THE FORAMINIFERA AND SEDIMENTS

OF

BISCAYNE BAY, FLORIDA

AND

THEIR ECOLOGY

by

JAMES BUSH

A thesis submitted in partial fulfillment

of the requirements for the degree of

DOCTOR OF PHILOSOPHY

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Approved by V. Standish Mallory

Department Geology.

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We have carefully read the thesis entitled ~~Sediments and Foraminifera of Biscayne Bay, Florida~~ The Foraminifera and Sediments of Biscayne Bay, Florida and their ecology submitted by Mr. James Bush in partial fulfillment of the requirements of the degree of PhD and recommend its acceptance. In support of this recommendation we present the following joint statement of evaluation to be filed with the thesis.

This dissertation is the result of an ambitious program of sampling in both the sediments and Foraminifera of Biscayne Bay, in the southeast corner of the peninsula of Florida. Mr. Bush establishes the relationships that exist in Biscayne Bay between the sedimentary and organic environment. The study of physical oceanographic factors of an area like this one leads him to the following conclusions:

1. The quartz sand is autochtonous in origin, being derived from reworking Pamlico sediments.
2. The quartz sand deposition areas are the least favorable organic environment of the Bay.
3. Limey sediments in the southwest Bay area are not precipitated in the Bay through the action of bacteria as had been supposed by other authors, but are fragmented organic debris.
4. Areas of limey $CaCO_3$ sediment deposition are the most favorable as organic environments.
5. The foraminiferal fauna is provincial in nature due to adaptation of the Foraminifera to rigorous changes in salinity and temperature, and isolation geologically.
6. Although the enclosed Bay fauna is relatively uninfluenced by the open ocean areas to the east, the physical oceanographic factors of the Bay affect the fauna of the open ocean. These are due to dilution of the ocean waters by the shore waters of the Bay.
7. Thirteen biotopes are recognized and shown to be influenced in their faunal composition by factors of current, constancy of salinity and temperature, and type of substrate.

Mr. Bush has done a tremendous amount of work collecting samples from 63 stations and making mechanical analyses of the sediment. The results of the analysis are given in the form of graphs. Distribution of $CaCO_3$ content of each sample was obtained by treatment with HCl. The residue from the acid treatment was centrifuged in tetrabromoethane and heavy minerals separated out and studied petrographically. Studies such as this by Mr. Bush provide much information of value not only from the standpoint of ecology and physical sedimentation but also potential data of great importance to geological interpretation.

THESIS READING COMMITTEE: V. Standish Mallory, Chairman

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Julian D. Barksdale

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ABSTRACT

Biscayne Bay is located in the southeastern portion of the peninsula of Florida, east and south of Miami. Numerous canals intermittently drain into the bay which in turn drains into the Straits of Florida. Circulation in the bay is governed by tidal action. The bay waters vary in depth between zero and fifteen feet. The water temperature ranges between sixty-eight and eighty-six degrees Fahrenheit. The salinity varies from two to thirty-nine parts per thousand and is more uniform in the northern than in the southern portion of the bay.

Life in Biscayne Bay is varied, and in places prolific. Typically warm-water marine life is found in the greater part of the bay. *Halimeda* and *Thalassia* are the two most common plants; the most abundant Foraminifera are *Archaias angulatus*, *Quinqueloculina lamarckiana*, *Q. poeyana*, *Q. torrei*, and *Triloculina flinti*. Though these species are unusually common, they are not the most characteristic of the thirteen biotopes found in the bay.

The bottom sediment of Biscayne Bay consists largely of fragmental calcareous shells and quartz grains. Heavy minerals compose less than one tenth of one per cent of the sediment with epidote the main heavy mineral constituent. Primarily, the sediment is sandy with a slight amount of silt and clay - size particles; foraminiferal tests compose approximately 0.5 per cent to 60 per cent of the deposits. The distribution of the characteristic Foraminifera and minerals are discussed.

INTRODUCTION

GENERAL STATEMENT

Sediment bottom samples were collected from Biscayne Bay, Florida, in the summer of 1948. The sediment was analyzed for its composition, physical parameters and included organic calcareous remains. The results of this analysis are compared with chemical and physical oceanographic factors obtained by others.

Bottom samples from Biscayne Bay had previously been collected and analyzed by other investigators. However, no one individual had ever sampled the bay nor analyzed any of the material with relation to areal distribution patterns and interrelation between the sediment and its included organic calcareous remains. Since it is primarily these calcareous remains which are preserved for geologic record, other forms of life were not studied.

The purpose of this study was made for the following reasons:

1. To obtain distribution patterns of the sediment in a warm water, marine, shallow bay environment.
2. To map the distribution pattern of the Foraminifera in the bay and compare them with those found outside the bay.
3. To find any relationship between the sediment and faunal distributions in order to better understand geologically recorded environments.

Assemblage mounts and biotopes of figured foraminiferal specimens are on deposit in the Paleontology Museum, University of Washington Geology Department, Seattle, Washington, as Lot No. 30.

ACKNOWLEDGMENTS

Sincere thanks are extended to Dr. F. G. Walton Smith, director of the Marine Laboratory, University of Miami, Coral Gables, Florida, who made the collection of the samples possible through the use of a boat. Appreciation is also extended to Dr. W. R. Taylor, Professor of Botany at the University of Michigan, who was kind enough to identify some algal specimens, and to Dr. R. Wright Barker of the Shell Development Company of Houston, Texas, for permission to use his extensive library of Foraminifera and his foraminiferal collection.

Special thanks are due Dr. J. J. Galloway of Indiana University under whom the preliminary master's thesis study was done on this area. My appreciation is also extended to Dr. Harry E. Wheeler, V. Standish Mallory, and Julian Dr. Barksdale, as well as other members of the University of Washington's Department of Geology under whose supervision this thesis was conducted.

LOCATION OF AREA

Biscayne Bay is located in the southeast corner of the Peninsula of Florida, east and south of Miami, from approximately 25°23' to 25°55'N latitude and from 80°08' to 80°20'W longitude. Its main axis lies N15°E with a total length of 35 nautical miles and a maximum width of 8.5 miles.

The northern fourth of the bay, the area west of Miami Beach, narrows to approximately two miles in width. This section has been disturbed by man in the process of building bridges, causeways and man-made islands, as well as by dredging of ship channels. Because of this continual change it was not included in the area of study.

The mainland, with its bordering mangrove swamps and intermittent streams, lies to the west. The Florida Keys are situated east of the bay, while still farther east is the Straits of Florida with the north-flowing Florida Current.

PREVIOUS WORK

Vaughan (1909-1935) and Vaughan and Shaw (1915) initiated an intensive and careful study of the shoal-water deposits of southern Florida and the Bahamas.

Vaughan (1909a) discussed the geologic work of mangroves in southern Florida, noting the modes of occurrence and processes by which mangroves build new land. Those on the west side of Biscayne Bay and their method of extending the land bayward were particularly stressed. He (1910) was the first to describe the bays to the south. At the northern end of the bay and at Virginia Key he found corals, and collected ten bottom samples from within the bay and four from east of the Keys. Matson (1910) analyzed these samples and described the sediment. However, he did not discuss in detail the associated life. Vaughan (1910, p. 114) stated that the purpose of collecting the samples was to ascertain the nature of the deposits "now being laid down behind the keys." He summarized (p. 116) the sediments of Biscayne Bay as follows:

"These observations on the bottom deposits of Biscayne Bay indicate that considerable quartz is being washed into the northern end of the bay, and that as one prodeeds southward the calcareous constituents become predominant, while the siliceous constituents become insignificant. The material, when collected, consisted mostly of oozes and no intimation of the formation of oolite was observed."

He continued, in summary (p. 119):

"The material at present being laid down inside of the keys consists mostly of silica and carbonate of lime. Silica is abundant in the form of sand in the northern portion of Biscayne Bay, it becomes rarer toward the southwest, and is present in small quantities as far as Big Pine Key. Toward the southwest, as the siliceous material becomes rarer, calcium carbonate becomes progressively more abundant, occurring as a flocculent sediment or ooze over practically the entire region from the lower portion of Biscayne Bay to the gulf end of Florida Bay."

In addition, Vaughan (p. 145) also described deltas forming on the seaward side of some passages between the keys.

Neither Matson nor Vaughan compared or related the distribution of the sediments with the distribution of the fauna. They did not mention the fauna in the sediment, even though Matson described the sediment from the area discussed in this report.

Drew (1914) did research on the precipitation of calcium carbonate by bacteria in the Florida - Bahama area. He concluded that bacteria were fundamentally responsible for upsetting the chemical equilibrium, causing precipitation of calcium carbonate. He stated (. 44):

"The very extensive chalky mud flats forming the Great Bahama Bank and those which are found in places in the neighborhood of the Florida Keys are now being precipitated by the action of the <u>Bacterium calcis</u> on the calcium salts present in solution in sea water."

Dole (1914) analyzed the waters in and around Biscayne Bay, stating (p. 75):

"No analyses of water from Miami River above tidal influence are available, but as it received drainage from the Everglades its water is doubtless similar in concentration and composition to that of Lake Okeechobee and Fort Lauderdale, analyses of calcium carbonate waters of low mineral content carrying considerable organic matter. Normally Miami River may be expected to contain a small amount of free carbon dioxide and no carbonate (CO_3)."

On p. 78 he states:

"The water in the south part of the bay is somewhat more concentrated, samples Nos. 9, 5, and 8 having salinities of 36.73, 36.64, and 36.64 respectively. This evidence that the water in this part of the bay is concentrated by evaporation during its retention in the shallows serves further to indicate that circulation there is not very rapid and that the greater bulk of the water inside the keys is not thoroughly mixed or shifted by the tides. The inside samples only as far as Old Man Beacon give evidence of dilution by fresh water; therefore it may be concluded that, at least at the time these samples were collected, the effect of Miami River on the water of the bay did not extend south of Soldier Key nor outside the keys. Sample 1 has a salinity obviously higher than the pure water of Miami River alone may be expected to have, and represents admixture with bay water; carbonates are absent from it, but bicarbonates are much higher and may be attributed to reaction of the carbon dioxide that the river water carries. In all other samples normal carbonates are present in sea-water and free carbon dioxide is entirely absent, but there are wide differences in the alkalinity from point to point."

Dole and Chambers (1918) did some further work on the waters near Biscayne Bay. They compared the precipitation at Miami with the salinity at Fowey Rocks, stating (p. 311):

"precipitation at Miami is almost invariably followed within twenty-four hours by reduction of content of chloride at Fowey Rock."

They further state:

"The quantitative effect of precipitation on the content of chloride is not entirely regular, for it is complicated by the effects of tide, wind, and current."

On p. 311 Dole and Chambers state:

> "Consequently it may be concluded that the normal salinity of the Gulf Stream off Fowey Rocks is like that of the Gulf of Mexico, but that it is decreased at times by rains and by discharge of fresh water from Miami River and underground aquifers along the coast.
>
> The water in the south part of the bay is somewhat concentrated . . . . This evidence, that the water in this part of the bay is concentrated by evaporation during its retention in the shallows, serves further to indicate that circulation there is not very rapid and that the greater bulk of the water inside the keys is not thoroughly mixed or shifted by the tides."

It is worth noting that Dole and Chambers considered the southern portion of the bay to be that area north of Featherbed Bank which, in this paper, is regarded as the central portion of the Bay. Dole and Chambers did not discuss the area south of Featherbed Bank.

Vaughan (1918, 1923) compared some life and bottom samples from the Florida and Bahama region with those from the areas in the western Pacific. Though the sediments and fauna were compared, only one sample was taken from the area of the present study. This sample was from the beach on the east side of Sands Key (station no. 68). The sediments were reported (p. 281) as being coarse (93.3% 2.0-0.5mm, 4.3% silt). The only abundant Foraminifera reported was Orbiculina adunca. Others listed as present were Orbitolites marginalis, Peneroplis pertusus, Quinqueloculina agglutinans, Triloculina linneiana, Biloculina carinata, Clavulina angularis, Trochammina inflata, Verneuilina affixa, Discorbina vilardeboana, and Planorbulina mediterranensis. Vaughan (pp. 285-6) further stated that there are three types of bottom samples from Florida: 1) beach sand, and 4.3% silt and clay; 2) lagoonal mud deposits; 3) deposits in 60 fathoms which are relatively coarse grained with benthonic and pelagic form s of life.

Cushman (1918a, 1920, 1922, 1922a, 1923, 1924a, 1929, 1930, 1931) published a series of papers on the Foraminifera of the Atlantic Ocean and on the shallow water Foraminifera of the Tortugas region. The earlier papers included some locations in and around Florida. The Foraminifera, environments, and the sediments, were not related nor was the Florida region particularly stressed.

Dole and Chambers (1918) tabulated the wind direction and velocity, the chloride content, salinity, and specific gravity of the sea water at Fowey Rock for a period of nineteen months during the years 1914 and 1915. A comparison was made between these analyses and the precipitation at Miami, 15 miles to the northwest. Another comparison was made between the empirical data derived at Fowey Rock and those from a few stations inside of Biscayne Bay. They noted (p. 313) the higher salinities (36.4-36.73), during the month of June in the southern part of the bay, which the attributed to concentration by evaporation aided by poor circulation and mixing. They also stated (p. 313):

> "it may be concluded that, at the time these samples were collected, the effect of Miami River on the water of the bay did not extend south of Soldier Key nor outside the keys. Yet the longer series later examined at Fowey Rocks shows that the diluting effect is at times apparent as far out as the lighthouse."

Norton (1930) published a paper on the ecologic relations of some Foraminifera. His stations were located in Australia as well as the Florida-Bahama region. He discussed the Foraminifera in relation to depth of water and temperature, and concluded (p. 361) that the Miliolidae, Nonionidae, Peneroplidae, and Rotaliidae, decreased in abundance with a decrease in temperature and increase in depth. However, the Globorotaliidae and Lagenidae increased with a decrease in temperature and increase in depth, but the Anomalinidae were not affected in their abundance with a change in temperature or depth. Of the Foraminifera listed, the Miliolidae were the most abundant types in the warm, shallow water, while the Globigerinidae were found to be most abundant in the stations which were deeper and colder. Norton noted that the open-sea pelagic Foraminifera were not washed into the lagoons, but that the shallow water lagoonal fauna was found intermingled with the deep sea and pelagic types, apparently after having been washed up on the beaches and transported into deeper water.

Thorp (1935, 1939) published the most detailed paper to date on the marine calcareous shallow water deposits of Florida and the Bahamas, listing 17 sample localities from the Biscayne Bay vicinity, of which 7 were inside the bay area, and the rest either on some of the keys or on the east side of the keys. He summarized the order of quantitative importance of the constituents composing the bottom deposits in the Florida region, as follows (1935, p. 52):

> "Calcareous algae, 25%; Mollusca, 17.5%; silt, 13.9%; coral, 9.3%; Foraminifera, 9.0%; clay, 7.8%; spicules, 4.3%; minerals, 3.9%; Crustacea, 1.4%; worm tubes, 1.48%; Bryozoa, 0.4%; oolites, 0.4%; pellets, trace."

Although Thorp showed histograms of the sediment analyses and catalogued the general type of life present, he identified the Foraminifera only to genus. The genus Archaias he listed as comprising the bulk of the Foraminifera (p. 57), the genera Peneroplis and Quinqueloculina as being frequent, while the genera Clavulina and Valvulina as being numerous in shallow waters. The most important algae were the Corallinacea, and the genus Halimeda. The presence of eel grass, Zostera, was also reported. (This is probably in error as eel grass does not normally occur in this area; the genus Thalassia, however, is common.) He further noted the occurrence of epidote and magnetite east of the keys but did not mention their presence within the bay itself. Quartz was listed as the principal non-calcareous mineral.

Haight (1935) published some notes on current observations around the Florida Keys. He stated (p. 142):

> "At stations 15 and 16, south of Key Biscayne, currents of between 1 and 1¼ knots, setting into and out of Biscayne Bay on the flood and ebb, respectively, were observed.
>
> Flood and ebb velocities exceeding 3 knots are indicated in Miami Entrance, Station 17. The results of a two-day series of observations taken in this Entrance in 1929 by the Coast and Geodetic Survey show a mean velocity of about 2½ knots at strength of flood and about 3 knots at strength of ebb.
>
> At station 18 in Norris Cut and station 19 in Bear Cut, passages into Biscayne Bay southward of Miami Entrance, velocities somewhat in excess of 1 knot were observed."

The direction of flood is from 240° - 290° from 1.1-3.6 knots while that of ebb from 110° - 150°, 1.0-3.2 knots.

Mann (1935) reported on the diatoms from the Bahamas and the Florida Keys. In five samples from immediately east of the Keys, he noted 24 genera which included 84 species. Diatoms were generally scanty and delicate with a large percentage of crippled and misshapen individuals, "as though each plant, during the period of its formation, was insufficiently supplied with the necessary amount of silica to give it external rigidity, resulting in frequent distortions." The genus Mastogloia was the most varied, and was more abundant in the Florida waters than in other parts of the world, although they suffered here from a lack of silica.

Stubbs (1940) published on the Foraminifera of the Miami area. Four of his stations were in Biscayne Bay, while three were outside of the bay. He listed 23 genera and 61 species as being present; the Miliolidae as the most predominant, followed in abundance by the Peneroplidae. Archaias angulatus and Elphidium sagrum were reported as abundant within the bay, while six other species were reported as common. Many of Stubbs identifications however, have been proven to be erroneous by subsequent investigators.

The geology of the area around Biscayne Bay, as well as that of southern Florida, was discussed in considerable detail by Parker and Cooke (1944). Although Cooke (1945) considered this same area, as well as the geology of the entire Florida region, neither was particularly concerned with the history of Biscayne Bay as such.

The relationship of salt water to fresh water in the substratum around Biscayne Bay was discussed by Brown and Parker (1945). They stated, (p. 241):

> "No visible springs now exist along the shore although in the early days before drainage lowered the water table, many springs flowed near the base of the limestone cliff along Silver Bluff and elsewhere along the coast.
>
> The land surface of the wave-cut bench is always moist, and near the shore is quite damp, indicating continuous ground water discharge."

Brown and Parker indicated that bay water was slowly encroaching upon the land below the water table. The saline water made its greatest advances along the canals and from there spread inland.

Weiss (1948) studied the fouling conditions and the organisms involved in fouling through the year. He investigated three areas: two located west of the southern end of Miami Beach in the vicinity of Government Cut, one located at Tahiti Beach, at approximately 25°42'N latitude and 80°15'W longitude. The organic remains most commonly found in the sediment were not recorded. Weiss indicated that the north bay water is isolated from that of the open sea, as indicated by the higher fluctuation of salinity in the bay from that in the open sea, and concluded (1948, p. 156):

> "little mixing occurs between water of the north bay and the ocean at each tidal cycle. Apparently, the bay water is pushed back by the ocean water entering at flood tide, but returns unchanged to its maximal extent with the ebb."

Weiss further noted the occurrence of the same species at all station but not in the same abundance, Tahiti being lowest in fouling organisms. This lack of fouling at Tahiti he allayed to the lack of tidal currents bringing in food to this area, and the absence of a source of fouling on the surrounding shores.

Bush (1949) described the general distribution of the foraminiferal genera from ten stations in Biscayne Bay.

Parker and Stringfield (1950) discussed the effects of factors affecting the water table of southern Florida, and related some oceanographic factors of Biscayne Bay to the neighboring fresh ground water levels and their fluctuations.

Parker (1951) stressed the geologic and hydrologic factors affecting the yield of the Biscayne aquifer. He stated (p. 825) that of the average 60 inch rainfall per year, 38 inches was lost by evapotranspiration to the atmosphere, and approximately 20 inches reached the Biscayne aquifer to be discharged from it by ground water flow, either into drainage canals and thence into Biscayne Bay, or directly into the bay. He further emphasized (p. 825) that a mile of drainage canal is ordinarily somewhat more than twice as effective as a mile of shore line along Biscayne Bay in discharging ground water.

Regarding the ground water under the keys, Parker said (p. 829):

> ".... on the Florida Keys ..... a small lens of fresh water, if present, rests entirely on and in equilibrium with sea water under each key."

Plankton samples taken from south Florida areas were discussed by Davis (1950). In two samples from South Beach and Miami Beach, just beyond the surf where 19.5% were foraminiferal remains, the Foraminifera were most common. Globigerina was found at 30 fathoms east of Cape Florida and off Miami Beach. Most of the Foraminifera encountered were tychopelagic, but they were not specifically identified. Davis noted that the plankton, except at some localities in the vicinity of cities, were relatively sparse. Sewage in the vicinity of Miami made for richer plankton.

Smith, Williams and Davis (1950) published on the ecology of subtropical inshore waters adjacent to Miami. They chose eleven stations distributed throughout most of the bay to represent ecologically distinct habitats, and compared sea water temperatures, salinities, phosphate-phosphorous, nitrite-nitrogen, plankton and fouling organisms. The conditions in Biscayne Bay, they concluded, exhibit a wide range, and the land drainage and sewage played a great part in the growth of plankton and sedentary growth, limited by the rate of phosphate production and a grazing rate limited by phytoplankton production.

Ginsburg (1956) discussed environments in Florida Bay, south of Biscayne Bay. He noted differences in the circulation - salinity across Florida Bay and suggested that (p. 2400):

> "The Bay can be divided into an outer or marginal zone where there is frequent tidal exchange with the reef tract and salinities are near normal, and a larger interior or central zone of semi-restricted circulation in which there may be larger fluctuations in salinity."

He further noted (p. 2402) that the differences between the two circulation-salinity zones are relatively minor. However, Ginsburg further stated (pp. 2403, 2404), that:

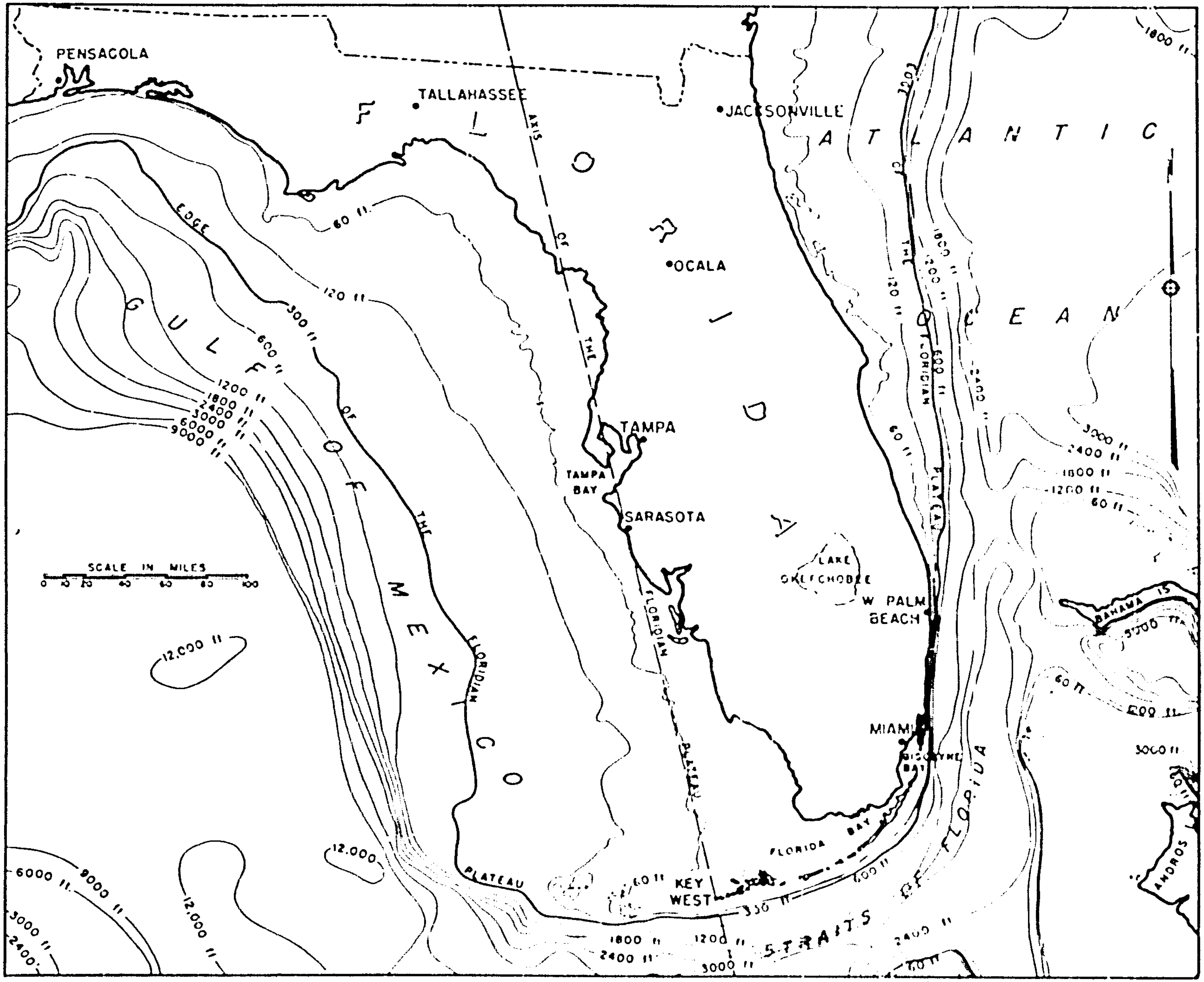
> "The percentage of Foraminifera is the only difference between the constituent compositions of the central and marginal zones. Samples from the central zone have 10 per cent or more Foraminifera, and those from the marginal zone have less than 10 per cent. Foraminifera are most abundant in samples taken near the mainland where salinity fluctuations are the rule. Perhaps the relatively greater abundance of Foraminifera in brackish water is due to a large population of a few species which are adapted to the changes in salinity, and the absence of mollusks able to withstand such changes."

In relation to variation of grain size in Florida Bay Ginsburg stated (p. 2411):

> "In all three traverses there is a general increase in the percentage of fines in the inner part of the back reef, especially in those parts of the area which are slightly deeper than their surrounding bottom. . . . In all three traverses the outer reef-arc and the near-by part of the back reef have little or no fines."

GEOLOGY

Vaughan (1910) regarded the peninsula of Florida as a part of the area known as the Floridian Plateau (see fig. 1). This plateau extends west to about the fifty fathom line, and



(after Parker & Cooke, 1944, p 13)

Fig.1 FLORIDIAN PLATEAU

south and east beyond the Florida Keys to the Straits of Florida. According to Pressler (1947, p. 1852) its steep east and south margins presumably represent major fault zones (see fig. 2).

Pressler (1947, p. 1851) subdivided the Floridian Plateau into two provinces: North Florida, characterized by a geologic section composed principally of clastic sedimentary rocks, and South Florida, characterized by a section composed for the greater part of non-clastic sedimentary rocks consisting of limestones, marls and evaporites.

The core of the plateau is probably compsed of igneous and metamorphic rocks (Mossom, 1926; Campbell, 1939, 1939a; Applin and Applin, 1944, p. 1723), whereas the Ocala uplift, an elongate dome trending northwest and plunging southeast, is the principal geologic structure in the state (see fig. 3). This uplift chiefly involves dolomites and limestones of Cretaceous to Oligocene age. The Miocene through Pleistocene overlying beds thicken southward from the uplift (see fig. 4).

The following geologic history of the Biscayne Bay area is summarized from Campbell (1939, pp. 97-105), Parker and Cooke (1944), Cooke (1945), Parker (1951), Naegli (1945), and Ericson and Naegli (1945).

The pre-Cretaceous history of this area is unknown because of the absence of identifiable Jurassic or earlier rocks. The earliest interpretable history is that of the Comanchian Lower Cretaceous. Thick layers of anhydrite intercalated with limestone, dolomite and black shales were deposited. Organisms were unable to live in the evaporating seas at the time of anhydrite deposition. However, shallow water Foraminifera thrived when fresh sea water was introduced, as shown by the association

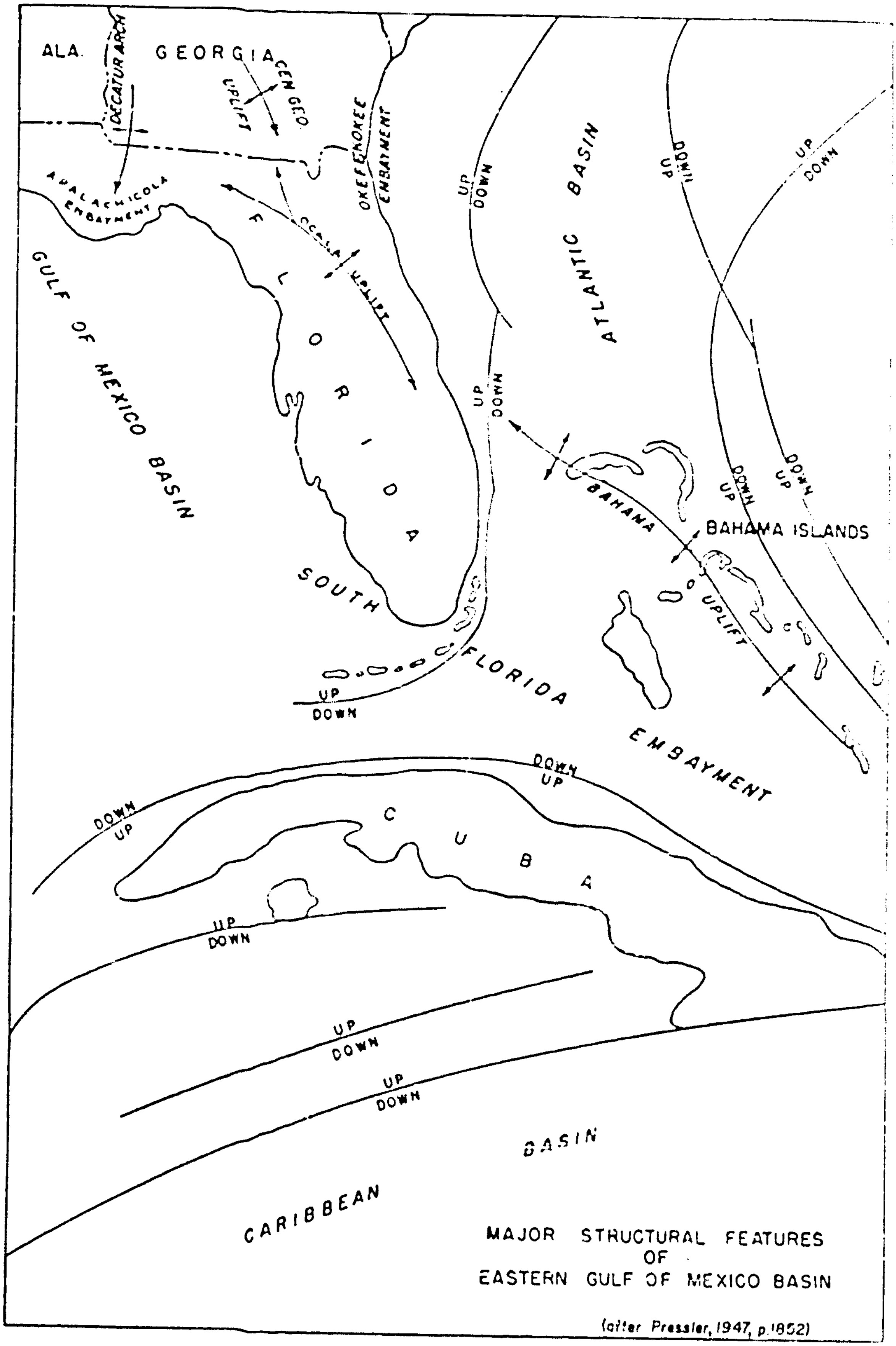

ALA.
GEORGIA
DECATUR ARCH
UPLIFT
CEN GEO.
OKEFENOKEE EMBAYMENT
APALACHICOLA EMBAYMENT
FLORIDA
OCALA UPLIFT
GULF OF MEXICO BASIN
ATLANTIC BASIN
UP
DOWN
BAHAMA UPLIFT
BAHAMA ISLANDS
SOUTH FLORIDA EMBAYMENT
CUBA
CARIBBEAN BASIN
MAJOR STRUCTURAL FEATURES
OF
EASTERN GULF OF MEXICO BASIN
(after Pressler, 1947, p.1852)

Fig. 2

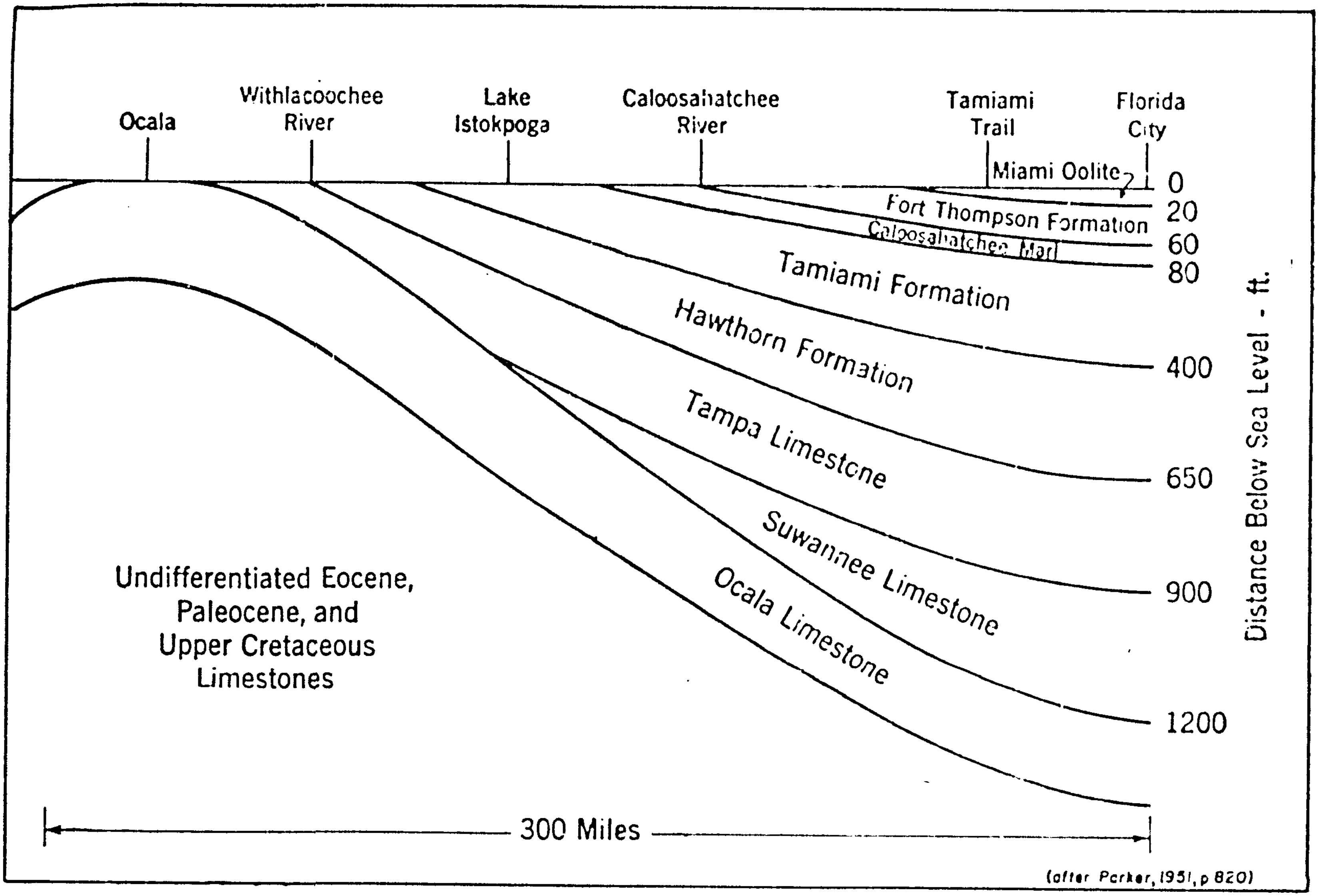


Fig. 3 **Generalized North-South Cross Section of Florida**

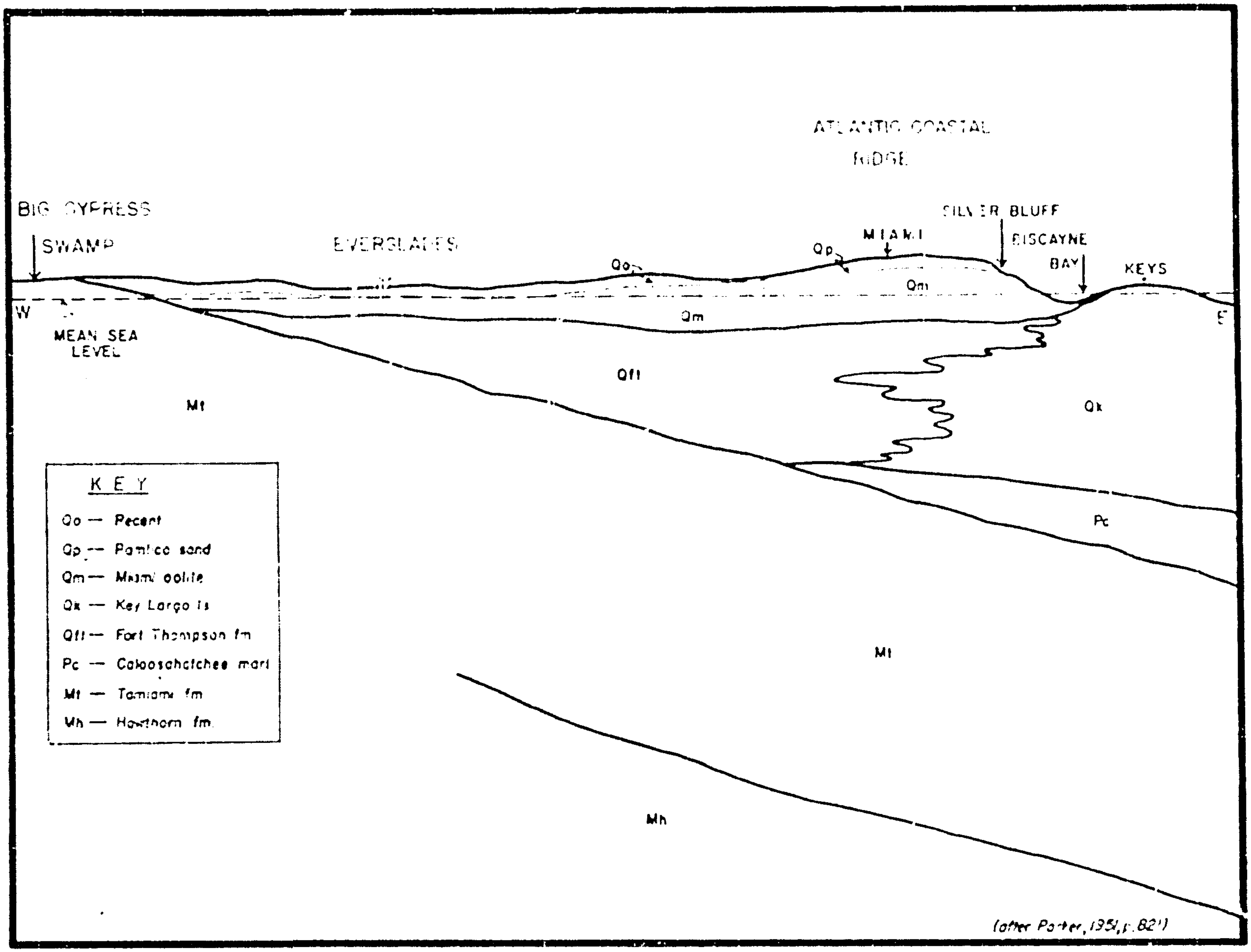


Fig. 4 IDEALIZED EAST-WEST CROSS SECTION OF MIAMI AREA

of Orbitolina concava texana, Dictyoconus walnutensis, Coskinoline adkinsi, Coskinolinoides sp., Textularia sp., and Choffatella sp. as well as ostracods, algae, oysters and echinoids with limestone and black shale deposits. Based on these data, the area is interpreted as having been under a warm, shallow sea which at times was shut off from open circulation with marine waters.

In Gulfian (Late Cretaceous) time the area was elevated, peneplaned, and then subjected to conditions similar to that of the Comanchian. The shallow water environment had deposited in it about 2,000 feet of limestone and dolomite intercalated with evaporites, and has a sparse fauna consisting of Lepidorbitoides sp., Cibicides harperi, Sulcoperculina cosdeni, rotalids, echinoids and Inoceramus sp.

Conditions continued favorable for the deposition of limestone throughout Paleocene and Eocene times without any apparent elevation of the area above sea level. A few interbedded evaporites indicate that occasionally the region became somewhat stagnate. Clays from the north were no longer transported this far south from the Appalachians, but were, instead, replaced by occasional sandy zones interspersed through the limestone. The area was still one of shallow, warm, marine waters as algae, pelecypods, bryozoa, ostracods, echinoids and the following Foraminifera were found in the sediments: Amphistegina sp., Borelis sp., Camagueya perplexa, Coskinolina elongata, C. floridana, Cribrospira sp., Dictyoconus americanus, D. cookei, Discorinopsis gunteri, Eponides gunteri, Fabularia vaughani, Flintina avonparkensis, Globigerina sp., Gumbelina sp. Lepidocyclina favosa, Lituonella floridana, miliolids, Miogypsina sp., orbitoloids, Planispira sp., Pseudochrysalidina sp., Pseudouvigerina sp., Reusella sp., Valvulammina nassauensis, and Valvulina floridana. It is interesting to note here the occurrence of the genus Globi gerina, which is indicative of deeper waters or of nearby connections with open oceans.

Limestone deposition, at times sandy, continued through Oligocene time with no apparent discontinuity. Though there is a distinct faunal break between the two epochs, there does not appear to have been aby change in the depositional environment. The fauna is still one representative of a warm, shallow, marine environment as evidenced by algae, corals, bryozoa, mollusks, echinoids, asteroids, barnacles, crabs and the following Foraminifera: Archaias floridanus, Dictyoconus cookei, Eponides jacksonensis, Globorotalia sp., Heterostegina texana, Lepidocyclina sp., Miogypsina sp., Operculinoides sp., Pyrgo sp., Sorites sp., and Textularia sp..

Elevation and erosion of the peninsula took place after Oligocene time. Subsequently the early Miocene, porous, white, sandy Tampa limestone was deposited unconformably on the eroded surface. A transgressing sea then conformably deposited a calcareous, shell-quartz sand upon the Tampa limestone. This latter formation, the Hawthorne, together with the underlying Tampa limestone, contain a very abundant fauna. These formations are particularly characterized by an abundance of mollusks together with Amphistegina chipolensis, Archaias floridanus, Cibicides floridanus, Elphidium chipolensis and Textularia barrettii. Again, the fauna is one representing a warm, shallow, marine sea near to land. The area was subsequently lifted and eroded and then followed by the conformable deposition of the Tamiami formation of the uppermost Miocene (see Parker, 1951, p. 823) and lowermost Pliocene age. This latter formation was deposited in a shallow sea which then receded and was followed by subsequent erosion of the land. The upper Pliocene, Caloosahatchee marl, was deposited in a littoral and neritic environment with shifting currents (see Parker and Cooke, 1944, p. 59), lying adjacent to a low land mass which contributed fine sediments consisting of sand, silt, clay and shells.

Late Pliocene time had been a period of widespread crustal instability, at which time the eastern extremity of the Coastal Plain was completely submerged and its gorges became submarine canyons. Later this area was emergent, tilted toward the west and actively eroded.

The following Pleistocene history is summarized from Cooke (1930, 1945) and Parker and Cooke (1944).

The Fort Thompson formation and Key Largo limestone were deposited in the Pleistocene seas while the sea rose and fell upon the area in response to the control of glaciation and deglaciation. There were five major stages of low sea level, corresponding to the Nebraskan, Kansan, Illinoian, early Wisconsin and late Wisconsin stages. In southeastern Florida these are represented by erosion surfaces, solution holes, soil zones and fresh-water limestones and marl.

Between each of the major low-water stages, the sea advanced landward to major high-water levels, corresponding to the Aftonian, Yarmouth, Sangamon and mid-Wisconsin interglacial stages, at which time terraces and wave-cut cliffs were formed.

The Key Largo limestone, which includes the Pleistocene reefs of southeastern Florida, is both older than and in part contemporaneous with the Miami oolite. The Miami oolite overlaps the Fort Thompson formation to the north and northwest.

The Miami overlaps the Fort Thompson formation to the north and northwest. The reef is about 90 miles long, and has a surficial width of approximately 3 miles, but is much wider at its base. Its thickness may exceed 50 feet. The limestone contains corals and bryozoans. Cavities in the limestone are filled with amorphous calcium carbonate, or detritus from wastage of the reef which fell, or was washed in. Subsequently this was incorporated in the rock as a limestone breccia.

The Miami oolite is soft, cross-bedded to massive, and grades from an almost pure calcium carbonate to sandy limestone to the north. It is thought to be a remnant of old calcareous dunes or beach ridge deposits in part, and marine in other parts. The Miami oolite was formed in a shallow-water marine environment in back of the Key Largo reef. At times bars were built up above sea level and calcareous dunes and beach ridges were deposited. Several pieces of cross-bedded oolite are embedded in structureless oolite; whereas in other areas, steep dipping, cross-bedded portions are truncated by horizontal beds containing marine shells.

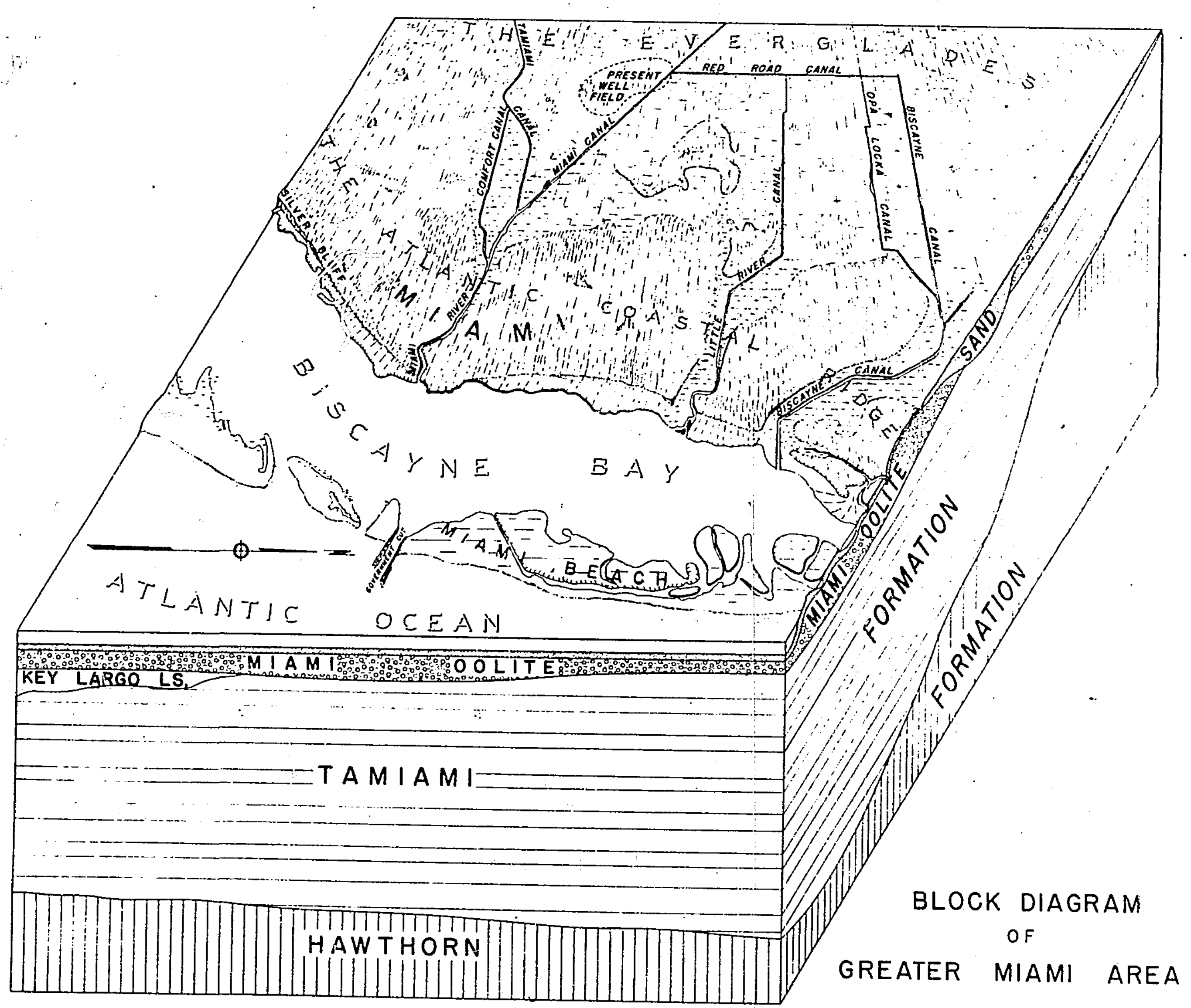
The Miami oolite and Key Largo limestones underwent solution and erosion in early Wisconsin time. Thereafter the Pamlico formation was deposited in mid-Wisconsin time. The Pamlico is restricted below an elevation of 25 feet above sea level. It consists of white quartz sand which filled in the solution holes in the underlying rocks. In places it is overlain by Recent muck, marl and swamp deposits. A shallow sea deposited the Pamlico sediment and, upon its recession, carved a wave - cut notch and bench at 8 and 5 feet above sea level in the Atlantic Coastal Ridge.

Biscayne Bay is situated east of the Atlantic Coastal Ridge, an irregular, low strip to the west of which are the lower-lying Everglades. The ridge rises imperceptibly from the Everglades and descends into the bay. Its altitude averages 8 feet above mean sea level and rises to approximately 25 feet just west of Coconut Grove at Dinner Key. East of the ridge in the bay area is a Pleistocene wave-cut terrace, which averages approximately 5 feet above sea level (see figs. 4 and 5, and Parker, 1951, p. 817) and is called the Silver Bluff (Parker and Cooke, 1944, p. 24).

From Soldier Key southward to Bahia Honda, Biscayne Bay is bound on the east by the Keys, which are composed of Key Largo limestone. North of Soldier Key they are composed primarily of quartz sand, which is now principally derived by the reworking of the underlying Pleistocene deposits. Sand is also transported from the north by the Counter Current and much of it is supposedly washed into and deposited in the northern part of the bay.

The open water lying between the Keys and the Florida Current, which flows northward in the Straits of Florida, is bound on its eastern side by a series of reefs consisting of living corals south of Fowey Rock, and of dead corals to the north. However, farther to the north there is no clearly defined reef. The Counter Current flows southward between the outside reefs and the east side of the Keys.

Biscayne Bay is the northern extension of Florida Bay (see fig. 6). Bounded by the mainland on the west and the Keys to the east, it is a lagoon affected by tides, currents and winds. The bay is the result of the rise of the Florida Platform, the deposition of the Miami oolite in shallow water,



(after Parker et al, 1944, p.4)

Fig. 5

and the simultaneous deposition of the Key Largo limestone on the southeastern border of the Platform. Deposition of an appreciable amount of sediment is not now taking place, for the Miami oolite occurs below a thin veneer of consolidated sediment, the Pleistocene Pamlico sand. Cooke and Mossom (1929) maintain that the Pleistocene limestone (Miami and Key Largo) are now being dissolved by the great influx of fresh water from the land, which is charged with humic acids and point to cavernous limestone in the Keys as proof.

The limestones are being taken into solution in the areas west of the bay, the exposed limestone reefs, and in the subterranean areas of the entire region by fresh water. According to Vaughan (1914d, pp. 27-28):

> "the sea water flowing into and out of the Tortugas Lagoon .... show that although both carbonate and bicarbonate radicals are in solution, uncombined carbon dioxide is not present, and that the water possesses no capacity for further solution of calcium carbonate by virtue of its content of free carbon dioxide; all the bays, sounds and lagoons within the Florida reef and key region are filling with sediment."

On this and other bases Vaughan concludes that the formation of lagoons by submarine solution may be definitely eliminated from consideration.

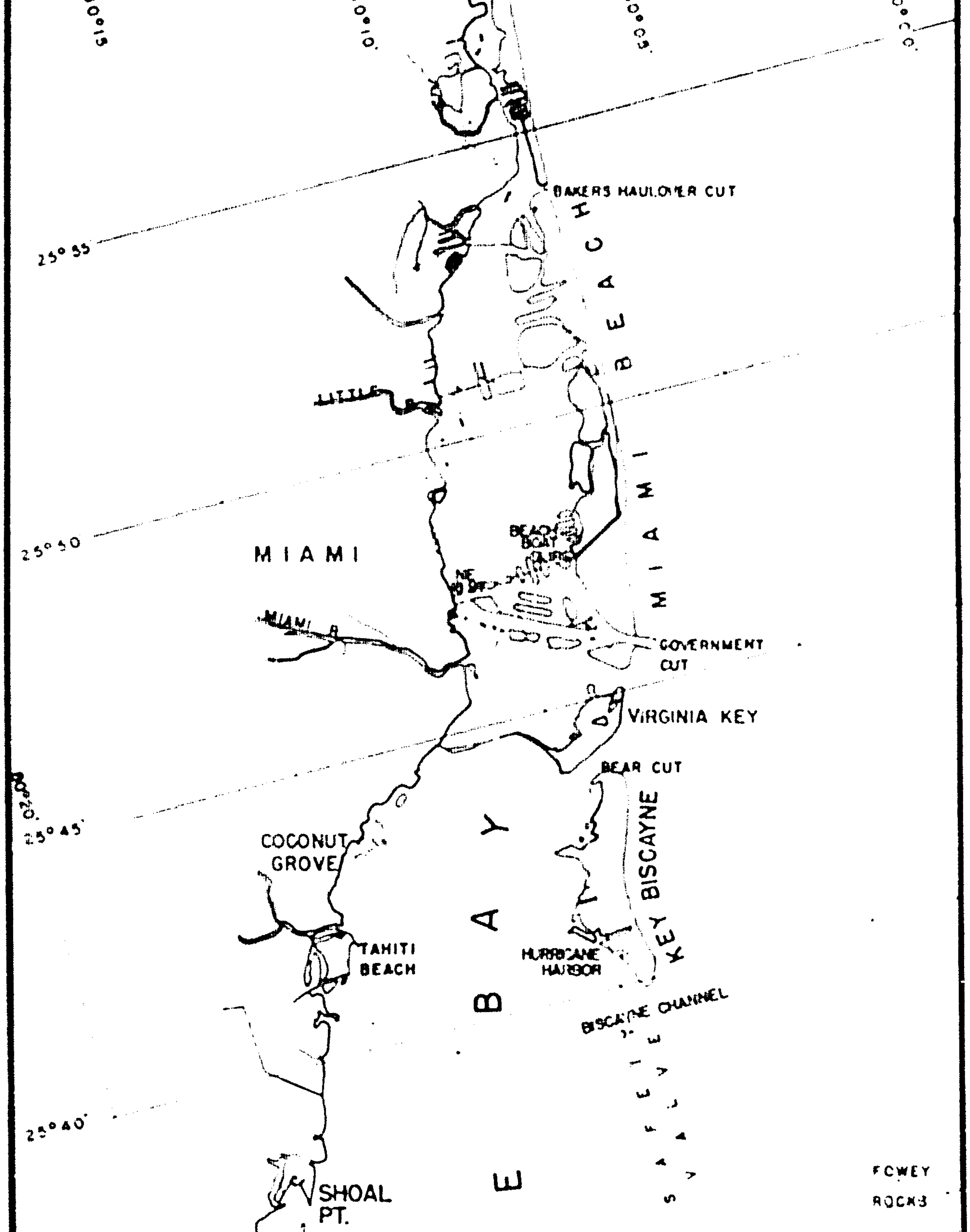
Dole (1914), in determinations of the salinity of the water within the Tortugas lagoon and at the southern end of Biscayne Bay, shows a higher concentration than that in the open sea-water on the outside, indicating that the tidal inflow and outflow are not sufficient to completely mix the water in the lagoons with the water of the surrounding sea, and that concentration by evaporation is taking place.

The author has observed a considerable deposit of calcareous silt in the deeper area running north-south through Biscayne Bay, which verifies the statement made by Vaughan. It is probable that the bay was formed by solution of the limestone, but, in the author's opinion, this solution ceased prior to the last submergence of the area. Since calcium carbonate is being deposited in the bay, it is unlikely that solution of the floor is concurrently taking place. The rocks composing Soldier Key show the action of solution, but these rocks are at or above tidal level where the work of the atmosphere and fresh water are active. The dilution of the bay water by surface runoff from the mainland is not sufficient, along with poor mixing of the bay water, to produce solution of the bedrock of the bay, but is, instead, readily transported out to the waters of the Keys (Dole and Chambers, 1918). Ginsburg (1953, p. 68) suggested that the activities of boring and burrowing organisms are a major factor in erosion at intertidal level on the Florida Keys.

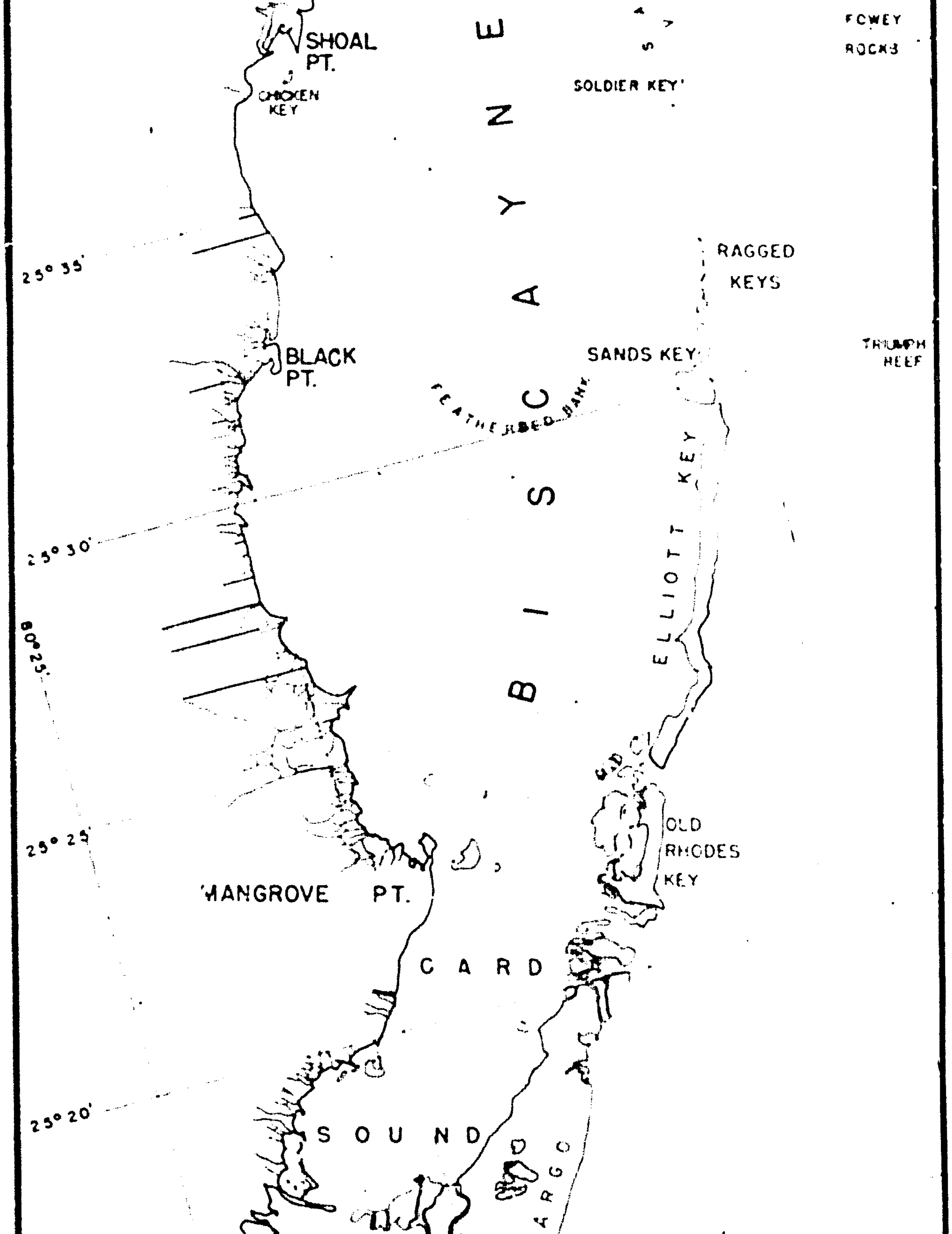
BOTTOM TOPOGRAPHY

The average depth in Biscayne Bay is from 7 to 11 feet (see fig. 7). The bay shallows toward the mainland to the west and toward the keys to the eastward. There are several small areas located on the western side of the Safety Valve where depths of as great as 21 feet are reached. These areas are very small and few. They result from scouring by ebb and flood tidal currents through the channels between the low and flat - lying "Coral Shoals" which make up the Safety Valve. The Main Channel, the ship channel through the northern end of the bay, is maintained by dredging to a depth of 30 feet.

Biscayne Bay is divided topographically into northern and



BAKERS HAULOVER CUT
MIAMI BEACH
MIAMI
GOVERNMENT CUT
VIRGINIA KEY
BEAR CUT
KEY BISCAYNE
HURRICANE HARBOR
BISCAYNE CHANNEL
COCONUT GROVE
TAHITI BEACH
SHOAL PT.
FOWEY ROCKS
25°55'
25°50'
25°45'
25°40'


SHOAL PT.
CHICKEN KEY
SOLDIER KEY
FOWEY ROCKS
RAGGED KEYS
SANDS KEY
BLACK PT.
FEATHERBED BANK
BISCAYNE
ELLIOTT KEY
OLD RHODES KEY
25° 35'
25° 30'
80° 25'
25° 25'
MANGROVE PT.
CARD SOUND
25° 20'

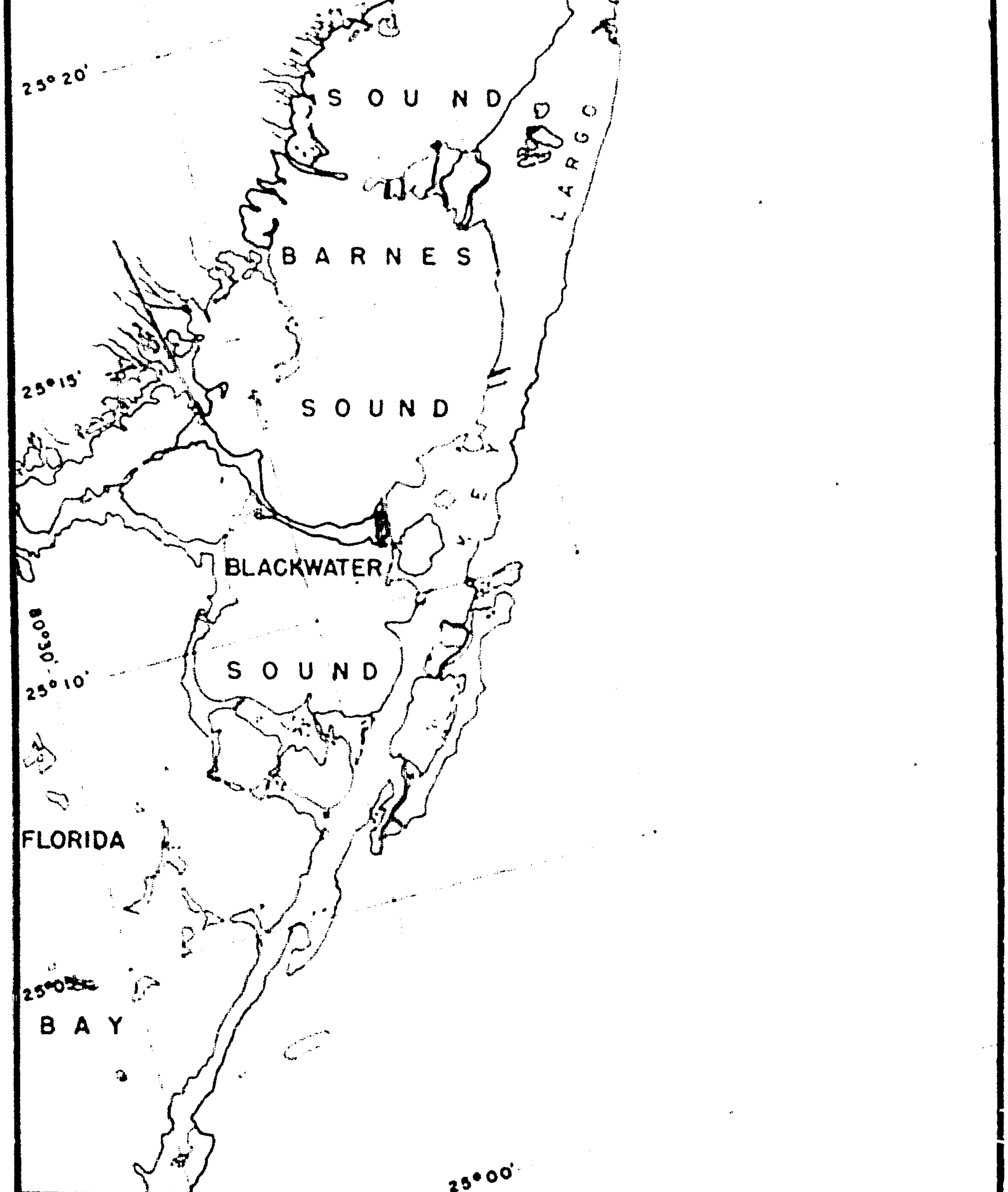
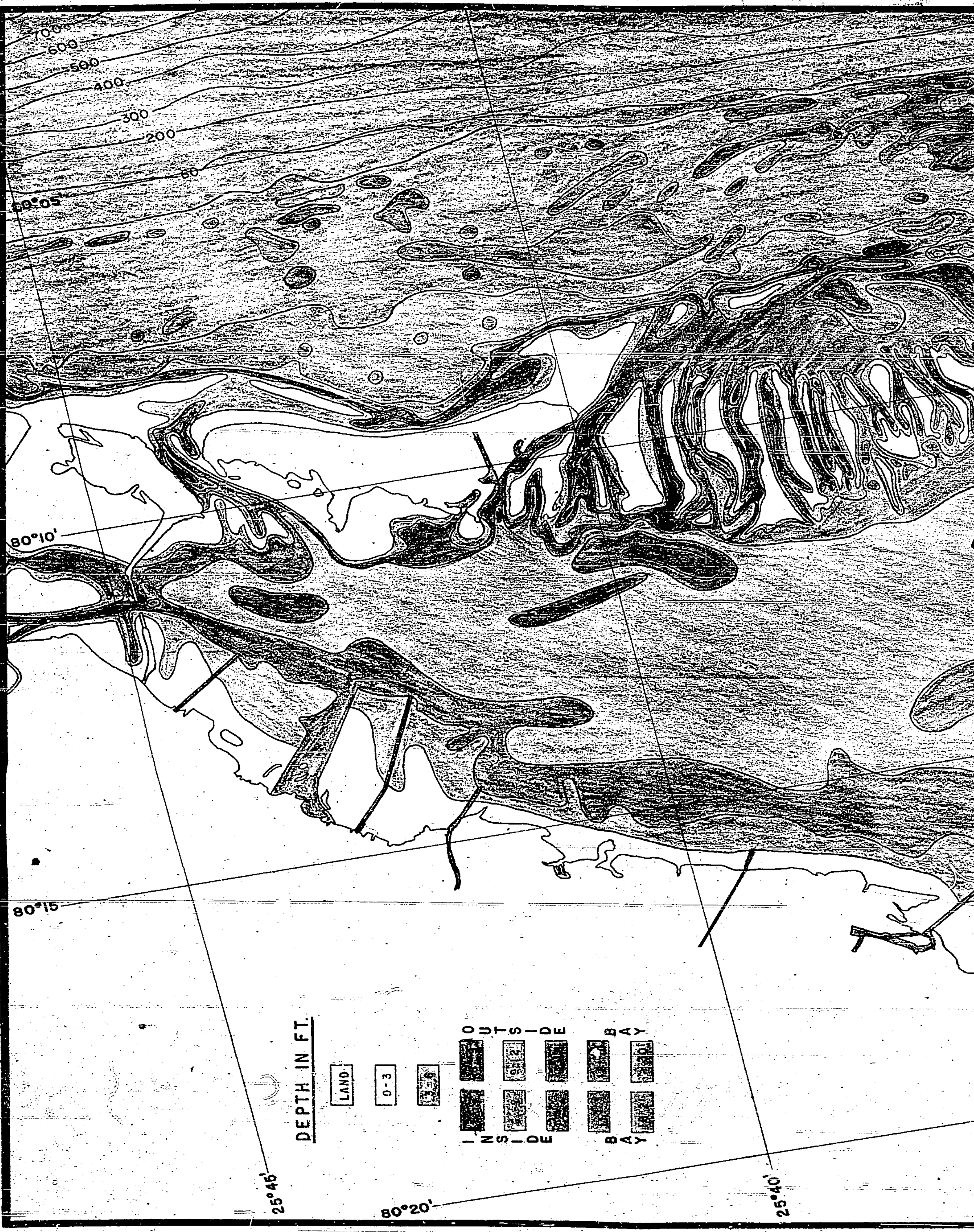
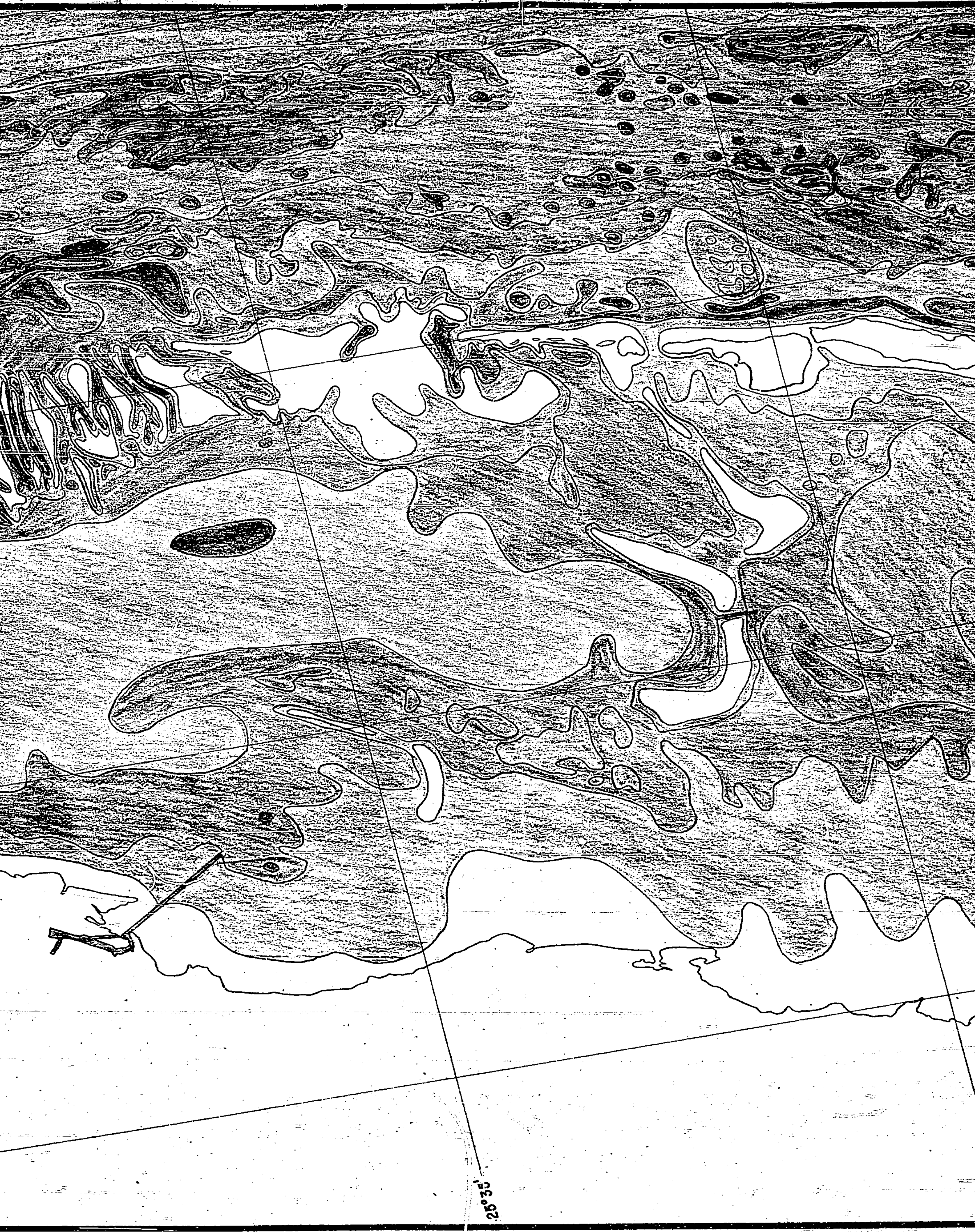


Fig. 6 GENERAL LOCATION MAP


700
600
500
400
300
200
60
80°05'
80°10'
80°15'
80°20'
25°45'
25°40'
DEPTH IN FT.
LAND
0-3
3-6
INSIDE BAY
OUTSIDE BAY


25°35'


25°30'
25°25'
BATHYMETRIC CHART
OF
BISCAYNE BAY, FLORIDA
(after U.S.C. & G.S. Charts 848 & 849)

southern areas. The northern, which is approximately twice the length of the southern, extends from the latitude of Virginia Key south to Featherbed Bank. The southern area lies south of the Bank.

Featherbed Bank is low, concave to the north, and is exposed at the surface during low tides. Another shallow area extends from approximately the central portion of the bay eastward to the keys. These two banks separate the bay into two definite areas, north and south. These vary not only topographically but also sedimentologically and oceanographically. Featherbed Bank is in no way a unique feature. Similar shallow separation areas occur between the southern portion of Biscayne Bay and Card Sound, between Card Sound and Little Card Sound, and between Little Card Sound and Barnes Sound. These banks thus separate the aligned bays, each of which has its own environmental characteristics.

PHYSICAL OCEANOGRAPHY

MOVEMENT OF WATER

The movement of water in the bay is eastward to the Florida Current and is governed by the tide, the influx of fresh water and the winds, which at times reach hurricane velocities. The tides produce a general change of 2-2½ feet in water level (U.S. Coast and Geodetic Survey). Because of increased rainfall, it is most pronounced from June to January.

The principal drainage into the bay from the land is by Miami River, Little River, The Tamiami Canal and other dredged canals. The two rivers merge 30 miles northwest of the City of

Miami and continue northwestward to Lake Okeechobee, a distance of approximately 70 miles. The Tamiami Canal goes westward and then northwestward from Miami across to Naples on the Gulf, or westward side of the peninsula. The intracoastal waterway, going lengthwise through the bay, brings in additional water, particularly from Barnes and Card Sounds located south of the bay. During the rainy season, principally the months of May, June, September and October, numerous additional canals also empty their waters into the bay.

Biscayne Bay in turn drains into the Straits of Florida, in which the Florida Current flows in a northerly direction. The main movement of water, both into the bay and out to sea, is by means of a series of narrow channels through Bakers Haulover Cut, Government Cut, Bear Cut, Sands Cut, Caesar Creek and that area known as the Safety Valve located between the southern end of Key Biscayne and the northern end of Ragged Keys (see fig. 6).

Currents between 1 and 1½ knots setting into and out of Biscayne Bay on the flood and ebb, respectively, were observed by Haight (1935). Velocities of as much as 2 knots at strength of flood and 3 knots at strength of ebb have been recorded by the U.S. Coast and Geodetic Survey. Where the water is shallow between the keys, the bottom is swept clean of sediment by strong oscillating tidal currents; but where the water is deeper, relatively finegrained sediments accumulate on bottoms above which, at the surface, currents may be rapid, although no observations have been made on such possible surface currents.

The bay north of Featherbed Bank has a free and fresh flow of tidal water primarily entering through the Safety Valve. A few narrow and comparatively shallow "cuts" act as drainage and means of entrance into and out of the southern portion of the bay. The exchange of bay and open-sea water, therefore, in the southern portion of the bay is slow and probably not complete during a tidal cycle (Dole and Chambers, 1918; Smith, Williams and Davis, 1950). It is much more complete in the northern portion of the bay, which area though larger, has a much greater amount of interchange of water during a tidal cycle. The amount of water interchange has a definite effect upon the salinity, oxygen content, chemical content of the waters and, subsequently, of the existing life in the two areas, and the movement of the sediments therein.

The color of the water in the bay varies from a light green on the eastern side, to a brownish green on the western side. This indicates a considerable amount of organic matter in the western portion of the bay in relation to that on the eastern area as brought out by Smith, Williams and Davis (1950). They noted higher plankton concentration and more fouling in the western part of Biscayne Bay than in the eastern part. This is probably caused by land drainage and sewage which increases the growth of plankton and sedentary organisms.

TEMPERATURE

The first recorded temperature survey of Biscayne Bay was made by Dole (1914). Eleven stations were observed, eight located in the bay, the other 3 in the Straits of Florida. The survey offers inconclusive data for comparative purposes because the temperatures were taken at different times of day, and only one observation was made at each station. The only other survey was by Smith, Williams and Davis (1950). Here, also, eleven stations were observed, nine inside the bay and two outside. In all a total of eight observations and comparative analyses were made at each of the eleven stations during July 1945 through June 1946. The authors summarized their temperature data (p. 122) by stating:

> "The seasonal variations in sea temperature show the expected correlation with air temperature and total hours of sunshine, as reported by the U.S. Weather Bureau. The temperature reached its lowest point at all stations in December and then increased rapidly in the Spring. All stations except Triumph Reef showed similar seasonal variation in temperature, varying from the extremes of 18.25°C in winter to 32.2°C in summer, with a range of 14°C.
>
> Triumph Reef water was cooler in summer and warmer in winter than water at any other station; it varied from 24.35° to 29.8°C. This small range is characteristic of oceanic conditions and is probably due to the water at Triumph Reef mixing with water from deeper parts of the Florida Current."

From the observations made by Smith, Williams and Davis (1950), it is apparent that the very shallow stations have the lowest winter temperatures and the warmest summer temperatures (see fig. 8). It also seems apparent that these shallow areas are also relatively stagnant in comparison with others which have steady tidal flow. Since there is very little variation in depth, the temperature variation between the surface and the bottom is insignificant. The temperature of the water varies from approximately 18.25°C in the winter to 32.2°C in the summer (Smith, Williams and Davis, 1950, p. 122).

SALINITY

In comparison with 36 parts per thousand for water in the open sea (Sverdrup et al, 1946, p. 123; Thorp, 1935, p. 285), the salinity of the bay varies from 2.59 parts per thousand at

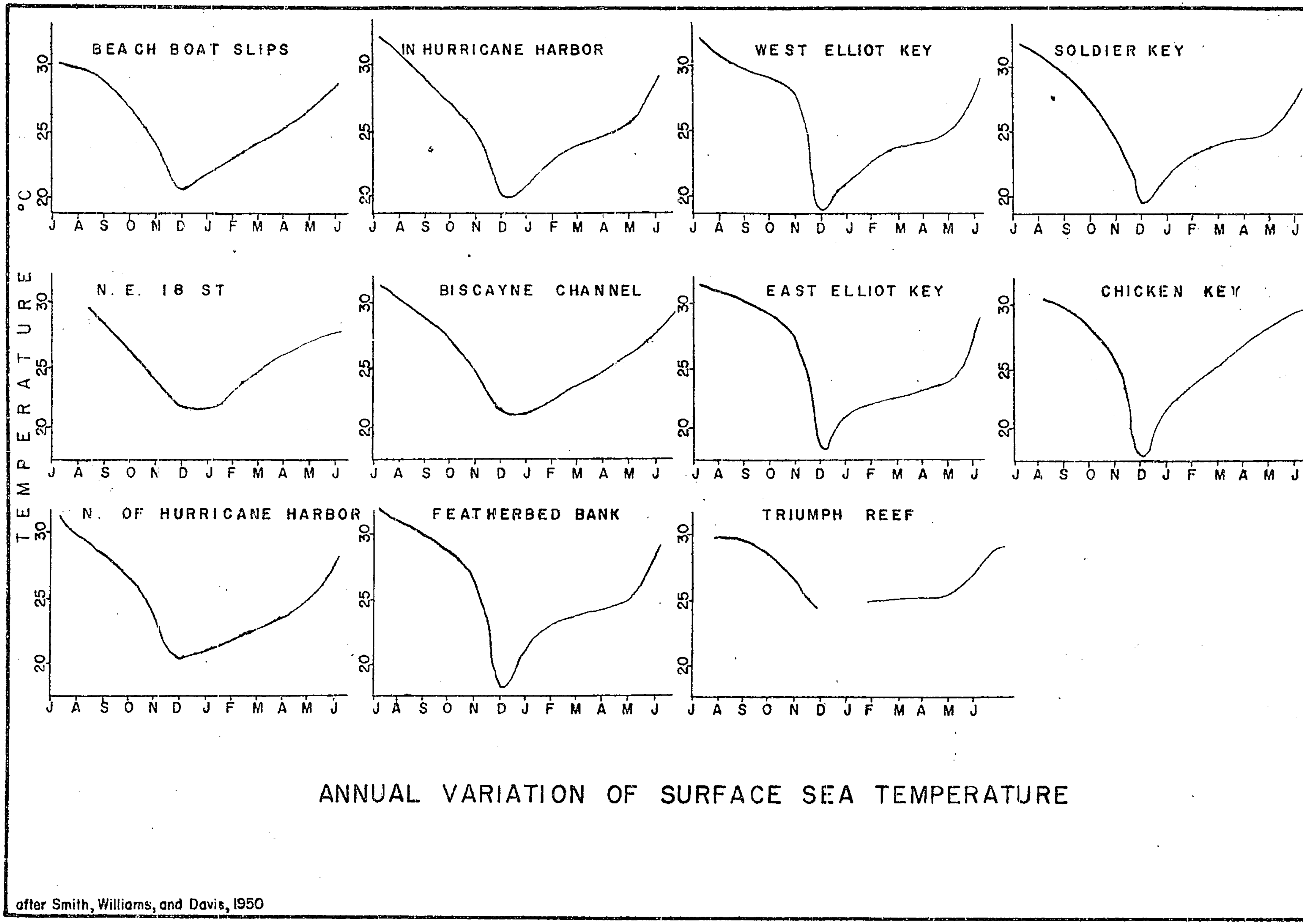
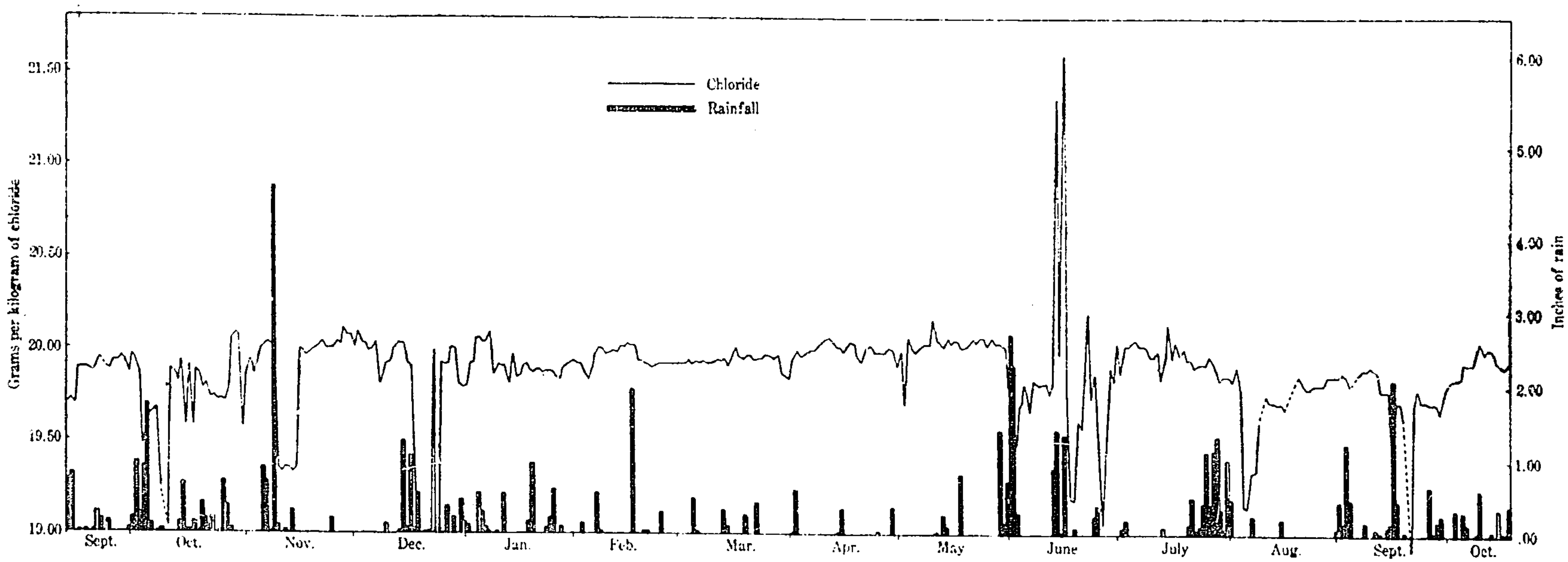

BEACH BOAT SLIPS
IN HURRICANE HARBOR
WEST ELLIOT KEY
SOLDIER KEY
N. E. 18 ST
BISCAYNE CHANNEL
EAST ELLIOT KEY
CHICKEN KEY
N. OF HURRICANE HARBOR
FEATHERBED BANK
TRIUMPH REEF
°C
TEMPERATURE
30
25
20
J A S O N D J F M A M J
ANNUAL VARIATION OF SURFACE SEA TEMPERATURE
after Smith, Williams, and Davis, 1950

Fig. 8

the mouth of Miami River to 39.09 parts per thousand at Featherbed Bank (Dole, 1909; Dole and Chambers, 1918; Smith Williams and Davis, 1950). According to the U.S. Weather Bureau records (U.S. Dept. Ag., 1941, p. 809), rainfall in southern Florida is about 60 inches per year, and is greatest in summer and fall. For any one locality salinity varies inversely with the rainfall. Precipitation in the Miami area has a definite effect on the chlorinity and salinity of Biscayne Bay, as well as upon the waters within the Straits of Florida. Precipitation at Miami is almost invariably followed within 24 hours by reduction of chloride content at Fowey Rock (Dole and Chambers, 1918, p. 311), as shown by fig. 9. It is obvious that if precipitation in the Miami area has such a great effect upon the chlorinity at Fowey Rock, then it most certainly has a greater effect on the salinity in Biscayne Bay itself. The area in the bay south of the latitude through Soldier Key is almost always more saline than that area to the north of this parallel, while lower salinities are found where fresh water from sewage and drainage outlets dilute the bay water, such as at the mouth of Miami River. The high salinities of 39.09o/oo found at Featherbed Bank during the month of July (Smith, Williams and Davis, 1950) is caused by evaporation of the water in the bay, producing higher concentrations and salinities. This is also pronounced in areas where the circulation is known to be poor as in Hurricane Harbor, just west of Key Biscayne, where the salinity reached as high as 38.69 o/oo in the same month.

Chemical and physical observations (Dole, 1909; Dole and Chambers, 1918; Smith, Williams and Davis, 1950) show that the waters in the southern portion of the bay tend to be colder in winter and hotter in summer than those in the northern portion. In addition, there is a tendency for higher salinities both winter and summer in the southern portion. Though the evaporation



Graph showing daily content of chloride of sea-water at Fowey Rocks and daily precipitation at Miami, Florida, September 12, 1914, to October 17, 1915.
(after Dole and Chambers, 1918, p. 311)

Figure 9

is equal throughout the entire bay, it has a more pronounced effect in the southern portion because of less mixing. A study of fig. 7 indicates that the northern portion of Biscayne Bay is open to a ready circulation from the Straits of Florida via the numerous channels and the Safety Valve, whereas the southern portion is connected to the open sea only by several narrow, shallow channels. That area south of Soldier Key has very few drainage channels, and is influenced by Featherbed Bank and its associated bank to its southeast, which have effectively stopped the circulation of the water in the southern portion of the bay from mixing with that in the northern portion.

ANALYTICAL PROCEDURES

SAMPLING METHODS

Sixty-three samples were collected during July, August and September 1948. The sample locations are indicated on fig. 10. The comparative University of Washington locality numbers are listed in Table III. Each sample was collected in one of three ways:

1. The "orange peel grabber" - This instrument was lowered to the bay floor by rope and upon reaching the bottom, automatically closed its four jaws grabbing some sediment.

The instrument worked well where the sediment was not covered with plants and was unconsolidated. If the floor of the bay had Thalassia or Halimeda growing, then it was impossible to use the "grabber," as it would bring up only the plants.

2. A can tied to the back of a navy-type anchor was used to drag the bottom. Upon pulling, the anchor would tend to sink into the sediment and the can would collect the sample. Where the grass was excessively thick, as at station no. 63, another large anchor was tied to the rope 10 feet in front of the navy-type anchor and can. The first anchor would gather the grass, making a clear path in which the anchor and can would follow to collect the sediment.

3. In cases where none of the above techniques worked, a third alternative was used - diving overboard with a small scoop and bottle to collect the sediment by shoveling. This method was always hesitantly resorted to as there were numerous shark, barracuda and rays in the waters.

SAMPLE ANALYSIS

To prepare for analysis, the sediment was first washed of the common sea salts and dried. The wash water was continually tested with silver chloride until it no longer showed evidence of a precipitate. Then the sediment was quartered. One portion was weighed and sieved through a set of square root of 2 Wentworth sieves. The material finer than sand-size was pipetted by standard techniques (for detailed description of methods of mechanical analysis of sediments, see Krumbein and Pettijohn, 1938). The sediment remaining on each sieve and that pipetted was weighed and a distribution curve plotted from the data. Each sieve size was analyzed for composition and roundness of grain.

Another portion of the sediment was analyzed for organisms, while still another was treated with HCl. The residue from the acid treatment was considered as quartz, while the

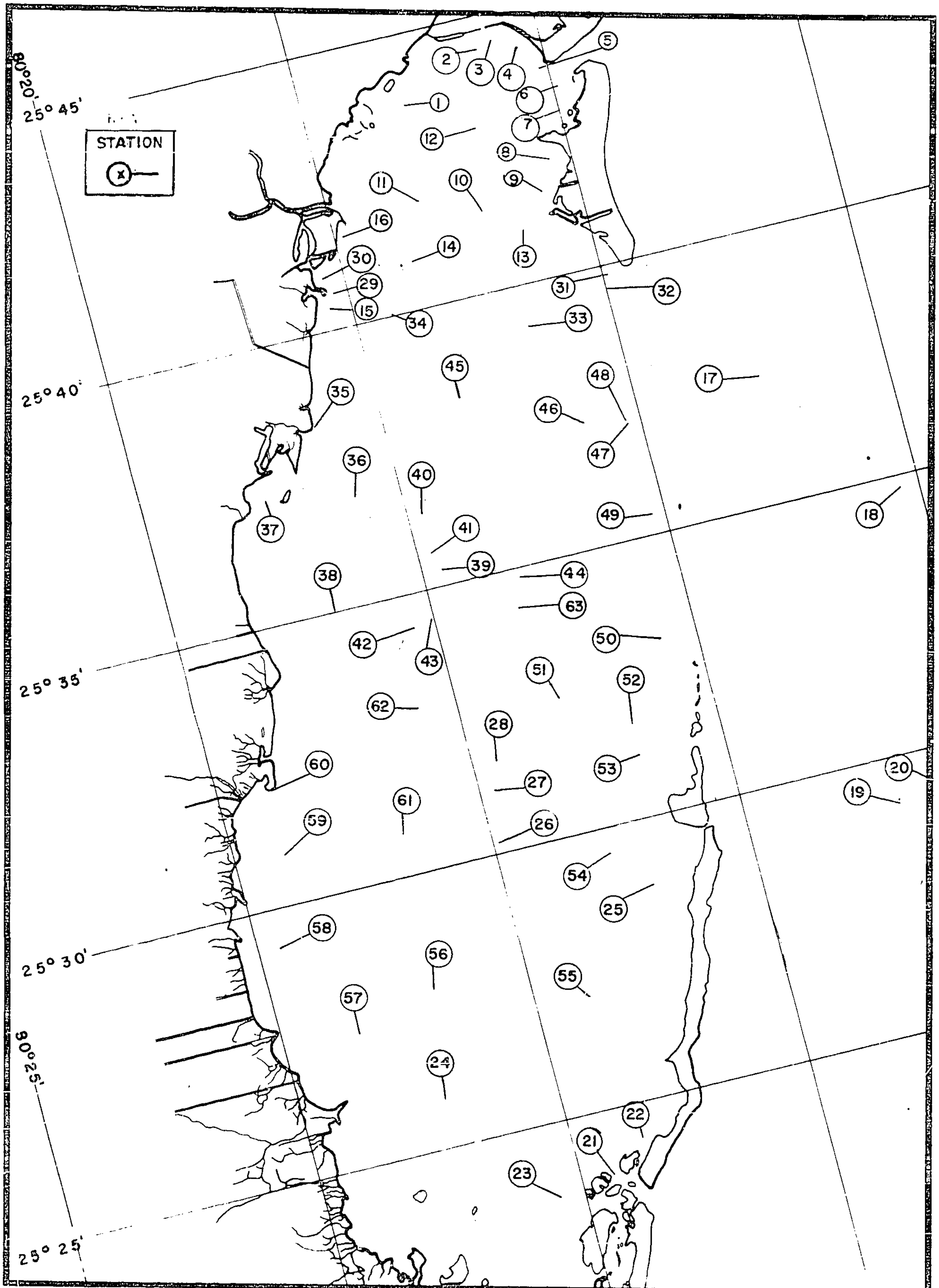
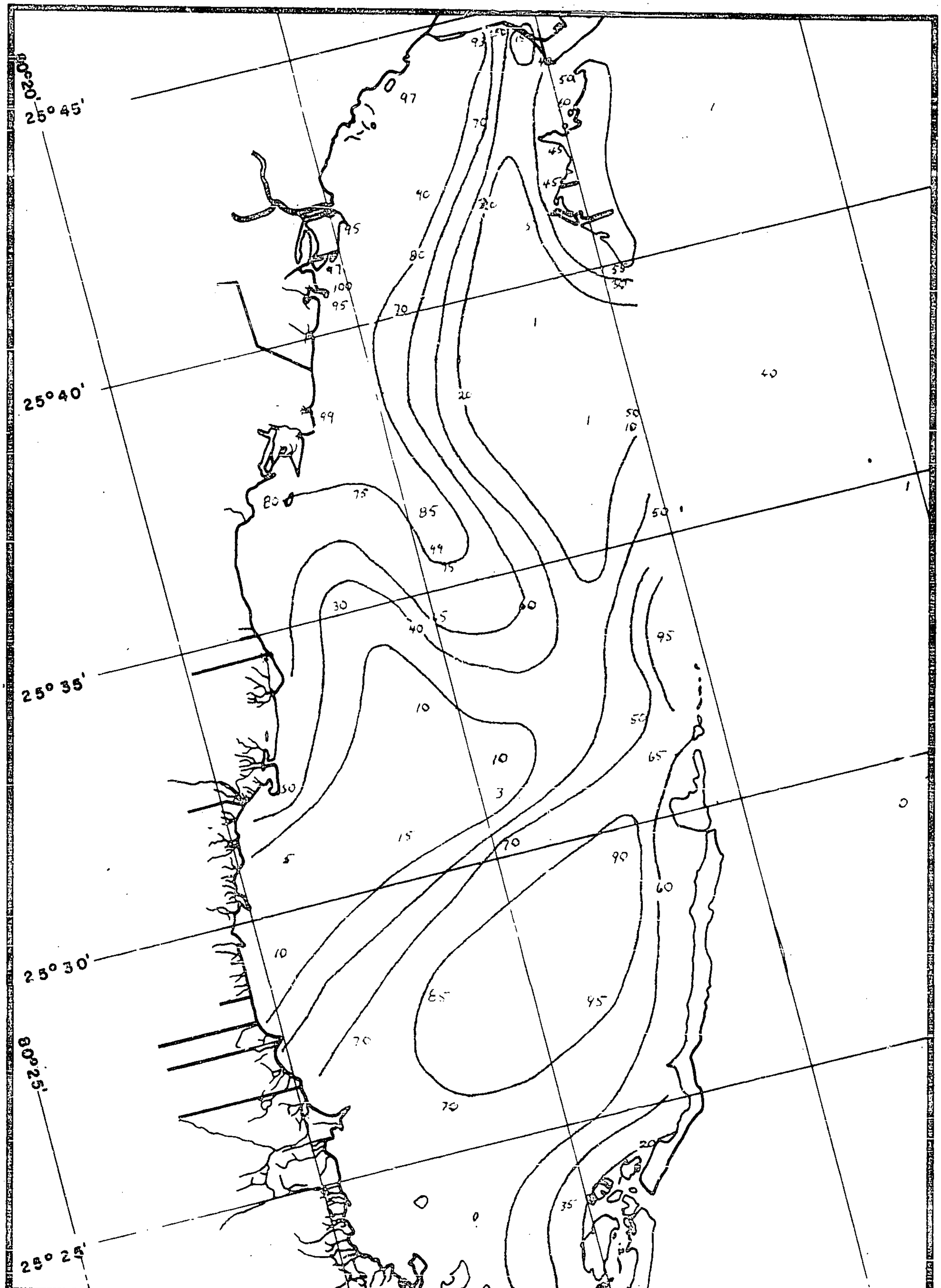


Fig. 10 **STATION LOCATIONS**

Figure 11 shows the percentage distribution of quartz in the bay. Quartz is the dominant mineral in the sediment of Biscayne Bay in two localities. The first is that of the western shore from Miami south to the vicinity of Black Point. Throughout most of this area quartz grains make up more than 90 per cent of the sediment. The quartz extends in tongue-like fashion from Tahiti Beach southeastward into the middle of the bay. The second area, located south of Featherbed Bank, extends in oval shape trending northeast-southwest in the deeper section of the bay.

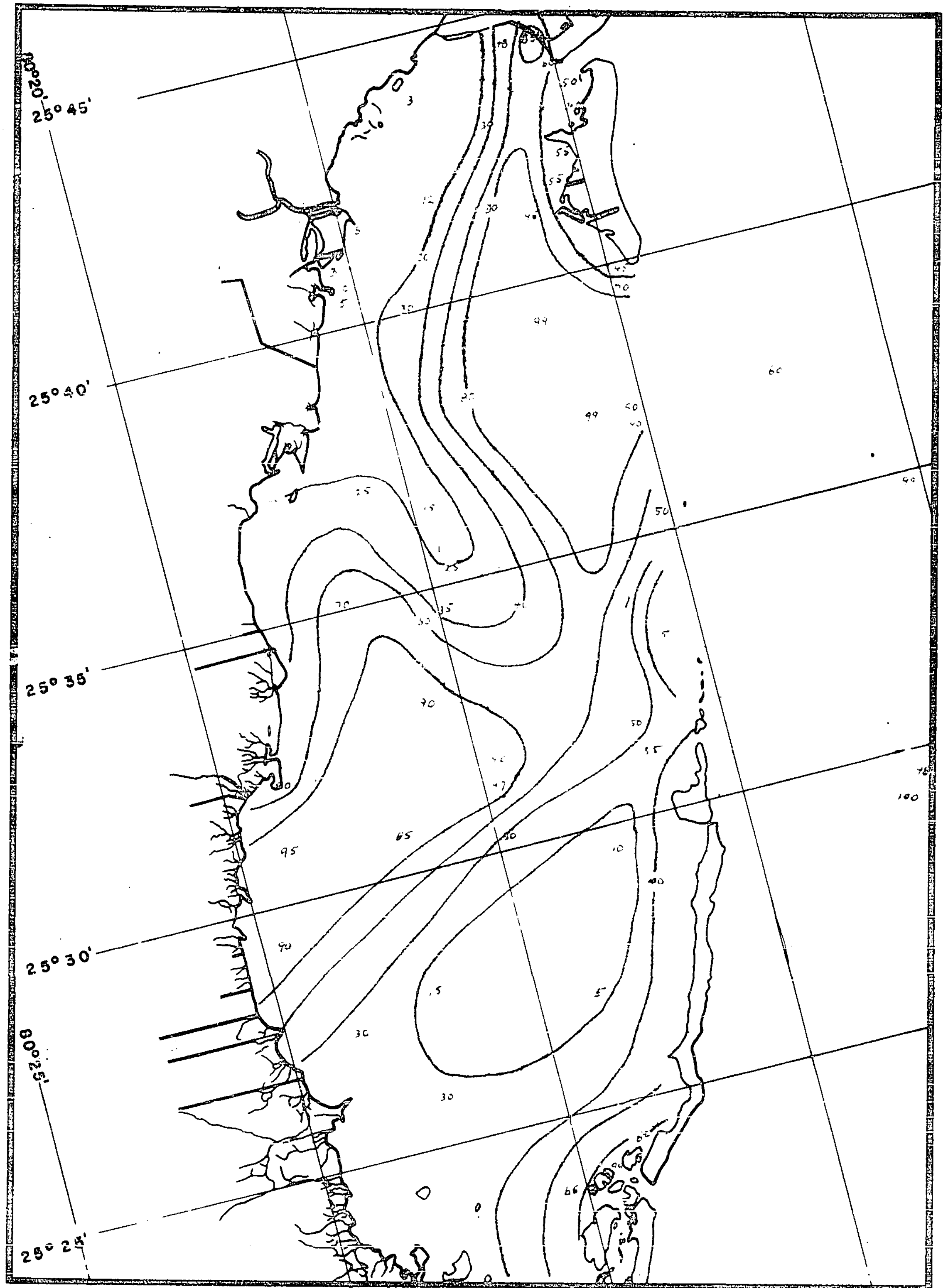
Fragmental calcium carbonate shell particles make up the other dominant material found in the sediment of Biscayne Bay. It is composed primarily of the organic remains of organisms which have lived in the bay, or are still living there. Figure 12 shows the percentage distribution of $CaCO_3$ in the bay. There are two predominant areas of Biscayne Bay in which calcium carbonate is the main constituent of the sediment. One is located in the vicinity of the Safety Valve wherein calcium carbonate composes more than 90 per cent of the sediment. However, the deep channels which go east-west through the Safety Valve have a higher percentage of quartz than those shallow areas immediately adjacent. This indicated that quartz is being transported through the channels into or out of the bay, whereas the shallow areas, generally less than two feet in depth at low tide, are composed of a high percentage of calcium carbonate derived from living organisms. The prime organism in this area is the genus Halimeda, a calcareous alga. The material which is not Halimeda is composed of other organisms and fragmental substance.

The second area of which calcium carbonate shell fragments is the main constituent, composing 90 or more per cent of the



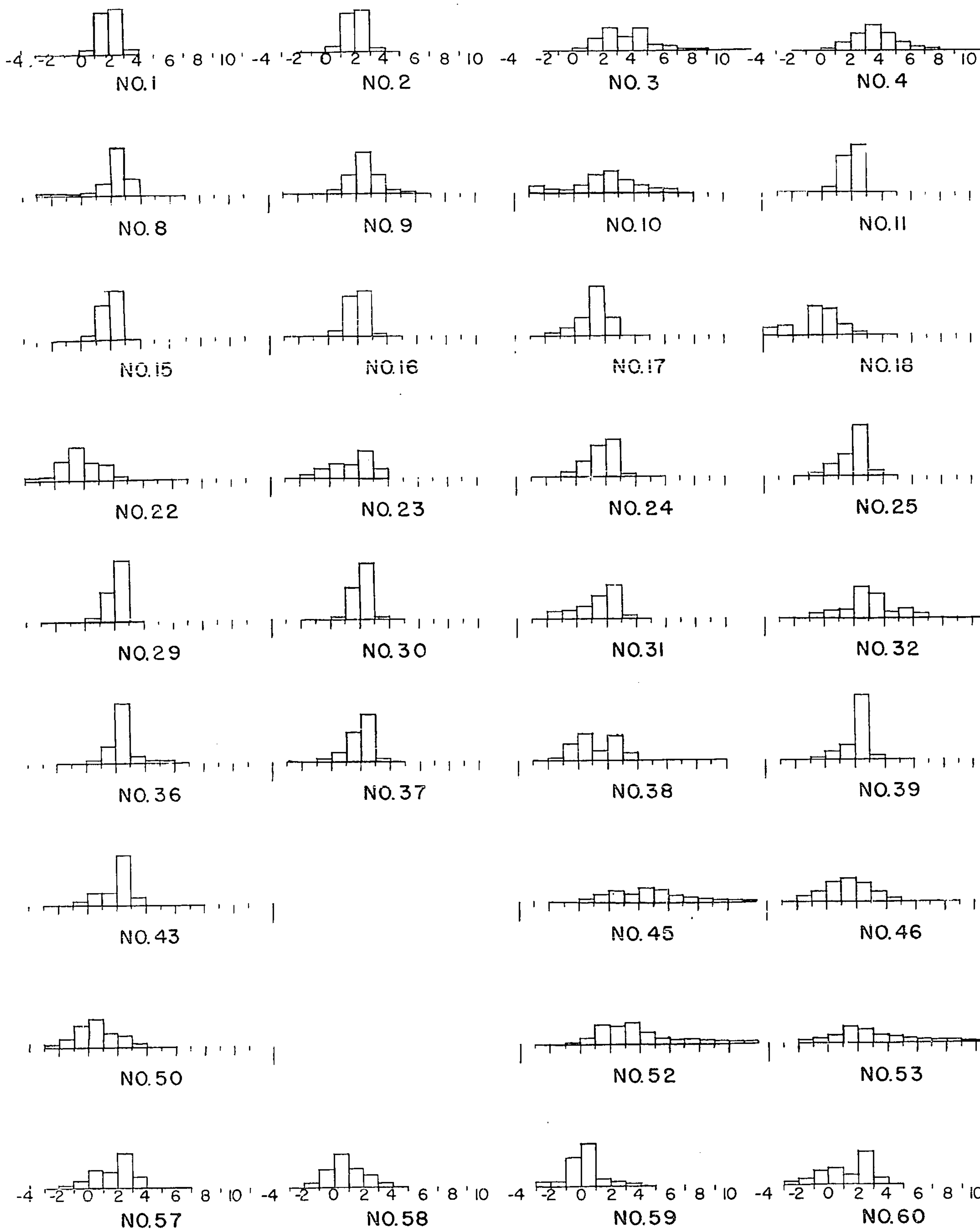
Numbers represent per cent quartz. Isopleths drawn for every 20%.

Fig. 11 DISTRIBUTION OF QUARTZ



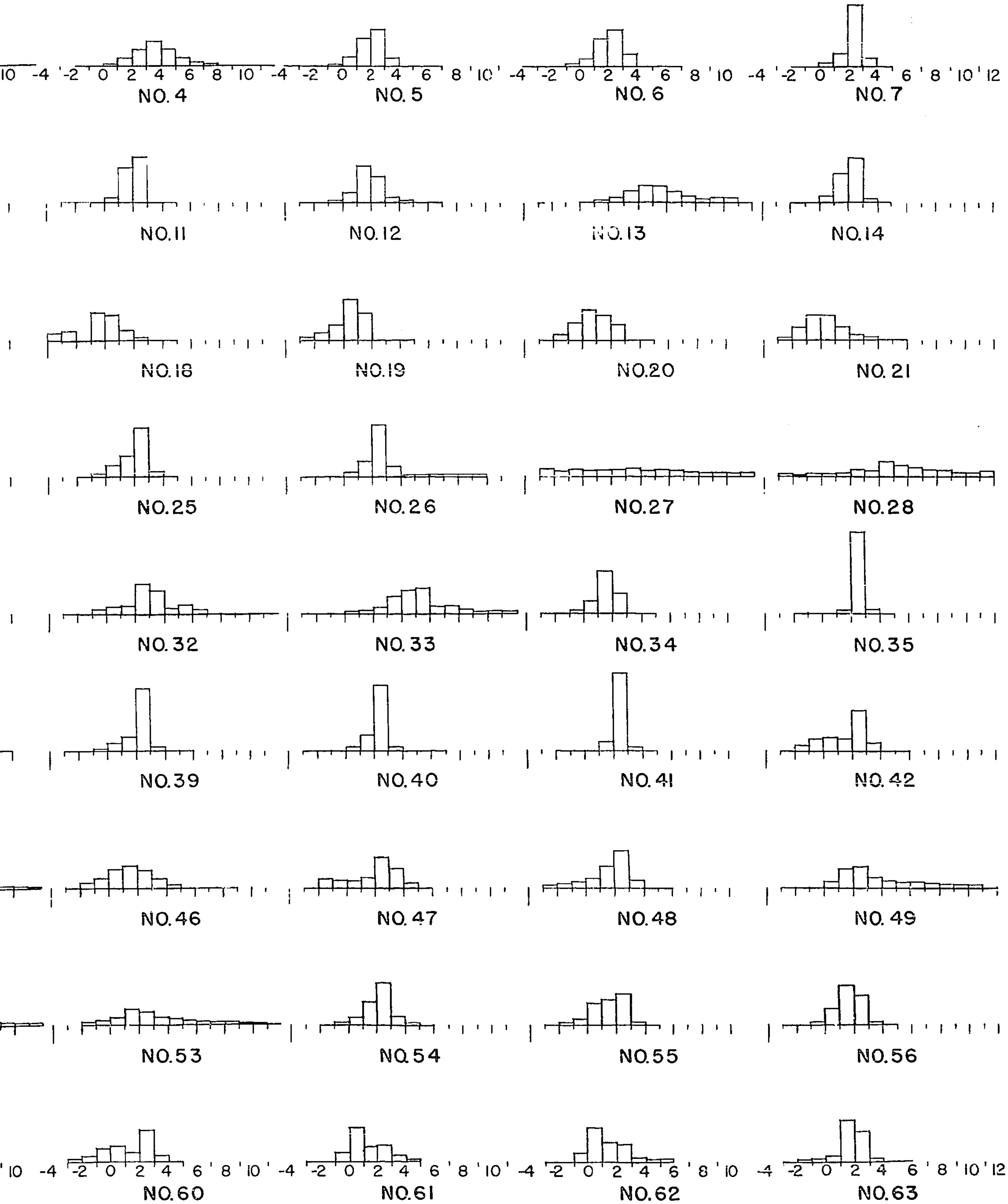
Numbers represent per cent calicum carbonate. Isopleths drawn for every 20%.

Fig. 12 DISTRIBUTION OF CALCIUM CARBONATE



Vertical scale in frequency of occurrence.
Horizontal scale in phi units.

HISTOGRAMS OF SAMPL



OGRAMS OF SAMPLES

Figure 13

sediment, is that section south of Black Point and north of the elongated quartz area. This extends in tongue-like fashion from the southwest shore of Biscayne Bay toward the northeast in the vicinity of Featherbed Bank. The calcium carbonate in this area is primarily black in color, as described in previous paragraphs.

The sediments east of Biscayne Bay and the Keys are composed mainly of calcium carbonate. Stations 18, 19 and 20 are almost 100 per cent calcium carbonate, whereas station 17 contains only 60 per cent calcium carbonate and 40 per cent quartz.

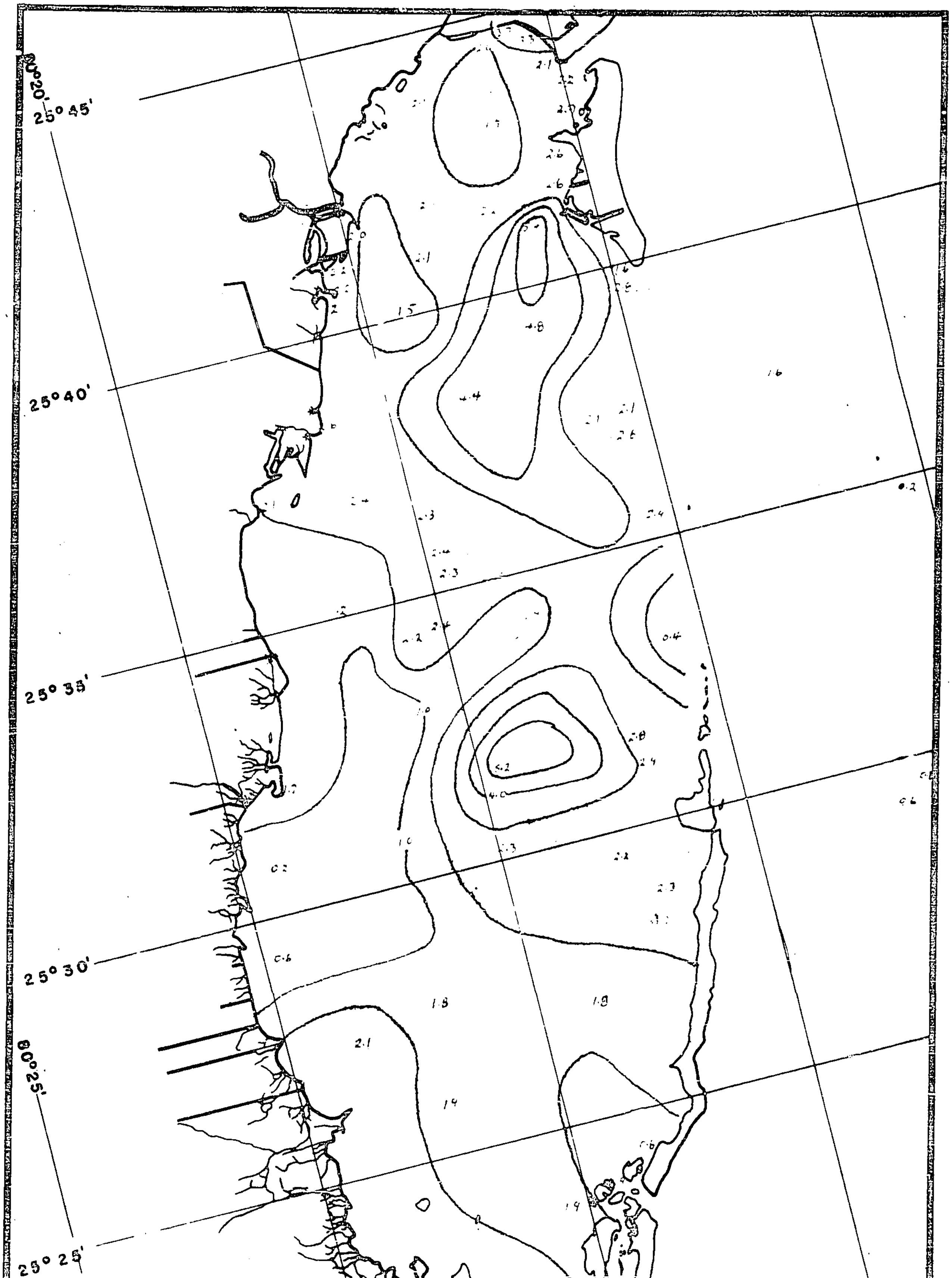
SIZE

Figure 13 shows the size distribution of the sediment at the different stations in the form of histograms. The abscissa is represented in terms of phi diameter, whereas the ordinate is represented in frequency of occurrence. The size distribution of the sediment at each station is hence quite apparent from the graphs. The 5th, 16th, 84th and 95th percentile diameters and the phi median diameters for the sediment at each station are listed in Table I.

The histograms for stations 38 and 45 are particularly interesting and characteristic of some areas. A double maximum occurs at both of these stations. This double maximum in the size-frequency is caused by the composition of the sediment. One peak is caused by the predominance of calcium carbonate at this diameter, whereas the other peak is produced by the dominance of quartz. If either mineral were not present, the curve would be a single-maximum curve. It is worthy of note that the presence of two dominant minerals in a sample with entirely different characteristics introduces a second peak in the curve. It is difficult, in an area where there is more than one dominant mineral present, to determine whether the multimaxima in the size-frequency curve is caused by the composition of the constituent minerals, or by a physical factor other than composition of the sediment, such as velocity of the transport medium, depth of water, etc. .

Figures 53 through 60 show the cumulative curves of the sediment at the different stations. The abscissa is again in phi diameter, whereas the ordinate is in per cent. The size parameters of the sediment were determined by use of the percentile rather than the quartile method (see Inman, 1951). Figures 14, 15 and 16 were all plotted in terms of the phi parameters rather than their equivalent diameters. All parameters are therefore directly related to Wentworth grades as units (Krumbein and Pettijohn, 1938, p. 234). Figure 14 shows the variation of the phi median diameter throughout the bay. It becomes obvious that the finest size material was located in the center of Biscayne Bay somewhat separated into two primary areas, one just north of Featherbed Bank wherein the phi median diameter reached 5.2, whereas the other area, just west of the Safety Valve, reached a phi median diameter of 5.4. The coarsest material reached a phi median diameter of 0.2 and was found in the area south of Black Point. Another area of coarse material was that just north and west of Ragged Keys wherein a phi median diameter of 0.4 was attained.

Generally speaking then, the sediment composed of calcium carbonate is finer in the center of the bay, where the depth is comparatively greater, and coarsens toward the margins of the bay.



Numbers represent phi median diameter. Isopleths drawn for every phi unit.

Fig. 14 DISTRIBUTION OF PHI MEDIAN DIAMETER

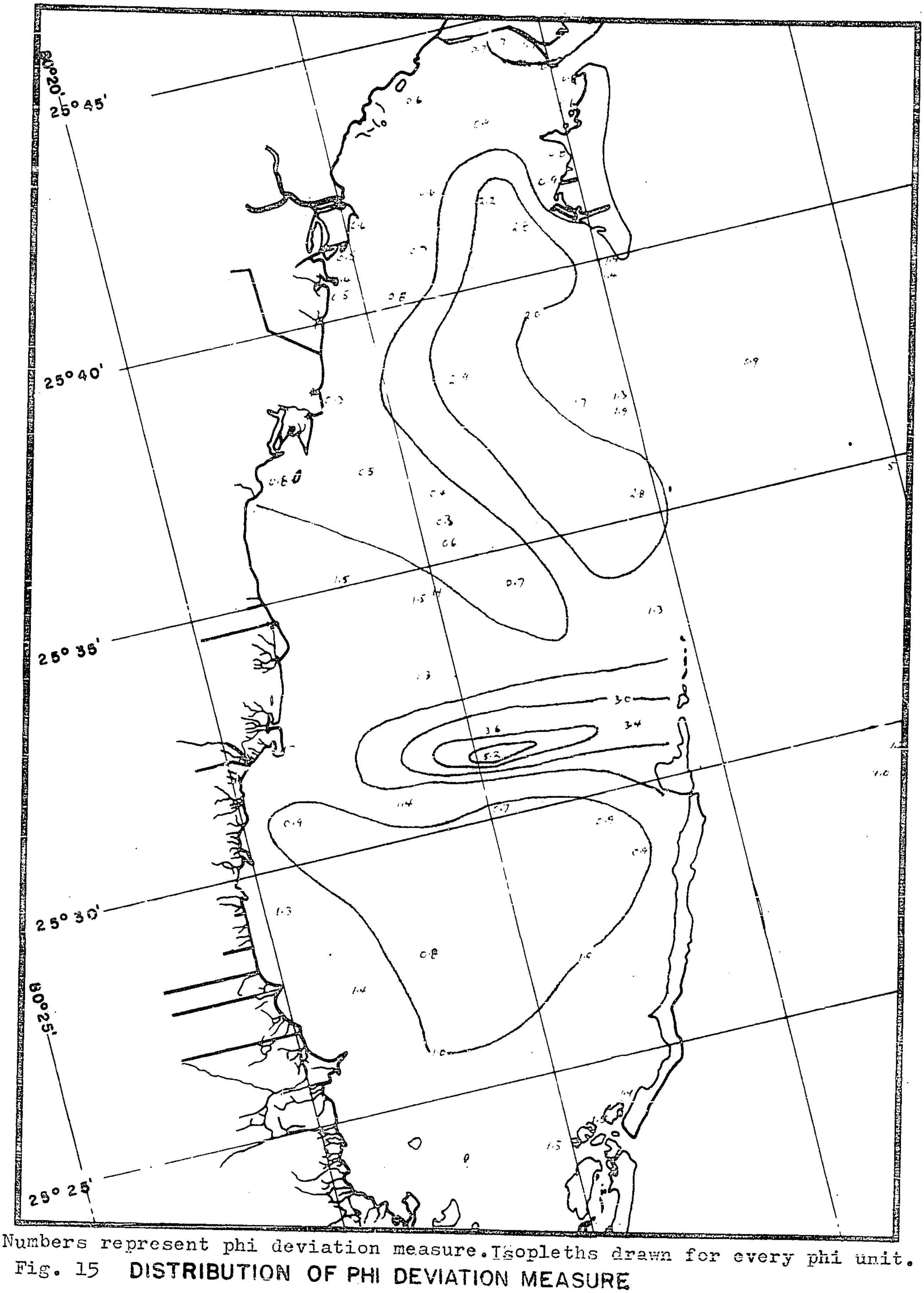
SORTING

In general, those areas which have a high phi median diameter, fine-sized material, have the poorest sorting, whereas, those which have the coarsest material tend to have better sorting. The phi deviation measure is listed in Table I for each station. Figure 15 shows the variation of sorting in Biscayne Bay in terms of the phi parameter. A similarity will be noted between the pattern of the variation of sorting as shown in figure 15 with the pattern of distribution of quartz or calcium carbonate, as shown in figures 12 and 13 respectively.

The well sorted sediment is located in the northwest shore area of Biscayne Bay and in the central portion of the bay. These are the same areas which have a predominance of quartz in the sediment, generally over 80 per cent by weight. The poorest sorting is found in an area just north of Featherbed Bank and is in that section which contains the finest sized sediment in Biscayne Bay. Almost as poorly sorted is the sediment found just west of the Safety Valve in the area having a very small size diameter, or a very large phi diameter. The tongue of quartz extending southeast from Tahiti Beach is superimposed upon the southeast tongue of the sorting pattern, as can readily be seen by comparing figure 12 with that of figure 15. The pattern of these two figures is very similar, and it becomes immediately evident that the quartz is by far the best sorted mineral, whereas the calcium carbonate is the most poorly sorted.

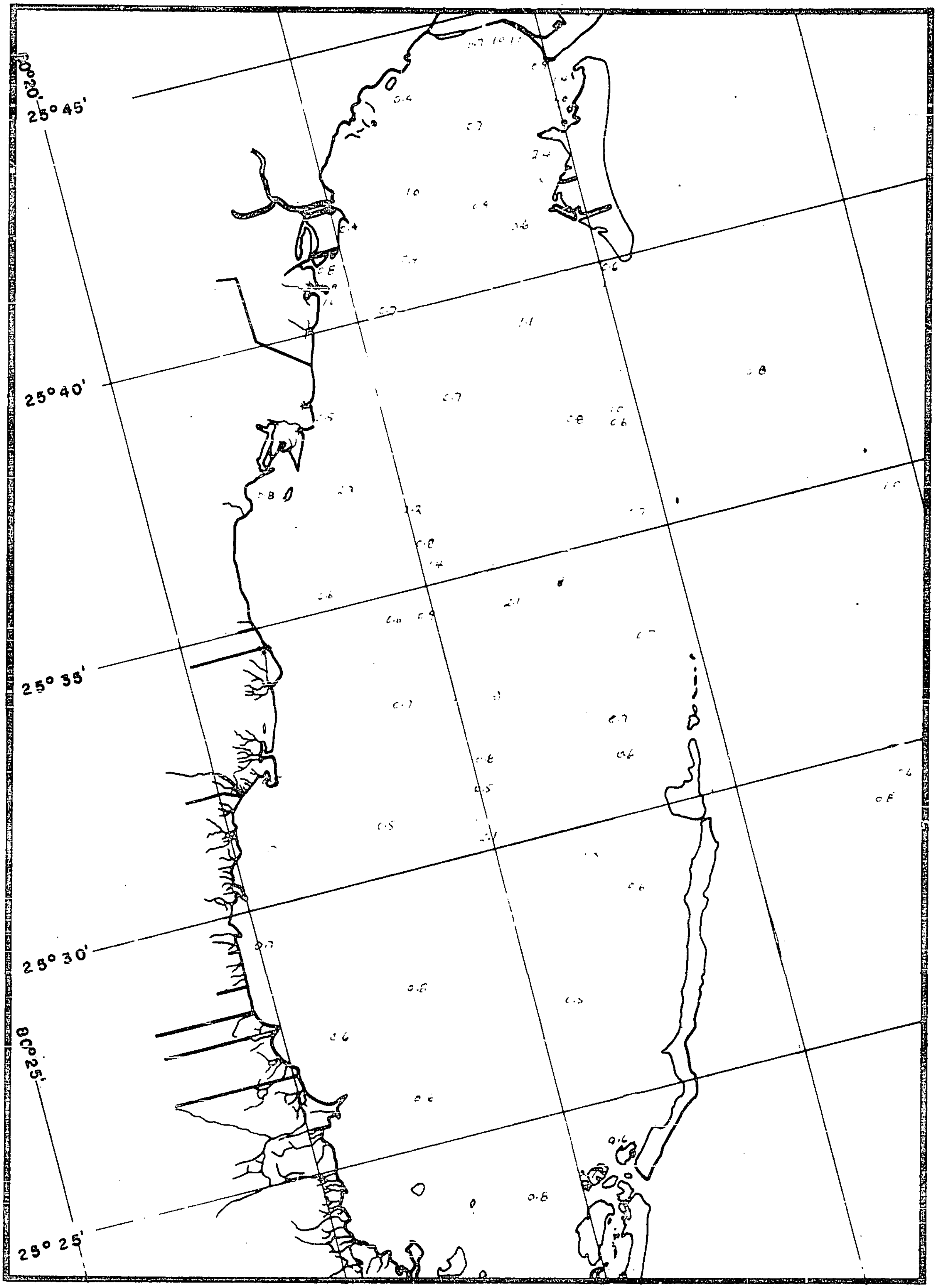
KURTOSIS

The variation of kurtosis of the sediment in Biscayne Bay is shown in figure 16 and listed in Table I. No parameter pat-



Numbers represent phi deviation measure. Isopleths drawn for every phi unit.

Fig. 15 **DISTRIBUTION OF PHI DEVIATION MEASURE**



Numbers represent phi kurtosis units.

Fig. 16 DISTRIBUTION OF PHI KURTOSIS MEASURE tern of distribution nor meaning can be interpreted from this figure.

The importance of kurtosis and an understanding of the history and ecology of an area in relation to kurtosis is therefore not apparent from this study.

SUMMARY

In summarizing, it may be stated that quartz is the dominant mineral in the sediment which is best sorted, and composes that sediment on the northwestern shore of the bay as well as that in an area immediately south of Featherbed Bank. It appears to be in the process of transportation in tongue-like form from Tahiti Beach southeast toward the central portion of the bay.

Calcium carbonate shell fragments are the other principal materials contained in the sediment. It composes both the coarsest and finest of the fragments in the sediment. In the central portion of the bay, extending in a north-south direction north of Featherbed Bank, it composes the finest sediment. The shallow reef-like area is composed of coarse material, as is that of the area south of Black Point where the sediment is considerably blackened by organic matter washed out of the mangrove swamps to the west. This black sediment can be traced in a northeasterly direction toward Bear Cut.

It appears anomalous that a tongue of sediment high in quartz is being transported southeast from Tahiti Beach, while another of blackened calcium carbonate is being carried northeast from the vicinity of Black Point. There is no doubt that the blackened sediment is transported past the southeasterly tongue of quartz sediment, since black shells are found at both stations 14 and 34 as well as at stations in the very northern portion of the bay. However, black shells are not found in any of the stations located on the tongue of quartz sediment extending southeast from Tahiti Beach. It is evident that this condition does exist and is probably caused by the transportation of the two types of sediments at different times of the year. It is possible that since the quartz tongue is now the predominant tongue in the bay containing no blackened calcium carbonate, it was being transported southeastward during the dummer months, the time at which the study samples were collected; whereas, the blackened calcium carbonate fragments were transported during another season of the year. Seasonal studies of the bay will have to be made to substantiate this hypthesis.

The fine clay-sized particles in Biscayne Bay are composed of calcium carbonate, not clay minerals. They appear to be, upon microscopic examination, derived by the breaking down of large fragments rather than by precipitation by any calcium carbonate forming bacteria as postulated by Drew (1914). Vaughan (1910, p. 116), stated that the sediment is mainly ooze, while the present study shows that most of the sediment is of sand - size. The calcium carbonate, being the dominant material in the sediment, is derived by the fragmentation of organisms which have a calcium carbonate shell. The author agrees with Thorp (1935, pp. 81, 82) that the quartz is derived from the Pamlico sediment and is not being brought in at any great rate by the currents at the present time from east of the bay, as proposed by Martens (1931) and Vaughan (1910, p. 116). High quartz concentration along the western shore of the bay substantiates Thorp's interpretation. This indicates the probability that the quartz is being derived from sediments formerly deposited on what is now the land, and that it is not now being brought in from outside of the bay.

LIFE

GENERAL

The fauna of Biscayne Bay and that of the general area of southeastern Florida has been discussed in varied detail by many authors. Most dealt with organisms which would not normally be fossilized and therefore not of interest to geologists. The following have some significance to the geologist: Thorp, 1935; a series of papers by Cushman, 1918a, 1920, 1922a, 1923, 1924a, 1929, 1930, and 1931; Stubbs, 1940; Weiss, 1948; Vaughan, 1918; Ginsburg, 1956. None of these dealt with the bay in its entirety.

Table I lists the presence by an "x" of all fauna, excluding the Foraminifera, and the flora found in the sediment at each station.

FLORA

Some floral remains are found in the sediment of the bay. Of these the most common are the calcareous algae of which the most common is the genus Halimeda. This alga lives in the area of the Safety Valve where there is shallow, continually flowing water. Halimeda is a great contributor to the calcareous deposits in this area. Another calcareous organism which adds to the deposits, though not to any great extent, is Neomeris alternatus. Only its cortical incrustations are found. Another important plant in the bay area is the genus Thalassia, more commonly known as Turtle Grass, similar to and often mistaken for the genus Zostera, Eel Grass, found in the more northern climes. The genus Thalassia is common in the central portion of the bay where the water is deeper and particles of sediment finer than that of the rest of the bay. The genus Thalassia was found growing at stations 11, 32, 34, 35, 36, 38, 45, 50, 51, 52, 54, 56, 62 and 63, and is most important at stations 32, 51, 52 and 54, all but the first having a depth of nine feet. Charophyta is occasionally found.

FAUNA

Many calcareous organic remains are found in the sediment of Biscayne Bay. The most important organisms contributing to the sediment are the Gastropoda, Pelecypoda, and the Foraminifera. Other remains are ostracos, vertebral oscicles, echinoid plates and spines, alcyonarian spicules, sponge spicules, Bryozoa, otoliths, corals and worm tubes. No attempt has been made to identify any of the organisms other than the Foraminifera. Very little work has previously been done on either the small or immature forms hence making the identification of the Gastropoda and Pelecypoda extremely difficult. The only other readily identifiable organisms would be the Ostracoda.

FORAMINIFERA

Twenty grams of sediment from each station were put through the 20, 40, 60 and 80 mesh sieves. All the sediment contained on these sieves, plus that remaining in the pan, were examined for Foraminifera as well as other organisms occurring therein. Counts were made as to frequency of occurrence of each species identified. The total count was not limited to any particular number of specimens.

Table II lists all species identified in the sediments from Biscayne Bay. Their per cent of occurrence at each station is listed under each station number. Table II also lists the number of Foraminifera counted per sample, the rate of occurrence of the species in the sediment, as well as the number of species per station. Figure 17 shows the per cent of occurrence of each species identified in relation to all other Foraminifera. The species are listed along the abscissa. The ordinate shows the frequency of occurrence for each species. Since there are a total of 61 stations where Foraminifera were identified, the maximum possible occurrence of any one particular species would be 6100 per cent. Each vertical line representing the occurrence of the species therefore represents the per cent of occurrence of that species in relation to all other spcies in the bay. The graph, which composes figure 17 indicates that those species which occur most frequently are: Quinqueloculina lamarckiana, Q. poeyana, Q. torrei, Triloculina flinti, Archaias angulatus, and Elphidium poeyanum. It should not, however, be thought that those Foraminifera which occur most frequently are necessarily the most important for an understanding of the ecology of the area. For instance, the species Quinqueloculina lamarckiana is the most common of all species present in Biscayne Bay, occurring a total of 721 per cent out of a possible total of 6100 per cent. The species of the genus Bolivina make up 5.3 per cent of total occurrence. Though the species Quinqueloculina lamarckiana is the most common, it is not necessarily characteristic of one particular environment, whereas the genus Bolivina is definitely characteristic of a particular environment in the bay.

Figures 18-52 show the distribution for particular species of Foraminifera throughout the area. The percentage of occurrence at each station for a particular species is indicated at the station location, and its distribution is apparent by referring to the figure for that species plotted. Only the most common of the Foraminifera are so plotted. It was thought impractical to figure each species, as those that occur at a few stations can readily have their distribution visualized by referring to Table II.

ECOLOGY

DESCRIPTIVE

Biscayne Bay and environs may be subdivided into several biotopes each with its own biocoenose. None of the biotopes is sharply delineated but blend one into the other and overlap. All of the factors which affect the biotope are not as yet understood, but the most important conditions may be surmised. The important factors which affect the biotopes are: salinity, temperature, oxygen and food supply, amount of mixing of sea and bay water, turbulence, depth of water, intensity of sun light, nearness to fresh water and land drainage, diameter of sediment, sorting of sediment. All biotopes are in shallow water less than 120 feet in depth.

Assemblage slides of the stations are on deposit in the University of Washington, Department of Geology, Museum of Paleontology. The biotopes with their key index species are as follows (the capital letter after the species name indicates the relative abundance of the species: A - abundant, C - common, R - rare):

1. The area of open waters east of the keys have a comparatively uniform environment. The temperature, normal marine saline content and food supply are relatively non-variable. This environment is represented by stations 17, 18, 19 and 20, and is characterized by the following species:

Bigenerina irregularis C
Gallowayus aff. G. antillarus R
G. redmondi C
Globigerinella aequilateralis R
Globulina caribea R
Massilina crenata R
Spiroloculina atlantica R
Triloculina tricarinata C

The following species are abundant in this biotope but are not to be particularly identified with only this one environment.

Amphistegina gibbosa A
Archaias angulatus A
Elphidium poeyanum C
Peneroplis proteus A
Praesorites orbitolitoides C
Quinqueloculina lamarckiana A
Q. torrei A
Rotalia rosea C

2. The second biotope, affected by the water east of the keys, includes those areas composed of the channels through thich the water flows into and out of the bay and their environments. The biocoenose is influenced by the saline waters of the "open sea," as well as the probable supply of food, and turbulence. In this area the bay waters are immediately affected by the water entering from the east of the keys. Stations 5, 6, 7, 8, 9, 13, 21, 31, 33, 46, 48, and 49 are within this biotope. The species which represent this area are:

Amphistegina gibbosa C
Arachaias compressus R
Asterigerina carinata C

Cibicides lobatulus R
C. pseudoungeriana R
Elphidium poeyanum C
Globigerinoides rubra R
Globorotalia menardii R
Globulina gibba R
Guttulina australis R
Heterostegina antillarum R
Neoalveolina schlumbergerina R
Nonionella atlantica R
Nummoloculina irregularis R
Peneroplis bradyi R
Rotalia rosea C
Sigmoilina cf. S. arenata R
Siphonina pulchra R
Textularia agglutinans R

All of the above species occur in this area and at the stations east of the keys. Loxostomum mayori R and Rectobolivina advena R also occur in this biotope but not in the stations east of the keys. It is believed that they are present in biotope 2 because of the influx of the open-sea water.

3. The shoal areas, which may be considered a living bioherm, compose a definite biotope. This area is very shallow, has a high intensity of sunlight, has strong turbulence and currents flowing into and out of the bay, and has abundant Halimeda. The stations within this biotope are numbers 32, 47, and 50. Stations 31, 48, and 49 may also be included in this area with a very similar fauna, but are in the channels rather than in the very shallow zone. The fauna restricted to this biotope is:

Cancris sagra R
Peneroplis antillarum R
Quinqueloculina collumnosa R

In addition to the above species, Archaias angulatus A and Quinqueloculina lamarckiana A are not restricted to this area but make up an important part of the population.

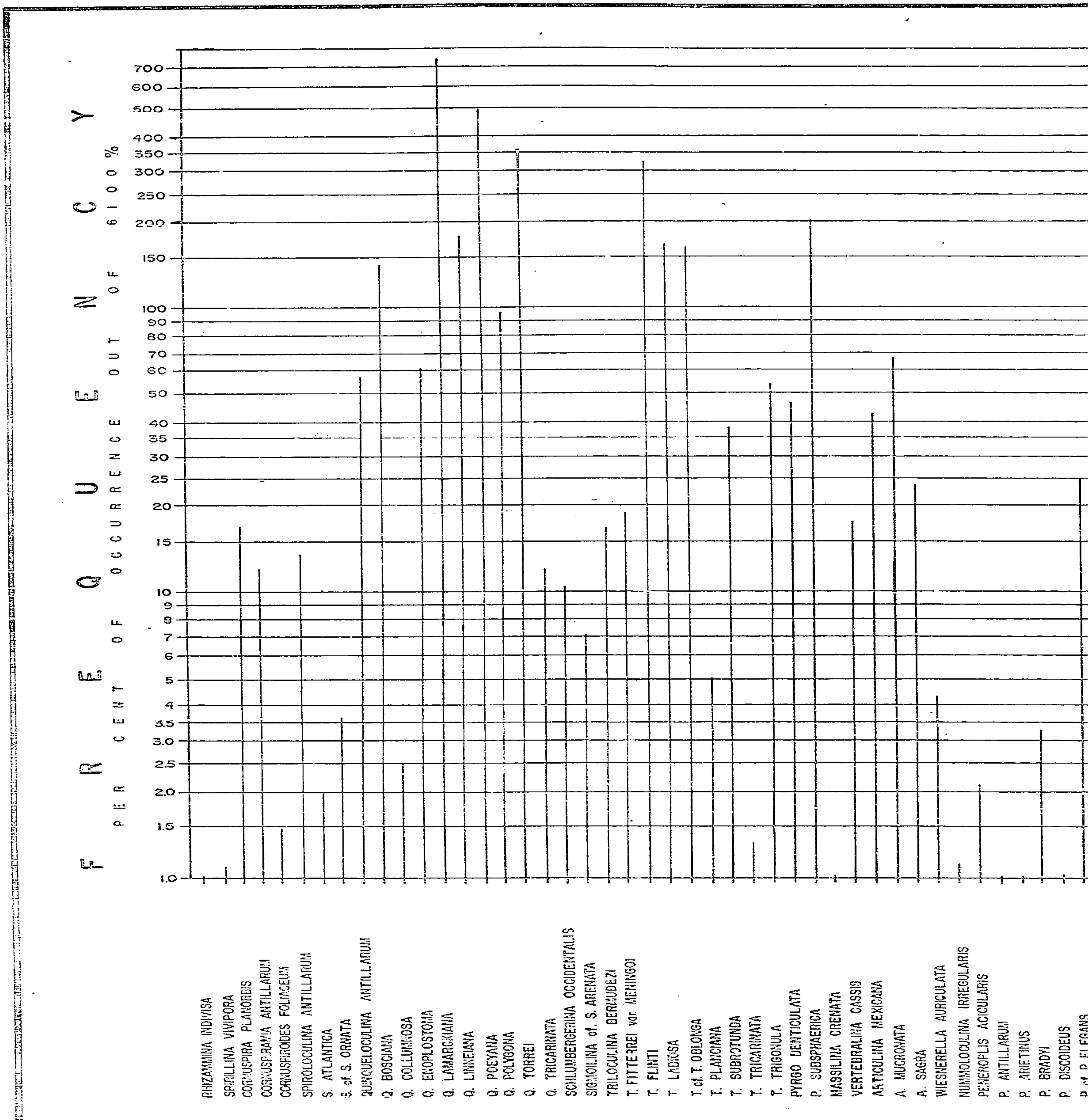
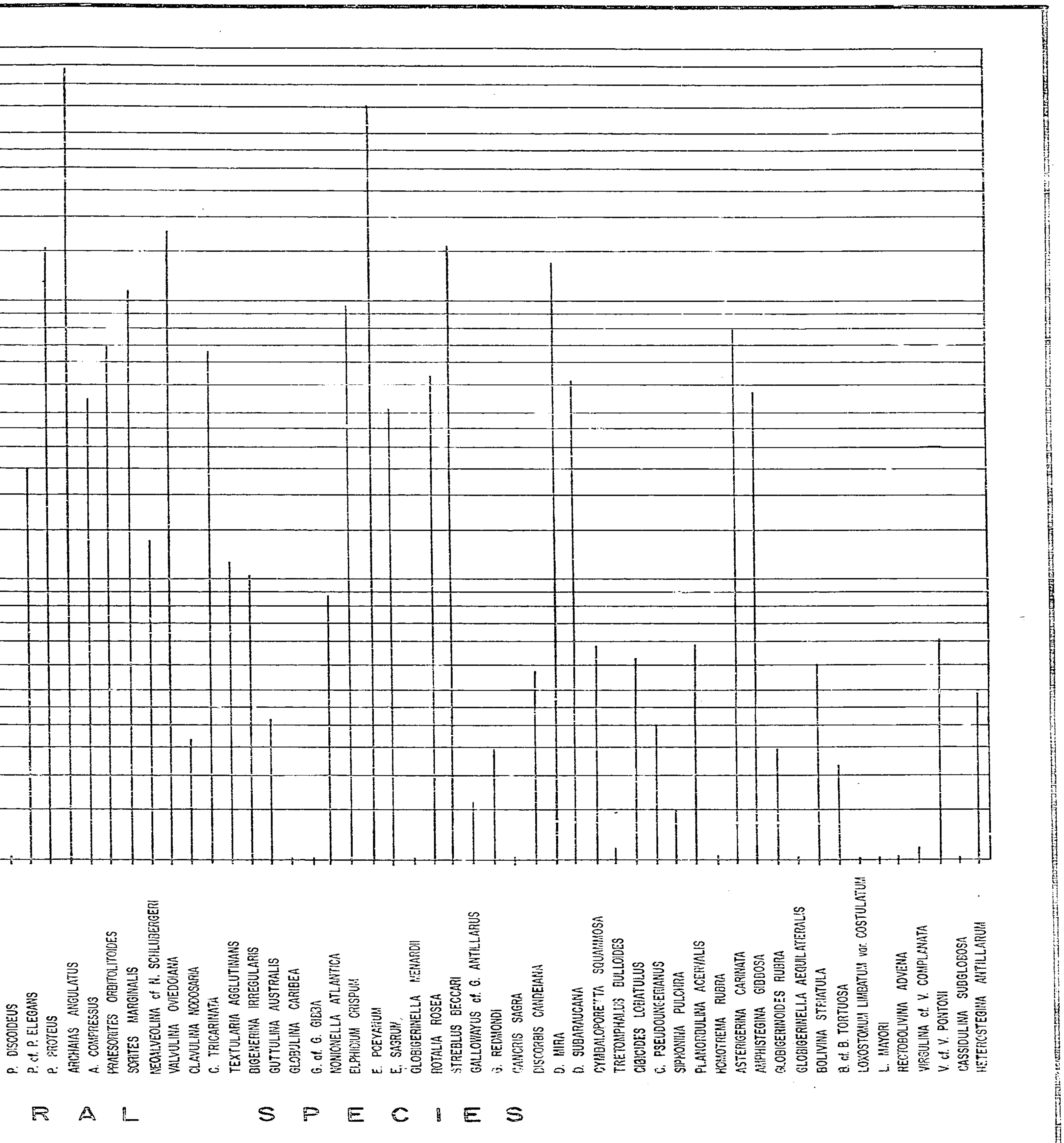


FIG. 17-FREQUENCY OF OCCURRENCE



...CE OF FORAMINIFERAL SPECIES

4. The shoal area and the area east of it make up in themselves a general biotope. This is characterized by a definite fauna, and may be interpreted as two separate biotopes which share three species in common. These are:

Cassidulina subglobosa R
Gallowayus antillarus R
Loxostomum limbatum var. costulatum R

The biotope is one in which there is open-sea water and an abundant supply of food.

5. Covering a very irregular area, this biotope is differentiated by the area inhabited by the genus Thalassia, and is represented by the following three species:

Elphidium crispum C
Peneroplis elegans R
Valvulina oviedoiana A

Valvulina oviedoiana is not limited to this one biotope, but is abundantly represented here.

6. Elphidium poeyanum C is the single species of the biotope which is representative of the area of the well sorted sediment.

7. The near-shore area within the bay is defined by the species Streblus beccarii C.

8. That area extending north-south through the center of the bay is more or less characterized by a fine sediment and is the deepest section in the bay. It is presumed that the water in it is not turbulent, as otherwise it would keep the fine-sized sediment particles in suspension. Since this is not the case, it is believed that the water is comparatively nonturbulent in character. The following species are character-

istic of this biotope:

> <u>Praesorites</u> <u>orbitolitoides</u> R
> <u>Quinqueloculina</u> <u>bosciana</u> R
> <u>Triloculina</u> <u>oblonga</u> R
> <u>T.</u> <u>subrotunda</u> R

9. The area within the bay north of Featherbed Bank, herein referred to as the North Bay, is characterized by an inflow of open-sea water and the admixture of fresh water from the shore to the west. Environmental conditions here are not as rigorous as that south of Featherbed Bank. The following species are characteristic of this biotope:

> <u>Bolivina</u> <u>striatula</u> R
> <u>Cornuspiramia</u> <u>antillarum</u> R
> <u>Cymbaloporetta</u> <u>squammosa</u> R
> <u>Elphidium</u> <u>poeyanum</u> A
> <u>Quinqueloculina</u> <u>polygona</u> C
> <u>Triloculina</u> <u>labiosa</u> A

10. The species <u>Sorites</u> <u>marginalis</u> C represents the environment in the northeast portion of the bay, and is affected more by the open-sea water than the rest of the northern portion of the bay.

11. The eastern margin of the bay shows a lesser effect of fresh water than the western portion. It is greatly affected by the influx of open-sea water. This eastern area is characterized by the following species:

> <u>Discorbis</u> <u>subaraucana</u> R
> <u>Elphidium</u> <u>sagrum</u> R
> <u>Peneroplis</u> <u>proteus</u> C
> <u>Quinqueloculina</u> <u>enoplostoma</u> R

12. In contrast to biotope 11, this occupies the western portion of the bay where drainage from the land is extensive. The species <u>Clavulina</u> <u>nodosaria</u> R is representative of this environment.

13. The southwestern portion of Biscayne Bay has a very rigorous environment. It is affected by the land drainage and the mangrove swamps, and by the high rate of evaporation during the summertime. At times a low saline content prevails while at other times of the year there is a very high saline content. The area is further affected by the staining from the mangrove trees. The species Clavulina tricarinata R is primarily limited to this area. Valvulina oviedoiana C, Quinqueloculina lamarckiana A and Archaias angulatus A are also very common to this area. This biotope is represented by stations 24, 56, 57, 58, 59, 60, and 61.

The writer's study shows that the presence of a high per cent of miliolids occurring with an abundant number of robust arenaceous specimens (not large variety of species) indicates a warm, shallow, marine environment. This is not in accord with the observations by Said and Kenawy (1956, p. 115) in the Upper Cretaceous and Lower Tertiary of Egypt:

> "where calcareous and arenaceous forms coexist, the classic idea that these forms indicated deep marine conditions seems to be true, although it appears that depth does not affect the total number of individuals so much as it affects the number of species."

While Galloway (1933) indicated the presence of many arenaceous forms with depth, he also mentioned others as characteristic of shallow waters. Norton (1930, fig. 1) showed that the greatest concentration of arenaceous forms exist at depth (16-60 fathoms) in the Tortugas region, rather than shallow water. However, it is interesting to note that the Miliolidae reach their minima with depth, whereas both forms are quite abundant in shallower and warmer waters. Stainforth (1950) suggested that a turbid - water environment appeared to be essential for the development of wholly arenaceous assemblages. Glaessner (1948, p. 190), on the contrary, stated that dominantly arenaceous assemblages indicate cold-water conditions.

Contrary to the above opinions, the waters of Biscayne Bay do not have any environment in which arenaceous forms are found alone. In figures 18-52 it is evident that the arenaceous forms particularly inhabit the southwestern portion of the bay and the area in the vicinity of Featherbed Bank. The porcellaneous species are likewise very common here, and also extend to the shoal water area in the vicinity of the Safety Valve. The arenaceous forms found in Biscayne Bay are robust and appear to be rugged species since they are particularly abundant where there are many environmental extremes.

COMPARISONS WITH OTHER AREAS

In comparing the provincial faunal assemblage of Biscayne Bay with fauna of other areas, many similarities and dissimilarities are found. Areas throughout the world having a provincial fauna are described by Bermudez (1935), Chapman (1900, 1905), Cushman (1918, 1921, 1921a, 1924), Flint (1899), Heron - Allen and Earland (1914), d'Orbigny (1839), and Vaughan (1923). As in Biscayne Bay, these have a warm, shallow, and marine environment. The species found there appear similar to that in the bay and yet in cases are conspicuously different. For example, Heron-Allen and Earland (1914) figured and described Quinqueloculina kerimbatica, a species similar in many aspects and yet different from that herein identified as Q. antillarum. This latter species, originally described by d'Orbigny (1839) from the Cuban area, is somewhat different from those specimens found in Biscayne Bay. However, many species described by d'Orbigny from the sands of Cuba are similar to those found in the bay.

Approximately one half of the species identified by Cushman (1921) from the north coast of Jamaica were also found in the sediment of Biscayne Bay. However, only one third of the species identified by Cushman (1922) from the Tortugas region were also identified by d'Orbigny (1839) from the shore sands of Cuba and also were identified by the author in the sediments from the Biscayne Bay area. Fifty per cent of the Foraminifera identified in this latter area were also identified by d'Orbigny (1839) from the shore sands of Cuba.

Though the fauna of Biscayne Bay is closely related to other areas in the Gulf of Mexico and Caribbean area by having many similar species, it also differs in having species which are equally dissimilar. In addition, even those species which are in common to the areas mentioned have notable differences which might even be taken as varietal features. However, until type material can be examined by one individual from these diverse areas it is impossible to say definitely what are the differences and similarities other than those due to personal variations and attitudes of the investigators.

Biscayne Bay is a back-reef, lagoonal area in which miliolids are very common, and the porcellaneous Foraminifera compose 74 per cent of the foraminifera present. This area may be compared with that described by Henson (1950) from the Cretaceous and Tertiary reef formation in the Middle East, wherein he described (p. 230) the sedimentation as follows:

> "Calcareous sand and mud composed of cominuted debris of reefs and indigenous organisms well rounded by surface-erosion; cemented by rapid lime precipitation in warm, shallow water, to form hard, poorly stratified Miliola limestone of porcellaneous texture and subconchoidal fracture . . . . Reef-patches occur sporadically and may be contemporaneous local growths or dead residuals of former reef-walls, eroded by surf and over-ridden by shoals as the living reef builds out seaward."

Henson further detailed the indigenous back-reef fauna by stating (p. 230):

> "Miliolids, Peneroplidae (large and small) and Alveolinidae are characteristic, with some Planorbulinidae, Rotaliidae, Amphisteginidae, and Orbitolinidae. Reef - builders, mollusk, etc. are sporadic."

This also describes the sedimentation and associated fauna of the Biscayne Bay area. A similar miliolid sediment deposition may also be likened to that described by Conkin and Conkin (1956).

Conkin and Conkin (1956, p. 895) suggested a lagoonal origin for the El Abra miliolid member and Upper Devils River limestone from the subsurface Lower Cretaceous of southwest Texas. Again, this miliolid deposition was reported from the subsurface of southern Florida by Naegli (1945) and Ericson and Naegli (1945). A back-reef, lagoonal type environment accounts for the sedimentation found in the rocks.

SUMMARY AND CONCLUSIONS

The data presented in the previous paragraphs leads to the following conclusions:

1. Physical oceanographic factors are active in Biscayne Bay producing a definite sorting and deposition of the sediment throughout the bay. The mineral quartz is being deposited along the northwestern shore of the bay with a tongue extending southeast from Tahiti Beach. Another area of quartz concentration is forming in the southern area just south of Featherbed Bank. The quartz is being derived by the reworking of the Pamlico sediment.

2. The areas of quartz deposition are more or less coincident with that of the best sorted sediment and have the least amount of life in them. The quartz grains are well sorted. They

are believed to be reworked from the Pamlico sediments which were previously transported a considerable distance from the Appalachian Mountains.

3. Calcium carbonate is being deposited in the southwest section of the bay, in the Safety Valve area, and just west of the shoal-water area. The calcium carbonate is made up of whole or worn fragments of organic life. It nowhere appears to be precipitated by the <u>Bacterium</u> <u>calcis</u>.

4. The average phi median diameter of the sediment is 2.10 or 0.23mm, fine sand size.

5. Quartz is characteristic of the sediment in the channels north of and through the Safety Valve, whereas it is absent in the channels south of this area. This sediment is generally coarser than that in the shoal areas on either side of the channels. The size differentiation is caused by the sorting effect of the current washing through these channels.

6. Organic calcium carbonate tests are being blackened in the southwest area of the bay. The blackening appears to be caused by included black organic matter rather than an inorganic chemical reaction. The blackened shells can be traced into the northeast section of the bay.

7. Those biotopes having a high quartz content of the sediment have a scarcity of organisms, and conversely, those high in calcium carbonate have a relative abundance of organisms.

8. Biscayne Bay contains a provincial foraminiferal fauna which is a consequence of the environment of the area.

The environment is comparatively normal on the east side of the keys, changing to a rigorous one in the very southern part of the bay where the salinity and temperature varies over a considerable range.

9. The waters of the open ocean east of the keys do not affect the fauna to the west to any great extent. However, the physical oceanography of the waters inside the bay has a great effect upon the fauna on the outside. The waters with a great range of salinity, caused by evaporation and dilution, are transported out of the bay area to that east of the keys. It is this range in salinity which is believed to prevent the pelagic fauna normal to the Florida Current from reaching the area of the keys. As a consequence, practically no pelagic forms are found within nor in the sediments immediately outside the bay.

10. Of the species of Foraminifera existing in the environs of Biscayne Bay, six compose four and one-half per cent arenaceous forms, thirty-seven compose twenty-one per cent hyaline forms, and forty-eight compose seventy-four and one-half per cent porcellaneous forms.

11. The most common species of Foraminifera in Biscayne Bay in their respective order of abundance are: Quinqueloculina lamarckiana, Archaias angulatus, Quinqueloculina poeyana, Elphidium poeyanum, Quinqueloculina torrei, and Triloculina flinti. Though these species are the most prolific, they are not characteristic of any one particular biotope found within this area.

12. The area of abundant miliolids characterize the back - reef environment of Biscayne Bay.

13. The sediment in the open-water and that on the shoals, which make up the Safety Valve, contains a more varied range of species than that found anywhere else in Biscayne Bay. These two areas are not affected by environmental changes as great as those within the bay itself.

14. Those areas with a more abundant fauna have fewer species. These species are not only well adapted to the environment, but flourish and fill the biotope. However, when the organisms are not so well adapted to the environment, a greater variety of species generally occupy the biotope.

15. The presence of a high per cent of miliolids occurring with an abundant number of robust arenaceous specimens (not large variety of species) indicates a warm, shallow, marine environment.

16. The arenaceous forms found in Biscayne Bay are robust and appear to be rugged species since they are particularly abundant where there are many environmental extremes.

Thirteen biotopes were recognized in the Biscayne Bay area. These are predominantly represented by porcellaneous foraminiferal species, but significant numbers of arenaceous and hyaline types are also important in at least seven of these. The most important factors in the biotopes with their representative fauna may be summarized as follows:

1. The open-water area east of the keys where the environment is uniform. The Florida Current steadily flows in this region, the temperature is variable with depth, there is an abundant supply of food, the salinity maintains itself at approximately 36 parts per thousand. The most representative

species found herein are Bigenerina irregularis, Gallowayus redmondi, and Triloculina tricarinata.

2. The channel areas are affected by the ebb and flow of the tides. The waters are turbulent, the velocity reaches three knots, the salinity approximates that of the open-sea, and an abundant supply of food and oxygen is available. The most representative species herein are Amphistegina gibbosa, Asterigerina carinata, Elphidium poeyanum, Rotalia rosea.

3. The very shallow shoal areas have a high intensity of sunlight, strong turbulent flow, abundant oxygen and food supply, and relatively constant salinity and temperature. The most representative species in this area where the plant genus Halimeda is very abundant are Cancris sagra, Peneroplis antillarum, Quinqueloculina collumnosa. Also very common to this biotope but not restricted herein are the species Archaias angulatus and Quinqueloculina lamarckiana.

4. The shoal area and that area east of it have in common open-sea water and an abundant oxygen and food supply, relatively constant salinity and temperature. These two areas share three species in common: Cassidulina subglobosa, Gallowayus antillarus, and Loxomstomum limbatum var. costulatum.

5. That area in which the plant genus Thalassia lives has common to it the following species: Archaias angulatus, Elphidium crispum, E. poeyanum, Quinqueloculina lamarckiana, and Valvulina oviedoiana.

6. That area having a well sorted sediment is best represented by the species Elphidium poeyanum.

7. The near-shore area within the bay is most greatly affected by surface water runoff from the nearby land and from the drainage canals. The most representative species of this biotope is Streblus beccarii.

8. The area extending north-south through the bay is characterized by a fine sediment, comparatively deep water, lack of turbulent flow, and lack of intense sunlight. The species Praesorites orbitolitoides, Quinqueloculina bosciana, Triloculina oblonga, and T. subrotunda are representative.

9. The north bay area has a ready admixture of fresh water from the land with the more saline waters of the open-sea. The conditions here are not as rigorous as those in the south bay area. The species most representative are Elphidium poeyanum, Quinqueloculina polygona, and Triloculina labiosa.

10. The northeast portion of the bay is greatly affected by the waters of the open-sea. Particularly representative of this area is the species Sorites marginalis.

11. The eastern margin of the bay is more affected by the open-sea water than that of the western portion. The representative species of this area are Discorbis subaraucana, Elphidium sagrum, Peneroplis proteus, and Quinqueloculina enoplostoma.

12. The western portion of the bay is greatly affected by drainage from the land. Clavulina nodosaria is representative of this area.

13. The southwestern portion of the bay experiences great fluctuations of temperature and salinity, little circulation,

and staining from the mangroves. Clavulina tricarinata is primarily limited to this biotope but the species Archaias angulatus, Quinqueloculina lamarckiana, and Valvulina oviedoiana are very common here.

FAUNAL DESCRIPTION

Ninety-one species were identified and are herein described. Identifications were based on the original descriptions and figures published by the authors who named the species and, in some cases, additional descriptions and discussions of the species by subsequent authors. All species discussed herein are figured in the following plates. The descriptions of the species follow. Holotypes, Paratypes, and Hypotype specimens are deposited in the Paleontology Museum, Department of Geology, University of Washington.

Family ASTRORHIZIDAE Brady, 1881
Subfamily ASTRORHIZINAE Brady, 1884
Genus RHIZAMMINA Brady, 1879
RHIZAMMINA INDIVISA Brady, 1884
Plate I, Figure 1

Rhizammina indivisa Brady, 1884, Rep. Voy. Challenger, Zoology, vol. 9, p. 277, pl. 29, figs. 5-7.

Test cylindrical, open at both ends; wall composed of chitinous material with cemented sand grains.

Hypotype No. U.W. 44,004.

This species is rare. It is found in the shoal waters of the Safety Valve where there is a free interchange of bay and fresh water. The sediment is high in calcium carbonate and coarse as represented by the cemented grains composing the arenaceous test of this species. The species occurs at station 32.

Family SPIRILLINIDAE Reuss, 1861
Subfamily SPIRILLININAE Brady, 1884
Genus SPIRILLINA Ehrenberg, 1843
SPIRILLINA VIVIPORA Ehrenberg, 1843
Plate I, Figure 2

Spirillina vivipora Ehrenberg, 1843, Abhandl. k. Akad. Wiss. Berlin, Phys.-Math. Cl., for 1841, p. 422, pl. 3, pt. 7, fig. 41.

Test circular, planispiral, evolute; periphery round; sutures distinct; chamber a long spiral, increasing gradually in diameter, overlapping slightly on the sides; wall coarsely perforate; aperture at the end of the tube, simple.

Hypotype No. U.W. 44,005.

This species is very rare, only two specimens having been found at stations 2 and 47. It does not appear to represent a particular environment.

Family MILIOLIDAE d'Orbigny, 1839
Subfamily CORNUSPIRINAE Reuss, 1861
Genus CORNUSPIRA Schultze, 1854
CORNUSPIRA PLANORBIS Schultze, 1854
Plate I, Figure 3

Cornuspira planorbis Schultze, 1854, Organ. Polythal., p. 40, pl. 2, fig. 21.

Test discoid, planispiral, evolute; the one coiled single chamber increasing gradually in size, partially overlapping the previous whorl; sutures distinct; periphery rounded; aperture terminal, round, the diameter of the entire tube.

Hypotype No. U.W. 44,006.

This species has a fairly wide distribution throughout the bay. It is found at seventeen stations (see fig. 18), namely: 1, 2, 9, 10, 12, 13, 21, 22, 23, 32, 33, 40, 42, 47, 50, 52, and 56.

Genus CORNUSPIRAMIA Cushman, 1928

(?)CORNUSPIRAMIA ANTILLARUM (Cushman, 1922)

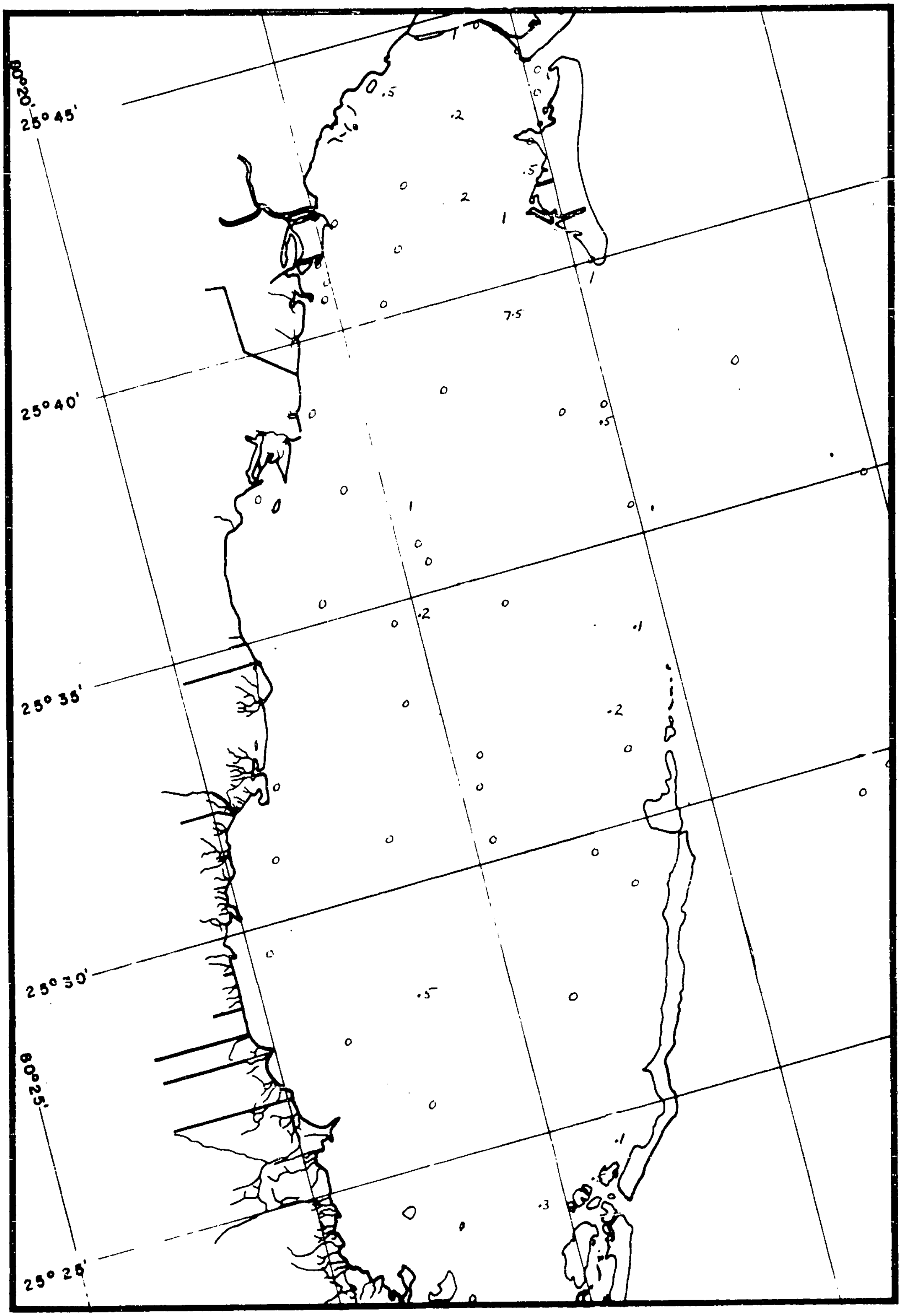
Plate I, Figure 4

Nubecularia antillarum Cushman, 1922, Carnegie Inst. Washington, Publ. No. 311, p. 58, figs. 7, 8.

Test attached; an irregularly branching tube, convex on top, flat on inside of attachment; wall rough, arenaceous covering over a porcellaneous base; aperture at the end of the tube projections.

Hypotype No. U.W. 44,007.

All specimens of this species were found unattached or broken. They may have been transported from some nearby locale wherein they lived. The species is limited to the area just west of Key Biscayne at stations 8 and 10.



Numbers represent per cent of species occurrence at station

Fig. 18 DISTRIBUTION OF CORNUSPIRA PLANORBIS

Genus CORNUSPIROIDES Cushman, 1928

CORNUSPIROIDES FOLIACEUM (Philippi, 1844)

Plate I, Figure 5

Orbis foliaceus Philippi, 1844, Enum. Moll. Siciliae, vol. 2, p. 147, pl. 24, fig. 26.

Test discoid, planispiral, evolute; the one coiled single chamber increasing in size rapidly; sutures distinct; periphery rounded; aperture terminal, the diameterof the tube.

Hypotype No. U.W. 44,008.

This species is very rare, only one specimen was found at station 9.

Genus SPIROLOCULINA d'Orbigny, 1826

SPIROLOCULINA ANTILLARUM d'Orbigny, 1839

Plate I, Figure 6

Spiroloculina antillarum d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, pp. 166, 167, pl. 9, figs. 3, 4.

Test fusiform in front view, compressed laterally; chambers inflated, tapering toward aperture, last chamber extended forming a neck, chambers ellongate and arcuate; sutures not distinct; surface ornamented with longitudinal striations; aperture round, with slight thickening of peristome, surrounding a short, narrow tooth.

Hypotype No. U.W. 44,009.

This is an uncommon species found irregularly distributed through the bay, and also out in the open-sea waters. It was identified at stations 4, 6, 8, 18, 20, 27, 28, 31, 34, 42, 46, 47, 50, and 61.

SPIROLOCULINA ATLANTICA Cushman, 1947
Plate I, Figure 7

Spiroloculina atlantica Cushman, 1947, Contrib. Cushman Lab. Foram. Res., vol. 23, pp. 88, 89, pl. 19, figs. 3-5.

Test fusiform in front view, greatly compressed laterally; periphery rounded, sides concave, edges slightly keeled; chambers distinct, increasing rapidly in size, early chambers with longitudinal axes not in same direction as latter longitudinal axes; sutures distinct, slightly depressed, aperture rectangular with a bifid tooth.

Hypotype No. U.W. 44,010.

This species is present only at station 17 in the open - water environment.

SPIROLOCULINA cf. S. ORNATA d'Orbigny, 1839
Plate I, Figure 8

Spiroloculina ornata d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 167, pl. 12, fig. 7.

Test flat, fusiform; chambers bicarinate, flat, arcuate, last chamber extending into long neck; wall smooth but for short, irregular, carinae; sutures not distinct; aperture round with short, linguiform tooth.

Hypotype No. U.W. 44,011.

This is a rare species found at stations 16, 47, and 50.

Subfamily MILIOLINAE Reuss, 1861

Much confusion has been found in the literature, as well as by the author, in identification of specimens from Biscayne Bay. Particular among this is the differentiation between three genera, namely *Quinqueloculina*, *Triloculina*, and *Pyrgo*. It is generally accepted that if five chambers are visible externally the specimen belongs to the genus *Quinqueloculina*, while it belongs to *Triloculina* and *Pyrgo* if it has three or two visible external chambers, respectively. It has often been found, by the author, that specimens which upon external visual observation would normally be placed under the genus *Pyrgo* are, actually, found to be triloculina forms when observed in section. The question then arising would be, is a form to be placed under the genus *Triloculina* when three chambers are visible upon sectioning or is it to remain under the genus *Pyrgo* when only two chambers are externally apparent without sectioning?

It is the author's contention that a form which has the successive chambers 144° apart, each adjacent chamber 72° apart, belongs to the genus *Quinqueloculina*, five chambers per whorl; that having the chambers 120° apart belongs to the genus *Triloculina*, three chambers per whorl; those having the chambers opposed at 180° belong to the genus *Pyrgo*, two chambers per whorl. It is so used herein.

Genus QUINQUELOCULINA d'Orbigny, 1826

QUINQUELOCULINA ANTILLARUM d'Orbigny, 1839

Plate I, Figures 9a and b

Quinqueloculina antillarum d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 193, pl. 12, figs. 4-6.

Test fusiform in front view, laterally compressed; periphery rounded to doubly carinate; chambers arcuate, if single carination then the carinate portion not along the median periphery but ut us sloping toward the posterior; the single carination may bifurcate toward the abapertural end of the ultimate chamber forming a bifurcate form or, the chamber may be bifurcate throughout or, the chamber may be slightly angled to rounded on the periphery: the last chamber tends to taper toward the apertural end; sutures distinct, very slightly depressed; wall pitted except around the aperture, the pitting arranged in oblique lines; aperture a long narrow slit with slightly thickened peristome which tapers in toward the aperture; the tooth is long and narrow, thickening slightly at free end.

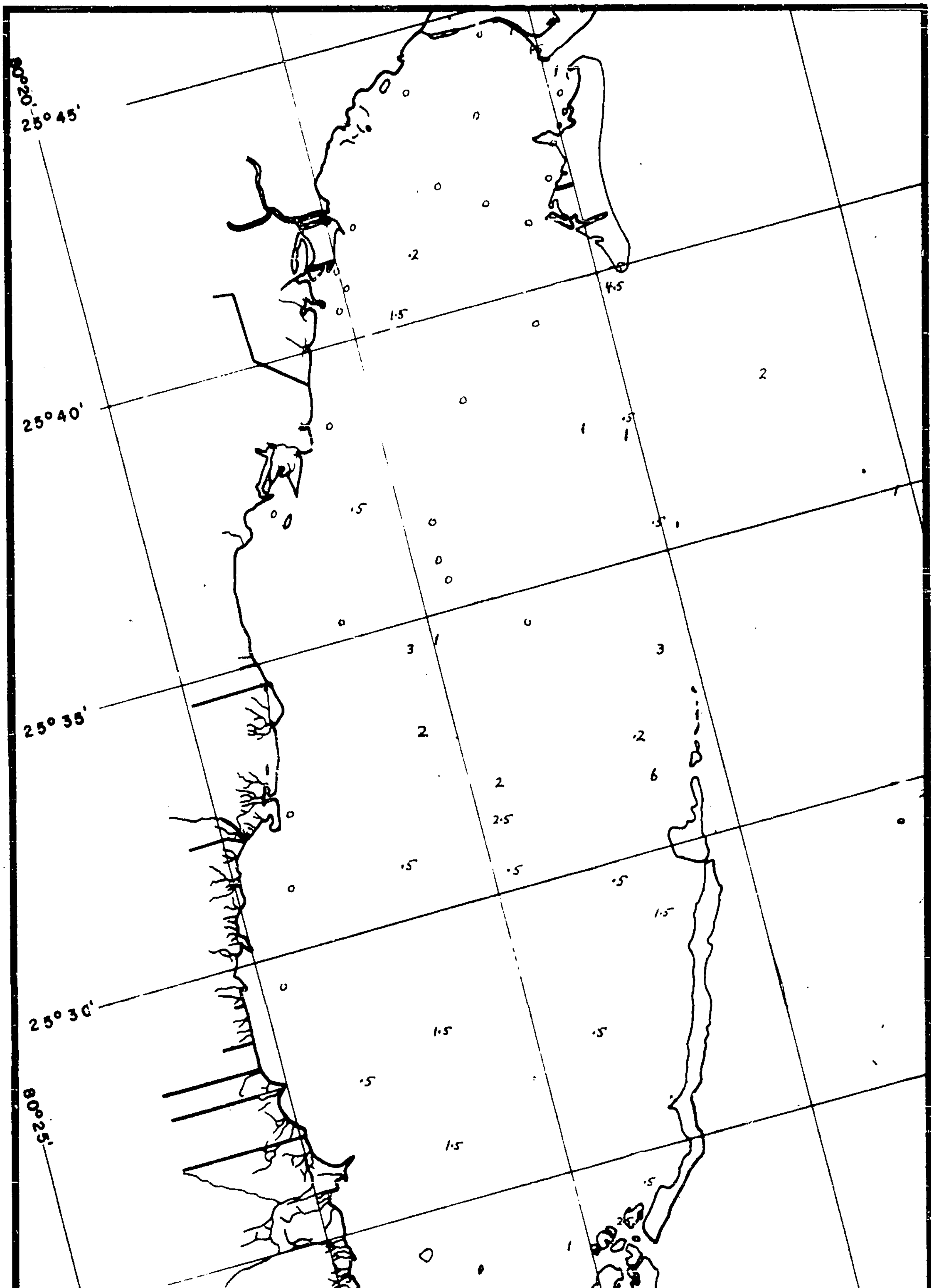
Hypotype No. U.W. 44,012.

This beautiful species is found irregularly distributed throughout most of the bay and occurs at thirty-four stations, numbers 4-6, 14, 17, 18, 20-28, 31, 32, 34, 36, 42, 43, 46-57, 61, and 62. This species appears to be more characteristic of the south central and southeastern portion of the bay where the waters are not greatly affected by fresh-water pollution from the swamps and surface runoff. The distribution of this species is readilly seen by referring to figure 19.

QUINQUELOCULINA BOSCIANA d'Orbigny, 1839

Plate I, Figure 10

Quinqueloculina bosciana d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 190, pl. 11, figs. 22-24.



Numbers represent per cent of species occurrence at station.

Fig. 19 DISTRIBUTION OF QUINQUELOCULINA ANTILLARUM

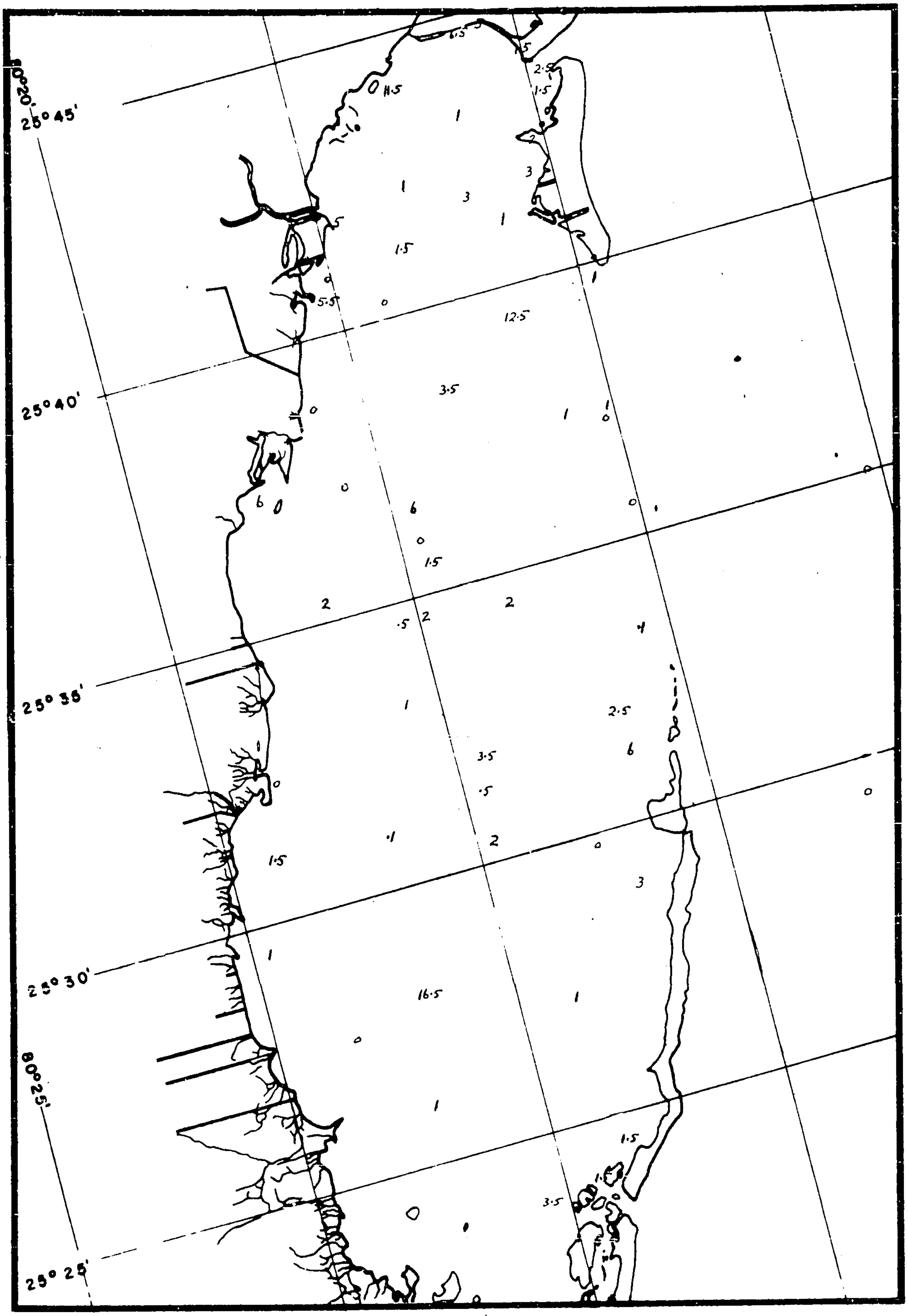
Test an elongate ellipse, slightly compressed laterally; periphery rounded; chambers elongate, very slightly arcuate, arranged oblique to the length of the test (most pronounced in the prepenultimate chambers), tapering slightly toward aperture, the ultimate chamber extending over the penultimate chamber on both ends; sutures very slightly depressed; wall smooth, translucent, glossy; aperture round, at the extreme end of the chamber, with short projection for a tooth.

Hypotype No. U.W. 44,013.

It is odd that this species has not been reported from the Gulf of Mexico - Caribbean area since originally described by d'Orbigny in 1839. It is common to most localities in the Biscayne Bay area. It may be that the specimen figured as Q. laevigata d'Orbigny in Cushman (1922, pl. 13, fig. 2) is actually this species.

This small, delicate species is found at almost all stations. However, it is strictly limited to the bay as it has not been identified in the sediment from stations 17, 18, 19, and 20, all outside of the bay. The distribution pattern for this species is shown in figure 20. This species is also not found in the environment of the shallow waters of the Safety Valve but is common to that of the channels in this area. No particular environmental factors appear to account for the distribution of this species other than the possible fluctuating factors which characterize the bay in relation to that outside of the bay.

QUINQUELOCULINA COLLUMNOSA Cushman, 1922
Plate I, Figure 11



Numbers represent per cent of species occurrence at station.

Fig. 20 DISTRIBUTION OF QUINQUELOCULINA BOSCIANA

Quinqueloculina collumnosa Cushman, 1922, Carnegie Inst. Washington, Publ. No. 311, p. 65, pl. 10, fig. 10.

Test irregular in shape but of general oval appearance; periphery angled; chambers irregularly elongate and arcuate, the last chambers extending past the previous chambers at the abapertural end where it is bluntly rounded, extending into a round and elongate neck at the apertural end; sutures not distinct; wall irregular with an undulating appearance, forming longitudinal crests which do not anastomose; aperture round, at the end of an extended neck, surrounded by a slightly flaring peristome.

Hypotype No. U.W. 44,014.

This species is primarily limited to the open-sea water though a few specimens were also identified at station 45. It is present at stations 18 and 20 where the relatively highly saline, nonfluctuating Florida Current waters flow.

QUINQUELOCULINA ENOPLOSTOMA d'Orbigny, 1839
Plate I, Figures 12a and b

Quinqueloculina enoplostoma d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 196, pl. 12, figs. 14-17.

Test ovoid in front view, slightly compressed laterally, periphery truncate, bicarinate, slightly concave; chambers elongate, arcuate, quadrangular, the ultimate chamber round and broad at abapertural end; sutures distinct, not pronounced; wall porcellaneous on the interior with an arenaceous exterior of medium roughness, tan in color; aperture oval, narrower at interior periphery than at exterior periphery, with thin, everted peristome; dentition consisting primarily of long and narrow tooth with bifid free end extending more than half way into apertural opening: that portion of peristome opposite the free end of the tooth is serrate with projections of calcareous material.

Hypotype No. U.W. 44,015.

The specimens found in Biscayne Bay may have the peristome completely serrate, a few serrations, or none at all. The number of calcareous projections is not a constant even at the same locality, but varies from specimen to specimen. Since the serrations may be completely absent or present in a varied number, it is questioned whether the genus Dentostomina Carman, 1933, is valid since it is differentiated from Quinqueloculina d'Orbigny, 1826, solely on the presence of apertural serrations.

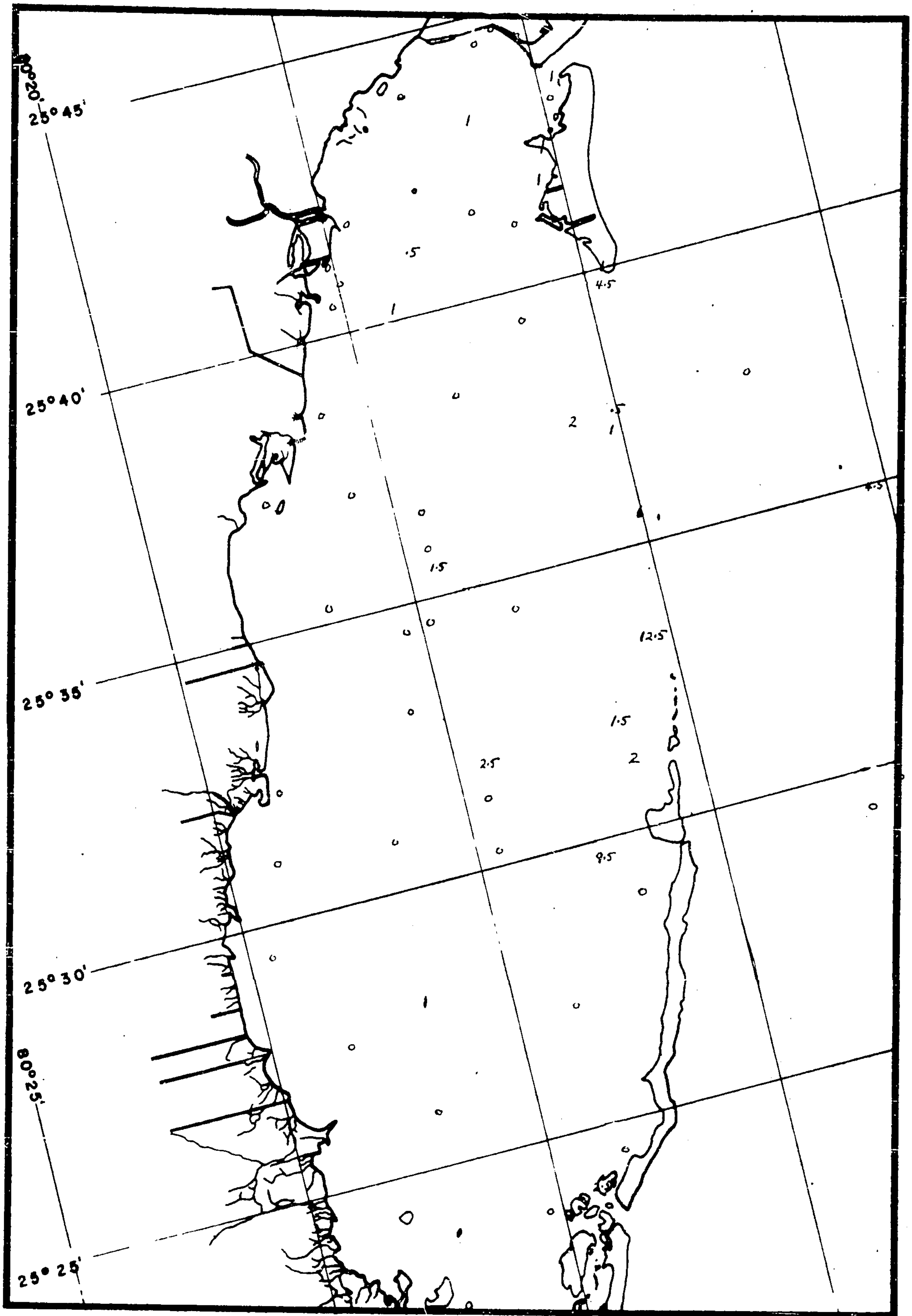
This hardy looking species is primarily distributed through the eastern portion of the bay (see fig. 21) in those areas affected by the open-sea water. It is found at stations 7, 9, 10, 12, 14, 18, 21, 28, 31, 32, 34, 39, 46-54, and 56.

QUINQUELOCULINA LAMARCKIANA d'Orbigny, 1839

Plate II, Figure 1a and b

Quinqueloculina lamarckiana d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 189, pl. 11, figs. 14, 15.

Test subovate, inflated posteriorly, subtriangular in apertural view; periphery rounded to slightly angled; chambers elongate, slightly arcuate, inflated-triangular in section, the ul-



Numbers represent per cent of species occurrence at station.

Fig. 21 DISTRIBUTION OF QUINQUELOCULINA ENOPLOSTOMA timate and penultimate chambers have sides sloping posteriorly, ultimate chamber extending past penultimate chamber at abapertural end where it is rounded; the ultimate chamber not extended into a long neck at apertural end; sutures distinct, slightly depressed, arcuate; wall smooth, white, with or without faint, longitudinal, intermittent striations; aperture round, with narrow, bifid tooth extending halfway into aperture.

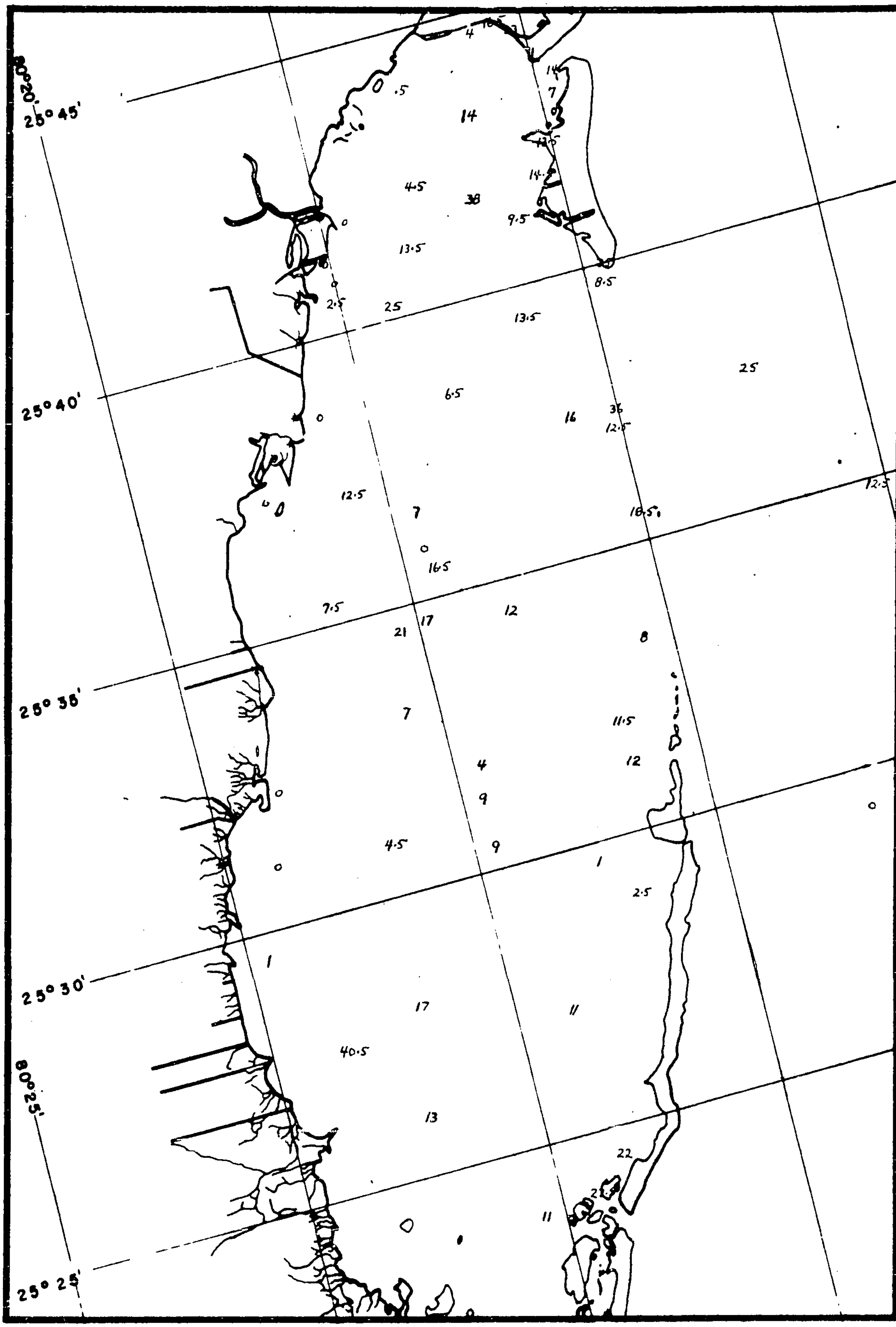
Hypotype No. U.W. 44,016.

This very abundant species is found to occur in practically all environments throughout the area. It is just as common to the open waters as it is to the bay. The only stations at which it is not found are 16, 19, 29, 30, 35, 37, 41, 59, and 60. These stations do not appear to have any particular environmental factor in common.

QUINQUELOCULINA cf. Q. LINNEIANA (Cushman, 1929)
Plate II, Figures 2a and b

Triloculina linneiana Cushman (non d'Orbigny), 1929, Bull. 104, U.S. Nat. Mus., pt. 6, pp. 61, 62, pl. 16, figs. 1, 2.

Test subovate in front view, compressed laterally, often deceptively appears to be triloculina in forms; periphery rounded; chambers elongate, arcuate, ultimate chamber rounded and extending past penultimate chamber at abapertural end, extending to form a very short neck at apertural end; sutures not pronounced; wall glossy, white, ornamented with oblique costae which meet in the form of a chevron on the periphery; the costae may be pronounced and form a keel on the periphery or they may be weak striations and vary in number from many to few; aperture round to horse-shoe-shaped, with thickened peristome: dentition consisting of narrow, bifid, convex tooth which projects above the



Numbers represent per cent of species occurrence at station.

Fig. 22 DISTRIBUTION OF QUINQUELOCULINA LAMARCKIANA peristome as seen in front view.

Hypotype No. U.W. 44,017.

The author believes that those specimens figured by Cushman would, upon sectioning, prove to be quinqueloculine forms rather than triloculine forms, and would be comparable with our specimens.

This species is the eighth most common in the Biscayne Bay area. It is found in almost all of the bay stations but is found at only one of the out-of-the-bay stations, namely number 18. This species should be considered as one characterizing the bay environment wherein the environment fluctuates considerably. Its distribution is shown in figure 23. It is found to occur at stations 3, 5-15, 18, 21-28, 31, 32, 34, 36-39, 41-43, and 46-63.

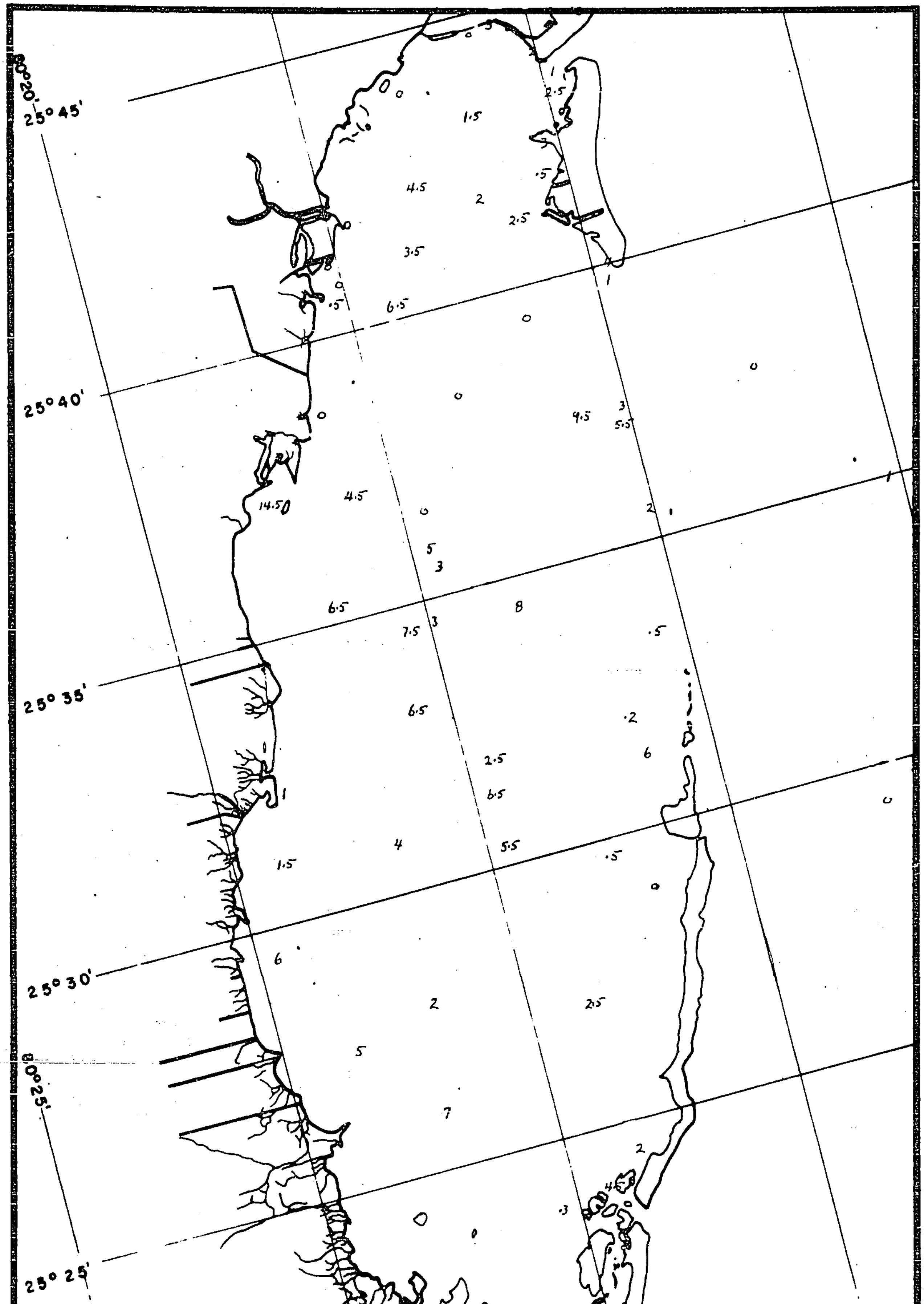
QUINQUELOCULINA POEYANA d'Orbigny, 1839
Plate II, Figure 3

Quinqueloculina poeyana d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, pp. 191, 192, pl. 11, figs. 25-27.

Test an elongate oval; chambers distinct, convex, narrow; sutures distinct, not strongly depressed; wall ornamented with longitudinal striae; aperture circular, at end of short neck with thickened peristome, dentition of narrow tooth thickened slightly at free end.

Hypotype No. U.W. 44,018.

This small species is the fourth most common in the area.



Numbers represent per cent of species occurrence at station.

Fig. 23 DISTRIBUTION OF QUINQUELOCULINA LINNEIANA

It is primarily characteristic of the bay: It is very rare in the open waters of the Florida Current. It is also comparatively rare in the region of the Safety Valve (see fig. 24), being most common in the areas least affected by the open-sea waters. The stations at which it has been identified are: 1-3, 5-9, 11-16, 18, 20-22, 24-34, 36-40, 42, 43, 46, 47, 49, 52-61.

QUINQUELOCULINA POLYGONA d'Orbigny, 1839
Plate II, Figure 4

Quinqueloculina polygona d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 198, pl. 12, figs. 21-23.

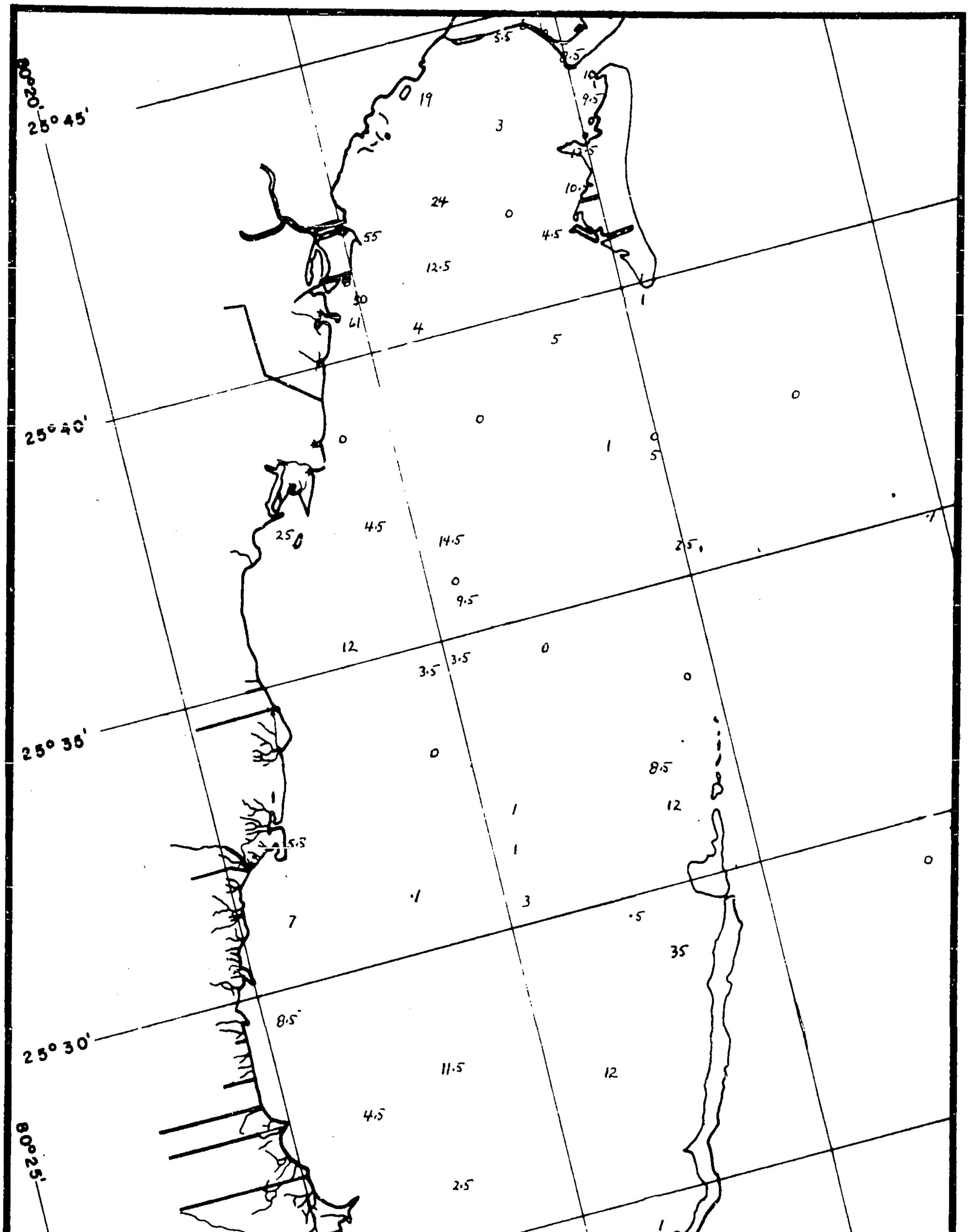
Test very elongate; chambers quadrangular, bicarinate, tapering toward aperture, flat to concave on periphery; sutures pronounced; aperture at end of extended neck, with everted peristome: dentition consisting of narrow tooth or bifurcate tooth extending well into aperture.

Hypotype No. U.W. 44,019.

This relatively common species is fairly well distributed through the bay (see fig. 25) except for the western inshore areas of the bay. It is more common to the southcentral portion of the north half of the bay than any other region and is more or less coincident with the occurrence of the plant genus Thalassia. The species was identified at stations 5, 6, 9, 10, 12, 14-16, 18, 20-28, 30-32, 34, 39-41, 43-53, 55, and 59-63.

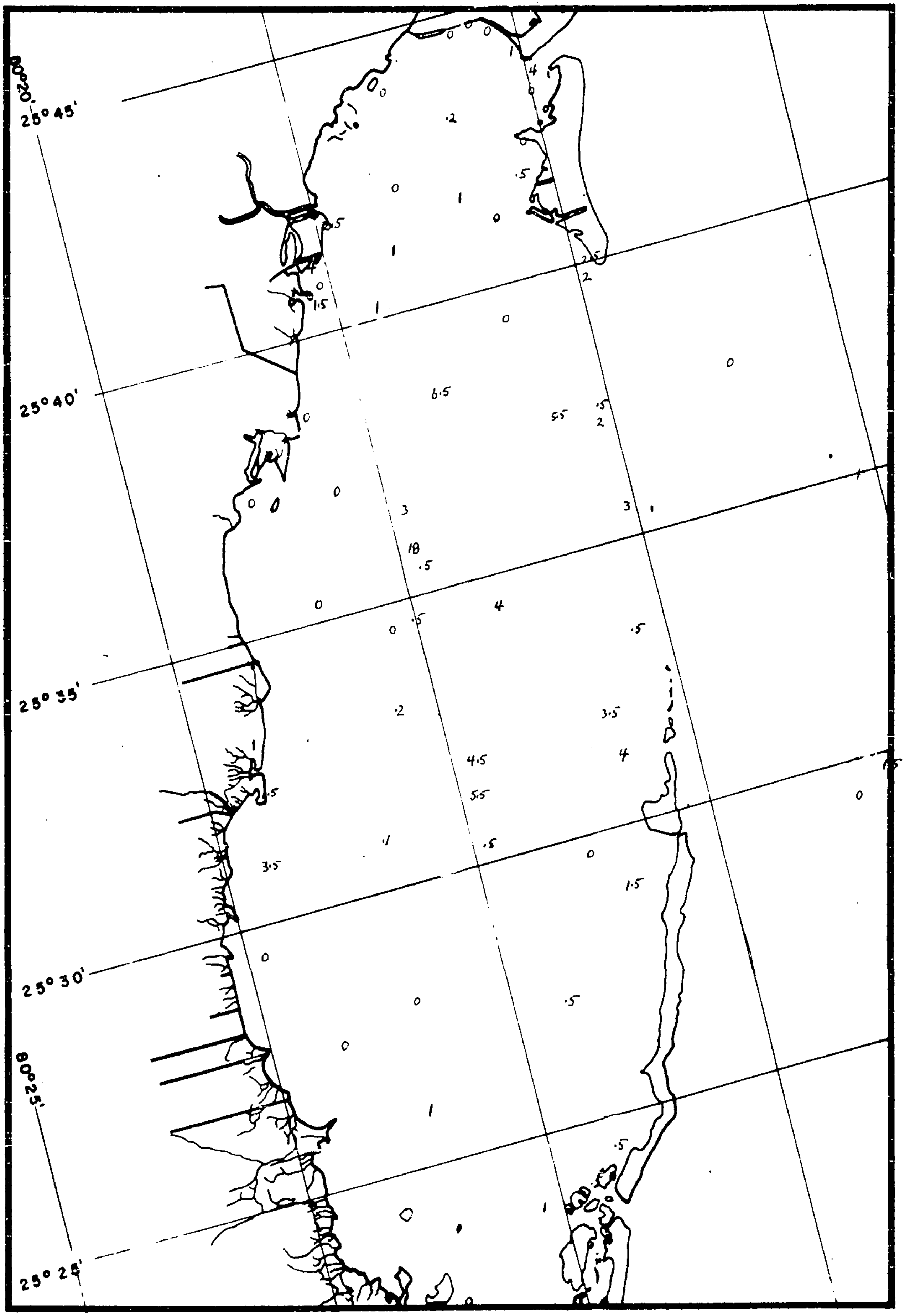
QUINQUELOCULINA TORREI Acosta, 1939
Plate II, Figure 5

Quinqueloculina torrei Acosta, 1939, Torreia, La Habana, Cuba, No. 1, pp. 1-4, pl. 1, figs. 1-5.



Numbers represent per cent of species occurrence at station

Fig. 24 DISTRIBUTION OF QUINQUELOCULINA POEYANA



Numbers represent per cent of species occurrence at station

Fig. 25 DISTRIBUTION OF QUINQUELOCULINA POLYGONA

Test subovate in front view, slightly compressed laterally; periphery rounded; chambers elongate, slightly arcuate, ultimate chamber overlapping at both extremities; sutures not always distinct, sometimes depressed; wall arenaceous, with little cement, not coarsely roughened; aperture surrounded by thickened peristome, horse-shoe-shaped, with narrow, bifid tooth extending at least half way into aperture.

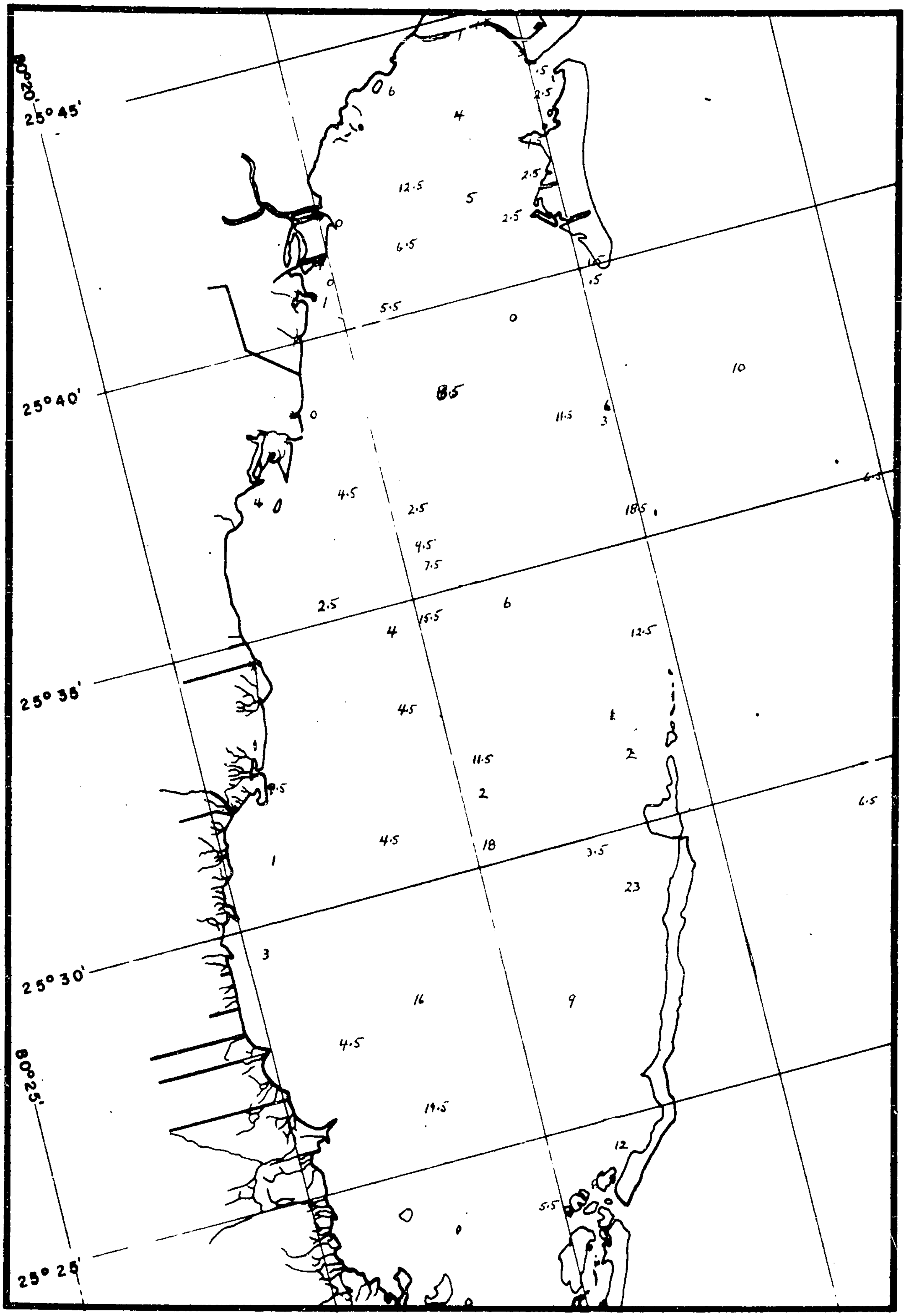
Hypotype No. U.W. 44,020.

The specimens from Biscayne Bay are more than twice the size of those described by Acosta from Cuba. This species is well distributed throughout the area and is the fifth most abundant species in the bay. The only stations at which it is not present are 4, 16, 20, 29, 33, and 35 (see fig. 26). This species is very well adapted to the environmental factors present in Biscayne Bay.

QUINQUELOCULINA TRICARINATA d'Orbigny, 1839
Plate II, Figure 6

Quinqueloculina tricarinata d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 189, pl. 11, figs. 7-9, 13.

Test elongate, fusiform in front view, compressed laterally; periphery rounded; chambers elongate, arcuate, indistinct, ultimate chamber considerably extended at both ends, rounded at abapertural end, a long neck at apertural end; sutures not distinct; wall ornamented with irregularly anastomosing ribs with strong depressions inbetween them; aperture surrounded by a lightly flaring peristome, round, with short bifid tooth not extending far into aperture.



Numbers represent per cent of species occurrence at station

Fig. 26 DISTRIBUTION OF QUINQUELOCULINA TORREI

Hypotype No. U.W. 44,021.

This rare species is found at stations 6, 18, 20, 21, 31, and 50. All of these stations are affected by the open-sea waters and are away from the rigorous effects of the bay waters.

Genus SCHLUMBERGERINA Munier-Chalmas, 1882
SCHLUMBERGERINA OCCIDENTALIS Cushman, 1929
Plate II, Figure 7

Schlumbergerina alveoliniformis (Brady), var. *occidentalis* Cushman, 1929, Bull. 104, U.S. Nat. Mus., pt. 6, p. 36, pl. 7, fig. 2.

Test fusiform; eight elongate, arcuate, narrow chambers visible from the exterior; sutures distinct, not pronounced; periphery rounded; wall porcellaneous with an arenaceous covering; aperture terminal, with a trematophore.

Hypotype No. U.W. 44,022.

This species is characteristically greater in diameter per length in Biscayne Bay than from Brady's locality. It is herein raised from a varietal rank to that of a species, as no other variations are found.

This rare species is found at stations 6, 7, 18, 20-22, 27, 34, 46, 48, 50, 52, and 61. All of these stations are widely distributed throughout and outside of the bay. No common environmental factor is evident from these diverse stations.

Genus SIGMOILINA Schlumberger, 1887

SIGMOILINA(?) cf. S. ARENATA (Cushman, 1921)

Plate III, Figure 1

Spiroloculina arenata Cushman, 1921, Proc. U.S. Nat. Mus., vol. 59, p. 63, pl. 14, fig. 17.

Test fusiform, compressed; periphery round; chambers elongate, arcuate, round in section, inflated at abapertural end, tapering toward apertural end; sutures not distinct, arcuate; wall arenaceous, rough; aperture round, without dentition, at end of extended neck.

Hypotype No. U.W. 44,023.

This species is very rare in Biscayne Bay. It is found at stations 5, 8, 18, 20, 21, 46, 47, and 50. None of these stations are affected by the rigors of the environmental fluctuations in the bay as they have ready access to open-sea waters during tidal flow.

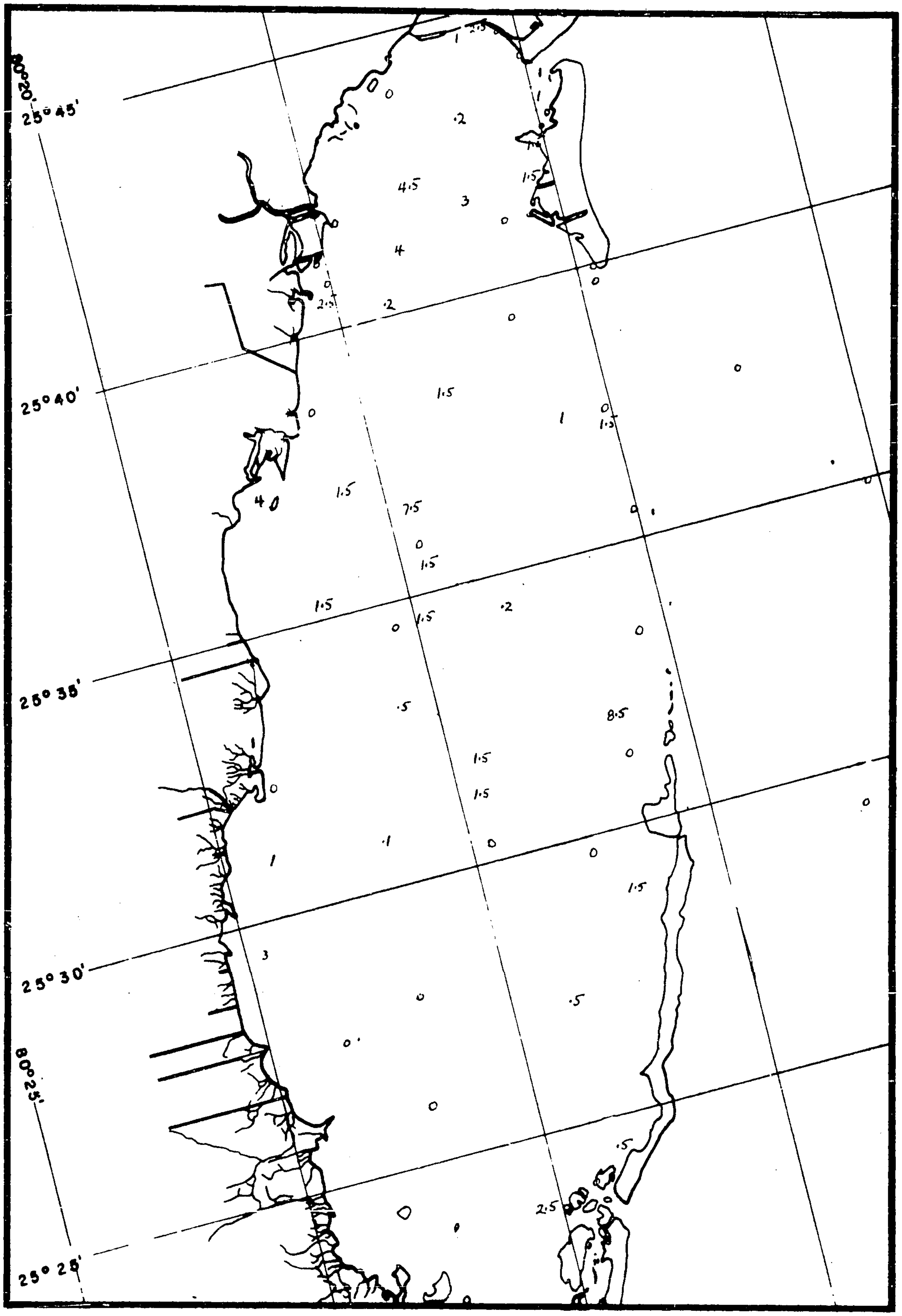
Genus TRILOCULINA d'Orbigny, 1826

TRILOCULINA BERMUDEZI Acosta, 1940

Plate III, Figure 2

Triloculina bermudezi Acosta, 1940, Soc. Cubana Hist. Nat. Mem., vol. 14, p. 37, pl. 4, figs. 1-5.

Test an elongate oval, appears slightly twisted; periphery round; three chambers visible, arcuate, elongate, slightly tapering toward aperture, laterally compressed at apertural end; sutures distinct, slightly depressed; aperture a very narrow, laterally compressed slit, terminal, almost completely filled with a narrow, elongate, convex tooth.



Numbers represent per cent of species occurrence at station

Fig. 27 DISTRIBUTION OF TRILOCULINA BERMUDEZI

Hypotype No. U.W. 44,024.

This fairly common, very small species is characteristic of the northern half of the bay. The species appears to be more dominant in the area having the plant genus Thalassia as shown in figure 27. The species is found at stations 2, 3, 6-12, 14, 15, 22, 23, 25, 27, 28, 34, 36-40, 43-47, 52, 55, 58, 59, and 61-63.

TRILOCULINA FITERREI var. MENINGOI Acosta, 1940
Plate III, Figure 3

Triloculina fiterrei var. meningoi Acosta, 1940, Torreia, Habana, Cuba, no. 3, pp. 25-26, pl. 4.

Test elongate, twisted, round abaperturally, tapering toward apertural end; chambers inflated, tapering toward aperture, elongated into flattened neck; periphery very rounded; sutures indistinct; surface ornamented with strong, obtuse costae, about ten in number per chamber (less in younger chambers); aperture an elongate oval, without dentition, everted peristome.

Hypotype No. U.W. 44,025.

This species is present at stations 1, 2, 5, 8, 9, 12, 14, 15, 18, 22, 26, 34, 36, 38, 39, 43, 47, 48, 55, 56, 58, 59, 61, and 62. It is primarily a bay rather than open-water fauna. It is not found, except for one specimen at station 18, anywhere near the areas immediately affected by the open-sea waters.

TRILOCULINA FLINTI Bush, nom. nov.

Plate III, Figure 4

Triloculina flinti Bush, nom. nov.

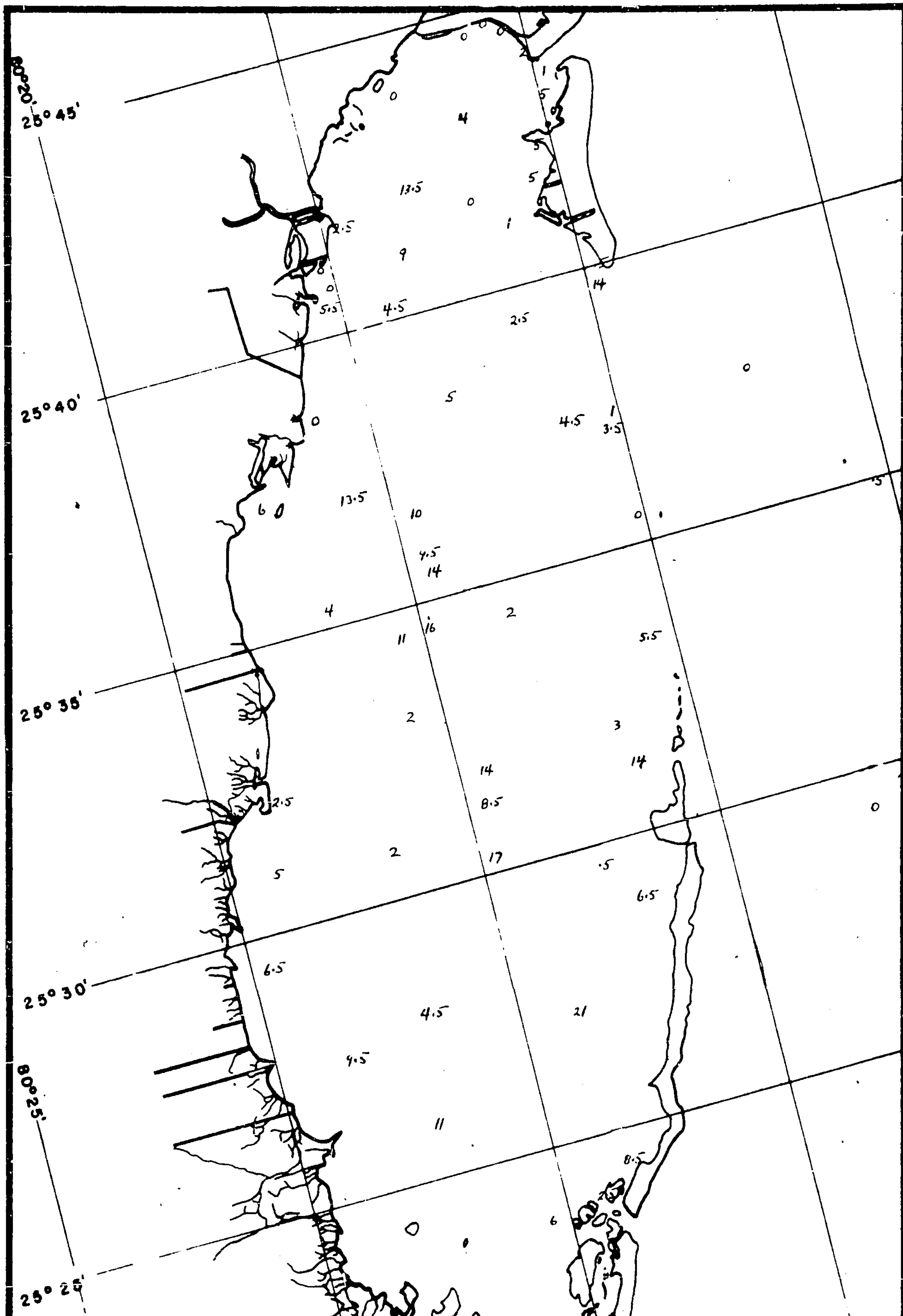
Test subovate; periphery broadly truncate, convex; chamber elongate, slightly arcuate, inflated, tapering toward apertural end where the peristome tends to pinch together; chambers may be rounded but most often with double carination inbetween which it is convex; sutures pronounced; surface smooth; aperture a long, narrow slit, or avicular, the peristome often protruding past the outer periphery of the test as if it were flaring; dentition consisting of a long, narrow tooth slightly thickened or bifurcate at the free end, extending almost the total length of the aperture.

Hypotype No. U.W. 44,026.

This species is very similar to *Triloculina quadrilatera* d'Orbigny except that the latter has a short tooth and square aperture.

Flint (1899, p. 300, pl. 46, fig. 1) described *Miliolina angularis* n. sp. . The species is definitely a triloculina form and would therefore be called *Triloculina angularis*. However, *T. angularis* was used by d'Orbigny in 1850 thus requiring a new name for Flint's species. A new name is herein proposed in honor of Dr. James M. Flint.

This species is the sixth most abundant in the bay area. It is very well distributed throughout the entire bay area but exceedingly rare outside of the bay. It is found at stations 5-9, 11-16, 18, 20-28, 31-34, 36-48, and 50-63.



Numbers represent per cent of species occurrence at station

Fig. 28 DISTRIBUTION OF TRILOCULINA FLINTI

TRILOCULINA LABIOSA d'Orbigny, 1839
Plate III, Figure 5

Triloculina labiosa d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 178, pl. 10, figs. 12-14.

Test oval, discoid; chambers very arcuate, the two last ones forming the major portion of the test; periphery rounded; sutures distinct; aperture v-shaped, at the base of the last chamber, at the periphery, surrounded by an everted peristome.

Hypotype No. U.W. 44,027.

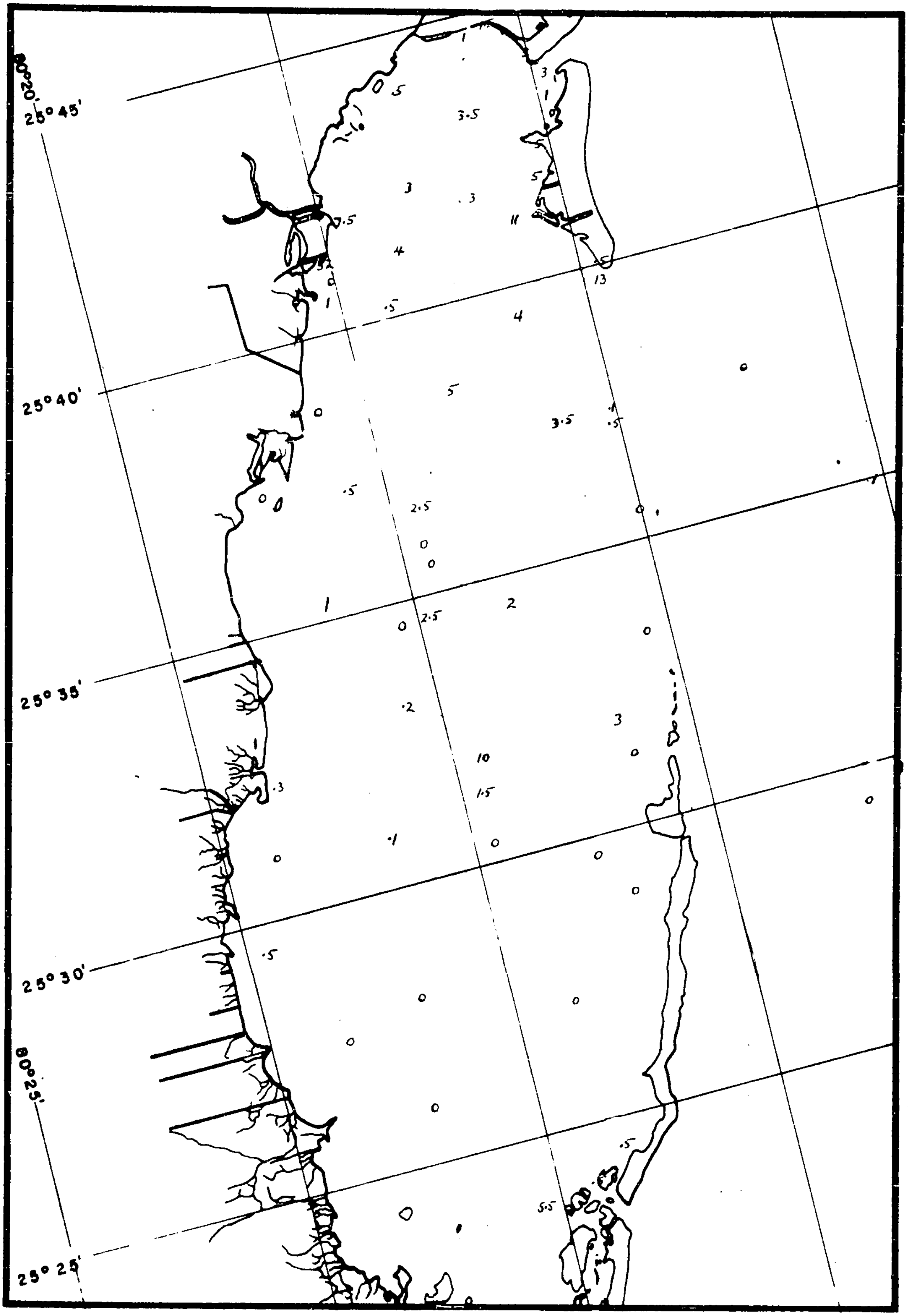
This species is the tenth most common in the bay area. It is primarily limited to the northern portion of the bay (see fig. 29), where the great salinity changes are not felt as in the southern portion of the bay. The species is found at stations 1-3, 5-16, 18, 20-23, 27, 28, 30-34, 36, 38, 40, 43-48, 52, and 58-63.

TRILOCULINA cf. T. OBLONGA Cushman, 1929
Plate III, Figure 6

Triloculina oblonga Cushman (non Montagu), 1929, Bull. 104, U.S. Nat. Mus., pt. 6, p. 57, pl. 13, figs. 4, 5.

Test ovate; chambers elongate, arcuate, the last chamber broadly rounded to truncate on its posterior, tapering slightly on each end; sutures distinct, slightly depressed, arcuate; wall smooth, porcelain-like; aperture terminal, circular, with a narrow, slightly bifid tooth extending half-way into apertural opening.

Hypotype No. U.W. 44,028.



Numbers represent per cent of species occurrence at station

Fig. 29 DISTRIBUTION OF TRILOCULINA LABIOSA

This is probably a new species. It is definitely unlike Vermiculum oblongum Montagu, 1803, but is very similar to that figured by Cushman as noted above. It is believed that many forms referred to under this species have used Cushman's figures as reference rather than those of Montagu (note: Bermudez, 1949, p. 112).

This species is the eleventh most common to the bay area. It is well distributed throughout the entire bay except for the very southwest, coastal section (see fig. 30). However, it is more common in the northern than in the southern portion of the bay occurring at stations 1-3, 5, 7-15, 18, 21-23, 27, 30-33, 36-42, 45-48, 52, 55, 56, 59, and 61-63.

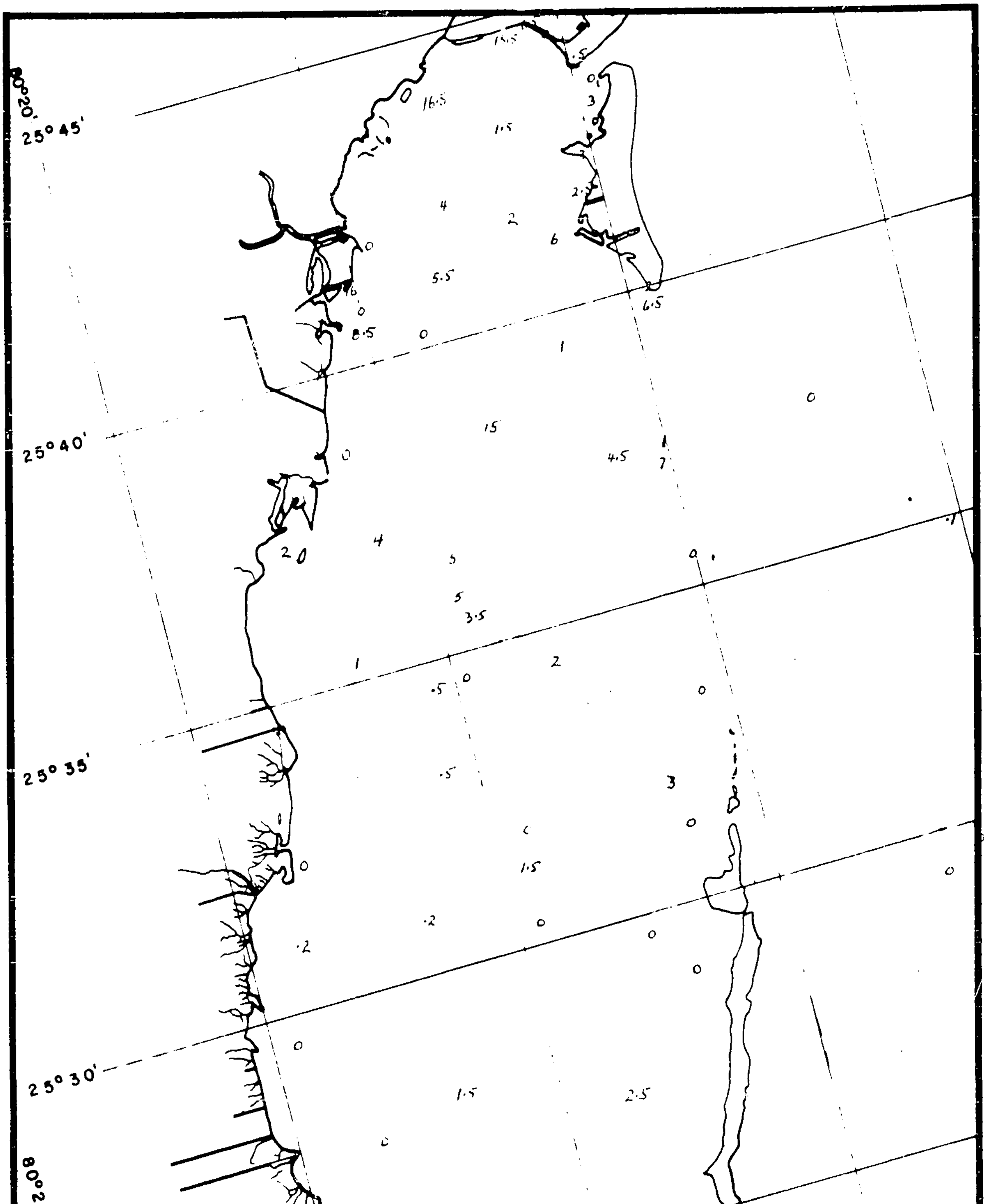
TRILOCULINA PLANCIANA d'Orbigny, 1839
Plate III, Figure 7

Triloculina planciana d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, pp. 173, 174, pl. 9, figs. 17, 19.

Test ovoid; periphery convex; chambers distinct, penultimate chamber appears as pointed at both ends; surface ornamented with small intermittent striations not parallel with the length of the chamber; aperture round, with narrow, bifid tooth.

Hypotype No. U.W. 44,029.

This species is only recorded as present in the bay. It was identified at stations 1, 9, 10, all in the very northern portion of the bay.



Numbers represent per cent of species occurrence at station

Fig. 30 DISTRIBUTION OF TRILOCULINA cf. T. OBLONGA

TRILOCULINA SUBROTUNDA (Montagu, 1803)
Plate III, Figure 8

Vermiculum subrotundum Montagu, 1803, Test. Brit., pt. 2, p. 521.

Test subcircular, slightly compressed laterally; periphery very rounded; three chambers visible, inflated, very arcuate; sutures distinct, slightly depressed; aperture terminal, a curved slit with a broad, flat, semicircular tooth.

Hypotype No. U.W. 44,030.

The specimens from Biscayne Bay are similar to that figured by Brady (1884, figs. 13, 14), but the tooth of our specimens covers more of the aperture.

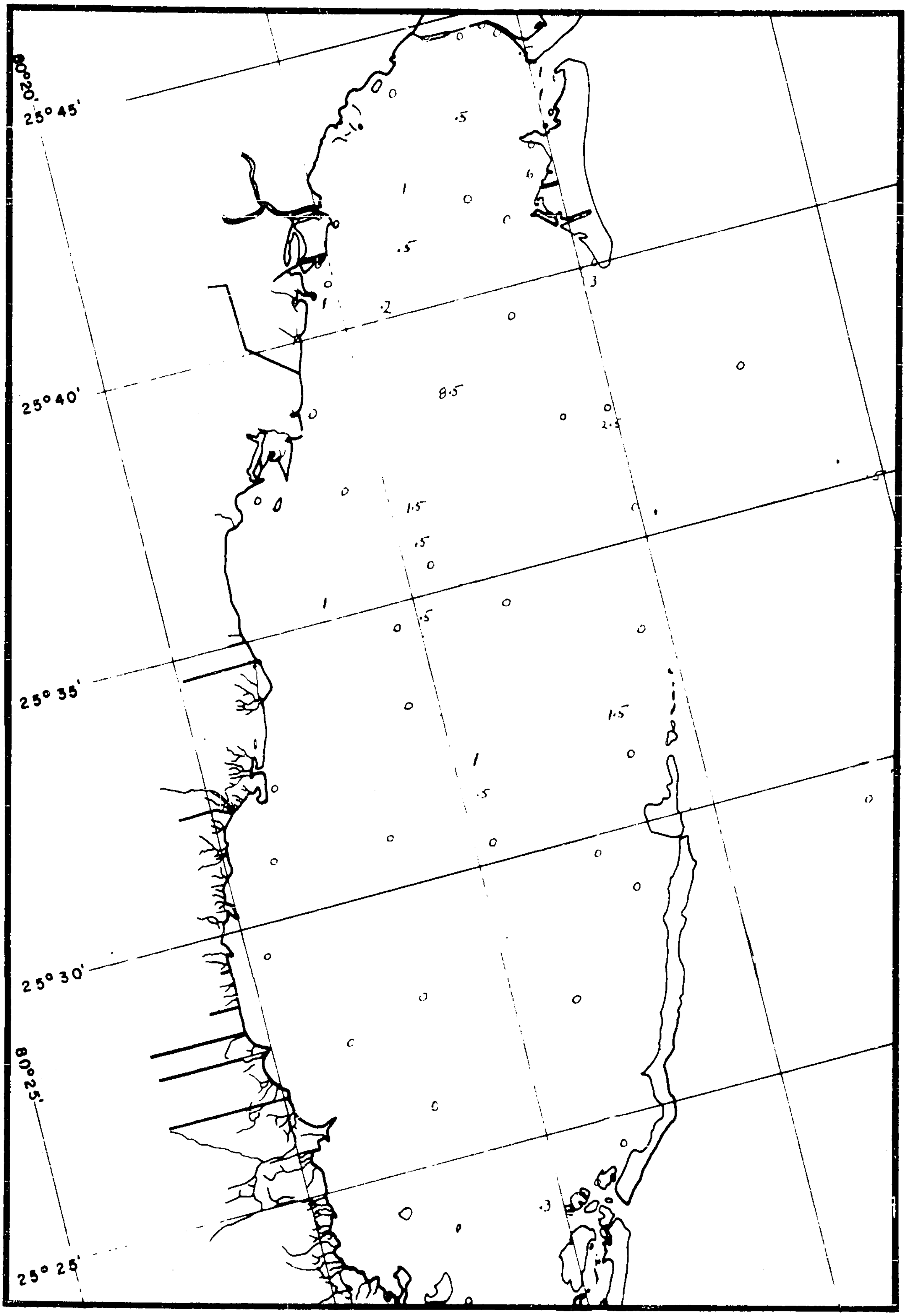
This rare species is primarily characteristic of the north-central portion of the bay wherein the genus *Thalassia* grows (see fig. 31). It is found at stations 5-7, 9, 11, 12, 14, 15, 18, 20, 23, 27, 28, 32, 34, 38, 40, 41, 43, 45, 47, and 52.

TRILOCULINA TRICARINATA d'Orbigny, 1826
Plate III, Figure 9

Triloculina tricarinata d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 299, no. 7.

Test inflated-fusiform in view, longer than wide; three chambers visible, carinate to sharply angled; sutures distinct; wall smooth; aperture round, terminal, with a short tooth, slightly bifid.

Hypotype No. U.W. 44,031.



Numbers represent per cent of species occurrence at station

Fig. 31 DISTRIBUTION OF TRILOCULINA SUBROTUNDA

This species is present at only four stations, 5, 18, 20, and 61. It is not characteristic of any particular environment.

TRILOCULINA TRIGONULA (Lamarck, 1801)
Plate III, Figure 10

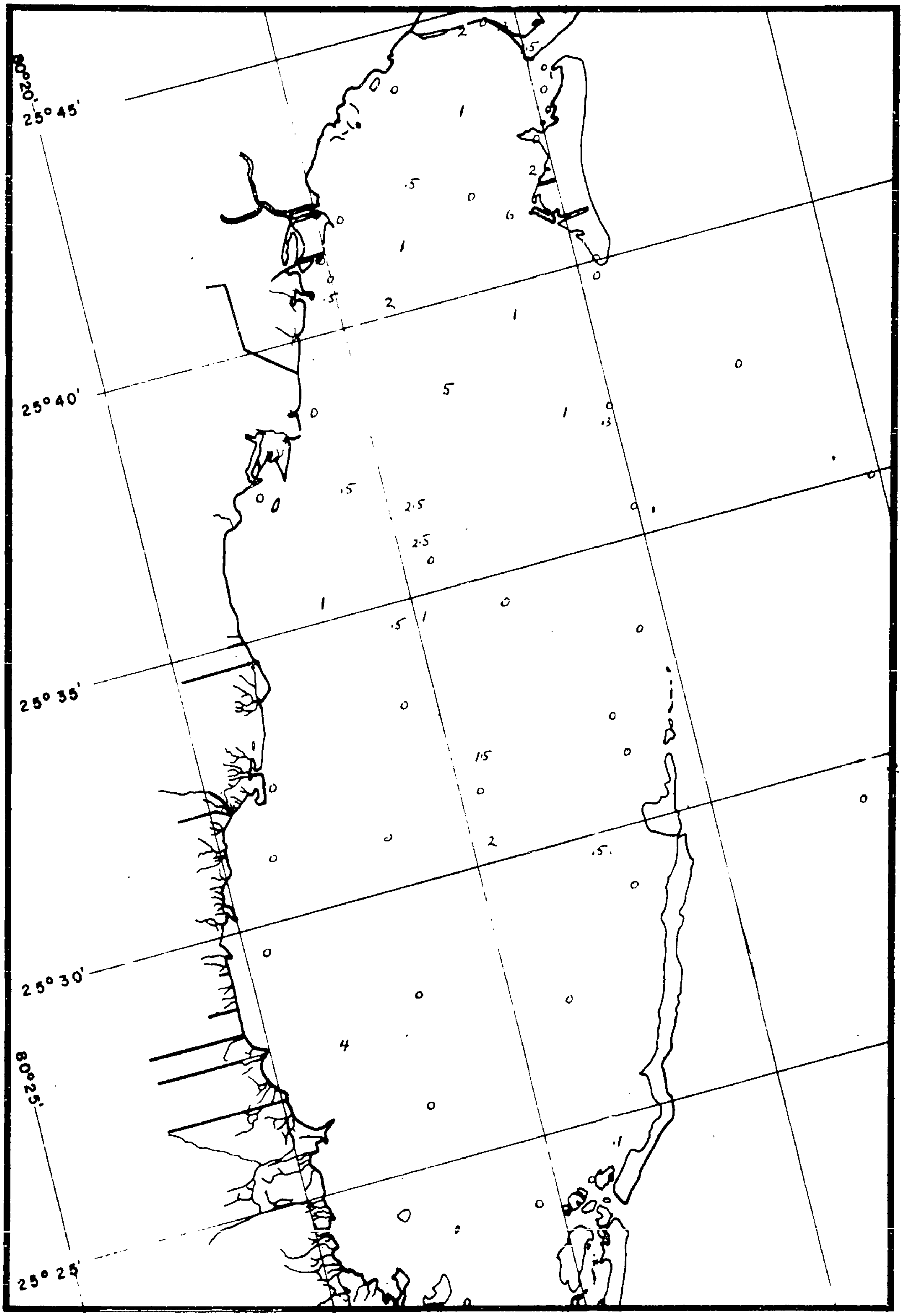
Miliola (Miliolites) trigonula Lamarck, 1801, Ann. Mus. Hist. Nat., Paris, vol. 5, p. 351.

Test ovate in side view, subtriangular in apertural view; periphery round; chambers fusiform in posterior view, arcuate in side view, edges round; sutures pronounced, depressed; wall smooth, glossy; aperture terminal, round, with narrow, bifid tooth extending one-third the distance into the aperture.

Hypotype No. U.W. 44,032.

It is doubtful whether many specimens identified by authors as Triloculina trigonula are actually the same as Lamarck's species. However, until topotype material can be carefully compared with material from Biscayne Bay the specimens from Florida will be temporarily referred to T. trigonula. It is, however, doubtful that the specimens are the same species since T. trigonula is from the Eocene of the Paris Basin. Certainly some changes should have transpired between the Eocene and Recent times. The specimens are probably homeomorphs at best.

This rare species is primarily limited to the environments in the northern portion of the bay (see fig. 32). It was identified at stations 2, 4, 5, 9, 11-15, 20, 22, 26, 28, 33, 34, 36, 38, 40-47, 54, and 57.



Numbers represent per cent of species occurrence of station

Fig. 32 DISTRIBUTION OF TRILOCULINA TRIGONULA

Genus PYRGO Defrance, 1824

PYRGO DENTICULATA (Brady, 1884)

Plate III, Figures 11a and b

Biloculina ringens Lamarck var. denticulata Brady, 1884, Rep. Voy. Challenger, Zoology, vol. 9, p. 143, pl. 3, figs. 4, 5.

Test oval in view, biconvex; two chambers clearly visible of almost equal size; periphery sharply angled, carinate; abapertural end with short spiny projections of irregular number and distribution; sutures not pronounced; aperture a narrow oval with tooth having long lateral projections.

Hypotype No. U.W. 44,033.

This very rare species is primarily limited to the environment of the eastern portion of the north part of the bay where the open-sea waters flow into the bay. It is found at stations 3, 5, 6, 9, 12-14, 16, 17, 20-22, 25-28, 32, 34, 37, 46-48, 50, 52, 59, and 61-63.

PYRGO SUBSPHAERICA (d'Orbigny, 1839)

Plate III, Figures 12a and b

Biloculina subsphaerica d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 162, pl. 8, figs. 25-27.

Test ovate; periphery rounded; chambers strongly inflated, slightly arcuate, the ultimate chamber not always covering all of the prepenultimate chamber making it appear superficially triloculine - the biloculine arrangement is clearly seen in sectional view; sutures distinct, not strongly depressed; wall smooth; aperture round to oval, with a narrow, strongly bifid tooth: the tooth is strongly convex upward, extending past the outline of the peristome.

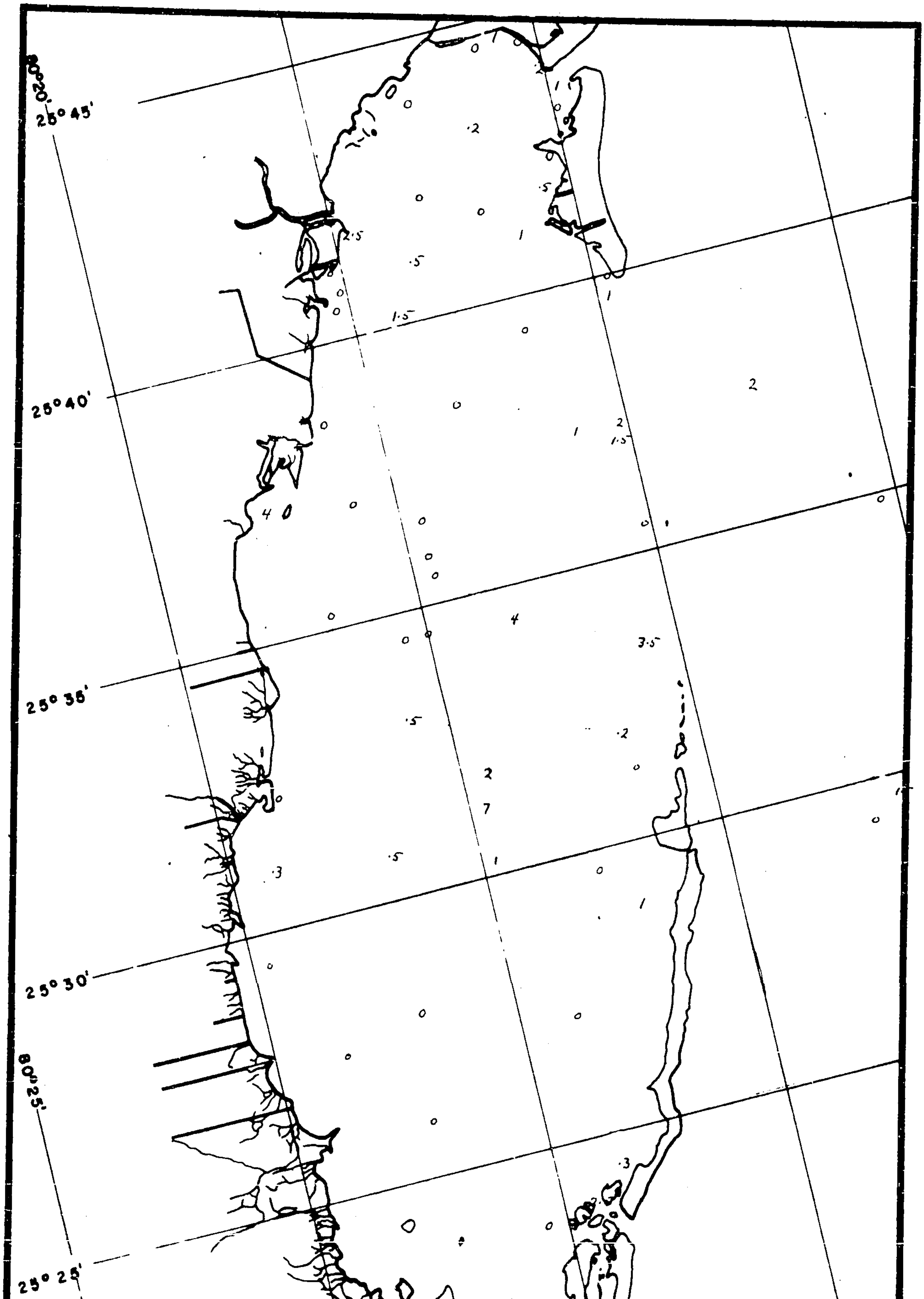


Fig. 33 DISTRIBUTION OF PYRGO DENTICULATA

Hypotype No. U.W. 44,034.

This species is the seventh most common in Biscayne Bay. It is very well distributed throughout and adapted to all environments (see fig. 34). It occurs at stations 1-3, 5, 6, 8-15, 18, 20-24, 26-28, 30-34, 36, 37, 39, 40, 42-56, and 58-63.

Subfamily HAUERININAE Brady, 1884
Genus MASSILINA Schlumberger, 1893
MASSILINA CRENATA (Karrer, 1868)
Plate IV, Figure 1

Spiroloculina crenata Karrer, 1868, Sitz. Akad. Wiss. Wien, vol. 57, p. 135, pl. 1, fig. 19.

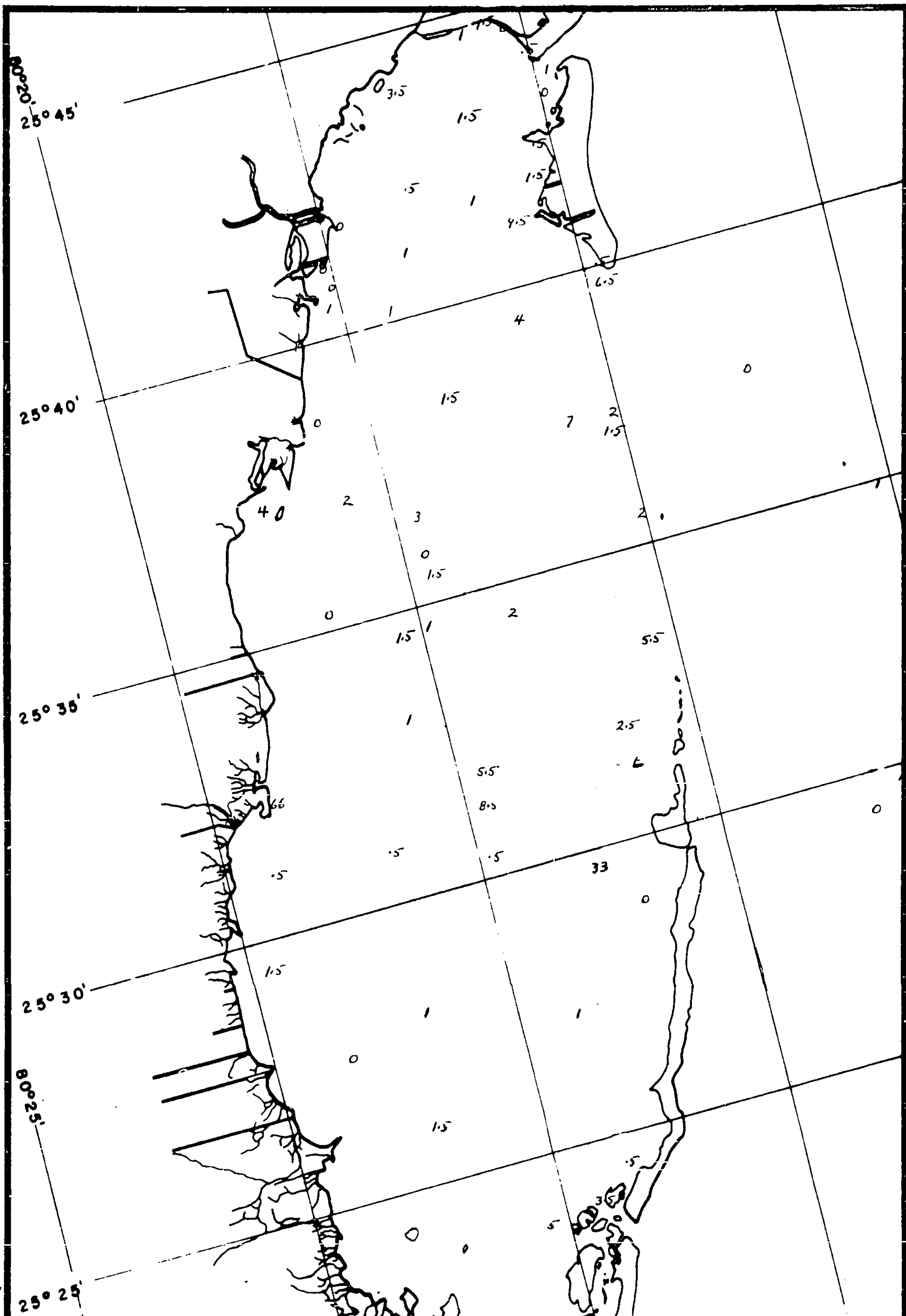
Test oval in front view, strongly compressed; periphery rounded; chambers arcuate, longitudinal, two per whorl, of about equal diameter throughout; sutures distinct, not strongly depressed; surface with broad crenulations transverse to the length of the chamber; aperture an opening at the end of the chamber.

Hypotype No. U.W. 44,035.

A single specimen of this species was found at station 18.

Genus VERTEBRALINA d'Orbigny, 1826
VERTEBRALINA CASSIS d'Orbigny, 1839
Plate IV, Figure 2

Vertebralina cassis d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 51, pl. 7, figs. 14, 15.



Numbers represent per cent of species occurrence at station

Fig. 34 DISTRIBUTION OF PYRGO SUBSPHAERICA

Test strongly compressed, planispiral, except for the neanic stage; periphery strongly carinate; three chambers per last whorl, the last two composing most of the test; wall ornamented with longitudinal costae; aperture terminal, elongate in the directions of compression, with everted peristome.

Hypotype No. U.W. 44,036.

This rare species was identified at stations 12, 13, 18, 20, 22, 27, and 28. No particular environmental factors appear to determine its distribution.

Genus ARTICULINA d'Orbigny, 1826

ARTICULINA MEXICANA Cushman, 1922

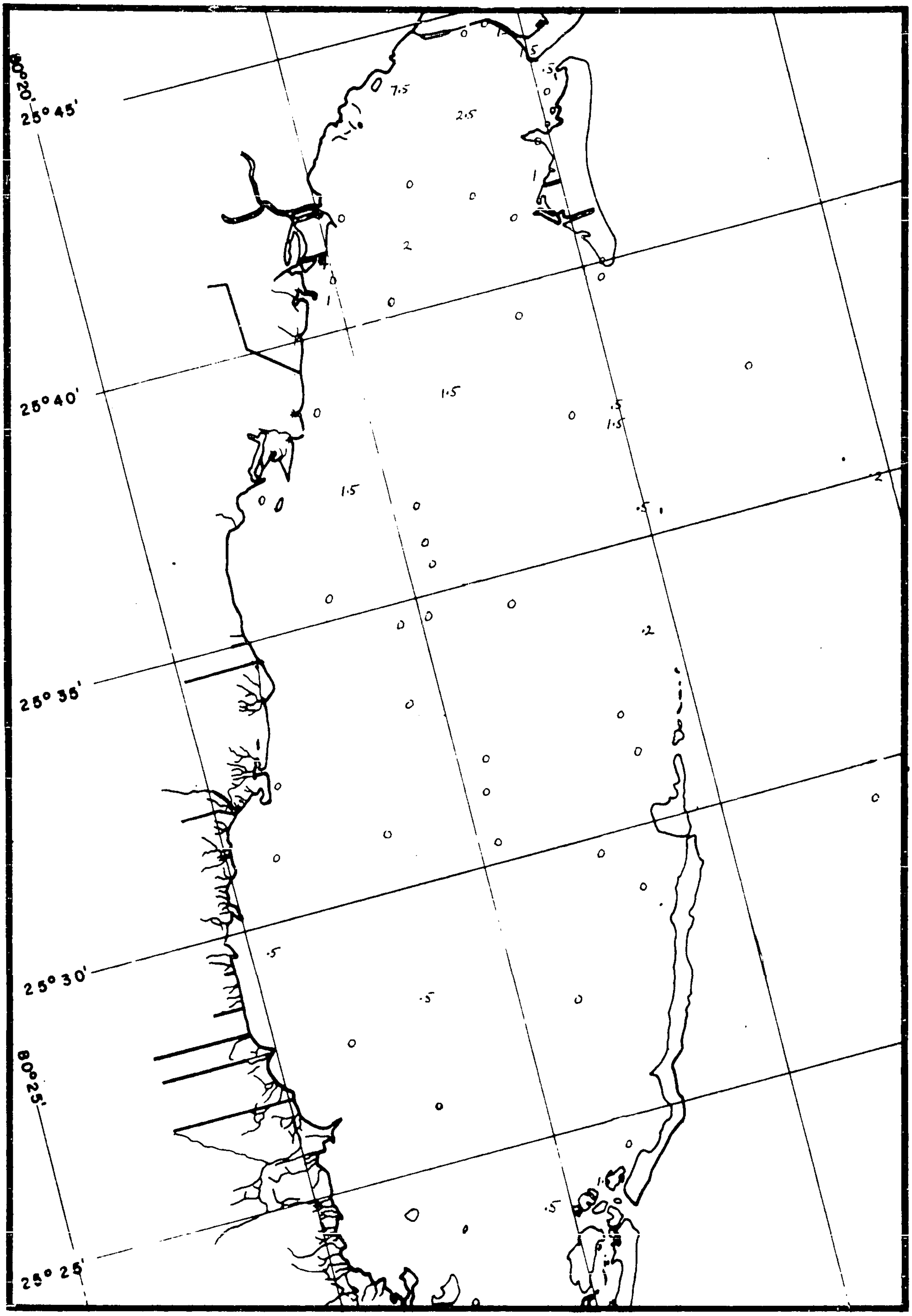
Plate IV, Figures 3a and b

Articulina mexicana Cushman, 1922, Publ. 311, Carnegie Inst. Washington, p. 70, pl. 11, figs. 7, 8.

Test discoid, inflated; periphery rounded; three chambers visible, indistinct; sutures indistinct, very slightly depressed if at all; wall smooth, white; aperture peripheral, elongate, narrow.

Hypotype No. U.W. 44,037.

This species is quite rare. It was identified at stations 1, 4-6, 9, 12, 14, 15, 18, 21, 23, 30, 36, 45, 47-50, 56, and 58. It is primarily found in the northern portion of the bay in the near-shore and Safety Valve regions (see fig. 35).



Numbers represent per cent of species occurrence at station

Fig. 35 DISTRIBUTION OF ARTICULINA MEXICANA

ARTICULINA MUCRONATA (d'Orbigny, 1839)
Plate IV, Figure 4

Vertebralina mucronata d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 52, pl. 7, figs. 16-19.

Test in the early stage quinqueloculina or triloculine, becoming linear; chambers compressed, rarely carinate, inflated at lower end, becoming narrow and then flaring to form the peristome; ornamentation consisting of longitudinal costae; aperture narrow, elongate, extending past the sides of the chamber, the peristome recurved and laterally pointing toward the earlier chambers.

Hypotype No. U.W. 44,038.

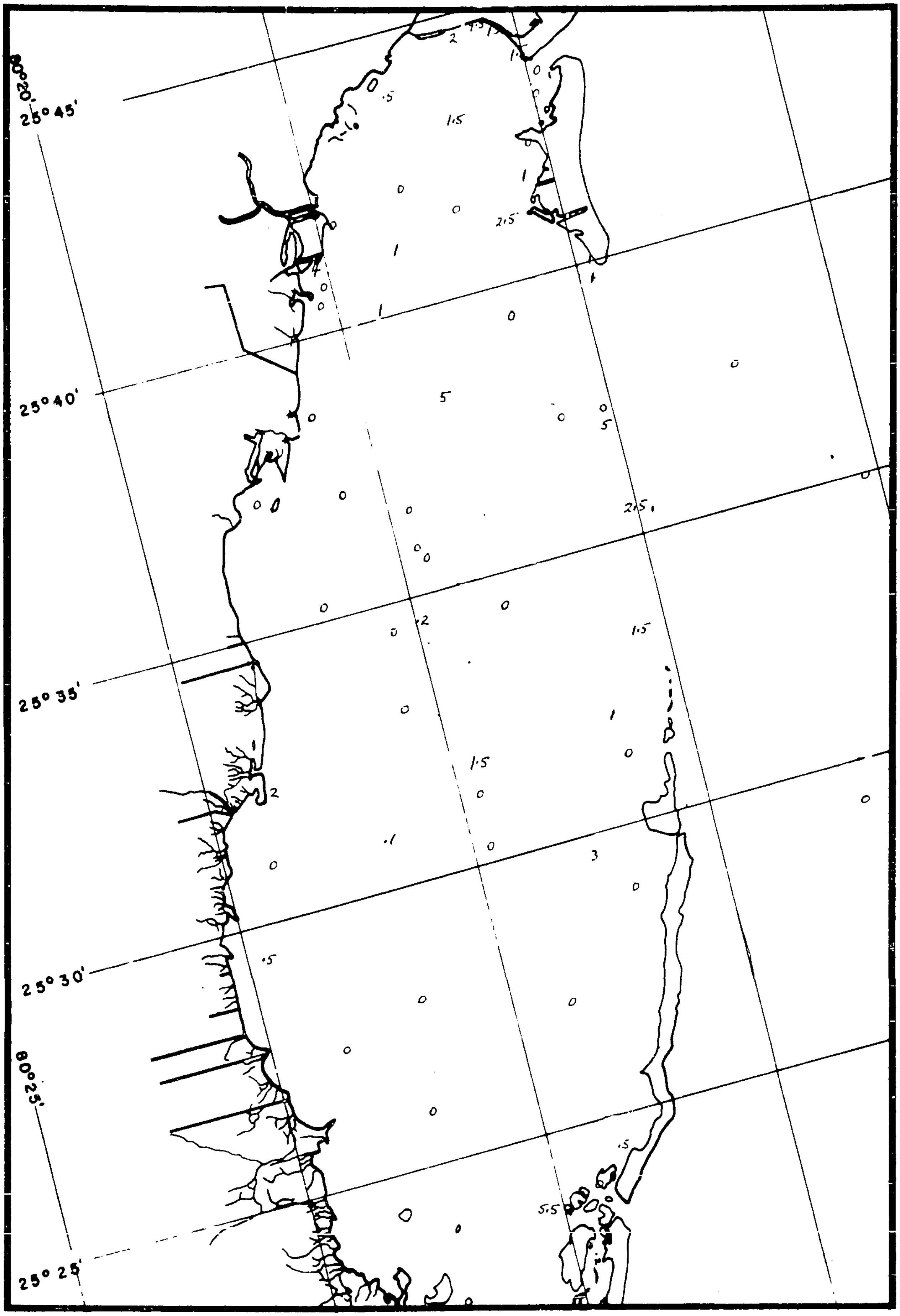
This species is limited to the north bay region except for its occurrence at the two stations just inside the channel north of Old Rhodes Key. The species probably needs the fresh, turbulent waters coming into the bay at tidal flow. The species is found at stations 1-5, 12-14, 22, 23, 30, 32, 34, 43, 45, 47, 49, 50, 52, 54, 58, 60, and 61.

ARTICULINA SAGRA d'Orbigny, 1839
Plate IV, Figure 5

Articulina sagra d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 183, pl. 9, figs. 23-26.

Test elongate, compressed; early chambers triloculine, becoming uniserial and straight; wall of test ornamented with longitudinal costae; aperture an elongate oval with strongly everted peristome, without tooth.

Hypotype No. U.W. 44,039.



Numbers represent per cent of species occurrence of station

Fig. 36 DISTRIBUTION OF ARTICULINA MUCRONATA

This rare species is limited strictly to the bay waters. It is probably greatly affected by the fresh waters along the western shore of the bay since the species is completely absent from this area. Specimens were found primarily in the southcentral, northcentral, and Safety Valve areas of the bay (see fig. 37). Specimens were identified from stations 2, 6, 8-10, 12, 14, 22-24, 27, 33, 34, 43-52, 55, and 56.

Genus WIESNERELLA Cushman, 1933
WIESNERELLA AURICULATA (Egger, 1893)
Plate IV, Figure 6

Planispirina auriculata Egger, 1893, Abhandl. kon. bay. Akad. Wiss., Cl. II, bd. 18, abth. 2, p. 245, pl. 3, figs. 13-15.

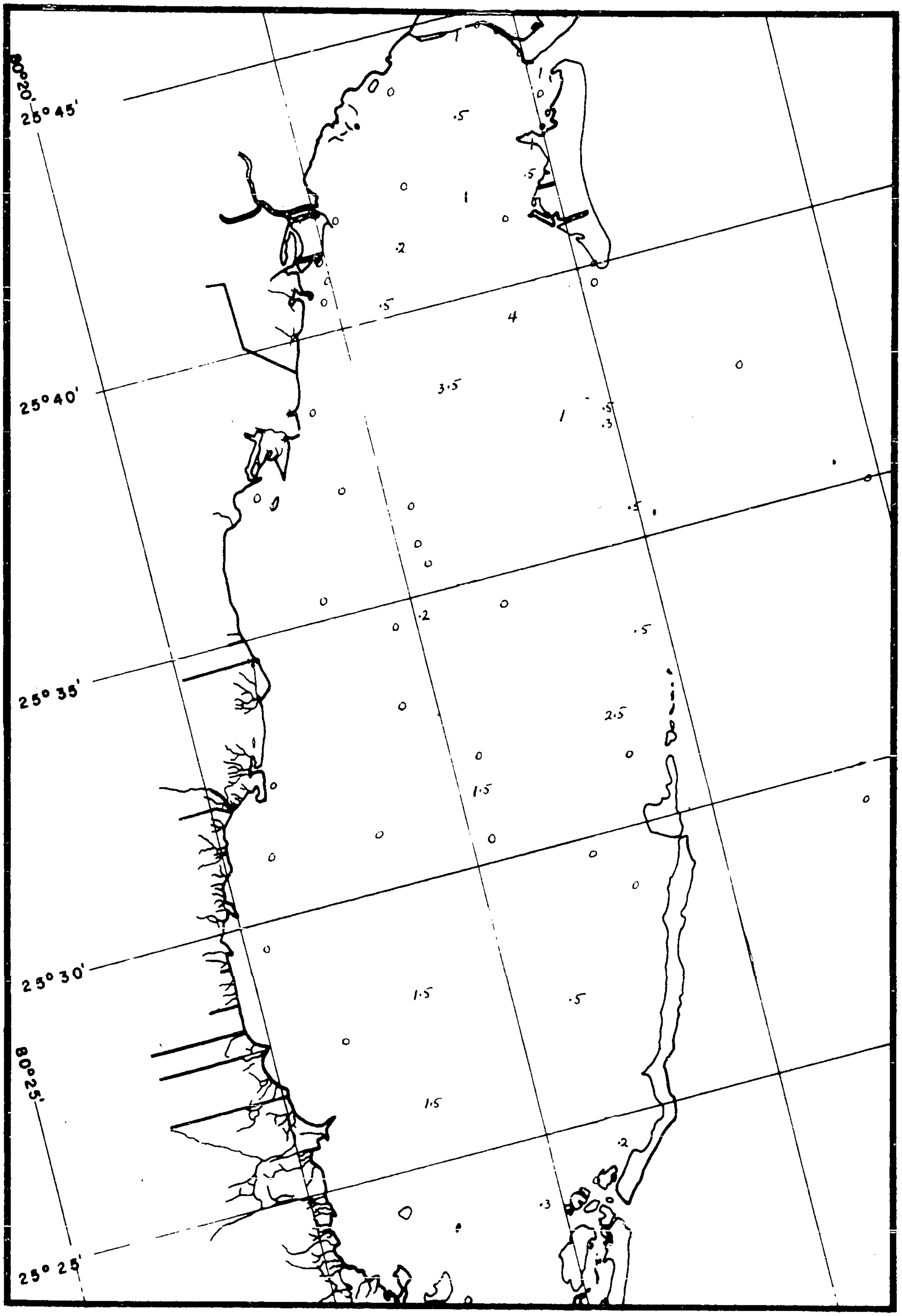
Test oval in side view, very compressed, flat; two chambers per last whorl, arcuate, last chamber flaring as a trumpet to form aperture; periphery with sharp keel; sutures not pronounced; aperture round.

Hypotype No. U.W. 44,040.

This species is listed as present from stations 5, 33, and 47. All these stations are located in an area affected equally by both the bay and open-sea waters.

Genus NUMMOLOCULINA Steinmann, 1881
NUMMOLOCULINA IRREGULARIS (d'Orbigny, 1839)
Plate IV, Figure 7

Biloculina irregularis d'Orbigny, 1839, in Voyage dans l'Amerique Meridionale, Foraminiferes, tome 5, pt. 5, p. 67, pl. 8, figs. 20,21.



Numbers represent per cent of species occurrence of station

Fig. 37 DISTRIBUTION OF ARTICULINA SAGRA

Test oval, inflated, slightly compressed on its sides; two chambers visible, laterally compressed, very convex; periphery rounded; sutures not distinct; aperture crescent-shape, terminal.

Hypotype No. U.W. 44,041.

This species is listed as present from stations 18, 20, and 31. It is primarily an open-sea fauna or one found in an area strongly affected by the open-sea waters.

Family SORITIDAE Galloway, 1933
Subfamily PENEROPLINAE Schultze, 1854
Genus PENEROPLIS Montfort, 1808
PENEROPLIS ACICULARIS (Batsch, 1791)
Plate IV, Figure 8

Nautilus (lituus) acicularis Batsch, 1791, Conch. Seesandes, p. 4, pl. 6, figs. 16a, b.

Test planispiral, involute, becoming evolute rectilinear, the rectilinear portion of the test composing the major portion; chambers increase gradually in size, 8 in the last whorl, 11 in the rectilinear series, all compressed, becoming rounded in the last few chambers; sutures distinct, slightly depressed; walls very finely perforate, longitudinally costate, the costae not continuous from chamber to chamber, the sutures free from costae; aperture terminal, a few pores or a large opening in the septal face.

Hypotype No. U.W. 44,042.

This species is present at stations 6, 22, 34, and 42.

PENEROPLIS ANTILLARUM d'Orbigny, 1839
Plate IV, Figure 9

Peneroplis (Dendritina) antillarum d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 58, pl. 7, figs. 3-6.

Test subcircular, planispiral, involute, compressed; periphery angulate; eleven chambers per last whorl; chambers arcuate triangles as seen in side view, increasing gradually in size; sutures pronounced, hardly depressed; wall ornamented with short costae not continuous from chamber to chamber, parallel to the periphery; aperture on the face of last septal face, dendritic.

Hypotype No. U.W. 44,043.

This species is present only at station 47, in the very shallow Safety Valve waters.

PENEROPLIS ARIETINUS (Batsch, 1791)
Plate IV, Figure 10

Nautilus (Lituus) arietinus Batsch, 1791, Conch. Seesandes, p. 4, pl. 6, fig. 15c.

Early portion of test planispiral, compressed, later portion evolute; chambers elliptical in section, longitudinally striate, striations continuous from one chamber to next; sutures markedly depressed in coiled portion, not depressed in uncoiled portion; aperture cribrate on the face of last chamber or a large, single opening.

Hypotype No. U.W. 44,044.

The specimens from Biscayne Bay differ from that pictured by Brady (1884, pl. XIII, figs. 18, 19, 22) in that the coiled portion is involute, not evolute as shown by Bardy. The specimens are similar to those reported from the Tortugas by Cushman (1930, pp. 43, 44, pl. 15, figs. 4, 5).

This very rare species is only found at station 2.

PENEROPLIS BRADYI Cushman, 1930

Plate IV, Figure 11

<u>Peneroplis</u> <u>bradyi</u> Cushman, 1930, Bull. 104, U.S. Nat. Mus., pt. 7, p. 40, pl. 14, figs. 8-10.

Test an irregular discoid; periphery bluntly rounded; neanic chambers planispiral, ephebic chambers becoming flaring; sutures distinct, slightly depressed, curved; wall smooth, translucent, punctate; aperture a series of peripheral pores.

Hypotype No. U.W. 44,045.

This species is present at stations 6, 18, 20, 43, 61, and 63. It appears to be adapted to the rigors of the bay waters as well as to the open-sea waters.

PENEROPLIS DISCOIDEUS Flint, 1899

Plate IV, Figure 12

<u>Peneroplis</u> <u>pertusus</u> var. <u>discoideus</u> Flint, 1899, Rep. U.S. Nat. Mus. for 1897, p. 304, pl. 49, figs. 1, 2.

Test discoid, flabelliform; periphery round; neanic chambers planispiral, involute, ephebic chamber flaring and annular; chambers not divided into chamberlets; sutures distinct, slightly depressed; wall smooth, punctate; aperture a series of peripheral pores.

Hypotype No. U.W. 44,046.

This species is present only at station 22.

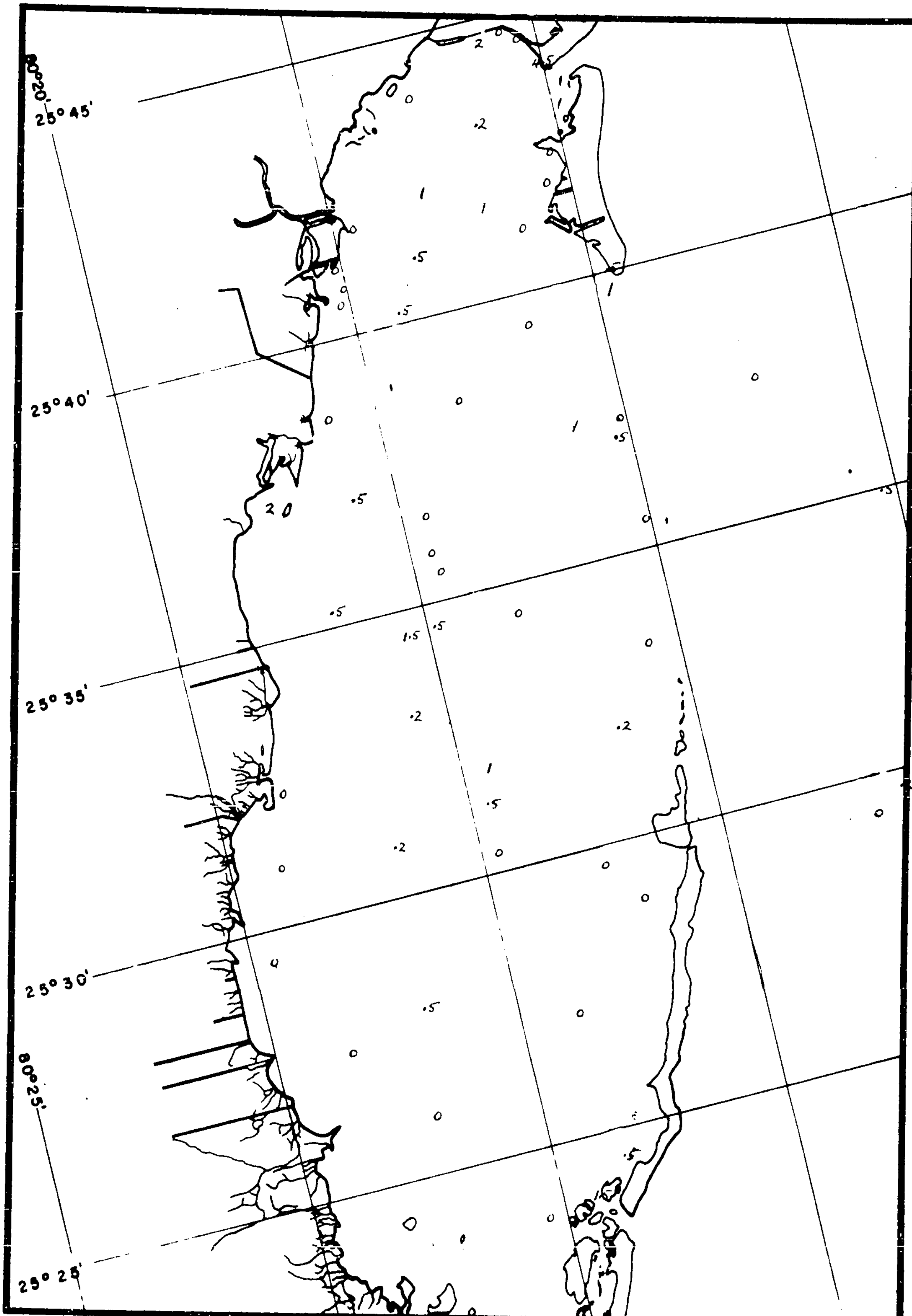
PENEROPLIS cf. P. ELEGANS d'Orbigny, 1839
Plate IV, Figure 13

Peneroplis elegans d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 61, pl. 7, figs. 1, 2.

Test planispiral, involute, compressed, biumbilicate, periphery slightly angled in side view; suture curved, distinct; walls imperforate, lightly striate, parallel to the direction of growth; aperture a series of pores on last septal face.

Hypotype No. U.W. 44,047.

This species differs from P. pertusus (Forskal, 1775). Forskal did not figure the species. Brady (1884, pl. 13, figs. 16, 17) figured what he called P. pertusus but figured it with a depressed spetal face. The specimens from Biscayne Bay have a convex apertural face similar to that figured by d'Orbigny. However, d'Orbigny's figure showed a series of pores on the apertural face while those specimens from Biscayne Bay have a more dendritic aperture. The author believes that the aperture is a variable feature and that, therefore, the species is P. elegans rather than Dendritina elegans. Other species of Peneroplis show both a dendritic and cribrate aperture all from the same locales. Because of the extreme variability of the aperture the genus Dendritina appears to be an invalid genus.



Numbers represent per cent of species occurrence at station

Fig. 38 DISTRIBUTION OF PENEROPLIS cf. P. ELEGANS

This rare species is fairly well distributed throughout the central portion of the bay (see fig. 38). It is particularly absent from that area immediately affected by the western coastal area of the bay. No specific environmental factors can be surmised to account for its particular pattern. The stations at which the species occurs are: 2, 5-7, 10-12, 14, 18, 20-22, 27, 28, 31, 32, 34, 36-38, 42, 43, 46, 47, 52, 56, 61, and 62.

PENEROPLIS PROTEUS d'Orbigny, 1839

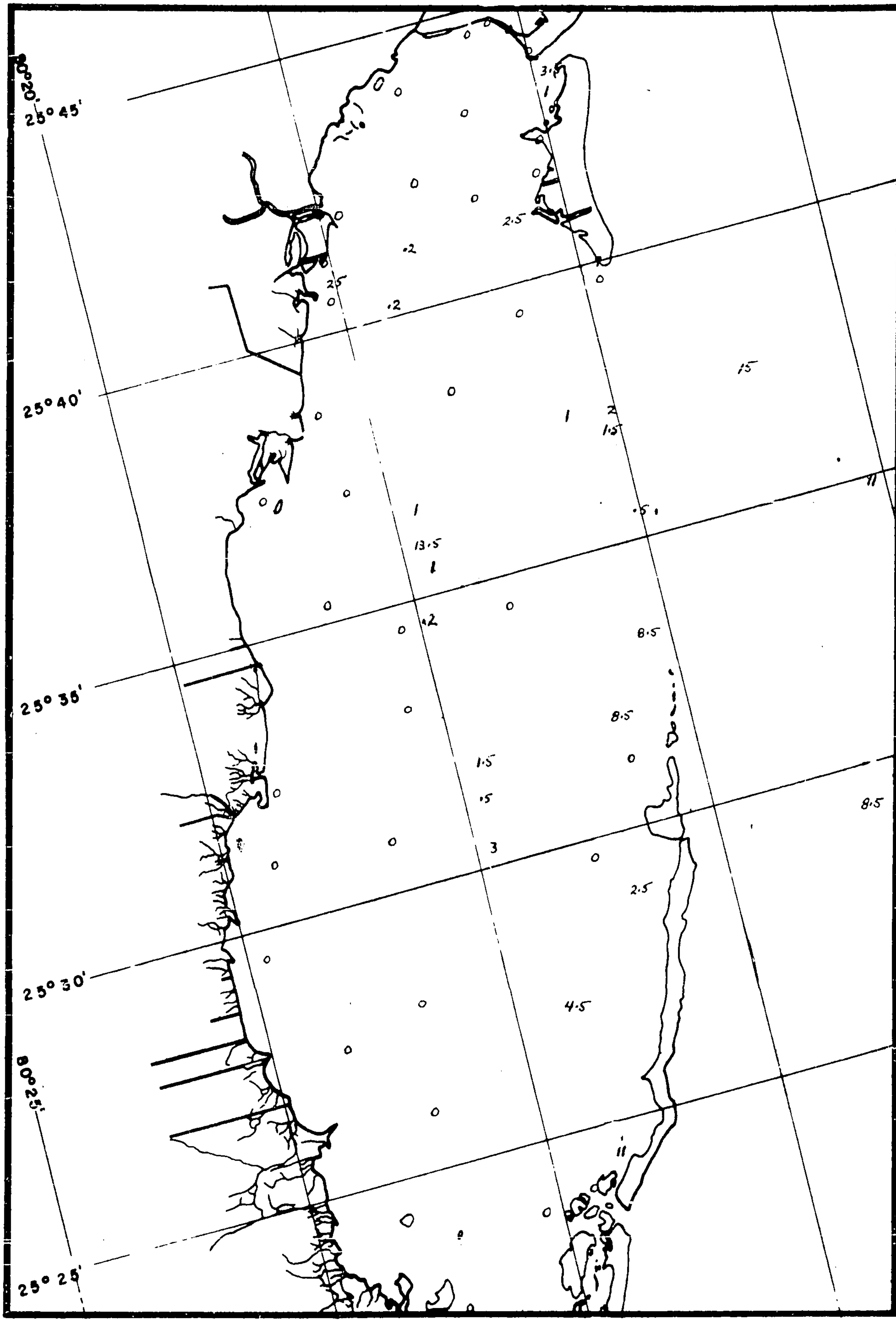
Plate IV, Figure 14

Peneroplis proteus d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 60, pl. 7, figs. 7-11.

Test planispiral, early portion involute, later portion involute or evolute becoming flaring and flabelliform; aperture consisting of a series of pores, round, forming a single line in the middle of the width of the last chamber.

Hypotype No. U.W. 44,048.

This species is the eleventh most common in the waters of Biscayne Bay. It is particularly limited areally to the middle of the bay and the Safety Valve region. It is this portion which is least affected by the rigors of the environmental extremes in the bay waters. The species is also very well adapted to the open-sea waters as evidenced by the large percentage of specimens present at stations 17, 18, 19, and 20. The distribution of this species is readily pictured in figure 39. The species occurs at stations 6, 7, 13, 14, 17-20, 22, 25-29, 31, 34, 39-41, 43, 46-52, 55, and 63.



Numbers represent per cent of species occurrence at station

Fig. 39 DISTRIBUTION OF PENEROPLIS PROTEUS

Subfamily ORBITOLITINAE Brady, 1881

Genus ARCHAIAS Montfort, 1808

ARCHAIAS ANGULATUS (Fichtel and Moll, 1803)

Plate V, Figure 1

Nautilus angulatus Fichtel and Moll, 1803, Test. Micr., p. 112, p. 21.

Test subcircular, planispiral, becoming flabelliform; chambers narrow, arcuate, divided into chamberlets; aperture a series of pores on the septal face; surface ornamented by minute punctations which do not penetrate the wall.

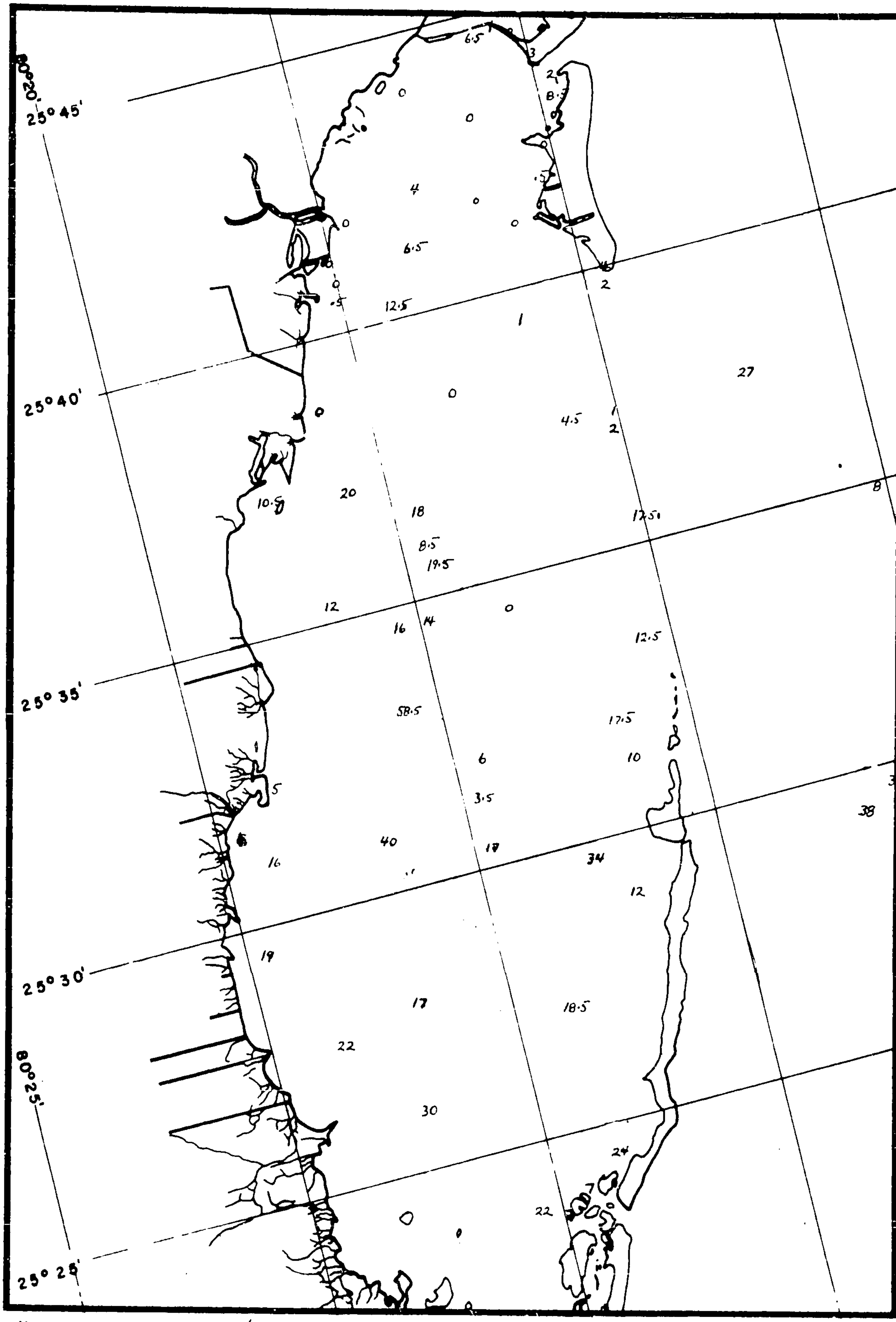
Hypotype No. U.W. 44,049.

Next to Quinqueloculina lamarckiana this species is the most abundant in the Biscayne Bay area. It is well distributed not only in the bay but is equally abundant in the open-sea waters. Even the southwestern near-shore bay area has abundant forms of this species. In addition, there is evidence of the adaptation of this species to the bay environment in the forming of large specimens as well as sports. The only stations at which this species is not found are 1, 4, 8, 10, 12, 13, 16, 29, 30, 35, 45, and 63 (see fig. 40). Most of these stations are in the very northern portion of the bay. What environmental factor is in this region that prevents the species from inhabiting this area is not known.

ARCHAIAS COMPRESSUS (d'Orbigny, 1839)

Plate V, Figure 2

Orbiculina compressa d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 66, pl. 8, figs. 4-7.



Numbers represent per cent of species occurrence at station

Fig. 40 DISTRIBUTION OF ARCHAIAS ANGULATUS

Test circular in outline, a flat disc with early chambers thickened; early chambers planispiral, later chambers becoming annular; chambers subdivided into chamberlets; aperture consisting of a series of pores on the periphery.

Hypotype No. U.W. 44,050.

This rare species is found at stations 18, 20, 22, 23, 50, 52, and 63. It is particularly limited in the environment where the open-sea waters enter the bay.

Genus PRAESORITES Douvillé, 1902

PRAESORITES ORBITOLITOIDES Hofker, 1930

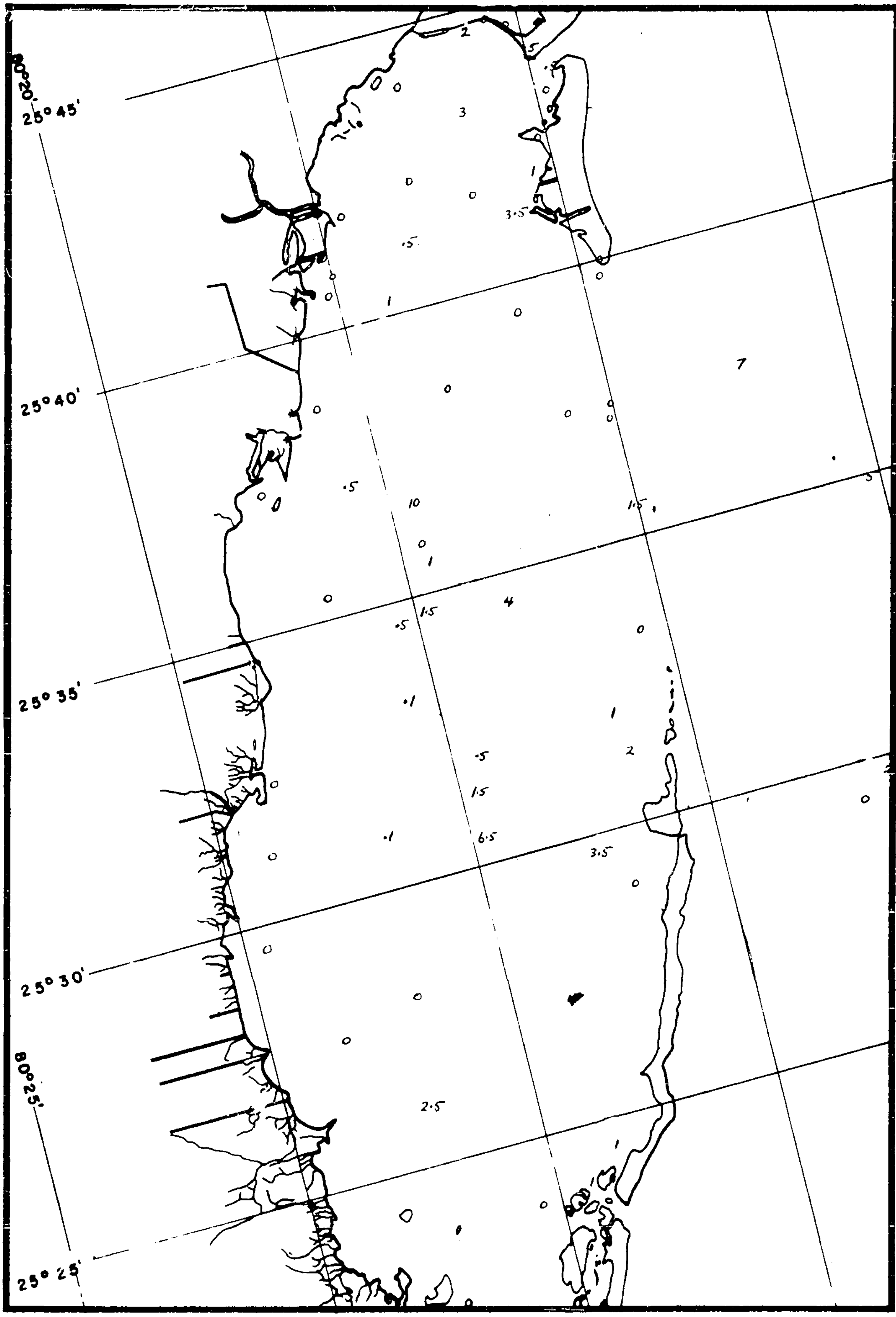
Plate V, Figure 3

Praesorites orbitolitoides Hofker, 1930, Siboga-Expedite, Part II, p. 149, pl. 55, figs. 8, 10, 11; pl. 57, figs. 4, 6; pl. 58, figs. 1-5; pl. 61, figs. 3, 14.

Test discoid; periphery bluntly rounded; neanic stage planispiral becoming flaring, the ephebic stage a series of annular chambers, all chambers divided into chamberlets; sutures pronounced, depressed, curved; wall smooth; aperture a series of peripheral pores.

Hypotype No. U.W. 44,051.

This species is characteristic to the environment in the middle portion of the bay as well as outside of the bay. It is not found anywhere near the western bayshore (see fig. 41). The stations at which the species is found are: 2, 5, 6, 9, 12-14, 17, 18, 20-22, 27, 29, 31-33, 45-47, 49, 50, 52, and 60.



Numbers represent per cent of species occurrence of station

Fig. 41 DISTRIBUTION OF PRAESORITES ORBITOLITOIDES

Genus SORITES Ehrenberg, 1840

SORITES MARGINALIS (Lamarck, 1816)

Plate V, Figure 4

Orbulites marginalis Lamarck, 1816, Hist. Nat. des Animaux sans Vert., vol. 2, p. 196.

Test discoid, strongly compressed; periphery rounded; neanic stage planispiral, evolute, becoming annularly arranged and divided into chamberlets in the ephebic stage, unilaminar; aperture in a single line, peripheral, not readily discernable on any specimens from Biscayne Bay.

Hypotype No. U.W. 44,052.

This species is the sixteenth most common to the Biscayne Bay region. It is limited to that area in the bay which is influenced by the immediate effects of the tidal flow; it is characteristic of the very northern part of the bay, the Safety Valve region as well as the Caesar Creek area (see fig. 42). The stations at which the species was identified are: 1, 3-7, 9-15, 18, 20-23, 27, 29, 31-33, 45-52, and 60.

Family ALVEOLINELLIDAE Cushman, 1928

Subfamily ALVEOLINELLINAE Galloway, 1933

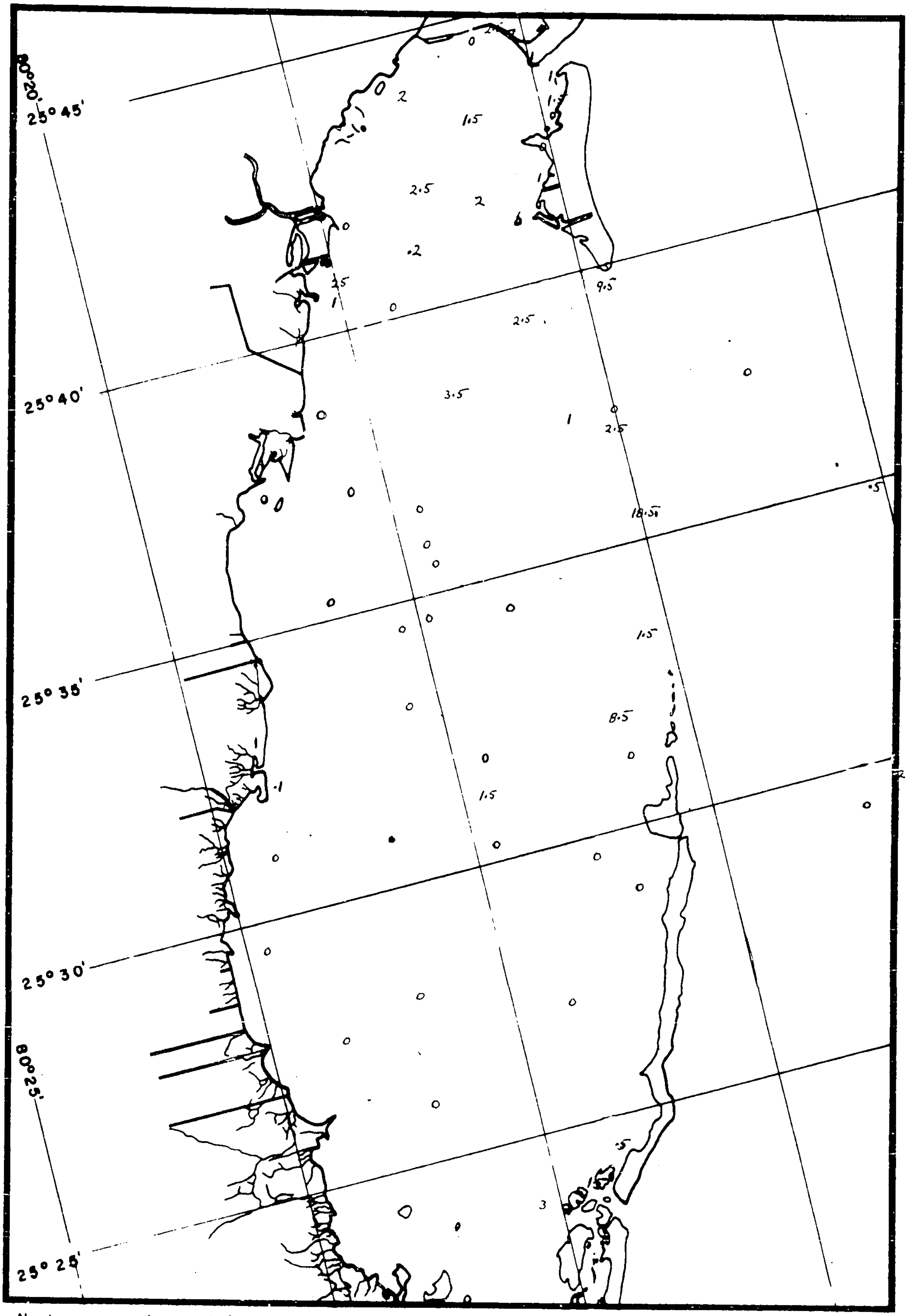
Genus NEOALVEOLINA Silvestri, 1928

NEOALVEOLINA cf. N. SCHLUMBERGERI Reichel, 1937

Plate V, Figure 5

Neoalveolina pygmaea var. schlumbergeri Reichel, 1937, Schweiz. Paleont. Ges., Mem. de la Soc. Paleon. Suisse, vol. 59, p. 108, pl. 10, fig. 1.

Test fusiform to globular; 6-7 chambers per last whorl; chambers divided into 18 chamberlets in a single layer; canal



Numbers represent per cent of species occurrence at station

Fig. 42 DISTRIBUTION OF SORITES MARGINALIS preseptal; sutures conspicuous; wall smooth; biumbilicate; aperture a single row of foramen, one for each chamberlet.

Hypotype No. U.W. 44,053.

The specimens from Biscayne Bay may be very globular or very fusiform. The typical fusiform specimens have dimensions as follows: length, 0.66mm; diameter, 0.34mm. Some specimens have only 18 chamberlets whereas others have as many as 26. According to Dr. ,. Reichel (personal communication), these are probably two new species. It will be left for Dr. Reichel, the authority on alveolinids, to describe these forms in detail since he is now in possession of the author's specimens from Biscayne Bay.

This rare species is found at stations 5, 6, 18, 19, 20, 31, 49, 50, 51, and 52. All of these locales are either in the open-sea waters or in an area immediately affected by the tidal flow of these waters.

Family ATAXOPHRAGMIIDAE Schwager, 1877
Subfamily ATAXOPHRAGMIINAE Galloway, 1933
Genus VALVULINA d'Orbigny, 1826
VALVULINA OVIEDOIANA d'Orbigny, 1839
Plate V, Figures 6, 7

Valvulina oviedoiana d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 103, pl. 2, figs. 21, 22.

Test trihedral, the initial end pointed, becoming rapidly diverging; periphery rounded; chambers inflated, rapidly increasing in size; sutures not distinct in neanic stage, distinct in ephebic stage, slightly depressed; slightly umbilicate on apertural side of test; aperture a large opening in the last septal face, extending from the base of the face up into the chamber, with a large, valvular tooth extending toward the umbilicus.

Hypotype No. U.W. 44,054 and 44,055.

The specimens from Biscayne Bay differ from that described by d'Orbigny. D'Orbigny figured specimens with chambers pointed toward the initial end. This characteristic is not evidenced in any of the Florida specimens.

Galloway (1933, p. 34), Cushman (1950, p. 6), Glaesner (1948, p. 59) and others stated that the megalospheric form is by far the most abundant of the dimorphic forms of the Foraminifera and also the smaller in total size of the two forms; conversely, the microspheric form is the rarer and larger of the two forms.

Cushman (1937, p. 10) states in reference to V. oviedoiana:

> "Test roughly triangular, in microspheric form short and broad, chambers triserial throughout, in the megalospheric form with the later chambers in the adult whorl more than three, test roughly conical."

He further states that the triangular form figured by d'Orbigny is the microspheric form while the

> "more elongate and much narrower specimens . . . with more than three chambers making up the last-formed whorl"

is the microspheric form.

The triangular form is by far the more common of the two in Biscayne Bay, whereas the conical form with more than three chambers per whorl is of equal size to the triangular form. It appears that possibly they are two distinct species or that the dimorphic rule relating to relative size and number of the two expressions of a single species is in error for this particular species. It is also characteristic of the microspheric form to show in the neanic stage some indication of the forms taken by the megalospheric form. Instead, the conical form discussed by Cushman as being the megalospheric form shows, in some specimens, evidence of a triangular form in the neanic stage.

This species is the ninth most common in Biscayne Bay. It is well represented in all areas except that in the very northern shore zones (see fig. 43). It is particularly abundant in the west central coastal area as well as in that area wherein is found Featherbed Bank. It is apparently, therefore, well adapted to the rigorous environment wherein temperature and salinity varies over a considerable range. The stations at which this species occurs are: 5, 11, 12, 14-18, 21-28, 31, 34, 36-50, 52, 54-59, 61, and 62.

Subfamily VERNEUILININAE Cushman, 1911

Genus CLAVULINA d'Orbigny, 1826

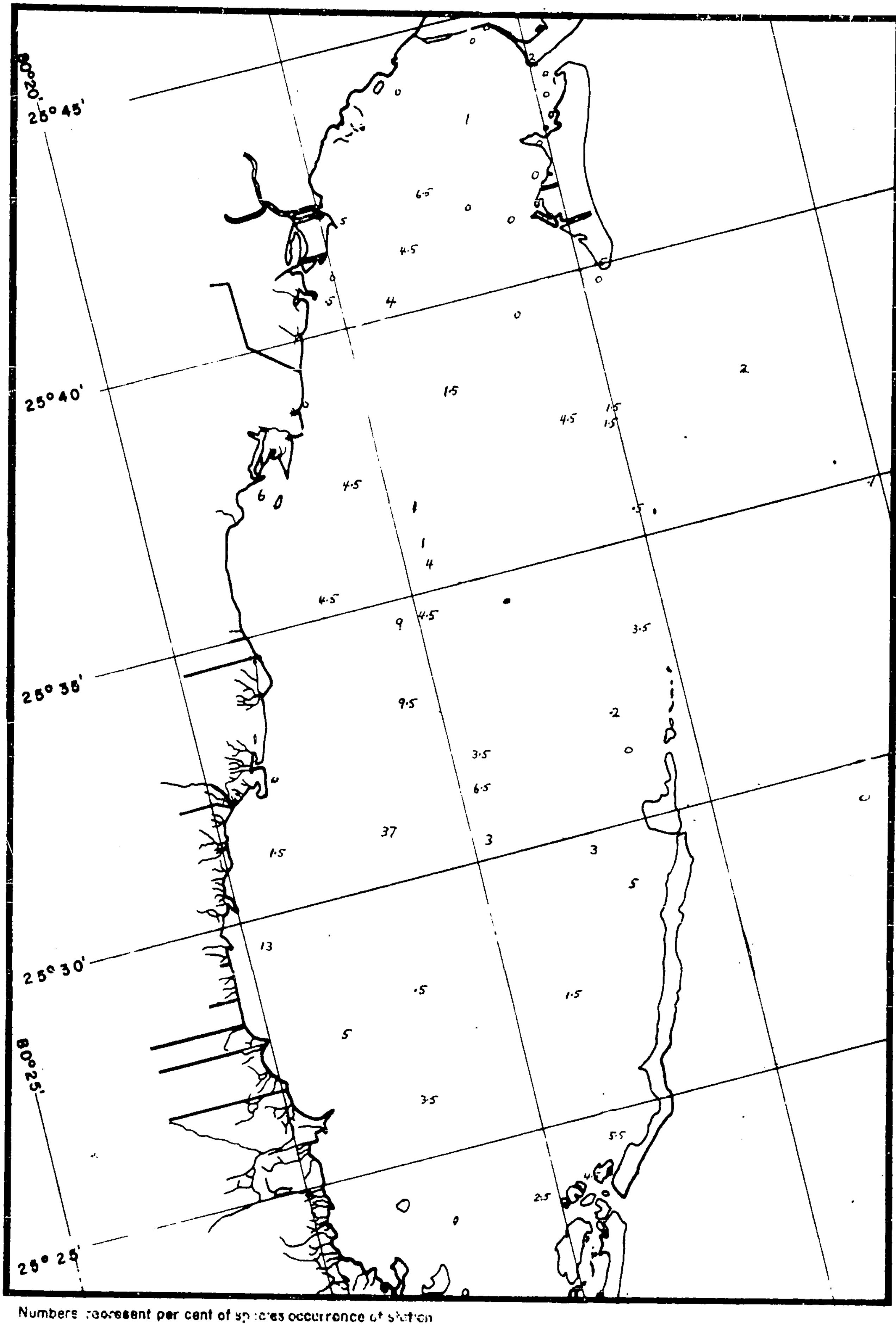
CLAVULINA NODOSARIA d'Orbigny, 1839

Plate V, Figure 9

Clavulina nodosaria d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 110, pl. 2, figs. 19, 20.

Test trihedral in early stages making up one-fourth of the length of the test, cylindrical, rectilinear in adult portion; sutures pronounced in cylindrical section of test, ill-defined in trihedral section; aperture round, tooth consisting of a narrow projection.

Hypotype No. U.W. 44,056.



Numbers represent per cent of species occurrence of station

Fig. 43 DISTRIBUTION OF VALVULINA OVIEDOIANA

This species is present at stations 22, 34, 38, 43, 58, and 60. The form is adapted to the less saline waters found near the western shore zone.

CLAVULINA TRICARINATA d'Orbigny, 1839

Plate V, Figure 8

Clavulina tricarinata d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 111, pl. 2, figs. 16-18.

Test elongate, tapering toward abapertural end; early triserial stage trihedral, making up less than one-fourth the length of test; uniserial stage triangular in section, making up more than three-fourths the length of test; triserial stage changing abruptly to uniserial stage; sutures distinct in uniserial section, convex upward; chamber with lateral prolongations at angled edge, pointing abaperturally; surface of test smooth; aperture round, with narrow, curved tooth.

Hypotype No. U.W. 44,057.

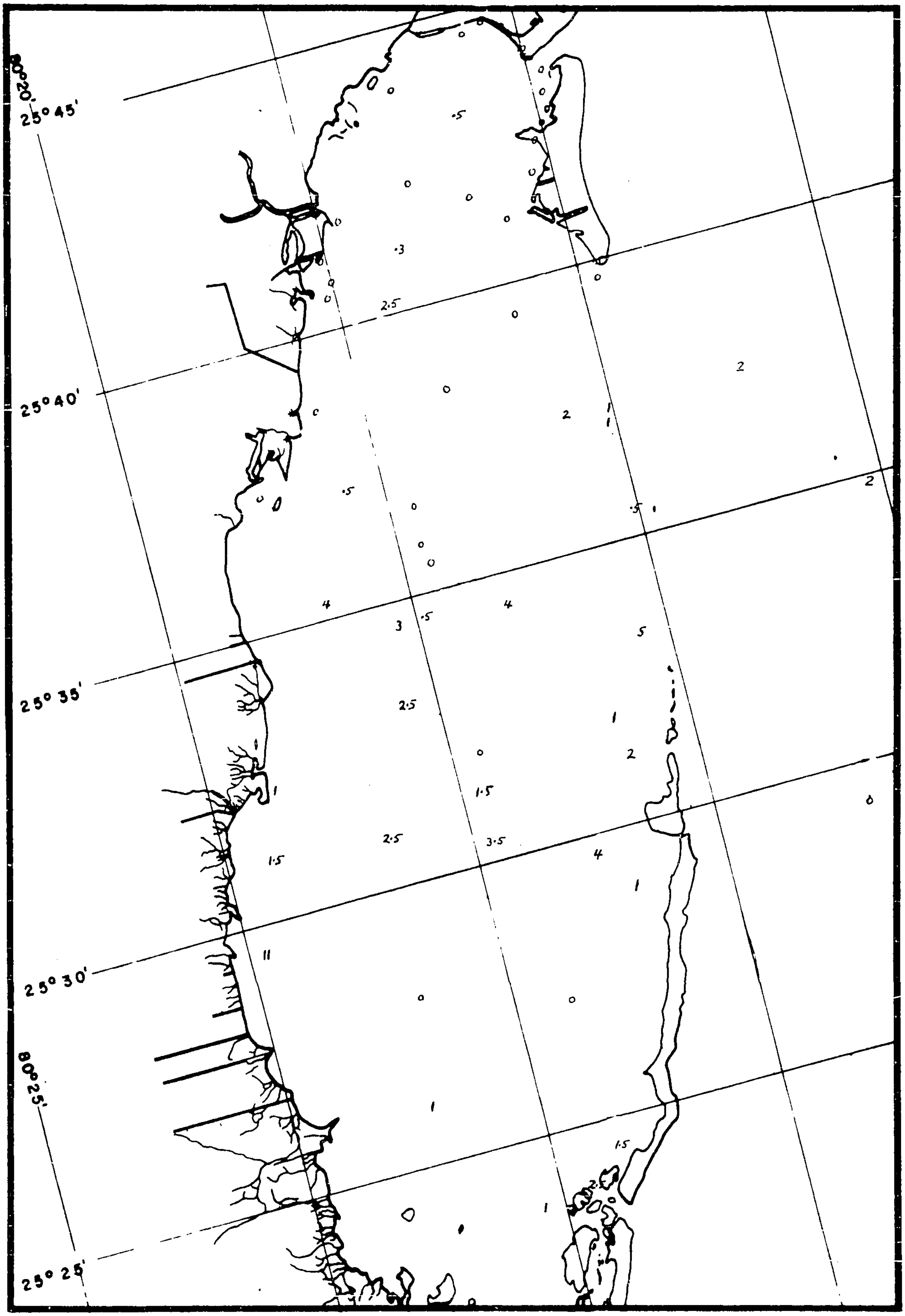
Many species belonging to the genus Clavulina appear to be either closely related forms or the same. Clavulina parisiensis multicamerata Chapman, 1907, was not described as having a tooth. Chapman states (1907, p. 127) that it is very similar to C. parisiensis d'Orbigny, 1826. The figure given by d'Orbigny for this latter species does not show the presence of a valve, however, Parker, Jones, and Brady (1865, p. 29) in referring to d'Orbigny's figure of C. parisiensis state that the model appears to have been taken from a specimen which has accidently lost its valve. This indicates that C. parisiensis is thought by others to have a valve. It is probable that Chapman knew this and that his species should also, therefore, have a valve.

D'Orbigny's C. parisiensis was from the environs of Paris and thus probably of Eocene age. Terquem (1882, p. 121, pl. XII, figs. 34a, b) indicated an orbicular tooth for C. parisiensis. Terquem's material was from the Eocene, Environs of Paris, the same environment as that of d'Orbigny's material. Undoubtedly, therefore, C. parisiensis should have an orbicular tooth as would Chapman's C. parisiensis multicamerata. Terquem also showed the chambers to be round rather than angular as in d'Orbigny's Model.

Many specimens from Biscayne Bay have an orbicular tooth similar to that shown by Terquem as C. parisiensis. Biscayne Bay has specimens which look like C. tricarinata, C. parisiensis, C. multicamerata, C. pacifica, as well as all stages inbetween these species. It is questioned, therefore, as to whether all these are valid species or whether they are, rather, specimens which show variations produced by some physical factor which is an adaptive rather than an hereditary characteristic.

This species is particularly characteristic of the Featherbed Bank area as well as the southwestern coastal section of the bay and the Safety Valve region (see fig. 44). The species is particularly common at station 58. It also occurs at stations 5, 12, 14, 17, 18, 20-25, 27, 28, 31, 34, 36, 38, 42, 43, 46-54, and 59-63. This species is particularly abundant in that area where the water is shallow and there is an influx of fresh water.

Family TEXTULARIIDAE d'Orbigny, 1846
Subfamily TEXTULARIINAE Schultze, 1854
Genus TEXTULARIA Defrance, 1824
TEXTULARIA AGGLUTINANS d'Orbigny, 1839
Plate VI, Figure 1



Numbers represent per cent of species occurrence of station

Fig. 44 DISTRIBUTION OF CLAVULINA TRICARINATA

<u>Textularia</u> <u>agglutinans</u> d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 144, pl. 1, figs. 17, 18, 32, 34.

Test tapering slightly toward initial end; chambers convex, arranged biserially; aperture a curved slit at the base of the last chamber.

Hypotype No. U.W. 44,058.

This very rare species occurs in the environments affected by the influx of tidal flow. It is found at stations 5, 6, 8, 9, 18, 20, 31, 32, 48, and 50.

Genus BIGENERINA d'Orbigny, 1826
BIGENERINA IRREGULARIS Phleger and Parker, 1951
Plate VI, Figure 2

<u>Bigenerina</u> <u>irregularis</u> Phleger and Parker, 1951, Geol. Soc. Amer., Mem. 46, p. 4, pl. 1, figs. 16-21.

Test elongate, tapering toward initial end, biserial in neanic stage, uniserial in ephebic stage; periphery round in uniserial section, angled in biserial section which is compressed and set at an angle to uniserial section; about four pairs of chambers per biserial section making up a very small portion of the entire test; biserial chambers strongly compressed, uniserial chambers strongly inflated, increasing gradually in size in a straight or curved line; sutures indistinct in biserial section, distinct, depressed, at right angles to the direction of growth in the uniserial section; wall arenaceous, coarse, tan; aperture terminal, round, at the end of a slight protrusion of the last chamber.

Hypotype No. U.W. 44,059.

Specimens from Biscayne Bay attain a length of 2.0mm. Some specimens have a much as a 0.6mm diameter but do not have as many chambers as those with half this diameter. This may represent the variation between the megalospheric and microspheric forms.

This rare species is found at stations 6, 18, and 20. It is characteristic of the open-sea waters where it is comparatively common.

Family POLYMORPHINIDAE d'Orbigny, 1846
Subfamily POLYMORPHININAE Brady, 1881
Genus GUTTULINA d'Orbigny, 1826
GUTTULINA AUSTRALIS (d'Orbigny, 1839)
Plate VI, Figure 3

Globulina australis d'Orbigny, 1839, Voy. Amer. Merid., vol. 5, Foraminiferes, p. 60, pl. 1, figs. 1-4.

Test irregular-fusiform, slightly compressed, both ends round, lobulate in section; chambers elongate, inflated, three per whorl, three whorls; sutures distinct and broadly depressed in ephebic stage, indistinct and not depressed in neanic stage; wall ornamented with numerous longitudinal striae which are continuous from one chamber to the next; aperture terminal, radial.

Hypotype No. U.W. 44,060.

This species inhabits that environment inside the bay wherein the tidal flow has its greatest effect. It is found in the very northern portion of the bay at stations 5, 6, 7, and 8 and also at station 20.

Genus GLOBULINA d'Orbigny, 1826

GLOBULINA CARIBEA d'Orbigny, 1839

Plate VI, Figure 4

Globulina caribea d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, pp. 135, 136, pl. 2, figs. 7, 8.

Test globullar, slightly laterally compressed, bluntly rounded at abapertural end, tapering and extended at apertural end; periphery broadly rounded; sutures not distinct; wall roughened by hirsute-like projections; chambers inflated, elongate, opposed; aperture radiate, small, very inconspicuous.

Hypotype No. U.W. 44,061.

This species as originally described and figured by d'Orbigny shows the test to be covered with projections at only the lower section of the test. Cushman (1930, p. 75) states that d'Orbigny's original specimen is lost and that material from Cuba shows the ornamentation covering the entire surface. D'Orbigny also states in his description and shows in his figure a spherical last chamber with a round aperture. Cushman's figure shows a radiate aperture. It may be possible that d'Orbigny's specimen was a broken one. If d'Orbigny was incorrect, and there is no reason to assume he was incorrect, Cushman's material is entirely different and should be classed as a separate species. However, no other specimens have been found in dredgings from Cuba to substantiate d'Orbigny's findings. Temporarily, for this work, Cushman's view will be accepted, but with reservation.

This species is limited to an environment which is moderate and comparatively nonvariable. It is present at stations 18 and 20.

GLOBULINA cf. G. GIBBA d'Orbigny, 1826
Plate VI, Figure 5

Globulina gibba d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 266, Modele No. 63.

Test subglobose; chambers inflated, three elongate chambers visible in front view, the ultimate and penultimate chambers forming an acute abgle, whereas the prepenultimate chamber is lower-centrally located appearing almost triangular; sutures distinct, flush; wall translucent, smooth; aperture terminal, radial.

Hypotype No. U.W. 44,062.

The two specimens found show signs of wear. The specimens most closely resemble d'Orbigny's Globulina gibba. Cushman (1923, p. 150) states that typical material is not found in the western Atlantic. Norton (1930) does not mention the occurrence of this species, nor does d'Orbigny in his Cuba Monograph. It is possible that this species is not found in the western Atlantic but, as stated by Cushman, the original specimen is lost, until more specimens from our area are found it would not be possible to run a comparative study with the "typical" form.

This species is present at stations 5 and 20. It is probably an open-sea form which may have been washed into the channel of the bay.

Family NONIONIDAE Reuss, 1860
Subfamily NONIONINAE Schultze, 1854
Genus NONIONELLA Cushman, 1926
NONIONELLA ATLANTICA Cushman, 1947
Plate VI, Figure 6

Nonionella atlantica Cushman, 1947, Cushman Lab. Foram. Res., vol. 23, pp. 90, 91, pl. 20, figs. 4, 5.

Test compressed, subovate; 10-12 chambers per last whorl, arcuate, inflated; periphery rounded; sutures distinct, not strongly depressed; wall lightly perforate; aperture extending from ventral to dorsal side, at the base of the last septal face.

Hypotype No. U.W. 44,063.

The specimens from Biscayne Bay differ from the species as described by Cushman in not having a papillate wall on the ventral lobe.

The species is found at stations 3, 5, 6, 9, 10, 20, 22, 31, 33, 47, 50, and 52. All of these stations are located in an environment affected by the tidal flow except for station 20 in the open-sea waters.

Subfamily ELPHIDIINAE Galloway, 1933
Genus ELPHIDIUM Montfort, 1808
ELPHIDIUM CRISPUM (Linnaeus, 1758)
Plate VI, Figure 7

Nautilus crispus Linnaeus, 1758, Systema Naturae, Ed. 10, p. 709.

Test ovate in peripheral view, circular in lateral view; chambers arcuate, gradually increasing in size; sutures strongly limbate with retral processes; periphery with rounded keel; biumbonate; last septal face clear and flat in the direction of its axis but convex in the direction of the diameter of the test; cribrate aperture apparent in all other than the last septal face.

Hypotype No. U.W. 44,064.

This species is confined to the central and eastern portion of the bay. It is evidently, therefore, not adapted to the influx of fresh-water from the mianland nor the depths and open-sea water in the Florida Current region. This foraminifer may live in association with some of the shallow-water plant life found within the bay. It is found at stations 1-3, 5-14, 21, 23, 26-28, 31, 32, 34, 36, 39, 40, 43, 46-50, 52, 54-56, and 62.

ELPHIDIUM POEYANUM (d'Orbigny, 1839)
Plate VI, Figure 8

Polystomella poeyana d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 55, pl. 6, figs. 25, 26.

Test ovate, wedge-shape in peripheral view; chambers increasing rapidly in size, embracing to umbilicus; sutures slightly depressed, with retral processes not extending past sutures; umbilicus slightly depressed, covered, at least in part, by extension of chambers; aperture at base of last septal face, the center of apertural face with clear area and large pores surrounded by an area with numerous, very fine pores which continue on sides of chamber wall.

Hypotype No. U.W. 44,065.

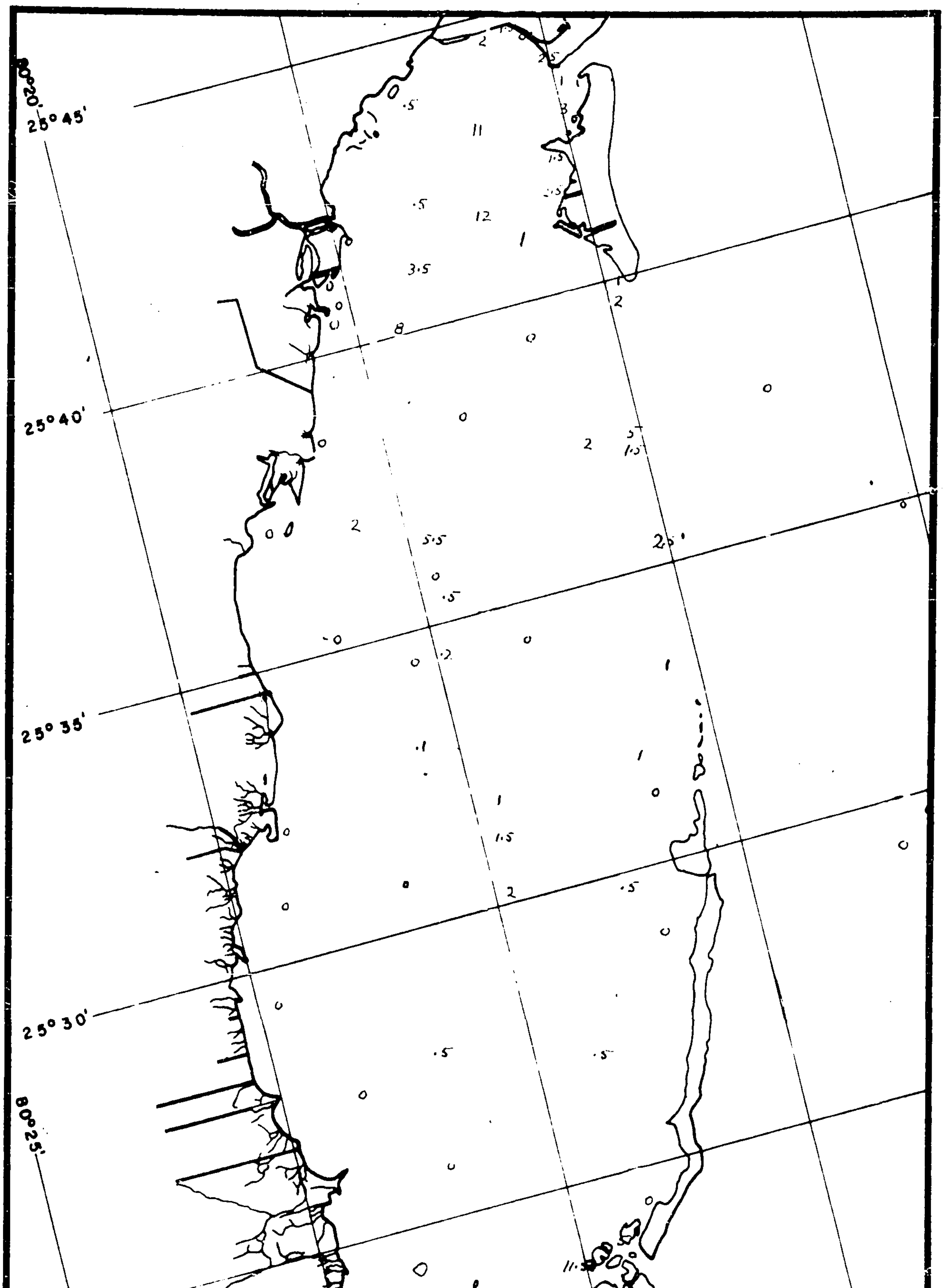


Fig. 45 DISTRIBUTION OF ELPHIDIUM CRISPUM

This species is the third most abundant in Biscayne Bay. It is well distributed throughout the entire bay and is also found in the Florida Current area. It is a fauna well adapted to a great range of environmental conditions. It is found at stations 1-16, 18, 20-28, 31-56, 58-61, and 63.

ELPHIDIUM SAGRUM (d'Orbigny, 1839)
Plate VI, Figure 9

Polystomella sagrum d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 55, pl. 6, figs. 19, 20.

Test subcircular, slightly compressed, tapering toward the periphery from the umbilical area; periphery bluntly angled; 13-14 chambers per last whorl, extending to umbilical area where they overlap previous chambers; sutures arcuate, with about eight very pronounced retral processes which are very large; last septal face flat in direction of the axis of test, convex in the direction of the radius; wall smooth, translucent; aperture a series of pores at the base of the last septal face with auxiliary pores dispersed over the last septal face.

Hypotype No. U.W. 44,066.

The specimens from Biscayne Bay are very similar to those described by d'Orbigny from Cuba. D'Orbigny gave a diameter of 1/3mm for this species, those from Biscayne Bay reach as much as 0.7mm diameter. D'Orbigny described his species as having two rows of apertures forming the sides of a triangle; this is not evident in specimens from Biscayne Bay.

This rare species is primarily found in the north-shore area, Safety Valve region, as well as in the vicinity of Feath-

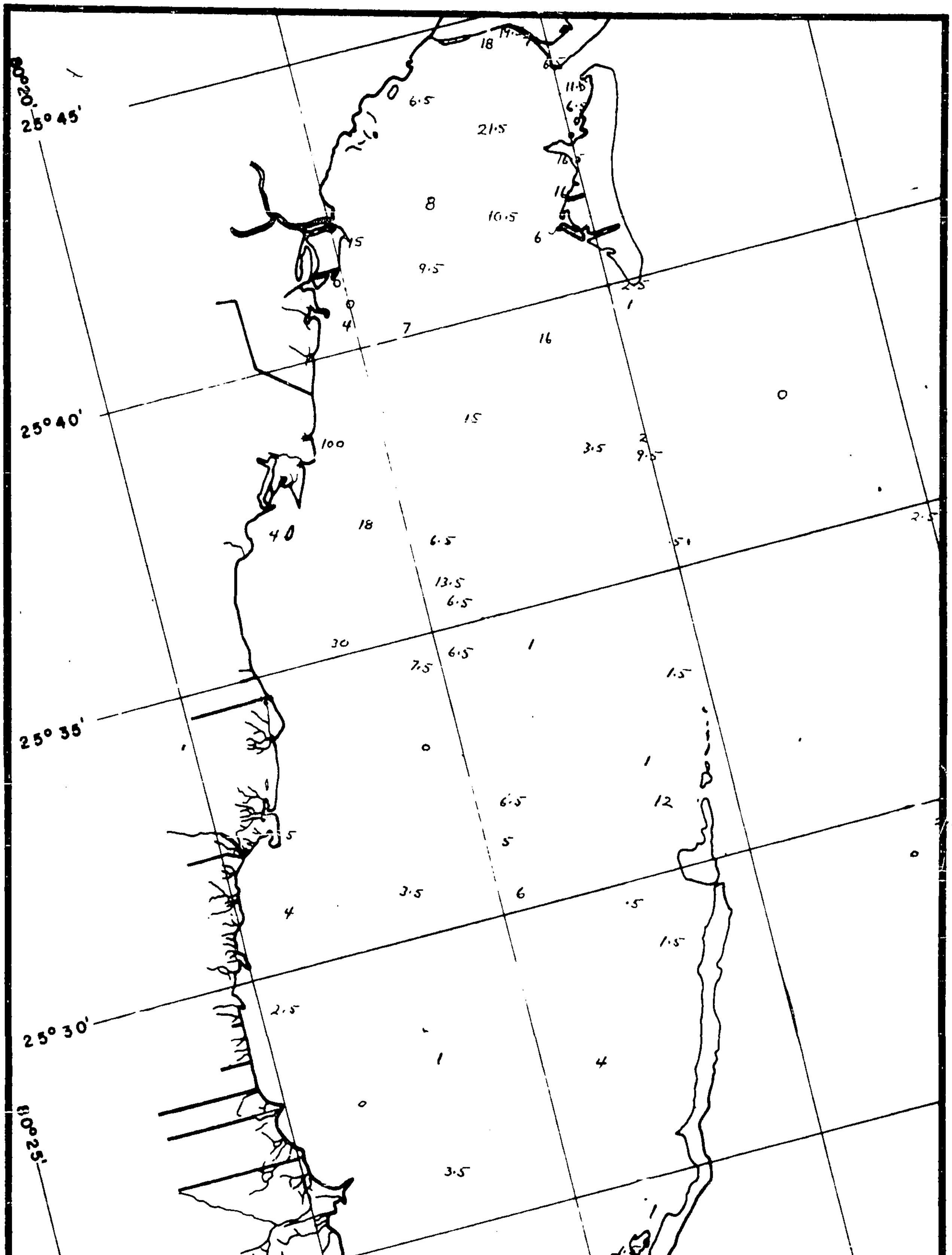


Fig. 46 DISTRIBUTION OF ELPHIDIUM POEYANUM

erbed Bank (see fig. 47). These are areas in which the current flow is comparatively rapid. The stations at which specimens were identified are: 1, 3, 5-9, 13, 20, 21, 23, 26-28, 31, 32, 42, 46-48, 50, 52, 54, 61, and 62.

Family ROTALIIDAE Reuss, 1860

Subfamily ROTALIINAE Schultze, 1854

Genus GLOBOROTALIA Cushman, 1927

GLOBOROTALIA MENARDII (d'Orbigny, 1826)

Plate VI, Figure 10

Rotalia menardii d'Orbigny, 1826, Ann. Sci. Nat., vol. 7, p. 273, No. 26; Modele No. 10.

Test subovate, compressed, biconvex, more convex ventrally than dorsally; periphery with rounded keel, lobulate; chambers increasing rapidly in size, 5-7 per last whorl; dorsal sutures arcuate, limbate, ventral sutures radial, depressed; ventrally umbilicate; wall transparent, smooth, conspicuously perforate; aperture ventral, a slit at the base of the last septal face between the periphery and umbilicus, with a projecting valvular lip near the umbilical area.

Hypotype No. U.W. 44,067.

This species is present at stations 9 and 18. The specimen found at station 9 shows signs of wear and was probably washed into the bay. The species is characteristic of the open - sea water.

Genus ROTALIA Lamarck, 1804

ROTALIA ROSEA (d'Orbigny, 1839)

Plate VI, Figure 12

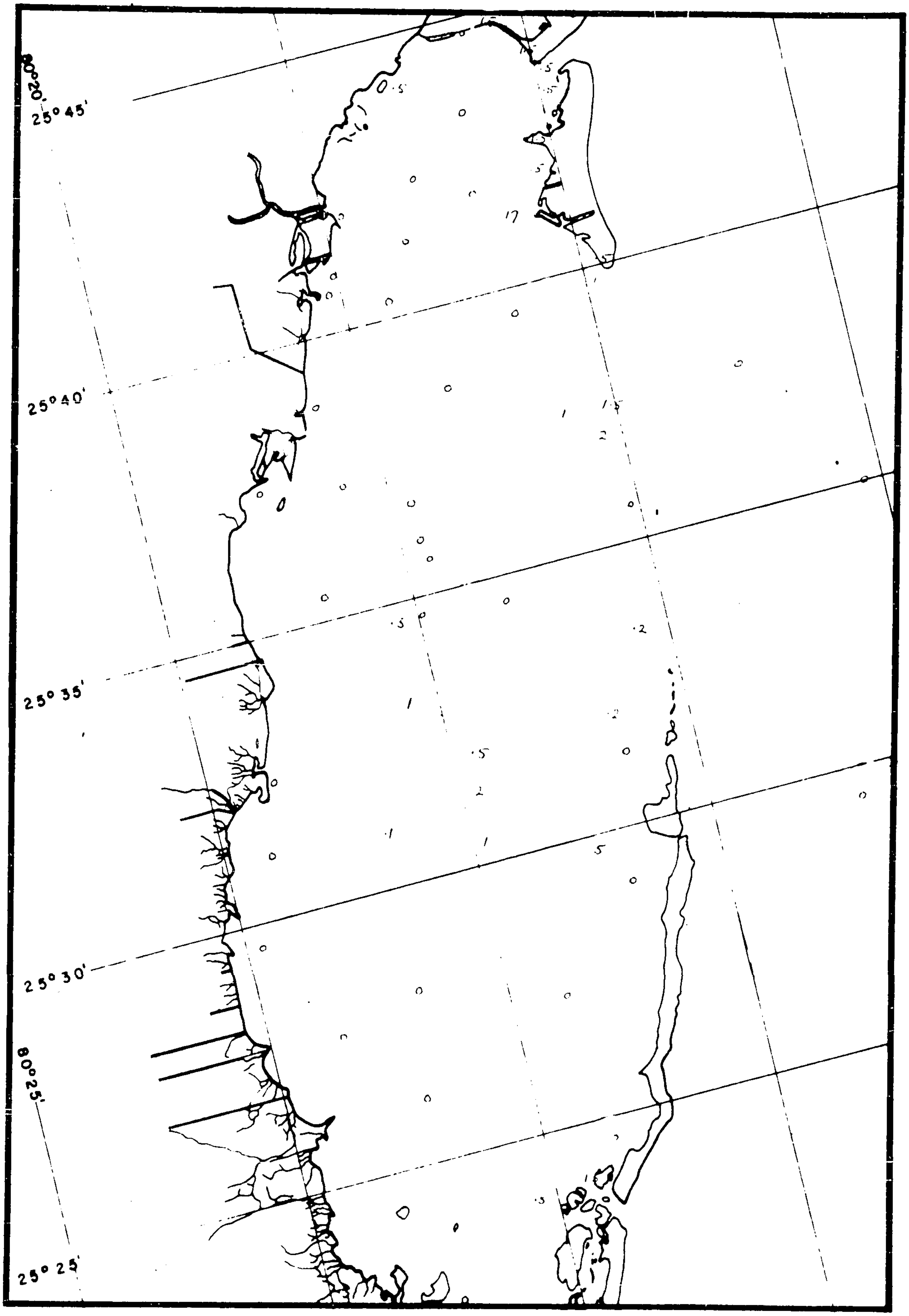


Fig. 47 DISTRIBUTION OF ELPHIDIUM SAGRUM

Rotalina rosea d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 72, pl. 3, figs. 9-11.

Test trochoid, biconvex, dorsal side strongly convex whereas ventral side is almost flat; eight chambers per last whorl; sutures strongly curved on dorsal side, smooth: ventral sutures radiate, not pronounced; ventral side with umbilical plug; color red; aperture ventral, at base of last septal face.

Hypotype No. U.W. 44,068.

This is primarily an open-water species and is also found in the very eastern portion of the bay in the area immediately affected by tidal flow (see fig. 48). This foraminifer cannot take the rigors of the bay environment. It is rare and found at stations 5-8, 18-20, 31, 32, 47, 48, and 62.

Genus STREBLUS Fischer, 1817

STREBLUS BECCARII (Linnaeus, 1758)

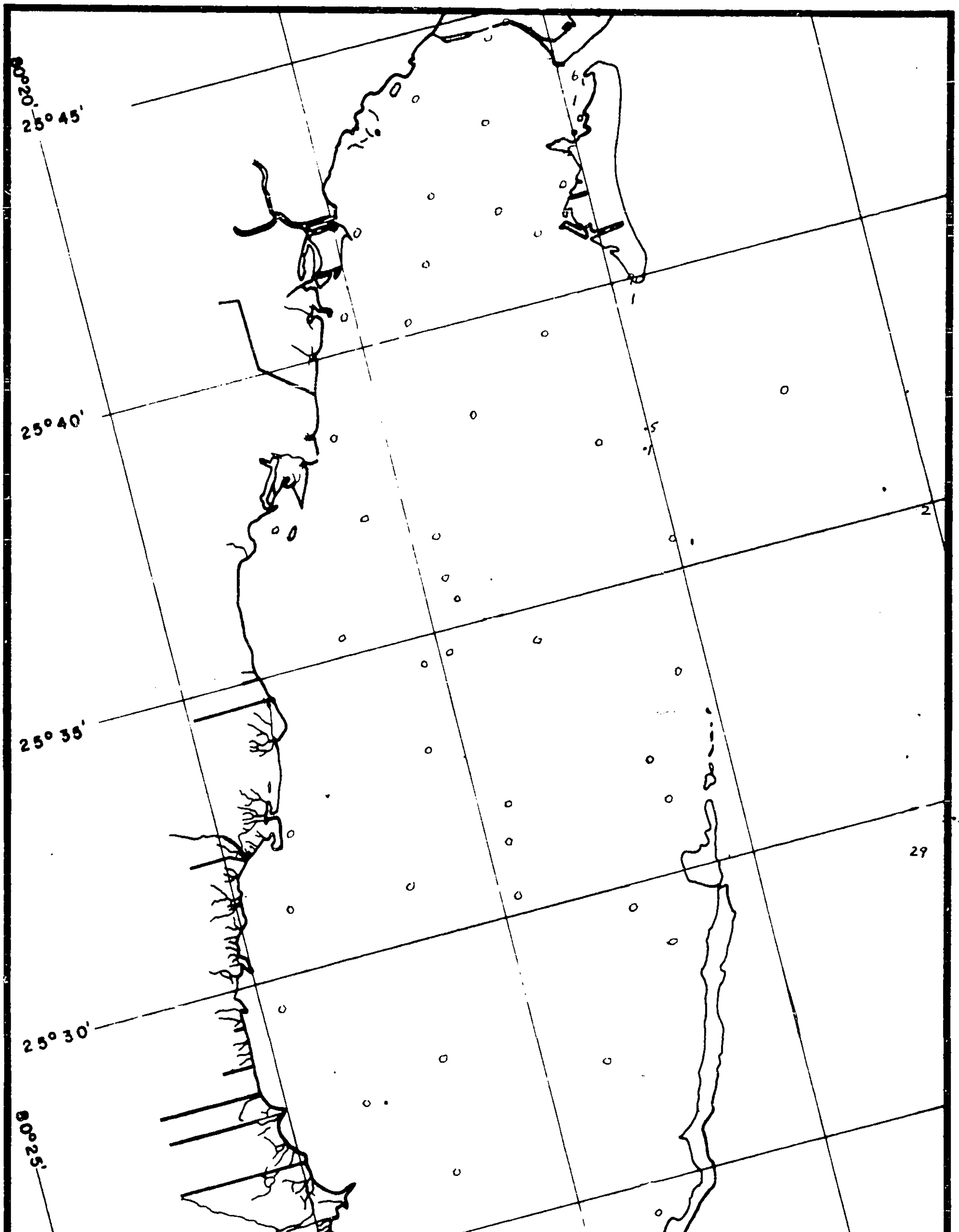
Plate VI, Figure 11

Nautilus beccarii Linnaeus, 1758, Systema Naturae, Ed. 10, p. 710, pl. 1, figs. 1a-c; pl. 19, figs. h, i.

Test trochoid, chambers gradually enlarging, biconvex, the dorsal side not as convex as the ventral; ten inflated chambers; dorsal side smooth, rarely with depressed sutures; ventral side with limbate sutures, umbilical plug and subsidiary exogenous material; aperture at the base of the last septal face, ventral.

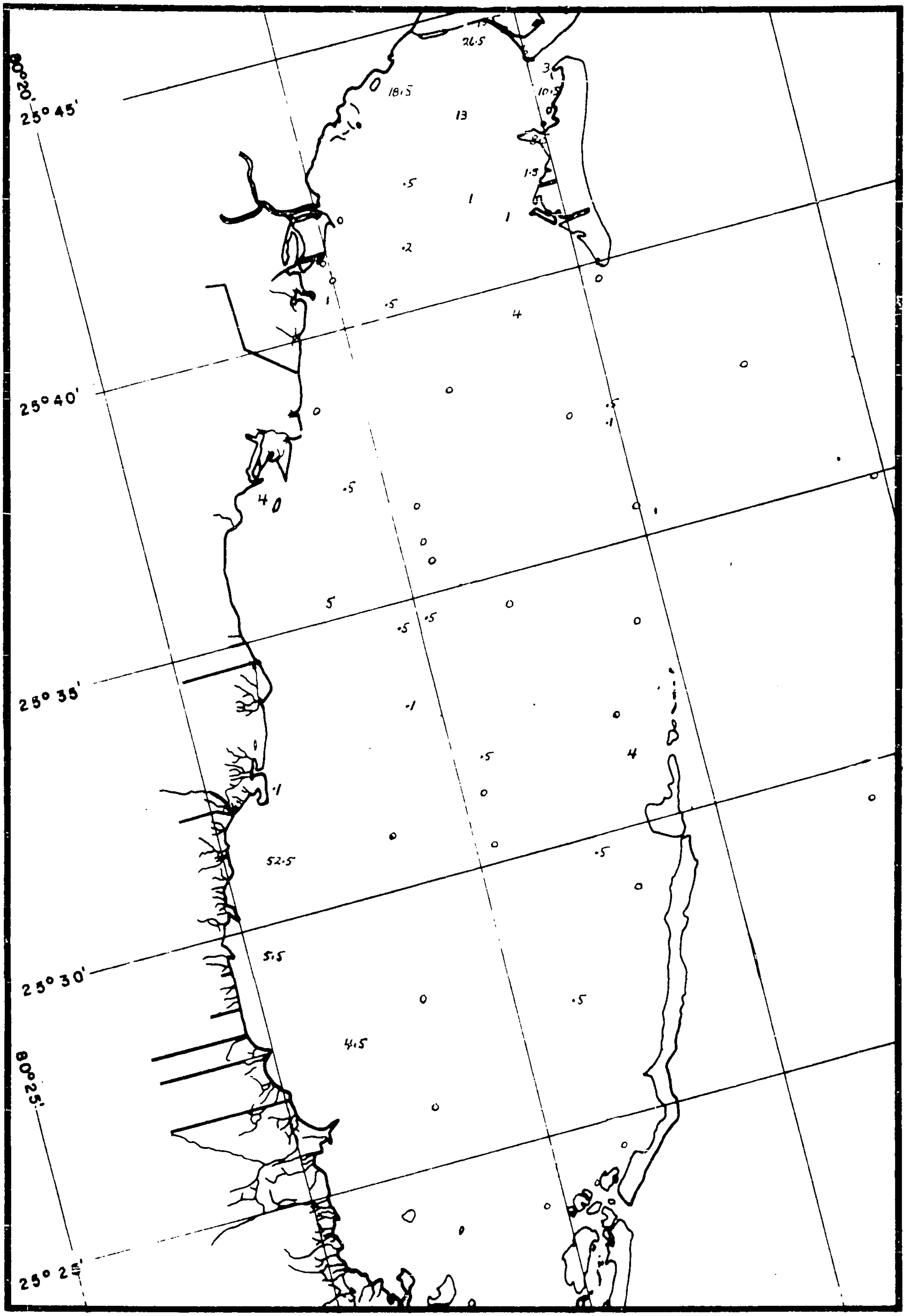
Hypotype No. U.W. 44,069.

This species is the twelfth most common in Biscayne Bay.



Numbers represent per cent of species occurrence of station

Fig. 48 DISTRIBUTION OF ROTALIA ROSEA



Numbers represent per cent of species occurrence of station

Fig. 49 DISTRIBUTION OF STREBLUS BECCARII

It normally characterizes those areas directly affected by the dilution of fresh water and weak currents. The distribution of this species is primarily limited to the near-shore areas (see fig. 49), and is found at stations 1-3, 5-14, 28, 31, 33, 34, 36-38, 42, 43, 47, 48, 53-55, and 57-62.

Genus GALLOWAYUS gen. nov.

Test trochoid, biconvex, periphery generally angled or keeled but may be somewhat rounded; wall calcareous, perforate, hyaline; chambers extend to the umbilical area, if umbilicus present it is very small, generally umbilicus filled with exogenous material or closed by coalescence of the chambers; sutures distinct, often limbate; aperture a slit at the base of the last septal face, ventral, between the periphery and the umbilical area.

This genus is erected for those species previously referred to as Eponides by most authors. The genus Eponides, as originally erected by Montfort (1808, p. 127), has for its genotype Nautilus repandus Fichtel and Moll, 1798. Montfort definitely indicates he had in mind a planispiral rather than a trochoid form. The species as figured by Fichtel and Moll (1798, pl. 3, figs. a-d) is unquestionably a planispiral form. Eponides cannot, therefore, be used as a generic name for those forms which are trochoid but must be reserved for a planispiral form (see Redmond, 1949). I find it necessary, therefore, to place all those forms generally referred to as Eponides, except the typical Nautilus repandus of Fichtel and Moll, 1798, and similar looking specimens, under the new genus Gallowayus, the genotype, by designation, Rotalina antillarum d'Orbigny, 1839.

The genus Gallowayus may be confused with the genus Poroeponides Cushman, 1944, but distinctly differs from this latter genus in having a filled or essentially closed umbilicus rather than an open umbilicus. The genus Gallowayus is named in honor of Dr. J. J. Galloway, Professor Emeritus of Geology, Indiana University.

GALLOWAYUS aff. G. ANTILLARUS (d'Orbigny, 1839)
Plate VII, Figure 1

Rotalina antillarum d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 75, pl. 5, figs. 4-6.

Test subcircular, biconvex; periphery acutely angled, slightly carinate; chambers increasing gradually in size, 3-4 whorls, the last whorl composed of 6-7 chambers strongly arcuate dorsally, triangular ventrally, last chamber with lobed extension near the periphery on the ventral side; sutures oblique dorsally, smooth, limbate, ventral sutures radiate and smooth; umbilicus slightly depressed or closed by the coalescence of the chambers, wall conspicuously perforate; aperture a slit at the base of the last septal face, ventral, between the umbilical area and the periphery, with a lip at the umbilical end.

Hypotype No. U.W. 44,070.

The specimens from Biscayne Bay most closely resemble this species which is in turn difficult to differentiate from the figures and description of Eponides parantillarum Galloway and Heminway, 1941. Type material will have to be studied in order to check similarities and differences.

This very rare species is present at only stations 18, 20, and 47. It is primarily an open-sea form.

GALLOWAYUS REDMONDI sp. nov.
Plate VII, Figure 2

sp. nov., Eponides repandus of authors (non Fichtel and Moll).

Test biconvex, broadly convex dorsally, strongly inflated to conical ventrally, subcircular in dorsal view; periphery slightly lobulate; 6-7 chambers per last whorl, about 3-4 whorls, chambers increasing gradually in size, closely appressed, last chamber with a lobed extension near the periphery on the ventral side; sutures smooth or limbate dorsally, strongly arcuate, depressed to limbate ventrally, slightly curved to radiate; wall finely perforate, last septal face may have large pores but this latter not a constant characteristic; umbilicus a very slight depression or covered by the coalescence of the chambers; aperture a crescent at the base of the last septal face, ventral, between the periphery and umbilicus.

Holotype: by designation, Pulvinulina repanda Brady, 1884, Rep. Voy. Challenger, Zool., vol. 9, p. 684, pl. 104, figs. 18a-c. Catalogue No. 85.10.5.557 British Museum.

Hypotype No. U.W. 44,071.

Derivation of name: the species is named in honor of Charles David Redmon, presently with Aramco in Saudi Arabia.

This very rare species is characteristic of the open-sea waters. It is present at stations 18 and 20.

Genus CANCRIS Montfort, 1808

CANCRIS SAGRA (d'Orbigny, 1839)

Plate VII, Figure 3

Rotalina sagra d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 77, pl. 11, figs. 13-15.

Test subovate, trochoid, biconvex, the ventral side more convex than that of the dorsal; periphery sharply carinate; one and one-half whorls; chambers increasing rapidly in size, arcuate, both dorsally and ventrally; dorsal sutures distinct, conspicuously depressed; wall completely perforate except for a small area of the ventral wall of the last septal face as well as areas of the previous chambers near the umbilicus; umbilicus depressed; aperture a curved slit at the base of the last septal face extending from the periphery to the umbilicus with a lobed lip extending over the umbilical area.

Hypotype No. U.W. 44,072.

This very rare species is present at stations 31 and 47. Its habitat is limited to that area in the vicinity of the Safety Valve where there is a ready change of intertidal waters.

Subfamily DISCORBINAE Cushman, 1927

Genus DISCORBIS Lamarck, 1804

DISCORBIS CANDEIANA (d'Orbigny, 1839)

Plate VII, Figure 4

Rosalina candeiana d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 97, pl. 4, figs. 2, 4.

Test trochoid, biconvex, concave near umbilicus; last whorl composed of five chambers increasing rapidly in size; periphery well rounded, lobulate; wall coarsely perforate; sutures depressed; aperture ventral, a slit at the base of the last septal face.

Hypotype No. U.W. 44,073.

This very rare species is present at stations 18, 20, and 47. It is characteristic of the open-sea waters.

DISCORBIS MIRA Cushman, 1922

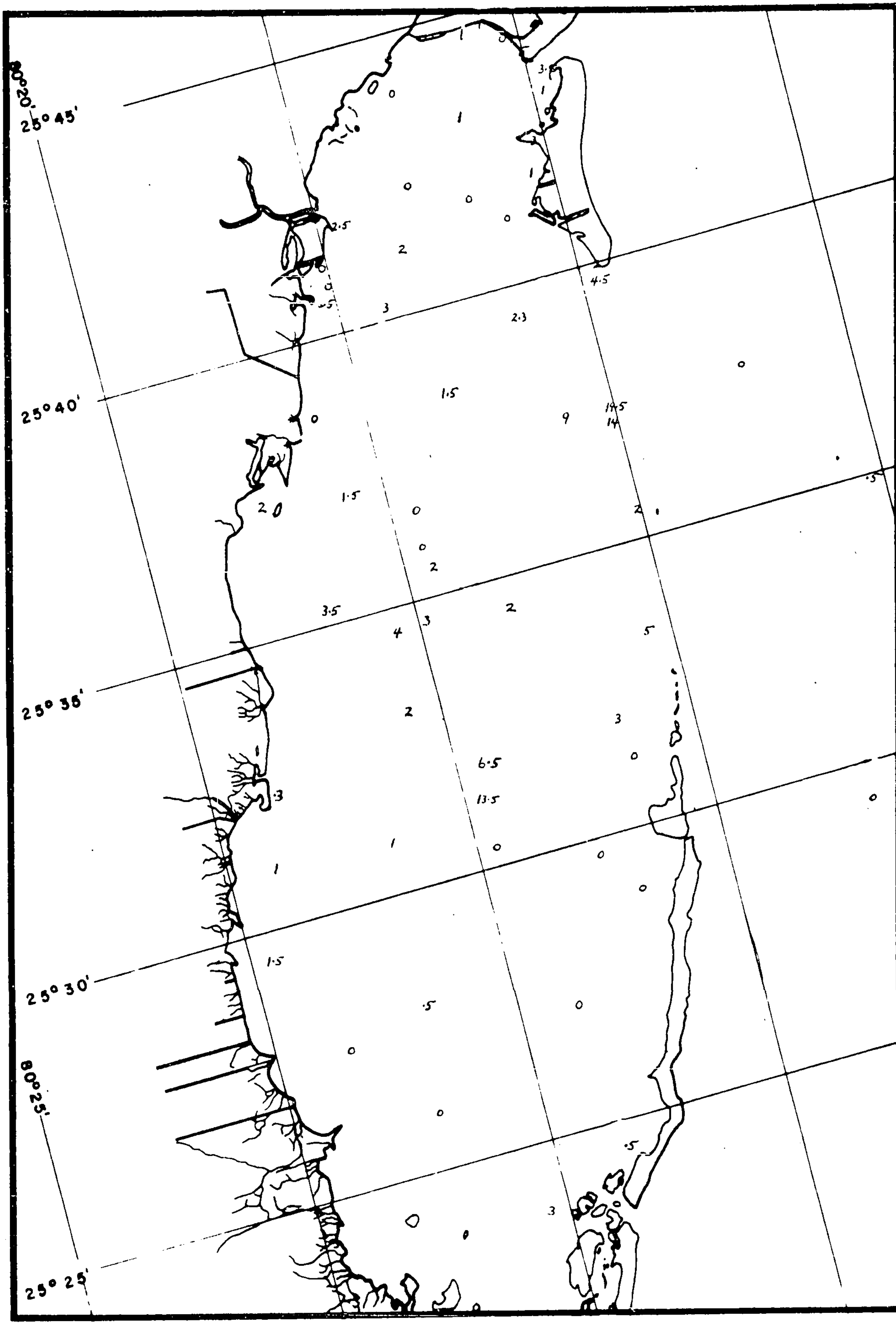
Plate VII, Figure 5

Discorbis mira Cushman, 1922, Carnegie Inst. Washington Publ. No. 311, p. 39, pl. 6, figs. 10, 11.

Test plano-convex, trochoid, the last whorl consisting of 5-6 chambers, dorsal side conical, ventral side slightly convex; periphery slightly lobulate, with rounded carina; sutures hardly depressed on dorsal side, strongly arcuate, ventral sutures radial, pronounced, chambers extending to umbilicus; umbilical area often filled with alar prolongations; wall coarsely perforate; aperture an arched slit at the base of the last septal face, ventral, extending to the umbilical area.

Hypotype No. U.W. 44,074.

This is the fourteenth most common species in Biscayne Bay. It is fairly well distributed throughout the bay (see fig. 50) but is particularly common to the Safety Valve region. It appears to most readily adapt itself to that portion of the bay area in which the tides have their greatest and most immediate effect. The species is found at stations 2, 3, 5-9, 12, 14-16, 18, 20-23, 27, 28, 31-34, 36-39, 42-50, 52, 56, and 58-63.



Numbers represent per cent of species occurrence of station

Fig. 50 DISTRIBUTION OF DISCORBIS MIRA

DISCORBIS SUBARAUCANA Cushman, 1922

Plate VII, Figure 6

Discorbis subaraucana Cushman, 1922, Carnegie Inst. Washington Publ. No. 311, p. 41, pl. 7, figs. 1, 2.

Test subcircular, unequally biconvex, dorsal side more so than ventral; periphery rounded, lobulate; five chambers per last whorl, increasing rapidly in size; umbilicus open, without exogenous material; sutures not pronounced, dorsal sutures arcuate, ventral ones almost radiate; surface of test coarsely perforate; aperture at the base of the last septal face, ventral.

Hypotype No. U.W. 44,075.

This bay species appears to prefer the normal bay environment except in the immediate vicinity of the western shore. This species evidently cannot adapt itself to the low saline content of the shore waters (except for one small area just south of Black Point). This foraminifer is found at stations 3, 5, 6, 8, 11-15, 22, 23, 25-27, 33, 34, 38-40, 47, 48, 50, 52, 54-56, 58, and 59.

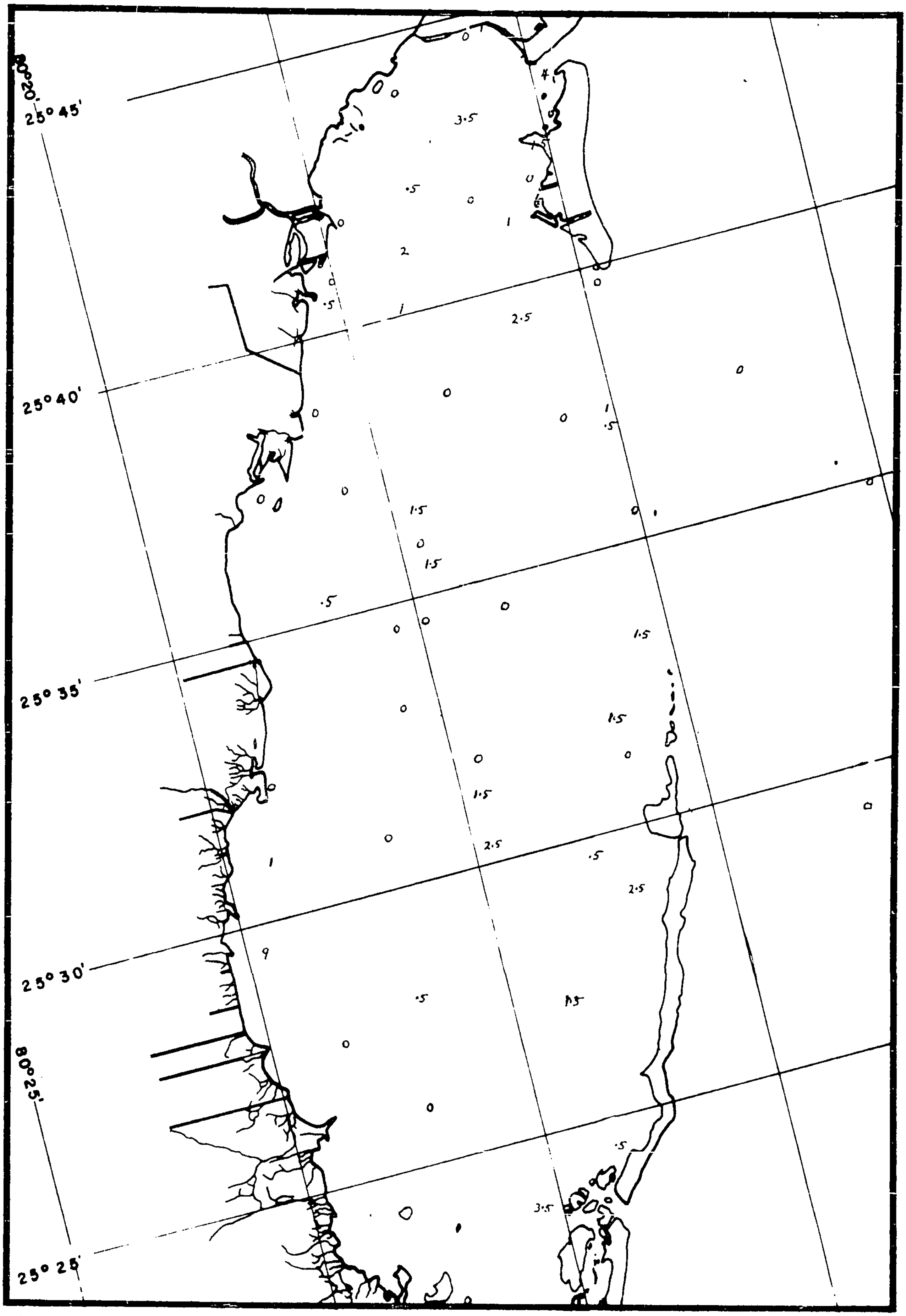
Genus CYMBALOPORETTA Cushman, 1928

CYMBALOPORETTA SQUAMMOSA (d'Orbigny, 1839)

Plate VII, Figure 7

Rosalina squammosa d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 91, pl. 3, figs. 12-14.

Test plano-convex, trochoid, dorsal side conical; five chambers in last whorl; periphery strongly lobulate, sharply angled; dorsal sutures curved, not pronounced, ventral sutures straight and pronounced; wall coarsely perforate dorsally,



Numbers represent per cent of species occurrence at station

Fig. 51 DISTRIBUTION OF DISCORBIS SUBARAUCANA smooth ventrally; ventral side with umbilicus with or without exogenous material; aperture at base of last septal face on ventral side.

Hypotype No. U.W. 44,076.

This rare species is found at stations 5, 6, 9, 12, 17, 18, 20, 23, 31, and 34. This form is not adapted to living in the bay environments but is more readily adapted to that found in the Florida Current region as well as to the channel entrances to the bay.

Genus TRETOMPHALUS Moebius, 1880
TRETOMPHALUS BULLOIDES (d'Orbigny, 1839)
Plate VII, Figure 8

Rosalina bulloides d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 98, pl. 3, figs. 2-5.

Test concavo-convex, trochoid; chambers increasing gradually in size; periphery well rounded; sutures distinct, wall coarsely perforate; aperture ventral, a slit at the base of the chambers, opening into the large ventral depression.

Hypotype No. U.W. 44,077.

This very rare species was found at stations 27, 58, and 60. It apparently represents the environment as found in the south portion of the bay. Though this form is known to be a pelagic foraminifer (see Cushman, 1931, p. 86) it has also been able to adapt itself in the neanic and prepelagic stage to the rigorous environment that exists in the southern bay.

Subfamily CIBICIDINAE Galloway, 1933

Genus CIBICIDES Montfort, 1808

CIBICIDES LOBATULUS (Walker and Jacob, 1798)

Plate VII, Figure 9

Nautilus lobatulus Walker and Jacob, 1798, Adams Essays, Kamacher's ed., p. 642, pl. 14, fig. 36.

Test trochoid, planoconvex to cancavoconvex; peripheral edge acute, slightly lobulate; 5-6 chambers per last whorl, increasing rapidly in size, strongly inflated ventrally, flat dorsally, with sharp shoulder; dorsal sutures limbate, flush, arcuate; ventral sutures depressed, radial; wall coarsely perforate; aperture a slit at the base of the last septal face, ventral, between the periphery and the umbilicus, with lip.

Hypotype No. U.W. 44,078.

This rare species is found at stations 5-8, 16, 17, and 47. This foraminifer occurs in that environment in which are found plants for its attachment.

CIBICIDES PSEUDOUNGERIANUS (Cushman, 1922)

Plate VII, Figure 10

Truncatulina pseudoungeriana Cushman, 1922, U.S. Geol. Surv., Prof. Pap. 129E, p. 97, pl. 20, fig. 9.

Test biconvex, circular, trocheid; chambers arcuate, increasing gradually in size, eleven in the last whorl; sutures pronounced; periphery sharply angled; aperture extending from the dorsal to the ventral side.

Hypotype Bo. U.W. 44,079.

This very rare species is found at stations 5, 6, 9, 17, 19, 31, and 47. It, like the aforementioned species, appears to live where there are plants for attachment.

Genus SIPHONINA Reuss, 1850
SIPHONINA PULCHRA Cushman, 1919
Plate VIII, Figure 1

Siphonina pulchra Cushman, 1919, Carnegie Inst. Washington Publ. No. 291, p. 42, pl. 14, fig. 7.

Test subcircular, trochoid, dorsal disc flat and curved, ventral side strongly inflated; periphery angled, slightly lobulate; chambers increasing gradually in size, five per last whorl; surface coarsely perforate; sutures not pronounced; aperture peripheral, with very short neck and everted peristome.

Hypotype No. U. W. 44,080.

This very rare species is found at stations 9, 18, and 20. It is probably adapted to the open-water environment and was only washed into the bay to be found at station 9.

Subfamily PLANORBULININAE Galloway, 1933
Genus PLANORBULINA d'Orbigny, 1826
PLANORBULINA ACERVALIS Brady, 1884
Plate VIII, Figure 2

Planorbulina acervalis Brady, 1884, Rep. Voy. Challenger, Zool., vol. 9, p. 657, pl. 92, fig. 4.

Test discoid; chambers coiled in neanic stage, becoming irregularly annular in ephebic stage; chambers flat on dorsal side, strongly convex on ventral side; wall of test coarsely perforate; sutures distinct; apertures at peripheral end of chambers, at end of short neck.

Hypotype No. U.W. 44,081.

This very rare species is present at stations 9-12, 18, 20, 31, 47, 48, 50, and 52. This foraminifer is adapted to an open-water environment and to that area in the bay in which plants are found.

Family ACERVULINIDAE Schultze, 1854
Subfamily RUPERTIINAE Galloway, 1933
Genus HOMOTREMA Hickson, 1911
HOMOTREMA RUBRA (Lamarck, 1816)
Plate VIII, Figure 3

Millepora rubra Lamarck, 1816, Hist. Nat. des Animaux sans Vert., Paris, vol. 2, p. 202.

Test attached, a honeycombed, irregular mass; chambers many sided, generally four or five, with thick septa separating each chamber from the next, the septa forming a network and raised above the chamber wall; septa thick, wall thin, perforate; color red to pink.

Hypotype No. U.W. 44,082.

This very rare species is present at stations 14 and 20. It inhabits that environment wherein it may attach itself, generally to a substratum.

Family ASTERIGERINIDAE d'Orbigny, 1839
Genus ASTERIGERINA d'Orbigny, 1839
ASTERIGERINA CARINATA d'Orbigny, 1839
Plate VIII, Figure 4

Asterigerina carinata d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 118, pl. 5, fig. 25; pl. 6, figs. 1, 2.

Test circular in ventral view, flat to slightly arched dorsally, cone-shaped ventrally; chambers trochoid, evolute on dorsal side, involute ventrally with eight chambers in the last whorl which alternate with seven "rosette" chambers; periphery slightly lobulate; wall smooth dorsally, papillate ventrally in immature specimens while mature specimens are only papillate ventrally in immature specimens while mature specimens are only papillate 120° from the last septal face on the earlier chambers of the last whorl; aperture ventral, a crescent at the base of the last septal face.

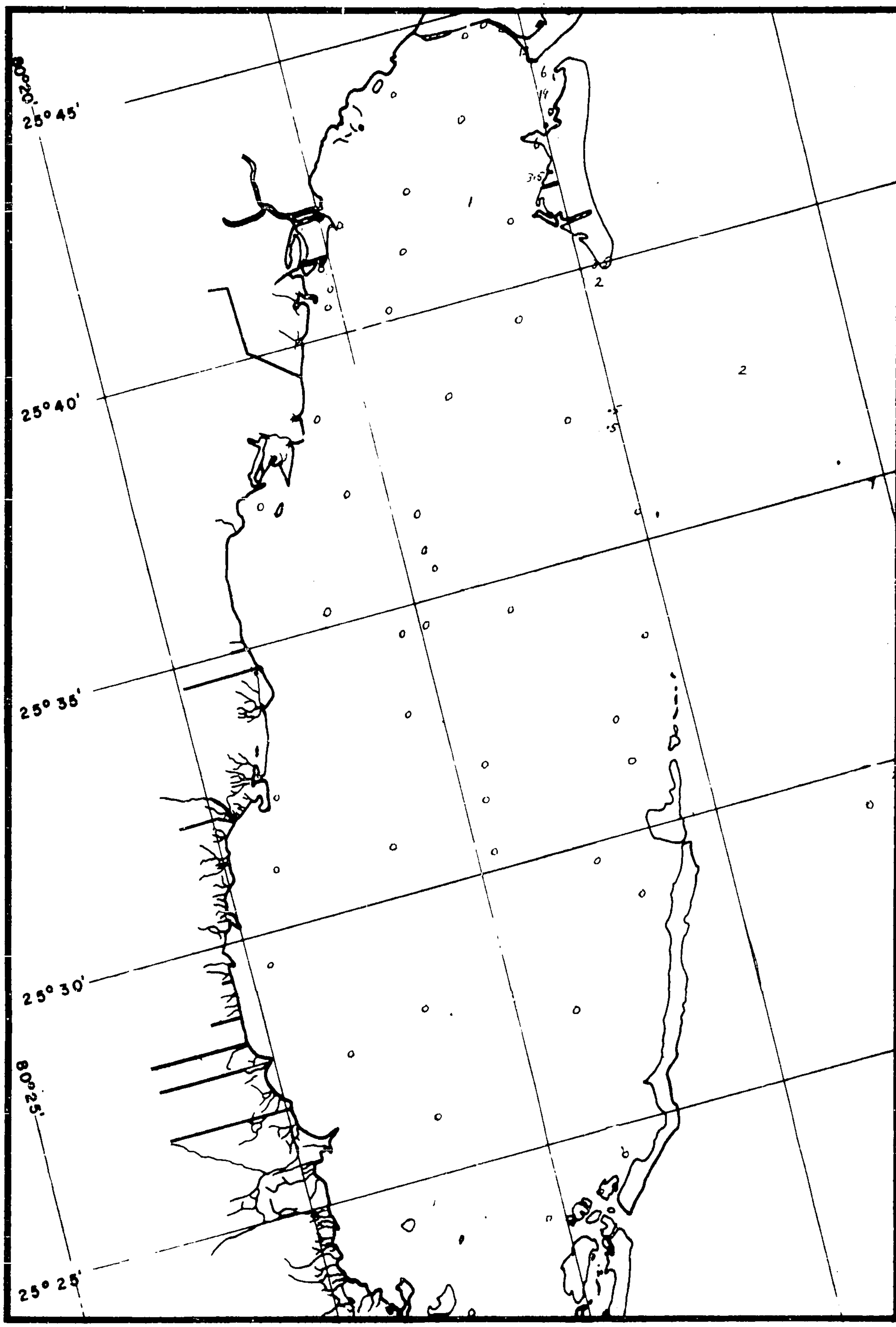
Hypotype No. U.W. 44,083.

This rare species inhabits the open-water environment and also the channel areas leading into the bay. It requires the high saline content of the open-water and probably also the temperate and well oxygenated waters.

Genus AMPHISTEGINA d'Orbigny, 1826
AMPHISTEGINA GIBBOSA d'Orbigny, 1839
Plate VIII, Figure 5

Amphistegina gibbosa d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, pp. 120, 121, pl. 8, figs. 1-3.

Test subcircular, peripheral edge not lobulate but sharply angled in peripheral view, slightly convex dorsally, strongly



Numbers represent per cent of species occurrence at station

Fig. 52 DISTRIBUTION OF ASTERIGERINA CARINATA convex ventrally; biumbonate; chambers form sinuous septa with additional rosette pattern on ventral side without median septa; sutures absent; ventral wall of early chambers of last whorl papillate; aperture a curved slit at base of last septal face.

Hypotype No. U.W. 44,084.

Cushman (1931, p. 79, pl. 16, figs. 1-3) put this species in synonymy with A. lessonii d'Orbigny, stating that he was unable to separate this form from the Pacific form.

The two species, A. lessonii and A. gibbosa are readily distinguishable. D'Orbigny (1839) readily differentiates the two species by stating (p. 121):

> "Par sa convexite du cote de la rosace, elle se raproche seulement de l'Amphistegina Quoyi de Rawack, mais elle s'en distingue nettement par las loges de la rosace sans cloisons medianes, caractere si prononce chez l'autre espece; elle differe encore par les memes loges, moins sinueses et plus tronguees a leur extremite."

(Note: A. lessonii and A. quoyi are accepted as being the same species.)

This species is common to stations 5-9, 18-21, 23, 31, 47, 48, and 52. It is characteristic of the open-water environment and that area in the bay immediately affected by the waters from east of the keys.

Family ORBULINIDAE Schultze, 1854

Genus GLOBIGERINOIDES Cushman, 1927

GLOBIGERINOIDES RUBRA (d'Orbigny, 1839)

Plate VIII, Figure 6

Globigerina rubra d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 82, pl. 4, figs. 12-14.

Test trochoid; three strongly inflated chambers per whorl; walls strongly reticulate; color pink to red in live specimens; aperture consisting of semicircular openings located at point of junction of the chamber and previous sutures.

Hypotype No. U.W. 44,085.

This very rare pelagic species was found at stations 9, 18, and 20.

Genus GLOBIGERINELLA Cushman, 1927

(?)GLOBIGERINELLA AEQUILATERALIS (Brady, 1879)

Plate VIII, Figure 9

Globigerina aequilateralis Brady, 1879, Quart. Journ. Micr. Sci., vol. 19, p. 71.

Test trochoid becoming planispiral in the adult; chambers globose, increasing rapidly in size, five in last whorl; periphery lobulate, rounded; sutures pronounced; wall cancellated; aperture a large arched opening at the base of the last chamber.

Hypotype No. U.W. 44,086.

This very rare pelagic species is present at station 18.

Family HETEROHELICIDAE Cushman, 1927

Subfamily BOLIVINITINAE Cushman, 1927

Genus BOLIVINA d'Orbigny, 1839

BOLIVINA STRIATULA Cushman, 1922

Plate VIII, Figure 7

Bolivina striatula Cushman, 1922, Carnegie Inst. Washington Publ. No. 311, p. 27, pl. 3, fig. 10.

Test elongate, tapering gradually toward rounded initial end, entire test compressed and slightly twisted; chambers inflated, pointed toward initial end on periphery; periphery rounded; sutures sinuous, pronounced; wall coarsely perforate, with faint striations in early portion of test; aperture elongate, from the base of the last septal face to the proximal end.

Hypotype No. U.W. 44,087.

This very rare species is found at stations 6, 8, 12, 33, 40, and 47. The species is limited to the northern portion of the bay and possibly lives in association with the plant life therein.

BOLIVINA cf. B. TORTUOSA Brady, 1881
Plate VIII, Figure 8

Bolivina tortuosa Brady, 1881, Quart. Journ. Micr. Soc., vol. 21, p. 57.

Test elongate, tapering toward initial end, twisted, compressed; periphery rounded to angled; chambers increasing rapidly in length but not in height, biserial; sutures oblique, slightly depressed; wall coarsely puctate; aperture terminal, an oval extending to base of septal face.

Hypotype No. U.W. 44,088.

The specimen from Biscayne Bay differs from the typical in having depressed sutures and in having inflated chambers which are rounded on the periphery rather than angled. One other specimen was found broken that answered the typical description better than that herein described.

This very rare species is present at stations 47 and 50. It is characteristic of the Safety Valve environment where there is much mixing of tidal waters and where the open-water effect is greatest in the bay area.

Genus LOXOSTOMUM Ehrenberg, 1854

LOXOSTOMUM LIMBATUM var. COSTULATUM (Cushman, 1922)

Plate VIII, Figure 10

Bolivina limbata var. costulata Cushman, 1922, Carnegie Inst. Washington Publ. Bo. 311, p. 26, pl. 3, fig. 8.

Test elongate, tapering at the ends, middle portion with sides nearly parallel, whole test twisted, compressed; chambers increasing rapidly in size in young stage, less so in adult; sutures limbate, strongly curved at initial end; wall coarsely perforate, with several costae in early portion of test; aperture oval, terminal with slightly extended and thickened peristome.

Hypotype No. U.W. 44,089.

This very rare species is present at stations 18 and 47. It is characteristic of the open-water environment.

LOXOSTOMUM MAYORI (Cushman, 1922)

Plate VIII, Figure 11

Bolivina mayori Cushman, 1922, Carnegie Inst. Washington Publ. No. 311, p. 27, pl. 3, figs. 5, 6.

Test elongate, twisted, compressed, early portion tapering, latter portion with parallel sides; periphery rounded; sutures distinct, depressed; wall coarsely perforate with few weak costae in early portion of test; chambers inflated, height greater than width, biserial portion composing major portion of test; aperture terminal, elliptical.

Hypotype No. U.W. 44,090.

This very rare species is present at stations 9 and 47. It probably lives in association with some of the plant life.

Genus RECTOBOLIVINA Cushman, 1927

RECTOBOLIVINA ADVENA (Cushman, 1922)

Plate VIII, Figure 12

Siphogenerina advena Cushman, 1922, Carnegie Inst. Washington Publ. No. 311, vol. 17, p. 35, pl. 5, fig. 2.

Test elongate, slightly compressed, sides of test parallel except neanic triangular portion; neanic chambers biserial, becoming uniserial, rectilinear: chambers inflated, round on the periphery; sutures distinct, depressed; wall coarsely perforate, early half of test coarsely costate, later section smooth, the costae very irregular, not continuous; aperture terminal, elongate, ovoid, appears entosolenian.

Hypotype No. U.W. 44,091.

This very rare species is only present at station 9. It probably lives in close association with some plant life in this area.

Family BULIMINIDAE Jones, 1876
Subfamily BULIMININAE Brady, 1884
Genus VIRULINA d'Orbigny, 1826
VIRGULINA cf. V. COMPLANATA Egger, 1893
Plate VIII, Figure 13

Virgulina complanata Egger, 1893, Abhandl. k. bay. Akad. Wiss. Munchen Cl. II, vol. 18, p. 292, pl. 8, figs. 91, 92.

Test very elongate, very twisted, not increasing in diameter to any great extent in the ephebic stage, tapering very gradually to the proloculus; lobulate in sectional view; chambers inflated, elongate, opposing pairs forming acute angle; sutures distinct in ephebic stage and depressed, indistinct and not depressed in neanic stage; wall finely perforate; aperture not visible.

Hypotype No. U.W. 44,092.

This very rare species is present at stations 33 and 47. Both of these stations are in the Safety Valve area where the tidal influence is great and where there is considerable plant life.

VIRGULINA cf. V. PONTONI Cushman, 1932
Plate VIII, Figure 14

Virgulina pontoni Cushman, 1932, Contrib. Cushman Lab. Foram. Res., vol. 8, p. 17, pl. 3, fig. 7.

Test elongate, slightly tapering, twisted, slightly depressed, triserial in the neanic stage becoming biserial in the ephenic stage; periphery rounded; chambers elongate, 3-5 times as long as wide, inflated, the angle between the pairs acute, one lateral series of chambers appear en echelon; sutures distinct, depressed; wall smooth, transparent; aperture at the base of the last septal face extending to become almost terminal, comma-shaped.

Hypotype No. U.W. 44,093.

This very rare species is found only at stations 5 and 33. Bothe of these stations are in areas affected by the incoming tidal flow.

Family CASSIDULINIDAE d'Orbigny, 1839
Genus CASSIDULINA d'Orbigny, 1826
CASSIDULINA SUBGLOBOSA Brady, 1881
Plate VIII, Figure 15

Cassidulina subglobosa Brady, 1881, Jour. Micr. Soc., vol. 21, p. 60.

Test subglobular, slightly compressed; periphery broadly ovoid; chambers inflated, 3-4 pairs in the last whorl; sutures distinct, slightly depressed; wall conspicuously perforate, smooth; aperture virguline, median, extending up from the base of the last septal face.

Hypotype No. U.W. 44,094.

This very rare species is present at stations 18 and 47. It is particularly characteristic of an environment affected by the open-waters.

Family CAMERINIDAE Meek and Hayden, 1865
Subfamily HETEROSTEGININAE Galloway, 1933
Genus HETEROSTEGINA d'Orbigny, 1826
HETEROSTEGINA ANTILLARUM d'Orbigny, 1839
Plate VIII, Figure 16

Heterostegina antillarum d'Orbigny, 1839, in De La Sagra, Hist. Phys. Pol. Nat. Cuba, Foraminiferes, p. 122, pl. 7, figs. 24, 25.

Test oval, planispiral, involute, very compressed, plano-convex; biumbonate; periphery not lobulate, with truncate keel; chambers numerous, increasing fairly rapidly in size, strongly arcuate, irregular, subdivided in a row of chamberlets at the peripheral half of the chamber; sutures irregular, limbate; apertures not visible.

Hypotype No. U.W. 44,095.

This rare species is found at stations 6, 19, 20, and 31. It is primarily characteristic of an open-water environment.

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PLATES

PLATE I

Figure 1. *Rhizammina indivisa* Brady. Hypotype no. U.W. 44,004. x25, lateral view.

Figure 2. *Spirillina vivipora* Ehrenberg. Hypotype no. U.W. 44,005. x70, lateral view.

Figure 3. *Cornuspira planorbis* Schultze. Hypotype no. U.W. 44,006. x75, lateral view.

Figure 4. (?)*Cornuspiramia antillarum* (Cushman). Hypotype no. U.W. 44,007. x100, lateral view.

Figure 5. *Cornuspiroides foliaceum* (Philippi). Hypotype no. U.W. 44,008. x105, lateral view.

Figure 6. *Spiroloculina antillarum* d'Orbigny. Hypotype no. U.W. 44,009. x75, front view.

Figure 7. *Spiroloculina atlantica* Cushman. Hypotype no. U.W. 44,010. x75, front view.

Figure 8. *Spiroloculina* cf. *S. ornata* d'Orbigny. Hypotype no. U.W. 44,011. x75, front view.

Figure 9a,b. *Quinqueloculina antillarum* d'Orbigny. Hypotype no. U.W. 44,012. a. x75, apertural view; b. x90, front view.

Figure 10. *Quinqueloculina bosciana* d'Orbigny. Hypotype no. U.W. 44,013. x70, front view.

Figure 11. *Quinqueloculina collumnosa* Cushman. Hypotype no. U.W. 44,014. x75, front view.

Figure 12a,b. *Quinqueloculina enoplostoma* d'Orbigny. Hypotype no. U.W. 44,015. a. x25, front view; b. x70, apertural view.

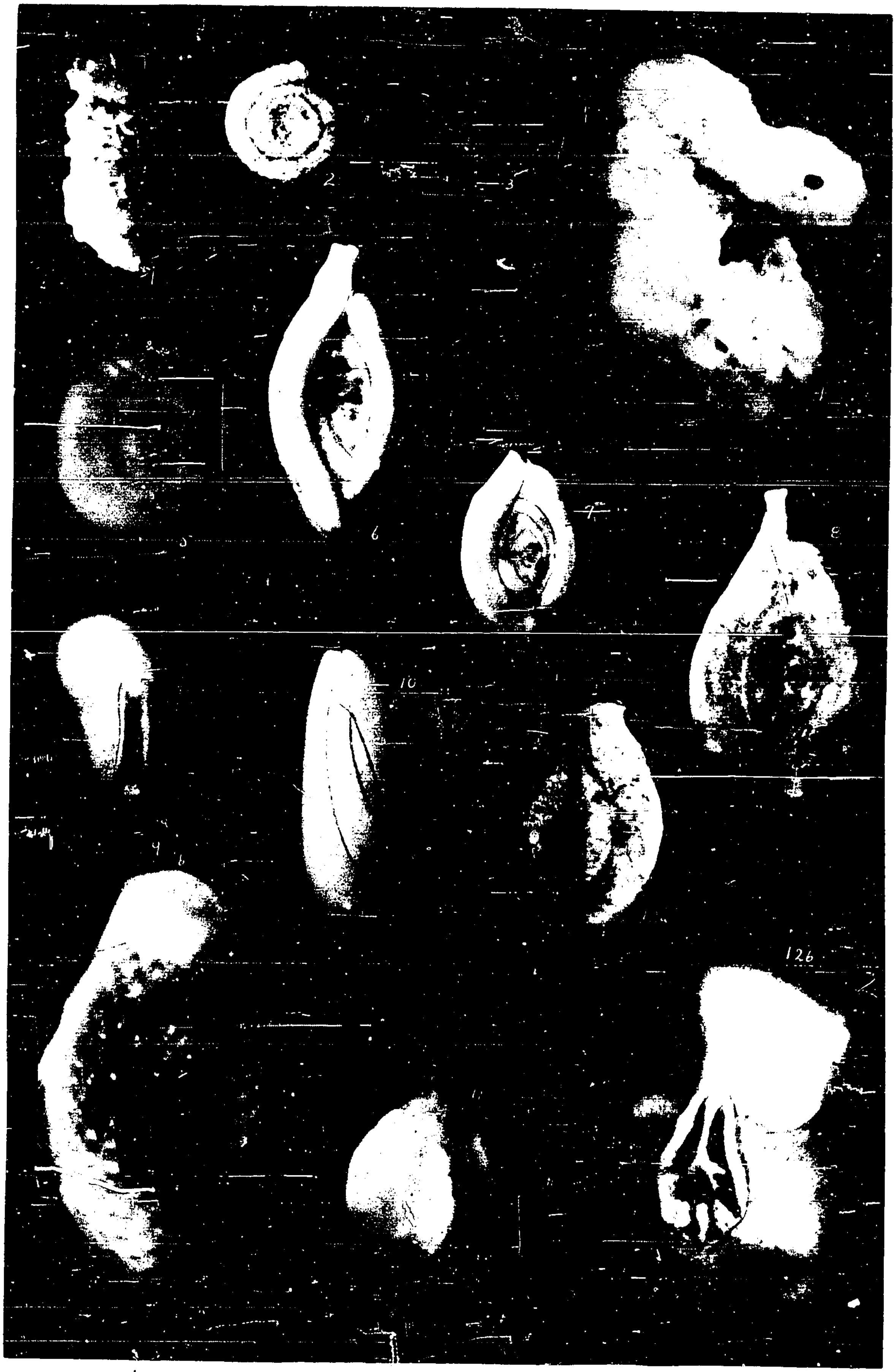


Plate I FORAMINIFERA OF BISCAYNE BAY

PLATE II

Figure 1a,b. *Quinqueloculina lamarckiana* d'Orbigny. Hypotype no. U.W. 44,016. a. x70, apertural view; b. x85, front view.

Figure 2a,b. *Quinqueloculina* cf. *Q. linneiana* (Cushman). Hypotype no. U.W. 44,017. a. x100, front view; b. x90, apertural view.

Figure 3. *Quinqueloculina poeyana* d'Orbigny. Hypotype no. U.W. 44,018. x70, front view.

Figure 4. *Quinqueloculina polygona* d'Orbigny. Hypotype no. U.W. 44,019. x70, front view.

Figure 5. *Quinqueloculina torrei* Acosta. Hypotype no. U.W. 44,020. x25, front view.

Figure 6. *Quinqueloculina tricarinata* d'Orbigny. Hypotype no. U.W. 44,021. x25, front view.

Figure 7. *Schlumbergerina occidentalis* Cushman. Hypotype no. U.W. 44,022. x70, front view.

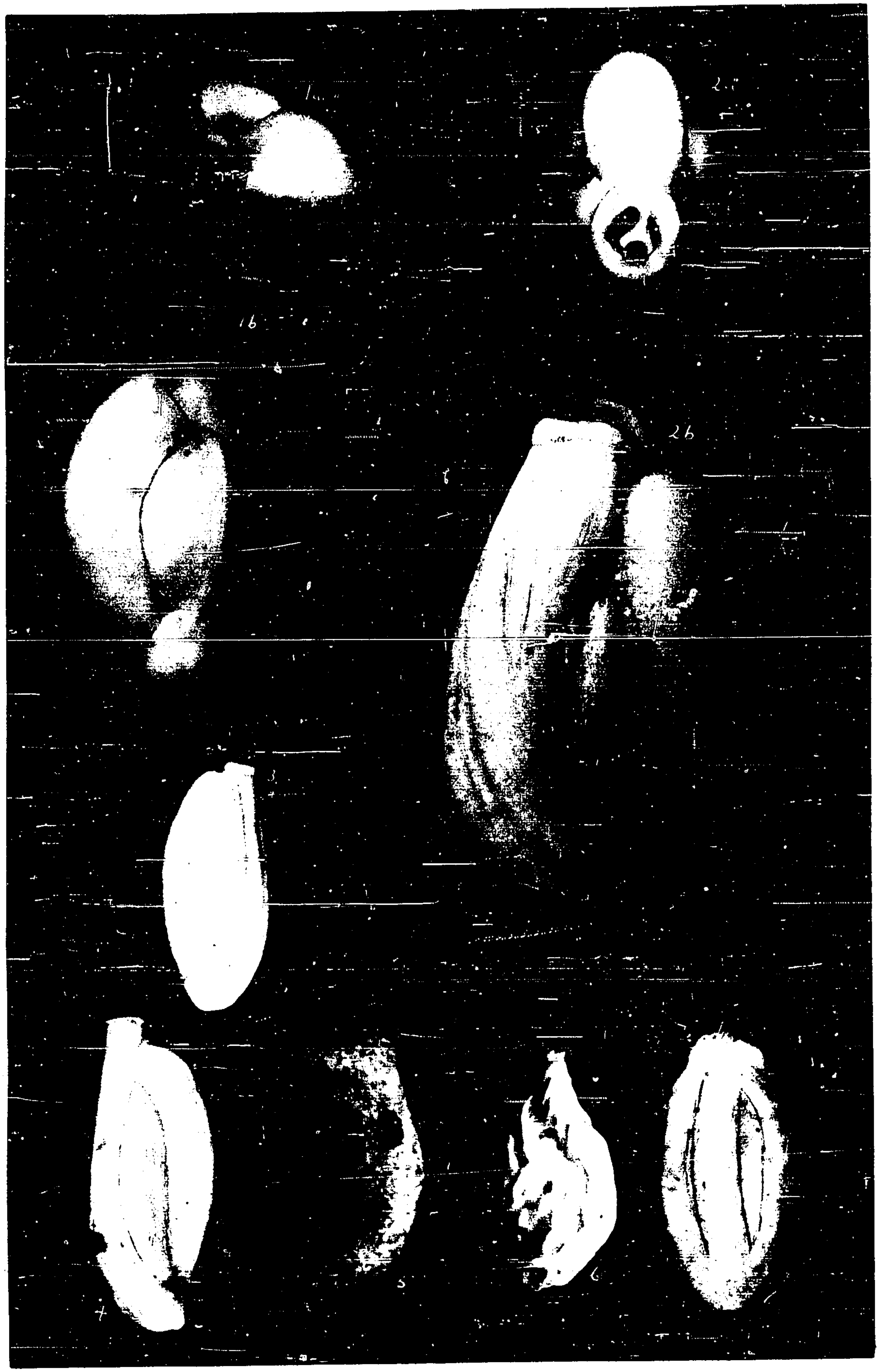


Plate II FORAMINIFERA OF BISCAYNE BAY

PLATE III

Figure 1. *Sigmoilina*(?) cf. *S. arenata* (Cushman). Hypotype no. U.W. 44,023. x70, front view.

Figure 2. *Triloculina bermudezi* Acosta. Hypotype no. U.W. 44,024. x55, front view.

Figure 3. *Triloculina fiterrei* var. *meningoi* Acosta. Hypotype no. U.W. 44,025. x105, front view.

Figure 4. *Triloculina flinti* Bush. Hypotype no. U.W. 44,026. x105, front view.

Figure 5. *Triloculina labiosa* d'Orbigny. Hypotype no. U.W. 44,027. x70, front view.

Figure 6. *Triloculina* cf. *T. oblonga* Cushman. Hypotype no. U.W. 44,028. x70, front view.

Figure 7. *Triloculina planciana* d'Orbigny. Hypotype no. U.W. 44,029. x75, front view.

Figure 8. *Triloculina subrotunda* (Montagu). Hypotype no. U.W. 44,030. x110, front view.

Figure 9. *Triloculina tricarinata* d'Orbigny. Hypotype no. U.W. 44,031. x105, front view.

Figure 10. *Triloculina trigonula* (Lamarck). Hypotype no. U.W. 44,032. x105, front view.

Figure 11a,b. *Pyrgo denticulata* (Brady). Hypotype no. U.W. 44,033. a. x75, apertural view; b. x105, front view.

Figure 12a,b. *Pyrgo subsphaerica* (d'Orbigny). Hypotype no. U.W. 44,034. a. x75, apertural view; b. x75, front view.

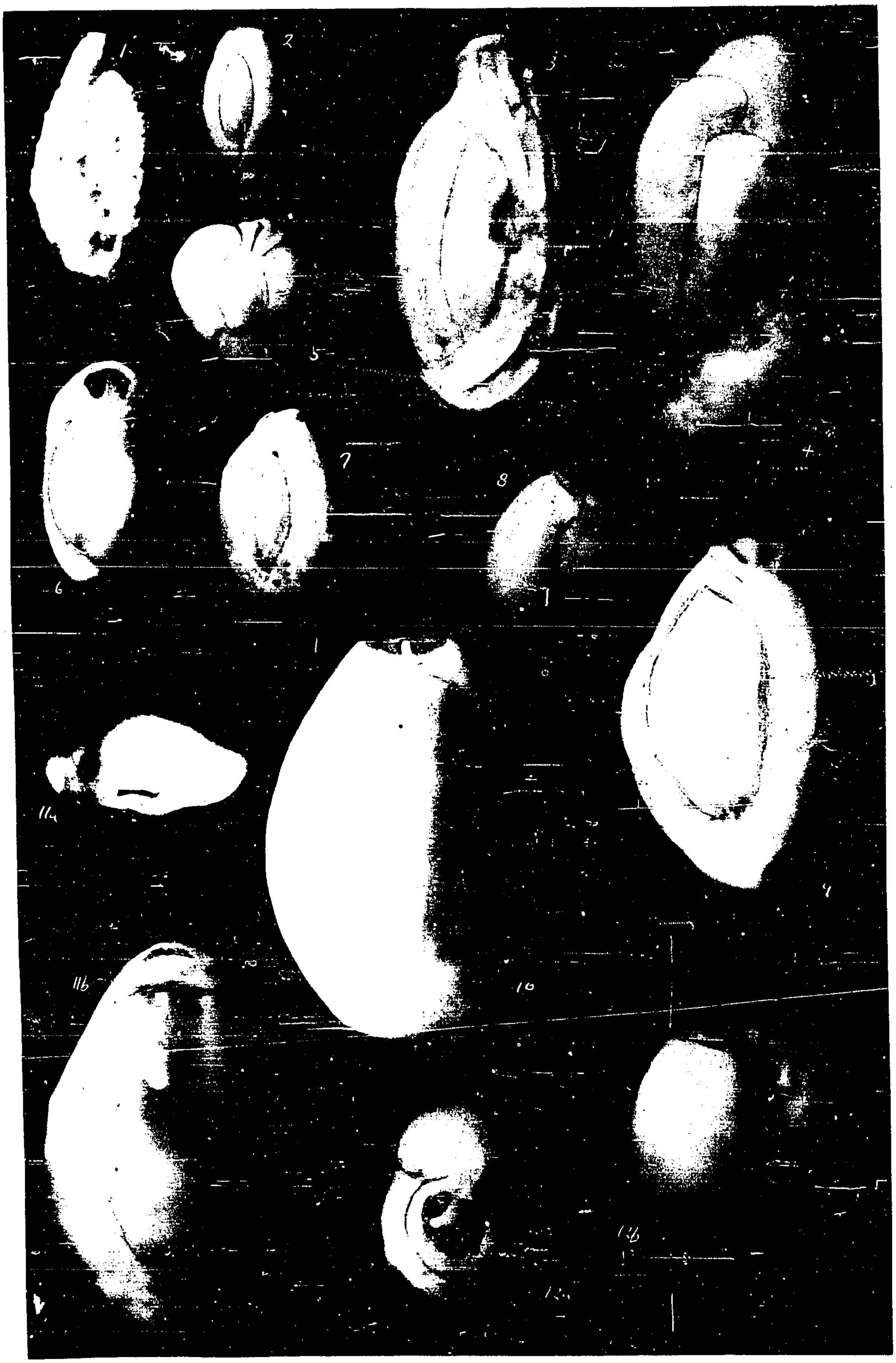


Plate III FORAMINIFERA OF BISCAYNE BAY

PLATE IV

Figure 1. *Massilina crenata* (Karrer). Hypotype no. U.W. 44,035. x75, front view.

Figure 2. *Vertebralina cassis* d'Orbigny. Hypotype no. U.W. 44,036. x105, lateral view.

Figure 3a,b. *Articulina mexicana* Cushman. Hypotype no. U.W. 44,037. a. x90, apertural view; b. x90, lateral view.

Figure 4. *Articulina mucronata* (d'Orbigny). Hypotype no. U.W. 44,038. x25, lateral view.

Figure 5. *Articulina sagra* d'Orbigny. Hypotype no. U.W. 44,039. x80, lateral view.

Figure 6. *Wiesnerella auriculata* (Egger). Hypotype no. U.W. 44,040. x100, lateral view.

Figure 7. *Nummoloculina irregularis* (d'Orbigny). Hypotype no. U.W. 44,041. x70, lateral view.

Figure 8. *Peneroplis acicularis* (Batsch). Hypotype no. U.W. 44,042. x75, lateral view.

Figure 9. *Peneroplis antillarum* d'Orbigny. Hypotype no. U.W. 44,043. x70, lateral view.

Figure 10. *Peneroplis arietinus* (Batsch). Hypotype no. U.W. 44,044. x60, lateral view.

Figure 11. *Peneroplis bradyi* Cushman. Hypotype no. U.W. 44,045. x75, lateral view.

Figure 12. *Peneroplis discoideus* Flint. Hypotype no. U.W. 44,046. x25, lateral view.

Figure 13. *Peneroplis* cf. *P. elegans* d'Orbigny. Hypotype no. U.W. 44,047. x70, lateral view.

Figure 14. *Peneroplis proteus* d'Orbigny. Hypotype no. U.W. 44,048. x25, lateral view.

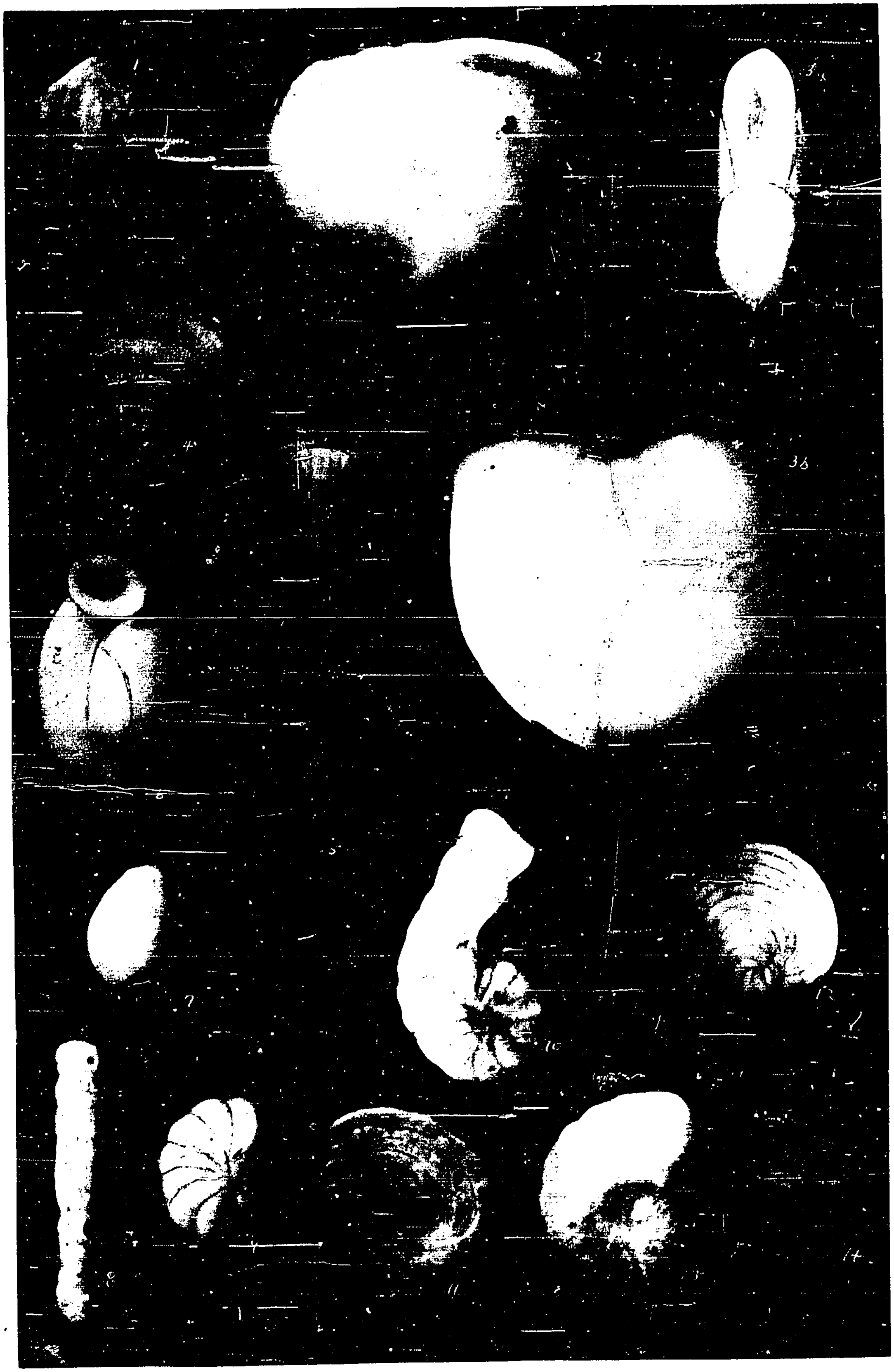


Plate IV FORAMINIFERA OF BISCAYNE BAY

PLATE V

Figure 1. *Archaias angulatus* (Fichtel and Moll). Hypotype no. U.W. 44,049. x30, lateral view.

Figure 2. *Archaias compressus* (d'Orbigny). Hypotype no. U.W. 44,050. x12, lateral view.

Figure 3. *Praesorites orbitolitoides* Hofker. Hypotype no. U.W. 44,051. x25, lateral view.

Figure 4. *Sorites marginalis* (Lamarck). Hypotype no. U.W. 44,052. x25, lateral view.

Figure 5. *Neoalveolina* cf. *N. schlumbergerina* Reichel. Hypotype no. U.W. 44,053. x70, apertural view.

Figures 6, 7. *Valvulina oviedoiana* d'Orbigny. Hypotype nos. U.W. 44,054 and 44,055. 6 and 7, x90, side views.

Figure 8. *Clavulina tricarinata* d'Orbigny. Hypotype no. U.W. 44,056. x25, side view.

Figure 9. *Clavulina nodosaria* d'Orbigny. Hypotype no. U.W. 44,057. x60, side view.

Plate V FORAMINIFERA OF BISCAYNE BAY

PLATE VI

Figure 1. *Textularia agglutinans* d'Orbigny. Hypotype no. U.W. 44,058. x70, side view.

Figure 2. *Bigenerina irregularis* Phleger and Parker. Hypotype no. U.W. 44,059. x25, side view.

Figure 3. *Guttulina australis* (d'Orbigny). Hypotype no. U.W. 44,060. x110, side view.

Figure 4. *Globulina caribea* d'Orbigny. Hypotype no. U.W. 44,061. x115, side view.

Figure 5. *Globulina* cf. *G. gibba* d'Orbigny. Hypotype no. U.W. 44,062. x110, side view.

Figure 6. *Nonionella atlantica* Cushman. Hypotype no. U.W. 44,063. x70, dorsal view.

Figure 7. *Elphidium crispum* (Linnaeus). Hypotype No. U.W. 44,064. x90, side view.

Figure 8. *Elphidium poeyanum* (d'Orbigny). Hypotype no. U.W. 44,065. x105, side view.

Figure 9. *Elphidium sagrum* (d'Orbigny). Hypotype no. U.W. 44,066. x115, side view.

Figure 10. *Globorotalia menardii* (d'Orbigny). Hypotype no. U.W. 44,067. x75, ventral view.

Figure 11. *Streblus beccarii* (Linnaeus). Hypotype no. UW. 44,068. x70, ventral view.

Figure 12. *Rotalia rosea* (d'Orbigny). Hypotype no. U.W. 44,069. x75, dorsal view.

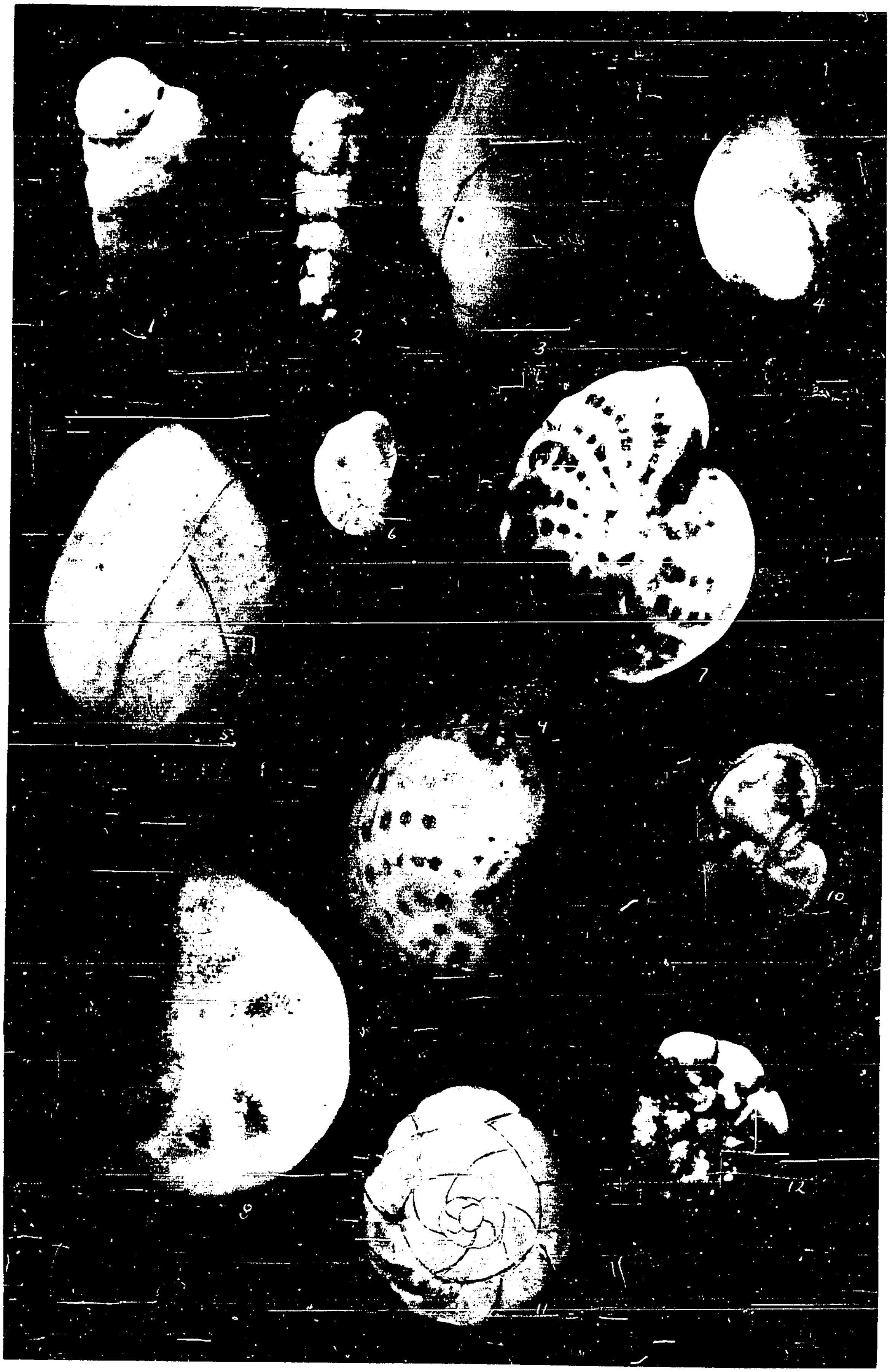


Plate VI FORAMINIFERA OF BISCAYNE BAY

PLATE VII

Figure 1. Gallowayus aff. G. antillarus (d'Orbigny). Hypotype no. U.W. 44,070. x75, ventral view.

Figure 2. Gallowayus redmondi Bush. Hypotype no. U.W. 44,071. x25, ventral view.

Figure 3. Cancris sagra (d'Orbigny). Hypotype no. U.W. 44,072. x110, ventral view.

Figure 4. Discorbis candeiana (d'Orbigny). Hypotype no. U.W. 44,073. x75, dorsal view.

Figure 5. Discorbis mira Cushman. Hypotype no. U.W. 44,074. x75, ventral view.

Figure 6. Discorbis subaraucana Cushman. Hypotype no. U.W. 44,075. x85, dorsal view.

Figure 7. Cymbaloporetta squammosa (d'Orbigny). Hypotype no. U.W. 44,076. x110, dorsal view.

Figure 8. Tretomphalus bulloides (d'Orbigny). Hypotype no. U.W. 44,077. x75, dorsal view.

Figure 9. Cibicides lobatulus (Walker and Jacob). Hypotype no. 44,078. x95, ventral view.

Figure 10. Cibicides pseudoungerianus (Cushman). Hypotype no. U.W. 44,079. x110, ventral view.

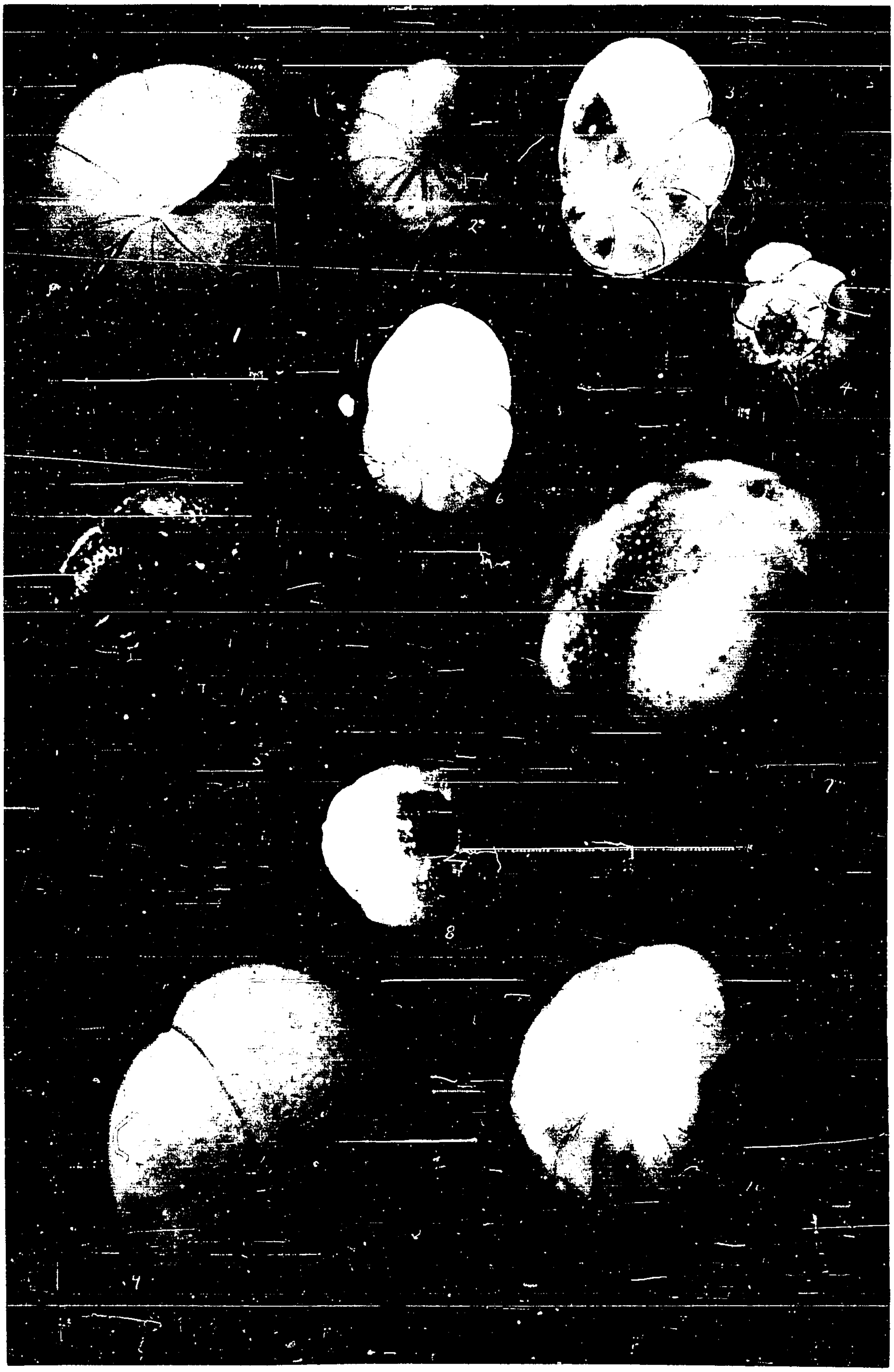


Plate VII FORAMINIFERA OF BISCAYNE BAY

PLATE VIII

Figure 1. *Siphonina pulchra* Cushman. Hypotype no. U.W. 44,080. x70, ventral view.

Figure 2. *Planorbulina acervalis* Brady. Hypotype no. U.W. 44,081. x30, top view.

Figure 3. *Homotrema rubra* (Lamarck). Figured specimen from other area; x11. Nonfigured specimen hypotype no. U.W. 44,082.

Figure 4. *Asterigerina carinata* d'Orbigny. Hypotype no. U.W. 44,083. x75, ventral view.

Figure 5. *Amphistegina gibbosa* d'Orbigny. Hypotype no. U.W. 44,084. x120, ventral view.

Figure 6. *Globigerinoides rubra* (d'Orbigny). Hypotype no. U.W. 44,085. x105, side view.

Figure 7. *Bolivina striatula* Cushman. Hypotype no. U.W. 44,086. x110, side view.

Figure 8. *Bolivina* cf. *B. tortuosa* Brady. Hypotype no. U.W. 44,087. x110, side view.

Figure 9. (?)*Globigerinella aequilateralis* (Brady). Hypotype no. U.W. 44,088. x110, dorsal view.

Figure 10. *Loxostomum limbatum* var. *costulatum* (Cushman). Hypotype no. U.W. 44,089. x110, side view.

PLATE VIII cont'd.

Figure 11. *Loxostomum mayori* (Cushman). Hypotype no. U.W. 44,090. x110, side view.

Figure 12. *Rectobolivina advena* (Cushman). Hypotype no. U.W. 44,091. x110, side view.

Figure 13. *Virgulina* cf. *V. complanata* Egger. Hypotype no. U.W. 44,092. x110, side view.

Figure 14. *Virgulina* cf. *V. pontoni* Cushman. Hypotype no. U.W. 44,093. x110, side view.

Figure 15. *Cassidulina subglobosa* Brady. Hypotype no. U.W. 44,094. x110, apertural view.

Figure 16. *Heterostegina antillarum* d'Orbigny. Hypotype no. U.W. 44,095. x30, side view.

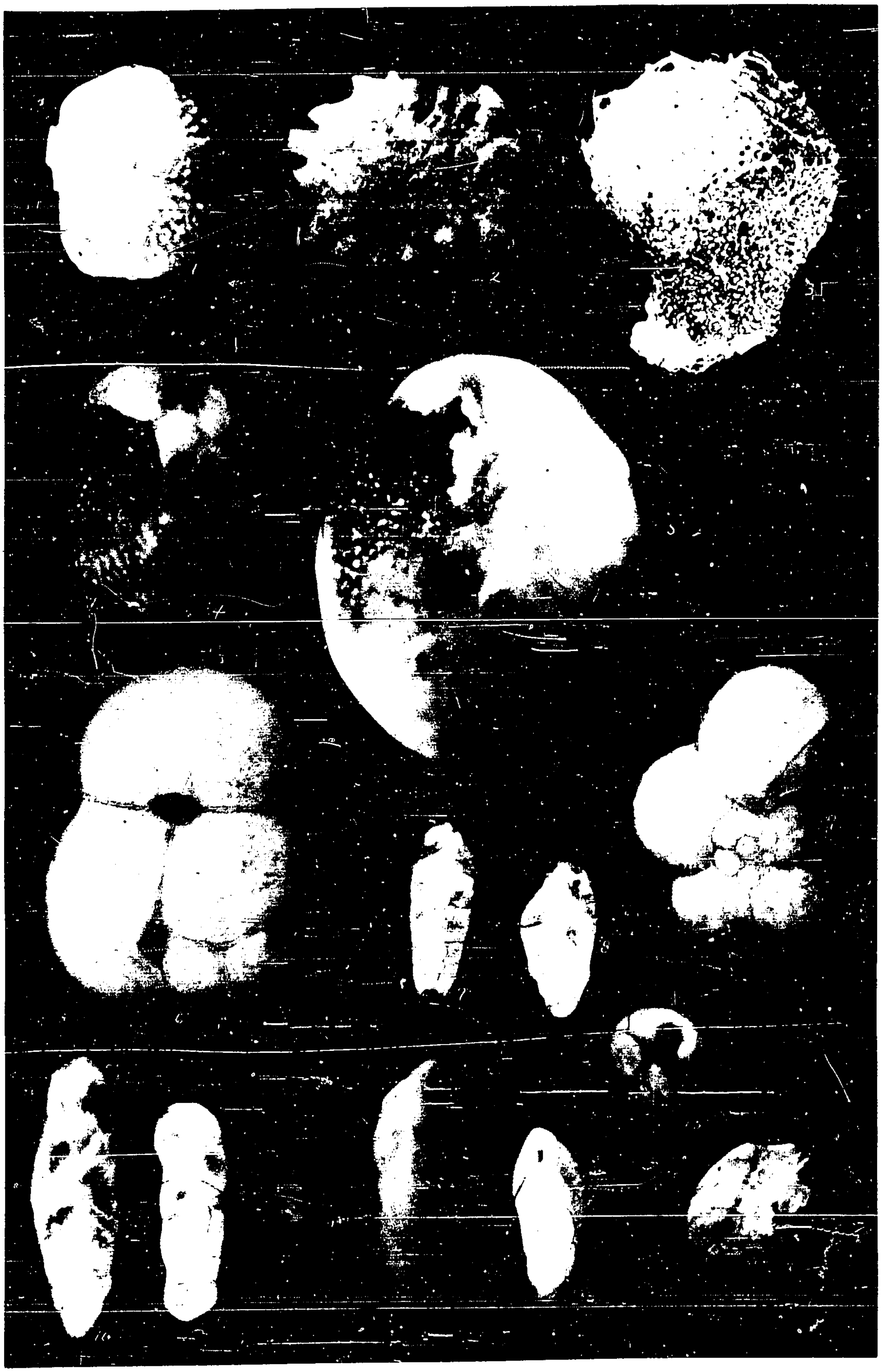


Plate VIII FORAMINIFERA OF BISCAYNE BAY

APPENDIX

STATION NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
latitude 25° –' –" N	43-45	44-25	44-30	44-15	43-45	43-25	43-00	42-10	41-35	41-30	42-00	43-00	41-00	40-55	40-25
longitude 80° –' –" W	12-50	11-40	10-55	10-30	10-10	9-55	10-00	10-25	10-45	12-00	13-10	11-40	11-15	13-30	15-25
depth in feet	4	4	9	7	1	15	2	3	8	10	8	11	15	8	4
5th percentile diameter	0.95	0.90	1.05	1.10	0.20	-0.15	0.85	-1.45	0.35	-2.20	0.60	-0.20	2.50	0.50	0.85
16th percentile diameter	1.50	1.40	1.85	2.20	1.10	1.40	1.75	1.55	1.60	-0.15	1.35	0.90	3.55	1.30	1.50
84th percentile diameter	2.60	2.70	5.30	5.55	2.95	3.05	2.95	3.10	3.35	4.20	2.45	2.75	9.15	2.65	2.50
95th percentile diameter	3.05	3.10	7.95	8.20	3.75	3.85	3.20	3.90	4.40	5.85	2.75	3.00	11.20	3.05	2.80
phi median diameter	2.05	2.00	3.65	3.25	2.10	2.15	2.65	2.60	2.60	2.15	2.05	1.85	5.40	2.05	2.05
phi mean diameter	2.05	2.05	3.85	3.88	2.03	2.23	2.35	2.38	2.48	2.03	1.90	1.83	6.35	1.98	2.00
phi deviation measure	0.55	0.65	1.73	1.68	0.93	0.83	0.60	0.78	0.88	2.18	0.55	0.93	2.80	0.68	0.50
phi skewness measure	0.00	0.77	-0.04	0.38	-0.08	0.10	-0.50	-0.28	-0.14	-0.06	-0.27	-0.02	0.34	-0.10	-0.10
2nd phi skewness measure	-0.91	0.00	0.49	0.83	0.03	-0.36	-1.03	-1.76	-0.14	-0.15	-0.67	-0.48	0.52	-0.40	-0.44
phi kurtosis	0.91	0.69	0.99	1.11	0.91	1.41	0.97	2.44	1.30	0.85	0.96	0.72	0.55	0.88	0.96
per cent $CaCO_3$	3	7	40	85	60	50	40	55	55	80	10	30	95	20	5
per cent quartz	97	93	60	15	40	50	60	45	45	20	90	70	5	80	95
per cent sand & coarser	100	98	57	59	96	96	99	95	92	82	99	95	23	99	99
per cent silt	0	2	39	36	4	4	1	5	8	18	1	5	56	1	1
per cent clay	0	0	4	5	0	0	0	0	0	0	0	0	21	0	0
blackened $CaCO_3$	x		x		x	x								x	
epidote	x					x	x				x			x	x
Gastropoda		x	x	x	x		x	x	x	x	x	x		x	x
Pelecypoda		x	x		x		x	x	x	x	x	x		x	x
Ostracoda		x	x	x		x	x	x	x	x	x	x	x	x	x
echinoid spines	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
alcyonarian spicules					x	x	x		x						
sponge spicules	x	x	x		x	x	x		x	x	x	x	x		x
vertebral ossicles		x	x	x	x	x	x	x		x					x
Bryozoa						x					x				
Coral															
Otolith													x		x
Worm tubes					x				x		x	x			
Thalassia		x							x		x				x
Halimeda					x				x	x					
Neomeris					x	x	x		x						
Charophyta					x										

STATION NUMBER	16	17	18	19	20	21	22	23	24	25	26	27	28	29
latitude 25° –' –" N	41-40	37-25	34-50	29-15	29-25	23-50	24-25	23-40	25-55	28-50	30-15	31-10	31-40	40-45
longitude 80° –' –" W	14-45	7-30	5-20	7-00	6-15	14-15	13-35	15-30	17-10	12-5	14-50	14-35	14-25	15-18
depth in feet	3	16	120	19	100	10	3	6	6	8	9	3	10	0
5th percentile diameter	0.75	-0.70	-4.20	-1.85	-1.30	-1.85	-1.20	-0.70	-0.10	0.30	0.70	-2.50	-1.20	1.30
16th percentile diameter	1.40	0.30	-2.05	-0.65	-0.40	-1.10	-0.30	0.15	0.60	1.01	1.80	-0.85	1.95	1.75
84th percentile diameter	2.50	2.05	0.95	1.25	2.00	1.90	2.40	3.05	2.50	2.80	3.20	9.60	9.10	2.50
95th percentile diameter	2.80	2.40	1.90	1.55	2.55	3.35	3.15	4.60	3.00	3.10	5.10	12.10	11.50	2.75
phi median diameter	2.00	1.55	-0.20	0.60	0.80	0.15	0.60	1.90	1.90	2.25	2.30	3.95	5.15	2.15
phi mean diameter	1.95	1.18	-0.55	0.30	0.80	0.40	1.05	1.60	1.55	1.91	2.50	4.38	5.53	2.13
phi deviation measure	0.55	0.88	1.50	0.95	1.20	1.50	1.35	1.45	0.95	0.90	0.70	5.23	3.58	0.38
phi skewness measure	-0.09	-0.42	-0.23	-0.32	0.00	0.17	0.33	-0.21	-0.37	-0.38	0.28	0.08	0.11	-0.05
2nd phi skewness measure	-0.40	-0.80	-0.63	-0.95	-0.14	0.40	0.28	0.03	-0.47	-0.61	0.86	0.16	0.00	-0.32
phi kurtosis	0.87	0.76	1.03	0.79	0.61	0.73	0.61	0.83	0.63	0.56	2.14	0.49	0.77	0.92
per cent $CaCO_3$	5	60	99	100-	98	99	80	65	30	40	30	97	90	0+
per cent quartz	95	40	1	0+	2	1	20	35	70	60	70	3	10	100-
per cent sand & coarser	99	100	99	100	100	97	98	93	98	99	91	50	31	100
per cent silt	1	0	1	0	0	[illegible]	2	7	2	1	9	27	47	0
per cent clay	0	0	0	0	0	0	0	0	0	0	0	23	22	0
blackened $CaCO_3$									x					
epidote	x	x									x			x
Gastropoda	x				x	x	x	x	x	x	x	x	x	x
Pelecypoda						x	x			x	x		x	
Ostracoda	x		x			x	x	x	x	x	x	x	x	x
echinoid spines				x		x		x						
alcyonarian spicules			x	x	x	x					x			
sponge spicules	x		x			x								
vertebral ossicles			x					x	x				x	
Bryozoa			x		x									
Coral						x				Oval worn fragments.				
Otolith								x						
Worm tubes														
Thalassia								x					x	
Halimeda		x		x		x		x				x	x	
Neomeris			x	x										
Charophyta														

27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
31-10	31-40	40-45	41-00	39-50	39-35	39-15	40-3	38-25	37-00	36-50	35-5	35-20	36-25	35-40	34-25	34-30	38-15	37-20	37-5	37-10	35-25	33-10	32-30	31-45	31-10	29-35	27-10	27-55	27-30	29-20	30-55	32-10	30-48	33-0	34-20
14-35	14-25	15-18	15-25	9-50	9-55	11-38	14-10	16-15	15-50	17-35	16-50	14-30	14-35	14-40	15-25	15-0	13-20	11-5	10-15	10-15	10-15	10-45	12-55	11-40	11-40	12-45	13-50	16-50	18-55	19-30	19-0	18-50	16-40	15-45	13-15
3	10	0	2	20	2	17	10	2	8	6	3	7	11	4	4	7	12	8	2	18	7	3	9	9	12	9	10	7	7	3	3	3	7	6	11
-2.50	-1.20	1.30	1.25	-3.10	0.00	1.65	0.05	2.05	0.95	-0.10	-0.60	0.40	1.25	1.80	-1.25	-0.10	1.00	-0.90	-1.50	-1.40	0.75	-1.55		0.35	-0.60	0.45	-0.55	0.10	-0.55	-1.15	-1.70	-1.70	-0.40	-0.35	-0.85
-0.85	1.95	1.75	1.70	-1.30	1.55	3.35	0.60	2.20	1.80	1.00	-0.10	1.55	1.90	2.05	-0.20	0.75	2.25	0.35	-0.35	0.30	1.60	-0.75		1.50	0.90	1.30	0.40	0.80	0.30	-0.30	-0.55	-0.50	0.10	0.10	1.05
9.60	9.10	2.50	2.60	2.50	4.25	7.40	2.20	2.85	2.90	2.65	2.90	2.65	2.65	2.70	2.80	2.90	8.00	3.70	3.35	2.85	7.25	1.80		7.40	7.75	3.00	2.40	2.40	3.00	2.30	1.15	2.80	2.80	2.70	2.40
12.10	11.50	2.75	2.85	2.95	5.60	10.25	2.70	3.00	4.60	2.90	4.10	3.00	3.60	2.95	3.40	4.10	10.55	5.10	4.10	3.75	10.10	2.75		10.35	10.20	4.20	2.95	2.85	3.75	3.15	2.85	3.30	3.60	4.00	3.35
3.95	5.15	2.15	2.15	1.55	2.80	4.75	1.50	2.55	2.40	2.10	1.15	2.25	2.30	2.35	2.20	2.35	4.40	2.05	2.55	2.10	2.90	0.40		2.75	2.85	2.20	1.75	1.80	2.10	0.60	0.20	1.70	1.00	1.00	1.85
4.38	5.53	2.13	2.15	0.60	2.90	5.38	1.40	2.53	2.35	1.83	1.40	2.10	2.28	2.38	1.30	1.83	5.13	2.03	1.50	1.58	4.43	0.53		4.45	4.33	2.15	1.40	1.60	1.65	1.00	0.30	1.15	1.45	1.40	1.73
5.23	3.58	0.38	0.45	1.90	1.35	2.03	0.80	0.33	0.55	0.83	1.50	0.55	0.38	0.33	1.50	1.08	2.88	1.68	1.85	1.20	2.83	1.28		2.95	3.43	0.85	1.00	0.80	1.35	1.30	0.85	1.65	1.35	1.30	0.68
0.08	0.11	-0.05	0.00	-0.50	0.07	0.31	-0.13	-0.06	-0.09	-0.33	0.17	-0.27	-0.05	0.09	-0.60	-0.48	0.25	-0.01	-0.57	-0.41	0.54	0.10		0.58	0.43	-0.59	-0.35	-0.25	-0.33	0.31	0.12	-0.33	0.33	0.31	-0.18
0.16	0.00	-0.32	-0.22	-1.38	0.00	0.59	-0.15	-0.06	0.80	-0.84	0.40	-1.00	0.34	0.09	-0.75	-0.32	0.48	0.03	-0.68	-0.72	0.89	0.16		0.88	0.57	0.15	-0.55	-0.40	-0.63	0.31	0.45	-0.55	0.44	0.64	-0.88
0.49	0.77	0.92	0.78	0.59	1.07	1.12	0.66	0.46	2.33	0.81	0.57	1.36	2.15	0.76	0.55	0.94	0.66	0.79	0.57	1.02	0.67	0.69		0.70	0.57	1.21	0.50	0.78	0.59	0.65	1.66	0.52	0.48	0.66	2.09
97	90	0+	3	45	70	99	30	1	25	20	70	25	15	1	60	35	80	99	90	50	50	5	*Thalassia, Halimeda* & sponges too thick to permit sampling.	50	35	10	5	15	30	90	95	50	85	90	40
3	10	100-	97	55	30	1	70	99	75	80	30	75	85	99	40	65	20	1	10	50	50	95		50	65	90	95	85	70	10	5	50	15	10	60
50	31	100	99	99	82	31	99	100	94	99	94	99	96	99	97	95	43	91	94	96	64	97		64	62	94	98	99	96	98	98	97	97	95	97
27	47	0	1	1	17	57	1	0	6	1	4	1	4	1	3	5	41	8	6	4	24	3		23	23	5	2	1	4	2	2	3	3	5	3
23	22	0	0	0	1	12	0	0	0	0	2	0	0	0	0	0	16	1	0	0	12	0		13	15	1	0	0	0	0	0	0	0	0	0
							x				x					x												x	x	x	x	x	x	x	
		x		x				x		x		x	x	x	x				x							x	x					x	x		
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x		x		x		x	x	x	x	x	x	x	x	x	x
	x		x	x	x	x		x		x	x	x	x		x	x		x	x	x		x		x		x	x		x	x	x	x	x	x	x
x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x	x	x	x	x		x	x	x	x	x
				x	x								x		x			x	x					x		x									x
				x											x											x	x								
					x	x									x		x	x	x		x	x						x				x			
	x														x			x									x					x	x	x	
				x															x	x															
				x																								x							
			x	x	x										x				x	x										x	x	x		x	
	x		x		x		x	x	x		x		x				x	x	x			x		x		x		x					x	x	x
x	x			x	x	x			x	x					x		x	x	x	x	x	x		x		x					x		x	x	
				x																					x										

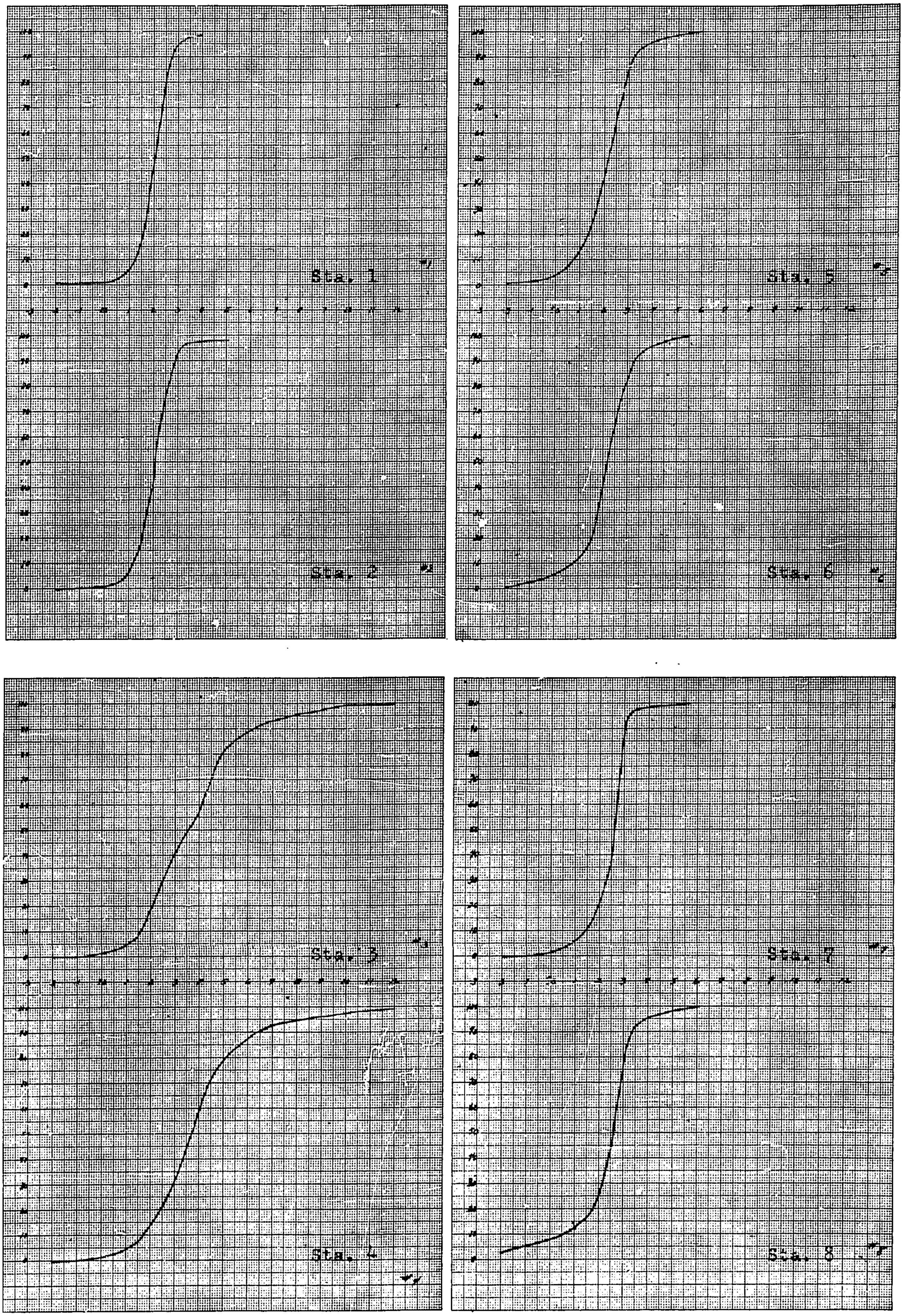
TABLE I

STATION DATA

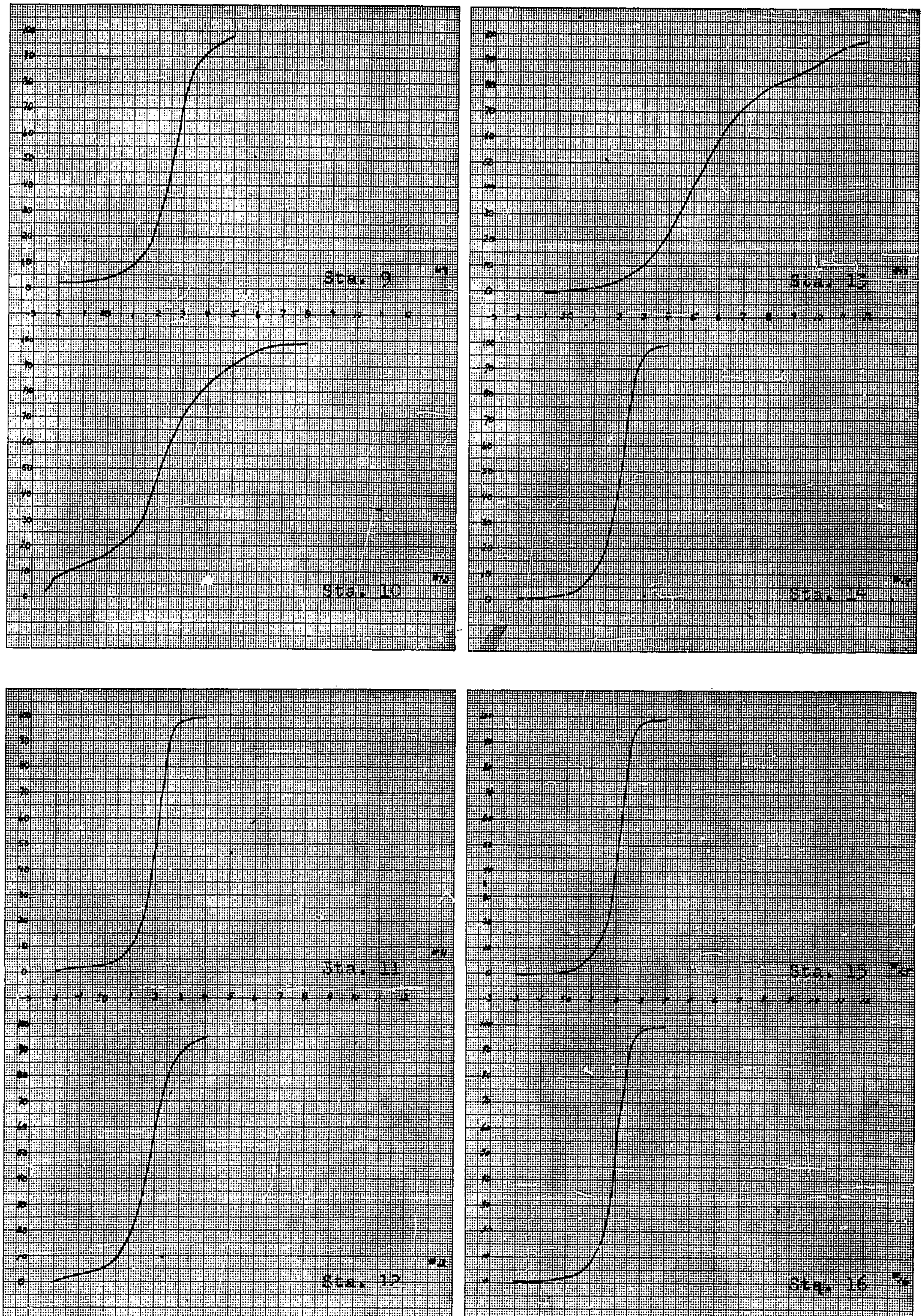
TABLE III

Thesis No.	Univ. Washington No.	Thesis No.	Univ. Washington No.
1	W.A. 154	33	W.A. 186
2	W.A. 155	34	W.A. 187
3	W.A. 156	35	W.A. 188
4	W.A. 157	36	W.A. 189
5	W.A. 158	37	W.A. 190
6	W.A. 159	38	W.A. 191
7	W.A. 160	39	W.A. 192
8	W.A. 161	40	W.A. 193
9	W.A. 162	41	W.A. 194
10	W.A. 163	42	W.A. 195
11	W.A. 164	43	W.A. 196
12	W.A. 165	44	W.A. 197
13	W.A. 166	45	W.A. 198
14	W.A. 167	46	W.A. 199
15	W.A. 168	47	W.A. 200
16	W.A. 169	48	W.A. 201
17	W.A. 170	49	W.A. 202
18	W.A. 171	50	W.A. 203
19	W.A. 172	51	W.A. 204
20	W.A. 173	52	W.A. 205
21	W.A. 174	53	W.A. 206
22	W.A. 175	54	W.A. 207
23	W.A. 176	55	W.A. 208
24	W.A. 177	56	W.A. 209
25	W.A. 178	57	W.A. 210
26	W.A. 179	58	W.A. 211
27	W.A. 180	59	W.A. 212
28	W.A. 181	60	W.A. 213
29	W.A. 182	61	W.A. 214
30	W.A. 183	62	W.A. 215
31	W.A. 184	63	W.A. 216
32	W.A. 185		

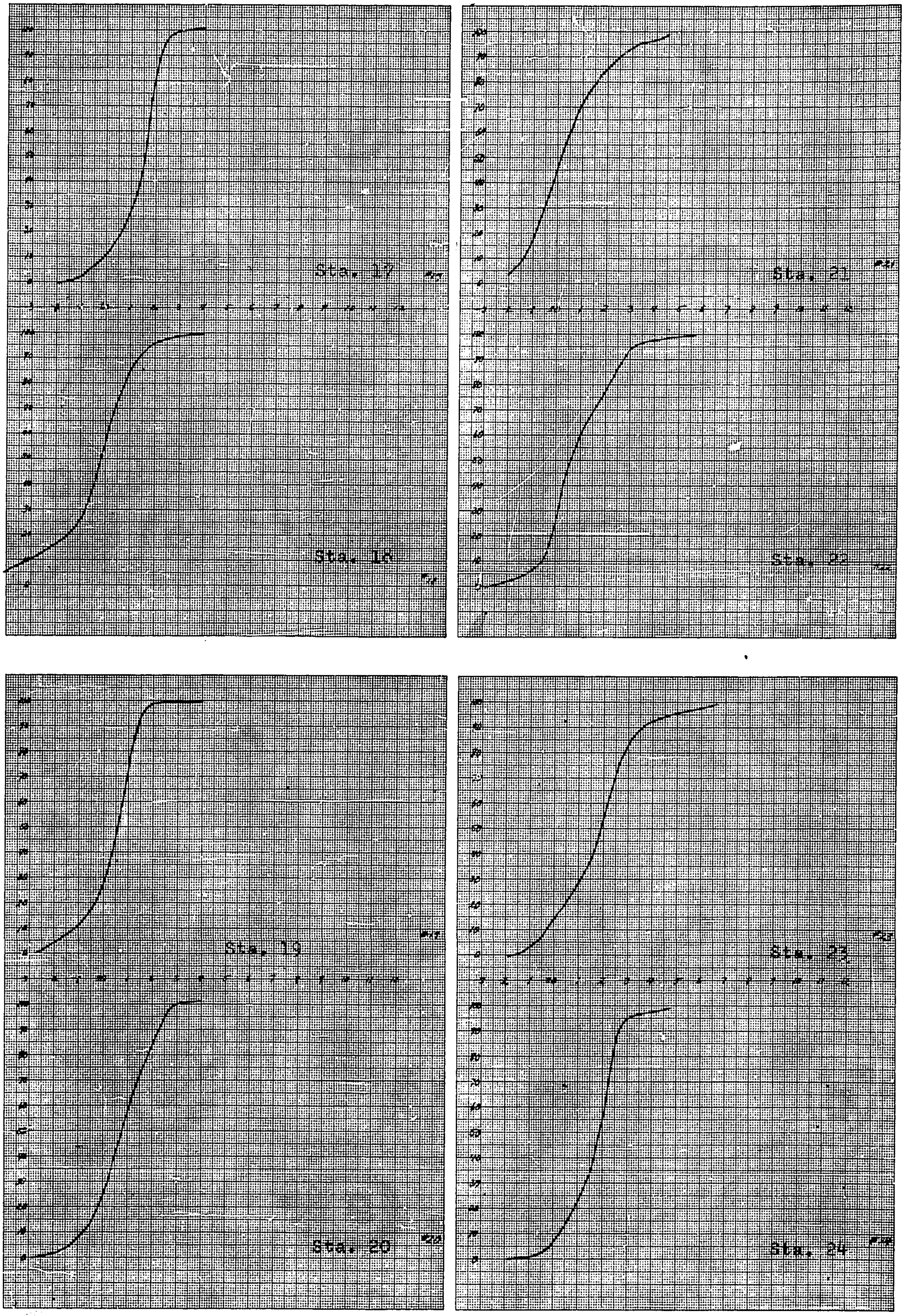
TABLE OF CONVERSION FROM THESIS STATION NUMBER TO UNIVERSITY OF WASHINGTON LOCALITY NUMBER



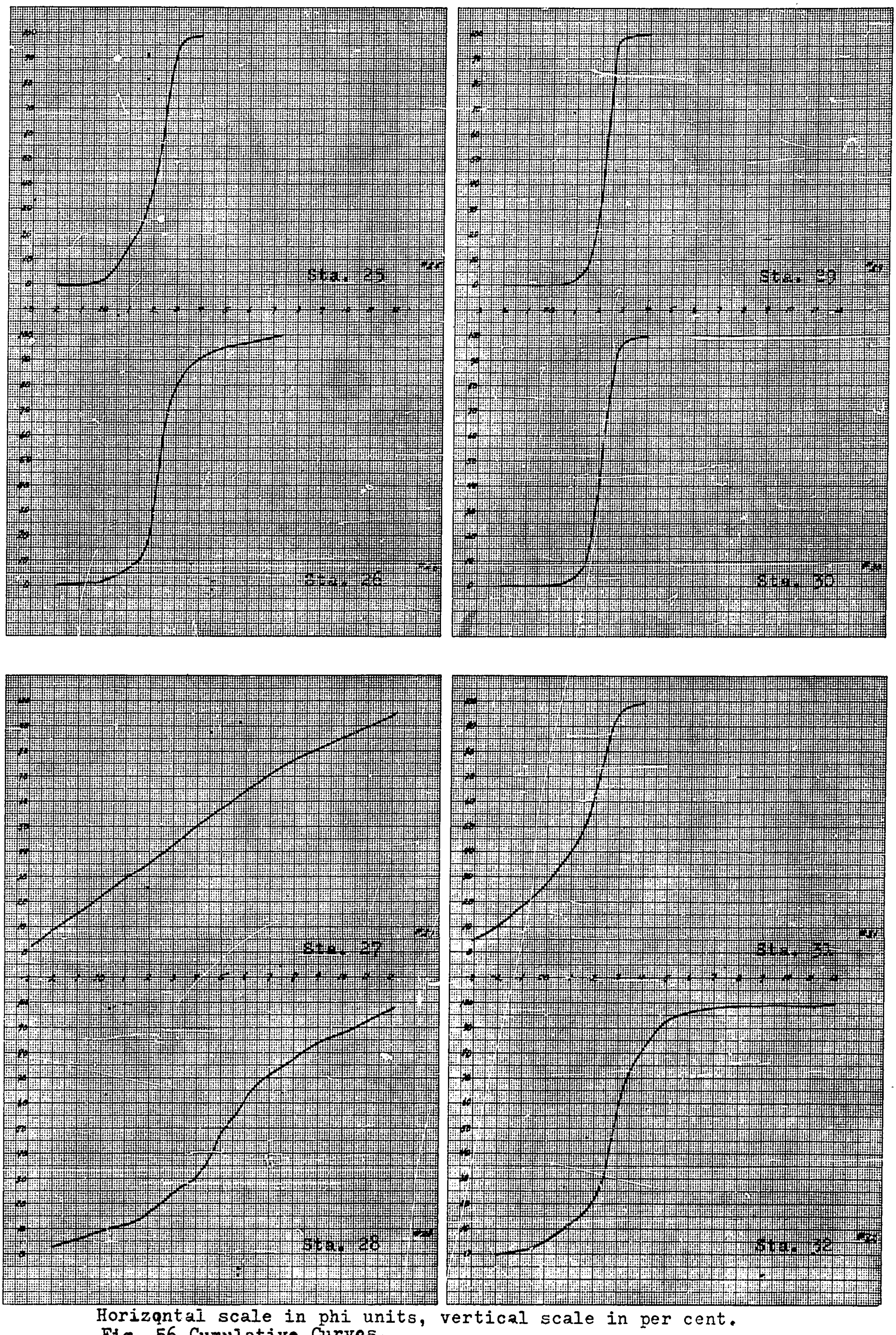
Horizontal scale in phi units, vertical scale in per cent.
Fig. 53. Cumulative Curves.



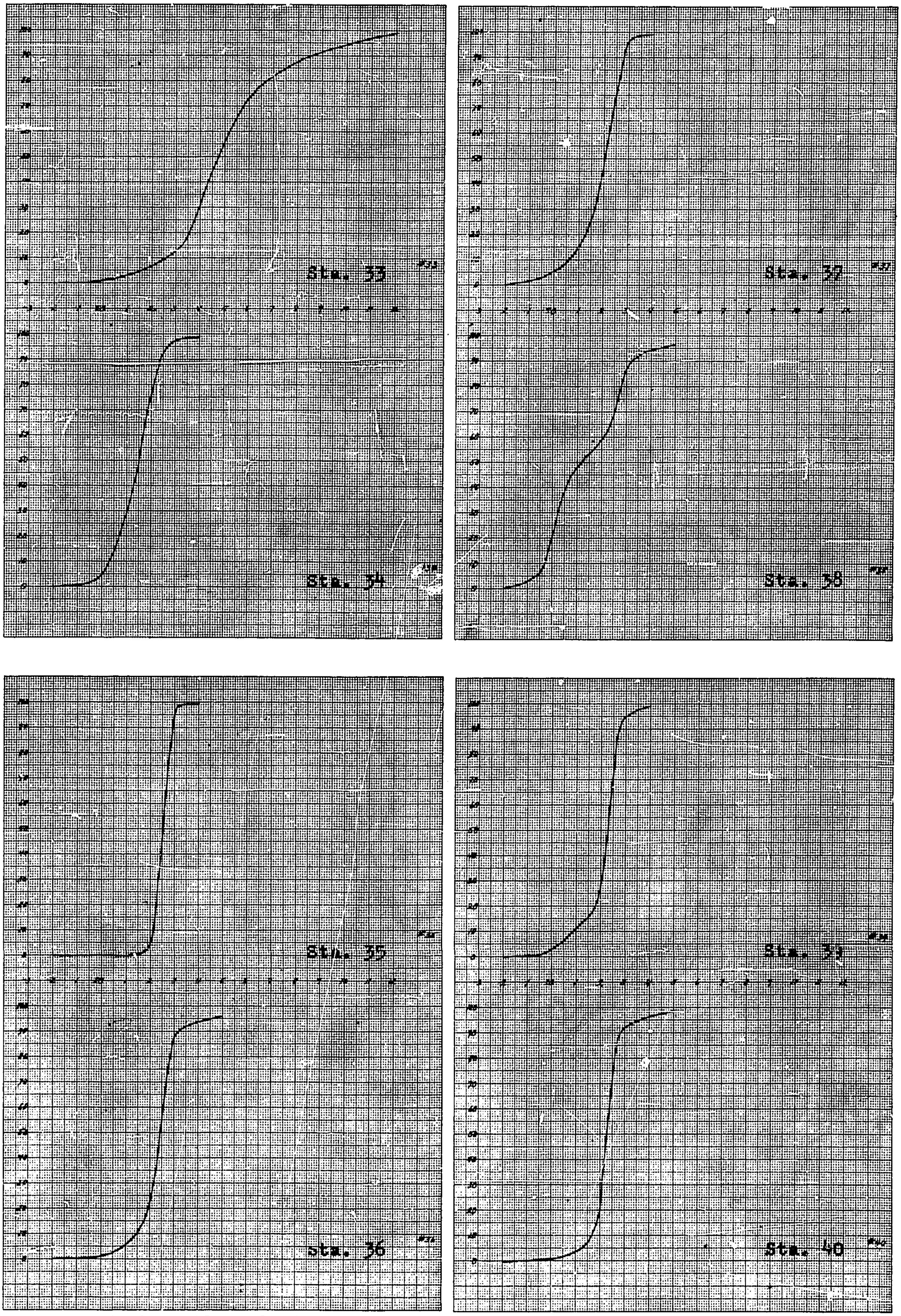
Horizontal scale in phi units, vertical scale in per cent.
Fig. 54 Cumulative Curve.



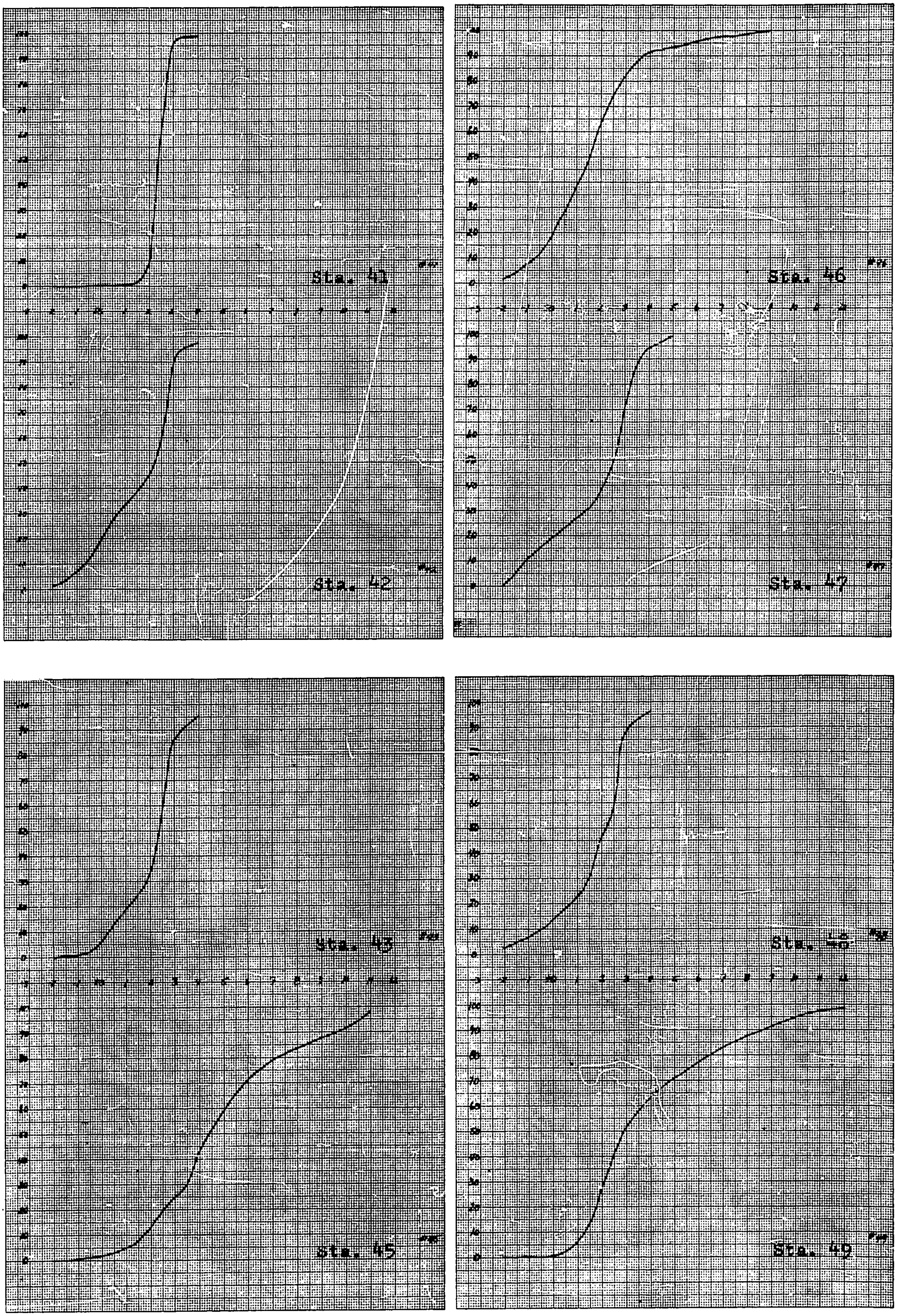
Horizontal scale in phi units, vertical scale in per cent.
Fig. 55. Cumulative Curves.



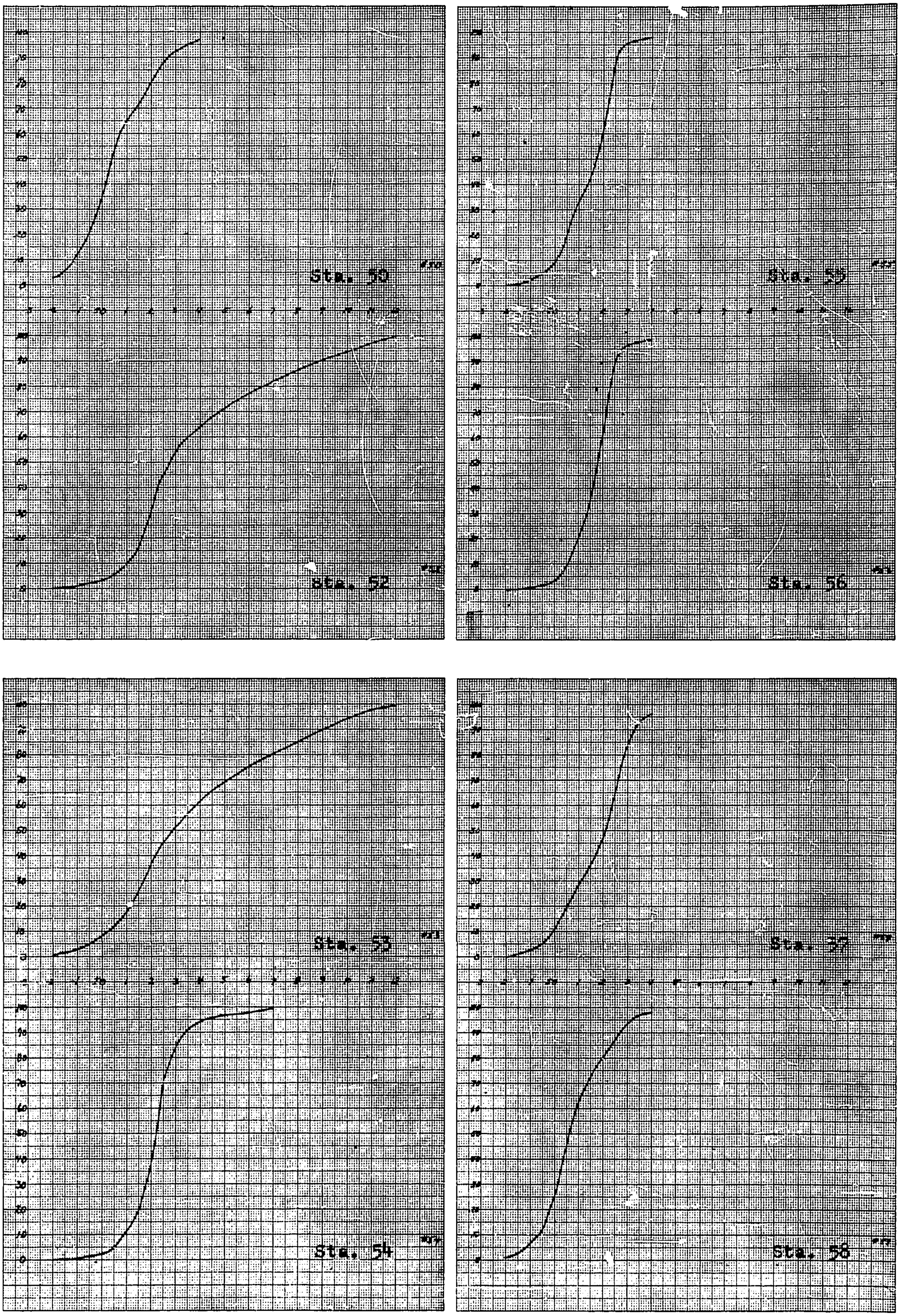
Horizontal scale in phi units, vertical scale in per cent.
Fig. 56 Cumulative Curves.



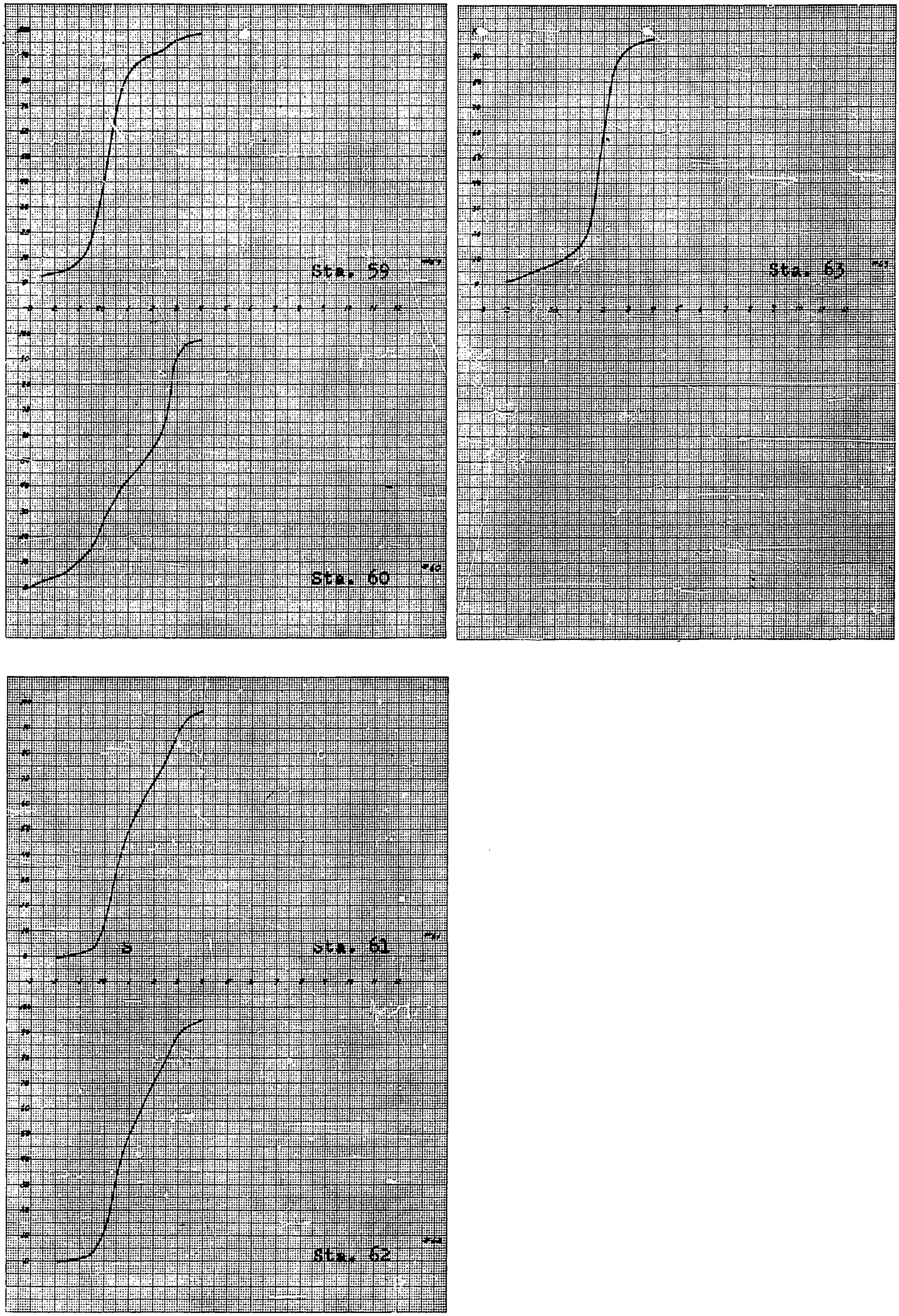
Horizonatl scale in phi units, vertical scale in per cent.
Fig. 57 Cumulative Curves.



Horizontal scale in phi units, vertical scale in per cent.
Fig. 58 Cumulative Curves.



Horizontal scale in phi units, vertical scale in per cent.
Fig. 59 Cumulative Curves.



Horizontal scale in phi units, vertical scale in per cent.
Fig. 60 Cumulative Curves.

VITA

James Bush was born in New York City, New York, on the 10th day of January 1920. His parents are A.M. Bush and Jean N. Bush. He attended elementary school and the Tilden High School in the City of New York. The New York University graduated him with an AB degree in geology in 1941. The AM degree in geology was granted him in 1949 from Indiana University, Bloomington, Indiana. At the present time he resides in Houston, Texas.