Distribution of Some Shallow-Water Foraminifera in the Gulf of Mexico

By ORVILLE L. BANDY

A SHORTER CONTRIBUTION TO GENERAL GEOLOGY

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A SHORTER CONTRIBUTION TO GENERAL GEOLOGY

DISTRIBUTION OF SOME SHALLOW-WATER FORAMINIFERA IN THE GULF OF MEXICO

By Orville L. Bandy*

ABSTRACT

This is a detailed study of the distribution of Foraminifera between depths of 27 and 130 feet in the Gulf of Mexico between Sabine Pass, Texas, and Grand Cheniere, Louisiana. The area extends about 75 miles off-shore and is about 50 miles wide. The frequency distribution of the species of Foraminifera is plotted against changes in depth, temperature, chlorinity and the median grain size of the sediments. Within the very restricted depth limits of the investigation, there is a marked faunal zonation making it possible to establish bathymetric zones of 30–55, 55–75, and 75–130 feet, and to predict positions even within these intervals.

The seasonal bottom-temperature range is vastly greater than the variation along the whole profile, indicating that the species involved possess considerable tolerance toward temperature variation. Temperature is therefore probably of little or no importance in explaining the faunal differentiation within the area.

Chlorinity appears to play an important role in the near-shore environment. The species of *Streblus* discussed in this paper were found to be mostly limited to brackish water. Three species of the genus *Elphidium* were found to be abundant in waters of both low and normal chlorinity, however, a fourth species was noted only in areas of normal chlorinity. Diversity of adaptations within a genus and even within a species is to be expected and this suggests that although *Streblus* proved to be especially well developed in waters of low chlorinity, there may well be related species that are characteristic of other conditions.

The bottom prominences were found to support a population of *Asterigerina carinata* d'Orbigny, and other characteristic species. The weight percentages of Foraminifera in the sediment and the numbers of species were found to increase away from shore. There is no apparent correlation between the median grain size and faunal trends.

INTRODUCTION

This paper records the distribution of some shallow-water Foraminifera in the northern part of the Gulf of Mexico and attempts to interpret the ecologic conditions controlling distribution. The percentage-abundance distribution of the foraminifers is plotted against changes in depth, temperature, chloride content, and median grain-size of the sediments. The Foraminifera were collected by Messrs. J. D. Frautschy and H. R. Joesting as a part of a reconnaissance gravity survey in the Gulf of Mexico for the U. S. Geological Survey in cooperation with the Office of Naval Research. The investigations were carried out on the U. S. Navy research vessel *Mentor*, operated under contract by Woods Hole Oceanographic Institution. The area surveyed extends seaward about 75 miles from the shore of the Gulf of Mexico between Sabine Pass, Texas, and Grand Cheniere, Louisiana. One of the objectives of the survey was to obtain information concerning the bottom sediments, and the following analysis of the foraminiferal elements is one phase of that objective.

As indicated on the preliminary map by Joesting and Frautschy (1947), the initial base line of targets for each of the three lines of stations was located by transit triangulation from U. S. Coast and Geodetic Survey triangulation stations on shore. The stations of the survey were then located by triangulation, using 3 centimeter radar and radar-reflector targets mounted on buoys. The maximum uncorrected longitude errors were not more than 2 miles and the corresponding latitude errors were not in excess of about one-quarter mile. The stations are located in three north-south traverses that are designated 1, 2, and 3 respectively from west to east (pl. 27). In addition, several samples were collected from intermediate points along the southern edge of the area, thereby joining the outer ends of the north-south lines of traverse.

The samples and data used in making up the curves for chlorinity, depth and median grain sizes were supplied by Mr. J. D. Frautschy, Scripps Institution of Oceanography. Dr. F. B. Phleger and Miss F. L. Parker of the same institution permitted the author to consult the taxonomy of an unpublished paper covering much of the Gulf of Mexico. The bottom-temperature data were obtained from Mr. Frederick C. Fuglister, Woods Hole Oceanographic Institution, Woods Hole, Massachusetts. The writer has attempted to present all of the significant results graphically and in this he was aided materially by the suggestions of Dr. K. O. Emery, University of Southern California. The work was done under the supervision of Dr. H. R. Joesting, Chief of the Geophysics Branch, U. S. Geological Survey.

PREVIOUS WORK

Studies of the Foraminifera of the Gulf of Mexico may be divided into two groups, those which are primarily taxonomic and those which emphasize distribution patterns and ecologic conditions. The first category includes the well known works of d'Orbigny (1939), Brady (1884), Cushman (1921, 1922, 1926),

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and Kornfeld (1931). Although these monographs are mainly of a taxonomic nature, they contain depth data from which some distributional trends and tendencies may be determined. More recent taxonomic papers include those of Acosta (1940), and Lalicker and Bermudez (1941).

Again, although there are depth data to be found in these papers, there is little information about the relative importance of the individual occurrences. Papers emphasizing the patterns of distribution and ecologic conditions include those of Vaughan (1918), Lowman (1949), and Phleger and Parker (1951). Vaughan's study is primarily an analysis of the bottom sediments but he includes lists of Foraminifera occurring at different stations and the characteristics of the environments. Lowman's paper is the first to attempt a graphic representation of the frequency distribution of Foraminifera from shore to deep water. He used categories broader than species and varieties, thus providing an excellent perspective of the general ranges and dependability of the genera and families. Phleger and Parker have completed a study that contributes much detailed information concerning the ranges of species and varieties of the foraminiferal population offshore. The present study in like manner deals with the Foraminifera of the nearshore area.

An excellent bibliography of publications dealing with the Gulf of Mexico generally by Geyer (1950) includes references to many papers dealing with ecology of organisms other than Foraminifera.

METHOD OF STUDY

Frequency counts of 160 samples were used as a basis for this investigation. The samples of traverse 2 were weighed before disaggregation and the percentages of Foraminifera in the sediment were computed. Although the samples of the other two profiles were not weighed, a roughly uniform quantity of each was selected. The material was washed on 150 mesh screens (0.105 mm) and the residue was then dried and treated with carbon tetrachloride to concentrate the Foraminifera by flotation. Some broken tests and specimens belonging to a few of the larger genera such as *Praesorites* did not float readily and had to be decanted from the residue. This last procedure was quite effective, for in the sediment-carbon tetrachloride mixture the Foraminifera are buoyed up much more than the sediment and can be decanted and raked out easily. Examination of the residues revealed fairly clean separation.

In making counts, a foraminiferal sample was split evenly a number of times, until a fraction was obtained that could be accommodated on one counting slide. In the beginning, test counts were made of the various size fractions to ascertain the percentage variation in the different fractions. The largest count was more than 1000 specimens, and it was found to differ from the small counts of about 100 specimens mainly in the number of rare species revealed. For this reason it was decided that counts of 200 to 500 specimens would provide sufficiently accurate results. In a very few samples fewer than 200 specimens were counted, and then only because specimens were rare.

The percentage method was used because it accurately reveals the relative importance of the various species and varieties in different samples and permits more ready comparisons with other studies of this kind. The percentage method brings out gradational changes more accurately than categories such as rare, common and abundant. Where the faunas are fairly large, the criticism of Said (1950) that the percentage method fails to provide a basis for correlation of the numbers of specimens in different samples is largely eliminated. As may be observed in the work of Phleger (1942), Parker (1948), Lowman (1949), and in the charts herein, the advantages of the percentage method lie in the relative ease of zone determination and in correlating gradational changes of faunas with changes in the physical environment.

FAUNAL ANALYSIS

GENERAL FEATURES

The area involved ranges in depth from about 25 ft near shore to approximately 130 ft at the outer edge. As may be seen on plate 27, the bottom is not smoothly sloping but is very irregular so that the three profiles exhibit several topographic highs, possibly salt dome features. Stations near each other geographically and bathymetrically have been averaged together where they seem to present identical faunal associations.

Because some of the stations were grouped together on the maps, it wasn't feasible to locate the stations and grouped stations according to the true horizontal scale, hence the stations are spaced equidistantly. This roughly approximates the proper horizontal spacing, inasmuch as the samples were collected from nearly equally spaced stations.

In the frequency counts of the species of the three traverses (figs. 11–13), it became apparent almost at once that about 8 to 15 species made up more than 90 percent of the fauna at any one station. It became equally apparent that there were three general classes of variation, viz. general trends such as that exhibited by *Streblus* and *Planulina ornata* (d'Orbigny), unusual faunas on topographic highs such as that at station 8, in figure 6, and sporadic occurrences of many species. The more abundant and diagnostic forms compared with the changes in the physical environment, showed little correlation excepting with depth and chlorinity (figs. 6–8). In such analyses there are many fluctuations and irregularities that are confusing; however, by making a composite picture of the frequency distri-

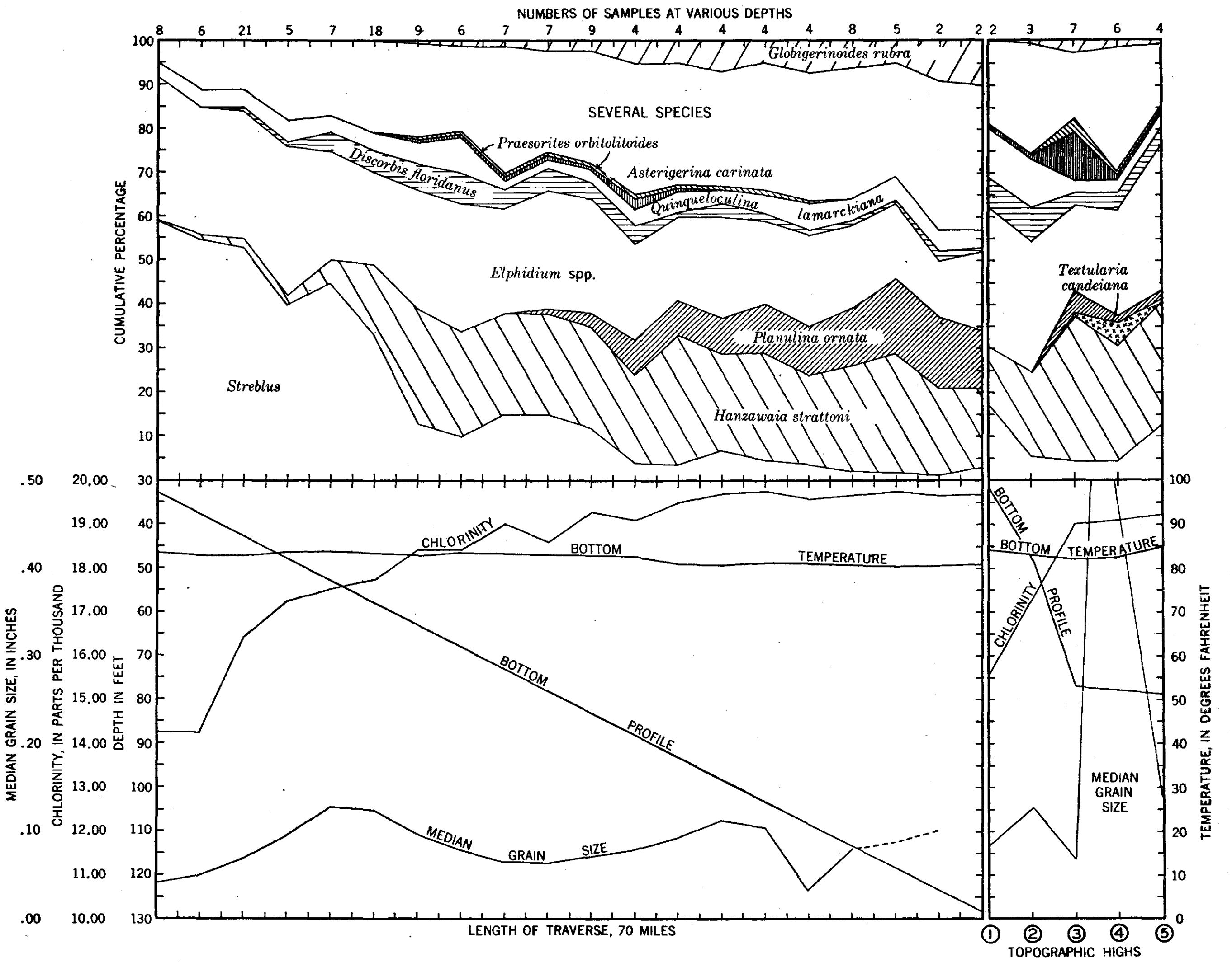

FIGURE 5. Composite frequency distribution of the significant Foraminifera plotted with changes in physical environment.

bution (figure 5, top) in the absence of the complicating factors associated with slope reversals, the frequency distribution smoothed out. A comparison of the generalized composite frequency distribution with that on the topographic highs (figure 5, bottom) shows a striking contrast, one which is possibly explained by less turbidity on the bottom highs.

It was found that the weight percentages of Foraminifera in the sediment increased erratically from the near-shore ends of the traverses outward, a condition probably produced by the dilution of foraminiferal elements by sediment nearer shore (fig. 9). The number of species near-shore was found to be generally about half the number making up the faunas of the stations near the outer ends of the traverses (fig. 6). This last is to be expected with the less turbid conditions and the normal chlorinity of the outer zone.

As may be seen in figures 5–8, the bottom temperatures taken when the samples were collected have a range of less than 5 degrees whereas the annual variation shows an annual average range of about 20 degrees for both the outer and inner portions of the area investigated (fig. 10). Therefore, species having considerable tolerance toward changes in temperature are characteristic of the faunas studied. The correlation of growth periods with times of maximum differences between the bottom temperature near-shore and off-shore may prove to be significant for some of the species but evidence of this kind is yet to be obtained. The fluctuations in grain size do not seem to correlate with the faunal trends and therefore appear to be non-significant.

ZONATION

In several bathymetric studies of the distribution patterns of the tests of Recent Foraminifera, well-defined zones have been recognized. Natland (1933) established five zones in his work off the southern California coast, Parker found four zones in her study of the Atlantic coast (1948), and Lowman recognized 12 faunal associations in his Gulf coastal work (1949). The present study is a detailed examination of an area which is roughly equivalent in depth to zone 2 of Natland,

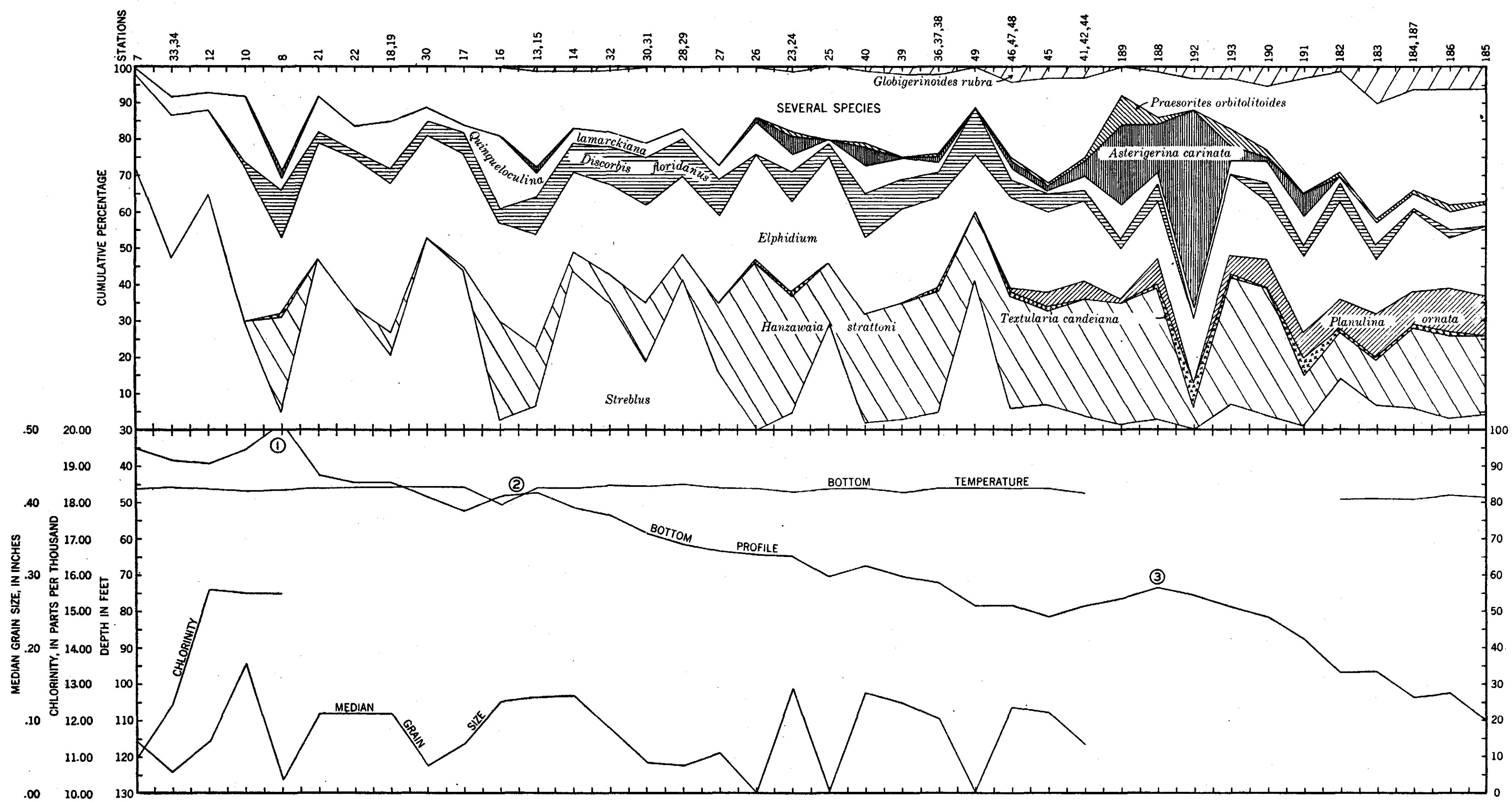

FIGURE 6. Frequency distribution of the more significant Foraminifera of traverse 1.

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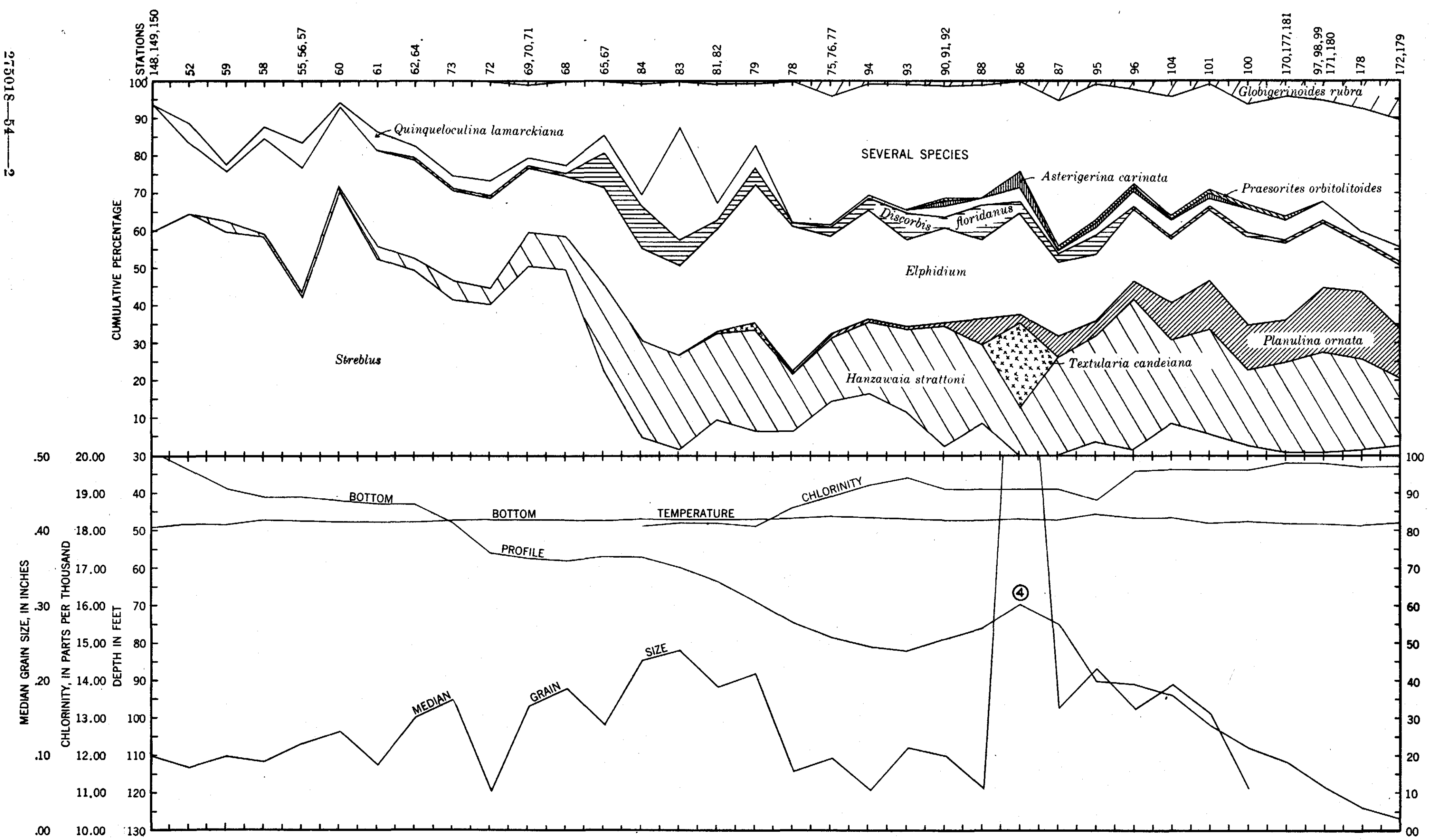

Figure 7. Frequency distribution of the more significant Foraminifera of traverse 2.

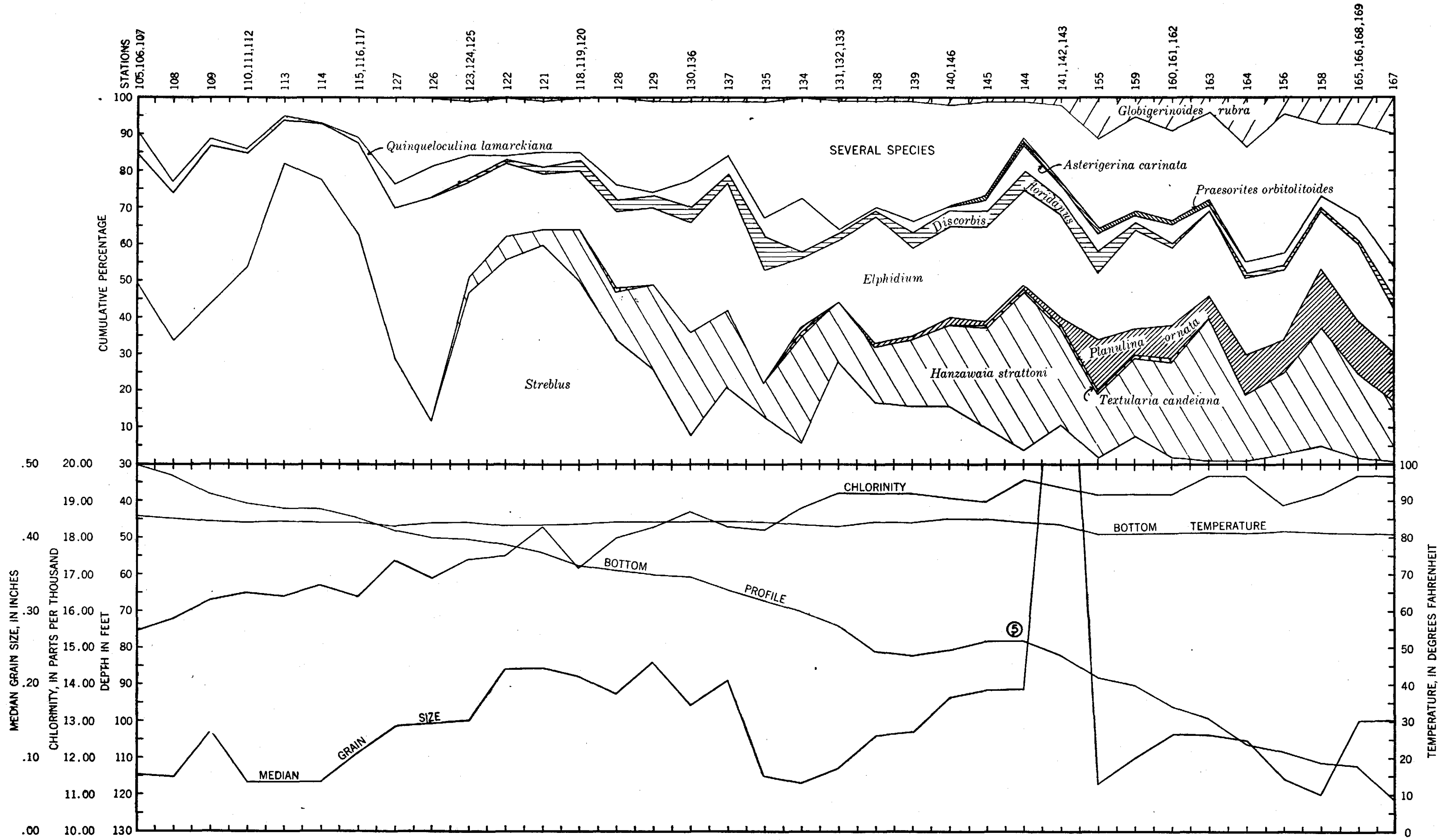

FIGURE 8. Frequency distribution of the more significant Foraminifera of traverse 3.

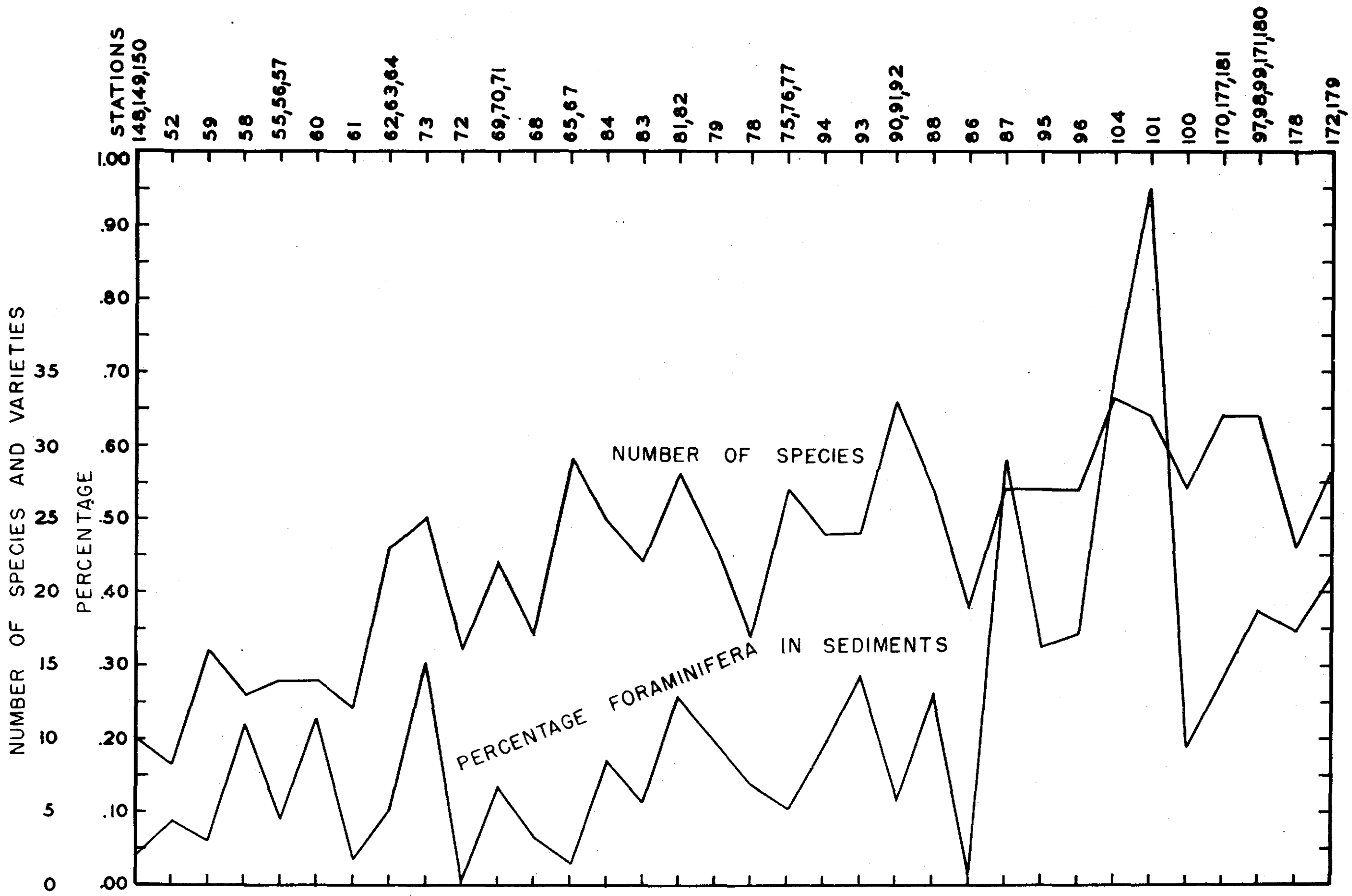

FIGURE 9. Percentages of Foraminifera in sediment, plotted with number of species for traverse 2.

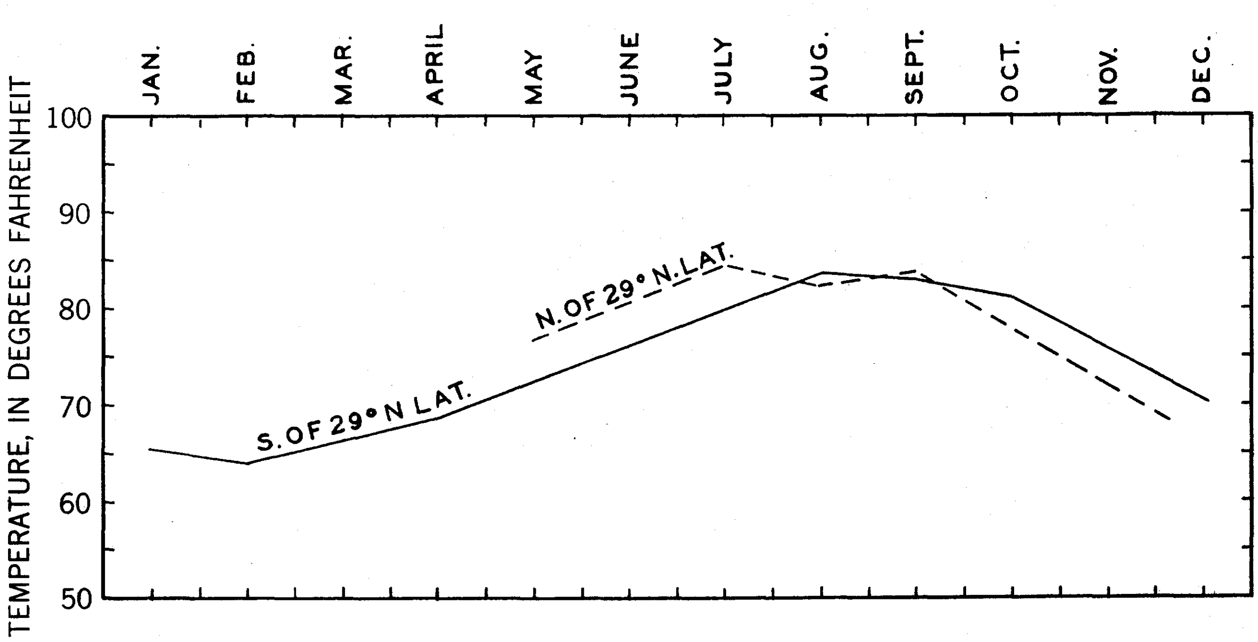

FIGURE 10. Generalized bottom-temperature curves, showing seasonal variation.

parts of zones 1 and 2 of Parker, and faunal associations 6 and 7 of Lowman. For discussion it is convenient to divide the traverses into 3 depth zones; these are of course phases of the more generalized zones of others, and only a means of analysis of the problem at hand. The general zonation with its gradational nature is marked (fig. 5). The general subdivisions, however, are clear, and these are tabulated and discussed below.

Relative abundance of species of Foraminifera in bottom samples taken at different depths

[Abundance of each species is expressed as the range of the percentage it makes up in the whole fauna.]

	Abundance in zones indicated		
	1 (30-55 ft.)	2 (55-75 ft.)	3 (75-130 ft.)
Streblus beccarii sobrinus, *S. b. tepidus*, and *S. rolshauseni*	40+	20-40	0-15
Elphidium discoidale, *E. gunteri galvestonense*, and *E. poeyanum*	25+	20-30	10-35
Hanzawaia strattoni	--------	10-45	10-40
Discorbis floridanus	--------	1-14	1-10
Planulina ornata	--------	0-1	2-18
Globigerinoides rubra	--------	--------	2-10
Cancris sagra	--------	--------	0-5
Eponides antillarum	--------	--------	0-5

ZONE 1, 30-55 FEET

It will be noted that there are many fluctuations in the frequency curves for the faunal indices in zone 1, and no single species is a dependable criterion; however, by setting the minimum total percentage of 60 percent for all of the species of the two genera listed above, allowance is made for exceptions such as that seen at station 126 in figure 8. At this station the cumulative percentage of the indices listed above is 73 whereas that of *Streblus* alone is only 12 percent. Another type of exception is that seen on bottom highs 1 and 2 (fig. 6) where the cumulative values are 25 and 38 percent respectively. *Asterigerina carinata* d'Orbigny appears and *Hanzawaia strattoni* (Applin) becomes very abundant, a condition typical of the frequency distribution in zone 2 (55-75 feet). The two occurrences are difficult to separate, about the only differences being in the probability of encountering *Planulina ornata* (d'Orbigny) and other deeper water species in zone 2 whereas they are characteristically absent on the shallow water bottom highs. The deeper water bottom highs usually show a much greater frequency of *Asterigerina carinata* d'Orbigny and the appearance of *Praesorites orbitolitoides* Hofker.

In the histogram charts (figs. 11-13) the two varieties of *Streblus beccarii* (Linne) are lumped together because their ranges are approximately identical and because of their similarity. In the composite charts,

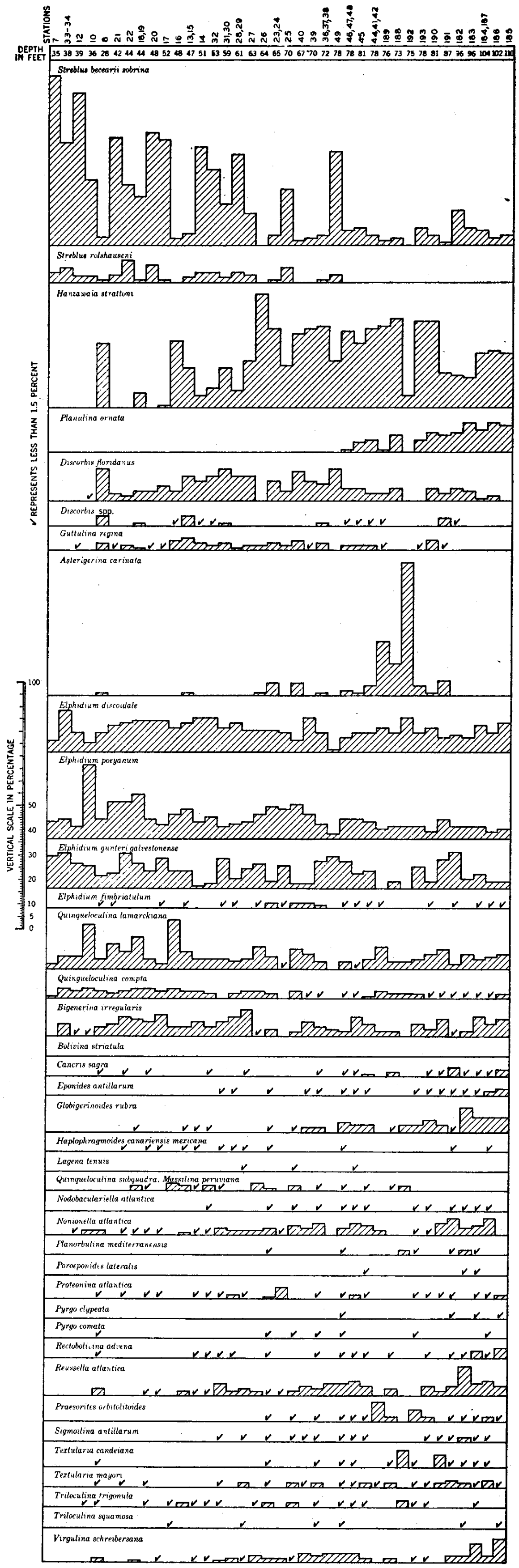

FIGURE 11. Frequency distribution of the Foraminifera of traverse 1.

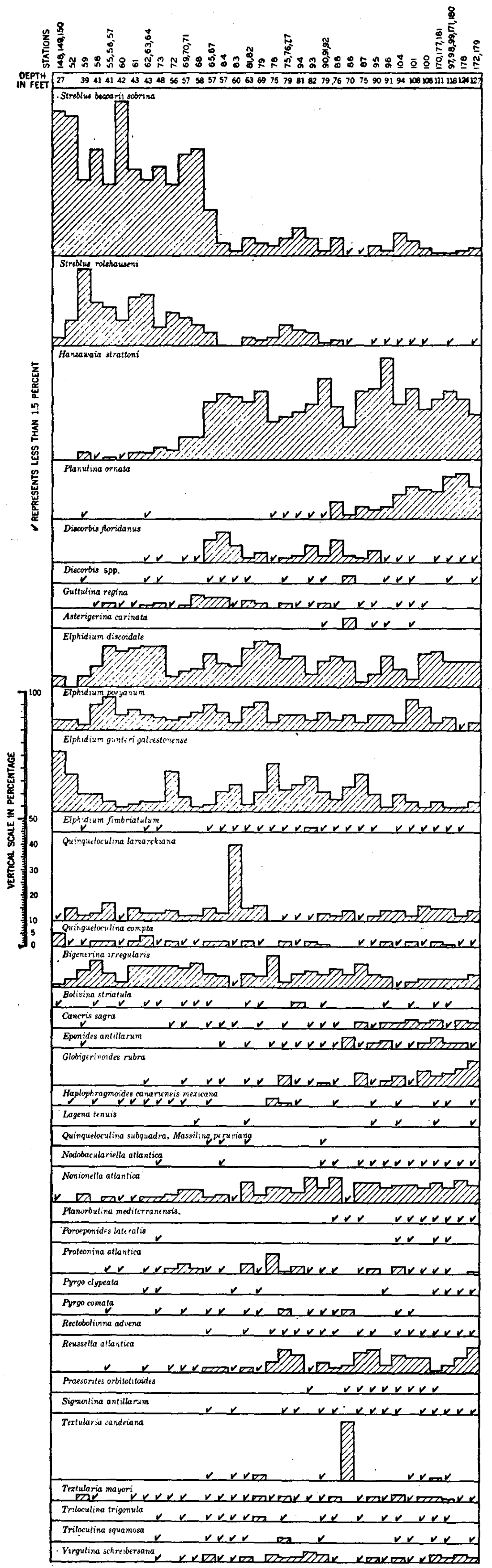

FIGURE 12. Frequency distribution of the Foraminifera of traverse 2.

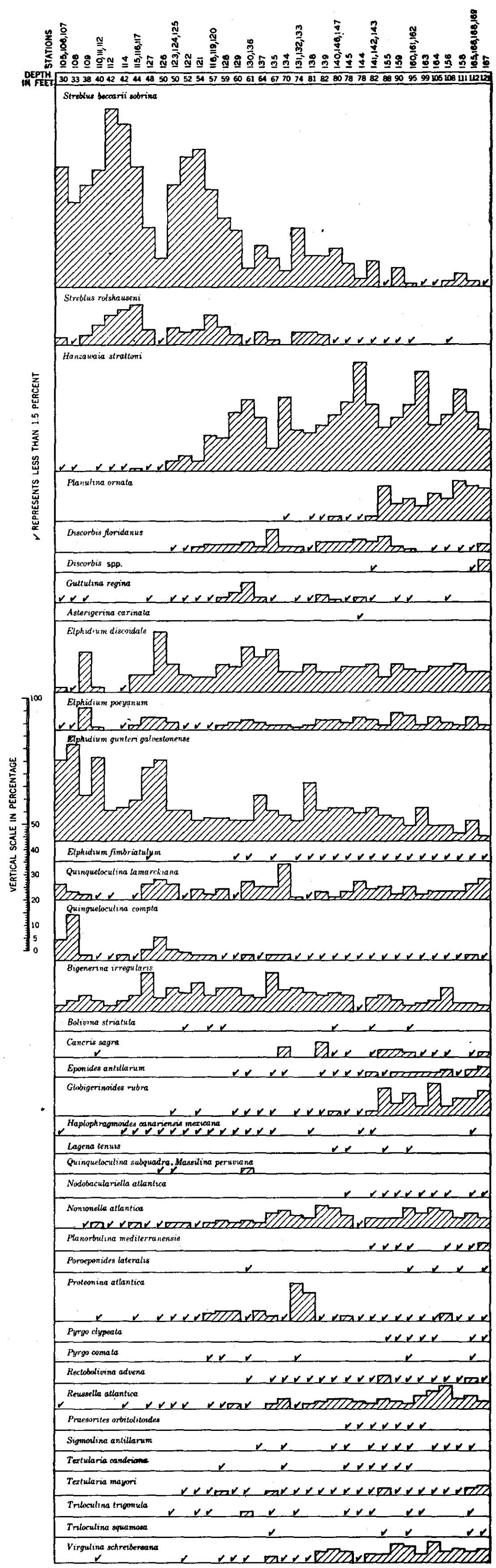

FIGURE 13. Frequency distribution of the Foraminifera of traverse 3.

all of the members of the genus *Streblus* are lumped together, again because of their similar ranges. Of the ecologic data available, there are two variables, depth and chloride content. According to Lowman, *Streblus* and *Elphidium* are dominant where the chlorinity is from 5 to 15 (1949, p. 1953). In the data herein, the chlorinity ranges from about 12 near the inner ends of the lines of traverse to about 19.8. *Streblus* and its various species were found to be most abundant where the chlorinity was less than 19 (figs. 5–8) and only common to rare where the chlorinity was 19 or above. Along the California coast, *S. beccarii* (Linne) and its variants are reported from only the lagoonal areas in shallow brackish water (Natland, 1933). Hedberg (1934) also noted this in Venezuela. A correlative factor is turbidity, for the waters of the Gulf were quite turbid out to about the 18 mile light when the samples were collected in August and September, 1947 (oral communication, J. D. Frautschy), a condition produced by the influx of mud-laden fresh water into the coastal waters of this area. This too, explains the low chlorinity near shore. *Streblus rolshauseni* (Cushman and Bermudez) drops to less than 1 percent beyond the depth of 80 feet; however, as much as 10 percent (in one case 14 percent) of the faunas of the outer zone may be made up of the varieties of *Streblus beccarii* (Linne). In summary, the species of *Streblus* encountered are apparently suited to maximum development in brackish waters but may tolerate shallow waters of near normal chlorinity.

The three species of *Elphidium* listed for this zone were lumped together for the composite analyses because their individual distribution patterns, as presented in figures 8–10, are nearly identical. These species are common to abundant in all of the samples, indicating that their ranges of tolerance exceed the ecologic variation found in the area of this study. The ability of this genus to tolerate considerable ranges of environmental change was brought out by Myers (1943) in his study of *E. crispum* (Linne). He found this species to be one of very few that thrives both in the intertidal and sublittoral zones. From the work of Lowman (1949, p. 1953) it is evident that *Elphidium* can tolerate moderately brackish water and that it thrives in the broad inner neritic zone. Its range of tolerance, however, exceeds that of *Streblus beccarii* (Linne) as may be seen in figure 5, for it is abundant throughout the area of this study. One exception to the range of this genus is *E. fimbriatulum* (Cushman). This species, which is rare, is restricted to samples obtained beyond the brackish water area and a few samples from some of the prominences in the shallower water.

Discorbis floridanus Cushman is absent from the shallower parts of the area studied, but is present at depths of 40 to 50 feet and is significant therefore as indicating the deeper part of this zone. *Quinqueloculina lamarckiana* d'Orbigny, a rather uniformly distributed species, exhibits a few significant deviations. There is a rather marked percentage increase of this form on the topographic highs in shallow water (fig. 5) and at stations 83 and 84 (fig. 7). At stations 83 and 84 a slight reversal in slope places this occurrence also in the bottom-high category.

ZONE 2, 55–75 FEET

This zone is transitional between the *Streblus-Elphidium* and the *Planulina ornata* zones (table, p. 132). It is chara cterized by theabundance of *Hanzawaia strattoni* (Applin) and a very low percentage or the complete absence of the deeper water form, *Planulina ornata*. As indicated in figure 5, the chlorinity is still slightly lower than that farther out, perhaps accounting for additional species appearing only gradually with increasing depth. It is also likely that turbid bottom conditions help determine the character and quantity of the benthonic fauna by reducing the translucency of the water and consequently the abundance of plant life.

The counts of *Hanzawaia strattoni* (Applin) include a very few specimens of *H. concentrica* (Cushman) which differs from *H. strattoni* in possessing a flat dorsal side and angled edge (Cushman, 1918, p. 64). As mentioned in the discussion for Zone 1, there may be a marked increase in this form on shallow bottom highs but in these cases, it is associated with *Asterigerina carinata* d'Orbigny and other rarer forms found in slightly deeper water (see station 8, fig. 11).

In general, this zone differs from Zone 1 in that *Hanzawaia strattoni* is more abundant than *Streblus*, and a few specimens of *Planulina ornata* and *Globigerinoides rubra* may be expected (see fig. 5).

ZONE 3, 75–130 FEET

Of the species listed as characteristic of this zone (table, p. 132) *Planulinia ornata*(d' Orbigny) is most significant in determining approximate positions within the zone. For example, the frequency of this species increases from about 2 to 10 percent between depths of 75 and 100 feet and is in excess of 10 percent below 100 feet. No known ecologic factor is correlated with the appearance and progressive percentage increase of this species, but may be related to the distribution of plant life and food supply.

Discorbis floridanus Cushman seems to be most abundant at depths of 50 to 100 feet. The upper limits of distribution fall in the shallower zones, and the lower limits, are at about 100 feet.

The gradual appearance of many species in progressively deeper water is marked as may be seen in figures 9, and 11–13. Some of these are rare, sporadically distributed and are seemingly of little importance in this study. The distribution of some others are important but are omitted from the composite charts to avoid over-crowding and confusion; however, they are shown in figures 11–13. In this last group are species such as *Cancris sagra* (d'Orbigny) and *Eponides antillarum* (d'Orbigny) whose abundance increases rapidly near the outer ends of the traverses.

The faunas of the prominences present an interesting digression from the general trends as may be seen by comparing the composite charts in figures 5–8. The prominences, whether in deep or shallow water, are characterized by the presence of *Asterigerina carinata* d'Orbigny; however, there is a much greater abundance of this species on the prominences lying at depths of 60 to 130 feet. Other species characteristic of these deeper-water prominences include *Praesorites orbitolitoides* Hofker and *Textularia candeiana* d'Orbigny which, although not restricted to the prominences, are more abundant there than elsewhere. With the exception of area no. 5, there seems to be a marked drop in the frequency of *Hanzawaia strattoni* (Applin) on the deep-water prominences whereas the percentages of Elphidium remain about the same.

On prominence 4 in traverse 2, a sharp increase in the frequency of *Textularia candeiana* d'Orbigny is associated with a marked increase in median grain size. This occurrence coincides with the presence of coarse sand particles usable in the building of the test, but there is no corresponding increase near prominence 5 in traverse 3, where the median grain size shows a marked increase with no significant change in the frequency of *T. candeiana.* With the one exception at prominence 4, there seems to be no dependable correlation between grain size and frequency distribution of the faunal elements studied.

CONCLUSIONS

1.—Within a depth range of about 100 feet, it is possible to establish three rather well defined faunal zones that parallel the coast. The zonation is gradational, enabling one to predict positions within the general zones.

2.—The seasonal range of bottom temperatures of about 20° F is much greater than the range of readings taken when the samples were collected. This would seem to rule out temperature as a determining factor in faunal differentiation within the area. The species involved apparently tolerate considerable temperature fluctuations.

3.—Chlorinity seems to play an important part in determining the distribution of *Streblus* and *Elphidium. Streblus* appears to be mostly limited to brackish water whereas *Elphidium* thrives in waters of both low and normal chlorinity. One species of *Elphidium* was found only in waters of normal chlorinity, indicating that there are different chlorinity tolerances within the genus.

4.—There is no obvious consistent correlation between median grain size and faunal trends.

5.—Many faunal trends could not be correlated with the physical conditions other than change in depth. Perhaps such trends will be found to correlate with turbidity conditions, light penetration, or characteristics of bottom plants.

6.—The weight percentages of Foraminifera and the number of species increase away from shore, because of more rapid sedimentation near shore and fairly stable normal chlorinity offshore.

7.—The prominences near shore have much the same fauna as the area slightly farther out, excepting for the appearance of *Asterigina carinata* d'Orbigny. The deeper water prominences are characterized by abundant *A. carinata* d'Orbigny, and the presence of *Praesorites orbitolitoides* (Hofker) and a few other species.

ANNOTATED SYNONYMIES

This section is an alphabetized reference list of the species. Usually, the original and one subsequent reference are given for each species. All the species are figured, and arranged systematically on the plates to bring related forms together. The illustrations were made by Miss Mary Taylor and the author. The hypotypes are deposited in the U. S. National Museum, Washington, D. C.

Asterigerina carinata d'Orbigny

Plate 31, figure 5

1839. *Asterigerina carinata* d'Orbigny, *in* Ramon de la Sagra, Histoire physique et naturelle de l'Ile de Cuba, A. Bertrand, Paris, France, p. 118; plates published separately, v. 8, pl. 5, fig. 25; pl. 6, figs. 1–2. Recent, marine sand, Cuba and Jamaica.

1931. *Asterigerina carinata* d'Orbigny. Cushman, U. S. Natl. Mus. Bull. 104, pt. 8, p. 77, pl. 15, figs. 4, 5. Recent, West Indies.

Most specimens exhibit a small ventral umbo, a feature which is not found in the type, and this form may therefore represent a variety of d'Orbigny's species.

Bigenerina irregularis Phleger and Parker

Plate 29, figures 8, 9

1922. *Bigenerina nodosaria* d'Orbigny. Cushman, Carnegie Inst. Washington Pub. 311, p. 25, pl. 2, figs. 5, 6. Recent, Tortugas region. (*Not B. nodosaria* d'Orbigny, 1826.)

1951. *Bigenerina irregularis* Phleger and Parker, Geol. Soc. America, Mem. 46, pt. 2, p. 4, pl. 1, figs. 16–21. Recent, Gulf of Mexico.

This species ranges from 0 to 15 percent, and presents a fluctuating frequency distribution that is not correlated with any of the environmental factors.

Bolivina striatula Cushman

Plate 31, figure 9

1922. *Bolivina striatula* Cushman, Carnegie Inst. Washington Pub. 311, p. 27, pl. 3, fig. 10. Recent, Tortugas region.

1937. *Bolivina striatula* Cushman. Cushman, Cushman Lab. Foram. Research Special Pub. 9, p. 154, pl. 18, figs. 30, 31.

This species is very rare, and sporadic in occurrence.

Cancris sagra (d'Orbigny) Cushman

Plate 30, figure 9

1839. *Rotalina sagra* d'Orbigny, *in* Ramon de la Sagra, Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, France, p. 77, pl. 5, figs. 13–15. Recent, Cuba and Jamaica.
1931. *Cancris sagra* (d'Orbigny) Cushman, U. S. Natl. Mus. Bull. 104, pt. 8, p. 74, pl. 15, fig. 2.
1942. *Cancris sagra* (d'Orbigny) Cushman. Cushman Lab. Foram. Research Contr., v. 18, pt. 4, p. 77, pl. 19, figs. 3–7.

This species is absent at shallow depths but fairly common at depths of 75 to 130 feet.

Discorbis floridanus Cushman

Plate 31, figure 1

1922. *Discorbis floridana* Cushman, Carnegie Inst. Washington Pub. 311, p. 39, pl. 5, figs. 11, 12. Recent, Tortugas region.

This species is most abundant at depths of about 50 to 100 feet.

Elphidium discoidale (d'Orbigny) Cushman

Plate 30, figure 4

1839. *Polystomella discoidalis* d'Orbigny, in Ramon de la Sagra, Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, France, p. 76, pl. 6, figs. 23, 24 Recent, Cuba and Jamaica.
1930. *Elphidium discoidale* (d'Orbigny) Cushman, U. S. Natl. Mus. Bull. 104, pt. 7, p. 22, pl. 8, figs. 8, 9.

In the percentage-abundance counts, *E. incertum* (Williamson) var. *mexicanum* Kornfeld (1931) was included with *E. discoidale* because the two forms seem to intergrade and the individual distributions were similar. Both forms are abundant throughout the area.

Elphidium fimbriatulum (Cushman)

Plate 29, figure 12

1918. *Polystomella fimbriatulum* Cushman, U. S. Geol. Survey Bull. 676, p. 20, pl. 8, figs. 5a, b. Miocene and Pliocene of Florida.

This species is rare, and limited to the middle and offshore parts of the area.

Elphidium gunteri Cole var. galvestonense Kornfeld

Plate 30, figure 2

1925. *Polystomella galvestonensis* Applin (nomen nudum), Am. Assoc. Petroleum Geologists Bull., v. 9, no. 1, p. 84,
1931. *Elphidium gunteri* Cole var. *galvestonensis* Kornfeld, Stanford Univ. Dept. Geology, Contr., v. 1, no. 3, p. 87, pl. 15, figs. 1–3. Recent, littoral zone, Texas and Louisiana.

Generally, this species is most abundant in waters less than 40 feet deep; however, the general distribution was found to be about the same as that of *E. discoidale* (d'Orbigny) and *E. poeyanum* (d'Orbigny).

Elphidium poeyanum (d'Orbigny) Cushman

Plate 30, figure 6

1839. *Polystomella poeyana* d'Orbigny, *in* Ramon de la Sagra, Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, France, p. 55, pl. 6, figs. 25, 26. Recent, Cuba and Jamaica.
1930. *Elphidium poeyanum* (d'Orbigny) Cushman, U. S. Natl. Mus. Bull. 104, pt. 7, p. 25, pl. 10, figs. 4, 5.
1939. *Elphidium poeyanum* (d'Orbigny) Cushman, U. S. Geol. Survey Prof. Paper 191, p. 54, pl. 14, figs. 25, 26.

This cosmopolitan species occurs in considerable abundance throughout the area investigated.

Eponides antillarum (d'Orbigny) Cushman

Plate 30, figure 8

1839. *Rotalina* (*Rotalina*) *antillarum* d'Orbigny, *in* Ramon de la Sagra, Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, France, p. 75, pl. 5, figs. 4–6. Recent, Cuba and Jamaica.
1922. *Pulvinulina incerata* Cushman, Carnegie Inst. Washington Pub. 311, p. 51, pl. 9, figs. 1–3. Recent, Tortugas region.
1931. *Eponides antillarum* (d'Orbigny) Cushman, U. S. Natl. Mus. Bull. 104, pt. 8, p. 42, pl. 9, fig. 2. Recent, Florida.

Previous records of this species indicate a somewhat deeper water habitat than that studied in this work. As indicated by figures 11 to 13, it assumes some importance in the outer part of the area.

Globigerinoides rubra (d'Orbigny) Cushman

Plate 31, figure 6

1839. *Globigerina rubra* d'Orbigny, *in* Ramon de la Sagra, Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, France, p. 82, pl. 4, figs. 12–14. Recent, Cuba and Jamaica.
1927. *Globigerinoides rubra* (d'Orbigny) Cushman, Cushman Lab. Foram. Research Contr., v. 3, p. 86.

This is the most abundant pelagic foraminifer in the material examined. A few other globigerinoids were noted but were not considered important enough to list.

This form appears at between 60 and 70 feet depth and is progressively more abundant away from shore.

Guttulina regina (Brady, Parker, and Jones) Cushman and Ozawa

Plate 29, figure 7

1870. *Polymorphina regina* Brady, Parker and Jones, Linnean Soc. Trans., v. 27, p. 241, pl. 41, fig. 32.
1930. *Guttulina regina* (Brady, Parker and Jones) Cushman and Ozawa, U. S. Natl. Mus. Proc., v. 77, art. 6, p. 34, pl. 6, figs. 1, 2. Recent, cosmopolitan.

This form has a sporadic occurrence, and rarely constitutes as much as 5 percent of the Foraminifera.

Hanzawaia strattoni (Applin)

Plate 31, figure 4

1925. *Truncatulina americana* Cushman var. *strattoni* Applin, Am. Assoc. Petroleum Geologists Bull., v. 9, no. 1, p. 99, pl. 3, fig. 3. Miocene, Louisiana.

1931. *Cibicides americana* (Cushman) var. *strattoni* (Applin) Kornfeld, Stanford Univ., Dept. Geology, Contr., v. 1, no. 3, p. 82, check list. Recent, Texas coastal region.

This species is commonly placed in the genus *Cibicides* Montfort, 1808; however, it belongs in the genus *Hanzawaia* Asano (1944, p. 98), which differs from *Cibicides* in being mostly involute dorsally with the spire partly or entirely concealed by dorsal flaps, and in being generally not as coarsely perforate. Specimens referable to this species are sometimes identified with *H. concentrica* (Cushman) but they are biconvex and have a rounded edge.

Haplophragmoides canariensis (d'Orbigny) var. mexicana Kornfeld

Plate 29, figure 6

1931. *Haplophragmoides canariensis* (d'Orbigny) var. *mexicana* Kornfeld, Stanford Univ., Dept. Geology, Contr., v. 1, no. 3, p. 83, pl. 13, fig. 4. Recent, littoral zone of Texas and Louisiana.

Specimens of this form are few and evidently fragile, as most of them are broken. The variety generally makes up less than 3 percent of the fauna.

Lagena tenuis (Bornemann)

Plate 29, figure 11

1855. *Ovulina tenuis* Bornemann, Deutsche geol. Gesell Zeitschr., Band 7, heft 2, p. 317, pl. 12, fig. 3. Oligocene, Germany.
1950. *Lagena perlucida* (Montagu) var. Cushman and McCulloch, Allan Hancock Pacific Expeditions, v. 6, no. 6, p. 343, pl. 46, figs. 3, 4.

This rare species is similar to many specimens that are identified as *L. perlucida* (Montagu). There is no similarity between Montagu's short, heavily costate species and this relatively smooth, elongate-ovate form that has ornamentation on the initial end only.

Massilina peruviana (d'Orbigny)

Plate 28, Figure 8

1839. *Quinqueloculina peruviana* d'Orbigny, Voyage dans l'Amérique Meridionale; Foraminiferes, v. 5, pt. 5, p. 73, pl. 4, figs. 1–3 (given on plate as *Q. meridionalis*). Recent, coast of Chile.
1931. *Massilina peruviana* (d'Orbigny) Kornfeld, Stanford Univ., Dept. Geology, contr., v. 1, no. 3, p. 85, pl. 14, fig. 1. Recent, Texas and Louisiana.

This species rarely amounts to 2 percent of the foraminiferal fauna and it was lumped together with another miliolid, *Quinqueloculina subquadra* Hada, in the statistical data.

Nodobaculariella atlantica Cushman and Hanzawa

Plate 29, figure 4

1937. *Nodobaculariella atlantica* Cushman and Hanzawa, Cushman Lab. Foram. Research Contr., v. 13, pt. 2, p. 42, pl. 5, figs. 7, 8. Recent, eastern coast of the U. S.
1948. *Nodobaculariella atlantica* Cushman and Hanzawa. Cushman, Foraminifera, Harvard Univ. Press, key pl. 47, fig. 9.

The similarity between this species and young specimens of *Vertebralina cassis* d'Orbigny is striking; however, in the present form there are three chambers per whorl in the adult portion whereas in *V. cassis* there are only two in the early coiled portion.

Nonionella atlantica Cushman

Plate 29, figure 10

1947. *Nonionella atlantica* Cushman, Cushman Lab. Foram. Research Contr., v. 23, pt. 4, p. 90, pl. 20, figs. 4, 5. Recent, Florida.

This species and *Nonionella grateloupi* (d'Orbigny) have the same distribution and were not differentiated in the present study.

Planorbulina mediterranensis d'Orbigny

Plate 31, figure 3

1826. *Planorbulina mediterranensis* d'Orbigny, Annales sci. nat., v. 7, p. 280, no. 2, pl. 14, figs. 4–6.
1931. *Planorbulina mediterranensis* d'Orbigny. Cushman, U. S. Natl. Mus. Bull. 104, pt. 8, p. 129, pl. 24, figs. 5–8. Recent, eastern and western Atlantic.

This form is rare, and seems to occur mostly in the area lying beneath at least 70 feet of water.

Planulina ornata (d'Orbigny) Cushman

Plate 31, figure 2

1839. *Truncatulina ornata* d'Orbigny, Voy. Am. Mérid., v. 5, pt. 5, Foraminiféres, p. 40, pl. 6, figs. 7–9. Recent, off the coast of Chile.
1927. *Planulina ornata* (d'Orbigny) Cushman, Scripps Inst. Oceanography Bull., Tech. ser., v. 1, no. 10, p. 176, pl. 6, fig. 12. Recent, eastern Pacific.

This species is significant in the outer zone of the area studied, appearing at depths of 70 to 80 feet and increasing fairly rapidly in abundance seaward.

Poroeponides lateralis (Terquem) Cushman

Plate 30, figure 1

1878. *Rosalina lateralis* Terquem, Soc. geol. France, Mem., ser. 3, tome 1, no. 3, p. 25, pl. 2, fig. 11. Upper Pliocene, Isle of Rhodes.
1934. *Rotalia repanda* (Fichtel and Moll) Shupack, Am. Mus. Novitates, no. 737, p. 7, fig. 3. Pleistocene and Recent, western Long Island and New York harbor.
1944. *Poroeponides lateralis* (Terquem) Cushman, Cushman Lab. Foram. Research Special Pub. 12, p. 34.
1948. *Poroeponides lateralis* (Terquem) Cushman. Parker, Harvard Coll. Mus. Comp. Zoology Bull., v. 100, no. 2, p. 239 (list), pl. 1, fig. 17. Recent, Atlantic coastal waters.

A second species is included with this one in the frequency counts. It is figured on plate 30, figure 3.

Praesorites orbitolitoides Hofker

Plate 29, figure 5

1930. *Praesorites orbitolitoides* Hofker, Siboga-Exped., Mon. 4a, p. 149, pl. 55, figs. 8, 10, 11; pl. 57, figs. 4, 6; pl. 58; pl. 61, figs. 3, 14. Recent.

This species was included with *Peneroplis proteus* d'Orbigny (1839, p. 60) in the frequency counts because the two occur together and the young stages of the two were sometimes difficult to distinguish.

Proteonina atlantica Cushman

Plate 28, figure 1

1944. *Proteonina atlantica* Cushman, Cushman Lab. Foram. Research Special Pub. 12, p. 5, pl. 1, fig. 4. Recent, off the New England coast.

1947. *Proteonina difflugiformis* (Brady) var. *calcarea* Cushman, Cushman Lab. Foram. Research Contr., v. 23, pt. 4, pl. 18, fig. 16. Recent off the Florida coast.

A series of specimens of this species shows that the type without the neck and that with a neck not only occur together but intergrade; the neckless form appears to have had the neck broken. Specimens of this form tend to be more abundant in the depressions.

Pyrgo clypeata (d'Orbigny)

Plate 28, figure 7

1846. *Biloculina clypeata* d'Orbigny, Foraminifères fossiles du basin tertiaire de Vienne (Autriche), Gide et Comp., Paris, p. 263, pl. 15, figs. 19–21. Tertiary (Miocene), Vienna basin.

This species is rare, and sporadic in occurrence.

Pyrgo comata (Brady) Cushman

Plate 28, figure 9

1881. *Biloculina comata* Brady, Quart. Jour. Micro. Soc., v. 21, p. 45.

1884. *Biloculina comata* Brady. Brady, Challenger Rept., Zoology, v. 9, p. 144, pl. 3, fig. 9. Recent, cosmopolitan.

1929. *Pyrgo comata* (Brady) Cushman, U. S. Natl. Mus. Bull. 104, pt. 6, p. 73, pl. 19, fig. 8. Recent, mostly deep water of the Atlantic.

This species is rare, and sporadic in the sediments studied. It rarely makes up more than 2 percent of the foraminiferal fauna.

Quinqueloculina compta Cushman

Plate 28, figure 2

1947. *Quinqueloculina compta* Cushman, Contr. Cushman Lab. Foram. Res., v. 23, pt. 4, p. 87, pl. 19, fig. 2.

The range and percentage distribution of this species was mostly non-significant within the area of this study.

Quinqueloculina lamarckiana d'Orbigny

Plate 28, figure 3

1839. *Quinqueloculina lamarckiana* d'Orbigny, *in* Ramon de la Sagra, Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, France, p. 189, pl. 11, figs. 14, 15. Recent, Cuba and Jamaica.

1930. *Quinqueloculina lamarckiana* d'Orbigny. Cushman, Stanford Univ., Dept. Geology, Contr., v. 1, no. 1, p. 10, pl. 1, figs. 9, 10. Recent, near the Channel Islands off southern Calif.

This species exhibits a remarkably uniform percentage distribution nearly throughout the three traverses. The only major exceptions are the small percentage increases on the prominences in shallow water.

Quinqueloculina subquadra Hada

Plate 28, figure 4

1931. *Quinqueloculina subquadra* Hada, Tohoku Imp. Univ. Sci. Repts., 4th ser., v. 6, p. 78, pl. 31. Recent, near Japan

This species is rare and unimportant in the area.

Rectobolivina advena (Cushman)

Plate 31, figure 8

1922. *Siphogenerina advena* Cushman, Carnegie Inst. Washington Pub. 311, p. 35, pl. 5, fig. 2. Recent, Tortugas region.

It is rare, and occurs mostly in the outer zone.

Reussella atlantica Cushman

Plate 31, figure 7

1947. *Reussella spinulosa* (Reuss) var. *atlantica* Cushman, Cushman Lab. Foram. Research Contr., v. 23, pt. 4, p. 91, pl. 20, figs. 6, 7. Recent, off the southeastern coast of the United States.

There is a gradual increase in the frequency of this species seaward from its first appearance at depths of about 40 or 50 feet.

Sigmoilina antillarum (d'Orbigny)

Plate 29, figure 1

1839. *Spiroloculina antillarum* d'Orbigny, *in* Ramon de La Sagra, Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, France, p. 166, pl. 9, figs. 3, 4. Recent, Cuba and Jamaica.

1944. *Spiroloculina antillarum* d'Orbigny. Cushman and Todd, Cushman Lab. Foram. Research Special Pub. 11, p. 44, pl. 6, figs. 28–32. Recent, West Indies.

This species is rare, and rather sporadic in occurrence, but was found most consistently in the outer zone. It is probably (Cushman, 1922, p. 66) conspecific with *S. subpoeyana* (Cushman).

Streblus beccarii (Linne) var. sobrinus (Shupack)

Plate 30, figure 7

1931. *Rotalia beccarii* (Linne) var. *parkinsoniana* (d'Orbigny). Kornfeld, Stanford Univ., Dept. Geology, Contr., v. 1, no. 3, p. 90, pl. 13, fig. 1. Recent, Texas and Louisiana.

1934. *Rotalia beccarii* (Linne) var. *sobrina* Shupack, Am. Mus. Novitates, no. 737, p. 6, fig. 4. Recent, Pleistocene, New York harbor.

This variety is characteristic of the nearshore area, making up more than 20 percent of the foraminiferal constituents out to a depth of about 55 feet *Streblus beccarii* (Linne) var. *tepidus* (Cushman) was included with this variety in the statistical study because the two varieties have the same distribution.

Streblus rolshauseni (Cushman and Bermudez)

Plate 30, figure 5

1946. *Rotalia rolshauseni* Cushman and Bermudez, Cushman Lab. Foram. Research Contr., v. 22, p. 119, pl. 19, figs. 11–13. Recent, Gulf of Mexico.

The holotype of this species was reported from a depth of 83 feet off the Rio Grande. In the present study it was found to be common in shallow water, more rare offshore, and to disappear at a depth of about 80 feet.

Textularia candeiana d'Orbigny

Plate 29, figure 2

1839. *Textularia candeiana* d'Orbigny, *in* Ramon de la Sagra, Histoire physique et naturelle de l'Ile de Cuba. A. Bertrand, Paris, France, p. 143, pl. 1, figs. 25–27. Recent, Cuba and Jamaica.

1948. *Textularia candeiana* d'Orbigny. Parker, Harvard Coll. Mus. Comp. Zoology Bull., v. 100, no. 2, 240, pl. 2, fig. 5. Recent, continental shelf between Maine and Maryland.

This species is sporadic in occurrence but seems to be most abundant on the prominences. Its greatest abundance is on prominence 4 (fig. 7). Parker (in the reference above) indicates that this species occurs in his zone 3 (90–300 meters) along the Atlantic coast, but is very rare.

Textularia mayori Cushman

Plate 29, figure 3

1922. *Textularia mayori* Cushman, Carnegie Inst. Washington Pub. 311, p. 23, pl. 2, fig. 3. Recent, Tortugas region.

It was noted that this species exhibits considerable variation in the length of the spinose projections of the chambers.

Triloculina squamosa Terquem

Plate 28, figure 6

1878. *Triloculina squamosa* Terquem, Soc. geol. France, Mem., ser. 3, tome 1, no. 3, p. 59, pl. 5, fig. 26. Upper Pliocene, Isle of Rhodes.

Several specimens were found which belong in this species; however, because of the rarity of this form and allied arenaceous miliolids, this is the only form figured. In the percentage counts, the arenaceous miliolids were lumped together when it was ascertained that none of them amounted to a significant percentage alone.

Triloculina trigonula (Lamarck) d'Orbigny

Plate 28, figure 5

1804. *Miliolites trigonula* Lamarck, Ann. Nat. Hist. Paris Mus., v. 5, p. 351, no. 3.

1807. *Miliolites trigonula* Lamarck. Lamarck, Ann. Nat. Hist. Paris Mus., v. 9, pl. 17, fig. 4.

1858. *Triloculina trigonula* (Lamarck) d'Orbigny, Ann. Sci. Nat., v. 7, p. 299, no. 1, pl. 16, figs. 5–9.

1929. *Triloculina trigonula* (Lamarck) d'Orbigny. Cushman, U. S. Natl. Mus. Bull. 104, pt. 6, p. 56, pl. 12, figs. 10, 11; pl. 13, figs. 1, 2.

This is a rare sporadic species in the samples studied. There is considerable variation in the angularity of the test; it is quite angular in some specimens and rounded in others.

Virgulina schreibersiana Czjzek

Plate 31, figure 10

1848. *Virgulina schreibersiana* Czjzek, Haidinger's Naturwiss. Abb., Band 2, p. 11, pl. 13, figs. 18–21. Miocene, Vienna Basin.

1937. *Virgulina schreibersiana* Czjzek. Cushman, Cushman Lab. Foram. Research Special Pub. 9, p. 13, pl. 2, figs. 11–20.

This species was rather common at some of the stations, particularly in the outer zone.

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PLATE 28

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4. *Quinqueloculina subquadra* Hada (p. 138).
Hypotype, USNM 547607, station 83. *a*. *c*, opposite sides; *b*, apertural view, × 68.

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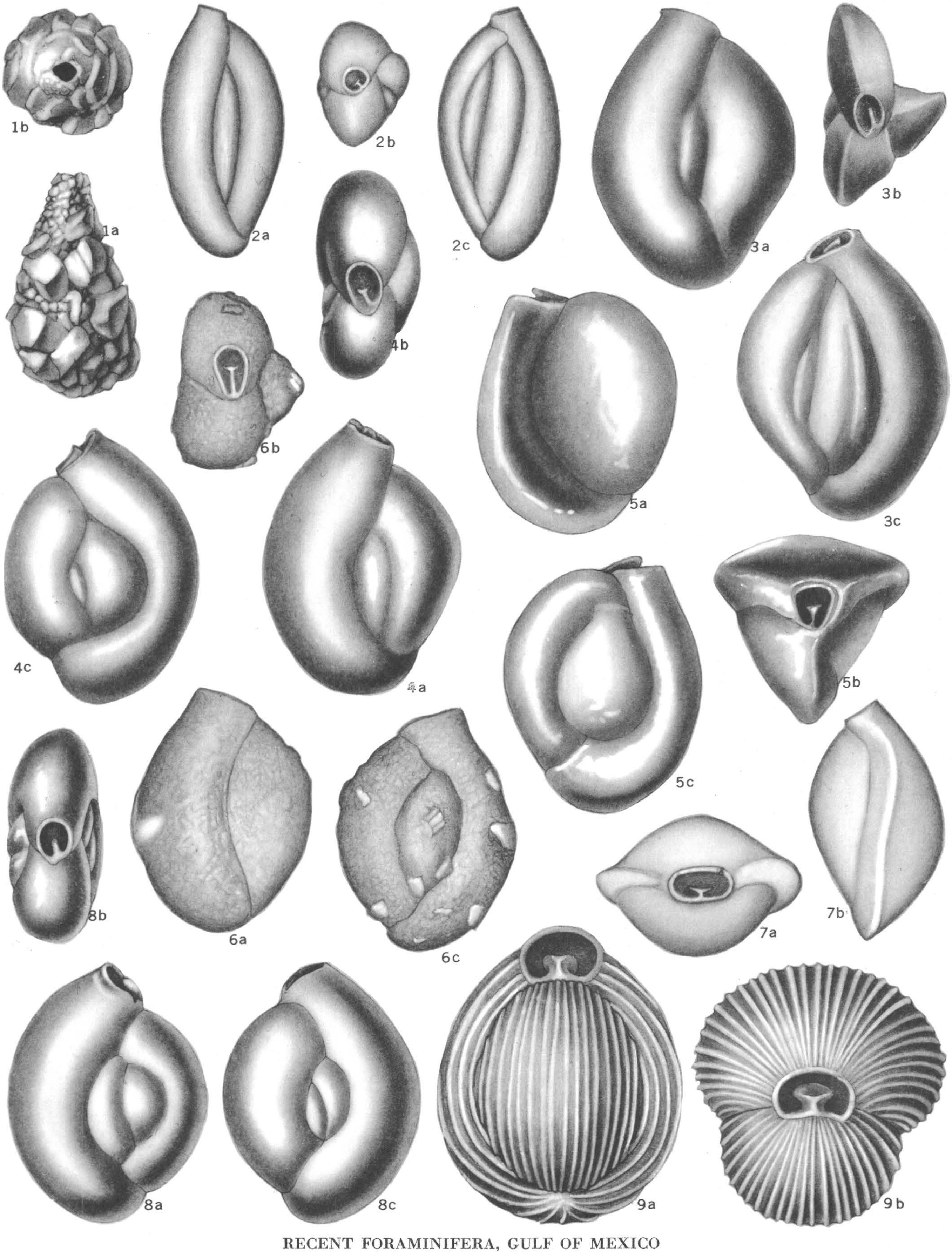

RECENT FORAMINIFERA, GULF OF MEXICO

PLATE 29

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RECENT FORAMINIFERA, GULF OF MEXICO

PLATE 30

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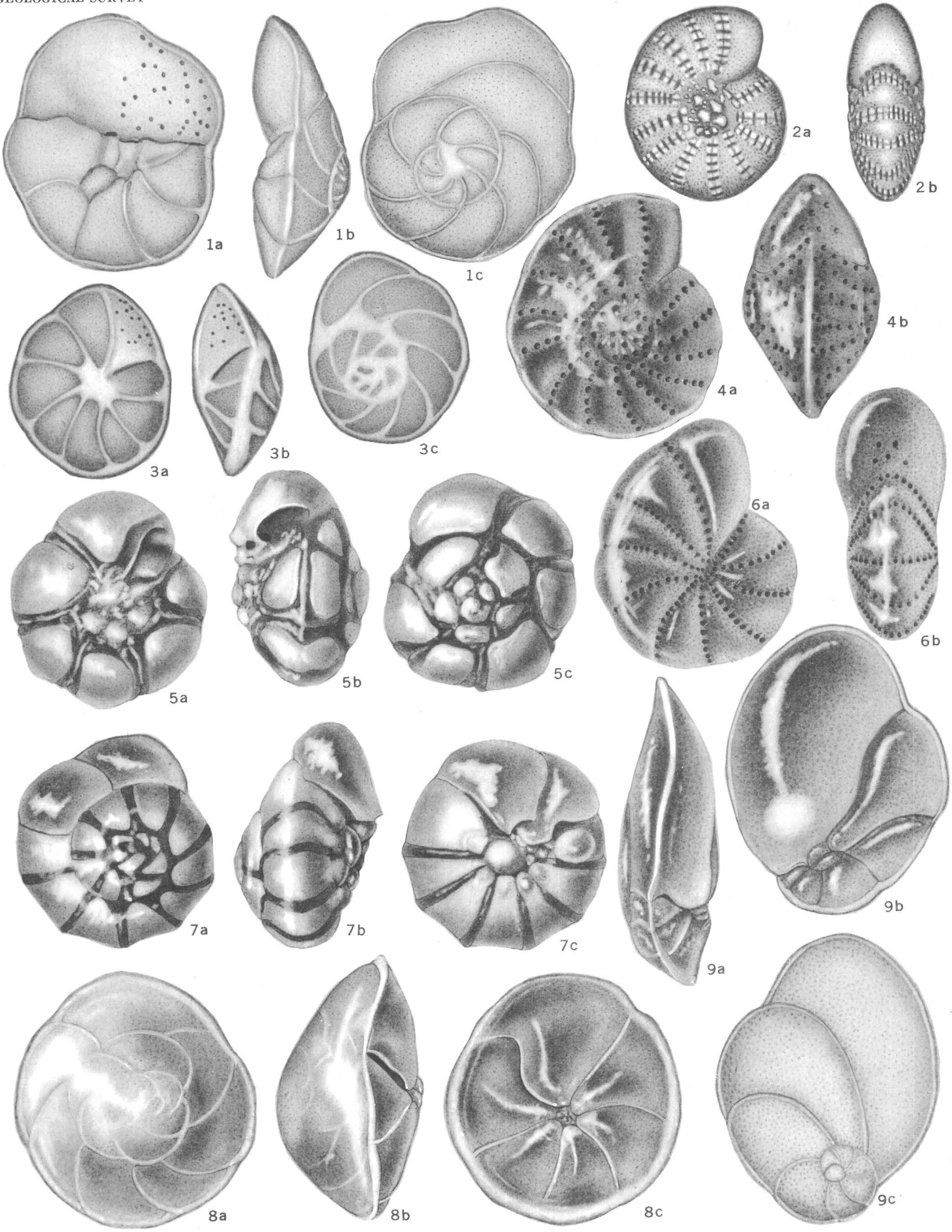
Hypotype, USNM 547591, station 58. *a*, side view; *b*, edge view. × 94.

7. *Streblus beccarii* (Linne) var. *sobrinus* (Shupack). (p. 138)
Hypotype, USNM 547611, station 21. *a*, dorsal view; *b*, edge view; *c*, ventral view. × 100.

8. *Eponides antillarum* (d'Orbigny) Cushman. (p. 136)
Hypotype, USNM 547592, station 97. *a*, dorsal view; *b*, apertural view; *c*, ventral view. × 87.

9. *Cancris sagra* (d'Orbigny) Cushman. (p. 136)
Hypotype, USNM 547585, station 182. *a*, edge view, *b*, ventral view; *c*, dorsal view. × 100.



RECENT FORAMINIFERA, GULF OF MEXICO

PLATE 31

FIGURE 1. *Discorbis floridanus* Cushman. (p. 136)
Hypotype, USNM 547587, station 15. *a*, ventral view; *b*, edge view; *c*, dorsal view. × 137.

2. *Planulina ornata* (d'Orbigny) Cushman. (p. 137)
Hypotype, USNM 547601, station 187. *a*, vental view; *b*, edge view; *c*, dorsal view. × 63.

3. *Planorbulina mediterranensis* d'Orbigny. (p. 137)
Hypotype, USNM 547600, station 183. *a*, ventral view; *b*, edge view; *c*, dorsal view. × 63.

4. *Hanzawaia strattoni* (Applin). (p. 136)
Hypotype, USNM 547586, station 83. *a*, ventral view; *b*, apertural view; *c*, dorsal view. × 87.

5. *Asterigerina carinata* d'Orbigny. (p. 135)
Hypotype, USNM 547581, station 192. *a*, dorsal view; *b*, apertural view; *c*, ventral view. × 63.

6. *Globigerinoides rubra* (d'Orbigny) Cushman. (p. 136)
Hypotype, USNM 547593, station 179. *a*, ventral view; *b*, edge view; *c*, dorsal view. × 87.

7. *Reussella atlantica* Cushman. (p. 138)
Hypotype, USNM 547610, station 81. *a*, side view; *b*, apertural view. × 100.

8. *Rectobolivina advena* (Cushman). (p. 138)
Hypotype, USNM 547609, station 81. *a*, side view; *b*, apertural view. × 100.

9. *Bolivina striatula* Cushman. (p. 135)
Hypotype, USNM 547584, station 94. *a*, side view; *b*, apertural view. × 210.

10. *Virgulina schreibersiana* Czjzek. (p. 139)
Hypotype, USNM 547619, station 81. *a*, side view; *b*, apertural view. × 100.

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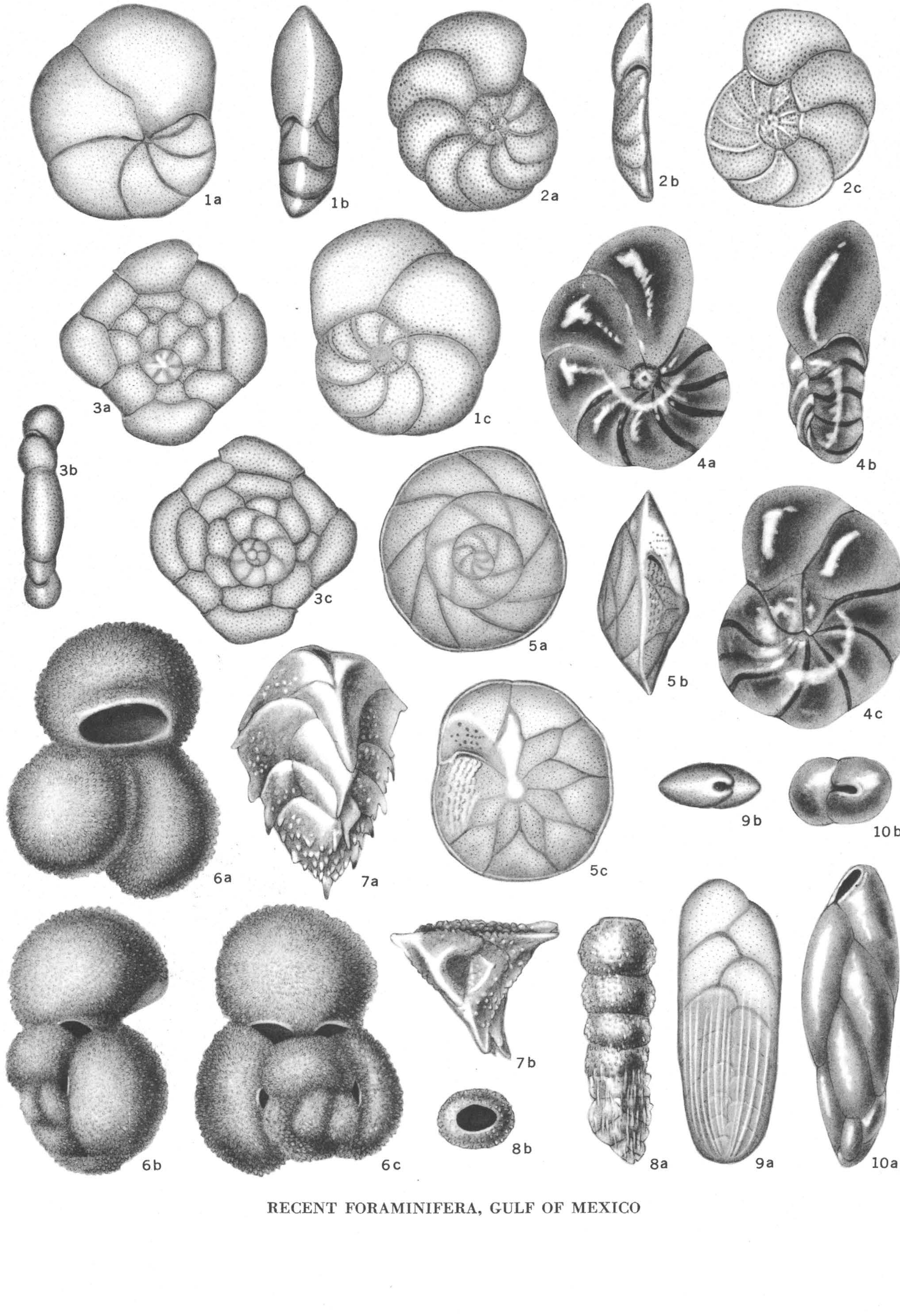

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