Smaller Foraminifera From Eniwetok Drill Holes

BIKINI AND NEARBY ATOLLS, MARSHALL ISLANDS

GEOLOGICAL SURVEY PROFESSIONAL PAPER 260-X

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By RUTH TODD *and* DORIS LOW

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ABSTRACT

Smaller Foraminifera were studied as loose specimens from 2 deep holes, about 22 miles apart, drilled to the basement rock underlying Eniwetok Atoll: hole E–1 about 4,200 feet deep on the southeastern part of the atoll and hole F–1 about 4,600 feet deep on the northwestern part of the atoll near where it adjoins a guyot.

In both holes, Miocene and upper Eocene sediments were recognized and in hole E–1 a 590-foot sequence of beds is tentatively placed in the lower Oligocene. Tentative correlation is made between a 350-foot sequence of upper Eocene faunas from the uppermost occurrence of Eocene beds in hole E–1 to the lowermost rocks in hole F–1. A thick sequence of Eocene *Globigerina* limestone represents the uppermost occurrence of Eocene beds in hole F–1 and signifies open-sea deposition. Globigerinids and deepwater forms in association with other species occur in the lower part of the section in hole F–1 and signify moderately deepwater deposition, probably on an outer slope of the atoll. No evidence on the deposition of the sediments found in the middle part of this hole can be based on smaller Foraminifera. The Miocene sediments in the upper part of the hole indicate shallow but possibly outer slope deposition.

Throughout the part of hole E–1 from which cuttings were obtained, the smaller Foraminifera indicate shallow-water deposition, with the possibility of two disconformities or diastems in the lower part. No smaller Foraminifera are available from the lowest 1,100 feet of this hole.

Comparison with the deep holes drilled on Bikini shows close conformity, particularly with hole E–1, in which deposition is of the same type as in the Bikini holes. Correlation of several tops of occurrences, however, shows that levels are slightly shallower at Eniwetok, as much as 250 feet.

Paleontologic affinities of the species seem to be about equally divided between the Eastern and Western Hemispheres. In the Eocene, notable ties are recognizable to the southeastern United States and the West Indies as well as to central Europe and the Near East. A few correlations can be made with the described East Indian faunas of smaller Foraminifera. In the lower Oligocene the major ties are to the Southeastern United States. In the Miocene, paleontologic affinities are noted mainly with Australia, New Zealand, Fiji, and other Pacific islands, and less frequently with the United States, West Indies, and Europe.

Altogether, 265 species, 4 subspecies, and 3 varieties, classified in 118 genera, are recognized in the material from the drill holes. Of these, 7 species are described as new, and 29 remain indeterminate because of lack of adequate material for identification or description.

INTRODUCTION

The present study covers the smaller Foraminifera from two deep holes drilled on two islands of Eniwetok Atoll. Unlike the holes drilled on Bikini Atoll (Todd and Post, 1954), these holes penetrated the entire sedimentary sequence and reached the basement rock thus providing a unique opportunity for studying the age and ecology of the sediments immediately overlying the basaltic foundation of a coral atoll.

The holes on Bikini Atoll were adjacent and were therefore studied as one hole. As shown in figure 256, those on Eniwetok Atoll were drilled on islands in different parts of the atoll, about 22 miles apart. Despite this geographic distance and the fact that the recovery of cores and cuttings differed in the holes, several points of correlation can be recognized from hole to hole as well as in the previously studied deep hole some 190 miles to the eastward on Bikini Atoll.

Some of these correlation points are approximated in table 1.

The smaller Foraminifera thus support the indication of the larger Foraminifera (Cole, 1957, table 3) that the stratigraphic breaks are at slightly shallower depths in the two Eniwetok holes than they are in the Bikini holes.

Throughout hole E–1 the smaller Foraminifera recovered are of types indicating deposition under relatively shallow-water conditions. No smaller Foraminifera were obtained from deeper than 3,130 feet in the hole, and thus only the uppermost 360 feet of the Eocene section were recovered from this drilling.

In hole F–1, on the contrary, nine cores (Nos. 7–15 inclusive) were obtained over an interval of 1,500 feet all of which is within the Eocene section. In the middle part of this interval, and to a lesser degree in the upper and lower parts, the composition of the fauna of smaller Foraminifera is such that moderately deep-water and

TABLE 1.—*Approximate tentative correlation points between the Bikini drillings and the two holes on Eniwetok*

[With two exceptions (*Austrotrillina striata* and *Liebusella exigua*), depths are designated by the top figure of the range of a single sample and indicate the tops of the major occurrences. Where two depths are given, the one in parentheses represents a rare occurrence higher than the major occurrence]

Species	Eniwetok drill holes		Bikini drillings (in feet)
	F-1 (in feet)	E-1 (in feet)	
Calcarina rustica	290	280	179
delicata	290	280	184½
Streblus beccarii [1]	680	200	242½
Pararotalia byramensis	640	590	600
Tubulogenerina tubulifera [1]	840	520	925
Marginopora vertebralis (brown-stained specimens)	740	690	925(?)
Discorbis balcombensis	870 (240)	690	925
Trimosina spinulosa	880	----------	925
Peneroplis honestus	770	780	1, 167
Asterigerina tentoria	1, 090	1,.100 (960)	1, 167
Triloculina fusa	1, 230	1, 020	1, 167
Valvulammina marshallana	----------	1, 030 (800)	1, 209 (852)
Valvulina prominens	----------	1, 080	1, 240
Spirolina? sp. A [1]	----------	990	1, 702½
Rotalia tectoria	1, 718	1, 658 (1, 452)	1, 797
Elphidium marshallana	----------	1, 776 (1, 541)	1, 797
Amphistegina bikiniensis	1, 718	1, 658 (1, 500)	1, 891½
Archaias eniwetokensis	----------	1, 805	1, 891½
Austrotrillina striata	----------	1, 835 to 2, 028	1, 996½ to 2, 102
Asterigerina marshallana	----------	2, 280	2, 091 (1, 597½)
Rosalina turgida	----------	2, 040 (1, 190)	2, 246
Liebusella exigua	----------	2, 370 to 2, 570	2, 298½ to 2, 493 (1, 209)
Massilina placida	----------	2, 220	2, 298½
Halkyardia bikiniensis	----------	2, 280	2, 349
Streblus flosculus	----------	2, 630 (2, 380)	2, 349
Cribrogoësella parvula n. sp.	----------	2, 180 (1, 020)	2, 451 (1, 293)
Valvulina martii	----------	2, 180 (1, 030)	2, 451 (1, 209)

[1] The rare occurrences of these species may make the tentative correlation of no value.

open-sea deposition is indicated. Two of the F-1 cores, Nos. 9 and 10, consist of indurated *Globigerina* ooze. In all the F-1 Eocene cores, planktonic species are present, and the benthonic ones are mostly of deeper water types.

Acknowledgments.—For suggestions and helpful discussions of our work we are indebted to many colleagues, chiefly to Esther R. Applin, W. Storrs Cole, Irene Crespin, Edwin L. Hamilton, A. F. M. Mohsenul Haque, H. S. Ladd, Frances L. Parker, S. O. Schlanger, A. H. Smout, R. M. Stainforth, J. I. Tracey, Jr., and I. M. van der Vlerk. We owe our thanks to Rita Post for the complete picking and mounting of specimens from the top 590 feet in hole E-1, and to Evelyn Bourne for the partial picking of random samples throughout both holes. The remainder of the picking and mounting was done by ourselves—the cuttings from hole E-1 mostly by the senior author and the cuttings and cores of hole F-1 by the junior author. Identification and discussion of species, including description of new species, was done jointly.

For the illustration of most of the specimens we are indebted to the U.S. National Museum for providing the services of Patricia Isham, artist, Department of Zoology.

ANALYSIS OF THE FAUNAS

Estimation of qualitative composition of fossil assemblages of smaller Foraminifera is fraught with many hazards and when the estimation must be made from cuttings rather than cores the hazards are multiplied. Nevertheless, a crude estimate is possible.

In the Recent and pre-Recent faunas, *Calcarina spengleri* (Gmelin) is overwhelmingly predominant. Because of its predominance—fresh and Recent specimens abundantly contaminate the cuttings down to the lowest parts in both holes; it is difficult to recognize the lowest actual occurrence of this species. However, it is likely that it does not occur in strata older than Pliocene, possibly not older than Pleistocene. In E-1 it appears to fall off somewhat at about 170 feet and was not found in the core at 170–190 feet in F-1. At Bikini it was found in abundance only down to 95 feet.

Amphistegina madagascariensis d'Orbigny occurs with *C. spengleri* but persists to deeper levels. Because of its great abundance, it is not clear where it is replaced as the dominant constituent. It is found in the F-1 core at 170–190 feet but not in the highest E-1 core at 2,000 feet. It does go down into the Miocene section, possibly as low as about 1,500 feet at which level transitional forms to *Amphistegina bikiniensis* Todd and Post are observed with it.

Next beneath *Calcarina spengleri*, *C. delicata* Todd and Post appears to be predominant from 280 to about 590 feet. Beneath this level to about 1,500 feet, *Pararotalia byramensis* (Cushman) occupies the place of *Calcarina delicata*, of which it may have been the ancester. *Asterigerina tentoria* Todd and Post becomes the dominant form at about 1,100 feet, being gradually replaced downward by *Amphistegina bikiniensis* Todd and Post from about 1,700 feet. Accompanying *A. bikiniensis* to about 2,280 feet, somewhat less abundant but comprising a significant part of the fauna, is *Rotalia tectoria* Todd and Post. At about 2,280 feet *Asterigerina marshallana* Todd and Post becomes the dominant form and continues so downward to about 2,770 feet. In the lower part of the range of *A. marshallana*, it is accompanied by *Streblus flosculus* (Todd and Post), which becomes more abundant below 2,630 feet.

Austrotrillina striata Todd and Post is found in great abundance within a narrow zone at about 1,835 to 2,028 feet, although even there it is somewhat overshadowed by *Amphistegina bikiniensis*, *Rotalia tectoria*, and *Asterigerina tentoria*.

The top of the Eocene coincides with the predominance of two species: *Peneroplis dusenburyi* Henson and *Triloculina trigonula* (Lamarck). These two continue downward with decreasing abundance to the lowest cuttings. However, in the lowest 80 feet of cuttings in hole E-1, from 3,050 feet downward, the position of dominance is occupied by *Asterigerina rotula* (Kaufmann).

CORRELATION BETWEEN ENIWETOK AND BIKINI

A remarkably close correlation can be made between drill hole E–1 and the holes on Bikini; in fact, a closer correlation than between drill holes E–1 and F–1 on Eniwetok. Only 8 of the 60 species and varieties reported from the deep holes at Bikini were not also found (a few of the identifications being under altered names) at Eniwetok. Five of the eight species and varieties, rare Recent or pre-Recent forms mostly from high in the Bikini cuttings, do not concern the matter of correlation between the drill holes. The remaining three are *Bolivina marginoserrata* LeRoy, *Bolivina marshallana* Todd and Post, and *Gypsina howchini* Chapman.

Although *Gypsina howchini*, which occurs rather abundantly in the upper parts of the Bikini drill holes, is not here reported at Eniwetok, it is possible that there is identity between a few of the specimens called *G. howchini* from Bikini and a few of those called *Planorbulinella larvata* from Eniwetok. But in general the Bikini specimens are thicker, have less discrete chambers, and are believed to belong to the Miocene species *Gypsina howchini*, which was not found at Eniwetok.

The composite range chart for the Bikini deep holes (Todd and Post, 1954, p. 552) included all the 60 species recognized. For the Eniwetok holes, where the fauna includes over 4½ times as many species as

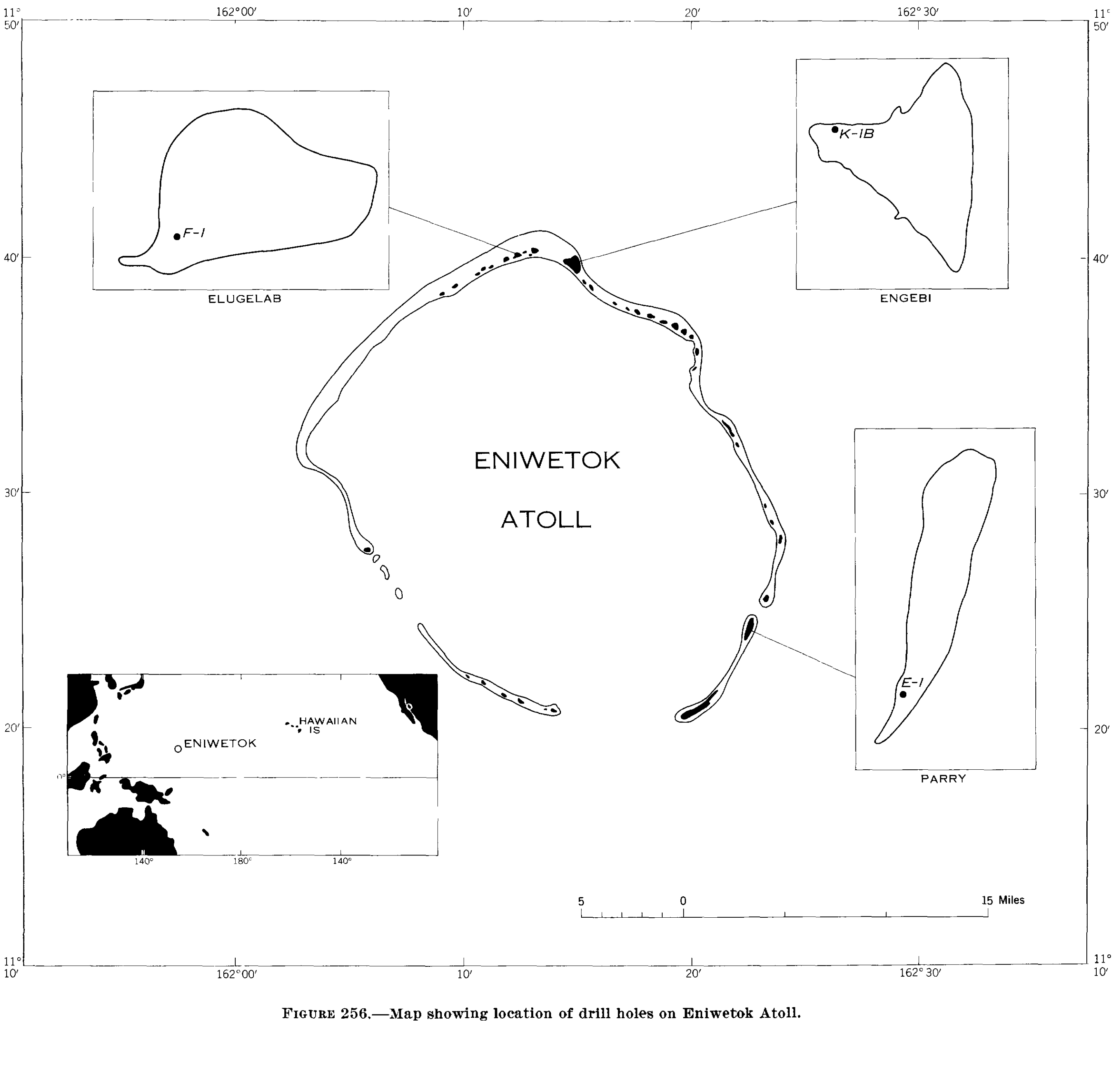

FIGURE 256.—Map showing location of drill holes on Eniwetok Atoll.

were recognized at Bikini, a range chart including all the species would be impractical and unwieldly because of the rarity of many of the species. Therefore, 67 of the diagnostic and more abundant species were selected for inclusion in the composite range chart for the Eniwetok holes. Comparision may be made between the Bikini chart and the upper (post-Eocene) part of this Eniwetok one by means of the 29 species in common (some under altered names) between the 2 areas. This comparison reveals the possibility of correlation between the following levels in the two areas:

Bikini (in feet)	Eniwetok (in feet)	
95–105	170–230	End of occurrence in place of *Calcarina spengleri* and highest occurrence of *Baculogypsina sphaerulata*.
1, 145–1, 209	1, 020–1, 100	Beginning of abundant *Asterigerina tentoria* (top of Tertiary *e*).
2, 150–2, 350	2, 220–2, 380	Beginning of *Massilina placida*, *Halkyardia bikiniensis*, and *Streblus flosculus* (top of Oligocene?).

DRILL HOLE E–1

On the basis of smaller Foraminifera alone, the top of the Miocene (Tertiary *g* of the Indonesian section) is not easily recognized. Working from the top downward, the first change in fauna that was noticed is at 200 feet, where *Streblus beccarii* (Linné) first appears (table 2). Between this level and 280 feet, the first appearances of *Baculogypsina sphaerulata* (Parker and Jones), *Elphidium craticulatum* (Fichtel and Moll), *Calcarina rustica* Todd and Post, and *C. delicata* Todd and Post, none of which are known from the Recent of Eniwetok, indicate a major faunal break. There exists the possibility of the break being due to change in ecology rather than difference in age, but such a possibility seems slight because the general type of species remains the same.

From about 510 to 540 feet another change in fauna is observed; a more subtle change marked by a considerable number of first appearances of rare species, which have more significance taken as a whole than when considered as individuals; by an increase in abundance of *Calcarina delicata;* and by a recurrence with greater frequency of rare species that are present higher in the hole.

Within this narrow interval, from 510 to 540 feet, are the first occurrences of *Tubulogenerina tubulifera* (Parker and Jones), *Loxostomum digitale* (d'Orbigny), *Asterigerina indistincta* Todd and Post, and *Nonion grateloupi* (d'Orbigny), none common, but which taken together may indicate the top of the Miocene.

The first appearance of *Pararotalia byramensis* (Cushman)—described erroneously as *Rotalia canalis* Todd and Post and reported in part as *Rotalia calcar* (d'Orbigny) from the Bikini drill holes—occurs at 590 feet.

At 690 feet the highest specimen of *Discorbis balcombensis* Chapman, Parr, and Collins was found. This species did not appear until 925 feet at Bikini. A single specimen of *Pavonina triformis* Parr occurring at 680 feet at Eniwetok and likewise not reported until 925 feet at Bikini may serve to confirm the higher position of comparable levels at Eniwetok.

Also at 690 feet, another striking change is observed: the sudden appearance of brown-stained specimens. The staining is most obvious in imperforate and thick-walled forms such as the miliolids and *Marginopora* and other peneroplids. For at least 200 feet above the first appearance of the brown specimens, the sediments also are light brown, becoming increasingly darker with depth.

First occurrences of brown-stained specimens were also observed at 740 feet in hole F–1 and at 684 feet in hole K–1B, drilled on the island of Engebi (fig. 256) near hole F–1. At Bikini the highest occurrence of brown specimens was more difficult to pick up because of poorer recovery of cuttings. A core at 925 feet yielded the first abundant brown-stained specimens (Todd and Post, p. 551, footnote; p. 557), but rare brown individuals were found in cuttings as high as 852 feet. Further search of cuttings, which are themselves light brown, from above this depth showed only the faintest traces of brown in the kinds of specimens which at 925 feet are clearly stained.

The cause of the brown stain, lateral extent of its occurrence, and thickness of the interval containing the brown specimens are all matters for conjecture. From the fact that brown specimens are found over such a distance (190 miles) as that between Bikini and Eniwetok, they do not seem to be a local feature. The actual brown color has been interpreted (Emery, Tracy, and Ladd, 1954, p. 85) as being due to very minute quantities of organic matter, quantities even less than those present in modern lagoonal sediments. The brown specimens appear to be restricted to an unrecrystallized interval of sediment in which shells and corals are still aragonite and some mollusk shells retain their nacreous luster and original markings. The interval in question thus has apparently never been above sea level.

The fact that the same species are found, unstained above and stained below the depth of highest occurrence of brown specimens, suggests that the staining is more related to lithology than to fauna. On the other hand, the first appearances of a number of species at or close to the highest occurrence of brown specimens, both at Eniwetok and at Bikini, indicate a possible connection with faunal or facies changes or with presence of a diastem.

The significance of the occurrence of the brown staining in the Marshall Islands is an unsolved problem. Although it cannot be assumed that the interval in which brown specimens occur is a correlation point between rocks of the same age, the occurrence of brown stain high in the Miocene rocks should be looked for in any future studies in the Marshall Islands, or indeed anywhere in the Pacific basin.

Of interest in this connection is a report of shiny brown-stained Foraminifera from the Gulf of Mexico (Ludwick and Walton, 1957, p. 2091), where they occur with both their unstained counterparts as well as glauconitized specimens, near, but shoreward from, a series of calcareous prominences near the edge of the Continental Shelf. These prominences or pinnacles were interpreted as a modified and partly buried reef that did not survive an elevation of sea level. The brown staining was interpreted to have taken place when the specimens were near, slightly above or below, sea level during a lower stand of the sea (Ludwick and Walton, 1957, p. 2096).

Through the generosity of W. R. Walton, we have

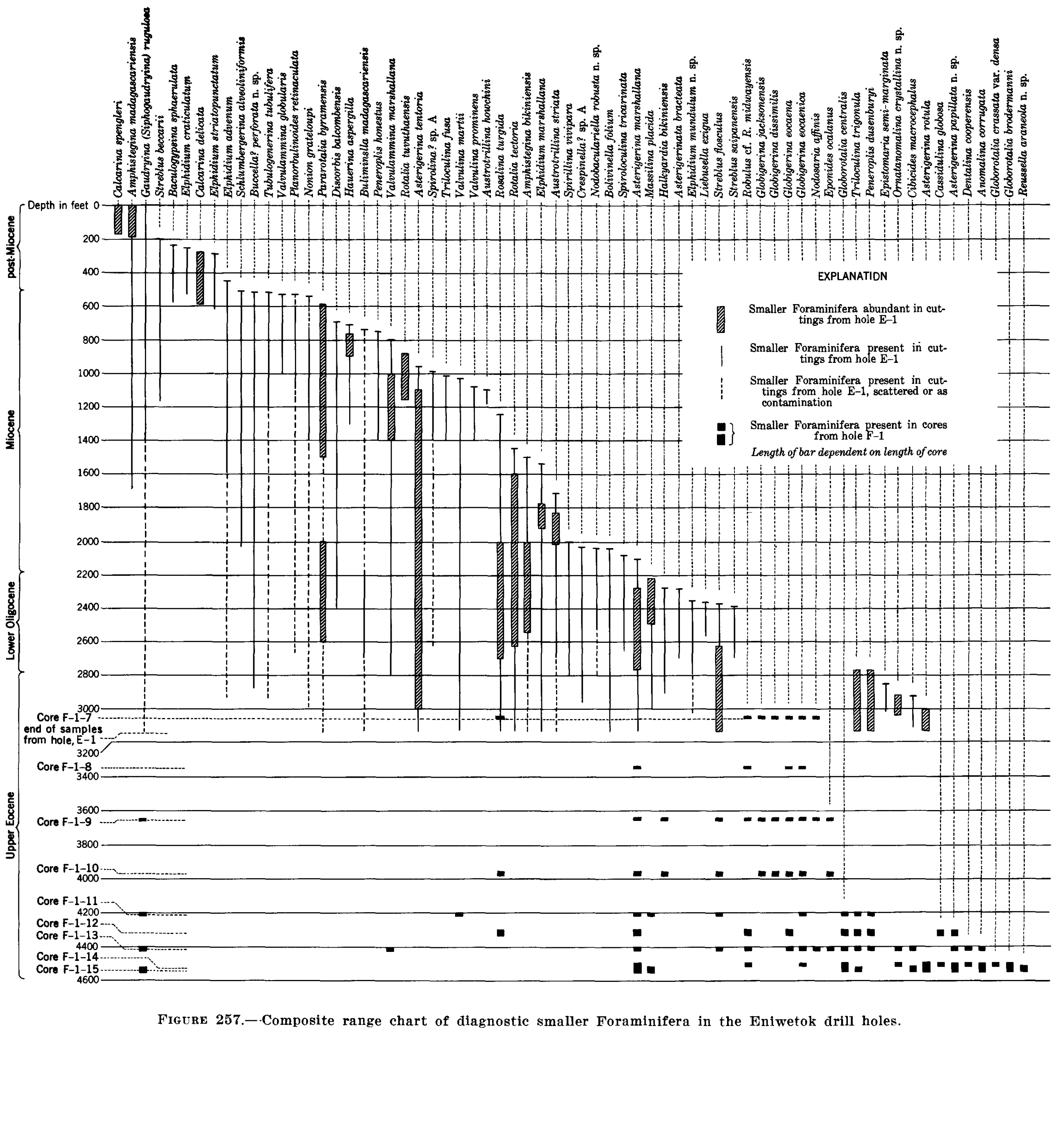

FIGURE 257.—Composite range chart of diagnostic smaller Foraminifera in the Eniwetok drill holes.

had the opportunity of comparing our specimens with both replaced and unreplaced specimens from the Gulf of Mexico. As compared with the brown shells from the Eniwetok holes and the zone of unrecrystallized limestone (580 to 1,020 feet) in the Bikini holes, the Gulf of Mexico specimens are distinctly darker and more highly polished. Whether these two occurrences of stained Foraminifera (Gulf of Mexico and Marshall Islands) are identical or even similar in mode of formation, remains to be determined.

Other conspicuous elements of the fauna that appear with the brown-stained specimens are *Peneroplis honestus* Todd and Post, *P. planatus* (Fichtel and Moll), and *Hauerina aspergilla* (Karrer), of which only *Peneroplis honestus* was found in the Bikini holes, but there not until 1,167 feet.

Valvulammina marshallana Todd and Post was first found in E–1 at 800 feet. On Bikini its highest occurrence was 852 feet—which is a relatively higher position than at Eniwetok as indicated in plate 264.

At 880 feet *Rotalia tuvuthaensis* Kleinpell, confined at Fiji (Kleinpell, 1954, p. 62, text fig. 3) to Tertiary g or h_1, first appears and continues down to 1,160 feet.

Between 1,020 and 1,100 feet, the appearance of the following species marks another change in fauna:

Asterigerina tentoria Todd and Post
Austrotrillina howchini (Schlumberger)
Cribrogoësella parvula n. sp.
Quinqueloculina akneriana d'Orbigny
Triloculina fusa Todd and Post
Valvulina martii Cushman and Bermudez
prominens Todd and Post

The comparable faunal break at Bikini takes place between 1,145½ and 1,209 feet. Thus the differential between the two holes remains at about 125 feet.

Between 1,452 and 1,541 feet, the first appearances of *Elphidium marshallana* Todd and Post and *Rotalia tectoria* Todd and Post provide correlation with the level at 1,800 feet at Bikini.

At Bikini, *Austrotrillina striata* Todd and Post first appeared above the first appearance of these species. However, at Eniwetok its first appearance was not until a depth of 1,688 feet, and its zone of abundance was from 1,835 to 2,028 feet. Its zone of abundance at Bikini was from 1,996½ to 2,102 feet. This miliolid is probably a facies fossil, as suggested by its apparent absence from hole F–1, and hence its position slightly out of context with its accompanying species is not unexpected.

Asterigerina marshallana Todd and Post also first appeared above the 1,800-foot level at Bikini (although does not occur in abundance there until about 2,100 feet) while on Eniwetok it was not found until 2,280 feet.

At Bikini, *Amphistegina bikiniensis* Todd and Post occupies a slightly shorter and higher range than does *Asterigerina marshallana* at Bikini, and a similar condition is true at Eniwetok, where *Amphistegina bikiniensis* begins to be common at about 1,658 feet and probably ends about 2,550 feet.

Archaias eniwetokensis Cole begins to appear at about 1,800 feet, about 100 feet higher than its appearance at Bikini. Between 1,800 feet and about 2,028 feet, the level of the highest core taken in hole E–1, only rare specimens of probably insignificant species make their appearance. The species present in the core E–1–1 (2,003–2,028 ft) confirm the Miocene age of the beds at this level. At about the level of this core, and slightly below, the following species first appear, or become common:

Crespinella? sp. A
Nodobaculariella robusta n. sp.
Rosalina turgida Dorreen=*Discorbis* "*globularis* (d'Orbigny)" of Todd and Post (1954, p. 560).

The next change in fauna is about 200 feet lower, at about 2,220 feet, where *Massilina placida* Todd and Post first appears. Close beneath it are *Halkyardia bikiniensis* Cole and *Asterigerina marshallana* Todd and Post at 2,280 feet and *Asterigerinata bracteata* (Cushman) at 2,290 feet. This nearly 300-foot interval (2,003 to 2,290 ft) may be approximately correlated with the 200-foot interval between 2,150 and 2,350 feet in the Bikini hole. Unlike at Bikini where they come in together, the first appearance of *Streblus flosculus* (Todd and Post) at Eniwetok is 100 feet below the first appearance there of *Halkyardia*. Thus the occurrence of *Halkyardia bikiniensis* at 2,280 feet and *Streblus flosculus* at 2,380 feet at Eniwetok provides correlation to some point within the bottom 200 feet of the Bikini hole. (See pl. 264.)

The occurrence of *Liebusella exigua* Todd and Post between 2,370 and 2,570 feet may be correlated with the lower range of this species at Bikini (between 2,298½ and 2,493 ft). At Eniwetok the species was not observed higher, as it was at Bikini. From this level downward, no other correlation points appear to be available between the Bikini and Eniwetok holes.

Between the level around 2,500 feet that is regarded as approximately equivalent to the lowest depth (2,556 ft) reached by the Bikini drillings, and the top of the Eocene at about 2,770 feet, few species make their first appearances, and none of them occur more than rarely.

Cuttings from hole E–1 were obtained from about 360 feet of Eocene beds. The fauna of smaller Foraminifera shows a major change from overlying beds, although obscured in large part by contamination from above.

The Eocene section of hole E–1 may be divided into three parts on the basis of smaller Foraminifera:

From 2,770 to 2,920 feet, characterized by—	
Epistomaria semi-marginata (d'Orbigny)	Rare
Peneroplis dusenburyi Henson	Abundant
Triloculina trigonula (Lamarck)	Abundant
Valvulina intermedia Applin and Jordan	Rare
From 2,920 to 3,010 feet, characterized by—	
Cibicides macrocephalus (Gümbel)	Rare
Gyroidina octocamerata Cushman and G. D. Hanna	Rare
Ornatanomalina crystallina n. sp	Common
Pyrgo lupheri Rau	Rare
From 3,010 to 3,130 feet, characterized by—	
Asterigerina rotula (Kaufmann)	Abundant
Cibicides akneriamus (d'Orbigny)	Rare

From below 3,130 feet no further cuttings were obtained. Nearly 1,100 feet of sedimentary rock was penetrated between this depth and the basalt at 4,208 feet. This interval is mostly unrepresented by either cuttings or cores, only a single core (E–1–3 at 4,078–4,100 ft.) having been obtained from near the bottom. The rock is too hard to be disintegrated and thin sections show no recognizable smaller Foraminifera.

DRILL HOLE F–1

In drill hole F–1, the usual difficulties encountered in the study of cuttings were further complicated by extended depths of unconsolidated material and cavities encountered in the drilling making up about 70 percent of the section (Ladd and others, 1953, p. 2259). Thus contamination was possible to an even greater degree than in hole E–1 with its firmer section and fewer cavities (Ladd and others, p. 2267).

Unlike material from E–1 in which the relative abundance could be noted with some good effect (table 2), the fauna from F–1 was relatively poor both in number of species and in number of specimens. Hence the fauna has been recorded in table 3 only with the symbol ×, indicating presence. Although the tops of many occurrences may be somewhat ambiguous in F–1, they do seem to have some significance in their relation to drill hole E–1 and the holes studied on Bikini Atoll (Todd and Post, 1954). Hence the following notes on the cuttings from F–1 are intended to emphasize the comparison of these occurrence records regardless of the seeming paucity of material.

The 45 feet at the top of drill hole F–1 consists mainly of unconsolidated sand with a short section at 12 feet 6 inches to 14 feet 6 inches of hard beach rock. In the highest cuttings recovered, 20–45 feet, almost 20 percent of the species found in F–1 cuttings make their first appearance. Of these 24 species, *Calcarina spengleri* (Gmelin) and *Amphistegina madagascariensis* d'Orbigny occur in typical abundance, persisting from there on down to the bottom (2,120–2,130 feet) in nearly all samples of cuttings. (See table 3.)

At about 110 feet, specimens and species become noticeably sparser with very few species being added to the fauna in the interval of 120–130 feet to 270–280 feet implying this section to be practically barren. Core F–1–1 taken at 170–190 feet helps to verify this implication, yielding only 1 or 2 specimens each of the following species:

Amphistegina madagascariensis d'Orbigny
Calcarina sp.
Nonion pacificum (Cushman)
Reussella simplex (Cushman)

All, except the poorly preserved indeterminate species of *Calcarina*, have higher occurrences in the section. The absence of *Calcarina spengleri* in the core at this level emphasizes the short vertical range of this species, though specimens persist to the bottom as previously noted.

The sample taken from 270–280 feet contains the first indication of change with top occurrences of 6 species, 2 of which are distinctive. Though found in modern seas elsewhere, *Nonion grateloupi* (d'Orbigny) has not been observed in Recent sediments in the Marshall Islands area. This is true also of *Planorbulinoides retinaculata* (Parker and Jones). The latter has been recorded from sediments of Pleistocene and Pliocene age in lower California.

Further indication of change at this point is noted in the appearance of *Calcarina delicata* Todd and Post at 290–300 feet, coinciding well with its top occurrence in hole E–1 at 280–290 feet. It is only rare and scattered in F–1, however, to 720–730 feet. It occurs again somewhat lower but with no significance. A broken specimen of *Peneroplis planatus* (Fichtel and Moll) was obtained from sample 440–450 feet which is a higher first occurrence than in E–1 at 730–740 feet.

The first evidence of Miocene is at 560–570 feet with the appearance of a well-preserved specimen of *Austrotrillina howchini* (Schlumberger). Although a core was taken at 600–627 feet (F–1–2) no cuttings were obtained. The core, being hard and firm, yielded no smaller Foraminifera. At 640–650 feet support is given to the evidence for Miocene age by the occurrence of *Pararotalia byramensis* (Cushman).

The presence of *Peneroplis honestus* Todd and Post at 770–780 feet coincides well with its appearance in hole E–1 at 750–760 feet, although these levels are considerably higher than that of 1,145½ in the Bikini hole. This was followed by the first distinctively brown specimens of *Marginopora vertebralis* Blainville at 790–800 feet. Dark specimens of other species were not observed until lower in the section (*Triloculina trigonula* at 890–900 feet and a questionable form of *Quinqueloculina sulcata* at 960–970 feet).

The material from 790–800 feet to 860–870 feet is so sparse that the section appears barren. However, at 840–850 feet one of the fossils indicative of the Miocene for this area, *Tubulogenerina tubulifera* (Parker and Jones), makes the first of its four scattered appearances in hole F–1.

Two distinctive miliolid species *Hauerina aspergilla* (Karrer) and *Quinqueloculina prisca* d'Orbigny were found together at 870–880 feet. *Rotalia tectoria* Todd and Post occurs first at 920–930 feet in hole F–1 which is higher than in either hole E–1 (1,452–1,482 ft) or the Bikini section (1,797 ft). *Quinqueloculina akneriana* d'Orbigny occurs at approximately the same level in the cuttings of both Eniwetok drill holes, at 940–950 feet in F–1 and at 1,080–1,090 feet in E–1. It was not reported from the Bikini drill holes, nor in Recent sediments in the Marshall Islands.

No samples were recovered in hole F–1 at 950 to 1,040 feet, but cuttings from 1,040–1,050 feet yielded *Archaias eniwetokensis* Cole, an occurrence which is about 800 feet higher than in hole E–1 or in the drill holes on Bikini Atoll. Another small gap in the samples follows this from 1,060 to 1,080 feet.

Asterigerina tentoria Todd and Post first appears at 1,090–1,100 feet followed by other rare and scattered occurrences to 1,230–1,240 feet. At 1,100–1,110 feet it is followed by *Rotalia tuvuthaensis* Kleinpell. *Clavulina serventyi* Chapman and Parr occurs at 1,140–1,160 feet, about the same level as in hole E–1, corresponding with the Bikini records of 946 to 1,891 feet.

The last two tops of possible significance were noted at 1,230–1,240 feet, although both are only tentative identifications—*Uvigerina* cf. *U. isidroensis* Cushman and Renz and *Loxostomum* cf. *L. gunteri* Cushman. Both species have been reported from Miocene beds in Florida, the former having been described from the upper Oligocene-upper(?) Miocene of Venezuela. Neither of the forms were found in hole E–1 or the Bikini drill hole material.

No cuttings were recovered from 1,240 to 2,000 feet with the exception of the short section at 1,975–1,978 feet. This latter material was virtually barren, containing only rare specimens of the contaminating *Calcarina spengleri* and *Amphistegina madagascariensis*. The lowest few samples of cuttings (between 2,000 and 2,130 ft) contained little except contamination from above, with no new occurrences being observed. The lowest 110 feet of this section was reported (Ladd and others, 1953, p. 2265) as: "Hard, dense, white crystalline limestone showing few traces of organic structure." From here to the bottom of the drill hole at a depth of 4,630 feet, no further cuttings were obtained.

As was true of core F–1–2 at 600–627 feet, the following cores were not suitable for specific determination of smaller Foraminifera: F–1–3 (1,232–1,249 ft); F–1–4 (1,718–1,740 ft); F–1–5 (1,978–2,006 ft); and F–1–6 (2,662–2,688 ft). These cores were all too hard for breaking down for the recovery of free specimens. Examination of thin sections of the cores, however, permitted a few, mostly tentative, observations.

The chief smaller Foraminifera in core 3 (1,232–1,249 ft) seem to be abundant miliolids with peneroplids, bolivinids, small rotaliids, and globigerinids comprising minor proportions of the fauna.

In cores 4 and 5 (from 1,718–1,740 ft and 1,978–2,006 ft) *Rotalia tectoria* and *Amphistegina bikiniensis* appear to constitute a large proportion of the rock. Their occurrence together at this depth is to be expected from their other occurrences in hole E–1 and at Bikini. (See table 1.) Thin sections from various parts of the 2 cores show varying relative abundance of these 2 species, and both seem to be less abundant in the lower core than in the upper one. In addition, rare miliolids and globigerinids were observed in the thin sections, none specifically identifiable.

In the thin sections of core 6 (2,662–2,688 ft.) smaller Foraminifera seem to be rather abundant and varied, but none are determinable with certainty. They seem to include *Bolivina-* or *Bolivinella*-like specimens, arenaceous forms (both biserial and uniserial), globigerinids, amphisteginids, small thin-walled rotaliform species, and possibly *Streblus*. In this core, however, unlike cores 4 and 5, the Foraminifera seem to form a relatively small proportion of the rock.

Of the 15 cores obtained from hole F–1, only those from the Eocene section contained significant faunas. Samples from cores 7–15 (between 3,052 and 4,553 ft) inclusive were crushed, washed, and screened, and most were found to contain rather rich assemblages of smaller Foraminifera.

All cores except core 7 came from deeper depths than any cuttings obtained from hole E–1; and the lowest core, No. 15, came from about 1,400 feet deeper than the deepest E–1 cuttings. Many of the same species are found in the cores from F–1 as in the cuttings from E–1. There are, however, striking contrasts between the faunas present in the cores and those recovered from the Eocene cuttings.

The smaller Foraminifera in cores 7, 8, 9, and 10 (between 3,052 and 3,988 ft), taken within approximately 1,000 feet of soft chalky limestone (Ladd and others, 1953, p. 2262–2263), proved to consist mainly of globigerinids. Analysis of the fauna provides confirmation for the statement (Ladd and others, 1953, p. 2263) that this 1,000-foot section had no counterpart at similar depths in hole E–1.

Smaller Foraminifera confirm the late Eocene age of these four cores by means of the globigerinid assemblage and the following benthonic species that are found only in these cores:

Eponides ocalanus Cushman
Lingulina wilcoxensis Cushman and Ponton
Nodosaria affinis Reuss
Robulus cf. *R. midwayensis* (Plummer)

In addition to the rich assemblage of globigerinids and the rare benthonic species listed above, the following other species, known also in the cuttings from E–1, are present:

Asterigerina marshallana Todd and Post
Gaudryina (*Siphogaudryina*) *rugulosa* Cushman
Gypsina globula (Reuss)
Halkyardia bikiniensis Cole
Streblus flosculus (Todd and Post)

In the E–1 cuttings *Halkyardia bikiniensis* ranges between 2,280 and 2,910 feet, and *Streblus flosculus* ranges from 2,380 to the lowest cuttings. As the other species have longer ranges, these two provide the best basis for estimate regarding equivalent age. On this basis the *Globigerina* limestones are considered to be an offshore facies of the interval represented by the E–1 cuttings not lower than 2,910 feet, and because the age is Eocene, not higher than 2,770 feet.

Cores 11 and 12 (between 4,197 and 4,341 ft) are relatively poorer than those above and below and seem to contain a transitional fauna between the largely planktonic one above and the largely benthonic one below. *Globorotalia centralis* Cushman and Bermudez, *Asterigerina papillata* Todd and Low, n. sp., and *Cassidulina globosa* Hantken first appear in this transitional zone but are better developed in the lower three cores. *Peneroplis dusenburyi* Henson, an abundant species in hole E–1, makes its first appearance in F–1 in core 11, and *Triloculina trigonula* (Lamarck) is found abundantly with it. These two species in combination provide good correlation between hole F–1 and the uppermost part of the Eocene section in hole E–1. (See pl. 264.)

In cores 13, 14, and 15 (between 4,406 and 4,553 ft) are the first appearances of 16 species of which the following seem to be most significant:

Alabamina cf. *A. wilcoxensis* Toulmin
Anomalina corrugata Cushman and Bermudez
Bulimina semicostata Nuttall
Dentalina cooperensis Cushman
Globigerina mexicana Cushman
Globorotalia brödermanni Cushman and Bermudez
crassata var. *densa* (Cushman)
Hantkenina alabamensis Cushman
Rectoeponides cubensis Cushman and Bermudez
Reussella araneola n. sp.

Together with these, are the first appearances in F–1 of the following species known from the lower cuttings of E–1:

Asterigerina rotula (Kaufmann)
Cibicides macrocephalus (Gümbel)
Cycloloculina sp. A
Ornatanomalina crystallina n. sp.
Pyrgo lupheri (Rau)

By means of these species a tentative correlation may be made between about 4,400 to 4,550 feet in F–1 with about 3,000 to 3,130 feet in E–1.

With the following considerations a further refinement of correlation may be possible. *Ornatanomalina crystallina* n. sp. and *Cibicides macrocephalus* occupy a higher position than *Asterigerina rotula* in the E–1 cuttings. In the F–1 cores the first two are found commonly together in core 13 (4,406–4,431 ft) while the third is restricted to cores 14 and 15 (4,500–4,553 ft). (See pl. 264.)

COMPARISON OF CONCLUSIONS BASED ON SMALLER AND LARGER FORAMINIFERA

A comparison of plate 264, showing tops of occurrences of certain significant smaller Foraminifera, with the chart (Cole, 1958, pl. 230) based on larger Foraminifera, showing correlation between the Eniwetok drill holes and those on Bikini, indicates there is no discrepancy in the evidence of smaller and larger Foraminifera regarding the top of the Miocene and the top of the Eocene. The lack of agreement lies only in the question of the Oligocene, whether it is present and, if so, where its top should be located.

There may be several explanations of the questionable interval overlying the top of the Eocene (2,770 ft in hole E–1, as recognized in cuttings from that depth, and 3,052–3,055 ft in hole F–1, as recognized by larger Foraminifera in a core at that depth). In hole E–1 the Eocene is quite certainly not higher than 2,770 feet, as a continuous series of cuttings extending downward from the Miocene core at about 2,000 feet in that hole fails to reveal any evidence of Eocene until a depth of 2,770 feet is reached. In hole F–1 the Eocene may be higher than its first occurrence, inasmuch as some 360 feet without samples intervene above the Eocene core at 3,052–3,055 feet and the next higher core at 2,662–2,688 feet, which is of undoubted Miocene age as determined by larger Foraminifera.

Thus in hole E–1 there is a maximum of about 770 feet unrepresented by core samples between two consecutive cores, the upper one Miocene and the lower one Eocene, while in hole F–1 the distance from the upper (Miocene) core to the next lower (Eocene) core is about 360 feet. While in the latter hole the

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interval is unrepresented by samples, in hole E–1 the interval is represented by a continuous series of cuttings, in the lower 590 feet of which some species of smaller Foraminifera with Oligocene affinities are found.

Unlike the 2 deep holes at Bikini which were closely adjacent and could be studied as 1 section, the 2 Eniwetok holes are separated by 22 miles. Thus an occurrence of undoubted Miocene at 2,662–2,688 feet in one hole cannot be justifiably assumed to prove that rocks at an equivalent depth in the other hole are of equivalent age. That they probably are not of equivalent age is suggested by the considerable discrepancy in depth at which a sequence of 3 Eocene zones occur in the 2 holes (see p. 812 and fig. 259) as well as by the difference in depth in each hole to the basement rock.

Figure 258 presents two explanations of the questionable interval between the unquestioned top of the Eocene and the overlying unquestioned Miocene. As shown in this diagram, both larger and smaller Foraminifera indicate the presence of this questionable interval. Evidence regarding its probable thickness and exact position in the three deep holes is two fragmentary and too poor to allow any more than indefinite boundaries for it.

As it occurs in a section of the holes unrepresented by any core material from which larger Foraminifera in place could be obtained, the determination of its age must, for the present, rest wholly on smaller Foraminifera.

MIOCENE

Many species of smaller Foraminifera in the cuttings from drill holes E–1 and F–1 confirm the presence of rocks of Miocene age in these holes.

Special search has been made for equivalent or similar recorded faunas in the geographically closest areas, such as Saipan, Fiji, East Indian islands, Japan, Formosa, Philippines, Australia, and New Zealand.

The Tagpochau limestone of Saipan, leaving out of consideration its Donni sandstone member, contains a fauna of smaller Foraminifera ecologically similar and probably close in age to the lower part of the Miocene section at Eniwetok.

Foraminifera described from Lau, Fiji (Kleinpell, 1954), originate from deposits that are ecologically similar to those making up the Miocene part of the Eniwetok section, and there are faunal similarities between the species found there and those occurring in the upper part of the Eniwetok Miocene section. The most striking tie with Fiji is *Rotalia tuvuthaensis* Kleinpell, as indicated in table 4, which was found in both drill holes. Other species in common are mentioned under the systematic descriptions.

Recorded Miocene faunas from various East Indian islands are mostly of relatively deepwater globigerine facies having little in common in generic makeup, and, excepting cosmopolitan forms, virtually no species in common with the Eniwetok Miocene section. From the other areas mentioned above, no very close comparisons have been found between formations of Miocene age having appropriate ecology and the Miocene section at Eniwetok. Such species as were observed to occur both at Eniwetok and at various Australian and New Zealand localities are included in table 4. Table 4 lists in order of their appearance downward 41 species that have first occurrences in the Miocene section, with their chief, but not in all cases exclusive, stratigraphic and geographic occurrences elsewhere.

Twenty-two (or 53 percent) of the species listed in table 4 also occur in the Miocene section of the Bikini drill hole. Of the 41 species, 11 are not known outside the Marshall Islands, 13 are characteristic Miocene species or Miocene to Recent species, 2 more occur in Miocene and Oligocene, 2 more are known from Oligocene to Recent, 5 are characteristically Oligocene species, 7 are characteristically Eocene species, and 1 is known from Oligocene and Eocene.

The presence in the Miocene section of the Eniwetok hole of species confined elsewhere to Eocene and Oligocene beds is not wholly unexpected. Four of the thirteen species known from Eocene or Oligocene beds elsewhere had previously been reported from beds at Bikini whose Miocene age is unquestioned. Furthermore, it has long been recognized that genera and species that became extinct in the Oligocene in North America continued to live in the Indo-Pacific region to the present. A striking example of this, the genus *Bolivinella*, was pointed out in 1922 (Cushman, 1922, p. 87–88). Hence, the presence of rare occurrences in the Miocene beds at Eniwetok of several species regarded as Eocene and Oligocene in age may be regarded either as a result of inadequate knowledge of the ranges of those species or as an example of the persistence locally of species that became extinct elsewhere. Such a phenomenon seems to weaken the case for recognition of Oligocene beds, as discussed below.

OLIGOCENE

Because there is no agreement as to where the boundary between Miocene and Oligocene in the Indo-Pacific area is to be placed, as to whether Aquitanian is to be regarded as lowermost Miocene or uppermost Oligocene, and as to whether Tertiary *e* is equivalent to the Aquitanian, to a part of it, or overlies it, it seems best to preface our discussion of the Oligocene with the statement that the presence of rocks of Oligocene age is highly questionable and that their designation as "lower"

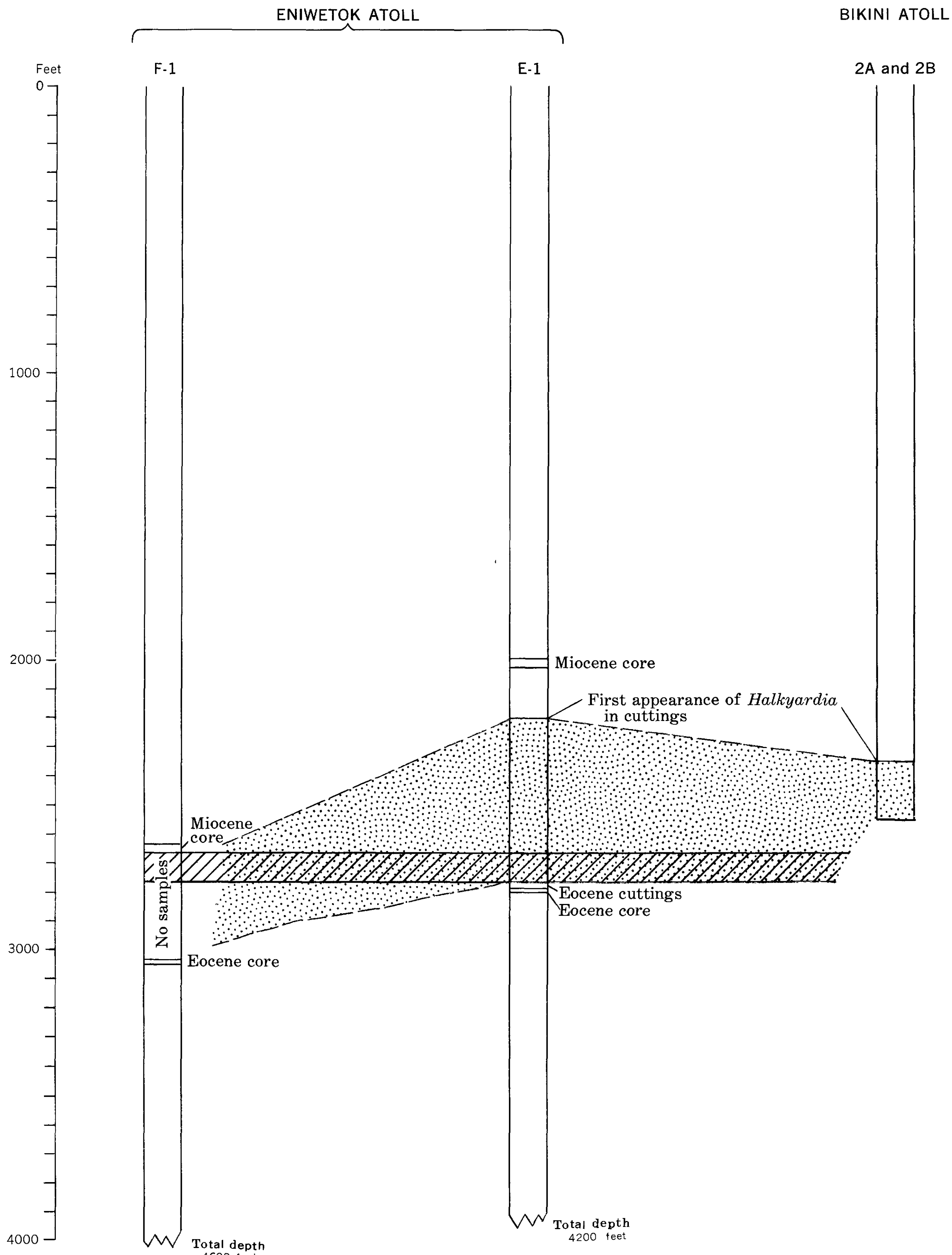


FIGURE 258.—Alternative interpretations of correlation of age between Eniwetok drill holes F–1 and E–1 and Bikini drill holes 2A and 2B in the questionable interval below unquestioned Miocene and above unquestioned Eocene. Correlation based on larger Foraminifera shown by crosshatched area inferred from Cole (1957, pl. 230). Suggested alternative correlation based on smaller Foraminifera shown by dotted area. Sections adapted from Cole (1957, pl. 230).

rather than "upper" is open to doubt. The evidence of the smaller Foraminifera favors lower Oligocene and the evidence of the larger Foraminifera, while favoring Miocene, does not rule out the possibility of upper Oligocene (W. Storrs Cole, written communication, Jan. 21, 1958).

The interpretation of Oligocene in hole E–1 is supported by several considerations. First, the level at about 2,280 to 2,380 feet can be correlated approximately with the level at about 2,350 feet which at Bikini was tentatively considered the top of Tertiary *c* (lower Oligocene) (Cole, 1954, p. 572; Todd and Post, 1954, p. 553). Second, the presence of the species listed alphabetically in table 5 with their chief stratigraphic and geographic occurrences elsewhere, suggests Oligocene age.

With the exception of *Halkyardia bikiniensis* which also occurs in the Eocene cores, these species occur between 2,180 and 2,700 feet, and all are rare. The smaller Foraminifera, therefore, indicate the closest age of the section in hole E–1 between 2,180 feet and the top of the Eocene at 2,770 feet to be early Oligocene.

The age significance of the genus *Halkyardia* is a matter on which there seems to be lack of agreement. Cole's discussion (1954, p. 585) summarizes the reported occurrences of the genus and suggests that it

TABLE 4.—*Significant species in the Miocene section and their age and occurrences elsewhere*

Species	Age	Occurrence
Tubulogenerina tubulifera (Parker and Jones) [1]	Eocene	France.
Valvulammina globularis (d'Orbigny)	Eocene	France.
Loxostomum digitale (d'Orbigny)	Miocene	Central and southern Europe and Egypt.
Asterigerina indistincta Todd and Post [2]	Late Miocene, post-Tertiary *e*	Bikini.
Nonion grateloupi (d'Orbigny) [1]	Miocene to Recent	Europe, United States, and West Indies.
Pararotalia byramensis (Cushman) [1]	Early Oligocene	Southeastern United States.
Rosalina assulata (Cushman)	Late Eocene	Southeastern United States and western Australia.
Pavonina triformis Parr [1]	Miocene and Oligocene	Australia.
Peneroplis planatus (Fichtel and Moll)	Miocene to Recent	Europe, West Indies, and Australia.
Discorbis balcombensis Chapman, Parr, and Collins [1]	Tertiary (Balcombian)	Australia.
Hauerina aspergilla (Karrer)	Miocene	Hungary.
Buliminella madagascariensis (d'Orbigny) [1]	Oligocene	Australia and United States.
	Recent	Australia, New Zealand, and Madagascar.
Peneroplis honestus Todd and Post [2]	Miocene, Tertiary *e* [3]	Bikini.
Quinqueloculina byramensis Cushman	Early Oligocene	Mississippi.
Valvulammina marshallana Todd and Post [2]	Miocene, Tertiary *e* [3]	Bikini.
Rotalia tuvuthaensis Kleinpell	Miocene, Tertiary *g*	Fiji.
Reussella cf. *R. byramensis* Cushman and Todd	Oligocene	Mississippi and Trinidad.
Asterigerina tentoria Todd and Post [2]	Miocene, Tertiary *e* [3]	Bikini.
Triloculina fusa Todd and Post [2]	Miocene, Tertiary *e* [3]	Bikini.
Cribrogoësella parvula n. sp.[2]	Miocene, Tertiary *e* [3]	Bikini.
Eponides duprêi ciervoensis Cushman and Simonson	Oligocene	California.
Valvulina martii Cushman and Bermudez [1]	Eocene	West Indies.
prominens Todd and Post [2]	Miocene, Tertiary *e* [3]	Bikini.
Quinqueloculina akneriana d'Orbigny	Oligocene to Recent	Europe and North America.
Bolivina plicatella Cushman	Miocene to Recent	Europe, North and South America, and Atlantic Ocean.
Austrotrillina howchini (Schlumberger) [1]	Miocene	Australia and Saipan.
Clavulina serventyi Chapman and Parr [1]	Recent	Australia and Tasmania.
Rosalina turgida (Dorreen) [1]	Late Eocene	New Zealand.
	Miocene	Australia.
Quinqueloculina prisca d'Orbigny	Eocene	France.
Rotalia tectoria Todd and Post [2]	Miocene, Tertiary *e*	Bikini.
Amphistegina bikiniensis Todd and Post [2]	Miocene, Tertiary *e*	Bikini.
Orbulina suturalis Bronnimann	Late Oligocene to Miocene	Worldwide.
Elphidium marshallana Todd and Post [2]	Miocene, Tertiary *e*	Bikini.
Austrotrillina striata Todd and Post [2]	Miocene, Tertiary *e*	Bikini.
Bolivina densa Todd	Miocene, Tertiary *e*	Saipan.
Archaias eniwetokensis Cole [2]	Miocene, Tertiary *e*	Bikini.
Cibicidina mississippiensis (Cushman)	Late Eocene and Oligocene	North and South America.
Mississippina monsouri Howe	Oligocene	Mississippi.
Spiroloculina tricarinata Terquem	Eocene	France.
Siphogenerina mayi Cushman and Parker	Miocene	California.
Articulina sulcata Reuss	Miocene	Austria.
Crespinella? sp. A [1]	As a genus, restricted to the Miocene of Australia.	

[1] Also occurs in the Miocene of Bikini.
[2] Recorded only from the Miocene of Bikini.
[3] According to Cole's (1957) revision based on larger Foraminifera.

TABLE 5.—*Significant species in the Oligocene section and their age and occurrences elsewhere*

Species	Age	Occurrence
Asterigerinata bracteata (Cushman)	Early and middle Oligocene	Mississippi, Alabama, and Texas.
Halkyardia bikiniensis Cole	Tertiary *c* or older	Bikini drill hole.
	Early Oligocene	Guam.
Loxostomum vicksburgense (Howe)	Early Oligocene	Mississippi and Alabama.
Quinqueloculina leonensis Applin and Jordan	Middle Oligocene	Florida (subsurface).
Valvulineria sculpturata Cushman	Early Oligocene	Mississippi and Alabama.
	Stampian	Aquitaine, France.
	Eocene(?)	Western Australia.

does not occur in beds younger than Oligocene. This conclusion is further supported by several published and unpublished occurrences in South and Central America. In the Aquitaine Basin of France the genus has been reported from upper Lutetian to Stampian (Sacal and Debourle, 1957, p. 44). A single exception to this generally accepted range of the genus *Halkyardia* is presented by Van der Vlerk (1955, p. 73, table 1) in a range chart for the Far East where *Halkyardia* is shown to range throughout Tertiary *c*, *d*, and *e*. The scope of this brief summary by Van der Vlerk did not permit the inclusion of specific details of occurrences. According to a written communication (Van der Vlerk, Feb. 11, 1959) his reported occurrence of *Halkyardia* in the upper part of Tertiary *e*, which he regards as correlatable with the Aquitanian, may be uncertain. On the other hand, his reported occurrence of *Halkyardia* in association with *Heterostegina borneensis* is undoubted in the lower part of Tertiary *e* which he regards as correlatable with Chattian age. Therefore, without verification of this reported existence of *Halkyardia* in the Aquitanian, we prefer to regard the range of the genus as Eocene and Oligocene only.

Van der Vlerk (1955, p. 75) has suggested that correlation between Europe and the Far East is possible at present only up through Tertiary *d*. At higher levels there seems to be an inversion of presumed zonal sequences (Van der Vlerk, 1955, p. 75), so that a form that survived the extinction of another form in Europe may have become extinct first in the Far East. Reversal of apparent zonal sequences by local extinction in one place or another, possibly due to facies control, is a likely cause.

For this reason and also in view of the extreme diversity of placement of certain zones based on planktonic Foraminifera (contrast Drooger, 1956, p. 188, fig. 1, with Todd and others, 1954, fig. 1 and p. 679) in the European time scale, we prefer to avoid for the present the placing of these as well as the Indonesian letter zones within the European time scale. As the European type sections are not identical in facies with the West Indian sections where the planktonic zones were originally established, correlation must necessarily be a two-stage process, assisted by larger Foraminifera, Mollusca, or some other group of fossils. Zones based on planktonic Foraminifera are without doubt the best means of long distance correlation and will probably eventually prove to be the most accurate means of fitting unknown beds into the standard time scale. Their use, however, must necessarily be limited to the appropriate facies. In the Eniwetok drill holes, deepwater facies containing planktonic Foraminifera are found only in the Eocene section of hole F–1.

A third consideration favoring the existence of Oligocene beds in the Eniwetok section is the recognition of *Asterigerina marshallana* Todd and Post and *Amphistegina bikiniensis* Todd and Post in the Oligocene of western Australia (Irene Crespin, written communication, Nov. 22, 1956). In western Australia, *Amphistegina bikiniensis* has been found abundantly in association with a typical lower "*e*" stage assemblage, regarded as of late Oligocene age, and also, but rarely, in the "*c*" stage, regarded as early Oligocene while *Asterigerina marshallana* was found in strata immediately overlying typical Eocene assemblages (Irene Crespin, written communication, Oct. 1, 1957).

This western Australia occurrence in the Oligocene of these two species with the same relative stratigraphic position as that in which they are found at Bikini and Eniwetok—that is *Asterigerina marshallana* first appearing within the section regarded as Oligocene and ranging downward into the Eocene and *Amphistegina bikiniensis* having its acme within the presumed Oligocene but also ranging upward into the Miocene—lends further support to the Oligocene age of the overlapping portion of their ranges in the Marshall Islands. This overlapping portion is from about 2,100 feet to about 2,550 feet at Eniwetok.

A fourth consideration, carrying less weight than the other three, is the presence in the beds regarded as Oligocene of certain species whose ranges at Bikini are comparable to those at Eniwetok. Two of these are restricted to the lower several hundred feet of the Bikini drill hole, and are unreported elsewhere: *Massilina placida* Todd and Post and *Reussella* sp. A of

Todd and Post. Three are known from the Miocene in E–1 but occur with increased frequency in the presumed Oligocene beds: *Buliminella madagascariensis* (d'Orbigny), *Cribrogoësella parvula* n. sp., and *Valvulina martii* Cushman and Bermudez. It seems significant that the distribution of the two latter species—*Valvulina martii* (Todd and Post, 1954, p. 552–553, fig. 166) and *Cribrogoësella parvula* n. sp. (see discussion of this species under Systematic descriptions)—is similar. At Bikini both these species showed distribution patterns similar to those observed at Eniwetok; that is, major occurrence in the lower part of the hole (that considered to be Oligocene) with additional occurrences at higher levels but separated by an hiatus. (See table 1.)

The basing of interpretation of Oligocene beds in hole E–1 upon a few Oligocene species appears to be weakened by the presence, higher in the hole, of a number of other species that are reported elsewhere only from beds of Oligocene or Eocene age. These are:

Cibicidina mississippiensis (Cushman)
Eponides duprèi ciervoensis Cushman and Simonson
Mississippina monsouri Howe
Quinqueloculina byramensis Cushman
prisca d'Orbigny
Reussella cf. *R. byramensis* Cushman and Todd
Rosalina assulata (Cushman)
Spiroloculina tricarinata Terquem
Valvulammina globularis (d'Orbigny)

All occur very rarely except *Valvulammina globularis*, a form which presents the most striking example of nonconformity in the Eniwetok hole. It has been reported only from the Eocene of the Paris Basin and the Netherlands. However, in hole E–1 it has been found in an unquestionable Miocene association. In addition, it is associated with and ranges higher in the section than the closely related species *V. marshallana*, inferring that the apparent restriction of *V. globularis* to the Eocene in Europe does not apply in the central Pacific.

Two additional species known only from the Eocene of the Paris Basin are included in the foregoing list: *Quinqueloculina prisca* and *Spiroloculina tricarinata*. From their occurrence with *Valvulammina globularis*, the probable extension of range suggested for that species may be assumed to have been likely for these two species also.

For the remaining six species the reported occurrences are in the United States; for all but *Eponides duprèi ciervoensis*, in the Southeastern United States. As pointed out above, there are several fossil species from North America still living in present-day Pacific waters. Thus, it is not beyond reason, or even surprising, to find fossil species whose stratigraphic range appears to be limited to Eocene and Oligocene in America, ranging into the Miocene in the western Pacific. Hence, the per se age indication of these species is outweighed by their associations.

Although contradictory evidence has been presented, the points supporting an Oligocene age should not be disregarded. In spite of the lack of unequivocal evidence regarding the age of the beds immediately overlying the Eocene beds at 2,770 feet, the best estimate that may be based on the smaller Foraminifera seems to be early Oligocene.

EOCENE

Among the many species of smaller Foraminifera present in the cuttings and cores that have been determined as Eocene, only 50 species seem to be confined there. Of these, 8 are indeterminate, 7 are questionably identified, and 3 are new. Of the remaining 32 species, 28 are listed alphabetically in table 6 with their chief, but not in all cases exclusive, stratigraphic and geographic occurrence elsewhere.

Although not all the species point to the same age, the overall indication is late Eocene. Faunal affinities are mainly with upper Eocene faunas of the southern part of the North American continent, with a few species having affinities with southern Europe and the Middle East. Some of the species also occur in the upper Eocene of Saipan in the western Pacific.

PALEOECOLOGIC INTERPRETATION

Smaller Foraminifera provide an excellent basis for interpretation of conditions of deposition at the sites of holes E–1 and F–1, located on opposite sides of the atoll. As shown in figure 256, drill hole E–1 is near the southeast edge of the atoll where it drops off to the abyss; whereas hole F–1 is in the northwest section of the atoll near one of the two guyots adjoining Eniwetok (Ladd and others, 1953, p. 2257–2258, fig. 1).

In the Eocene sections of both holes, a 350-foot sequence of benthonic faunas appears with a 1,400- to 1,600-foot differential between the holes but with the same relative position in each hole, as follows:

	E–1 (*in feet*)	*F–1* (*in feet*)
Peneroplis-Triloculina assemblage	2, 770–2, 940	4, 200–4, 400
Ornatanomalina assemblage	2, 940–2, 960	4, 420
Asterigerina rotula assemblage	3, 010–3, 120	4, 500–4, 550

If we assume no differential deformation of the earth's crust between these two sites which are about 22 miles apart, then the 1,400- to 1,600-foot differential would mean a difference in depth of deposition of 230 to 270 fathoms, a depth range greater than one in which we could reasonably expect to find identical marine faunas. Therefore, we assume either that the two appearances of the sequence of assemblages are not synchronous but are an instance of homotaxy; or that the two sequences are synchronous and some differential movement has lowered the site of F–1 or raised the site of E–1 at some time in the early Tertiary; or that the two appearances are synchronous, with the lower one (that in F–1) having been deposited on a former outer slope of the atoll. The normal gradient on the outer slope of an atoll is such that present-day sites of contemporaneous deposition differ by as much as 500 fathoms within a horizontal distance of a mile. On such a gradient, downward movement of large amounts of shallow-water sediment is to be expected and has been observed around Bikini where a shallow core taken at 240 fathoms on the outer slope of the northwestern part of Bikini Atoll (Bik 1173) yielded shallow-water species—*Amphistegina madagascariensis* d'Orbigny and *Calcarina spengleri* (Gmelin) —with percentage compositions comparable to lagoon sediments (Cushman, Todd, and Post, 1954, table 4).

Confirmatory evidence for the third alternative consists of the fact that in hole F–1 the three above-mentioned assemblages are accompanied by minor amounts of planktonic specimens; in hole E–1, on the other hand, no planktonic specimens were found in the Eocene section and none of the accompanying benthonic species are of known deepwater types.

Therefore, we favor the third alternative—that correlation can be made between the lowest cores of hole F–1 and the Eocene section of hole E–1 and that the former represents the contemporaneous outer slope deposition of the latter.

TABLE 6.—*Significant species in the Eocene section and their age and occurrences elsewhere*

Species	Age	Occurrence
Anomalina corrugata Cushman and Bermudez	Late Eocene	Cuba.
Asterigerina rotula (Kaufmann)	Late Eocene	Switzerland, Poland, Iraq, and Syria.
Bolivina ventricosa Galloway and Heminway	Late Oligocene to late Miocene	Puerto Rico and Dominican Republic.
Bulimina semicostata Nuttall	Eocene	Mexico, Cuba, Saipan, and New Zealand.
Cassidulina globosa Hantken	Eocene	Hungary and United States.
Cibicides macrocephalus (Gümbel)	Eocene	Bavaria.
Dentalina cooperensis Cushman	Late Eocene, Oligocene	United States.
	Late Eocene	Saipan.
Epistomaria semi-marginata (d'Orbigny)	Middle Eocene	Florida.
	Lutetian	France.
Eponides ocalanus Cushman	Late Eocene	Alabama and Florida.
Globigerina dissimilis Cushman and Bermudez	Late Eocene to middle Oligocene	West Indies, Ecuador, Alabama, Algeria, Spain, Italy, Czechoslovakia, Formosa.
eocaena Gümbel	Eocene	Bavaria, Mexico, and Barbados.
	Paleocene	Mid-Pacific seamount.
eocaenica Terquem	Eocene	Paris Basin.
mexicana Cushman	Eocene	Mexico, Louisiana, Dominican Republic, Spain, and Peru.
jacksonensis Bandy	Eocene	Alabama and mid-Pacific seamount.
Globorotalia brödermanni Cushman and Bermudez	Early Eocene	Cuba.
centralis Cushman and Bermudez	Eocene, Jackson and upper Claiborne equivalent	West Indies, southern Europe, central Pacific, and Saipan.
crassata var. *densa* (Cushman)	Eocene	Mexico, California, Atlantic continental shelf, Virginia, Trinidad, and mid-Pacific seamount.
Gyroidina octocamerata Cushman and G. D. Hanna	Eocene	North and South America, Europe, and Australia.
Hantkenina alabamensis Cushman	Late Eocene	Southeastern United States, West Indies, Central and South America, mid-Pacific seamount, India, Caucasus, Moravia, Austria, and Spain.
Lingulina wilcoxensis Cushman and Ponton	Early Eocene	Alabama.
Nodosaria affinis Reuss		Widely distributed geographically and stratigraphically.
Nonion micrum Cole	Middle and late Eocene	Mexico, United States, Trinidad, and Saipan.
planatum Cushman and Thomas	Middle Eocene	United States.
	Late Eocene	Saipan.
Peneroplis dusenburyi Henson	Late, middle, and early (?) Eocene	Iraq.
Pyrgo lupheri Rau	Oligocene	Washington.
	Eocene	Ecuador.
Rectoeponides cubensis Cushman and Bermudez	Middle and late Eocene	Cuba, Dominican Republic, and France.
Textularia subhauerii Cushman	Eocene, Oligocene	Southeastern United States.
Valvulina intermedia Applin and Jordan	Middle Eocene	Florida and Dominican Republic.

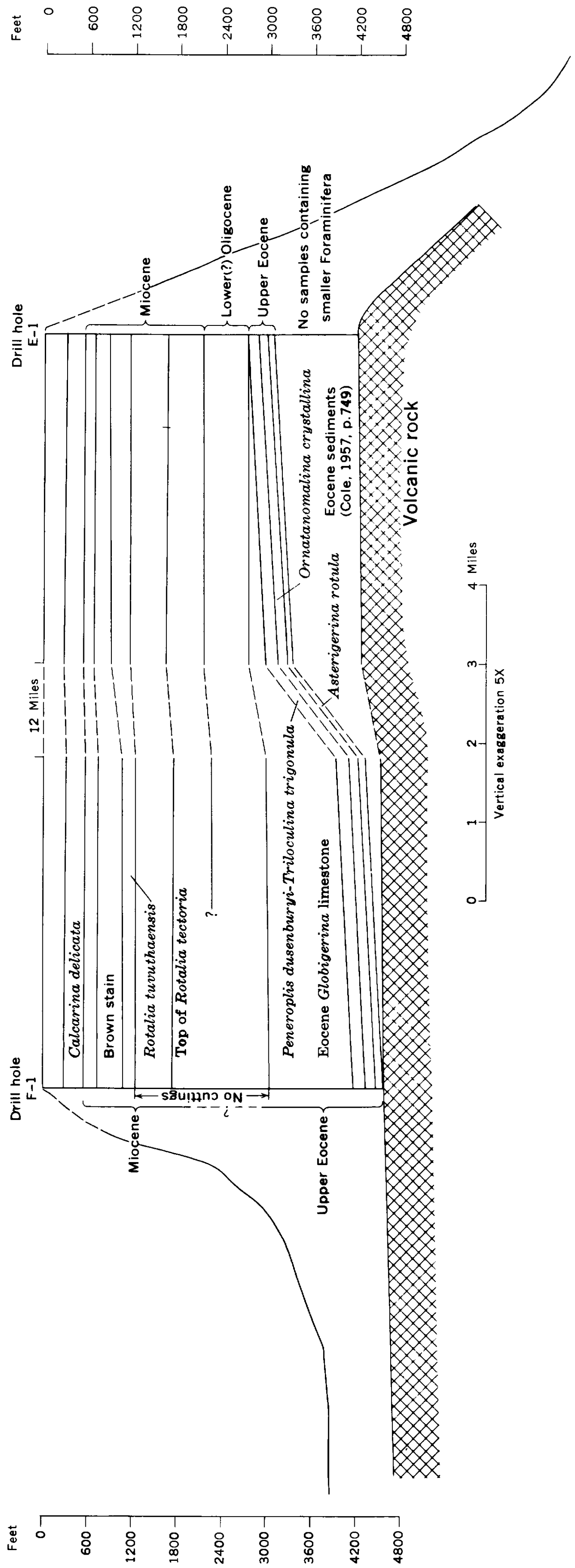


FIGURE 259.—Interpretation of relations between strata penetrated by drill holes F–1 and E–1. Outer slope profiles adapted from Emery, Tracey, and Ladd, 1954, text fig. 44 (profile no. 24, near the island of Elugelab in the northwest and profile no. 11, near Parry Island in the southeast). Volcanic rock profile adapted from Raitt, 1957, text figs. 231 and 232 (section A–I in northwest and section H–L in southeast—see text fig. 219).

Between the lowest cuttings from hole E–1 and the basalt at the bottom of the hole, about 1,100 feet of rock were penetrated from which no smaller Foraminifera were obtained. Evidence of the larger Foraminifera in the core near the bottom (Cole, 1957, table 4) proves the sediments to be Eocene. The Eocene sediments in this 1,100-foot interval seem to have no counterpart in hole F–1. The fact that this thickness of sediments exists at E–1 provides further confirmation of the presumed outer slope deposition at the site of F–1. For if the atoll grew northwestward, as suggested below, the site of F–1 would have been on the Eocene outer slope over which the atoll developed during Miocene to Recent times.

Emery, Tracey, and Ladd (1954, p. 143, text fig. 68) point out the rather striking inequality of reef width around Eniwetok Atoll, widest in the north-northwest. Because of more flourishing seaward growth toward the north and east, greater erosion of seaward margins on the south, and the major lagoonal sedimentation taking place on the west side of the lagoon (Emery, Tracey, and Ladd, 1954, p. 145), it is here inferred that reef growth would tend to be northerly. It would seem to follow from these relations, if growth and erosion conditions remained the same during geologic time, that the atoll may have grown outward over its northern outer slope. In addition, the configuration of the platform, at least 400 feet higher in its southeastern (hole E–1) than its northwestern (hole F–1) part, suggests the initial reef would have started near the site of hole E–1, with the site of hole F–1 occupying a northern off-reef slope.

Overlying the section that is correlated with the Eocene of hole E–1, there is a nearly 1,000-foot interval in hole F–1 from which 4 cores were taken. These cores yield a more or less rich *Globigerina*-bearing limestone of Eocene age that is quite unlike anything represented elsewhere in the subsurface sediments of the Marshall Islands. Insofar as these 4 cores are typical of the interval in which they were taken, it is inferred that nearly 1,000 feet of material was deposited at considerable depth (probably not less than 100 fathoms) and away from much influence of a slope down which shallower water sediments could move to be deposited with the deeper water ones.

The interpretation of deepwater *Globigerina* limestone overlying probably shallower, or at least outer slope, conditions, presents the problem of what became of the presumed outer slope when conditions changed there to more strictly open-sea conditions. Two possibilities for such a change in condition of deposition might be diastrophic movement and change in direction of major currents. The relation of the site of hole F–1 to the adjoining guyot at 700 fathoms (4,200 feet, which is slightly deeper than the Eocene *Globigerina* limestone in F–1) may have had an effect in some way not apparent on deposition at the site of hole F–1. We find no evidence among the smaller Foraminifera that would throw further light on this problem. As this thick section of Eocene limestone overlies sediments that are correlated with the highest occurrence of Eocene sediments in hole E–1, its absence in E–1 suggests a disconformity or diastem above the highest Eocene there.

Above the Eocene *Globigerina* limestone in hole F–1, it is about 900 feet upward to the point from which the deepest cuttings were obtained, and no smaller Foraminifera were recovered that might bear on that interval. Furthermore, the deepest cuttings from F–1 also yield no pertinent evidence, as they seem to contain only contamination from above. Hence, the deepest cuttings of significance in hole F–1 are from 1,230–1,240 feet, where the hole is in Miocene strata. Between this level and the surface, the species indicate generally shallow-water deposition with meager indications of outer slope conditions, as follows: *Loxostomum karrerianum* (Brady), a species characteristic of deep water around Bikini, occurs only in hole F–1; *Pegidia dubia* (d'Orbigny), an outer slope species at Bikini, was found only in hole F–1; *Austrotrillina striata* Todd and Post, a Miocene miliolid presumed to be of shallow-water origin, while forming a major constituent of the fauna in a 200-foot interval in E–1, is not found in hole F–1.

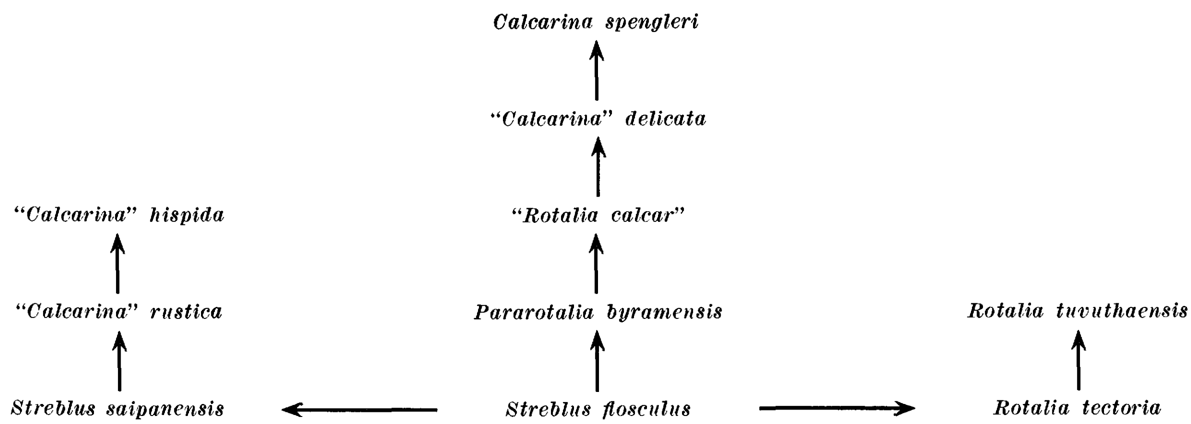
In hole E–1, the smaller Foraminifera do not indicate any noticeable change in ecologic condition from the lowest cuttings (3,120–3,130 ft.) to the surface. Evidence for disconformity or diastem at two levels is indirect and very tenuous: between the Eocene and presumed Oligocene, and between the presumed Oligocene and the directly overlying Miocene. Evidence for the former is the absence of sediments corresponding to the 1,000 feet of Eocene *Globigerina* limestone that occurs in hole F–1. Evidence for the latter is the fact that the Oligocene seems to be lower Oligocene only, with upper Oligocene lacking.

The cuttings from hole E–1 provide what seems to be a complete section through the Miocene, an interval of rock interpreted as of about 1,650 feet in thickness, all of relatively shallow-water deposition. The top 510 to 540 feet of sediments are interpreted as of Pliocene, Pleistocene, and Recent age and show no significant change in type of deposition from that of the Miocene.

CORRECTIONS OF TAXONOMY

The relationships between the genera *Calcarina*, *Streblus*, *Pararotalia*, and *Rotalia* are in need of clarification. These four genera are all present in the Marshall Islands; the first abundantly in the Recent, the second rarely in the Recent but commonly in the Tertiary, and the third and fourth commonly in the Tertiary only.

Although preservation of specimens is usually inadequate for recognition of the possibly transitional relationships between species within this group of genera, indications are that the evolutionary lines were as follows:



The relation of *Streblus beccarii* and its subspecies *tepida* to these lines is obscure.

The specimens from the Bikini drill holes that were placed in the genera *Calcarina* and *Rotalia* have been restudied together with specimens of the same species from Eniwetok and also some related species from the Tertiary of Australia received through the generosity of Miss Irene Crespin. As a result of this study some corrections of identification are necessary. Undoubtedly, further corrections will result from the study of additional and better preserved material from this as well as other Pacific areas.

The major correction involves the identification of fossil specimens from Bikini as *Rotalia calcar* (d'Orbigny), a species described from Martinique, Île de France, and Madagascar. Specimens in the Cushman Collection, No. 12841, from Mauritius (Île de France) conform to the model of the species and may be considered topotypes of *Calcarina calcar*.

In these specimens the chambers protrude outward as individual points extending into short, regularly spaced fibrous spines that lie in the plane of coiling of the test. The later chambers are thinner walled and perforate, particularly on the ventral side, and resemble the final chambers of *C. hispida* and the delicate, overlapping chambers seen on some fresh specimens of *C. spengleri*. The ventral umbilical area is occupied by a plug of shell material and is usually surrounded closely by a ring of small papillae, in size about equal to the papillae that ornament the central part of the dorsal surface.

The purpose in describing these topotypes of *Calcarina calcar* d'Orbigny, is to point out the transitional position of this species between *Calcarina* on the one hand and *Streblus* on the other. That it cannot belong in the genus *Rotalia* is obvious by comparison with *R. trochidiformis* Lamarck, the type species of *Rotalia*.

Restudy of the Bikini specimens and comparison of them with the topotypes from Mauritius shows that *Calcarina calcar* d'Orbigny cannot be placed in *Rotalia*, that *Calcarina calcar* d'Orbigny probably does not exist in the Tertiary sediments of the Marshall Islands, that the specimens determined as *Rotalia calcar* (d'Orbigny) in the Bikini drill holes need new identifications, and that the generic position of the two species *Calcarina delicata* and *C. rustica*, described from the Bikini drill holes, is probably intermediate between *Calcarina*, *Streblus*, and *Pararotalia*. The new identifications for the specimens called *Rotalia calcar* in the Bikini drill holes are indicated in table 7.

To summarize: in the Bikini drill holes the upper limit of *Calcarina delicata* remains unchanged while that of *C. rustica* is elevated to 179–190 feet, though not found in typical form at that level. The upper limit of *Pararotalia byramensis* (Cushman)—formerly known as *Rotalia canalis* Todd and Post—is elevated to 600–610½ feet, but this species also is not found in typical form until lower levels.

SYSTEMATIC DESCRIPTIONS

Family HYPERAMMINIDAE

Genus SAGENINA Chapman, 1900

Sagenina frondescens (Brady)

Sagenina frondescens (H. B. Brady). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 328.

Attached arenaceous tubes referred to this species are reported from moderate depths (16–200 fathoms) in

TABLE 7.—*New identifications for specimens called* Rotalia calcar (*d'Orbigny*) *in the Bikini drill holes*

Bikini drill hole and depth (in feet)	New identifications		
	Calcarina delicata Todd and Post	*Calcarina rustica* Todd and Post	*Pararotalia byramensis* (Cushman)
2A: 179–190	×	×	-----
2A: 192–200½	-----	×	-----
2A: 221½–232	-----	×	-----
2A: 232–242½	×	-----	-----
2A: 242½–253	-----	×	-----
2A: 253–263½	-----	×	-----
2A: 263½–274	×	×	-----
2A: 274–284½	×	×	-----
2A: 284½–295	×	×	-----
2A: 295–305½	-----	×	-----
2A: 305½–312	×	-----	-----
2A: 312–316	-----	×	-----
2B: 442½–453	×	-----	-----
2B: 495–505½	×	-----	-----
2A: 504½–510	×	-----	-----
2A: 510–514½	×	-----	-----
2A: 514–525	×	×	-----
2B: 558–568½	×	-----	-----
2A: 567–578	-----	×	-----
2B: 600–610½	-----	-----	×
2A: 631½–642	-----	×	-----
2B: 642–652½	×	-----	-----
2B: 694½–705	×	×	×
2A: 731–736½	×	×	-----
2B: 747–757½	-----	×	×
2A: 778½–784	×	-----	-----
2B: 810–820½	-----	×	×
2A: 841½–847	×	×	-----
2B: 841½–852	-----	-----	×
2B: 852–862½	-----	-----	×
2B: 862½–873	-----	-----	×
2A: 898½–904	-----	×	-----
2A: 925–935½	-----	-----	×
2A: 946–956½	-----	×	×
2A: 1103½–1114	×	×	-----
2A: 1145½–1156	-----	-----	×
2A: 1208½–1219	-----	-----	×
2B: 1272–1282½	-----	-----	×
2A: 1292–1303	-----	-----	×

the lagoons of coral atolls and on the outer slopes. Specimens were found only at 2,090–2,100 feet in hole E–1.

Family TEXTULARIIDAE

Although this family has abundant and diversified representatives in the faunas of the lagoons and outer slopes of the Marshall Islands, not many specimens were found in the Eniwetok drill holes.

Genus TEXTULARIA Defrance, 1824

Textularia agglutinans d'Orbigny

Textularia agglutinans d'Orbigny. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 328, pl. 83, fig. 2.

Very rare specimens in both holes may be present as contamination from the Recent. There is a possibility that young forms of *Textularia kerimbaensis* Said are indistinguishable from *T. agglutinans*, and some may be included here.

Textularia candeiana d'Orbigny

Textularia candeiana d'Orbigny. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 329, pl. 83, fig. 3.

A single typical example of this Recent species is recorded from the top of drill hole F–1.

Textularia conica d'Orbigny

Textularia conica d'Orbigny. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 329, pl. 83, fig. 4.

One broken specimen was found in E–1 cuttings, probably as a result of Recent contamination.

Textularia foliacea Heron-Allen and Earland var. oceanica Cushman

Textularia foliacea var. *oceanica* Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 329, pl. 83, fig. 8.

In Recent sediments of the Pacific this variant is usually found with the typical form of the species. Here it occurs between 530 and 940 feet in hole E–1, mostly rarely except at 740–750 feet where it is common. It was found only at 830–840 feet in F–1. Although not recorded from the Bikini drill holes, brown-stained specimens indicate it is in place in the Miocene section in the Eniwetok drill holes.

Textularia kerimbaensis Said

Textularia kerimbaensis Said. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 329, pl. 83, fig. 11.

Some of the forms included here tend to have slightly higher and more bulging final chambers and a smoother surface than those recorded from the Recent material of the Marshalls, but these differences do not warrant separation. The species occurs in cuttings from both holes and is best developed between about 600 and 1,100 feet.

In some specimens referred here, the wall is seen to be porous, as it is in *Gaudryina rugulosa* Cushman, suggesting a close relationship or possible confusion between these two species.

Textularia semialata Cushman

Textularia semialata Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 330, pl. 83, fig. 5.

Rare specimens from hole E–1 are the same as those reported from the Recent material of Bikini and of the Tropical Pacific (Cushman, 1932). They have a thin smooth wall and inflated chambers and probably are not the same as the types from off the coast of the Philippines which are heavier walled and compressed with a sharp periphery. However, present material is inadequate for erection of a new species.

Textularia subhauerii Cushman

Plate 255, figure 1

Textularia subhauerii Cushman, 1922, U.S. Geol. Survey Prof. Paper 129–E, p. 89, pl. 14, fig. 2.

This species described from the Byram formation of Oligocene age has been recorded almost exclusively in the Eocene and Oligocene of the Gulf Coastal Plain. Its occurrence in some abundance in hole E–1 cuttings at 3,000–3,010 feet supports the Eocene designation for this section.

Genus BIGENERINA d'Orbigny, 1826

Bigenerina nodosaria d'Orbigny

Bigenerina nodosaria d'Orbigny, 1826, Annales sci. nat., v. 7, p. 261, pl. 11, figs. 9–12; modèles no. 57, 3rd. livr.

Only one broken specimen was found in E–1, but it compares favorably with Recent material from the Dry Tortugas, off Florida, in the U.S. National Museum collections. It was not found in Recent material from the Marshall Islands or in the Bikini drill holes.

Genus VULVULINA d'Orbigny, 1826

Vulvulina cf. V. arenacea (Bagg)

Plate 263, figure 2

Specimens occur that are close to *Vulvulina arenacea* (Bagg, 1908, p. 132, pl. 5, figs. 4–6), described from near the Hawaiian Islands and also recorded from Guam and the Philippines. It is known mostly from deep water.

At Eniwetok it occurs in the cuttings from the upper part of the Miocene section of hole E–1 only, but a single specimen was found in the cuttings from 1,272–1,282½ feet at Bikini.

Family VERNEUILINIDAE

The chief representative of this family in the Recent sediments of the Marshall Islands, *Gaudryina* (*Siphogaudryina*) *rugulosa* Cushman, is likewise its chief representative in the drill hole cuttings and cores where it is even more abundant.

Genus GAUDRYINA d'Orbigny, 1839

Gaudryina triangularis angulata Cushman

Gaudryina triangularis var. *angulata* Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 331, pl. 83, fig. 14.

In addition to being found in E–1 cuttings from 700 to 1,300 feet, this Recent arenaceous subspecies was found in core E–1–1–1 at 2,000 feet. Specimens from the core tend to have a smaller triangular part and a longer and broader biserial part.

Subgenus SIPHOGAUDRYINA Cushman, 1935

Gaudryina (Siphogaudryina) rugulosa Cushman

Plate 255, figure 2; plate 263, figure 3

Gaudryina (*Siphogaudryina*) *rugulosa* Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 331, pl. 82, fig. 1.

This species, by virtue of its large size, forms a conspicuous component of most of the cuttings down to around 1,300 feet in both holes and also occurs in scattered samples at lower levels. Although there have been no previous fossil records of *Gaudryina rugulosa*, its presence in some of the Eocene cores indicates its long range in the central Pacific. It was not reported from the Bikini drill holes.

Well-preserved specimens display the porosity of the arenaceous wall, as was also shown in the original figure of the holotype (Cushman, 1932, p. 15, pl. 4, fig. 1). This feature—perforations through arenaceous walls—has previously been observed in various species (Carter, 1877, p. 202–208, pl. 13, fig. 7*e*; Moebius, 1880, p. 93, pl. 9, figs. 1–8; Brady, 1884, p. 390, pl. 49, figs. 6, 7) and has been discussed (Wood, 1949, p. 234) as to its possible significance in classification.

As has been suggested (Cushman, 1937, p. 82), *Gaudryina rugulosa* comprises part of a group in which specific distinction may prove to be transitional and hence wholly artificial. This group seems to include the following species and possibly others from widely separated localities:

Gaudryina (*Siphogaudryina*) *rugulosa* Cushman	Recent, Pacific
(*S.*) *tumidula* Cushman	Pliocene, Italy; Miocene, Hungary
rhodiensis Cushman	Pliocene, Ile of Rhodes
victoriana Cushman	Miocene, Australia
interjuncta Cushman	Miocene, Hungary
glabrata (Cushman)	Oligocene, United States
youngi Howe	Oligocene, United States

The possibility that such a group may prove to be largely the diverse manifestations of a single species in many diverse geographic localities, together with the apparent long range at Eniwetok of *G. rugulosa* in virtually unchanged form, suggests that the separations of the species listed above are more subspecific than specific.

Gaudryina (Siphogaudryina) siphonifera (Brady)

Gaudryina (*Siphogaudryina*) *siphonifera* (H. B. Brady). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 331, pl. 83, fig. 17.

In the Recent of the Marshall Islands this species was found mostly in the outer slope sediments. Although not reported from the Bikini holes, it occurs in the tops of both Eniwetok drill holes.

Subgenus PSEUDOGAUDRYINA Cushman, 1936

Gaudryina (Pseudogaudryina) cf. G. (P.) atlantica (Bailey)

Plate 263, figure 1

Specimens similar to those discussed and illustrated by Cushman (1937, p. 95, pl. 14, figs. 4, 5) were found in E–1 cuttings from 830 to 2,640 feet, and a single specimen in F–1 at 1,170–1,180 feet. Our specimens are somewhat shorter, broader, and more flaring than the typical form. It was described from the Atlantic Ocean but has also been recorded from the Miocene and Oligocene of the West Indies and California.

Family VALVULINIDAE

This family is better represented in the Tertiary than in the Recent faunas of Eniwetok.

Genus VALVULINA d'Orbigny, 1826

Valvulina davidiana Chapman

Valvulina davidiana Chapman. Cushman, Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 331, pl. 82, fig. 2.

Typical specimens of this Recent species are confined to the upper parts of both holes with scattered occurrences to 150 feet in F–1 and somewhat below, and more scattered occurrences in E–1 to about 650 feet. At 810 to 950 feet in F–1 and 690 to about 1,200 feet in E–1 are smaller brown specimens that are very likely in place. Below these levels, the specimens seem to be mostly contamination from above, some Recent and some fossil (brown). However, typical *Valvulina davidiana* is present in core E–1–1 at 2,000 feet and again in the cuttings below that level to 2,080 feet, seemingly typical and in place. Occurrences farther below are only contamination from above.

Valvulina intermedia Applin and Jordan

Plate 255, figure 3

Valvulina intermedia Applin and Jordan, 1945, Jour. Paleontology, v. 19, p. 134, pl. 18, fig. 4.

This slender, arenaceous species was found in drill hole E–1 in Eocene cuttings and the core at 2,800 feet, with a questionable occurrence at about 4,400 feet in F–1 (core F–1–13–2). It was described from subsurface rocks of later middle Eocene age in Florida with subsequent records from the middle Eocene of the Dominican Republic.

Valvulina martii Cushman and Bermudez

Valvulina martii Cushman and Bermudez. Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 553, pl. 198, fig. 1.

Specimens comparing well both with paratypes from the Eocene of Cuba and with the material from the Bikini drill holes occur in core E–1–2 (2,800 feet) as well as in E–1 cuttings from 1,030 feet to the bottom of the hole. The species was also found in core F–1–11 at 4,200 feet.

Valvulina prominens Todd and Post

Valvulina? prominens Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 553, pl. 198, fig. 2.

Better preserved specimens than those described from the Bikini drill holes confirm the generic assignment of this species. It occurs only in E–1 cuttings at depths (1,080 to 1,394 feet) comparable to those in the Bikini hole, proving it to be a good marker for this section. Some specimens in lower cuttings, below 1,400 feet, are not as well preserved and may not belong in this species.

Genus CLAVULINA d'Orbigny, 1826

Clavulina angularis d'Orbigny

Clavulina angularis d'Orbigny. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 332, pl. 83, fig. 18.
Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 554.

Clavulina pacifica Cushman, 1924, Carnegie Inst. Wash. Pub. 342, p. 22, pl. 6, figs. 7–11.
Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 332, pl. 83, fig. 19.

The Pacific species (*Clavulina pacifica*) and the Mediterranean one (*C. angularis*) are separated on only slight physical differences. These differences involve height of the uniserial chambers, degree of inflation of the final few chambers, and smoothness of the wall, and seem inadequate for specific separation. The species occurs rarely and in scattered samples.

Clavulina difformis Brady

Clavulina difformis Brady. Cushman, 1937, Cushman Lab. Foram. Research Spec. Pub. 8, p. 23, pl. 3, figs. 4–10.

Although this Recent species is probably not specifically separable from *Clavulina angularis* d'Orbigny, it is easily recognizable by its roughened wall and tendency toward overlapping chambers. It may be 3-, 4-, or 5-sided. It occurs in cuttings of both holes.

Clavulina multicamerata Chapman

Clavulina multicamerata Chapman. Cushman, 1937, Cushman Lab. Foram. Research Spec. Pub. 8, p. 24, pl. 3, figs. 13–16.

This Recent shallow-water species was described from off Victoria, Australia. It occurs only rarely in the E–1 cuttings.

Clavulina serventyi Chapman and Parr

Clavulina serventyi Chapman and Parr. Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 554, pl. 198, fig. 4.

Rare but distinctive specimens occur at about 1,100 feet in both holes. Specimens down to 2,760 feet in E–1 are apparently contamination from above. A good comparison can be made with the material from between 946 and 1,891 feet in the Bikini holes. The species was well illustrated in the fauna from Bikini.

Genus VALVULAMMINA Cushman, 1933

Valvulammina globularis (d'Orbigny)

Plate 261, figure 3

Valvulammina globularis (d'Orbigny). Cushman, 1937, Cushman Lab. Foram. Research Spec. Pub. 8, p. 29, pl. 3, figs. 23, 24.

Although not found in the material from the Bikini drill holes, this species occurs in the E–1 cuttings between 530 and 1,000 feet. It seems to have a relationship, possibly evolutionary, with *Valvulammina marshallana* Todd and Post which occurs below it in the section. However, the two species do occur together between 800 and 1,000 feet. In contrast to *Valvulina davidiana* Chapman, its dorsal surface is rounded, not angular; and in contrast to *Valvulammina marshallana*, its final whorl consists of no more than four chambers.

Valvulammina globularis was described from the Eocene of the Paris Basin, with only one subsequent record from the middle Eocene of Limburg, Netherlands (Van Bellen, 1946, p. 30, pl. 2, figs. 6–9).

Valvulammina marshallana Todd and Post

Plate 255, figure 4

Valvulammina marshallana Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 554, pl. 198, fig. 3.

This species, described and recorded only from Bikini, seems to have an evolutionary relationship to *Valvulammina globularis* (d'Orbigny) above and to *Coskinolina rotaliformis* Cole below, although with overlapping ranges both upward and downward.

Two core occurrences, in E–1–2–1 (2,802–2,808 ft) and F–1–13–2 (4,406–4,431 ft), confirm its presence in the Eocene. Its acme, however, was in the upper part of Miocene, between 1,000 and 1,400 feet, in the section placed in the lower part of Tertiary *f* and the upper part of Tertiary *e*.

Genus CRIBROGOËSELLA Cushman, 1935

Cribrogoësella parvula Todd and Low, n. sp.

Plate 261, figures 1, 2

Test elongate, rounded in section, tapering, greatest breadth at apertural end, biserial stage very short; chambers low, distinct, not much inflated; sutures more distinct toward apertural end, slightly depressed; wall rough, distinctly arenaceous; aperture a bulging cribrate plate with about 25 pores which are distinct and surrounded by raised rims when the test is eroded but when uneroded, indistinct and giving the impression of a spongy covering to the aperture. Length up to about 1.6 mm; diameter of final chamber 0.55–0.70 mm.

Holotype, USNM 626186, from drill hole E–1, from cuttings at 2,180–2,190 feet, Parry Island, Eniwetok Atoll, in the Marshall Islands.

This species differs from *Cribrogoësella jarvisi* Cushman from the Miocene of Jamaica by being more distinctly tapering with a much smaller initial triangular part and by the chambers being lower, more regular, and more distinctly separated by the sutural depressions.

It was found in the cuttings of drill hole E–1 only and although its highest occurrence is at 1,020–1,030 feet, it is most abundant and well developed at 2,180–2,190 feet, just above the Oligocene section.

At Bikini, two sepcimens of this species were erroneously identified as *Liebussella exigua* Todd and Post; one from 2,451–2,461½ feet and a questionable fragmentary specimen from 1,293–1,303½ feet.

Genus LIEBUSELLA Cushman, 1933

Liebusella exigua Todd and Post

Liebusella exigua Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 554, pl. 198, figs. 5, 6.

In Eniwetok this species is restricted to the Oligocene section—between 2,370 and 2,570 feet—of drill hole E–1 only. It was described from an equivalent level at Bikini, but there it was also found in the Miocene at about 1,200 to 1,300 feet.

Family MILIOLIDAE

As in the Recent sediments of the Marshall Islands, miliolids are diversified and usually common throughout the sections penetrated by both holes, with the exception of the globigerinid limestone in the Eocene section of hole F–1. Many of the species serve well as markers at various levels.

Genus QUINQUELOCULINA d'Orbigny, 1826

Quinqueloculina agglutinans d'Orbigny

Plate 261, figure 4

Quinqueloculina agglutinans d'Orbigny, 1839, *in* De la Sagra, Histoire physique, politique et naturelle de l'Île de Cuba, Foraminifères, p. 195, pl. 12, figs. 11–13.

Described from Recent sands of Cuba, this species is widely distributed in Recent and fossil sediments—at least as old as Miocene, as in the Wiener Becken (Vienna basin). Surface characteristics vary considerably with type of material available; ours are rather fine-grained. It occurs mostly between 1,800 and 2,250 feet in drill hole E–1, never abundantly, and with two widely separated occurrences in F–1.

Quinqueloculina akneriana d'Orbigny

Plate 261, figure 6

Quinqueloculina akneriana d'Orbigny, 1846, Foraminifères fossiles du bassin tertiaire de Vienne, p. 290, pl. 18, figs. 16–21.

Described from the Miocene of the Wiener Becken (Vienna basin), this species is also widely known from Recent localities though not often abundant. It is widespread in this material ranging downward from about 1,080 feet in E–1 and 940 feet in F–1. It was found also in both Miocene and Eocene cores.

Quinqueloculina bidentata d'Orbigny

Quinqueloculina bidentata d'Orbigny. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 332, pl. 83, fig. 31.

Rare specimens from the cuttings in the upper parts of both holes compare favorably with the Recent material illustrated from the Marshall Islands. It was recorded rarely also in the shallow drill holes on Bikini.

Quinqueloculina byramensis Cushman

Plate 260, figure 3; plate 261, figure 7

Quinqueloculina byramensis Cushman, 1923, U.S. Geol. Survey Prof. Paper 133, p. 54, pl. 8, fig. 5.

This distinctively ornamented species was described from the Oligocene of Mississippi. Illustrations show the differences between fresh and eroded specimens. The species was not found in the Bikini material and only in hole E–1 on Eniwetok.

Quinqueloculina subcuneata Cushman

Quinqueloculina crassa var. *subcuneata* Cushman, 1921, U.S. Natl. Mus. Bull. 100, v. 4, p. 423, pl. 89, fig. 4.

Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 333, pl. 83, fig. 22.

Rare, scattered specimens in the tops of both holes persist downward to 550 feet in E–1 and to 600 feet in F–1, probably as contamination from above. This form is probably not varietally or subspecifically related to *Quinqueloculina crassa* d'Orbigny from the Eocene of the Paris Basin.

Quinqueloculina distorqueata Cushman

Quinqueloculina distorqueata Cushman, *in* Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 333, pl. 83, fig. 27.

This Marshall Islands species was described from the lagoon of Rongerik Atoll and appeared in some abundance in sediments of the other atolls also. The specimens found at 710 feet and lower in hole E–1 are apparently in place, being brown like some of the other associated species at that depth. It is somewhat like *Quinqueloculina kerimbatica* (Heron-Allen and Earland) but has a slender cylindrical neck. It appears more twisted than *Q. samoaensis* Cushman.

Quinqueloculina ferussaci d'Orbigny

Quinqueloculina ferussacii d'Orbigny. Parker, Jones, and Brady, 1865, Annals and Mag. Nat. History, ser. 3, v. 16, p. 24, pl. 1, fig. 12.

Quinqueloculina cf. *Q. ferussacii* d'Orbigny. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 333, pl. 83, fig. 30.

Forms attributable to this species are found mostly in drill hole E–1 with only two occurrences in F–1. The wall has a matte surface and is often slightly striate.

Quinqueloculina leonensis Applin and Jordan

Plate 260, figure 1

Quinqueloculina leonensis Applin and Jordan, 1945, Jour. Paleontology, v. 19, no. 2, p. 136, pl. 18, fig. 9.

Our specimens closely resemble the types from the Suwannee limestone of Oligocene age in the subsurface of Florida. The surface, originally described as "finely papillate," appears rather coarsely perforate with the perforations being filled. Occurrence of this species in the Eniwetok material is limited to the Oligocene section of hole E–1.

Quinqueloculina neostriatula Thalmann

Quinqueloculina neostriatula Thalmann. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 333, pl. 83, fig. 28.

This species is scattered but never abundant in both holes and generally occurs deeper than *Quinqueloculina subcuneata* Cushman. At 700 feet in E–1 and 800 feet in F–1, one starts to find brown specimens—indication that they are in place in the Miocene. Brown specimens continue to 1,394 feet in E–1 and 940 feet in F–1, but below these depths are white ones probably from near the surface.

Quinqueloculina parkeri (Brady)

Quinqueloculina parkeri (H. B. Brady). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 333, pl. 83, fig. 23.

This distinctively ornamented species makes scattered appearances in both of the Eniwetok drill holes.

Quinqueloculina prisca d'Orbigny

Plate 260, figure 2; plate 261, figures 8, 9

Quinqueloculina prisca d'Orbigny, 1826, Annales sci. nat., v. 7, p. 302.

Fornasini, 1905, Accad. sci. Ist. Bologna Mem., ser. 6, v. 2, p. 68, pl. 4, fig. 5.

The only previous records for this species are from the Eocene of the Paris Basin. Our specimens were found in the Oligocene and lower part of the Miocene section. In core E-1-1-1 and cuttings from both holes, the forms show a variation ranging from elongate and striate to a broader and smoother appearance.

Quinqueloculina sulcata d'Orbigny

Quinqueloculina sulcata d'Orbigny. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260-H, p. 334, pl. 84, figs. 1, 2.

In addition to being found in Recent deposits of the Marshall Islands, this species was present in the drill holes on Bikini and in both holes on Eniwetok. It is much better represented in F-1 than in E-1, where it was not observed above 660 feet. The lowermost records are probably contamination from above.

Quinqueloculina tubus Todd

Quinqueloculina tubus Todd, 1957, U.S. Geol. Survey Prof. Paper 280-H, p. 306, pl. 85, fig. 18.

Specimens from two samples from hole E-1 compare favorably with this Recent species described from the lagoon at Saipan, Mariana Islands.

Genus MILIOLINELLA Wiesner, 1931

Miliolinella australis (Parr)

Miliolinella australis (Parr). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260-H, p. 334, pl. 84, figs. 3, 4.

Well illustrated from the Bikini Recent sediments, this species occurs rarely in the upper parts of both holes, with very scattered lower occurrences, probably as contamination.

Miliolinella labiosa (d'Orbigny)

Plate 261, figure 10

Triloculinella labiosa (d'Orbigny). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260-H, p. 334, pl. 84, figs. 5, 6.

Recent specimens occur at the tops of both holes, sifting down in the cuttings. However, in drill hole E-1 they are in place in the brown-stained zone and persist to about 1,400 feet. Casts in the Eocene cores seem to belong to the same species.

Genus MASSILINA Schlumberger, 1893

Massilina misrensis Said

Plate 261, figure 12

Massilina misrensis Said, 1949, Cushman Lab. Foram. Research Spec. Pub. 26, p. 11, pl. 1, fig. 32.

Described from Recent sediments of the Red Sea, this form appears related both to *Triloculina terquemiana* (Brady) and *T. reticulata* d'Orbigny but the ornamentation is less regular than in these species. Some forms seem to be transitional to *Quinqueloculina parkeri* (Brady). It was found in the E-1 cuttings only, in the upper part of the Miocene section, mainly between 740 and 1,270 feet.

Massilina placida Todd and Post

Massilina placida Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260-N, p. 555, pl. 198, figs. 11, 12.

This species is restricted to the deepest part of hole 2B on Bikini. In Eniwetok drill hole E-1 it occurs commonly to abundantly from 2,220 to around 2,500 feet—confirming its value as a marker for this section—then intermittently down to around 3,000 feet. It also appears rarely in the Eocene cores E-1-2 (2,802-2,808 ft); F-1-11-1 (4,196-4,222 ft); and F-1-15-12 (4,528-4,553 ft), thus extending its range into the upper Eocene.

Massilina planata Cushman

Massilina planata Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260-H, p. 334, pl. 84, fig. 16.

Four typical specimens of this Recent species were found in the top of drill hole F-1.

Genus SPIROLOCULINA d'Orbigny, 1826

Spiroloculina angulata Cushman

Spiroloculina angulata Cushman. Cushman and Todd, 1944, Cushman Lab. Foram. Research Spec. Pub. 11, p. 50, pl. 7, figs. 18-22.

Spiroloculina angulata Cushman has a similar geographic and ecologic range to that of *S. corrugata* Cushman and Todd in shallow water of the Indo-Pacific region. Only one true fossil record has been noted, from Pliocene rocks of Japan (Asano, 1951, p. 12, figs. 85, 86). The record from hole 3 on Bikini (Todd and Post, 1954, p. 551) is discounted because of the possibility of the core being out of place. It does apparently occur as a fossil in the Eniwetok material, although there is a possibility the specimens may be merely the more angulate form of *S. corrugata*.

Spiroloculina clara Cushman

Spiroloculina clara Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260-H, p. 335, pl. 84, fig. 9.

This species occurs rarely and only near the top in hole F-1 with isolated occurrences, probably contamination, around 1,100 and 1,200 feet. It was originally described from Rongelap Atoll and is common in Recent sediments of the Marshall Islands.

Spiroloculina communis Cushman and Todd

Spiroloculina communis Cushman and Todd. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260-H, p. 335, pl. 84, fig. 13.

Rare specimens occur only in the Miocene section of drill hole E-1. The only previous fossil records for this species are from the Pliocene of Japan (Asano, 1951, p. 13, figs. 87, 88; Higuchi, 1954, pl. 3, fig. 10).

Spiroloculina corrugata Cushman and Todd

Spiroloculina corrugata Cushman and Todd. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 335, pl. 84, figs. 17, 18.

Recorded from Miocene to Recent sediments indicative of shallow water (less than 30 fathoms) from the Indo-Pacific region, this species is rare and scattered in both holes to about 900 feet.

Spiroloculina folium Todd

Spiroloculina sp. A, Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 336, pl. 84, figs. 21, 22.
Spiroloculina folium Todd, 1957, U.S. Geol. Survey Prof. Paper 280–H, p. 307, pl. 87, fig. 5.

This distinctive miliolid was described from the lagoon at Saipan, and most of its occurrences in the Recent of the Marshall Islands are from lagoon localities with rare specimens being obtained from the outer slope of Bikini Atoll. All occurrences in Eniwetok are from hole F–1 except one from 1,375–1,394 feet in E–1, and all are rare.

Spiroloculina marshallana Todd

Spiroloculina marshallana Todd, *in* Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 335, pl. 84, fig. 8.

One broken but apparently fresh specimen was found at 10–20 feet in E–1, and a brown one at 910–920 feet. Although this species was described from Recent sediments of the Marshall Islands, it was not found in the drill holes on Bikini.

Spiroloculina mayori Cushman

Spiroloculina mayori Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 336, pl. 84, fig. 15.

This Recent Indo-Pacific species indicative of shallow waters was found only near the top of hole F–1.

Spiroloculina tricarinata Terquem

Plate 255, figure 5

Spiroloculina tricarinata Terquem [not d'Orbigny], 1882, Soc. géol. France Mém., ser. 3, v. 2, p. 158, pl. 16 (24), figs. 19–21.
Cushman and Todd, 1944, Cushman Lab. Foram. Research Spec. Pub. 11, p. 10, pl. 1, fig. 10; pl. 2, figs. 19–23.
Spiroloculina bicarinata d'Orbigny, 1826, Annales sci. nat., v. 7, p. 298; 1850, Prodrome de Paléontologie, v. 2, p. 409.
Fornasini, 1904, Accad. sci. Ist. Bologna Mem., ser. 6, v. 1, p. 4, pl. 1, fig. 5.
Cushman, 1917, U.S. Natl. Mus. Bull. 71, pt. 6, p. 10, text fig. 8.

This angular, costate species, originally described from the Eocene of the Paris Basin, occurs in the Eniwetok material in the Eocene and Oligocene sections and lower part of the Miocene section of drill hole E–1.

Spiroloculina venusta Cushman and Todd

Spiroloculina venusta Cushman and Todd, 1944, Cushman Lab. Foram. Research Spec. Pub. 11, p. 60, pl. 8, figs. 16, 17.

The only previous report for this species is from the Caroline Islands. It occurs in two of the Eniwetok cuttings at the top of drill hole F–1. The specimens show well the strongly depressed sutures and openings between the chambers, features which make *Spiroloculina venusta* distinct from *S. caduca* Cushman, a species known mostly from the warm waters of the Atlantic Ocean.

Genus ARTICULINA d'Orbigny, 1826

Articulina pacifica Cushman

Articulina pacifica Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 336, pl. 84, fig. 25.

Rare specimens in each hole seem typical; however, none of ours show the uniserial development seen in those obtained from Recent sediments in this region.

Articulina sulcata Reuss

Articulina sulcata Reuss, 1850, Akad. Wiss. Wien, Math.-naturwiss. Kl., Denkschr., v. 1, p. 383, pl. 49, figs. 13–17.

Test of medium size for the genus; chambers distinct, inflated; sutures only slightly depressed; wall ornamented with numerous fine, longitudinal costae, not anastomosing, extending nearly to edge of aperture; aperture elongate, elliptical, slightly flaring, with a slight lip.

Our specimens differ from *Articulina advena* (Cushman) by the chambers being more inflated and lacking a pinched edge. Also the wall is more substantial, lacking the delicate appearance of *A. advena.*

Well-preserved forms with clear costae from cuttings at 2,040–2,050 feet from hole E–1 compare favorably with material in the U.S. National Museum from the Miocene of Lapugy, Austria (Cushman colln. No. 39977). One worn specimen from core E–1–2–1 (2,800 feet) also seems to belong here in spite of the costae being somewhat obscure.

Howchin (1889, p. 5) reported rare occurrences of forms comparable to this species from the Older Tertiary of Australia (the Lower Bed at Muddy Creek, Victoria), but no figures were given.

Genus NUBECULINA Cushman, 1924

Nubeculina? sp. A

Two clean specimens were obtained from near the top of drill hole F–1. Compared to *Nubeculina divaricata* (Brady) the specimens are finer grained, with little or no lip and no teeth being observed. The tube does not show between chambers, which are more elongate than globular as in *N. divaricata.* The specimens show some similarity to *N. chapmani* Cushman.

Genus HAUERINA d'Orbigny, 1839

Hauerina aspergilla (Karrer)

Plate 261, figure 11

Peneroplis aspergilla Karrer, 1868, Akad. Wiss. Wien Sitzungsber., v. 58, pt. 1, p. 154, pl. 3, fig. 9.

Test robust, completely involute, nearly circular, periphery very slightly lobulate, usually rounded; chambers distinct, 3½–4 in adult whorl, earlier formed chambers occasionally compressed, final chamber slightly inflated; sutures distinct, slightly depressed, curved; wall calcareous, imperforate, matte, finely roughened; aperture strongly projecting, deep cribrate plate adding to enlarged appearance of last formed chamber. Diameter about 0.70 mm; thickness about 0.35 mm.

Hauerina aspergilla (Karrer) most resembles *H. diversa* Cushman and is probably ancestral to it. However, *H. aspergilla* is distinctive in its robustness and much enlarged cribrate plate.

This distinctive species has not been recorded from any other region than the Miocene of Hungary, and our material compares favorably with topotypes (Cushman colln. No. 17004) from Kostej im Banat, Hungary.

The species first occurred in drill hole E–1 at 710–720 feet, reaching its peak of abundance at 770–780 feet. At about 900 feet it starts to dwindle, with broken specimens occurring intermittently to 1,688–1,715 feet. Two small specimens were obtained in material from 870–880 feet and 960–970 feet in drill hole F–1.

Hauerina diversa Cushman

Hauerina diversa Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 337, pl. 84, figs. 30, 31.

Specimens from the upper parts of both holes compare well with Recent specimens from Bikini. They are smaller and much more compressed than *Hauerina aspergilla* (Karrer).

Hauerina involuta Cushman

Hauerina involuta Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 337, pl. 84, figs. 28, 29.

Specimens were found in 6 isolated occurrences in hole F–1 between 280 and 1,100 feet; there were more numerous occurrences in hole E–1 between 340 and 1,629 feet, yet fewer specimens. Those below about 800 feet in each hole show the brown color typical of this section and tend to be smaller and more compressed. However, none of these resemble *Hauerina speciosa* (Karrer) (1868, p. 135, pl. 1, fig. 8), a similarly ornamented species from the Miocene of Europe.

Genus SCHLUMBERGERINA Munier-Chalmas, 1882

Schlumbergerina alveoliniformis (Brady)

Plate 263, figure 4

Schlumbergerina alveoliniformis (H. B. Brady). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 337, pl. 85, fig. 1.

This species, not heretofore recorded from fossil material, occurs fairly commonly in the Miocene core at about 2,000 feet in drill hole E–1. It occurs also in the cuttings of both holes, first appearing brown at 960 feet. It was not noted in the Bikini drill hole material.

Genus AMMOMASSILINA Cushman, 1933

Ammomassilina alveoliniformis (Millett)

Massilina alveoliniformis Millett, 1898, Royal Micros. Soc. Jour., p. 609, pl. 13, figs. 5–7.

One broken, but identifiable, fossil specimen was found in E–1 cuttings at 810–820 feet, and two questionable specimens were noted in the same hole. The genus has not previously been reported as a fossil, and the species has not been previously reported from the Marshall Islands.

Genus TRILOCULINA d'Orbigny, 1826

Triloculina earlandi Cushman

Triloculina earlandi Cushman, *in* Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H. p. 338, pl. 85, fig. 3.

Although this shallow-water species was described from Marshall Islands sediments, only one specimen was found in drill hole F–1 at 1,170–1,180 feet, undoubtedly as contamination from above.

Triloculina fusa Todd and Post

Triloculina fusa Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 555, pl. 198, fig. 7.

Triloculina fusa Todd and Post var., Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 555, pl. 198, fig. 8.

Triloculina fusa Todd and Post was described from hole 2B, Bikini, where it occurred commonly to abundantly below 1,167 feet. We now regard the specimens having a slight development of transverse corrugations as not worthy of separation from the typical form of this species. In the Eniwetok material the species appears in place in drill hole E–1 from 1,020 to about 1,400 feet, then is scattered to the bottom. There are only two occurrences in hole F–1.

Triloculina irregularis (d'Orbigny)

Triloculina irregularis (d'Orbigny). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 338, pl. 85, fig. 12.

This species is fairly well represented in both holes, although rare. It is characterized by the matte surface of the wall and may be transitional to *Quinqueloculina* *ferussaci* d'Orbigny and *Q. sulcata* d'Orbigny. It is present in Recent sediments of the Marshall Islands but was not reported in the drill holes on Bikini Island.

Triloculina kerimbatica (Heron-Allen and Earland)

Miliolina kerimbatica Heron-Allen and Earland, 1915, Zool. Soc. London Trans., v. 20, p. 574, pl. 43, figs. 13–23.

Triloculina kerimbatica (Heron-Allen and Earland). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 339, pl. 85, figs. 10, 11.

Triloculina kerimbatica occurs rarely in cuttings from the upper parts of both holes and in core E–1–1 at about 2,000 feet. This species was also reported from Marshall Islands Recent sediments and in one core from shallow drill hole 3 on Bikini.

Triloculina oblonga (Montagu)

Triloculina cf. *T. oblonga* (Montagu). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 339, pl. 85, figs. 5–7.

This species is scattered in the cuttings of both holes, more abundant at the top but sifting down nearly to the bottom. Those in the Miocene section appear to be in place, and similar forms are found in the cores (E–1–2–1, F–1–8–1 and F–1–10–8) as casts.

Triloculina rotunda d'Orbigny

Plate 261, figure 5

Triloculina rotunda d'Orbigny, 1826, Annales sci. nat., v. 7, p. 299.

Schlumberger, 1893, Soc. Zool. France Mém., v. 6, p. 206, pl. 1, figs. 48–50; text figs. 11, 12.

Fornasini, 1902, Acad. sci. Ist Bologna Mem., ser. 5, v. 10, p. 22, text fig. 12.

Described from Recent material from Rimini, this species probably has a worldwide distribution. It occurs in the present material in hole E–1 only, between 1,150 and 2,770 feet. It resembles specimens from both Miocene and Recent sediments of Florida.

Triloculina subplanciana Cushman

Triloculina subplanciana Cushman, *in* Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 339, pl. 85, fig. 17.

Although originally described from the Recent of the Marshall Islands, this species appears to be in place in the Miocene of hole E–1 where it is brown and very rare. In shape it is quite similar to *Triloculina oblonga* (Montagu) but is distinguished by having a neck and lip.

Triloculina trigonula (Lamarck)

Plate 255, figure 6

Triloculina trigonula (Lamarck). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 340, pl. 85, fig. 18.

This species occurs from nearly the top in both Eniwetok drill holes, but it does not become abundant until 2,770–2,780 feet in E–1 and is also abundant in the Eocene cores F–1–11, F–1–13, and F–1–15. There is a discrepancy of approximately 1,400 feet in the depth at which it is abundant in the two holes—core E–1–2 at about 2,800 feet and core F–1–11 at about 4,200 feet. When well preserved in the Eocene section, the specimens are often finely striate. Higher in the section, and even in cores F–1–8 and F–1–9, they tend to be rare, small, and somewhat more angular.

Genus AUSTROTRILLINA Parr, 1942

Austrotrillina howchini (Schlumberger)

Trillina howchini Schlumberger. Chapman, 1913, Royal Soc. Victoria Proc., v. 26, p. 169, pl. 16, fig. 4.

Austrotrillina howchini (Schlumberger). Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 555.

Two specimens were obtained from 1,100–1,110 feet and 1,170–1,190 feet in drill hole E–1 and one from 560–570 feet in F–1. The latter, unexpected at such a shallow depth, is identified without question. They compare favorably with a specimen kindly sent by Irene Crespin, though ours are smaller and not as well preserved. The species is well illustrated by Chapman in the reference given above. These occurrences correlate with those in the Bikini drill holes, and here, as there, the material is rare.

Austrotrillina striata Todd and Post

Plate 261, figure 22

Austrotrillina striata Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 555, pl. 198, fig. 9.

It appears only in drill hole E–1, abundantly both in the cuttings between 1,835 and 2,003 feet and in core E–1–1 at about 2,000 feet. Levels of appearance and peak of abundance agree very well with the occurrence in the Bikini drillings. Preservation of free specimens is even better here than at Bikini, and a specimen showing the cribrate aperture is illustrated.

We are indebted to A. H. Smout for the suggestion (written communications Aug. 17, 1956, and July 17, 1957) that *A. striata* is specifically close to specimens of probably Chattian age from the Middle East. This undetermined Chattian (?) species of *Austrotrillina* is regarded as intermediate between *A. paucialveolata* Grimsdale (1952, p. 229, pl. 20, figs. 7–10) from the lower Oligocene (Lattorfian or Rupelian) and *A. howchini* which in the Middle East occurs in the high Aquitanian and Burdigalian.

More needs to be learned about the stratigraphic and geographic ranges of benthonic species such as these miliolids, before they can be used for close age determinations. Presumably their rate of dispersal would be much slower than rate of dispersal of planktonic forms.

Genus PYRGO Defrance, 1824

Pyrgo denticulata (Brady)

Plate 261, figure 14

Pyrgo denticulata (H. B. Brady). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 340, pl. 85, fig. 22.

This species is found in cuttings and cores from both holes on Eniwetok, though to a lesser degree in F–1. It was not noted in the Bikini drill hole samples. Specimens from the lower cores, F–1–11 and F–1–13, are casts in only a fair state of preservation, while those found in core E–1–2 are filled but in good condition. One specimen in the Miocene section of F–1 (790–800 feet) was brown, evidence of its being in place. Casts were also noted in the cuttings below 2,840 feet in E–1.

Pyrgo lupheri Rau

Plate 255, figure 9

Pyrgo lupheri Rau, 1948, Jour. Paleontology, v. 22, no. 2, p. 160, pl. 28, figs. 8, 9.

Pyrgo pseudoinornata Cushman and Stainforth, 1951, Jour. Paleontology, v. 25, no. 2, p. 145, pl. 25, fig. 39.

Although our material consists entirely of casts, it compares favorably with that of Rau's from the Eocene of Grays Harbor County, Wash. Examination of types indicates *Pyrgo pseudoinornata* Cushman and Stainforth, from the Eocene of Ecuador, is almost certainly the same species. The test is nearly circular in outline with distinct inflated chambers and distinct depressed suture.

It occurs in core E–1–2, from which a specimen is figured, and in the E–1 cuttings at and below 2,940–2,950 feet. It is in core F–1–15 where it occurs somewhat less rarely than in drill hole E–1.

Pyrgo oblonga (d'Orbigny)

Biloculina oblonga d'Orbigny, 1839, *in* De la Sagra, Histoire physique, politique, et naturelle de l'Île de Cuba, Foraminifères, p. 163, pl. 8, figs. 21–23.

Rare specimens in scattered occurrences below 2,230 feet in hole E–1 seem to belong in this species described from Recent material from Cuba. One questionable specimen, a cast, was noted in the Eocene core F–1–8.

Pyrgo sp. A

Two broken specimens are recorded from F–1, 220–230 feet, and E–1, 930–940 feet. They are elongate and plump, being most similar in outline to the casts referred to *Pyrgo oblonga* (d'Orbigny).

Other miliolids

In addition to those specifically identified, there are additional miliolids, some of which could be identified if better preserved. Some, however, may belong with the species already recognized, differing in degree or type of ornamentation. Most of them seem to have been eroded before deposition or are otherwise in an imperfect state of preservation.

Family OPHTHALMIDIIDAE

This family, related to the miliolids, is quite rare in the Eniwetok drill holes.

Genus CORNUSPIRA Schultze, 1854

Cornuspira planorbis Schultze

Cornuspira planorbis Schultze. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 341, pl. 85, fig. 27.

One very poor specimen was found in cuttings from 190–200 feet in drill hole E–1.

Genus NODOBACULARIELLA Cushman and Hanzawa, 1937

Nodobaculariella robusta Todd and Low, n. sp.

Plate 261, figure 15

Test robust, only slightly compressed, umbilical area depressed, periphery subrounded, some specimens showing a tendency toward a faint keel; chambers planispiral, indistinct, 2½–3 in adult whorl, involute, later chambers becoming progressively more inflated; sutures very indistinct, slightly incised; wall calcareous, ornamented by distinct low closely spaced costae, having some tendency to anastomose at base of chambers; aperture ovate with slightly everted, thickened, and polished lip. Diameter 0.65–0.80 mm; thickness 0.15–0.25 mm.

Holotype, USNM 626183, from drill hole E–1, from cuttings at 2,060–2,070 feet, Parry Island, Eniwetok Atoll, in the Marshall Islands.

This seems distinctly different from any described species of *Nodobaculariella*, mainly in its robust shape and subrounded periphery. The Recent Pacific species *N. insignis* (Brady) is also distinctly costate, but the costae anastomose to the point of being almost reticulated. In addition, *N. insignis* is very compressed and has a keel.

It occurs between 2,050 and 2,800 feet in hole E–1 and is most common at the top of its range.

Genus VERTEBRALINA d'Orbigny, 1826

Vertebralina striata d'Orbigny

Vertebralina striata d'Orbigny. Cushman and Todd, 1944, Cushman Lab. Foram. Research Contr., v. 20, pt. 3, p. 74, pl. 12, figs. 7–11.

Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 341.

There are only three occurrences, all rare, of this species in drill hole E–1, between 2,210 and 2,240 feet, in the section interpreted as Oligocene.

Genus PARRINA Cushman, 1931

Parrina bradyi (Millett)

Parrina bradyi (Millett). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 342, pl. 85, figs. 31–34.

This wild-growing form is found scattered and rare in cuttings from both holes. Probably most of the specimens are of Recent derivation, dropping down from above.

Family PLACOPSILINIDAE

Rare specimens belonging in this family are found in both holes.

Genus BDELLOIDINA Carter, 1877

Bdelloidina aggregata Carter

Plate 263, figure 8

Bdelloidina aggregata Carter, 1877, Annals and Mag. Nat. History, ser. 4, no. 111, p. 201, pl. 13, figs. 1–8.

Rare fragments of this large encrusting form were found in both holes. The species was originally described from a coral reef habitat.

Genus HADDONIA Chapman, 1897

Haddonia torresiensis Chapman

Plate 261, figure 16

Haddonia torresiensis Chapman, 1897, Linnean Soc. London Jour., Zoology, v. 26, p. 454, pl. 28.
Haddonia minor Chapman, 1902, Linnean Soc. London Jour., Zoology, v. 28, p. 384, pl. 36, figs. 1, 2.

This species has been subject to different interpretations. It was originally described as adherent on coral rock from Torres Strait, and a close relationship to the genus *Bdelloidina* Carter, 1877, was implied. In both genera the interior was described as being divided more or less completely by secondary septae resulting in a labyrinthic structure. In both genera the wall was described as perforate—coarsely perforate in *Haddonia* (Chapman, 1898, p. 453), but in *Bdelloidina* with coarse openings on the interior surface of the wall, branching and becoming constricted outward between the grains of the wall; hence in *Bdelloidina* the openings are not visible from the exterior unless revealed by erosion of the outer surface (Carter, 1877, p. 202, pl. 13, figs. 5, 7). Brady (1884, p. 320, pl. 36, fig. 6), in illustrating and discussing these presumed perforations, interpreted them as mere superficial depressions which are probably a "rudimentary condition of the cancellated structure which finds its fullest development amongst recent types in the genus *Cyclammina*."

Heron-Allen and Earland (1924, p. 615, pl. 35, figs. 17–22) in recording *Haddonia torresiensis* from Lord Howe Island, omit mention of wall perforations in this species, but they describe and illustrate the extreme wild-growing and monstrous forms the species may assume, which they say could as well be regarded as biological freaks. They suggest that *Haddonia* belongs with the Textulariidæ rather than with a labyrinthic family. In his original and later descriptions Chapman (1898, p. 454, pl. 28, figs. 1, 2; 1900, p. 6) indicated the wild-growing character of the species and its superficial resemblance to *Textularia*. Another species of *Haddonia*, *H. minor* Chapman (1902, p. 384, pl. 36, figs. 1, 2), was described from Funafuti Atoll. As it differs only by being smaller, by sometimes having a triserial early portion, and by the final part being unattached, it seems not worthy of separation from *H. torresiensis*. Our present material is too meager to shed further light on the nature and relationships of this species.

The rare specimens in the Eniwetok cuttings resemble those illustrated from Lord Howe Island, by their textulariid beginnings, small area of attachment and consequent easy detachment from whatever foreign object they grew upon, and final unattached cylindrical section with terminal aperture. They occur sparingly down to 1,090 feet in E–1 and to 750 feet in F–1. A single specimen showing the rarely occurring spiral initial stage and the partial division of the interior by imperfect septae is illustrated from cuttings at 1,080–1,090 feet in hole E–1.

Family LAGENIDAE

This family, with two rare exceptions, is confined to the Eocene cores from hole F–1. In general, species of the family are mostly confined to deeper water sediments and no lagenids were found in the Bikini drill holes.

Genus ROBULUS Montfort, 1808

Robulus cf. R. midwayensis (Plummer)

Plate 255, figure 7

Common to rare in the F–1 core material, these close-coiled specimens are circular in outline with a subangular periphery and 10–12 narrow chambers in the adult whorl. The sutures are curved, but the sutural ridges are not always distinct. The face of the final chamber is broad with the terminal aperture worn or obscured by crystalline preservation. In these features, specimens compare well with material from the Midway group of Texas, but poor preservation makes identification tentative. The specimens also resemble those recorded by Cushman and Stone (1949, p. 51, pl. 9, figs. 7, 8) from the Chacra formation of middle Eocene age of Talara, Peru.

Genus ASTACOLUS Montfort, 1808

Astacolus sp. A

Three unidentifiable crystallized specimens of the genus *Astacolus* were found in the Eocene section of drill hole F–1, cores F–1–9–2 and F–1–12–3.

Genus DENTALINA d'Orbigny, 1826

Dentalina communis d'Orbigny

Nodosaria (Dentalina) communis d'Orbigny. Parker, Jones, and H. B. Brady, 1871, Annals and Mag. Nat. History, ser. 4, v. 8, p. 158, pl. 9, fig. 46.

Dentalina communis d'Orbigny. Cushman, 1931, Cushman Lab. Foram. Research Contr., v. 7, pt. 3, p. 68, pl. 8, figs. 22, 23.

The apertural end of a broken specimen was found at 690–700 feet in hole E–1, probably as contamination from Recent material.

Dentalina cooperensis Cushman

Plate 255, figures 11, 12

Dentalina cooperensis Cushman, 1933, Cushman Lab. Foram. Research Contr., v. 9, p. 8, pl. 1, fig. 17.

Although fragmentary and crystalline, some specimens from the lower cores of hole F–1 show the robust and gently curved form of *Dentalina cooperensis* with quite distinct sutures. This species has been previously reported from the upper Eocene and lower Oligocene of the Southeastern United States, California, Panama, Cuba, Trinidad, and the Dominican Republic. It has also been found in the Lutetian-Bartonian of France.

Genus NODOSARIA Lamarck, 1812

Nodosaria affinis Reuss

Plate 255, figure 10

Nodosaria affinis Reuss, 1845, Versteinerungen böhm. Kreideformation, pt. 1, p. 26, pl. 13, fig. 16.

Nodosaria affinis d'Orbigny [not Reuss], 1846, Foraminifères fossiles du bassin tertiaire de Vienne, p. 39, pl. 1, figs. 36–39.

Our material consists of large costate fragments which are filled. Some are the initial ends with a typical blunt spine. The species was described by Reuss from the Cretaceous of Germany and has subsequently been found to have a wide distribution in the Upper Cretaceous and Paleocene. The form described as new by d'Orbigny in 1846 from the Miocene of the Wiener Becken (Vienna Basin) is considered the same. This species is also restricted to the Eocene cores of F–1.

Genus LINGULINA d'Orbigny, 1826

Lingulina wilcoxensis Cushman and Ponton

Plate 255, figure 13

Lingulina wilcoxensis Cushman and Ponton, 1932, Cushman Lab. Foram. Research Contr., v. 8, p. 58, pl. 7, fig. 14.

One complete specimen attributed to this species, previously reported only from the lower Eocene of Alabama, was found in core F–1–9–3. The sutures are not as distinct as those of the types, being somewhat obscured in the middle of the test. Otherwise, the resemblance is quite striking.

Genus VAGINULINA d'Orbigny, 1826

Vaginulina sp. A

Plate 255, figure 14

The single illustrated specimen from core F–1–14–27 seems to belong in this genus.

Genus LAGENA Walker and Jacob, 1798

Lagena sp. A

Two incomplete specimens of an indeterminate species of *Lagena* were found in the upper part of drill hole E–1. They have fine irregular striations.

Family POLYMORPHINIDAE

In Recent sediments of the Marshall Islands, polymorphinids are very rare and mostly found in the outer slope and guyot samples.

Genus GLOBULINA d'Orbigny, 1839

Globulina sp. A

Two rare and indeterminate specimens were found in drill hole E–1 only.

Family NONIONIDAE

This family, excluding the genus *Elphidium* which is now placed in the Elphidiidae, is only rarely found in in Eniwetok drill holes. In the Recent faunas it is likewise very rare in the Marshall Islands and confined mostly to the outer slope and guyot samples.

Genus NONION Montfort, 1808

Nonion grateloupi (d'Orbigny)

Nonion grateloupi (d'Orbigny). Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 556, pl. 198, fig. 10.

This species occurs slightly higher in the Eniwetok drill holes than in the Bikini ones, where it was first recorded at 747 feet. Here it occurs in the cuttings of both holes as well as in core E–1–1–4 at about 2,000 feet.

Nonion micrum Cole

Plate 255, figure 8

Nonion micrus Cole, 1927, Bull. Am. Paleontology, v. 14, no. 51, p. 22, pl. 5, fig. 12.

Todd, 1957, U.S. Geol. Survey Prof. Paper 280–H, p. 267 [tab.], pl. 65, fig. 26.

Only a single specimen was found in core F–1–12–3 (at 4,320 ft). The species has also been recorded from Saipan and Australia. It is well known in the Eocene of America.

Nonion pacificum (Cushman)

Nonion pacificum (Cushman). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 345, pl. 86, fig. 25.

This species occurs in the tops of both holes and sifts down to about 1,100 feet in each, with scattered lower appearances in E–1. Typical specimens were obtained from the meager fauna in core F–1–1–1 at 170–190 feet. In addition to rare Recent occurrences around Bikini Atoll, it was found only in the shallow holes on Bikini.

Nonion planatum Cushman and Thomas

Plate 255, figure 15

Nonion planatum Cushman and Thomas, 1930, Jour. Paleontology, v. 4, p. 37, pl. 3, fig. 5.
Todd, 1957, U.S. Geol. Survey Prof. Paper 280–H, p. 267 [tab.], pl. 65, fig. 28.

Two specimens occur at a depth of almost 3,000 feet in drill hole E–1. The species was described from the Claiborne group (middle Eocene) of Texas and is widely distributed in the Eocene of the Southeastern United States. Along with *Nonion micrum* Cole, this species was found in the Hagman and Densinyama formations of Eocene age on Saipan, Mariana Islands.

Family CAMERINIDAE

This family is included in chapter V, by W. Storrs Cole (1957, p. 752–766).

Genus HETEROSTEGINA d'Orbigny, 1826

Heterostegina suborbicularis d'Orbigny

Heterostegina suborbicularis d'Orbigny. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 346, pl. 82, figs. 7, 8; pl. 87, fig. 2.
Cole, 1954, U.S. Geol. Survey Prof. Paper 260–O, p. 576, pl. 205, figs. 5–8.

Specimens of this Recent species are present in scattered samples in the upper parts of both holes, down to about 600 feet, probably largely as contamination. The species is present in abundance in the Recent lagoonal and outer slope sediments.

Family PENEROPLIDAE

Well represented in Recent, particularly shallow, sediments of the Marshall Islands, this family is also well represented in the Tertiary of the drill holes.

Genus PENEROPLIS Montfort, 1808

Peneroplis carinatus d'Orbigny

Peneroplis carinatus d'Orbigny. Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 557, pl. 199, fig. 3.

This species is scattered nearly throughout the section below 730 feet in drill hole E–1 and in the core at about 2,000 feet, but little significance is attached to its distribution. Some specimens are thick and tight-coiled with raised sutures. Others are more compressed and smooth and have depressed sutures. Still others, in the Eocene section, are much compressed disks with incised sutures.

Peneroplis dusenburyi Henson

Plate 255, figures 16–18

Peneroplis dusenburyi Henson, 1950, Middle Eastern Tertiary Peneroplidæ, p. 32, pl. 4, figs. 1, 4, 5.

Peneroplis dusenburyi Henson, in association with abundant *Triloculina trigonula* (Lamarck), marks a sudden change in type of assemblage at the top of the Eocene section in hole E–1. *P. dusenburyi* occurs commonly or abundantly from its first appearance down to about 2,940 feet where it falls off in abundance, although continues to the bottom of the hole. In hole F–1 it is present, again abundantly and in association with abundant specimens of *T. trigonula*, but well below the top of the Eocene in that hole, that is in cores at about 4,200 and 4,400 feet.

The species was described from upper Eocene limestone in Iraq and also recorded from beds of early (?) and middle Eocene age in Iraq and Oman.

We are indebted to A. H. Smout for his courtesy in examining some of our specimens and for his opinion (written communication, July 17, 1957) that, although they are smaller and hence composed of almost one whorl less and their septæ are slightly straighter, they are the same species as that described from the Middle East. Our specimens show a high degree of variation from flat to thickened, and many have a tendency toward uncoiling.

Peneroplis honestus Todd and Post

Peneroplis honestus Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 557, pl. 199, fig. 1.

Occurring in the Bikini holes between 1,150 and 1,700 feet, this species first appears in drill hole E–1 at 750 feet, continuing down to about 1,400 feet after which it is quite scattered. Only a single specimen was found in hole F–1 (at 770–780 ft). Some specimens show a tendency toward uncoiling, as in the genus *Spirolina*.

Peneroplis planatus (Fichtel and Moll)

Plate 261, figure 13

Nautilus planatus Fichtel and Moll, 1798, Testacea microscopica, p. 91, pl. 16, figs. a–h.
Peneroplis planatus (Fichtel and Moll). Cushman, 1933, U.S. Natl. Mus. Bull. 161, pt. 2, p. 61, pl. 19, figs. 1–3.

This species is found fairly consistently from 700 feet down to about 1,400 feet in E–1. It is scattered below this point even into the Eocene section where it is quite certainly not in place. There is a single occurrence in F–1 at 440–450 feet. It has been recorded from the Tertiary of Europe. It was not found in the Recent fauna of the Marshall Islands area nor in the drill holes on Bikini.

Genus SPIROLINA Lamarck, 1804

Spirolina arietina (Batsch)

Spirolina arietina (Batsch). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 348, pl. 87, figs. 4, 5.

Spirolina sp., Todd and Post [part], 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 557 [not pl. 199, fig. 2].

Spirolina arietina (Batsch) is less well represented in the Eniwetok cuttings than in the Recent fauna from the Marshall Islands. All the typical specimens in the cuttings seem to have come down from the Recent. The others seem to be immature—or possibly incipient—forms of the species. They are scattered, never abundant, and seem to be of no significance. A few brown specimens noted were considered to be in place in the Miocene. The species also occurs rarely in the Miocene core E–1–1.

A few specimens in the Miocene sectio ' of the Bikini holes, between 925 and 2,256 feet, were erroneously separated from this species as indicated by the above synonymy.

Spirolina? sp. A

Plate 261, figures 17–21

Spirolina sp., Todd and Post [part], 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 557, pl. 199, fig. 2.

Test elongate, cylindrical with close-coiled initial stage, increasing gradually in diameter to the final chamber; chambers distinct, low, slightly inflated; sutures straight, slightly incised; wall thick, with a thick spongy-appearing outer layer and a thinner smooth and polished imperforate inner layer; aperture terminal, an irregular opening with inward-projecting teeth. Length up to 1.35 mm; maximum diameter of uniserial part about 0.4 mm; diameter of coiled part about 0.45 mm.

Specimens are too few for complete description. The spongy wall appears only in certain specimens, perhaps as a result of abrasion of the surface. These are quite unlike any other known *Spirolina*.

The species occurs in E–1 cuttings from 990 to about 1,400 feet, then is scattered to 2,620 feet. It appears to be the same as that noted in the Bikini drill hole material from cuttings at about 1,700 and 1,900 feet.

Genus MONALYSIDIUM Chapman, 1900

Monalysidium politum Chapman

Monalysidium politum Chapman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 348, pl. 87, fig. 7.

The present specimens have distinct striations and incised sutures. Although no complete specimens were obtained, some show the definite neck and lip on the final chamber. All are brownish, from which it is inferred that even those in the E–1 cuttings (760–770 ft and 860–870 ft) must be nearly in place. The species occurs also in core E–1–1 at about 2,000 feet. No previous fossil record for this species has been reported.

Genus ARCHAIAS Montfort, 1808

Archaias angulatus (Fichtel and Moll)

Archaias angulatus (Fichtel and Moll). Cushman, 1946, Cushman Lab. Foram. Research Spec. Pub. 17, p. 15, pl. 4, figs. 2–5.

Smout and Eames, 1958, Palaeontology, v. 1, pt. 3, p. 210, pl. 39, figs. 1–5.

The Red Sea locality given in the original description of this species seems (Smout and Eames, 1958, p. 212–213) to be doubtful. The species probably does not occur in the Mediterranean region but is abundant and widespread in the West Indian region, both Recent and fossil. The statement (Cushman, 1946, p. 15) that it "is widely distributed in warm, shallow waters of the Indo-Pacific" seems to have no basis in recorded occurrences. In the Central Pacific the species has not been reported from the Recent. Rare specimens were found in the upper parts of the Eniwetok drillings; in hole E–1 at 590–600 feet and in F–1 between 500 and 1,210 feet.

Archaias eniwetokensis Cole

Archaias? sp., Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 557, pl. 202, figs. 6, 7.

Archaias eniwetokensis Cole, 1958, U.S. Geol. Survey Prof. Paper 260–V, p. 766, pl. 240, figs. 14, 15 [imprint date, 1957].

Rare free specimens similar to those found in the lower part of the Bikini section occur in hole E–1 in the core at 2,000 feet and the cuttings between 1,805 and 2,870 feet.

Genus SORITES Ehrenberg, 1840

Sorites marginalis (Lamarck)

Sorites marginalis (Lamarck). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 348, pl. 82, fig. 4.

Only one specimen was found in F–1 cuttings at 70–80 feet. The species is rare in the Recent material of the Marshall Islands and was not found in the Bikini drill holes.

Genus MARGINOPORA Blainville, 1830

Marginopora vertebralis Blainville

Marginopora vertebralis Blainville. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 348, pl. 82, figs. 5, 6.
Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 557, pl. 203, figs. 3c, d.
Marginopora vertebralis Quoy and Gaimard. Cole, 1954, U.S. Geol. Survey Prof. Paper 260–O, p. 582, pl. 210, figs. 10–13; pl. 211, figs. 3–29.

No specimens of *Marginopora vertebralis* were obtained from any of the cores studied, although the species persists from the top to the bottom in the cuttings from both holes. Absence of this species from the Miocene core at 2,000 feet, where other species indicate a favorable facies, shows it was a rather late comer to the area. The significance of the change from white to brown specimens in the upper part of the Miocene is discussed in the section on correlation between Eniwetok and Bikini.

Family HETEROHELICIDAE

Genus BOLIVINELLA Cushman, 1927

Bolivinella folium (Parker and Jones)

Plate 262, figure 2

Bolivinella folia (Parker and Jones). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 349, pl. 87, figs. 10, 11.

In this material there is variation in the amount of ridging of sutures, and some sutures are slightly beaded, but all the forms apparently belong to a single species which seems indistinguishable from *Bolivinella folium* as present in the Recent fauna of the Marshall Islands. In hole E–1 it has only scattered occurrences above 1,835 feet. At 2,050 feet, and continuing to the bottom, it persists with some regularity. There is only one record in hole F–1 at 1,220–1,230 feet.

Genus PLECTOFRONDICULARIA Liebus, 1903

Plectofrondicularia sp. A

Plate 255, figure 24

One broken specimen was obtained from core F–1–9–3. It most closely resembles *Plectofrondicularia packardi* Cushman and Schenck, described from the Bassendorff shale of Oregon, in the short distinct costae over its slightly rounded initial end and the angle of its increase in width. However, it is not as compressed as *P. packardi* and has a rounded instead of acute periphery. The coiling in the early part is obscure, but the later uniserial stage is faintly visible when wet; the chambers are of similar height and curvature as *P. packardi*, and the sutures slightly limbate and flush.

Family BULIMINIDAE

From the Eocene to the Recent, this family is represented by 12 genera and 41 species, none common. In number of species in this Eniwetok material, this family is second only to the Miliolidae.

Genus BULIMINELLA Cushman, 1911

Buliminella madagascariensis (d'Orbigny)

Buliminella madagascariensis (d'Orbigny). Cushman and Parker, 1947, U.S. Geol. Survey Prof. Paper 210–D, p. 68, pl. 17, figs. 15–17.
Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 558.

This species occurs rarely, and only in drill hole E–1 including cores E–1–1 and E–1–2. It was rare also in Bikini drill holes 2A and 2B.

Genus BULIMINA d'Orbigny, 1826

Bulimina semicostata Nuttall

Plate 255, figure 20

Bulimina semicostata Nuttall, 1930, Jour. Paleontology, v. 4, p. 285, pl. 23, figs. 15, 16.
Todd, 1957, U.S. Geol. Survey Prof. Paper 280–H, p. 267 [tab.], pl. 66, fig. 7.

The Eniwetok specimens are crystalline and hard to see, but the striations on the early part are faintly visible, comparing favorably with types from the Eocene of Mexico. It was reported from both the Hagman and the Densinyama formations (Eocene) of Saipan. Specimens from beds of Eocene age from the west side of Pahi Peninsula, Kaipara Harbour, New Zealand (Cushman colln. 64864) also compare very well with the present material. All have some degree of crystalline appearance, with the striations showing faintly on the initial part and the sutures only barely visible in the later part.

This species was found only in sections of core F–1–14 at about 4,500 feet.

Bulimina sp. A

One indeterminate specimen from 2,440–2,450 feet in hole E–1 has the general shape of *Bulimina jarvisi* Cushman and Parker but is much smaller and less coarsely perforate and has a blunter initial end.

Genus PLECTOFRONDICULARIA Liebus, 1903

Fissurina circularis Todd

Fissurina circularis Todd, *in* Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 351, pl. 87, fig. 27.

One specimen of this Recent species described from the Marshall Islands was found in E–1 at 550–560 feet.

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Fissurina formosa (Schwager)

Fissurina formosa (Schwager). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 351, pl. 87, fig. 31.

The one specimen obtained from 1,000–1,010 feet in E–1 compares very well with the Recent specimen figured from the Marshall Islands. The species was described from the Pliocene of Kar Nicobar.

Fissurina lacunata (Burrows and Holland)

Fissurina lacunata (Burrows and Holland.) Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 351, pl. 87, fig. 28.

At 1,120–1,130 feet in hole F–1 a single specimen was obtained that resembles closely the material of Recent age from the Marshall Islands.

Fissurina marginato-perforata (Seguenza)

Lagena marginato-perforata Seguenza, 1880, R. accad. Lincei Atti, ser. 3, v. 6, p. 332, pl. 17, fig. 34.

Typical forms of this species described from the Pliocene of Sicily occur rarely in the cuttings of both drill holes on Eniwetok Atoll.

Fissurina orbignyana flintii (Cushman)

Lagena orbignyana (Seguenza) var. *flintii* Cushman, 1922, U.S. Geol. Survey Prof. Paper 129–F, p. 129, pl. 29, fig. 11.

Fissurina orbignyana Seguenza var. *flintii* (Cushman). Todd and Kniker, 1952, Cushman Found. Foram. Research Spec. Pub. 1, p. 22, pl. 4, fig. 15.

Ornamentation on our specimens is somewhat obscured but is discernible when wet. Secondary keel and general outline of test compare well, and the concentrically alined perforations, when wet, are quite distinctive.

The subspecies was described from rocks of Oligocene age in the Gulf Coastal Plain. It is also reported from the Agua Fresca shale of Eocene age of Magallanes Province, southernmost Chile. The present specimens were found in core F–1–14 at about 4,500 feet.

Fissurina spp.

Rare, small, indeterminate specimens of this genus were found in the cuttings of both drill holes.

Genus BOLIVINA d'Orbigny, 1839

Bolivina carinata Terquem

Plate 255, figure 23

Bolivina carinata Terquem. Todd, 1957, U.S. Geol. Survey Prof. Paper 280–H, p. 267 (tab.), pl. 66, fig. 12.

Specimens from the cuttings in the Eocene section of hole E–1 and cores F–1–9 and F–1–14 compare very well with Eocene material from the Paris Basin and from the Densinyama and Hagman formations of Eocene age on Saipan. The crystalline condition of the material obscures the keel and median carina, but these are made visible by wetting the specimens.

Bolivina cf. B. choctawensis Cushman and McGlamery

Poor preservation of the surface limits the comparison, but two specimens from hole E–1 (2,570–2,580 ft. and 2,700–2,710 ft.) show strong resemblance to *Bolivina choctawensis* described (Cushman and McGlamery, 1938, p. 108, pl. 26, fig. 4) from the lower Oligocene of Alabama. Size and contour of test are similar, and wetting the surface reveals similarly shaped sutures. Although slightly larger than the holotype, they compare well in size with other material referred to this species from the Oligocene of Alabama and Mississippi.

Bolivina compacta Sidebottom

Bolivina compacta Sidebottom. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 352, pl. 87, fig. 37.

Rare, scattered occurrences of this species are recorded from the cuttings of E–1 only.

Bolivina densa Todd

Bolivina densa Todd, 1957, U.S. Geol. Survey Prof. Paper 280–H, p. 297, pl. 82, fig. 2.

This species, described from the Tagpochau limestone of Miocene age on Saipan, shows considerable variation in the striations on the early part of the test and tends to be keeled. It occurs in association with *Bolivina subrhomboidalis* Todd, described from the upper Eocene of Saipan, and is also found lower in the Eniwetok section. *B. densa* appears to have evolved from *B. subrhomboidalis* although the picture is obscured and confused through contamination of cuttings in the lower section of the drill hole.

Bolivina cf. B. plicatella Cushman

One well-preserved specimen from 830–840 feet of drill hole F–1 has much in common with *Bolivina plicatella* Cushman (1930, p. 46, pl. 8, fig. 10) described from the Miocene of Florida but differs by being slightly more crenulated. Two very poorly preserved specimens recorded from about 1,100 feet in hole E–1 may be the same.

Bolivina pseudopygmaea Cushman

Bolivina pseudopygmaea Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 352, pl. 87, fig. 39.

Very distinctive specimens occur near the top of E–1 only, appearing as low as 1,310–1,320 feet. All previous records are from the vicinity of the Marshall Islands.

Bolivina rhomboidalis (Millett)

Bolivina rhomboidalis (Millet). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 353, pl. 87, figs. 41, 42.

This species was found in Recent material from the Marshall Islands but not in the Bikini drill holes. On Eniwetok Atoll it occurs below 950 feet in hole E–1 and very scattered to 2,570 feet; it also occurs in the Miocene core at about 2,000 feet and in the F–1 cuttings.

Bolivina cf. B. spinea Cushman

One specimen from 1,010–1,020 feet in hole E–1 strongly resembles *Bolivina spinea* Cushman (1936, p. 58, pl. 8, fig. 11), which was described from a depth of 40–50 fathoms off Fiji. Though well preserved, it lacks a spine on the initial end, but the spinose projections on the middle of the chambers are quite distinct, as are the strongly depressed sutures. The species was not found in any of the Bikini material, Recent or fossil.

Bolivina striatula Cushman

Bolivina striatula Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 353, pl. 87, fig. 43.

Occurring in cuttings from both holes and in core E–1–1 are finely striated specimens belonging in this species.

Bolivina subrhomboidalis Todd

Bolivina subrhomboidalis Todd, 1957, U.S. Geol. Survey Prof. Paper 280–H, p. 297, pl. 66, figs. 13–15.

Specimens in the lower part of hole E–1 seem to belong in this species, described from the Eocene of Saipan, but may be transitional to the Miocene species *Bolivina densa* Todd that is found higher in the drill hole.

Bolivina tortuosa Brady

Bolivina tortuosa H. B. Brady. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 353, pl. 87, figs. 45–47.

This widely distributed species occurs scattered in the cuttings of both holes and is present in cores E–1–1 (Miocene) and F–1–14 (Eocene). It was reported from the Recent of the Marshall Islands but not from the Bikini drill holes.

Bolivina variabilis (Williamson)

Bolivina variabilis (Williamson). Cushman, 1937, Cushman Lab. Foram. Research Spec. Pub. 9, p. 158, pl. 16, figs. 6, 12–14.

Representatives of this Recent species were found at about 600 feet in hole E–1. It was not reported from either the Recent or fossil sediments of Bikini.

Bolivina ventricosa Galloway and Heminway

Plate 255, figures 21, 22

Bolivina ventricosa Galloway and Heminway, 1941, New York Acad. Sci., Sci. Survey Porto Rico and Virgin Islands, v. 3, pt. 4, p. 420, pl. 31, fig. 5.

Found only in core F–1–14–28, our specimens are distinctive in their overall shape and swollen center area and seem to fit the original description and accompanying figures (cited above). The species was described from the Ponce limestone of Oligocene age of Puerto Rico.

Bolivina sp. A

Plate 262, figure 3

Granular preservation makes identification of this species impossible. The specimens are shield shaped with a slight twist to the test. When wet, slightly depressed and limbate sutures are visible, and are accented by faint costae. Rare specimens occur in the Miocene section of hole F–1 only.

Genus LOXOSTOMUM Ehrenberg, 1854

Loxostomum digitale (d'Orbigny)

Plate 262, figure 1

Polymorphina digitale d'Orbigny, 1846, Foraminifères fossiles du bassin tertiaire de Vienne, p. 235, pl. 14, figs. 1–4.

Loxostomum digitale (d'Orbigny). Cushman, 1937, Cushman Lab. Foram. Research Spec. Pub. 9, p. 180, pl. 21, figs. 10–12.

This Miocene species is widely scattered from 530 feet down to 1,482 feet in hole E–1, appearing again at the very bottom of the hole. It occurs only twice in the upper part of hole F–1.

Loxostomum karrerianum (Brady)

Loxostomum karrerianum (H. B. Brady). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 353, pl. 88, fig. 7 [not fig. 6 as erroneously indicated].

A single broken specimen was found in hole F–1 (1,230–1,240 ft). This deepwater species was recorded from 410 and 592 fathoms off Bikini.

Loxostomum limbatum (Brady)

Loxostomum limbatum (H. B. Brady). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 353, pl. 88, fig. 8 [not fig. 7 as erroneously indicated].

This species occurs in cuttings of both holes, being widely scattered in E–1. Our material includes both smooth and ornamented specimens.

Loxostomum vicksburgense (Howe)

Pleurostomella vicksburgensis Howe, 1930, Jour. Paleontology, v. 4, p. 331, pl. 27, fig. 5.
Loxostomum vicksburgense (Howe). Todd, 1952, U.S. Geol. Survey Prof. Paper 241, p. 30, pl. 4, fig. 31.

The hooded appearance of the specimens is striking. In size, shape, and arrangement of chambers they agree very well with the holotype and identified specimens in the U.S. National Museum collection. The species was described from the lower Oligocene of Mississippi, and its only occurrences have been from rocks of Oligocene age in Mississippi and Alabama. At Eniwetok it occurs rarely in hole E–1 between 2,180 and 2,500 feet.

Loxostomum? sp. A

Plate 262, figure 4

Unique in its spiny peripheral tubercles, this indeterminate species has an elongate twisted tapering test that is widest across the final chambers. The sutures are depressed and the wall perforate and translucent. Although the aperture is most like that of a *Loxostomum*, it cannot be certainly attributed to that genus. Only a single specimen was found at 1,080–1,090 feet in hole E–1.

Genus RECTOBOLIVINA Cushman, 1927

Rectobolivina sp. of Boomgaart

Rectobolivina sp. of Boomgaart. Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 559, pl. 199, fig. 4.

Rare specimens of this Pliocene to Miocene form, found in hole 2B of Bikini, occur in Eniwetok drill hole E–1 between 560 and 730 feet.

Genus SIPHOGENERINA Schlumberger, 1883

Siphogenerina cf. S. mayi Cushman and Parker

A single specimen from the 2,028–2,040 feet cuttings in hole E–1 strongly resembles the type of *Siphogenerina mayi* Cushman and Parker (1931, p. 10, pl. 2, fig. 7) described from the Miocene of California. It is smaller and less well preserved but has the distinct longitudinal costæ that extend slightly beyond the base of the chambers with deep excavations beneath.

Siphogenerina raphana (Parker and Jones)

Siphogenerina raphana (Parker and Jones). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 356, pl. 88, figs. 23, 24.

In addition to its occurrence in Recent samples in the Marshall Islands, this species was found in the core at 137–158 feet in Bikini drill hole 1. Specimens from holes E–1 and F–1 on Eniwetok Atoll are quite fresh and appear to be of Recent origin.

Genus UVIGERINA d'Orbigny, 1826

Uvigerina cf. U. isidroensis Cushman and Renz

One poorly preserved specimen from 1,220–1,230 feet in F–1 bears a strong resemblance to types of *Uvigerina isidroensis* Cushman and Renz (1941, p. 20, pl. 3, fig. 16) described from upper Oligocene to upper? Miocene beds in Venezuela. Costæ are present, although worn, and the sutures are distinctly depressed.

Genus TUBULOGENERINA Cushman, 1927

Tubulogenerina tubulifera (Parker and Jones)

Tubulogenerina tubulifera (Parker and Jones). Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 559, pl. 199, fig. 7.

This Eocene fossil described from the Paris Basin is considered to be diagnostic of the Miocene in the Pacific. It is found in the cuttings of both Eniwetok drill holes and in the Miocene core E–1–1, mostly as single occurrences. It provides good correlation between the Eniwetok and Bikini sections.

A single fragmentary specimen from the "Miopliocene" of Buton, Malay Archipelago, described as *Tubulogenerina butonensis* (Keyzer, 1953, p. 277, pl. 2, figs. 8–13), seems quite similar; it has a single row of tubules and as many as 11 apertural pores on the terminal face.

Genus REUSSELLA Galloway, 1933

Reussella araneola Todd and Low, n. sp.

Plate 255, figure 19

Test triserial, triangular in transverse section with elongate spines extending from each of the three angles, sides concave, initial end sharply pointed, having a spine in well-preserved specimens, increasing rapidly in width, greatest breadth at base of spines in main body of test, apertural end truncate, bluntly rounded; chambers indistinct, not inflated; sutures indistinct, flush, very slightly curved; wall calcareous, smooth, surface obscured by crystalline preservation; aperture a circular opening in center of terminal face. Maximum length about 0.50 mm; maximum breadth across spines about 0.55 mm.

Holotype, USNM 626280, from core F–1–15–7 (4528–4553 ft.) in drill hole F–1, Island of Elugelab, Eniwetok Atoll, in the Marshall Islands.

Because of poor surface preservation, the structural features are distinguishable only by wetting the test and observing it at various angles as it dries. In the present material there were two pairs of specimens attached in plastogamy, a condition that has been observed in other fossil species of *Reussella* (Parr, 1932, p. 224, pl. 22, fig. 49).

In outward appearance this species most closely resembles *Chrysalidinella cubana* Cushman and Bermudez in its concave sides and spinose projections. However, in none of the specimens of *Reussella araneola* studied was a final uniserial stage observed. Also the specimens lack a triangular apertural face with cribrate openings. Another attenuated species, *R. recurvata* (Halkyard), differs by the angles of its test appearing as bladelike projections extending from the apertural to the initial end, instead of as distinct elongate spines as in our species.

It was found only in core F–1–15 at 4528–4553 feet.

Reussella cf. R. byramensis Cushman and Todd

Specimens compared with *Reussella byramensis* Cushman and Todd (1946, p. 94, pl. 16, figs. 4, 5) are very rare and are found in hole E–1 only. There are six widely separated occurrences, the highest of which is at 920–930 feet. Chambers are narrow and separated by high-arched sutures. The test is small and compact, and the features are difficult to see.

Reussella decorata (Heron-Allen and Earland)

Reussella decorata (Heron-Allen and Earland). Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 559, pl. 199, fig. 8.

There are nine occurrences of this species in the E–1 cuttings between 810 and 1,290 feet. In Bikini drill hole 2B it was found rarely from 1,272–1,282½ feet to 2,091–2,102 feet.

Reussella simplex (Cushman)

Reussella simplex (Cushman). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 354, pl. 88, figs. 1, 2.

Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 549 (table).

Reussella sp. B, Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 559, pl. 199, fig. 10.

Reussella sp. C, Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 559, pl. 199, fig. 11.

In this Eniwetok material *Reussella* sp. B and *Reussella* sp. C, as reported from the Bikini drill holes, were recognized; but additional study makes it seem inadvisable to separate them from the Recent species *R. simplex*. The species is scattered throughout the cuttings of both holes as well as in cores F–1–1 and F–1–13, in the latter core questionably. Its absence from the Miocene core at about 2,000 feet in hole E–1 suggests that the species was a rather late arrival in the Marshall Islands and that its presence in the lower cuttings is due to contamination.

Reussella sp. A of Todd and Post

Reussella sp. A, Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 559, pl. 199, fig. 9.

There are four occurrences, all rare, of this indeterminate species originally found near the bottom of Bikini drill hole 2B. The range of 2,180 to 2,280 feet in hole E–1 on Eniwetok correlates well with the range on Bikini of from 2,143 feet to the bottom of the hole.

Reussella sp. B

Three specimens bearing strong resemblance to the upper Eocene species *Reussella moodysensis* Bandy (1949, p. 133, pl. 25, fig. 13) were found in the E–1 cuttings from the section regarded as Oligocene. They expand rather broadly on the initial end, become thickest in the central part, and then taper again to a rounded apertural end. The structure, however, is obscured making even a tentative identification impossible.

Genus TRIMOSINA Cushman, 1927

Trimosina spinulosa (Millett)

Trimosina spinulosa (Millett). Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 559.

A single specimen from F–1, 880–890 feet, appears to be the same as those recorded from Bikini hole 2A, 925–935½ feet.

Genus PAVONINA d'Orbigny, 1826

Pavonina triformis Parr

Pavonina triformis Parr. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 355, pl. 88, fig. 10.

Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 559, pl. 199, fig. 12.

The single specimen obtained from drill hole E–1, 680–690 feet, compares favorably with material from Bikini holes 2A and 2B. The species was also found in a short core from Sylvania guyot adjoining Bikini Atoll.

Family SPIRILLINIDAE

This family is as rarely represented in the drill holes as in the Recent sediments.

Genus SPIRILLINA Ehrenberg, 1843

Spirillina decorata Brady

Spirillina decorata H. B. Brady. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 356, pl. 88, figs. 32, 33.

This species occurs in the upper parts of both drill holes. It was reported also from Recent sediments in the Marshall Islands.

Spirillina denticulo-granulata Chapman

Spirillina denticulo-granulata Chapman, 1907, Quekett Micros. Club Jour., ser. 2, v. 10, p. 133, pl. 10, fig. 6.

The ornamentation of this species is like that of *Spirillina tuberculato-limbata* Chapman found in Recent sediments of the Marshalls, except for the presence of transverse grooves. The top occurrence in both Eniwetok holes is in cuttings from about 120 feet, and the specimens probably had their origin in Recent material.

Spirillina spinigera Chapman

Spirillina spinigera Chapman, 1899, Linnean Soc. London Jour., Zoology, v. 28, p. 10, pl. 1, fig. 7.
Cushman, 1924, Carnegie Inst. Washington Pub. 342, p. 32, pl. 9, figs. 6, 7.
Spirillina decorata H. B. Brady var. of Sidebottom. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 357, pl. 88, fig. 35.

A single Recent specimen was found in drill hole E–1, 60–70 feet. It was recorded as rare in the Marshall islands sediments and was not found at all in the Bikini drill holes.

Spirillina tuberculato-limbata Chapman

Spirillina tuberculato-limbata Chapman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 357, pl. 88, fig. 34.

This species, described from the borings on Funafuti Atoll, is found in the upper parts of both holes on Eniwetok. None of the specimens appear to be fossil; all probably had their origin in Recent sediments. This species was not found in the Bikini holes, but single specimens were found in Recent sediments of Bikini and Eniwetok.

Spirillina vivipara Ehrenberg

Plate 260, figure 4

Spirillina vivipara Ehrenberg, 1841, K. preuss. Akad. Wiss. Berlin, Abh., p. 422, pl. 3, sec. 7, fig. 41.

This cosmopolitan species has not been reported in typical form in Recent sediments of the Marshall Islands. As a fossil it occurs in hole E–1, rarely and with many breaks, from about 2,000 feet downward to 2,820 feet. Tests are somewhat concavo-convex and usually granular in appearance, but petrographic examination shows them to be calcareous, not arenaceous. The same form with the same type of preservation occurs in the Tagpochau limestone of Miocene age of Saipan (*Spirillina?* sp., Todd, 1957, p. 278 [table], pl. 82, fig. 5).

Spirillina vivipara Ehrenberg var. densepunctata Cushman

Spirillina vivipara var. *densepunctata* Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 357, pl. 88, fig. 31.

Single specimens occurring near the tops of both holes are Recent forms similar to those from waters around Rongerik Atoll.

Genus CONICOSPIRILLINA Cushman, 1927

Conicospirillina semi-involuta Cushman

Conicospirillina semi-involuta Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 357, pl. 88, fig. 38.

The only previous records for this species are from the Recent of Fiji, where it was described, and Rongerik lagoon. On Eniwetok it is found only in hole E–1, between 40 and 1,230 feet. The test is convex and nearly involute with radial lines on one side and slightly concave and lightly papillose on the other side.

Family DISCORBIDAE

In this family, as separated from the family Rotaliidae, are included most of the rotaliform species; none are common, and as a whole they do not constitute a significant part of the total assemblage.

Genus ROSALINA d'Orbigny, 1826

Rosalina assulata (Cushman)

Plate 260, figure 5

Discorbis assulata Cushman, 1933, Cushman Lab. Foram, Research Contr., v. 9, p. 15, pl. 2, fig. 2.

Described from the upper Eocene of Georgia, this species is widespread in beds of that age in the Southeastern United States. Rare, small (about 0.25 mm) specimens were found in hole E–1.

Rosalina baconica (Hantken)

Plate 256, figure 3

Discorbina baconica Hantken, 1881, K. ungar, geol. Anstalt Mitt. Jahrb., v. 4 (1875), p. 76, pl. 10, fig. 3.

Specimens from the deep cores in hole F–1 and cuttings at 3,060–3,070 feet in E–1 are referred to this species described from the Eocene of Hungary.

Rosalina rugosa d'Orbigny

Discorbis rugosa (d'Orbigny). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 359, pl. 89, fig. 14.

A single specimen was found near the top of hole E–1. This coarsely perforate species was recorded in shallow sediments from the four atolls studied in the Marshall Islands—Rongerik, Rongelap, Bikini and Eniwetok.

Rosalina subaraucana (Cushman)

Discorbis subaraucana Cushman, 1922, Carnegie Inst. Washington Pub. 311, p. 41, pl. 7, figs. 1, 2.

This species, described from the Recent of the Dry Tortugas, off Florida, is widely distributed in both the Atlantic and Pacific Oceans and has been recorded as a fossil in the Gulf Coast region from rocks as old as late Eocene. In addition to being well scattered throughout the cuttings of holes E–1 and F–1, it is in the Miocene and Eocene cores of E–1 and even in the Eocene core F–1–15 at 4,550 feet.

The test is planoconvex, finely punctate, with usually 6 or 7 chambers in the final whorl. The two Recent species, *Discorbis opima* Cushman and *D. micens* Cushman, described from and widely recorded in the tropical Pacific, may prove to be synonymous with *Rosalina subaraucana*.

Rosalina turgida (Dorreen)

Lamarckina turgida Dorreen, 1948, Jour. Paleontology, v. 22, p. 297, pl. 39, fig. 6.

Discorbis "globularis (d'Orbigny)." Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 560, pl. 199, fig. 13.

This species first occurs in the E–1 cuttings at 1250–1260 feet but is not well developed until about 2,000 feet where it is found abundantly in the Miocene core E–1–1. Some poorly developed specimens from the F–1 Eocene cores are also referred to this species. At Bikini it was best developed between 2,246 feet and the bottom of the hole at 2,556 feet, although a single small specimen was recorded at 1,272–1,282½ feet.

Rosalina turgida (Dorreen) was described from the upper Eocene of New Zealand. Although we have it in the Eocene part of the section on Eniwetok, specimens are better developed in the Miocene, where most forms are somewhat larger than the types. In Recent sediments of the Marshall Islands, there seems to be no counterpart of this rather heavy-walled, globular form. However, comparison of type material indicates a close relationship between *Lamarckina turgida* Dorreen and *Discorbis australis* Parr from Recent shore sand of San Remo, Victoria, Australia.

This species is distinctive in its coarse perforations, which are confined to the dorsal side, and in the inward-projecting radial ridges on the concave ventral surface. These features suggest it was attached at least temporarily, during life.

Rosalina sp. A

Plate 256, figure 4

Four specimens of an apparently undescribed species were found in the Eocene core F–1–13 at about 4,420 feet. They are distinguished by the concavo-convex shape, small raised umbilical plug, and lobulated periphery.

Genus NEOCONORBINA Hofker, 1951

Neoconorbina cf. N. bulla (Cushman)

Plate 256, figure 1

A single specimen, figured, from core F–1–13 at about 4,400 feet seems very close to this species originally described as *Discorbis* (Cushman, 1933, p. 16, pl. 2, fig. 6) from the Ocala limestone of late Eocene age in Alabama.

Neoconorbina cf. N. celsa (Todd)

Plate 256, figure 2

Neoconorbina celsa was described from the Matansa limestone of late Eocene age of Saipan, Mariana Islands, as *Discorbis* (Todd, 1957, p. 299, pl. 67, fig. 20) and was reported to have six chambers visible on the ventral side. Our specimens from core 15 in the Eocene section of drill hole F–1 are much smaller and some have only four chambers.

Neoconorbina tabernacularis (Brady)

Plate 262, figure 6

Discorbina tabernacularis Brady, 1884, *Challenger* Rept., Zoology, v. 9, p. 648, pl. 89, figs. 5–7.

Discorbis patelliformis (H. B. Brady). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 359, pl. 89, fig. 7.

This species is distinguished by its high conical test with radial costae from the tip of the spire. The aperture, as shown on plate 262, figure 6*b*, compares well with that figured by Brady in his plate 89, figure 5, referred to above. The species is scattered in the cuttings of both holes from the surface to near the bottom, but mostly near the top.

Neoconorbina terquemi (Rzehak)

Rosalina orbicularis Terquem, 1876, Essai classement animaux Dunkerque, pt. 2, p. 75, pl. 9, fig. 4.

Discorbina terquemi Rzehak, 1888, Austria Geol. Reichsanst., Verh., p. 228.

Conorbina orbicularis (Terquem). Parker, 1954, Harvard Mus. Comp. Zoology Bull., v. 111, no. 10, p. 522, pl. 8, figs. 13, 14.

Very rare specimens are found widely scattered in the cuttings of both holes and are also found in the Miocene core E–1–1, but not in any of the Eocene ones. This widespread species was described from the Recent of Dunkirk.

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Neoconorbina williamsoni (Parr)

Rotalina nitida Williamson, 1858, Recent Foraminifera of Great Britain, p. 54, pl. 4, figs. 106–108.

Discorbis williamsoni Chapman and Parr, 1937, Australasian Antarctic Exped., ser. C, v. 1, pt. 2, p. 105, pl. 8, fig. 23.

This species was described off England and has been recorded also in Recent material from off Victoria, Australia, and from the Antarctic. Our specimens, found only in hole E–1, are small and very rare.

Genus DISCORBIS Lamarck, 1804

Discorbis balcombensis Chapman, Parr, and Collins

Plate 262, figure 7

Discorbis balcombensis Chapman, Parr, and Collins, 1934, Linnean Soc. London Jour., Zoology, v. 38 (no. 262), p. 562, pl. 8, fig. 10.

Discorbina turbo Brady [not d'Orbigny], 1884, *Challenger* Rept., Zoology, v. 9, p. 642, pl. 87, fig. 8.

Rotorbinella sp., Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 562, pl. 200, fig. 2.

Epistomaria sp., Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 562.

Test trochoid, subcircular in outline, unequally biconvex, dorsal side almost conical with a flattened limbate border that may be slightly upturned, ventral side less convex, being only slightly so in larger specimens; periphery subacute, surrounded by an imperforate limbate keel; chambers 5 or 6 in the final whorl, increasing gradually in size as added, slightly inflated on the ventral side in smaller specimens, not inflated in larger ones; on larger specimens chambers tend to dimple toward umbilicus on ventral side; sutures on dorsal side barely visible in early parts, slightly more distinct on final whorl, oblique, flush, sutures on ventral side deeply incised, nearly radical except for a slight backward curve near periphery; wall calcareous, smooth, indistinctly perforate in early part, coarsely perforate in final whorl; on dorsal side of larger specimens, perforations form an even row bordering peripheral keel; aperture an arched slit at base of last-formed chamber extending from near periphery to umbilicus.

This species cannot be placed in *Rotorbinella* as it lacks an umbilical plug. In broken or eroded specimens, however, the thickened umbilical area may give the appearance of a plug. It belongs to the group of *Discorbis vesicularis* Lamarck of the Eocene of the Paris Basin (which is the genotype of *Discorbis*). Another species similar to the present one is *Discorbis pseudodiscoides* (Van Bellen, 1946, p. 53, pl. 6, figs. 10–15) described from the middle Eocene of the Netherlands. Also belonging to the same group is *D. cycloclypeus* Howchin and Parr from the Pliocene of Australia, but *D. balcombensis* is a smaller species and has fewer chambers (5 or 6 instead of 10 or 11). Most of our specimens are about 0.35 mm in diameter although 3 are larger (0.50–0.65 mm) and may be microspheric forms.

Discorbis balcombensis occurs rarely in both holes; in E–1 from 690 feet in scattered samples to about 2,400 feet, and in F–1 from 270 feet to 1,220 feet. At Bikini the species ranged in the middle of the section, from 925 to 1,713 feet.

Genus EPONIDES Montfort, 1808

Eponides dupréi ciervoensis Cushman and Simonson

Plate 260, figure 7

Eponides dupréi Cushman and Schenck var. *ciervoensis* Cushman and Simonson, 1944, Jour. Paleontology, v. 18, p. 201, pl. 34, fig. 2.

This subspecies was described and recorded only from the Tumey formation of Atwill (1935) of Oligocene age of California. Specimens have five chambers in the final whorl; the umbilicus is closed; and no aperture is observed. The wall is smooth and delicate.

It is very rare in this material, occurring in E–1 only and ranging from the lower part of the Miocene through the Oligocene section into the upper part of the Eocene.

Eponides ocalanus Cushman

Plate 256, figure 7

Eponides ocalanus Cushman, 1935, U.S. Geol. Survey Prof. Paper 181, p. 47, pl. 18, fig. 5.

This species occurs only in the Eocene cores between 3,650 and 4,420 feet in drill hole F–1. It was described and is only known from the Ocala limestone of late Eocene age in Alabama and Florida.

Genus POROEPONIDES Cushman, 1944

Poroeponides cribrorepandus Asano and Uchio

Poroeponides cribrorepandus Asano and Uchio. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 360, pl. 89, figs. 24, 25.

Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 548, 550, table 1.

In addition to being widely distributed in Marshall Islands Recent sediments, this species was found in two shallow Bikini cores at 137–158 feet and 211–232 feet. It starts near the tops of both Eniwetok drill holes and continues downward to about 1,250 feet in each.

Poroeponides lateralis (Terquem)

Rosalina lateralis Terquem, 1878, Soc. géol. France Mém., ser. 3, v. 1, p. 25, pl. 2 (7), fig. 11.

Poroeponides lateralis (Terquem). Cushman, 1944, Cushman Lab. Foram. Research Spec. Pub. 12, p. 34, pl. 4, fig. 23.

One specimen only was found in F–1 cuttings at 280–290 feet. It was described from the Pliocene of the Isle of Rhodes and has been reported as rare in the Pliocene of Japan.

Genus **RECTOEPONIDES** Cushman and Bermudez, 1936

Rectoeponides cubensis Cushman and Bermudez

Plate 256, figure 10

Rectoeponides cubensis Cushman and Bermudez, 1936, Cushman Lab. Foram. Research Contr., v. 12, p. 31, pl. 5, fig. 18.
Bermudez, 1949, Cushman Lab. Foram. Research Spec. Pub. 25, p. 250, pl. 17, figs. 31–33.
Sacal and Debourle, 1957, Soc. géol. France, Mém. 78, p. 38, pl. 18, figs. 2, 3.

The only records of this species seem to be those of the original description from the upper Eocene of Cuba, a rare occurrence in the upper Eocene of the Dominican Republic, and the Lutetian of the Aquitaine Basin. Specimens from cores F–1–14 and F–1–15 compare very well with the types.

Genus **PARAROTALIA** LeCalvez, 1949

Pararotalia byramensis (Cushman)

Plate 262, figures 11, 12

Rotalia byramensis Cushman, 1922, U.S. Geol. Survey Prof. Paper 129–E, p. 99, pl. 23, fig. 1.
Pararotalia byramensis (Cushman). Loeblich and Tappan, 1957, Smithsonian Misc. Colln., v. 135, No. 2, p. 10, pl. 1, fig. 1.
Rotalia canalis Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 561, pl. 200, fig. 4.
Rotalia calcar (d'Orbigny). Todd and Post [in part], 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 560 [not pl. 202, fig. 1; pl. 203, figs. 2, 3].

In the Bikini holes this species, as discussed in the section on corrections of taxonomy, was erroneously combined with two species, the generic position of which remains in doubt but which are tentatively placed in *Calcarina*. Taking into consideration these corrected identifications, the range of *Pararotalia byramensis* at Bikini is from 600 to 2,307 feet and at Eniwetok, from 590 feet to about 1,500 feet, then again from about 2,000 to about 2,600 feet. At Eniwetok it is found in the Miocene core at about 2,000 feet, but its presence in place below this level cannot be verified, and it is doubtful that it occurs before the Miocene.

This species was described from the Oligocene of Mississippi and has been reported from the Oligocene and lower Miocene of the Southeastern United States and Puerto Rico. In America the species seems to have become extinct in the later Tertiary, while in the Pacific it appears to have lived until the end of the Miocene, when it may have given rise to such transitional forms as *Calcarina delicata*, *C. rustica* and later, *C. hispida*, and, through them, the genus *Calcarina* s. s. Pacific specimens of *Pararotalia byramensis* are noticeably more spinose than American specimens, and they become progressively more spinose higher in the section, so that the separation point between the youngest specimens of *Pararotalia* and the oldest specimens of *Calcarina delicata* is an arbitrary point.

There appears to be a close relationship between *Pararotalia byramensis* and "*Rotalia verriculata* Howchin and Parr" which species also belongs in the genus *Pararotalia*, as shown by specimens from the lower Miocene at New Quarry, Australian Portland Cement Works, Batesford near Geelong, Victoria, Australia, received through the generosity of Miss Irene Crespin.

Genus **HERONALLENIA** Chapman and Parr, 1931

Heronallenia sp. A

A single poorly preserved specimen was found at 1,394–1,424 feet in drill hole E–1.

Genus **VALVULINERIA** Cushman, 1926

Valvulineria sculpturata Cushman

Plate 260, figure 6

Valvulineria sculpturata Cushman, 1935, Cushman Lab. Foram. Research Contr., v. 11, pt. 2, p. 37, pl. 5, fig. 10.
Parr, 1938, Royal Soc. Western Australia Jour., v. 24, p. 83, pl. 2, fig. 10.
Sacal and Debourle, 1957, Soc. géol. France Mém. 78, p. 35, pl. 12, fig. 3.

This species occurs in hole E–1 in the section interpreted as Oligocene, just below the first appearance of *Halkyardia bikiniensis* Cole. It was described from lower Oligocene rocks in Mississippi and has also been reported from Alabama. In the Aquitaine Basin of France it occurs in the Stampian. Parr reported one typical specimen from borings of late Eocene age in western Australia.

The best preserved specimens in the Eniwetok material are from the two higher samples (2,410–2,420 ft and 2,430–2,440 ft), with the thickened lip over the aperture showing well. The sutures of the holotype, with which this material was compared, are slightly more incised than in the present specimens. The coarsely perforate wall and inflated chambers suggest it may have been a planktonic form.

Genus **GYROIDINA** d'Orbigny, 1826

Gyroidina octocamerata Cushman and G. D. Hanna

Gyroidina soldanii d'Orbigny var. *octocamerata* Cushman and G. D. Hanna, 1927, Calif. Acad. Sci. Proc., ser. 4, v. 16, no. 8, p. 223, pl. 14, figs. 16–18.

Described from the Eocene of California and widely distributed elsewhere, this species appears to be a good marker for the upper Eocene, and perhaps for the Oligocene. It is found in our material between 2,930 and 3,000 feet in 3 single occurrences, the first being about 150 feet below the top of the Eocene.

Genus CANCRIS Montfort, 1808

Cancris cf. C. cubensis Cushman and Bermudez

Although smaller than typical, one specimen from 2,690–2,700 feet in hole E–1 bears a strong resemblance to *Cancris cubensis* Cushman and Bermudez. It is most similar, however, to specimens referred to that species from the McBean formation (Eocene) of Georgia (Cushman and Herrick, 1945, p. 69, pl. 11, fig. 7).

Genus BAGGINA Cushman, 1926

Baggina sp. A

A well-preserved single specimen from 1,000–1,010 feet in E–1 appears somewhat similar to *Baggina xenoula* Hadley from the Oligocene of the Gulf Coast region. The last-formed chambér of the Eniwetok specimen is more elongate, however; and there is a projecting boss over the initial chamber.

Genus BUCCELLA Andersen, 1952

Buccella? perforata Todd and Low, n. sp.

Plate 262, figures 9, 10

Eponides sp. A LeRoy. Todd and Post [not LeRoy], 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 560, pl. 200, fig. 1.

Test biconvex or planoconvex with the ventral side nearly flat, periphery rounded to subangular, slightly lobulated around last few chambers; chambers indistinct, about 7 in final whorl, about 3 whorls visible from dorsal side; sutures distinct on ventral side where they are straight and radial nearly to the periphery before curving backward, and depressed but filled with a separate shell deposit that extends nearly out to periphery, less distinct on dorsal side where they are slightly depressed, oblique, and slightly curved; wall calcareous, smooth but rather coarsely perforate, equally so on both dorsal and ventral sides; apertures not observed on adult specimens. Diameter of adults 0.50–0.65 mm, of juveniles about 0.25 mm; thickness of adults about 0.30 mm, of juveniles about 0.13 mm.

Holotype, USNM 626171, from drill hole E–1, from cuttings at 1,080–1,090 feet, Parry Island, Eniwetok Atoll, in the Marshall Islands.

This species is placed in *Buccella* only tentatively for the following reasons: Unlike other described species of *Buccella* (Andersen, 1952) the wall is quite coarsely perforate on both dorsal and ventral surfaces, in this respect suggesting the family Anomalinidae; the ventral sutural fillings are more like discrete channel fillings than like the pustulose coating described in *Buccella.*

On the other hand, small specimens that occur with the large ones in the Eniwetok material (see pl. 262, fig. 9), while lacking the heavy channel fillings of the ventral sutures, do show the primary aperture on the ventral side of the final chamber and, likewise on the ventral side, the supplementary apertures along the postero-sutural margin of the previous chambers. These smaller specimens, regarded as juveniles, also differ by being proportionally thicker and more nearly biconvex and by having a slightly more lobulated periphery.

The species is scattered in drill hole E–1 between 1,030 and about 1,570 feet with a single higher occurrence at 520–530 feet and several lower occurrences to 2,880 feet. Further study of specimens from Bikini hole 2B from 1,150 to 1,400 feet, proves that those referred to as *Eponides* sp A LeRoy are the same as the species described as new here.

Genus SVRATKINA Pokorny, 1956

Svratkina sp. A

Epistominella sp. D. Todd, 1957, U.S. Geol. Survey Prof. Paper 280–H, p. 292 [tab.], pl. 92, fig. 2.

This species has been illustrated under another generic name from shallow sediments of Tanapag Lagoon, Saipan, Mariana Islands. It seems to belong in this recently erected genus (Pokorny, 1956, p. 257–259), the other representatives of which are reported from the upper Eocene to Miocene of Europe, the Miocene of Australia, and the Recent of the Atlantic and the Gulf of Mexico. The form is very rare and not well developed in the cuttings of both Eniwetok drill holes.

Genus MISSISSIPPINA Howe, 1930

Mississippina monsouri Howe

Mississippina monsouri Howe, 1930, Jour. Paleontology, v. 4, p. 330, pl. 27, fig. 4.

Todd, 1952, U.S. Geol. Survey Prof. Paper 241, p. 40, pl. 6, fig. 6.

One broken specimen occurring at 1925–1955 feet in hole E–1 compares favorably with material in the U.S. National Museum collections from the Oligocene of Mississippi.

Genus EPISTOMARIA Galloway, 1933

Epistomaria semi-marginata (d'Orbigny)

Plate 256, figure 8

Rotalia (Turbinulina) semi-marginata d'Orbigny, 1826, Annales sci. nat., v. 7, p. 276.

Rotalia semimarginata d'Orbigny, 1850, Prodrome de paleontologie stratigraphique universelle des animaux mollusques et rayonnes, v. 2, p. 407.

Rotalina semi-marginata d'Orbigny. Terquem, 1882, Soc. géol. France Mém., ser. 3, v. 2, p. 56, pl. 3 (11), figs. 12–14.

Turbinulina semimarginata d'Orbigny. Fornasini, 1906, R. accad. sci. Istit. Bologna Mem., ser. 6, v. 3, p. 68, pl. 4, fig. 5 (original figure of type specimen).

Epistomaria semimarginata (d'Orbigny). Applin and Jordan, 1945, Jour. Paleontology, v. 19, no. 2, p. 131 (list); p. 144, pl. 19, fig. 6.

Discorbina rimosa Parker and Jones, 1865, Philos. Trans., p. 385, 421, pl. 19, fig. 6.

Epistomaria rimosa (Parker and Jones). Applin and Jordan, 1944, Am. Assoc. Petroleum Geologists Bull., v. 28, no. 12, pl. 3, fig. 8.

Rare and scattered occurrences of this distinctive species are found between 2,850 feet and the bottom of drill hole E–1. The only previous published records are the Lutetian of France and the middle Eocene subsurface beds of Florida. It has also been found in the Meting limestone of early Eocene age of West Pakistan (A. F. M. Mohsenul Haque, oral communication, Oct. 9, 1957).

Genus EPISTOMAROIDES Uchio, 1952

Epistomaroides polystomelloides (Parker and Jones)

Epistomaroides polystomelloides (Parker and Jones). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 360, pl. 89, fig. 26.

There are rare occurrences of this species in both holes, and some appear to be fossil forms. The species occurs in Recent sediments of the Marshall Islands but was not found in the Bikini drill holes.

Genus SIPHONINA Reuss, 1849

Siphonina sp. A

An indeterminate species occurs in hole E–1, in core E–1–1 and scattered below 1,993 feet in the cuttings, and from 55–60 feet in the F–1 cuttings.

Genus SIPHONINOIDES Cushman, 1927

Siphoninoides echinata (Brady)

Siphoninoides echinata (H. B. Brady). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 361, pl. 89, figs. 31, 32.

There were single occurrences near the tops of both holes of this species reported as rare from the Recent sediments of the Marshall Islands. It was not found in the Bikini drillings.

Family ROTALIIDAE

As defined and discussed by Smout (1954, 1955), this family includes genera that are distinguished on the basis of their wall structure and type of apertural openings—canaliculate wall composed of radial, laminated calcite; test without aperture or with a series of pores.

In contrast to the Recent sediments, the late Tertiary, particularly post-Eocene, sediments of Eniwetok contain abundant specimens belonging in this family.

Genus NOTOROTALIA Finlay, 1939

This genus has been only provisionally placed in the Rotaliidae.

Notorotalia sp. A

Plate 256, figure 9

A single specimen was obtained from F–1–14–1 at 4,500–4,525 feet. This Tertiary and Recent genus is characteristically found in Australia and New Zealand.

Genus CRESPINELLA Parr, 1942

The family placement of *Crespinella* is uncertain, as well as the recognition of it in the Eniwetok material.

Crespinella? sp. A

Plate 260, figure 11

Test involute, biconvex, apertural face slightly excavated, periphery subacute, entire or very slightly angled; chambers indistinct, about nine constituting the final whorl; sutures indistinct, not depressed; wall calcareous, thick, coarsely and densely perforate, ornamented with indistinct low short parallel ridges set at an angle to sutures and fanning outward and forward from umbilical area, especially over last-formed chambers; aperture a low, narrow, arched opening at base of apertural face, under a slight overhanging rim. Diameter about 0.70 mm.

The distinctive feature of this species, its densely perforate and ornamented wall, has not been observed in *Crespinella umbonifera* (Howchin and Parr) from the Miocene of Australia which also differs by being larger. However, broken sections of the present indeterminate species resemble broken sections of *C. umbonifera* by showing transverse tubules through the wall.

We have noted scattered rare occurrences in the cuttings from drill hole E–1 starting with 2,040–2,050 feet and ending with 2,960–2,970 feet.

Genus STREBLUS Fischer, 1817

In this genus the umbilical plug consists of a single pillar while in *Rotalia* it consists of multiple pillars.

Streblus beccarii (Linné)

Rotalia beccarii (Linné). Cushman, 1928, Cushman Lab. Foram. Research Contr., v. 4, pt. 4, p. 104, pl. 15.

Rotalia beccarii (Linné) var., Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 560, pl. 200, fig. 3.

The present specimens and those of the Bikini drill holes are all considered the same, the variation not being enough to justify separation from the typical form of *Streblus beccarii*.

This species occurs deeper at Eniwetok than at Bikini, probably due to contamination. Highest occurrences are at 200–210 feet in E–1 and 680–690 feet in F–1. None were found in Recent material from the Marshall Islands.

Streblus beccarii tepida (Cushman)

Rotalia cf. *R. beccarii* var. *tepida* Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 360, pl. 89, fig. 22.

Only two specimens were found in drill hole E–1. Although reported as fairly common in Recent sediments, this subspecies was not found in the Bikini drill holes.

Streblus flosculus (Todd and Post)

Plate 256, figure 5

Rotalia flosculа Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 561, pl. 200, fig. 5.

Described from the lowermost part of Bikini drill hole 2B, this species first appears in the Eniwetok drill hole E–1 at 2,380–2,390 feet just below the first occurrence of *Halkyardia bikiniensis* Cole and continues nearly to the bottom of the section represented by cuttings. It is also found in the F–1 cores from the Eocene. It appears to be ancestral to the genus *Pararotalia* and transitional to *Rotalia tectoria* Todd and Post but differs from the latter by being smaller, smoother, and less papillose and by having a more indented periphery.

Streblus saipanensis Cole

Streblus saipanensis Cole, 1953, U.S. Geol. Survey Prof. Paper 253, p. 27, pl. 5, figs. 8, 9.

This compact form with raised knobs is rare in the Oligocene section of Eniwetok with a few being found below. It was described from the Miocene, Tertiary *e*, of Saipan.

Streblus sp. A.

Plate 256, figure 6

Test compressed, periphery subangular, entire around the earlier part, somewhat serrate around later chambers; chambers indistinct, about nine constituting final whorl, not inflated; sutures indistinct, radial on both sides, flush on dorsal side, slightly incised on ventral side; wall calcareous, ornamented with transverse ridges most strongly developed at peripheral parts of each chamber, and by papillae surrounding umbilicus and on some specimens by an umbilical plug; aperture a low slit at base of ventral face of final chamber. Diameter about 0.75 mm; thickness about 0.30 mm.

These few specimens from drill hole E–1 are distinctive in their flattened and noninflated shape and in the test being rather delicately ornamented for this genus. They are found chiefly within a 200-foot section just above *Elphidium marshallana* Todd and Post and *Austrotrillina striata* Todd and Post, but rare specimens are also found in the Eocene section.

Streblus? sp. B

Plate 260, figure 9

Test trochoid, rather high spired, deeply umbilicate; periphery rounded, lobulated; chambers distinct, inflated rather rapidly increasing in size as added, about 7 constituting final whorl, about 2 whorls constituting entire test; sutures distinct, incised, radial on ventral side, slightly curved on dorsal side; wall calcareous, smooth, rather coarsely perforate; aperture a low opening into the umbilicus from the inner part of final chamber. Diameter 0.30–0.40 mm; thickness about 0.20 mm.

This indeterminate form occurs rarely, mostly in the presumed Oligocene part of the section penetrated by hole E–1. It may be ancestral to *Streblus beccarii* (Linné).

Genus ROTALIA Lamarck, 1804

Rotalia tectoria Todd and Post

Rotalia tectoria Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 561, pl. 202, figs. 2–4.

Free specimens of this species, described from the drill holes on Bikini Atoll, are found in the cuttings of both holes on Eniwetok and in the Miocene core E–1–1 at 2,003–2,028 feet. From thin sections it appears to be a conspicuous constituent of cores 4 and 5 (1,718–1,740 ft and 1,978–2,006 ft) in hole F–1. Although specimens continue to the bottom of hole E–1 in the cuttings, they become much less abundant, and the species is surely not in place in the lower part of the drill hole. On Bikini it was recorded from 1,800 to 2,200 feet.

Rotalia tuvuthaensis Kleinpell

Plate 263, figures 6, 7

Rotalia tuvuthaensis Kleinpell, 1954, B. P. Bishop Mus. Bull. 211, p. 61, pl. 7, figs. 1–4.

This species, described from the Miocene, Tertiary *g*, of Lau, Fiji, seems to be restricted to the interval between 880 and 1,160 feet in hole E–1, and to the interval between 1,100 and 1,220 feet in hole F–1. Although specimens continue about 230 feet deeper in cuttings of hole E–1, their presence is probably due to contamination from above.

Specimens are large (up to 1.2 mm in diameter), coarsely papillate, and pitted on all sides, so that no chambers are visible from either dorsal or ventral surfaces. They form a conspicuous part of the assemblage wherever present. Smaller, smoother specimens with dark limbate sutures visible on the dorsal side occur with the larger specimens and are considered immature forms.

Family PEGIDIIDAE

Genus PEGIDIA Heron-Allen and Earland, 1928

Pegidia dubia (d'Orbigny)

Pegidia dubia (d'Orbigny). Heron-Allen and Earland, Royal Micros. Soc. Jour. 1928, p. 290, pl. 1, figs. 8–15.
Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 361.

A single specimen at 45–55 feet in the F–1 cuttings seems identical with the one dredged from 44 to 25 fathoms on the outer slope of Bikini Atoll.

Family AMPHISTEGINIDAE

As a family this group has persisted from the Eocene to the Recent in the Eniwetok area, and specimens of both *Amphistegina* and *Asterigerina* are found commonly or abundantly. However, the genus *Asterigerina* became extinct in the region of the Marshall Islands sometime between Miocene and Recent, with *Amphistegina* remaining as one of the dominant Recent genera, occupying both lagoonal and outer slope environments.

Genus ASTERIGERINATA Bermudez, 1949

Asterigerinata bracteata (Cushman)

Plate 260, figure 8

Asterigerina bracteata Cushman, 1929, Cushman Lab. Foram. Research Contr., v. 5, pt. 2, p. 48, pl. 8, fig. 6.
Asterigerinata? bracteata (Cushman). Bermudez, 1952, Soc. Ciencias Nat. LaSalle Mem., v. 12, no. 32, p. 210, pl. 3, figs. 7–9.

This species is confined to the presumed Oligocene section of drill hole E–1, where it is rare. It was described from the lower Oligocene Byram formation, of Byram, Miss.

Genus ASTERIGERINA d'Orbigny, 1839

Asterigerina indistincta Todd and Post

Plate 262, figure 13

Asterigerina indistincta Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 562, pl. 201, fig. 1.

This species was described from the section above Tertiary *e* in the Bikini holes. It is found in cuttings from both hole E–1 and hole F–1 on Eniwetok. It may be confused with *Amphistegina madagascariensis* d'Orbigny but can be distinguished by its lack of irregular lines. It is characterized by very short supplementary chambers and lack of a distinct spiral suture. The center of the dorsal side is wholly indistinct.

It is very rare, possibly because it represents the dying out of the genus in the Marshalls. A specimen better preserved than the holotype from Bikini is here illustrated.

Asterigerina marshallana Todd and Post

Plate 257, figure 6

Asterigerina marshallana Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 562, pl. 201, fig. 3.

This species has been reported to occur in some abundance in the Oligocene of western Australia (Irene Crespin, written communication, Nov. 22, 1956). In the Eniwetok cuttings it begins at 2,280–2,290 feet although there are some transitional forms from about 2,100 feet. It appears to be ancestral to *Asterigerina tentoria* Todd and Post, differing by having a larger, flatter test, more chambers (about 12), and a sharp periphery. Specimens occur, but with different preservation, in the Eocene cores of both holes.

Asterigerina papillata Todd and Low, n. sp.

Plate 257, figure 4

Test fairly large for the genus, robust, about equally biconvex, periphery entire, subacute but not keeled; chambers indistinct, not inflated, narrow, 10–15 constituting the last-formed whorl, supplementary chambers not extending to the periphery in all specimens; sutures indistinct, flush, curved and oblique on dorsal side, strongly curved on ventral side, spiral suture indistinct, only faintly visible when moistened; wall calcareous, with numerous rounded papillae covering central area on both sides, better developed on dorsal side; aperture not observed, apparently a very low opening usually obscured by fine granulation that characteristically surrounds ventral apertural area in this genus. Diameter 0.70–1.00 mm; thickness 0.40–0.65 mm.

Holotype, USNM 626256, from core F–1–13–2 (4,406–4,431 ft) in drill hole F–1, island of Elugelab, Eniwetok Atoll, in the Marshall Islands.

By having many chambers and papillose ornamentation this species seems to be comparable to *Asterigerina angulata* Cushman from the Miocene of Santo Domingo and to *A. simiensis* Cushman and McMasters from the Eocene of California. However, the papillae on *A. papillata* n. sp. are much heavier and cover a larger part of both dorsal and ventral surfaces than on either of these species. Though the knobs follow suture lines as on *A. simiensis*, they are denser and more concentrated over the central areas on *A. papillata* n. sp. The Eniwetok specimens have narrower and more indistinct chambers than those of *A. simiensis*. In addition *A. papillata* n. sp. is more equally biconvex than *A. angulata*, with the umbonal area being obscured by the papillae rather than transparent.

In outward appearance it is most similar to *Eponides gratiosus* Cushman and Bermudez described from the Paleocene of Cuba. However, in addition to the generic difference, *Asterigerina papillata* n. sp. is more equally biconvex and its papillae more strongly defined on both surfaces.

Specimens occur only in the four deepest Eocene cores between 4,316 and 4,553 feet, from drill hole F-1.

Asterigerina rotula (Kaufmann)

Plate 257, figure 2

Hemistegina rotula Kaufmann, 1867, Beitr. geol. Karte Schweiz, v. 5, p. 150, pl. 8, fig. 19.

Pulvinulina rotula (Kaufmann). Uhlig, 1886, Geol. Reichsanst. Jahrb., v. 36, p. 193, pl. 3, fig. 5; pl. 5, figs. 6, 7.

Asterigerina rotula (Kaufmann). Grimsdale, 1952, British Mus. (Nat. History) Bull., Geology, v. 1, no. 8, p. 238, pl. 23, figs. 10, 11; pl. 24, figs. 1, 2.

Test unequally biconvex, dorsal side slightly bulging, ventral side conical, periphery entire, subacute; chambers not visible from surface, arranged in about 2 whorls, about 20 constituting final whorl, gradually increasing in size and thickness ventrally as added; sutures not visible except spiral suture as a very faint dark trace when test is moistened, septae between chambers very slightly curved; wall calcareous, radial, much thickened dorsally and ventrally with numerous laminae, smooth; aperture not observed, presumably only slightly open. Diameter about 1.00 mm; height about 0.80 mm.

Our specimens differ from the described types in the following respects which do not seem of specific importance: test consists of about 2 instead of 3 whorls, and about 20 instead of 15 chambers per final whorl.

Specimens occur abundantly in the lowest E-1 cuttings, first appearing at 3,010 feet which is about 250 feet below the top of the Eocene, and in the two lowest cores in F-1, between 4,500 and 4,550 feet.

The species was described from the upper Eocene of Switzerland and has also been recorded from Poland, Egypt, Iraq, and Syria. According to Grimsdale (1952, p. 239), its range is not clearly established although it seems to be restricted to the upper Eocene and upper part of the middle Eocene.

Asterigerina tentoria Todd and Post

Asterigerina tentoria Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260-N, p. 562, pl. 201, fig. 2.

This species is first observed at 960-970 feet in hole E-1 but is not abundant until 1,100-1,110 feet. It is rare in F-1, occurring only scattered from 1,090 to 1,240 feet. It is abundant in the Miocene core E-1-1 at about 2,000 feet. In addition, it is present in 2 Eocene cores—E-1-2 and F-1-8—extending its range downward beyond that of the Bikini record which was 1,167 to 2,007 feet.

Asterigerina sp. A

Although, as previously noted, the genus *Asterigerina* is not found in Recent sediments of the Marshalls, there occur a few fossil forms in hole F-1 between 450 and 470 feet, well above the first appearance of *A. tentoria* Todd and Post. These are small, biconvex forms with a sharp, flanged periphery and they have about 10 much curved chambers per whorl.

Genus AMPHISTEGINA d'Orbigny, 1826

Amphistegina bikiniensis Todd and Post

Amphistegina bikiniensis Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260-N, p. 563, pl. 201, fig. 4.

This species seems to be ancestral to *Amphistegina madagascariensis* d'Orbigny from which it differs by its more distinct sutures, less prominent umbones, sharper periphery, and flatter test lacking irregular sutural lines.

At Bikini the species occurred only between 1,891 and 2,206½ feet. In the Eniwetok cuttings from hole E-1 it begins to appear around 1,500 feet. At 1,700 feet it is well established, but the 2 types (*A. madagascariensis* and *A. bikiniensis*) occur together, and the specimens from 1,746-1,776 feet show the transition well. By 2,000 feet the specimens of *Amphistegina* are exclusively *A. bikiniensis* with only a few specimens of *A. madagascariensis* from above. By about 2,550 feet it becomes rarer, and its presence is probably due only to contamination from higher levels. *A. bikiniensis* occurs in typical form in the Miocene core, E-1-1, at about 2,000 feet but was not found in the Eocene cores or in any of the F-1 cuttings.

This species has been reported with *Asterigerina marshallana* Todd and Post from the Oligocene of western Australia (Irene Crespin, written communication, Nov. 22, 1956).

Amphistegina madagascariensis d'Orbigny

Amphistegina madagascariensis d'Orbigny. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260-H, p. 362, pl. 90, figs. 1, 2.

Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260-N, p. 548-551, table 1.

This Recent species characteristically has a translucent, yellowish, and almost spherical test. Specimens are present in cuttings almost throughout the entire hole but are quite rare and scattered below about 2,400 feet and are probably not in place because they do not occur in the core at 2,000 feet. Possibly *A. madagascariensis* occurs in place as low as about 1,700 feet.

Family CALCARINIDAE

The relationships of this family are not clear. In the Marshall Islands, it seems to have been a rather late arrival, sometime in the late Miocene, and reached its acme in the Recent with *Calcarina spengleri* Gmelin.

Genus CALCARINA d'Orbigny, 1826

Taking the large Recent reef-dwelling species *Calcarina spengleri* as typical of the genus *Calcarina*, the three other species placed in the genus may be considered to be transitional between *Calcarina* s. s. and a rotaliid genus such as *Streblus*. One of these other species, *Calcarina hispida* Brady, is a Recent lagoon-dwelling form and the others, *C. delicata* Todd and Post and *C. rustica* Todd and Post, are fossil but similar to *C. hispida* and are presumed to have occupied a similar type of environment.

Calcarina delicata Todd and Post

Calcarina delicata Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 563, pl. 201, figs. 5, 6.

Described from Bikini drill hole 2B, this species is characterized by a depressed umbilicus and channeled ventral side. Its top occurrences at Eniwetok are at 280 feet in hole E–1 and at 290 feet in hole F–1. At Bikini it was found from 300 to 1,150 feet.

Calcarina hispida Brady

Calcarina hispida H. B. Brady. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 363, pl. 90, figs. 9–12.
Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 548–550, table 1.

This Recent species is present in the upper parts of both drill holes. It appears to be transitional to *Pararotalia byramensis* (Cushman).

Calcarina rustica Todd and Post

Calcarina rustica Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 563, pl. 201, fig. 7.

This species is much less abundant than *Calcarina delicata* Todd and Post and is distinguished from it by being larger, wholly papillose, and without a ventral depression. It occurs in the upper parts of both drill holes.

Calcarina spengleri Gmelin

Calcarina spengleri Gmelin. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 363, pl. 82, figs. 10, 11; pl. 92, figs. 1–7.
Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 548–551, table 1.
Cole, 1954, U.S. Geol. Survey Prof. Paper 260–O, p. 584, pl. 205, figs. 1–4.

Although this abundant Recent species is present by contamination from top to bottom in both Eniwetok drill holes, there are no specimens in any of the cores, even the highest one at 170–190 feet in F–1. Therefore, we assume that *Calcarina spengleri* occurs in place no deeper than 170 feet.

Genus BACULOGYPSINA Sacco, 1893

As on Bikini, this common Recent reef-dwelling genus was not observed in any Recent sediments, but is found at shallow depths in drill hole E–1. Its presence in the subsurface but not in Recent sediments of the Marshall Islands is another example of local extinction.

Baculogypsina sphaerulata (Parker and Jones)

Baculogypsina sphaerulata (Parker and Jones). Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 563.

This species is very rare in cuttings between 230 and 580 feet from hole E–1 only, whereas it occurred fairly commonly in the Bikini cuttings. This material is abraded with the surface bosses broken out leaving small holes.

Family ELPHIDIIDAE

Because of their radial wall structure, the Elphidiidae are separated from the Nonionidae and recognized as related to the Rotaliidae.

Genus ELPHIDIUM Montfort, 1808

Elphidium advenum (Cushman)

Elphidium advenum (Cushman). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 345, pl. 86, fig. 30.
Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 548, table 1.

Specimens from the cuttings of E–1 and F–1 compare very well with those from Recent sediments of this region. *Elphidium advenum* seems most closely related to *E. striatopunctatum* (Fichtel and Moll), with which it is associated in this and in the Bikini material as indicated by restudy of the Bikini specimens identified as *E. striatopunctatum*. As a result of this restudy, the range of *Elphidium advenum* at Bikini is extended downward to 956½ feet in hole 2A and 1,219 feet in hole 2B.

The test in *Elphidium advenum* is consistently smaller than in *E. striatopunctatum*, however, with a somewhat angular periphery appearing in some specimens to be almost keeled. The chambers are similar to those in *E. striatopunctatum* but become even narrower with the retral processes tending to be more elongate, giving a striate appearance to the early part of the test.

Elphidium craticulatum (Fichtel and Moll)

Nautilus craticulatus Fichtel and Moll, 1803, Testacea Microscopica, p. 51, pl. 5, figs. h–k.

Rare but distinctive specimens occur in E–1 from 250–260 feet to 520–530 feet; one well-preserved individual was found as apparent contamination at 1,776–1,805 feet with *Elphidium marshallana* Todd and Post from which it may have evolved. It is a larger species than *E. marshallana*, being similar in having a large circular umbonal region which is distinctly pitted. It differs by having an angled periphery that is almost keeled and by its narrow, even chambers with elongate and almost flush retral processes. Its circular outline is one of its most distinctive features.

Elphidium jenseni (Cushman)

Elphidium jenseni (Cushman). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 346, pl. 86, fig. 32.

Rare small specimens of this species are widely scattered in hole E–1. It was not recorded from the Bikini drill holes. The species is distinguished by its flat test.

Elphidium marshallana Todd and Post

Elphidium marshallana Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 556, pl. 198, fig. 13.

This robust species described from 1,797½–1,807½ feet in hole 2B at Bikini is even more common in Eniwetok hole E–1. It was found from 1,541 to 3,020 feet, being most common between 1,776 and 1,955 feet. It is distinguished by its large flattened test with prominent glassy umbilical knob and short distinct retral processes.

Elphidium simplex Cushman

Elphidium simplex Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 346, pl. 86, fig. 33.

Rare occurrences of poorly preserved forms of this species are found in the cuttings of both Eniwetok holes. Although present in Recent sediments of the Marshall Islands it did not occur in the Bikini drill holes.

Elphidium mundulum Todd and Low, n. sp.

Plate 260, figure 10

Test small for the genus, compressed, periphery rounded, little if at all lobulated, umbilicus prominent, consisting of clear shell material, neither raised nor depressed; chambers distinct, about 12 constituting adult whorl, not inflated; sutures distinct, very slightly depressed, somewhat curved, retral processes not fully developed with 4 or 5 pores visible along outer part of suture in side view, inner part of each suture lacking retral processes and thus marked by a short narrow trough; wall calcareous, perforate, smooth; aperture not observed. Diameter 0.38–0.50 mm; thickness about 0.15 mm.

Holotype, USNM 626197, from drill hole E–1, from cuttings at 2,490–2,500 feet, Parry Island, Eniwetok Atoll, in the Marshall Islands.

This species differs from *Elphidium hauerinum* (d'Orbigny) from the Miocene of the Wiener Becken (Vienna basin) by having a more prominent umbilicus and by the inner ends of the sutures being free of retral processes. The present species also differs by its lack of inflation.

The species occurs in the E–1 cuttings from 2,360 feet downward and thus is restricted to the section presumed to be Oligocene. It is the oldest species of the genus in the Eniwetok material and may have an evolutionary relationship to *E. marshallana* Todd and Post.

Elphidium striatopunctatum (Fichtel and Moll)

Nautilus striatopunctatus Fichtel and Moll, 1803, Testacea Microscopica, p. 61, pl. 9, figs. a–c.
Elphidium striatopunctatum (Fichtel and Moll). Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 557.

A restudy of the forms referred to this species in the Bikini drill holes indicates some of them belong in *Elphidium advenum* (Cushman) as indicated in the foregoing discussion of that species in this paper. The elongate retral processes of *E. striatopunctatum* give the early part of the test a striate appearance, but the test itself is more robust than that of *E. advenum* and has a more rounded periphery. The chambers are less narrow than those of *E. advenum*, and the small umbilical knob may be almost indiscernible.

It occurs in the cuttings of both E–1 and F–1, between 290 and 620 feet in E–1 and 450 and 1,220 feet in F–1.

Family CASSIDULINIDAE

Only very rare specimens belonging in this family are found in the Tertiary material.

Genus EPISTOMINELLA Husezima and Maruhasi, 1944

Epistominella pulchra (Cushman)

Pulvinulinella pulchra Cushman, 1933, Cushman Lab. Foram. Research Contr., v. 9, pt. 4, p. 92, pl. 9, fig. 10.
Epistominella pulchra (Cushman). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 365.

Four single occurrences of this species are recorded from the E–1 cuttings only, in the upper part of the section.

Epistominella tubulifera (Heron-Allen and Earland)

Epistominella tubulifera (Heron-Allen and Earland). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 365, pl. 90, fig. 20.
Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 548, table 1.

This species was found in Recent sediments of the Marshall Islands and in the Bikini drill holes and is here reported from cuttings near the tops of both Eniwetok drill holes.

Genus ALABAMINA Toulmin, 1941

Alabamina cf. A. wilcoxensis Toulmin

Plate 257, figure 1

Two specimens, one of which is figured, were found in core F–1–13–2. The comparison with *Alabamina wilcoxensis* Toulmin (1941, p. 603, pl. 81, figs. 10–14; text fig. 4) is good, but the Eniwetok material is somewhat obscure, making positive identification impossible. The range of the genus is from Paleocene to lower Oligocene.

Genus CASSIDULINA d'Orbigny, 1826

Cassidulina globosa Hantken

Plate 257, figure 3

Cassidulina globosa Hantken, 1881, K. ungar. geol. Anstalt Mitt. Jahrb., v. 4 (1875), p. 64, pl. 16, fig. 2.
Beck, 1943, Jour. Paleontology, v. 17, no. 6, p. 609, pl. 108, figs. 7, 13, 14.

Described from the Eocene of Hungary, this species is also recorded and well illustrated from beds of Eocene age in the State of Washington. It occurs only in the Eocene cores F–1–12 and F–1–14 on Eniwetok.

Family CYMBALOPORIDAE

Genus CYMBALOPORETTA Cushman, 1928

Cymbaloporetta bradyi (Cushman)

Plate 260, figure 12

Cymbaloporetta bradyi (Cushman). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 364, pl. 90, figs. 13, 14.
Kleinpell, 1954, B. P. Bishop Mus. Bull. 211, p. 68, pl. 9, fig. 3.

This species ranges mainly between the surface and 1,200 feet in both holes. The specimens in the upper part of the holes may all be from Recent or sub-Recent; however, some forms from between 2,370 and 2,930 feet, one of which is figured, are definitely fossil, probably Oligocene or Eocene in age. At Lau, Fiji, it is recorded from the Ndalithoni formation of Tuvutha, regarded as Tertiary *g* in age.

Cymbaloporetta squammosa (d'Orbigny)

Cymbaloporetta squammosa (d'Orbigny). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 364, pl. 90, figs. 15, 16.

This high-spired species, having coarser pores and with fewer chambers visible from the ventral side, also occurs in both the Eniwetok drill holes. There are generally fewer specimens of this species than of *Cymbaloporetta bradyi* (Cushman). It probably does not occur in place as deep, although specimens were found to about 1,200 feet.

Genus PYROPILUS Cushman, 1934

Pyropilus rotundatus Cushman

Pyropilus rotundatus Cushman. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 364, pl. 90, fig. 8.

Rare specimens occur in the upper levels of both holes as Recent contamination, first at 280–290 feet in E–1 and at 100–110 feet in F–1. It was reported as rare in Recent lagoon samples in the Marshall Islands.

Genus HALKYARDIA Heron-Allen and Earland, 1919

Halkyardia bikiniensis Cole

Plate 259, figure 15

Halkyardia bikiniensis Cole, 1954, U.S. Geol. Survey Prof. Paper 260–O, p. 584, pl. 210, figs. 1–5.
Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 564, pl. 200, fig. 7.

This species was described from the lowermost section of the Bikini drill holes (2,349 feet to the bottom at 2,556 feet), a section tentatively assigned to Tertiary *e*. In the Eniwetok material excellent specimens were obtained from E–1 cuttings starting at 2,280–2,290 feet and from Eocene cores F–1–9 (3,655–3,665 feet) and F–1–10 (3,962–3,988 feet). Cole's discussion (1954, p. 585) emphasizes the Eocene and Oligocene age of the genus *Halkyardia*. Its occurrence in the Eniwetok section supports the presumed Oligocene age of the 590-foot section overlying the top of the Eocene.

Family GLOBIGERINIDAE

Specimens belonging in this planktonic family, which is known to have been well developed and abundant under pelagic conditions throughout the Tertiary, are to be expected in an area surrounded by open ocean. However, study of distribution and abundance of species of this family within and around modern coral atolls (Cushman, Todd, and Post, 1954, table 5) indicates that relatively few species are found in shallow sedimentary deposits, and not commonly there, whereas the outer slopes and guyots are the only places where globigerinids are found to constitute a significant proportion of the Foraminifera fauna.

In the cuttings from the upper parts of both drill holes, globigerinids are very rarely found and are mostly of the kinds that occur in shallower sediments of the Marshall Islands. In the Eocene cores from hole F–1 globigerinids are extremely abundant; in two of the cores they comprise *Globigerina* limestones. From this difference in abundance it is inferred that hole F–1, in its lower part, passed through an interval of beds that were deposited in deeper water than the beds penetrated by hole E–1.

Genus GLOBIGERINA d'Orbigny, 1826

Globigerina bulloides d'Orbigny

Globigerina bulloides d'Orbigny. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 368, pl. 91, fig. 2.

Although less common than the species *Globigerinoides rubra* (d'Orbigny), *G. sacculifera* (Brady), and *G. conglobata* (Brady), this species is found near the top of holes E–1 and F–1. In E–1 it ranges from 450 to 2,490 feet, being very scattered below 1,240 feet.

Globigerina dissimilis Cushman and Bermudez

Plate 259, figure 5

Globigerina dissimilis Cushman and Bermudez, 1937, Cushman Lab. Foram. Research Contr., v. 13, p. 25, pl. 3, figs. 4–6.

This species was described from beds of Eocene age in Cuba. It is distinguished by a small smooth final chamber covering the umbilicus. In the present material it is found only in the Eocene cores, being rare in F–1–7 (3,052–3,055 ft), F–1–10 (3,963–3,988 ft), and F–1–13 (4,406–4,431 ft), and common to abundant in F–1–9 (3,655–3,665 ft) and F–1–12 (4,316–4,361 ft).

Globigerina eggeri Rhumbler

Globigerina eggeri Rhumbler. Phleger, Parker, and Peirson, 1953, Swedish Deep Sea Exped. Repts., v. 7, Sediment cores, no. 1, p. 12, pl. 1, figs. 11, 12.

Globigerina subcretacea Lomnicki. Cushman, Todd, and Post [not Lomnicki], 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 368, pl. 91, fig. 1.

Rare specimens of this Recent species are found in hole E–1 only, between 180 and 1,050 feet, very scattered above 520 feet and below 770 feet. These fossil specimens are not typical.

Globigerina eocaena Gümbel

Plate 259, figure 1

Globigerina eocaena Gümbel, 1870, K. bayer. Akad. Wiss., Math.-phys. Abt., Abh., Kl. 2, v. 10, p. 662, pl. 2, fig. 109.

Cole, 1928, Am. Paleontology Bull., v. 14, no. 53, p. 217 (17), pl. 1, fig. 20.

Hamilton, 1953, Jour. Paleontology, v. 27, no. 2, p. 222, pl. 31, fig. 25.

Beckmann, 1954, Eclogae Geol. Helvetiae, v. 56, no. 2, p. 392, pl. 25, fig. 11 [1953].

Hagn, 1954, Neues Jahrb. Geol. Pal. Abh., v. 98, no. 3, p. 419 [list], pl. 26, fig. 4.

This identification of specimens from the *Globigerina* limestone from the F–1 cores seems good. The species was originally described from the "lower Eocene" of upper Bavaria and has been recorded from Eocene rocks in the Barbados, Mexico, and Hess Guyot in the central Pacific. It is characterized by a rather strongly lobulated outline around the adult whorl composed of usually 4 (but sometimes only 3) chambers of nearly equal size. The test is flattened with the initial spire obscure and the inner ends of the chambers not overhanging the ventral umbilicus. The aperture is small and in the center of the umbilicus. At Eniwetok, specimens are abundant at about 3,650 feet and rare above and below (3,050 to 4,450 feet).

Globigerina eocaenica Terquem

Plate 259, figure 3

Globigerina eocaenica Terquem, 1882, Soc. géol. France Mém., ser. 3, v. 2, p. 86, pl. 9 (17), fig. 4.

Bandy, 1944, Jour. Paleontology, v. 18, no. 4, p. 376, pl. 62, fig. 5.

Bandy, 1949, Bull. Am. Paleontology, v. 32, no. 131, p. 120, pl. 23, fig. 2.

This species was described from the Eocene of the Paris Basin. Among numerous other records are two, included above, that seem by their illustrations to be typical. They are from the middle Eocene of Oregon and the upper Eocene of Alabama.

At Eniwetok, specimens occur in the cores between about 3,050 and 4,500 feet and are common or abundant in the middle part of their range (from about 3,350 to 4,000 feet).

Specimens are distinguished by their thick, compact test in which three chambers, rapidly increasing in size, constitute the final whorl. The aperture is a long, narrow offcenter slit that is overhung by the final chamber.

Globigerina mexicana Cushman

Plate 259, figures 6, 7

Globigerina mexicana Cushman, 1925, Cushman Lab. Foram. Research Contr., v. 1, p. 6, pl. 1, fig. 8.

Rare specimens of this widespread upper Eocene species were found in cores F–1–14 and F–1–15.

Globigerina jacksonensis Bandy

Plate 259, figure 4

Globigerina rotundata var. *jacksonensis* Bandy, 1949, Bull. Am. Paleontology, v. 32, no. 131, p. 121, pl. 23, fig. 6.
Hamilton, 1953, Jour. Paleontology, v. 27, no. 2, p. 223, pl. 32, fig. 15.

This species was described from the upper Eocene of Alabama and is also found in the Eocene of the mid-Pacific seamounts. It has a compact test, with thickness about equal to diameter and the sutures so little depressed that the direction of coiling is difficult to make out from the dorsal side. The aperture is small, in the center of the ventral side, under an overhanging projection of the final chamber. The four chambers of the final whorl are very nearly of equal size. It appears to have no close relationship to the Recent species *Globigerina rotundata* d'Orbigny and hence is here raised to specific rank.

At Eniwetok the form only occurs in the Eocene cores of hole F–1, rare at 3,050 feet, abundant at 3,650 feet, and rare at 3,975 feet.

Globigerina sp. A

Plate 259, figure 2

Test compact, somewhat compressed, spire low and indistinct, umbilicus small and not much depressed, periphery slightly lobulated; four chambers of nearly equal size constituting final whorl; sutures incised; nature of surface ornamentation obscured by preservation; aperture a low elongate opening extending from umbilicus to periphery under edge of final chamber. Diameter about 0.50 mm; thickness about 0.38 mm.

The species appears to be undescribed, but material is not well enough preserved to permit erection of a new species. Specimens occur only in the Eocene cores from F–1; rarely at 3,050 feet, commonly or abundantly at about 3,650 and 3,975 feet. The species is distinctive in the aperture not opening into the umbilicus and in the fact that coiling direction is obvious from the dorsal side.

Globigerina sp. B

Plate 262, figure 8

Rare specimens, similar to the one figured, occur mostly in the Miocene section. They look like an attenuated form of *Globigerina bulloides* d'Orbigny but have a surface similar to that of *Globigerinoides sacculifera* (Brady).

Genus GLOBIGERINOIDES Cushman, 1927

Globigerinoides conglobata (Brady)

Globigerinoides conglobata (H. B. Brady). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 368, pl. 91, fig. 12.

This Recent to Miocene species occurs in the cuttings of both holes near the top, first appearing in E–1 at 250–260 feet and in F–1 at 220–230 feet. It is not present in any of the cores.

Globigerinoides rubra (d'Orbigny)

Globigerinoides rubra (d'Orbigny). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 369, pl. 91, fig. 6.

Although occurring in Recent sediments of the Marshall Islands, this species is not found in the cuttings until 510–520 feet in E–1 and 640–650 feet in F–1.

Globigerinoides sacculifera (Brady)

Globigerinoides sacculifera (H. B. Brady). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 369, pl. 91, fig. 7.
Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 548–550, table 1.

This species first appears high in both holes (80–90 ft), but many of the specimens are small and difficult to distinguish from *Globigerinoides rubra* (d'Orbigny) and *G. conglobata* (Brady).

Genus ORBULINA d'Orbigny, 1839

Orbulina suturalis Bronnimann

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.
Todd, 1957, U.S. Geol. Survey Prof. Paper 280–H, p. 274 [table], pl. 74, fig. 11.

One poorly preserved specimen at 1541–1569 feet in E–1 seems referable to this species, which is a worldwide marker for lower Miocene and upper Oligocene rocks. As it occurs well below the section in E–1 where other globigerinids are found, its occurrence in place is doubtful.

Orbulina universa d'Orbigny

Orbulina universa d'Orbigny. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 369.

This Recent to Miocene species is present as 2 single occurrences at about 540 feet at the top of the globigerinid-bearing section in E–1.

Genus PULLENIATINA Cushman, 1927

Pulleniatina obliquiloculata (Parker and Jones)

Pulleniatina obliquiloculata (Parker and Jones). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 369, pl. 91, fig. 11.

Two single specimens in hole E–1 (540–550 ft and 1,260–1,270 ft) seem to be fossil forms of this Recent to Miocene species recorded from the deeper water samples of Bikini and Eniwetok. It was not found in the Bikini drill holes.

Family HANTKENINIDAE

Genus HANTKENINA Cushman, 1924

Hantkenina alabamensis Cushman

Plate 259, figure 14

Hantkenina alabamensis Cushman, 1924, U.S. Natl. Mus. Proc., v. 66, art. 30, p. 3, pl. 1, figs. 1–6; pl. 2, fig. 5.

One beautifully preserved specimen together with one in which the spines were broken off was found in core F–1–13–2 (4,406–4,431 ft). Comparison with the types is quite striking though early chambers on the Eniwetok specimens appear slightly more inflated and the later chambers are slightly thicker.

Thalmann (1942, table 1) reports *Hantkenina alabamensis* as ranging in the Bartonian and questionably in the Lutetian. It is widely reported around the world in the equatorial region (Thalmann, 1942, p. 819).

Family GLOBOROTALIIDAE

Genus GLOBOROTALIA Cushman, 1927

Globorotalia brödermanni Cushman and Bermudez

Plate 259, figure 8

Globorotalia brödermanni Cushman and Bermundez, 1949, Cushman Lab. Foram. Research Contr., v. 25, p. 40, pl. 7, figs. 22–24.

A small spiny *Globorotalia*, with six chambers in the final whorl and an open ventral umbilicus, accompanies *G. centralis* in the lower part of its range; that is, in cores F–1–14 and F–1–15. Specimens are 0.25–0.50 mm in diameter and seem identical with types of *G. brödermanni* described from the lower Eocene of Cuba. Similar specimens have been recorded from the upper Ypresian to lower Lutetian in Spain (Colom, 1954, p. 156, pl. 5, figs. 19–29).

Globorotalia centralis Cushman and Bermudez

Plate 259, figures 9–12

Globorotalia centralis Cushman and Bermudez, 1937, Cushman Lab. Foram. Research Contr., v. 13, p. 26, pl. 2, figs. 62–65.

Todd, 1957, U.S. Geol. Survey Prof. Paper 280–H, p. 268 [table], pl. 71, figs. 1, 3.

This widespread species was described from the Eocene of Cuba and is especially well known in the Caribbean region. It was recorded from the Hagman and Densinyama formations, both of Eocene age, on Saipan, Mariana Islands. On Eniwetok it occurs only in the Eocene cores: rarely in F–1–11, F–1–12, and F–1–15; abundantly in F–1–13 and F–1–14.

Globorotalia crassata var. densa (Cushman)

Plate 259, figure 13

Globorotalia crassata (Cushman) var. *densa* (Cushman). Cushman, 1939, Cushman Lab. Foram. Research Contr., v. 15, p. 74, pl. 12, fig. 20.

This widespread Eocene form is present, though very rare, in core F–1–14. This variety is usually but not always associated with the typical form.

Globorotalia menardii (d'Orbigny)

Globorotalia menardii (d'Orbigny). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 370, pl. 91, fig. 19.

This Recent to Miocene species occurs rarely between 110 and 560 feet in drill hole E–1. It was found in some abundance in deeper water samples off the Marshall Islands (Cushman, Todd, and Post, 1954, p. 321, 322), but no specimens were observed in the Bikini drill hole material.

Genus CYCLOLOCULINA Heron-Allen and Earland, 1908

Cycloloculina sp. A

Plate 257, figure 5

Cycloloculina sp., Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 564, pl. 200, fig. 6.

We have two single occurrences of an indeterminate species in core F–1–15 (4,528–4,553 ft) and E–1 cuttings at 2,870–2,880 feet, both from the Eocene. The specimens are of about the same size though the one from the core has a very small initial stage while the one from the E–1 cuttings has a large initial stage with no wholly annular chambers. In the Miocene part of the Bikini section (1,891½–1,902 ft) were three specimens of *Cycloloculina* probably belonging to the same species as the Eocene specimens from Eniwetok.

The genera *Cycloloculina* and *Sherbornina* are alike except that *Sherbornina* has an external layer of small overlapping spatulate chamberlets, which gives it a spongy appearance. *Sherbornina*, an Eocene genus, seems to be restricted to Tasmania and Australia. *Cycloloculina*, a Paleocene to Miocene genus, has thus far been recorded from England, France, Pakistan, and the Caribbean.

Family ANOMALINIDAE

Genus ANOMALINA d'Orbigny, 1826

Anomalina corrugata Cushman and Bermudez

Plate 257, figures 10, 11

Anomalina corrugata Cushman and Bermudez, 1937, Cushman Lab. Foram. Research Contr., v. 13, p. 27, pl. 2, figs. 57–59.

Specimens from cores F–1–13, F–1–14, and F–1–15 seem identical with this species described from the

Eocene of Cuba. The original illustrations are unrealistic, but examination of types shows a close comparison. Their planoconvex shape is indicative of their probably having been attached.

Genus **ORNATANOMALINA** Haque, 1956

Ornatanomalina crystallina Todd and Low, n. sp.

Plate 257, figures 7–9

Test complanate, rapidly expanding, inequilateral, biumbilicate, periphery subrounded to subangular, appearing slightly crenulate in some specimens; chambers indistinct, compressed in early part, enlarging gradually as added, about 13 in adult whorl; sutures indistinct, not depressed, radial in early part, slightly curved between last few chambers; wall calcareous, perforate, granular, ornamented by fine interrupted costae giving a granular or crystalline appearance to the surface, and by small papillae occupying the depressed umbilicus on both sides of the test; aperture an elongate loop-shaped opening at base of last-formed chamber, tangential to the peripheral plane. Greater diameter 0.80–1.30 mm, thickness about 0.30 mm.

Holotype, USNM 626209, from the Eocene, drill hole E–1, from cuttings at 2,990–3,000 feet, Parry Island, Eniwetok Atoll, in the Marshall Islands.

Our specimens are restricted to the lowest part of the E–1 cuttings, with the first occurrence noted at 2,920–2,930 feet, becoming most common between 2,940 and 2,960 feet. It occurs also in cores F–1–13 and F–1–14, being more common in the former.

This species appears to belong in the genus *Ornatanomalina* Haque, described from beds of Paleocene to early Eocene age in Pakistan, both by description (Haque, 1956, p. 196–197) and by examination of specimens of *O. hafeezi* Haque (Haque p. 200, pl. 18, fig. 6) which are deposited in the U.S. National Museum collection. Apertural differences exclude the genus *Thalmannita* Bermudez (1952, p. 76), in which the aperture extends into the ventral region rather than remaining at the base of the last-formed chamber. There is a close resemblance to *Rotalia? palmerae* Cushman and Bermudez (1947, p. 26, pl. 6, figs. 5–7) from the middle Eocene of Cuba, which we would also consider as belonging to the genus *Ornatanomalina* rather than to *Thalmannita* as indicated by Bermudez (1952, p. 76). This, too, is distinct in its compressed early part and expanded and angled later chambers and aperture which appears more like that of *Ornatanomalina* than that of *Thalmannita* in the material observed. Another species which may prove to be a Recent representative of this genus was noted in the course of our study: *Polystomella milletti* Heron-Allen and Earland (1915, p. 735, pl. 53, figs. 38–42) from Recent sediments of the Kerimba Archipelago.

Genus **PLANULINA** d'Orbigny, 1826

Planulina cf. P. marialana Hadley

Plate 258, figure 3

Specimens from cores F–1–12 and F–1–14 resemble closely the species *Planulina marialana* Hadley (1934, p. 27, pl. 4, figs. 4–6) described from the Oligocene of Cuba. However, the Eniwetok forms have narrower chambers resulting in about 15 chambers per whorl. Examination of the type specimens proves them to be more evolute than the type figure indicates.

Planulina sp. A

Plate 258, figures 1, 2

Three specimens from cores F–1–14 and F–1–15 and one from E–1 cuttings at 3,080–3,090 feet are distinguished by having raised irregular reticulate ornamentation over the central part, such as is present on *Planulina jabacoensis* Bermudez from the Eocene of Cuba. But the present specimens have more numerous chambers, about 10 or more, per whorl.

Genus **ANOMALINELLA** Cushman, 1927

Anomalinella rostrata (Brady)

Anomalinella rostrata (H. B. Brady). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 371, pl. 91, fig. 24.
Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 564.
Kleinpell, 1954 B. P. Bishop Mus. Bull. 211, p. 74, pl. 10, fig. 5.

This widespread Recent species appears rarely in hole F–1 from the top to 1,240 feet with many extended breaks. In hole E–1 it first occurs at 360–370 feet becoming most common from 510 to 650 feet and persisting rarely to about 1,400 feet. In the Bikini holes this species was much more abundant than it is at Eniwetok. It was found in the Tertiary *g* section at Lau, Fiji.

Genus **CIBICIDES** Montfort, 1808

Cibicides aknerianus (d'Orbigny)

Plate 258, figure 5

Rotalina akneriana d'Orbigny, 1846, Foraminifères fossiles du bassin tertiaire de Vienne, p. 156, pl. 8, figs. 13–15.

Specimens from the Eocene cuttings from hole E–1 (below 2,990 ft.) and the Eocene cores F–1–7, F–1–14, and F–1–15 are referred to this species described from the Miocene of the Wiener Becken (Vienna basin).

The present specimens are characterized by a faint iridescence, especially visible when moistened.

Cibicides cf. C. dutemplei (d'Orbigny)

Plate 258, figure 10

Rare specimens from cores F–1–11, F–1–12, and F–1–14 bear a close resemblance to this species originally described as *Rotalina dutemplei* (d'Orbigny, 1846, p. 157, pl. 8, figs. 19–21) from the Miocene of the Vienna Basin. The material is inadequate for a positive identification.

Cibicides lobatulus (Walker and Jacob)

Cibicides lobatulus (Walker and Jacob). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 371, pl. 91, figs. 27, 28.

This almost universal species shows a rather interesting distribution pattern in the Eniwetok holes. In E–1 it is very scarce down to about 520 feet, and specimens are small and poorly developed. At 1,030 feet a large well-developed form appears and continues downward to about 1,300 feet where it begins to fall off within a short distance, although scattered specimens are found to the bottom of the hole. Most of the specimens in the lower section of the hole may not be in place as only two specimens were observed in the Eocene core.

In hole F–1 the species is also rare, and most of the specimens are small. The zone of large specimens present between 1,030 and 1,300 feet in hole E–1 was not recognized in hole F–1; in 2 samples (950–960 ft and 1140–1160 ft) in F–1, rare specimens of the large form were observed. In Recent sediments of this area this species is most common and best developed in the outer slope and guyot samples around Bikini (Cushman, Todd, and Post, 1954, p. 371, table 5). It may be supposed that the zone of its abundance and large size in hole E–1 indicates deposition under outer slope conditions and relatively deeper water than elsewhere in the hole.

Cibicides macrocephalus (Gümbel)

Plate 258, figure 4

Rotalia macrocephala Gümbel, 1870, K. bayer. Akad. Wiss., Math.-phys. Abt., Abh., Kl. 2, v. 10, p. 652, pl. 2, fig. 91.

Our material was compared with topotypes from the Eocene of Bavaria. The specimens are of fairly good size (>1 mm) and appear to have been attached by the flat ventral side. They occur in the cuttings of hole E–1, starting at 2,930 feet, and in cores F–1–13 and F–1–15, being more abundant in the former.

Cibicides mayori (Cushman)

Cibicides mayori (Cushman). Cushman, Todd, and Post, 1954, U. S. Geol. Survey Prof. Paper 260–H, p. 371, pl. 91, figs. 29, 30.

This Recent species occurs and is probably in place in the Miocene section. It was found only rarely in the upper part of hole E–1.

Cibicides refulgens Montfort

Plate 262, figure 14

Cibicides refulgens Montfort, 1808, Conchyliologie systematique, v. 1, p. 123, 31st genre.
Cushman, 1931, U.S. Natl. Mus. Bull. 104, pt. 8, p. 116, pl. 21, fig. 2.

Small conical forms in the upper part of the section in both holes seem referable to this widely distributed species. It occurs down to about 1,200 feet with scattered records below; it is never abundant. About seven chambers are visible on the flat dorsal side. The conical ventral side sometimes shows a pearly luster as is also observed in *Cibicides aknerianus*.

Genus CIBICIDINA Bandy, 1949

Cibicidina mississippiensis (Cushman)

Plate 258, figure 8

Anomalina mississippiensis Cushman, 1922, U.S. Geol. Survey Prof. Paper 129–E, p. 98, pl. 21, figs. 6–8.

Nearly all records of this species in our material are single specimens from the presumed Oligocene and Eocene sections of the E–1 cuttings and the Eocene F–1 cores. There was one occurrence noted in the Miocene cuttings of E–1. The species was described from the Byram formation of Oligocene age, Mississippi.

Genus NEOGYROIDINA Bermudez, 1949

Neogyroidina? cf. N. elongata (Cushman and Bermudez)

Plate 258, figure 7

High, conical, planoconvex specimens with closed umbilicus, found in cores F–1–14 and F–1–15, appear related to material originally described as *Gyroidina elongata* Cushman and Bermudez (1937, p. 22, pl. 2, figs. 36–38) from the Eocene of Cuba, although ours are smaller than the types. A study of the type species of *Neogyroidina* (*Gyroidina protea* Cushman and Bermudez) indicates the genus may be a synonym of *Cibicides*; hence, the species *elongata* may also belong in *Cibicides*.

Genus CIBICIDELLA Cushman, 1927

Cibicidella variabilis (d'Orbigny)

Cibicidella variabilis (d'Orbigny). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 372, pl. 82, fig. 13.

Most of the Eniwetok specimens referred to this species are forms in the initial stage, casting some doubt on their identity. The occurrences are scattered throughout the holes and very rare.

Family PLANORBULINIDAE

Most of the specimens belonging in this family are attached, at least during part of their development. The family seems less well developed in the Tertiary than in the Recent of this area.

Genus PLANORBULINA d'Orbigny, 1826

Planorbulina acervalis Brady

Planorbulina acervalis H. B. Brady. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 372, pl. 82, fig. 14; pl. 91, figs. 34–36.

This species is present toward the tops of both holes and in the Eocene cores.

Planorbulina mediterranensis d'Orbigny

Planorbulina mediterranensis d'Orbigny, 1826, Annales sci. nat., v. 7, p. 280, pl. 5, figs. 4–6; Modèles no. 79.

Specimens attributed to this species are much more regularly developed than *Planorbulina acervalis* Brady, although the two species seem to grade into one another. Hence the separation here is an arbitrary one. It is less abundant than *P. acervalis* and mostly confined to the upper parts of hole E–1.

Genus PLANORBULINELLA Cushman, 1927

Planorbulinella larvata (Parker and Jones)

Plate 258, figure 6; plate 263, figure 5

Planorbulina larvata Parker and Jones, 1865, Philos. Trans., p. 380, pl. 19, fig. 3.
Planorbulinella larvata Kleinpell, 1954, B. P. Bishop Mus. 211, p. 76, pl. 9, fig. 12.
Planorbulinella zelandica Finlay, 1947, New Zealand Sci. and Tech. Jour., v. 28, no. 5 (sec. B), p. 290, pl. 8, figs. 119–124.

This species occurs abundantly in the upper part of hole E–1, from 280 feet down to about 600 feet. Below this level specimens are rarer and smaller; yet what appears to be the same species is found even in the Eocene cores from hole F–1.

On Lau, Fiji, this species occurs in Tertiary *g* (Ndalithoni formation) and also in Tertiary *f* (lower member of Futuna limestone). A species decribed as new from the "Aquitanian" of New Zealand appears to be the same.

Genus PLANORBULINOIDES Cushman, 1928

Planorbulinoides retinaculata (Parker and Jones)

Plate 262, figure 5; plate 263, figure 10

Planorbulina retinaculata Parker and Jones, 1865, Philos. Trans., p. 380, pl. 19, fig. 2.
Acervulina inhaerens Cushman [not Schultze], 1941, Smithsonian Misc. Colln., v. 99, no. 9, p. 13, pl. 2, fig. 10.
Carpenteria proteiformis Todd [not Goës], 1957, U.S. Geol. Survey Prof. Paper 280–H, p. 292 [table], pl. 93, fig. 18.

This encrusting species occurs in both holes, in E–1 from about 600 to 1,100 feet, and scattered below, and in F–1, scattered from 270 to 1,170 feet. It may be more abundant than the cuttings indicate because the specimens are large when unbroken. Although described as a Recent species, it was not found in Recent sediments of the Marshall Islands nor does it occur up to the surface in the Eniwetok holes.

Genus ACERVULINA Schultze, 1854

Acervulina inhaerens Schultze

Acervulina inhaerens Schultze. Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 372, pl. 91, figs. 37, 38.

There are relatively few specimens in the drill-hole material, the only good ones being toward the surface. Lower in the section they are hard to separate from *Gypsina plana* (Carter) and *Planorbulina acervalis* Brady. The species does not occur in the Eocene section.

Genus GYPSINA Carter, 1877

Gypsina globula (Reuss)

Plate 258, figure 9

Gypsina globula (Reuss). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 373, pl. 91, fig. 30.

This species apparently ranges from Eocene to Recent and is found in the present material throughout the cuttings and in the F–1 cores. Even in the Eocene cores the specimens are large and well preserved, and the surface is bubbly, and the cellules are larger than in the corroded specimens from the cuttings.

Gypsina plana (Carter)

Gypsina plana (Carter). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 373, pl. 93, fig. 1.

This species is probably much more abundant and widespread than our records indicate. Only a few planar fragments of large encrustations have been mounted, mostly from the upper parts of both holes.

Gypsina vesicularis (Parker and Jones)

Gypsina vesicularis (Parker and Jones). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 373, pl. 82, fig. 12.

Much less abundant than *Gypsina globula* (Reuss), this species seems to be confined to the Recent, Pleistocene, and possibly Pliocene levels at Eniwetok, and the lowest occurrence is at 780 feet in hole E–1. *G. vesicularis* is much coarser textured, in size of the cellules, than *G. globula* and is usually hemispherical in shape, owing to attachment.

Family RUPERTIIDAE

Genus CARPENTERIA Gray, 1858

Carpenteria monticularis Carter

Carpenteria monticularis Carter. Brady, 1884, *Challenger* Rept., Zoology, v. 9, p. 677, pl. 99, figs. 1–5.

A single fresh, probably Recent, specimen was found at 180–190 feet in hole F–1. It is widely reported from warm shallow waters and has also been recorded from Eocene rocks of the Coastal Plain.

Carpenteria proteiforms Goës

Plate 263, figure 9

Carpenteria proteiformis Goës. Brady, 1884, *Challenger* Rept., Zoology, v. 9, p. 679, pl. 97, figs. 8–14.
Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N. p. 548, table 1.

This species was described from the Caribbean Sea, but is also known to be widespread, both living and fossil, ranging from at least the Eocene. It was found only in core F–1–9–3 at Eniwetok. At Bikini it was recorded from the shallow drill holes 1 and 3.

Family HOMOTREMIDAE

Genus HOMOTREMA Hickson, 1911

Homotrema rubrum (Lamarck)

Homotrema rubrum (Lamarck). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 373, pl. 82, fig. 17; pl. 92, fig. 8; pl. 93, fig. 2.
Todd and Post, 1954, U.S. Geol. Survey Prof. Paper 260–N, p. 548–551, table 1.
Miniacina miniacea (Pallas). Cushman, Todd, and Post, 1954, U.S. Geol. Survey Prof. Paper 260–H, p. 374, pl. 82, fig. 16.

Red, pink, and white specimens of this encrusting form were found commonly in the tops of both holes with rare fragments contaminating to as deep as 2,500 feet in E–1 and to 1,230 feet in F–1. The more slender branching tests previously attributed to *Miniacina miniacea* (Pallas), have been interpreted (Emiliani, 1951) as one of the many variable forms of *Homotrema rubrum* and are included here as such.

As indicated in the foregoing synonymy, the species was recorded from Recent sediments of the Marshall Islands and the Bikini shallow drill holes 1 and 3.

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[Italic numbers indicate descriptions]

PLATES 255–264

PLATE 255

FIGURE 1. *Textularia subhauerii* Cushman (p. 818).
USNM 626210, × 40; Hole E–1, 3,000–3,010 feet; *a*, front view; *b*, top view.

2. *Gaudryina (Siphogaudryina) rugulosa* Cushman (p. 818).
USNM 626221, × 40; Hole F–1, core F–1–9–3; *a*, front view; *b*, top view.

3. *Valvulina intermedia* Applin and Jordan (p. 819).
USNM 626212, × 40; Hole E–1, core E–1–2–1; *a*, front view; *b*, top view.

4. *Valvulammina marshallana* Todd and Post (p. 820).
Young specimen, USNM 626203, × 40; Hole E–1, 2,570–2,580 feet; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

5. *Spiroloculina tricarinata* Terquem (p. 823).
USNM 626214, × 40; Hole E–1, core E–1–2–1.

6. *Triloculina trigonula* (Lamarck) (p. 825).
USNM 626213, × 40; Hole E–1, core E–1–2–1; *a*, side view; *b*, apertural view.

7. *Robulus* cf. *R. midwayensis* (Plummer) (p. 827).
USNM 626222, × 40; Hole F–1, core F–1–9–3; *a*, side view; *b*, peripheral view.

8. *Nonion micrum* Cole (p. 828).
USNM 626250, × 75; Hole F–1, core F–1–12–3; *a*, side view; *b*, peripheral view.

9. *Pyrgo lupheri* Rau (p. 826).
Internal cast, USNM 626215, × 40; Hole E–1, core E–1–2–1; *a*, side view; *b*, top view.

10. *Nodosaria affinis* Reuss (p. 828).
USNM 626223, × 20; Hole F–1, core F–1–9–3.

11, 12. *Dentalina cooperensis* Cushman (p. 828).
11. USNM 626251, × 40; Hole F–1, core F–1–13–2.
12. USNM 626252, × 40; Hole F–1, core F–1–13–2.

13. *Lingulina wilcoxensis* Cushman and Ponton (p. 828).
USNM 626224, × 15; Hole F–1, core F–1–9–3; *a*, front view; *b*, apertural view.

14. *Vaginulina* sp. A (p. 828).
USNM 626267, × 40; Hole F–1, core F–1–14–27.

15. *Nonion planatum* Cushman and Thomas (p. 829).
USNM 626208, × 75; Hole E–1, 2,960–2,970 feet; *a*, side view; *b*, peripheral view.

16–18. *Peneroplis dusenburyi* Henson (p. 829).
16. USNM 626216, × 40; Hole E–1, core E–1–2–1.
17. USNM 626217, × 40; Hole E–1, core E–1–2–1.
18. USNM 626218, × 40; Hole E–1, core E–1–2–1.

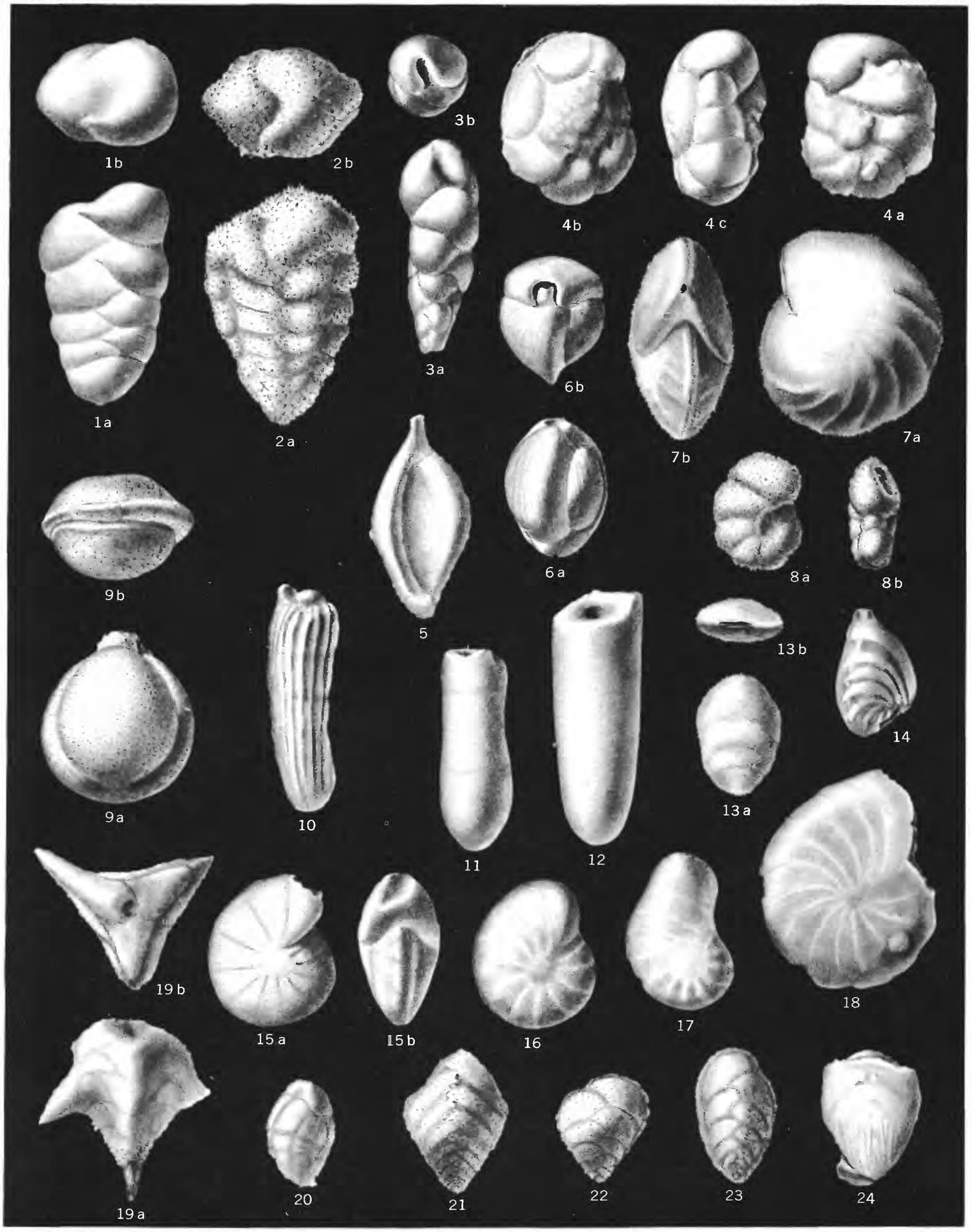
19. *Reussella araneola* Todd and Low, n. sp. (p. 834).
Holotype, USNM 626280, × 75; Hole F–1, core F–1–15–7; *a*, side view; *b*, top view.

20. *Bulimina semicostata* Nuttall (p. 831).
USNM 626268, × 40; Hole F–1, core F–1–14–27.

21, 22. *Bolivina ventricosa* Galloway and Heminway (p. 833).
21. UNSM 626276, × 75; Hole F–1, core F–1–14–28.
22. USNM 626277, × 75; Hole F–1, core F–1–14–28.

23. *Bolivina carinata* Terquem (p. 832).
USNM 626275, × 75; Hole F–1, core F–1–14–28.

24. *Plectofrondicularia* sp. A (p. 831).
USNM 626225, × 15; Hole F–1, core F–1–9–3.



UPPER EOCENE SMALLER FORAMINIFERA FROM ENIWETOK—FAMILIES TEXTULARIIDAE TO BULIMINIDAE

PLATE 256

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

FIGURE 1. *Neoconorbina* cf. *N. bulla* (Cushman) (p. 837).
USNM 626254, × 40; Hole F–1, core F–1–13–2.

2. *Neoconorbina* cf. *N. celsa* (Todd) (p. 837).
USNM 626281, × 46; Hole F–1, core F–1–15–7.

3. *Rosalina baconica* (Hantken) (p. 836).
USNM 626278, × 40; Hole F–1, core F–1–14–28.

4. *Rosalina* sp. A (p. 837).
USNM 626253, × 40; Hole F–1, core F–1–13–2.

5. *Streblus flosculus* (Todd and Post) (p. 842).
USNM 626248, × 40; Hole F–1, core F–1–11–1.

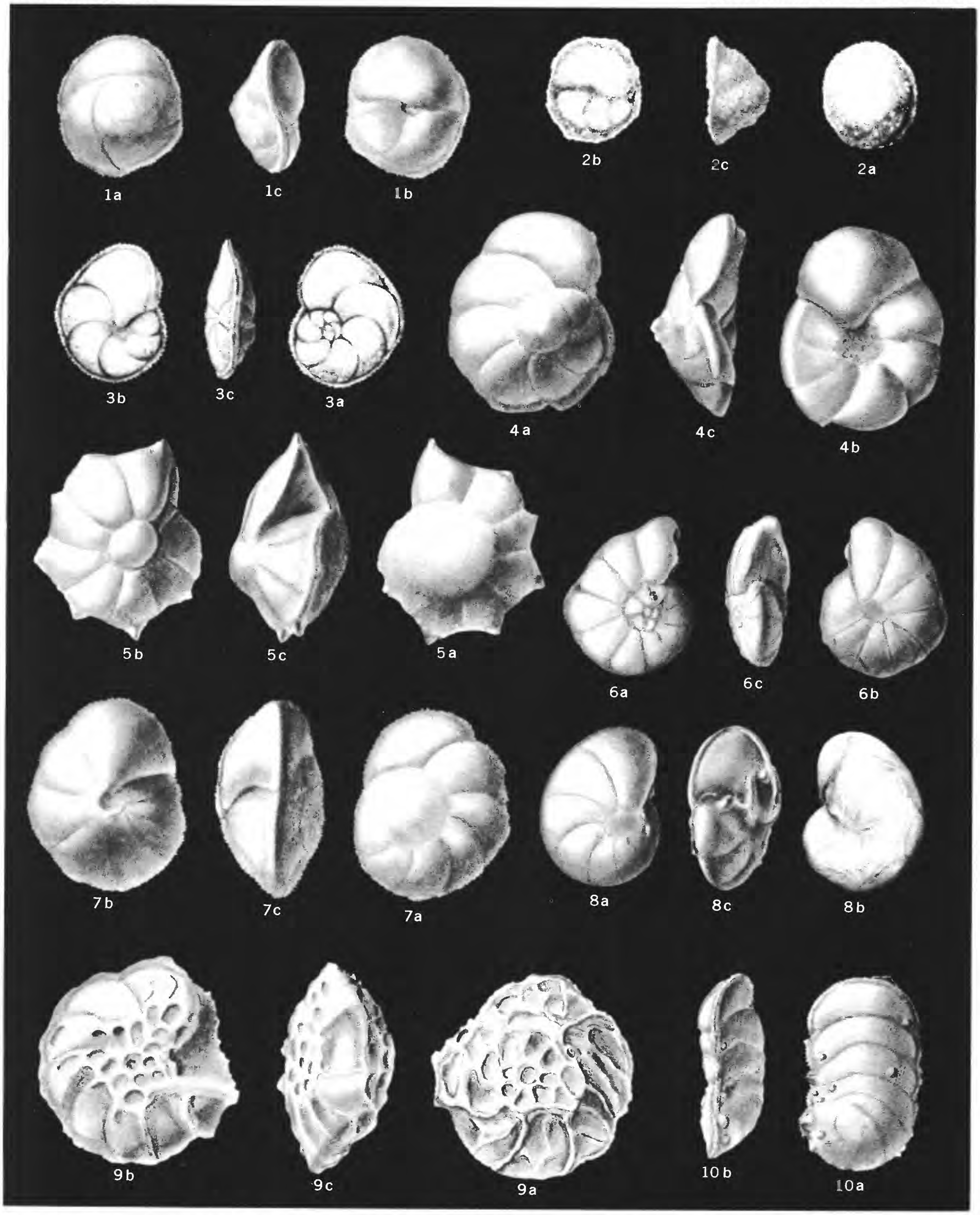
6. *Streblus* sp. A (p. 842).
USNM 626206, × 40; Hole E–1, 2,890–2,900 feet.

7. *Eponides ocalanus* Cushman (p. 838).
USNM 626219, × 40; Hole F–1, core F–1–9–2.

8. *Epistomaria semi-marginata* (d'Orbigny) (p. 840).
USNM 626205, × 40; Hole E–1, 2,880–2,890 feet.

9. *Notorotalia* sp. A (p. 841).
USNM 626264, × 75; Hole F–1, core F–1–14–1.

10. *Rectoeponides cubensis* Cushman and Bermudez (p. 839).
USNM 626282, × 40; Hole F–1, core F–1–15–7; *a*, side view; *b*, peripheral view.



UPPER EOCENE SMALLER FORAMINIFERA FROM ENIWETOK—FAMILIES DISCORBIDAE AND ROTALIIDAE

PLATE 257

FIGURE 1. *Alabamina* cf. *A. wilcoxensis* Toulmin (p. 847).
USNM 626257, × 40; Hole F–1, core F–1–13–2; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

2. *Asterigerina rotula* (Kaufmann) (p. 844).
USNM 626211, × 23; Hole E–1, 3,050–3,060 feet; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

3. *Cassidulina globosa* Hantken (p. 847).
USNM 626265, × 75; Hole F–1, core F–1–14–1; *a*, *b*, opposite sides.

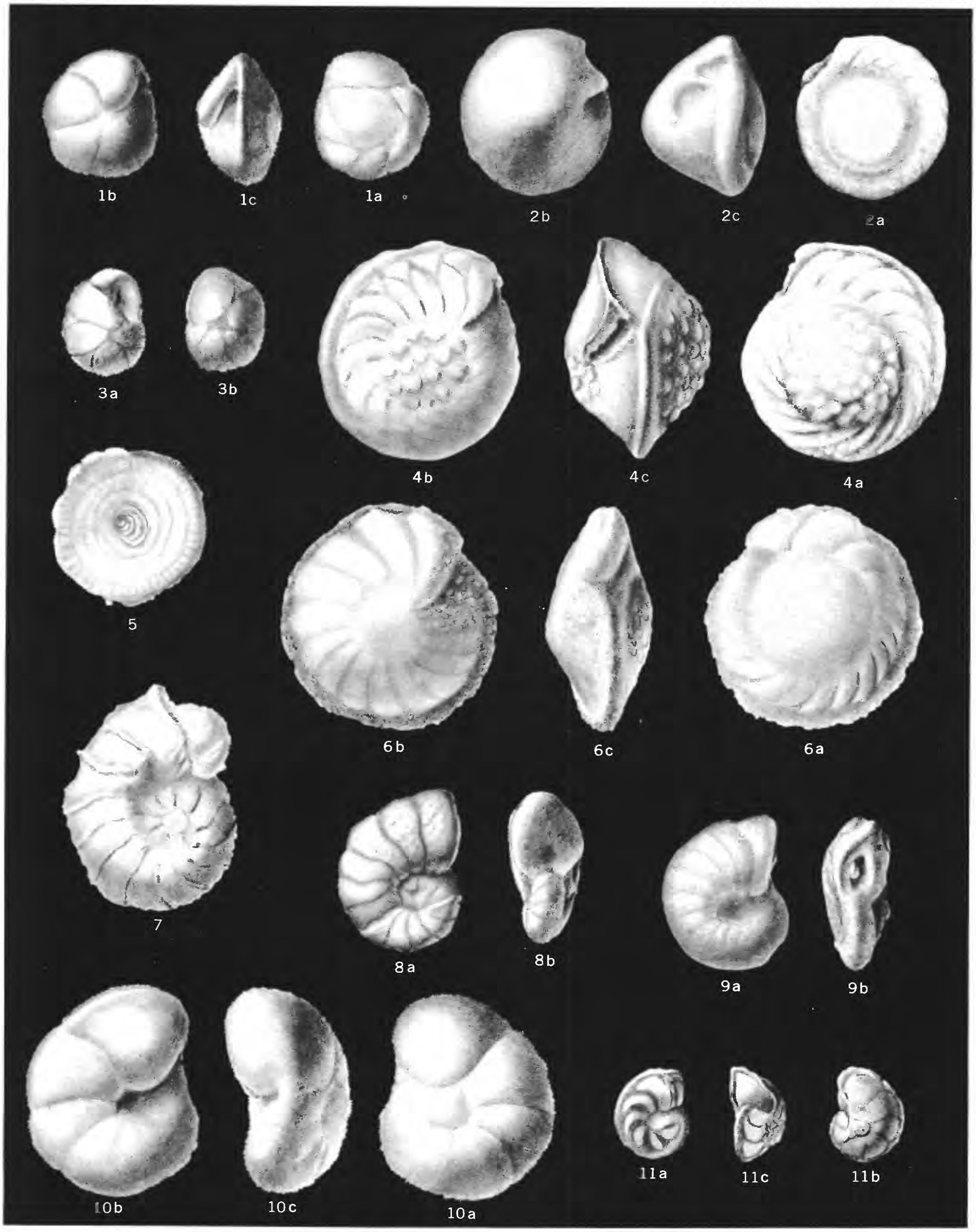
4. *Asterigerina papillata* Todd and Low, n. sp. (p. 843).
Holotype, USNM 626256, × 40; Hole F–1, core F–1–13–2; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

5. *Cycloloculina* sp. A (p. 850).
USNM 626283, × 40; Hole F–1, core F–1–15–7.

6. *Asterigerina marshallana* Todd and Post (p. 843).
USNM 626255, × 40; Hole F–1, core F–1–13–2; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

7–9. *Ornatanomalina crystallina* Todd and Low, n. sp. (p 851).
- 7. Young specimen, USNM 626207, × 75; Hole E–1, 2,950–2,960 feet.
- 8. USNM 626261, × 40; Hole F–1, core F–1–13–2; *a*, side view; *b*, peripheral view.
- 9. Holotype, USNM 626209, × 40; Hole E–1, 2,990–3,000 feet; *a*, side view; *b*, peripheral view.

10, 11. *Anomalina corrugata* Cushman and Bermudez (p. 850).
- 10. USNM 626262, × 40; Hole F–1, core F–1–13–2; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
- 11. Young specimen, USNM 626272, × 40; Hole F–1, core F–1–14–27; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.



UPPER EOCENE SMALLER FORAMINIFERA FROM ENIWETOK—FAMILIES AMPHISTEGINIDAE TO ANOMALINIDAE

PLATE 258

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

FIGURES 1, 2. *Planulina* sp. A (p. 851).
1. USNM 626274, × 40; Hole F–1, core F–1–14–27.
2. USNM 626288, × 40; Hole F–1, core F–1–15–12.

3. *Planulina* cf. *P. marialana* Hadley (p. 851).
USNM 626273, × 40; Hole F–1, core F–1–14–27.

4. *Cibicides macrocephalus* (Gümbel) (p. 852).
USNM 626263, × 40; Hole F–1, core F–1–13–2.

5. *Cibicides aknerianus* (d'Orbigny) (p. 851).
USNM 626266, × 75; Hole F–1, core F–1–14–1.

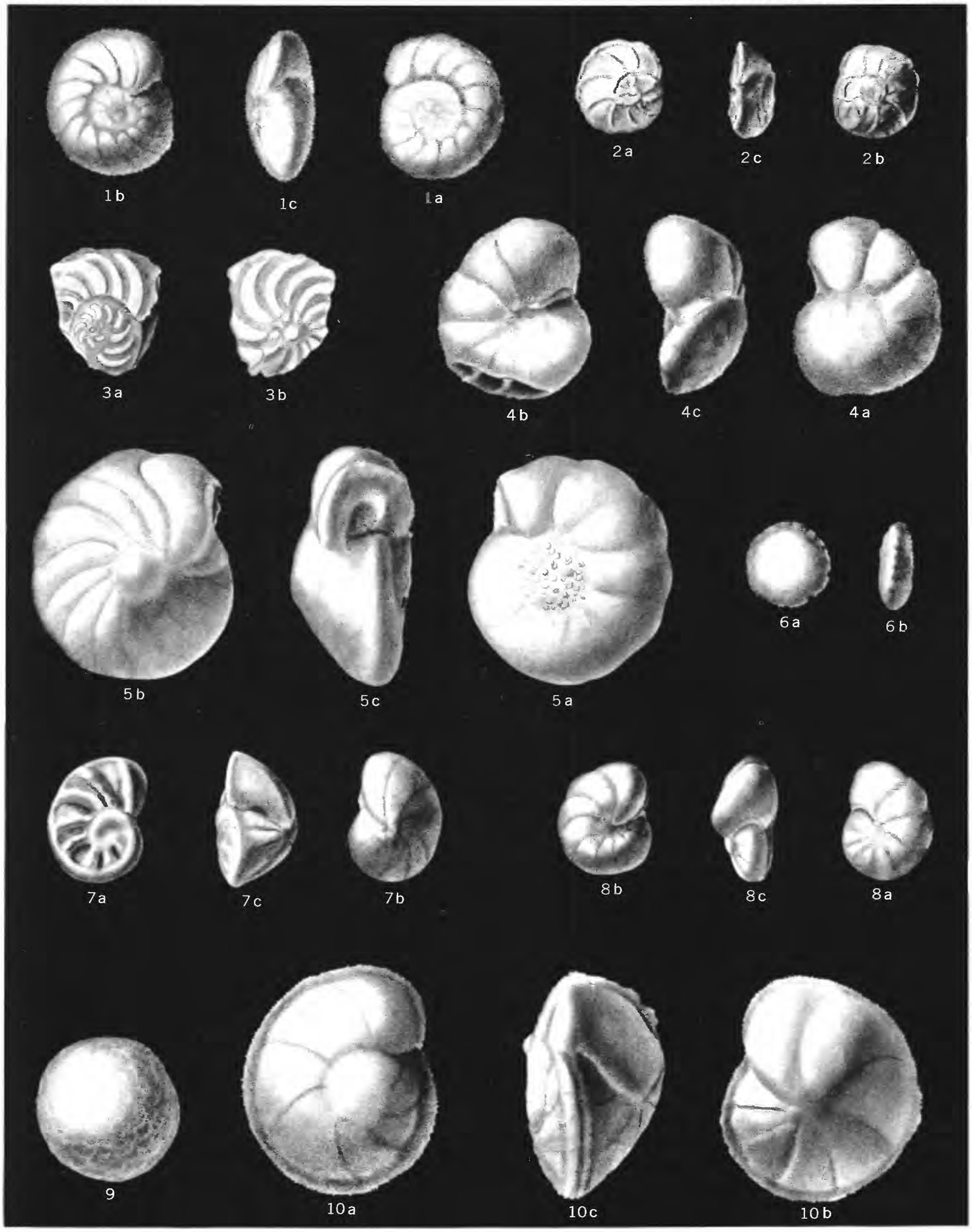
6. *Planorbulinella larvata* (Parker and Jones) (p. 853).
USNM 626246, × 15; Hole F–1, core F–1–10–8; *a*, side view; *b*, peripheral view.

7. *Neogyroidina*? cf. *N. elongata* (Cushman and Bermudez) (p. 852).
USNM 626285, × 40; Hole F–1, core F–1–15–7.

8. *Cibicidina mississippiensis* (Cushman) (p. 852).
USNM 626204, × 75; Hole E–1, 2,770–2,780 feet.

9. *Gypsina globula* (Reuss) (p. 853).
USNM 626247, × 40; Hole F–1, core F–1–10–8.

10. *Cibicides* cf. *C. dutemplei* (d'Orbigny) (p. 852).
USNM 626249, × 75; Hole F–1, core F–1–11–35.



UPPER EOCENE SMALLER FORAMINIFERA FROM ENIWETOK—FAMILIES ANOMALINIDAE AND PLANORBULINIDAE

PLATE 259

[*a*, Dorsal view; *b*, ventral view; *c*, peripheral view, except as indicated. All figures × 40]

FIGURE 1. *Globigerina eocaena* Gümbel (p. 848).
USNM 626241; core F-1-9-3.

2. *Globigerina* sp. A (p. 849).
USNM 626245; core F-1-10-8.

3. *Globigerina eocaenica* Terquem (p. 848).
USNM 626242; core F-1-9-3.

4. *Globigerina jacksonensis* Bandy (p. 849).
USNM 626243; core F-1-9-3.

5. *Globigerina dissimilis* Cushman and Bermudez (p. 848).
USNM 626258; core F-1-13-2.

6, 7. *Globigerina mexicana* Cushman (p. 848).
6. USNM 626287; core F-1-15-12; *a*, side view; *b*, basal view.
7. USNM 626279; core F-1-14-28.

8. *Globorotalia brödermanni* Cushman and Bermudez (p. 850).
USNM 626286; core F-1-15-12.

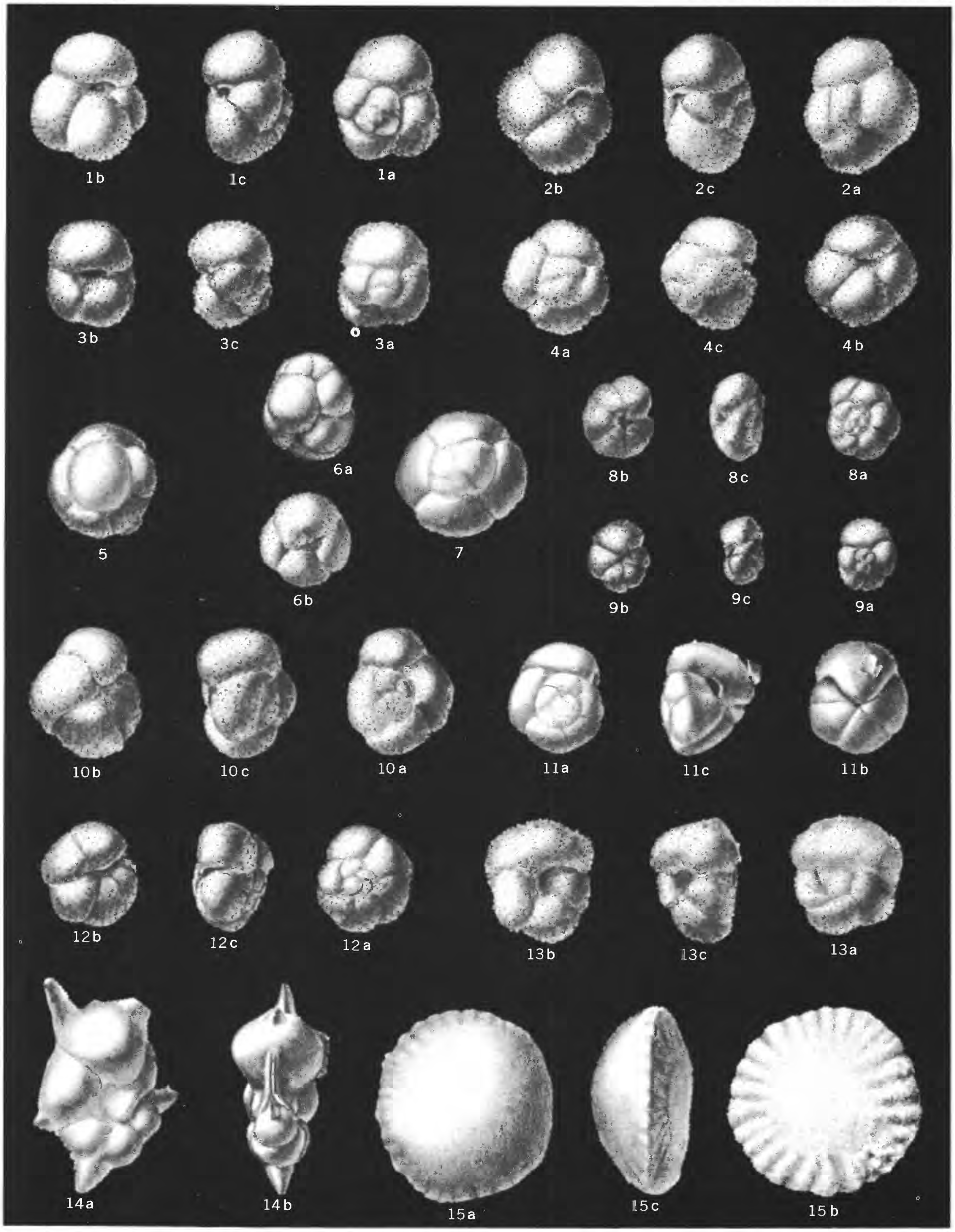
9. *Globorotalia* cf. *G. centralis* Cushman and Bermudez (p. 850).
USNM 626284; core F-1-15-7.

10-12. *Globorotalia centralis* Cushman and Bermudez (p. 850).
10. USNM 626270; core F-1-14-27.
11. USNM 626259; core F-1-13-2. Specimen showing embedded dolomite crystal.
12. USNM 626271; core F-1-14-27.

13. *Globorotalia crassata* var. *densa* (Cushman) (p. 850).
USNM 626269; core F-1-14-27.

14. *Hantkenina alabamensis* Cushman (p. 850).
USNM 626260; core F-1-13-2; *a*, side view; *b*, peripheral view.

15. *Halkyardia bikiniensis* Cole (p. 847).
USNM 626220; core F-1-9-2.



UPPER EOCENE FORAMINIFERA, MOSTLY PLANKTONIC, FROM CORES IN ENIWETOK DRILL HOLE F-1

PLATE 260

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

FIGURE 1. *Quinqueloculina leonensis* Applin and Jordan (p. 821).
USNM 626199, × 40; 2,610–2,620 feet; *a*, side view; *b*, apertural view.

2. *Quinqueloculina prisca* d'Orbigny (p. 821).
USNM 626195, × 40; 2,430–2,440 feet.

3. *Quinqueloculina byramensis* Cushman (p. 821).
USNM 626196, × 40; 2,430–2,440 feet.

4. *Spirillina vivipara* Ehrenberg (p. 836).
USNM 626200, × 75; 2,660–2,670 feet; *a*, side view; *b*, peripheral view.

5. *Rosalina assulata* (Cushman) (p. 836).
USNM 626192, × 75; 2,410–2,420 feet.

6. *Valvulineria sculpturata* Cushman (p. 839).
USNM 626194, × 75; 2,410–2,420 feet.

7. *Eponides duprêi ciervoensis* Cushman and Simonson (p. 838).
USNM 626193, × 75; 2,410–2,420 feet.

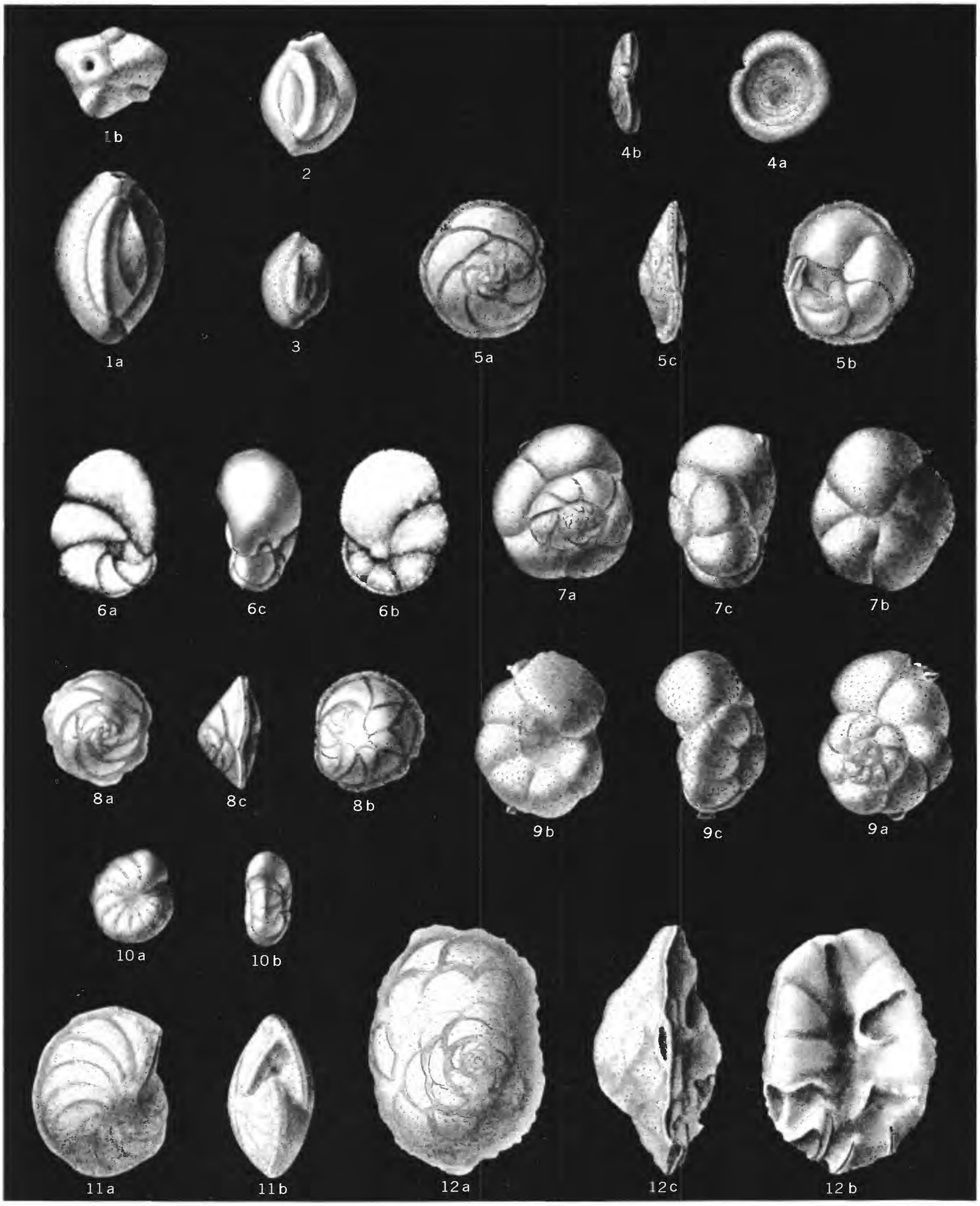
8. *Asterigerinata bracteata* (Cushman) (p. 843).
USNM 626201, × 75; 2,690–2,700 feet.

9. *Streblus*? sp. B (p. 842).
USNM 626190, × 75; 2,180–2,190 feet.

10. *Elphidium mundulum* Todd and Low, n. sp. (p. 846).
Holotype, USNM 626197, × 40; 2,490–2,500 feet; *a*, side view; *b*, peripheral view.

11. *Crespinella*? sp. A (p. 841).
USNM 626198, × 40; 2,490–2,500 feet; *a*, side view; *b*, peripheral view.

12. *Cymbaloporetta bradyi* (Cushman) (p. 847).
USNM 626202, × 75; 2,710–2,720 feet.



SMALLER FORAMINIFERA FROM THE SECTION IN ENIWETOK DRILL HOLE E-1
PRESUMED TO BE LOWER OLIGOCENE

PLATE 261

[All figures × 40, except as indicated]

FIGURES 1, 2. *Cribrogoësella parvula* Todd and Low, n. sp. (p. 820).
1. Holotype, USNM 626186; Hole E–1, 2,180–2,190 feet; *a*, side view; *b*, top view.
2. USNM 626165; Hole E–1, 1,020–1,030 feet.

3. *Valvulammina globularis* (d'Orbigny) (p. 820).
USNM 626154; Hole E–1, 690–700 feet; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

4. *Quinqueloculina agglutinans* d'Orbigny (p. 820).
USNM 626180; Hole E–1, 1,805–1,835 feet; *a*, side view; *b*, apertural view.

5. *Triloculina rotunda* d'Orbigny (p. 825).
Q USNM 626187; Hole E–1, 2,240–2,250 feet; *a*, side view; *b*, apertural view.

6. *uinqueloculina akneriana* d'Orbigny (p. 821).
USNM 626188; Hole E–1, 2,260–2,270 feet; *a*, side view; *b*, apertural view.

7. *Quinqueloculina byramensis* Cushman (p. 821).
USNM 626176; Hole E–1, 1,090–1,100 feet; *a*, side view; *b*, apertural view.

8, 9. *Quinqueloculina prisca* d'Orbigny (p. 821).
8. USNM 626181; Hole E–1, 1,805–1,835 feet; *a*, side view; *b*, apertural view.
9. USNM 626185; Hole E–1, 2,080–2,090 feet.

10. *Miliolinella labiosa* (d'Orbigny) (p. 822).
USNM 626166; Hole E–1, 1,070–1,080 feet; *a*, side view; *b*, apertural view.

11. *Hauerina aspergilla* (Karrer) (p. 824).
USNM 626158; Hole E–1, 910–920 feet.

12. *Massilina misrensis* Said (p. 822).
USNM 626167; Hole E–1, 1,080–1,090 feet; *a*, side view; *b*, apertural view.

13. *Peneroplis planatus* (Fichtel and Moll) (p. 829).
USNM 626157; Hole E–1, 800–810 feet.

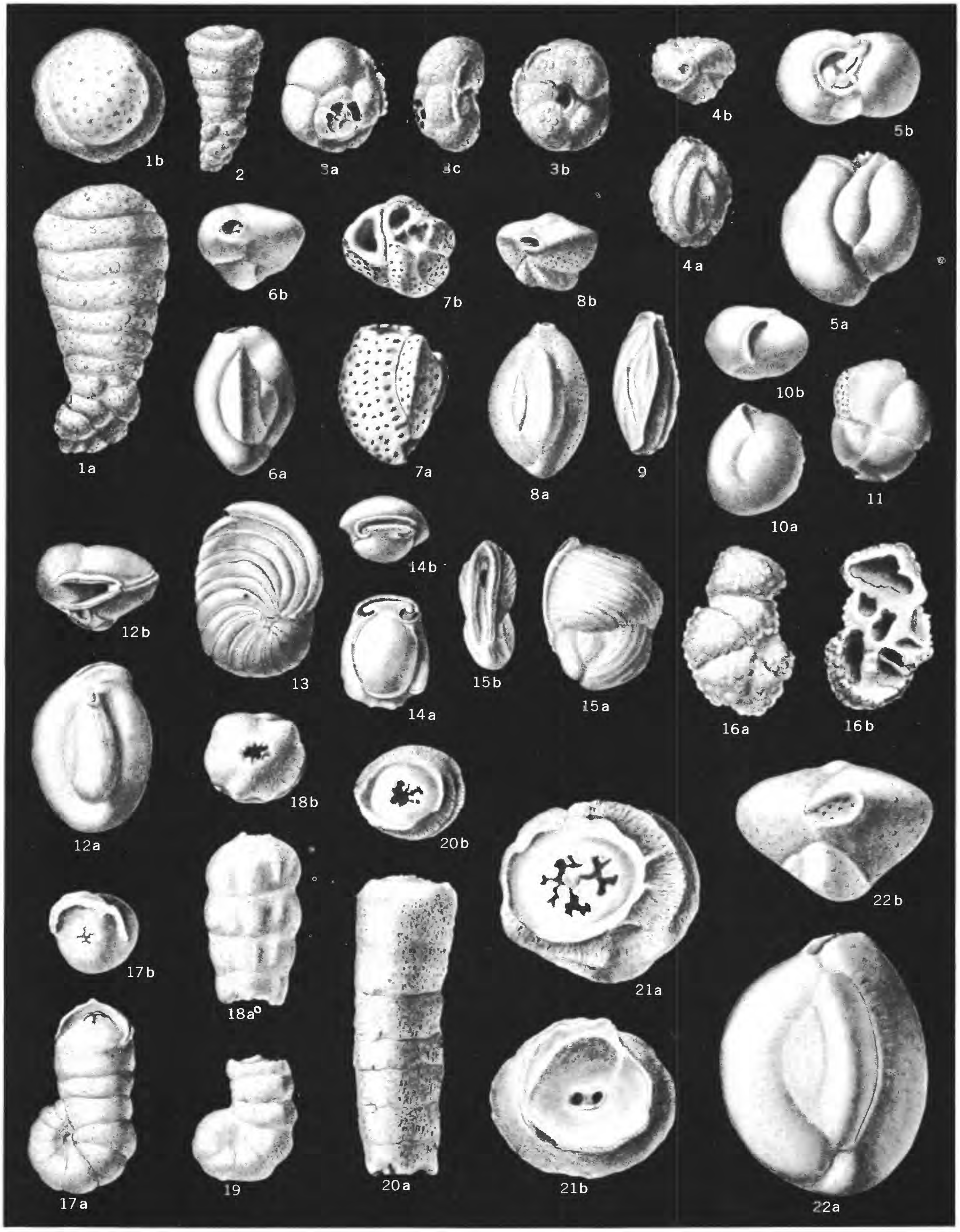
14. *Pyrgo denticulata* (Brady) (p. 826).
USNM 626147; Hole F–1, 790–800 feet; *a*, side view; *b*, apertural view.

15. *Nodobaculariella robusta* Todd and Low, n. sp. (p. 826).
Holotype, USNM 626183; Hole E–1, 2,060–2,070 feet; *a*, side view; *b*, apertural view.

16. *Haddonia torresiensis* Chapman (p. 827).
USNM 626168; Hole E–1, 1,080–1,090 feet; *a*, *b*, opposite sides; *b*, side showing former attachment.

17–21. *Spirolina*? sp. A (p. 830).
17. USNM 626161; Hole E–1, 990–1,000 feet; *a*, side view; *b*, top view.
18. USNM 626174; Hole E–1, 1,090–1,100 feet; *a*, side view; *b*, top view.
19. USNM 626175; Hole E–1, 1,090–1,100 feet.
20. USNM 626164; Hole E–1, 1,010–1,020 feet; *a*, side view; *b*, top view.
21. USNM 626162, ×75; Hole E–1, 990–1,000 feet; *a*, *b*, opposite ends.

22. *Austrotrillina striata* Todd and Post (p. 825).
USNM 626182; Hole E–1, 1,985–1,993 feet; *a*, side view; *b*, apertural view.



MIOCENE SMALLER FORAMINIFERA FROM ENIWETOK—FAMILIES VALVULINIDAE TO PENEROPLIDAE

PLATE 262

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

FIGURE 1. *Loxostomum digitale* (d'Orbigny) (p. 833).
USNM 626177, × 75; Hole E–1, 1,150–1,160 feet.

2. *Bolivinella folium* (Parker and Jones) (p. 831).
USNM 626184, × 75; Hole E–1, 2,060–2,070 feet.

3. *Bolivina* sp. A (p. 833).
USNM 626149, × 75; Hole F–1, 950–960 feet.

4. *Loxostomum*? sp. A (p. 834).
USNM 626169, × 75; Hole E–1, 1,080–1,090 feet.

5. *Planorbulinoides retinaculata* (Parker and Jones) (p. 853).
USNM 626173, × 40; Hole E–1, 1,080–1,090 feet.

6. *Neoconorbina tabernacularis* (Brady) (p. 837).
USNM 626151, × 75; Hole E–1, 30–40 feet.

7. *Discorbis balcombensis* Chapman, Parr, and Collins (p. 838).
USNM 626148, × 75; Hole F–1, 840–850 feet.

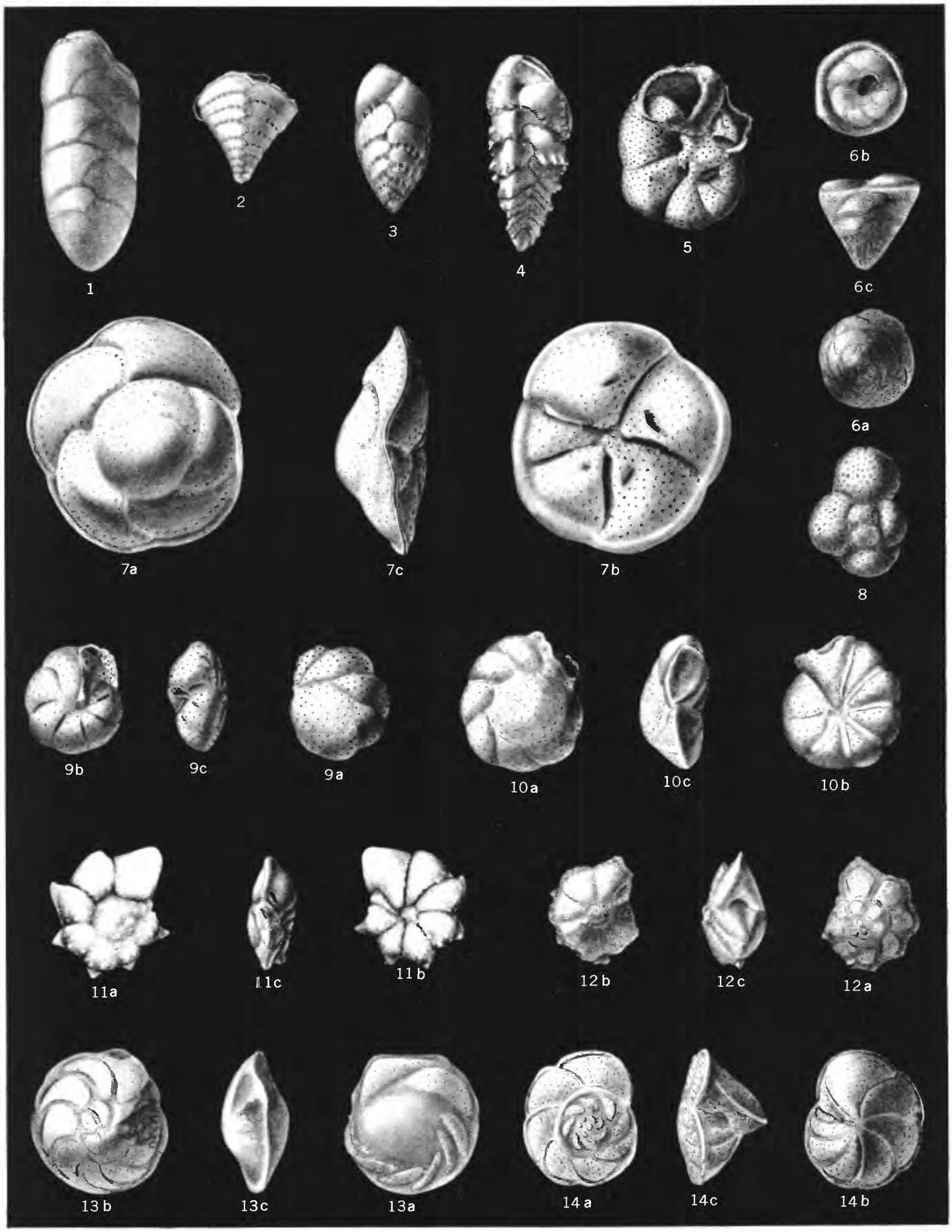
8. *Globigerina* sp. B (p. 849).
USNM 626172, × 40; Hole E–1, 1,080–1,090 feet.

9, 10. *Buccella*? *perforata* Todd and Low, n. sp. (p. 840).
9. Young specimen, USNM 626178, × 75; Hole E–1, 1,160–1,170 feet
10. Holotype, USNM 626171, × 40; Hole E–1, 1,080–1,090 feet.

11, 12. *Pararotalia byramensis* (Cushman) (p. 839).
11. USNM 626170, × 46; Hole E–1, 1,080–1,090 feet.
12. USNM 626189, × 40; Hole E–1, core E–1–1–4.

13. *Asterigerina indistincta* Todd and Post (p. 843).
USNM 626150, × 40; Hole F–1, 1,090–1,100 feet.

14. *Cibicides refulgens* Montfort (p. 852).
USNM 626152, × 75; Hole E–1, 610–620 feet



MIOCENE SMALLER FORAMINIFERA FROM ENIWETOK—FAMILIES HETEROHELICIDAE TO PLANORBULINIDAE

PLATE 263

[All figures × 20 except fig. 5]

FIGURE 1. *Gaudryina* (*Pseudogaudryina*) cf. *G.* (*P.*) *atlantica* (Bailey) (p. 819).
USNM 626179; Hole E–1, 1,688–1,715 feet, Miocene; *a*, front view; *b*, top view.

2. *Vulvulina* cf. *V. arenacea* (Bagg) (p. 818).
USNM 626153; Hole E–1, 680–690 feet, Miocene.

3. *Gaudryina* (*Siphogaudryina*) *rugulosa* Cushman (p. 818).
USNM 626156; Hole E–1, 740–750 feet, Miocene.

4. *Schlumbergerina alveoliniformis* (Brady) (p. 824).
USNM 626160; Hole E–1, 960–970 feet, Miocene; *a*, side view; *b*, apertural view.

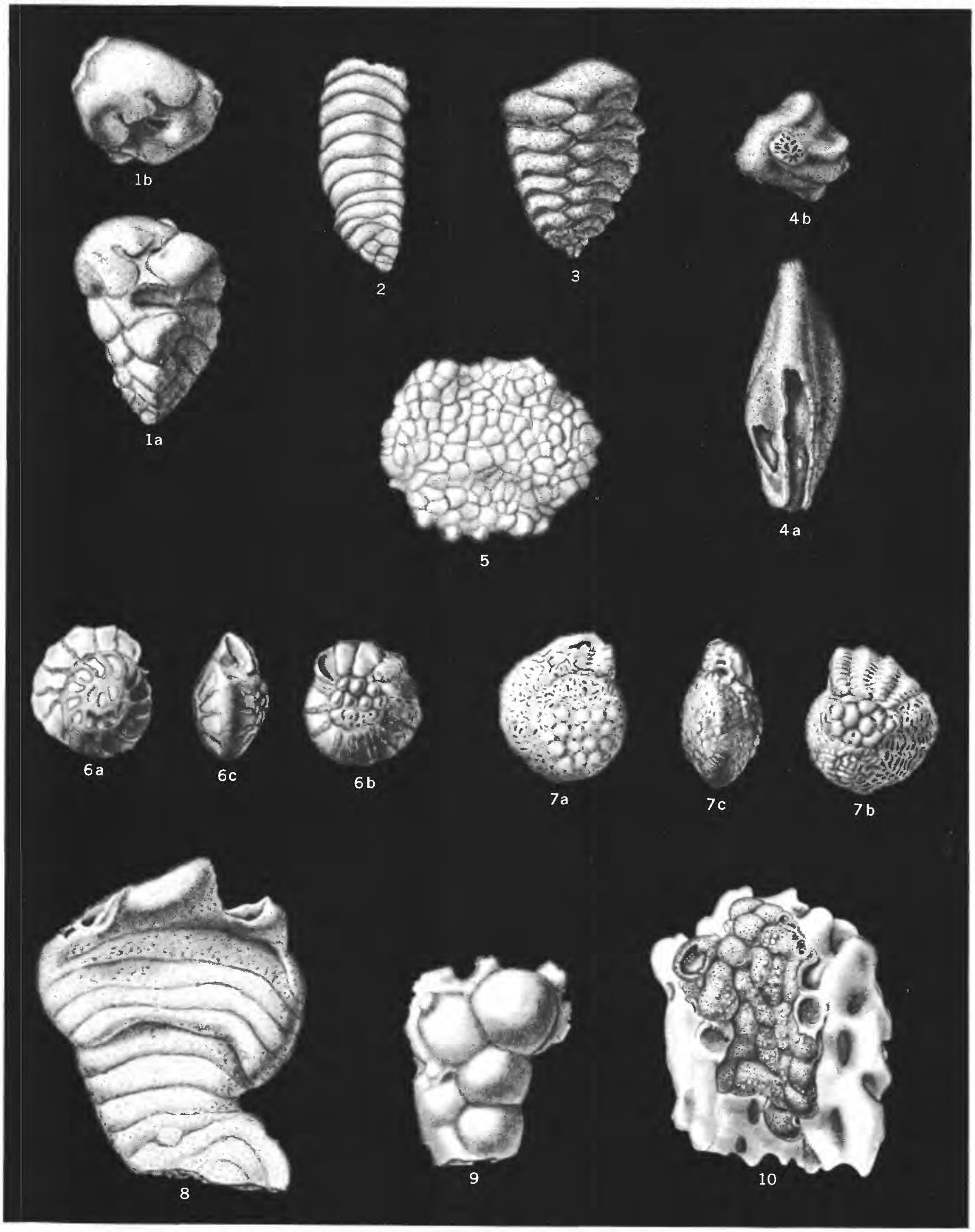
5. *Planorbulinella larvata* (Parker and Jones) (p. 853).
USNM 626191, × 30; Hole E–1, 2,290–2,300 feet, lower Oligocene (?).

6, 7. *Rotalia tuvuthaensis* Kleinpell (p. 842).
6. Young specimen, USNM 626163; Hole E–1, 990–1,000 feet, Miocene; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.
7. USNM 626159; Hole E–1, 920–930 feet, Miocene; *a*, dorsal view; *b*, ventral view; *c*, peripheral view.

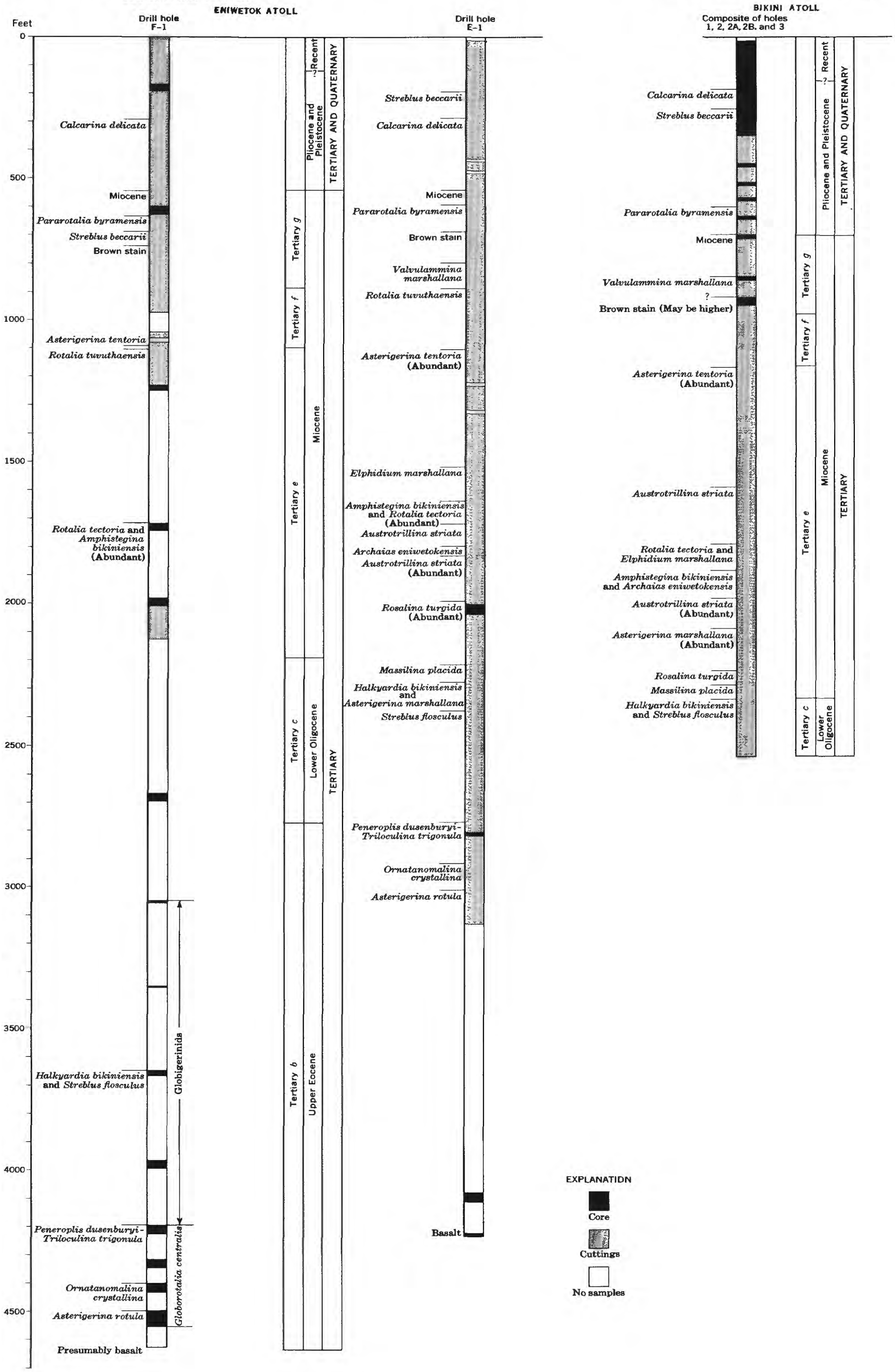
8. *Bdelloidina aggregata* Carter (p. 827).
USNM 626146; Hole F–1, 250–260 feet, Miocene.

9. *Carpenteria proteiformis* Goës (p. 854).
USNM 626244; Hole F–1, core F–1–9–3, upper Eocene.

10. *Planorbulinoides retinaculata* (Parker and Jones) (p. 853).
USNM 626155; Hole E–1, 710–720 feet, Miocene.



MISCELLANEOUS SMALLER FORAMINIFERA OF MIOCENE TO LATE EOCENE AGE FROM ENIWETOK



Comparison of age of beds and tops of occurrence of certain significant smaller Foraminifera in Eniwetok drill holes F–1 and E–1 and the Bikini drill holes.