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ECOLOGY OF LIVING BENTHONIC FORAMINIFERA FROM THE SAN DIEGO, CALIFORNIA, AREA

BY

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ECOLOGY OF LIVING BENTHONIC FORAMINIFERA FROM THE SAN DIEGO, CALIFORNIA, AREA

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ABSTRACT

One hundred and fifty-seven samples from the sea floor off San Diego, California, were studied for both living and total (living plus dead) populations of Foraminifera.

Seven benthonic Foraminifera depth assemblages are recognized on the basis of the living distributions and abundances. The boundaries are at depths of approximately 13, 45, 100, 250, 350, and 450 fathoms. Based on the Scripps Institution's study of hydrography it appears that the 13-fathom boundary may be interpreted as approximating the base of the turbulent zone, the 45-fathom boundary the bottom of the seasonal thermocline, the 100-fathom boundary the bottom of the California Current, the 250-fathom boundary the top of the permanent thermocline, the 350-fathom boundary the oxygen minimum layer, the 450-fathom boundary the bottom of the permanent thermocline. The shallowest assemblage is divided into two facies and difference of sediment types may be one of the principle causes of such differentiation.

Comparison of depth ranges of living and empty tests of 95 species shows that some of the tests of almost all species are transported toward deeper water after death. Total population counts are valid in defining the general composition and distribution where little or no displacement of sediment is expected, but generally these counts are not indicative of distribution of living specimens. Maximum abundance of living benthonic Foraminifera occurs between 55 and 150 fathoms and approximately coincides with the greatest number of species and genera. Temperature, food, and sediment type are considered important factors for depth distribution and size of population of living benthonic Foraminifera.

Ratios of living to total populations from sediment samples appear to be indicative of the rate of sedimentation. The ratios support the suggestion of Dietz (1952) that sediments from the land are deposited either nearshore or on the lower part of the continental slope and in basins, bypassing the outer shelf and upper continental slope. Rates of sedimentation calculated from an assumed rate of reproduction of Foraminifera are 97 years per centimeter of sediment in the San Diego Trough and 0.36 years per centimeter in the nearshore area.

Three methods of calculating the amount of sea-level change by using benthonic Foraminifera are discussed. Five to ten fathoms of deepening is suggested at some time later than the Pleistocene.

The presence of shallow-water Foraminifera and Pleistocene Foraminifera in sand layers of a clayey silt core, and in sandy silt on the surface of the floor of the San Diego Trough, where clayey silts usually are found, proves displacement of sediments from shallow to deep water.

Siltstones were cored at three stations in and near Loma Sea Valley and Coronado Canyon, and are Miocene in age based on assemblages of Foraminifera, diatoms, and Radiolaria.

One hundred and sixty species of benthonic Foraminifera are figured, of which seventy species are discussed as to their ranges of variation of forms and/or synonymies. Two new genera are described: **Paradentalina** and **Recurvoidella**; thirty-four new species are described: **Ammomarginulina sandiegoensis, Arenoparrella oceanica, Asterigerinata pacifica, Bigenerina hoeglundi, Bolivina peirsonae, B. subargentea, Buccella angulata, Cassidulina bradshawi, C. subcarinata, Cassidulinoides waltoni, Cibicides phlegeri, Cornuspira lajollaensis, Eggerella scrippsi, Epistominella sandiegoensis, Globobulimina hoeglundi, Gyroidina quinqueloba, Haplophragmoides neobradyi, H. quadratus, Involutina hoeglundi, Karreriella parkerae, Nonion lankfordi, N. parkerae, Nonionella (?) fragilis, Recurvoidella parkerae, Spiroloculina fragilis, Spiroplectammina bathyca, Textularia sandiegoensis, Trochammina chitinosa, T. discorbinoides, T. labiata, T. rhumbleri, Virgulina apertura, V. delicatula, V. sandiegoensis.**

PART I: ECOLOGY

INTRODUCTION

The submarine geology, oceanography, and taxonomy of the Foraminifera in the San Diego, California, area are relatively well-known. One hundred and fifty-seven samples were studied in this area for the following purposes: 1) to establish the faunal assemblages of living benthonic Foraminifera in various environments and to relate the distribution of the living faunas with known physical and chemical factors and sediment types; 2) to compare the living benthonic faunas with the non-living benthonic faunas at each station; 3) to investigate relative rates of sedimentation and the displacement of sediments by using Foraminifera.

The field work was done on board the research vessels of the Scripps Institution of Oceanography of the University of California. Laboratory facilities were furnished by the Marine Foraminifera Laboratory and the Division of Marine Geology and Geochemistry of the same institution. The laboratory work was supported in part by a contract of the Office of Naval Research with the University of California. The entire work was supervised by Fred B Phleger, and, in addition, R. S. Arthur, M. N. Bramlette, U. S. Grant, IV, M. W. Johnson, H. W. Menard, Miss F. L. Parker, F. P. Shepard and E. L. Winterer read the manuscript and offered suggestions. The writer is especially indebted to J. S. Bradshaw who aided him in numerous ways in the field and laboratory work. R. R. Lankford assisted in collecting samples, and Jean P. Hosmer assisted in the grain size analyses of the sediments. Taro Kanaya identified the diatom flora in a Miocene rock. The writer is also indebted to Dr. C. G. Adams of the British Museum (Natural History), London, for examining type material of *Recurvoides contortus* Earland and lending two topotypes of *Eggerella bradyi* (Cushman) to the writer.

DESCRIPTION OF THE AREA

This area was studied by Emery, Butcher, Gould and Shepard (1952, p. 511-548) who summarized the present state of knowledge of the submarine geology of the area. The main features are as follows (see Text Fig. 1):

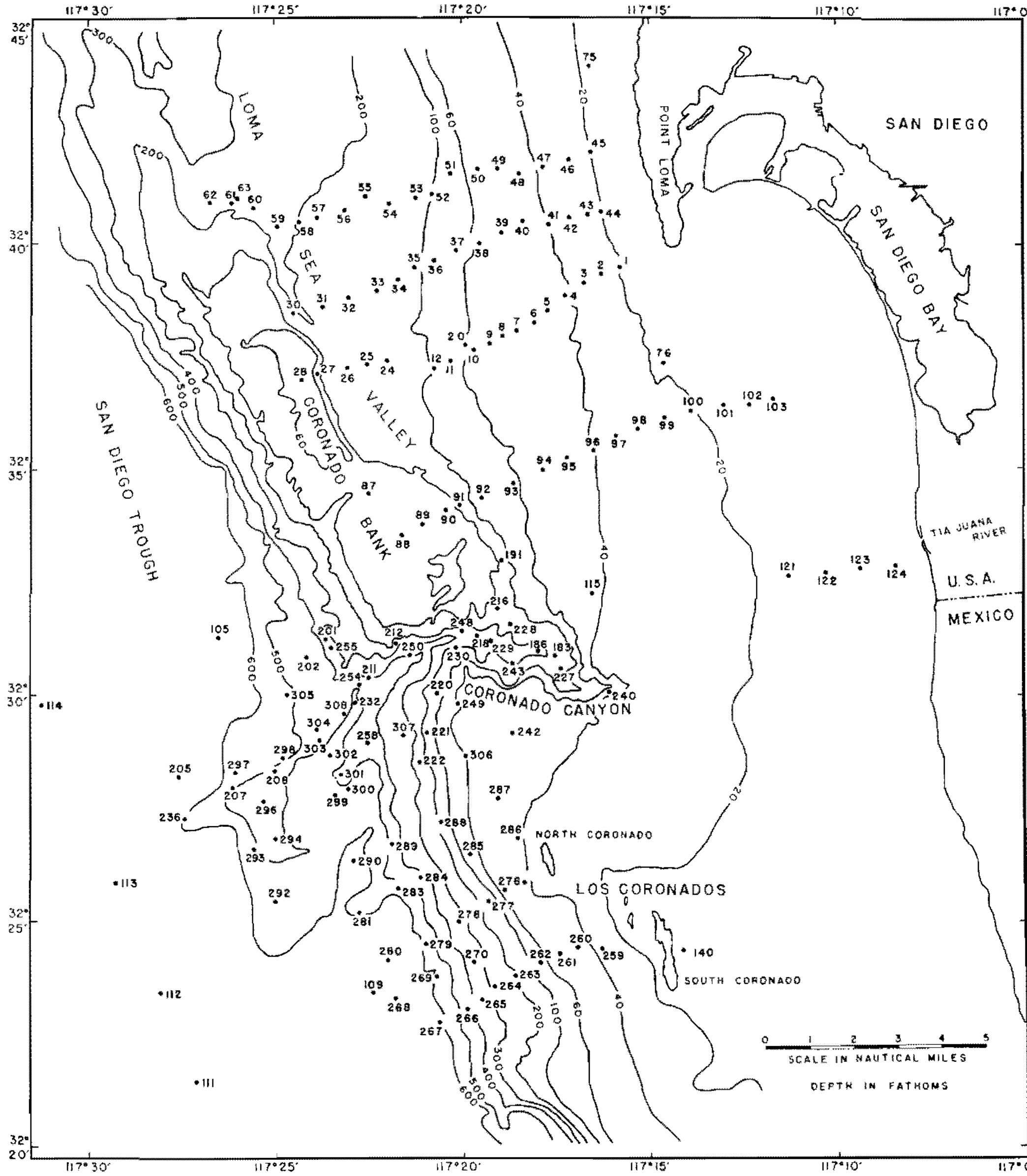
(1) The beach consists of sands except in the Point Loma area where there are cliffs of Cretaceous and Eocene rocks.

(2) The Tia Juana River, near the International Boundary, is mostly dry throughout the year and its estuary is relatively wide and is influenced by tides. There is almost no river run-off at present except during floods, but the river had a strong influence on the distribution of sediments during the Pleistocene.

(3) The continental shelf is narrow, approximately 4 nautical miles wide near Point Loma and 10 nautical miles near the Coronados Islands. The shelf break is at a depth of approximately 60 fathoms, and a continental borderland extends seaward.

(4) Loma Sea Valley borders the shelf in the north and extends approximately NW-SE from the head of the Coronado Canyon to the San Diego Trough. Rocks are exposed on the valley wall in many places and the bottom is covered by silt which contains coarse sands and pebbles in many places.

(5) Coronado Bank (and its extension, the Coro-



Text Figure 1. Locations of stations; bathymetry (after Emery *et al.*, 1952).

nado Ridge) trends parallel to Loma Sea Valley, and is separated from the Coronados Islands by Coronado Canyon. The shallowest depth on the bank is less than 60 fathoms and it gradually becomes deeper toward the northwest. The bank consists essentially of rocks but is covered in places by very thin sediments of Recent and Pleistocene age.

(6) Coronado Canyon cuts into Coronado Bank and the shelf and is connected with the head of Loma Sea Valley. The canyon wall is steep and rocks are exposed along it. The upper half of the canyon widens into a broader valley. The floor of the canyon is covered by silty sand and in some places by coarser materials, but the valley is covered by silt. The canyon extends southwest into the San Diego Trough. A delta-like feature at the canyon mouth consists of clayey silt, but fine sands commonly are present which are transported from the nearshore area along the canyon by turbidity currents or some similar mechanism.

(7) The Coronados Islands are the extension of Coronado Bank and Coronado Ridge and probably consist of Miocene rocks.

(8) A prominent slope leads down into the San Diego Trough beyond the break at the outer edge of the shelf and the bank. A series of small and somewhat discontinuous valleys cut the escarpment.

(9) The San Diego Trough, with a maximum depth of approximately 720 fathoms, is wide and flat and is covered by a thick layer of fine-grained sediments. Seismic measurements made by R. W. Raitt (1949) show a fill of 7000-9000 feet above basement rocks in the part of the trough directly off San Diego.

PREVIOUS STUDIES OF RECENT FORAMINIFERA OFF CALIFORNIA*

There are many papers on the taxonomy of the Recent and Pleistocene Foraminifera of tbe Pacific coast of America. Most of these are listed at the end of this paper.

Walton (1955, p. 958) summarized the ecologic studies of the Recent Foraminifera of the California coast, which were published from 1933 till 1953. These earlier works dealt only with empty tests.

Crouch (1954) analyzed 78 samples (snapper and dredge) taken at depths of 2 to 90 fathoms off San Pedro Harbor, of which 41 are Recent and others are rocks of early Pleistocene to Miocene age. He also dealt only with empty tests of Foraminifera.

Walton (1955) collected and analyzed living Foraminifera assemblages in 215 sediment samples in Todos Santos Bay, Baja California, Mexico, of which many are duplicate samples taken at different times of the year for seasonal study. He also analyzed the dead Foraminifera assemblages of 110 samples. He recognized four geographic assemblages, outer bay, middle bay, inner bay, and marginal bay facies; and five depth facies at less than 30 fathoms, 30-50 fathoms, 50-100 fathoms, 100-350 fathoms, and deeper than 350-400 fathoms. He thought that variation in sediment type, food, etc., might limit the distribution of benthonic Foraminifera, in addition to depth and/or temperature variations. He found that dead population counts are valid to define the faunal composition and general distribution of benthonic Foraminifera faunas but are not indicative of the actual abundances of living faunas. Maximum abundances of living benthonic Foraminifera occurred during the late spring and summer and the maximum populations were at 20-50 fathoms. He suggested that the ratio of living to dead population was indicative of relative rate of sedimentation at each location.

Natland (1957) published a paper on the paleoecology of west coast Tertiary sediments together with the ecology of Recent west coast Foraminifera. His basis of discussion is essentially the same as in his previous paper (1933), although this is supplemented by the work of Crouch (1952) and Bandy (1953) and by his knowledge of the distribution of fossil and Recent Foraminifera species. All the discussions are based on the distribution of empty tests of Foraminifera, not of living ones. He discussed the origin of fossil basins such as Los Angeles, Ventura and San Joaquin based on the distribution of *Bolivina vaughani* Natland. He said (p. 555) "*Bolivina vaughani* is a very hardy species, equally at home in shallow and abyssal waters. It thrives, to the exclusion of most all other species, in deep, stagnant basins with shallow sills. . . . " He also said (p. 549) "The areas where this species dominates may have been the sites of local closed basins with abnormal thermal gradients." For examples of such basins he mentioned the Gulf of California and fossil basins of San Joaquin, Los Angeles, Ventura, and Santa Maria. Living specimens of this species, however, are found at depths ranging from 5 (perhaps shallower) to 105 fathoms in the San Diego area and from 0 to 250 fathoms in Todos Santos Bay, Baja California, Mexico (Walton, 1955). Empty tests are found at many stations in the San Diego Trough (*ca.* 500-650 fathoms). Thus it is possible that Natland's discussion on the origin of such basins is wrong.

Bandy and Arnal (1957) studied the distribution of Recent Foraminifera off the west coast of Central America. They recognized 5 faunal zones based on the distribution of the empty tests from only 36 samples at depths ranging from 1 to 1,045 fathoms and over a distance of approximately 1,200 nautical miles. Their faunal zones are as follows: Inner shelf fauna (0-25 fathoms), Outer shelf fauna (25-66 fathoms), Upper bathyal fauna (66-333 fathoms), Middle bathyal fauna

* Editor's note: The paper of Resig (1958) and subsequent papers were not available to the author at the time of writing. References to Resig's species were added later.

(333-666 fathoms), Lower bathyal fauna (666-1,045 fathoms).

HYDROGRAPHY

The following generalizations have been based on data from stations occupied by research vessels of the Scripps Institution of Oceanography ("Physical and Chemical Data" 1949-1957). The temperature at the surface is warmest in August or September (*ca.* 20.00°C.) and coldest in January or February (13.12°C.). The top of the seasonal thermocline is deeper in winter than in summer. It lies at *ca.* 30 m. (17 fathoms) in January, at *ca.* 20 m. (11 fathoms) from February to June, at *ca.* 10 m. (5.6 fathoms) from July to October (except in August when it lies almost at the surface of the sea), and at *ca.* 20 m. (11 fathoms) in November. The depth of the bottom of the seasonal thermocline is at *ca.* 75 m. (42 fathoms) throughout the year. The temperature at the top of the seasonal thermocline is slightly lower than that at the surface of the sea and changes with the seasons (minimum 13.1°C. in January and maximum 19.3°C. in September). The temperature at the bottom of the seasonal thermocline is *ca.* 9.3-11.6°C.

Surface salinity is generally higher in summer and lower in winter, with a minimum of 33.19 o/oo in February and a maximum of 33.79 o/oo in October. Salinity at all seasons decreases slightly with depth to a poorly defined salinity minimum, then gradually increases with increase of depth. The depth of the salinity minimum changes seasonally and yearly but lies below the top and within the seasonal thermocline. It lies between 30 and 75 m. (16.7-42 fathoms). Here the salinity ranges from 33.17 to 33.53 o/oo being highest in April and May and lowest in February and March.

The oxygen minimum layer is at approximately 600-700 m. (333-389 fathoms). The depth of the layer and the amount of oxygen change seasonally and yearly but are approximately as follows:

May-November at *ca.* 367-389 fathoms, 0.25-0.48 ml/L.
November-April at *ca.* 333-367 fathoms, 0.32-0.37 ml/L.

METHODS OF STUDY

Field Methods

The field work was carried out during five cruises as follows:

Date	*Station Number*
July 19-23, 1954	1-103
September 14-15, 1954	104-114
August 16-17, 1955	115-139
November 7-8, 1955	140-200
June 26-28, 1956	201-239
August 13-16, 1956	240-336

Samples were collected along several traverses with an average distance between stations of approximately ½ nautical mile. The traverses were spaced about 1½ nautical miles apart. Stations were located by using sextant angles on known shore positions, dead reckoning, and bathymetry.

All the samples were taken with a small, gravity coring tube except at a few places where the bottom sediments consist of a mixture of very coarse sand, gravel or cobble, where an orange peel dredge was used (see Phleger, 1951b, p. 3-5; 1952, p. 320). The coring tube obtains a short, relatively undisturbed core 1⅜ inches in diameter. As the cores were taken from the tube, the top centimeter was cut off and placed in a sample jar with the sea water above the sediment-water interface and preserved in a 10% solution of neutralized formalin. A small amount of sodium carbonate was added to the samples to maintain an alkaline solution, since neutralized formalin becomes acidic with time. All the samples thus obtained contain approximately the same volume of sediment and represent the same area of surface sediment as those collected by Walton (1955); therefore, the Foraminifera populations of the San Diego and Todos Santos Bay areas can be compared.

In addition to sediment sampling, measurements of sediment temperatures were made during August 13-17, 1956, at 75 stations from depths of 40-630 fathoms. These were obtained on the deck of the vessel when the samples were brought to the surface and do not represent the temperatures *in situ*. Compared with the temperatures *in situ* (measured by Scripps Institution personnel) of water at depths of about 100, 300, and 500 fathoms, the bottom temperatures taken in this manner on the deck of the vessel are approximately 0.5°, 0.7° and 1.5°C. higher respectively.

Laboratory Work

Living populations were counted in 162 samples and dead populations in 156 samples. Sediment size analyses and descriptions of the constituents in the sediment fraction coarser than 0.062 mm. were made on 19 samples.

The living populations were determined by the rose Bengal staining method (Walton, 1952). "Living" is used throughout this paper to indicate those specimens which contained protoplasm when collected as indicated by the rose Bengal stain. The word "dead" refers to those Foraminifera tests which did not contain protoplasm at the time of collection. The reliability of these assumptions is discussed by Walton (*op. cit.*, p. 59). Samples 1-140 were washed through a sieve with an opening of 0.074 mm., and samples 141-326 through a sieve with an opening of 0.062 mm. The residues were stained in a rose Bengal solution for 3-24 hours. All living specimens in each sample were counted while wet.

After the living population count was made the sediment was washed, dried, and then split by using an Otto Microsplit in order to obtain a workable size from which the total population was counted. Five hundred or more specimens were identified in most samples, but in a few only about 150 were counted. The number of planktonic specimens was counted for all the samples, and the ratio of benthonic to planktonic population (B/P) was calculated.

SEDIMENTS

A distribution chart of sediment types was published by Emery *et al.* (1952, fig. 7) based on 1,656 samples. The number of stations occupied during the present study was 337, of which 254 stations were successfully cored. At the other stations sediments were not obtained, but often coarse sands were observed in the core-catcher, or the core-nose was bent which suggests the presence of rock bottom. The sediment distribution shown by these new samples is almost the same as that of Emery *et al.* who divided the modern sediments into three broad groups:

(1) clastic sediments.—subdivided into five major types and four minor ones according to grain size and color.

(2) calcareous organic sediments.—shell sand and Foraminifera sand.

(3) mixed clastic and calcareous organic sediments.—mixture of (1) and (2), each about 50%.

Emery (1952) briefly summarized the continental shelf sediments of southern California from data on Santa Monica Bay (Shepard and Macdonald, 1938), San Pedro Bay (Moore, 1951) and the area off San Diego (Emery *et al.*, 1952). These studies reveal a complex distribution of continental shelf sediments in which there is a notable absence of progressive decrease of grain size with distance from shore. This fact is contrary to the previous concept that the sediments are gradational from coarse-grained near shore to fine-grained off shore. Emery (1952) classified the continental shelf sediments of southern California into five types: (1) authigenic (glauconite, phosphorite); (2) organic (Foraminifera, shell); (3) residual (washed from underlying rock); (4) relict (remnant from a different earlier environment); and (5) detrital (presently supplied chiefly from adjacent river mouths, beaches or sea-cliffs). Representatives of the first four groups occur in such places as banks, hills, and the outer edge of the shelf where they are not masked by the more rapidly deposited detrital sediments. The detrital sediments, taken alone, present a relatively simple gradation from coarse-grained to fine-grained in a seaward direction. The present patchy distribution is evidently the result of insufficient time since post-glacial rise of sea-level for the present supply of detrital sediment to bury completely the irregular topography.

Shale was cored at station 75 at 13 fathoms on the edge of a kelp bed near Point Loma. The rock has been bored by burrowing organisms. It contains no Foraminifera, but may be Cretaceous in age since it has a lithology similar to known Cretaceous rocks which occur nearby.

A siltstone was cored at station 61 at 214 fathoms on the west wall of Loma Sea Valley. The rock is covered by a thin layer of modern sediment. It is rich in diatom remains and is stratified. The Foraminifera are very abundant and very fresh in appearance, and the following species were identified:

Abundant species:
- *Bolivina floridana* Cushman
- *Bolivina* sp. cf. *B. seminuda* Cushman
- *Bolivina woodringi* Kleinpell
- *Bolivina* sp.
- *Buliminella subfusiformis* Cushman
- *Virgulina californica purisima* Bramlette

Common species:
- *Bolivina bramlettei* Kleinpell
- *Bulimina ovula* var. *pedroana* Kleinpell
- *Discorbinella* (?) *valmonteensis* Kleinpell
- *Epistominella* sp.
- *Hopkinsina magnifica* Bramlette
- *Nonion montereyanum* Cushman and Galliher
- *Uvigerina* sp. cf. *U. subperegrina* Cushman and Kleinpell

Rare species:
- *Anomalina hughesi* Rankin
- *Cassidulina* sp.
- *Nonionella miocenica* Cushman
- *Pullenia* sp.
- *Virgulinella* sp. cf. *V. pertusa* (Reuss)
- *Virgulinella* sp.

These Foraminifera show that the age of the siltstone is late Miocene.

The following diatom species were identified by Taro Kanaya:
- *Actinoptychus senarius* (Ehrenberg)
- *Actinoptychus* spp.
- *Asteromphalus* sp.
- *Campyloneis grevillei* (W. Sm.) Grunow var. *argus* Grunow
- *Coscinodiscus aeginensis* A. Schmidt
- *Coscinodiscus asteromphalus* Ehrenberg
- *Coscinodiscus marginatus* Ehrenberg
- *Coscinodiscus denarius* A. Schmidt
- *Coscinodiscus oculus-iridis* Ehrenberg
- *Dicladia pylea* Hanna and Grant
- *Hemiaulus polymorphus* Grunow
- *Hemiaulus* sp.
- *Lithodesmium undulatus* Ehrenberg
- *Melosira sol* (Ehrenberg) Kützing
- *Melosira sulcata* (Ehrenberg) Kützing
- *Navicula californica* Greville
- *Navicula lyra* Ehrenberg
- *Navicula ornata* Schmidt
- *Nitzschia nelsoni* Hanna and Grant
- *Periptera tetracladia* Ehrenberg

TRAVERSE	I																		
STATION	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
DEPTH IN FATHOMS	20	33	38	42	47	53	80	94	118	137	157	164	181	194	208	223	214	247	238
LIVING POPULATION	234	1177	869	762	1354	689	894	528	1036	372	712	346	225	193	116	550	171	1252	29
Alliatina primitiva		.1	.1	.5			.7	.2			1	2	1	2	2	.5		1	9
Alveolophragmium advena	2																		
A. columbiense	2	.9	.7	1	2	2	.6	1	.6	1	.6	2	1						
Ammobaculites catenulatus						.1	.2	.2	.5	4	6	7	6	6	2	6	2	2	
Ammotium planissimum	2	1	.5	1	.7	1	.9	.2	.6	2	.3		1	2		5	.6	.2	
Angulodiscorbis charlottensis																			
Angulogerina angulosa	3	.4			.7	4	3	1	.3	3	2	.6	1				7	.2	
Arenoparrella oceanica		.1		.1	.3	1	.7	.9	.4										
Asterigerinata pacifica																			
Astrononion viragoensis							.3												
Bigenerina höglundi		.1																	
Bolivina acuminata		.3	.9	.7	9	13	4	5	1	1		.9	1						
B. acutula	2	.3	.2	.7	1	.6													
B. bicostata											.1								
B. filacostata																			
B. minuta											.1	.6	2	4	5	2	5	2	
B. pacifica	.8	13	14	13	19	6	12	35	70	18	17	8	6	6	7	.7	15	3	3
B. peirsonae																			
B. spissa										3		4		6	3	3	13	2	
B. subargentea									.4	8	6	3	2	2	2	2	.6	27	7
B. subexcavata	.4																		
B. vaughani	1	.4	.7	.1															
Buccella angulata		3	2	2	5	12	6	.6											
Bulimina denudata		.1	.2	.5	.7	2	4	1	3		.6			.5				.1	
B. mexicana																			
B. pagoda																			
B. subacuminata																			
Buliminella elegantissima	2	4	2	1	.5	.1													
B. tenuata																		1	
Cancris auricula	1	.1		.3	3	.3	3	.8	.1	.3		.3							
C. inaequalis																	1		
Cassidulina bradshawi																			
C. californica																			
C. delicata											.1	.3			.9	.2	.6	.6	
C. depressa	1	.7	.1	1	.4	.1	9	2	3	3	.1								
C. limbata					2	.6	.5	2	1	5									
C. subcarinata													.5			.2	2	.1	
C. subglobosa		.1	.1			.7	1	.4	1	3	5	9	19	8	.9		4		
C. tortuosa																			
C. sp. cf. C. orientalis																			
Cassidulinoides waltoni								.2		.3		.3	1			.2	.6		
Chilostomella ovoidea						.1	9	.2	1	1	.3	4				.4		3	
Cibicides fletcheri	.4		.1																
C. mckannai					.1	2	1	.8	.5	.3									
C. phlegeri																			
C. spiralis																			
Cornuspira lajollaensis																			
Cornuspiroides foliaceus		.1					.1												
Ehrenbergina compressa																		.1	
Elphidium spp.																			
Epistominella sandiegoensis	1	.2	.2		.1	.9	.8	.2	.1	.3	.1	.3	.5				.6	.1	
E. smithi																		.1	
Eponides leviculus						.3	2	2	.4	.8	.1	.3	2						
E. subtenerus																			
Gaudryina arenaria				.1	.6	2	.9	.2											
G. subglabrata						.4													
Goësella flintii		5	8	9	7	2	1		.5	3	2	3	14	10	10	31	14	3	10
Globobulimina barbata																			
G. höglundi																			
G. pacifica		.1	.8	1	.6	.9	2	13	2	.5	6	6	10	2	2			7	
G. spinifera																			
Glomospira gordialis																			
Gyroidina gemma																			
G. quinqueloba																			
Hanzawaia nitidula	3																		
Haplophragmoides neobradyi					.4	2	1			.3									
H. quadratus																			
H. sp.																			
Höglundina elegans										.3							.6		
Cassidulina sp.																			

TRAVERSE	II														
STATION	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30
DEPTH IN FATHOMS	20	29	34	39	42	46	53	73	87	104	114	121	135	148	180
LIVING POPULATION	153	1293	1932	731	795	685	680	811	976	412	129	669	861	523	190
Alliatina primitiva		.1		.1	.6	.3	2	2	1			2	.1	3	8
Alveolophragmium advena		.9	.6	.6			.3	2							
A. columbiense	3	.1			.5	1	.5		.3	.4	.8	.8	.1		.5
Ammobaculites catenulatus					.4	.7	.1	.1	.2	.2	.8	1	2	1	2
Ammotium planissimum		.6	.6	.4	2	1		.6		.2	5	3	.5		2
Angulodiscorbis charlottensis															
Angulogerina angulosa	1	.5			.4	1	1	.2	.5	1	3	1	1	.6	2
Arenoparrella oceanica			.1	.1	.6	2	.7	1	.1		1	.3	.1	.4	2
Asterigerinata pacifica															
Astrononion viragoensis															
Bigenerina höglundi															
Bolivina acuminata			.6	.3	3	10	11	2	.5	.7	2	3	.7	.6	
B. acutula		.2	.4	.1	.8	.6	.6								
B. bicostata															
B. filacostata															
B. minuta											.8		.1	.2	
B. pacifica	.7	5	10	17	16	9	23	21	45	21	18	17	36	29	33
B. peirsonae															
B. spissa															
B. subargentea											.8	1	2	8	.5
B. subexcavata															
B. vaughani	.7	.5	.3		.3	.2									
Buccella angulata		1	3	2	7	16	6	7	1						
Bulimina denudata		.2			.3	1	.9	3	1	.4	14	6	2	.8	
B. mexicana															
B. pagoda															
B. subacuminata															
Buliminella elegantissima	.7	3	3	2	.6	.4	2	.4	.1						
B. tenuata									.1						
Cancris auricula						.6	2	2	.4					.4	4
C. inaequalis															
Cassidulina bradshawi															
C. californica										.2					
C. delicata															
C. depressa	22	1	.5	.4	2	1	3	.9	2	.7	9	8	2	.2	
C. limbata						.2	.1	.9	.7	.7	2	5	.5		
C. subcarinata															
C. subglobosa		.2				.2	.5	4	.5	.2	3	3	2	2	4
C. tortuosa								.1							
C. sp. cf. C. orientalis															
Cassidulinoides waltoni													.1		
Chilostomella ovoidea								6	3				.1	.2	2
Cibicides fletcheri	.7														
C. mckannai					.1	.3	.7	2	.4		4	1			
C. phlegeri															
C. spiralis															
Cornuspira lajollaensis	2														
Cornuspiroides foliaceus															
Ehrenbergina compressa															
Elphidium spp.															
Epistominella sandiegoensis		.8	.2	.1		.3	.9	1			1	.8	.1	.6	
E. smithi															
Eponides leviculus					.3		.3	.4	.3	.7	3		.2		
E. subtenerus															
Gaudryina arenaria					.1	.4	.7	2	.4			.3			
G. subglabrata															
Goësella flintii		1	4	5	20	6	1	.5			.8	.1	.1	.5	28
Globobulimina barbata															
G. höglundi															
G. pacifica		1	1	.3	.6	1	.3	.9	8	8	9	4	17	5	.5
G. spinifera															
Glomospira gordialis															
Gyroidina gemma															
G. quinqueloba															
Hanzawaia nitidula	8														
Haplophragmoides neobradyi					.1	1		.6	.2						
H. quadratus															
H. sp.															
Höglundina elegans															1
Cassidulina sp.							1		.1				.1		

TRAVERSE	III																		IV		
STATION	1	2	3	4	5	6	7	8	9	10	20	11	12	24	25	26	27	28	03	02	01
DEPTH IN FATHOMS	19	20	35	40	44	45	47	49	52	56	59	74	92	112	123	157	92	71	15	17	20
LIVING POPULATION	195	212	142	96	207	534	800	328	562	761	591	408	83	418	1050	358	406	65	143	79	141
Alliatina primitiva							.1	.3	.7	1	1	2		1	1	2		2			
Alveolophragmium advena																					
A. columbiense	11	2	.7	3	3	8	2		1	1	.7	2	2	.7	.5	.4	.7	1	10	22	.7
Ammobaculites catenulatus										.3	.2			1	.5	3					
Ammotium planissimum		14		5		1	.1	2	.4	.3	.5	.7		3	.8	2	.7			3	4
Angulodiscorbis charlottensis																					
Angulogerina angulosa	7	5			1	2		5	2	9	9	3	1	1	.4	.8	6	6			.7
Arenoparrella oceanica										1	1	.7	1	1	1	.2	1				
Asterigerinata pacifica																					
Astrononion viragoensis																					
Bigenerina höglundi							.1	.6	.4		.2						.5				
Bolivina acuminata				4	1	8	4	2	7	5	4	8	17	6	.7	1	.5	5			
B. acutula				1	3	.7	.2		2	5	2	3							2		.7
B. bicostata																					
B. filacostata											.5										
B. minuta												.2			.1	2					
B. pacifica		1	4	2	10	8	7	12	15	19	18	30	12	8	21	21	15	11	1		
B. peirsonae																					
B. spissa																.4					
B. subargentea															1	9					
B. subexcavata										.4											
B. vaughani		.5					.2			.3	.2								.9	1	
Buccella angulata		1	1	4	5	8	2	3	1	2	2	.5	1						.7	1	3
Bulimina denudata	1	1		2	1	.6	1	.5	.4	.5	.7	.7	1	.7	.8						
B. mexicana																					
B. pagoda																					
B. subacuminata																					
Buliminella elegantissima	2	.7				1	1	.9	1										14		3
B. tenuata																					
Cancris auricula						.2	3		7	8	10	8		.2	.1	3	8	3			
C. inaequalis																					
Cassidulina bradshawi																					
C. californica										.8		.2									
C. delicata																.4					
C. depressa							.4			1	2	1		4	1		.7	11			
C. limbata									.4	3	1	1		2	.6			1			
C. subcarinata																					
C. subglobosa	8	3		13	2			2	2	9	4	4	4	1	.9	5	.7	3		1	2
C. tortuosa										.9		.5									
C. sp. cf. C. orientalis																					
Cassidulinoides waltoni																	.2				
Chilostomella ovoidea									.4	.4	.7	4			4	.8	3	6			
Cibicides fletcheri	2	1					.2	.6	.4												
C. mckannai	2				2				.6	.4	2		.2	4	.5	.3	2	5			
C. phlegeri																					
C. spiralis																					
Cornuspira lajollaensis		1					.2	.3												4	
Cornuspiroides foliaceus																					
Ehrenbergina compressa																					
Elphidium spp.		2																	4		.7
Epistominella sandiegoensis							1	.6	.2	.4	.2			.5	.1	.4	.2				
E. smithi																.4					
Eponides leviculus							.2			1	3		4	.2	.2		.7				
E. subtenerus																					
Gaudryina arenaria					.5	.6	.1	1			.3	.5									
G. subglabrata											.3										
Goësella flintii		2	4	25	7	16		.3	2	.5		1		.5	.4	3					.7
Globobulimina barbata																					
G. höglundi																					
G. pacifica			5	1	1	1	2	2	1	.7	.2	.5	4	5	8	6	.2	1			
G. spinifera																					
Glomospira gordialis																					
Gyroidina gemma																					
G. quinqueloba																					
Hanzawaia nitidula	1	.5								.5	2						1	6			
Haplophragmoides neobradyi										.3	.3										
H. quadratus																					
H. sp.										.4	.7						.2				
Höglundina elegans																	.5				
Cassidulina sp.							.2		.2												

Table 1. Occurrences of living benthonic Foraminifera in percent of living population.

Rutilaria epsilon Greville
Stephanopyxis antiqua Pantocsek
Stephanopyxis grunowii Grove and Sturt
Thalsionema nitzschioides Grunow
Thalassiothrix sp.
Xanthiopyxis globosa Ehrenberg
Xanthiopyxis maculata Hanna
Xanthiopyxis ovalis Lohman
Xanthiopyxis oblonga Ehrenberg

According to Kanaya (personal communication), *Rutilaria epsilon* and *Navicula ornata* are well-known forms

STATION	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63
Involutina pacifica		.1	.3	1	.2	.6	.3	.6	.2	.8	1	2	3	1	.9	.4	1	.3	
Lagena & related spp.	5	.2	.1	.1	.3	.9	1	.4	.3	.9	.7	.6	.5	.5					
Lagenidae (other)	2						.6	.4	.2	.3									
Loxostomum bradyi																			
L. pseudobeyrichi																.5		4	7
Neoconorbina terquemi																			
N. parkeri																			
Eggerella advena	.8	1	1		.7	2	1	.8	.1	.3	.1	3				12	3	1	
E. scrippsi			1	.1	.2														
Nonion lankfordi																			
N. parkerae																			
Nonionella basispinata	15	3	.7	.7															
N. (?) fragilis																			
N. stella	21	39	24	15	19	16	19	15	2	9	8	4	.5	2	11		2	3	3
N. sp. aff. N. globosa								.8	.1	3	3	2		3	17	.4		2	
Nouria harrisii					.1		.2												
N. polymorphinoides					.1				.5	.3									
Patellina corrugata																			
Planulina ornata																			
Placopsilina bradyi																			
Polymorphinidae	2																		
Saccammina longicallis		.7	.2						.7	.2	1			.5					
Pullenia salisburyi							.1	.2	.7										
Recurvoides sp.		.2					2		.7	3	2		2				4		
Recurvoidella parkerae					.1	.2													
Remaneica cf. helgolandica																			
Reophax excentricus								.2											
R. gracilis	5	14	20	23	12	6	2	6	6	.5	22	2	.5	2	10	2		12	10
R. horridus																			
R. micaceous						.4		.4	.1		4	3	5	24	.4		2	3	
R. communis		.3	.3	.4	.4	.4	.2												
R. scorpiurus	2	1	1	1	1	.4	[illegible]	.8	.6	.5	.3	.6	.5				2		
R. subfusiformis																			
R. spp.																			
Robertinoides charlottensis	.4																		
Rosalina columbiensis																			
R. campanulata	3	.1	.9	.3															
R. turbinata																			
Seabrookia earlandi					.1		.3	1		.8	.7	.9	1	1		.2	2	.3	4
Sigmoilina tenuis				.1	.1			.2	.2	.3			.5						
Spiroloculina fragilis																			
Spiroplectammina bathyca																			
S. biformis																			
Suggrunda (?) eckisi											.6	1							
Textularia cf. abbreviata			3	.1		.4	.2		.1										
T. earlandi		2	.2	.1	.8	.6													
T. sandiegoensis		.2	.2	.7	.5	.7		.2	.7		.1							1	4
T. schencki		.6																	
Tritaxis bullata																			
Trochammina charlottensis	10	.2																	
T. chitinosa																			
T. conica							.2			1		.6					.6		
T. discorbinoides																			
T. globigeriniformis																			
T. kellettae		4	12	9	5	3	5	2	.5	.3	1	3	4	5	5	.9	2	.7	24
T. lobiata																			
T. nitida																			
T. pacifica & var.	.4	.1	.7	.3	.1	.1	2	.2	.7	2	1	1	2	2		1	5	.4	3
T. rhumbleri	.4	.4	1	1	4	1	1	1	.9	9	2	16	.5		7				
T. squamiformis		.4	.1																
Uvigerina auberiana																			
U. curticosta															2	31		17	14
U. juncea					.6	4	.7			.8		.3					.6		
Valvulineria araucana																	1	.4	
V. glabra																	4		
Virgulina apertura																			
V. bramlettei																		.1	
V. complanata																			
V. cornuta																			
V. delicatula											.6	4	.5	4	2			.2	
V. sandiegoensis	.8	2	2	4	6	1	.1		.1	2	4	2	1					.7	
V. seminuda										1	.7	4	8	6	8			1	4
Miliolidae	8	.6											1	.5	.9				
Miscellaneous spp.	9				.2	.4	.1	.6	.3		.2	1	2				5	.2	

STATION	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30
Involutina pacifica				.3	.8	.2		.3		.2	.8	.3	.5	.8	.5
Lagena & related spp.	2		.1		1	1	2	.6	.2			.1	.2	.2	
Lagenidae (other)		.2				.2		.1							
Loxostomum bradyi															
L. pseudobeyrichi															
Neoconorbina terquemi															
N. parkeri															
Eggerella advena	2	3	2	2	1	1	1	.7	.7		.8	.5	3		2
E. scrippsi															
Nonion lankfordi					.1										
N. parkerae															
Nonionella basispinata	5	9	12	15	1		.6	4	.5		.8				
N. (?) fragilis															
N. stella	1	55	39	10	18	10	9	15	10	4	5	2	.3		
N. sp. aff. N. globosa										.2	.8	.6	.3	1	3
Nouria harrisii															
N. polymorphinoides															
Patellina corrugata															
Planulina ornata	.7				.1										
Placopsilina bradyi															
Polymorphinidae												.1			
Saccammina longicallis				1	.1							1	.5	2	
Pullenia salisburyi															
Recurvoides sp.	1	.5	.2		.4	2	3	.7	.1	.2		.8			
Recurvoidella parkerae						3									
Remaneica cf. helgolandica															
Reophax excentricus					.1			.4	.2	.2					
R. gracilis		7	13	29	9	13	14	4	14	51	2	26	19	26	3
R. horridus											.8				
R. micaceous						.6	.1	3		.2		2		7	.5
R. communis		.4	.6	1	.4	2	1								
R. scorpiurus	.7	.5	.4	.6	4	3	1	1	.4			.5	.1		
R. subfusiformis															
R. spp.															
Robertinoides charlottensis															
Rosalina columbiensis															
R. campanulata	23	.2	.4			.2	.1								
R. turbinata															
Seabrookia earlandi				.1	.1	.2		.2	.6			.6	.3	.4	
Sigmoilina tenuis								.5		.2		.5	.2		
Spiroloculina fragilis															
Spiroplectammina bathyca															
S. biformis															
Suggrunda (?) eckisi															
Textularia cf. abbreviata				.1	.3			.2							
T. earlandi		.4	1	.6	.1	.6	2	.1			.8				
T. sandiegoensis			.2	.4	.6	.4	.9	.5	.2	.7		1		1	
T. schencki			.4		.1	.3	.3	.2							
Tritaxis bullata															
Trochammina charlottensis	14	.5													
T. chitinosa															
T. conica								.1	.3						.5
T. discorbinoides									.1						
T. globigeriniformis															
T. kellettae	2	3	2	9	2	3	2	2	1	1	7	2	2	1	.5
T. lobiata															
T. nitida															
T. pacifica & var.		.2	.2	.3				1		.2	.8	2	.5	3	
T. rhumbleri		.3	.7	.6	2	2	.7	3	4	2		1	7	3	
T. squamiformis	2														
Uvigerina auberiana															
U. curticosta															
U. juncea													.1		
Valvulineria araucana															
V. glabra															
Virgulina apertura															
V. bramlettei															
V. complanata															
V. cornuta															
V. delicatula													.8		
V. sandiegoensis		3	4	.8	3	2	.5	.1	.1	.2	1			1	
V. seminuda												.6	.6	.4	.5
Miliolidae	1	.1			.6		.3	.7	.5	.2				.2	
Miscellaneous spp.	6					.5			.2	.2		1	.7	.6	.5

STATION	1	2	3	4	5	6	7	8	9	10	20	11	12	24	25	26	27	28	103	102	101
Involutina pacifica	5				1	2	1			.4	.5	1				.4	.2	1			
Lagena & related spp.	2	3	.7	1	1	.2	1	.3	.4	1	.3	.4		.2					4	4	7
Lagenidae (other)							.1			.2	.4	.2				.4		2			
Loxostomum bradyi																					
L. pseudobeyrichi																					
Neoconorbina terquemi																					
N. parkeri																					
Eggerella advena	.5	2			.5	.2	1	.6		.7	.8				.1			2	1		1
E. scrippsi																	.5				
Nonion lankfordi								.3			.3										
N. parkerae																					
Nonionella basispinata	1	16	5	4	2	.7	.2		1		1	1			.7	.8			39	26	29
N. (?) fragilis																					
N. stella		17	73	28	48	21	46	34	18	7	13	11	8	4	6	3	24		18	23	33
N. sp. aff. N. globosa																.4					
Nouria harrisii										.4	.3										
N. polymorphinoides																					
Patellina corrugata																					
Planulina ornata	.5																				
Placopsilina bradyi											6						27				
Polymorphinidae	5																				
Saccammina longicallis	3	4		1	.5	.7	.1	.6	1	.4	.8	3		2	.7				1	1	.7
Pullenia salisburyi										.4	.3			.2							
Recurvoides sp.						3	3	.6	.2	.3											
Recurvoidella parkerae																					
Remaneica cf. helgolandica																					
Reophax excentricus									.2							1	.2				
R. gracilis		.3				5	9	13	16	6	2	4	6	38	37	14	1	18			
R. horridus														.7	.2						
R. micaceous							.1							3	4	2					
R. communis							.2	2	.5												
R. scorpiurus	.5	2	4	4	2	8	4	5	7	.5	.7	3		.7	.2	.4	.5		.7		.7
R. subfusiformis									.2												
R. spp.		.5			1	.2				.1											
Robertinoides charlottensis																					
Rosalina columbiensis	25											.2									
R. campanulata	3	3	.7		.5					.5	.5										
R. turbinata																					
Seabrookia earlandi							.2			.8	.7	.5		2	.5	.8	2	2			
Sigmoilina tenuis									.2												
Spiroloculina fragilis																					
Spiroplectammina bathyca																					
S. biformis																					
Suggrunda (?) eckisi																					
Textularia cf. abbreviata					1																
T. earlandi	.5	.5			1		.1														
T. sandiegoensis						.4								1	.1						
T. schencki							.1	.3													
Tritaxis bullata																					
Trochammina charlottensis																					
T. chitinosa																					
T. conica										.1	.7										
T. discorbinoides																					
T. globigeriniformis																					
T. kellettae		2	2	2	3			4	2	5	2	1	28	1	.6	2	.7				.7
T. lobiata																					
T. nitida											.2										
T. pacifica & var.	18	2				.2				.3	.2			1	.2	2	1				
T. rhumbleri						1	1			.3		.7	1	6	6	4					
T. squamiformis																					
Uvigerina auberiana																					
U. curticosta																					
U. juncea					1	.2	.6	.6	4	1		1				2	.9				
Valvulineria araucana																					
V. glabra																					
Virgulina apertura																					
V. bramlettei																					
V. complanata																					
V. cornuta																					
V. delicatula																					
V. sandiegoensis		1					4	3	2	.3	.8			.5	.6	1					2
V. seminuda														.5	.5	4	.2				
Miliolidae	3	7				.2	.2	.9	.4	.1	.2			.5	.2				4	12	11
Miscellaneous spp.	2	.5				.8		.3	.7	1	4	.2		2		.4	1	11		1	.7

Table 1 (continued). Occurrences of living benthonic Foraminifera in percent of living population.

in the Monterey shale (Hanna, 1928), with which this rock seems to correlate.

William Riedel examined the radiolarian fauna of the rock, and he also thought the age to be Miocene.

A soft grey siltstone was cored at stations 221 and 312 under a thin layer of Recent sediment. The siltstone at station 221 contains a small patch of sand and pebbles (diameter *ca.* 2 mm.). Foraminifera are rare and most of them are *Cassidulina limbata* Cushman and Hughes and *Cassidulina tortuosa* Cushman and Hughes, which characterize the Pleistocene Foraminifera sand on Coronado Bank. Diatoms are very abundant but were not studied. Radiolaria are common, and indicate that the age of the rock is Miocene or Pliocene, most probably Miocene (W. Riedel, personal communication). The interpretation of these fossil studies is that the age of the siltstone at station 221 is Miocene and the patchy sand, from which the *Cassidulina* fauna appeared to be derived, is a secondary fill in cavities of the siltstone.

TRAVERSE	IV													
STATION	100	99	98	97	96	95	94	93	92	91	90	89	88	87
DEPTH IN FATHOMS	21	25	30	33	40	45	48	61	80	104	65	63	64	75
LIVING POPULATION	79	136	228	128	239	296	260	343	394	178	109	437	1237	675
Alliatina primitiva									1		2	5	3	4
Alveolophragmium advena													.1	
A. columbiense		1	3	1		1	3	.9	3	1	5	.5	1	3
Ammobaculites catenulatus														
Ammotium planissimum	5	4	.4	2	8	5	2	1	.3		3			
Angulodiscorbis charlottensis														
Angulogerina angulosa	8	1	2	3	.4	3	6	4	2	2	5	5	2	2
Arenoparrella oceanica												.7	1	.4
Asterigerinata pacifica														
Astrononion viragoensis												.2	.1	
Bigenerina höglundi											.9	.5		
Bolivina acuminata					1	2	8	8	18	9	9	6	6	5
B. acutula		5	4	2	1	4	3	2			.9	.9	.4	
B. bicostata									.5					
B. filocostata							.4	.6	.3	.5	2		.3	.3
B. minuta								.6	2	2				
B. pacifica				.8	2	3	1	2	5	12	18	14	39	25
B. peirsonae														
B. spissa										.5				
B. subargentea										.5				
B. subexcavata					.4		.8		.7			3	2	7
B. vaughani					.4	.3	.4	.6	.8	1				
Buccella angulata		3	4	2	.4	3	4	2	.5					
Bulimina denudata	6	2	2	2	5	3	6	5	3	6	.9	.2		.9
B. mexicana														
B. pagoda														
B. subacuminata														
Buliminella elegantissima							.4					.2	.1	
B. tenuata														
Cancris auricula	1		.4	6		.9	2	4	4	9	7	3	5	3
C. inaequalis														
Cassidulina bradshawi												2	.1	1
C. californica												.5	.2	
C. delicata														
C. depressa				1	2		.8				9		.6	2
C. limbata			3	3		3	5	10	9	13	.6	2	.8	.7
C. subcarinata														
C. subglobosa	5	6	14	10	6	8	13	15	10	6	2	1	.3	2
C. tortuosa	3		10	7	3	4	.4	1	.3				.1	
C. sp. cf. C. orientalis														
Cassidulinoides waltoni														
Chilostomella ovoidea								.9	7	.5			.1	.3
Cibicides fletcheri	9	5		2	.4	1	1	.3				1	.2	
C. mckannai			1	4	.4	.3	1	4	5	5		.9	.4	.3
C. phlegeri														
C. spiralis														
Cornuspira lajollaensis					.4			.6						
Cornuspiroides foliaceus														
Ehrenbergina compressa										.5				
Elphidium spp.	3	3	2			.3	.4							
Epistominella sandiegoensis					.4	1	3	5	3	1		2	.5	.1
E. smithi														
Eponides leviculus												2	.6	2
E. subtenerus														
Gaudryina arenaria			3	.8	.4		1						.2	.4
G. subglabrata						.3							.1	
Goësella flintii			5		6	16	2	.3	1	3		.5		
Globobulimina barbata														
G. höglundi														
G. pacifica	4	.7		5	1	2	2	2	6	10				.1
G. spinifera														
Glomospira gordialis												.2		
Gyroidina gemma														
G. quinqueloba														
Hanzawaia nitidula	3		2	2		.3					2	2	.6	.6
Haplophragmoides neobradyi						1	.4	.3						
H. quadratus													.2	.3
H. sp.														
Höglundina elegans									.5					
Cassidulina sp.								.6				2	.1	1

TRAVERSE																				
STATION	140	124	123	122	121	259	115	260	240	286	275	242	287	261	306	276	249	262	285	277
DEPTH IN FATHOMS	5	7	9	11	11	38	39	40	40	41	45	47	50	53	53	55	57	64	67	98
LIVING POPULATION	132	203	304	217	283	493	231	693	1548	581	388	818	642	1034	1501	1074	1193	982	417	845
Alliatina primitiva						.8		5	.3	1	2	.4	.8	3	.7	2	2	2	5	2
Alveolophragmium advena									.1			.1				.1				
A. columbiense			2	1	12	.2	.4	2	2	.3		.7	.3	.2	.1	1		.3	.2	.5
Ammobaculites catenulatus				.5			.4	.1								.1		.1		
Ammotium planissimum						.4	.4	9	.5	.3			.3	.2	.7		.4			
Angulodiscorbis charlottensis																				
Angulogerina angulosa		.5				.2	9	2	.8	2	2	3	1	.1	.1	2	.5	1	.2	
Arenoparrella oceanica						2	6	3	5	4	2	2	2	3	3	2	3	1	15	5
Asterigerinata pacifica				1																
Astrononion viragoensis																				
Bigenerina höglundi								.1		.3					.1	.1		.1	.2	
Bolivina acuminata						1	.4	3	2	2	2	3	8	7	9	12	9	8	6	
B. acutula						.2		2	1	3	2	2	2	.8	1	2	2	.8	.7	
B. bicostata																				
B. filocostata								.1			1			.1		.5	.1	.2		
B. minuta																				
B. pacifica			.6			12	2	23	19	29	10	44	19	20	24	24	35	28	25	58
B. peirsonae																				
B. spissa								.1										.1		
B. subargentea																				
B. subexcavata									.6				.3					.2		
B. vaughani	6	.5	14	2	2	.8		.1	.5									.3		
Buccella angulata		.5	.6	2	2		1													
Bulimina denudata									.3	.2		.2	2	.7	.8	.4	.2	.4		
B. mexicana																				
B. pagoda																				
B. subacuminata																				
Buliminella elegantissima		11	34	42	13	.6	.4		.1		.3	.1	.3	.4	.3		.2	.3		.2
B. tenuata																				
Cancris auricula						.2		3	.8	1	7	3	3	.4	3	8	2	.7	3	.8
C. inaequalis																				
Cassidulina bradshawi								.1		1		1	.2		.5	.4			.2	
C. californica											.3				.1					
C. delicata																				
C. depressa						3	2	3	4	.5	1	3	.6	.4		.1	.9		.2	
C. limbata								.1		.3	1	.6	.2	.2		.3		1	.5	
C. subcarinata																				
C. subglobosa							2	.3			1	.7	.6	.5	.5	.2	1	.1		
C. tortuosa							37				.5	.1						.5	.5	
C. sp. cf. C. orientalis																				
Cassidulinoides waltoni																				
Chilostomella ovoidea								.9				.4	1	.5	1	2	.8	1	2	3
Cibicides fletcheri	.7								.1		.3	.2		.1				.2		
C. mckannai							.4		.1			.4		.4	.5	.3	.6	.2	.5	
C. phlegeri																				
C. spiralis																				
Cornuspira lajollaensis																				
Cornuspiroides foliaceus														.1						
Ehrenbergina compressa																				
Elphidium spp.		28	12	21	26															
Epistominella sandiegoensis									.4	.3		.9	.6	.3	.5	.8	1			
E. smithi																				
Eponides leviculus								.4	.1	.7	.5			1	.2	2	.3	.4		
E. subtenerus																				
Gaudryina arenaria							2			.2		.1	.2	.3	.1	.1	.5	.1		
G. subglabrata								.1					.2							
Goësella flintii							2	.3		.2			.2	.2	.1		.2	.1		.1
Globobulimina barbata																				
G. höglundi																				
G. pacifica						4		10	1	4	.8	.4	5	2	.9	1	2	.3	.5	.4
G. spinifera																				
Glomospira gordialis											.3									
Gyroidina gemma																				
G. quinqueloba																				
Hanzawaia nitidula							.4	.6			1	.7	.2		.1	.2	.1	1	2	
Haplophragmoides neobradyi								.6	.4	.5		.1	.2			.1				
H. quadratus												1	.2	.2		.3				
H. sp.								.4	.1	.2		.2								
Höglundina elegans																				
Cassidulina sp.								.1		1		1	.2		.5	.4		4	.2	.2

TRAVERSE																					
STATION	191	216	220	227	288	183	228	221	230	243	263	218	229	186	248	212	264	321	323	324	270
DEPTH IN FATHOMS	120	125	128	134	140	150	160	167	180	200	213	218	234	248	250	275	280	285	310	328	345
LIVING POPULATION	1277	1119	696	1771	916	1289	1212	306	598	443	517	808	510	1232	834	240	1379	69	210	119	167
Alliatina primitiva	2	3	5	1	2	2	3	4	6	4	1	2	8	3	2	6	2				.6
Alveolophragmium advena																					
A. columbiense		1	.3	.2	.1		.2			.3									.5	.8	
Ammobaculites catenulatus	1	.2	3			.2	.2	2	.5	.2			.2	.2	.8	.8	.5		1		
Ammotium planissimum	.3	.4	.9					.6	.2	1		4	4		6			3	2		.6
Angulodiscorbis charlottensis																					
Angulogerina angulosa	2	.2	1	.2			.3	.9	.7		.2			.7	.1			3	.5		
Arenoparrella oceanica	4	2	3	3	6	4	5	2	3	1	.2	2	2	5	2	.4	.2				
Asterigerinata pacifica																					
Astrononion viragoensis																					
Bigenerina höglundi																					
Bolivina acuminata	5	.2	2	2	.1	3	.7		.3	.2				6		1					
B. acutula										.1											
B. bicostata																					
B. filocostata	.1																				
B. minuta								.7	1			.5	1		1		.8			1	.8
B. pacifica	39	67	18	27	51	41	24	23	31	59	74	38	19	40	24	47	28	4	4	2	
B. peirsonae																					
B. spissa	.1	.5	.9			.1		.7	2	.1	.2				12	3	4		9	3	8
B. subargentea	.6	1	.9			.5	.3	1	1	.7	.4	3	2		3		28				2
B. subexcavata																					
B. vaughani						.1										.4					
Buccella angulata	.1																				
Bulimina denudata	7	2	1	2	.1	1	3		.5	.6		.3		1							
B. mexicana																					
B. pagoda																					
B. subacuminata																					
Buliminella elegantissima				.1																	
B. tenuata															.4		.7				.6
Cancris auricula	.3	.4	.9	.7	5	.7	.7	4	.2	.3				.5	.1				.5		
C. inaequalis	.1	.1	3					9											1	3	
Cassidulina bradshawi			.7																		
C. californica									.3				.2								
C. delicata									.2		.2				.6	.4	.1		13	9	4
C. depressa	.4	.4	2	3		.2	1	2	.8	.5			.2	1	2	.8	1		5	.8	2
C. limbata	2	.5	.1	.1		.2		.4	.2					.9							
C. subcarinata															.1		.2		3	6	4
C. subglobosa	.6	.9	2	.1			.3	2	.3		.2	.3	.4	.1	.1	.4					.6
C. tortuosa																					
C. sp. cf. C. orientalis			.3																		
Cassidulinoides waltoni			.4		.3						.2										
Chilostomella ovoidea	.1	.1	.1	.3	12	.2	.3	.6	.3	.1	.4		.8	.8	4	.4		19	2	3	.7
Cibicides fletcheri		.1	.3						4												
C. mckannai	.6	.1		.1		.2		1						.4							
C. phlegeri			.9			.2		2	.5						.9					2	
C. spiralis																					
Cornuspira lajollaensis																					
Cornuspiroides foliaceus																					
Ehrenbergina compressa									1											3	
Elphidium spp.																					
Epistominella sandiegoensis	.9	.6	.9	.4	.2	.2	.6	.6	6	.5		.4		2	.5	.4	.2		4	3	
E. smithi																	.1		.5	3	6
Eponides leviculus	2		2	.8	.2	3	.1	.3	2					6	.2				1		
E. subtenerus																					
Gaudryina arenaria	.6	.7	.6					1						.2							
G. subglabrata																					
Goësella flintii		.3	.3	.2			.8	2	9	3	10	29	31	.4	.6	2		7	3	2	
Globobulimina barbata																					
G. höglundi																			1	8	
G. pacifica	3	.9	2	14		3	6		4	3		2	4	.4	2	5	3	6	2	4	5
G. spinifera																					
Glomospira gordialis							.1	.3													.6
Gyroidina gemma																					
G. quinqueloba															.2						
Hanzawaia nitidula			.4		.4			2	.3						.6						
Haplophragmoides neobradyi		.1		.1	.2		.2		.3					1						2	3
H. quadratus			.7			.1			2												
H. sp.																				8	
Höglundina elegans								.7											.5	3	
Cassidulina sp.	.1		.7	.1		.1			.2	.1				.2							

Table 2. Occurrences of living benthonic Foraminifera in percent of living population.

LIVING BENTHONIC FORAMINIFERA

Depth Distribution of Species

Occurrences of the species of living benthonic Foraminifera are listed in Tables 1-3. In addition, the important species have been arranged in diagrammatic form according to depth ranges and frequencies in Text Figs. 2-9. Distribution charts of fifteen significant species were made, of which four are shown in Text Figs. 10-13 as examples (the others are on record at the Scripps Institution of Oceanography and the University of California, Los Angeles). These figures show that each species has a more or less characteristic

STATION	100	99	98	97	96	95	94	93	92	91	90	89	88	87	140	124	123	122	121	259	115	260	240	286	275	242	287	261	306	276	249	262	285	277	191	216	220	227	288	183	228	221	230	243	263	218	229	186	248	212	264	322	323	324	270
Involutina pacifica			.4	.8	.4	1	.4	1	.2	1		.9	.6	1					1	.2	1	.6	.5			.5	.2	.3	.1	1	.3	.4	2	.2	.8	.4	1	.4		.3	.4	.6	2	.1			.2	.2	.2			10	7	3	4
Lagena & related spp.		7	2	2	2	3	.8	.9			.7	.5	.5	.7				2	.4	3	.4	2	.9	.7	.5	.9	1	.5	.7	.4	.8	.7	.5		.4	.5	.4	.3		.1	.2	.6	1	.4	.2	.1	.2	.2		.4	.1		.5	.8	1
Lagenidae (other)										.5	.9	.2		.1			3			.2		.1	.1			.2		.2		.2	.1	.1			.1			.2					.2					.1							
Loxostomum bradyi																						.1			.3																													3	
L. pseduobeyrichi																																											.2						2		3		2	.8	4
Neoconorbina terquemi															72																																								
N. parkeri																																																							
Eggerella advena	1		4		1		1		3		9	3	.6	3			6	1	7	2	5	.3	.5	.7	3	.1	2	2	.6	2	3	2	1	.1	2	.8	3	.7	1	3	1	.7	.8			.1		2	.1		.3	2	.5		
E. scrippsi																				.4		.4	1	.5	.3	.1	.9	2	3	2	2	.5	1	.1	.1	.3	.9	.2		.2	1	1	.8	.6	2		.8	.3	1	1			1		
Nonion lankfordi						.7	.8	.9					.2	.4						.6		.4			.3		.6	.1		.1																									
N. parkerae																																																							
Nonionella basispinata	10	4	3	4	2	.7	1	.6	1			1	.7	.4		1	11	20	22	4	6	.1	4	4	3	.1	1	.7	.9	.5	.3	.8		.1	.1	.2		.2	.1					.2				.7							
N. (?) fragilis																																																							
N. stella	9	30	8	26	31	10	6	10	5	.5	.9	12	12	6		1	6	4	6	15	13	12	25	17	22	8	14	15	18	10	10	5	7	2	4		3	8	2	7	7	4	2	2	3	1	2	4	1		7	13	2		2
N. sp. aff. N. globosa										1																									.2		.1	.2								.3		.1	.4		.3				
Nouria harrisii													1							.2		1			.5	2	.5		.1	1		.5	.5	.1			.1		.2		.1	.7	.5												
N. polymorphinoides																												.1						.1		.6		.4			.4			.2		.3			.1	.4					
Patellina corrugata																																																							
Planulina ornata	4		2	3		.3	.4					.5		.1									.1		.3				.1			.1	.2															.1						3	
Placopsilina bradyi												5	4												.5					.5		6	3	.8			7		2			8													
Polymorphinidae		2	2		.4	.3																	.1										.2																						
Saccammina longicollis	1	1	2	.8	2	3	5	2	1	2	6						.6											.2				.2													1						2		1		1
Pullenia salisburyi				2		.3	1	.6	.3				.3	.1								.3		.2		.4				2						.1		.2		.1	.1		.2					.1							
Recurvoides sp.													.2								1		.1			.2	.5	.1	.1	.3			.2							.1	.1												.5	.8	
Recurvoidella parkerae													.4													.2		.5		.3																									
Remaneica cf. helgolandica												.2								.8		.3		.2		.1	.2				.2																								
Reophax excentricus							.4	2	2	2			.2							.6			.2				.5	.8	.1		.3					.4	.7	.1				.6	.5	.5		.1	1								
R. gracilis					1	.3	1	.3	.5	2	3	4	2	4						20	3	8	9	13	19	7	14	12	9	6	5	18	5	9	9	2	12	2	3	2	1	5	2	7	2	2	2		4	2	2	3	2	2	
R. horridus						.3																.4					.2		.1	.1		.1				.1							.2	.6		.7	2	.1	.8	.4	.4	2	.5		.6
R. micaceous																																.4						2			2			.4		1		.3	3	.4		1			
R. communis												.5	.4	.7		.5	.3	.5	.9		1		.5	.5	3			.4	.2	.2	.1		.5							.2															
R. scorpiurus		4	3		12	9	9	5	2	1	3	.7	.3	.1						.8		1		.3	.8	.6	.5	.8	.4	.5	.7		.5	.2		.4	.7		.2																
R. subfusiformis																																																							
R. spp.		2	2	.4	4	.7	2			1																	.6				.1						.9				.3		.5			.4		.4	.2						
Robertinoides charlottensis	3				.4	.7														.2	.4	.4	.2		.3	.2		.3	.1	.1					.1																				
Rosalina columbiensis															12																																								
R. campanulata	10	7	4	3	2	2	1	.3				.9	.2	.1	.7	.5	.3				1	.1						.1	.1																										
R. turbinata																																																							
Seabrookia earlandi							.4			.5	4	1	1	2						.2		.6		.3		1	.5	1		.5	.1	.4	1	.4	.8	.3	.7	.5	.5	.2	1	.3	1	.3		.1		.5	.1	1	.1	4		.8	
Sigmoilina tenuis				.8	.4	.3		.3															.3			.5		.3		.1	.2	.1			.1			.1			.2		.2	.2				.7	.1						
Spiroloculina fragilis																																																							
Spiroplectammina bathyca																																							.1															.8	
S. biformis																																																							
Suggrunda (?) eckisi																																				.1		2		1	2		.5	2	.8	.1	.2	.2		.4					
Textularia cf. abbreviata	1	.7	2	.8	.4	.3	.4			1			.2											.2	.3			2	.3	.1		.1				.3	.7						.3	.2											
T. earlandi						.7		.3					1	.1						.4		.4	1	.2			.8	.6	.5	.1	2		.7	.1	.1	.5	1	.3		.5	.6		1	.2				.7							
T. sandiegoensis												.7	.3	1						.2		.4	.9	.2	.3	.1	.6	2	.7		1	.4	1	12	.5	1	2	1	8	.9	1	1	2	2	2	.9	2	4	5	.8	4	2	.5		.6
T. schencki																										.4																													
Tritaxis bullata													.4														.2								.8							.7							.2						
Trochammina charlottensis													.3				.3		.4		1				1						.1		.5																						
T. chitinosa																																																				13	9	3	
T. conica														.6			.3							.2	.5					.2					.2		1					2													
T. discorbinoides												.5	.2	.4							.4				.5	.1	.2			.5			.2	.1			.6		.1																
T. globigeriniformis																																																							
T. kellettae	1				1	.3	1	.3		1		2		.1	3	1	.3			12		2	.1	.9	1	1	2	.6	.1	.3	.7		.7	.2	.1		.6								.8	.3		.1		9	1		2		3
T. labiata																																																							
T. nitida												.2	1	.3						.2				.2			.3		.1	4	.1						.3																		
T. pacifica & var.											3		.4			.5		1	4		.4	4	.3	.2	.5	.8	.5	.3	.1	.2	1	.2			.6	4	1	.2	.2	.3	.3		2	.7		.1		.7	.5			4	3	3	.6
T. rhumbleri												2	.8	.6				1		.2		.4	2	.3	.5		3	1	.2	.7	1	.1	.7	.6	.8	3	.6	2	.7		2	.7	1	.1			.2	.1	.2						
T. squamiformis												2	1	2					.4		.4		2	.3	2	.2	.3	1	1	.2	1		6	.6	.4	.1	2		3			2							.1						.6
Uvigerina auberiana																																																							
U. curticosta																																											.3				.2		3	7	1		2		4
U. juncea						1	2	3	2	4	4	4	1	2									.1		2		.7	.5		3	2				1	.5	3	2		6	2			.6			.8	7	.9						
Valvulineria araucana																																									.1		.2						2		.1				4
V. glabra																																																							
Virgulina apertura												1	2	7								.3	2		.3	2	2	3	8	1	3	.2	4	4	4	.4	.6	19		17	26	1	2	4		9	7	2	4		4		2	6	13
V. bramlettei																																																	.6		.4				2
V. complanata																																								.1															
V. cornuta																																																							
V. delicatula																																		.8	.9	.5	2	.6	.8	.7	1	.6	.7	3	1	2	1	.8	.8	8	4			.8	2
V. sandiegoensis		.7										1	2	.9						11		.9	12	6	3	.8	4	8	8	1	2	.4	2	.1	.1		.3	.3		.2	.1			.5		.3		.1							
V. seminuda														.1																				.7	.4	.2	2	2	.4		2	1	.9	.8		.7	1	.6	6	.8	1		4	3	6
Miliolidae	1	3	.4		.4							.4	.1	.1	5	55	9	.5	3	.8	.4	.4	2	2	1	.1	.6	1	.3			1			.5	.1	.7			.2	.1	.6	2				.4	.1	.1		.1		2	.8	
Miscellaneous spp.	11	8	8			2	1	1	3	2	.9	3		.1	.7			.5				.6	.1	.2	.5	.6	.4			.4			1			.1	2	.1	.4		.3	4	.2				.2	.5			.2	4	2	2	.6

Table 2 (continued). Occurrences of living benthonic Foraminifera in percent of living population.

depth range, but that there are also rather general boundaries between different assemblages. These boundaries are based on upper and lower limits of several species and also on their frequencies. Seven faunas can be recognized with boundaries at 13, 45, 100, 250, 350, and 450 fathoms. The detailed discussions of these faunas and boundaries are not presented for the sake of brevity but are on record at the above-mentioned institutions.

Possible Causes of Depth Zonation

There may be many factors which influence the physiological activities and hence the distribution of living Foraminifera. Temperature and food are considered most important by many workers. Also of possible importance are salinity, sediment type, rate of sedimentation, oxygen content, pressure, light penetration, pH, Eh, turbulence, currents, and submarine topography. These factors are interrelated. For example, pressure, temperature, light penetration and salinity may be entirely or in part related to depth. The food and the nature of the substrate are related to sediment types. It is not known, however, which factor or com-

TRAVERSE																																																
STATION	201	307	265	278	325	255	326	250	211	266	304	258	202	294	303	284	289	296	254	208	308	301	207	298	300	302	292	293	305	232	299	290	297	279	269	283	281	236	109	280	114	267	268	112	205	113	111	105
DEPTH IN FATHOMS	345	350	350	350	350	355	385	390	395	420	430	430	440	450	455	455	460	460	465	473	485	490	505	505	505	515	515	520	525	528	530	550	560	565	570	580	580	585	599	605	608	615	630	635	638	639	640	650
LIVING POPULATION	693	106	621	587	79	1154	269	9300	564	805	421	598	570	335	273	506	351	183	793	300	443	236	253	307	467	712	162	207	689	475	455	146	204	488	433	409	172	198	150	380	90	566	357	252	307	118	192	29
Alliatina primitiva	1	2	1	1	1	2	1	2		.9	.5	.3	5	.9	.7	1	.9		1	1	.2	.9	.4	.7	1	.3		2	.3	.2	5	3		.4	.2	.5		.5	.7	.5		.5	1	1	3	.8	1	
Alveolophragmium advena																																																
A. columbiense												.7	.2					.5	.4	2						.1			.1											.8		.9						
Ammobaculites catenulatus	1	2	1	.9	5	1	3	.1	3	.5	2	4	2	.3		1	.6	1		9		.4	2	2	.4		.6	.5	.4	.2		2	1	2	.7	.2	4		.7	.3	1	.7	.3	4	2	6	2	
Ammotium planissimum	.6			.2		.4		.1	.2																																							
Angulodiscorbis charlottensis																																																
Angulogerina angulosa																																																
Arenoparrella oceanica	.1			.2	1	.2	.7			1	2	1	4	.3	.4	.4	1	.5	1		.2	1	.8	1	2	.8	3		.9	1	2		.5	.2	2	1	1			.5	1	2	3	2		.8	4	
Asterigerinata pacifica																																																
Astrononion viragoensis																																																
Bigenerina höglundi																																																
Bolivina acuminata						.2																																										
B. acutula																																																
B. bicostata																																																
B. filacostata																																																
B. minuta	.9		2	.5	3	.2	.4	.2	4	.6	.5	.8	.7	.3	.4	.6	.3		.4	.1	.6				.2						.4			.4		.5			.7	.3		.5	.3	.4				
B. pacifica	21	10	2	28	27	25	3	33	23	13	4	9	6	3	2	17	17	.5	10	2	7	6	2	1	12	10	6	2	2	20	8	.7	1	5	1	8	1		.7	2		3	.6	2	1	.8	3	
B. peirsonae																																																
B. spissa	11	6	11	6	3	13	16	5	12	10	16	15	16	14	12	12	6	5	6	12	10	7	10	7	8	4		10	4	15	4	3	.5	8	3	3	.6	3	2	4		3	1		2		2	
B. subargentea	2	.9	1	2		.5		12	3			.3	.2			.4			.3		.9									.2				.6														
B. subexcavata																																																
B. vaughani						.1														.1																												
Buccella angulata																																																
Bulimina denudata																																		.2									.3					
B. mexicana																X																X							X		X			X		X	X	X
B. pagoda																																																
B. subacuminata										.9	.7		.7			1	.6				2				.6			.5			.2	.7	3	.2	.5					.8	1	.3	2		1	3	.5	
Buliminella elegantissima																																																
B. tenuata	1	3	1	4		2		4	2			.7	.2						.5							.1			.1	.2																		
Cancris auricula																																																
C. inaequalis	.1						2	.1	.2	.1		2									.2									.4																		
Cassidulina bradshawi										2									.4																							.3						
C. californica																																																
C. delicata	4	3	2	1	6	2	.4	.1	3	6	3	9	3	11	3	2	6	7	4	4	7	9	2	2	5	.7	7	1	3	2	2	4	3	2	3	5	5		2	5	1	7	3	1	1	2	3	14
C. depressa			3	.2		.2					.7	2												.3				3	.9		.4			2	1	.7							.3				.5	
C. limbata																																																
C. subcarinata	3		2	.7		.6			.5	.4		3	.3	.9	3	1	.9	3	.5	3	3	3	.4	2	3	.4	3	1	2	2	4	6	9	4	4	.7	1	1	3	3	2	2	5	3	1	2	3	14
C. subglobosa														.6	.7			3		2		.4	1			.3			.4	.4							1			.5			.3					3
C. tortuosa																																																
C. sp. cf. C. orientalis																																																
Cassidulinoides waltoni																																																
Chilostomella ovoidea	7	3	10	3		11	.4	5	2	5	1		.5	.3		8	6	1	11		4	.9	.8	2	1	2	3	2	3	3	2	3	.5	2	3	3	5	4	2	2	5	2	4	4	2	2	3	3
Cibicides fletcheri																																																
C. mckannai																																												4				
C. phlegeri	.1		.9	.5	4	.3	2		.7	3	1	3	3	.6	1	.8	.3		.3	1	.7		.4		.2				1		.7	1		2	.7	2	3			.5	1	1	.3	2	.7	15	1	
C. spiralis																							.4	2				.5				1	10		.2	.2	1	1	.7	2	9	.9	5	4	2	21	6	14
Cornuspira lajollaensis																																																
Cornuspiroides foliaceus																																																
Ehrenbergina compressa																																																
Elphidium spp.																																																
Epistominella sandiegoensis	6		.8	2	1	.5	1	.1	2	2	.5	2	.3	.6	2	1	.3	1		.7		.9		.3	.9	.1	1	.5	.1	.4	1	.7		4	.5	.2		.5	.7	3		.7	1	.4	2		.5	
E. smithi	2	5	6	2		2		.4	7	.9		1	.5			.4	.3		.3		.5					.1									.2	.5	.6					2						
Eponides leviculus	.1		.2	.2	3	.7	3		.4	2	1	2	1	.3	3	2	1	2	.3	4	1	2		2	.6	.1	1	2	.7	1	.7	3	2	3	.9	3		1		5	1	.3	2	.8	6	11		
E. subtenerus														.3									.8				.6	1				1	3	.6	.5	.7		1	3	2		.7	.3	.4	3		2	7
Gaudryina arenaria																																																
G. subglabrata																																																
Goësella flintii	.4	.9		.3			.7	.1	.2	.2		1	1	2	.7		.3	.5	.3	3	.9		1				2		.3	.6		1	2		.5		1	.5					2	.8	.7	.8	3	
Globobulimina barbata		2	1												.4	.4	.3			.3				.3		.6					.2	.7	1			1								.8	.3		.5	10
G. höglundi	3		.5			.1					.7			.6		.4		1		1	.2			1				.5	.1	1				.4	.7	.2	1		.7			.2						
G. pacifica		8	2	.5		1	1	7	.4				.3	2	3	2	2	2		3	.2		2	3		.1	3	2	.3			4		2			2	1	1	.8	1	.5	.3	.8	1	.8	.5	
G. spinifera	1			.3		.1				.1		.2	8																	.2	.2									.3								
Glomospira gordialis	.3			.5			.7		.2	.7		.5	3	3	2		1	.5	.1	.3			2	2	1	.4		3	.7		.2	4	2	.6	.2	2	2	5		1	1	.3	1		2	2	2	
Gyroidina gemma			.2				.7				1	.8	.2								.2	1		.3				2	.4		.2		2		1							.2	1		3		1	
G. quinqueloba	.1					.1				.1			.3						.3																.2	.2				.3			.9					
Hanzawaia nitidula																																																
Haplophragmoides neobradyi			2				5		1		5	.5	6	5	6	2	.6	1	3	1	.9	2	16	3	.6	.4	1		.7	.2	.2			3	1	3		2		4	2	.3	1	2				.3
H. quadratus																															.2		1		.2							.2			.3			
H sp.				.3	1		5				2		.7	2	3			7				1	5	10	.2	.4	2	3	.9			1	7	.4		.2		3		3	5		2	.8	.3	2	3	
Höglundina elegans							1			.1	.2	.2	.2	1	1	2	1	2		4	.9		7	4	.2		4	.5	.3	.2	.4	.7	4	.8	.5	.2	1	4		1		1	1	.4	1		.5	
Cassidulina sp.																			.1																													

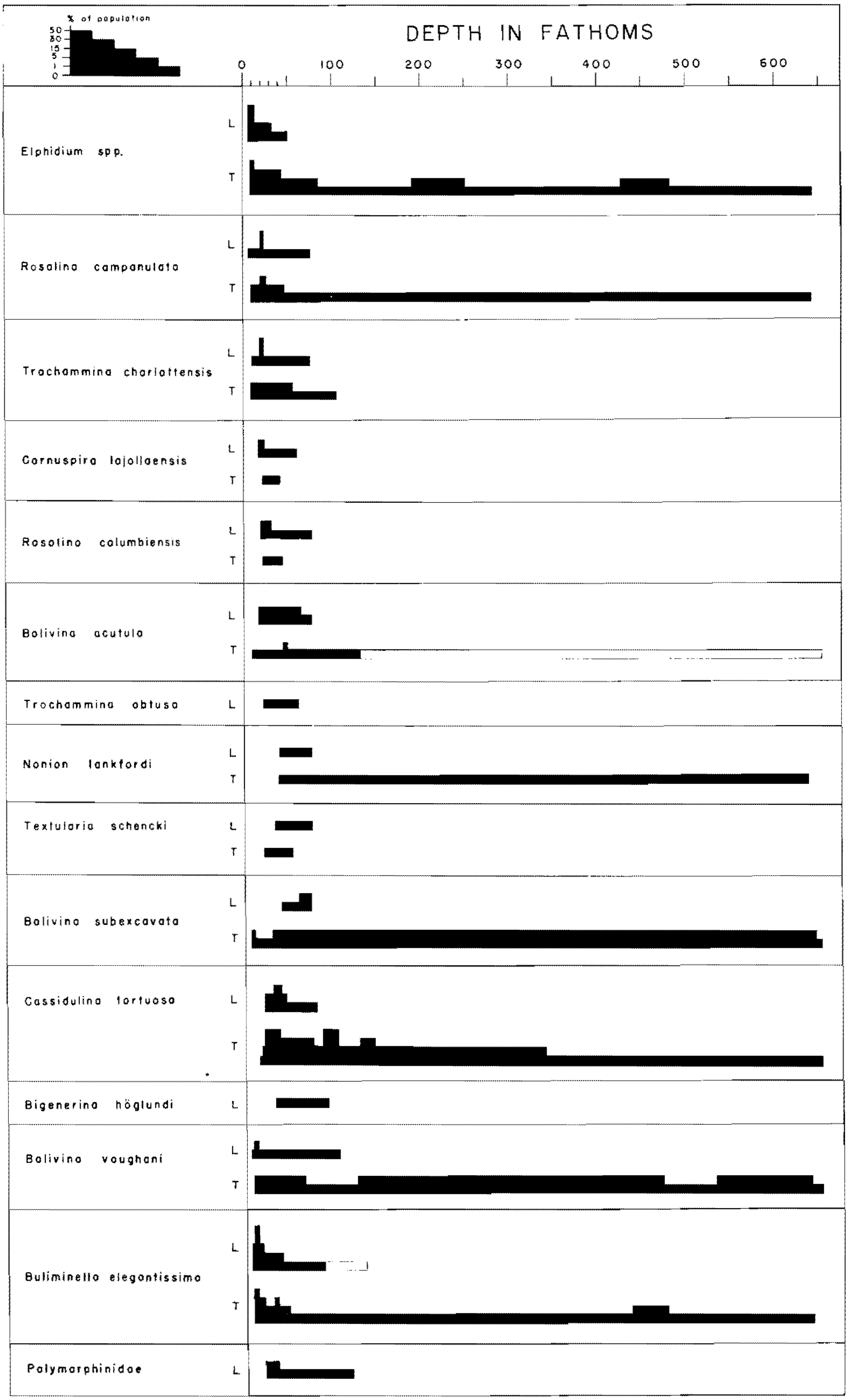
Table 3. Occurrences of living benthonic Foraminifera in percent of living population.

STATION	201	307	265	278	325	255	326	250	211	266	304	258	202	294	303	284	289	296	254	208	308	301	207	298	300	302	292	293	305	232	299	290	297	279	269	283	281	236	109	280	114	267	268	112	205	113	111	105
Involutina pacifica	.9	2	2	.5		.9	1		.9	3	2	2	3	3	2	1	1	.5	.4	2	.5	.4	.8	3	.6	.3		2	1	.2	1	2	7	4	2	3	1	12	4	2	8		.9	7	6		3	
Lagena & related spp.			.6			.1	.4			.1	.5		.3	.3	.7	.2	.3	.5	.1		.7	.4		.6	.6		1	1	.3	.6		.7	1	.4		.2	.6				1		.6	.8	1	.8		
Lagenidae (other)										.1								.5												.2														.4				
Loxostomum bradyi							3				1	.3								.7	.2					.1																						
L. pseduobeyrichi	.6	.9	.3	3		2		5	5	1	.5	2	.5		.4	.4			4			.9			.2	.1		2	.3	2	.9			.2	4	.2				.3		.3						
Neoconorbina terquemi																																																
N. parkeri																																																
Eggerella advena	.3					.2			.2		.2	.2	.2		.7								.4										.5							.8		.2			.7	.8	.5	
E. scrippsi	.4						10			.9	2	1	2	1	7			2		2		.4	2	2			1	2	2			2	2	.2	.2			.5		.5	1	.3	.9					
Nonion lankfordi																																																
N. parkerae																		.5																														
Nonionella basispinata															.7	.6			.1	.3		.4	2	.3		.1				.4			.5	.4	.5			1				.2						
N. (?) fragilis																																									1					.8		
N. stella	3	17	6	3		2	.4	1	1	.6	.7		2	.9	1	1	.6	1	2	2	1	2	2	1	2	2	3	1	3	1	3	3		3	3	13	2	3	14	.8	1	7	1	2	.3		1	
N. sp. aff. N. globosa				.3		.3		.5									.3																															
Nouria harrisi																																																
N. polymorphinoides	2	5	4	2		.3		.1	.2	.1	.2	.2	.2			.4	2	1	2		1	.4			2	2	8	4	1		3	3		2	1	3		.5		.3					1			
Patellina corrugata																																																
Planulina ornata							.4		.4		.2	.2								.3																												
Placopsilina bradyi																																																
Polymorphinidae																																																
Saccammina longicollis																						.4			.2			.5						.2									8					
Pullenia salisburyi												.3	.3	.9											.2			.5				.7	1						.7								.5	
Recurvoides sp.																								1	.2				.7			.7											.3					
Recurvoidella parkerae			.3				1			7				.3				.5				.9				.1												.5		.5								
Remaneica cf. helgolandica																																										.2			.3	.8		
Reophax excentricus						1	.4							2			.6	.5			.2	.9			.2	.3			.3		.2			.2														
R. gracilis	3		2	3	1	5	.7	.4	1		3	2	2	2	2	2	5	.5	3	3	2	3	4	3	1	2	3	2	.7	6	2	.7	1	2	2	2	1	1	5	1	1	2	3	.8			2	
R. horridus	1	.9	.6	.2		.6		.1	.4	.4		.2		.9		.8	.9		.5		.5					.3							1											.4				
R. micaceous	.1		.3	4		3	.4	.2	2		3	.2			1	.8	2	.5	2		.9	11		3		3				.8	2		3		1			2	1		1			1	5			
R. communis																																																
R. scorpiurus										2					1																		.5					1										
R. subfusiformis																																																
R. spp.	1				2	2			1	2	3	2	.9		.7						.7	2		.3	1	.2	3		.2	.8	3	.7	2	1	4	2		3			2	.2	2	4	5		1	
Robertinoides charlottensis													.2																																.3			
Rosalina columbiensis																																																
R. campanulata			.2																																													
R. turbinata																																																
Seabrookia earlandi	.1		.3			.1	.4		.2	.4		.2	.2	.3	.4	.2						.4		.7		.1			.1					.2	.2							.2	.3					
Sigmoilina tenuis																.2																																
Spiroloculina fragilis																			.1					.7		.1			.4				1		.5	.2							2	2	1	.8	1	
Spiroplectammina bathyco	.1								.9	.7		.3	1		1				.1		.2					.1			.3	.4	.4				.2						2	.5	1	2	2	3		
S. biformis																																2				.2						.2	1	.8		10	.5	.2
Suggrunda (?) eckisi									.2																																							
Textularia cf. abbreviata																																																
T. earlandi												.2																																				
T. sandiegoensis	2	4	2	16		4		11	.9	.6		.2	.2			.2	.3		1		.2	.4			.9	1				.6	3				.2	.2		1					.6		.6			
T. schencki																																																
Tritaxis bullata	.1									3	.2	1		.9		.8														.6					.2								.9			.8	.5	.5
Trochammina charlottensis																																																
T. chitinosa	3		2	.2		.9				.5	7		1	.9	.4	1	3	2	4		3	4		1	2	3	4	3	3	7	4	1		3	8	5	7	1	8	2	1	3	1	.4	.3		2	
T. conica								X		.2		.5	1		.7			2	.3					1	.6	.3					.2			3		.2				1					2			
T. discorbinoides														.3																																		
T. globigeriniformis								X					.5																.1				3							2	2		1	.4	.7		1	
T. kellettae	2	7	.8	.7					.5	.1	1				.7	3	6	4	.8			2	1	1	6	.1	8	3	2		4	6	7	2	1	3	7	.5	3	2			5	.4	.3	.8	1	14
T. lobiata	.1						1		.4	1	.7	6	.2		1				.3		.5	.4		.3					.1	.6		.7	3	.6	1			3		2				4	4	.8		.5
T. nitida																																																
T. pacifica & var.						.1						.5	.9	.9	1								.8				.6			.4	.4						.6		.7	.3							2	
T. rhumbleri	.3					.1	2	2				2	.5		.4								.4	1					.4				.5					3		.5			.9					
T. squamiformis							.4																																			.2					.5	
Uvigerina auberiana																								1	.2							2	3	.4	.5	1		2	1	1	1	.5	2	.4	2		.5	
U. curticosta	.4			.3	1	1	.7	1	2	.4			.9	2	1	.4		1	2	1	6	2	.4		.2	.4		2	.9	3	.2	6		.2		.2		1		.5	4	.2		.4		2		7
U. juncea			.6															.5		.7			.4	.3																								
Valvulineria araucana	.6	3	.5	.9		.6	9	X	.2	1	.5		.2	.9	.4	.4			5	.3		.4	1	2				2	1		2	1	3	2	.9	2		8	.7	1	4	2	1	1	4		3	
V. glabra	.1					.1	.4			1	4	.8	6	7	7	2		9	1	6	.7	.9	11	4	1	.4	6	5	3	.8	2	2	3	6	5	3	2	2	.7	3		3	.6	6	3		2	
Virgulina apertura	.3	8	19	7	3	8	15	7	7		20	17	6	22	17	24	22	31	24	24	32	27	15	24	40	62	22	29	56	25	33	25	2	14	35	21	46	23	32	30	20		14	25	14	.8	28	4
V. bramlettei	.6	.9	1	.2		.5		.6	.4			.2							.5				1							.6				.4	.2		.6		.7								.5	
V. complanata	.1		.5					.9													4	.9																										
V. cornuta	.1		.5					.9														.9																										
V. delicatula	3	.9	1			2	2	.8	3	2	.2	.7				.4	.9		2		.2				2	.1	.6		1		.9			7	.2	3	1			3		9		.4	1			
V. sandiegoensis				.2						.9		.2																																				
V. seminuda	3	4	6	3			2	.5	1	1	.7	.3		4	.7	1	3		.9	.7		.9			.4	.4	1	3		2	1			2	.2		.6		5		6	.5		.8		2	1	3
Miliolidae			.3	.2		.3	.4		.4	.5	.2	.3	.3		1	.8		2			.7		2	2		.4		1	.3		.4	1		1	.5	1		.5		2			.9		.6		.5	
Miscellaneous spp.	1				1	1	2	.2	2	2	12	.2	5	1	6	3	.8	.5	1	5		4		1	1	.1		1	.4	.2		1		.4	3	.2	.6	2	2	1	2	1	12	4	.8	9	1	.5

Table 3 (continued). Occurrences of living benthonic Foraminifera in percent of living population.

bination of factors is most important to Foraminifera ecology.

Some workers have attempted by laboratory experiments to evaluate these various factors. The results of such experiments are useful in indicating the relative importance of many factors existing in nature. But the natural environments are always changing, the dimensions are extremely large, and dynamic equilibria may exist among many factors. A laboratory culture, on the other hand, is small in scale and static in nature. One should use care in applying results from experiments to natural phenomena.



Text Figure 2. Depth distributions of benthonic Foraminifera. L: living population; T: total population. Height of bar: average frequency; solid bar: consistent occurrence; open bar: scattered occurrence.

Text Figure 3. Depth distributions of benthonic Foraminifera. L: living population; T: total population. Height of bar: average frequency; solid bar: consistent occurrence; open bar: scattered occurrence.

The differentiation of fauna 1 (shallow-water fauna) into two facies appears to depend on sediment types. Large grains are necessary for attached Foraminifera and the heavier the grains the better for Foraminifera living in the turbulent zone. *Poroeponides cribrorepandus* Asano and Uchio is found only as an attached form in the nearshore zone. *Rectocibicides miocenicus* Cushman and Ponton and *Placopsilina bradyi* Cushman are also found only as attached forms in relatively shallow water.

The boundary at 13-20 fathoms which separates faunas 1 and 2 may be interpreted as the base of the turbulent zone. This appears to be supported by the observation of C. Limbaugh (personal communication) that wave action decreases abruptly at approximately 40 feet (*ca.* 7 fathoms) and has no influence on the bottom at approximately 100 feet (17 fathoms) near the Scripps Institution of Oceanography. Turbulent water brings up nutrient salts from the bottom, but at the same time it carries a portion of phytoplankton continuously down to depths where light is insufficient, and this may affect benthonic Foraminifera which feed on the phytoplankton. Turbulent water also carries organic detritus from the sediments offshore and leaves the sediment barren.

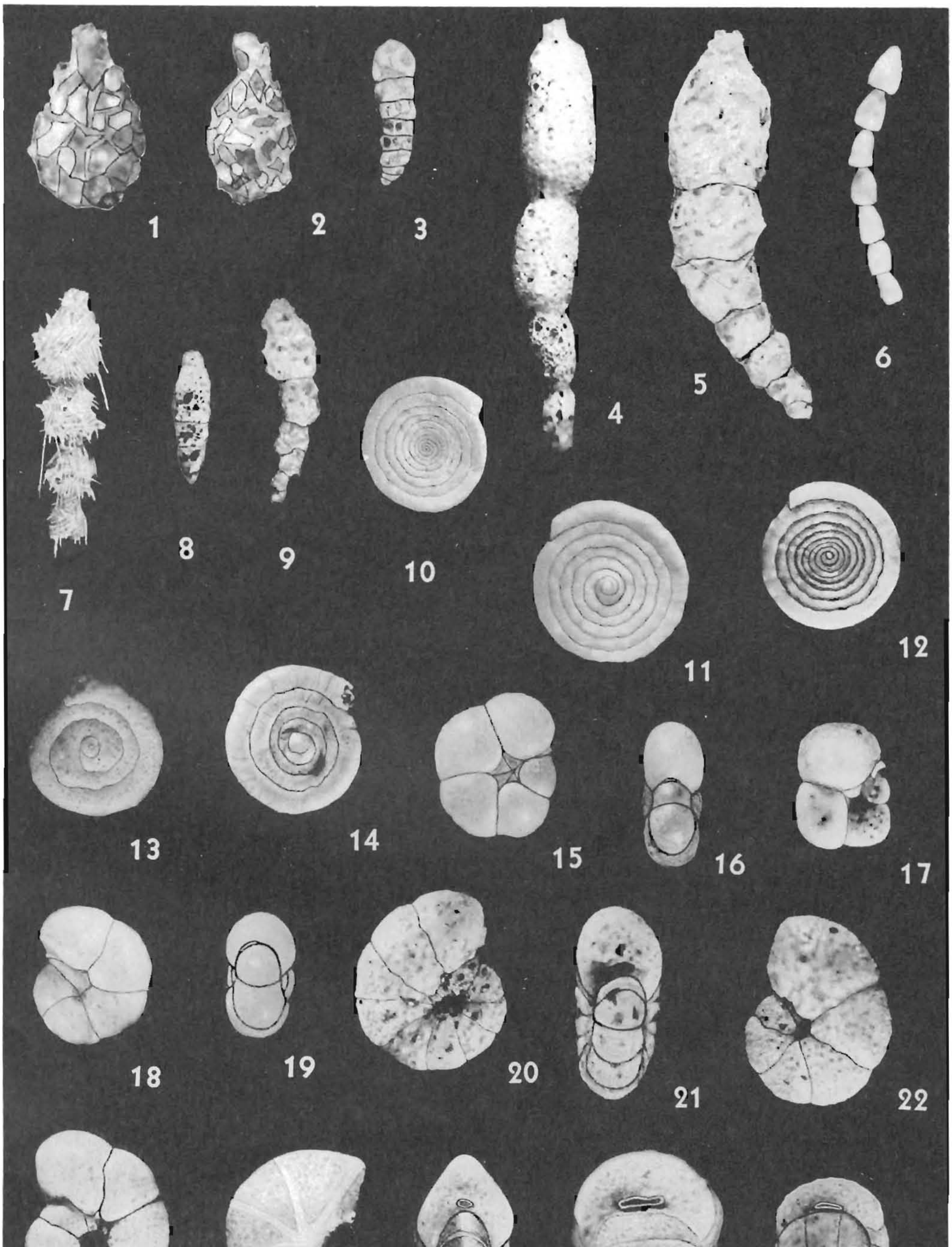
The boundary at 45 fathoms between faunas 2 and 3 may represent the bottom of the seasonal thermocline. Therefore, fauna 2 is influenced by the seasonal thermoclinal layer which includes the salinity minimum. The species in this layer may be considered relatively eurythermal compared with those on the bottom in deep water.

The boundary at 100 fathoms between faunas 3 and 4 may represent the boundary between the California Current and an underflowing current from the southern hemisphere. The current flowing toward the north under the California Current off the west coast of North America is the Equatorial Pacific Water mass, and the Equatorial Water, in turn, probably is formed off the coast of South America by gradual transformation of the Subantarctic Water (Sverdrup *et al.*, 1942, p. 706). The ecological importance of this hydrographic boundary appears to be supported by the fact that characteristic species commonly found shallower than 100 fathoms also occur off British Columbia, Canada, and those deeper than 100 fathoms also occur off South America in deep water. These other occurrences are based on distribution of empty tests. Species shallower than 100 fathoms whose distributions are limited to the northern shallow sea are as follows:

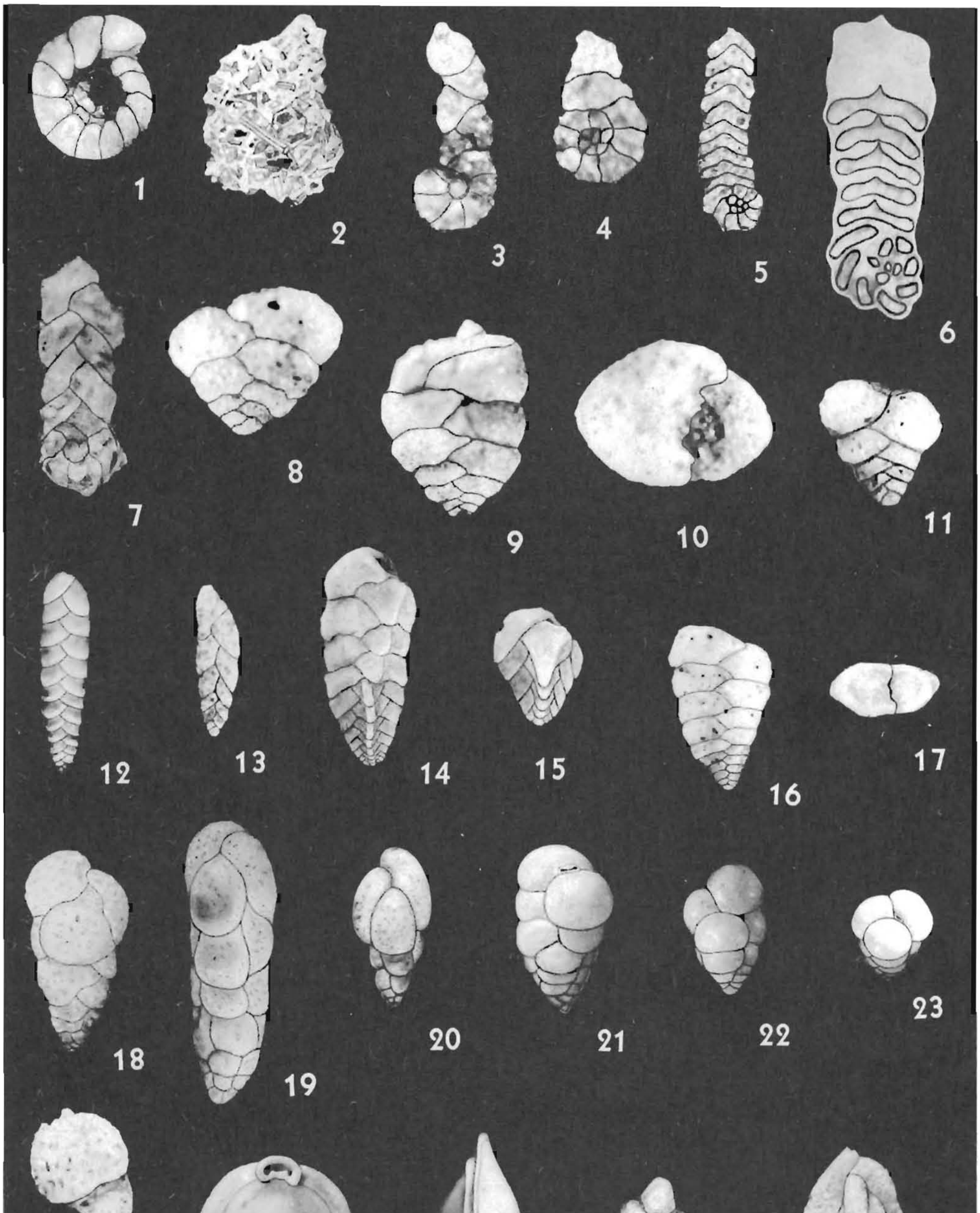
Alveolophragmium advena (Cushman)
Alveolophragmium columbiense (Cushman)
Angulodiscorbis charlottensis (Cushman)
Astrononion viragoense Cushman and Edwards
Cassidulina limbata Cushman and Hughes
Cassidulina tortuosa Cushman and Hughes
Elphidium sp. cf. *E. subarcticum* Cushman
Gaudryina arenaria Galloway and Wissler

EXPLANATION OF PLATE 1

Figs.		Page
1, 2.	*Saccammina longicollis* (Wiesner) .... Hypotypes (U.S.N.M. Nos. 626572, 626573), ×47, ×48.	50
3.	*Reophax communis* Lacroix. Hypotype (U.S.N.M. No. 626574), ×102.	
4.	*Reophax dentaliniformis* Brady. Hypotype (U.S.N.M. No. 626575), ×19.	
5.	*Reophax excentricus* Cushman. Hypotype (U.S.N.M. No. 626576), ×19.	
6.	*Reophax gracilis* (Kiaer). Hypotype (U.S.N.M. No. 626577), ×44.	
7.	*Reophax horridus* Cushman. Hypotype (U.S.N.M. No. 626578), ×18.	
8.	*Reophax micaceous* Earland. Hypotype (U.S.N.M. No. 626579), ×47	50
9.	*Reophax scorpiurus* Montfort. Hypotype (U.S.N.M. No. 626580), ×17.	
10, 11.	*Involutina flavida* (Höglund). 10, Microspheric form. Hypotype (U.S.N.M. No. 626581), ×5. 11, Megalospheric form. Hypotype (U.S.N.M. No. 626582), ×5.	
12.	*Involutina hoeglundi* Uchio, n. sp. .... Holotype (U.S.N.M. No. 626583), ×46.	51
13.	*Involutina minutissima* (Cushman and McCulloch). Hypotype (U.S.N.M. No. 626584), ×60.	
14.	*Involutina pacifica* (Cushman and Valentine) .... Hypotype (U.S.N.M. No. 626585), ×18.	51
15, 16.	*Haplophragmoides neobradyi* Uchio, n. sp. .... 15, Holotype (U.S.N.M. No. 626587), ×99. 16, Paratype (U.S.N.M. No. 626588), ×103.	51
17.	*Haplophragmoides quadratus* Uchio, n. sp. .... Holotype (U.S.N.M. No. 626590), ×46.	52
18, 19.	*Recurvoidella parkerae* Uchio, n. gen., n. sp. .... 18, Holotype (U.S.N.M. No. 626603), ×99. 19, Paratype (U.S.N.M. No. 626604), ×96.	53
20, 21.	*Alveolophragmium advena* (Cushman) .... Hypotypes (U.S.N.M. Nos. 626594, 626595), ×28, ×29.	52
22.	*Alveolophragmium columbiense* (Cushman) .... Hypotype (U.S.N.M. No. 626596), ×41.	52
23.	*Alveolophragmium evolutum* (Natland). Hypotype (U.S.N.M. No. 626597), ×22.	
24, 25.	*Alveolophragmium lenticulare* (Natland). Hypotypes (U.S.N.M. Nos. 626598, 626599), ×30, ×26.	
26, 27.	*Recurvoides subglobosus* (G. O. Sars) .... Hypotypes (U.S.N.M. Nos. 626601, 626602), ×21, ×26.	52



Uchio: Living Foraminifera, San Diego, California



Uchio: Living Foraminifera, San Diego, California

Nonionella sp. aff. *N. globosa* Ishiwada
Nonionella stella Cushman and Moyer
Robertinoides charlottensis (Cushman)
Rosalina columbiensis (Cushman)

Species occurring deeper than 100 fathoms and characteristic of South American water as as follows:

Cancris inaequalis (d'Orbigny)
Cassidulina braziliensis Cushman
Valvulineria araucana (d'Orbigny)

The boundary at 250 fathoms between faunas 4 and 5 may represent the top of the permanent thermocline.

The boundary at 350 fathoms between faunas 5 and 6 may be related to the oxygen minimum layer, which may limit the vertical movement of some species. Many workers have discussed the origin of the oxygen minimum layer, but have come to no definite conclusion about it. If, as Wüst (1935) proposes, it is due to minimum replenishment of oxygen due in turn to minimum movement of water at the boundary between two water masses which move in opposite directions, then the oxygen minimum layer represents a boundary of two water masses, and a distinct faunal break can be expected. The ocean on the whole, even in abyssal depths, is well supplied with oxygen for organisms, and oxygen is not a determining factor in the distribution of most marine life except in certain environments.

The boundary at 450 fathoms between fauna 6 and fauna 7 may represent the bottom of the permanent thermocline.

Size of Living Population

Description.—Sizes of the standing crops of living benthonic Foraminifera per standard sample are shown on Text Fig. 14. Several generalizations may be made from these distributions.

There is a population of less than 200 specimens per sample in the shallow areas. This low population occurs at less than 40 fathoms in most of the San Diego area, but is at less than 20 fathoms in the region west of Point Loma.

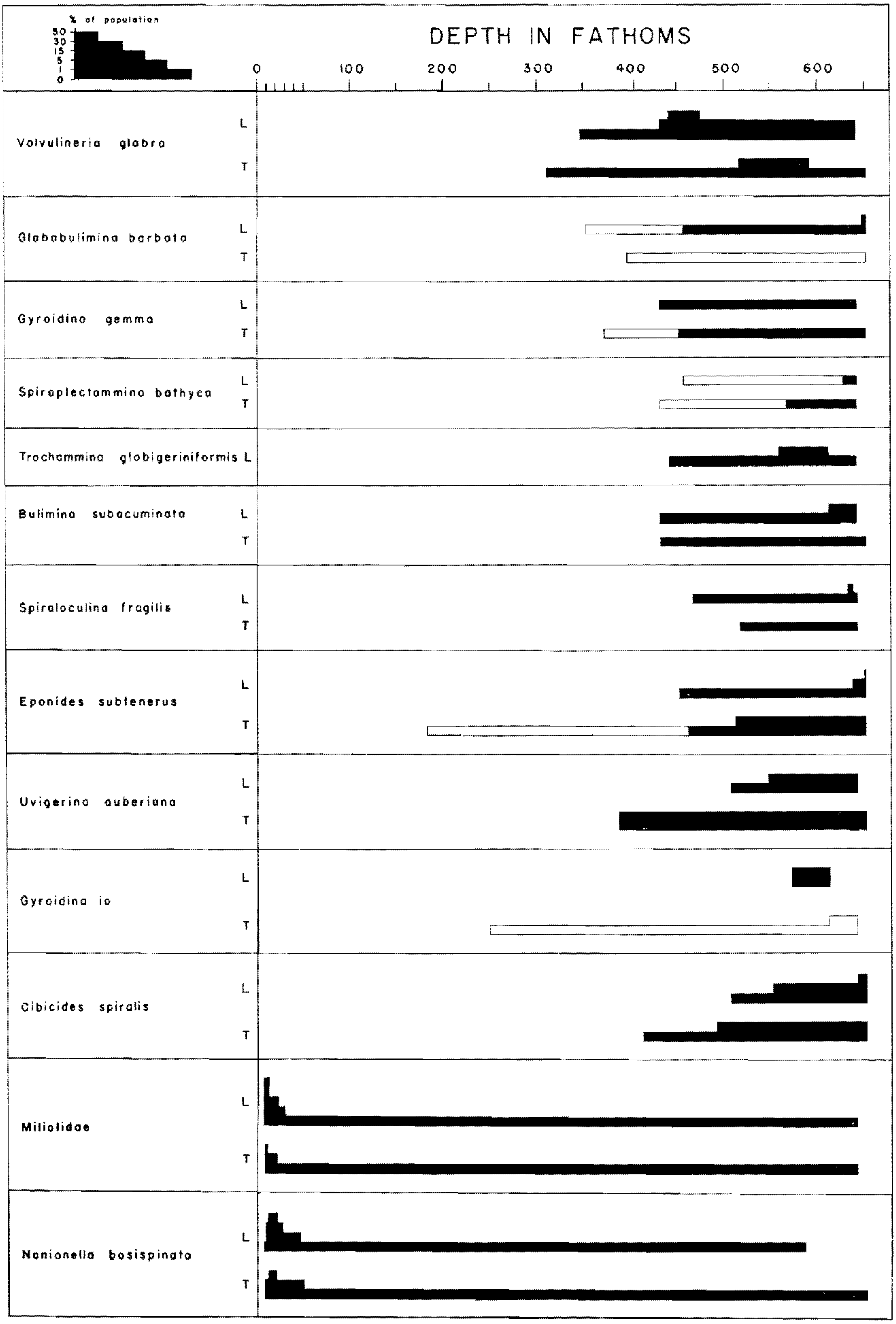
Intermediate populations of 200-1000 per sample occur seaward from the low population area. The depth ranges from 20-40 fathoms north of Coronado Canyon, but ranges from 35-55 fathoms south of Coronado Canyon. A small area of intermediate population also occurs near the mouth of the Tia Juana River.

A high population area occupies a narrow band along the outer edge of the shelf and in the head of Coronado Canyon. This zone has an average population of more than 1000 per sample. The depth of this zone ranges from 55 to 100 fathoms along the outer shelf and from 60 to 150 fathoms in the head of Coronado Canyon. This narrow band may be expected farther north, on the western side of Coronado Bank, but the present study does not include this area. There is no apparent reason why this highest population band does not exist on the eastern side of Coronado Bank. Several small patchy areas also have more than 1000 specimens per sample.

EXPLANATION OF PLATE 2

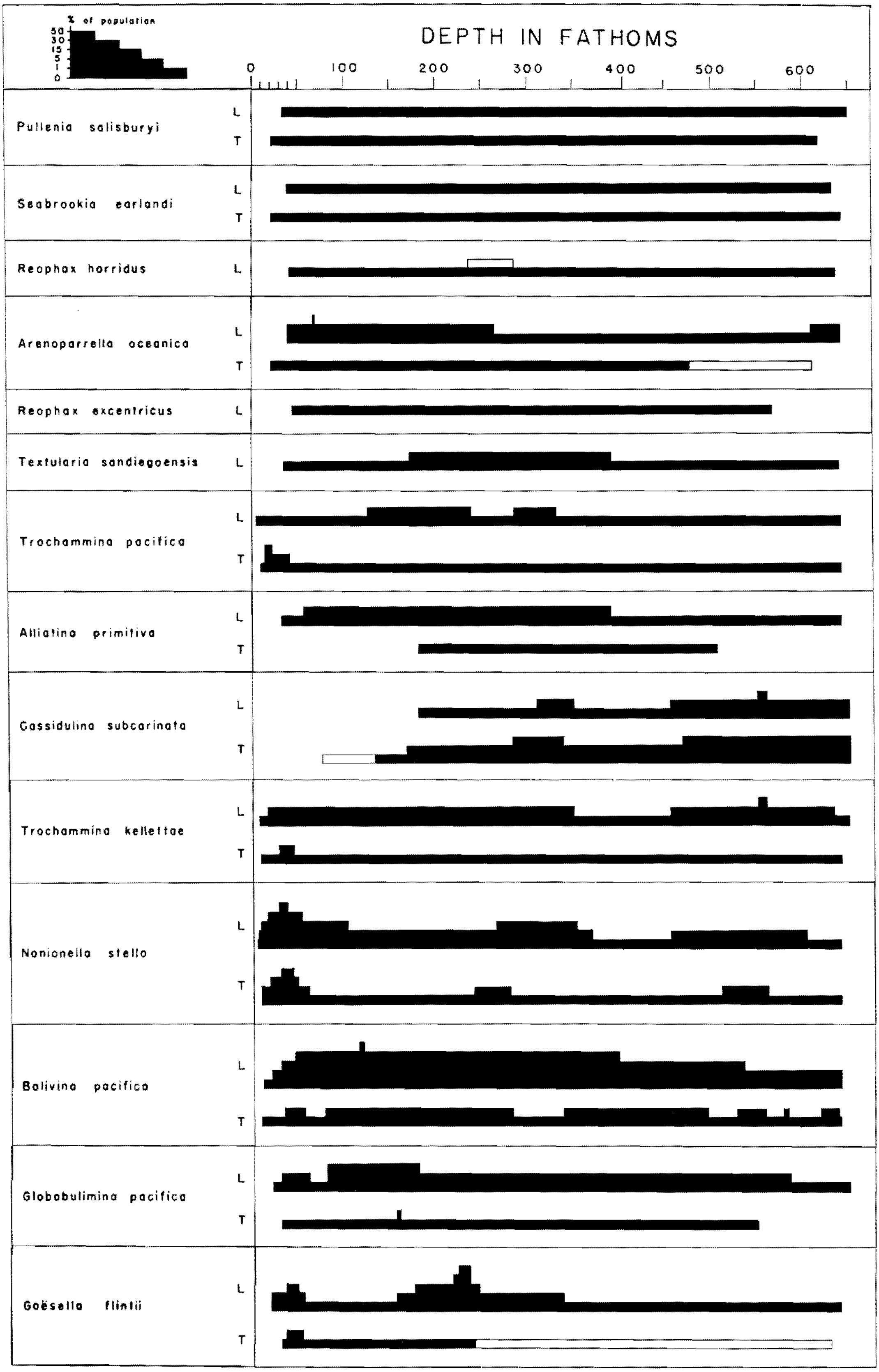
Figs.		Page
1.	*Alveolophragmium veleronis* (Cushman and McCulloch). Hypotype (U.S.N.M. No. 626600), ×29.	
2.	*Ammotium planissimum* (Cushman). Hypotype (U.S.N.M. No. 626606), ×20.	
3, 4.	*Ammobaculites catenulatus* Cushman and McCulloch. Hypotypes (U.S.N.M. Nos. 626607, 626608), ×97, ×99.	
5, 6.	*Ammomarginulina sandiegoensis* Uchio, n. sp. 5, Holotype (U.S.N.M. No. 626613), ×46. 6, Paratype (U.S.N.M. No. 626614), ×96.	54
7.	*Spiroplectammina bathyca* Uchio, n. sp. Holotype (U.S.N.M. No. 626616), ×94.	54
8-10.	*Textularia* sp. cf. *T. abbreviata* d'Orbigny (U.S.N.M. Nos. 626619-626621), ×29, ×21, ×35.	54
11.	*Textularia schencki* Cushman and Valentine Hypotype (U.S.N.M. No. 626624), ×42.	55
12.	*Textularia sandiegoensis* Uchio, n. sp. Holotype (U.S.N.M. No. 626623), ×100.	55
13.	*Bigenerina hoeglundi* Uchio, n. sp. Holotype (U.S.N.M. No. 626625), ×60.	56
14, 15.	*Gaudryina arenaria* Galloway and Wissler Hypotypes (U.S.N.M. Nos. 626626, 626627), ×28, ×46.	56
16, 17.	*Gaudryina subglabrata* Cushman and McCulloch. Hypotypes (U.S.N.M. Nos. 626628, 626629), ×33.	
18.	*Eggerella advena* (Cushman). Hypotype (U.S.N.M. No. 626630), ×100.	
19.	*Eggerella pusilla* (Goës). Hypotype (U.S.N.M. No. 626631), ×99.	
20.	*Eggerella scrippsi* Uchio, n. sp. Holotype (U.S.N.M. No. 626632), ×98.	56
21-23.	*Karreriella parkerae* Uchio, n. sp. 21, Holotype (U.S.N.M. No. 626633), ×48. 22, 23, Paratypes (U.S.N.M. Nos. 626634, 626635), ×46, ×47.	56
24.	*Goesella flintii* Cushman. Hypotype (U.S.N.M. No. 626636), ×19.	
25, 26.	*Pyrgo murrhina* (Schwager). Hypotypes (U.S.N.M. Nos. 626639, 626640), ×36, ×45.	
27, 28.	*Quinqueloculina granulosa* Natland. Hypotypes (U.S.N.M. Nos. 626637, 626638), ×46, ×47.	

Text Figure 4. Depth distributions of benthonic Foraminifera. L: living population; T: total population. Height of bar: average frequency; solid bar: consistent occurrence; open bar: scattered occurrence.



Text Figure 5. Depth distributions of benthonic Foraminifera. L: living population; T: total population. Height of bar: average frequency; solid bar: consistent occurrence; open bar: scattered occurrence.

Text Figure 6. Depth distributions of benthonic Foraminifera. L: living population; T: total population. Height of bar: average frequency; solid bar: consistent occurrence; open bar: scattered occurrence.



Text Figure 7. Depth distributions of benthonic Foraminifera. L: living population; T: total population. Height of bar: average frequency; solid bar: consistent occurrence; open bar: scattered occurrence.

Deep areas have a moderate population of 200-1000 per sample. The depth ranges from 100-150 to 600 fathoms in Coronado Canyon and the San Diego Trough. In the northern region, however, where there is no large area of high population, moderate populations occur from 20-40 to 200 fathoms.

There is a deep-water low population area of less than 200 per sample. This occurs at deeper than 600 fathoms in the San Diego Trough and deeper than 200 fathoms in the lower part of Loma Sea Valley.

Walton (1955) calculated the frequency distribution of the average population of living benthonic Foraminifera in Todos Santos Bay, Mexico, per 5-fathom interval, regardless of sediment type. This approach does not appear to be reasonable because benthonic Foraminifera populations vary not only with depth, but also with other environmental factors such as sediment type. Also, there is an areal change in the population due to changes in sediment type, submarine topography and amount of food supply, etc. It is of interest, therefore, to relate the population size to some of these factors.

The average population size has been correlated with different sediment types found in the San Diego area and also with all the sediment types combined at 10-fathom intervals respectively. As shown in Table 4, there are some irregularities in the population size within the same sediment type and depth range; nevertheless, some generalizations can be made.

Coarse sands, including brown sands and shell sands (with or without pebbles), and glauconite sands have a relatively small standing crop, regardless of depth. These coarse sands are mostly distributed in the near-shore area (shallower than 35 fathoms), but the glauconite sands (about 80% of the total weight is glauconite) are distributed along the eastern side of the Coronado Ridge (280-390 fathoms). The average population of this group of sediments is 149 specimens per sample. Rocky bottom, which is partly covered by a thin layer of detrital sediments, also has a small standing crop regardless of depth with an average of 146 per sample, almost exactly the same size as that of coarse sands.

Fine sands are much more productive than coarse sands, with an average standing crop of 578 specimens per sample at all depths. The standing crop suddenly increases at 40 fathoms and seems to begin to decrease at approximately 450 fathoms.

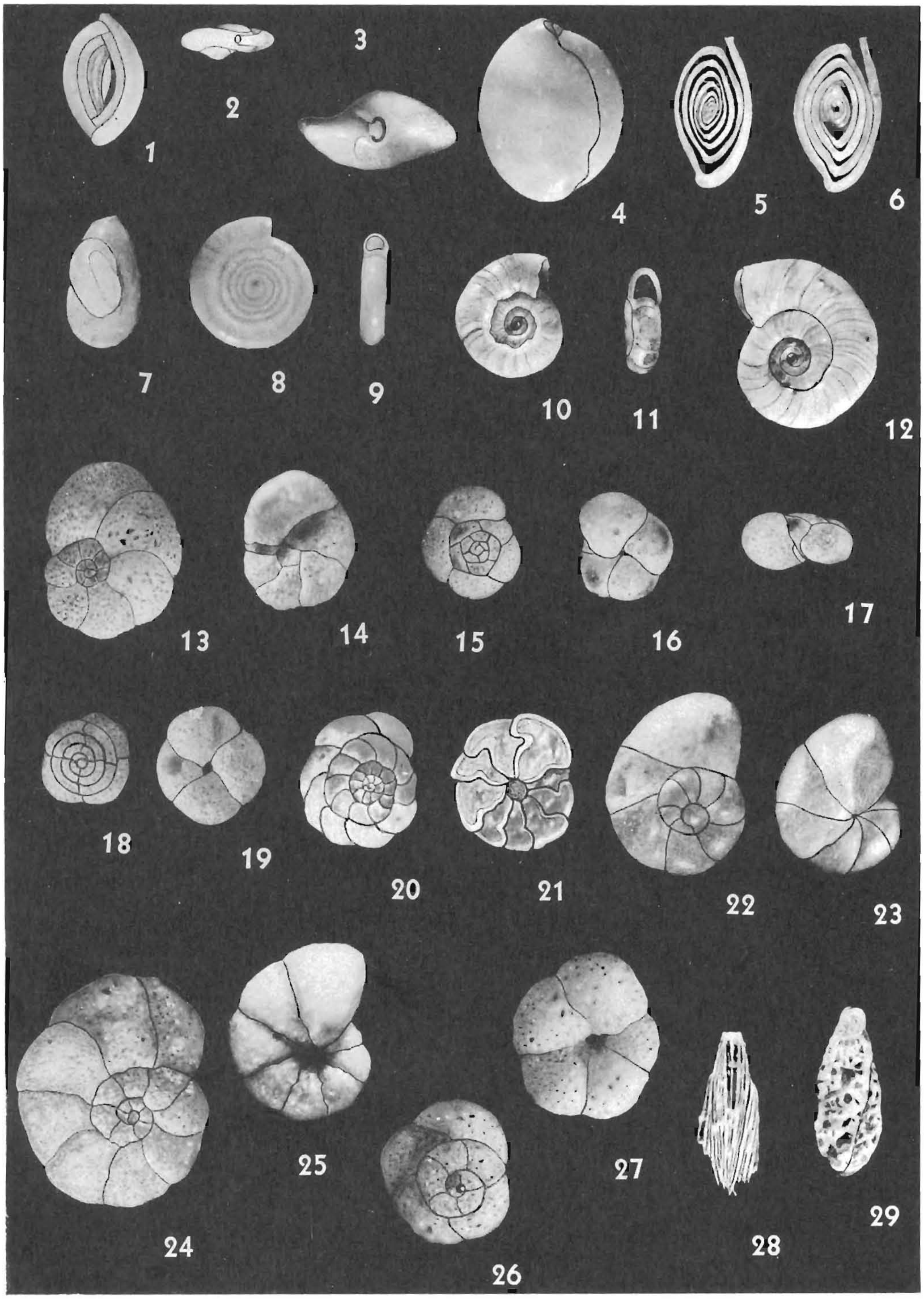
Silts are as productive as fine sands with an average standing crop at all depths of 568 specimens per sample. There is also a striking change in the size of population with depth, with an increase at 20-30 fathoms and a gradual decrease deeper than approximately 300 fathoms.

Clayey silts also have relatively large standing crops with an average for all depths of 536 specimens per sample. No clayey silts are found shallower than 30 fathoms. Very large and very small standing crops are found at both shallow and deep stations, but the standing crop seems to be rather constantly small at depths greater than 550 fathoms in the San Diego Trough. This may be due to lower temperature and lower oxygen content in this region.

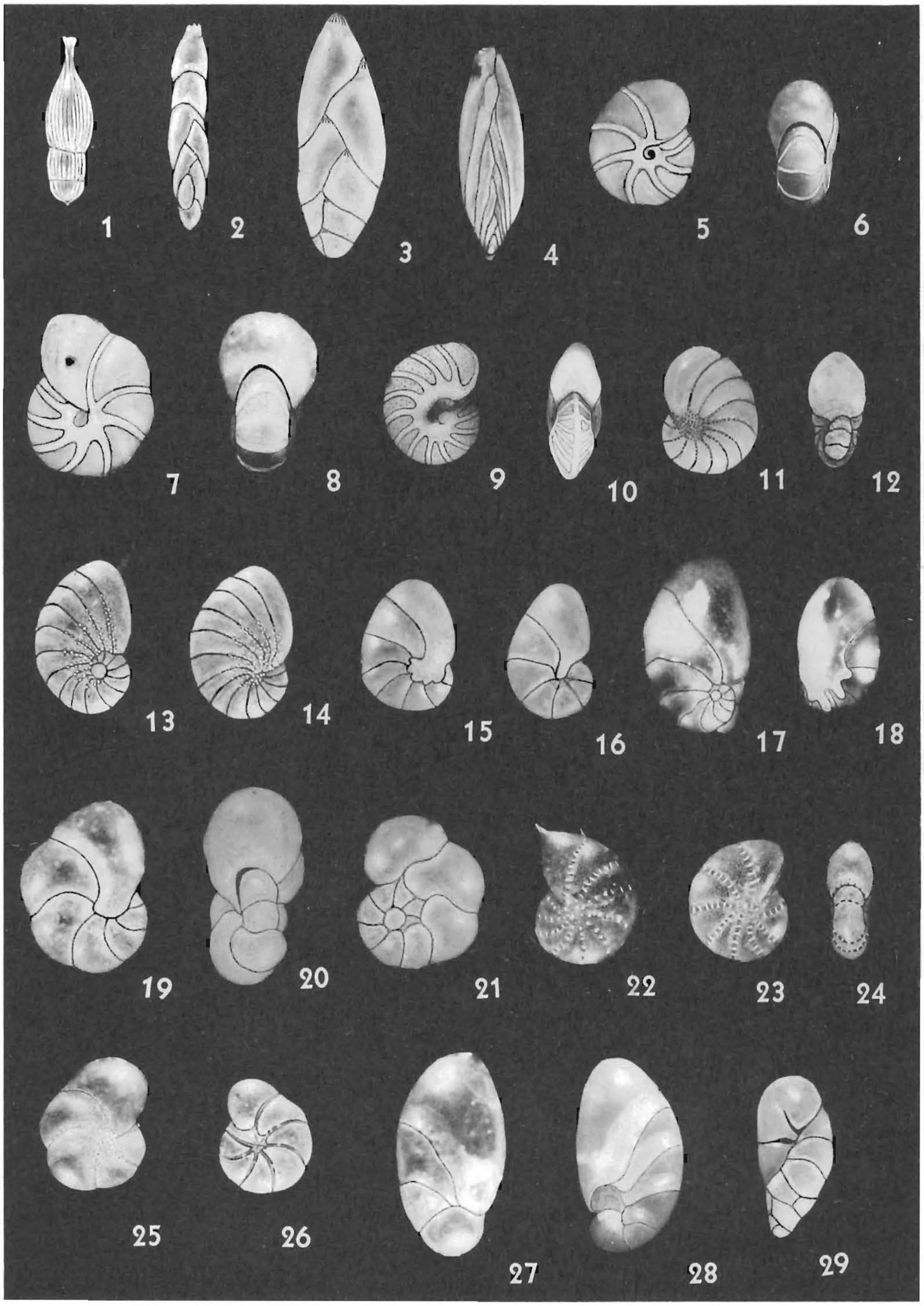
Foraminifera sands and/or silts are very productive

EXPLANATION OF PLATE 3

Figs.		Page
1, 2.	*Sigmoilina tenuis* (Czjzek) ... Hypotypes (U.S.N.M. Nos. 626643, 626644), ×45, ×48.	57
3, 4.	*Sigmoilina victoriensis* Cushman. Hypotypes (U.S.N.M. Nos. 626645, 626646), ×48, ×39.	
5, 6.	*Spiroloculina fragilis* Uchio, n. sp. ... 5, Holotype (U.S.N.M. No. 626641), ×46. 6, Paratype (U.S.N.M. No. 626642), ×47.	57
7.	*Seabrookia earlandi* Wright. Hypotype (U.S.N.M. No. 626863), ×94.	
8, 9.	*Cornuspira lajollaensis* Uchio, n. sp. ... 8, Holotype (U.S.N.M. No. 626647), ×48. 9, Paratype (U.S.N.M. No. 626648), ×45.	57
10, 11.	*Gordiospira fragilis* Heron-Allen and Earland. Hypotypes (U.S.N.M. Nos. 626650, 626651), ×39, ×40.	
12.	*Cornuspiroides foliaceus* (Philippi). Hypotype (U.S.N.M. No. 626652), ×31.	
13, 14.	*Trochammina charlottensis* Cushman ... Hypotypes (U.S.N.M. Nos. 626653, 626654), ×46.	58
15-17.	*Trochammina labiata* Uchio, n. sp. ... 15, Holotype (U.S.N.M. No. 626663), ×94. 16, 17, Paratypes (U.S.N.M. Nos. 626664, 626665), ×94, ×95.	59
18, 19.	*Trochammina discorbinoides* Uchio, n. sp. ... 18, Holotype (U.S.N.M. No. 626657), ×100. 19, Paratype (U.S.N.M. No. 626658), ×93.	58
20, 21.	*Trochammina kellettae* Thalmann ... Hypotypes (U.S.N.M. Nos. 626661, 626662), ×65.	58
22, 23.	*Trochammina chitinosa* Uchio, n. sp. ... 22, Holotype (U.S.N.M. No. 626655), ×96. 23, Paratype (U.S.N.M. No. 626656), ×83.	58
24, 25.	*Trochammina nitida* Brady. Hypotypes (U.S.N.M. No. 626666, 626667), ×104.	
26, 27.	*Trochammina pacifica* Cushman ... Hypotypes (U.S.N.M. Nos. 626668, 626669), ×47, ×44.	59
28.	*Nouria harrisii* Heron-Allen and Earland. Hypotype (U.S.N.M. No. 626678), ×47.	
29.	*Nouria polymorphinoides* Heron-Allen and Earland. Hypotype (U.S.N.M. No. 626679), ×46.	



Uchio: Living Foraminifera, San Diego, California



Uchio: Living Foraminifera, San Diego, California

with an average standing crop at all depths of 629 specimens per sample. No Foraminifera sands and/or silts are found at depths shallower than 45 fathoms or deeper than 167 fathoms. The term "Foraminifera sands and/or silts" is used loosely because often it is difficult to separate this type of sediment from others. The term applies to a type of sediment which contains a high percent of supposedly late Pleistocene residual sediment. Usually this type of sediment appears to be a mixture of coarse and fine sediments owing to a high content of Foraminifera tests, often with coarse sands, pebbles, and shell fragments. There is a considerable variation in the size of the standing crop in sediment of this type, perhaps due to the different amounts of the finer fractions of a sample and the physico-chemical character of the bottom.

The size of the average population plotted at 10-fathom intervals is shown in Table 4 and at 50-fathom intervals in Text Fig. 15. The occurrence of the largest living population at 55-150 fathoms on the eastern escarpment of the San Diego Trough and in an area between Coronados Islands and the head of the Coronado Canyon, and at 100-150 fathoms in the whole area agrees with distributions in the Todos Santos Bay area (Walton, 1955, p. 996).

Discussion.—The low population area nearshore may be due to the presence of coarse sediment and hence little organic material, although the relatively higher temperature found there is favorable for physiological activity. Turbulence may be advantageous in bringing food closer, getting oxygen from the air and taking waste away, or disadvantageous in mechanical agitation, hindering light-penetration, etc., but there is no direct evidence. An area near the Tia Juana River mouth which has a slightly higher population, has micaceous fine sand which may contain more organic matter.

The low population in the San Diego Trough and in the lower part of Loma Sea Valley may be due to low temperature, very fine sediments, and a slight excess of organic matter. Trask (1932) and Emery *et al.* (1952, p. 537, fig. 10) pointed out that the content of organic matter in the sediment is very high in the San Diego Trough, although lower than in marsh areas. Because of this high organic content, oxygen will be used to oxidize organic matter and CO_2 and/or H_2S will be formed and Eh will become lower. Some tests of Foraminifera from this environment were filled with pyrite. These factors may hinder the growth of organisms and thus tend to reduce the size of their populations.

The area which has the highest population occurs at 50-150 fathoms where there are intermediate temperatures. The sediment type seems to be of no importance to the population size since it includes clayey silt, silt, fine sand and Foraminifera sand. The explanation for the narrow zone of exceptionally high population probably is some physico-chemical factor, perhaps intermediate temperature and/or tidal effect. All the stations in this zone lie in the canyon head or at the outer edge of the shelf. According to Fleming and Revelle (1939, p. 134-136), the tidal currents reach a

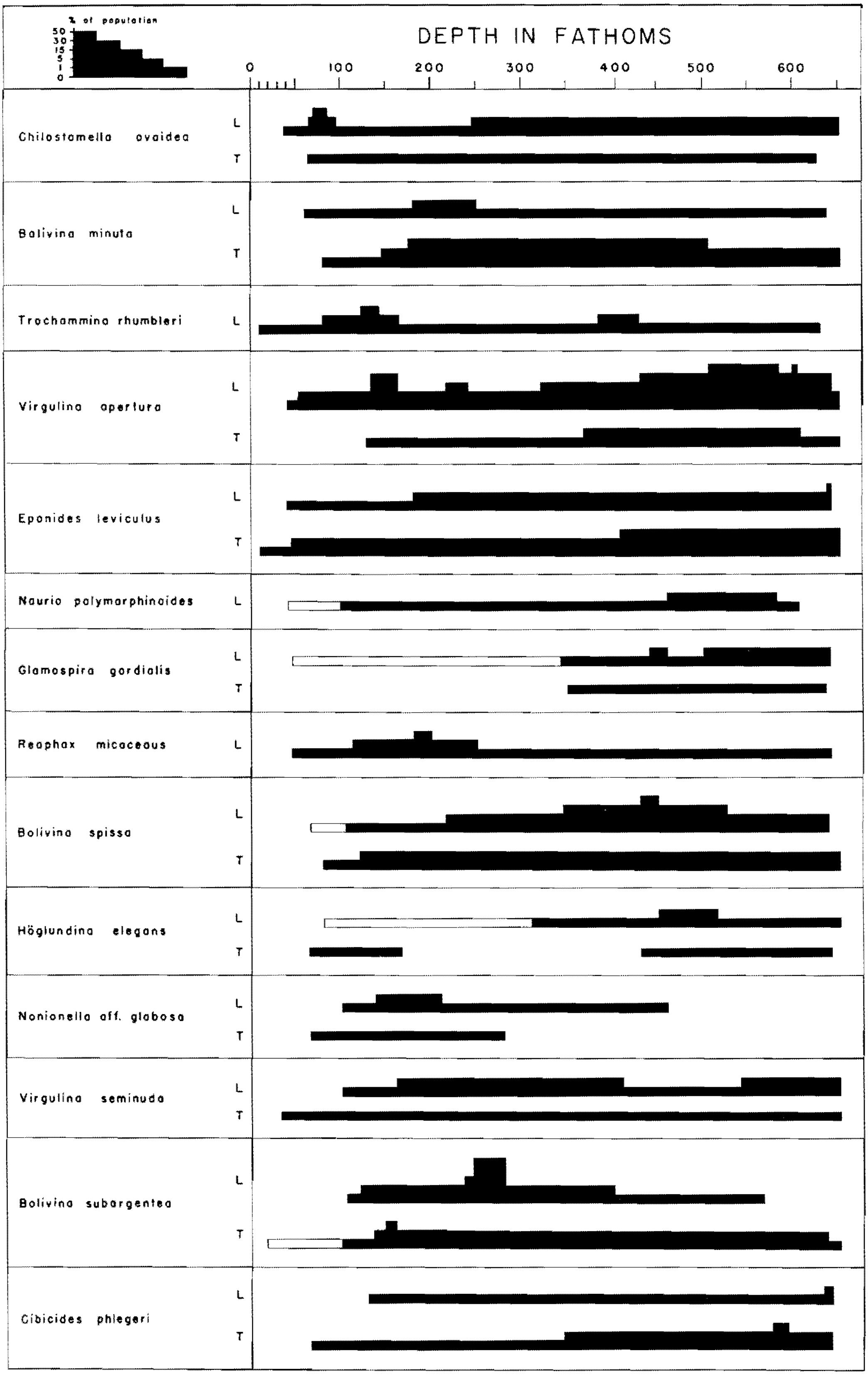
EXPLANATION OF PLATE 4

Figs.		Page
1.	*Nodosaria* sp. cf. *N. perversa* (Schwager). (U.S.N.M. No. 626681), ×47.	
2.	*Paradentalina muraii* (Uchio), n. gen. Hypotype (U.S.N.M. No. 626682), ×47.	60
3.	*Pseudopolymorphina charlottensis* (Cushman). Hypotype (U.S.N.M. No. 626683), ×19.	
4.	*Sigmomorphina frondiculariformis* (Galloway and Wissler). Hypotype (U.S.N.M. No. 626684), ×33.	
5-8.	*Nonion lankfordi* Uchio, n. sp. 5, 6, Holotype (U.S.N.M. No. 626685), ×98. 7, 8, Paratype (U.S.N.M. No. 626686), ×98.	60
9, 10.	*Nonion parkerae* Uchio, n. sp. Holotype (U.S.N.M. No. 626687). 9, ×47. 10, ×51.	60
11, 12.	*Nonionella atlantica* Cushman. Hypotypes (U.S.N.M. Nos. 626689, 626690), ×33, ×34.	
13, 14.	*Nonionella basispinata* (Cushman and Moyer) Hypotypes (U.S.N.M. Nos. 626691, 626692), ×33.	61
15, 16.	*Nonionella stella* Cushman and Moyer Hypotypes (U.S.N.M. Nos. 626698, 626699), ×45, ×122.	61
17, 18.	*Nonionella* sp. aff. *N. globosa* Ishiwada. (U.S.N.M. Nos. 626696, 626697), ×90, ×92.	
19-21.	*Nonionella* (?) *fragilis* Uchio, n. sp. 19, 20, Paratypes (U.S.N.M. Nos. 626693, 626694), ×100, ×91. 21, Holotype (U.S.N.M. No. 626695), ×97.	62
22.	*Elphidium spinatum* Cushman and Valentine. Hypotype (U.S.N.M. No. 626700), ×47.	
23, 24.	*Elphidium spinatum* var. *translucens* Natland Hypotypes (U.S.N.M. Nos. 626701, 626702), ×40, ×46.	62
25.	*Elphidium* sp. cf. *E. subarcticum* Cushman. (U.S.N.M. No. 626703), ×119.	
26.	*Elphidium* sp. cf. *E. incertum* (Williamson). (U.S.N.M. No. 626704), ×46.	
27, 28.	*Alliatina primitiva* (Cushman and McCulloch) Hypotypes (U.S.N.M. Nos. 626705, 626706), ×104, ×94.	62
29.	*Robertinoides charlottensis* (Cushman) Hypotype (U.S.N.M. No. 626707), ×46.	62

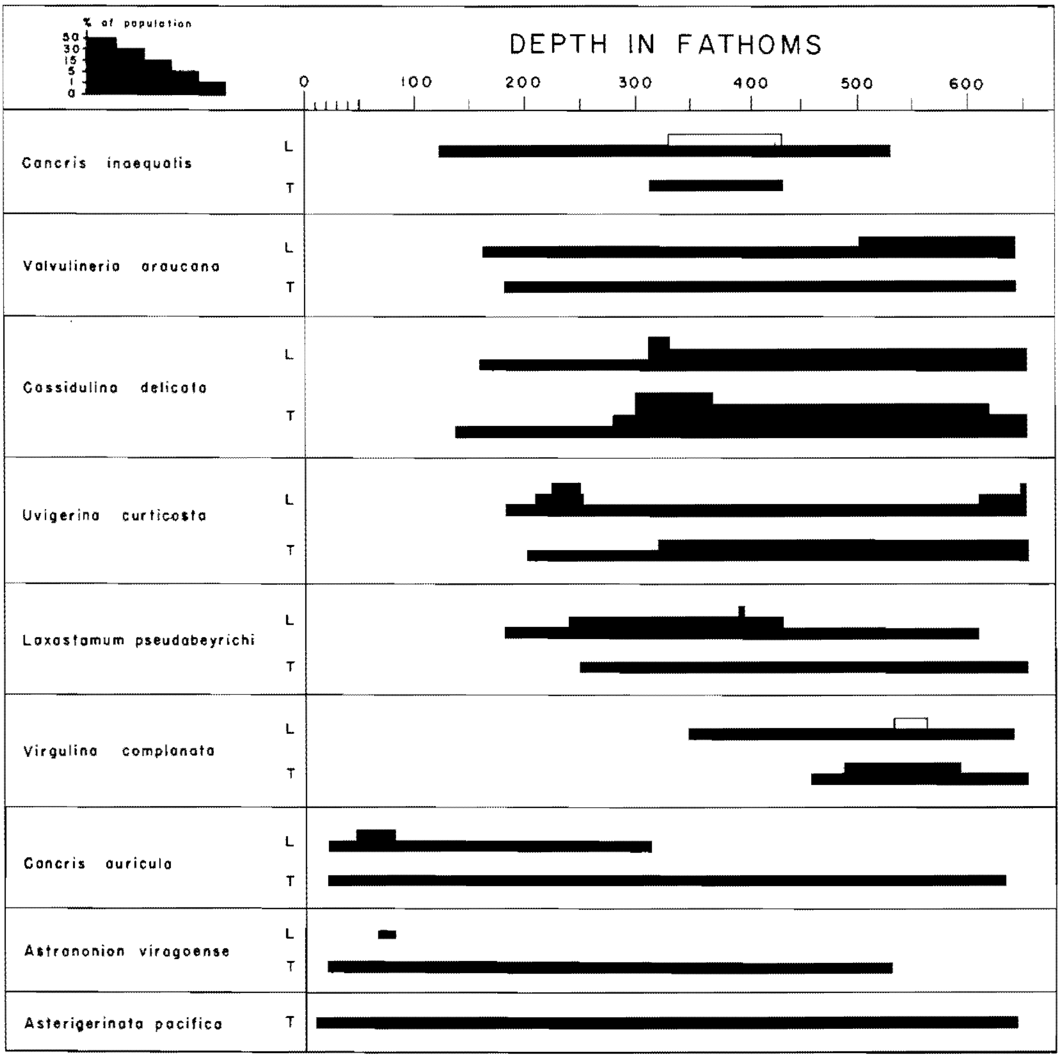
Depth Range (Fathoms)	Coarse Sand no. of samples	Coarse Sand av. pop.	Fine Sand no. of samples	Fine Sand av. pop.	Silt no. of samples	Silt av. pop.	Clayey Silt no. of samples	Clayey Silt av. pop.	Foram. Sand no. of samples	Foram. Sand av. pop.	All no. of samples	All av. pop.
0 - 10	1	132			2	254					3	213
10 - 20	1	153	1	239	6	179					8	184
20 - 30	4	149	1	239	1	1293					6	355
30 - 40	2	184	2	890	2	593	6	825	3	511	12	688
40 - 50			4	897	6	545	5	643	3	511	18	613
50 - 60			2	296	3	801			5	636	10	873
60 - 70					1	343			5	637	6	588
70 - 80					3	699			3	416	6	541
80 - 90					3	755					3	755
90 - 100							2	305	2	625	5	466
100 - 110							2	295			2	295
110 - 120					1	1277	3	528			4	715
120 - 130			1	1119	1	1277	2	855	1	696	5	962
130 - 140							3	759	1	916	4	799
140 - 150							2	906	1	916	3	909
150 - 160					1	258	3	1071			4	868
160 - 170							2	779	1	306	3	621
170 - 180	1	190			1	598					2	394
180 - 190	1	190			1	598	1	225			3	338
190 - 200					1	943	1	183			2	563
200 - 210					1	943	1	116			2	530
210 - 220					1	517	1	808			2	662
220 - 230					1	550					1	550
230 - 240					1	510					1	510
240 - 250			1	834			2	1242			3	1106
250 - 260			1	834							1	834
260 - 270												
270 - 280					1	1379					1	1379
280 - 290	1	69			1	1379					2	724
290 - 300												
300 - 310	1	210									1	210
310 - 320	1	210									1	210
320 - 330	1	119									1	119
330 - 340												
340 - 350	1	79			5	435					6	376
350 - 360	1	79			3	438					5	509
360 - 370												
370 - 380												
380 - 390	1	269									1	269
390 - 400							1	564			1	564
400 - 410												
410 - 420							1	805			1	805
420 - 430			1	421			2	702			3	608
430 - 440			1	421			2	584			3	530
440 - 450					1	335	1	570			2	453
450 - 460			2	228	1	335	2	429			5	349
460 - 470			1	183			2	572			3	442
470 - 480			1	300							1	300
480 - 490							2	340			2	340
490 - 500							1	236			1	236
500 - 510			1	253	1	307	1	467			3	342
510 - 520							3	360			3	360
520 - 530							4	456			4	456
530 - 540							1	455			1	455
540 - 550							1	146			1	146
550 - 560							2	175			2	175
560 - 570							3	375			3	375
570 - 580							3	338			3	338
580 - 590							3	260			3	260
590 - 600							1	150			1	150
600 - 610							2	235			2	235
610 - 620							1	566			1	566
620 - 630							1	357			1	357
630 - 640							5	247			5	247
640 - 650							2	111			2	111
0 - 650	12	149	15	578	35	568	70	536	21	629	156	523

Table 4. Depth distribution of average populations of living benthonic Foraminifera.

Note. Stations occurring at depth boundaries are calculated for the depth ranges both above and below the boundaries. Station 250 is not included in this table.



Text Figure 8. Depth distributions of benthonic Foraminifera. L: living population; T: total population. Height of bar: average frequency; solid bar: consistent occurrence; open bar: scattered occurrence.



Text Figure 9. Depth distributions of benthonic Foraminifera. L: living population; T: total population. Height of bar: average frequency; solid bar: consistent occurrence; open bar: scattered occurrence.

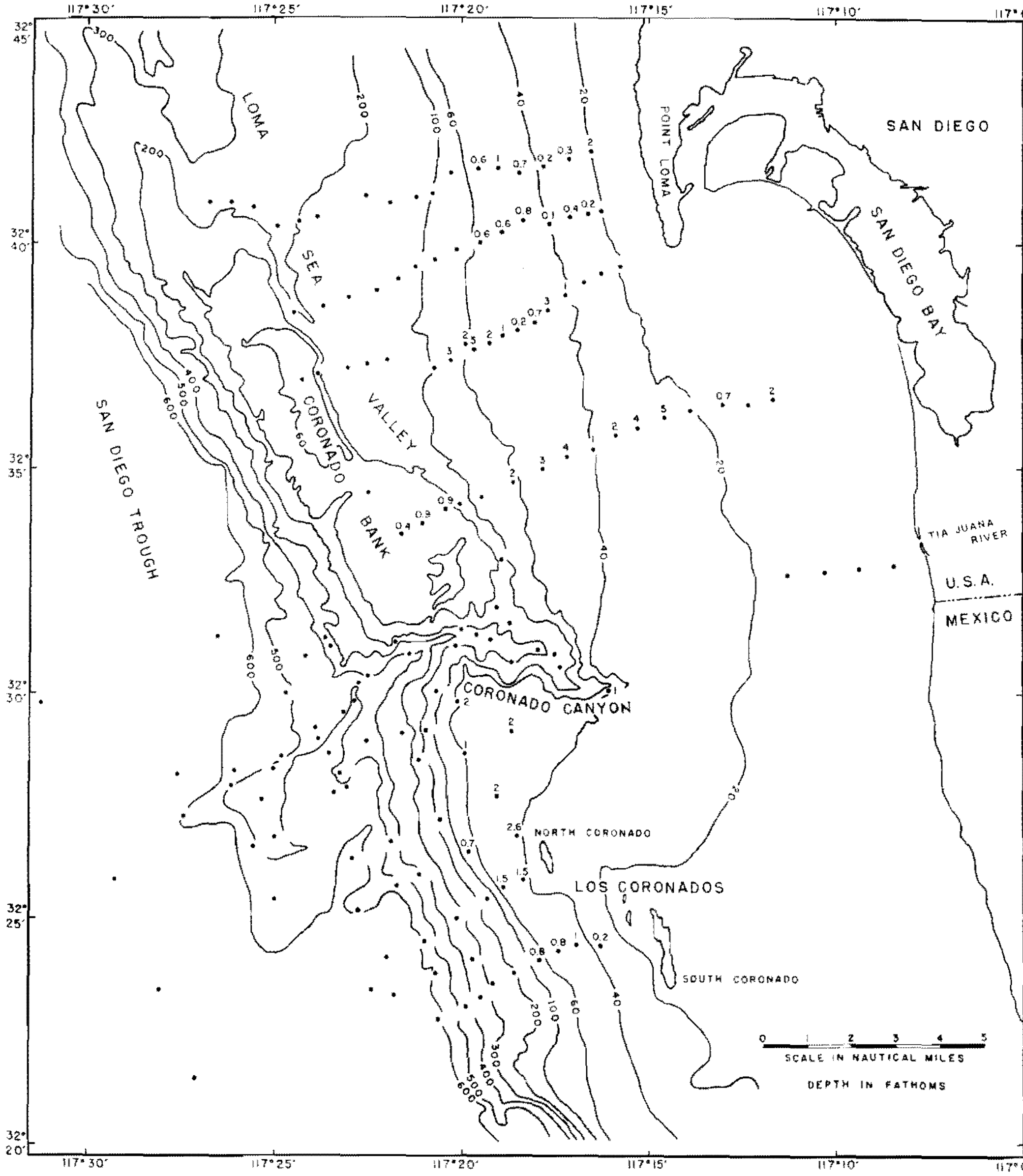
maximum where they impinge on the outer edges of continental shelves and over banks and seamounts. Such a daily effect may stir up bottom sediments, renew food and oxygen, and remove waste products.

It is difficult to explain why the living population is smaller in Todos Santos Bay than in the San Diego area as shown below.

Average Living Population Per Sample

Location	*Depth Range*	
	0-50 fathoms	*50-100 fathoms*
Todos Santos	104	142
San Diego	502	679

A part of the reason may be that the Todos Santos Bay samples were collected during February and the San Diego samples were collected during the summer months. Walton (1955) shows that the average living populations in August were the highest and approximately three times larger than those in February. Another possible reason why the Todos Santos Bay area has a smaller living population than the San Diego area is that specimens smaller than 0.088 mm. were not counted by Walton. In the deep area (deeper than 350 fathoms) *Virgulina apertura* Uchio, n. sp., a very tiny species, constitutes more than 20% of the population at each station in the San Diego area.



Text Figure 10. Distribution of living *Bolivina acutula* Bandy in percent of living population.

TOTAL POPULATIONS OF BENTHONIC FORAMINIFERA

Depth Distribution of Species

Depth ranges and frequencies of the empty tests of many benthonic species are quite different from those of living ones as shown in Text Figs. 2-9. Comparison of depth ranges of the total Foraminifera fauna (living plus dead) with those of living ones reveals striking differences, particularly at depths greater than 47 fathoms. Total Foraminifera assemblages depend upon the productivity of living Foraminifera and contamination with displaced and/or residual or fossil faunas from other places. Occurrences of the species of benthonic Foraminifera in percent of total (living plus dead) populations are listed in Tables 5-7.

The most remarkable differences between the living and total faunas are that 7 living faunas are recognized in this area while only 4 total faunas are recognized, and the depths of the boundaries of these two faunal types differ from each other.

The following generalizations can be made from the comparison of the depth ranges of the total faunas with those of the living faunas (see Table 8):

The total fauna shallower than 20 fathoms appears to represent the living fauna. The probable reason is that the deeper fauna can not be transported to shallower water (except under very unusual conditions), and few fossil specimens are supplied to the nearshore fauna (in the samples studied) from sea-cliffs where Cretaceous and Eocene rocks are exposed.

The total faunas deeper than 280 fathoms are marked by abundances of *Cassidulina subcarinata* Uchio, n. sp., *C. delicata* Cushman, and *Epistominella sandiegoensis* Uchio, n. sp. Living specimens of *Cassidulina subcarinata* and *C. delicata* begin to occur at 250 fathoms and are important members of deep-sea faunas, although they do not constitute as high percentages as dead specimens in the total fauna. Living specimens of *Epistominella sandiegoensis* are eurybathic, found from nearshore to the bottom of San Diego Trough but in low frequency. The total fauna present deeper than 280 fathoms is represented by living species there, but the frequencies differ.

The total faunas between 20 and 280 fathoms are characterized by an abundance of species of *Cassidulina*. In addition, there are species which are indigenous to those depths and other species whose living specimens are found only in shallow water. The species which are most abundant in the fauna are characteristic of Pleistocene "Foraminifera sand." Thus the total faunas at 20-280 fathoms are quite different from the living assemblages at those depths.

Size of Total Population

There are striking differences in the areal distributions of living and total (living plus dead) populations (see Text Figs. 14, 16). In the San Diego area the distribution of the total population generally can be correlated with distribution of sediment type except on the shelf off Point Loma (see Table 9).

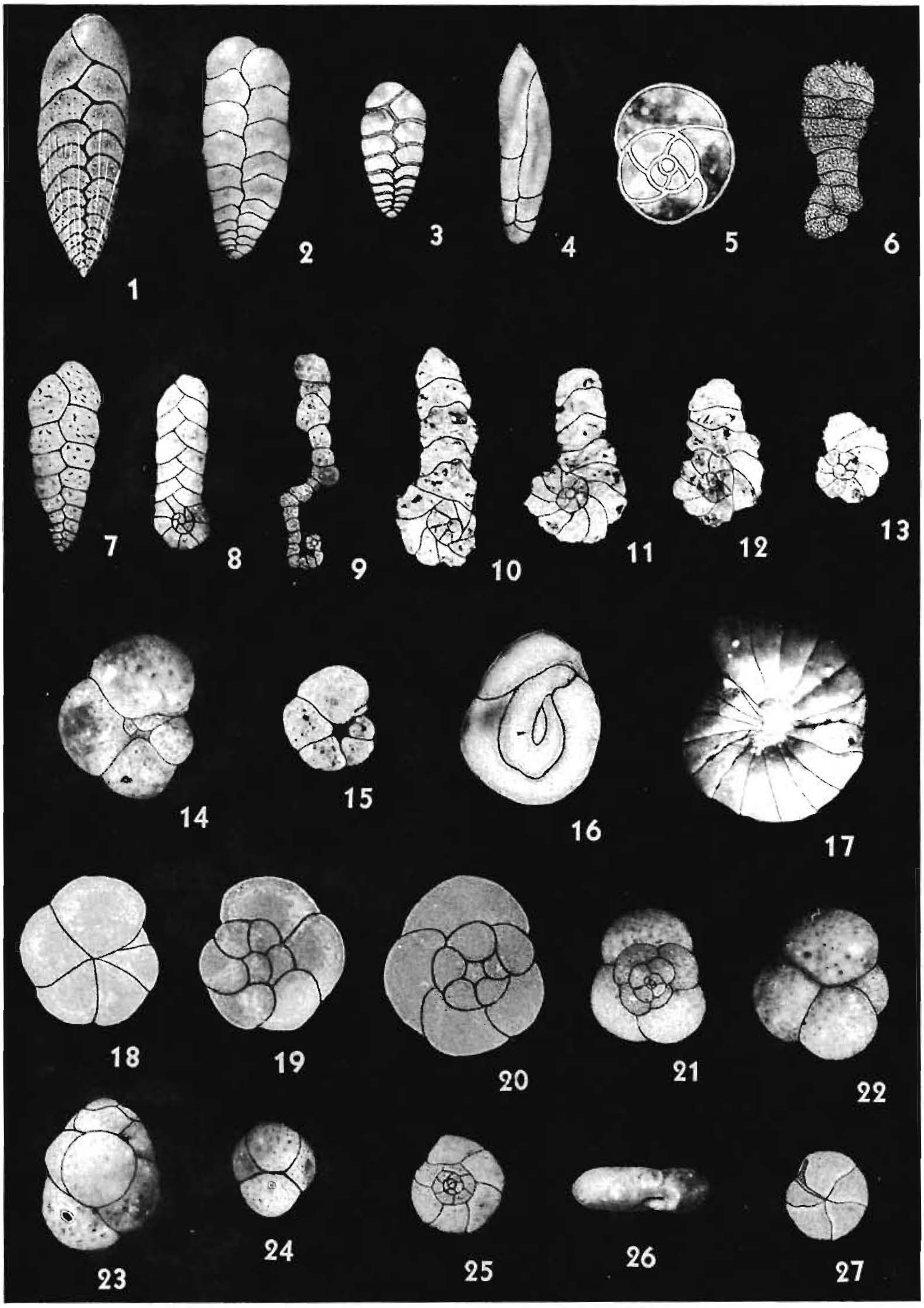
The area which has a relatively low total population, less than 10,000 per sample, is divided into two parts. The first is shallower than 40 fathoms and approximately coincides with the distribution of coarse sediments (fine to coarse grey sand, medium to coarse brown sand, shell sand) and rocky bottom. This zone extends along the shelf west of Point Loma. The second is deeper than about 600 fathoms in the San Diego Trough. Shallower than 20 fathoms the total population usually is less than 2000 per sample.

The highest total population, more than 50,000 per sample, is on Coronado Bank and its southern extension which is separated from the bank by Coronado Canyon. The depth range is about 40 to 300 fathoms. Another high population area is on the shelf between Coronado Bank and Point Loma at about 50 to 75 fathoms. Intermediate total populations between 10,000 and 50,000 per sample occur between the two areas mentioned above.

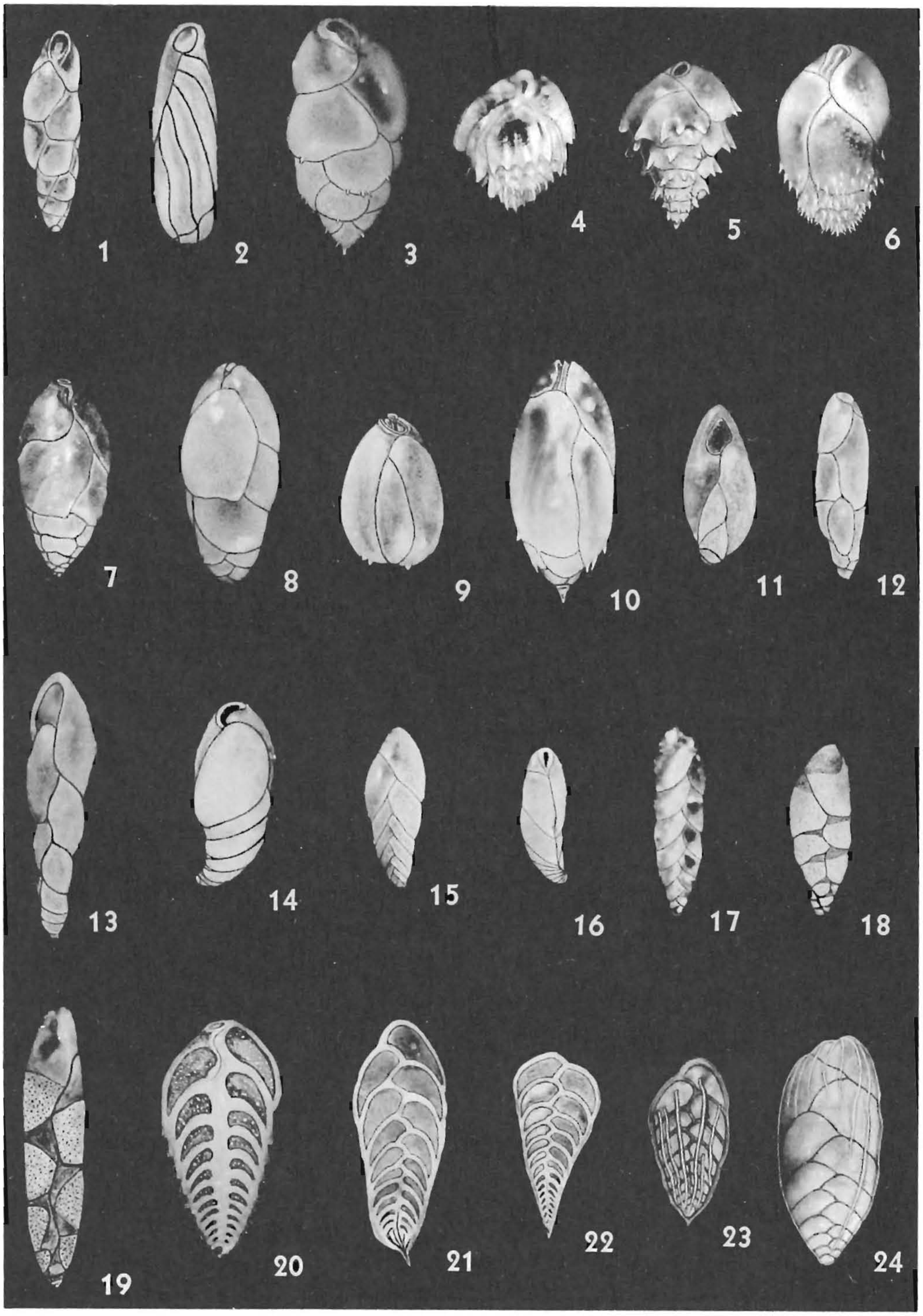
The size of the population of empty tests (therefore, that of the total population) is primarily a function of: (1) rate of production of tests, (2) dilution of populations by detrital sediments, and (3) preservation of empty tests (Walton, 1955, p. 977). The sediment of high total population areas is composed of relatively pure Foraminifera sands or contains a high

EXPLANATION OF PLATE 5

Figs.		Page
1.	*Bolivina acutula* Bandy. Hypotype (U.S.N.M No. 626733), ×95.	
2.	*Bolivina vaughani* Natland .... Hypotype (U.S.N.M. No. 626747), ×100.	64
3.	*Bolivina lowmani* Phleger and Parker. Hypotype (U.S.N.M. No. 626736), ×128.	
4.	*Virgulina delicatula* Uchio, n. sp. .... Holotype (U.S.N.M. No. 626724), ×99.	63
5.	*Neoconorbina parkeri* (Natland). Hypotype (U.S.N.M. No. 626765), ×109.	
6.	*Rectocibicides miocenicus* Cushman and Ponton .... Hypotype (U.S.N.M. No. 626854), ×38.	69
7.	*Textularia earlandi* F. L. Parker. Hypotype (U.S.N.M. No. 626622), ×92.	
8.	*Spiroplectammina biformis* (Parker and Jones). Hypotype (U.S.N.M. No. 626618), ×101.	
9.	*Placopsilina bradyi* Cushman and McCulloch. Hypotype (U.S.N.M. No. 626680), ×31.	
10-13.	*Ammomarginulina foliacea* (Brady). Hypotypes (U.S.N.M. Nos. 626609-626612), 10, ×32; 11-13, ×36.	
14.	*Haplophragmoides quadratus* Uchio, n. sp. .... Paratype (U.S.N.M. No. 626591), ×67.	52
15.	*Haplophragmoides* sp. (U.S.N.M. No. 626593), ×46.	
16.	*Glomospira gordialis* (Jones and Parker). Hypotype (U.S.N.M. No. 626586), ×123.	
17.	*Cyclammina pusilla* Brady. Hypotype (U.S.N.M. No. 626615), ×24.	
18-20.	*Trochammina rhumbleri* Uchio, n. sp. .... 18, 19, Holotype (U.S.N.M. No. 626670), ×144 20, Paratype (U.S.N.M. No. 626671), ×150.	59
21, 22.	*Trochammina globigeriniformis* Brady. Hypotypes (U.S.N.M. No. 626659, 626660), ×30.	
23, 24.	*Tritaxis bullata* (Höglund) .... Hypotypes (U.S.N.M. No. 626672, 626673), ×106, ×107.	59
25-27.	*Arenoparrella oceanica* Uchio, n. sp. .... 25, 26, Paratypes (U.S.N.M. No. 626675, 626676), ×99, ×149. 27, Holotype (U.S.N.M. No. 626674), ×98.	59



Uchio: Living Foraminifera, San Diego, California



Uchio: Living Foraminifera, San Diego, California

percent of Foraminifera sands which are mostly residual faunas of Pleistocene age. Coronado Bank is a non-depositional area at present, as shown by the very thin cover of Recent sediments and the presence of glauconite and phosphorite nodules. For this reason there is almost no dilution of the Foraminifera tests by detrital sediments. The low total population in the San Diego Trough may be due to low production and low temperature and also to dilution by detrital sediments. The low total population in the nearshore area is explained by low production suggested by the presence of small living populations. The presence of a tongue-like area of intermediate total populations in the San Diego Trough is explained by the presence along Coronado Canyon of fine sand which has been displaced from the intermediate total population area on the shelf.

Usually the size of the living population is very small compared to that of the dead population, and, therefore, the size of the dead population is almost the same as that of the total population (see Walton, 1955, text-figs. 8, 9). For this reason the distribution of the L/T (Living population/Total population) ratios is more influenced by total population than by living population.

Walton (1955, p. 977, text-fig. 12) finds that the frequency distribution of dead population per 5-fathom interval is multimodal, and that the high population of dead Foraminifera does not correspond to the areas or depth of the maximum production of living Foraminifera in Todos Santos Bay at the time of collection. He does not mention the dead benthonic population in the deeper traverse, but his table 4 shows the irregularity down to 490 fathoms. Bandy (1956, p. 185), instead of counting dead or total populations, estimates the weight percentage of the Foraminifera (including benthonic and planktonic) in sediments, and concludes that the percentage fluctuates from less than one percent near the shore to two percent on the outer part of the continental shelf. Deeper, they increase rapidly down the continental slope; this increase coincides with the progressive increase of planktonic tests in the sediments. After examining Bandy's charts (*op. cit.*, charts 3-7) which deal with offshore Foraminifera, the writer finds that Bandy's conclusion is correct in three traverses (*op cit.*, charts 3, 6, 7), but is not correct in two other traverses (*op. cit.*, charts 4, 5).

NUMBER OF SPECIES AND GENERA OF LIVING BENTHONIC FORAMINIFERA

Bandy (1954, p. 135) in his study of shallow-water Foraminifera in the Gulf of Mexico concluded that the number of species increased away from shore because of the more rapid sedimentation near shore and the fairly stable normal chlorinity offshore. Later in his ecologic study of Foraminifera in the northeastern Gulf of Mexico, he also concluded that the number of species generally increased from about 20 in the nearshore area to more than 50 at the outer ends of the deeper profiles (Bandy, 1956, p. 184-185). His conclusion applies to the present study in the San Diego area, but it should be remembered that he dealt with the empty tests of Foraminifera and a different result might have been obtained if he had dealt with living Foraminifera only. If one considers only total populations from dried samples there is no way to distinguish Forami-

EXPLANATION OF PLATE 6

Figs.		Page
1.	*Buliminella tenuata* Cushman. Hypotype (U.S.N.M. No. 626709), ×46.	
2.	*Buliminella elegantissima* (d'Orbigny). Hypotype (U.S.N.M. No. 626708), ×103.	
3.	*Bulimina denudata* Cushman and Parker. Hypotype (U.S.N.M. No. 626710), ×100.	
4.	*Bulimina mexicana* Cushman. Hypotype (U.S.N.M. No. 626711), ×50.	
5.	*Bulimina pagoda* Cushman. Hypotype (U.S.N.M. No. 626712), ×47.	
6.	*Globobulimina barbata* (Cushman). Hypotype (U.S.N.M. No. 626713), ×52.	
7, 8.	*Globobulimina hoeglundi* Uchio, n. sp. 7, Holotype (U.S.N.M. No. 626714), ×38. 8, Paratype (U.S.N.M. No. 626715), ×38.	64
9.	*Globobulimina pacifica* Cushman. Hypotype (U.S.N.M. No. 626717), ×18.	
10.	*Globobulimina spinifera* (Cushman). Hypotype (U.S.N.M. No. 626718), ×70.	
11.	*Virgulina apertura* Uchio, n. sp. Holotype (U.S.N.M. No. 626719), ×100.	63
12.	*Virgulina bramlettei* Galloway and Morrey. Hypotype (U.S.N.M. No. 626721), ×35.	
13.	*Virgulina complanata* Egger. Hypotype (U.S.N.M. No. 626722), ×96.	63
14.	*Virgulina cornuta* Cushman. Hypotype (U.S.N.M. No. 626723), ×46.	
15, 16.	*Virgulina rotundata* Parr. Hypotypes (U.S.N.M. Nos. 626726, 626727), ×47, ×46.	
17, 18.	*Virgulina sandiegoensis* Uchio, n. sp. 17, Holotype (U.S.N.M. No. 626728), ×155. 18, Paratype (U.S.N.M. No. 626729), ×136.	63
19.	*Virgulina seminuda* Natland. Hypotype (U.S.N.M. No. 626731), ×92.	
20.	*Bolivina acuminata* Natland. Hypotype (U.S.N.M. No. 626732), ×83.	
21, 22.	*Bolivina subargentea* Uchio, n. sp. 21, Holotype (U.S.N.M. No. 626744), ×33, megalospheric form. 22, Paratype (U.S.N.M. No. 626745), ×34, microspheric form.	64
23.	*Bolivina interjuncta bicostata* Cushman. Hypotype (U.S.N.M. No. 626734), ×34.	
24.	*Bolivina tongi filacostata* Cushman and McCulloch. Hypotype (U.S.N.M. No. 626735), ×102.	

TRAVERSE	I																			II														
STATION	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30
DEPTH IN FATHOMS	20	33	38	42	47	53	80	94	118	137	157	164	181	194	208	223	214	247	238	20	29	34	39	42	46	53	73	87	104	114	121	135	148	180
TOTAL POPULATION	11600	6600	4700	9400	11200	2100	6700	6600	14200	13900	3400		6100	8300	35400	19700	9100	52100		700	6100	5300	2400	7100	2500	7700	24400	23900	11800	28400	52500	14500	19800	20500
Alliatina primitiva													.1			.2																		.2
Alveolophragmium advena																																		
A. columbiense	.1		.4	.3	.4	.8														1	1		1											
Ammobaculites cafenulatus					.1	.8					2		1	.2			.7	.5											.5			.5	.6	1
Ammotium planissimum	.3		.4		.4	1	.2		.1												.3			.5	.5									
Angulodiscorbis charlottensis																																		
Angulogerina angulosa	3	2	2	4	6	12	11	6	5	5	6		5	7	8	5	8	7		1	2	3	1	4	10	12		6	7	4	4	5	6	10
Arenoparrella oceanica		.2			.1		.1													.6			1											
Asterigerinata pacifica				.3				.7					1									.3												
Astrononion viragoensis	.1													.2	.1	.2																	.2	
Bigenerina höglundi																																		
Bolivina acuminata	.3		.4	1	2	5	4	3	3	.8	.2					.2								1	2	3		1	3	2	1	1	.2	.2
B. acutula		.5	.7	2	1	.8	.6	.2										.5						2	1	.4								
B. bicostata																																	.2	
B. filocostata																								.2							.1	.1		
B. minuta									.1	.5	2		10	23	20	15	18	20										.3	.3	.2		1	2	5
B. pacifica		2	5	2	4	1	4	3	4	3	2		.8	.2	1			.2			1	5	4	5	6	4		3	1	1	.5	1	1	3
B. peirsonae																																		
B. spissa									.3	2	3		9	6	6	4	1	2											.3	.6	1	4	4	3
B. subargentea									.2	2	8		4	2	2	.8	.3	6												.3	.2	3	9	3
B. subexcovata	.7	4	1	1	1	.4	.1	.7	.2	.3	1		.8	1	.2	4		1		.6	1	2	.9	2	.6	.4		.8	1	.3	.6	.4	.3	.5
B. vaughani	.6	2	3	1	2	.4	1	1	.3	.3			.3	1	.4	.3					2	1	.6	2	.8	.4		1		.7	.1	.5	.5	.2
Buccella angulata	.6	5	9	15	6	6	3	.7	.1	.1	.7		.3			.3					6	8	6	8	13	3		1	.8					.2
Bulimina denudata	.3	.2	.4	1	2	7	3	4	7	4	1		2	1		.6					.5	.3		2	6	4		4	7	6	8	8	3	
B. mexicana																																		
B. pagoda																																		
B. subacuminata																																		
Buliminella elegantissima		7	3	2	.7		.4						.1		.2					1	7	8	5	2	1	.4		.3						
B. tenuata																																		
Cancris auricula	.1	.2			.4	.8	.5				1		.1	.4		.2					.3		.3		.8	2		.3	.3	.1	.6	.3		2
C. inaequalis																																		
Cassidulina bradshawi																																		
C. californica																																		
C. delicata											.2		.4	1	.6	2	9	9														.1	.6	.3
C. depressa	6	8	10	17	14	2	20	44	39	27	15		12	13	10	10	3	8		9	4	2	10	22	8	19		25	37	45	24	27	18	5
C. limbata				.7	6	1	2	6	11	13	3		4	1		.2	2								.8	4		7	10	11	20	9	4	3
C. subcarinata										.1	.5		2	2	4	5	6	12														.1	.8	1
C. subglobosa	3	3	3	4	4	5	14	5	8	21	28		32	25	20	30	34	9		.6	3	2	1	2	6	13		13	7	9	20	20	34	26
C. tortuosa	3				5	1	.4						.3				7	.2		37						4								3
C. sp. cf. C. orientalis																																	.2	
Cassidulinoides waltoni													.1		.2																.1			.5
Chilostomella ovoidea							.4		.1	.6			.7	.2	1			.7										.3						
Cibicides fletcheri	34	5	5	2	4	.8	.5	3	2	.3	1		.7	.8	3	2	.7			9	5	2	.3	2		.8		2		1		.9	1	3
C. mckannai					.6		1		1	.3	.2		.1	.2		2				1						.8		.8	.8	.8	1	.2		.7
C. phlegeri																		1													.1		.2	.3
C. spiralis																																		
Cornuspira lajollaensis	.1																			.6														
Cornuspiroides foliaceus																																		
Ehrenbergina compressa							.1						.1			.6	2	3										.3		.1		.1	.2	6
Elphidium spp.	.6	6	6	6	4	.4	1	.7		.2	.2		.1		.2	.6				1	10	5	4	8	5	4		.5	.3	.2	.1	.2	.3	.3
Epistominella sandiegoensis	1	3	1	1	6	10	16	15	8	6	9		10	6	7	6		6		.6	3	2	3	3	6	12		17	7	7	5	7	7	2
E. smithi													.1					2																
Eponides leviculus					1	.8	1	2	3	3	4		1	4	5	3	.7	2					.6	.5	3	.4		6	2	3	2	2	2	.8
E. subtenerus																																		
Gaudryina arenaria					.3	.8	1	.5	.4	.3	.2		.3	.8		.2							.6	.2	.3	2		2	.3	.6	1	1	.3	1
G. subglabrata	.3																																	.7
Goësella flintii		1	1	2	.9	1	.1				.5				.2	.5	1					.9	1	3	2									2
Globobulimina barbata																																		
G. höglundi																																		
G. pacifica					.6		1	.5	.2	.6	1		.1		.4	.5	.3	.5			.3	.9		.2	.5				1	.6	.2	.7	.8	.8
G. spinifera																																		
Glomospira gordialis																																		
Gyroidina gemma																																		
G. quinqueloba																																		
Hanzawaia nitidula	1				.7												1											.3			.1			1
Haplophragmoides neobrodyi				.7	.6	7	.7																	.2	2							.1	.3	
H. quadratus																																		
H. sp.																																		
Höglundina elegans																																.1		1
Cassidulina sp.																																		

TRAVERSE	III																		IV		
STATION	1	2	3	4	5	6	7	8	9	10	20	11	12	24	25	26	27	28	103	102	101
DEPTH IN FATHOMS	19	20	35	40	44	45	47	49	52	56	59	74	92	112	123	157	92	71	15	17	20
TOTAL POPULATION	2000	6100	7000	12700	15200	2700	7800	28500	55400	152300	184700	261600	22200	16500	24900	24400	111600	547800	3600	2300	1800
Alliatina primitiva																					
Alveolophragmium advena								.1												1	.9
A. columbiense	.8	.5		.1	.2															2	6
Ammobaculites cafenulatus															.1	.3					
Ammotium planissimum				.3	.2		.2		.1					.2		.8			1	.7	.2
Angulodiscorbis charlottensis																					
Angulogerina angulosa	.8	4	6	4	2		7	10	14	13	7	14	10	4	5	11	10	10	1	.7	
Arenoparrella oceanica				.3	.3		.4	.1													
Asterigerinata pacifica										.2			.1							.7	
Astrononion viragoensis										.2	.7			.1							
Bigenerina höglundi																					
Bolivina acuminata				.6	1		1	1	.5	.8	4	1	4	3	2	.5	.5	1			
B. acutula		.5	.8	.9	.3		1	.5	.5	.5			.1		.3						
B. bicostata																1					
B. filocostata									.1			.2	.3				.2				
B. minuta													.1	1	1	3					
B. pacifica			.8	4	5		4	.9	.3	.8		.2	2	.4	.9	2	.7		.7		.4
B. peirsonae																					
B. spissa													.3	.2	2	4					
B. subargentea														.3	2	9				.4	
B. subexcovata		1	.8	3	2		1	.7	.5	.5	.7	1	3	.7	1	.3	1	.4	.4		1
B. vaughani		.5	.8	1	1		1	.2		1	.7	.4	.4	.5	.1	.3	.2	.2	1	3	2
Buccella angulata	.8	6	8	6	22		5	.6	.5	.2		.4	.3						8	6	3
Bulimina denudata				1	.9		4	1	1	.5			5	4	3	2			2	1	.4
B. mexicana																					
B. pagoda																					
B. subacuminata																					
Buliminella elegantissima		2	4	3	1		.6	.1	.2				.1	.2					7	5	15
B. tenuata																					
Cancris auricula							1	.7	.5	.8		.6	.4	.3	1	.5	.5	.7			
C. inaequalis																					
Cassidulina bradshawi																					
C. californica							.2	.1	.5	.7						3					
C. delicata																					
C. depressa			9		20		14	13	10	5	13	7	27	43	25		4	4	.9	.7	
C. limbata					.2			13	9	13	11	15	6	10	12	7	28	21			
C. subcarinata												.2			.1	.3					
C. subglobosa		7	3	25	2		8	12	17	13	15	19	10	10	20	34	10	23	.7		.2
C. tortuosa	14	3	2				1	16	15	17	18	10	.6	.6	.1	1	28	17	.2		
C. sp. cf. C. orientalis			2		.2		1												.7		
Cassidulinoides waltoni															.1						
Chilostomella ovoidea														.1	.4	.3					
Cibicides fletcheri	11	23	4	8	.5		.8	3	8	11	4	14	2	1	2	4	4	11	1		
C. mckannai				.3			.2	4	2	2		4	4	2	1	.5	4	3			
C. phlegeri																					
C. spiralis																					
Cornuspira lajollaensis																					
Cornuspiroides foliaceus																					
Ehrenbergina compressa												.8	.7	.2		1	.5	.9			
Elphidium spp.		5	6	7	5		3	4	2	1		.2		.1	.1			.2	10	9	13
Epistominella sandiegoensis				.9	2		7	7	10	4	7	3	9	5	7	3	.7	3	.2	.7	
E. smithi															.3						
Eponides leviculus					.5		3	1	.5	.5	2	1	4	2	2		.2	.4			
E. subtenerus																					
Gaudryina arenaria			.8				1	.7	.2	.3		.8	2	.8	1	.5	.7	.2			
G. subglabrata																	.2				
Goësella flintii			2	1	.5		.6								.1	.3					
Globobulimina barbata																					
G. höglundi																					
G. pacifica				.3	.2		1	.3					.3	.7	.5	2		.2			
G. spinifera																					
Glomospira gordialis																					
Gyroidina gemma																					
G. quinqueloba																					
Hanzawaia nitidula							.4	.3	.2	2	.7	.6	.3			.3	.9	.2			
Haplophragmoides neobrodyi					.2		1	.3													
H. quadratus																					
H. sp.																					
Höglundina elegans												.2			.1		.5				
Cassidulina sp.										3											

Table 5. Occurrences of benthonic Foraminifera in percent of total (living plus dead) population.

nifera indigenous to an area from those which have come from other environments. One can expect more species in mixed sediments of different origins than in sediments of a single origin.

Bandy (1954, p. 135) also pointed out that there was a correlation between weight percentages of Foraminifera and the number of species. This is probably true, but it should be pointed out also that the greater the number of specimens examined the greater the likelihood of finding rare species. The larger the population, therefore, or the higher the weight percentage of Foraminifera in a sediment, the larger the number of species.

In most of the San Diego area the number of species

STATION	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	44	43	42	41	40	39	38	37	36	35	34	33	32	31	30	1	2	3	4	5	6	7	8	9	10	20	11	12	24	25	26	27	28	103	102	101
Involutina pacifica			.4		.1		.1		.1	.1	.2		.1			.2							.3					.3			.1						.8	.1	.2		.6							.1							
Lagena & related spp.	.8	3	5	4	2	2	10	1	10	1	.2		2	.8	1	2	2	2			4	3	.3	2	2	1		1	2	1	1	1	1	2			2				2	2	.6	2	4			1	1	.8	.7	2	3	2	3
Lagenidae (other)				.3										.2							.3			.2								.2		.2				.2							.7	.2		.1	.3				.2		
Loxostomum bradyi																																																			.2				
L. pseduobeyrichi																		.2																																					
Neoconorbina terquemi																																																							
N. parkeri	2																																																						
Eggerella advena	.7	.9	7	1	2	7	.6	.2	.2											.6	12	16	13	2	3	.4			.3	.1		.1			.8	2	3	1	2		3	.3	.1	.2			.3	.2					24	31	23
E. scrippsi				.3		.4											.7	.2						.2										.2																					
Nonion tonkfordi				.3			.5	.2	.1	.1			.1					.5					.3			.8				.2	.1								.3					.2				.1							
N. parkerae																																																							
Nonionella basispinata	2	.7		.7	.3									.2	2	.2		.2		1	4	5	1	.2	.5				.3					.5		1	2	3	3		2	.1	.1			.2	.9	.2		.8			5	6	7
N. (?) fragilis																																																							
N. stella	.6	19	18	21	13	7	6		.8	.2	.7			.2	.2	.2		1		1	16	15	12	19	5	4		3	2	.4	.1	.1	.5	.5		8	24	13	16		14	3	2	.9		.6	1	.7	.9	.5	.5		14	10	10
N. sp. aff. N. globosa								.2	.2	.5	2		.5		.6	.2														.1	.2	.1		.7																.3	.2				
Nouria harrisii																																									.2		.1							.5					
N. polymorphinoides			.4																																																				
Patellina corrugata	.1							.2																																		.1													
Planulina ornata	3				.6												1			.6	.3												.2	.3	.8	2	.8	.6	.2		.6	1		3	2	2	.4	.3		.3	2	.7	.2		
Placopsilina bradyi																																																							
Polymorphinidae	.1																			3				.2											.8			.1			.2	.1								.3	.2				
Saccammina longicollis			.8			1			.1				.3							.6		1			3			.3		.2	.1					2		.5			.2							.6	.1						
Pullenia salisburyi	.3						.1		.3	.3						.6		.5						.2	.8						.2	.2	.5	.3							.4	.3	.8	.5	.7	.2	.4	.5	.1	.5		.2			
Recurvoides sp.		.2			.1	3	.4		.1	.1	.5		.1									.6		.2	3	.4		.3	.3		.1	.2							.2		.8									.3					
Recurvoidella parkerae																																																							
Remaneica cf. helgolandica																																																							
Reophax excentricus																						.3				.4																													
R. gracilis	.1	.5							.1													.3																.3										.1	.1						
R. horridus																																																							
R. micaceous																																																							
R. communis	.1	.5			.3	.8															.3	.9	.6		.5																.6	.1											2	2	2
R. scorpiurus		.5	.4			2	.7		.1														.3	.2	1	.4												.4				.1													
R. subfusiformis																																																							
R. spp.																																		.4												.2									
Robertinoides charlottensis	.1																																																						
Rosalina columbiensis					.6																2			1											43	3																			
R. campanulata	21	1	1	2																13	1	2	1			2		.3							23	12	3		.5			.8	.6	.3	.7		.1						.7		.2
R. turbinata	2																																			5																			
Seabrookia earlandi					.3				.3	.9	.7		1	.2	1	.6	.3	.2										.5	.8	.4	.2	.5	.3						.2					.3			.3	.6	.4	.3	.2				.2
Sigmoilina tenuis			.4							.5	.7		.3	.4	1													.3	1	.3	.7	1	.2	.5		.5		.1				.1	.2	.3	.7	.2	.4	.6	.6						
Spiroloculina fragilis																																																							
Spiroplectammina bathyca																																																							
S. biformis																																																							
Suggrunda (?) eckisi											.2		.1					.2																																.3					
Textularia cf. abbreviata			2		.1																								.3					.2				.1	.3							.2									
T. earlandi		6	6	1	2	3	.1		.1												2	5	6	.7	1											.5	2	3	3		2	.5											.2	.4	.2
T. sandiegoensis																																									.2														
T. schencki	.4					.8																		.2										.3																					
Tritaxis bullata																																									.4														
Trochammina charlottensis	.8		3	2		2														4	4	3	4	.9	1									.2			2																		
T. chitinosa																																																							
T. conica						.4	.4	.2	.1								.3																	1																.3					
T. discorbinoides			.4															.2													.1			.3												.2									
T. globigeriniformis																																																							
T. kellettae	.1	.5	3	4	4		.5	.7													2	2	7	2	.3						.1					.5	.8	.8	1		.6								.1				.7		.2
T. labiata																																																							
T. nitida																					.8																.8																		
T. pacifica & var.	1	4	1		1	1	.3		.1		.5					.2	.7			.6	.8	.3	2	.5	.3			.3		.6	.1	.1		.2			3		.5		.8						1	.5	.1	.5			12	7	6
T. rhumbleri		.2			.1	.4															2		11	.2																															
T. squamiformis																																																							
Uvigerina auberiana																																																							
U. curticosta															.2	2		1																																					
U. juncea					.5	3		1	3				.3												.6							.1		2					.2		1	.3	.3	.6	1	.6			.3	1	.2	.2			
Valvulineria araucana																																		.2																					
V. glabra																																																							
Virgulina apertura																																																							
V. bramlettei																		X																																					
V. camplanata																																																							
V. carnuta																																																							
V. delicatula											.5			.4																																									
V. sandiegoensis		2	1	.7	2								.3								.5	1	.3													.5			.2		.4												1	.4	.7
V. seminuda		.2									.5		.7		.4	.2														.8				.2				.8	.5		.2							.1		.3					
Miliolidae	3				.3				.2	.1								.2		4			.6	.2	.3	.4		.3	.5			.3	.2	.3	3	.5									2				.1	.3	.2		1	2	
Miscellaneous spp.	5	1		.3	.3		1		.1	5	5		.3	1	3	1	.7	2		7	1	2	.3	.2	2	1		.8	5	2	7	3	2	2	1	11	4	.3	1		1	.1	.3	4	.7	.2	1	4	5	1	.6	.4	2	6	4

Table 5 (continued). Occurrences of benthonic Foraminifera in percent of total (living plus dead) population.

is less than 20 at a depth less than 20 fathoms, then gradually increases with increase of depth offshore reaching a maximum of more than 50 species at 60-100 fathoms. There is a gradual decrease in number of species with the increase of depth in the northern part of this area where the slope of the bottom is gentle down to the bottom of the Loma Sea Valley.

In the southern part of the area, where the shelf ends abruptly and there is a steep escarpment down to the bottom of the San Diego Trough, the situation is different from that in the northern part. The number of species is small at a depth shallower than 20 fathoms, then increases with increase of depth reaching a maximum at 45-100 fathoms, and then decreases again. Another maximum is found at 400-600 fathoms. The area of delta-like topography at the lower end of the Coronado Canyon does not show such a second maximum. The true deep floor of the San Diego Trough has a moderate but unexpectedly high number (average 41) of species. There is no positive correlation of the areal distribution of the number of species with that of the size of the living population, the total popula-

TRAVERSE	IV																																																						
STATION	100	99	98	97	96	95	94	93	92	91	90	89	88	87	140	124	123	122	121	259	115	260	240	286	275	242	287	261	306	276	249	262	285	277	191	216	220	227	188	183	228	221	230	243	263	218	229	186	248	212	264	322	323	324	270
DEPTH IN FATHOMS	21	25	30	33	40	45	48	61	80	104	65	63	64	75	5	7	9	11	11	38	39	40	40	41	45	47	50	53	53	55	57	64	67	78	120	125	128	134	140	150	160	167	180	200	213	218	234	248	250	275	280	285	310	328	345
TOTAL POPULATION	19400	8800	14300	1800	12800	13900	6700	24500	43500	22500	186700	467500	505900	247300	2900	700	1900	400	1200	217100	9600	58100	62300	290800	175900	214300	235800	120300	263700	151800	351700	62100	191000	161300	37600	50600	163200	19600	262700	16900	17300	72100	40100	29900	114400	19300	38800	50300	43900	16200	96000	23000	18900	15500	33900
Alliatina primitiva																																															.2			.6			.3		
Alveolophragmium advena																																																							
A. columbiense			.5		.5	.5											.6	1	7			.4	.4													.3					.1							.2							
Ammobaculites catenulatus							.6		.1									.2																							.4				.1				.6	.6	.1		5	4	
Ammotium planissimum	.2	X	.1	.7	.3	.6				.3																											.4							.2		.3	.2								
Angulodiscorbis charlottensis																6	3																																						
Angulogerina angulosa	8	9	11	17	12	10	8	15	9	10	15	18	13	8		.4	.4	.2		3	8	10	5	17	12	20	6	4	8	10	9	9	9	13	13	10	9	3	10	4	4	7	5	7	5	6	5	8	5	7	2	5	9	4	2
Arenoparrella oceanica							.6						.3							.3		.9								.3			.3		.3	.1		.6		1	.5		.2	.4	.1	.3		.2	.3		.2				
Asterigerinata pacifica		.4					.3						.3	.4			.2	2	.7	.6			.6	.3				.8	.4		.3	.3	.3	.3	.7		.4	.2		.4	.5		.2		.1	.3	.2	1	.3						
Astrononion viragoensis				.1	.3			.1			.1		.3												.4	.3															.1			.4	.1		.2	2	.3						
Bigenerina höglundi																																																							
Bolivina acuminata				.1	.1	.4	2	2	5	2	1	2	.3	.8						.9		1	.6	.3	.4	.3		2	2	3	1	1	.6	.9	1	3	.4	1		2	.9		.5	.6		1	2	1	.9	.6	.2				
B. acutula	.4	.2	.8	.9	.9	1	2		.2		.1					.2	.2	.2			.2	2	.2	.7	.4	.6		2								.3	.8																1	.8	
B. bicostata																																					.4							.2				.5							
B. filocostata							.3	.1			.3			.4												.6	.4					.1	.3										.2								.2				.2
B. minuta									.7																										.7	.8			.4		.5		.7	.4	3	2	3		3	4	8	13	9	5	8
B. pacifica	.3	.7	.2	.4	2	2	2	.5	2	1	3	.6		.4		1	.4	.5		.6	.5	2	1	.3	.4	.3	.4	2	2	.3		.6	.7	2	2	2	.8	6	3	7	6	.5	3	3	2	6	1	3	1	3	7	.4		.4	.2
B. peirsanoe																																																	X						
B. spissa									.6	1																									1	.5	1					1	2	.6	2	1	.8	.8	.9	3	3	2	3	3	4
B. subargentea									.2	.3																									.3	.9	.4	.2		.4	.6		1	1	3	4	2	.3	2		8	.7	1		4
B. subexcavata	.4	.4	.1	.3	2	.5	1	.9	1	2	1	2	2	2		2	1	.2	.1	21		7	5	2	5	.9	10	12	10	1	2	4	1	.3	5	2	3	8	2	8	9		6	6	10	9	8	9	8	4	6			.8	2
B. vaughani	2	2	.1		1	.4	1	.8	.4	.3	.3	1			2	2	6	1	2	7	1	5	3	2	.7		3	6	3	2	2	2		.6	2	.8	1	4	.8	4	3		2	2	3	6	3	1	2	6	2	1		.4	
Buccella angulata	4	8	3	2	3	1	1	2	.4	.3						5	6	5	4	.6	.2	2	.2		.4	.3		2		.6	.3	.3			.7	.3		.2		.4			.3			.3		.8	7		.2		.3		.4
Bulimina denudata	.5	1	.3	.5	.4	2	2	1	1	3	.3	.3					.2	.2		.9	.2	.4		.7	.4	.3	.4	.4	3	1	.3	1	.3		6	2	2	3		3	2	3	.8	2	.7	.8	1	1	.6	1	.3				.6
B. mexicana																																																							
B. pagoda																																																						.4	
B. subacuminata																																																							
Buliminella elegantissima	2	1	.1		1	1	1	.1	.2	.3						17	21	27	25	.3		.4	.4				.7	.4				.8				.4	.8	.5		1	.6		.3	.4	.5	.5	.5	1			.5	.4		.9	.6
B. tenuata																																																		.6					
Cancris auriculo	.1			.1		.2	2	.1	1	1	.4	.3		.8						.3	.3	.9		.3	.4	.6	1	1		.6	.3	1	.6	.6		.5	2		.4	.2	.3	1	.2	.2	.5	.3	.2		.3	.6	.1				.2
C. inaequalis																																																					.3		
Cassidulina bradshawi																																													X										
C. californica					.1				.2		.1		1	.4										.3					.4		.3		.9	.3		.3	.4												.3						
C. delicata																																										.5		.9	.8	.5	.2		.9	.6	6	4	21	20	18
C. depressa		12	2	.8	2	.9	33		22	24	6	6	7	10		.7				21		19	58	10	16	12	26	19	22	12	10	11	8	6	23	15	11	23	3	29	18	.5	10	11	15	15	13	18	8	15	15	15	6	9	16
C. limbata			.7	3	.3	.8	2	6	4	3	11	9	13	21						1	.7	6	.8	4	6	10	6	1	4	16	21	18	24	21	7	6	10	.2	17	1	.7	34	4	4	3	1	3	4	1	2	.2				
C. subcarinata										.6																								.3								1			.3						6	21	15	17	11
C. subglobosa	5	2	17	19	44	41	3	45	19	10	17	13	21	19			2		.1	3	9	3	6	15	11	19	11	3	11	13	19	10	13	10	8	12	11	3	13	7	5	31	17	15	7	3	14	4	9	11	4	6	3	3	3
C. tortuosa	16	1	38	33	5	12	2	4	3	2	14	10	15	16						2	62	3	2	7	13	12	5	.8	4	11	14	8	22	23	2	2	11		22	.6		7	3	3	2		2	1	4	1	.2			1	.2
C. sp. cf. C. orientalis		.3					.3			.3								.2	.3			.4			.7	.3		.4										1			.4		.5	.4	.4	1		1							
Cassidulinoides waltoni																																													.1										
Chilostomella ovoidea									.2	.3				.4																	.1				.3				.4	.2	.1		.2								.4	.4			.6
Cibicides fletcheri	11	7	4	5	2	1	2	.4	6	3	17	11	10	7	32	4	3			4	1	9	.8	17	12	4	5	3	2	3	2	6	3	6	4	5	7	2	6	1	.8		8	6	4	4	4	11	8	6	2	.4		1	.4
C. mckannai		X	.4	1	.5	.6		1	2	2	2	4	5	.8						.3	.8	.9		3	4	4	.7	.8	2	4	.7	3	5	3	1	1	.8		4	1	.5	4	1	3		.1	2	.3	2		.4		.7		.2
C. phlegeri																																.1					.4	.3			.1		.7		.3		.5		.3	.6	.7	4	.3	.8	.6
C. spiralis																																																							
Cornuspira lajollaensis			.1												2						.2																																		
Cornuspiroides foliaceus																																																							
Ehrenbergina compressa									.3	.8	.1		.3	1												.3				.3				.9	.3	.3	.4		1		.1	.5	.5		2	.2	.6		.3		.3	.4	.7	.4	.2
Elphidium spp.	5	7	3	.8	1	2	2	1	1	3	.5			2		28	29	33	35	.9			1	2	.7		1	2	2	1	1	1			.3	.5	.4	1		.6	1		1	1	3	2	2	2	.3		.9			.4	.2
Epistominella sandiegoensis	.1	1	.2	.6	3	2	7	8	12	10	1	5	2	7		.2		.2		5	.3	2	4	2	2	2	6	12	12	5	6	7	2	2	8	13	8	11		6	13		8	11	11	10	10	8	8	11	16	7	8	6	5
E. smithi										.3																																	.2	.9	.5	.1		2	.6		2	.4	.3	.8	12
Eponides leviculus							2		2	2	.3	1	1	2				.2		.6	.3	2	.6	.7	1	2	1	2	3	1	2	2	.6	.6	3	3	2	3	.4	4	4	1	3	1	3	3	4	2	2	5	2	5	4	9	2
E. subtenerus																																											2						.6					.4	
Gaudryina arenaria		.7	.6	.3	.3	.9	.3	.4	.6	3		.3		.4							.2				.4		.4				.3	.2		.3	2	3	.4	.2	2	.4	.3		.2	.4				.8	.9		.2			.8	
G. subglabrata	.4			.2	.1					.6		.3								.6		.9			.4	.9							.3						.4	.2			.2		.3	.3	.3		.6						
Goësella flintii			.1	.1	.1	.5																																								.7	.2								
Globobulimina barbata																																																							
G. höglundi																																																							
G. pacifica				.2	.1	.5		.3		.8	.1											.4	.2									.1			.7	.1		.5		.2	.1			.2		.8	.2		.6		.2	.7		.4	
G. spinifera																																																			.1				.2
Glomospira gordialis																																																							
Gyroidina gemma																																									.1												.7		
G. quinqueloba																																																				3			
Hanzawaia nitidula	1	.4	1	1	.1	.4			.3		2	2	.7	.4						.3		.4		1			1			.6		.6	1	1	.3	1	.8		.8	.6	.5		.6		.4	.5	.3	.2	.3	2	.5				.2
Haplophragmoides neobradyi				.1	.4	.2	2			.3																	.4											.2			.1								.3						.2
H. quadratus																																	.3																						
H. sp.																																																							
Höglundina elegans												.3		.4																							.4		.4			1													
Cassidulina sp.							.3					2	.3	.8			.2			4	10	.9		.3			2	5	5	1	1	5	2	.9	2	4	2	11	.8	1	8	.5	5	5	6	5	5	2	6	5	.5				

Table 6. Occurrences of benthonic Foraminifera in percent of total (living plus dead) population.

tion, or the L/T ratio. Further study of the deeper area is necessary to establish the relationship of number of species with depth.

A possible reason for the small number of species in nearshore and very deep areas is that the more rigorous the environment the fewer the species which can become established.

The morphological features by which a species is characterized are less fundamental and presumably of more recent origin than those characterizing genera. But when one tries to apply the knowledge of modern distributions to paleoecology, one finds that most of the Recent species are not found in strata older than early Pliocene or late Miocene. In such cases the

STATION	100	66	68	67	69	65	64	63	62	61	60	86	88	87	140	124	123	122	121	256	115	260	240	289	275	242	287	261
Involutina pacifica				.1		.2			.2	.3									.3									
Lagena & related spp.	3	5	2	1	4	2	1	2	1		.4	1	.3	2		1	4	2	3	2	1	3	3	2	1	1	3	2
Lagenidae (other)		.4								1						.4	.2				.2			.3				
Loxostomum bradyi																												
L. pseudobeyrichi																												
Neoconorbina terquemi															7		.2											
N. parkeri																8												
Eggerella advena	4	7	1	.5	3	.7	3	.4	.3				.3	.8		.8	3	2	3	.6	.3	1	1					1
E. scrippsi																												
Nonion lankfordi					X		.3		.7	.8				.8						.3							.4	1
N. parkerae																												
Nonionella basispinata	2	5	2	1	2	.8	3	.3	.6	1	.3					1	4	12	10	.3	.3	.9	.8				.4	.4
N. (?) fragilis																												
N. stella	11	9	2	3	.8	6	6	3	.7	.6		.3	.3	.4		.8	2	2	3	4	2	6	2	1	.7	.6	3	7
N. sp. aff. N. globosa																												
Nouria harrisii							.3		.1																			
N. polymorphinoides																												
Patellina corrugata	.1															.2												.4
Planulina ornata	4	2	2	3	.9	1		1	.6	.8	4	4	4	.8		.2				.3		.9	1	3	3	5	.9	
Placopsilina bradyi																												
Polymorphinidae		.2	.4	.1		.1													.3		.7				.4			
Saccammina longicollis	.2			.1	.1	.7																						
Pullenia salisburyi	.3		.1	.8	.1		.6	.1		.3	.4	.3		.4							.2			.3	.4	.3		.4
Recurvoides sp.			.3	.1	.1	.1	.3																					
Recurvoidella parkerae																												
Remaneica cf. helgolandica																												
Reophax excentricus																												
R. gracilis	.3				.1			.1				.3																
R. horridus																												
R. micaceous																												
R. communis		.5					.3										.4	.2					.2					
R. scorpiurus		X	.1	.1		1	.3																					
R. subfusiformis																												
R. spp.				.1																								
Robertinoides charlottensis	.2					.1																						
Rosalina columbiensis	1																10											
R. campanulata	4	7	3	.2	2	2	.9	.7	.1	.8	2	2	1	.4	12	3	2	.5	.1	2	.5	.9	.8	3	1		.7	.8
R. turbinata															10										.4			
Seabrookia earlandi				.1	.3	.1	.6	.3		.8	.1	.9														.3	1	
Sigmoilina tenuis				.1				.3	.2	.6	.9											.9		.3			.4	.4
Spiroloculina fragilis																												
Spiroplectammina bathyca																												
S. biformis																												
Suggrunda (?) eckisi										.3																		
Textularia cf. abbreviata	.2	X	.6		.3	.1		.3														.4				.3		
T. earlandi	.9	.4	.1	.1	1	.2	1													.3		.4	.2			.3	1	.4
T. sandiegoensis																.2												
T. schencki																												
Tritaxis bullata																												
Trochammina charlottensis										.3						2	.2	2	1									
T. chitinosa																												
T. conica																									.4	.3		
T. discorbinoides										.6												.4				.3		
T. globigeriniformis																												
T. kellettae	.4	.4		.1	.1	.1	.3									.6						.4	.2					.4
T. labiata																												
T. nitida												.3																
T. pacifica & var.		4									.1					.4	.2	.5	1		.3			.3		.3		
T. rhumbleri																		.5										
T. squamiformis																												
Uvigerina auberiana																												
U. curticosta																												
U. juncea								.8	.7	2	.3																	
Valvulineria araucana																												
V. glabra																												
Virgulina apertura																												
V. bramlettei																												
V. complanata																												
V. cornuta																												
V. delicatula																												
V. sandiegoensis	.2	.4			.1		.6															.4	.2					.8
V. seminuda																												
Miliolidae	.5	.4			.1	.5		.5				.6			7	14	2	.5	2	.3		.4	.2	.7	1			
Miscellaneous spp.	11	.2	2	2	2	1	1	.3	.4		1	3	1	.4		.6	.2	4	.9	10		7	.4	6	4	.6	2	2

STATION	306	276	249	262	285	277	19	216	220	227	288	183	228	221	230	243	263	219	229	186	248	212	264	322	323	324	270
Involutina pacifica										.2			.2		.2										1		.4
Lagena & related spp.	.4	1	1	1	.9	.6	1	2	1	1		1	2		1	2	2	2	2	1	1	2	2	1	2	1	1
Lagenidae (other)		.3					.3			.2		.6					.1				.6				.3		
Loxostomum bradyi																				.8							
L. pseudobeyrichi															.2										.3		.2
Neoconorbina terquemi																											
N. parkeri																											
Eggerella advena	2		.3	.5	.3	.3		.1	.4	2		.2	2		1	.9	.1	1	.8	1	.9		.2				.2
E. scrippsi																											
Nonion lankfordi				.3		.3		.1		.3			.2		.7	.4	.5	.5	1	.8	.6		.3				
N. parkerae																											
Nonionella basispinata				.2			.3	.3	.4	.2		.8	.1		.7	.2	.2	.3	.3	.8	.6	1	.2				
N. (?) fragilis																											
N. stella	2	2	1	.9		.6	1	.5	2	3		3	3	.5	1	.9	1	4	.5	3	2	1	1	.7	.3		.8
N. sp. aff. N. globosa				.1		.3			.8								.1						.4				
Nouria harrisii																											
N. polymorphinoides																											
Patellina corrugata								.1									.1	.1	.2	.2							
Planulina ornata	1	3	2	.8	2	2		.9	2	.5	3	.6	.5	.5	1	.6	.3	.5	.3	.8	.6	1		.4	.3		
Placopsilina bradyi																											
Polymorphinidae		.6	.3								.4					.2											
Saccammina longicollis																											
Pullenia salisburyi	.4	1	.3	.2							.4	.4	.3			.9		.2	.5	.2		.6					
Recurvoides sp.																											
Recurvoidella parkerae								.1		.2			.1														
Remaneica cf. helgolandica																											
Reophax excentricus																											
R. gracilis																											
R. horridus																							.1				
R. micaceous																											
R. communis										.2						.2											
R. scorpiurus								.1																			
R. subfusiformis																											
R. spp.																							.1				
Robertinoides charlottensis																											
Rosalina columbiensis																											
R. campanulata	.4	.3		.5		2	.7	.1	.4		2	.2	.2		1	1	1			1			.1				
R. turbinata																					2						
Seabrookia earlandi			.3	.3		.3	.3	.5	2	.3		.4	1		.7		1	2	.5	.3	.9	.6	.9	1	.3		.4
Sigmoilina tenuis	.8	.3		.4		1	1	.5	.4		.4	1	.1		1		.9	.3	.2	.5	.6		.1	.7			.2
Spiroloculina fragilis																											
Spiroplectammina bathyca																											
S. biformis																											
Suggrunda (?) eckisi										2		2	2			.2	.1	.7	.5								.2
Textularia cf. abbreviata					.6		.3														.3						
T. earlandi	.8	.3	.3	.1				.1	.8	2		2	2		1	.6	.2	.2	.5	.5			.2	.4			
T. sandiegoensis				.1																	.6		.1				
T. schencki																											
Tritaxis bullata							.3	.1					.3		.2	.2		.3									
Trochammina charlottensis																											
T. chitinosa																											
T. conica									.4																		
T. discorbinoides			.3					.3		.2		.6	.8		.8	.6	.1	.3	.8	.5	.6						
T. globigeriniformis																											
T. kellettae				.1						.3			.2		.2												
T. labiata																											
T. nitida																											
T. pacifica & var.				.3												.2							.1				.2
T. rhumbleri																											
T. squamiformis				.1							.4		.1								.3						
Uvigerina auberiana																											
U. curticosta																.2	.2		.5		.3			1	5	5	
U. juncea	.4	.6		.1		.6		3		.2	.4	.2	1		2	1	2	3	2	.8	.6				.3	1	.6
Valvulineria araucana							.1								.2	.2					.3		.2			.4	.2
V. glabra																									.3		.2
Virgulina apertura									.4	1			3		.2		.8	1	.6		.6	3	2			.4	.2
V. bramlettei																											
V. complanata																											
V. cornuta																											
V. delicatula												.2	.3				.3	.5			.3		.1				
V. sandiegoensis		.6		.1				.3		2		2	.1		.2												
V. seminuda													.1			.2		.3					.1				.8
Miliolidae							.3		.4		.4		.1					.2			.3		.3				.4
Miscellaneous spp.		.9	.7	2	1	1	.3	1	3	1	.4	.4	.2	3		2	1		.8	1	8	.6	1	2	5	1	1

Table 6 (continued). Occurrences of benthonic Foraminifera in percent of total (living plus dead) population.

knowledge of genera may be more important than that of species.

On the basis of the *Challenger* data Murray (1913) states that the ratio of species to genera decreases regularly from coastal to offshore deep water, so that in the deepest zone the ratio of species to genera is 5 to 4, whereas in the shallow coastal water it is 3 to 1. Sverdrup, Johnson and Fleming (1942, p. 807) state that a striking characteristic of the deep-sea fauna is the relatively smaller number of species in proportion to the number of genera.

In the San Diego area the distribution of the number of genera coincides, in a general way, with the number of species. The number of genera ranges from 9 to 39, and is less than 15 at depths shallower than 20 fathoms, then gradually increases with increase of depth offshore reaching a maximum of more than 30 at 60-100 fathoms. There is a gradual decrease in

TRAVERSE																								
STATION	201	307	265	278	325	255	326	250	211	266	304	258	202	294	303	284	289	296	254	208	308	301	207	298
DEPTH IN FATHOMS	345	350	350	350	350	355	385	390	395	420	430	430	440	450	455	455	460	460	465	473	485	490	505	505
TOTAL POPULATION	47900	67200	34600	45800	22000	24400	13700		16000	17000	9700	16300	32900	15500	9400	11400	14900	17600	8100	16300	4700	11100	35000	21000
Alliatina primitiva																			.2					.3
Alveolophragmium advena																								
A. columbiense																								
Ammobaculites catenulatus		.2	1			.6	2				4		1	.4	.7	1	3	.6	1		2	1		.9
Ammatium planissimum							2									.5								
Anguliodiscorbis charlottensis																								
Angulogerina angulosa	.5	2	3	4		.6			4	5	4	4	1	3	.7	5	2	2	4	4	6	3	1	1
Arenaporrella oceanica		.2		.3					.2			.2							.4	.7				
Asterigerinata pacifica											.4	.4		.2		.5			.6		.7	.7		.3
Astrononion viragoensis										.6												.7		
Bigenerina höglundi																								
Bolivina acuminata		.8		.3					.6	1	.2	.2		.8				.6	.2	.6	.7			.3
B. acutula						.6									.7									
B. bicostata																								
B. filacostata		.2								.6				.2										
B. minuta	4	3	6	8	.9	8			8	4	6	5	10	5	8	8	12	6	6	7	5	2	.3	5
B. pacifica	3	2	1	.3	.9	.6			4		.4	.2	1	2		.5			3	1	2			
B. peirsonae			X																					
B. spissa	6	2	4	2	8	2			2	5	2	3	6	1	3	2	4	6	2	4	3	3	4	3
B. subargentea	2	3	1	3		3			3	1	.7	2	2	.8	1	.5	2		.8		1			
B. subexcavata	4	6		3		1			5	4	4	4	2	4	1	1	2	.3	5	5	4		1	2
B. vaughani	1	2	.6	.8		1			2	2	1	.6	1	.8	2	1	1	1	2	.7	.7		.6	.3
Buccella angulata			.2						.4	.6	.2		.5	.2							.3			
Bulimina denudata		.4	1	.6					.2	2	.2			.4			.6		.6		.3			
B. mexicana																								
B. pagoda																				.7				
B. subacuminata											2		.5	.6		1	1	1		1	.3	.7	2	
Buliminella elegantissima	1	.2	.2								1	.2	2	.2	3			1	1	2	.3		.6	.6
B. tenuata	.5	.2				.6												.6						
Cancris auricula		.2				.6						.8		.6		1			.4		.3			.6
C. inaequalis						.6					.2	.2												
Cassidulina bradshowi					2					1						.5			.8	.7		.7		
C. californica		.6				1								.2										
C. delicata	18	5	18	19	25	23	11		7	8	8	15	14	6	9	14	10	14	6	8	6	15	13	9
C. depressa	3	17	14	8	2	3	2		13	9	8	9	3	10	3	6	3	1	12	3	4	10	5	6
C. limbata		.4	.4		1	.6	2				.2			.2	.7	1		.8		1	3		.3	.4
C. subcarinata	14	7	8	6	11	10	11		3	6	7	7	5	11	10	11	12	20	4	15	9	15	13	17
C. subglobosa	2	4	4	2		.6	2		3	3	9	3	6	5	4	5	2	6	3	6	7	6	8	10
C. tortuosa		.2		.3			5		.4		.4												.6	
C. sp. cf. C. orientalis	.5										.2					1						.7		
Cassidulinoides waltoni					2																			
Chilostomella ovoidea		.4	.2			2			.6	.6	.4			.6	1		1		.4		.3	.7		
Cibicides fletcheri	1	4	3	2					2	5	.9	.8		2			1		2		2			.9
C. mckannai		.8	.6		1	2			.6			.2	1	.6	1	3					2			.3
C. phlegeri	1	2	.7	3		2			1	3	3	5	2	3	.7	2	2	1	1	1	2	.7	1	3
C. spiralis					.9													.6					2	
Cornuspira lajollaensis																								
Cornuspiroides foliaceus																								
Ehrenbergina compressa		.4	.2	.6						.6		.4												
Elphidium spp.	.5	1	1	1					.6	.9	3	1	1	1	3				1	1	.7	.7	.6	2
Epistominella sandiegoensis	16	13	9	13	3	14	7		11	12	9	13	11	16	19	12	12	11	10	12	9	10	7	8
E. smithi	6	5	7	6	.9	7	2		3	2	.9	4	3	.8	2	3	2	.6	1	3	1	1	4	4
Eponides leviculus	6	4	4	4	3	2	2		4	9	6	8	5	8	5	5	12	7	5	3	6	6	7	9
E. subtenerus					2		2											1		1		.7		2
Gaudryina arenaria			.2						.2	1	.4													
G. subglobrata																								
Goësella flintii							2																	
Globobulimina barbata									.4		.2													
G. höglundi	.5											.4		.4						.6				
G. pacifica		.2	.9																					
G. spinifera				.3		.6									.7	.5		.6			.3	.7		
Glomospira gordialis				.3		.6					.2	.2	.5	.2	1									
Gyroidina gemma	.5										.4			.2	1		1							
G. quinqueloba						1	5		.4				1	.4			1	1				1	.3	.3
Hanzawaia nitidula			.4	.6					.8	.6		.4				.5					.7			
Haplophragmoides neobradyi			.2				2				.7			.4	.7						.3			.3
H. quadratus																								
H. sp.																								
Höglundina elegans					.9						.2	.2		.2				.6			.3			.3
Cassidulina sp.	1	2		4		2	2		5	2	2	6	1	2		1	3	.6	6	4	6	.7	.6	1

TRAVERSE																								
STATION	300	302	292	293	305	232	294	290	297	279	269	263	281	236	109	280	114	267	268	112	205	113	111	105
DEPTH IN FATHOMS	505	515	515	520	525	528	530	550	560	565	570	580	580	585	594	605	608	615	630	635	638	639	640	650
TOTAL POPULATION	7700	8500	8000	9800	11500	14000	7400	11300	5600	10400	8900	9500	9300	18900	6400	7000	9600	28500	17100	5600	16700	10000	6000	11000
Alliatina primitiva																								
Alveolophragmium advena																								
A. columbiense																1								
Ammobaculites catenulatus	.6	1	.6	1	1		1	1	1	.2	.7	6		2	2	4	1	1	2	4	2		2	
Ammatium planissimum																								
Anguliodiscorbis charlottensis																								.6
Angulogerina angulosa	3	4	.6	2	3	5	2	1		2	4	1	2		2	4	1	4	2	4	.5	.5		3
Arenaporrella oceanica																	.2							
Asterigerinata pacifica	.2	.4		.4							.7		.6				.2	.5				.2		
Astrononion viragoensis						.9																		
Bigenerina höglundi																								
Bolivina acuminata	1	2		.4		2	.4			.6						.9	.5		.5	.8				.3
B. acutula																								.3
B. bicostata																								
B. filacostata																							.3	
B. minuta	5	6	1	6	5	3	5	3	2	5	.7	9	3	4	6	2	5	5	2	3	5	4	5	6
B. pacifica	.6	.2	2	.6	.4	.6	3	1		.9	.7	1	2	.8	.9	.9			2	2			.8	.8
B. peirsonae								X															X	
B. spissa	4	5	2	.3	3	.9	3	2	3	3	2	2	2	3	2	2	.7	2	2		.6	.5	1	4
B. subargentea	.6	.8					1	1		.9	2	.6			2			2	3				.5	.9
B. subexcavata	2	1		.9	3		5	1	1	3	2	4	5	3	.9	5	1	1				.2	1	.3
B. vaughani	.8	1	.6	.4		.9	3	2		2	.7	2	2	3	.4	2	1	1	2	1		.2	.8	.6
Buccella angulata	.4	.4																			.6		.3	
Bulimina denudata		.8				.9				.9	2				.4		.2	2	.8	3	.5			
B. mexicana																								
B. pagoda								3	1															.3
B. subacuminata	.4	1	.6	.4			2		1	.3	.7				.4	.5	2		2			1	.8	2.6
Buliminella elegantissima	.6	.8		.4			.4		1								.3					.2	.3	
B. tenuata		.4								.3						.2								
Cancris auricula	.4									.6	.7					.5		.5	2					
C. inaequalis																								
Cassidulina bradshowi			.6				.4	2				.6											.3	.6
C. californica							.4															.2		
C. delicata	10	8	13	7	6	7	5	8	4	5	3	7	7	3	7	5	3	6	4	.7	2	4	5	14
C. depressa	7	5	6	4	3	3	5	4	1	5	4	2	3		5	6	3	6	8	4	2	1	5	2
C. limbata	1	1				.9	.9	4	1	.6	2							2					.3	.3
C. subcarinata	15	9	20	22	20	26	12	8	23	14	18	9	8	27	21	11	22	10	23	18	26	21	16	21
C. subglobosa	5	6	4	7	4	9	5	9	9	5	16	3	7	12	9	6	4	9	4	2	7	4	4	7
C. tortuosa		.4				6				.6	.7								2			.2		.3
C. sp. cf. C. orientalis											.7													
Cassidulinoides waltoni							.4																	
Chilostomella ovoidea	.2	.4	1	.4			.4			.3		.6				.2	.5							.6
Cibicides fletcheri	2	.8		.4		.9	.9			2	2					1		.5				.2		1
C. mckannai		.4				3	.4			.6					.9	.2	.7		.8	1		.6	.5	2
C. phlegeri	3	2	4	3	4	3	4	3		2	2	3	9	11	.4	2	4	2	1	5	3	5	3	
C. spiralis			.6		.6			1	8	.6	.7				2	.5	3	2	2	3	4	3	5	2
Cornuspira lajollaensis																								
Cornuspiroides foliaceus																								
Ehrenbergina compressa	.2																	.5						
Elphidium spp.	.8	1	.6		1	.9				1	3	.6	.6		.4	.9	.5	.5	.8	.3	.5	.2	1	
Epistominella sandiegoensis	14	13	9	6	8	9	11	19	6	12	10	12	11	3	4	10	7	11	18	3	7	6	6	4
E. smithi	2	1	1	.9		.9				1	4		.6		.4	.7	.3	2	2		.6	.3	.8	2
Eponides leviculus	8	5	8	10	5	6	7	6	10	6	8	8	11	10	4	6	15	9	11	15	16	16	11	7
E. subtenerus	.4	.4	3	.4	2			1	10	1	.7		.6		1	.9	2	1		1	4	2	3	.6
Gaudryina arenaria																.2			.8					
G. subglobrata																								
Goësella flintii																			.8					
Globobulimina barbata		.4																						
G. höglundi			.6				.4																	
G. pacifica					.6			1																
G. spinifera																			.8					
Glomospira gordialis				.4	1		.4			.6						.5			.8	.9				
Gyroidina gemma			.6						1					3			.3		.8	.3		.3	1	.6
G. quinqueloba	.8	.4		.4	1	.9				.9	.9		.6		.4	.5	1	1			1	.6	1	.6
Hanzawaia nitidula								1										1						
Haplophragmoides neobradyi		.4					.4			1										.3				
H. quadratus																								
H. sp.																								
Höglundina elegans		.4	.6			.9												.5			.6	.3	.3	
Cassidulina sp.	2	3	1			3	2			2		2	2		.4	.4	.7	2	3	2	.5	.3	2	3

Table 7. Occurrences of benthonic Foraminifera in percent of total (living plus dead) population.

STATION	201	307	265	278	325	255	326	250	211	266	304	258	202	294	303	284	289	296	254	208	308	301	207	298
Involutina pacifica			.4						.4				.5					.6	.4		.3			
Lagena & related spp.	.5	2	1	2	4	1			1		2	.8	2	2	1	2	1		1		.7	.7	1	.9
Lagenidae (other)					.9							.2	.5		.7				.2			.7		
Loxostomum bradyi																								
L. pseudobeyrichi	.5	.4	.4						.6		.2	.2		.2	.7				.4		1			
Neoconorbina terquemi																								
N. parkeri																								
Eggerella advena		.2		.3					.8			.6		.2			1		2					
E. scrippsi														.2	.7									
Nonion lankfordi	.5	.4	2						.4			.2	.5		.7	.5		.6	.4		.3			.3
N. parkerae					6																	1		
Nonionella basispinata		.4		.3							.2			.8					.6					
N. (?) fragilis											.2													
N. stella		.8	.9	.8					1	.6	.7	.2		.4					2		1	.7	.6	.3
N. sp. aff. N. globosa																								
Nouria harrisii																								
N. polymorphinoides																								
Patellina corrugata																								
Planulina ornata	.5	.6	.2		.9	.6	2		.2	1			.5		1				.2			.7		
Placopsilina bradyi																								
Polymorphinidae																								
Saccammina longicollis																								
Pullenia salisburyi		.2			.9						.4										.3		.6	
Recurvoides sp.																								
Recurvoidella parkerae						.6									.7				.6		.3			
Remaneica cf. helgolandica																								
Reophax excentricus														.2										
R. gracilis																								.3
R. horridus					.9																			
R. micaceus																								
R. communis																								
R. scorpiurus														.2					.2					
R. subfusiformis																								
R. spp.																			.6					
Robertinoides charlottensis																								
Rosalina columbiensis																								
R. campanulata			.2						.2			.2									.7			
R. turbinata																								
Seabrookia earlandi		.8	.6	.3					1	1		.2	.5	.2			.6		.8		.3		1	
Sigmoilina tenuis			.2						.4		.2						1							
Spiroloculina fragilis																								
Spiroplectammina bathyca											.4					.5								.3
S. biformis							2				.2				.7									.3
Suggrunda (?) eckisi		.2							.4								.6		.2		.7			.3
Textularia cf. abbreviata																								
T. earlandi																			.2				.6	
T. sandiegoensis									.4		.2								.2					
T. schencki																								
Tritaxis bullata																			.2		.7			
Trochammina charlottensis																								
T. chitinosa											.2			.2										
T. conica											.7								.8					
T. discorbinoides			.2								.2								.2	.6				
T. globigeriniformis														.4										
T. kellettae	.5	.4																.6			.7			
T. labiata																								
T. nitida																								
T. pacifica & var.												.2		.4					.2					.6
T. rhumbleri														.2										
T. squamiformis									.6	.6				.2					.1					
Uvigerina auberiana							2						1		2	1	2	7	.6	2	.3	3	8	.3
U. curticosta	2	.9	2	.8	12	.6	9		2	1	2	.4	7	1	4	2	3	4	.8	6	2	.7	6	2
U. juncea		.2								2	2		.5	2					.4					3
Valvulineria araucana	1		.2	.3	3	.6	2		.2			.6			.7			.6	1	1	.3			.3
V. glabra	1	.2	.2	.6	.9	1	4		.2	.6	.4		1	2		1	1	.6	.6		.3	3	.6	.6
Virgulina apertura		.6	.7				2		2	2	1		.5	.8	.7	2			2	1	2		.6	
V. bramlettei	.5		.2	1				X											X					
V. complanata																.5	1				1	2		.9
V. cornuta																								
V. delicatula		.8	.4						.4	1									.8		.7		.6	
V. sandiegoensis									.6									.6						
V. seminuda		.6	.6	.3		1			.4		.4	1		2	1					.7	.3	1		.9
Miliolidae											.2									.6		.7		.3
Miscellaneous spp.	1	1	3	1		3	6		1	1	2	2	.5	.2		3			1	1	2	3	.6	1

STATION	300	302	292	293	305	232	299	290	297	279	269	283	281	236	109	280	114	267	268	112	205	113	111	105
Involutina pacifica	.2			4					1			.6		.8			.2	.5						
Lagena & related spp.	1	1	2	2	4	.9	2	4	1	1	.7	2	1	3	3	1	2		2	3		2	1	3
Lagenidae (other)	.6		.6		.6									.2	.9	.2	.2				1	.2		
Loxostomum bradyi								1																
L. pseudobeyrichi	.4		.6	.4						.3							.2	.5		.3				.6
Neoconorbina terquemi																								
N. parkeri																								
Eggerella advena	.2			1	.6		.9			.9						.7				1		.2	.3	
E. scrippsi					.6																			
Nonion lankfordi	.2	.4		.4			.9						.6		.4		.5					.3		
N. parkerae																								
Nonionella basispinata	.4				.6	2	.4			.6			.6			.2							.3	.3
N. (?) fragilis	.6		.6	.4	2				1		.7	2	7		2	.7	2	2	2	5	2	3	.3	.9
N. stella		1			2		2		1		.7	4	1		.4	3	.2					.3	2	
N. sp. aff. N. globosa																								
Nouria harrisii																								
N. polymorphinoides																								
Patellina corrugata																								
Planulina ornata	.2						.9	2		.3						.2			.8					
Placopsilina bradyi																								
Polymorphinidae				.4																				
Saccammina longicollis																								
Pullenia salisburyi										.3								.5				.2		
Recurvoides sp.																								
Recurvoidella parkerae					1					.6		.6												
Remaneica cf. helgolandica																								
Reophax excentricus																								
R. gracilis																								
R. horridus																								
R. micaceus																								
R. communis																								
R. scorpiurus																				.3				
R. subfusiformis																								
R. spp.		.4								.6						.5								
Robertinoides charlottensis																								
Rosalina columbiensis																								
R. campanulata	.2	.4													.4								.3	
R. turbinata																								
Seabrookia earlandi		.8		1	1			1				1	.6					.5	.8				.5	
Sigmoilina tenuis												.6												
Spiroloculina fragilis		.4								.3						.5		.5					.3	
Spiroplectammina bathyca										.3	.7	2								1			.3	
S. biformis										.3						.2	.5		.8	.6	1	.3	.8	
Suggrunda (?) eckisi	.2						.4						.6											
Textularia cf. abbreviata																								
T. earlandi												.6				.5								
T. sandiegoensis																								
T. schencki																								
Tritaxis bullata	.2	.4										.6												
Trochammina charlottensis																								
T. chitinosa		.4																						
T. conica																								
T. discorbinoides		.8					.4			.3				v	.4	2	1		2	3	.5	1	1	.3
T. globigeriniformis	.2				.6				1	2					.4	.9	.2	.5		.9	.6		2	
T. kellettae	.8	1		.4			.4			.3						.2		1	.8	.3		.2	.3	
T. labiata																								
T. nitida																		.5						
T. pacifica & var.		.4	.6												.9				2				.8	
T. rhumbleri																								
T. squamiformis			.6							.3							.3			.6				
Uvigerina auberiana	.8	1	6	6	5	.9	2	2	11	3	.7	4	1	7	7	5	7	3	2	6	4	13	3	8
U. curticosta	.8	2	3	.9			1	3	1	.6		2		.8	2	.5	.8	1		1	.6	1	2	2
U. juncea	.8	.4			1		.9			.3						2							.3	
Valvulineria araucana	.4			.4	.6				1						1	.2	.7			.6		.5		
V. glabra	.6	.8	2	2	2	.9	2	1		.6	2	1	2		.9	.7	.2	.5			.5		.3	1
Virgulina apertura	.2	2	.6	.4	3		2	1		.3		2	3		1	2	.7	1	.8		.5	.5	.3	.3
V. bramlettei																						X	X	
V. complanata	.2	.4	.6	2	2		2			2	.7	3			.9	1	1	.5		1	2	1	.8	.3
V. cornuta													3											
V. delicatula	.2	.4						2					.6											.6
V. sandiegoensis											.7		.6					.5						
V. seminuda		.4						1					.6	.8	.9					.6	.6	.3	.3	.3
Miliolidae		.4		.4	.6	.9	.4			.9			1		.4				.8	.3	.5	.2	.3	.3
Miscellaneous spp.		.4	.6	.8	2	3	.4	2	3	.9	1	1			3	.5	3	1	3	3	3	2	4	1

Table 7 (continued). Occurrences of benthonic Foraminifera in percent of total (living plus dead) population.

number with increase of depth in the northern part of the area where the bottom slope is gentle down to the bottom of Loma Sea Valley. In the southern part of the area, where the shelf ends abruptly and there is a steep escarpment down to the bottom of the San Diego Trough, the situation is quite different from that in the northern part. The number of genera is small at a depth shallower than 20 fathoms and then increases with increase of depth, reaching a maximum at 45-100 fathoms, then decreases again. Another maximum is

Depth in Fath.	Living Fauna	Total Fauna	Depth in Fath.
0	Fauna 1: Coarse sand: *Rosalina columbiensis*, *Rosalina campanulata*, *Neoconorbina terquemi*, *Cibicides fletcheri*, Miliolids; Fine sand, silt: *Elphidium* spp., *Buliminella elegantissima*, *Nonionella basispinata*	Fauna 1: Coarse sand: *Rosalina campanulata*, *Rosalina columbiensis*, *Cibicides fletcheri*; Fine sand, silt: *Elphidium* spp., *Nonionella stella*, *Buliminella elegantissima*	0
13	Fauna 2: *Nonionella stella*, *Nonionella basispinata*, *Reophax gracilis*, *Alveolophragmium columbiense*	Fauna 2: *Nonionella stella*, *Cassidulina depressa*, *Cassidulina quadrata*	20
45	Fauna 3: *Bolivina pacifica*, *Bolivina acuminata*, *Nonionella stella*, *Reophax gracilis*, *Chilostomella ovoidea*	Fauna 3: *Cassidulina depressa*, *Cassidulina quadrata*, *Epistominella sandiegoensis*, *Cassidulina limbata*, *Cassidulina tortuosa*	47
100	Fauna 4: *Bolivina pacifica*, *Goesella flintii*, *Reophax gracilis*		
250	Fauna 5: *Bolivina pacifica*, *Bolivina subargentea*, *Nonionella stella*	Fauna 4: *Cassidulina subcarinata*, *Cassidulina delicata*, *Epistominella sandiegoensis*	280
350	Fauna 6: *Bolivina pacifica*, *Bolivina spissa*, *Virgulina apertura*		
450	Fauna 7: *Virgulina apertura*, *Bolivina pacifica*, *Bolivina spissa*		
650			650

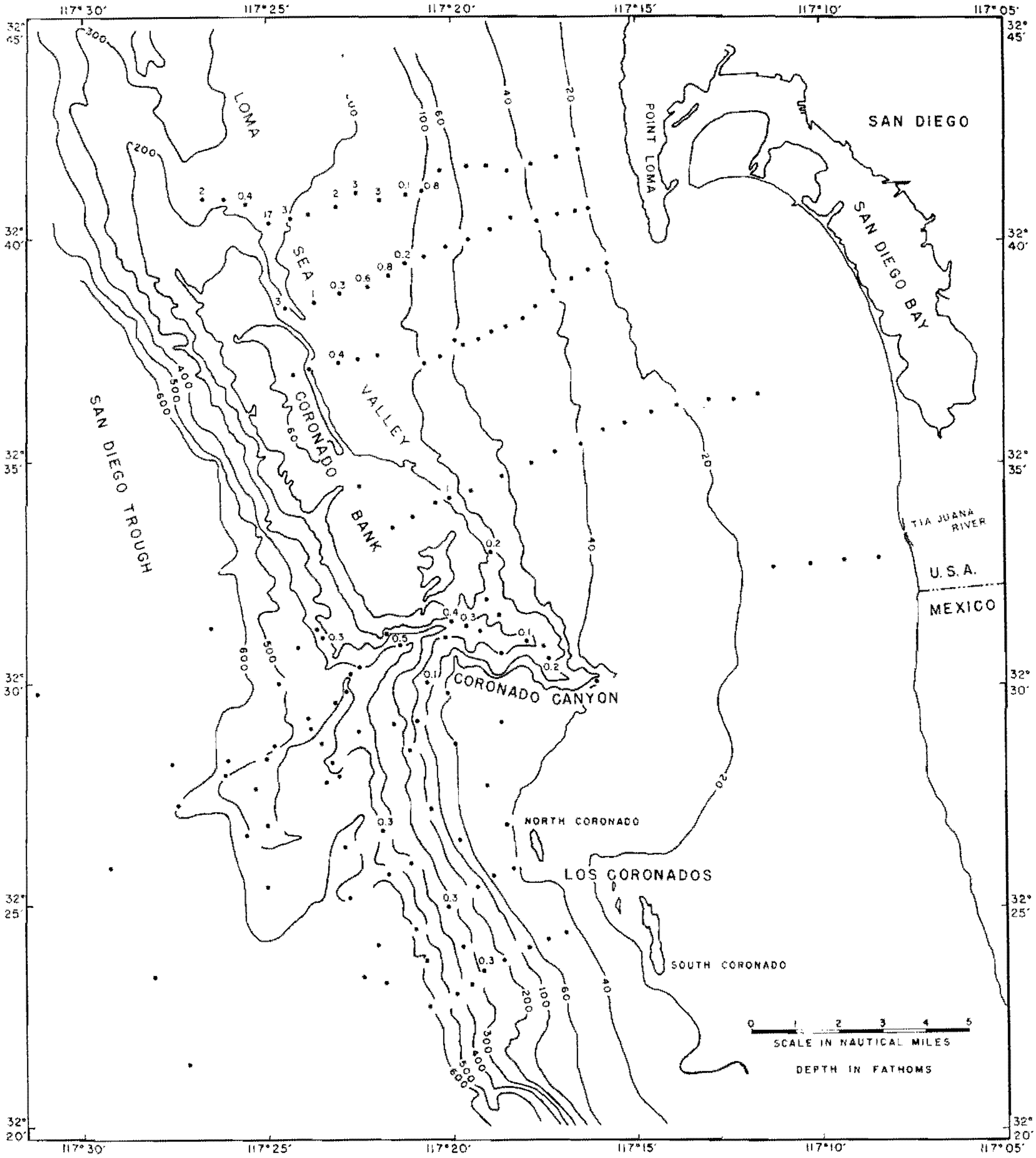
Table 8. Comparison of living and total faunas.

found at 400-600 fathoms. The deep floor of the San Diego Trough has a moderate number (average 25) of genera.

The ratio of number of species to number of genera in the San Diego area ranges from 1.1 to 1.96 and the average is as follows:

Depth Range (fathoms)	*No. of Stations*	*Average ratio*
0-60 (shelf)	51	1.52
60-500 (escarpment, canyon, valley)	82	1.54
500-650 (trough)	24	1.72
0-650	157	1.58

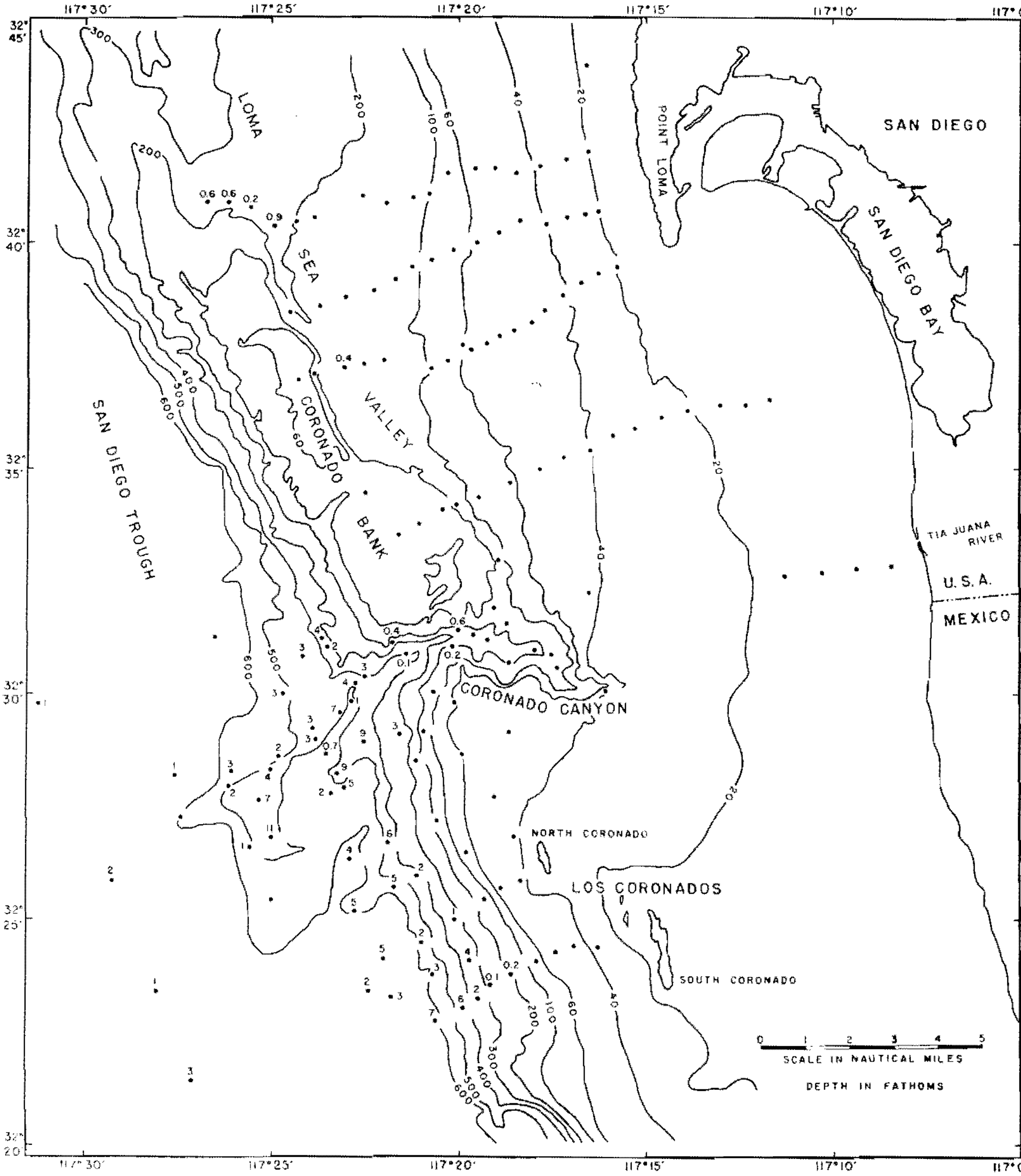
It appears strange that the average ratio of number of species to number of genera increases with increase of depth in this area, which is contrary to the *Challenger* data. In the San Diego area the differences of the ratios at the various stations are very slight, and for this reason the ratio can be considered to be about the same throughout the area. The highest ratio in shallow water does not reach 3, and in deep water is not as small as 1.25 as shown by the *Challenger* data. One reason for this is that the *Challenger* data are based on a larger part of the animal kingdom while the present study is based only on Foraminifera. A more important reason is that genera and species, at least in



Text Figure 11. Distribution of living *Nonionella* sp. aff. *N. globosa* Ishiwada in percent of living population.

the case of the Foraminifera, are now subdivided more than in the *Challenger* days. If samples are taken much deeper than 650 fathoms, which is the greatest depth sampled for the present study, the ratio may decrease down to 1.25 as shown by the *Challenger* data. Foraminifera are among the most primitive animals and can survive in almost any marine environment, while more advanced animal groups may be less widely distributed.

There is no positive correlation of areal distribution of number of genera, as in the case of species, with that of the size of living and total populations, nor with that of L/T ratio. The depth distribution of the highest living populations (50-150 fathoms), however, generally agrees with that of the greatest number of living species and genera. This can be interpreted in two ways. One is that Foraminifera are more prosperous at those depth ranges than at other depths, and thus the greatest number of species and genera are originated. The other is that the greater the number



Text Figure 12. Distribution of living *Cassidulina delicata* Cushman in percent of living population.

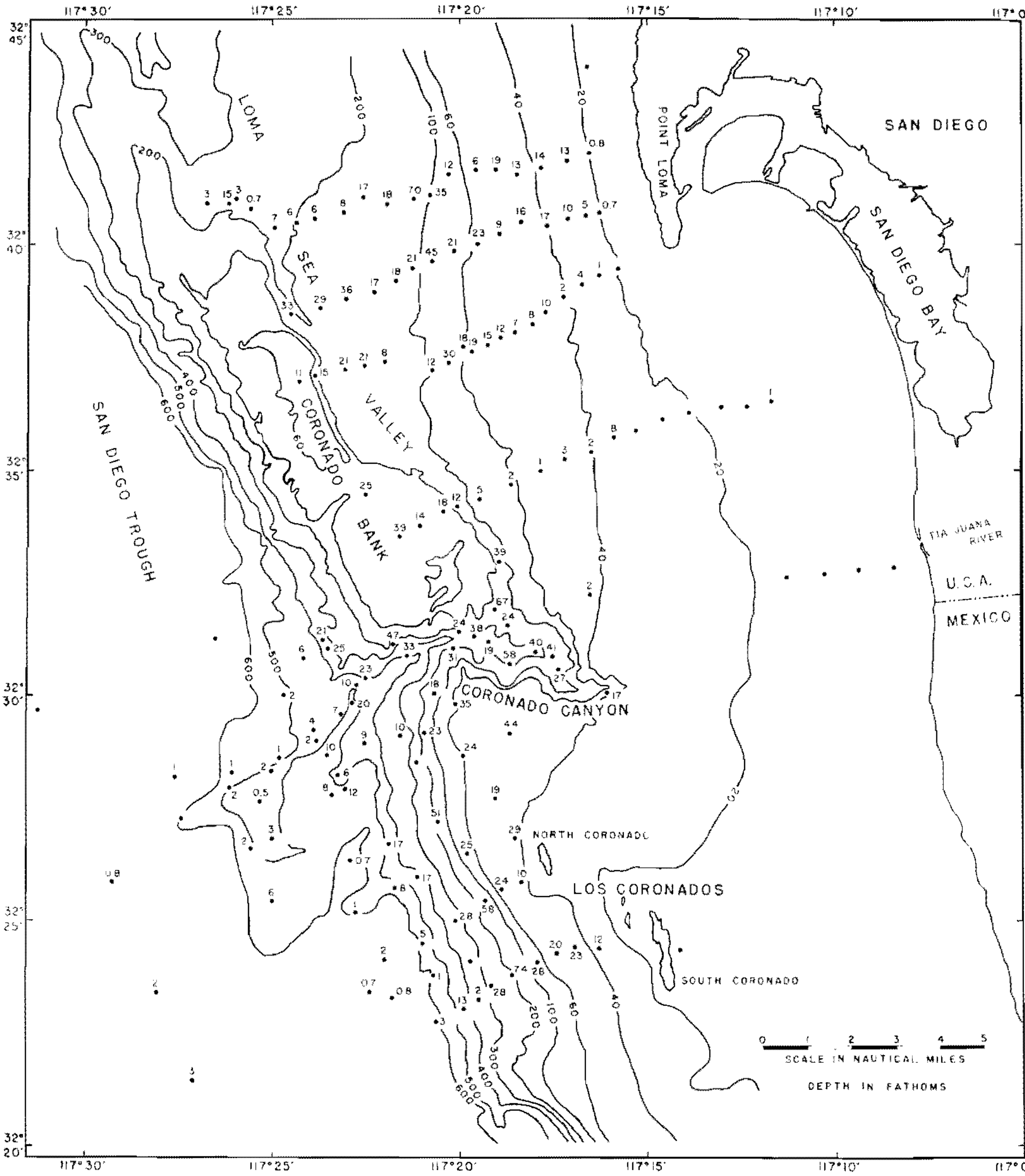
of specimens found the greater the likelihood of finding more species and genera.

Areal as well as depth changes in the number of families were not analyzed because of the differing opinions among workers in the grouping of genera into families.

PLANKTONIC FORAMINIFERA

No detailed study of the planktonic Foraminifera was made. A few specimens of living planktonic Foraminifera were found in some samples while counting living benthonic Foraminifera. Numerous empty tests of planktonic Foraminifera were found in almost every sample studied. They were not identified specifically but were counted together as "planktonics," since the ratio of benthonic to planktonic populations may provide useful information in understanding sedimentary environments.

The areal distribution of the ratio of benthonic population to planktonic population (B/P) shows the following (Text Fig. 17): The B/P value on the northern shelf is high near shore and decreases down to the



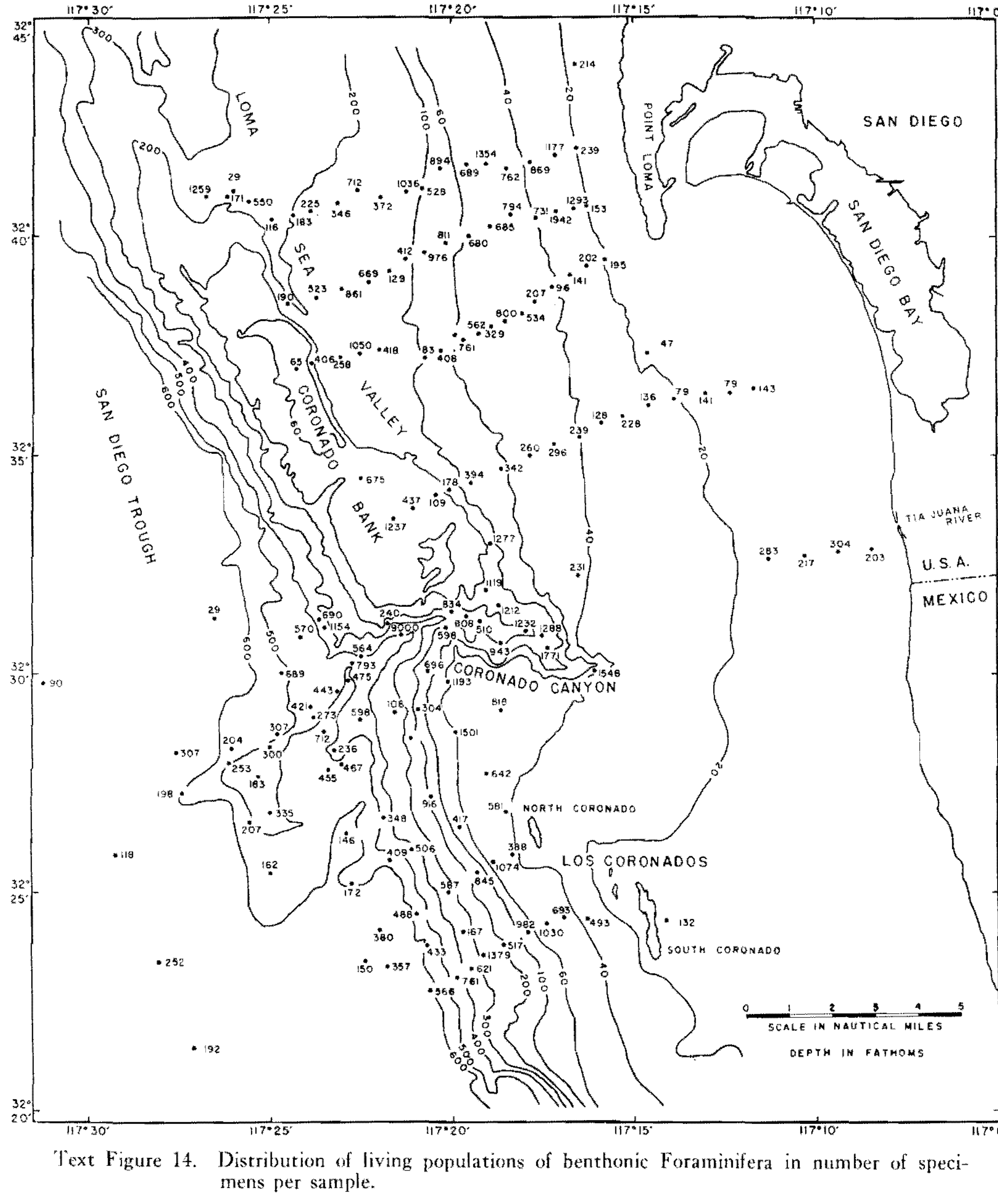
Text Figure 13. Distribution of living *Bolivina pacifica* Cushman and McCulloch in percent of living population.

Loma Sea Valley. The area of the highest B/P value is found between Point Loma and off the Tia Juana River. In most of the area, except on the above-mentioned northern shelf, the B/P value is low and irregular. Four stations have a value larger than 5 and at these Foraminifera sands are exposed. At other stations where Foraminifera sands are exposed, however, the B/P value is not high. One station on the lee side of the South Coronado Island has a relatively high value (9.0).

It is a general concept that the planktonic foraminiferal population increases offshore if there is neither displacement nor residual sediment, hence, the value of B/P decreases in an offshore direction. The data collected in the San Diego area support this concept only in the area very near shore.

The planktonic species which were found are:

Globigerina bulloides d'Orbigny
Globigerina eggeri Rhumbler
Globigerina hexagona Natland



Text Figure 14. Distribution of living populations of benthonic Foraminifera in number of specimens per sample.

Globigerina quinqueloba Natland
Globigerina sp. cf. *G. pachyderma* (Ehrenberg)
Globigerinita glutinata (Egger)
Globigerinoides minutus Natland
Globigerinoides ruber (d'Orbigny)
Globorotalia truncatulinoides (d'Orbigny)
Orbulina universa d'Orbigny

Living specimens of *Globigerinoides minutus* Natland occur in many bottom sediments.

RATES OF SEDIMENTATION

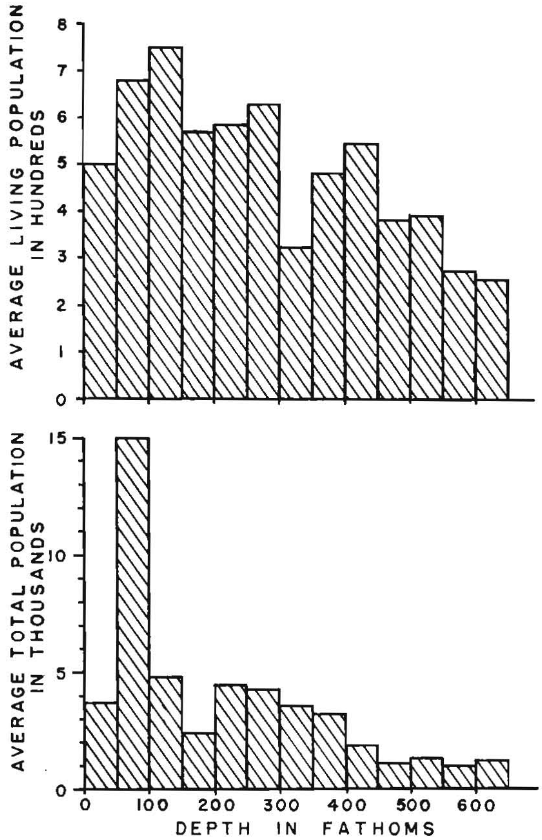
Walton (1955) suggested that the ratio of living population to dead population (L/D) was proportional to the rate of sedimentation. Phleger (1955, pp. 733-734) revised this ratio to the ratio of living population to total (living plus dead) population (L/T). The writer shows living and total populations of benthonic Foraminifera in the top centimeter of short cores in Tables 1-3, 5-7. If one selects stations where there are

Depth Range (Fathoms)	Coarse Sand		Fine Sand		Silt		Clayey Silt		Foram. Sand		All	
	no. of samples	av. pop.	no. of samples	av. pop.	no. of samples	av. pop.	no. of samples	av. pop.	no. of samples	av. pop.	no. of samples	av. pop.
0 - 50	6	12.5	6	103.8	16	20.8	10	8.1	3	139.6	41	37.3
50 - 100			2	249.8	8	31.6	2	14.4	15	217.1	27	150.0
100 - 150			1	50.6	1	37.6	12	21.3	2	213.0	16	48.1
150 - 200	1	20.5			3	31.5	5	10.4	1	72.1	10	23.9
200 - 250			1	43.9	4	50.7	4	39.3			9	44.9
250 - 300	1	17.2	1	43.9	1	96.0					4	43.3
300 - 350	3	18.8			3	53.6	2	34.3			8	35.7
350 - 400	2	17.9			2	56.5	3*	25.0			7*	32.0
400 - 450			1	9.7			4	20.4			5	18.3
450 - 500			3	12.6			6	11.0			9	11.5
500 - 550			2	28.0			8	9.8			10	13.4
550 - 600							8	10.0			8	10.0
600 - 650							9	12.4			9	12.4
0 - 650	12	15.3	15	72.2	35	32.8	69*	15.3	21	198.9	152*	50.3

Note. Stations occurring at depth boundaries are calculated for the depth ranges both above and below the boundaries.
* not including Station 250.

Table 9. Depth distribution of average populations of total benthonic Foraminifera in thousands of specimens.

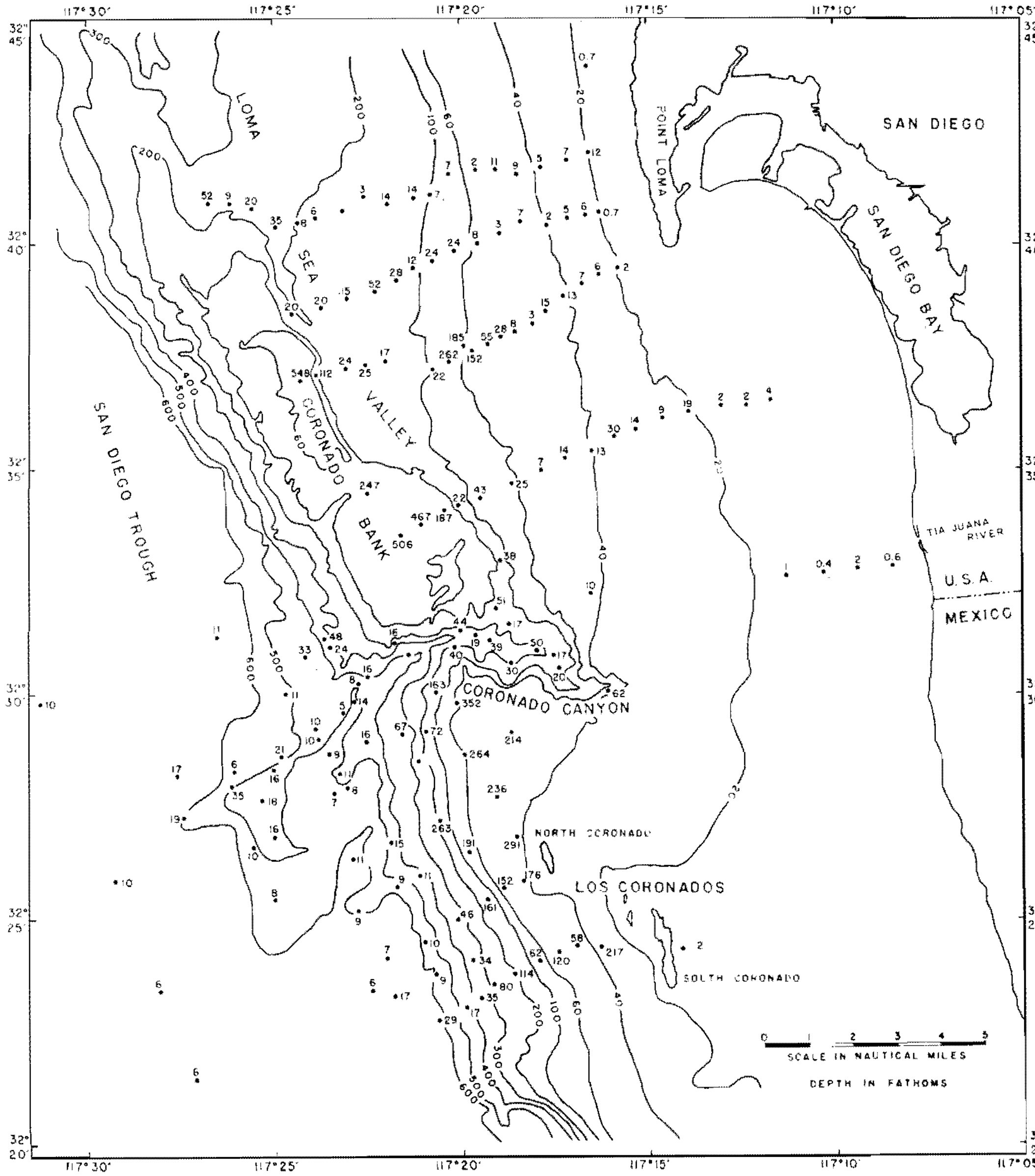
no displaced Foraminifera, and knows the average reproductive period of all the species and the living populations at these stations, one can calculate the number of tests reproduced in a year (assuming all the tests are preserved in the sediments). It is generally accepted that each area sampled has reached its own maximum population, that is, the benthonic population can be considered to be in a steady condition (in equilibrium between environmental factors and population) (Clarke, 1954, p. 340, 485). If these assumptions are correct one can calculate the rate of sedimentation. The equation is: $1 \div R = T \div L/P$ where $R =$ rate of sedimentation (cm./year) and $P =$ average reproductive period (year).



Text Figure 15. Depth distributions of average living and total populations of benthonic Foraminifera.

The average living population of benthonic Foraminifera of 9 samples at 600-650 fathoms in the San Diego Trough is 255, the average total population in the top centimeter of the cores at these stations is 12,400 specimens per sample. The average reproductive period of Foraminifera is not well-known, particularly that of deep-sea species. *Streblus beccarii* (Linné) (Bradshaw, 1957), *Rotaliella heterocaryotica* Grell (Grell, 1954), and *Patellina corrugata* Williamson (Myers, 1935), all nearshore species, reproduce every 2 to 4 weeks in laboratory cultures. *Bolivina* sp. (shallow water species), according to Bradshaw (personal communication), apparently reproduces every 2 months in laboratory cultures (temperature about 20°C). *Elphidium crispum* (Linné) reproduces every 2 years at Plymouth, England, and once a year at La Jolla, California (Myers, 1942). The colder the temperature, the slower the metabolic activity appears to be, hence a longer reproductive period is expected. Assuming a reproductive period of 2 years at the bottom of the San Diego Trough, then the average rate of accumulation of tests would be 128 per year, and the average rate of sedimentation would be 1 cm. per 97 years.

At stations 109, 111, 112, 113 and 114 in the San

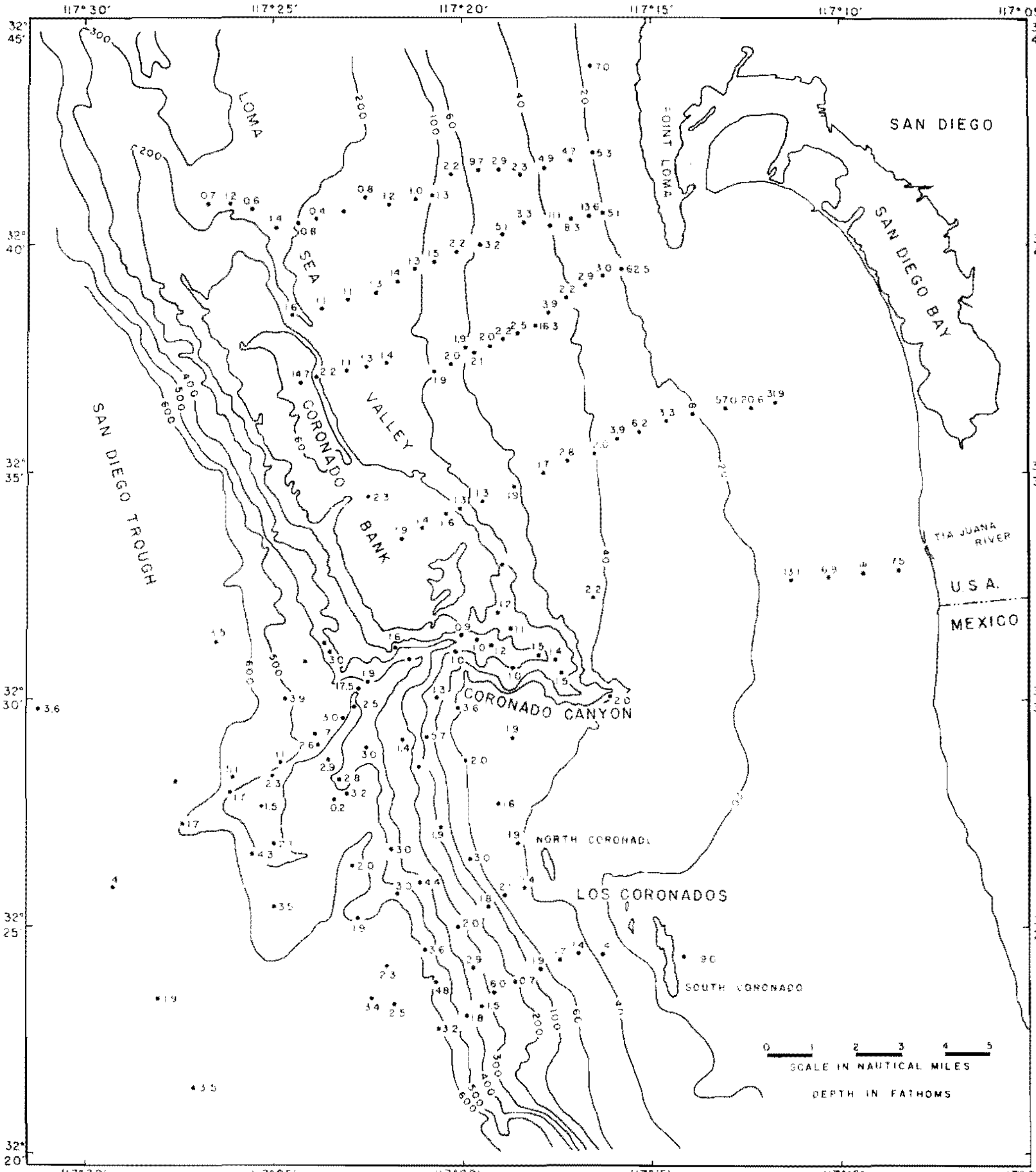


Text Figure 16. Distribution of total (living plus dead) populations of benthonic Foraminifera in thousands of specimens per sample.

Diego Trough at 599-640 fathoms living and total populations are relatively constant and there seem to be no displaced sediments. The average living population at these stations is 160, the average total population in the top centimeter is 7,514 per sample. Assuming a 2-year reproductive period, the rate of sedimentation would be one centimeter per 94 years.

In the nearshore area there are four stations (121, 122, 123 and 124) which do not contain displaced sediments (all fine micaceous sands at 6.5-11 fathoms). The average living population is 252 per sample and the average total population in the top centimeter is 1,048. Assuming a reproductive period for the species at this depth to be one month, the rate of sedimentation would be one centimeter per 0.36 years, that is, about 3 cm. per year at these stations. This rate of sedimentation seems to be very high for the fine micaceous sands at these stations, and the assumed reproductive period may be much shorter than it really is.

Revelle and Shepard (1939) have calculated the rate

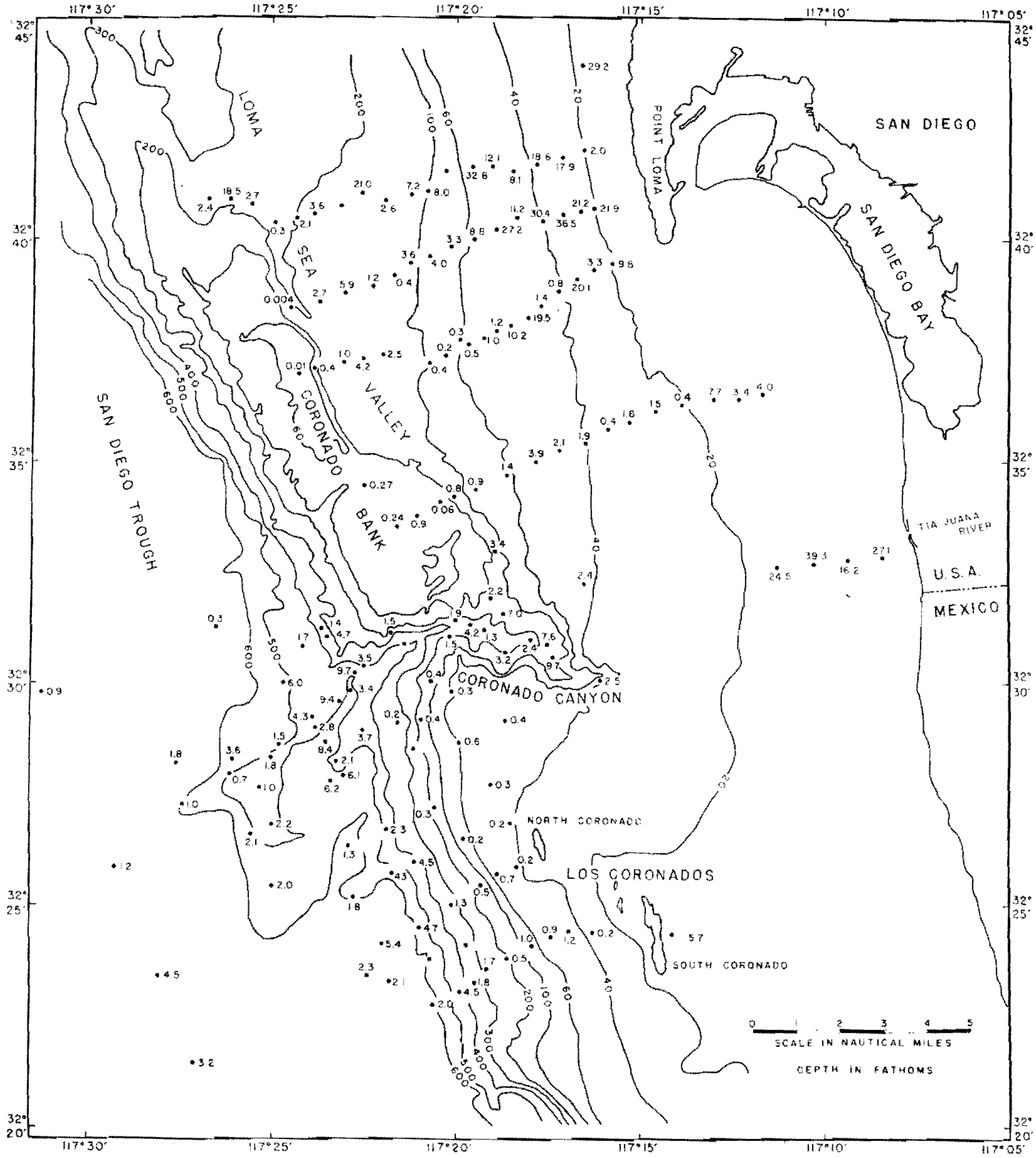


Text Figure 17. Distribution of ratios of total benthonic population to total planktonic population (B/P).

of sedimentation in the offshore basins of southern California, based on the rate of erosion of the local watersheds and the relative areas of erosion and deposition, and obtained a value of about 25 cm. per 1,000 years, that is, one centimeter per 40 years. The value obtained by them shows a rate of sedimentation about 2½ times higher than that based on Foraminifera. It would be necessary for the Foraminifera in the San Diego Trough to reproduce every 10 months if the value of Revelle and Shepard is correct.

The areal distribution of L/T (in %) is shown in Text Fig. 18. Coronado Bank and its southern extension (except Coronados Islands) have a low L/T value (less than 1) and this agrees quite well with the fact that the area appears to be non-depositional at present. Another small area between Coronado Bank and Point Loma also has a very low L/T value. Foraminifera sands are exposed at all these areas.

The highest L/T areas are off the Tia Juana River and off Point Loma, but most of the shelf has an inter-



Text Figure 18. Distribution of ratios of living population to total population (L/T).

mediate L/T value. The bottom of the San Diego Trough and Coronado Canyon and the lower part of the escarpment from Coronado Bank and its extension have intermediate L/T values (between 1 and 10).

These data seem to agree with Dietz's suggestion (1952) that sediments from the land are deposited either nearshore or on the lower part of the continental slope and in basins, bypassing the outer shelf and upper continental slope.

CHANGE IN SEA-LEVEL

During and after the Pleistocene glacial period there is evidence that sea-level rose and fell with melting and freezing of ice-caps in polar regions. The elevation of sea-level after the last glacial age to the present time is relatively well known. In the following the writer discusses methods of estimating the amount of sea-level change using Foraminifera and gives some of the results obtained. There are three ways to estimate the amount of sea-level change using benthonic Foraminifera.

Vertical Change of Foraminifera Fauna in Cores

First, one must assume that the depth distribution of living Foraminifera in an area is known. If the dead Foraminifera fauna is different from the living one, the difference of the depths indicated by the two is the amount of sea-level change. The amount of sea-level change thus obtained is that since the beginning of deposition of the particular sediment sample. In this analysis one assumes no contamination with sediments from other sources. Phleger (1952, p. 360), in his work on the Foraminifera from Portsmouth, New Hampshire, found striking differences between the upper and lower faunas of many cores. His interpretation is that this lower fauna (which indicates a shallow sand facies) was covered rapidly by mud with increase of depth (post-glacial rise of sea-level), and that the amount of the change was at least 60-75 m. Walton (1955, p. 988) found nearshore coarse sands which contained some *Elphidium crispum* (Linné) and large populations of miliolids which indicate a much shallower depth than the depths at which the sediments occur. He interpreted these sands as being "relict" sediments deposited during a time of lower sea-level.

Lateral Change of Foraminifera Fauna

If the distributions of the living and dead faunas in samples taken along a traverse from shallow to deep water are different, the difference of depth of the boundaries of equivalent living and dead faunas is the amount of sea-level change. For example, if there are depth boundaries of living Foraminifera fauna at 30, 50 and 100 fathoms, and those of the representative faunas of dead Foraminifera lie at 40, 60 and 110 fathoms, the amount of sea-level change during the time of deposition of the samples is 10 fathoms.

Depth Change of Size of Benthonic Populations

Walton (1955, p. 977, text-fig. 11) shows that the average size of living populations of benthonic Foraminifera is highest at 30-35 fathoms. In reality there are many irregularities in the depth distribution of living populations as the writer has pointed out (see p. 25). If one smooths out these irregularities by averaging 5-, 10- or 50-fathom intervals, however, one can generalize on the depth distributions of the average living populations. The depth of the highest average dead or total population may be different from that of the living one. The difference of the depths of the highest average populations of living and dead (or total) benthonic Foraminifera is the amount of sea-level change during the time represented by the samples.

Discussion

The writer has tried these methods in the San Diego area. As is shown, however, on the distribution tables (Tables 1-3, 5-7) and the frequency charts (Text Figs. 2-9) many empty tests are transported in a deeper or shallower direction; also many of them come from residual sediments. The only place which has been little influenced by contamination with other sediments is the northeastern part of this area. Medium to coarse sands were sampled at stations 45, 44 and 1, at 20, 20 and 19 fathoms respectively. The main components of the living and total faunas at stations 1 and 44 are essentially the same. At station 45, however, the total fauna has the same main components as that at station 1 and 44 but the living components are different. In the total fauna *Cibicides fletcheri* Galloway and Wissler makes up 34%, *Rosalina campanulata* (Galloway and Wissler) 21%, *Rosalina columbiensis* (Cushman) 3% and miliolids 3%, while the living fauna contains *Nonionella stella* Cushman and Moyer 21%, *Nonionella basispinata* (Cushman and Moyer) 15%, *Trochammina charlottensis* Cushman 10%, miliolids 8% and *Rosalina campanulata* (Galloway and Wissler) 3%. Thus, the living fauna is characteristic of a fine sand or silt fauna at 15-20 fathoms, and the total fauna has the characteristics of a coarse sand fauna at a depth shallower than 20 fathoms, most probably shallower than 13 fathoms. The dead fauna, therefore, lived at a depth approximately 5 fathoms shallower than the present depth.

There are distinct differences between the living and total faunas at stations 101, 102, and 103, the depths of which are 19.5, 17 and 15 fathoms respectively. At all these stations *Nonionella basispinata* (Cushman and Moyer) makes up 26-39%, *N. stella* Cushman and Moyer 12-32% and *Buliminella elegantissima* (d'Orbigny) 0-14% in the living faunas, while *Eggerella advena* (Cushman) occupies 23-31%, *Nonionella basispinata* (Cushman and Moyer) 5-9%, *N. stella* Cushman and Moyer 10-14%, *Buliminella elegantissima* (d'Orbigny) 5-15%, *Buccella angulata* Uchio, n. sp., 3-8%, *Elphidium* spp. 8-13%, and *Trochammina pacifica* Cushman 6-12% in the total faunas. Living specimens of *Eggerella advena* (Cushman) are most abundant at depths shallower than 10 fathoms in Todos Santos Bay, where more shallow samples are available than from the San Diego area. *Elphidium* spp., *Buliminella elegantissima* (d'Orbigny) and miliolids are most abundant shallower than 13 fathoms both in the San Diego and Todos Santos Bay areas. The empty tests at stations 101, 102 and 103 lived at a depth of less than 10 fathoms, approximately 5-10 fathoms shallower than the present depth.

These interpretations suggest that there was a recent rise of sea-level of about 5 fathoms. A change of 5 fathoms may be within a range of error, however, and more extensive study is needed to establish such a small oscillation of sea-level.

The most striking change of sea-level suggested by

Foraminifera assemblages in the San Diego area is the one since the "Foraminifera sand and/or silt" was deposited on the Coronado Bank and its vicinity. The sedimentary environment of the "Foraminifera sand" is complicated. This sediment seems to have been subjected to wave action or strongly agitated water judging from the scratched surfaces of the Foraminifera tests. Relatively pure Foraminifera sands actually are not sands but contain a rather high amount of the finer fractions and should be called sandy silt. The sorting is poor as is shown by the high value (2.25) of ø (phi standard deviation measure of Inman), and perhaps more than two sediment types of different kinds are mixed together. This is supported by the Foraminifera assemblage in the sediments, which is characterized by high percentages of *Cassidulina limbata* Cushman and Hughes (15-28%, average of 9 samples is 19%), *C. tortuosa* Cushman and Hughes (11-28%, average 17%), *C. quadrata* Cushman and Hughes (10-21%), *Angulogerina baggi* (Galloway and Wissler) (including *A. hughesi*) (8-13%), *Cibicides fletcheri* Galloway and Wissler (7-10%) and *Cassidulina depressa* Asano and Nakamura (7-10%). From the frequency distribution of living specimens of these species at least two different faunal associations may be recognized. One is the nearshore fauna represented by *Elphidium* spp., *Poroeponides cribrorepandus* Asano and Uchio, *Cibicides fletcheri* Galloway and Wissler, *Rosalina campanulata* (Galloway and Wissler) and *Asterigerinata pacifica* Uchio, n. sp., etc. The other, which forms the main part of the entire assemblage, is characterized by species of *Cassidulina and Angulogerina* which indicate a depth range of 20 to 130 fathoms, most probably 30 to 60 fathoms. This shows that the sediment was deposited essentially 5-45 fathoms shallower than the present depth. However, the whole block of Coronado Bank and Coronados Islands may have been faulted up from the San Diego Trough and tilted gently toward the north during the late Pleistocene. Therefore, it is very difficult to speculate on the amount of sea-level change which has taken place since the time of deposition of this sediment.

DISPLACED FORAMINIFERA

Phleger (1951a) discussed the Foraminifera faunas in sand layers which are embedded in clay or silt in the San Diego Trough. He studied cores taken at depths of 407-642 fathoms and concluded that the shallow-water species of Foraminifera in these deep sand layers were displaced by turbidity currents or other mechanisms. Judging from his faunal assemblages none of the sand layers mentioned above contained pure, shallow-water faunas but a mixture of several faunas which presently exist between the nearshore area and the San Diego Trough. His discussion was based on the depth distributions of empty tests of benthonic Foraminifera and needs further revision based on the distribution of living Foraminifera.

Ludwick (1950) studied deep water sand layers in a wide area off San Diego, including La Jolla Canyon. Most of the sands are fine grained and well-sorted and differ little in general character from typical fine-grained beach sands. In the present study only one core sample included two thin layers of fine sand be-

EXPLANATION OF PLATE 7

FIGS. PAGE

1. *Bolivina minuta* Natland. Hypotype (U.S.N.M. No. 626737), ×130.
2. *Bolivina pacifica* Cushman and McCulloch. Hypotype (U.S.N.M. No. 626738), ×99.

3, 4. *Bolivina peirsonae* Uchio, n. sp. 63
3, Holotype (U.S.N.M. No. 626739), ×33. 4, Paratype (U.S.N.M. No. 626740), ×47.

5, 6. *Suggrunda* (?) *eckisi* Natland. Hypotypes (U.S.N.M. No. 626748, 626749), ×91, ×110.

7, 8. *Bolivina spissa* Cushman. Hypotypes (U.S.N.M. Nos. 626742, 626743), ×42. 7, megalospheric form; 8, microspheric form.

9. *Loxostomum bradyi* (Asano) 64
Hypotype (U.S.N.M. No. 626751), ×47.

10. *Loxostomum pseudobeyrichi* (Cushman). Hypotype (U.S.N.M. No. 626753), ×34.

11. *Uvigerina auberiana* d'Orbigny 65
Hypotype (U.S.N.M. No. 626754), ×98.

12, 13. *Uvigerina curticosta* Cushman 65
Hypotypes (U.S.N.M. No. 626755, 626756). 12, typical form, ×35. 13, *U. dirupta* type, ×34.

14. *Uvigerina excellens* Todd. Hypotype (U.S.N.M. No. 626757), ×42.

15-17. *Uvigerina juncea* Cushman and Todd 65
Hypotypes (U.S.N.M. Nos. 626758-626760). 15, *U. cushmani* type, ×47. 16, typical form, ×45. 17, form with a smooth surface, ×47.

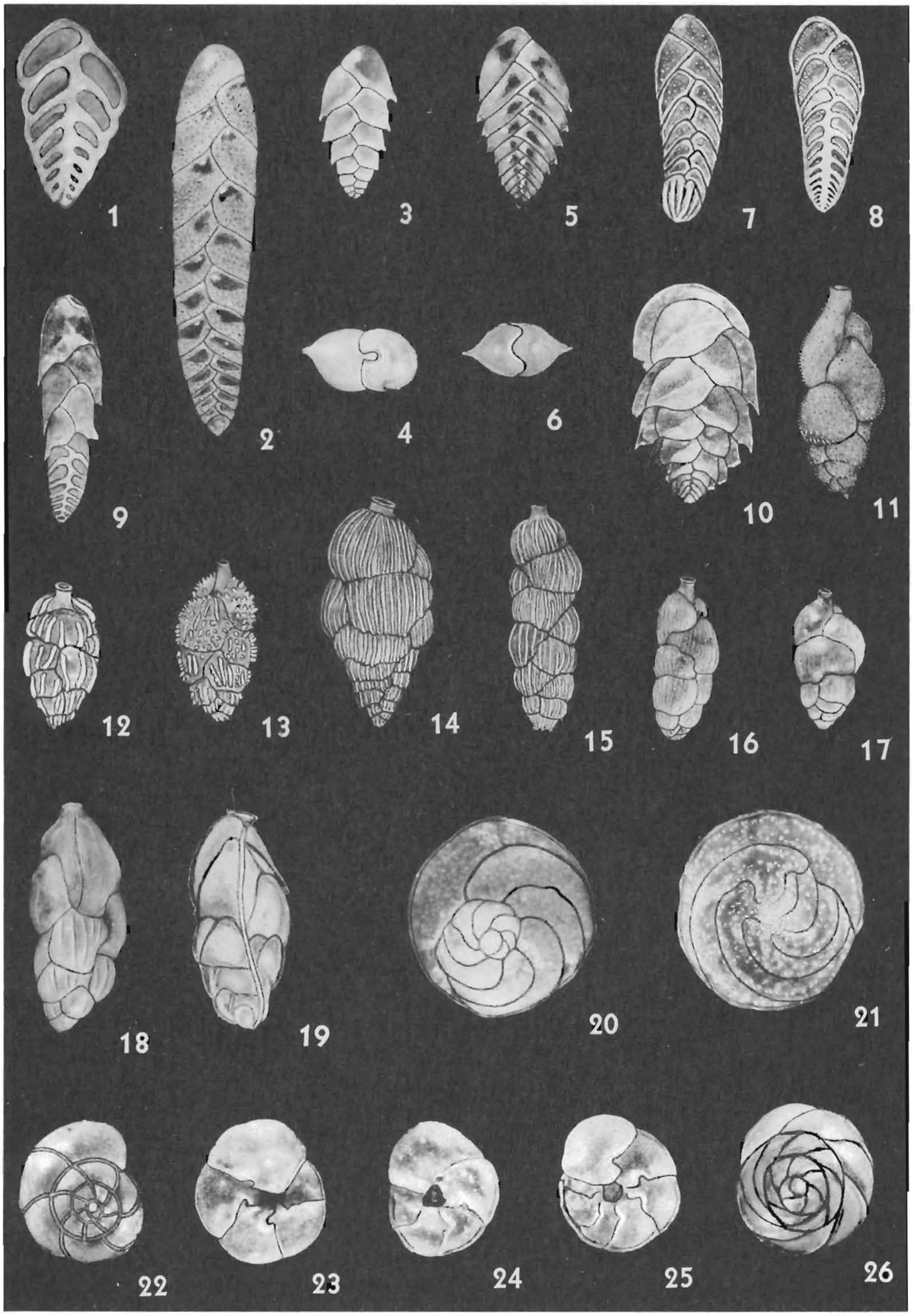
18. *Angulogerina angulosa* (Williamson). Hypotype (U.S.N.M. No. 626761), ×97.

19. *Angulogerina carinata* Cushman 66
Hypotype (U.S.N.M. No. 626762), ×30.

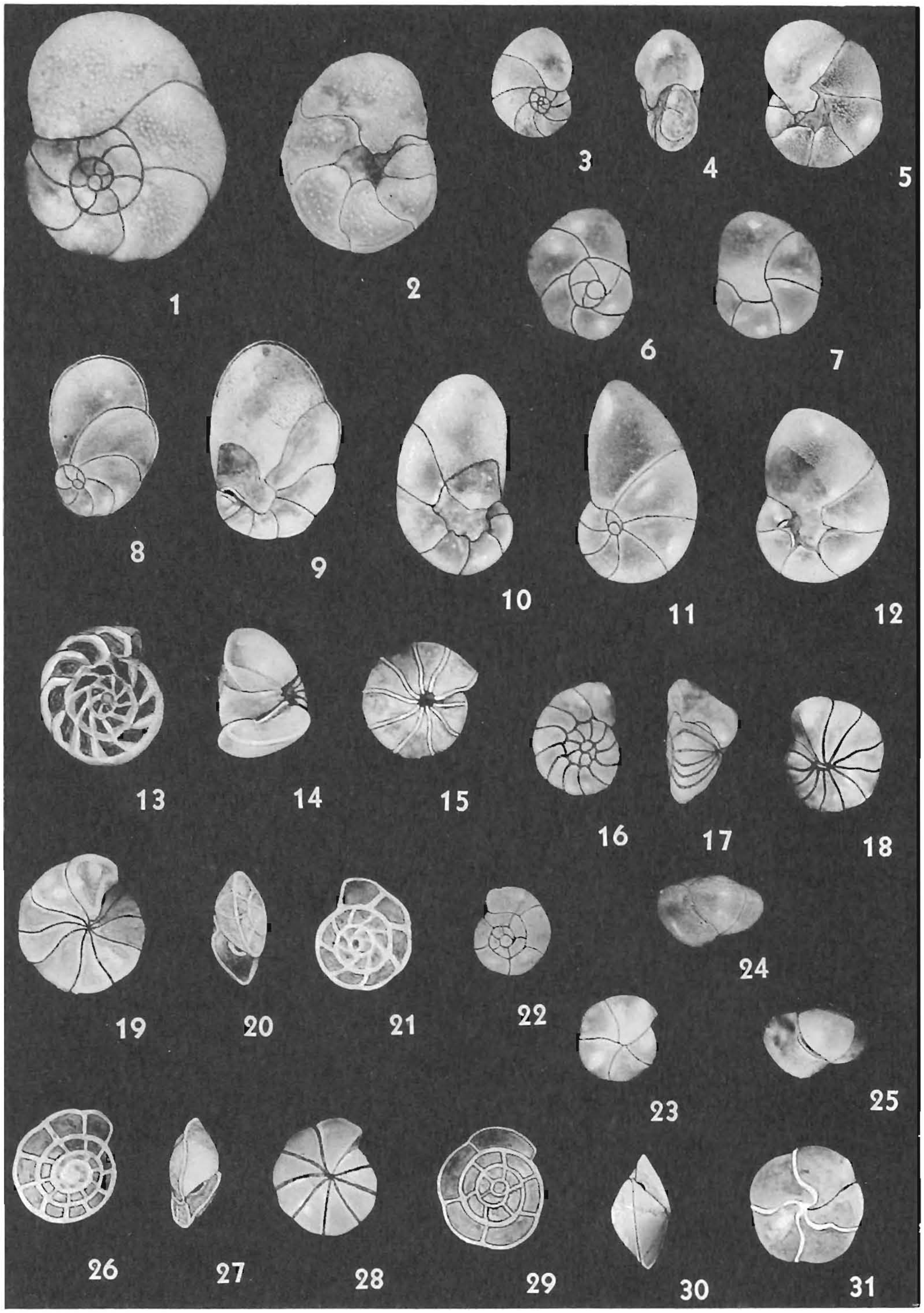
20, 21. *Neoconorbina terquemi* (Rzehak). Hypotypes (U.S.N.M. Nos. 626763, 626764), ×101.

22-25. *Rosalina* sp. 66
Hypotypes (U.S.N.M. Nos. 626766-626769), ×46.

26. *Rosalina campanulata* (Galloway and Wissler) 66
Hypotypes (U.S.N.M. No. 626770), ×46.



Uchio: Living Foraminifera, San Diego, California



Uchio: Living Foraminifera, San Diego, California

neath the typical clayey surface sediment of the San Diego Trough. Most cores taken were not long enough to penetrate any sand layers which might exist in the deep area.

At station 268 in the San Diego Trough a short core was taken at 630 fathoms. The top centimeter was analyzed for living and total counts and the results are listed in Tables 3 and 6. The core consists of clayey silt with two fine sand layers, 0.5 mm. and 3 mm. thick, at 20 cm. and 25 cm. from the top respectively. The entire length of the core is only *ca.* 30 cm. The living and total faunas of the top centimeter differ from each other in the percentage frequencies of the individual species but the faunal compositions are the same. The Foraminifera fauna of the lower sand layer is as follows:

*	*Bolivina spissa* Cushman	19%
**	*Cassidulina quadrata* Cushman and Hughes	14%
*	*Uvigerina curticosta* Cushman	10%
*	*Epistominella smithi* R. E. and K. C. Stewart	9%
*	*Cassidulina delicata* Cushman	6%
*	*Bolivina subargentea* Uchio, n. sp.	5%
*	*Eponides subtenerus* Galloway and Wissler	4%
*	*Cassidulina subcarinata* Uchio, n. sp.	4%
*	*Cassidulina* cf. *C. braziliensis* Cushman	3%
**	*Angulogerina* cf. *A. hughesi* (Galloway and Wissler)	3%
**	*Cassidulina limbata* Cushman and Hughes	3%
**	*Cassidulina tortuosa* Cushman and Hughes	2%
**	*Bulimina denudata* Cushman and Parker	2%
*	*Bulimina subacuminata* Cushman and Stewart	2%
*	*Cibicides spiralis* Natland	2%
*	*Gyroidina altiformis* Stewart and Stewart	1%
*	*Gyroidina gemma* Bandy	1%
	Sigmoilina tenuis (Czjzek)	1%
	Epistominella sandiegoensis Uchio, n. sp.	1%
**	*Bolivina minuta* Natland	1%
**	*Elphidium* spp.	1%
**	*Buliminella elegantissima* (d'Orbigny)	0.5%
**	*Rosalina campanulata* (Galloway and Wissler)	0.5%
	Miscellaneous (8 species)	4.8%

This assemblage, of which 227 specimens were counted, shows that this is a mixed fauna composed of species (*) normal to this depth and amounting to *ca.* 65%, and displaced species (**) from Foraminifera sand amounting to *ca.* 27%. This shallow-water fauna came from a depth of 50-150 fathoms on the upper part of the escarpment west of the Coronados Islands. Vertical displacement of the Foraminifera sand at station 268 is approximately 500 fathoms. Mineral grains are well sorted, mostly with a diameter of 0.12-0.35 mm. They consist mostly of terrigenous material such as angular quartz, some feldspar, hornblende, pyroxene, and biotite.

Other evidence of displaced sandy silt is found in surface sediments at stations 207, 208, 296, 298, 303 and 304, at depths of 505, 473, 458, 505, 485 and 430 fathoms respectively. The living and total Foraminifera faunas are listed in Tables 3 and 6. The latter show the environments of deposition of the sands before they were transported to the present positions. Displaced Foraminifera at stations 207, 208, 296, 298, 303 and 304 are approximately 10, 17, 5, 5, 12 and 15% of the total fauna respectively. These 5 stations are located on a delta-like feature at the mouth of Coronado Canyon, but not in the channel or canyon floor. The sediment in the channel is partly clayey silt which is to be expected at its present depth, while that on the delta-like feature is coarser and is composed of sandy silt. This fact suggests that sandy silt was first deposited at the mouth of the present canyon forming the delta-like feature. Later the canyon cut this delta-like feature and the canyon floor was covered by the clayey silt which is widely distributed at the bottom of the San Diego Trough. Shepard (*in* Emery *et al.*, 1952) suggested that the delta-like feature might represent a true delta when the sea-level was much lower

EXPLANATION OF PLATE 8

Figs.		Page
1, 2.	*Rosalina columbiensis* (Cushman). Hypotypes (U.S.N.M. Nos. 626771, 626772), ×96.	66
3-5.	*Valvulineria araucana* d'Orbigny. Hypotypes (U.S.N.M. Nos. 626773-626775), ×28, ×34, ×51.	
6, 7.	*Valvulineria glabra* Cushman. Hypotypes (U.S.N.M. Nos. 626776, 626777), ×95.	
8, 9.	*Cancris auricula* (Fichtel and Moll). Hypotypes (U.S.N.M. Nos. 626778, 626779), ×36.	
10-12.	*Cancris inaequalis* d'Orbigny). Hypotypes (U.S.N.M. Nos. 626780-626782), ×23, ×29, ×39.	
13-15.	*Gyroidina altiformis* R. E. and K. C. Stewart. Hypotypes (U.S.N.M. Nos. 626783-626785), ×40, ×33, ×32.	
16-18.	*Gyroidina io* Resig. Hypotypes (U.S.N.M. Nos. 626786-626788), ×81, ×94, ×98.	
19-21.	*Gyroidina gemma* Bandy. Hypotypes (U.S.N.M. Nos. 626789-626791), ×46.	
22-25.	*Gyroidina quinqueloba* Uchio, n. sp. 22, 23, 25, Paratypes (U.S.N.M. Nos. 626793-626795), ×96, ×117, ×132. 24, Holotype (U.S.N.M. No. 626792), ×107.	66
26-28.	*Eponides subtenerus* (Galloway and Wissler). Hypotypes (U.S.N.M. Nos. 626800-626802), ×42.	
29-31.	*Pseudoeponides umbonatus* (Reuss). Hypotypes (U.S.N.M. Nos. 626803-626805), ×43.	

(*ca.* 400 fathoms) than at present. The displaced Foraminifera at these stations include very shallow (shallower than 20 fathoms) species such as *Buliminella elegantissima* (d'Orbigny), *Buccella angulata* Uchio, n. sp., *Asterigerinata pacifica* Uchio, n. sp., *Nonionella basispinata* (Cushman and Moyer), *Bolivina vaughani* Natland, *B. lowmani* Phleger and Parker, *Elphidium* sp., and *Bolivina acutula* Bandy, etc., but in very small percents. The remaining species are those which are indigenous to the present depths. The empty tests of such very shallow-water species also are found at stations in the canyon floor, and they may be reworked from sediment on the delta-like feature or displaced directly from a nearshore area.

At station 248, in the middle of Coronado Canyon at a depth of 250 fathoms, displaced sands occur at the surface of the sediment. Here displaced Foraminifera forming approximately 45% of the total fauna came from Foraminifera sands on the Coronado Bank and the nearshore area. It is quite reasonable that this station should contain more displaced Foraminifera than other stations, since it is located just below Coronado Bank. The general tendency is for the percent of displaced Foraminifera gradually to decrease with distance from Coronado Bank.

Another example of sediment displacement is found at station 30 below Coronado Bank at 180 fathoms. Displaced specimens form at least 25% of the total fauna. The sediment is composed of very coarse sand with some shell fragments. Apparently most of this sediment came from the top of Coronado Bank.

These displaced sediments are easily recognized by their coarse grain size. Many examples of displacement or mixing of sediments can be found even in fine-grained sediment, however, if the depth distributions of living Foraminifera or other organisms are known. Text Figs. 2-9 show the depth ranges of the main species of living and total (mostly dead) Foraminifera in this area. That the depth range of dead specimens of a species extends much deeper than that of the living specimens is clearly demonstrated.

PART 2: SYSTEMATICS

INTRODUCTION

Many micropaleontologists who are interested primarily in stratigraphy and/or taxonomy tend to split Foraminifera into varieties, subspecies or even species on the basis of minor changes in the morphology of the test. These species, subspecies or varieties, as well as those of the early workers, are based in many cases on a few specimens so that the range of variation is unknown. On the other hand, ecologists, who deal with a large number of specimens, are apt to lump these species, etc., for practical reasons, and also because they have a clear idea of the range of variation of the forms. However, taxonomy is the basis of ecology. It is desirable for workers to understand the point of view of the taxonomist, stratigrapher and ecologist. In the following section the writer briefly discusses his views on the range of variation of significant species used in this study and describes two new genera and thirty-four new species. Complete synonymies are not listed but the original references, in some cases later ones of special interest, are given. In many cases references of synonymous species are also included. The distributions of the living and empty tests of the species are given in Part I: Ecology. All figured specimens are deposited in the U. S. National Museum, Washington, D. C. Duplicate sets of the assemblages are in the collection of the Scripps Institution of Oceanography of the University of California, La Jolla, California. It should be noted that many more species are figured than shown by the plate and figure references in the text.

SYSTEMATIC DESCRIPTIONS OF SPECIES

Family SACCAMMINIDAE

Saccammina longicollis (Wiesner)

Plate 1, figures 1, 2

Proteonina longicollis Wiesner, 1929, Deutsche Sud-Polar-Exped., v. 20, p. 82, pl. 6, fig. 55; Cushman and McCulloch, 1939, Allan Hancock Pacific Expeds., vol. 6, n. 1, p. 42, pl. 1, figs. 7-9.

Proteonina atlantica Walton (not Cushman), 1955, Jour. Paleontology, vol. 29, p. 1012, pl. 99, fig. 1.

This species was originally described from the Atlantic. The San Diego specimens have a shorter neck than the type specimen, but may represent forms whose long necks have been broken off. The San Diego specimens are also similar to *S. limnetica* (Hada) (1937, p. 342, text-fig. 5), which was originally described from a small lake near Tottori, a western city in Japan on the Japan Sea, but the latter has a more globular test. The San Diego form is transitional between *S. longicollis* and *S. limnetica,* and these three forms may belong to the same species, *S. longicollis.*

Family REOPHACIDAE

Reophax micaceous Earland

Plate 1, figure 8

Reophax micaceous Earland, 1934, *Discovery* Reports, London, vol. 10 (1935), p. 82, pl. 2, figs. 37-40.

This species was originally described from the Atlantic (depth not given). *Proteonina* sp. Walton (1955, p. 1012, pl. 99, figs. 2, 3) seems to belong to *R. micaceous.* Walton said that this species had a single undivided chamber, that the chamber wall was chitinous and was covered by small detrital particles, mostly mica. This species seems to have a single chamber at first glance, particularly the young form, but in reality has more than two chambers. Walton's figures show an indication of segmentation.

Family TOLYPAMMINIDAE

Involutina hoeglundi Uchio, n. sp.

Plate 1, figure 12

? *Ammodiscus planorbis* HÖGLUND, 1947, (part), Zoologiska Bidrag fran Uppsala, vol. 26, p. 107, 115, 125, pl. 28, fig. 16, text-fig. 92 (not pl. 8, figs. 4, 9; pl. 25, figs. 13-15, text-figs. 91, 105, 109).

Test small, thin, very regularly planispiral; whorls up to 12 in number; spiral suture very distinct; proloculus central; wall finely arenaceous with very small sand grains and an excess of cement, surface with fine radial striations but otherwise smooth and polished, color brownish. Diameter up to 0.5 mm. (average 0.4 mm.); peripheral thickness up to 0.029 mm.; proloculus diameter up to 0.025 mm. (average 0.018 mm.).

Holotype (U. S. N. M. No. 626583) from station SD-337 (Lat. 32° 38′ N., Long. 117° 31′ W.; 610 fathoms). Diameter *ca.* 0.45 mm.

Remarks.—Höglund (1947, *op. cit.*, p. 125, pl. 8, figs. 4, 9; pl. 28, figs. 13, 14, text-figs. 91, 105, 109) described "*Ammodiscus planorbis*" from the Skagerak and included two other forms (one from the Gulf of Mexico, *op. cit.*, p. 125, pl. 28, fig. 16, text-fig. 92, the other from the Atlantic, off Portugal, p. 125, pl. 28, fig. 15) with some hesitation due to differences in proloculus diameter and the size of the test. F. L. Parker (1958, p. 253, pl. 1, figs. 1, 2) in her study of eastern Mediterranean Foraminifera has found *Involutina planorbis* (Höglund) (of the type from off Portugal) from the Aegean Sea and from off Egypt. The San Diego specimens are different from the Mediterranean form in having a much less inflated chamber, and consequently a much thinner test, and a very narrowly rounded periphery. The San Diego specimens are identical to "*A. planorbis*" of the Gulf of Mexico type, but differ from "*A. planorbis*" of the type locality, that is from the Skagerak, by their greater diameter and much larger proloculus.

Involutina pacifica (Cushman and Valentine)

Plate 1, figure 14

Ammodiscus pacifica CUSHMAN and VALENTINE, 1930, Dept. Geol. Stanford Univ., Contr., vol. 1, no. 1, p. 7, pl. 1, fig. 1.

The differentiation of *I. pacifica* from *I. minutissima* (Cushman and McCulloch) is difficult because *I. minutissima* only differs in its smaller size and in having a polished, chitinous wall. *I. minutissima* may be a young form of *I. pacifica.* So far as known (Cushman and McCulloch, 1939, p. 69, 70) the geographic distribution and depth range of the empty tests of the two species are almost the same. In the population counts of this study the two species were tentatively separated, but in view of probable misidentifications, due to the above reasons, the species were later combined and listed in the tables (Part I: Ecology, Tables 1-3, 5-7) as *I. pacifica.*

I. pacifica is easily separated from *I. flavida* (Höglund) (1947, p. 127, pl. 28, figs. 1, 2; pl. 29, fig. 3; text-figs. 99, 100, 105, 106, 108, 109) by its very much smaller and more inflated test. *I. flavida* is found only in the San Diego Trough, while *I. pacifica* is found in shallow water.

Family LITUOLIDAE

Haplophragmoides neobradyi Uchio, n. sp.

Plate 1, figures 15, 16

Test free, minute, planispiral, much compressed, incompletely involute; chambers inflated, 5 chambers in the last whorl but very rarely 4½ in young specimens, those of the previous whorl slightly exposed in the depressed umbilical region; periphery lobulate in side view, moderately rounded in edge view; sutures distinct, depressed, straight, radiate; wall finely arenaceous, smooth, polished, color brownish yellow; aperture a short slit at the base of the apertural face of the last chamber, with a lip.

Holotype (U. S. N. M. No. 626587) from station SD-337 (Lat. 32° 38′ N., Long. 117° 31′ W.; 610 fathoms). Length *ca.* 0.21 mm.; width *ca.* 0.19 mm.; thickness *ca.* 0.09 mm.

Comparison.—This new species is very similar to *Haplophragmoides bradyi* (Robertson), which was first figured by Wright (1891, p. 469, pl. 20, fig. 4). F. L. Parker (1952, p. 339, pl. 2, fig. 11; 1954, p. 486, pl. 1, fig. 16) figured *H. bradyi* from off Portsmouth, New Hampshire, and from the northeastern Gulf of Mexico. The writer has examined her specimens and British specimens and found that the former are different from the latter and should be referred to a new subspecies. Höglund (1947, p. 134, pl. 10, fig. 1, text-fig. 111) described *H. bradyi* from the Gullmar Fjord and from the Skagerak, but his specimens also differ from the British ones.

Remarks.—The writer has examined 5 specimens of *H. bradyi* from southwest of Ireland at a depth of 53 fathoms. They do not show any variation in morphological features and quite agree with Wright's figure. They seem to represent a nonvariable form. Höglund also mentioned such a lack of variability in external appearance, number of chambers and whorls in his "*H. bradyi.*" The writer has examined 79 specimens of *H. neobradyi* at one station and more at other stations in the San Diego area. The British specimens have 5-5½ chambers in the last whorl (one more than San Diego specimens), are more evolute, always show a part of the previous 2 whorls and hence are more deeply umbilicate, are more firmly built and darker in color. San Diego specimens are completely involute (in young specimens) or slightly evolute (in large specimens) and a part of only one previous whorl can be seen in the umbilical area.

Haplophragmoides quadratus Uchio, n. sp.

Plate 1, figure 17; Plate 5, figure 14

Test free, finely arenaceous, thin, broadly rectangular in side view, planispiral, consisting of 4 chambers in the last whorl, slightly evolute so that the early portion is slightly visible; chambers increasing rapidly in size as added, last one occupying about ½ or ⅓ of the size of the test, inflated but not globose, quadrangular; sutures very distinct, very depressed; periphery distinctly lobulate in side view, moderately broad in apertural view; aperture a long, narrow arched opening at the base of the apertural face of the last chamber, with a distinct lip.

Holotype (U. S. N. M. No. 626590) from station SD-220 (Lat. 32° 30′ N., Long. 117° 20.7′ W.; 128 fathoms). Length *ca.* 0.39 mm.; width *ca.* 0.30 mm.

Remarks.—This new species is easily distinguished from any other species of the genus by the quadrangular shape of the test and chambers, the number of chambers in the last whorl, and the rapidly increasing size of the chambers as added. The holotype is perhaps one of the largest specimens of this species.

Alveolophragmium advena (Cushman)

Plate 1, figures 20, 21

Haplophragmoides advena CUSHMAN, 1925, Cushman Lab. Foram. Research, Contr., vol. 1, p. 38, pl. 6, fig. 1.

According to the original description this species has about 10 chambers in the last whorl and the test is involute and umbilicate. Many specimens in the San Diego area have 9 chambers in the last whorl and are involute to slightly evolute.

Alveolophragmium columbiense (Cushman)

Plate 1, figure 22

Haplophragmoides columbiense CUSHMAN, 1925, Cushman Lab. Foram. Research, Contr., vol. 1, p. 39, pl. 6, figs. 2a, b.

This species always has 6-6½ chambers in the last whorl. Some specimens have a broadly rounded periphery as shown in Cushman's type figures, some an angular one, but adult specimens usually have a narrow periphery. Therefore, it seems that the character of the periphery is not significant in this species. Some specimens are slightly evolute while others are involute and umbilicate. Therefore, *A. columbiense* var. *robustum* (Cushman and McCulloch) is just a variant form of *A. columbiense* and has no ecological significance. It is included with *A. columbiense* in this study.

Genus **Recurvoides** Earland, 1934, emend. Uchio

Type species: *Recurvoides contortus* Earland

The test is free, arenaceous, composed of several convolutions, each containing many chambers. The convolutions are planispiral and partially embracing but arranged in two series, the axis of winding of the second series being oblique (not necessarily at right angles) to that of the previous or earlier series. Therefore, the second series envelops the first, but leaves the peripheral edge of the final convolutions of the first series visible on one of the faces as a raised line of chambers extending across the umbilical portion of the adult test. Composed of sand grains of varying sizes with a considerable amount of ferruginous cement. Aperture a narrow slit slightly above the base of the apertural face of the last chamber, frequently with a distinct lip.

Remarks.—Earland did not describe the apertural character of the genus in detail, nor that of the type species, *R. contortus.* Dr. C. G. Adams, curator at the Foraminifera section, British Museum (Natural History), London, has kindly examined Earland's type material. According to his personal communication to the writer, "Earland's type slide 2F3470 contains 30 specimens, 13 of which are illustrated in the *Discovery* Report volume X, plate X. No holotype was designated, the 13 figured specimens thus becoming syntypes, and the 17 unfigured specimens paratypes." Adams has selected a lectotype and intends to publish a short description, together with photographs. The photograph of the proposed lectotype shows a 30° change in the axis of winding of the second series from that of the first series rather than a right angle change; the aperture is a narrow slit a little above the base of the apertural face of the last chamber, with a protruding lip. The apertural character of the other 5 specimens, which Adams sketched for the writer, shows that the apertures are slightly above the base of the apertural face. Further discussion of the genus is given in the description of *R. subglobosus* (G. O. Sars).

Recurvoides subglobosus (G. O. Sars)

Plate 1, figures 26, 27

Lituola subglobosa M. SARS, 1868 (1869), Forh. Vid. Selsk. Christiania, p. 250 (*nomen nudum*); G. O. SARS, *ibid.*, p. 253.

Haplophragmium latidorsatum BRADY, 1884 (not *Nonionina latidorsatum* Bornemann, 1885), Rept. Voy. *Challenger*, Zool., vol. 9, p. 307, pl. 34, figs. 7-10, 14 (?).

Haplophragmoides subglobosum (G. O. Sars), CUSHMAN, 1910, U. S. Natl. Mus., Bull., vol. 71, pt. 1, p. 105, text-figs. 162-164.

Cribrostomoides bradyi CUSHMAN, 1910, *ibid.*, p. 109, text-fig. 167.

Haplophragmoides subglobosus (G. O. Sars), EARLAND, 1934, *Discovery* Rept., vol. 10, p. 89.

Haplophragmoides subglobosum (G. O. Sars), CUSHMAN and MCCULLOCH, 1939, Allan Hancock Pacific Expeds., vol. 6, p. 80, pl. 6, figs. 9-11.

Labrospira subglobosa (G. O. Sars), HÖGLUND, 1947, Zool. Bidrag. fran Uppsala, vol. 26, p. 144, pl. 11, fig. 2, text-fig. 126.

Alveolophragmium subglobosum (G. O. Sars), F. L. PARKER, 1954, Mus. Comp. Zool., Bull., vol. 111, no. 10, p. 487, pl. 2, figs. 1-2.

The first figures of this species appeared in Brady's *Challenger* Report, but he did not mention the presence of an apertural lip, nor did he describe the aperture in detail. He said that the aperture was at the base of the apertural face of the last chamber. His figure 7 shows an aperture at the base of the apertural face, but figure 8 shows an aperture that is slightly above the base of the last chamber. His figure 9 shows an irregular aperture and Cushman proposed the new generic and species name "*Cribrostomoides bradyi*" for this form. However, as the result of the study of many specimens of this species Earland and Höglund considered this an abnormal specimen. Höglund, Parker, and Cushman and McCulloch all showed the presence of an apertural lip and the position of the aperture slightly above the base of the apertural face of the last chamber.

Parker says, "This species appears to be intermediate between *Recurvoides* and *Alveolophragmium* but is more closely allied to the latter in adult specimens." From the standpoint of evolution *Recurvoides* seems to be derived from *Alveolophragmium*. However, as Parker mentioned, adult specimens of *R. subglobosus* are more *Alveolophragmium*-like. Therefore, *Alveolophragmium* seems to be derived from *Recurvoides*. This seems to be contradictory, but if the plane of coiling changed again at the *Recurvoides* stage, the form could become of the *Alveolophragmium* type again. Therefore, the young form of this species may show an *Alveolophragmium* stage, then a *Recurvoides* stage, and finally in very large specimens an *Alveolophragmium* stage. This can be proved or disproved by sectioning many specimens. Here the writer tentatively refers the species to *Recurvoides*, because it always shows a change in the plane of coiling.

Genus **Recurvoidella** Uchio, n. gen.

Type species: *Recurvoidella parkerae* Uchio, n. sp.

The test is free, arenaceous, composed of several whorls, each containing many chambers. The whorls are planispiral and partially embracing but arranged in two series, the axis of winding of the second series being oblique (not necessarily at right angles) to that of the first or earlier series. The second series, therefore, envelops the first, but leaves the peripheral edge of the final whorl of the first series visible on one of the faces as a raised line of chambers extending across the umbilical portion of the adult test. The umbilical portion of the opposite face is more depressed. The test is composed of sand grains of varying size with a considerable amount of ferruginous cement. The aperture is small, narrow, at the base of the last chamber, sometimes with a protruding upper lip.

Remarks.—This new genus is very similar to *Recurvoides* Earland (1934, p. 90) in its arrangement of chambers, but differs from it in having the aperture at the base of the apertural face of the last chamber, while that of *Recurvoides* is slightly above the base of the apertural face of the last chamber. This relationship is like that between *Haplophragmoides* Cushman, 1910, and *Alveolophragmium* Stschedrina, 1936 (including *Labrospira* Höglund, 1947).

Recurvoidella parkerae Uchio, n. sp.

Plate 1, figures 18, 19

Test free, small, nearly circular, early portion planispiral, later portion planispiral but with a slightly changed plane of coiling from that of the previous portion, resulting in its being slightly evolute on one side and less so or completely involute on the other side; chambers inflated, numerous, usually 5 (4½ in small specimens and 5½ in large specimens) in the last whorl; periphery broadly rounded in edge view, lobulate in side view; sutures distinct, depressed, straight, radiate from the umbilical area; wall finely arenaceous with much cement, surface smooth, shining, polished; aperture a narrow crescentic slit at the base of the apertural face of the last whorl on the periphery of the involute side, with an upper lip; color yellowish brown. Diameter up to *ca.* 0.18 mm.; thickness up to *ca.* 0.1 mm.

Holotype (U. S. N. M. No. 626603) from station SD-50 (Lat. 32° 41.6′ N., Long. 117° 19.6′ W.; 53 fathoms).

Comparison.—*Haplophragmoides bradyi* and *H. neobradyi* are very similar to this new species, but it has a thicker test than either of them and the chamber arrangement gradually changes from a *Haplophragmoides* type to a *Recurvoidella* type becoming progressively like *H. bradyi*, *H. neobradyi* and *R. parkerae*. The umbilical area is broadest and deepest in *H. bradyi* and least so in *R. parkerae*. Some specimens in the northeastern Gulf of Mexico referred to *H. bradyi* by Parker are almost identical with this new species, but become larger in size. Höglund's specimens from the Gullmar Fjord and the Skagerak are very close to British specimens of *H. bradyi* in side view but have much thicker tests.

Remarks.—It is interesting to note that living specimens of *R. parkerae* seem to prefer shallower water and *H. neobradyi* deeper. A similar phenomenon was noted by Höglund in the Gullmar Fjord and the

Skagerak. *H. bradyi* of Höglund is widely distributed but at scattered depths, being very scarce at intermediate depths in the Gullmar Fjord, and on the contrary increasing with greater depths in the Skagerak. For this reason it may be that Höglund included two very similar species or varieties in one species.

Ammomarginulina sandiegoensis Uchio, n. sp.

Plate 2, figures 5, 6

Test crosier-shaped, complanate, very thin, coarsely arenaceous, flat on both sides; consisting of numerous chambers, early ones forming two or three convolutions of a flat spire, the later ones arranged in a straight, linear series; chambers distinct, earlier ones rectangular, later ones of the linear series with a slightly inverted V-shape; sutures not very clear in dried specimens, but very distinct in Canada balsam or when wet, slightly depressed; periphery slightly lobulate at the sutures in side view; aperture terminal, small, rounded, at the end of a distinct neck.

Holotype (U. S. N. M. No. 626613) from station SD-337 (Lat. 32° 38′ N., Long. 117° 31′ W.; 610 fathoms). Length *ca.* 0.60 mm.; width *ca.* 0.16 mm.

Comparison.—This new species is closely related to *A. foliacea* (Brady), but differs in having chambers with a slightly transverse V-shape, a distinct apertural neck, and fewer chambers in the spiral portion.

Family TEXTULARIIDAE

Spiroplectammina bathyca Uchio, n. sp.

Plate 2, figure 7

Test minute, elongate, much compressed, coarsely arenaceous, broadest at the spiral portion, with the sides of the biserial portion either parallel or slightly increasing in breadth toward the apertural end; chambers distinct, earlier ones planispiral, forming about two coils, later biserial, low and broad, about twice as broad as high, last chamber protruding; sutures slightly depressed, oblique, not distinct in dried specimens, but distinct in specimens mounted in Canada balsam or when wet; periphery lobulate; aperture a low opening at the base of the last chamber.

Holotype (U. S. N. M. No. 626616) from station SD-268 (Lat. 32° 23.3′ N., Long. 117° 21.8′ W.; 630 fathoms). Length *ca.* 0.34 mm.; width *ca.* 0.11 mm.

Comparison.—This species is similar to *S. typica* Lacroix (1931, p. 14, text-fig. 9; 1932, p. 7, text-figs. 2-3), which was described from sands at 30-60 m. near Cape Martin in the Mediterranean Sea, but differs from it by having more oblique sutures, more elongate and lower chambers and by not having a triangular last chamber. The thickness of the test of *S. bathyca* does not increase rapidly but is rather constant although sometimes the spiral portion is a little thicker than the biserial portion. The shallowest depth of living specimens of *S. bathyca* is 345 fathoms.

Textularia sp. cf. **T. abbreviata** d'Orbigny

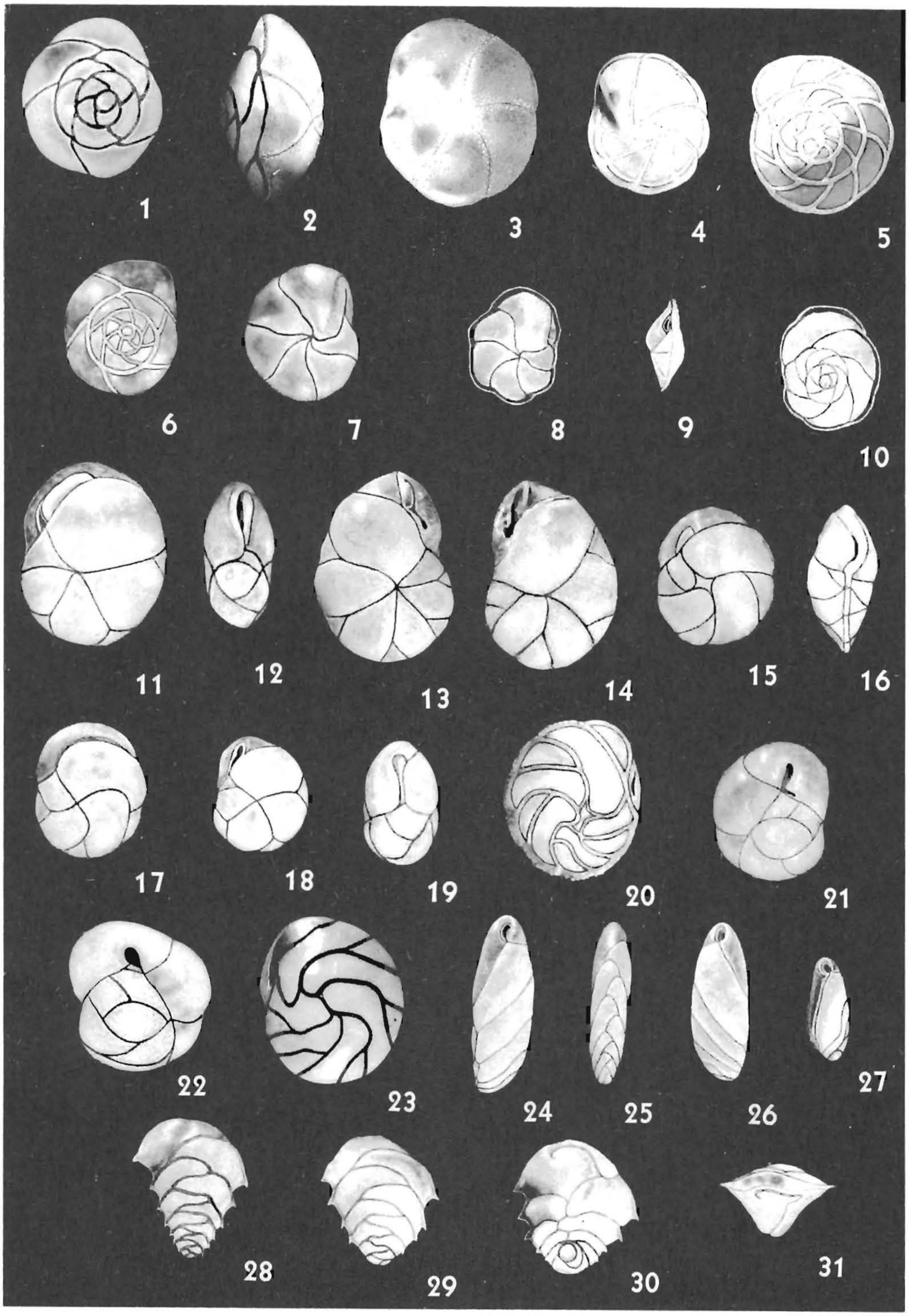
Plate 2, figures 8-10

Textularia abbreviata Lalicker and McCulloch (not d'Orbigny, 1846), 1940, Allan Hancock Pacific Expeds., vol. 6, no. 2, p. 116, pl. 13, fig. 1.

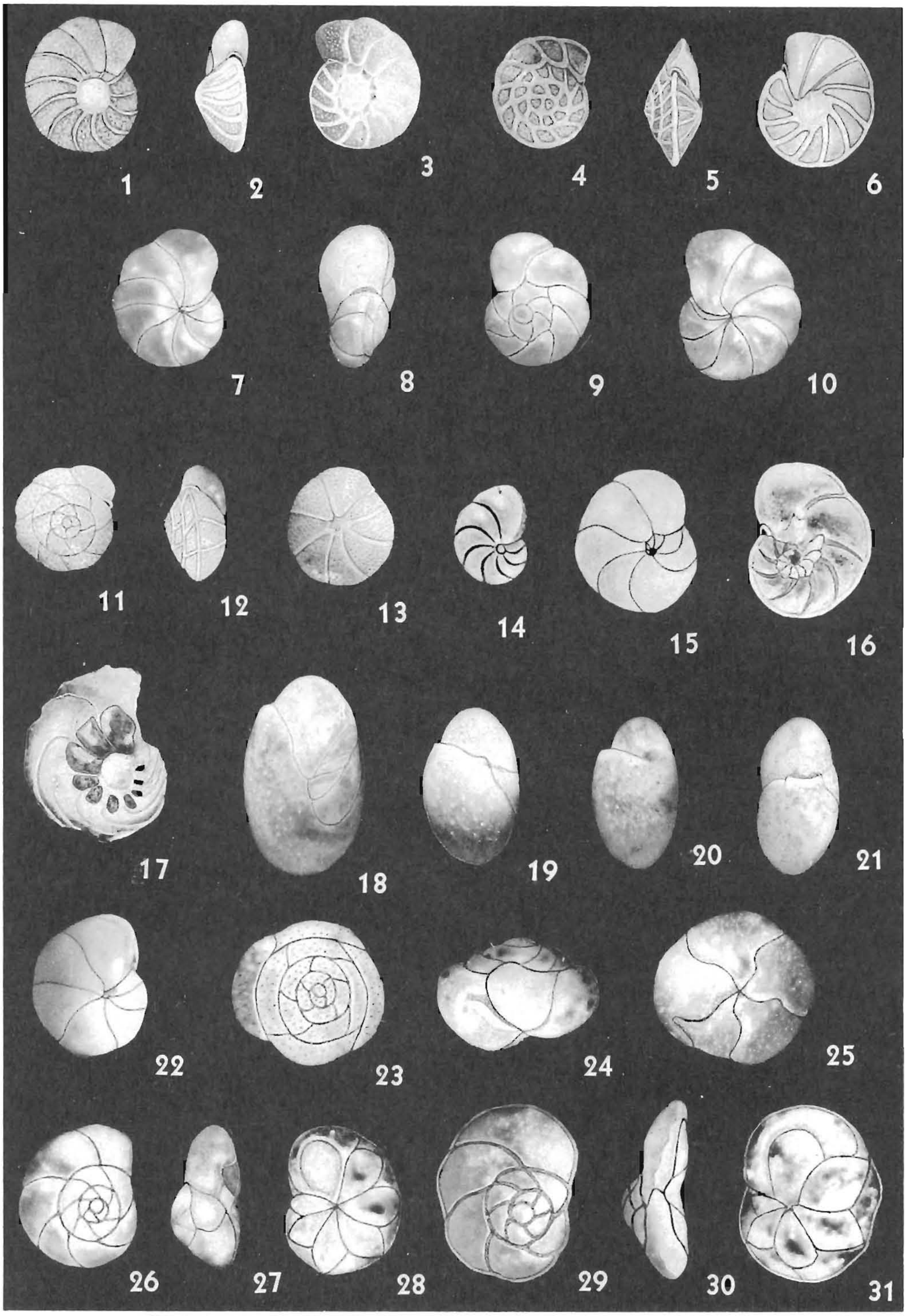
Textularia cf. *abbreviata* Cushman, 1927, Scripps Inst.

EXPLANATION OF PLATE 9

Figs.		Page
1-3.	*Buccella angulata* Uchio, n. sp. Holotype (U.S.N.M. No. 626806), ×28, ×24, ×24.	67
4, 5.	*Hoeglundina elegans* (d'Orbigny). Hypotypes (U.S.N.M. Nos. 626808-626809), ×21.	
6, 7.	*Epistominella sandiegoensis* Uchio, n. sp. 6, Paratype (U.S.N.M. No. 626813), ×115. 7, Holotype (U.S.N.M. No. 626812), ×94.	68
8-10.	*Epistominella smithi* (R. E. and K. C. Stewart). Hypotypes (U.S.N.M. Nos. 626815-626817), ×47, ×49, ×46.	
11, 12.	*Cassidulina bradshawi* Uchio, n. sp. 11, Holotype (U.S.N.M. No. 626818), ×96. 12, Paratype (U.S.N.M. No. 626819), ×101.	68
13-14.	*Cassidulina braziliensis* Cushman. Hypotypes (U.S.N.M. Nos. 626821, 626822), ×38.	
15, 16.	*Cassidulina subcarinata* Uchio, n. sp. 15, Holotype (U.S.N.M. Nos. 626827), ×94. 16, Paratype (U.S.N.M. No. 626828), ×96.	68
17.	*Cassidulina delicata* Cushman. Hypotype (U.S.N.M. No. 626823), ×94.	68
18, 19.	*Cassidulina depressa* Asano and Nakamura. Hypotypes (U.S.N.M. Nos. 626824, 626825), ×103, ×100.	68
20.	*Cassidulina limbata* Cushman and Hughes. Hypotype (U.S.N.M. No. 626826), ×46.	
21.	*Cassidulina subglobosa* Brady. Hypotype (U.S.N.M. No. 626830), ×94.	
22.	*Cassidulina subglobosa* var. *quadrata* Cushman and Hughes. Hypotype (U.S.N.M. No. 626831), ×108.	
23.	*Cassidulina tortuosa* Cushman and Hughes. Hypotype (U.S.N.M. No. 626832), ×38.	69
24-27.	*Cassidulinoides waltoni* Uchio, n. sp. 24, Holotype (U.S.N.M. No. 626833), ×37. 25-27, Paratypes (U.S.N.M. Nos. 626834-626836), ×38, ×38, ×37.	69
28-31.	*Ehrenbergina compressa* Cushman. Hypotypes (U.S.N.M. Nos. 626838-626841), ×46, ×46, ×48, ×47.	



Uchio: Living Foraminifera, San Diego, California



Uchio: Living Foraminifera, San Diego, California

Oceanography, Bull., Tech. Ser., vol. 1, no. 10, p. 136 (part).

In the San Diego specimens the side view of young forms is broadly triangular and very similar to that of *T. abbreviata* d'Orbigny (1846, p. 249, pl. 15, figs. 9-12) but the later portion becomes elongate and the sides nearly parallel as in *T. articulata* d'Orbigny (1846, p. 250, pl. 15, figs. 16-18). The periphery is acute but not keeled, becoming round in the adult form, and is, therefore, more like that of *T. abbreviata* than *T. articulata*. *T. articulata* of Lalicker and McCulloch (1940, p. 118, pl. 13, fig. 3) seems to be the adult form of *T. abbreviata* in the San Diego area, but the size of the figured specimen is smaller than that of the figured *T. abbreviata*. *T. conica* Lalicker and McCulloch (not d'Orbigny, 1839) seems to be the same as their T. *abbreviata* but consists of finer grains. *T. conica* d'Orbigny (1839, p. 143, pl. 1, figs. 19, 20) was originally described from the Recent marine sands near Cuba, and seems to be different from *T. abbreviata* or *T. articulata*. *T. calva* Lalicker (*in* Lalicker and McCulloch, 1940, p. 120, pl. 13, figs. 6a-d) and *T. schencki* Lalicker and McCulloch (not Cushman and Valentine, 1930) (1940, p. 140, pl. 16, fig. 23) seem to be the adult form of *T.* sp. cf. *T. abbreviata* in the San Diego area. The Recent distributions of *T. abbreviata*, *T. articulata* and *T. conica*, all of Lalicker and McCulloch, are all about the same, in the shallow waters of southern California to the northern part of South America.

Cushman's specimens referred to *T.* sp. cf. *T. abbreviata* became the types of *T. schencki* Cushman and Valentine. The writer has examined 9 specimens which were collected 2½ miles south of the Scripps Institution's pier at a depth of 200-210 feet, and identified as *T.* cf. *abbreviata* by Cushman (deposited at the Scripps Institution of Oceanography); 8 specimens are conspecific with *T.* sp. cf. *T. abbreviata*, and the other is conspecific with *T. schencki*.

Textularia sandiegoensis Uchio, n. sp.
Plate 2, figure 12

Test minute, very elongate, straight or slightly curved, oval in cross section, early chambers close coiled with the initial end rounded, later ones biserial, consisting of very fine grains and chitinous cementing matter, very fragile, easily broken, about 5 or 6 times longer than broad, sides nearly parallel; periphery slightly lobulate; sutures oblique, slightly depressed when wet, but distinctly so when dried; chambers about 1½ times as broad as high, slightly inflated when wet, smooth except at the lower margins which are slightly thickened, gradually increasing in size as added except in the later portion; aperture a narrow slit at the base of the apertural face of the last chamber.

Holotype (U. S. N. M. No. 626623) from station SD-250 (Lat. 32° 30.9′ N., Long. 117° 20.4′ W.; 390 fathoms). Length *ca.* 0.27 mm.; width *ca.* 0.07 mm.

Comparison.—This species is similar to *T. praelonga* Schwager (1866, p. 252, pl. 7, fig. 104), which was originally described from the Pliocene of Kar Nicobar in the Indian Ocean, but differs from it in having a much smaller (about ⅛ the length), more compressed, smoother test and a less lobulate periphery.

Textularia schencki Cushman and Valentine
Plate 2, figure 11

Textularia schencki CUSHMAN and VALENTINE, 1930, Dept. Geol. Stanford Univ., Contr., vol. 1, no. 1, p. 8, pl. 1, fig. 3.

Textularia cf. *abbreviata* CUSHMAN (not d'Orbigny 1846), 1927, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, no. 10, p. 136 (part).

In their original description of *T. schencki*, Cushman and Valentine included *T.* cf. *T. abbreviata* Cushman as a synonym, and said that this species occurred abundantly off La Jolla. This was later designated as the type locality of *T. schencki* by Lalicker and McCulloch (1940, p. 140). The writer has exam-

EXPLANATION OF PLATE 10

FIGS.		PAGE
1-3.	*Cibicides fletcheri* Galloway and Wissler. Hypotype (U.S.N.M. No. 626842), ×29.	
4-6.	*Cibicides mckannai* Galloway and Wissler. Hypotypes (U.S.N.M. Nos. 626843-626845), ×31.	
7-10.	*Cibicides phlegeri* Uchio, n. sp. 7-9, Paratypes (U.S.N.M. Nos. 626846-626848), ×162, ×171, ×159. 10, Holotype (U.S.N.M. No. 626849), ×156.	69
11-13.	*Cibicides spiralis* Natland. Hypotypes (U.S.N.M. Nos. 626851-626853), ×46.	
14-16.	*Hanzawaia nitidula* (Bandy) Hypotypes (U.S.N.M. Nos. 626855-626857), ×30, ×30, ×31.	70
17.	*Laticarinina pauperata* (Parker and Jones). Hypotype (U.S.N.M. No. 626858), ×30.	
18-21.	*Chilostomella ovoidea* Reuss. Hypotypes (U.S.N.M. Nos. 626859-626862), ×43, ×54, ×43, ×41.	
22.	*Pullenia salisburyi* R. E. and K. C. Stewart. Hypotype (U.S.N.M. No. 626864), ×24.	
23-25.	*Eponides leviculus* (Resig) Hypotypes (U.S.N.M. Nos. 626797-626799), ×145, ×155, ×168.	67
26-31.	*Asterigerinata pacifica* Uchio, n. sp. 26-28, Holotype (U.S.N.M. No. 626810), ×171. 29-31, Paratype (U.S.N.M. No. 626811), ×173.	67

ined 9 specimens, which were collected 1½ miles south of the Scripps Institution Pier at a depth of 200-210 feet and identified by Cushman (deposited at the Scripps Institution of Oceanography) and has found that only one specimen can be referred to *T. schencki* (see below), while the other 8 specimens are the same as *T.* sp. cf. *T. abbreviata* as identified by the writer in the San Diego area. The one specimen referrable to *T. schencki* was compared with 12 specimens collected off San Diego, which were in turn compared with the type specimens at the U. S. National Museum by F. L. Parker. According to her (personal communication) these specimens may be *T. schencki,* although they may be a part of a "*T. schencki-T. articulata*" series. The writer has examined specimens identified as *T. articulata* by Parker, and finds that they are conspecific with the adult form of *T.* sp. cf. *T. abbreviata* of the writer. Parker says of them, "They are very close to paratypes of *T. schencki* but not as similar to the holotype." Thus it seems that *T. schencki* has two forms, that is: *T. schencki* (*s.s.*) and the adult form of *T.* sp. cf. *T. abbreviata* of the writer or *T. articulata* of Parker. Little is known at present about the range of variation of *T. schencki.*

T. schencki of Lalicker and McCulloch (1940, pl. 16, fig. 23) is the adult form of *T.* sp. cf. *T. abbreviata* of the writer; however, *T. candeiana* Lalicker and McCulloch (not d'Orbigny) (1940, pl. 13, fig. 7) and *T. aura* Lalicker and McCulloch (1940, pl. 13, fig. 5) are conspecific with *T. schencki* (*s.s.*).

Bigenerina hoeglundi Uchio, n. sp.

Plate 2, figure 13

Textularia bigenerinoides Höglund (not Lacroix), 1947, Zool. Bidrag fran Uppsala, vol. 26, p. 181, pl. 13, fig. 6, text-fig. 159.

Test small, elongate, fusiform, compressed, consisting of fine grains with much cementing matter, surface smooth, rather fragile, broadest part above the middle, tapering gradually towards both ends which are bluntly pointed; chambers biserial but becoming uniserial, very slightly if at all inflated; sutures oblique, slightly depressed but sometimes indistinct; aperture terminal, produced, an elongate oval.

Holotype (U. S. N. M. No. 626625) from station SD-9 (Lat. 32° 37.7′ N., Long. 117° 19.3′ W.; 52 fathoms). Length *ca.* 0.34 mm.; width *ca.* 0.10 mm.

Comparison.—*B. hoeglundi* is similar to *Textularia bigenerinoides* Lacroix (1932, p. 24, text-figs. 27-31), originally described from the Mediterranean (near Cape Martin), but differs from it in having a smoother and more inflated test, a more or less regularly denticulate margin and no distinctly pointed apertural neck. *Textularia* (?) sp. of Cushman and Kellett (1929, p. 3, pl. 1, fig. 4) may be referrable to this new species.

Remarks.—This is a transitional form between *Textularia* and *Bigenerina* in its chamber arrangement but its aperture is that of *Bigenerina.*

Family VERNEUILINIDAE

Gaudryina arenaria Galloway and Wissler

Plate 2, figures 14, 15

Gaudryina arenaria Galloway and Wissler, 1927, Jour. Paleontology, vol. 1, p. 68, pl. 11, fig. 5.

The tests of specimens from deep samples are made of fine sand with silty cementing matter. For this reason their surfaces are smoother than those from shallow samples where coarse sands are available to form tests.

Specimens of the younger stages are triangular in transverse section, while those with later stages become quadrangular.

Family VALVULINIDAE

Eggerella scrippsi Uchio, n. sp.

Plate 2, figure 20

Test small, elongate, tapering, earliest whorl very short with more than three chambers, remainder of test triserial, broadest near the apertural end; chambers inflated, sutures depressed; wall very finely arenaceous with much chitinous material; aperture in a deep depression at the inner margin of the last chamber.

Holotype (U. S. N. M. No. 626632) from station SD-122 (Lat. 32° 32.7′ N., Long. 117° 10.3′ W., 10.5 fathoms). Length *ca.* 0.22 mm.; diameter *ca.* 0.11 mm.

Comparison.—This species is very similar to *E. advena* (Cushman), but differs from it in its much more finely arenaceous test which has a smoother surface. Living specimens of both species are found together in samples but they seem to prefer different types or sizes of material for constructing their tests. When the writer began to count populations he combined both species but later differentiated them, so that they appear in the tables (Part I: Ecology, Tables 1-3, 5-7) either separately or combined.

Karreriella parkerae Uchio, n. sp.

Plate 2, figures 21-23

Test small, a trochoid spiral, later triserial, rarely with a final biserial stage, elongate, usually short, stout, about 1½-2 times as long as broad, tapering to initial end, broadest at apertural end; chambers numerous, distinct, overlapping, inflated particularly in the last few chambers; sutures distinct, depressed particularly near the apertural end, nearly horizontal throughout most of the test; wall finely arenaceous with much cement, smoothly finished, somewhat polished; aperture an elongate opening with a low lip at the base near the middle of, or very slightly above, the base of the apertural face of the last chamber.

Holotype (U. S. N. M. No. 626633) from station

SD-337 (Lat. 32° 38′ N., Long. 117° 31′ W.; 610 fathoms). Length *ca.* 0.48 mm.; breadth *ca.* 0.29 mm.

Comparison.—This species has been identified by many workers as *Eggerella bradyi* (Cushman) or *Karreriella bradyi* (Cushman), which represent two different forms. The writer has examined two topotypes of *Eggerella bradyi* (Cushman) (*Verneuilina pygmaea* Brady, not Egger) through the courtesy of C. G. Adams of the British Museum (Natural History), London. They are identical to Brady's type figure. *K. parkerae* differs from *E. bradyi* in its much smaller test, more globular chambers, and slightly raised apertural lip. The sutures of *K. parkerae* are depressed but flat, while those of *E. bradyi* are depressed. The specimen figured by F. L. Parker (1954, p. 494, pl. 3, fig. 17) is almost identical to *K. parkerae.*

Family MILIOLIDAE

Sigmoilina tenuis (Czjzek)

Plate 3, figures 1, 2

Quinqueloculina tenuis CZJZEK, 1848, Naturw. Abh. Wien, Bd. 2, Abth. 1, p. 149, pl. 13, figs. 31-34.

Spiroloculina tenuissima REUSS, 1867, K. Akad. Wiss. Wien, Nath.-Naturw. Cl., Sitzber., Bd. 55, Abth. 1, p. 71, pl. 1, fig. 11.

Sigmoilina elliptica GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, p. 39, pl. 7, figs. 2a, b.

Sigmoilina tenuis (Czjzek), CUSHMAN, 1946, Cushman Lab. Foram. Research, Contr., vol. 22, p. 32, pl. 5, figs. 13-15; MARKS, 1951, Cushman Found. Foram. Research, Contr., vol. 2, p. 39, pl. 7, figs. 2a, b; PURI, 1953, Florida Geol. Survey, Bull., no. 36, p. 90, pl. 14, figs. 6-8.

Sigmoilina miocenica CUSHMAN, 1946, Cushman Lab. Foram. Research, Contr., vol. 22, p. 33, pl. 5, figs. 19-22.

Sigmoilina cf. *S. miocenica* WALTON, 1955, Jour. Paleontology, vol. 29, p. 1015, pl. 100, figs. 22, 23.

Cushman and Marks considered *S. tenuissima* to be a synonym of *S. tenuis*. Cushman says that *S. elliptica* is very similar to *S. tenuis*, and Recent specimens from the Pacific also are close to *S. tenuis*. He described *S. miocenica* from the Miocene of Florida, but Puri (1953), in his Miocene study of the Florida Panhandle, included Cushman's figure of *S. tenuis* (1929, pl. 12, figs. 12-14), which was later included in *S. miocenica*, as a synonym of *S. tenuis*. According to Cushman *S. miocenica* differs from *S. tenuis* in the relatively broader, more strongly sigmoid test, much less developed apertural neck, and the broader chambers. The young stages resemble *S. tenuis* very much. The writer has examined many specimens at station SD-290 (550 fathoms, dead specimens) off San Diego, which according to Cushman are close to *S. tenuis*, and has found that they show a wide range of variation, having weakly to strongly sigmoid tests, tests varying in width, and necks of varying length. Therefore, *S. miocenica* Cushman is within the range of variation of *S. tenuis*.

Spiroloculina fragilis Uchio, n. sp.

Plate 3, figures 5, 6

Test minute, fragile, less than twice as long as broad, slightly depressed in the central portion, periphery rounded; chambers very distinct, numerous, narrow, arched, tubular, earlier ones very narrow, later ones gradually increasing in size and thickness as added; the successive coils separated or loosely connected by deeply depressed sutures; apertural end projecting, but becoming extended out beyond the normal line of coiling in the larger specimens because of the loose connection between successive coils. Sutures distinct, very strongly depressed in the adult; wall dull white; aperture at the end of a neck, circular, without a tooth, with a lip.

Holotype (U. S. N. M. No. 626641) from station SD-112 (Lat. 32° 23.4′ N., Long. 117° 28.1′ W.; 635 fathoms). Length *ca.* 0.48 mm.; width *ca.* 0.25 mm.

Comparison.—*S. tenuiseptata* Brady (1884, p. 153, pl. 10, fig. 5, *not* fig. 6) is very similar to this new species. In fact, Brady's fig. 6 may represent it. Cushman and Todd (1944, p. 47) also questioned the identification of figure 6. *S. fragilis* is easily separated from *S. tenuiseptata* by its rounded periphery, smooth wall and smaller size (less than 0.5 mm. in length). It is obvious that Brady included two species in *S. tenuiseptata* because he said that the peripheral edge was square or rounded. His figure 5 shows a square periphery, and figure 6 is not shown in apertural view but seems to be rounded. Brady did not say which specimen was the holotype, but the specimen shown in figure 5 has priority, is well figured, and is referred to as the holotype by Cushman and Todd (1944, p. 53).

Family OPHTHALMIDIIDAE

Cornuspira lajollaensis Uchio, n. sp.

Plate 3, figures 8, 9

Test free, thick, circular in side view, very slightly concave on each side except for the umbilical area which is slightly raised; periphery broadly rounded in edge view; chambers inflated, consisting of a proloculus and a long planispiral coiled tube, with up to 6 whorls (in the megalospheric form), the diameter of the tube almost the same throughout except in the last whorl, which is broader, and the proloculus which is very large and inflated in the megalospheric form, each coil considerably overlapping the previous one for about ⅓ of the width of the tube so that only ⅓ of the width shows the translucent wall with the remainder opaque; spiral suture distinct, mostly flush with the surface, but very slightly depressed between the last two whorls; surface smooth, polished, sometimes showing very weak transverse growth lines; color white.

Holotype (U. S. N. M. No. 626647) from station LJ-4, 75 m. north of La Jolla Cove at 22 fathoms. Diameter *ca.* 0.4 mm.; thickness *ca.* 0.1 mm.

Comparison.—This new species is similar to *C. planorbis* Schultze (1854, p. 40, pl. 2, fig. 21) which was originally described from Recent mud off the coast of Mozambique, southeastern Africa, but differs from it by greater overlapping of the whorls leaving a narrower translucent area in each whorl. Specimens from the Atlantic and the Gulf of Mexico show less overlapping of the whorls resulting in a translucent test, and seem to be identical with *C. planorbis. C. lajollaensis* is also similar to *C. tasmanica* Parr, which was based on six microspheric specimens. The San Diego specimens are all megalospheric forms and, therefore, the species can not be compared directly to *C. tasmanica.* However, *C. lajollaensis* apparently differs from *C. tasmanica* by the greater overlapping of the whorls, the almost flat surfaces, and tbe more broadly rounded periphery.

Family TROCHAMMINIDAE

Trochammina charlottensis Cushman

Plate 3, figures 13, 14

Trochammina charlottensis CUSHMAN, 1925, Cushman Lab. Foram. Research, Contr., vol. 1, p. 39, pl. 6, fig. 4; CUSHMAN and MCCULLOCH, 1939, Allan Hancock Pacific Expeds., vol. 6, no. 1, p. 104, pl. 11, figs. 5, 6.

This species was originally described from Queen Charlotte Sound, off British Columbia, together with *T. pacifica.* The former, according to the original description, differs from the latter in having more curved sutures on the dorsal side, a much less umbilicate ventral side, and a somewhat compressed test. However, the type figure of *T. charlottensis* does not show the apertural view, so one can not compare the degree of compression with that of *T. pacifica. T. pacifica* also has slightly curved sutures on the dorsal side, and can not be easily separated from the type figure of *T. charlottensis* in this respect. In other words, one can not easily separate these species by their original figures. However, Cushman and McCulloch figured *T. charlottensis,* which is distinct from the type figures of both *T. charlottensis* and *T. pacifica* in having a much compressed test, distinctly curved dorsal sutures and a shallow but sometimes round umbilicus in which the earlier whorl can be seen to a small extent. The San Diego specimens are identical with this form.

Trochammina chitinosa Uchio, n. sp.

Plate 3, figures 22, 23

Test free, medium in size for the genus, chitinous, trochoid, dorsal side slightly inflated, ventral side convex, umbilical area rather flat but deeply umbilicate in well preserved specimens; consisting of about two coils besides the proloculus, the last whorl occupying most of the test; chambers somewhat inflated, usually 6, sometimes 6½ or 7 in the last whorl, increasing very rapidly in size as added; sutures slightly depressed, straight or very slightly curved on both sides; periphery rounded in edge view; aperture a narrow slit at the base of the apertural face of the last chamber. Color light brown. Length up to *ca.* 0.28 mm.; width *ca.* 0.21 mm.

Holotype (U. S. N. M. No. 626655) from station SD-265 (Lat. 32° 23.2′ N., Long. 117° 19.5′ W.; 350 fathoms). Length *ca.* 0.28 mm.; width *ca.* 0.21 mm.

Remarks.—This species has almost no possibility of being preserved as fossil or in Recent dried sediments. The only form that can be compared to it is the specimen figured by Rhumbler (1911, pl. 25, fig. 6, "*T. perforata*" *nom. nud.*).

Trochammina discorbinoides Uchio, n. sp.

Plate 3, figures 18, 19

Test free, small, trochoid, finely arenaceous, surface smooth, not polished, consisting of 5 whorls, all visible from the dorsal side, only the last one from the ventral side, dorsal side moderately convex, ventral side depressed, umbilicus very deep; periphery narrowly rounded in edge view, lobulate in side view; chambers somewhat inflated, elongate, somewhat rectangular in dorsal view, nearly triangular on ventral view, 4 in the last whorl; sutures distinct, depressed, nearly radial on both sides; aperture a narrow slit at the base of the apertural face of the last chamber. Diameter up to *ca.* 0.18 mm.

Holotype (U. S. N. M. No. 626657) from station SD-220 (Lat. 32° 30′ N., Long. 117° 20.7′ W.; 128 fathoms). Diameter *ca.* 0.14 mm.

Comparison.—This new species is similar to *T. discorbis* Earland (1934, p. 104, pl. 3, figs. 28-31), which was originally described from the Recent sediments of the Falkland sector of the Antarctic region, but differs from it in having a lower spiral test, radial sutures on the dorsal side, a narrowly rounded periphery and a much deeper umbilicus.

Trochammina kellettae Thalmann

Plate 3, figures 20, 21

Trochammina peruviana CUSHMAN and KELLETT (not W. Berry, 1928), 1929, U. S. Natl. Mus., Proc., vol. 75, art. 25, p. 4, pl. 1, figs. 8a, b.

Trochammina kellettae THALMANN, 1932, Eclog. Geol. Helv., vol. 25, no. 2, p. 313.

The test of this species has an excess amount of cementing or chitinous material and when dried usually shrinks, or sometimes collapses completely. For this reason the description and figures of dried specimens do not always, or perhaps in most cases, represent the true character of the species. This is one of the *Trochammina squamata* group which includes about nine species, eight of which were discussed in detail by Rhumbler (1938) and Höglund (1947).

Living specimens of this species do not stain well with rose Bengal because the test is so compressed that the amount of protoplasm contained in it is very small; since the color of the test is brownish the red color of the stain does not show clearly. The result is that the distribution of living specimens appears to be from all depths in the area studied, but some specimens may have been wrongly identified as living. According to Walton (1955) living specimens of this species are limited to shallow water.

Trochammina labiata Uchio, n. sp.

Plate 3, figures 15-17

Test free, trochoid, spire very low, dorsal side almost flat, ventral side somewhat flat but umbilicus very deep, consisting of 3 whorls besides the proloculus, the last whorl occupying about ¾ of the dorsal surface; periphery broadly rounded in edge view, lobulate in side view; chambers inflated, 4-5 in the last whorl, increasing rapidly in size as added; sutures distinct, depressed, nearly straight and nearly radial or slightly oblique on the dorsal side, radial and nearly straight or slightly curved on the ventral side; wall finely arenaceous with much cement, smooth, not polished; aperture a narrow slit at the base of the apertural face of the last chamber, extending from the umbilicus almost to the periphery, with a distinct lip. Length up to *ca.* 0.18 mm.; width up to *ca.* 0.15 mm.

Holotype (U. S. N. M. No. 626663) from station SD-297 (Lat. 32° 28.3′ N., Long. 117° 26.1′ W.; 560 fathoms). Length *ca.* 0.17 mm.; width *ca.* 0.15 mm.; thickness *ca.* 0.09 mm.

Comparison.—This new species is easily distinguished from others of the genus by the characters described above, particularly the distinct apertural lip and very finely arenaceous, smooth, unpolished test.

Trochammina pacifica Cushman

Plate 3, figures 26, 27

Trochammina pacifica CUSHMAN, 1925, Cushman Lab. Foram. Research, Contr., vol. 1, p. 39, pl. 6, figs. 3a-c.

Trochammina pacifica Cushman var. *simplex* CUSHMAN and MCCULLOCH (not Friedberg 1902), 1939, Allan Hancock Pacific Expeds., vol. 1, no. 1, p. 104, pl. 11, fig. 4.

Trochammina pacifica Cushman var. *simplissima* CUSHMAN and MCCULLOCH, 1948, Cushman Lab. Foram. Research, Contr., vol. 24, p. 76.

Cushman and McCulloch say that *T. simplissima* has a smaller test than the typical form, *T. pacifica.* It is not, however, a variety of *T. pacifica*, but a young form, and has been included in the population counts of *T. pacifica.*

Trochammina rhumbleri Uchio, n. sp.

Plate 5, figures 18-20

Test free, small for the genus, trochoid, dorsal side slightly inflated, ventral side slightly depressed, umbilicate, consisting of 2½ whorls; periphery lobulate in side view, rounded in edge view; chambers somewhat inflated, 4½ or 5 in the last whorl; sutures slightly depressed, curved on dorsal side, radial and almost straight on the ventral side; wall consisting of chitinous material which collapses when dried; aperture a narrow slit at the base of the apertural face of the last chamber. Diameter up to *ca.* 0.17 mm.

Holotype (U. S. N. M. No. 626670) from station SD-35 (Lat. 32° 39.5′ N., Long. 117° 21.2′ W.; 104 fathoms). Length *ca.* 0.16 mm.; width *ca.* 0.14 mm.

Comparison.—This new species is chitinous and there is probably little chance of its being preserved as fossil, even in dried Recent sediments. The only comparable form is "*Haplophragmium nana* Brady var. *truncatulinoides* Rhumbler" (1911, pl. 24, fig. 15), which is a *nomen nudum* according to the Rules of Zoological Nomenclature. Rhumbler's figure is almost identical to the San Diego form but there is no way of confirming this identity since there is no description.

Tritaxis bullata (Höglund)

Plate 5, figures 23, 24

Trochamminella bullata HÖGLUND, 1947, Zoologiska Bidrag fran Uppsala, vol. 26, p. 213, pl. 17, fig. 5, text-figs. 194, 195.

The San Diego specimens are identical to the Höglund species except that they sometimes have a higher spire. In the population counts this species included *Trochammina* cf. *T. inconspicua* Earland because of the similarity of the two, both having a very small, globose test with 4 chambers in the last whorl. Both are deep water forms.

Arenoparrella oceanica Uchio, n. sp.

Plate 5, figures 25-27

Test small, nearly circular in outline, compressed, trochoid, ventral side more inflated than the dorsal side which is almost flat; periphery moderately rounded, all chambers visible from the dorsal side and only those of the last whorl from the ventral side which is umbilicate, chambers very slightly inflated, consisting of equidimensional, fine-grained sands, usually six in the last whorl; sutures depressed on both sides, oblique and almost straight on the dorsal side, radial on the ventral side; aperture a slit-like opening at the base of the last chamber extending from the periphery about half way to the umbilicus, its long axis oriented approximately parallel to the plane of coiling. Diameter up to *ca.* 0.13 mm.

Holotype (U. S. N. M. No. 626674) from station SD-240 (Lat. 32° 30′ N., Long. 117° 16.1′ W.; 40 fathoms). Diameter *ca.* 0.13 mm.

Comparison.—Only one other species belonging to this genus is known, *A. mexicana* (Kornfeld). *A. mexicana* is limited to a brackish marsh environment or to bays near marsh. *A. oceanica* differs from it in its smaller size (about one half), less inflated chambers, more coarsely arenaceous test, oblique sutures on the dorsal side, and the absence of an apertural lip.

Remarks.—According to the emended description of Andersen (1951, p. 96), this genus has supplementary openings at the apex of the final chamber. The writer has examined many specimens of the type species, *A. mexicana,* from Rockport, Texas, but none of them has supplementary openings, nor are they seen in *A. oceanica.*

The test of *A. oceanica* is fragile and usually collapses when dried so that it looks almost flat on both sides and the sutures are not distinct.

Family POLYMORPHINIDAE

Genus **Paradentalina** Uchio, n. gen.

Type species: *Paradentalina muraii* (Uchio)
= *Enantiodentalina muraii* Uchio

Test calcareous, elongate, subcylindrical, straight or slightly arcuate, chambers alternating in the early portion, uniserial in the adult and less embracing, sutures very oblique; aperture terminal, radiate, slightly projecting. Cretaceous to Recent.

Remarks.—The type species of *Enantiodentalina* Marie, 1941, is *Dentalina communis* d'Orbigny, which is also the type species of *Dentalina,* 1826. There has been some confusion about the type species of *Dentalina.* Jones (1883, p. 241) designated *Nodosaria (Dentalina) communis* d'Orbigny as the type species. Cushman (1948, p. 215) and Galloway (1933, p. 246) adopted *N. (D.) obliqua* d'Orbigny (designated by Galloway and Wissler, 1927). *N. communis,* however, has priority over *N. obliqua* as the type species of *Dentalina,* and *Enantiodentalina* becomes a synonym of *Dentalina.*

There is confusion about *Dentalina communis* d'Orbigny. D'Orbigny's *Dentalina communis* was described from Recent sediment of the Adriatic Sea, and has a uniserial series of chamber arrangement throughout, while Marie's *D. communis* d'Orbigny, which is the type species of *Enantiodentalina,* was described from the Cretaceous of France, and is biserial in the early portion and uniserial in the later portion, and thus can not be the same species as d'Orbigny's. The writer proposes a new genus for the forms which were referred to *Enantiodentalina.*

Paradentalina muraii (Uchio)

Plate 4, figure 2

Enantiodentalina muraii Uchio, 1953, Japanese Jour. Geology Geography, vol. 23, p. 152, pl. 14, figs. 1, 2.

This species was originally described from the Plio-Pleistocene of Japan, and was later found in the late Pleistocene of Japan. No living specimens have been found in the area studied. Clean tests of this species are found at 41, 56 and 64 fathoms at a very low frequency. The writer also has found 3 specimens from Recent sediments of the northeastern Gulf of Mexico at 47 fathoms. Therefore, this species seems to be limited to depths ranging from about 40 to 65 fathoms.

Family NONIONIDAE

Nonion lankfordi Uchio, n. sp.

Plate 4, figures 5-8

Test small, nearly circular in side view, umbilical area deeply depressed with its margin limbate and flush with the surface or slightly raised; wall moderately perforate, not thick; periphery broadly rounded; chambers distinct, inflated, about 8 in the last whorl, increasing in size as added; sutures limbate, flush with the surface in the early portion but depressed, slightly curved in the later portion; aperture a low arched opening at the base of the apertural face of the last chamber extending to the umbilical area.

Holotype (U. S. N. M. No. 626685) from station SD-287 (Lat. 32° 27.7′ N., Long. 117° 19.1′ W.; 50 fathoms). Length *ca.* 0.20 mm.; width *ca.* 0.16 mm.

Comparison.—This species is similar to *N. pacificum* (Cushman) (1942, p. 48, pl. 16, fig. 3) which was originally described from the Island of Samoa, Pacific, but differs from it by having limbate sutures and a limbate umbilical margin.

Nonion parkerae Uchio, n. sp.

Plate 4, figures 9, 10

Nonion umbilicatula (Montagu) var. *pacifica* Cushman (not Cushman, 1942), 1927, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, no. 10, p. 149, pl. 2, fig. 5.

Test small, compressed, nearly circular in side view; wall coarsely perforate, thick, umbilical area deeply depressed with its margin limbate, slightly raised; periphery narrowly rounded in edge view, lobulate in later portion in side view; chambers distinct, slightly inflated, slightly compressed near periphery, about 13 in the last whorl, increasing regularly in size as added; sutures strongly limbate, slightly curved; aperture a low arched slit at the base of the last chamber extending toward the umbilical area.

Holotype (U. S. N. M. No. 626687) from station SD-337 (Lat. 32° 38′ N., Long. 117° 31′ W.; 610 fathoms). Length *ca.* 0.39 mm.; width *ca.* 0.31 mm.

Comparison.—This new species is similar to *Nonion pacificum* Cushman but differs from it by having more chambers in the last whorl, limbate sutures, and a narrowly rounded periphery. It is very similar to *N. barleeanum* (Williamson), which was originally described from the vicinity of the British Isles. The writer has examined 16 specimens of *N. barleeanum* from the southwest of Ireland (N. Lat. 51° 12′, W. Long. 11° 55′, in 661-680 fathoms) and has found that the periphery of that species is rounded and lobulate, the test less coarsely perforate, and the sutures limbate and generally flush with the surface, rarely very slightly raised. *N. parkerae* has a lobulate periphery and less inflated chambers, particularly near the periphery, limbate and raised sutures, and a more coarsely perforate and rough surface. *N. affinis* (Reuss), which was originally described from the Oligocene of Hermsdorf, near Berlin, Germany, has a test which is slightly longer than broad, a broadly rounded and non-lobulate periphery, fewer chambers in the last whorl and slightly depressed and gently curved sutures.

Nonionella basispinata (Cushman and Moyer)

Plate 4, figures 13, 14

Nonion pizarrensis Berry var. *basispinata* CUSHMAN and MOYER, 1930, Cushman Lab. Foram. Research, Contr., vol. 6, p. 54, pl. 7, fig. 18.

The number of chambers in the last whorl is not given in the original description. The figured specimen (holotype ?) has 12 chambers; its greater diameter or length is *ca.* 0.72 mm., and it has a narrowly rounded periphery (The figure in Ellis and Messina's *Catalogue of Foraminifera* has a sharply angular periphery and is a poor reproduction of the original figure). The type specimens were described from off San Pedro at 35-50 fathoms. The San Diego specimens show a wide range of variation. Young specimens have 10 chambers, but the adult (maximum size up to *ca.* 0.96 mm.) specimens usually have 14, rarely 15, chambers in the last whorl. Cushman and Moyer's figured specimen is larger but has fewer chambers in the last whorl, therefore the San Diego specimens can be considered as a subspecies. But it is necessary to determine the range of variation by studying many specimens from off San Pedro in order to determine whether or not the San Diego forms are a new subspecies.

The empty tests at station SD-3 are more inflated and have fewer (*ca.* 10) chambers in the last whorl. They are identical to *N. atlantica* Cushman (1947, p. 90, pl. 20, figs. 4, 5). The writer has examined 16 topotypes of *N. atlantica* deposited at the Scripps Institution of Oceanography and has found that they have about 10-11 chambers in the last whorl, and that most of them have a more inflated test, although a few have compressed tests. Such compressed forms are identical with the original figure of *N. basispinata*. From the above-mentioned facts it may be concluded that *N. atlantica* was present in the San Diego area during the Pleistocene, and that after the Panama Isthmus emerged *N. basispinata* developed from *N. atlantica*. *N. basispinata*, however, was described earlier than *N. atlantica*, therefore, *N. atlantica* is a subspecies of *N. basispinata*.

Nonionella stella Cushman and Moyer

Plate 4, figures 15, 16

Nonionella miocenica Cushman var. *stella* CUSHMAN and MOYER, 1930, Cushman Lab. Foram. Research, Contr., vol. 6, p. 56, pl. 7, figs. 7a-c.

Nonionella pulchella HADA, 1931, Tohoku Imp. Univ. Sci. Rept., ser. 4, Biology, vol. 6, p. 120, fig. 79 (in text).

Nonionella basiloba CUSHMAN and MCCULLOCH, 1940, Allan Hancock Pacific Expeds., vol. 6, no. 3, p. 18, fig. 3.

Nonionella opima CUSHMAN, 1947, Cushman Lab. Foram. Research, Contr., vol. 23, p. 90, pl. 20, figs. 1-3.

The writer has examined *N. miocenica* collected from the Upper Miocene siltstone at station SD-61. It is quite different from *N. stella* in having more inflated chambers, deeply depressed sutures, and more chambers in the last whorl. *N. stella* is not a variation nor a subspecies of *N. miocenica*.

N. stella has a wide range of morphological variation. The number of chambers in the last whorl varies from 7 to 9, usually 8. In typical *N. pulchella* the more chambers there are in the last coil, the longer and narrower they are, while the opposite is true of typical *N. stella*. The writer has examined many specimens from fine sands off Kushiro, Hokkaido, which is close to the type locality of *N. pulchella*, and from Yokosuka Harbor in Tokyo Bay, and has found that in every instance *N. stella* grades into *N. pulchella*. The stellate character of the inner end of the last chamber on the ventral side is quite variable. The young form has a very round lobe, smaller in proportion to the size of the test; the young adult specimen has a larger but non-stellate lobe; the adult specimen has a large lobe with finger-like processes over the previous sutures as found in typical *N. stella* and *N. pulchella*. Occasionally the last chamber becomes extraordinarily inflated with the end of the lobe reaching almost to the base of the test. Such forms are called *N. basiloba* (in the Pacific) or *N. opima* (in the Gulf of Mexico). F. L. Parker (1954, p. 507, pl. 6, figs. 10-12) showed such variation in *N. opima*. In the San Diego area the *N. basiloba* stage is smaller than typical *N. stella*.

This species occurs from shallow to deep water, but the typical forms are found in fine sands of shallow water.

Nonionella (?) fragilis Uchio, n. sp.

Plate 4, figures 19-21

Test free, small for the genus, biconvex, translucent, fragile; periphery broadly rounded in edge view, lobulate in side view; chambers usually 6-7 in the last whorl, rapidly increasing in size and inflation as added, last chamber slightly extended toward the umbilical area; sutures very distinct, deeply depressed, often with a narrow opening like a sutural supplementary aperture developed along the inner side of the sutures and spiral suture; wall very thin, very finely perforate; aperture a wide crescentic opening at the base of the apertural face of the last chamber, extending to the umbilical area.

Holotype (U. S. N. M. No. 626695) from station SD-337 (Lat. 32° 38′ N., Long. 117° 31′ W., 610 fathoms). Length *ca.* 0.23 mm.; width *ca.* 0.18 mm.; thickness *ca.* 0.10 mm.

Comparison.—This species is very easily distinguished from all the previously described ones by its deeply depressed sutures and sutural openings between chambers and whorls. It may belong to a new genus, but the writer prefers to wait until more similar species are known. Its general shape and structure resemble *Valvulineria,* but the aperture is closed off by the umbilical lobe.

Family ELPHIDIIDAE

Elphidium spinatum var. **translucens** Natland

Plate 4, figures 23, 24

Elphidium translucens NATLAND, 1938, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 4, no. 5, p. 144, pl. 5, figs. 3, 4.

According to the original description, this species has 12 to 13 chambers in the last whorl, but the many specimens examined by the writer have 9 to 12, usually 9 or 10. This form grades into *E. spinatum* Cushman and Valentine (1930, p. 21, pl. 6, figs. 1, 2) at the same localities, but is more common than the latter. Since *E. spinatum* has priority over *E. translucens,* the latter should be called a variety of the former, although the latter is the normal form and the former is the variant.

Family CERATOBULIMINIDAE

Alliatina and *Robertinoides* are here tentatively placed in this family, though there are some different opinions (*see* J. C. Troelsen, 1954).

Alliatina primitiva (Cushman and McCulloch)

Plate 4, figures 27, 28

Cushmanella primitiva CUSHMAN and MCCULLOCH, 1940, Allan Hancock Pacific Expeds., vol. 6, no. 3, p. 163, pl. 18, figs. 6-8, 10.

The test of this species is aragonitic and very thin and fragile. Therefore, the species is very rare in dried samples, though not rare in wet samples used for population counts of living specimens. In almost all cases the supplementary chambers are broken and consequently there is a large opening at the base of the apertural face of the last primary chamber.

Robertinoides charlottensis (Cushman)

Plate 4, figure 29

Cassidulina charlottensis CUSHMAN, 1925, Cushman Lab. Foram. Research, Contr., vol. 1, p. 41, pl. 6, figs. 6, 7.

Robertina californica CUSHMAN and PARKER, 1936, *ibid.,* vol. 12, p. 97, pl. 16, fig. 14.

Höglund described *Robertinoides* which differed from *Robertina* d'Orbigny, 1846, in having a supplementary aperture at the base of the apertural face, which was believed not to be present in *Robertina.* F. L. Parker (1952, p. 416) discussed the relationship of the two genera.

The differentiation of species of this group is difficult, because they never occur abundantly and the range of variation within a species is not known. Therefore, it appears that more than one species has been erected for what in reality is one. Walton's figures of *Robertina charlottensis* (1955, p. 1014, pl. 102, figs. 11, 12) are identical to the young form of the San Diego specimens but do not show a supplementary aperture. *Robertina austriaca* Cushman and McCulloch (not Reuss) (1948, p. 240, pl. 29, figs. 9a-c) is also very close to the young form of the San Diego specimens but again has no supplementary aperture. Their figured specimen seems to be different from figured specimens of *Robertina austriaca* Reuss (Cushman and Parker, 1947, p. 73, pl. 18, figs. 8, 22) from the Miocene of the Vienna Basin.

Robertinoides charlottensis (Cushman) was originally described from Queen Charlotte Sound, British Columbia in 20-25 fathoms and *R. californica* (Cushman and Parker) was from the Pliocene of Santa Barbara, California (also reported from Timms Point, San Pedro, Calif.). The adult form of the San Diego specimens is identical to *R. californica.* Cushman and Parker (1947, p. 74) said that *R. californica* was related to, and probably the ancestral form of, *R. charlottensis.* The present writer believes that they are conspecific, *R. charlottensis* representing an abnormal form and *R. californica* a normal form. Loeblich and Tappan (1953, p. 109) examined holotypes and paratypes of the two species and concluded that they were conspecific.

The specimen figured by Cushman and McCulloch (1948, p. 241, pl. 29, fig. 10) as *Robertina californica* is not referrable to either *Robertina* or *Robertinoides.*

Family BULIMINIDAE

Virgulina apertura Uchio, n. sp.

Plate 6, figure 11

Test very small, inflated, fusiform, both ends gradually tapering, biserial, slightly twisted, about twice as long as broad; chambers numerous, much inflated, increasing very rapidly in size as added, usually the last two chambers occupying *ca.* ¾ - ⅘ of the test, each chamber embracing almost all of the previous chambers; sutures distinct, depressed; wall thin, very finely perforate, translucent; aperture very large, nearly triangular in shape or broadly arched as in *Pleurostomella*, but without teeth at either side of the apertural base.

Holotype (U. S. N. M. No. 626719) from station SD-267 (Lat. 32° 22.8′ N., Long. 117° 20.6′ W.; 615 fathoms). Length *ca.* 0.24 mm.; width *ca.* 0.11 mm.

Comparison.—This new species can easily be distinguished from other species of this genus by its very large aperture and very large *Globobulimina*-like last two chambers.

Virgulina complanata Egger

Plate 6, figure 13

Virgulina schreibersiana Czjzek var. *complanata* EGGER, 1895, Abhandl. k. bay. Akad. Wiss. München, vol. 18, pt. 2, p. 292, pl. 8, figs. 91, 92.

Virgulina davisi CHAPMAN and PARR, 1937, Australasian Antarctic Exped. 1911-1914, Sci. Repts., ser. C, vol. 1, pt. 2, p. 88, pl. 8, fig. 15.

Virgulina concava HÖGLUND, 1947, Zoologiska Bidrag fran Uppsala, vol. 26, p. 257, pl. 23, figs. 3, 4; pl. 32, figs. 4-7; text-figs. 273-275.

Virgulina loeblichi FEYLING-HANSSEN, 1954, Norsk Geol. Tidsskr., Bergen, vol. 33, no. 3-4, p. 191, pl. 1, figs. 14-18; p. 192, text-fig. 3.

Höglund described *V. concava* in detail, but was not sure whether or not his species was a synonym of *V. davisi*. His figures 3 and 4 on plate 23 show the broadest portion to be in the middle of the test, but figures 4-7 and text-figure 273 show it at the apertural end. Feyling-Hanssen shows similar variation in *V. loeblichi*.

The original figure of *V. complanata* is also not complete but the later interpretation of this species seems to be established as shown in the studies of Cushman (1937, p. 26, pl. 4, figs. 14-17, and 13 (?)), Phleger and Parker (1951, pl. 9, figs. 1-3) and Parker (1954, pl. 7, fig. 6). The San Diego specimens are identical to those of *V. complanata* from the Gulf of Mexico and the North Atlantic.

Virgulina delicatula Uchio, n. sp.

Plate 5, figure 4

Test very small for the genus, slightly twisted, triserial stage short, later biserial, elongate, fusiform, tapering toward both ends, sometimes slightly curved, broadest above the middle of the test or near the apertural end, basal end rounded, apertural end pointed, ventral side of initial portion slightly compressed; periphery non-lobulate, rounded; chambers somewhat inflated, increasing somewhat rapidly in size as added; sutures slightly depressed; aperture terminal, broadly loop-shaped; wall thin, very finely perforate, translucent.

Holotype (U. S. N. M. No. 626724) from station SD-250 (Lat. 32° 30.9′ N., Long. 117° 20.4′ W.; 390 fathoms). Length *ca.* 0.30 mm.; width *ca.* 0.09 mm.

Comparison.—This species is closely related to *V. mexicana* Cushman (1922, p. 120, pl. 23, fig. 8), but is much more slender, smaller in size, and has more chambers. *V. delicatula* is also similar to *V. bradyi* Cushman (1922, p. 115, pl. 24, fig. 1), which was originally described from deep water of the western Atlantic, but differs from it in its non-lobulate periphery, less depressed sutures, pointed apertural end, more rapid increase in size, much smaller size (about a half), and thinner, fragile test.

Virgulina sandiegoensis Uchio, n. sp.

Plate 6, figures 17, 18

Test minute, elongate, oval in cross section, broadest near the apertural end, tapering toward the initial end which is rounded and without a spine; chambers inflated, increasing in height and size as added, particularly in the last few chambers, triserial part very short, indistinct, usually 4-6 pairs making up the biserial part; sutures distinct, depressed; periphery slightly lobulate in side view and broadly rounded in edge view; wall of each chamber with a band of clear shell material surrounding a finely perforate and relatively opaque area, the clear shell area iridescent; aperture subterminal, elongately oval.

Holotype (U. S. N. M. No. 626728) from station SD-240 (Lat. 32° 30′ N., Long. 117° 16.1′ W.; 40 fathoms). Length *ca.* 0.26 mm.; width *ca.* 0.07 mm.

Comparison.—This new species has a shape which is transitional between *Bolivina pacifica* Cushman and McCulloch and *Virgulina seminuda* Natland. However, it can be easily distinguished from *V. seminuda* in having the broadest portion near the apertural end, and a slightly lobulate periphery. It differs from *B. pacifica* in having a more inflated and twisted test, a lobulate, broadly rounded periphery, and fewer chambers.

Bolivina peirsonae Uchio, n. sp.

Plate 7, figures 3, 4

Bolivina pygmaea CUSHMAN (not Brady 1881), 1927, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, no. 10, p. 156, pl. 3, fig. 9; CUSHMAN and MCCULLOCH (part), 1942, Allan Hancock Pacific Expeds., vol. 6, no. 4, p. 204, pl. 25, figs. 9-12 (not 8).

Test stout, large, slightly twisted; periphery broadly rounded in edge view, serrate in side view; chambers comparatively few, 15 at maximum, distinct, later ones becoming distinctly inflated and terminated by a distinct short spine at the outer posterior angle, early chambers smooth and more compressed; sutures distinct, greatly depressed especially in the later chambers, wall smooth, very finely perforate, translucent; aperture broadly oval, at the base of the last chamber in the median line.

Holotype (U. S. N. M. No. 626739) from station SD-290 (Lat. 32° 26.3′ N., Long. 117° 22.9′ W.; 550 fathoms). Length *ca.* 0.51 mm.; width *ca.* 0.25 mm.

Comparison.—Cushman and McCulloch included this species with *Suggrunda eckisi* Natland. Only one of their figures (*op. cit.* pl. 25, fig. 8), however, represents that species. *B. peirsonae* can be easily distinguished from it by its much larger test, more inflated chambers which are differently shaped, and much more depressed sutures.

Bolivina subargentea Uchio, n. sp.

Plate 6, figures 21, 22

Bolivina argentea Cushman and McCulloch (not Cushman 1926), 1942, Allan Hancock Pacific Expeds., vol. 6, no. 4, p. 188, pl. 22, figs. 2-4 (not 5); Walton, 1956, Jour. Paleontology, vol. 29, p. 1001, pl. 101, figs. 26, 27.

Bolivina interjuncta Cushman var. *bicostata* Cushman and McCulloch (not Cushman 1926) (part), 1942, Allan Hancock Pacific Expeds., vol. 6, no. 4, p. 195, pl. 23, fig. 15 (not figs. 9-11, 13, 14, 16).

Test usually triangular, elongate, about 2½ to 3 times as long as broad, very much compressed, periphery acute, usually keeled; chambers very distinct, narrow in the young, in the adult about 2½ times as long as broad; sutures oblique and curved, early ones limbate but somewhat depressed; wall very finely perforate, smooth except for the very basal portion which usually has a short spine and one or more weak costae extending from proloculus to the second or third pair of chambers; aperture an elongate, narrow opening occupying the whole area of the apertural face; color light silvery grey, polished. Length up to 1.29 mm.; breadth 0.50 mm.

Holotype (U. S. N. M. No. 626744) from station SD-62 (Lat. 32° 40.9′ W., Long. 117° 26.7′ W.; 247 fathoms). Length *ca.* 1.01 mm.; breadth *ca.* 0.42 mm.

Comparison.—This is one of the characteristic and abundant forms of the western coast of America, and has been wrongly referred by most workers to *B. argentea* Cushman (1926, p. 42, pl. 5, fig. 5). This species, however, differs from it in having a short spine at the basal end and a keeled periphery. The width of the test increases very gradually with growth in the microspheric form, but in the megalospheric form increases slowly after the first few chambers.

Bolivina vaughani Natland

Plate 5, figure 2

Bolivina vaughani Natland, 1938, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 4, no. 5, p. 146, pl. 5, fig. 11.

There are two forms of *Bolivina* which are very similar and may represent juveniles and adults of the same species. The adult specimens are probably referrable to *B. vaughani* although the writer has not been able to compare them with types. Comparative specimens, however, in the Marine Foraminifera Laboratory collection of the Scripps Institution of Oceanography, have been compared with the holotype by Miss F. L. Parker. The smaller specimens, which may represent juveniles, are conspecific with *B. lowmani* Phleger and Parker.

It is difficult to separate *B. vaughani* and *B. lowmani* in wet samples, and for this reason they have been listed together as *B. vaughani* in the population counts (Part I: Ecology, Tables 1-3, 5-7). The writer has examined Walton's (1955) specimens, which are deposited in the Marine Foraminifera Laboratory, and has found that his *B. vaughani* includes two other species, *B. lowmani* and *B. subexcavata* Cushman and Wickenden. Most of his specimens, however, may be referred to *B. vaughani*.

Loxostomum bradyi (Asano)

Plate 7, figure 9

Bolivina beyrichi Brady (not Reuss 1851), 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 422, pl. 53, fig. 1.

Bolivina bradyi Asano, 1938, Geol. Soc. Japan, Jour., vol. 45, p. 603, pl. 16, fig. 2.

Loxostomum instabile Cushman and McCulloch, 1942, Allan Hancock Pacific Expeds., vol. 6, no. 4, p. 221, pl. 27, figs. 15-17; pl. 28, figs. 1-7.

Bolivina bramlettei Cushman and McCulloch (not Kleinpell 1938), 1942, *op. cit.,* p. 189, pl. 22, figs. 7-13.

According to Cushman and McCulloch there is a great deal of variation in this species as was shown by their figures. The San Diego specimens show such variation. Young specimens show a *Bolivina*-like character and are identical with their figures of "*Bolivina bramlettei.*" However, *B. bramlettei* Kleinpell, which was originally described from the Miocene of California, differs from *Loxostomum bradyi* in having a more inflated test and sinuous sutures. *B. bramlettei* is found only in the upper Miocene siltstone at station SD-61 in the Loma Sea Valley.

Globobulimina hoeglundi Uchio, n. sp.

Plate 6, figures 7, 8

Bulimina subaffinis Walton (not Cushman 1921), 1955, Jour. Paleontology, vol. 29, p. 1004, pl. 102, fig. 14.

Test fusiform in side view and circular in end view, apical end sharply pointed but without a spine in the microspheric form and rounded in megalospheric form, broadest part a little above the middle of the test; sutures sometimes slightly limbate but depressed, particularly in the neighborhood of the aperture, nearly horizontal at the base of the chamber; chambers distinct, moderately inflated, the last one extending half way back to the apical end; wall smooth, thin, hyaline, translucent, finely perforate particularly in the last chamber; aperture a loop-shaped opening filled with a somewhat fan-shaped tooth. Length up to *ca.* 0.76 mm. in the microspheric form and 1.0 mm. in the megalospheric form; breadth up to *ca.* 0.36 mm. in the microspheric form and 0.5 mm. in the megalospheric form.

Holotype (U. S. N. M. No. 626714), microspheric form, and paratype (U. S. N. M. No. 626715), megalospheric form, from station SD-337 (Lat. 32° 38′ N., Long. 117° 31′ W.; 610 fathoms). Length *ca.* 0.76 mm.; width *ca.* 0.36 mm.

Comparison.—*Globobulimina* sp. C of Höglund (1947, p. 247, pl. 21, fig. 3; pl. 22, fig. 4; text-figs. 243-246) may be conspecific with this new species. *G.* sp. C was originally described from the Gulf of Mexico, based on 10 specimens of which only one is a microspheric form. This species is also similar to *Globobulimina subaffinis* (Cushman) (1921, p. 166, text-fig. 7), which was originally described from Sogod Bay, southern Leyte, Philippines, in 554 fathoms, but differs from it in having a greater number of chambers, the broadest portion above the middle of the test (at the middle in *G. subaffinis*), and nearly horizontal sutures at the base of the chambers.

Uvigerina auberiana d'Orbigny

Plate 7, figure 11

Uvigerina auberiana D'ORBIGNY, 1839, *in* De la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," vol. 8, p. 106, pl. 2, figs. 23, 24.

Uvigerina ampullacea BRADY, 1884, Rept. Voy. *Challenger,* Zool., vol. 9, p. 579, pl. 75, figs. 10, 11.

Uvigerina proboscidea Schwager var. *vadescens* CUSHMAN, 1933, Cushman Lab. Foram. Research, Contr., vol. 9, p. 85, pl. 8, figs. 14, 15.

The Pacific species is identical with *U. auberiana* found in many parts of the North Atlantic, in the Gulf of Mexico, and at Culebra Island, north of St. Thomas, West Indies. *U. ampullacea* is within the range of variation of *U. auberiana*. *U. proboscidea* var. *vadescens*, although it was described from shallow water (21 fathoms), Guam Anchorage, Ladrone Island, is also within the range of variation. *U. auberiana bella* Bandy (a new name for *U. auberiana laevis* Goës, not Ehrenberg) (1956, p. 199, pl. 31, fig. 13) is probably a synonym of *U. auberiana*.

Uvigerina curticosta Cushman

Plate 7, figures 12, 13

Uvigerina pigmea d'Orbigny var. *curticosta* CUSHMAN, 1927, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, no. 10, p. 157, pl. 4, fig. 1.

Uvigerina peregrina Cushman var. *curticosta* Cushman, TODD (*in* CUSHMAN and MCCULLOCH), 1948, Allan Hancock Pacific Expeds., vol. 6, no. 5, p. 266, pl. 34, figs. 2a, b.

Uvigerina peregrina Cushman var. *dirupta* TODD (*in* CUSHMAN and MCCULLOCH), 1948, *ibid.*, p. 267, pl. 34, figs. 3a-c.

Uvigerina peregrina BANDY (not Cushman 1923), 1953, Jour. Paleontology, vol. 27, no. 2, p. 177, pl. 25, figs. 1a, b.

Uvigerina peregrina was described from Albatross Station D2029 in 1168 fathoms off the northeastern coast of the U. S. A. The writer has compared the Pacific specimens of so called *U. peregrina* with topotypes and many other specimens from many parts of the Atlantic and finds that the Atlantic and Pacific species differ from each other and are quite distinct. The Pacific species has on each chamber fewer but more prominent costae, which are more plate-like than those of the Atlantic species. *U. peregrina* var. *dirupta* Todd is not a variety of *U. peregrina,* but is gradational into *U. curticosta* and is included with that species in the population counts (Part I: Ecology, Tables 1-3, 5-7). However, *U. dirupta* is generally found in deep water and *U. curticosta* in relatively shallow water. Thus the two forms are gradational in morphological character but seem to prefer different environments and are worth separating from the ecological point of view.

Uvigerina peregrina Cushman var. *latalata* R. E. and K. C. Stewart (1930, p. 66, pl. 8, fig. 7) may be conspecific with *U. curticosta.*

Uvigerina juncea Cushman and Todd

Plate 7, figures 15-17

Uvigerina juncea CUSHMAN and TODD, 1941, Cushman Lab. Foram. Research, Contr., vol. 17, p. 78, pl. 20, figs. 4-11.

Uvigerina cushmani TODD (*in* CUSHMAN and MCCULLOCH), 1948, Allan Hancock Pacific Expeds., vol. 6, no. 5, p. 257, pl. 33, figs. 1a, b.

Uvigerina hollicki Thalmann (1950, p. 45) was originally described from off the northeastern coast of the U. S. A. (1781 fathoms) under the name of *U. peregrina* Cushman var. *bradyana* Cushman (not Fornasini 1900) (1923, p. 168, pl. 42, fig. 12). It is different from the form which has been called *U. hollicki* in the Pacific. The latter should be referred to *U. juncea*.

U. cushmani is very variable in its morphological character as was shown in the original figures. The costae are weak and often disappear entirely so that the surface, particularly that of the last few chambers, becomes rather smooth. The fully costate form has been called *U. cushmani*, the gradational form *U. juncea*, and the smooth form *U. hollicki* in the Pacific. Todd says that *U. cushmani* has more prominent costae than *U. juncea*, but it should be taken into account that the latter is a fossil form and its costae may be somewhat worn. The forms which Todd (1948) called *U. bradyana*, *U. senticosa* and *U. hollicki*, and which Bandy (1953) called *U. hollicki*, all seem to be referable to *U. juncea*.

The writer has examined 12 paratypes of *U. senticosa* Cushman deposited at the Scripps Institution of Oceanography. They are large in size, brownish in color, and are probably fossils. This species is quite distinct from *U. juncea*.

In the present study the writer has separated three types of *U. juncea* (costate, intermediate, smooth forms), but the separation is quite artificial and there is no definite boundary between them. Therefore they are combined and listed as *U. juncea* in the tables (Part I: Ecology, Tables 1-3, 5-7).

Angulogerina carinata (Cushman)

Plate 7, figure 19

Angulogerina carinata CUSHMAN, 1927, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, no. 10, p. 159, pl. 4, fig. 3.

Angulogerina carinata Cushman var. *bradyana* CUSHMAN, 1932, Cushman Lab. Foram. Research, Contr., vol. 8, p. 45, pl. 6, figs. 9, 10.

Angulogerina carinata Cushman var. *vana* TODD, 1948, Allan Hancock Pacific Expeds., vol. 6, no. 5, p. 287, pl. 35, fig. 10.

This species is omitted from the tables (Part I: Ecology, Tables 1-3, 5-7) since living specimens have been found at only four stations at depths of 118 fathoms (0.1%), 121 fathoms (0.1%), 125 fathoms (0.1%) and 167 fathoms (1%). They are all typical forms. Dead specimens are found widely but in low frequency in Recent sediments in the San Diego Trough and in Pleistocene sediments. They include both typical and variant forms.

Family DISCORBIDAE

Rosalina campanulata (Galloway and Wissler)

Plate 7, figure 26

Globorotalia campanulata GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, p. 58, pl. 9, fig. 14.

Rotalia versiformis BANDY, 1953, *ibid.*, vol. 27, p. 179, pl. 22, fig. 5.

Rotalia lomaensis BANDY, 1953, *loc. cit.*, pl. 22, fig. 6.

Rotalia spp. WALTON, 1955, *ibid.*, vol. 29, p. 1014, pl. 103, figs. 18, 19, 24.

This species was originally described from the Pleistocene of Lomita Quarry, San Pedro, California, and is variable in its umbilical character as the original authors mentioned "the umbilicus depressed or sometimes with a rounded knob of clear shell material." The writer has examined topotypes of *R. campanulata* and finds that *R. versiformis* and *R. lomaensis* are synonyms of *R. campanulata*.

Rosalina columbiensis (Cushman)

Plate 8, figures 1, 2

Discorbis columbiensis CUSHMAN, 1925, Cushman Lab. Foram. Research, Contr., vol. 1, p. 43, pl. 6, fig. 13.

This species is very variable in its morphological character. The number of chambers in the last whorl is 4-6, usually 5-6. The shape and size are variable, particularly in the last one or two chambers. When the last one or two chambers are irregular, the number of chambers in the last whorl is only 4. A progressively greater size of the perforations on the dorsal side with growth is characteristic.

It is observed in the tide pools north of The Scripps Institution's pier that a few living specimens of *Tretomphalus bulloides* (d'Orbigny) occur together with many specimens of *R. columbiensis*, and the former seems to be a reproductive stage of the latter. This relationship can be ascertained only by culturing the species in a laboratory.

Rosalina sp.

Plate 7, figures 22-25

Discorbis rosacea CUSHMAN and VALENTINE (not *Rotalia rosacea* d'Orbigny 1826), 1930, Dept. Geology Stanford Univ., Contr., vol. 1, no. 1, pl. 6, fig. 5.

Discorbis spp. WALTON, 1955, Jour. Paleontology, vol. 29, p. 1006, pl. 102, figs. 27-29.

Cushman (1931, p. 31) examined many topotypes of "*Rotalia rosacea*" from the Miocene of Bordeaux, France, and concluded that the species was an *Amphistegina*.

This species is variable in its umbilical character as is *R. campanulata*. That is, the umbilical plug is large or small and sometimes even disappears. This species occurs with *R. campanulata* at many stations and is sometimes difficult to distinguish from it. The two species are combined in the population counts and are listed as *R. campanulata* in the tables (Part I: Ecology, Tables 1-3, 5-7).

Gyroidina quinqueloba Uchio, n. sp.

Plate 8, figures 22-25

Test free, small for the genus, nearly circular in side view, trochoid, consisting of 2½ or 3 whorls, all visible on the dorsal side, only the last one on the ventral side; dorsal side slightly convex but more so in the early portion, ventral side strongly convex, umbilicus slightly depressed but usually hidden by the last chamber; periphery broadly rounded in apertural view; chambers inflated, relatively few, usually 5 in the last whorl, increasing rather rapidly in size as added; wall thin, finely perforate; sutures distinct, depressed, very slightly limbate, nearly radial on the dorsal side, nearly radial but slightly curved on the ventral side; aperture an elongate narrow slit at the base of the apertural face of the last chamber midway between the umbilicus and periphery, with a distinct lip.

Holotype (U. S. N. M. No. 626792) from station SD-326 (Lat. 32° 46.3′ N., Long. 117° 31.2′ W.; 385 fathoms). Length *ca.* 0.14 mm.; width *ca.* 0.13 mm.; thickness *ca.* 0.09 mm.

Comparison.—This species is closely related to *Gyroidina umbonata* (Silvestri) (*Rotalia soldanii* d'Orbigny var. *umbonata* Silvestri, 1898, p. 329, pl. 6, fig. 14), which was originally described from the Pliocene of Italy. The writer has examined 11 specimens of *G. umbonata* from the Pliocene of Ponticello, near Bologna, Italy. *G. quinqueloba* differs from *G. umbonata* in its smaller size (*ca.* ½ in diameter), thinner test, much less convex ventral side, less broadly rounded periphery, and shorter aperture (aperture of *G. umbonata* extends from periphery to umbilicus). This species may be a subspecies of *G. umbonata.*

Eponides leviculus (Resig)
Plate 10, figures 23-25

Epistominella levicula Resig, 1958, Micropaleontology, vol. 4, p. 304, text-fig. 16.

Remarks.—Resig considered this species an *Epistominella.* The present writer has examined many specimens and finds that the aperture is a narrow slit with a lip midway between the umbilicus and the periphery, though the test has a slight indentation of the wall of the last septal face which is parallel to the periphery on the ventral side and has, like *Alabamina,* no opening into the interior of the chamber. This species may be an *Alabamina,* whose geologic range has hitherto been limited to the Tertiary, but it has a lip around the aperture and the wall is rather coarsely perforate. Therefore, the writer has tentatively placed it in *Eponides.*

Buccella angulata Uchio, n. sp.
Plate 9, figures 1-3

Test small, trochoid, biconvex with the dorsal side slightly convex and ventral side convex, with a depressed umbilicus, composed of about 3 whorls with 5 (rarely 6) chambers in the last whorl; periphery angular in edge view, rounded and slightly lobulated in side view; sutures on the ventral side depressed, nearly radial, partly covered with opaque pustulose material, those on the dorsal side limbate, slightly depressed or flush with the surface, oblique and slightly curved; aperture at the base of the apertural face of the last chamber on the ventral side with supplementary apertures along the ventral sutures.

Holotype (U. S. N. M. No. 626806) from station SD-50 (Lat. 32° 41.6′ N., Long. 117° 19.6′ W.; 53 fathoms), living when collected. Diameter *ca.* 0.18 mm.

Comparison.—This species is similar to *B. frigida* (Cushman), but differs from it in having fewer chambers in the last whorl, an angular periphery and nearly plano-convex test. This species is also close to *B. inusitata* Andersen, but differs from it in the smaller size of the test and fewer chambers in the last whorl (*B. inusitata* usually has 9 chambers). Furthermore, the megalospheric form of *B. inusitata* has an equally biconvex test and the microspheric form has a nearly flat ventral side and a very convex dorsal side, while *B. angulata* has a nearly flat dorsal side and very convex ventral side.

Asterigerinata pacifica Uchio, n. sp.
Plate 10, figures 26-31

Test small, compressed, very slightly convex on the dorsal side, slightly concave on the ventral side, with secondary plates forming over the apertures and extending to the periphery to form a star-shaped central portion; periphery narrow, rounded in the megalospheric (?) form, acute and keeled in the microspheric (?) form; chambers 6-6½ in the last whorl, increasing gradually in size as added, uninflated in the microspheric (?) form, slightly inflated in the megalospheric (?) form, each secondary plate successively covering the aperture of the previous chamber; sutures on the dorsal side slightly limbate, slightly curved, on the ventral side slightly depressed; wall thin, finely perforate, often translucent; aperture loop-shaped, large, occupying more than half of the last chamber. Maximum diameter 0.15 mm.

Holotype (U. S. N. M. No. 626810), megalospheric (?) form; paratype (U. S. N. M. No. 626811), microspheric (?) form, from station SD-186 (Lat. 32° 31′ N., Long. 117° 18′ W.; 248 fathoms) (empty tests). Diameter of holotype *ca.* 0.13 mm.; paratype *ca.* 0.15 mm.

Comparison.—This species is similar to *A. pulchella* (F. L. Parker) (Parker, 1952, p. 420, pl. 6, figs. 18-20), which was described from shallow sediments in the Atlantic, but differs from it in having fewer chambers (6-6½ in the former, 7-9 in the latter) in the last whorl, in having the secondary plates extending to the periphery (except in young forms) rather than extending only halfway to the periphery as in *A. pulchella,* and in the larger aperture. The microspheric (?) form of this new species is similar to *A. nitidula* (Chaster) which was described from off the coast of England, but differs from it in having fewer chambers (*A. nitidula* has 8 chambers in the last whorl).

Remarks.—There are two forms of this genus in the San Diego area, one with a rounded periphery and the other with a keeled periphery. The number of chambers in the last whorl is the same in both forms, which were found together at three stations (all specimens dead when collected). Therefore, the writer considers the two forms to be conspecific, one megalospheric (?) and the other microspheric (?). Living specimens were found only at shallow depths, 10.5, 13 and 45 fathoms. Dead specimens were found at 9-430 fathoms. The writer has also found the species in Todos Santos Bay, Baja California, Mexico, at a depth of 28 fathoms.

Heminwayina Bermudez, 1951, seems to be a synonym of *Asterigerinata* Bermudez, 1948, though Bermudez says that the aperture of the former is larger than that of the latter and occupies only the basal area of the last chamber. The aperture of *Heminwayina gallowayi* Bermudez is low, arch-shaped, and the species seems to belong to *Asterigerinata*.

Family CASSIDULINIDAE

Epistominella sandiegoensis Uchio, n. sp.

Plate 9, figures 6, 7

Test free, trochoid, biconvex, slightly umbilicate, nearly circular but slightly truncate on the apertural side; periphery narrowly rounded in edge view, slightly lobulate in side view; chambers distinct, numerous, 4 to 6, usually 6, in the last whorl, slightly inflated on the dorsal side, more so on the ventral side; sutures distinct, slightly limbate, flush with the surface but sometimes very slightly depressed, oblique and straight on the dorsal side, slightly curved and very slightly recurved on the ventral side; wall smooth, finely perforate; aperture elongate, narrow, nearly parallel to the periphery.

Holotype (U. S. N. M. No. 626812) from Station SD-265 (Lat. 32° 23.2′ N., Long. 117° 19.5′ W.; 350 fathoms). Length *ca.* 0.21 mm.; width *ca.* 0.18 mm.

Comparison.—This new species differs from *E. bradyana* (Cushman) in having fewer chambers (*E. bradyana* usually has 8) in the final whorl, a less sharply angled periphery, and straight sutures on the dorsal side. It differs from *E. exigua* (Brady) in its smaller size, more rounded periphery, and in having usually 6 chambers in the last whorl (*E. exigua* has 5). It is possible that a study of the types of *E. exigua* will show that *E. sandiegoensis* bears a subspecific relationship to Brady's species.

Remarks.—Natland (1933), Bandy (1953) and Walton (1955) did not record *E. sandiegoensis*. The writer, however, has found many specimens in samples from Sebastian Vizcaino Bay, Mexico.

Cassidulina bradshawi Uchio, n. sp.

Plate 9, figures 11, 12

Test small, nearly circular in side view, lenticular in edge view; periphery rounded, not lobulated; sutures very slightly depressed, nearly straight except near the periphery; chambers usually 4 pairs, but sometimes 5 pairs, in the last coil; wall thin, transparent, hyaline, smooth; aperture an elongate slit following the curve of the previous chamber, with a tooth.

Holotype (U. S. N. M. No. 626818) from station SD-254 (Lat. 32° 30.2′ N., Long. 117° 22.8′ W.; 465 fathoms). Length *ca.* 0.28 mm.; width *ca.* 0.23 mm.

Comparison.—This new species is similar to *C. islandica norvangi* Thalmann (*in* Phleger, 1952, p. 83, pl. 14, fig. 30), but differs from it by having a nonlobulated periphery, less depressed sutures and a thinner wall.

Cassidulina delicata Cushman

Plate 9, figure 17

Cassidulina delicata CUSHMAN, 1927, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 1, no. 10, p. 168, pl. 6, fig. 5.

Cassidulina cushmani R. E. and K. C. STEWART, 1930, Jour. Paleontology, vol. 4, p. 71, pl. 9, figs. 5a, b.

The writer has examined many specimens of this species. Cushman's original figure is not representative and for this reason R. E. and K. C. Stewart described *C. cushmani*, the figures of which are like specimens within the range of variation of *C. delicata*. Both types, together with gradational specimens, have been found together at many stations, but most specimens are of the "*C. cushmani*" type. Some adult specimens have a peripheral keel; many have no keel but a sharply angled periphery.

Cassidulina depressa Asano and Nakamura

Plate 9, figures 18, 19

Cassidulina subglobosa depressa ASANO and NAKAMURA, 1937, Japanese Jour. Geology Geography, vol. 14, nos. 3-4, p. 148, pl. 13, figs. 8a-c.

San Diego specimens have been compared with topotypes from Sematanoseki, Shito-mura, Chiba-ken, Japan, and found to be conspecific, although they are a little smaller.

It is difficult to separate this species from young forms of *C. californica*. *Cassidulina subglobosa* var. *subcalifornica* Drooger (1953, p. 140, pl. 22, figs. 8, 9) seems to be a synonym of *C. depressa*.

Cassidulina subcarinata Uchio, n. sp.

Plate 9, figures 15, 16

Cassidulina laevigata WALTON (not d'Orbigny 1826), 1955, Jour. Paleontology, vol. 29, p. 1004, pl. 104, figs. 2, 7.

Test small, biconvex, lenticular in edge view, periphery slightly lobulate, acute with a narrow keel; central umbilical region mostly clear, showing the chambers of the earlier coils; chambers distinct, elongate, 3-4 pairs but usually 4 pairs in the last coil, slightly inflated; sutures distinct, slightly depressed, slightly curved; wall thin, finely perforate, semi-translucent; aperture an elongate, narrow slit parallel to the periphery, with a thin triangular tooth.

Holotype (U. S. N. M. No. 626827) from station SD-290 (Lat. 32° 26.3′ N., Long. 117° 22.9′ W.; 550 fathoms). Length *ca.* 0.21 mm.; width *ca.* 0.18 mm.; thickness *ca.* 0.09 mm.

Comparison.—This new species most closely resembles *C. laevigata* var. *carinata* Silvestri (1896, p. 104, pl. 2, figs. 10a-c) which was described from the Pliocene of Italy. The writer has examined many topotypes from Coroncina, Italy. *C. carinata* has a larger test, more curved sutures, but has not the translucent umbilical area through which chambers of earlier coils are seen, which is characteristic of *C. subcarinata.*

C. subcarinata is similar to *C. neocarinata* Thalmann described from Recent sediments off Florida at 75 fathoms, but differs from it in having a thicker, more coarsely perforate, less translucent wall, and a less distinct keel. Many specimens of *C. neocarinata* from the Gulf of Mexico were studied for comparison.

C. subcarinata is also similar to *C. norcrossi* Cushman (1933, p. 7, pl. 2, figs. 7a-c) and *C. kasiwazakiensis* Husezima and Maruhasi (1944, p. 399, pl. 34, figs. 13a-c) but differs from them in having a tooth in the aperture and differently shaped chambers (*C. norcrossi* and *C. kasiwazakiensis* have wedge-shaped chambers).

Cassidulina tortuosa Cushman and Hughes

Plate 9, figure 23

Cassidulina tortuosa CUSHMAN and HUGHES, 1925, Cushman Lab. Foram. Research, Contr., vol. 1, p. 14, pl. 2, figs. 4a-c.

Cassidulina reflexa GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, p. 80, pl. 12, figs. 13a, b.

Cassidulina wakasaensis ASANO and NAKAMURA, 1937, Japanese Jour. Geology Geography, vol. 14, nos. 3-4, p. 149, pl. 14, figs. 7a-c.

Cassidulina tumida NATLAND, (not *C. laevigata* var. *tumida* Heron-Allen and Earland, 1922), 1938, Scripps Inst. Oceanography, Bull., Tech. Ser., vol. 4, p. 148, pl. 6, figs. 2, 3a, b.

Natland's *C. tumida* is very rare, found only in Pleistocene "Foraminifera sand." It seems to be an irregular variety of *C. tortuosa.*

Cassidulinoides waltoni Uchio, n. sp.

Plate 9, figures 24-27

Cassidulinoides sp. WALTON, 1955, Jour. Paleontology, vol. 29, p. 1005, pl. 104, fig. 1.

Test compressed, elongate, slightly convex on the dorsal side; periphery sometimes slightly lobulated, narrowly rounded; earliest portion closely coiled, later portion uncoiled, biserial; initial end rounded in the megalospheric form; chambers elongate, distinct, narrow, depressed, strongly oblique; wall thin, smooth, polished; aperture large, elongately oval and slightly comma-shaped in a depression of the apertural face.

Holotype (U. S. N. M. No. 626833) from station SD-288 (Lat. 32° 27.2′ N., Long. 117° 20.6′ W.; 140 fathoms). Length *ca.* 0.69 mm.; width *ca.* 0.24 mm.

Comparison.—This new species is similar to *C. simplex* Cushman and Todd (1945, p. 63, pl. 10, fig. 15) in side view but the latter has a cylindrical test and indistinct sutures.

Family ANOMALINIDAE

Cibicides phlegeri Uchio, n. sp.

Plate 10, figures 7-10

Test very small, fragile, convex on the ventral side with a slightly depressed umbilicus, flat or slightly convex on the dorsal side; periphery rounded, and slightly lobulated; chambers inflated, numerous, 7-8, usually 8 in the last whorl, all visible from the dorsal side, only those of the last whorl from the ventral side; sutures on the dorsal side distinct, depressed, oblique, slightly curved, on the ventral side slightly curved; wall thin, translucent, very finely perforate on the ventral side, coarsely perforate on the dorsal side, brownish in color in fresh tests; aperture a narrow slit along the base of the last chamber on the ventral side, extending from near the umbilicus to the periphery. Length up to *ca.* 0.15 mm.; width up to *ca.* 0.12 mm.; thickness up to *ca.* 0.07 mm.

Holotype (U. S. N. M. No. 626849) from station SD-326 (Lat. 32° 46.3′ N., Long. 117° 31.2′ W.; 385 fathoms). Length *ca.* 0.15 mm.; width *ca.* 0.12 mm.

Comparison.—The nearest species is *C. robertsonianus* (Brady). The writer has examined many specimens of *C. robertsonianus* from the Gulf of Mexico and North Atlantic both young and adult, but *C. phlegeri* is much smaller than the young of *C. robertsonianus,* is more compressed and has a thinner wall. The number of chambers in the last whorl of *C. robertsonianus* is variable, 6-13. Both species are deep sea forms.

Rectocibicides miocenicus Cushman and Ponton

Plate 5, figure 6

Rectocibicides miocenicus CUSHMAN and PONTON, 1932, Cushman Lab. Foram. Research, Contr., vol. 8, p. 2, pl. 1, figs. 5-7.

This species was originally described from the Miocene of Florida, but living specimens are found in the San Diego area. They are always attached to shell fragments or pebbles, etc., and, therefore, their depth distribution is limited to shallow water (shallower than 20 fathoms). The shape and size of the tests depend upon those of the substrate to which they are attached. Sometimes many specimens crowd on a small pebble or shell fragment and interfere with each other, resulting in changes in growth direction and shape and size of chambers. Such specimens were found near Cedros Island, Baja California, Mexico.

Hanzawaia nitidula (Bandy)

Plate 10, figures 14-16

Cibicidina basiloba (Cushman) var. *nitidula* BANDY, 1953, Jour. Paleontology, vol. 27, p. 178, pl. 22, figs. 3a-c.

The dorsal side of adult specimens is slightly evolute but that of young specimens is involute. The dorsal sutures are strongly limbate and slightly raised in the early portion of test, later becoming limbate and flush with the surface; later still the sutures become depressed and non-limbate.

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