FORAMINIFERAL POPULATIONS AND FAUNAS IN BARRIER-REEF TRACT AND LAGOON, BRITISH HONDURAS[1]

DONALD E. CEBULSKI[2]

Donald Cebulski died in an automobile accident at Shark Bay, Western Australia, in July 1965. The work which formed the basis of this paper was done during the tenure of a studentship at Texas A & M University, 1959–1961. The manuscript, which was incomplete at the time of the author's death, was finished by Brian W. Logan, Department of Geology, The University of Western Australia, Nedlands, Western Australia.

ABSTRACT

Analysis of foraminiferal faunas in 89 sediment samples from the barrier reef and lagoon of British Honduras showed that the largest living and total foraminiferal populations are on the leeward side of mangrove and coral-sand cays in the reef tract, and in the lagoon near the mouths of rivers.

The living Foraminifera were divided into the barrier-reef-tract and lagoon faunas, reflecting the two major environments of the area. The reef-tract fauna was divided further into the main-reef, reef-margin, and reef-channel assemblages.

Temperature and salinity measurements of 41 bottom-water samples indicated a decrease in temperature and an increase in salinity from the mainland toward the barrier reef.

INTRODUCTION

This paper is a summary of a study of modern foraminiferal populations in the coastal areas of British Honduras. This region, which is characterized by a humid, tropical hinterland and major rivers, is bordered by an extensive barrier-reef-tract and lagoonal complex.

The objectives of the study were (1) to compare the patterns of distribution of living and total (living and dead) foraminiferal populations in the barrier-reef-tract and lagoon environments; (2) to determine the foraminiferal assemblages characteristic of the reef and lagoon floor; and (3) to measure certain ecologic factors which may have controlled the distribution of living foraminiferal populations. This information may be useful in the interpretation of environments from ancient reef and lagoon desposits.

PREVIOUS WORK

Recent Foraminifera from the coastal area of British Honduras had not been investigated previously, although there are numerous publications on Foraminifera from adjacent areas in the West Indian zoogeographic province. The earliest of these works were the taxonomic papers of d'Orbigny (1839) and Brady (1884). Later studies were made by Vaughan (1918), Cushman (1921, 1922, 1926), Cushman and Brönimann (1948a, b), Kornfeld (1931), and Saunders (1957, 1958); these papers include ecologic data concerning water depth and substrate.

Ecologic works on West Indian Foraminifera are by Bandy (1954, 1956), Lankford (1959), Lehmann (1957), Moore (1957), Parker *et al.* (1953), Phleger (1954, 1955, 1956, 1960), Phleger and Lankford (1957), Phleger and Parker (1951), Post (1951), and Walton (1960). Most of these investigations concern the distribution of living and dead foraminiferal populations and environmental parameters.

[1] Manuscript received, March 20, 1967.

[2] Deceased, July 1965. Department of Geology, The University of Western Australia, Nedlands, Western Australia.

This study was supported by the Office of Naval Research Contract N7onr 487(02) to the Department of Oceanography and Meteorology, Texas A&M University, and by the shipboard training fund of Texas A&M University. Appreciation is extended to Brian W. Logan for his assistance in supervising this study. The writer also thanks Richard G. Bader for arranging financial assistance, and for suggestions and criticisms concerning the original draft. Karl J. Koenig and Fred L. Smith critically read the manuscript. Appreciation is extended to Lee M. Hunt for supplying the writer with sediment data and to Capt. Homer Hadley and the crew of the R/V *Hidalgo* for their efforts in the collection of the samples. F. Sullivan and E. Chiburis aided in the preparation of the photomicrographs.

Fro. 1.—Location of British Honduras and area studied.

The general geology of the British Honduras area is described by Ower (1928), Dixon (1957), and Flores (1952). The bathymetry and physiography of the barrier reef and lagoon are described by Vermeer (1959); Stoddart (1962) gives a comprehensive account of the geology of the barrier-reef zone.

DESCRIPTION OF AREA

British Honduras is a crown colony in Central America which shares borders with Mexico on the north and Guatemala on the south; the country is bounded on the east by the Caribbean Sea (Fig. 1). The coastal region of British Honduras is subdivided into three major physiographic zones: a zone of coastal swamps, a reef lagoon, and a barrier-reef tract. The hinterland is humid and is drained by numerous major rivers which open either into the coastal swamps or directly into the main lagoon. The chief rivers, from north to south, are the Belize, Sibun, Manatee, and Sarstoon.

The barrier-reef tract is fronted on the Caribbean side by an almost continuous reef wall composed of skeletons of *Acropora* and other coral communities (Stoddart, 1962). This wall rises into the surf zone and forms a barrier to incoming waves from the Caribbean Sea. Leeward from the reef wall is a wide "reef flat" characterized by extensive seagrass meadows, coral knolls, and emergent mangrove cays. The shape of the reef tract, a series of broad arcs, is probably a reflection of underlying structure; the reef is thought to be situated on the margins of large fault scarps which plunge to abyssal depths in the Gulf of Honduras (Stoddart, 1962). The reef tract is terminated on the south where it breaks up into a series of isolated patch reefs and microatolls. About 15 mi southeast of Belize, Eastern Channel, with an average depth of about 100 ft, meanders through the reef tract. Dixon (1957) suggests that this channel is a drowned river valley and, following Ower (1928), considers it to be the former path of the Belize or Sibun River.

The lagoon is between the mainland and the barrier reef. It is approximately 90 mi long and averages about 17 mi in width. According to Vermeer (1959), the Belize Harbor segment of the lagoon is a basin, partly closed on the south by two westward projections of the barrier reef. South of Belize Harbor the lagoon is an oblong basin which gradually narrows toward the south and opens again into the Gulf of Honduras.

The lagoon floor deepens gradually from the mainland shore; maximum depths are adjacent to the leeward margin of the reef tract. There is also a general deepening of the lagoon floor from north to south. Within Belize Harbor, the water deepens from the mainland toward the reef to a maximum depth of 42 ft. South of Belize Harbor the water deepens toward the barrier reef and has a depth of 72 ft about 12 mi from the mainland. Despite the depth variation caused by the presence of the numerous coral banks and patch reefs in the southern lagoon, there is a general deepening toward the barrier reef to a maximum depth of 120 ft near the reef. In a north-south direction, from Belize Harbor to the southernmost part of the lagoon, the water deepens from 42 to 120 ft in a distance of nearly 90 mi, an average north-south slope of slightly more than 1 ft/mi (Fig. 2).

METHOD OF STUDY

Collection of samples.—Eighty-nine sediment samples and 41 samples of bottom water were collected from the reef tract and lagoon. Station locations are shown on Figure 3. Three types of sampling equipment were used to collect the sediment samples. The lagoon samples (excluding those from Belize Harbor) were collected with a 2-in.-diameter gravity coring tube. Samples from

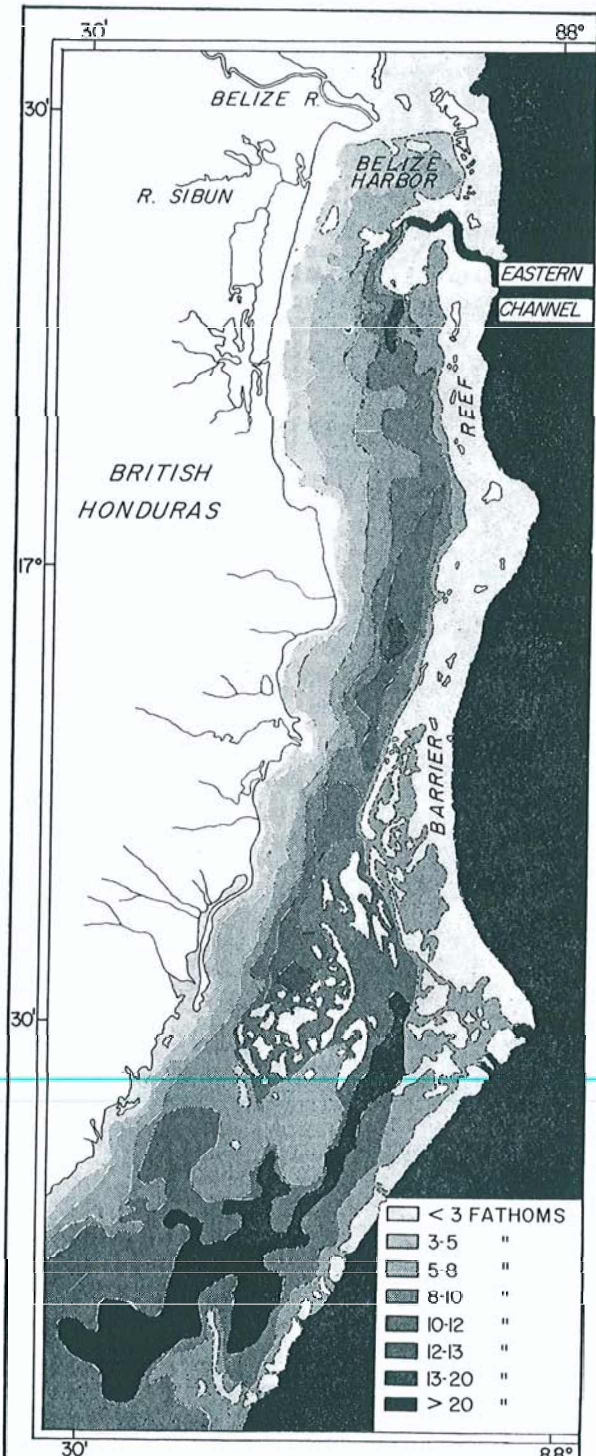

FIG. 2.—Generalized bathymelric chart.

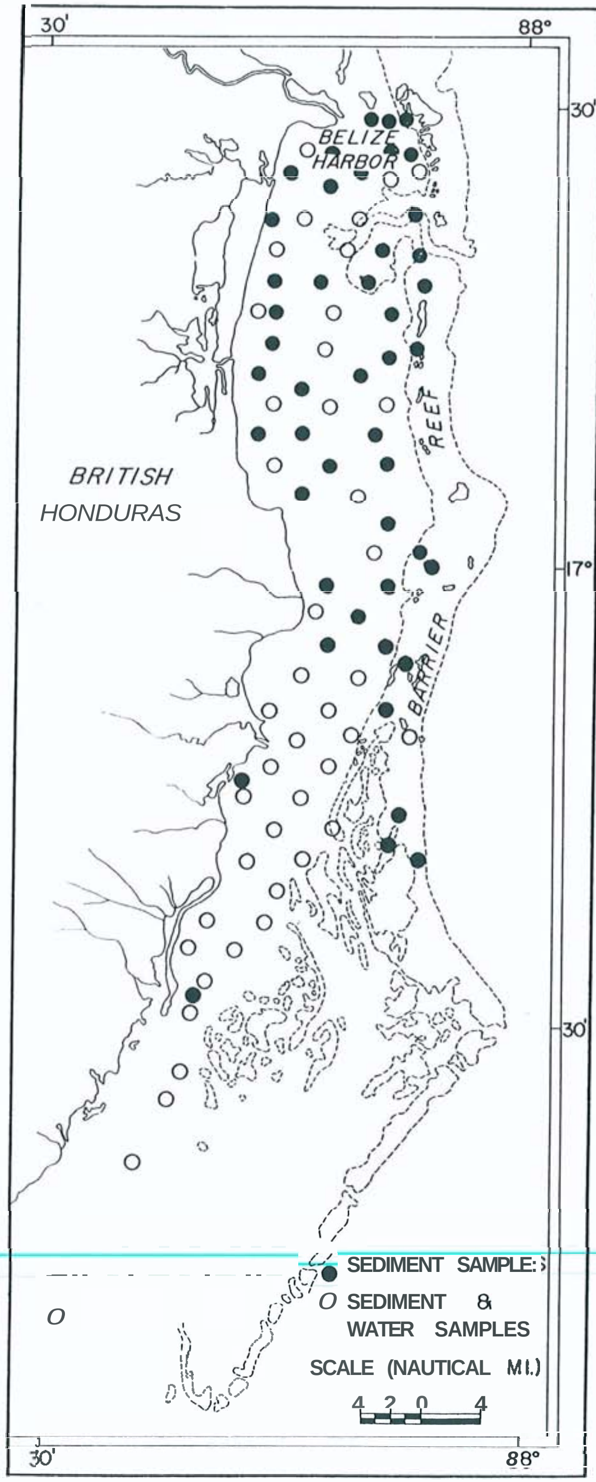

FIG. 3.—Locations of stations.

Belize Harbor and some from the barrier reef were collected from a small boat by use of a smaller coring tube 18 in. long and 1⅜ in. in diameter. Because of the nature of the substratum it was impossible to core in the barrier-reef tract, and a small Van Veen sampler was used.

Before a core was extruded from the core liner, the water was siphoned off carefully to 1 in. above the sediment-water interface. The remaining water was poured into a sample jar and the core was extruded partially from the liner. A constant-volume device, patterned after the one described by Walton (1955), was used to separate the top 1 cm from the rest of the core. The sediment sample was placed in the sample jar with the previously collected water, and alcohol was added to preserve the protoplasm of the living foraminifers. It was impossible to use this procedure for samples collected by means of the Van Veen sampler. Instead, the constant-volume device was filled with sediment carefully removed from the top of the sampler.

Laboratory methods.—Procedures in the laboratory consisted of identifying the foraminifers, determining the living and total foraminiferal populations, and photographing some of the more important foraminiferal species.

Three operations were necessary to determine the living and total foraminiferal populations in each sample: (1) the protoplasm of the living specimens in each sediment sample was stained with rose bengal by a method similar to that of Walton (1952); (2) the stained foraminifers in each sediment sample were identified and counted; and (3) all of the specimens, living or dead, in each sediment sample were identified and counted. The term "living foraminifers" refers to specimens which contained protoplasm at the time of sampling; "dead foraminifers" refers to specimens which did not contain protoplasm at the time of sampling. To facilitate the counting procedure, the foraminifers were concentrated by use of carbon tetrachloride. If the populations in any fraction were very large, they were split by means of an Otto microsplitter (Otto, 1933). No fraction was split more than four times.

The foraminifers considered significant for determining the various assemblages in the barrier reef and lagoon were photographed (Pls. I-III). The photomicrographic unit employed consisted of a Zeiss GFL Pol microscope and universal camera attachment. The film used was Polaroid Pola Pan, Type 62; the sources of illumination were microscope lamps. The procedure suggested by Fournier (1956) was used to clean and stain the specimens.

Sediment analyses were limited to determining the relative percentages of sand-, silt-, and clay-size constituents in each barrier-reef sample. Standard methods of sieve and pipette analysis were used (Krumbein and Pettijohn, 1938). In addition, Lee M. Hunt, of the National Academy of Science, Washington, D.C., made available lithologic descriptions and sediment grain-size data for samples collected from the lagoon.

Temperature, Salinity, and Sediments

Temperature.—The range of bottom-water temperature in the lagoon is about 3°C. The highest temperature, 30.8°C, was recorded in Belize Harbor and the lowest, 27.6°C, in the southern lagoon (Fig. 4). In general, bottom-water temperature decreases from north to south and from the mainland toward the barrier reef, corresponding to increasing water depth.

Salinity.—The range in salinity of bottom water in the lagoon is about 3 parts per thousand. The highest and lowest salinity values recorded were 36.4 parts per thousand near the reef tract and 33.1 parts per thousand near the mainland (Fig. 5). There appears to be a definite gradation of salinity within the lagoon, decreasing from the barrier reef toward the mainland. The lower salinity near the mainland probably is the result of dilution by fresh water supplied by the streams which empty into the lagoon. The bottom-water samples were collected near the end of the local rainy season.

Bottom sediments.—The patterns of sediment distribution in the reef tract and lagoon are shown in Figure 6. The reef tract is an area of biogenic (carbonate) sedimentation, and the main bottom types are biohermal limestone, skeletal calcarenite, and calcilutite. The lagoonal sediments are mainly terrigenous silts and clays that include varied quantities of skeletal debris derived from autochthonous, shell-secreting communities. Apparently, little reef-derived material is being deposited in the lagoon, possibly because seagrasses in the reef tract stabilize sediment and prevent dispersal into leeward areas.

Skeletal calcarenites are the main sediments in the northern part of the reef tract; these sands are also common in the southern part of the reef, near the leeward margin, and on the flanks of the coral patch reefs and microatolls. The sediments within the seagrass meadows of the reef tract are mainly calcilutites. The bottom sediments adjacent to the mouths of the Belize and Sibun Rivers are composed of shelly silt. This sediment is found also on the flanks of the reef tract in the southern parts of the lagoon. Silty clays are present in the northern lagoon and increase in abundance southward.

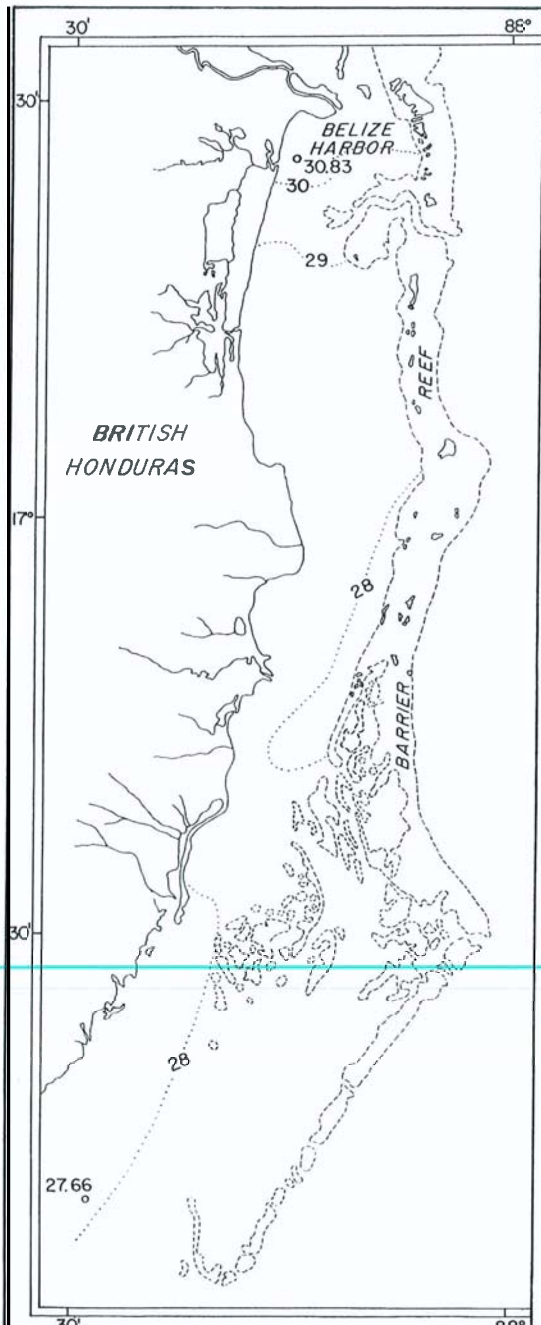

FIG. 4.—Generalized distribution of bottom-water temperature in degrees centigrade,

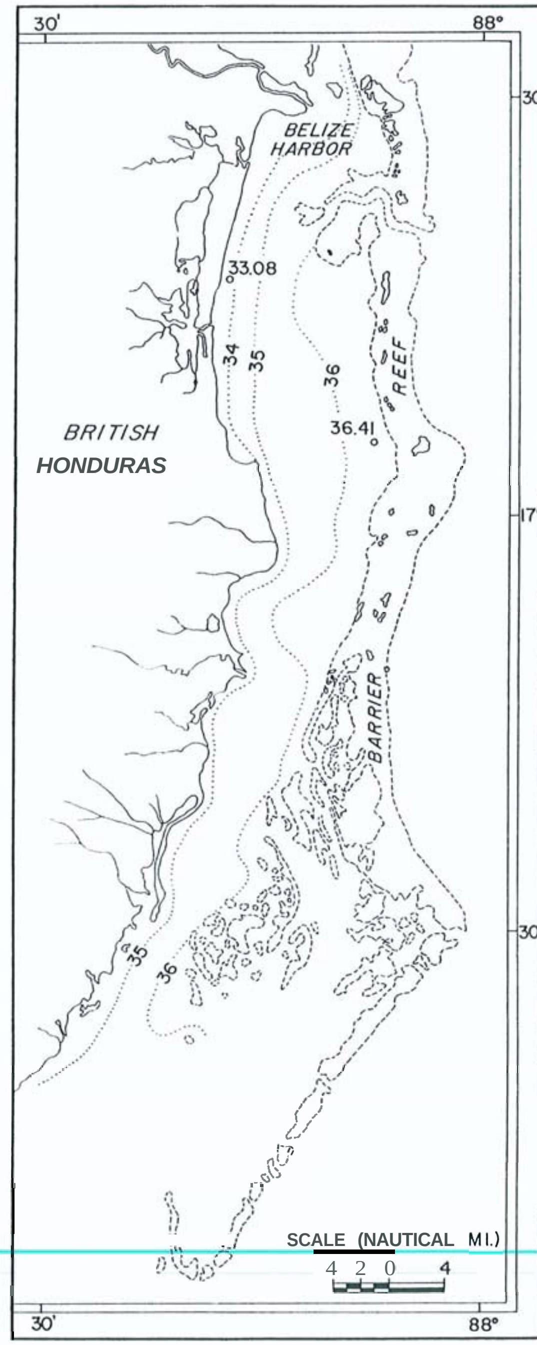

FIG. 5.—Generalized distribution of bottom-water salinity in parts per thousand.

LIVING FORAMINIFERAL POPULATIONS

Barrier-reef tract.—Samples collected from

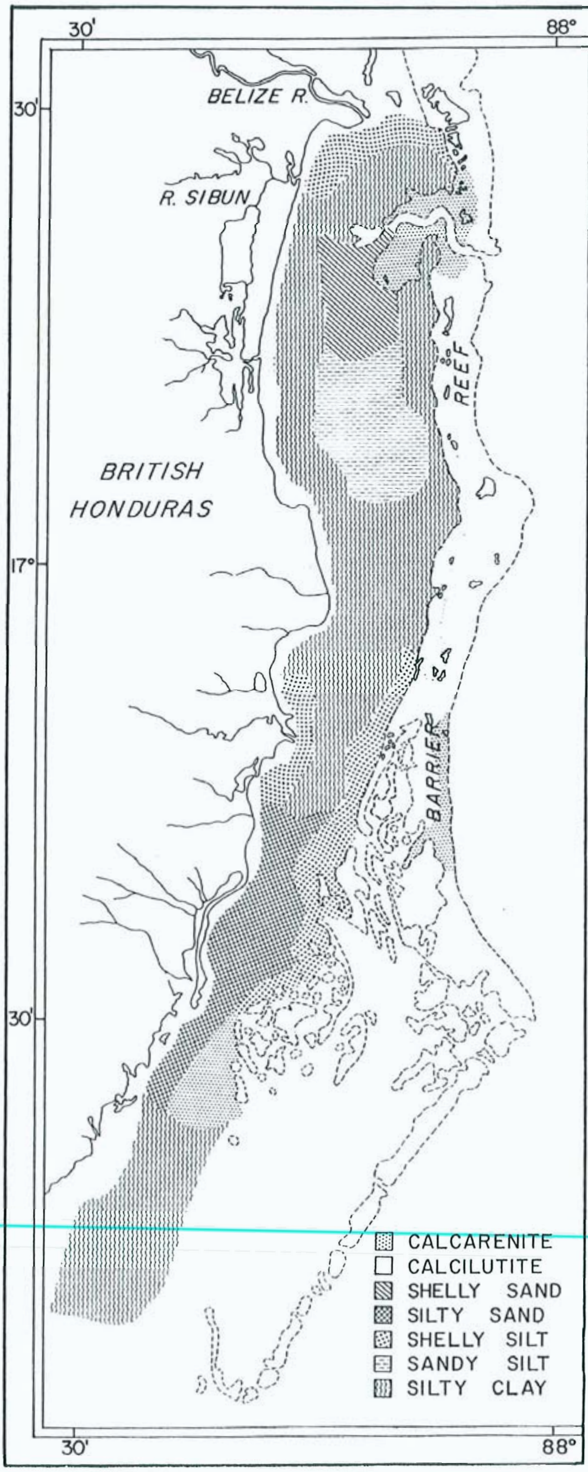

FIG. 6.—Areal distribution of sediment types.

the leeward side of mangrove or coral-sand cays had the largest living foraminiferal populations; there were approximately 1,000–2,800 specimens per 10 ml of wet sediment. The largest living population (2,784) was found at station 11A (Fig. 7).

The smallest living populations were found in open areas remote from mangrove and coral-sand cays. The range in these areas is 100–500 specimens per 10 ml of wet sediment. Sediment sam-

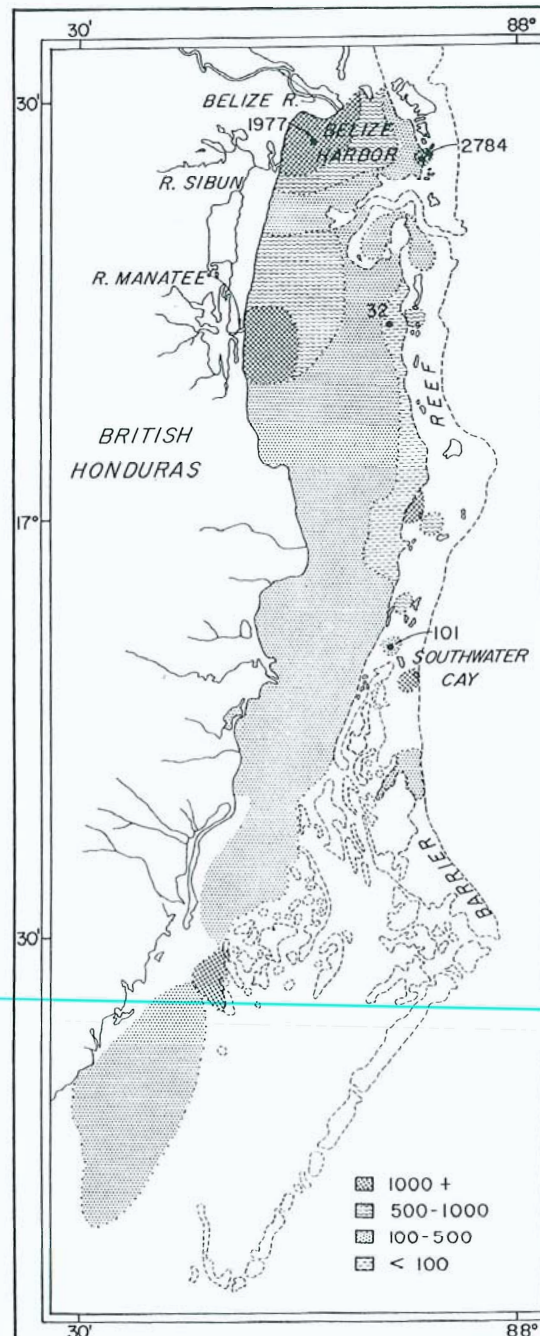

FIG. 7.—Areal distribution of living populations expressed as numbers of specimens per 10 ml of wet sediment.

ples collected from the windward side of some cays had smaller living populations than those from stations leeward from cays. The living populations at these stations range from 500 to 1,000 specimens per 10 ml of wet sediment (Fig. 7).

Lagoon.—The largest living foraminiferal populations in the lagoon were found near the mouths of the Belize, Sibun, and Manatee Rivers, and near the maze of coral banks in the southern lagoon. The living populations in these areas are larger than 1,000 specimens per 10 ml of wet sediment. From the mouth of the Belize River to the mouth of the Manatee River, the coastline is fringed by mangrove swamp. The Belize, Sibun, and Manatee Rivers cross this swamp and could transport an abundance of nutrient materials into the lagoon, especially during seasons of high rainfall. Phleger (1956) and Lankford (1959) found relatively large living populations in areas of river discharge. The standing crops recorded by Phleger near the effluent of the Guadalupe River, which drains into San Antonio Bay on the Central Texas Gulf Coast, were similar in magnitude to those recorded in this study. The standing crops in the East Mississippi Delta area, recorded by Lankford, were larger than those recorded in this study. In Belize Harbor the living populations decrease in number from the mainland toward the barrier reef. Sediment samples collected from approximately midharbor had living populations that ranged from 500 to 1,000 specimens per 10 ml of wet sediment; samples collected closer to the barrier reef had 100–500 specimens per 10 ml (Fig. 7).

The living populations in the rest of the lagoon have a distribution pattern similar to that observed in Belize Harbor, decreasing in number from the mainland toward the barrier reef. The sediment samples collected adjacent to the barrier reef, south of the westward projections of the reef, had living populations of less than 100 specimens per 10 ml of wet sediment.

Total Foraminiferal Populations

Barrier-reef tract.—The distribution of total populations in the barrier-reef tract roughly parallels the distribution of living populations in the same area. The sediment samples collected on the leeward side of cays had total populations in excess of 10,000 specimens per 10 ml of wet sediment. The largest single total population recorded was 37,966 living and dead specimens leeward from Southwater Cay; the smallest total population, 501 specimens at station 17A, was in an area remote from mangrove or coral-sand cays (Fig. 8).

Lagoon.—The distribution pattern for total populations in the lagoon is opposite, in part, to the distribution of living populations in the same area. The largest total population, 24,677 specimens at station 9, was found near the mouth of the Sibun River (Fig. 8). Total populations near the effluents of the Belize and Sibun Rivers are higher than total populations elsewhere in the lagoon. The range near the river mouths is 5,000–10,000 specimens' per 10 ml of wet sediment (Fig. 8). The largest living populations in the lagoon also were found near the mainland, between the Belize and Manatee Rivers, and in this respect distributions of the living and total populations in the lagoon agree.

In Belize Harbor the total population decreases in number toward the barrier reef, parallel with the distribution trends of living-population numbers in that area. Elsewhere in the lagoon (excluding the few samples collected near the mouth of the Manatee River), the total populations increase from the mainland toward the barrier reef —a trend which is the reverse of the distribution of living populations in the lagoon. Sediment samples collected near the reef had total populations in the range of 2,500–5,000 specimens per 10 ml of wet sediment. Stations adjacent to the mainland between Stann Creek and Tonathan Point had total populations of less than 1,000 specimens per 10 ml of wet sediment (Fig. 8).

The relatively large total populations in the near-reef lagoon are probably the result of a slower rate of sedimentation in that area, which permitted the accumulation of dead specimens. It is not likely that these large total populations can be attributed to greater foraminiferal productivity in the near-reef area, because the largest standing crops of living foraminifers are near the mainland and the smallest are adjacent to the reef. Considering the slope of the lagoon floor, it is possible that dead specimens were transported

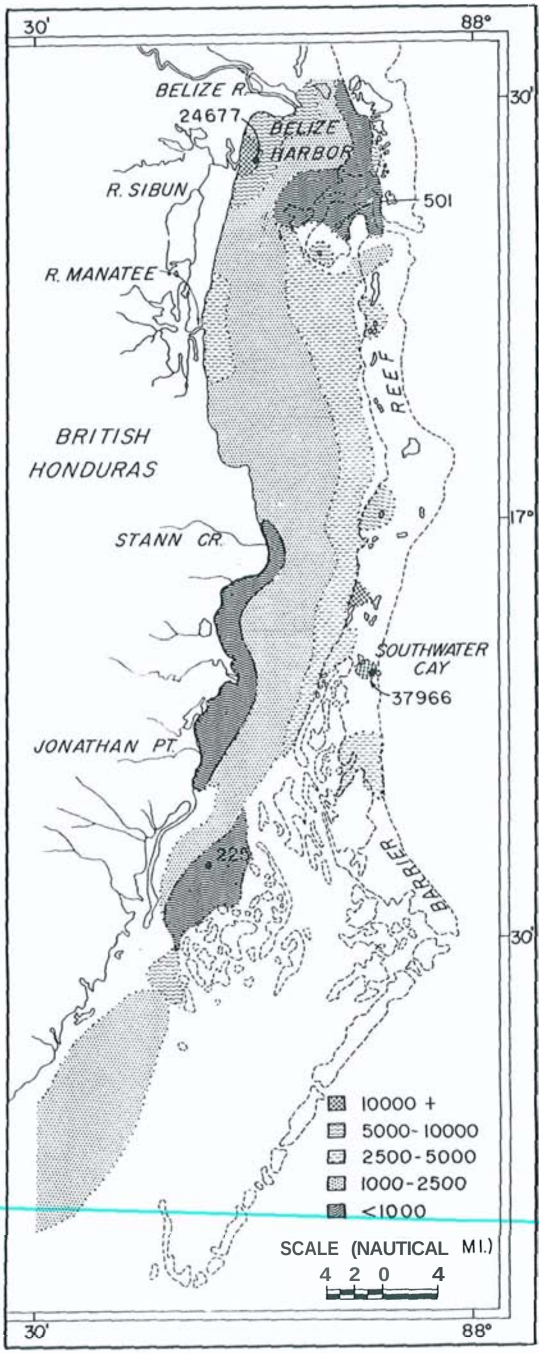

FIG. 8.—Areal distribution of total (living and dead) populations expressed as numbers of specimens per 10 ml of wet sediment.

downslope from areas of high productivity near the mainland to areas of low productivity in the reef area. Postmortem transportation from the reef tract to the adjacent parts of the reef lagoon is possible also, but is unlikely because very few dead specimens of forms indigenous to the barrier reef were found in the lagoon.

LIVING FORAMINIFERAL FAUNAS

The living foraminifers were divided into the reef-tract and lagoon faunas, reflecting the two major environments of the area. The reef-tract fauna was subdivided into three assemblages on the basis of the presence or absence of certain species or the variation in abundance of certain species.

REEF-TRACT FAUNA

The reef-tract fauna is characterized by (1) the presence of species of the families Alveolinellidae, Amphisteginidae, Cymbaloporidae, and Peneroplidae, which were found living only in the reef-tract area; (2) the abundance and diversity of the family Miliolidae; and (3) the overall diversity of the fauna in comparison with the lagoon fauna. All of the living foraminiferal species identified from both the reef-tract and lagoon environments were present in the barrier-reef fauna; however, only 22 of the total of 70 species identified contributed to the lagoon fauna. The reef-tract fauna was divided into the main-reef, reef-margin, and reef-channel assemblages.

Main-reef assemblage.—The main-reef assemblage is characterized by the presence of *Articulina mucronata, Archaias angulatus, Asterigerina carinata, Borelis pulchra, Cymbaloporetta squammosa, Neoconorbina orbicularis, Quinqueloculina subpolygona, Triloculina carinata, T. linneiana* and *Valvulina oviedoina.*

Living specimens of these species were found only in the reef tract; therefore, they are considered diagnostic of that environment (Fig. 9). A few samples from the lagoon contained dead specimens from the main-reef assemblage (Fig. 10) but no living specimens were found in the lagoon. Figure 12 shows the general distribution of the main-reef assemblage, and photomicrographs of most of the diagnostic main-reef species are shown in Plate I.

Reef-margin assemblage.—The reef-margin assemblage is characterized by *Amphistegina lessonii, Articulina pacifica, Articulina sagra, Discorbis candeiana, Neoconorbina floridensis, Peneroplis carinatus, P. pertusus, P. proteus, Planorbulina acervalis,* and *Sorites marginalis.*

Foraminifera	Main Reef	Marginal Reef	Reef Channel	Lagoon
Articulina mucronata	······			
Archaias angulatus	······			
Asterigerina carinata	······			
Borelis pulchra	······			
Cymbaloporetta squammosa	······			
Neoconorbina terquemi	······			
Quinqueloculina subpolygona	······			
Triloculina carinata	······			
Triloculina linneiana	······			
Valvulina oviedoina	······			
Amphistegina lessonii	······	······		
Articulina pacifica	······	······		
Articulina saqra	······	······		
Discorbis candeiana	······	······		
Neoconorbina floridensis	······	······		
Peneroplis carinatus	······	······		
Peneroplis pertusus	······	······		
Peneroplis proteus	······	······		
Planorbulina acervalis	······	······		
Sorites marginalis	······	······		
Bigenerina irregularis	······	······	═══	
Hanzawaia strattoni	······	······	———	
Textularia agglutinans	······	······	------	······
Textularia candeiana	······	······	------	······
Elphidium discoidale	······	------		———
Elphidium poeyanum	······	———	······	≡≡≡
Nonion grateloupi	······	------	······	———
Streblus beccarii vars.	······	······		------

······ 1-10% ——— 21-30% ≡≡≡ 41-50%
------ 11-20% ═══ 31-40%

FIG. 9.—Significant living foraminiferal species expressed as percent of living population in each faunal assemblage.

Living specimens of these species are present in the main-reef assemblage, but, unlike the species considered diagnostic of that assemblage, the reef-margin species also inhabit parts of the lagoon, marginal to the reef tract. The species *Elphidium poeyanum, Elphidium discoidale, Nonion grateloupi,* and *Streblus beccarii* vars., which are present throughout the barrier reef and lagoon, are of intermediate abundance in the reef-margin areas (Fig. 9). The distribution of the family Miliolidae shows a similar relationship. The miliolids are most common in the barrier-reef tract, least common in the nearshore lagoon (adjacent to the mainland of British Honduras), and of intermediate abundance in the near-reef parts of the lagoon (Fig. 11).

The reef-margin facies is a transitional or "mixed" zone because it contains foraminifers which are found commonly in the reef tract but not in the lagoon, foraminifers which are more abundant in the lagoon than in the reef tract, and foraminifers which are more abundant in the reef tract than in the lagoon.

The reef-margin assemblage is present adjacent

Foraminifera	Main Reef	Marginal Reef	Reef Channel	Lagoon
Articulina mucronata	···········			
Archaias angulatus	···········			
Asterigerina carinata	···········	···········	···········	
Borelis pulchra	···········			
Cymbaloporetta squammosa	···········		···········	···········
Neoconorbina terquemi	···········	···········		···········
Quinqueloculina subpolygona	···········	···········		···········
Triloculina carinata	···········	···········	···········	
Triloculina linneiana	···········	···········		
Valvulina oviedoina	···········	···········	···········	
Amphistegina lessonii	···········	···········		
Articulina pacifica	···········	···········		
Articulina sagra	···········	···········	···········	···········
Discorbis candeiana	- - - - - -	···········	···········	···········
Neoconorbina floridensis	- - - - - -	···········	···········	···········
Peneroplis carinatus	···········	···········	···········	···········
Peneroplis pertusus	···········	···········	···········	···········
Peneroplis proteus	···········	···········	···········	···········
Planorbulina acervalis	···········	···········	···········	
Sorites marginalis	···········	···········		
Bigenerina irregularis	···········	···········	- - - - - -	
Hanzawaia strattoni	···········	···········	════	···········
Textutaria agglutinans	···········	···········	···········	···········
Textularia candeiana	···········	···········	···········	···········
Elphidium discoidale	···········	···········	···········	···········
Elphidium poeyanum	- - - - - -	────	···········	≡≡≡≡
Nonion grateloupi	···········	···········	···········	···········
Streblus beccarii vars.	···········	- - - - - -	···········	────

········ 1-10% ──── 21-30% ≡≡≡≡ 41-50%
- - - - - 11-20% ════ 31-40' ≡≡≡≡ 51-60%

FIG. 10.—Significant total (living and dead) foraminiferal species expressed as percent of total population in each faunal assemblage.

to the barrier reef in the Belize Harbor area and adjacent to part of the reef complex in the southern reaches of the lagoon (Fig. 12). Photomicrographs of the species diagnostic of the assemblage are shown on Plate II.

Reef-channel assemblage.—The reef-channel assemblage is composed of *Bigenerina irregularis, Hanzawaia strattoni, Textularia agglutinans*, and *T. candeiana.*

Living specimens of *Bigenerina irregularis* and *Hanzawaia strattoni* are distributed throughout most of the barrier reef; however, they are much more common in Eastern Channel than elsewhere. *Bigenerina, irregularis* forms 31–40 percent of the living foraminiferal population in Eastern Channel, and *Hanzawaia strattoni* contributes 21–30 percent (Fig. 9). According to Parker *et al.* (1953) and Phleger (1955), *Bigenerina irregularis* and *Hanzawaia strattoni* generally inhabit open-ocean, inner-continental-shelf environments. The depth of water in Eastern Channel averages about 100 ft.

Textularia agglutinans and *Textularia candeiana* were found living throughout the barrier reef and

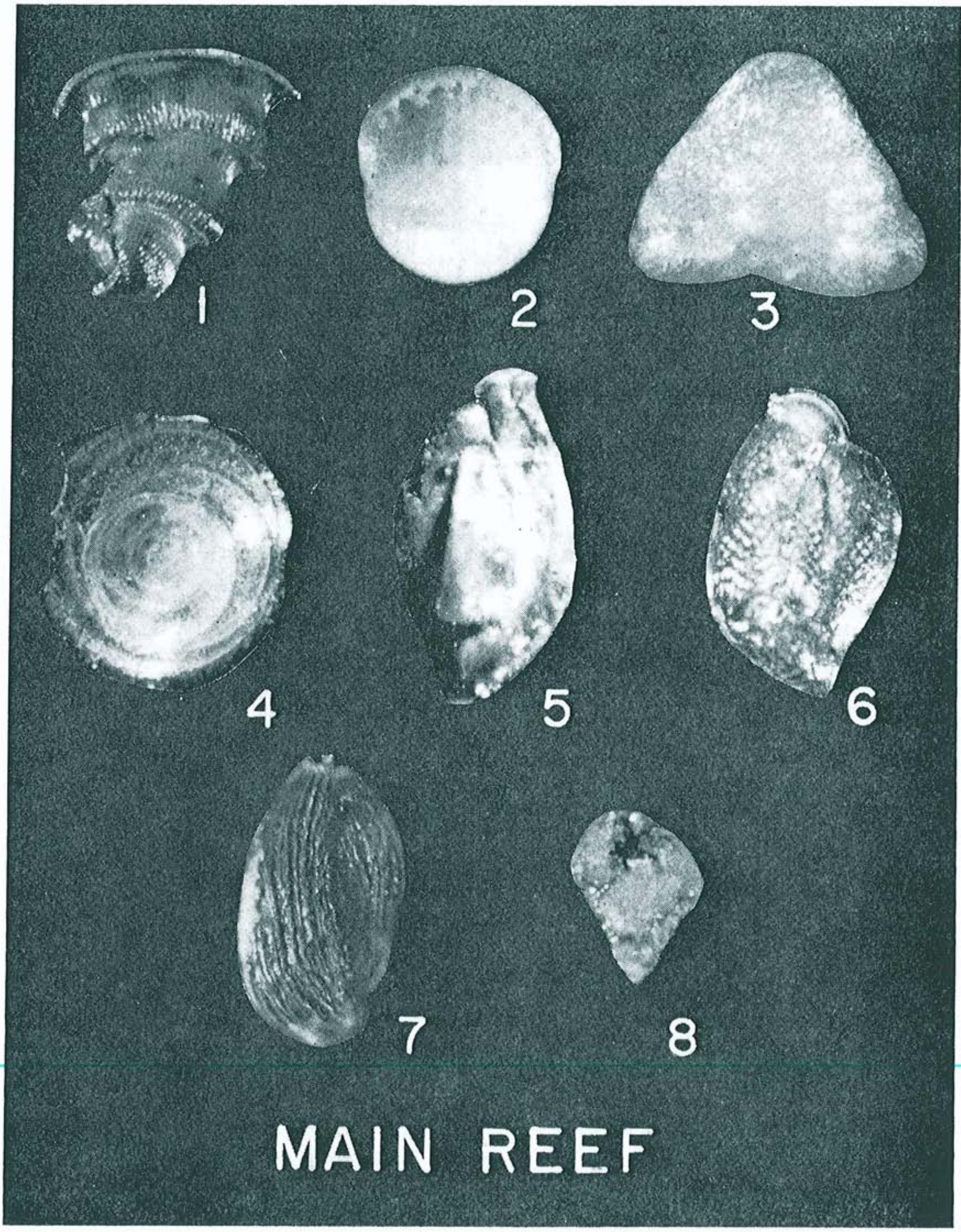

PLATE I. -Main-Reef Assemblage

1. *Articulina mucronata* (d'Orbigny), side view, 22×.
2. *Borelis pulchra* (d'Orbigny), apertural view, 41×.
3. *Cymbaloporetta squammosa* (d'Orbigny), side view, 44×.
4. *Neoconorbina terquemi* (Rzehak), dorsal view, 37×.
5. *Quinqueloculina subpolygona* Parr, side view, 39×.
6. *Triloculina carinata* d'Orbigny, side view, 22×.
7. *Triloculina linneiana* d'Orbigny, side view, 37×.
8. *Valvulina oviedoina* d'Orbigny, side view, 26×.

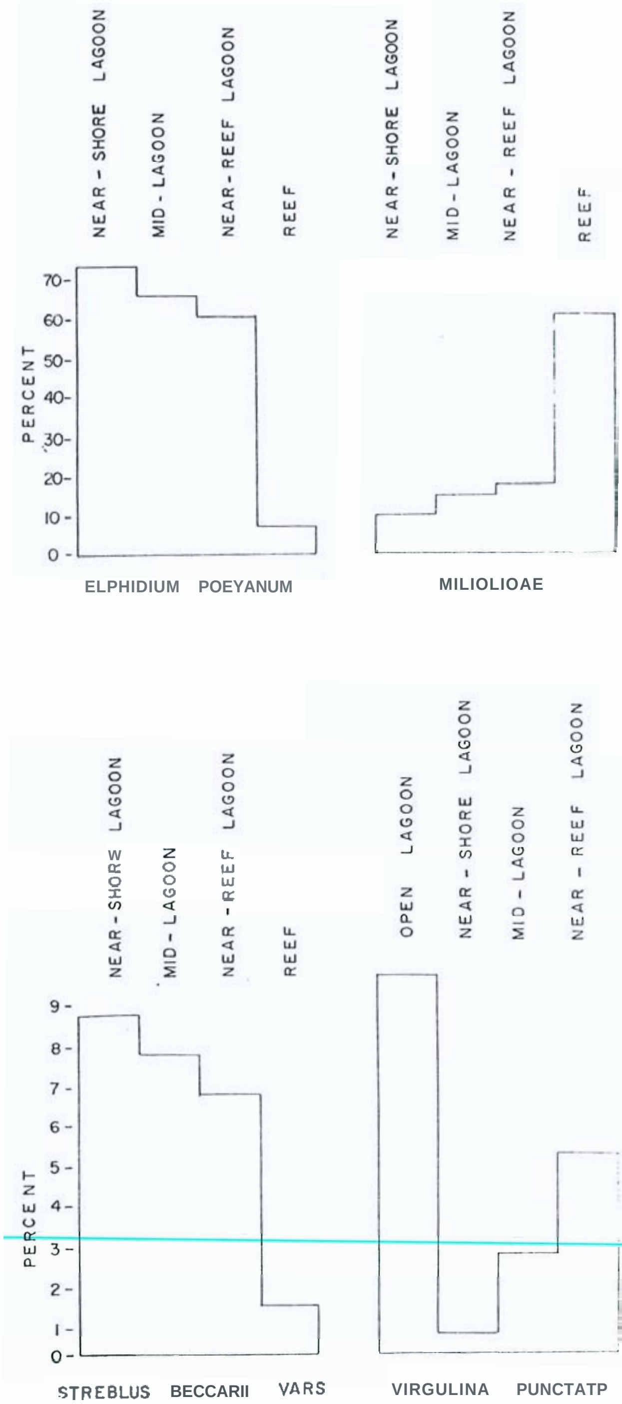

FIG. 11.—Relative mean abundance of some significant living Foraminifera from various geographic areas sampled.

lagoon, but these species are markedly more common in Eastern Channel (Fig. 9).

Dead specimens of *C a d s oblonga* and *Lagena perlucida* also were identified in the Eastern Channel samples. Both of these species are considered (from previous investigations in other areas) to be open-ocean forms. Photomicrographs of the diagnostic reef-channel species are shown on Plate III.

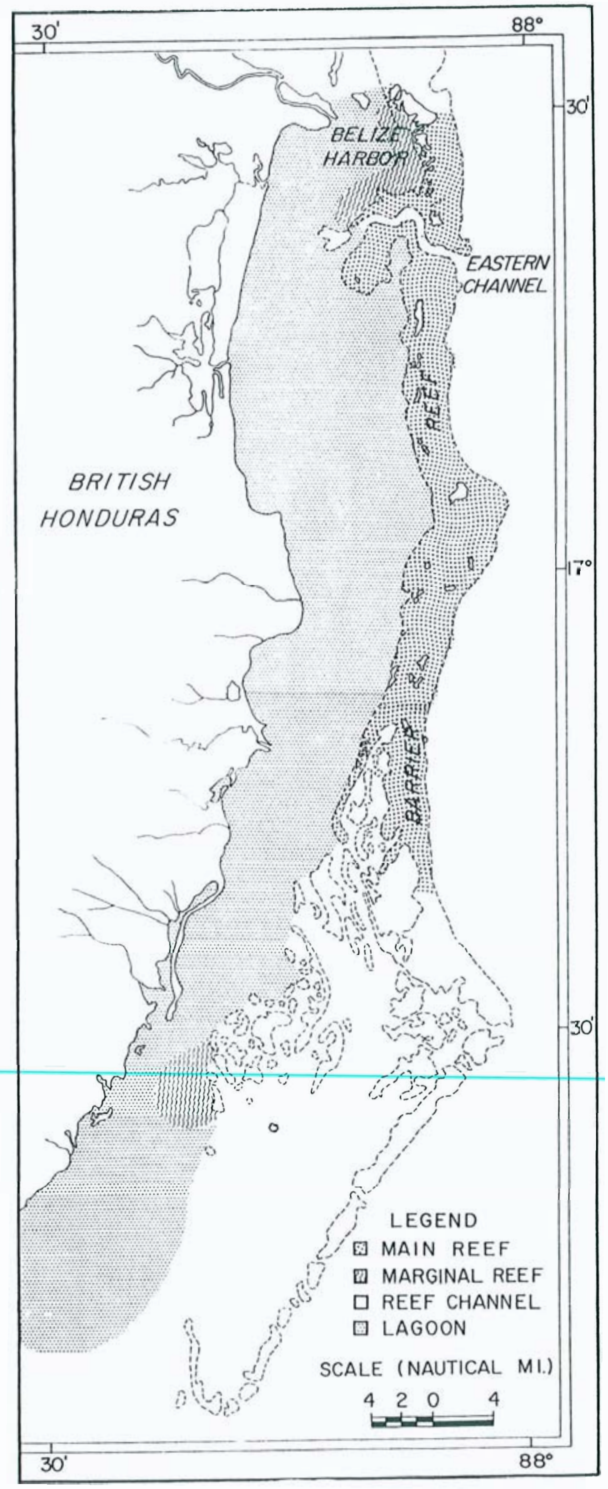

FIG. 12.—Areal distribution of faunal assemblages.

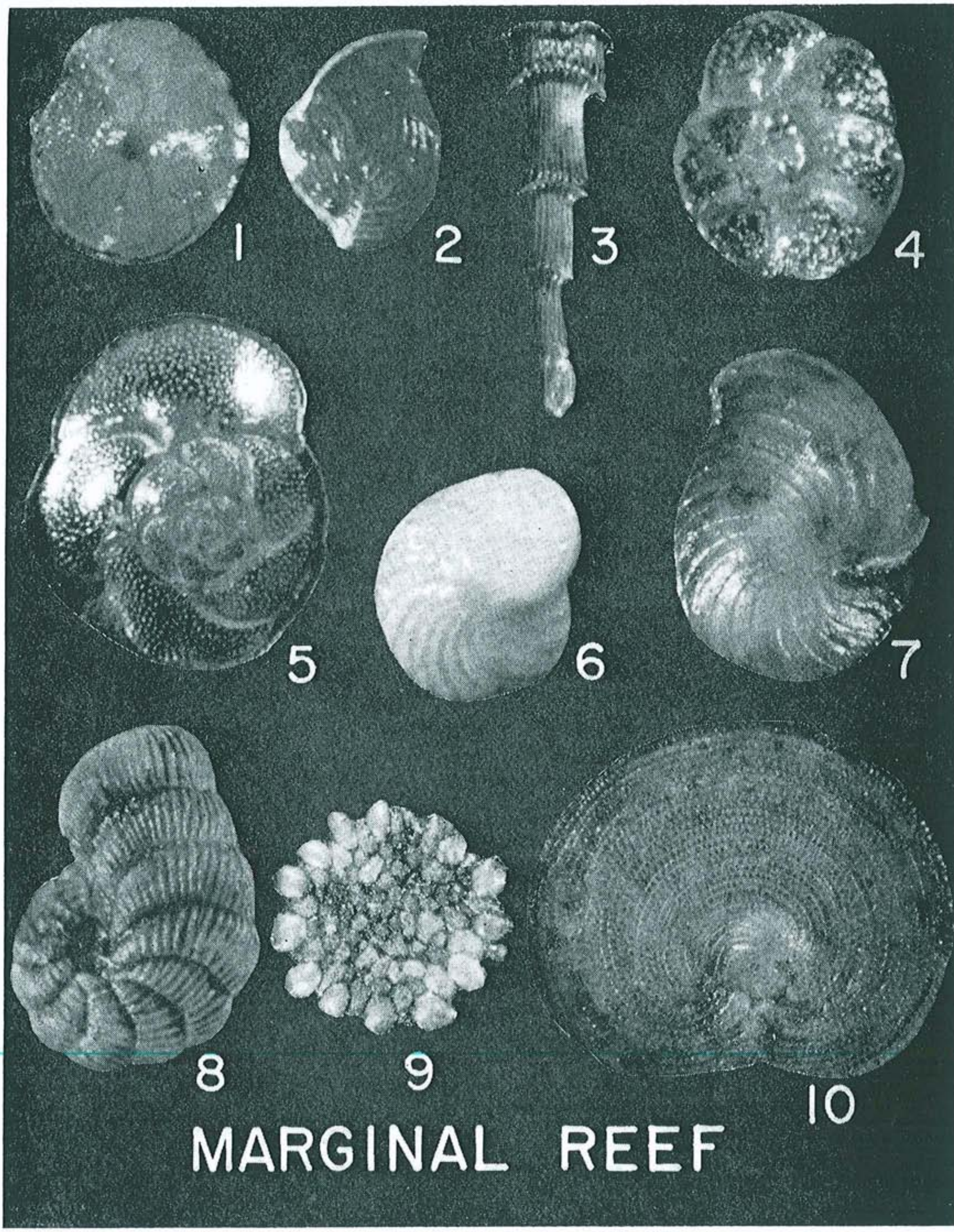

PLATE 11.—Reef-Margin Assemblage

1. *Amphistegina lessonii* d'Orbigny, side view, 22×
2. *Articulina pacifica* Cushman, side view, 22×.
3. *Articulina sagra* d'Orbigny, side view, 22×.
4. *Discorbis candeiana* (d'Orbigny), dorsal view, 42×
5. *Neoconorbina floridensis* (Cushman), dorsal view, 42×
6. *Peneroplis carinatus* d'Orbigny, side view, 22×.
7. *Peneroplis proteus* d'Orbigny, side view, 22×.
8. *Peneroplis pertusus* (Forskal), side view, 22×.
9. *Planorbulina acervalis* Brady, side view, 12×.
10. *Sorites marginalis* (Lamarck), side view, 10×.

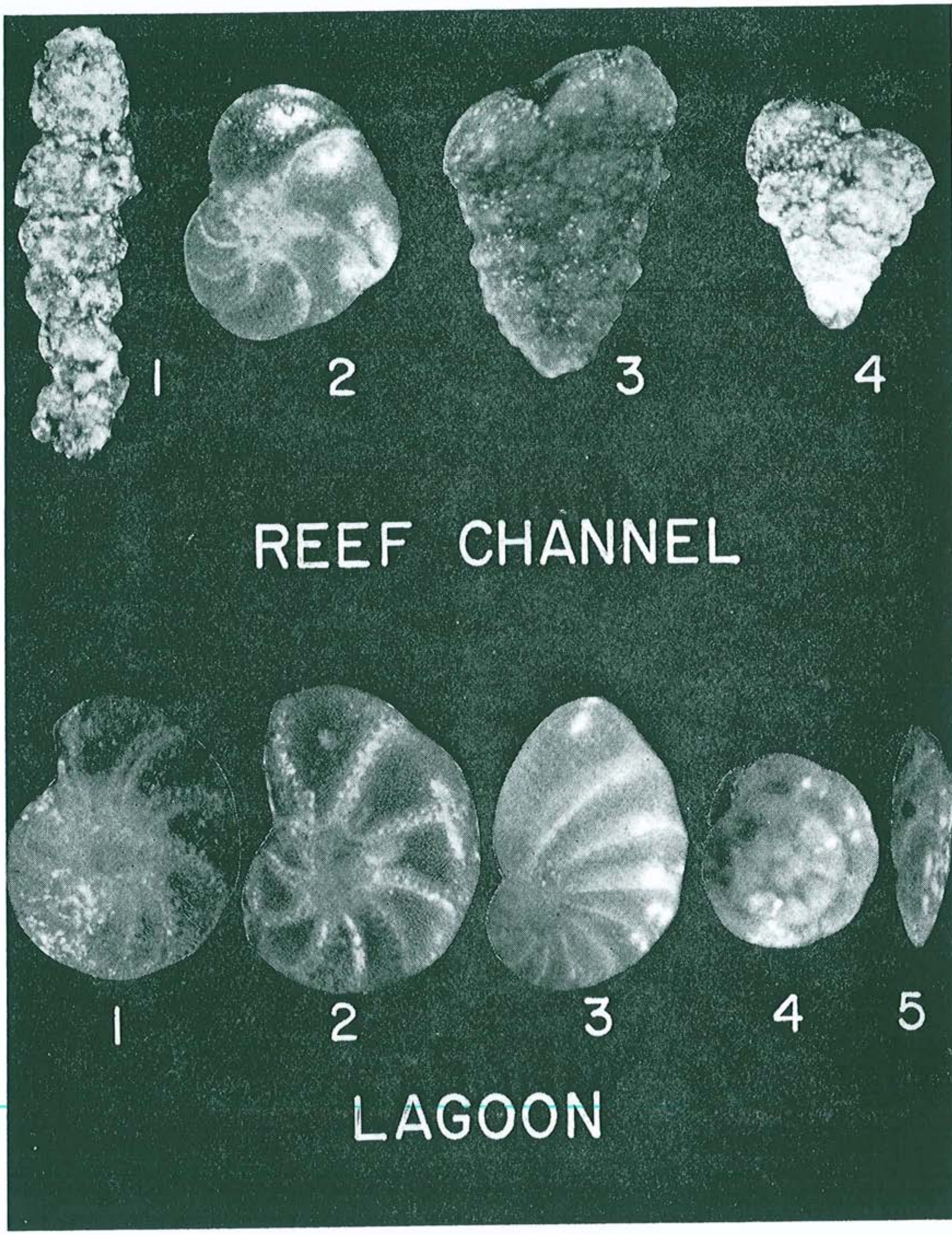

PLATE III.—Reef-Channel Assemblage and Lagoon Fauna

Reef-Channel Assemblage

1. *Bigenerina irregularis* Phleger and Parker, side view, 22×.
2. *Hanzawaia strattoni* (Applin), dorsal view, 22×.
3. *Textularia agglutinans* d'Orbigny, side view, 37×.
4. *Textularia candeiana* d'Orbigny, side view, 30×.

Lagoon Fauna

1. *Elphidium discoidale* (d'Orbigny), side view, 37×.
2. *Elphidium poeyanum* (d'Orbigny), side view, 37×.
3. *Nonion grateloupi* (d'Orbigny), side view, 41×.
4. *Streblus beccarii* (Linne), dorsal view, 22×.
5. *Fursenkoina punctata* d'Orbigny, side view, 48×.

LAGOON FAUNA

The lagoon fauna is characterized by (1) the abundance of species of *Elphidium* and *Nonion*, (2) the relatively common presence of the variants of *Streblus beccarii*, (3) the relatively rare presence and lack of diversity in the family Miliolidae in comparison with the reef-tract fauna, and (4) the scarcity of living species of the families Alveolinellidae, Amphisteginidae, Cymbaloporidae, and Peneroplidae, which are common in the reef tract.

Species considered characteristic of the lagoon fauna are *Elphidium discoidale*, *Elphidium poeyanum*, *Nonion grateloupi*, and *Streblus beccarii* vars.

Living species of *Elphidium discoidale* and *Elphidium poeyanum* were found in most parts of the reef as well as in the lagoon, but they are much more common in the lagoon (Fig. 9). Living specimens of *Elphidium discoidale* were not found in the deeper waters of Eastern Channel. Figure 11 shows that *Elphidium poeyanum* in the lagoon decreases in abundance from the mainland toward the barrier reef. Dead specimens of *Elphidium gunteri*, *E. matagordanum*, and *E. sagrum* also were found in the lagoon. Phleger (1960) reported that species of *Elphidium* were predominant in Laguna Madre, Texas, where the bottom sediments were silt or clay. The sediments of the lagoon are composed mainly of terrigenous silt- and clay-size particles derived from the mainland, whereas the sediments of the barrier reef consist of sand- and silt-size shell fragments. Phleger and Lankford (1957) and Phleger (1960) contended that miliolids prefer a sand or shell substrate. It was observed in this study that the miliolids are more abundant and diverse in the reef tract than in the lagoon, and their abundance in the lagoon decreases from the reef to the mainland. This distribution pattern is the reverse of the one shown by *Elphidium poeyanum*.

The distribution of living species of *Nonion grateloupi* and variants of *Streblus beccarii* is similar to the pattern of *Elphidium poeyanum* in that these species are present throughout most parts of the lagoon and reef tract but are more abundant in the lagoon area (Fig. 9). The data summarized in Figure 11 also indicate that *Streblus beccarii* vars. decrease in abundance from the mainland toward the barrier reef. Figure 12 shows the general distribution of the lagoon fauna, and photomicrographs of the diagnostic species are shown in Plate III.

Living specimens of *Fursenkoina punctata* are increasingly common in the deeper waters of the lagoon. Figure 11 indicates that the species averages slightly more than 9 percent of the living population in the open lagoon (that part of the southern lagoon which opens into the Gulf of Honduras) and 5 percent in the near-reef lagoon, whereas in other parts of the lagoon the species is less common. The depth of water at station 150, in the southern lagoon, was 120 ft, and *Fursenkoina punctata* at that station composed 28 percent of the living population.

CONCLUSIONS

Comparison of the distribution charts for the significant living and total Foraminifera (Figs. 9, 10) indicates the importance of studying the living fauna. If this study had been based entirely on the total population (living and dead specimens undifferentiated), it would have been very difficult to separate the various barrier-reef-tract assemblages, because tests of species restricted in life to certain parts of the reef were found in the reef channel and elsewhere in the lagoon. For example, dead specimens of *Asterigerina carinata*, a species which was found living only in the reef tract, were found in the reef channel and in the lagoon adjacent to the reef. In fact, all of the species diagnostic of the main-reef assemblage, except *Articulina mucronata*, *Archaias angulatus*, and *Borelis pulchra*, contribute dead specimens to other parts of the barrier reef and/or lagoon. Dead specimens of *Neoconorbina floridensis* and several other diagnostic reef-margin species are present throughout the barrier reef and lagoon, but living specimens are restricted to the barrier reef and the part of the lagoon adjacent to the reef. Dead specimens of typical lagoon forms such as *Elphidium discoidale* and variants of *Streblus beccarii* also were found in the deeper waters of Eastern Channel.

Whether the differences between the living and total foraminiferal distribution patterns are the result of postmortem transportation of tests from one site to another or the influence of a previous hydrologic cycle cannot be ascertained from the available data. A study including measurements of fluctuations in the environment with respect to seasonal variations throughout a year or several years, along with denser sample coverage and more exacting measurements of the various ecologic factors, would be necessary to solve the problem.

Faunal Reference List

The following list includes the foraminiferal species identified in the study.

Amphistegina lessonii d'Orbigny: Phleger and Parker, 1951, Geol. Soc. America Mem. 46, pt. 2, pl. 13, figs. 12a, b, 14a, b; pl. 14, figs. la, b.

Archaias angulatus (Fichtel and Moll): Cushman, 1928, Cushman Lab. Foram. Research Spec. Pub. 1, p. 218, pl. 31, fig. 9.

Articulina lineata H. B. Brady: Cushman, 1922, Carnegie Inst. Washington Pub. 311, p. 70, pi. 12, fig. 4.

Articulina mucronata (d'Orbigny): Cushman, 1944, Cushman Lab. Foram. Research Spec. Pub. 10, p. 12, pl. 2, figs. 11–18.

Articulina pacifica Cushman: Cushman, 1944, Cushman Lab. Foram. Research Spec. Pub. 10, p. 17, pl. 4, figs. 14–18.

Articulina sagra d'Orbigny: Cushman, 1944, Cushman Lab. Foram. Research Spec. Pub. 10, p. 11, pl. 2, figs. 6–10.

Asterigerina carinata d'Orbigny: Phleger and Parker, 1951, Geol. Soc. America Mem. 46, pt. 2, p. 26, pl. 14, fig. 2a, b.

Bigenerina irregularis Phleger and Parker: Phleger and Parker, 1951, Geol. Soc. America Mem. 46, pt. 2, p. 4, pi. 1, figs. 16–21.

Bolivina pulchella (d'Orbigny): Cushman, 1922. Carnegie Inst. Washington Pub. 311, p. 25, pi. 1, figs. 8, 9.

Bolivina striatula Cushman: Cushman, 1922, Carnegie Inst. Washington Pub. 311, p. 27, pi. 3, fig. 10.

Borelis pulchra (d'Orbigny): Cushman, 1930, U.S. Natl. Mus. Bull. 104, pt. 7, p. 55, pl. 15, figs. 9, 10.

Cancris oblonga (Williamson): Phleger and Parker, 1951, Geol. Soc. America Mem. 46, pt. 2, p. 20, pl. 9, figs. 17a, b, 18, 19.

Clavulina tricarinata d'Orbigny: Cushman, 1922, Carnegie Inst. Washington Pub. 311, p. 29, pi. 3, fig. 3.

Cornuspira planorbis Schultze: Phleger and Parker, 1951, Geol. Soc. America. Mem. 46, pt. 2, p. 8, pl. 4, figs. 8, 9.

Cymbaloporetta squammosa (d'Orbigny): Cushman, 1931, U.S. Natl. Mus. Bull. 104, pt. 8, p. 83, pl. 16, figs. 4 a-c.

Discorbis candeiana (d'Orbigny): Cushman, 1922, Carnegie Inst. Washington Pub. 311, p. 47, pl. 6, figs. 7, 9.

Discorbis subaraucana Cushman: Cushman, 1931, U.S. Natl. Mus. Bull. 104, pt. 8, p. 32, pl. 7, figs. 2a-c.

Elphidium advenum (Cushman): Cushman, 1930, U.S. Natl. Mus. Bull. 104, pt. 7, p. 25, pl. 10, figs. 1, 2.

Elphidium discoidale (d'Orbigny): Cushman, 1930, U.S. Natl. Mus. Bull. 104, pt. 7, p. 22, pl. 8, figs. 8, 9.

Elphidium matagordanum (Kornfeld): Parker, Phleger, and Peirson, 1953, Cushman Found. Foram. Research Spec. Pub. 2, p. 8, pl. 3, figs. 24, 25.

Elphidium poeyanum (d'Orbigny): Cushman, 1930, Florida Geol. Survey Bull. 4, p. 33, pl. 7, figs. 3, 4.

Elphidium sagrum (d'Orbigny) Cushman: Cushman and Cahill, 1933, U.S. Geol. Survey Prof. Paper 175-A, p. 22, pl. 7, figs. 9a, b.

Eponides antillarum (d'Orbigny): Phleger and Parker, 1951. Geol. Soc. America Mem. 46, pt. 2, p. 20, pl. 10, figs. 9a, b, 10a, b.

Fursenkoina punctata d'Orbigny: Cushman, 1922, Carnegie Inst. Washington Pub. 311, p. 31, pl. 3, fig. 9

Hanzawaia strattoni (Applin): Bandy, 1954, U.S. Geol. Survey Prof. Paper 254-F, pl. 31, fig. 4.

Hauerina bradyi Cushman: Cushman, 1926, Carnegie Inst. Washington Pub. 344, p. 82.

Hauerina ornatissima (Karrer): Cushman, 1929, U.S. Natl. Mus. Bull., 104, pt. 6, p. 47, pi. 10, figs. 10, 12.

Lagena perlucida (Montagu): Cushman, 1923. U.S. Natl. Mus. Bull. 104, pt. 4, p. 26, pl. 8, figs. 12, 13.

Massilina peruviana (d'Orbigny): Parker, Phleger, and Peirson, 1953, Cushman Found. Foram. Research Spec. Pub. 2, pl. 1, figs. 44, 45.

Neoconorbina floridensis (Cushman): Anderson, 1961, Louisiana Geol. Survey Bull. 35, pt. 2, p. 101, pl. 21, figs. 6 a-c.

Neoconorbina terquemi (Rzehak): Parker, 1960, Soc. Econ. Paleontologists and Mineralogists Spec. Pub. 9, p. 182, pl. 88, figs. 4–8.

Nonion grateloupi (d'Orbigny): Cushman, 1930, U.S. Natl. Mus. Bull. 104, pt. 7, p. 10, pl. 3, figs. 9, 11; pl. 4, figs. 1–4.

Peneroplis carinatus d'Orbigny: Cushman, 1922, Carnegie Inst. Washington Pub. 311, p. 79.

Peneroplis pertusus (Forskal): Cushman, 1926, Carnegie Inst. Washington Pub. 344, p. 83.

Peneroplis proteus d'Orbigny: Cushman, 1922, Carnegie Inst. Washington Pub. 311, p. 79.

Planorbulina acervalis Brady: Cushman, 1922, Carnegie Inst. Washington Pub. 311, p. 45, pl. 6.

Proteonina difflugiformis (H. B. Brady): Phleger and Parker, 1951, Geol. Soc. America Mem. 46, pt. 2, p. 2, pl. 1, figs. 4, 5.

Pyrgo denticulata (H. B. Brady): Cushman, 1929, U.S. Natl. Mus. Bull. 104, pt. 6, p. 69, pl. 18, figs. 3, 4.

Pyrgo denticulata (H. B. Brady) var. *striolata* (H. B. Brady): Cushman, 1929, U.S. Natl. Mus. Bull. 104, pt. 6, p. 69, figs. 5 a-c.

Pyrgo subsphaerica (d'Orbigny): Cushman, 1929, U.S. Natl. Mus. Bull. 104, pt. 6, p. 68, pl. 18, figs. 1, 2.

Quinqueloculina agglutinans d'Orbigny: Cushman, 1921, U.S. Natl. Mus. Proc., v. 59, p. 65, pl. IS, figs. 9, 10.

Quinqueloculina bicostata d'Orbigny: Phleger and Packer, 1951, Geol. Soc. America Mem. 46, p. 7, pl. 3, figs. 15a, b.

Quinqueloculina bidentata d'Orbigny: Cushman, 1922, Carnegie Inst. Washington Pub. 311, p. 64.

Quinqueloculina bradyana Cushman: Cushman, 1917, U.S. Natl. Mus. Bull. 71, pt. 6, p. 52, pl. 18, fig. 2.

Quinqueloculina candeiana d'Orbigny: Cushman, 1922, Carnegie Inst. Washington Pub. 311, p. 65, pl. 13, fig. 1.

Quinqueloculina lamarckiana d'Orbigny: Cushman, 1921, U.S. Natl. Mus. Proc., v. 59, p. 65, pl. 15, figs. 13, 14.

Quinqueloculina poeyana d'Orbigny: Cushman, 1924, U.S. Natl. Mus. Bull. 104, pt. 5, p. 31, pl. 5, figs. 2a, c.

Quinqueloculina polygona d'Orbigny: Cushman, 1924, U.S. Natl. Mus. Bull. 104, pt. 5, p. 28, pl. 3, figs. 5 a, c.

Quinqueloculina subpolygona Parr: Parr, 1945, Royal Soc. Victoria Proc., v. 56, pt. 2, p. 196, pl. 12, figs. 2a, c.

Quinqueloculina vulgaris d'Orbigny: Cushman, 1929, U.S. Natl. Mus. Bull. 111, pt. 6, p. 25, pl. 2, figs. 3 a-c.

Sorites marginalis (Lamarck): Cushman, 1930, U.S. Natl. Mus. Bull. 104, pt. 7, p. 49, pl. 18, figs. 1-4.

Streblus beccarii vars. (Linne): Linne, 1758, Systema Naturae, ed. 10, p. 710.

Textularia agglutinans d Orbigny: Cushman, 1921, U.S. Natl. Mus. Proc., v. 4, p. 106, pi. 20, fig. 8; Carnegie Inst. Washington Pub. 311, 1922, pi. 1, fig. 6.

Textularia candeiana d Orbigny: De la Sagra, 1839, Histoire Physique et Naturelle de l'Ile de Cuba, "Foraminiferes," p. 143, pl. 1, figs. 25–27.

Textularia conica d Orbigny: Cushman, 1922, Carnegie Inst. Washington Pub. 311, p. 24, pl. 2, fig. 4.

Textulariu mayori Cushman: Cushman, 1922, Carnegie Inst. Washington Pub. 311, v. 17, p. 23, pl. 2, fig. 3.

Triloculina carinata d Orbigny: Cushman, 1922, Carnegie Inst. Washington Pub. 311, p. 75, pi. 12, fig. 6.

Triloculina circularis Bornemann: Cushman, 1929, U.S. Natl. Mus. Bull. 104, pt. 6, p. 58, pl. 13, figs. 6, 7; pl. 14, figs. 1, 2.

Triloculina linneiana d'Orbigny: Cushman, 1929, U.S. Natl. Mus. Bull. 104, pt. 6, p. 61, pl. 16, figs. 1, 2.

Triloculina rotunda d Orbigny: Cushman, 1929, U.S. Natl. Mus. Bull. 104, pt. 6, p. 59, pi. 14, figs. 3 a-c.

Triloculina suborbicularis d'Orbigny: Cushman, 1921, U.S. Natl. Mus. Bull. 100, v. 4, p. 461.

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

Valvulina oviedoina d'Orbigny: Cushman, 1922, Carnegie Inst. Washington Pub. 311, p. 297, pi. 2, figs. 7, 8.

References

Bandy, O. L., 1953, Ecology and paleoecology of some California Foraminifera; Pt. 1, The frequency distribution of Recent Foraminifera off California: Jour. Paleontology, v. 27, p. 161–183.

——— 1954, Distribution of some shallow water Foraminifera in the Gulf of Mexico: U.S. Geol. Survey Prof. Paper 254-F, p. 125–141.

——— 1956, Ecology of Foraminifera in northeastern Gulf of Mexico: U.S. Geol. Survey Prof. Paper 274-C, p. 1–204.

Brady, H. B., 1884, Report on the Foraminifera dredged by H.M.S. *Challenger* during the years 1873–1876, *in* Report on the voyage *Challenger:* London, Zoologist, 3d ser., v. 9, p. 1–814.

Cushman, J. A., 1921, Foraminifera from the north coast of Jamaica: U.S. Natl. Mus. Proc., v. 59, p. 156–172.

——— 1922a, Shallow water Foraminifera of the Tortugas region: Carnegie Inst. Washington Pub. 311, v. 17, p. 1–85.

——— 1922b, The Foraminifera of the Atlantic Ocean; Pt. 3, Textularidae: U.S. Natl. Mus. Bull. 104, pt. 3, p. 1–137.

——— 1923, The Foraminifera of the Atlantic Ocean; Pt. 4, Lagenidae: U.S. Natl. Mus. Bull. 104, pt. 4, p. 1–179.

——— 1926, Recent Foraminifera from Puerto Rico: Carnegie Inst. Washington Pub. 344, p. 1–49.

——— and P. Brönimann, 1948a, Some new genera and species of Foraminifera from brackish water of Trinidad: Cushman Lab. Foram. Research Contr., v. 24, pt. 1, p. 15–21.

——— and ——— 1948b, Additional new species of arenaceous Foraminifera from shallow waters of Trinidad: Cushman Lab. Foram. Research Contr., v. 24, pt. 2, p. 37-48.

Dixon, C. G., 1957, Geology of southern British Honduras: Geol. Survey Dept., Brickdam, Georgetown, British Guiana, p. 1–85.

Flores, G., 1952, Geology of northern British Honduras: Am. Assoc. Petroleum Geologists Bull., v. 36, p. 404–413.

Fournier, G., 1956, New methods and techniques in the photography of microfossils: Micropaleontology, v. 2, no. 1, p. 37–51.

Kornfeld, M. M., 1931, Recent littoral Foraminifera from Texas and Louisiana: Stanford Univ. Dept. Geol. Contr., v. 1, no. 3, p. 77–101.

Krumbein, W. C., and F. J. Pettijohn, 1938, Manual of sedimentary petrography: New York, Appleton-Century-Crofts Inc., p. 167–189.

Lankford, R. R., 1959, Distribution and ecology of Foraminifera from east Mississippi Delta margin [La.] : Am. Assoc. Petroleum Geologists Bull., v. 43, no. 9, p. 2068–2099.

Lehmann, E. P., 1957, Statistical study of Texas Gulf Coast foraminiferal facies: Micropaleontology, v. 3, no. 4, p. 325–356.

Moore, W. E., 1957, Ecology of Recent Foraminifera in northern Florida Keys: Am. Assoc. Petroleum Geologists Bull., v. 41, no. 4, p. 727–741.

Orbigny, A. D. d', 1839, Voyage dans l'Amérique méridionale-foraminifères: v. 5, Paris, Pitois-Levrault et Cie; Strasbourg, V. Levrault.

Otto, G. H., 1933, Comparative tests of several methods of sampling heavy mineral concentrations: Jour. Sed. Petrology, v. 3, p. 30-39.

Ower, L. H., 1928, The geology of British Honduras: Geol. Survey Dept., Brickdam, Georgetown, British Guiana, p. 1–24.

Parker, F. L., F. B Phleger, and J. F. Peirson, 1953, Ecology of Foraminifera from San Antonio Bay and environs, southwest Texas: Cushrnan Found. Foram. Research Spec. Pub. 2, p. 1–75.

Phleger, F. B, 1954, Ecology of Foraminifera and associated micro-organisms from Mississippi Sound and environs: Am. Assoc. Petroleum Geologists Bull., v. 38, no. 4, p. 585–647.

——— 1955, Ecology of Foraminifera in southeastern Mississippi Delta area: Am. Assoc. Petroleum Geologists Bull., v. 39, no. 5, p. 712–752.

——— 1956, Significance of living foraminiferal populations along the Central Texas Coast: Cushman Found. Foram. Research Contr., v. 7, pt. 4, p. 106–152.

——— 1960, Foraminiferal populations in Laguna Madre, Texas: Tohoku Univ., Sendai, Japan, Sci. Repts., 2d ser. (Geol.), no. 4, p. 83–91.

——— and R. R. Lankford, 1957, Seasonal occurrences of living and benthonic Foraminifera in some Texas bays: Cushman Found. Foram. Research Contr., v. 8, pt. 3, p. 93–105.

——— and F. L. Parker, 1951, Ecology of Foraminifera, northwest Gulf of Mexico; Pt. 2, Foraminifera species: Geol. Soc. America Mem. 46, p. 1–4.

——— and W. R. Walton, 1950, Ecology of marsh and bay Foraminifera, Barnstable, Massachusetts: Am. Jour. Sci., v. 248, p. 274–294.

Post, R. J., 1951, Foraminifera of the South Texas coast: Inst. Marine Sci., Univ. Texas, v. 2, no. 1, p. 166–176.

Saunders, J. B., 1957, Trochamminidae and certain Lituolidae (Foraminifera) from the Recent brackish-water sediments of Trinidad, British West Indies: Smithsonian Misc. Colln., v. 134, no. 5, Pub. 4270.

——— 1958, Recent Foraminifera of mangrove swamps and river estuaries and their counterparts in Trinidad: Micropaleontology, v. 4, no. 1, p. 79–92.

Stoddart, D. R., 1962, Three Caribbean atolls: Turneffe Islands, Lighthouse Reef, and Glover's Reef, British Honduras: Natl. Acad. Sci.–Natl. Research Council, Pacific Sci. Board, Atoll Research Bull. 87, p. 150.

Vaughan, T. W., 1918, Study of the stratigraphic geology of the fossil corals and associated organisms in several of the small West Indian islands: Carnegie Inst. Washington Year Book 16, 319 p.

Vermeer, D. E., 1959, The cays of British Honduras: Unpub. thesis, Dept. Geography, Univ. California (Berkeley).

Walton, W. R., 1952, Techniques for recognition of living Foraminifera: Cushman Found. Foram. Research Contr., v. 3, pt. 2, p. 56–60.

——— 1955, Ecology of living benthonic Foraminifera, Todos Santos Bay, Baja California: Jour. Paleontology, v. 29, no. 6, p. 952–1018.

——— 1960, Diagnostic faunal characteristics on and near a barrier island, Horn Island, Mississippi: Gulf Coast Assoc. Geol. Socs., v. 10, p. 7–27.