

CONTRIBUTIONS
FROM THE
CUSHMAN FOUNDATION
FOR
FORAMINIFERAL RESEARCH

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VOLUME XIV, PART 2, APRIL, 1963

260. DISTRIBUTION OF FORAMINIFERA IN JUAN DE FUCA
AND GEORGIA STRAITS, BRITISH COLUMBIA, CANADA

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ABSTRACT

Two main faunal divisions comprising nine separate faunas may be recognized in the total benthonic foraminiferal populations of the Juan de Fuca and Georgia straits. The deep-water, mud-bottomed area north of the Fraser River delta contains low numbers of predominantly arenaceous foraminifera; to the south, the bottom is shallower and sandy, and calcareous foraminifera are abundant both qualitatively and quantitatively. Sediment grain size, depth, temperature and salinity are considered in interpreting the faunal pattern.

INTRODUCTION

This paper is a description of the geographical distribution of benthonic foraminifera in the Juan de Fuca and Georgia straits. Only the total population of foraminifera has been examined, this being considered adequate in delimiting gross faunal changes and localizing areas for further study. In addition, grain-size analyses of the sediments were undertaken in order to learn something about their distribution and find whether or not this has any influence on the faunal patterns established.

The Juan de Fuca and Georgia straits are situated between Vancouver Island and the mainland of British Columbia and Washington (text figure 1). Juan de Fuca is a more or less west to east aligned channel separated from the northwest - southeast trending Strait of Georgia by the San Juan Archipelago. The former strait covers an area of approximately 1150 square nautical miles and is 80 nautical miles long. To the north the San Juan Archipelago extends for 18 nautical miles and has an area of almost 500 square nautical miles. The Strait of Georgia occupies the largest area, being about 2100 square nautical miles with a length of 120 nautical miles and an average width of under 20 nautical miles.

Connection with the Pacific Ocean is through the Juan de Fuca Strait and, to a much lesser extent, along Discovery Passage and Johnstone Strait at the north end of the Strait of Georgia. Several inlets open into the Strait of Georgia and, at its southern end, the Fraser River which has a considerable influence on the physical oceanography of the region (Waldichuck, 1957).

PREVIOUS WORK

Very little work has been published on the foraminifera of the Juan de Fuca and Georgia Straits. Those from the San Juan Archipelago and parts of the Juan de Fuca Strait were described by Cushman and Todd in 1947. They recorded 77 species, two of them, *Poly-*

morphina kincaidi and *Discorbis sanjuanensis*, being new. A further two species were first described from Dallas Bank in the eastern Juan de Fuca Strait, namely *Elphidium fax fax* (Nicol, 1944) and *Buccella inusitata*, (Andersen, 1952) which is a junior synonym of *B. tenerima* (see Bandy, 1961). The only previous record of foraminifera from the Strait of Georgia is by Loeblich and Tappan (1953) who identified *Alveolophragmium crassimargo* from north of Gabriola Island.

Most sediment studies in this region have been concerned with the Fraser River delta. However, one author (Waldichuck, 1953) has briefly discussed the bottom sediments in the Strait of Georgia.

The physical oceanography of the Strait of Georgia was studied by Waldichuck (1957); his paper also gives some information on the Juan de Fuca Strait and the waterways around the San Juan Archipelago. Tidal currents in the Juan de Fuca Strait have been described by Herlinveaux (1954).

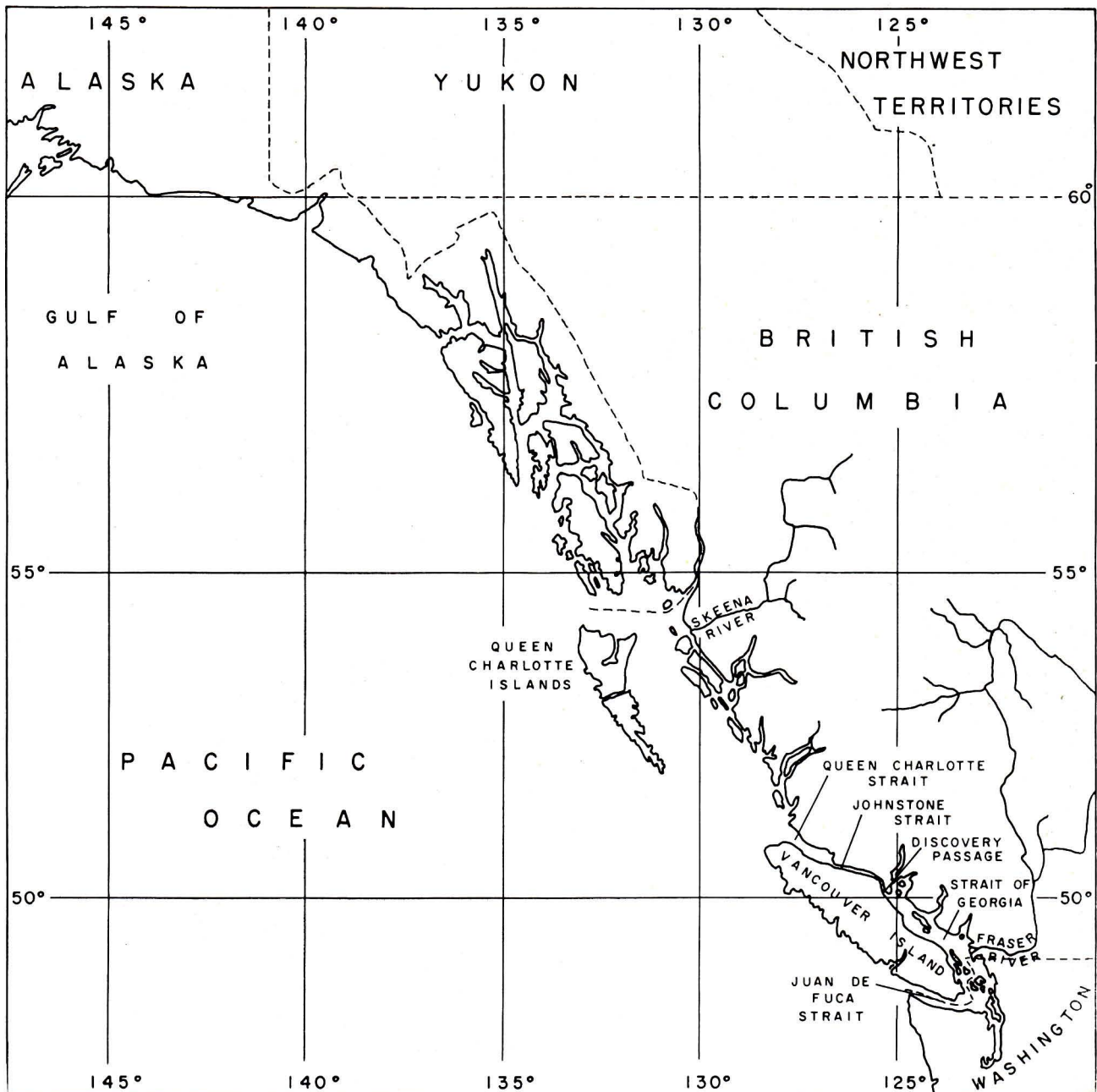
ACKNOWLEDGEMENTS

The author would like to thank the Royal Canadian Navy for making available CNAV *Oshawa* and CNAV *Whitethroat* for the field work. Mr. B. Ferrill assisted in collecting the samples and the sediment analyses were performed by Messrs. G. J. de Boer and G. Trepard. The text figures were drawn by Mr. T. Killam. Drs. O. L. Bandy, B. M. Bary, W. H. Mathews and G. L. Pickard kindly read and criticised the manuscript. Finally, the author is grateful to his colleagues in the Institute of Oceanography for their many helpful discussions and suggestions.

METHODS AND TECHNIQUES

The samples used in this survey were collected from CNAV *Oshawa* and CNAV *Whitethroat* during two cruises from 18 - 19 February 1960 and 28 March - 8 April 1960. They were taken at stations spaced, as far as possible, on a four mile grid. Areas floored by mud were sampled with a Phleger corer and an orange peel grab was used on sand bottom. The positions of the stations at which samples were collected are shown in text figure 2 (a); a list of the station data is compiled in table 1.

Of the 175 stations occupied, 24 were unsuccessful or provided too little material for analysis. The chief areas where sampling was poor were in Haro Strait and south of Cape Mudge. In the former area no samples were obtained and in the latter area only a very small amount of sand was collected. Eighty-six



TEXT FIGURE 1

Outline map of northeast Pacific Ocean showing location of Juan de Fuca and Georgia straits region.

samples were examined for foraminifera and 144 were analysed for sediment grain size.

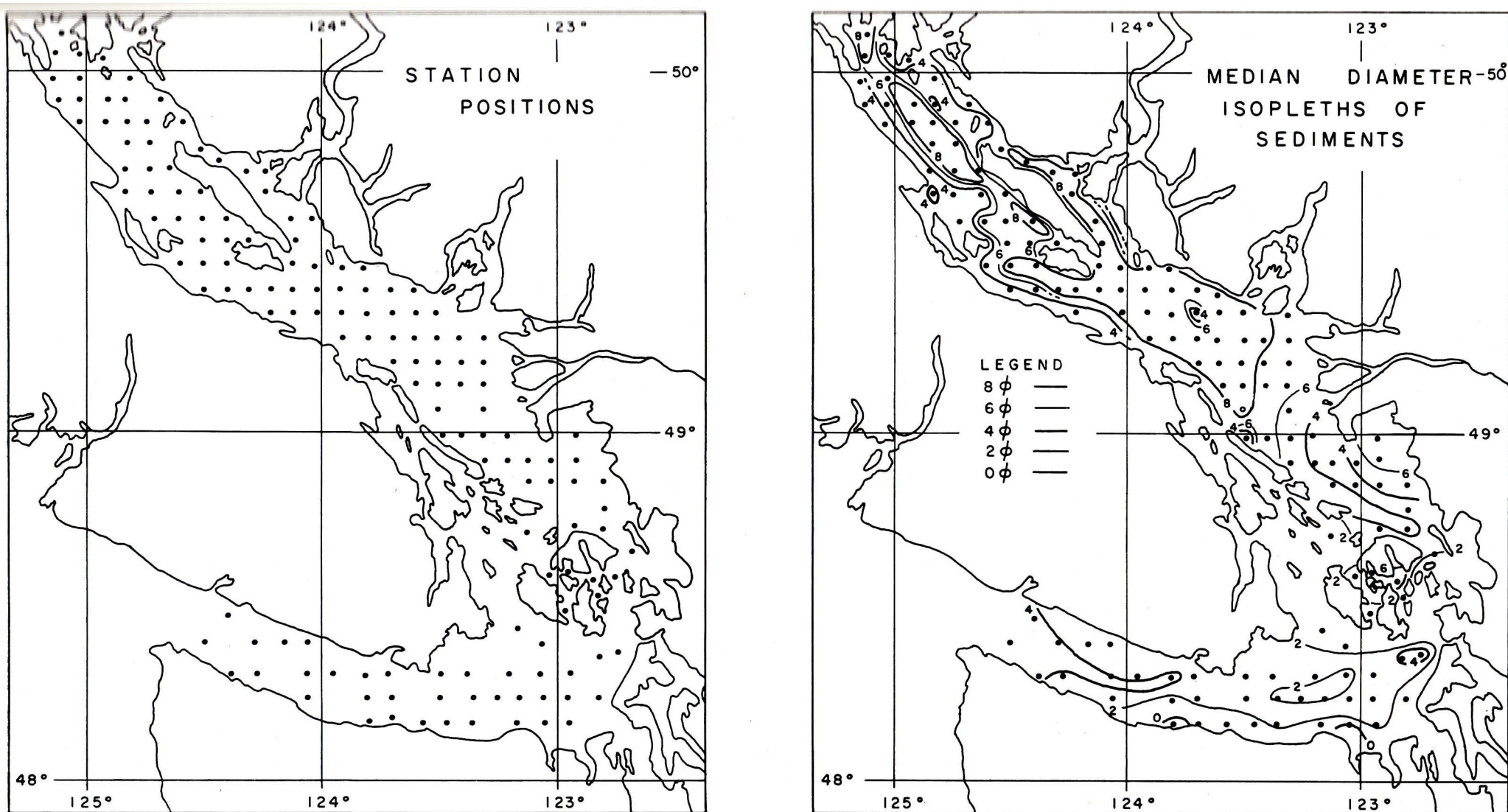
All the samples were preserved in neutralized formalin and stained with rose Bengal. In the present account, the stained, living foraminifera are not described. The top two centimetres of each core sample, which has a cross sectional area of 9.5 square centimetres, or an equivalent volume from the grab samples was washed through a 200 mesh sieve (0.074 mm.) and the residue examined for foraminifera. At least 250 specimens were identified and counted, except in those samples which contained very few foraminifera when usually half the residue was picked over. From this examination the percentage frequency of each species was determined. The total number of foraminifera in each two centimetre sub-sample was also calculated. In this paper the total number of foraminifera is reported for each two centimetre sub-sample, that is,

on a volume basis and not on a weight basis (see Phleger, 1960).

Samples for sedimentary analysis were taken from the five centimetre portion of each core below the top two centimetres and an approximately equal amount of material was used from the grab samples. The grain size of the coarse material was determined by sieving and fine-fraction analysis was done by the hydrometer method.

SUBMARINE TOPOGRAPHY

A chart showing the submarine topography of the region is given in text figure 3. In the south is the moderately deep channel of the Juan de Fuca Strait which leads into the shallower waters around the San Juan Archipelago. North of here the sea again deepens in the basin of the Strait of Georgia. These three areas are discussed below.



TEXT FIGURE 2

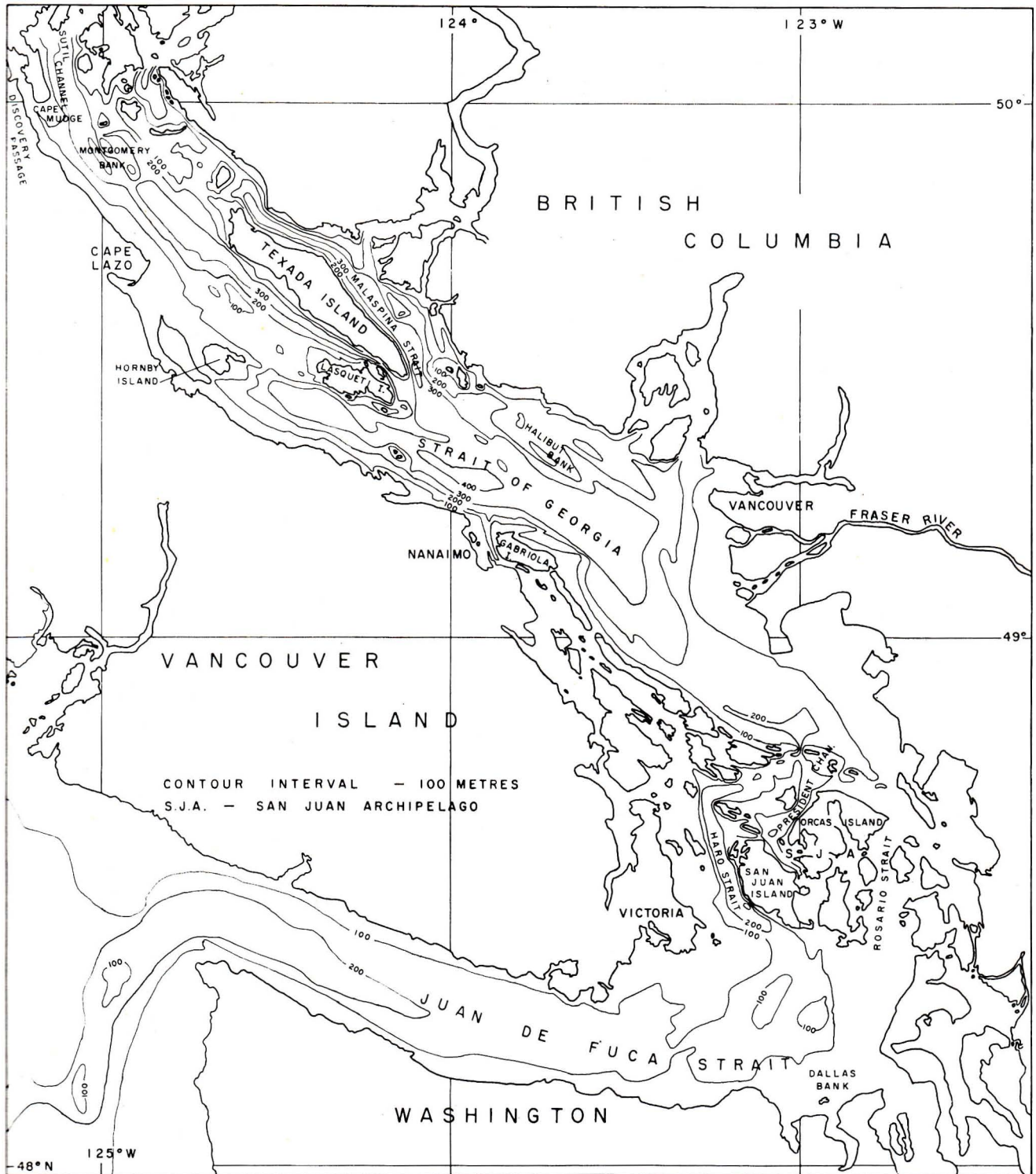
Maps showing (a) station positions and (b) median diameter isopleths of sediments.

TABLE 1
STATION DATA

Station no.	Latitude N.	Longitude W.	Depth (metres)	Station no.	Latitude N.	Longitude W.	Depth (metres)
3	48° 51' 30"	123° 07' 00"	158	108	48 15 12	123 10 54	135
5	48 55 40	123 13 06	140	109	48 15 12	123 17 42	86
6	48 55 36	123 18 10	202	110	48 15 12	123 24 24	140
7	48 59 36	123 18 12	190	111	48 15 12	123 31 24	170
8	48 59 24	123 25 18	255	113	48 15 00	123 45 00	171
9	48 59 38	123 31 48	89	114	48 19 48	123 45 00	162
10	49 03 36	123 31 42	287	117	48 10 48	123 51 48	40
12	49 03 30	123 19 18	175	119	48 15 00	124 05 24	165
13	49 07 50	123 19 14	112	121	48 19 36	124 19 12	184
14	49 07 43	123 25 30	267	122	48 19 36	124 25 36	65
15	49 07 41	123 31 42	372	124	48 24 30	124 32 30	174
18	49 11 36	123 31 36	350	126	48 29 06	124 25 36	135
19	49 11 42	123 25 36	293	128	48 24 24	124 19 12	192
20	49 11 48	123 19 36	178	129	48 24 24	124 12 00	147
21	49 15 30	123 19 48	215	130	48 24 12	124 05 42	96
22	49 15 30	123 26 00	215	131	48 19 36	124 05 30	175
23	49 15 18	123 31 48	325	132	48 19 30	123 58 42	166
24	49 15 42	123 38 00	370	133	48 10 06	123 45 00	88
33	49 23 30	124 13 48	340	134	48 10 36	123 38 12	88
36	49 23 24	123 55 30	420	135	48 10 36	123 31 24	30
38	49 19 30	123 49 42	380	136	48 10 36	123 24 24	113
44	49 23 12	123 38 00	162	138	48 10 36	123 10 48	88
49	49 27 18	124 01 42	265	139	48 10 36	123 04 00	69
58	49 45 24	124 25 36	330	140	48 10 36	122 57 18	48
62	49 58 48	124 48 30	200	142	48 14 48	122 49 30	16
64	49 58 54	125 01 48	123	143	48 21 30	122 51 12	83
66	50 06 48	125 07 24	250	144	48 22 48	122 45 06	81
67	50 02 48	125 07 36	258	147	48 36 08	122 46 00	53
68	49 58 54	125 07 30	42	148	48 39 48	122 42 12	88
69	49 54 42	125 07 24	50	149	48 43 12	122 47 48	108
74	49 50 42	124 50 18	300	150	48 43 48	122 54 48	70
76	49 51 18	125 01 24	105	151	48 43 06	123 07 00	144
81	49 43 18	124 42 42	325	153	48 35 12	123 02 54	134
82	49 43 48	124 49 36	103	155	48 29 36	122 58 06	76
84	49 39 30	124 43 36	139	157	48 23 54	123 04 18	99
85	49 39 24	124 37 36	117	158	48 26 24	123 10 00	107
89	49 35 30	124 37 36	169	163	48 47 12	122 48 12	34
90	49 35 30	124 43 36	100	165	48 51 18	122 54 30	115
100	48 19 42	123 31 24	84	166	48 51 24	123 00 42	206
101	48 19 42	123 24 24	108	167	48 55 30	123 06 48	119
103	48 20 06	123 11 30	103	168	48 55 30	123 00 12	129
106	48 15 16	122 57 12	52	170	48 59 00	122 53 30	28
107	48 15 12	123 04 18	161	173	48 35 00	122 51 42	28

The Juan de Fuca Strait shallows gradually from west to east. In the western portion a channel occupies the centre of the strait and reaches a maximum depth of 247 metres. This channel passes seaward into the Juan de Fuca Trough (Shepard, 1948) which cuts across the continental shelf in a northeast - southwest direction. In most of the eastern part of the strait the water is shallower than 100 metres but there is a slightly deeper channel connecting this area with Haro Strait.

The second area comprises the waterways around the San Juan Archipelago. The deeper channels are on the western side; Haro Strait contains a deep basin attaining a depth of over 300 metres off San Juan Island. In President Channel, to the east, the sea is over 200 metres deep in one small area but in the remaining passages, for example, Rosario Strait, the depth is rarely greater than 100 metres. Thus there is a contrast between the deep Haro Strait on the west side and the shallow Rosario Strait on the east.



TEXT FIGURE 3

Submarine topography of the Juan de Fuca and Georgia straits.

In the third area, the Strait of Georgia, the average depth is more than 200 metres and only local shoal areas less than 100 metres are found. Most of the topographical features have a northwest - southeast trend, parallel to that of the Strait itself. There are two main basins separated by a shallow ridge lying between Cape Lazo and Lasqueti Island. The southern basin is the larger and extends from off the Fraser River delta to south of Hornby Island with a branch running up the Malaspina Strait. North of Nanaimo a maximum depth of 430 metres was recorded. The northern basin is situated close to the western coast

of Texada Island and extends to Montgomery Bank. From here two branches continue northwards, the eastern one for a short distance, the western one up into Sutil Channel. The northern basin is slightly shallower than the southern one, the depth being a little over 350 metres.

The ridge separating the two basins is less than 200 metres deep and for most of its distance is under 150 metres. Between Lasqueti and Texada Islands there is a sill at a depth of more than 250 metres which connects the northern and southern basins.

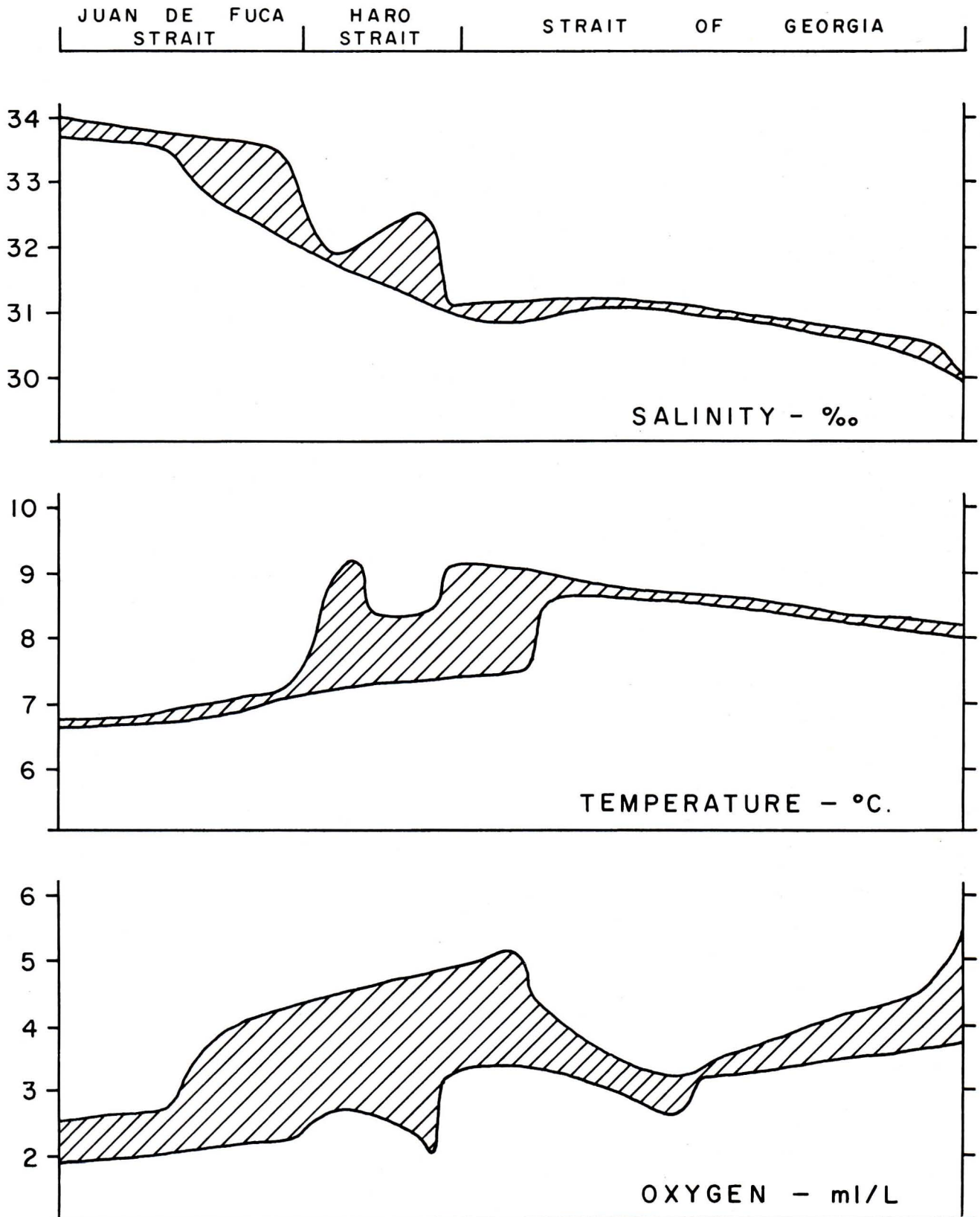
There are three shoal areas where the water is less

than 100 metres deep in the Strait of Georgia: (1) on the east side of the southern basin, for example Halibut Bank, (2) the banks on the Cape Lazo - Lasqueti Island ridge and (3) to the east of the northern basin, north of Montgomery Bank.

PHYSICAL OCEANOGRAPHY

Waldichuck (1957) has given a very full account of the physical oceanography of the Strait of Georgia.

He recognizes three water masses in the Juan de Fuca and Georgia straits region: (1) a low salinity surface layer, mainly due to the discharge from the Fraser River, (2) a saline deep water of about 33.8 parts per thousand salinity and 7°C temperature flowing in from the Juan de Fuca Strait and (3) a mixture of the previous two water masses formed in the waterways around the San Juan Archipelago. The salinity of this latter water mass is about 31.0 parts per thousand and



TEXT FIGURE 4

Seasonal variation in salinity, temperature and dissolved oxygen in the bottom waters of the region.

the temperature about 9°C; it flows out, towards the open sea, at the surface in the Juan de Fuca Strait and also sinks into the deep portion of the Strait of Georgia. Although in the surface waters of the Strait of Georgia seasonal changes are marked, the bottom water is subject to only small variations. This is also true of the Juan de Fuca Strait bottom water.

Text figure 4 is a section through the Juan de Fuca and Georgia straits, taken from data supplied in Waldichuck's paper, showing the seasonal changes in temperature, salinity, and dissolved oxygen of the bottom water from September 1952 to March 1953. Whilst these data are not sufficient to suggest a mean annual range for these properties, some generalizations may be made. The distribution of temperature and salinity enables the region to be divided into three areas, corresponding approximately to the Juan de Fuca Strait, San Juan Archipelago and Strait of Georgia. The temperature and salinity ranges in the Juan de Fuca Strait and the Strait of Georgia are very small and contrast with the pronounced seasonal variation in these properties in the intervening area of mixing. The dissolved oxygen distribution follows a similar pattern but the threefold division is less well marked.

In the Juan de Fuca Strait the temperature of the bottom water is slightly less than 7°C and the salinity is nearly 34.0 parts per thousand. The temperature in the Strait of Georgia varies from 8°C in the north to about 9°C off the Fraser River. Similarly, the salinity rises from 30.0 parts per thousand in the north to 31.0 parts per thousand in the south. There is a seasonal temperature range of about 0.2°C and a salinity range of under 0.4 parts per thousand in both Juan de Fuca Strait and the Strait of Georgia. Around the San Juan Archipelago the temperature range is from 9°C in September to 7.5°C in March and the salinity range for the same months is from 31.0 parts per thousand to 33.5 parts per thousand. The concentration of dissolved oxygen shows a gradual increase from two millilitres per litre at the mouth of the Juan de Fuca Strait to 5.5 millilitres per litre at the north end of the Strait of Georgia. Whilst the seasonal range is 0.5 millilitres per litre or less in the north and south, in the San Juan Archipelago area the values vary from two millilitres per litre in September to over five millilitres per litre in March.

SEDIMENTS

Distribution

The sediments encountered in the Juan de Fuca and Georgia straits range in size from clay to sand and gravel. Broadly speaking, the Strait of Georgia is floored by fine-grained muds falling into the silt and clay size range, whereas the remaining areas have a sand or gravel bottom. The overall distribution pattern agrees with that determined by Waldichuck (1953). A contoured map of the median diameter of the sediments in phi units is given in text figure 2 (b).

Comparison of the sediment distribution map with the submarine topography (text figure 3) shows a close correlation between the two, particularly in the Strait of Georgia. The deep basins contain very fine-grained sediment with median diameters greater than 8 phi. Coarser sediments are found on the Cape Lazo - Lasqueti Island ridge, more especially in the northwest portion. Off the Fraser River delta the grain size decreases with distance away from the shore, from around 6 phi to over 8 phi. Grain size also decreases from south to north immediately off the mouth of the Fraser River. A narrow band of coarse material, less than 4 phi, extends in a southeast direction from the southern mouth of the Fraser. The only shoal area sampled in the Strait of Georgia (Halibut Bank) yielded sand in strong contrast with the surrounding silts and clays. South of Cape Mudge the bottom is sandy (Waldichuck, 1953) but the samples collected there in the present study were too small to permit accurate analysis.

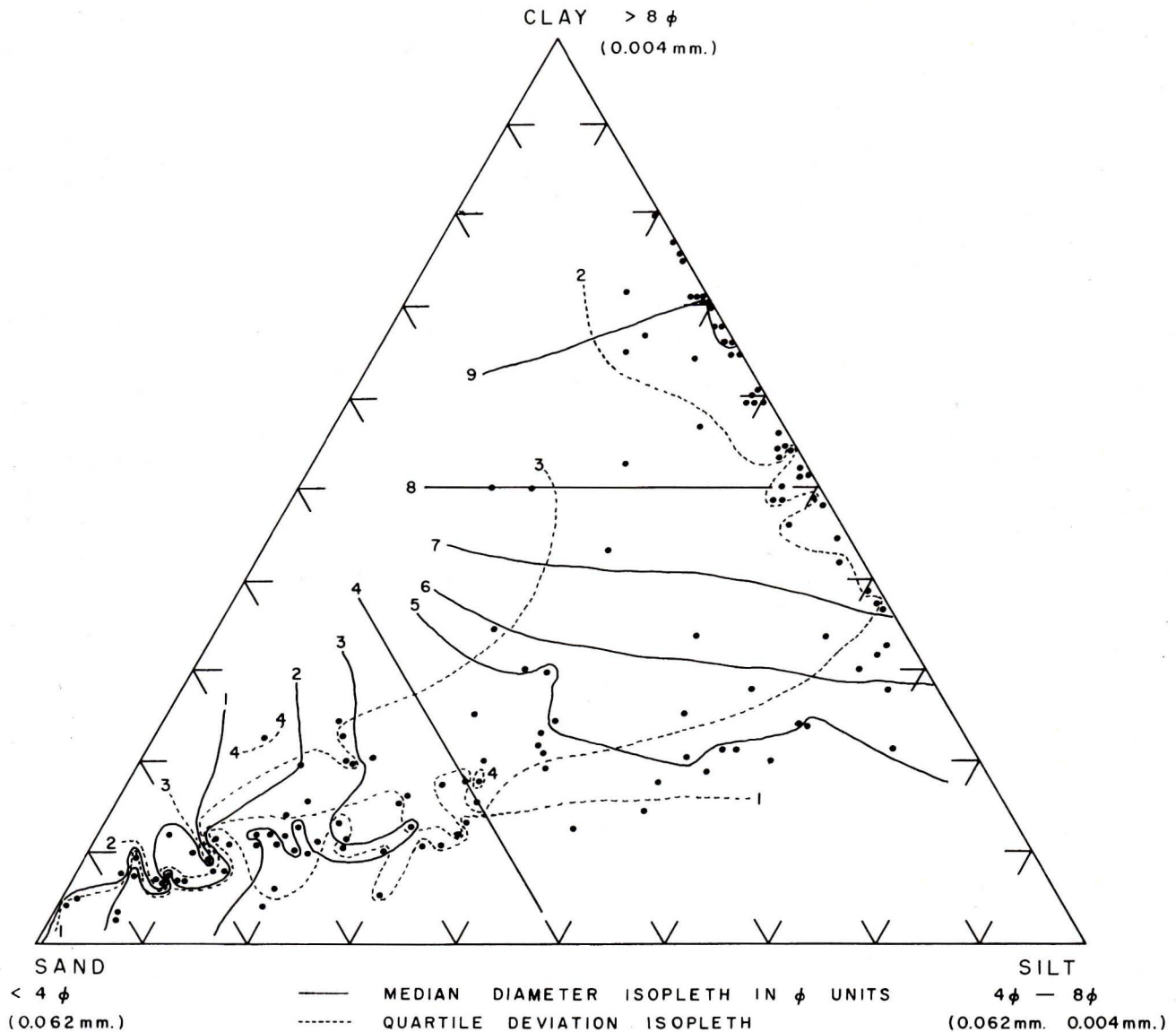
It is difficult to obtain a clear picture of grain-size distribution in the San Juan Archipelago because of the small number of samples collected. Most of the area contains coarse sediments with median diameters of 2 phi and less. Finer-grained material (4 phi to 7 phi in median diameter) is present south of Orcas Island.

In Juan de Fuca Strait the grain size appears to decrease seawards. Median diameters of 3 phi and over are common in the western Strait whilst in its eastern parts the average value is around 2 phi. Some local areas have coarser sediment than the surrounding bottom and at the southern end of Rosario Strait there is a patch of silty sand. Along the southern side of the Juan de Fuca Strait the sediment is usually very coarse, averaging 1 phi in median diameter.

Grain-Size Analysis

The sand - silt - clay ratio of each sample is plotted on the accompanying triangular diagram (text figure 5). Median diameter and quartile deviation are also contoured on this diagram (see Plumley and Davis, 1956). Full details of the grain-size analyses will be found in a data report mimeographed by the Institute of Oceanography at the University of British Columbia (Data Rept., 1962). Most of the samples fall into two fields: (1) those with less than 5 percent sand and from 45 to 75 percent clay and (2) those with more than 5 percent sand and a silt - clay ratio averaging 65 : 35 or approximately 2 : 1. The former group includes the sediments from the Strait of Georgia north of the Fraser River delta whilst the Juan de Fuca Strait and south Strait of Georgia samples belong to the latter group.

Group (1) sediments have median diameters ranging in size from 7.5 phi to over 9 phi and the quartile deviation is usually 2 or less. Most of the samples have a skewness between 0.2 and -0.2 with a mean



TEXT FIGURE 5
Sand-silt-clay ratios of the sediments.

value of 0.0. These sediments lie in the silty-clay grade of Shepard (1954).

The sediments comprising group (2) are more varied. Median diameters are from 7.5 phi to less than 1 phi in size with one or two samples showing negative phi values. The quartile deviation varies from 4.5 to 0.5. Skewness also has a wide range with a preponderance of values around 0.5, that is, many of the sediments are skewed on the fine side. Group (2) sediments may be classed as sands, silty sands, sand-silt-clays and clayey silts (Shepard 1954).

Median diameter expressed in phi units displays a fair correlation with depth, as may be anticipated from a comparison of text figures 2 (b) and 3 and as can be seen in text figure 6. The sediments tend to become finer grained as the depth of water increases.

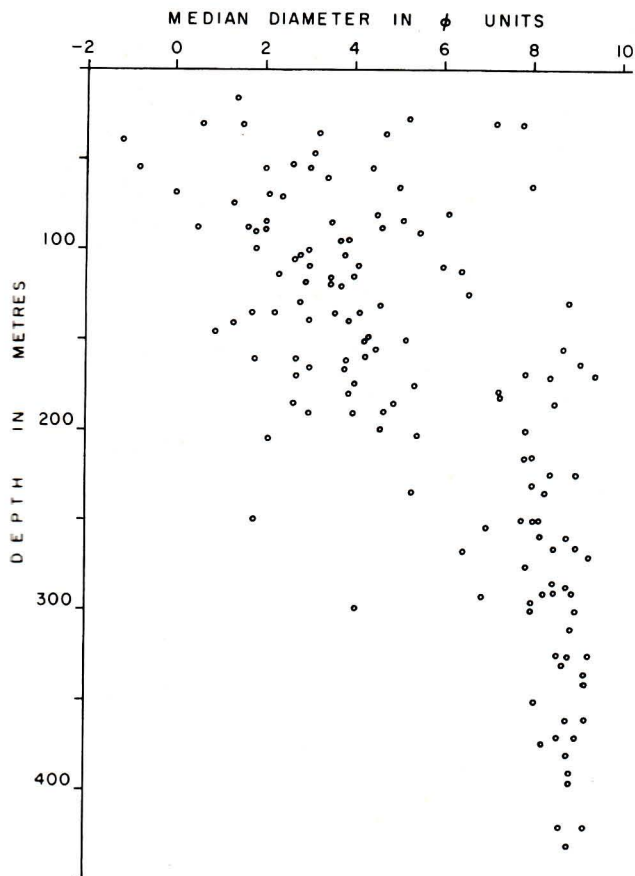
FORAMINIFERA

Introduction

As Cushman and Todd (1947) have pointed out, the foraminiferal fauna of the region is remarkable for the small number of species dominating the fauna. Of

the 83 species recorded in the present study the most abundant are *Cassidulina limbata*, *C. californica*, *Elphidiella nitida*, *Elphidium clavatum*, *E. subarcticum*, *Buccella* spp. (including *Buccella frigida*, and *B. tenerrima*), *Cibicides lobatulus* and *C. fletcheri*. These nine species comprise over 70 percent of the calcareous foraminifera. The commonest arenaceous species are *eggerella advena*, *Adercotryma glomerata*, *Ammotium planissimum*, *Spiroplectammina biformis*, *Recurvoides turbinatus* and *Trochammina* spp. As would be expected in a nearshore area, planktonic foraminifera are extremely rare and have been encountered in only five samples. The percentage frequency of all species identified from each station is shown in table 2.

The chief feature of the foraminiferal distribution is the marked change in faunal composition off the Fraser River delta. To the south arenaceous foraminifera constitute less than 15 percent of the fauna and the total number of foraminifera averages over 3000 specimens per sample. North of the Fraser River delta the faunal assemblage is predominantly arenaceous and consists, usually, of fewer than 100 speci-



TEXT FIGURE 6

Diagram showing relationship between depth and median diameter of sediments.

mens per sample. This change occurs in a transitional zone about ten nautical miles in width.

Within the two areas thus defined nine faunal subdivisions may be recognised. The areal distribution of each fauna is shown in text figure 7(d) and a composite frequency diagram showing the change in the faunas throughout the region is given in text figure 8. The southern area contains six subdivisions and there are three in the northern area. Four of these subdivisions include 77 percent of the stations examined and cover the major part of the region.

Much of the Juan de Fuca Strait is occupied by a fauna in which *Cassidulina limbata* is the dominant species (fauna A1). This fauna gives place immediately south of the San Juan Archipelago to one characterized by *Elphidium clavatum* and *Elphidiella nitida* (A4). The *Elphidium* - *Elphidiella* fauna extends north towards the Fraser River delta where a transitional fauna (A5) passes into the predominantly arenaceous assemblage (B1) which occurs over most of the Strait of Georgia. *Recurvoides turbinatus* and *Elphiophragmoides neobradys* are the characteristic species in this fauna.

The remaining five faunas cover only a small total area. In the western Juan de Fuca Strait two faunas occur north of the *C. limbata* fauna, which here occupies the south side of the strait. A fauna with *C. californica* (A2) is present in the centre of the strait and on the north side an arenaceous fauna (A3) is found

with *Psammatomendron arborescens* as a characteristic species. Another arenaceous fauna (A6) exemplified by only one station occurs south of Orcas Island in the San Juan Archipelago.

Two more faunal assemblages are found in the north-west part of the Strait of Georgia. Southeast of Cape Lazo, on the Cape Lazo - Lasqueti Island ridge, a fauna with abundant *Eggerella advena* is present (B2); to the north, off Cape Mudge, a poorly defined fauna occurs in which calcareous species, especially *Cibicides lobatulus*, are common (B3).

Number of Foraminifera (text figure 7a)

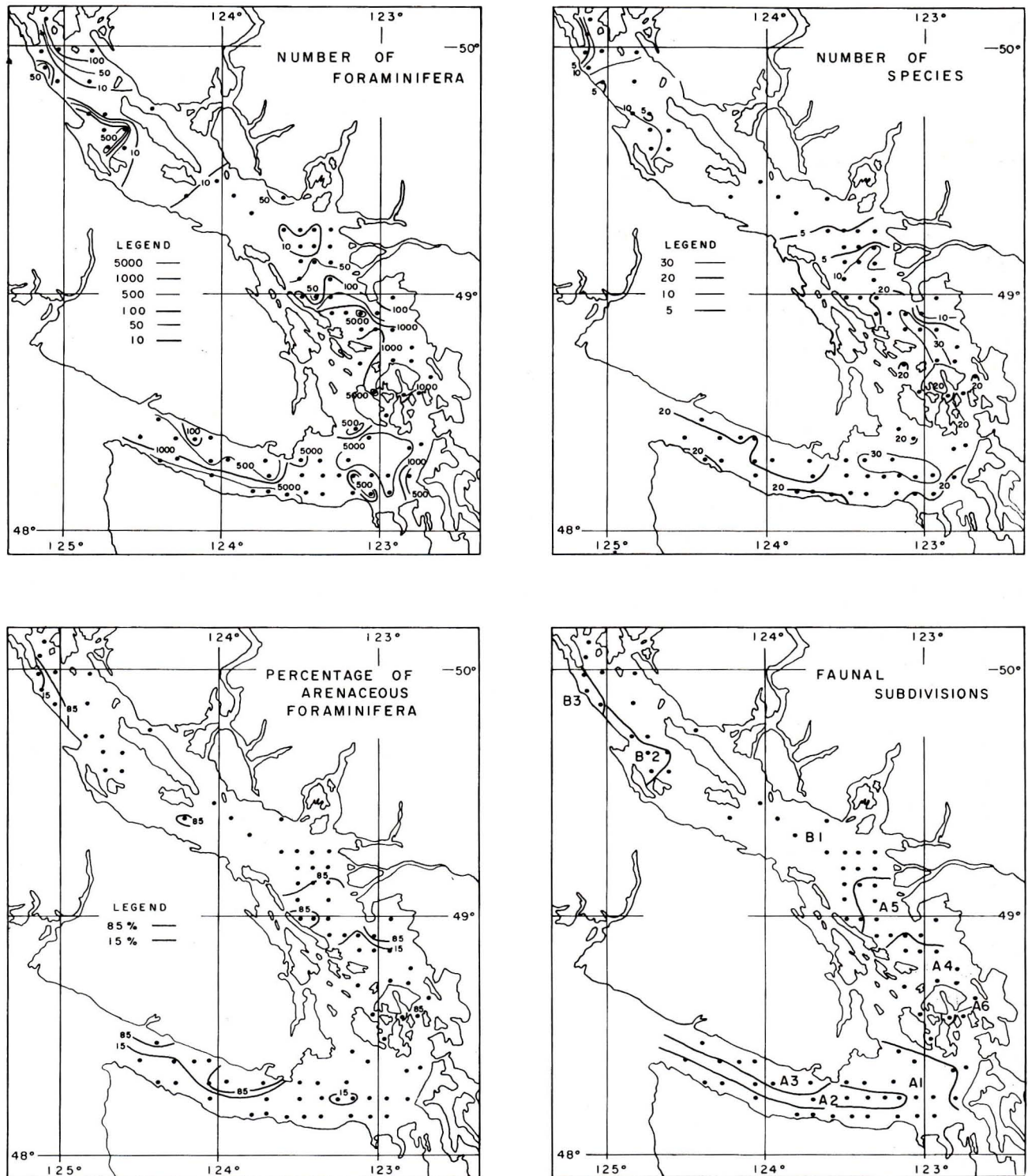
The number of foraminifera per sample exceeds 5000 and attains a maximum value of 23000 on the south side of the Juan de Fuca Strait. Over 5000 specimens per sample are also present in the centre of the eastern Juan de Fuca Strait. In the western portion of this strait numbers drop off from south to north and there are two small areas in the eastern strait with less than 500 specimens per sample. Around the San Juan Archipelago the numbers are fairly high, between 1000 and 8000. There seem to be higher numbers of foraminifera in Rosario Strait as compared with Haro Strait, judging from the limited number of samples. North of Orcas Island the average number of foraminifera per sample is 3000, reaching over 10,000 at station 167. Off the Fraser River delta the number decreases very sharply until less than 100 foraminifera per sample are found. These low values characterize most of the Strait of Georgia except for two areas. In the extreme north up to 300 foraminifera per sample are present and southeast of Cape Lazo the numbers increase to over 500.

Number of Species (text figure 7b)

The number of species per sample follows the variation in the number of foraminifera fairly closely. In the Juan de Fuca Strait it is about 25. The number decreases from south to north across the western strait and again off the Fraser River delta. There are two main areas with high numbers of species; south of the San Juan Archipelago and south of the Fraser River delta; in both areas the number is over 30. The former area corresponds to a large number of foraminifera whereas the latter area does not show such a good correlation. Over most of the Strait of Georgia the number of species is low, between five and ten. These values rise to over ten at the northern end of the strait and southeast of Cape Lazo.

Percentage of Arenaceous Foraminifera (text figure 7c)

Almost the whole region south of the Fraser River has less than 15 percent of arenaceous foraminifera per sample. On the north side of the western Juan de Fuca Strait the percentage increases to over 85 and



TEXT FIGURE 7

Distribution maps of (a) number of foraminifera, (b) number of species, (c) percentage of arenaceous foraminifera and (d) faunal subdivisions.

one sample from south of Orcas Island contains an entirely arenaceous fauna. North of the delta the percentage rises to over 85 and is usually 100. In the northwest part of the Strait of Georgia the arenaceous foraminifera decrease in frequency and are even absent from one station.

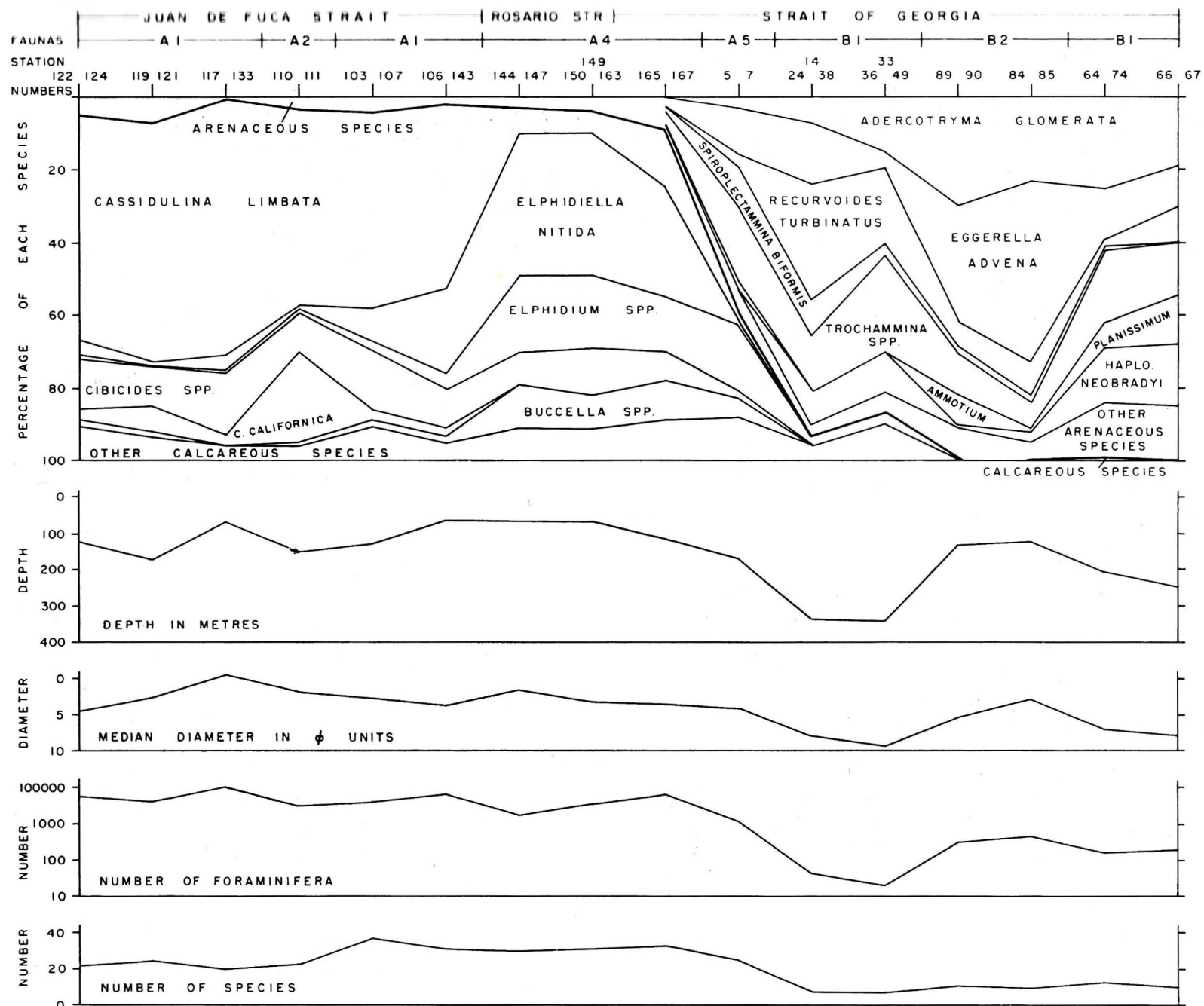
DESCRIPTION OF THE FAUNAS

Table 3 shows the average composition of each fauna together with some data on depth and sediments. This is also presented diagrammatically in text

figure 13. Frequency distribution maps for some of the more important species in these faunas are to be found in text figures 9, 10 and 11.

A. Southern Faunas

The predominantly calcareous faunas south of the Fraser River delta are characterized by high numbers of species and foraminifera. Of the arenaceous species present, *Psammotodendron arborescens*, *Gaudryina* spp., *Trochammina squamiformis* and *Trochammina?* sp. are found only in this area, whilst *Haplophrag-*



TEXT FIGURE 8

Frequency diagram showing the faunal change along a north-south profile through Juan de Fuca and Georgia straits.

TABLE 3

Average percentage frequency composition of each faunal subdivision.

	A1	A2	A3	A4	A5	A6	B1	B2	B3
Number of Stations	20	7	5	14	8	1	24	4	3
ARENACEOUS SPECIES	5	21	85	6	78	100	97	100	22
<i>Adercotryma glomerata</i>	0.1	0.1	4.5	0.2	1	2	21	18	..
<i>Alveolophragmium columbiense</i>	0.5	1.5	6.5	0.7	4	..	1.3	1.2	..
<i>Ammotium planissimum</i>	..	0.1	..	0.1	3	37	4	3	17
<i>Eggerella advena</i>	0.2	4	14	1	26.5	22	15	50	..
<i>Gaudryina</i> spp.	1.2	1.5	1.5	0.2	..	..	..	..	..
<i>Haplophragmoides neobradyi</i>	..	..	2	..	..	..	5	1	..
<i>Psammatodendron arborescens</i>	0.7	0.5	13.5	0.5	1	1	..	..	..
<i>Recurvoides turbinatus</i>	0.2	0.5	5	0.1	3.5	1	22	4.5	..
<i>Spiroplectammia biformis</i>	0.1	1	4.5	0.2	19.5	11	3	3.5	..
<i>Trochammina</i> spp.	1.2	6.5	27	2	16.5	14	13	11.5	2
Others	0.8	5.3	6.5	1	3	12	12.7	7.3	2
CALCAREOUS SPECIES	95	79	15	94	22	0	3	0	78
<i>Buccella</i> spp.	2	1.3	0.8	10.6	2.5	..	..	..	..
<i>Cassidulina californica</i>	2.5	19	..	0.1	..	..	..	..	..
<i>C. limbata</i>	57	41	2.5	13	2	..	0.1	..	12
<i>Cibicides fletcheri</i>	2	1	2	4	0.5	..	..	..	3
<i>C. lobatulus</i>	12	9	2	6	0.1	..	0.1	..	46
<i>Elphidiella nitida</i>	8	0.5	0.2	35	0.5	..	..	..	10
<i>Elphidium clavatum</i>	1	0.5	0.5	12.7	10	..	0.2	..	..
<i>E. subarcticum</i>	0.5	..	0.2	3	..	..	..	..	2
Others	10	7.7	6.8	9.6	6.4	..	2.6	..	5
Depth in metres	95	155	140	100	155	28	265	115	66
Number of foraminifera	5800	1340	420	3200	530	790	70	540	30
Number of species	24	21	17	26	15	14	8	11	6
Median diameter (ϕ)	2.2	2.6	3.8	2.5	5.5	5.2	8.0	3.2	..
Quartile deviation	1.9	2.4	1.2	2.1	1.6	1.6	1.7	0.9	..

moides neobradyi and *Reophax* spp. are of rare occurrence. *Cassidulina limbata* and *Elphidiella nitida* form nearly 50 percent of the calcareous fauna and seem to be inversely proportional to each other, *C. limbata* being more common in the south (A1) and *E. nitida* in the north (A4).

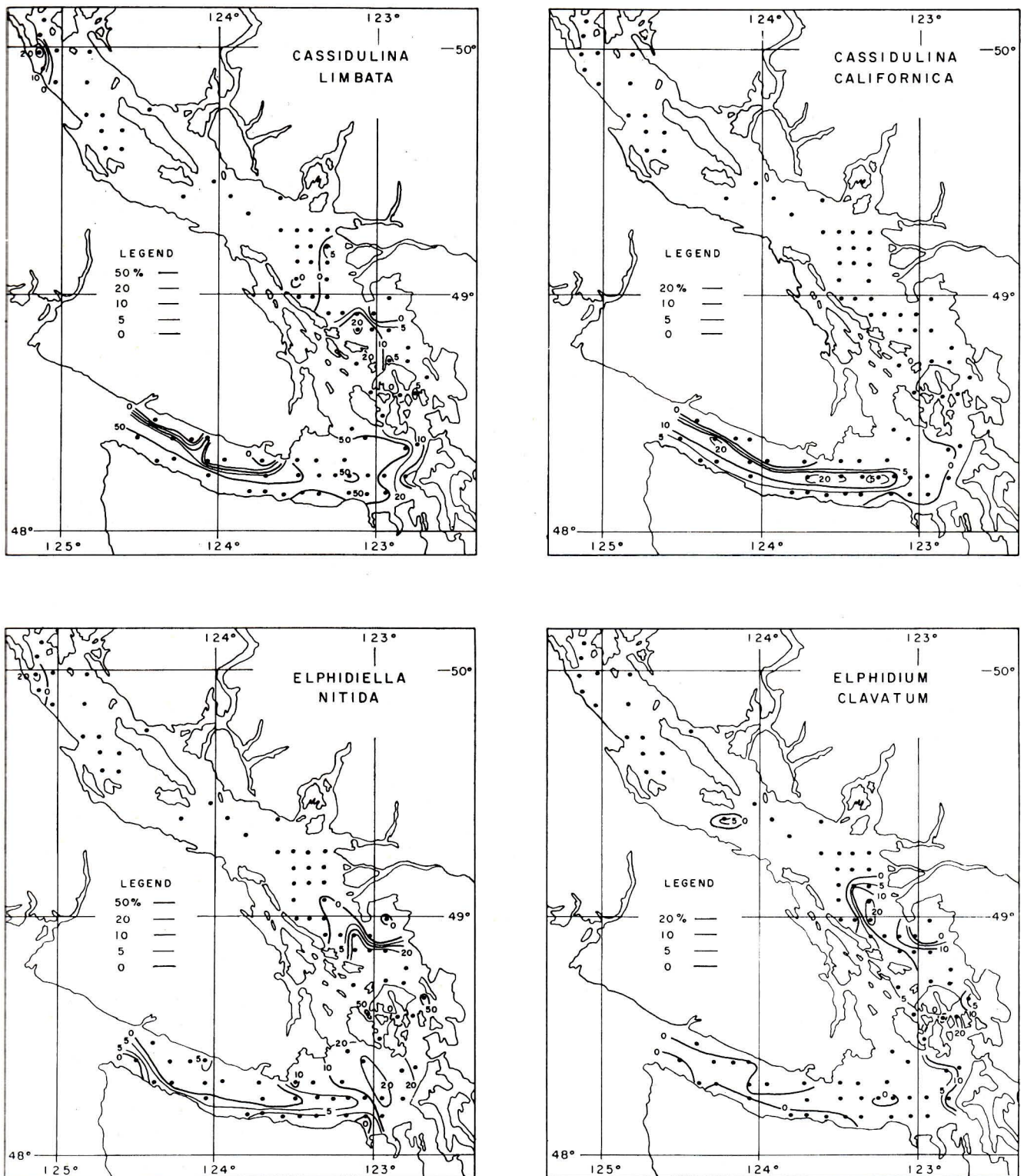
Fauna A1.—*Cassidulina limbata* is the most widespread calcareous foraminifer in the Juan de Fuca and Georgia Straits region and reaches its highest concentration in the southern straits. Fauna A1 contains an average of 57 percent of *C. limbata* (text figure 9a). *Cibicides lobatulus* and *Elphidiella nitida* with average percentages of 12 and 8 respectively are the next most common species. Amongst the rare species, *Poroepoides cribroropandus*, *Pseudononion auricula*, *Cassidulina depressa*, *C. tortuosa*, *Rosalina campanulata* and *Robulus* spp. are more or less restricted to this fauna. *Cassidulina californica* averages 2.5 percent in fauna A1; in contrast, fauna A2 which borders this assemblage in the western Juan de Fuca Strait contains 19 percent. Arenaceous species are not common and have an average frequency of 5 percent; *Psammatodendron arborescens*, *Gaudryina arenaria*, *G. subglabrata* (text

figure 10b) and *Trochammina pacifica* (text figure 10c) are the most frequently occurring.

The average number of foraminifera is 5800 and this is the highest value for all faunas. The mean depth is 95 metres which is the same as that of fauna A4. This is significantly shallower than faunas A2 and A3. Sandy sediments, with a median diameter averaging 2.2 phi are associated with this faunal assemblage.

The boundary between fauna A1 and the neighbouring ones is well defined. At the southern end of Rosario Strait the change in faunal composition from station 143 in the *C. limbata* fauna to station 144 in the *Elphidium* - *Elphidiella* fauna is very abrupt (see text figure 8). In the western Juan de Fuca Strait this fauna passes northwards into the *C. californica* fauna (A2) which in turn grades into fauna A3. The relationship among these three faunas is brought out in text figure 13b.

Fauna A2.—Although *C. limbata* is still the commonest species in this fauna, averaging 41 percent, *C. californica* reaches its greatest abundance here (19 percent, see text figure 9b). Arenaceous foraminifera make up 21 percent of the fauna and most of the are-



TEXT FIGURE 9

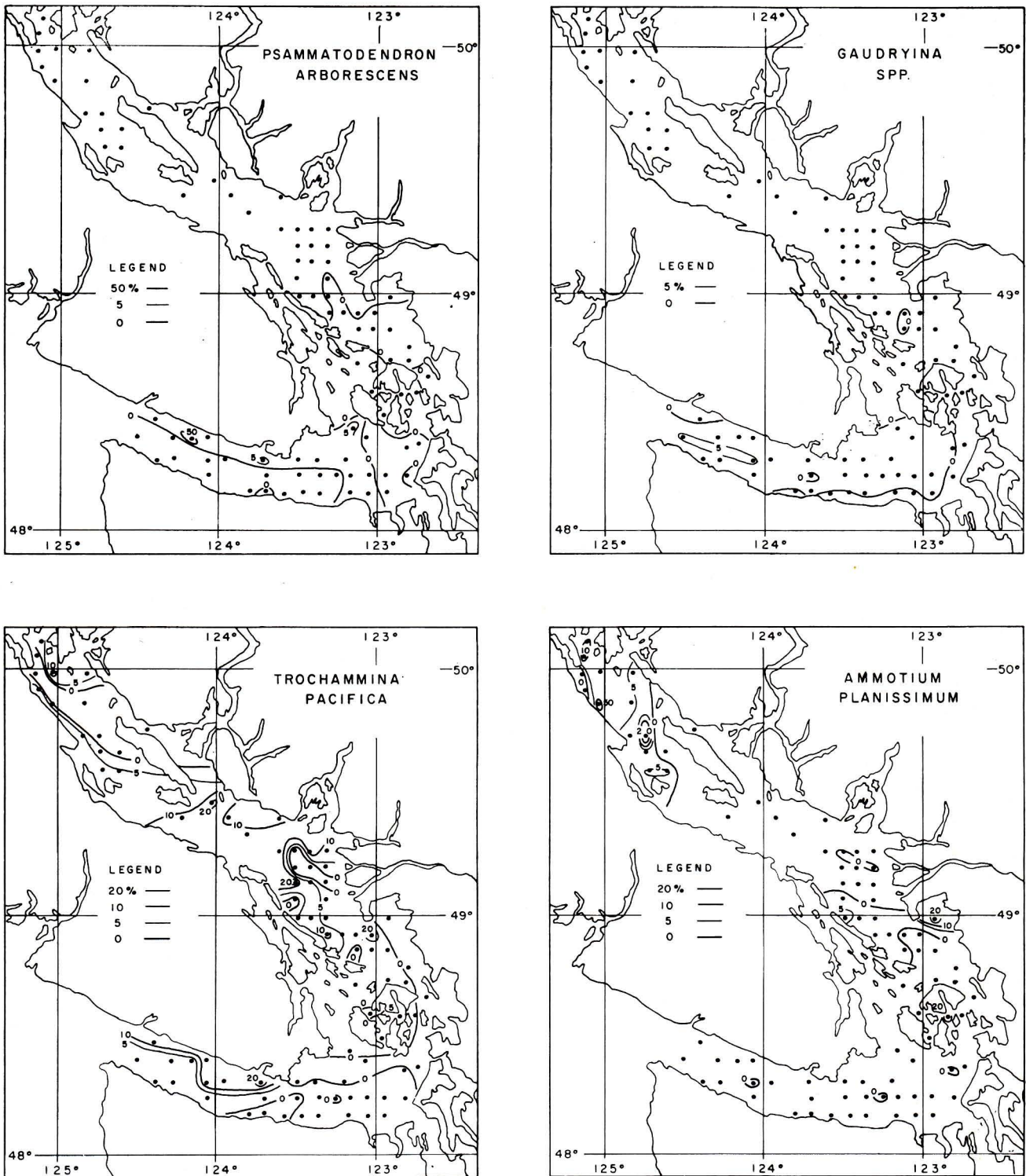
Distribution maps of (a) *Cassidulina limbata*, (b) *C. californica*, (c) *Elphidiella nitida* and (d) *Elphidium clavatum*.

naceous and calcareous species are intermediate in abundance between fauna A1 to the south and A3 to the north. *Globobulimina* and *Nonionella* are rare, whilst *Fissurina*, *Robulus*, *Rosalina* and miliolids are absent. *Trochammina* and *Eggerella* are the most abundant arenaceous genera.

The average depth of this fauna is 153 metres making this the deepest calcareous fauna in the region. The number of foraminifera, 1340, is somewhat lower than in the other southern faunas. As in the previous fauna the sediments are sandy, the average median diameter being 2.6 phi.

Fauna A3.—Arenaceous foraminifera average 85 percent in this fauna; the most abundant species are *Trochammina pacifica*, *T. discorbis*, *Eggerella advena*, *Psammatodendron arborescens* (text figure 10a) and *Alveolophragmium columbiense*. This is the only fauna in the southern area to contain *Haplophragmoides neobradyi*. *Cassidulina limbata* and *Cibicides* spp. are the commonest calcareous species. Lagenids, *Rosalina* and *Robulus* are absent, and miliolids are rare.

The average depth of 140 metres is similar to that of the previous fauna. The number of foraminifera has an average value of 420. Slightly fine sediments with



TEXT FIGURE 10

Distribution maps of (a) *Psammotodendron arborescens*, (b) *Gaudryina* spp., (c) *Trochammina pacifica* and (d) *Ammotium planissimum*.

an average grain size of 3.8 phi are present with this assemblage.

Fauna A4.—In this fauna *Elphidiella nitida* (text figure 9c) replaces *C. limbata* as the commonest species and has an average frequency of 35 percent. *Elphidium clavatum* (text figure 9d), *E. subarcticum*, *Buccella* spp. and *Cibicides fletcheri* which occur rarely in the *C. limbata* fauna are more common in this fauna. *Bolivina compacta* is more or less restricted to fauna A4. *C. californica* has been found in low frequencies at only two stations. As mentioned previ-

ously, several species found in fauna A1 are absent from the *Elphidium* - *Elphidiella* fauna, for example *Cassidulina tortuosa*, *Poroeponides cribroropandus* and *Rosalina campanulata*. Arenaceous foraminifera comprise 6 percent of the fauna. *Trochammina* spp., *Eggerella advena*, *Alveolophragmium columbiense* and *Psammotodendron arborescens* are the commonest species.

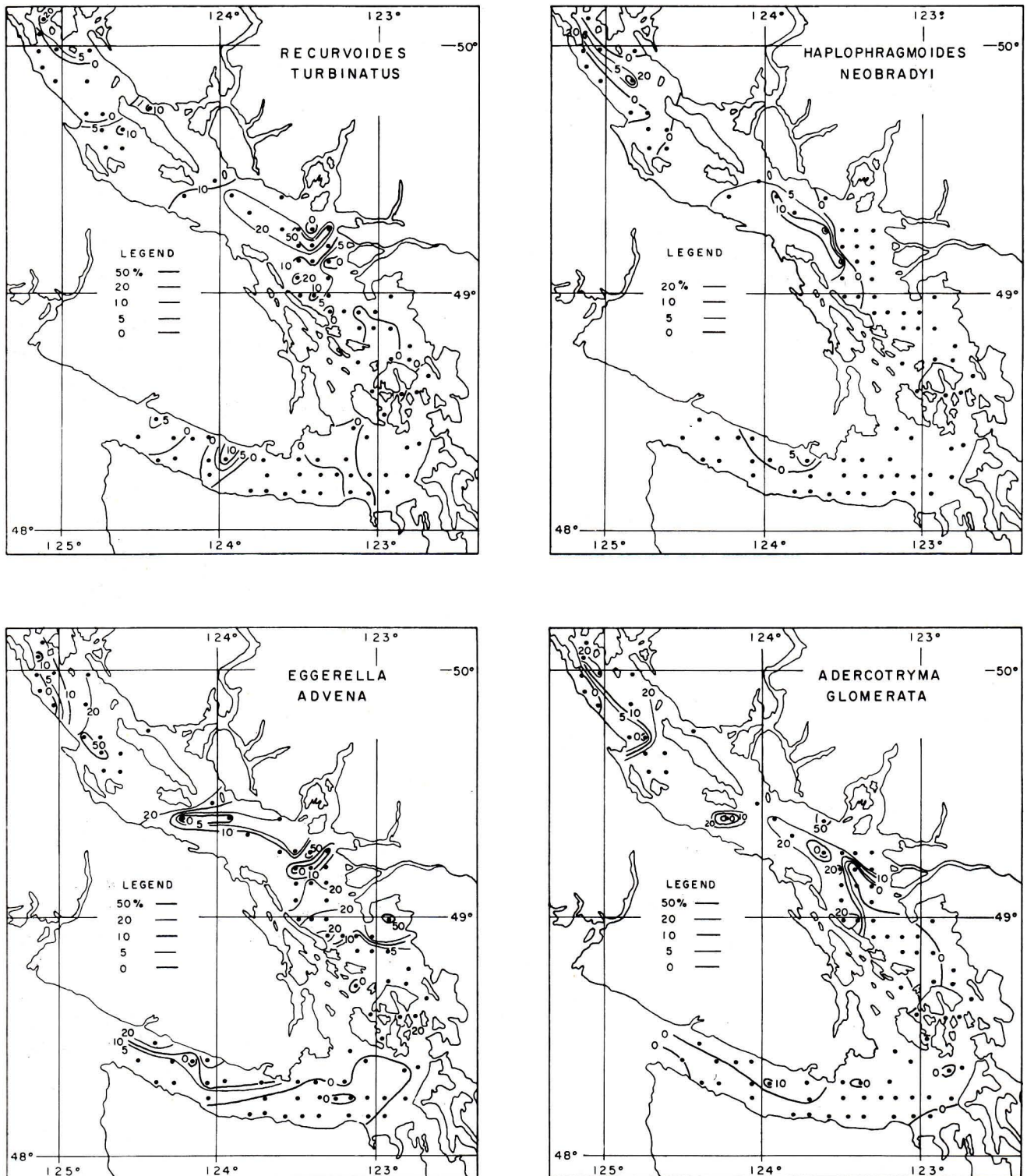
The number of foraminifera is high, averaging 3200. This is somewhat lower than in the *C. limbata* fauna. It is of interest that despite this the number of species here averages 26 as compared with 24 in the *C. lim-*

bata fauna. The mean depth is 100 metres and the grain size averages 2.5 phi.

To the south, the junction with the *C. limbata* fauna is quite sharp. On the northern side a transitional zone may be recognized between this fauna and the *Recurvoides* - *Haplophragmoides* fauna of the Strait of Georgia.

Fauna A5.—In consequence of the transitional nature of the fauna, the boundaries of this area are not well defined. They have been arbitrarily drawn, on the south side along the 15 percent arenaceous foraminifera

isopleth and on the north side at the limit of *Elphidium clavatum*. This is the commonest calcareous species in the transition zone and makes up 10 percent of the fauna. Arenaceous foraminifera predominate and average 78 percent. *Eggerella advena* and *Spiroplectammina biformis* are more common here than in the fauna to the north whilst *Adercotryma glomerata* and *Recurvoides turbinatus* are less common. *Psammotendron arborescens* does not extend north of this area. In depth, number of foraminifera and sediment grain size this fauna is intermediate between those on the north and south sides.



TEXT FIGURE 11

Distribution maps of (a) *Recurvoides turbinatus*, (b) *Haplophragmoides neobradyi*, (c) *Eggerella advena* and (d) *Adercotryma glomerata*.

Fauna A6.—One station (number 173) just south of Orcas Island in the San Juan Archipelago has a purely arenaceous fauna with *Ammotium planissimum* (text figure 10d) as the commonest species followed by *Eggerella* and *Trochammina*. The number of foraminifera is 790 in this sample. Depth and sediment grain size make this fauna unique in the region. The assemblage occurs in extremely shallow water (28 metres) and the sediment is a clayey silt with a median diameter of 5.5 phi.

B. Northern Faunas

Calcareous foraminifera are uncommon in the area north of the Fraser River delta, except in fauna B3. Most of the arenaceous species reach their maximum percentage frequency here although in terms of total numbers they are less common than in the southern faunas. Only five arenaceous species found in the south are absent from the northern faunas, namely *Psammotodendron arborescens*, *Gaudryina arenaria*, *G. subglabrata*, *Trochammina squamiformis* and *Trochammina? sp.*; *Trochammina charlottensis* and *T. nana* are very rare. *Recurvoides turbinatus*, *Haplophragmoides neobradyi*, *Adercotryma glomerata* and *Eggerella advena* reach their highest frequencies in these northern faunas.

Fauna B1.—This fauna occupies most of the Strait of Georgia. The average percentage of arenaceous foraminifera is 97 although at many stations there are no calcareous foraminifera. *Recurvoides turbinatus* (text figure 11a) and *Haplophragmoides neobradyi* (text figure 11b) are characteristic of this fauna. The former species is the most abundant one in the area, averaging 22 percent, followed by *Adercotryma glomerata* (21 percent; text figure 11d), *Eggerella advena* (15 percent; text figure 11c) and *Trochammina* spp. (13 percent; text figure 10c). *H. neobradyi* (5 percent) reaches its maximum abundance in this fauna. Calcareous foraminifera are very local in their occurrence and include *Cassidulina limbata*, *Cibicides lobatulus* and *Nonionella labradorica*. *Pseudopolymorphina charlottensis* occurs at stations 36 and 38, but the specimens are very badly worn and may be reworked.

The mean depth of the *Recurvoides* - *Haplophragmoides* fauna is 265 metres and the number of foraminifera averages 70. Very fine-grained silts and clays (median diameter averaging 8 phi) are found with this assemblage.

In the north of the Strait of Georgia (stations 62, 64 and 66) the number of foraminifera rises to over 300 and *Ammotium planissimum* becomes very common. These features suggest that further study may show this area to contain a distinct fauna.

Fauna B2.—*Eggerella advena* forms 50 percent of this fauna, which is entirely arenaceous. Several species, for example *Adercotryma glomerata*, *Spiroplectammina bififormis* and *Trochammina* spp., are equally abundant in faunas B1 and B2. On the other hand

the frequencies of *Recurvoides turbinatus* (4.5 percent) and *Haplophragmoides neobradyi* (1 percent) are much lower than in the previous faunal assemblage.

The number of foraminifera averages 540, an increase over the neighbouring fauna. A mean depth of 115 metres and an average grain size of 3.2 phi are further contrasts with assemblage B1.

Fauna B3.—This fauna is based on three stations, each with a very small number of foraminifera (average value 30) but it presents some striking differences from the surrounding arenaceous faunas. Calcareous foraminifera make up 78 percent of the assemblage, the commonest species being *Cibicides lobatulus* (46 percent) and *Elphidiella nitida* (10 percent). *Ammotium planissimum* with an average frequency of 17 percent is the most abundant arenaceous species. The dominance of calcareous foraminifera is, at first sight, remarkable in this area. Fauna B3 occurs in shallow water, the mean depth being 66 metres. No sediment analyses are available for these stations; the foraminifera are found in a fairly coarse sand.

FACTORS AFFECTING THE FORAMINIFERAL DISTRIBUTION

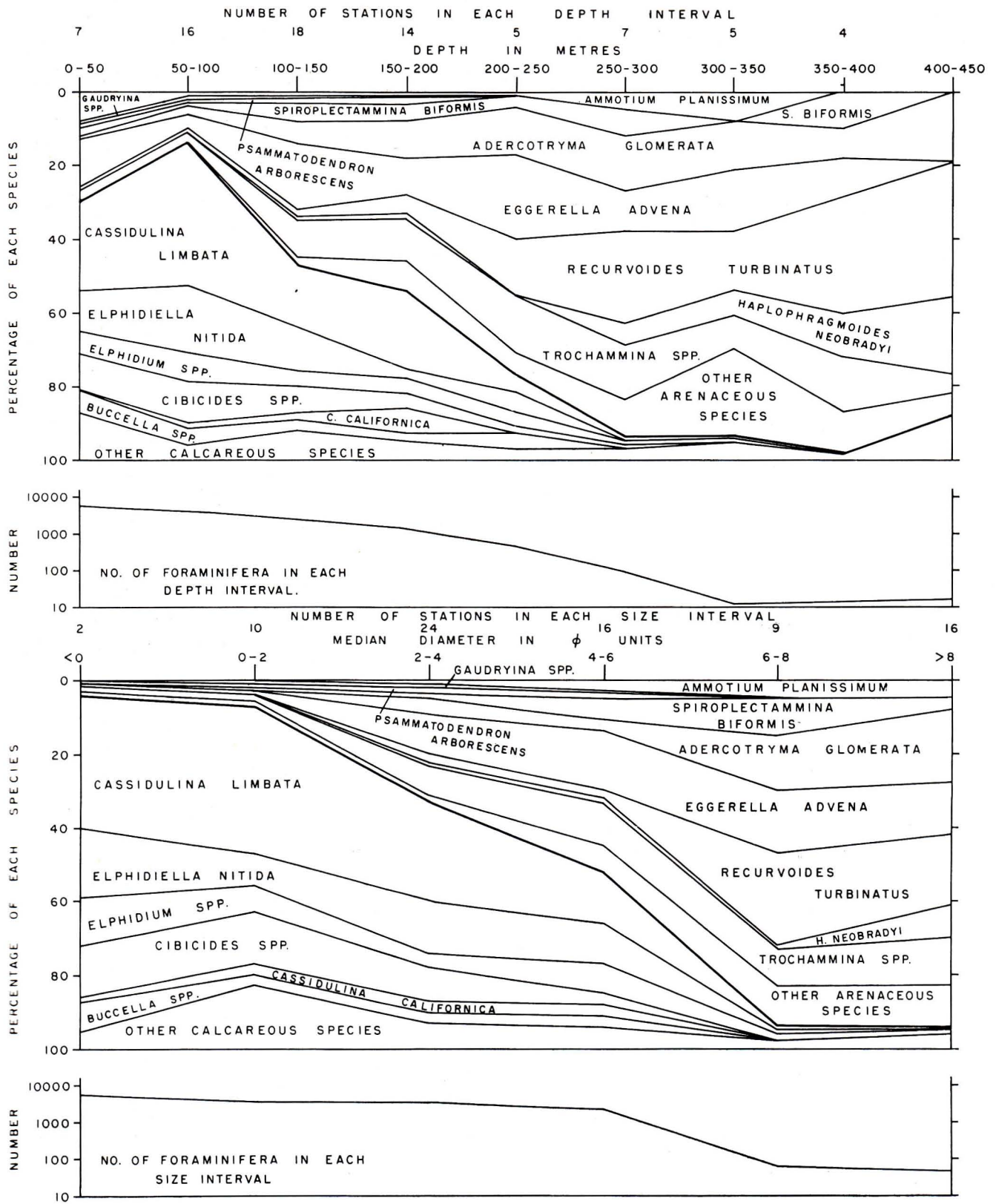
In examining possible factors bearing on the distribution of foraminifera in the region, it must be borne in mind that total populations were studied and these do not necessarily correspond with the living populations either in numbers or relative proportions of the species. The factors which will be considered are depth, type of sediment, temperature and salinity, and geography of the region.

Depth

Depth and median diameter of the sediments are fairly closely related in this region (text figure 6) but it is useful to consider them separately. The percentage frequency distribution of the most commonly occurring species is plotted against depth in text figure 12(a); the average number of foraminifera in each depth interval is also shown.

The total number of foraminifera drops off with increasing depth as does the percentage of calcareous species. Nearly all the calcareous foraminifera show a decreasing frequency with increasing depth and rarely occur below 250 metres, for example *Cassidulina limbata* and *Elphidiella nitida*. However, the percentage frequency of *C. californica* increases with depth, reaching a maximum between 150 and 200 metres. *Elphidium* spp. decrease slightly with depth but continue to greater depths than most other calcareous species.

In general the arenaceous foraminifera increase in frequency with depth. An exception is in the 0 - 50 metre interval where they form 25 percent of the total, this large value being due to a high percentage of *Ammotium planissimum* and *Eggerella advena*, chiefly at two stations in this depth range. Since the 400 - 450 metre interval is represented by only one station, too much attention need not be paid to the increase in



TEXT FIGURE 12

Frequency diagrams showing the relationship of foraminifera to (a) depth and (b) median diameter of sediments.

calcareous foraminifera at this depth (see below). Arenaceous species showing a good correlation with depth are *Adercotryma glomerata*, *Haplophragmoides neobradyi* and *Recurvoides turbinatus*. *Gaudryina* spp. and *Psammatodendron arborescens* are exceptional amongst the arenaceous foraminifera in that they are not found below 200 metres.

The depth distribution of total foraminiferal populations may be influenced, to some extent, by the dis-

placement of species from shallow to deep water. In this region the area most likely to contain displaced foraminifera is the Strait of Georgia for it is here that steep slopes are present. Displacement has possibly occurred in the transitional zone (A5) where the depth increases fairly rapidly. The presence of calcareous species in the deeper portions of the Strait of Georgia may be due, in part, to their downward displacement from the south. It is probably significant

in this connection that nearly all the deep stations containing calcareous foraminifera are at the southern end of the strait, adjacent to the dominantly calcareous faunas.

Sediments

A frequency distribution diagram similar to that used in discussing depth has been drawn with percentage frequency of foraminifera plotted against median diameter (text figure 12b). The average number of foraminifera in each class size is also given. The picture that emerges resembles that described for the depth distribution, as might be expected. Total number of foraminifera decreases and percentage of arenaceous foraminifera increases with decreasing grain size. There is no obvious correlation between grain size and the calcareous foraminifera beyond a gradual decrease in frequency down to less than 6 percent at 6 phi median diameter. Arenaceous foraminifera on the other hand show a slightly better correlation. *Ammotium planissimum* reaches its maximum frequency in fine-grained sediments of 6 phi and larger median diameters; its distribution now has only one peak as opposed to two when plotted against depth. Three species, *Adercotryma glomerata*, *Haplophragmoides neobradys* and *Recurvoides turbinatus* have their maximum frequency distribution in fine sediments. *Gaudryina* spp. and *Psammotodendron arborescens* are not found in sediments finer than 6 phi in median diameter.

Temperature and Salinity

It was suggested in a previous section that the region could be broadly divided into three areas on the basis of the temperature and salinity of the bottom water. In the Juan de Fuca Strait where the temperature and salinity are approximately 7°C and 34 parts per thousand respectively the *Cassidulina limbata* fauna (A1) is well developed. Fauna B1, the *Recurvoides* - *Haplophragmoides* assemblage, is typical of the Strait of Georgia in which the temperature is above 8°C and the salinity 31 parts per thousand or less. Both areas are subject to only small changes in these properties. The *Elphidium* - *Elphidiella* fauna (A4) and, to a lesser extent, the transitional fauna (A5) occupy the intervening area where the seasonal variation in temperature and salinity is from 7.5°C to 9°C and 31 to 33.5 parts per thousand.

Geography

By "geography" is meant the position of the region with respect to neighbouring areas which may be of importance in the case of fauna B3. This predominantly calcareous fauna is isolated from the southern calcareous assemblages by the arenaceous faunas in the Strait of Georgia, but connects northwards via Discovery Passage and Johnstone Strait with Queen Charlotte Strait. The fauna of the latter area has been examined on a reconnaissance basis and is a calcareous one, resembling fauna A1 in many respects, although *Nonionella* and *Elphidium* are more common in Queen

Charlotte Strait. It is possible that fauna B3 represents an invasion of the Strait of Georgia from the north through Johnstone Strait.

POSSIBLE CAUSES OF THE FAUNAL DISTRIBUTION

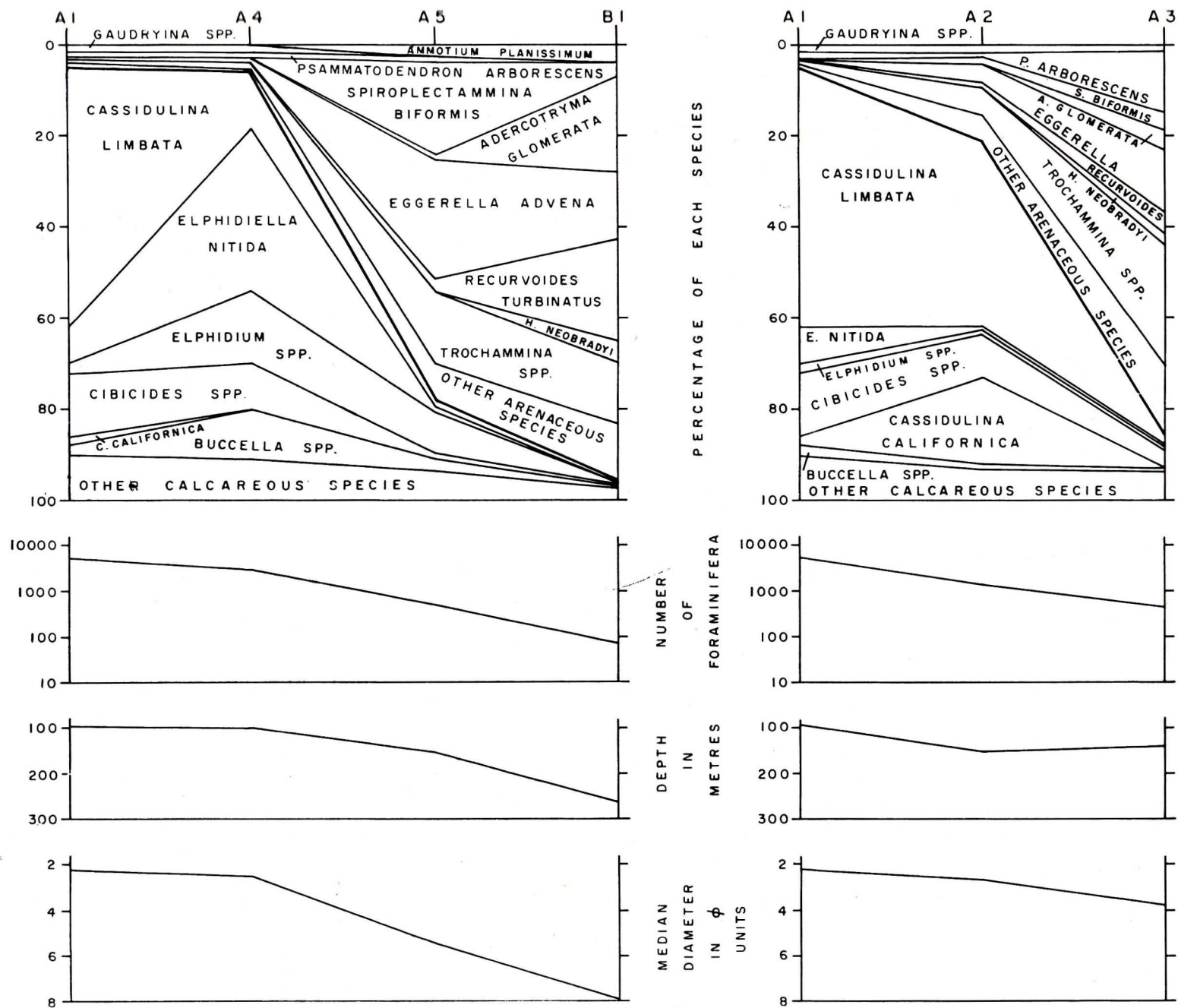
Utilizing the evidence summarized in the previous paragraphs, it is possible to suggest reasons for the faunal differentiation observed in the Juan de Fuca and Georgia Straits. Comparison of the frequency distribution diagrams plotted for depth and median diameter (text figure 12a and 12b) with one showing the average composition of the four main faunas, A1, A4, A5 and B1 (text figure 13a) is instructive. The latter figure may be regarded as a profile through the region from the southern seaward end to the northern semi-enclosed Strait of Georgia. Although more stations have been considered in constructing the depth and median diameter diagrams than are included in the faunal section, the three diagrams are broadly comparable. The frequency diagrams all bring out the change from southern to northern faunas but only in the faunal section is the change from A1 to A4 shown. This suggests that factors other than depth and sediment type must be taken into account in order to explain the latter change. The fact that only the faunal section shows the two major changes, from A1 to A4 and from A5 to B1, seems to indicate that distance from the open sea—and hence physical oceanographical characteristics—is the most important factor affecting the distribution. Since depth in general also increases in the same sense this may be a contributory factor, at least in accounting for the differences between the northern and southern faunas. The sediment distribution in this region is probably controlled mainly by depth of water, particularly in the Strait of Georgia, and the relationship between foraminifera and sediments may be more apparent than real. Each fauna will be discussed separately with reference to these factors.

Fauna A1

The *Cassidulina limbata* fauna is probably distinct from the *Elphidium* - *Elphidiella* fauna because of temperature and salinity differences in the areas inhabited by these faunas. Possibly this fauna cannot tolerate the wider seasonal range of temperature and salinity present in the waters around the San Juan Archipelago and therefore does not extend north of the eastern Juan de Fuca Strait.

Fauna A2

Two features stand out in explaining the distribution of this fauna. The first is the abundance of *Cassidulina californica* and the second is the transitional nature of most of the species frequencies between fauna A1 to the south and A3 to the north. *C. californica* is the only calcareous foraminifer in the region showing a depth preference. It is probable that



TEXT FIGURE 13

Frequency diagrams showing the gross faunal change in (a) faunas A1, A4, A5 and B1; and (b) faunas A1, A2 and A3.

it is abundant in the centre of the Juan de Fuca Strait owing to the suitable depth of water existing there. The transitional elements of the fauna will be discussed in the next section.

Fauna A3

In average depth and median diameter of sediment this fauna agrees well with the previous one; probably therefore these factors have little or no bearing on the faunal distribution. Herlinveaux (1954) has shown that the flood tide is more pronounced on the southern shore of Juan de Fuca Strait whilst the ebb tide is concentrated on the northern shore; net outward transport is much greater on the north side. This probably has some effect on the foraminiferal distribution but precisely in what way is unknown. Possibly some sort of gradient is thereby maintained favouring arenaceous foraminifera on the north shore of the strait and calcareous species on the south. Fauna A2 will also be influenced by this gradient.

Fauna A4

The greater seasonal variation in temperature and salinity in this area may be preferential to *Elphidium* and *Elphidiella* and enable them to dominate the fauna here.

Fauna A5

This is the transitional zone between the southern and northern faunas. Besides occupying an intermediate position with respect to faunas A4 and B1, displaced foraminifera may also contribute towards the gradual but marked faunal change in this area.

Fauna A6

Calcareous foraminifera are absent from this assemblage. The one station on which fauna A6 is based is in shallow water with a mud bottom. It is possible that the muddy sediment has some influence on the establishment of the arenaceous species found here, in particular *Ammotium planissimum*.

Fauna B1

The change from the southern to the northern faunas first apparent in the transitional zone is completed here. This faunal change coincides with an increase in depth and a decrease in sediment grain size, combined with a higher temperature and a lowered salinity. In addition to the increased percentage of arenaceous species in the northern faunas the total number of foraminifera per sample falls to low values. These facts suggest that the environment in the Strait of Georgia basins is more restricting in its properties than that to the south. Which of the factors is most important in determining this faunal change is uncertain. Perhaps the rise in temperature associated with the increase in depth, which is not the usual condition in the open sea, controls the distribution of this faunal assemblage.

Fauna B2

The frequency diagrams referred to previously (text figures 12a and 12b) obscure the fact that whilst this fauna has a mean depth, and the associated sediments a median diameter, within the range found in the southern faunal assemblages, the composition of the faunas is very different. This need not invalidate any conclusions which may be drawn concerning the influence of depth and sediments on the faunas. B2 is a shallow-water area within the northern faunas and any modifications necessitated by the changed environment must be made on the surrounding B1 fauna. The source of calcareous foraminifera typical of this depth and median diameter range is to the south, across an intervening area covered by the B1 fauna, which presumably they cannot cross. The shallow depth of fauna B2 may favour the establishment of *Eggerella advena* and restrict the abundance of *Recurvoides* and *Haplophragmoides*.

Fauna B3

This faunal assemblage possibly represents an area populated from the Queen Charlotte Strait. Evidence from the southern faunas suggests that shallow water and a sandy bottom, both of which are present here, can support a calcareous fauna if the physical oceanographical conditions are right. The temperature and salinity relationships are not well known; Waldichuck (1957) points out that Discovery Passage is a region of mixing.

COMPARISON WITH CONTINENTAL TERRACE FAUNAS

General trends in the foraminiferal distribution on the continental terrace have been summarized by Bandy and Arnal (1960), Phleger (1960) and for the west coast of North America by Natland (1957). It appears that the number of benthonic individuals and species increases with depth and distance away from shore, reaching maximum values beyond the edge of the continental shelf. In the Juan de Fuca and Georgia straits the converse is true, the number of foraminifera and species decreasing with increasing depth. As Bandy and Arnal (1960) have pointed out a similar decrease occurs below sill depth in enclosed basins; in some respects the Strait of Georgia may be so regarded.

Natland (1957) recognizes two main faunas in waters above 50 metres depth. *Elphidium* spp., *Elphidiella hannai* and *Buccella frigida* characterize the 0 - 40 metre interval and below this another fauna with *Cassidulina limbata*, *C. tortuosa*, *C. californica*, *Eponides repandus* and *Polymorphina charlottensis* is found. These two faunas approximately correlate with faunas A4 and A1 respectively. In this region depth does not appear to be a controlling factor in their differentiation, and temperature and salinity differences may be more important. Data presented by Natland show that the *Elphidium* fauna is associated with a higher mean temperature and a greater seasonal range

than the *Cassidulina limbata* fauna. This is also found to be the case with faunas A4 and A1 although the mean temperatures are lower and the seasonal ranges much smaller.

Continental terrace faunas below 250 metres are not well known from Canadian waters; farther south various species of *Bulimina*, *Bolivina*, *Uvigerina*, *Virgulina* and *Valvulineria* are abundant at these depths (Natland, 1957). Thus the deeper water arenaceous fauna of the Strait of Georgia has no counterpart in the depth zonation on the continental terrace. This is probably because the fauna is a somewhat modified one in the sense that it is adjusted to the special conditions existing in the strait.

SUMMARY AND CONCLUSIONS

The sediment distribution in the region is closely related to depth, the deeper basins in the Strait of Georgia being floored by fine silty clay whilst the Juan de Fuca Strait contains sandier material.

A marked faunal break off the Fraser River delta enables two main divisions to be recognized. The southern fauna contains large numbers of chiefly calcareous foraminifera; the northern fauna is predominantly arenaceous and consists of few foraminifera per sample. Further subdivisions, on the basis of dominant species, are possible, the most important and widespread being the southern *Cassidulina limbata* and *Elphidium* - *Elphidiella* faunas and the northern *Recurvoides* - *Haplophragmoides* fauna.

Depth, median diameter of sediment and number of foraminifera are apparently related although the relationship between sediment and foraminifera may be fortuitous. The main causes of faunal differentiation in this region are probably depth, temperature and salinity. Depth may play a part in explaining the change from southern to northern faunas whereas temperature and salinity appear to be more important in the case of the *C. limbata* and *Elphidium* - *Elphidiella* faunas.

The evidence from one fauna (A6) suggests that grain size rather than depth may control the distribution of some arenaceous species. Another fauna (B3) possibly indicates that foraminifera from the Queen Charlotte Strait have found their way into the north of the region.

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261. THE LITTORAL FORAMINIFERAL BIOCOENOSES
OF PUERTO DESEADO (PATAGONIA, ARGENTINA)¹

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ABSTRACT

Foraminifera were examined from 42 bottom samples gathered in the intertidal zone in the vicinity of Deseado Harbor (Patagonia, Argentina). Forty-four species (among them 28 living) were identified. Some biological, zoogeographical and taxonomic conclusions have been drawn.

INTRODUCTION

The Patagonian coastline extends more or less meridionally from the mouth of the Colorado River (Lat. 40°S.) to the Strait of Magellan (Lat. 52°S.). The coastal organic life of this region has been little studied up to the present time. Several groups have not been investigated and some have been examined very briefly. The available data are scarce and incomplete. This refers also to the foraminifera. Only three papers deal with the littoral foraminifera of Patagonia: d'Orbigny (1839), Cushman and Parker (1931) and Boltovskoy (1954b).

d'Orbigny studied shore sand which he collected himself and anchor mud obtained by merchant ship captains from between the bay of San Blas and the Valdez Peninsula. He found and described 19 species in this area, all new. Cushman and Parker worked on bottom samples collected at anchorages in the harbors of San Julian and Puerto Deseado. They identified 10 species there. Boltovskoy furnished records of 104 species of foraminifera from San Blas Bay. Strictly speaking, all the samples listed, except those gathered by d'Orbigny himself, do not belong to the littoral zone, although they were taken quite near shore, since they came from below the lowest spring tides. Other papers on Patagonian foraminifera are not mentioned here since they deal with material from other parts of the shelf, at a considerable distance from shore.

The defect in all these investigations is that the foraminifera studied do not represent biocoenoses but thanatocoenoses. The technique for determining living specimens has been known for some time but only after the simplification proposed by Walton (1952) has it received general recognition and common usage. The material studied in the papers listed above was gathered without considering the possible separation of living specimens. These specimens were not studied at the time and cannot be separated in the stored material. Studying living specimens in Recent faunas is generally preferable and particularly so in the Patagonian area. Its shores are covered in many places by Quaternary transgressions and there are numerous

Quaternary terraces. Quaternary foraminiferal tests are washed out and redeposited on the present beaches. This phenomenon certainly can confuse the real character of biocoenoses since the transgression sediments contain some species which do not live on those parts of the shelf.

The aim of this study was:

- 1) to investigate for the first time the biocoenoses of the Patagonian littoral foraminifera;
- 2) to draw possible conclusions from biological, zoogeographical and systematic characters.

The present study should be considered as preliminary. The setting up of the new Marine Biological Station in Puerto Deseado has allowed us to begin the collection of material according to an integrated plan which will permit the study of the Patagonian foraminifera from various points of view.

DESCRIPTION OF THE AREA

Deseado Creek flows into the South Atlantic Ocean on the east coast of South America at latitude 47°45'S. and longitude 65°55'W. Its maximum depth near Deseado Harbor is about 3.5 m.

The harbor of Puerto Deseado is situated to the south of the city, about 3-4 km. from the ocean.

The area studied is characterized by a very large tidal range with amplitudes of nearly 6 m. The tidal currents are very strong. Their velocities in the middle of the creek are up to 10 km. per hour.

At the present time, there is little information on temperature and salinity. During 1960 and 1961, the staff of the Biological Station took measurements twice a day on water temperature at the surface in the vicinity of the station. The lowest temperature registered during this period was 3.8°C. (August, 1961) and the highest 14.5°C. (February, 1961). No sudden changes have been observed.

Salinity has been regularly determined since July, 1960, at three points: Cape of Cavendish, Biological Station, and Cañadon Torcido. The following extremes characterize them:

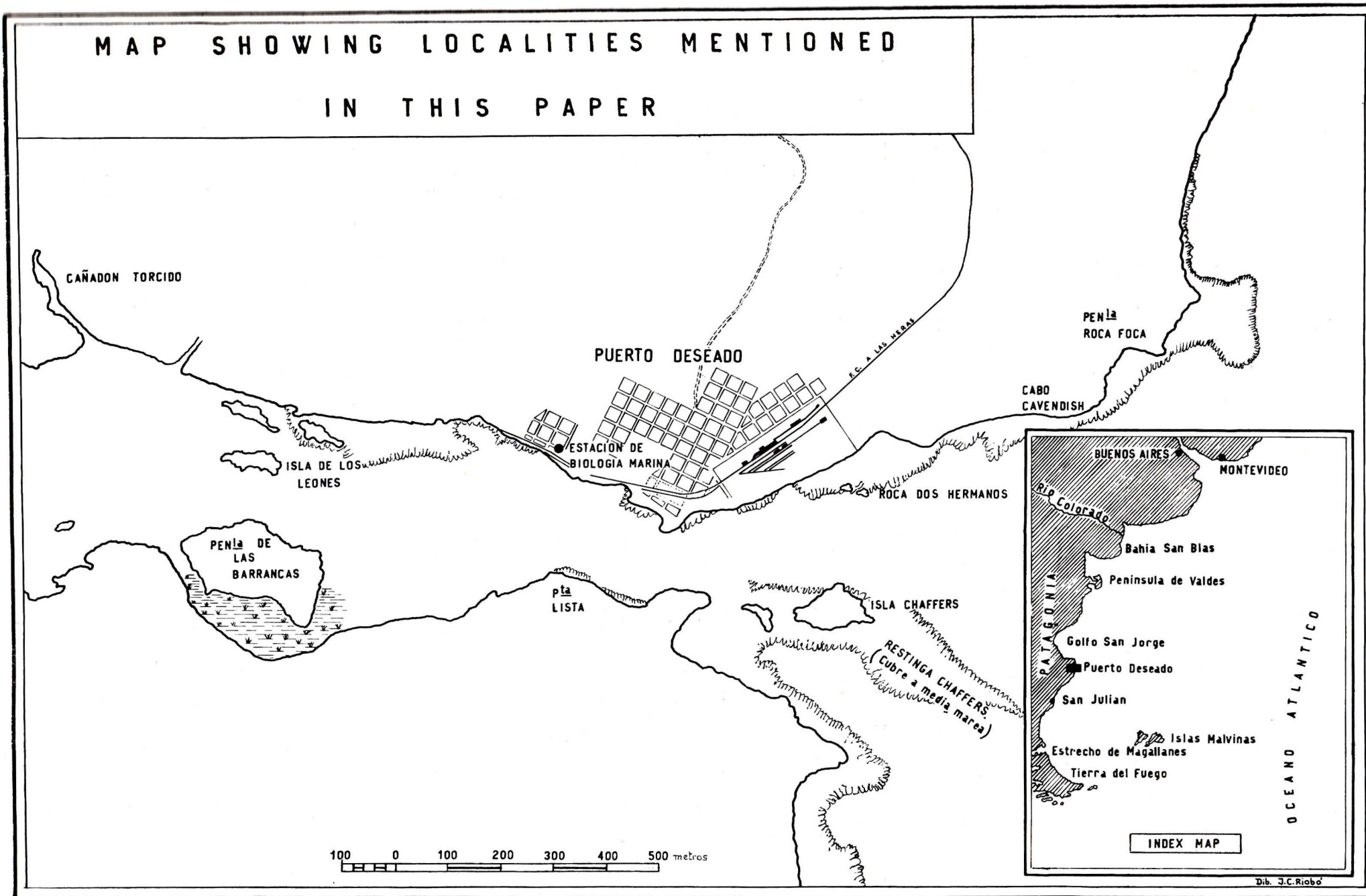
Cañadon Torcido:

- Minimum, 32.3 o/oo (high water, Sept., 1961)
- Maximum, 33.9 o/oo (high water, Dec., 1960)

Biological Station:

- Minimum, 32.4 o/oo (low water, Sept., 1961)
- Maximum, 33.7 o/oo (high water, Nov., 1960)

¹ This is Contribution no. 3 of the Puerto Deseado Marine Biological Station.



TEXT FIGURE 1

Cape of Cavendish:

Minimum, 31.82 o/oo (low water, Oct., 1961)

Maximum, 33.95 o/oo (high water, Dec., 1960)

Summarizing, we can conclude that neither temperature nor salinity is subject to great variations.

The temperature can be considered as typical of Subantarctic water. Antarctic water at the Antarctic Convergence in the warmest month, as a maximum, is 3.5°C. An upper limit of 14.5°C. is generally accepted for the Subantarctic water (although in some cases this can be considerably higher).

The salinity listed is typical of the coastal zone water. It is somewhat lower than that of the Subantarctic water (about 34-35 o/oo). Practically speaking, this salinity does not present any obstacle for the foraminiferal distribution. According to the classification of marine waters proposed by Remane (see Hiltermann, 1949), it represents the salinity of truly marine waters.

The sediments on the shores of the creek are composed chiefly of pebbles, but in some places the sediments are composed of sand, sandy silt or clayey mud.

MATERIAL STUDIED

The collections that form the basis of the present study were gathered at or near low tide level by using a sampling gear described by Shupack (1934). But since the tide varies greatly, all the collecting spots are not covered with water during the low water springs. On the other hand, many samples were taken in tidepools and small ponds situated among the rocks on the shore, somewhat higher than the height of the spring tide. They are never dry because they get sea water from time to time by means of storm surge and surf waves.

In the tidepools accessible to the sea, the water is typically marine. In the small ponds accessible only during gales, the salinity changes owing to evaporation or dilution by rainfall. Also, some chemical changes may take place because of the life activities of plants and animals. No special measurements were made to determine these changes. The foraminiferal fauna gathered in these pools and small ponds did not differ specifically from those encountered in the entire area. The single striking figure was the somewhat larger number of monstrosities. It is a well-known fact that chemical changes in the environment can cause abnormalities of the foraminiferal tests.

Thus, although the zone of collecting is littoral, it does not mean that all the places where foraminifera were gathered are dry at low tide.

A total of 42 samples was collected and studied. The average weight was 0.5 kg. Thanks are due to Sr. Pedro Medina of the Marine Biological Station of Puerto Deseado for his help in collecting the material studied.

The area covered by sampling comprised the follow-

ing places: the north side of Deseado Creek from Roca Foca Peninsula to Cañadon Torcido, corresponding to approximately 12 km. of shore line; on the south side of Deseado Creek from Restinga Chaffers to Las Barrancas Peninsula, corresponding to about 6 km. of shore line. The center of this region is situated just across Deseado Harbor. All these names are to be found on text figure 1.

METHOD OF STUDY

Neutralized formalin was added to the samples at the time of collection to preserve the foraminifera living at that time. On the same day, at the Biological Station, the samples were washed through a sieve with average openings of 0.074 mm. (U. S. Sieve Series Mesh, No. 200), processed with rose Bengal, the foraminifera picked out and examined while wet. It is important to study all the tests before the samples are dried because in so doing some of the species may be destroyed (Parker and Athearn, 1959).

It should be noted that many empty tests were also affected to some degree by the staining. Therefore, care must be exercised to distinguish the living specimens. There is further discussion of this subject below.

The preliminary study of the samples on the day of collection kept a close watch on the character of the material collected and, thus, guided the collecting program for the next day. Later, in the laboratory at Buenos Aires, all the specimens picked were restudied in greater detail.

SYSTEMATIC PART

The following section will be considered as briefly as possible to save space. All the generic and specific names are given alphabetically. Usually only the original reference is given in the synonymy but in a few cases others are included. No descriptions of the species are given and in the observations on morphology only the most striking and important features are included. Sometimes it has been found necessary to add brief notes on the systematics. Observations and conclusions other than those relating to the systematics are in a later section.

The following species have been found in the material studied:

1. *Bolivina compacta* Sidebottom, 1905. Plate 6, figure 2
1905 *Bolivina robusta* H. B. BRADY var. *compacta* SIDEBOTTOM, Delos, p. 15, pl. 3, fig. 7.
Some very rare isolated examples, among them only two living.
2. *Bolivina pseudoplicata* Heron-Allen and Earland, 1930. Plate 6, figure 4
1930 *Bolivina pseudoplicata* HERON-ALLEN and EARLAND, Plymouth, p. 81, pl. 3, figs. 36-40.
A single living specimen and rare dead specimens.
3. *Buccella frigida* (Cushman), 1921. Plate 6, figures 1, 5

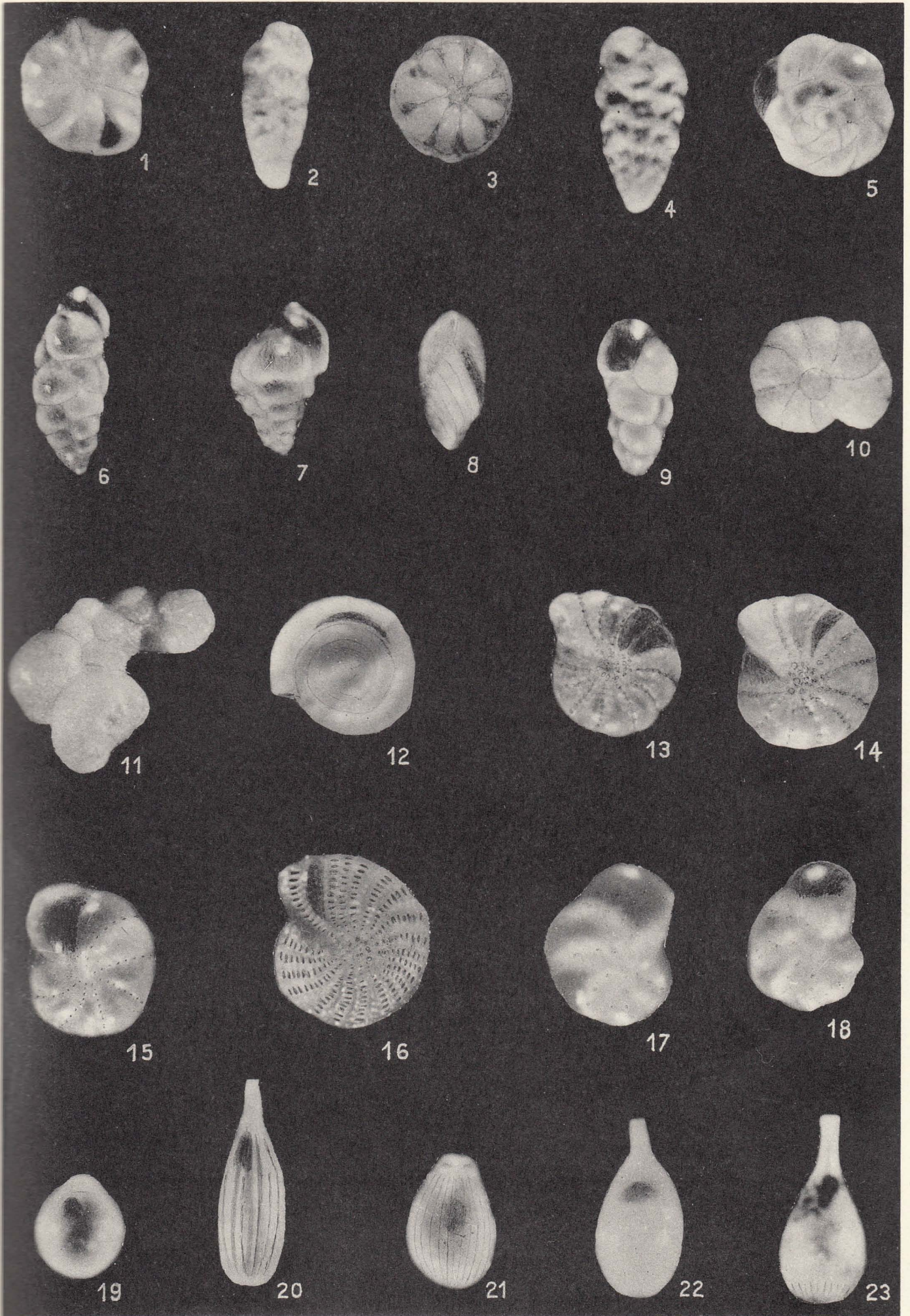
- 1921 *Pulvinulina frigida* CUSHMAN, Hudson Bay, p. 12 [*cit. apud* Cushman, 1931].
- 1931 *Eponides frigida* (Cushman). Cushman, Atlantic Ocean, p. 45.
- One of the most widely distributed species.
4. *Buccella peruviana campsi* (Boltovskoy), 1954. Plate 6, figure 3
1954a *Eponides peruvianus campsi* BOLTOVSKOY, San Jorge, p. 205, pl. 17, figs. 6-8.
Occurs less frequently than *B. frigida*, with fewer specimens.
5. *Bulimina elongata* d'Orbigny, 1826. Plate 6, figure 6
1826 *Bulimina elongata* D'ORBIGNY, p. 296, no. 9.
1846 *Bulimina elongata* d'Orbigny. D'ORBIGNY, Vienna Basin, p. 187, pl. 11, figs. 19, 20.
Only a single living specimen was found.
6. *Bulimina marginata* d'Orbigny, 1826. Plate 6, figure 7
1826 *Bulimina marginata* D'ORBIGNY, p. 269, no. 4, pl. 12, figs. 10-12.
One living specimen and several empty tests were found.
7. *Bulimina patagonica* d'Orbigny, *forma glabra* Cushman and Wickenden, 1929. Plate 6, figure 9
1929 *Bulimina patagonica* d'Orbigny var. *glabra* CUSHMAN and WICKENDEN, Juan Fernandez Id., p. 9, pl. 4, fig. 1.
Present at several stations but always as isolated specimens.
8. *Buliminella elegantissima* (d'Orbigny), 1839. Plate 6, figure 8
1839 *Bulimina elegantissima* D'ORBIGNY, Amér. Mérid., p. 51, pl. 7, figs. 13, 14.
This is a rather common species in the area studied. As in all the other species, there are considerably fewer living specimens than dead ones.
9. *Cibicides aknerianus* (d'Orbigny), 1846. Plate 6, figure 10
1846 *Rotalina akneriana* D'ORBIGNY, Vienna Basin, p. 156, pl. 8, figs. 13-15.
The interpretation of this species varies among authors. The present author is following that of Brady (1884). The species occurs rather frequently but only two living specimens were found.
10. *Cibicides variabilis* (d'Orbigny), *forma biserialis* Cushman and Valentine, 1930. Plate 6, figure 11
1826 *Truncatulina variabilis* D'ORBIGNY (pars), p. 279, no. 8.
1930 *Dyocibicides biserialis* CUSHMAN and VALENTINE, Channel Id., off California, p. 31, pl. 10, figs. 1, 2.
According to Heron-Allen and Earland (1932), d'Orbigny's species *T. variabilis* as well as the genera *Cibicidella* Cushman and *Dyocibicides* Cushman and Valentine have no zoological value but represent specimens whose peculiar shape is caused by growth on various substrata. In some of my previous papers (Boltovskoy, 1957, 1959), I have expressed the same idea although with insufficient material to confirm it. Now, after the study of abundant material from various localities in the South Atlantic, I am sure that the character of the substratum, as well as other ecological conditions, has a primary role in the chamber arrangement of many species of *Cibicides*. For this reason, many species and even genera (for instance, *Cibicidella*, *Dyocibicides*, *Cyclocibicides*, etc.) are invalid. Recently this was very well shown by Nyholm (1961) as a result of the culturing over a four year period of *Cibicides lobatulus* (Walker and Jacob). He demonstrated that among the descendants of this species were found representatives of the genera *Cibicidella*, *Dyocibicides*, *Cyclocibicides*, and even *Planorbulina* and *Webbinella*. The entire group of *Cibicides* and *Cibicides*-like species should be restudied and without doubt many names would be rejected. Now, as a stopgap measure, I believe that the best way to interpret many "species" of *Cibicides* is to use the taxonomic category *forma*. This category has no status and, therefore, does not enlarge our systematic household. At the same time it "saves" all the small differences which, although of infraspecific character, are nevertheless interesting from the ecological point of view. Thus, in respect to the "species" living on the Argentine shelf, we have three main *formae*:
Cibicides variabilis (d'Orbigny), *forma typica*
Cibicides variabilis (d'Orbigny), *forma uniserialis* (corresponds to *Dyocibicides uniserialis* Thalmann)
Cibicides variabilis (d'Orbigny), *forma biserialis* (corresponds to *Dyocibicides biserialis* Cushman and Valentine)
Only two specimens (both dead) of the last *forma* have been found in the material studied.
11. *Cornuspira involvens* (Reuss), 1850. Plate 6, figure 12
1850 *Operculina involvens* REUSS, Tertiary of Austria, p. 370, pl. 46, fig. 20.
Isolated living specimens and rare dead ones occur.
12. *Elphidium articulatum* (d'Orbigny), 1839. Plate 6, figure 15
1839 *Polystomella articulata* D'ORBIGNY, Amér. Mérid., p. 30, pl. 3, figs. 9, 10.
Rare living specimens were found.
13. *Elphidium gunteri* Cole, 1931. Plate 6, figures 13, 14
1931 *Elphidium gunteri* COLE, Florida Pliocene, p. 34, pl. 4, figs. 9, 10.
The specimens appear to be identical with Cole's species although they differ from the description and figures of the holotype in having fewer cham-

- bers in the last whorl (10-13 instead of 14) and in being somewhat smaller. Very rare.
14. *Elphidium macellum* (Fichtel and Moll), 1798. Plate 6, figure 16
1798 *Nautilus macellus* FICHEL and MOLL, p. 66, var. α , pl. 10, figs. e-g; var. β , pl. 10, figs. h-k.
This is the most widely distributed species in the area studied. It varies in its morphological features a good deal and is quite near to or intergrades into *E. crispum*. Probably it would be better to interpret *E. macellum* as a *forma* of *E. crispum*. The confusion in the taxonomy of the entire *E. crispum* group can be resolved only by detailed study.
15. *Elphidium magellanicum* Heron-Allen and Earland, 1932. Plate 6, figures 17, 18
1932 *Elphidium* (*Polystomella*) *magellanicum* HERON-ALLEN and EARLAND, Discovery Rept., p. 440, pl. 16, figs. 26-28.
Living specimens are very rare.
16. *Epistominella exigua* (Brady), 1884
1884 *Pulvinulina exigua* BRADY, p. 696, pl. 13, figs. 13, 14.
Rather frequent; the dead shells are much more numerous than living specimens, as usual.
17. *Fissurina compressa* (d'Orbigny), 1839. Plate 6, figure 19
1839 *Oolina compressa* D'ORBIGNY, Amér. Mérid., p. 18, pl. 5, figs. 1, 2.
Isolated specimens occur. One was seen with a reddish spot in the interior.
18. *Fissurina* aff. *F. earlandi* Parr, 1950
Aff. 1950 *Fissurina earlandi* PARR, Antarctic., p. 306, pl. 8, fig. 8.
Taxonomic discussion of this species is to be found in Boltovskoy (1954a, p. 160). Four specimens were found but it is not certain whether or not they were all dead.
19. *Fissurina quadricostulata* (Reuss), 1870. Plate 7, figure 1
1870 *Lagena quadricostulata* REUSS, Septarienthon, p. 469.
1870 *Lagena quadricostulata* REUSS. Schlict, Septarienthon, pl. 6, figs. 25-30.
Same comment as for the previous species.
20. *Lagena caudata* (d'Orbigny), 1839
1839 *Oolina caudata* D'ORBIGNY, Amér. Mérid., p. 19, pl. 5, fig. 6.
Isolated specimens were found, one with a brownish spot in the interior.
21. *Lagena interrupta* Williamson, 1848. Plate 6, figure 20
1848 *Lagena striata* var. *interrupta* WILLIAMSON, British *Lagena*, p. 14, pl. 1, fig. 7.
In the interpretation of this species, I am following Cushman's point of view since, according to Williamson, the species should have a wider test with more irregular costae. Very rare specimens were found, some with a small brownish spot in the interior.
- 22a. *Lagena laevis* (Montagu), *forma typica*. Plate 6, figure 22
1803 *Vermiculum laeve* MONTAGU, p. 524.
Isolated specimens occur.
- 22b. *Lagena laevis* (Montagu), *forma perlucida* Montagu, 1803. Plate 6, figure 23
1803 *Vermiculum perlucidum* MONTAGU, p. 525, pl. 14, fig. 3.
L. perlucida differs from *L. laevis* only in having ornamentation on the lower part of the test. I do not think this is sufficient difference for specific separation and therefore prefer to interpret the "species" as a *forma*.

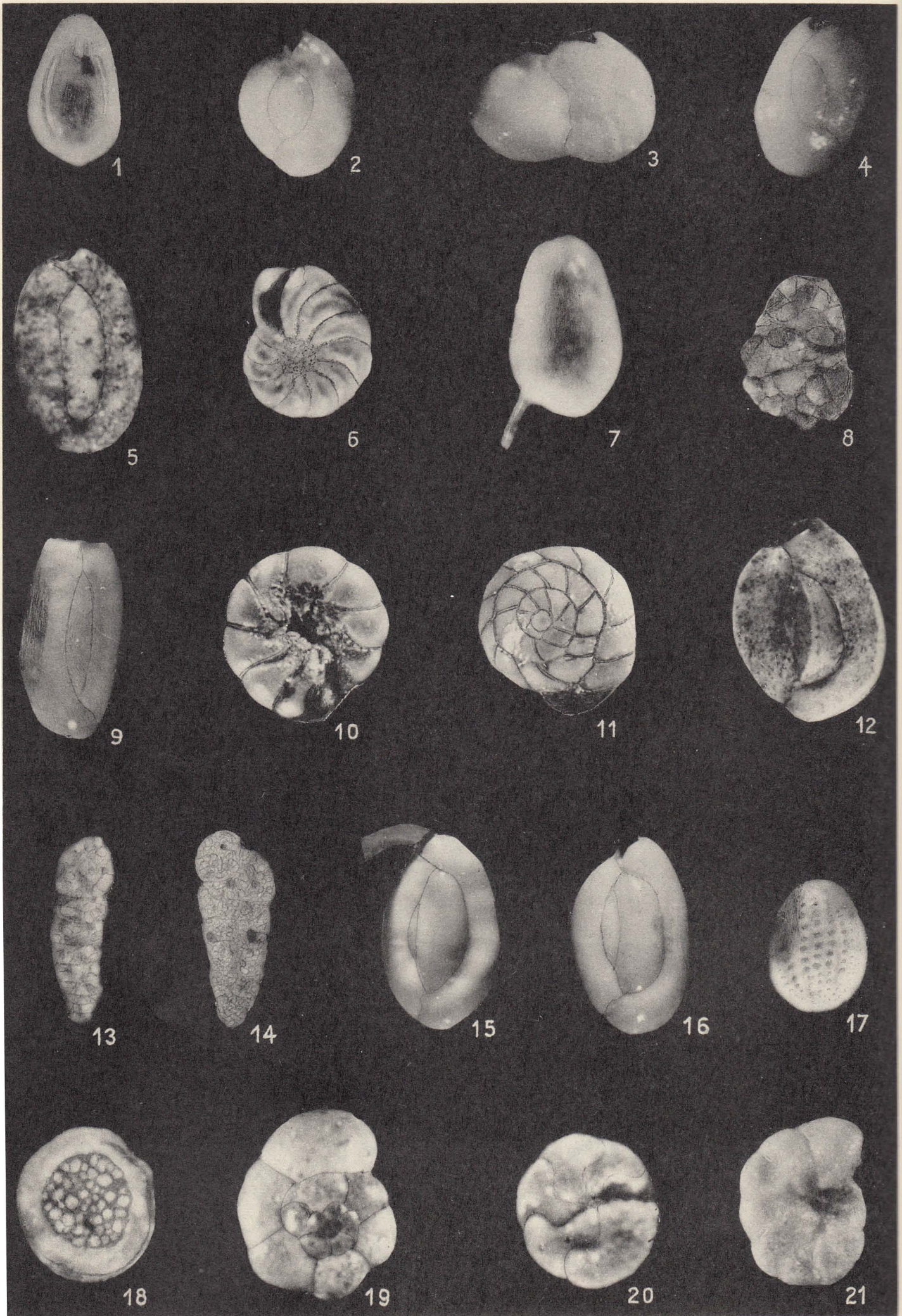
EXPLANATION OF PLATE 6

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

FIGS.		PAGE
1.	<i>Buccella frigida</i> (Cushman) (0.32 mm.), ventral view.	60
2.	<i>Bolivina compacta</i> Sidebottom (0.38 mm.).	60
3.	<i>Buccella peruviana campsi</i> (Boltovskoy) (0.34 mm.), ventral view.	61
4.	<i>Bolivina pseudoplicata</i> Heron-Allen and Earland (0.38 mm.).	60
5.	<i>Buccella frigida</i> (Cushman) (0.34 mm.), dorsal view.	60
6.	<i>Bulimina elongata</i> d'Orbigny (0.64 mm.).	61
7.	<i>Bulimina marginata</i> d'Orbigny (0.34 mm.).	61
8.	<i>Buliminella elegantissima</i> (d'Orbigny) (0.23 mm.).	61
9.	<i>Bulimina patagonica</i> d'Orbigny, <i>forma glabra</i> Cushman and Wickenden (0.38 mm.).	61
10.	<i>Cibicides aknerianus</i> (d'Orbigny) (0.45 mm.), dorsal view.	61
11.	<i>Cibicides variabilis</i> (d'Orbigny), <i>forma biserialis</i> Cushman and Valentine (0.68 mm.), dorsal view.	61
12.	<i>Cornuspira involvens</i> (Reuss) (0.33 mm.).	61
13, 14.	<i>Elphidium gunteri</i> Cole (0.53 mm.).	61
15.	<i>Elphidium articulatum</i> (d'Orbigny) (0.4 mm.).	61
16.	<i>Elphidium macellum</i> (Fichtel and Moll) (0.72 mm.).	62
17, 18.	<i>Elphidium magellanicum</i> Heron-Allen and Earland (0.33 and 0.30 mm.).	62
19.	<i>Fissurina compressa</i> (d'Orbigny) (0.19 mm.).	62
20.	<i>Lagena interrupta</i> Williamson (0.43 mm.).	62
21.	<i>Oolina lineata</i> (Williamson) (0.21 mm.).	64
22.	<i>Lagena laevis</i> (Montagu), <i>forma typica</i> (0.36 mm.).	62
23.	<i>Lagena laevis</i> (Montagu), <i>forma perlucida</i> Montagu (0.38 mm.).	62



Boltovskoy: Littoral Foraminifera of Puerto Deseado



Boltovskoy: Littoral Foraminifera of Puerto Deseado

- The majority of the specimens were empty tests. Only isolated specimens were found having a small cluster of brownish or reddish spots in the interior of the tests. The quantity of this substance, as well as its color, makes it questionable as to whether or not it is protoplasm. Probably we have here symbiotic algae which are zooxanthellae (?). Red and rust-brown algae were observed in *Peneroplis* by Winter (1907). He observed, in dead specimens of macrospheric *Peneroplis*, dead algae which formed brown globules within the empty tests. Maybe the same phenomenon is occurring in the *Fissurina*, *Lagena* and *Oolina* specimens of my material. The material available was too poor to make a detailed investigation of this.
23. *Miliammina fusca* (Brady), 1870. Plate 7, figure 5
1870 *Quinqueloculina fusca* BRADY, tidal river, p. 268, pl. 1, fig. 2.
Rather a large number of specimens occur, only a few of which contained protoplasm.
24. *Miliolinella lutea* (d'Orbigny), 1839. Plate 7, figure 4
1839 *Triloculina lutea* D'ORBIGNY, Amér. Mérid., p. 70, pl. 9, figs. 6-8.
Several living specimens have been found.
- 25a. *Miliolinella subrotunda* (Montagu), *forma typica*, 1803. Plate 7, figure 2
1803 *Vermiculum subrotundum* MONTAGU, p. 521.
Same comment as for previous species.
- 25b. *Miliolinella subrotunda* (Montagu), *forma labiosa* (d'Orbigny), 1839. Plate 7, figure 3
1840 *Triloculina labiosa* D'ORBIGNY, Cuba, p. 157, pl. 10, figs. 12-14.
The species described by Montagu as *Vermiculum subrotundum* and that described by d'Orbigny as *Triloculina labiosa* are widely distributed on the Argentine and Brazilian shelves. Although their typical representatives are rather distinct, there is a complete gradation between them and in many places the two forms are found together. In many cases it is absolutely impossible to decide to which species to refer a given specimen. I believe that the best way to solve this problem is to interpret d'Orbigny's form as a *forma* of *Miliolinella subrotunda*. The figures on plate 7 of the present paper represent typical individuals. Only isolated specimens (some alive) have been found.
26. *Morulaepecta bulbosa* Höglund, 1947
1947 *Morulaepecta bulbosa* HÖGLUND, Gullmar Fjord, p. 165, pl. 12, fig. 2; text fig. 142.
Very rare dead specimens occur.
27. *Nonion depressulum* (Walker and Jacob), 1798. Plate 7, figure 6
1798 *Nautilus depressulus* WALKER and JACOB, p. 641, pl. 14, fig. 33.
1884 *Nonionina depressula* WALKER and JACOB, sp. Brady, p. 725, pl. 109, figs. 6, 7.
The interpretation of this cosmopolitan species varies with different authors which is the logical consequence of the inadequate figures given by the original authors. I am following the interpretation of Brady (*loc. cit.*). This is one of the most widely distributed species in the area studied.
28. *Oolina borealis* Loeblich and Tappan, 1953
1858 *Entosolenia costata* WILLIAMSON (*not* Egger, 1857), British Isles, p. 9, pl. 1, fig. 18, [emend., Loeblich and Tappan, 1953].
Two small dead specimens were found.
29. *Oolina caudigera* (Wiesner), 1931. Plate 7, figure 7
1931 *Lagena (Entosolenia) globosa* var. *caudigera* WIESNER, p. 119, pl. 18, fig. 214.
1931 *Lagena (Entosolenia) ovata* var. *caudigera* WIESNER, pl. 18, fig. 215.
A few dead specimens were encountered.

EXPLANATION OF PLATE 7

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

FIGS.	PAGE
1. <i>Fissurina quadricostulata</i> (Reuss) (0.30 mm.)	62
2. <i>Miliolinella subrotunda</i> (Montagu), <i>forma typica</i> (0.40 mm.)	63
3. <i>Miliolinella subrotunda</i> (Montagu), <i>forma labiosa</i> d'Orbigny (0.36 mm.)	63
4. <i>Miliolinella lutea</i> (d'Orbigny) (0.36 mm.)	63
5. <i>Miliammina fusca</i> (Brady) (0.5 mm.)	63
6. <i>Nonion depressulum</i> (Walker and Jacob) (0.43 mm.)	63
7. <i>Oolina caudigera</i> (Wiesner) (0.36 mm.)	63
8. <i>Saccamina atlantica</i> (Cushman) (0.47 mm.)	64
9. <i>Quinqueloculina patagonica</i> d'Orbigny (0.40 mm.)	64
10. 11. <i>Rotalia beccarii</i> (Linné): ventral view (0.85 mm.), dorsal view (0.11 mm.)	64
12. <i>Quinqueloculina arctica</i> Cushman (0.96 mm.)	64
13. <i>Reophax arctica</i> Brady (0.30 mm.)	64
14. <i>Textularia earlandi</i> Parker (0.32 mm.)	64
15. 16. <i>Quinqueloculina seminulum</i> (Linné) (1 mm.)	64
17. <i>Oolina melo</i> d'Orbigny (0.21 mm.)	64
18. <i>Spirillina dimidiata</i> Wiesner (0.36 mm.), ventral view	64
19. <i>Trochammina inflata</i> (Montagu) (0.51 mm.), dorsal view	64
20. <i>Trochammina ex gr. T. squamata</i> Jones and Parker (0.30 mm.), ventral view	64
21. <i>Trochammina macrescens</i> Brady (0.36 mm.), ventral view	64

30. *Oolina lineata* (Williamson), 1848. Plate 6, figure 21
1848 *Entosolenia lineata* WILLIAMSON, British Isles, p. 18, pl. 2, fig. 18.
Isolated specimens, probably none living, were found.
31. *Oolina melo* d'Orbigny, 1839. Plate 7, figure 17
1839 *Oolina melo* d'ORBIGNY, Amér. Mérid., p. 20, pl. 3, fig. 9.
Occurs rather frequently. Some specimens have been found having a small brownish spot or cluster inside the test. In one case, this cluster was relatively large, much larger than in all other cases in *Lagena*, *Fissurina* and *Oolina*.
32. *Pyrgo quadrata* (Heron-Allen and Earland), 1930
1930 *Biloculina elongata* d'Orbigny var. *quadrata* HERON-ALLEN and EARLAND, Plymouth, p. 50, pl. 2, figs. 1-4.
One rather typical, dead specimen was found.
33. *Quinqueloculina arctica* Cushman, 1933. Plate 7, figure 12
1933 *Quinqueloculina arctica* CUSHMAN, p. 2, pl. 1, fig. 3.
The specimens are rather large and some of them have slightly roughened surfaces. In other respects they are typical.
34. *Quinqueloculina patagonica* d'Orbigny, 1839. Plate 7, figure 9
1839 *Quinqueloculina patagonica* d'ORBIGNY, Amér. Mérid., p. 74, pl. 4, figs. 14-16.
Three specimens, one of them alive, occurred.
35. *Quinqueloculina seminulum* (Linné), 1767. Plate 7, figures 15, 16
1767 *Serpula seminulum* LINNÉ, p. 1264, no. 791.
This is a common species in this area. Many living specimens were found; they are striking in having the protoplasm protruding from the aperture.
36. *Reophax arctica* Brady, 1881. Plate 7, figure 13
1881 *Reophax arctica* BRADY, p. 405, pl. 21, fig. 2.
Few specimens were found, only one of them alive.
37. *Robulus rotulatus* (Lamarck), 1804
1804 *Lenticulites (rotulata)* LAMARCK, p. 188, no. 3, pl. 62, fig. 11 (1806).
Two dwarfed, dead specimens occurred.
38. *Rotalia beccarii* (Linné), 1767. Plate 7, figures 10, 11
1767 *Nautilus beccarii* LINNÉ, p. 1162.
This species is one of the most abundant.
39. *Saccamina atlantica* (Cushman), 1944. Plate 7, figure 8
1944 *Proteonina atlantica* CUSHMAN, New England, p. 5, pl. 1, fig. 4.
Two specimens (one apparently living) have been found.
40. *Spirillina dimidiata* Wiesner, 1931. Plate 7, figure 18
1931 *Spirillina dimidiata* WIESNER, p. 128, pl. 21, fig. 250.
Only one living specimen, none dead, was found.
41. *Textularia earlandi* Parker, 1952. Plate 7, figure 14
1954 *Textularia earlandi* PARKER. Parker, NE Gulf of Mexico, p. 490, pl. 2, fig. 12.
Only one living specimen and very few dead ones were found.
42. *Trochammina inflata* (Montagu), 1808. Plate 7, figure 19
1808 *Nautilus inflatus* MONTAGU, p. 81, pl. 18, fig. 3.
This species has been found in rather large quantities but only at a few stations. Several specimens were living.
43. *Trochammina macrescens* Brady, 1870. Plate 7, figure 21
1870 *Trochammina inflata* var. *macrescens* BRADY, tidal river, p. 290, pl. 11, fig. 5.
Some isolated specimens have been found one of which may have been living at the time of collection, although there is no certainty of this.
44. *Trochammina ochracea* (Williamson), 1858
1858 *Rotalina ochracea* WILLIAMSON, British Isles, p. 55, pl. 4, fig. 112; pl. 5, fig. 113.
Isolated dead specimens were found.
45. *Trochammina ex gr. T. squamata* Jones and Parker, 1860. Plate 7, figure 20
Ex gr. 1860 *Trochammina squamata* JONES and PARKER, Mediterranean, p. 304.
There is much confusion in the interpretation of this species which is subject to morphological variation and in addition has many related forms. This circumstance has forced me to add "*ex gr.*" to the citation (*ex grege* = "out of the herd"). It is advisable to use this form of citation if the specimens found have the characteristic features of a widely distributed species which has many related forms. This species was found at only a few stations, but rather frequently and always dead.

SPECULATIONS AND CONCLUSIONS

The total number of benthonic species found was 45. Of these, 28 species were found living at the time of collection. They are:

<i>Bolivina compacta</i>	<i>Cornuspira involvens</i>
<i>Bolivina pseudoplicata</i>	<i>Elphidium articulatum</i>
<i>Buccella frigida</i>	<i>Elphidium gunteri</i>
<i>Buccella peruviana campsi</i>	<i>Elphidium macellum</i>
<i>Bulimina elongata</i>	<i>Elphidium magellanicum</i>
<i>Bulimina marginata</i>	<i>Epistominella exigua</i>
<i>Bulimina patagonica</i> (f. <i>glabra</i>)	<i>Miliammina fusca</i>
	<i>Miliolinella lutea</i>
<i>Buliminella elegantissima</i>	<i>Miliolinella subrotunda</i> (f. <i>typica</i> and f. <i>labiosa</i>)
<i>Cibicides aknerianus</i>	

<i>Nonion depressulum</i>	<i>Rotalia beccarii</i>
<i>Quinqueloculina arctica</i>	<i>Saccamina atlantica</i>
<i>Quinqueloculina patagonica</i>	<i>Spirillina dimidiata</i>
<i>Quinqueloculina seminulum</i>	<i>Textularia earlandi</i>
<i>Reophax arctica</i>	<i>Trochammina inflata</i>

In the case of 8 species there was some uncertainty as to whether or not they were living or dead. These species are:

<i>Fissurina compressa</i>	<i>Lagena laevis</i> (f. <i>typica</i> and
<i>Fissurina</i> aff. <i>F. earlandi</i>	f. <i>perlucida</i>)
<i>Lagena caudata</i>	<i>Oolina lineata</i>
<i>Lagena interrupta</i>	<i>Oolina melo</i>
	<i>Trochammina macrescens</i>

Nine species have been found dead:

<i>Cibicides variabilis</i> (f. <i>biserialis</i>)	<i>Pyrgo quadrata</i>
	<i>Robulus rotulatus</i>
<i>Fissurina quadricostulata</i>	<i>Trochammina ochracea</i>
<i>Morulaeplecta bulbosa</i>	<i>Trochammina</i> ex gr. <i>T.</i>
<i>Oolina borealis</i>	<i>squamata</i>
<i>Oolina caudigera</i>	

No planktonic specimens were found.

In the ecological environments of both beach and tidepools, *Elphidium macellum* predominated. This species was particularly abundant in the tidepools where a calcareous alga also was plentiful.

To a somewhat less extent the following were found: *Buccella frigida*, *Miliammina fusca*, *Miliolinella subrotunda*, *Nonion depressulum*, *Quinqueloculina seminulum*, and *Rotalia beccarii*.

In a somewhat lesser number of samples occurred the following: *Buliminella elegantissima*, *Cibicides annerianus*, *Oolina melo*, and representatives of *Trochammina*.

The remaining species occurred very rarely, mostly as single specimens or a few isolated ones.

In the samples studied, all species were represented by a considerably higher number of empty tests than by those with protoplasm. In the cases where samples were taken using sampling gear, this phenomenon can be easily explained by the fact that the greater part of the material gathered by the sampler comes from below the surface where foraminifera cannot live. The maximum depth of penetration into the sediments by living foraminifera (*Nonion depressulum*) observed up to now is 4 cm. (Richter, 1961). Our sampling gear certainly grasped a greater thickness of sediment than this. In cases where the material was collected by means of a knife which scraped just the surface of the sediment, the presence of a large number of empty tests can be explained by the speculation that many redeposited tests from the Quaternary sediments are present. Nevertheless, in both cases, at least in the present area, it is shown that the rapid solution of empty calcareous tests postulated for the marshes of Poponesset Bay by Parker and Athearn (1959) does not take place.

Foraminifera which live in the littoral zone are subject to sudden and great changes in their ecological conditions and to strong scouring action by tides and surf. It is believed that those species which can retain their positions against these forces are more apt to live in the littoral zone. Species having small compressed tests, for example *Trochammina*, and species attached to the bottom or to plants, like *Cibicides*, thrive in this milieu. Those species able to make prompt readaptation to the sudden changes in ecological conditions will thrive the best. Probably this ability is possessed by *Elphidium macellum*, *E. articulatum*, *Buliminella elegantissima*, *Miliammina fusca*, *Miliolinella subrotunda* and a few others. It is quite understandable that not many species will be common to the littoral and sublittoral zones. Nevertheless, the entire assemblage found, except for some rare species, is quite similar to that now living in the sublittoral part of the same Patagonian shelf. This means that probably many of the species found alive did not really belong in the littoral zone but were carried into it from the sublittoral zone by tidal currents and wave action. Some of the living specimens were able to continue to live under the new conditions and were included in the present sampling. This explanation seems very probable; it is the one given also by Cooper (1961) in his paper on the intertidal foraminifera of the California and Oregon coast.

It is rather difficult to distinguish exactly which species are really indigenous to the littoral zone as opposed to those introduced from the sublittoral zone. In any case, taking into consideration the foregoing circumstance, the number of samples studied, their relatively great weight, the preliminary study of each sample on the day of collection which promoted more successful collecting the following day, and the fact that all the specimens encountered have been identified, it is possible to say that the fauna found is neither very rich qualitatively nor quantitatively.

In addition, the following circumstance should be taken into account. As pointed out previously, the highest temperature was in February coinciding with the period when the samples were collected. This is summer in the Southern Hemisphere. According to Myers (1935) and Bradshaw (1961), the reproductive rate increases with the higher temperatures. Consequently, summer is the period when reproduction in the sea is highest. Thus, it should be assumed that the population gathered is the greatest possible for the area studied. This conclusion was confirmed by collections made somewhat later in the season. At exactly the same locality, near the Dos Hermanos Rocks, samples have been taken weekly over a long period. The comparison of foraminiferal assemblages collected in February and July shows that in February the assemblage was considerably richer both qualitatively and quantitatively.

Thus, taking all the circumstances mentioned into

account, we can conclude that the foraminiferal fauna of Deseado Harbor is not very rich. It should be noted also that the average size of several species is somewhat smaller than normal.

It is interesting to compare the fauna discussed with that found in San Jorge Gulf (Boltovskoy, 1954a). This gulf is situated approximately 100 km. north of the present locality and extends roughly from Lat. 47° to 45° S. Both faunas are very similar, some differences being due to the different depths from which the corresponding material was collected (Puerto Deseado - littoral zone; San Jorge Gulf - between 40 and 98 m.). However, more than half of the species common to both areas are represented by much smaller, and more poorly developed specimens in San Jorge Gulf than in Puerto Deseado.

The difference in size and development is still more evident if we compare the assemblage of Puerto Deseado with that of San Blas Bay. The latter is characterized by depauperate and even smaller specimens.

On the other hand, the foraminiferal assemblage in the neighborhood of Tierra del Fuego and the Strait of Magellan is better developed and much richer than that of Puerto Deseado.

The problem of the impoverishment of the foraminiferal fauna of the various regions on the northern part of the Argentinian shelf has already been discussed in an earlier paper (Boltovskoy, 1956) and will not be discussed here. The Gulf of San Jorge undoubtedly belongs among the regions where the foraminiferal fauna is depauperate. How far south this impoverishment extends — if the region of Puerto Deseado - San Julian is interpreted as having this character — and to what degree, is a matter for discussion. Are these features too slight at this locality to be worthy of discussion? This problem can be solved after supplementary study of material from nearby localities is made.

With regard to the zoogeographical zonation, it is interesting to emphasize that the foraminiferal faunas of the above-mentioned region — San Blas Bay, San Jorge Gulf and Deseado Harbor — belong undoubtedly to the same province. d'Orbigny (1839, p. 14), Cushman and Parker (1931, p. 2) and Heron-Allen and Earland (1932, p. 299) point out that the foraminiferal faunas of the east and west sides of South America for the most part are quite different. This contradicts the generally accepted opinion that Deseado Harbor and San Jorge Gulf belong to one province (Magellan) whereas the Bay of San Blas lies in another (Argentinian). The former province extends to the south from Lat. 37° on the Chilean coast, and at Tierra del Fuego continues into the Patagonian area as far north as Lat. 43° on the Argentinian coast (Carcelles, 1950; Carcelles and Williamson, 1951). According to Norman (1937), this boundary should be found at Lat. 42° S. Ekman (1953, p. 214) states that it is not known how far the Magellan Province extends

since "the region between Patagonia and Rio de Janeiro is one of the world's least known regions as far as the coastal fauna is concerned. The greatest change in the fauna may possibly take place as far up as the mouth of the La Plata where the temperature of the water rises extraordinarily quickly in a northerly direction."

The probable explanation of these contradictions between the majority of the zoologists and the foraminiferal data lies in the geological history of the South American continent. According to Ihering (1927), up to the Quaternary, Tierra del Fuego and Patagonia were connected by an isthmus with the Malvin Islands and Graham Land. In the second half of the Quaternary, this isthmus disappeared and the main marine organic life on both sides of South America began to mix. But if, since that time, the mollusks, as well as many other metazoans, have had sufficient time to mix to a certain degree, this has not been the case with the benthonic foraminifera. To solve this problem once and for all it is necessary first to study all the Quaternary foraminifera of both areas.

It was impossible to correlate the distributions of the species found with the salinity and temperature measurements. As far as could be seen, these properties are not subject to great variations in the area studied.

It is believed that the species distributions in this area depend chiefly on bottom conditions as well as those conditions which characterize the various localities of beach, small ponds and tidepools from which the material was taken. It was impossible to consider all these conditions separately and for this reason the observations made below are of a general nature.

It was observed that where the bottom was composed of pebbles practically no living foraminifera were encountered. Only once was a small living specimen of *Buccella frigida* found on a beach covered only with rather large pebbles. It was not clear how this individual could live in such conditions. On the same type of bottom but one having some admixture of sand grains, the most frequent living species were: *Elphidium macellum*, *Quinqueloculina seminulum*, *Miliolinella subrotunda*, *Buccella frigida*.

On sandy mud sediments the fauna is quantitatively and qualitatively richer, but the specimens are smaller. These observations on the relationship between foraminiferal abundance and the median grain size of the sediment is in complete accord with the conclusions drawn by Reiter (1959) in his study of the littoral foraminifera of Santa Monica Bay. He says (p. 628). "This is the result of the settling rate of the Foraminifera tests, which, in most instances, are in the same grade range of the sand in which they are found."

The following observations are also of interest.

Many specimens of *Buccella frigida*, *B. peruviana campsi*, *Buliminella elegantissima*, *Elphidium macel-*

lum, *E. gunteri*, *E. articulatum* and *Nonion depressulum* were green at the time of collection and this color has not completely disappeared even now, a year later. The specimens of *Buccella* retained this color the best whereas in *Buliminella elegantissima* it was not so evident and *Elphidium macellum* had lost it almost completely. *Nonion depressulum* became yellowish and only in rare specimens did this yellow color take on a green tinge. This same green color was observed by the author in some planktonic species, especially *Globorotalia menardii*, collected at the surface in the South Atlantic. Many specimens of *Globigerinoides ruber* contained green protoplasm also, either in the last chamber only or in all the chambers but the last, which was transparent.

It is believed that this color is due principally to the presence of some symbiotic unicellular algae which, depending on their color, are called by the common names zoochloellae (with green chromatophores) and zooxanthellae (with yellow or brown chromatophores). Up to now, the former have been observed mainly in fresh water Protozoa and are represented most of all by *Chlorella* (order Chlorococcales). The latter, at least in large part, belong to the dinoflagellates (McLaughlin and Zahl, 1959). These symbiotic algae are well known in several lower animals, among them nearly all Radiolaria, except those which live in deep water where their presence is excluded by the lack of light (Dogel, 1951). In most cases, the yellow symbionts are encountered in the peripheral parts of the hosts but the younger stages of these hosts usually do not contain them. This means that a fresh infection of each generation is necessary.

These algae have also been observed in foraminifera. Probably the first such observation was made as far back as 1856 by Schultze. He saw the symbiotic algae in *Rotalia*, but explained their presence erroneously as a protoplasmic formation. Winter (1907) paid great attention to the symbiotic algae found in *Peneroplis*. Rumbler (1911) was the first to pay much attention to this phenomenon in respect to the planktonic foraminifera. He noted the presence of symbionts in the form of fusiform corpuscles (8.9-19.4 microns in length) in *Globigerina* and *Orbulina*. Subsequent observations dealing with symbiotic algae in foraminifera are scarce. Perhaps the most detailed are those of Myers. According to him (Myers, 1943, p. 30), the symbiotic algae have been seen in foraminiferal species that possess a relatively large aperture (*Peneroplis*, *Sarites*, *Marginopora*). Recently Bé (1960) reported the probable presence of symbiotic algae in the protoplasm of some planktonic foraminifera.

The role of symbiotic algae certainly is beneficial to their hosts since to begin with they supply the latter with oxygen and consume carbon dioxide. There are further observations on their metabolic significance that could be made but for the sake of brevity these will not be discussed here. It has been shown that in

some animals, for example Radiolaria, that during a period of starvation the symbionts can be digested, thus, serving as food. According to Winter (1907), this is not true of *Peneroplis*. The importance of algal symbionts has been demonstrated by Pringsheim (1928) who found that the Infusoria *Paramaecium* thrived and multiplied in a solution to which no solid food had been added but in which there were algal symbionts. Certainly these cultures were exposed to light. Atoda (1951) found that budding corals increased in zooxanthellae content.

Although Myers pointed out that only large-apertured species of foraminifera have algal symbionts, it is not extraordinary that we have found them in our samples in species with small apertures. The mouth openings of *Buccella*, *Buliminella*, *Elphidium* and *Nonion* are large enough to make possible the entrance of the algae. *Chlorella* is only about 3 microns in diameter. It is also not improbable that they could enter as autospores.

It is not quite clear why many specimens with a strong green color, apparently containing algae, have not shown the presence of protoplasm after using Walton's staining technique. Perhaps they died and their protoplasm decomposed while the algae continued to live inside their tests. Fretsch (1935, p. 659) points out (not particularly in respect to foraminifera) that: "When motile reproductive stages are produced by the animal or when the latter dies, the zooxanthellae are set free in the living condition and can then multiply to form small palmelloid masses. Both here and within the animal body the cells are enveloped by a thin cellulose wall" On the other hand one can understand that in the same population many living specimens were encountered which lacked these symbionts. It is known that although the relation between algae and their hosts is beneficial, it is not obligatory. The above-mentioned worker (*ibid.*, p. 189) states that: ". . . in most cases by no means all the animal individuals contain algal cells, and there is no evidence that the colorless forms under normal circumstances thrive less well than those provided with green cells."

I do not hesitate to interpret the greenish color to the presence of symbiotic algae. Dr. J. Acorinti, the algologist, kindly examined the specimens of foraminifera discussed and confirmed this conclusion. Unfortunately, due to the lapse of time, these algae were partly decomposed. Nevertheless, it was possible to distinguish sufficiently clearly an enormous quantity of small green unicellular circular-shaped algae belonging to the order Chlorococcales and probably to the genus *Chlorella* in the tests of *Buccella frigida*. In other species, the state of preservation was worse and corresponded well to the loss of color or to the change of the green color to yellow, as mentioned above. In spite of these conditions, it was still possible to recognize the presence of the unicellular algae.

It is interesting to note that the green-colored foraminifera were considerably fewer in samples taken in July than in those collected in February and the color was not so well-pronounced, being clearer. It is believed that the explanation lies in the much lower metabolic activity of the algae in the winter.

It is not clear why various foraminiferal species lost their green color in different ways. This may be due to the fact that they contain certain distinct species of algae which, in turn, have different resistances to decomposition. It is a logical assumption that zoochlorellae are host-specific.

Finally, the following phenomenon is worth describing here. It is known that formalin denatures protoplasm and causes its shrinking and hardening. Subsequent staining with rose Bengal enables us to see this protoplasm through the test walls (especially when wet), or outside the test. It is interesting to note that different genera and species behave differently in this respect. *Quinqueloculina seminulum* shows its protoplasm in the form of a rounded (in cross section) tongue which protrudes from the aperture. At the end of this tongue there are often adherent sand grains. The last chamber, as well as several of the previous ones, are also filled with the shrunken protoplasm, but it possesses its natural yellowish color. Evidently the rose Bengal did not penetrate the interior of the test. The same phenomenon of unstained protoplasm is observed in other species such as various species of *Bulimina*. It is interesting that although *Miliolinella subrotunda* and *Miliammina fusca* have the same type of construction as *Quinqueloculina seminulum* (large aperture which permits protruding protoplasm), no specimen of these two species showed this feature. In *Buccella*, *Elphidium* and *Nonion*, the colored protoplasm was in the ultimate and penultimate chambers. In exceptional cases, it might occupy the antepenultimate chamber (or two chambers together). The previous chambers also contained protoplasm but it was colorless. *Rotalia beccarii* contained colored protoplasm usually in the last-formed chamber and only occasionally would it appear also in the penultimate chamber. The representatives of *Bolivina* and especially the Lagenidae (*Lagena*, *Fissurina*, *Oolina*) are worthy of attention. As we already know, the majority of these were empty, but some contained reddish-brown spots or clusters which were relatively very small. It is not quite clear if this substance is algal (zooxanthellae?) or plasmatic in origin. Perhaps in the future it will be possible to consider this characteristic as another method for the recognition of the true relationships to be found between foraminiferal genera and species.

It is possible to see some specimens showing these dark spots among the figured specimens (this paper). These spots represent the protoplasm inside the tests as seen through the walls. The protoplasmic tongue of

Quinqueloculina seminulum is seen clearly also, on the same plate.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XIV, PART 2, APRIL, 1963
RECENT LITERATURE ON THE FORAMINIFERA

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

- ADAMS, C. G., and KIRK, H. J. C. The Madai-Baturong Limestone Member of the Chert-Spilitite Formation, North Borneo.—*Geol. Mag.*, v. 99, No. 4, July-Aug. 1962, p. 289-303, pls. 12-14, text figs. 1-4 (maps, drawings).—Illustrations of Campanian planktonics.
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- ANDERSON, LEE, and HOFFMAN, ERVIN. Concentration of microfaunal samples by the use of a Syntron.—*Micropaleontology*, v. 9, No. 1, Jan. 1963, p. 105-106, text fig. 1, table 1.
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- BACH-WASBUZKY, ILSE. Zur Foraminiferenfauna der mittleren Blankenburgschichten (Santon).—*Beiträge zur Geol.*, Berlin, No. 1, 1959, p. 94-112, 1 pl., 1 occur. and abund. chart.—Thirty-five species, none new, recorded and their abundance indicated in a well section.
- BANG, INGER. Preliminary note on the occurrence of *Globorotalia* cf. *reissi* Loeblich and Tappan in the Danian deposits of Denmark.—*Medd. Dansk Geol. Forening*, Bd. 15, hefte 1, 1962, p. 104-106, pls. 1, 2.
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- BERMÚDEZ, PEDRO J. Foraminiferos de las lutitas de Ponta Tolete, Territorio Delta Amacuro (Venezuela).—*Geos, Escuela de Geol. Minas Metal.*, Caracas, No. 8, Oct. 1962, p. 35-38.—Species listed from beds whose age is assigned to the *Globigerina ampliapertura* zone.
- BETTENSTAEDT, FRANZ. Evolutionsvorgänge bei fossilen Foraminiferen.—*Mitt. Geol. Staatsinst. Hamburg*, Heft 31, 1962, p. 385-460, text figs. 1-18 (graphs, drawings, photographs).—Several Lower Cretaceous species used as examples of variation within species and evolutionary relationships between species.
- BIELECKA, WANDA, and DUDZIAK, EDWIN. On the species *Trocholina conica* (Schlumberger) (English summary of Polish text).—*Poland Instyt. Geol., Biul.* 156, 1961, p. 5-14, pl. 1.—Restudy of abundant specimens suggests the 3 additional species are merely damaged specimens that should be combined with *Trocholina conica* as synonyms.
- BIGNOT, G. Étude micropaléontologique de la formation de Varengueville du gisement éocène du Cap d'Ailly (Seine-Maritime).—*Revue de Micropaléontologie*, v. 5, No. 3, Dec. 1962, p. 161-184, pls. 1-4, text figs. 1-5 (graphs, drawings).—Thirty species (1 new) of Foraminifera from rocks dated as basal Cuisian.
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- COLE, W. STORRS. *Asterocyclina* from New Zealand and the Chatham Islands.—Bull. Amer. Pal., v. 44, No. 203, Nov. 16, 1962, p. 339-357, pls. 67, 68, tables 1-3.—Three species.
- COLEMAN, P. J. Tertiary larger Foraminifera of the British Solomon Islands, southwest Pacific.—Micropaleontology, v. 9, No. 1, Jan. 1963, p. 1-38, pls. 1-9, text figs. 1-3 (maps, columnar sections).—Includes illustrations and descriptions of 33 species, 2 described as new. Three faunas (Aquitanian, Burdigalian, and post-Miocene) are recognized.
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- EBENSBERGER, HANS. Stratigraphische und Mikropaläontologische Untersuchungen in der Aachener Oberkreide, besonders der Maastricht-Stufe.—Palaeontographica, Band 120, Abt. A, 1962, p. 1-120, pls. 1-12, text figs. 1-19 (maps, drawings), table 1.—Illustrated systematic catalog of about 125 species and subspecies. *Diplostoma siamese* n. gen., n. sp., a lagenid with an aperture at both ends, is described.
- ESCANDELL, B., and COLOM, G. Una revision del Nummulitico Mallorquin.—Notas y Comunic., Instit. Geol. Min. España, No. 66, Año 1962, p. 73-142, pls. 1-4, map, text figs. 1-28 (geol. sections, maps, drawings).—Species characteristic of the

several transgressions between Lutetian and Oligocene are illustrated and 5 new species are erected.

- GAWOR-BIEDOWA, EUGENIA.** Micropaleontological stratigraphy of the Upper Cretaceous from several bore-holes on Lake Goplo in Kujawy (English summary of Polish text).—Poland Instyt. Geol., Biul. 156, 1961, p. 15-60, pls. 1-3 (occurrence and abundance charts), text fig. 1 (graph), table 1.—Correlation by Foraminifera.
- GERKE, A. A.** Frondikuljarii iz Permskikh, Triasovykh i Lejasovykh Otlozhenij Severa Thentral'noj Sibiri.—Russia Nauchno-issl. instit. geol. Arktiki, Trudy, tom 127, 1962, p. 97-175.—A further installment includes descriptions of about 50 species of *Fronidularia* (a few new) from the Permian, Triassic and Liassic of central Siberia, illustrations of which have already been published (refer to Gerke 1961 paper mentioned in Contributions v. 13, pt. 4, 1962, p. 155).
- Lingulinelly i Linguliny (Foraminifera) iz Permskikh i Nizhnevezozojkskikh Otlozhenij Severa Thentral'noj Sibiri.—Sbornik statei paleont. biostrat., Leningrad, vyp. 21, 1960, p. 29-70, pls. 1-4.—Ten species (6 new) and 5 varieties (all new) in the genera *Lingulinella* and *Lingulina*, from the Permian and lower Mesozoic of central Siberia.
- GEROCH, STANISLAW.** *Thalmannammina* and *Plectrorecurvoides* (Foraminifera) in the Lower Cretaceous of the Flysch Carpathians (English summary of Polish text).—Ann. Soc. Géol. Pologne, v. 32, fasc. 2, Année 1962, p. 281-300, text figs. 1-5 (drawings, diagrams, range chart).—Three species, 2 new.
- GUTSCHICK, R. C.** Arenaceous Foraminifera from oncolites in the Mississippian Sappington Formation of Montana.—Jour. Paleontology, v. 36, No. 6, Nov. 1962, p. 1291-1304, pls. 174, 175, figs. 1-6 (map, foram drawings), table 1.—Ten species (3 new) described and illustrated from hydrochloric acid residues. *Oxinoxis* n. gen. (genotype *O. botrys* n. sp.) erected in Reophacidae.
- HAY, W. W.** The type level of some of Ehrenberg's Foraminifera.—Jour. Paleontology, v. 36, No. 6, Nov. 1962, p. 1392-1393.—Two localities thought to be Cretaceous or early Tertiary in 1854 shown to be Neogene, and an appeal in opposition to the possible resurrection of long-unused names of well-known species described from these localities.
- HOLEY, R. H.** The significance of an "inner chitinous lining" in saccamminid organisation, with special reference to a new species of *Saccamina* (Foraminifera) from New Zealand.—New Zealand Jour. Sci., v. 5, No. 3, Sept. 1962, p. 375-389, text figs. 1-7 (drawings, photomicrographs).—Saccamminids, like allogromiids, are basically a protoplasmic body enclosed by an organic shell which is modified to form an oral complex. In saccamminids the whole organism is surrounded by a simple arenaceous shell with a single aperture.
- HENRICI, H., and HILTERMANN, H.** London-Ton und Moler-Formation und andere Ablagerungen der Tertiär-Meere bei Lamstedt (NW von Stade).—Naturhist. Ges., Ber., Hannover, Band 106, p. 27-38, pl. 1, text figs. 1-3 (maps).
- HILTERMANN, HEINRICH.** Fortschritte der Mikropaläontologie in Deutschland mit einer Bibliographie für das Jahr 1961.—Paläont. Zeitschr., Band 36, No. 3/4, Aug. 1962, p. 203-225.
- HOFMANN, GERHARD W.** Der Muldenbau in der subalpinen Molasse des Prienprofils im östlichen Oberbayern.—Zeitschr. deutsch. geol. Ges., Jahrgang 1961, Band 113, Teil 2-3, July 1962, p. 557-570, text figs. 1-4 (maps, columnar section, geol. section).—Species of smaller Foraminifera useful in marking boundaries between Rupelian, Chattian, Aquitanian, and Burdigalian.
- HORNIBROOK, N. DE B.** Three new species of *Cribrorotalia* (Foraminifera) from the Oligocene of New Zealand.—New Zealand Jour. Geol. Geophys., v. 5, No. 4, Nov. 1962, p. 646-651, figs. 1-9.
- IBARAKI, MASAKO, and SAMESHIMA, TERUHIKO.** Fine structures of *Lepidocyclina nipponica* from Shimoshiraiwa, Izu, central Japan.—Repts. Liberal Arts and Sci. Fac., Shizuoka Univ., sec. Nat. Sci., v. 3, No. 3, March 1962, p. 147-148, pl. 2.
- ISHIWADA, YASUFUMI, HIGUCHI, YU, and KIKUCHI, YOSHIKI.** Correlation by the smaller Foraminifera on the southern Kanto Gas Field.—Jour. Japan. Assoc. Petr. Tech., v. 27, No. 3, May 1962, p. 68-79, 1 pl., text figs. 1-10 (maps, columnar section, range and abund. chart, biostratigraphic correl. charts).—Eight faunules are used in subdividing the Pliocene and in local subsurface correlation.
- KASIMOVA, G. K.** O nekotorykh vidakh rebristykh lentikulin iz srednejurskikh otlozhenij Azerbajdzhana.—Akad. Nauk Azerbajd. SSR, Izvest., ser. geol.-geogr. nauk nefti, no. 3, 1962, p. 61-72, pls. 1, 2.—Seven species of *Lenticulina* (4 new) and 2 new varieties from the Middle Jurassic.
- KENNETT, J. P.** The Kapitean stage (upper Miocene) at Cape Foulwind, West Coast.—New Zealand Jour. Geol. Geophys., v. 5, No. 4, Nov. 1962, p. 620-625, text fig. 1 (map), tables 1, 2.—Foraminifera listed from 8 samples taken in a 350-foot section.
- DE KLASZ, I.** Bibliographie Micropaléontologique de l'Afrique Noire Occidentale depuis 1950 (Foraminifères et Ostracodes).—Bull. Instit. Français Afrique Noire, tome 24, ser. A, No. 4, 1962, p. 1242-1245.
- DE KLASZ, I., and RÉRAT, D.** Quelques nouvelles espèces du genre *Buliminella* du Crétacé Supérieur

- du Gabon (Afrique Équatoriale).—Revue de Micropaléontologie, v. 5, No. 2, Sept. 1962, p. 69-74, pl. 1, range chart, map.—Three species one having 3 subspecies, are described from the Senonian.
- LISZKOWA, J. Classification du Crétacé de la série subsiléssienne des Carpates Polonaises, basée sur la présence de microfaune.—Ann. Instit. Geol. Publ. Hungarici, v. 49, fasc. 3, 1961, p. 889-902, text figs. 1, 2 (map, columnar section).
- MAJZON, L. *Globotruncana*-bearing sediments in Hungary (English summary of Hungarian text).—Ann. Instit. Geol. Publ. Hungarici, v. 49, fasc. 3, 1961, p. 745-787, pls. 1-7, maps 1, 2, tables 1-4.
- Nomenclatural modification of the paper "The fauna of the beds with *Clavulina Szaboi*" by Miksa Hantken.—Bull. Hungarian Geol. Soc., v. 92, No. 3, July-Oct. 1962, p. 268-273, pls. 29-44.—A reprinting of the Hantken plates with, in many instances, changed generic assignments.
- MORIKAWA, ROKURO. Solidgraphical study of Fusulinid Foraminifera.—Jour. Geol. Soc. Japan, v. 68, No. 804, Sept. 1962, p. 518-521, pl. 5, text figs. 1-4 (drawings).
- ODRZYWOLSKA-BIENIEK, EWA. Permian microfauna from Sieroszowice (English summary of Polish text).—Poland Instyt. Geol., Biul. 156, 1961, p. 79-93, pls. 1, 2.—Descriptions and illustrations of 22 specimens in thin section.
- OZONKOWA, HELENA. The genus *Umbellina* (Foraminifera)—an index fossil in the Devonian of the Holy Cross Mts. (English summary of Polish text).—Ann. Soc. Géol. Pologne, v. 32, fasc. 1, Année 1962, p. 107-117, pls. 7, 8, text figs. 1-3 (map, drawings).—Three species, 2 new.
- PAVLOVEC, RAJKO. On the derived large foraminifers in Flysch.—Geologija, Razprave in Porocila, Ljubljana, No. 7, p. 247-255, 2 text figs., 1 range chart.
- PESAGNO, EMILE A., JR. Planktonic Foraminifera from the Juana Diaz formation, Puerto Rico.—Micropaleontology, v. 9, No. 1, Jan. 1963, p. 53-60, pls. 1-3, text figs. 1, 2 (table, drawing).—Seven species and 4 subspecies (1 new), indicating an age of *Globigerina ampliapertura* and *Globorotalia opima opima* zones for the Juana Diaz formation.
- PROTIC, MILKA. *Fabiania cassis* (Oppenheim) dans les sédiments d'Eocène de la Côte Adriatique de Monténégro (French résumé of Yugoslavian text).—Vesnik Geologija, Yugoslavia Instit. Recherches Geol. Geophys., ser. A, tome 18, 1960, p. 149-156, pls. 1, 2, text fig. 1 (map).
- RADOICIC, RAJKA. Les caractéristiques générales micropaléontologiques du Crétacé aux environs de Titograd (French résumé of Yugoslav text).—IIIème Congrès Géol. Yougoslavie, tome 1, 1961, p. 201-216.
- REISS, Z. Stratigraphy of Phosphate deposits in Israel.—Israel Geol. Survey, Bull. No. 34, 1962, p. 1-23, text figs. 1-5 (range chart, columnar sections, graphic log, phylomorphogeny diagram).—Quantitative and gross qualitative analysis of the Foraminifera fauna in the Upper Campanian to Danian section of a borehole. Ranges are shown for 38 stratigraphically significant species. Phylomorphogeny of *Neoflabellina* as represented in the borehole is shown.
- Comments on wall structure of Foraminifera.—Micropaleontology, v. 9, No. 1, Jan. 1963, p. 50-52.—In support of lamellar structure of all perforate Foraminifera by addition of lamellae per instar.
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