CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XV, PART 3, JULY, 1964

283. BENTHONIC FORAMINIFERA OF THE CHUKCHI SEA[1]

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ABSTRACT

A total of 116 samples from the shallow southeastern part of the Chukchi Sea contained an Arctic Fauna dissimilar to Northeast Pacific assemblages. Three ecologic units were differentiated by the percentages of **Eggerella advena**, **Buccella frigida**, and **Elphidium clavatum**. Depth, temperature and salinity restricted a few species but the fauna was affected most by sediment type. A diverse calcareous assemblage was found on coarse sediment and an arenaceous assemblage with few species on fine sediment.

INTRODUCTION

North of the Bering Strait is a shallow shelf sea where conditions usually considered important in the ecology of Foraminifera have only slight variations. This is the southeastern part of the Chukchi Sea, (text fig. 1), where bottom gradients are small, the bottom salinities (away from the coast) do not vary more than 1.0 o/oo and the bottom temperatures remain constant for six to eight months when the area is covered by ice. The range of depths, from 20 to 200 feet, is within the shallowest ecologic unit set by other Arctic foraminiferal ecologists (Phleger, 1960). The object of this paper is to interpret the ecologic factors affecting the distribution of the Foraminifera. This study was financed by Atomic Energy Commission Contract AT-45-1-540, Office of Naval Research Contract Nonr-477(10) Project NR 083 012, and National Science Foundation Grant GP 337. The author wishes to express her gratitude to Joe S. Creager, Department of Oceanography, University of Washington, for suggesting and organizing this problem. Appreciation is also extended to Dean McManus and V. Standish Mallory for their helpful suggestions and criticism. Betty J. Enbysk also gave time to critical analysis of the manuscript and guidance in ecologic interpretations. The author is indebted to Creager and McManus for the use of sedimentary, current and bathymetric data from a manuscript in press. The summer physical and chemical data were taken from a technical report by Fleming and staff (1961) and the winter data from an unpublished report of the Department of Oceanography, University of Washington on the 1960 cruise of the U. S. Coast Guard icebreaker NORTHWIND. The drawings are by Zella Schultz and Janet Griffin.

The paper has been presented at the Tenth Pacific Science Congress of the Pacific Science Association, held at the University of Hawaii, Honolulu, Hawaii, U. S. A., 21 August to 6 September, 1961, and sponsored by the National Academy of Sciences, Bernice Pauahi Bishop Museum, and the University of Hawaii.

The 116 samples used in this study were collected by the M. V. BROWN BEAR, research vessel of the Department of Oceanography, University of Washington, during the summers of 1959 (1 August - 2 September) and 1960 (26 July - 28 August). Text figure 2 shows the locations of the stations.

PREVIOUS WORK IN THE AREA

Previous foraminiferal studies in this area have been meager. LaFond, Dietz, and Pritchard (1949) presented a list of Foraminifera that was compiled from thirty samples scattered throughout the Bering and Chukchi seas, but no indication was given of distribution or frequencies, except that a single foraminifera was noted as being abundant. Carsola (1953) reported the occurrence of Foraminifera from the Beaufort and northern Chukchi seas. His samples were all taken in water deeper than that in the area discussed here. Scholl and Sainsbury (1959) included a list of Foraminifera identified by Patsy Smith (U. S. Geological Survey), which contained most of the predominant species that are identified in the present report, but covered only five stations in the vicinity of Cape Thompson.

Anderson (1961) had three stations in this area. The assemblages contained the same species in similar percentages as listed in this report. He noted that these stations had unusually high populations in comparison with the northern Chukchi Sea stations.

DESCRIPTION OF THE AREA

The portion of the Chukchi Sea studied in this paper extends from the Bering Strait (Lat. 65.5°N) to the latitude of Cape Lisburne (69.0°N) and from the Alaskan coast west to 169°W longitude (text fig. 1). It is a large, open embayment with a total area of 20,000 square nautical miles, bounded along most of the eastern perimeter by a low, rolling, poorly drained coastal plain. The southern portion of Kotzebue Sound, the area near Cape Thompson, and most of the coast between Point Hope and Cape Lisburne are bounded by 600 - to 800 - foot shore cliffs.

Bathymetry

This shelf sea is quite shallow, with depths less than 200 feet, and the bottom is unusually flat (text fig. 3). The gradients in the central area range

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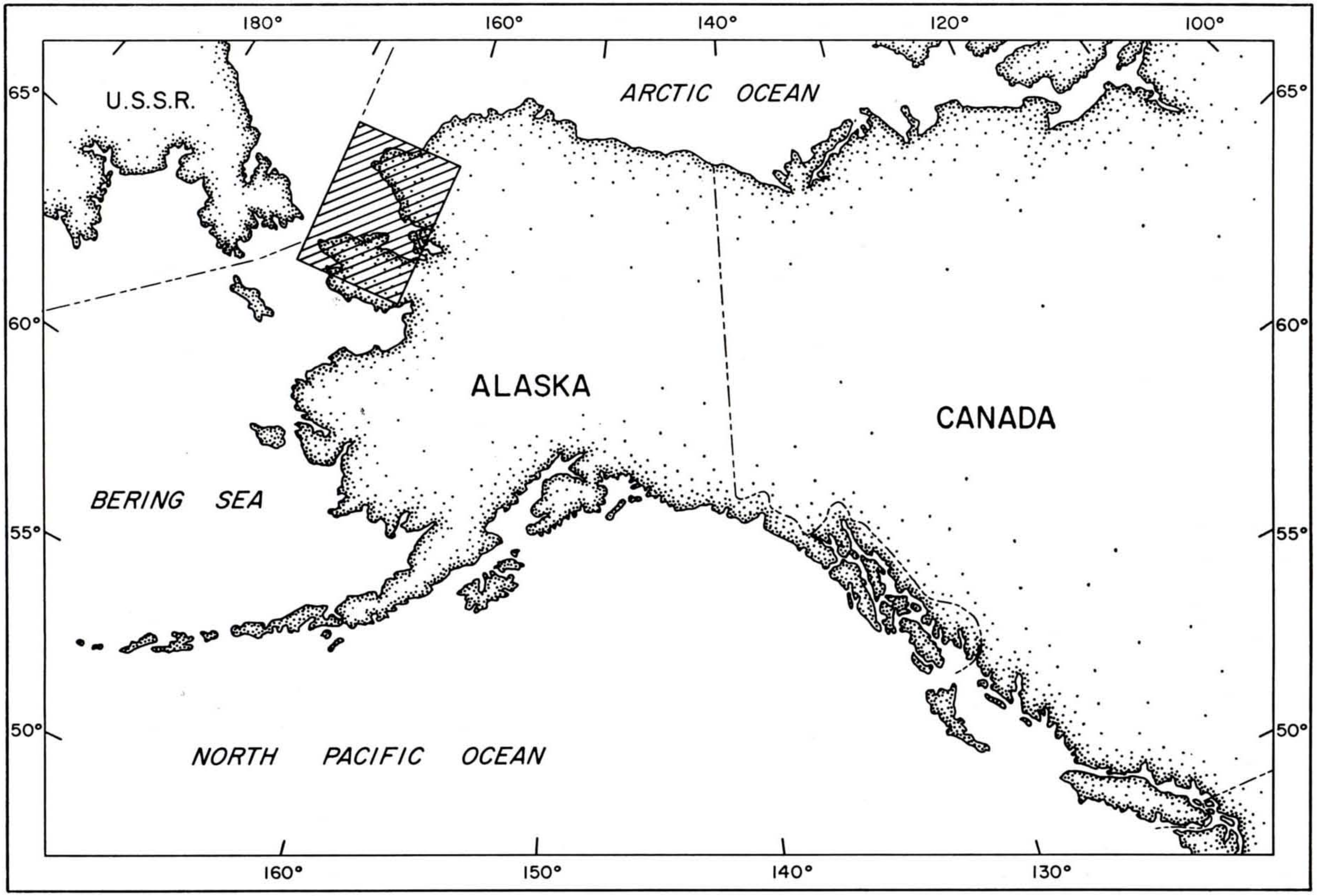
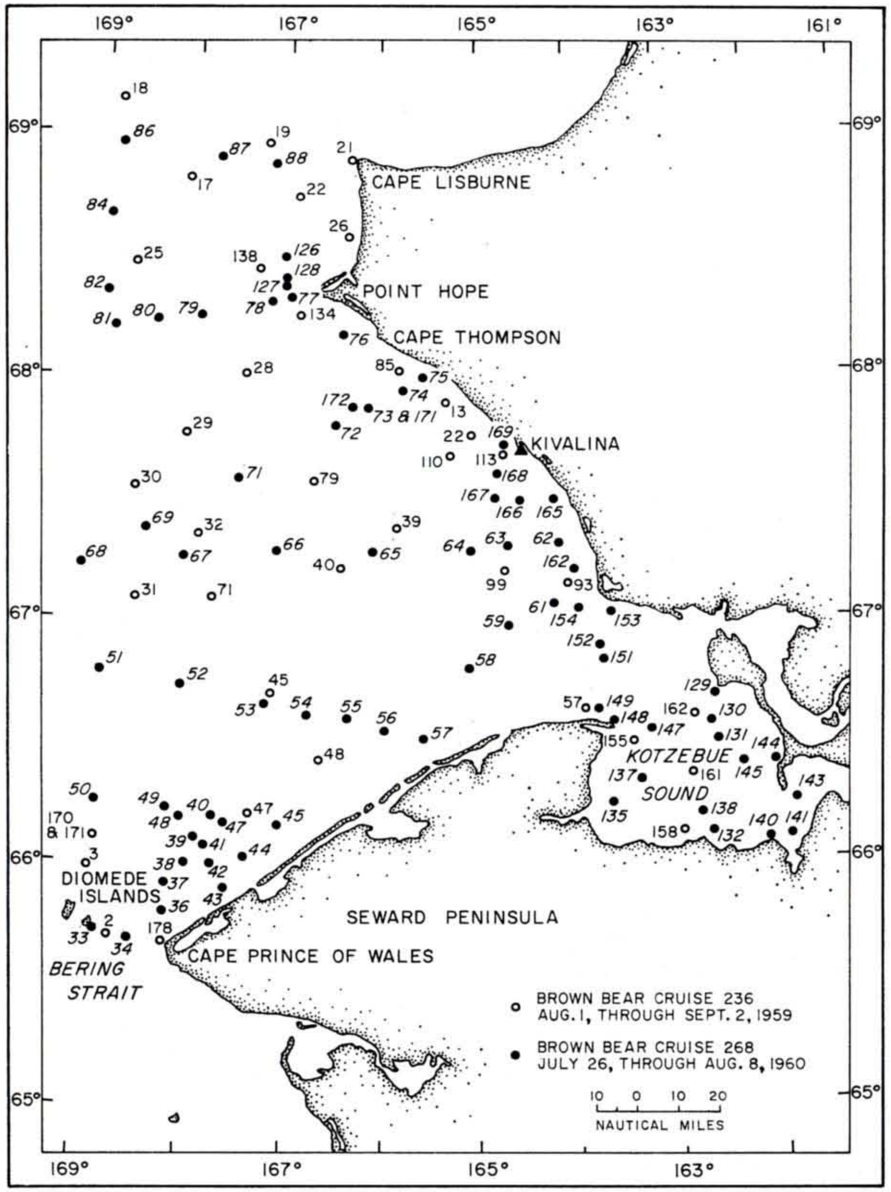
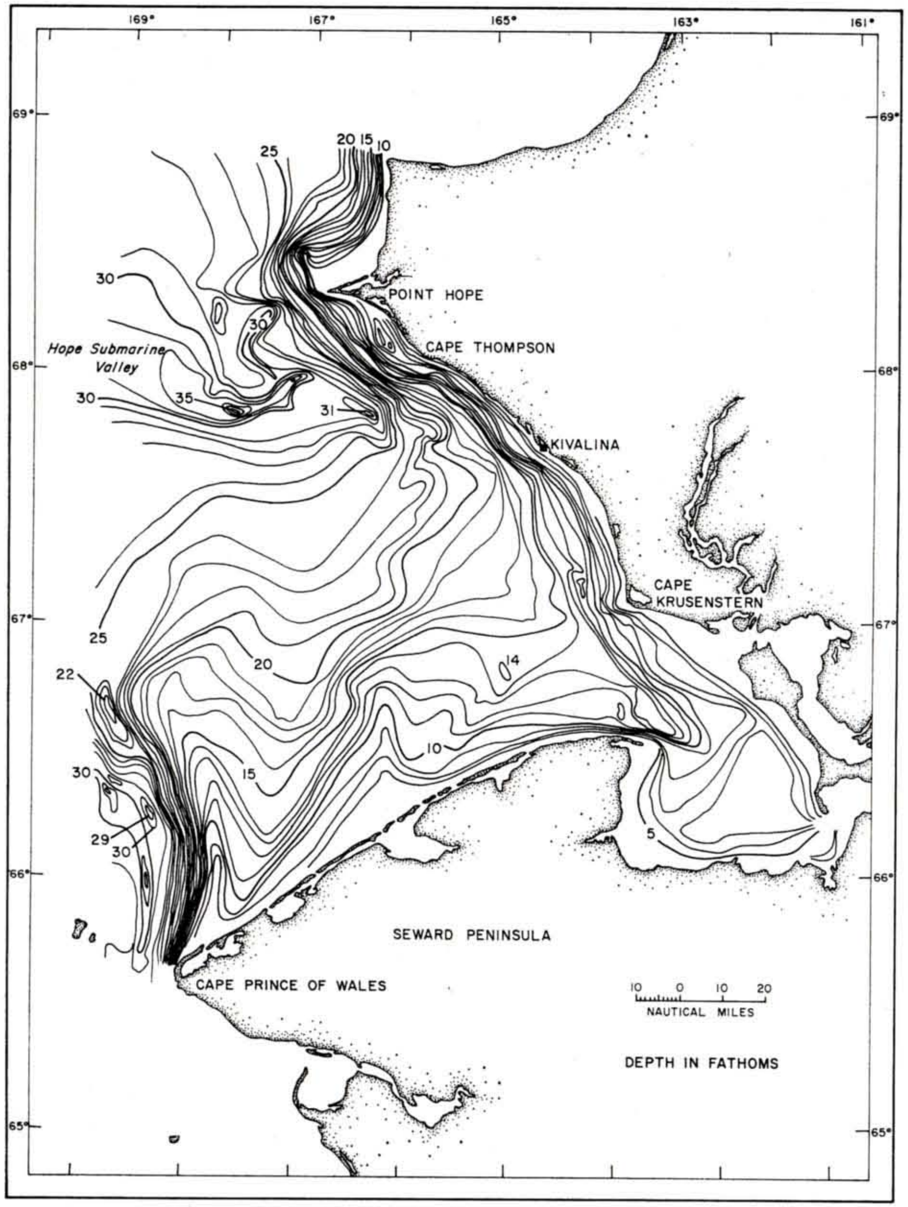
[1] Contribution No. 277, University of Washington, Department of Oceanography.



TEXT FIGURE 1
Location of study area, the southeast Chukchi Sea.



TEXT FIGURE 2
Location of Stations.



TEXT FIGURE 3
Bathymetry with a contour interval of 1 fathom showing the Hope Submarine Valley and the Prince of Wales Shoal north of Cape Prince of Wales.

from four feet per mile down to tenths of feet per mile. This flat featureless plain is broken only by low relief features such as the shoals at Cape Prince of Wales and Point Hope and the Hope Submarine Valley. Prince of Wales Shoal, which is 80 miles long and 30 miles wide, has maximum gradients of only 31 feet per mile. In general, the depths gradually increase with distance from shore. Kotzebue Sound has depths of less than 40 feet. The shelf is very wide in this Arctic region, 600 miles in many places. Depths are less than 200 feet, 250 to 300 miles seaward of Cape Lisburne.

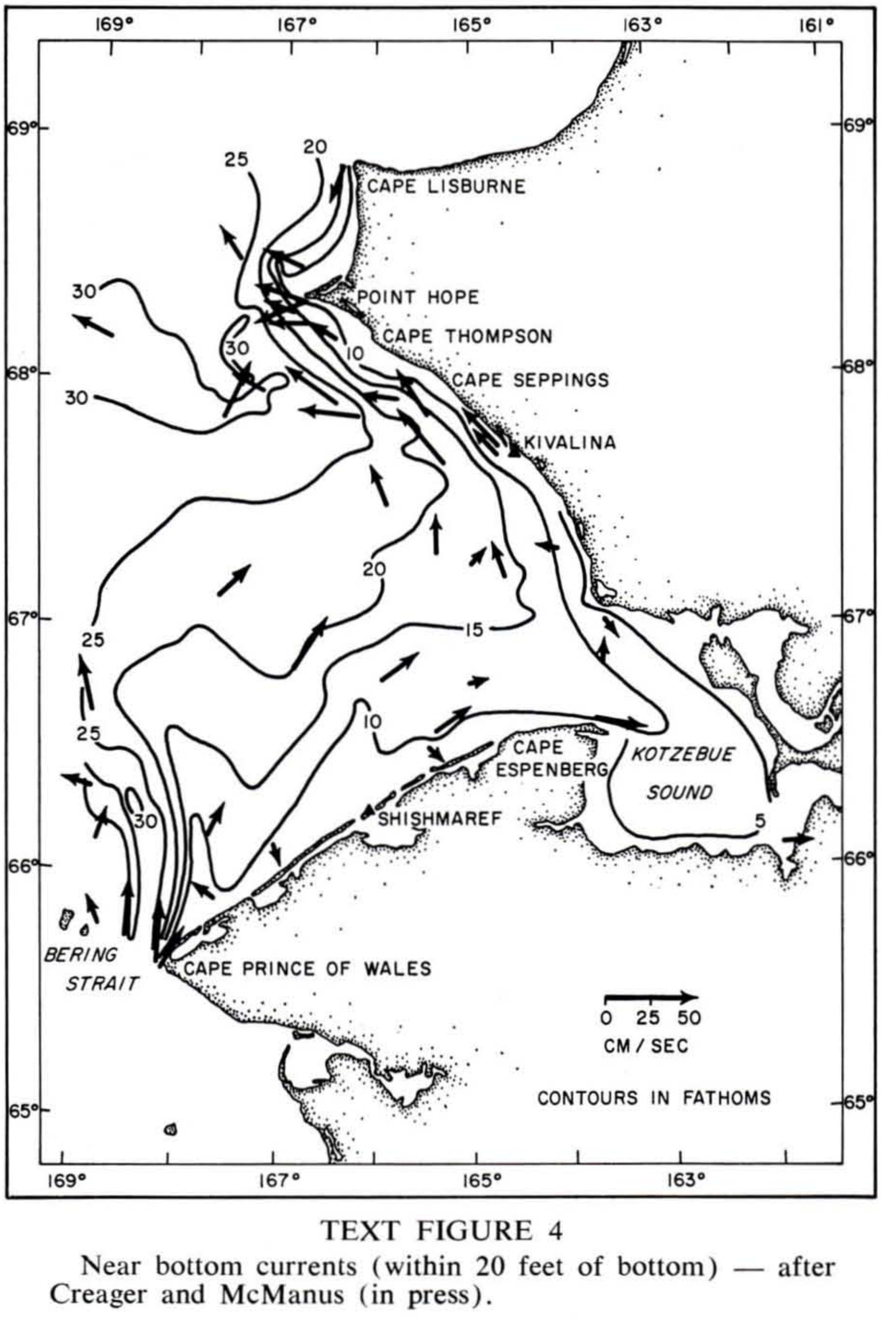
Currents

A surface current with an average speed of 15 to 72 cm/sec sets northward through the Bering Strait. This current flows parallel to the isobaths around the north end of Prince of Wales Shoal into the central portion of the embayment and then northwestward along the north side past Point Hope. In the central portion of the embayment, the average current speeds are reduced to 5 to 25 cm/sec, but along the north side the speeds approach those of the Bering Strait. The currents through the entrance to Kotzebue Sound appear to be tidal (Ozturgut, 1960), flowing in to the south and out to the north with speeds of 4 to 26 cm/sec. Within Kotzebue Sound, the currents are much reduced, with speeds ranging from 8 to 16 cm/sec.

Bottom currents within 20 feet of the bottom reflect the surface currents (text fig. 4). Maximum speeds of 30 to 34 cm/sec were observed in Bering Strait and along the north coast. In the central portion of the embayment, speeds were less than 5 to 25 cm/sec. The average speeds through the entrance to Kotzebue Sound ranged from 4 to 23 cm/sec and within Kotzebue Sound from 8 to 16 cm/sec.

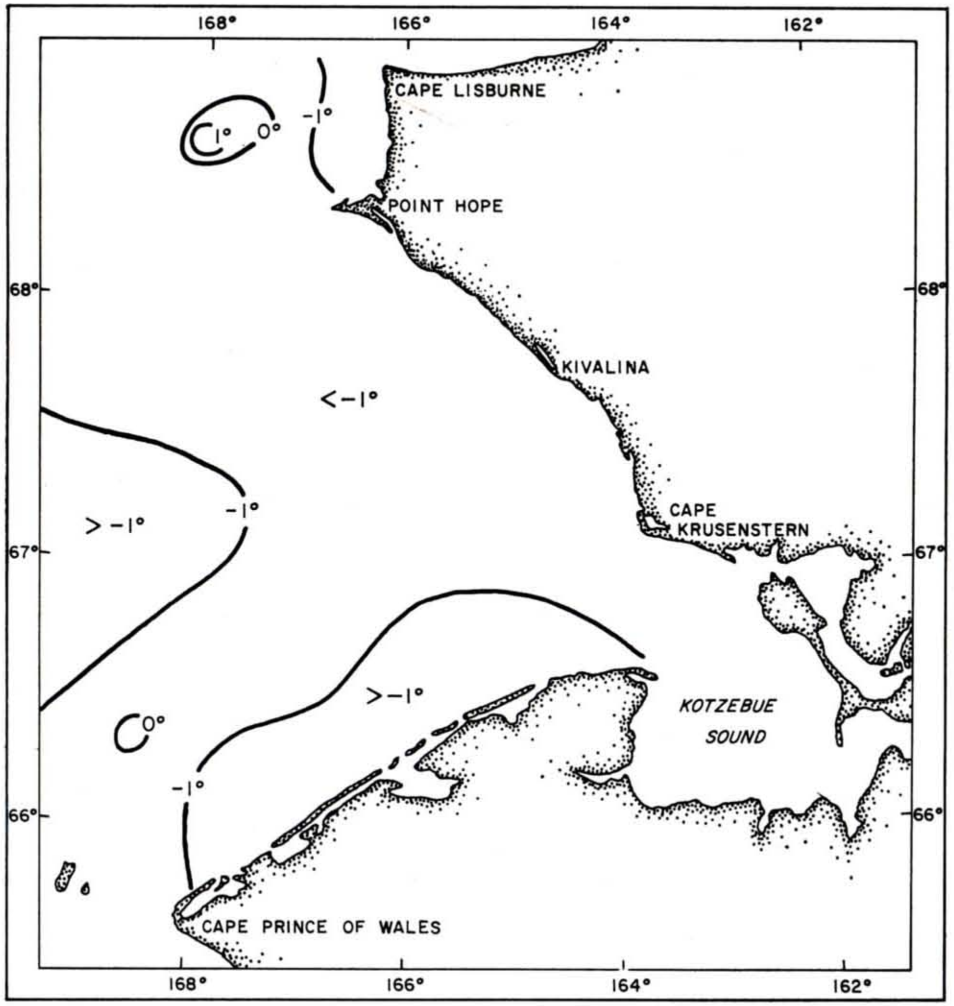
Temperature and Salinity

For seven or eight months, from October or No-

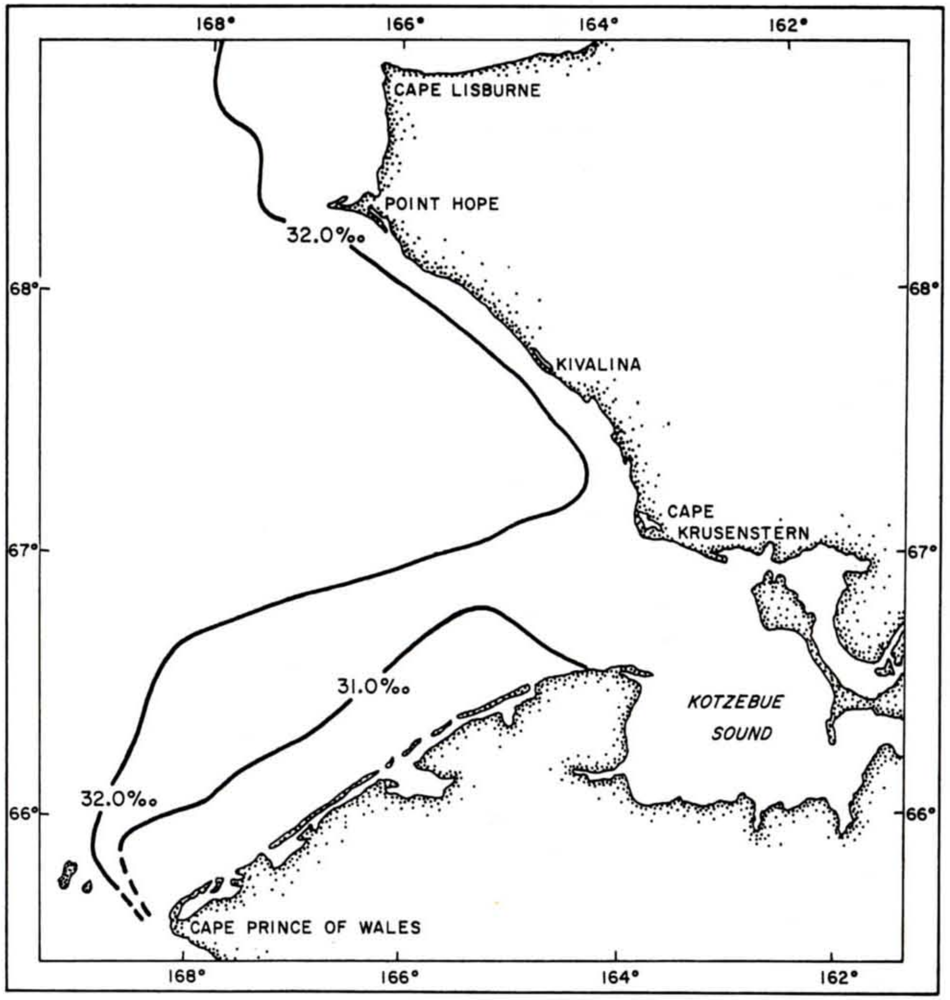


TEXT FIGURE 4

Near bottom currents (within 20 feet of bottom) — after Creager and McManus (in press).



TEXT FIGURE 5
Winter temperatures (°C) taken within 5 meters of bottom.



TEXT FIGURE 6
Winter salinities (o/oo) taken within 5 meters of bottom.

vember to June, this area is covered with ice. The winter temperatures and salinities taken within five meters of the bottom by the U. S. Coast Guard icebreaker NORTHWIND in 1960 show very little variation. The temperatures (text fig. 5) vary from −1.8° to +1.0°C. The salinities (text fig. 6) are greater than 32 o/oo in the central part of the Chukchi Sea and decrease to 31.0 o/oo along the coasts.

The summer temperatures and salinities (text figs. 7, 8), taken within five meters of the bottom, show more variation. A warm, relatively dilute, coastal water is formed which overrides the cold, more saline, offshore water. In Kotzebue Sound, warm water was found in different places in the two different years so the isotherms were not extended. Two isolated occurrences of cold (0°C), saline (32.5 o/oo) water have been found which were residual from the previous winter (Ozturgut, 1960). Near the river mouths in Kotzebue Sound the salinities are less than 29.0 o/oo.

Oxygen and phosphate values have been examined but no correlation with the fauna could be determined. The oxygen values range from .865 to .539 mg/atoms/liter and phosphates from 2.00 to .72μ-atoms/liter.

Sediments

The sediment distribution shown in text figure 9 is based on mean particle diameter using phi-notation: $\phi = \log_2 d$ where d = grain diameter in millimeters (Krumbein, 1934, p. 76). The classic picture of the coarse sediment nearshore grading to finer sediment offshore occurs off the northeast coast between Kivalina and Point Hope. But in the area around Bering Strait, the gradation is reversed. There the sediments are gravel in the deeper water of the Strait and grade to coarse silts near Cape Prince of Wales. The finest sediment, clayey silt (three end-member classification of Shepard, 1954), occurs along the northwestern margin in the central portion of the area and in Kotzebue Sound. Gravel is found along the coast between Kivalina and Point Hope and in Bering Strait. The rest of the area is covered by sands.

The sorting is poor in the entire area but the best sorted sediment is found along the Seward Peninsula. Most of Kotzebue Sound has poorly to very poorly sorted silts indicating that this is an area of quiet water deposition. Several deposits of coarse, poorly sorted sediments near the coast of Kotzebue Sound have their source in local cliffs.

The current flowing through Bering Strait decreases in speed after leaving the narrow part of the Strait, diminishing its capacity and producing the deposits of the Prince of Wales Shoal. North of the Strait the sediment size decreases from −2 ϕ to the silt sizes of the central area, and the sorting is improved.

PROCEDURE

The 116 samples were collected with a van Veen grab sampler, which penetrates to a maximum depth of 9 inches. The samples were frozen immediately and thawed just prior to analysis. They were split to about 30 grams, a quantity assumed to be representative of the entire sample. They were then dried, weighed and graded into whole phi sizes, according to the Wentworth classification, using the phi transformation. The samples were examined for Foraminifera: the larger phi sizes were picked completely and the 3 and 4 ϕ sizes were split with the Otto Microsplit (Otto, 1933), weighed and a representative fraction examined. Because the samples were previously dried for sediment analysis, it was not possible to stain them with rose bengal to get living-dead ratios. The ratio of Foraminifera per gram was computed from the dry sample weight to give a rough comparison of the abundance of organisms. The identifications were made and the total populations and percentages were computed.

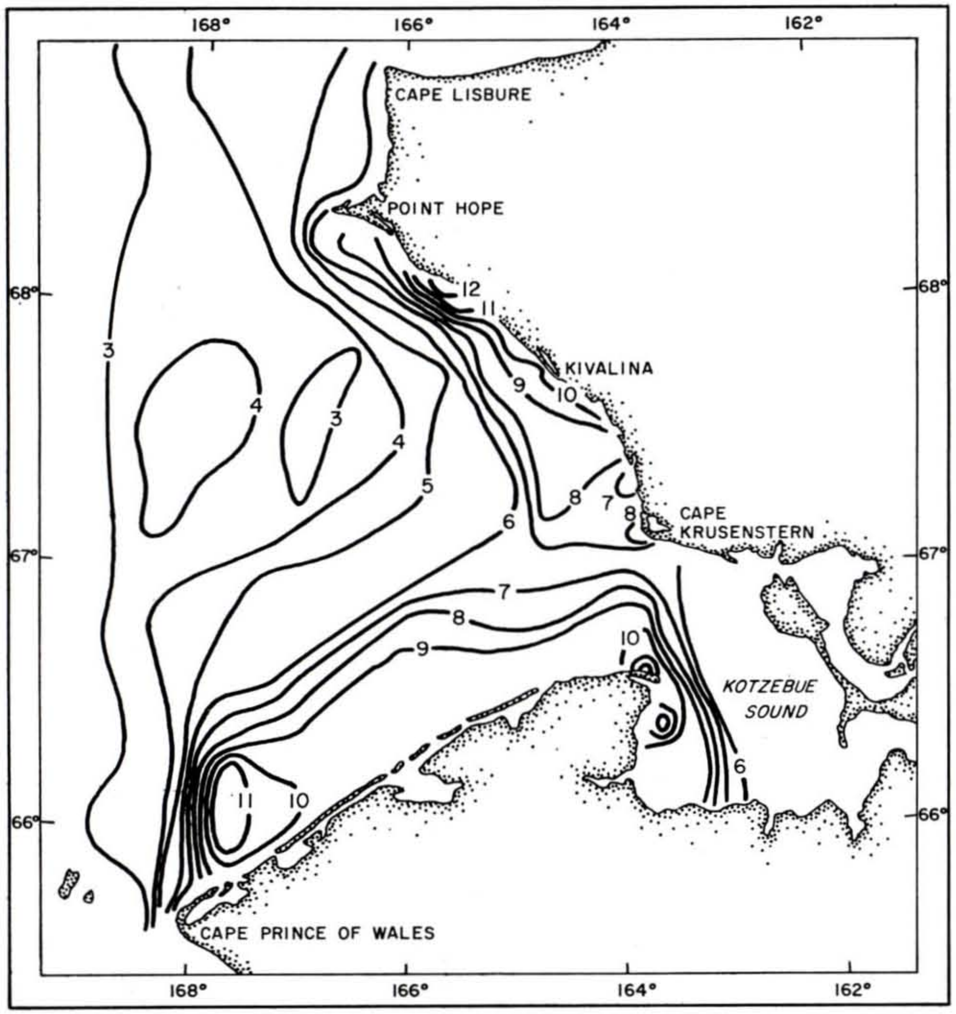
FAUNA

The Chukchi Sea fauna varied from sparse, predominantly arenaceous assemblages to rich calcareous assemblages. The arenaceous Foraminifera were represented by few species but comprised large percentages of some populations. Where the calcareous Foraminifera dominated the populations, many different species occurred. The imperforate calcareous Miliolidae were found rarely.

The number of species was small, even for the Arctic region, but the number of individuals (0-368 tests/gram) was about the same as in the Northeast Pacific (Enbysk, 1960), and in the Bering Sea (Anderson, 1961). The size of the populations varied in different areas. Two stations, 236-162 in Kotzebue Sound and 268-81 west of Point Hope, had no Foraminifera, but nearby stations contained 30-70 tests/gram. Several stations had very high populations, as high as 300 tests/gram, but surrounding stations did not have a corresponding abundance of forms. Foraminifera, like other organisms, may have patchy distributions even under the apparently same ecologic conditions.

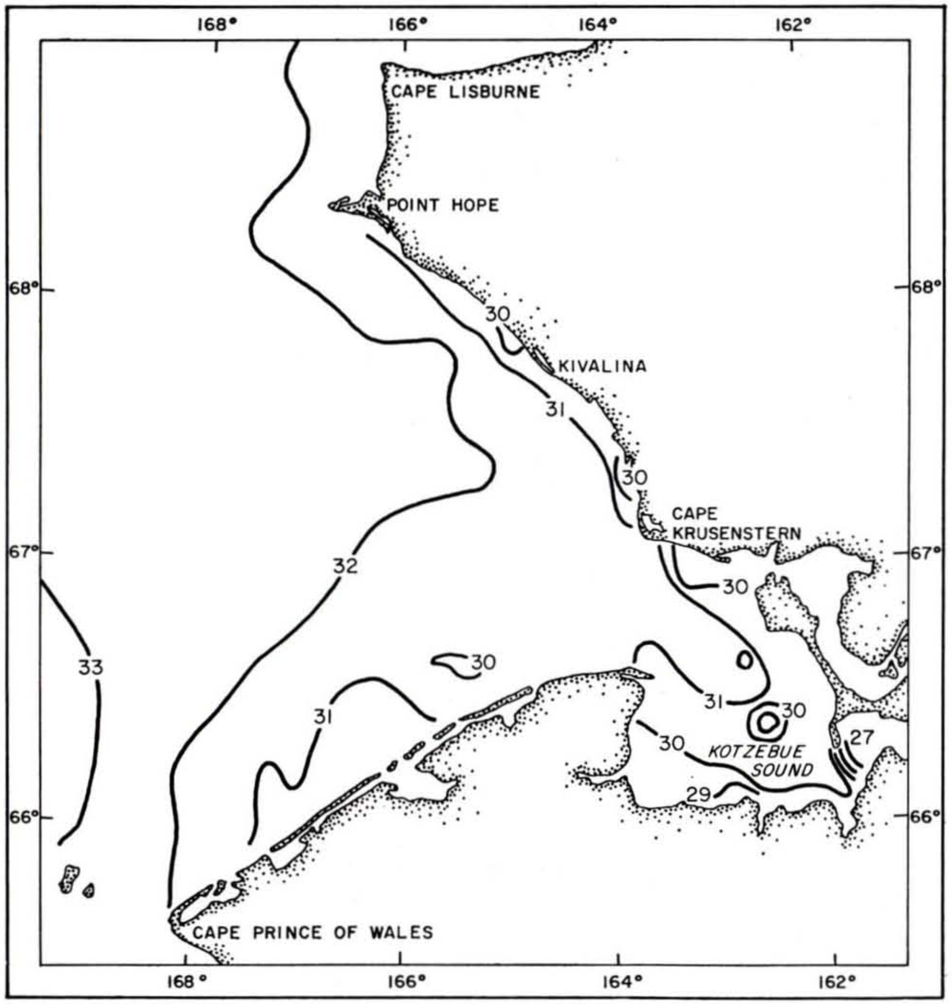
In Bering Strait two stations, 268-48 and 49 (text fig. 2) had unusually high populations, over 230 tests/gram. These stations were surrounded by areas where the populations were about 100 tests/gram. Many juvenile forms were present in the populations and few broken or worn specimens were found which indicate that this probably was an area of high productivity.

The specimens were the same size as those found in the Northeast Pacific (Enbysk, 1960). The only abnormality recorded was bent specimens of *Eggerella advena*. There were several occurrences of *Buccella frigida* attached at right angles while



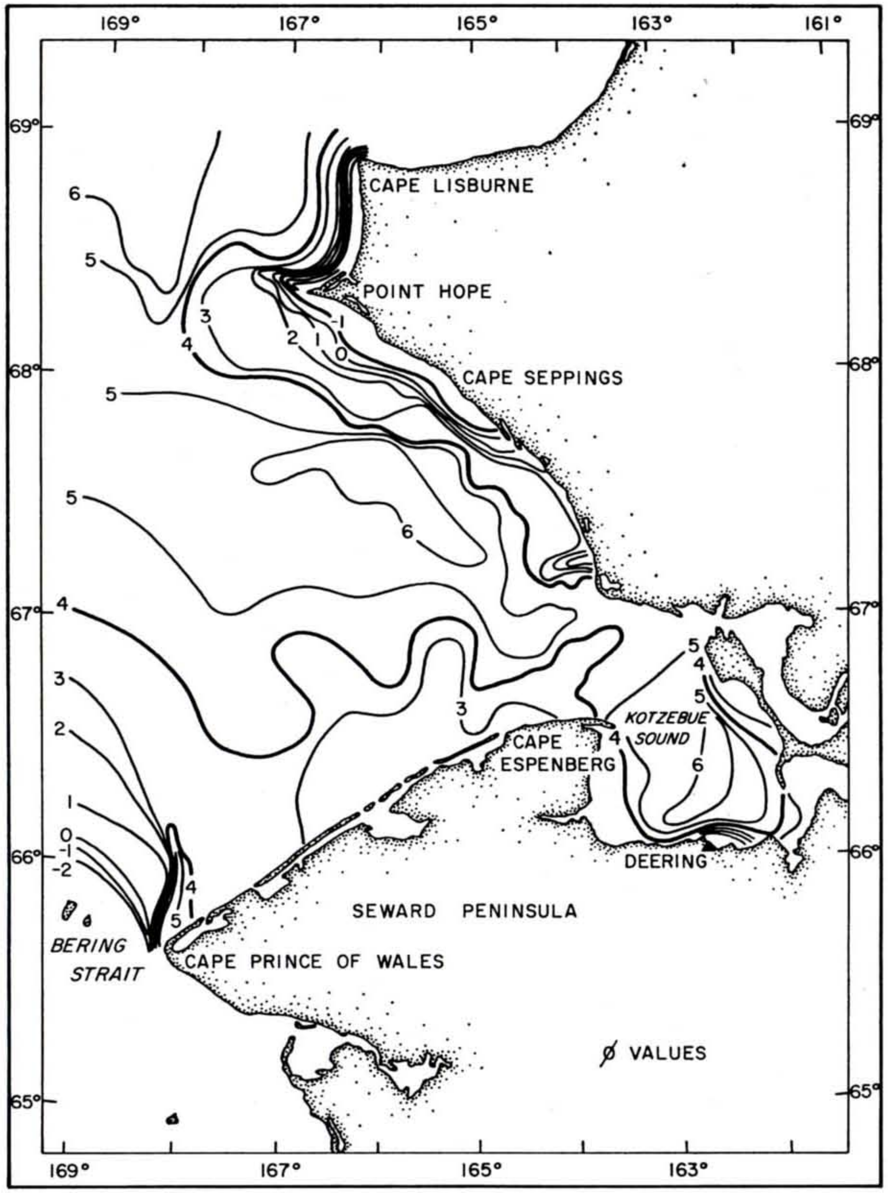
TEXT FIGURE 7

Summer temperatures (°C) taken within 5 meters of bottom. The contours are not extended into Kotzebue Sound as the warmer water was found in different places in two summers.



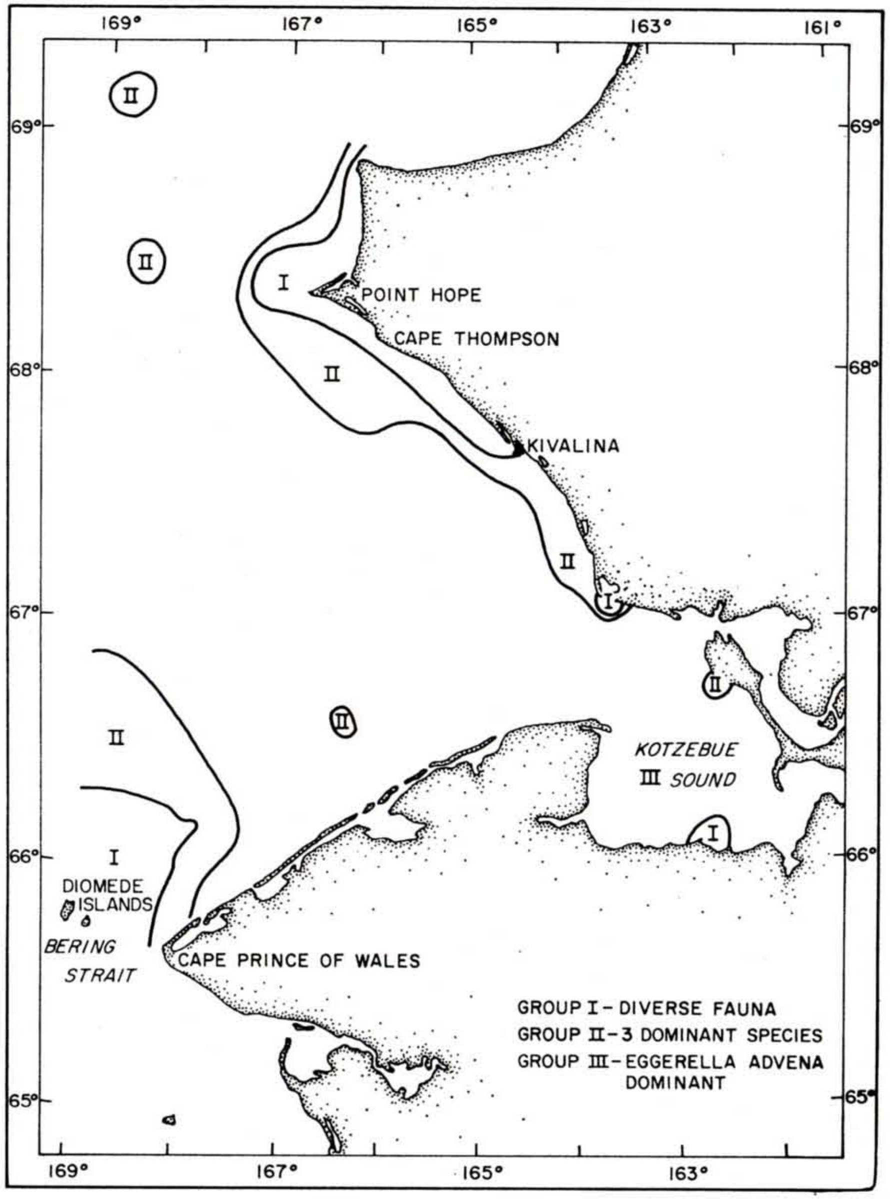
TEXT FIGURE 8

Summer salinities (o/oo) taken within 5 meters of bottom.



TEXT FIGURE 9

Mean particle diameter (ø values) — after Creager and McManus (in press).



TEXT FIGURE 10

Faunal Zones.

others had their dorsal sides cemented together, probably in plastogomy.

Faunal Assemblages

Three faunal assemblages were distinguished: (1) a diverse assemblage, (2) an assemblage that was dominated by *Eggerella advena, Buccella frigida* and *Elphidium clavatum* and (3) a widespread assemblage that was dominated by arenaceous forms, usually *Eggerella advena*. The areal distribution of each group is shown in text Figure 10. Three species: *Eggerella advena, Elphidium clavatum,* and *Buccella frigida* are dominant in the whole area and the degree of dominance is the basis for the differentiation of the assemblages. The characteristic faunal assemblages are listed in Table 1.

Group I is found where the sediment is coarser than 2.0 ø: through Bering Strait, along the northeast coast between Kivalina and Point Hope, and at one station near the coast in Kotzebue Sound (text fig. 10). The assemblages are dominated by calcareous forms with as many as 25 species at one station. The populations may be low, as on very coarse sediment, or unusually high, like the stations north of the Strait, but the characteristic diverse calcareous assemblage is retained. The three dominant species of the entire area are usually present but in small percentages at some stations. *Cibicides lobatulus,* which is usually associated with coarse sediment, *Trochammina squamata,* and *Fissurina marginata* occur only in this group. The *Elphidium* are numerous and varied. Many intergradations exist between the end member forms of *Elphidium* species.

Group II is found where the sediments have a mean size of about 3.0 ø, on Prince of Wales Shoal, and seaward of the first group (text fig. 10). This assemblage is characterized by a large percentage of the three main species. *Eggerella advena, Buccella frigida,* and *Elphidium clavatum* comprise about 70 percent of the population. *Eggerella advena* makes up 33 to 66 percent and *Elphidium clavatum* and *Buccella frigida* the remainder. The rest of the species are mainly calcareous. Other

TABLE 1

FAUNAL ASSEMBLAGES

GROUP I	GROUP II	GROUP III
Eggerella advena	*Eggerella advena*	*Eggerella advena*
Buccella frigida	*Buccella frigida*	*Buccella frigida*
Elphidium clavatum	*Elphidium clavatum*	*Elphidium clavatum*
Elphidium bartletti	*Elphidium bartletti*	*Elphidium bartletti*
Elphidium orbiculare	*Elphidium orbiculare*	*Elphidium orbiculare*
Elphidium subarcticum	*Elphidium* variants	*Textularia torquata*
Elphidium frigidum		*Reophax arctica*
Elphidium variants		*Ammotium cassis*
Trochammina squamata		*Spiroplectammina biformis*
Rosalina wrightii		

COSMOPOLITAN SPECIES	SPECIES NOT OCCURRING IN CENTRAL AREA
Pseudopolymorphina novangliae	*Quinqueloculina agglutinata*
Cassidulina islandica	*Trochammina lobata*
Nonionella auricula	*Rosalina wrightii*
	Asterellina pulchella
	Cibicides lobatulus

RARE SPECIES

Proteonia atlantica
Proteonia fusiformis
Reophax curtus
Reophax nodulosa
**Reophax scotti*
Reophax sp.
**Protoschista findens*
Recurvoides turbinatus
Textularia earlandi
Quinqueloculina arctica
Quinqueloculina seminula
Quinqueloculina sp.
**Pateoris hauerinoides*
Trochammina rotaliformis
Dentalina sp.
Lagena apiopleura
Lagena gracillima
Lagena mollis
Lagena cf. *L. striata*
**Lagena semilineata*
**Oolina costata*
Oolina globosa
**Oolina lineata*
Oolina melo
Fissurina marginata
Fissurina ventricosa
**Sigmomorphina gallowayi*
Globulina glacialis
**Laryngosigma hyalascida*
**Guttulina problema*
Buliminella elegantissima
Elphidiella arctica
Elphidiella groenlandica
Elphidiella sp.
**Bolivina pseudopunctata*
**Cornuspira carinata*
Patellina corrugata
**Buccella inusitata*

* restricted to Group I

arenaceous forms are not uncommon, but do not comprise over 10 percent of the population. Scattered localized occurrences of Group II are found in Kotzebue Sound, the central area and in the extreme northwest region.

Group III is found in the broad central area and Kotzebue Sound, where the mean size of sediment is in the silt range (text fig. 10). Few species, chiefly arenaceous forms, characterize this assemblage. *Eggerella advena* comprises 50 to 97 percent of the total population. At many stations the populations are very low, whereas at others *Eggerella advena* occurs in such abundance that the populations are quite large for this region. Usually several *Elphidium bartletti* or *Elphidium orbiculare* are found in the 1 and 2 ø sizes, while the finer fractions contain many arenaceous forms. *Ammobaculites cassis, Spiroplectammina biformis* and *Reophax arctica* are the common arenaceous Foraminifera besides *Eggerella advena*. In a few stations in the northwest region and in Kotzebue Sound, these species occur in such numbers that *Eggerella advena* comprises less than 50 percent of the population. The assemblages are still characteristically dominated by arenaceous forms and have few species; thus they are included in this group.

Table 1 lists the species characteristic of each faunal assemblage, restricted species, and species that occur throughout the whole area. *Pseudopolymorphina novangliae, Cassidulina islandica,* and *Nonionella auricula* are found in small percentages at scattered stations over the entire area. *Quinqueloculina agglutinata, Rosalina wrighti, Trochammina lobata* and *Asterellina pulchella* are found near the coasts and in Kotzebue Sound in a wide range of depths, but never occur in the broad central area. *Trochammina lobata* is found only where the salinity is less than 31.5 o/oo. The species listed under "Rare" occur at a few scattered locations in frequencies of about 1 percent. Those marked with an asterisk (*) are restricted to Group I.

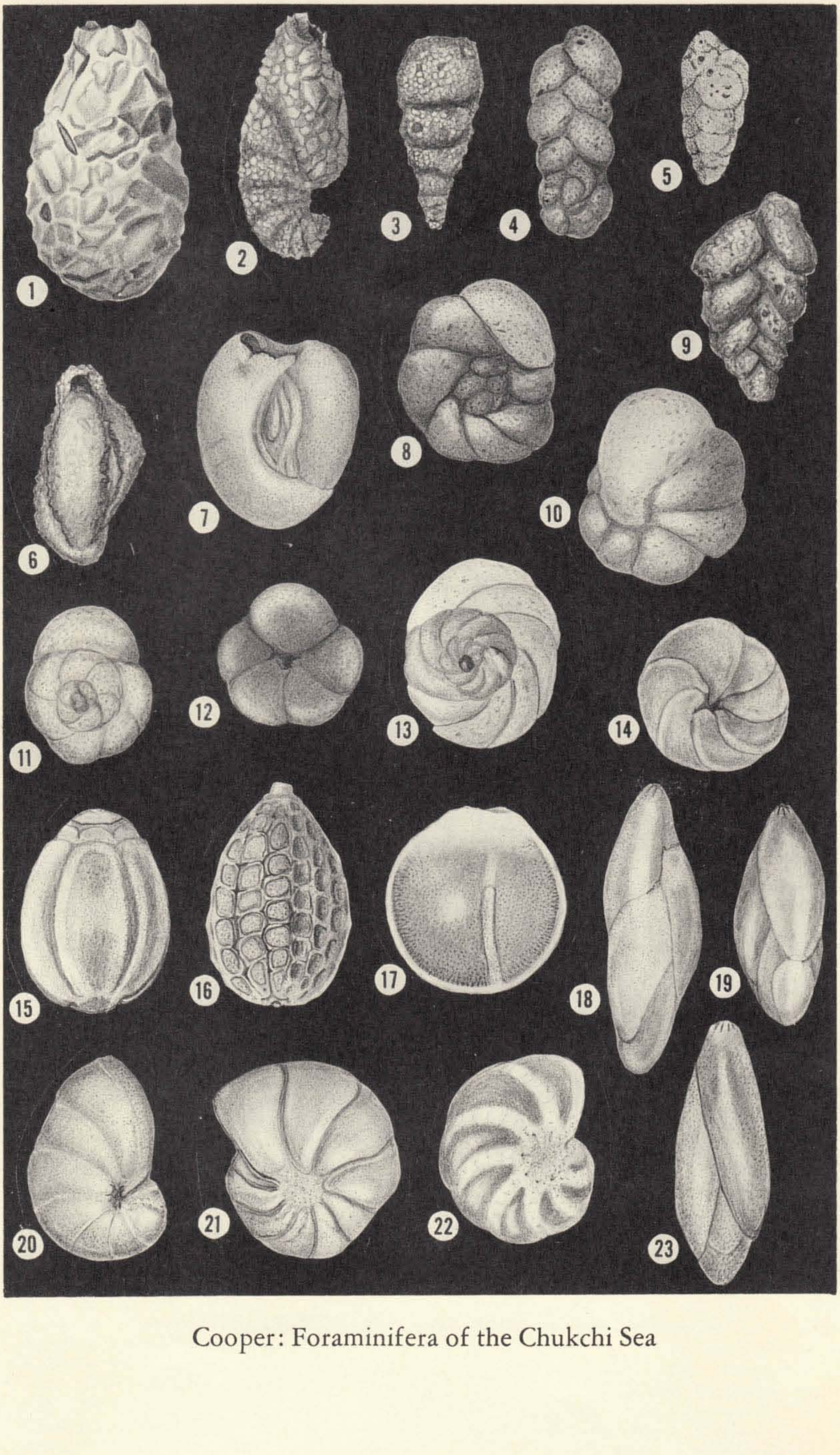
Prince of Wales Shoal and Kotzebue Sound. There are two areas in the Chukchi Sea, Kotzebue Sound and Prince of Wales Shoal, which show that sediment size is an important factor in foraminiferal distribution. In Kotzebue Sound, the depths are less than 40 feet and tides and currents are weak. The salinity is less than 31.5 o/oo and drops to 23.0-26.0 o/oo where rivers flow into the Sound. The temperatures fluctuate seasonally as much as 12°C. It is not known whether the pockets of cold, saline water which have been reported, persist through several seasons. Ozturgut (1960) suggests that the tides and currents do not flush Kotzebue Sound. The assemblage at one station within this anomalous water had a higher number of species than nearby stations, but was still dominated by arenaceous forms, while another was barren. Near the coast in Kotzebue Sound where the salinity is less than 30.0 o/oo, *Buccella frigida* is not found but it occurs in areas of low salinity in the Chukchi Sea.

Most of the Sound contains fine (3.5 to 6.0 ø) sediment; however, at one location near the coast there is a coarse sediment with a mean size of 0.9 ø. The assemblage which occurs at this station contains only five percent arenaceous Foraminifera,

EXPLANATION OF PLATE 5

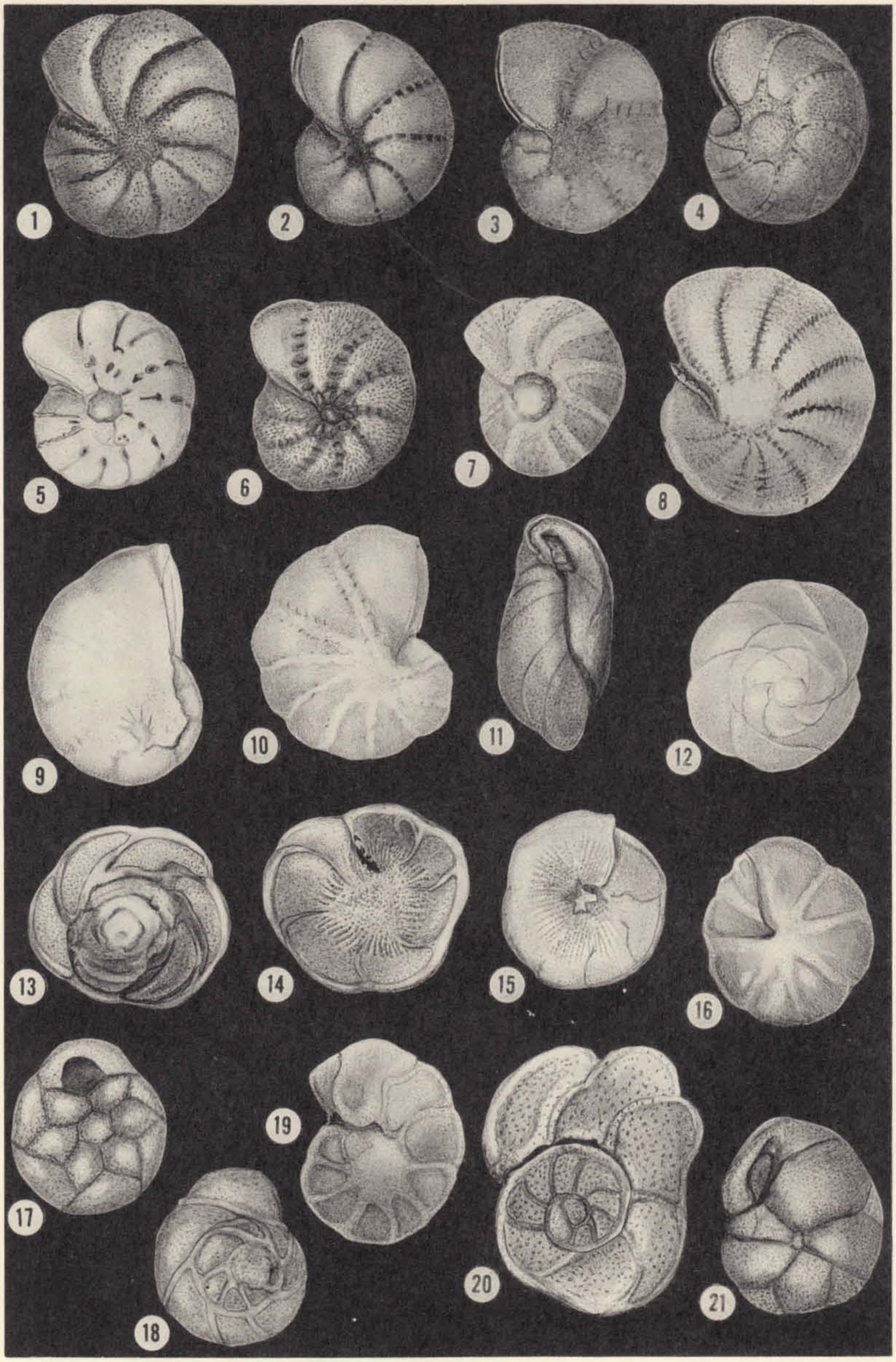
(Size of hypotypes after each specific name, in parentheses)

FIGS.		PAGE
1.	*Proteonia atlantica* Cushman. (1.78 mm) × 29	92
2.	*Ammotium cassis* (Parker). (0.70 mm) × 67	92
3.	*Reophax arctica* Brady. (0.24 mm) × 153	92
4.	*Spiroplectammina biformis* (Parker and Jones). (0.31 mm) × 131	92
5.	*Eggerella advena* (Cushman). (0.34 mm) × 88	94
6.	*Quinqueloculina agglutinata* Cushman. (0.45 mm) × 85	94
7.	*Pateoris hauerinoides* (Rhumbler). (0.45 mm) × 85	94
8.	*Trochammina lobata* Cushman. (0.4 mm) × 86	94
9.	*Textularia torquata* F. Parker. (0.28 mm) × 142	94
10.	*Trochammina lobata* Cushman. (0.4 mm) × 94	94
11.	*Trochammina rotaliformis* Wright. (0.18 mm) × 166	94
12.	*Trochammina rotaliformis* Wright. (0.13 mm) × 207	94
13.	*Trochammina squamata* Parker and Jones. (0.4 mm) × 90	94
14.	*Trochammina squamata* Parker and Jones. (0.18 mm) × 162	94
15.	*Lagena apiopleura* Loeblich and Tappan. (0.24 mm) × 162	94
16.	*Oolina melo* d'Orbigny. (0.44 mm) × 97	94
17.	*Fissurina marginata* (Montagu). (0.33 mm) × 109	94
18.	*Pseudopolymorphina novangliae* (Cushman). (0.82 mm) × 68	95
19.	*Pseudopolymorphina novangliae* (Cushman). (0.61 mm) × 69	95
20.	*Nonionella auricula* Heron-Allen and Earland. (0.54 mm) × 72	95
21.	*Elphidium orbiculare* (Brady). (0.54 mm) × 69	95
22.	*Elphidium subarcticum* Cushman. (0.84 mm) × 43	95
23.	*Pyrulina gutta* (d'Orbigny). (0.37 mm) × 137	94



Cooper: Foraminifera of the Chukchi Sea

PLATE 6



Cooper: Foraminifera of the Chukchi Sea

while nearby stations contain 50 to 80 percent arenaceous forms.

In general, the faunal assemblages are in Group III, with the exception of the station on coarse sediment, which is in Group I. Arenaceous forms dominate but a wider variety of species is found than in the broad central area.

Four species, *Pyrulina gutta, Asterellina pulchella, Textularia torquata* and *Ammotium cassis* occurred often with frequencies up to 10 percent. One arenaceous species, *Spiroplectammina biformis,* which was present at stations deeper than 100 feet in the northwest and central region, was not found in the sound. *Elphidiella groenlandica* occurred only in Kotzebue Sound except for one station south of Kivalina near the coast.

The temperatures vary so much that all the species which occur probably are able to withstand a wide seasonal range. Salinity variations affect the assemblages slightly, but a change in sediment type completely alters the fauna.

Although the Prince of Wales Shoal is one of the most prominent topographic features of the Chukchi Sea, it has a very low gradient: 31 feet per mile on the current slope and 10 feet per mile on the eastern slope. Text figure 11 shows the sedimentary environments delineated by McManus and Creager. The sediments in the strait are gravel and sand, while those on the current slope are fine sands and silts. The shoal crest has fine sand and on the sheltered eastern slope a moderately sorted very fine sand is found. The changing percentages of *Eggerella advena* and *Buccella frigida* in these areas are shown in Table 2.

The percentages of *Buccella frigida* and *Eggerella advena* vary from the strait to the eastern slope with the greatest change occurring between the strait and the current slope where there is the most

TABLE 2

Percentages of *Buccella frigida* and *Eggerella advena* across shoal

STRAIT			CURRENT SLOPE			SHOAL CREST			EASTERN SLOPE		
	PERCENT			PERCENT			PERCENT			PERCENT	
STA.	B	E	STA.	B	E	STA.	B	E	STA.	B	E
236-2	19	8	268-36	2	51	268-39	19	24	236-47	2	98
3	20	1	38	10	63	42	0	49	268-40	10	55
170	17	0	48	0	75	43	2	91	41	11	51
268-33	18	11							44	16	77
34	19	9							45	2	84
37	24	9							47	5	60
49	35	13									
50	15	28									
RANGE	15-38	0-28		0-10	51-75		0-19	24-91		2-16	51-98
AVG.	20	10		4	63		7	55		8	71

EXPLANATION OF PLATE 6

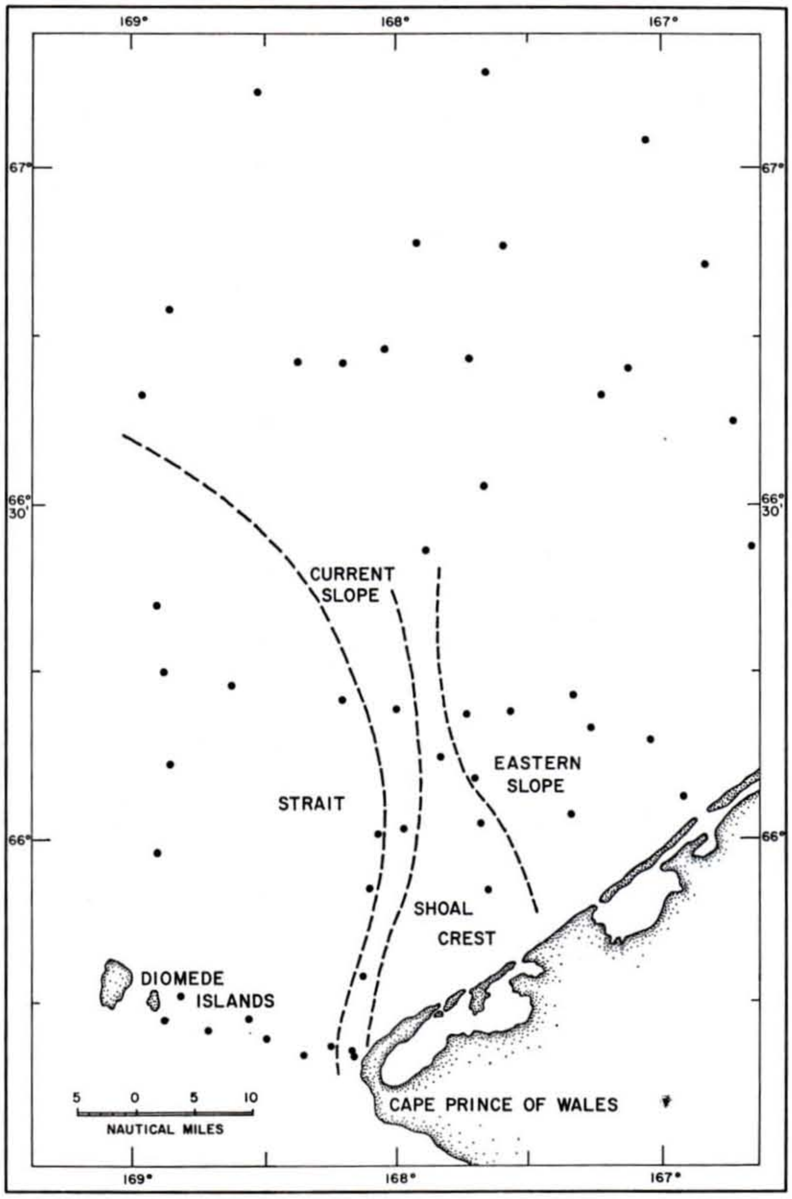
(Size of hypotypes after each specific name, in parentheses)

FIGS.		PAGE
1.	*Elphidium bartletti* Cushman. (0.58 mm) × 68	95
2.	*Elphidium bartletti* Cushman. (0.45 mm) × 82	95
3.	*Elphidium frigidum* Cushman. (0.42 mm) × 91	95
4.	*Elphidium frigidum* Cushman. (0.22 mm) × 170	95
5.	*Elphidium clavatum* (Cushman). (0.44 mm) × 77	95
6.	*Elphidium clavatum* (Cushman). (0.38 mm) × 89	95
7.	*Elphidium clavatum* (Cushman). (0.21 mm) × 150	95
8.	*Elphidiella groenlandica* (Cushman). (0.78 mm) × 57	95
9.	*Elphidiella* sp. (0.83 mm) × 51	102
10.	*Elphidiella arctica* (Parker and Jones). (1.05 mm) × 40	95
11.	*Buliminella elegantissima* (d'Orbigny). (0.26 mm) × 164	95
12.	*Buccella frigida* (Cushman). (0.47 mm) × 91	102
13.	*Rosalina wrightii* (Brady). (0.66 mm) × 56	102
14.	*Rosalina wrightii* (Brady). (0.74 mm) × 50	102
15.	*Rosalina wrightii* (Brady). (0.39 mm) × 75	102
16.	*Buccella frigida* (Cushman). (0.47 mm) × 91	102
17, 18.	*Asterellina pulchella* (Parker). (0.12 mm) × 256	102
19.	*Cibicides lobatulus* (Walker and Jacob). (0.33 mm) × 111	102
20.	*Cibicides lobatulus* (Walker and Jacob). (0.68 mm) × 72	102
21.	*Cassidulina islandica* Nørvang. (0.47 mm) × 141	102

marked sediment size change. Two factors, depth and water mass properties, have been considered but are not responsible for the faunal shift. The average depth in the strait is 166 feet, on the current slope, 104 feet and on the shoal crest, 57 feet. The depth change between each two adjacent areas is about the same. This does not rule out the possibility that depth is important, but the calcareous fauna in the deep water of the strait is more like the fauna along the northwest coast (Group I) than the other areas over 150 feet, where an arenaceous fauna (Group III) is found. The coastal water mass, with high summer temperatures and low salinities, extends to the western side of the current slope. The abrupt change in faunal assemblage might be linked to this, but the assemblages of the shoal crest and the eastern slope are similar to the assemblages in the broad central area (Group III), not to the other coastal areas where this warm, dilute water is present (Group I).

COMPARISON WITH OTHER SHALLOW COLD WATER FAUNAS

The fauna of the Chukchi Sea has many of the same species as the faunas found along the eastern continental shelf of North America by Parker (1948, 1952), Phleger (1952 a & b), and Athearn (1954). However, there are fewer species in the Chukchi Sea than any of the eastern faunas except off the Labrador coast, where Athearn reported only six species as abundant. Phleger (1952a) found a correlation between sediment type and Foraminifera in the Gulf of Maine, but as depth and sediment type varied together and the restricted Foraminifera were found nearby on different types of sediment, he concluded that the distribution was



TEXT FIGURE 11

Enlarged view of Prince of Wales Shoal showing sedimentary environments (after McManus and Creager, in press).

affected more by depth and other ecologic factors than by sediment type.

Phleger (1952b) reported a fauna from the Canadian and Greenland Arctic that contained only a few species which were not found in the Chukchi Sea. *Cassidulina norcrossi* was found in large percentages. *Haplophragmoides glomeratum* and *Proteonina atlantica* also occurred frequently in the shallow samples, but they are found rarely in the Chukchi Sea.

Loeblich and Tappan (1953) reported a faunal change with a change in sediment type off Point Barrow, Alaska. This took place in shallow water, less than 50 meters, or the same depths as the Chukchi Sea. They found a diverse fauna on very coarse sediment and a meager fauna associated with mud.

Samples taken off the southwest coast of Japan (Uchio, 1959) contained a shallow water fauna that has a remarkable resemblance to the Chukchi Sea assemblages. The depth zonations at 20 meters and 50 meters were marked by shifts in frequency of *Pseudononion japonicum, Buccella frigida, Elphidium clavatum,* and *Eggerella advena.* The described area had three currents, two warm and one cold, which fluctuated over the area. Seasonal variations of temperature and salinity were also recorded and affected the fauna to a depth of 50 meters. No correlation of the assemblages with sediment type was attempted but it was noted that lower populations occurred with an increase in pumice grains in the sediment.

Saidova (1960) recognized 21 different assemblages in the Okhotsk Sea based on depth, temperature, salinity, oxygen, sediment type and locality. *Buccella frigida* was cosmopolitan and *Elphidium clavatum* had a broad range. In general, the species found in the shallow areas are common to the Chukchi Sea. However, the calcareous forms were dominant in most of the shallow areas with one exception, and the arenaceous species of that sample were not found in the Chukchi Sea.

In the western part of the Bering Sea, Beljaeva (1960) also found a predominance of calcareous forms in five shelf faunas. These faunas include species found in the Chukchi, but there were also many other calcareous forms.

Both Saidova and Beljaeva found mainly calcareous forms in shallow water. No shallow arenaceous assemblage was described that was similar to those of the Chukchi Sea. The same species were identified, but there were fewer arenaceous forms in actual numbers and in comparison with the calcareous populations. Reported total populations varied from 20 to 600 forms for 50 grams of sediment. This appears to be low in comparison with the 0.4-368 tests/gram found in the Chukchi Sea, but the method of sampling was different. The method described by Saidova (1956) is to take 50 grams of sediment from the grab sampler and wash it through a 20 x 15 cm sack of Miller's gauze No. 61 which retains particles larger than 0.1 mm (3.33 ø). Since the sediment is weighed wet and only sediment coarser than 0.1 mm is picked, the total population cannot be compared with populations in this report which are calculated from a dry weight and are picked from sediment coarser than .062 mm (4.0 ø). Many *Reophax arctica* and *Eggerella advena* were found in the fraction finer than 3 ø.

In the Northeast Pacific, Enbysk (1960) did not find *Rosalina wrightii, Asterellina pulchella* or *Textularia torquata,* and found only a few *Reophax arctica.* However, many Foraminifera of the Pacific fauna are not found in the Chukchi Sea. Only one species each of *Bulimina, Cassidulina* and *Nonionella* were found and there were no *Bolivina, Uvigerina, Angulogerina,* or *Robulus.* All these forms were numerous in the shallow water of the Gulf of Alaska. *Globulimina auriculata,* which was found both in the Pacific and near Point Barrow (Loeblich and Tappan, 1953) does not occur in this area. Calcareous forms were dominant in the majority of shelf stations (less than 100 fathoms) along the coasts of Alaska, Vancouver Island and Washington.

Anderson (1961) found that the inner shelf assemblage in the Bering Sea was similar to the fauna of the Chukchi Sea. He also recorded few species, and arenaceous forms dominate at most stations. The assemblages which occurred north of Cape Lisburne contained the same species as those listed in this report. *Spiroplectammina biformis* was abundant only in the Chukchi Sea. In restricted brackish environments, *Elphidium clavatum* dominated the samples but stations just outside the bay or inlet were dominated by *Eggerella advena.* Salinity was recorded as the major factor affecting distribution. Sediment size analyses were not run for any open ocean stations, but the percentages of *Elphidium clavatum* and sand seemed to vary together in Elson Lagoon and Newak Lake.

DISCUSSION

The fauna of the Chukchi Sea contains species that are circumpolar. These species have joint occurrences in the shallow areas of the Okhotsk, Bering and Chukchi seas as well as the Canadian and Greenland Arctic. The paucity of arenaceous forms in Russian faunas may be due to differences in sampling methods. However, shallow stations along the Aleutian Islands, Alaska, Vancouver Island and Washington were dominated by calcareous forms, very different from the Arctic species. The Aleutian Islands may be an effective block but the similarity of the Japanese and Arctic faunas is an interesting factor. More study is needed to determine if similar rigorous conditions produced the Japanese fauna or if there are real connections.

In the Chukchi Sea, which is shallower than the depth boundaries of Stschedrina (1953), Carsola (1953), and Phleger (1960), definite faunal variations were noted. Where temperature, salinity, and other conditions have large seasonal fluctuations, it is likely that factors other than depth become important for the distribution of Foraminifera, such as sediment size.

Phleger (1960) has included *Eggerella advena, Buccella frigida, Elphidium subarcticum, Trochammina lobata* and *T. squamata* in the list of species that are common to more than one environment. He suggested that they are primarily adapted to inner continental shelf water, and thus are able to withstand variable conditions. It is particularly significant that these species make up most of the fauna of the southeastern Chukchi Sea, bearing out Phleger's conclusions. *Eggerella advena* seems to thrive in different shelf conditions throughout the world. In this area it dominates many of the populations and sometimes occurs in numbers as high as 100 tests/gram.

The small number of species compared to other Arctic areas suggests conditions which are conducive only to hardy Foraminifera. During the winter months when the area is covered by ice, bottom temperatures remain very cold. This might be one of the reasons for the small number of species, but other shallow Arctic areas, except the Bering Sea and Labrador coast, contain at least 15 species in each sample, while many stations in this area have only 5 or 6 species.

The salinity does not vary seasonally more than 1.0 o/oo except in Kotzebue Sound, which contains all but three of the significant species. Several Foraminifera are affected by depth and salinity, but in this area the assemblages are more reasonably correlated with change in sediment type. On coarse sediment a diverse calcareous assemblage is present and on the fine sediment an arenaceous assemblage with few species occurs.

SUMMARY

1) The Chukchi Sea fauna is a meager Arctic fauna that is predominately arenaceous.

2) In this area ecologic units can be differentiated by the percentages of *Eggerella advena, Buccella frigida* and *Elphidium clavatum.*

3) Depth, temperature and salinity changes restrict a few species but have only slight effects on faunal assemblages.

4) In this shallow Arctic Sea where the conditions vary from the wide changes in Kotzebue Sound to the small gradations of the central area, the hardy fauna is affected most by change in sediment type.

DISTRIBUTION OF SPECIES

Proteonia atlantica Cushman, 1944, Special Publication 12, Cushman Laboratory Foraminiferal Research, p. 5, pl. 1, fig. 4.

This species was found at ten stations, five in Kotzebue Sound, two near Bering Strait and three others deeper than 160 feet, associated with a variety of sediment types, temperatures and salinities.

Proteonia fusiformis Williamson, 1858, Recent Foraminifera of Great Britain, Ray Soc., London, England, p. 1, pl. 1, fig. 1.

This form was present in small percentages at several stations that had predominately arenaceous Foraminifera but a wide range of depths and summer temperatures and salinities. The mean size of sediment ranged from 2.0 to 4.0 ø.

Reophax arctica Brady, 1881, Ann. Magazine Natural History, ser. 5, vol. 8, no. 48, p. 405, pl. 21, figs 2a, b.

This species occurred at forty stations throughout the whole area, but had its greatest concentration at deeper stations with sediment in the silt range, summer temperatures between 2.5°C and 5.0°C and salinities greater than 31.5 o/oo. In these arenaceous dominated assemblages, five stations, (268-66, 68, 71, 82, and 84), *Reophax arctica* constituted over 20 percent of the population, probably replacing *Eggerella advena* which drops from 60-70 percent in surrounding stations, to as low as 33 percent.

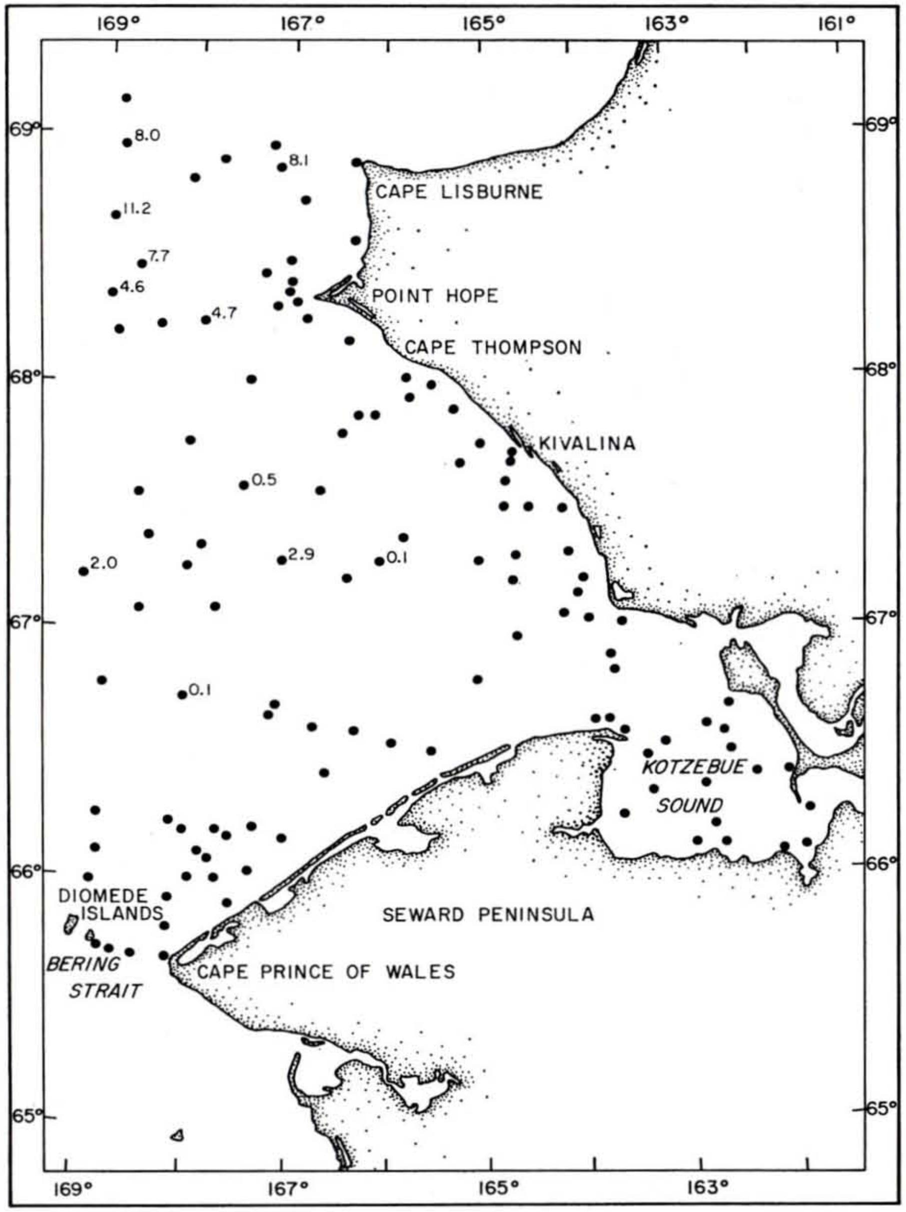
Ammotium cassis (Parker) = *Lituola cassis* Parker, 1870, *in* Dawson, Can. Nat. n. ser., vol. 5, pp. 177, 180, fig. 3.

Ammotium cassis was found at twenty-one stations, nine of which were in Kotzebue Sound. Although it occurred at stations with a wide range of depth (32-180 feet), sediment size (1.5-6.00 ø), summer temperature (—.06 to 10.40°C), and salinity (30.3-32.7 o/oo) it was found most frequently in percentages over 1.0 percent in Kotzebue Sound.

Spiroplectammina biformis (Parker and Jones) = *Textularia agglutinans* d'Orbigny var. *biformis.* Parker and Jones, 1865, Phil. Trans. Roy. Soc. London, vol. 155, p. 370, pl. 15, figs. 23, 24.

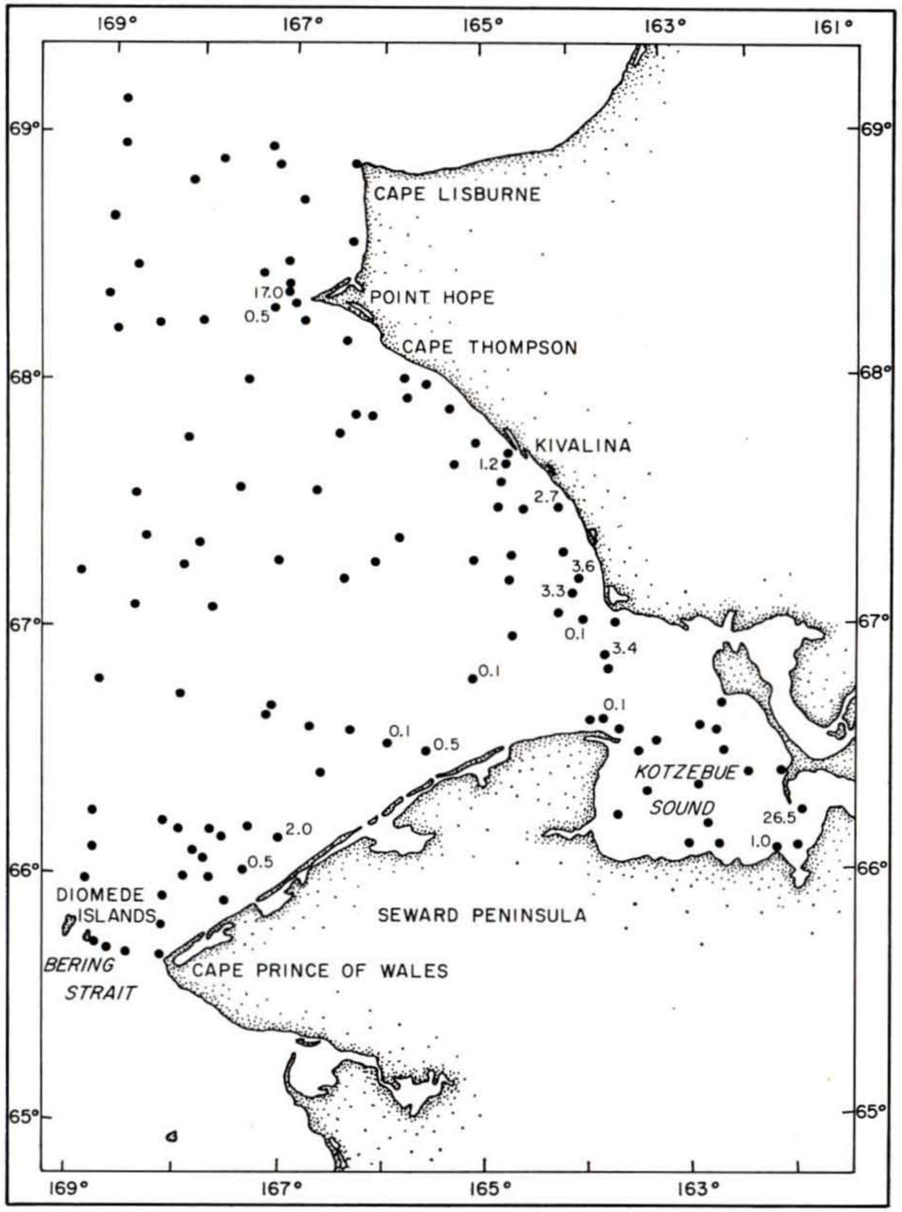
This species occurred at eleven stations, all deeper than 100 feet. Six of these stations were in the northwest region, north of 68°N. latitude (text fig. 12). The summer temperatures and salinities had small ranges from 1.4 to 4.3°C and 31.9 to 32.9 o/oo, whereas the sediment size varied from 2.0 to 6.4 ø. Although the small variations of temperatures and salinities are associated with the deeper water of the central and northwest region, this species did not occur at the deeper stations in Bering Strait or near Point Hope.

Textularia earlandi F. Parker, 1952, Harvard Coll., Museum Comp. Zool. Bull., vol. 106, (1951-1952), no. 10, p. 458, = *Textularia tenuissima*



TEXT FIGURE 12

Distribution of *Spiroplectammina biformis* (Parker and Jones) in percent of total population.



TEXT FIGURE 13

Distribution of *Trochammina lobata* Cushman in percent of total population.

EARLAND, 1933, Discovery Repts., vol. 7, p. 95, pl. 3.

This species occurs at three stations, 268-32, 82 and 86.

Textularia torquata F. PARKER, 1952, Bull. Mus. Comp. Zool., vol. 106, (1951-1952), no. 9, p. 403, pl. 3, fig. 9-11.

This species is present at thirty-five stations, with a wide range of temperatures, salinities, sediment sizes and depths. However, it appears most often in Group III assemblages, especially in Kotzebue Sound.

Eggerella advena (CUSHMAN) = *Verneuilina advena* CUSHMAN, 1922, Contr. Can. Biol., no. 9, (1921), p. 141.

This species dominated the entire area. Where the sediment was coarse, it comprised under 20 percent of the population but in areas with silt it comprised up to 99 percent. However, at a few stations it was replaced by other arenaceous forms. At stations 268-66, 68, 71, 82 and 84, *Reophax arctica* was found in such numbers that *Eggerella advena* made up a smaller percentage than it did at nearby stations. *Textularia torquata* comprised greater than 10 percent at stations 268-131, 144 and 145 in Kotzebue Sound and the percentage of *Eggerella advena* was appreciably lower.

Quinqueloculina agglutinata CUSHMAN, 1917, U. S. Nat. Mus. Bull. 71, pt. 6, p. 43, pl. 9, fig. 2.

This species occurred at eleven stations along Seward Peninsula, in Kotzebue Sound and along the northeast coast near Kotzebue Sound in very small percentages associated with a wide range of temperatures, salinities, and sediment sizes. It appeared only at stations near the coast; however, the depths of these stations range from 42-128 feet.

Quinqueloculina seminula (LINNE) = *Serpula seminulium* (LINNE), 1758, System Nat., ed. 10, p. 786, pl. 2, fig. 1a-c.

This species was found at three stations 268-40, 86 and 80.

Quinqueloculina sp. There were several occurrences of *Quinqueloculina,* but the forms were broken or worn and identification was not possible. These forms were found along Seward Peninsula and near Point Hope in frequencies under 1 percent.

Pateoris hauerinoides (RHUMBLER) = *Miliolina seminulum* (LINNE) var. *disciformis* (MACGILLIVRAY) Williamson, 1858, Recent Foraminifera of Great Britain, p. 86, pl. 7, figs. 188, 189.

This species occurs at five stations all associated with coarse sediment in Bering Strait and along the northeast coast.

Trochammina lobata CUSHMAN, 1944, Spec. Pub. 12, Cushman Lab. Foram. Res., p. 18, pl. 2, fig. 10.

This species was found at seventeen stations along the Seward Peninsula, in Kotzebue Sound and along the northeast coast (text fig. 13). It has a wide range of depths (21-140 feet), and sediment size (1.5-4.8 ø), but the temperature range, from 5.8-12.2°C and the salinity range, from 26.4 to 31.66 o/oo seemed to indicate that this form was primarily adapted to near-shore conditions.

Trochammina rotaliformis WRIGHT, 1911, *in* Heron-Allen and Earland, Journal Roy. Micr. Soc., p. 309.

This species occurred at five stations, 236-32, 268-48, 50, 76 and 172, associated with different conditions.

Trochammina squamata PARKER and JONES, 1865, Phil. Trans. Roy. Soc. London, vol. 155, p. 407, pl. 15, figs. 30-31a-c.

This species was found at fourteen stations, with the largest percentages near Point Hope where the mean sediment size was coarser than 1.0 ø. It occurred most frequently on coarse sediment associated with Group I assemblages.

Lagena spp. *Lagena gracillima, Lagena mollis, Lagena* cf. *L. striata* and *Lagena semilineata* had one occurrence each at scattered stations.

Lagena apiopleura LOEBLICH and TAPPAN, 1953, Smithsonian Misc. Coll. vol. 121. n. 7, p. 59, pl. 10, figs. 14, 15.

This species was found at four stations, all on coarse sediment associated with Group I assemblages.

Oolina globosa (MONTAGU) = *Vermiculum globosa* MONTAGU, 1803, Testacea Britannica, p. 523.

This species occurred at three stations, 236-85, 268-37, and 64 associated with different conditions.

Oolina melo D'ORBIGNY, 1839, Voyage dans l'Amerique meridionale, Foraminiferes, vol. 5, pt. 5, p. 20, pl. 5, fig. 9.

This form was found at three stations, 268-33, 48, and 49, on a variety of sediment sizes, all deeper than 95 feet.

Fissurina marginata (MONTAGU) = *Vermiculum marginatum* MONTAGU, 1803, Testacea Britannica, p. 524.

This species was found at seven stations, six near Bering Strait and one near Point Hope. It occurred in small percentages associated with depths greater than 95 feet, on sediment ranging in size from —3.6 to 4.0 ø. The salinities were greater than 32.5 o/oo and the temperatures were less than 4.0°C.

Pyrulina gutta (D'ORBIGNY) = *Polymorphina gutta* D'ORBIGNY, 1826, Ann. Sci. Nat., ser. 1, vol. 7, p. 267.

This species was found at eight stations, all except two in Kotzebue Sound. Only one or two specimens were found at each station. This species was reported by Brady in 2300 fathoms in the North Pacific (Barker, 1960), and by Jarke (1960) in 220 and 380 meters in the Barents Sea.

Pseudopolymorphina novangliae (CUSHMAN) = *Polymorphina lactea* (WALKER and JACOB) var. *novangliae* CUSHMAN, 1923, Bull. 104, U. S. Nat. Mus., pt. 4, p. 146, pl. 39, figs. 6-8.

This species occurred at ten stations throughout the whole area and did not appear to be limited by region or conditions. Several smaller, more rounded forms were found but they probably were young specimens.

Buliminella elegantissima (D'ORBIGNY) = *Bulimina elegantissima* D'ORBIGNY, 1839, Voyage dans l'Amerique Meridionale, Foraminiferes, vol. 5, pt. 5, p. 51, pl. 7, figs. 13, 14.

This species occurs at four stations, three on Prince of Wales Shoal and one near Point Hope, in percentages less than 1 percent. Phleger (1960) listed this as an open ocean species and all the stations where it occurred had salinities greater than 31.5 o/oo.

Nonionella auricula HERON-ALLEN and EARLAND, 1930, Journal Royal Micro. Soc. ser. 3, vol. 50, p. 192, pl. 5, figs. 68-70.

This species was widespread and occurred in percentages up to 12.2 percent. Most of the twenty-two stations were northwest of Point Hope and near Cape Thompson, but a few were scattered through the central area and in Bering Strait. No preference for sediment type was shown. The summer temperatures were around 2.5°C and the summer salinities above 31.0 o/oo except for a few shallow stations. This species occurred in significant numbers in different conditions.

Elphidium bartletti CUSHMAN, 1933, Smithsonian Inst. Misc. Coll., vol. 89, no. 9, p. 4, pl. 1, fig. 9.

This *Elphidium* species occurred commonly in the entire area, but had its highest percentages along the northeast coast, and to the north of Bering Strait and on Prince of Wales Shoal. In Group III assemblages, it occurred in frequencies of less than 7 percent. Plate 6, figures 1 and 2 illustrate the variations which occurred. In smaller forms, it was difficult to distinguish from *E. subarcticum, E. frigidum,* and occasionally *E. orbiculare*. The *Elphidium* genus is notorious for intergradations between species and this area is no exception. Complete suites of specimens could be laid out, grading from every *Elphidium* species to another.

Elphidium clavatum (CUSHMAN) = *Elphidium incertum* var. *clavatum* CUSHMAN, 1930, U. S. Nat. Mus. Bull. 104, pt. 7, p. 20, pl. 7, fig. 10.

One of the three dominant species of the area, *E. clavatum* varied from a translucent yellow pinnate texture to a porcellaneous one, occasionally on different chambers of the same specimen. The elaborate umbilical boss and retral processes made this form distinctive. It occurred at almost all stations, but had its highest frequencies on Prince of Wales Shoal and near Point Hope. There were several scattered stations in Kotzebue Sound, the central area and north of Point Hope, with frequencies over 30 percent.

Elphidium frigidum CUSHMAN, 1933, Smithsonian Misc. Coll., vol. 89, no. 9, p. 5, pl. 1, fig. 8.

This species was found where the calcareous forms were dominant; near the Bering Strait, and two stations off Point Hope and at two stations near Kivalina, and did not occur in any other areas.

It graded into *E. subarcticum* and *E. bartletti*. A smaller form without the striae similar to the small holotype of Loeblich and Tappan (1953), pl. 18, fig. 10 is figured on plate 6, fig. 4.

Elphidium orbiculare (BRADY) = *Nonionina orbicularis* BRADY, 1881, Ann. Mag. Nat. Hist., ser. 5, vol. 8, no. 48, p. 415, pl. 21, fig. 5a, b.

This robust form was present at many stations throughout the entire area. In Group III assemblages, a few large specimens of *E. orbiculare* and *E. bartletti* often were the only forms present besides the three dominant species. The highest percentages occurred along the northeast coast from Kivalina to Cape Lisburne and north of Bering Strait.

Elphidium subarcticum CUSHMAN, 1944, Cushman Lab. Foram. Res., Spec. Publ. 12, p. 27, pl. 3, figs. 34, 35.

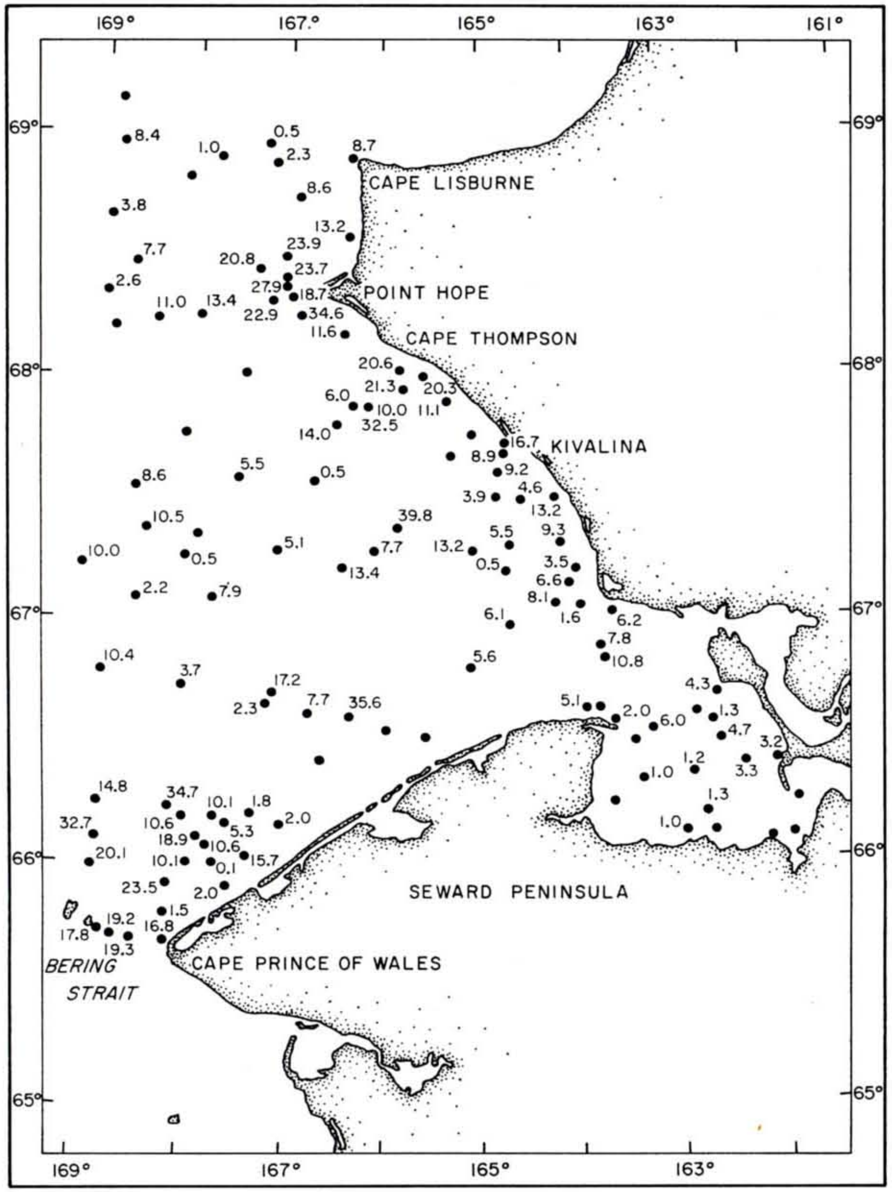
This species is found in Group I assemblages, along the northwest coast and in Bering Strait where there are many other *Elphidium* species. The wide band along the sutures is present in the larger forms but the smaller specimens grade into *E. frigidum*.

Elphidiella arctica (PARKER and JONES) = *Polystomella arctica,* PARKER and JONES, 1864, *in* H. B. Brady, Trans. Linn. Soc. London, Zool., vol. 24, pt. 3, p. 471, pl. 48, fig. 18.

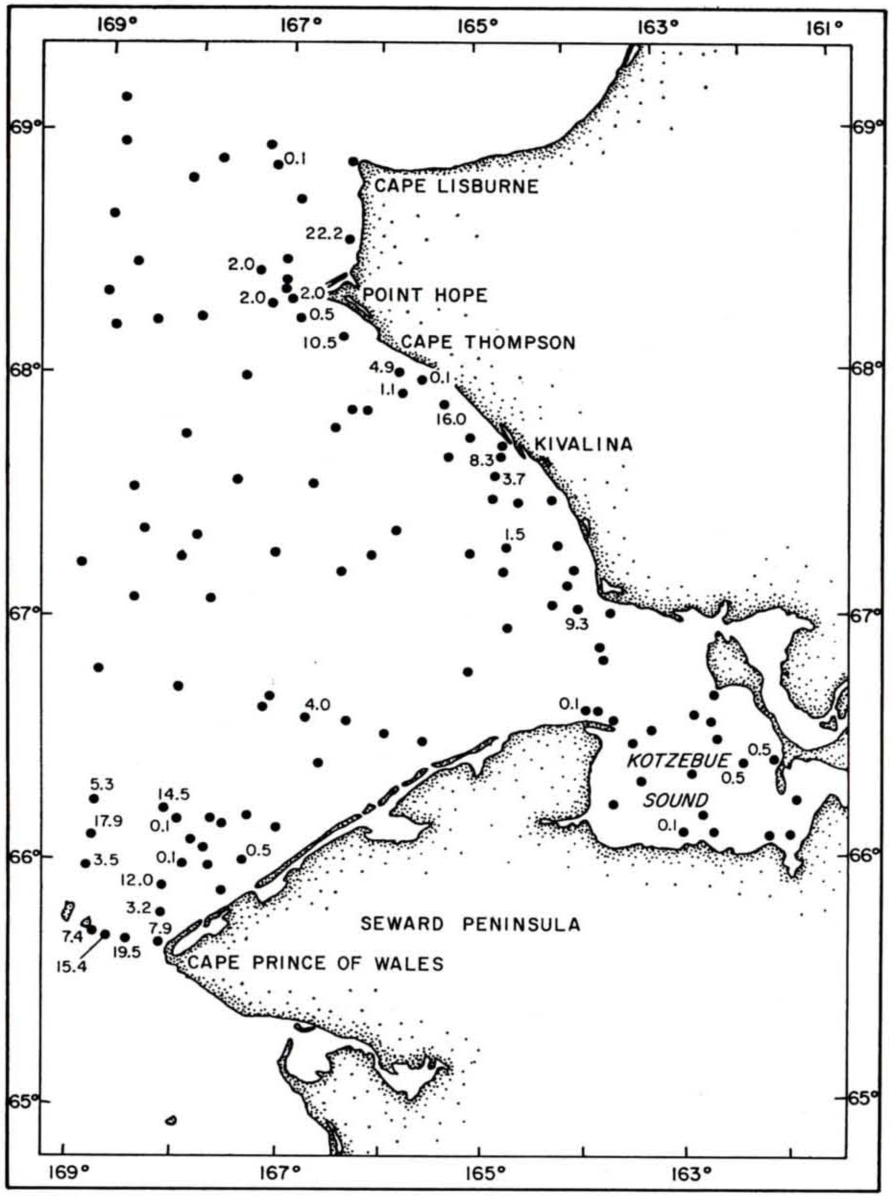
This species was found at eight stations on coarse sediments, seven near Bering Strait and one off Point Hope. Most of the assemblages were in Group I, and all of them were at depths greater than 120 feet, salinities greater than 32.4 o/oo and temperatures less than 3.5°C.

Elphidiella groenlandica (CUSHMAN) = *Elphidium groenlandicum* CUSHMAN 1933, Smithsonian Inst. Misc. Coll., vol. 89, no. 9, p. 4, pl. 1, fig. 10.

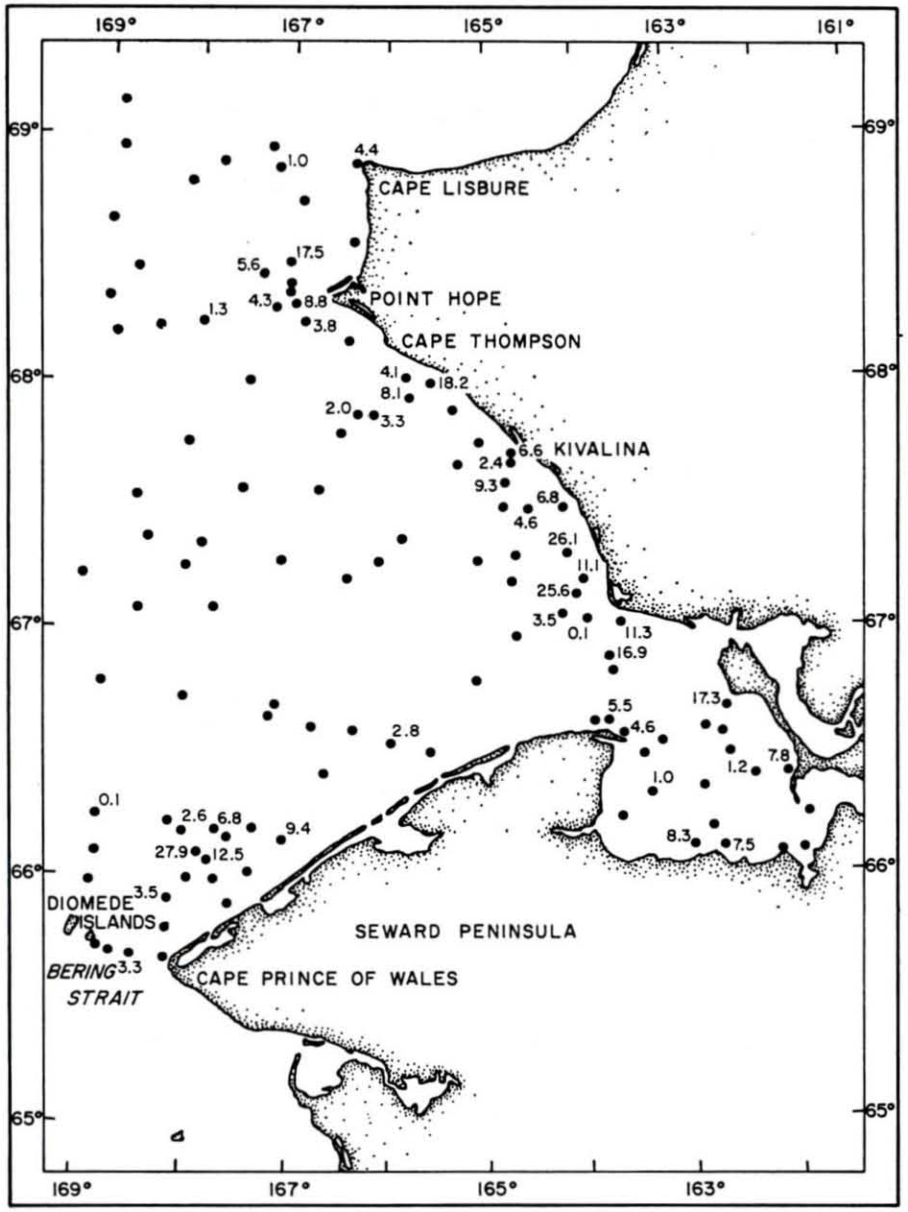
This distinctive form was found only in Kotzebue Sound and at one station south of Kivalina. The depths were less than 60 feet, and the temperatures and salinities had wide annual fluctuations. The



TEXT FIGURE 14
Distribution of *Buccella frigida* (Cushman) in percent of total population.

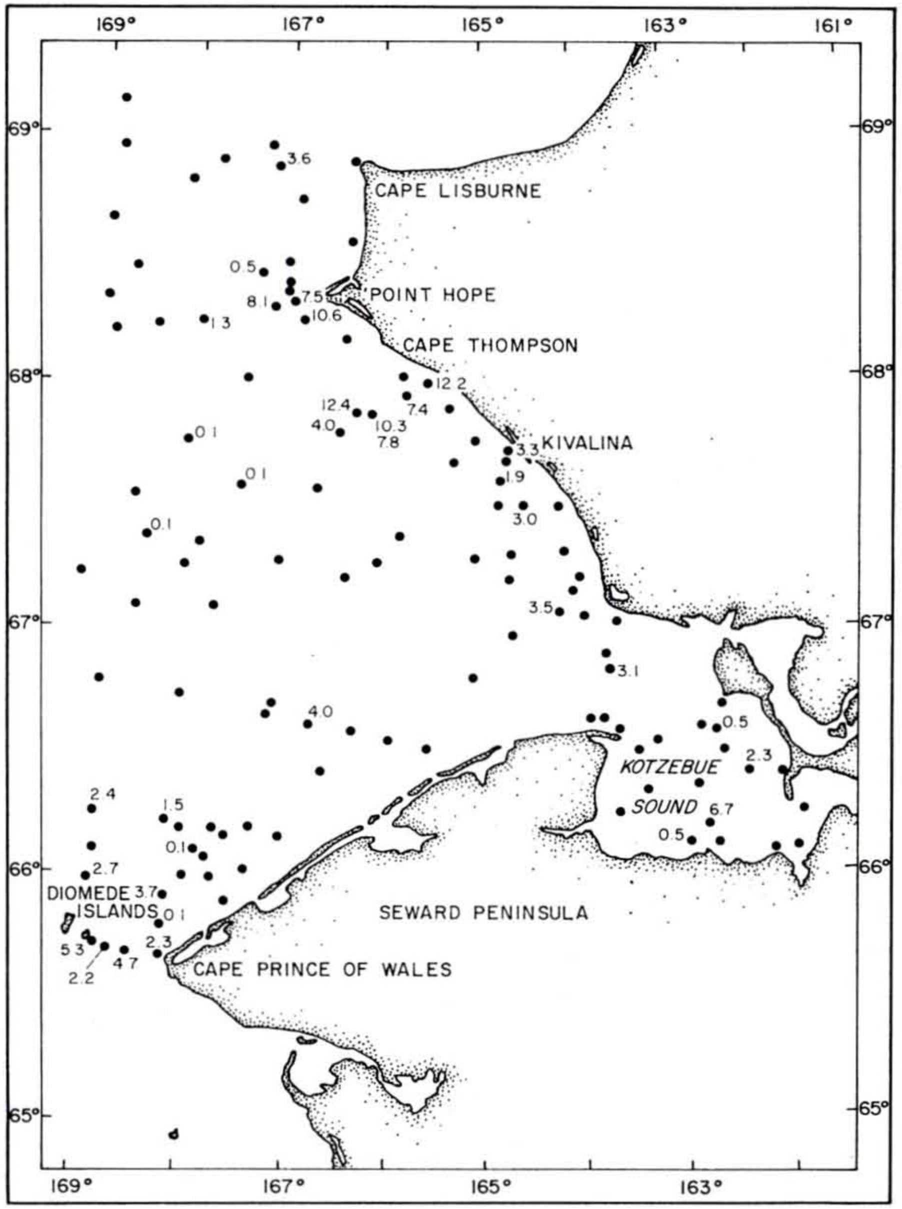


TEXT FIGURE 15
Distribution of *Rosalina wrightii* (Brady) in percent of total population.



TEXT FIGURE 16

Distribution of *Asterellina pulchella* (F. Parker) in percent of total population.



TEXT FIGURE 17

Distribution of *Cassidulina islandica* (Nørvang) in percent of total population.

TABLE 3

Occurrences of Foraminifera in percent of total population

Cruise No.	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236	268	268	268	268	268	236	268	236	268	268	268	268	268	236
Station No.	2	3	13	17	18	19	21	22	25	26	28	29	30	31	32	33	34	36	37	38	39	39	40	40	41	42	43	44	45
Depth (in feet)	167	171	42	165	165	150	80	130	176	58	167	164	165	153	143	160	170	120	128	98	129	45	115	60	50	70	55	62	120
Total Population	178	1443	81	380	47	1148	190	1013	13	1334	49	494	323	3184	394	1403	801	2104	2252	4424	355	2329	459	3715	2828	1685	6787	1313	543
Foraminifera/Gram	3.2	26.5	1.5	14.7	3.4	37.0	4.0	33.2	1.0	17.8	1.6	21.7	11.6	107.1	13.8	28.1	11.7	58.9	35.1	101.9	11.4	55.8	15.1	85.0	74.4	33.1	133.6	36.4	12.3
Species																													
Eggerella advena	8.4	1.3	8.6	96.5	36.5	86.0	25.6	80.5	38.5	—	80.0	88.5	79.1	97.3	74.8	11.4	9.3	51.0	9.3	62.6	7.4	23.8	57.4	55.5	50.5	48.7	90.9	77.0	55.7
Buccella frigida	19.2	20.1	11.1	—	—	0.4	8.7	8.6	7.7	13.2	—	—	8.6	2.2	—	17.8	19.3	1.5	23.5	10.1	39.1	18.9	13.4	10.1	10.6	0.1	2.0	15.7	17.1
Elphidium clavatum	8.6	36.3	12.4	2.1	32.8	8.4	23.2	7.8	38.5	43.0	20.0	11.1	4.6	0.3	2.8	25.5	16.1	24.9	22.9	22.0	42.6	24.0	17.6	24.2	12.3	34.9	3.0	—	17.2
Elphidium bartletti	7.6	11.0	12.4	—	14.3	1.2	19.7	1.8	—	12.4	—	—	—	0.1	—	9.2	8.0	2.3	9.0	0.8	7.4	5.1	—	0.5	8.1	8.2	—	5.6	—
Elphidium orbiculare	—	2.9	12.4	1.4	2.1	0.2	12.6	0.4	—	6.4	—	—	—	—	—	2.1	0.3	4.6	5.3	0.4	—	0.3	—	1.0	5.0	1.0	—	0.7	—
Reophax arctica	3.4	—	—	—	—	—	—	—	7.7	—	—	—	—	—	—	0.4	—	—	—	—	—	—	9.2	0.5	—	7.0	4.1	—	—
Rosalina wrightii	15.4	3.5	16.1	—	—	—	—	—	—	22.2	—	—	—	—	—	7.4	19.5	3.2	12.1	0.1	—	—	—	—	—	—	—	0.3	—
Asterellina pulchella	—	—	—	—	—	—	4.3	—	—	—	—	—	—	—	—	—	3.3	—	3.5	—	—	27.9	—	6.8	12.5	—	—	—	—
Textularia torquata	—	—	—	—	—	3.4	—	—	—	—	—	—	—	—	14.8	0.4	—	—	—	—	—	—	—	—	—	—	—	—	10.0
Cassidulina islandica	2.3	2.7	—	—	—	—	—	—	—	—	—	0.2	—	—	—	5.3	4.7	—	0.1	3.7	—	0.1	—	—	—	—	—	—	—
Nonionella auricula	—	—	—	—	12.2	0.4	—	0.9	—	—	—	—	—	—	—	0.5	1.4	—	—	—	—	—	—	—	—	—	—	—	—
Trochammina squamata	—	—	1.2	—	—	—	4.3	—	—	—	—	—	—	—	—	2.9	—	—	6.2	0.2	—	—	—	—	0.3	—	—	—	—
Trochammina lobata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.7	—
Pyrulina gutta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pseudopolymorphina novangliae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.3	—	—	—	—
Elphidium subarcticum	22.0	6.0	9.9	—	—	—	—	—	—	—	—	—	—	—	—	3.6	12.4	2.2	4.2	—	—	—	—	—	—	0.1	—	—	—
Elphidiella arctica	0.6	2.0	—	—	—	—	—	—	—	—	—	—	—	—	—	6.1	0.5	1.9	—	—	—	—	—	—	—	—	—	—	—
Elphidium frigidum	1.1	2.8	—	—	—	—	1.1	—	—	—	—	—	—	—	—	3.0	3.8	0.4	2.7	—	—	—	0.2	—	0.5	—	—	—	—
Cibicides lobatulus	3.4	5.8	—	—	—	—	—	—	—	—	—	—	—	—	—	0.5	1.5	0.4	0.7	—	—	—	—	—	—	—	—	—	—
Elphidiella groenlandica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ammotium cassis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—
Spiroplectammina biformis	—	—	—	—	—	—	—	—	7.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Quinqueloculina agglutinata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	0.1	—	0.1	—
Quinqueloculina spp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—
Lagena spp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	0.5	—	—	—	—	—
Oolina costata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—
Reophax fusiformis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Buliminella elegantissima	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.5	—	—	—	—	—
Elphidium spp.	3.5	5.2	8.6	—	—	—	—	—	—	1.9	—	—	—	—	—	—	—	—	—	—	2.9	—	2.1	—	—	—	—	—	—
Trochammina rotaliformis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	7.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Proteonia atlantica	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fissurina marginata	0.6	0.6	—	—	—	—	—	—	—	—	—	—	—	—	—	0.7	—	—	0.2	—	—	—	—	—	—	—	—	—	—
Others	4.0	—	3.7	—	2.1	—	0.5	—	—	0.9	—	0.2	7.7	0.2	0.3	3.1	—	7.5	0.7	0.1	—	—	—	0.5	0.1	—	—	—	—

TABLE 3 — Continued

Occurrences of Foraminifera in percent of total population

Cruise No.	268	236	268	236	268	268	268	268	268	268	268	268	268	236	268	268	268	268	268	268	268	268	268	268	268	268	236	268	268
Station No.	45	47	47	48	48	49	50	51	52	53	54	55	56	57	57	58	59	61	62	63	64	65	66	67	68	69	71	71	72
Depth (in feet)	55	65	65	60	95	172	180	148	100	110	114	55	55	57	54	85	85	70	70	83	105	125	145	135	160	157	130	150	160
Total Population	1913	1144	2086	379	17258	9383	4101	727	3900	1100	1438	320	1661	4610	550	2710	570	4342	2570	3720	860	3386	756	1262	2317	1469	1232	1362	719
Foraminifera/Gram	41.1	29.7	61.1	9.5	368.2	232.6	95.3	20.3	133.5	27.5	52.5	8.9	35.7	129.6	14.8	72.8	22.3	105.5	65.7	73.4	38.8	147.1	42.9	47.8	61.9	35.0	43.5	76.2	29.8
Species																													
Eggerella advena	83.8	98.2	60.1	74.8	51.2	13.0	27.8	59.5	72.1	86.4	71.7	45.2	96.2	80.2	77.7	92.0	82.3	68.4	61.7	78.2	55.8	78.7	49.0	82.0	31.3	76.9	59.9	59.8	55.9
Buccella frigida	2.1	1.8	5.3	—	10.6	34.7	14.8	10.3	3.7	8.4	7.7	35.6	—	5.1	—	5.6	6.1	8.2	9.3	5.6	13.2	7.7	5.0	0.3	10.0	10.5	7.9	5.5	14.1
Elphidium clavatum	0.1	0.1	31.0	12.5	13.5	12.6	28.0	11.0	0.5	2.6	4.0	—	0.1	8.5	13.6	—	8.5	11.7	2.7	14.7	21.8	3.4	6.8	7.7	2.7	3.8	30.8	5.1	14.7
Elphidium bartletti	0.2	—	1.9	0.3	2.2	5.0	3.3	14.3	3.7	2.6	3.7	1.6	0.7	—	—	2.1	—	0.1	—	—	4.9	—	1.5	—	—	0.1	1.4	0.1	—
Elphidium orbiculare	2.3	—	1.2	11.9	2.3	2.3	1.3	4.9	0.3	—	—	17.3	0.1	2.1	7.8	—	—	—	—	—	3.8	0.1	—	—	—	0.1	—	—	0.3
Reophax arctica	—	—	—	—	3.4	1.9	1.2	—	16.0	—	—	—	—	—	—	—	—	3.5	—	—	0.1	7.8	34.1	7.1	52.8	8.3	—	26.3	—
Rosalina wrightii	—	—	—	—	0.1	14.4	5.3	—	—	—	4.0	—	—	0.1	—	—	—	—	—	1.5	—	—	—	—	—	—	—	—	—
Asterellina pulchella	9.4	—	—	—	2.6	—	0.3	—	—	—	—	—	2.8	—	—	—	—	3.5	26.1	—	—	—	—	—	—	—	—	—	—
Textularia torquata	—	—	—	—	—	—	0.1	—	3.2	—	2.0	—	—	—	—	—	—	—	—	—	—	1.9	—	2.4	—	—	—	2.3	7.9
Cassidulina islandica	—	—	—	—	—	1.5	2.4	—	—	—	4.0	—	—	—	—	—	—	3.5	—	—	—	—	—	—	—	0.1	—	0.1	4.0
Nonionella auricula	—	—	—	—	1.7	0.1	—	—	—	—	0.8	—	—	—	—	0.1	—	—	—	—	—	—	0.1	—	—	—	—	0.3	3.1
Trochammina squamata	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	3.1	—	—	—	—	—	—	—	—	—	—	—	—
Trochammina lobata	2.1	—	—	—	—	—	—	—	—	—	—	—	0.1	—	0.4	0.1	—	—	0.1	—	—	—	—	—	—	—	—	—	—
Pyrulina gutta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pseudopolymorphina novangliae	0.1	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	0.2	—
Elphidium subarcticum	—	—	—	—	0.9	6.1	8.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Elphidiella arctica	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Elphidium frigidum	—	—	—	—	1.0	2.8	2.3	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—
Cibicides lobatulus	—	—	—	—	0.1	1.6	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Elphidiella groenlandica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ammotium cassis	—	—	—	—	4.3	—	0.3	—	0.2	—	—	—	—	—	0.2	0.1	—	0.1	—	0.1	—	—	—	—	—	—	—	—	—
Spiroplectammina biformis	—	—	—	—	—	—	—	—	0.2	—	—	—	—	—	—	—	—	—	—	—	—	0.2	2.9	—	2.0	—	—	0.4	—
Quinqueloculina agglutinata	—	—	—	—	—	—	—	—	—	—	—	—	0.1	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Quinqueloculina spp.	—	—	—	0.3	—	0.4	—	—	—	—	—	0.3	0.1	4.0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lagena spp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—
Oolina costata	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Reophax fusiformis	—	—	—	0.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—
Buliminella elegantissima	—	—	0.6	—	0.9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Elphidium spp.	—	—	—	—	—	1.1	—	—	—	—	2.0	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	0.1	—	—	—
Trochammina rotaliformis	—	—	—	—	3.4	—	1.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Proteonia atlantica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Fissurina marginata	—	—	—	—	0.1	—	0.8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Others	0.1	—	—	—	1.8	2.6	1.0	—	—	—	—	—	0.1	0.1	0.4	—	—	1.3	—	—	0.2	0.3	0.3	0.6	1.0	0.1	—	—	—

TABLE 3 — Continued
Occurrences of Foraminifera in percent of total population

Cruise No.	268	268	268	268	268	268	236	268	268	268	268	268	236	268	268	268	236	236	236	236	268	268	268	268	268	268	268	236	268
Station No.	73	74	75	76	77	78	79	79	80	81	82	84	85	86	87	88	93	99	110	113	126	127	128	129	130	131	132	134	135
Depth (in feet)	157	105	60	55	100	140	147	160	170	175	182	—	55	170	155	140	76	101	119	41	135	133	140	37	42	44	28	111	32
Total Population	1673	3020	1757	235	424	4677	961	1670	813	0	1348	731	988	457	403	3041	1432	458	243	407	1030	20	132	1106	2289	1057	433	10280	3577
Foraminifera/Gram	39.5	46.0	22.4	1.6	10.8	108.0	38.7	43.6	30.9	0	67.0	39.4	11.6	17.2	22.7	132.8	29.8	21.2	8.9	7.2	34.2	0.3	1.9	19.6	68.3	33.2	6.0	215.4	73.8
Species																													
Eggerella advena	35.8	33.4	18.2	5.8	20.2	25.7	91.7	54.0	66.7	—	47.6	33.1	4.1	67.4	65.4	74.3	61.1	87.1	91.5	29.3	29.1	—	8.1	52.4	77.7	54.1	5.0	10.7	93.7
Buccella frigida	32.5	21.3	20.3	11.6	18.7	22.9	0.3	13.4	11.0	—	2.6	3.8	20.6	8.4	0.7	2.3	6.6	0.5	—	8.9	23.9	23.7	27.8	4.3	1.3	4.7	—	34.6	—
Elphidium clavatum	16.7	18.5	12.2	11.5	15.1	22.5	5.7	12.9	13.8	—	8.4	5.7	23.8	8.6	32.8	1.9	3.3	6.2	—	19.0	17.2	—	41.2	17.3	4.6	1.7	64.1	24.3	—
Elphidium bartletti	6.1	0.1	—	7.2	12.3	2.9	—	1.8	0.9	—	—	3.2	13.1	—	0.5	0.3	0.1	—	—	16.7	10.2	23.7	15.2	—	1.0	1.9	13.1	5.5	0.2
Elphidium orbiculare	0.5	—	0.5	19.2	10.6	1.6	—	—	0.1	—	—	2.0	10.4	1.8	0.3	0.1	—	—	—	9.9	2.1	—	3.6	—	0.4	1.9	7.8	5.1	—
Reophax arctica	—	—	12.2	—	—	1.4	1.1	9.3	7.5	—	23.6	33.1	—	—	—	4.4	—	—	—	0.6	—	—	—	—	2.9	4.7	—	—	3.0
Rosalina wrightii	—	1.1	0.2	10.5	2.0	2.1	—	—	—	—	—	—	4.8	—	—	—	—	—	—	8.3	—	—	—	—	—	—	—	0.6	—
Asterellina pulchella	—	8.1	18.2	—	8.8	4.3	—	1.3	—	—	—	—	4.1	—	—	0.9	25.6	—	—	2.4	17.5	—	—	17.3	—	—	7.5	3.8	—
Textularia torquata	—	—	6.1	4.9	—	—	1.1	1.3	—	—	12.2	7.3	—	2.9	—	1.8	—	—	—	1.2	—	—	—	4.3	5.8	28.1	—	—	3.0
Cassidulina islandica	7.8	7.4	12.2	—	7.5	8.1	—	1.3	—	—	—	—	—	—	—	3.6	—	—	—	—	—	—	—	—	0.4	—	—	10.6	—
Nonionella auricula	0.7	—	—	—	—	0.3	—	—	—	—	—	0.1	—	1.3	0.3	0.1	—	—	—	—	—	—	—	—	—	—	—	0.3	—
Trochammina squamata	—	—	—	17.4	2.5	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	35.6	—	—	—	—	—	—	—
Trochammina lobata	—	—	—	—	—	0.5	—	—	—	—	—	—	—	—	—	—	3.3	—	—	1.2	—	17.0	—	—	—	—	—	—	—
Pyrulina gutta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pseudopolymorphina novangliae	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	0.1	—	—	—	—	—	—	—	—	0.2	—	—	0.8	—
Elphidium subarcticum	—	—	—	0.4	1.3	5.2	—	—	—	—	—	—	0.8	—	—	—	—	—	—	—	—	—	4.1	—	—	—	—	0.1	—
Elphidiella arctica	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Elphidium frigidum	—	—	—	—	1.0	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cibicides lobatulus	—	4.7	—	0.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.4	—
Elphidiella groenlandica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.2	0.1	—	—	0.1
Ammotium cassis	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	2.0	—	—	—	1.2	—	—	—	4.3	5.5	2.8	—	—	—
Spiroplectammina biformis	—	—	—	—	—	—	—	4.7	—	—	4.7	11.2	—	7.8	—	8.1	—	—	—	—	—	—	—	—	—	—	—	—	—
Quinqueloculina agglutinata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	0.1	—	—	—	—
Quinqueloculina spp.	—	—	—	0.4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—
Lagena spp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—
Oolina costata	—	—	—	—	—	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.6	—
Reophax fusiformis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Buliminella elegantissima	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Elphidium spp.	—	—	—	—	—	1.0	—	—	—	—	—	—	17.0	—	—	0.2	—	—	—	—	—	—	—	—	—	—	—	1.7	—
Trochammina rotaliformis	—	—	—	2.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Proteonia atlantica	—	—	—	—	—	—	—	—	—	—	0.6	0.1	—	—	—	—	—	—	—	—	—	—	—	—	0.1	0.2	—	—	—
Fissurina marginata	—	—	—	—	—	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Others	—	5.4	—	8.2	—	0.5	—	—	—	—	0.4	0.1	1.3	1.8	—	—	0.1	6.2	8.5	1.2	—	—	—	—	—	—	2.5	—	—

TABLE 3 — Continued
Occurrences of Foraminifera in percent of total population

Cruise No.	268	236	268	268	268	268	268	268	268	268	268	268	268	268	268	236	236	236	236	268	268	268	268	268	268	236	268	268	236
Station No.	137	138	138	140	141	143	144	145	147	148	149	151	152	153	154	155	158	161	162	162	165	166	167	168	169	170	171	172	178
Depth (in feet)	44	128	44	34	20	21	32	45	72	80	—	66	52	42	54	53	40	42	47	30	45	78	102	91	45	178	157	175	45
Total Population	14160	196	684	4260	1403	444	3902	1485	839	5931	10491	3600	2147	1422	1844	1409	523	159	0	1657	5825	3427	1862	1467	731	608	261	1364	359
Foraminifera/Gram	304.8	2.9	16.1	81.6	28.4	7.7	79.1	35.7	18.1	159.2	277.2	72.6	43.9	42.1	102.9	41.4	19.8	6.7	0	31.2	170.5	80.7	57.1	36.2	18.6	11.9	6.7	27.6	15.5
Species																													
Eggerella advena	95.6	6.7	56.2	87.4	96.3	64.1	67.3	47.5	89.4	88.2	88.3	73.7	71.8	21.5	88.3	99.7	70.7	98.7	—	62.8	66.2	71.3	75.9	62.5	36.7	—	46.8	50.8	—
Buccella frigida	0.9	20.8	1.3	—	—	—	3.2	3.4	6.0	2.0	—	10.8	7.9	6.2	1.6	—	0.8	1.3	—	3.5	13.2	4.6	3.9	9.2	16.9	16.8	10.0	6.0	32.7
Elphidium clavatum	—	18.5	24.0	2.3	3.7	—	4.7	18.9	2.1	2.0	2.2	2.8	—	49.6	0.3	0.3	14.0	—	—	3.9	5.4	6.1	11.7	13.0	20.8	26.0	26.5	10.5	8.5
Elphidium bartletti	0.1	6.2	—	—	—	8.5	0.1	2.6	2.5	1.3	0.2	0.3	—	3.9	0.3	—	—	—	—	3.6	0.3	1.5	0.6	—	4.0	12.7	3.2	—	17.9
Elphidium orbiculare	0.8	2.6	4.6	—	—	—	0.9	2.2	—	0.1	—	3.1	0.1	2.3	0.1	—	1.3	—	—	11.5	0.1	—	1.0	0.3	9.5	14.0	—	—	22.2
Reophax arctica	—	—	—	2.4	—	—	1.7	5.3	—	0.9	2.0	3.1	—	—	—	—	—	—	—	—	4.6	—	—	—	2.3	—	—	—	—
Rosalina wrightii	—	2.0	—	—	—	—	0.5	0.4	—	—	—	—	—	—	9.0	—	0.2	—	—	—	—	—	—	3.7	—	7.9	—	—	17.9
Asterellina pulchella	0.8	5.6	—	—	—	—	7.7	1.2	—	4.6	5.0	—	16.9	11.3	0.2	—	8.3	—	—	11.1	6.8	4.6	—	9.3	6.6	—	3.3	2.0	—
Textularia torquata	1.6	—	—	7.0	—	—	12.0	14.8	—	0.9	2.0	3.1	—	—	—	—	—	—	—	—	0.1	—	6.8	—	—	—	—	2.0	—
Cassidulina islandica	—	0.5	6.7	—	—	—	—	2.3	—	—	—	3.1	—	—	—	—	0.4	—	—	—	—	3.0	—	1.9	3.3	2.3	10.0	12.4	—
Nonionella auricula	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.4	—	—	—	—	—	2.0	—
Trochammina squamata	—	36.7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Trochammina lobata	—	—	—	0.9	—	26.4	—	—	—	—	—	—	3.4	—	0.2	—	—	—	—	3.6	2.7	—	—	—	—	—	—	—	—
Pyrulina gutta	—	—	3.4	—	—	0.5	0.2	0.6	—	—	—	—	0.1	2.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Pseudopolymorphina novangliae	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	0.1	—	—	—	—	—	—	—
Elphidium subarcticum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Elphidiella arctica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	13.8	—	—	—
Elphidium frigidum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.5	—	—	—
Cibicides lobatulus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1.5	—	—	—
Elphidiella groenlandica	—	—	1.3	—	—	0.5	0.1	—	0.1	—	—	—	—	—	—	—	0.2	—	—	—	0.1	—	—	—	—	0.2	—	—	—
Ammotium cassis	0.1	—	1.3	—	—	—	0.7	0.8	—	—	0.2	—	—	2.6	—	—	—	—	—	—	0.5	4.4	—	—	—	—	—	2.0	—
Spiroplectammina biformis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Quinqueloculina agglutinata	—	—	—	—	—	—	—	0.1	—	0.1	—	0.1	—	—	—	—	—	—	—	—	0.1	—	—	—	—	—	—	—	—
Quinqueloculina spp.	—	—	—	—	—	—	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lagena spp.	—	—	1.3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oolina costata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Reophax fusiformis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3.0	—	—	—	—	—	1.0	—
Buliminella elegantissima	—	0.5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Elphidium spp.	—	—	—	—	—	—	—	—	—	—	—	—	—	0.1	—	—	4.2	—	—	—	—	—	—	—	—	—	—	—	0.6
Trochammina rotaliformis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.0	—
Protecnia atlantica	0.1	—	—	—	—	—	0.1	—	—	—	0.1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2.2	—
Fissurina marginata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Others	0.1	—	—	—	—	—	0.2	0.1	—	—	—	—	—	0.1	—	—	—	—	—	—	0.1	0.1	—	—	—	2.3	—	7.2	0.3

mean sediment sizes were finer than 3.3 ø. Loeblich and Tappan noted that this species may be a fossil from Pleistocene sediments but in this region every station where a worn specimen was found there were several fresh specimens.

Elphidiella sp.

This form appeared at stations 236-3, 170, 268-33, 34 and 49. The porcellaneous texture, heavy test and flat sides with the final chamber covering the umbilical region distinguished this species from *E. arctica*. In many cases the sutural pores were indistinct. The specimen illustrated in Plate 6, figure 9 shows the striations at the base of the last chamber which occurred in some forms.

Buccella frigida (CUSHMAN) = *Pulvinulina frigida* CUSHMAN, 1922, Contr. Can. Biol. no. 9 (1921), p. 12, (144).

This widespread species was found in the greatest percentages in Bering Strait, on Prince of Wales Shoal and along the northeast coast (text fig. 14). However, two stations, 236-39 and 268-39, in the central area had unusually high frequencies, over 35 percent. Many stations in Kotzebue Sound did not contain *B. frigida* and three stations on the Seward Peninsula also were barren. The large seasonal fluctuations may affect this species but it has been reported from shallow, low salinity stations in other regions.

Buccella inusitata ANDERSON, 1952, Journ. Washington Acad. Sci., vol. 42, no. 5, p. 148, figs. 10a-11c.

This species occurred in Bering Strait, on Prince of Wales Shoal and along the northeast coast where the sediment is coarse and the populations are predominantly calcareous.

Rosalina wrightii (Brady) = *Discorbina wrightii* Brady, 1881, Ann. Mag. Nat. Hist., London, Ser. 5, vol. 8, no. 48, p. 413.

This species comprised as high as 22 percent in Bering Strait and along the northeast coast but did not occur in the central area (text fig. 15). It was found associated with a variety of sediment types, depths, salinities and temperatures. The factors affecting the distributions of this species are not known. Plate 6, fig. 15 shows a younger specimen with very little ornamentation and fig. 14 shows a mature specimen with the umbilical region almost filled.

Asterellina pulchella (PARKER) = *Pninaella* (?) *pulchella* PARKER, 1952, Harvard Coll., Mus. Comp. Zool. Bull., vol. 106 (1951-1952), no. 9, p. 420, pl. 6, figs. 18-20.

This species under several different generic names, has been recorded from the Gulf of Maine, Long Island Sound, Bering Sea and from late Pleistocene sediments on Sado Island on the west coast of Japan. It occurred in this area at thirty-two stations, on the Prince of Wales Shoal, along the northeast coast and in Kotzebue Sound (text fig. 16). It was found at a wide range of depths, sediment sizes, temperatures and salinities.

Cassidulina islandica NØRVANG, 1945, Foraminifera, Zoology of Iceland, vol. 2, pt. 2, p. 41, text figs. 7, 8d-f.

This species was found over the entire area but had its highest percentages near Bering Strait, Point Hope and Kivalina (text fig. 17). Associated with a range of conditions, it did not comprise over 12.5 percent of the populations but was found at thirty-two stations.

Cibicides lobatulus (WALKER and JACOB) = *Nautilus lobatulus* WALKER and JACOB, 1798, Adams Essays, Kannmacher's ed. (ed. II), p. 642, pl. 14, fig. 36.

This species occurred at fourteen stations, associated mainly with coarse sediment on stations deeper than 80 feet. The salinities varied from 31.1 to 33.0 o/oo and the temperatures from 2.5 to 8.1°C. *Cibicides lobatulus* had variations in size (Plate 6, figs. 19, 20) but they occurred at the same stations and it was assumed they were the same species.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XV, PART 3, JULY, 1964

284. STATISTICAL INVESTIGATIONS ON THE VARIABILITY OF *BOLIVINA ARGENTEA* CUSHMAN[1]

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ABSTRACT

Variation studies of **Bolivina argentea** living off the coast of Southern California reveal relationships between test morphology and environment. Low oxygen contents in the bottom waters of enclosed basins are particularly significant in influencing the construction of the tests.

Width-length-ratios, length of costae, and length of the basal spine were noted to increase progressively from the basin-biotope to the slope-biotope. The resulting extreme populations are connected by a complete lineage of transitional populations. Different biological interpretations of these morphological changes are discussed, and it is suggested, that the changes are merely phenotypic variation.

A taxonomic implication of the study rests in the fact that previous investigations of limited environments have resulted in the assignment of variations of **B. argentea** to separate species. Subsequently it is concluded that in the definition of any species, variation scales and material from several localities should be investigated in order to detect possible transitional populations.

INTRODUCTION

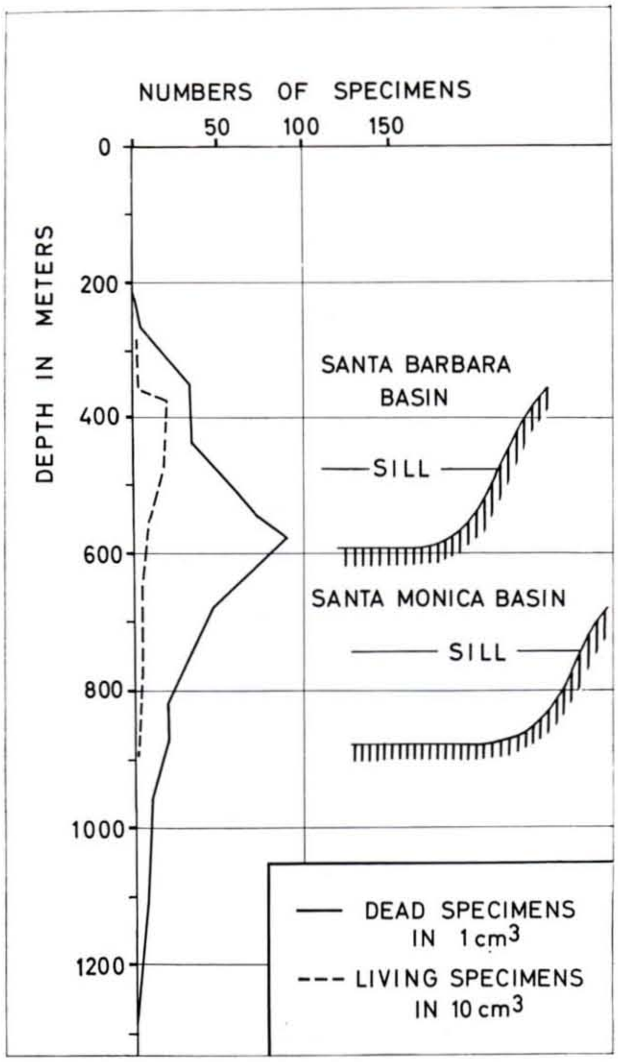
Micropaleontologists of large oil companies have returned to the practice of using numerical nomenclature for foraminifera because the number of species names has increased to the point of becoming unwieldy. In recent times, many writers have referred to the consequences of continued splitting, for instance F. L. Parker (1962, p. 219): "The artificial splitting of species produces complications which are endless, as each worker emphasizes different criteria." Years ago, the taxonomy of many genera obviously reached a stage in which the erection of new species names should have been considered as unnecessary and useless in general (e.g., *Lenticulina, Astacolus, Reophax*). The perpetual output of publications introducing large numbers of new species names in spite of this, therefore, indicates the use of an unnatural species concept in most of these papers (e.g., Said and Barakat 1958, Vella 1961, Lalicker 1950).

Under these circumstances, it seems to be necessary to investigate the variability of species more systematically, employing Recent forms. Investigations of this kind were made with several Southern California *Bolivina,* which change their morphology in different environments. The ecological aspects and the possibilities of paleoecological application were discussed in a previous paper (Lutze 1962). Factors connected with the species concept will be illustrated in the present paper with *Bolivina argentea* Cushman.

The study was carried out with use of the facilities and the samples of the Allan Hancock Foundation, University of Southern California, and was supported by a grant of the National Research Council of Germany (D.F.G). The writer is indebted to Prof. Orville L. Bandy for helpful advice and discussions of various problems. Thanks are due to Miss Johanna M. Resig for critical reading of the manuscript.

ENVIRONMENT

Bolivina argentea is living off the southern California coast at a depth at which the slope is interrupted by basins (text figure 1). The resulting



TEXT FIGURE 1

Computed depth-range of *Bolivina argentea* off Southern California.—The peaks of the curves correspond with the range of the two basins, which are sketched in cross section.

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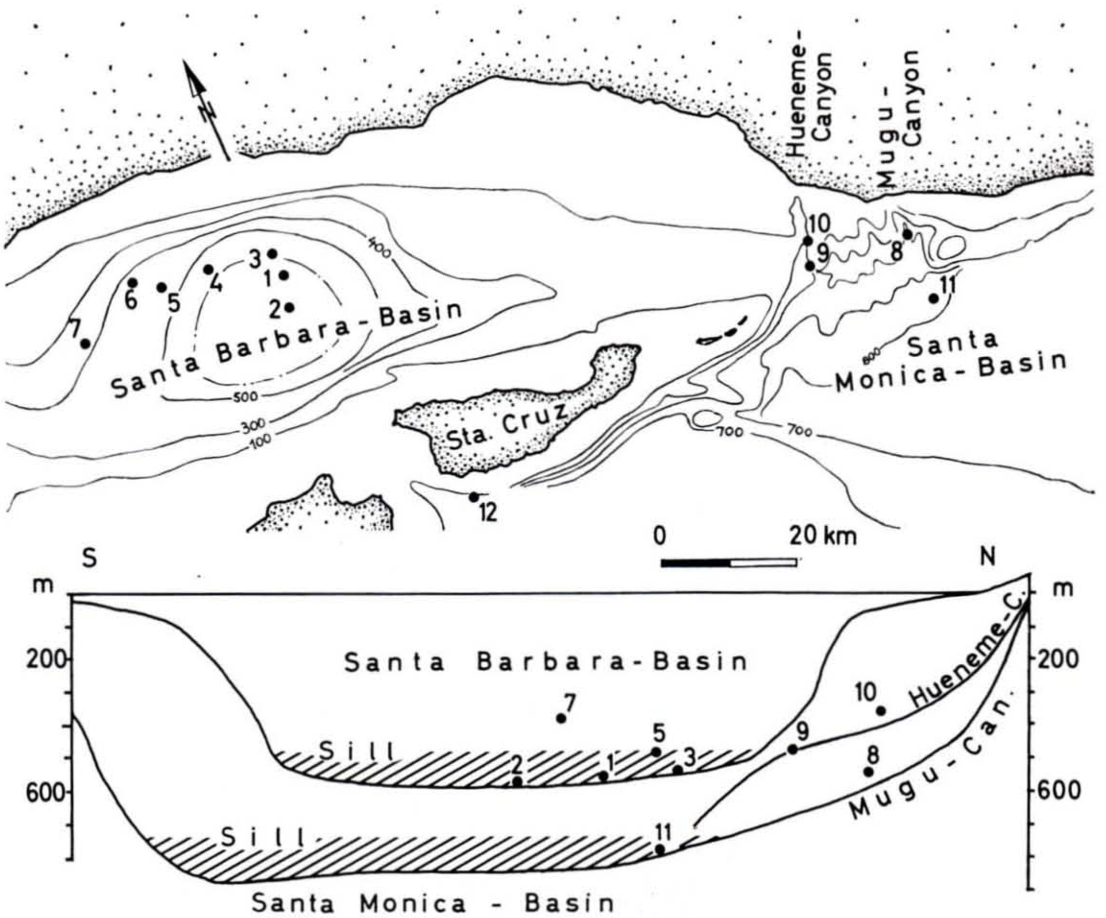
[1] Contribution of the Allan Hancock Foundation.

topography provides two different biotopes which are both populated by the species. Samples investigated in this paper were taken in an area where sedimentary and oceanographic properties are known from the work of Emery and Hülsemann (1962). The interstitial waters of the surface sediment contain hydrogen sulfide in the deep central area of the Santa Barbara Basin, according to these authors, and the concentration of dissolved oxygen in the basin water near the bottom is so low that only a minor amount of benthic life can exist. At sill depth the average oxygen content is between 0.1 and 0.3 ml/L, whereas at the basin floor (15 m above the bottom) less than half of this average concentration is normal (minimum values of 0.05 ml/L). Although no hydrogen sulfide could be detected in the bottom water itself, these conditions should be regarded as extreme from the biological point of view. This environment will be termed basin-biotope.

The low oxygen conditions of the basin are partly due to the fact that the sill, over which waters pass to fill the deeper parts of the basin, lies within the range of the oxygen minimum of the open sea (Emery 1960, p. 106-113). Water entering the basin is therefore primarily low in oxygen content. The decomposition of a large amount of organic matter sinking down from the euphotic zone reduces the oxygen even more. Basin water would become depleted of oxygen were it not for internal waves which provide a means of oxygen replenishment through mixing with overlying water (Emery and Hülsemann, 1962). This mixing creates conditions more favorable for life in the region of sill-level and, therefore, a gradual increase of benthic life can be observed in this area (ibid., fig. 3d). It can be surmised that this gradual change is indicative of a corresponding transition from the basin-biotope to a biotope normal to an uncomplicated slope. Thus, no sharp boundaries between the different biotopes exist. The conditions of this area of transition may be regarded as a transition-biotope.

A third series of samples was taken in canyons cut into the upper basin slope of the adjacent Santa Monica Basin, in an environment termed slope-biotope in this paper. In this area, oxygen concentration is 5 to 10 times as high as in the sub-sill Santa Barbara Basin, whereas depth, temperature and salinity correspond (compare locations of samples nr. 8, 9, 10 on cross section on text figure 2). Depth, temperature and salinity are, therefore, effectively eliminated as factors which might influence possible morphologic changes of the test.



TEXT FIGURE 2

Sample locations and cross sections of the basins.—Note that the canyon samples 8 and 9 are from depths comparable to the basin samples of Santa Barbara Basin.

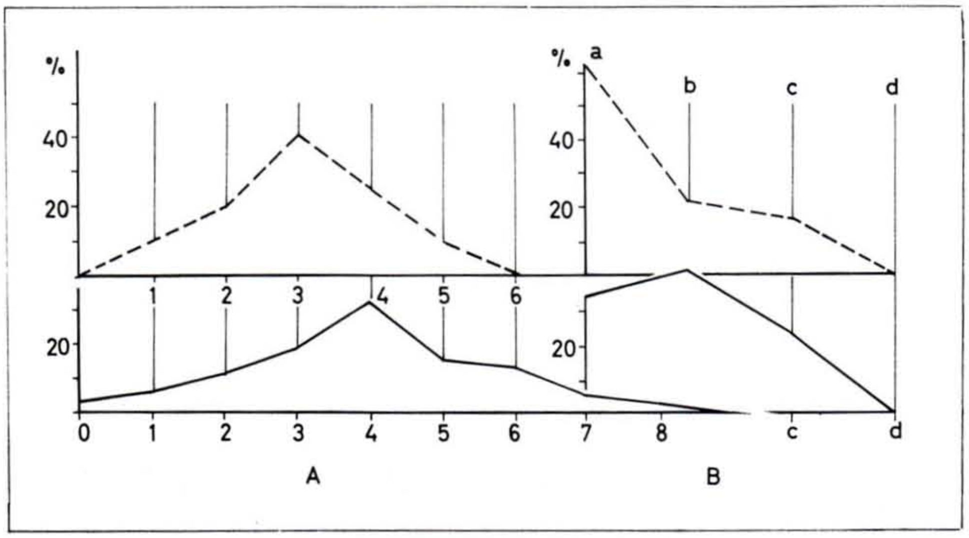
In addition, physical and chemical conditions are variable in contrast to the basin-biotope.

Another sample (nr. 11) was taken from below sill level of Santa Monica where water is nearly 300 meters deeper but oxygen conditions are similar to those of sub-sill Santa Barbara Basin.

IDENTIFICATION OF LIVING SPECIMENS

The basic necessity in all variation studies of recent as well as fossil foraminifera is to evaluate real populations wherever possible. This can be achieved with fossil forms only by using large surface samples of some millimeter thickness (Grabert, 1959, p. 23). In studies of Recent foraminifera, living specimens and thus true biological populations, can be separated from older tests by a staining method introduced by Walton (1952). Living populations of *Bolivina argentea* from the transition-biotope and the slope, were large enough for statistical analysis. In the sub-sill Santa Barbara Basin, large numbers of stained specimens were found only rarely. It was necessary, therefore, to use empty tests for statistical analysis. Living populations were approximated by selecting well preserved specimens which differed distinctly in appearance from the older silvery-grey tests. Using this method, it must be considered that contamination by relatively well preserved tests out of deeper sediment layers may occur. This possibility was heightened by the use of the Campbell-grab, which was necessary to get populations large enough for statistical purposes.

In a sample from the southern margin of the Santa Barbara Basin, stained specimens were relatively frequent. Although not available for the width-length-ratio because of broken younger chambers, they provided distinct curves for the intensity of sculpture and length of the spines (text figure 3). These differ from the curves of the unstained specimens, by having a tendency towards the basin type. Unstained tests which are less "basin-like" may be derived from homogeneous sediment layers deposited under more favorable oxygen conditions (Emery and Hülsemann, 1962). These layers underlie the presently formed undisturbed finely laminated layers. If contaminations are thus less basin-like, they would only obliterate the morphological difference between basin- and other populations. In addition, it may be surmised that they could not produce a progressive displacement of variation-scales as demonstrated in this paper, because mixing would not always occur in the same intensity. It might be justifiable, therefore, to consider the trends produced from unstained basin material as valid in this instance.



TEXT FIGURE 3

Variation-curves of the length of costae (A) and the basal spine (B) of a living and a dead "population" from the same sample (southern part of Santa Barbara Basin, 518 m).—Broken line: stained, i.e. living when sample was taken. a: no spine, b: hint of a spine, c: distinct spine, d: long spine.

VARIABILITY

In order to define variability of the test as completely as possible, several characteristics have been measured: width-length-ratio, number of pairs of chambers covered with ribs, and the length of the basal spine. Generally, 50 to 100 specimens were analyzed. Adult megalospheric tests were used exclusively to eliminate frequency changes of the different generations and to avoid errors resulting from the different width-length-ratio of immature forms. Therefore, a minimum of 150 specimens was necessary to get the required amount of material.

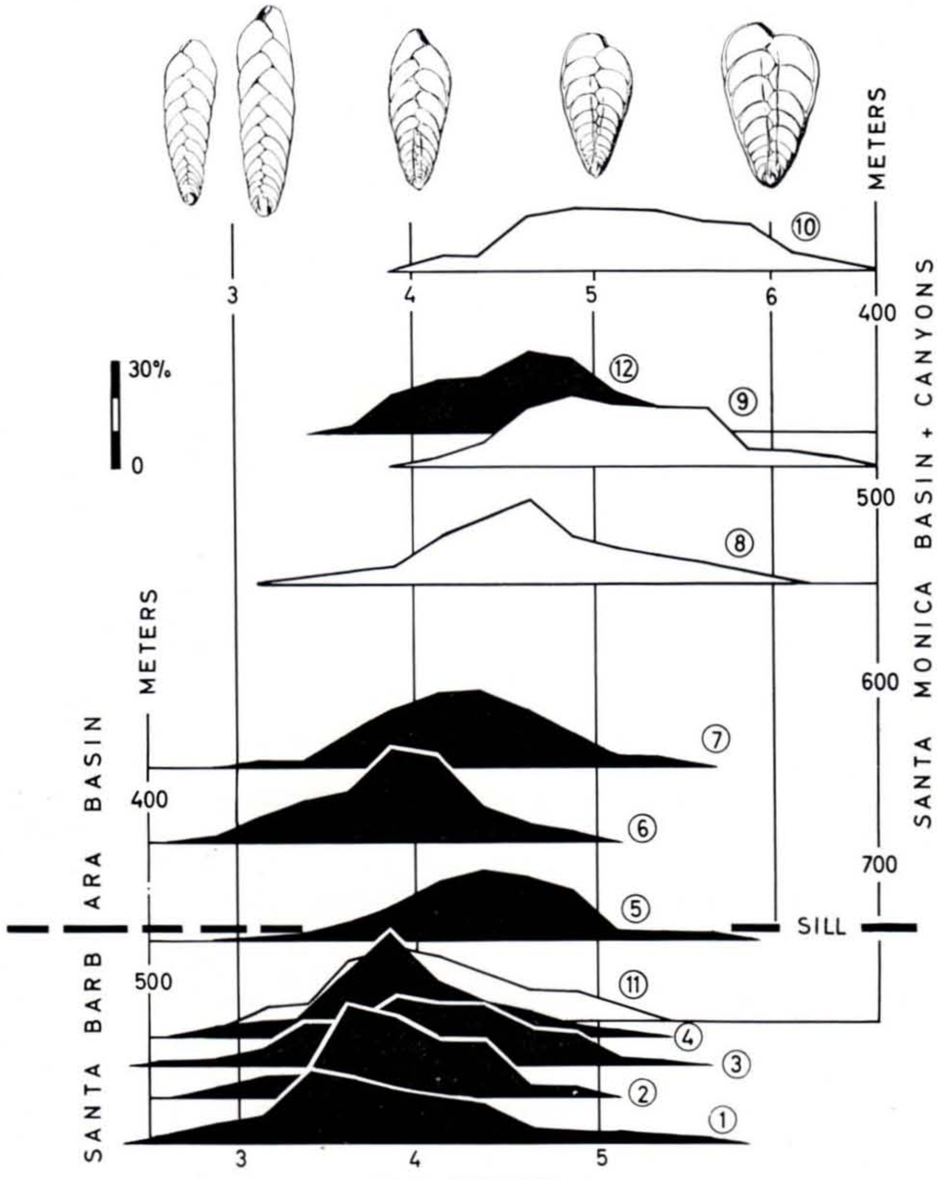
The values of the width-length-ratio have been combined in groups of values and then plotted in percentage of the total population (text figure 4). As for the other characteristics, the results were variation curves (frequency distribution curves) with distinct varying position of the peaks. In the basins, the values of the width-length-ratio usually are scattered between 3 and 5, with peaks between 3.4 and 3.8. In the area of sill level, where frequent mixing of waters supposedly creates the transition-biotope, peaks are around 4, whereas in the slope-biotope they reach the value 5. The relatively wide variation-scale of this characteristic is remarkable.

In the arrangement of the curves, the sill levels of both basins serve as a comparative datum-plane. Population nr. 11 (stained) from the Santa Monica Basin exhibits a position of the peak identical to the populations of the Santa Barbara Basin taken at the same distance below sill level, in spite of the fact that the water is nearly 300 meters deeper. On the other hand, the populations nr. 4 and 8 of similar water depth show distinct differences in the position of the peak. (The extraordinary position of the curve of population nr. 12 might be influenced by a different environment; the sample is from the Santa Cruz Canyon, which belongs to an outer basin.)

There is, in general, a distinct gradual displacement of variation-scales towards broader tests with increase in distance from the sub-sill basins. The extreme variants of the single populations are connected by a complete series of transitional forms.

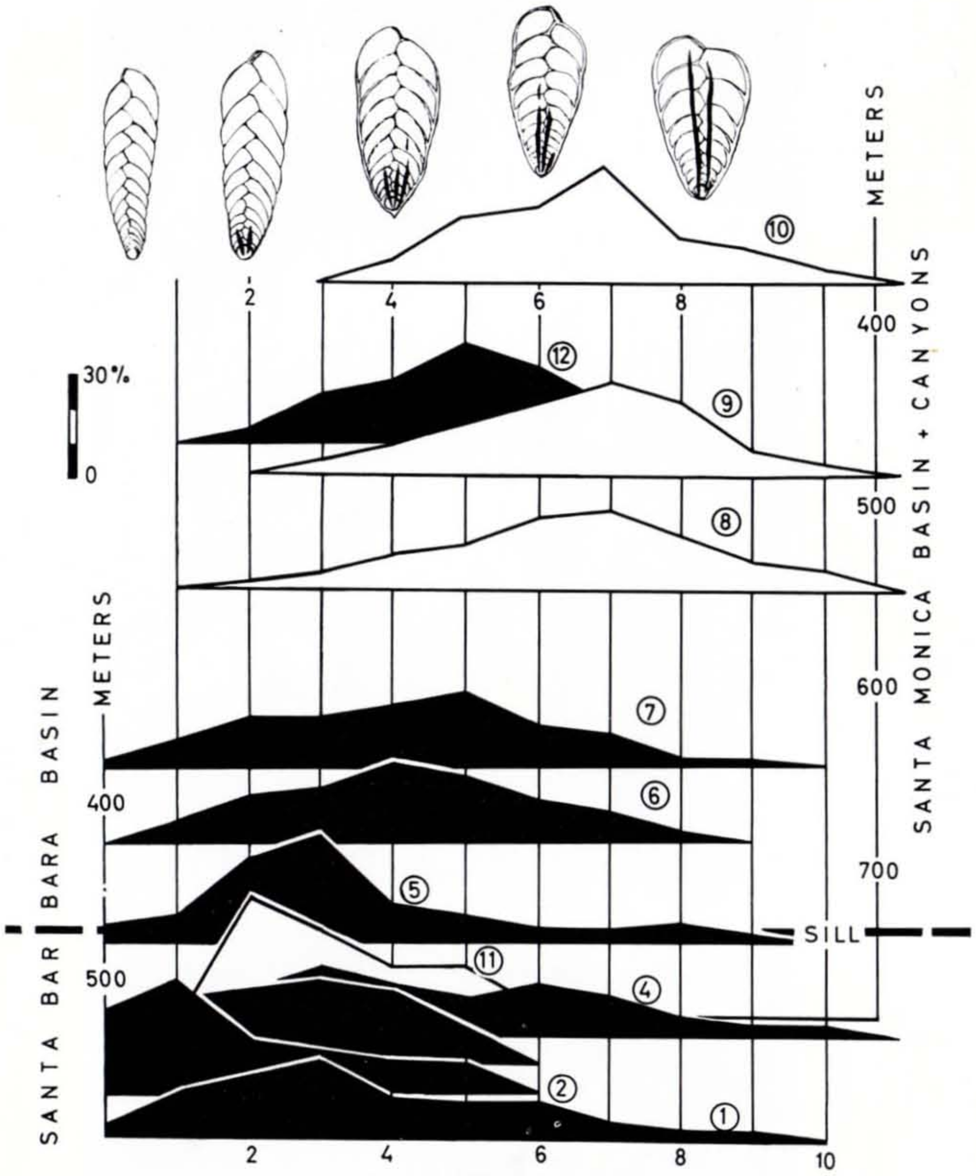
The costae, which start from the proloculus, show a similar change: tests without ribs or with very short ribs prevail in the basins. Generally only 2 or 3 pairs of chambers are covered with ribs. (text figure 5). As with the width-length-ratio, the populations of the transition-biotope (e.g., nr. 6 and 7) provide intermediate values. They are between 4 and 5, whereas the populations from the canyons (slope-biotope) usually have 6 to 8 costaed pairs of chambers. The length of costae might be considered a reflection of sculptural intensity, because along with the extension of costae, the width of the keel is enlarged.

Spineless specimens are dominant in both basins,



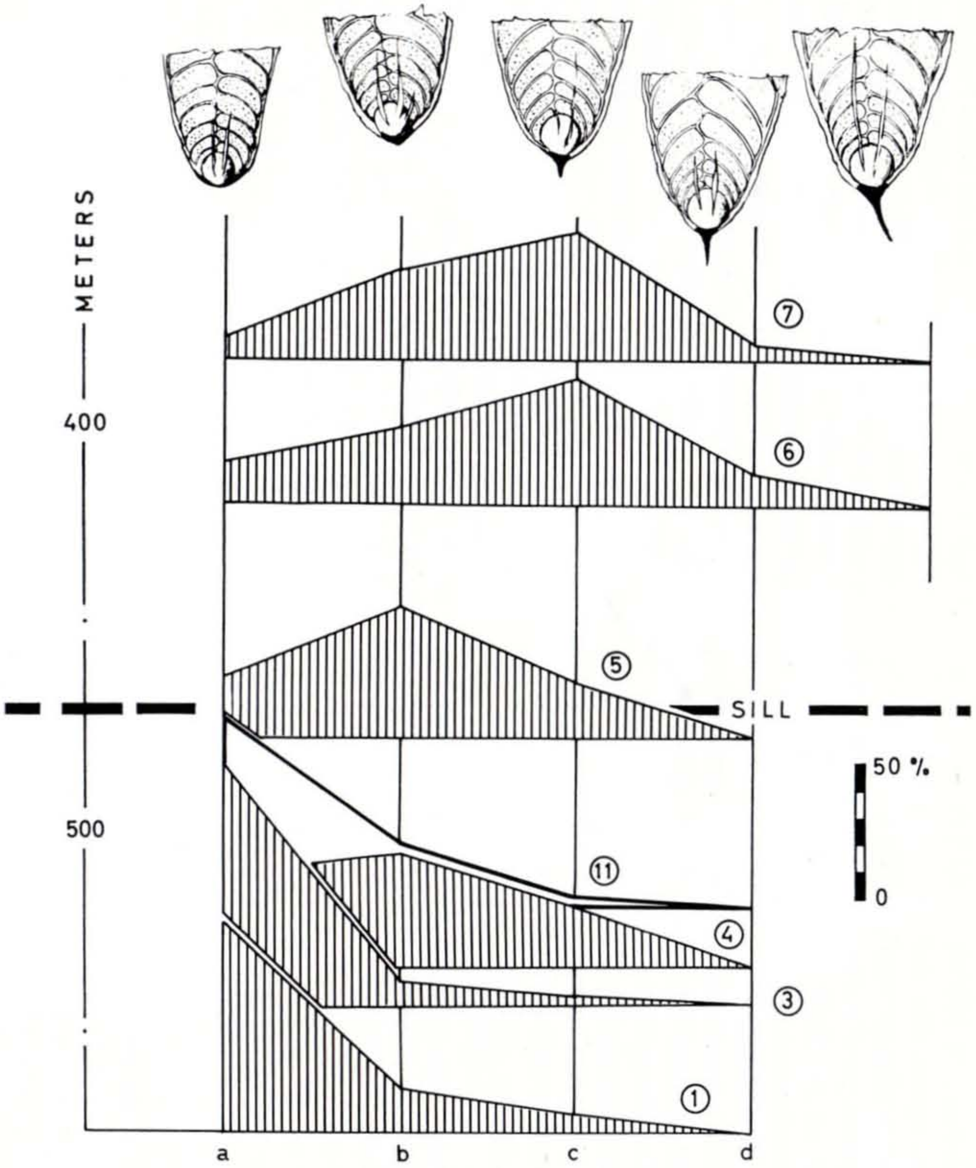
TEXT FIGURE 4

Variability of the width-length-ratios (width x lo/length). Not filled: Populations of the Santa Monica Basin and its Canyons.



TEXT FIGURE 5

Variability of the length of costae, according to the number of chambers covered.



TEXT FIGURE 6

Length variability of the basal spine.—a: no spine, b: hint of a spine, c: distinct spine, d: long spine.

as might be expected following the example of the costae (text figure 6). Along with these forms, only tests with a slight hint of a spine form a significant proportion of the population. At sill level (population nr. 5) slight spines prevail, whereas in the transition-biotope, tests with distinct spines are dominant. It was impossible to follow this characteristic into the slope-biotope, as there the extension of spines is masked by the widening of the keel which girdles the proloculus.

To summarize, slender and less sculptured basin forms are connected with heavily ribbed and keeled slope forms by transitional populations.

INTERPRETATION

The morphological changes from basin populations to slope populations as shown in Text Figures 4-6, correspond with an increase in oxygen concentration. According to the present knowledge, other properties do not provide similar trends (temperature!). As previously mentioned (Lutze, 1962, p. 256) there are two explanations for these changes:

1. Genotypic variation: *Basin forms and slope forms are genetically different.* In the extreme biotope of the low oxygen and hydrogen sulfide environment of the basins a local race (or subspecies?) is formed by selection and concentration of favorable mutants. Under continued isolation this new taxon would probably develop into a separate species. If living slope forms enter the basins (e.g., turbidity currents), they either could not exist at all, or they would have to compete with basin forms specialized to the basin environment.

2. Phenotypic variation: *All observed forms represent a genetic unit.* They belong to one species, which populates both main biotopes as well as the connecting transition-biotope. This species possesses the ability to adapt its physiological processes to meet varying environmental conditions (reaction-scale). Subsequently, with the changed physiological processes, the growth of the test is changed: less secretion of calcium carbonate by the basin forms = less costae, keels and spines; less size increase of the newly formed chambers by slower growth = a more slender shape of the test. In a reverse manner, the appearance of the slope forms is changed.

The potential total variability is fixed genetically. From this potential variability, there is realized from time to time, a certain scale of variants through adaptation to the surroundings. Thus, broad and sculptured slope forms transported into a basin would continue their growth as a basin form with a more slender, less sculptured test, and they would produce offspring of that kind. The opposite effect would take place if basin forms are artificially introduced into a slope environment.

It is conceivable, however, that this phenotypic flexibility might be lost in the course of evolution by specialization (defect-mutation), thus creating also a genetic separation of the morphological different forms.

Several considerations favor the second explanation (the morphological changes are modifications), for instance the evolving lineage of transitional populations and the fact that both basins are populated by identical morphological types. It seems un-

TEXT FIGURE 7

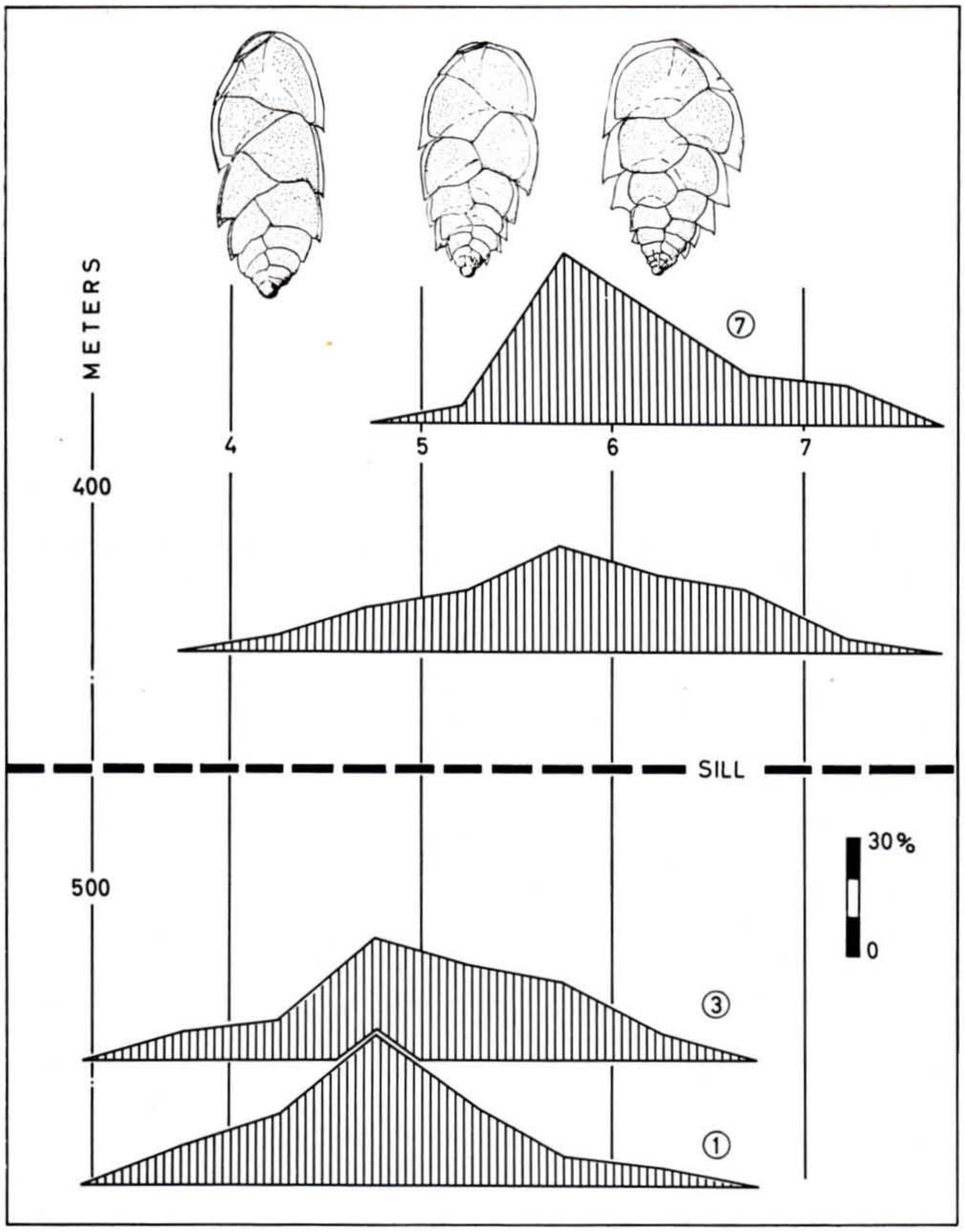
Specimens of *Bolivina argentea* with growth interruptions and subsequent changes in the mode of test construction. Santa Barbara Basin, sample AHF 7194.

likely that corresponding mutations with subsequent selection would occur simultaneously in both basins producing curves with this degree of conformity.

Another indication may be drawn from sample AHF 7194 from the central part of Santa Barbara Basin. This sample contains a considerable number of tests with distinct growth-interruptions (text figure 7). The initial parts of these tests (about one quarter of total length) are brownish, corroded and opaque; the later parts thin and transparent. The growth-interruptions are indicated by a sharp line separating the differently preserved parts of the tests and by some irregular chambers. Most specimens continued their growth after the interruption in a more slender, basin-like mode. Specimens with long costae always show an abrupt termination of the costae at the interruption. The absence of these growth peculiarities from nearly all other samples makes it probable that they belong to a single population and that they are caused by unusual environmental conditions of local and temporary range. It is difficult to explain these conditions, but regardless of the interpretations, it must be realized that the morphological potency of the individuals is greater than indicated by the single normal variation-scale.

Bolivina pseudobeyrichi Cushman, living in the Santa Barbara Basin, changes its test morphology in a way similar to *Bolivina argentea* (text figure 8; see Lutze, 1962, p. 257). Certainly, corresponding mutations can occur with related species of a genus and a similar direction of evolution can be taken, but here also phenotypic variation is more probable than a genetic difference.

It should be considered, moreover, that selection toward the goal of test stability in the sense of Rhumbler (1909) can hardly exist in the given example because the less sculptured basin forms



TEXT FIGURE 8

Variability of the width-length-ratios of *Bolivina pseudobeyrichi* Cushman in the Santa Barbara Basin.

would have to be considered as "newly formed." Stability of the test seems to have less importance for selection than is generally believed (Pokorny, 1958, p. 154-155). Inasmuch as no selectional advantage for the morphology of the basin forms can be recognized, selection of these forms is only possible in combination with physiological characteristics by pleiotrope genes.

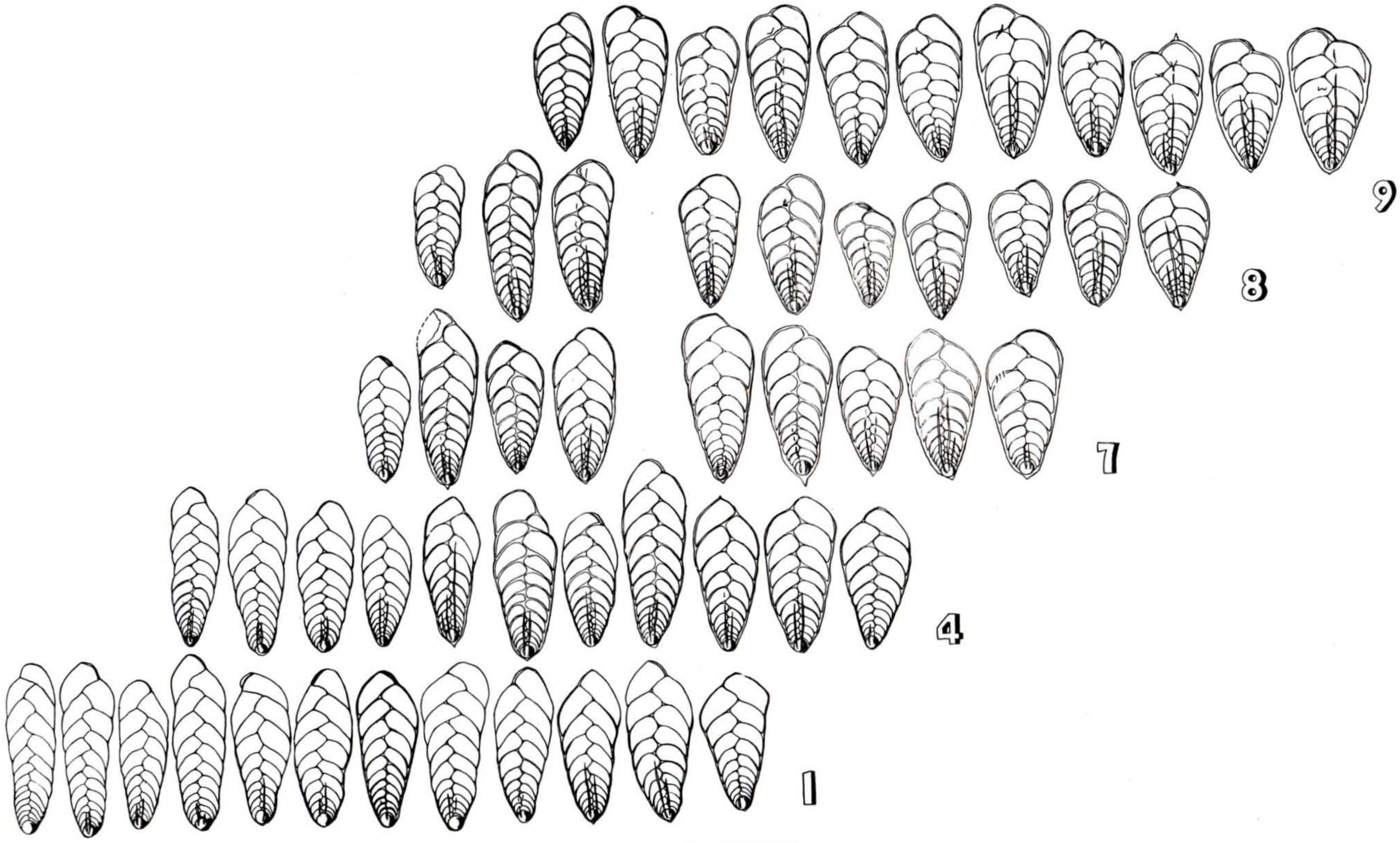
In summary, it can be stated that most observations indicate the described variations to be merely modifications. It must be realized, however, that in addition to a phenotypic adaptation (modification) corresponding mutations may occur. If these mutants are favored by selection, the former phenotypic characteristic may (or might have) become inheritable. This is the reason for the difficulty of distinguishing between modification and mutation, as expressed by many authors (e.g., Rensch, 1954, p. 198: "Wenn trotzdem immer noch lamarckistische Auffassungen geäußert werden, so ist dies wohl auf die oft so verblüffenden Übereinstimmungen von Modifikation und Mutation zurückzuführen. Bei diesen Phänokopien handelt es sich ja nicht nur um eine phänotypische Gleichheit, sondern auch darum, daß die Außenfaktoren, an die eine derartige Erbänderung angepaßt ist, die gleichen sind wie die, welche die Modifikationen erzeugen. So sind z.B. erbliche größere Warmblüterrassen an kühlere Temperaturen angepaßt (BERGMANNsche Regel), und durch Temperaturerniedrigung lassen sich auch experimentell größere Modifikanten hervorbringen . . . . . .").

A real proof for either interpretation, therefore, cannot be given solely with paleontological and morphological methods. Future investigations of *B. argentea* will provide additional information, but it is clear that new important arguments can only be attained by laboratory experiments. Such experiments should determine whether test morphology is changed with experimental alteration of environmental conditions. Similar experiments on other foraminifera (Arnold, 1953, 1954; Bradshaw, 1957, Nyholm, 1961) provided far reaching results not yet applied to taxonomy, but involved almost exclusively shallow water species. As the biotope of these species is characterized by many varying properties, too many factors must be taken into account for generalized applications. Therefore, the investigation of deep water forms living under more constant conditions would be important. Until today, there has been no success in producing the reproduction of deep water foraminifera in the laboratory. Experiments of the writer with *B. argentea* failed. It can be surmised, however, that special experiments would positively succeed, if main life conditions could be kept constant from the moment of sampling. It would be desirable if, in connection with the world-wide intensified research in marine biology, suitable methods could be developed to come closer to a solution of the above-outlined problems. This would be of fundamental importance for the interpretation of many morphological lineages, for instance those published by O. L. Bandy (1960, e.g., buliminids, *Uvigerina*).

TAXONOMY AND NOMENCLATURE

Species names are a necessity for scientists in order that they may register data and observations in the event of questions which may arise. Nomenclature is further needed to establish a scheme of relations among the different forms and an understanding of phylogenetic changes and evolution. In either instance, the purpose is one of data-filing, and splitting into morphological units which are too small is obviously "overfiling," well known in business-management. The result, which can be observed everywhere, is an unwieldy system leading to difficulty in the comparison of the results of different authors, especially when they come from different "schools." The often cited "practical purpose of nomenclature," therefore, cannot justify an unnatural splitting into artificial taxons defined merely by extreme variants. The variation of *Bolivina argentea* demonstrates this principle.

On text figure 9 the most important types of tests out of five populations are figured. The specimens are so arranged, that each row reflects the visual impression of one total population. The populations nr. 1 and 4 represent the basin-biotope, nr. 7 the transition-biotope, and nr. 8 and 9 the slope-biotope. Morphologically similar forms are arranged in vertical lines. Comparing only the outer right extreme variant of population nr. 9 with the outer left form of population nr. 1, leads one to the conclusion that these specimens are taxonomically different and distinguishable. Insisting on this standpoint, however, means that boundaries must be drawn. Every reader may practically try to find his own solution of this taxonomic problem by using a pencil on text figure 9. He may, for instance, perform a three-fold division with vertical lines of separation. This would create a slender basin form, a transition form present in all samples, and an extreme, wide slope form. It would certainly be possible to work with such units, if we would restrict ourselves to isolating "typical" specimens in the usual manner and mounting them in type-slides. In any further analysis, however, we would fail because of the difficulty of cutting natural populations. The divisions would have to intersect the middle of the variation curves and thus not only some extreme variants, but the bulk of all specimens would remain unclearly identified. In a statistical analysis, therefore, the same forms would automatically be evaluated one time for the one, next time for the other "species." Obviously, no



TEXT FIGURE 9
Variation scales of *Bolivina argentea* in different environments.—1 and 4: basin-biotope, 7: transition-biotope, 8 and 9; slope-biotope.

clear idea of the connection between morphology and environment can be achieved by this method.

Similar difficulties arise when horizontal lines of separation are tried. In this instance it has to be realized, that between all of the populations figured on text figure 9, countless transitional populations exist. This method would, therefore, lead to the same inaccuracy as the first one.

As a matter of fact, such arbitrary and at the same time impractical separations are made if one uses the literature uncritically. Cushman's types for *Bolivina argentea* are in accord with the basin form. The general form of the transition-biotope corresponds with the types of Uchio's *B. subargentea*. For the slope form Zalesny (see below) established *B. argentea monicana*, which was renamed *B. argentea resigae* because of homonymy. Following the present investigation, there remains no doubt that these species (subspecies) are synonymous. According to the figures, *B. cacozela* Vella, 1957 (from the Cook strait, New Zealand, in 105 meters depth) also belongs to *B. argentea*. The list of synonyms, therefore, contains at the moment the following.

v 1922 *Bolivina argentea* Cushman, n. sp. — CUSHMAN, Contr. Cushman Lab. foram. Res., 2, (2), p. 42, pl. 6, fig. 5.

? 1957 *Bolivina cacozela* Vella, n. sp. — VELLA, New Zealand Geol. Survey, Pal. Bull., 28, p. 33, pl. 8, fig. 162-163.

v 1959 *Bolivina argentea* Cushman var. *monicana* Zalesny, new var. — ZALESNY, Micropaleontology, 5, p. 121, pl. 1, fig. 1 — new name, see Ellis and Messina, catalogue: *B. argentea* var. *resigae* Zalesny 1959.

v 1960 *Bolivina subargentea* Uchio, n. sp. — UCHIO, Cushman Found. foram. Res., spec. Publ., 5, p. 64, pl. 6, fig. 21-22.

Furthermore, relationships are closer between *Bolivina argentea* and two older species from the Mediterranean and the Atlantic than with all other species of *Bolivina*:

1850 *Brizalina aenariensis*, n. sp. — COSTA, Accad. Pontianiana Napoli, 7, p. 297, pl. 15, fig. 1a-b (Pleistocene).

v 1922 *Bolivina subaenariensis* Cushman, n. sp. — CUSHMAN, U. S. nation. Mus. Bull., 104, p. 46, pl. 7, fig. 6.

At the moment, there is insufficient material available to determine the variation-scale of these forms. Hence, no further information about the relationship to California forms can be given at the present time, in spite of striking similarities in test construction. We continue, therefore, in referring California forms (mainly distinguished by their extraordinary size) to *B. argentea*. It is to be realized, however, that they may perhaps only be a subspecies of these older species. In any event, the present nomenclatural praxis is unsatisfactory, as both Mediterranean as well as west Atlantic forms are simply referred to *B. subaenariensis*. This conflicts with the fact that differences between them are at least as great as between Atlantic forms and the California specimens (after inspection of the material at the Scripps Inst. of Oceanography and the U. S. National Museum). In addition, many species erected for Pleistocene and Miocene forms may turn out to be synonymous forerunners or just subspecies. As there are some old names among them (e.g., *B. marginata* Cushman, 1918), taxonomy and nomenclature of this group must be considered as completely unclarified at the present time. Unfortunately this confusion does not constitute a rare exception, but is even surpassed in many other genera of foraminifera. Especially writers impressed by the taxonomic possibilities of inner characteristics show a remarkable trend to generalized splitting (see Vella, 1961: "Variability is a bogey which has inhibited advance in taxonomy . . . "). It seems advisable, therefore, to apply taxonomical methods corresponding with the result of the *B. argentea* example and to utilize a wider species-concept.

In the present study, advantageous circumstances supported the investigations. A high frequency, a large amount of samples, and the presence of different biotopes made it possible to detect relations between morphology and environment and to view the range of variations. Less material would have caused the failure of the study. This demonstrates clearly that more specimens than usually believed are necessary if connections between varying forms are to be detected or the taxonomic independence of similar forms is to be proved. *Therefore, no new species should be erected if material is available from one locality only and no attempt has been made to find eventual transitional populations from different biotopes.* The same principles should be observed in paleontology, where insufficient material is even more frequent (Imbrie, 1957, p. 140: ". . . chief taxonomic difficulties which arise in dealing with paleontological materials are due not so much to the limitations inherent in postmortem examination of skeletal anatomy, but rather to the incompleteness of the available fossil record.")

If even in the example of the Recent *B. argentea* no proof was found for a genetic separation, no chance for such a proof can be expected in similar fossil examples. On the other hand, a dubious genetic separation is by no means sufficient reason for taxonomic separation, because it would burden taxonomy with mere theories. It must be pointed out in this connection that it is the duty of any taxonomist to prove the independence of his new species himself according to the momentary stage of research (variation studies included). The opposite principle, as applied by many authors, means to separate morphologically different forms as a preventative measure and to name them, even if incomplete materials are investigated. These "species" might be assigned to a single species later on, if they ever become inseparable by investigation of additional materials. This method might have been usable in early times of micropaleontology, when only few names were available. However, applying it today means that the real work would be left to future authors. Nomenclatural merits would be claimed by the original author for publishing, in many cases, no more than a few lines of description. Facing the inflation of foraminiferal names, one must apply the reversed principle: assignment of different forms to one species name as long as the taxonomic difference is not proved by variation statistics. A combination of morphologic data and environmental measurements in the form of diagrams is enough to fix all possible observations in a sufficient degree of completeness.

The often-mentioned apprehension that other authors might be faster in establishing a new species does not by any means justify preventative splitting. Erecting a new species is not a scientific achievement but a technical preliminary.

In recent times, phylogenetic lineages have been used in stratigraphy by several authors (Hiltermann and Koch, 1950, Bettenstaedt, 1952, 1958, 1962; B. Grabert, 1959). The example of *Bolivina* makes it conceivable that a long-range progressive change of environmental conditions could correspond with a similar lineage of phenotypical variation (modification) and thus simulate a phylogenetic evolution. Such gradual alterations of environment are given, for instance, when a basin is filled with sediments and its floor passes through different depth zones. Comparable stages of such lineages would not be useful as time indicators, but would merely announce a similar facies. Shorter "phylogenetische Reihen" which can not be traced over a long period of time and through different facies, as it can be done with the *Gaudryina*-lineages of Grabert (1959), should be revised (e.g., the *Lagena*-lineage of Zedler, 1959).

On the other hand, it is possible that sudden alterations of the biotope (e.g., neutralization of basin-conditions by faulting) may occur. This might cause the formation of two sediment layers each one containing the extreme populations of a modification lineage. The lack of any transitional populations, therefore, does not always indicate a hiatus nor can it be considered proof of the taxonomic separation of two "guide fossils." Hence, even the replacement of a form by a related but distinctly different type in an overlying layer of the section is not in all cases a proof of the specific independence of these forms.

CONCLUSIONS

1. In the erection of new foraminiferal species, not only should the variation-scale of the population be studied, but attempts should be made to investigate samples from different localities or different sediments in order to see the total variability. No more new species without material from different localities!

2. Certain shorter "phylogenetic lineages" of fossil foraminifera should be restudied to determine whether they might be simulated by a lineage of modifications.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XV, PART 3, JULY, 1964

285. A HISTORY OF THE HOLOTYPE, ONTOGENY AND DIMORPHISM OF *GLOBOROTALOIDES TURGIDA* (FINLAY)

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ABSTRACT

The holotype of **Globorotaloides turgida** (Finlay) is figured for the first time and described. The ontogeny and dimorphism in specimens of this species from the type sample are described and illustrated.

INTRODUCTION

Finlay's original description of *Globigerina linaperta* Finlay var. *turgida* Finlay (1939: 125) was all too brief: "... a variety of *linaperta,* which reaches a much larger size, has swollen chambers, and a strong tendency to cover the aperture with a supplementary small, smooth chamber." Due probably to an oversight on Finlay's part it was not figured.

The holotype is here described and a description made of the ontogeny and dimorphism of *Globorotaloides turgida* as seen in the type sample.

The drawings for this publication were prepared by Mr. R. C. Brazier, palaeontological artist with the New Zealand Geological Survey.

SYSTEMATICS

Globorotaloides turgida (Finlay)

Plate 8, No. 13a-c

Globigerina linaperta Finlay var. *turgida* FINLAY. New Zealand Foraminifera: Key Secies in Stratigraphy - No. 2. Roy. Soc. New Zealand, Trans. Proc., Wellington, New Zealand 1939, vol. 69, pt. 1, p. 125.

Holotype: Test trochospiral, biconvex; equatorial periphery quadrilobate with a rounded axial periphery. Wall calcareous, perforate with very small hexagonal and pentagonal pits, the walls separating them thickened especially in the earlier chambers and on the test surface of the first three chambers of the final whorl surrounding the bulla on the umbilical side. Chambers ovate to spherical, about 17 in number plus a bulla, arranged in 3½ whorls.

The five chambers of the second whorl surround a slight depression which locates the first whorl and proloculus. Sutures on the spiral and umbilical sides depressed and radial. The umbilicus is covered by a flattened bulla, the infralaminal aperture of the bulla opens towards the antipenultimate chamber; the bulla wall is smoother than the rest of the test. Due to bad preservation the open end of the bulla is broken but in the better preserved microspheric specimens from the type sample the bulla normally has a thickened lip. Largest diameter of holotype: 0.65 mm.

Age of the Sample: Bortonian Stage (Middle Eocene).

Stratigraphic range: Eocene.

Locality and Types: Pahi, greasy marl, sample F3310. Holotype deposited in the collections of the New Zealand Geological Survey No. 1079/1; paratypes 1079/2 - 1079/6 (inclusive).

ONTOGENY AND DIMORPHISM

The ontogeny of *G. turgida* was studied initially by an examination of the spiral side of the adult tests but it was found that the primary whorl and the encircled proloculus were normally obscured by accreted test material. Neither application of glycerine to these parts nor the conversion of the infilled tests to fluorite improved matters.

A thorough picking of all grades down to about 0.1 mm diameter yielded a growth series, with the largest specimen having a maximum length of 0.7 mm down to the smallest juvenile test with a maximum length of 0.12 mm (Plate 7, figs 1a-11a; 1b-10b; Plate 8, 1c-11c; 1d-10d). In progressively smaller specimens the test wall becomes thinner due to less accreted material over the initial parts. Thus in the smaller specimens up to about the 2-whorled stage all the chambers could be normally located and examined. A few pyritised forms on application of glycerine showed excellently preserved and clearly visible chambers (Plate 8, figs. 11 and 12).

Due to the nature of the infilled tests and the difficulty experienced in measuring the proloculus in most adult tests it was not possible to ascertain with absolute certainty that there were only the two sizes of proloculus within the population of *G. turgida* in the type sample. The significant fact which emerged from the study was that two end forms, here termed micro-and megalospheric, could be distinguished within the sample and that most of the specimens were allocated with reasonable confidence to these two categories.

In the microspheric form the proloculus is 0.01 mm (approx.) in diameter as opposed to 0.03 mm (approx.) in the megalospheric form. The first two whorls in the microspheric test are composed of 5 chambers each and thereafter 4 decreasing to 4-

3½ chambers in the final whorl. Only the first whorl of the megalospheric form has 5 chambers and the succeeding whorls show a reduction to 4, with 3½-4 in the final whorl. The greatest length of the second whorl in both micro- and megalospheric tests is fairly constant at 0.2 mm (±0.02 mm). The measurement of this whorl and counting of the numbers of chambers in the second whorl can be used to distinguish the two forms even in the largest adult tests.

The two-whorled stage of the microspheric tests has a flattened spiral side with the first whorl and the proloculus situated in a depression. Even the accretion of shell material onto this part of the test, which is connected with an increase in chamber numbers, does not normally obscure this concavity.

The bulla of the microspheric tests normally has a pronounced lip and is flattened. In the megalospheric tests the bulla is more inflated and is tongue-like in appearance normally without a lip in the adult tests. In both conditions the bulla normally only has one opening. One microspheric specimen was found having two large infralaminal apertures; the extra aperture positioned in the suture in between the first and second chambers of the final whorl (Plate 7, fig. 7a).

The primary aperture in the juvenile tests of the microspheric form is a low arch, interiomarginal, umbilical- extra umbilically positioned. This position is maintained up to about the 12-13 chamber stage but with the addition of further chambers its position changes to be centrally placed in the low umbilicus. It is then a low arch which becomes progressively larger and is slightly higher arched in the larger forms. In the megalospheric forms the smallest size available in the sample have a maximum length of about 0.15 mm, the aperture is a low arch, positioned interiomarginal, umbilical-extra-umbilical and has a small lip. Thereafter larger forms have a low arched, umbilical, lipped aperture.

The numbers of chambers in the adult microspheric form is 16-17 plus a bulla with a maximum length of 0.65-0.70 mm as opposed to 13-14 chambers in the megalospheric form with a maximum length of 0.55-0.60 mm. Thus there is a significant size difference between the maximum development of the two forms of adult test.

REMARKS

H. M. Bolli (1957a) first described the genus *Globorotaloides* from the Cipero formation of Trinidad. The ontogeny of the *Globorotaloides* species was described by Bolli: "The first stage is that of a *Globorotalia* with a distinct interiomarginal, umbilical-extra umbilical primary aperture, followed by a *Globigerina*-like stage where the aperture becomes umbilical. The presence of a bulla-like final chamber covering a part or the whole umbilicus indicates the *Catapsydrax*-like stage." All these stages are present in the ontogeny of *G. turgida*.

Of the two species described by Bolli only *G. suteri* occurs in the Eocene (Bolli, 1957b). Dr. Bolli kindly sent mounted specimens of this species from the *G. opima opima* zone of the type section of the Cipero formation. Of the nine specimens received the largest was only 0.35 mm maximum length and the *Globorotalia* stage showed a much larger opening than found in *G. turgida*. From these specimens and the description of *G. suteri* and the Miocene species *G. variabilis* it is obvious that *G. turgida* is a much larger species than either of these.

It is possible that *Globorotaloides* cf. *suteri* Bolli (1957a, pl. 27, fig. 14a-c) may be closely related to *G. turgida* (Finlay). This conclusion is based on the figure which shows a large specimen having a flattened bulla with a well developed lip.

G. turgida is easily distinguished from *Globigerina linaperta* Finlay. The holotype of *G. linaperta* (Finlay, 1939, pl. 13, figs. 54-56; Hornibrook, 1958, pl. 1, figs. 19-21) shows three chambers in the final whorl with a compressed final chamber. The aperture is a large low arched opening with a well developed lip. It should be emphasized that *G. turgida* is not here regarded as a form of *Globigerina linaperta* with more inflated chambers which develops an umbilical bulla, as Finlay suggested.

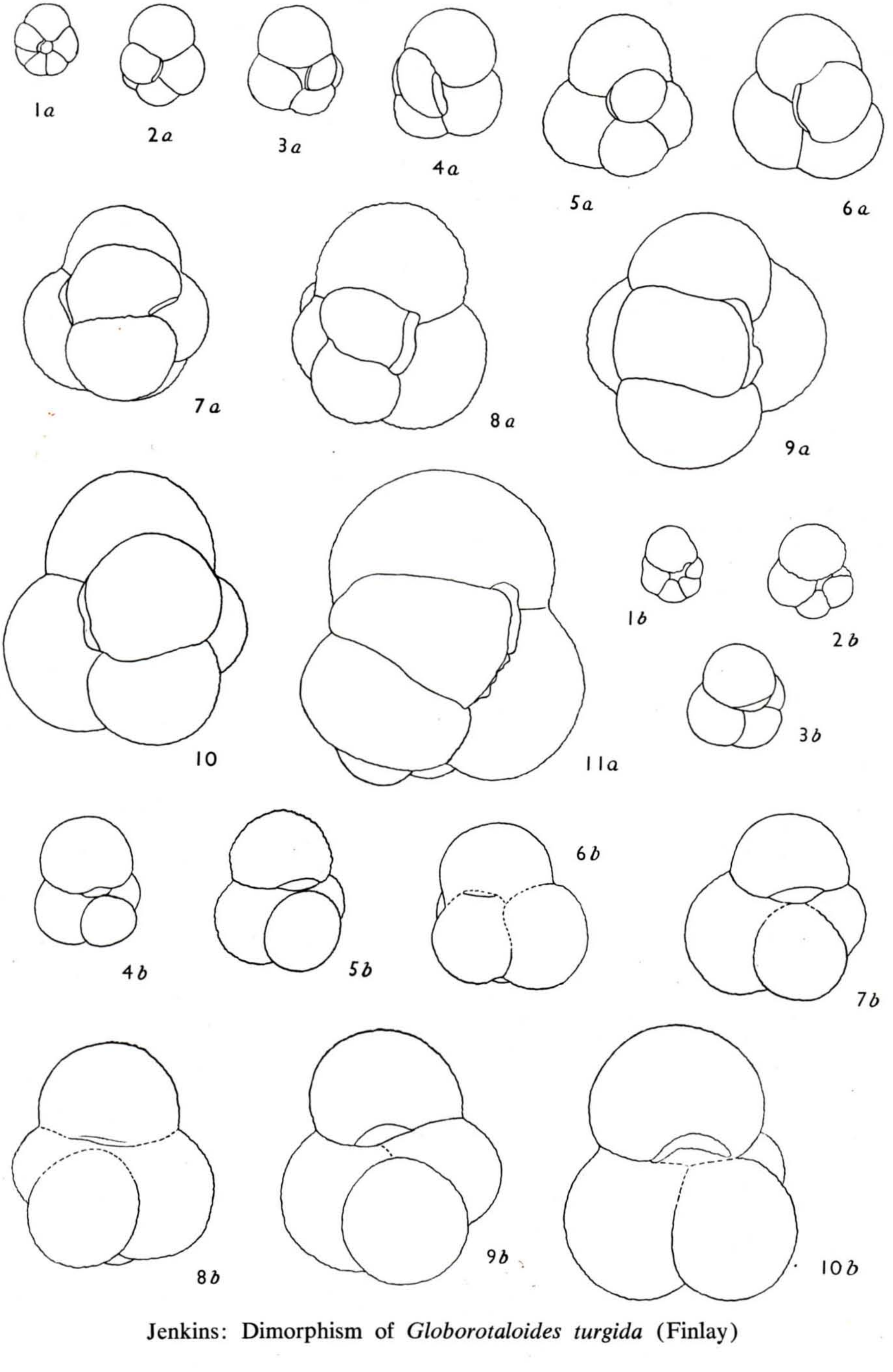
There is an undescribed *Catapsydrax* sp. in the type sample which differs from *G. turgida* in having a much more compact test with less separated chambers and a thicker test wall. A growth series of this *Catapsydrax* sp. does not appear to have *Globorotalia* stage in the smallest forms examined, these having a maximum length of 0.2 mm.

CONCLUSION

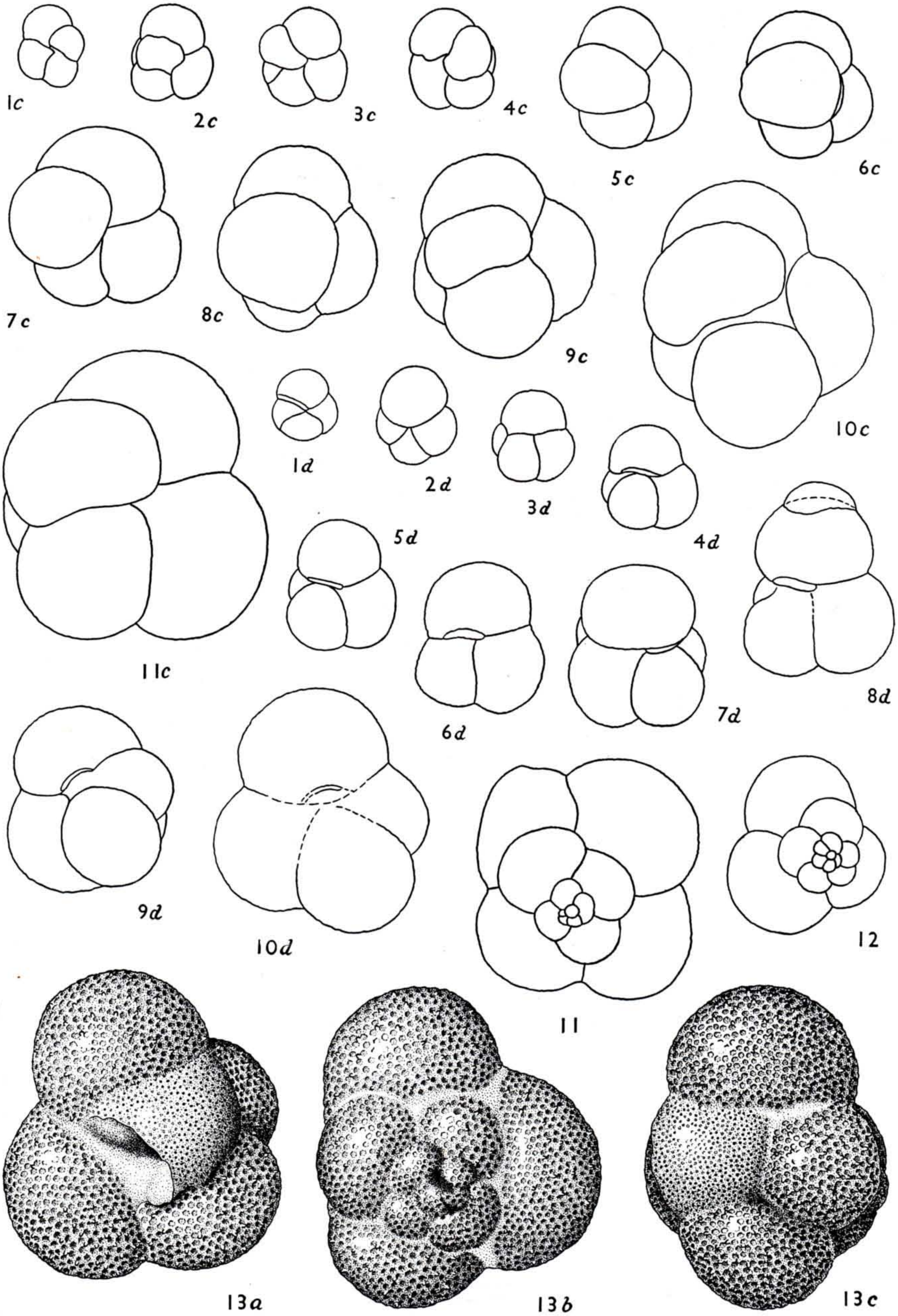
The differences in the morphology between the micro- and megalospheric forms could have led to the unnecessary splitting of *G. turgida* into two taxa. Further work is necessary on the ontogeny of planktonic Foraminifera because it could help to simplify the overburdened taxonomy of the group.

EXPLANATION OF PLATE 7

Outline drawings showing ontogeny of the microspheric form of *Globorotaloides turgida* (Finlay): 1a - 11a tests possessing bullae and 1b - 10b equivalent sized tests which did not develop bullae; 2a and 2b are the 0.02 mm growth stages. All figures × 75.



Jenkins: Dimorphism of *Globorotaloides turgida* (Finlay)



Jenkins: Dimorphism of *Globorotaloides turgida* (Finlay)

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FINLAY, H. J. (1939), New Zealand Foraminifera: Key Species in Stratigraphy No. 2. Roy. Soc. New Zealand, Vol. 69, pl. 1, 89-128, pls. 11-14.

HORNIBROOK, N. DE B. (1958), New Zealand Upper Cretaceous and Tertiary foraminiferal zones and some overseas correlations. Micropaleontology, Vol. 4, No. 1, 25-38, pl. 1, tables 1-2.

EXPLANATION OF PLATE 8

Outline drawings showing the ontogeny of the megalospheric form of *Globorotaloides turgida* (Finlay); 1c - 11c tests possessing bullae and 1d - 10d equivalent sized tests which did not develop bullae; 3a and 3d are the 0.02 mm growth stages. 11: spiral side of a megalospheric form and 12: spiral side of a microspheric form showing chamber arrangement; 13a-c: *G. turgida* holotype. All figures × 75.

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286. REDESCRIPTION OF *ANOMALINA EAGLEFORDENSIS* MOREMAN[1]

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ABSTRACT

Anomalina eaglefordensis Moreman, 1927, is a benthonic species, now questionably assigned to the genus **Planulina.** Planktonic specimens formerly referred to it belong in **Globigerinelloides caseyi** (Bolli, Loeblich and Tappan, 1957).

During a study of planktonic Foraminifera from sediments believed to be early Late Cretaceous (Cenomanian) in age, the question was posed as to the real concept of the species originally described as *Anomalina eaglefordensis* Moreman (1927, p. 99, pl. 16, fig. 9). Loeblich and Tappan interpreted it to be a planktonic form and placed it in the genus *Globigerinelloides* (1961, p. 268, pl. 2, figs. 3-7).

Examination of Moreman's holotype (TCU no. 1118), on loan from Texas Christian University in Fort Worth, indicates that *Anomalina eaglefordensis* is a benthonic species, probably of the family Anomalinidae. The type is here redescribed as *Planulina*? *eaglefordensis* (Moreman), and outline drawings (text fig. 1) are provided for comparison with planktonic specimens erroneously referred to this species.

In placing *Anomalina eaglefordensis* in the planktonic genus *Globigerinelloides,* Loeblich and Tappan considered *Planomalina caseyi* Bolli, Loeblich, and Tappan (1957, p. 24, pl. 1, figs. 4, 5) to be a synonym. Examination of the type specimens of *P. caseyi* in the U. S. National Museum makes it clear that this distinctive planktonic species does belong in *Globigerinelloides.* Other planktonic specimens that have since been referred by other authors to *G. eaglefordensis* (Moreman), following Loeblich and Tappan, are here considered to belong to *G. caseyi* (Bolli, Loeblich, and Tappan), as indicated below.

I appreciate the kind cooperation of Edward Heuer, Associate Professor of Geology at Texas Christian University, for loaning the holotype of *Anomalina eaglefordensis* Moreman.

Planulina? eaglefordensis (Moreman), 1927

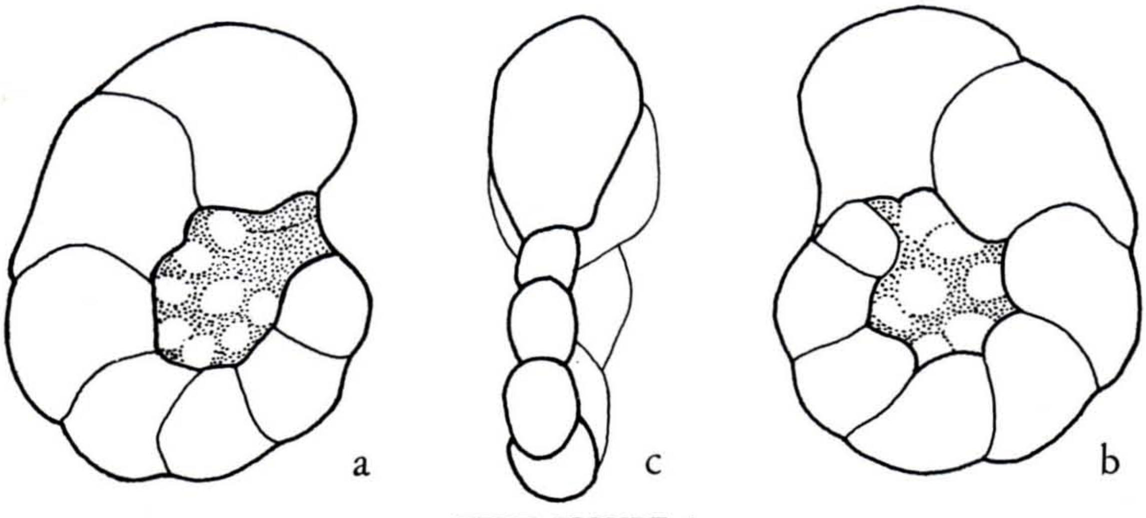
Text figure 1

Anomalina eaglefordensis MOREMAN, 1927, Jour. Paleontology, v. 1, p. 99, pl. 16, fig. 9.

Not *Planulina eaglefordensis* (Moreman). CUSHMAN, 1940, Cushman Lab. Foram. Research Contr., v. 16, p. 32, pl. 6, figs. 4, 5; U.S. Geol. Survey Prof. Paper 206, p. 156, pl. 64, figs. 8, 9.

Not *Globigerinelloides eaglefordensis* (Moreman). LOEBLICH and TAPPAN, 1961, Micropaleontology, v. 7, p. 268, pl. 2, figs. 3-7.

Test small for the genus, compressed, slightly longer than wide, planispiral, biumbilicate, almost completely evolute, equally so on both sides, about 2½ whorls visible, periphery little indented, subangular to subrounded; chambers ovate, quite com-



TEXT FIGURE 1

Planulina? *eaglefordensis* (Moreman), × 120.

Camera lucida outlines of the holotype, TCU 1118, from zone of Eagle Ford Formation-Austin Chalk transition, 2.2 miles north of Hebron, Denton County, Texas. *a, b,* Opposite sides; *c,* peripheral view.

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[1] Publication authorized by the Director, U. S. Geological Survey.

pressed in early part, increasing in size and slightly in inflation to the final chamber, inner edges of last 2 chambers overhanging umbilical area on both sides giving a slight appearance of a flap, last 4 chambers (especially the penultimate one) appearing to overlap preceding chambers on periphery, 7½ in final whorl; sutures distinct, depressed, curved, more sharply curved backward at peripheral edge between last 4 chambers; wall calcareous, distinctly perforate, otherwise quite smooth; aperture unobserved, probably concealed beneath projecting edge of final chamber, possibly opening into both umbilici. Greater diameter of holotype, 0.42 mm; lesser diameter, 0.32 mm; thickness of final chamber, 0.12 mm; thickness of early chamber in final whorl, 0.04 mm.

This description is of the holotype only; no other material was available. Although Moreman gave a diameter measurement of 0.7 mm for his species, the greater diameter of the holotype is about 0.4 mm. He emphasized the fact that the species is "much compressed," and his peripheral view of the type (his pl. 16, fig. 9b) confirms this. These compressed chambers are quite unlike those in *Globigerinelloides caseyi* (Bolli, Loeblich, and Tappan, 1957, p. 24), described as spherical to ovate. In addition, the holotype of *Planulina*? *eaglefordensis* (Moreman) completely lacks the arched aperture as well as the relict apertures and accompanying lips attributed to *Globigerinelloides caseyi*. The overhang of the inner edge of the chambers around the umbilici, noted above, is typical of species in the Anomalinidae and bears no resemblance to the distinctive flaps of relict apertures known to encircle the umbilici of species in the planktonic family Planomalinidae as discussed by Loeblich and Tappan (1961, p. 267).

Being evolute instead of involute, the species seems more correctly to belong in the genus *Planulina*. However, this designation is made with reservations as the type is planispiral instead of trochoid and is equally depressed on both sides at the umbilicus. A firmer decision as to the generic assignment would require additional material.

Specimens in the U. S. National Museum collection (Cushman Colln. nos. 39609, 39610, 34488-34494), referred to *Planulina eaglefordensis* (Moreman) by Cushman, are correctly assigned generically but are not synonymous with Moreman's species. Examination of these specimens confirmed the suggestion by Loeblich and Tappan (1961, p. 268) that they probably belong in *Planulina kansasensis* Morrow (1934, p. 201, pl. 30, figs. 2, 12, 15).

Globigerinelloides caseyi (Bolli, Loeblich, and Tappan), 1957

Planomalina caseyi BOLLI, LOEBLICH, and TAPPAN, 1957, U.S. Natl. Mus. Bull. 215, p. 24, pl. 1, figs. 4, 5.

Globigerinelloides eaglefordensis (Moreman). LOEBLICH and TAPPAN, 1961, Micropaleontology, v. 7, p. 268, pl. 2, figs. 3-7.—AYALA-CASTANARES, 1962, Soc. Geol. Mexicana Bol., v. 25, no. 1, p. 15, pl. 1, fig. 2; pl. 6, figs. 2, 3.—BORSETTI, 1962, Giornale Geol., Ann. Mus. Geol. Bologna, ser. 2, v. 29, 1960-61, p. 29, pl. 2, figs. 1, 2; text figs. 20-24.

The full descriptions and excellent illustrations cited above preclude the necessity of additional ones being presented here. Examination of the holotype (USNM P4869) and several paratypes (USNM P4870-P4872) indicates that this species should be retained in the genus *Globigerinelloides* as it lacks the keel or poreless margin of the genus *Planomalina*, as previously stated by Loeblich and Tappan (1961, p. 268).

In overall characteristics, *Globigerinelloides caseyi* compares most closely with *G. bentonensis* (Morrow) (Loeblich and Tappan, 1961, p. 267, pl. 2, figs. 8-10), but it is distinct in becoming more evolute with a more open umbilicus and in having, on an average, a maximum of nine instead of seven chambers in the final whorl.

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BOLLI, H. M., LOEBLICH, A. R., JR., and TAPPAN, HELEN, 1957, Planktonic foraminiferal families Hantkeninidae, Orbulinidae, Globorotaliidae, and Globotruncanidae: U.S. Natl. Mus. Bull. 215, p. 3-50, pls. 1-11, figs. 1-9.

LOEBLICH, A. R., JR., and TAPPAN, HELEN, 1961, Cretaceous planktonic Foraminifera. Part 1—Cenomanian: Micropaleontology, v. 7, p. 257-304, pls. 1-8.

MOREMAN, W. L., 1927, Fossil zones of the Eagle Ford of North Texas: Jour. Paleontology, v. 1, p. 89-101, pls. 13-16, fig. 1.

MORROW, A. L., 1934, Foraminifera and Ostracoda from the Upper Cretaceous of Kansas: Jour. Paleontology, v. 8, p. 186-205, pls. 29-31.

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RECENT LITERATURE ON THE FORAMINIFERA

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

AUBERT, JANE, COUSTAU, DANIÈLE, and GENDROT, CÉCILE. *Montsechiana* nov. gen., un nouveau genre de Foraminifère du Crétacé Supérieur a facies récifal de l'Espagne et des Martigues (France).—Revue de Micropaléontologie, v. 6, No. 3, Dec. 1963, p. 169-174, pls. 1, 2.—Assigned questionably to the Peneroplidae.

BANDY, ORVILLE L. Cenozoic planktonic foraminiferal zonation.—Micropaleontology, v. 10, No. 1, Jan. 1964, p. 1-17, text figs. 1-6 (temperature range charts, graph, geologic range charts, drawings), table 1.—Geologic range in terms of both absolute age and stratigraphic age is indicated for 71 species and subspecies having ranges restricted to various parts of the Cenozoic. Tentative correlation between 29 tropical and warm-temperate planktonic foram zones and the European time scale is shown. Ocean distribution with respect to latitude and to temperature is shown for about 20 modern species. Greatest abundances of specimens occur in the tropics and the polar seas; least in the temperate zone. Greatest diversity of species is found in the tropics and the temperate zone; least in the polar seas. Keeled and non-keeled species of *Globorotalia* are limited by temperatures colder than 17° and 9° C respectively.

BANNER, F. T., and WOOD, G. V. Lower Cretaceous-Upper Jurassic stratigraphy of Umm Shaif field, Abu Dhabi marine areas, Trucial Coast, Arabia.—Bull. Am. Assoc. Petroleum Geologists, v. 48, No. 2, Feb. 1964, p. 191-206, text figs. 1-3 (map, columnar section, range chart).—Ranges between Upper Jurassic and Cenomanian are indicated for about 35 species of Foraminifera.

BARR, F. T., and CORDEY, W. G. Some Upper Cretaceous Foraminifera from the Chapman collection (1892).—Jour. Paleontology, v. 38, No. 2, March 1964, p. 306-310, pl. 49.—Seven species, with lectotypes proposed for 4 of them, from the phosphatic chalk of Taplow.

BÉ, ALLAN W. H., and ERICSON, DAVID B. Aspects of calcification in planktonic Foraminifera (Sarcodina).—Ann. New York Acad. Sci., v. 109, Art. 1, May 31, 1963, p. 65-81, text figs. 1-10.—Living specimens of *Globorotalia truncatulinoides* from depths of 300-1000 meters acquire a calcitic encrustation upon the bilamellar test wall.

BERGGREN, W. A. Problems of Paleocene stratigraphic correlation.—Revue Instit. Français Pétrole, v. 18, Nos. 10, 11, Oct.-Nov. 1963, p. 134-143, text figs. 1, 2 (correl. charts).—Correlations between European and American sections by means of planktonic Foraminifera, and discussion of the possibility of partial correlation between Danian and Montian.

Biostratigraphy of the Paleocene-Lower Eocene of Luxor and nearby Western Desert.—Petr. Explor. Soc. Libya, 6th Ann. Field Conf., 1964, Guidebook to the Geology and Archaeology of Egypt, p. 149-176, pls. 1, 2, text figs. 1-8 (maps, columnar sections, geol. section), tables 1-4, correl. chart, 2 illustrated charts showing stratigraphic ranges and phylogenetic relationships.—A compilation of previous work.

BORSETTI, ANNA MARIA. Micropaleontologia del pozzo "M. Stillo 1" (Foggia) (in Italian with English summary).—Boll. Soc. Geol. Ital., v. 81, fasc. 4, 1962 (1963), p. 387-400, pls. 1-6, well section.—Foraminifera listed and illustrated in thin section from a well that penetrates from Quaternary down to lower Albian.

BRUNEI SHELL PETROLEUM COMPANY, LIMITED. Status of micropalaeontological studies in Brunei, North Borneo and Sarawak.—United Nations, Econ. Comm. for Asia and the Far East, Proc. Second Symposium on the Development of Petroleum Resources of Asia and the Far East, Min. Res. Dev. Ser., No. 18 (v. 1), 1963, p. 203-206, tables 89, 90.—Ranges of Foraminifera genera shown in the Indonesian time scale.

BURDETT, I. D. J., HEDLEY, R. H., HORNIBROOK, N. DE B., and HURDLE, C. M. *Gaudryina convexa* (Karrer) 1865—Upper Eocene to Recent; an example of variation and synonymy among Foraminifera.—New Zealand Jour. Sci., v. 6, No. 4, Dec. 1963, p. 513-530, text figs. 1-6 (5 pls. and 1 map).—This variable species, known under several different names, has existed since upper Eocene in the Australian-New Zealand region and is still found living around New Zealand.

BUTLER, E. ANN. Species concepts and Foraminifera.—Trans. Gulf Coast Assoc. Geol. Soc., 13th Ann. Conv., Shreveport, Oct. 30-31, Nov.

1, 1963, p. 121-125, text figs. 1, 2 (diagrams). —Typological and biological species discussed.

Cicha, Ivan. Neue Stratigraphische Auswertung der Mikrofauna aus den Sog. Kattischen Schichten der Südslowakei in Beziehung zu den Ablagerungen der Paratethys (German summary of Czeck text).—Geol. Práce, Bratislava, zosit 57, 1960, p. 157-216.—One hundred and three species, none new, of the Middle Tertiary.

Cita, M. B., and Chierici, M. A. Crociera talassografica adriatica 1955. V. Ricerche sui foraminiferi contenuti in 18 carote prelevate sul fondo del Mare Adriatico.—Istit. Paleont. Univ. Milano, ser. P, Pubbl. No. 126, 1962, p. 297-359, pls. 1-8, tables 1-9, text figs. 1-27 (map, graphs, drawings).—Statistical analysis of Foraminifera in 18 deep-sea cores from 23 to 853 meters depth, and interpretation of temperature fluctuations. Assemblages are illustrated.

Closs, Darcy, and Barbarena, Mario Costa. Foraminíferos Recentes das Praias do Litoral Sul-Brasileiro. 1. Arroio Chuí (RGS)—Araranguá (SC).—Instit. Ciencias Nat., Univ. Rio Grande do Sul, Bol. No. 16, 1962, p. 1-55, pls. 1-7, text figs. 1, 2 (map, distrib. table).—Illustrated systematic catalog of 37 species and 8 forma of littoral Foraminifera.

Closs, Darcy, and Madeira, Marly. Tecamebas e Foraminíferos do Arroio Chuí (Santa Vitória do Palmar, R. Grande do Sul, Brasil).—Iheringia, Porto Alegre, ser. Zool., No. 19, Jan. 1962, p. 1-43, pls. 1-7, map, distrib. table.—Eighteen species of Foraminifera are included and their distribution shown in various parts of a brackish creek.

Conkin, James E., and Conkin, Barbara M. Mississippian Foraminifera of the United States. Part 1—The Northview Formation of Missouri. —Micropaleontology, v. 10, No. 1, Jan. 1964, p. 19-47, pls. 1, 2, text figs. 1-17 (map, correl. chart, geol. section, columnar sections, occurrence charts, range chart), tables 1-24.—Seventeen species (6 new and 2 indeterminate).

Dallan, Laura. Contributo alla geologia dell'Appennino tosco-emiliano. II. Ricerche micropaleontologiche nei Flysch dei dintorni di Pievepelago (Appennino modenese) (in Italian with French summary).—Boll. Soc. Geol. Ital., v. 81, fasc. 3, 1962, p. 77-115, pls. 1-6, text figs. 1-3 (columnar section, photographs).—Lists and illustrations of Oligocene smaller Foraminifera and description of *Ammosphaeroidina emilianii* n. sp.

Davis, Richard A., Jr. Foraminiferal assemblages of Alacran Reef, Campeche Bank, Mexico.—Jour. Paleontology, v. 38, No. 2, March 1964, p. 417-421, text figs. 1, 2 (map, graph), table 1 (distrib.).—Table shows distribution of 78 species in 7 samples.

Dondi, L. Nota paleontologico-stratigrafica sul Pedeappennino Padano, Part *e, in* AGIP Mineraria, Contributo alle conoscenze geologiche del Pedeappennino Padano.—Boll. Soc. Geol. Ital., v. 81, fasc. 4, 1962 (1963), p. 113-245, pls. 1-27 (assemblage photomicrographs), text figs. 38-62 (stratigraphic sections, photos of forams, range charts).—Ranges and abundance are indicated for many species between Oligocene and Quaternary, and assemblages of smaller Foraminifera are illustrated from numerous local stratigraphic sections. Fifteen columnar sections are subdivided into biostratigraphic zones on the basis of their characteristic species of smaller Foraminifera. *Globorotalia bononiensis* is described from the upper part of the lower Pliocene and basal part of the middle Pliocene.

Echols, Dorothy Jung, and Levin, Harold L. Chalk crayons and microfossil contamination. —Micropaleontology, v. 10, No. 1, Jan. 1964, p. 80, text fig. 1.—Microforaminifera in chalk dust, a possible source of contamination.

Emiliani, Cesare. Paleotemperature analysis of the Caribbean Cores A254-BR-C and CP-28. —Bull. Geol. Soc. America, v. 75, No. 2, Feb. 1964, p. 129-144, text figs. 1-7 (map, graphs). —Analysis by the O^{18}/O^{16} method of a section of the older Pleistocene permits tentative extension of the generalized temperature curve to 375,000 years B.P. Correlations among 4 Caribbean cores are done on the basis of (a) isotopic temperature of *Globigerinoides sacculifer,* (b) disappearance of *Globorotalia menardii flexuosa,* (c) percentage of right-coiling in *G. truncatulinoides,* and (d) rarity of *G. truncatulinoides.*

Frizzell, Don L. *Chapmanina* Silvestri, 1931 (Foraminifera): proposed designation of a type-species under the plenary powers.—Bull. Zool. Nomenclature, v. 20, pt. 6, Dec. 1963, p. 432-434.—*Chapmania gassinensis* Silvestri, 1905.

Ghelardoni, R., Lucchetti, L., Pieri, M., and Pirini, C. I Rapporti tra "Macigno" E "Marnoso Arenacea" tra le Valli del Dolo e dell'Idice (Appennino tosco-emiliano) (in Italian with English summary).—Boll. Soc. Geol. Ital., v. 81, fasc. 3, 1962, p. 195-212, text figs. 1-21 (maps, geol. sections, columnar sections, photographs, photomicrographs).—Assemblages of smaller Foraminifera illustrated and listed from the upper Oligocene-lower Miocene.

GIANNINI, E., and TAVANI, G. Foraminiferi miocenici e pliocenici di un sondaggio effettuato in Val di Trossa (Toscana).—Palaeontographia Italica, v. 55 (n. ser. v. 25), Anno 1960, p. 25-90, pls. 2-10, check list.—Illustrated systematic catalog of 169 species and subspecies of Messinian and Plaisancian age obtained from a core. Three are new and one is given a new name.

HAGN, HERBERT, and HERM, DIETRICH. Der Aufbau der mikropaläontologischen Abteilung der Bayerischen Staatssammlung für Paläontologie und historische Geologie in München.—Mitt. Bayer. Staatssamml. Paläont. hist. Geol., Band 3, Nov. 1, 1963, p. 107-122, pls. 7, 8, text figs. 1-3.—Describes methods of organizing and cataloguing micropaleontologic objects.

HAMAOUI, M. *Reissella ramonensis* gen. nov., sp. nov. (Foraminifera) from the Cenomanian of Israel.—Israel Jour. Earth-Sciences, v. 12, No. 2, 1963, p. 58-64, pl. 1, text fig. 1.—Probably belonging in the Peneroplidae.

HAMLIN, WILLIAM H., and BÉ, ALLAN W. H. A plankton picker.—Deep-Sea Research, v. 10, 1963, p. 459-461, text figs. 1-4.

HARMAN, ROBERT A. Distribution of Foraminifera in the Santa Barbara Basin, California.—Micropaleontology, v. 10, No. 1, Jan. 1964, p. 81-96, text figs. 1-12 (maps, graphs, photomicrographs, morphologic gradation diagram), tables 1-4.—About 40 species (8 planktonic and 32 benthonic) occupy the slopes and basin plain of the submarine basin between 372 and 588 meters in depth. The species are grouped into slope fauna, basin plain fauna, cosmopolitan fauna and displaced shelf fauna. In the low oxygen environment below the sill depth, light and dark laminated beds, of seasonal origin and having abnormally high concentrations of certain species unique to waters off California, are deposited. Specimens having thin fragile walls and lacking surface ornamentation are characteristic of this low oxygen environment. In the higher oxygen environment of the basin slopes, homogeneous sediment (a result of burrowing activities or of turbidity flows) is found. A photomicrograph of specimens of *Bolivina argentea* aligned on a bedding plane is included. Paleoecological interpretation of Late Cenozoic sediments in California is attempted through recognition of similar sedimentary features and through comparison of fossil homeomorphs with species of the Santa Barbara Basin.

HOFKER, J. Les Foraminifères du Crétacé le plus supérieur de Falx-les-Caves, Wansin et Orp-le-Petit.—Ann. Soc. Geol. Belgique, tome 86, 1962-63, Bull. No. 7-10, Feb. 1964, p. B377-B396, figs. 1-37 (on 5 pls.), text figs. A-D (sections).—Foraminifera listed and illustrated from several zones, between lower Campanian and upper Maestrichtian. One new *Spiroplectammina*.

HUANG, TUNYOW. "*Rotalia*" group from the upper Cenozoic of Taiwan.—Micropaleontology, v. 10, No. 1, Jan. 1964, p. 49-62, pls. 1-3, text figs. 1-3 (map, range chart, photomicrograph). —Through re-study of the group, 20 species, 3 subspecies, and 1 variety (none new) were distinguished and reclassified in the genera *Ammonia, Asterorotalia, Pararotalia,* and *Pseudorotalia*. Ranges in three areas of Taiwan are shown for all forms; 11 of them extinct before the Recent.

IGO, HISAYOSHI. On some *Pseudoschwagerina* and *Zellia* from Japan.—Jour. Paleontology, v. 38, No. 2, March 1964, p. 281-293, pls. 45, 46, text figs. 1-4 (chart, map, graphs), tables 1-3.—Three species, one new.

IOVCHEVA, P., and VRUBLYANSKI, B. About the presence of Lower Cretaceous in the Kraishte area (in Bulgarian with English summary).—Review of the Bulgarian Geol. Soc., v. 24, No. 2, 1963, p. 215-217, text fig. 1 (plate).—Includes illustration of assemblage of smaller Foraminifera interpreted as of Albian age.

ISHIZAKI, KUNIHIRO. Upper Carboniferous fusulinids from the Nakahata Formation of the Hida Massif—with special reference to fusulinids similar to *Fusulinella pseudobocki* (Lee and Chen).—Trans. Proc. Pal. Soc. Japan, n. ser., No. 51, Sept. 10, 1963, p. 102-114, pl. 16, tables 1-6.—Six species, one new.

JENDREJAKOVA, OTILIA. Die Vertreter der Gattung *Haplophragmoides* im Alb der westlichen Karpaten der Slowakei.—Geol. Sbornik, Bratislava, roc. 14, cis. 2, 1963, p. 287-294, text figs. 1-7.—Five species, 1 new and 2 indeterminate, from the Albian.

JENKINS, D. GRAHAM. The Eocene-Oligocene boundary in New Zealand.—New Zealand Jour. Geol. Geophysics, v. 6, No. 5, Nov. 1963, p. 707.—The boundary, based on ranges of larger Foraminifera, was formerly regarded as coinciding with the extinction of the planktonic genera *Hantkenina* and *Globigerapsis* but is now considered to be higher than these extinctions. In New Zealand this boundary is based on ranges of planktonics because it is interpreted that warmer-water benthonics failed to reach the remote southern latitudes at the same time as they appeared in equatorial regions.

A new planktonic foraminiferal subspecies from the Australasian Lower Miocene.—Micropaleontology, v. 10, No. 1, Jan. 1964, p. 72, text fig. 1.

Kavary, Emadeddin, and Frizzell, Don L. Upper Cretaceous and Lower Cenozoic Foraminifera from West Central Iran.—Univ. Missouri School of Mines and Metallurgy, Tech. Ser., Bull. No. 102, Aug. 1963, p. 1-89, pls. 1-13, text figs. 1-3 (map, geol. section, columnar section), table 1.—A 129-foot section is subdivided by smaller Foraminifera into Senonian, Maestrichtian, Danian, and Paleocene. Illustrated systematic catalog includes 185 species and subspecies, 16 new.

Khalilov, D. M. Mikrofauna i Stratigrafija Paleogenovykh Otlozhenii Azerbajdzhana.—Akad. Nauk Azerbajdnzhan. SSR, Instit. Geol., 1962, p. 1-326, text figs. 1-45.—Includes a check list of occurrence of about 900 species of Foraminifera between Maestrichtian and upper Oligocene.

Kiesel, Yvonne, and Lotsch, Dieter. Zur Mikrofauna des südbrandenburgischen Obereözans.—Geologie, Berlin, Jahrgang 12, Beiheft 38, April 1963, p. 1-71, pls. 1-16, 1 chart.—Descriptions and illustrations of 36 species (7 new) and 4 subspecies.

de Klasz, Ivan, Le Calvez, Yolande, and Rérat, Daniel. Un nouveau genre de Foraminifères (*Planomiliola*) du Miocène du Gabon (Afrique équatoriale).—C. R. S. Soc. Géol. France, fasc. 10, 1963, p. 343, 344, text fig.

de Klasz, I., Magné, J., and Rérat, D. Quelques formes nouvelles de Buliminidae caractéristiques du Crétacé Supérieur du Gabon (Afrique Équatoriale).—Revue de Micropaléontologie, v. 6, No. 3, Dec. 1963, p. 145-152, pls. 1, 2.—Eight species and 4 subspecies, all new.

Loeblich, Alfred R., Jr., and Tappan, Helen. Protista 2, Sarcodina, chiefly "Thecamoebians" and Foraminiferida (with some systematic descriptions of Foraminiferida by R. Wright Barker, W. Storrs Cole, R. C. Douglass, Manfred Reichel, and M. L. Thompson), (in 2 volumes), *in* Treatise on Invertebrate Paleontology, Part C.—Geol. Soc. America and Univ. Kansas Press, 1964, p. i-xxxi, 1-900, text figs. 1-653.

Lokke, Donald H. Lower Cretaceous *Orbitolina* from East Potrillo Mountains, Dona Ana County, New Mexico.—Bull. Am. Assoc. Petroleum Geologists, v. 48, No. 2, Feb. 1964, p. 231-233, text fig. 1 (map), table 1.

Ludbrook, N. H. Correlation of the Tertiary Rocks of South Australia.—Trans. Royal Soc. So. Australia, v. 87, 1963, p. 5-15, text figs. 1-4 (correl. table, illustrated foram chart, map, mollusk range chart).—Includes a chart showing approximate stratigraphic positions between Eocene and Pliocene of about 45 significant smaller Foraminifera.

McGugan, A. Lower Cenomanian Foraminifera from Belfast, Northern Ireland.—The Irish Naturalists' Jour., v. 14, No. 9, Jan. 1964, p. 189-194, pl. 3.—Illustrated systematic catalog of 20 species.

McKnight, W. M., Jr. The distribution of Foraminifera off parts of the Antarctic coast.—Bull. Am. Paleontology, v. 44, No. 201, Aug. 27, 1962, p. 61-158, pls. 9-23, text figs. 1-7 (maps, distrib. charts, graphs).—Quantitative study based on 28 Phleger cores taken around Antarctica (mostly in the Ross Sea) from depths between 164 and 2995 meters includes an illustrated systematic catalog of 151 species (18 indeterminate). Distribution appears to be only little affected by the ecologic factors of depth, temperature, salinity, grain size, and organic carbon. Standard deviation of the sediment was the most significant parameter tested.

Matsunaga, Takashi. Benthonic smaller Foraminifera from the Oil Fields of northern Japan.—Sci. Repts. Tohoku Univ., 2nd Ser. (Geol.), v. 35, No. 2, Nov. 20, 1963, p. 67-122, pls. 24-52, text figs. 1-4 (maps), tables 1-21 (charts showing foram zones and ranges of species).—Five zones, all but one based on benthonic species, allow the subdivision of the Neogene in northeastern Honshu and the possible intercorrelation between 18 local oil fields. About 360 species and subspecies are illustrated; 35 are described as new and *Echigoina* n. gen. (type species *E. hataii* n. sp.) is erected.

Medioli, Franco. Foraminiferi ed Ostracodi del Calabriano della Val Rovacchia presso Tabiano (Parma).—Boll. Soc. Geol. Ital., v. 81, fasc. 4, 1962 (1963), p. 261-286, pls. 1, 2, text figs. 1, 2 (map, columnar section), distrib. tables.—Smaller Foraminifera listed and illustrated in assemblages.

Moore, Walter L. Notes on the morphology and taxonomic position of the fusulinid *Millerella marblensis* Thompson.—Jour. Paleontology, v. 38, No. 2, March 1964, p. 294-305, pls. 47, 48, tables 1-3.

Murray, J. W. Ecological experiments on Foraminiferida.—Jour. Marine Biol. Assoc. U. K., v. 43, No. 3, Nov. 1963, p. 621-642, text figs. 1-6 (graphs, drawings), tables 1-12.—Details of 15 experiments, using for each experiment 10 individuals of *Elphidium crispum*, to investigate feeding, movement, substratum, and salinity. Feeding rate decreases with salinity. Lowered temperatures aid in survival in subsaline water. Notches in periphery (a result of smaller chambers) is attributed to food shortage. Movement over the substratum is normally random but *E. crispum* is capable of directed movement to avoid a clay substratum.

NOGAMI, YASUO. Fusulinids from Portuguese Timor.—Mem. College Sci., Univ. Kyoto, ser. B, v. 30, No. 2, Geol. and Mineral., art. 2, Sept. 1963, p. 59-68, pl. 3, 1 text fig. (map).—Four species of Early Permian age: 2 indeterminate and 1 new.

OBERHAUSER, RUDOLF. Eine labyrinthische Foraminifere aus der sübalpinen Trias.—Verhandl. Geol. Bundesanstalt, 1963, Heft 1/2, p. 28-33, text figs. 1, 2.—*Pragsoconulus* (genotype *P. robustus* nov. sp.), a nearly solid cone with a Christmas-tree-like ramified cavity within and a single opening in the middle of the base.

PAPANI, G., and PELOSIO, G. La serie Plio-Pleistocenica del T. Stirone (Parmense occidentale) (in Italian with English and French summaries).—Boll. Soc. Geol. Ital., v. 81, fasc. 4, 1962 (1963), p. 293-335, pls. 1-7, text figs. 1-10 (maps, photo, graph, pie diagrams).—Interpretations of age and of depth of deposition are based on quantitative analysis of Foraminifera populations in a 100-meter section through Calabrian to lower Pliocene. The cold marker, *Anomalina balthica,* marks the Plio-Pleistocene boundary.

PAVLOVEC, RAJKO. Die stratigraphische Entwicklung des älteren Palaeogens im südwestlichen Teil Sloweniens (German summary of Slovakian text).—Acad. Sci. Art. Slovenica, Cl. IV: Hist. Nat. et Med., Razprave, v. 7, 1963, p. 419-556, text figs. 1-52 (drawings, graph, photomicrographs, maps), tables 1-3.—Includes descriptions and illustrations of nummulite fauna.

PETROVIC, MIODRAG V. Beitrag zur Kenntnis der Mikrofauna aus der Umgebung von Stubik, Veliki Izvor und Vojilovo (Ostserbien).—Bull. Mus. Hist. Nat. Belgrade, ser. A, livre 14-15, 1961, p. 27-43, pls. 1-3, range and abund. chart, map.—Foraminifera in the Tortonian are listed and a few illustrated.

PODDAR, M. C. Geology and oil possibilities of the Tertiary rocks of western India.—United Nations, Econ. Comm. for Asia and the Far East, Proc. Second Symposium on the Development of Petroleum Resources of Asia and the Far East, Min. Res. Dev. Ser., No. 18 (v. 1), 1963, p. 226-230, 1 table.—Foraminifera listed from various formations.

PODOBINA, V. M. On application of immersion liquids for study of inner structure of Foraminifer shells (in Russian).—Akad. Nauk SSSR, Geol. Geofiz., No. 12, 1963, p. 156-158, text figs. 1-4.

PUTRJA, F. S. Lentikuliny Verkhnego Mela i Paleogena Zapadno-Sibirskoj Nizmennosti.—Nauchno-issl. instit. geol. Arktiki, gosud. geol. komit. SSSR, Uchenye Zapiski, Paleont. Biostrat., vyp. 1, 1963, p. 35-78, pls. 1-6, range chart, map.—Illustrated systematic catalog of 20 species (13 new) in *Lenticulina, Planularia,* and *Robulus* from the Upper Cretaceous and Paleocene of western Siberia.

RAGHAVENDRA RAO, V. Status of foraminiferal studies in India.—United Nations, Econ. Comm. for Asia and the Far East, Proc. Second Symposium on the Development of Petroleum Resources of Asia and the Far East, Min. Res. Dev. Ser., No. 18 (v. 1), 1963, p. 338-344.—Includes bibliography.

RAU, WELDON W. Foraminifera from the northern Olympic Peninsula, Washington.—U. S. Geol. Survey Prof. Paper 374-G, April 13, 1964, p. G1-G33, pls. 1-7 (locality map, 3 columnar sections with distrib. tables, photos of specimens), text figs. 1, 2 (correl. chart, frequency chart), tables 1-6 (distrib. charts, lists).—Includes illustrated systematic catalog of about 40 species from four formations extending from Eocene to Miocene, plus 60 more listed from the area.

REISS, ZEEV. Note sur la structure des Foraminifères planctoniques.—Revue de Micropaléontologie, v. 6, No. 3, Dec. 1963, p. 127-129, pl. 1.—Lamellar structure and double septa in *Globorotalia* and *Globotruncana.*

RESIG, JOHANNA M. The southernmost occurrence of *Elphidiella hannai* (Cushman and Grant), 1927, off the west coast of North America.—Jour. Paleontology, v. 38, No. 2, March 1964, p. 393-396, text figs. 1-3 (maps, graphs, outline drawings).—Living specimens are not found south of Point Dume, southern California. Fossil occurrences in Baja California indicate a northward migration of more than 6° latitude since Pleistocene.

RISDAL, DAG. The foraminiferal fauna in some cores from inner Oslo Fjord (English summary of Norwegian text).—Norges Geol. Unders., Nr. 224, 1963, p. 1-90, text figs. 1-7 (maps, bottom profiles, symbol chart), diagrams 1-13 (charts of occurrence and abundance), table 1.—Qualitative and quantitative analysis of 13 sea-bottom cores and systematic catalog of about 25 arenaceous and 80 calcareous species.

Four ecological regions are recognized. Total population, as well as live population, decreases with increasing pollution and anaerobic conditions.

ROSS, CHARLES A. Two significant fusulinid genera from Word Formation (Permian), Texas. —Jour. Paleontology, v. 38, No. 2, March 1964, p. 311-315, pl. 50, text figs. 1, 2 (map, chart), table 1.—*Skinnerina* n. gen. (type species *S. typicalis* n. sp.).

SAIDOVA, KH. M. O Zonal'nom Kolichestvennom Raspredelenii Donnykh Foraminifer v Tikhom Okeane.—Akad. Nauk SSSR, Voprosy Mikropaleont., vyp. 7, 1963, p. 196-208, text figs. 1-5 (graphs, maps).—Areas of equal abundance of secreted and agglutinated Foraminifera are plotted on maps of Pacific and Antarctic.

SAMUEL, ONDREJ. Some remarks on the Paleogene of the Klippes-zone and on the stratigraphico-biofacial position of the "Malcov" and Saris beds in the East-Slovakia.—Geol. Prace, Bratislava, Zosit 60, 1961, p. 137-148, map, range chart, correl. table.—Planktonics used in correlation.

SCHEIBNEROVA, VIERA. Some new informations on the Cretaceous of the Klippen Belt of West Carpathians.—Geol. Sbornik, Bratislava, roc. 14, cis. 2, 1963, p. 221-268, text figs. 1-82 (drawings, graphs).—Illustrations and descriptions of 47 species, 2 new, from the Coniacian.

STEMPROKOVA-JIROVA, DANA. The genus *Eouvigerina* from the Bohemian Cretaceous.—Acta Univ. Carolinae, Geologica 1, 1963, p. 83-95, pls. 1, 2, text figs. 1-4.—Three species, 1 new.

The genus *Tappanina* and *Loxostomum* from the Bohemian Cretaceous.—Acta Univ. Carolinae, Geologica 2, 1963, p. 141-147, pl. 1, table 1 (range chart).—Three species, 1 new.

UJIIÉ, HIROSHI. Planktonic Foraminifera from the Naganuma Formation, Kanagawa Prefecture, Japan. Pt. 2, Systematic Description.—Bull. Nat. Sci. Mus. (Tokyo), v. 6, No. 4 (No. 53), Dec. 1963, p. 378-404, pls. 54-60, text figs. 1-5 (graphs, diagrams, outline drawings), tables 1, 2.—Descriptions and illustrations of the wall structure (thickness, surface ornamentation and pores) of 31 planktonic species.

VAPTSAROVA, YA. On the presence of the Danian near Novo Selo and Koshava villages, District of Vidin (in Bulgarian with English summary). —Review of the Bulgarian Geol. Soc., v. 24, No. 1, 1963, p. 84-86, text fig. 1 (plate).—Includes illustration of assemblage of smaller Foraminifera from bore holes.

VELLA, PAUL. Foraminifera from upper Miocene turbidites, Wairarapa, New Zealand.—New Zealand Jour. Geol. Geophysics, v. 6, No. 5, Nov. 1963, p. 775-793, text figs. 1-3 (map, columnar section, graph), tables 1-6.—Rhythms about 3 feet thick consist of (a) a thin basal sandstone containing species from shallow water, (b) an intermediate bedded layer barren of fossils, and (c) a massive mudstone with abundant fossils.

Size-sorting of Foraminifera in graded beds, Wairarapa, New Zealand.—New Zealand Jour. Geol. Geophysics, v. 6, No. 5, Nov. 1963, p. 794-800, text figs. 1, 2 (graphs), table 1.—Difference in average sizes of shells in sandstone and mudstone phases of turbidite rhythms indicates mechanical sorting.

VIALOV, O. S., DABAGYAN, N. V., and MYATLYUK, E. V. On the age of Globigerine (Sheshorian) horizon of the Carpathian Flysch (English summary of Russian text).—Doklady Akad. Nauk Ukrains. RSR, No. 10, 1963, p. 1368-1372.—Upper Eocene based on Foraminifera.

VISSER, W. A., and HERMES, J. J., compilers. Geological results of the exploration for oil in Netherlands New Guinea.—Verhandel. Kon. Nederlands Geol.-Mijnbouw. Genootschap, The Hague, Geol. ser., v. 20, 1962, 265 pp., 18 enclosures (maps, tables, range chart, columnar sections, photographs of fossils), numerous illustrations.—Larger and smaller Foraminifera are used in zonation and numerous planktonic species are illustrated.

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