

CONTRIBUTIONS  
FROM THE  
CUSHMAN FOUNDATION  
FOR  
FORAMINIFERAL RESEARCH

---

VOLUME X, Part 2  
April, 1959

---

Contents

	PAGE
No. 196. Ecology of Living Planktonic Foraminifera in the North and equatorial Pacific Ocean John S. Bradshaw .....	25
Recent Literature on the Foraminifera Ruth Todd .....	65



## JOHN B. REESIDE, JR.

1889 - 1958

John B. Reeside, Jr., Vice-President and a founder of the Cushman Foundation, died of heart failure at his home in Hyattsville, Maryland, July 2, 1958. He was born in Baltimore, Maryland, June 24, 1889, educated in the public schools and The Johns Hopkins University, and received the doctor of philosophy degree in 1915. While a graduate student at Johns Hopkins, he was employed during three summer seasons as a field assistant on the United States Geological Survey and for his dissertation prepared a report on the Helderberg limestone, Lower Devonian, of western Maryland and central Pennsylvania. During World War, Part I, he served a year and two months as a first lieutenant in the Field Artillery, United States Army. On May 3, 1918, he married Adelaide C. Quesenbery who, with their two children, Corinna and John B. III, survive him.

Dr. Reeside's entire professional career was spent as a geologist and paleontologist of the United States Geological Survey. Concurrently he also cooperated as a custodian and eventually as an Honorary Research Associate of the United States National Museum. After graduation in 1915, he was employed as a technical aide and in 1916 as a geologist on the Survey staff. He was within a year of the statutory retirement age of 70 when he died.

At an early stage in Dr. Reeside's Survey career, he began his studies of the rocks and fossils of the Mesozoic and adjacent formations in the western and southwestern States. He alone and jointly with other authors published approximately 60 reports on the stratigraphy and paleontology of this area. The breadth and quality of these contributions are impressive, but it is possible that other aspects of his contributions were even more important than those conveyed in publications. He had an active interest in the principles of geology and paleontology and an exceptionally broad knowledge of the stratigraphic record in the United States. As the discernment and extent of his understanding became recognized, more and more persons discussed their scientific problems with him and increased calls were made on his time both in the Survey and in scientific societies for participation in field conferences or committee investigations and reports. In this way, his personal contributions through discussions with colleagues, committee conferences, field conferences, editing, and manuscript criticism gave an immeasurable but certainly a very large contribution to the progress of thought in his profession.

Dr. Reeside was modest and exceedingly generous. Though a very busy person, colleagues within and outside the Survey and Museum staffs, including those who served under his supervision, felt free to discuss scientific problems with him at any time or length. These discussions commonly took the form intellectually of a joint exploration and ended in clarified thinking or better points of view. In close scientific association such as I had with him for several years, differences in interpretation or opinion were bound to happen. One of the most gratifying things about that experience was the absence of his indicating, or of my feeling, a sense of personal victory or defeat on the outcome of the argument. It wasn't in his nature to impose his will or his ideas. He was patient with persons who annoyed him. For these reasons it is easy to understand his capacity for getting the confidence and cooperation of people of diverse abilities and character.

As Chief for 17 years of the Paleontology and Stratigraphy Branch in the Survey, Reeside gave every possible support to the work of J. A. Cushman at the Cushman Laboratory for Foraminiferal Research in Sharon, Massachusetts. Inasmuch as Cushman's death, April 16, 1949, brought an end to the Cushman Laboratory, Reeside took an active role in organizing the Cushman Foundation for Foraminiferal Research to preserve as much as possible of the program of that famous Laboratory. The perpetuation of the quarterly journal CONTRIBUTIONS, which was then in its 25th year and the oldest continuing paleontological journal in this country, and of the SPECIAL PUBLICATION series of longer papers and monographs was successfully undertaken. The support of the profession was immediate and has increased at a gratifying rate.

Since the organization of the Foundation, now in its 10th year, Dr. Reeside served as a member of the Board of Directors and at various times as an officer. At all times, he was one of the strongest and most



active supporters of the service given by the Foundation. All subscribers who benefit from the program of the Foundation are in some measure indebted to this man. Those of us who have served in close association with him are most aware and feel most keenly the loss of his counsel and cooperation.

It is gratifying to know that Dr. Reeside must have experienced much personal satisfaction and reward from his work. Among the honors he received were membership in the National Academy of Sciences, the Mary Clark Thompson Award for distinguished contributions in paleontology and stratigraphy, and scientific offices indicating the esteem of his profession. It was tragic that he should have died at a peak of energy and scientific production.

LLOYD G. HENBEST<sup>1</sup>

Published with approval of the Director, U. S. Geological Survey.

<sup>1</sup> Geologist, U. S. Geological Survey, Washington 25, D. C., President, Cushman Foundation for Foraminiferal Research. A detailed account of Dr. Reeside's life and work is being published by Ralph W. Imlay in the proceedings of the Geological Society of America, 1959.



CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION  
FOR FORAMINIFERAL RESEARCH

VOLUME X, PART 2, APRIL, 1959

196. ECOLOGY OF LIVING PLANKTONIC FORAMINIFERA  
IN THE NORTH AND EQUATORIAL PACIFIC OCEAN<sup>1</sup>

JOHN S. BRADSHAW

Scripps Institution of Oceanography, La Jolla, California

## ABSTRACT

Planktonic Foraminifera were examined from over 700 plankton tows taken at more than 400 stations in the North and equatorial Pacific Ocean. Twenty-seven species were identified and their frequencies determined.

Most specimens occur in the upper 100 m of water. The species appear to be randomly distributed throughout the upper levels with no indication of layering of the abundant species.

The planktonic Foraminifera in the North and equatorial Pacific can be grouped into four faunas: a cold-water fauna, a transition fauna, and two warm-water faunas. The regions they inhabit appear to be differentiated by characteristic temperature and salinity values. The cold-water fauna is limited to the area occupied by the Subarctic Water mass while the warm-water faunas are found throughout the region occupied by the Equatorial and Central water masses.

Highest populations per unit volume of water occur in the Subarctic Water and at limited localities in the equatorial region, lowest concentrations being found in the central oceanic areas. Abundance may be controlled by variations in distribution of inorganic phosphate.

## INTRODUCTION

Planktonic Foraminifera are important constituents of the plankton and are major contributors to extensive calcareous deposits covering the ocean floor. They inhabit surface waters of all the oceans from the tropics to the polar seas. It is necessary to understand their ecology to interpret their distributions in modern and ancient sediments and in deep-sea cores. The purposes of the present study are: (1) to determine the species of living planktonic Foraminifera which occur in the North and equatorial Pacific, (2) to describe the distribution and abundance of each species, and (3) to relate the distribution and abundance of the species to known environmental factors.

Most of the laboratory and field work was carried out using ships and facilities of the Scripps Institution of Oceanography. The study was supervised by Fred B Phleger. Frances L. Parker, Jean P. Hosmer, Robert R. Lankford, and Takayasu Uchio of the Marine Foraminifera Laboratory aided in identification of species, and with suggestions. Allan H. Bé of the Lamont Geological Observatory sent Atlantic specimens for comparison and made helpful suggestions. Robert H. Bieri aided both in the collection of field data and in discussions regarding the interpretation of

the results. James Moriarty drafted many of the illustrations.

## PREVIOUS WORK IN THE PACIFIC OCEAN

Work on the ecology of planktonic Foraminifera in the North Pacific has lagged behind that in the Atlantic. Most of the papers include descriptions of bottom specimens dredged near oceanic islands but give little pertinent information about environmental relationships.

The first systematic sampling of living planktonic Foraminifera in the Pacific was carried out by the CHALLENGER in 1874. Forty-five plankton samples, scattered throughout the North and South Pacific, were reported by Brady (1884) and Murray (1895). Agassiz (1902) reported (but did not identify) planktonic Foraminifera from net tows during the voyage of the ALBATROSS (1899-1900) to the tropical Pacific. Three plankton samples from near New Zealand were analyzed for planktonic Foraminifera by Heron-Allen and Earland (1922).

Recently, interest in the ecology of planktonic organisms has led to the systematic collection of thousands of plankton samples by many agencies throughout the world. The Pacific Oceanic Fisheries Investigation (POFI) based at Hawaii has taken many samples in the equatorial Pacific from 1950 to the present. In the early work of this organization various plankton groups (including Foraminifera) were analyzed separately. The reports of King and Hida (1957) furnish extensive information on the variations in abundance of Foraminifera in the equatorial Pacific although no information is given concerning the distribution of species.

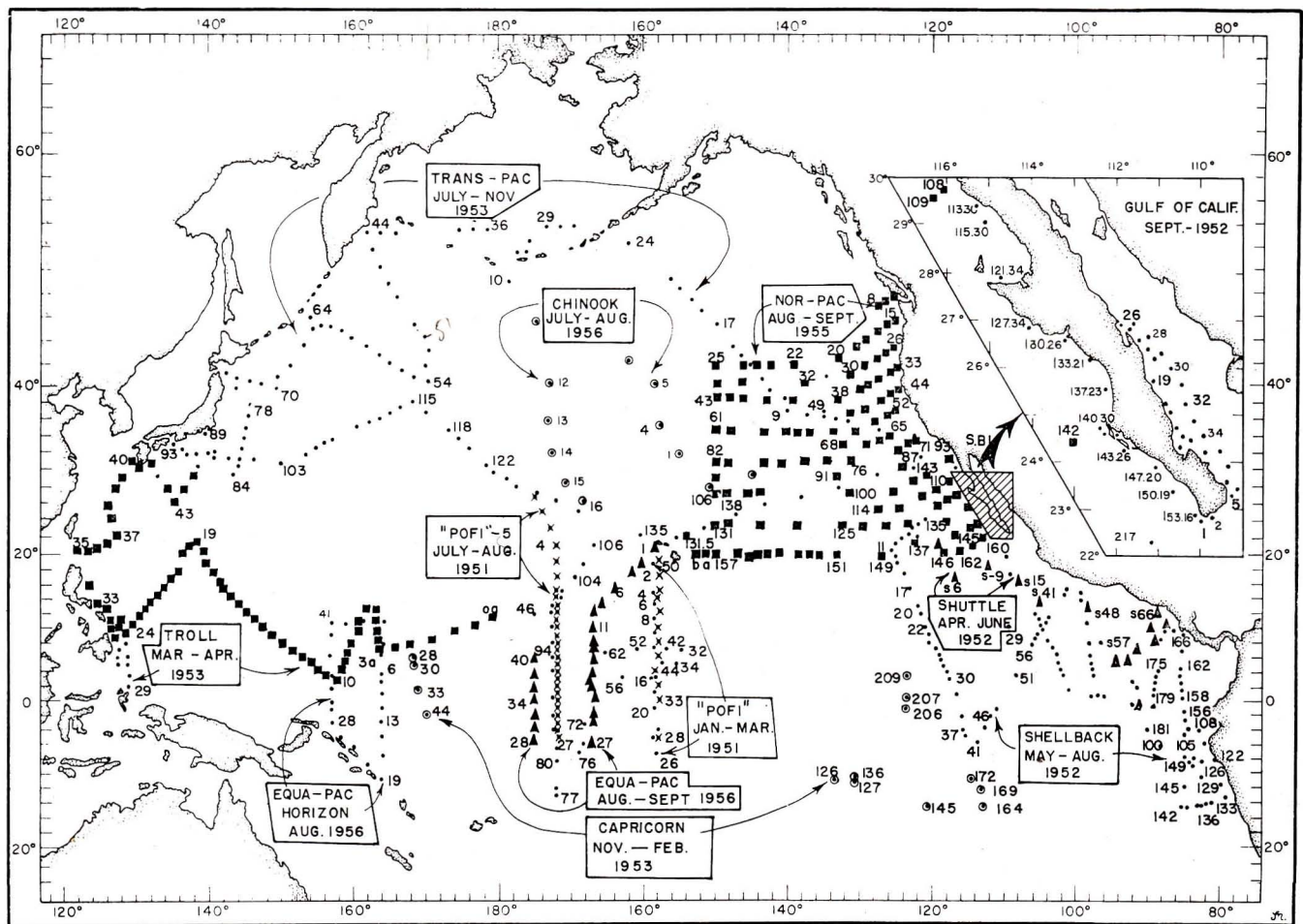
## METHODS OF STUDY

*Field Methods*

The Foraminifera studied were from more than 700 plankton samples taken during expeditions of the Scripps Institution of Oceanography, the U. S. Fish and Wildlife Service, the Pacific Oceanic Fisheries Investigation (POFI), and the U. S. Navy Electronics Laboratory (*see* Text fig. 1). Station data including positions, methods of sampling, physical and chemical observations etc., are on file at the Scripps Institution and, in part, at the library of the University of California, Los Angeles. Some of the physical data have been published (Cromwell, 1954; Wooster and Cromwell, 1958). Observations of temperature (Text fig.

<sup>1</sup> Contribution from the Scripps Institution of Oceanography, New Series. Contribution no. 29, Marine Foraminifera Laboratory.





TEXT FIGURE 1  
Locations of stations.

2), salinity (Text fig. 3) and organic phosphate concentrations (Text fig. 6) are given here.

Three types of plankton nets were used for sampling: the standard one meter net, the 17 cm truncated net, and the Clarke-Bumpus sampler. The meter net has been routinely used by Scripps expeditions and by the POFI program in the Pacific. This net has a mouth diameter of 1 m and a length of approximately 5 m. The front and middle sections are made of no. 30xxx silk grit gauze with apertures of 0.65 mm when new, shrinking to about 0.55 mm after use. The rear section and cod end are of no. 56xxx silk grit gauze with effective apertures of 0.31 mm. A current meter is fitted in the net mouth to record the approximate amount of water filtered. A detailed description of this net has been given by King and Demond (1953). By adding a non-filtering canvas section for a puckering line this same net was used as a closing net to obtain uncontaminated deep samples during the Norpac Expedition.

The 17 cm net consists of two sections, a non-filtering, truncated front portion and a filtering cone-shaped rear section. The non-filtering section has a mouth diameter of 17 cm and a length of 15 cm. The filtering portion, which is 46 cm long, has a diameter at the forward end of 24 cm, becoming narrower toward the cod end. The cod end is an 8 oz. glass jar with a

diameter of 5 cm. The truncated front section is of muslin, the rear section of no. 20 bolting silk (average opening 0.07 mm).

The Clarke-Bumpus sampler (Clarke and Bumpus, 1940) will record the approximate quantity of water filtered and can be made to open and close at any desired depth. In the present work it was fitted with nets of either no. 8 or no. 20 bolting silk with apertures of 0.14 mm and 0.07 mm respectively.

The oblique tows were made by lowering the net slowly at uniform speed and, when the required depth was reached, raising it at a uniform rate of approximately 5 m per minute. Throughout the period of the haul the time and wire angle were noted. Depth and duration of tow at each depth were calculated by assuming that the towing wire describes a straight line. Approximately equal amounts of time were spent at all depths from the surface to the greatest depth sampled. Horizontal tows for study of vertical distribution were made with the same equipment but the net was opened by messenger at predetermined depths. Vertical hauls with the 17 cm net were made while the boat was stopped. The net, with a weighted cod end, was attached to a light line and lowered slowly by hand to the maximum depth and then retrieved at a rate of approximately one-half meter per second. Plankton clinging to the upper part of the net was



washed into the cod end and transferred to a sample jar. Neutralized formalin was added to make a 5 to 10 per cent solution.

#### *Laboratory Methods*

The rose Bengal staining technique described by Walton (1952) was used in the early stages of the work to distinguish living from dead specimens. Staining procedures were used in the analysis of samples for vertical distribution studies but the routine staining of samples from the upper water layers was discontinued when it was observed that most of the Foraminifera contained protoplasm. The use of stains in analyzing plankton samples is time-consuming, makes identification more difficult, and often decreases the usefulness of the sample for other purposes. Furthermore, the living specimens can usually be distinguished from the empty tests by the color of their unstained protoplasm. It is possible that some empty tests have been included in the counts of each species. The error caused by these few extra tests in samples from the upper layers is believed to be insignificant, particularly in view of the much larger errors involved in other phases of plankton sampling.

The entire sample was poured into a gridded, plastic counting tray. It was found that frequently the lighter elements of the plankton could be decanted from the tray leaving the Foraminifera and pteropods behind. An efficient separation could be made in tropical samples where the foraminiferal tests were large and heavy but when smaller specimens (usually spinose) occurred this was not true. The plankton was distributed evenly in the tray and all specimens of Foraminifera were examined. Those smaller than 140  $\mu$ , with the exception of *Globigerinoides* cf. *G. minuta*, were excluded from the counts since identification of these small forms is subject to error. All the specimens from samples containing fewer than 200-300 specimens were counted. In many larger samples, the more abundant forms in a known fraction were counted, although the entire sample was used for counting the rarer ones. Several specimens of each species were picked by pipette from each sample for reference. Distributions of each species are shown in Text figures 7-33. More detailed information on occurrences of species and the population per 1000  $m^3$  is on file, as previously mentioned.

#### *Effect of Different Sampling Methods*

Ideally, to sample the entire foraminiferal population of an area, all the specimens in a water sample of known volume should be counted. This was done by Hentschel (1934) for *Globigerina*. In one-liter samples of the surface water from many localities in the Atlantic he found the number to vary from 0 to 50 specimens of all size groups. The individuals from such small samples, however, were mostly small forms which were difficult to identify. To obtain a sample con-

taining sufficient specimens for accurate species identification much larger quantities of water must be collected. The difficulties involved in handling and analyzing such large volumes of water are so great that fine-mesh nets have almost always been used for routine sampling. Presumably some of the very smallest individuals are still lost but since identification of these is almost impossible at present this loss does not alter the data on species distributions obtained.

It is believed that the 17 cm net and the Clarke-Bumpus samplers with fine-mesh nets sample the smaller specimens adequately, since the aperture of the netting used is fine enough to prevent all but the smallest stages from passing through. However, the smaller volume of water filtered (1-4  $m^3$ ), as compared with approximately 1,000  $m^3$  for the meter net, results in the inadequate sampling of rare species and larger forms. A further disadvantage of fine-mesh nets is that they retain large quantities of phytoplankton which makes foraminiferal analysis difficult.

The meter net filters large quantities of water (approximately 1,000  $m^3$  for a 30-minute tow) and obtains large numbers of easily identifiable specimens with very few phytoplankton. Since the effective aperture of the front section of the net is relatively large (0.55 mm), many smaller individuals may pass through and not be represented proportionately in the sample. Some specimens of smaller size, nevertheless, are still found in the sample, probably because they are retained by the finer section of the net. This may be due also to the spinose nature of the specimens and some decrease of mesh size by clogging.

The use of samples obtained with three different nets and three different mesh sizes introduces problems in interpretation of results. Comparisons between the total number of specimens of Foraminifera retained by nets of the different mesh sizes (0.55 mm and 0.14 mm) taken during the Transpac Expedition show that for the same depths and volume of water filtered the tow using the finer mesh caught from 9 to 370 times as many specimens as that using the coarser net. Similar results are indicated by data presented by King and Hida (1957). In their work a comparison was made of the effect of two different mesh sizes on the plankton volume, the number of zooplankters per unit of water strained, and the percentage composition of the catch. Pairs of consecutive hauls, the first with a net of 0.31 mm apertures and the second with a net having apertures of 0.55 mm, were made at three stations in the equatorial region. King and Hida found that the average plankton volume obtained by the finer mesh nets for the same volume of water filtered was from  $1\frac{1}{4}$  to  $1\frac{3}{4}$  times that of the coarser mesh nets. The fine-mesh nets retained three to five times as many organisms as the coarse-mesh nets, the greatest difference being in the larger numbers of Foraminifera and copepods retained in the fine-mesh nets.



### Variations Due to Patchiness

In some areas the drawing of closely spaced isopleths showing Foraminifera concentrations has not been possible because of extreme fluctuations in numbers from adjoining stations. Certain other regions, however, show generally consistent values over wide areas. The patchiness of plankton has been noted by many workers and contributes an unknown source of error in quantitative sampling. The filtering of a large volume of water over long horizontal distances may minimize variations due to uneven distributions.

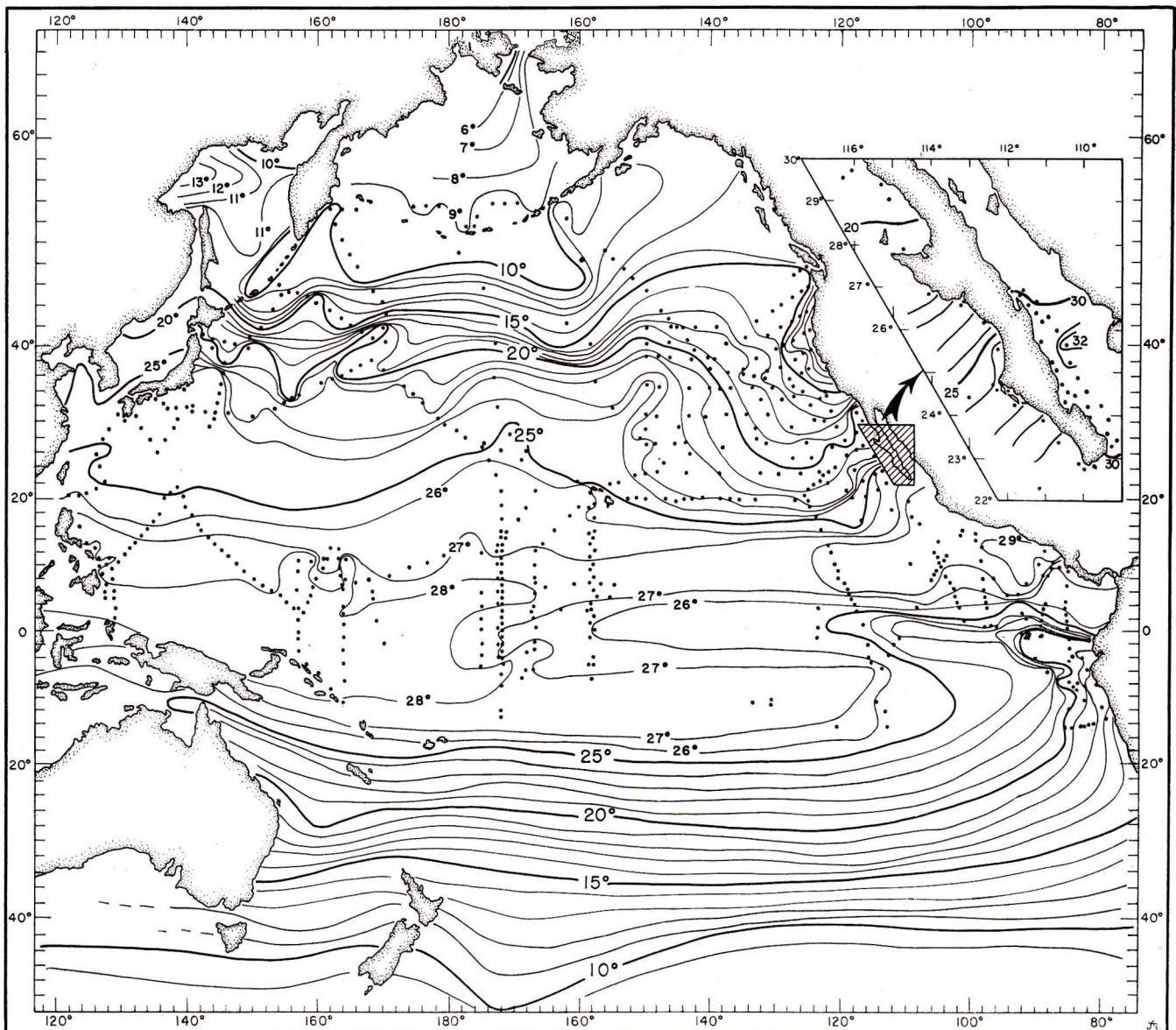
Not so well-known are the facts that the vertical distribution of Foraminifera and the depth of the water filtered by the net also will influence the quantitative results. For example, an oblique tow to 200 m samples the upper 50 m only 25 percent of the time. If the bulk of the population is in the surface layers of 0 to 50 m depth, such a tow will indicate a smaller number of specimens per unit volume than actually occurs at the level of maximum concentration.

Certain irregularities have been introduced in this study by considering all stations equally, regardless of season or time of day. More detailed studies of seasonal and diurnal variations will be necessary to understand fully the variations caused by these factors.

## DESCRIPTION OF THE ENVIRONMENT

### General Features

The area of investigation includes the North Pacific and a part of the South Pacific extending to approximately 16° S Lat. The physical oceanography of this large area is complex. Distributions of sea-surface temperature (Text fig. 2) are primarily related to the greater heating of the water in the tropics than in higher latitudes. The salinity values (Text fig. 3) are dependent upon the relation between the processes of evaporation and precipitation with the result that the maximum salinities are found not in the equatorial regions but in the sub-tropical belt. Nevertheless, there is a general correlation between surface temper-



TEXT FIGURE 2

Distribution of sea surface temperatures (°C). N. Pacific values at time of collection; S. Pacific values for August (after Sverdrup *et al.*, 1942)



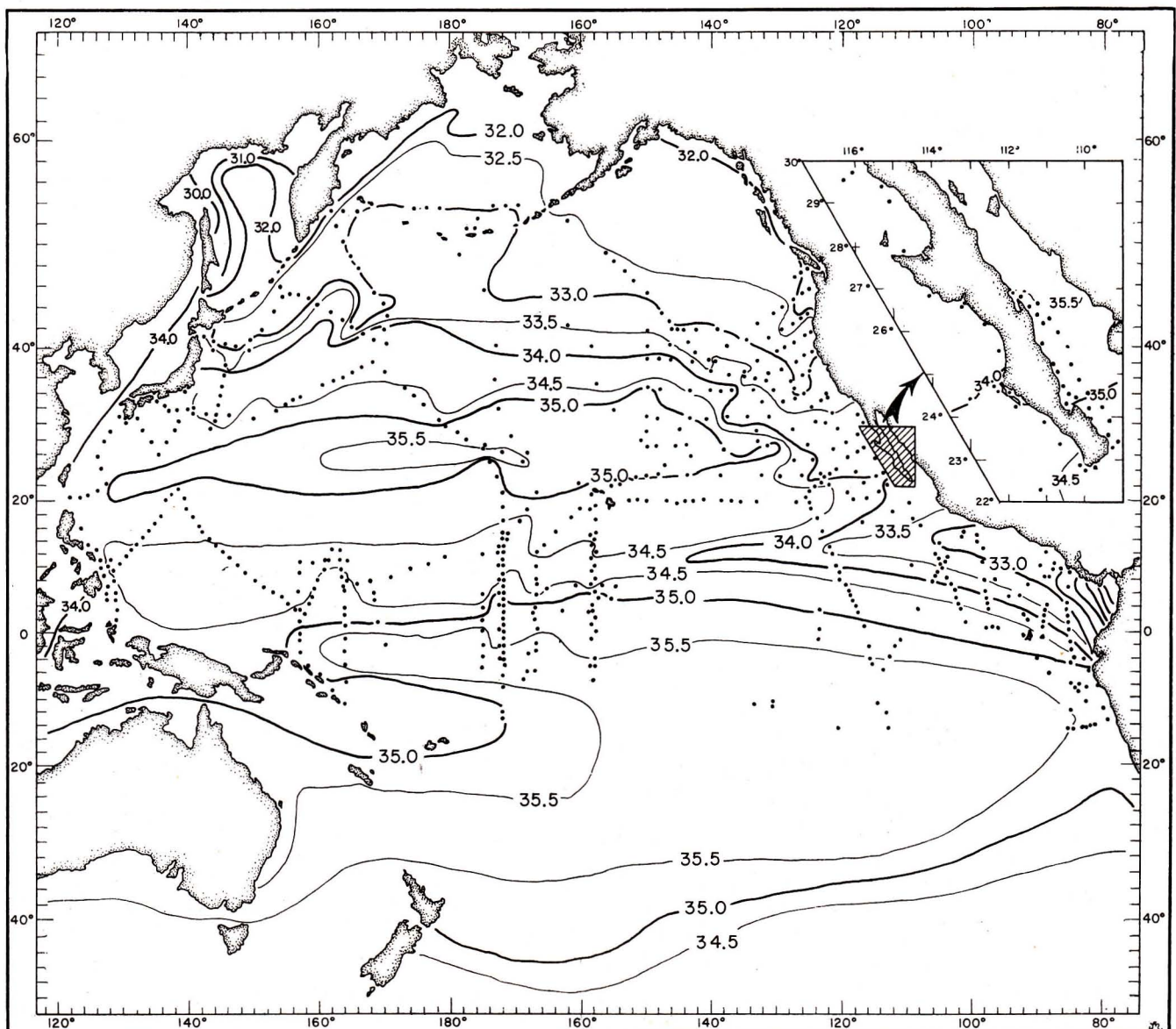
atures and salinities so that high temperatures usually are associated with high salinities and low temperatures with low salinities. The greatest horizontal change in these variables occurs in the North Pacific at the Arctic Convergence (or Polar Front) near 40° N Lat. The steepest gradients are found in the western North Pacific off Japan, whereas the eastern North Pacific is characterized by less abrupt changes.

Prevailing winds and the density structures of the various water masses have resulted in a series of clockwise circulations for the North Pacific (see Text fig. 4). The North and South Equatorial currents flow westward between the equator and Lats. 20° to 25° N and sandwiched between (in Lats. 5° to 10° N) is the Equatorial Countercurrent flowing to the east. Near the Philippine Islands the North Equatorial Current divides, part turning north to become the warm Kuroshio. Along the Japanese coast at about 35° N Lat. the Kuroshio turns seaward and divides into two branches. The smaller northern branch continues to

the northeast where it mixes with the cold, low salinity Oyashio flowing down from the north. The main stream continues to the east as the warmer North Pacific Current and sends off numerous eddies to the south as it goes.

Along the boundary of the Kuroshio and Oyashio, mixing of the surface waters results in the formation of the cold Subarctic Current which flows eastward between the Aleutian Islands and Lat. 42° N. Upon reaching the American west coast most of the water turns southward as the broad, cool, low salinity California Current, which can be traced to about Lat. 25° N where it merges with the North Equatorial Current to complete the major current gyre in the North Pacific.

The combination of density differences, due to unequal heating and evaporation at the surface, and the action of surface currents have resulted in the formation of large semi-permanent masses of water having certain characteristic properties. These large bodies of



TEXT FIGURE 3

Distribution of sea surface salinities (o/oo)



water are called *water masses* and are defined oceanographically on the basis of their temperature and salinity distributions. The characteristic temperature and salinity values reflect to some extent the climate of the source region. As currents move this water from its place of origin, mixing occurs with other waters, but the various sources can still be recognized. Water masses undoubtedly have other physical and chemical characteristics that are as yet too subtle for analysis but which may be important for various constituents of the plankton. Text figure 4 shows the geographic extent of the upper water masses of this region.

#### *Subarctic North Pacific Region*

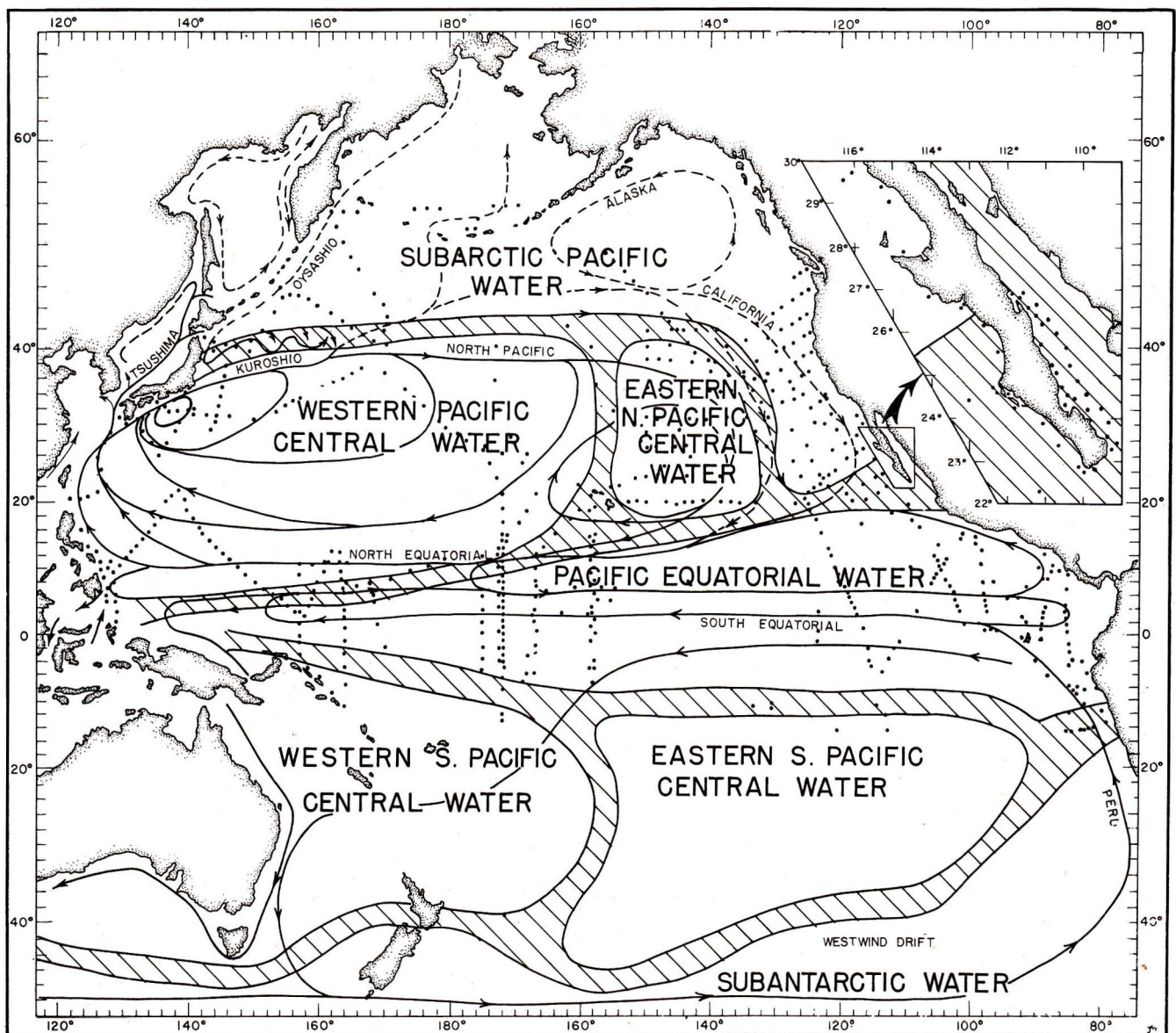
Subarctic Water is found north of Lat.  $45^{\circ}$  N where it is characterized at the surface by low temperatures and salinities (*see* Text fig. 5). North of the Aleutian Islands, the surface temperature varies from near  $0^{\circ}$  C in the coldest month (February) to about  $8^{\circ}$  C in the warmest (August). Surface currents transport large

amounts of this water toward the east and south along the west coast of North America. As it travels from the source region the temperature and salinity increase so that the water gradually loses its subarctic character. The greatest annual temperature range ( $21^{\circ}$  C) occurs at approximately  $40^{\circ}$  N Lat. near Japan. From this maximum value the temperature range decreases toward the northeast and east to approximately  $5^{\circ}$  C off the coast of North America (Lat.  $40^{\circ}$  N).

The surface phosphate concentration is generally high throughout this region (*see* Text fig. 6). Wooster (1953, p. 50) reports a sharp increase just south of the boundary between the Aleutian and North Pacific currents, and high values throughout the area to the north.

#### *Transition Region (California Current)*

Sverdrup *et al.* (1942) limit this region to the area between Lats.  $48^{\circ}$  and  $23^{\circ}$  N where the southward-flowing Subarctic Water converges with the Equatorial



TEXT FIGURE 4

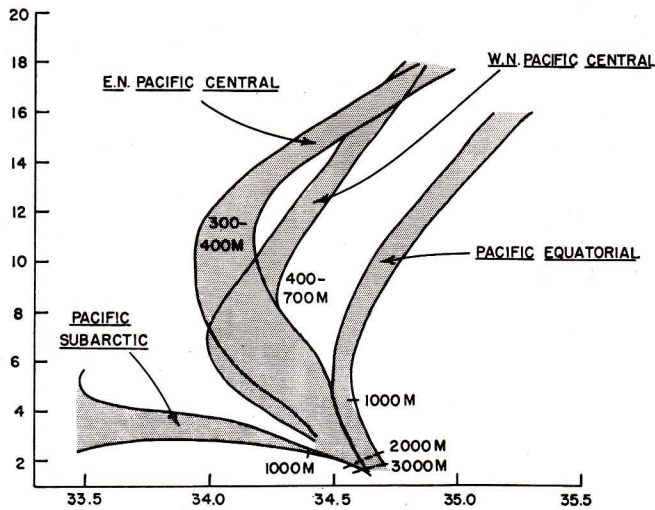
Approximate boundaries of the upper water masses of the Pacific Ocean together with course of the major ocean currents.



Water. The western extent is represented by the boundary of the Subarctic and the North Pacific Central waters. The annual surface temperature range is not extreme, varying from approximately 7° C in the northwest to 3° C in the southwest. Near the coast the seasonal range varies from 3° C along the coast of Washington to 6° C at various localities along south-

ern California and Baja California. This region is dominated by the southward, slow-moving California Current, but seasonal changes in the upper layers cause more complex conditions in certain localities.

Sverdrup and Fleming (1941) report a subsurface counter current (below 200 m) close to the coast carrying large quantities of Equatorial Water northward. In the fall and winter this water is present at the surface as the Davidson Current, which flows north on the coastal side of the California Current at least as far as Lat. 48° N. The predominance of northwesterly winds, together with sharp breaks in the coastline, result in the offshore transport of surface water causing upwelling of cold subsurface water at various points along the coast. There is some upwelling throughout the year but the strongest occurs during spring and early summer. In this region upwelling returns nutrients, including relatively high concentrations of phosphate, into the euphotic zone so that usually there is an increase in phyto- and zooplankton production.

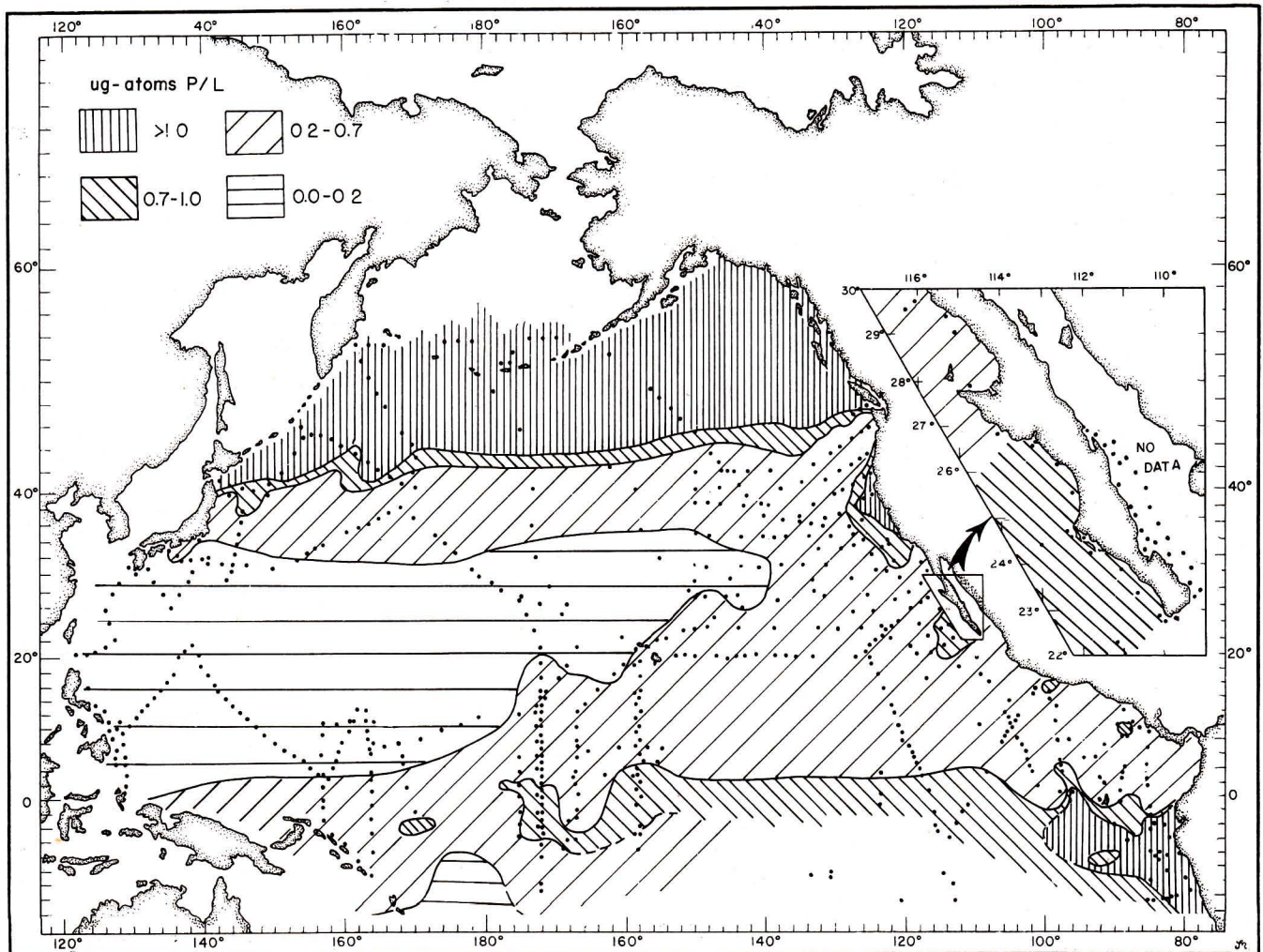


TEXT FIGURE 5

Temperature-salinity relations of the surface water masses of the North Pacific Ocean.

*North Pacific Central Region*

In general, the water masses characteristic of this region have properties intermediate between the Subarctic Water and the Equatorial Water. The eastern



TEXT FIGURE 6

Distribution of inorganic phosphate in the surface layers (information taken from various sources).



portion, extending from the longitude of Hawaii to the transitional water of the California Current, differs slightly in its temperature-salinity character from the larger western expanse and has been designated as a separate water mass. This Eastern North Pacific Central Water is distinguished from the Western North Pacific Central Water by lower salinity values at depths of 300-400 m. In the center of the western North Pacific gyral the yearly temperatures vary from a minimum of 23° C to a maximum of 27.5° C. The annual range decreases towards the south and east from a maximum of 12° C off Japan to less than 2° C at the northern boundary of the California Current.

Graham and Moberg (1944) report that the surface phosphate values throughout this region are extremely low, with the low concentrations extending to considerable depths. They associated the low values with the steep density gradients and the poorly-developed current systems, both of which prevent upwelling of phosphate-rich water.

#### *Equatorial Pacific Region*

This region includes part of the equatorial warm-water belt which in the eastern Pacific lies between Lats. 18° S and 20° N. Towards the west it becomes narrower and finally disappears at the equator north of New Guinea.

In this area a mixed layer extends from the surface downwards to a narrow transition zone, below which lies the true Equatorial Water mass of very uniform character (*see* Text fig. 5). The base of the mixed layer varies from a depth of 50 m in the east to deeper than 150 m in the western Pacific. In the region of the equator, upwelling caused by the divergence of the surface water brings this base nearer the surface. The annual range of temperature is small over most of this region, the greatest changes occurring south of the Galapagos Islands (5° C annual range) and at the zones of upwelling along the equator. Throughout most of the region the seasonal range of temperature varies only 1-2° C.

## THE SPECIES OF PLANKTONIC FORAMINIFERA

### *General Statement*

Planktonic Foraminifera immersed in sea water are different in appearance from dried specimens. This fact, together with the presence of long, thin spines in many species and the presence of protoplasm and organic detritus, increases the difficulty of identification. This is particularly true of small specimens and, therefore, the identification of specimens with a diameter smaller than 140  $\mu$  was not attempted, except for the extremely small species *Globigerinoides* cf. *G. minuta*.

Since this was not primarily a taxonomic study, the nomenclature used by Phleger, Parker and Peirson (1953) in their study of North Atlantic Foraminifera has been used for simplicity. Since the completion of this work some of the generic designations have been questioned by various authors (*see* Bolli, Loeblich and Tappan, 1957, Hofker 1959, etc.) Admittedly the taxonomy needs revision but the author feels that our lack of knowledge of internal structure and the biological relationships of the planktonic species does not permit us to clarify the status of these forms at the present time.

A detailed synonymy and taxonomic discussion of each species is not given. The synonymies include the original reference and others of special interest. Species not listed by Phleger *et al.* (1953) are briefly described and a short summary of the information gained through this study is included. The species are listed in alphabetical order. Figured hypotypes have been deposited at the U. S. National Museum, Washington, D. C.

## SYSTEMATIC DISCUSSION

### *Candeina nitida* d'Orbigny

Plate 7, figure 19

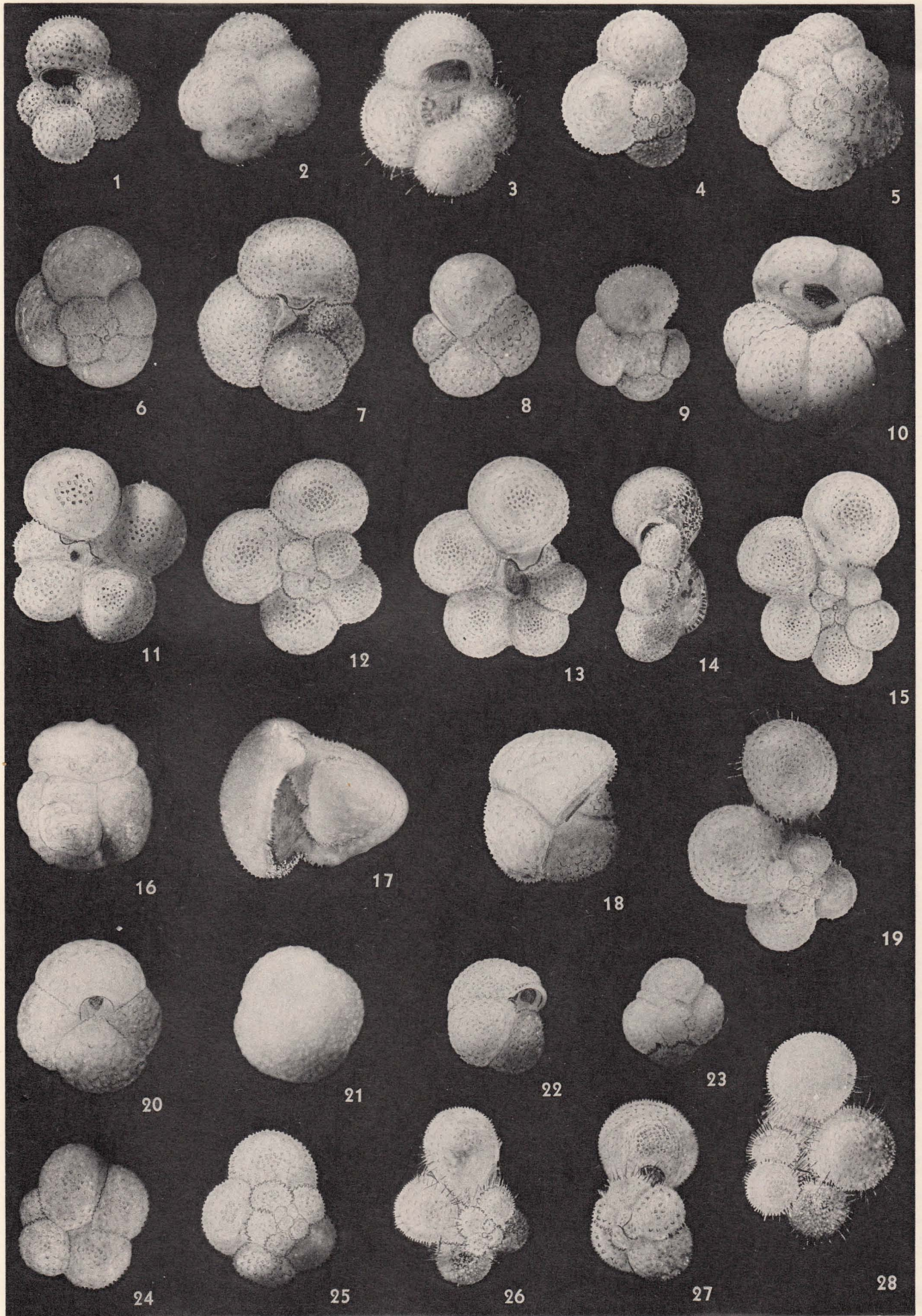
*Candeina nitida* d'ORBIGNY, 1839, in DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 108, pl. 2, figs. 27, 28.

This species (Text fig. 7) is found in the tropical and warm-temperate regions of the Pacific with its

## EXPLANATION OF PLATE 6

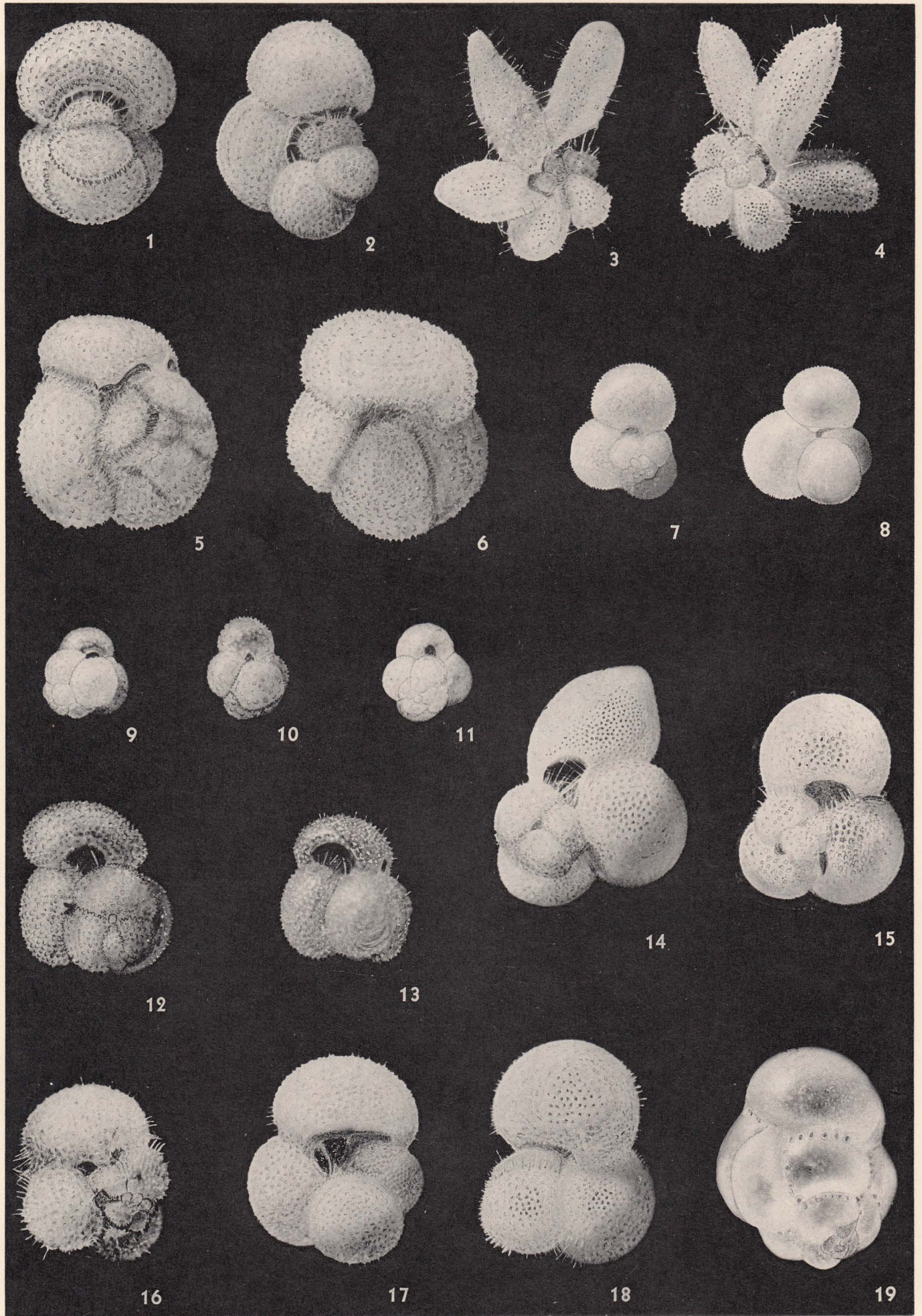
FIGS.	PAGE
1-4. <i>Globigerina bulloides</i> d'Orbigny. $\times$ 67. 1, 4, Shellback sta. 136; 2, 3, Transpac sta. 32 .....	33
5, 8-10. <i>Globigerina eggeri</i> Rhumbler. $\times$ 65. 5, 10, adult specimens; 8, 9, juvenile specimens. Transpac. sta. 13 .....	35
6, 7. <i>Globigerina conglomerata</i> Schwager. 6, $\times$ 47; 7, $\times$ 31. Equapac-s sta. 21 .....	33
11-15. <i>Globigerina hexagona</i> Natland. $\times$ 65. 11, 12, Shellback sta. 76; 13-15, variant form, Shellback sta. 61 .....	36
16-18. <i>Globigerina inflata</i> d'Orbigny. $\times$ 65. Transpac sta. 108 .....	36
19, 26-28. <i>Globigerina</i> sp. $\times$ 47. Equapac-s sta. 21 .....	38
20-23. <i>Globigerina pachyderma</i> (Ehrenberg). 20, 21, $\times$ 102, Transpac sta. 32; 22, 23, variant forms, $\times$ 65, Transpac sta. 22 .....	36
24, 25. <i>Globigerina quinqueloba</i> Natland. $\times$ 102. Transpac sta. 15 .....	38





Bradshaw: Living Planktonic Foraminifera, Pacific Ocean





Bradshaw: Living Planktonic Foraminifera, Pacific Ocean



maximum concentration near the Hawaiian Islands. Patches with lower concentrations occur within the Equatorial Water from Panama to the Philippines.

**Globigerina bulloides** d'Orbigny  
Plate 6, figures 1-4

*Globigerina bulloides* D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 277, no. 1; Modèles, no. 76; and young, no. 17.

The Pacific specimens are slightly more compact than those reported by Phleger *et al.* (1953) from the Atlantic but it is doubtful that this constitutes a specific difference.

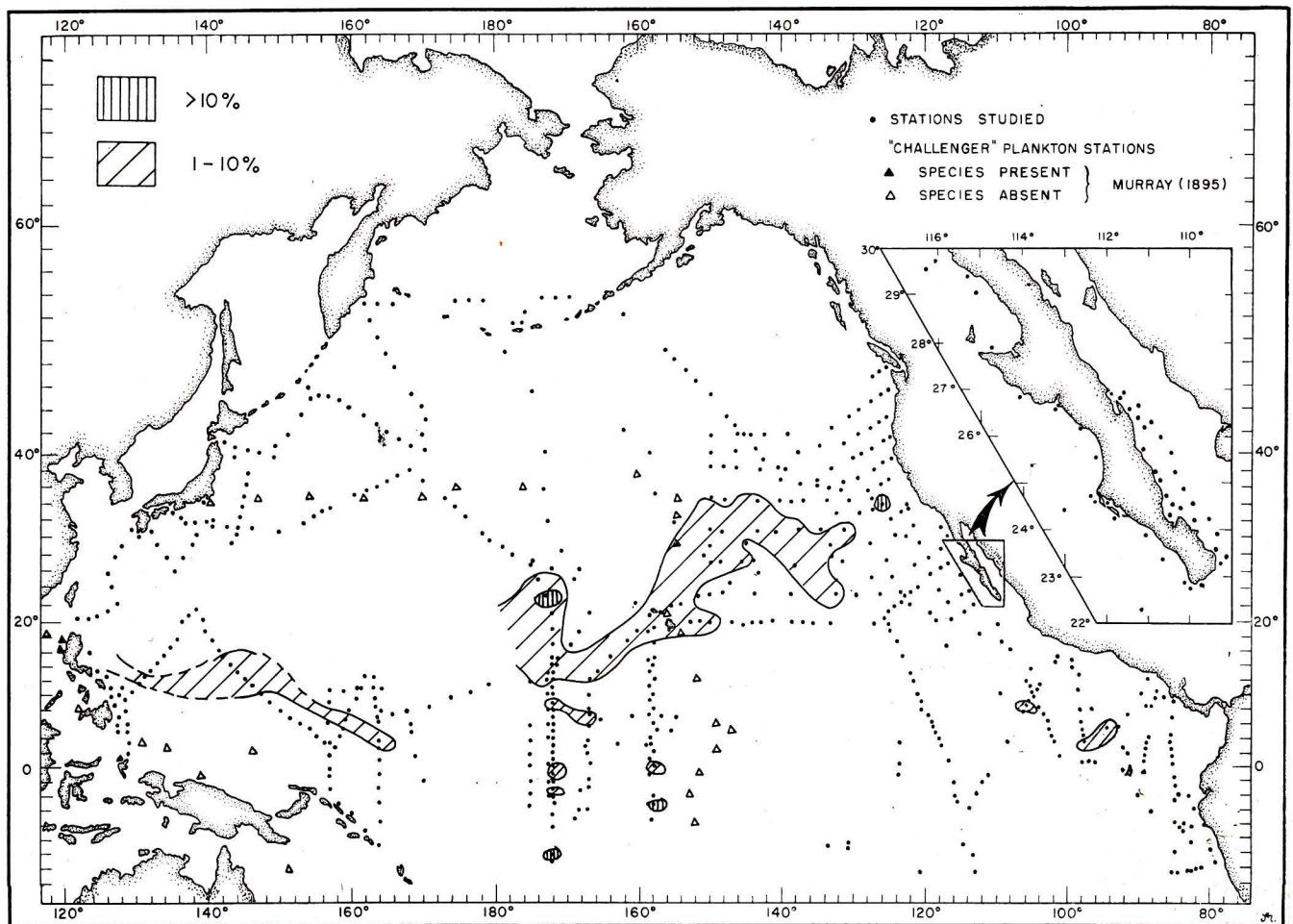
There has been some confusion in the literature regarding this species. Some authors (for example, Cushman, 1914, 1927) have included in their "G.

*bulloides*" forms which are now included in *Globigerinoides sacculifera*.

Highest frequencies (Text fig. 8) occur in northern latitudes and occasionally low frequencies were noted in equatorial waters. *Globigerina bulloides* shows the closest affinity to the "cold-water fauna." In temperate latitudes it occurs throughout the water column sampled. Rare occurrences in deep oblique hauls in the equatorial Pacific suggest that it may live at greater depths in this region.

**Globigerina conglomerata** Schwager  
Plate 6, figures 6, 7

*Globigerina conglomerata* SCHWAGER, 1866, Novara-Exped., Geol. Theil, vol. 2, p. 255, pl. 7, fig. 113.

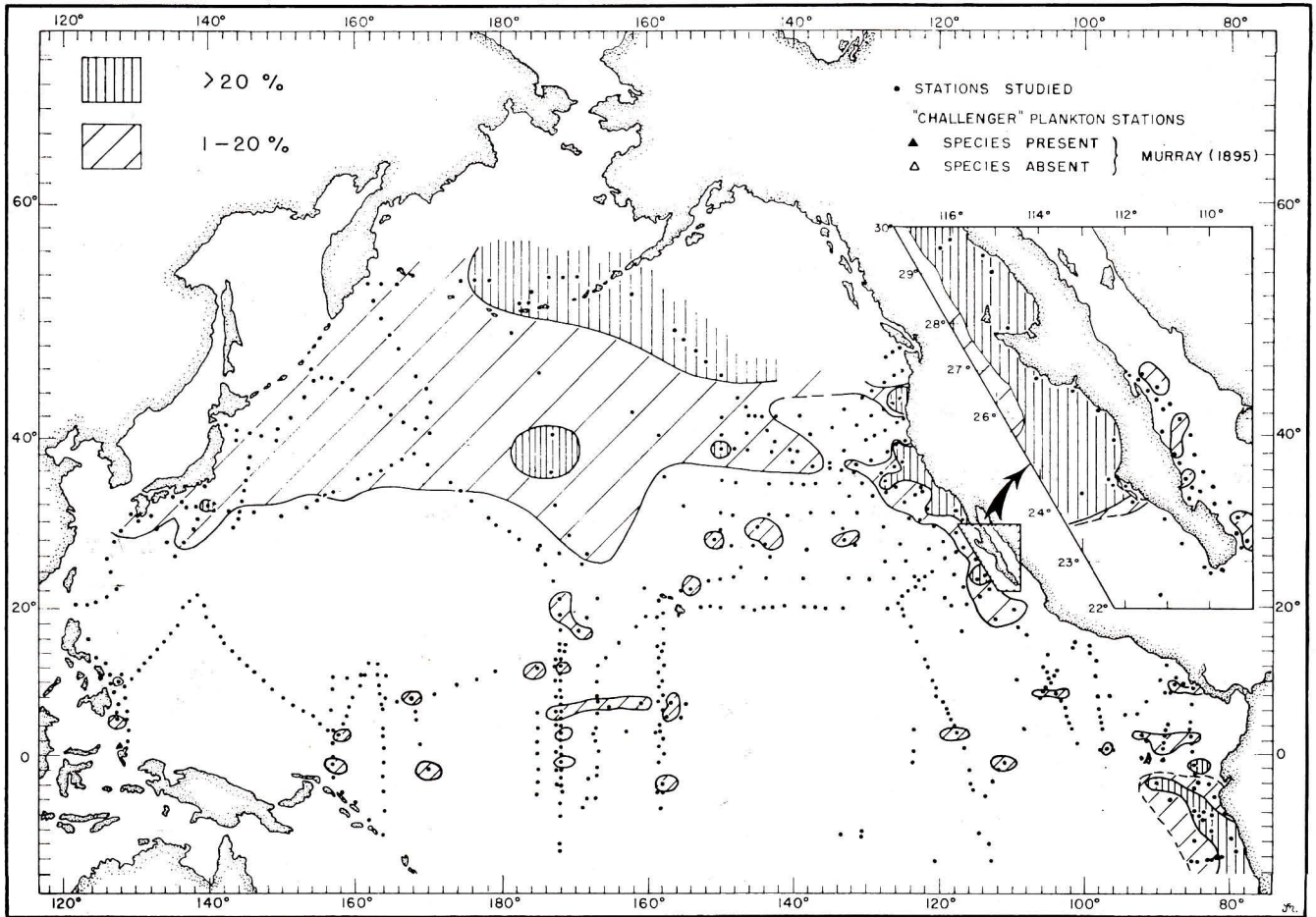


TEXT FIGURE 7  
Distribution of *Candeina nitida* d'Orbigny

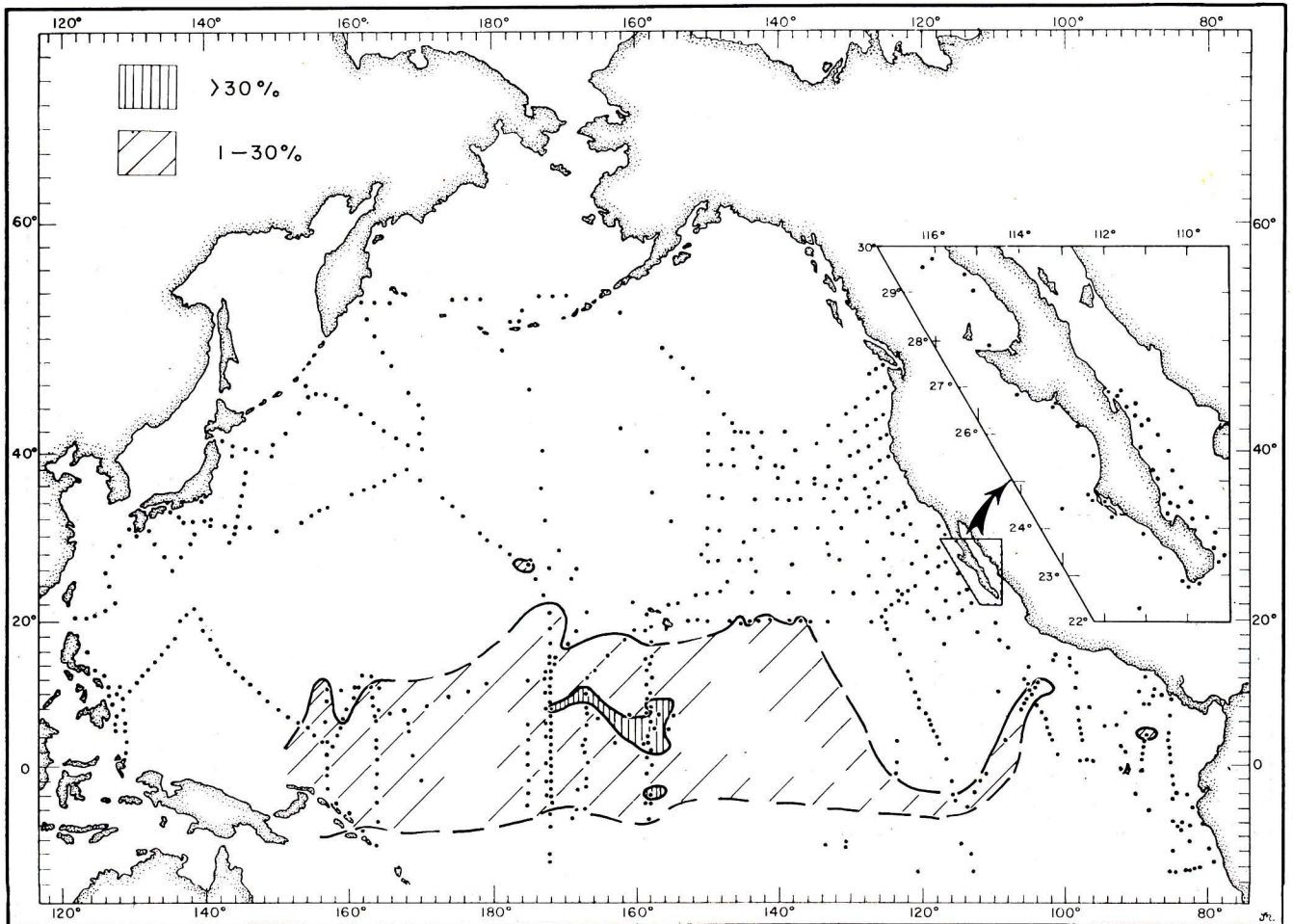
EXPLANATION OF PLATE 7

FIGS.		PAGE
1, 2.	<i>Globigerinella aequilateralis</i> (Brady). × 47. Equapac-s sta. 21 .....	38
3, 4.	<i>Globigerinella</i> sp. × 31. Troll sta. 14 .....	38
5, 6.	<i>Globigerinoides conglobata</i> (Brady). × 47. Troll sta. 17A .....	40
7, 8.	<i>Globigerinita glutinata</i> (Egger). × 65. POFI-5 sta. 20 .....	40
9-11.	<i>Globigerinoides</i> cf. <i>G. minuta</i> Natland. × 102. Transpac sta. 51 .....	40
12, 13.	<i>Globigerinoides rubra</i> (d'Orbigny). × 65. Equapac-s sta. 21 .....	42
14, 15, 18.	<i>Globigerinoides sacculifera</i> (Brady). × 47. Shellback sta. 80 .....	42
16, 17.	<i>Globigerinoides</i> sp. × 47. Shellback sta. 30 .....	42
19.	<i>Candeina nitida</i> d'Orbigny. × 47. Troll sta. 16A .....	32





TEXT FIGURE 8  
Distribution of *Globigerina bulloides* d'Orbigny



TEXT FIGURE 9  
Distribution of *Globigerina conglomerata* Schwager



This species superficially resembles *G. bulloides* in having four chambers in the last-formed whorl but differs from it in having a slightly less lobate and more massive structure and an aperture which is smaller and not so smoothly rounded. The last chamber has a characteristic triangular shape, often with a lip extending partially into the aperture.

This form has been confused by some authors with *G. eggeri* Rhumbler. Brady (1884, p. 596), for example, after examining specimens of *G. conglomerata* from Kar Nicobar considers them to be almost identical with his "*G. dubia*" Egger" (= *G. eggeri*). Cushman's (1921, 1927) records of "*G. conglomerata*" from the west coast of North America and the Philippines are doubtful in view of his confusion of this species with *G. eggeri*.

This is the first recorded occurrence of this species from plankton tows. It is confined to the equatorial Pacific (Text fig. 9).

#### *Globigerina digitata* Brady

*Globigerina digitata* BRADY, 1879 (part), Quart. Jour. Micr. Sci., vol. 19, p. 72; 1884 (part), Rept. Voy. CHALLENGER, Zool., vol. 9, p. 559, pl. 80, figs. 6-10 (not pl. 82, figs. 6, 7).

Brady appears to have included two distinct species in his *G. digitata*. Parker (1958) has designated the

trochoid form as *G. digitata* and has referred the planispiral form to the genus *Globigerinella*. *Globigerina digitata* occurs rarely in the region studied.

#### *Globigerina eggeri* Rhumbler

Plate 6, figures 5, 8-10

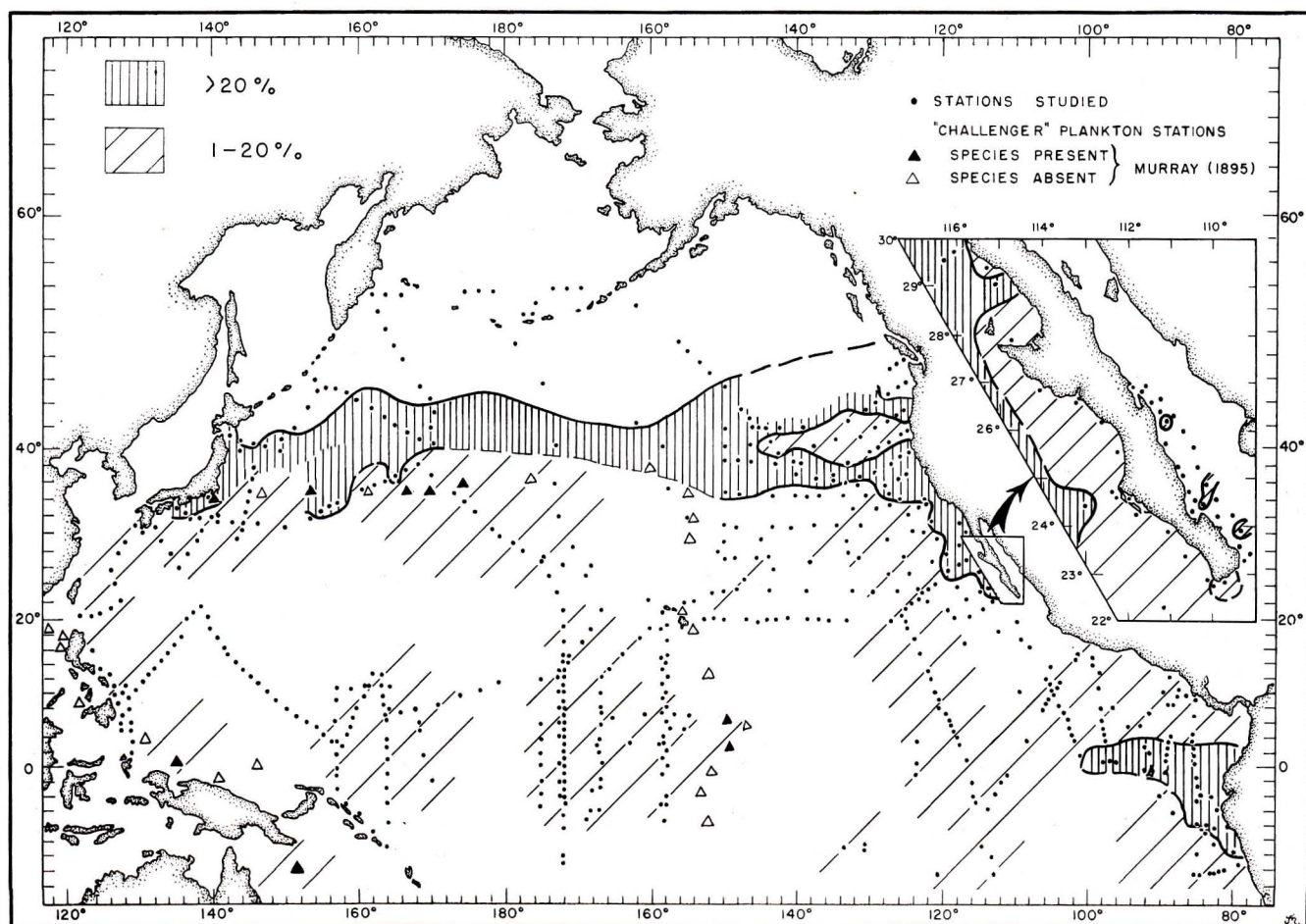
*Globigerina bulloides* form no. 3, OWEN (not D'ORBIGNY, 1826), 1868, Jour. Linn. Soc., vol. 9, p. 157, pl. 5, fig. 9.

*Globigerina dubia* BRADY (not EGGER, 1857), 1879, Quart. Jour. Micr. Sci., vol. 19, n. ser., p. 71; 1884, Rept. Voy. CHALLENGER, Zool., vol. 9, p. 595, pl. 79, fig. 17.

*Globigerina cretacea* BRADY (not D'ORBIGNY) (= *G. subcretacea* LOMNICKI), 1884 (part), Rept. Voy. CHALLENGER, Zool., vol. 9, p. 596, pl. 82, fig. 10 (not fig. 11).

*Globigerina eggeri* RHUMBLER, 1900, Nordische Plankton, pt. 14, Foraminiferen, p. 19, text fig. 20.

There appears to be a gradational series between typical large, highspired *G. eggeri* and other forms such as *G. subcretacea*. Juvenile specimens are occasionally difficult to distinguish from forms similar to "*G. dutertrei*" (see Ovey in Wiseman and Ovey, 1950) and *G. pachyderma*. In this study *G. eggeri*, "*G. subcretacea*" and young specimens of *G. eggeri* and/or *G.*



TEXT FIGURE 10

Distribution of *Globigerina eggeri* Rhumbler



*pachyderma*-“*dutertrei*” are grouped together because of the difficulty of positive identification, particularly of their young stages.

Specimens of the *G. eggeri* group as defined above are found throughout the warm-water, transitional and subarctic regions of the Pacific. The frequency of occurrence varies, reaching a maximum in the transition areas of the California Current, Peru Current and areas of mixing between cold and warm water such as the junction of the Kuroshio and Oyashio currents northeast of Japan.

Typical adult *G. eggeri* (Pl. 6, figs. 5, 10; Text fig. 10) is not found throughout the above range but is limited to the warm and transitional regions.

#### *Globigerina hexagona* Natland

Plate 6, figures 11-15

*Globigerina hexagona* NATLAND, 1938, Bull. Scripps Inst. Oceanography, Tech. Ser., vol. 4, no. 5, p. 149, pl. 7, fig. 1.

It is possible that several distinct forms have been included with this species. Figures 11 and 12 illustrate the form closest to Natland's. Figures 13-15 show a more compressed form that occurs within the same geographic range. The highest frequency (Text fig. 11) is in the equatorial west-central region with scattered occurrences in the transitional waters of the Peru and California currents.

#### *Globigerina inflata* d'Orbigny

Plate 6, figures 16-18

*Globigerina inflata* d'ORBIGNY, 1839, in BARKER-WEBB and BERTHELOT, Hist. Nat. Îles Canaries, vol. 2, Foraminifères, p. 134, pl. 2, figs. 7-9.

Like *Globorotalia truncatulinoides*, this species (Text fig. 12) is most common in the central-water fauna extending from California almost to Japan and from Lats. 25° N to 40° N. Occasional occurrences in the transition region are believed to reflect central-water influence.

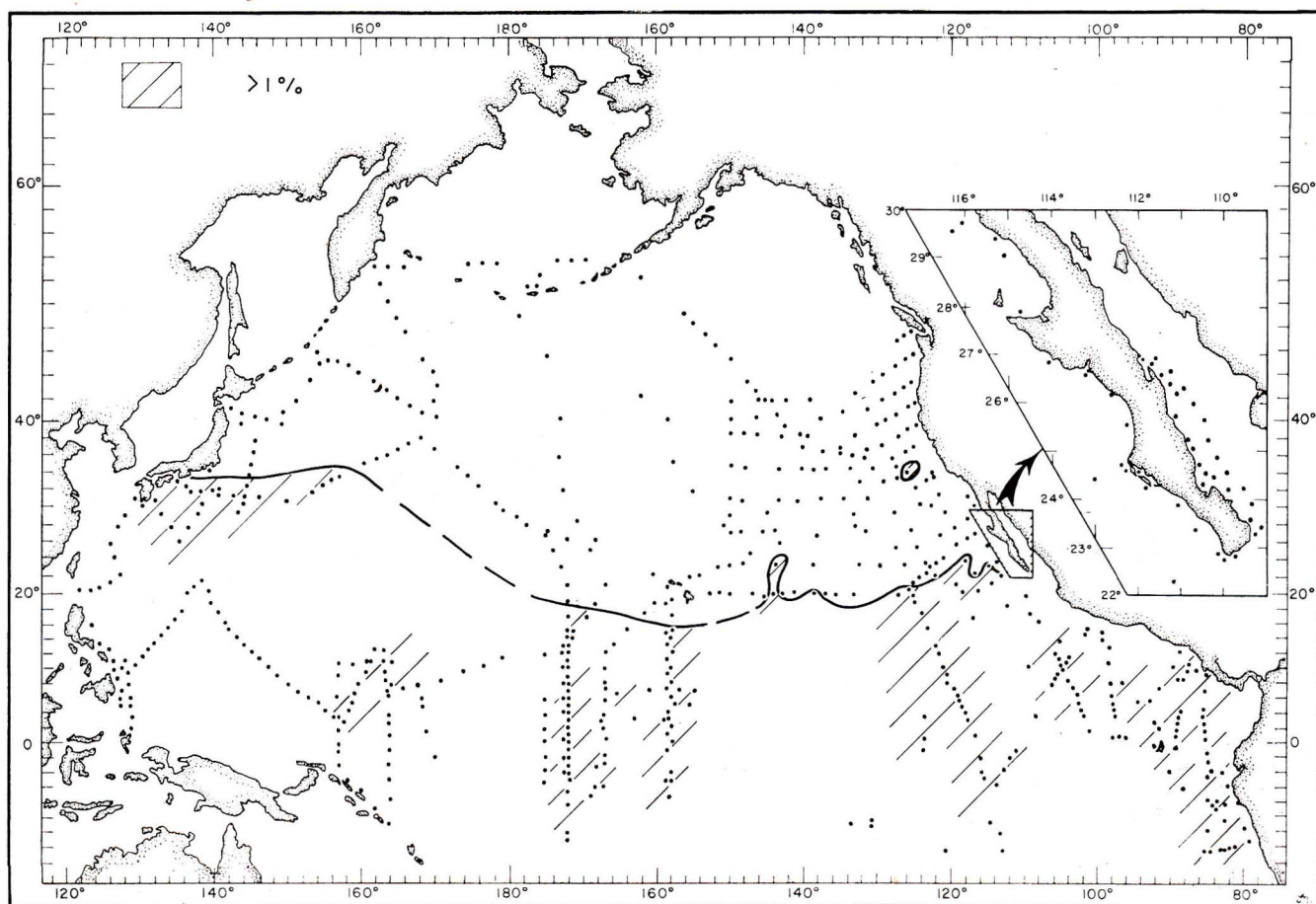
#### *Globigerina pachyderma* (Ehrenberg)

Plate 6, figures 20-23

*Aristerospira pachyderma* EHRENBERG, 1861, Monats. k. preuss. Ak., Wiss. Berlin, p. 303; 1872 (1873), Abhandl. Ak. k. Wiss. Berlin, pl. 1, fig. 4.

This species is sometimes difficult to separate from small specimens of *G. bulloides* but generally may be distinguished by its characteristic crystalline wall structure and constricted aperture.

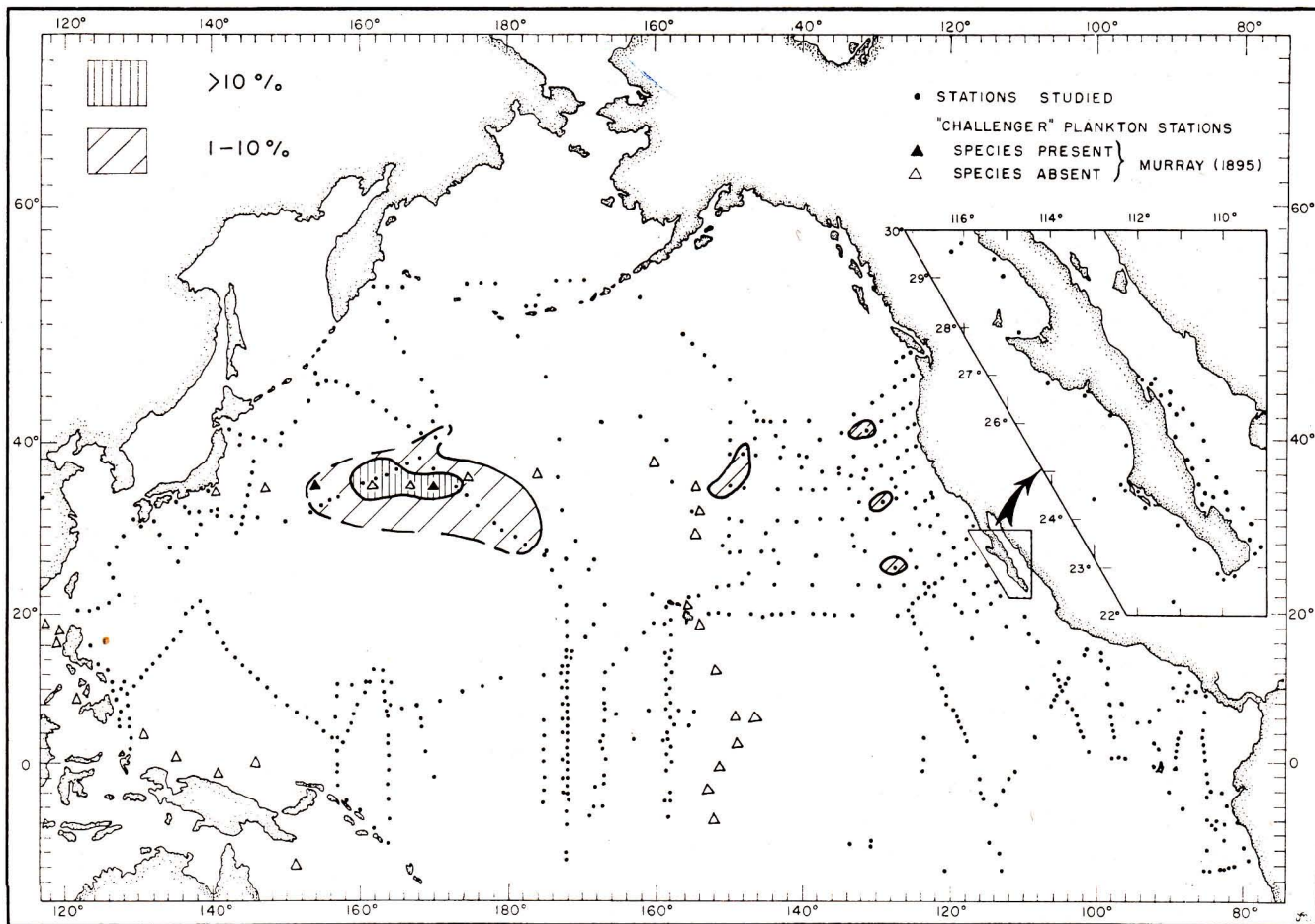
This species (Text fig. 13) is found in the cold waters of the Subarctic Water mass north of Lat. 40° N and occasionally in the California Current and off northern Japan.



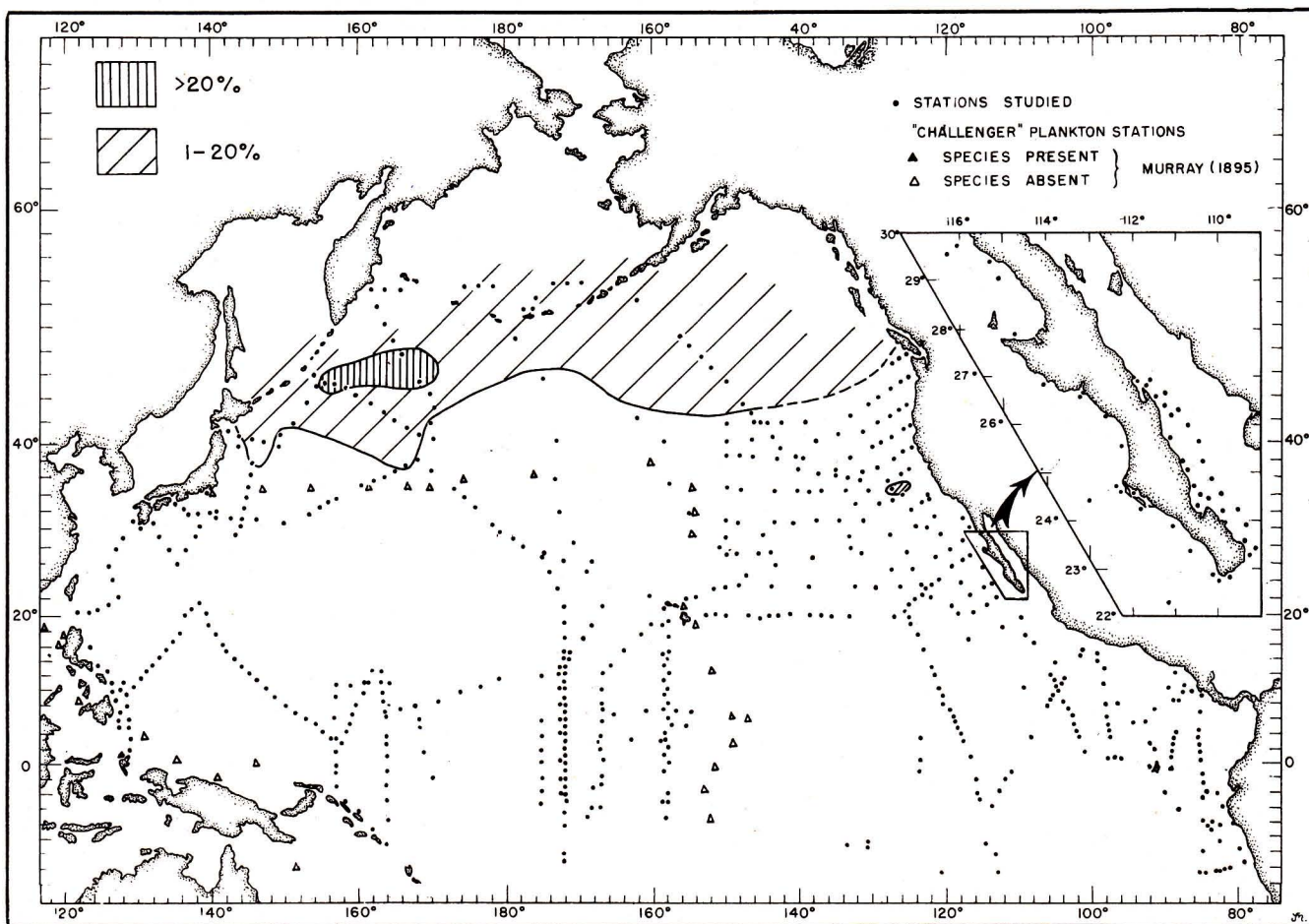
TEXT FIGURE 11

Distribution of *Globigerina hexagona* Natland





TEXT FIGURE 12  
Distribution of *Globigerina inflata* d'Orbigny



TEXT FIGURE 13  
Distribution of *Globigerina pachyderma* (Ehrenberg)



***Globigerina quinqueloba* Natland**

Plate 6, figures 24, 25

*Globigerina quinqueloba* NATLAND, 1938, Bull. Scripps Inst. Oceanography, Tech. Ser., vol. 4, no. 5, p. 149, pl. 6, fig. 7.

Typical specimens have an extension of the last chamber overlapping the umbilical area. In cold water many small spinose specimens without this overlapping chamber are found. These occur with specimens of typical *G. quinqueloba* and are considered to represent immature stages.

This is the first recorded occurrence of this species from plankton tows. It is common in the cold waters of the subarctic region north of Lat. 40° N (Text fig. 14). It is also found in the transition region represented by the water of the California and Peru currents. Some scattered occurrences are found along the equator.

***Globigerina* sp.**

Plate 6, figures 19, 26-28

Test trochoid; 4-5 chambers in last whorl, earlier chambers small and regular, later ones rapidly becoming elongate; aperture sunken and partially covered by later chambers.

This species has certain similarities to both *G.*

*bulloides* and *Globigerinella aequilateralis* and has probably been included by authors with these species. It is similar to *G. bulloides* in having 4 to 5 chambers in the last whorl but may be distinguished by its less conspicuous, compressed aperture. It may be differentiated from non-planispiral specimens of *Globigerinella aequilateralis* by the smaller number of more elongate chambers.

*Globigerina* sp. (Text fig. 15) occurs at scattered localities throughout the tropical Pacific.

***Globigerinella aequilateralis* (Brady)**

Plate 7, figures 1, 2

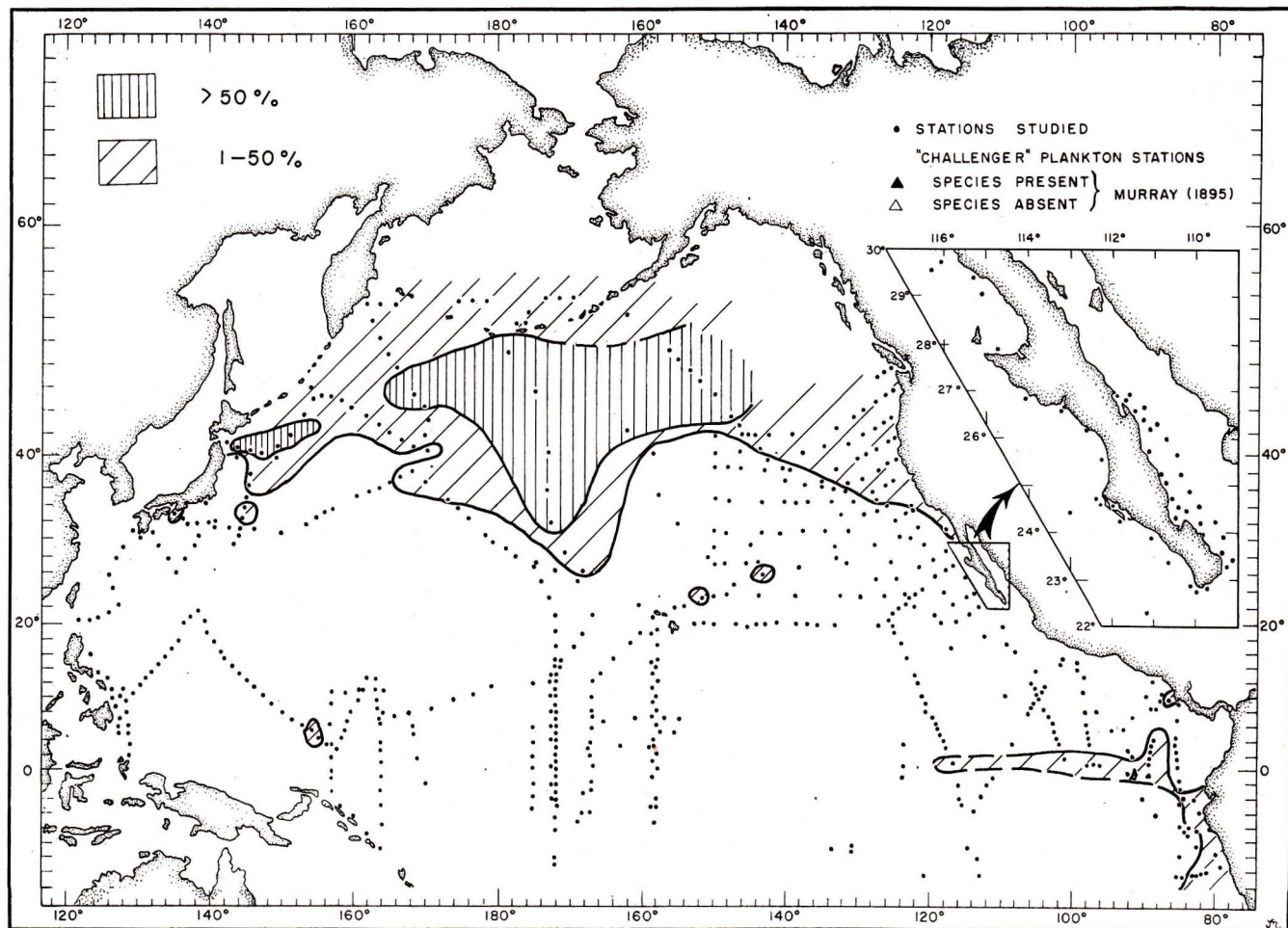
*Globigerinella aequilateralis* BRADY, 1879, Quart. Jour. Micr. Sci., vol. 19, p. 71; 1884, Rept. Voy. CHALLENGER, Zool., vol. 9, p. 605, pl. 80, figs. 18-21.

This species (Text fig. 16) is most abundant in the tropical and warm-temperate regions. The highest frequencies occur in the equatorial Pacific.

***Globigerinella* sp.**

Plate 7, figures 3, 4

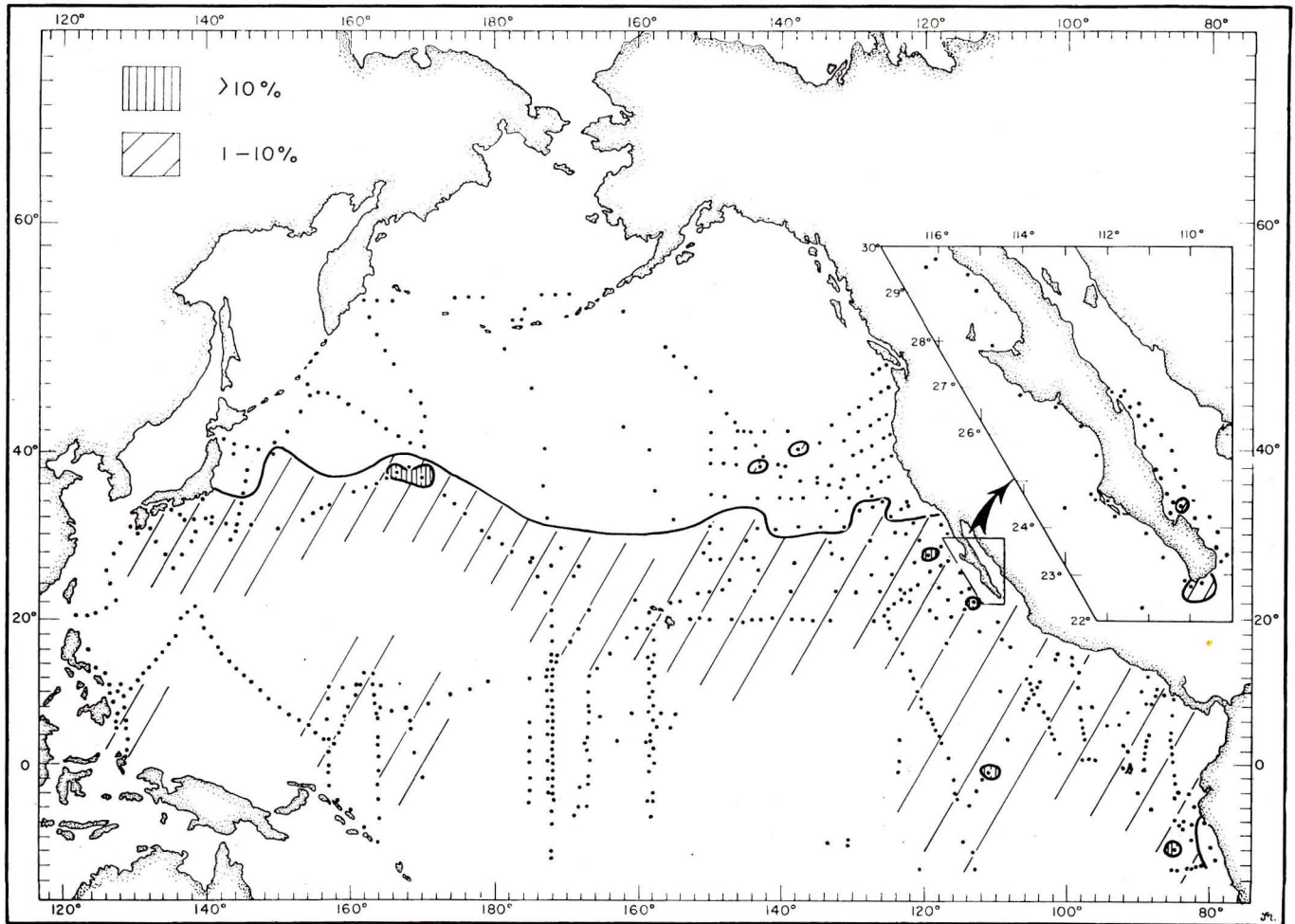
*Globigerinella digitata* BRADY (part), 1879, Quart. Jour. Micr. Sci., vol. 19, p. 72; 1884 (part), Rept. Voy.



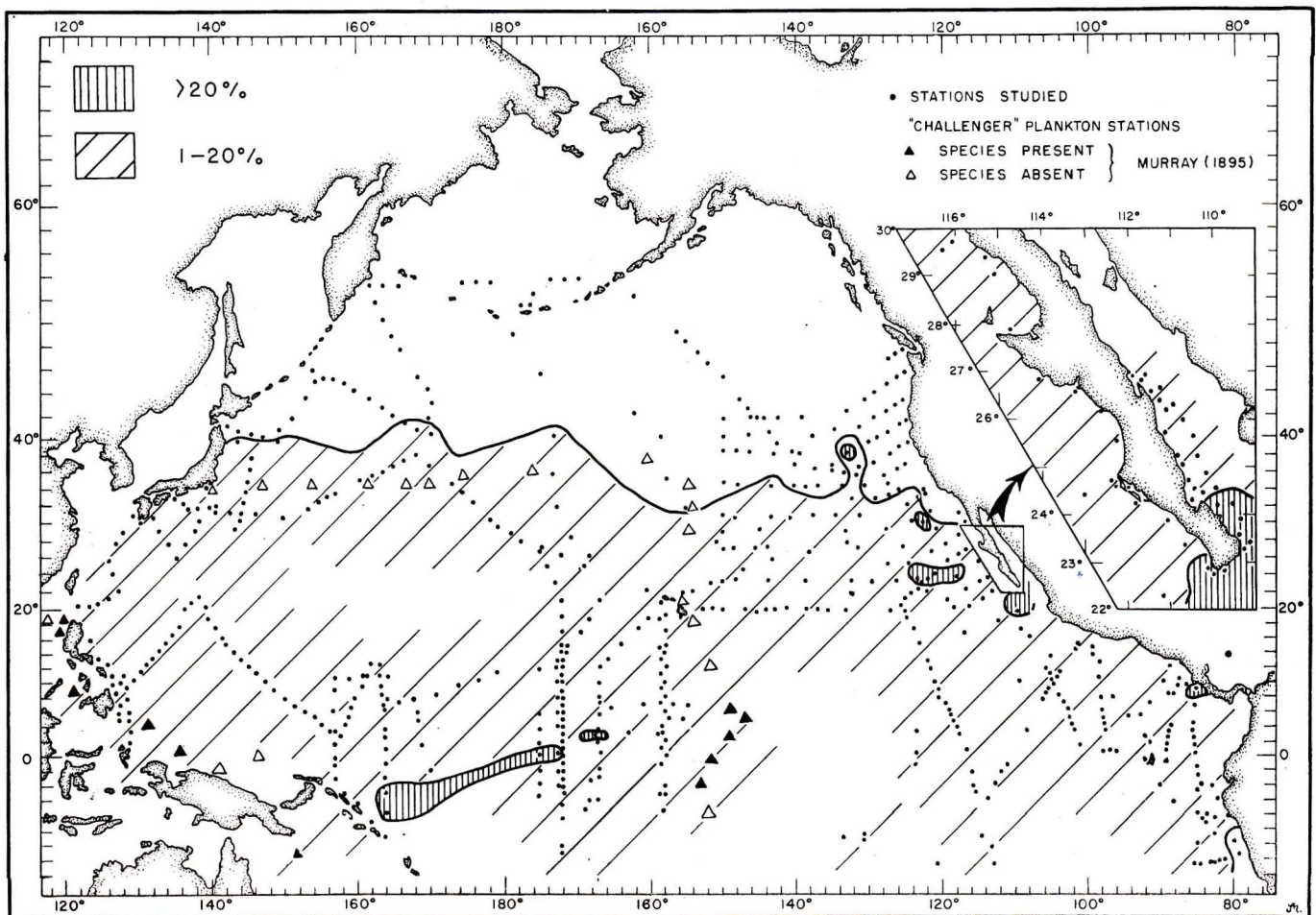
TEXT FIGURE 14

Distribution of *Globigerina quinqueloba* Natland





TEXT FIGURE 15  
Distribution of *Globigerina* sp.



TEXT FIGURE 16  
Distribution of *Globigerinella aequilateralis* (Brady)



CHALLENGER, Zool., vol. 9, p. 599, pl. 82, figs. 6, 7 (not pl. 80, figs. 6-10).

Parker (1958) states that the form described by Brady includes two distinct species. Brady (1884, pl. 82, figs. 6, 7) has illustrated a planispiral form which he describes as being "radiate in a palmate manner" and a trochoid form (Pl. 80, figs. 6-10) which "resembles an outstretched index finger." Parker has designated the trochoid form, which is worldwide, as *Globigerina digitata*. The planispiral one she refers to the genus *Globigerinella*. The latter form is most frequent in Pacific plankton tows while the trochoid species is only rarely observed. In this study the distribution of *Globigerinella* sp. also includes rare occurrences of *Globigerina digitata*.

Highest concentrations of *Globigerinella* sp. (Text fig. 17) are found in the equatorial Pacific region. Significant frequencies also occur in waters of the Kuroshio in the west-central Pacific.

#### *Globigerinita glutinata* (Egger)

Plate 7, figures 7, 8

*Globigerina glutinata* EGGER, 1893, Abhandl. K. bay. Akad. Wiss. Munchen, Cl. II, vol. 18, p. 371, pl. 13, figs. 19-21.—RHUMBLER, 1911, Ergeb. Plankton-Exped. Humboldt Stift., vol. 3, p. 148, pl. 29, figs. 14-26; pl. 33, fig. 20; pl. 34, fig. 1.

This species (Text fig. 18) is most abundant in the tropical regions but it (or a closely related form) also ranges into the subarctic water. The colder-water specimens are smaller than those from the tropics.

#### *Globigerinoides conglobata* (Brady)

Plate 7, figures 5, 6

*Globigerina conglobata* BRADY, 1879, Quart. Jour. Micr. Sci., vol. 19, p. 72; 1884, Rept. Voy. CHALLENGER, Zool., vol. 9, p. 603, pl. 80, figs. 1-5; pl. 82, fig. 5.

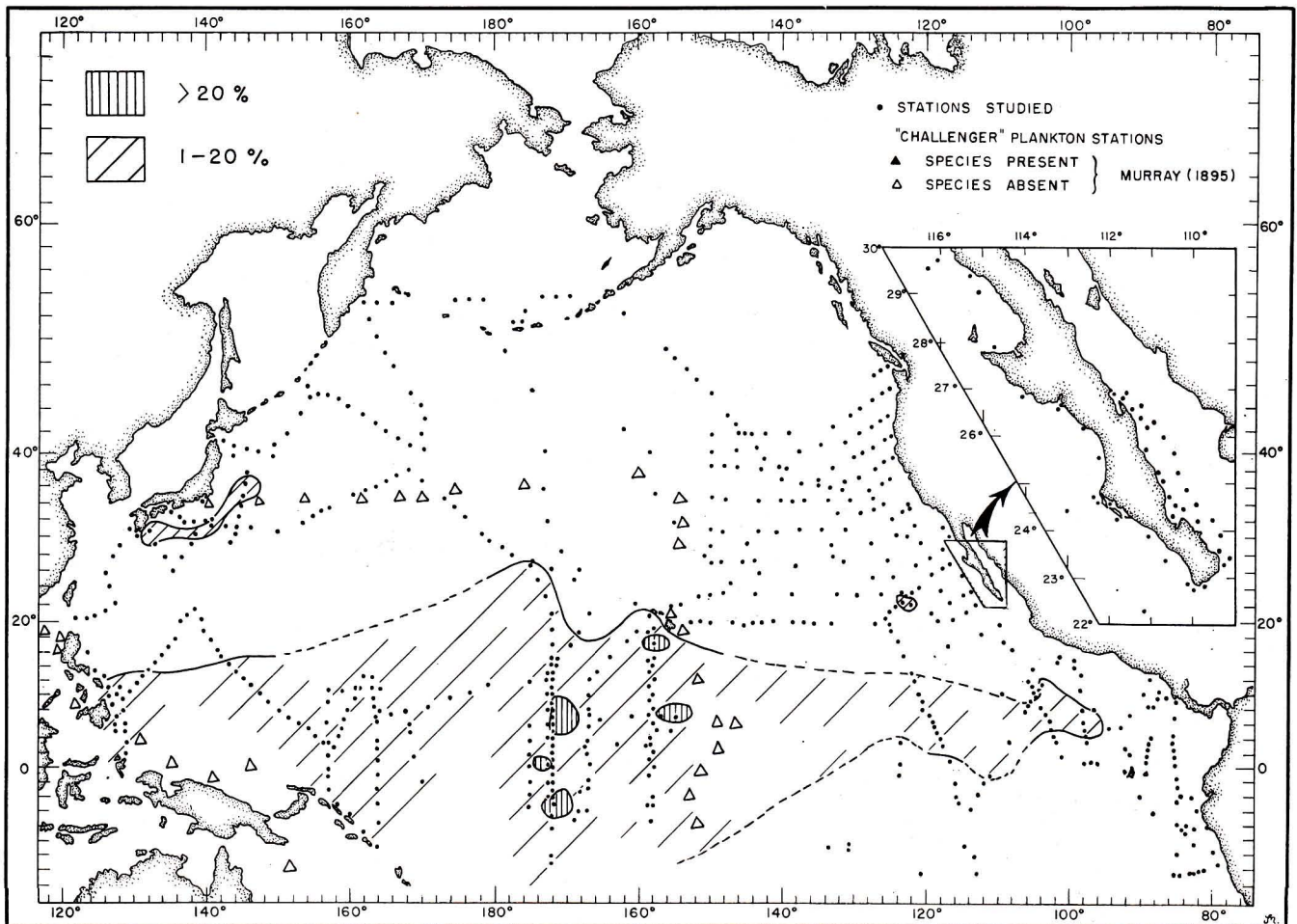
Large adult specimens of this species have a very massive and compact appearance. The primary aperture consists of a narrow arched opening on the ventral surface. Accessory apertures are present along the sutures on the dorsal side. Younger specimens are usually less compact and the aperture is larger and more distinct. These immature forms are very similar to specimens of *Globigerinoides* sp. and are difficult to distinguish from that species.

This species (Text fig. 19), which is limited to the warm-water region, has its greatest abundance in the equatorial Pacific.

#### *Globigerinoides* cf. *G. minuta* Natland

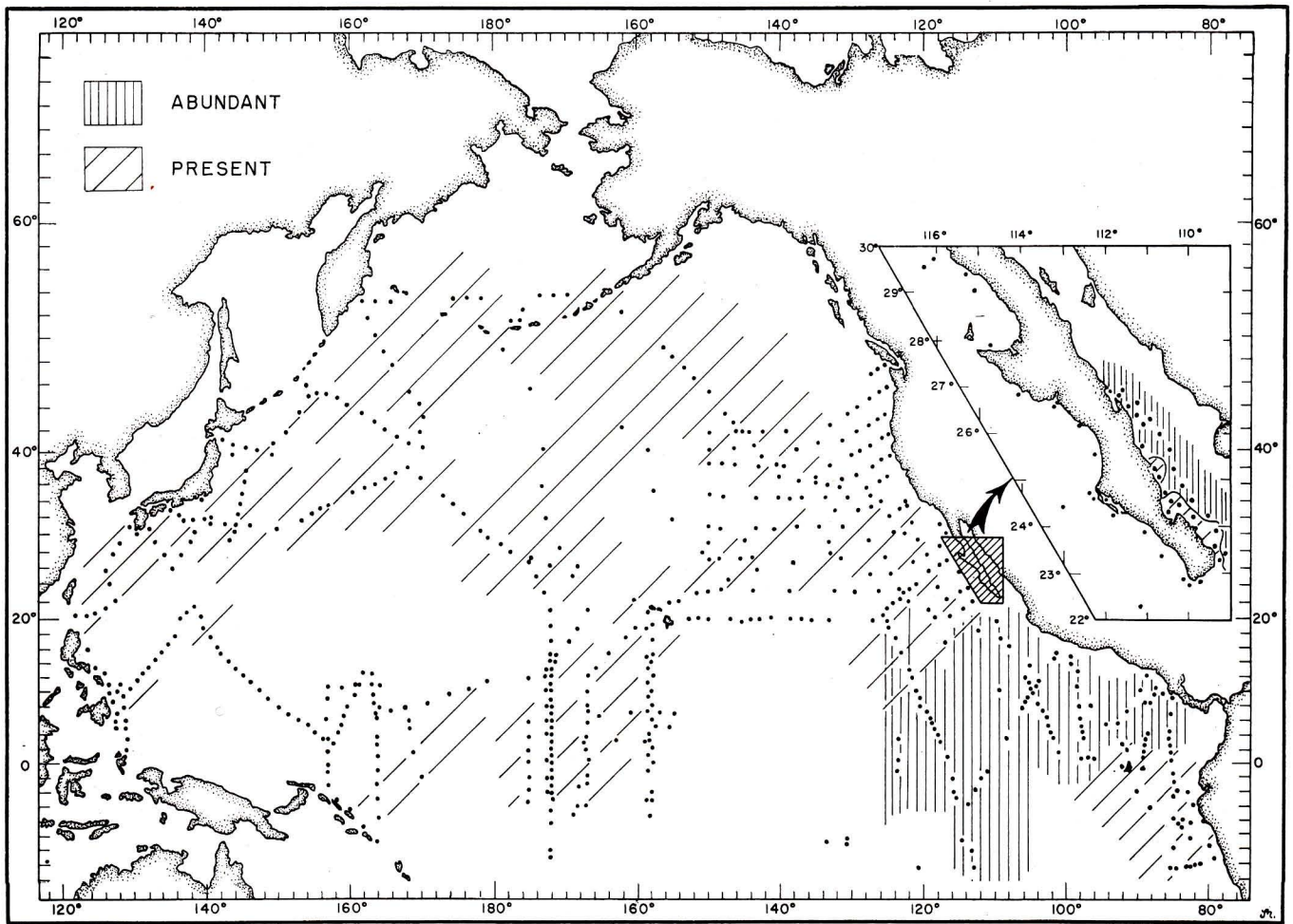
Plate 7, figures 9-11

This form is closely related to Natland's (1938)

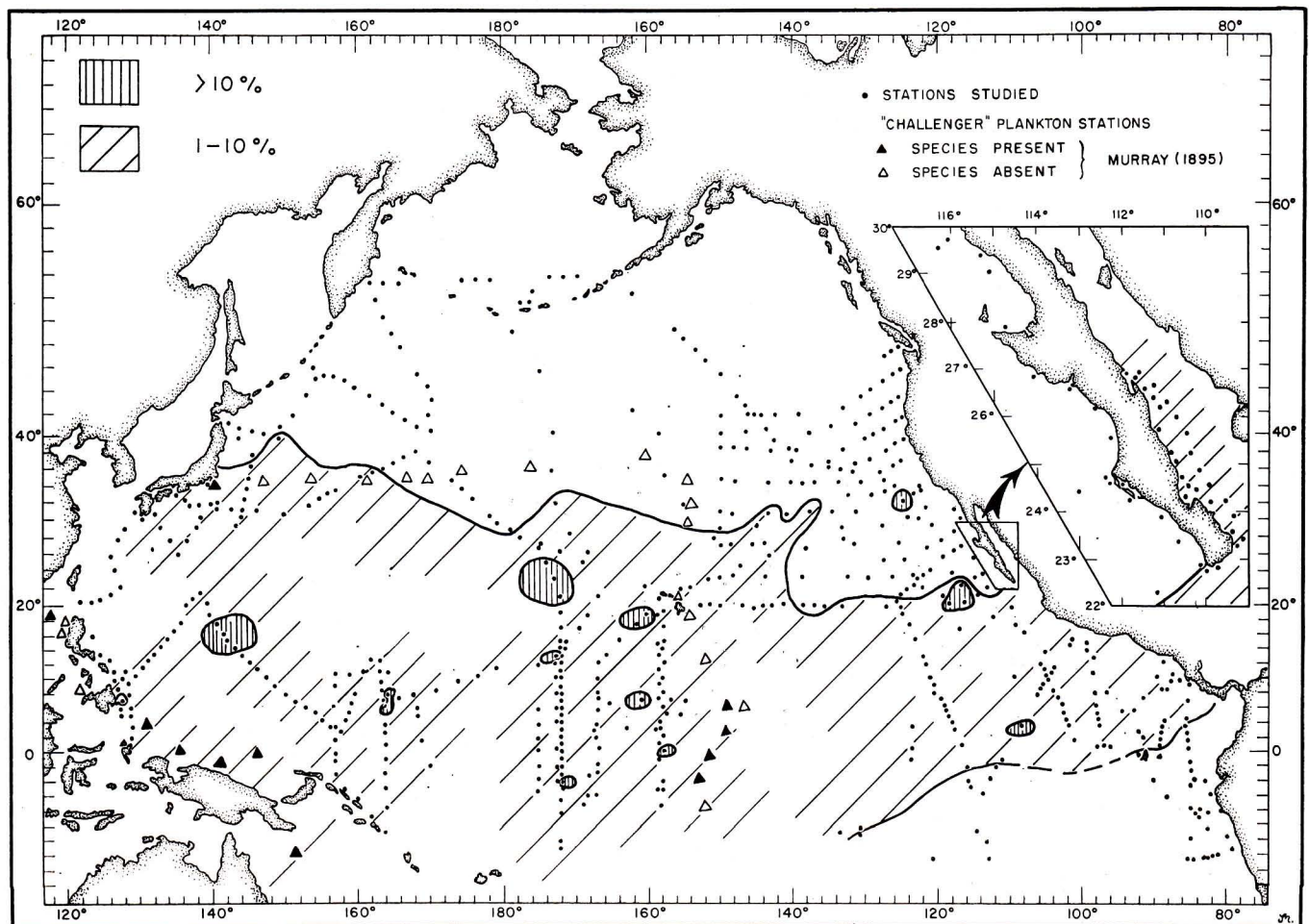


TEXT FIGURE 17  
Distribution of *Globigerinella* sp.





TEXT FIGURE 18  
Distribution of *Globigerinita glutinata* (Egger)



TEXT FIGURE 19  
Distribution of *Globigerinoides conglobata* (Brady)



species but has a slightly more spinose surface. Accessory apertures are present. Immature stages are difficult to separate from juvenile specimens of *Globigerinita glutinata* that occur with them; adult specimens may be differentiated by their relatively higher spires when compared with equal sized individuals of the latter species.

This species (Text fig. 20) is most abundant in the subarctic region but occasionally occurs in the temperate zone.

***Globigerinoides rubra* (d'Orbigny)**

Plate 7, figures 12, 13

*Globigerina rubra* D'ORBIGNY, 1839, in DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 82, pl. 4, figs. 12-14.

This species (Text fig. 21) is found throughout the tropical and temperate regions of the Pacific. Highest frequencies occur in equatorial waters but considerable numbers also are found within the transition zone. The greatest concentrations (up to 2,586/1,000 m<sup>3</sup>) are recorded in the Gulf of California.

***Globigerinoides sacculifera* (Brady)**

Plate 7, figures 14, 15, 18

*Globigerina sacculifera* BRADY, 1877, Geol. Mag., vol.

4, p. 535; 1879, Quart. Jour. Micr. Sci., vol. 19, p. 73; 1884, Rept. Voy. CHALLENGER, Zool., vol. 9, p. 604, pl. 80, figs. 11-17; pl. 82, fig. 4.

Specimens of this species do not always have the characteristic elongated final chamber. Some authors have considered such sac-less specimens to be a separate species (*Globigerina triloba* Reuss), and others (for instance, Cushman, 1914, pl. 2, figs. 7, 8, 9) have referred them to *Globigerina bulloides*.

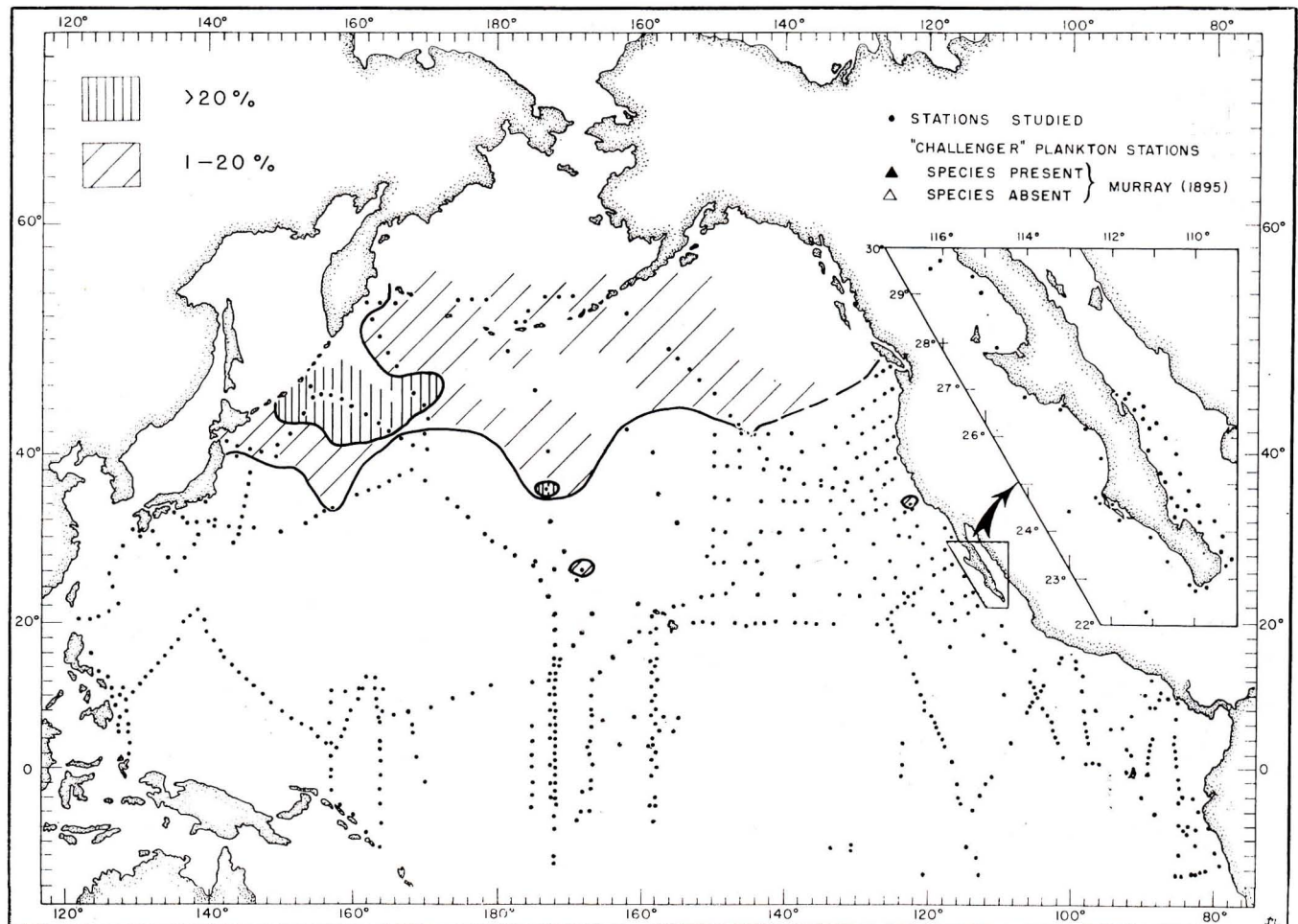
This species (Text fig. 22) is restricted to the warm regions, reaching its maximum frequency in the equatorial Pacific.

***Globigerinoides* sp.**

Plate 7, figures 16, 17

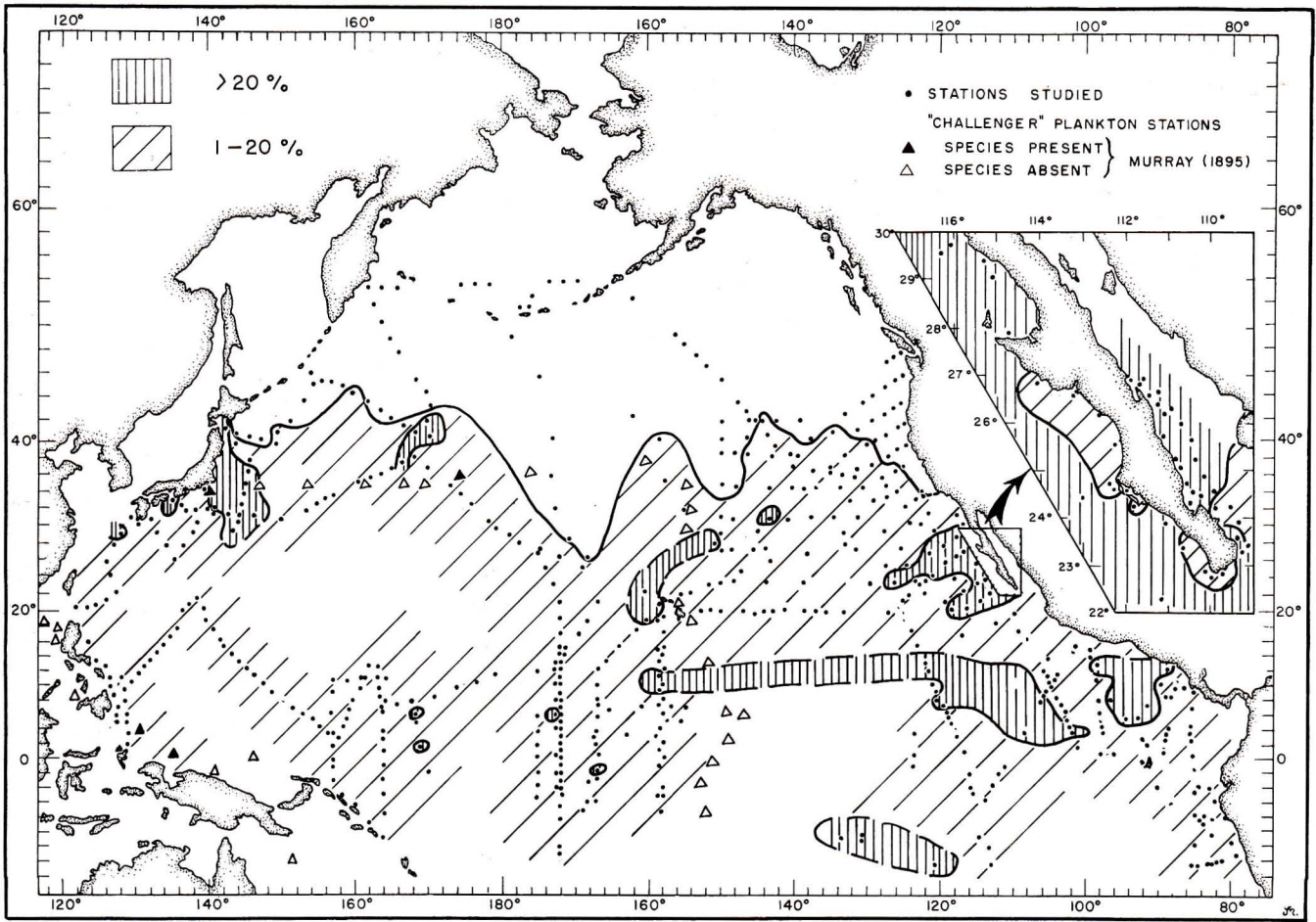
Test trochoid, rotaliform; 4 chambers in last whorl, large and inflated, gradually increasing in size; primary aperture a large arched opening with several secondary apertures located in the sutural depressions on the dorsal side; walls coarsely perforate and spinose.

This form is somewhat similar to *G. rubra* and *Globigerina bulloides*. It may be distinguished from the former in having four chambers in the final whorl and smaller accessory apertures. The accessory apertures distinguish it from *G. bulloides*. There is a possibility that this form is a variant of *Globigerinoides conglobata*.

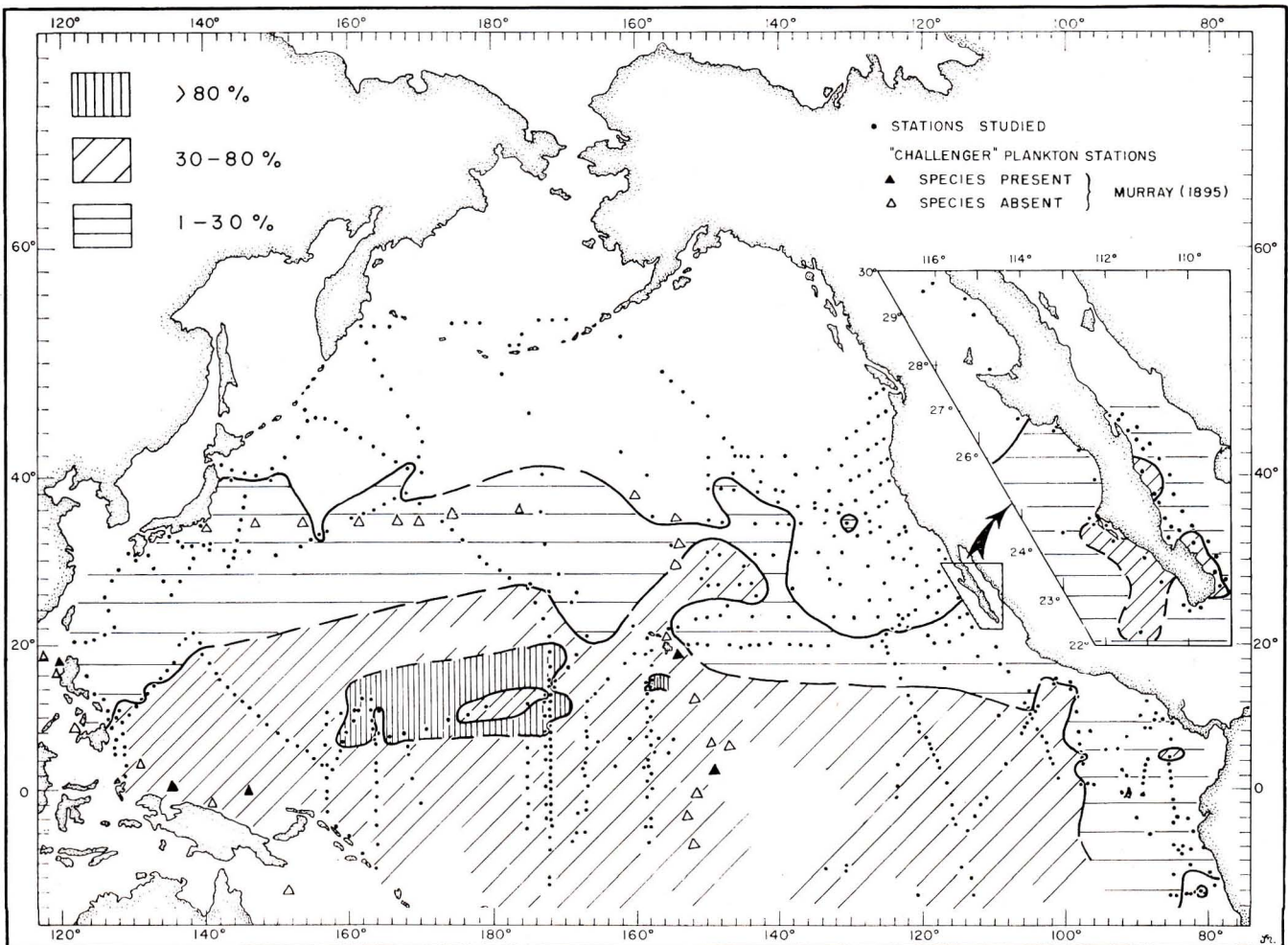


TEXT FIGURE 20  
Distribution of *Globigerinoides* cf. *G. minuta* Natland





TEXT FIGURE 21  
Distribution of *Globigerinoides rubra* (d'Orbigny)



TEXT FIGURE 22  
Distribution of *Globigerinoides sacculifera* (Brady)



This species (Text fig. 23) is found throughout the tropical and temperate regions of the Pacific.

**Globorotalia hirsuta** (d'Orbigny)

Plate 8, figures 1, 2

*Rotalina hirsuta* D'ORBIGNY, 1839, in BARKER-WEBB and BERTHELOT, Hist. Nat. Îles Canaries, vol. 2, pt. 2, "Foraminifères," p. 131, pl. 1, figs. 37-39.

*Pulvinulina canariensis* BRADY (not D'ORBIGNY, 1839), 1844, Rept. Voy. CHALLENGER, Zool., vol. 9, p. 692, pl. 103, figs. 8-10.

*Globorotalia hirsuta* (D'ORBIGNY). CUSHMAN, 1931, Bull. 104, U. S. Nat. Mus., pt. 8, p. 99, pl. 17, fig. 6.

This species (Text fig. 24) occurs at widely scattered localities throughout the tropical and warm-temperate regions, being more abundant in the former.

**Globorotalia menardii** (d'Orbigny)

Plate 8, figures 3, 4

*Rotalia menardii* D'ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 273, no. 26; Modèles, no. 10.

*Pulvinulina menardii* (D'ORBIGNY). BRADY, 1884, Rept. Voy. CHALLENGER, Zool., vol. 9, p. 690, pl. 103, figs. 1, 2.

This species may be distinguished from *G. tumida* by its flattened shape and lack of a visibly crystalline

wall structure. Plate 8, figures 10-12 show an intergrade which has been included with *G. menardii*.

This species (Text fig. 25) is found only in the tropical and warm-temperate zones. Its greatest frequencies are in the equatorial regions.

**Globorotalia scitula** (Brady)

Plate 8, figures 5, 6

*Pulvinulina scitula* BRADY, 1882, Proc. Roy. Soc. Edinburgh, vol. 11, p. 716.

*Pulvinulina patagonica* BRADY (not D'ORBIGNY, 1839), 1884, Rept. Voy. CHALLENGER, Zool., vol. 9, p. 693, pl. 103, fig. 7.

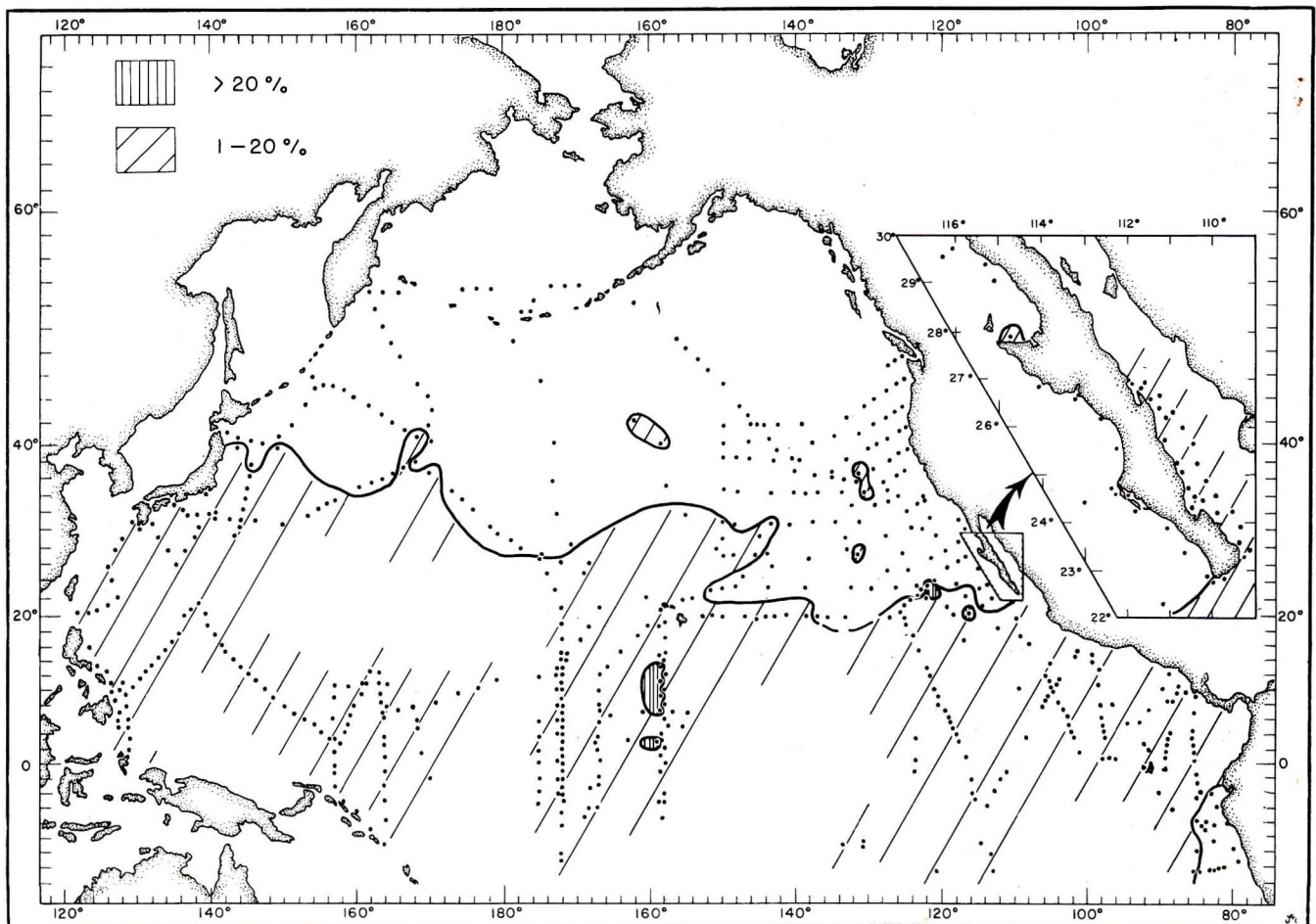
This species (Text fig. 26) is widely distributed throughout the North Pacific. High concentrations are found off the coast of Washington in the cold waters of the California Current. There are scattered occurrences near the boundary of the Kuroshio and Oyashio, in the Peru Current, and in the equatorial Pacific.

**Globorotalia truncatulinoides** (d'Orbigny)

Plate 8, figures 7, 8

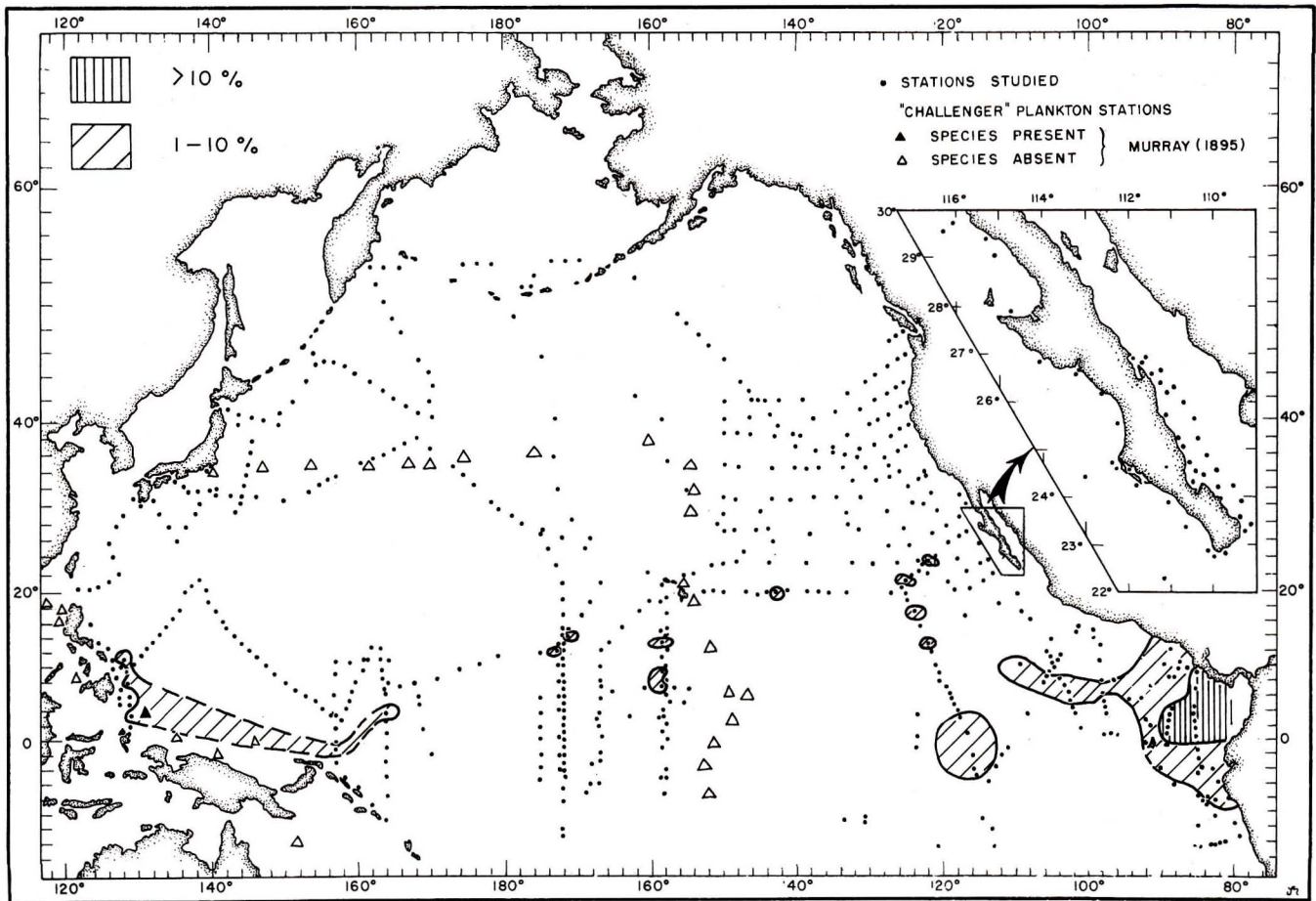
*Rotalina truncatulinoides* D'ORBIGNY, 1839, in BARKER-WEBB and BERTHELOT, Hist. Nat. Îles Canaries, vol. 2, pt. 2, "Foraminifères," p. 132, pl. 2, figs. 25-27.

*Pulvinulina michelineana* BRADY (not D'ORBIGNY,

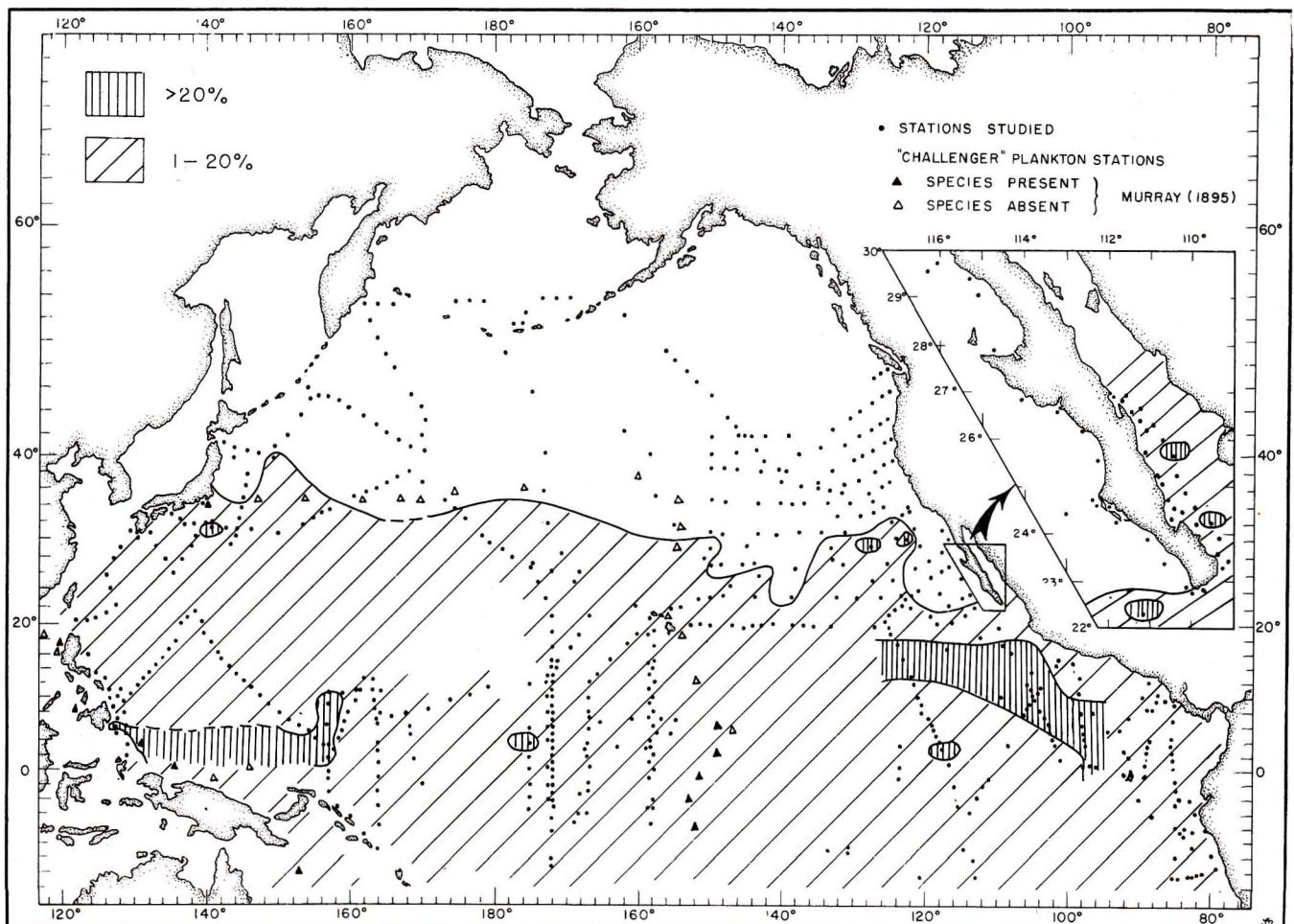


TEXT FIGURE 23  
Distribution of *Globigerinoides* sp.



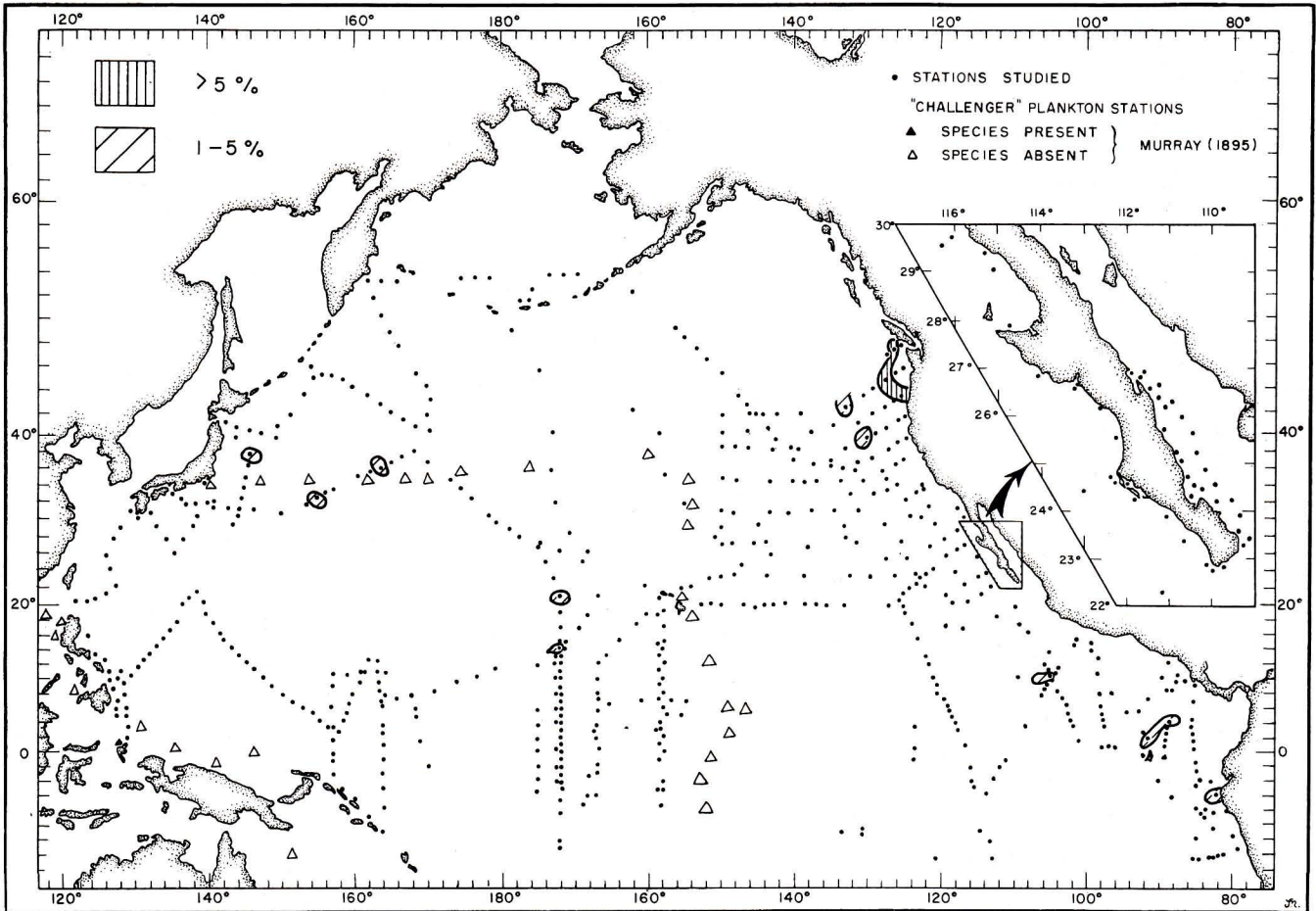


TEXT FIGURE 24  
Distribution of *Globorotalia hirsuta* (d'Orbigny)

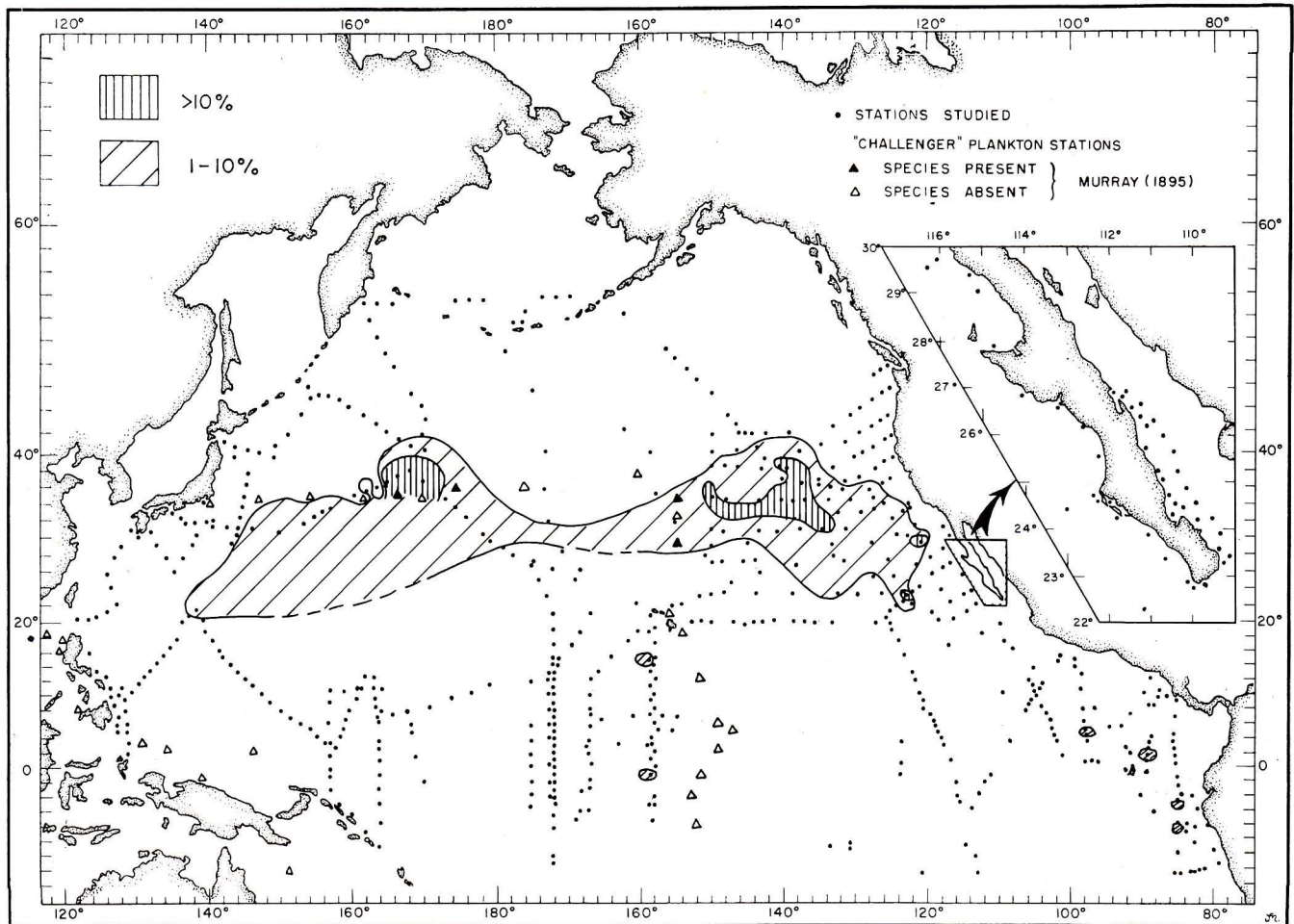


TEXT FIGURE 25  
Distribution of *Globorotalia menardii* (d'Orbigny)





TEXT FIGURE 26  
Distribution of *Globorotalia scitula* (Brady)



TEXT FIGURE 27  
Distribution of *Globorotalia truncatulinoides* (d'Orbigny)



1840), 1884, Rept. Voy. CHALLENGER, Zool., vol. 9, p. 694, pl. 104, figs. 1, 2.

This species (Text fig. 27) is most abundant in a relatively narrow band extending across the North Pacific from approximately 40° N Lat. to 20° N Lat. It is also recorded at low frequencies from three stations along the equator and from one station approximately 5° south of Hawaii. The highest concentration occurs in the Western Central Water mass at the boundary of the warm Kuroshio and the cold Oyashio currents. Like *Globigerina inflata* it appears to be primarily a central-water species that is occasionally found in the transition region.

It is of interest that *Globorotalia truncatulinoides* occurs in approximately similar latitudinal ranges in both the North and South Pacific.

### *Globorotalia tumida* (Brady)

Plate 8, figures 9, 13

*Pulvinulina menardii* D'ORBIGNY var. *tumida* BRADY, 1877, Geol. Mag., vol. 4, p. 294.

*Pulvinulina tumida* BRADY, 1884, Rept. Voy. CHALLENGER, Zool., vol. 9, p. 692, pl. 103, figs. 4-6.

This form is separated from *G. menardii* by its more tumid form and the crystalline nature of its wall.

This species (Text fig. 28) is found only in the tropical regions. It appears to be less tolerant of cold

temperatures than *G. menardii* and is not found as far north as that species. The highest concentrations of *G. tumida* occur nearer the equator and farther west than the greatest abundance of *G. menardii*.

### *Hastigerina pelagica* (d'Orbigny)

Plate 8, figures 14, 15

*Nonionina pelagica* D'ORBIGNY, 1839, Foram. Amér. Mérid., p. 27, pl. 3, figs. 13, 14.

*Hastigerina pelagica* (D'ORBIGNY). BRADY, 1884, Rept. Voy. CHALLENGER, Zool., vol. 9, p. 613, pl. 83, figs. 1-8.

This species (Text fig. 29) is found widely distributed in the tropical and warm-temperate regions. The greatest concentrations occur in the central oceanic regions. More than 700 specimens per 1000 m<sup>3</sup> occur near Hawaii.

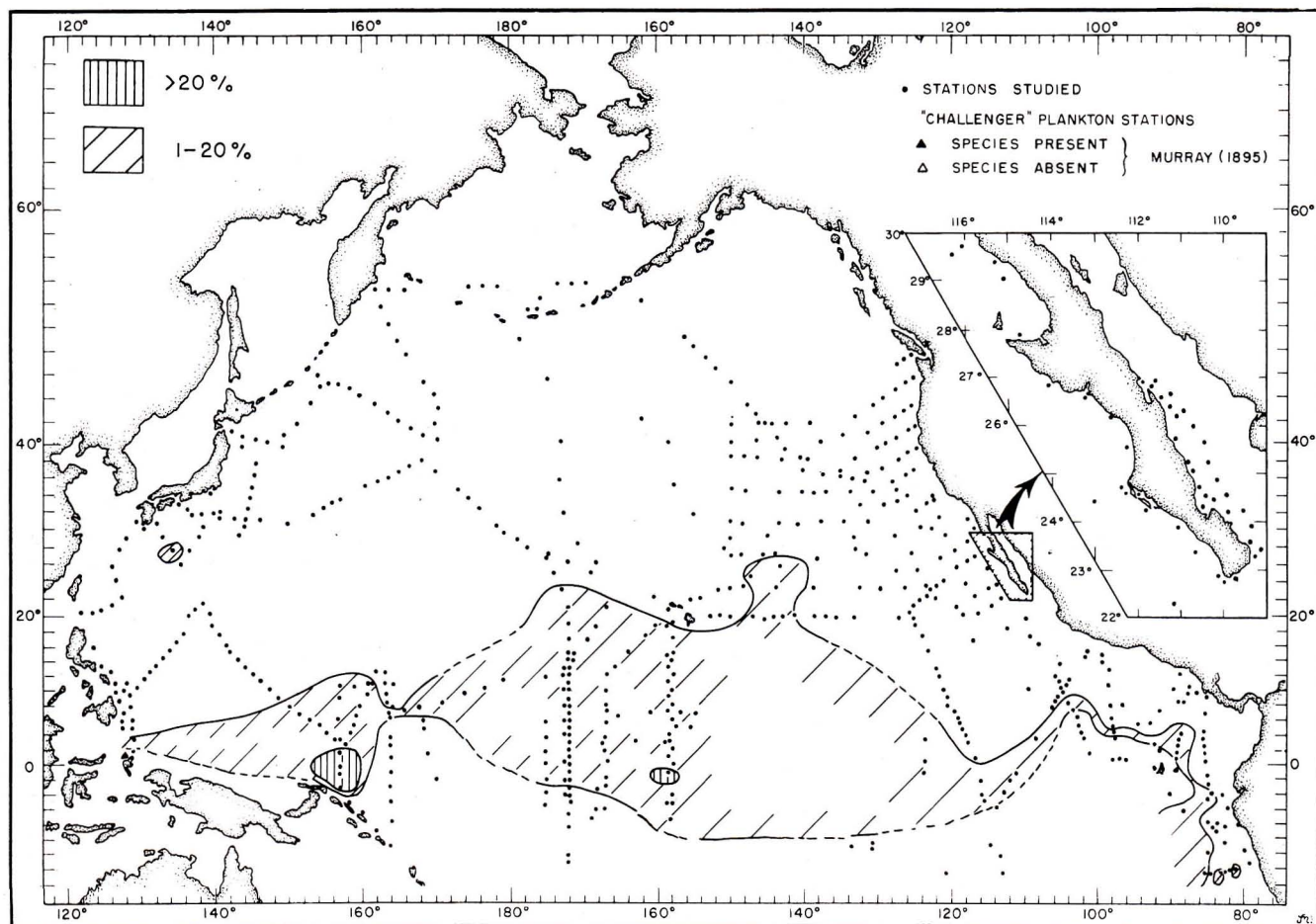
### *Hastigerinella rhumbleri* Galloway

Plate 8, figure 16

*Hastigerina digitata* RHUMBLER (not *Globigerina digitata* BRADY), 1911, Ergeb. Plankton-Exped. Humboldt Stift., vol. 3, pt. 1, p. 202, pl. 37, fig. 9.

*Hastigerinella digitata* (RHUMBLER). WIESNER, 1931, Deutsche Sud-Polar Exped., vol. 20, Zool., p. 135, pl. 22, figs. 264-266.

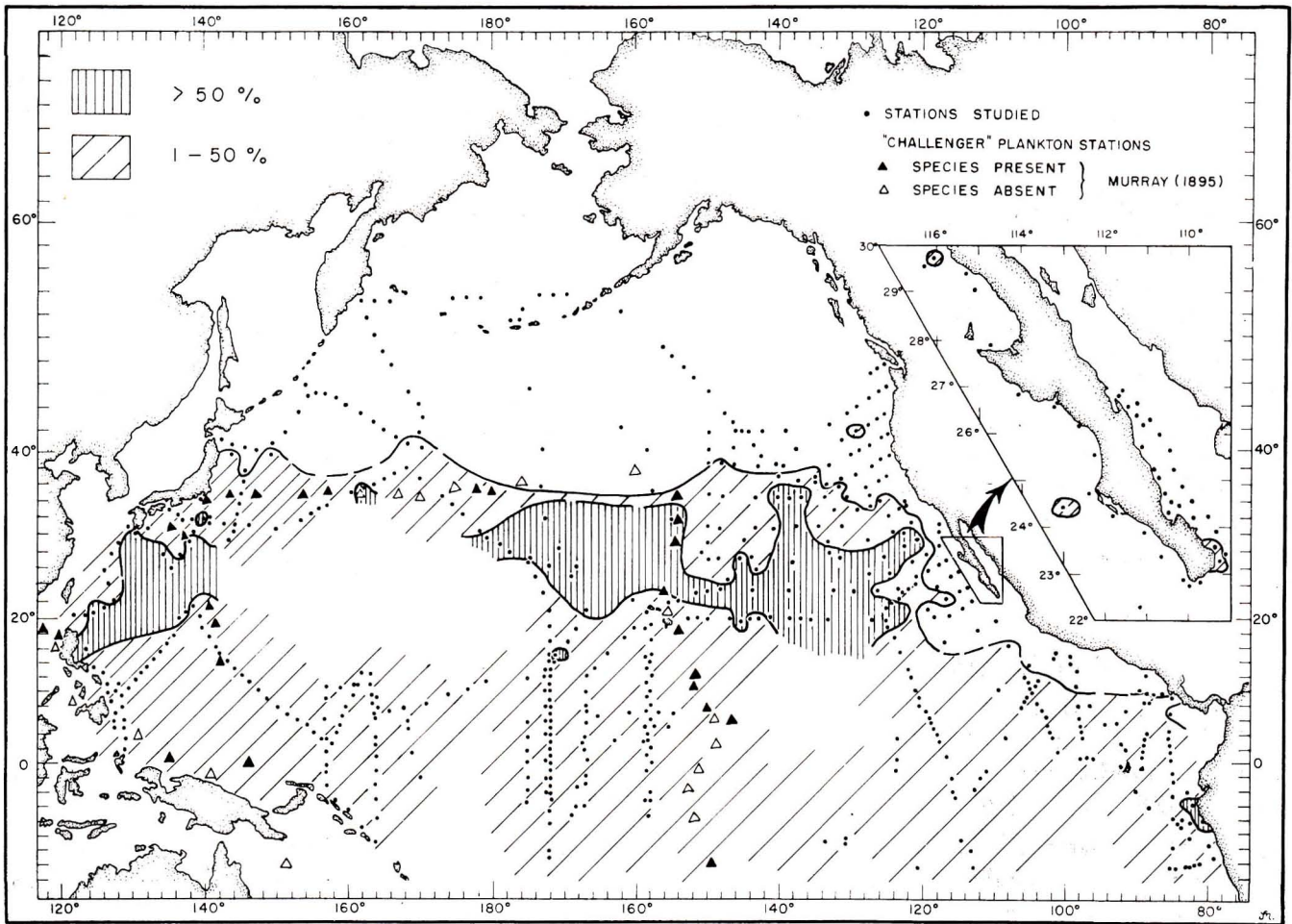
*Hastigerinella rhumbleri* GALLOWAY, 1933, A Manual



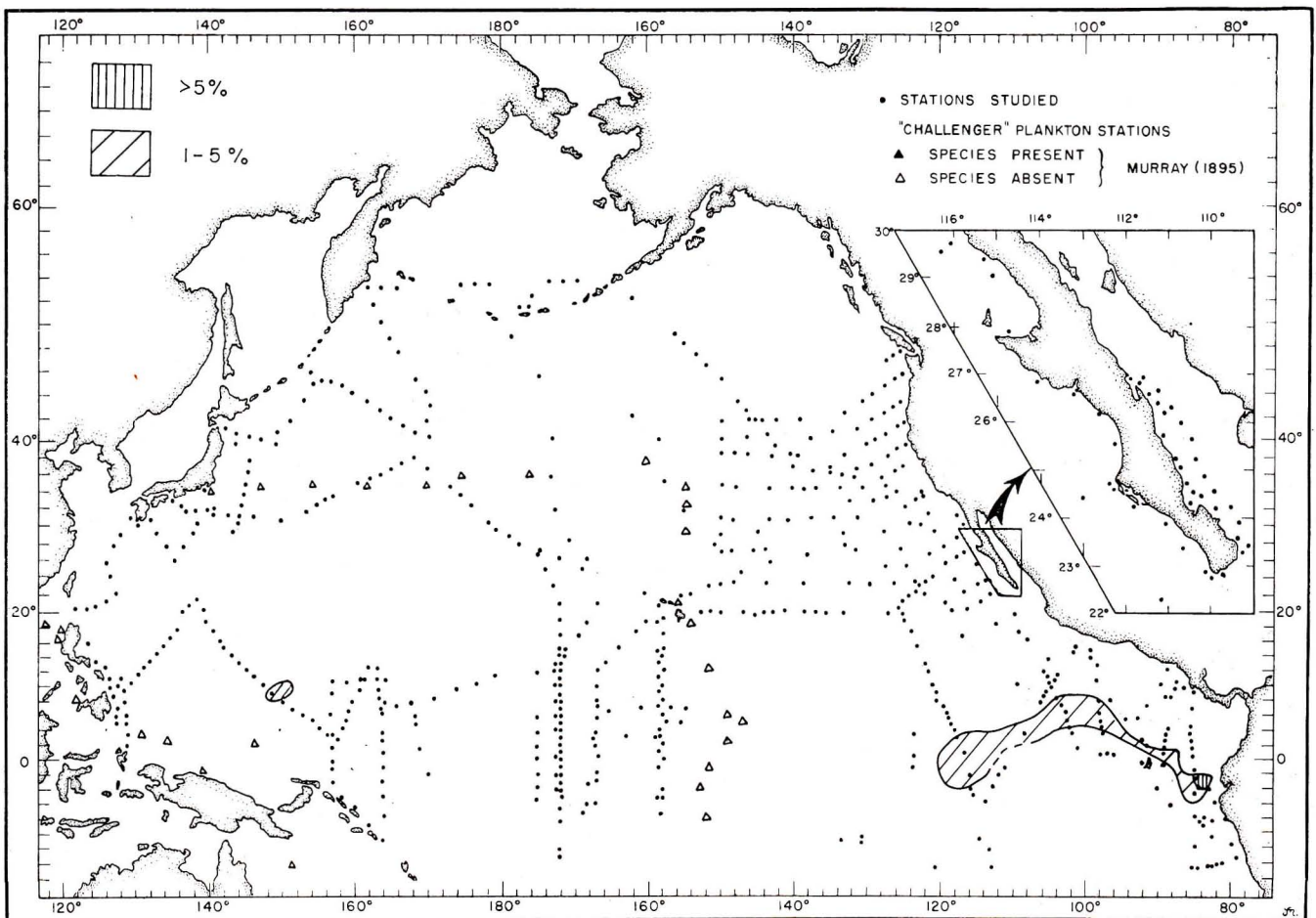
TEXT FIGURE 28

Distribution of *Globorotalia tumida* (Brady)





TEXT FIGURE 29  
Distribution of *Hastigerina pelagica* (d'Orbigny)



TEXT FIGURE 30  
Distribution of *Hastigerinella rumbleri* Galloway



of Foraminifera, Bloomington, Ind., p. 333, pl. 30, fig. 9.

This is a very rare and fragile species which probably explains why there are no reports of its presence in bottom sediments. The specimen illustrated by Cushman, Todd and Post (1954, pl. 91, figs. 9, 10) appears to be the *Globigerinella* sp. reported in this study.

*Hastigerinella rhumbleri* (Text fig. 30) is found in the tropical and temperate regions of the Pacific. It occurs in the upper water layers at 12 stations in the equatorial region, all within 8° of the equator. Two deep occurrences (not shown in the surface distribution in Text fig. 30) lie outside of this region; one from a deep tow at the junction of the Kuroshio and Oyashio currents, the other from a deep open-and-closing haul off San Diego, California.

#### *Orbulina universa* d'Orbigny

Plate 8, figures 17, 18

*Orbulina universa* d'ORBIGNY, 1839, in DE LA SAGRA, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 3, pl. 1, fig. 1.

Most of the specimens are similar to the type but occasionally bilocular ones are found.

This species (Text fig. 31) is very widely distributed in the tropical and temperate regions. The highest concentration is recorded near Hawaii but high

numbers also were noted within the cool California Current extending northward into the Gulf of Alaska, along the equator, and near the boundary of the Kuroshio and Oyashio currents.

#### *Pulleniatina obliquiloculata* (Parker and Jones)

Plate 8, figures 19, 20

*Pullenia obliquiloculata* PARKER and JONES, 1865, Philos. Trans., vol. 155, p. 368, pl. 19, fig. 4.

Immature specimens of this species do not have the crescent-shaped aperture characteristic of the adult and are more lobate and coarsely perforate.

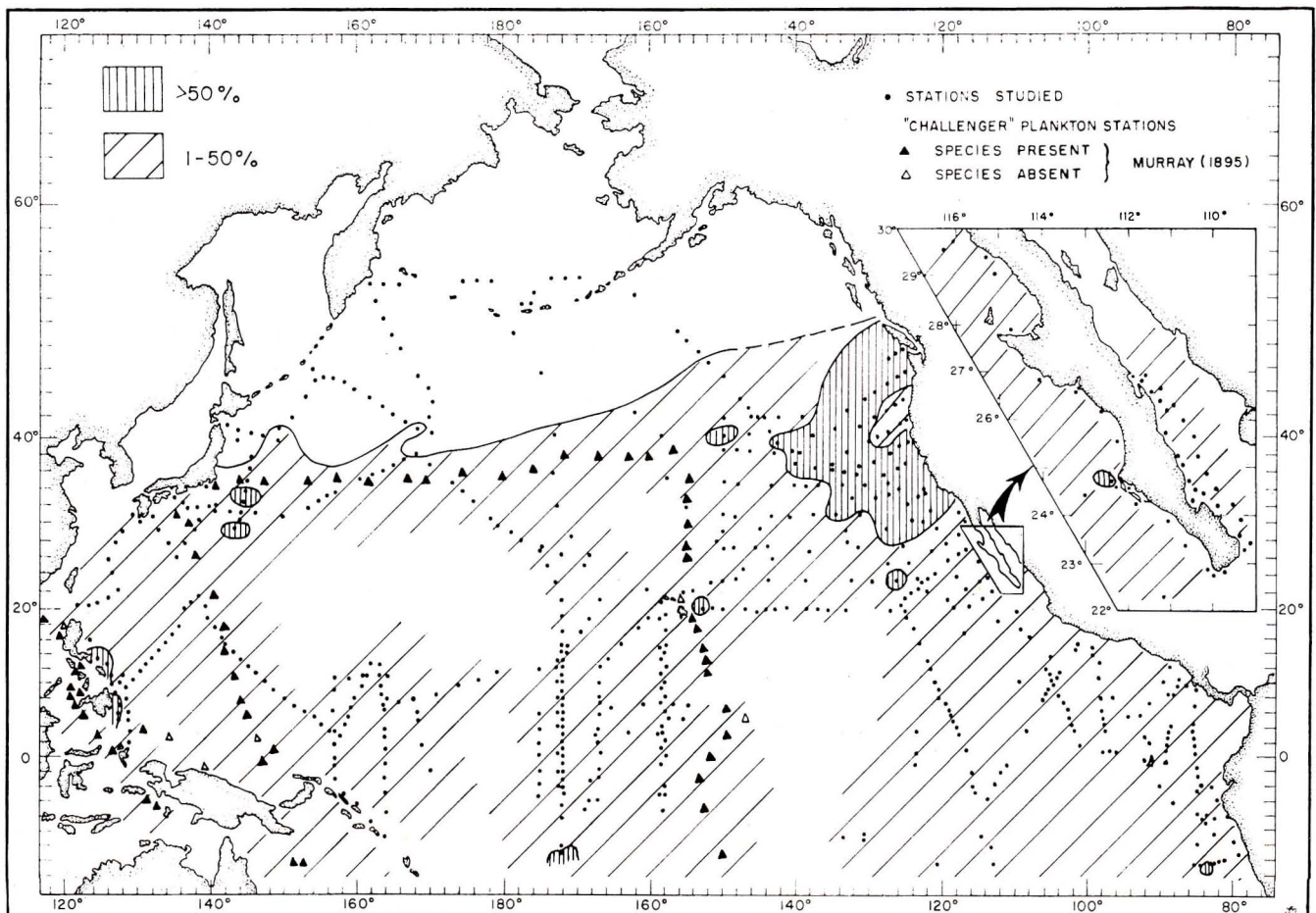
This species (Text fig. 32) is most common in the tropical region. The area of maximum abundance (> 1000 specimens/1000 m<sup>3</sup>) lies in the center of the Pacific Equatorial Water mass south of Hawaii. The concentrations appear to diminish to the east and west.

#### *Sphaeroidinella dehiscens* (Parker and Jones)

Plate 8, figures 21-23

*Sphaeroidina dehiscens* PARKER and JONES, 1865, Philos. Trans., vol. 155, p. 369, pl. 19, fig. 5.

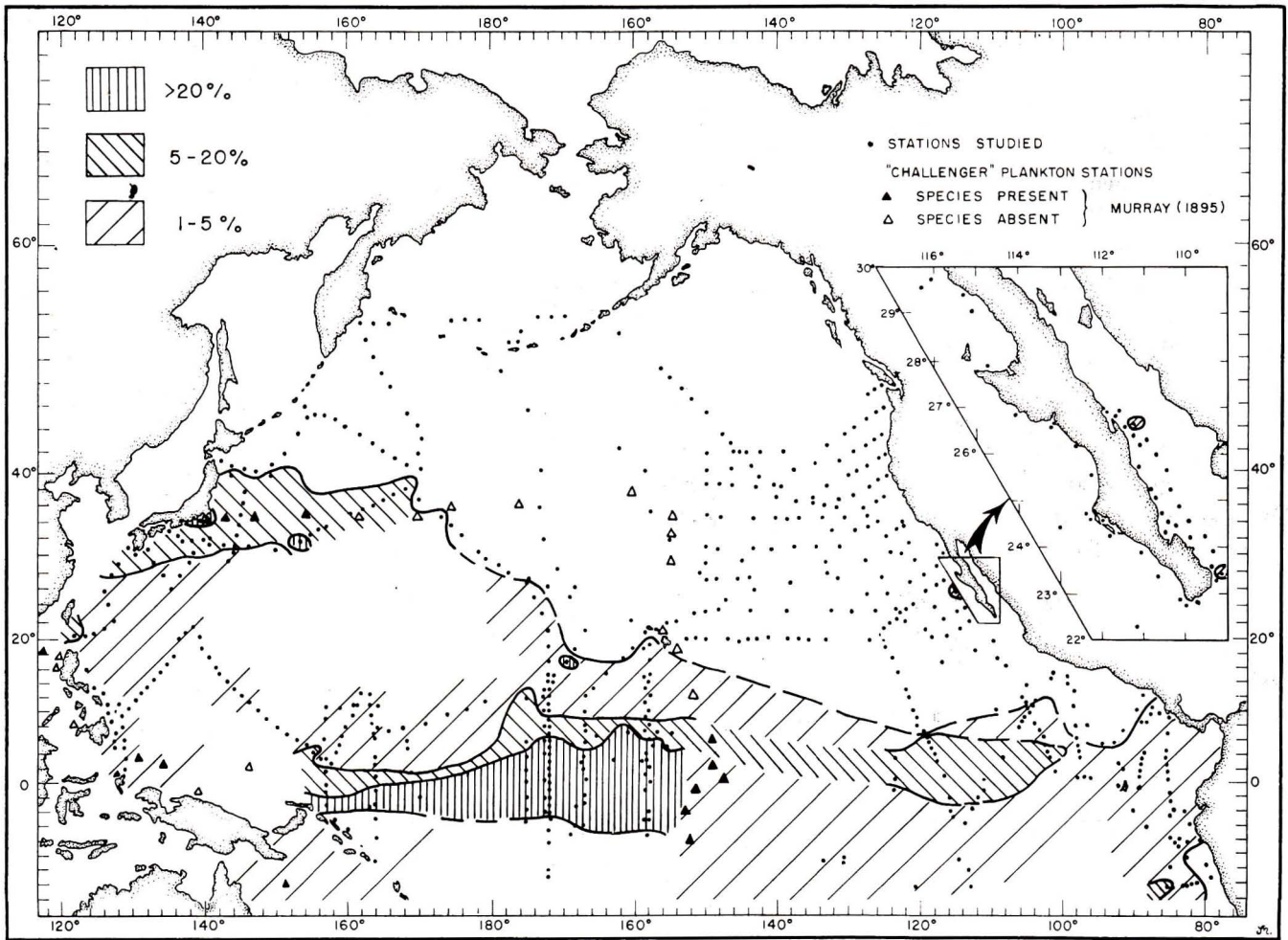
*S. dehiscens* (Text fig. 33) is most abundant in the center of the equatorial Pacific region. To the east and west the frequencies become lower. One occurrence is recorded from the Kuroshio off southern Japan.



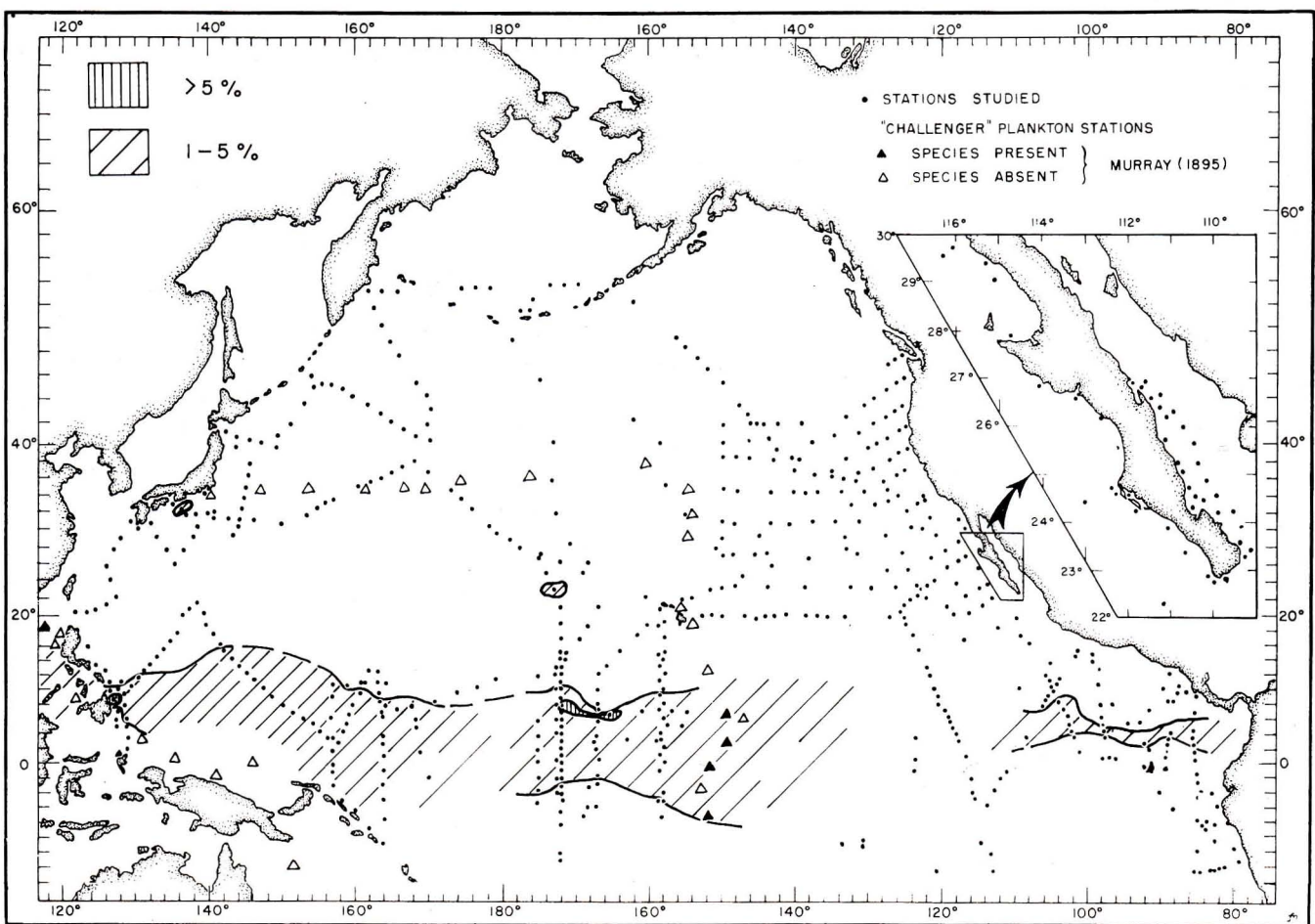
TEXT FIGURE 31

Distribution of *Orbulina universa* d'Orbigny





TEXT FIGURE 32  
Distribution of *Pulleniatina obliquiloculata* (Parker and Jones)



TEXT FIGURE 33  
Distribution of *Sphaeroidinella dehiscens* (Parker and Jones)



SPECIES	COLD		WARM	
	SUB-ARCTIC FAUNA	TRANSITION FAUNA	CENTRAL FAUNA	EQUATORIAL west-central FAUNA
<i>Globigerina pachyderma</i>	█			
<i>Globigerinoides cf. minuta</i>	█			
<i>Globigerina quinqueloba</i>	█			
<i>Globigerina bulloides</i>	█	█		
<i>Globigerina eggeri (small)</i>	█	█		
<i>Globigerinita glutinata</i>	█			
<i>Globigerina eggeri (large)</i>		█		
<i>Orbulina universa</i>		█		
<i>Globorotalia scitula</i>		█		
<i>Globigerinoides rubra</i>		█	█	
<i>Globigerinella aequilateralis</i>			█	
<i>Globigerina sp.</i>			█	
<i>Globigerina hexagona</i>			█	
<i>Hastigerina pelagica</i>		█	█	
<i>Globorotalia truncatulinoides</i>		█	█	— ? —
<i>Globigerina inflata</i>			█	
<i>Candeina nitida</i>			█	
<i>Globigerinoides sacculifera</i>			█	█
<i>Globorotalia menardii</i>			█	█
<i>Globigerinoides sp.</i>			█	█
<i>Globigerinoides conglobata</i>			█	█
<i>Globorotalia tumida</i>			█	█
<i>Globorotalia hirsuta</i>			█	█
<i>Pulleniatina obliquiloculata</i>				█
<i>Globigerinella sp.</i>				█
<i>Sphaeroidinella dehiscens</i>				█
<i>Globigerina conglomerata</i>				█
<i>Hastigerinella digitata</i>			?	█

TEXT FIGURE 34

Generalized ranges of species

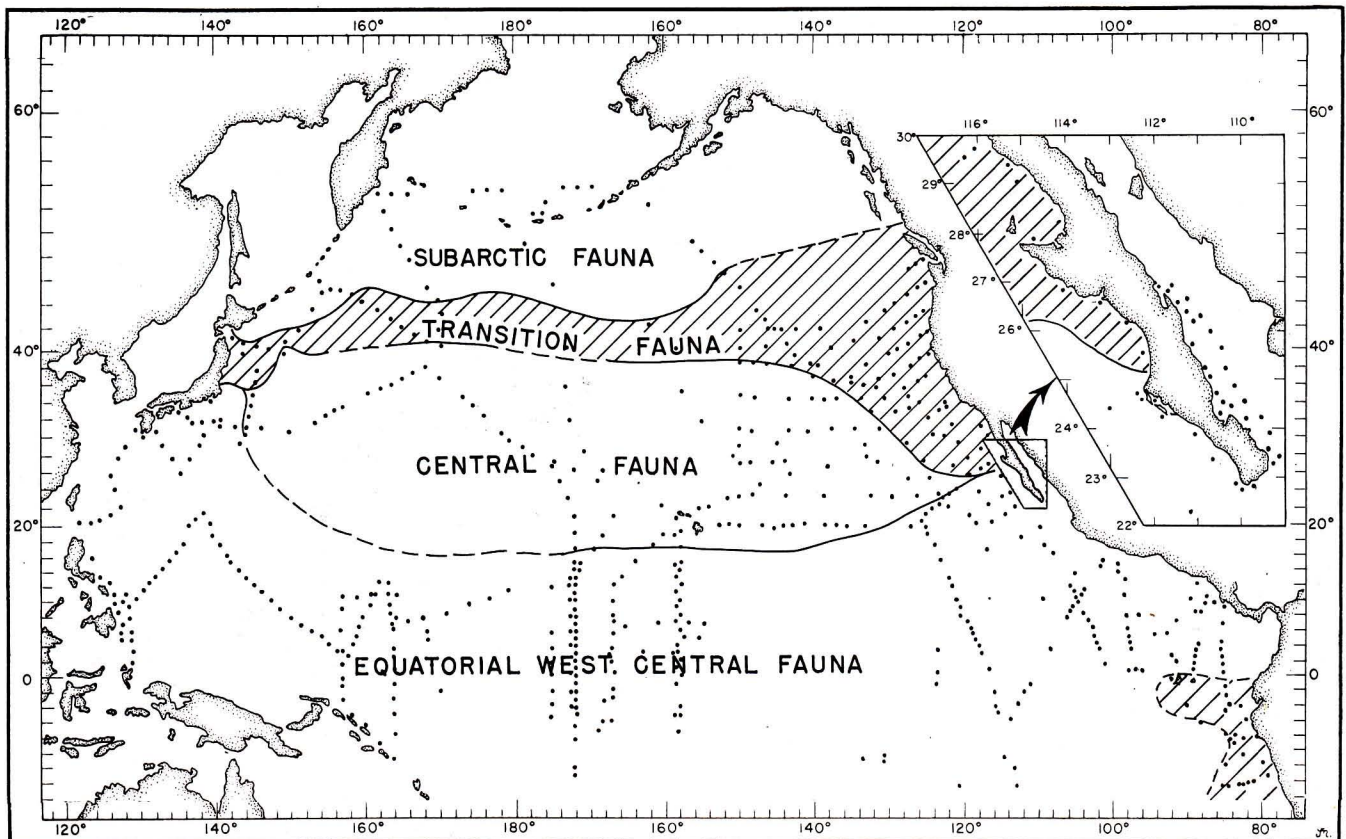
DISTRIBUTION OF PLANKTONIC FORAMINIFERA IN THE PACIFIC

*Geographic Distribution of Faunas*

Distributions of species in the surface water of the North and equatorial Pacific (Text figs. 7-33) may be divided into three general groups, a northern cold-water or subarctic fauna, a southern warm-water fauna, and a transition fauna composed of species of both the cold- and warm-water groups. Species of the warm-water fauna are not uniformly distributed throughout the region and may be further grouped into minor assemblages. In general, these natural groupings based upon the distribution of the species coincide with the geography of the surface water masses as previously described. Text figure 34 shows the generalized ranges of all the species. The geographic extent of the faunas is shown in Text figure 35. The faunal boundaries in the southern hemisphere are hypothetical and have been extrapolated from what is known in the North Pacific.

*Cold-water (Subarctic) fauna.*—This fauna contains species that are restricted to the subarctic region and also includes a few wide-ranging forms that extend into the warm region to the south. The following species have their highest frequencies in this region: *Globigerina* cf. "*G. dutertrei*," *G. pachyderma*, *G. quinqueloba*, *Globigerinoides* cf. *G. minuta*.

The following forms occur with this fauna, some-



TEXT FIGURE 35

Generalized distribution of faunal assemblages



times in high frequency, although they are also found in the transition fauna to the south: *Globigerina bulloides*, *G. eggeri* (dwarfed forms including specimens referred to "*G. dutertrei*"), *Globigerinita glutinata*.

The northern limit of this group is not known but the occurrence of *Globigerina bulloides* and *G. pachyderma* in sediments of the Beaufort and Chukchi Seas (Carsola, 1952) suggests that at least certain elements of this fauna range well into the arctic region. Phleger (1952) reports these species in sediment samples from the Canadian and Greenland arctic. The southern limit of the fauna approximates the Polar Front, or Subarctic Convergence, found between 40-45° N Lat. Where no distinct front occurs the 15° C summer isotherm marks the southern boundary.

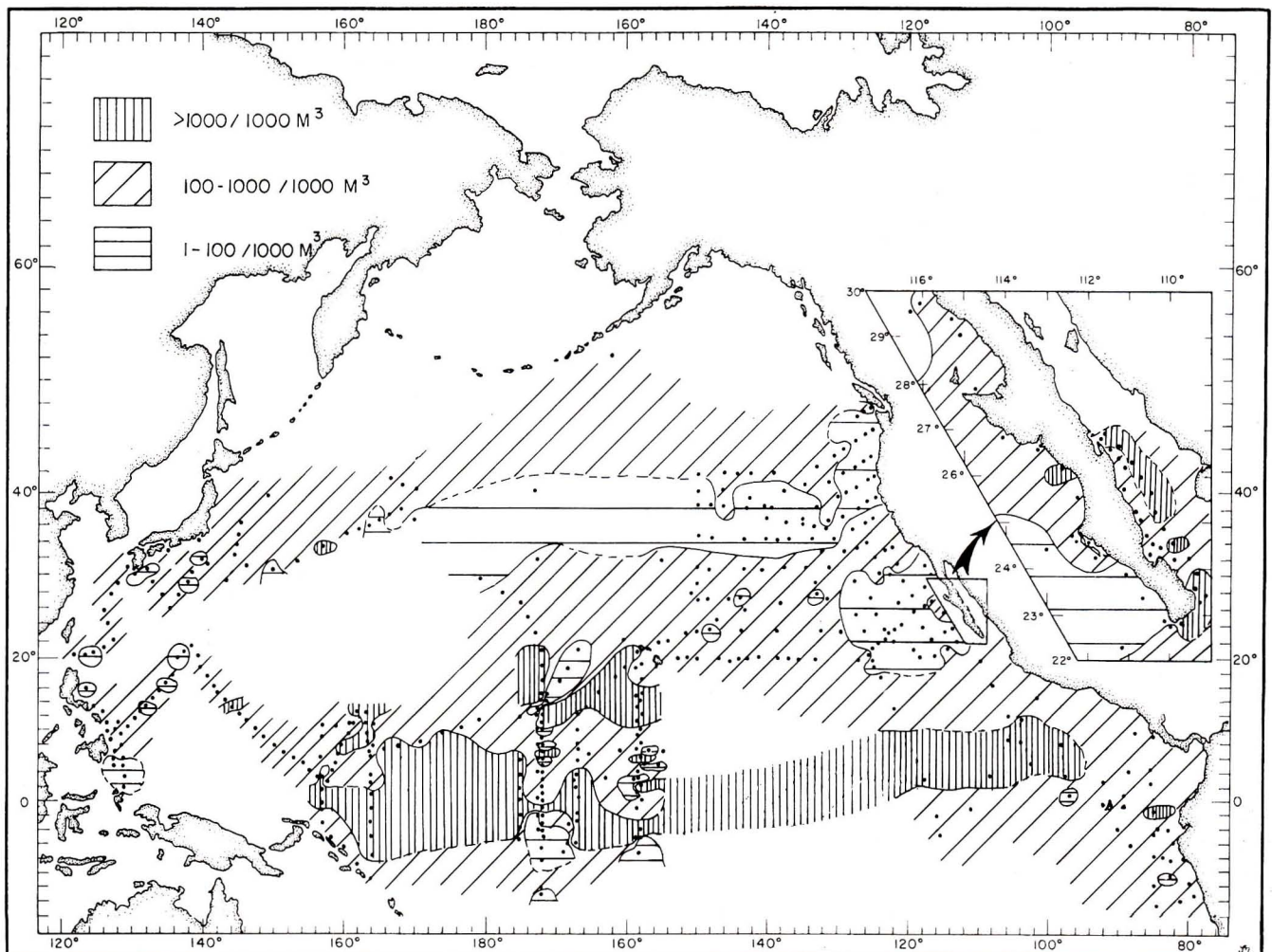
*Transition fauna.*—Between the subarctic and warm-water regions lies an extensive area of faunal mixing. The characteristic fauna contains elements of both the northern subarctic and the warm-water faunas to the south and west. The species composition varies depending upon the distance from the original faunas and the degree of mixing.

The following species are common in this region: *Globigerina bulloides*, *G. eggeri* (large specimens), *G. quinqueloba*, *Globigerinoides rubra*, *Orbulina universa*.

The northern boundary of the transition region is arbitrarily defined as the northern limit of the distribution of *Orbulina universa* and large specimens of *G. eggeri*. The southern boundary is marked by the appearance of equatorial species such as *Globigerinoides sacculifera* and *Globorotalia menardii*.

The 15° C and 20° C summer isotherms are closely associated with these limits to the north and south respectively, the California Current marking part of the boundary in the northeast Pacific. The geographic limits of this region are not fixed but appear to vary in response to seasonal changes. In summer occasional specimens of *Hastigerina pelagica*, *Globorotalia truncatulinoides*, *Globigerina inflata*, and *Globigerinella aequilateralis* are found, especially in the southern portion, but they appear to be "terminal immigrants" carried in by warm water from the regions to the south and west.

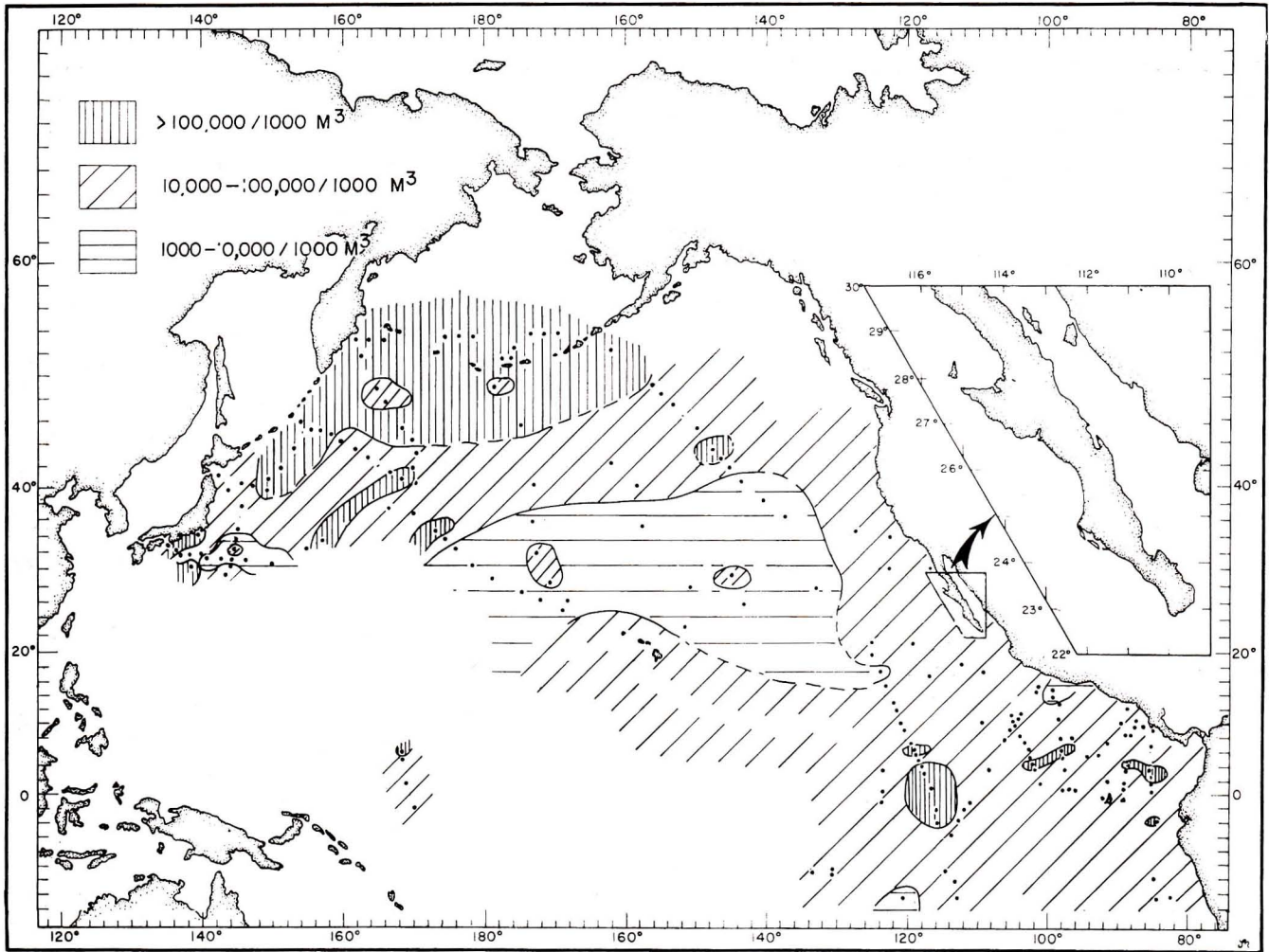
Although the transition fauna is best developed along the west coast of North America, there are also indications of its occurrence in other localities along the boundary of the cold and warm faunas. The species from Chinook stations 5 and 6 in the mid-Pacific and Transpac stations 52, 55, 56 and 60 north-east of Japan appear to belong to this group. The lack



TEXT FIGURE 36

Distribution of total planktonic Foraminifera from meter net samples





TEXT FIGURE 37

Distribution of total planktonic Foraminifera from Clarke-Bumpus and 17 cm. net tows

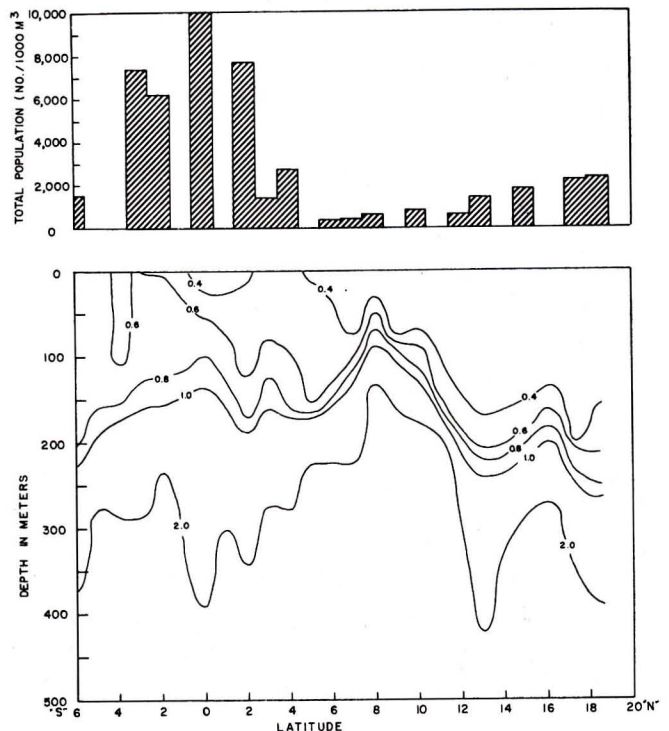
of closely spaced samples in these areas of rapid faunal change prevent more detailed delimitation of the areal extent of this fauna. There are indications of the presence of a transition fauna in the Peru Current, where the oceanographic conditions are similar to those of the California Current.

*Warm-water faunas.*—The area covered by these faunas includes the equatorial region and the central regions of the North and South Pacific. The northern boundary corresponds to the southern limit of the transition region as defined above. The 20° C isotherm associated with this boundary also presumably marks the southern extent of these faunas in the South Pacific.

Within this large region several minor faunal groups can be defined:

1. Central-water assemblage. This group is found in both the Western and Eastern Central Water masses of the North Pacific but appears to be absent, at least in surface layers, from the equatorial region. Representative species of this assemblage are: *Globigerina inflata*, *Globorotalia truncatulinoides*.

2. Equatorial west-central assemblage. This group consists of those species limited to water of the most tropical character, which in this area is defined by the Pacific Equatorial and Western North Pacific Central



TEXT FIGURE 38

Variations in abundance of total planktonic Foraminifera from one traverse across the equatorial region. Below are given phosphate concentrations ( $\mu\text{g-atoms P/L}$ ) for the same section.



water masses. The following species are restricted to this area: *Globigerina conglomerata*, *Globigerinella* sp., *Globorotalia tumida*, *Pulleniatina obliquiloculata*, *Sphaeroidinella dehiscens*.

One of these species (*Globigerina conglomerata*) may be limited to the equatorial region since it has not yet been reported from the west-central Pacific.

*Mixed warm-water fauna*.—Many species are found throughout the entire warm-water region although they may occur in higher frequencies in either the equatorial or the central assemblage.

The following species are more common in the central fauna although they also occur in the equatorial west-central region: *Candeina nitida*, *Globorotalia scitula*, *Hastigerina pelagica*.

The following species are more common in the equatorial west-central region although they also occur in the central fauna: *Globigerina hexagona*, *Globigerinella aequilateralis*, *Globigerinita glutinata*, *Globigerinoides conglobata*, *G. rubra*, *G. sacculifera*, *G. sp.*, *Globorotalia hirsuta*, *G. menardii*, *Hastigerinella rhumbleri*.

#### Geographic Variations

##### in Abundance of Planktonic Foraminifera

Text figures 36 and 37 show areal distributions of total populations from coarse and fine mesh net samples. Text figure 38 shows changes in the total population on one traverse crossing the equatorial region. In general, the various oceanographic regions support different concentrations of Foraminifera. The boundaries of these areas are generally similar to those defined for the faunal groups. The subarctic region (north of 45° N Lat.) is characterized by large total populations although the number of species is small. The greatest concentrations at a single station (560 specimens per m<sup>3</sup>) was found at Transpac station 24 in this region.

The transition region contains a greater number of species than the subarctic and has somewhat smaller populations. At several stations near the mixing of the Kuroshio and Oyashio relatively small populations were recorded.

Samples from the equatorial region have variable total populations. At localities in the Equatorial Current system and in certain localized areas, such as the Gulf of California, extremely high populations are recorded from the coarse net samples. Elsewhere the populations may be relatively low. The few fine-mesh net hauls in this region indicate that total populations are lower than those in the subarctic region.

The central-water region generally supports the lowest foraminiferal concentrations found throughout the entire area examined.

#### Vertical Distribution of Foraminifera

*Introduction*.—A knowledge of the vertical range of planktonic Foraminifera in the water column is necessary for a better understanding of their regional dis-

tribution and for a better analysis of their complex relationships to their environment. Furthermore, in using planktonic Foraminifera from the sediments to interpret climatic conditions it is necessary to know what water depths are being interpreted. Phleger (1945, 1951) has discussed these problems and suggested certain methods of attack, some of which were used in the present study.

Most of the previous samples of living planktonic Foraminifera were taken by shallow net tows and were not quantitative. Very little direct evidence was available to support the idea expressed by Murray (1897, p. 22) that the planktonic Foraminifera live only at the ocean surface. Murray's opinion was based on the distribution of empty tests on the sea bottom and only partly on an analysis of net samples. Carpenter (1875) and Brady (1884), on the other hand, believed that the smaller and younger forms were to be found at the surface and that the larger, older ones lived on the bottom. Little evidence was presented favoring either viewpoint and it was not until the work of Lohmann (1920) that more facts were made available. Lohmann, in analyzing water samples from the Atlantic, found more specimens of *Globigerina* in the upper 100 m of water than at greater depths. The following table is taken from Lohmann's data:

Depth	Number of individuals
0 m	100
50 m	67
100 m	60
200 m	7
400 m	3

Schott (1935) presented data based on Nansen closing-net samples taken by the Meteor Expedition in the equatorial Atlantic Ocean. These data have been analyzed by Phleger (1945) as follows:

Depth in meters	No. of tows	Mean no. of spec./tow
0-100	71	489
100-200	7	8
200-400	13	24
400-600	19	10
600-800	12	11
800-1000	19	28

In these earlier studies on vertical distribution no distinction was made between the living Foraminifera and their empty tests. Only the living organisms should be considered when determining the living environment since dead or dying specimens sinking to the bottom would be expected at every depth. Phleger (1945, 1951) used a modification of the biuret test for protein in differentiating the living from the empty tests in plankton tows from the North Atlantic and the Gulf of Mexico. Phleger's data indicate a higher concentration of living and dead specimens in the upper 100 meters, although at some of his stations a



greater concentration of living Foraminifera was found deeper.

*Variations of total population with depth.*—In addition to the samples taken for determination of geographic distribution, 61 samples were taken for the purpose of determining the depth preferences of the planktonic Foraminifera.

Table 1 shows the vertical distribution of various species from tows made at one locality in the Pacific. The following general observations have been drawn from these data:

1. The samples taken directly from the sea surface contain fewer specimens, in most of the tows, than those taken slightly deeper.
2. The highest concentrations of Foraminifera occur between 6 to 30 m in most tows. In no tow does the greatest concentration occur below 100 m.

3. The depth of greatest decrease in number per cubic meter occurs between 50 and 100 m in most tows.

4. Relatively low concentrations of specimens were noted below 200 m.

*Diurnal migration.*—Diurnal vertical migrations by many planktonic animals are well-known. At night the highest concentrations of individuals are reported near the surface while in the daytime the greatest concentrations are in the deeper water (Sverdrup *et al.*, 1942). Owen (1868, pp. 148, 156) reports that the highest concentrations of planktonic Foraminifera are near the surface at night. Rhumbler (1911, chart A) compares night and day tows in the North Atlantic, showing that in general the day tows have much higher concentrations of Foraminifera. Allan Bé (personal communication) reports that in surface net tows off Bermuda, "Three night tows were 30-40% poorer

LOCATION	LAT. 33°02'N. LONG. 118°23'W.																												
STATION	A							B							C							D							
TYPE OF NET	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C	C
DEPTH IN METERS	0	0	10	50	100	5	10	25	40	60	60	80	100	150	200	400	0-5	10	25	40	5	10	25	40	50	60	80	100	
TOTAL SAMPLE POPULATION	39	122	222	132	74	103	130	96	139	204	158	218	104	59	38	49	102	179	106	90	41	166	67	162	181	145	50	56	
POPULATION PER 1000 M <sup>3</sup>	36,000	53,000	89,000	70,000	53,000	40,000	124,000	107,000	87,000	85,000	93,000	64,000	28,000	18,000	15,000	21,000	79,000	200,000	101,000	65,000	22,000	123,000	67,000	108,000	87,000	79,000	50,000	11,000	
<i>Candeina nitida</i>																													
<i>Globigerina bulloides</i>	13	20	20	16	27	32	23	12	22	30	22	23	18	7	5	10	17	22	23	22	22	25	16	20	22	22	18	21	12
<i>conglomerata</i>																													
<i>eggeri</i>	36	29	47	54	54	34	37	46	49	39	54	51	55	79	60	48	37	50	49	51	27	48	45	45	42	43	32	46	44
<i>hexagona</i>																													
<i>inflata</i>				1						1				1		12			1										
<i>pachyderma</i>																2	3												4
<i>quinqueloba</i>																	2												2
sp.																													
<i>Globigerinella aequilateralis</i>			1			1	1	2	1	1		2	4				1	1	4	1	2	2	2	2	1	2	8	2	3
sp.																													2
<i>Globigerinita glutinata</i>										3	3	3	6	1	5	2	3	3	3	7	10	3	6	3	10	10	10	5	7
<i>Globigerinoides conglobata</i>																													
<i>cf. minuta</i>																													
<i>rubra</i>	20	20	18	6	5	9	14	20	16	14	11	5	2	2	8	4	20	12	9	4	20	11	13	15	10	6	10	11	12
<i>sacculifera</i>																													
sp.	5	3	2	3		3	1	3		1	1						1	1	1	12	1		1	2	1				
<i>Globorotalia hirsuta</i>																													
<i>menardii</i>										1	1			3			1									1	2	2	
<i>scitula</i>													3																3
<i>truncatulinoidea</i>													1																
<i>tumida</i>																													
<i>Hastigerina pelagica</i>																	4												3
<i>Hastigerinella rhumbleri</i>																													1
<i>Orbulina universa</i>	2	2	1	3	5	3	3	1	1	5	1	3	3	11	4	4	3	3		2	3	3	4	2	1	4	4		3
<i>Pulleniatina obliquiloculata</i>																													
<i>Sphaeroidinella dehiscens</i>																													
unidentified globigerinids	25	26	10	19	11	16	21	14	8	10	4	10	14	5	5	14	17	7	7	9	5	7	15	10	11	15	16	11	18
unidentified globorotaliids																													6

TABLE 1  
Occurrence of planktonic Foraminifera at different depths in per cent of total population.



than the seven day tows taken at the same place. A similar observation is true between 2 day tows and 1 night tow taken at the same location in the Caribbean.”

A comparison has been made between the concentrations of total planktonic Foraminifera per cubic meter in surface hauls at day and night stations in the Pacific to discover whether a similar relationship holds true here. The data have been taken from King and Demond (1953) for POFI cruises 2, 5, and 8. Data for POFI cruise 16 were taken from Hilda and King (1955). The ratio of night/day hauls in all cases is less than 1, indicating that there was greater concentration at the surface during the day.

POFI cruise 16 obtained data on concentration of total planktonic Foraminifera at the surface, in intermediate depths, and in deep water. Analysis shows that surface Foraminifera during the day are generally more abundant than they are at night, but in the deep samples the night catches average more than the day samples. This suggests that Foraminifera ascend to the surface during the day and descend at night.

A possible mechanism for this may be found in the probable day and night differences in oxygen production by the symbiotic algae in the protoplasm. During the day the oxygen may be produced so rapidly that bubbles are formed, causing the Foraminifera to rise toward the surface. The utilization of oxygen for respiration during the night would cause an increase of specific gravity resulting in the sinking from the upper layers.

## DISCUSSION

### *Ecologic Factors*

Each species tends to extend its range whenever possible by continuous pressure against its boundaries. The boundaries to a large extent are determined by the limiting effects of various environmental factors of which a large number exist. Hutchins (1947) has shown the importance of temperature in the observed ranges of benthic species and similar reasoning may be extended also to planktonic organisms. Food, oxygen, salinity, pH, dissolved inorganic and organic substances, and biological interactions are but a few of the possible additional factors having a direct effect upon distribution. For each species there exist maximum and minimum environmental limits for survival and reproduction. When the range of tolerance for many factors is wide the species may live over an extensive geographic range; if the range is narrow the form usually is restricted to a smaller area.

The tolerance range for reproduction generally is more limited than that for the mere survival of the adult forms. The occurrence of adult specimens does not necessarily indicate that the organism can reproduce there since currents may carry individuals into regions where ecologic factors will not permit reproduction.

Only a few of the known environmental factors appear to be so variable that they affect the distribution

of the planktonic Foraminifera in the region sampled. For example, oxygen concentrations are very close to saturation in the surface water, varying from approximately 4 to 6.5 ml per liter. The oxygen content may reach lower values at certain localities such as the Gulf of California where concentrations of 0.17 ml/L have been reported at 100 m. However, Sverdrup *et al.* (1942) state that even such low oxygen values as this are not known to be limiting to most planktonic organisms.

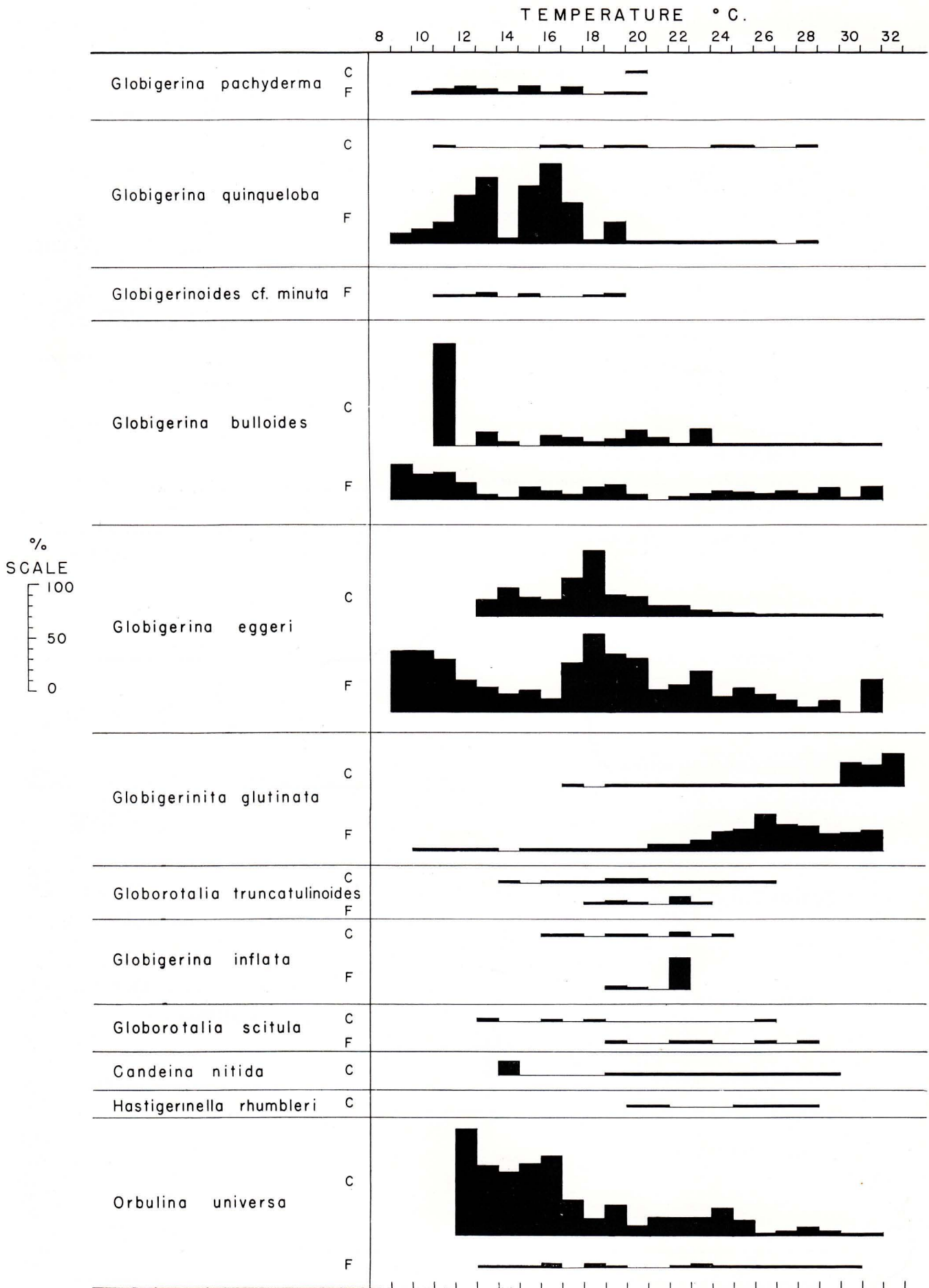
*Temperature.*—The distributions of most species show a general agreement with latitude, but an even better correlation with sea surface temperatures. For example, in the western Pacific off Japan the northern boundary of the “warm” fauna (typified by *Globorotalia menardii*) occurs at about 40° N Lat. but in the eastern Pacific the boundary is depressed farther south to approximately 20° N Lat. This boundary generally follows the 20° C surface isotherm.

The temperature ranges of the species, based on surface temperatures observed when the specimens were collected, are shown in Text figures 39 and 40. No one temperature can be shown to form a common boundary for any of the faunal groups but there are ranges of temperatures in which the greatest faunal changes are observed.

Text figure 41 shows the maximum number of species that have been found at each of the indicated temperatures during this study. It shows that as the temperature increases more species appear until an “optimum plateau” is reached. Fewer species are found at the highest temperatures. The region of greatest faunal change for all samples occurs between 12° and 18° C which corresponds to the temperature range at the Subarctic Convergence. The sharpness of the faunal boundary appears to depend upon the steepness of the horizontal temperature gradient. Marked temperature changes occur at the junction of the Kuroshio and Oyashio currents. Text figure 42 shows the dramatic change of fauna that occurs within a relatively short distance in this area. The broad transition zone, with no sharp faunal boundaries, along the west coast of North America can be correlated with the lack of a strong temperature gradient.

Water movement at the boundary of the warm and cold faunas confuses the picture to a certain extent. Text figure 42 shows that cold water from the Oyashio, which flows under the warm Kuroshio, is transporting cold water forms to the south. Warm water species carried to the north can survive only if they remain in the upper layer. Large-scale eddies are found where the mixing of the Kuroshio and Oyashio takes place. Eddies of water, each with its characteristic plankton community, may from time to time break off from the main water masses and carry the contained organisms a limited distance into unsuitable areas. Eventually the eddies or patches of warm or cold water will reach

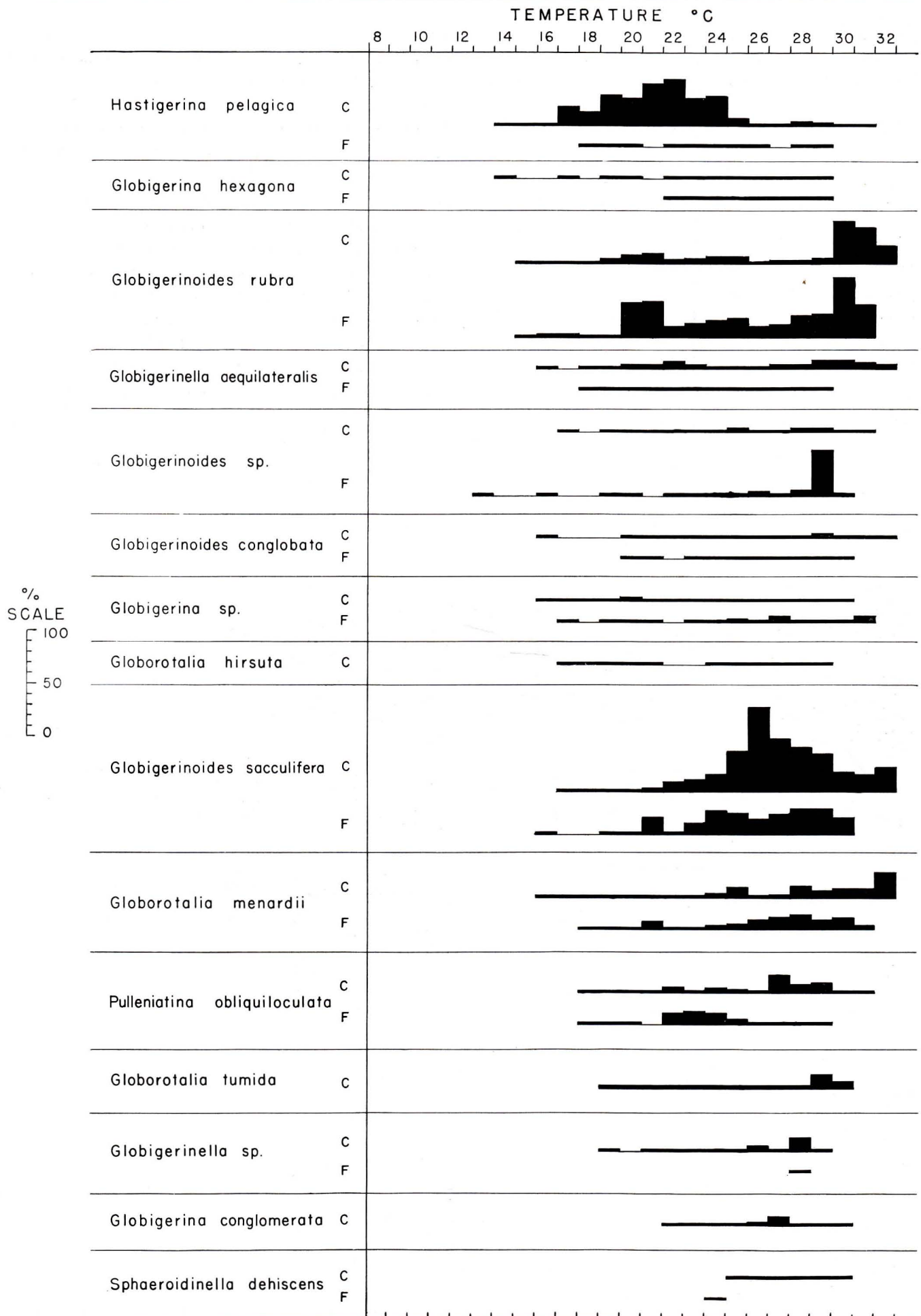




TEXT FIGURE 39

Frequency of abundance of planktonic Foraminifera at different temperatures  
 "C" refers to coarse mesh samples (> 0.55 mm); "F" indicates fine mesh samples (> 0.14 mm).



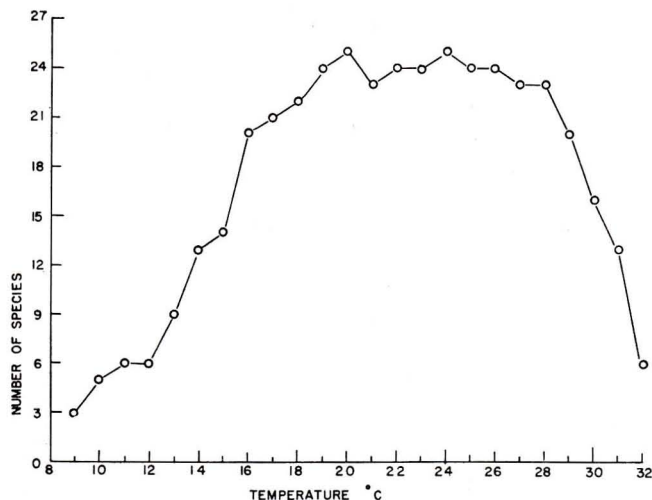


TEXT FIGURE 40

Frequency of abundance of planktonic Foraminifera at different temperatures  
 "C" refers to coarse mesh samples (>0.55 mm); "F" indicates fine mesh samples (>0.14 mm).



the temperature of the surrounding water and the contained organisms will be affected. When a warm-water form is carried into cold waters it may maintain

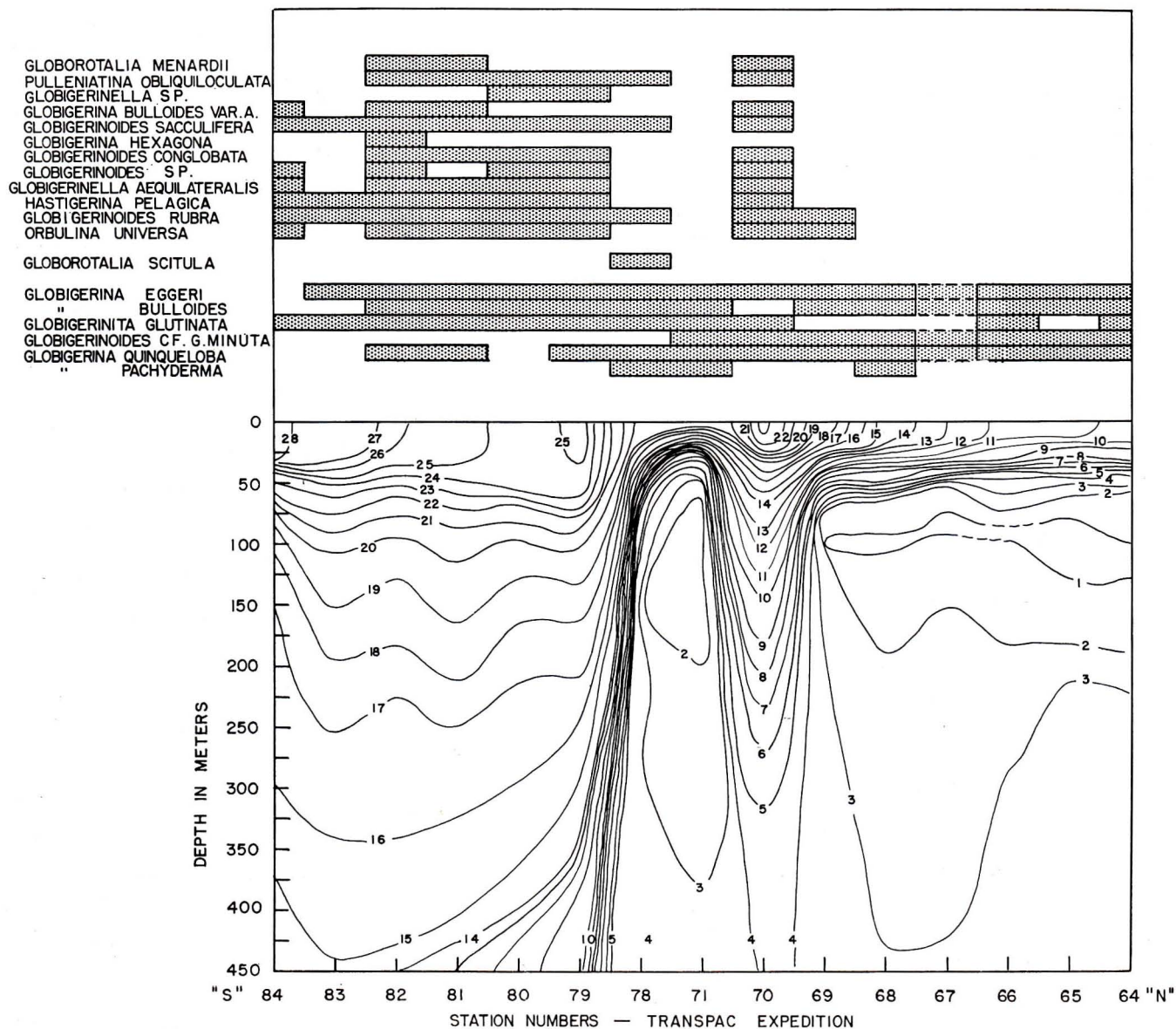


TEXT FIGURE 41

Graph showing the maximum number of species found at the indicated temperatures.

itself for limited periods although it may not successfully reproduce. Bigelow (1926) and Redfield and Beale (1940) have shown that certain species of Chaetognatha and other organisms are not immediately killed when carried into colder water but, if conditions are not too extreme, will even grow to a larger size than they do in their normal warm-water habitat. In the Pacific a "sterile distribution" presumably occurs in the extensions of the Kuroshio into northern latitudes. This "cold tolerance" of planktonic forms and the problems in identifying very young stages make it difficult to define precisely the reproductive boundaries of each species.

The physiological effects of different temperatures upon living planktonic Foraminifera are not known since these forms have not been successfully cultured in the laboratory. It is possible that generalized information may be gained by controlled study of the effect of temperature upon benthonic species. Laboratory studies (Bradshaw, 1957) on *Streblus beccarii* (Linné) var. *tepida* (Cushman) indicate that a de-



TEXT FIGURE 42

Vertical section across boundary of Kuroshio and Oyashio currents showing warm and cold faunal boundary



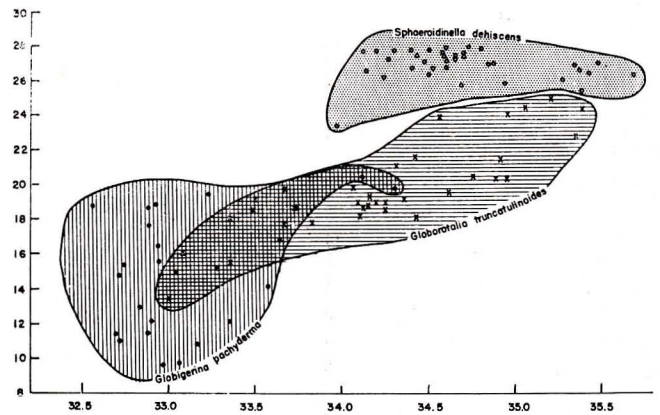
crease in temperature results in a slower rate of growth, increased time to sexual maturity, and a larger size than was found in specimens kept at normal environmental temperatures. Lowering the temperature below 10° C appeared to halt the reproductive process indefinitely although the organisms remained alive and healthy.

*Salinity.*—Salinity usually is not considered as important an ecologic factor as temperature in the open sea. Very little is known of its effect upon oceanic plankton, however, and relatively slight changes of salt content may be important for such forms.

There appears to be a general relationship between the distribution of species of planktonic Foraminifera and surface salinities. There is the same southward depression of salinity values in the eastern Pacific as was noted in the temperature distribution. There is also a steep salinity gradient across the sharp faunal boundary off Japan while more gradual changes are found off the west coast of North America.

*Ecologic water masses.*—Variations of temperature and salinity are closely interrelated and until the effects of the two can be separated it may be best to consider them together. Simultaneous plots of temperature and salinity have been used by physical oceanographers as convenient descriptions of oceanographic water masses and as aids in differentiating one from another. Seasonal and local variations, however, limit the strict use of these defined water masses to depths deeper than 100 to 200 meters. The upper limit of the traditional water masses thus lies below the depth of maximum concentration of Foraminifera as indicated by this study. The need for a more comprehensive concept of the biological environment has led to the generalization of an ecologic water mass. This has been defined by Phleger (1954) as "any body of water which has a uniform ecologic effect and supports a uniform assemblage of organisms."

Although the temperature and salinity relationship of such a water mass is of obvious importance in limiting the distribution of species, more subtle, unknown biochemical factors undoubtedly play an important role.



TEXT FIGURE 43

Temperature and salinity relations of water inhabited by three species of planktonic Foraminifera.

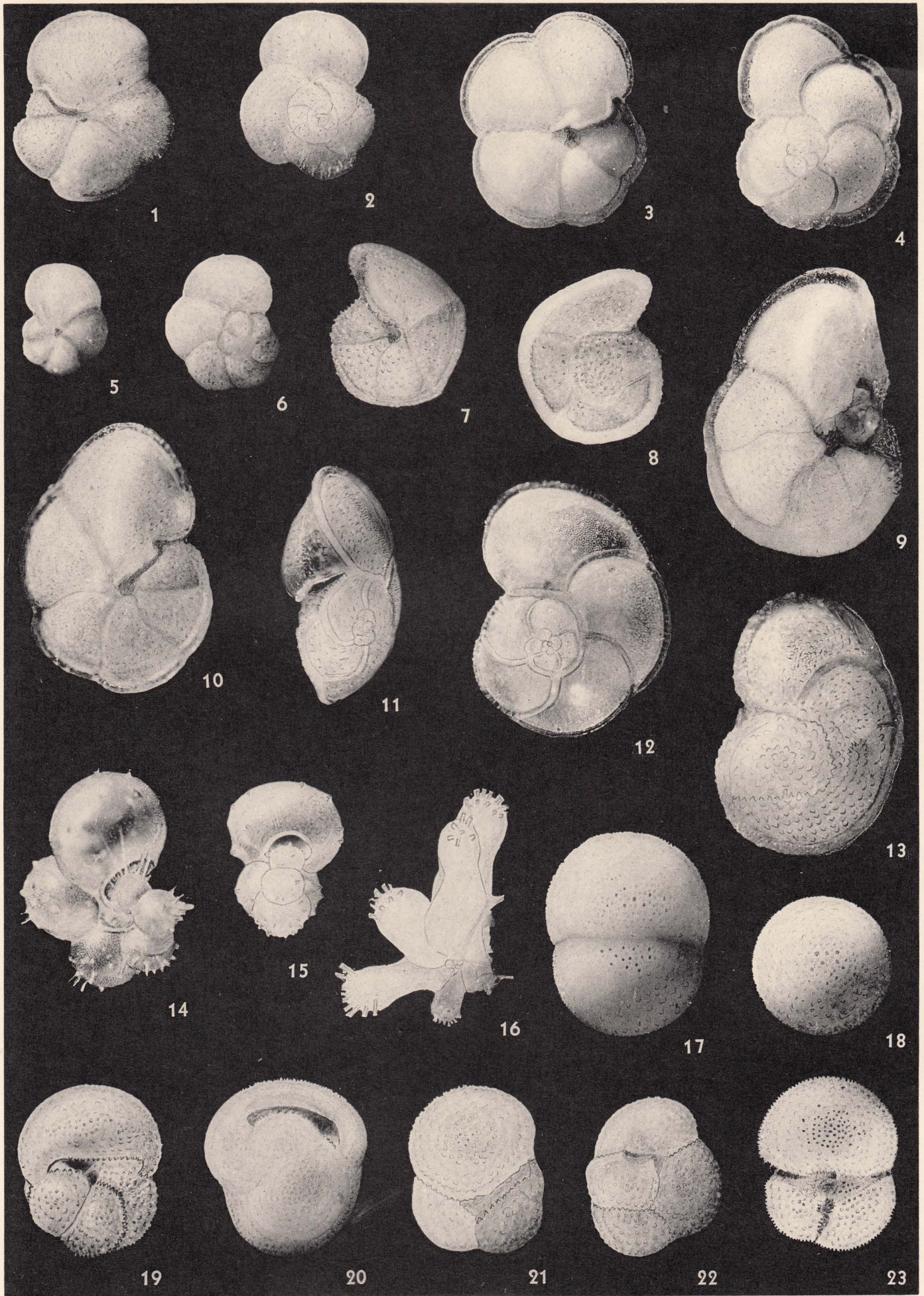
Bigelow (1926), Fraser (1954), Johnson (1939, 1949, 1954), Russell (1935), and Russell and Hastings (1933) have utilized planktonic organisms as indicators of water movements and to recognize bodies of water of varying but usually limited extent. Indicator organisms are often so sensitive to changes in physical-chemical properties that they have been used to identify water masses, where traditional oceanographic techniques fail. Bieri (1957), Brinton (1957) and Hida (1957) have used species of chaetognaths, euphausiids, and pteropods, respectively, to recognize large faunal regions in the Pacific that appear to be closely related to the surface oceanographic water masses.

The ranges in temperature and salinity values of the water inhabited by three species of Foraminifera, each illustrating one of the major faunal groups, are shown in Text figure 43. The values for the surface water are outside the limits of the defined water masses as shown in Text figure 5. Nevertheless, there still appears to be a natural division of the values into several clusters which in general represent the surface water overlying each of these water masses. One such grouping of high temperature and salinity, illustrated by *Sphaeroidinella dehiscens*, appears to be closely related to the Equatorial Pacific Water mass. A second group with lower temperatures and salinities, typified by *Globigerina pachyderma*, represents a surface mani-

#### EXPLANATION OF PLATE 8

FIGS.		PAGE
1, 2.	<i>Globorotalia hirsuta</i> (d'Orbigny). × 47. Shellback sta. 175 .....	44
3, 4.	<i>Globorotalia menardii</i> (d'Orbigny). × 47. Shellback sta. 80 .....	44
5, 6.	<i>Globorotalia scitula</i> (Brady). × 102. Shellback sta. 154 .....	44
7, 8.	<i>Globorotalia truncatulinoides</i> (d'Orbigny). × 47. Transpac sta. 115 .....	44
9, 13.	<i>Globorotalia tumida</i> (Brady). × 47. Norpac sta. 154.5 .....	47
10-12.	<i>Globorotalia</i> cf. <i>G. menardii</i> . × 47. Variant form, Equapac-s sta. 36 .....	44
14, 15.	<i>Hastigerina pelagica</i> (d'Orbigny). × 47. Shellback sta. 80 .....	47
16.	<i>Hastigerinella rhumbleri</i> Galloway. × 47. Shellback sta. 80 .....	47
17, 18.	<i>Orbulina universa</i> d'Orbigny. × 31. Troll sta. 14 .....	49
19, 20.	<i>Pulleniatina obliquiloculata</i> (Parker and Jones). × 65. Equapac-s sta. 21 .....	49
21-23.	<i>Sphaeroidinella dehiscens</i> (Parker and Jones). 21, 22, × 47; 23, variant form, × 31. Equapac-s sta. 21 .....	49





Bradshaw: Living Planktonic Foraminifera, Pacific Ocean



festation of the Pacific Subarctic Water, while *Globorotalia truncatulinoides* illustrates a third grouping of intermediate values related to the Central Water masses. There is a certain amount of overlapping of these groups but it is believed that they reflect real differences in the character of the water.

#### *Abundance of Planktonic Foraminifera*

The Foraminifera form a significant fraction of the zooplankton. King and Demond (1953) show that Foraminifera average from 1.3 to 9.9 per cent of the total number of zooplankton organisms although they constitute a small fraction of the total mass of zooplankton. Marked seasonal changes in the relative abundance of Foraminifera are indicated by the change in average percentage composition from 1.8, 3.0, and 2.5 per cent in the three fall and winter cruises to 8.6 per cent in summer. In the winter cruises the most abundant zooplankton group was Copepoda, followed by Chaetognatha, Tunicata, Euphausiacea, Siphonophora, and Foraminifera. In summer (cruise 5) Foraminifera increased in numerical importance becoming the third most numerous group, exceeded only by Copepoda and Chaetognatha. At two of their stations (7 and 9) Foraminifera made up 60 and 58 per cent of the total number of zooplankters, exceeding even the copepods. It should be remembered that these values are limited to the relatively large forms retained by the meter net. When finer mesh nets are used the relative numerical importance of the Foraminifera becomes even greater. Hida and King (1955) using Clarke-Bumpus samplers with nets of 0.31 mm aperture report that Foraminifera are the second most abundant zooplankton group during the summer in the equatorial Pacific.

Occurrence of Foraminifera in the plankton at any time reflects a complex interaction of physical-chemical and biological factors. The need for sufficient quantities of acceptable food is obvious. Since the food of planktonic Foraminifera consists of other plankters, their concentration is controlled in part by the same factors that control the bulk of the zooplankton.

The total zooplankton volumes (chart on file at Scripps Inst. Oceanography) and the concentration of total Foraminifera in the upper layers (Text figs. 36, 37) show the same pattern as the distribution of inorganic phosphate. The regions of abundant Foraminifera (equatorial, subarctic and along the American west coast) are also areas of high phosphate. These are in marked contrast to those in the centers of the great current gyres which contain relatively low concentrations of Foraminifera and phosphate.

The large populations of Foraminifera near the equator probably are related to the greater overall fertility in this region than in the adjacent ones to the north and south. Vertical circulation and its effect on the abundance of total zooplankton in the equatorial region has been discussed by Cromwell (1953), King and Demond (1953) and King and Hida (1957). Ac-

ording to Cromwell (1953), the prevailing winds at the equator cause a divergence of the surface layers resulting in upwelling of nutrient-rich water. This fertilization is followed by extensive phytoplankton development and eventually by large zooplankton populations. A zone of convergence and associated sinking of the surface waters are expected to concentrate the zooplankton so that the highest numbers of individuals occur in the convergent zone. During south or southeast winds the convergence is believed to occur north of the equator, and south of the equator during a north or northeast wind. Since the prevailing winds in this region are east and southeasterly, the maximum concentration of zooplankton generally is expected north of the equator.

#### *Variations with Depth*

Tests of Foraminifera occur at all depths of water from the surface to the bottom. Ecological relationships of planktonic Foraminifera should be determined from specimens capable of carrying out their complete life cycle and not from specimens which are dead or incapable of reproduction. It is doubtful that species with highest concentrations in warm surface layers will be equally active in cold deep water. A species in this unfavorable position would soon die out were it not continuously restocked from the normal habitat above.

In the present study the largest specimens of many species were frequently found in the deepest samples. Similar observations have been reported by Murray (1895). The larger size may be due to continued growth of the organism if reproduction does not occur. Various examples of this in benthonic Foraminifera and other zooplankters have been mentioned previously.

#### *Possible Faunal Changes with Depth*

Closing-net tows were taken at various depths off San Diego, California, to determine if there were any restricted vertical distributions of species. The results are given in table 1. These data show no good evidence for restriction of the listed species to particular depths. Similar results were obtained by Phleger (1951) in the Gulf of Mexico and by Bé (personal communication) in the North Atlantic.

Some workers have postulated that various species are restricted to different depth levels. Emiliani (1954), using temperature data derived from the isotopic composition of Foraminifera tests, has calculated the depths at which various species live. This technique is based on the assumption that planktonic Foraminifera deposit calcium carbonate in equilibrium with the water. This is not necessarily true since exchange may occur between the oxygen liberated by the symbiotic organisms known to occur in many species of planktonic Foraminifera and the calcium carbonate which is being deposited. Problems of this



type have been discussed by Emiliani (1955, p. 544) and by Epstein and Lowenstam (1953).

Emiliani (*op. cit.*, p. 545) notes that his isotopic temperatures represent the weighted average temperature of shell deposition of the foraminiferal population. Several hundred tests of each species were required to make up the 5 mg. of calcium carbonate required for each temperature determination and these tests were taken from core sections several centimeters in thickness representing long time-periods. It seems rather hazardous to use average isotopic temperatures over such a long time-period when the range of variations of these temperatures is unknown. It is well known, for example, that numerous fluctuations of climate have occurred in the last 1000 years. Taylor, Bigelow and Graham (1957) have shown that fluctuations of climate since 1900 are reflected in changes in distribution of certain marine species. Various warm- and cold-water species of planktonic Foraminifera also probably vary their geographic range in response to climatic trends. Certain cold-water species may be absent from an area during warm periods but be abundantly represented during cold periods.

Limited seasonal studies of planktonic Foraminifera (unpublished data) show that in areas of marked seasonal change different faunas may be present at different times of the year. Such seasonal changes in other planktonic organisms are well-known and usually have been related to changes in temperature of the water. Thus the empty tests of certain species found on the bottom may reflect the temperatures at certain periods only and not the mean temperatures as suggested by Emiliani (1955).

Bandy (1956, p. 187) suggested the minimum water depths at which certain species of planktonic Foraminifera live in the Gulf of Mexico. These depths are not based on the study of the Foraminifera in plankton samples but upon the depths at which their tests were found on the sea floor. The upper limits of the same species from plankton tows taken in the present study and by Phleger (1951, tables 2-9) do not agree with Bandy's findings. Many species reported by Bandy below his listed depths were found at or nearer the surface in the above plankton studies. Moreover, the order of occurrence of the tests of different species from shallow to greater depths in the Gulf of Mexico sediments corresponds approximately to the order of abundance of those species in the sediments, as listed by Parker (1954, p. 477). Thus, in shallow-water samples, which usually contain small numbers of planktonic specimens, the most common form would be more apt to appear than the rarer species. The probability of finding uncommon forms increases in deep water because of higher populations in the sediment.

There is some evidence, however, that cold-water species that live at the surface in the subarctic and temperate zones may live at lower temperatures below

the warm surface water in the equatorial regions. This is true of many other planktonic organisms such as copepods, siphonophores, polychaetes, amphipods, chaetognaths, and radiolarians (Ekman, 1953, pp. 252 and 321). In view of this widespread occurrence in other invertebrate groups it would be surprising if planktonic Foraminifera did not exhibit this phenomenon, at least to a limited extent. "Tropical submergence" would be expected to influence primarily the cold-water group such as *Globigerina pachyderma*, *G. bulloides*, *G. quinqueloba*, and *Globigerinoides* cf. *G. minuta*, but also perhaps the temperate, stenothermal species such as *Globorotalia truncatulinoides* and *Globigerina inflata*. Eurythermal species, such as *Globigerina eggeri* and *Globigerinita glutinata*, can apparently tolerate warm temperatures and need not migrate into deeper waters to survive.

The lack of deep open-and-closing tows in the tropical Pacific prevents a thorough test of this hypothesis. However, occasional specimens of *Globigerina bulloides*, *G. quinqueloba*, *Globigerinoides* cf. *G. minuta* and *Globorotalia truncatulinoides* have been found in deep oblique tows from the equatorial and warm temperate regions. This suggests that they may occur at greater depths in that area. An alternative possibility is that they occur in the upper layers but at very low concentration. More extensive work on vertical distribution in the tropical regions is needed to decide this point.

Data from many deep open-and-closing hauls from 100 to 1000 m depth in the equatorial Atlantic were taken by Schott (1935, p. 62). *Globigerina bulloides* and *G. inflata* (both cold-temperate forms) were found in the deep tows but were not present in the surface waters (0 to 100 m) of the same region. Schott interpreted this as indicating submergence into colder waters for these normally cold-water species. His data suggest that *Globorotalia truncatulinoides* also may exhibit tropical submergence since it was found at 200 to 400 m depth and not in the upper layers of the equatorial Atlantic.

Although temperature appears to be the most critical factor in limiting the bathymetric distribution of various species, other factors, such as the effects of pressure, may be also of importance. The fact that the greatest populations are found in the upper zone of the sea, where the light is most intense, may be more than mere coincidence and may show sunlight to be of direct importance through its effect on the symbiotic algae known to be associated with the Foraminifera.

#### REFERENCES

- AGASSIZ, ALEXANDER, 1902, Report on the scientific results of the expedition to the tropical Pacific. I. Preliminary report and list of stations: Mus. Comp. Zool., Mem. 26 (1), pp. 1-114.
- BANDY, O. L., 1956, Ecology of Foraminifera in north-



- eastern Gulf of Mexico: U. S. Geol. Surv. Prof. Paper 274-G, pp. 179-204.
- BIERI, ROBERT, 1957, Distribution of the planktonic Chaetognatha in the water masses of the Pacific. Unpublished PhD thesis, Univ. of Calif., Scripps Inst. Oceanography, La Jolla, Calif.
- BIGELOW, H. B., 1926, Plankton of the offshore waters of the Gulf of Maine: U. S. Bur. Fisheries, Bull. 40 (for 1924), pt. 2, 509 pp.
- BOLLI, H. M., LOEBLICH, A. R., JR., and TAPPAN, HELEN, 1957, Planktonic foraminiferal families Hantkeninidae, Orbulinidae, Globorotaliidae, and Globotruncanidae: *in* Studies in Foraminifera, U. S. Nat. Mus. Bull. 215, pp. 3-50.
- BRADSHAW, J. S., 1957, Laboratory studies on the rate of growth of the foraminifer, "*Streblus beccarii* (Linné) var. *tepida* (Cushman)": Jour. Paleontology, vol. 31, no. 6, pp. 1138-1147.
- BRADY, H. B., 1884, Report on the Foraminifera dredged by H. M. S. "Challenger" during the years 1873-1876: Rept. Voy. *Challenger*, Zoology, vol. 9, 1 vol. text, 814 pp.; 1 vol. pls. 1-115.
- BRINTON, EDWARD, 1957, Distribution, faunistics and evolution of Pacific euphausiids: Unpublished PhD thesis, Univ. of Calif., Scripps Inst. Oceanography, La Jolla, Calif.
- CARPENTER, W. B., 1875, Remarks on Prof. Wyville Thomson's preliminary notes on the nature of the sea-bottom procured by the soundings of H. M. S. "Challenger": Proc. Royal Soc. 23, pp. 234-245.
- CARSOLA, A. J., 1952, Marine geology of the Arctic Ocean and adjacent seas off Alaska and northwestern Canada: Unpublished PhD thesis, Univ. of Calif., Scripps Inst. Oceanography, La Jolla, Calif.
- CLARKE, G. L., and BUMPUS, D. F., 1940, The plankton sampler, an instrument for quantitative plankton investigations: Amer. Soc. Limnology and Oceanography, Spec. Publ. 5, pp. 1-8.
- CROMWELL, TOWNSEND, 1953, Circulation in a meridional plane in the central equatorial Pacific: Jour. Mar. Res., vol. 12, no. 2, pp. 196-213.
- , 1954, Mid-Pacific oceanography. II. Trans-equatorial waters, June-August 1950, January-March 1951: U. S. Fish and Wildlife Serv., Spec. Sci. Rept. no. 131, 180 pp.
- CUSHMAN, J. A., 1914, A monograph of the Foraminifera of the North Pacific Ocean. Pt. IV. Chlostomellidae, Globigerinidae, Nummulitidae: U. S. Nat. Mus. Bull. 71, pt. 4, pp. 1-46.
- , 1921, Contributions to the biology of the Philippine Archipelago and adjacent seas: U. S. Nat. Mus., Bul. 100, pp. 1-608.
- , 1927, Recent Foraminifera from off the west coast of America: Bull. Scripps Inst. Oceanography, Tech. Ser., vol. 1, no. 10, pp. 119-188.
- , TODD, RUTH and POST, R. J., 1954, Recent Foraminifera of the Marshall Islands: U. S. Geol. Survey Prof. Paper 260-H, pp. 319-384.
- EKMAN, SVEN, 1953, Zoogeography of the Sea: Sidgwick and Jackson Ltd., London, 417 pp.
- EMILIANI, CESARE, 1954, Depth habitats of some species of pelagic Foraminifera as indicated by oxygen isotope ratios: Amer. Jour. Sci., vol. 252, pp. 149-158.
- , 1955, Pleistocene temperatures: Jour. Geology, vol. 63, no. 6, pp. 538-578.
- EPSTEIN, S. and LOWENSTAM, H. A., 1953, Temperature-shell-growth relations of Recent and interglacial Pleistocene shoal water biota from Bermuda: Jour. Geology, vol. 61, pp. 424-438.
- FRASER, J. H., 1954, Warm water species in the plankton off the English Channel entrance: Jour. Mar. Biol. Assoc. U. K., vol. 33, pp. 345-346.
- GRAHAM, H. W. and MOBERG, E. G., 1944, Scientific results of Cruise VII of the CARNEGIE during 1928-1929, Chemistry I. Chemical results of the last cruise of the CARNEGIE: Publ. Carnegie Inst. Washington, no. 562, pp. 1-58.
- HENTSCHEL, E., 1934, Allgemeine Biologie des Südatlantischen Ozeans. Ergeb. deutsch. Atlantische Exped. METEOR 1925-1927, Bd. XI, pp. 3-344.
- HERON-ALLEN, E. and EARLAND, A., 1922, Foraminifera: British Antarctic ("Terra Nova") Exped., vol. 6, no. 2, pp. 25-268.
- HIDA, T. S., 1957, Chaetognaths and pteropods as biological indicators in the North Pacific: U. S. Fish and Wildlife Service, Spec. Sci. Rept. no. 215, 13 pp.
- , and KING, J. E., 1955, Vertical distribution of zooplankton in the central equatorial Pacific, July to August 1952: U. S. Fish and Wildlife Service, Spec. Sci. Rept. 144, pp. 1-22.
- HUTCHINS, L. W., 1947, The bases for temperature zonation in geographic distribution: Ecol. Monogr., vol. 17, pp. 325-335.
- HOFKER, J., 1959, On the splitting of *Globigerina*: Contr. Cushman Found. Foram. Research, vol. 10, pt. 1, pp. 1-9.
- JOHNSON, M. W., 1939, The correlation of water movements and dispersal of pelagic larval stages of certain littoral animals, especially the sand crab, *Emerita*: Jour. Mar. Research, vol. 2, no. 3, pp. 236-245.
- , 1949, Zooplankton as an index of water exchange between Bikini Lagoon and the open sea: Am. Geophysics Union Trans., vol. 30, pp. 238-244.



- , 1954, Plankton of the northern Marshall Islands: U. S. Geol. Survey Prof. Paper 260-F, pt. 2, Oceanography (Biologic), pp. 301-314.
- KING, J. E. and DEMOND, J., 1953, Zooplankton abundance in the central Pacific: U. S. Fish and Wildlife Service, Fish. Bull. 82, pp. 111-144.
- , and HIDA, T. S., 1957, Zooplankton abundance in the central Pacific, Part 2: U. S. Fish and Wildlife Service Fish. Bull. 118, pp. 365-395.
- LOHMANN, HANS, 1920, Die Bevölkerung des Ozeans mit Plankton nach den Ergebnissen der Zentrifugenfänge während der Ausreise der "Deutschland" 1911: Arch. Biontologie, vol. 4, no. 3, pp. 1-617.
- MURRAY, JOHN, 1895, Summary of the scientific results obtained at the sounding, dredging and trawling stations of H. M. S. CHALLENGER: Challenger Repts., Summary, pts. 1 and 2, pp. 1-1608.
- , 1897, On the distribution of the pelagic Foraminifera at the surface and on the floor of the ocean: Nat. Sci., vol. 11, pp. 17-27.
- NATLAND, M. L., 1938, New species of Foraminifera from off the west coast of North America and from the later Tertiary of the Los Angeles Basin: Bull. Scripps Inst. Oceanography, Tech. Ser., vol. 4, pp. 137-164.
- OWEN, S. R. J., 1868, On the surface-fauna of mid-ocean: Jour. Linn. Soc. London (Zoology), vol. 9, pp. 147-157.
- PARKER, F. L., 1954, Distribution of the Foraminifera in the northeastern Gulf of Mexico: Bull. Mus. Comp. Zool., vol. 106, pp. 391-423.
- , 1958, Eastern Mediterranean Foraminifera: Repts. Swedish Deep-Sea Exped. 1947-48, vol. 8, fasc. 2, No. 4, pp. 219-283.
- PHLEGER, F. B., 1945, Vertical distribution of pelagic Foraminifera: Am. Jour. Sci., vol. 243, pp. 377-83.
- , 1951, Ecology of Foraminifera, northwest Gulf of Mexico. Pt. 1, Foraminifera distribution: Geol. Soc. America, Mem. 46, pp. 1-88.
- , 1952, Foraminifera distribution in some sediment samples from the Canadian and Greenland Arctic: Contr. Cushman Found. Foram. Research, vol. 3, pp. 80-89.
- , 1954, Foraminifera and deep-sea research: Deep-sea Research, vol. 2, pp. 1-23.
- , PARKER, F. L., and PEIRSON, J. F., 1953, North Atlantic Foraminifera: Repts. Swedish Deep-Sea Exped., vol. 7, fasc. 1, pp. 3-122.
- REDFIELD, A. C. and BEALE, A., 1940, Factors determining the distribution of populations of Chaetognatha in the Gulf of Maine: Biol. Bull., vol. 79, pp. 459-487.
- RHUMBLER, LUDWIG, 1911, Die Foraminiferen (Thalophoren) der Plankton-Expedition, etc., Pt. 1. Systematik: Ergeb. Plankton-Exped. Humboldt Stift., Bd. 3, 331 pp.
- RUSSELL, F. S., 1935, On the value of certain plankton animals as indicators of water movements in the English Channel and North Sea: Jour. Mar. Biol. Assoc. U. K., vol. 20, no. 2, pp. 309-332.
- , and HASTINGS, A. B., 1933, On the occurrence of pelagic tunicates (Thaliacea) in the waters of the English Channel off Plymouth: Jour. Mar. Biol. Assoc. U. K., vol. 18, no. 2, pp. 635-640.
- SCHOTT, W., 1935, Die Foraminiferen in dem äquatorialen Teil des Atlantischen Ozeans: Wiss. Ergeb. deutsch. Atlantische Exped. METEOR 1925-1927, Bd. 3, pt. 3, Sect. B, pp. 43-134.
- SVERDRUP, H. U., and FLEMING, R. H., 1941, The waters off the coast of southern California, March to July 1937: Bull. Scripps Inst. Oceanography, vol. 4, no. 10, pp. 261-378.
- , JOHNSON, M. W., and FLEMING, R. H., 1942, The Oceans, their physics, chemistry and general biology: Prentice Hall, N. Y., 1087 pp.
- TAYLOR, C. C., BIGELOW, H. B., and GRAHAM, H. W., 1957, Climatic trends and the distribution of marine animals in New England: U. S. Fish and Wildlife Service, Fish. Bull. 115, vol. 57, pp. 293-345.
- WALTON, W. R., 1952, Techniques for the recognition of living Foraminifera: Contr. Cushman Found. Foram. Research, vol. 3, pp. 56-60.
- WISEMAN, J. D. H., and OVEY, C. D., 1950, Recent investigations on the deep-sea floor: Proc. Geol. Ass., vol. 61, pt. 1, pp. 28-84.
- WOOSTER, W. S., 1953, Phosphate in the eastern North Pacific Ocean: Unpublished PhD thesis, Univ. of Calif., Scripps Inst. Oceanography, La Jolla, Calif.
- , and CROMWELL, TOWNSEND, 1958. An oceanographic description of the eastern tropical Pacific: Bull. Scripps Inst. Oceanography, vol. 7, no. 3, pp. 169-282.



CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION  
FOR FORAMINIFERAL RESEARCH

VOLUME X, PART 2, APRIL, 1959

## RECENT LITERATURE ON THE FORAMINIFERA

Below are given some of the more recent works on the Foraminifera that have come to hand.

- ANTONOVA, Z. A. Some remarks on the evolution of certain representatives of Ophthalmitidae, based on their development in the river Loba basin during the Jurassic period (in Russian).—Doklady Akad. Nauk SSSR, tom 122, No. 5, 1958, p. 913-916, text fig. 1, tables 1, 2.
- AUROUZE, GERMAINE, and BIZON, JEAN-JACQUES. Rapports et différences des deux genres de Foraminifères: *Kilianina* Pfender et *Meyendorffina* n. gen.—Revue de Micropaléontologie, v. 1, No. 2, Oct. 1958, p. 67-74, pls. 1-3.—*Kilianina blancheti* Pfender and *Meyendorffina bathonica* n. sp. (genotype of *Meyendorffina* n. gen., erected for forms previously attributed to *Kilianina* from the Paris Basin) are found together with *Orbitammina* cf. *elliptica* d'Archiac in the Dogger of the Hautes-Alpes.
- BALAKHMATOVA, V. T. Foraminifery Verkhnego Mela.—Russia Vses. geol. instit. Materialy, nov. ser., vyp. 2, 1955, p. 20-64, pls. 2-4, text figs. 1-14.—Ten species (1 new), 4 varieties (2 new) and 1 new subspecies from Upper Cretaceous of western Siberia.
- BARTENSTEIN, HELMUT. Alttertiäre Mikrofaunen aus dem Reinhardswald, ein Beitrag zur Frage der Südverbreitung marinen Prä-Mittelligozäns.—Notizbl. hess. L.-Amt Bodenforsch., Band 86, Aug. 15, 1958, p. 269-280, pls. 17, 18, text fig. 1 (map).—Lists and photographs of Oligocene Foraminifera.
- BETTENSTAEDT, FRANZ. Phylogenetische Beobachtungen in der Mikropaläontologie.—Paläont. Zeitschr., v. 32, No. 3/4, August 1958, p. 115-140, text figs. 1-3 (range chart, graphs).—Examples of phylogenetic development: *Globorotalites bartensteini* and sub-species from middle Barremian to lower Albian; and species of *Bolivinoidea* from upper Santonian to upper Maastrichtian.
- BLACKMON, PAUL D., and TODD, RUTH. Mineralogy of some Foraminifera as related to their classification and ecology.—Journ. Pal., v. 33, No. 1, Jan. 1959, p. 1-15, text fig. 1 (graph), tables 1-4.—A tabulation of 186 determinations in 131 genera, belonging in 29 calcareous families, as to whether  $\text{CaCO}_3$  is in the form of calcite or aragonite and as to amount of Mg substitution in calcite. No combinations of calcite and aragonite have been found in Foraminifera. Most Foraminifera are calcite. Aragonite ones are probably restricted to two families. Magnesium substitution appears to be determined by family affiliation and to be affected by temperature of environment. A family classification based on mineralogical characteristics is suggested.
- BONET, F. Zonificación Microfaunística de las Calizas Cretácicas del Este de México.—XX Congr. Geol. Internat., 1956, p. 1-102, pls. 1-31, text figs. 1-4, tables 1-3.—Four species of larger Foraminifera are described and illustrated in thin section, one new: *Nummuloculina heimi*.
- BRAZHNIKOVA, N. E. Foraminifery, chapter in Fauna i flora Kamennougol'nykh Otlozhenij Galithijsko-Volynskoj Vpadiny.—Akad. Nauk Ukrain SSSR Institut. geol. nauk, Trudy, ser. strat. i pal., vyp. 10, 1956, p. 16-103, pls. 1-17, distrib. table.—Forty-two species, subspecies, and varieties, 23 new, from the Carboniferous.
- CAIRE, ANDRÉ, and MARIE, PIERRE. L'Éocène dans le massif du Djebel Kasbah: Coupe de Nador (Algérie).—Publ. Service Carte Géol. Algérie (n. ser.) Bull. No. 13, Travaux des Collaborateurs, 1956 (1957), p. 139-151, 1 distrib. table.—Lists of Foraminifera.
- CANOVIC, MIRUNA, and DZODZO-TOMIC, RADOJKA. Vorläufige Mitteilung über die Oligozäne Mikrofauna aus der Bohrung Us-6 bei Ulcinj (Montenegro) (in Croatian with German summary).—Institut. Géol. Montenegro, Bull. Géol., livre II, 1958, p. 203-213, 1 map.—Foraminifera listed.
- CICHA, IVAN, and DORNIC, JAN. Neuer Fund der Kreideformation im Westlichen Teil der Boskovicer Furche bei Lomnice, Nordlich Tisnov (in Czech with German summary).—Vestnik Ustred. Ustavu Geol., roc. 33, c. 6, 1958, p. 443-444.
- CICHA, IVAN, and ZAPLETALOVA, IRENA. Bemerkungen zum Alter der Basalen Miozänklastiken in der Umgebung von Stefanov und Petrova Ves im Wiener Becken (in Czech with Germany summary).—Vestnik Ustred. Ustavu Geol., roc. 33, c. 6, 1958, p. 440-442.—A facies of the lower Burdigalian not previously known here.
- COLACICCHI, ROBERTO. Sulla microradiografia dei foraminiferi.—Riv. Min. Siciliana, Anno IX, March-April 1958, No. 50, 2 p.
- Sul presunto Langhiano della zona di Pachino.—Boll. Accad. Gioenia Sci. nat. Catania, ser. IV, v. IV, fasc. 4, 1958, p. 184-190, map.—List of Foraminifera from lower Pliocene.
- COLE, W. STORRS. Names of and variation in certain American larger Foraminifera, particularly the Discocyclinids.—No. 3.—Bull. Amer. Pal., v. 38, No. 176, Nov. 15, 1958, p. 407-429, pls. 50-53.—Three California species, with their respective synonyms. A key to the known species belonging in the subgenus *Proporocyclina* is included, in which 11 species remain as valid.
- COLLINS, A. C. Foraminifera.—British Mus. (Natural History), Great Barrier Reef Exped. 1928-29, Sci. Repts., v. VI, No. 6, Foraminifera, Sept. 16, 1958, p. 335-437, pls. 1-5, text figs. 1-3.—Three hundred and ninety-one species and subspecies, 46 new, from 53 samples, taken from mangrove swamp pools, reef flats, shallow water dredgings ranging to 28 fathoms, and deep water dredgings from between 205 and 600 meters. Four new genera: *Discobotellina* (type species *D. biperforata* n. sp.) in the Astorhizidae, *Edentostomina* (type species *Miliolina cultrata* Brady) in the Miliolidae, *Nubeculopsis* (type species *N. queenslandica* n. sp.) in the Ophthalmitidae, and *Globulotuba* (type species *G. entosoleniformis* n. sp.) in the Polymorphinidae. On the 5 beautiful plates, a few of the species are illustrated.



- COLOM, GUILLERMO. The age of the beds with *Miogypsina mediterranea* Bronnimann on the island of Majorca.—*Micropaleontology*, v. 4, No. 4, Oct. 1958, p. 347-362, text figs. 1-4 (maps, section), table. 1.—*M. mediterranea* is restricted to Burdigalian (=Langhian) where it is associated with species found in the "Upper Oligocene" to Lower Miocene of Central America. It is absent in the discordantly overlying Helvetian-Tortonian beds of Majorca. Numerous smaller Foraminifera are listed as evidence of the major distinction between Burdigalian and Helvetian-Tortonian.
- CRESPIN, IRENE. Permian Foraminifera of Australia.—*Australia Bur. Min. Resources, Geol. Geophys.*, Bull. No. 48, 1958, p. 1-207, pls. 1-33, tables 1-10, map.—Correlations between formations in various parts of Australia based on Foraminifera assemblages. One hundred and eleven species (50 new and 1 new name) are described and illustrated. Four new genera are erected: *Sacculinella* (type species *S. australe* sp. nov.) in the Saccamminidae and *Hyperamminita* (type species *Hyperammina* (?) *rudis* Parr), *Pseudohyperammina* (type species *P. radiostoma* sp. nov.), and *Giraliarella* (type species *G. angulata* sp. nov.) in the Hyperamminidae.
- DANILOVA, ALEKSANDRA. Mikropaläontologische Daten aus der Zone des höheren Senon in der Bucht von Kattaro (Montenegro) (in Croatian with German summary).—*Instit. Géol. Montenegro, Bull. Géol.*, livre II, 1958, p. 223-241, pls. 23-27, 1 columnar section.—Lists of Foraminifera and thin-section photographs.
- DREXLER, EDITH. Foraminiferen und Ostracoden aus dem Lias a von Siebeldingen/Pfalz.—*Geol. Jahrb.*, Band 75, Oct. 1958, p. 475-554, pls. 20-27, text figs. 1-25.—About 40 species, mostly illustrated, are recorded and briefly described. Stratigraphic range and abundance are graphically indicated for 16 of the most significant ones.
- DROOGER, C. W. Foraminifères importants pour les subdivisions et limites du Miocène inférieur-moyen.—83<sup>e</sup> Congrès Soc. savantes, 1958, p. 171-179, 1 diagram.—Restricted ranges of several miogypsinid species between Chattian and Helvetian.
- DROOGER, C. W., PAPP, A., and SOCIN, C. Über die Grenze zwischen den Stufen Helvet und Torton.—*Anzeiger Osterreich. Akad. Wissenschaften, Math.-Nat. Kl.*, Jahrg. 1957, No. 1, p. 1-10, 1 table.—Discussion of boundary based on miogypsinids and globigerinids.
- DUFAURE, PH. Contribution a l'étude stratigraphique et micropaléontologique du Jurassique et du Néocomien, de l'Aquitaine a la Provence.—*Revue de Micropaléontologie*, v. 1, No. 2, Oct. 1958, p. 87-115, pls. 1-6, 1 map.—Foraminifera listed and illustrated in thin section from various microfacies.
- DZODZO-TOMIC, RADOJKA. A paleontological treatise of microfauna from the surroundings of Ulcinj (Montenegro) (in Croatian with English summary).—*Instit. Géol. Montenegro, Bull. Géol.*, livre II, 1958, p. 333-342.—Miocene Foraminifera.
- FERREIRA, J. MARTINS. Algumas observações sobre a presença do género *Elphidium* Montfort, 1808, em Portugal.—*Assoc. Portuguesa Progresso Ciências*, 1957, 9 p., 1 pl.—Eleven species and one variety, none new, from various parts of the Tertiary.
- Ocorrência de Foraminíferos planctónicos no Terciário de Luanda.—*Assoc. Portuguesa Progresso Ciências*, 1957, 8 p.—Nine species, none new.
- FERREIRA, J. MARTINS, and ROCHA, A. TAVARES. Foraminíferos do Senoniano de Catumbé'a (Angola).—*Garcia de Orta*, v. 5, No. 3, 1957, p. 517-545, tables 1-3.—Record of 56 species (none new) from Maestrichtian-Campanian stage, and ecologic interpretation.
- Observações geológicas e paleontológicas sobre a Serra da Arrábida.—*Publ. Liga para Protecção Natureza*, v. 14, 1958, p. 25-73, pls. 1, 2, tables 1, 2, 2 maps, 10 photographs.—Thirty-five species and 3 varieties, none new, from upper Oligocene-lower Miocene of Portugal.
- FURON, RAYMOND. Découverte, paléontologie et stratigraphie des grands Foraminifères du Tertiaire de l'Ouest Africain.—*Bull. Mus. Natl. Hist. Nat. (Paris)*, ser. 2, v. 30, No. 3, April 1958, p. 313-320.
- GLOWACKI, EDWARD, JURKIEWICZ, HENRYK, and KARNKOWSKI, PIOTR. Occurrence of the Carboniferous in the bore-hole at Bratkowice (Carpathian Foreland) (in Polish).—*Przeglad Geol.*, rok 6, nr. 10, 1958, p. 437-442, pl. 1, text figs. 1-3.—Foraminifera listed and illustrated from various levels.
- GOFMAN, E. A. New finds of Jurassic Globigerina (in Russian).—*Russia Minister. vys. obraz. SSSR, Nauch. doklady vys. shkoly, Geol.-geogr. nauki*, No. 2, 1958, p. 125-126, 1 text fig.—*Globigerina jurassica* sp. nov. from lower Callovian beds of southeastern Crimea.
- GOLUBTHOV, V. K. Stratigrafija i Foraminifery Vizejskogo Jarusa Pripjatskogo Progiba in Paleontologija i stratigrafija BSSR, Sbornik II.—*Akad. nauk Belorusskoj SSR, Instit. geol. nauk, Minsk*, 1957, p. 44-209, pls. 1-9, text fig. 1 (map), tables, sections.—Seventy-one species (11 new) and 32 varieties (12 new), mostly primitive fusulines and *Tetrataxis* and related forms.
- HAGN, HERBERT. Das Profil des Beckens von Gosau (österreichische Kalkalpen) in mikropaläontologischer Sicht.—*Anzeiger Osterreich. Akad. Wissenschaften, Math.-Nat. Kl.*, Jahrg. 1957, No. 1, p. 31-68, 1 correl. table.—Includes lists of Upper Cretaceous Foraminifera.
- HANZLIKOVA, EVA. Vorläufiger Bericht über die Mikrobiostratigraphischen Verhältnisse des Lubovnia-Hügellandes (in Czech with German summary).—*Vestnik Ustred. Ustavu Geol.*, roc. 33, c. 6, 1958, p. 429-440, 3 charts.—From Albion to Oligocene biofacies based on smaller Foraminifera.
- HENBEST, LLOYD G. Geologic and ecologic significance of the Upper Paleozoic Foraminifera in the Hartville area, Wyoming.—*Wyo. Geol. Assoc. Guidebook*, 13th Ann. Field Conf., 1958, p. 127-131, text fig. 1 (columnar section and range chart).—Discussion of local ranges of fusulinid genera in middle and upper Pennsylvanian.
- HERCOGOVA, JITKA. Mikrobiostratigraphische Erforschung der Kreidesedimente aus einigen Lokalitäten des Teplice V Cechach (Teplitz)- und Lovosice-Gebietes (in Czech with German summary).—*Vestnik Ustred. Ustavu Geol.*, roc. 33, c. 6, 1958, p. 445-446.
- Die Ergebnisse der Mikropaläontologischen Bearbeitung der Südwestlich von Teplice V Cechach (Teplitz) Durchgeführten Bohrungen (in Czech with German summary).—*Vestnik Ustred. Ustavu Geol.*, roc. 33, c. 6, 1958, p. 446-453, table.—List of Upper Cretaceous Foraminifera.
- HILTERMANN, HEINRICH. Allochthone Foraminiferen in den Neurather Sanden und in einem Zwischenmittel im Flöz Frimmersdorf.—*Fortschr. Geol. Rheinld. u.*



- Westf., Band 1, July 1958, p. 159-164, pl. 1, text fig. 1.—Photographs of 4 mixed assemblages.
- HOFKER, J. Foraminifera from the Cretaceous of southern Limburg, XXXII. On some agglutinated Foraminifera.—*Natuurhist. Maandblad*, 47<sup>e</sup> Jrg., No. 1-2, Feb. 28, 1958, p. 22-26, text figs. 1-6.—Three generations of *Gaudryina faujasi*, including both textularian and gaudyrine forms; *Textularia plummerae* from the lower Paleocene; and *Bermudezina bentonensisiformis* n. sp. described from Maestrichtian.
- XXXIII. On some other Foraminifera from the Maestrichtian tuff chalk showing evidence of Tertiary age of that sediment.—*Natuurhist. Maandblad*, 47<sup>e</sup> Jrg., No. 3-4, April 29, 1958, p. 42-44, text figs. 1-8.—Four species originally described by Plummer from the Midway of Texas.
- XXXIV. On some Lagenidae occurring in the Kunrade Chalk, suggesting a Danio-Paleocene age of that chalk.—*Natuurhist. Maandblad*, 47<sup>e</sup> Jrg., No. 5-6, June 27, 1958, p. 64-66, text figs. 1-10.—Ten species, one new.
- XXXV. On the initial stages of *Omphalocyclus macroporus* (Lamarck).—*Natuurhist. Maandblad*, 47<sup>e</sup> Jrg., No. 7-8, August 29, 1958, p. 98-101, text figs. 1-12.
- XXXVI. The evolution of *Mississippina binkhorsti* (Reuss).—*Natuurhist. Maandblad*, 47<sup>e</sup> Jrg., No. 7-8, August 29, 1958, p. 101-103, text figs. 1-6.—Evolution and extinction in the Maestrichtian.
- Supplément sur quelques Rotalidés.—*Instit. Royal Sci. Nat. Belgique, Mém.* No. 142, June 30, 1958, p. 55-63, text figs. 1-5.—Three species of *Streblus* (1 new), 2 of *Pseudoeponides*, and 1 of *Pararotalia*, and discussions of the 3 genera.
- Les Foraminifères du Crétacé supérieur de Glons.—*Ann. Soc. Géol. Belgique*, v. 81, Bull. no. 9, July 1958, p. B467-B493, pls. 1-8, text figs. 1-3 (graphs, range chart).—Ranges in a quarry and a boring are shown for about 100 species, indicating 5 stages from upper Campanian to upper Maestrichtian. About 45 species (1 new) are illustrated.
- HORNIBROOK, N. DE B. New Zealand Foraminifera: Key species in stratigraphy—No. 6.—*New Zealand Jour. Geol. Geophys.*, v. 1, No. 4, Nov. 1958, p. 653-676, pls. 1-3.—A continuation of the series started by Finlay. Thirteen species, 9 new.
- JARKE, JOACHIM. Sedimente und Mikrofaunen im Bereich der Grenzschwelle zweier ozeanischer Räume, dargestellt an einem Schnitt über den Island-Färöer-Rücken (Nordatlantischer Ozean Rosengarten-Europäisches Nordmeer).—*Geol. Rundschau*, Band 47, heft 1, 1958, p. 234-249, text figs. 1-3 (map, graphs), tables 1-5.—Quantitative analysis of planktonic and benthonic Foraminifera from 9 stations across the Iceland-Faeroe ridge reveal striking differences between the North Atlantic and the North Sea.
- KAEVER, MATTHIAS. Über *Globorotalites* Brotzen 1942 und *Conorotalites* nov. gen.—*Geol. Jahrb.*, Band 75, Sept. 1958, p. 433-436, text figs. 1, 2.—*Conorotalites* (genoholotype *Globorotalites bartensteini aptiensis* Bettenstaedt) ranges from middle Barremian to Albanian.
- KIEKEN, MAURICE, and MAGNÉ, JEAN. Aperçu géologique sur les Monts de la Mina (Tell Oranais, Algérie).—*Publ. Service Carte Géol. Algérie (n. ser.)*, Bull. No. 13, Travaux des Collaborateurs, 1956 (1957), p. 177-218, pls. 1-4.—Includes many lists of Foraminifera from the Tertiary and Cretaceous.
- KRISTAN, E. Neue Namen für zwei Foraminiferengattungen aus dem Rhät.—*Verhandl. Austria Geol. Bundes.*, heft 1, 1958, p. 114.—*Coronipora* for *Coronella* and *Galeanella* for *Galea*.
- KSIAZKIEWICZ, M. On the Turonian in the Pieniny Klippes Belt.—*Bull. Acad. Polonaise Sci., ser. sci. chim., geol., geogr.*, v. VI, Nov. 8, 1958, p. 537-544, text figs. 1-3 (pls. of fossils).—Lists and outline drawings of numerous Globotruncanidae.
- LADD, HARRY S. Ecology, paleontology, and stratigraphy.—*Science*, v. 129, No. 3341, Jan. 9, 1959, p. 69-78, text figs. 1-6.—Interesting summary of recent developments and prospects. Includes comparison of an Eocene *Globigerina* ooze with a Recent one, both from the surface of Sylvania Guyot in the Marshalls.
- LIPMAN, R. KH. Foraminifery Paleogena.—*Russia Vses. geol. instit. Materialy, nov. ser.*, vyp. 2, 1955, p. 65-102, pls. 5-8, tables.—Nineteen species (7 new and 2 indeterminate) from Paleogene of western Siberia.
- MARKOVIC, OLIVERA, and OBRADOVIC, SULTANA. Situation stratigraphique de l'étroite ceinture Crétacée qui se trouve entre les gares du chemin de fer de Knezevac-Kijevo, faite a la base des données micro- et mega-fauniques (in Serbian with French summary).—*Jugoslavia Geol. instit. "Jovan Zujovic," Recueil Travaux*, v. 9, 1957, p. 37-48, pls. 1-3.—Lower Cretaceous Foraminifera.
- MITJANINA, I. V. O Foraminiferakh Jurskikh Otlozhenij Jugo-Zapada Belorussii in Paleontologija i stratigrafija BSSR, Sbornik II.—*Akad. nauk Belorusskoj SSR, Instit. geol. nauk, Minsk*, 1957, p. 210-239, pls. 1, 2, 2 distrib. charts.—Nineteen species (7 new) and one new variety from the Jurassic of southwestern Belorussia. *Trochospirillina* n. gen. (genotype *T. granulosa* n. sp.).
- MOHAN, KRISHNA. Miogypsinidae from western India.—*Micropaleontology*, v. 4, No. 4, Oct. 1958, p. 373-390, pls. 1-3, text figs. 1-7, tables 1, 2.—Five species (2 new) described and illustrated and subgenus *Lepidosemicyclina* Ruten 1911 reinstated. Discussion of principles of classification.
- MOREL, FRANÇOIS. Étude Géologique du Djebel Belkif.—*Publ. Service Carte Géol. Algérie (n. ser.)*, Bull. No. 13, Travaux des Collaborateurs, 1956 (1957), p. 253-281, pls. 1-10, 1 geol. map.—Occurrence of Foraminifera in about 2800 meters of Upper Cretaceous section is indicated.
- NEMKOV, G. I., and BARKHATOVA, N. N. The study of Nummulitic fauna in the USSR (in Russian).—*Vestnik Leningrad. Univ.* No. 12, vyp. 2, 1958, p. 49-56.
- OBRADOVIC, SULTANA N. Sarmatische Mikrofauna der Bohrung V-I aus Umgebung von Brcko (in Serbian with German summary).—*Yugoslavia Geol. instit. "Jovan Zujovic," Recueil Travaux*, v. 9, 1957, p. 213-221.
- POKORNY, VLADIMIR. Grundzüge der Zoologischen Mikropaläontologie. Band I.—Berlin, 1958, 582 p., 549 text figs.—Well illustrated textbook in German including, besides Foraminifera which occupy 60% of the book, chapters on Radiolaria, Thecamoebina, Tintinnina, Chitinozoa, Hystriochosphaera, and other microorganisms. Sections on techniques, morphology, ecology, and geologic distribution are included. In the systematic part, 56 families (including 42 subfamilies) are grouped into 8 superfamilies of Foraminifera.



- era. One new family of Foraminifera, Schackoinidae, is erected.
- The age of the Cretaceous sediments of Pavlovske Kopce (southern Moravia, Czechoslovakia) (in Czech with English summary).—*Casopis pro Min. Geol.*, roc. 3, No. 3, 1958, p. 299-315, text figs. 1-17.—Eleven species (1 new) from lower part of upper Campanian.
- Lenticulina (Robulus) zuratkensis** n. sp. (Foraminifera), a characteristic species from the upper Oligocene of the Zdanice Flysch (southern Moravia, Czechoslovakia) (in Czech with English summary).—*Casopis pro Min. Geol.*, roc. III, No. 4, 1958, p. 422-425, pl. 3, text figs. 1-3.—A form having multiple peripheral keels, found in association with **Cassigerinella baudcensis**.
- POZNER, V. M., KIRINA, T. I., PORFIR'EV, G. S., et al. Volgo-Ural'skaja Neftenoshaja Oblast', Kamenougol'nye Otlozhenija (Volga-Ural oil-bearing district, Carboniferous deposits).—Russia Vses. neft. nauchnoissl. geol.-razved. instit., Trudy, n. ser., vyp. 112, 1957, p. 1-287, text figs. 1-41.
- PURI, HARBANS S. Reclassification, structure and evolution of the family Nummulitidae.—*Jour. Pal. Soc. India*, v. 2, 1957, p. 95-108, pls. 10-13, text figs. 1-10 (diagram, stereograms, evolution chart).—Eleven genera are grouped into 4 subfamilies, one new (Assiliniinae), on the basis of test structure (involute or evolute test, spiral laminae in direct contact or not, and presence or absence of chamberlets). Genetic relationships are discussed and stratigraphic distribution of genera is graphically represented.
- RADOICIC, RAJKA. Les resultats des premiers examens micropaléontologiques du Flysch de Durmitor (in Croatian with French summary).—*Instit. Geol. Montenegro*, Bull. Géol., livre II, 1958, p. 119-155, pls. 10-17, 1 map, 1 stratigraphic section.—Upper Cretaceous planktonics and larger Foraminifera studied in section.
- RAUZER-CHERNOUSOVA, D. M. Opyt Sverkhdrobnogo Raschlenenija Razreza Verkhnekamennougol'nykh Otlozhenij V Rajone Kujbyshevskoj Gehs.—*Akad. Nauk SSSR Geol. Institut. Trudy*, vyp. 13, 1958, p. 121-138, pls. 1, 2, text fig. 1, table 1.—Seven species and 2 varieties of **Triticites** and 1 species of **Daixina**, all new.
- RAUZER-CHERNOUSOVA, D. M., and SCHERBOVICH, S. F. O Shvagerinovom Gorizonte Thentralbnog Chasti Russkoj Platformy.—*Akad. Nauk SSSR Geol. Institut. Trudy*, vyp. 13, 1958, p. 3-56, pls. 1-6, text fig. 1 (columnar sections), table 1.—Fusulinids classified in nineteen species (7 new), 7 subspecies (3 new), 5 varieties (3 new), and 6 formas (4 new).
- REISS, Z., and MERLING, P. Structure of some Rotaliidea.—*Israel Geol. Survey Bull.* No. 21, July 1958, p. 1-19, pls. 1-5.—The genera **Rotalia**, **Ammonia**, **Asterotalia**, **Pararotalia**, **Calcarina**, **Nototalia**, and several others are compared as to such structural features as apertures, foramina, toothplates, canal systems, etc. **Pseudotalia** n. gen. (type species **Rotalia schroeteriana** Parker and Jones) is erected.
- REY, M. Le genre **Almaena** en Aquitaine Occidentale.—*Revue de Micropaléontologie*, v. 1, No. 2, Oct. 1958, p. 59-63, pl. 1.—One species from the upper Lutetian and another with its variety from the Aquitanian; all three forms new. Lists are included of the species associated with the new species as well as with **A. epistominoides** from the Bartonian.
- ROMANOVA, V. I. Foraminifery Neokoma.—Russia Vses. geol. instit. Materialy, nov. ser., vyp. 2, 1955, p. 6-19, pl. 1.—Seven species (2 new and 1 indeterminate) and 1 new variety from Neocomian of western Siberia.
- ROZOVSKAJA, S. E. Fuzulinidy I Biostratigraficheskoe Raschlenenie Verkhnekamennougol'nykh Otlozhenij Samarskoj Luki.—*Akad. Nauk SSSR Geol. Institut. Trudy*, vyp. 13, 1958, p. 57-120, pls. 1-15, text figs. 1, 2, table 1.—Fusulinids classified in 79 species (17 new), 2 varieties, and 22 subspecies (3 new).
- RUTSCH, R. F., DROOGER, C. W., and OERTLI, H. J. Neue Helvetien-Faunen aus der Molasse zwischen Aare und Emme (Kt. Bern) (Foraminifera, Mollusca, Ostracoda).—*Mitteil. Naturforsch. Gesellschaft Bern*, n. f., band 16, June 1958, p. 1-36, pls. 1, 2, text figs. 1-3 (maps), tables 1, 2.—Four species of Foraminifera recorded and illustrated by Drooger.
- SAAKJAN-GEWZALJAN, N. A. Foraminifery Tretichnykh Otlozhenij Erevanskogo Bassejna.—*Akad. Nauk Armjanskoj SSR, Institut. Geol. Nauk, Erevan*, 1957, 140 p., 18 pls., maps, table.—Thirty-two species (18 new) and 2 new subspecies and 6 varieties (5 new) from Eocene of Erevan basin of Armenia.
- SAHNI, M. R., and SASTRI, V. V. A monograph of the orbitolines found in the Indian continent (Chitral, Gilgit, Kashmir), Tibet and Burma, with observations on the age of the associated volcanic series.—*Mem. Geol. Survey India*, n. ser., v. 33, No. 3, 1957, p. 1-50, pls. 1-6, text figs. 1-15 (map, section, outline drawings).—Fifteen species (6 new) and 2 new varieties in **Orbitolina**, and one new species in the new genus **Birbalina** (genotype **B. pulchra** n. sp.). Ranges, distribution, and distinguishing characteristics are given for each form.
- SCHEIBNER, ERVIN. On the occurrence of the so-called "Globigerine-Radiolarian" beds in the Kysuca evolution of the Pieniny serie in the interior klippen belt in West Karpaty (English summary).—*Slovenska Akad. Vied, Bratislava, Geol. Sbornik*, roc. 9, c. 2, 1958, p. 182-187, pls. 1-3.—Upper Albanian.
- SCHEIBNER, ERVIN, and SCHEIBNER, VIERA. Kysuca and Sneznica beds—the new articles of Cretaceous of Pieniny serie in Kysuca evolution (English summary).—*Slovenska Akad. Vied, Bratislava, Geol. Sbornik*, roc. 9, c. 2, 1958, p. 178-181.—Lower Turonian.
- SCHEIBNER, VIERA. The species **Globotruncana helvetica** Bolli at Kysuca evolution of Pieniny serie of the interior klippen belt from West Karpaty (English summary).—*Slovenska Akad. Vied, Bratislava, Geol. Sbornik*, roc. 9, c. 2, 1958, p. 188-194, pl. 4, text figs. 1, 2.—Record of **G. helvetica** at Cenomanian-Turonian boundary and re-assignment to the genus **Praeglobotruncana**.
- SCOTT, G. H. Distribution of populations of fossil Foraminifera.—*New Zealand Jour. Geol. Geophys.*, v. 1, No. 3, Aug. 1958, p. 474-484, text figs. 1-4 (graphs), table 1.—Experimental work on distribution of individual members of a faunule within a lithologic unit, and hence on homogeneity or heterogeneity of populations, indicates that generalizations based on single or widely spaced samples are unreliable.
- SHAMOV, D. F. Gruppya Vzdueto-Veretenobraznykh Pseudofuzulin Iz Shvagerinovogo Gorizonta I Shibaev-Sterlitamakskogo Neftenosnogo Rajona.—*Akad. Nauk SSSR Geol. Institut. Trudy*, vyp. 13, 1958, p. 139-154, pls. 1-3.—Five species (all new) and 5 varieties (3 new) of **Pseudofusulina**.



- SHENG, JING-CHANG. Some fusulinids from Changhsing Limestone.—*Acta Palaeontologica Sinica*, v. III, 1955, p. 298-308, pls. 1-4.—Seven species (3 new) and 2 new varieties.
- SNAVELY, PARKE D., JR., BROWN, R. D., JR., ROBERTS, ALBERT E., and RAU, W. W. Geology and coal resources of the Centralia-Chehalis district, Washington.—*U. S. Geol. Survey Bull.* 1053, 1958, p. 1-159, pls. 1-13, text figs. 1-25, 1 chart, 1 table.—Lists of Foraminifera from one Oligocene and two Eocene formations.
- STELCK, C. R., WALL, J. H., and WETTER, R. E. Lower Cenomanian Foraminifera from Peace River area, western Canada.—*Research Council of Alberta, Geol. Div., Bull.* 2, Part I, 1958, p. 5-35, pls. 1-4, text figs. 1, 2 (map, sections), table 1.—Sixteen species are described and illustrated, 1 new and 12 indeterminate, dominantly arenaceous. Associations of microfaunal assemblages with megafaunal sequences are recorded. Environment changed progressively from deep, normal salinity toward shallow, brackish and finally fresh, deltaic conditions.
- STEWART, HARRIS B., JR. Sedimentary reflections of depositional environment in San Miguel Lagoon, Baja California, Mexico.—*Bull. Amer. Assoc. Petr. Geol.*, v. 42, No. 11, Nov. 1958, p. 2567-2618, text figs. 1-30 (maps, graphs, photos), tables 1-3.—Quantitative record of a few species of Foraminifera in 34 lagoon samples.
- STEWART, WENDELL J. Some fusulinids from the upper Strawn, Pennsylvanian, of Texas.—*Jour. Paleo.*, v. 32, No. 6, Nov. 1958, p. 1051-1070, pls. 132-137, text figs. 1, 2 (map, columnar sections).—Seventeen species (11 new and 1 indeterminate) in 5 genera (2 new). *Fruentella* n. gen. (type species *F. exempli* n. sp.) and *Plectofusulina* n. gen. (type species *P. franklinensis* n. sp.).
- TERASMAE, JAAN. "Microforaminifera" from Pleistocene deposits, Prince Edward Island, Canada.—*Micro-paleontology*, v. 4, No. 4, Oct. 1958, p. 429, pl. 1.
- TINOCO, IVAN DE MEDEIROS. Foraminíferos Cuaternarios de Olinda, Estado de Pernambuco.—*Div. Geol. Min., Rio de Janeiro, Mon.* XIV, 1958, p. 1-61, pls. 1-9.—Systematic descriptions and illustrations of 138 species and varieties (10 new and 37 indeterminate).
- VOLOGDIN, A. G. The Lower Cambrian Foraminifera of Tuva (in Russian).—*Doklady Akad. Nauk SSSR*, tom 120, No. 2, 1958, p. 405-408, text figs. 1-22.—A new order, Reitlingerellida, in which are included 9 genera, 7 new as follows: *Tuvaellina* (genotype *T. prima* n. sp.), *Bostrychosaria* (genotype *B. bistorta* n. sp.), *Flexurella* (genotype *F. obvoluta* n. sp.), *Kordeella* (genotype *K. campylodroma* n. sp.), *Lukashevella* (genotype *L. spiralis* n. sp.), *Lebedevaella* (genotype *L. involventis* n. sp.), and *Reitlingerella* (genotype *R. densa* n. sp.). Of the 14 species illustrated, 12 are new.
- YOSHIDA, SABURO. The foraminiferal fauna of the Upper Cretaceous Hamanaka and Kiritappu formations of eastern Hokkaido, Japan.—*Jour. Hokkaido Gakugei Univ.*, v. 9, No. 1, July 1958, p. 250-264, pls. 1-3, text figs. 1, 2 (maps), table 1.—Twenty-one species, 4 new and 7 indeterminate, described and illustrated.
- Miocene Foraminifera from the Okawa, Oikamanai and Toberi formations of the Toyokoro Hill, Tokachi Province, Hokkaido.—*Jour. Hokkaido Gakugei Univ.*, v. 9, No. 1, July 1958, p. 265-277, pls. 1-4, text fig. 1. (map), table 1.—Twenty species, 3 new and 9 indeterminate, described and illustrated.
- ZANS, V. A. *Homotrema rubrum* (Lamarck), a red sessile foraminifer of our coral reefs.—*Geonotes*, Quarterly newsletter of the Jamaica group of the Geol. Assoc. London, v. 1, No. 4, Oct. 1, 1958, p. 100-103, text figs. A-C.—Notes on growth forms and associations of *H. rubrum* around Jamaica.

RUTH TODD