

CONTRIBUTIONS
FROM THE
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FOR
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FOR FORAMINIFERAL RESEARCH

VOLUME XIV, PART 4, OCTOBER, 1963

268. LARGER LIVING FORAMINIFERA OF THE
CONTINENTAL BORDERLAND OF SOUTHERN CALIFORNIA¹ORVILLE L. BANDY²

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ABSTRACT

Larger living foraminifera were studied in samples from basins and deeper waters of the continental borderland of southern California. Twenty-two species were found which may be grouped into six faunas based upon increasing depth of upper occurrences of each. Two mutually exclusive groups serve to divide the borderland basins into northern (*Globobulimina*) and southern (*Glandulina-Martinottiella*) areas. *Cyclammina cancellata*, *Martinottiella* spp., *Pyrgo* spp., and *Robulus thalmanni* all appear to become larger with increasing depth, pressure, oxygen content, and with decreasing temperature. *Pyrgoella sphaera* has a maximum size about twice that of its largest size in bathyal waters of the Arctic Ocean.

INTRODUCTION

Biologists of the Allan Hancock Foundation have been conducting an intensive study of the larger benthic animals in many of the basins of the continental borderland of southern California (Hartman, 1955, 1956; Hartman and Barnard, 1958) for a number of years. In their approach large samples are taken and the sediment and minute shells are passed through a sieve in order to concentrate and preserve the larger animals for study. Sediment and foraminiferal assemblages have been collected by somewhat different means, using smaller sampling devices and corers. In the concentrating procedures of the biologists, a number of large foraminifera were noted from time to time and they were brought to the attention of the writer. These larger specimens (1.0 mm. and larger) were examined and it was found that from several to more than 100 specimens per sample were retained on the coarse screens used in concentrating the larger animals. This fraction would represent the total specimens from about one fifth or one sixth of a cubic meter of original sediment. Thus, they are extremely rare, amounting to an infinitesimal part of the total foraminiferal assemblage in terms of numbers of specimens. This explains why some of the larger forms have escaped notice in a number of earlier reports (Crouch, 1952; Resig, 1958; Zalesny, 1959; Uchio, 1960).

DISTRIBUTION PATTERNS
OF LARGER FORAMINIFERA

General

A study was made of the larger foraminifera (those exceeding one millimeter in diameter or length) and it was discovered that the basins of the continental

borderland could be grouped together and identified by the larger types of foraminifera living in each. Protoplasmic material was noted in at least some of the specimens of each species, indicating that all of those included in the study are indigenous to the basins indicated. In Table 1, the San Diego Trough, Patton Escarpment, and basins are all listed in order of increasing depth of water from left to right and the larger foraminifera are listed in groups in order of increasing depth of the upper limit of occurrence of each. Six faunal groups are recognized (A-F inclusive). Glass sponge spicules were very abundant in several of the deeper basins (Table 1).

Fauna A

Fauna A is composed of 9 species of larger foraminifera which are most characteristic of San Pedro and Santa Monica basins (text figure 1). These basins have a bottom water temperature of about 5° C., an oxygen content of 0.2-0.3 ml/l, and a salinity of about 34.3 parts per thousand (Emery, 1960). The species are:

- Bolivina spissa* Cushman
- Bulimina affinis* d'Orbigny
- Chilostomella ovoidea* Reuss
- Globobulimina pacifica pacifica* Cushman
- Globobulimina pyrula spinescens* (Brady)
- Planulina ornata* (d'Orbigny)
- Reophax agglutinans* Cushman
- Robulus thalmanni* Hessland
- Valvulineria inaequalis* (d'Orbigny)

To date, no larger specimens of foraminifera have been observed in samples from Santa Barbara basin although a number of biological samples were investigated in addition to those listed in Table 1. The most unique species of Fauna A is *Globobulimina pyrula spinescens* which has not been reported previously from the California area. Another interesting feature is the large size of *Robulus thalmanni*. The maximum size of this species is 1.2 mm. in the shallower basins and as much as 4 mm. in deeper colder waters. Species of *Robulus* on the continental shelf are usually one half of a millimeter or smaller. *Chilostomella ovoidea* is only about 0.6 mm. in length in the inner basins; however, it attains almost three times this dimension in deeper colder waters. A few of the species of Fauna A are mostly restricted to the inner basins and Santa Catalina basin (Table 1, text fig. 1). It is important to note that the *Globobulimina* species of Fauna A

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TABLE 1—Maximum diameters of *larger living bathyal benthonic foraminifera off southern California.

NOTE: ALL SIZES IN MILLIMETERS		SANTA BARBARA BASIN	SANTA MONICA BASIN	SAN PEDRO BASIN	SANTA CATALINA BASIN	SANTA CRUZ BASIN	SAN NICOLAS BASIN	TANNER BASIN	SAN DIEGO TROUGH	WEST CORTES BASIN	EAST CORTES BASIN	PATTON ESCARPMENT	SAN CLEMENTE BASIN	VELERO BASIN
BASIN BOTTOM DEPTH (METERS)		691	938	912	1357	1966	1833	1551		1796	1979		2107	2571
SILL DEPTH		475M	737M	737M	982M	1085M	1106M	1165M		1362M	1415M		1816M	1902M
DEPTH OF SAMPLE									1200M			1610M		
ALLAN HANCOCK FOUNDATION SAMPLES		3504 3731 3733	3020 3411 3412	2332 2333 2364	2169 3026 4742 5935	5925 5926 5927 5928 5929	5116 5931 5933	5120	6090	5939 5940 5941	5942 5943 5944	5938	5945 5946 6089 6090 6091 6092	5947 5948
A	BOLIVINA SPISSA		1.2	1.2										
	BULMINA AFFINIS		1.3	1.5	2.0	---	---	1.2	1.5	1.5	1.5	1.7	1.5	---
	CHILOSTOMELLA OVOIDEA		0.6	---	1.8	1.5	1.5	---	1.6	1.5	1.5	---	2.0	---
	GLOBOBULIMINA PYRULA													
	SPINESCENS		1.3	1.5	1.9	2.0	2.0	1.6					1.5	
	PACIFICA													
	PLANULINA ORNATA		1.8	2.0	1.5									
	REOPHAX AGGLUTINANS		5.0	5.0	3.0									
	ROBULUS THALMANNI		?	1.2	3.0	>2.0	2.5	3.0	3.0	3.0	2.0	4.0	3.0	2.0
	VALVULINERIA INAEQUALIS		1.5	1.7										
B	DENTALINA COMMUNIS				4.5				3.0					
	HOEGLUNDINA ELEGANS				2.0	1.5	2.0	2.0	2.2	2.5	2.0	1.5	2.25	2.5
	PYRGO MURRHINA				1.2		1.5	1.6	1.5	2.0	2.0	1.2	4.0	4.0
	P. RINGENS													
C	CIBICIDES WUELLERSTORFI					1.5	1.5	1.7	1.5	2.0	1.5	1.5		
	CYCLAMMINA CANCELLATA						1.5	-?-	4.0	-?-	-?-	6.0	5.25	4.0
D	GLANDULINA LAEVIGATA								1.6 apic.	1.2 apic.	>1.0 apic.	1.5	1.5 apic.	2.0 apic.
	HAPLOPHRAGMOIDES								1.5					
	MARTINOTTIELLA COMMUNIS													
	OCCIDENTALIS								4.0	4.0	3.5	4.0	>5.0	>5.0
	M. COMMUNIS													
	PALLIDA													
E	LATICARININA PAUPERATA											2.0	2.0	2.0
F	AMMODISCUS PACIFICUS												2.5	3.0
	PYRGOELLA SPHAERA												5.0	>3.0
GLASS SPONGE SPICULES					ABUND.	?	?	?	?	ABUND.	ABUND.	?	ABUND.	ABUND.

*Specimens larger than one millimeter in diameter or length.

define the basins of the northern half of the continental borderland and were not found in the deeper southern ones (text fig. 2, Table 1).

Fauna B

Fauna B is composed of 4 species of larger foraminifera which occur in the outer and central basins but not the shallow nearshore basins (Table 1). Santa Catalina is the shallowest basin of occurrence of Fauna B. This basin has a bottom water temperature of about 4.02° C., an oxygen content of about 0.4 ml/l, and a salinity of 34.42 parts per thousand (Emery, 1960). The species are:

- Dentalina communis* d'Orbigny
- Hoeglundina elegans* (d'Orbigny)
- Pyrgo murrhina* (Schwager)
- Pyrgo ringens* (d'Orbigny)

Dentalina communis was noted in only one basin and the San Diego Trough. *Hoeglundina elegans* is about 2 mm. or more in diameter throughout most of the central and outer basins. Specimens of this species in shallower warmer waters are usually less than 0.6 mm. in diameter. *Pyrgo murrhina* and *P. ringens* are unique in this fauna from the standpoint that they attain

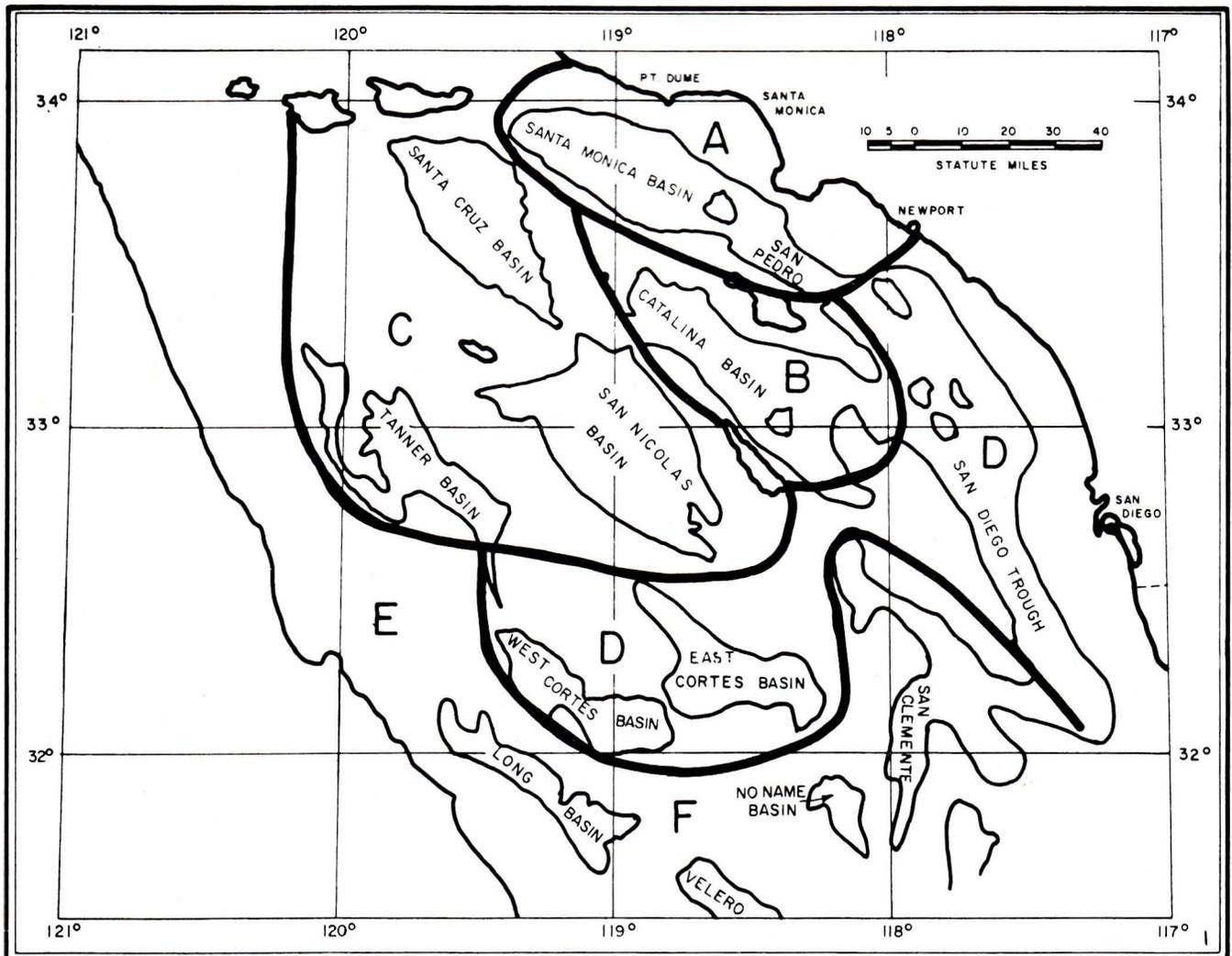
maximum diameters of about 1.2 mm. in Santa Catalina basin, 1.5 to about 2.0 mm. in many of the intermediate basins, and 4 mm. in the deepest basins. This trend appears to correlate with decreasing temperatures from above 4° C. in the shallowest occurrence, between 3° and 4° C. in the intermediate basins, and less than 3° C. in the deepest basins (Emery, 1960). Another factor is the oxygen content which is less than 1 ml/l in most of the basins excepting those deepest ones in which values of 1.3 to 2.0 ml/l are attained.

Fauna C

Fauna C is made up of just two species of larger foraminifera which make their appearance in the next deeper basins beyond Santa Catalina basin: Santa Cruz and San Nicolas basins (Table 1, text fig. 1). These basins have a bottom water temperature of 3.71-4.15° C., an oxygen content of 0.5-0.8 ml/l, and a salinity of 34.52 parts per thousand (Emery, 1960). The two species are:

- Cibicides wuellerstorfi* (Schwager)
- Cyclammina cancellata* Brady

Cibicides wuellerstorfi averages about 1.5 mm. which is the maximum size indicated in Table 1 for the shallow



TEXT FIGURE 1

Basin foraminiferal faunas (larger species) based upon bathyal increments in basins and deeper waters of the continental borderland (see Table 1).

lowest occurrence. It attains a maximum of 2 mm. in West Cortes basin; however, there is no clear size gradient. An important species, from a paleontological standpoint, is *Cyclammmina cancellata*, an agglutinated type with a vesicular interior. Akers (1954) reviewed the literature regarding the occurrences of this species and concluded that it usually occurs between about 500 and 2000 meters in modern oceans. No data were then available regarding the size characteristics of this species. Maximum size of this species in the shallowest basin of its occurrence, San Nicolas basin, is about 1.5 mm. and the average size is very little less than this among the larger forms of this study. Most specimens in deeper, colder waters have a diameter of 4 or 5 mm. and the largest specimens are between 5.25 and 6 mm. The larger specimens are associated with temperatures of 2.6° C. or less and oxygen values of 1.3-2.0 ml/l.

The combination of *Cibicides wuellerstorfi* and *Cyclammmina cancellata* defines three of the northern outer basins (text fig. 1); however, *Cyclammmina cancellata* occurs only in San Nicolas basin and in other southern basins along with other faunas (text fig. 3). Higher oxygen values, low temperatures, and possibly higher

organic content may be the factors controlling the distribution of this species. Cold, well oxygenated shallow waters of the Arctic [Anderson, 1961] do not favor the development of this species, indicating more complex factors controlling the distribution of this species. Perhaps it is the pressure-temperature relationship along with the other factors mentioned.

Fauna D

Fauna D is composed of foraminifera which are most characteristic of the southern and outer part of the continental borderland (text fig. 2). These basins have bottom temperatures of less than 3.5° C., oxygen contents of 0.9 to 2.0 ml/l, and a salinity range of about 34.52 to 34.58 parts per thousand (Emery, 1960). The species are:

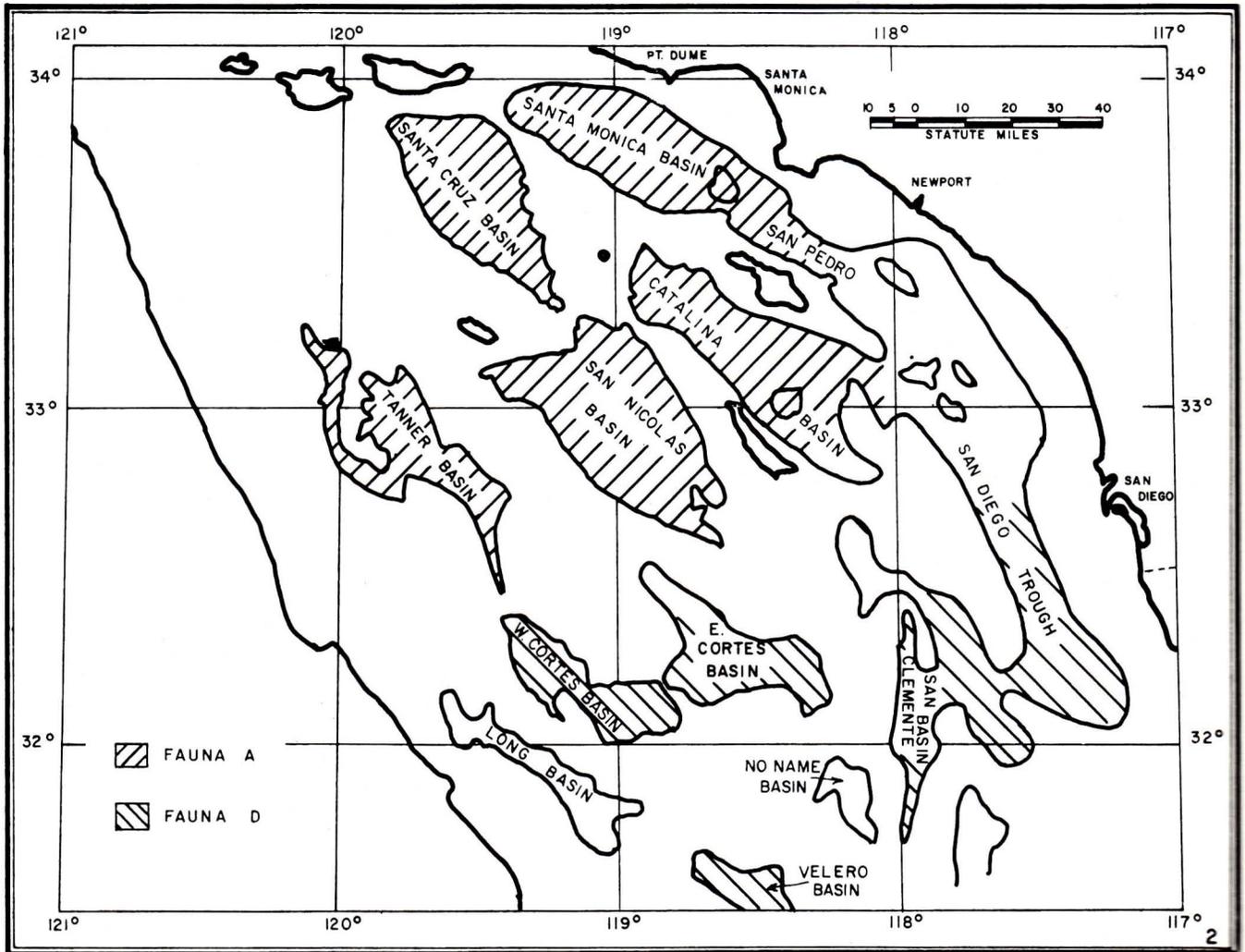
Glandulina laevigata d'Orbigny

Haplophragmoides sp.

Martinottiella communis occidentalis (Cushman)

Martinottiella communis pallida (Cushman)

Glandulina laevigata develops an apicule or spine on its apex in a number of the deeper basins. Some specimens are without a spine, others show gradations into spined forms, and a number of specimens are like the



TEXT FIGURE 2

Distribution of *Globobulimina* spp. and Fauna D in basins and deeper water areas of the continental borderland (see Table 1).

Fauna A (Part) >1.2 MM
Globobulimina pacifica pacifica
Globobulimina pyrula spinescens

Fauna D >1.0 MM
Glandulina laevigata
Haplophragmoides sp.
Martinottiella communis occidentalis
Martinottiella communis pallida

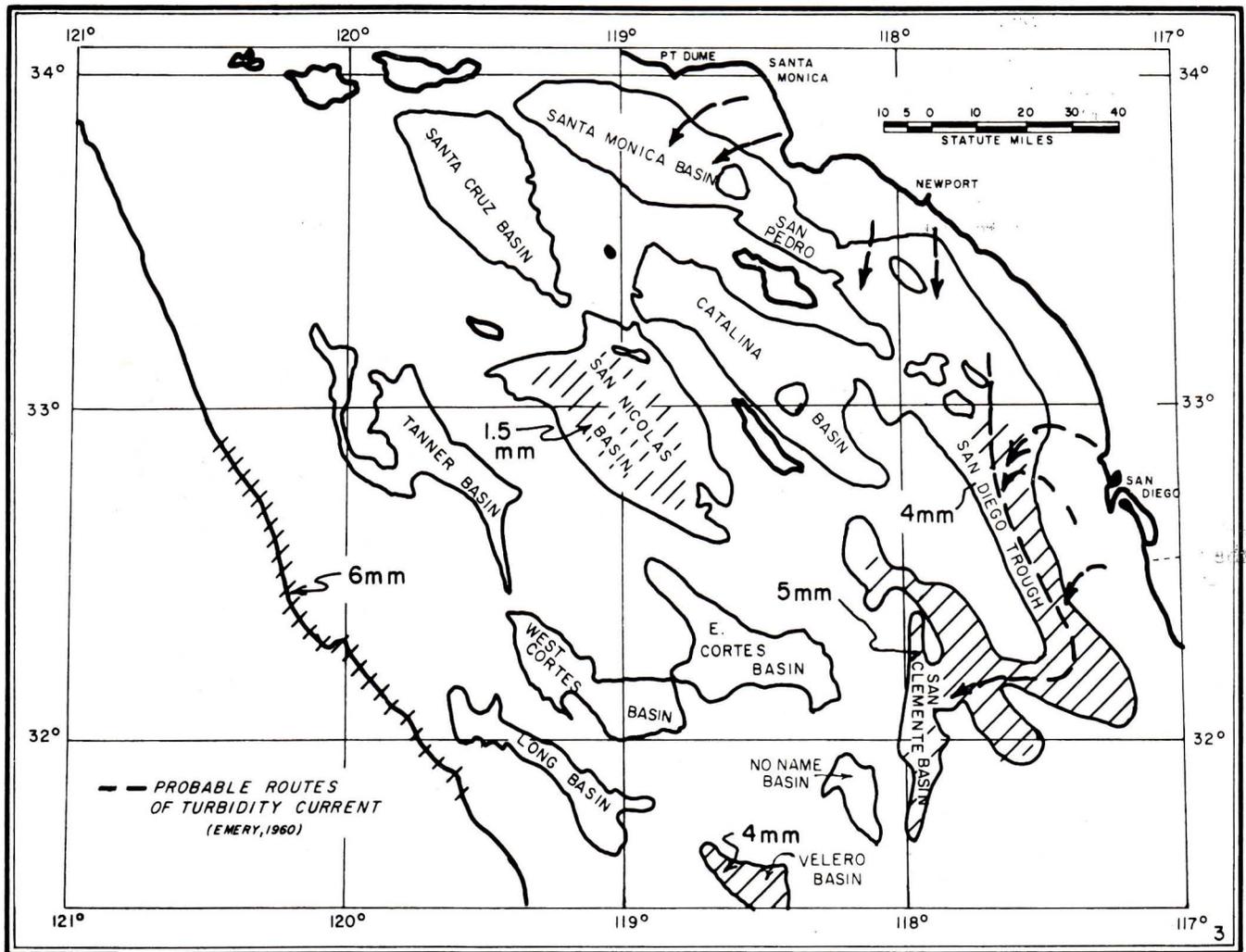
original figure and section by d'Orbigny (see Ellis and Messina, *Catalogue of Foraminifera*). Specimens of this species are mostly less than 0.5 mm. in shallow waters of the world and they are between 2 and 4 times larger than this in the deeper basins of the continental borderland off southern California (Table 1). *Martinottiella* is represented by two subspecies; however, these are possibly dimorphic variants of the same species, judging from serial studies of the group. An average size of between 3.5 and 4.5 mm. is likely, although a number of specimens larger than 5.0 mm. were found in the deepest southern basins. It appears that *Martinottiella* and *Cyclammina* are progressively larger in deeper, colder, and better oxygenated waters.

Fauna E

Fauna E is represented by *Laticarinina pauperata* Parker and Jones. Smaller specimens of this species occur in somewhat shallower waters of the Gulf of

Mexico and elsewhere; however, large specimens averaging between 1.5 and 2.0 mm. in diameter occur only in the deep southern basins and the outer Patton Escarpment (Table 1) in this study. The basins, San Clemente and Velero, have bottom water with a temperature range of 2.52-2.6° C., an oxygen content of 1.3-2.0 ml/l, and a salinity range of 34.56-34.58 parts per thousand (Emery, 1960). It would appear that this species also reflects an increase in maximum diameter with increasing depth of water and correlated changes in the environment.

Barker (1960) placed *Laticarinina pauperata* Parker and Jones in synonymy with *Robulina halophora* Stache, 1864; however, the original figure of the latter shows a robuline aperture and it is believed that the two are two different genera by this author. Some species of *Robulus* develop a very wide flange in deep cold water and they do have a superficial similarity to *Laticarinina* in this respect.



TEXT FIGURE 3

Distribution of *Cyclammmina cancellata* in basins and deeper water areas of the continental borderland (see Table 1). Areas of occurrence indicated by crosshatching; approximate maximum diameter of specimens noted in millimeters.

Fauna F

Fauna F is composed of *Ammodiscus pacificus* Cushman and Valentine and *Pyrgoella sphaera* (d'Orbigny). A number of authors have used the name *Involutina* in recent years for agglutinated planispiral evolute species. Loeblich and Tappan (1961) have recently clarified the status of *Ammodiscus*, showing it to be the correct generic designation for agglutinated planispiral foraminifera. Uchio (1960) considers that there is a good separation of *Ammodiscus flavidus* Höglund, 1947, and *A. pacificus* Cushman and Valentine, 1930. Specimens of *A. pacificus* in this study compared with the types in the U. S. National Museum and serial studies indicate the probability that Höglund's species is an environmental variant of *A. pacificus*. Small forms of the latter do occur in shallower waters on the continental shelf; however, the largest individuals are restricted to the deepest basins (Table 1). Characteristics of these basins were given above under Fauna E.

Pyrgoella sphaera is a unique porcelaneous form which attains a size of about 5 mm. in the deeper basins of the southern part of the continental borderland. Green (1960) reports it in the Arctic Ocean at

depths of 619 and 878 meters, in bottom water temperatures of between 0° and 1° C. These arctic specimens were usually no larger than about 2.5 mm. (Green, personal communication). Specimens off southern California were fragile and often broken in processing or mounting them.

SUMMARY AND CONCLUSIONS

1. Six faunas of larger living foraminifera are recognized by evaluating the upper depth limits of foraminifera larger than 1 millimeter from basins and deeper-water areas of the continental borderland. These permit the subdivision of the continental borderland into six general basin or deep-water divisions.

2. Two major mutually exclusive groups of larger foraminifera are (1) the *Globobulimina pyrula spinescens*-*Globobulimina pacifica pacifica* larger foraminifera of the northern basins with sill depths shallower than 1200 meters and (2) Fauna D of larger foraminifera (*Glandulina*-*Martinottiella*) which characterizes the southern basins with sills deeper than 1200 meters and also the San Diego Trough and the Patton Escarpment.

3. Deep-water forms of *Glandulina laevigata* develop an apical spine.

4. *Pyrgoella sphaera* appears to be more than twice as large in deep, cold, well oxygenated waters of the continental borderland as in shallower bathyal waters of the Arctic Ocean.

5. *Hoeglundina elegans*, an aragonitic foraminifer (Bandy, 1954), is an important larger species throughout the central, southern and outer basins of the continental borderland.

6. *Cyclammina cancellata* and a number of other larger foraminifera show a marked increase in maximum diameter with increasing depth, pressure, temperature, and oxygen content. Bradshaw (1961), in laboratory experiments, found a significant inverse relationship between size and temperature. Lutze (1962) has found an apparent direct correlation between oxygen content and the amount of secondary deposits in the tests of *Bolivina* off southern California. Findings in the present study are consistent with these earlier reports and it is concluded that both oxygen content and temperature are important factors in determining size and the amount of secondary deposits in the foraminifera.

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269. DOMINANT PARALIC FORAMINIFERA
OF SOUTHERN CALIFORNIA AND THE GULF OF CALIFORNIA¹

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ABSTRACT

A study was made of dominant foraminiferal populations in depositional paralic environments of southern California and the Gulf of California. Dominant and mostly restricted marsh species are *Jadammina polystoma*, *Miliammina fusca*, and *Saccamina* sp. Dominant lagoonal faunas include *Ammonia beccarii tepida*, *Elphidium articulatum*, *Quinqueloculina akneriana* vars., *Hopkinsina pacifica*, and various arenaceous species. Beach faunas are characterized by an abundance of *Cibicides fletcheri*, *Rotorbinella* spp., *Trochammina kellestae*, and a few others. Upper sublittoral or inner shelf faunas include usually high percentages of *Buccella* spp., *Buliminella elegantissima*, *Hanzawaia nitidula*, *eggerella advena*, and several miliolids.

Other species proved to be abundant in both lagoonal and inner shelf environments. These include various subspecies of *Elphidium poeyanum*, *Nonionella basispinata*, and *Trochammina* spp. *Bulimina marginata denudata* is quite unique in being common in both lagoonal areas and in the outer shelf and upper bathyal zones.

Dominant marsh faunas are entirely arenaceous or siliceous. Of the calcareous species, those in lagoonal areas are finely perforate whereas those in intertidal and inner shelf areas include coarsely perforate species. Broken, damaged, and worn specimens are scarce in lagoonal areas, abundant in many beach samples, and usually rare in inner shelf samples.

INTRODUCTION

This study is designed to demonstrate quantitatively the dominant foraminiferal trends in depositional paralic environments of southern California and the Gulf of California (text fig. 1). Criteria established in this way may be useful in the interpretation of paralic facies of the geologic past. Marshes, lagoons, beaches, and the inner shelf regions of the sea are considered to be the major paralic divisions. Although each of these may be broken down into a multiplicity of subdivisions, it is important to note that these smaller subdivisions are usually mixed and telescoped into small stratigraphic units as a result of fluctuating environmental conditions over geologic time. Rocky coasts and erosional areas provide unique ecologic niches with specially adapted faunas; however, these faunas are destroyed ultimately or they are transported to a depositional site where they become mingled with the remains of other populations. Depositional divisions of the paralic environment are essentially sequential in a stratigraphic sense, varying with temporary fluctuations in sea level and with rates of subsidence versus sedimentation.

Investigations providing the basis for the present synthesis are those of LoBue (1958, Ballona Creek, Playa del Rey), Reiter (1959, intertidal foraminifera of Santa Monica Bay), Cooper (1961, intertidal foraminifera of California and Oregon), Walton (1955, Todos Santos Bay, Baja California), Bandy (1961, Gulf of California), and Watkins (1961, Orange County sublittoral zone, California). In addition, data included from term-paper studies are as follows: Easom (Playa del Rey Lagoon), Babcock (Seal Beach Lagoon), Browne (Long Beach, Colorado Lagoon), Haga (Ballona Creek), Gilmour (Newport Lagoon), Lessard (Newport Lagoon), and Haga (Agua Hedionda Lagoon, near Carlsbad, California).

FAUNAL ANALYSES

General Faunal Trends

Interesting and important general faunal trends in paralic divisions of southern California include relative dominance of specific faunal indices, foraminifera/ostracode ratios, species abundance, general wall structure, the size of perforations of the test, and preservation of the tests.

It is important to note that the dominant and significant faunal elements of each of the paralic subdivisions comprises a significant portion of the fauna in each case (text fig. 2). The average value for the dominant living marsh fauna in its typical facies is 71 percent; values for the dominant faunas of beaches in their typical facies are between 23 and 75 percent; and values for the dominant upper sublittoral fauna in its typical facies is 16 to 77 percent of the total foraminiferal fauna. Note that the marsh fauna is generally specific for marshes; however, it is reported in very minor percentages in channels (Table 1). The dominant lagoonal fauna (1A-C) amounts to 5 percent or less of the marsh, beach, and sublittoral faunas. Although the dominant beach fauna (2A-D) makes up less than 5 percent of lagoonal facies and is not found in marsh deposits of Todos Santos Bay, it intergrades with the upper sublittoral facies. The upper sublittoral fauna is quite restricted and shows a marked progressive increase in frequency offshore. Some of its components, especially *BULIMINELLA ELEGANTISSIMA*, are of importance in some beach deposits, in channels, and in the seaward portions of some lagoons.

Foraminiferal/ostracode ratios reveal a most significant trend in that values of 12 or less characterize lagoonal facies, whereas ratios of beach and sublittoral

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² Contribution of the Allan Hancock Foundation. No. 250.

facies are very high, usually very much in excess of 100 (text fig. 2). The primary trend in species abundance is the increase from less than 30 species in marsh, lagoon, beach biofacies to more than 50 in the sublittoral zone.

TABLE 1—Live-dead Foraminiferal Faunas of Marsh and Channel Environments of Todos Santos Bay. Data from Walton, 1955. Values in percentage of total population of living and dead.

	Marsh		Channel	
	Live	Dead	Live	Dead
<i>Species—Living</i>				
<i>Ammonia beccarii</i>		×		4
<i>Arenoparella mexicana</i>	2	7		2
<i>Cibicides fletcheri</i>	-	-	3	10
<i>Elphidium poeyanum</i> vars.	1	1	42	30
<i>Elphidium</i> sp. 1	5	9		2
(<i>E. galvestonensis</i>)				
* <i>Jadammina polystoma</i>	9	10		×
* <i>Miliammina fusca</i>	33	20	7	5
<i>Miliolinella obliquinoda</i> ?	9	12		
Miliolids			30	13
* <i>Saccammina</i> sp.	29	7	15	5
<i>Tretomphalus</i> sp.			3	2
<i>Trochammina inflata</i>	12	32		4
<i>Species—Dead</i>				
<i>Angulogerina angulosa</i>				×
<i>Buliminella bassendorfensis</i>				9
<i>Discorinopsis aguayoi</i>		1		
<i>Lamellodiscorbis</i> sp.				2
<i>Nonionella basispinata</i>				1
<i>Planulina ornata</i>				×
<i>Reophax</i> sp.		×		6
<i>Textularia earlandi</i>		×		3
SPECIMEN TOTAL	258	1130	352	1048
Percentage Hyaline	6	11	48	62
Percentage Porcelaneous	9	12	30	13
Percentage Arenaceous	85	77	22	25
Planktonic specimens				[×]

× = Less than one percent.

* = Dominant marsh species.

General wall structure is an important characteristic in evaluating paralic facies (Tables 1, 2). All of the significant members of the marsh fauna are arenaceous or siliceous (*Miliammina*), lagoonal faunas contain highly variable numbers of arenaceous species, a small species of *Trochammina* is dominant in some of the beach samples, and several arenaceous species are relatively important in the sublittoral zone. With respect to the latter, it has been noted by Zalesny (1959), Resig (1960), and Watkins (1961) that *Trochammina pacifica* and *Eggerella advena* become dominant around the sewage outfalls of the southern California shelf. Among perforate calcareous foraminifera, only finely perforate species (pores less than 6 microns) occur in

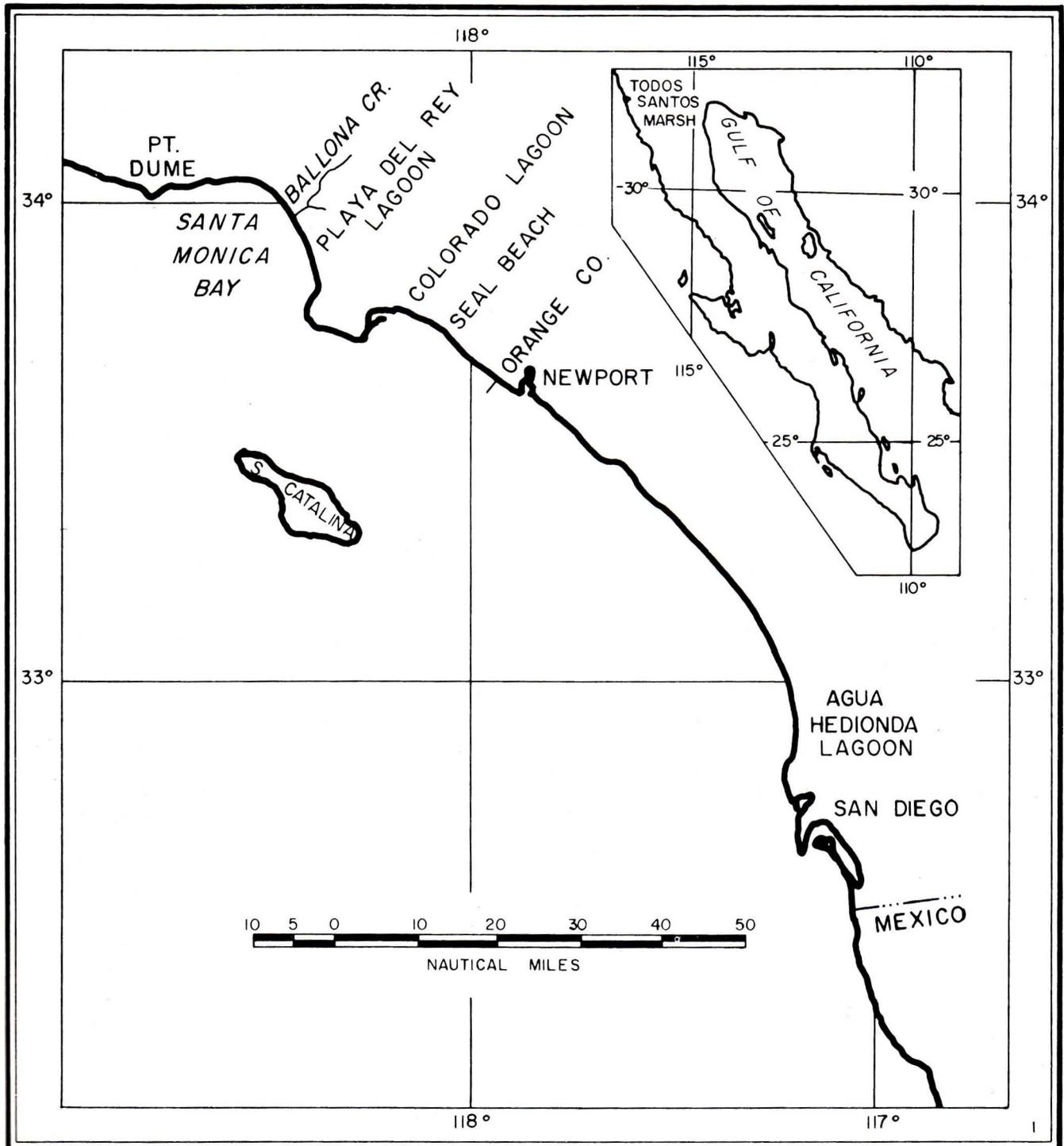
the marsh and lagoonal biofacies whereas coarsely perforate species (pores larger than 6 microns) such as *Cibicides fletcheri* occur in channels, beaches, and the sublittoral zone. The highest values prevail in the beaches (Table 2). The greatest percentages of broken and worn specimens are found in beach sands and in the upper part of the sublittoral zone.

Specific Faunal Trends

Paralic biofacies are segregated into those that are more restricted indices and others which are cosmopolitan in distribution (Tables 1, 2). Dominant and restricted marsh species are *Jadammina polystoma*, *Miliammina fusca*, and *Saccammina* sp. It is important to note that these are arenaceous and siliceous (*Miliammina*) species which are not subject to solution under conditions of variable and low pH in marsh deposits (5.7-6.9, Table 3). They comprise 71 percent of the total living marsh population and 37 percent of the dead population. Another dominant arenaceous species is *Trochammina inflata* which is not so restricted in its occurrence. According to Emery (1960) marsh deposits are poorly sorted, they have a median diameter of about 10 microns (p. 182), they are low in calcium carbonate, high in organic matter, and low in pH. Thus, the dominant and restricted foraminifera of the marsh environment of Todos Santos Bay are types capable of being preserved there. They include an association of *Trochammina* with a high organic content as is true on the continental shelf around sewer outfalls (Watkins, 1961).

Lagoonal foraminifera are much more diversified than marsh faunas (Tables 1 and 2). Some lagoons are closed bodies of water, others have restricted and/or intermittent openings to the sea. It is difficult to separate a lagoonal biofacies from a channel biofacies in many respects, especially the seaward portion of lagoons which are more subject to periodic invasions of sea water. Lagoonal biofacies include the dominant and restricted species *Ammonia beccarii tepida*, *Bolivina striatula*, *Buccella depressa*, *Elphidium articulatum*, *Hopkinsina pacifica*, *Quinqueloculina akneriana*, and several arenaceous species (Table 2). Unrestricted or cosmopolitan species in lagoonal facies include several subspecies of *Elphidium poeyanum*, *Bulimina marginata denudata*, *Quinqueloculina boschiana*, and species of *Trochammina*. It is important to note that some of these, such as *Bulimina marginata denudata*, comprise as much as 17 percent of a lagoonal fauna and also as much as 13 percent of the upper bathyal fauna in the Gulf of California (Bandy, 1961). *Trochammina inflata* and *T. pacifica* are also quite cosmopolitan, being important in lagoons and also around many of the outfalls of southern California, as mentioned before.

Beach biofacies of southern California and the Gulf of California have been studied rather extensively (Reiter, 1959; Cooper, 1961; Bandy, 1961). Diagnostic dominant indices of beach faunas include *Buccella*



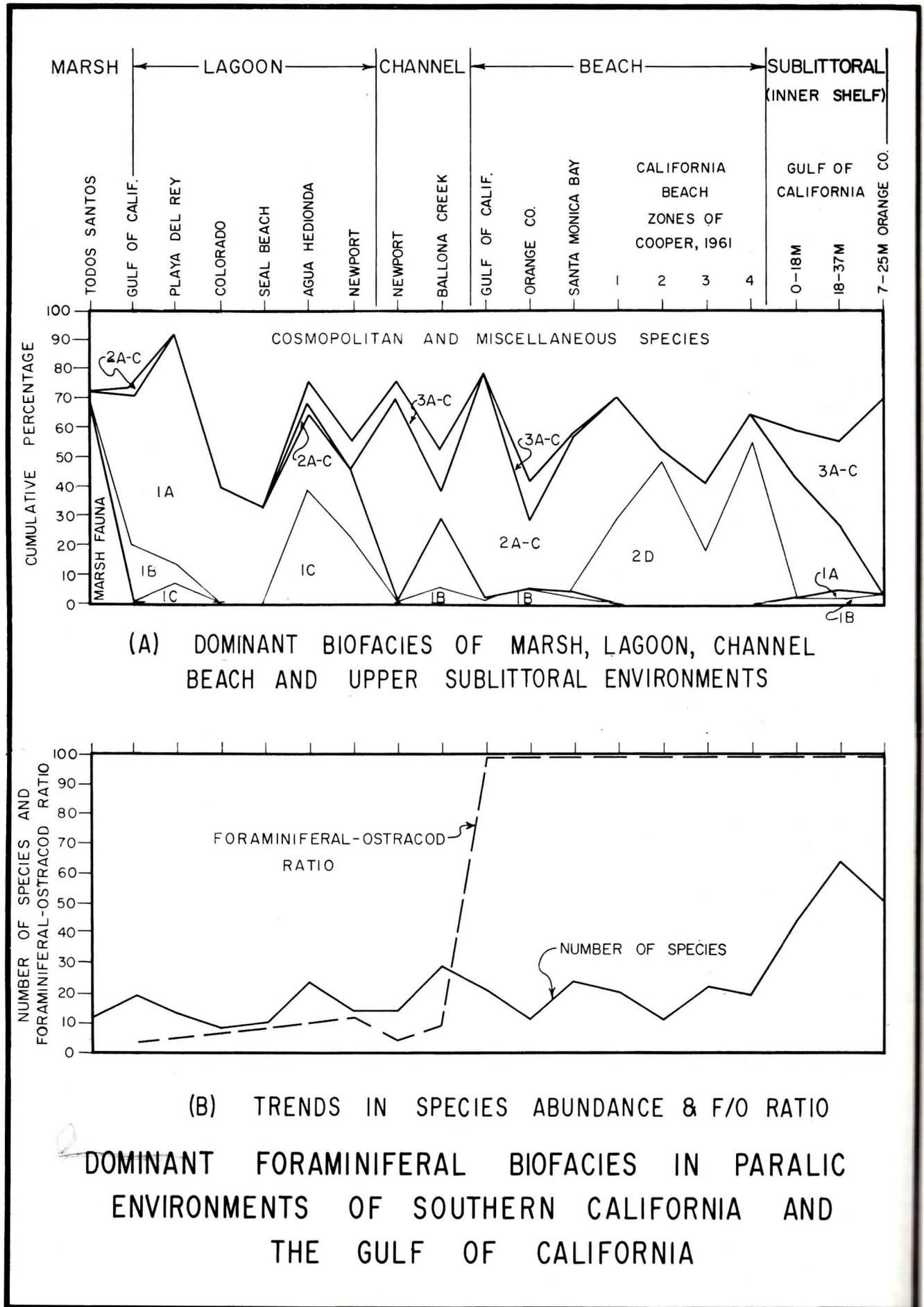
TEXT FIGURE 1

Location map, southern California coast and Gulf of California.

tenerrima, *Elphidium crispum*, *Rotorbinella lomaensis*, *Rotorbinella versiformis*, *Cibicides fletcheri*, and *Trochammina kellettae*. These species may occur in channels leading into lagoons, but they are not otherwise associated with lagoonal biofacies. Perhaps the most cosmopolitan of species is *Elphidium poeyanum* and its subspecies which are dominant in sediments of beaches, lagoons, and the upper sublittoral zone. Mainland beaches and channel sediments are coarse with median diameters of 240 and 320 respectively (Table 3). The pH is 8 or higher in both cases, percent of organic matter is very low, and the Trask sorting coefficient is 1.2 for beaches and 1.5 for channel sands.

A major difference is the high percentage of calcium carbonate (80) in channel sediments in contrast to low values in beaches (6.3). Environmentally, there is great turbulence associated with beaches and somewhat less with channel bottom deposits. This is, of course, responsible for the abundance of broken and worn specimens in beach sediments; it is also likely responsible for the more coarsely perforate species there. Coarsely perforate foraminifera also occur in bathyal and abyssal deposits indicating that the problem is more complicated than this.

Upper sublittoral biofacies of this study are those of the surf zone and just beyond, embracing depths of a



TEXT FIGURE 2

Faunal trends for depositional paralic environments of southern California and the Gulf of California. See Tables 1 and 2 for tabulation.

TABLE 2—Relative abundance of dominant benthonic foraminifera in paralic environments of southern California and the Gulf of California.

VALUES IN AVERAGE PERCENTAGE OF BENTHIC FORAMINIFERA FOR EACH LOCATION	LAGOONS					CHANNELS		BEACHES							SUBLITTORAL (INNER SHELF)			
	GULF OF CALIFORNIA	PLAYA DEL REY	COLORADO LAGOON	SEAL BEACH	AGUA HEDIONDA	NEWPORT	NEWPORT	BALLONA CREEK	GULF OF CALIFORNIA	ORANGE COUNTY	SANTA MONICA BAY	1961				GULF OF CALIFORNIA	CALIFORNIA	ORANGE CO.
												1	2	3	4			
1. LAGOONAL BIOFACIES																		
A. CALCAREOUS, FINELY PERFORATE WALLS																		
AMMONIA BECCARII TEPIDA	37	78	26	28	9		18			2							2	
BOLIVINA STRIATULA					3	4												
BUCCELLA DEPRESSA					11	8												
ELPHIDIUM ARTICULATUM	13		13	4		11	1	6									1	
HOPKINSINA PACIFICA					3													
B. PORCELANEOUS WALLS																		
QUINQUELOCULINA AKNERIANA																		
Q. AKNERIANA	19	1					5		5	2							3	
Q. AKNERIANA																		
BELLATULA		6							1							2	2	
C. AGGLUTINATED WALLS																		
AMMOBACULITES SALSUS		6				4												
REOPHAX COMMUNIS																		
R. EXCENTRICUS						25	8											
TEXTULARIA EARLANDI						13	10											
2. BEACH BIOFACIES																		
A. CALCAREOUS, FINELY PERFORATE WALLS																		
BUCCELLA TENERRIMA									9					8	3	1	2	
ELPHIDIUM CRISPUM									16							4	1	
ROTORBINELLA LOMAENSIS and																		
R. VERSIFORMIS							48		12	8	20	13		5	1	9	5	
TRETOMPHALUS MYERSI					4		9		12	9	1	3	5	2	1			
B. CALCAREOUS, COARSELY PERFORATE WALLS																		
CIBICIDES FLETCHERI	3																	
ROTORBINELLA ROSEA and																		
R. TURBINATA									2			2				1	1	
C. PORCELANEOUS WALLS																		
QUINQUELOCULINA LAMARCKIANA VARS.							9		8							12	7	
BROKEN MILIOLIDS									18							11	2	
D. AGGLUTINATED WALLS																		
TROCHAMMINA KELLETTAE													29	48	18	54		
3. UPPER SUBLITTORAL BIOFACIES																		
A. CALCAREOUS, FINELY PERFORATE WALLS																		
BUCCELLA MANSFIELDI																		
BULIMINELLA ELEGANTISSIMA						7	10	5	14		12	2				4	2	
HANZAWAIA NITIDULA																2	10	
B. PORCELANEOUS WALLS																		
QUINQUELOCULINA POEYANA																4	1	
C. AGGLUTINATED WALLS																		
ALVEOLOPHRAGMIUM COLUMBIENSE										1							6	
EGGERELLA ADVENA																	14	
TEXTULARIA CONICA and																6	5	
T. SCHENCKI																		
4. COSMOPOLITAN PARALIC BIOFACIES																		
A. CALCAREOUS, FINELY PERFORATE WALLS																		
BOLIVINA QUADRATA					4		2	5									1	
BULIMINA MARGINATA DENUDATA					7	17	1										3	
ELPHIDIUM POEYANUM																		
MICROGRANULOSUM																		
E. POEYANUM POEYANUM																		
E. POEYANUM SPINATUM	3	42	42	4	10	11	30	1	44	14	3	2	14	10	4	5	14	
E. POEYANUM TRANS-LUCENS																		
E. POEYANUM TUMIDUM																		
NONIONELLA BASISPINATA							4			5	2						4	
B. PORCELANEOUS WALLS																		
QUINQUELOCULINA BOSCIANA					16	2										2	2	
C. AGGLUTINATED WALLS																		
TROCHAMMINA INFLATA and																		
T. PACIFICA			19	6	6	10		3		2	2						10	
5. MISCELLANEOUS SPECIES																		
	28	6	0	4	2	8	8	10	22	10	29	28	46	45	26	33	35	3
FORAMINIFERAL/OSTRACODE RATIO	3			8		12	4	9	100	100	100	100	100	100	100	100	100	100
									+	+	+	+	+	+	+	+	+	+
NUMBER OF STATIONS AVERAGED	3	10	2	8	6	6	6	7	6	8	7	2	9	3	9	10	15	18

TABLE 3—Characteristics of Sediments from Pertinent Paralic Environments^a

Characteristics	Mainland		Mainland Shelves	
	Marsh	Channel Sand Beaches		
Median Diameter in Microns	10	320	240	130
Trask Sorting Coefficient	4.2	1.5	1.2	1.6
CaCO ₃ in Percent	0.6	80	6.3	9.2
Organic Matter in Percent	18		0.05	0.9
pH	5.7-6.9	8+	8.2± ^b	8.0-8.2

^aData from Emery, 1960.

^bFluctuates widely due to ground water seepage and rainfall.

few meters to about 37 meters. Dominant, mostly restricted, species of this zone include *Buccella manskeldi*, *Buliminella elegantissima*, *Hanzawaia nitidula*, *Quinqueloculina poeyana*, *Alveolophragmium columbiense*, *Eggerella advena*, *Textularia conica*, and *T. schencki*. *Buliminella elegantissima*, a small, delicate species, is also characteristic of many channel samples and some beach samples. These cases are thought to be due to transportation of specimens, in large part. Subspecies of *Elphidium poeyanum* comprise the most characteristic cosmopolitan group in the sublittoral area. One of the greatest differences between the sediments of mainland beaches and mainland shelves is the decrease in median diameter of the sediment from 240 microns in beach sands to 130 microns in mainland shelf sands. There is a prominent difference also in the greater stability of the marine environment of the sublittoral zone, providing conditions more suitable for the propagation of shelf type foraminifera. This is to be seen in the increase in number of species offshore (text fig. 2).

SUMMARY AND CONCLUSIONS

Dominant foraminiferal faunas of paralic depositional environments are: marsh, *Miliammina fusca* fauna; lagoons, *Ammonia beccarii tepida* fauna; beaches, *Cibicides fletcheri*-*Rotorbinella*-*Trochammina kellestae* fauna; and the inner shelf, *Buliminella elegantissima* fauna. Channel deposits form a fifth environment which is generally characterized by a blending of beach, upper sublittoral, and lagoonal faunas.

Marsh foraminifera include dominant simple arenaceous forms that are likely to be preserved under conditions of variable and low pH values that prevail in this environment. A high organic content in the sediments may be the common denominator explaining the abundance of *Trochammina* in marsh sediments and also around many of the sewer outfalls on the continental shelf of southern California.

A euryhaline fauna, dominated by *Ammonia beccarii*

tepida, is well developed in lagoons; however, it is likely that this fauna would be displaced seaward onto the shelf if there were a sufficient influx of fresh water in the region. This seaward shift is illustrated in the northern Gulf of Mexico (Bandy, 1954, 1956). Thus, the interface separating a euryhaline from stenohaline biofacies will shift along with the shifting of the interface between these two kinds of water masses.

Beach faunas are subject to great turbulence, great diurnal temperature ranges, evaporation, water seepage and runoff, and a highly unstable substrate. This biofacies is characterized by relatively high percentages of broken specimens in many cases, and by the presence of common to abundant coarsely perforate calcareous foraminifera.

Upper sublittoral faunas are markedly different from the other paralic faunas. There are more species, specimens, and there is a considerable change in the species complex. Although *Buliminella elegantissima* is the dominant species in many cases, more than 50 species compose the faunas of samples of the sublittoral zone beyond the surf zone; less than 30 species occur in most samples from the other paralic facies.

One of the more unique occurrences in paralic faunas of this study is the bimodal occurrence of *Bulimina marginata denudata*. This species is common in both lagoonal areas and in the outer shelf and upper bathyal zones; it is not important in the other paralic faunas.

FAUNAL REFERENCE LIST

The original references to species mentioned in this study are arranged alphabetically below. The references in which these species are figured are: Walton, 1955; Bandy, 1961; and the *Catalogue of Foraminifera* by Ellis and Messina. Trinomials represent genus, species, subspecies.

Alveolophragmium columbiense (Cushman) = *Haplophragmoides columbiense* CUSHMAN, 1925, Contr. Cushman Lab. Foram. Research, vol. 1, pt. 2, p. 39, pl. 6, fig. 2.

Ammobaculites salsus CUSHMAN and BRONNIMANN, 1948, Contr. Cushman Lab. Foram. Research, vol. 24, p. 16, pl. 3, figs. 7-9.

Ammonia beccarii beccarii (Linnaeus) = *Nauticola beccarii* LINNAEUS, 1758, Syst. Nat., 10 ed., p. 710, pl. 1, fig. 1.

Ammonia beccarii tepida (Cushman) = *Rotalia beccarii tepida* CUSHMAN, 1926, Carnegie Inst. Washington, Pub. no. 344, p. 79, pl. 1.

Angulogerina angulosa (Williamson) = *Uvigerina angulosa* WILLIAMSON, 1858, Recent foram. Gt. Britain, Ray Soc., p. 67, pl. 5, fig. 140.

Arenoparella mexicana (Kornfeld) = *Trochammina inflata mexicana* KORNFELD, 1931, Contr. Stanford Dept. Geology, vol. 1, p. 86, pl. 13, fig. 5.

Bolivina quadrata CUSHMAN and McCULLOCH, 1942, Allan Hancock Pacific Exped., vol. 6, no. 4, p. 215, pl. 25, fig. 13.

- Bolivina striatula* CUSHMAN, 1922, Carnegie Inst. Washington, Pub. 311, p. 27, pl. 3, fig. 10.
- Buccella depressa* ANDERSEN, 1952, Washington Acad. Sci., Jour., vol. 42, no. 5, p. 145, 147, tfs. 7-8.
- Buccella mansfieldi* (Cushman) = *Eponides mansfieldi* CUSHMAN, 1930, Florida Geol. Survey, Bull. 4, p. 54, pl. 11, fig. 1.
- Buccella tenerrima* (Bandy) = *Rotalia tenerrima* BANDY, 1950, Jour. Paleontology, vol. 24, no. 3, p. 278, pl. 42, fig. 3. *Buccella inusitata* Andersen, 1952, is a junior synonym of *B. tenerrima*.
- Bulimina marginata denudata* Cushman and Parker = *Bulimina denudata* CUSHMAN and PARKER, 1938, Contr. Cushman Lab. Foram. Research, vol. 14, p. 57, pl. 10, figs. 1-2.
- Buliminella bassendorffensis* CUSHMAN and PARKER, 1937, Contr. Cushman Lab. Foram. Research, vol. 13, pt. 1, p. 40, pl. 4, figs. 13a, b.
- Buliminella elegantissima* (d'Orbigny) = *Bulimina elegantissima* D'ORBIGNY, 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 51, pl. 7, figs. 13-14.
- Cibicides fletcheri* GALLOWAY and WISSLER, 1927, Jour. Paleontology, vol. 1, no. 1, p. 64, pl. 10, figs. 8-9.
- Discorinopsis aguayoi* (Bermudez) = *Discorbis aguayoi* BERMUDEZ, 1935, Mem. Soc. Cubana, Hist. Nat., vol. 9, no. 3, p. 204, pl. 15, figs. 10-14.
- Eggerella advena* (Cushman) = *Verneuillina advena* CUSHMAN, 1922, Contr. Canadian Biology, no. 9, p. 141.
- Elphidium articulatum* (d'Orbigny) = *Polystomella articulata* D'ORBIGNY, 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 30, pl. 3, figs. 9-10.
- Elphidium crispum* (Linné) = *Nautilus crispus* LINNÉ, 1758, Syst. Nat., ed. 10, p. 709.
- Elphidium poeyanum microgranulosum* Galloway and Wissler = *Elphidium microgranulosum* GALLOWAY and WISSLER, 1951, Eclog. Geol. Helv., vol. 43, no. 2, p. 222.
- Elphidium poeyanum poeyanum* (d'Orbigny) = *Polystomella poeyana* D'ORBIGNY, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 55, pl. 6, figs. 25-26.
- Elphidium poeyanum spinatum* Cushman and Valentine = *Elphidium spinatum* CUSHMAN and VALENTINE, 1930, Contr. Dept. Geology, Stanford Univ., vol. 1, no. 1, p. 31, pl. 6, figs. 1a-2. This subspecies may be an abnormal manifestation of *E. poeyanum* in unfavorable environments (see Watkins, 1961).
- Elphidium poeyanum translucens* Natland = *Elphidium translucens* NATLAND, 1938, Bull. Scripps Inst. Oceanography, tech. ser., vol. 4, no. 5, p. 144, pl. 5, figs. 3, 4.
- Elphidium poeyanum tumidum* Natland = *Elphidium tumidum* NATLAND, 1938, Bull. Scripps Inst. Oceanography, tech. ser., vol. 4, no. 5, p. 144, pl. 5, figs. 5, 6.
- Elphidium* sp.
- Hanzawaia nitidula* (Bandy) = *Cibicidina basiloba nitidula* BANDY, 1953, Jour. Paleontology, vol. 27, no. 2, p. 178, pl. 22, fig. 3.
- Hopkinsina pacifica* CUSHMAN, 1933, Contr. Cushman Lab. Foram. Research, vol. 9, pt. 4, p. 86, pl. 8, fig. 16.
- Jadammina polystoma* BARTENSTEIN and BRAND, 1938, Senckenbergiana, Bd. 20, p. 381, text figs. 1a-c, 2a-l, 3.
- Lamellodiscorbis* sp.
- Miliammmina fusca* (Brady) = *Quinqueloculina fusca* BRADY, 1870, Ann. Mag. Nat. Hist., ser. 4, vol. 6, p. 47, (286), pl. 11, fig. 2.
- Miliolids
- Miliolinella obliquinoda* (Riccio) = *Triloculinella obliquinodus* RICCIO, 1950, Contr. Cushman Found. Foram. Research, vol. 1, pts. 3-4, p. 90, pl. 15, figs. 1-2.
- Nonionella basispinata* (Cushman and Moyer) = *Nonion pizarrensis basispinata* CUSHMAN and MOYER, 1930, Contr. Cushman Lab. Foram. Research, vol. 6, p. 54, pl. 7, fig. 18.
- Planulina ornata* (d'Orbigny) = *Truncatulina ornata* D'ORBIGNY, 1839, Voy. Amér. Mérid., Foraminifères, vol. 5, pt. 5, p. 40, pl. 6, figs. 7-9.
- Quinqueloculina akneriana akneriana* D'ORBIGNY, 1846, Foram. fossiles Vienne, p. 290, pl. 18, figs. 16-21.
- Quinqueloculina akneriana bellatula* BANDY, 1950, Jour. Paleontology, vol. 24, no. 3, p. 273, pl. 41, fig. 1.
- Quinqueloculina boschiana* D'ORBIGNY, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 191, pl. 11, figs. 22-24.
- Quinqueloculina lamarckiana* D'ORBIGNY, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 189, pl. 11, figs. 14-15.
- Quinqueloculina poeyana* D'ORBIGNY, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 191, pl. 11, figs. 25-27.
- Reophax communis* LACROIX, 1930, Bull. Institut. Oceanographique, no. 549, p. 4, figs. 5-7.
- Reophax excentricus* CUSHMAN, 1910, Bull. 71, U. S. Nat. Mus., pt. 1, p. 92, fig. 134.
- Reophax* sp.
- Rotorbinella lomaensis* (Bandy) = *Rotalia lomaensis* BANDY, 1953, Jour. Paleontology, vol. 27, no. 2, p. 179, pl. 22, fig. 6.
- Rotorbinella rosea* (d'Orbigny) = *Rotalia rosea* D'ORBIGNY, 1826, Ann. Sci. Nat. Foraminifères, sér. I, vol. 7, p. 272; Modèles no. 35.
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- Rotorbinella versiformis* (Bandy) = *Rotalia versiformis* BANDY, 1953, Jour. Paleontology, vol. 27, no. 2, p. 179, pl. 22, fig. 5.

Saccamina sp.

Textularia conica D'ORBIGNY, 1839, in de la Sagra, Hist. Phys. Pol. Nat. Cuba, "Foraminifères," p. 143, vol. 8, pl. 1, figs. 19-20.

Textularia earlandi PARKER, 1952, Bull. Mus. Comp. Zoology, Harvard, vol. 106, no. 10, p. 458.

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

Tretomphalus myersi CUSHMAN, 1943, Contr. Cushman Lab. Foram. Research, vol. 19, p. 26, pl. 6, figs. 4-6.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
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270. FORAMINIFERA FROM THE UPPER PART
OF THE POUL CREEK FORMATION OF SOUTHEASTERN ALASKA¹

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Olympia, Washington

ABSTRACT

Nineteen species of Foraminifera are illustrated and discussed from the upper part of the Poul Creek Formation exposed in the Yakataga district of southeastern Alaska. The assemblage is referred to the Saucian Stage of the Miocene sequence of the Pacific Coast. A comparison of the assemblage with modern faunas is best made with those from moderately shallow and warm marine water.

INTRODUCTION

Foraminifera from the uppermost part of the Poul Creek Formation (Miller, 1957) of the Yakataga district in southeastern Alaska are illustrated and their stratigraphic and paleoecologic significance is discussed. Although Foraminifera are known from various parts of the Poul Creek Formation, they usually are spotty in occurrence and they are not found in great number at any locality. To the writer's knowledge, the assemblage discussed is the largest and one of the best preserved from the formation. Furthermore, it is reasonably diagnostic of both the geologic age and environment of deposition. The assemblage was brought to the attention of the writer by the late Don J. Miller of the U. S. Geological Survey. Because of interesting stratigraphic and paleoecologic implications, the assemblage is considered worthy of formal discussion.

According to Miller (written communication), material containing the assemblage was collected from Oil Creek in the Yakataga district (text fig. 1) in June 1938 by G. D. Hanna in company with C. E. Leach and J. G. Hazzard during a geologic field reconnaissance sponsored jointly by the Standard Oil Company of California, the Tidewater Associated Oil Company, and the Union Oil Company of California. A slide containing a representative assemblage was subsequently deposited at the California Academy of Science at which time catalog number C.A.S. 29268 was assigned to the slide. Most of the specimens studied and figured in the report are from this slide, and the illustrated specimens are deposited in the California Academy of Science. Recently, S. G. Wissler of the Union Oil Company of California kindly gave the writer additional material from the same collection. Specimens from this material were used to supplement the study of those from the California Academy of Science.

Field notes and records made at the time of collection and Miller's detailed knowledge of the area have made it possible to locate the collecting area rather precisely both geographically and stratigraphically.

The California Academy of Science catalog description of the locality is as follows:

"C.A.S. 29268. Oil Creek, Yakataga District, Alaska. Middle (main) fork. Collection from cannonball shale which is black when wet, glauconitic and iron-stained on fractures. Foraminifera abundant near top. Concretions up to three feet in diameter are limestone and contain a few fossils. In place. June 2, 1938. (Field No. 17)."

Field notes taken by G. D. Hanna state the following:

". . . Walked up Oil Creek to 1,500 feet elevation A thick body of dark shale (150 feet) contained many *Siphogenerina*. We have referred to this as the "cannonball shale." In a sandy zone just above the shale there is a zone of abundant *Turritellas* and above this many *Acila*. . . . found a small oil seep at elevation of about 750 feet."

Miller (written communication, 1960) made the following interpretation regarding the collecting locality:

"The collection containing Foraminifera is from a zone of complex structure on Oil Creek, where the upper part of the Poul Creek Formation and lower part of the Yakataga Formation are exposed on both flanks of the Sullivan anticline, and where the Poul Creek beds are cut by the Sullivan fault (Miller, 1957). The original locality description and the location plotted on the map available in 1938 indicate that the collection is from the north flank of the Sullivan anticline, but do not allow precise determination of its stratigraphic position or its location on the modern base map. The lithology, as described in the catalog and in the field notes of the collector, G. D. Hanna, places the collection definitely in the Poul Creek Formation as now defined (Miller, 1957). Not more than the upper 1,400 feet of the Poul Creek Formation is exposed on Oil Creek."

Miller further states that "the preponderance of the evidence indicates that the collection is from the upper half of this interval (1,400 feet), and suggests that it is most likely from the uppermost 300 feet of the Poul Creek Formation."

For a detailed discussion of the geology in the surrounding area of the collecting locality see Miller (1957).

FAUNAL COMPOSITION

Those species contained in the assemblage are listed

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

below together with a general indication of their relative abundance.

- Robulus* sp. — few
Dentalina cf. *D. consobrina* d'Orbigny — rare
Dentalina sp. A — few
Dentalina sp. B — rare
Rectoglandulina sp. — rare
Lagena semistriata Williamson, of Cushman and Parker — rare
Buliminella subfusiformis Cushman — common
Bolivina marginata adelaidana Cushman and Kleinpell — common
Uvigerina subperegrina Cushman and Kleinpell — common
Siphogenerina kleinPELLI Cushman — abundant
Angulogerina aff. *A. hughesi* (Galloway and Wissler) — few
Valvulineria menloensis Rau — few
Cancris cancriformis (Kleinpell) — common
Cassidulina cf. *C. laevigata carinata* Cushman, of Cushman and Parker — few
Cassidulina cf. *C. margareta* Karrer — common
Sphaeroidina variabilis Reuss — common
Cibicides elmaensis Rau — common
Cibicides cf. *C. pseudoungerianus evolutus* Cushman and Hobson — few
Cibicides? sp. — rare

The assemblage can be properly referred to as a *Siphogenerina* fauna as there are substantially more individuals of that genus than any other. *Cibicides* is the next best represented genus. *Buliminella* and *Cancris* are the next most abundant in the assemblage and are almost equally well represented. Substantial numbers of specimens of *Bolivina*, *Uvigerina*, *Cassidulina*, and *Sphaeroidina* are also present. These eight genera comprise the major part of the assemblage.

PALEOECOLOGY

Because the abundantly represented species in an assemblage are most likely to reflect the depositional environment of the entire assemblage, conclusions regarding the probable paleoecologic conditions of the

Poul Creek fauna are based on its eight most abundant species. Even though only four of these species are known to live in present-day seas, they are nevertheless represented today by very similar species. Therefore, the paleoecology of the fossil assemblage in question is concluded largely from depth and temperature records of living species that are morphologically similar to the fossil species.

Depth and temperature records of various living species can be found throughout much of the literature, but most of the information used in this report was summarized from the following sources: Bandy, 1953; Bermudez, 1935; Brady, 1884; Cushman, 1927; Cushman and McCulloch, 1942; Cushman and Moyer, 1930; Cushman and Todd, 1947; and Phleger and Parker, 1951.

Records of *Siphogenerina raphanus* (Parker and Jones), a living form similar to *S. kleinPELLI*, suggest that it is most frequently found at depths between 0 and 600 feet at temperatures between 60° and 50° F. This species is most common in the Indo-Pacific but is known from the West Indies and Caribbean region. It is recorded from off Madagascar, Ceylon, Honolulu, and as far north as the island of Hokkaido, Japan. It is recorded from littoral depths to 7,500 feet, but is far more commonly known from moderately shallow depths, littoral to 600 feet. Records show that the species lives in temperatures ranging from 46° to 59° F., but is most commonly found where water temperatures are above 50° F.

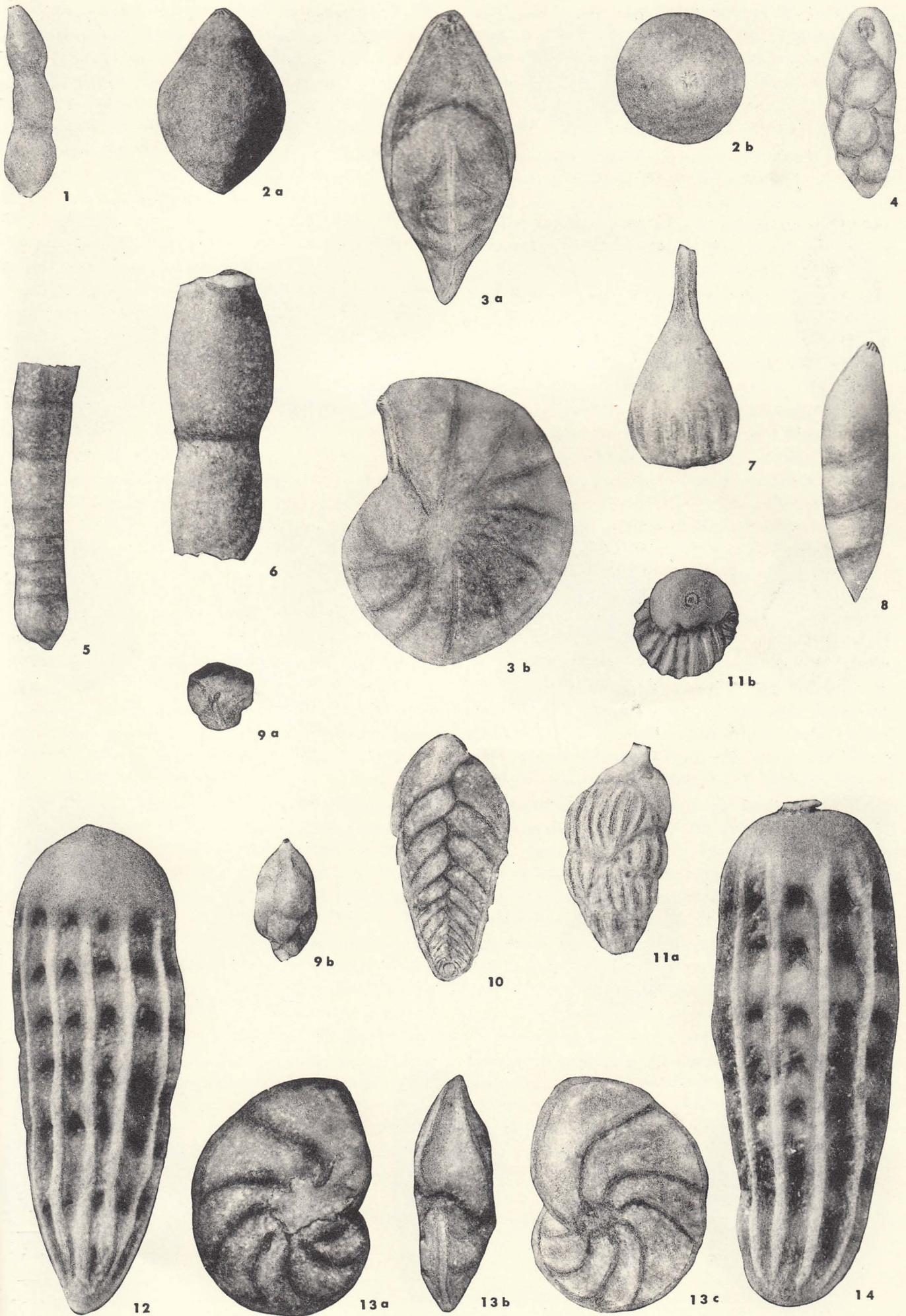
Cancris cancriformis has been recorded as *C. baggi planus* Cushman and Todd (1942) from Recent material from off southern California, but no temperature or depth records are given. Other modern forms similar to *Cancris cancriformis* such as *C. auricula* (Fichtel and Moll) and *C. oblonga* (Williamson) are most frequently recorded from littoral depths to 1,200 feet. No specific temperature data are available, but these species favor relatively warm temperatures.

Uvigerina peregrina Cushman, a form very similar to *U. subperegrina*, is known from a wide range of depths and temperatures. It is recorded from depths

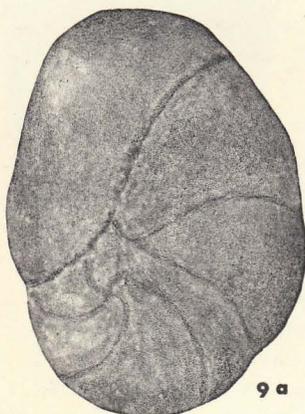
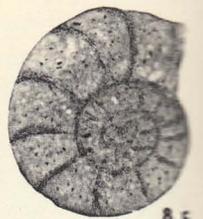
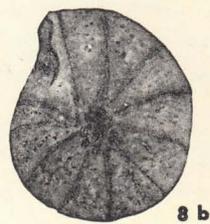
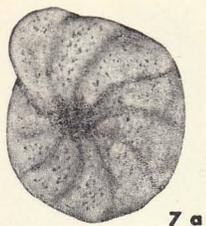
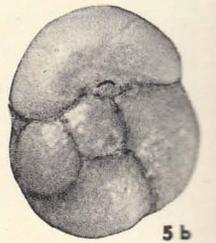
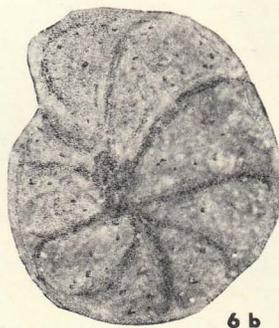
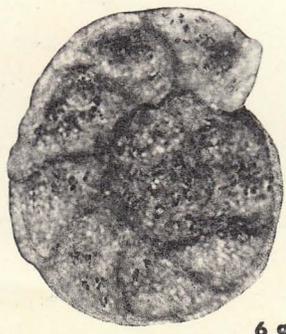
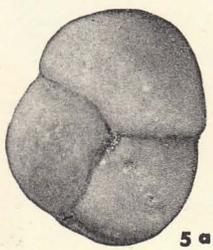
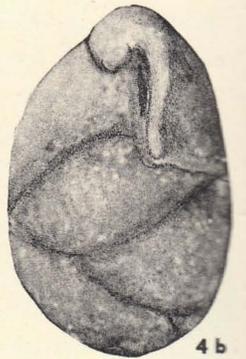
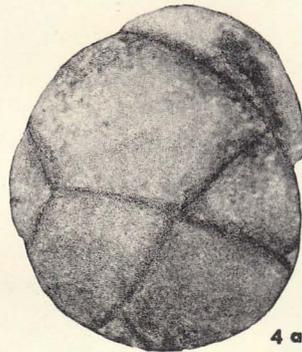
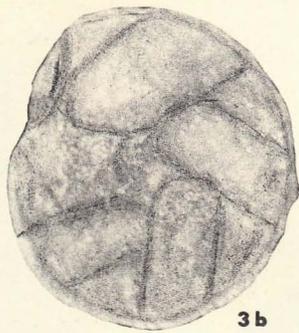
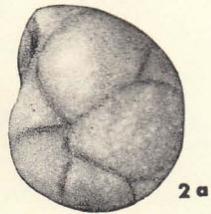
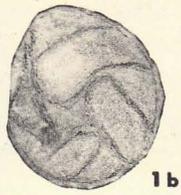
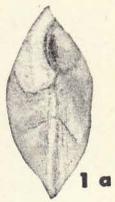
EXPLANATION OF PLATE 12

All specimens are from an upper part of the Poul Creek Formation exposed in Oil Creek in the Yakataga district of southeastern Alaska. All figures $\times 60$ except figure 2, $\times 90$.

FIGS.	PAGE
1, 6. <i>Dentalina</i> cf. <i>D. consobrina</i> d'Orbigny	139
2. <i>Rectoglandulina</i> sp.	139
3. <i>Robulus</i> sp.	139
4. <i>Buliminella subfusiformis</i> Cushman	140
5. <i>Dentalina</i> sp. A.	139
7. <i>Lagena semistriata</i> Williamson, of Cushman and Parker	140
8. <i>Dentalina</i> sp. B.	139
9. <i>Angulogerina</i> aff. <i>A. hughesi</i> (Galloway and Wissler)	141
10. <i>Bolivina marginata adelaidana</i> Cushman and Kleinpell	140
11. <i>Uvigerina subperegrina</i> Cushman and Kleinpell	140
12, 14. <i>Siphogenerina kleinPELLI</i> Cushman	141
13. <i>Valvulineria menloensis</i> Rau	141



Rau: Poul Creek Formation, Alaska



of 50 to 11,000 feet, but is found most commonly between depths of 1,000 and 4,000 feet where temperatures are between 53° and 35° F.

Sphaeroidina bulloides d'Orbigny, sometimes placed in synonymy with *S. variabilis*, is recorded from many parts of the world from the North and South Pacific Ocean and the North and South Atlantic Ocean. It is recorded also from the Mediterranean Sea, Red Sea, Adriatic Sea, and Indian Ocean at depths ranging from 200 to 15,600 feet. No specific temperature information is available, but it is apparent that the species also has a wide temperature tolerance.

Bolivina marginata adelaidana has been recorded from present-day seas off Colombia at 108 feet depth, off the southern part of California from depths between 650 and 950 feet, and off the west coast of Mexico (Cushman and McCulloch, 1942). Although no temperature information is given, the shallow depths reported in low latitudes suggest relatively warm water conditions.

Cibicides floridanus (Cushman), a form closely related to *C. elmaensis*, apparently thrives at a depth of 500 feet or less in water temperatures of 50° F. or above. This form is recorded from off the north coast of Cuba from depths between 180 and 10,000 feet. However, it is recorded as rare at 10,000 feet. All other records are from much shallower water. It is recorded as abundant to common from depths of about 500 feet where the water temperature is 50° F. or higher.

Buliminella subfusiformis and closely related forms are known in present-day seas from depths down to 2,400 feet but are most commonly found at depths less than 300 feet in warm water.

Cassidulina californica Cushman and Hughes, a form very similar to *C. cf. C. margareta* of the present collection, shows a preference for depths between 150 and 650 feet in temperatures between 60° and 50° F. It is recorded from Puget Sound from 60-foot depths, Queen Charlotte Sound from 150 feet, off San Francisco between 500 and 2,000 feet at temperatures between 50° and 41° F., off San Diego at depths between 100 and 2,600 feet at temperatures between 59° and 41° F. In the latter area it is very common and a very important part of the fauna at depths between 160 and 650 feet.

From these records it is apparent that living species most closely resembling the common species of the

upper part of the Poul Creek Formation, would, as a group, prefer moderately warm water temperatures at rather shallow depths. Probably they would thrive in temperatures between 55° and 45° F. at depths between 200 and 800 feet.

AGE AND CORRELATION

A few assemblages examined by the writer from the basal part of the Poul Creek Formation are at least as old as the Refugian Stage and possibly even the Narizian Stage of the Pacific Coast Tertiary sequence. Many additional assemblages from other parts of the formation are best referred to the Zemorrian Stage. The assemblage discussed in this report from the uppermost part of the formation represents a somewhat younger age, probably the Saucesian Stage.

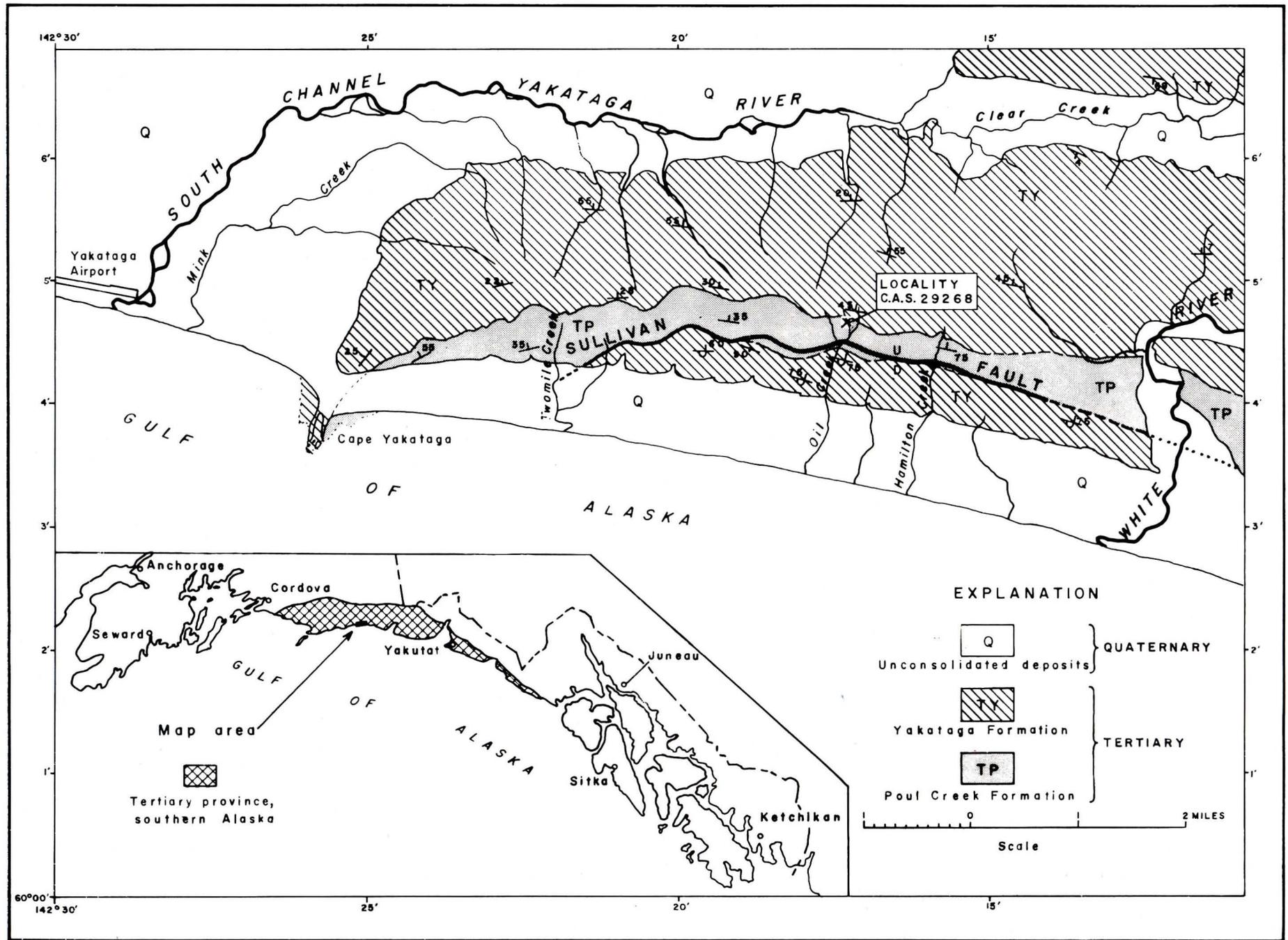
All but a few of the species identified in the assemblage are unknown below the Zemorrian Stage; as one assemblage they are most commonly found in rocks of Saucesian age. The common occurrence of *Siphogenerina kleinpelli* substantiates an age no older than the Saucesian Stage because this species is believed to have developed shortly after the close of Zemorrian time and to have reached its greatest development during Saucesian time (Kleinpell, 1938, p. 183).

The presence of *Cancris cancriformis* would at first appear to suggest a slightly younger age, as Kleinpell (1938) records this species only from the lower part of the Relizian Stage. However, subsequent to his study there have been informal reports of this species in association with assemblages that are believed to be older than Relizian in age. If the assemblage were Relizian in age, it is very likely that it would contain other species characteristic of the stage, particularly *Siphogenerina branneri* (Bagg) or *S. hughesi* Cushman in addition to *S. kleinpelli*. A few specimens approach *S. branneri* in appearance but are nevertheless more closely comparable to *S. kleinpelli*. This tendency for some of the specimens to approach the more striate form, *S. branneri*, may represent an incipient stage in development of *S. branneri*. If this assumption is correct a late Saucesian age is suggested, because *S. branneri* is believed to have developed during the latter part of this stage (Kleinpell, 1938, p. 183). Furthermore, if the assemblage were as young as the Relizian Stage, representatives of other species that make their earliest occurrence in the Relizian Stage would likely be present. None of the Poul Creek species is known

EXPLANATION OF PLATE 13

All specimens are from an upper part of the Poul Creek Formation exposed in Oil Creek in the Yakataga district of southeastern Alaska. All figures $\times 60$.

FIGS.	PAGE
1, 3. <i>Cassidulina</i> cf. <i>C. laevigata carinata</i> Cushman, of Cushman and Parker	142
2, 4. <i>Cassidulina</i> cf. <i>C. margareta</i> Karrer	142
5. <i>Sphaeroidina variabilis</i> Reuss	142
6. <i>Cibicides elmaensis</i> Rau	143
7. <i>Cibicides</i> cf. <i>C. pseudoungerianus evolutus</i> Cushman and Hobson	143
8. <i>Cibicides?</i> sp.	143
9. <i>Cancris cancriformis</i> (Kleinpell)	141



TEXT FIGURE 1

Generalized geologic map showing position of collecting locality of this report. Insert shows position of map area in the Tertiary province of southern Alaska. (Geology generalized from Miller (1957)).

to make its earliest occurrence as late as the Relizian Stage and therefore an age no younger than late Saucesian is further substantiated.

In view of the above evidence, the assemblage from the Poul Creek Formation is best referred to the Saucesian Stage. Furthermore, it may possibly represent an upper part of the stage.

Reasonably good comparisons of the assemblage from the upper part of the Poul Creek Formation can be made with other local assemblages of the Pacific Coast, all regarded by the writer as Saucesian in age. The known fauna of the Astoria Formation of Oregon (Cushman, Stewart, and Stewart, 1947) compares most closely with the assemblage in question. Those rocks in Washington tentatively assigned to the Astoria Formation contain many of these species and suggest a good faunal correlation (Rau, 1951, 1958). In California the known fauna from the Los Sauces Creek section (Cushman and Laiming, 1931) contains several species that are identical and a number of others that are similar to species from the upper part of the Poul Creek Formation.

Correlation of the Saucesian Stage on a world-wide basis is made with the lower Miocene by some workers, upper Oligocene by others, and "Oligo-Miocene" by still others. According to F. E. Eames (written communication) of the British Petroleum Company Limited, planktonic Foraminifera sent to him from known rock of the Saucesian Stage compare best with those from the lower part of the Aquitanian Stage of Europe.

ACKNOWLEDGMENTS

The writer is indebted to the late Don J. Miller of the U. S. Geological Survey for assistance with geographic and geologic technicalities, as well as for his personal interest in the report. Thanks are due to Stanley G. Wissler of The Union Oil Company of California for loaning supplementary material for study. Acknowledgments are also due to the Standard Oil Company of California, the Tidewater Oil Company, and The Union Oil Company of California for their consent to publish on the assemblage. Dr. G. D. Hanna of the California Academy of Science kindly made the assemblage available for study and aided in the review of the manuscript.

SYSTEMATIC DISCUSSION

Synonymies included in the following discussions give only the original reference to each species and, when available, any additional references considered significant to the discussion, one of which includes a more complete synonymy of the species.

All figured specimens are from California Academy of Science locality 29268.

Family LAGENIDAE

Genus *Robulus* Montfort, 1808

Robulus sp.

Plate 12, figures 3a, b

The collection contains a few specimens of *Robulus* which, although somewhat varied in size, probably represent a single species. In view of the great variation of form included under one name by some authors and the multitude of names applied to each slightly different form by others, the application of a specific name to the present specimens would have no practical significance. A typical representative of those in the collection is illustrated in order that the Poul Creek assemblage be completely shown.

Figured specimen (C.A.S. 12547).

Genus *Dentalina* d'Orbigny, 1826

Dentalina cf. *D. consobrina* d'Orbigny

Plate 12, figures 1, 6

One complete specimen and several broken ones compare well with illustrations of the type *D. consobrina* d'Orbigny (1846, p. 46, pl. 2, figs. 1-3). The three-chambered specimen figured on plate 12, figure 1, of this report is also particularly similar to that illustrated by Kleinpell (1938, pl. 17, fig. 4) from Chico Martinez Creek in California.

The main features of the present specimens from Alaska are the depressed sutures, inflated and slightly elongated chambers, a suggestion of a spine on the initial chamber, and a protruding, slightly radiating aperture.

Figured specimens (C.A.S. 12548 and 12549).

Dentalina sp. A

Plate 12, figure 5

A few fragmentary specimens of the genus *Dentalina* have chambers that are slightly longer than they are broad and show practically no inflation. The sutures are not depressed and there is a suggestion of a spine on the initial chamber.

Figured specimen (C.A.S. 12550).

Dentalina sp. B

Plate 12, figure 8

A single specimen has a fusiform shape and is rounded in cross section. The sutures are essentially flush with the surface and are decidedly oblique to the axis of elongation forming a V-shaped pattern on one edge of the test. The last two chambers are slightly inflated, but the early ones are not.

Because this form is represented by a single specimen, satisfactory specific identification cannot be made.

Figured specimen (C.A.S. 12551).

Rectoglandulina Loeblich and Tappan, 1955

Rectoglandulina sp.

Plate 12, figures 2a, b

This form has an apertural angle of approximately 70° and an average initial angle of at least 90°.

Breadth-length ratio is 8 to 11 with the greatest breadth near the center. The last chamber makes up about three-fourths the entire test. The general shape of this form is similar to illustrations of the type *Glandulina inflata* Bornemann (1855, p. 320, pl. 12, figs. 6, 7) from the Oligocene of Germany and also other specimens referred to this species as *Pseudoglandulina inflata* (Bornemann) from the Lincoln Formation of Weaver (1912) of Washington (Cushman and Frizzell, 1943, p. 84, pl. 14, fig. 14; Rau, 1948, p. 168, pl. 30, fig. 3). However, the present form differs from *P. inflata* in that the aperture angle is less than the angle formed by the initial part of the test. Because this form is rare in the present material it is not known if its characteristics constitute a distinct species or if they represent variations of *P. inflata*.

The term *Rectoglandulina* is used in place of *Pseudoglandulina* in accordance with a revision of some glanduline Nodosariidae (Loeblich and Tappan, 1955).

Figured specimens (C.A.S. 12552).

Genus *Lagena* Walker and Jacob, 1798

Lagena semistriata Williamson,
of Cushman and Parker
Plate 12, figure 7

Lagena semistriata Williamson. CUSHMAN and PARKER, 1931, p. 7, pl. 1, fig. 23.

This form is rare in the present collection. It is characterized by the nearly flat base, costae over the lower part of the test, and an elongated neck that is square in cross section and somewhat twisted. It is essentially identical to *L. semistriata* Williamson of Cushman and Parker from the Miocene of California. However, it differs from Williamson's type figure in that the base is more nearly flat. A new specific name may be warranted for the present form, but the material is not sufficient to adequately establish the characteristics of a species.

Cushman and Parker's specimen is from the Temblor Formation of California, a part that is regarded as early Saucian in age (Kleinpell, 1938, p. 226).

Figured specimen (C.A.S. 12553).

Family BULIMINIDAE

Genus *Buliminella* Cushman, 1911
Buliminella subfusiformis Cushman

Plate 12, figure 4

Buliminella subfusiformis CUSHMAN, 1925b, p. 33, pl. 5, fig. 12; KLEINPELL, 1938, p. 251, pl. 9, fig. 8; CUSHMAN and PARKER, 1947, p. 64, pl. 16, fig. 21; RAU, 1951, p. 439, pl. 65, fig. 5.

This species is common in the present collection. Specimens vary somewhat in size and shape. The smaller ones are fusiform whereas the larger specimens display more nearly parallel sides.

Buliminella subfusiformis has a widespread geographic distribution in rocks of Miocene age. Accord-

ing to Cushman and Parker (1947, p. 64) the species is known from Florida, North Carolina, and central Sumatra. Records also show that it is known throughout rocks of Miocene age in California (Kleinpell, 1938, p. 251). In Oregon it is recorded from the Astoria Formation (Cushman, Stewart, and Stewart, 1947, p. 17) and has been observed in abundance by the writer in the Nye Mudstone and less commonly in the upper part of the Toledo Formation. In Washington it is known from the Astoria (?) Formation and the Blakeley Formation and rocks of equivalent age (Rau, 1951, p. 439; 1958; in press). The species is also recorded from the Recent seas off southern California (Cushman and Moyer, 1930, p. 56). Although *B. subfusiformis* is found throughout much of the Miocene of the Pacific Coast, it is rarely found in rocks older than the upper part of the Zemorrian Stage.

Figured specimen (C.A.S. 12554).

Genus *Bolivina* d'Orbigny, 1839

Bolivina marginata adelaidana Cushman and Kleinpell
Plate 12, figure 10

Bolivina marginata adelaidana CUSHMAN and KLEINPELL, 1934, p. 10, pl. 2, figs. 1, 2; CUSHMAN, 1937, p. 87, pl. 10, figs. 11-14; CUSHMAN, STEWART, and STEWART, 1947, p. 18, pl. 2, figs. 13a, b; RAU, 1951, p. 443, pl. 65, fig. 14.

This form is common in the present collection. Its sutures are strongly limbate and many of the chambers are extended forming a serrate periphery.

The type was described from rocks of Miocene age in the Adelaida quadrangle of California. Although most of the subsequent records of the species are from the Miocene of the Pacific coast, it has been recorded also from the Recent seas off southern California, west coast of Mexico, and the coast of Colombia (Cushman and McCulloch, 1942, p. 200). The Miocene records of the species in California are from strata that are regarded as early Saucian in age (Kleinpell, 1938, p. 277). In Oregon it is recorded from the Astoria Formation (Cushman, Stewart, and Stewart, 1947) and has been observed by the writer from the Nye Mudstone. The foraminiferal faunas of both these Oregon units compare well with that of the Saucian Stage. Washington records of this form are from rocks of both the Zemorrian and Saucian ages (Rau, 1958; in press). In the Pacific Northwest *B. marginata adelaidana* is taken to indicate an age no older than Zemorrian.

Figured specimen (C.A.S. 12555).

Genus *Uvigerina* d'Orbigny, 1826

Uvigerina subperegrina Cushman and Kleinpell
Plate 12, figures 11a, b

Uvigerina subperegrina CUSHMAN and KLEINPELL, 1934, p. 12, pl. 2, figs. 9-11; CUSHMAN and TODD, 1941, p. 52, pl. 14, figs. 19-23; CUSHMAN and GRAY, 1946, p. 36, pl. 6, fig. 14; CUSHMAN, STEWART,

and STEWART, 1947, p. 19, pl. 2, figs. 14, 15; *idem*, 1949, p. 153, pl. 17, fig. 8.

One of the more common forms in the present collection from Alaska is referred to here as *Uvigerina subperegrina* Cushman and Kleinpell. The test is small, sutures depressed, chambers inflated and independently ornamented with numerous costae. The aperture is terminal at the end of a distinct neck.

This species is recorded from the Miocene of Virginia, Florida, California, and Oregon. It is also recorded from the Pliocene of California and Washington. Although most records of this species are from rocks assigned to the upper part of the Miocene and Pliocene, it occurs in Washington and Oregon in rocks as old as the Saucian Stage (early Miocene).

Figured specimen (C.A.S. 12556).

Genus *Siphogenerina* Schlumberger, 1883

Siphogenerina kleinPELLI Cushman

Plate 12, figures 12, 14

Siphogenerina kleinPELLI CUSHMAN, 1925a, p. 3, pl. 4, fig. 5; KLEINPELL, 1938, p. 301, pl. 7, fig. 24, pl. 11, fig. 4.

Siphogenerina transversa Cushman. RAU, 1951, p. 445, pl. 65, figs. 25-27.

The genus *Siphogenerina* is represented by substantially more individuals than any other genus of the present assemblage. Specimens vary considerably in shape and number of costae. As a group they are characterized by 11 to 13 heavy longitudinal, occasionally incomplete costae, and asymmetric test.

Although the differences between *S. kleinPELLI* and *S. transversa* are poorly defined, further studies of type material suggest to the writer that the specimens in question, as well as those figured from the Miocene of Washington State, are best referred to *S. kleinPELLI* rather than to *S. transversa*.

This conclusion is based on the asymmetry of the test, occasional incomplete costae, and lower, rather blunt, and more numerous costae than are shown on *S. transversa*. A few specimens approach *S. branneri* in that the costae are more like striae and more numerous than are displayed on typical specimens of *S. kleinPELLI*. Nevertheless these characteristics are not well enough developed on any of the specimens to regard them as *S. branneri* and, therefore, they are all referred to *S. kleinPELLI*.

The species was originally described from the Monterey Shale of California. It has since been recorded from a number of other Miocene localities of Saucian, Relizian, and Luisian ages in California (Kleinpell, 1938, p. 301). Forms similar to those from Alaska are referred to *S. branneri* from the Astoria Formation of Oregon (Cushman, Stewart, and Stewart, 1947). Specimens referred to *S. transversa* from Miocene rocks of Washington are here regarded as conspecific with the type *Siphogenerina kleinPELLI* as

well as with those of the present collection from Alaska.

Figured specimens (C.A.S. 12557 and 12558).

Genus *Angulogerina* Cushman, 1927

Angulogerina aff. *A. hughesi* (Galloway and Wissler)

Plate 12, figures 9a, b

A few specimens resemble *Angulogerina hughesi* (Galloway and Wissler): the test is subtriangular in cross section in the later part of its development while the early part is conical; the early chambers are inflated and the later ones are flattened, forming a subtriangular outline of the test. The early chambers of most specimens are faintly ornamented by fine striae. These specimens differ from *A. hughesi* in that they have a greater width with respect to length and that the greatest width is nearer the apertural end.

This form has many of the characteristics of the genus *Uvigerinella* but differs mainly in that the latter part of the test is subtriangular in cross section. With this exception the form could be compared generally with *Uvigerinella californica* Cushman and closely related forms.

Figured specimen (C.A.S. 12559).

Family ROTALIIDAE

Genus *Valvulineria* Cushman, 1926

Valvulineria menloensis Rau

Plate 12, figures 13a, b, c

Valvulineria menloensis RAU, 1951, p. 446, pl. 66, figs. 17-22.

A few specimens are essentially identical to the type specimens of *V. menloensis* from the Willapa valley of southwest Washington.

The species is recorded from the Lincoln(?) and Astoria(?) Formations of southwest Washington (Rau, 1958) and the upper part of the Twin River Formation of northwest Washington (Rau, in press). It has also been observed by the writer from the type section of the Blakeley Formation exposed on Bainbridge Island, Washington. All rocks in which this species is known are referred to either the Zemorrian or Saucian Stage of "Oligo-Miocene" age.

Figured specimen (C.A.S. 12560).

Genus *Cancris* Montfort, 1808

Cancris cancriformis (Kleinpell)

Plate 13, figures 9a, b, c

Baggina cancriformis KLEINPELL, 1938, p. 324, pl. 9, figs. 24a-c.

Cancris baggi planus CUSHMAN and TODD, 1942, p. 84, pl. 21, figs. 11a-c.

Cancris(?) cancriformis (Kleinpell). CUSHMAN and TODD, 1944, p. 105.

Cancris cancriformis (Kleinpell). CUSHMAN, STEWART, and STEWART, 1947, p. 21, pl. 3, figs. 5a-c.

This form is well represented in the present collection. The specimens show considerable variation in size, roundness of the periphery, and flatness of the

dorsal side. Some approach the more rounded form, *Cancris baggi* Cushman and Kleinpell. However, a large majority of specimens compare best with the holotype of *Baggina cancriformis* Kleinpell. The compressed nature of the test and distinct lobelike extension of the final chamber into the umbilical area indicate that the species should be referred to the genus *Cancris* rather than *Baggina*. The holotype of the species as well as the specimens in question also compare well with the description and illustrative material of *Cancris baggi planus* Cushman and Todd. Therefore these forms are considered conspecific.

Cancris cancriformis (Kleinpell) was originally described from Miocene rocks of the Reliz Canyon, California. At the same time, the species was recorded from the Modelo Formation of Los Sauces Creek and the Adelaida quadrangle of California (Kleinpell, 1938, p. 325). All of these occurrences are from the lower part of the Relizian Stage. Subsequently *C. baggi planus* Cushman and Todd was recorded from the upper middle Miocene Choctawhatchee Formation of Florida and Recent material off the California coast (Cushman and Todd, 1942, p. 84).

In the Pacific Northwest *C. cancriformis* is recorded from the Astoria Formation of Oregon (Cushman, Stewart, and Stewart, 1947, p. 21).

Figured specimen (C.A.S. 12561).

Family CASSIDULINIDAE

Genus *Cassidulina* d'Orbigny, 1826

Cassidulina cf. *C. laevigata carinata* Cushman,
of Cushman and Parker
Plate 13, figures 1a, b; 3a, b

Cassidulina laevigata carinata Cushman. CUSHMAN and PARKER, 1931, p. 14, pl. 2, fig. 14.

A few specimens compare well with a form referred to as *C. laevigata carinata* by Cushman and Parker but not the type of the form figured by Cushman (1922, p. 124, pl. 25, figs. 6, 7). The present specimens differ from Cushman's type in that there are fewer chambers and the sutures are more nearly straight, but in these and other respects they are much like the figures shown by Cushman and Parker. The present specimens vary in size from approximately .30 mm. to .55 mm. in diameter.

Cassidulina laevigata carinata is recorded from much of the lower and middle Miocene of California (Kleinpell, 1938, p. 333). It is also known from the Astoria Formation of Oregon (Cushman, Stewart, and Stewart, 1947) and, although not recorded, similar forms have been observed by the writer in rocks of Miocene age in Washington State.

Figured specimens (C.A.S. 12562 and 12563).

Cassidulina cf. *C. margareta* Karrer

Plate 13, figures 2a, b; 4a, b

Cassidulina margareta Karrer. CUSHMAN and PARKER, 1931, p. 15, pl. 2, figs. 13a, b; CUSHMAN and LAIM-

ING, 1931, p. 116, pl. 13, figs. 7a-c; KLEINPELL, 1938, p. 333, pl. 7, fig. 20, pl. 8, fig. 10.

Common representatives of the genus *Cassidulina* are semiglobular in shape with four pairs of chambers in the outer whorl. The sutures are distinct but not depressed. This form compares well with illustrations of several specimens referred to *C. margareta* from the Miocene of California. However, Karrer's illustration and description of the type from Germany indicates some differences from the present specimens. Karrer's illustration shows that the chambers are inflated and his description further suggests that the periphery may be more angular than that of the present specimens. He also states that the diameter is 1.0 mm. which is much greater than any of the specimens figured from California. The present specimens vary from approximately 0.35 to 0.60 mm. in diameter. Without a comparison with Karrer's type material the present specimens are only tentatively referred to *C. margareta* Karrer, but they are regarded as identical to those known in the Miocene of California.

Cassidulina californica Cushman and Hughes has many of the features of the specimens in question also, but differs in that it is much larger and has five instead of four pairs of chambers in the last coil.

Cassidulina margareta Karrer was originally described from the Miocene of Germany. In America it is recorded only from Miocene rocks of California of the Zemorrian, Saucian, and Relizian Stages (Kleinpell, 1938, p. 333).

Figured specimens (C.A.S. 12564 and 12565).

Family CHILOSTOMELLIDAE

Genus *Sphaeroidina* d'Orbigny, 1826

Sphaeroidina variabilis Reuss
Plate 13, figures 5a, b

Sphaeroidina variabilis REUSS, 1851, p. 88, pl. 7, figs. 61-64; CUSHMAN, 1929, p. 101, pl. 14, figs. 15a-c; BARBAT and VON ESTORFF, 1933, p. 173, pl. 23, figs. 19a-c.

Sphaeroidina cf. *bulloides* d'Orbigny. CUSHMAN, STEWART, and STEWART, 1947, p. 22, pl. 4, figs. 1, 2.

This form is fairly common in the present collection. It compares well with illustrations of the type and figures of other specimens referred to *S. variabilis* Reuss.

The species is recorded from many European localities of Oligocene and Miocene age. It is also recorded from the middle Tertiary of Venezuela, the Oligocene of Mexico, and the Zemorrian and Saucian Stages, "Oligo-Miocene," of the Pacific Coast of the United States (Kleinpell, 1938). A form comparable to that of the present collection is recorded from the Astoria Formation of Oregon (Cushman, Stewart, and Stewart, 1947, p. 22). In Washington State the writer has encountered representatives of the genus only in rocks of Zemorrian age and younger (Rau, 1958; in press).

Figured specimen (C.A.S. 12566).

Family ANOMALINIDAE

Genus *Cibicides* Montfort, 1808*Cibicides elmaensis* Rau

Plate 13, figures 6a, b, c

Cibicides elmaensis RAU, 1948, p. 173, pl. 31, figs. 21-23.*Cibicides floridanus* (Cushman). CUSHMAN and FRIZZELL, 1943, p. 88, pl. 15, figs. 11, 12; CUSHMAN, STEWART, and STEWART, 1947, p. 23, pl. 4, figs. 7a-c.*Cibicides* aff. *C. perlucida* Nuttall. RAU, 1951, p. 452, pl. 67, figs. 23-25.

This species is very common in the present collection. It is biconvex but is much more strongly convex ventrally than dorsally. *Cibicides elmaensis* was originally described from the Lincoln Formation of Washington (Rau, 1948) as displaying great variation in form. Specimens of the present assemblage represent one extreme in this variation in that they are strongly convex on the ventral surface. Studies of Tertiary Foraminifera from the Pacific Northwest, subsequent to the original description of the species, have shown that at least in that area the form with high convexity of the ventral surface and a nearly flat dorsal side is the only form of the species whose range extends stratigraphically above the Refugian Stage. It therefore appears that the highly variable species of the Refugian Stage became somewhat standardized thereafter and perpetuated only the form with the highly convex ventral surface. It might be thought that this strain should be divided into more than one species as this would be useful for stratigraphic purposes. However, because complete gradation in form is shown within individual assemblages, it is difficult to make this distinction. Therefore the writer prefers to regard the entire strain as one species.

The form occurring in the present collection has the greatest stratigraphic range and is recorded from rocks of the Refugian, Zemorrian, and Saucesian Stages in western Washington (Rau, 1958, see *Cibicides elmaensis* var. A). It is also known from the Astoria Formation of Oregon.

Figured specimen (C.A.S. 12567).

Cibicides cf. *C. pseudoungerianus**evolutus* Cushman and Hobson

Plate 13, figures 7a, b, c

A few specimens are nearly equally biconvex, completely evolute on the dorsal side, and have about 10 chambers in the last whorl. They are rather coarsely perforate and the sutures are distinct on the ventral surface ending in the umbonal area in a small plug. The sutures are less distinct on the dorsal surface. Apertural features are not clear but appear to extend back from the periphery at least one chamber on the dorsal side. Because there are only a few specimens of the form in the present collection, specific identification is only tentatively suggested.

Cibicides pseudoungerianus evolutus is recorded from the San Lorenzo and Vaqueros Formations, the Gaviota Formation of Effinger (1935) of the California Coast Range, and the type Blakeley Formation of Washington (Kleinpell, 1938, p. 355; Wilson, 1954, p. 144). Effinger's Gaviota Formation represents the Refugian Stage whereas all other occurrences of the form are from rocks that are referred to the Zemorrian Stage.

Figured specimen (C.A.S. 12568).

Cibicides? sp.

Plate 13, figures 8a, b, c

A single specimen is tentatively referred to the genus *Cibicides*. It is involute on one side, but all chambers are visible on the other side. The surface is rather coarsely perforate. The sutures are not depressed and are nearly straight on both sides. The final chamber is broken and therefore the apertural features cannot be observed.

Figured specimen (C.A.S. 12569).

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271. WHAT IS *DISCORBIS VESICULARIS* LAMARCK?

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ABSTRACT

The type species of *Discorbis*, *D. vesicularis* Lamarck from the Lutetian of the Paris Basin, is analyzed. There is a distinct toothplate in each chamber dividing the protoforamen from the deuteroforamen and forming a large tenon on the ventral side which partly covers the umbilical hollow. There is a poreless band along the periphery of the test. A second species, *D. margaritifera* (Le Calvez), also from the Lutetian, has the same characteristics as the type species. *Discorbis* differs from *Neoconorbina*, *Discopulvinulina*, *Conorbella*, *Heronallenia*, *Glabratella* and *Rosalina*.

INTRODUCTION

Discorbis vesicularis Lamarck (1806, pl. 62, fig. 7) was described from the Lutetian of the Paris Basin but was poorly figured. Cushman (1927, p. 123, pl. 24, fig. 1) redescribed it and Le Calvez (1949, p. 16, pl. 3, figs. 36-38) gave a better figure of the species, but no description. The result is that although *D. vesicularis* is the type species of the genus *Discorbis*, our knowledge of this type species is extremely scanty.

This species occurs in many samples of the Lutetian of the Paris Basin; the preservation is usually very good and empty tests are common.

DESCRIPTION OF THE
MEGALOSPHERIC FORM

Test oval, trochoid, compressed. On the dorsal side all chambers visible, with 5 chambers in the last-formed whorl in most specimens. Sutures in the first whorl slightly raised and thickened, with the central part often covered by secondary chalk; later sutures depressed; all sutures curved backward. The calcareous wall pierced by relatively large and distinct, rounded pores. The marginal end of the aperture can be seen in the last-formed chamber as a protruding part.

The periphery is rounded to slightly subacute and there is a distinct, smooth, poreless band along each chamber.

On the ventral side each chamber has distinctly depressed sutures, usually slightly curved backward, with a deep protoforamen. Distally from this a large tenon is formed which covers the greater part of the umbilical cavity, the tenon of a subsequent chamber partly covering the earlier one; distally from the tenon a large deuteroforamen extends up to and over the periphery, where it is bordered by a somewhat thickened lip. When seen in peripheral view, this deuteroforamen is distinctly separated from the portion of the test covered by the tenon; which portion ends with the protoforamen on the other side of the tenon. This dividing indentation is the beginning of a well-developed tooth-

plate of which the poreless tenon is the free-folding part. The whole ventral wall, except for the tenon, is pierced by rather coarse pores.

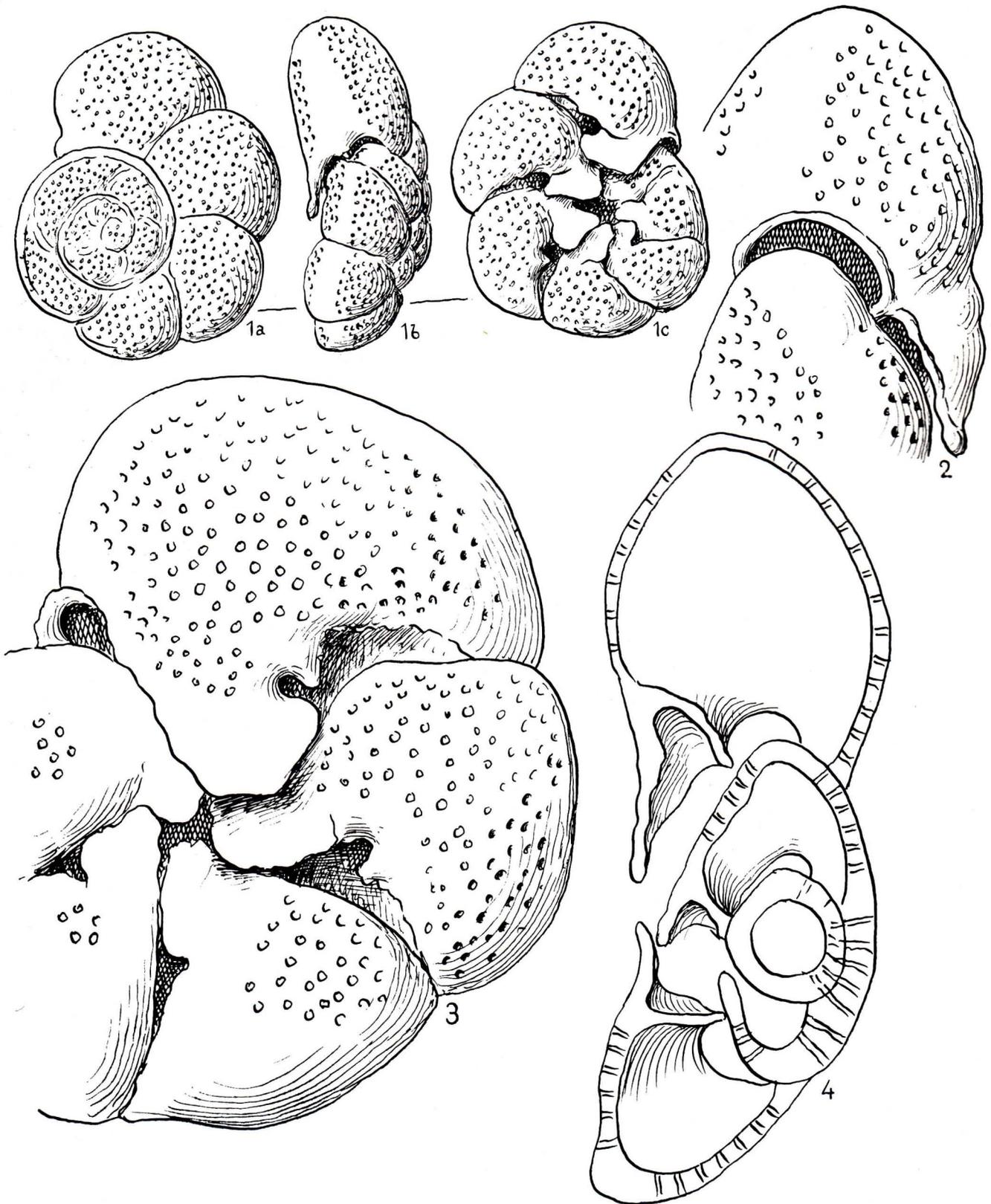
Transverse sections show that in each chamber there is a distinct toothplate which goes from the tenon in a dorsal direction and forms the part which separates the protoforamen from the deuteroforamen. Even in the first-formed chambers the poreless periphery is clearly seen.

Horizontal sections show that the septa are simple. Secondary thickening occurs only in the center of the dorsal side.

DISCUSSION

This analysis clearly establishes the systematic position of the type species of *Discorbis*. It belongs to the Deuteroforaminata and unlike *Discopulvinulina* Hofker, 1951, which is close to it, has a very distinct toothplate which divides the protoforamen from the deuteroforamen. This toothplate distinguishes *Discorbis* from *Discopulvinulina* since in most species of the latter genus the toothplate is absent though in most cases there is a protoforamen. Like *Discopulvinulina*, *Discorbis* has a poreless periphery, which indicates that *Discorbis* is the ancestral form. *Discorbis* can be distinguished from *Neoconorbina* Hofker, 1951, by the almost conical test of the latter. It may be a descendant of *Conorbooides* Hofker, 1952, differing from that genus in having a widely opened umbilicus and in the fact that *Conorbooides* is a protoforaminate genus. *Discorbis* seems to be very close to *Globorotalia*; both genera have a proto- and a deuteroforamen separated by a tenon (toothplate); both have a poreless peripheral area, in *Globorotalia* appearing as a keel, in *Discorbis* as a broad band. In *Globorotalia*, however, the inner part of the toothplate is greatly reduced as it is in *Discopulvinulina*. Both genera have an open umbilicus covered by strongly developed tena.

It may be found eventually that there is an orthogenetic series of *Discorbis* in which the toothplate is reduced more and more, ending with *Discopulvinulina*. *Hanzawaia* Asano, 1944, also is a genus in which the toothplate is absent and the protoforamen reduced; the chambers overlap dorsally so that the first coils of chambers on the dorsal side are covered by the overlapping dorsal parts of the later chambers. If it is true that such an orthogenetic series exists, all the forms of this series would fall into a greatly emended genus, *Discorbis*. Up to now, however, transition forms have not yet been discovered and so it is better to use the name *Discorbis* only for those species which have



TEXT FIGURES 1-4

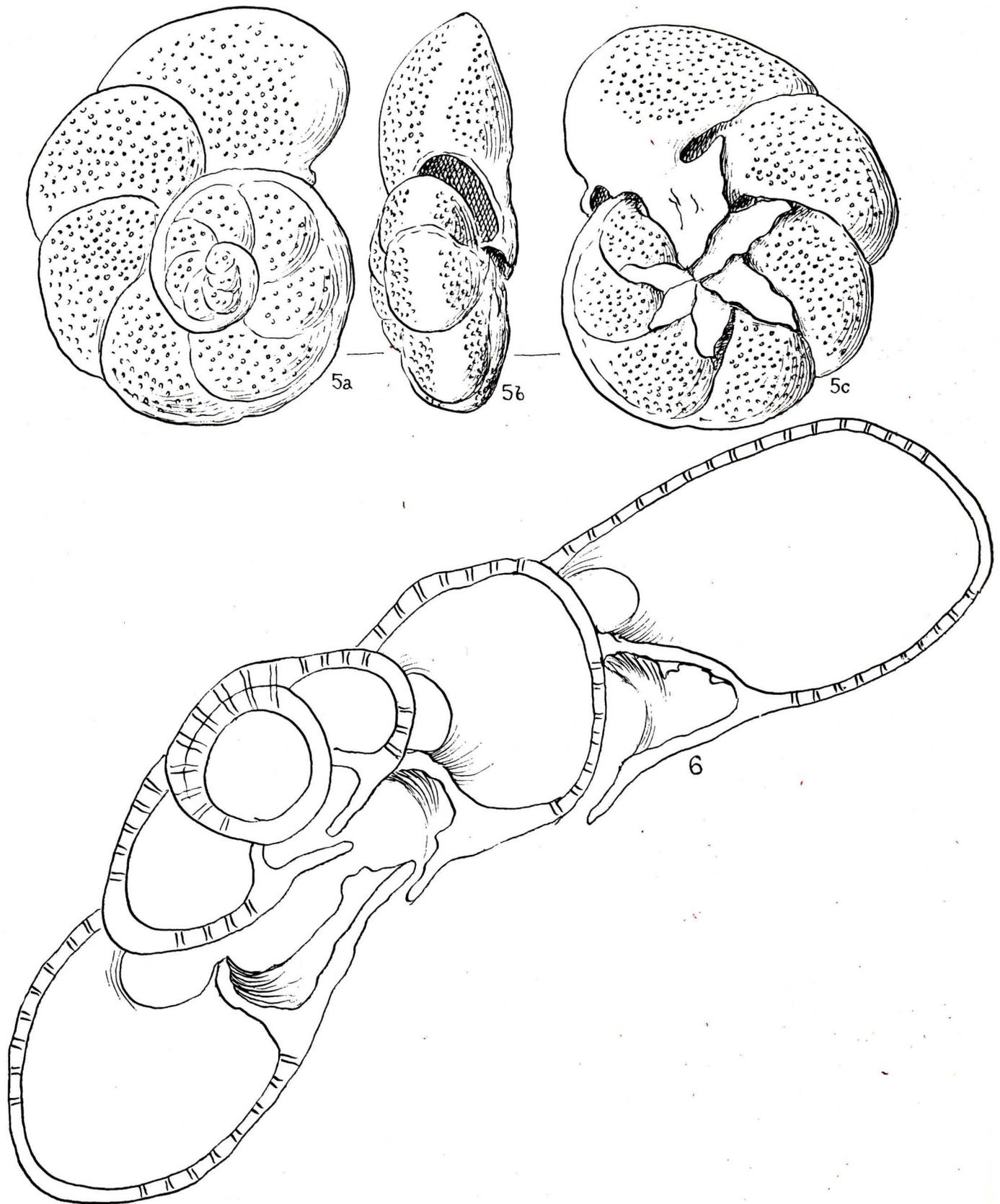
Discorbis vesicularis Lamarck, Lutetian, Saint Frédéric, Paris Basin

1, $\times 103$; a, dorsal side; b, edge view; c, ventral side. 2, aperture of dextrally coiled individual; $\times 258$. 3, same specimen as fig. 2, larger part of ventral side showing the protoforamen and deuteroforamen with the toothplate tenon between; $\times 258$. 4, transverse section showing the toothplates separating the protoforamina from the deuteroforamina; $\times 258$.

the characteristics of the type species: a flat trochoid test, distinct protoforamen and deuteroforamen separated by a well-developed toothplate which ends in a distinct poreless tenon covering at least part of the umbilical hollow into which the chambers open, and

a nonperforate periphery. To know whether or not a species should be referred to *Discorbis*, it is necessary to examine transverse sections.

The available samples from the Lutetian of the Paris Basin contain specimens of *D. vesicularis* nearly all of



TEXT FIGURES 5, 6

Discorbis margaritifera (Le Calvez), Lutetian, Saint Frédéric, Paris Basin

5, $\times 103$; a, dorsal side; b, edge view; c, ventral side. 6, transverse section, showing toothplates; $\times 258$.

which have 5-6 chambers in the last-formed whorl. The specimen figured by Le Calvez has 8 chambers but all the other characteristics are the same as those of specimens with 6 chambers in the last-formed whorl, except that the peripheral view of Le Calvez' specimen does not show the wide poreless band. This appears to

be a *lapsus*, but the greater number of chambers is characteristic of microspheric specimens.

In these same samples several species of true *Discorbis* can be found. They are: *D. propinqua* (Terquem), *D. bractifera* Le Calvez, *D. alata* Le Calvez, none of the other species referred to *Discorbis* by

Le Calvez (1949) should be included. *Anomalina margaritifera* Le Calvez (1949, p. 44, pl. 4, figs. 60-62) should be referred to *Discorbis*, as shown here by the illustrations (text figs. 5, 6). This species is much larger than *D. vesicularis*. The poreless periphery, though not shown by Le Calvez, is quite distinct; the tena with prolongations over the ventral sutures and partly covering the protoforamen are typical. These prolongations form a star-shaped structure which is emphasized by the fact that the umbilical hollow is nearly covered by these tena. Transverse sections show the close resemblance of this species to the type species of the genus. They show the distinct toothplates separating the protoforamina from the deuteroforamina.

The genus *Discorbis* is known to occur only in the lower and middle Tertiary. Those species hitherto assigned to this genus but having reduced toothplates should be referred to *Discopulvinulina*; species with a conical transverse section, a distinct ventral tenon separating the protoforamen from the deuteroforamen and a well-developed toothplate belong to *Neoconorbina*; species with a conical shape and a tenon on the ventral side separating a reduced protoforamen from the deuteroforamen, but lacking an inner toothplate, belong to *Rosalina* as emended by Brotzen (1948). Species with a conical shape but lacking a distinct ventral tenon and two foramina per chamber, but having on the ventral side distinct striae radially arranged, belong to the genus *Conorbella* Hofker, 1951. These striae are formed by rows of pustules; inner toothplates are not developed. The species with a lower spire, one ventral aperture which is obviously a proto-

foramen, and with fine radial striae on the ventral side (not formed by rows of pustules) belong to *Glabratella* Dorreen, 1948. Species with very hyaline walls, often without distinct pores, with a protoforamen on the ventral side connected with a complicated inner toothplate which forms the entire ventral wall, and with fine furrows on the ventral walls of the chambers running radially towards the periphery do not belong to the Rotaliidae but should be referred to the genus *Heronallenia* Chapman and Parr, 1931, which is related to *Buliminella*.

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XIV, PART 4, OCTOBER, 1963
272. STAINFORTHIA HOFKER
OR CHILOGUEMBELINA LOEBLICH AND TAPPAN?

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ABSTRACT

The genus *Stainforthia* Hofker, July 1956, has priority over *Chiloguembelina* Loeblich and Tappan, November 1956; its type species, *S. concava* (Höglund), is a *Virgulina*-like species with a tendency to become biserial and with typical apertural characteristics including toothplates. All species referred to *Chiloguembelina*, including the type species *C. midwayensis* (Cushman), have the characteristic aperture and triserial arrangement of the initial chambers, as do all the other species mentioned here. *Stainforthia* is redescribed; it comprises all *virgulina* species with a hyaline wall, including those referred to *Chiloguembelina* and "*Guembelitria*" *vivans* Cushman. Toothplates are found in all species studied. Thus, *Stainforthia* (*Chiloguembelina* of authors) cannot belong to the Heterohelicidae, which according to Cushman do not have toothplates or teeth. Genera referred by authors to the Heterohelicidae, but which have toothplates, are reviewed briefly.

DISCUSSION

In July 1956, Hofker (p. 908) proposed a new generic name for small Tertiary and Recent "*Bolivina*" Foraminifera, *Stainforthia*, with the type species *Virgulina concava* Höglund. In November of the same year, Loeblich and Tappan (1956, p. 340) proposed the generic name *Chiloguembelina* for small "*Bolivina*" Foraminifera from the Tertiary, with the type species *Guembelina midwayensis* Cushman.

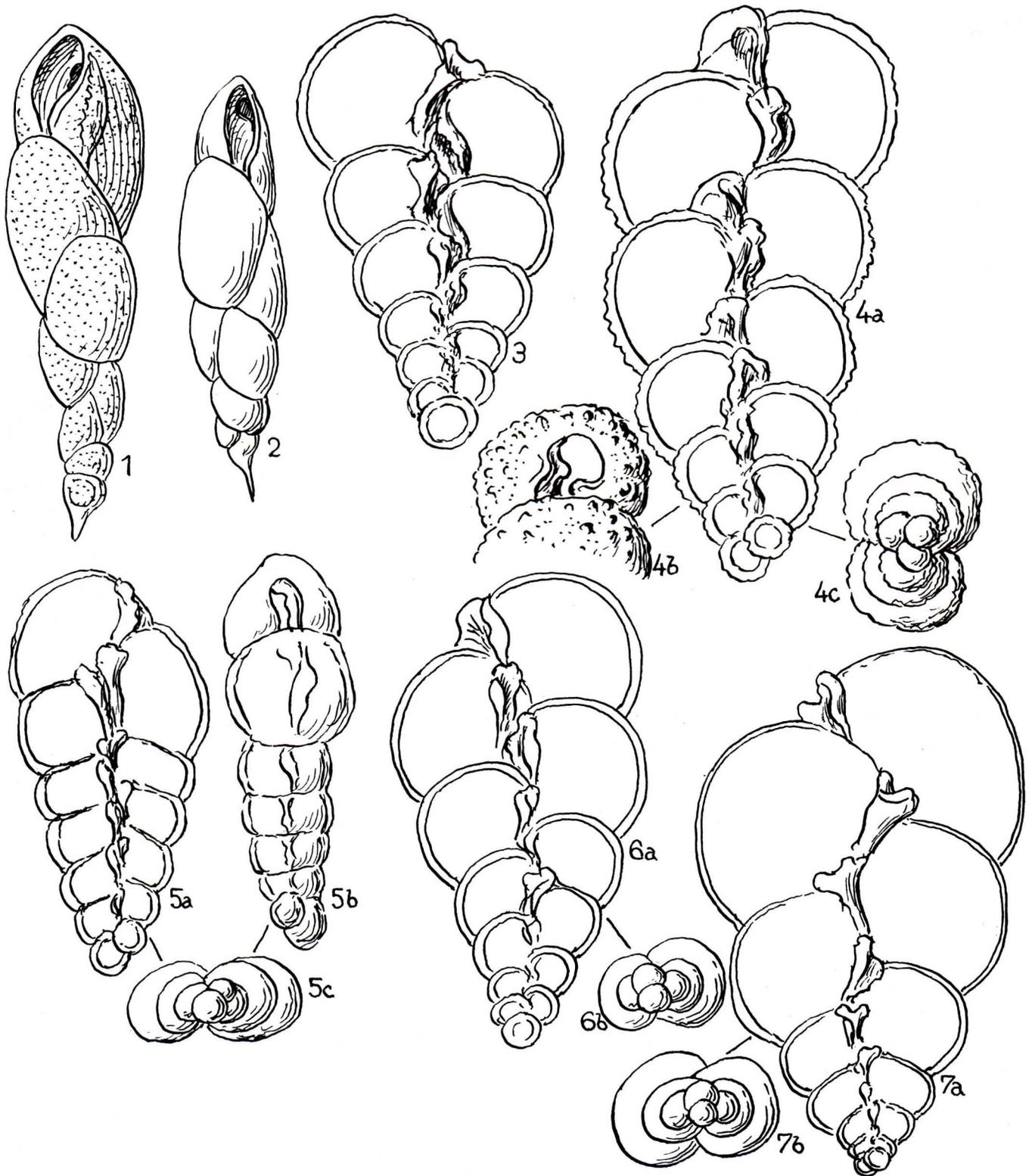
Virgulina concava is well described by Höglund (1947, p. 257, pl. 23, figs. 3, 4; pl. 32, figs. 4-7; text figs. 273-275). He says (p. 261) "It is questionable whether my species really belongs to the genus *Virgulina*." I have studied many specimens of this species and have come to the same conclusion. There is a *Virgulina*-like initial end but the later chambers tend to become biserially arranged. The aperture is loop-shaped and differs from those of *Bolivina* and *Virgulina* by the striking characteristic that within the loop-shaped opening there is a funnel-shaped poreless area at the bottom of which lies the real aperture which has a small but distinct toothplate. *V. concava* thus differs strongly from a normal *Virgulina* as Höglund rightly pointed out, but its most striking characteristic is the hyaline wall.

When studying *Guembelina venezuelana* Nuttall from various localities, I found that this species also begins with a short *Virgulina*-like initial end and then later becomes bolivinid. Here, too, the aperture is loop-shaped with a funnel-shaped area leading to the small aperture having the typical, somewhat reduced toothplate. For this reason, I included this species in *Stainforthia* which thus also contains *Virgulina*-like

species having a *Bolivina*-like later development and this peculiar apertural structure. All these species are small. Beckmann (1957, p. 83) has denied the occurrence of a triserial stage in *G. venezuelana* but a re-study of specimens from Ecuador confirms its presence. The twisted appearance of many of these Tertiary forms is well known but neither Beckmann (1957) nor Montanaro Gallitelli (1955) give any description of the finer structure of the aperture.

In the Danian of Denmark well-preserved specimens of several *Chiloguembelina* species occur, and, in addition, topotype material of the type species, *Guembelina midwayensis*, was available to me. A close study reveals that even the type species, in well-preserved specimens, shows a distinctly twisted initial end, often with the proloculus offset to one side of the next two chambers as described for *Stainforthia venezuelana* from Ecuador. Well-preserved specimens also have the typical loop-shaped aperture with the funnel-shaped inner part leading to a small opening having a somewhat reduced toothplate emerging to form a "lip," as described for the type species of *Chiloguembelina*. In some species of *Chiloguembelina*, for example *C. parallela* Beckmann from the Danian of Denmark (only appearing in the upper part of that stage), the toothplates are so well formed that there can be no doubt of their existence. These small but typical toothplates form the lips, or flanges, mentioned by Loeblich and Tappan and by Beckmann. They can be followed, running from aperture to aperture, in all the chambers from the beginning of the test. However, in some species they may be very much reduced or they can be dissolved after death.

Since in the original description of the Heterohelicidae, based on the type genus *Heterohelix*, the apertures are described as "simple, usually large for the size of the test, without teeth . . .," species having apertures with toothplates cannot be placed in this family. Later, Cushman included in this family many forms which do not have a simple aperture without a tooth, but the type genus *Heterohelix* does have such an aperture. Montanaro Gallitelli (1957), when revising the family Heterohelicidae, did not follow Cushman's original description when she included "*Guembelitria*" *vivans* Cushman (having the typical aperture of *Stainforthia*), *Bolivinoidea* (with an aperture typical of *Bolivina*), *Bolivinita quadrilatera* (Schwager) which has all the characteristics of a true *Bolivina*, *Tappanina selmensis* (Cushman) with its toothplates



TEXT FIGURES 1-7

Figs. 1, 2, *Stainforthia concava* (Höglund). 1, Nias Deep, south of Sumatra, Recent; $\times 330$. 2, after Höglund (1947), Gullmar Fjord, Recent; $\times 127$. Fig. 3, *Stainforthia midwayensis* (Cushman), Midway Formation, Texas, U.S.A., Paleocene (coll. by H. J. Plummer); longitudinal section; $\times 344$. Fig. 4, *Stainforthia morsei* (Kline), Krosager, Hofker sample 857, middle Danian, Denmark; a, longitudinal section; b, aperture; c, initial part of the test showing triserial first part; $\times 344$. Fig. 5, *Stainforthia parallela* (Beckmann), Hofker sample 1012, Sevel, upper Danian, Denmark; a, longitudinal section; b, test seen from the side to demonstrate the long narrow aperture and the position of the toothplates; c, initial end with triserial first chambers; $\times 344$. Fig. 6, *Stainforthia midwayensis* (Cushman), Hofker sample 1012, Sevel, upper Danian, Denmark; a, longitudinal section; b, initial end with triserially arranged first chambers; $\times 344$. Fig. 7, *Stainforthia venezuelana* (Nuttall), sample unit 5a, upper Eocene, Ecuador; a, longitudinal section; b, initial end with triserially arranged first chambers; $\times 258$.

Eowigerina and *Siphogenerinoides* both with well-developed toothplates. In addition, *Bolivinitella eleyi* (Cushman) has been included. This species, according to my careful examination (see Hofker, 1951, pp. 107-111), does not have toothplates but also does not have the perforate wall which according to Cushman's original description is characteristic of this family.

From the above discussion, it is obvious that *Stainforthia* has priority over *Chiloguembelina* which becomes a junior synonym of the former genus, and, in addition, that *Stainforthia* should not be referred to the family Heterohelcidae; Hofker (1956), comparing its chamber arrangement with that of microspheric forms of *Protoglobobulimina*, placed it in the family Globobuliminidae Hofker.

In order to avoid further confusion, a description of *Stainforthia* is given here.

Genus *Stainforthia* Hofker

Stainforthia HOFKER, 1956, Jour. Paleontology, vol. 30, no. 4 (July), p. 908.

Chiloguembelina LOEBLICH and TAPPAN, 1956, Jour. Washington Acad. Sci., vol. 46, no. 11 (November), p. 340.

Type Species.—*Virgulina concava* Höglund.

Description.—Test is always minute, ranging from species having only a twisted trochoid stage (*Stainforthia vivans* (Cushman)) to those having an entirely biserial test such as that found in *Bolivina*. Intermediate species may have only an initial trochoid stage, or may show such a stage only in the microspheric form. The early trochoid stage may also be seen in planktonic species.

The chambers in planktonic forms are inflated, tending to become globular.

The aperture is usually loop-shaped but in planktonic species, because of the globular form of the chambers, it may be crescent-shaped although still asymmetric. The loop-shaped aperture extends downward in a funnel-shaped process at the bottom of which is found the apertural opening from which the toothplate protrudes. This toothplate in some forms is well developed, in others, especially the planktonic species, it is more or less reduced but is never absent; it forms asymmetrical lips or flanges at the border of the apertural opening.

The test is always calcareous, thin-walled, hyaline, with fine, densely placed perforations; in some species,

the pores may be confined to special parts of the chamber walls.

Remarks.—The type was in some respects ill chosen since many species of the genus show only a small part, or even none, of the trochoid spire. This species, however, emphasizes the fact that this is a coiled virguline genus which has a tendency to become biserial but which bears no relationship to *Guembelina* or *Heterohelix*. On the other hand, *Virgulina* (type species *V. squamosa* d'Orbigny) comprises all virguline species with a microgranular test which always appears to be greyish when placed in oil and viewed with transmitted light. Loeblich and Tappan (1961, p. 314) have proposed a new generic name for *Virgulina* d'Orbigny, *Fursenkoina*; whether it would be wise to change the well-known name *Virgulina*, used from 1826 on, is very questionable, however.

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273. SOME NEW EOCENE FORAMINIFERA
FROM THE STATE OF WASHINGTON

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ABSTRACT

Six new species: *Bathysiphon vernoni*, *Psammosphaera janeae*, *Protonina sarahae*, *Trochamminoides malloryi*, *Cyclammina welshi* and *Textulariella janeae* are described and figured.

INTRODUCTION

The author collected two hundred and five outcrop samples during the summer of 1961 in the vicinity of Quilcene, Washington (about 40 miles west of Seattle). Subsequent examination of the samples disclosed six new agglutinated Foraminifera ranging in age from late middle Eocene (late Ulatisian) to early late Eocene (early Narizian).

The type locations given in the systematics are plotted from the Mount Walker and Quilcene 7½' quadrangle maps of Washington State, published by the U. S. Geological Survey, Washington, D. C.

The figured types are deposited in the Foraminifera Lot Number 130 in the United States National Museum, Washington, D. C. Additional specimens are deposited in the Museum of Micropaleontology, Department of Geology, University of Washington, Seattle. The photographs are by the author. This is Lamont Geological Observatory Contribution No. 647.

Family RHIZAMMINIDAE

Genus *Bathysiphon* M. Sars, 1872

Bathysiphon vernoni Hamlin, n. sp.

Plate 14, figures 1, 2

Description.—Test free, composed of medium-size sand grains, well cemented; somewhat coarse in texture; glassy, translucent; dark internal tube usually visible through test wall. Test may or may not be crinkly. All fragments were open at both ends; test and internal tube flattened; wall thick, internal tube about ½ the size of the test. Many specimens have slight constrictions along the surface of the test.

Remarks.—No tri- or quadri-radiate fragments characteristic of the genus *Rhabdammina* Sars or the bulbous chambers characteristic of the genus *Hyperammina* Brady were found. On this basis *B. vernoni* was assigned to the genus *Bathysiphon*.

Comparisons.—*B. vernoni* resembles *B. alexanderi* Cushman but differs from it by having thicker walls, a coarser texture and by being glassy.

It differs from *B. perampla* Cushman and Goudkoff by being much smaller and glassy.

The new species differs from *B. sakuensis* Asano by being glassy, smaller, and coarser in texture.

It differs from *B. sanctaecrusis* Cushman and Klein-

pell by being glassy, slightly larger and composed of coarser sand grains.

	Length	Short	Long
		Diameter	Diameter
Holotype	0.82 mm.	0.10 mm.	0.29 mm.
(pl. 14, fig. 1)			
Paratype	0.90 mm.	0.11 mm.	0.28 mm.
(pl. 14, fig. 2)			

Type Level.—Middle and upper Eocene (Ulatisian and Narizian).

Locality of Holotype.—Two miles south southeast of Quilcene, Washington in the NW¼ NW¼ NE¼ Sec. 36, T. 27 N., R. 2 W., (opposite south end of abandoned railroad trestle) in shale on beach 15 feet east of the limestone pod.

Locality of Paratype.—Two and four tenths miles northwest of Quilcene, Washington in the NW¼ SW¼ SE¼ Sec. 2, T. 27 N., R. 2 W., on the east side of the Little Quilcene River, 224 feet east of the axis of a sharp river bend; 18 inches along siltstone bed from low-water level.

Depository.—Holotype (fig. 1) USNM 640589; paratype (fig. 2), USNM 640590.

Family SACCAMMINIDAE

Subfamily PSAMMOSPHAERA

Genus *Psammosphaera* Schulze, 1875

Psammosphaera janeae Hamlin, n. sp.

Plate 14, figure 4

Description.—Test free, single chamber, no neck. Thick wall, circular in outline; compressed, some more than others. Periphery rounded. Test composed of medium-size sand grains. Well cemented. Surface slightly rough, glassy. Some specimens show less translucency than others. May or may not have a dark core. Aperture indefinite.

Remarks.—All specimens were compressed to some degree. The tests may have been distorted after burial. Most specimens have a small depression on the surface of the test, varying in position from individual to individual. The aperture may be located in this depression. The holotype (pl. 14, fig. 4) shows this depression. The black spot is biotite which may be plugging the aperture. Because the actual opening was not seen, the aperture's position must remain indefinite.

Comparisons.—The new species differs from *P. eo-cenica* Cushman and Stainforth by being more compressed, glassy, and in having a slightly rougher surface and less cement.

It differs from *P. gigantea* Dunn by being more compressed, glassy and by having a thicker wall.

P. janeae differs from *P. laevigata* White by being larger, glassy, and composed of coarser sand grains.

It differs from *P. pusilla* Parr by being compressed, glassy, larger and composed of coarser sand grains.

Dimensions.—	Diameter	Thickness
Holotype	0.93 mm.	0.45 mm.
(pl. 14, fig. 4)		

Type Level.—Upper Eocene (early Narizian), Twin River Formation.

Locality of Holotype.—Three and three tenths miles northwest of Quilcene, Washington, in the NW¼ NE¼ NW¼ NW¼ Sec. 2, T. 27 N., R. 2 W., in a cut along the Little Quilcene River road, 254 feet S. 40 E., from the intersection of the median line of the road and the axis of the Ripley Creek culvert; 6.2 feet directly above road level.

Depository.—Holotype (fig. 4) USNM 640591.

Subfamily SACCAMMININAE
Genus *Proteonina* Williamson, 1858
Proteonina sarahae Hamlin, n. sp.
Plate 14, figure 3

Description.—Test free, single chamber, adult large, pyriform, usually slightly compressed, base broadly rounded, then tapering gradually toward the truncated apertural end; greatest diameter about ⅓ of distance from base; test wall composed of coarse sand grains, with small amount of cement; surface very rough; aperture terminal, more or less circular, sometimes with edge of a sand grain projecting into it.

Comparisons.—The new species differs from *P. atlantica* Cushman by its wider cross section, larger size, coarser texture and a better-defined neck.

It differs from *P. hancocki* Cushman and McCulloch by being much larger in size, not as compressed, coarser in texture, having a smaller aperture and a less distinct neck.

P. sarahae differs from *P. eocenica* Cushman by its larger size, less compressed test, less distinct neck, smaller aperture and a coarser texture.

It differs from *P. harangensis* Smith by its larger size, pyriform shape, and the greater extension of the neck.

Dimensions.—	Length	Diameter
Holotype	0.85 mm.	0.65 mm.
(pl. 14, fig. 3)		

The largest specimen found (not figured) measured 1.04 mm. long and 0.84 mm. wide.

Type Level.—Upper Eocene (early Narizian), Twin River Formation.

Locality of Holotype.—Two and four-tenths miles northwest of Quilcene, Washington in the NW¼ SW¼ SE¼ Sec. 2, T. 27 N., R. 2 W., on the east side of the

Little Quilcene River, 206 feet east of the axis of a sharp river bend, 3 feet along siltstone bed from low-water level.

Depository.—Holotype (fig. 3) USNM 640592.

Family LITUOLIDAE
Subfamily HAPLOPHRAGMININAE
Genus *Trochamminoides* Cushman, 1910
Trochamminoides malloryi Hamlin, n. sp.
Plate 14, figures 6, 7

Description.—Test free, planispirally coiled, division between whorls indistinct, no visible sutures, not labyrinthic; chambers divided by constrictions, interval between chambers small, sometimes connected by a short tube. Individual chambers enlarge rapidly, abruptly decreasing in size at the constriction. Chambers increasing slightly and sometimes irregularly in size as added. The number of chambers in the last whorl is variable, seven to nine in the young and ten to twelve in the adult. Test composed of coarse sand grains, rough surface, somewhat glassy, amount of cement variable. Aperture is a small opening about ⅓ of the way up from the base of the apertural face.

Comparisons.—The new species differs from *T. discotrochus* Smith by being divided into chambers back to proloculus and by having more than six chambers in the last whorl.

T. malloryi differs from *T. thompsoni* Smith by the lack of visible sutures and the greater number of chambers in the last whorl.

Dimensions.—	Diameter	Thickness
Holotype	0.76 mm.	0.16 mm.
(pl. 14, fig. 6)		
Paratype	0.62 mm.	0.15 mm.
(pl. 14, fig. 7)		

Name Derivation.—The species is named in honor of Professor V. Standish Mallory of the University of Washington, Seattle.

Type Level.—Upper middle Eocene (Ulatisian).

Locality of Holotype and Paratype.—Two miles south southeast of Quilcene, Washington in the NW¼ NW¼ NE¼ Sect. 36, T. 27 N., R. 2 W. (opposite south end of abandoned railroad trestle) in shale on beach 15 feet east of the limestone pod.

Depository.—Holotype (fig. 6) USNM 640593; paratype (fig. 7) USNM 640594.

Subfamily LITUOLINAE
Genus *Cyclammina* Brady, 1876
Cyclammina welshi Hamlin, n. sp.
Plate 14, figures 8, 9, 10

Description.—Test free, planispirally coiled, partially evolute, last whorl exposing about ⅓ of the previous whorl, thus creating a broad, deep umbilicus. Test very compressed; periphery acute but slightly rounded. Sutures generally indistinct, but worn and distorted specimens show traces of sutures. Number of chambers in the last whorl variable, about twelve in the

young and about eighteen in the adult. Chambers and whorls increasing gradually in size as added, not inflated. Test composed of medium-size sand grains, surface rough. Aperture a low arch at the base of the last chamber, slightly overhanging the periphery.

Comparisons.—*C. welshi* differs from *C. evolvinatus* Smith by being thinner, having a wider umbilicus and rougher surface and by being unpolished.

It differs from *C. gracilis* Gryzbowski by its lack of inflated chambers, its indistinct sutures and a greater degree of exposure of the previous whorls.

The new species resembles the specimen *C. aff. C. simiensis* Cushman and McMasters figured by Rau (1956, pl. 14, figs. 10, 11). However, it differs from Rau's figures and description by having a wider umbilicus, a coarser texture, generally indistinct sutures and by the apparent lack of the sigmoid character of the sutures.

<i>Dimensions.</i> —	<i>Diameter</i>	<i>Thickness</i>
Holotype (pl. 14, fig. 9)	1.29 mm.	0.21 mm.
Paratype (pl. 14, fig. 8)	1.21 mm.	0.19 mm.
Paratype (pl. 14, fig. 10)	0.99 mm.	0.15 mm.

Name Derivation.—The new species is named in honor of Vernon M. Welsh.

Type Level.—Upper middle Eocene (Ulatisian).

Locality of Holotype and Paratypes.—Two miles south southeast of Quilcene, Washington in the NW¼ NW¼ NE¼ Sect. 36, T. 27 N., R. 2 W. (opposite south end of abandoned railroad trestle), 3.5 feet east of limestone pod.

Depository.—Holotype (fig. 9) USNM 640595; paratype (fig. 8) USNM 640596; paratype (fig. 10) USNM 640597.

Family VALVULINIDAE
Subfamily EGGERELLINAE
Genus *Textulariella* Cushman, 1927
Textulariella janeae Hamlin, n. sp.
Plate 14, figure 5

Description.—Test free, elongate spiral, four or five chambers in young, becoming biserial in the adult, circular in cross section. Chambers evenly and regularly divided into chamberlets back to the initial part of the test. First ⅓ of test tapering, then sides become parallel. Chamber sutures flush, spiral suture flush in young, becoming incised in the adult. Composed of fine sand grains, small amount of cement,

smoothly finished. Aperture a low arch at the inner margin of the last chamber.

Comparisons.—The new species differs from *T. barrettii* (Parker and Jones) by its smoother finish, incised sutures and more regular chamber subdivisions.

T. janeae differs from *T. pacifica* Cushman by its blunter end, incised sutures, the finely arenaceous wall, and the more regular chamber subdivisions.

It differs from *T. simplex* Cushman by its finer arenaceous wall and the well-developed chamber subdivisions.

<i>Dimensions.</i> —	<i>Length</i>	<i>Width</i>
Holotype (pl. 14, fig. 5)	1.19 mm.	0.61 mm.

Type Level.—Upper Eocene (Narizian), Twin River Formation.

Locality of Holotype.—Two and six-tenths miles north northeast of Quilcene, Washington in west side of road cut (Center Road) in the E½ SW¼ SW¼ NW¼ Sect. 7, T. 27 N., R. 1 W.; 288 feet north of side road, in thin sandstone and siltstone interbeds, 2.3 feet along bed from road level.

Depository.—Holotype (fig. 5) USNM 640598.

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274. THE STRUCTURE OF *AMMONIA BECCARII* (LINNÉ)

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ABSTRACT

The wall of *Ammonia beccarii*, rather than being both radial hyaline and granular hyaline as claimed by Cifelli (1962), is radial hyaline only. The septa are imperforate, as he stated, but both septa and walls are laminated, a layer of calcite being added to the preceding part of the test as each new chamber is added.

A paper by Cifelli (1962) gave details of the morphology and structure of *Ammonia beccarii* (Linné). The value of two features of importance in the classification of the foraminifera appears to be considerably undermined by his findings. In this species, he stated, both radial hyaline and granular hyaline shell structure are present. Further, when a chamber is added, a lamina of calcite is not laid down over the preceding part of the test. In consequence, he claimed, the septa are composed of a single lamina, and are quite different from those of *Rotalia trochidiformis* (Lamarck).

We have examined specimens of *A. beccarii* from Lido di Sottomarina, near Chioggia, some 75 miles north of Rimini. The septa are imperforate, as Cifelli claims, but they are radial hyaline in structure, in the sense of Wood (1949). The accompanying figures show clearly the extinction of the septa in polarized light (Plate 15, figures 1-2). It must be conceded that observation is not easy, the shape of the septum below the plane of focus of the microscope, in the thickness of the section, has certain effects, acting sometimes as a lens, bending the rays of polarized light before they reach the analyser. In such a case the crystals in the

septum do not extinguish at all. Remains of the lateral walls of the chambers, attached to the septum, also affect the extinction of the crystals in the septa, subtracting or adding to the total birefringence. In sections in which the septum lies truly transverse to the slide, and the bottom and top surfaces are accurately parallel, extinction occurs four times in a revolution of the microscope stage in the normal manner, and a wave of extinction can be traced from the wall into the septum. Furthermore, when a single septum lies in the plane of the slide the majority of the crystals are in permanent extinction (Plate 15, figures 4-5). This proves that the individual calcite crystals lie with their c-axes normal to the septal surface, this orientation being identical with that in the walls and septa of all radial hyaline foraminifera. In the specimen figured the septum is not perfectly flat, so that in some areas crystals are slightly inclined to one side or the other and thus show yellow polarization tints of the first order. When the septum is viewed in polarized light on a universal stage, slight tilting causes a wave of extinction to pass from the centre of the septum towards the margin, as each part of the curved septum comes to lie in turn accurately transverse to the axis of the microscope.

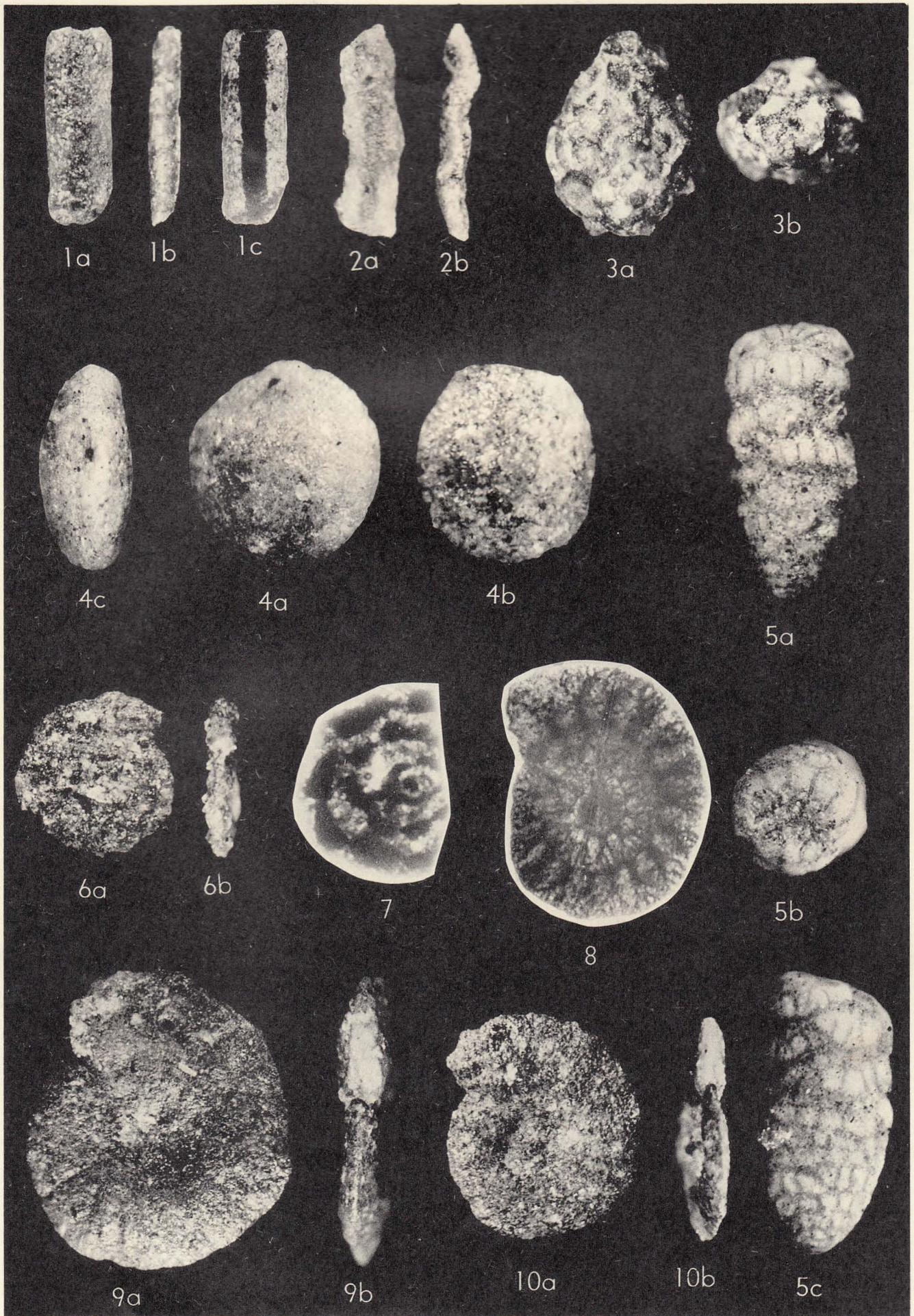
The septa often show a median line which divides them into two approximately equal halves, as shown in our Plate 15, figure 2 and in figure 6 of Cifelli's Plate 22. This appears to show that a layer of calcite

EXPLANATION OF PLATE 14

Figures approx. $\times 35$, except figure 7

Photographs unretouched unless otherwise stated

FIGS.	PAGE
1, 2. <i>Bathysiphon vernoni</i> Hamlin, n. sp.	153
1. Holotype, (USNM 640589). 2. Paratype, (USNM 640590). 1a, 2a. Side views. 1b, 2c. Edge views. 1c. Side view, showing internal details, photographed in glycerine using transmitted light.	
3. <i>Proteonina sarahae</i> Hamlin, n. sp.	154
Holotype, (USNM 640592). 3a. Side view. 3b. Apertural view.	
4. <i>Psammospaera janeae</i> Hamlin, n. sp.	153
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6, 7. <i>Trochamminoides malloryi</i> Hamlin, n. sp.	154
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Hamlin: New species, Eocene, Washington



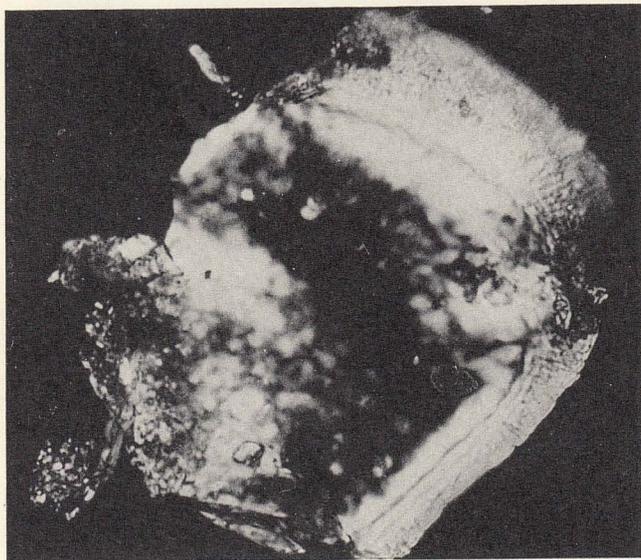
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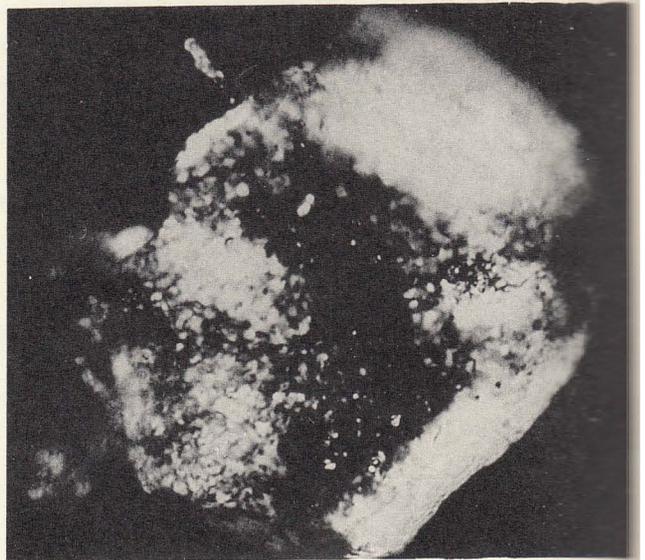
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3



4



5

is laid down over the previous apertural face as each new chamber is added. This central line passes outwards into a septal fissure, into which pores from the preceding chamber open. Some septa, however, appear homogeneous in section. It is possible to consider that these were more completely fused. Observation on broken specimens shows that the inner margin of the outer wall passes smoothly, without interruption, into the glass-clear septal surface, on both sides of the septum. No abutment of the outer wall of the last chamber against the surface of the previous apertural face can be seen.

Finally, we agree that laminae are rarely visible in the outer wall but consider that the gradual increase in thickness of the wall, backwards from the final chamber, shown in Cifelli's Plate 22, figure 1, is best explained by assuming that a layer of calcite was laid down over the preceding part of the test as each new chamber was added. This layer may well have been thinner than the outer wall of the chamber itself, and

quite probably varied in thickness over the ornamented portion of the test. The specimen shown in our Plate 15, figure 3 shows laminae in the wall, probably intensified along lines of weakness as the section was ground, and the increase in thickness of the outer wall from one chamber into the preceding one can be appreciated. The inner lamina of the earlier-formed chamber can be seen to bend down into the septum. Growth in thickness of the chamber wall certainly appears to be due to accretion on the outer surface.

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EXPLANATION OF PLATE 15

Ammonia beccarii (Linné)

(see page 156)

FIGS.

1. Transverse section. $\times 150$. Under crossed nicols. The central septum, lying horizontal in the photograph, is in extinction.
2. The same, under crossed nicols, and rotated through 45° . The septum which was formerly in extinction is brightly illuminated. Note also that this septum is double.
3. Transverse section. $\times 430$. Ordinary light. To show lamination in the wall and the increased wall thickness in the inner (right hand) chamber. The septum is double.
4. Single septum, lying in the plane of the slide. $\times 430$. Under crossed nicols. The microscope was focused on the remains of the outer wall, which is perforate and shows two arms of a black cross.
5. The same, under crossed nicols, with the septal surface in focus. The septum is not quite flat, so that the central portion of a distorted black cross is produced. In this region the crystals are in permanent extinction, in the illuminated areas they show yellows of the first order.

CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION
FOR FORAMINIFERAL RESEARCH
VOLUME XIV, PART 4, OCTOBER, 1963
RECENT LITERATURE ON THE FORAMINIFERA

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

- BANDY, ORVILLE L. Aquitanian planktonic Foraminifera from Erben Guyot.—*Science*, v. 140, No. 3574, June 28, 1963, p. 1402, 1403, text fig. 1 (range chart and drawings).—This note includes an absolute time scale from mid-Eocene through the Miocene and indicates the ranges of 7 planktonic species by means of which the Erben Guyot sediments are dated as 26 or 27 million years old.
- BARNARD, TOM. The morphology and development of species of *Marssonella* and *Pseudotextulariella* from the Chalk of England.—*Palaeontology*, v. 6, pt. 1, April 1963, p. 41-54, pl. 7, text figs. 1-9 (drawings, range chart, diagrams).—Four species of *Marssonella* and 1 of *Pseudotextulariella* are stratigraphically useful in the Upper Cretaceous.
- Evolution in certain biocharacters of selected Jurassic Lagenidae, in *Evolutionary Trends in Foraminifera*.—Elsevier Publ. Co., Amsterdam, May 3, 1963, p. 79-92, text figs. 1-4 (columnar sections, drawings, evolution diagrams).—Groups of species in *Lingulina*, *Frondicularia*, *Rectoglandulina*, and *Dentalina* are used to illustrate progressive evolution of ornament in the first two and production of heterochronous homeomorphs in the last two.
- BIEDA, FRANCISZEK. Sur un faciès calcaire dans l'Éocène supérieur du Flysch des Karpates Polonaises (French summary of Polish text).—*Ann. Soc. Géol. Pologne*, v. 32, fasc. 3, 1962, p. 399-414, pls. 38, 39.—*Grzybowskiia*, *Discocyclina*, and *Nummulites*.
- BROTZEN, F. Evolutionary trends in certain calcareous Foraminifera on the Palaeozoic-Mesozoic boundary, in *Evolutionary Trends in Foraminifera*.—Elsevier Publ. Co., Amsterdam, May 3, 1963, p. 66-78, text figs. 1-6 (graph, drawings, chart).—In the 2 superfamilies, Nodosariidea and Rotaliidea, the wall structure evolved from agglutinated or compound calcareous imperforate to calcareous perforate. Two new genera are erected to distinguish the *Geinitzina*-like and *Spandelina*-like genera in the Liassic from their Permian counterparts that have compound or agglutinated walls as well as from their Cretaceous counterparts that have perforate and radiate walls. The new Liassic genera are *Neogeinitzina* nov. gen. (type species *Marginulina tenera* Bornemann 1854) and *Neospandelina* nov. gen. (type species *Frondicularia bicostata* d'Orbigny 1849).
- CHALILOV, D. M. Novye Predstoviteli *Almaena* Verkhnego Eothena Azerbaidzhana.—*Izvest. Akad. Nauk Azerbaid. SSR, Baku, ser. geol.-geogr. nauk i nefti*, 1962, No. 6, p. 5-18, pls. 1-4.—Descriptions and illustrations of 5 species and 4 varieties, all new, from the upper Eocene.
- CHANG, LI-SHO. A biostratigraphic study of the so-called Hori slate in central Taiwan based on smaller Foraminifera.—*Proc. Geol. Soc. China*, No. 6, April 1963, p. 3-17, pls. 1, 2, text figs. 1-5 (maps), tables 1-4.—Foraminifera recorded and illustrated from 4 stages—latest Aquitanian, Oligocene, and 2 (possibly synchronous) Eocene stages. The ages of the Miocene and Oligocene stages are determined by planktonics.
- Mid-Tertiary planktonic foraminiferal zones of the Hengchun Peninsula, Taiwan.—*Proc. Geol. Soc. China*, No. 6, April 1963, p. 61-66, pls. 1, 2, text fig. 1 (map).—Three of the Caribbean planktonic zones are recognized and the Kosyun Formation is subdivided into 3 members in accordance with their lithology and Foraminifera.
- CHRISTODOULOU, G. Auffindung von *Globotruncana stuarti* De Lapp. im Bereich von Geroplatanos-Epirus (Adriatisch-Ionische Zone) (German summary of Greek text).—*Bull. Geol. Soc. Greece*, v. 3, No. 1, 1956/58, 1958, p. 21-23.
- Über einige Foraminiferen des Pliozäns von Rafina (German summary of Greek text).—*Bull. Geol. Soc. Greece*, v. 3, No. 1, 1956/58, 1958, p. 24-30, 4 text figs. (columnar section, map, pie diagrams).
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- Über das Alter einiger Formationen von Samothraki (German summary of Greek text).—*Bull. Geol. Soc. Greece*, v. 3, No. 1, 1956/58, 1958, p. 40-45, pls. 1-4, 2 text figs. (map, geol. section).—Species listed from the Priabonian and the Oligocene, and illustrated in thin section.
- Die pliozänen Foraminiferen von Kalamata (Peloponnes) (German summary of Greek text).—*Bull. Geol. Soc. Greece*, v. 4, No. 1, 1959/61, 1961, p. 85-97, geol. section, distrib. table.—Qualitative distribution chart of Foraminifera in a well profile through a lower Pliocene littoral facies.
- The occurrence of *Neovalvolina melo* (Fichtel and Moll) in Miocene formations of Kasos Island and some remarks on the geology of that Island (English summary of Greek text).—*Bull. Geol. Soc.*

- Greece, v. 4, No. 1, 1959/61, 1961, p. 156-162, pls. 12, 13.
- CHRISTODOULOU, G., and HARALAMBOUS, D. Über das Alter des Neogens von Pylos (Navarina, SW—Peloponnes) (German abstract of Greek text).—Bull. Geol. Soc. Greece, v. 4, No. 1, 1959/61, 1961, p. 69-80, distrib. table.—Foraminifera listed from Pliocene samples.
- CICHA, IVAN, and ZAPLETALOVA, IRENA. Die Vertreter der Gattung *Bolivina* (Foraminifer-Protozoa) im Miozän der Westkarpaten.—Sbornik Ustred. Ustavu Geol., sv. 28, odd. paleont., 1961 (1963), p. 115-183, text figs. 1-48 (drawings, graphs), Beil. 1 (illustrated range chart).—Descriptions and illustrations of 29 species (6 new) and 10 subspecies (7 new) classified in 6 groups of the genus *Bolivina*.
- Wichtige Vertreter der Familie Lituolidae Reuss, 1861 (Foraminifera) aus dem Miozän der Westkarpaten.—Sbornik Geol. Ved. Paleontologie, rada P, sv. 1, 1963, p. 75-121, text figs. 1-21.—Descriptions and illustrations of 19 species (4 new) and 2 subspecies (both new) classified in 6 genera.
- CITA-SIRONI, MARIA BIANCA. Tendances évolutives des Foraminifères planctiques (Globotruncanae) du Crétacé Supérieur, in *Evolutionary Trends in Foraminifera*.—Elsevier Publ. Co., Amsterdam, May 3, 1963, p. 112-138, text figs. 1-19 (drawings), pls. 1, 2 (generic range chart, zone chart).—Diversification of the Globotruncanae shows 3 periods of explosive evolution: (a) maximum development of *Hedbergella* and *Ticinella* during end of Albian and beginning of Cenomanian, (b) flowering of *Rotalipora* and *Praeglobotruncana* during Cenomanian, and (c) maximum development of *Globotruncana* and *Abathomphalus* during upper part of Senonian and Maestrichtian.
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- Analysis of *Lepidocyclina radiata* (Martin).—Bull. Amer. Paleontology, v. 46, No. 208, May 21, 1963, p. 153-185, pls. 42-47.—The concept of *L. radiata* is enlarged to include specimens with bilocular, nephrolepidine, eulepidine, trybliolepidine, and irregular embryonic chambers, as well as variable external shapes. Twelve synonyms are listed.
- COLOM, G. Micropaleontología del cretácico al NW de Bogotá (Colombia).—Bol. Geol., Univ. Industr. Santander, No. 10, 1962, p. 69-75, pls. 1-5 (photomicrographs).—Samples from Hauterivian to Coniacian are studied in thin section. Globigerines and specimens of *Siphogenerinoides* are observed.
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- HENBEST, LLOYD G. Biology, mineralogy, and diagenesis of some typical Late Paleozoic sedentary Foraminifera and algal-foraminiferal colonies.—Spec. Publ. No. 6, Cushman Found. Foram. Res., July 10, 1963, p. 1-44, pls. 1-7, text figs. 1, 2.—An important study including both speculations about and data on these primitive and obscure forms. Detailed descriptions and excellent illustrations of tubiform genera and species (both as individuals and in thin section) in the agglutinate subfamily Tolypammininae and the porcellaneous calcitic subfamily Cornuspirinae. *Dryorhizopsis* n. g. (type

- species *D. cadyi* n. sp.) is questionably placed in the family Hyperamminidae. *Hedraites* n. g. (type species *H. plummerae* n. sp.), erected in the subfamily Cornuspirinae, is distinguished from *Apterrinella* by its pitted surface. The new name *Minammodytes* is proposed for *Serpulopsis* Girty, 1911, and the genus, originally regarded as a worm, is placed in the subfamily Tolypammininae. *Pseudovermiporella* Elliott, 1958, is reclassified as a cornuspirinid foraminifer. *Calcitornella* is placed in synonymy with *Apterrinella*, and *Orthovertella* is treated as an unrecognizable form. Two form genera of algal-foraminiferal colonies are emended, and two new genera of shell-penetrating thallophytes are erected.
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- DE KLASZ, IVAN, and RÉRAT, DANIEL. *Pseudocassidulinoides* nov. gen., nouveau genre de Foraminifères du Gabon et du Cameroun.—C. R. S. Séances Soc. Géol. France, fasc. 3, March 4, 1963, p. 78, 79, text figs. A-F.—*Pseudocassidulinoides galoa* nov. sp., marker for the lower Miocene, differs from *Cassidulinoides* in that its aperture is not joined to any suture.
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- MACGILLAVRY, H. J. Phylomorphogenesis and evolutionary trends of Cretaceous orbitoidal Foraminifera, in *Evolutionary Trends in Foraminifera*.—Elsevier Publ. Co., Amsterdam, May 3, 1963, p. 139-197, pls. 1-8, text figs. 1-9 (drawings), tables 1-4 (evolution diagrams).—Five types of phylomorphogenesis are distinguished: *Cycloclypeus*-type, *Planorbulinella*-type, *Helicolepidina*-type, *Miogypsinoides*-type, and *Omphalocyclus*-type. These types result from various combinations of such features as additional apertures, retrovert apertures, contravert apertures, limitation of the number of primary chambers, formation of secondary chambers within the spiral wall. In connection with the discussion of family subdivisions, a new genus is described in the Pseudorbitoididae: *Helicorbitoides* nov. gen. (genoholotype *Pseudorbitoides longispiralis* Papp and Küpper 1953), and *Hellenocyclus* Reichel 1949 is regarded as an isolated genus and is removed from the Lepidorbitoididae.
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- MARAGOUKAKIS, N. The Neogene Foraminifera of Corfu Island (English summary of Greek text).—Bull. Geol. Soc. Greece, v. 4, No. 1, 1959/61, 1961, p. 65-68.—Foraminifera listed from lower Pliocene beds.
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- SOKOLOV-KOCHEGAROV, A. S., KHASINA, G. I., and NEMKOV, G. I. Pervaja Nakhodka Verkhnesonskykh Orbitoidov v Tadzhikskoj Depressii i ee Stratigraficheskoe Znachenie.—*Geol. Razved., Izvest. Vys. Ucheb. Zaved.*, No. 9, 1962, p. 138-140, 1 fig.—*Orbitoides media* in the upper Senonian.
- STAMPANONI, GIORGIO. Morfologia e stratigrafia delle formazioni Plio-Pleistoceniche relative al Foglio 163 "Lucera" (I e II quadrante).—*Boll. Serv. Geol. Italia*, v. 81, Anno 1959, fasc. 4-5, 1961, p. 581-591, text fig. 1 (columnar section), distrib. and abund. table.—Numerous Foraminifera recorded from 5 samples.
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- VLAICU-TATARIM, N. Stratigrafia Eocenului din regiunea de la sud-vest de Cluj.—*Edit. Acad. Repub. Pop. Romine*, 1963, 204 p., 19 pls., map, 20 text figs.—Includes descriptions and illustrations of 8 species of *Nummulites*.

VOIGT, EHRHARD. Orbitoidenführendes Kieselgestein als nordisches Geschiebe aus der Umgebung von Hamburg (Ober-Maastrichtien, Obere Kreide).—*Geol. Jahrb.*, Band 80, March 1963, p. 495-511, pls. 37, 38, text fig. 1 (map).—Occurrence of the warm-water species *Lepidorbitoides minor* (Schlumberger) in drift boulders that originated on the edge of the Fenno-Scandian shield requires the northward extension of the Maestrichtian sea.

YOSHIDA, SABURO. Upper Cretaceous Foraminifera

from the Nemuro Group, Eastern Hokkaido, Japan.—*Jour. Hokkaido Gakugei Univ.*, v. 13, No. 2, March 1963, p. 211-241, pls. 1-17, text figs. 1-3 (maps, columnar section), tables 1-5.—Illustrated systematic catalog includes 109 species (33 new) from several districts. Age is interpreted as Maestrichtian.

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