blunt angle extending from its highest point at the umbilicus outward toward the periphery, where the angularity disappears into a smoothly rounded surface. In the previous chambers, this angle tends to be covered up by the overlapping of each later chamber but can be observed in the resulting deep indentation of sutures on the ventral side. The dorsal surface of this subspecies is more strongly convex as compared to the nearly flat surface of the typical form of *menardii.*

Because of their smaller than normal size for *G. menardii* and the fact that the test outline is more likely to be elongate than circular and because the wall is never coated with calcareous pustules, the possibility was considered that these specimens might be all immature individuals. But such a possibility is thought to be unlikely because no larger but similar forms were found which could logically be regarded as the corresponding adults.

This is the same form that Cushman distinguished from the typical form of *G. menardii* and labeled "var. *tumescens*" in his preliminary work in the 1930's on the tropical Pacific collections of the *Albatross*, 1899–1900, but this name was never published. Although the form occurs together with *G. menardii* s. s., its characters appear to be of subspecific rather than varietal rank. When the microenvironments in which Foraminifera live are more clearly understood, many forms that are found together may prove not to actually live together.

Besides its occurrence in the Caribbean-Antillean region, this subspecies apparently is widespread in the Pacific. It is well illustrated from Pacific plankton collections (Bradshaw, 1959, p. 44, pl. 8, figs. 10–12). In addition a species described from near the Hawaiian Islands, *Pulvinulina gilberti* Bagg, is probably identical (Bagg, 1908, p. 161, pl. 5, figs. 11–15). Examination of the figured cotypes reveals that only one remains unbroken. Hence, because all are almost completely buried in glue, it seems expedient to let this species remain in limbo where it has been for more than 50 years and to adopt the more recent name based on a well-preserved type specimen.

In the Eniwetok core material, it is fairly well developed but with many transitional forms tying it into the *G. menardii* complex. It is almost always smaller than *G. menardii* s. s.

Globorotalia menardii (d'Orbigny) var. fimbriata (Brady)

Pulvinulina menardii d'Orbigny var. *fimbriata* Brady, 1884, *Challenger* Rept., Zoology, v. 9, p. 691, pl. 103, fig. 3.

Globorotalia menardii (d'Orbigny) var. *fimbriata* (Brady). Cushman, 1931, U.S. Natl. Mus. Bull. 104, pt. 8, p. 94, pl. 17, fig. 2.

Cushman and Bermudez, 1949, Cushman Lab. Foram. Research Contr., v. 25, p. 30, pl. 5, fig. 7.

Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 370, pl. 91, fig. 20.

This beautifully ornamented form was described from Recent sands of the West Indies. It has been recorded from both oceans but never abundantly and is a warm-water indicator. Its only recorded fossil occurrence seems to be that of Schubert (1911, p. 111) who reported it as rare in one sample from Middle New Mecklenburg, in the Bismarck Archipelago.

The fimbriate ornamentation around the keel, on some specimens only faintly developed, was observed on specimens of *G. menardii* s. s. and *G. menardii ungulata*. Fimbriate specimens were found only in the three younger core samples.

Globorotalia tumida (Brady)

Plate 294, figure 3

Pulvinulina menardii d'Orbigny var. *tumida* Brady, 1877, Geol. Mag. [Great Britain], dec. 2, v. 4, p. 535.
  Banner and Blow, 1960, Cushman Found. Foram. Research Contr., v. 11, p. 26, pl. 5, fig. 1.
Pulvinulina tumida Brady, 1884, *Challenger* Rept., Zoology, v. 9, p. 692, pl. 103, figs. 4–6.
Globorotalia tumida (Brady). Phleger, Parker, and Peirson (part), 1953, Swedish Deep-Sea Exped. Repts., v. 7, Sediment Cores, no. 1, p. 22, pl. 3, figs. 3, 6.
  Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 47, pl. 8, figs. 9, 13.

Globorotalia tumida was originally described from fossil material, a chalky deposit of the New Britain group in the Bismarck Archipelago, although at the same time Brady noted that the same form existed commonly in many deep-sea dredgings. It has been widely recorded from both the Atlantic and the Pacific and is a warm-water indicator.

The verified recorded occurrences of *G. tumida* as a fossil include the Pliocene of Fiji and the Miocene, Donni Sandstone Member of the Tagpochau Limestone, of Saipan. But among the Saipan assemblages of *G. tumida* not many are typical; I now regard most of them as *G. menardii-tumida* transition forms.

Ericson and others (1961, p. 263) visualize *G. tumida* as a subspecies of *G. menardii* and recognize it as a distinctive form only in the uppermost layers of the Atlantic deep-sea cores (postglacial=zone z and last glacial=zone y), that is later than 65,000 years.

They visualize Phleger, Parker, and Peirson's "*G. menardii-tumida* group" as an interbreeding group which included, in the earlier zones (last interglacial= zones u and v, early part of last glaciation=zone w, and interstadial during last glaciation=zone x), three subspecies, namely *menardii*, *tumida*, and *flexuosa*, with an abundance of intermediate forms connecting the three. With the elimination of *flexuosa* in zone y, *menardii* and *tumida* began their coexistence with few intermediate forms and a distinctly bimodal pattern.

G. tumida was found in all the Eniwetok core samples but occurs abundantly in only one of the Quaternary ones. In the pre-Quaternary samples, it is both less typical and less abundant and is always rarer than the *G. menardii-tumida* transition form.

Globorotalia tumida flexuosa (Koch)

Plate 294, figure 4

Pulvinulina tumida Brady var. *flexuosa* Koch, 1923, Eclogae geol. Helvetiae, v. 18, p. 357, text figs. 9, 10.
Globorotalia tumida (Brady) cf. *G. tumida* var. *flexuosa* (Koch). Hamilton and Rex, 1959, U.S. Geol. Survey Prof. Paper 260–W, p. 793, pl. 254, figs. 8–10.
Globorotalia menardii (d'Orbigny) var. *flexuosa* (Koch). Boomgaart, 1949, Thesis, Univ. Utrecht, p. 145, pl. 10, fig. 9.
Globorotalia menardii flexuosa (Koch). Ericson, Ewing, Wollin, and Heezen, 1961, Geol. Soc. America Bull., v. 72, no. 2, p. 263, pl. 3.
Globorotalia tumida (Brady). Phleger, Parker, and Peirson (part), 1953, Swedish Deep-Sea Exped. Repts., v. 7, Sediment Cores, no. 1, p. 22, pl. 3, figs. 10, 11.

This distinctive form was originally described from the late Tertiary of Kabu, Java. It has not been reported from Recent material. Its recorded fossil occurrences include the upper Miocene or possibly Pliocene of Sylvania Guyot off the Marshall Islands; deep-sea cores of the North Atlantic; Pliocene near Ngimbang in East Java; Pliocene to Miocene at Bodjonegoro, Java; and Young Neogene of Central Seran and East Seran, island of Ceram.

Ericson and others (1961, p. 263) found this flexuose subspecies to be an abundant indicator for their zone x, warm interstadial in the last glaciation, between 95,000 and 65,000 years ago, in the Atlantic. They speculated that "presumably rigorous selection during the last ice age removed from the population the genes responsible for *G. menardii flexuosa*."

Flexuose specimens were not found in the Quaternary samples but were found in all the pre-Quaternary core samples; they were best developed in 27–15, 27–25, and 20–13. As these three samples are interpreted, from other evidence, as upper Miocene (or at the very youngest Pliocene), these Pacific flexuose specimens are not equivalent in time with those used to recognize one of the Pleistocene interstadial periods in the North Atlantic.

Globorotalia fohsi robusta Bolli

Plate 295, figure 1

Globorotalia fohsi robusta Bolli, 1950, Cushman Found. Foram. Research Contr., v. 1, p. 88, pl. 15, fig. 3.
  Bolli, 1957, U.S. Natl. Mus. Bull. 215, p. 119, pl. 28, fig. 16.
  Blow, 1959, Bull. Am. Paleontology, v. 39, no. 178, p. 213, pl. 16, fig. 114.

This subspecies was originally described from the upper part of the Cipero Formation of Trinidad, formerly placed in the Oligocene. Later Bolli (1957, p.

101, text fig. 18) designated *G. fohsi robusta* as one of the zone markers in that formation, the upper part of which was at that time regarded as Miocene in age.

The only recorded occurrences of this subspecies are from Trinidad and Venezuela, where it is narrowly restricted at the top of the range of *Globorotalia fohsi* s. l.

The age of the *Globorotalia fohsi robusta* zone, in terms of the standard European time scale, has been estimated variously. Blow (1959, p. 213, chart 1) shows it as equivalent to the upper part of the Burdigalian. From Stainforth's range chart (1960, p. 221), approximately the same equivalence may be interpreted. However, from Drooger's tentative correlation chart (1956, text fig. 1), the age of the *G. fohsi robusta* zone would fall within the Tortonian.

In several of the Eniwetok deep-sea core samples, specimens referable to *G. fohsi robusta* were found. Compared with the type specimens they seem to be identical. Their occurrence in sample 23–20, where they are associated with two other Miocene species, namely *Globoquadrina altispira* and *Globorotalia menardii praemenardii* is not surprising. But their occurrence in sample 18–3, which on other bases is presumed to be Quaternary is surprising. However, this occurrence is not the only anomalous occurrence in this sample; other extinct species found in 18–3, and not found in the other two younger samples, are *Globigerinoides sacculifer fistulosa*, *Globoquadrina altispira*, and *Orbulina suturalis*. Moreover, the mode of preservation and faint orange color of some of the specimens suggests mixing of older with younger specimens in this sample.

The resemblances between *Globorotalia fohsi* s. l. and *G. menardii* s. l. are many, but I believe these species belong to separate lineages and are not fundamentally related in their evolution. Their essential morphologic differences may perhaps be described as follows: In *G. fohsi* the chambers tend to be narrower, more elongate, and thicker than in *G. menardii* and, hence, the shape of the test is elongate and not lobulated. In contrast, the chambers of *G. menardii* are rounded and peripherally bulging but flat, resulting in a flatter more circular and somewhat lobulate test. In addition, the umbilicus in *G. fohsi* seems to be more constricted, with the apertural opening lower and narrower and the ventral parts of the chambers not much raised up around it. On the other hand, the opposite is true in *G. menardii* where the umbilicus is often an actual open depression or at least a slight depression with the inner ends of the chambers slightly bulging around it and with the aperture an arched opening rather than a narrow slit.

Globorotalia hirsuta (d'Orbigny)

Rotalina hirsuta d'Orbigny, 1839, *in* Barker-Webb and Berthelot, Histoire Nat. Îles Canaries, v. 2, pt. 2, Foraminifères, p. 131, pl. 1, figs. 37–39.

Globorotalia hirsuta (d'Orbigny). Phleger, Parker, and Peirson, 1953, Swedish Deep-Sea Exped. Repts., v. 7, Sediment Cores, no. 1, p. 19, pl. 4, figs. 1–7.

Bé, 1959, Micropaleontology, v. 5, p. 83 (list), pl. 1, figs. 4, 8.

Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 44, pl. 8, figs. 1, 2.

This species, described off the Canaries, has been recorded from Recent seas, both Atlantic and Pacific and probably extends back into the Miocene, at least the upper part. Some of its recorded fossil occurrences are: Miocene of Italy, upper Miocene to Pliocene of Azores, Vindobonian and Pliocene of Spain, Miocene of Saipan, and Pleistocene of Australia. It was found in all the Eniwetok deep-sea core samples, never more than rarely.

Globorotalia hirsuta has 4–4½ chambers in the final whorl. The ventral parts of the chambers are bulging but depressed at the umbilicus. The sutures are distinctly depressed, more so ventrally than dorsally. The wall is distinctly and densely porous with the hispidity increasing toward the apertural area, but the shell never becomes as heavily encrusted as that of *G. tumida*. There is no excess shell material, that is, no limbation, at the periphery. A distinct lip extends out over the aperture, which is a low opening. There is some variation in thickness of test and thickness of the wall.

Globorotalia (Truncorotalia) punctulata (d'Orbigny)

Plate 293, figure 1

Globigerina punctulata d'Orbigny, 1826, Annales sci. nat., v. 7, p. 277, no. 8.

Fornasini, 1898, Palaeontographia Italica, v. 4, p. 210, text fig. 5.

Globorotalia punctulata (d'Orbigny). Cushman, 1941 (part), Cushman Lab. Foram. Research Contr., v. 17, p. 41, pl. 10, fig. 25; pl. 12, fig. 1 (not pl. 10, fig. 24).

Phleger and Parker, 1951, Geol. Soc. America Mem. 46, pt. 2, p. 36, pl. 20, figs. 3–7.

Phleger, Parker, and Pierson, 1953, Swedish Deep-Sea Exped. Repts., v. 7, Sediment Cores, no. 1, p. 20, pl. 4, figs. 8–12.

Longinelli, 1956, Palaeontographia Italica, v. 49 (new ser. v. 19), Anni 1954–56, p. 181, pl. 15, fig. 16.

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Bé, 1959, Micropaleontology, v. 5, p. 83 (list), pl. 1, figs. 9–11.

Globorotalia puncticulata (d'Orbigny). Kane, 1953, The Micropaleontologist, v. 7, no. 3, p. 30, pl. 1, fig. 9.

Colom, 1954, Inst. geol. min. España Bol., v. 66, p. 217, pl. 19, figs. 18–25.

Colom, 1958, *in* Krejci-Graf, Frechen, Wetzel, and Colom, Senckenbergiana Lethaea, v. 39, no. 5/6, p. 339, pl. 5, figs. 22–24.

Pulvinulina crassa d'Orbigny, sp. Brady, 1884, *Challenger* Rept., Zoology, v. 9, p. 694, pl. 103, figs. 11, 12.

Globorotalia crassa (d'Orbigny). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 370, pl. 91, fig. 16.

This species, originally described from the Adriatic, off Rimini, is a worldwide species, an indicator of moderate temperatures. It seems never to be abundant. Some of its recorded fossil occurrences include the following: Miocene of Jamaica, Miocene and Pliocene of Spain, upper Miocene to Pliocene of the Azores, Pliocene and Pleistocene of Italy, Pliocene(?) and Pleistocene of Sicily, and lower Pleistocene of Louisiana.

In test morphology, *Globorotalia punctulata* is about halfway between *G. truncatulinoides* and *G. hirsuta*. It is planoconvex like *G. truncatulinoides* but without the deep open umbilicus; also the final chamber does not extend outward. It has only four chambers in the final whorl and the outline tends to be squarish rather than smoothly rounded. From *G. hirsuta*, which it resembles in chamber arrangement, it differs in being highly planoconvex. Also it has a rougher, beaded surface, especially over the earlier chambers. The periphery is blunt angled, not sharp angled as in *G. hirsuta*, and the outline is squarish, not lobulate as in *G. hirsuta*.

In the Eniwetok cores, *Globorotalia punctulata* is very rare and few, if any, specimens look convincingly Recent. Even in the Recent sediments of the Marshalls, the only reported occurrences are from the seamount where they could have had a pre-Recent origin. The species is, however, known from the Recent elsewhere and has been reported from Pacific plankton samples from the region south of about lat 35° S. (Parker, 1960, p. 79). Possibly it is locally extinct in the Equatorial Pacific.

Globorotalia (Truncorotalia) truncatulinoides (d'Orbigny)

Plate 293, figure 2

Rotalina truncatulinoides d'Orbigny, 1839, *in* Barker-Webb and Berthelot, Histoire naturelle des Îles Canaries, Paris, v. 2, pt. 2, Foraminifères, p. 132, pl. 2, figs. 25–27.

Globorotalia truncatulinoides (d'Orbigny). Bolli, Loeblich, and Tappan, 1957, U.S. Natl. Mus. Bull. 215, p. 41, pl. 10, fig. 3.

Bradshaw, 1959, Cushman Found. Foram. Research Contr., v. 10, p. 44, pl. 8, figs. 7, 8.

This widespread warm to temperate indicator was originally described from the Canary Islands. Whereas most of the common Recent planktonics seem to have originated in the Miocene, the recorded fossil occurrences of *Globorotalia truncatulinoides* suggest it was a relatively late comer. Most of the reported fossil occurrences are of Pleistocene age (western Victoria, Italy, cores from the continental slope in the western North Atlantic, and Boston Basin). I have been unable to verify a reported Miocene occurrence in the Bowden Formation of Jamaica but believe it may be suspect. This Miocene record of *G. truncatulinoides* is placed in doubt by the absence of the species from a facies favorable for its presence. The only other recorded occurrence from the Miocene is that of Grimsdale (1951, fig. 1), who indicated it extends back into the upper Miocene in the Gulf of Mexico and Caribbean areas but without notation as to exact localities. In the Mediterranean it is reported to be present only in the Quaternary and upper Pliocene (AGIP Mineraria, 1957, pl. 48, fig. 9), and in New Zealand it is reported to have appeared first in the Pliocene (Geiger, 1962, text fig. 2).

In light of the above, it would seem likely that *Globorotalia truncatulinoides* may prove to be one of the best available species for interpretation of age, being useful in planktonic facies both when present and when absent, (a) by its presence to serve as a marker for the Pleistocene and possibly upper Pliocene and (b) by its absence to serve as an indication of the Miocene, or possibly lower part of the Pliocene.

The restricted occurrence of this species to the three younger (Recent or Pleistocene) samples of the Eniwetok cores tends to support the postulated very late appearance of *G. truncatulinoides*.

Globorotalia (Turborotalia) acostaensis Blow

Plate 292, figure 5

Globorotalia acostaensis Blow, 1959, Bull. Am. Paleontology, v. 39, no. 178, p. 208, pl. 17, figs. 106, 107.

Jenkins, 1960, Micropaleontology, v. 6, p. 358, pl. 4, fig. 1.

This species was originally described from the Miocene, Pozón Formation, of eastern Falcón, Venezuela, and has been reported from the upper part (zones 10 and 11, down to about 450 ft) of the Miocene section penetrated by an oil shaft in Victoria, Australia. In Venezuela its range was reported to be high in the Miocene, probably Sarmatian, first appearing after the extinction of *Globorotalia mayeri* Cushman and Ellisor. In the Australian sequence, it overlaps the upper part of the range of *G. mayeri* and extends upward from it. Blow distinguished it from *G. mayeri* in having more inflated chambers, a thicker test, radial instead of tangential sutures (and hence a less rapidly expanding coil), a more distinctive apertural lip, and a more rapidly opening spire.

The species seems more closely related to *Globigerina eggeri* than to *Globorotalia mayeri*. Its essential difference from *Globigerina eggeri* is the essential difference between the genera *Globigerina* and *Globorotalia*, that is, that the aperture of *Globigerina eggeri* opens into the umbilicus, whereas that of *Globorotalia acostaensis* is an elongate opening extending from the umbilical area to the periphery. *Globorotalia acostaensis* also differs from *Globigerina eggeri* in being slightly more compact and tight coiled with the initial whorl nearly buried and not raised up above the level of the final whorl.

There is considerable variation in the Eniwetok specimens, especially in size and thickness. They are slightly more robust than the types. Except for a single specimen in sample 23-6, *Globorotalia acostaensis* was found only in the pre-Quaternary core samples.

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INDEX

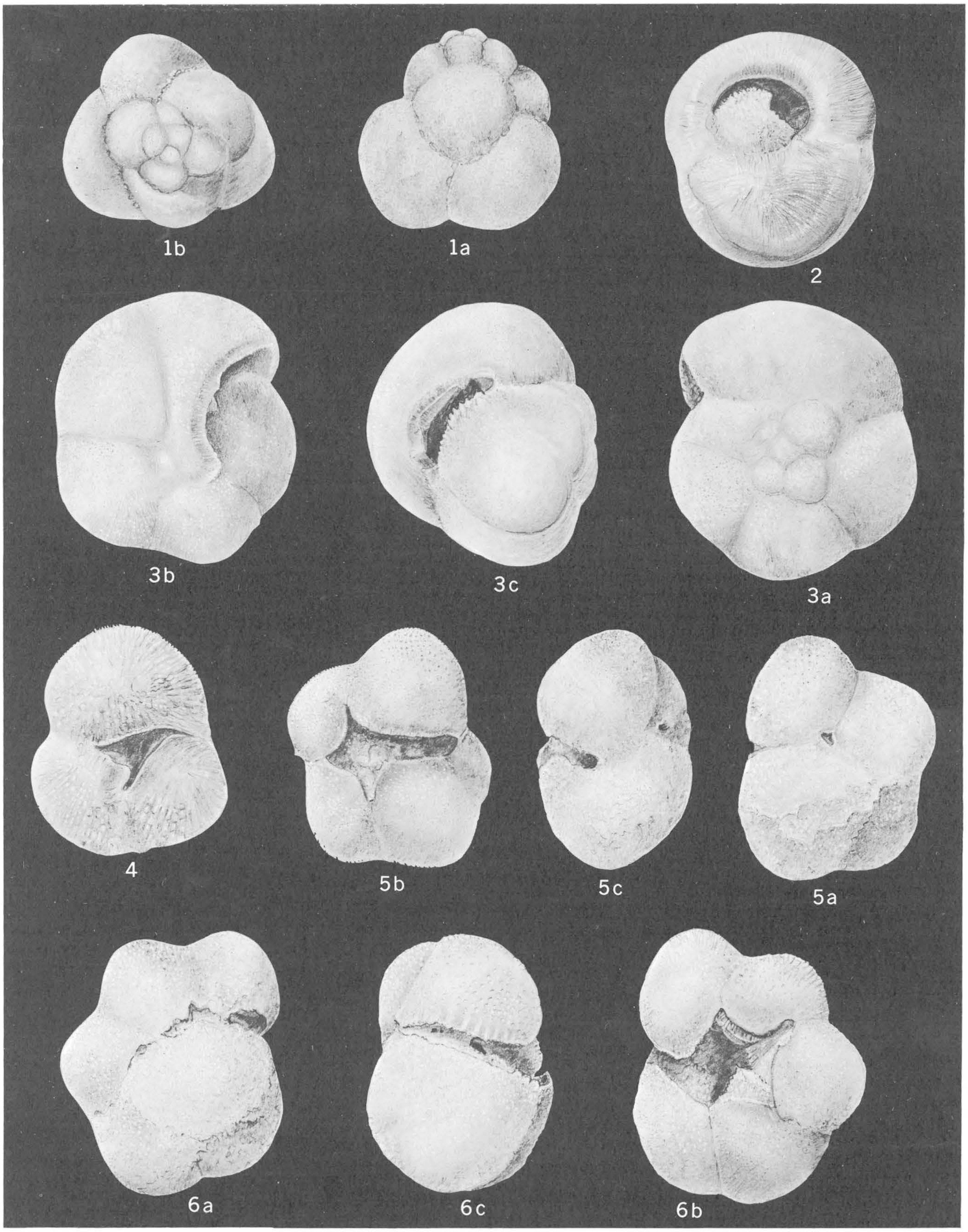
[Italic numbers indicate descriptions]

PLATES 289–295

PLATE 289

[*a*, Dorsal view; *b*, ventral view; *c*, peripheral view, except as indicated]

FIGURE 1. *Candeina nitida* d'Orbigny (p. 1090).
USNM 639108, × 88; sample 20–13; *a*, side view; *b*, top view.
2, 3. *Pulleniatina obliquiloculata* (Parker and Jones) (p. 1089).
2. USNM 639089, × 56; sample 27–8.
3. USNM 639099, × 88; sample 4–10.
4. *Sphaeroidinella dehiscens* (Parker and Jones) (p. 1088).
USNM 639090, × 44; sample 27–8.
5, 6. *Sphaeroidinella kochi* (Caudri) (p. 1088).
5. USNM 639116, × 44; sample 20–13.
6. USNM 639117, × 44; sample 20–13.



1b 1a 2

3b 3c 3a

4 5b 5c 5a

6a 6c 6b

GLOBIGERINIDAE FROM DEEP-SEA CORES OFF ENIWETOK ATOLL

PLATE 290

[*a*, Dorsal view; *b*, ventral view; *c*, peripheral view, except as indicated]

FIGURE 1. *Orbulina suturalis* Bronnimann (p. 1087).
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  2. USNM 639118, × 56; sample 20–13.
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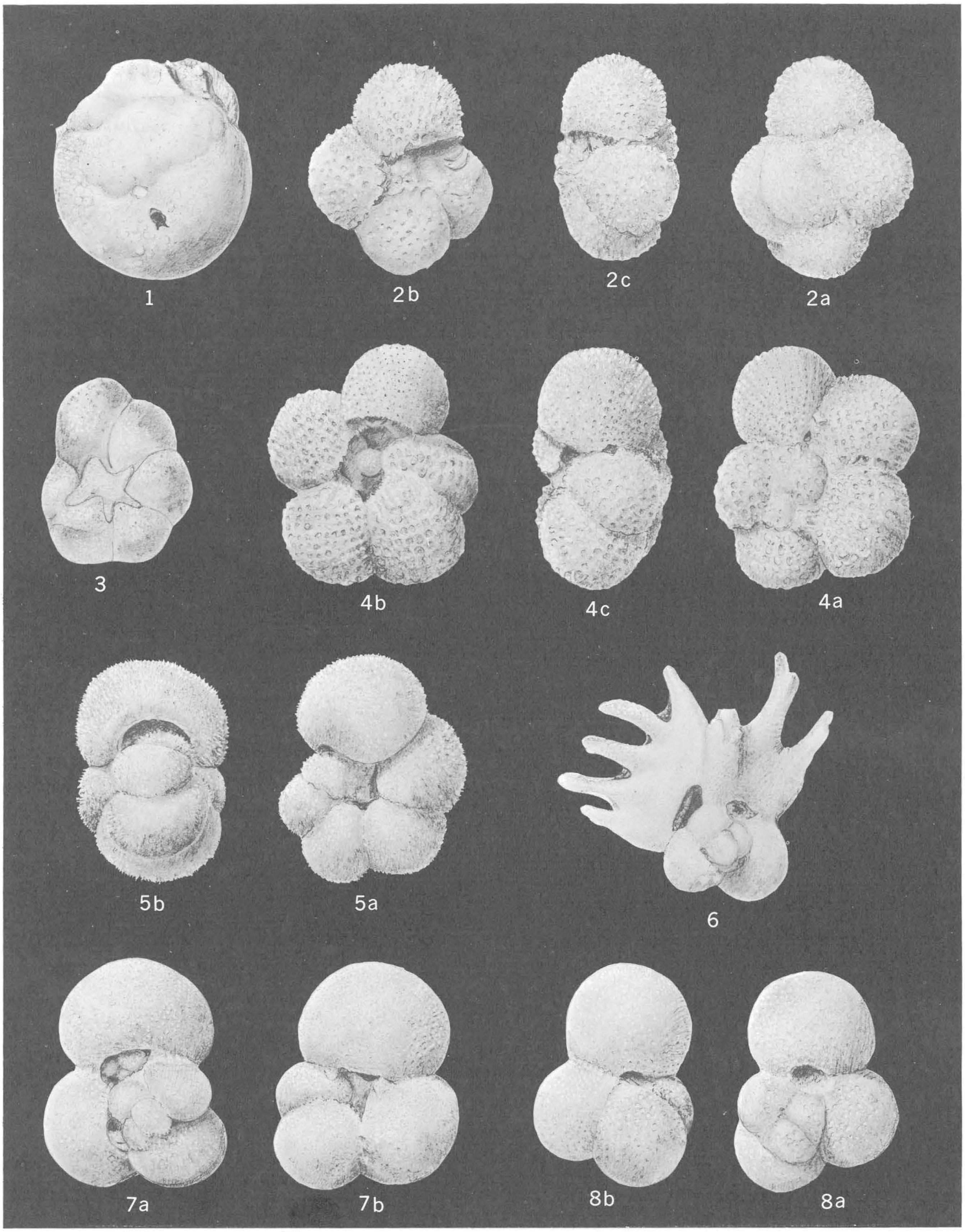
  7. Typical form, USNM 639110, × 44; sample 20–13.
  8. Primitive form, USNM 639111, × 44; sample 20–13.



GLOBIGERINIDAE FROM DEEP-SEA CORES OFF ENIWETOK ATOLL

PLATE 291

FIGURE 1. *Globigerinoides ruber* (d'Orbigny) (p. 1083).
USNM 639086, × 88; sample 27–8; *a*, dorsal view; *b*, side view.

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6. USNM 639085, × 56; sample 27–8. Dorsal view.

4, 5. *Globoquadrina altispira* (Cushman and Jarvis) (p.1081).
4. USNM 639105, × 88; sample 27–25; *a*, ventral view; *b*, side view.
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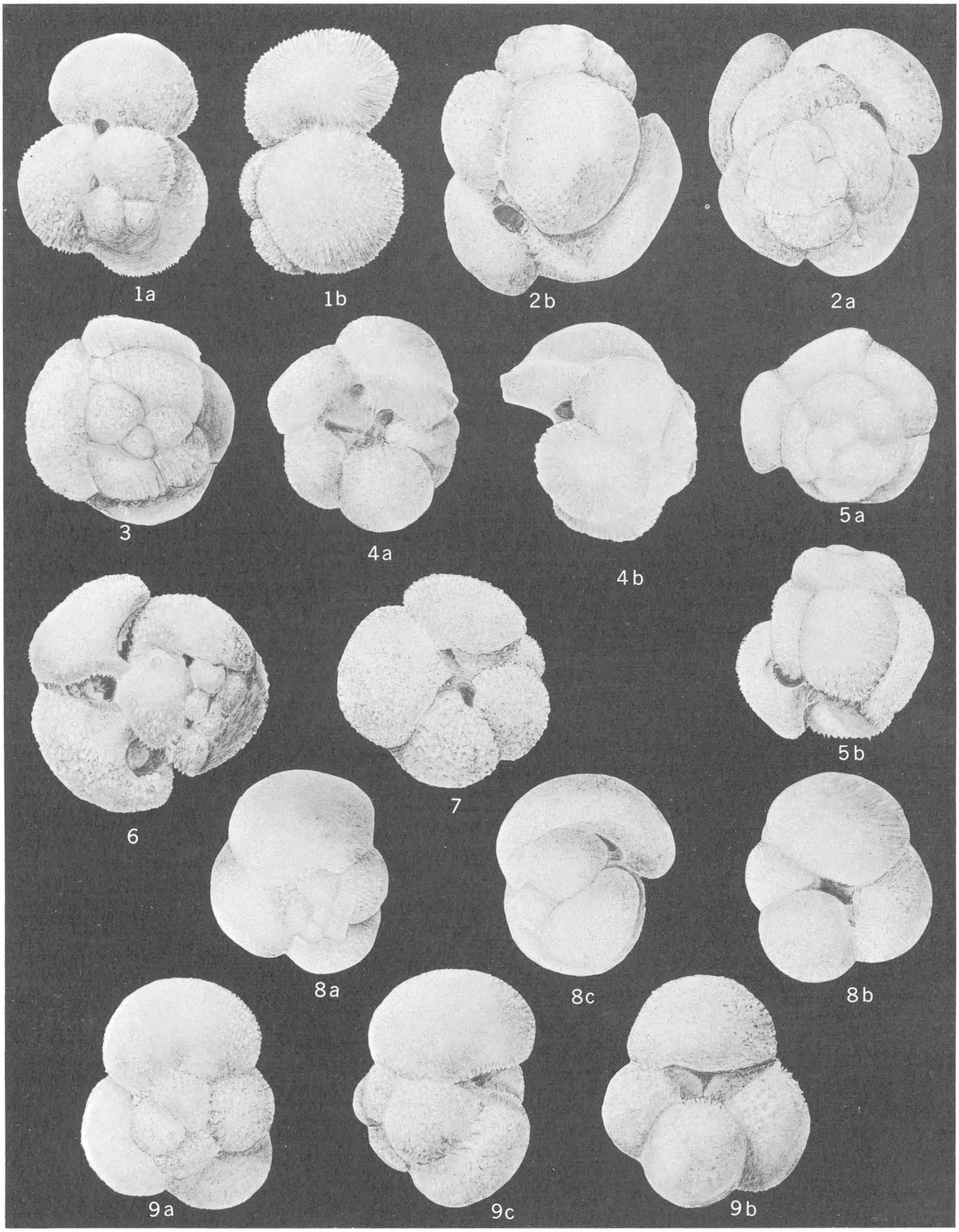
8. USNM 639083, × 44; sample 27–8; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
9. USNM 639109, × 56; sample 20–13; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.



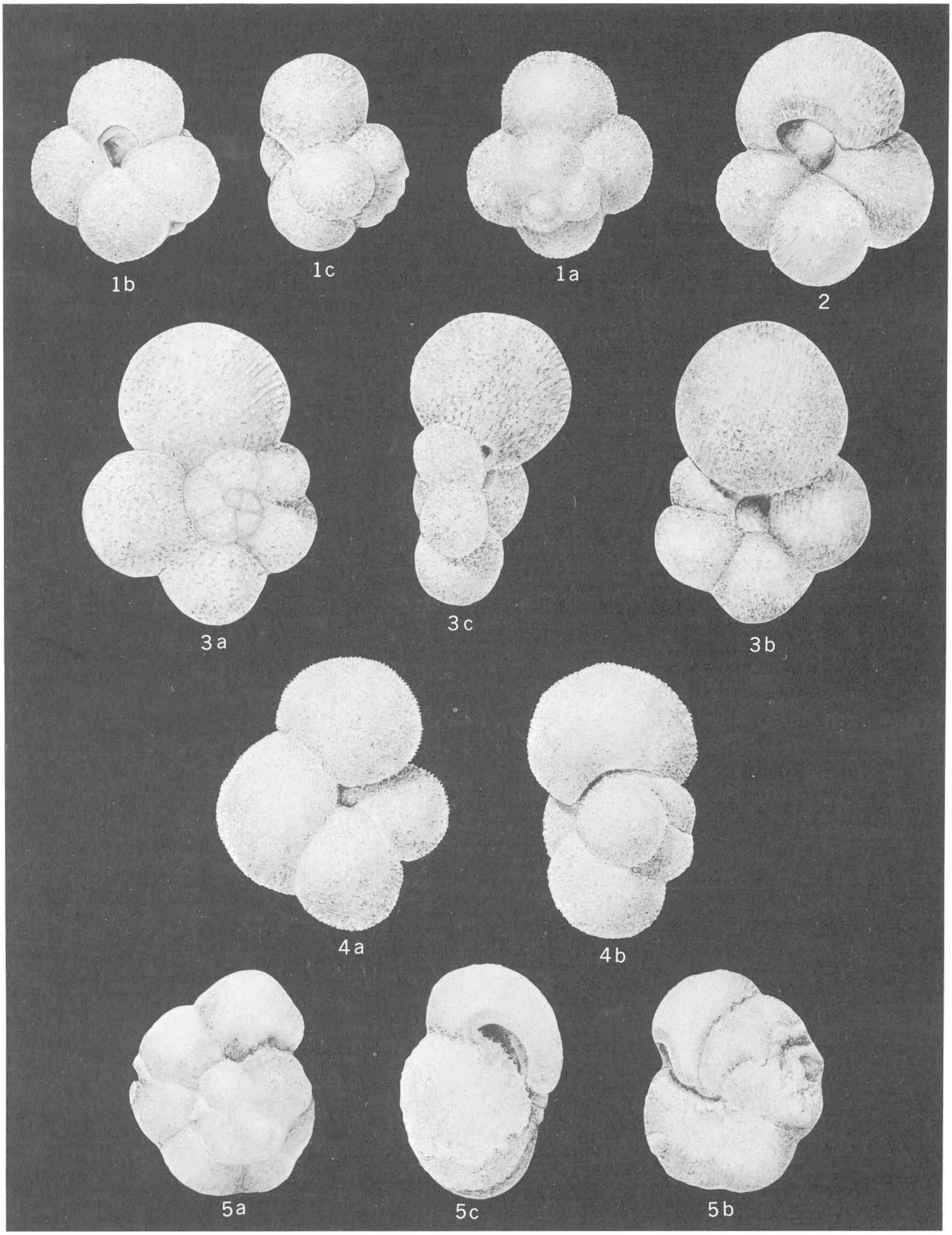
GLOBIGERINIDAE FROM DEEP-SEA CORES OFF ENIWETOK ATOLL

678-878 O - 64 - 3

PLATE 292

[*a*, Dorsal view; *b*, ventral view; *c*, peripheral view, except as indicated]

FIGURE 1. *Globigerina rubescens* Hofker (p. 1080).
USNM 639097, × 140; sample 23–6.
2. *Globigerina* sp. aff *G. apertura* Cushman (p. 1078).
USNM 639095, × 140; sample 23–6; ventral view.
3. *Globigerina (Globorotaloides) hexagona* Natland (p. 1080).
USNM 639096, × 140; sample 23–6.
4. *Globigerina obesa* (Bolli) (p. 1079).
USNM 639113, × 112; sample 20–13; *a*, ventral view; *b*, peripheral view.
5. *Globorotalia (Turborotalia) acostaensis* Blow (p. 1096).
USNM 639104, × 88; sample 27–25.

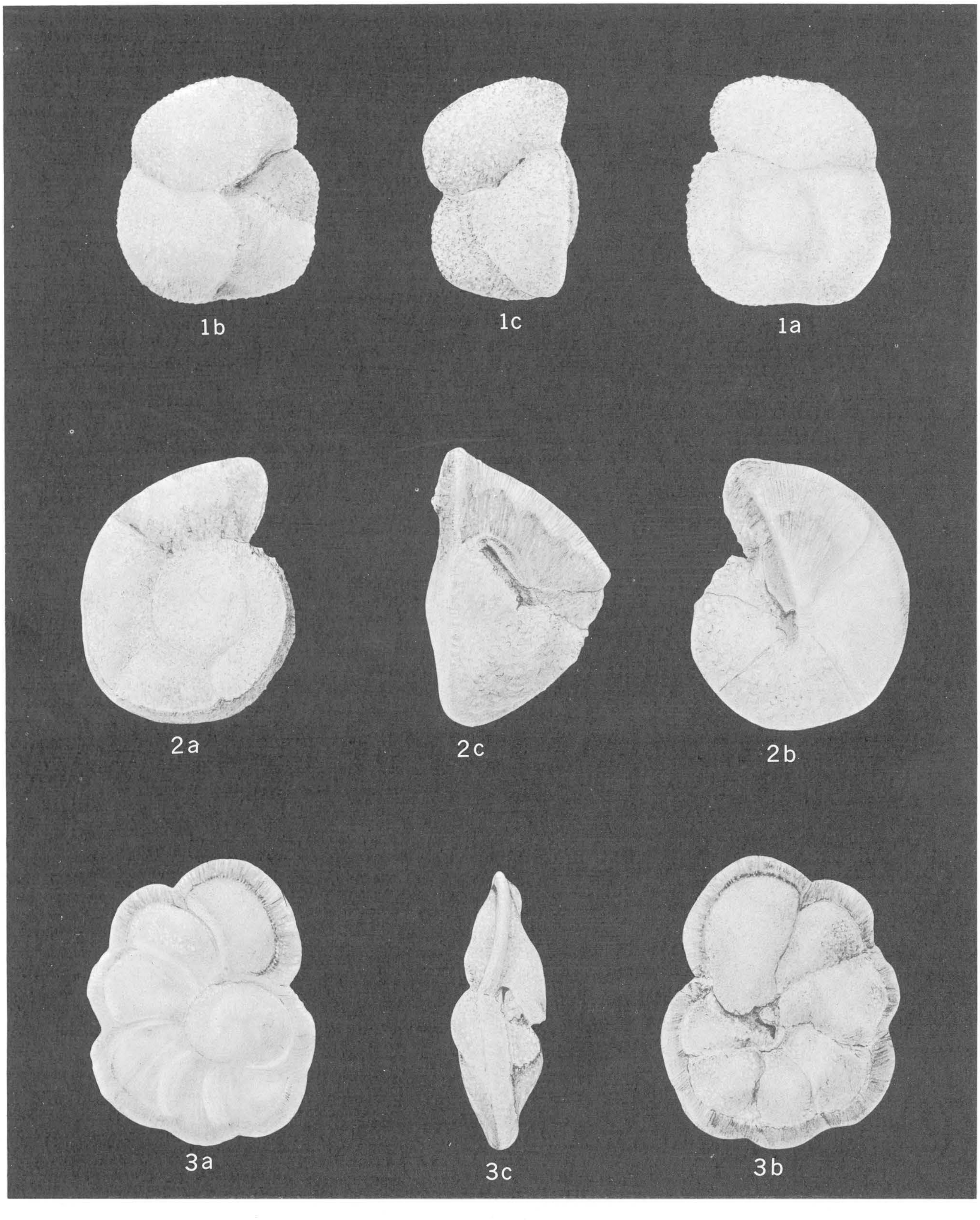


SPECIES OF *GLOBIGERINA* AND *GLOBOROTALIA* FROM DEEP-SEA CORES OFF ENIWETOK ATOLL

PLATE 293

[*a*, Dorsal view; *b*, ventral view; *c*, peripheral view]

FIGURE 1. *Globorotalia* (*Truncorotalia*) *punctulata* (d'Orbigny) (p. 1095).
USNM 639102, × 88; sample 18–15.
2. *Globorotalia* (*Truncorotalia*) *truncatulinoides* (d'Orbigny) (p. 1096).
USNM 639091, × 88; sample 27–8.
3. *Globorotalia* (*Globorotalia*) *menardii multicamerata* Cushman and Jarvis (p. 1092).
USNM 639114, × 44; sample 20–13.

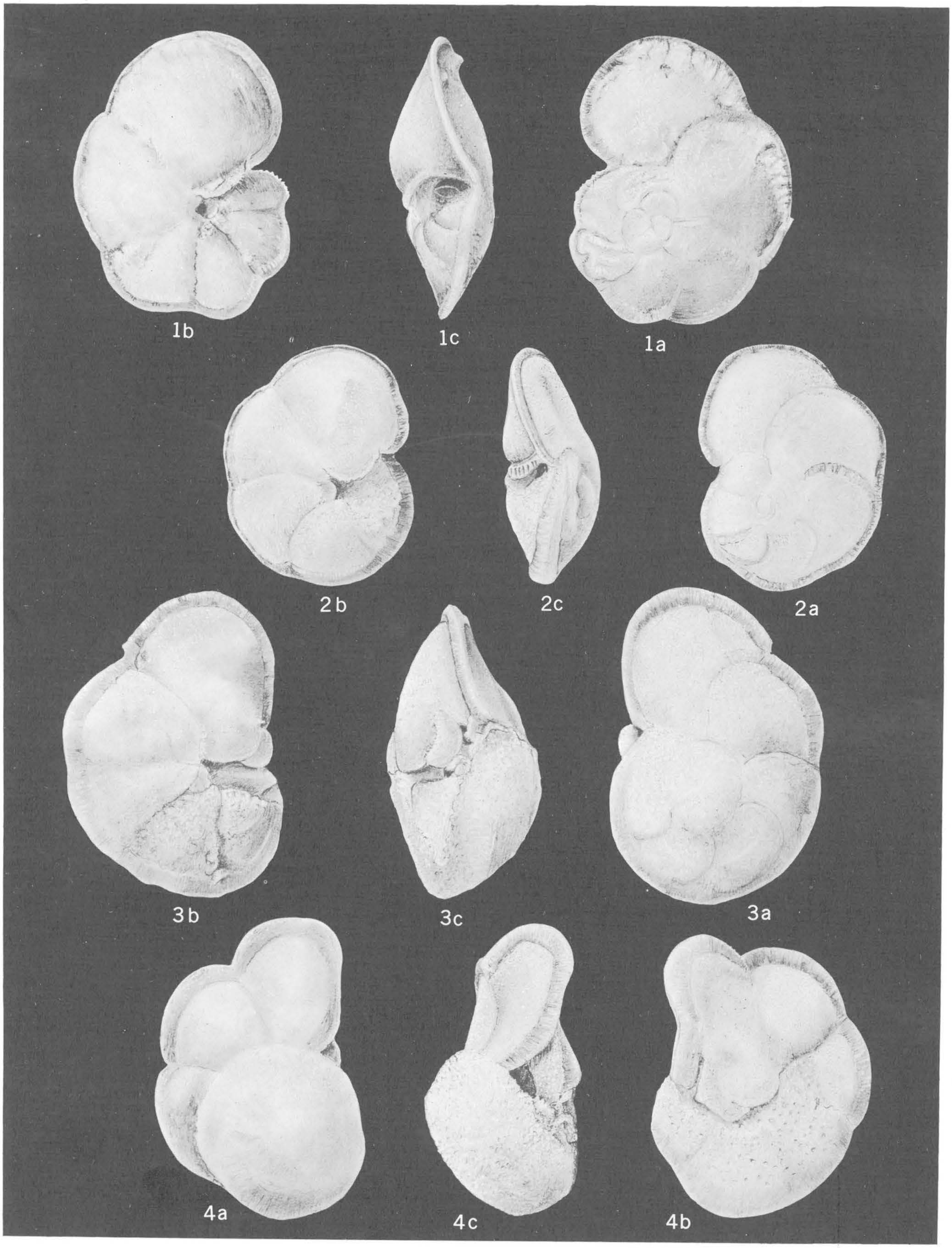


SPECIES OF *GLOBOROTALIA* FROM DEEP-SEA CORES OFF ENIWETOK ATOLL

PLATE 294

[*a* Dorsal view; *b*, ventral view; *c*, peripheral view]

FIGURE 1. *Globorotalia* (*Globorotalia*) *menardii* (d'Orbigny) (p. 1091).
USNM 639098, × 56; sample 4–10.
2. *Globorotalia* (*Globorotalia*) *menardii-tumida* transition form (p. 1092).
USNM 639092, × 44; sample 18–3.
3. *Globorotalia* (*Globorotalia*) *tumida* (Brady) (p. 1094).
USNM 639103, × 44; sample 27–25.
4. *Globorotalia* (*Globorotalia*) *tumida flexuosa* (Koch) (p. 1094).
USNM 639115, × 44; sample 20–13.



SPECIES OF *GLOBOROTALIA* FROM DEEP-SEA CORES OFF ENIWETOK ATOLL

PLATE 295

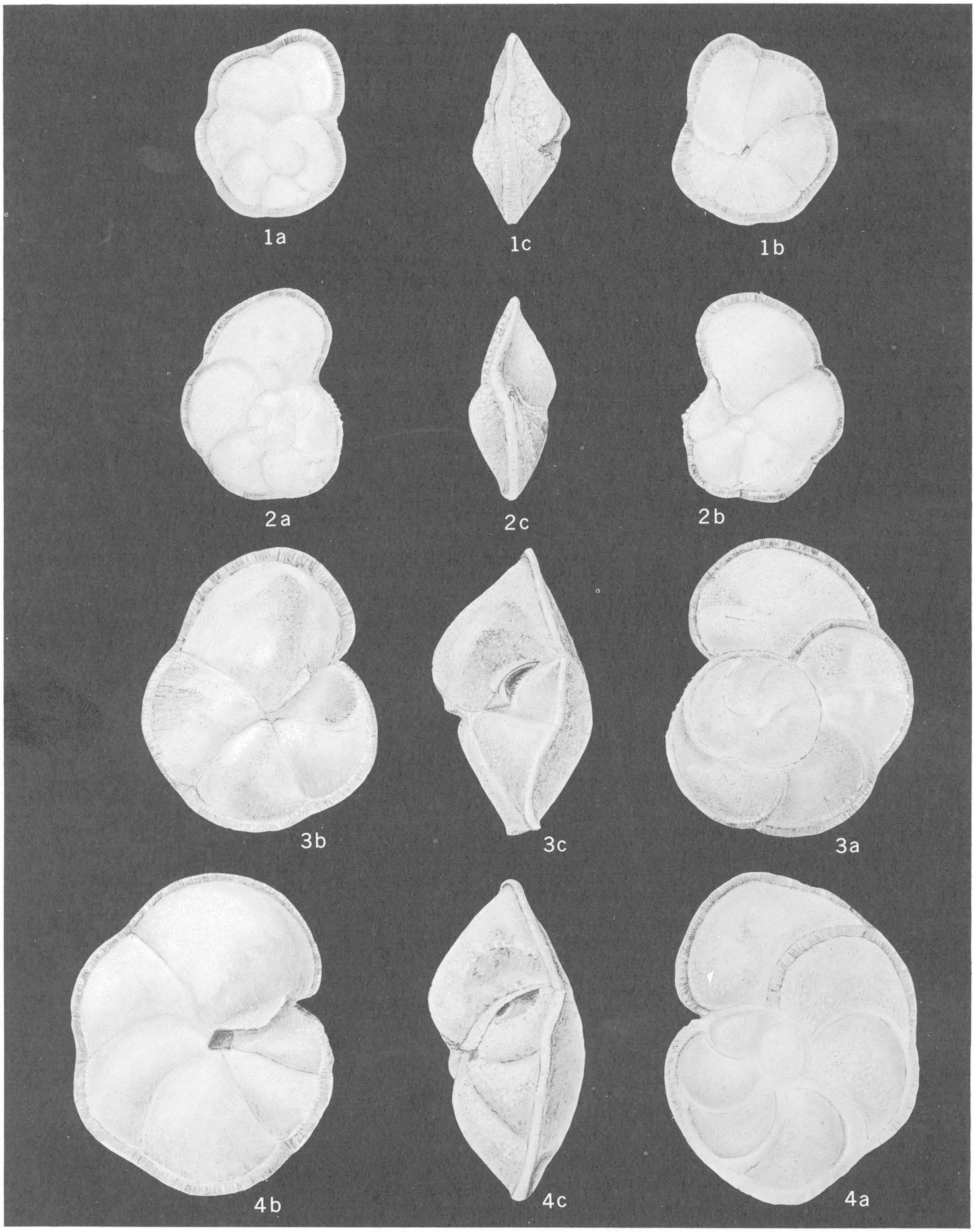
[*a*, Dorsal view; *b*, ventral view; *c*, peripheral view]

FIGURE 1. *Globorotalia (Globorotalia) fohsi robusta* Bolli (p. 1094).
USNM 639121, × 56; sample 23–20.

2. *Globorotalia (Globorotalia) menardii praemenardii* Cushman and Stainforth (p. 1092).
USNM 639120, × 56; sample 23–20.

3. *Globorotalia (Globorotalia) menardii ungulata* Bermudez (p. 1093).
USNM 639093, × 140; sample 23–6. In apertural view (*c*), the aperture of the penultimate chamber is observable within the widely open final aperture.

4. *Globorotalia (Globorotalia) menardii miocenica* Palmer (p. 1093).
USNM 639094, × 140; sample 23–6.



SPECIES OF *GLOBOROTALIA* FROM DEEP-SEA CORES OFF ENIWETOK ATOLL