U.S. DEPARTMENT OF THE INTERIOR
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PALEOENVIRONMENTAL ANALYSIS OF LATEST QUATERNARY LEVEE DEPOSITS OF MONTEREY FAN, CENTRAL CALIFORNIA CONTINENTAL MARGIN: FORAMINIFERS AND POLLEN, CORE S3-15G.

by
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INTRODUCTION

Monterey Fan is one of several submarine fans in the northeast Pacific Ocean resulting from the deposition of turbidity current material at the base of one or more submarine canyons (Normark, 1970; Normark and Hess, 1980). Located off central California, this particular fan has been the focus of an ongoing project investigating depositional processes and growth patterns of these deep-sea turbiditic deposits (Normark and Hess, 1980; Normark and others, 1984; EEZ-Scan 84 Scientific Staff, 1986, 1988; Normark and Gutmacher, 1988). Yet to this date, there is little information on the foraminiferal, palynological and sedimentologic trends of Monterey Fan (Brunner and Ledbetter, 1987, in press; Brunner and Normark, 1985; McGann, 1986, 1987; McGann and Brunner, 1987, 1988). It is the purpose of this report to present microfossil and sedimentologic data from the hemipelagic and submarine fan overbank deposits of a single core (S3-15G) recovered near the crest of the western levee of the Monterey fan valley. This open file is a slightly edited, condensed version of the Master's thesis I completed at the University of California, Berkeley in 1986. It is presented in two parts, discussing foraminifers and palynology, respectively, of core S3-15G.

I would like to thank William Normark of the U.S. Geological Survey for making core S3-15G available for study, and Christina Gutmacher (U.S.G.S.) and Charlotte Brunner (University of Southern Mississippi) for enthusiastically aiding in the core description. Particular thanks are due Charlotte for ably fulfilling the role of mentor throughout the project. I would also like to acknowledge Kristin McDougall and Paula Quinterno (both of the U.S.G.S.) for their careful reviews of this report as well as their efforts in refining the systematics and paleoecological concepts applicable to the Monterey Fan foraminiferal fauna.

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Part I:

Paleoenvironmental analysis of latest Quaternary foraminifers of Monterey Fan, central California continental margin

Abstract

Monterey Fan is a Neogene deep-sea deposit off central California containing hemipelagic and turbiditic sediments. Gravity core samples were selected from the western levee of the Monterey fan valley to determine microfossil variations between the typical hemipelagic and submarine fan overbank deposits.

Using cluster analysis, the samples were separated into groups reflecting sediment source, faunal adaptation to changing climatic conditions, and the effects of dissolution.

The turbiditic sands originate in the shelf to upper middle bathyal zones. They are characterized by high foraminiferal abundance and faunal diversity, resulting from the addition of the displaced shallow-water species to the endemic deep-water fauna at the final deposition site. In contrast, the muds are composed of hemipelagic, turbiditic and mixed sediments, and are characterized by a less abundant and diverse lower bathyal foraminiferal assemblage than the turbiditic sands.

Calcium carbonate preservation is cyclic in the mud deposits, greatly influencing the character of the microfaunal assemblages. Glacial and cool transitional climatic periods are distinguished by minimal dissolution and a auna dominated by planktonic foraminifers. Warm periods are characterized by dissolution pulses and high relative proportions of benthonic foraminifers and radiolarians.

Pyrite occurs frequently in the shells of foraminifers, radiolarians and diatoms in these deep-sea deposits. Benthonic foraminifers endemic to low-oxygen environments, or those characterized by finely perforate tests, are most often affected. Pyritization may occur within the oxygen-minimum zone or at well-oxygenated water depths. Post-depositional pyrite formation occurs in oxygen-depleted environments produced by rapid burial of carbon-rich sediments within foraminiferal tests and/or turbiditic deposits.

Introduction

Monterey Fan is one of several submarine fans in the northeast Pacific Ocean resulting from the deposition of turbidity current material at the base of one or more submarine canyons (Normark, 1970a; Normark and Hess, 1980). Located off central California, this particular fan has been the focus of an ongoing project investigating depositional processes and growth patterns of these deep-sea turbiditic deposits (Normark and Hess, 1980; Normark and others, 1984).

There has been little information to date correlating faunal and sediment trends of Monterey Fan. Brunner and Ledbetter (1985) and Brunner and Normark (1985), investigating the faunal assemblages of turbiditic sequences taken from three cores on the fan, determined that the displaced faunas showed considerable evidence of hydraulic sorting. They also concluded that distinguishing turbiditic and hemipelagic muds was necessary to obtain "high-resolution biostratigraphy or paleo-oceanography" in regions affected by turbidities. Hein and Griggs (1972) utilized another Monterey Fan core to analyze the distribution of authigenic pyrite, including that seen as microfossil test infillings and worm tubes, in deep-sea deposits. The present study continues to investigate the relationship between the faunal and sedimentological constituents of Monterey Fan. It distinguishes between the benthonic foraminiferal assemblages of the hemipelagic and turbiditic deposits, identifies the source of the displaced faunas, documents the distribution of authigenic pyrite, and uses foraminifers and radiolarians to discern local calcium carbonate dissolution cycles during the latest Quaternary.

The distribution of foraminifers off central California has not been well documented. In Monterey Bay, studies have focused primarily on the microfauna of the shallower bay waters. Included are the early sporadic faunal reports made in conjunction with comprehensive Pacific Ocean benthonic foraminiferal distributional studies by the U.S. Fisheries Steamer Albatross (Cushman, 1910, 1911, 1913a, 1914, 1915, 1917) and the Allan Hancock Pacific Expeditions (Cushman and McCulloch, 1939, 1940, 1942, 1948, 1950; Lalicker and McCulloch, 1940). In addition, the distribution of a few live shallow-water benthonic foraminiferal genera in Monterey Bay was investigated by Martin (1930, 1931, 1932) and Cushman and Martin (1935).

Valuable information on deep-water foraminifers off central California has been provided by surface and core samples obtained off the Russian River (Gardner and others, 1983, 1984, in press), scattered surface and core samples recovered off San Francisco Bay (Bandy, 1953a; Morin, 1971), and box and gravity core samples taken from the oxygen-minimum zone off Point Sur (Vercoutere, 1984; Mullins and others, 1985).

Setting

Presently, Monterey Fan is an area of active fan growth that extends more than 300 km from the base of the central California continental slope (Figure 1; Normark and Hess, 1980). This deep-sea turbiditic deposit encompasses 44,000 km^2 of ocean floor, making it the largest submarine fan lying off California (Normark and others, 1984). The fan is comprised of littoral drift sediments funneled to it by three distinct submarine canyon systems: Monterey, Ascension and Lucia-Partington-Sur (Hess and Normark, 1976). The greatest supply of sediments to Monterey Fan appears to have been channeled through the first two canyon systems (Normark and Hess, 1980).

The Monterey Bay region is the general site at which the major fan-valley systems of Monterey Fan head. Initially, the Ascension fan valley was the main conduit for sediment transport to the Fan (Normark and Hess, 1980; Normark and others, 1984). However, because it heads on the upper slope, the Ascension fan valley is thought to be inactive during high stands of sea level. In contrast, the Monterey fan valley transects the entire continental shelf, enabling it to remain active despite changes in sea level (Normark and Hess, 1980; Normark and others, 1980).

The Monterey fan valley is characterized by a Holocene-aged slump (Hess and others, 1979) and an abrupt channel meander (Shepard, 1966). The latter marks the site of probable late Pleistocene-aged channel diversion resulting in the abandonment of the Monterey East fan valley, piracy of the lower end of the Ascension fan valley, and subsequent erosion of the Ascension fan valley into a hanging tributary of the Monterey fan valley (Normark, 1970a, 1970b). Consequently, the primary source of sediments for Monterey Fan in the late Neogene is Monterey Canyon (Normark and others, 1984).

Both the Monterey and Ascension fan valleys are characterized by extensive levee development (Normark, 1970a, 1970b; Hess and Normark, 1976; Normark and others, 1984). The western levee of the Monterey fan valley is the largest of the fan and is contiguous

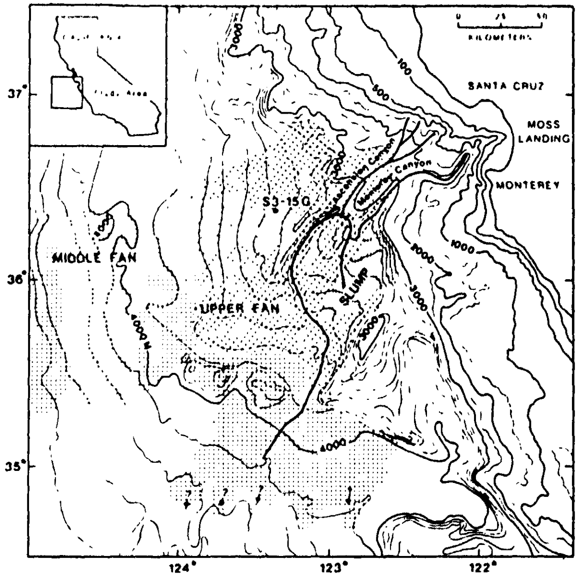

Figure 1. Location map illustrating the present bathymetry (contours in meters) of Monterey Fan as well as the position of the upper and middle fans, the slump on the east side of the Monterey fan valley, and the site of core S3-15G (after Brunner and Normark, 1985).

with that of the Ascension fan valley below their convergence (Normark, 1970b). The backside of this levee, away from the channel floor, is marked by the presence of sediment waves trending generally subparallel to the levee crest (Normark and others, 1980, 1984). These sediment waves are considered depositional bedforms resulting from channel-overflow of downslope-transported fine-grained material of large turbidity currents (Normark and others, 1980). Turbidity flows of silt and mud may originate in the outer shelf or upper slope due to earthquake-induced slumping, increased terrigenous input by local rivers during peak discharge, and the breaking of internal waves along the continental margin (Southard and Cacchione, 1972; Normark and others, 1980; Piper and Normark, 1983). These fine-grained turbidity flows move at low speeds (~10 cm/sec; Normark and others, 1980) compared to the faster-moving (~10-20 m/sec; Komar, 1977) sandier deposits that are generally restricted to the channels, excepting rare overbank transport.

The object of this study, a 4.72 m gravity core (S3-15G), was recovered 18 km from the crest of the western levee of the Monterey fan valley (Figure 1; Brunner and Normark, 1985). It was obtained at a depth of 3491 m, approximately 135 km southwest of Santa Cruz (36°23.53'N, 123°20.52'W).

Oceanography

The distribution of distinct foraminiferal assemblages reflects the water mass boundaries of that region (Ingle, 1980). Off central California, the shallower water masses are assignable to the California Current System (Simpson and others, 1984). This system includes the California Current, the California Undercurrent, and the Deep Poleward Flow. Underlying these water masses is the Antarctic-originating Pacific Deep Water (Sverdrup and others, 1942). All of these water masses are stratified in relationship to one another as a result of their unique physical and chemical properties. In turn, they come in contact with the continental margin in particular bathymetric intervals which may be correlated with the benthonic foraminiferal biofacies (Figure 2; Ingle, 1980).

The dominant current in the California Current System is the southward-flowing California Current. This surficial water mass constitutes the eastern limb of the North Pacific gyre and is restricted to the upper 200 m over the continental shelf (Hickey, 1979). It is composed of subarctic waters and, therefore, is characterized by low temperature and salinity, and

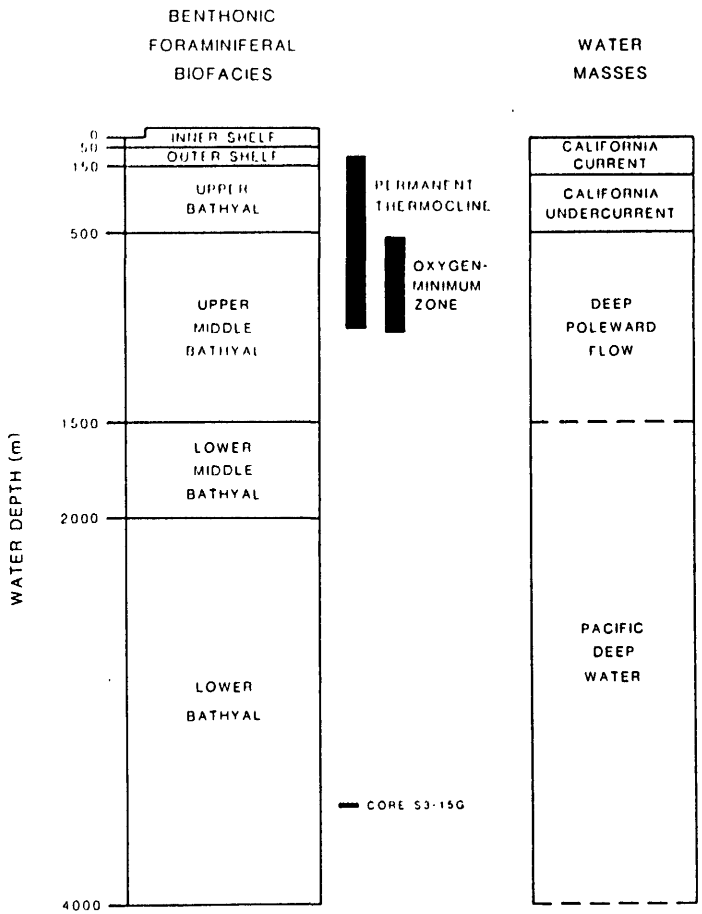

Figure 2. Benthonic foraminiferal biofacies, water masses, and position of permanent thermocline, oxygen-minimum zone and site of core S3-15G off central California. Biofacies after Ingle (1980), and water masses and oceanographic parameters after Sverdrup and others (1942), Broenkow and Greene (1981), and Simpson and others (1984).

a high concentration of dissolved oxygen and phosphate (Reid and others, 1958; Simpson and others, 1984). The California Current encompasses the inner shelf, outer shelf, and the upper portion of the upper bathyal foraminiferal biofacies.

Lying below the California Current is the poleward-flowing California Undercurrent (Cannon and others, 1975). Comprised of Equatorial Pacific Water, it is characterized by a low oxygen content as well as high temperature and phosphate (Simpson and others, 1984). Unlike the California Current, however, this water mass is one of the most saline in the Pacific Ocean (Pickard, 1964) and is seasonally variable in location, depth and intensity (Sverdrup and Fleming, 1941; Hickey, 1979). However, it usually becomes fully developed off central California between the depths of 200 and 500 m (Wickham, 1975). Eddies develop commonly within the California Undercurrent (Simpson and others, 1984) and may be observed intermittently in the Monterey Bay region (Skogsberg, 1936; Carter, 1967; Broenkow and Smethie, 1978). The California Undercurrent is associated with the upper bathyal foraminiferal biofacies.

In the late fall and winter, as the northwest winds begin to weaken, the California Current is forced offshore and a northward-flowing countercurrent surfaces over the shelf (Broenkow and Smethie, 1978; Hickey, 1979). This water mass is referred to as the Davidson Current (Reid and others, 1958; Reid and Schwartzlose, 1962; Schwartzlose, 1963; Pavlova, 1966; Wickham, 1975; Huyer and Smith, 1976). Its relationship to the California Undercurrent has not, as yet, been established (Hickey, 1979).

The Deep Poleward Flow is the least understood water mass of the California Current System (Simpson and others, 1984). It is comprised of North Pacific Intermediate Water (Reid and Mantyla, 1978) and flows poleward at depths below 500 m (Simpson and others, 1984). The waters of the Deep Poleward Flow are characterized by abundant nutrients, low temperature, and particularly low salinty and dissolved oxygen contents (Pickard, 1964; Reid and Mantyla, 1978; Simpson and others, 1984). These parameters differentiate it from the overlying California Undercurrent flowing in the same direction. The paucity of oxygen in the Deep Poleward Flow has resulted in the development of an extensive oxygen-minimum (<0.5 ml/l) zone in the eastern Pacific Ocean (Barkley, 1968; Reid and Mantyla, 1978). Off central California, the oxygen-minimum zone is presently established between 525 and 1025 m, with the dissolved oxygen content declining to

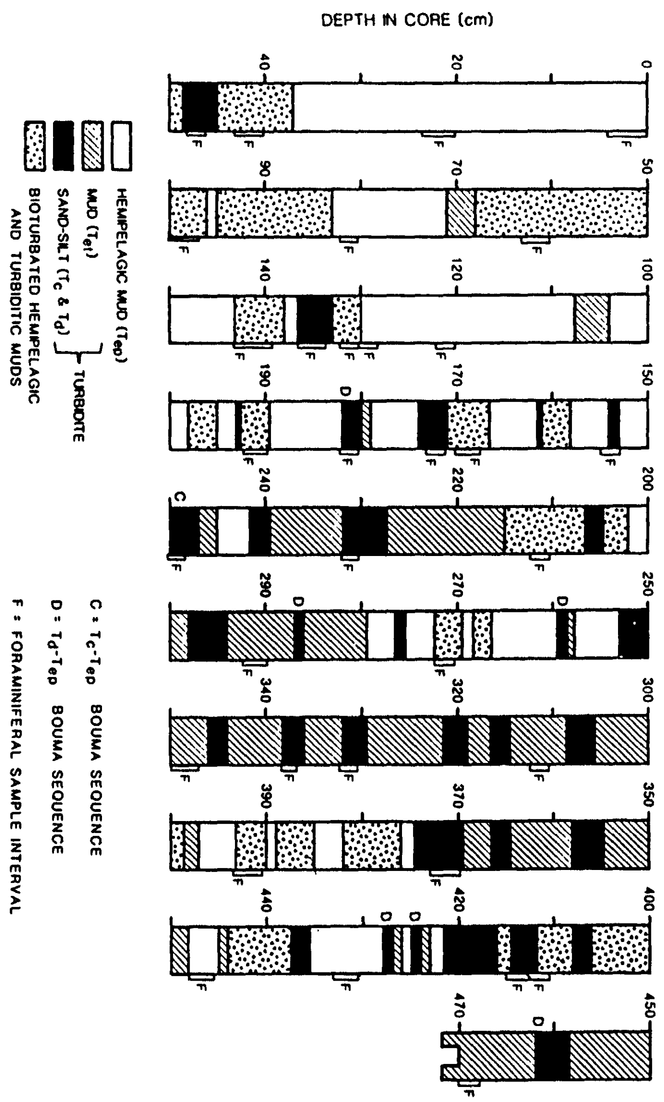

Figure 3. Generalized lithology of core S3-15G. The core is composed of sand-silt turbidites (Tc and Td), turbiditic (Tet) and hemipelagic (Tep) mud layers, and bioturbated intervals. Bouma sequences Tc-ep and Td-ep are designated by a C and D, respectively, on the left side of the core. Bouma sequence abbreviations after Bouma (1962) and Howell and Normark (1982).

a minimum of 0.27 ml/l at a depth of 750 m (Broenkow and Greene, 1981). The position of the Deep Poleward Flow coincides with the upper middle bathyal foraminiferal biofacies (Ingle, 1980), characterized by low oxygen-adapted benthonic foraminiferal species.

The transition zone between the Deep Poleward Flow and the underlying Pacific Deep Water lies between 1000 and 2000 m in the northeast Pacific Ocean; the water masses probably mix vertically within this depth range (Pytkowicz and Kester, 1966). The region of low-oxygen (the dysaerobic zone of Mullins and others, 1985), however, continues to a depth of approximately 1500 m off central California (Broenkow and Greene, 1981). This relationship suggests that the boundary between the Deep Poleward Flow and the Pacific Deep Water lies at least this deep in the study area. Yet, it remains unclear as to how much of the lower middle bathyal foraminiferal biofacies is influenced by one (or both) of these water masses.

The lower bathyal foraminiferal biofacies, located between 2000 and 4000 m (Ingle, 1980), is associated with the Pacific Deep Water. This water mass is characterized by low temperature and high salinity and oxygen, as well as great amounts of phosphates, nitrates and silicates (Sverdrup and others, 1942). The core site of S3-15G, lying at a depth of approximately 3500 m, is situated within this water mass. However, as evidenced by the extensive dissolution of foraminifers in the core-top sediments of this and surrounding cores (this study; Brunner and Normark, 1985), the core site is presently located near the local calcium carbonate compensation depth (CCD).

Lithology

Deep-sea core S3-15G consists of turbiditic fine-grained sand, silt and mud overbank deposits interspersed with hemipelagic muds (Figure 3). The mud deposits dominate the core and display open and filled burrows, mottles, and deformed sediment layers characteristic of bioturbation (Griggs and others, 1969).

The turbiditic sands are typically deposited in laminated sequences referrable to Bouma's (1962) T_d depositional division; cross-bedded (T_c) turbiditic units occur only rarely. The basal members of the Bouma cycle (T_{ab}) are missing, supporting the contention that complete Bouma sequences (T_{ae}) are rarely evident in deep-sea cores

(Rupke, 1978). The fine-grained turbiditic sands and silts are, for the most part, laterally continuous in the upper 370 cm of the core, becoming more fragmented with greater core depth.

The turbiditic sands of core S3-15G are invariably overlain by mud deposits referrable to the fifth Bouma division (T_e). This depositional unit has been further subdivided into turbiditic (T_{et}) and hemipelagic (T_{ep}) muds (Kuenen, 1964; Howell and Normark, 1982), a strategy employed in this study. No attempt was made to distinguish between the three depositional units of turbiditic muds proposed by Piper (1978), or the nine divisions of Stow (1977) and Stow and Shanmugam (1980).

The upper 215 cm of the core is composed primarily of hemipelagic muds and mildly bioturbated turbiditic muds with hemipelagic mud mottles. Turbiditic muds are common between 215 and 370 cm, becoming particularly dominant below 280 cm. Bioturbation increases greatly at a core depth of 370 cm, resulting in a highly deformed mixture of sands, silts, and turbiditic and hemipelagic muds to the base of the core.

Methods

Sampling Procedure

Thirty-three sediment samples, obtained from the undisturbed central portion of the split 4.72 m gravity core, were analyzed for foraminifers and radiolarians. The core was sampled at approximately 20 cm intervals, with each sample consisting of 10 to 20 cm^3 of sediment.

Samples were acquired from discrete lithologic units within the core: twenty-five mud and eight turbiditic sand deposits were studied. An attempt was also made to further subdivide the muds based upon color, as deep-sea turbiditic and hemipelagic muds often display distinct color differences (darker and lighter, respectively) in recent and ancient deposits (Rupke and Stanley, 1974; Hesse, 1975; Rupke, 1975; Sagri, 1979; Howell and Normark, 1982; Piper and Normark, 1983). Yet, bioturbation and post-collection color fading of the sediments, particularly in the lower 100 cm of the core, complicated their differentiation.

Preparation Procedure

Bulk microfaunal samples were oven dried and weighed on a Mettler H31AR balance. Subsequently, the samples were immersed in a dilute solution of sodium hexametaphosphate and ammonium hydroxide and left overnight. Following disaggregation, the samples were sieved through nested 115-mesh (125 μm) and 250-mesh (63 μm) screens and then dried. Foraminifers were extracted exclusively from the coarser fraction (>125 μm). If this residue contained less than 300 benthonic foraminifers, all that were present were picked. Otherwise, the residue was split into an aliquot containing approximately 300 benthonic foraminifers with the aid of a modified Otto microsplitter. The picked benthonic foraminifers were mounted on slides and identified (Appendix 2). Select diatoms, ostracods, fish bones and teeth, echinoderm spines, sponge spicules, seeds and volcanic ash debris were also recovered at this time. In addition, the abundance of planktonic foraminifers and radiolarians was determined for each aliquot, but individual specimens were not extracted from the residue.

The Data

Foraminiferal numbers (benthonic, planktonic, and benthonic + planktonic) were determined by calculating the number of pertinent specimens in the >125 μm size fraction/gm of dry sediment (Schott, 1935; Boltovskoy and Wright, 1976). Benthonic foraminiferal faunal diversity was determined by the Fisher alpha diversity index method (Murray, 1968, 1973; Douglas, 1979; Olsson and Nyong, 1984). This index of diversity (α) is derived by plotting the number of species against the number of individuals in each sample. It is a valuable measure of diversity in that it accounts for variations in sample size and treats abundant and rare species equally (Boltovskoy and Wright, 1976).

Relative benthonic foraminiferal species abundances were computed using a sum of total benthonic foraminifers. Once converted to frequency data, the species counts were subjected to cluster analysis to describe the relationship between the benthonic foraminiferal assemblages of core S3-15G. The cluster analysis groups species (R-mode) and samples (Q-mode) according to their degree of similarity. The data of both the R- and Q-modes were clustered separately by the unweighted pair group method utilizing a chi-square correlation coefficient and amalgamated by a centroid linkage strategy (Dixon, 1983). The University of California's biomedical computer program, BMDP-P2M, was utilized to accomplish this analysis (Dixon, 1983).

Generally, samples containing 300 or more benthonic foraminifers are considered representative samples (Douglas, 1973) and may be reliably subjected to multivariate analytical techniques. In core S3-15G however, little difference was noted between the results of the cluster analysis when the localities containing >200 and >300 individuals were utilized. As a result, this study employed the frequency data of the most abundant species (Table 1) from the 28 samples containing >200 benthonic foraminifers.

Sediment Age

The relative proportion of left- and right-coiling forms of the planktonic foraminifer, *Neogloboquadrina pachyderma* (Ehrenberg), was used to determine the age of these overbank deposits (Bandy, 1959, 1960a, 1967; Gorsline and others, 1968; Kheradpir, 1970; Morin, 1971). Brunner (1985, pers. commun.) noted the presence of two distinct shifts from left- to right-coiling forms in core S3-15G (Figure 4). The Pleistocene/Holocene boundary, by definition (Bandy, 1960a), lies within the upper of these two shifts. Therefore, it lies between 212 and 241 cm in core S3-15G. Additionally, a period of climatic deterioration (the Younger Dryas; Duplessy and others, 1981) may be recognized (243-256 cm) between the two abrupt increases in right-coiling forms.

Two similar shifts in the ratio of left- and right-coiling forms of *Neogloboquadrina pachyderma* were recognized in a deep-sea core (V1-80-P3) recovered off the Russian River (Gardner and others, in press). Correlating the faunal shifts noted in core V1-80-P3 with the oxygen isotope record of those same deposits, Gardner and others (in press) determined that they occurred approximately 15,000 and 10,500 years B.P. The boundary between oxygen isotope stages 1 and 2 lies somewhere between these two faunal shifts, and has been estimated at 11,000 years B.P. (Kominz and others, 1979; Pisias and Moore, 1981; Gardner and others, in press).

Illustrations

Photographs of the benthonic foraminifers of core S3-15G were obtained by two techniques.

Table 1. Benthonic foraminiferal species utilized in the cluster analysis of core S3-15G.

- *Bolivina argentea* Cushman
- *Buccella* spp.
    - *Buccella frigida* Cushman
    - *Buccella tenerrima* (Bandy)
- *Bulimina striata mexicana* Cushman
- *Buliminella tenuata* Cushman
- *Cassidulina minuta* Cushman
- *Cassidulinoides bradyi* (Norman)
- *Cibicides lobatulus* (Walker and Jacob)
- *Elphidium* spp.
    - *Elphidium excavatum clavata* Cushman
    - *Elphidium excavatum lidoensis* Cushman
    - *Elphidium excavatum selseyensis* (Heron-Allen and Earland)
    - *Elphidium gunteri* Cole
    - *Elphidium magellanicum* (Heron-Allen and Earland)
- *Epistominella pacifica* (Cushman)
- *Epistominella smithi* (Stewart and Stewart)
- *Globobulimina affinis* (d'Orbigny)
- *Gyroidina* cf. *G. planulata* Cushman and Renz
- *Hoeglundina elegans* (d'Orbigny)
- *Karreriella grammostomata* (Galloway and Wissler)
- *Loxostomum pseudobeyrichi* (Cushman)
- *Melonis barleeanus* (Williamson)
- *Melonis pompilioides* (Fichtel and Moll)
- *Nonionella miocenica* Cushman
- *Oridorsalis umbonatus* (Reuss)
- *Planulina wuellerstorfi* (Schwager)
- *Pullenia bulloides* (d'Orbigny)
- *Rosalina columbiensis* (Cushman)
- *Uvigerina hispida* Schwager
- *Uvigerina peregrina* Cushman
- *Uvigerina proboscidea* Schwager
- *Uvigerina senticosa* Cushman
- *Valvulineria araucana* (d'Orbigny)

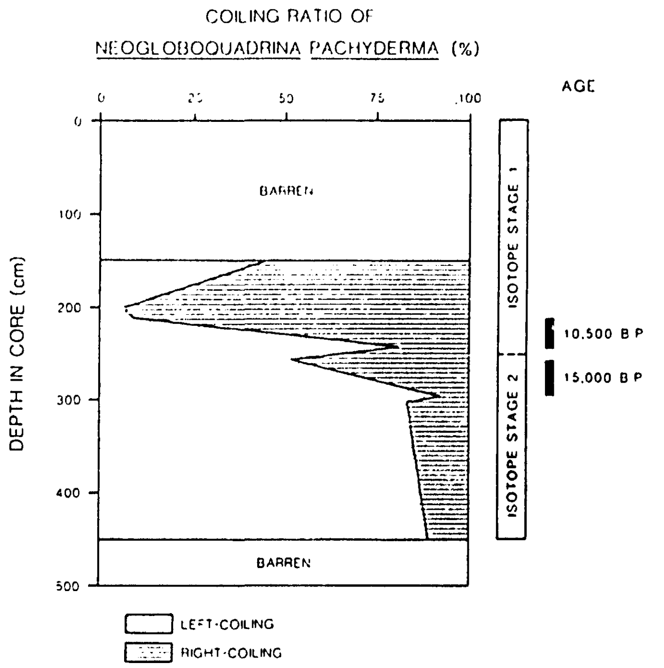

Figure 4. Coiling ratio of left- and right-coiling <u>Neogloboquadrina pachyderma</u> (Ehrenberg) plotted with depth in core S3-15G. The Pleistocene-Holocene boundary lies between 212 and 241 cm, based upon the prominent shift from left-coiling Pleistocene to right-coiling Holocene populations (data and interpretation provided by C. Brunner, 1985, pers. commun.). Isotope stages and ages (B.P.) after Gardner and others (in press).

Plates 1 to 24 feature those obtained by utilizing a Wild M5A stereo microscope with a Nikon FX-35A camera and Nikon Microflex UFX photomicrographic attachment. The remaining micrographs (Plates 25 to 29) were taken by a Cambridge Stereoscan Mark II scanning electron microscope. Individual specimens were mounted on an aluminum plug, coated with a 60% gold, 40% palladium alloy in a vacuum chamber, and then exposed to an electron beam. Some specimens, similarly coated with this alloy, were also subjected to energy dispersive X-ray analysis utilizing a standard EDX system interfaced with the scanning electron microscope. The EDX spectrometer employed was a Model 5500 of Tracor Northern.

Results

The sediments of deep-sea core S3-15G are deposited in 45 turbiditic depositional units (Figure 3). Twice as many of these cycles occur in the Pleistocene portion of the core compared to the Holocene.

Depositional units often are horizontally discontinuous within the core. Consequently, samples thought to represent a particular lithologic unit based upon the appearance of the surface of the split core were actually found to be comprised of two or more units. As a result, graphic representation of the general lithology of core S3-15G (Figure 3) is greatly simplified (see the detailed lithology, Appendix 1) and most samples are comprised of a mixed lithology. Therefore, due to a paucity of unadulterated hemipelagic and turbiditic mud samples, this study was unable to discern faunal differences between these two depositional units. Instead, variations in the microfossil assemblages of the mud (hemipelagic, turbiditic, and mixed) and turbiditic sand samples were investigated.

Several microfaunal trends may be discerned from the data (Tables 2-3). The turbiditic sand deposits are characterized by nearly twice the benthonic foraminiferal faunal diversity, and between 3.5 and 9 times the abundance of foraminifers (both benthonic and planktonic) as that of the muds. Additionally, an average of 75% of the benthonic foraminiferal assemblages of the turbiditic sand sediments are displaced shallow-water taxa, compared to an average of only 16% in the muds.

The Pleistocene muds are characterized by an enrichment in allochthonous benthonic foraminifers (24%) over that noted in their Holocene counterparts (7%). In contrast, the average benthonic

Table 2. Dry sediment weight, fossil numbers, relative frequency of displaced and pyritized benthonic foraminifers (determined for samples containing >200 benthonic foraminifers), and Fisher alpha diversity index values (determined for samples containing >100 benthonic foraminifers) in core S3-15G.

Depth In Core (cm)	Dry Sediment Weight (gm)	Foram Number (Tests/gm)	Number of Benthonic Foram Tests Counted	Displaced Benthonic Forams (%)	Pyritized Benthonic Forams (%)	Benthonic Foram Number (Tests/gm)	Fisher Alpha Diversity Index
0-4	3.2	3.1	8	-	-	2.5	-
20-23.5	29.3	9.5	253	2.8	0.4	8.6	10.5
40-43	30.1	4.5	106	-	-	3.5	5.5
46-48	5.3	80.4	368	81.0	45.1	69.4	9.5
60-63	29.5	3.9	106	-	-	3.6	6.5
80-82	9.3	47.2	303	0.7	20.1	32.6	6.5
96.5-100	34.8	22.5	334	3.6	9.9	9.6	7.5
120-122	12.0	179.3	329	5.2	15.2	27.4	12.5
128-130	12.7	75.0	225	8.4	13.3	17.7	12.5
130-132	20.4	29.3	69	-	-	3.4	-
133.5-136.5	7.7	147.9	378	69.1	62.4	49.1	~24.0
139-143	49.2	40.3	409	10.0	11.5	8.3	14.5
152.5-154.5	14.5	133.2	325	4.3	20.9	22.4	9.5
167.5-170	34.2	143.2	606	7.3	12.1	17.7	11.0
171-173	6.2	155.8	352	78.4	32.7	56.8	~24.0
180-182	16.4	210.2	1250	52.6	35.9	76.2	16.5
189.5-192	34.8	33.6	224	12.1	18.3	6.4	8.0
210-212	19.6	37.6	308	18.8	9.7	15.7	11.0
230-232	18.5	73.7	785	63.6	45.6	42.4	19.5
248-250	0.7	1247.1	403	90.3	45.4	575.7	13.0
270-272	18.8	37.3	392	16.6	16.6	20.9	15.0
289.5-292	41.5	12.7	457	14.9	16.6	11.0	10.5
310-312	23.8	34.2	337	25.2	11.9	14.2	8.0
330-332	23.9	94.4	332	26.8	18.4	13.9	10.5
336.5-338	9.4	102.8	375	85.1	60.8	39.9	15.0
346.5-349.5	40.6	77.1	544	19.3	14.9	13.4	10.0
369.5-372.5	42.1	64.3	343	26.2	14.3	8.1	12.5
390-393	30.4	90.3	377	17.8	17.2	12.4	11.5
410-412.5	33.8	185.0	490	38.2	10.6	14.5	11.5
412-414.5	3.5	587.7	746	78.8	22.8	213.1	18.5
430-432.5	39.1	79.1	337	42.7	8.6	8.6	7.5
445-447.5	37.1	112.3	387	10.9	4.4	10.4	7.5
467.5-469.5	16.2	26.0	83	-	-	5.1	-

Table 3. Fossil numbers, fossil ratios, Q-mode group, lithology, and dissolution in core S3-15G. The lithology abbreviations are as follows: H, hemipelagic mud; T, turbiditic mud; S, turbiditic sand; M, mixed lithology of hemipelagic and turbiditic muds and/or turbiditic sand. Samples containing <200 benthonic foraminifers were not included in the Q-mode cluster analysis.

Depth In Core (cm)	Number of Planktonic Foram Tests Counted	Planktonic-Benthonic Foram Ratio (%)	Planktonic Foram Number (Tests/gm)	Radiolarian-Planktonic Foram Ratio (%)	Q-Mode Cluster Analysis Sample Number	Q-Mode Cluster Group	Lithology	Dissolution
0-4	2	20.0	0.6	100.0	-	-	H	Very High
20-23.5	26	9.3	0.9	100.0	1	G	H	Very High
40-43	30	22.1	1.0	99.3	-	-	M	Very High
46-48	58	13.6	10.9	-	2	E	S	Very High
60-63	8	7.0	0.3	100.0	-	-	M	Very High
80-82	136	31.0	14.6	99.1	3	F	M	Very High
96.5-100	449	57.3	12.9	99.1	4	F	M	Very High
120-122	1822	84.7	151.8	65.9	5	F	H	Low
128-130	727	76.4	57.2	96.3	6	F	M	Low
130-132	528	88.4	25.9	81.2	-	-	M	High
133.5-136.5	761	66.8	98.8	-	7	E	S	Low
139-143	1575	79.4	32.0	85.8	8	F	M	Low
152.5-154.5	1607	83.2	110.8	78.1	9	F	M	Low
167.5-170	4290	87.6	125.4	-	10	F	M	Low
171-173	614	63.6	99.0	-	11	E	S	Low
180-182	2197	63.7	134.0	-	12	E	S	Low
189.5-192	947	80.9	27.2	64.1	13	F	M	Low
210-212	428	58.1	21.8	90.2	14	F	M	High
230-232	579	42.4	31.3	-	15	E	S	High
248-250	470	53.8	671.4	-	16	E	S	High
270-272	310	44.2	16.5	93.1	17	G	M	High
289.5-292	71	13.5	1.7	88.7	18	G	T	High
310-312	476	58.5	20.0	87.3	19	G	M	High
330-332	1925	85.3	80.5	90.0	20	G	M	Low
336.5-338	591	61.2	62.9	-	21	E	S	Low
346.5-349.5	2586	82.6	63.7	77.5	22	G	T	Low
369.5-372.5	2364	87.3	56.2	59.3	23	G	M	Low
390-393	2368	86.3	77.9	51.4	24	G	M	Low
410-412.5	5763	92.2	170.5	35.1	25	G	M	Low
412-414.5	1311	63.7	374.6	-	26	E	S	Low
430-432.5	2754	89.1	70.4	36.9	27	G	H	Low
445-447.5	3781	90.7	101.9	-	28	G	M	Low
467.5-469.5	338	80.3	20.9	95.9	-	-	T	High

foraminiferal faunal diversity did not alter significantly between the Pleistocene (α = 11.6) and Holocene (α = 12.2) fine-grained sediments; neither did foraminiferal abundance (73.9 and 54.4 tests/gm, respectively).

The abundance of foraminifers, and the relative proportion of planktonic foraminifers, benthonic foraminifers, and radiolarians, is cyclic in the mud deposits of core S3-15G. At a core depth of 320-472 cm, and again from 110-200 cm, foraminiferal abundance is high (averaging 91 tests/gm), with planktonic foraminifers accounting for approximately 85% of the foraminiferal population. Similarly, planktonic foraminifers reach peak abundance in core S3-15G during these intervals, comprising about one-third of the pelagic fauna. A reverse in these faunal trends is noted between 200 and 320 cm, and the core-top to 110 cm downcore. Average foraminiferal abundance is low (23 tests/gm), benthonic foraminifers comprise from more than half to two-thirds of the foraminiferal assemblage, and radiolarians account for nearly all (95%) of the pelagic assemblage.

Pyrite occurs commonly in the shells of benthonic foraminifers, diatoms and radiolarians recovered in these overbank deposits. An average of nearly 44% of the benthonic foraminifers in the turbiditic sand deposits are pyritized, in contrast to only 13% in both the Pleistocene and Holocene muds. Qualitative assessment of the microfaunal assemblages also suggests that there is a slight increase in pyritized diatoms and radiolarians downcore. Additionally, an abrupt appearance of pyritized "worm tubes" occurs at a depth of 348 cm and greater.

Single and multiple bore holes are occasionally observed on the Monterey Fan benthonic foraminiferal tests. Preyed-upon specimens were recovered from mud samples as well as turbiditic sand deposits containing foraminifers characteristic of low-oxygen conditions.

Discussion

R-Mode Cluster Analysis

The R-mode cluster analysis amalgamated the benthonic foraminifers into four groups (A-D, Figure 5). Based upon the bathymetric distribution of modern foraminifers in the eastern Pacific (Table 4; Appendices 8-9), this analysis discerned the major

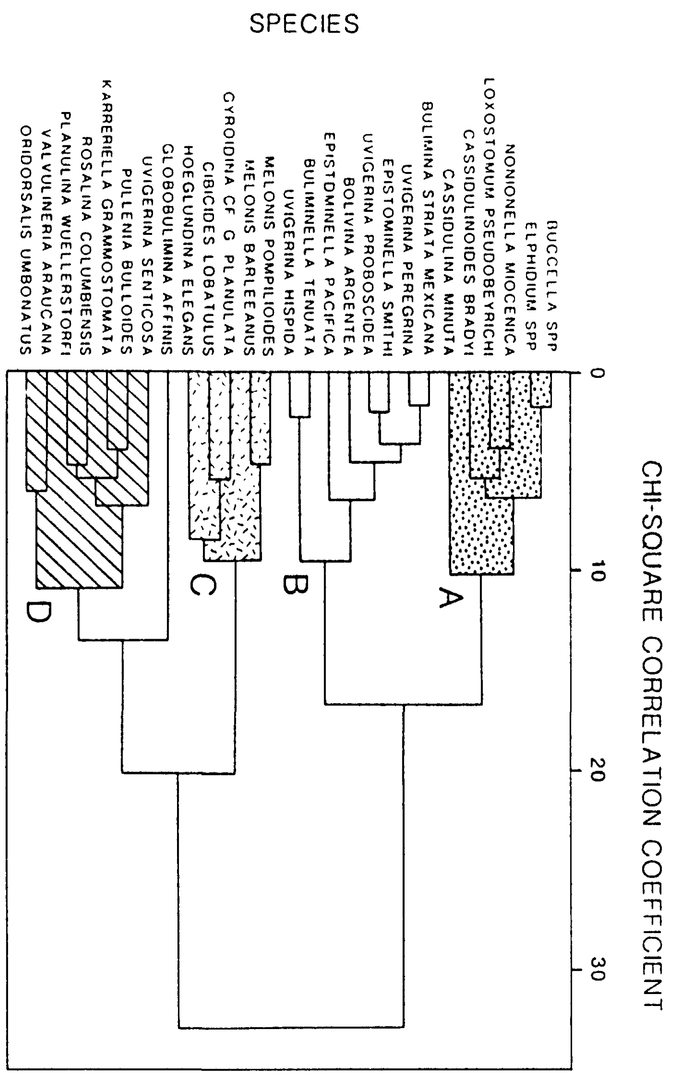

Figure 5. R-mode cluster diagram of the faunal associations of core S3-15G. The benthonic foraminifers were grouped into four associations (A-D) based upon the correlation of 27 taxa (Table 1; Appendix 3) measured in the 28 samples from hemipelagic and turbiditic deposits.

Table 4. Bathymetric distribution of modern benthonic foraminifers in the eastern Pacific Ocean. Numbers following the species refer to the studies listed below.

Water Depth (meters)	Biofacies	Species
0		
	INNER SHELF	*Buccella frigida* - 1,2,3,10,11,13,15,16 *Buccella tenerrima* - 1,3,11,13 *Cibicides lobatulus* - 8,11,13 *Elphidium excavatum clavata* - 11,13,14,15,16,17,18,19,20 *Elphidium excavatum lidoense* - 19,20 *Elphidium excavatum selseyensis* - 19,20 *Elphidium gunteri* - 18,19,20 *Elphidium magellanicum* - 18,19,20 *Nonionella miocenica* - 1,9 *Rosalina columbiensis* - 13
50		
	OUTER SHELF	*Buccella frigida* - 2,8,11,13,16 *Cassidulina minuta* - 1,3,4,5,10 *Cibicides lobatulus* - 7,11,13 *Elphidium excavatum clavata* - 11,13,14,16,17 *Elphidium excavatum lidoense* - 20 *Elphidium excavatum selseyensis* - 20 *Elphidium gunteri* - 20 *Elphidium magellanicum* - 20 *Rosalina columbiensis* - 13
150		
	UPPER BATHYAL	*Buliminella tenuata* - 3,5,11,21 *Cassidulina minuta* - 1,5,10 *Cibicides lobatulus* - 7,11 *Elphidium excavatum clavata* - 11,13,14,16,17 *Epistominella pacifica* - 5,7,9,11,13 *Epistominella smithi* - 10,14,21 *Hoeglundina elegans* - 1,5,8 *Loxostomum pseudobeyrichi* - 1,11 *Oridorsalis umbonatus* - 8,21 *Uvigerina peregrina* - 1,3,5,7,10,11
500		

Table 4. Bathymetric distribution of modern foraminifers in the eastern Pacific Ocean (continued).

Water Depth (meters)	Biofacies	Species
500		
	UPPER MIDDLE BATHYAL	*Bolivina argentea* - 1,6,7 *Bulimina striata mexicana* - 2,3,5,8 *Buliminella tenuata* - 1,3,4,5,6,10,11,21 *Epistominella pacifica* - 1,2,6,7,9,10,11 *Epistominella smithi* - 2,3,4,9,10,12,14,21 *Globobulimina affinis* - 1,3,4,5,6,7,10,21 *Hoeglundina elegans* - 3,4,5,8,21 *Oridorsalis umbonatus* - 1,9,21 *Planulina wuellerstorfi* - 3,8,16 *Uvigerina peregrina* - 2,4,5,7,8,10,11,21 *Valvulineria araucana* - 1,3,6,7,9,10,11,21
1500		
	LOWER MIDDLE BATHYAL	*Cibicides lobatulus* - 5,8 *Globobulimina affinis* - 2,4,5,6 *Hoeglundina elegans* - 3,4,5 *Melonis barleeanus* - 1,3,4,5,9 *Planulina wuellerstorfi* - 16 *Pullenia bulloides* - 1,4,5,6,9 *Uvigerina hispida* - 1,2,3,5 *Uvigerina peregrina* - 4,7,11 *Uvigerina proboscidea* - 1,2,3,4 *Valvulineria araucana* - 4,7,11
2000		
	LOWER BATHYAL	*Cibicides lobatulus* - 8 *Gyroidina planulata* - 12 *Hoeglundina elegans* - 2,3,4 *Melonis barleeanus* - 4 *Melonis pompilioides* - 1,2,3,5,8,9,11,12 *Planulina wuellerstorfi* - 16 *Pullenia bulloides* - 3,5,6,7,8,9,12 *Uvigerina senticosa* - 1,2,3,4,5,6,7,9,11,12
4000		

1. Ingle, 1980
2. Bandy, 1953a
3. Bandy, 1961
4. Bandy & Arnal, 1957
5. Ingle & others, 1980
6. Cushman, 1927a
7. Natland, 1933
8. Barker, 1960
9. Arnal, 1976
10. Zalesny, 1959
11. Bergen & O'Neil, 1979
12. Bandy & Rodolfo, 1964
13. Cockbain, 1963
14. Loeblich & Tappan, 1953
15. Lagoe, 1979a
16. Lagoe, 1979b
17. Todd & Low, 1967
18. Arnal & others, 1980
19. Bandy & Arnal, 1960
20. Murray, 1973
21. Butcher, 1951

faunal associations that characterize the Monterey Fan overbank deposits.

Cluster A represents the shallowest benthonic foraminiferal association encountered in this study. Combining the foraminifers *Buccella* spp. (*B. frigida* and *B. tenerrima*), *Elphidium* spp. (*E. excavatum* vars. *clavta*, *lidoense* and *selseyensis*, *E. gunteri* and *E. magellanicum*), *Nonionella miocenica*, *Loxostomum pseudobeyrichi*, *Cassidulinoides bradyi*, and *Cassidulina minuta*, this cluster typifies the assemblage of an inner- to outer-shelf biofacies. It also appears that, in general, the members of this association are more prevalent in the Pleistocene portion of the core (Figure 6; Appendix 3).

Cluster B joins another group of shallow water foraminifers: *Bulimina striata mexicana*, *Uvigerina peregrina*, *U. proboscidea*, *U. hispida*, *Epistominella smithi*, *E. pacifica*, *Bolivina argentea*, and *Buliminella tenuata*. This association is indicative of upper middle bathyal depths (Table 4), with its members occurring more frequently in the Holocene sediments investigated.

Cluster C pairs together the foraminifers *Melonis pompilioides*, *M. barleeanus*, *Gyroidina* cf. *G. planulata*, *Cibicides lobatulus* and *Hoeglundina elegans*. With the exception of *Cibicides lobatulus*, this faunal association represents the endemic population of the core site's lower bathyal deposits. *Cibicides lobatulus*, however, is generally considered a shelf species. This is particularly true when deformed tests are encountered (Cushman, 1948; Corliss, 1985). Yet, the undeformed morphotype (as pictured in Barker, 1960), characteristic of this study, has been recovered at bathyal and abyssal depths (Barker, 1960; Gooday and Haynes, 1983). Therefore, it appears that *Cibicides lobatulus* may be a valid representative of lower bathyal depths in this investigation. The foraminifers of Cluster C occur in greatest abundance in the Holocene samples of the core.

Cluster D associates the foraminifers *Uvigerina senticosa*, *Pullenia bulloides*, *Karreriella grammostomata*, *Rosalina columbiensis*, *Planulina wuellerstorfi*, *Valvulineria araucana* and *Oridorsalis umbonatus*. The members of this group are most prevalent in the Pleistocene samples of core S3-15G and are, for the most part, indicative of lower bathyal depths. The presence of *Rosalina columbiensis* is an anomaly, however, as the taxon was expected to cluster with the shelf species. Its presence in this deep-water association may be

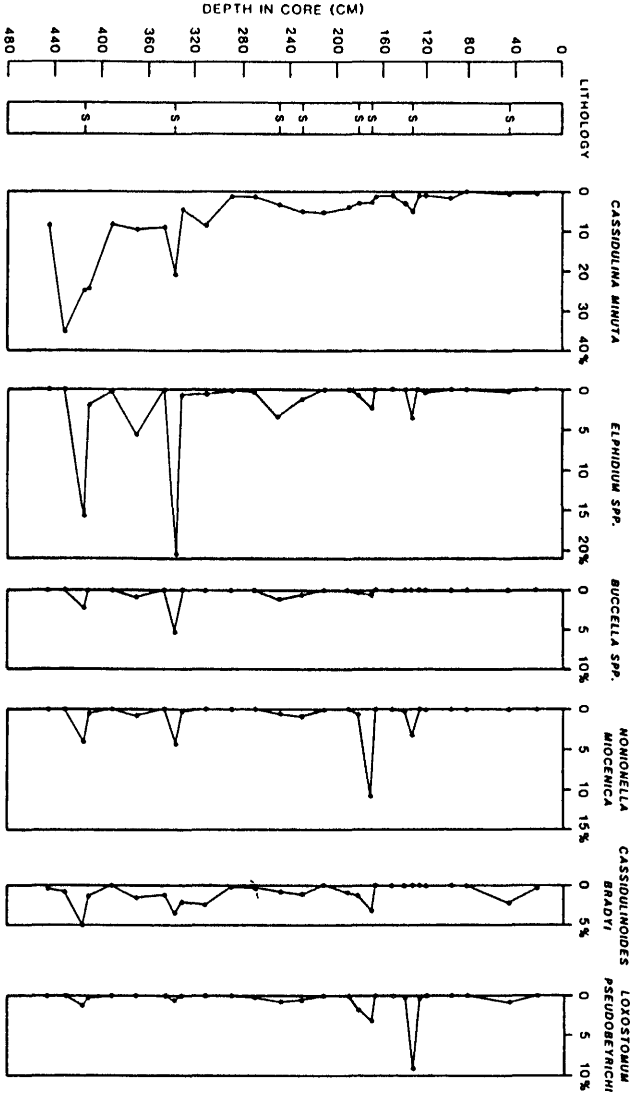

Figure 6. Percentage abundance of the prominent benthonic foraminifers plotted with depth in core S3-15G. Location of the turbiditic sand samples denoted by an "S" in the lithology column.

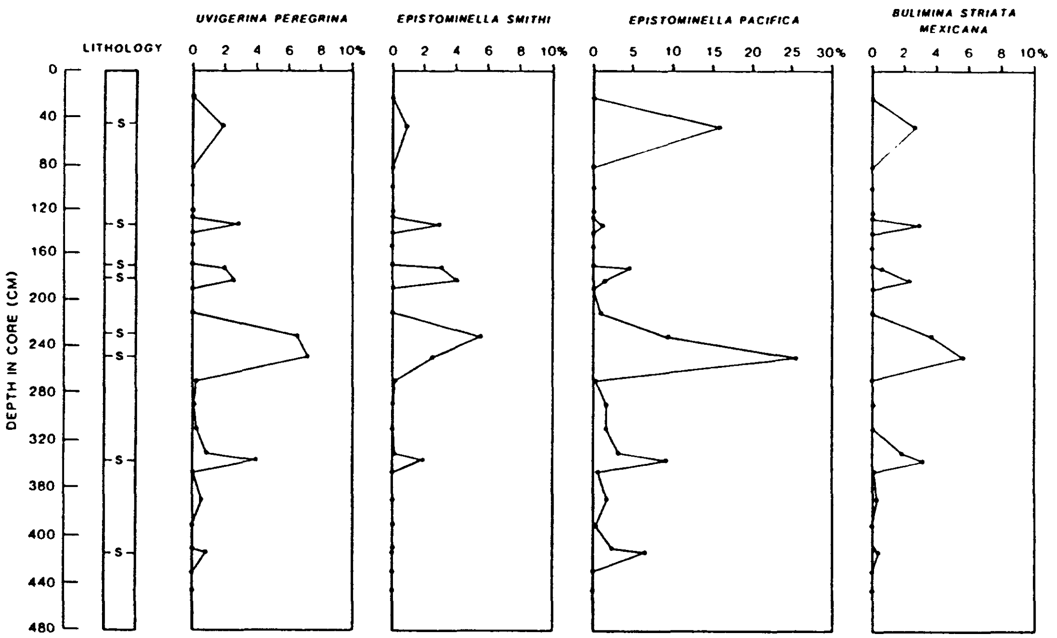

Figure 6. Percentage abundance of the prominent benthonic foraminifers plotted with depth in core S3-15G (continued).

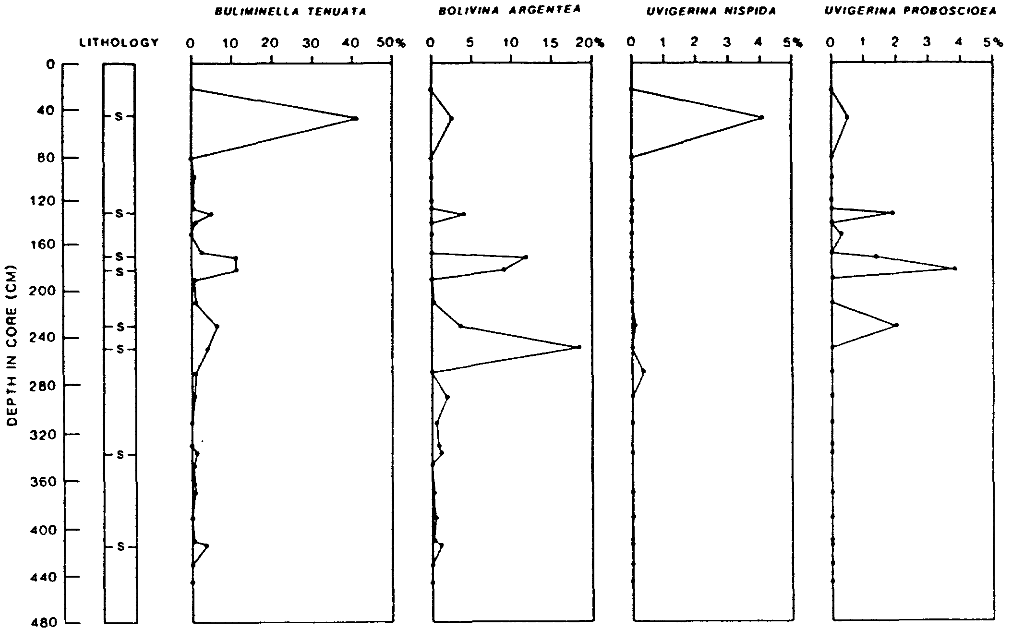

Figure 6. Percentage abundance of the prominent benthonic foraminifers plotted with depth in core S3-15G (continued).

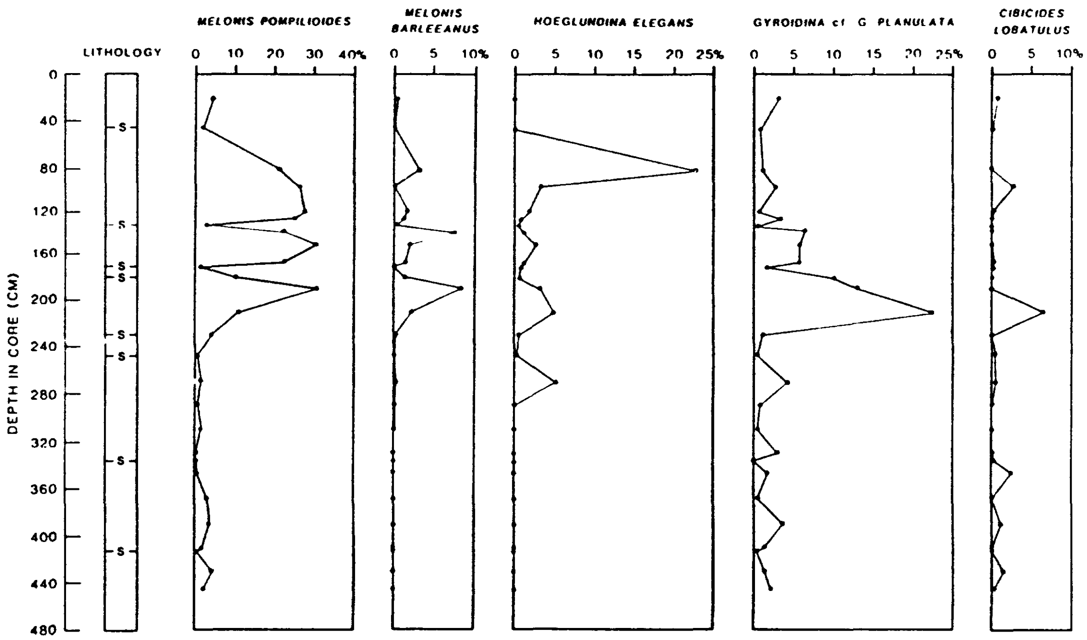

Figure 6. Percentage abundance of the prominent benthonic foraminifers plotted with depth in core S3-15G (contined).

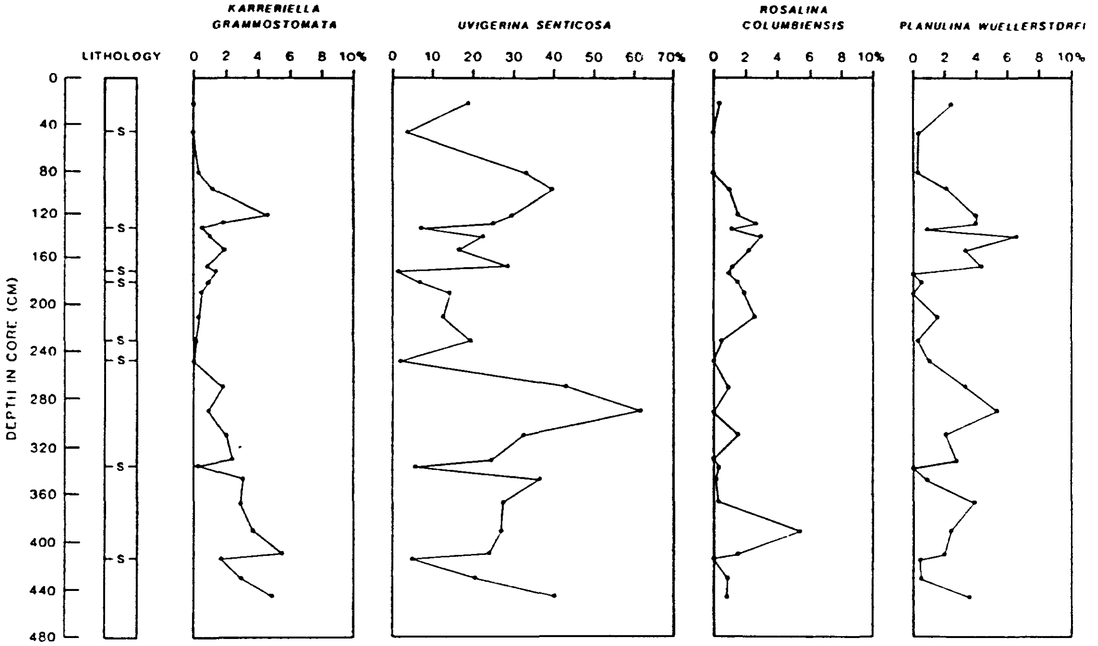

Figure 6. Percentage abundance of the prominent benthonic foraminifers plotted with depth in core S3-15G (continued).

attributable to the downslope transport of seaweed to which it commonly attaches (Lessard, 1980; M. Dumont and T. Dignes, 1984, pers. commun.).

Q-Mode Cluster Analysis

The Q-mode cluster analysis associated the samples into three clusters (E-G, Figure 7). Examination of the clustering patterns, sample lithologies, faunal diversity, and preservational state of the foraminiferal assemblages (Table 3) suggests that there are several major factors responsible for grouping the samples.

Sediment source is the primary factor: Cluster E is comprised solely of the eight turbiditic sand samples. Clusters F and G associated the Holocene and Pleistocene mud samples, respectively, reflecting the benthonic foraminiferal faunal adaptation to changing climatic conditions. Within all three clusters, sample groupings are further constrained by the amount of dissolution they have undergone.

Within Cluster E, the two lowermost sand samples (#21 and #26) amalgamated first. They are both characterized by low dissolution (Table 3) and very similar frequencies of the eight most abundant displaced species (Table 5). Particularly dominant are the foraminifers Cassidulina minuta and Elphidium spp. The prevalent fauna recovered in these samples indicates that the majority of displaced foraminifers originated in the well-oxygenated outer shelf region. Far less common are displaced specimens from the inner shelf, upper bathyal, and oxygen-deficient upper middle bathyal zones.

The remaining sand samples contain a higher proportion of displaced foraminifers originating in deeper waters. Samples 7 and 11 grouped together because their assemblages are relatively well preserved and are composed of foraminifers from a variety of faunal zones, as evidenced by their unusually high species diversity index (ȧ~24). Sample 7 is comprised of nearly equal abundances of the constituents from every biofacies (inner shelf to upper middle bathyal), whereas sample 11 contains a preponderance of inner shelf and low-oxygen upper middle bathyal species. Sample 12 is similar in that dissolution is low and many biofacies are represented. It differs, however, by its particularly high frequency of upper middle bathyal constituents. Samples 15 and 16 are typified by high dissolution, low to moderate abundances of inner to outer shelf species, and highest frequencies of upper

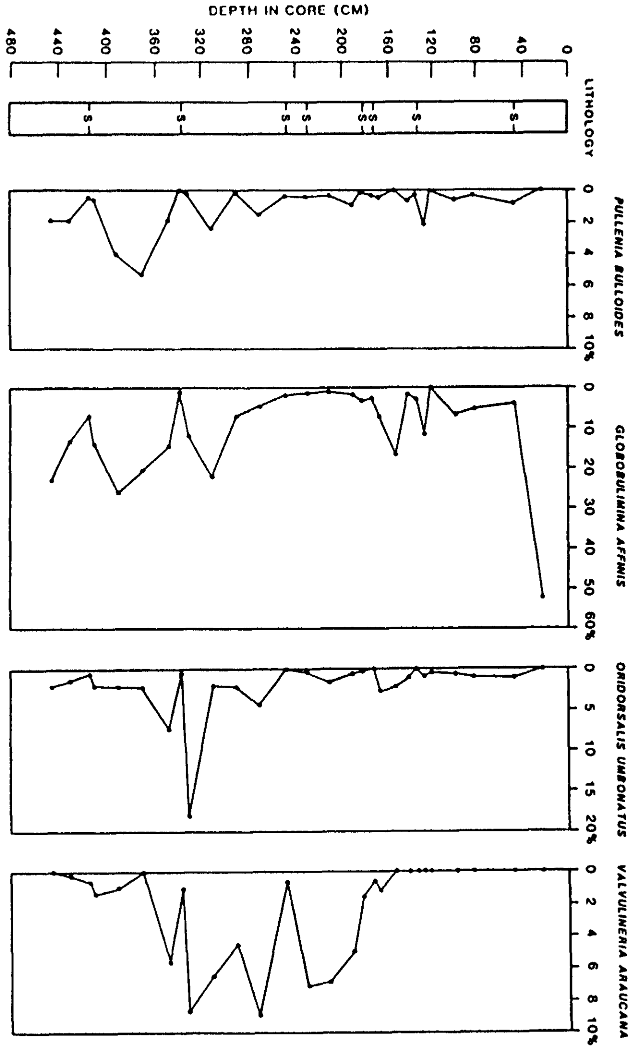

Figure 6. Percentage abundance of the prominent benthonic foraminifers plotted with depth in core S3-15G (continued).

Table 5. Relative species frequencies, age, Fisher alpha diversity index and prevalent biofacias of the benthonic foraminiferal faunas in the turbiditic sand samples of core S3-15G. Biofacies abbreviations are as follows: IS = inner shelf; OS = outer shelf; UB = upper bathyal; and UMB = upper middle bathyal (after Ingle, 1980)

	Preferred Biofacies	46-48 cm	133.5-136.5 cm	171-173 cm	180-182 cm	230-232 cm	248-250 cm	336.5-338 cm	412-414.5 cm
Bolivina argentea	UMB	2.7%	4.0%	11.1%	8.6%	3.6%	17.6%	1.3%	1.2%
Buccella spp.	IS-OS	-	-	0.6%	0.2%	0.6%	1.2%	5.3%	2.3%
Buliminella tenuata	UMB	41.9%	5.0%	11.1%	11.1%	6.1%	4.0%	1.3%	1.9%
Cassidulina minuta	OS-UB	0.8%	5.3%	2.8%	2.9%	5.1%	3.5%	21.1%	24.9%
Elphidium spp.	IS-OS	0.3%	3.7%	2.3%	0.9%	1.3%	3.8%	20.6%	15.8%
Epistominella pacifica	UB-UMB	15.8%	1.3%	4.6%	1.5%	9.4%	25.6%	9.3%	7.6%
Nonionella miocenica	IS	-	3.2%	10.8%	0.6%	0.9%	0.5%	4.3%	4.0%
Uvigerina peregrina	UB-UMB	1.9%	2.9%	2.0%	2.6%	6.5%	7.2%	4.0%	0.8%
Age	-	Holocene	Holocene	Holocene	Holocane	Holocene	Pleistocene	Pleistocene	Pleistocene
Fisher Alpha Diversity Index	-	9.5	~24	~24	16.5	19.5	13.0	15.0	18.5
Prevalent Biofacies Represented	-	UMB	IS-OS-UB-UMB	IS, UMB	UB-UMB	UB-UMB	UB-UMB	OS	OS
Dissolution	-	Very High	Low	Low	Low	High	High	Low	Low

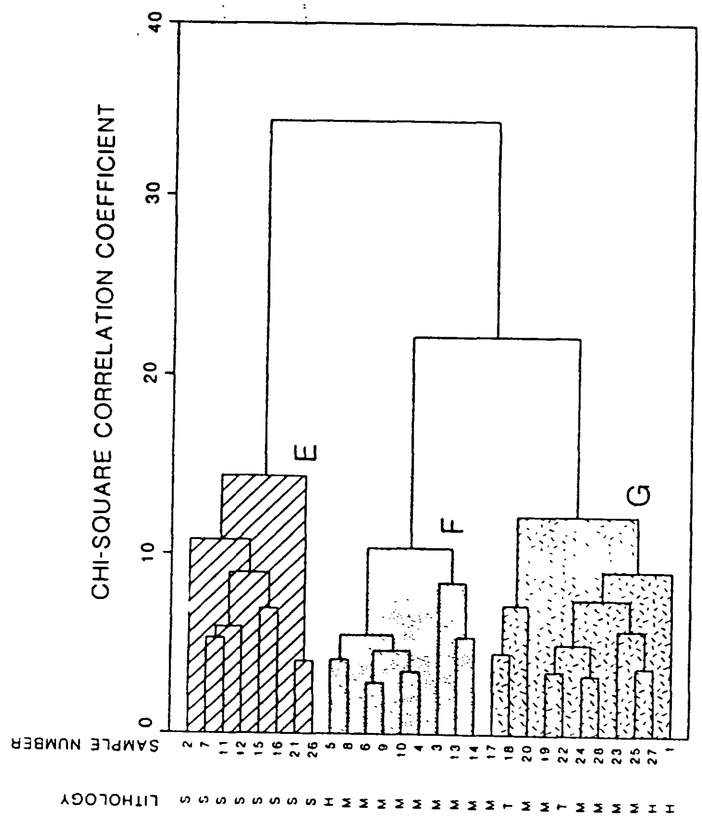

Figure 7. Q-mode cluster diagram of 28 samples in core S3-15G. The samples were grouped into three associations (E-F) based upon the correlation of 27 variables (Table 1; Appendix 2) measured in the 28 samples from hemipelagic and turbiditic deposits. The lithology of the samples is indicated as follows: H, hemipelagic mud; T, turbiditic mud; S, turbiditic sand; M, mixed lithology of hemipelagic and turbiditic muds and/or sand.

bathyal to upper middle bathyal faunas. Both have relatively high proportions of *Epistominella pacifica* and *Uvigerina peregrina.*

The last sample to amalgamate in Cluster E is #2. This sample is unique in that it is characterized by very high dissolution, rare shelfal types, low species diversity (ȧ = 9.5), and a high dominance of low-oxygen forms (particularly *Buliminella tenuata* and *Epistominella pacifica*). Dysaerobic environments are commonly characterized by assemblages of lower relative faunal species diversity and domination by a few species (Phleger and Soutar, 1973; Ingle and others, 1980; Govean and Garrison, 1981). Therefore, it appears that this turbidite originated primarily in the oxygen-deficient upper middle bathyal zone.

With the exception of the uppermost sample used in the cluster analysis (20-23.5 cm), the Holocene and Pleistocene mud samples clearly separated into Clusters F and G, respectively. Both the Monterey Fan levee deposits, and a core recovered at a depth of 1600 m off the Russian River (Gardner and others, in press), document this foraminiferal faunal change about 11 to 10,000 years B.P. Although the upper middle bathyal species common to the Russian River study were observed only in the sporadic turbiditic sands of core S3-15G, roughly analogous faunal variations (specifically, in the foraminifers *Epistominella pacifica*, *E. smithi*, *Uvigerina peregrina* and *U. proboscidea*; Figure 6) were noted in both.

In the relatively deeper deposits of the Monterey Fan, the Holocene fauna endemic to the lower bathyal zone (Cluster F) includes *Melonis pompilioides*, *M. barleeanus*, *Hoeglundina elegans*, *Gyroidina* cf. *G. planulata*, *Uvigerina senticosa* and *Planulina wuellerstorfi* (Figure 6). Furthermore, with the exception of one sample (130-132 cm), the Holocene muds from 110-200 cm are characterized by low dissolution and those between the core-top and 110 cm are severely dissolved. In the Pleistocene (Cluster G), *Uvigerina senticosa* and *Planulina wuellerstorfi* are still abundant, but are associated instead with *Pullenia bulloides*, *Globobulimina affinis*, *Valvulineria araucana* and *Oridorsalis umbonatus.* Additionally, the Pleistocene mud samples may be further subdivided into two subclusters: those of low (320-457 cm) and high (200-320 cm) dissolution.

The anomalous upper sample used in the cluster analysis (20-23.5 cm) groups with the Pleistocene mud deposits (Figure 7). This amalagamation does not appear to result from either sample lithology or dissolution, as Holocene-aged Cluster F contains samples characterized by both features of the upper sample: hemipelagic mud (#5) and very highly dissolution-affected assemblages (#3-#4). Instead, this sample may reflect a faunal shift back into a "glacial mode". Balsam (1985, pers. commun.) believes a similar trend may be occurring in the modern benthonic foraminiferal assemblages of the Atlantic Ocean. The faunal variations observed in the foraminiferal assemblages of the Monterey Fan overbank deposits, therefore, appear to adequately reflect adaptations to a progressively changing deep-water mass off central California during the Pleistocene and Holocene.

Downslope Displacement

Faunal contamination is commonplace in marine sediments (Table 6; Natland and Kuenen, 1951; Bandy and Arnal, 1960; Kheradpir, 1970; Sliter and Baker, 1972; Merrill and Guber, 1982), particularly in regions of substantial bathymetric relief (Phleger, 1951; Bandy, 1953b; Phleger and others, 1953; Arnal, 1976). Mixing of foraminiferal faunas most often results from the downslope transport of sediments by slump or turbidity currents (Natland and Kuenen, 1951; Bandy, 1953b, 1964; Phleger and others, 1953; Murray, 1973; Douglas and Heitman, 1979; Bock, 1982; Guber and Merrill, 1983). However, allochthonous foraminifers may also be introduced by passive ingestion by fish or birds (Todd, 1961; Daniels and Lipps, 1978; Lessard, 1980) and by the downslope transport of objects upon which the shallow-water species are attached: vegetation (marine algae and continental plants), arenaceous worm colonies and man-made objects (Bandy, 1960b; Murray, 1973; Lessard, 1980). Faunal displacement may be discerned by the presence of several biofacies within a sample (Natland and Kuenen, 1951; Bandy, 1953b; Bandy and Arnal, 1960; Arnal, 1976) and appears to correlate positively with bathymetry (Table 6).

Foraminifers are equivalent in size to sand-sized particles (Phleger and others, 1953; Phleger, 1960; Sandifer, 1969; Boltovskoy and Wright, 1976). Yet, because their traction and settling velocities are lower (Berger and Piper, 1972; Kontrovitz and others, 1978, 1979) than those of mineral grains of the same size (Brush and Brush, 1972; Pettijohn, 1975), they will behave differently than terrigenous particles during transport (Stow and others, 1984).

Coarser-grained turbidity flows are estimated to travel between 7 and 22 m/sec (Menard, 1964;

Table 6. Average abundance of displaced benthonic foraminifers recovered in previous studies.

Study	Average Abundance of Displaced Benthonic Foraminifers
Uchio, 1960, San Diego Trough	45% in sands of upper bathyal 25% in very coarse sands of upper bathyal 5-17% in upper middle bathyal 27% in upper middle bathyal
Bandy, 1961, Gulf of California	0% in inner shelf 49% in outer shelf 70-91% in upper bathyal 72-90% in middle bathyal 39-100% in lower bathyal
Bandy, 1964, San Pedro and Santa Monica Basins	3% in hemipelagic basin floor sediments 25-26% in mud beds of subsea fans 78% in sand beds of subsea fans
Harman, 1964, Santa Barbara Basin	Displaced shelfal species rarely exceed 1% of fauna in Santa Barbara Basin
Douglas and Heitman, 1979, California Continental Borderland	0-80% displaced species in deep basins of California Continental Borderland
Ingle, 1980, Gulf of California	Displaced faunas commonly constitute well over 50% of assemblages within middle and lower continental margin deposits (utilizing data obtained by Phleger, 1964)
Ingle and others, 1980, Peru-Chile Trench	30% in upper bathyal 75% in lower bathyal
Brunner and Normark, 1985, Monterey Fan, Central California	0% in hemipelagic samples 1-19% unclear >30% in turbiditic mud samples 0-73% in abyssal sediments

Komar, 1969, 1970, 1977; Krause and others, 1970). As a result, traction and settling velocities of foraminiferal tests (moving on the order of cm/sec; Berger and Piper, 1972; Kontrovitz and others, 1978, 1979) entrained within these flows will have little bearing on the outcome of deposition. Instead, breakage of tests becomes a major factor in determining the character of these displaced foraminiferal assemblages. In contrast, fine-grained turbidity flows move at speeds low enough (~10 cm/sec; Normark and others, 1980) to be comparable to the foraminiferal traction and settling velocities. Foraminiferal tests will be selectively entrained within these turbidity flows and differentially deposited in the overbank deposits due to their shape-dependent hydraulic behaviors (Berger and Piper, 1972; Kontrovitz and others, 1978, 1979; Kontrovitz and Snyder, 1981). As a result, the turbiditic muds (and to a lesser degree, the turbiditic sands) of core S3-15G will contain a biased foraminiferal assemblage. Yet, general conclusions may still be drawn regarding the source(s) of these displaced deposits.

Allochthonous benthonic foraminifers are abundant in the Monterey Fan overbank deposits: a minimum of 65 displaced species were recovered (Appendix 2). In core S3-15G, the relative abundance of displaced foraminifers correlates positively with grain size (Table 7; Figure 8) and with sediment age (Table 2; Figure 8).

Table 7. Sample lithology and range in frequency abundance (in percent) of associated displaced benthonic foraminifers in core S3-15G.

Hemipelagic muds (Tep)	0.7-5.2%
Hemipelagic and turbiditic muds (Tet + Tep):	3.6-16.6%
Turbiditic muds (Tet):	14.9-19.3%
Hemipelagic and/or turbiditic muds and laminated sands (Tep + Tet + Td):	18.8-38.2%
Laminated sands (Td):	52.6-85.1%
Cross-bedded sands (Tc):	90.3%

Transported coarser-grained sediments commonly are characterized by higher relative abundance of displaced benthonic foraminifers than are finer-grained deposits (Phleger, 1951; Bandy, 1964). The species of benthonic foraminifers entrained within the turbiditic sands of this deep-sea core suggest that the sands originated at several sources, ranging from inner shelf to upper middle bathyal depths. Therefore, the relatively high benthonic and planktonic foraminiferal numbers (Tables 2-3; Figure 8) and benthonic foraminiferal species diversity (Table 2; Figure 9) in the sand deposits may result from a combination of several factors: particularly favorable ecological conditions for foraminifers at the source of the turbidity currents (Hessler and Sanders, 1967; Sanders and Hessler, 1969; Douglas and Woodruff, 1981), the addition of these displaced species to the endemic deep-water fauna at the final deposition site (Sliter and Baker, 1972; Ingle, 1980), and a reduction in the effects of dissolution due to an increase in the speed of deposition.

The Pleistocene assemblages of both the sand and mud deposits contain a greater relative abundance of displaced specimens than do their Holocene counterparts (Table 2; Figure 8). Studies of Quaternary deep-sea cores obtained in the basins off southern California have reported similar findings (Bandy, 1964; Kheradpir, 1970). This Pleistocene-aged enrichment in allochthonous foraminifers may be attributable to heightened turbidity current activity during the Pleistocene (this study; Kulm and Nelson, 1967; Gorsline and others, 1968; Hess and Normark, 1976; Nelson, 1976; Stow and others, 1984) due to direct deposition on the slope during times of lowered sea level, or may be related to the disturbance of sediments by the transgression that followed.

Dissolution

Calcium carbonate preservation is cyclic in the overbank mud deposits of Monterey Fan, reflecting the effects of Quaternary climatic changes in the marine realm off central California. The climatic fluctuations may be discerned by microfaunal assemblage variations as well as shifts in foraminiferal abundance, the ratio of planktonic to benthonic foraminifers, and the ratio of the pelagic constituents: radiolarians and planktonic foraminifers (Appendix 3; Tables 2-3; Figure 10).

The lower 152 cm of core S3-15G (320-472 cm), characterized by a preponderance of left-coiling Neogloboquadrina pachyderma (Ehrenberg) (Figure 4), correlates with the cold subpolar planktonic foraminiferal fauna recovered in Pleistocene sediments off the Russian River (Gardner and others, in press). Dissolution of deep-sea carbonates subsides during glacial stages (Berger, 1973, 1979; Thompson and

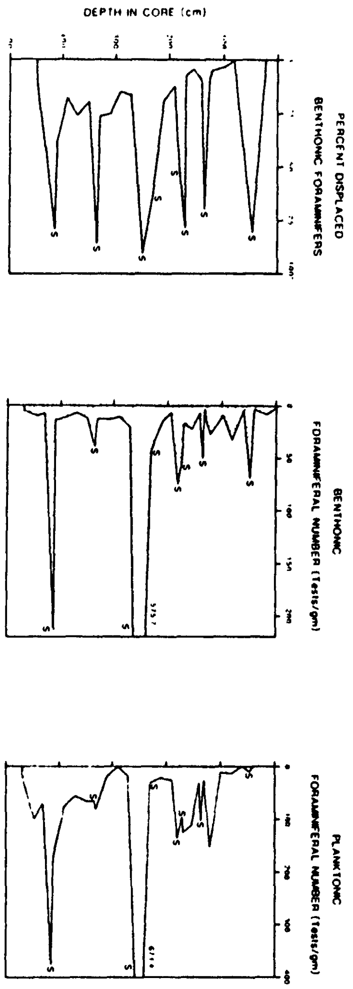

Figure 8. Frequency of displaced benthonic foraminifers, benthonic foraminiferal number, and planktonic foraminiferal number plotted with depth in core S3-15G. S = location of the turbiditic sand samples.

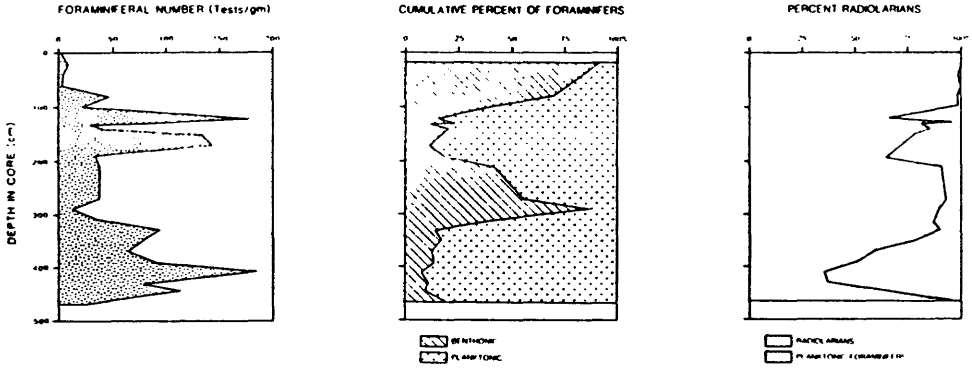

Figure 10. Foraminiferal number, cumulative frequency of benthonic and planktonic foraminifers, and cumulative frequency of radiolarians and planktonic foraminifers plotted with depth in core for the mud samples of core S3-15G.

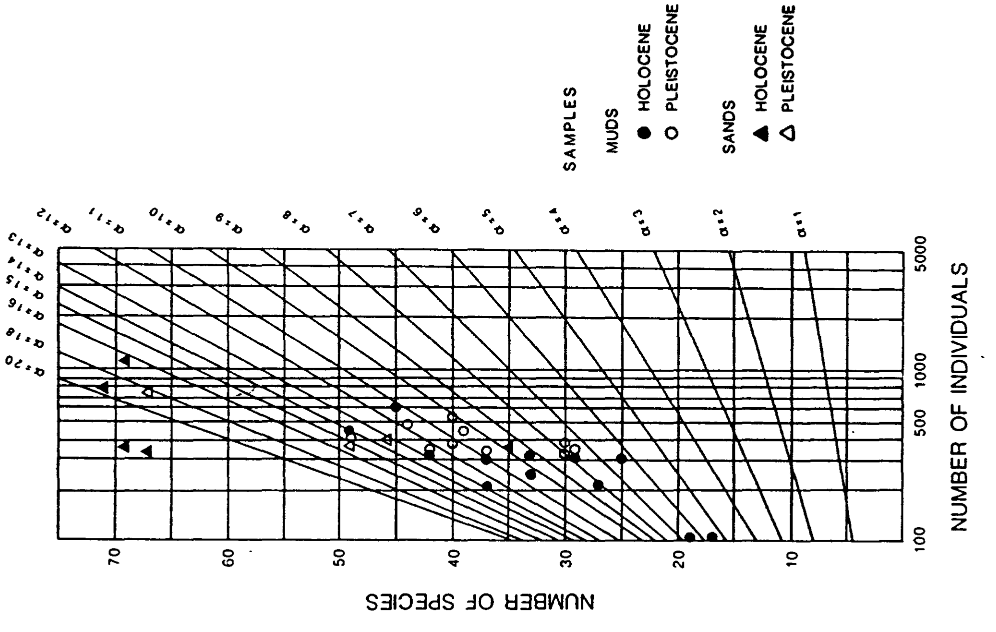

Figure 9. Fisher alpha diversity index of the benthonic foraminiferal assemblages of core S3-15G.

Saito, 1974) and is reflected by a relatively high abundance of foraminifers in the lower portion of the core. The planktonic/benthonic ratio also suggests that this interval has undergone little dissolution. This is due to the fact that the ratio is more a measure of calcium carbonate preservation in sediments obtained near the lysocline and CCD (Douglas, 1979; Ingle and others, 1980; Douglas and Woodruff, 1981) because planktonic foraminifers are nearly three times more susceptible to dissolution than benthonic foraminifers (Berger, 1973). The high relative proportion of planktonic foraminifers to radiolarians in these sediments also supports the low-dissolution contention.

Above the glacial interval lies a transitional zone (200-320 cm), as evidenced by a fluctuating *N. pachyderma* coiling ratio in core S3-15G. These sediments correlate with a transitional period observed by Gardner and others (in press) off the Russian River that is characterized by an alternation of transitional, cool and cold subpolar planktonic foraminiferal faunas. In the Monterey Fan deposits, this zone shows considerable evidence of dissolution: the foraminiferal abundance is low, the foraminiferal fauna is comprised, to a large extent, of benthonic constituents, and radiolarians overwhelmingly dominate the pelagic assemblage.

In the overbank deposits (150-200 cm) just above the Pleistocene/Holocene boundary, a slight increase is noted in the relative proportion of cool-water (left-coiling) *N. pachyderma*. This interval correlates with the subpolar planktonic foraminiferal fauna documented in sediments deposited from 6,000 to 9,500 years B.P. off the Russian River (Gardner and others, in press). Based upon a decrease in carbonate dissolution, as suggested by a high foraminiferal number and an increase in planktonic foraminifers at the expense of benthonic foraminifers and radiolarians, this cool climatic period continues to a depth of 110 cm.

The upper 110 cm of core S3-15G shows the effects of severe carbonate dissolution. The overall preservation of foraminiferal tests is low, with the particularly depauparate assemblages dominated by benthonic foraminifers. Low abundances of planktonic foraminifers in Holocene sediments have also been reported elsewhere in the eastern Pacific (Arrhenius, 1952; Uchupi and Emery, 1963; Nayudu, 1964; Hays and others, 1969; Morin, 1971). Interglacial stages are characteristically associated with intense solution resulting in fewer planktonic specimens and decreased foraminiferal abundance in general (Berger, 1973, 1979; Thompson and Saito, 1974). As a result, the pelagic assemblage is dominated by radiolarians (this study; Duncan and others, 1970; Hein and Griggs, 1972; Barnard and McManus, 1973). This interval of intense carbonate dissolution correlates with that noted in sediments deposited during the last 5,000 years off the Russian River (Gardner and others, in press). It reflects changing oceanographic conditions and appears to represent the deglaciation-induced (Shackleton and Opdyke, 1973, 1976) Holocene dissolution pulse documented elsewhere in the Pacific Ocean (Thompson and Saito, 1974; Berger, 1979; Vercoutere, 1984).

Although dissolution remains severe to the core-top, the benthonic foraminiferal assemblage of the Holocene mud sample from 20-23.5 cm clusters with the Pleistocene samples of similar lithology. Unfortunately, a similar conclusion can not be reached regarding the core-top sample, as its depauparate assemblage precluded it from being included in the cluster analysis. If the benthonic foraminiferal assemblage from 20-23.5 cm truly reflects an adaptation to a glacial resurgence, this is not yet apparent in the planktonic foraminiferal and radiolarian assemblages: the ratio of planktonic foraminifers to radiolarians is low. This fact suggests that climatic changes in the oceanographic realm off central California are not synchronous between the surface and deeper waters. A similar trend was noticed at the Pleistocene/Holocene boundary. The sample groupings yielded by the Q-mode cluster analysis suggest that the major discontinuity in the benthonic foraminiferal assemblages of core S3-15G occurs between 252 and 270 cm (samples #16 and #17). The adaptation of the foraminiferal assemblages in the surface waters to the changing climatic conditions, as indicated by the shift from left- to right-coiling *Neogloboquadrina pachyderma*, does not occur until 212-241 cm.

Predation

Evidence of predatory attacks (bore holes) on benthonic foraminiferal tests in the Monterey Fan levee deposits are occasionally observed. In agreement with previous investigations (Douglas, 1973; Sliter, 1975), most of the preyed-upon specimens were hyaline taxa; rare attacks on some porcelaneous individuals were noted, but no agglutinated species appeared to be involved. Bored tests recovered in core S3-15G include those of the following taxa: *Buccella frigida*, *Globobulimina affinis*, *Pullenia bulloides*, *Pyrgo murrhina*, *Rosalina columbiensis* and *Sigmoilina* sp.

A variety of fauna are known to prey upon foraminifers: fish, shrimp, bivalves, gastropods, scaphopods, echinoderms, other foraminifers (specifically, *Oolina marginata* [Montagu] and *Rosalina carnivora* Todd), sponges, polychaetes, nematodes and flatworms (Myers, 1943; LeCalvez, 1950; Todd, 1965; Knudsen, 1967; Sliter, 1971, 1975; Bilyard, 1974; Daniels and Lipps, 1978; Haynes, 1981; Hickman and Lipps, 1983). The preyed-upon tests encountered in this study (Plates 27-29) commonly display irregularly rounded holes with internal shelves or beveled edges (Plate 28, figures 1 and 3). These features are characteristic of the predatory attacks of gastropods, nematodes and polychaetes (Sliter, 1971, 1975; Arnold and others, 1985). The well-defined predatory holes differ from the irregular character of holes resulting from test dissolution and mechanical breakage (Plate 27, figure 3). Additionally, pitted test surfaces (Plate 29, figure 1) may be the result of mechanical abrasion by coarse sand grains or attacks by predators other than gastropods (Hickman, 1984, pers. commun.).

Qualitative observation suggests that predation attempts on the benthonic foraminifers in core S3-15G occur most commonly in the ultimate and penultimate chambers, although other chambers in the last whorl may be affected. The position of these bore holes may suggest the site of least resistance to penetration, the region of maximum protoplasm occurrence, the preferred living position of the taxon, or an avoidance response of the prey to predation (Sliter, 1971; Arnold and others, 1985). In addition, it is not uncommon to see repeated predatory attacks on individual specimens (Plate 29, figure 1; Sliter, 1971, 1975; Arnold and others, 1985).

Although bored specimens typically were recovered from mud deposits, a few were obtained from turbiditic sand samples containing benthonic foraminifers characteristic of low-oxygen conditions (Table 5). This fact suggests that either the foraminifers were preyed-upon after redeposition or that the oxygen cocentration in the sediments at the bathyal source did not fall below the level necessary for infaunal predators to survive. In the oxygen-minimum zone off central California, bioturbation is evident even in regions where the oxygen content drops to 0.3 ml/l (Thompson and others, 1985).

Pyrite

Although abundant authigenic pyrite is not common in deep-sea deposits (Regnell, 1961; Berner, 1982, 1984), it has been observed in Precambrian to recent sediments (Love and Amstutz, 1966). Recently, the origin, formation and relationship of pyrite to microorganisms has come under closer scrutiny (Zobell, 1939; Myers, 1943; Love, 1957, 1962; Smirnow, 1958; Emery, 1960; Love and Zimmerman, 1961; Hein and Griggs, 1972; Seiglie, 1973; Sliter, 1975; Schallreuter, 1984). It has been documented that the protoplasm of living foraminifers may become pyritized (LeCalvez, 1951; Seiglie, 1973) and that microfossil tests may be replaced by internal iron sulfide casts or by complete or partial replacement by framboidal pyrite (Hein and Griggs, 1972; Sliter, 1975).

Framboidal pyrite is a weakly cohesive spheroidal aggregate of pyrite microcrystallites (Schallreuter, 1984), recognizable by its raspberry appearance (Plate 25, figure 1). Each "framboid" ranges in size from <1 to >100 micrometers in diameter (Schallreuter, 1984). Framboidal pyrite formation results from the decomposition of organic matter by sulfate-reducing bacteria, a process occurring only in the absence of free oxygen (Berner, 1970, 1982, 1984). Consequently, it may form either in oxygen minima of the water column or in the anoxic sediment zone beneath the mixed sediment layer.

Pyritized benthonic foraminifers are a common constituent of the Monterey Fan levee deposits (Table 2; Figure 11). Scanning electron micrographs of the foraminifers *Cassidulina minuta* and *Melonis pompilioides* (Plate 25, figures 1-2) display the characteristic octahedral crystallites of framboidal pyrite. In addition, energy dispersive X-ray analyses of the aggregates (A and B, Figure 12) prove that they consist primarily of the pyrite constituents, iron and sulfur.

The pyritized benthonic foraminiferal tests display variable degrees of chamber infilling, ranging from the presence of a few framboids anywhere inside the test to completely pyritized individuals. Qualitative observation suggests that no particular degree of infilling dominates the pyritized specimens in this study. However, if entire chambers are infilled, the ultimate chamber is most commonly involved. This is followed by the pyritization of successive chambers in the whorl. Wholly pyritized specimens display no evidence of pyrite overgrowth or test disruption (Schallreuter,

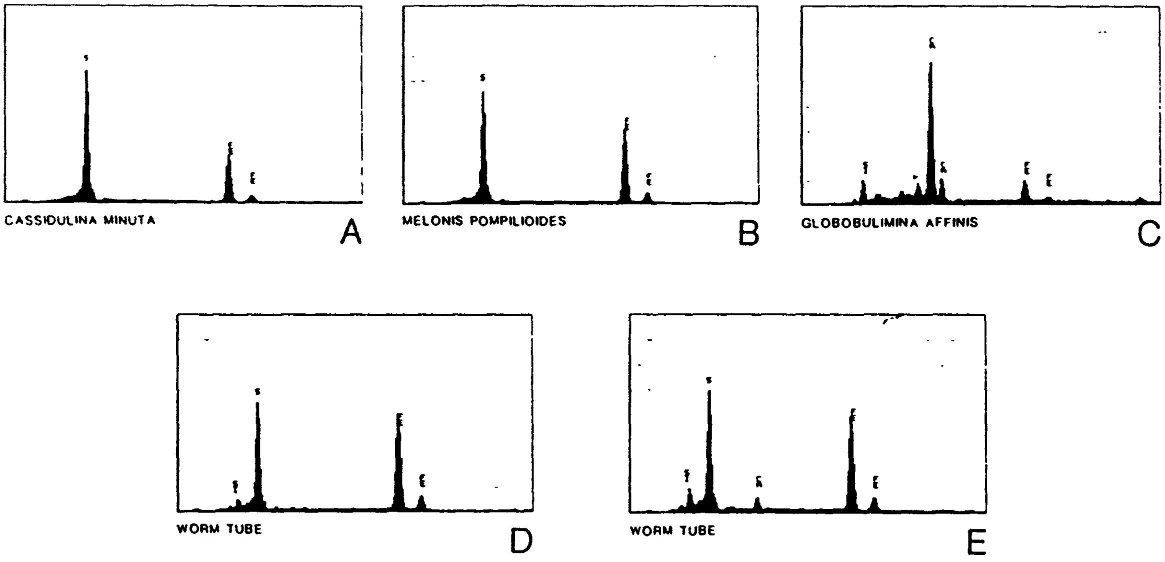

Figure 12. Energy dispersive X-ray spectra for faunal constituents of Monterey Fan core S3-15G, showing peaks for S, Fe, Si, Ca, and K. A. Cassidulina minuta Cushman, Sample 336.5-338 cm. B. Melonis pompilioides (Fichtel and Moll), Sample 97.5-99.5cm. C. Globobulimina affinis (d'Orbigny), Sample 346.5-349.5 cm. D. Worm tube, iridescent purple-blue crystallites, Sample 346.5-349.5 cm. E. Worm tube, golden crystallites, Sample 410-412.5 cm.

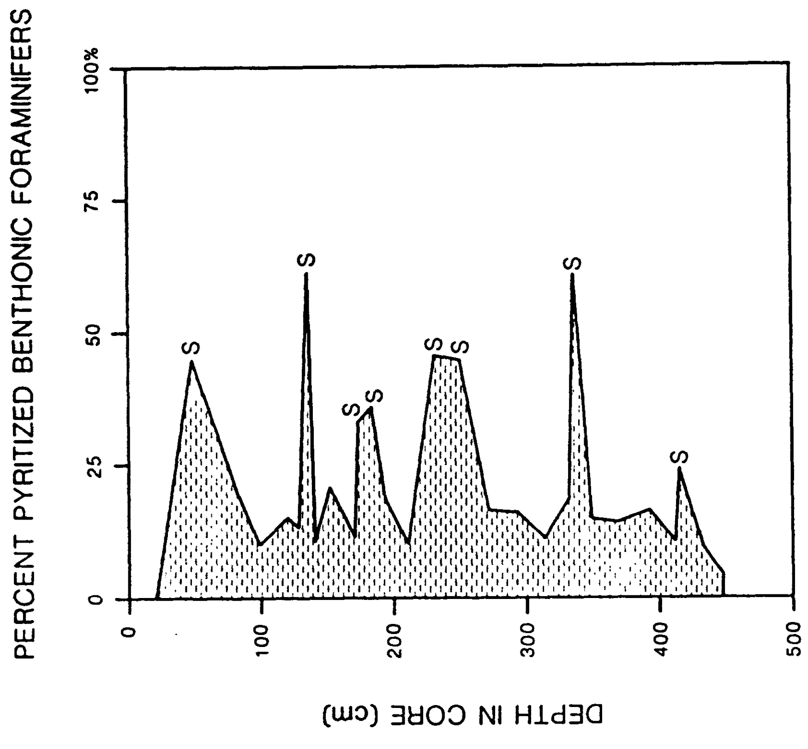

Figure 11. Percentage abundance of pyritized benthonic foraminifers plotted with depth in core S3-15G. S = location of the turbiditic sand samples.

1984). This restricted growth pattern is characteristic of pyrite formation and is especially well illustrated by the light micrographs of the following thin-walled and finely perforate species recovered in the Monterey Fan levee deposits: *Dentalina californica* (Plate 6, figure 8), *Globobulimina pacifica* (Plate 13, figure 8), *Nonionella* sp. (Plate 10, figures 5-6), and *Fissurina* sp. (Plate 8, figure 9). The frequency abundance of pyritized specimens, here defined to include tests displaying any degree of pyritized chamber infilling, is presented in Appendix 4.

Of the 164 benthonic foraminiferal species recovered in the Monterey Fan levee deposits, 63% are characterized by some degree of pyritization. Among those species represented by at least 50 individuals in this study, 17 are distinguished by having a minimum of one-third of their representatives pyritized (Table 8). In support of Sliter's (1975) contention, 14 of these 17 most commonly pyritized species are thin-walled and finely perforate types, or those foraminifers prone to living in oxygen-deficient (primarily upper middle bathyal) environments (Table 8; Phleger and Soutar, 1973; Douglas, 1979; Govean and Garrison, 1981; Corliss, 1985). Although other low-oxygen forms (e.g., *Bolivina seminuda*, *Fursenkoina cornuta* and *Suggrunda eckisi*) were recovered in low abundances in core S3-15G, one-half to more than two-thirds of these individuals were also found pyritized.

Pyritized benthonic foraminiferal tests were not found to increase in abundance downcore (Table 2; Figure 11). This is in contrast to the results presented by Seiglie (1973) for a 5 m core taken in Mayaguez Bay, Puerto Rico. Instead, a significant difference (at the 99% confidence level) was found between the number of pyritized tests in the mud (13%) and sand (44%) deposits.

Because 10 of the 12 most commonly pyritized species in the sand intervals are finely perforate and/or low-oxygen forms, it is suggested that many foraminifers become pyritized within the oxygen-minimum zone and are subjected to downslope displacement by turbidity currents. This contention is supported by the fact that McDougall and Vercoutere (1986, pers. commun.) found an abundant pyritized foraminiferal assemblage associated with the oxygen-minimum zone off central California. Pyritization, however, may also occur at well-oxygenated water depths; rapid burial of carbon-rich sediments within transported material (Myers, 1943; Boltovskoy, 1966; Berner, 1984) and/or foraminiferal tests (Sliter, 1975) produces low-oxygen conditions

Table 8. Relative frequencies and preferred biofacies of the commonly pyritized benthonic foraminiferal species in core S3-15G. Numeric values indicate the ratio of pyritized benthonic individuals to the total number of benthonic specimens recovered for each species. Biofacies abbreviations are as follows: IS = inner shelf; OS = outer shelf; UB = upper bathyal; LUB = lower upper bathyal; UMB = upper middle bathyal; LMB = lower middle bathyal; LB = lower bathyal; LA = lower abyssal (after Ingle, 1980).

Species	Preferred Biofacies	Relative Frequency
Bolivina argentea Cushman	UMB	40%
Buccella spp.	IS-OS	44%
Bulimina striata mexicana Cushman	UMB	63%
Buliminella tenuata Cushman	LUB-UMB	49%
Cassidulina cushmani Stewart and Stewart	UMB	64%
Cassidulinoides bradyi (Norman)	UMB-LMB	44%
Elphidium spp.	IS-OS	43%
Epistominella pacifica (Cushman)	UB-UMB	54%
E. smithi (Stewart and Stewart)	UMB	72%
Globobulimina barbata Cushman	UMB-LMB	33%
Globobulimina spp.	UB-UMB	38%
Hoeglundina elegans (d'Orbigny)	OS-LA	38%
Loxostomum pseudobeyrichi (Cushman)	UB-UMB	32%
Melonis barleeanus (Williamson)	UMB-LB	44%
Nonionella miocenica Cushman	IS	36%
Uvigerina peregrina Cushman	UB-UMB	45%
Valvulineria araucana (d'Orbigny)	UMB-LMB	69%

conducive to post-depositional pyrite formation. Porcelaneous and finely perforate hyaline tests are particularly susceptible to pyritization, as oxygen exchange is restricted between the chambers and the environment.

The iridescent black, blue-black, or purple pyrite crystals were not found solely in benthonic foraminiferal tests, either; diatom frustules and radiolarian tests were similarly affected. Additionally, a single mass of planktonic foraminifers was found fused together by pyrite.

A qualitative assessment of the occurrence of pyrite in core S3-15G indicates that it increases with depth in core, due to the gradual increase of pyritized radiolarians and diatoms. In addition, there is an abrupt appearance of pyritized burrows or "worm tubes" at a depth of 348 cm and greater. Hein and Griggs (1972) reported a similar trend at a depth of 345 cm and greater in an 8 m core obtained approximately 21 km from core S3-15G. These "worm tubes" are partially or completely replaced by pyrite crystallites (Plate 26, figures 1-2). Energy dispersive X-ray analyses (D and E, Figure 12) documents the fact that they are composed of the pyrite constituents iron and sulfur, as well as smaller concentrations of silica and calcium.

A thin brown to rust-brown precipitate was also observed on the inner surface of some benthonic foraminiferal tests. A scanning electron micrograph of the chamber coating failed to record the presence of framboidal pyrite (Plate 27, figure 1), and the energy dispersive X-ray analysis showed that it is composed of calcium, iron, silica and potassium (C, Figure 12). The finely perforate tests of *Globobulimina affinis* most commonly display this precipitate, but it was also observed on the tests of the following foraminifers: *Cassidulina minuta*, *Cassidulinoides bradyi*, *Cibicides lobatulus*, *Globocassidulina subglobosa*, *Gyroidina quinqueloba*, *Melonis pompilioides*, *Oridorsalis umbonatus*, *Planulina wuellerstorfi*, *Rosalina columbiensis*, *Uvigerina senticosa* and *Valvulineria araucana*. Without further study, it remains unclear as to what the relationship is, if any, between this chamber coating and pyrite.

Conclusions

1. A gravity core obtained from the western levee of Monterey Fan is composed of Pleistocene- and Holocene-aged hemipelagic and overbank turbiditic sediments deposited in 45 turbiditic cycles. Twice as many of these depositional units occur in the Pleistocene portion of the core, reflecting heightened turbidity current activity induced by low Pleistocene sea level and the subsequent transgression.
2. An R-mode cluster analysis grouped the foraminiferal taxa into four clusters, suggesting that the Monterey Fan levee deposits are characterized by four benthonic foraminiferal associations: shelf, upper middle bathyal, and lower bathyal of Pleistocene and Holocene age.
3. The turbiditic sands originate in the shelf to upper middle bathyal zones. They are distinguished by high benthonic and planktonic foraminiferal abundance, an extremely diverse benthonic foraminiferal assemblage, and a large proportion of allochthonous benthonic foraminifers. These faunal characteristics result from the addition of the displaced shallow-dwelling species to the endemic deep-water fauna at the final deposition site and a reduction in dissolution due to rapid burial.
4. The mud deposits, composed of hemipelagic, turbiditic, and mixed sediments, are characterized by lower foraminiferal abundance, faunal diversity, and proportion of displaced tests than are the sands. They primarily contain a lower bathyal foraminiferal assemblage endemic to the core site.
5. The Q-mode cluster analysis amalgamated the samples into three clusters, reflecting sediment source, faunal adaptation to changing climatic conditions, and dissolution.
6. Calcium carbonate preservation is cyclic in the overbank mud deposits of Monterey Fan. Glacial (320-472 cm) and cooler transitional climatic periods (110-200 cm) are distinguished by minimal dissolution, whereas warmer climatic periods (200-320 and 23.5-110 cm) are characterized by deglaciation-induced dissolution pulses. A glacial resurgence is indicated in the uppermost (0-23.5 cm) sediments.
7. Microfaunal adaptations to changing climatic conditions in the oceanographic realm off central California during the latest Quaternary are not synchronous between the surface and deep waters.
8. Evidence of predatory attacks are occasionally observed on the ultimate and penultimate chambers of hyaline benthonic foraminiferal taxa. Although most preyed-upon specimens were recovered from the mud deposits, some were obtained from deep-sea sands containing benthonic foraminiferal assemblages characteristic of low-oxygen conditions. It is unclear whether

predation occurs within the oxygen-minimum zone, because the oxygen content in this region is not so low as to eliminate all infaunal predators, or after downslope transport.

9. Pyritization of benthonic foraminiferal tests occurs commonly in the Monterey Fan overbank deposits. Foraminifers endemic to low-oxygen environments, or those characterized by finely perforate tests, are most often affected. This suggests that post-depositional pyrite formation occurs either within the oxygen minima of the water column, or at well-oxygenated lower bathyal depths due to the burial of calcium-rich sediments within the anoxic sediment zone beneath the mixed sediment layer.

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Part II:
Latest Quaternary terrestrial and marine paleoclimates: pollen and foraminiferal evidence from Monterey Fan, central California continental margin

Abstract

Pollen and foraminifers were analyzed from identical samples of a latest Quaternary deep-sea core obtained from Monterey Fan. A Q-mode cluster analysis divided the pollen samples into five groups based primarily upon variations in the relative abundance of the four major pollen types: pine, redwood, oak and Compositae. These groups, in turn, were used to define five pollen zones.

The earliest zone is characterized by very abundant pine and rare fir pollen, reflecting the vegetational response to climatic conditions of the last glacial interval. Overlying this is a zone containing a pollen assemblage indicative of vegetation in a transitional climatic regime. *Pediastrum* and dinoflagellates are common and are attributable to increased nutrient-rich coastal runoff. The upper three zones are characterized by decreasing pine pollen and increasing frequencies of redwood, oak and Compositae. They reflect changes in vegetation during the Holocene.

The terrestrial and marine records were correlated based upon varying pollen and benthonic foraminiferal species frequencies, shifts in the ratio of left- and right-coiling forms of the planktonic foraminifer, *Neogloboquadrina pachyderma* (Ehrenberg), and the following calcium carbonate dissolution indices: foraminiferal abundance, benthonic to planktonic foraminiferal ratio, and radiolarian to planktonic foraminferal ratio. These climatic indicators suggest that the vegetational and faunal responses to changing climatic conditions in the coastal central California region during the latest Quaternary were not synchronous.

Introduction

Marine palynology can provide insight into the vegetational patterns and terrestrial climate of the adjacent continent from which the pollen and spores were derived (Groot and Groot, 1964, 1966b; Zaklinskaya, 1978; Cronin and others, 1981). Similarly, foraminifers and radiolarians act as climatic indicators of the marine realm. Analyzed together, concurrent responses to global climatic changes may be discerned for both the continental and oceanographic provinces. Pollen and microfaunal data obtained from identical samples of a Monterey Fan deep-sea core provide an excellent opportunity to correlate terrestrial and marine paleoclimatic changes in the coastal central California region during the latest Quaternary.

Although central coastal California is characterized by a diverse mozaic of plant communities (Ornduff, 1974), the number of studies investigating recent and fossil pollen is remarkably low (Adam, 1985). Published studies include the modern continental and offshore coastal California pollen investigations by Heusser (1983) and Heusser and Balsam (1977), a correlation of Quaternary marine deposits from the continental slope west of the mouth of the Russian River with sediments from Clear Lake, California (Gardner and others, 1983, in press), the Quaternary record produced by Adam and others (1981) for the Laguna de las Trancas marsh of coastal northern Santa Cruz County, and the late Holocene pollen study of Pearson's Pond located near La Honda in the northern portion of the Santa Cruz Mountains (Adam, 1975).

A concurrent study (McGann, 1986) investigating the relationship between climatically-induced faunal changes, taphonomy, and dissolution effects on the microfaunal assemblages of the Monterey Fan deep-sea deposits, and the references utilized therein, provide the marine paleoclimatic comparison for this present work.

Setting

Monterey Fan is an active depositional region, presently encompassing 44,000 km^2 of ocean floor (Normark and Hess, 1980), that lies west of the continental slope off central California (Figure 1). This deep sea turbiditic deposit receives sediments from the continental shelf and upper slope primarily via the Monterey and Ascension submarine canyon systems. However, both systems have not contributed sediments equally to the fan during the Quaternary. Because the Monterey fan valley transects the entire continental shelf, it has remained a viable conduit for sediment transport to the fan throughout the Quaternary despite changes in sea level (Normark and Hess, 1980; Normark and others, 1980). In contrast, the Ascension fan valley heads on the upper slope and is inactive during high stands of

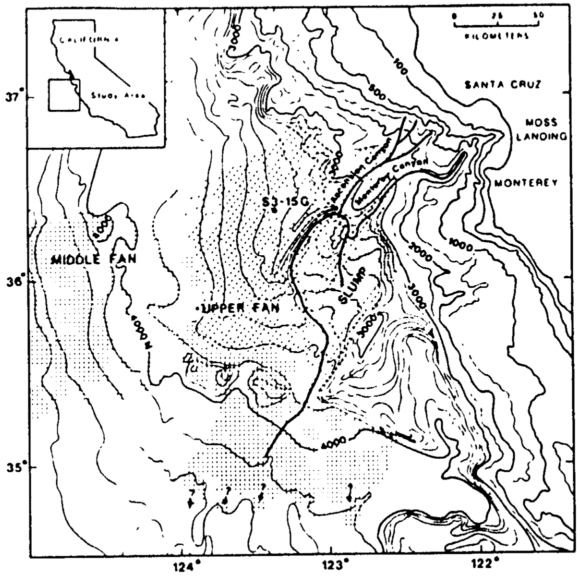

Figure 1. Location map illustrating the present bathymetry (contours in meters) of Monterey Fan as well as the position of the upper and middle fans, the slump on the east side of the Monterey fan valley, and the site of core S3-15G (after Brunner and Normark, 1985).

sea level (Normark and Hess, 1980; Normark and others, 1980).

Both the Monterey and Ascension fan valleys are characterized by extensive levee development (Normark, 1970a, 1970b; Hess and Normark, 1976; Normark and others, 1984). The western levee of the Monterey fan valley is the largest of the fan (Normark, 1970b). Its western slope, away from the channel floor, is characterized by sediment waves trending generally subparallel to the levee crest (Normark and others, 1980, 1984). These sediment waves are considered depositional bedforms resulting from channel-overflow of fine-grained material transported downslope by slow-moving turbidity currents (Normark and others, 1980). Sandier turbiditic deposits also overbank the channels on rare occasions. Turbidity flows of sand, silt and mud may originate in the outer shelf or upper slope due to increased terrigenous input by local rivers during times of peak discharge, earthquake-induced slumping, and the breaking of internal waves along the continental margin (Southard and Cacchione, 1972; Normark and others, 1980; Piper and Normark, 1983).

Gravity core S3-15G was recovered 18 km from the crest of the western levee of the Monterey fan valley (Figure 1; Brunner and Normark, 1985). It was obtained at a depth of 3491 m, approximately 135 km southwest of Santa Cruz (36°23.53'N, 123°20.52'W). The core site presently is situated near the local calcium carbonate compensation depth (CCD), as evidenced by the extensive dissolution of foraminifers in core-top sediments of S3-15G (McGann, 1986) and neighboring cores (Brunner and Normark, 1985).

Lithology

Core S3-15G consists of mud, silt and fine-grained sand overbank deposits interspersed with hemipelagic muds (Figure 2). The mud deposits dominate the core and display characteristic features of bioturbation: deformed sediment layers, mottles, and open and filled burrows (Griggs and others, 1969).

The basal members of the Bouma (1962) cycle (Tab) are missing in core S3-15G, supporting the contention that complete Bouma sequences (T_{ae}) are rarely evident in deep-sea cores (Rupke, 1978). Instead, the turbiditic sands are typically deposited in laminated sequences referrable to Bouma's T_d depositional division; cross-bedded (T_c) turbiditic units occur only rarely. The fine-grained turbiditic sands and silts are, for the most part, laterally continuous in the uper 370 cm of the core. They become more fragmented with greater core depth.

Mud deposits referrable to the fifth Bouma division (T_e) invariably overlie the turbiditic sands of core S3-15G. These muds have been further subdivided into turbiditic (T_{et}) and hemipelagic (T_{ep}) mud components (Kuenan, 1964; Howell and Normark, 1982) in this study. No attempt was made to distinguish between the three depositional units of turbiditic muds proposed by Piper (1978), or the nine divisions of Stow (1977) and Stow and Shanmugam (1980).

Hemipelagic muds and mildly bioturbated turbiditic muds with hemipelagic mud mottles are the primary constituents of the upper 215 cm of the core. Turbiditic muds are common between 215 and 370 cm, becoming particularly dominant below 280 cm. At a core depth of 370 cm, bioturbation increases greatly. As a result, a highly deformed mixture of sands, silts, and turbiditic and hemipelagic muds occur between 370 and the base of the core.

Terrestrial Vegetation

The plant associations presently occupying the coastal central California region are diverse and geographically somewhat localized (Figure 3; Critchfield, 1971; Little, 1971; Munz and Keck, 1973; Ornduff, 1974; Griffin and Critchfield, 1976; Barbour and Major, 1977; Kuchler, 1977). In the Monterey Bay region, Monterey pine (*Pinus radiata* D. Don), Bishop pine (*P. muricata* D. Don), Gowen cypress (*Cupressus goveniana* Gord.), Monterey cypress (*C. macrocarpa* Hartw.) and coast live oak (*Quercus agrifolia* Nee) are distributed sporadically in the coastal zone. Other nearshore regions are characterized by grassy meadows and low shrubs. Locally important is coyote brush (*Baccharis pilularis* spp. *consanguinea* (DC.) C. B. Wolf), together with California sagebrush (*Artemisia californica* Less.), blue brush (*Ceanothus thyriflorus* Esch.) and coffeeberry (*Rhamnus californica* Esch.). In drier coastal regions drought-deciduous shrubs such as California sagebrush, California buckwheat (*Eriogonum fasciculatum* Benth.), white and black sage (*Salvia apiana* Jeps. and *S. mellifera* Greene), and coyote brush are locally common.

Further inland, mesic sites are dominated by redwoods (*Sequoia sempervirens* (D. Don) Endl.)

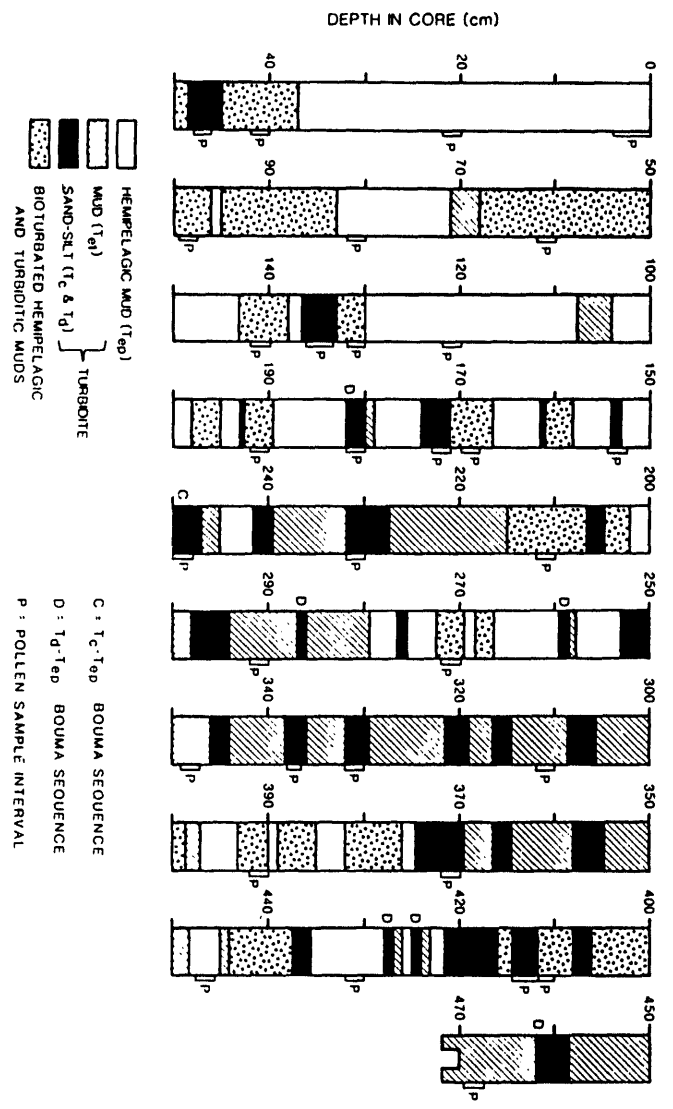

Figure 2. Generalized lithology of core S3-15G. The core is composed of sand-silt turbidites (Tc and Td), turbiditic (Tet) and hemipelagic (Tep) mud layers, and bioturbated intervals. Bouma sequences Tc-ep and Td-ep are designated by a C and D, respectively, on the left side of the core. Bouma sequence abbreviations after Bouma (1962) and Howell and Normark (1982).

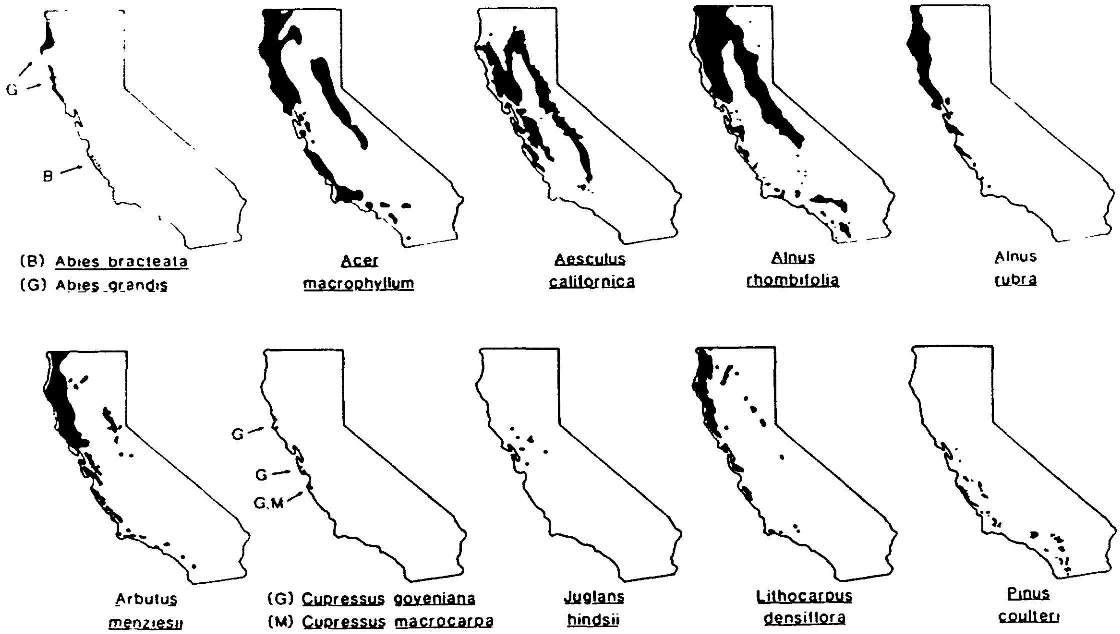

Figure 3. Modern tree distributions in California (after Little, 1971; Griffin and Critchfield, 1976).

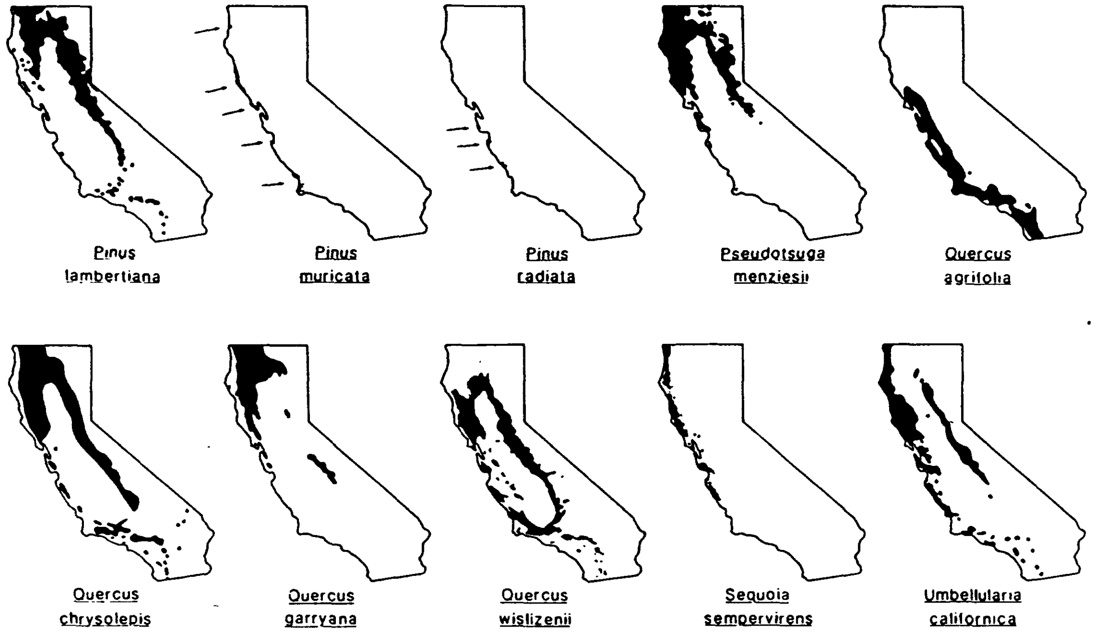

Figure 3. Modern tree distributions in California (continued).

together with tanoak (*Lithocarpus densiflora* (Hook. and Arn.) Rehd.), California bay (*Umbellularia californica* (Hook. and Arn.) Nutt.), madrone (*Arbutus menziesii* Pursh), and interior live oak (*Quercus wislizenii* A. DC.). Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) dominates the drier locations and is commonly associated with Oregon white oak (*Quercus garryana* Dougl.). Riparian woodland bordering the San Lorenzo River and Soquel and Aptos Creeks includes red and white alders (*Alnus rubra* Bong. and *Alnus rhombifolia* Nutt.), bigleaf maple (*Acer macrophyllum* Pursh). and willow (*Salix* spp.).

On progressively warmer and drier slopes in the eastern Coast Ranges, the vegetation consists primarily of coast live oak, canyon oak (*Quercus chrysolepis* Liebm.) and madrone, as well as California buckeye (*Aesculus californica* (Spach) Nutt.), tanoak, Coulter and sugar pines (*Pinus coulteri* D. Don and *P. lambertiana* Dougl.), coyote brush, and Santa Lucia fir (*Abies bracteata* D. Don ex Poiteau).

Methods

Sampling Procedure

The 4.72 m gravity core was split and the undisturbed central portion sampled at approximately 20 cm intervals. Thirty-two samples, each consisting of 1 cm^3 of sediment, were obtained from discrete lithologic units within the core: twenty-five mud and eight turbiditic sand deposits were studied.

Because recent and ancient deep-sea turbiditic and hemipelagic muds are often characterized by color differences (darker and lighter, respectively; Rupke and Stanley, 1974; Hesse, 1975; Rupke, 1975; Sagri, 1979; Howell and Normark, 1982; Piper and Normark, 1983), an attempt was also made to further subdivide the muds based upon color. Differentiation, however, was complicated by bioturbation and post-collection color fading of the sediments, particularly in the lower 100 cm of the core. In addition, samples thought to represent one lithologic unit were found to be comprised of two or more because the units are not always horizontally continuous within the core. As a result, most samples are characterized by a mixed lithology, making the generalized lithology of the core (Figure 2) oversimplified (see detailed core description, Appendix 1). Consequently, unadulturated hemipelagic and turbiditic mud samples are rare and the study has focused on the variations between the palynological assemblages of the mud (hemipelgic, turbiditic, and mixed) and turbiditic sand samples.

Preparation Procedure

Dry and wet weights were obtained for the pollen samples, after which each was spiked with 22,600 ± 400 *Lycopodium* marker grains in order to determine the absolute pollen concentration (Stockmarr, 1971). The pollen samples were then prepared in the following manner: successive immersion in 10% hydrochloric acid (overnight), warm sodium pyrophosphate (15 min; Bates and others, 1978), 52% hydrofluoric acid (overnight), 10% hydrochloric acid (2 min), 70% nitric acid (3 min), and a modified acetolysis solution of nine parts glacial acetic acid to one part concentrated sulfuric acid (5 min). Subsequently, the residues were stained with two drops of safranin and mounted in silicone oil (Anderson, 1960, 1965). At no time were samples sieved; the fine-grained material was decanted and retained while the coarse-grained material was discarded.

Pollen Types

Utilizing an Olympus BH-2 compound microscope, a minimum of 350 pollen grains and spores was counted and identified in each sample (Appendix 5). The abundances of *Pediastrum* colonies, dinoflagellates, organic membranes of foraminifers, and a distinctive fungal spore (type-A) were also noted.

Identification of some of the major pollen types, such as Taxodiaceae-Cupressaceae-Taxaceae and Chenopodiaceae-Amaranthaceae is taxonomically difficult, as reliable criteria for their differentiation to the genus or species level are presently lacking (Heusser, 1978b; Adam and others, 1981). Consequently, these pollen types were combined under the categories TCT and Cheno-Ams, respectively. However, since most of the TCT grains recovered in this study are characterized by a relatively thick exine, locally dense verrucae, and a short papilla, they are considered to be redwood pollen (Kapp, 1969; Adam and others, 1981). Furthermore, because redwood is now locally common in the Monterey Bay area (Kuchler, 1977; Zinke, 1977), the TCT curve is assumed to reflect changes in redwood abundance.

Pine pollen also constitutes a taxonomic problem. Although several authors have suggested that distinctions can be made between the various species of pine utilizing light microscopy (Cain, 1940; Cain and Cain, 1948; Ting, 1966; Hansen and Cushing, 1973), their methods require the measurement of various morphological characters that are commonly obscured or poorly preserved on pollen grains recovered from marine sediments (Heusser and Balsam, 1977; Heusser, 1978b). Therefore, no attempt was made to identify the pine pollen recovered to the species level.

The Compositae is represented by several pollen types in core S3-15G; dominant are the high- (cf. *Baccharis*) and low-spined (cf. *Ambrosia*) morphotypes. Additionally, representatives of the Polypodiaceae and Lycopodiaceae, as well as rare constituents of other related families, were placed in the general categories of monolete and trilete spores.

Very poorly preserved grains were assigned to the indeterminate category. Included in the TCT group may be representatives of the genera *Cupressus*, *Juniperus* and *Torreya*. Even though these genera are found as macrofossils in Quaternary deposits in San Mateo County (Helley and others, 1972), their thin-walled grains are commonly crumpled and are not well represented in marine records. Redeposited grains, detected by their poor preservational state and yellow/brown color due to lack of absorption of the Safranin-O stain (Stanley, 1966), were also noted.

Replicate Counts

In palynology, the assumption is made that replicate pollen counts are possible from all slides made from the processed residue of a single sample. In this study, a brief test was undertaken to ensure that slide preparation and counting procedures were not violating this tenet (Appendix 6). Three successive slides were produced from the pollen residue of sample 168-170 cm and scanned for palynomorphs. A total of 363 pollen grains were counted on each slide. Cursory examination of the counts reveals how remarkably similar the results of the three trials were; a chi-square test performed on these data suggests that (at the 95% confidence level) pollen counts from strewn slides are highly replicable.

The Data

Pollen percentages were calculated utilizing a sum of total pollen; *Pediastrum*, dinoflagellates, and fungal spore type-A were computed with a sum of total pollen + palynomorphs. Once converted to frequency data, the pollen counts were subjected to a Q-mode cluster analysis in order to group samples according to their degree of similarity. The data set consists of the relative abundance of the most common pollen types (Table 1) in the 32 samples. These samples were clustered by the unweighted pair group method utilizing a chi-square correlation coefficient and amalgamated by a centroid linkage strategy (Dixon, 1983). The University of California's biomedical computer program, BMDP-2M, was utilized to accomplish this analysis (Dixon, 1983).

Sediment Age

The age of these overbank deposits was determined by discerning changes in the relative proportion of left- and right-coiling forms of the planktonic foraminifer *Neogloboquadrina pachyderma* (Ehrenberg) (Bandy, 1959, 1960, 1967; Gorsline and others, 1968; Kheradpir, 1970; Morin, 1971). Brunner (1985, pers. commun.) noted the presence of two distinct shifts from left- to right-coiling forms in core S3-15G (Figure 4). The Pleistocene/Holocene boundary, by definition (Bandy, 1960), lies within the upper of these two shifts. Therefore, it lies between 212 and 241 cm in this core. Additionally, a period of climatic deterioration (the Younger Dryas; Duplessy and others, 1981) may be recognized (243-256 cm) between the two abrupt increases in right-coiling forms.

Two similar shifts in the ratio of left- and right-coiling forms of *Neogloboquadrina pachyderma* were recognized in a deep-sea core (V1-80-P3) recovered off the Russian River (Gardner and others, in press). Correlating the faunal shifts noted in core V1-80-P3 with the oxygen isotope record of those same deposits, Gardner and others (in press) determined that they occurred approximately 15,000 and 10,500 years B.P. The boundary between oxygen isotope stages 1 and 2 lies somewhere between these two faunal shifts, and has been estimated at 11,000 years B.P. (Kominz and others, 1979; Pisias and Moore, 1981; Gardner and others, in press).

Table 1. Pollen and spores utilized in the Q-mode cluster analysis of core S3-15G.

- *Abies*
- *Aesculus*
- *Alnus*
- *Artemisia*
- Carophyllaceae
- Chenopodiaceae-Amaranthaceae (Cheno-Ams)
- *Eriogonum*
- *Galium*
- Gramineae
- High-spine Compositae
- Indeterminates
- *Juglans*
- Liguliflorae
- *Lithocarpus*
- Low-spine Compositae
- Malvaceae
- Monolete Spores
- *Plantago*
- *Pinus*
- *Quercus*
- Rhamnaceae
- *Rumex*
- *Salix*
- cf. *Salix*
- *Salvia*
- Taxodiaceae-Cupressaceae-Taxaceae (TCT)
- Trilete Spores
- *Typha-Sparganium*
- Umbelliferae
- Unknowns
- Urticaceae

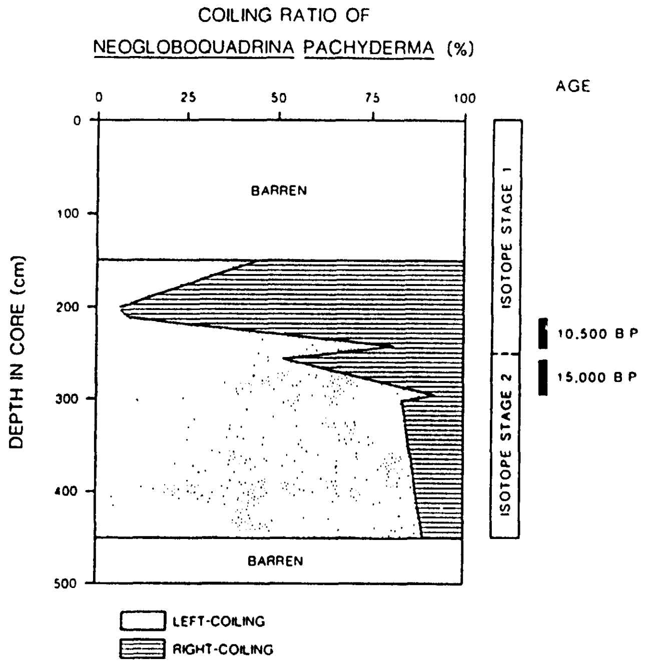

Figure 4. Coiling ratio of left- and right-coiling *Neogloboquadrina pachyderma* (Ehrenberg) plotted with depth in core S3-15G. The Pleistocene-Holocene boundary lies between 212 and 241 cm, based upon the prominent shift from left-coiling Pleistocene to right-coiling Holocene populations (data and interpretation provided by C. Brunner, 1985, pers. commun.). Isotope stages and ages (B.P.) after Gardner and others (in press).

Illustrations

Light micrographs of the palynomorphs (Plate 30) were obtained using an Olympus BH-2 compound microscope and an Olympus PM-10AD photomicrographic system.

Results

Analysis of the core yielded 33 pollen and spore types (Appendix 5; Figures 5-6), 22 of which were identified to the generic level. Several trends may be discerned from the data (Table 2). Consistently lower absolute pollen concentrations were obtained in the sand intervals and the Pleistocene muds (averaging 5537 and 7458 grains/gm, respectively) than in the Holocene muds (9460 grains/gm). Pine, redwood, oak and Compositae were the most abundant pollen types recovered, while the minor constituents include Cheno-Ams, Rhamnaceae, tanoak, alder, grass, willow-type, low-spine Compositae and buckwheat.

Redeposited pollen grains are rare: a total of only nine were encountered, with no more than two occurring in any one sample. Similarly, a single *Eucalyptus* pollen grain was recovered at a depth of 20-22 cm. Pollen of this genus was used as a time marker for the year 1880 by Mudie and Byrne (1980) in a study of the Marin County saltmarsh areas. However, as only one grain was obtained in core S3-15G, it seems more likely that it is a recent downcore contaminant resulting from the disturbance of near surface sediments during the coring operation. Therefore, its value as a stratigraphic marker is deemed questionable in this study.

Planispiral, trochoidal and triserial foraminiferal organic inner membranes (Plate 30, figures 10-11) were recovered in such low abundance in the deposits of core S3-15G that their quantitative values were not recorded. Dinoflagellate cysts also are only a minor constituent, but increase slightly in abundance in the Holocene samples. Additionally, only one or two *Pediastrum* colonies were recovered in most samples (Plate 30, figures 13-14), but the count peaked at 7.3% at a depth of 230-232 cm.

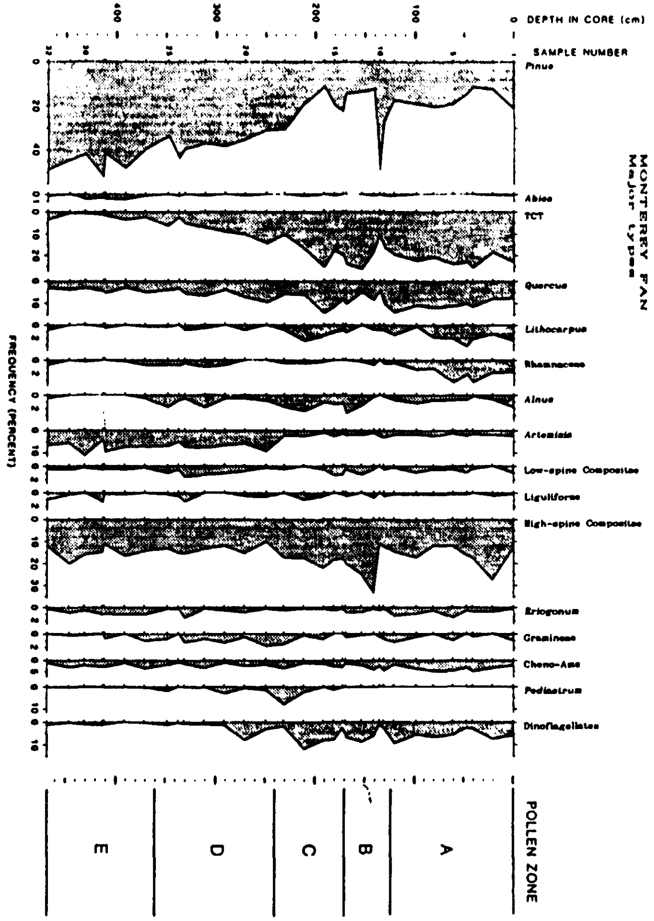

Figure 5. Pollen diagram for the major types plotted with depth in core S3-15G. The horizontal scale is in percentage and is not the same for all curves.

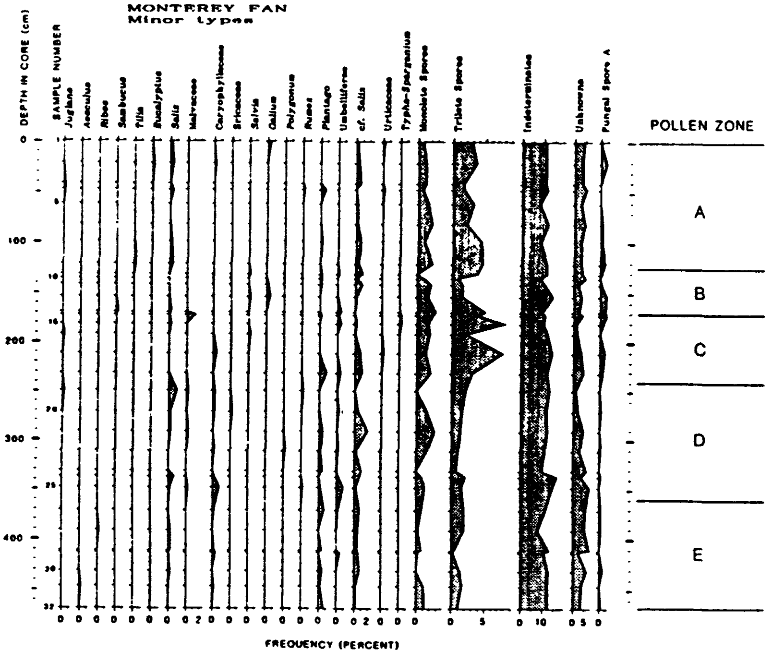

Figure 6. Pollen diagram for the minor types plotted with depth in core S3-15G. The horizontal scale is in percentage and is not the same for all curves.

Table 2. Dry sediment weight, fossil numbers, absolute pollen concentration, Q-mode cluster group and lithology in core S3-15G. Broken pine grains counted as half. The lithology abbreviations are as follows: H, hemipelagic mud; T, turbiditic mud; S, turbiditic sand; M, mixed lithology of hemipelagic and turbiditic muds and/or turbiditic sand.

Depth In Core (cm)	Sample Number	Dry Sediment Weight (gm)	Number of Pollen Grains Counted	Number of *Lycopodium* (Controls) Counted	Absolute Pollen Concentration (Grains/gm)	Number of Pine Grains Counted	Broken-Whole Pine Grain Ratio (%)	Q-Mode Cluster Group	Lithology
0-4	1	0.48	377	1679	10572	81	80.3	A	H
20-22	2	0.52	411	1872	9542	52.5	67.6	B	H
40-42	3	0.59	416	1101	14473	49	69.4	A	M
46-48	4	0.90	396.5	946	10525	57.5	61.7	A	S
60-62	5	0.52	380	1794	9206	73	90.4	A	M
80-82	6	0.54	371	1767	8787	76	81.6	A	M
97.5-99.5	7	0.62	398	1805	8038	76	69.7	A	M
120-122	8	0.56	390	2616	6017	69	73.9	A	H
130-132	9	0.83	371	875	11545	101	65.4	C	M
133.5-136.5	10	1.23	386	1147	6183	189	65.1	D	S
140-142	11	0.68	381.5	1377	9208	47.5	70.5	B	M
152.5-154.5	12	0.72	383	1918	6268	52	76.9	B	M
168-170	13	0.85	362.5	989	9745	52.5	71.4	B	M
171-173	14	1.07	375.5	1578	5026	83.5	53.3	C	S
180-182	15	0.71	361.5	2084	5522	70.5	77.3	C	S
190-192	16	0.72	366	1035	11100	42	81.0	B	M
210-212	17	0.86	372	1153	8479	71	62.0	C	M
230-232	18	0.76	383.5	1941	5875	116.5	78.5	C	S
248-250	19	1.52	381	2771	2044	102	73.5	D	S
270-272	20	0.75	375.5	1445	7830	131.5	74.9	D	M
290-292	21	0.83	367.5	1119	8942	139.5	71.3	D	T
310-312	22	0.78	369.5	1248	8579	135.5	72.0	D	M
330-332	23	0.87	381.5	1453	6821	148.5	78.5	D	M
336.5-338	24	1.19	368	1971	3546	160	59.4	E	S
347-349	25	0.83	383.5	1358	7689	128.5	76.7	D	T
370-372	26	0.94	365	1225	7164	145	64.8	E	M
390-392	27	0.89	360	1771	5162	173	61.9	E	M
410-412	28	0.90	386	1193	8125	160.5	70.1	E	M
412-414.5	29	1.07	360.5	1365	5578	188	56.9	E	S
430-432	30	0.81	371.5	1113	9313	155.5	68.5	E	H
445.5-447.5	31	0.77	367	1465	7353	163	63.8	E	M
467.5-469.5	32	1.01	380.5	1681	5065	186	71.0	E	T

Discussion

Pollen Dispersal

Pollen and spores may be transported to the core site by wind, water and sediments. Due to the prevailing onshore winds in the Monterey Bay region (U.S. Weather Bureau, 1961), however, eolian transport of palynomorphs from the adjacent mainland to the core site is probably negligible at the present time. Wind transported pollen most likely is derived from vegetation directly along the coast, with some allochthonous grains having been transported over long distances (Faegri and Iversen, 1964; Heusser and Balsam, 1977). However, changes in upwelling patterns during the latest Quaternary off central California (Hemphill and others, 1985; J. Gardner, 1986, pers. commun.) suggest that wind patterns also varied during this time. Because Monterey Fan lies within the common limit of wind dispersion of pollen (10-150 km; Heusser, 1978b), wind has probably played an important role, at least at times, in transporting pollen to the core site.

It has been demonstrated that terrigenous influx via rivers correlates positively with pollen concentration (Cross, 1973; Peck, 1973) and that higher abundances of pollen in the marine realm are recovered opposite major stream drainage areas (Cross and Schaefer, 1965; Cross and others, 1966; Groot and others, 1967; Heusser and Balsam, 1977; Heusser, 1978a). In addition, Griggs and Hein (1980) determined that coastal rivers are the major source of fine-grained Holocene sediments in the ocean off northern and central California and that sediment plumes enter Monterey Bay from the rivers and creeks of its drainage basin. Therefore, with a combined total of suspended discharge in excess of 1.8 million tons annually (Griggs and Hein, 1980), these rivers (Figure 7) probably are a major source of pollen and spores to Monterey Fan.

Upon reaching the ocean, palynomorphs are subjected to net southward transport by the wind-induced littoral current system (Cherry, 1966; Minard, 1971). Consequently, some pollen and spores from the major streams to the north (e.g., Sacramento, Russian, Eel and Klamath) may be included in the deposits of core S3-15G. Similarly, allochthonous palynomorphs could be introduced to the Monterey Fan sediments by the surficial water masses of the California Current System (Simpson and others, 1984). Therefore, the pollen record of this deep-sea core is dominated by the adjacent

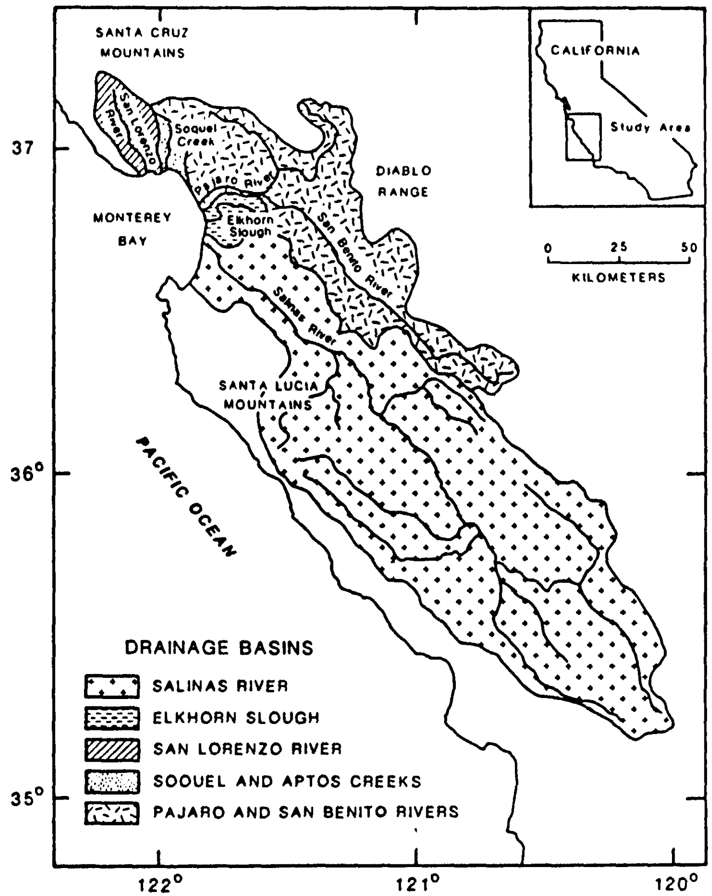

Figure 7. Mountain ranges and drainage basins of the Monterey Bay region (after Yancey, 1968).

continental vegetation, but includes minor allochthonous components as well.

Not only are pollen grains transported as suspended matter in rivers and currents, as suggested by their presence in the hemipelagic sediments of core S3-15G, but in the bed load as well. Both coarse- and fine-grained turbidity flows, deposited as overbank material on Monterey Fan, are characterized by a diverse pollen assemblage.

Absolute Pollen Concentration

The absolute pollen concentration in the Monterey Fan overbank deposits (2,000-14,500 grains/gm; Table 2) is comparable to pollen quantities reported from the northeast Pacific Ocean off the Columbia River and San Francisco Bay (Heusser and Balsam, 1977), from the Pacific Ocean (Groot and Groot, 1971), the Middle America Trench (Habib and others, 1970) and the Orinoco delta and shelf (Muller, 1959). It is considerably less, however, than the pollen abundances reported in marine sediments from the Gulf of California (80,000 grains/gm, Cross and others, 1966).

Pollen abundance in core S3-15G correlates negatively with grain size (Table 2; Figure 8); the turbiditic sand deposits contain significantly fewer (at the 99% confidence level) palynomorphs than do the muds. A similar trend was also documented in the Gulf of California by Cross and others (1966). However, because the turbiditic sands of the Monterey Fan levee core originated in the inner shelf to upper slope region (McGann, 1986), this trend conflicts with the typical pattern of higher pollen abundances in marine sediments lying closer to their continental source (Muller, 1959; Koreneva, 1964; Groot and Groot, 1966a; Traverse and Ginsburg, 1966; Groot and others, 1967; Heusser and Balsam, 1977; Heusser, 1978b; Melia, 1984). Since most pollen and spores are smaller in size than the coarse sediments comprising the turbiditic sands (Koreneva, 1964; Brush and Brush, 1972; Heusser, 1978b), it is suggested that these deposits contain fewer palynomorphs because the smaller pollen types have been selectively removed by sorting (Hopkins, 1950; Traverse and Ginsburg, 1966; Brush and Brush, 1972; Davis and Brubaker, 1973). Typically higher proportions of morphologically-large pine pollen (Kapp, 1969) in the turbiditic sand deposits, with a concomittant reduction in the frequency of smaller-sized oak, redwood, alder, Compositae and Cheno-Am pollen and dinoflagellates,

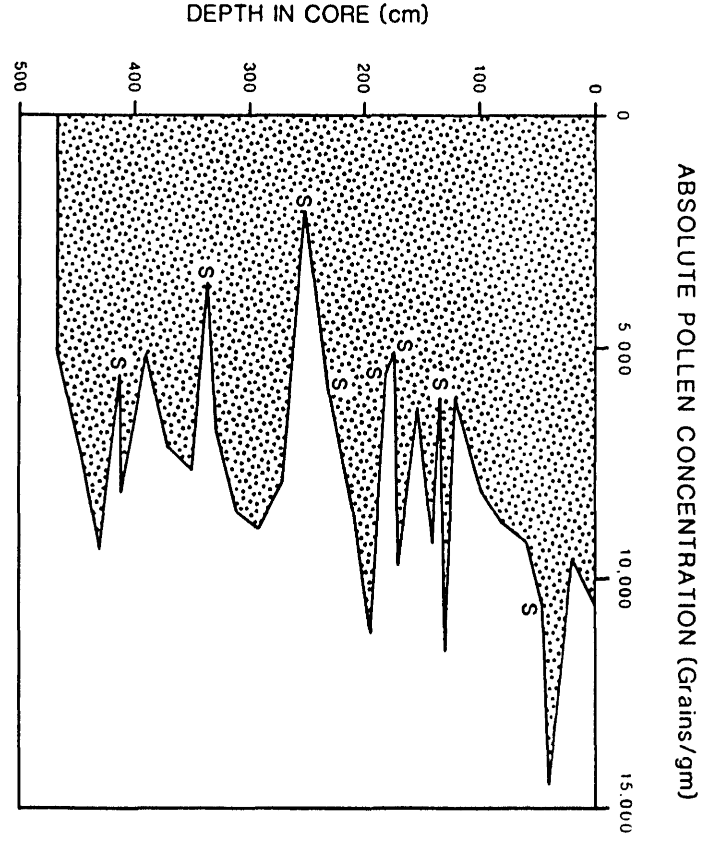

Figure 8. Absolute pollen concentration plotted with depth in core S3-15G. S = location of the turbiditic sand samples.

support the contention that they contain a pollen assemblage biased by hydraulic fractionation during downslope transport.

Utilizing only the mud deposits, the Pleistocene samples contain significantly (at the 99% confidence level) fewer pollen grains than do their Holocene counterparts. Typically, Pleistocene-aged deep-sea sediments contain more pollen than do Holocene deposits due to the lowering of sea level and resulting closer proximity of the deposition site to the source area (Groot and Groot, 1964; Groot and others, 1967). But the continental shelf is so narrow in the Monterey Bay region (Figure 1; Hess and Normark, 1976), that low stands of sea level do not greatly reduce this distance. Instead, lower pollen abundances in the Pleistocene muds may reflect increased inorganic terrigenous input to the core site due to sediments bypassing the shelf.

Q-Mode Cluster Analysis

In order to discern changes in regional vegetation, the palynomorph frequencies were analyzed with Q-mode cluster analysis (Adam, 1974). This analysis associated the samples into five clusters (A-E, Figure 9). For the most part, the groupings are stratigraphically homogeneous (Table 2), with each cluster encompassing between approximately 50 and 150 cm of the core.

A cursory examination of the Q-mode cluster diagram (Figure 9) suggests that there is no relationship between sample lithology and clusters; the clusters contain various combinations of hemipelagic muds, turbiditic sands and muds, and mixed (bioturbated) deposits. This finding is in direct contrast to the relationship observed between lithology and the benthonic foraminifers also recovered from levee core S3-15G (McGann, 1986). The distribution of benthonic foraminifers in the overbank sediments reflects either their in situ lower bathyal source or the effects of downslope transport. In contrast, continentally derived pollen grains and spores may only reach the core site by transport processes. Therefore, it follows that the distribution of pollen in marine sediments will not be as lithologically constrained as the marine faunal element.

A more detailed inspection of the cluster diagram and the Q-mode cluster groups on Table 2 reveals that a major discontinuity exists between the pollen assemblages of the samples lying above 232 cm and below 248 cm (Samples 1-18 and 19-32). As

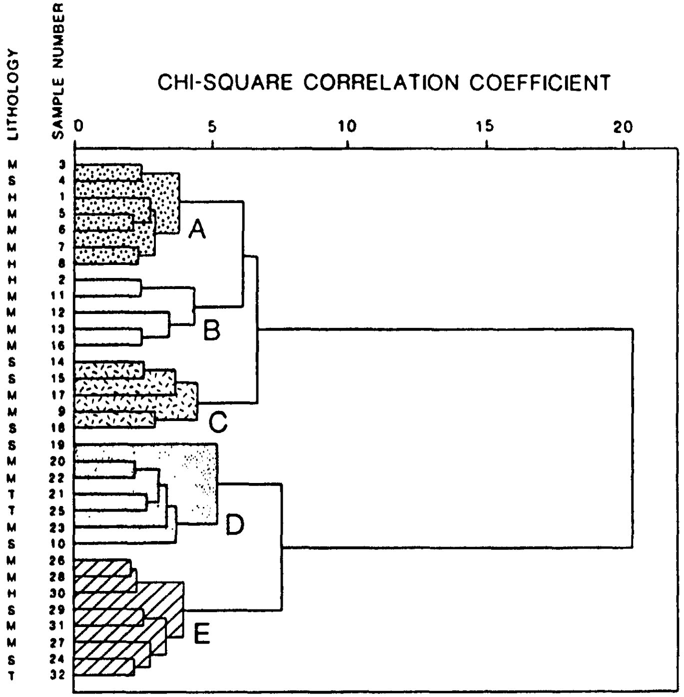

Figure 9. Q-mode cluster diagram of 32 samples in core S3-15G. The samples were grouped into five associations (A-E) based upon the correlation of 31 variables (Table 2; Appendix 1) measured in the 32 samples from hemipelagic and turbiditic deposits. The lithology of the samples is indicated as follows: H, hemipelagic mud; T, turbiditic mud; S, turbiditic sand; M, mixed lithology of hemipelagic and turbiditic muds and/or sand.

previously stated, this depth also roughly corresponds to the upper shift in the percentage of left- and right-coiling forms of the planktonic foraminifer *Neogloboquadrina pachyderma* (Ehrenberg), marking the position of the Pleistocene/Holocene boundary (Bandy, 1960) in core S3-15G. Because pollen preservation, as determined subjectively and by the ratio of broken to whole pine grains (Table 2; Figure 10; Cushing, 1964, 1967; Adam, 1967), did not vary significantly within the unbiased Pleistocene and Holocene muds, it appears that that the major division between the lower and upper core pollen assemblages truly reflects a regional change in vegetation from Pleistocene to Holocene climatic conditions and is not an artifact of taphonomic processes. A detailed record of this vegetational change is elucidated by a comparison of the five Q-mode clusters (Figure 9) and the pollen diagram (Figures 5-6) for core S3-15G.

The pollen diagram can be divided into five zones which approximate the five Q-mode clusters; they differ only in the placement of some of the biased turbiditic sand samples. A generalized summary of the abundances of the four major pollen types (pine, oak, redwood and Compositae) within the five pollen zones is presented in Table 3.

Zone E. (360-472 cm). The basal zone is most readily characterized by its very high abundance of pine. The pollen may have been produced by several species of closed-cone pines (Monterey, Bishop and knobcone) that are locally common along the central California coast today (Figure 3). Associated with this pollen are moderate amounts of Compositae and *Artemisia*, as well as rare oak, redwood and fir. The poor preservational state of the fir pollen precludes it from being identified with any taxonomic precision. However, Santa Lucia fir presently grows south of Monterey Bay in the Santa Lucia Mountains and grand fir (*Abies grandis* (Dougl.) Lindl.) inhabits the coastal regions of California north of the Russian River (Figure 3; Griffin and Critchfield, 1976).

The dominance of pine in the lower meter of the core, as well as the presence of fir and *Artemisia*, suggests that Zone E represents the last full glacial interval (the upper Wisconsinan in the mid-continent; Adam, 1967; Adam and others, 1981). However, the presence of at least some redwood pollen in Zone E implies that the climate during this period was not so severe as to eradicate redwood from the Santa Cruz Mountains and surrounding regions. The moderate abundances of Compositae also suggest that

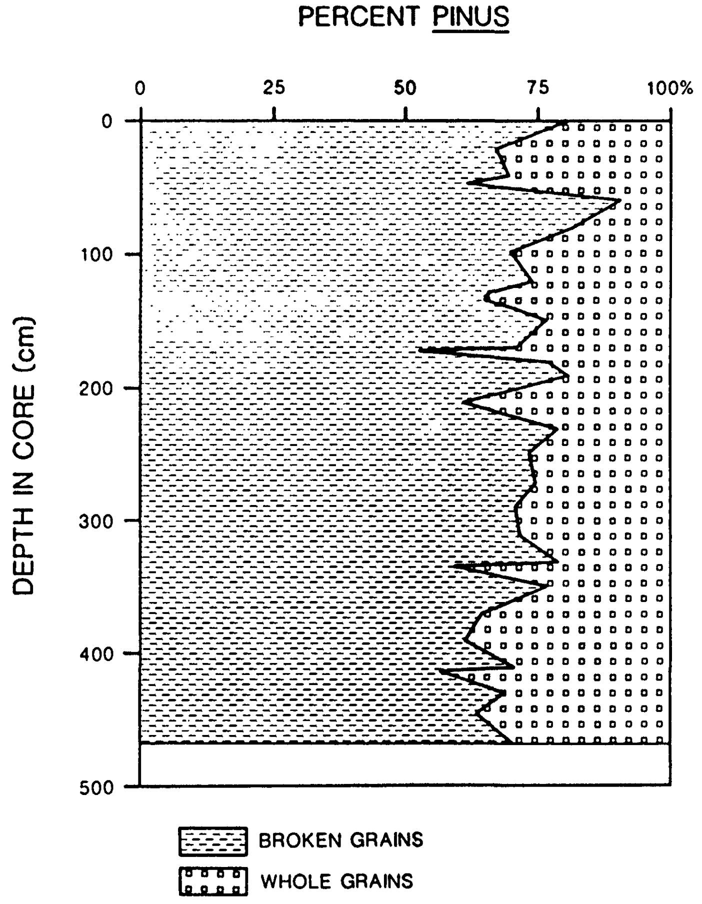

Figure 10. Breakage of *Pinus* pollen plotted with depth in core S3-15G.

the coastal central California area was not entirely forested.

Zone D. (240-360 cm). Zone D is characterized by a unique pollen assemblage which includes slightly decreasing, but still very abundant amounts of pine, moderate abundances of Compositae, and few representatives of oak and Artemisia. On the rise are redwood pollen and dinoflagellates. Also noteworthy is the fact that Pediastrum colonies and alder pollen begin to appear in appreciable amounts in this zone.

Pediastrum is a colonial planktonic green algae restricted to living in freshwater ponds or shallow lakes (Cookson, 1953; Whiteside, 1965; Hutchinson, 1967; Tappan, 1980). As a result, it is not commonly found in marine deposits (Evitt, 1963; Davey, 1971; Heusser, 1978a). Yet, the appearance of appreciable quantities of two species of Pediastrum in core S3-15G (Appendix 7), as well as the pollen of riparian-dwelling alders (Heusser, 1978b), suggests that Zone D is indicative of continental deglaciation (Heusser and Shackleton, 1979). This wetter and warmer climatic interval was conducive to the retention of open water conditions in summer ponds and lakes, algal blooms, and the runoff of waters rich in Pediastrum (Adam, 1975). The improving climate is also reflected by the gradual increase in abundance of redwood and oak, the virtual elimination of fir pollen, and the slow decline in pine abundance.

An abrupt rise in dinoflagellates, normally indicators of coastal upwelling (Melia, 1984), occurs within Zone D as well. However, the recovery of an annually varved core off the Russian River (Hemphill and others, 1985) suggests that upwelling remained a continual feature in that area from at least 21,000 to 4,300 years B.P., and appears to correlate well with a varved core obtained from the Monterey Bay region (J. Gardner, 1986, pers. commun.). Therefore, this sudden increase in dinoflagellates, as with the rise in Pediastrum, may reflect an increase in nutrient-rich coastal runoff at the end of the Pleistocene (Davey, 1971; Wall, 1971; Heusser and Balsam, 1977).

Zones C and B. (125-240 cm). The cluster and pollen diagrams suggest that a major vegetational change occurs around 240 cm. Zones D and E have been tied to the cooler conditions prevailing in the Pleistocene; the upper 3 zones reflect the adaptation to the Holocene climatic regimes. Zones C and B are very similar to one another in that they document the sharp decline in pine and Artemisia, with a

Table 3. The relative abundance of the four major pollen types (pine, oak, redwood and high-spine Compositae) within the five pollen zones (A-E) of core S3-15G. The relative abundance notation corresponds to the following percentages: rare, 0-5%; few, 5-10%; common, 10-20%; abundant, 20-30%; very abundant, >30%.

Major Pollen Types	Pollen Zone A (0-125 cm)	Pollen Zone B (125-170 cm)	Pollen Zone C (170-240 cm)	Pollen Zone D (240-360 cm)	Pollen Zone E (360-472 cm)
Pine	common	common	abundant	very abundant	very abundant
Oak	common	few	common	few	rare
Redwood	abundant	abundant	common	few	rare
High-Spine Compositae	abundant	abundant to very abundant	common	common	common

concomittant rise in redwood, oak, Compositae, alder and tanoak.

Zone C (170-240 cm) contains progressively less pine, common amounts of oak, and moderate abundances of redwood and Compositae. It is also characterized by few trilete spores and small amounts of tanoak and alder, as well as low *Pediastrum* counts. Similarly, Zone B (125-170 cm) displays a further reduction in pine abundance, moderately abundant redwood, and still rare alder. This zone differs from Zone C, however, in its substantial increase in Compositae, slight drop in abundance of oak, trilete spores, and tanoak, and the virtual elimination of *Pediastrum*.

As evidenced by the increasing abundances of redwood, oak, tanoak and Compositae, combined with the decline of pine and *Artemisia*, the Holocene of the coastal central California region is characterized by warmer climatic conditions. In both Zones C and B, the increased importance of the Mediterranean-type climate, and the associated coastal fog and humid coastal marine influence in general, is indicated by the rising redwood frequency (Gardner and others, in press). Increased abundances of oak, tanoak and Compositae pollen in Zone C suggests that they dominate the surrounding drier slopes. This is followed by drier conditions in Zone B, as grassland areas dominated by Compositae increase at the expense of the oak and tanoak. In addition, the drier conditions of Zone B are indicated by the lack of *Pediastrum*, although the continued presence of alder pollen implies that the riparian habitat is still well established in the region.

Zone A. (0-125 cm). This zone reflects the modern pattern of vegetation in the coastal central California region (Figure 3). The pollen record is characterized by abundant redwood and Compositae, moderate amounts of pine and oak, and fairly rare tanoak, *Artemisia* and cheno-ams. Rhamnaceae increases slightly for the first time, while *Eriogonum*, alder and grasses remain scarely represented. Heusser (1983) and Heusser and Balsam (1977), investigating the distribution of pollen in recent continental and marine sediments bordering the Pacific northwest recovered the major pollen types (pine, redwood, oak and Compositae) in frequencies in agreement with those obtained in the core-top deposits of S3-15G.

Comparison With Other Studies

The results of previous studies on the distribution of pollen in latest Quaternary sediments in the coastal central California region are in general agreement with those presented in this paper (Figure 11). Based upon varying pollen frequencies, glacial, transitional, and interglacial modes were noted in a deep-sea core (V1-80-P3) taken at a depth of 1600 m off the Russian River (Gardner and others, in press), while Adam and others (1981) discerned pine, pine-fir and redwood zones in a core from the Laguna de las Trancas marsh in northern coastal Santa Cruz County. Planktonic foraminifers are the basis for stratigraphic correlation between the Monterey Fan investigation and these two studies, although it remains unclear as to how Adam and others (1981) obtained the tentative dates suggested for their zonal boundaries. In addition, an interval of severe calcium carbonate dissolution (dated at approximately 0 to 5,000 years B.P.) in the core utilized by Gardner and others (in press), is tentatively correlated with a severely dissolution-affected interval in core S3-15G (0-120 cm) and an unrepresented interval in the Laguna de las Trancas marsh (Adam and others, 1981).

The glacial mode of Gardner and others (in press), established until 18,000 years B.P., correlates with Zone E. Both are characterized by very abundant pine and very rare redwood and alder pollen. They differ slightly however, in that oak is missing off the Russian River, but comprises up to 5.4% of the Zone E Monterey Fan pollen assemblage. Both the glacial mode and Zone E pollen records reflect the vegetational adaptation to glacial climatic conditions in the California Coast Ranges.

Gardner and others' (in press) transitional mode is dated from 18,000 to 13,500 years B.P. and correlates somewhat with Zone D. The continued low frequency of redwood is apparent in both. Alder pollen, although only a minor constituent, is recorded in appreciable amounts in the two as well. However, pine constitutes a minor portion of the transitional mode assemblage, whereas it is still very abundant in Zone D. Likewise, oak pollen in Zone D is increasing while it still has not been detected in the offshore Russian River material.

The pine-fir zone discerned in the Laguna de las Trancas marsh sediments (Adam and others, 1981), and approximately dated at 24,000 to 12,000 years B.P., is characterized by a pollen assemblage similar to both Zones D and E. They are all characterized by rare oak and redwood, abundant pine, and an increase in alder near the

Pleistocene/Holocene boundary. However, the pine-fir zone differs from Zones D and E in its abundant fir, moderate amount of Douglas fir and low abundance of Ericaceae.

The differences in the two pollen assemblages may be explained by proximity of source, taphonomic processes, and differential pollen production. The fir pollen in the Laguna de las Trancas marsh is thought to represent the grand fir (Adam and others, 1981), a species that at present reaches its southern limit north of the Russian River (Figure 3; Griffin and Critchfield, 1976). Its abundance in the marsh core and rare occurrence in core S3-15G is probably due to the fact that its large grains are not well suited for wind transport (Adam and others, 1981). Douglas fir pollen was not recovered in core S3-15G, nor in marine surface samples obtained off Monterey Bay (Heusser and Balsam, 1977). This anomaly may be explained by the fact that Douglas fir produces remarkably small amounts of pollen and that its grains are large, and therefore, poorly dispersed (Kapp, 1969; Baker, 1976). The lack of Ericaceae pollen in the Monterey Fan core is attributable to the fact that most members of this family are insect-pollinated. The relatively few grains that are produced are large (Kapp, 1969) and, as a result, are not widely dispersed by wind and water (Hyde and Williams, 1944; Potter and Rowley, 1960; Whitehead, 1969; Proctor and Yeo, 1972; Brasier, 1980; Heusser, 1983; Melia, 1984). Therefore, they too will not be well represented in marine pollen records.

The Holocene portion of core S3-15G (Zones A-C) correlates with the interglacial mode off the Russian River. The redwood zone of the Laguna de las Trancas marsh may only be compared with Zones B and C, however, as the pollen record of the upper 5,000 years B.P. in the marsh core was not presented in their study. The three vegetational records are similar in that pine pollen decreases, oak is abundant, alder is rare, fir is no longer present, and redwood is one of the most common pollen types. A major difference may be discerned, however. Pine is considerably less abundant in the marsh core than in the sediments of the two offshore studies. This may simply reflect pine pollen's greater hydraulic efficiency (Heusser and Balsam, 1977).

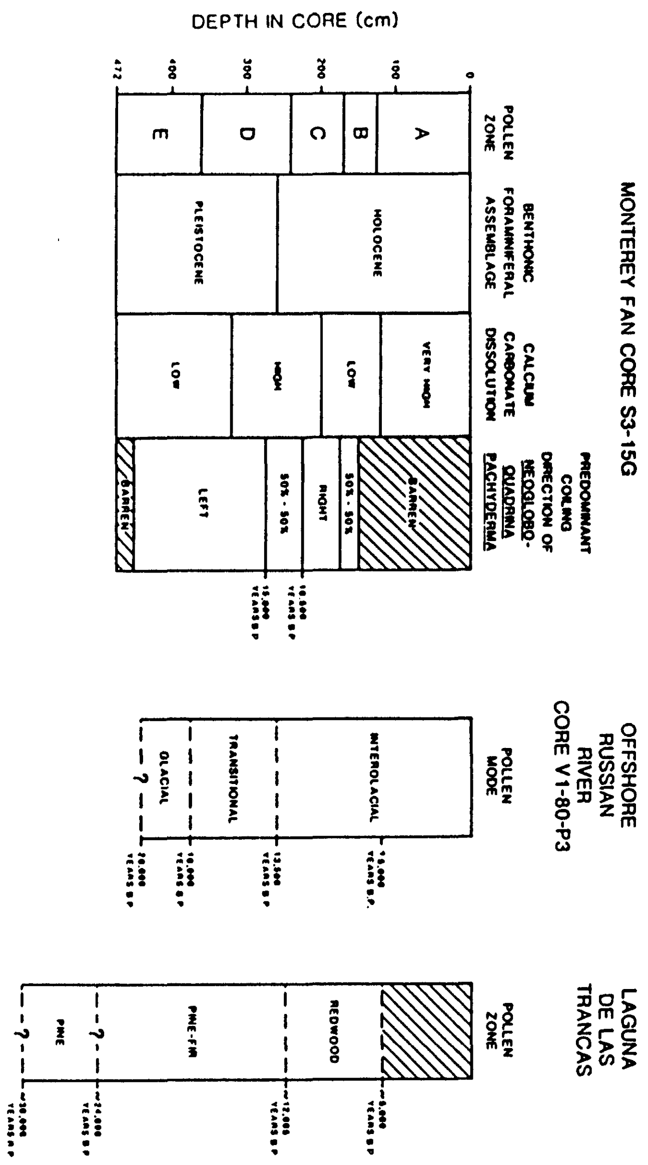

Figure 11. Correlation of pollen and microfaunal records from Monterey Fan core S3-15G (this study), offshore Russian River core V1-80-P3 (Gardner and others, in press), and Laguna de las Trancas marsh core (Adam and others, 1981).

Correlation of Continental and Marine Records

In general, both the terrestrial vegetation (this study) and marine microfaunal records (McGann, 1986) of the Monterey Fan overbank deposits show similar responses to changing climatic conditions from the Pleistocene to the Holocene (Figure 11). Yet, closer examination of the data suggest that these floral and faunal shifts are not synchronous.

Pollen Zone E (360-472 cm), characterized by fir, *Artemisia* and especially very abundant pine, represents the vegetational response in the central California coastal region to the cold climate of the last full glacial interval. The microfaunal assemblage of the lower 137 cm of core S3-15G also displays an adaptation to glacial conditions. It is apparent in that left-coiling (cold-water indicating) forms of *Neogloboquadrina pachyderma* far outnumber the right-coiling morphotypes. Also, dissolution of the faunal assemblage is minimal, as reflected by high foraminiferal numbers, high planktonic to benthonic foraminiferal ratios, and high ratios of planktonic foraminifers to radiolarians (Figure 12). Decreased dissolution of deep-sea carbonates is associated with glacial stages (Berger, 1973, 1979; Thompson and Saito, 1974).

Pollen Zone D (240-360 cm), characterized by declining fir and pine abundances, increasing oak and redwood, and enhanced coastal runoff indicated by increases in alder pollen, *Pediastrum* and dinoflagellates, represents changes in vegetation in response to continental deglaciation. Although the reponse is delayed, the microfaunal assemblage also reflects this general warming trend. Right-coiling *Neogloboquadrina pachyderma* become more abundant above 275 cm and there is considerable evidence of dissolution beginning at 320 cm: foraminiferal abundance is low, the foraminiferal fauna is composed primarily of benthonic species, and radiolarians overwhelmingly dominate the pelagic assemblage.

The faunal record of core S3-15G appears to be more sensitive than the pollen record to the climatic changes at the end of the Pleistocene, however. Two shifts from left- to right-coiling forms of *Neogloboquadrina pachyderma* are noted between 212 and 295 cm (C. Brunner, 1985, pers. commun.). The stratigraphically higher increase in abundance of left-coiling forms, just before the Pleistocene/Holocene boundary (243-256 cm), signals the smaller re-advance of glaciation (the Younger Dryas; Duplessy and others, 1981) dated at

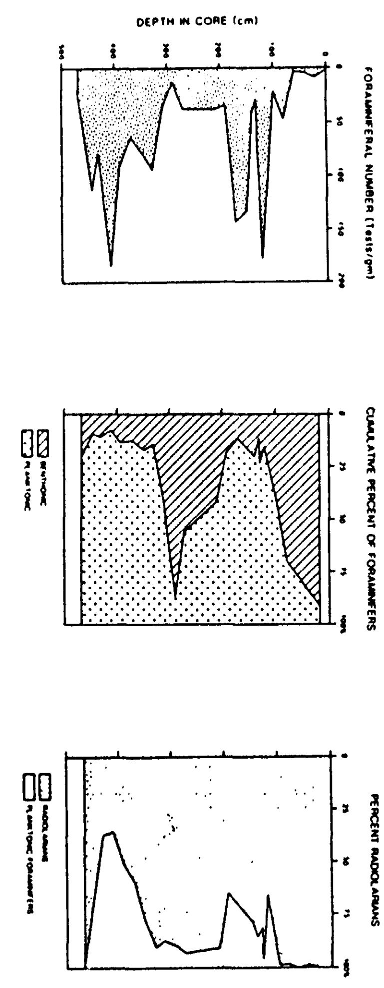

Figure 12. Foraminiferal number, cumulative frequency of benthonic and planktonic foraminifers, and cumulative frequency of radiolarians and planktonic foraminifers plotted with depth in core for the mud samples of core S3-15G.

approximately 13,000 years B.P. off central California (J. Gardner, 1986, pers. commun.). In contrast, the pollen assemblage does not appear to shift significantly within this interval. However, this may be due to the fact that a turbiditic sand deposit was sampled at this level, and turbiditic sands in core S3-15G have been shown to have biased pollen assemblages.

Marine and terrestrial responses to changing climatic conditions at the Pleistocene/Holocene boundary also are not concurrent. The upper shift from left- to right-coiling *Neogloboquadrina pachyderma*, defined as the Pleistocene/Holocene boundary, occurs at approximately 225 cm (the mid-point of the interval in which the shift occurs). Both the benthonic foraminiferal and pollen assemblages, however, change their character before (at 260 and 240 cm, respectively) the planktonic foraminiferal shift. These data suggest that the terrestrial and deep-water masses are responding to the climatic change before the shallower oceanic realm.

Pollen Zone C (170-240 cm) is characterized by warmer and wetter conditions, as indicated by its peak in *Pediastrum* and increased abundance of oak and redwood pollen. The peak in abundance of right-coiling *Neogloboquadrina pachyderma* througout the interval, and high dissolution indices at least at the beginning, similarly signifies warmer oceanographic conditions.

A discrepancy exists between the terrestrial and marine paleoclimatic records from approximately 125 to 170 cm, however. Pollen Zone B, characterized by the elimination of *Pediastrum* and a substantial increase in Compositae, is indicative of a warmer and drier terrestrial climate. Yet, the data suggests that the marine realm is cooling: the abundance of left-coiling *Neogloboquadrina pachyderma* is increasing and calcium carbonate dissolution is on the decline. It remains unclear why the latter should respond in this manner.

Pollen Zone A (0-125 cm) is characterized by a pollen assemblage reflecting the vegetational adaptation to the warm interglacial climatic conditions of the Holocene: high abundances of oak, redwood and Compositae, and decreasing frequencies of pine. The faunal assemblage similarly reflects the warm climatic conditions; carbonate dissolution is so severe in the upper 120 cm of core S3-15G that the coiling ratio of left- and right-coiling *Neogloboquadrina pachyderma* could not be discerned within this interval.

Conclusions

1. Analysis of a gravity core obtained from the western levee of Monterey Fan, composed of hemipelagic and overbank turbiditic deposits, has yielded a record of vegetational change in coastal central California during the latest Quaternary.
2. A cluster analysis divided the pollen samples into five groups based primarily upon varying frequencies of the four major pollen types: pine, redwood, oak and Compositae. In turn, these groups were used to define five pollen zones. The lowermost pollen zone reflects the vegetational response to the climatic regime of the last full glacial interval and is followed by a late Pleistocene transitional assemblage. The three uppermost pollen zones reflect changes in vegetation during the Holocene.
3. High values of *Pediastrum* and dinoflagellates at the termination of the last glacial interval are assumed to reflect improving climatic conditions and an increase in nutrient-rich fluvial runoff.
4. An abrupt change in the pollen frequencies occurs slightly before the Pleistocene/Holocene boundary.
5. Pollen abundance is lowest in the turbiditic sand and Pleistocene mud deposits. Relatively fewer pollen grains in the sands reflect the effects of sorting, whereas low pollen concentrations in the Pleistocene muds result from increased inorganic terrigenous input to the core site due to sediments bypassing the shelf during low stands in sea level.
6. Within the resolution of the sampling interval employed in this study, and considering the effects of bioturbation, the terrestrial and marine responses to changing climatic conditions in the coastal central California region were not synchronous during the latest Quaternary. Additionally, the climatically-induced floral and faunal changes inferrred from core S3-15G appear consistent with those discerned by other studies of the region.

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Plate 1

1. *Bathysiphon* (?) sp. X83. Sample 248-250 cm.
2. *Jaculella acuta* Brady. X60. Sample 0-4 cm.
3. *Bathysiphon* sp. X20. a, side view; b, cross section. Note test wall composed of sponge spicules. Sample 20-23.5 cm.
4. *Reophax communis* Lacroix. X125. Sample 20-23.5 cm.
5. *Reophax* (?) sp. X125. Sample 60-63 cm.
6. *Saccammina spherica* M. Sars. X60. Sample 0-4 cm.
7. *Reophax dentaliniformis* Brady. X60. Sample 20-23.5 cm.
8. *Reophax distans gracilis* Earland. X60.Sample 20-23.5 cm.
9. *Recurvoides* sp. X125. a, side view; b, apertural view; c, side view. Sample 20-23.5 cm.

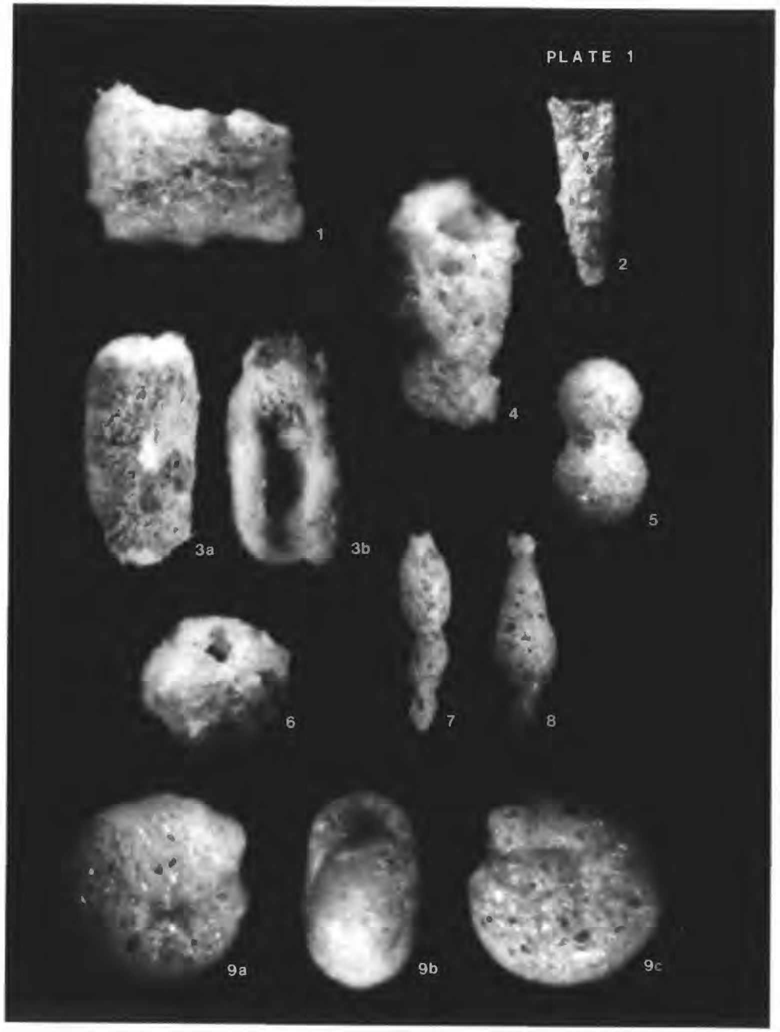


Plate 2

1. *Cyclammina* sp. X20. Pyritized. a, side view; b, apertural view; c, side view. Sample 445-447.5 cm.
2. *Karreriella grammostomata* Galloway and Wissler. X125. a, side view; b, apertural view; c, side view. Sample 390-393 cm.
3. *Martinottiella communis* (d'Orbigny). X60. Juvenile. a, side view; b, apertural view; c, side view. Sample 139-143 cm.
4. *Martinottiella communis* (d'Orbigny). X30. Adult. Sample 445-447.5 cm.
5. *Eggerella bradyi* (Cushman). X60. a, side view; b, side view; c, apertural view. Sample 390-393 cm.
6. *Eggerella* sp. X60. a, side view; b, side view. Sample 230-232 cm.

Plate 3

1. *Karreriella baccata* (Schwager). X125. a, side view; b, apertural view; c, side view. Sample 120-122 cm.
2. *Karreriella novangliae* (Cushman). X60. a, side view; b, apertural view; c, side view. Sample 445-447.5 cm.
3. *Trochammina pacifica simplissima* Cushman and McCulloch. X125. a, dorsal view; b, ventral view; c, edge view. Sample 20-23.5 cm.
4. *Trochammina globigeriniformis* (Parker and Jones). X125. Aberrant form. a, dorsal view; b, edge view; c, ventral view. Sample 20-23.5 cm.
5. *Trochammina globigeriniformis* (Parker and Jones). X60. a, ventral view; b, dorsal view; c, edge view. Sample 20-23.5 cm.
6. *Quinqueloculina akneriana* d'Orbigny. X60. a, side view; b, apertural view; c, side view. Sample 410-412.5 cm.

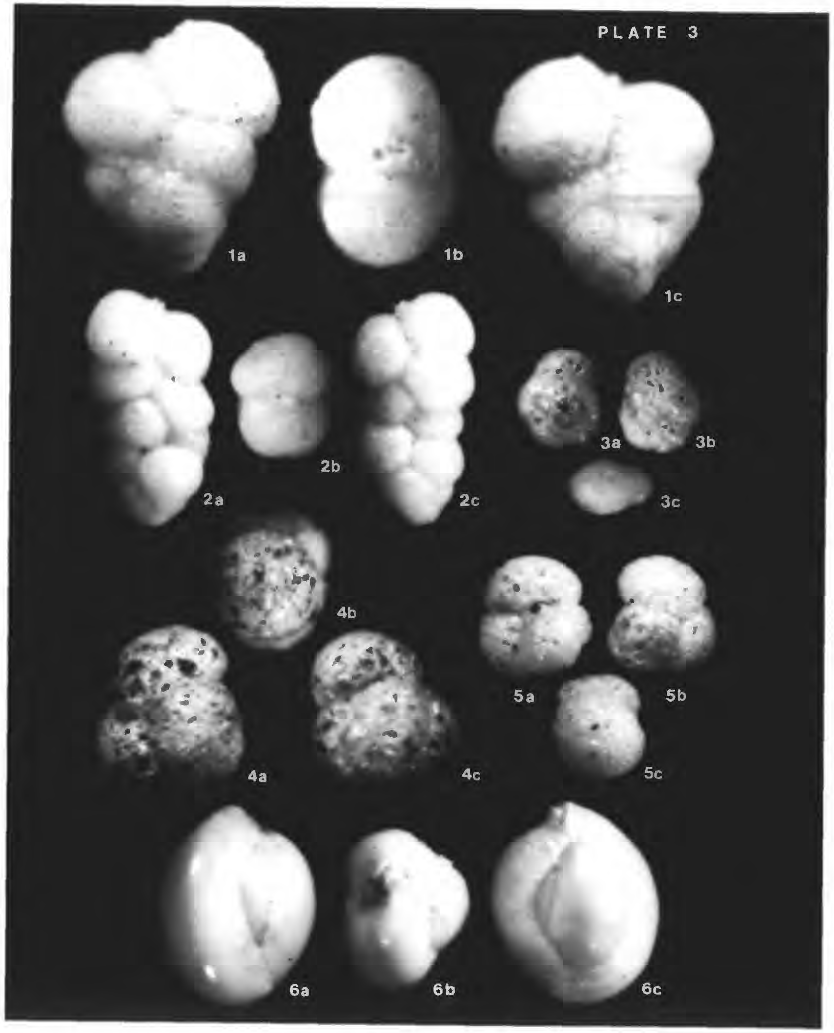


Plate 4

1. *Quinqueloculina* sp. A. X60. a, side view; b, apertural view; c, side view. Sample 369.5-372.5 cm.
2. *Quinqueloculina elongata* Natland. X60. a, side view; b, side view; c, apertural view. Sample 346.5-349.5 cm.
3. *Miliolinella californica* Rhumbler. X125. a, side view; b, edge view; c, apertural view; d, side view. Sample 390-393 cm.
4. *Miliolinella californica* Rhumbler. X125. a, side view; b, side view; c, basal view; d, apertural view. Sample 412-414.5 cm.
5. *Sigmoilina* sp. X125. a, side view; b, apertural view. Sample 133.5-136.5 cm.
6. *Sigmoilina* cf. *S. tenuis* Czjzek. X125. a, apertural view; b, side view. Sample 336.5-338 cm.
7. *Quinqueloculina* sp. B. X60. a, side view; b, apertural view; c, side view. Sample 167.5-170 cm.
8. *Triloculina tricarinata* d'Orbigny. X125. a, side view; b, apertural view. Sample 180-182 cm.
9. *Triloculina trigonula* (Lamarck). X60. a, side view; b, apertural view; c, edge view. Sample 20-23.5 cm.

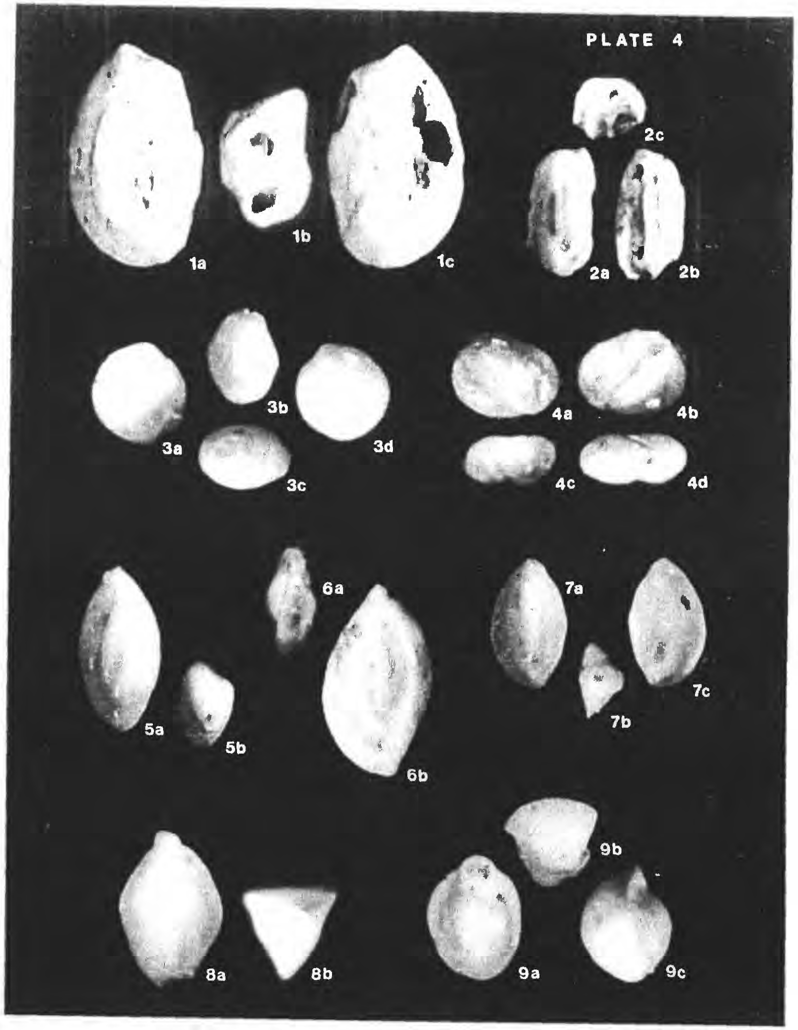


Plate 5

1. Pyrgo murrhina (Schwager). X60. Adult. a, side view; b, apertural view. Sample 120-122 cm.

2. Pyrgo murrhina (Schwager). X125. Juvenile. a, side view; b, apertural view. Sample 120-122 cm.

3. Pyrgo depressa (d'Orbigny). X60. a, side view; b, apertural view. Sample 189.5-192 cm.

4. Lenticulina sp. X125. a, side view; b, edge view; c, side view. Sample 139-143 cm.

5. Lenticulina sp. X60. a, side view; b, edge view. Sample 139-143 cm.

6. Lenticulina sp. X60. a, side view; b, edge view; c, side view. Sample 346.5-349.5 cm.

7. Lenticulina sp. X125. a, side view; b, edge view. Sample 346.5-349.5 cm.

8. Lenticulina sp. X125. a, edge view; b, side view. Sample 270-272 cm.

9. Saracenaria sp. X60. a, side view; b, side view; c, edge view. Sample 139-143 cm.

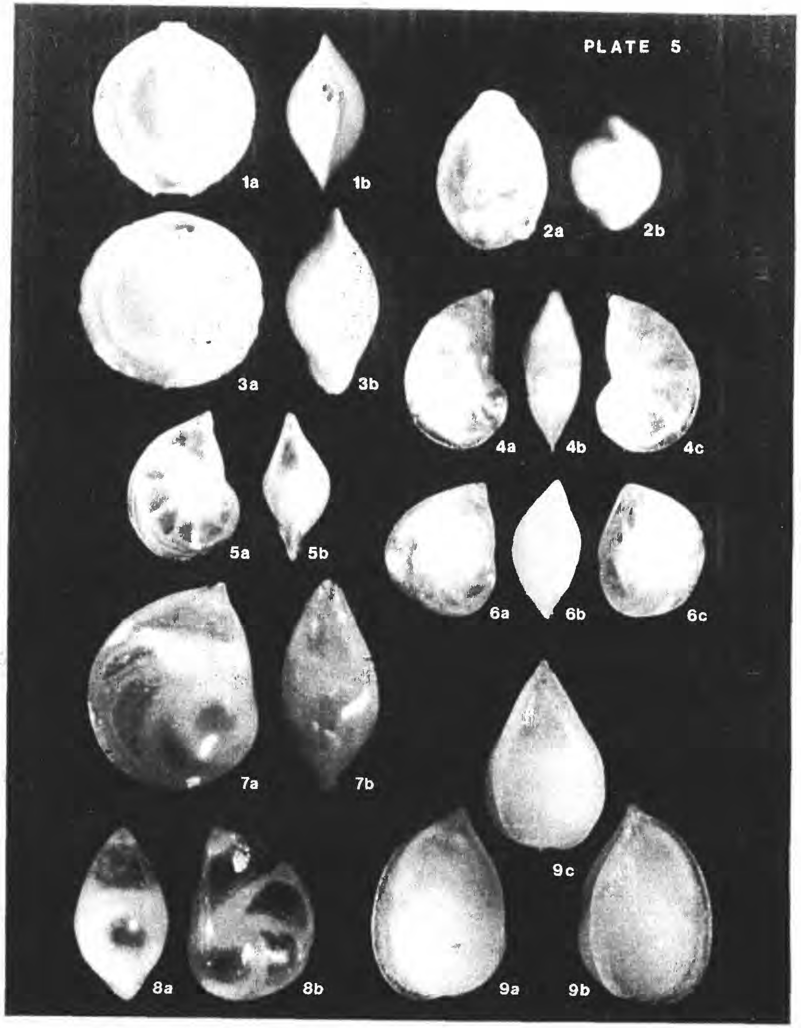


Plate 6

1. *Astacolus* sp. X125. a, side view; b, edge view; c, apertural view. Sample 167.5-170 cm.
2. *Marginulina* sp. X125. a, apertural view; b, side view; c, edge view. Sample 167.5-170 cm.
3. *Marginulina* sp. X125. a, side view; b, edge view; c, apertural view. Sample 330-332 cm.
4. *Marginulina obesa* Cushman. X60. a, side view; b, apertural view; c, edge view. Sample 120-122 cm.
5. *Marginulina* sp. X125. a, side view; b, apertural view; c, edge view. Sample 139-143 cm.
6. *Frondicularia* sp. X125. Sample 46-48 cm.
7. *Dentalina* sp. X60. Sample 369.5-372.5 cm.
8. *Dentalina californica* Cushman and Gray. X125. Pyritized. Sample 133.5-136.5 cm.
9. *Dentalina pauperata* d'Orbigny. X30. Sample 390-393 cm.
10. *Dentalina frobisherensis* Loeblich and Tappan. X60. Sample 139-143 cm.
11. *Dentalina mucronata* Neugeboren. X125. Sample 330-332 cm.

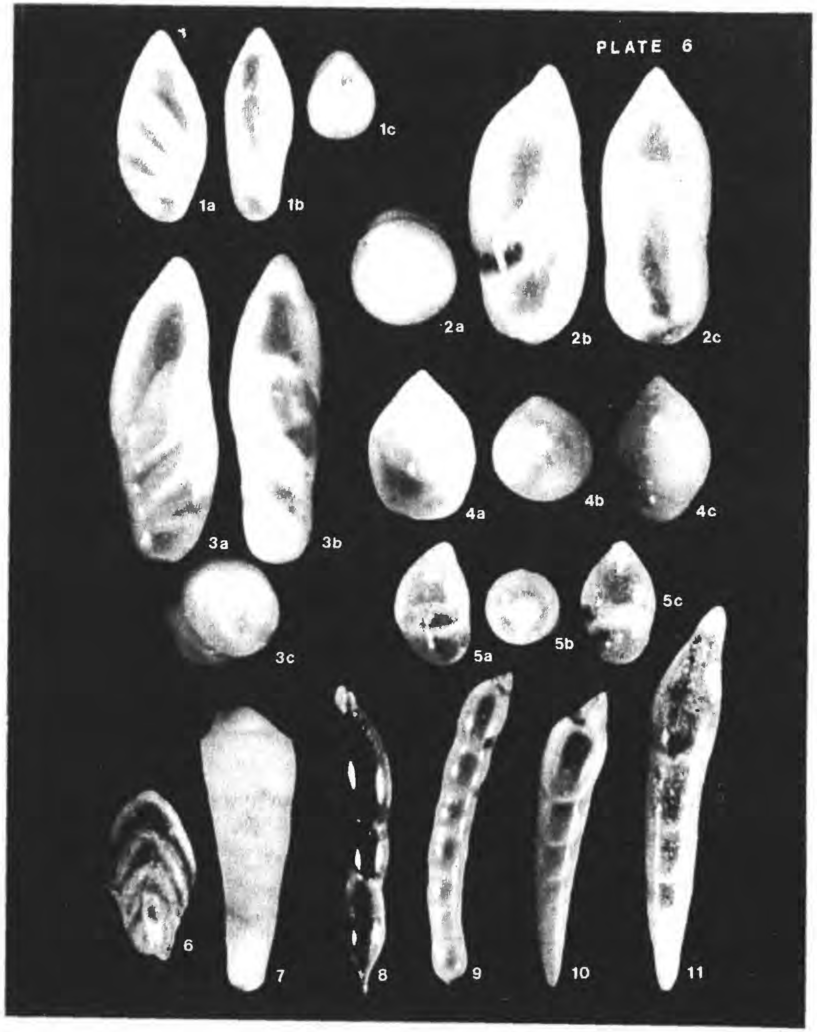


Plate 7

1. *Nodosaria* cf. *N. tympaniplectriformis* Schwager. X125. a, side view; b, apertural view. Sample 60-63 cm.
2. *Stilostomella* sp. X125. Sample 133.5-136.5 cm.
3. *Stilostomella* cf. *S. lepidula* (Schwager). X125. Sample 133.5-136.5 cm.
4. *Lagena sulcata spicata* Cushman and McCulloch. X125. a, side view; b, apertural view. Sample 133.5-136.5 cm.
5. *Lagena acuticosta* Reuss. X125. a, side view; b, apertural view. Sample 130-132 cm.
6. *Lagena acuticosta* Reuss. X125. a, apertural view; b, side view. Sample 410-412.5 cm.
7. *Lagena alcocki* White. X125. a, apertural view; b, side view. Sample 133.5-136.5 cm.
8. *Lagena* sp. X125. a, side view; b, apertural view. Sample 171-173 cm.
9. *Lagena sulcata laevicostata* Cushman and Gray. X125. a, side view; b, apertural view. Sample 230-232 cm.
10. *Lagena sulcata laevicostata* Cushman and Gray. X125. a, apertural view; b, side view. Sample 152.5-154.5 cm.
11. *Lagena sulcata* (Walker and Jacob). X125. a, side view; b, apertural view. Sample 120-122 cm.
12. *Lagena striata* (d'Orbigny). X125. a, apertural view; b, side view. Sample 270-272 cm.
13. *Lagena* sp. X125. a, side view; b, apertural view. Sample 336.5-338 cm.
14. *Lagena hispidula* Cushman. X125. a, apertural view; b, side view. Sample 133.5-136.5 cm.

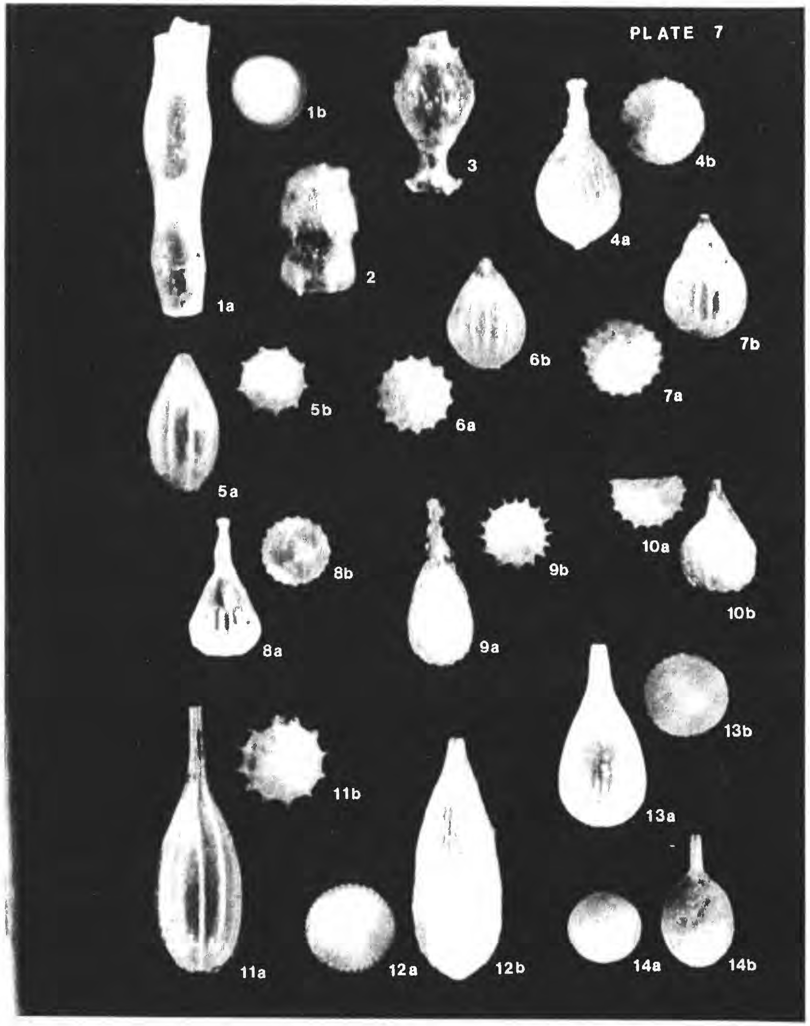


Plate 8

1. Lagena distoma Parker and Jones. X60. Sample 139-143 cm.
2. Lagena elongata (Ehrenberg). X60. Sample 412-414.5 cm.
3. Lagena sp. X125. a, side view; b, apertural view, low focus; c, apertural view, high focus. Sample 336.5-338 cm.
4. Oolina melo d'Orbigny. X125. a, apertural view; b, side view. Sample 139-143 cm.
5. Oolina catenulata (Williamson). X125. a, apertural view; b, side view. Sample 139-143 cm.
6. Oolina (?) sp. X60. a, side view; b, apertural view. Sample 152.5-154.5 cm.
7. Fissurina sp. X125. a, side view; b, apertural view. Sample 46-48 cm.
8. Parafissurina sp. X125. a, side view; b, apertural view. Sample 20-23.5 cm.
9. Fissurina sp. X125. a, side view; b, apertural view. Sample 152.5-154.5 cm.
10. Fissurina sp. X125. a, side view; b, apertural view. Sample 133.5-136.5 cm.
11. Parafissurina kerguelenensis Parr. X125. a, side view; b, apertural view. Sample 133.5-136.5 cm.
12. Parafissurina cf. P. kerguelenensis Parr. X125. a, apertural view; b, side view. Sample 330-332 cm.
13. Parafissurina kerguelenensis Parr. X125. a, apertural view; b, side view. Sample 167.5-170 cm.

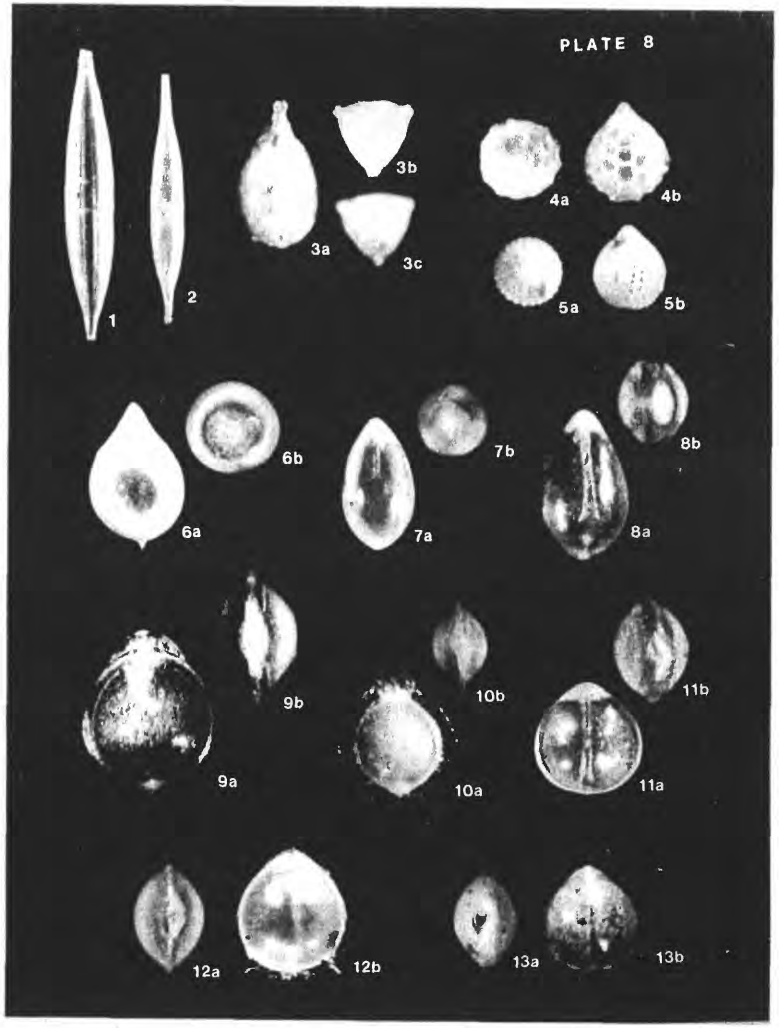


Plate 9

1. *Fissurina* sp. X60. a, side view; b, apertural view. Sample 20-23.5 cm.

2. *Oolina* sp. A. X125. a, oblique view; b, apertural view; c, side view. Sample 80-82 cm.

3. *Oolina* sp. B. X125. a, apertural view; b, side view. Sample 139-143 cm.

4. *Fissurina* sp. X125. a, apertural view; b, side view. Sample 133.5-136.5 cm.

5. *Fissurina* sp. X125. a, apertural view; b, side view. Sample 133.5-136.5 cm.

6. *Fissurina* sp. X125. a, side view; b, apertural view. Sample 133.5-136.5 cm.

7. *Fissurina* sp. X125. a, apertural view; b, side view. Sample 171-173 cm.

8. *Fissurina lagenoides* (Williamson). X125. a, apertural view; b, side view. Sample 133.5-136.5 cm.

9. *Fissurina* sp. X125. a, side view; b, apertural view. Sample 120-122 cm.

10. *Parafissurina tectulostoma* Loeblich and Tappan. X125. a, apertural view; b, side view. Sample 167.5-170 cm.

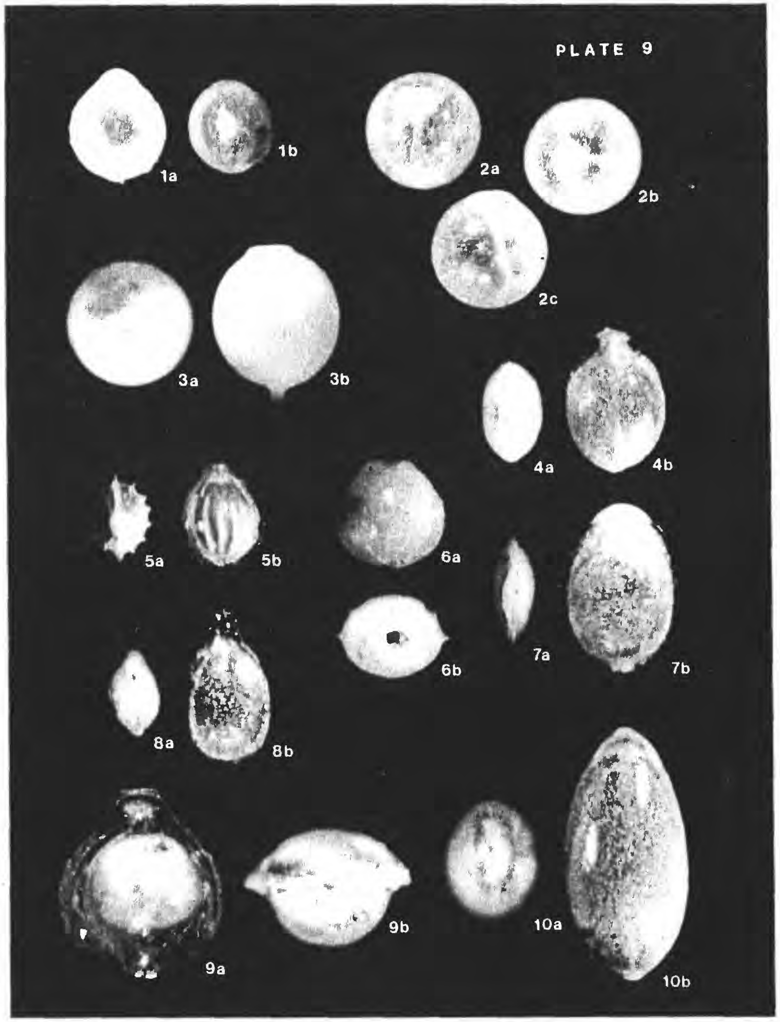


Plate 10

1. *Nonionella decora* Cushman and McCulloch. X125. a, side view; b, apertural view; c, side view. Sample 412-414.5 cm.

2. *Florilus labradoricus* (Dawson). X125. a, side view; b, apertural view; c, side view. Sample 369.5-372.5 cm.

3. *Nonionella basispinata* (Cushman and Moyer). X125. a, side view; b, apertural view; c, side view. Sample 230-232 cm.

4. *Nonionella japonica mexicana* Cushman and McCulloch. X125. a, side view; b, apertural view; c, side view. Sample 171-173 cm.

5. *Nonionella* sp. X125. Pyritized. a, side view; b, apertural view; c, side view. Sample 40-43 cm.

6. *Nonionella* sp. X125. Pyritized. a, side view; b, apertural view; c, side view. Sample 430-432.5 cm.

7. *Nonionella miocenica* Cushman. X125. a, side view; b, apertural view; c, side view. Sample 369.5-372.5 cm.

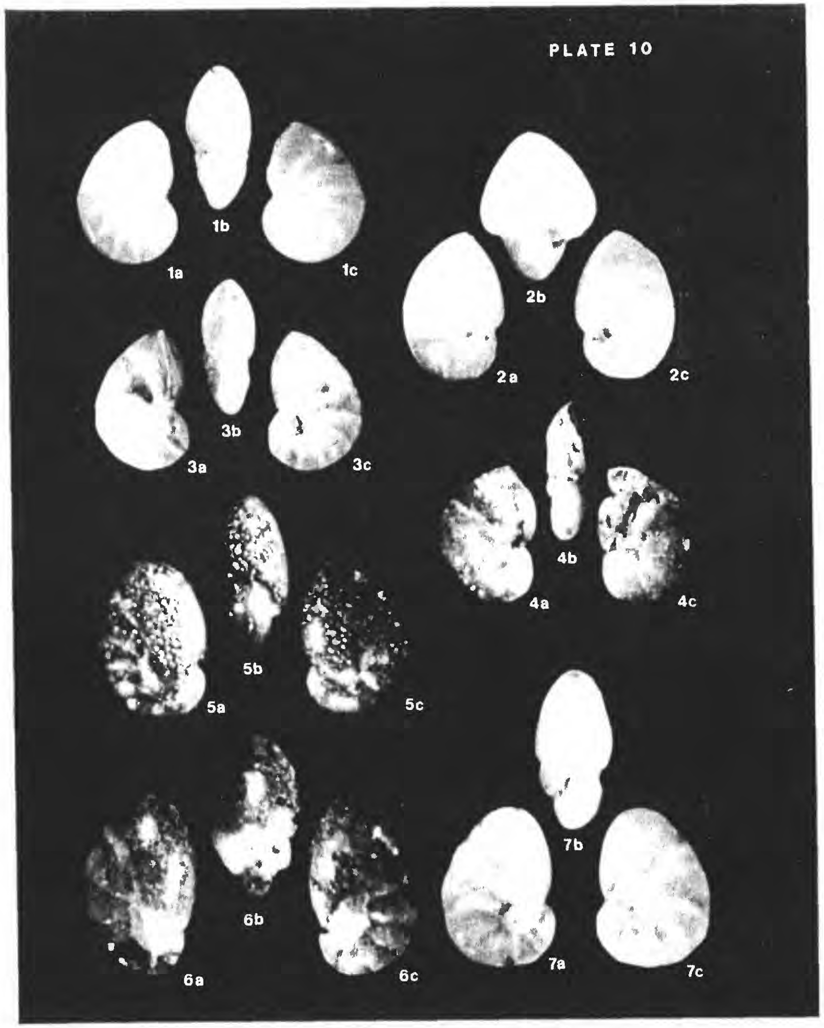


Plate 11

1. *Nonionella stella* Cushman and Moyer. X125. a, side view; b, apertural view; c, side view. Sample 412-414.5 cm.
2. *Astrononion gallowayi* Loeblich and Tappan. X125. a, side view; b, apertural view; c, side view. Sample 336.5-338 cm.
3. *Melonis pompilioides* (Fichtel and Moll). X125. a, side view; b, apertural view; c, side view. Sample 180-182 cm.
4. *Melonis barleeanus* (Williamson). X125. a, side view; b, apertural view; c, side view. Sample 180-182 cm.

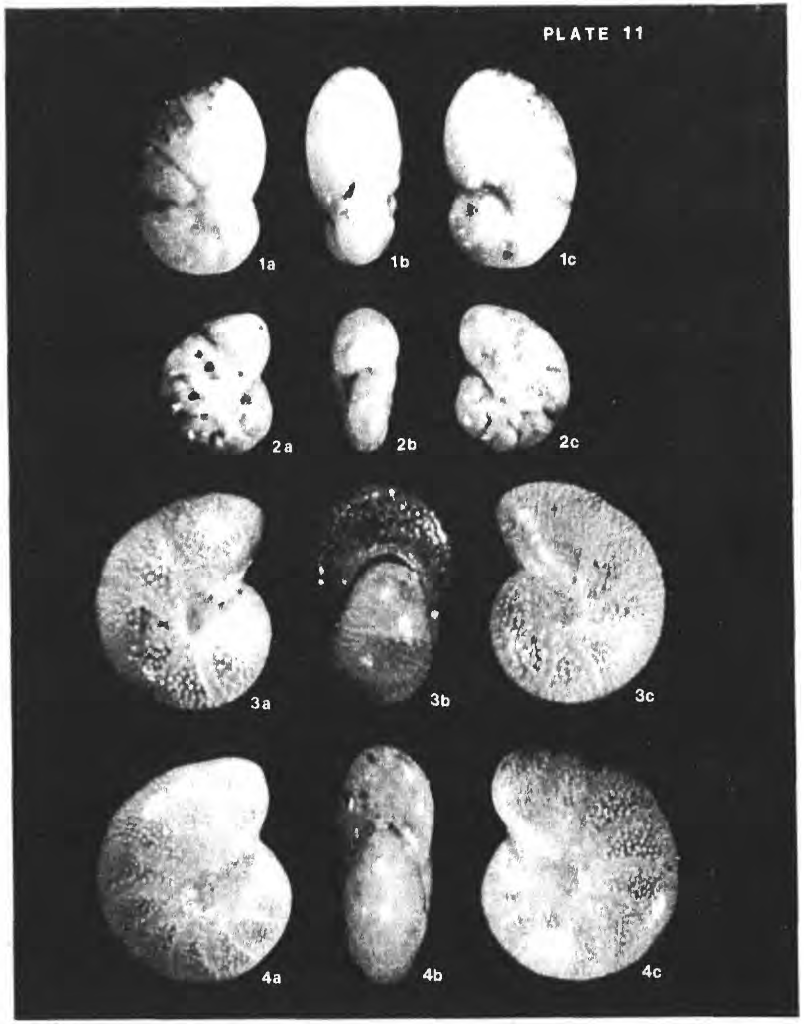


Plate 12

1. *Elphidium excavatum clavata* Cushman. X125. a, side view; b, apertural view; c, side view. Sample 336.5-338 cm.

2. *Elphidium gunteri* Cole. X125. a, side view; b, apertural view; c, side view. Sample 180-182 cm.

3. *Elphidium excavatum selseyensis* (Heron-Allen and Earland). X125. a, side view; b, apertural view; c, side view. Sample 336.5-338 cm.

4. *Elphidium magellanicum* Heron-Allen and Earland. X125. a, side view; b, apertural view; c, side view. Sample 336.5-338 cm.

5. *Elphidium excavatum lidoensis* Cushman. X125. a, side view; b, apertural view; c, side view. Sample 248-250 cm.

6. *Buliminella curta* Cushman. X60. a, apertural view; b, side view; c, side view. Sample 412-414.5 cm.

7. *Buliminella elegantissima* (d'Orbigny). X125. a, side view; b, apertural view; c, side view. Sample 336.5-338 cm.

8. *Robertina bradyi* Cushman and Parker. X125. a, side view; b, apertural view; c, side view. Sample 210-212 cm.

9. *Buliminella tenuata* Cushman. X125. a, apertural view; b, side view; c, side view. Sample 180-182 cm.

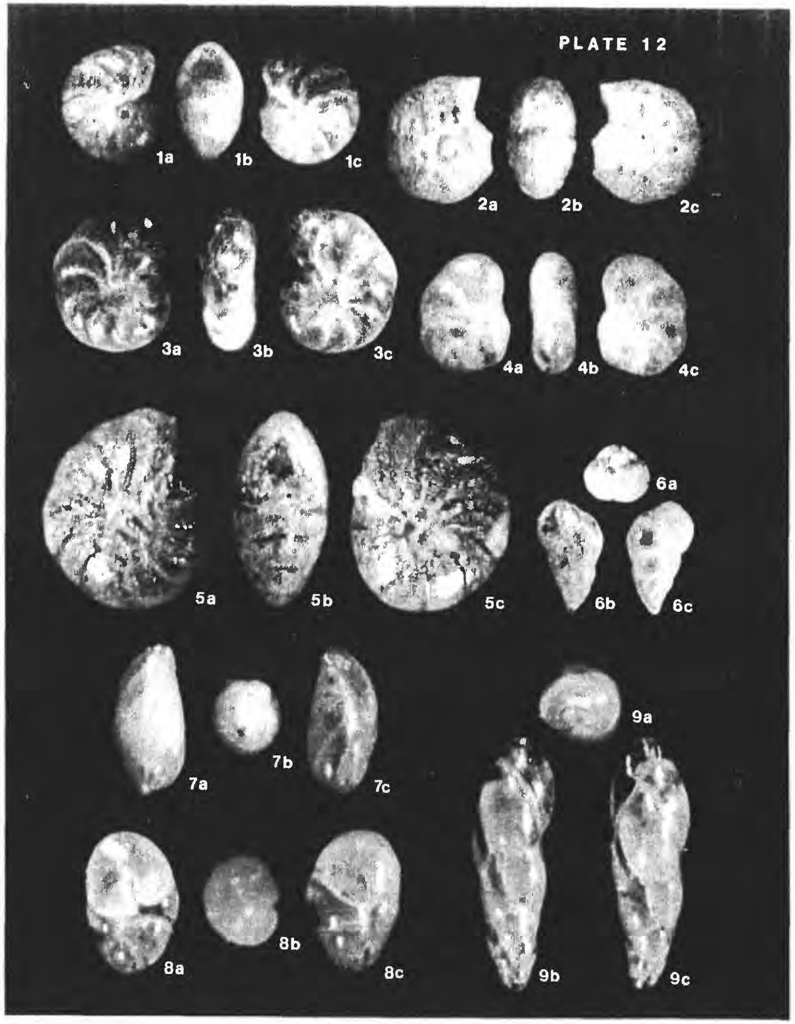


Plate 13

1. *Bulimina rostrata* Brady. X125. a, side view; b, apertural view; c, side view. Sample 189.5-192 cm.
2. *Bulimina denudata* Cushman and Parker. X125. a, side view; b, apertural view; c, side view. Sample 180-182 cm.
3. *Globobulimina barbata* (Cushman). X60. a, side view; b, apertural view; c, side view. Sample 120-122 cm.
4. *Bulimina pagoda* Cushman. X125. a, side view; b, apertural view; c, side view. Sample 133.5-136.5 cm.
5. *Bulimina striata mexicana* Cushman. X60. a, side view; b, apertural view; c, side view. Sample 248-250 cm.
6. *Bulimina striata mexicana* Cushman. X125. a, side view; b, apertural view; c, side view. Sample 180-182 cm.
7. *Globobulimina spinifera* (Cushman). X60. a, side view; b, apertural view; c, side view. Sample 248-250 cm.
8. *Globobulimina pacifica* Cushman. X125. Pyritized. a, side view; b, apertural view; c, side view. Sample 152.5-154.5 cm.
9. *Globobulimina pacifica* Cushman. X125. a, side view; b, apertural view; c, side view. Sample 167.5-170 cm.

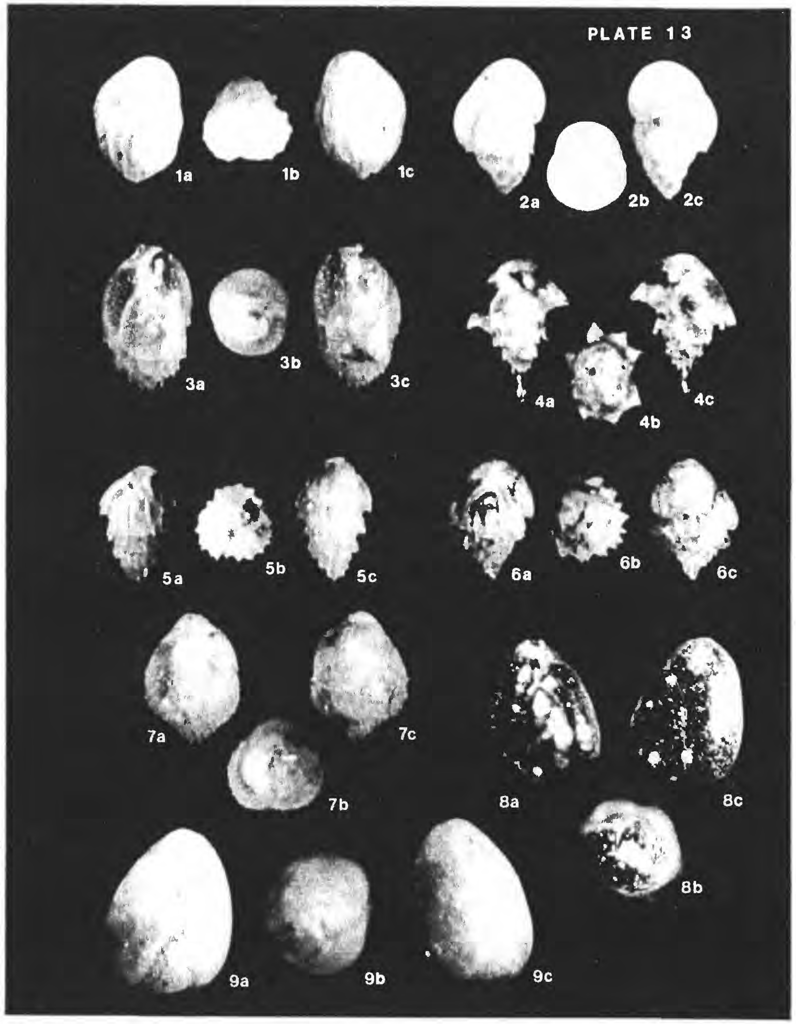


Plate 14

1. *Globobulimina* cf. *G. marginospinata* (Cushman and Parker). X125. a, side view; b, side view; c, apertural view. Sample 133.5-136.5 cm.

2. *Globobulimina ovula* (d'Orbigny). X60. Megalospheric form. a, side view; b, side view; c, apertural view. Sample 248-250 cm.

3. *Globobulimina affinis* (d'Orbigny). X60. a, side view; b, side view; c, apertural view. Sample 20-23.5 cm.

4. *Globobulimina ovula* (d'Orbigny). X60. Microspheric form. a, side view; b, side view; c, apertural view. Sample 248-250 cm.

5. *Globobulimina affinis* (d'Orbigny). X60. a, side view; b, side view; c, apertural view. Sample 346.5-349.5 cm.

6. *Globobulimina affinis* (d'Orbigny). X60. a, side view; b, side view; c, apertural view. Sample 60-63 cm.

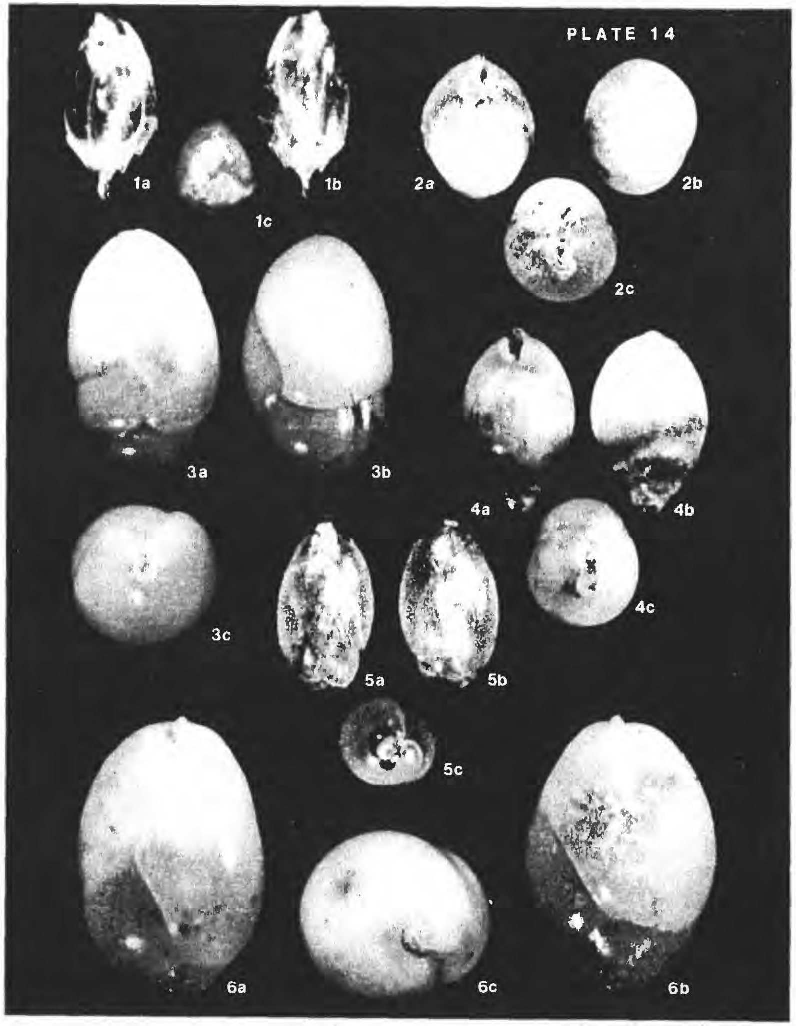


Plate 15

1. Stainforthia complanata (Egger). X125. a, side view; b, side view. Sample 171-173 cm.

2. Stainforthia nodosa (Stewart and Stewart). X125. a, side view; b, side view. Sample 230-232 cm.

3. Fursenkoina seminuda (Natland). X125. a, side view; b, side view. Sample 133.5-136.5 cm.

4. Fursenkoina sp. X60. a, side view; b, side view; c, apertural view. Sample 46-48 cm.

5. Bolivina pacifica Cushman and McCulloch. X125. a, side view; b, side view; c, apertural view. Sample 412-414.5 cm.

6. Bolivina seminuda Cushman. X60. a, side view; b, side view; c, apertural view. Sample 248-250 cm.

7. Fursenkoina rotundata (Parr). X125. a, side view; b, side view; c, edge view. Sample 133.5-136.5 cm.

8. Bolivina seminuda Cushman. X125. a, side view; b, side view; c, apertural view. Sample 412-414.5 cm.

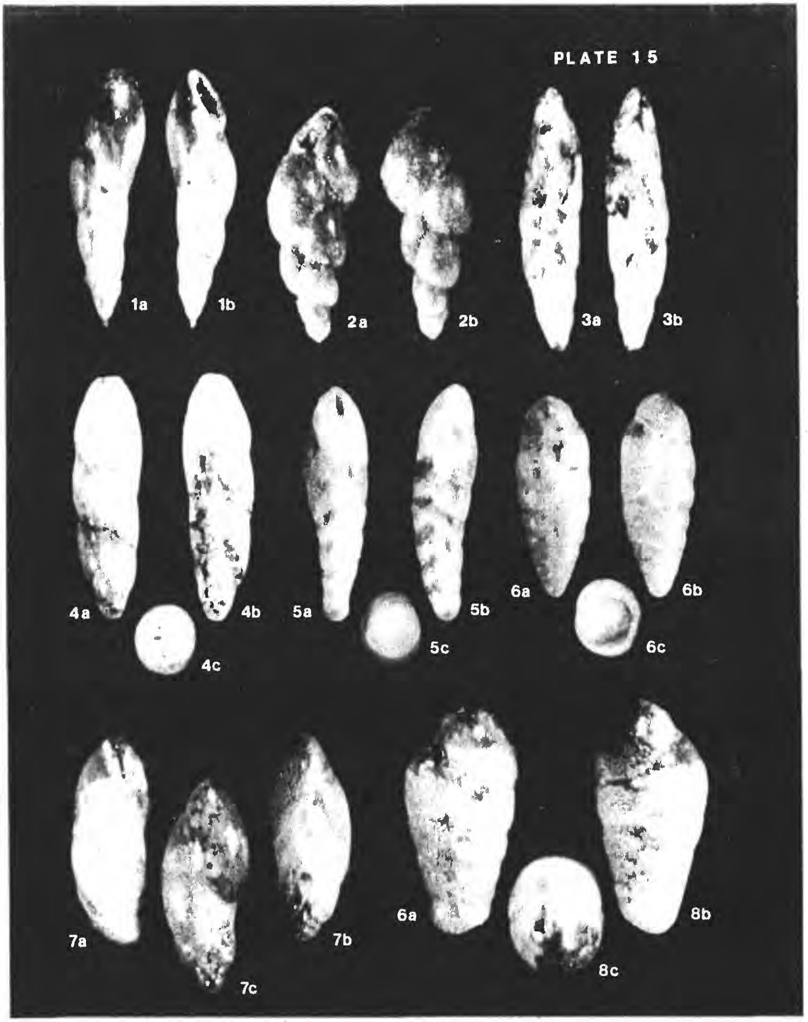


Plate 16

1. Bolivina advena striatella Cushman. X60. a, side view; b, apertural view; c, side view. Sample 248-250 cm.
2. Bolivina tongi filacostata Cushman and McCulloch. X125. a, side view; b, apertural view; c, side view. Sample 180-182 cm.
3. Bolivina argentea Cushman. X60. Megalospheric form. a, side view, wet; b, apertural view. Sample 248-250 cm.
4. Bolivina argentea Cushman. X60. Microspheric form. a, side view, wet; b, apertural view. Sample 248-250 cm.
5. Loxostomum pseudobeyrichi (Cushman). X60. Aberrant form. Sample 248-250 cm, Rare.
6. Loxostomum pseudobeyrichi (Cushman). X60. a, side view; b, apertural view. Sample 412-414.5 cm.
7. Bolivina interjuncta bicostata Cushman. X60. a, side view; b, apertural view; c, side view. Sample 248-250 cm, Rare.
8. Suggrunda eckisi Natland. X125. a, side view; b, apertural view. Sample 230-232 cm.

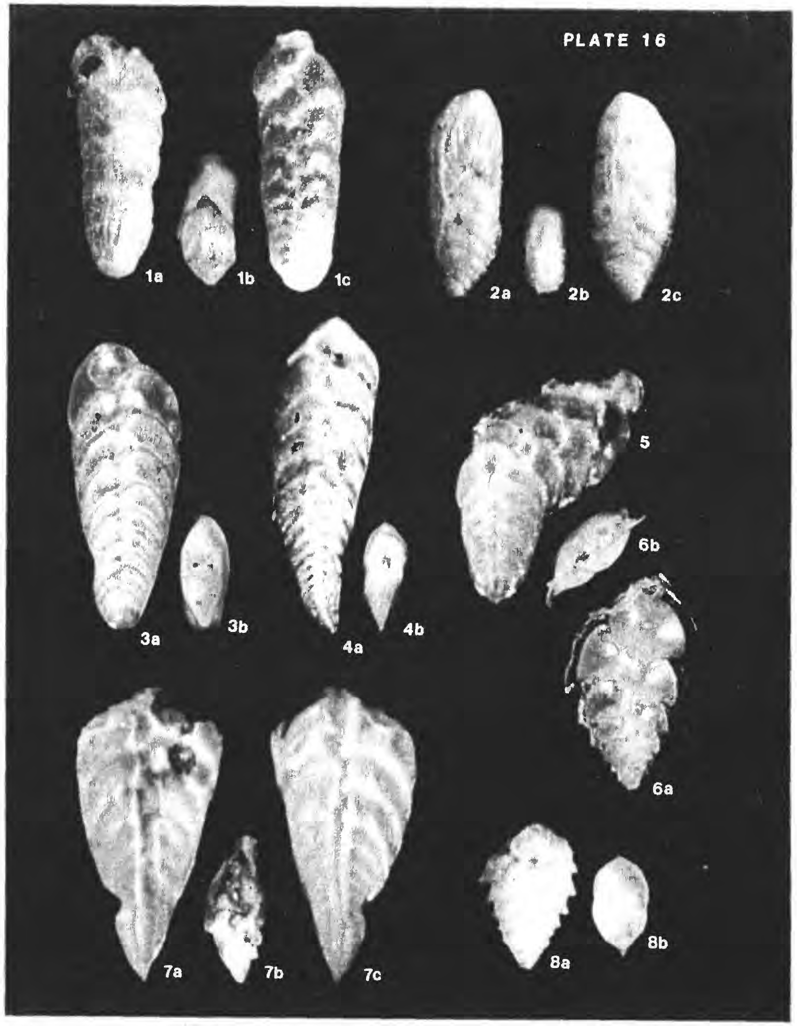


Plate 17

1. *Uvigerina juncea* Cushman and Todd. X125. a, side view; b, apertural view. Sample 46-48 cm.
2. *Uvigerina proboscidea* Schwager. X125. a, side view; b, apertural view. Sample 171-173 cm.
3. *Uvigerina hispida* Schwager. X125. a, side view; b, apertural view. Sample 46-48 cm.
4. *Uvigerina senticosa* Cushman. X60. a, side view; b, apertural view. Sample 120-122 cm.
5. *Uvigerina peregrina* Cushman. X60. a, side view; b, apertural view. Sample 248-250 cm.
6. *Uvigerina peregrina* dirupta Todd. X60. a, side view; b, apertural view. Sample 310-312 cm.
7. *Trifarina angulosa* (Williamson). X125. a, side view; b, apertural view. Sample 336.5-338 cm.
8. *Trifarina hughesi* (Galloway and Wissler). X125. a, side view; b, apertural view. Sample 171-173 cm.
9. *Epistominella exigua* (Brady). X125. a, dorsal view; b, apertural view; c, ventral view. Sample 336.5-338 cm.
10. *Epistominella evax* Bandy. X125. a, ventral view; b, apertural view; c, dorsal view. Sample 336.5-338 cm.
11. *Epistominella bradyana* (Cushman). X125. a, dorsal view; b, apertural view; c, ventral view. Sample 248-250 cm.

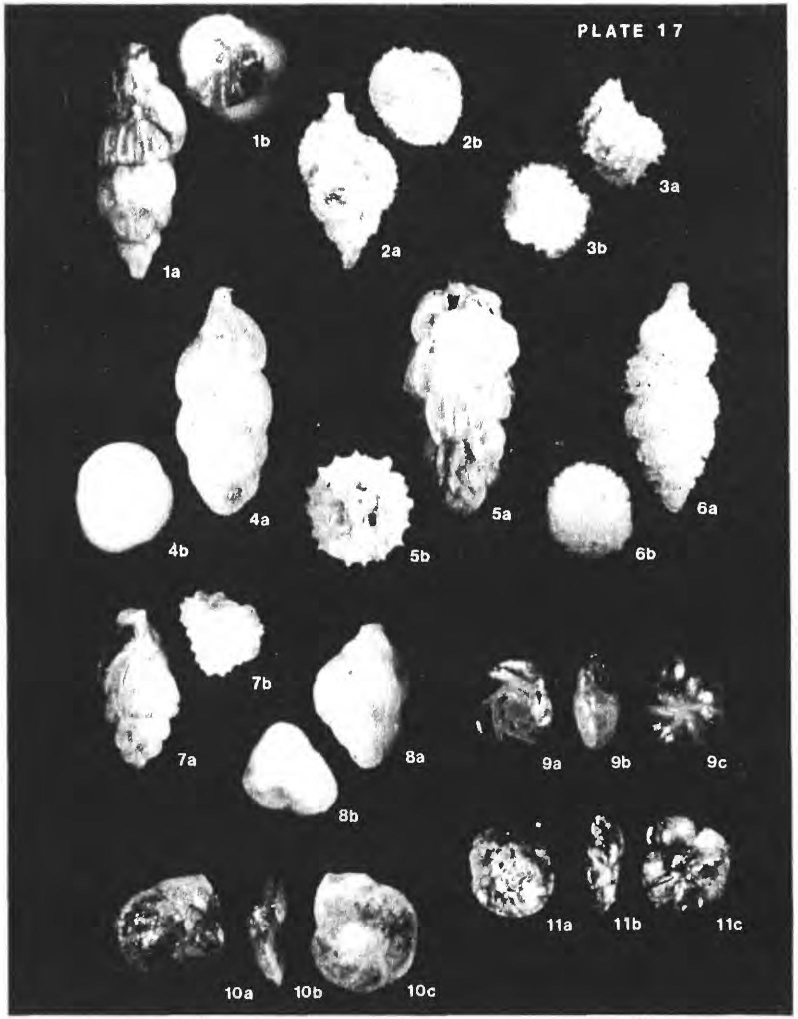


Plate 18

1. *Epistominella pacifica* (Cushman). X60. a, ventral view; b, apertural view; c, dorsal view. Sample 336.5-338 cm.
2. *Epistominella smithi* (Stewart and Stewart). X60. a, dorsal view; b, apertural view; c, ventral view. Sample 180-182 cm.
3. Unknown. X125. a, dorsal view; b, ventral view; c, apertural view. Sample 171-173 cm.
4. *Buccella tenerrima* (Bandy). X125. a, ventral view; b, apertural view; c, dorsal view. Sample 412-414.5 cm.
5. *Buccella frigida* (Cushman). X125. a, dorsal view; b, apertural view; c, ventral view. Sample 336.5-338 cm.
6. *Valvulineria laevigata* Phleger and Parker. X125. a, dorsal view; b, apertural view; c, ventral view. Sample 96.5-100 cm.
7. *Valvulineria araucana* (d'Orbigny). X125. a, dorsal view; b, apertural view; c, ventral view. Sample 180-182 cm.
8. Unknown. X125. a, dorsal view; b, edge view; c, ventral view. Sample 139-143 cm.

Plate 19

1. *Gyroidina tumidulus* (Brady). X125. a, ventral view; b, apertural view; c, dorsal view. Sample 445-447.5 cm.

2. *Gyroidina turgida* (Phleger and Parker). X125. a, dorsal view; b, apertural view; c, ventral view. Sample 152.5-154.5 cm.

3. *Gyroidina altiformis* Stewart and Stewart. X60. a, ventral view; b, apertural view; c, dorsal view. Sample 120-122 cm.

4. *Gyroidina altiformis* Stewart and Stewart. X60. Aberrant form. a, dorsal view; b, apertural view; c, ventral view. Sample 96.5-100 cm.

5. *Gyroidina quinqueloba* Uchio. X125. a, dorsal view; b, apertural view; c, ventral view. Sample 80-82 cm.

6. *Oridorsalis umbonatus* (Reuss). X60. a, ventral view; b, apertural view; c, dorsal view. Sample 346.5-349.5 cm.

7. *Gyroidina gemma* Bandy. X60. a, dorsal view; b, apertural view; c, ventral view. Sample 139-143 cm.

8. *Gyroidina gemma* Bandy. X60. a, ventral view; b, apertural view; c, dorsal view. Sample 210-212 cm.

9. *Hoeglundina elegans* (d'Orbigny). X60. a, ventral view; b, apertural view; c, dorsal view. Sample 80-82 cm.

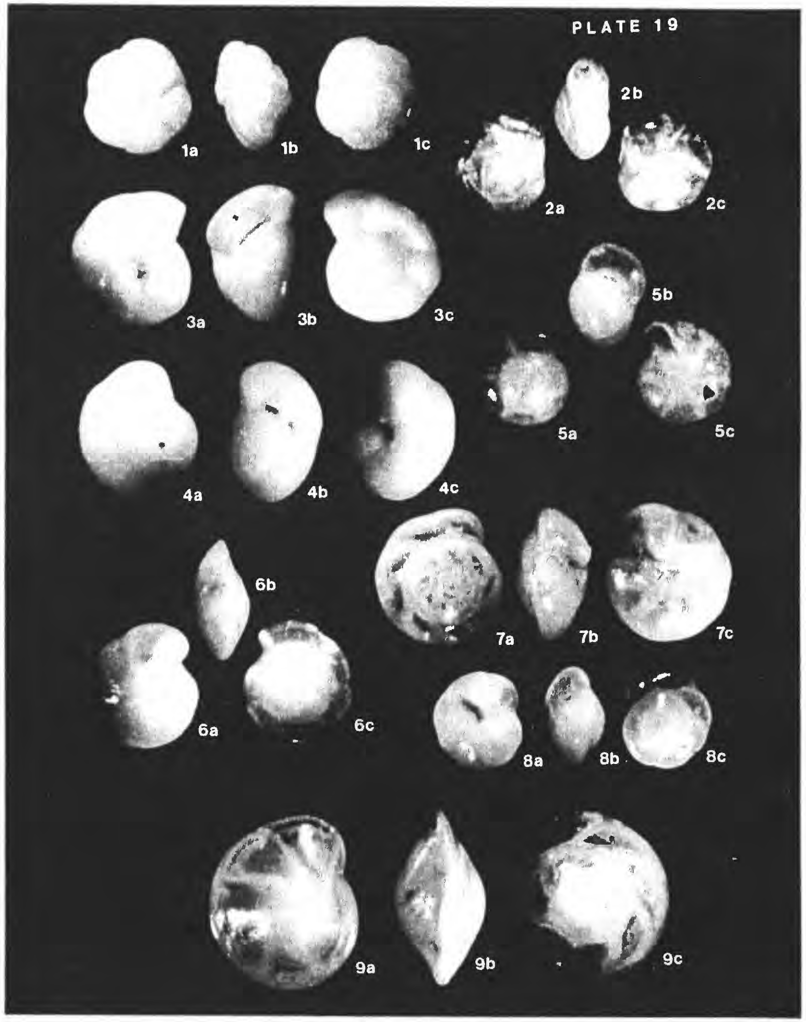


Plate 20

1. *Cassidulina minuta* Cushman. X125. a, side view; b, apertural view; c, side view. Sample 390-393 cm.

2. *Globocassidulina subglobosa* (Brady). X125. a, side view; b, apertural view; c, side view. Sample 133.5-136.5 cm.

3. *Cassidulina* sp. X60. a, side view; b, apertural view; c, side view. Sample 289.5-292 cm.

4. *Cassidulina cushmani* Stewart and Stewart. X125. a, side view; b, apertural view; c, side view; Sample 230-232 cm.

5. *Cassidulina translucens* Cushman and Hughes. X125. a, side view; b, apertural view; c, side view. Sample 248-250 cm.

6. *Cassidulina tumida* Natland. X125. a, side view; b, apertural view; c, side view. Sample 248-250 cm.

7. *Cassidulina tumida* Natland. X60. a, side view; b, apertural view; c, side view. Sample 248-250 cm, Rare.

8. *Cassidulina* sp. X125. a, side view; b, apertural view; c, side view. Sample 412-414.5 cm.

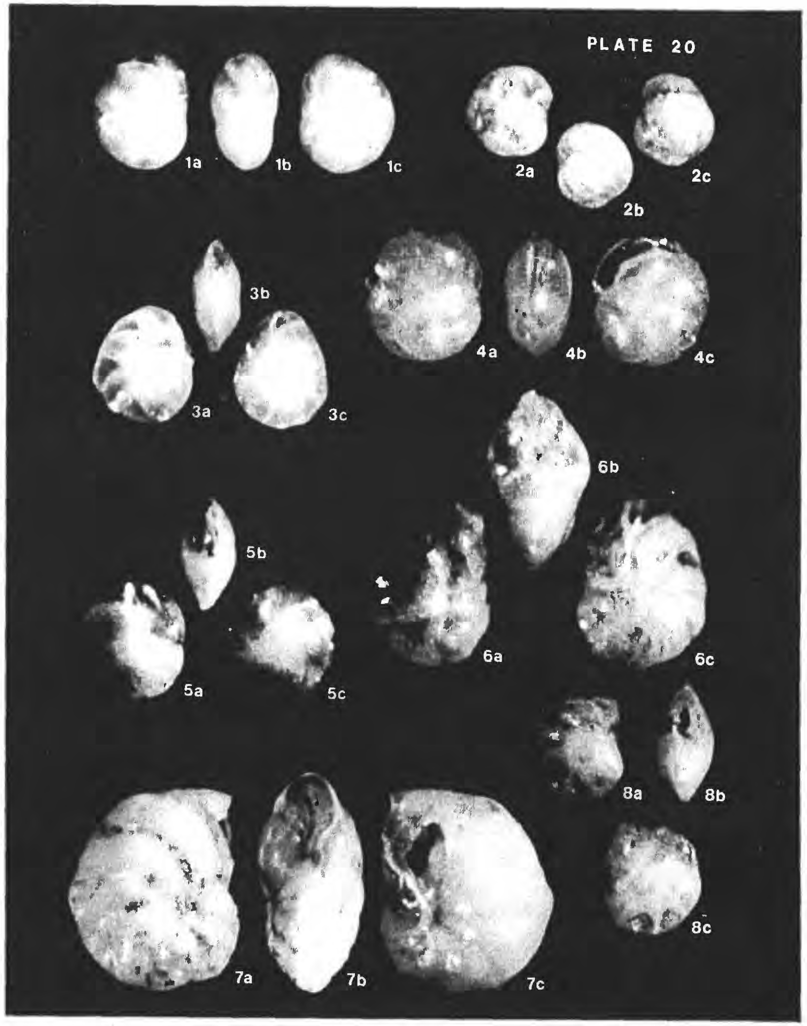


Plate 21

1. Fursenkoina cornuta (Cushman). X125. a, side view; b, apertural view; c, side view. Sample 180-182 cm.

2. Cassidulinoides bradyi (Norman). X125. a, side view; b, apertural view; c, side view. Sample 180-182 cm.

3. Chilostomella oolina Schwager. X60. a, side view; b, apertural view; c, edge view. Sample 412-414.5 cm.

4. Chilostomellina fimbriata Cushman. X60. a, side view; b, edge view; c, side view. Sample 248-250 cm.

5. Chilostomella ovoidea Reuss. X60. a, side view; b, apertural view; c, edge view. Sample 248-250 cm.

6. Pullenia salisburyi Stewart and Stewart. X125. a, side view; b, apertural view. Sample 133.5-136.5 cm.

7. Pullenia quinqueloba (Reuss). X125. a, apertural view; b, side view. Sample 230-232 cm.

8. Pullenia salisburyi Stewart and Stewart. X125. a, side view; b, apertural view. Sample 210-212 cm.

Plate 22

1. *Pullenia* sp. A. X125. a, side view; b, apertural view; c, side view. Sample 80-82 cm.
2. *Pullenia* sp. C. X60. a, side view; b, apertural view. Sample 270-272 cm.
3. *Pullenia bulloides* (d'Orbigny). X125. Four-chambered form. a, side view; b, apertural view; c, side view. Sample 369.5-372.5 cm.
4. *Pullenia bulloides* (d'Orbigny). X125. Five-chambered form. a, side view; b, apertural view; c, side view. Sample 369.5-372.5 cm.
5. *Pullenia* sp. B. X125. a, apertural view; b, side view. Sample 120-122 cm.
6. *Planulina ornata* (d'Orbigny). X60. a, dorsal view; b, apertural view; c, ventral view. Sample 289.5-292 cm.
7. *Planulina wuellerstorfi* (Schwager). X60. a, dorsal view, wet; b, dorsal view; c, apertural view; d, ventral view. Sample 167.5-170 cm.

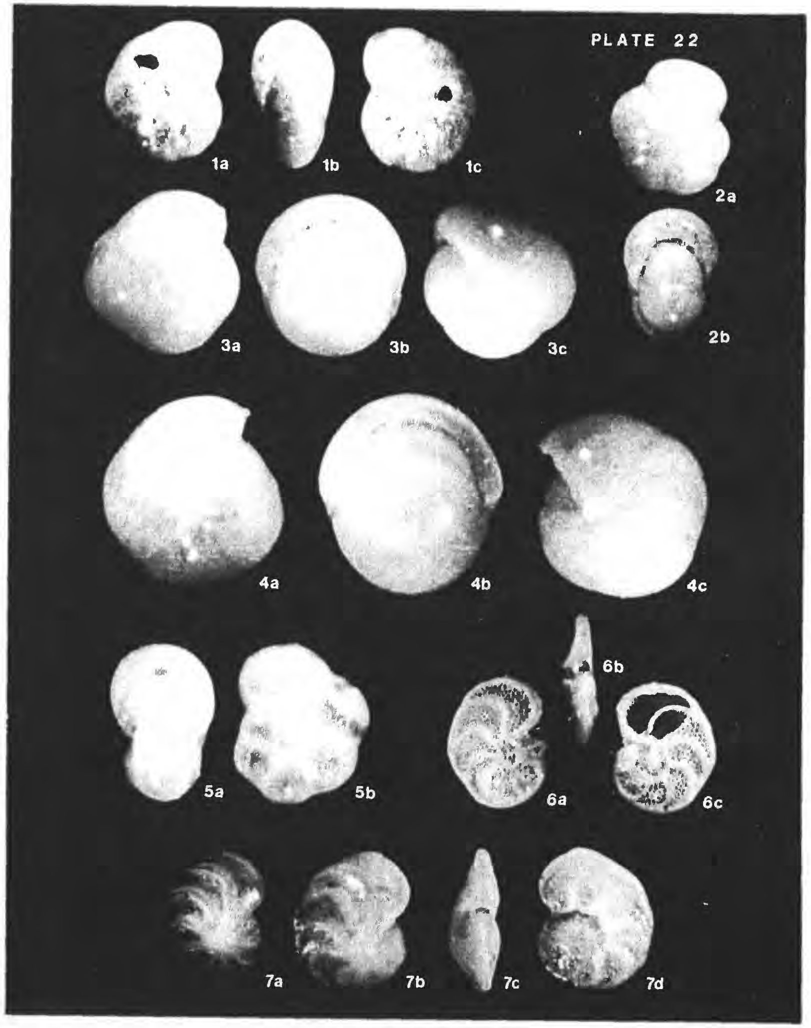


Plate 23

1. *Cibicidoides kullenbergi* (Parker). X60. a, dorsal view; b, apertural view; c, ventral view. Sample 152.5-154.5 cm.

2. *Cibicides mckannai* Galloway and Wissler. X60. a, dorsal view; b, apertural view; c, ventral view. Sample 120-122 cm.

3. *Rosalina columbiensis* (Cushman). X125. a, dorsal view; b, apertural view; c, ventral view. Sample 390-393 cm.

4. *Cibicides lobatulus* (Walker and Jacob). X60. a, ventral view; b, apertural view; c, dorsal view. Sample 120-122 cm.

5. *Rosalina columbiensis* (Cushman). X125. Irregular form. a, dorsal view; b, apertural view; c, ventral view. Sample 390-393 cm.

6. *Cibicides lobatulus* (Walker and Jacob). X60. a, dorsal view; b, apertural view; c, ventral view. Sample 210-212 cm.

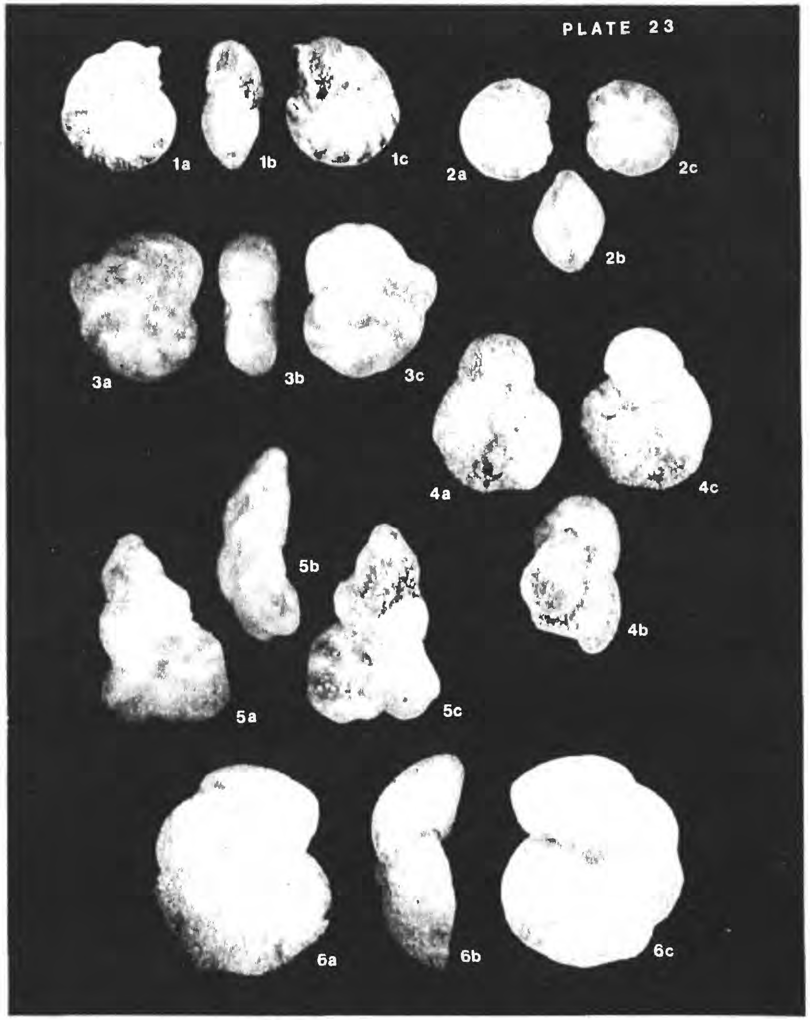


Plate 24

1. *Rosalina columbiensis* (Cushman). X125. Irregular form. a, ventral view; b, apertural view; c, dorsal view. Sample 390-393 cm.

2. *Dyocibicides* sp. X60. a, dorsal view; b, edge view; c, ventral view. Sample 430-432.5 cm.

3. *Dyocibicides biserialis* Cushman and Valentine. X125. a, ventral view; b, apertural view; c, dorsal view. Sample 346.5-349.5 cm.

4. Volcanic ash. X125. a, side view; b, top view. Sample 330-332 cm.

5. Echinoderm spine. X83. a, side view; b, cross section. Sample 248-250 cm.

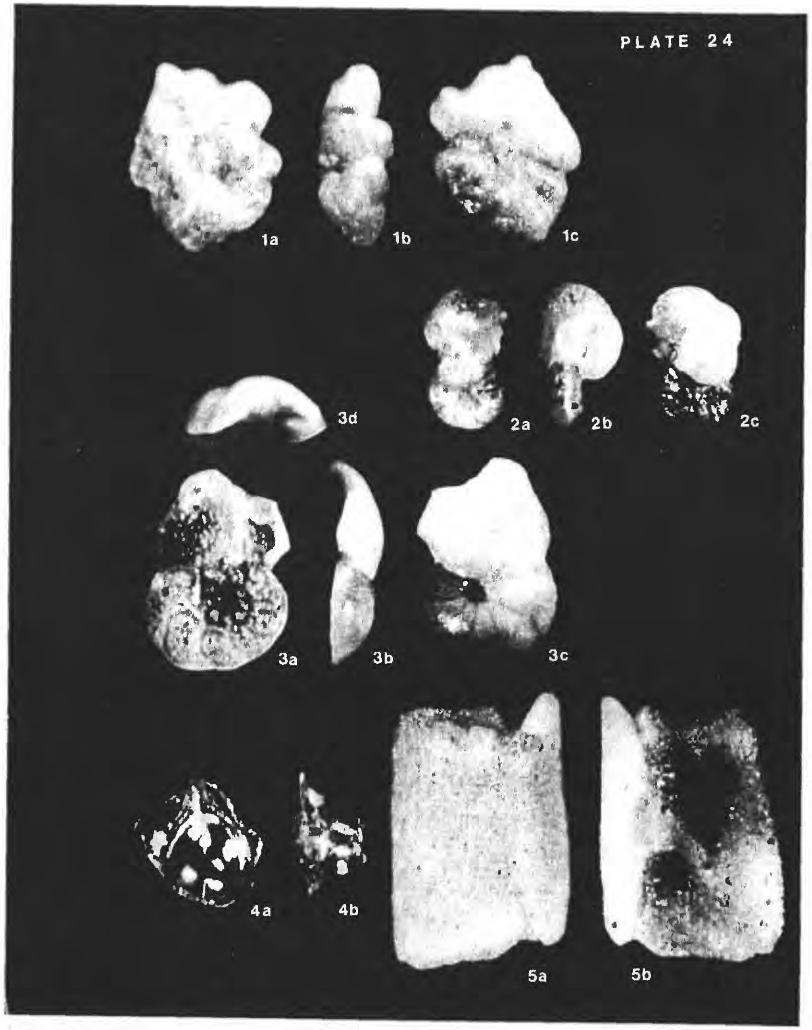
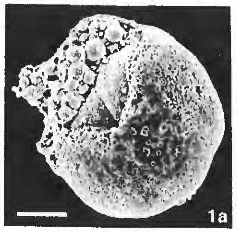


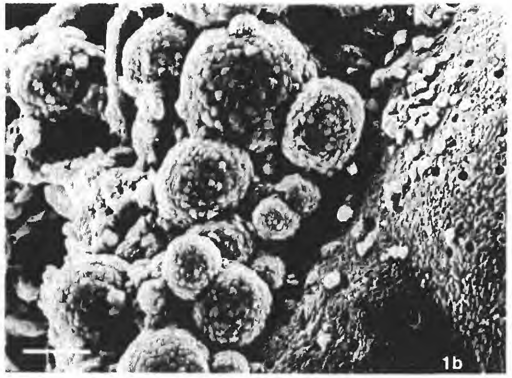
Plate 25

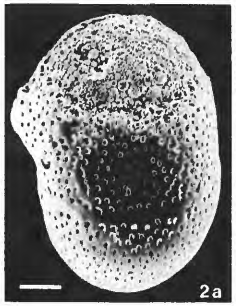
1. *Cassidulina minuta* Cushman. a, side view. Bar=50 μm. Note development of framboidal pyrite in ultimate chamber; b, detail of framboidal pyrite. Bar=10 μm. Note how framboids are composed of octahedral crystallites. Sample 336.5-338 cm.

2. *Melonis pompilioides* (Fichtel and Moll). a, edge view. Bar=50 μm. Note development of framboidal pyrite in ultimate chamber; b, detail of framboidal pyrite. Bar=20 μm. Note large size of pores in chamber wall. Sample 97.5-99.5 cm.

PLATE 25







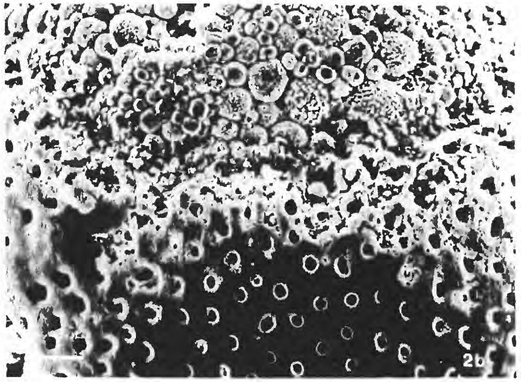


Plate 26

1. "Worm tube." a, side view. Bar=400 µm. Tube replaced by coarse, golden crystallites of pyrite; b, detail of surface structure. Bar=40 µm. Note mixture of pyrite framboids and calcite crytals. Sample 410-412.5 cm.

2. "Worm tube." a, side view. Bar=200 µm. Tube replaced by iridescent purple-blue framboidal pyrite crystallites; b, detail of surface structure. Bar=20 µm. Note well-formed pyrite framboids. Sample 346.5-349.5 cm.

PLATE 26

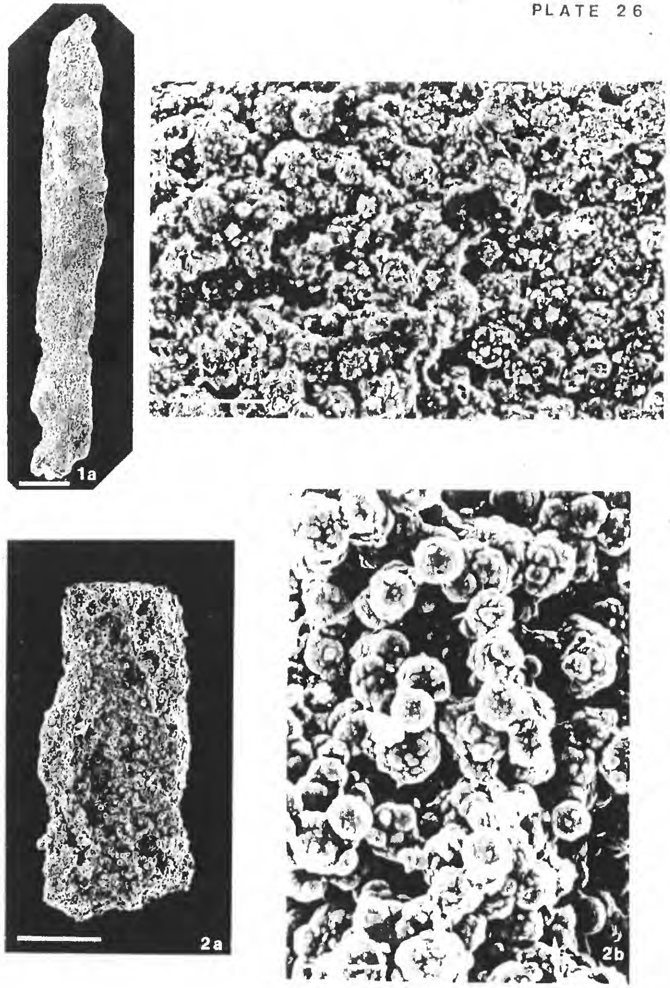


Plate 27

1. *Globobulimina affinis* (d'Orbigny). Bar=20 μm. Detail of crystalline structure of rust-brown stain on chamber wall. Deposit proved to be rich in iron, calcium, silica and potassium. Absence of framboids of pyrite is apparent. Sample 346.5-349.5 cm.

2. *Sigmoilina* sp. a, side view. Bar=50 μm. Note bore hole in ultimate chamber; b, detail of bore hole. Bar=20 μm. Hole is round and well-defined, suggesting it is the product of predation. Sample 133.5-136.5 cm.

3. *Uvigerina senticosa* Cushman. a, side view. Bar=50 μm. Note hole in ultimate chamber; b, detail of hole. Bar=20 μm. Irregular border of hole suggests it is the result of dissolution and mechanical breakage. Sample 346.5-349.5 cm.

PLATE 27

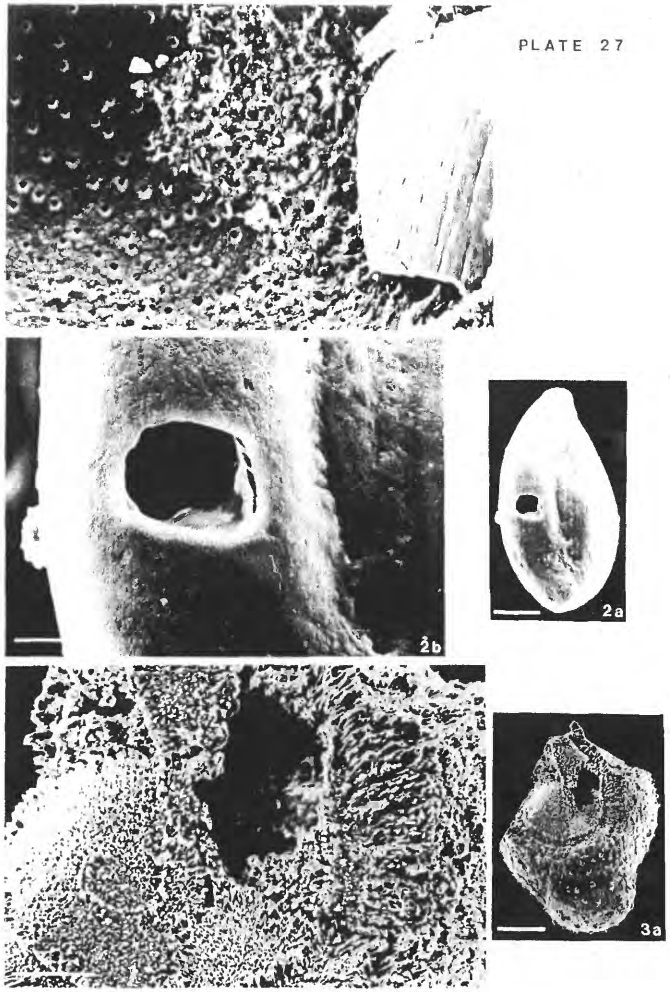


Plate 28

1. *Pullenia bulloides* (d'Orbigny). a, side view. Bar=40 µm. Note bore hole in ultimate chamber; b, detail of hole. Bar=10 µm. Evidence of predation is suggested by the large, round hole and internal shelf. Sample 310-312 cm.

2. *Rosalina columbiensis* (Cushman). a, ventral view. Bar=50 µm. Note bore holes in the last whorl; b, detail of bore hole in ultimate chamber. Bar=10 µm. Note incomplete bore hole, possibly the result of cessation of boring or of recrystallization or sediment infilling of the hole. Sample 120-122 cm.

3. *Globobulimina affinis* (d'Orbigny). a, side view. Bar=200 µm. Bore holes most prevalent in ultimate and penultimate chambers; b, detail of bore holes in ultimate chamber. Bar=20 µm. Predatory nature of these holes is suggested by their large, rounded outlines and distinctive beveled edges. Sample 40-43 cm.

PLATE 28

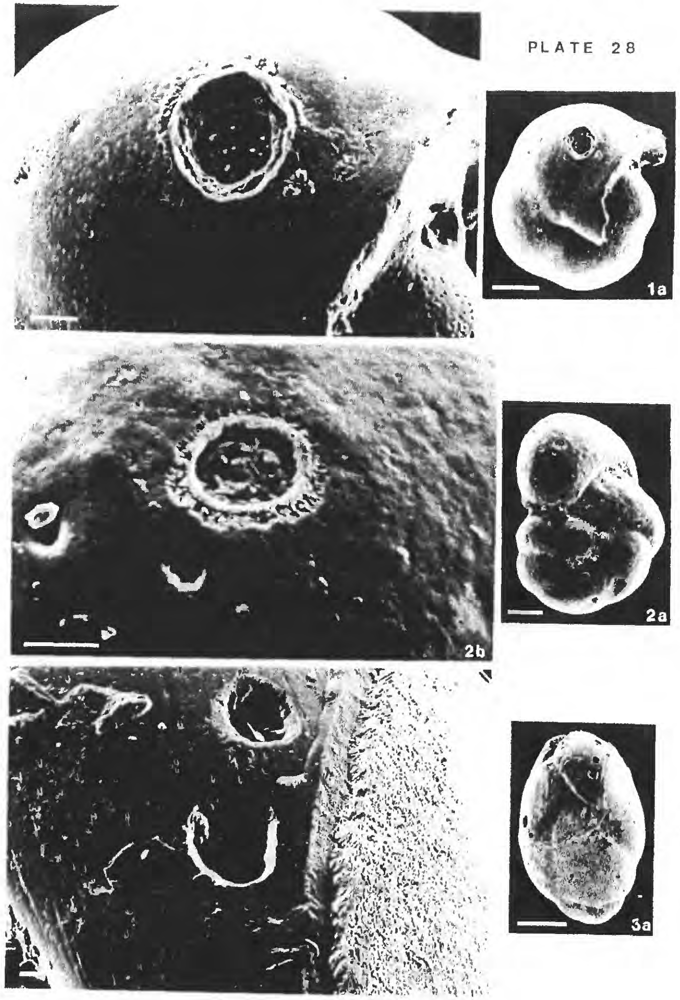


Plate 29

1. *Pyrgo murrhina* (Schwager). a, side view. Bar=100 μm. Note numerous bore holes in the same chamber; b, detail of predatory bore holes. Bar=40 μm. Note large, rounded nature of bore holes and pitted surface in the adjacent area; c, detail of pitted surface. Bar=20 μm. May be the result of mechanical abrasion by coarse sand grains. Sample 96.5-100 cm.

PLATE 29

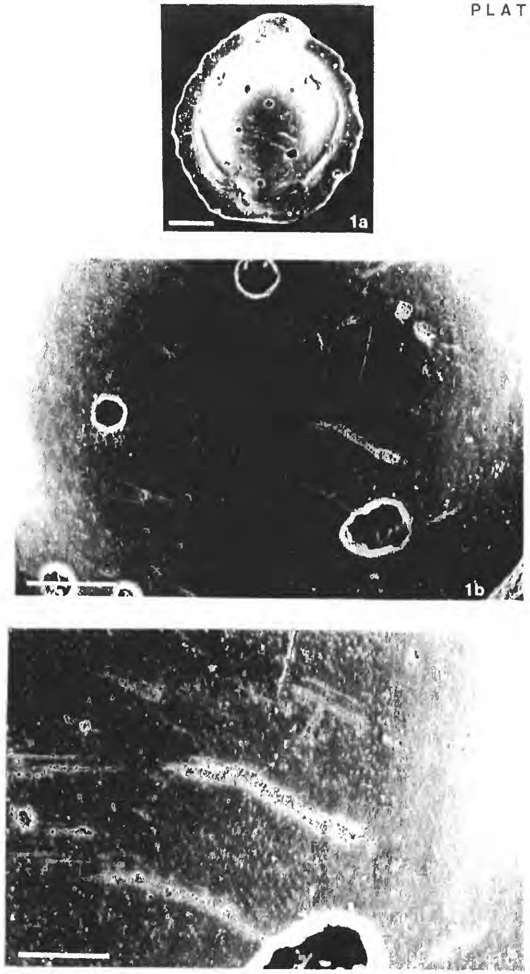
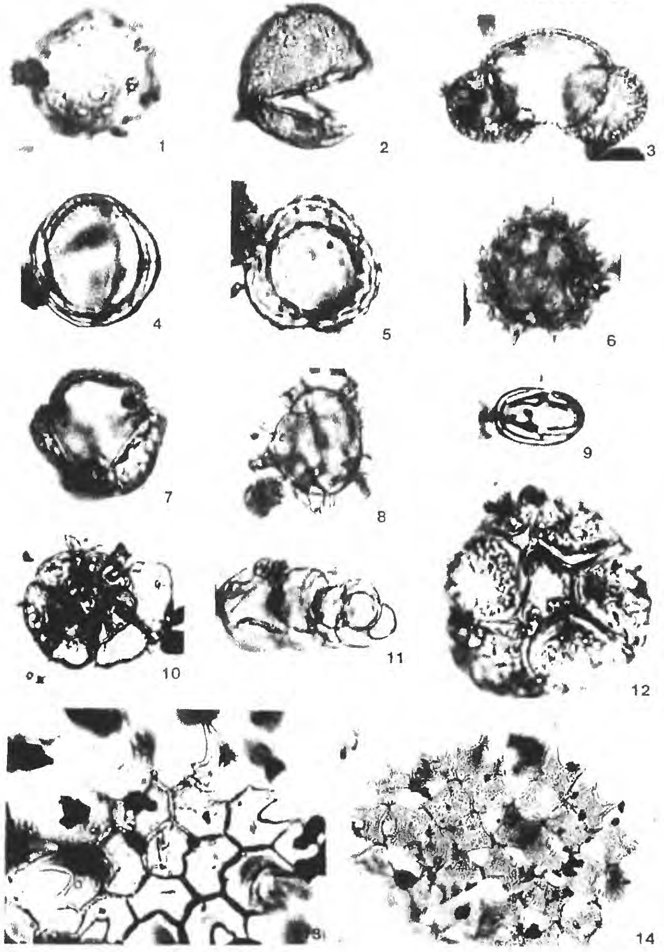


Plate 30

1. Chenopodiaceae-Amaranthaceae. 21 μm x 24 μm. Sample 168-170 cm.
2. *Sequoia*. 38 μm x 40 μm. Sample 210-212 cm.
3. *Pinus*. 60 μm x 108 μm. Sample 168-170 cm.
4. *Artemisia*. 28 μm x 28 μm. Sample 168-170 cm.
5. Low-spine Compositae. 28 μm x 28 μm. Sample 210-212 cm.
6. High-spine Compositae. 28 μm x 28 μm. Sample 168-170 cm.
7. *Quercus*. 25 μm x 36 μm. Sample 168-170 cm.
8. Dinoflagellate. 17 μm x 23 μm. Sample 168-170 cm.
9. *Lithocarpus*. 8 μm x 11 μm. Sample 210-212 cm.
10. Microforaminifer. Trochoidal, chitinous inner membrane. 21 μm x 25 μm. Sample 168-170 cm.
11. Microforaminifer. Triserial, chitinous inner membrane. 21 μm x 36 μm. Sample 168-170 cm.
12. Colonial fungi. 56 μm x 63 μm. Sample 168-170 cm.
13. *Pediastrum* sp. A. 30 μm x 42 μm. Sample 210-212 cm.
14. *Pediastrum* sp. B. 45 μm x 60 μm. Sample 210-212 cm.

PLATE 30



Appendices

Appendix 1. Detailed core description of S3-15G.

A 472 cm gravity core, S3-15G, was obtained off central California approximately 135 km southwest of Santa Cruz (36°23.53'N, 123°20.52'W). The core was recovered from the west levee of the Monterey fan valley, 18 km from the levee crest, at a depth of 3491 m. The core contains hemipelagic and overbank sediments from both the Monterey and Ascension canyon systems.

The core consists primarily of fine-grained hemipelagic (Tep) and turbiditic (Tet) muds; the muds differ in color and are interbedded throughout the length of the core. The hemipelagic muds are dark olive (5Y4/3), while the turbiditic muds are a darker olive gray (5Y4/2). The presence of an open burrow (114-115.5 cm downcore) and common dark olive (5Y4/3) and olive gray (5Y4/2) mottles suggests that these muds have undergone extensive bioturbation. Abundant turbiditic sand layers, lenses, and stringers are also present. The sands are cross-bedded (Tc) or laminated (Td) and most often appear dark olive gray (5Y3/2). Occasionally, however, the sand deposits are olive (5Y4/3), olive brown (2.5Y4/4) or reddish brown (5YR4/4). The sands are fine- to very fine-grained, commonly contain mud interlayers, and contact the adjacent mud deposits sharply, gradationally, or transitionally.

A detailed description and stratigraphic column (Figure A1) of core S3-15G are presented below.

0-37 cm
Hemipelagic mud

Unconsolidated (gooey) mud from 0-20 cm; transitional contact to consolidated mud below which lies from 20-37 cm; transitional lower contact.

37-46 cm
Turbiditic mud with hemipelagic mud mottles

Transitional upper contact and gradational lower contact; mottles <1 cm across.

45-48.5 cm
Sand (Td)

Gradational upper contact, transitional lower contact; muddy, structureless fine-grained dark olive gray (5Y3/2) sand.

48-60 cm
Turbiditic mud with hemipelagic mud mottles

Transitional upper contact and diagonal transitional lower contact from 55-60 cm.

55-68.5 cm
Hemipelagic mud with turbiditic mud mottles

Transitional upper and lower contacts; structureless except for mottles which are <0.5 cm across.

68-71 cm
Turbiditic mud

Transitional upper and lower contacts.

71-83.5 cm
Hemipelagic mud with few turbiditic mud mottles

Transitional upper and lower contacts.

83-95.5 cm
Turbiditic mud with hemipelagic mud mottles

Transitional upper and lower contacts.

95-96.5 cm
Hemipelagic mud

Transitional upper and lower contacts.

96-100.5 cm
Turbiditic mud with hemipelagic mud mottles

Transitional upper and lower contacts.

100-104 cm
Hemipelagic mud

Transitional upper and lower contacts; dark wisps present.

102-107.5 cm
Turbiditic mud

Transitional upper contact, distinct color change at lower contact.

107.5-129 cm
Hemipelagic mud

Distinct upper contact and transitional lower contact; open burrow at 114-115.5 cm, approximately 1 x 1.5 cm; dark wisps present from 122-127 cm; few turbiditic mud mottles from 107.5-110 cm.

129-134.5 cm
Turbiditic mud with hemipelagic mud mottles

Transitional upper and lower contacts.

133-136.5 cm
Sand (Td) with turbiditic mud interlayers

Transitional upper and sharp lower contact; ungraded fine-grained dark olive gray (5Y3/2) sand with thin mud interlayers.

135-138 cm
Hemipelagic mud

Sharp upper contact and transitional lower contact.

135-142.5 cm
Turbiditic mud with hemipelagic mud mottles

Transitional upper and lower contacts.

142-158.5 cm
Hemipelagic mud with sand (Td) stringer

Transitional upper and distinct lower contact; dark wisps from 147-150 cm; fine-grained dark olive gray (5Y3/2) sand stringer from 152-154.5 cm.

156-161.5 cm
Turbiditic mud with hemipelagic mud mottles

Distinct upper contact and transitional lower contact; lens of fine-grained dark olive gray (5Y3/2) sand on left half of core.

160.5-166.5 cm
Hemipelagic mud

Transitional upper and lower contacts.

165.5-172 cm
Turbiditic mud with hemipelagic mud mottles

Transitional upper and lower contacts; mottles <0.5 cm across.

171-174 cm
Sand (Td) with mud interlayers

Transitional upper contact and sharp lower contact; fine-grained dark olive gray (5Y3/2) sand layer with faint mud interlayers.

172.5-179.5 cm
Hemipelagic mud

Sharp upper contact, transitional lower contact.

179-180.5 cm
Turbiditic mud

Transitional upper and lower contacts.

180-182 cm
Sand (Td)

Transitional upper and lower contacts; fine-grained dark olive gray (5Y3/2) sand wisps and sand stringers.

180-189.5 cm
Hemipelagic mud

Transitional upper and lower contacts.

189.5-195 cm
Turbiditic mud with hemipelagic mud mottles

Transitional upper and lower contacts.

192.5-195 cm
Sand (Td)

Transitional upper and lower contacts; fine-grained dark olive gray (5Y3/2) sand stringer.

192.5-195 cm
Hemipelagic mud

Transitional upper and lower contacts.

195-198.5 cm
Turbiditic mud with hemipelagic mud mottles

Transitional upper and lower contacts.

197.5-202.5 cm
Hemipelagic mud

Transitional upper and lower contacts.

202-205 cm
Turbiditic mud with hemipelagic mud mottles

Transitional upper contact, sharp lower contact; mottles 1 cm across.

204.5-206.5 cm
Sand (Td)

Sharp upper and lower contacts; fine-grained, ungraded dark olive gray (5Y3/2) sand layer with small mud blebs.

206-216 cm
Turbiditic mud with hemipelagic mud mottles

Sharp upper contact, transitional lower contact; small fine-grained dark olive gray (5Y3/2) sand bleb with transitional contacts from 210.5-211 cm; few small hemipelagic mud mottles from 215-216 cm.

215-229.5 cm
Turbiditic mud

Transitional upper and lower contacts; few dark wisps from 221-225 cm.

227.5-231 cm
Sand (Td)

Transitional upper contact and sharp lower contact; two fine-grained dark olive gray (5Y3/2) sand layers with a turbiditic mud interbed.

229-240.5 cm
Turbiditic mud

Sharp upper contact, transitional lower contact; sandy mud layer at 237 cm with transitional contacts; small dark olive gray (5Y3/2) sand patch from 230-231 cm.

240-245.5 cm
Hemipelagic mud

Transitional upper and lower contacts; very fine-grained diagonal sandy mud layer from 239.5-241.5 cm, transitional upper and lower contacts.

245-250.5 cm
Turbiditic mud

Transitional upper and lower contacts.

243-255 cm
Sands (Tc and Td) with few mud interlayers

Transitional upper and lower contacts; medium fine-grained dark olive gray (5Y3/2) sand layers: diagonal interval of cross-bedded (Tc) sands from 247-249 cm with transitional upper and sharp lower contacts; triangular sand (Td) deposit from 247.5-249.5 cm; sands (Td) from 250-254 cm; four mud stringers between sands (Td) from 252-254 cm.

253-258.5 cm
Hemipelagic mud

Transitional upper and lower contacts.

257-259 cm
Turbiditic mud

Transitional upper and lower contacts.

257.5-259.5 cm
Sand (Td)

Transitional upper contact and sharp, but irregular, lower contact; very fine-grained dark olive gray (5Y3/2) sand layer.

258.5-266.5 cm
Hemipelagic mud

Sharp, irregular upper contact and transitional lower contact.

266.5-269 cm
Turbiditic mud with hemipelagic mud mottles

Transitional upper and lower contacts.

267.5-269.5 cm
Hemipelagic mud

Transitional upper and lower contacts.

269.5-272.5 cm
Turbiditic mud with hemipelagic mud mottles

Transitional upper and lower contacts; dark wisps present.

270.5-276 cm
Hemipelagic mud

Transitional upper and lower contact; dark wisps present, especially from 272-275 cm.

275.5-276.5 cm
Sand (Td)

Transitional upper contact and irregular, sharp lower contact; very fine-grained dark olive gray (5Y3/2) sand layer.

276-280 cm
Hemipelagic mud

Sharp upper contact, transitional lower contact; dark wisps present.

279.5-295 cm
Turbiditic mud

Transitional upper contact and irregular, sharp lower contact; dark wisps present from 282-284 cm; discontinuous sand laminae from 286-287 cm, dark olive gray (5Y3/2) with a touch of olive brown (2.5Y4/4), exhibiting transitional upper and lower contacts.

294-298 cm
Sand (Tc)

Irregular, sharp upper contact and sharp lower contact; fine-grained dark olive gray (5Y3/2) sand layer with a few deformed mud interlayers between 294 and 295 cm.

296.5-300 cm
Turbiditic mud

Sharp upper contact and transitional lower contact.

300 cm
Sand (Td)

Transitional upper contact and core catcher for lower contact; dark olive gray (5Y3/2) sand stringer.

300-307 cm
Turbiditic mud

Upper contact disturbed due to coring, transitional lower contact; dark wisps and four dark olive gray (5Y3/2) sand patches present from 302.5-305 cm.

305.5-308.5 cm
Sand (Td)

Transitional upper and lower contacts; dark olive gray (5Y3/2) sand patches surrounding a dark olive gray (5Y3/2) graded sand lens which fines upward.

307-320.5 cm
Turbiditic mud

Transitional upper contact and distinct lower contact; dark wisps present from 310.5-313 cm and 317-319 cm; discontinuous dark olive gray (5Y3/2) sandy mud layer from 314.5-316.5 cm with transitional upper and lower contacts.

319-321.5 cm
Sand (Td)

Distinct upper contact and sharp lower contact; muddy dark olive gray (5Y3/2) sand layer grading upward from fine-grained to very fine-grained.

320-330.5 cm
Turbiditic mud

Sharp upper contact and transitional lower contact; few dark wisps and small sand patches present.

329.5-332 cm
Sandy mud

Transitional upper contact and distinct lower contact; very fine-grained dark olive gray (5Y3/2) sandy mud layer.

330.5-337 cm
Turbiditic mud

Distinct upper contact, transitional lower contact.

336-337.5 cm
Sand (Td)

Transitional upper contact and sharp lower contact; sand layer which grades upward from fine-grained to very fine-grained; upper sand is olive brown (2.5Y4/4), lower sand is dark olive gray (5Y3/2).

337-345 cm
Turbiditic mud

Sharp upper contact, transitional lower contact.

344-346 cm
Sand (Td)

Transitional upper contact and sharp lower contact; very fine-grained dark olive gray (5Y3/2) sand stringer from 344-345 cm; sandy mud present between 344 and 346 cm with mud interlayers; fine-grained olive brown (2.5Y4/4) sand lens from 345-346 cm.

345-357 cm
Turbiditic mud

Sharp upper contact and sharp to transitional lower contact; fine-grained dark olive gray (5Y3/2) sand lens, 0.2 x 1.0 cm with transitional contacts at 347 cm; hemipelagic mud bleb at 354.5 cm.

354.5-363.5 cm
Sand (Td)
Upper and lower contacts are irregular and sharp to transitional; deformed fine-grained olive (5Y4/3) sand layer with mud interlayers, some grading seen with fine-grained sands inside to very fine-grained sands outside.

355.5-366 cm
Turbiditic mud

Sharp to transitional upper contact and transitional lower contact.

364.5-366.5 cm
Sand (Td)

Transitional upper and sharp lower contact; discontinuous sand layer, grading from fine-grained to very fine-grained, lower dark olive gray (5Y3/2) sand grades up into the upper olive brown (2.5Y4/4) sand.

366-371 cm
Turbiditic mud

Sharp upper contact and transitional lower contact.

369.5-373 cm
Sandy mud

Transitional upper and lower contacts.

372-374.5 cm
Sand (Td)

Transitional upper and sharp lower contact; fine-grained diagonal sand lens terminating in layered muds, olive brown (2.5Y4/4) with dark olive gray (5Y3/2) around edges.

372-378 cm
Hemipelagic mud
Sharp to transitional upper contact; transitional lower contact; irregular hemipelagic mud interval.

374.5-378.5 cm
Turbiditic mud

Transitional upper and lower contacts; irregular turbiditic mud interval; hemipelagic mud bleb from 375.5-376.5 cm.

377.5-380 cm
Sand (Td)

Transitional upper contact and sharp lower contact; discontinuous sand layer, grading upward from fine to very fine-grained sand, left side sand is olive (5Y4/3), right side sand is olive brown (2.5Y4/4) with dark olive gray (5Y3/2) around edges.

378-380.5 cm
Hemipelagic mud

Transitional to sharp upper contact, transitional lower contact; two sand blebs from 379-380 cm.

380-382 cm
Turbiditic mud

Transitional upper and lower contacts; two very fine-grained reddish brown (5YR4/4) sand lenses from 381-383 cm, distinct upper and lower contacts.

380.5-390.5 cm
Hemipelagic mud

Transitional upper and lower contacts; a faint (questionable) discontinuous interval of turbiditic mud with hemipelagic mud mottles appears from 385-389 cm.

390-392 cm
Turbiditic mud with hemipelagic mud mottles

Transitional upper and lower contacts; few tiny dark olive gray (5Y3/2) sand blebs appear at the left side of the lower contact.

391.5-397.5 cm
Hemipelagic mud

Transitional upper and lower contacts; hard unidentifiable lump, part of which is reddish brown (5YR4/4), is present from 393-394 cm.

397-398.5 cm
Turbiditic mud

Transitional upper and lower contacts.

398-408 cm
Hemipelagic mud

Transitional upper and lower contact; fine-grained olive (5Y4/3) sand patch with transitional contacts from 398.5-399 cm; several sandy mud intervals between 399.5 and 405.5 cm; two fine-grained reddish brown sand lenses with transitional contacts are located at 401-402 cm and 402.5-404 cm; olive (5Y4/3) sand patch present at 402.5 cm.

406-408 cm
Sandy mud

Transitional upper and lower contacts.

406.5-408 cm
Sand (Td)

Transitional upper contact and distinct lower contact; olive (5Y4/3) sand laminae grading upward from fine-grained to very fine-grained.

407.5-417 cm
Hemipelagic and turbiditic muds combined

Distinct upper contact and transitional lower contact; hemipelagic mud from 407.5-416.5 cm; turbiditic mud lenses from 407.5-409 cm, 409.5-413 cm, 415-417 cm, all contacts transitional; sandy mud patch from 412-413.5 cm on left side of core; two fine-grained olive (5Y4/3) sand lenses from 412-414 cm on right side of core, surrounded by sandy mud from 412-415 cm.

416-420 cm
Sandy mud

Transitional upper and lower contacts; four fine-grained olive (5Y4/3) sand blebs from 416.5-417.5 cm; hemipelagic mud bleb from 418.5-419.5 cm.

416-424.5 cm
Hemipelagic mud

Transitional upper and lower contacts; fine-grained olive brown (2.5Y4/4) sand lens from 420-421.5 cm with transitional contacts and a mud interlayer.

421.5-424.5 cm
Turbiditic mud

Transitional upper and lower contacts; discontinuous turbiditic mud layer.

422.5-425 cm
Sand (Td)

Transitional upper contact and sharp lower contact; discontinuous fine-grained dark olive gray (5Y3/2) sand lens grading to mostly olive brown (2.5Y4/4).

424.5-425.5 cm
Hemipelagic mud

Transitional upper and lower contacts.

425.5-427 cm
Turbiditic mud

Transitional upper and lower contacts.

426.5-427.5 cm
Sand (Td)

Transitional upper contact and sharp lower contact; fine-grained dark olive gray (5Y3/2) sand laminae.

427-439.5 cm
Hemipelagic mud

Sharp upper contact and transitional lower contact; fine-grained sand patch from 427-429 cm, grading from olive brown (2.5Y4/4) at the bottom to dark olive gray (5Y3/2) at the top with transitional contacts; fine-grained olive brown (2.5Y4/4) sand bleb with transitional contacts at 435.5-436 cm; fine-grained olive brown (2.5Y4/4) sand lens with sharp upper, side and lower contacts from 435.5-437.5 cm; turbiditic mud interlayers from 438-439 cm.

437.5-439.5 cm
Turbiditic mud

Transitional upper and lower contacts; turbiditic mud stringer with single fine-grained dark olive gray sand bleb at 439.5 cm.

437.5-444.5 cm
Hemipelagic and turbiditic muds combined

Transitional upper and lower contacts; interfingering of discontinuous hemipelagic and turbiditic mud layers; few dark wisps present.

443.5-446 cm
Turbiditic mud

Transitional upper and lower contacts; hemipelagic mud bleb at 435 cm.

444.5-447.5 cm
Hemipelagic mud

Transitional upper and lower contacts.

446-460.5 cm
Turbiditic mud

Transitional upper and lower contacts; few dark wisps near 451 and 456 cm; fine-grained dark olive gray sand blebs from 454-455 and 456-456.5 cm.

459-462 cm
Sand (Td)

Transitional upper and lower contacts; crack and separation of the core partly along a fine-grained olive brown (2.5Y4/4) sand layer; crack continues along the left side of the core from 456-460.5 cm and across the core from 458.5-459.5 cm and 460.5-461.5 cm; fine-grained dark olive gray sand (5Y3/2) surrounds the olive brown from 459-462 cm.

460.5-472 cm
Turbiditic mud

Transitional upper contact, lower contact is the bottom of the core; possible hemipelagic mud bleb from 463-464 cm; dark wisps present from 466-468 cm; crack along the right side of the core from 469.5-471 cm.

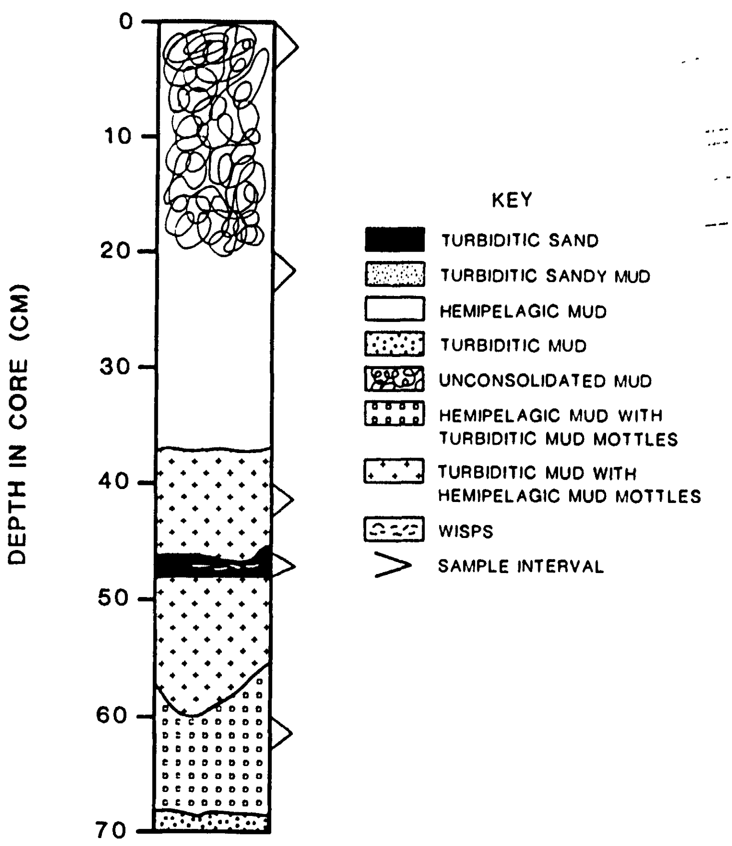


Figure A1. Detailed lithology of Monterey Fan core S3-15G.

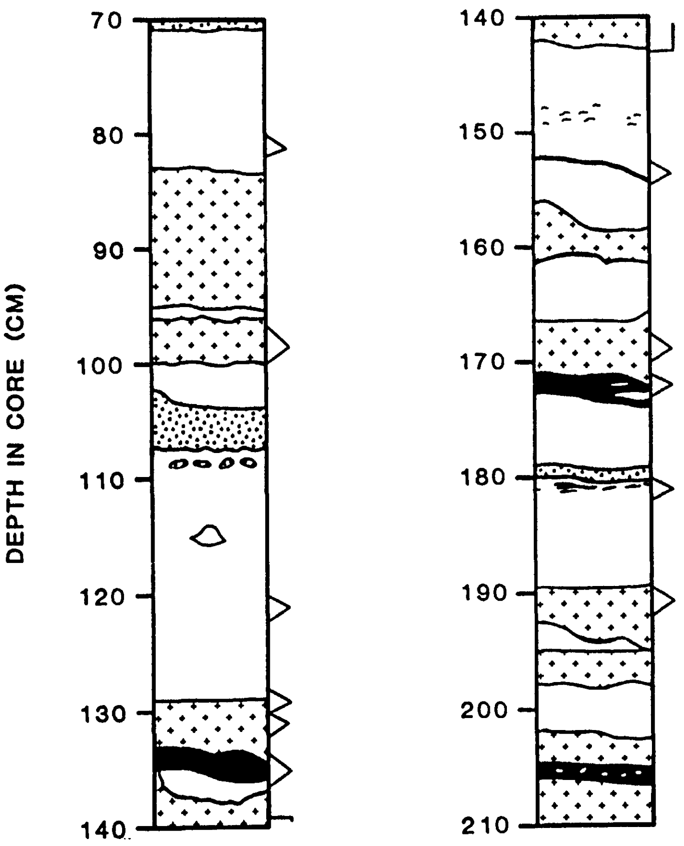


Figure A1. Detailed lithology of Monterey Fan core S3-15G (continued).

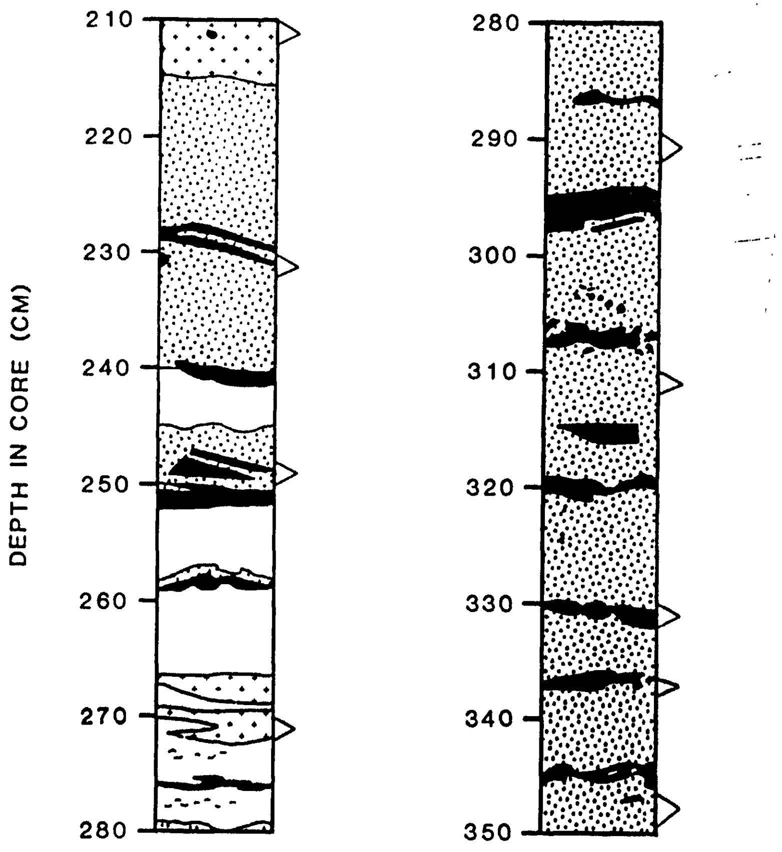


Figure A1. Detailed lithology of Monterey Fan core S3-15G (continued).

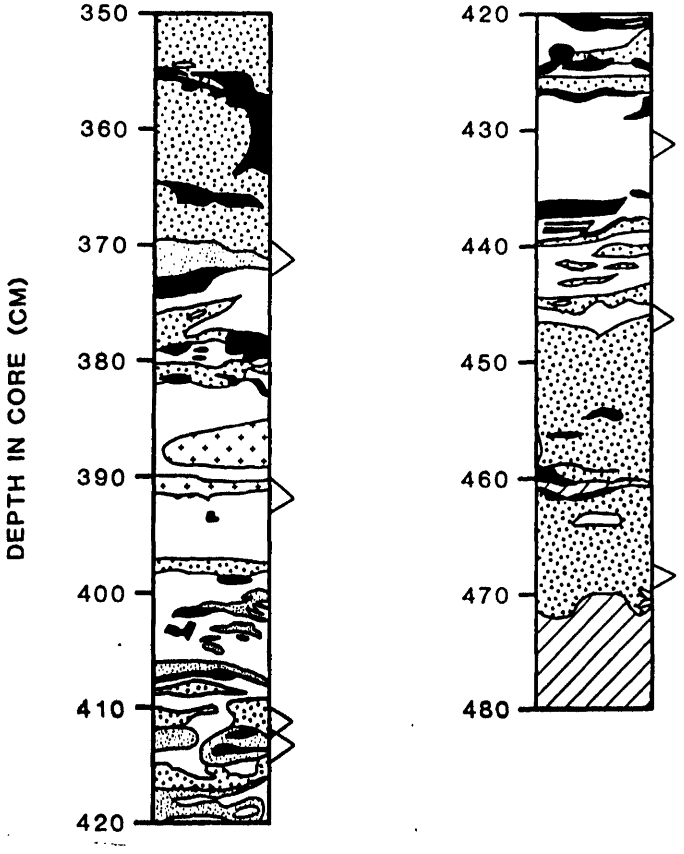


Figure A1. Detailed lithology of Monterey Fan core S3-15G (continued).

Appendix 2. Benthonic foraminiferal faunal reference list.

Modern names, original descriptions and references are provided for the benthonic foraminifers identified in this study. Species considered displaced in the Monterey Fan overbank deposits are preceeded by an asterisk. Illustrated specimens are denoted by plate and figure numbers provided within brackets following the species description.

Anomalina globulosa Chapman and Parr, 1937, p. 117, pl. 9, fig. 27.

Astacolus sp., Loeblich and Tappan, 1953, p. 53-54, pl. 9, fig. 5 [pl. 6, fig. 1].

*_Astrononion gallowayi_ Loeblich and Tappan = *Astrononion stellatum* Cushman and Edwards, 1937, p. 32, pl. 3, figs. 9-11 [pl. 11, fig. 2].

Bathysiphon sp. Several fragmented, straight, open-ended tubes represent this genus. Walls are composed of sponge spicules or coarse sand grains [pl. 1, figs. 1 (?), 3].

*_Bolivina advena striatella_ Cushman, 1925a, p. 30, pl. 5, fig. 3 [pl. 16, fig. 1].

*_Bolivina argentea_ Cushman, 1926b, p. 42, pl. 6, fig. 5 [pl. 16, figs. 3-4].

*_Bolivina interjuncta bicostata_ Cushman, 1937, p. 116, pl. 22, fig. 23 [pl. 16, fig. 7].

*_Bolivina pacifica_ Cushman and McCulloch = *Bolivina acerosa* Cushman var. *pacifica* Cushman and McCulloch, 1942, p. 185, pl. 21, figs. 2-3 [pl. 15, fig. 5].

*_Bolivina seminuda_ Cushman, 1911, p. 34, fig. 55 [pl. 15, figs. 6-8].

*_Bolivina tongi filacostata_ Cushman and McCulloch, 1942, p. 214-215, pl. 27, figs. 7-11 [pl. 16, fig. 2].

*_Buccella frigida_ (Cushman) = *Pulvinulina frigida* Cushman, 1922, p. 12 [pl. 18, fig. 5].

*_Buccella tenerrima_ (Bandy) = *Rotalia tenerrima* Bandy, 1950, p. 278-279, pl. 42, fig. 3 [pl. 18, fig. 4].

*_Bulimina denudata_ Cushman and Parker = *Bulimina pagoda* Cushman var. *denudata* Cushman and Parker, 1938, p. 57, pl. 10, figs. 1-2 [pl. 13, fig. 2].

*_Bulimina pagoda_ Cushman, 1927a, p. 152, pl. 2, fig. 16 [pl. 13, fig. 4].

Bulimina rostrata Brady, 1884, p. 408, pl. 51, figs. 14-15 [pl. 13, fig. 1].

*_Bulimina striata mexicana_ Cushman, *in* Cushman and Parker, 1940, p. 16, pl. 3, fig. 9 [pl. 13, figs. 5-6].

*_Buliminella curta_ Cushman, 1925a, p. 33, pl. 5, fig. 13 [pl. 12, fig. 6].

*_Buliminella elegantissima_ (d'Orbigny) = *Bulimina elegantissima* d'Orbigny, 1839a, p. 51, pl. 7, figs. 13-14 [pl. 12, fig. 7].

*_Buliminella tenuata_ Cushman = *Buliminella subfusiformis* Cushman var. *tenuata* Cushman, 1927a, p. 149, pl. 2, fig. 9 [pl. 12, fig. 9].

*_Cassidulina cushmani_ Stewart and Stewart, 1930, p. 71, pl. 9, fig. 5 [pl. 20, fig. 4].

*_Cassidulina minuta_ Cushman, 1933, p. 92-93, pl. 10, fig. 3 [pl. 20, fig. 1].

*_Cassidulina translucens_ Cushman and Hughes, 1925, p. 15, pl. 2, fig. 5 [pl. 20, fig. 5].

*_Cassidulina tumida_ Natland, 1938, p. 148-149, pl. 6, figs. 2-3 [pl. 20, figs. 6-7].

Cassidulina spp. Six individuals were recovered, one of which shows similarities to *Cassidulina norcrossi* Cushman [pl. 20, figs. 3, 8].

*_Cassidulinoides bradyi_ (Norman) = *Cassidulina bradyi* Norman, in Brady, 1881, p. 59 [pl. 21, fig. 2].

*_Chilostomella oolina_ Schwager, 1878, p. 527, pl. 1, fig. 16 [pl. 21, fig. 3].

*_Chilostomella ovoidea_ Reuss, 1850, p. 380, pl. 48, fig. 12 [pl. 21, fig. 5].

Chilostomella spp. Several crushed and fragmented ovoid tests, displaying two very involute chambers per specimen, are assigned to this genus. The walls of the specimens are very finely perforate and the apertures are usually obscured or missing due to poor preservation.

*_Chilostomellina fimbriata_ Cushman, 1926a, p. 78-79, pl. 11 fig. 22 [pl. 21, fig. 4].

Cibicides lobatulus (Walker and Jacob) = Nautilus lobatulus Walker and Jacob, 1798, p. 642, pl. 14, fig. 36 [pl. 23, figs. 4, 6].

*Cibicides mckannai Galloway and Wissler, 1927, p. 65-66, pl. 10, figs. 5-6 [pl. 23, fig. 2].

Cibicides spp. Rare and poorly preserved trochoidal specimens with plano-convex to biconvex tests and peripheral interiomarginal apertures are assigned to this genus.

Cibicidoides kullenbergi (Parker) = Cibicides kullenbergi Parker, in Phleger, Parker and Peirson, 1953, p. 49, pl. 11, figs. 7-8, [pl. 23, fig. 1].

Cyclammina sp. The single specimen displays a greatly pyritized, planispiral involute test comprised of approximately 14 chambers. The aperture, partly obscured by pyrite, appears interiomarginal [pl. 2, fig. 1].

*Dentalina californica Cushman and Gray, 1946, p. 66, p. 12 figs. 3-5 [pl. 6, fig. 8].

Dentalina frobisherensis Loeblich and Tappan, 1953, p. 55-56, pl. 10, figs. 1-9 [pl. 6, fig. 10].

Dentalina mucronata Neugeboren, 1856, p. 83, pl. 3, figs. 8-11 [pl. 6, fig. 11].

Dentalina pauperata d'Orbigny, 1846, p. 46, pl. 1, figs. 57-58 [pl. 6, fig. 9].

Dentalina spp. Rare, and often broken, arcuate uniserial tests are assigned to this genus. Most specimens display terminal radiate apertures and somewhat oblique sutures. One individual's aperture appears terminal and rounded, displaying neither a cylindrical neck and phialine lip, nor radiate characteristics [pl. 6, fig. 7].

Dyocibicides biserialis Cushman and Valentine, 1930, p. 31, pl. 10, figs. 1-2 [pl. 24, fig. 3].

Dyocibicides sp. The single specimen is characterized by an initial biconvex, trochoidal test, later uncoiling and growing in an irregular pattern. The aperture of the later portion is a single, elongate interiomarginal slit with a very slight lip. Due to the variable nature of test development common to this genus, the individual may indeed be an additional example of D. biserialis Cushman and Valentine.

Eggerella bradyi (Cushman) = Verneuilina bradyi Cushman, 1911, p. 54-55, t.f. 87 [pl. 2, fig. 5].

Eggerella spp. Finely arenaceous specimens displaying four to five chambers per whorl in their early stages and only three in the adult are assigned to this genus. The aperture is always poorly preserved but appears to be a small slit on the inner margin of the last formed chamber [pl. 2, fig. 6].

*Elphidium excavatum clavata Cushman = Elphidium incertum (Williamson) var. clavatum Cushman, 1930, p. 20, pl. 7, fig. 10 [pl. 12, fig. 1].

*Elphidium excavatum lidoensis Cushman = Elphidium lidoense Cushman, 1936, p. 86-87, pl. 15, fig. 6 [pl. 12, fig. 5].

*Elphidium excavatum selseyensis (Heron-Allen and Earland) = Polystomella striatopuncata (Fichtel and Moll) var. selseyensis Heron-Allen and Earland, 1909, p. 695, pl. 21, fig. 2 [pl. 12, fig. 3].

*Elphidium gunteri Cole, 1931, p. 34, pl. 4, figs. 9-10 [pl. 12, fig. 2].

*Elphidium magellanicum Heron-Allen and Earland, 1932, p. 440, pl. 16, figs. 26-28 [pl. 12, fig. 4].

*Elphidium spp. Three specimens, either poorly preserved or exhibiting abnormal growth, are assigned to this genus. All display depressed sutures and are planispiral involute. Apertures are obscured.

*Epistominella bradyana (Cushman) = Pulvinulinella bradyana Cushman, 1927a, p. 165, pl. 5, figs. 11-13 [pl. 17, fig. 11].

*Epistominella evax Bandy, 1953a, p. 179, p. 23, fig. 1 [pl. 17, fig. 10].

*Epistominella exigua (Brady) = Pulvinulina exigua Brady, 1884, p. 696, pl. 103, figs. 13-14 [pl. 17, fig. 9].

*Epistominella pacifica (Cushman) = Pulvinulina pacifica Cushman, 1927a, p. 165, pl. 5, figs. 14-15 [pl. 18, fig. 1].

*Epistominella smithi (Stewart and Stewart) = Pulvinulina smithi Stewart and Stewart, 1930, p. 70, pl. 9, fig. 4 [pl 18, fig. 2].

Fissurina lagenoides (Williamson) = Entosolenia marginata (Walker) var. lagenoides Williamson, 1858, p. 11, pl. 1, figs. 25-26 [pl. 9, fig. 8].

Fissurina lucida (Williamson) = Entosolenia marginata (Montagu) var. lucida Williamson, 1848, p. 17, pl. 2, fig. 17.

Fissurina marginata (Montagu) = Vermiculum marginatum Montagu, 1803, p. 524.

Fissurina spp. Rare individuals were recovered, all characterized by single chambered, finely perforate tests. Apertures are terminal and either round or elliptical. In well preserved specimens, the internal tube is apparent [pl. 8, figs. 6-7, 9-10; pl. 9, figs. 1-7, 9].

*Florilus labradoricus (Dawson) = Nonionina labradorica Dawson, 1860, p. 191-192, t.f. 4 [pl. 10, fig. 2].

Frondicularia sp. The single specimen is characterized by the initial chambers being coiled into a sphere and the later chambers chevron-shaped and uniserially arranged. The aperture is radiate and a few delicate costae adorn the early chambers [pl. 6, fig. 6].

*Fursenkoina cornuta (Cushman) = Virgulina cornuta Cushman, 1913b, p. 637, pl. 80, fig. 1 [pl. 21, fig. 1].

*Fursenkoina rotundata (Parr) = Virgulina rotundata Parr, 1950, p. 337, pl. 12, fig. 14 [pl. 15, fig. 7].

*Fursenkoina seminuda (Natland) = Virgulina seminuda Natland, 1938, p. 145, pl. 5, fig. 12 [pl. 15, fig. 3].

*Fursenkoina sp. The tests assigned to this genus are elongate, slightly twisted, and very finely perforate. The initial chambers are triserially arranged, while the later chambers become biserial. The aperture is terminal and loop-shaped [pl. 15, fig. 4].

Globobulimina affinis (d'Orbigny) = Bulimina affinis d'Orbigny, 1839b, p. 105, pl. 2, figs. 25-26 [pl. 14, figs. 3, 5-6].

Globobulimina barbata (Cushman) = Bulimina barbata Cushman, 1927a, p. 151, pl. 2, fig. 11 [pl. 13, fig. 3].

Globobulimina cf. G. marginospinata (Cushman and Parker) = Bulimina marginospinata Cushman and Parker, 1938, p. 57, pl. 9, fig. 11 [pl. 14, fig. 1].

*Globobulimina ovula (d'Orbigny) = Bulimina ovula d'Orbigny, 1839a, p. 51, pl. 1, figs. 10-11 [pl. 14, figs. 2, 4].

Globobulimina pacifica Cushman, 1927b, p. 67, pl. 14, fig. 12 [pl. 13, figs. 9-10].

*Globobulimina spinifera (Cushman) = Bulimina spinifera Cushman (in part), 1927a, p. 151, pl. 2, fig. 15 [pl. 13, fig. 7].

Globobulimina spp. Several crushed and fragmented tests, displaying loop-shaped apertures and inflated, highly involute, often triserially arranged chambers in the adult, are assigned to this genus.

*Globocassidulina subglobosa (Brady) = Cassidulina subglobosa Brady, 1881, p. 60 [pl. 20, fig. 2].

Gyroidina altiformis Stewart and Stewart = Gyroidina soldanii d'Orbigny var. altiformis Stewart and Stewart, 1930, p. 67, pl. 9, fig. 67 [pl. 19, figs. 3-4].

Gyroidina gemma Bandy, 1953a, p. 179, pl. 23, fig. 4 [pl. 19, figs. 7-8].

Gyroidina cf. G. planulata Cushman and Renz, 1941, p. 23, pl. 4, fig. 1.

Gyroidina quinqueloba Uchio, 1960, p. 66-67, pl. 8, figs. 22-25 [pl. 19, fig. 5].

Gyroidina tumidulus (Brady) = Truncatulina tumidula Brady, 1884, p. 666, pl. 95, fig. 8 [pl. 19, fig. 1].

Gyroidina turgida (Phleger and Parker) = Eponides turgidus Phleger and Parker, 1951, p. 22, pl. 11, fig. 9 [pl. 19, fig. 2].

Gyroidina spp. Poorly preserved specimens, with trochoidal, plano-convex to biconvex tests and an interiomarginal aperture located towards the umbilical area, are assigned to this genus.

Hoeglundina elegans (d'Orbigny) = Rotalia (Turbinuline) elegans d'Orbigny, 1826, p. 276 [pl. 19, fig. 9].

Jaculella acuta Brady, 1879, p. 35, pl. 3, figs. 12-13 [pl. 1, fig. 2].

Karreriella baccata (Schwager) = Gaudryina baccata Schwager, 1866, p. 200, pl. 4, fig. 12 [pl. 3, fig. 1].

Karreriella grammostomata (Galloway and Wissler) = Gaudryina grammostomata Galloway and Wissler, 1927, p. 69, pl. 11, fig. 6 [pl. 2, fig. 2].

Karreriella novangliae (Cushman) = Gaudryina baccata Schwager var. novangliae Cushman, 1922, p. 76, pl. 13, fig. 4 [pl. 3, fig. 2].

Lagena acuticosta Reuss, 1862, p. 305, pl. 1, fig. 4 [pl. 7, figs. 5-6].

Lagena alcocki White = Entosolenia williamsoni Alcock, 1865, p. 193 [pl. 7, fig. 7].

Lagena distoma Parker and Jones, in Brady, 1864, p. 467, pl. 48, fig. 6 [pl. 8, fig. 1].

Lagena elongata (Ehrenberg) = Miliola elongata Ehrenberg, 1844, p. 274 [pl. 8, fig. 2].

Lagena hispidula Cushman, 1913a, p. 14, pl. 5, figs. 2-3 [pl. 7, fig. 14].

Lagena striata (d'Orbigny) = Oolina striata d'Orbigny, 1839a, p. 21, pl. 5, fig. 12 [pl. 7, fig. 12].

Lagena sulcata (Walker and Jacob) = Serpula (Lagena) sulcata Walker and Jacob, 1798, p. 634, pl. 14, fig. 5 [pl. 7, fig. 11].

Lagena sulcata laevicostata Cushman and Gray, 1946, p. 68, pl. 12, figs. 13-14 [pl. 7, figs. 9-10].

Lagena sulcata spicata Cushman and McCulloch, 1950, p. 360-361, pl. 48, figs. 3-7 [pl. 7, fig. 4].

Lagena spp. Several specimens, characterized by a single chamber, perforate walls, elongate neck and rounded aperture are assigned to this genus.

Lenticulina spp. Planispiral, bilaterally symmetrical tests with radiate apertures are assigned to this genus. Most specimens are closely coiled, involute forms, with tests moderately inflated. Microspheric individuals display approximately seven to eight chambers; four to five chambers are seen in the megalospheric forms. One specimen appears to be transitional between Lenticulina and Saracenaria. This same specimen possesses a very flattened test composed of seven chambers, and possibly begins to uncoil in its later stages of growth [pl. 5, figs. 4-8].

*Loxostomum pseudobeyrichi (Cushman) = Bolivina pseudobeyrichi Cushman, 1926b, p. 45 [pl. 16, figs. 5-6].

Marginulina obesa Cushman = Marginulina glabra d'Orbigny var. obesa Cushman, 1923, p. 128, pl. 37, fig. 1 [pl. 6, fig. 4].

Marginulina spp. Four morphologically distinct specimens were recovered. All four individuals are characterized by a subcylindrical test, a slightly coiled initial portion which becomes uncoiled in the later chambers, and a radiate aperture which is terminal and central. The tests differ in the angle, direction and degree of uncoiling in the later chambers and in the extent of elongation of these chambers. Time did not permit the identification of these individuals to the specific level [pl. 6, figs. 2, 3, 5].

Martinottiella communis (d'Orbigny) = Clavulina communis d'Orbigny, 1826, p. 268, modeles no. 4 [pl. 2, figs. 3-4].

Melonis barleeanus (Williamson) = Nonionina barleeana Williamson, 1858, p. 32, pl. 3, figs. 68-69 [pl. 11, fig. 4].

Melonis pompilioides (Fichtel and Moll) = Nautilus pompilioides Fichtel and Moll, 1798, p. 31, pl. 2, figs. a-c [pl. 11, fig. 3].

Miliolinella californica Rhumbler, 1936, p. 215 [pl. 4, figs. 3-4].

Nodosaria cf. N. tympaniplectiformis Schwager, 1866, p. 223, pl. 5, fig. 34 [pl. 7, fig. 1].

*Nonionella basispinata (Cushman and Moyer) = Nonion pizarrensis Berry var. basispinata Cushman and Moyer, 1930, p. 54, pl. 7, fig. 18 [pl. 10, fig. 3].

*Nonionella decora Cushman and McCulloch, 1940, p. 160-161, pl. 17, figs. 11-12 [pl. 10, fig. 1].

*Nonionella japonica mexicana Cushman and McCulloch, 1940, p. 160, pl. 17, fig. 10 [pl. 10, fig. 4].

*Nonionella miocenica Cushman, 1926c, p. 64 [pl. 10, fig. 7].

*Nonionella stella Cushman and Moyer, 1930, p. 56, pl. 7, fig. 17 [pl. 11, fig. 1].

*Nonionella sp. The tests are comprised of 8 to 10 chambers in the adult whorl, yet they most often display 9. On both the ventral and dorsal sides, the last chamber develops a large basal lobe which completely covers the umbilicus. The basal lobes may be equally or unequally developed and never appear to reach the periphery. Sutures are distinct and barely, if at all, depressed. The aperture lies at the base of the apertural face, extending under the lobes on either side. The tests are often found intensely pyritized.

Oolina catenulata (Williamson) = Entosolenia squamosa Montagu var. catenulata Williamson, 1858, p. 13, pl. 1, fig. 31 [pl. 8, fig. 5].

Oolina melo d'Orbigny, 1839a, p. 20, pl. 5, fig. 9 [pl. 8, fig. 4].

Oolina spp. One test is characterized by a single globular chamber which displays a rounded to slightly ovate aperture and an entosolenian tube. The other also has a single globular chamber, as well as a rounded aperture and a basal spine.

Oolina (?) sp. The test is comprised of a single globular chamber, a pronounced radiate aperture, and basal spine. It appears to lack an entosolenian tube.

Oridorsalis umbonatus (Reuss) = Rotalina umbonata Reuss, 1851, p. 75, pl. 5, fig. 35 [pl. 19, fig. 6].

Parafissurina fusuliformis Loeblich and Tappan, 1953, p. 79-80, pl. 14, figs. 18-19.

Parafissurina kerguelenensis (Parr) = Fissurina kerguelenensis Parr, 1950, p. 305, pl. 8, fig. 7 [pl. 8, figs. 11, 13].

Parafissurina cf. P. kerguelenensis (Parr) = Fissurina kerguelenensis Parr, 1950, p. 305, pl. 8, fig. 7. The test of this species has the same shape and apertural characteristics as those of Parafissurina kerguelenensis (Parr). It differs by displaying a thin flange around the lower portion of the test instead of the two to four isolated spines along the base of the latter. In addition, well preserved individuals of Parafissurina cf. P. kerguelenensis (Parr) exhibit a slight longitudinal ridge along the medial axis which extends up approximately one-sixth the distance of the test from its base [pl. 8, fig. 12].

Parafissurina tectulostoma Loeblich and Tappan, 1953, p. 81, pl. 14, fig. 17 [pl. 9, fig. 10].

Parafissurina spp. Several specimens, all characterized by single chambers and a sub-terminal, arched aperture lying under a hood, are assigned to this genus. When the finely perforate wall structure is well preserved, an internal tube can be discerned [pl. 8, fig. 8].

*Planulina ornata (d'Orbigny) = Truncatulina ornata d'Orbigny, 1839a, p. 40, pl. 6, figs. 7-9 [pl. 22, fig. 6].

Planulina wuellerstorfi (Schwager) = Anomalina wuellerstorfi Schwager, 1866, p. 258, pl. 7, figs. 105, 107 [pl. 22, fig. 7].

Pullenia bulloides (d'Orbigny) = Nonionina bulloides d'Orbigny, 1826, p. 293 [pl. 22, figs. 3-4].

*Pullenia quinqueloba (Reuss) = Nonionina quinqueloba Reuss, 1851, p. 71, pl. 5, fig. 31 [pl. 21, fig. 7].

*Pullenia salisburyi Stewart and Stewart, 1930, p. 72, pl. 8, fig. 2 [pl. 21, figs. 6, 8].

Pullenia sp. A. The single specimen is characterized by a planispiral involute test composed of eight non-inflated chambers. The aperture is a very thin, elongate, interiomarginal slit running nearly from umbilicus to umbilicus. Sutures are barely, if at all, depressed [pl. 22, fig. 1].

Pullenia sp. B. The four specimens are characterized by a planispiral involute test made up of six inflated chambers, resulting in a lobate periphery. The aperture is a rather wide crescentic arch, interiomarginally located, running nearly from umbilicus to umbilicus. The sutures are distinctly depressed [pl. 22, fig. 5].

Pullenia sp. C. Three large indidividuals, characterized by planispiral involute tests composed of five inflated chambers, are assigned to this species. Each test has a lobate periphery and an inflated apertural face. The aperture is a thin interiomarginal arch running nearly from umbilicus to umbilicus and the sutures are depressed [pl. 22, fig. 2].

Pyrgo depressa (d'Orbigny) = Biloculina depressa d'Orbigny, 1826, p. 298, modeles no. 91 [pl. 5, fig. 3].

Pyrgo murrhina (Schwager) = Biloculina murrhyna Schwager, 1866, p. 203, pl. 4, fig. 15 [pl. 5, figs. 1-2].

*Quinqueloculina akneriana d'Orbigny, 1846, p. 290, pl. 18, figs. 16-21 [pl. 3, fig. 6].

Quinqueloculina elongata Natland, 1938, p. 141-142, pl. 4, fig. 5 [pl. 4, fig. 2].

Quinqueloculina spp. One specimen is characterized by a robust test, which is slightly elongate in side view and approximately two times as long as broad. Its surface is smooth and it displays a very large apertural opening with no tooth [pl. 4, fig. 1]. Another specimen is of normal size for the genus, and is approximately two times as long as broad. It, too, has a smooth surface texture, but displays a small apertural opening with no tooth [pl. 4, fig. 7]. Other specimens were recovered but were in an exceptionally poor preservational state.

Recurvoides spp. Three specimens are assignable to this genus. Their tests are primarily finely arenaceous, but occasional coarse grains are seen. The chambers are initially planispirally arranged, but begin to coil in a slighltly different direction in the adult test. The aperture is usually not apparent, but in one specimen it is an interiomarginal oval surrounded by a lip [pl. 1, fig. 9].

Reophax communis Lacroix, 1930, p. 4-5, tfs. 5-7 [pl. 1, fig. 4].

Reophax dentaliniformis Brady, 1881, p. 49 [pl. 1, fig. 7].

Reophax distans gracilis Earland, 1933, p. 76, pl. 2, fig. 21 [pl. 1, fig. 8].

Reophax (?) sp. The single specimen is characterized by two uniserial, non-overlapping spherical chambers. The wall is finely arenaceous and no aperture is apparent [pl. 1, fig. 5].

Robertina bradyi Cushman and Parker, 1936, p. 99, pl. 16, fig. 9 [pl. 12, fig. 8].

*Rosalina columbiensis (Cushman) = Discorbis columbiensis Cushman, 1925b, p. 43, pl. 6, fig. 13 [pl. 23, figs. 3, 5; pl. 24, fig. 1].

Saccammina spherica M. Sars, 1869, p. 248 [pl. 1, fig. 6].

*Saracenaria sp. The four specimens assigned to this genus are all megalospheric forms. The tests are characterized by a low number of chambers, usually three, with the later chambers uncoiling. The apertural face is greatly broadened and roughly triangular, with a radiate aperure present at the peripheral margin [pl. 5, fig. 9].

Sigmoilina cf. S. tenuis (Czjzek) = Quinqueloculina tenuis Czjzek, 1848, p. 149, pl. 13, figs. 31-34 [pl. 4, fig. 6].

Sigmoilina sp. Specimens assigned to this genus are characterized by an imperforate test and a terminal, rounded aperture. Four chambers are exposed on one side, five on the other. Chambers are added in such a way as to form a somewhat sigmoid appearance in apertural view [pl. 4, fig. 5].

Siphotextularia catenata (Cushman) = Textularia catenata Cushman, 1911, p. 23, figs. 39-40.

*Stainforthia complanata (Egger) = Virgulina schreibersiana Czjzek var. complanata Egger, 1895, p. 292, pl. 8, figs. 91-92 [pl. 15, fig. 1].

*Stainforthia nodosa (Stewart and Stewart) = Virgulina nodosa Stewart and Stewart, 1930, p. 64, pl. 8, fig. 4 [pl. 15, fig. 2].

Stilostomella cf. S. lepidula (Schwager) = Nodosaria lepidula Schwager, 1866, p. 210, pl. 5, figs. 27-28 [pl. 7, fig. 3].

Stilostomella sp. The single fragmented specimen is characterized by two slightly embracing, uniserial chambers separated by a depressed suture at right angles to the axis of the test. The aperture is terminal and round and the test wall finely perforate. The lower half of each chamber is adorned with eight costae of low relief, which fall in a direct line with those of the preceeding chamber [pl. 7, fig. 2].

*Suggrunda eckisi Natland, 1950, p. 23, pl. 9, fig. 12 [pl. 16, fig. 8].

*Trifarina angulosa (Williamson) = Uvigerina angulosa Williamson, 1858, p. 67, pl. 5, fig. 140 [pl. 17, fig. 7].

*Trifarina hughesi (Galloway and Wissler) = Uvigerina hughesi Galloway and Wissler, 1927, p. 76, pl. 12, fig. 5 [pl. 17, fig. 8].

Trifarina (?) sp. A single, very fragile and partly broken specimen was recovered. The test is slightly pyritied, and as a result, the inner chambers are obscured. The aperture is also broken, but appears to have a neck instead of a slit as is found in Reussella (i.e., an elongate opening from the base of the chamber in the apertural face). The test is triangular in transverse section, with each side appearing slightly concave.

Triloculina tricarinata d'Orbigny, 1826, p. 299, modeles no. 94 [pl. 4, fig. 8].

Triloculina trigonula (Lamarck) = Miliolites trigonula Lamarck, 1804, p. 351, pl. 17, fig. 4 [pl. 4, fig. 9].

Trochammina globigeriniformis (Parker and Jones) = Lituola nautiloidea Lamarck var. globigeriniformis Parker and Jones, 1865, p. 407 [pl. 3, fig. 4].

Trochammina pacifica simplissima Cushman and McCulloch = Trochammina pacifica Cushman var. simplex Cushman and McCulloch, 1939, p. 104, pl. 11, fig. 4 [pl. 3, fig. 3].

*Uvigerina hispida Schwager, 1866, p. 249, pl. 7, fig. 95 [pl. 17, fig. 3].

*Uvigerina juncea Cushman and Todd, 1941, p. 78, pl. 20, figs. 4-11 [pl. 17, fig. 1].

**Uvigerina peregrina* Cushman, 1923, p. 166, pl. 42, figs. 7-10 [pl. 17, fig. 5].

**Uvigerina peregrina dirupta* Todd, *in* Cushman and McCulloch, 1948, p. 267, pl. 34, fig. 3 [pl. 17, fig. 6].

**Uvigerina proboscidea* Schwager, 1866, p. 250, pl. 7, fig. 96 [pl. 17, fig. 2].

Uvigerina senticosa Cushman, 1927a, p. 159, pl. 3, fig. 14 [pl. 17, fig. 4].

**Valvulineria araucana* (d'Orbigny) = *Rosalina araucana* d'Orbigny, 1839a, p. 44, pl. 6, figs. 16-18 [pl. 18, fig. 7].

**Valvulineria laevigata* Phleger and Parker, 1951, p. 25, pl. 13, figs. 11-12 [pl. 18, fig. 6].

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G. P = occurrence of fragmentary arenaceous species that were not included in the total specimen count.

Species	Depth in Core (cm)						
	0-4	20-23.5	40-43	46-48	60-63	80-83	96.5-100
Anomalina globulosa	-	-	-	-	-	-	-
Astacolus sp.	-	-	-	-	-	-	-
Astrononion gallowayi	-	-	-	-	-	-	-
Bathysiphon sp.	-	P	-	-	-	-	-
Bolivina advena striatella	-	-	-	-	-	-	-
B. argentea	-	-	-	10	-	-	-
B. interjuncta bicostata	-	-	-	-	-	-	-
B. pacifica	-	-	-	-	-	-	-
B. seminuda	-	-	-	-	-	-	-
B. tongi filicostata	-	-	-	-	-	-	-
Buccella frigida	-	-	-	-	-	-	-
B. tenerrima	-	-	-	-	-	-	-
Bulimina denudata	-	-	-	-	-	-	-
B. pagoda	-	-	-	-	-	-	-
B. rostrata	-	-	-	2	-	1	-
B. striata mexicana	-	-	-	10	-	-	-
Buliminella curta	-	-	-	-	-	-	-
B. elegantissima	-	-	-	-	-	-	-
B. tenuata	1	1	1	154	5	-	2
Cassidulina cushmani	-	-	-	1	-	-	-
C. minuta	-	2	-	3	-	-	6
C. translucens	-	-	-	-	-	-	-
C. tumida	-	-	-	-	-	-	-
C. spp.	-	-	-	1	-	-	-
Cassidulinoides bradyi	-	1	-	8	-	-	-
Chilostomella oolina	-	-	1	5	-	-	-
C. ovoidea	-	-	-	-	-	-	-
C. spp.	-	-	-	2	-	-	-
Chilostomellina fimbriata	-	-	-	-	-	-	-
Cibicides lobatulus	-	2	-	-	-	-	9
C. mckannai	-	-	-	-	-	1	-
C. spp.	-	-	2	1	1	-	1
Cibicidoides kullenbergi	-	-	-	-	-	-	1
Cyclammina sp.	-	-	-	-	-	-	-
Dentalina californica	-	-	-	-	-	-	-
D. frobisherensis	-	-	-	-	-	-	-
D. mucronata	-	-	-	-	-	-	-
D. pauperata	-	-	-	-	-	-	1
D. spp.	-	-	-	-	-	1	-
Dyocibicides biserialis	-	-	-	-	-	-	-
D. sp.	-	-	-	-	-	-	-
Eggerella bradyi	2	1	-	-	1	5	2
E. spp.	-	-	-	-	-	-	-
Elphidium excavatum clavata	-	-	-	1	-	-	-
E. excavatum lidoensis	-	-	-	-	-	-	-
E. excavatum selseyensis	-	-	-	-	-	-	-
E. gunteri	-	-	-	-	-	-	-
E. magellanicum	-	-	-	-	-	-	-
E. spp.	-	-	-	-	-	-	-
Epistominella bradyana	-	-	-	-	-	-	-
E. evax	-	-	-	-	-	-	-
E. exigua	-	-	-	-	-	-	-
E. pacifica	-	-	-	58	-	-	-
E. smithi	-	-	-	3	-	-	-
Fissurina lagenoides	-	-	-	-	-	-	-
F. lucida	-	-	-	-	-	-	-
F. marginata	-	-	-	-	-	-	-
F. spp.	-	1	-	1	2	5	1
Frondicularia sp.	-	-	-	1	-	-	-
Fursenkoina cornuta	-	-	-	-	-	-	-
F. rotundata	-	-	-	-	-	-	-
F. seminuda	-	-	-	-	-	-	-
F. sp.	-	-	-	1	-	-	-
Globobulimina affinis	1	132	50	15	23	16	22
G. barbata	-	-	-	1	-	-	1
G. cf. *marginospinata*	-	-	-	-	-	-	-
G. ovula	-	-	-	-	-	-	-
G. pacifica	-	-	-	6	-	-	-
G. spinifera	-	-	-	-	-	-	-
G. spp.	-	-	1	-	-	-	-

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G (continued).

Species	Depth in Core (cm) 0-4	20-23.5	40-43	46-48	60-63	80-83	76.5-100
Globocassidulina subglobosa	-	1	1	-	-	-	-
Gyroidina altiformis	-	1	1	2	1	3	5
G. gemma	-	1	-	6	2	1	9
G. cf. planulata	-	8	3	3	3	4	9
G. quinqueloba	-	2	-	-	-	4	-
G. tumidulus	-	-	-	-	-	-	-
G. turgida	-	-	-	-	-	-	-
G. spp.	-	-	1	-	-	-	-
Hoeglundina elegans	-	-	-	-	-	69	11
Jaculella acuta	P	-	-	-	-	-	-
Karreriella baccata	-	-	-	-	-	-	-
K. grammostomata	-	-	-	-	-	1	4
K. novangliae	-	-	-	-	-	-	-
Lagena acuticosta	-	-	1	-	1	-	-
L. alcocki	-	-	-	-	-	-	-
L. distoma	-	-	-	-	-	-	-
L. elongata	1	1	-	3	1	-	2
L. hispidula	-	2	1	-	1	2	3
L. striata	-	1	2	-	-	-	-
L. sulcata	-	-	-	-	-	-	-
L. sulcata laevicostata	-	-	-	-	-	-	-
L. sulcata spicata	-	-	-	-	-	-	-
L. spp.	-	-	-	-	-	-	-
Lenticulina spp.	-	-	-	-	-	-	-
Loxostomum pseudobeyrichi	-	-	-	3	-	-	-
Marginulina obesa	-	1	-	-	-	-	-
M. spp.	-	-	-	-	-	-	-
Martinottiella communis	-	-	-	-	-	-	1
Melonis barleeanus	1	1	-	-	-	10	-
M. pompilioides	-	12	9	7	10	64	87
Miliolinella californica	-	-	-	-	-	-	-
Nodosaria tympaniplectiformis (?)	-	-	-	-	1	-	-
Nonionella basispinata	-	-	-	-	-	-	-
N. decora	-	-	-	-	-	-	-
N. japonica mexicana	-	-	-	-	-	-	-
N. labradorica	-	-	-	-	-	-	-
N. miocenica	-	-	-	-	-	-	-
N. stella	-	-	-	-	-	-	-
N. sp.	-	-	1	-	-	-	-
Oolina catenulata	-	-	-	-	-	-	1
O. melo	-	-	-	-	-	2	2
O. spp.	-	-	-	-	-	1	-
O. (?) sp.	-	-	-	-	-	-	-
Oridorsalis umbonatus	-	-	-	4	-	3	2
Parafissurina fusuliformis	-	-	-	-	-	-	-
P. kerguelenensis	-	-	-	-	-	-	-
P. cf. kerguelenensis	-	-	-	-	-	-	-
P. tectulostoma	-	-	-	-	-	-	-
P. spp.	-	3	-	-	-	-	-
Planulina ornata	-	-	-	-	-	-	-
P. wuellerstorfi	-	6	1	1	2	1	7
Pullenia bulloides	-	-	-	3	1	1	2
P. quinqueloba	-	-	-	-	-	1	-
P. salisburyi	-	-	-	-	-	-	-
P. sp. A	-	-	-	-	-	1	-
P. sp. B	-	-	-	-	-	-	-
P. sp. C	-	-	-	-	-	-	-
Pyrgo depressa	-	-	-	-	-	-	-
P. murrhina	-	-	-	-	-	2	3
Quinqueloculina akneriana	-	-	-	-	-	-	-
Q. elongata	-	-	-	-	-	-	-
Q. spp.	-	-	-	-	-	-	-
Recurvoides spp.	-	3	-	-	-	-	-
Reophax communis	-	P	-	-	-	-	-
R. dentaliniformis	-	3	-	-	-	-	-
R. distans gracilis	-	P	-	-	-	-	-
R. (?) sp.	-	-	-	-	1	-	-
Robertina bradyi	-	-	-	-	-	-	-
Rosalina columbiensis	-	1	1	-	1	-	3
Saccammina spherica	1	-	-	-	1	-	1

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G (continued).

Species	Depth in Core (cm) 0-4	20-23.5	40-43	46-48	60-63	80-83	96.5-100
Saracenaria sp.	-	-	-	-	-	-	-
Sigmoilina cf. S. tenuis	-	-	-	-	-	-	-
S. sp.	-	-	-	-	-	-	-
Siphotextularia catenata	-	2	-	-	-	-	-
Stainforthia complanata	-	-	-	-	-	-	-
S. nodosa	-	-	-	-	-	-	-
Stilostomella cf. S. lepidula	-	-	-	-	-	-	-
S. sp.	-	-	-	-	-	-	-
Suggrunda eckisi	-	-	-	-	-	-	-
Trifarina angulosa	-	-	-	2	-	-	-
T. hughesi	-	-	-	-	-	-	-
T (?) sp.	-	-	-	-	-	-	-
Triloculina tricarinata	-	1	-	-	-	2	-
T. trigonula	-	1	-	-	-	-	-
Trochammina globigeriniformis	-	9	-	-	-	-	-
T. pacifica simplissima	-	1	-	-	-	-	-
Uvigerina hispida	-	-	-	15	-	-	-
U. juncea	-	-	-	10	-	-	-
U. peregrina	-	-	-	7	-	-	-
U. peregrina dirupta	-	-	-	-	-	-	-
U. proboscidea	-	-	-	2	-	-	-
U. senticosa	-	47	29	14	46	100	132
Valvulineria araucana	-	-	-	-	-	-	-
V. laevigata	-	1	-	-	-	-	1
Unknowns	-	6	-	2	2	2	3
Total Specimens	8	253	106	368	106	303	334

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G (continued).

Species	Depth in Core (cm)						
	120-122	128-130	130-132	133.5-136.5	139-143	152.5-154.5	167.5-170
Anomalina globulosa	-	2	-	-	1	1	3
Astacolus sp.	-	-	-	-	-	-	1
Astrononion gallowayi	-	-	-	-	-	-	-
Bathysiphon sp.	-	-	-	-	-	-	-
Bolivina advena striatella	-	-	-	-	-	-	-
B. argentea	-	-	-	15	-	-	-
B. interjuncta bicostata	-	-	-	1	-	-	-
B. pacifica	-	-	-	-	1	-	-
B. seminuda	-	1	-	7	-	-	-
B. tongi filicostata	-	-	-	-	-	-	-
Buccella frigida	-	-	-	-	-	-	-
B. tenerrima	-	-	-	-	-	-	-
Bulimina denudata	-	-	-	-	-	-	-
B. pagoda	-	-	-	2	-	-	-
B. rostrata	-	1	-	-	-	1	2
B. striata mexicana	-	-	-	11	-	-	-
Buliminella curta	-	-	-	-	-	-	-
B. elegantissima	-	-	-	-	-	-	-
B. tenuata	1	1	-	19	4	-	16
Cassidulina cushmani	-	-	-	11	-	-	-
C. minuta	4	3	3	20	13	4	10
C. translucens	-	-	-	2	-	-	-
C. tumida	-	-	-	-	-	-	-
C. spp.	-	-	-	1	-	-	-
Cassidulinoides bradyi	-	-	-	-	-	-	1
Chilostomella oolina	-	2	-	5	-	-	-
C. ovoidea	-	-	-	-	-	-	-
C. spp.	1	-	-	-	1	-	-
Chilostomellina fimbriata	-	-	-	-	-	-	-
Cibicides lobatulus	1	-	1	-	-	1	
C. mckannai	1	-	-	-	-	-	-
C. spp.	-	2	-	3	-	-	-
Cibicidoides kullenbergi	3	1	-	-	6	4	11
Cyclammina sp.	-	-	-	-	-	-	-
Dentalina californica	-	-	-	1	-	-	-
D. frobisherensis	-	-	-	-	1	-	-
D. mucronata	-	-	-	1	-	-	-
D. pauperata	-	-	-	-	-	-	1
D. spp.	-	-	-	2	-	2	-
Dyocibicides biserialis	-	-	-	-	-	-	-
D. sp.	-	-	-	-	-	-	-
Eggerella bradyi	4	-	-	1	2	2	2
E. spp.	1	-	-	-	-	-	-
Elphidium excavatum clavata	1	-	-	-	-	-	-
E. excavatum lidoensis	-	-	-	-	-	-	-
E. excavatum selseyensis	-	-	-	14	-	-	-
E. gunteri	-	-	-	-	-	-	-
E. magellanicum	-	-	-	-	-	-	-
E. spp.	-	-	-	-	-	-	-
Epistominella bradyana	-	-	-	1	-	-	-
E. evax	-	-	-	-	-	-	-
E. exigua	-	-	-	2	-	-	-
E. pacifica	-	-	-	5	-	-	-
E. smithi	-	-	-	11	-	-	-
Fissurina lagenoides	-	-	-	1	-	-	-
F. lucida	-	-	-	1	-	3	3
F. marginata	-	-	-	-	-	-	-
F. spp.	8	5	-	5	6	1	1
Frondicularia sp.	-	-	-	-	-	-	-
Fursenkoina cornuta	-	-	-	13	-	-	-
F. rotundata	-	-	-	5	-	-	-
F. seminuda	-	-	-	2	-	-	-
F. sp.	-	-	-	-	-	-	-
Globobulimina affinis	-	26	7	11	7	54	43
G. barbata	3	-	1	2	4	4	9
G. cf. *marginospinata*	-	-	-	3	-	-	-
G. ovula	-	-	-	-	-	-	-
G. pacifica	2	-	-	4	-	-	1
G. spinifera	-	-	-	-	-	-	-
G. spp.	4	1	1	-	-	2	1

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G (continued).

Species	Depth in Core (cm)						
	120-122	128-130	130-132	133.5-136.5	139-143	152.5-154.5	167.5-170
Globocassidulina subglobosa	-	-	-	3	2	-	-
Gyroidina altiformis	11	7	1	-	9	7	10
G. gemma	5	3	-	2	6	5	12
G. cf. *planulata*	2	7	-	2	26	19	35
G. quinqueloba	2	1	-	-	3	-	4
G. tumidulus	3	-	-	-	1	-	5
G. turgida	1	1	-	-	1	2	-
G. spp.	-	-	-	-	-	-	-
Hoeglundina elegans	6	2	-	2	5	9	7
Jaculella acuta	-	-	-	-	-	-	-
Karreriella baccata	1	1	1	1	1	1	1
K. grammostomata	15	4	1	2	4	6	5
K. novangliae	1	-	-	-	1	-	2
Lagena acuticosta	-	-	1	1	1	-	-
L. alcocki	-	-	-	1	-	-	-
L. distoma	-	-	-	3	1	-	-
L. elongata	-	-	1	-	2	-	-
L. hispidula	2	3	1	2	5	2	-
L. striata	2	-	-	-	2	-	1
L. sulcata	1	-	-	-	1	-	1
L. sulcata laevicostata	-	-	-	-	-	1	-
L. sulcata spicata	-	-	-	1	-	-	-
L. spp.	-	-	-	-	-	-	-
Lenticulina spp.	-	-	-	-	2	-	-
Loxostomum pseudobeyrichi	-	1	-	35	1	-	-
Marginulina obesa	1	-	-	-	-	-	-
M. spp.	-	1	-	-	1	-	1
Martinottiella communis	1	-	-	-	1	-	-
Melonis barleeanus	6	3	-	1	32	7	9
M. pompilioides	91	57	16	11	91	100	138
Miliolinella californica	-	-	-	-	-	-	-
Nodosaria tympaniplectiformis (?)	-	-	-	-	-	-	-
Nonionella basispinata	-	-	-	1	-	-	-
N. decora	-	-	-	-	-	-	-
N. japonica mexicana	-	-	-	2	-	-	-
N. labradorica	-	-	-	-	-	-	-
N. miocenica	-	-	-	12	1	-	-
N. stella	-	-	-	-	-	-	-
N. sp.	-	1	-	-	-	-	-
Oolina catenulata	1	2	1	-	3	2	-
O. melo	1	2	1	2	8	1	-
O. spp.	-	-	-	-	1	-	-
O. (?) sp.	-	-	-	-	-	1	-
Oridorsalis umbonatus	2	2	3	-	3	7	17
Parafissurina fusuliformis	2	-	-	-	-	-	-
P. kerguelenensis	-	1	-	1	-	-	6
P. cf. *kerguelenensis*	-	-	-	-	-	-	-
P. tectulostoma	-	-	-	-	-	-	4
P. spp.	1	-	2	6	2	1	2
Planulina ornata	-	-	-	-	-	-	-
P. wuellerstorfi	13	9	2	3	27	11	26
Pullenia bulloides	-	5	2	1	3	-	3
P. quinqueloba	-	-	-	-	-	-	1
P. salisburyi	5	2	-	4	3	2	1
P. sp. A	-	-	-	-	-	-	-
P. sp. B	1	-	-	-	-	-	-
P. sp. C	-	-	-	-	-	-	-
Pyrgo depressa	6	1	-	1	1	-	5
P. murrhina	10	2	-	1	1	-	8
Quinqueloculina akneriana	-	-	-	-	-	-	-
Q. elongata	-	-	-	-	-	-	-
Q spp.	-	-	-	-	-	-	1
Recurvoides spp.	-	-	-	-	-	-	-
Reophax communis	-	-	-	-	-	-	-
R. dentaliniformis	-	-	-	-	-	-	-
R. distans gracilis	-	-	-	-	-	-	-
R. (?) sp.	-	-	-	-	-	-	-
Robertina bradyi	-	-	-	-	-	-	-
Rosalina columbiensis	5	6	5	4	12	7	7
Saccammina spherica	-	-	-	-	-	-	-

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G (continued).

Species	Depth in Core (cm)						
	120-122	128-130	130-132	133.5-136.5	139-143	152.5-154.5	167.5-170
Saracenaria sp.	-	-	-	-	3	-	-
Sigmoilina cf. *S. tenuis*	-	-	-	-	-	-	-
S. sp.	-	-	-	2	-	-	-
Siphotextularia catenata	-	-	-	-	-	-	6
Stainforthia complanata	-	-	-	-	-	-	-
S. nodosa	-	-	-	-	-	-	-
Stilostomella cf. *S. lepidula*	-	-	-	1	-	-	-
S. sp.	-	-	-	1	-	-	-
Suggrunda eckisi	-	-	-	12	-	-	-
Trifarina angulosa	-	-	-	1	-	-	-
T. hughesi	-	-	-	-	-	-	-
T (?) sp.	-	-	-	1	-	-	-
Triloculina tricarinata	-	1	-	1	-	1	-
T. trigonula	-	-	-	-	-	-	-
Trochammina globigeriniformis	-	-	-	-	-	-	-
T. pacifica simplissima	-	-	-	-	-	-	-
Uvigerina hispida	-	-	-	-	-	-	-
U. juncea	-	-	-	10	-	-	-
U. peregrina	-	-	-	11	-	-	-
U. peregrina dirupta	-	-	-	-	-	-	-
U. proboscidea	-	-	-	7	-	1	-
U. senticosa	97	55	17	26	92	54	172
Valvulineria araucana	-	-	-	-	-	-	7
V. laevigata	-	-	-	7	1	-	1
Unknowns	-	-	1	6	2	-	-
Total Specimens	329	225	69	378	409	325	606

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G (continued).

Species	Depth in Core (cm)						
	171-173	180-182	189.5-192	210-212	230-232	248-250	270-272
Anomalina globulosa	-	-	-	-	-	-	-
Astacolus	-	-	-	-	-	-	-
Astrononion gallowayi	-	-	-	-	-	-	-
Bathysiphon sp.	-	-	-	-	-	P	-
Bolivina advena striatella	-	-	-	-	-	15	-
B. argentea	39	108	-	1	28	71	-
B. interjuncta bicostata	3	5	-	-	-	3	-
B. pacifica	6	-	-	-	-	-	-
B. seminuda	2	1	-	-	14	12	1
B. tongi filicostata	1	1	-	-	-	-	-
Buccella frigida	2	2	-	-	5	2	-
B. tenerrima	-	-	-	-	-	3	-
Bulimina denudata	-	4	-	-	-	-	-
B. pagoda	2	4	-	-	-	-	-
B. rostrata	-	1	2	2	3	-	1
B. striata mexicana	2	29	-	-	29	23	-
Buliminella curta	-	-	-	-	-	-	-
B. elegantissima	-	-	-	-	-	-	-
B. tenuata	39	139	1	4	48	16	5
Cassidulina cushmani	1	6	-	-	20	8	-
C. minuta	10	36	9	17	40	14	7
C. translucens	1	-	-	-	2	3	-
C. tumida	-	-	-	-	-	1	-
C. spp.	-	-	-	-	-	1	-
Cassidulinoides bradyi	11	16	2	-	8	3	1
Chilostomella oolina	4	12	-	-	1	-	-
C. ovoidea	1	-	-	-	-	1	-
C. spp.	1	4	-	-	1	1	-
Chilostomellina fimbriata	7	5	-	-	1	3	-
Cibicides lobatulus	-	-	-	20	-	1	2
C. mckannai	-	-	-	-	-	-	-
C. spp.	2	-	-	3	2	-	1
Cibicidoides kullenbergi	-	4	1	4	2	-	3
Cyclammina sp.	-	-	-	-	-	-	-
Dentalina californica	-	-	-	-	-	-	-
D. frobisherensis	-	-	-	-	-	-	-
D. mucronata	-	-	-	-	-	-	-
D. pauperata	-	-	-	1	-	-	-
D. spp.	-	-	-	-	-	-	-
Dyocibicides biserialis	-	-	-	-	-	-	-
D. sp.	-	-	-	-	-	-	-
Eggerella bradyi	1	7	-	1	5	-	3
E. spp.	-	-	-	1	1	-	-
Elphidium excavatum clavata	1	-	-	-	-	9	-
E. excavatum lidoensis	-	-	-	-	-	2	-
E. excavatum selseyensis	4	5	-	-	10	2	-
E. gunteri	-	1	-	-	-	-	-
E. magellanicum	3	3	-	-	-	-	1
E. spp.	-	-	-	-	-	1	-
Epistominella bradyana	-	-	-	-	-	1	-
E. evax	-	-	-	-	-	-	-
E. exigua	2	-	-	-	3	2	-
E. pacifica	16	19	-	3	74	103	1
E. smithi	11	53	-	-	43	10	1
Fissurina lagenoides	-	-	-	-	-	-	-
F. lucida	2	2	1	4	1	-	1
F. marginata	2	-	-	-	-	-	-
F. spp.	2	10	1	-	2	2	2
Frondicularia sp.	-	-	-	-	-	-	-
Fursenkoina cornuta	2	14	-	-	2	-	-
F. rotundata	8	-	-	-	-	-	-
F. seminuda	3	-	-	-	-	-	-
F. sp.	-	1	-	-	1	-	-
Globobulimina affinis	9	41	4	4	11	8	18
G. barbata	2	26	6	9	10	3	
G. cf. *marginospinata*	2	-	-	-	-	-	-
G. ovula	-	-	-	-	1	15	-
G. pacifica	4	7	-	2	-	-	-
G. spinifera	-	-	-	-	-	2	-
G. spp.	2	7	-	-	1	1	3

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G (continued).

Species	Depth in Core (cm) 171-173	180-182	189.5-192	210-212	230-232	248-250	270-272
Globocassidulina subglobosa	6	-	-	1	6	-	-
Gyroidina altiformis	-	18	8	9	1	-	3
G. gemma	-	11	1	2	5	2	5
G. cf. *planulata*	6	126	29	69	10	2	17
G. quinqueloba	-	-	1	-	3	-	-
G. tumidulus	-	1	-	-	2	-	-
G. turgida	-	1	-	1	-	-	1
G. spp.	1	-	-	-	2	-	-
Hoeglundina elegans	3	8	7	15	5	1	20
Jaculella acuta	-	-	-	-	-	-	-
Karreriella baccata	-	-	-	-	-	-	-
K. grammostomata	5	11	1	1	1	-	7
K. novangliae	-	-	-	-	-	-	-
Lagena acuticosta	-	1	-	-	-	-	-
L. alcocki	-	1	-	-	-	-	-
L. distoma	1	1	-	-	-	-	-
L. elongata	2	2	-	2	2	-	-
L. hispidula	4	14	3	5	2	-	3
L. striata	-	2	-	-	1	-	2
L. sulcata	2	-	-	-	-	-	-
L. sulcata laevicostata	-	-	-	-	1	-	1
L. sulcata spicata	-	-	-	-	-	-	-
L. spp.	1	-	-	-	-	-	-
Lenticulina spp.	-	-	-	-	-	-	1
Loxostomum pseudobeyrichi	11	23	-	-	4	3	1
Marginulina obesa	-	-	-	-	-	-	-
M. spp.	-	-	-	-	-	-	-
Martinottiella communis	-	-	-	-	-	-	-
Melonis barleeanus	-	19	19	7	2	-	1
M. pompilioides	6	129	69	34	33	2	5
Miliolinella californica	-	-	-	-	-	-	-
Nodosaria tympaniplectiformis (?)	-	-	-	-	-	-	-
Nonionella basispinata	3	-	-	-	1	-	-
N. decora	-	-	-	-	-	-	-
N. japonica mexicana	2	-	-	-	-	-	-
N. labradorica	-	-	-	-	1	-	-
N. miocenica	38	8	-	-	7	2	-
N. stella	-	-	-	-	-	-	-
N. sp.	-	2	-	-	-	-	-
Oolina catenulata	1	3	-	-	1	-	-
O. melo	2	5	3	-	4	-	1
O. spp.	-	-	-	-	-	-	-
O. (?) sp.	-	-	-	-	-	-	-
Oridorsalis umbonatus	-	2	1	5	3	-	17
Parafissurina fusuliformis	-	-	-	-	-	-	-
P. kerguelenensis	-	5	-	-	2	-	-
P. cf. *kerguelenensis*	-	2	-	-	-	-	13
P. tectulostoma	-	-	-	-	-	-	-
P. spp.	1	8	1	-	-	-	-
Planulina ornata	-	-	-	-	-	-	-
P. wuellerstorfi	-	7	-	5	2	4	13
Pullenia bulloides	1	3	2	1	3	1	6
P. quinqueloba	-	4	-	-	1	-	1
P. salisburyi	2	7	-	1	1	-	2
P. sp. A	-	-	-	-	-	-	-
P. sp. B	-	2	-	-	-	-	1
P. sp. C	-	-	-	-	-	-	1
Pyrgo depressa	-	-	1	-	-	-	-
P. murrhina	-	4	1	2	3	-	2
Quinqueloculina akneriana	-	-	-	-	-	-	-
Q. elongata	-	-	-	-	-	-	-
Q. spp.	-	-	-	-	-	-	-
Recurvoides spp.	-	-	-	-	-	-	-
Reophax communis	-	-	-	-	-	-	-
R. dentaliniformis	-	-	-	-	-	-	-
R. distans gracilis	-	-	-	-	-	-	-
R. (?) sp.	-	-	-	-	-	-	-
Robertina bradyi	-	-	-	1	-	-	-
Rosalina columbiensis	3	19	4	8	4	-	3
Saccammina spherica	-	-	-	-	-	-	-

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G (continued).

Species	Depth in Core (cm) 171-173	180-182	189.5-192	210-212	230-232	248-250	270-272
Saracenaria sp.	-	-	-	-	-	-	-
Sigmoilina cf. *S. tenuis*	-	-	-	-	-	-	2
S. sp.	-	-	-	-	-	-	-
Siphotextularia catenata	-	-	-	-	1	-	1
Stainforthia complanata	1	-	-	-	-	-	1
S. nodosa	-	-	-	-	1	-	-
Stilostomella cf. *S. lepidula*	-	-	-	-	-	-	-
S. sp.	-	-	-	-	-	-	-
Suggrunda eckisi	3	1	-	-	2	-	2
Trifarina angulosa	1	-	-	-	1	-	-
T. hughesi	3	-	-	-	-	-	-
T (?) sp.	-	-	-	-	-	-	-
Triloculina tricarinata	5	12	-	1	2	1	-
T. trigonula	-	-	-	-	-	-	-
Trochammina globigeriniformis	-	-	-	-	-	-	-
T. pacifica simplissima	-	-	-	-	-	-	-
Uvigerina hispida	-	-	-	-	1	-	1
U. juncea	-	-	-	-	13	2	-
U. peregrina	7	32	-	-	51	29	1
U. peregrina dirupta	-	-	-	-	1	-	-
U. proboscidea	5	47	-	-	16	-	-
U. senticosa	5	90	32	39	152	8	169
Valvulineria araucana	2	20	11	21	56	3	35
V. laevigata	4	18	-	2	1	-	1
Unknowns	2	8	3	-	5	1	1
Total Specimens	352	1250	224	308	785	403	392

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G (continued).

Species	Depth in Core (cm)						
	289.5-292	310-312	330-332	336.5-338	346.5-349.5	369.5-372.5	390-393
Anomalina globulosa	-	-	-	-	-	-	-
Astacolus sp.	-	-	-	-	-	-	-
Astrononion gallowayi	-	-	-	1	-	-	-
Bathysiphon sp.	-	-	-	-	-	-	P
Bolivina advena striatella	3	-	3	1	-	-	-
B. argentea	8	2	3	5	-	1	2
B. interjuncta bicostata	1	-	-	-	-	-	-
B. pacifica	-	-	-	-	2	2	1
B. seminuda	4	-	-	-	1	-	-
B. tongi filicostata	-	-	-	-	-	-	-
Buccella frigida	-	-	-	20	-	3	-
B. tenerrima	-	-	-	-	-	-	-
Bulimina denudata	-	-	-	-	-	-	-
B. pagoda	-	-	-	-	-	-	-
B. rostrata	1	-	1	-	-	-	-
B. striata mexicana	-	-	6	12	1	1	-
Buliminella curta	-	-	2	-	-	-	-
B. elegantissima	-	-	-	4	-	-	-
B. tenuata	2	-	-	5	2	3	-
Cassidulina cushmani	-	-	1	1	-	-	-
C. minuta	7	29	16	79	50	34	32
C. translucens	-	-	-	2	-	-	-
C. tumida	-	-	-	-	-	-	-
C. spp.	2	-	-	-	-	-	-
Cassidulinoides bradyi	1	8	7	13	7	5	-
Chilostomella oolina	-	-	-	-	-	-	-
C. ovoidea	-	-	-	-	-	-	-
C. spp.	-	-	-	-	-	-	-
Chilostomellina fimbriata	-	-	-	-	-	-	-
Cibicides lobatulus	-	-	-	1	13	-	4
C. mckannai	5	1	-	-	-	-	-
C. spp.	4	-	-	-	1	-	2
Cibicidoides kullenbergi	-	2	-	1	3	-	3
Cyclammina sp.	-	-	-	-	-	-	-
Dentalina californica	-	-	-	-	-	-	-
D. frobisherensis	-	-	-	-	-	-	-
D. mucronata	-	-	1	-	1	-	-
D. pauperata	-	-	-	-	-	-	1
D. spp.	-	-	1	-	-	1	1
Dyocibicides biserialis	-	-	-	-	1	-	-
D. sp.	-	-	-	-	-	-	-
Eggerella bradyi	1	-	1	-	1	-	1
E. spp.	-	-	-	-	-	-	-
Elphidium excavatum clavata	1	-	2	9	-	4	-
E. excavatum lidoensis	-	-	-	-	-	-	-
E. excavatum selseyensis	-	-	-	49	-	6	-
E. gunteri	-	-	-	-	-	-	-
E. magellanicum	-	2	1	19	-	9	1
E. spp.	-	-	-	-	-	-	-
Epistominella bradyana	-	-	-	-	-	-	-
E. evax	-	-	-	1	-	-	-
E. exigua	-	-	-	4	-	-	-
E. pacifica	8	6	11	35	4	6	1
E. smithi	-	-	2	7	-	-	-
Fissurina lagenoides	-	-	-	-	-	-	-
F. lucida	-	1	-	-	-	-	-
F. marginata	-	-	-	-	-	-	-
F. spp.	3	-	-	-	1	1	-
Frondicularia sp.	-	-	-	-	-	-	-
Fursenkoina cornuta	-	-	-	-	-	-	-
F. rotundata	-	-	-	-	-	-	-
F. seminuda	-	-	-	-	-	-	-
F. sp.	-	-	-	-	-	-	-
Globobulimina affinis	32	75	40	4	79	71	98
G. barbata	2	-	-	-	-	-	-
G. cf. marginospinata	-	-	-	-	-	-	-
G. ovula	-	-	-	-	2	-	-
G. pacifica	-	-	-	-	-	-	1
G. spinifera	-	-	-	-	-	-	-
G. spp.	1	5	-	1	3	-	1

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G (continued).

Species	Depth in Core (cm)						
	289.5-292	310-312	330-332	336.5-338	346.5-349.5	369.5-372.5	390-393
Globocassidulina subglobosa	-	-	2	-	-	1	-
Gyroidina altiformis	-	-	8	3	16	5	1
G. gemma	1	5	5	-	17	4	2
G. cf. planulata	4	2	10	-	10	2	14
G. quinqueloba	-	-	-	-	-	-	-
G. tumidulus	2	-	-	-	1	-	1
G. turgida	-	-	-	-	-	-	-
G. spp.	2	3	-	1	-	-	-
Hoeglundina elegans	-	-	-	-	-	-	-
Jaculella acuta	-	-	-	-	-	-	-
Karreriella baccata	-	-	-	-	-	-	-
K. grammostomata	4	7	8	1	17	10	14
K. novangliae	-	-	-	1	-	-	-
Lagena acuticosta	-	-	-	-	-	2	-
L. alcocki	-	-	-	-	-	-	-
L. distoma	-	-	-	-	-	-	1
L. elongata	-	-	-	-	-	1	1
L. hispidula	-	5	-	1	2	2	2
L. striata	1	2	-	2	2	1	1
L. sulcata	-	-	-	-	-	1	-
L. sulcata laevicostata	-	-	-	-	-	-	-
L. sulcata spicata	-	-	-	-	-	-	-
L. spp.	-	-	-	3	-	-	-
Lenticulina spp.	-	-	1	-	3	-	-
Loxostomum pseudobeyrichi	-	-	-	2	-	-	-
Marginulina obesa	-	-	-	-	-	-	1
M. spp.	-	-	1	-	-	-	-
Martinottiella communis	-	-	-	-	-	-	1
Melonis barleeanus	1	-	-	-	-	-	-
M. pompilioides	3	6	1	2	4	11	13
Miliolinella californica	-	-	-	-	-	-	6
Nodosaria tympaniplectiformis (?)	-	-	-	-	-	-	-
Nonionella basispinata	-	-	-	3	-	-	-
N. decora	-	-	-	-	-	-	-
N. japonica mexicana	-	-	-	-	-	-	-
N. labradorica	1	-	-	1	-	3	-
N. miocenica	-	-	1	16	-	3	-
N. stella	-	-	-	-	-	-	-
N. sp.	-	-	-	-	-	-	-
Oolina catenulata	-	-	-	-	1	-	-
O. melo	1	-	1	2	1	1	-
O. spp.	-	-	-	-	-	-	-
O. (?) sp.	-	-	-	-	-	-	-
Oridorsalis umbonatus	10	7	60	2	40	8	8
Parafissurina fusuliformis	-	-	-	-	-	-	-
P. kerguelenensis	-	3	-	-	1	-	-
P. cf. kerguelenensis	5	-	4	3	3	-	-
P. tectulostoma	-	-	-	-	-	-	-
P. spp.	-	-	-	-	-	-	-
Planulina ornata	1	-	-	-	-	-	-
P. wuellerstorfi	24	7	9	-	5	13	9
Pullenia bulloides	1	8	1	-	10	18	15
P. quinqueloba	-	-	-	-	-	-	-
P. salisburyi	1	5	-	1	2	1	1
P. sp. A	-	-	-	-	-	-	-
P. sp. B	-	-	-	-	-	-	-
P. sp. C	-	1	-	-	-	-	-
Pyrgo depressa	-	-	-	-	-	-	-
P. murrhina	-	-	-	-	-	-	-
Quinqueloculina akneriana	-	-	-	-	-	1	3
Q. elongata	-	-	-	-	2	-	-
Q. spp.	-	-	1	-	-	1	-
Recurvoides spp.	-	-	-	-	-	-	-
Reophax communis	-	-	-	-	-	-	-
R. dentaliniformis	-	-	-	-	-	-	-
R. distans gracilis	-	-	-	-	-	-	-
R. (?) sp.	-	-	-	-	-	-	-
Robertina bradyi	-	-	-	-	-	-	-
Rosalina columbiensis	-	5	-	1	1	1	20
Saccammina spherica	-	-	-	-	-	-	-

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G (continued).

Species	Depth in Core (cm) 289.5-292	310-312	330-332	336.5-338	346.5-349.5	369.5-372.5	390-393
Saracenaria sp.	-	-	-	-	1	-	-
Sigmoilina cf. *S. tenuis*	-	-	1	1	-	-	-
S. sp.	-	-	-	-	-	-	-
Siphotextularia catenata	-	2	2	1	-	1	4
Stainforthia complenata	-	-	-	-	1	-	1
S. nodosa	-	3	-	2	-	1	-
Stilostomella cf. *S. lepidule*	-	-	-	-	-	-	-
S. sp.	-	-	-	-	-	-	-
Suggrunda eckisi	-	-	-	-	-	-	-
Trifarina angulosa	-	-	-	2	-	-	1
T. hughesi	-	-	-	-	-	-	-
T (?) sp.	-	-	-	-	-	-	-
Triloculina tricarinata	-	-	-	1	-	2	2
T. trigonula	-	-	-	-	-	-	-
Trochammina globigeriniformis	-	-	-	-	-	-	-
T. pacifica simplissima	-	-	-	-	-	-	-
Uvigerina hispida	-	-	-	-	-	-	-
U. juncea	-	-	-	3	-	-	-
U. peregrina	1	1	3	15	-	2	-
U. peregrina dirupta	1	1	-	-	-	2	-
U. proboscidea	-	-	-	-	-	-	-
U. senticosa	283	110	81	22	199	94	102
Valvulineria araucana	21	22	29	4	31	-	4
V. laevigata	2	-	1	2	-	1	-
Unknowns	1	1	4	3	2	3	-
Total Specimens	457	337	332	375	544	343	377

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G (continued).

Species	Depth in Core (cm) 410-412.5	412-414.5	430-432.5	445-447.5	467.5-469.5
Anomalina globulosa	-	-	-	-	-
Astacolus sp.	-	-	-	-	-
Astrononion gallowayi	-	-	-	-	-
Bathysiphon sp.	-	-	-	-	-
Bolivina advena striatella	-	-	-	-	-
B. argentea	1	9	-	-	-
B. interjuncta bicostata	-	-	-	-	-
B. pacifica	2	13	2	-	-
B. seminuda	-	4	-	-	-
B. tongi filicostata	-	-	-	-	-
Buccella frigida	-	11	-	-	-
B. tenerrima	-	6	-	-	-
Bulimina denudata	-	-	-	-	-
B. pagoda	-	-	-	-	-
B. rostrata	-	-	-	-	-
B. striata mexicana	1	3	-	-	-
Buliminella curta	1	7	-	-	-
B. elegantissima	-	5	-	-	-
B. tenuata	2	14	-	-	-
Cassidulina cushmani	-	10	-	-	-
C. minuta	119	186	119	34	6
C. translucens	-	3	-	-	-
C. tumida	-	-	-	-	-
C. spp.	-	1	-	-	-
Cassidulinoides bradyi	7	37	3	1	1
Chilostomella oolina	-	7	-	-	1
C. ovoidea	-	-	-	-	-
C. spp.	1	1	1	-	-
Chilostomellina fimbriata	-	4	-	-	-
Cibicides lobatulus	-	-	5	1	-
C. mckannai	-	-	-	-	-
C. spp.	-	-	-	-	-
Cibicidoides kullenbergi	-	-	1	-	-
Cyclammina sp.	-	-	-	1	-
Dentalina californica	-	-	-	-	-
D. frobisherensis	-	-	-	-	-
D. mucronata	-	-	-	-	-
D. pauperata	-	-	1	-	-
D. spp.	-	-	-	2	-
Dyocibicides biserialis	-	-	-	-	-
D. sp.	-	-	1	-	-
Eggerella bradyi	-	1	-	3	-
E. spp.	1	-	-	-	-
Elphidium excavatum clavata	-	22	-	-	-
E. excavatum lidoensis	-	-	-	-	-
E. excavatum selseyensis	7	71	-	-	-
E. gunteri	-	-	-	-	-
E. magellanicum	3	22	-	-	-
E. spp.	-	2	-	-	-
Epistominella bradyana	-	-	-	-	-
E. evax	-	-	-	-	-
E. exigua	-	4	-	-	-
E. pacifica	12	57	-	-	-
E. smithi	-	-	-	-	-
Fissurina lagenoides	-	-	-	-	-
F. lucida	1	1	2	-	-
F. marginata	-	-	-	-	-
F. spp.	1	1	-	-	-
Frondicularia sp.	-	-	-	-	-
Fursenkoina cornuta	-	1	-	-	-
F. rotundata	1	3	-	-	-
F. seminuda	-	2	-	-	-
F. sp.	-	-	-	-	-
Globobulimina affinis	69	57	46	89	15
G. barbata	-	-	-	-	-
G. cf. *marginospinata*	-	-	-	-	-
G. ovula	-	3	1	-	-
G. pacifica	2	-	1	-	-
G. spinifera	-	3	-	-	-
G. spp.	12	1	10	6	-

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G (continued).

Species	Depth in Core (cm) 410- 412.5	412- 414.5	430- 432.5	445- 447.5	467.5 469.5
Globocassidulina subglobosa	1	-	-	1	-
Gyroidina altiformis	3	-	7	6	-
G. gemma	5	2	2	-	1
G. cf. *planulata*	7	4	5	8	2
G. quinqueloba	-	-	-	-	-
G. tumidulus	1	1	-	1	-
G. turgida	-	-	-	-	-
G. spp.	-	-	2	-	-
Hoeglundina elegans	-	-	-	-	-
Jaculella acuta	-	-	-	-	-
Karreriella baccata	-	-	-	-	-
K. grammostomata	27	13	10	19	4
K. novangliae	-	-	-	1	-
Lagena acuticosta	3	1	-	1	-
L. alcocki	-	-	-	-	-
L. distoma	-	-	-	-	-
L. elongata	1	1	-	1	-
L. hispidula	3	1	-	2	-
L. striata	-	3	-	-	-
L. sulcata	-	-	-	-	-
L. sulcata laevicostata	-	-	-	-	-
L. sulcata spicata	-	-	-	-	-
L. spp.	-	-	-	-	-
Lenticulina spp.	-	-	-	-	-
Loxostomum pseudobeyrichi	1	8	-	-	-
Marginulina obesa	-	-	-	-	-
M. spp.	-	-	-	-	-
Martinottiella communis	-	-	-	1	-
Melonis barleeanus	-	-	-	-	-
M. pompilioides	10	7	14	9	6
Miliolinella californica	1	1	-	1	-
Nodosaria tympaniplectiformis (?)	-	-	-	-	-
Nonionella basispinata	1	1	-	-	-
N. decora	-	1	-	-	-
N. japonica mexicana	-	-	-	-	-
N. labradorica	-	2	-	-	-
N. miocenica	4	30	-	-	-
N. stella	-	4	-	-	-
N. sp.	-	1	10	-	-
Oolina catenulata	-	1	-	-	-
O. melo	-	-	-	1	-
O. spp.	-	-	-	-	-
O. (?) sp.	-	-	-	-	-
Oridorsalis umbonatus	10	5	5	8	-
Parafissurina fusuliformis	-	-	-	-	-
P. kerguelenensis	2	-	-	-	-
P. cf. *kerguelenensis*	-	2	-	-	-
P. tectulostoma	-	-	-	-	-
P. spp.	-	-	-	-	-
Planulina ornata	-	-	-	-	-
P. wuellerstorfi	10	4	2	14	5
Pullenia bulloides	3	3	6	7	2
P. quinqueloba	-	-	-	-	-
P. salisburyi	4	4	1	1	1
P. sp. A	-	-	-	-	-
P. sp. B	-	-	-	-	-
P. sp. C	-	1	-	-	-
Pyrgo depressa	-	-	-	-	-
P. murrhina	-	-	-	-	1
Quinqueloculina akneriana	2	1	-	2	-
Q. elongata	-	-	-	-	-
Q. spp.	-	-	-	1	-
Recurvoides spp.	-	-	-	-	-
Reophax communis	-	-	-	-	-
R. dentaliniformis	-	-	-	-	-
R. distans gracilis	-	-	-	-	-
R. (?) sp.	-	-	-	-	-
Robertina bradyi	-	-	-	-	-
Rosalina columbiensis	8	-	3	3	4
Saccammina sphaerica	-	-	-	-	-

Appendix 3. Quantitative distribution of benthonic foraminiferal species in core S3-15G (continued).

Species	Depth in Core (cm) 410- 412.5	412- 414.5	430- 432.5	445- 447.5	467.5 469.5
Saracenaria sp.	-	-	-	-	-
Sigmoilina cf. *S. tenuis*	-	-	-	-	-
S. sp.	-	-	-	-	-
Siphotextularia catenata	4	1	3	5	-
Stainforthia complanata	3	1	-	-	-
S. nodosa	-	4	4	-	2
Stilostomella cf. *S. lepidula*	-	-	-	-	-
S. sp.	-	-	-	-	-
Suggrunda eckisi	-	-	-	-	-
Trifarina angulosa	-	-	-	-	-
T. hughesi	-	-	-	-	-
T (?) sp.	-	-	-	-	-
Triloculina tricarinata	5	7	-	1	1
T. trigonula	-	-	-	-	-
Trochammina globigeriniformis	-	-	-	-	-
T. pacifica simplissima	-	-	-	-	-
Uvigerina hispida	-	-	-	-	-
U. juncea	-	2	-	-	-
U. peregrina	-	6	-	-	-
U. peregrina dirupta	-	2	-	-	-
U. proboscidea	-	-	-	-	-
U. senticosa	117	39	69	156	29
Valvulineria araucana	7	5	1	-	-
V. laevigata	-	-	-	-	-
Unknowns	4	5	-	-	2
Total Specimens	490	746	337	387	83

Appendix 4. Quantitative distribution of pyritized benthonic foraminifers in core S3-15G.

	No. Specimens Present In Sand Samples	Prct. Pyritized Specimens In Sand Samples	No. Specimens Present In Mud Samples	Prct. Pyritized Specimens In Mud Samples	Total No. Specimens In Study	Prct. Pyritized Specimens In Study
Astrononion gallowayi	1	100	-	-	1	100
Bolivina advena striatella	16	38	6	50	22	41
B. *argentea*	285	39	18	67	303	40
B. *interjuncta bicostata*	12	75	1	100	13	77
B. *pacifica*	19	42	10	20	29	34
B. *seminuda*	40	58	7	57	47	57
Buccella frigida	42	52	3	33	45	51
B. *tenerrima*	9	11	-	-	9	11
Bulimina pagoda	8	50	-	-	8	50
B. *rostrata*	6	33	12	42	18	39
B. *striata mexicana*	119	65	9	44	128	63
Buliminella curta	7	14	3	-	10	10
B. *elegantissima*	9	67	-	-	9	67
B. *tenuata*	434	51	44	27	478	49
Cassidulina cushmani	58	64	1	100	59	64
C. *minuta*	388	32	515	12	903	20
C. *translucens*	13	23	-	-	13	23
C. *tumida*	1	100	-	-	1	100
C. spp.	4	75	2	50	6	67
Cassidulinoides bradyi	96	53	44	23	140	44
Chilostomella oolina	34	26	2	50	36	28
C. *ovoidea*	2	50	-	-	2	50
C. spp.	10	40	4	50	14	43
Chilostomellina fimbriata	20	45	-	-	20	45
Cibicides lobatulus	2	-	58	12	60	12
C. *mckannai*	-	-	8	38	8	38
C. spp.	8	50	14	29	22	36
Cibicidoides kullenbergi	7	86	43	21	50	30
Cyclammina sp.	-	-	1	100	1	100
Dentalina californica	1	100	-	-	1	100
D. *mucronata*	1	100	2	50	3	67
Dentalina spp.	2	100	8	-	10	20
Dyocibicides biserialis	-	-	1	100	1	100
Eggerella bradyi	15	33	29	-	44	11
Elphidium excavatum clavata	42	50	8	50	50	50
E. *excavatum lidoensis*	2	100	-	-	2	100
E. *excavatum selseyensis*	155	49	13	23	168	47
E. *magellanicum*	47	21	17	35	64	25
Epistominella bradyana	2	100	-	-	2	100
E. *evax*	1	100	-	-	1	100
E. *exigua*	17	59	-	-	17	59
E. *pacifica*	367	55	52	52	419	54
E. *smithi*	138	72	3	67	141	72
Fissurina lucida	7	-	16	6	23	4
F. spp.	23	9	37	11	60	10
Florilus labradoricus	4	50	4	50	8	50

Appendix 4. Quantitative distribution of pyritized benthonic foraminifers in core S3-15G (continued).

	No. Specimens Present In Sand Samples	Prct. Pyritized Specimens In Sand Samples	No. Specimens Present In Mud Samples	Prct. Pyritized Specimens In Mud Samples	Total No. Specimens In Study	Prct. Pyritized Specimens In Study
Fursenkoina cornuta	32	63	-	-	32	63
F. *rotundata*	16	50	1	100	17	53
F. *seminuda*	7	57	-	-	7	57
F. sp.	3	33	-	-	3	33
Globobulimina affinis	119	42	962	10	1081	14
G. *barbata*	44	43	38	21	82	33
G. cf. *marginospinata*	5	80	-	-	5	80
G. *ovula*	19	26	3	33	22	27
G. *pacifica*	21	10	9	22	30	13
G. *spinifera*	5	60	-	-	5	60
G. spp.	13	38	48	38	61	38
Globocassidulina subglobosa	15	27	9	11	24	21
Gyroidina altiformis	24	8	119	9	143	9
G. *gemma*	28	39	72	18	100	24
G. cf. *planulata*	153	35	277	19	430	25
G. *quinqueloba*	3	-	17	6	20	5
Gyroidina tumidulus	4	50	15	47	19	47
G. *turgida*	1	100	7	-	8	13
G. spp.	4	50	7	-	11	18
Hoeglundina elegans	19	11	151	34	170	32
Karreriella grammostomata	33	21	164	9	197	11
Lagena acuticosta	3	33	7	14	10	20
L. *alcocki*	2	50	-	-	2	50
L. *distoma*	5	40	2	-	7	29
L. *elongata*	10	20	11	-	21	10
L. *hispidula*	24	4	46	-	70	1
L. *striata*	8	13	15	7	23	9
L. *sulcata*	2	-	4	25	6	17
L. *sulcata spicata*	1	100	-	-	1	100
Lenticulina spp.	-	-	7	14	7	14
Loxostomum pseudobeyrichi	89	46	4	-	93	44
Marginulina obesa	-	-	3	33	3	33
M. spp.	-	-	4	50	4	50
Melonis barleeanus	22	32	96	38	118	36
M. *pompilioides*	197	27	819	17	1016	19
Miliolinella californica	1	-	8	38	9	33
Nonionella basispinata	9	67	1	100	10	70
N. *japonica mexicana*	4	100	-	-	4	100
N. *miocenica*	113	47	9	22	122	45
N. *stella*	4	75	-	-	4	75
N. sp.	3	100	11	36	14	50
Oolina melo	15	20	25	4	40	10
O. (?) sp.	-	-	1	100	1	100
Oridorsalis umbonatus	16	25	215	13	231	14
Parafissurina kerguelenensis	8	13	13	8	21	10
P. cf. *kerguelenensis*	7	14	25	8	32	9
P. spp.	15	20	10	20	25	20

Appendix 4. Quantitative distribution of pyritized benthonic foraminifers in core S3-15G (continued).

	No. Specimens Present In Sand Samples	Prct. Pyritized Specimens In Sand Samples	No. Specimens Present In Mud Samples	Prct. Pyritized Specimens In Mud Samples	Total No. Specimens In Study	Prct. Pyritized Specimens In Study
Planulina wuellerstorfi	21	29	211	15	232	16
Pullenia bulloides	15	53	92	7	107	13
P. quinqueloba	5	60	3	33	8	50
P. salisburyi	19	37	32	22	51	27
P. sp. A	-	-	1	100	1	100
P. sp. B	2	-	2	100	4	50
Pyrgo murrhina	8	13	31	3	39	5
Quinqueloculina akneriana	1	-	8	25	9	22
Q. elongata	-	-	2	50	2	50
Q. spp.	-	-	4	25	4	25
Rosalina columbiensis	31	32	97	16	128	20
Sigmoilina cf. *S. tenuis*	1	100	3	-	4	25
Siphotextularia catenata	3	-	30	7	33	6
Stainforthia complanata	2	50	6	-	8	13
S. nodosa	7	29	8	-	15	13
Stilostomella cf. *S. lepidula*	1	100	-	-	1	100
Suggrunda eckisi	18	72	2	50	20	70
Trifarina angulosa	7	43	1	-	8	38
T. (?) sp.	1	100	-	-	1	100
Triloculina tricarinata	29	14	16	6	45	11
Uvigerina hispida	16	38	1	-	17	35
U. juncea	40	55	-	-	40	55
U. peregrina	112	71	8	50	120	69
U. proboscidea	77	30	1	-	78	29
U. senticosa	356	15	2200	5	2556	7
Valvulineria araucana	90	43	189	35	279	38
V. laevigata	32	63	11	18	43	51

Appendix 5. Quantitative distribution of palynomorphs in core S3-15G. Broken pine grains counted as one-half.

Pollen Type	Depth in Core (cm)						
	0- 4	20- 22	40- 42	46- 48	60- 62	80- 82	97.5- 99.5
Pinus	81	52.5	49	57.5	73	76	76
Abies	1	0.5	-	-	-	-	-
TCT	87	78	107	91	92	77	89
Quercus	30	34	49	41	44	45	44
Juglans	-	-	1	1	-	-	-
Aesculus	-	-	-	-	-	-	-
Lithocarpus	9	6	9	13	8	7	1
Rhamnaceae	7	8	14	9	13	5	6
Ribes	-	-	-	-	-	-	-
Sambucus	-	-	-	-	-	-	-
Tilia	-	-	-	-	-	-	-
Eucalyptus	-	1	-	-	-	-	-
Salix	1	2	-	2	-	-	1
Alnus	7	3	1	3	3	3	5
Artemisia	10	9	8	10	6	10	8
Low-Spine Compositae	4	-	2	4	2	2	4
Liguliflorae	1	2	-	1	1	1	1
High-Spine Compositae	49	115	73	65	47	45	69
Malvaceae	-	-	-	-	-	-	-
Caryophyllaceae	-	1	-	-	-	-	-
Ericaceae	-	-	-	-	-	-	-
Salvia	-	-	-	-	-	-	-
Galium	2	-	-	-	-	-	-
Eriogonum	1	3	3	2	6	2	4
Polygonum	-	-	-	-	-	-	-
Rumex	-	-	-	1	-	-	-
Plantago	-	-	-	3	-	-	1
Umbelliferae	-	-	-	-	-	-	-
Salix-type	1	2	3	-	1	1	3
Gramineae	4	-	2	-	4	-	2
Cheno-Ams	9	15	22	14	19	19	16
Urticaceae	1	-	-	1	-	-	-
Typha-*Sparganium*	-	-	-	-	-	-	-
Monolete Spores	3	5	5	3	6	8	4
Trilete Spores	11	15	7	7	12	8	17
Indeterminates	41	46	45	46	31	44	34
Unknowns	17	16	16	22	12	18	13
Total Pollen	377	414	416	396.5	380	371	398
Lycopodium (Controls)	1679	1872	1101	946	1794	1767	1805
Pediastrum	1	-	1	-	-	-	-
Dinoflagellates	23	32	13	11	22	25	23
Fungal Spore Type-A	-	4	-	-	-	1	1
Redeposited Pollen	-	-	-	-	-	-	-

Appendix 5. Quantitative distribution of palynomorphs in core S3-15G (continued).

Pollen Type	Depth in Core (cm)						
	120-122	130-132	133.5-136.5	140-142	152.5-154.5	168-170	171-173
Pinus	69	101	189	47.5	52	52.5	83.5
Abies	1	1	-	1	-	-	-
TCT	78	61	43	69	100	87	74
Quercus	56	38	17	33	19	38	31
Juglans	-	-	-	-	-	-	-
Aesculus	-	-	-	-	-	-	-
Lithocarpus	6	3	3	3	-	4	3
Rhamnaceae	2	2	-	3	1	-	-
Ribes	-	-	-	-	-	-	-
Sambucus	-	-	-	-	-	1	-
Tilia	1	-	-	-	-	-	-
Eucalyptus	-	-	-	-	-	-	-
Salix	2	-	-	-	-	1	-
Alnus	3	1	-	1	6	10	5
Artemisia	8	12	11	5	8	8	6
Low-Spine Compositae	1	2	-	2	5	2	5
Liguliflorae	1	2	-	3	-	2	1
High-Spine Compositae	58	47	44	127	95	73	67
Malvaceae	-	-	-	-	-	-	5
Caryophyllaceae	-	-	-	-	-	-	-
Ericaceae	-	-	-	-	-	-	-
Salvia	-	1	-	-	1	-	-
Galium	-	-	-	1	2	-	-
Eriogonum	5	1	2	1	3	3	1
Polygonum	-	-	-	-	-	-	-
Rumex	-	-	-	-	-	-	-
Plantago	-	1	1	1	-	-	1
Umbelliferae	-	1	-	-	-	2	1
Salix-type	2	4	1	4	1	-	-
Gramineae	5	3	2	-	1	2	-
Cheno-Ams	8	18	10	17	9	6	12
Urticaceae	-	-	-	-	-	-	-
Typha-*Sparganium*	-	-	-	-	-	-	1
Monolete Spores	9	-	4	8	6	10	9
Trilete Spores	18	14	4	6	6	18	15
Indeterminates	46	43	34	41	54	34	40
Unknowns	14	15	21	8	14	9	15
Total Pollen	393	371	386	381.5	383	362.5	375.5
Lycopodium (Controls)	2616	875	1147	1377	1918	989	1578
Pediastrum	-	-	-	1	1	2	2
Dinoflagellates	38	11	6	24	34	25	11
Fungal Spore Type-A	3	1	-	1	4	3	4
Radeposited Pollen	-	1	-	1	2	1	-

Appendix 5. Quantitative distribution of palynomorphs in core S3-15G (continued).

Pollen Type	Depth in Core (cm)						
	180-182	190-192	210-212	230-232	248-250	270-272	290-292
Pinus	70.5	42	71	116.5	102	131.5	139.5
Abies	1	-	1	-	-	1	-
TCT	64	93	64	40	48	39	34
Quercus	42	53	23	22	32	28	15
Juglans	-	1	-	-	1	-	-
Aesculus	-	-	-	-	-	-	-
Lithocarpus	4	6	9	3	-	3	-
Rhamnaceae	-	1	2	2	-	-	3
Ribes	-	-	-	-	-	-	-
Sambucus	-	-	-	-	-	-	-
Tilia	-	-	-	-	-	-	-
Eucalyptus	-	-	-	-	-	-	-
Salix	1	-	-	-	4	1	1
Alnus	5	4	9	7	3	2	2
Artemisia	10	4	10	9	31	23	25
Low-Spine Compositae	5	2	-	2	1	3	4
Liguliflorae	-	2	4	-	2	2	-
High-Spine Compositae	66	81	66	67	34	58	45
Malvaceae	-	-	-	-	1	-	1
Caryophyllaceae	-	-	2	-	1	1	-
Ericaceae	-	-	-	-	-	1	-
Salvia	-	1	-	-	-	-	-
Galium	-	-	-	-	-	-	-
Eriogonum	2	1	1	2	1	3	2
Polygonum	-	-	-	-	-	-	-
Rumex	-	-	-	-	1	-	-
Plantago	-	-	-	4	-	-	2
Umbelliferae	2	-	-	2	-	1	-
Salix-type	1	-	3	4	-	2	7
Gramineae	-	3	1	6	6	2	5
Cheno-Ams	11	6	5	14	7	10	5
Urticaceae	-	-	1	-	-	-	-
Typha-*Sparganium*	1	-	-	-	-	-	-
Monolete Spores	6	7	5	8	-	6	10
Trilete Spores	29	8	29	12	7	6	5
Indeterminates	36	44	53	46	43	44	45
Unknowns	5	6	13	17	4	8	17
Total Pollen	361.5	365	372	383.5	309	375.5	367.5
Lycopodium (Controls)	2084	1035	1153	1941	2184	1445	1119
Pediastrum	6	1	10	31	6	3	12
Dinoflagellates	29	30	45	8	11	31	6
Fungal Spore Type-A	2	-	3	2	-	1	-
Redeposited Pollen	-	1	-	-	-	-	-

Appendix 5. Quantitative distribution of palynomorphs in core S3-15G (continued).

Pollen Type	Depth in Core (cm) 310-312	330-332	336.5-338	347-349	370-372	390-392	410-412
Pinus	135.5	148.5	160	128.5	145	173	160.5
Abies	1	-	1	-	1	3	2.5
TCT	27	20	10	25	10	14	8
Quercus	25	22	13	16	19	11	21
Juglans	-	-	-	-	-	-	-
Aesculus	-	-	-	-	-	-	-
Lithocarpus	2	3	-	1	1	-	2
Rhamnaceae	4	2	3	3	3	1	-
Ribes	-	-	-	-	-	1	-
Sambucus	-	-	-	-	-	-	-
Tilia	-	-	-	-	-	-	-
Eucalyptus	-	-	-	-	-	-	-
Salix	-	-	3	1	-	1	1
Alnus	7	2	3	7	2	-	-
Artemisia	29	28	19	27	27	27	37
Low-Spine Compositae	5	6	2	4	1	2	2
Liguliflorae	-	5	2	1	-	1	1
High-Spine Compositae	50	59	56	51	53	60	44
Malvaceae	-	-	-	1	-	-	-
Caryophyllaceae	1	-	1	4	1	-	1
Ericaceae	-	-	-	-	-	-	-
Salvia	-	-	-	-	-	-	-
Galium	-	-	-	-	-	-	-
Eriogonum	1	6	1	1	4	4	4
Polygonum	1	-	-	-	-	-	-
Rumex	-	-	-	1	-	-	-
Plantago	1	2	-	1	3	-	2
Umbelliferae	1	-	1	4	1	-	-
Salix-type	1	4	3	1	3	2	2
Gramineae	3	5	-	3	4	-	3
Cheno-Ams	13	6	4	8	14	5	12
Urticaceae	-	-	-	-	-	-	-
Typha-*Sparganium*	-	-	-	-	-	-	-
Monolete Spores	6	-	3	5	3	1	3
Trilete Spores	4	3	8	6	7	7	2
Indeterminates	41	37	61	56	42	28	50
Unknowns	11	23	14	28	21	19	28
Total Pollen	369.5	381.5	368	383.5	365	360	386
Lycopodium (Controls)	1248	1453	1971	1358	1225	1771	1193
Pediastrum	2	1	-	8	2	1	2
Dinoflagellates	5	4	2	6	2	-	5
Fungal Spore Type-A	1	-	1	-	1	1	-
Redeposited Pollen	-	-	1	-	-	-	1

Appendix 5. Quantitative distribution of palynomorphs in core S3-15G (continued).

Pollen Type	Depth in Core (cm) 412-414.5	430-432	445.5-447.5	467.5-469.5
Pinus	188	155.5	163	186
Abies	1.5	3	-	0.5
TCT	6	4	3	14
Quercus	17	12	14	12
Juglans	-	-	-	-
Aesculus	-	-	1	-
Lithocarpus	1	-	-	3
Rhamnaceae	-	1	-	3
Ribes	-	-	-	-
Sambucus	-	-	-	-
Tilia	-	-	-	-
Eucalyptus	-	-	-	-
Salix	-	1	-	-
Alnus	-	-	-	2
Artemisia	16	42	21	26
Low-Spine Compositae	2	1	2	2
Liguliflorae	5	-	1	4
High-Spine Compositae	54	60	74	47
Malvaceae	-	-	-	-
Caryophyllaceae	2	-	1	-
Ericaceae	-	-	-	-
Salvia	-	-	-	-
Galium	-	-	-	-
Eriogonum	4	2	3	1
Polygonum	-	-	-	-
Rumex	-	-	-	-
Plantago	-	2	1	3
Umbelliferae	2	-	-	-
Salix-type	2	3	1	1
Gramineae	-	1	1	-
Cheno-Ams	11	9	12	5
Urticaceae	-	-	-	-
Typha-*Sparganium*	-	-	-	-
Monolete Spores	1	-	4	5
Trilete Spores	1	5	6	4
Indeterminates	38	47	45	48
Unknowns	9	23	14	14
Total Pollen	360.5	371.5	367	380.5
Lycopodium (Controls)	1365	1113	1465	1681
Pediastrum	1	1	1	1
Dinoflagellates	6	5	2	5
Fungal Spore Type-A	-	2	-	1
Redeposited Pollen	-	1	-	-

Appendix 6. Statistical test of the slide preparation and counting methods.

A test was completed to determine if the preparation and counting techniques used in this study are reproducible. Three slides were prepared from a single sample (168-170 cm) and counted according to the methods of Byrne (1984, pers. commun.). In each case, the first 363 pollen grains and spores were tabulated. The 3 trials were compared and a multinomial homogeneity test was completed to determine if a statistical difference existed between the different number of specimens of a genus for each count of the same material on the different slides. The statistical analysis follow that of Mosimann (1965, p. 646-649). The palynomorph counts of the three trials are presented here:

Palynomorphs	Trial Number 1	2	3
Pinus	53	54	57
TCT	87	88	92
Quercus	38	33	39
Lithocarpus	4	10	6
Rhamnaceae	0	1	1
Sambucus	1	0	0
Salix	1	1	0
Alnus	10	9	4
Artemisia	8	11	5
Low-Spine Compositae	2	1	2
Liguliflorae	2	0	1
High-Spine Compositae	73	77	78
Eriogonum	3	4	1
Rumex	0	0	1
Umbelliferae	2	0	1
Gramineae	2	3	0
Cheno-Ams	6	4	8
Monolete Spores	10	3	6
Trilete Spores	18	18	14
Indeterminates	34	34	39
Unknowns	9	12	8
Total Pollen	363	363	363
Lycopodium (Controls)	989	988	994
Pediastrum	2	2	2
Dinoflagellates	25	24	25

Note: The Lycopodium, Pediastrum and dinoflagellate counts are outside the fixed pollen sum for each trial and are not included in the chi-square test that follows.

Chi-square tests are validly applied when the pollen sum is large; theoretical frequencies should not be less than five (Mosimann, 1965). Therefore, the rare taxa were grouped into the category "Others" in order to satisfy the above condition. Consequently, the data are as follows:

Palynomorphs	Trial Number 1	2	3	Total Counted	Mean
Pinus	53	54	57	164	54.67
TCT	87	88	92	267	89.01
Quercus	38	33	39	110	36.66
High-Spine Compositae	73	77	78	228	76.01
Others	112	111	97	320	106.67
Total Pollen	363	363	363	1089	

The estimates of the proportions of pine, TCT, oak, high-spine Compositae and "others" are:

$p1 = 164/1089 = 0.1506$
$p2 = 267/1089 = 0.2452$
$p3 = 110/1089 = 0.1010$
$p4 = 228/1089 = 0.2094$
$p5 = 320/1089 = 0.2938$

The chi-square values for each trial may then be calculated:

Trial 1 = 0.54
Trial 2 = 0.58
Trial 3 = 1.28

Chi-square (total) = sum of Trials 1-3 = 2.40

With eight degrees of freedom, this chi-square value is significant at the 0.950 level (Snedecor, 1956, p. 28). Therefore, the hypothesis that the three trials are homogeneous is accepted.

Appendix 7. Pediastrum species descriptions.

Two species of Pediastrum were recovered in the Monterey Fan overbank deposits. Species A (Plate 30, figure 13) is comprised of a flat coenobium of 16 coenocytes (figured is an aberrant form with only 15) arranged in three rings. A central coenocyte is present and the coenobium is entire. The morphologies of the inner and marginal coenocytes differ, with each of the latter displaying two well developed horn-like processes that lie within the same plane. This species has been described by Adam (in press) as Pediastrum sp. X from Clear Lake, California, and shows affinities to P. boryanum (Turpin) Meneghini. Unfortunately, scanning electron micrographs are necessary to precisely identify Pediastrum species (Parra Barrientos, 1979), but were not utilized in this study.

Pediastrum sp. B (Plate 1, figure 14) is characterized by a flat 32-celled coenobium arranged in four rings. The individual coenocytes are not contiguous, being separated by primarily triangular, as well as a few rectangular, perforations. The central coenocyte is absent and the inner and peripheral cells are similar in shape: rectangular, characteristically wider than high. As with species A, two processes are present in a single plane on each marginal cell, but the species B morphotype is considerably less incised. This species is the equivalent of Adam's (in press) Pediastrum sp. O from Clear Lake and is similar to Pediastrum delicatities, first described by Wilson and Hoffmeister (1953) from Paleogene deposits in southern Sumatra.

Appendix 8. Systematics of the benthonic foraminifers.

The modern names, original descriptions and a few pertinent references are provided for the benthonic foraminifers identified in the Monterey Fan levee deposits. Genera, species and subspecies, as well as morphotypes, are listed alphabetically below. When appropriate, brief remarks regarding morphology are included. Those species illustrated by light micrographs in the present report are designated by the plate and figure numbers following their preferred modern names.

Previous studies of the distribution of benthonic foraminifers in modern and ancient oceans provide the basis for ecological interpretation in this work. If available, the pertinent ecological information ascertained by these studies (i.e., the foraminifers' bathymetric and geographic distribution, percentage abundance and commonly associated taxa), and the oceanographic parameters (salinity, dissolved oxygen content and water temperature) associated with the study area are listed under the appropriate species. These previous studies are presented in geographic order from the North to South Pacific Oceans, followed by Atlantic Ocean investigations and general works on benthonic foraminifers. For the most abundant taxa, the ecological information is followed by a summary suggesting the manner and extent to which that species' presence aids in an ecological interpretation of the Monterey Fan sediments from which it was recovered.

In contrast, ecological information elucidated by previous investigations that pertains to the minor constituents of the Monterey Fan benthonic foraminiferal assemblage is presented in an abbreviated form. A citation of the author's name, date of publication, age of the assemblages investigated (designated by the following abbreviations: Cret = Cretaceous; N = Neogene; Mio = Miocene; Plio = Pliocene; Q = Quaternary; Pleis = Pleistocene; and R = Recent) and a brief explanation of the generalized subject or geographic location of the study area is followed by the ecological information relevant to that species. It is apparent that many of the citations are incomplete; the present compilation is serving as a working document to be subsequently expanded.

In addition, the occurrence and frequency of the benthonic foraminiferal taxa recovered in core S3-15G are presented.

Anomalina globulosa Chapman and Parr

Anomalina grosserugosa (Gumbel); Brady, 1884, p. 673, pl. 94, figs. 4-5.
Anomalina sp. nov. aff. *grosserugosa* (Gümbel); Thalmann, 1932, p. 309.
Anomalina globulosa Chapman and Parr; Chapman and Parr, 1937, p. 117, pl. 9, fig. 27; Barker, 1960, p. 194, pl. 94, figs. 4-5.

Ecology

Brady, 1884, R, *Challenger* Expedition.
Barker, 1960, R, *Brady's Challenger* Expedition.
Chapman & Parr, 1937, R, *Australasian*-Antarctic Exped.

Distribution

Individuals of *Anomalina globulosa* account for less than 1% of the *faunal assemblage* in four mud intervals between the depths of 128 and 170 cm downcore.

Astacolus sp.
Plate 6, figure 1

Astacolus sp.; Loeblich and Tappan, 1953, p. 53-54, pl. 9, fig. 5.

The single specimen displays a bilaterally symmetrical, compressed test with chambers beginning to uncoil. The test is composed of four very finely perforate chambers and a radiate aperture. Time did not permit identification to the specific level.

Ecology

Loeblich & Tappan, 1953, R, Arctic forams.

Distribution

Only one representative of *Astacolus* was recovered in this study. It was found associated with the mud deposits of the interval lying from 167.5 to 170 cm downcore.

Astrononion gallowayi Loeblich and Tappan
Plate 11, figure 2

Astrononion stellatum Cushman and Edwards; Cushman and Edwards, 1937, p. 32, pl. 3, figs. 9-11; Cushman and McCulloch, 1940, vol. 6, no. 3, p. 168, pl. 18, fig. 11; Phleger, 1952, p. 83, pl. 14, fig. 11; Walton, 1955, p. 1001, pl. 101, fig. 21; Hornibrook, 1964, p. 338.
Astrononion gallowayi Loeblich and Tappan; Loeblich and Tappan, 1953, p. 90-92, pl. 17, figs. 4-7; Ingle, 1973, p. 549; Scott and others, 1980, p. 226, pl. 4, fig. 5; Todd and Low, 1981, p. 34, 43, fig. 102.

Ecology

The genus *Astrononion* has been reported extensively from recent *sediments of* the Arctic region. Lagoe (1979a) identified it as a member of the Beaufort Sea shallow shelf fauna in a study of benthonic foraminifers in Prudhoe Bay, Alaska. Living in one to six meters of water, Lagoe concluded that this shallow water faunal member was one of the most opportunistic species of this region due to the severity of its environment and recurring need to repopulate the region. The genus was also reported as a rare member of the recent shallow water fauna (17 to 350 meters) of the Amerasian Basin of the Arctic Ocean (Lagoe, 1979a).

The species *Astrononion gallowayi* has been reported from *boreal waters as well*. Green (1960) noted its presence in recent sediments from the central Arctic Basin and Phleger (1951a, 1952) found it to comprise 5% or less of the recent fauna in Baffin Bay in waters less than approximately 250 meters. The taxon is also found in 3 to 223 meters of water off Point Barrow, Alaska (Loeblich and Tappan, 1953), and in Holocene and questionable Pleistocene deposits in the eastern Gulf of Alaska between Montague Island and Yakutat Bay (Quinterno, Carlson, and Molnia, 1980).

Astrononion gallowayi is geographically widespread in the *colder waters of the North* Atlantic as well, being found off Newfoundland and Iceland (Phleger, 1951a). It also occurs in the southwestern Gulf of Maine, but does not appear to live south of Massachusetts (Phleger, 1951b). On the continental shelf east and north of Cape Cod, Parker (1948) found the species to occur throughout, though in rare numbers, on a traverse from 145 to 203 meters.

This species' southerly distribution is considerably greater in the Pacific Ocean. In the high latitude waters as far north as the Gulf of Alaska, Smith (1963b) reported Astrononion gallowayi in recent shelfal deposits at 146 meters down to bathyal waters at 1950 meters. In addition, it comprised <1% of the fauna in questionable Pleistocene-aged deposits recovered in the same study. Astrononion gallowayi also appeared rarely in recent sediments of the Gulf of Alaska's Pamplona Searidge in 155 and 183 meters water depth (Todd and Low, 1967). In southeastern Alaska near Juneau, the species was found rarely in 21 and 46 meters of water in Taku Harbor and Excursion Inlet, respectively. Todd and Low's (1967) study also noted that Astrononion gallowayi was a common member of the fauna at Gambier Bay in 18 meters water depth.

To the south, specimens of Astrononion gallowayi were recovered from recent sediments in the Juan de Fuca and Georgia Straits of British Columbia, Canada (Cockbain, 1963). In this area between Vancouver Island and the mainlands of British Columbia and Washington, the taxon was found in deposits between 30 and 206 meters of water. Cushman and Todd (1947a) also report collecting the species at a depth of 18 meters in Griffin Bay of the San Juan Islands off the coast of Washington. Additionally, specimens have been obtained from recent intertidal deposits along the Oregon and Californian coasts (Cooper, 1961). The species has been recovered from deposits in the offshore basins of the southern California borderland as well, where it was found to be a minor constituent of the bank assemblage (Douglas and Heitman, 1979). The associated fauna resided on the ridges and bank tops of the outlying borderland in the California Current and Transitional Water offshore, at a depth range of from 20 to 400 meters. The assemblage's mean upper depth limit was 50 meters and it was present in waters between 7.0 and 12.0°C and salinities of 33.4 to 34.2‰. Nearby, the Allan Hancock Pacific Expedition collected Astrononion gallowayi near the Channel Islands off California and close to Guadalupe Island, Mexico, at a depth of 62 to 269 meters (Cushman and McCulloch, 1940), while Walton (1955) found only dead specimens of this taxon in Todos Santos Bay, Baja California.

To summarize, Astrononion gallowayi appears to thrive in the colder waters of the low northern latitudes of the Arctic, Pacific and Atlantic Oceans. It seems to be most commonly associated with waters of 250 meters or less in depth.

Distribution

One specimen of Astrononion gallowayi was recovered in this study. The individual was found associated with the sediments of the sand interval located from 336.5 to 338 cm downcore.

Bathysiphon sp.
Plate 1, figures 1 (?), 3

Bathysiphon sp. Several fragmented, straight, open-ended tubes represent this genus. Walls are composed of sponge spicules or coarse sand grains.

Ecology

Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Blanc-Vernet, 1969, R, Mediterranean.
Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Three intervals between the depths of 20 and 393 cm downcore, which included both muds and sands, yielded specimens of Bathysiphon. Because of their fragmented nature, these tests were not included in the statistical count.

Bolivina advena striatella Cushman
Plate 16, figure 1

Bolivina advena Cushman, var. striatella Cushman; Cushman, 1925a, p. 30, pl. 5, fig. 3; Cushman, Stewart and Stewart, 1930, p. 68; Cushman and McCulloch, 1942, p. 187, pl. 21, figs. 7-11.

Ecology

Cushman & Moyer, 1930, R, San Pedro, CA.
    This species was found only between the depths of 64 and 91 meters.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Sliter (?), 1970, R, so. CA.-Mexico, neritic Bolivinitidae.
Butcher, 1951, R, Coronado Bank, San Diego, CA.
    This species was found occurring in low relative frequency between the depths of 120 and 130 meters and in high relative frequency from 440 to 910 meters.
Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.
Brenner, 1962, R, shallow, Gulf of California.
Phleger & Ewing (?), 1962, R, lagoons, Baja CA., Mexico.

Smith, 1964, R, El Salvador & Nicaragua.
Bandy, 1956, general trends.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman & McCulloch, 1942, R, Hancock Exp, Virgulinidae
Smith, 1963a, R, Bolivinidae, El Salvador & Nicaragua.

Distribution

With the exception of one rare occurrence in the mud interval located from 289.5 to 292 cm, this species was found associated exclusively with the sand lenses sampled in this study. Bolivina advena striatella comprises 3.7% of the faunal assemblage in the sand interval between 248 and 250 cm downcore, and less than 1% in two sand layers from 330 to 338 cm downcore.

Bolivina argentea Cushman
Plate 16, figures 3, 4

Bolivina argentea Cushman; Cushman, 1926b, p. 42, pl. 6, fig. 5; Cushman and McCulloch, 1942, p. 188-189, pl. 22, figs. 2-6; Walton, 1955, p. 1001, pl. 101, figs. 26-27; Resig, 1958, p. 305; Zalesny, 1959, p. 121, pl. 1, fig. 1; Bandy, 1964, p. 141; Harman, 1964, p. 94, t.f. 6; Douglas, 1979, p. 46-47, fig. 22; Douglas and Heitman, 1979, p. 235, 239-240; Ingle, 1980, p. 172; McDougall, 1985, p. 390.
Bolivina subargentea Uchio; Uchio, 1960, p. 64, pl. 6, figs. 21-22.
Brizalina argentea (Cushman); Matoba and Yamaguchi, 1982, p. 1037, pl. 1, figs. 18-20.

Ecology

Harman, 1964, R, Santa Barbara Basin, CA.
Bolvina argentea was recovered between the depths of 372 and 588 meters in this study. The species comprised from 1 to 72% of the faunal assemblage, reaching maximum abundance at a depth of 439 meters.
Resig, 1958, R, Santa Cruz Basin, CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Douglas & Heitman, 1979, R, so. California borderland.
Ingle, 1980, Tertiary, so. CA. continental borderland.
This species is a constituent of the upper middle bathyal biofacies, located between the depths of 500 and 1500 meters. It is found associated with Bolivina seminuda, Buliminella tenuata, Epistominella pacifica, Globobulimina ovula, Oridorsalis umbonatus, and Pullenia quinqueloba.
Uchio, 1960, R, living & dead, San Diego, CA.
Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Cushman & McCulloch, 1942, R, Hancock Exp. Virgulinidae
Douglas, 1979, benthic foram ecology & paleoecology.

Distribution

Bolivina argentea was found associated primarily with the sand intervals of this study, but was recovered in low percentages from the muds as well. In the sand intervals from a depth of 46 to 414.5 cm downcore, the taxon comprises between less than 1 and 17.6% of the faunal assemblage. In the muds lying from 210 to 412.5 cm, Bolivina argentea constitutes less than 1 to 1.8% of the fauna.

Bolivina interjuncta bicostata Cushman
Plate 16, figure 7

Bolivina costata d'Orbigny var. bicostata Cushman; Cushman, 1926b, p. 42; Cushman and Moyer, 1930, p. 57.
Bolivina interjuncta Cushman var. bicostata Cushman; Cushman, 1937b, p. 116, pl. 22, fig. 23; Cushman and McCulloch (in part), 1942, p. 195, pl. 23, fig. 15; Cushman and Gray, 1946b, p. 35, pl. 6, fig. 3.
Bolivina interjuncta Cushman (in part); Crouch, 1952, p. 830.
Brizalina interjuncta bicostata (Cushman); Matoba and Yamaguchi, 1982, p. 1040, pl. 1, fig. 21.

Ecology

Crouch, 1952, R, 11 deep basins off southern CA.
Cushman & Moyer, 1930, R, San Pedro, CA.
Cushman and McCulloch, 1942, R, Hancock Exp., Virgulininae.
Murray, 1973, R, general ecology & distribution.

Distribution

With the exception of a single individual occurring in the mud interval located from 289.5 to 292 cm, Bolivina interjuncta bicostata was found associated exclusively with the sand lenses sampled between 133.5 and 250 cm downcore.

Wherever present, it comprises less than 1% of the faunal assemblage.

Bolivina pacifica Cushman and McCulloch

Plate 15, figure 5

Bolivina acerosa Cushman var. *pacifica* Cushman and McCulloch; Cushman and McCulloch, 1942, p. 185, pl. 21, figs. 2-3.
Bolivina pacifica Cushman and McCulloch; Bandy, 1953a, p. 176, pl. 24, fig. 8; Uchio, 1960, pl. 7, fig. 2; Phleger, 1964, p. 382, pl. 2, figs. 11-12; Ingle, 1973, p. 563; Lankford and Phleger, 1973, p. 115, pl. 4, fig. 7; Matoba and Yamaguchi, 1982, p. 1036, pl. 1, figs. 8-9.
Bolivina (*Bolivina*) *pacifica* Cushman; Smith, 1963a, p. A16, pl. 29, figs. 8-9.

Ecology

Bolivina pacifica Cushman and McCulloch is a delicate and widely distributed species, recorded primarily along the western North American coast but also from the North Atlantic, Arctic, and Central and South American regions (Todd and Low, 1967). In the Gulf of Alaska, this species was found rarely on the Pamplona Searidge at a depth of 155 to 183 meters (Todd and Low, 1967) and on the shelf and slope from 76 to 2070 meters by Smith (1963b). In questionable Pleistocene deposits obtained from a core taken in this same region, this taxon accounted for <1% of the faunal assemblage (Smith, 1963b). *Bolivina pacifica* has also been recovered from recent southeastern Alaskan sediments, occurring commonly at depths from 86 to 104 meters in the Kasaan Bay (Todd and Low, 1967) and at 4 meters off Wrangell (Cushman and McCulloch, 1942). In the Juan de Fuca and Georgia Straits region of British Columbia, Canada, this species was found in recent sediments from 34 to 206 meters (Cockbain, 1963). In addition, *Bolivina pacifica* has been collected from the shallow waters surrounding the islands and off the Washington coast, at two locations at a depth of 18 meters (Cushman and Todd, 1947).

Another shallow water occurrence of this species was noted in a study of the benthonic foraminifers of the western North American nearshore turbulent zone (Lankford, 1962; Lankford and Phleger, 1973). *Bolivina pacifica* was found to be a member of the "cosmopolitan" fauna, living from northern Washington to the tip of Baja California, Mexico. The species characteristically inhabited waters from 183 meters to the study's depth limit of 238 meters, but was found in lower frequencies in the shallower waters (Lankford, 1962).

Bolivina pacifica has been collected from sediments on a transect off San Francisco Bay in 122 to 213 meters of water as well (Bandy, 1953a). The surrounding hydrologic environment was characterized by a temperature range of 7.4 to 13.0°C, salinity of 33.2 to 34.0^{o}/oo and a dissolved oxygen content of 1.4 to 5.4 ml/1.

Numerous specimens of *Bolivina pacifica* have been obtained in the waters off southern California. Harman (1964), studying recent benthic foraminifers within the Santa Barbara Basin, considered it a member of his cosmopolitan fauna. The species was found between 372 and 588 meters water depth, comprising 4% of both the slope and basin faunas. Dwarfed forms of *Bolivina pacifica* were found associated with the low-oxygen zone of the Santa Barbara Basin, exhibiting particularly thin and fragile tests. Another study in the Santa Barbara region, specifically the Channel, recovered this species in the upper upper bathyal depths of 183 to 325 meters (Marks and others, 1980). This marked the highest depth occurrence of a moderate number of the species in this area.

In the Los Angeles region, several studies have recorded *Bolivina pacifica* off the coast. Natland (1933) noted the species' presence off Santa Catalina from 90 to 280 meters water depth, while McGlasson (1959) reported individuals in this same are from 75 to >183 meters. In this latter investigation, the waters were characterized by temperatures of 8.0 to 11.1°C, salinity of 33.5 to 34.1^{o}/oo and oxygen content of 1.6 to 4.7 ml/1. The living population contained abundant *Bolivina pacifica*, with the percentage abundance increasing with greater depth. Dead specimens of this taxon were not found to be indicative of a particular depth range, but were usually more abundant on the outer portions of the shelf. In a study of living and dead foraminifers in San Pedro Bay, it was found the *Bolivina pacifica* belonged to the deepest species group investigated. This group as a whole comprised <2% of the total assemblage inshore of 100 meters, but abruptly increased to 10 to >30% of the total population at the shelf edge near 100 meters (Bandy and others, 1964). *Bolivina pacifica* was also found living in nearly all parts of Santa Monica Bay, where it showed little preference for any particular substrate (Zalesny, 1959). It ranged from 12 to 841 meters water depth, but exhibited its greatest abundance at approximately 82 meters. This species has also been recorded along the southern California continental borderland by Ingle (1980), where it appears indicative of the upper bathyal biofacies of 150 to 500 meters.

To the south, off San Diego, *Bolivina pacifica* was found to range from 100 to 1025 meters water depth, with its greatest abundance in the shallower waters of the Coronado Bank region (Butcher, 1951). Bandy (1953a), in a transect study also off San Diego, included this species as part of his lower neritic fauna. The waters here were characterized by temperatures of 8.8 to 13.6°C, salinity of 33.6 to 34.2°/oo and oxygen content of 1.8 to 4.7 ml/l at a depth of 61 to 244 meters. This species was also recorded as both living and dead from 60 to 1170 meters off San Diego by Uchio (1960).

In addition to being present in the inner-neritic zone along the southern California coast, *Bolivina pacifica* continues at this same bathymetric interval along the northwestern Mexican shoreline (Sliter, 1970). The species was collected by the Allan Hancock Pacific Expedition off Ensenada de Los Muertos at 18 meters and in other areas of the Gulf of California from 102 to 229 meters (Cushman and McCulloch, 1942). Bandy (1961) cited the species as part of his recent outer shelf Gulf of California fauna, ranging in depth from 73 to 152 meters in waters with a temperature of 10.0 to 12.5°C. Shortly thereafter, Brenner (1962) extended *Bolivina pacifica*'s known distribution in the Gulf, where it was reported as a rare faunal constituent in both the northern and southern areas at a depth of from 10.2 to 73.8 meters. Living specimens have been reported from 33 to 3164 meters in the Gulf as well (Phleger, 1964), while Matoba and Yamaguchi (1982) compiled evidence from earlier works to suggest that its greatest abundance occurs in the upper middle bathyal zone from 600 to 900 meters. In addition, Walton (1955) found the taxon present in its highest percentages between approximately 91 and 183 meters, as a member of the outer bay facies in Todos Santos Bay, Baja California.

In an excellent review of recent Bolivinidae off Central America, Smith (1963a, 1964) noted that *Bolivina pacifica* ranges in depth from 47 to 3100 meters. It was found very rarely at 50 meters, rarely at 144 and 1700 meters and abundantly at 80 and 82 meters (Smith, 1963a). Studying the species' abundance, length and growth characteristics (e.g., number of chambers, width, flare), she determined that, contrary to some of the other Bolivinidae, *Bolivina pacifica* showed little morphological variation with depth off El Salvador. Smith (1964) concluded that this species was a dominant member of her Zone C from 60 to 150 meters water depth, which is the equivalent of Bandy and Arnal's (1957) "outer shelf fauna" off Central America. The base of this zone appears to lie around 200 to 250 meters off California (Smith, 1964).

Further south, the Allan Hancock Pacific Expedition recovered specimens of *Bolivina pacifica* in 37 meters of water off the Galapagos Islands and at 101 meters off Colombia (Cushman and McCulloch, 1942). Sliter (1970) has reported the taxon from the Caribbean area as well.

In summary, *Bolivina pacifica* exhibits a cosmopolitan distribution along the western shores of North and South America. Its test wall is often very fragile and may exhibit only subtle morphological variations with increasing depth. Throughout its extensive geographical distribution, *Bolivina pacifica* appears to remain associated with shallow "outer shelf" waters, ranging commonly down to approximately 250 meters water depth.

Distribution

Both mud and sand intervals yielded specimens of *Bolivina pacifica*. The taxon comprises less than 1% of the fauna in five mud samples recovered between the depths of 139 and 432.5 cm downcore. *Bolivina pacifica* also accounts for 1.7% of the assemblage in the two sand lenses from 171 to 173 cm and 412 to 414.5 cm.

Bolivina seminuda Cushman
Plate 15, figures 6, 8

Bolivina seminuda Cushman; Cushman, 1911, p. 34, fig. 55; Cushman, 1927a, p. 157, pl. 3, fig. 6; Natland, 1940, p. 21, pl. 5, fig. 19; Bandy, 1961, p. 14, pl. 4, fig. 8; Smith, 1964, p. B16, fig. 15; Bandy and Rodolfo, 1964, p. 827, fig. 5A; Ingle, Keller and Kolpack, 1980, p. 131, pl. 1, fig. 5; Matoba and Yamaguchi, 1982, p. 1036, pl. 1, figs. 10-14.
Bolivina (*Bolivina*) *seminuda* Cushman; Smith, 1963a, p. A15, pl. 29, figs. 1-7.

Ecology

Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Harman, 1964, R, Santa Barbara Basin, CA.
Crouch, 1952, R, 11 deep basins off southern CA.
Marks and others, 1980, R, Santa Barbara Channel, CA.
Cushman & Moyer, 1930, R, San Pedro, CA.
    This species was found only at a depth of 338 meters.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Martin, 1952, Plio, Los Angeles Basin, CA.
    Bolvina seminuda was recorded as present in the Repetto and Pico Formations.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Govean & Garrison, 1982, Mio, Monterey Fm., cen.-so. CA.
Butcher, 1951, R, Coronado Bank, San Diego, CA.
    This species was found occurring in low relative frequency between the depths of 125 and 910 meters.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
    This species was a dominant member of the upper bathyal biofacies between 366 and 610 meters, in temperatures ranging from 4.5 to 6.0°C.

Brenner, 1962, R, shallow, Gulf of California.
Natland, 1950, Plio-Pleis, Gulf of CA., outcrops.
This species was first described from Bowers Bank in the Bering Sea at a depth of 1067 meters. Off southern California, it was reported between the depths of 270 and 1000 meters. *Bolivina seminuda* was also obtained off the west coast of Central America in 147 to 2250 meters of water, occurring most abundantly between 360 and 1760 meters.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Smith, 1963a, R, Bolivinidae, El Salvador & Nicaragua.
Smith, 1964, R, El Salvador & Nicaragua.
Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
This species was found between the depths of 135 and 1864 meters with a rare occurrence at a depth of 4500 meters. The taxon comprised a maximum of 3.9% of the faunal assemblage at 1864 meters. Because of its upper depth limit, *Bolivina seminuda* was considered a non-dominant member of the outer shelf biofacies in the well-oxygenated waters between 135 and 150 meters.
Boltovskoy and others, 1980, R, shelf, SW Atantic.
Bandy, 1956, general trends.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman, 1911, R, Pacific Ocean, Textularids.
Cushman & McCulloch, 1942, R, Hancock Exp , Virgulinidae
Cushman, 1942, R, tropical Pacific, Hetero.-Bulimin.
Cushman, 1926b, Plio, *Bolivina* from California.

Distribution

Bolivina seminuda was recovered from both mud and sand intervals in this study. It comprises less than 1% of the faunal assemblage in the mud intervals from 128 to 349.5 cm downcore. It also constitutes from less than 1 to 3.0% of the fauna in the sands between the depths of 133.5 and 414.5 cm.

Bolivina tongi filacostata Cushman and McCulloch
Plate 16, figure 2

Bolivina tongi Cushman, var. *filacostata* Cushman and McCulloch; Cushman and McCulloch, 1942, p. 214-215, pl. 27, figs. 7-11; Uchio, 1960, pl. 6, fig. 24; Matoba and Yamaguchi, 1982, p. 1036.
Bolivina (Bolivina) tongi filacostata Cushman and McCulloch; Smith, 1963a, p. A21, pl. 30, figs. 18-19.

Ecology

Bolivina tongi filacostata Cushman and McCulloch is a small benthonic foraminifer which appears sporadically in sediments offshore North, Central and South America. Near Santa Catalina Island, this species was dredged up from a depth of 329 meters by the Allan Hancock Pacific Expedition (Cushman and McCulloch, 1942). An even shallower occurrence was recorded by Ingle (1980) in sediments along the southern California continental borderland, where *Bolivina tongi filacostata* was a member of the outer shelf biofacies at a depth of 50 to 150 meters.

In a study of recent foraminifers fifteen miles offshore San Diego, California in the vicinity of the Coronado Bank, Butcher (1951) recovered rare individuals of *Bolivina tongi filacostata* from between 100 and 630 meters. Uchio (1960), completing a more extensive survey of the same region, found living and dead individuals of this taxon to make up less than 1% of the total faunal assemblage whenever encountered. The living specimens ranged from 73 to 219 meters, whereas the total population of *Bolivina tongi filacostata* was reported consistently, but rarely, between 73 and 256 meters water depth and in scattered occurrences down to 1170 meters.

This species has also been recovered by the Allan Hancock Pacific Expedition in the Gulf of California in waters ranging from 15 to 366 meters deep (Cushman and McCulloch, 1942). Matoba and Yamaguchi (1982) reported it in material collected by the Deep Sea Drilling Project from the Guaymas Basin of the Gulf of California as well and found it to comprise only 1 to 2% of the faunal assemblage. Based on the works of others in the area (Bandy, 1961; Phleger, 1964, 1965), they concluded that it is normally found in this region between approximately 40 and 600 meters.

To the south, *Bolivina tongi filacostata* has been found off Central America between 9 and 84 meters water depth (Cushman and McCulloch, 1942). Off El Salvador, its observed depth range was from 80 to 1700 meters (Smith, 1963a, 1964). It occurred extremely abundantly at 80 meters, commonly at 82 meters, rarely at 144 and 450 meters and extremely rarely at 435 and 1700 meters water depth. Smith (1963a) also concluded that this species shows little morphological variation with increasing depth in the waters off El Salvador. The Allan Hancock Pacific Expedition also recovered this taxon off South America near the Galapagos Islands in 16 to 320 meters of water (Cushman and McCulloch, 1942).

In general, *Bolivina tongi filacostata* is a rare component of the benthonic foraminiferal assemblages off California, becoming more abundant to the south. From the limited ecological data provided, it seems to inhabit very shallow marine waters, ranging often from approximately 40 to 350 meters deep.

Distribution

One individual of Bolivina tongi filacostata was recovered from each of the two sand layers sampled between 171 and 182 cm downcore.

Buccella frigida (Cushman)

Plate 18, figure 5

Pulvinulina frigida Cushman; Cushman, 1922, p. 12.
Eponides frigidus (Cushman); Cushman, 1941, p. 37, pl. 9, figs. 16-17; Bandy, 1950, p. 278, pl. 42, fig. 5; Bandy, 1953a, p. 177, pl. 23, fig. 5.
Buccella frigida (Cushman); Anderson, 1952, p. 144-145, figs. 4-6; Loeblich and Tappan, 1953, p. 115, pl. 22, figs. 2-3; Walton, 1955, p. 1003, pl. 103, figs. 3-4; Barker, 1960, p. 216, pl. 105, figs. 8-9; Ingle, 1973, p. 545, 549, 560, 562; Sloan, 1981, p. 257-259, pl. 1, fig. 2; Todd and Low, 1981, p. 41, 43, fig. 127; Matoba and Yamaguchi, 1982, p. 1040.

Ecology

Loeblich & Tappan, 1953, R, Arctic forams.

The lectotype of this species was obtained from a depth of 18.3 meters in the south end of Black Whale Harbor in the Canadian Arctic. Specimens were also collected off Point Barrow, Alaska between the depths of 21 and 136 meters and at an unrecorded depth in the Fox Channel. In Frobisher Bay, the taxon was recorded from 55 to 101 meters, while off Akpatok Island in Ungava Bay, it was obtained between 48 and 73 meters. Off Greenland, the species was found at a depth of 13 meters and between the depths of 24 and 46 meters.

Lagoe, 1977, R, central Arctic Ocean.

The species was found between the depths of 1069 and 3576 meters, comprising less than 1% of the benthonic foraminiferal assemblages at the depths of the two end members. Buccella frigida constituted a maximum of 1% of the fauna at the depth of 1753 meters.

Lagoe, 1979a, R, deep, Arctic Ocean.

Buccella frigida, as well as Elphidium clavatum-incertum, occurs rarely within the Trochammina nana biofacies, defined by Lagoe to occur between the depths of 17 and 350 meters. Because of its sparse occurrence there, Lagoe suggested that Buccella frigida "...may not be characteristic of that biofacies."

Lagoe, 1979b, R, shallow, Prudhoe Bay, Alaska.

In the shallow waters of Prudhoe Bay, between the depths of 1 and 6 meters, Lagoe found a fauna "...overwhelmingly dominated by Elphidium spp. and related [Buccella] genera." Off the 19 species which he recorded, Buccella frigida and Elphidium clavatum were the only two in common with the Monterey Fan study. Noting that all of the species found here were also present on the nearby shallow shelf, Lagoe concluded that "...only the most opportunistic species in the shallow Arctic..." were present in Prudhoe Bay. The normally dominant arenaceous forms of the Canadian Artic were found to be extremely rare in this arctic region.

Susan Cooper, 1964, R, Chukchi Sea, Alaska.

In samples taken between the depths of 6 and 61 meters, this species was one of three dominant taxa found in the study. The varying percentages of Buccella frigida was one of the parameters used to define the assemblages.

Smith, 1963b, Pleis & R, Gulf of Alaska.

This species was present on the shelf between the depths of 117 and 240 meters. Living specimens comprised 1% of the faunal assemblage at a depth of 117 meters. Smith also found that dead individuals made up <1% of the fauna at the depths of 230 and 240 meters, and comprised a maximum of 3.5% of the assemblage in 146 meters of water.

Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.

Todd and Low did not find Buccella frigida in their samples from the Pamplona Searidge in the Gulf of Alaska, but did obtain the taxon in several areas of southeastern Alaska. The species was common in assemblages obtained in the Clarence Strait at a depth of 393 meters, in Excursion Inlet at 45.7 meters and in Lynn Canal at a depth of 19 meters. Buccella frigida was abundant in Kasaan Bay between the depths of 86 and 104 meters and was rare in Gambier Bay in 18 meters of water. The authors noted that this "...species was described from the Canadian Arctic and is typical of areas of cold water."

Bergen & O'Neil, 1979, R, Gulf of Alaska.

This species was found associated primarily with the inner, middle and outer neritic deposits in the Gulf of Alaska between the depths of 18 and 190 meters but was also recovered in bathyal depths down to 2623 meters. Buccella frigida comprised a maximum of 12, 19, and 31% of the faunas at 82, 110, and 51 meters, respectively. It's frequency abundance decreased significantly near the outer neritic zone's boundary of approximately 190 meters, below which it accounted for only 2% or less of the faunal assemblage. Bergen and O'Neil considered this taxon to be a eurythermal species because it displayed similar bathymetric distributions in the Gulf of Alaska and off California. "Environmental factors other than water temperature, perhaps water chemistry, turbulence or food supply, probably control..." its distribution.

Smith, 1973, Pleis? & Holocene, North Pacific Ocean.

Buccella frigida was obtained at only one locality in this study: in Kodiak Harbor of Kodiak Island. The specimens were obtained at a depth of 10 meters and comprised 42% of the faunal assemblage.

Lagoe, 1983, Oligocene-Plio, Gulf of Alaska.

Middle Pliocene deposits from the Yakataga Reef section in the Gulf of Alaska have yielded specimens of the arctic species *Buccella frigida*. This species was found to become initially established in the *Epistominella pacifica* biofacies, determined by Lagoe to be representative of deposition in the outer shelf to upper bathyal regions. Associated species include *Elphidium clavatum* and *Melonis zaandamae*.

Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.

Buccella spp., including *B. frigida*, were found at a depth of 16 to 206 meters and were one of the most common genera in the study.

Cushman & Todd, 1947a, R, shallow water, coast of WA.

The species was one of six to dominate the faunal assemblage in "...the shallow waters surrounding the islands and off the Washington coast." The samples in this study were obtained between the shore and approximately 80 meters.

Cooper, 1961, R, intertidal, CA. & Oregon coast.

Cooper found this species to be a member of his intertidal faunal assemblage recovered along the California and Oregon coasts.

Bandy, 1950, Eocene, Plio-Pleis, Cape Blanco, Orgon.

Bandy found *Eponides* [*Buccella*] *frigidus* to comprise 5% of the faunal assemblage in the middle or upper Pliocene deposits of the Port Orford Formation. The taxon was found associated with *Nonionella basispinata*, *Nonionella miocenica*, *Cibicides lobatus* and *Buliminella elegantissima*. Bandy concluded that this fauna showed great similarity to the Pliocene foraminifers of Humboldt County (Cushman, Stewart and Stewart, 1930) and that a "...very shallow cool environment of deposition is indicated..."

Bandy (?), 1953a, R, San Francisco to San Diego, CA.

Referred to as *Eponides frigidus* (Cushman) by Bandy, this species is associated with the middle neritic zone off San Francisco, Point Arguello and San Diego. Off San Francisco, this zone is found at a depth of 37 to 110 meters, and is characterized by a temperature of 8.5 to 13.2°C, salinity of 33.2 to 33.8^{o}/oo, and an oxygen content of 3.6 to 6.2 ml/l. The taxon comprised a maximum of approximately 10% of the faunal assemblage in this region. Off Point Arguello at a depth of 73 meters, the middle neritic zone displays these parameters: temperature from 8.6 to 13.2°C, salinity of 33.8 to 34.2^{o}/oo and an oxygen content of 3.2 to 6.2 ml/l. Bandy found *Eponides frigidus* constituting approximately 7% of the faunal assemblage off Point Arguello. To the south off San Diego, the portion of the middle neritic zone containing the taxon ranges between the depths of 30 and 61 meters. The species comprised approximately 7% of the assemblage here as well, with the temperature ranging between 10.6 and 15.4°C, salinity of between 33.3 and 33.9^{o}/oo and an oxygen content of from 3.1 to 6.4 ml/l.

Bandy, Ingle & Resig, 1964, R, San Pedro Bay, CA.

In a study of living and dead foraminifers of the San Pedro Bay, Bandy, Ingle and Resig found *Buccella frigida* to be a constituent of the inshore areas between the shoreline and 150 meters. The taxon was considered a member of the *Buliminella elegantissima* biofacies, and was found associated with that species as well as *Fissurina lucida*.

Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.

Living representatives of this species were found between the depths of 12 and approximately 119 meters in the Santa Monica Bay, while dead individuals were recovered between 12 and 408 meters. Living and dead specimens of *Buccella frigida* together comprised 8% of the fauna at a depth of 66 meters, 10% at 44 meters and 14% of the assemblage at the depth of 37 meters.

Bandy, 1963b, R, paralic, so. CA. & Gulf of CA.

Bandy determined that high percentages of *Buccella* spp. and *Buliminella elegantissima* were associated with the upper sublittoral and inner shelf biofacies in the shallow waters off southern California and in the Gulf of California.

Ingle, 1980, Tertiary, so. CA. continental borderland.

This species is a constituent of the inner shelf biofacies, located between the depths of 0 and 50 meters. It is found associated with *Buliminella elegantissima*, *Buccella tenerrima*, *Nonionella miocenica*, *N. miocenica stella*, *N. basispinata* and *Quinqueloculina akneriana*.

Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.

This species, as well as *Uvigerina peregrina* Cushman vars. (in part), *Bolivina pacifica*, *Trifarina angulosa* and *Globobulimina* spp., occurred most abundantly between the depths of approximately 91 and 183 meters.

Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.

This species was found to be a non-dominant member of the inner shelf biofacies between the depths of 0 and 18 meters, with temperatures ranging from 11.0 to 33.0°C.

Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.

Buccella frigida was recovered only rarely in the sediments collected by the Deep Sea Drilling Project in the Guaymas Basin of the Gulf of California. The taxon comprised 1% of the fauna in the Pleistocene deposits obtained at Hole 478, and 1 to 2% of the Pleistocene assembage collected from Hole 481A. Based upon the works of Bandy (1961) and Phleger (1964, 1965) involving recent foraminiferal distributions in the Gulf of California, Matoba and Yamaguchi concluded that *Buccella frigida* is characteristic of the shelf environment, between a depth of 0 and 150 meters.

Todd & Low, 1981, R, NE U.S., Nova Scotia to Cape Hatteras.

This species is characteristic of "...brackish inlets and littoral zone, New York northward and as a fossil at least as far south as Maryland."

Boltovskoy, 1959, R, Argentina.

In "...an undersized and somewhat depauperate foraminiferal fauna..." from the Argentine epicontinental sea, *Buccella frigida* was found in recent coastal zone deposits with *Buliminella elegantissima*.

Murray, 1971, R, British forams.

Living specimens are reported in the estuarine deposits of Christchurch Harbour, where they are "...slightly tolerant of hyposaline conditions...", and off Plymouth at a depth of 10 to 60 meters. Murray concludes that the taxon is characteristic of shallow shelfal waters, but is not restricted to the inner shelf. "This appears to be a northern species whose southerly limit of distribution is the English Channel." Dead individuals were reported by Murray in the Barents Sea, in the northern region of the North Sea, and along the Belgian Coast.

Distribution

Buccella frigida was found associated exclusively with the *sand intervals* investigated in this study. The species comprises from less than 1 to 5.3% of the faunal assemblage in the sands lying from 171 to 414.5 cm downcore.

Buccella tenerrima (Bandy)

Plate 18, figure 4

Rotalia tenerrima Bandy; Bandy, 1950, p. 278-279, pl. 42, fig. 3.

Buccella inusitata Anderson; Anderson, 1952, p. 148, figs. 10-11.

Buccella tenerrima (Bandy); Ingle, 1973, p. 549; *Lankford and Phleger, 1973*, p. 116, pl. 4, fig. 19; Wagner, 1978, p. 200-201, pl. 3, figs. 8-9; Matoba and Yamaguchi, 1982, p. 1040, pl. 3, fig. 7.

Ecology

Loeblich & Tappan, 1953, R, Arctic forams.

Referred to as *Buccella inusitata*, Loeblich and Tappan found this taxon off Point Barrow, Alaska between the depths of 3 and 223 meters. In Frobisher Bay, it was recorded between the depths of 24 and 143 meters, while it was listed as just present in the Fox Channel. Off Greenland, the species was obtained between the depths of 24 and 201 meters, and near Akpatok Island in Ungava Bay, it was found between the depths of 48 and 73 meters. The taxon was also obtained in the Fox Basin, near Melville Island, in the Cincinnati Press Channel at a depth of 147 meters, and at *Albatross* station D in 17 meters of water.

Green, 1960, R, central Arctic Basin.

This species was found between the depths of 497 and 1710 meters.

Susan Cooper, 1964, R, Chukchi Sea, Alaska.

This species was only rarely present in the study's bathymetric limits between 6 and 61 meters.

Bergen & O'Neil, 1979, R, Gulf of Alaska.

Buccella tenerrima was found in only three samples collected in this study of offshore deposits in the Gulf of Alaska. It comprised 6% of the inner neritic faunal assemblage at a depth of 31 meters and 1 and 5% of the upper bathyal assemblages at the depths of 232 and 300 meters.

Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.

Buccella spp., including *B. tenerrima*, were found between 16 and 206 meters and was one of the most common genera in the study.

Lankford, 1962, R, turbulent zone, W. coastal N. America.

In a study of the nearshore turbulent zone between the United States-Canadian border and the southern extension of Baja California, Mexico, Lankford found *Buccella tenerrima* associated with his shallow Oregonian and Californian faunas. The taxon occurred most abundantly in the Oregonian fauna, defined from just north of Washington to Point Conception, California. In addition, it was commonly recovered between the shoreline and approximately 12 to 15 meters, "...on very turbulent and mobile sand bottoms. Under these conditions, *Buccella tenerrima* was found associated with *Cibicides lobatulus* and *Buliminella elegantissima*. Lankford also considered the taxon to be a member of the "level-sand bottom fauna," as opposed to the "rocky-bottom fauna," which occurred at all depths in the Oregonian and Californian provinces.

Cooper, 1961, R, intertidal, CA. & Oregon coast.

Cooper found living individuals of this species to occur abundantly in intertidal samples along the California and Oregon coasts as well as in Pliocene and

Pleistocene deposits along the coast. The taxon was found to be a significant member of the beach fauna which characterized the coastal region between the Oregon border and Point Arguello, the tidepool fauna from the same geographic area but occurring most prominently between Point Arena and San Francisco, and in the combined beach and tidepool faunas between Point Arena and Point Arguello.

Bandy, 1950, Eocene, Plio-Pleis, Cape Blanco, Orgon.

Bandy found Rotalia [Buccella] tenerrima to comprise 18% of the faunal assemblage in Pleistocene deposits of the Elk River Formation. The taxon was found associated with Fissurina lucida, Cibicides lobatus and Uvigerina bradyana [U. hollicki Thalmann]. Bandy concluded that this taxon's dominant abundance, in part, defined a faunal zone and that a "...very shallow cool environment of deposition is indicated..."

Haller, 1980, Plio, Humboldt Basin, California.

Buççella tenerrima, as well as Cassidulina limbata were found abundantly in the Eel River section of the Rio Dell Formation. In the Holocene, these species are associated primarily with the inner-shelf environment, between the depths of 0 and 50 meters. Haller notes, however, that Buccella tenerrima "...may also be found in considerable numbers in central-shelf environments." The taxon was also found to be a dominant member of the Rio Dell Formation, replacing the uvigerinids at the shallower depths. Again, Haller, based upon the works of Bandy (1960b) and Lankford (1962), concludes that the species is indicative of Holocene inner and central shelf environments in the northern latitudes. In general terms, this species is said to abundantly inhabit the inner shelf waters between approximately 12 and 45 meters, and to continue as a less dominant constituent down to approximately 85 meters.

Bandy, 1963b, R, paralic, so. CA. & Gulf of CA.

Bandy determined that high percentages of Buccella spp. and Buliminella elegantissima were associated with the upper sublittoral and inner shelf biofacies in the shallow waters off southern California and in the Gulf of California. He also noted that Buccella tenerrima, specifically, was one of six dominant members of the beach fauna in these same regions. "The species may occur in channels leading into lagoons, but...[it is]...not otherwise associated with lagoonal biofacies."

Ingle, 1980, Tertiary, so. CA. continental borderland.

Ingle determined this species to be characteristic of the inner shelf biofacies between the depths of 0 and 50 meters.

Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.

This species was found associated with the intertidal beach fauna in waters ranging between 11.0 and 33.0°C.

Phleger (?), 1964, living, Gulf of California.

Listed under Buccella tenerrima var., Phleger found this taxon to be present between the depths of 13 and 80 meters. The deep limit of the species, as well as those for eleven other taxa, was used to define the boundary of the 73 to 91 meter fauna.

Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.

Buccella tenerrima was obtained in late Pliocene, Pleistocene and Holocene deposits by the Deep Sea Drilling Project in the Guaymas Basin of the Gulf of California. The taxon comprised 1% of the late Pliocene assemblage, 1 to 4% of the Pleistocene fauna, and only 1% of the Holocene assemblage. Based upon the works of Bandy (1961) and Phleger (1964, 1965) involving recent foraminiferal distributions in the Gulf of California, Matoba and Yamaguchi concluded that Buccella tenerrima is characteristic of the shelf environment, between a depth of 0 and 150 meters.

Distribution

Individuals of Buccella tenerrima were recovered from only two sand intervals sampled in this study. The taxon comprises less than 1% of the faunal assemblage in the samples located between 248 and 250 cm and 412 and 414.5 cm downcore.

Bulimina denudata Cushman and Parker

Plate 13, figure 2

Bulimina pagoda Cushman var. denudata Cushman and Parker; Cushman and Parker, 1938, p. 57, pl. 10, figs. 1-2.

Bulimina denudata Cushman and Parker; Cushman and Parker, 1947, p. 117-118, pl. 27, figs. 13-14; Cushman and McCulloch, 1948a, p. 245, pl. 30, fig. 7; Bandy, 1953a, p. 176, pl. 24. fig. 11; Matoba and Yamaguchi, 1982, p. 1040.

Ecology

Bandy, 1953a, R, San Francisco to San Diego, CA.
Bandy, Ingle & Resig, 1964, R, San Pedro Bay, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Douglas & Heitman, 1979, R, so. California borderland.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Uchio, 1960, R, living & dead, San Diego, CA.
Brenner, 1962, R, shallow, Gulf of California.

Phleger, 1964, living, Gulf of California.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Bandy, 1956, general trends.
Cushman & Parker, 1947, Mio-R, *Bulimina*.
Cushman & McCulloch, 1948a, R, *Hancock* Exp, Buliminidae.

Distribution

Four individuals of this species, comprising less than 1% of the faunal assemblage, were found associated with the sand interval lying between 180 and 182.5 cm downcore.

Bulimina pagoda Cushman
Plate 13, figure 4

Bulimina pagoda Cushman; Cushman, 1927a, p. 152, pl. 2, fig. 16; Cushman and Parker, 1940, p. 17, pl. 3, fig. 11; Uchio, 1960, pl. 6, fig. 5; Smith, 1964, p. B32, pl. 2, fig. 5; Ingle, 1973, p. 563; Matoba and Yamaguchi, 1982, p. 1040, pl. 2, fig. 3.

Ecology

The morphologically distinctive benthonic foraminifer *Bulimina pagoda* Cushman has been recovered in Tertiary and recent deposits from the Gulf of Alaska to the vicinity south of Panama. To the north, the species was obtained in Late Tertiary cored material which was drilled in depths of 1419 and 1434 meters by the Deep Sea Drilling Project from the upper continental slope southeast of Kodiak Island (Ingle, 1973). Information regarding the species' abundance or depth recovered in the core was not presented in the study.

Considerably farther south, the taxon has been reported present in a study of recent foraminifers from eleven deep basins off the southern California coast from Santa Barbara to San Diego. Crouch (1952) determined that *Bolivina pagoda* seemed to be confined to the hydrological environment in this region where the temperature remained constant at approximately 4.0°C. Its distribution was within the confines of Crouch's Zone T5 biozone, which was located at 610 to 1219 meters deep in the basins off southern California.

Bulimina pagoda has also been recovered in Pliocene sediments of the Repetto and Pico Formations of the Los Angeles Basin (Lewis Martin, 1952). Martin concluded that his Tertiary assemblage was nearly identical to the recent taxa associated with Natland's (1933) Zone IV, found distributed off southern California between 274 and 1981 meters in temperatures ranging from 4.0 to 8.5°C.

Further south, only dead specimens of *Bulimina pagoda* were reported in a study of living and dead foraminifers from the Coronado Bank and vicinity off San Diego (Uchio, 1960). The taxon was recovered between 600 and 1189 meters water depth, where it normally comprised 1% or less of the total population. *Bulimina pagoda*'s greatest abundance in this study, constituting 3% of the assemblage, occurred at a depth of 1006 meters.

This species has also been found in Pleistocene through Holocene material cored by the Deep Sea Drilling Project in the Guaymas Basin of the Gulf of California (Matoba and Yamaguchi, 1982). Although occurring sporadically, when present the taxon comprised between 1 and 2% of the faunal assemblage in all five cores taken in this region. Unfortunately, none of the late Pliocene sediments recovered in the drilling effort yielded any specimens of *Bulimina pagoda*.

The species was found to have a very restricted depth range in a study of recent sediments off El Salvador (Smith, 1964). Occurring between only 800 and 885 meters of water, this taxon comprised merely a small portion of Smith's Zone E biofacies, which is equivalent to Bandy and Arnal's (1957) middle bathyal zone. *Bulimina pagoda*'s distribution in Bandy and Arnal's (1957) study of recent foraminifers between Acapulco and the Gulf of Panama was somewhat greater though, as it was found to range between 520 and 1246 meters. These depths correspond to the lower portion of the upper bathyal and the middle bathyal regions of their zonation scheme. Most of the species' depth range lies within the middle bathyal zone however, which is characterized by temperatures of from 3.5 to 7.5°C and a salinity of about 34.7 ^{o}/oo. And lastly, the taxon was a common constituent of the faunal assemblage obtained south of Panama in recent deposits at a depth of 783 meters by an expedition aboard the U.S. Coast and Geodetic Survey ship *Lydonia* (Cushman, 1927a; Cushman and Parker, 1947).

Bulimina pagoda is normally a minor constituent of the benthonic foraminiferal assemblages in the Eastern Pacific. It is geographically widespread, having been found in Pliocene to Holocene deposits from the Gulf of Alaska to south of Panama. The species has been reported at depths between 274 and 1981 meters, but is most often found associated with the upper middle bathyal biofacies from approximately 600 to 1200 meters. One study suggested that the taxon seems to prefer inhabiting waters near 4.0°C (Crouch, 1952).

Distribution

This taxon was recovered exclusively from the sand lenses obtained between the depths of 133.5 and 182 cm downcore in this study. In its three occurrences, Bulimina pagoda always comprises less than 1% of the faunal assemblage.

Bulimina rostrata Brady
Plate 13, figure 1

Bulimina rostrata Brady; Brady, 1884, p. 408, pl. 51, figs. 14-15; Cushman, 1911, p. 87, fig. 140; Cushman, 1927a, p. 180, pl. 2, fig. 12; Cushman and Parker, 1940, p. 13, pl. 2, figs. 29-31; Bandy, 1953a, pl. 24, fig. 12; Barker, 1960, p. 104, pl. 51, figs. 14-15; Bandy, 1961, p. 26, pl. 5, fig. 15; Bandy and Rodolfo, 1964, p. 828, fig. 5B; Ingle, 1973, p. 536, 545, 553.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.
Ingle, 1973, N, DSDP Site 177, Vancouver Is., Canada.
Ingle, 1973, N, DSDP Site 174, Columbia River, WA.-OR.
Ingle, 1973, N, DSDP Site 175, central Oregon.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Ingle, 1973, N, DSDP Site 173, Cape Mendocino, no. CA.
Bandy, 1953a, R, San Francisco to San Diego, CA.
Morin, 1971, late Q, San Francisco, L.A., Baja CA.
Bandy & Arnal (?), 1960, Mio-R, San Joaquin Valley, CA.
Bandy, 1953b, Mio-Plio-Pleis, Ventura Basin, CA.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Bandy & Chierici, 1966, R, California & Mediterranean.
White, 1956, Mio-Plio, Capistrano Fm., Orange Co., CA.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
    Bulimina rostrata was found to be a dominant member of the lower bathyal biofacies, here defined to lie between the depths of 2438 and 2743 meters, with water temperatures hovering near 2.0°C.
Smith, 1964, R, El Salvador & Nicaragua.
Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Cushman, 1929b, Late Tertiary, Venezuela & Ecuador.
Bandy, 1956, general trends.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman, 1911, R, Pacific Ocean, Textularids.
Cushman & Parker, 1947, Mio-R, Bulimina.
Cushman, 1942, R, tropical Pacific, Hetero.-Bulimin.

Distribution

Bulimina rostrata was recovered primarily from mud, but also sand, intervals between the depths of 46 and 332 cm downcore. It comprises less than 1% of the faunal assemblage in all of its occurrences.

Bulimina striata mexicana Cushman
Plate 13, figures 5, 6

Bulimina inflata Sequenza var. mexicana Cushman; Cushman, 1922, p. 95, pl. 21, fig. 2.
Bulimina striata d'Orbigny var. mexicana Cushman; Cushman and Parker, 1940, p. 16, pl. 3, fig. 9; Phleger and Parker, 1951, pl. 16, pl. 7, figs. 26, 32; Bandy, 1953a, pl. 24, fig. 13; Barker, 1960, pl. 51, figs. 10-12; Bandy, 1961, pl. 5, fig. 2; Bandy and Chierci, 1966, p. 269, fig. 9; Ingle, 1973, p. 536, 542, 545, 553, 563.
Bulimina mexicana Cushman; Uchio, 1960, pl. 6, fig. 4; Matoba and Yamaguchi, 1982, p. 1040, pl. 2, fig. 2.
Bulimina striata mexicana Cushman and Parker; Ingle, Keller and Kolpack, 1980, p. 131, pl. 4, fig. 4.

Ecology

Bulimina striata mexicana Cushman has been recovered in recent deposits throughout the Pacific and Atlantic Oceans. It was reported as early as 1884 when Brady dredged the North Pacific while on board the H.M.S. Challenger (Barker, 1960), and later it was concluded that the species inhabited Pacific Ocean waters as far north as 43°N latitude (Cushman and Parker, 1947). The taxon's known distribution has been expanded greatly through more recent works.

The species has been recovered as far north as the Gulf of Alaska in the Pacific Ocean. It was found in cored Tertiary to recent deposits acquired by the Deep Sea Drilling Project at depths of 1419 and 1434 meters on the upper continental slope southeast of Kodiak Island (Ingle, 1973). Information regarding where the species was recovered downcore or in what abundances it was present was not made available in this study. Nearby, from the Kodiak shelf to Cape Fairweather, the species was found to inhabit middle to lower bathyal waters between 833 and 2623 meters (Bergen and O'Neil, 1979). Its maximum abundance in this study was found to be 7% of the total faunal assemblage at a depth of 833 meters.

Bulimina striata mexicana has also been recovered farther south off Canada and Oregon in cored material obtained by the Deep Sea Drilling Project (Ingle, 1973). Once again, data pertaining to the species' abundance and position downcore is not available, but it is known that cores taken in the following locations contained the taxon: the northwest extension of the Paul Revere Ridge west of Vancouver Island, Canada; the distal portion of the Astoria Fan westward of the mouth of the Columbia River; and on the lower continental slope off central Oregon.

Closer to the region investigated in this study, *Bulimina striata mexicana* was recovered in a Deep Sea Drilling Project core obtained just south of Cape Mendocino, California, from the slope of the Delgada Fan (Ingle, 1973). The species was also discovered in recent sediments on a transect extending 137 km offshore San Francisco to beyond the Cordell Bank, where it inhabited the upper abyssal zone between 1829 and 2103 meters (Bandy, 1953a). The waters at this depth were characterized by a temperature range of from 1.9 to 2.2°C, salinity of 34.6 to 34.7 ‰ and a dissolved oxygen content of 1.6 to 1.9 ml/l.

On another offshore transect further south of Point Arguello, Bandy (1953a) reported *Bulimina striata mexicana* existing in both the lower bathyal and upper abyssal zones. In this area, the parameters of the lower bathyal zone were: depth from 853 to 1829 meters; temperature from 3.8 to 4.4°C; and salinity of 34.3 ‰. The upper abyssal zone was characterized by a depth range of 1829 to 2377 meters, temperatures of 1.8 to 2.2°C, salinity ranging from 34.6 to 34.7 ‰ and a dissolved oxygen content ranging between 1.8 and 2.2 ml/l. In general, Bandy concluded that *Bulimina striata mexicana* was a dominant member of his northern assemblage of the lower bathyal zone, lying at approximately 914 to 1828 meters, off California.

Nearby, in a study of living and dead foraminifers of the Santa Cruz Basin off Santa Barbara, Resig (1958) discovered only dead specimens of *Bulimina striata mexicana* between approximately 549 and 1865 meters water depth. Similar results were obtained by Crouch (1952) in an investigation of the relationship between temperature, bathymetry and benthonic foraminifers in eleven deep basins off southern California from Santa Barbara to San Diego. He concluded that the taxon was a common faunal member in waters with temperatures below 5.0°C in this region, but occurred most abundantly when the temperature was about 4.0°C. These parameters correspond to Crouch's biozone T5, which was found to lie approximately 610 to 1219 meters deep in the open ocean.

Bulimina striata mexicana was also reported in recent sediments obtained from three cores from a depth of 1200 meters in the Tanner Basin off Los Angeles (Kheradpir, 1970). The taxon was one of only twelve benthonic species acquired in these cores and Kheradpir noted that the benthonic foraminiferal fauna was usually found to comprise <20% of the total foraminiferal population. The species has been reported in Pliocene and Pleistocene outcrops in the Ventura Basin as well (Bandy, 1953b). Based on recent studies conducted off San Francisco, Point Arguello and La Jolla, it was concluded that this taxon is "...most characteristic of a depth of approximately [914 meters]...in the absence of the deeper water species" (Bandy, 1953b). Uchio (1960) reported finding live individuals at somewhat similar depths off San Diego, where they were obtained between 832 and 1189 meters.

In the Gulf of California, Bandy (1961) discovered that *Bulimina striata mexicana* was a dominant member of his upper middle bathyal biofacies, inhabiting depths between 610 and 914 meters in waters from 3.5 to 4.5°C. The species was also recovered in Pleistocene to Holocene deposits cored by the Deep Sea Drilling Project in the Guaymas Basin of the Gulf of California, where it comprised up to 12% of the total faunal assemblage (Matoba and Yamaguchi, 1982). In most cases, however, the species only accounted for 1 to 2% of the population. Based on the works of Bandy (1961) and Phleger (1964, 1965), Matoba and Yamaguchi (1982) concluded that *Bulimina striata mexicana* commonly inhabits recent deposits in the Gulf of California between approximately 600 and 1900 meters. Bandy and Chierici (1966), in a comparison of California and Mediterranean bathyal foraminifers, also noted that the taxon occurs deeper than 600 meters in the Gulf of California and off California. But because it is found as shallow as approximately 100 meters deep in the Gulf of Mexico, they concluded that *Bulimina striata mexicana* is a heterobathyal species: that is, it exhibits a different upper bathymetric limit in various oceanic regions.

Considerably further south, the species has been associated with the fauna of Smith's (1964) Zone F off El Salvador, which she equated with Bandy and Arnal's (1957) lower bathyal zone, Bandy's (1953a) abyssal zone and Natland's (1933) Zone V off southern California. *Bulimina striata mexicana* was found only rarely and at a single depth in Smith's study: 1700 meters. The taxon was recovered at considerably shallower depths in the Peru-Chile Trench area, however (Ingle, Keller, and Kolpack, 1980). In this study off South America, *Bulimina striata mexicana* was reported present in recent sediments between 428 and 2568 meters, with a rare occurrence reported at a depth of 3550 meters. It was found to comprise 5.1% of the fauna at 1864 meters, 6.1% in 962 meters of water, 7.2% at a depth of 1326 meters and a maximum of 9.8% of the assemblage at the depth of 1242 meters. The authors concluded that it was a dominant member of the oxygen-poor waters associated with the upper middle-bathyal biofacies in this region.

The taxon has also been reported from a wide variety of regions besides the Eastern Pacific. It was obtained in recent and cored deposits in the middle latitudes of the

North Atlantic by the Swedish Deep-Sea Expedition (Phleger, Parker, and Peirson, 1953). *Bulimina striata mexicana* was recovered between the depths of 80 and 2430 meters in the recent material and was associated with four displaced faunal assemblages as determined by Phleger, Parker and Peirson (1953). The species also occurred in a core taken at 1995 meters of water in this study. In addition, it has also been reported from the Western Atlantic along the coast of Georgia and to the south (Cushman and Parker, 1947). In the Gulf of Mexico, *Bulimina striata mexicana* has been collected in the Louisiana-Mississippi offshore region at a depth of 384 meters (Cushman and Parker, 1947) and in the northwest area of the Gulf as well (Phleger, 1951b). In the latter, it occurred above 200 meters but became common primarily from 200 to approximately 1000 meters. The taxon was also reported once at a depth of 2800 meters in this study. Recent individuals have been found near the Philippines (Cushman and Parker, 1947) and Miocene representatives of the taxon from Buff Bay, Jamaica (Cushman and Todd, 1945).

Bulimina striata mexicana is considered a heterobathyal species which has been found in Miocene, Pleistocene and Holocene deposits of the Pacific and Atlantic Oceans. It has been recovered in numerous Deep Sea Drilling Project cores along the Eastern Pacific margin and, therefore, may be indicative of other Tertiary epochs as well. The species occurs as shoal as 100 meters in the Gulf of Mexico, but is most abundant between 200 and about 1000 meters in this region. In the North Pacific Ocean however, *Bulimina striata mexicana* is not found until a depth of approximately 550 meters. Along the west coasts of North, Central and South America, the taxon is commonly reported in sediments to a depth of 2000 meters, but becomes a dominant member of the assemblage between about 600 and 1300 meters. This bathymetric range coincides with the upper middle bathyal biofacies of Ingle (1980). In addition, *Bulimina striata mexicana* has been reported to prefer inhabiting waters below 5.0°C, becoming most abundant when the temperature hovers near 4.0°C (Crouch, 1952).

Distribution

With the exception of singular occurrences of the taxon in two mud intervals between the depths of 346.5 and 412.5 cm, *Bulimina striata mexicana* was found associated exclusively with sand intervals from 46 to 414.5 cm downcore. In the sand layers, the species comprises from less than 1 to 5.7% of the faunal assemblage.

Buliminella curta Cushman
Plate 12, figure 6

Buliminella curta Cushman; Cushman, 1925a, p. 33, pl. 5, fig. 13; Cushman and Parker, 1947, p. 64-65, pl. 16, fig. 22; Cushman and McCulloch, 1948, p. 235, pl. 29, fig. 1; Matoba and Yamaguchi, 1982, p. 1041, pl. 1, fig. 2.

Ecology

Ingle, 1980, Tertiary, so. CA. continental borderland.
Bandy & Arnal, 1957, R, W. coast of Central America.
Cushman & Parker, 1947, Mio-R, *Bulimina*.
Cushman & McCulloch, 1948a, R, Hancock Exp, Buliminidae.
Murray, 1973, R, general ecology & distribution.

Distribution

Only one individual of *Buliminella curta* was recovered from the mud layer between 410 and 412.5 cm downcore. Still rare, but slightly more numerous, occurrences of the taxon were found associated with two sand lenses located between the depths of 330 and 414.5 cm downcore. In both cases, the species comprises less than 1% of the faunal assemblage.

Buliminella elegantissima (d'Orbigny)
Plate 12, figure 7

Bulimina elegantissima d'Orbigny; d'Orbigny, 1839a, p. 51, pl. 7, figs. 13-14.
Buliminella elegantissima (d'Orbigny); Natland, 1940, p. 17; Cushman and McCulloch, 1942, p. 226-228, p. 29, fig. 4; Hoglund, 1947, p. 215-218, pl. 18, fig. 1; Phleger and Parker, 1951, p. 17, pl. 8, figs. 3-4; Bandy, 1953a, pl. 24, fig. 14; Barker, 1960, p. 104, pl. 50, figs. 20-22; Phleger, 1964, pl. 2, fig. 15; Ingle, 1973, p. 542, 549, 560; Lankford and Phleger, 1973, p. 116, pl. 4, fig. 12; Wagner, 1978, p. 189-190, pl. 3, fig. 4; Poag, 1981, p. 50, pl. 33, fig. 2 and pl. 34, fig. 2; Sloan, 1981, p. 260-262, pl. 1, fig. 3; Todd and Low, 1981, p. 31, 43, fig. 92; Matoba and Yamaguchi, 1982, p. 1041.

Ecology

Green, 1960, R, central Arctic Basin.
Lagoe, 1977, R, central Arctic Ocean.
Susan Cooper, 1964, R, Chukchi Sea, Alaska.
Smith, 1963b, Pleis & R, Gulf of Alaska.
Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Smith, 1973, Pleis? & Holocene, North Pacific Ocean.
Cushman, 1925b, R, British Columbia, Canada.
Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.
This species was found between the depths of 34 and 206 meters.
Cushman & Todd, 1947a, R, shallow water, coast of WA.
Cooper, 1961, R, intertidal, CA. & Oregon coast.
Bandy, 1950, Eocene, Plio-Pleis, Cape Blanco, Oregon.
Lankford, 1962, R, turbulent zone, W. coastal N. America.
Lankford & Phleger, 1973, R, W. coastal N. America.
Arnal and others, 1980, R, San Francisco Bay, CA.
Bandy, 1953a, R, San Francisco to San Diego, CA.
Haller, 1980, Plio, Humboldt Basin, California.
Bandy & Arnal, 1960, Mio-R, San Joaquin Valley, CA.
Harman, 1964, R, Santa Barbara Basin, CA.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Bandy, Ingle & Resig, 1964, R, San Pedro Bay, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Bandy, 1963b, R, paralic, so. CA. & Gulf of CA.
Bagg, 1912, Plio-Pleis (?), so. CA., Timms Point+.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Uchio, 1960, R, living & dead, San Diego, CA.
Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a dominant member of the inner shelf biofacies between the depths of 18 and 37 meters, with temperatures ranging from 14.0 to 18.0°C.
Phleger, 1964, living, Gulf of California.
Phleger & Ewing, 1962, R, lagoons, Baja CA., Mexico.
Natland, 1950, Plio-Pleis, Gulf of CA., outcrops.
"...since the world over, regardless of temperature, this species abounds on shallow, muddy bottoms." Off southern California, its bathymetric range is from 1 to 550 meters, being most abundant between 1 and 25 meters. Off the west coast of Central America, the taxon has been reported from 6 to 640 meters, occurring most abundantly between 63 and 104 meters.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Smith, 1964, R, El Salvador & Nicaragua.
Cushman & Kellett, 1929, R, Ecuador to Chile.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Todd & Low, 1981, R, NE U.S., Nova Scotia to Cape Hatteras.
Boltovskoy, 1959, R, Argentina.
Parker, 1948, R, cont. shelf, Gulf of Maine-Maryland.
Phleger, 1951b, R, Northwest Gulf of Mexico.
Phleger & Parker, 1951, R, NW Gulf of Mex. & Atlantic.
Boltovskoy and others, 1980, R, shelf, SW Atantic.
Murray, 1971, R, British forams.
Cushman & Parker, 1947, Mio-R, *Bulimina*.
Cushman & McCulloch, 1948a, R, *Hancock* Exp, Buliminidae.
Murray, 1973, R, general ecology & distribution.

Distribution

Two sand intervals yielded specimens of *Buliminella elegantissima*. The taxon comprises less than 1% of the assemblage in the sample taken between 412 and 414.5 cm downcore and 1.1% of the fauna in the sand interval from 336.5 to 338 cm.

Buliminella tenuata Cushman
Plate 12, figure 9

Buliminella subfusiformis Cushman var. *tenuata* Cushman; Cushman, 1927a, p. 149, pl. 2, fig. 9.
Bulimina exilis H.B. Brady; Cushman and Parker, 1940, p. 11-12, pl. 2, figs. 18-21.
Bulimina exilis H.B. Brady, var. *tenuata* (Cushman); Cushman and McCulloch, 1948, p. 248, pl. 31, fig. 2; Bandy, 1961, p. 14, pl. 4, fig. 10; Ingle, 1973, p. 542, 545, 553, 560, 562, 563.
Buliminella exilis (H.B. Brady); Bandy, 1953a, p. 176, pl.25, fig. 9.
Buliminella tenuata Cushman; Uchio, 1960, pl. 6, fig. 1; Ingle, Keller and Kolpack, 1980, p. 131, pl. 4, figs. 2-3; Matoba and Yamaguchi, 1982, p. 1041, pl. 1, figs. 4-5.
Bulimina tenuata (Cushman); Smith, 1964, p. B32, pl. 2, fig. 8.

Ecology

Buliminella tenuata Cushman was recovered as early as the late 1800's by Brady while on board the H.M.S. *Challenger* in the North Pacific (Cushman, 1911). In this pioneering study, the species was obtained in bottom sediments dredged at a depth of 631 meters (Brady, 1884). Through later works, it has become apparent that the taxon resides in the North Atlantic and Arctic Oceans and in the Eastern Pacific from the Gulf of Alaska southward to the vicinity of the Peru-Chile Trench (Bergen and O'Neil, 1979;

Cushman and McCulloch, 1948; Ingle, 1973; Ingle, Keller, and Kolpack, 1980; Loeblich and Tappan, 1953).

Loeblich and Tappan (1953) reported the presence of this taxon (=Bulimina exilis) in shallow boreal waters from Greenland to Alaska. They found it in recent deposits in northeastern Greenland at Cape Stosch, Gotthaob Island in 12.8 meters of water and between Shannon and Hochstetter Islands. Buliminella tenuata was also recovered in their samples off northwestern Greenland near Disko Island, off the southern end of the Humboldt Glacier at a depth of 201.2 meters and in the vicinity of North Wolstenholme Island between 23.8 and 45.7 meters. Additionally, the authors discovered the species in 65.9 and 73.2 meters of water off Akpatok Island in Ungava Bay, Canada and nearby in Frobisher Bay in waters 31.1, 54.9, 142.6 and 146.3 meters deep. Further west, in the Arctic Ocean, Loeblich and Tappan (1953) reported Buliminella tenuata present in six bottom samples taken off Point Barrow, Alaska at depths between 21.6 and 64.8 meters.

In the Eastern Pacific, this species has been collected from the Kodiak shelf to Cape Fairweather in the northern region of the Gulf of Alaska (Bergen and O'Neil, 1979). The shallowest occurrence of Buliminella tenuata in this study was found to be associated with the lower portion of the upper bathyal zone, here defined to exist between 232 and 564 meters. The taxon was collected in samples from 275 to 2623 meters water depth in this region, but comprised a maximum of 10 and 16% of the total faunal assemblage at 503 and 564 meters, respectively. The Deep Sea Drilling Project also recovered Buliminella tenuata in cored material from the Gulf of Alaska: on the upper continental slope southeast of Kodiak Island (Site 182), from the eastern portion of the Aleutian Trench (Site 180) and at Site 181, approximately 2000 meters above the trench (Ingle, 1973). No information regarding the species' abundance or location downcore was presented in the study.

The Deep Sea Drilling Project reported Buliminella tenuata's presence in downcore deposits collected further southward off the Canadian and northwestern United States coasts as well (Ingle, 1973). The taxon was recovered at drilling Site 177 from the northwest end of the Paul Revere Ridge west of Vancouver Island, Canada and at two locations off Oregon: on the lower continental slope off central Oregon (Site 175) and at the base of the continental slope westward of the mouth of the Columbia River on the distal portion of the Astoria Fan (Site 174). In addition, the species was recovered in recent deposits off Oregon at depths of 704, 1055, 1086 and 1646 meters in bottom samples taken by the U.S. Coast and Geodetic Survey ship Guide (Cushman, 1927a).

In the Eastern Pacific off northern California, Bandy (1953a) recovered Buliminella tenuata (=B. exilis Brady) in recent deposits obtained on a traverse approximately 133 km in length from San Francisco Bay westward across Cordell Bank. In this study, the species was found associated with the upper abyssal zone, ranging from 1829 to 2103 meters. The surrounding waters were characterized by a temperature of 1.9 to 2.2°C, salinity of 34.6 to 34.7°/oo and an oxygen content of 1.6 to 1.9 ml/l. The taxon was also obtained in bottom samples dredged by the U.S. Coast and Geodetic Survey ship Discoverer at a depth of 1494 and 2921 meters near Monterey Bay (Cushman, 1927a).

Further south off Santa Barbara, Harman (1964) reported that this species was a constituent of the faunal assemblage between 389 and 576 meters in grab samples obtained in the Santa Barbara Basin. Normally, it comprised 2 and 3% of the slope and basin plain assemblages, respectively, but peaked at 5% of the population at 430, 508 and 576 meters. Harman also investigated the benthonic foraminifers in five piston cores within this same region, finding very fragile forms of Buliminella tenuata to be restricted to the laminated sediments. No examples of the species were recovered from the homogeneous core sediments. The upper depth limit of the taxon was found to be a little shallower in Quaternary deposits of the Santa Barbara Channel (Marks and others, 1980). Associated with Cassidulina delicata, C. translucens, Epistominella smithi, Fursenkoina cornuta, Globobulimina affinis, Loxostomum pseudobeyrichi and Suggrunda eckisi, Buliminella tenuata was considered part of the lower upper bathyal biofacies, ranging in depth from 325 to 457 meters.

The recent benthonic foraminifers of eleven deep-sea basins, from Santa Barbara to San Diego, were investigated by Crouch (1952) as well. He discovered that Buliminella tenuata was common offshore in waters ranging between 4.0 and 5.0°C. The species also became a member of the dominant group between 549 and 841 meters in the Santa Monica Bay, where it was associated with water temperatures between 4.9 and 5.6°C and salinities from 34.38 to 34.42°/oo (Zalesny, 1959). In this bay, the taxon's dead representatives were recovered in waters between 430 and 841 meters, where they comprised 3 and 14% of the assemblage, respectively. On the other hand, live specimens were found from 494 to 695 meters water depth, constituting more than 60% of the total living faunal assemblage at 695 meters in the Redondo Submarine Canyon region of the Santa Monica Bay.

Elsewhere off southern California, Buliminella tenuata has been reported at 86 and 724 meters water depth (Cushman, 1927a; Cushman and McCulloch, 1948; Cushman and Parker, 1947). It has also been found in the San Pedro area in waters of 82 meters and near Santa Catalina Island at 521, 549, 894, and most abundantly, at 1097 meters (Cushman and McCulloch, 1948). Live specimens of Buliminella tenuata have been reported from the southern continental borderland as well, where they were associated with both the lower slope and basin floor assemblages (Douglas and Heitman, 1979). On the inner slopes of the nearshore basins, the species occurred in low numbers between 300 and 450 to 500 meters, occupying the zone immediately above the oxygen minimum layer, with values between 1.5 and <0.5 ml/l. The waters here are further characterized by a temperature range of between 4.8 and 7.0°C and salinity from 34.2 to 34.4^{o}/oo. At approximately 450 to 500 meters and continuing down to basin depths of 900 meters, *Buliminella tenuata* increases in abundance. In this lower part of the nearshore basin's lower slope assemblage, the faunas reside in the East Pacific Intermediate Water environment. In the outer basins, this species becomes noticeable only in the deeper region of the lower slope assemblage, occurring primarily at the sill depths of the basins and below. Temperature, salinity and oxygen content remain fairly constant in this region (i.e., 4.1 to 8.0°C, 34.3 to 34.4^{o}/oo, 0.3 to 1.1 ml/l) and are not associated with the faunal changes, but a change in sediment type from fine sandy silt to silt and clay may be responsible for the faunal distributions noted (Douglas and Heitman, 1979). *Buliminella tenuata* becomes an important member of the basin floor assemblage in both the nearshore and outer basins. The basinal waters of the nearshore basins are characterized by temperatures from 4.8 to 6.1°C, salinity of 34.3 to 34.4^{o}/oo and an oxygen content of 0.08 to 0.9 ml/l at a depth from 550 to 950 meters. The water parameters associated with the basin floor assemblage in the offshore basins at 1200 to 1900 meters water depth are quite similar: temperature between 4.1 and 6.2°C, salinity from 34.2 to 34.4^{o}/oo and a dissolved oxygen content range of 0.25 to 0.5 ml/l (Douglas and Heitman, 1979). A similar depth range for *Buliminella tenuata* was summarized by Ingle (1980) in his review of benthic foraminifers of the southern California continental borderland, where the species was found associated with the upper middle bathyal biofacies, lying at a depth of 500 to 1500 meters.

In the San Diego offshore region, the U.S. Coast and Geodetic Survey ship *Guide* collected *Buliminella tenuata* in bottom samples at a depth of 724, 785, 850 and 1011 meters and in waters 468 meters deep near the United States-Mexico border (Cushman, 1927a). Butcher (1951) reported low relative frequencies of the taxon 25 km from the San Diego coast in the Coronado Bank and associated regions, at a depth of 180 to 1025 meters. Uchio (1960) also reported the presence of live and dead individuals of this species in a later study from the same area, with the total population discovered between 391 and the study's limit of 1106 meters. The greatest percentage of living specimens, comprising 4% of the living faunal assemblage, occurred at 640 and 713 meters. In the total (living plus dead) population, *Buliminella tenuata* comprised a maximum of 0.6% of the assemblage at depths of 503, 649 and 841 meters.

Buliminella tenuata has also been found associated with oceanic deposits off Mexico. In Todos Santos Bay, Baja California, Walton (1955) found this species to be associated with his offshore fauna, which occurred just outside the bay itself, at approximately 640 meters, to a depth of at least 1097 meters. Elsewhere off Mexico, it was recovered by the Allan Hancock Pacific Expeditions at 29 and 335 meters water depth (Cushman and McCulloch, 1948). In the Gulf of California, Bandy (1961) reported this species as a dominant constituent of his upper bathyal biofacies, which was associated with a depth of 366 to 610 meters in waters ranging in temperature from 4.5 to 6.0°C. In addition, *Buliminella tenuata* was obtained in late Pliocene, Pleistocene and Holocene deposits by the Deep Sea Drilling Project in the Guaymas Basin of the Gulf of California (Matoba and Yamaguchi, 1982). The taxon comprised 5, 6, and 20% of the late Pliocene assemblages, 1 to 67% of the Pleistocene faunas, and 1 to 27% of the Holocene assemblages. Based upon the works of Bandy (1961) and Phleger (1964, 1965), involving recent foraminiferal distributions in the Gulf of California, Matoba and Yamaguchi (1982) concluded that *Buliminella tenuata* was most commonly found between approximately 350 and 1200 meters (upper to upper middle bathyal) and 1550 and 2125 meters (lower middle bathyal) water depth in this region. In addition, it was mentioned that the species showed a variable morphology, particularly in its diameter, in this study (Matoba and Yamaguchi, 1982).

From Acapulco to the Gulf of Panama, this species was found to be a prominent member of the middle bathyal faunal zone at a depth of 610 to 1219 meters, in waters with a temperature range of 3.5 to 7.5°C and salinity of about 34.7^{o}/oo (Bandy and Arnal, 1957). It was found associated with *Bolivina spissa*, *Cassidulina delicata*, *Epistominella smithi* and costate *Uvigerinas* (e.g., *Uvigerina peregrina*) and comprised a maximum of 20% of the faunal assemblage at a depth of 823 meters. Off El Salvador, Smith (1964) found *Buliminella tenuata* associated with her Zone E, essentially equivalent to Bandy and Arnal's (1957) middle bathyal zone, with the species present between 435 and 1700 meters water depth. In addition, the species was obtained in bottom samples taken by the U.S. Coast and Geodetic Survey ship *Lydonia* off Panama at a depth of 783 and 1715 meters of water (Cushman, 1927a).

The taxon has also been found off South America. The Allan Hancock Pacific Expeditions recovered it near the Galapagos Islands at 42 meters and off Ecuador in 18 meters of water (Cushman and McCulloch, 1948). It has also been found as far south as the Peru-Chile Trench area, where it ranged between 190 and 2568 meters water depth in the upper and lower bathyal regions (Ingle, Keller, and Kolpack, 1980). The species was reported to comprise 2.9% of the fauna at the depths of 962 and 1326 meters and a maximum of 3.4% of the assemblage at a depth of 428 meters. *Buliminella tenuata* was noted as being present in the shallow oxygen-minimum zone lying between 150 and 400 meters and as one of the less dominant, yet still significant, species in the oxygen-rich Antarctic Intermediate Water present below 428 meters in the upper bathyal biofacies.

Buliminella tenuata has been recovered in recent sediments from the Arctic and North Atlantic Oceans and is a common member of the benthonic foraminiferal assemblage in the Eastern Pacific from the Gulf of Alaska to Chile. It has been found in offshore deposits between 12 and 2921 meters of water, but is most often associated with depths between approximately 400 and 1100 meters. This distribution is representative of the lower upper bathyal to upper middle bathyal faunal zones along much of the western American coast (Ingle, 1980). The associated water mass is characterized by a temperature range of about 4.0 to 6.0°C and salinities of from approximately 34.2 to 34.7°/oo. One study suggested that *Buliminella tenuata* has a variable morphology: *specifically, in the diameter* of its test (Matoba and Yamaguchi, 1982).

Distribution

Buliminella tenuata is a dominant species in the *Monterey Fan levee deposits*, occurring from the core-top to a depth of 414.5 cm downcore. It is found in greatest abundance in the upper 250 cm of the core, particularly in the sand lenses, where it comprises between less than 1 and 41.9% of the assemblage. In contrast, it ranges from less than 1 to a maximum of 2.6% of the fauna in the mud layers.

Cassidulina cushmani Stewart and Stewart
Plate 20, figure 4

Cassidulina cushmani Stewart and Stewart; Stewart and *Stewart, 1930, p. 71*, pl. 9, fig. 5; Natland, 1950, p. 34, pl. 9, fig. 9; Bandy, 1953a, p. 176; Smith, 1964, p. B39, pl. 3, fig. 5.
"Islandiella" cushmani (Stewart and Stewart); Matoba and *Yamaguchi, 1982, p. 1045*, pl. 2, fig. 1.

Although Stewart and Stewart (1930) would disagree, the length and slit-like nature of the aperture and degree of development of the keel appear to be the only morphological characters separating *Cassidulina cushmani* Stewart and Stewart and *C. delicata* *Cushman. As* a *continuum* between these two *end-members* was noted in the Monterey Fan levee deposits, the author followed Uchio (1960) in synonymizing the two. In contrast to Uchio, however, both taxa were placed under *Cassidulina cushmani* in this study.

Ecology

Smith, 1963b, Pleis & R, Gulf of Alaska.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Bandy, 1953a, R, San Francisco to San Diego, CA.
Haller, 1980, Plio, Humboldt Basin, California.
Resig, 1958, R, Santa Cruz Basin, CA.
Crouch, 1952, R, 11 deep basins off southern CA.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Martin, 1952, Plio, Los Angeles Basin, CA.
The species was reported as being present in the Repetto and Pico Formations.
White, 1956, Mio-Plio, Capistrano Fm., Orange Co., CA.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
The species was found to a dominant member of the upper bathyal biofacies between the depths of 366 and 610 meters, with temperatures ranging from 4.5 to 6.0°C.
Brenner, 1962, R, shallow, Gulf of California.
Natland, 1950, Plio-Pleis, Gulf of CA., outcrops.
This species was recovered off southern California between the depths of 250 and 2700 meters. It has also been obtained off the west coast of Central America from 275 to 2250 meters, occurring most abundantly in waters 520 to 782 meters deep.
Bandy & Arnal, 1957, R, W. coast of Central America.
Smith, 1964, R, El Salvador & Nicaragua.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
McCulloch, 1977, more Allan Hancock Exped. forams.
Murray, 1973, R, general ecology & distribution.

Distribution

Cassidulina cushmani was recovered exclusively from the sand *lenses investigated* in this study. Comprising from less than 1 to a maximum of 2.9% of the faunal assemblage, the taxon was obtained between the depths of 46 and 414.5 cm downcore.

Cassidulina minuta Cushman
Plate 20, figure 1

Cassidulina minuta Cushman; Cushman, 1933b, p. 92-93, pl. *10, fig. 3; Smith*, 1964, p. B39, pl. 3, fig. 8; Ingle, 1973, p. 536, 542, 553, 562, 563; Haller, 1980, p. 260, pl. 12, fig. 6; Ingle, Keller, and Kolpack, 1980, p. 132, pl. 1, fig. 13.

Ecology

Phleger, 1951a, R, Canadian and Greenland Arctic.
In Baffin Bay, this species was found to be a member of the recent arctic fauna and appeared to be "...generally indicative of water depths less than about 250 m..."

Cooper, 1961, R, intertidal, CA. & Oregon coast.
Cooper found this species to be a member of the intertidal faunal assemblage along the California and Oregon coasts.

Haller, 1980, Plio, Humboldt Basin, California.
Cassidulina minuta was found occurring rarely to frequently in the Centerville coastal section of the lower, middle and upper Rio Dell Formation, as defined by Haller. In the Scotia-Eel River section, the taxon was reported to be frequent in the Pullen Formation and rare to common in the lower, middle and upper sections of the Rio Dell Formation. Based upon the works of Bandy (1960b) and Lankford (1962), involving the bathymetric distribution of recent foraminifers, Haller concluded that Cassidulina minuta lives in abundance in the central and outer shelf regions between approximately 60 and 150 meters, and in lesser percentages in the upper bathyal environment to a depth of nearly 600 meters.

Harman, 1964, R, Santa Barbara Basin, CA.
This species was present in both the slope and basin faunas recovered between the depths of 372 and 576 meters. It comprised less than 1% of the faunal assemblage at all depths with the exception of 467 meters, where the taxon accounted for 3% of the fauna. Because it was present on both the slope and in the basin, Harman considered it a member of his cosmopolitan fauna.

McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Living and dead individuals of Cassidulina minuta were recovered by McGlasson off Santa Catalina Island. The taxon, as well as Bolivina pacifica and Trifarina angulosa, was found to be "...equally abundant in sediments of all grain sizes." Living specimens of Cassidulina minuta did not appear to be representative of any specific depth range, whereas dead individuals, as well as the other species of Cassidulina recovered, dominated the faunal assemblage between the depths of 75 and >183 meters.

Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
This species was found between the depths of 22 and 841 meters in the Santa Monica Bay. The taxon comprised a maximum of 4% of the fauna at the depths of 59, 192 and 201 meters and 6% at 91 meters. It also constituted 10% of the assemblage at 174 meters and 16% at 841 meters. Cassidulina minuta was not one of the four Cassidulina species mentioned by Zalesny to live predominantly on rock, gravel and sand surfaces. Instead, he implied that its preferred habitat included silts and sands.

Ingle, 1980, Tertiary, so. CA. continental borderland.
"Species exhibiting a transitional distribution from outer shelf to upper bathyal depths and generally indicative of the shelf-edge environment." Ingle defined the outer shelf biofacies as lying between 50 and 150 meters, whereas his upper bathyal biofacies ranges from 150 to 500 meters.

Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a dominant member of the outer shelf biofacies between the depths of 37 and 73 meters, with temperatures ranging from 12.5 to 18.0°C.

Bandy & Arnal, 1957, R, W. coast of Central America.
In a study from Acapulco to the Gulf of Panama, this taxon was found to comprise 19% and 1% of the faunal assemblage at the depths of 90 and 329 meters, respectively. This small form, characterized by a rounded edge, constituted such a large percentage of the assemblage in the outer shelf region between 46 and 122 meters that this zone's biofacies was referred to by Bandy and Arnal as the Cassidulina minuta fauna. This depth interval is characterized by a temperature range from 14.0 to 20.0°C and salinity from 34.2 to 34.6°/oo. It was found commonly associated with Cibicides mckannai and "...together, they appear to represent a transitional fauna between the outer shelf and the upper bathyal faunal zones."

Smith, 1964, R, El Salvador & Nicaragua.
Cassidulina minuta was found between the depths of 50 and 144 meters.

Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
This species was found between the depths of 135 and 3550 meters, comprising a maximum of 5.9% of the faunal assemblage at the depth of 1948 meters.

Lessard, 1980, R, shallow, tropical Pacific Ocean.

Boltovskoy and others, 1980, R, shelf, SW Atantic.
Boltovskoy and others, in studying the recent shelfal foraminifers of the southwestern Atlantic, concluded that Cassidulina minuta was a euhaline species in this region. The taxon was found associated with Trifarina angulosa, Buliminella elegantissima, Bolivina seminuda, Cibicides lobatulus, Elphidium magellanicum, E. gunteri, Epistominella exigua and Hoeglundina elegans, among others.

Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

Cassidulina minuta was found to be a ubiquitous member of the Monterey Fan levee deposits. Occurring in both mud and sand intervals between the depths of 20 and 469.5 cm downcore, this taxon accounts for less than 1 to 5.5% of the fauna in sediments down to 292 cm. The species' abundance rises dramatically below this core depth, where it contributes from 4.8 to 35.3% of the faunal assemblage.

Cassidulina translucens Cushman and Hughes
Plate 20, figure 5

Cassidulina translucens Cushman and Hughes; Cushman and Hughes, 1925, p. 15, pl. 2, fig. 5; Cushman, 1925c, p. 54, pl. 9, figs. 3-4; Galloway and Wissler, 1927, p. 80-81, pl. 12, fig. 11; Church, 1928, p. 266; Natland, 1950, p. 35, pl. 9, fig. 10; Bandy, 1953a, p. 176, pl. 25, fig. 6; Ingle, 1973, p. 545, 562, 563.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.
Cooper, 1961, R, intertidal, CA. & Oregon coast.
Bandy, 1953a, R, San Francisco to San Diego, CA.
Haller, 1980, Plio, Humboldt Basin, California.
Marks and others, 1980, R, Santa Barbara Channel, CA.
Cushman & Moyer, 1930, R, San Pedro, CA.
  This species was found only at a depth of 732 meters.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Church, 1928, lower Plio, Los Angeles Basin, CA.
Martin, 1952, Plio, Los Angeles Basin, CA.
  This species was reported as present in the Repetto and Pico Formations.
Galloway & Wissler, 1927, Pleis, Palos Verdes, CA.
White, 1956, Mio-Plio, Capistrano Fm., Orange Co., CA.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Butcher, 1951, R, Coronado Bank, San Diego, CA.
  This species was found to occur in low relative frequency between the depths of 140 and 1025 meters.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
  This species was found to be a dominant member of the upper bathyal biofacies between the depths of 366 and 610 meters, with temperatures ranging from 4.5 to 6.0°C.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman & Hughes, 1925, Plio-Pleis, Palos Verdes, CA.
McCulloch, 1977, more Allan Hancock Exped. forams.
Murray, 1973, R, general ecology & distribution.

Distribution

Rare occurrences of *Cassidulina translucens*, always comprising less than 1% of the faunal assemblage, were found associated exclusively with the six sand intervals investigated between the depths of 133.5 and 414.5 cm downcore.

Cassidulina tumida Natland
Plate 20, figures 6, 7

Cassidulina tumida Natland; Natland, 1938, p. 148-149, pl. 6, figs. 2-3; Smith, 1964, p. B40, pl. 3, figs. 7, 11; Matoba and Yamaguchi, 1982, p. 1041, pl. 3, fig. 12.

Ecology

Crouch, 1952, R, 11 deep basins off southern CA.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Smith, 1964, R, El Salvador & Nicaragua.
Murray, 1973, R, general ecology & distribution.

Distribution

One representative of this species was recovered in the sand interval lying between 248 and 250 cm downcore.

Cassidulina spp.
Plate 20, figures 3, 8

Cassidulina spp. Six individuals were recovered, two of which are figured. One shows similarities to *Cassidulina norcrossi* Cushman. Time did not permit identification to the specific level.

Ecology

Cushman, 1933d, R, arctic, Fox Basin and Greenland.
Lagoe, 1979b, R, shallow, Prudhoe Bay, Alaska.
McGlasson (?), 1959, R, living & dead, S. Catalina Is., CA.
Murray, 1973, R, general ecology & distribution.

Distribution

Four of the six *Cassidulina* spp. were found associated with an equal number of sand layers located between the depths of 46 and 414.5 cm downcore. The remaining two individuals were recovered from the mud interval lying from 289.5 to 292 cm.

Cassidulinoides bradyi (Norman)
Plate 21, figure 2

Cassidulina bradyi Norman; Norman, in Brady, 1881, p. 59; Brady (in part), 1884, p. 431, pl. 54, figs. 6-9; Cushman, 1925c, p. 52, pl. 8, figs. 3-5.
Cassidulinoides bradyi (Norman); Barker, 1960, p. 112, pl. 54, figs. 6-9; Ingle, 1973, p. 563; Haller, 1980, p. 261, pl. 13, fig. 6.

Ecology

Cushman & Todd, 1947b, Plio? Pleis?, Amchitka Is., AK.
Quarry samples yielded questionable representatives of this taxon. The "...fauna is decidedly one of cold waters, it is not by any means arctic..."

Cushman, 1927a, R, W. coast, Oregon to Central Amer.
The species was recovered south of Monterey Bay at the depths of 1346 and 1494 meters, off southern Baja, Mexico at a depth of 1677 meters, and near the United States-Mexico border at a depth of 1353 meters.

Haller, 1980, Plio, Humboldt Basin, California.
Cassidulinoides bradyi was obtained in only a few samples from the lower member of the Rio Dell Formation, as exposed in the Centerville coastal section. It comprised a maximum of between 2.5 and 5% of the faunal assemblage in these Pliocene (Venturian-Wheelerian) deposits. Based upon the works of Bandy (1960b) and Lankford (1962), investigating the bathymetric distribution of recent foraminifers, Haller concluded that *Cassidulinoides* spp. are abundantly represented in the bathyal and abyssal environments between approximately 150 and >4000 meters.

Crouch, 1952, R, 11 deep basins off southern CA.
Crouch found this species, which he referred to as *Cassidulinoides* cf. *C. bradyi*, common in water temperatures between 4.0 and 5.0C. He also noted that individuals became more compressed and rare in abundance when the temperature dropped below 3.0C.

Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
This species was reported in both the upper- and lower-middle bathyal zones in the Peru-Chile Trench area. The taxon occurred rarely at a depth of 800 meters and comprised <1% of the faunal assemblage in 1864 and 3550 meters of water.

Resig, 1976, Eocene-R, DSDP, Nazca Plate, Peru.
Utilizing only the sand size (>0.062 mm) fraction of the DSDP core material, Resig reported obtaining *Cassidulinoides bradyi* in Pleistocene-Holocene sediments from the Nazca Plate. The taxon was found in only sample, where it comprised 3% of the faunal assemblage.

Parker, 1948, R, cont. shelf, Gulf of Maine-Maryland.
On the continental shelf from Cape Cod to Maryland, *Cassidulinoides bradyi* was found to be a dominant member of Parker's Zone 3, lying between the depths of 90 and 300 meters. This taxon was found associated with *Oridorsalis umbonatus*, *Gyroidina soldanii*, *Trochammina globigeriniformis*, *Chilostomella ovoidea* and *Trifarina angulosa*.

Murray, 1971, R, British forams.
Murray concluded that *Cassidulinoides bradyi* is characteristic of "...the outer shelf and the top of the continental slope (100-1000 m)." This outer shelf species was found living on the shelf edge by the western approaches to the English Channel between the depths of 420 and 1002 meters. Dead specimens were also found at this locality, as well as in the Bay of Biscay.

Cushman & Todd, 1945, Mio, Buff Bay, Jamaica.
The species has been reported in Miocene sediments from Buff Bay, Jamaica which were deposited at "...medium depths and not close to shore..."

Cushman, 1911, R, Pacific Ocean, Textularids.
The species was found south of Japan at a depth of 631 meters, off the Philippines in 174 meters of water, near Guam at 1629 meters, off the Midway Islands at a depth of 3639 meters and near the Hawaiian Islands in 4071 meters of water.

Distribution

Specimens of *Cassidulinoides bradyi* were recovered from both mud and sand intervals between the depths of 20 and 469.5 cm downcore. In the mud layers, the taxon accounts for less than 1 to 2.4% of the fauna and increases in abundance downcore. In addition, *Cassidulinoides bradyi* is slightly more prevalent in the sand units, with its maximum abundance reaching 5.0%.

Chilostomella oolina Schwager
Plate 21, figure 3

Chilostomella oolina Schwager; Schwager, 1878, p. 527, pl. 1, fig. 16; Cushman, 1926a, p. 74-75, pl. 11, figs. 3-10; Phleger and Parker, 1951, p. 29, pl. 15, fig. 10; Barker, 1960, p. 112, pl. 55, figs. 12-14, 17, 18; Ingle, 1973, p. 545; Haynes, 1981, p. 271, key fig. 12.9, figs. 9-10.

Ecology

Chilostomella oolina Schwager is a benthonic foraminifer thought by some to be pelagic during part of its life cycle (Cushman, 1926a). The type specimen was described from Pliocene deposits of Sicily (Schwager, 1878) and it has since been reported in recent sediments from the Pacific and Atlantic Oceans.

Brady (1884) reported collecting the species from the North and Central Pacific while on a cruise of the H.M.S. *Challenger*. He dredged up specimens south of Japan, in the vicinity of the Philippines and at the Ki Islands at depths of 631, 174 to 183 and 1061 meters, respectively (Barker, 1960). The taxon has also been found ubiquitously in the Eastern Pacific, generally occurring in very low abundances throughout its distribution (Cushman, 1927a). *Chilostomella oolina* has been obtained in Holocene bottom sediments in the Gulf of Alaska from the Kodiak shelf to Cape Fairweather (Bergen and O'Neil, 1979). The taxon was found in middle to lower bathyal waters between the depths of 564 and 2623 meters, comprising a maximum of 5% of the total faunal assemblage in 1043 meters of water. It has also been recovered off the Oregon coast in recent deposits taken by the U.S. Coast and Geodetic Survey ship *Guide*, in waters 150 to 1086 meters deep (Cushman, 1927a). More recently, individuals were obtained in a core (Site 175) extracted by the Deep Sea Drilling Project from the lower continental slope of central Oregon, but information regarding their abundance or location within the late Tertiary deposits was not provided (Ingle, 1973).

Thirteen stations visited by the U.S. Coast and Geodetic Survey ship *Discoverer* in the vicinity of Monterey Bay, California, yielded specimens of *Chilostomella oolina* (Cushman, 1927a). These localities ranged in depth from 651 to 3325 meters, with more than half lying at approximately 3000 meters. A much shallower distribution of individuals of this species was found in the Santa Cruz Basin off Santa Barbara, however, where they were recovered at a restricted depth between approximately 550 and 900 meters (Resig, 1958).

Chilostomella oolina has also been reported in numerous localities to the south. It was a constituent of a recent benthonic foraminiferal assemblage collected off San Pedro, being obtained at a depth of 732 meters (Cushman and Moyer, 1930). The species was recovered at seven sites off San Diego by the U.S. Coast and Geodetic Survey ship *Guide* as well, in waters between 463 and 1057 meters deep (Cushman, 1927a). The *Guide* also collected the taxon offshore near the United States-Mexico border at depths of 468 and 1490 meters and off southern Mexico between 702 to 704 and 973 meters. The *Guide*'s sister ship, the *Lydonia*, scoured the depths off Baja California, Mexico and reported scattered occurrences of *Chilostomella oolina* in the samples they obtained (Cushman, 1927a). It was found at a depth of 1617 meters near central Baja, at 1677 and 2021 meters off southern Baja and in waters 3127 meters deep near the tip of the peninsula. In addition, the *Lydonia* reported the species from as far south as Panama, where it recovered individuals at a depth of 783 to 1940 meters.

Studies of benthonic foraminifers in the Eastern Pacific off South America have turned up *Chilostomella oolina* as well. Off Callao, Peru, on the eastern edge of the Nazca plate, the species comprised a maximum of 10% of the total faunal assemblage in Pleistocene to Holocene sediments obtained by the Deep Sea Drilling Project (Resig, 1976). In a study of bottom samples from the Peru-Chile Trench area, however, Ingle, Keller and Kolpack (1980) found this species to comprise only 1 and 2% of the population at 1326 and 1948 meters depth, respectively.

In the Atlantic Ocean, *Chilostomella oolina* was obtained at a depth of 90 to 300 meters on the continental shelf between the Gulf of Maine and Maryland (Parker, 1948), while the Swedish Deep-Sea Expedition to the low and mid-latitudes of the North Atlantic found the species to occur primarily below 200 meters (Phleger, Parker and Peirson, 1953). In recent sediments collected from the northwest Gulf of Mexico, the taxon's bathymetric distribution ranged mostly between 200 and 1000 meters, with one occurrence reported at both 110 and 1100 meters water depth (Phleger, 1951b).

Murray (1973) has concluded that living species of this genus generally inhabit muddy sediments of outer shelf and bathyal depths between approximately 80 and 1190 meters. He also stated that they prefer an environment in which the bottom temperatures are cold and the waters are of normal marine salinity (33 to 37°/oo). In this ecological review, it has become apparent that *Chilostomella oolina* is a widely distributed species geographically which most often comprises a low percentage of the faunal assemblage. The taxon is found between 150 and 3325 meters in the Pacific, but is obtained more commonly at a depth of approximately 450 to 2000 meters. This bathymetric range would fall within Ingle's (1980) definition for the upper- and lower-middle bathyal biofacies of the California borderland. It is possible that the noted occurrences of this species at considerably greater depths in the Alaskan, Monterey Bay and southernmost Baja Californian regions may be a result of downslope displacement by turbidity currents.

Distribution

Chilostomella oolina occurs in low abundance in both the mud and sand intervals. It was recovered in the mud layers between the depths of 40 cm and the lowermost sample at 469.5 cm and comprises less than 1% of the assemblage when present. In the sands, the taxon was obtained between the depths of 46 and 414.5 cm downcore, constituting from less than 1 to 1.4% of the fauna.

Chilostomella ovoidea Reuss
Plate 21, figure 5

Chilostomella ovoidea Reuss; Reuss, 1850, p. 380, pl. 48, fig. 12; Cushman, 1926a, p. 74, pl. 11, fig. 1; Uchio, 1960, pl. 10, figs. 18-21; Barker, 1960, p. 112, pl. 55, figs. 15-16, 19-23; Phleger, 1964, p. 383, pl. 2, fig. 34; Ingle, 1973, p. 536, 553; Matoba and Yamaguchi, 1982, p. 1041, pl. 4, fig. 1.

Ecology

Lagoe, 1979a, R, deep, Arctic Ocean.
Harman, 1964, R, Santa Barbara Basin, CA.
Resig, 1958, R, Santa Cruz Basin, CA.
Crouch, 1952, R, 11 deep basins off southern CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Bandy, 1963a, R, so. CA. continental borderland.
Douglas & Heitman, 1979, R, so. California borderland.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Uchio, 1960, R, living & dead, San Diego, CA.
Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a non-dominant member of the outer shelf biofacies between the depths of 73 and 152 meters, with water temperatures between 10.0 and 12.5°C.
Phleger, 1964, living, Gulf of California.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Parker, 1948, R, cont. shelf, Gulf of Maine-Maryland.
Cushman, 1914, R, Pacific Ocean, *Pullenia* and others.
Sliter and Baker, 1972, Cret, benthic foram paleobathymetry.

Distribution

Only two individuals of this species were recovered in the Monterey Fan levee deposits. One representative was obtained in the sand lens located between 171 and 173 cm, and the other in the sand lens present from 248 to 250 cm downcore.

Chilostomella spp.

Chilostomella spp. Several crushed and fragmented ovoid tests, displaying two very involute chambers per specimen, are assigned to this genus. The walls of the specimens are very finely perforate and the apertures are usually obscured or missing due to poor preservation.

Ecology

Walton, 1964, R, northern Gulf of Mexico.
Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Rare, fragmented representatives of the genus *Chilostomella* were recovered from mud and sand intervals investigated in this study. In all cases, the specimens account for less than 1% of the faunal assemblage and were obtained in samples taken between the depths of 46 and 432.5 cm downcore.

Chilostomellina fimbriata Cushman
Plate 21, figure 4

Chilostomellina fimbriata Cushman; Cushman, 1926a, p. 78-79, pl. 11, fig. 22; Cushman, 1927a, p. 170, pl. 6, fig. 9; Loeblich and Tappan, 1953, p. 93-94, pl. 17, fig. 3.

Ecology

Chilostomellina fimbriata Cushman occurs rather sporadically in both the Arctic Ocean and the eastern Pacific from the northern boreal waters to San Diego. It was recovered from three miles offshore Point Barrow, Alaska in the Arctic Ocean at a depth of 37 meters (Loeblich and Tappan, 1953). The taxon was also obtained at two localities in the Bering Sea from the highly variable depths of 505 and 2562 meters by a cruise of the U.S. Bureau of Fisheries steamer *Albatross* (Cushman, 1926a, 1927; Loeblich and Tappan, 1953).

An expedition by the U.S. Coast and Geodetic Survey ship *Guide* discovered *Chilostomellina fimbriata* in recent sediments to the south off Oregon in 415 and 1086 meters of water and in the vicinity of San Diego at a depth of 724 meters (Cushman, 1927a; Loeblich and Tappan, 1953). In addition, the species was recovered near Monterey Bay in waters 1346 and 1494 meters deep by the U.S. Coast and Geodetic Survey ship *Discoverer* (Cushman, 1927a; Loeblich and Tappan, 1953).

Chilostomellina fimbriata is an infrequent constituent of benthonic foraminiferal assemblages in the Arctic Ocean and eastern North Pacific. Based upon a limited amount of data, it appears that the species is restricted to the colder waters which flow along the North American coast as far south as San Diego (Cushman, 1927). Bathymetrically, the taxon ranges from a depth of 37 to 2562 meters, but is most commonly associated with Ingle's (1980) upper middle bathyal zone between approximately 500 and 1500 meters.

Distribution

Individuals of *Chilostomellina fimbriata* account for less than 1 to a maximum of 2.0% of the faunal assemblage in five sand intervals between the depths of 171 and 414.5 cm downcore.

Cibicides lobatulus (Walker and Jacob)
Plate 23, figures 4, 6

Nautilus spiralis lobatus anfractibus suprarotundatis subtus depressioribus Walker and Boys; Walker and Boys, 1784.
Nautilus lobatulus Walker and Jacob; Walker and Jacob, 1798, p. 642, pl. 14, fig. 36.
Serpula lobata Montagu; Montagu, 1803, p. 515.
Truncatulina lobatula (Walker and Jacob); Cushman, 1915, p. 31-33, pl. 15, fig. 1, t.f. 34.
Cibicides lobatulus (Walker and Jacob); Galloway and Wissler, 1927, p. 64-65, pl. 11, fig. 1; Phleger, Parker and Peirson, 1953, p. 49, pl. 11, figs. 9, 14; Todd and Bronnimann, 1957, p. 41, pl. 12, fig. 11; Barker, 1960, p. 190, pl. 92, fig. 10, and pl. 93, figs. 1, 4-5; Ingle, 1973, p. 562, 563; Wagner, 1978, p. 205-206, pl. 4, fig. 5; Sloan, 1981, p. 294; Todd and Low, 1981, p. 42-43, fig. 130.
Cibicides lobatus (d'Orbigny); Bandy, 1953a, p. 176, pl. 24, fig. 3.

Ecology

Green (?), 1960, R, central Arctic Basin.
Referred to by the author as *Cibicides lobatus*, this taxon was recovered in the recent arctic deposits of this study.

Phleger, 1951a, R, Canadian and Greenland Arctic.
The species was found to be abundant and widespread in the recent arctic deposits studied. In Baffin Bay, the taxon appeared to be "...generally indicative of water depths less than about 250 m...". Phleger concluded that *Cibicides lobatulus* "...is a very widespread attached form, probably characteristic of shallow water..."

Phleger, 1952, R, Canadian and Greenland Arctic.
This species was found to be one of the eight dominant members of this arctic fauna which was essentially uniformly distributed throughout the study area.

Susan Cooper, 1964, R, Chukchi Sea, Alaska.
This species was a non-dominant taxon collected between the study's limits of 6 and 61 meters. It was found associated primarily with the coarse sediments.

Smith, 1963b, Pleis & R, Gulf of Alaska.
This species was found in the shelf samples between the depths of 117 and 240 meters. Living individuals comprised 2% of the fauna at 117 meters and 1% of the assemblage at 240 meters, while dead specimens made up <1% of the assemblage at both 240 meters and the bathyal sample recovered in 810 meters of water.

Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Todd and Low found *Cibicides lobatulus* to occur

commonly in their Pamplona Searidge samples taken at the depths of 155, 174, 183, and between 243 and 271 meters in the Gulf of Alaska. In addition, it was obtained only rarely in this area at a depth of 375 meters. The taxon was recovered at five localities in southeastern Alaska as well. It occurred rarely in the Clarence Strait at a depth of 393 meters and in Lynn Canal at 19 meters, and was found commonly in sediments taken from Taku Harbor at a depth of 21 meters. The species was also abundant in Kasaan Bay between 86 and 104 meters, in the Excursion Inlet region at a depth of 45.7 meters and in Gambier Bay at 18 meters. The authors referred to Cibicides lobatulus as an "almost cosmopolitan species" and found a wide range of morphological variations in its tests. Because of previous field experience and Nyholm's (1961) culture studies involving this species, Todd and Low concluded that the variability was within the expected range. The authors also noted that they considered Dyocibicides biserialis to be a (spreading) growth stage of Cibicides lobatulus.

Bergen & O'Neil, 1979, R, Gulf of Alaska.

This species was found in neritic and bathyal deposits in the Gulf of Alaska. Especially abundant in the middle and outer neritic zones, Cibicides lobatulus decreased significantly in frequency abundance below the outer neritic boundary of 190 meters. Present between the depths of 18 and 1790 meters, this taxon comprised 20, 24 and 26% of the faunal assemblages at the depths of 146, 135, and 154 meters, respectively. In contrast, it only accounted for <1, 1, 3, and 4% of the bathyal faunas, with the higher percentages occurring at 232 and 409 meters. Bergen and O'Neil considered it to be a stenothermal species, stating that its distribution was strongly influenced by temperature because it displayed a shallower abundant occurrence in the Gulf of Alaska than off California.

Smith, 1973, Pleis? & Holocene, North Pacific Ocean.

Cibicides lobatulus was collected in a single sample from the Aleutian Terrace at a depth of 121 meters. The taxon comprised 6% of the faunal assemblage in this core-top sample.

Cushman & Todd, 1947b, Plio? Pleis?, Amchitka Is., AK.

Quarry samples contained individuals of this taxon which Cushman and Todd determined were members of a decidedly cold water fauna, "...not by any means arctic...This species is widely recorded stratigraphically throughout the Tertiary and is abundant in many localities in the present oceans, more widely known in the colder waters."

Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.

Cibicides lobatulus was one of the most commonly found species in this study and was recovered between the depths of 16 and 287 meters.

Cushman & Todd, 1947a, R, shallow water, coast of WA.

This taxon was one of six which comprised the bulk of the assemblages "...collected from the shallow waters surrounding the islands and off the Washington coast...This variable species has a very wide range, both living and fossil." Reported from many stations in this study, it occurred between the depths of 18 and 45 meters.

Cooper (?), 1961, R, intertidal, CA. & Oregon coast.

Listed under the species Cibicides lobatus, Cooper found this taxon to be a member of his intertidal faunal assemblage found along the California and Oregon coasts.

Bandy (?), 1950, Eocene, Plio-Pleis, Cape Blanco, Oregon.

Referred to as Cibicides lobatus, Bandy found the taxon comprising 1% of the middle or upper Pliocene deposits of the Port Orford Formation. The author found the species associated with Buliminella elegantissima, Eponides [Buccella] frigida and Nonionella miocenica in these sediments which he felt had been deposited in shallow and cool waters. Cibicides lobatus was also recovered in the Pleistocene deposits of the Elk River Formation, where it was a rare member of the Elphidiella zone and constituted 10% of the Rotalia [Buccella] tenerrima zone. Bandy determined that the fauna of the former zone was indicative of Natland's (1933) Zone II, characterized by a depth ranging from 4 to 38 meters and bottom temperatures between 13.20 and 21.43C. The author also concluded that the latter faunal zone had been deposited in shallow and cool waters.

Lankford, 1962, R, turbulent zone, W. coastal N. America.

In a study of the nearshore turbulent zone between northern Washington and the southern extension of Baja California, Mexico, Lankford found Cibicides lobatulus from the United States-Canadian border to approximately Point Conception, California, and no further south. In this region, the taxon was associated with Lankford's shallow Oregonian fauna, which resided between the shore and approximately 12 to 15 meters water depth, "...on very turbulent and mobile sand bottoms." The other species displaying maximum percentage abundances under these conditions included Buccella tenerrima and Buliminella elegantissima.

Hanna & Church, 1927, R, San Francisco Bay, CA.

"This highly variable species is found in all oceans and is usually a shallow-water dweller." The maximum depth of the study was 155 meters and the taxon was found to be a common constituent of the fauna.

Bandy, 1953a (?), R, San Francisco to San Diego, CA.

Referred to by Bandy as Cibicides lobatus, this species was listed as present in the study area.

Haller, 1980, Plio, Humboldt Basin, California.

Defined by Haller as a inner shelf species characteristic of depths between 0 and 50 meters, *Cibicides lobatulus* was recovered rarely in the Pullen and Eel River Formations, as well as in the middle to upper members of the Rio Dell Formation, as exposed in his Centerville coastal section. In addition, Haller discovered the taxon occurring rarely in the Eel River Formation and upper member of the Rio Dell Formation of his Scotia-Eel River section.

Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.

Natland reported collecting *Cibicides lobatulus* in the San Pedro Channel, from San Pedro to Santa Catalina Island, between the depths of 58 and 329 meters. The taxon was not obtained in the land-based Hall Canyon section studied by the author near Ventura, California.

McGlasson (?), 1959, R, living & dead, S. Catalina Is., CA.

Referred to by the author as *Cibicides lobatus* in a study of the foraminifers surrounding Santa Catalina Island between the shoreline and a depth of >183 meters, McGlasson found both living and dead representatives of the species.

Zalesny (?), 1959, R, living & dead, Santa Monica Bay, CA.

Referred to by the author as *Cibicides lobatus*, Zalesny found the taxon between the depths of 12 and 408 meters in the Santa Monica Bay. The species comprised 5% of the fauna at the depths of 23 and 62 meters and a maximum of 6% of the assemblage at the depth of 91 meters.

Bagg, 1912, Plio-Pleis (?), so. CA., Timms Point+.

In this early work, Bagg concluded from the published data that *Cibicides lobatulus* was geographically universal in its distribution and bathymetrically wide-ranging.

Galloway & Wissler (?), 1927, Pleis, Palos Verdes, CA.

Referred to by the author as *Cibicides lobatus*, Galloway and Wissler found the species present in Pleistocene-aged quarry deposits in southern California. The authors noted that the assemblage recovered was similar to that obtained in Pleistocene sediments near Santa Barbara and included *Bolivina spissa*, *Cibicides mckannai*, *Quinqueloculina akneriana*, *Globobulimina pacifica*, *Cassidulina translucens*, *Trifarina hughesi* and *Uvigerina peregrina*.

Ingle (?), 1980, Tertiary, so. CA. continental borderland.

Referred to by the author as *Cibicides lobatus*, Ingle found this taxon to be characteristic of the inner shelf biofacies between the depths of 0 and 50 meters. Commonly associated with the taxon in this biofacies were these species: *Buliminella elegantissima*, *Buccella frigida*, *B. tenerrima*, *Nonionella miocenica*, *N. stella* and *Quinqueloculina akneriana*.

Brenner, 1962, R, shallow, Gulf of California.

The maximum depth of samples taken in this study was 79.4 meters in the Gulf of California and this species was found distributed in both halves of the Gulf. Brenner also noted that *Cibicides lobatulus* has a world-wide distribution.

Bandy & Arnal (?), 1957, R, W. coast of Central America.

Referred to by the authors as *Cibicides lobatus*, this taxon was found to comprise 3% of the faunal assemblage at a depth of 55 meters in a study of foraminifers from Acapulco to the Gulf of Panama. This depth distribution would place the species in the outer shelf biofacies, characterizing the depths between 46 and 122 meters with the temperature ranging between 14.0 and 20.0°C and salinity from 34.2 to 34.6°/oo.

Ingle, Keller & Kolpack (?), 1980, R, Peru-Chile Trench.

Referred to by the authors as *Cibicides lobatus*, this taxon was obtained between the depths of 860 and 1864 meters. It comprised <1% of the faunal assemblage at the depths of 860, 962 and 1864 meters.

Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.

The species is reported from a wide variety of depths in the foraminiferal literature from the North Atlantic. *Cibicides lobatulus* was considered a questionably displaced species in this study because it was found associated with an assemblage that was not necessarily displaced. The samples in this study were taken between the depths of approximately 2000 and 7500 meters, with most occurring in waters greater than 4000 meters.

Boltovskoy and others, 1980, R, shelf, SW Atantic.

Boltovskoy and others, studying the recent shelfal foraminifers of the southwestern Atlantic, found *Cibicides lobatulus* to be a euhaline species in this region. It was found associated with *Trifarina angulosa*, *Buliminella elegantissima*, *Bolivina seminuda*, *Cassidulina minuta*, *Elphidium gunteri*, *E. magellanicum*, *Epistominella exigua* and *Hoeglundina elegans*, among others.

Murray, 1971, R, British forams.

Murray concluded that *Cibicides lobatulus* is an inner shelf species, characterizing the faunas between the depths of 0 and 100 meters. "This is a very common form in areas of seaweed growth and in regions of the sea floor subject to powerful currents. This species lives clinging to seaweeds, rocks, dead polyzoans, tunicates, and other firm substrates." Living representatives were obtained off Clifden and Connemara, off Plymouth between 10 and 60 meters, in the English Channel from 84 to 95 meters and rarely in the Celtic Sea between 128 and 138 meters. Dead specimens were "...very abundant and widespread in other areas."

Douglas & Woodruff, 1981, deep-sea benthonic forams.

Cushman, 1915, R, Pacific Ocean, Rotaliidae.

This species was collected by Brady aboard the H.M.S. *Challenger* in the North Pacific at a depth of 3840 meters, while Bagg obtained it near the Hawaiian

Islands at the depths of 37 and 717 meters. Off Guam, it was recorded in waters 1629 meters deep and in shallow water material near Japan. *Cibicides lobatulus* was also collected at a depth of 3239 meters in the Bering Sea from Holothurian stomachs and from Guam to Yokohama at the depths of 1328 and 3533 meters.
Nyholm, 1961, R, morphology of *Cibicides lobatulus*.

Distribution

With the exception of singular specimens of *Cibicides lobatulus* occurring in two sand intervals from 248 to 250 and 336.5 to 338 cm downcore, this taxon was found associated exclusively with the mud intervals in this study. Recovered between the depths of 20 and 447.5 cm, this species commonly comprises between less than 1 and 1.5% of the assemblage. However, in the mud intervals located from 346.5 to 349.5, 96.5 to 100, and 210 to 212 cm, *Cibicides lobatulus* rises to 2.4, 2.7 and 6.5% of the fauna, respectively.

Cibicides mckannai Galloway and Wissler
Plate 23, figure 2

Cibicides mckannai Galloway and Wissler; Galloway and Wissler, 1927, p. 65-66, pl. 10, figs. 5-6; Church, 1928, p. 266; Walton, 1955, p. 1006, pl. 104, figs. 13-14; White, 1956, p. 249-250, pl. 28, fig. 6; Uchio, 1960, pl. 10, figs. 4-6; Phleger, 1964, pl. 3, figs. 26-27; Ingle, 1973, p. 545; Ingle, Keller and Kolpack, 1980, p. 132, pl. 7, fig. 2; Matoba and Yamaguchi, 1982, p. 1041.

Ecology

Cooper, 1961, R, intertidal, CA. & Oregon coast.
Resig, 1958, R, Santa Cruz Basin, CA.
Crouch, 1952, R, 11 deep basins off southern CA.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Church, 1928, lower Plio, Los Angeles Basin, CA.
Galloway & Wissler, 1927, Pleis, Palos Verdes, CA.
White, 1956, Mio-Plio, Capistrano Fm., Orange Co., CA.
Reported to occur rarely to commonly in Pliocene deposits of the Upper Capistrano Formation.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Butcher, 1951, R, Coronado Bank, San Diego, CA.
This species was found in high relative frequency between the depths of 100 and 1025 meters.
Uchio, 1960, R, living & dead, San Diego, CA.
Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a non-dominant member of the outer shelf biofacies between the depths of 73 and 152 meters, with water temperatures ranging from 10.0 to 12.5C.
Phleger, 1964, living, Gulf of California.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Smith, 1964, R, El Salvador & Nicaragua.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Boltovskoy and others, 1980, R, shelf, SW Atantic.

Distribution

Cibicides mckannai was found associated exclusively with the mud intervals in this study. The taxon comprises from less than 1 to 1.1% of the faunal assemblage in four samples taken between the depths of 80 and 312 cm downcore.

Cibicides spp.

Cibicides spp. Rare and poorly preserved trochoidal specimens with plano-convex to biconvex tests and peripheral, interiomarginal apertures are assigned to this genus. Time did not permit identification to the specific level.

Ecology

Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Recovered from both mud and sand intervals between the depths of 40 and 393 cm downcore, unidentified specimens of *Cibicides* account for between less than 1 and 1.0% of the faunal assemblage.

Cibicidoides kullenbergi (Parker)
Plate 23, figure 1

Cibicides kullenbergi Parker; Phleger, Parker and Peirson, 1953, p. 49, pl. 11, figs. 7-8; Ingle, 1973, p. 525, 542, 545, 556.
Cibicidoides kullenbergi (Parker); Lohmann, 1978, p. 29, pl. 2, figs. 5-7; Ingle, Keller and Kolpack, 1980, p. 132.

Ecology

Ingle, 1973, N, DSDP Site 172, between CA. & Hawaii.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Parker, 1954, R, Gulf of Mexico.
Lohmann, 1978, R, western South Atlantic.
Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

With the exception of extremely rare occurrences of the taxon in three sand layers between 180 and 338 cm downcore, Cibicidoides kullenbergi was found associated with the mud intervals in the Monterey Fan levee deposits. Most commonly comprising less than 1% of the faunal assemblage in deposits lying between 96.5 and 432.5 cm, the taxon reaches a maximum abundance of 1.8% at a depth of 167.5 to 170 cm downcore.

Cyclammina sp.
Plate 2, figure 1

Cyclammina sp. The single specimen displays a greatly pyritized, planispiral involute test comprised of approximately 14 chambers. The apertural face is partly obscured by pyrite but an interiomarginal aperture is still suggested in the specimen.

Ecology

Bandy & Arnal, 1960, Mio-R, San Joaquin Valley, CA.
Saidova, 1967, Q, Pacific Ocean.
Akers, 1954, R, Cyclammina.
Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

One representative of the genus Cyclammina was recovered from the mud interval located 445 to 447.5 cm downcore.

Dentalina californica Cushman and Gray
Plate 6, figure 8

Dentalina californica Cushman and Gray; Cushman and Gray, 1946a, p. 66, p. 12, figs. 3-5; Cushman and Gray, 1946b, p. 13-14, pl. 3, figs. 1-3; Cushman and McCulloch, 1950, p. 312-313, pl. 41, figs. 8-10.

Ecology

Dentalina californica Cushman and Gray is represented by both fossil and recent forms. The type was recovered from the Pliocene deposits of Timms Point, off San Pedro, California, where the species occurred fairly commonly (Cushman and Gray, 1946a). Recent specimens were also dredged up nearby in the Channel Islands, where they occupied waters between 64 and 439 meters (Cushman and McCulloch, 1950). The average depth of the taxon was found to be 130 meters in this region.

The Allan Hancock Pacific Expeditions also recovered Dentalina californica farther south along Central and South America (Cushman and McCulloch, 1950). It was acquired in 55 to 91 meters of water off Bahia Honda, Panama and from 27 to 203 meters near the Galapagos Islands. In addition, the taxon was obtained between 37 and 64 meters near Ecuador and at 46 meters off Colombia.

The species has also been reported in recent offshore sediments as far away as Europe and Africa (Cushman and McCulloch, 1950). Off Rotterdam, The Netherlands, it was recovered at a depth of 13 meters and at only 9 meters water depth near the city of Funchal of the Madeira Islands off the northwestern coast of Africa.

Dentalina californica appears to be a very shallow water inhabitant from the limited data provided here. It occupies the eastern Pacific at least between northern California, as discovered in this study, and Colombia and off The Netherlands and northwestern Africa as well. It has been found associated with inner shelf to upper bathyal (0 to 500 meters) waters, but prefers living in the shelfal environment between approximately 10 to 150 meters (Ingle, 1980).

Distribution

One specimen of Dentalina californica was recovered from the sand interval located between 133.5 and 136.5 cm downcore.

Dentalina frobisherensis Loeblich and Tappan
Plate 6, figure 10

Dentalia frobisherensis Loeblich and Tappan; Loeblich and Tappan, 1953, p. 55-56, pl. 10, figs. 1-9; Lagoe, 1977, p. 121, pl. 3, fig. 1.

This species is very similar to Dentalina mucronata Neugeboren but differs by having a more robust test. The chambers are slightly lower and broader, the apertural end much less produced, and the base less tapered (Loeblich and Tappan, 1953, p. 55-56).

Ecology

Dentalina frobisherensis Loeblich and Tappan is a hyaline species which is most often found associated with the boreal waters of the Arctic. Green (1960) reported the taxon in a diverse assemblage recovered in the central Arctic Basin, while Loeblich and Tappan (1953) obtained it in recent deposits between 37 and 223 meters water depth off Point Barrow, Alaska. Lagoe (1977) found the species in considerably deeper recent deposits in the central Arctic Ocean, where it comprised less than 1% of the total faunal assemblage at 2049 and 2372 meters.

The taxon has also been reported from recent deposits in the cold, shallow waters of Frobisher Bay, Baffin Island, Canada. In the bay, Dentalina frobisherensis was found at 24, 31, 101 and 143 meters water depth, while nearby in the Cincinnati Press Channel, located at 63°11'N latitude, 67°50'W longitude, it was found slightly deeper at 146 meters (Loeblich and Tappan, 1953). Just to the south, 33 km off Akpatok Island in Ungava Bay, Quebec, Canada, Loeblich and Tappan (1953) reported the taxon present at a depth of 659 meters. They also found the species at an unrecorded depth in northeastern Greenland between the Shannon and Hochstetter Islands and in north Greenland near North Star Bay in 31 meters of water.

Dentalina frobisherensis inhabits cold, boreal waters of the Arctic Ocean and Labrador and Greenland Seas. It has been found at highly variable depths, ranging between 24 and 2372 meters. Even though the taxon does not provide us with concise bathymetric information, it seems possible to conclude that it is indicative of a cold water environment.

Distribution

One representative of this species was obtained from the sediments of the mud interval located between 139 and 143 cm downcore.

Dentalina mucronata Neugeboren
Plate 6, figure 11

Dentalina mucronata Neugeboren; Neugeboren, 1856, p. 83, pl. 3, figs. 8-11; Cushman, 1913a, p. 56-57, pl. 25, fig. 2, and pl. 27, figs. 5-7; Cushman and Todd, 1945, p. 21, pl. 3, figs. 14-15.

Ecology

Dentalina mucronata Neugeboren occurs rarely, but geographically widespread, in Tertiary and recent faunal assemblages. It has been reported in Oligocene deposits of Cuba and in Tertiary outcrops in Japan (Cushman and Todd, 1945). The species has been found associated with Miocene medium-depth foraminifers of Buff Bay, Jamaica and in Paleocene sediments in Alabama (Cushman and Todd, 1945). In recent Pacific Ocean deposits, Dentalina mucronata has been dredged from the vicinity of the Hawaiian Islands in 496 meters of water (Cushman, 1913a). Reporting primarily on the results of the voyages of the U.S. Fisheries steamer Albatross and U.S.S. Nero at the turn of the century, Cushman (1913a) noted that the taxon was found between Guam and Japan at 2434, 3323, 3875 and 3915 meters. Near Japan itself, the species was obtained at considerably shallower depths: 631 and 1750 meters (Cushman, 1913a).

Dentalina mucronata exhibits a test morphology which seems to have been persistent throughout the Tertiary fossil record, as demonstrated by outcrops in Cuba, Jamaica, Alabama and Japan. In recent sediments, the species has been reported near Hawaii and on a transect from Guam to Japan, at depths from 496 to 3915 meters. It appears that with the data presently available, Dentalina mucronata's presence does little to shed any light on the ecological conditions under which the Monterey Fan sediments were deposited.

Distribution

Rare examples of *Dentalina mucronata* were obtained from both sand and mud intervals in the Monterey Fan levee deposits. One invidual was found in each of two sand lenses at 133.5 to 136.5 cm downcore and from 330 to 332 cm. An additional representative of the taxon was recovered from the mud interval lying between 346.5 and 349.5 cm.

Dentalina pauperata d'Orbigny
Plate 6, figure 9

Dentalina pauperata d'Orbigny; d'Orbigny, 1846, p. 46, pl. 1, figs. 57-58; Cushman, 1929b, p. 85, pl. 12, figs. 23-24; Cushman, Stewart and Stewart, 1947, p. 14, pl. 1, fig. 10; Loeblich and Tappan, 1953, p. 57-58, pl. 9, figs. 7-9.

Ecology

Dentalina pauperata d'Orbigny is a geographically widespread benthonic foraminifer in both the recent and fossil records. D'Orbigny originally described the taxon from Miocene deposits in the Vienna Basin and numerous fossil occurrences have surfaced since, especially from the Miocene of North and South America (Cushman, Stewart and Stewart, 1947). In fact, in the Miocene Astoria Formation material recovered from the vicinity of the mouth of the Columbia River, *Dentalina pauperata* was found to be a fairly common member of the faunal assemblage (Cushman, Stewart and Stewart, 1947).

In recent deposits, the species has been found from the Arctic Ocean to South America. Lagoe (1977), studying benthic foraminifers of the central Arctic Ocean, discovered that *Dentalina pauperata* comprised less than 1% of his total faunal assemblage at depths of 1753, 2674 and 3633 meters. Further west in the boreal waters of Frobisher Bay, Baffin Island, Canada, the taxon was retrieved in waters 31, 55 and 101 meters deep (Loeblich and Tappan, 1953). It has also been obtained nearby at a depth of 48 meters, 33 km from Akpatak Island, Ungava Bay, Quebec, Canada. Additionally, Loeblich and Tappan (1953) reported the presence of the species in 31 meters of water near North Star Bay in north Greenland and at an undisclosed depth between Shannon and Hochstetter Islands in northeastern Greenland.

Closer to the geographical region examined in this study, Hanna and Church (1927) recovered *Dentalina pauperata* in a single large bottom sample of recent fine-grained sand collected off San Francisco between Point Reyes and the Farallon Islands. The taxon was recovered in waters 143 to 155 meters deep and no comment was made regarding its relative abundance in the assemblage. Further offshore, in the vicinity of the Hawaiian Islands, *Dentalina pauperata* was collected from 190 to 390 and 503 to 673 meters water depth by Bagg while on an *Albatross* cruise at the turn of the century (Cushman, 1913a).

Considerably further south, *Dentalina pauperata* was reported as a constituent of a recent benthonic foraminiferal fauna collected off El Salvador, where it was recovered in water depths between 800 and 1600 meters (Smith, 1964). This distribution corresponded to Smith's Zone E and the uppermost part of her Zone F, which are equivalent to the middle bathyal and upper portion of the lower bathyal zones of Bandy and Arnal (1957), respectively. The species was also collected in 1896 by Göes on an *Albatross* expedition between the Galapagos Islands and the coasts of Mexico and Central America (Cushman, 1913a). In this tropical region, the species was obtained in 1789, 2070 and 3182 meters of water.

Dentalina pauperata has been reported in Miocene to recent sediments along much of the western portions of North and South America. It inhabits a wide depth range in the northern boreal waters, having been recovered between 31 and 3633 meters water depth. The species' distribution is more restricted off San Francisco and the Hawaiian Islands, however, where it has been obtained between 143 and 673 meters. Further south, off El Salvador and the Galapagos Islands vicinity, its depth range drops once again, to lie between 800 and 3182 meters. Due to its widespread geographical and bathymetrical range, it seems apparent that *Dentalina pauperata*'s presence in the Monterey Fan sediments contributes little to our understanding of the deposition of those sediments.

Distribution

Single representatives of the taxon were recovered from five distinct mud intervals lying between 96.5 and 432.5 cm downcore.

Dentalina spp.
Plate 6, figure 7

Dentalina spp. Rare, and often broken, arcuate uniserial tests are assigned to this genus. Most specimens display terminal radiate apertures and somewhat oblique sutures. One individual's (Plate 6, figure 7) aperture appears terminal and rounded, displaying neither a cylindrical neck and phialine lip, nor radiate characteristics.

Ecology

Blanc-Vernet, 1969, R, Mediterranean.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Rare and often fragmented representatives of the genus *Dentalina* were recovered from both mud and sand intervals in this study. The individuals always comprise less than 1% of the faunal assemblage and were obtained in samples taken between the depths of 80 and 447.5 cm downcore.

Dyocibicides biserialis Cushman and Valentine

Plate 24, figure 3

Dyocibicides biserialis Cushman and Valentine; Cushman and Valentine, 1930, p. 31, pl. 10, figs. 1-2; Walton, 1952, p. 1006, pl. 104, figs. 22-23; Drooger, 1953, p. 147, pl. 23, figs. 12-14; Barker, 1960, p. 192, pl. 93, fig. 6; Lankford and Phleger, 1973, p. 119, pl. 6, figs. 16-17.

Ecology

Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Cushman & Todd, 1947b, Plio? Pleis?, Amchitka Is., AK.
Cushman & Todd, 1947a, R, shallow water, coast of WA.
Cooper, 1961, R, intertidal, CA. & Oregon coast.
Lankford, 1962, R, turbulent zone, W. coastal N. America.
Lankford & Phleger, 1973, R, W. coastal N. America.
Resig, 1958, R, Santa Barbara Is., CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Cushman & Valentine, 1930, R, Channel Ids., so. CA.
Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.
Brenner, 1962, R, shallow, Gulf of California.
Phleger & Ewing, 1962, R, lagoons, Baja CA., Mexico.
Natland, 1950, Plio-Pleis, Gulf of CA., outcrops.

"It prefers a shallow, clear-water habitat and generally grows attached to seaweed and other plants."

Bandy & Arnal, 1957, R, W. coast of Central America.
Smith, 1964, R, El Salvador & Nicaragua.
Cushman & Todd, 1945, Mio, Buff Bay, Jamaica.

Distribution

One specimen of *Dyocibicides biserialis* was recovered from the mud interval lying between 346.5 and 349.5 cm downcore.

Dyocibicides sp.

Plate 24, figure 2

Dyocibicides sp. The single specimen is characterized by an initial biconvex, trochoidal test, later uncoiling and growing in an irregular pattern. The aperture of the later portion is a single, elongate interiomarginal slit with a very slight lip. Due to the variable nature of test development common to this genus, the individual may indeed be an additional example of *D. biserialis* Cushman and Valentine.

Ecology

Nyholm, 1961, R, morphology of *Cibicides lobatulus*.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

A single mud interval of the Monterey Fan levee deposits investigated in this study, located between 430 and 432.5 cm downcore, yielded a specimen of *Dyocibicides*.

Eggerella bradyi (Cushman)

Plate 2, figure 5

Verneuilina bradyi Cushman; Cushman, 1911, p. 54-55, t.f. 87.
Eggerella bradyi (Cushman); Cushman, 1933a, p. 33, pl. 4, fig. 1; Cushman, 1937a, p. 52, pl. 5, fig. 19; Phleger and Parker, 1951, p. 6, pl. 3, figs. 1-2; Phleger, Parker and Peirson, 1953, p. 27, pl. 5, figs. 8-9; Barker, 1960, pl. 47, figs. 4-7; Ingle, 1973, p. 525, 536, 542, 545, 553,

556; Haller, 1980, p. 230, pl. 2, fig. 1.

Ecology

Smith, 1963b, Pleis & R, Gulf of Alaska.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Smith, 1973, Pleis? & Holocene, North Pacific Ocean.
Ingle, 1973, N, DSDP Site 172, between CA. & Hawaii.
Crouch, 1952, R, 11 deep basins off southern CA.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Resig, 1976, Eocene-R, DSDP, Nazca Plate, Peru.
Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
Phleger, 1951b, R, Northwest Gulf of Mexico.
Phleger & Parker, 1951, R, NW Gulf of Mex. & Atlantic.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman, 1937a, R, Valvulinidae.
Cushman, 1911, R, Pacific Ocean, Textularids.

Distribution

Representatives of Eggerella bradyi were found in very low abundance in both the mud and sand intervals of this study. Most often comprising less than 1% of the assemblage, this taxon was obtained in samples between the coretop and 447.5 cm downcore. Only in the mud intervals lying from 80 to 82 and 120 to 122 cm does Eggerella bradyi constitute a maximum of 1.7 and 1.2% of the faunas, respectively.

Eggerella spp.
Plate 2, figure 6

Eggerella spp. Finely arenaceous specimens displaying four to five chambers per whorl in their early stages and only three in the adult are assigned to this genus. The aperture is always poorly preserved but appears to be a small slit on the inner margin of the last formed chamber.

Ecology

Saidova, 1967, Q, Pacific Ocean.
Blanc-Vernet, 1969, R, Mediterranean.
Murray, 1973, R, general ecology & distribution.

Distribution

Singular specimens of the genus Eggerella were recovered from one sand and three mud intervals between the depths of 120 and 412.5 cm downcore.

Elphidium excavatum clavata Cushman
Plate 12, figure 1

Elphidium incertum (Williamson) var. clavatum Cushman; Cushman, 1930, p. 20, pl. 7, fig. 10.
Elphidium excavatum clavata (Cushman); Wagner, 1978, p. 213-214, pl. 6, fig. 3.
Elphidium clavatum Cushman; Ingle, 1973, p. 542, 549, 556, 560, 562, 563; Todd and Low, 1981, p. 35, 43, fig. 108.
Elphidium excavatum forma clavata Cushman; Miller, and others, 1982, p. 124, 126, 128; pl. 1, figs. 5-8.

Ecology

Loeblich & Tappan, 1953, R, Arctic forams.
This species was found between the depths of 3 and 223 meters off Point Barrow, Alaska. In Frobisher Bay, it was recorded between the depths of 24 and 143 meters, and its presence was noted in the Fox Channel as well. Off Greenland, the taxon was found between 13 and 46 meters, and at a depth of 55 meters in Hamilton Inlet, Labrador. Near Akpatok Island in the Ungava Bay, Elphidium clavatum was recovered between the depths of 48 and 73 meters. In the Cincinnati Press Channel and at Albatross station D, the species has been recorded at the depths of 147 and 17 meters, respectively. The taxon has also been noted present in the waters near Melville Island.

Lagoe, 1979a, R, deep, Arctic Ocean.
Elphidium clavatum-incertum, as well as Buccella frigida, occur rarely within the Trochammina nana biofacies, defined by Lagoe to occur between the depths of 17 and 350 meters. Because of its sparse occurrence there, Lagoe suggested that Elphidium clavatum-incertum "...may not be characteristic of that biofacies."

Lagoe, 1979b, R, shallow, Prudhoe Bay, Alaska.
In the shallow waters of Prudhoe Bay, between the depths of 1 and 6 meters, Lagoe found a fauna "...overwhelmingly dominated by Elphidium spp. and related genera." Of the 19 species which he recorded, Elphidium clavatum and Buccella frigida were the only two in common with the Monterey Fan study. Noting that

all of the species found here were also present on the nearby shallow shelf, Lagoe concluded that "...only the most opportunistic species in the shallow Arctic..." were present in Prudhoe Bay. The normally dominant arenaceous forms of the Canadian Arctic were found to be extremely rare in this arctic region. The author also mentions that the genera Elphidium, as well as several others, was found to be dominant in the shallow shelf faunas of the Beaufort Sea (Loeblich and Tappen, 1953; Carsola, 1952).

Susan Cooper, 1964, R, Chukchi Sea, Alaska.

In samples taken between the depths of 6 and 61 meters, this species was one of three dominant taxa found in this study. The varying percentages of Elphidium excavatum clavata was one parameter used to define the assemblages.

Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.

Todd and Low found Elphidium clavatum to be a rare constituent of their recent Pamplona Searidge samples taken from the depths of 155, 174, 183, and 243 to 271 meters in the Gulf of Alaska. The taxon was also found to be a common member of the faunas in Clarence Strait at a depth of 393 meters, in Kasaan Bay between 86 and 104 meters and in Taku Harbor in 21 meters of water. Ephidium clavatum comprised a rare part of the assemblage at a depth of 45.7 meters in Excursion Inlet as well. The authors concluded that this "...well-known and widely reported species...has been reported from the Arctic and from as far south as New York on the Atlantic side and as far south as British Columbia on the Pacific side of the North American Continent. Elphidium clavatum is also a common or abundant constituent of Pleistocene deposits."

Bergen & O'Neil, 1979, R, Gulf of Alaska.

The genus Elphidium dominated the littoral zone, constituting nearly 90% of the faunal assemblage. This zone is characterized by wide annual fluctuations in temperature and considerable wave turbulence. Elphidium clavatum occupied the littoral to lower bathyal zones and decreased significantly in frequency abundance below the outer neritic zone's boundary of 190 meters. The taxon comprised 77 and 80% of the littoral zone fauna, a maximum of 53% of the inner neritic assemblage at 31 meters, 26% of the middle neritic fauna at 82 meters, 32% of the outer neritic assemblage at 99 meters, 21% of the upper bathyal fauna at 473 meters, <1% of the middle bathyal assemblage at 650 meters, and 5% of the lower bathyal fauna at a depth of 1976 meters.

Quinterno and others, 1980, R, Gulf of Alaska.

Elphidium clavatum is generally a shallow-water, inner shelf species and was a dominant faunal member with Epistominella pacifica in samples collected in Kayak Trough between 146 and 234 meters water depth and in Hinchinbrook Sea Valley at 205 meters. Elphidium clavatum comprised at least 10% of the fauna at these two localities. The authors suggested that the co-occurrence of Elphidium clavatum and Epistominella pacifica might indicate a depression (trough or sea valley), restricted from open-ocean conditions.

Smith, 1973, Pleis? & Holocene, North Pacific Ocean.

Elphidium clavatum was obtained in a single sample collected off the Aleutian Islands at a depth of 2410 meters. The specimens were not present in the core-top but were found downcore at the depths of 10, 20, 40 and 60 cm. Only one representative of the species was collected at each depth, with the exception of seven individuals between 20 and 21 cm.

Lagoe, 1983, Oligocene-Plio, Gulf of Alaska.

Middle Pliocene deposits from the Yakataga Reef section in the Gulf of Alaska have yielded specimens of the arctic species Elphidium clavatum. This species was found to become initially established in the Epistominella pacifica biofacies, determined by Lagoe to be representative of deposition in the outer shelf to upper bathyal regions. Associated species include Buccella frigida and Melonis zaandamae.

Arnal and others, 1980, R, San Francisco Bay, CA.

Elphidium clavatum, as well as Elphidium gunteri, occurred at most stations in the southern part of San Francisco Bay in this study of benthonic foraminifers between 0 and 22 meters. In Zone 1 (inner coastal), characterized by few species and a large number of individuals between the depths of 0 and 2 meters, Elphidium clavatum comprised 3 to 4% of the fauna. The taxon constituted 2 to 4% of the assemblage in Zone 2 (outer coastal), found from 2 to 8 meters deep, in which the species number doubled over that found in the shallower biofacies and the number of individuals remained high. Zone 3 (deep bay) contained Elphidium clavatum at 3 to 8%, in waters that were 8 to 15 meters deep and characterized by the presence of the greatest number of genera obtained in this study. And in Zone 4 (deep channel), between 12 and 22 meters, the taxon constituted 3 to 4% of the fauna, in which the oceanic influence became the most pronounced. The authors noted that, on occasion, live individuals of the taxon were recovered.

Distribution

With the exception of singular occurrences of this taxon in two mud intervals, Elphidium excavatum clavata was found restricted to the sand layers sampled between 46 and 414.5 cm downcore. The species comprises from less than 1 to a maximum of 3.0% of the faunal assemblage.

Elphidium excavatum lidoensis Cushman
Plate 12, figure 5

Elphidium lidoense Cushman; Cushman, 1936, p. 86-87, pl. 15, fig. 6.
Elphidium excavatum lidoensis Cushman; Wagner, 1978, p. 214-216, pl. 6, fig. 4-5.
Elphidium excavatum forma *lidoensis* Cushman; Sloan, 1981, p. 277-278, pl. 1, fig. 6; Miller, Scott, and Medioli, 1982, p. 134, 136, pl. 1, figs. 17-20.

Ecology

Wagner, 1978, R, San Francisco Bay, CA.
Sloan, 1981, R, San Francisco Bay, CA.
Bandy and Arnal, 1960, Mio-R, San Joaquin Valley, CA.
"Inner shelf biofacies include *Buliminella elegantissima* and several species of *Nonionella*, and *Elphidium*. These genera are abundantly represented in shoal inner shelf habitats of many areas of the world."
Murray, 1971, R, British forams.
Murray noted that all species of *Elphidium* characterize the inner shelf between the depths of 0 and 100 meters.
Cushman, 1936, R, *Elphidium* and related genera
Cushman found this species in recent beach sand. The holotype of *Elphidium excavatum lidoensis* was collected in Lido, Venice, Italy.
Phleger, 1960, R, general ecology & distribution.
Murray, 1973, R, general ecology & distribution.

Distribution

Two representatives of *Elphidium excavatum lidoensis*, comprising less than 1% of the faunal assemblage, were recovered in the sand interval located from 248 to 250 cm downcore.

Elphidium excavatum selseyensis
(Heron-Allen and Earland)
Plate 12, figure 3

Polystomella striatopuncata (Fichtel and Moll) var. *selseyensis* Heron-Allen and Earland; Heron-Allen and Earland, 1909, p. 695, pl. 21, fig. 2.
Elphidium excavatum seleseyensis (Heron-Allen and Earland); Wagner, 1978, p. 222-223, pl. 6, figs. 6-8, pl. 7, fig. 1.
Elphidium excavatum (Terquem) forma *selseyensis* (Heron-Allen and Earland); Sloan, 1981, p. 275-277, pl. 1, fig. 5; Miller, Scott, and Medioli, 1982, p. 132, 134, pl. 1, figs. 13-16.

This species appears similar to *Elphidium magellanicum* (Heron-Allen and Earland), but differs by having a larger number of chambers in the last whorl (8-9 instead of only 5-6). It has a circular and slightly lobulate outline, and a depressed umbilicus. *Elphidium magellanicum* (Heron-Allen and Earland) displays a more elongate and flatter test.

Ecology

Wagner, 1978, R, San Francisco Bay, CA.
Sloan, 1981, R, San Francisco Bay, CA.
Murray, 1971, R, British forams.
Murray noted that Haynes and Dobson (1969) found *Elphidium selseyense* [*E. selseyensis*] to be a non-dominant species of the low marsh in Dovey estuary, Wales. Associated with the taxon was *Spartina townsendi*, *Protelphidium depressulum*, *Ammonia beccarii* and *Miliammina fusca*. Murray also noted that all species of *Elphidium*, including *E. selseyensis*, characterize in inner shelf between the depths of 0 and 100 meters.
Murray, 1973, R, general ecology & distribution.

Distribution

Representatives of *Elphidium excavatum selseyensis* were obtained exclusively from sand and sandy mud intervals between the depths of 133.5 and 414.5 cm downcore. The taxon comprises from less than 1 to 13.1% of these faunal assemblages.

Elphidium gunteri Cole
Plate 12, figure 2

Elphidium gunteri Cole; Cole, 1931, p. 34, pl. 4, figs. 9-10; Wagner, 1978, p. 216-218, pl. 7, figs. 2-6; Sloan, 1981, p. 285-288, pl. 2, fig. 4; Todd and Low, 1981, p. 35, 43, fig. 107.
Cellanthus gunteri (Cole); Lankford and Phleger, 1973, p. 116, pl. 3, fig. 17.
Elphidium gunteri Cole forma *typicum*; Poag, 1981, p. 61-62, pl. 37, fig. 1, pl. 38, fig. 1.

Ecology

Lankford & Phleger, 1973, R, W. coastal N. America.

The taxon, referred to as *Cellanthus gunteri*, was recovered in this study of the nearshore turbulent zone from north of Washington to the southern extension of Baja California, Mexico. The authors noted that "...species of...Elphidiidae [as well as *Buccella* and *Buliminella*]...live preferentially on the more turbulent sand bottoms and have not been found living on less turbulent but nearby rocky bottoms at equivalent depths and are rare in deeper water. The authors conclude that effects of turbulence and a shifting mobile substrate may be the principal requirement of this group or they may not be able to compete elsewhere, while being hardy enough to withstand this unfavorable environment."

Wagner, 1978, R, San Francisco Bay, CA.

Sloan, 1981, R, San Francisco Bay, CA.

Arnal and others, 1980, R, San Francisco Bay, CA.

Elphidium gunteri, as well as *Elphidium clavatum*, occurred at most stations in the southern part of San Francisco Bay in this study of benthonic foraminifers between 0 and 22 meters. In Zone 1 (inner coastal), characterized by few species and a large number of individuals between the depths of 0 and 2 meters, *Elphidium gunteri* comprised 2 to 9% of the fauna. The taxon constituted 2 to 7% of the assemblage in Zone 2 (outer coastal), found from 2 to 8 meters deep, in which the species number doubled over that found in the shallower biofacies and the number of individuals remained high. Zone 3 (deep bay) contained *Elphidium gunteri* once again at 2 to 9%, in waters that were 8 to 15 meters deep and characterized by the presence of the greatest number of genera obtained in this study. And in Zone 4 (deep channel), between 12 and 22 meters, the taxon constituted 0 to 9% of the fauna, in which the oceanic influence became the most pronounced.

Bandy & Arnal, 1960, Mio-R, San Joaquin Valley, CA.

"Inner shelf biofacies include *Buliminella elegantissima* and several species of *Nonionella*, and *Elphidium*. These genera are abundantly represented in shoal inner shelf habitats of many areas of the world."

Brenner, 1962, R, shallow, Gulf of California.

Defined as a subtropical species by Brenner, *Elphidium gunteri* was found commonly in both halves of the Gulf. Samples in this study were recovered to a maximum depth of 79.4 meters, with the taxon appearing in greater abundances in the north. "It is very abundant in mud bottoms with a high organic content, in which poor circulation causes a reducing environment." Also reported off North Carolina, Beaufort, in the Gulf of Mexico and first described in Pliocene deposits of Florida.

Phleger & Ewing, 1962, R, lagoons, Baja CA., Mexico.

Elphidium gunteri variant was one of five of the most abundant benthonic foraminifers in an assemblage of 20 species from the inner lagoon of the Laguna Ojo de Liebre area.

Boltovskoy and others, 1980, R, shelf, SW Atantic.

Boltovskoy and others, studying the recent shelfal foraminifers of the southwestern Atlantic, found *Elphidium gunteri* to be a euhaline species in this region. It was found associated with *Trifarina angulosa*, *Buliminella elegantissima*, *Bolivina seminuda*, *Cassidulina minuta*, *Cibicides lobatulus*, *Elphidium magellanicum*, *Epistominella exigua* and *Hoeglundina elegans*, among others. The authors also noted that this species "...occurs in the brackish waters of Lagoa dos Patos and Rio Quequèn."

Distribution

One representative of this taxon was recovered from the mud and sand interval located between 180 and 182 cm downcore.

Elphidium magellanicum Heron-Allen and Earland

Plate 12, figure 4

Elphidium (*Polystomella*) *magellanicum* Heron-Allen and Earland; Heron-Allen and Earland, 1932, p. 440, pl. 16, figs. 26-28.

Elphidium magellanicum Heron-Allen and Earland; Wagner, 1978, p. 219-220, pl. 7, fig. 7, pl. 8, fig. 1; Sloan, 1981, p. 288-290, pl. 2, fig. 5.

Tests of *Elphidium magellanicum* display five to six chambers in the last whorl and are characterized by a lobate outline and depressed sutures. The specimens possess a somewhat granular umbilicus, with the granules covering either exclusively the sutures or the entire test. In addition, some chambers may be very translucent. This form is similar to *Elphidium excavatum selseyensis* (Herland-Allen and Earland). See discussion there for differences.

Ecology

Smith, 1963b, Pleis & R, Gulf of Alaska.
Only dead individuals of this species were collected in a single shelfal sample obtained at a depth of 76 meters. The taxon comprised 10% of the faunal assemblage at this depth.

Smith, 1973, Pleis? & Holocene, North Pacific Ocean.
Elphidium magellanicum was only collected in a single sample on the Aleutian Terrace at a depth of 76 meters in this study. Present in the core-top, this taxon comprised 14% of a depauperate foraminiferal assemblage, totaling fifty individuals, obtained at this site.

Wagner, 1978, R, San Francisco Bay, CA.

Sloan, 1981, R, San Francisco Bay, CA.

Arnal and others, 1980, R, San Francisco Bay, CA.
Both living and dead individuals of *Elphidium magellanicum* were recovered in the southern part of San Francisco Bay in this study of the benthonic foraminifers between the depths of 0 and 22 meters. This species was not found to be one of the dominant faunal members in any of the four zones defined by the authors.

Bandy & Arnal, 1960, Mio-R, San Joaquin Valley, CA.
"Inner shelf biofacies include *Buliminella elegantissima* and several species of *Nonionella*, and *Elphidium*. These genera are abundantly represented in shoal inner shelf (30 plus or minus 30 meters) habitats of many areas of the world."

Boltovskoy and others, 1980, R, shelf, SW Atantic.
Boltovskoy and others, studying the recent shelfal foraminifers of the southwestern Atlantic, found *Elphidium magellanicum* to be a euhaline species in this region. It was found associated with *Trifarina angulosa*, *Buliminella elegantissima*, *Bolivina seminuda*, *Cassidulina minuta*, *Cibicides lobatulus*, *Elphidium gunteri*, *Epistominella exigua* and *Hoeglundina elegans*, among others.

Murray, 1971, R, British forams.
Murray found *Elphidium magellanicum* associated with the hyposaline lagoons and estuaries, and the innermost shelf regions. Living representatives of the taxon were obtained along the south coast of Cornwall from 14 to 42 meters and in Christchurch Harbour. Dead specimens were obtained at these same localities as well as in Bristol Channel, in Shoreham Harbour and off Dunkirk.

Distribution

Representatives of *Elphidium magellanicum* were recovered from both the sands and muds of this study. In the sand layers located between 171 and 414.5 cm downcore, the taxon comprises from less than 1 to a maximum of 5.1% of the assemblage. In contrast, *Elphidium magellanicum* always constitutes less than 1% of the fauna in the mud intervals between 270 and 412.5 cm.

Elphidium spp.

Elphidium spp. Three specimens, either poorly preserved or exhibiting abnormal growth, are assigned to this genus. All display depressed sutures and are planispiral involute. Apertures are obscured.

Ecology

Phleger, 1960, R, general ecology & distribution.
Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Three very rare representatives of this genus were recovered from two sand intervals in this study. They were found to constitute less than 1% of the faunal assemblages in the samples taken between 248 and 250, and 412 and 414.5 cm downcore.

Epistominella bradyana (Cushman)
Plate 17, figure 11

Pulvinulinella bradyana Cushman; Cushman, 1927a, p. 165, pl. 5, figs. 11-13.
Epistominella bradyana (Cushman); Martin, 1952, p. 136, pl. 24, fig. 9; Bandy, 1961, p. 15, pl. 3, fig. 16.
Epistominella bradyana (Cushman); Uchio, 1960, p. 68.
Pseudoparrella bradyana (Cushman); Matoba and Yamaguchi, 1982, p. 1045, pl. 3, fig. 2.

Ecology

Lankford, 1962, R, turbulent zone, W. coastal N. America.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Bandy & Arnal, 1960, Mio-R, San Joaquin Valley, CA.
Harman, 1964, R, Santa Barbara Basin, CA.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Bandy, Ingle & Resig, 1964, R, San Pedro Bay, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Martin, 1952, Plio, Los Angeles Basin, CA.

This species was found present in the Repetto and Pico Formations.

White, 1956, Mio-Plio, Capistrano Fm., Orange Co., CA.

Reported to occur abundantly in Pliocene deposits of the Upper Capistrano Formation.

Butcher, 1951, R, Coronado Bank, San Diego, CA.

This species was found occurring in high relative frequency between the depths of 100 and 1025 meters.

Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.

Epistominella bradyana was found to be a dominant member of the outer shelf biofacies between the depths of 73 and 152 meters, with water temperatures ranging from 10.0 to 12.5°C. It was also reported as being a dominant constituent of the upper bathyal biofacies between 152 and 244 meters, with the temperature ranging from 8.0 to 10.0°C.

Natland, 1950, Plio-Pleis, Gulf of CA., outcrops.

The taxon is comparatively rare offshore southern California, having been obtained in the San Pedro Channel at a depth of 275 meters. Off the west coast of Central America, it was found between 210 and 2300 meters, being most abundant between 275 and 782 meters.

Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Smith, 1964, R, El Salvador & Nicaragua.

Distribution

Singular representatives of *Epistominella bradyana* were recovered from two sand intervals located between 133.5 and 136.5, and 248 and 250 cm downcore.

Epistominella evax Bandy
Plate 17, figure 10

Epistominella evax Bandy; Bandy, 1953a, p. 179, pl. 23, fig. 1.

Ecology

Bandy, 1953a, R, San Francisco to San Diego, CA.

Distribution

One representative of *Epistominella evax* was recovered from the sand interval located from 336.5 to 338 cm downcore.

Epistominella exigua (Brady)
Plate 17, figure 9

Pulvinulina exigua Brady; Brady, 1884, p. 696, pl. 103, figs. 13-14
Pulvinulinella exigua (H.B. Brady); Hanna and Church, 1927, p. 200.
Pseudoparrella exigua (H.B. Brady); Phleger and Parker, 1951, p. 28, pl. 15, figs. 6-7.
Epistominella exigua (Brady); Barker, 1960, p. 212, pl. 103, figs. 13-14; Ingle, 1973, p. 536, 542, 545, 549, 553, 556, 557, 560, 562, 563; Haller, 1980, p. 254, pl. 10, fig. 3.

Ecology

Epistominella exigua (H.B. Brady) is a widely distributed benthonic foraminifer. Brady (1884) dredged up specimens while on the H.M.S. *Challenger* in the North Pacific at depths from 27 to 4206 meters (Cushman, 1915). Individuals have also been recovered from Guam to Yokohama and from the Hawaiian to Midway Islands in 1517 to 3837 meters of water (Cushman, 1915).

Much shallower occurrences have been reported along the western coast of North America though. Hanna and Church (1927) noted that *Epistominella exigua* was first described by Brady as a deep water inhabitant, but reported finding a number of specimens in material collected near the Farallon

Islands off San Francisco at a depth of only 146 meters. Other recent sediments, collected in the Santa Barbara Channel, yielded this species in a lower neritic environment between 92 and 183 meters (Marks and others, 1980). In addition, Ingle (1980) included this taxon in his upper bathyal biofacies, ranging between 150 and 500 meters, in a study of Neogene sediments of the Southern California continental borderland.

Additional correlations between Epistominella exigua and shallow water environments have been reported in the Gulf of California. Bandy (1961) found it to be a dominant member of the recent upper bathyal fauna, which lies between 366 and 610 meters in this area, in waters ranging in temperature between 4.5 and 6.0°C. The species was also found in Brenner's (1962) recent Gulf study, but he only located individuals at one site in the northern half of the Gulf at 73.8 meters. Epistominella exigua is also reported inhabiting the waters off Central and South America. Off El Salvador, it ranges from 37 to 140 meters water depth, but is in greatest abundance on the outer shelf and upper slope between 65 and 130 meters (Smith, 1964). From the Galapagos Islands to the coast of Mexico and Central America, Goes collected specimens at 2227 meters (Cushman, 1915). Cushman (1929b) notes that this species is recognized primarily as a recent Pacific ocean species, but finds it in some Late Tertiary (probably Miocene) deposits from Ecuador.

The species is equally widespread in the Atlantic Ocean. In recent samples from the equatorial and low latitude North Atlantic, the Swedish Deep-Sea Expidition found Epistominella exigua at depths greater than 117 meters with most occurrences greater than 275 meters (Phleger and Parker, 1951; Phleger and others, 1953). Along the Atlantic continental shelf and slope from Maine to Maryland, Parker (1948) found this taxon from 90 to 300 meters water depth and in the Atlantic it is recorded from 117 to 4900 meters (Phleger and Parker, 1951). Recent deposits from the northwest Gulf of Mexico contain specimens from 20 to 1800 meters (Phleger, 1951b). The species is also very abundant in recent shelf deposits in the Southwestern Atlantic (Boltovskoy and others, 1980), where it displays a great range in size, outline and structural morphology, and convexity. Its widespread ecological distribution includes inhabiting the brackish waters of the Rio de la Plata and Rio Quequén (Boltovskoy, and others, 1980).

In conclusion, Epistominella exigua appears geographically and bathymetrically diverse. Yet, reports from the waters directly off California imply that it is a fairly shallow water indicator in this region, possibly reflecting an upper bathyal habitat.

Distribution

Epistominella exigua was found associated exclusively with the sand intervals investigated in this study. Present between the depths of 133.5 and 414.5 cm downcore, the taxon comprises from less than 1 to 1.1% of the faunal assemblage.

Epistominella pacifica (Cushman)
Plate 18, figure 1

Pulvinulinella pacifica Cushman; Cushman, 1927a, p. 165, pl. 5, figs. 14-15.
Epistominella pacifica (Cushman); Martin, 1952, p. 136, pl. 24, fig. 8; Bandy, 1953a, p. 177, pl. 23, fig. 2; Ingle, 1973, p. 536, 542, 549, 560, 562, 563; Haller (in part), 1980, p. 254, pl. 10, fig. 6.

Ecology

Epistominella pacifica (Cushman) has been collected in recent sediments as far north as the Gulf of Alaska (Smith, 1963b; Todd and Low, 1967; Bergen and O'Neil, 1979). Smith (1963b) obtained both live and dead specimens in shelfal and bathyal samples between the depths of 230 and 810 meters. Live individuals comprised 3 and 9% of the assemblages at 240 and 230 meters, respectively. Dead specimens made up <1, 4.5, and 15% of the benthonic foraminiferal fauna at their respective depths of 810, 240 and 230 meters. She also noted that Epistominella pacifica was a characteristic shelfal species in the Gulf of Alaska, but that in California it was generally associated with bathyal depths. Todd and Low (1967) found rare representatives of the taxon on the Pamplona Searidge between the depths of 243 and 271 meters and as a common constituent of a fauna obtained at a depth of 393 meters in the Clarence Strait. In addition, they noted that the type was recovered in 1344 meters of water off California and it that "...probably has a large but discontinuous area of distribution in and around the North Pacific basin." Bergen and O'Neil (1979) also recovered the taxon in Gulf of Alaskan samples collected between 70 and 2623 meters of water. Epistominella pacifica was found to be particularly abundant between the outer neritic waters at 113 meters and the lower bathyal depth of 1830 meters. The taxon comprised a maximum of 26% of the outer neritic fauna at 165 meters, 12% of the upper bathyal assemblage at 503 meters, 24% of the middle bathyal fauna at 833 meters and 8% of the lower bathyal assemblage at the depths of 1458 and 1830 meters. The authors consider

Epistominella pacifica to be a stenothermal species, noting that its distribution must be greatly influenced by temperature because it has a shallower abundant occurrence in the Alaskan region than off California.

Middle Pliocene deposits from the Yakataga Reef section in the Gulf of Alaska have yielded specimens of Epistominella pacifica as well (Lagoe, 1983). Dominating the Epistominella pacifica biofacies along with "Haplophragmoides" spp., the taxon was also found to be associated with the initial appearances of Buccella frigida, Elphidium clavatum and Melonis zaandamae. Lagoe, based upon the works of Bergen and O'Neil (1979) and Echols and Armentrout (1980), concluded that the biofacies "...represents deposition at outer shelf to upper bathyal depths."

The taxon has also been recovered in recent sediments from the Juan de Fuca and Georgia Straits regions of British Columbia, Canada, in 34 to 184 meters of water (Cockbain, 1963). In addition, it is a dominant member of the Pliocene deposits of the Rio Dell Formation in Humboldt County, California (Haller, 1980). Haller (1980) noted that this taxon occurs in the Holocene as well, being indicative of a central-shelf to an upper-bathyal environment.

To the south, Bandy (1953a) collected Epistominella pacifica in a single transect off the San Francisco Bay. The species was present in waters as shallow as 610 meters, but became a dominant member of the assemblage in his upper abyssal zone between 1829 and 2103 meters. These deeper waters were characterized by temperatures between 1.9 and 2.2°C, salinity from 34.6 to 34.7°/oo, and oxygen content from 1.6 to 1.9 ml/1. Bandy found Epistominella pacifica's distribution to be considerably shallower farther south off Point Arguello (see below) and suggested that this anomaly be attributed to downslope displacement.

The taxon has also been reported from middle Tertiary deposits from the San Joaquin Valley of California, where the fossils are homeomorphs of those found in the middle bathyal regions along the west coast of North and Central America today (Bandy and Arnal, 1960). Bandy (1953a) reported a bathyal zone niche from this species as well, from a single transect off Point Arguello, California. It inhabited waters here from 549 to 732 meters deep, with temperatures ranging from 4.0 to 5.5°C, salinities of 34.2 to 34.0°/oo, and an oxygen content from 0.4 to 0.6 ml/1. In addition, Ingle's (1980) study of Neogene benthic foraminifers of the California continental borderland cited Epistominella pacifica as being distributed transitionally between upper bathyal (150-500 m) and upper middle (500-1500 m) bathyal environments.

Likewise in the Southern California region, this taxon is a consistent member of the assemblage. It is found in upper Miocene deposits of the Ventura Basin; in recent waters it indicates depths of approximately 610 meters (Bandy, 1953a, 1953b). Furthermore, it is a constituent of the Pliocene Repetto and Pico Formation faunas of the Los Angeles Basin (Martin, 1952). In recent sediments of the Santa Barbara Channel, this species was found associated with the lower neritic environment ranging between 92 and 183 meters (Marks and others, 1980).

In a study of living and dead foraminifers of the Santa Monica Bay, Zalesny (1959) found the taxon represented between the depths of 549 and 841 meters. The species comprised 4% of the fauna at a depth of 549 meters and a maximum of 6% of the assemblage in 695 meters of water. The author also discovered that a substantial change in the foraminiferal biota occurred in the lower end of the Redondo submarine canyon between the depths of 549 and 841 meters. Epistominella pacifica, as well as E. smithi, Cassidulina delicata, Buliminella tenuata, Valvulineria araucana and Bolivinita minuta became the dominating taxa. Between these depths, the temperature ranged between 4.9 and 5.6°C and the salnity ranged from 34.38 to 34.42°/oo. Epistominella pacifica has additionally been found in the waters between the mainland at Long Beach and Santa Catalina and Santa Cruz Islands (Natland, 1933), where it was found abundantly in Natland's Zone IV faunal-zone. The waters of this life-zone were characterized by a depth range of 274 to approximately 1981 meters and temperatures of 4.0 to approximately 8.5°C. Recent forms of the species are also rarely present in the deep basins offshore from Santa Barbara to San Diego, where they are assigned to Crouch's (1952) biozone T4. This zone exists between approximately 274 and 610 meters in the open ocean with a temperature range from approximately 5.0 to 8.5°C (Crouch, 1952). This same study also discovered that the taxon became abundant in the waters south of the border.

Ingle, Keller, and Kolpack (1980) have also noted Epistominella pacifica's occurrence as far south as the Peru-Chile Trench region. The species was found in only one sample, at a depth of 190 meters, where it comprised <1% of the faunal assemblage. This bathymetric occurrence coincided with the shallow oxygen minimum zone, with oxygen levels below 1 ml/1, which the authors reported existed between 150 and 400 meters.

Epistominella pacifica appears to be a common member of the upper bathyal environment, inhabitating waters of 250 to 650 meters off California.

Distribution

Epistominella pacifica was found associated primarily with the sand intervals in the upper portion of the core, and with both muds and sands below. Recovered from the sand layers between the depths of 46 and 414.5 cm, the taxon comprises from 1.3 to 25.6% of the fauna. In the mud intervals between 210 and 412.5 cm downcore, Epistominella pacifica accounts for less than 1 to 2.5% of the benthonic foraminiferal assemblage.

Epistominella smithi (Stewart and Stewart)
Plate 18, figure 2

Pulvinulinella smithi R.E. and K.C. Stewart; R.E. and K.C. Stewart, 1930, p. 70, pl. 9, fig. 4.
Epistominella smithi (R.E. and K.C. Stewart); Bandy, 1953a, p. 177, pl. 23, fig. 7; Uchio, 1960, pl. 9, figs. 8-10; Bandy, 1961, p. 15, pl. 5, fig. 6; Matoba and Yamaguchi, 1982, p. 1044, pl. 3, fig. 1.
Epistominella pacifica smithi; Bandy and Rodolfo, 1964, p. 827, fig. 5A.
Epistominella smithi (Stewart and Stewart); Wagner, 1978, p. 203-204.
Epistominella pacifica (Cushman); Haller (in part), 1980, p. 254, pl. 10, fig. 5.

Ecology

Green, 1960, R, central Arctic Basin.
Epistominella smithi was one of the species found to be present in this study.

Bandy, 1953a, R, San Francisco to San Diego, CA.
On a single transect off Point Arguello, this species was found to be one of the dominant taxa in the middle bathyal zone lying between 549 and 732 meters. The waters here are characterized by a temperature between 4.0 and 5.5°C, salinity of from 34.2 to 34.4^{o}/oo, and an oxygen content of 0.4 to 0.6 ml/l.

Morin, 1971, late Q, San Francisco, L.A., Baja CA.

Harman, 1964, R, Santa Barbara Basin, CA.
This species was considered a member of Harman's cosmopolitan fauna because it was recovered from both slope and basin deposits between the depths of 372 and 563 meters. In all cases, it comprised less than 1% of the faunal assemblage. The taxon was recovered from the laminated sediments of the Santa Barbara Basin and was found to have a very fragile test.

Resig, 1958, R, Santa Cruz Basin, CA.
Both living and dead specimens of this taxon were recovered from the Santa Barbara Basin. Living individuals were obtained between the depths of 457 and 1829 meters, occurring in the highest abundance at a depth of 1463 meters. Only this species was found to live both above and below the sill, the depth of which was placed here at 1083 meters. The taxon's living distribution was at the upper limit of the test distributions, although to a lesser extent than the other species, and therefore indicates downslope displacement of the tests. Resig found Epistominella smithi living on the west side of the basin near the sill depth with Bolivina spissa, Globobulimina pacifica, Pullenia salisburyi, Uvigerina peregrina and Fursenkoina seminuda. Dead representatives of the taxon were recovered between the depths of 732 and 1865 meters.

Crouch, 1952, R, 11 deep basins off southern CA.
Epistominella smithi was found to be a common foraminifer in Crouch's Zone T4, residing in water temperatures between 4.0 and 8.5°C and between the depths of approximately 274 and 610 meters in the open ocean.

Marks and others, 1980, R, Santa Barbara Channel, CA.
The upper depth limit of a moderate number of individuals of this species was found to be the lower upper bathyal zone between the depths of 325 and 457 meters in the Santa Barbara Channel. The taxon was reported to be associated with Loxostomum pseudobeyrichi, Cassidulinoides cornuta, Suggrunda eckisi, Cassidulina delicata, C. translucens and Globobulimina affinis.

Cushman & Moyer, 1930, R, San Pedro, CA.
This species was found only at a depth of 732 meters.

Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Zalesny found this species occurring between the depths of 207 and 841 meters in the Santa Monica Bay. The taxon comprised 5% of the fauna at a depth of 777 meters, 8% at 549 meters and a maximum of 12% of the assemblage at a depth of 695 meters. In the lower end of the Redondo submarine canyon, between the depths of 549 and 841 meters, Zalesny noted a substantial change in the foraminiferal fauna. Epistominella smithi, as well as E. pacifica, Cassidulina delicata, Buliminella tenuata, Valvulineria aruacana and Bolivinita minuta, became the dominating taxa. Between these depths, the temperature ranged between 4.9 and 5.6°C and the salinity ranged from 34.38 to 34.42^{o}/oo.

Kheradpir, 1970, R, Tanner Basin, so CA.
This species was one of twelve obtained in recent material collected in three cores at a depth of 1200 meters in the Tanner Basin off southern California. Kheradpir noted that the benthonic foraminiferal species usually accounted for only <20% of the total foraminiferal population in these cores.

Douglas & Heitman, 1979, R, so. California borderland.
Epistominella smithi, as well as Loxostomum pseudobeyrichi, Valvulineria araucana and Globobulimina pacifica, was found to be isobathyal in the nearshore basins of Santa Monica, San Pedro and the northern San Diego Trough. Yet interestingly, the authors noted that "...populations of Bolivina argentea and Epistominella smithi...vary in numbers by a factor of 3 to 10 between winter and summer seasons in deeper slope stations." In the nearshore basins, the taxon was found to be a dominant member of the group II lower slope assemblage and first appeared at a depth of from 450 to 500 meters. The assemblage, which included Valvulineria araucana, was associated with the East Pacific Intermediate Water between the depths of 400 and 950 meters.

When measured during this study, the East Pacific Intermediate Water in the California borderlands area ranged in temperature from 4.8 to 7.0°C and contained a salinity and oxygen content of 34.2 to 34.4‰ and 0.1 to 0.8 ml/l, respectively. In the offshore basins of Santa Cruz, Catalina, San Nicolas and Tanner, Epistominella smithi was also a dominant member of the group II lower slope assemblage. Once again, the fauna resided within the East Pacific Intermediate Water, characterized by a temperature ranging from 4.1 to 8.0°C, salinity between 34.3 and 34.4‰ and an oxygen content of 0.3 to 1.1 ml/l between the depths of 300 and 1900 meters.

Bandy & Chierici, 1966, R, California & Mediterranean.
Based upon various previous works, Bandy and Chierici determined that the upper depth limit of this taxon off California was in the bathyal waters at a depth of 400 meters, plus or minus 100 meters. The species was not reported in bathyal deposits in the Mediterranean.

White, 1956, Mio-Plio, Capistrano Fm., Orange Co., CA.
Reported to occur rarely to abundantly in Pliocene deposits of the Upper Capistrano Formation. Based upon the works of Natland (1933) and Bandy (1953a), White concluded that this species prefers to inhabit waters between the depths of 549 and 732 meters.

Butcher, 1951, R, Coronado Bank, San Diego, CA.
This species was found between the depths of 100 and 1025 meters with a high relative frequency recorded from 350 to 1025 meters.

Uchio, 1960, R, living & dead, San Diego, CA.
Both living and dead representatives of Epistominella smithi were obtained off San Diego. Living individuals comprised <1% of the fauna at the depths of 287, 452, 512 and 567 meters, 3% at 600 meters and a maximum of 6% of the assemblage at a depth of 631 meters. Total (dead plus living) specimens of Epistominella smithi were recovered between 190 and the study's limit of 631 meters, where the taxon usually constituted <1% of the fauna. However, the species comprised 2% of the assemblage at the depths of 454 and 512 meters and a maximum of 12% in the study's deepest sample at 631 meters.

Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.
Walton found Epistominella smithi associated with his offshore fauna, which occurred primarily from just outside Todos Santos Bay, at a depth of approximately 640 meters, to at least 1097 meters. Other taxa comprising this fauna included Valvulineria araucana, Cassidulina delicata, Bulimina tenuata, Hoeglundina elegans and Loxostomum pseudobeyrichi.

Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a dominant member of the upper middle bathyal biofacies, located between 610 and 914 meters with a temperature ranging between 3.5 and 4.5°C.

Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Matoba and Yamaguchi recovered Epistominella smithi from late Pliocene, Pleistocene and Holocene deposits collected from seven holes in the Guaymas Basin of the Gulf of California. The taxon comprised 4% of the late Pliocene benthonic foraminiferal assemblage. In addition, it commonly constituted a very large percentage of the Pleistocene faunas, ranging between 1 and a maximum of 60%, with several values lying between 20 and 35%. And in the Holocene, Epistominella smithi comprised 1 to 37% of the assemblage, maximizing at 14, 23 and 37%.

Bandy & Arnal, 1957, R, W. coast of Central America.
In a study from Acapulco to the Gulf of Panama, this taxon was found at a depth of 59 meters and between the depths of 777 and 1600 meters. It comprised <1% of the fauna at 59 meters, 4% of the assemblage at 1246 meters, 6% at 969 meters and 8% of the fauna at a depth of 777 meters. Bandy and Arnal found Epistominella smithi to be a prominent member of their middle bathyal fauna, which was found between the depths of 610 and 1219 meters. This depth zone displayed a temperature range from 3.5 to 7.5°C and salinity near 34.7‰. This species was found associated with these other dominant taxa: Cassidulina delicata, Bolivina spissa, Buliminella tenuata and costate Uvigerinas.

Smith, 1964, R, El Salvador & Nicaragua.
Epistominella smithi was found between the depths of 450 and 1700 meters.

Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.
This species was found commonly in the cores and not the trawls. Bandy and Rodolfo assigned it to their group 2C, whose upper depth limit was 300 to 500 meters. Epistominella smithi was recovered between 796 and 6000 meters, with maximum abundances between 796 and 1000 meters and also at approximately 2000 meters.

Distribution

With the exception of a singular specimen of the taxon in the mud interval from 270 to 272 cm, Epistominella smithi occurs exclusively in sand and sandy mud layers of this core. Recovered between the depths of 46 and 338 cm downcore, the species comprises from less than 1 to 5.5% of the faunal assemblage.

Fissurina lagenoides (Williamson)
Plate 9, figure 8

Entosolenia marginata (Walker) var. lagenoides Williamson; Williamson, 1858, p. 11, pl. 1, figs. 25-26.
Fissurina lagenoides (Williamson); Barker, 1960, p. 124, 126, pl. 60, figs. 6, 9.

This species is similar in morphology to Fissurina serrata (Schlumberger) but has a much longer neck. The single specimen recovered in the Monterey Fan sediments has an entosolenian tube, neck and lip, and most of the thin border has succumbed to dissolution.

Ecology

Barker, 1960, R, Brady's Challenger Expedition.
Lessard, 1980, R, shallow, tropical Pacific Ocean.

Distribution

One representative of this taxon was recovered from the sand interval located between 133.5 and 136.5 cm downcore.

Fissurina lucida (Williamson)

Entosolenia marginata (Montagu) var. lucida Williamson; Williamson, 1848, p. 17, pl. 2, fig. 17.
Entosolenia lucida Williamson; Cushman and Gray, 1946b, p. 30, pl. 5, figs. 16-18.
Fissurina lucida (Williamson); Todd and Low, 1967, p. A28, pl. 3, fig. 31; Ingle, 1973, p. 545, 556; Lankford and Phleger, 1973, p. 119, pl. 3, fig. 7; Wagner, 1978, p. 187-188, pl. 3, fig. 3; Bergen and O'Neil, 1979, p. 1290; Haller, 1980, p. 238, pl. 5, fig. 2; Sloan, 1981, p. 296.

Ecology

Loeblich & Tappan, 1953, R, Arctic forams.
Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Cushman & Todd, 1947b, Plio? Pleis?, Amchitka Is., AK.
Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.
This species was found between the depths of 34 and 267 meters.
Cushman & Todd, 1947a, R, shallow water, coast of WA.
Cooper, 1961, R, intertidal, CA. & Oregon coast.
Bandy, 1950, Eocene, Plio-Pleis, Cape Blanco, Oregon.
Lankford, 1962, R, turbulent zone, W. coastal N. America.
Lankford & Phleger, 1973, R, W. coastal N. America.
Harman, 1964, R, Santa Barbara Basin, CA.
Bandy, Ingle & Resig, 1964, R, San Pedro Bay, CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Smith, 1964, R, El Salvador & Nicaragua.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Boltovskoy and others, 1980, R, shelf, SW Atantic.
Murray, 1971, R, British forams.

Distribution

With the exception of an occurrence in the mud interval from 210 to 212 cm downcore, where Fissurina lucida comprises 1.3% of the assemblage, the taxon accounts for less than 1% of the fauna in both mud and sand layers. The species was recovered between the depths of 133.5 and 432.5 cm in this study.

Fissurina marginata (Montagu)

Vermiculum marginatum Montagu; Montagu, 1803, p. 524.
Fissurina marginata (Montagu); Loeblich and Tappan, 1953, p. 77, pl. 14, figs. 6-9; Bergen and O'Neil, 1979, p. 1290; Todd and Low, 1980, p. 23.

Ecology

Loeblich & Tappan, 1953, R, Arctic forams.
Susan Cooper, 1964, R, Chukchi Sea, Alaska.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Cushman & Todd, 1947b, Plio? Pleis?, Amchitka Is., AK.
Cooper, 1961, R, intertidal, CA. & Oregon coast.
Smith, 1964, R, El Salvador & Nicaragua.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Murray, 1971, R, British forams.
Le Calvez, 1950, R, Fissurina marginata as parasite.
Loeblich & Tappan, 1964, Treatise on Invert. Paleo.

Distribution

Two representatives of Fissurina marginata, comprising less than 1% of the faunal assemblage, were recovered from the sand interval located between the depths of 171 and 173 cm downcore.

Fissurina spp.
Plate 8, figures 6, 7, 9, 10;
Plate 9, figures 1 to 7, 9

Fissurina spp. Rare individuals of several different species are present in the Monterey Fan levee deposits. All are characterized by single chambered, finely perforate tests. Apertures are terminal and either round or elliptical. In well preserved specimens, the internal tube is apparent. Time did not permit their identification to the specific level.

Ecology

McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Martin, 1952, Plio, Los Angeles Basin, CA.
Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Various unidentified examples of this genus were recovered from both the mud and sand intervals of this study. Obtained from sediments between the depths of 20 and 414.5 cm downcore, these individuals most often comprise less than 1% of the assemblages. In the mud layers, Fissurina spp. account for a maximum of 2.4% of the fauna, while in the sands they peak at 1.3%.

Florilus labradoricus (Dawson)
Plate 10, figure 2

Nonionina labradorica Dawson; Dawson, 1860, p. 191-192, t.f. 4.
Nonion labradorica (Dawson); Cushman, 1927a, p. 148, pl. 2, figs. 7-8.
Nonionella labradorica (Dawson); Bandy, 1953a, pl. 22, fig. 1; Ingle, 1973, p. 542, 549, 553, 556, 560, 562, 563; Todd and Low, 1981, p. 34, 44, fig. 103.
Nonion labradoricum (Dawson); Loeblich and Tappan, 1953, p. 86-87, pl. 17, fig. 1.
Florilus labradoricus (Dawson); Bergen and O'Neil, 1979, p. 1290, pl. 5, figs. 11-12.

Ecology

Loeblich & Tappan, 1953, R, Arctic forams.
Lagoe, 1979a, R, deep, Arctic Ocean.
Lagoe, 1979b, R, shallow, Prudhoe Bay, Alaska.
Phleger, 1951a, R, Canadian and Greenland Arctic.
Smith, 1963b, Pleis & R, Gulf of Alaska.
Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Smith, 1973, Pleis? & Holocene, North Pacific Ocean.
Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Bandy, 1953a, R, San Francisco to San Diego, CA.
Bandy & Arnal, 1960, Mio-R, San Joaquin Valley, CA.
Marks and others, 1980, R, Santa Barbara Channel, CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Martin, 1952, Plio, Los Angeles Basin, CA.
Murray, 1971, R, British forams.

Distribution

With the exception of a singular specimen obtained from the mud interval lying between 289.5 and 292 cm downcore, Florilus labradoricus was recovered exclusively from sand and sandy mud deposits located between the depths of 230 and 414.5 cm. In each of the five samples containing the taxon, Florilus labradoricus always accounts for less than 1% of the faunal assemblage.

Frondicularia sp.
Plate 6, figure 6

Frondicularia sp. The single specimen is characterized by the initial chambers being coiled into a sphere and the later chambers chevron-shaped and uniserially arranged. The aperture is radiate and a few delicate costae adorn the early chambers. Time did not permit identification to the specific level.

Ecology

Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

One example of the genus Frondicularia was recovered from the sand interval lying from 46 to 48 cm downcore.

Fursenkoina cornuta (Cushman)
Plate 21, figure 1

Virgulina cornuta Cushman; Cushman, 1913b, p. 637, pl. 80, fig. 1; Cushman, 1927a, p. 154, pl. 3, fig. 2; Cushman, 1937b, p. 28, pl. 4, figs. 20-21; Walton, 1952, p. 133, pl. 23, fig. 9; Uchio, 1960, pl. 6, fig. 14
Cassidulinoides cornuta (Cushman); Ingle, 1973, p. 545, 549, 553, 562; Haller, 1980, p. 261, pl. 13, fig. 5.
Fursenkoina cornuta (Cushman); Matoba and Yamaguchi, 1982, p. 1044, pl. 3, fig. 8.

Ecology

Fursenkoina cornuta (Cushman) is known from the western Pacific near the Philippines (Cushman, 1927a, 1937b) and has been reported inhabiting the eastern Pacific from the extreme north to Chile. In a study of the Gulf of Alaska from the Kodiak shelf to Cape Fairweather, Bergen and O'Neil (1979) found the taxon restricted to their deepest sample, situated at a depth of 2623 meters. In this lower bathyal faunal zone, the authors discovered Fursenkoina cornuta associated with Pullenia bulloides (d'Orbigny), Oridorsalis umbonatus (Reuss), Bulimina rostrata Brady and several arenaceous species, with the taxon comprising less than 1% of the total faunal assemblage. The Deep Sea Drilling Project also recovered the species at Site 181 in the Gulf of Alaska, located approximately 2000 meters above the Aleutian Trench (Ingle, 1973). Sediments here were recovered in 3080 meters of water and Ingle determined that the species' presence indicated that these deposits originated at an upper middle bathyal depth of 500 to 1500 meters. Ingle (1973) reached a similar conclusion regarding the depth of deposition of some of the sediments recovered at the Deep Sea Drilling Project sites off Vancouver Island (Site 177), the Columbia River (Site 176) and central Oregon (Site 175), due in part to the presence of Fursenkoina cornuta in these deposits.

This species has been reported to the south off Santa Barbara as well. Harman (1964), investigating recent foraminifers in the Santa Barbara Basin, recovered Fursenkoina cornuta between 389 and the study's limit of 588 meters. Remarkably, it comprised 10% of the total faunal assemblage at a depth of 476 meters. Harman concluded that the taxon was characteristic of the basin plain fauna lying between 550 and 589 meters, where it was associated with Suggrunda eckisi Natland, Bolivina seminuda Cushman and Buliminella tenuata Cushman. A shallow-water occurrence for Fursenkoina cornuta was also reported from the Santa Barbara Channel, where the upper depth limit of a moderate number of the species lies in the lower upper bathyal between 325 and 457 meters (Marks and others, 1980). In this study, Fursenkoina cornuta was found associated with Loxostomum pseudobeyrichi (Cushman), Suggrunda eckisi Natland, Epistominella smithi (Stewart and Stewart), Cassidulina delicata Cushman, C. translucens Cushman and Hughes, Globobulimina affinis (d'Orbigny), and Buliminella tenuata Cushman.

Crouch (1952), investigating recent forms inhabiting the deep basins off southern California from Santa Barbara to San Diego, determined that Fursenkoina cornuta was a common faunal constituent in waters characterized by temperatures ranging between 4.0 and 5.0°C. In a slope and basin study also along the California borderland, Douglas and Heitman (1979) associated the taxon with their basin floor assemblage in both the nearshore and offshore basins. In the nearshore basins, Fursenkoina cornuta was found between 550 and 950 meters, associated with the East Pacific Intermediate Waters. These waters are charactized by a temperature ranging between 4.8 and 6.1°C, salinity of 34.3 to 34.4^{o}/oo and an oxygen content of 0.25 to 0.5 ml/l. In spite of the fact that Fursenkoina cornuta commonly produces a delicate test which is susceptible to diagenetic destruction (Douglas and Heitman, 1979), the taxon was a numerically dominant constituent of the basin floor assemblage of the California borderland.

Numerous other occurrences of the species have been reported from the southern California region. Off San Pedro, Cushman and Moyer (1930) reported the appearance of Fursenkoina cornuta at a depth of 732 meters. Shortly thereafter, Natland (1933) discovered the species in the San Pedro Channel between San Pedro and Santa Catalina Island in waters 488 to 884 meters deep. He also reported the taxon's presence in a sample collected from a depth of 1814 meters by Dr. Parker Trask in the region between Santa Catalina and Santa Cruz Islands. In nearby Santa Monica Bay, Zalesny (1959) studied the distribution of living and dead benthonic foraminifers and reported Fursenkoina cornuta comprising 1 and 2% of the faunal assemblage at depths of 695 and 777 meters, respectively.

Southern California continental borderland deposits have also yielded specimens of the taxon. Natland (1933) discovered the presence of Fursenkoina cornuta in his Zone 4 of the Pliocene-aged Pico Formation deposits exposed in the Hall Canyon section near Ventura. In 1952, Lewis Martin investigated similar aged outcrops of the Repetto and Pico Formations in the Los Angeles Basin and reported the species as a constituent of his diverse fauna. Later, White (1956) uncovered rare specimens of Fursenkoina cornuta in two Pliocene-aged localities of the Upper Capistrano Formation of Orange County. And Ingle (1980), in an extensive review of foraminiferal-bearing Cenozoic strata along southern California, found the species to be associated with the upper bathyal biofacies lying between 150 and 500 meters water depth.

Fursenkoina cornuta has been reported from offshore San Diego as well. In the early part of this century, the U.S. Coast and Geodetic Survey ship Guide recovered the species in this region at depths of 785, 850 and 1011 meters (Cushman, 1927a). Considerably later, Uchio (1960) reviewed the distribution of living and dead benthonic foraminifers, including Fursenkoina cornuta, off San Diego and south to the Coronados Islands. He found live specimens present between 631 and 713 meters, comprising, at most, 0.9% of the faunal assemblage. In contrast, dead individuals were only reported at a single locality from a depth of 1061 meters, where they totaled 3% of the population.

Southward, in the Gulf of California, Bandy (1961) investigated recent foraminifers from the intertidal zone to just greater than 1800 meters. He reported Fursenkoina cornuta to be a minor element in the upper bathyal biofacies, lying between 366 and 610 meters, in waters ranging in temperature between 4.5 and 6.0°C. Matoba and Yamaguchi (1982) also found the taxon in Pleistocene and Holocene deposits recovered in the Guaymas Basin by the Deep Sea Drilling Project. Based on the works of Bandy (1961) and Phleger (1964, 1965) in this region, Matoba and Yamaguchi (1982) defined Fursenkoina cornuta as primarily an upper to upper middle bathyal species, noting that it prefers to live at depths between approximately 350 and 1800 meters.

The taxon has been collected offshore as far south as Central and South America as well. Smith (1964), in a review of recent foraminifers off El Salvador and Nicaragua, found Fursenkoina cornuta existing between 800 and 885 meters water depth. In addition, the U.S. Coast and Geodetic Survey ship Lydonia reported the species in 783 meters of water south of Panama (Cushman, 1927a). Bandy and Arnal (1957), surveying recent foraminifers from off Acapulco to the Gulf of Panama, discovered Fursenkoina cornuta at a single locality at a depth of 1341 meters, where it comprised less than 1% of the faunal assemblage. The authors assigned it to their lower bathyal zone, lying between 1220 and 1911 meters, in waters characterized by a temperature of 2.6 to 3.8°C and a salinity of approximately 34.7°/oo.

Rare specimens of Fursenkoina cornuta have also been found as far south as Chile where they were collected in the southern Peru-Chile Trench area (Ingle, Keller and Kolpack, 1980). The taxon was reported from a depth of 1800 meters, lying within the lower middle bathyal zone from 1500 to 2000 meters, as defined by the authors.

Possibly due to its delicate test which is susceptible to destruction, Fursenkoina cornuta appears to be a non-dominant, but ubiquitous, faunal constituent of benthonic foraminiferal assemblages throughout the eastern Pacific Ocean. It seems to favor living in the lower upper bathyal to upper middle bathyal biofacies, commonly residing between the depths of 350 and 1000 meters.

Distribution

Representatives of Fursenkoina cornuta were recovered exclusively from the sand lenses investigated in this study. Obtained from five sand layers between the depths of 133.5 and 414.5 cm downcore, this taxon accounts for less than 1 to 3.4% of the faunal assemblage.

Fursenkoina rotundata (Parr)

Plate 15, figure 7

Virgulina subsquamosa Egger; Brady, 1884, pl. 52, figs. 10-11, not figs. 7-9.
Virgulina rotundata Parr; Parr, 1950, p. 337, pl. 12, fig. 14; Uchio, 1960, pl. 6, figs. 15-16.
Fursenkoina rotundata (Parr); Matoba and Yamaguchi, 1982, p. 1044, pl. 3, fig. 9.

Ecology

Uchio, 1960, R, living & dead, San Diego, CA.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

With the exception of a singular specimen of the taxon obtained in the mud interval between 410 and 414.5 cm, Fursenkoina rotundata was recovered exclusively from the sand deposits investigated in this study. The taxon comprises 1.3% of the fauna from 133.5 to 136.5 cm, 2.3% in the interval from 171 to 173 cm downcore, and less than 1% of the assemblage in the sand layer lying from 412 to 414.5 cm.

Fursenkoina seminuda (Natland)
Plate 15, figure 3

Virgulina seminuda Natland; Natland, 1938, p. 145, pl. 5, fig. 12; Cushman and McCulloch, 1942, p. 185, pl. 21, fig. 1; Uchio, 1960, pl. 6, fig. 19; Smith, 1964, p. B34, pl. 2, fig. 9; Wagner, 1978, p. 192-192, pl. 3, fig, 5.
Fursenkoina seminuda (Natland); Phleger, 1964, pl. 2, fig. 7; Lankford and Phleger, 1973, p. 120, pl. 4, fig. 16; Matoba and Yamaguchi, 1982, p. 1044.

Ecology

Smith, 1963b, Pleis & R, Gulf of Alaska.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Lankford, 1962, R, turbulent zone, W. coastal N. America.
Lankford & Phleger, 1973, R, W. coastal N. America.
Govean & Garrison, 1984, Mio, Monterey Fm., cen.-so. CA.
Harman, 1964, R, Santa Barbara Basin, CA.
Resig, 1958, R, Santa Cruz Basin, CA.
Crouch, 1952, R, 11 deep basins off southern CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Douglas & Heitman, 1979, R, so. California borderland.
Uchio, 1960, R, living & dead, San Diego, CA.
Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a non-dominant member of the upper bathyal biofacies between the depths of 366 and 610 meters, with water temperatures ranging between 4.5 and 6.0°C.
Phleger, 1964, living, Gulf of California.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Smith, 1964, R, El Salvador & Nicaragua.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman & McCulloch, 1942, R, Hancock Exp, Virgulinidae

Distribution

Fursenkoina seminuda was obtained from three sand layers between the depths of 133.5 and 414.5 cm downcore. In all cases, the taxon comprises less than 1% of the faunal assemblage.

Fursenkoina sp.
Plate 15, figure 4

Fursenkoina sp. The tests assigned to this genus are elongate, slightly twisted, and very finely perforate. The initial chambers are triserially arranged, while the later chambers become biserial. The aperture is terminal and loop-shaped. Time did not permit identification to the specific level.

Ecology

Murray, 1973, R, general ecology & distribution.

Distribution

Singular representatives of the genus *Fursenkoina* were recovered from three sand intervals lying between 46 and 232 cm downcore.

Globobulimina affinis (d'Orbigny)
Plate 14, figures 3, 5, 6

Bulimina affinis d'Orbigny; d'Orbigny, 1839b, p. 105, pl. 2, figs. 25-26; Cushman, 1911, p. 79, fig. 130; Bandy, 1953a, pl. 24, fig. 9; Bandy, 1961, pl. 5, fig. 4; Smith, 1964, pl. 2, figs. 2-3.
?*Globobulimina hoeglundi* Uchio; Uchio, 1960, pl. 6, figs. 7-8.
Globobulimina affinis (d'Orbigny); Ingle, 1973, p. 536, 542, 545, 549, 553, 556, 562; Haller, 1980, p. 281, pl. 7, fig. 6; Ingle, Keller and Kolpack, 1980, p. 136, pl. 4, figs. 10-11; Matoba and Yamaguchi, 1982, p. 1044-1045, pl. 2, figs. 5-7.

Ecology

Smith, 1973, Pleis? & Holocene, North Pacific Ocean.

Collected from a single locality at a depth of 2410 meters near the Aleutian Islands, Globobulimina affinis was present in downcore samples at the depths of 10, 30, 50 and 60 cm. Only one individual was collected in the assemblages at 10 and 60 cm, while 2 and 3 were obtained at 30 and 50 cm, respectively. All of the samples were particularly depauperate in this core, with the maximum number of individuals collected in any one sample only being 10.

Cushman, 1927a, R, W. coast, Oregon to Central Amer.

Globobulimina affinis was collected off Oregon in 1911 meters of water and near San Diego at the depths of 635, 724, 753, 785, and 973 meters. The taxon was also found near the United States-Mexico border at the depths of 889 and 1490 meters. Off central and southern Baja, Mexico, Globobulimina affinis was reported from 3493 and 2021 to 2224 meters, respectively. In addition, it was collected off Panama at a depth of 1289 meters and south of Panama in 1481 meters of water. Cushman notes that the megalospheric forms of Globobulimina affinis and G. ovata are difficult to distinguish from one another.

Bandy, 1953a, R, San Francisco to San Diego, CA.

Bandy considered this species to be a dominant member of his upper abyssal zone off San Francisco. The zone lies between the depths of 1829 and 2103 meters offshore and is characterized by temperatures between 1.9 and 2.2°C, salinities of from 34.6 to 34.7 °/oo and an oxygen content of 1.6 to 1.9 ml/l.

Morin, 1971, late Q, San Francisco, L.A., Baja CA.

Harman, 1964, R, Santa Barbara Basin, CA.

This species was recovered from both slope and basin deposits between the depths of 439 and 531 meters. It comprised less than 1% of the assemblage at 467 and 476 meters, as well as between the depths of 488 and 531 meters. Globobulimina affinis also consituted 1% of the fauna at 439 meters and 2% at 476 meters.

Resig, 1958, R, Santa Cruz Basin, CA.

No live individuals of this taxon were recovered in this study but dead specimens were obtained between the depths of 366 and 1737 meters.

Marks and others, 1980, R, Santa Barbara Channel, CA.

The upper depth limit of a moderate number of individuals of this species was found to be the lower upper bathyal zone between the depths of 325 and 457 meters in the Santa Barbara Channel. The taxon was reported to be associated with Loxostomum pseudobeyrichi, Cassidulinoides cornuta, Suggrunda eckisi, Epistominella smithi, Cassidulina delicata, C. translucens and Buliminella tenuata.

Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.

Globobulimina affinis was found between the depths of 506 and the study's limit of 884 meters in the San Pedro Channel between San Pedro and Santa Catalina Island. It was also reported in the sample collected at Guide Station 17, taken at a depth of 1011 meters off San Diego.

Bandy, Ingle & Resig, 1964, R, San Pedro Bay, CA.

In a study of living and dead foraminifers of the San Pedro Bay, Bandy, Ingle and Resig found Globobulimina affinis to be a constituent of the outer shelf and upper bathyal zones between the depths of 20 and 120 meters. The taxon was considered a member of the Bulimina marginata denudata biofacies, and was found associated with that species as well as Nonionella scapha basispinata and Nonionella stella.

Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.

This species was found between the depths of 549 and 841 meters in the Santa Monica Bay. It comprised 2% of the fauna at a depth of 695 meters and a maximum of 4% of the assemblage at a depth of 777 meters.

Bandy, 1963a, R, so. CA. continental borderland.

Specimens of Globobulimina affinis larger than 1 mm were found between the depths of 912 and 2107 meters, as well as in 2571 meters of water, in the basins offshore southern California. Considered a member of Bandy's "Fauna A", this taxon's largest average size ranged from 1.2 mm in the Tanner Basin with a basin bottom depth of 1551 meters to 2.0 mm in the Santa Catalina Basin with a basin bottom depth of 1357 meters. The species did not appear to display a size gradient with depth.

Douglas & Heitman, 1979, R, so. California borderland.

Globobulimina affinis was found to be a non-dominant member of Douglas and Heitman's "basin floor" assemblage in the nearshore basins (Santa Monica, San Pedro and the northern extent of the San Diego Trough). This assemblage included the dominant abundance of Buliminella tenuata, Cassidulinoides [Fursenkoina] cornuta and Fursenkoina seminumda, and was reported to be associated with the East Pacific Intermediate Water offshore southern California. The assemblage was characterized by a depth range of from 550 to 950 meters in waters 4.8 to 6.1°C, with a salinity value of 34.3 to 34.4 °/oo and an oxygen content of 0.08 to 0.9 ml/l.

White, 1956, Mio-Plio, Capistrano Fm., Orange Co., CA.

Reported to occur rarely in Pliocene deposits of the Upper Capistrano Formation.

Ingle, 1980, Tertiary, so. CA. continental borderland.

This species was found to be representative of the upper middle bathyal biofacies between the depths of 500 and 1500 meters. Commonly associated with Globobulmina affinis are Bolivina argentea, B. seminuda,

B. spissa, Buliminella tenuata, Cassidulina delicata, Epistominella pacifica, Pullenia quinqueloba and Valvulineria araucana.

Butcher, 1951, R, Coronado Bank, San Diego, CA.
This species was found occurring in high relative frequency between the depths of 280 and 1025 meters.

Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.
Walton found the combined group "Globobulimina spp.," in which he included Bulimina [Globobulimina] affinis, most abundant between the depths of 91 and 183 meters. Other taxa displaying their greatest percentages between these depths included Buccella frigida, Bolivina pacifica, Angulogerina [Trifarina] angulosa, Reophax gracilis and Uvigerina peregrina Cushman vars. (in part). He also associated "Globobulimina spp." with his outer bay facies, which was restricted to the deep channel and the deeper parts of the bay.

Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a non-dominant member of the upper middle bathyal biofacies between the depths of 1219 and 1524 meters, with water temperatures ranging from 2.5 to 3.5°C.

Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Matoba and Yamaguchi recognized several different forms of Globobulimina affinis in cored material obtained by the Deep Sea Drilling Project in the Guaymas Basin of the Gulf of California. In Pleistocene deposits, all of the morphotypes combined comprised between 1 and 9% of the assemblage, but most commonly constituted only 1 to 3% of the fauna. The taxon also was reported as occurring in Holocene sediments, where it was found at the low to moderate abundances of 1, 2, 5, 6, and 8% of the faunal assemblage.

Bandy & Arnal, 1957, R, W. coast of Central America.
In a study from Acapulco to the Gulf of Panama, this taxon was found between the depths of 823 and 1600 meters. It comprised 6% of the fauna at a depth of 1353 meters, 5% at 823 meters and 4% of the assemblage at 1600 meters. Such a depth distribution would be associated with the middle (610 to 1219 meters) and lower (1219 to 1911 meters) bathyal faunas, as defined by Bandy and Arnal.

Smith, 1964, R, El Salvador & Nicaragua.
Globobulimina affinis was found to be a non-dominant species between the depths of 800 and 3100 meters off Central America.

Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
This species was found between the depths of 274 and 2568 meters and was associated with both the shallow and deep oxygen minimum zones reported in this region. Most of the occurrences of Globobulimina affinis were at <1% of the fauna, but it peaked at 1.5% of the assemblage at a depth of 1864 meters. A variety of this taxon was found to constitute <1% of the fauna at 800 meters and 1.4% of the assemblage at 1948 meters.

Resig, 1976, Eocene-R, DSDP, Nazca Plate, Peru.
Utilizing only the sand size (>0.062 mm) fraction of DSDP core material from the Nazca Plate, Resig obtained the taxon in Pleistocene/Holocene deposits, where it comprised 1 and 12% of the faunal assemblage.

Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
In the Atlantic Ocean, this species is found at depths greater than 97 meters. In this study of the equatorial and low- and mid-latitudes of the North Atlantic between the depths of approximately 2000 and 7500 meters, Globobulimina affinis was recorded in 4181 and 4554 meters of water.

Distribution

With the exception of the mud interval between 120 and 122 cm downcore, Globobulimina affinis was recovered from every sample investigated in this study. In the mud layers, the taxon comprises from 1.1 to 52.2% of the assemblage. In contrast, Globobulimina affinis accounts for 1.1 to 7.6% of the fauna in the sand intervals. With the exception of three peaks in the upper portion of the core, the taxon was also found to increase in abundance with depth in core.

Globobulimina barbata (Cushman)

Plate 13, figure 3

Bulimina barbata Cushman; Cushman, 1927a, p. 151, pl. 2, fig. 11; Cushman and Parker, 1947, p. 126, pl. 29, fig. 8; Cushman and McCulloch, 1948a, p. 248-249, pl. 31, fig. 3; Bandy, 1953a, p. 176, pl. 24, fig. 10; Bandy and Rodolfo, 1964, p. 829, fig. 5C.
Globobulimina barbata (Cushman); Uchio, 1960, pl. 6, fig. 6; Ingle, 1973, p. 545.
Praeglobobulimina barbata (Cushman); Matoba and Yamaguchi, 1982, p. 1045.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Bandy, 1953a, R, San Francisco to San Diego, CA.
Uchio, 1960, R, living & dead, San Diego, CA.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.

Bandy & Arnal, 1957, R, W. coast of Central America.
Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Bandy, 1956, general trends.
Cushman & Parker, 1947, Mio-R, *Bulimina*.
Cushman & McCulloch, 1948a, R, *Hancock* Exp, Buliminidae.

Distribution

Globobulimina barbata was recovered in fairly low abundance from both the mud and sand layers of the upper two thirds of this core. In the mud layers lying from 96.5 to 292 cm, the taxon accounts for less than 1 to 2.9% of the fauna. Slightly lower quantities of *Globobulimina barbata* were obtained from the sand intervals between the depths of 46 and 250 cm downcore: from less than 1 to 2.1% of the assemblage.

Globobulimina cf. *G. marginospinata* (Cushman and Parker)

Plate 14, figure 1

Bulimina marginospinata Cushman and Parker; Cushman and Parker, 1938, p. 57, pl. 9, fig. 11; Martin, 1952, p. 131, pl. 22, fig. 9.
Globobulimina spinifera (Cushman); Uchio, 1960, pl. 6, fig. 10.

This species is similar to *Globobulimina marginospinata* in that the last three chambers make up much of the larger part of the test and that the test's lower portion is beset with a small number of short spines. It differs from *G. marginospinata* in having the final chambers much more elongate, so that they nearly obliviate the initial chambers. As a result, the five whorls of the adult *G. marginospinata* are not apparent. This species is unique in that it possesses a single, rather prominent basal spine.

Ecology

Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Representatives of this taxon were only recovered from two sand intervals in this study: 133.5 to 136.5 and 171 to 173 cm downcore. In both cases, *Globobulimina* cf. *G. marginospinata* comprises less than 1% of the faunal assemblage.

Globobulimina ovula (d'Orbigny)

Plate 14, figures 2, 4

Bulimina ovula d'Orbigny; d'Orbigny, 1839a, p. 51, pl. 1, figs. 10-11; Cushman, 1927a, p. 150, pl. 2, fig. 10; Cushman and Parker, (in part), 1940, p. 10, pl. 2, figs. 13-14; Cushman and Parker, 1947, p. 122, pl. 28, figs. 20-22.
Globobulimina ovula (d'Orbigny); Ingle, 1973, p. 546; Matoba and Yamaguchi, 1982, p. 1045.
Globobulimina ovula ovula (d'Orbigny); Ingle, 1980, p. 172.

Ecology

Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Matoba & Yamaguchi, 1982, DSDP, Gulf of California.
Cushman & Parker, 1947, Mio-R, *Bulimina*.
Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Rare occurrences of *Globobulimina ovula* were obtained in two mud intervals lying from 346.5 to 349.5 and 430 to 432.5 cm downcore. The taxon also accounts for less than 1% of the fauna in the sand intervals from 230 to 232 and 412 to 414.5 cm, while reaching a peak abundance of 3.7% of the assemblage in the sand layer at a depth of 248 to 250 cm downcore.

Globobulimina pacifica Cushman

Plate 13, figures 9, 10

Globobulimina pacifica Cushman; Cushman, 1927b, p. 67, pl. 14, fig. 12; Natland, 1940, p. 19, pl. 5, fig. 10; Hoglund, 1947, p. 237; Cushman and McCulloch, 1948, p. 250, pl. 31, fig. 5; Barker, 1960, p. 102, pl. 50, figs. 7-10; Uchio, 1960, pl. 6, fig. 9; Phleger, 1964, pl. 3, figs. 12, 16-17; Ingle, 1973, p. 536; Haller, 1980, p. 246-247, pl. 7, fig. 8; Matoba and Yamaguchi, 1982, p. 1045, pl. 2, fig. 8.

Ecology

Smith, 1963b, Pleis & R, Gulf of Alaska.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Smith, 1973, Pleis? & Holocene, North Pacific Ocean.
Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.
  This species was found between the depths of 83 and 174 meters.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Bandy, 1953a, R, San Francisco to San Diego, CA.
Harman, 1964, R, Santa Barbara Basin, CA.
Resig, 1958, R, Santa Cruz Basin, CA.
Crouch, 1952, R, 11 deep basins off southern CA.
Cushman & Moyer, 1930, R, San Pedro, CA.
  This species was found only at a depth of 338 meters.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Bandy, 1963a, R, so. CA. continental borderland.
Douglas & Heitman, 1979, R, so. California borderland.
Galloway & Wissler, 1927, Pleis, Palos Verdes, CA.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Butcher, 1951, R, Coronado Bank, San Diego, CA.
  This species was found occurring in low relative frequency between the depths of 175 and 1025 meters.
Uchio, 1960, R, living & dead, San Diego, CA.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
  This species was found to be a non-dominant member of the upper bathyal biofacies between the depths of 366 and 610 meters, with water temperatures ranging from 4.5 to 6.0°C.
Phleger, 1964, living, Gulf of California.
Natland, 1950, Plio-Pleis, Gulf of CA., outcrops.
  "Has thin, translucent walls which are not easily preserved in fossil sediments. When found they usually are preserved as internal molds of calcite or pyrite." Off southern California, it is found between 275 and 1100 meters, whereas off Central America, its bathymetric range lies between 49 and 4140 meters. "The abundance of this species is so uniform over the wide range in depth as to suggest a pelagic mode of life for the species."
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Smith, 1964, R, El Salvador & Nicaragua.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Cushman & Parker, 1947, Mio-R, Bulimina.
Cushman & McCulloch, 1948a, R, Hancock Exp, Buliminidae.

Distribution

Minimal abundances of Globobulimina pacifica were recovered from both mud and sand deposits of this study. The taxon was obtained between the depths of 46 and 432.5 cm downcore. It comprises less than 1% of the mud interval faunas and between less than 1 and 1.6% of the sand layer assemblages.

Globobulimina spinifera (Cushman)

Plate 13, figure 7

Bulimina spinifera Cushman; Cushman (in part), 1927, p. 151, pl. 2, fig. 15; Cushman and Parker, 1947, p. 126, pl. 29, fig. 9; Crouch, 1952, p. 826, pl. 2, fig. 6. Globobulimina spinifera (Cushman); Uchio, 1960, pl.6, fig. 10; Ingle, 1973, p. 542, 545, 553. Praeglobobulimina spinifera (Cushman); Matoba and Yamaguchi, 1982, p. 1045.

Ecology

Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Crouch, 1952, R, 11 deep basins off southern CA.
  A few specimens of Bulimina [Globobulimina] spinifera were found offshore in waters below 3.0°C.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Douglas & Heitman, 1979, R, so. California borderland.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Cushman & Parker, 1947, Mio-R, Bulimina.

Distribution

Representatives of Globobulimina spinifera were only recovered from two sand layers in this study: lying from 248 to 250 and 412 to 414.5 cm downcore. In both cases, the taxon comprises less than 1% of the faunal assemblage.

Globobulimina spp.

Globobulimina spp. Several crushed and fragmented tests, displaying loop-shaped apertures and inflated, highly involute, often triserially arranged chambers in the adult, are assigned to this genus.

Ecology

Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Fragmented examples of Globobulimina were recovered from both mud and sand intervals between the depths of 40 and 447.5 cm downcore. Most often accounting for less than 1% of the fauna, these poorly preserved specimens peak at 2.5 and 3.0% of the assemblage near the bottom of the core.

Globocassidulina subglobosa (Brady)
Plate 20, figure 2

Cassidulina subglobosa Brady; Brady, 1881, p. 60; Cushman, 1925c, p. 54, pl. 8, figs. 48-50; Phleger, Parker and Peirson, 1951, p. 45, pl. 10, fig. 4; Phleger and Parker, 1951, p. 27, pl. 14, figs. 11-13; Walton, 1952, p. 1005, pl. 103, fig. 21; Drooger, 1953, p. 140, pl. 24, fig. 13; Uchio, 1960, pl. 9, fig. 21; Barker, 1960, p. 112, pl. 54, fig. 17; Matoba and Yamaguchi, 1982, p. 1041.
Cassidulina subglobosa subglobosa Brady; Ingle, 1973, p. 525, 536, 545, 553, 556, 560, 562, 563; Ingle, Keller and Kolpack, 1980, p. 132, pl. 1, figs. 14-15.
Globocassidulina subglobosa (Brady); Lohmann, 1978, p. 26, pl. 2, figs. 8-9.

Ecology

Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Smith, 1973, Pleis? & Holocene, North Pacific Ocean.
Cooper, 1961, R, intertidal, CA. & Oregon coast.
Lankford, 1962, R, turbulent zone, W. coastal N. America.
Ingle, 1973, N, DSDP Site 172, between CA. & Hawaii.
Hanna & Church, 1927, R, San Francisco Bay, CA.
Bandy, 1953a, R, San Francisco to San Diego, CA.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Douglas & Heitman, 1979, R, so. California borderland.
Bandy & Chierici, 1966, R, California & Mediterranean.
Bagg, 1912, Plio-Pleis (?), so. CA., Timms Point+.
Uchio, 1960, R, living & dead, San Diego, CA.
Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
  This species was found to be a non-dominant member of the upper bathyal biofacies between the depths of 152 and 244 meters, with water temperatures ranging from 8.0 to 10.0C.
Brenner, 1962, R, shallow, Gulf of California.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Cushman, 1929b, Late Tertiary, Venezuela & Ecuador.
Resig, 1976, Eocene-R, DSDP, Nazca Plate, Peru.
Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
Phleger, 1951b, R, Northwest Gulf of Mexico.
Phleger & Parker, 1951, R, NW Gulf of Mex. & Atlantic.
Bock, 1976 & 1982, R, shallow, Gulf of Mexico.
Lohmann, 1978, R, western South Atlantic.
Boltovskoy and others, 1980, R, shelf, SW Atantic.
Cushman & Todd, 1945, Mio, Buff Bay, Jamaica.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman, 1911, R, Pacific Ocean, Textularids.

Distribution

Representatives of Globocassidulina subglobosa were recovered in low abundance from both the mud and sand intervals lying from 20 to 447.5 cm downcore. In nearly all cases, the taxon accounts for less than 1% of the assemblage. The exception to this rule occurs in the sand interval from 171 to 173 cm, where Globocassidulina subglobosa comprises 1.7% of the fauna.

Gyroidina altiformis Stewart and Stewart
Plate 19, figures 3, 4

Gyroidina soldanii d'Orbigny var. altiformis Stewart and Stewart; Stewart and Stewart, 1930, p. 67, pl. 9, fig. 67.
Gyroidina altiformis Stewart and Stewart; Walton, 1955, p. 1009, pl. 103, figs. 10-11; Smith, 1964, p. B42; Ingle, Keller and Kolpack, 1980, p. 138, pl. 7, figs. 5-6; Matoba and Yamaguchi, 1982, p. 1045.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.
Resig, 1958, R, Santa Cruz Basin, CA.
No live individuals of this taxon were recovered in this study but dead specimens were obtained between the depths of 366 and 1865 meters.
Douglas & Heitman, 1979, R, so. California borderland.
Bandy & Chierici, 1966, R, California & Mediterranean.
Smith, 1964, R, El Salvador & Nicaragua.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.

Distribution

Gyroidina altiformis was found to be a ubiquitous taxon in this study. Present in both mud and sand intervals, it was recovered between the depths of 20 and 447.5 cm downcore. The species comprises from less than 1 to 3.6% of the fauna in the mud layers and between less than 1 and 1.4% of the sand interval assemblages.

Gyroidina gemma Bandy
Plate 19, figures 7, 8

Gyroidina gemma Bandy; Bandy, 1953a, p. 179, pl. 23, fig. 4; Ingle, 1973, p. 536, 542, 545; Ingle, Keller and Kolpack, 1980, p. 138, pl. 7, figs. 8-9.
Gyroidina? *gemma* Bandy; Matoba and Yamaguchi, 1982, p. 1045, pl. 4, fig. 9.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.
Bandy, 1953a, R, San Francisco to San Diego, CA.
Morin, 1971, late Q, San Francisco, L.A., Baja CA.
Resig, 1958, R, Santa Cruz Basin, CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Zalesny found this species to occur in only one sample, where it comprised 1% of the faunal assemblage at a depth of 777 meters.
Bandy & Chierici, 1966, R, California & Mediterranean.
Based upon various previous works, Bandy and Chierici determined that the upper depth limit of this taxon off California was in the bathyal zone at a depth of 700 meters, plus or minus 100 meters. The taxon was not reported in recent bathyal deposits in the Mediterranean.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Ingle determined this species to be characteristic of the lower middle bathyal biofacies between the depths of 1500 and 2000 meters.
Uchio, 1960, R, living & dead, San Diego, CA.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a dominant member of the lower bathyal biofacies between the depths of 2438 and 2743 meters, with the water temperature lying at 2.0°C.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.
The species was common in the cores and not in the trawls. Bandy and Rodolfo placed *Gyroidina gemma* in their bathymetric group 3B which occurred "...shallower near the equator, [and] successively deeper along the west coast of South America." The upper depth limit of group 3B was 1171 meters; its distribution ranged between 1171 and approximately 3000 meters, and from nearly 3500 to 6000 meters.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

Representatives of *Gyroidina gemma* were recovered from both the mud and sand intervals of this study. Those specimens isolated from the mud layers comprise from less than 1 to 3.1% of the assemblage and were obtained in samples between 20 and 432.5 cm downcore. In the sand intervals from 46 to 414.5 cm, *Gyroidina gemma* accounts for less than 1 to a maximum of 1.6% of the fauna.

Gyroidina cf. *G. planulata* Cushman and Renz

Gyroidina planulata Cushman and Renz; Cushman and Renz, 1941, p. 23, pl. 4, fig. 1; Bandy and Rodolfo, 1964, p. 830, fig. 5c.

Ecology

Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.
The species was common in the cores and not the trawls. Bandy and Rodolfo assigned *Gyroidina planulata* to their bathymetric group 4C which had an upper depth limit of

1932 meters. The group was found between 1932 and 6000 meters: in large percentages between 1932 and nearly 3000 meters, and between 4000 and nearly 5900 meters. "This middle bathyal group contains a number of good depth indices, most of which are not known to live in water depths much less than that recorded for the Peru-Chile Trench area."

Distribution

Gyroidina cf. *G. planulata* was found to be a ubiquitous faunal member in the Monterey Fan levee deposits. Recovered in nearly every sample, the taxon's maximum abundance appears to occur between approximately 139 and 212 cm downcore. In the mud layers, *Gyroidina* cf. *G. planulata* accounts for less than 1 to 22.4% of the benthonic foraminiferal assemblage. The taxon also comprises between less than 1 and 10.1% of the fauna in the sand intervals.

Gyroidina quinqueloba Uchio
Plate 19, figure 5

Gyroidina quinqueloba Uchio; Uchio, 1960, p. 66-67, pl. 8, figs. 22-25.

Ecology

Smith (?), 1973, Pleis? & Holocene, North Pacific Ocean.
Ingle (?), 1973, N, DSDP Site 172, between CA. & Hawaii.
Uchio, 1960, R, living & dead, San Diego, CA.
Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

With the exception of a single sandy mud layer lying from 230 to 232 cm downcore, specimens of *Gyroidina quinqueloba* were recovered strictly from the mud intervals sampled in the upper portion of the core. The taxon was obtained between the depths of 20 and 232 cm and reaches a maximum abundance of 1.3% in the mud interval from 80 to 82 cm. In its other occurrences, *Gyroidina quinqueloba* always comprises less than 1% of the faunal assemblage.

Gyroidina tumidulus (Brady)
Plate 19, figure 1

Truncatulina tumidula Brady; Brady, 1884, p. 666, pl. 95, fig. 8.
Gyroidina tumidulus (H.B. Brady); Phleger and Parker, 1951, p. 21, pl. 11, figs. 7-8.
Eponides tumidulus (Brady); Barker, 1960, p. 196, pl. 95, fig. 8.

Ecology

Smith, 1963b, Pleis & R, Gulf of Alaska.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
> This species was found to be a dominant member of the lower middle bathyal biofacies between the depths of 2134 and 2438 meters, with the water temperature lying at 2.0°C.

Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
Phleger, 1951b, R, Northwest Gulf of Mexico.
Phleger & Parker, 1951, R, NW Gulf of Mex. & Atlantic.
Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

Very low percentages of *Gyroidina tumidulus* were recovered from both mud and sand intervals between the depths of 120 and 447.5 cm downcore. In its eleven occurrences in this study, the taxon always accounts for less than 1% of the faunal assemblage.

Gyroidina turgida (Phleger and Parker)
Plate 19, figure 2

Eponides turgidus Phleger and Parker; Phleger and Parker, 1951, p. 22, pl. 11, fig. 9.
Gyroidina turgida (Phleger and Parker); Ingle, 1973, p. 536, 556.

Ecology

Smith, 1964, R, El Salvador & Nicaragua.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Phleger, 1951b, R, Northwest Gulf of Mexico.
Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

Representatives of *Gyroidina turgida* were only recovered from the upper portion of the core. Obtained between the depths of 120 and 272 cm downcore, the taxon always comprises less than 1% of the benthonic foraminiferal assemblage. And with the exception of a singular specimen acquired from the sandy mud sample located from 180 to 182 cm downcore, *Gyroidina turgida* was found associated exclusively with the mud deposits of core S3-78-SC, 15G.

Gyroidina spp.

Gyroidina spp. Poorly preserved specimens, with trochoidal, plano-convex to biconvex tests and an interiomarginal aperture located towards the umbilical area, are assigned to this genus.

Ecology

Saidova, 1967, Q, Pacific Ocean.
Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Unidentified specimens of *Gyroidina*, always comprising less than 1% of the faunal assemblage, were recovered in mud and sand intervals between the depths of 40 and 432.5 cm downcore.

Hoeglundina elegans (d'Orbigny)

Plate 19, figure 9

Rotalia (*Turbinuline*) *elegans* d'Orbigny; d'Orbigny, 1826, p. 276.
Hoglundina elegans (d'Orbigny); Phleger and Parker, 1951, p. 22, pl. 12, fig. 1; Bandy, 1953a, pl. 23, fig. 9; Barker, 1960, p. 216, pl. 105, figs. 3-6; Haller, 1980, p. 257, pl. 12, fig. 1.
Hoeglundina elegans (d'Orbigny); Ingle, 1973, p. 536, 542, 545, 553; Ingle, Keller and Kolpack, 1980, p. 138, pl. 2, fig. 11.

Ecology

Hoeglundina elegans (d'Orbigny) is an unusual benthonic foraminifer in that it is one of the few to have a test composed of aragonite instead of calcite (Bandy, 1954). Bandy's (1954) early study of the foraminiferal wall composition discovered only ten species with aragonitic tests, 80% of which were fossil taxa, compared to an estimated 1700 to 2000 species which utilized the conventional calcite material. The aragonite appears to be chemically quite stable and may be used by some arenaceous species as a cementing agent in their test construction (Bandy, 1954).

This species occupies offshore sediments in the Pacific Ocean from Alaska to Chile. In the North Pacific, Smith (1973) discovered rare, small and often corroded individuals in waters from 32 to 54°N latitude. Near the Aleutian Islands, she recovered two poorly preserved specimens from 2410 meters water depth, while farther south she collected one individual at 5000 meters and another eight at 5400 meters. Bergen and O'Neil (1979) also obtained *Hoeglundina elegans* from a single Gulf of Alaskan deposit recovered at the lower bathyal depth of 2623 meters. The taxon comprised <1% of the faunal assemblage at this depth.

An assemblage including *Hoeglundina elegans*, as well as *Melonis barleeanus*, *M. pompilioides* and *Uvigerina senticosa*, was also found in Dills' samples from the sea floor off Monterey Canyon near Monterey, California, obtained at a lower abyssal depth of approximately 3658 meters (Bandy, 1953a).

The waters off Santa Barbara have yielded numerous individuals of *Hoeglundina elegans*. Bandy (1953a), in studying the foraminifers obtained in a transect running approximately 120 km out to sea from Point Arguello, discovered the species comprising more than 10% of the fauna of the lower abyssal zone. This zone was characterized by waters at 1.53°C, salinity of 34.66 to 34.68^{o}/oo and oxygen content of 2.9 to 3.0 ml/l at a depth of about 2438 to 3658 meters. Since *Hoeglundina elegans* comprised so much of the faunal assemblage at this depth and was not seen farther upslope along the transect, it has been thought that the individuals were living at the site of collection (Resig, 1958). In Resig's (1958) work in the Santa Cruz Basin off Santa Barbara, the taxon was found from approximately 120 to 1865 meters depth, with live specimens recovered between about 130 and 400 meters. The greatest abundance of living individuals fell between 137 and 183 meters of water though, which is in sharp contrast to the lower abyssal determination of Bandy (1953a) and Walton's (1955) reports of occurrences at 732 meters and greater off Todos Santos Bay, Mexico. Resig (1958) hypothesized that the depth discrepancy in the various areas may be due to environmental factors other than temperature, or that Bandy's specimens were indeed not living, but transported, individuals. In Quaternary sediments of the Santa Barbara Channel, *Hoeglundina elegans*' upper depth limit was found associated with the middle bathyal fauna between 457 and 915 meters (Marks and others, 1980).

In a study of the relationship between temperature and bathymetry distributions of recent benthonic foraminifers from eleven deep basins off southern California between Santa Barbara and San Diego, Crouch (1952) found *Hoeglundina elegans* to exhibit a wide temperature tolerance. He found the species to range in environments between 2.5 and 13.0°C in his study area. This species was also found in recent sediments of the Tanner Basin off Los Angeles (Kheradpir, 1970), and was associated with the upper bathyal biofacies, at a depth of from 150 to 500 meters, in a study of the southern California continental borderland (Ingle, 1980). Bandy's (1963a) investigation of the benthonic foraminifers 1 mm and larger in size in this same region found *Hoeglundina elegans* to be an important species throughout the continental borderland's central, southern and outer basins. In the central and outer basins, its diameter was constantly 2 mm or greater, whereas in the shallower warmer waters, the diameter was usually <0.6 mm. The species ranged between 982 and 2571 meters water depth in his investigation, with its shallowest occurrence coinciding with the Santa Catalina Basin. This basin is characterized by a temperature of approximately 4.02°C, salinity of 34.42°/oo and an oxygen content of about 0.4 ml/l (Emery, 1960). A considerably shallower occurrence of *Hoeglundina elegans* was discovered by McGlasson (1959) in a review of the living and dead foraminifers of Santa Catalina Island. Dead, but excellently preserved specimens, were obtained at depths of 91 meters and greater. This shoal distribution is significant because these shallow waters experience high annual temperature variations, which implies that the species has a greater temperature tolerance than previously thought (McGlasson, 1959). Such a shallow distribution also greatly expands the taxon's known bathymetric range.

Offshore San Diego, in the vicinity of the Coronado Bank, Butcher (1951) recovered *Hoeglundina elegans* between 100 and 1025 meters, with the species occurring at a higher relative frequency from 600 to 1025 meters. Uchio's (1960) study from the same area obtained both living and dead individuals. The living specimens of this species ranged from 146 to 1170 meters water depth, peaking in abundance at 7% of the total living fauna at a depth of 924 meters. In the total (living plus dead) population, however, *Hoeglundina elegans* maximally comprised only 1% of the fauna and ranged from 115 to 1170 meters.

To the south, this species has also been recovered off Mexico, Central and South America. In a study of recent sediments in Todos Santos Bay, Baja California, Walton (1955) found *Hoeglundina elegans* to be a member of his offshore fauna, always occurring at depths greater than 732 meters and extending down to at least 1097 meters outside the immediate vicinity of the bay. Off El Salvador, this species was associated with the Zone F fauna of Smith (1964) and was found to range between 800 and 1700 meters water depth. Additionally, this taxon appeared in recent offshore deposits collected between Acapulco and the Gulf of Panama, where its depth range was from 777 to 1600 meters (Bandy and Arnal, 1957). *Hoeglundina elegans* normally comprised 1% or less of the fauna in this study, but reached a maximum of 4% at 1353 meters. Bandy and Arnal's (1957) faunal assignment of this taxon was very similar to Smith's (1964) for this same region: the lower bathyal. This zone is characterized by a temperature range of 2.6 to 3.8°C and a salinity of about 34.7°/oo at a depth of between 1219 and 1911 meters of water (Bandy and Arnal, 1957). *Hoeglundina elegans*' bathymetric range was found to be slightly more extensive in recent deposits of the Peru-Chile Trench area (Ingle, Keller, and Kolpack, 1980). The species was recovered from the shelf-edge to the lower bathyal zone, between the depths of 142 and 1948 meters, with a rare occurrence at 3550 meters. It comprised 1.5% of the fauna at a depth of 1864 meters, 2.4% at 274 meters and a maximum of 2.8% of the assemblage at a depth of 1948 meters.

Hoeglundina elegans is known to be widespread in the Atlantic Ocean as well, recovered from depths between 42 and 4330 meters (Phleger and Parker, 1951; Phleger, Parker, and Peirson, 1953). In the low latitudes of the North Atlantic and the equatorial region, this species was found scattered in core and surface samples collected by the Swedish Deep-Sea Expedition. Recent individuals have been collected off Tampa, Florida in 183 meters of water (Bandy, 1954) and were considered a non-dominant part of the upper continental slope fauna (i.e., Fauna 5) in a study of the distribution of recent foraminifers in the coastal waters off western Florida (Bandy, 1957). This fauna's depth range fell between 77 and 183 meters in this region. Another study in the Gulf of Mexico, but from the northwestern area, discovered the taxon to be widespread and characteristic of many deep samples (Phleger, 1951b). Here, the species ranged in depth between 90 and 3550 meters.

In the southwestern Atlantic, Hoeglundina elegans has been associated with both recent shallow water and abyssal sediments. Boltovskoy and others (1980), recorded the species in recent shelfal deposits and considered it to be a euhaline taxa. On the other hand, Lohmann (1978) found Hoeglundina elegans to have its maximum abundance between 2200 and 4000 meters, being a major contributor to the diverse faunal assemblage associated with the North Atlantic Deep Water in this region.

Hoeglundina elegans is an aragonitic benthonic foraminifer (Bandy, 1954) which resides in a wide geographical region in waters that are highly variable in depth and temperature (Bandy and Arnal, 1957). It is a taxon commonly found in the eastern Pacific from the Aleutian Islands to Chile, as well as in the Gulf of Mexico and the Mediterranean Sea (Bandy and Chierici, 1966). It is considered an isobathyal species, in that it exhibits nearly the same upper depth limit in numerous oceanic realms (Bandy and Chierici, 1966). In its case, that upper limit has been defined by Bandy and Chierici (1966) to be 100 meters, give or take 50 meters. But evidence suggests that Hoeglundina elegans is not always associated with such shallow depths (Bandy, 1953a, 1963b; Bandy and Arnal, 1957; Smith, 1964, 1973; Walton, 1955; Sliter and Baker, 1972). As nearly equal numbers of studies have been produced to support its presence in both shallow and deep water assemblages, no conclusion regarding its bathymetric significance can be formulated. At this time it is still unclear which environmental factor, if any, controls its distribution. Temperature does not seem to be a viable candidate, as Crouch (1952) found it associated with waters between 2.5 and 13.0°C. In addition, the species has been recovered from thermally variable waters (e.g., surrounding Santa Catalina Island; McGlasson, 1959) as well as the abyssal region where the temperature alters very little at all (Phleger, 1960; Douglas and Woodruff, 1981). What has been seen is that Hoeglundina elegans' size may reflect water temperature, increasing in diameter with decreasing temperature (Bandy, 1963b). Yet, one must question this conclusion as well, because Bandy's specimens were collected by the somewhat biased sampling procedure of a trawl (Douglas and Woodruff, 1981). With the highly variable ecological data obtained on this species to this date, whether it be due to true faunal variation or simply collecting and analyzing procedures, Hoeglundina elegans remains bathymetrically ubiquitous and of little assistance in the ecological interpretation of the Monterey core samples.

Distribution

Representatives of Hoeglundina elegans were found restricted primarily to the upper half of the core, being recovered between the depths of 80 and 272 cm downcore. Although the taxon was obtained from both mud and sand intervals, considerably higher abundances of the species occur within the muds. In those fine-grained layers, Hoeglundina elegans comprises from less than 1 to a maximum of 22.8% of the assemblage. In contrast, the species always constitutes less than 1% of the fauna in the sand intervals.

Jaculella acuta Brady
Plate 1, figure 2

Jaculella acuta Brady; Brady, 1879, p. 35, pl. 3, figs. 12-13; Cushman, 1910, p. 70, figs. 90-91; Cushman, 1948, p. 85, key pl. 3, fig. 4; Barker, 1960, p. 44, pl. 22, figs. 14-18; Haynes, 1981, p. 106, key fig. 6.8, fig. 8.

Ecology

Jaculella acuta Brady is an arenaceous benthonic foraminifer that is characterized by a very simple, tube-like test. The test commonly expands to a slightly conical shape and often compresses when fossilized. It has been recovered in recent abyssal deposits from a depth of 5540 meters in the Gulf of Alaska, where it comprised less than 1% of the total faunal assemblage (Smith, 1963b). The species has also been reported from the North Pacific between 46 and 53°N latitude in the vicinity of the Aleutian Islands (Smith, 1973). Absent from the Aleutian Terrace but commonly associated with the Aleutian Trench area's recent sediments, and rarely present on the nearby deep-sea plain, Jaculella acuta was found inhabiting the depths between 4430 and 7230 meters. Often comprising only approximately 1% of the total population, this species exhibited its maximum abundance at about 6% in 4430 meters of water depth. Four individuals of the taxon were also recovered from the interval between 10 and 11 cm in a core taken at this depth, but no precise age determination was assigned to these sediments.

Other localities in the North Pacific have yielded specimens of Jaculella acuta. Brady (1884) reported its presence in deposits collected while aboard the H.M.S. Challenger: specifically, at 5303 meters in the mid-Pacific. The species has also been obtained near the Hawaiian Islands at 4782 meters and at Guide Station 3 located off northern

Baja California, Mexico in waters 2542 meters deep (Cushman, 1910, 1927a; Natland, 1933). It has been collected off the California coast as well, at a depth of 2052 meters (Cushman, 1910), and from outcrops of the "Upper Pico" Formation from Hall Canyon, near Ventura, California (Natland, 1933).

In contrast to residing in tremendously deep waters in the North Pacific, Blanc-Venet (1965) discovered Jaculella acuta between 10 and 40 meters in Antarctica. The species was obtained near Adelie Land and was believed to live attached to holothurians and algae.

Jaculella acuta's known distribution in the North Pacific and Antarctica suggests that it prefers the cold water conditions. In the North Pacific, it inhabits the abyssal depths and has been recorded most often between 4400 and 7230 meters. It is normally a minor constituent of benthonic foraminiferal populations. This is true even in the arenaceously dominated faunas located below the calcium carbonate compensation depth (Douglas and Woodruff, 1981), which lies at approximately 4000 meters in the North Pacific (Saidova, 1961). Slightly shallower occurrences were reported off California and in the North Pacific at 2052 and 2542 meters, respectively (Cushman, 1910; Natland, 1933).

Distribution

Only one representative of the taxon was recovered in this study. It was one of eight benthonic foraminifers obtained in the mud deposits of the core-top sample taken from 0 to 4 cm downcore.

Karreriella baccata (Schwager)
Plate 3, figure 1

Gaudryina baccata Schwager; Schwager, 1866, p. 200, pl. 4, fig. 12.
Karreriella baccata (Schwager); Cushman, 1937a, p. 133, pl. 15, figs. 20-24, pl. 16, fig. 1; Todd and Low, 1967, p. A17-18, pl. 2, fig. 10.

Ecology

Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Seven specimens of Karreriella baccata, one in each of seven successive samples, were recovered between the depths of 120 and 170 cm downcore. The samples include both mud and sand deposits and in all cases the taxon comprises less than 1% of the faunal assemblage.

Karreriella grammostomata (Galloway and Wissler)
Plate 2, figure 2

Gaudryina grammostomata Galloway and Wissler; Galloway and Wissler, 1927, p. 69, pl. 11, fig. 6.
Karreriella grammostomata (Galloway and Wissler); Cushman, 1937a, p. 134-135, pl. 16, fig. 5.

Ecology

Galloway & Wissler, 1927, Pleis, Palos Verdes, CA.
Cushman, 1937a, R, Valvulinidae.
Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Present in 27 of 33 samples investigated in this study, Karreriella grammostomata was recovered from mud, sand and sandy mud layers between the depths of 80 and 469.5 cm downcore. The taxon displays its lowest abundances in the sand and sandy mud intervals and also exhibits a general increase in abundance downcore. In the mud deposits, the species comprises from less than 1 to 5.5% of the assemblage. In contrast, in the sand and sandy mud layers, Karreriella grammostomata consistently accounts for less than 1% of the fauna, but peaks at 1.4 and 1.7%.

Karreriella novangliae (Cushman)
Plate 3, figure 2

Gaudryina baccata Schwager; Brady, 1884, p. 379, pl. 46, figs. 8-11.
Gaudryina baccata Schwager var. novangliae Cushman; Cushman, 1922, p. 76, pl. 13, fig. 4.

Karreriella novangliae (Cushman); Cushman, 1937a, p. 136, pl. 16, figs. 12, 13; Barker, 1960, p. 94, pl. 46, figs. 8-10; Herb, 1971, p. 298, pl. 2, fig. 3, pl. 4, fig. 4; Ingle, Keller and Kolpack, 1980, p. 140.
?Karreriella baccata (Schwager); Todd and Low, 1967, p. A17-A18, pl. 2, fig. 10.

Ecology

Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Barker, 1960, R, Brady's Challenger Expedition.
Herb, 1971, R, Drake Passage, Antarctica.
Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman, 1937a, R, Valvulinidae.

Distribution

Always constituting less than 1% of the faunal assemblage, Karreriella novangliae was obtained in five samples between the depths of 120 and 447.5 cm downcore. With the exception of the sand interval lying from 336.5 to 338 cm, all of the samples containing the taxon were comprised of mud deposits.

Lagena acuticosta Reuss
Plate 7, figures 5, 6

Lagena acuticosta Reuss; Reuss, 1862, p. 305, pl. 1, fig. 4.
Lagena acuticosta Reuss, var.; Cushman and McCulloch, 1950, p. 329, pl. 43, figs. 9-10.
Lagena williamsoni (Alcock); Natland, 1950, p. 13, pl. 4, fig. 5.
Lagena sp. nov.?; Barker, 1960, p. 119, pl. 58, fig. 21.

Ecology

Cushman & Todd, 1947b, Plio? Pleis?, Amchitka Is., AK.
Cushman & Todd, 1947a, R, shallow water, coast of WA.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Bagg, 1912, Plio-Pleis (?), so. CA., Timms Point+.
Martin, 1952, Plio, Los Angeles Basin, CA.
Smith, 1964, R, El Salvador & Nicaragua.
Boltovskoy and others, 1980, R, shelf, SW Atantic.
Cushman, 1913a, R, Pacific Ocean, Lagenidae.
Cushman & McCulloch, 1950, R, Hancock Exp., Lagenidae.
Cushman, 1933c, R, tropical Pacific, Lagenidae-Alveolin.

Distribution

Lagena acuticosta was recovered from both mud and sand deposits between the depths of 40 and 447.5 cm downcore. In all occurrences, the taxon comprises less than 1% of the faunal assemblage.

Lagena alcocki White
Plate 7, figure 7

Entosolenia williamsoni Alcock; Alcock, 1865, p. 193.
Lagena williamsoni (Alcock); Wright, 1877, p. 104, pl. 4, fig. 14; Cushman and McCulloch, 1950, p. 362, pl. 48, figs. 14-15; Matoba and Yamaguchi, 1982, p. 1045.
Lagena alcocki White; White, 1956, p. 246, pl. 27, fig. 7; Haller, 1980, p. 235-236, pl. 4, fig. 6.

Ecology

Green, 1960, R, central Arctic Basin.
Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Cushman & Todd, 1947b, Plio? Pleis?, Amchitka Is., AK.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Martin, 1952, Plio, Los Angeles Basin, CA.
White, 1956, Mio-Plio, Capistrano Fm., Orange Co., CA.
Natland, 1950, Plio-Pleis, Gulf of CA., outcrops.
Off southern California, recent specimens were obtained at a depth of 45 to 2120 meters. Off the west coast of Central America, the species was obtained between 123 and 1875 meters, occurring rather commonly and widespread geographically.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Murray, 1971, R, British forams.
Cushman & McCulloch, 1950, R, Hancock Exp., Lagenidae.
Cushman, 1933c, R, tropical Pacific, Lagenidae-Alveolin.

Distribution

Singular specimens of *Lagena alcocki*, accounting for less than 1% of the faunal assemblage, were obtained from a sand layer lying from 133.5 to 136.5 cm and a sandy mud layer located between 180 and 182 cm downcore.

Lagena distoma Parker and Jones
Plate 8, figure 1

[*Lagena laevis* (Montagu) var. *striata* (Montagu)] Parker and Jones; Parker and Jones, 1857, p. 278, pl. 11, fig. 24. *Lagena distoma* Parker and Jones M.S.; Brady, 1864, p. 467, pl. 48, fig. 6; Cushman, 1913a, p. 22, pl. 13, figs. 1-2; Cushman and McCulloch, 1950, p. 337, pl. 44, fig. 12; Boltovskoy and others, 1980, pl. 19, figs. 13-17.

Ecology

Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.
 This species was found at a depth of 34 to 206 meters.
Hanna & Church, 1927, R, San Francisco Bay, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Martin, 1952, Plio, Los Angeles Basin, CA.
Smith, 1964, R, El Salvador & Nicaragua.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Boltovskoy and others, 1980, R, shelf, SW Atantic.
Cushman, 1913a, R, Pacific Ocean, Lagenidae.
Cushman & McCulloch, 1950, R, Hancock Exp., Lagenidae.

Distribution

Four samples, between the depths of 133.5 and 182 cm downcore, as well as another from 390 to 393 cm, contained specimens of *Lagena distoma*. Always comprising less than 1% of the faunal assemblage, this taxon was recovered from both mud and sand deposits.

Lagena elongata (Ehrenberg)
Plate 8, figure 2

Miliola elongata Ehrenberg; Ehrenberg, 1844, p. 274. *Lagena elongata* (Ehrenberg); Cushman, 1913a, p. 12-13, pl. 1, fig. 5; Cushman, 1929a, p. 67, pl. 11, fig. 1; Cushman and McCulloch, 1950, p. 338, pl. 44, fig. 14; Barker, 1960, p. 116, pl. 56, figs. 27-29; Matoba and Yamaguchi, 1982, p. 1045.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.
Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.
 This species was found only found at a depth of 88 meters.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Cushman & Moyer, 1930, R, San Pedro, CA.
 This species was found only found at a depth of 338 meters.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Bagg, 1912, Plio-Pleis (?), so. CA., Timms Point+.
Martin, 1952, Plio, Los Angeles Basin, CA.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Cushman, 1913a, R, Pacific Ocean, Lagenidae.
Cushman & McCulloch, 1950, R, Hancock Exp., Lagenidae.

Distribution

Rare specimens of *Lagena elongata*, comprising less than 1% of the faunal assemblage in all occurrences, were obtained from both mud and sand intervals between the core-top and a depth of 447.5 cm downcore.

Lagena hispidula Cushman
Plate 7, figure 14

Lagena hispidula Cushman; Cushman, 1913a, p. 14, pl. 5, figs. 2-3; Cushman and McCulloch, 1950, p. 339-340, pl. 45, figs. 8-10; Todd and Bronnimann, 1957, p. 31, pl. 5, figs. 6-7; Barker, 1960, p. 114, pl. 56, figs. 10-11; Boltovskoy and others, 1980, p. 96, pl. 19, figs. 20-22.

Ecology

Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Hanna & Church, 1927, R, San Francisco Bay, CA.
Cushman & Moyer (?), 1930, R, San Pedro, CA.
This species was found at a depth of 64 to 91 meters.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Boltovskoy and others, 1980, R, shelf, SW Atantic.
Cushman, 1913a, R, Pacific Ocean, Lagenidae.
Cushman & McCulloch, 1950, R, Hancock Exp., Lagenidae.

Distribution

The most prolific species of Lagena found in this study, Lagena hispidula was recovered from 25 of the 33 samples investigated. In the mud layers, the taxon comprises less than 1 to a maximum of 1.6% of the fauna. In the sand intervals however, it only peaks in abundance at 1.1%.

Lagena striata (d'Orbigny)
Plate 7, figure 12

Oolina striata d'Orbigny; d'Orbigny, 1839a, p. 21, pl. 5, fig. 12.
Lagena cf. L. striata (d'Orbigny); Cushman and McCulloch, 1950, p. 350-351, pl. 47, figs. 1-4.
Lagena striata (d'Orbigny); Todd and Bronnimann, 1957, p. 31, pl. 5, figs. 12-15; Barker, 1960, p. 118, pl. 57, figs. 19, 22, 24, 28; Ingle, 1973, p. 563; Boltovskoy and others, 1980, p. 98, pl. 20, figs. 11-14; Haller, 1980, p. 236-237, pl. 4, fig. 9; Ingle, Keller and Kolpack, 1980, p. 140, pl. 4, fig. 13.

Ecology

Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Hanna & Church, 1927, R, San Francisco Bay, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Bagg, 1912, Plio-Pleis (?), so. CA., Timms Point+.
Martin, 1952, Plio, Los Angeles Basin, CA.
Smith, 1964, R, El Salvador & Nicaragua.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Cushman & Wickenden, 1929, R, J. Fernandez Ids., Chile.
Boltovskoy and others, 1980, R, shelf, SW Atantic.
Cushman, 1913a, R, Pacific Ocean, Lagenidae.
Cushman, 1933c, R, tropical Pacific, Lagenidae-Alveolin.

Distribution

Rare occurrences of Lagena striata, always comprising less than 1% of the faunal assemblage, were obtained from both mud and sand samples between the depths of 20 and 414.5 cm downcore.

Lagena sulcata (Walker and Jacob)
Plate 7, figure 11

Serpula (Lagena) sulcata Walker and Jacob; Walker and Jacob, 1798, p. 634, pl. 14, fig. 5.
Lagena sulcata (Walker and Jacob); Cushman, 1929a, p. 70, pl. 11, fig. 5; Haynes, 1981, p. 199, key fig. 9.6, fig. 13.

Ecology

Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.
The species, and its varieties, were found at a depth of 16 to 158 meters.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Bagg, 1912, Plio-Pleis (?), so. CA., Timms Point+.
Brenner, 1962, R, shallow, Gulf of California.
Smith, 1964, R, El Salvador & Nicaragua.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Boltovskoy and others, 1980, R, shelf, SW Atantic.
Murray, 1971, R, British forams.

Distribution

Lagena sulcata was recovered in low abundance from three mud intervals between 120 and 170 cm downcore, from a sand layer lying at 171 to 173 cm, and a sandy mud deposit located from 369.5 to 372.5 cm. In all occurrences, the taxon constitutes less than 1% of the fauna assemblage.

Lagena sulcata laevicostata Cushman and Gray
Plate 7, figures 9, 10

Lagena sulcata (Walker and Jacob) var. *laevicostata* Cushman and Gray; Cushman and Gray, 1946, p. 68, pl. 12, figs. 13-14; Cushman and McCulloch, 1950, p. 361, pl. 48, figs. 8-10.

Ecology

McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Cushman & Gray, 1946b, Plio, Timms Point, California.
Martin, 1952, Plio, Los Angeles Basin, CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Cushman & McCulloch, 1950, R, Hancock Exp., Lagenidae.

Distribution

Singular specimens of *Lagena sulcata laevicostata* were obtained from the mud intervals lying from 152.5 to 154.5 and 270 to 272 cm downcore, as well as in the sandy mud layer from 230 to 232 cm.

Lagena sulcata spicata Cushman and McCulloch
Plate 7, figure 4

Lagena sulcata (Walker and Jacob), var. *apiculata* Cushman; Cushman (in part), 1913a, p. 23, pl. 9, fig. 3.
Lagena sulcata (Walker and Jacob) var. *spicata* Cushman and McCulloch; Cushman and McCulloch, 1950, p. 360-361, pl. 48, figs. 3-7.
Lagena sulcata (Walker and Jacob) var. *spicata* Cushman and McCulloch?; Barker (in part), 1960, p. 119, pl. 58, figs. 4-6, not figs. 17-18.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.
Cooper, 1961, R, intertidal, CA. & Oregon coast.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Cushman & McCulloch, 1950, R, Hancock Exp., Lagenidae.

Distribution

One representative of *Lagena sulcata spicata* was recovered from the sand layer located from 133.5 to 136.5 cm downcore.

Lagena spp.
Plate 7, figures 8, 13; Plate 8, figure 3

Lagena spp. Several specimens, characterized by a single chamber, perforate walls, elongate neck and rounded aperture are assigned to this genus. Time did not permit identification to the specific level.

Ecology

Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Representatives of this genus, not identified to the specific level, comprise less than 1% of the faunal assemblage. They were recovered from two sand intervals lying from 171 to 173 and 336.5 to 338 cm downcore.

Lenticulina spp.
Plate 5, figures 4 to 8

Lenticulina spp. Planispiral, bilaterally symmetrical tests. All have radiate apertures. Most specimens are closely coiled, involute forms, with tests moderately inflated. Microspheric individuals display approximately seven to eight; four to five are seen in the megalospheric forms. One specimen appears to be transitional between *Lenticulina* and *Saracenaria*, demonstrating a condition noted by Cushman (1948, p. 213). This specimen possesses a very flattened test composed of seven chambers, and possibly begins to uncoil in its later stages of growth.

Ecology

Blanc-Vernet, 1969, R, Mediterranean.
Murray, 1973, R, general ecology & distribution.

Distribution

Seven examples of *Lenticulina*, obtained from four mud intervals, account for less than 1% of the faunal assemblage in all cases. They occur in the mud layers from 139 to 143, 270 to 272, 330 to 332 and 346.5 to 349.5 cm downcore.

Loxostomum pseudobeyrichi (Cushman)

Plate 16, figures 5, 6

Bolivina beyrichi Reuss, var. *alata* Cushman (not Sequenza); Cushman, 1911, p. 35, fig. 57.
Bolivina pseudobeyrichi Cushman; Cushman, 1926b, p. 45; Cushman, 1927a, p. 156, pl. 3, fig. 7; Natland, 1940, p. 21, pl. 5, fig. 18; Drooger, 1953, p. 131, pl. 21, figs. 9-10; Smith, 1964, p. B16, fig. 14.
Bolivina (*Bolivina*) *pseudobeyrichi* Cushman; Smith, 1963, pl. 31, figs. 3-8.
Loxostomum pseudobeyrichi (Cushman); Uchio, 1960, pl. 7, fig. 10; Bandy, 1961, pl. 4, fig. 11; Ingle, 1973, p. 563.
"*Loxostomum pseudobeyrichi*" (Cushman); Matoba and Yamaguchi, 1982, p. 1045, pl. 1, fig. 25.

Ecology

Loxostomum pseudobeyrichi (Cushman) is a geographically widespread species along the eastern Pacific coastline which prefers cold-water habitats (Cushman, 1937b). In the Gulf of Alaska, Smith (1963b) recognized it in her recent lower shelf (240 meters) and upper bathyal (810 meters) facies, where it comprised <1% of the assemblage. Todd and Low (1967) also report its occurrence in the Alaskan region, but at only one of their localities: the Clarence Strait of southeastern Alaska. At this site, the species occurred abundantly in a sample taken at 393 meters. The specimens, including their spinose keels, were beautifully preserved.

Considerably farther south, *Loxostomum pseudobeyrichi* has been noted off Santa Barbara, California. Harman (1964) found it from 396 to 588 meters in recent sediments of the Santa Barbara Basin. The species comprised 21% of the total faunal assemblage at a depth of 523 meters. He concluded that it was a member of his cosmopolitan fauna, accounting for, on the average, 7% and 4% of the slope and basin assemblages, respectively. This taxon was also found within the low-oxygen zone of the basin, where the individuals exhibited dwarfed, thin and very fragile morphologies. In the nearby Santa Cruz Basin, Resig (1958) found the species between approximately 540 and 1100 meters, with the sill depth of the basin lying at 1083 meters. No living *Loxostomum pseudobeyrichi* were encountered in her study. Quaternary deposits in the Santa Barbara Channel contained this taxon as well, with its upper depth limit situated in the lower upper bathyal zone between 325 and 457 meters (Marks and others, 1980).

In a comprehensive study of the foraminifers of eleven offshore basins from Santa Barbara to San Diego, Crouch (1952) determined that *Loxostomum pseudobeyrichi* was most common in basinal waters between 4.0 and 5.0C, whereas it was very rare in water temperatures below 3.5C. The species was also recovered between 494 and the study's limit of 841 meters in the Santa Monica Bay, where it comprised only 1% or less of the total fauna (Zalesny, 1959). Natland (1933, 1950) found this species off southern California from 400 to 1300 meters, and Cushman and Moyer (1930) noted that its most typical and abundant specimens were present at 732 meters off San Pedro. The taxon has also been considered a constituent of the upper bathyal biofacies, lying between 150 and 500 meters, in a study of the southern California continental borderland (Ingle, 1980).

In the vicinity of the Coronado Bank off San Diego, Butcher (1951) recovered *Loxostomum pseudobeyrichi* in low relative frequencies in recent deposits between 500 and 810 meters water depth. Uchio (1960) also discovered low amounts of the species in his study of the same area, finding the total population to range between 329 and the study's limit of 1189 meters in abundances of usually <1%. The live population of the species was nearly identical in occurrence, ranging from a depth of 329 to 1125 meters. At one locality, the abundance of living individuals peaked at 7% of the total faunal assemblage.

Loxostomum pseudobeyrichi has been dredged from offshore Mexico as well. The Allan Hancock Pacific Expedition recovered specimens near Los Frailes Point in 293 meters of water (Cushman and McCulloch, 1942), while Walton (1955) found living and dead specimens associated with his offshore fauna in Todos Santos Bay, Baja California. In this latter work, the taxon was reported from depths greater than approximately 640 meters down to the region outside the bay which lies at least in 1097 meters of water. In the Gulf of California, recent upper bathyal sediments, in waters from 4.5 to 6.0C at a depth of 366 to 610 meters, contained *Loxostomum pseudobeyrichi* in less than dominant percentages (Bandy, 1961). Cushman and McCulloch (1942) also report finding this species at 274 meters water depth in the region, while Matoba and Yamaguchi (1982) report its presence in cored material obtained by the Deep Sea Drilling Project in the Guaymas Basin of the Gulf. From the combined ecological information reported by Bandy (1961) and Phleger (1964, 1965), Matoba and Yamaguchi (1982) concluded that this species was associated with the upper and upper middle bathyal zones, ranging from approximately 375 to 1550 meters water depth. In their Late Pliocene to Holocene deposits, *Loxostomum pseudobeyrichi* comprised up to 9% of the total faunal assemblage. Pliocene to Pleistocene remains of the species were also recovered from outcrops on four islands in the Gulf of California obtained on the 1940 cruise of the *E.W. Scripps* (Natland, 1950).

Off Central America, this species has been reported to occur between 290 and 2110 meters of water (Natland, 1950). In a study from Acapulco to the Gulf of Panama, Bandy and Arnal (1957) considered *Loxostomum pseudobeyrichi* a part of their outer shelf assemblage, inhabiting waters characterized by a temperature range of 14.0 to 20.0°C and salinity of from 34.2 to 34.6 °/oo at a depth of 46 to 122 meters. Specifically, this species was found to range between 90 and 969 meters, where it comprised up to 2% of the fauna. The authors noted the discrepancy between their shallow water assignment of the taxon and Walton's (1955) conclusion that it was to be found deeper than 640 meters at Todos Santos Bay.

Along the coast of El Salvador, *Loxostomum pseudobeyrichi* was observed to have a depth range of from 435 to 1700 meters, occurring commonly at 450, 800 and 885 meters, rarely at 1600 meters, and very rarely at 435 and 1700 meters (Smith, 1963a, 1964). The species was considered part of Smith's (1964) Zone E, which is equivalent to the middle bathyal zoane of Bandy and Arnal (1957), and was found associated with *Cassidulina tumida*, *C. cushmani*, *Bolivina argentea* and *B. seminuda*. Smith (1963a, 1964) also investigated structural changes in some foraminifers, including *Loxostomum pseudobeyrichi*, with bathymetry. She concluded that, contrary to other Bolivinidae encountered in this study which exhibited highly variable morphologies with depth (e.g., *Bolivina seminuda*, *B. interjuncta*, *B. bicostata* and *B. subadvena*), *Loxostomum psuedobeyrichi* was quite consistent in shape and size. Although representatives of the species did not vary in length or growth index, their keels showed a consistent pattern with depth: they were extremely narrow in the shallower samples at 435 and 450 meters and were wide and fragile in the deeper water. In the rare appearances of *Loxostomum pseudobeyrichi* in the Monterey Fan deposits, both keeled and non-keeled individuals are present. For example, at 133.5 to 136.5 cm downcore, 80% of this species exhibited the morphologic pattern of the wide and fragile keel, while the remainder displayed virtually no keels whatsoever. Therefore, Smith's generalizations regarding bathymetry and morphology of this species off El Salvador may not apply to offshore northern California regions. Smith (1963a) also suggested that this species may live floating on top of the slope sediments as a result of its flattened shape, wide keel and thin and fragile test punctured by extremely fine pores. This is in contrast to those with rounded or thick-walled forms containing coarse pores (e.g., *Bolivina subadvena*), which she states might live within the sediments as a consequence of their test morphology. This hypothetical microenvironment-morphology relationship needs to be investigated further.

The eastern Pacific off South America is characterized by *Loxostomum pseudobeyrichi* as well. The species was collected off Colombia in deposits 101 meters deep by the Allan Hancock Pacific Expeidition (Cushman and McCulloch, 1942).

In summary, the flattened and buoyant-efficient (Hendrix, 1958) tests of the fragile benthonic foraminifer *Loxostomum pseudobeyrichi* are distributed in the eastern Pacific between at least Alaska and Colombia. The species has been recovered in upper Pliocene deposits of the Los Angeles Basin as well (Cushman, 1937), in addition to the upper Pliocene to Holocene sediments explored in the Gulf of California (Natland, 1950; Matoba and Yamaguchi, 1982). It has been suggested that its test morphology precludes it from living in the sediments and that it may float above them instead (Smith, 1963a). *Loxostomum pseudobeyrichi*'s bathymetric distribution ranges from approximately 90 to 1700 meters, but it appears to be most commonly associated with the upper to upper middle bathyal zone from about 300 to 900 meters water depth. Several studies also suggest that it prefers to inhabit waters between approximately 4.0 and 6.0°C (Crouch, 1952; Bandy, 1961).

Distribution

Loxostomum pseudobeyrichi was recovered from both mud and sand deposits in this study. The taxon's abundance is consistently minimal in the mud intervals from 128 to 412.5 cm downcore, where it comprises less than 1% of the fauna. In contrast, *Loxostomum pseudobeyrichi* accounts for less than 1 to 9.3% of the benthonic foraminiferal assemblage in the sand layers located from 46 to 414.5 cm. The taxon displays its highest abundances in the upper portion of the core.

Marginulina obesa Cushman
Plate 6, figure 4

Marginulina glabra Flint (not d'Orbigny); Flint, 1899, p. 133, pl. 60, fig. 1.
Marginulina glabra d'Orbigny var. *obesa* Cushman; Cushman,

1923, p. 128, pl. 37, fig. 1; Crouch, 1952, p. 823, pl. 1, fig. 7.
Marginulina obesa Cushman; Barker, 1960, p. 134, pl. 65, figs. 5-6.

Ecology

Crouch, 1952, R, 11 deep basins off southern CA.
Barker, 1960, R, Brady's *Challenger* Expedition.
Blanc-Vernet, 1969, R, Mediterranean.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Singular representatives of this species were recovered from three mud intervals between the depths of 20 and 23.5, 120 and 122, and 390 and 393 cm downcore.

Marginulina spp.
Plate 6, figures 2, 3, 5

Marginulina spp. Four morphologically distinct specimens were recovered. All four individuals are characterized by a subcylindrical test, a slightly coiled initial portion which becomes uncoiled in the later chambers, and a radiate aperture which is terminal and central. The tests differ in the angle, direction and degree of uncoiling in the later chambers and in the extent of elongation of these chambers. Time did not permit the identification of these individuals to the specific level.

Ecology

Blanc-Vernet, 1969, R, Mediterranean.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

One unidentified example of the genus was found in each of four samples investigated in this study. Three of the individuals were recovered from mud intervals lying between 128 and 154.5 cm downcore. The remaining specimen of *Marginulina* was obtained from the sample taken at a depth of 330 to 332 cm, where a mixture of mud and sand is present.

Martinottiella communis (d'Orbigny)
Plate 2, figures 3, 4

Clavulina communis d'Orbigny; d'Orbigny, 1826, p. 268, modeles no. 4; Cushman, 1911, p. 72-73, figs. 115-117.
Martinottiella communis (d'Orbigny); Cushman, 1948, p. 138, key pl. 8, figs. 6-8; Barker, 1960, pl. 48, figs. 3-4, 6-8; Bandy and Rodolfo, 1964, p. 828, fig. 5B; Haller, 1980, p. 230-231, pl. 1, fig. 9; Ingle, Keller and Kolpack, 1980, p. 140, pl. 4, figs. 14-15.
Martinottiella communis (d'Orbigny); Ingle, 1973, p. 536, 542, 553.

Plate 2, figure 4. This illustrates an adult individual which exhibits the multiserial (4 to 5) to uniserial growth stages. The test is coarsely arenaceous. The aperture is terminal, bordered with a lip, and located at the center of the last formed chamber.

Plate 2, figure 3. This illustrates the juvenile condition with the multiserial (4 to 5) to triserial chamber arrangement. The test is coarsely arenaceous. The aperture is terminal with a bordering lip and is positioned at the base of the last formed chamber.

Ecology

Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Bandy, 1963a, R, so. CA. continental borderland.
Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Murray, 1971, R, British forams.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman, 1932, R, tropical Pacific, Astrohiz.-Trocham.
Cushman, 1911, R, Pacific Ocean, Textularids.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Singular specimens of *Martinottiella communis* were recovered from five mud intervals between the depths of 96.5 and 447.5 cm downcore. In all occurrences, the taxon constitutes less than 1% of the faunal assemblage.

Melonis barleeanus (Williamson)
Plate 11, figure 4

Nonionina barleeana Williamson; Williamson, 1858, p. 32, pl. 3, figs. 68-69.
Nonion barleeanus (Williamson); Bandy, 1953a, p. 177, pl. 21, fig. 8; Bandy, 1961, p. 26, pl. 5, fig. 9.
Gavelinonion barleeanum (Williamson); Barker, 1960, p. 224, pl. 109, figs. 8-9.
Melonis barleeanus (Williamson); Ingle, 1973, p. 536, 542, 545, 553, 557, 560, 563; Haller, 1980, p. 265, pl. 16, figs. 4, 6.

Ecology

Haller, 1980, Plio, Humboldt Basin, California.
Haller found *Melonis barleeanus* and *M. pompilioides* occurring in the Centerville coastal of the Pullen Formation. Because they occurred only rarely, and because other mid-depth foraminifers were also present, he concluded that these sediments were deposited at middle bathyal depths.

Bandy, 1953a, R, San Francisco to San Diego, CA.
Bandy found this species to be a dominant member of the lower abyssal zone off Point Arguello between the depths of 2438 and 3658 meters. The taxon was found associated with *Melonis pompilioides*, *Hoeglundina elegans* and particularly high abundances of *Uvigerina senticosa*. "This assemblage was also found in samples...taken from the sea floor off Monterey Canyon at a depth of about 2000 fathoms [3658m]." Oceanographic parameters of this zone, taken at a depth of 3584 meters, include the following: temperature of 1.53°C, salinity of from 34.66 to 34.68 °/oo and an oxygen content of between 2.9 and 3.0 ml/l.

Crouch, 1952, R, 11 deep basins off southern CA.
Species is abundant in water temperatures between 1.7 and 5.0°C. "Similar forms found in the North Atlantic, west of Ireland..." at a depth of nearly 915 meters

Ingle, 1980, Tertiary, so. CA. continental borderland.
"Species exhibiting transitional distributions from upper middle [500 to 1500 meters] to lower middle [1500 to 2000 meters] bathyal depths."

Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a dominant member of the lower middle bathyal biofacies between the depths of 1524 and 1829 meters, with water temperatures ranging from 2.0 to 2.5°C.

Bandy & Arnal, 1957 (?), R, W. coast of Central America.
Listed as *Nonion* cf. *barleeanus* by Bandy and Arnal, this taxon was recovered between the depths of 1143 and 1911 meters in a study from Acapulco to the Gulf of Panama. The species comprised 2% of the fauna at a depth of 1400 meters, 3% of the assemblage at 1600 meters and 4% of the fauna at 1911 meters. It was found to be a less abundant member of the lower bathyal fauna, which Bandy and Arnal suggested was present between the depths of 1219 and 1911 meters. These waters were characterized by a temperature range from 2.6 to 3.8°C and a salinity of approximately 34.7 °/oo. The taxon was found associated with *Pullenia bulloides*, *Pyrgo murrhina*, *Valvulineria araucana*, *V. glabra* and *Virgulina* [*Fursenkoina*] *nodosa*.

Smith, 1964, R, El Salvador & Nicaragua.
Found between the depths of 1600 and 3100 meters

Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
This species was found between the depths of 800 and 3550 meters in the Peru-Chile Trench region. It comprised 1.8% of the fauna at a depth of 1864 meters and a maximum of 2.5% of the assemblage in 800 meters of water. The authors considered *Melonis barleeanus* a non-dominant, yet significant, member of the upper middle bathyal biofacies between the depths of 500 and 1500 meters.

Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
The authors state that "...too much confusion [exists] within this group to report its distribution [in the North Atlantic, from the literature] accurately..."

Murray (?), 1971, R, British forams.
Murray illustrates a rather compressed form, appearing somewhat more like *Melonis barleeanus* than *M. pompilioides*. He associates this species with the shelfal environment, having obtained living representatives in Portree Harbour, off Skye, in the Celtic Sea between 128 and 138 meters, and on the shelf edge by the western approaches to the English Channel between the depths of 420 and 1002 meters. Dead specimens of the taxon were obtained from these same localities, as well as from the Barents Sea, the southern portion of the Northern Sea, the Bay of Biscay and off Galicia.

Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

Specimens of Melonis barleeanus were found to be restricted primarily to the upper portion of the core, having been recovered between the core-top and 292 cm downcore. The taxon was obtained from both mud and sand samples, but occurs in greater abundance in the former. In the mud layers, Melonis barleeanus ranges between less than 1 and 8.5% of the fauna, while in the sandy mud interval from 180 to 182 cm, it makes up 1.5% of the assemblage. The species only occurs in two of the sand layers investigated, comprising less than 1% of the faunal assemblage in both instances.

Melonis pompilioides (Fichtel and Moll)
Plate 11, figure 3

Nautilus pompilioides Fichtel and Moll; Fichtel and Moll, 1798, p. 31, pl. 2, figs. a-c.
Nonionina pompilioides (Fichtel and Moll); Cushman, 1914, p. 25-26, pl. 17, fig. 2.
Nonion pompilioides (Fichtel and Moll); Bandy, 1953a, p. 177, pl. 21, fig. 12; Bandy, 1961, p. 21, pl. 5, fig. 12; Bandy and Rodolfo, 1964, p. 831, fig. 5D; Phleger, 1964, pl. 1, fig. 32.
Melonis "Nonion" pompilioides; Bandy and Chierici, 1966, p. 268, fig. 8.
Melonis pompilioides (Fichtel and Moll); Douglas, 1973, p. 614, 619-620, pl. 9, figs. 8-9; Ingle, 1973, p. 536, 542, 545, 551, 553, 556, 557, 560, 562; Haller, 1980, p. 265, pl. 16, fig. 5; Ingle, Keller and Kolpack, 1980, p. 142, pl. 9, figs. 14-15.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.
This species was recovered from a single lower bathyal sample in deposits from the Gulf of Alaska. The taxon comprised <1% of the faunal assemblage at the depth of 2281 meters.

Smith, 1973, Pleis? & Holocene, North Pacific Ocean.
Only one specimen of this taxon was collected in a single core taken from the deep-sea plain at a depth of 4810 meters at latitude 32°N. This tiny individual was referred to this species "...due to [the] thickness and coarsely perforate wall."

Lagoe, 1983, Oligocene-Plio, Gulf of Alaska.
Deposits of the PC unit of the Yakataga Reef section in the Gulf of Alaska studied by Lagoe contain Melonis pompilioides and appear to be representative of the Zemorrian (approximately Oligocene) Stage. The taxon appears throughout this Poul Creek Formation section and has been recovered with Gyroidina orbicularis planata, Bulimina inflata, Pullenia bulloides and Sphaeroidina variabilis. All of these taxa have been associated with bathyal deposits in previous works (Bandy and Arnal, 1969; Ingle, 1980).

Douglas, 1973, Mio-R, DSDP, central North Pacific.
Melonis pompilioides, as well as M. affinis and Uvigerina proboscidea, first appears in the Pliocene deep-sea assemblage recovered by the Deep Sea Drilling Project in the mid-Pacific.

Bandy, 1953a, R, San Francisco to San Diego, CA.
Bandy reported this species to be a dominant member of his lower abyssal zone situated off Point Arguello between the depths of 2438 and 3658 meters. The taxon was found associated with Melonis barleeanus, Hoeglundina elegans and particularly high abundances of Uvigerina senticosa. A similar assemblage was obtained in samples "...taken from the sea floor off Monterey Canyon at a depth of about 2000 feet [3658m]." Oceanographic parameters of this zone, lying at a depth of 3584 meters off Point Arguello, include the following: temperature of 1.53°C, salinity of from 34.66 to 34.68 °/oo, and an oxygen content of from 2.9 to 3.0 ml/l. Natland and Kuenen (1951) reported Melonis pompilioides existing off Panama and La Jolla between the depths of 1219 and 1524 meters, but did not present the depth of its maximum abundance. Bandy's investigation was not able to determine the exact upper limit of this taxon's distribution.

Morin, 1971, late Q, San Francisco, L.A., Baja CA.

Haller, 1980, Plio, Humboldt Basin, California.
Haller found Melonis pompilioides and M. barleeanus occurring in the Centerville coastal section of the Pullen Formation. Because they occurred only rarely, and because other mid-depth foraminifers were also present, he concluded that these sediments were deposited at middle bathyal depths. Rare abundances of Melonis pompilioides and Oridorsalis umbonatus were also recovered from the Centerville coastal section of the Eel River Formation. For the same reasons cited above, Haller suggested a an upper to middle bathyal environment for deposition.

Crouch, 1952, R, 11 deep basins off southern CA.
Crouch found this species to be common in waters characterized by temperatures between 1.7 and 3.0°C. He assigned Melonis pompilioides to his Zone T6, which was found at a depth of approximately 1219 to 2286 meters.

Bandy, 1953b, Mio-Plio-Pleis, Ventura Basin, CA.
In the early Pliocene, Nonion [Melonis] pompilioides and Bulimina rostrata became dominant members of the fauna. Today they occur at a depth of approximately

1830 meters or greater off Point Arguello, and "Natland and Kuenen (1951) indicate that the shallowest occurrence of these species is between 4000 [1219m] and 5000 [1524m] feet." Melonis pompilioides occurs abundantly below 2438 meters and from "...a frequency standpoint, the shallowest depth of maximum development for these two species is probably no less than about 5000 [1524m] or 6000 [1829m] feet."

Bandy & Chierici, 1966, R, California & Mediterranean.
Based on previous works, Bandy and Chierici determined that the upper depth limit of this taxon off California was in the bathyal zone at a depth of 2400 meters, plus or minus 600 meters. The authors suggest that the shallower depth ranges presented by Crouch (1952) and Natland (1957) for offshore California, between 1200 and 2300 meters, probably reflect uplifted Pleistocene deposits. The taxon has also been reported from the Mediterranean, but was not included in Bandy and Chierici's generalized bathyal zonation for this region. They conclude that Melonis pompilioides is an isobathyal species, "...occurring deeper than 2,300 m in general...in the Gulf of Mexico, the Gulf of California, off the coast of southern California, and in the Antarctic..."

Martin, 1952, Plio, Los Angeles Basin, CA.
This species was present in the Repetto and Pico Formations.

White, 1956, Mio-Plio, Capistrano Fm., Orange Co., CA.
This species was reported to occur rarely in Pliocene deposits of the Upper Capistrano Formation.

Blake & Douglas, 1980, Pleis, M. pomp., CA. borderland.

Ingle, 1980, Tertiary, so. CA. continental borderland.
Ingle concluded that this species is a member of the lower bathyal biofacies, occurring at a depth of 2000+ meters.

Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a dominant member of the lower bathyal biofacies at a depth of 2743 meters and greater, with the water temperature lying at 2.0C.

Phleger, 1964, living, Gulf of California.
Living individuals of this taxon were found between the depths of 2368 and 3049 meters in the Gulf of California. The shallow limit of Melonis pompilioides, as well as those for three others species, was used to define a faunal boundary at 2377 meters.

Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.
The species was found in the cores and not the trawls. Bandy and Rodolfo assigned Melonis pompilioides to their bathymetric group 5B, which had an upper depth limit of 2489 meters. The authors noted that the group first appeared more deeply off the Peru-Chile Trench than off Panama, and that it was found between 2489 and nearly 6000 meters. The taxon was recovered in fairly low percentages throughout its distribution. Bandy and Rodolfo also noted that the species of this group "...appear to be quite restricted to these greater depths...Nonion pompilioides is indicative of depths similar to those off southern California and in the Antarctic (Bandy and Echols, 1964)."

Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
This species was only found at a depth of 3550 meters in the Peru-Chile Trench region, where it comprised 4.5% of the faunal assemblage. The authors concluded that Melonis pompilioides, along with Uvigerina senticosa to a lesser extent, was a dominant representative of the lower bathyal biofacies defined between 2000 and 4000 meters in this region.

Cushman, 1929b, Late Tertiary, Venezuela & Ecuador.
Commonly found in Late Tertiary deposits of Trinidad and ?Miocene beds of Ecuador and Venezuela. Widely distributed species in the Late Tertiary.

Resig, 1976, Eocene-R, DSDP, Nazca Plate, Peru.
Utilizing only the sand size (>0.062 mm) fraction of DSDP core material from the Nazca Plate, Resig found Melonis pompilioides restricted to the Pleistocene/Holocene deposits, where it comprised 4 and 8% of the faunal assemblage.

Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
The authors state that "...too much confusion [exists] within this group to report its distribution [in the North Atlantic, from the literature] accurately."

Phleger & Parker, 1951, R, NW Gulf of Mex. & Atlantic.
Found in the Atlantic Ocean between 100 and 4600 meters.

Lohmann, 1978, R, western South Atlantic.

Murray (?), 1971, R, British forams.
Murray illustrates a rather compressed form, appearing somewhat more like Melonis barleeanus than M. pompilioides. He associates this species with the shelfal environment, having obtained living representatives in Portree Harbour, off Skye, in the Celtic Sea between 128 and 138 meters, and on the shelf edge by the western approaches to the English Channel between the depths of 420 and 1002 meters. Dead specimens of the taxon were obtained from these same localities.

Eade, 1970, upper Mio , New Zealand.

Douglas & Woodruff, 1981, deep-sea benthonic forams.

Cushman, 1933c, R, tropical Pacific, Lagenidae-Alveolin.
This species was obtained in southern and tropical Pacific sediments between the depths of 1114 and 4729 meters. Cushman concluded that it is "...essentially a deep-water species...", supported by the fact that seven of the fourteen occurrences noted lie at greater than 3658 meters and eleven of the fourteen were at depths greater than 2377 meters.

Cushman, 1914, R, Pacific Ocean, Pullenia and others.
This species was collected in the North Pacific by Brady on the H.M.S. Challenger at the depths of 3383

and 4115 meters. It has also been reported from the Bering Sea at a depth of 3239 meters and near the Hawaiian Islands in 2390 meters of water. Off Japan, it was collected at a depth of 238 meters, while from the Hawaiian to Midway Islands, it was obtained at the depths of 3316, 3383 and 3519 meters. The species has also been found between Guam and Japan in waters 2416 to 4115 meters deep.

Distribution

Representatives of *Melonis pompilioides* were recovered in every sample except the core-top, which in this study was obtained between 0 and 4 cm. The greatest abundances occur within the upper half of the core however, and also in the mud deposits. Obtained in the mud layers from 20 to 469.5 cm downcore, the taxon ranges between less than 1 and 30.8% of the assemblage. Particularly high abundances occur in the mud deposits between 80 and 170 cm, where values as high as 22% and greater are not uncommon. In contrast, *Melonis pompilioides* comprises from less than 1 to 4.2% of the fauna in the sand intervals located between 46 and 414.5 cm downcore.

Miliolinella californica Rhumbler
Plate 4, figures 3, 4

Triloculina circularis Bornemann; Cushman and Valentine, 1930, p. 15, pl. 4, fig. 4.
Miliolinella californica Rhumbler; Rhumbler, 1936, p. 215; Lankford and Phleger, 1973, p. 123, pl. 2, fig. 8.

Ecology

Lankford, 1962, R, turbulent zone, W. coastal N. America
Lankford & Phleger, 1973, R, W. coastal N. America.
Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Miliolinella californica was obtained only from the lowermost samples of the core, between the depths of 390 and 447.5 cm. Six specimens, comprising 1.6% of the fauna, were recovered from the mud interval lying between 390 and 393 cm. Singular examples of the taxon were also acquired from two other mud layers, as well as from the sand deposit located between 412 and 414.5 cm downcore.

Nodosaria cf. *N. tympaniplectriformis* Schwager
Plate 7, figure 1

Nodosaria tympaniplectriformis Schwager; Schwager, 1866, p. 223, pl. 5, fig. 34; Haller, 1980, p. 235, p. 3, fig. 10.

Ecology

Haller, 1980, Plio, Humboldt Basin, CA.

Distribution

A single fragmented specimen, tentatively assigned to this species, was recovered from the mud interval located between 60 and 63 cm downcore.

Nonionella basispinata (Cushman and Moyer)
Plate 10, figure 3

Nonion pizarrensis Berry var. *basispinata* Cushman and Moyer; Cushman and Moyer, 1930, p. 54, pl. 7, fig. 18; Cushman and McCulloch, 1940, p. 158, pl. 17, figs. 8-9, pl. 18, figs. 4-5.
Nonionella basispinata (Cushman and Moyer); Bandy, 1953a, pl. 21, fig. 13; Uchio, 1960, pl. 4, figs. 13-14; Bandy, 1961, p. 16, pl. 2, fig. 10; Phleger, 1964, pl. 1, figs. 30, 35-36; Smith, 1964, pl. 4, fig. 7; Wagner, 1978, p. 206-207; Sloan, 1981, p. 300-301.
Florilus basispinata (Cushman and Moyer); Lankford and Phleger, 1973, p. 119, pl. 3, fig. 15.
Pseudononion basispinatum (Cushman and Moyer); Matoba and Yamaguchi, 1982, p. 1045.

Ecology

Lagoe, 1979a, R, deep, Arctic Ocean.
Lagoe, 1979b, R, shallow, Prudhoe Bay, Alaska.
Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.

This species was found between the depths of 48 and 206 meters.
Cushman & Todd, 1947a, R, shallow water, coast of WA.
Cooper, 1961, R, intertidal, CA. & Oregon coast.
Bandy, 1950, Eocene, Plio-Pleis, Cape Blanco, Oregon.
Lankford, 1962, R, turbulent zone, W. coastal N. America.
Lankford & Phleger, 1973, R, W. coastal N. America.
Bandy, 1953a, R, San Francisco to San Diego, CA.
Harman, 1964, R, Santa Barbara Basin, CA.
Resig, 1958, R, Santa Barbara Is., CA.
Cushman & Moyer, 1930, R, San Pedro, CA.
This species was found between the depths of 64 and 91 meters.
Bandy, Ingle & Resig, 1964, R, San Pedro Bay, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Douglas & Heitman, 1979, R, so. California borderland.
Bandy, 1963b, R, paralic, so. CA. & Gulf of CA.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Uchio, 1960, R, living & dead, San Diego, CA.
Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a dominant member of the inner shelf biofacies between the depths of 18 and 37 meters, with the water temperature ranging from 14.0 to 18.0°C.
Phleger, 1964, living, Gulf of California.
Phleger & Ewing, 1962, R, lagoons, Baja CA., Mexico.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Smith, 1964, R, El Salvador & Nicaragua.
Cushman & McCulloch, 1940, R, Hancock Exp., Nonionidae.

Distribution

With the exception of a singular specimen of Nonionella basispinata in the mud interval from 410 to 412.5 cm downcore, all occurrences of this taxon are associated with sand deposits. Recovered between the depths of 133.5 and 414.5 cm, the species always comprises less than 1% of the faunal assemblage.

Nonionella decora Cushman and McCulloch
Plate 10, figure 1

Nonionella decora Cushman and McCulloch; Cushman and McCulloch, 1940, p. 160-161, pl. 17, figs. 11-12.

Ecology

Lagoe, 1979a, R, deep, Arctic Ocean.
Lagoe, 1979b, R, shallow, Prudhoe Bay, Alaska.
Bandy & Arnal, 1960, Mio-R, San Joaquin Valley, CA.
Cushman & McCulloch, 1940, R, Hancock Exp., Nonionidae.

Distribution

Only one specimen of Nonionella decora was recovered in this study. The taxon was found associated with the sand deposit located between 412 and 414.5 cm downcore.

Nonionella japonica mexicana
Cushman and McCulloch
Plate 10, figure 4

Nonionella japonica (Asano) var. mexicana Cushman and McCulloch; Cushman and McCulloch, 1940, p. 160, pl. 17, fig. 10. Florilus mexicanus (Cushman and McCulloch); Lankford and Phleger, 1973, p. 119, pl. 3, fig. 10.

Ecology

Lagoe, 1979a, R, deep, Arctic Ocean.
Lagoe, 1979b, R, shallow, Prudhoe Bay, Alaska.
Lankford & Phleger, 1973, R, W. coastal N. America.
Arnal and others (?), 1980, R, San Francisco Bay, CA.
Bandy & Arnal, 1960, Mio-R, San Joaquin Valley, CA.
Cushman & McCulloch, 1940, R, Hancock Exp., Nonionidae.

Distribution

Four pyritized and poorly preserved specimens of Nonionella japonica mexicana were obtained from two sand intervals ranging from 133.5 to 136.5 and 171 to 173 cm downcore. In both instances, the taxon comprises less than 1% of the faunal assemblage.

Nonionella miocenica Cushman
Plate 10, figure 7

Nonionella miocenica Cushman; Cushman, 1926c, p. 64; Cushman, Stewart and Stewart, 1930, p. 61, pl. 8, fig. 6; Cushman and McCulloch, 1940, p. 161-162, pl. 18, fig. 1; Ingle, Keller and Kolpack, 1980, p. 142, pl. 2, figs. 15-18.

Ecology

In the Northern boreal waters, calcareous benthonic foraminifers, including *Nonionella*, dominate the shallow shelf faunas (Loeblich and Tappan, 1953). This trend has been demonstrated in the Beaufort Sea as a whole, for example, but does not hold true in some of the associated bays and inlets (Lagoe, 1979b). Prudhoe Bay in the Arctic Ocean is a good illustration of this point; Lagoe (1979b) found species of *Nonionella* to be absent in this region and concluded that "...specialized environmental conditions..." accounted for this unusual occurrence. Bandy and Arnal (1957) have also noted that *Nonionella* species are associated with shallow Eastern Pacific waters in both the Northern and Southern hemispheres.

Nonionella miocenia, specifically, is no exception to this bathymetric trend. As the name suggests, this benthonic foraminifer is typical of Miocene deposits, with the type being described from just such strata in California (Cushman and McCulloch, 1940; Cushman, Stewart and Stewart, 1930). Yet, it has been found in later Tertiary sediments along the western coast of America and in the recent deposits associated with the Eastern Pacific from Alaska to South America.

The taxon was recovered at a depth of 4 meters in Holocene sediments offshore as far north as Wrangell, Alaska by the Allan Hancock Pacific Expeditions (Cushman and McCulloch, 1940). Specimens almost exactly like the types were also reported in dredging obtained by the U.S. Coast and Geodetic Survey ship *Guide* off Oregon in 219 meters of water (Cushman, 1927a). Pliocene deposits of the Port Orford Formation at Cape Blanco, Oregon yielded *Nonionella miocenica* as well (Bandy, 1950). The species comprised 3% of the total faunal assemblage in this outcrop study and its presence, in part, was responsible for Bandy determining that these sediments were deposited in a cool and very shallow environment.

The Cape Blanco Pliocene fauna reported by Bandy (1950) correlates quite well with a similar aged assemblage from Humbolt County of Northern California (Cushman, Stewart and Stewart, 1930). However, *Nonionella miocenica* was considerably less abundant in this California study, as it was found to occur only rarely in two Pliocene localities. Middle Tertiary deposits in the San Joaquin Valley also contained a *Nonionella* fauna which Bandy and Arnal (1960) concluded, based upon its known living habitat, represented an inner shelf biofacies at a depth of 30 plus or minus 30 meters.

Nonionella miocenica has also been reported from deposits to the south. In the greater Los Angeles region, White (1956) noted its rare occurrence in two localities of Pliocene-aged strata of the Upper Capistrano Formation. The taxon was included in a study of the southern California continental borderland as well, where Ingle (1980) concluded that it was a constituent of the inner shelf biofacies from approximately 0 to 50 meters water depth. Living species have been reported of the coast of Mexico (Cushman and McCulloch, 1940) and in the Gulf of California (Brenner, 1962). In the latter study, *Nonionella miocenica* was found inhabiting primarily the northern half, but also the southern half, of the Gulf in a review of the distribution of shallow benthonic foraminifers living between 0 and 91 meters.

This species has been discovered off Central and South America as well. In a study near El Salvador, Smith (1964) reported the species in recent bottom sediments between 37 and 450 meters of water. It was also obtained at a depth of 5 to 18 meters at Port Culebra, Costa Rica, by the Allan Hancock Pacific Expeditions (Cushman and McCulloch, 1940). In the Peru-Chile Trench area off South America, *Nonionella miocenica* was recovered in waters 135 to 1864 meters deep and was merely recorded as present in the uncounted aliquot at the depth of 2634 meters (Ingle, Keller, and Kolpack, 1980). It appears that this latter occurrence was the result of downslope displacement. The taxon was found to comprise 3.0% of the fauna at a depth of 135 meters and a maximum of 7.6% of the assemblage in 200 meters of water. The authors considered *Nonionella miocenica* a non-dominant member of the outer shelf biofacies, inhabiting the waters between 135 and 150 meters in this region. This biozone was found to lie "...within the oxygen-rich waters of the Peru-Chile Current."

Nonionella miocenica exhibits a long geologic record, having been reported in Miocene to recent sediments from Alaska to Chile. It has been most commonly associated with the inner shelf biofacies in the Eastern Pacific, defined by Ingle (1980) to lie between 0 and 50 meters. Occasionally though, the species has been obtained at outer shelf biofacies depths, ranging down to approximately 200 meters.

Distribution

Except for the occurrence of a single specimen of *Nonionella miocenica* in the mud interval from 139 to 143 cm downcore, the taxon was found associated exclusively with the sand and sandy mud layers of this study. Recovered between the depths of 133.5 and 414.5 cm, Nonionella miocenica comprises from less than 1 to 10.8% of the fauna in the sand intervals. In addition, the species accounts for less than 1% of the assemblage in five sandy mud deposits located from 180 to 412.5 cm downcore.

Nonionella stella Cushman and Moyer
Plate 11, figure 1

Nonionella miocenica Cushman var. stella Cushman and Moyer; Cushman and Moyer, 1930, p. 56, pl. 7, fig. 17; Cushman and McCulloch, 1940, p. 162, pl. 18, fig. 2; Bandy, 1953a, pl. 22, fig. 2; Ingle, 1973, p. 542, 545, 549, 560, 562. Nonionella stella Cushman and Moyer; Uchio, 1960, p. 61, pl. 4, figs. 15-16; Phleger, 1964, pl. 1, figs. 33-34; Lankford and Phleger, 1973, p. 123, pl. 3, figs. 13-14; Wagner, 1978, p. 207-208, pl. 5, fig. 2; Sloan, 1981, p. 301, 302; Matoba and Yamaguchi, 1982, p. 1045, pl. 4, fig. 4.

Ecology

Green, 1960, R, central Arctic Basin.
Lagoe, 1979a, R, deep, Arctic Ocean.
Lagoe, 1979b, R, shallow, Prudhoe Bay, Alaska.
Smith, 1963b, Pleis & R, Gulf of Alaska.
Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.
    This species was found between the depths of 34 and 206 meters.
Cushman & Todd, 1947a, R, shallow water, coast of WA.
Cooper, 1961, R, intertidal, CA. & Oregon coast.
Lankford, 1962, R, turbulent zone, W. coastal N. America.
Lankford & Phleger, 1973, R, W. coastal N. America.
Bandy, 1953a, R, San Francisco to San Diego, CA.
Bandy & Arnal, 1960, Mio-R, San Joaquin Valley, CA.
Harman, 1964, R, Santa Barbara Basin, CA.
Cushman & Moyer, 1930, R, San Pedro, CA.
    This species was found between the depths of 64 and 91 meters.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Bandy, Ingle & Resig, 1964, R, San Pedro Bay, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Douglas & Heitman, 1979, R, so. California borderland.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Butcher, 1951, R, Coronado Bank, San Diego, CA.
    This species was found occurring in low relative frequency between the depths of 100 and 800 meters.
Uchio, 1960, R, living & dead, San Diego, CA.
Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
    This species was found to be a non-dominant member of the inner shelf biofacies between the depths of 18 and 37 meters, with water temperatures ranging from 14.0 to 18.0°C.
Phleger, 1964, living, Gulf of California.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Cushman & McCulloch, 1940, R, Hancock Exp., Nonionidae.

Distribution

Four representatives of Nonionella stella, comprising less than 1% of the faunal assemblage, were recovered from the sand interval located between 412 and 414.5 cm downcore.

Nonionella sp.
Plate 10, figures 5, 6

Nonionella sp. The tests are comprised of 8 to 10 chambers in the adult whorl, yet they most often display 9. On both the ventral and dorsal sides, the last chamber develops a large basal lobe which completely covers the umbilicus. The basal lobes may be equally or unequally developed and never appear to reach the periphery. Sutures are distinct and barely, if at all, depressed. The aperture lies at the base of the apertural face, extending under the lobes on either side. The tests are often found intensely pyritized in the Monterey Fan levee deposits.

Ecology

Blanc-Vernet, 1969, R, Mediterranean.
Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Pyritized and poorly preserved specimens of Nonionella sp. were recovered from mud, sandy mud and sand deposits in this study. In the mud intervals from 40 to 43 and 128 to 130 cm, in the sandy mud layer lying from 180 to 182 cm, and in the sand deposit between 412 and 414.5 cm downcore, *Nonionella* sp. accounts for less than 1% of the fauna. In contrast, ten individuals, comprising 3.0% of the assemblage, were obtained from the mud interval located between 430 and 432.5 cm downcore.

Oolina catenulata (Williamson)
Plate 8, figure 5

Entosolenia squamosa (Montagu) var. α, *catenulata* Jeffreys; Williamson, 1848, p. 19, pl. 2, fig. 20.
Entosolenia squamosa Montagu var. *catenulata* Williamson; Williamson, 1858, p. 13, pl. 1, fig. 31.
Entosolenia catenulata Williamson; Cushman, 1913a, p. 18, pl. 7, figs. 1-2; Cushman, 1923, p. 9, pl. 1, fig. 11; Cushman, 1944, p. 21, pl. 3, fig. 9; Cushman and Todd, 1947, p. 19-20, pl. 3, fig. 10.

Ecology

Cushman & Todd, 1947b, Plio? Pleis?, Amchitka Is., AK.
Cushman & Todd, 1947a, R, shallow water, coast of WA.
Cooper, 1961, R, intertidal, CA. & Oregon coast.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Murray, 1973, R, general ecology & distribution.

Distribution

Oolina catenulata comprises less than 1% of the faunal assemblage in several mud, sandy mud and sand intervals collected between the depths of 96.5 and 414.5 cm downcore.

Oolina melo d'Orbigny
Plate 8, figure 4

Oolina melo d'Orbigny; d'Orbigny, 1839a, p. 20, pl. 5, fig. 9; Barker, 1960, p. 120, pl. 58, figs. 28-31; Lankford and Phleger, 1973, p. 123, pl. 3, figs. 8-9; Wagner, 1978, p. 188-189; Sloan, 1981, p. 302; Todd and Low, 1981, p. 26, 44, fig. 75; Matoba and Yamaguchi, 1982, p. 1045.
Lagena scalariformis (Williamson); Martin, 1952, p. 121, pl. 18, fig. 5.
Lagena melo d'Orbigny; Haller, 1980, p. 236, pl. 4, fig. 11.

Ecology

Loeblich & Tappan, 1953, R, Arctic forams.
Green, 1960, R, central Arctic Basin.
Lagoe, 1977, R, central Arctic Ocean.
Susan Cooper, 1964, R, Chukchi Sea, Alaska.
Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.
Lankford & Phleger, 1973, R, W. coastal N. America.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Bagg, 1912, Plio-Pleis (?), so. CA., Timms Point+.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Boltovskoy and others, 1980, R, shelf, SW Atantic.
Murray, 1973, R, general ecology & distribution.

Distribution

Specimens of *Oolina melo* were recovered between the depths of 80 and 447.5 cm downcore in mud, sandy mud and sand deposits of this study. In the mud intervals, the taxon accounts for between less than 1 and 2.0% of the assemblage. In the sandy mud and sand layers, *Oolina melo* always comprises less than 1% of the fauna.

Oolina spp.
Plate 9, figures 2, 3

Oolina sp. A. Plate 9, figure 2. The test of this individual is characterized by a single globular chamber which displays a rounded to slightly ovate aperture and an entosolenian tube.

Oolina sp. B. Plate 9, figure 3. This taxon's test is composed of a single globular chamber, a rounded aperture and a basal spine.

Ecology

Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Singular representatives of this genus were recovered from two mud intervals lying between 80 and 82, and 139 and 143 cm downcore.

Oolina (?) sp.
Plate 8, figure 6

Oolina (?) sp. The test of this individual is characterized by a single globular chamber and a pronounced radiate aperture. The specimen displays a basal spine and appears to lack an entosolenian tube.

Ecology

Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

A single individual, questionably referred to this genus, was obtained from the mud layer located between the depths of 152.5 and 154.5 cm downcore. This interval also contains a sand stringer.

Oridorsalis umbonatus (Reuss)
Plate 19, figure 6

Rotalina umbonata Reuss; Reuss, 1851, p. 75, pl. 5, fig. 35.
Truncatulina tenera H.B. Brady; Cushman, 1915, p. 37, pl. 16, fig. 2, pl. 23, fig. 6.
Eponides tenera (H.B. Brady); Cushman, 1927a, p. 163, pl. 5, figs. 6-7.
Eponides umbonata (Reuss); Cushman, 1929b, p. 98, pl. 14, fig. 8.
Eponides umbonatus (Reuss); Phleger and Parker, 1951, p. 22, pl. 11, figs. 10, 13-14; Bergen and O'Neil, 1979, p. 1290.
Eponides tener (Brady); Bandy, 1953a, pl. 23, fig. 3.
Eponides (?) *tenera* (Brady); Barker, 1960, p. 196, pl. 95, fig. 11.
Pseudoeponides umbonatus (Reuss); Uchio, 1960, p. 49, pl. 8, figs. 29-31; Smith, 1964, p. B43, pl. 4, fig. 8.
Oridorsalis umbonatus (Reuss); Ingle, 1973, p. 536, 542, 545, 553, 556, 557, 563; Haller, 1980, p. 257, pl. 11, fig. 3; Matoba and Yamaguchi, 1982, p. 1045, pl. 4, fig. 11.
Oridorsalis tener (Brady); Ingle, Keller and Kolpack, 1980, p. 142, pl. 5, figs. 5-6.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.
The species occurs in lower bathyal deposits in the Gulf of Alaska between the depths of 1662 and 2205 meters. It comprises <1% of the faunal assemblage at the depths of 1662, 1696, and 2205 meters, 1% at 2144 meters and 4% at a depth of 1830 meters.

Cushman & Todd, 1947b, Plio? Pleis?, Amchitka Is., AK.
Quarry samples containing a decidedly cold water fauna but "...not by any means arctic..." included this taxon. The authors note that *Eponides* [*Oridorsalis*] *umbonatus* has been reported in recent sediments in the North Atlantic and Antarctic regions.

Haller, 1980, Plio, Humboldt Basin, California.
Haller found *Oridorsalis umbonatus* and *Melonis pompilioides* occurring in the Centerville coastal section of the Eel River Formation. Because they occurred only rarely, and because other mid-depth foraminifers were also present, he concluded that these sediments were deposited at upper to middle bathyal depths.

Crouch, 1952, R, 11 deep basins off southern CA.
Species is abundant in water temperatures between 1.7 and 5.0C. "Colder water forms become more umbonate, and sutures become irregular toward the umbo."

Ingle, 1980, Tertiary, so. CA. continental borderland.
Ingle concluded that this species was characteristic of the upper middle bathyal biofacies, between the depths of 500 and 1500 meters.

Butcher, 1951, R, Coronado Bank, San Diego, CA.
Eponides [*Oridorsalis*] *umbonatus* was found occurring in low relative frequency between the depths of 175 and 1025 meters on the Coronado Bank and surrounding regions offshore San Diego.

Brenner, 1962, R, shallow, Gulf of California.
Brenner found that only a single locality yielded this species: *Oridorsalis umbonatus* comprised 8% of the total benthonic foraminiferal assemblage at a depth of 73.8 meters. The taxon was one of only four to be recovered exclusively in the northern half of the Gulf.

Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Oridorsalis umbonatus was recovered in Pleistocene and Holocene deposits in material collected by the Deep Sea Drilling Project in the Guaymas Basin of the Gulf of

California. The taxon most commonly comprised 1 to 4% of the Pleistocene assemblages, but occurred at a maximum of 35, 37 and 42% of the Pleistocene fauna in Hole 478. It also was found in high abundances in the Holocene material, constituting between 7 and 63% of those faunal assemblages.

Smith, 1964, R, El Salvador & Nicaragua.
Member of Zone F which is present between the depths of 1300 and 3200 meters.

Cushman, 1929b, Late Tertiary, Venezuela & Ecuador.
The species occurs rather abundantly in the Ecuadorian deposits but rarely in the Late Tertiary of Venezuela. Cushman notes that it has been recorded in deposits as low as Middle Eocene and continues to the present where it is commonly referred to as *Eponides* (*Oridorsalis*) *tenera* (Brady).

Resig, 1976, Eocene-R, DSDP, Nazca Plate, Peru.
Utilizing only the sand size (>0.062 mm) fraction of DSDP core material collected from the Nazca Plate, Resig found the taxon comprising 1 and 2% of the Eocene faunas, 1 to 4% of the Oligocene assemblages, 1, 5 and 8% of the Miocene biotas and 2, 3, 8, and 13% of the Pleistocene/Holocene faunal assemblages. Based primarily upon previous works in this region, Resig determined that *Oridorsalis umbonatus*, when present in recent deposits, often constitutes approximately 5% of the fauna from about 250 to 1000 meters and as great as 20% of the assemblage between 1000 and 4250 meters.

Parker, 1948, R, cont. shelf, Gulf of Maine-Maryland.
On the continental shelf from Cape Cod to Maryland, *Eponides* [*Oridorsalis*] *umbonatus* occurred in Parker's Zone 3, from 90 to 300 meters deep, and in her Zone 4 between the depths of 300 and at least 680 meters. Zone 3 was characterized by the taxon as well as *Cassidulinoides bradyi*, *Trochammina globigeriniformis*, *Chilostomella ovoidea* and *Angulogerina* [*Trifarina*] *angulosa*. In Zone 4, *Uvigerina peregrina* began to dominate the faunal assemblage. To the north, on a traverse located east and north of Cape Cod (referred to as the Cape Cod Light Traverse), Parker found *Oridorsalis umbonatus* occurring only rarely between the depths of 145 and 203 meters.

Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
In the North Atlantic, this species was found at depths greater than 42 meters. In the equatorial Atlantic region, it was widespread in the study's bathymetric range from nearly 2000 to 7500 meters.

Phleger, 1951b, R, Northwest Gulf of Mexico.
The species occurs largely at depths greater than 80 meters, down to 3000 meters.

Phleger & Parker, 1951, R, NW Gulf of Mex. & Atlantic.
In the Atlantic Ocean, this species was found between the depths of 42 and 5200 meters.

Lohmann, 1978, R, western South Atlantic.
Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

This species was recovered in samples spanning nearly the entire length of the core, being obtained from a depth of 46 to 447.5 cm. However, *Oridorsalis umbonatus* is generally lacking or present in very low quantities in the sand and sandy mud intervals and displays an increase in abundance in the lower half of the core. In the mud layers, the species comprises between less than 1 and 2.8% of the assemblage in the upper portion of the core, increasing to a maximum of 18.1% in the lower half of the core in the interval from 330 to 332 cm. In contrast, *Oridorsalis umbonatus* accounts for less than 1 to 1.1% of the faunal assemblage in the sand and sandy mud layers.

Parafissurina fusuliformis Loeblich and Tappan

Parafissurina fusuliformis Loeblich and Tappan; Loeblich and Tappan, 1953, p. 79-80, pl. 14, figs. 18-19.

Ecology

Loeblich & Tappan, 1953, R, Arctic forams.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Two examples of this taxon were recovered from the mud interval located between 120 and 122 cm downcore.

Parafissurina kerguelenensis (Parr)
Plate 8, figures 11, 13

Fissurina kerguelenennsis Parr; Parr, 1950, p. 305, pl. 8, fig. 7; Barker, 1960, p. 122, pl. 59, figs. 8-11; Todd and Low, 1980, p. 23, pl. 2, fig. 9.

Individuals combined under this species display the varying morphotypes described by Parr: spines may or may not be developed on the base. When present, the number of basal spines on the Monterey Fan sediment specimens commonly range between two and four. Parr (1950) also noted that in one of his specimens, "...the sides of the aperture are of different heights, and the specimen would therefore, in the absence of the other specimens, have been referred to the genus *Parafissurina* Parr." Because all of the individuals recovered in this study display this asymmetrical aperture, they have been referred to the genus *Parafissurina* instead of *Fissurina*.

Ecology

Todd & Low, 1980, R, Kara & Greenland Seas.
Barker, 1960, R, Brady's *Challenger* Expedition.
Parr, 1950, R, Antarctic *Expedition*.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Representatives of *Parafissurina kerguelenensis* were obtained in low abundance from both the muds and sands of this study. Most often accounting for less than 1% of the faunal assemblage, but peaking at 1% in the mud interval from 167.5 to 170 cm downcore, this taxon was recovered in sediments between 128 and 412.5 cm in core S3-78-SC, 15G.

Parafissurina cf. *P. kerguelenensis* (Parr)
Plate 8, figure 12

The test of this species has the same shape and apertural characteristics as those of *Parafissurina kerguelenensis* (Parr). It differs by displaying a thin flange around the lower portion of the test instead of the two to four isolated spines along the base. In addition, well preserved individuals of *Parafissurina* cf. *P. kerguelenensis* (Parr) exhibit a slight longitudinal ridge along the medial axis which extends up approximately one-sixth the distance of the test from its base.

Ecology

Todd & Low, 1980, R, Kara & Greenland Seas.
Barker, 1960, R, Brady's *Challenger* Expedition.
Parr, 1950, R, Antarctic *Expedition*.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Seven of the samples investigated in this study yielded examples of this taxon. Present in both the muds and sands, the species was recovered between the depths of 180 and 414.5 cm downcore. In the mud layers, *Parafissurina* cf. *P. kerguelenensis* accounts for less than 1 to 3.3% of the assemblage, while comprising between less than 1 and 1.2% in the sands.

Parafissurina tectulostoma Loeblich and Tappan
Plate 9, figure 10

Parafissurina tectulostoma Loeblich and Tappan; Loeblich and Tappan, 1953, p. 81, pl. 14, fig. 17; Todd and Low, 1980, p. 24, pl. 2, fig. 5.

Ecology

Loeblich & Tappan, 1953, R, Arctic forams.
Todd & Low, 1980, R, Kara & Greenland Seas.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Four specimens of *Parafissurina tectulostoma*, comprising less than 1% of the faunal assemblage, were recovered in the mud interval between the depths of 167.5 and 170 cm downcore.

Parafissurina spp.
Plate 8, figure 8

Parafissurina spp. Several specimens, all characterized by single chambers and a sub-terminal, arched aperture lying beneath a hood, are assigned to this genus. When the finely perforate wall structure is well preserved, an internal tube can be discerned. Time did not permit identification to the specific level.

Ecology

Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Both mud and sand intervals, located between 20 and 192 cm downcore, yielded specimens of this genus. In the mud layers, *Parafissurina* spp. comprises from less than 1 to 1.2% of the assemblage. In the sands, it accounts for between less than 1 and 1.6% of the fauna.

Planulina ornata (d'Orbigny)
Plate 22, figure 6

Truncatulina ornata d'Orbigny; d'Orbigny, 1839a, p. 40, pl. 6, figs. 7-9.
Planulina ornata (d'Orbigny); Cushman, 1927a, p. 176; Cushman and Valentine, 1930, p. 29; Natland, 1950, p. 38; Crouch, 1952, p. 842; Bandy, 1953a, p. 177, pl. 24, fig. 4; White, 1956, p. 242; Bandy, 1957, p. 196; Bandy and Arnal, 1957, p. 2052; Resig, 1958, p. 295; McGlasson, 1959, p. 236; Zalesny, 1959, p. 125; Cooper, 1961, p. 62; Lankford, 1962, p. 55; Morin, 1971, p. 481; Lankford and Phleger, 1973, p. 125; Ingle, 1980, p. 171; Matoba and Yamaguchi, 1982, p. 1045.

Ecology

Cooper, 1961, R, intertidal, CA. & Oregon coast.
Lankford, 1962, R, turbulent zone, W. coastal N. America.
Lankford & Phleger, 1973, R, W. coastal N. America.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Bandy, 1953a, R, San Francisco to San Diego, CA.
Morin, 1971, late Q, San Francisco, L.A., Baja CA.
Resig, 1958, R, Santa Cruz Basin, CA.
Crouch, 1952, R, 11 deep basins off southern CA.
Cushman & Moyer, 1930, R, San Pedro, CA.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Cushman & Valentine, 1930, R, Channel Ids., so. CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Bandy, 1963a, R, so. CA. continental borderland.
White, 1956, Mio-Plio, Capistrano Fm., Orange Co., CA.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Butcher, 1951, R, Coronado Bank, San Diego, CA.
Uchio, 1960, R, living & dead, San Diego, CA.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
Natland, 1950, Plio-Pleis, Gulf of CA., outcrops.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Smith, 1964, R, El Salvador & Nicaragua.
Cushman & Todd, 1945, Mio, Buff Bay, Jamaica.
Cushman, 1929c, Tertiary, *Planulina*.

Distribution

One specimen of *Planulina ornata* was obtained in the mud interval located 289.5 to 292 cm downcore.

Planulina wuellerstorfi (Schwager)
Plate 22, figure 7

Anomalina wuellerstorfi Schwager; Schwager, 1866, p. 258, pl. 7, figs. 105, 107.
Truncatulina wuellerstorfi (Schwager); Cushman, 1915, p. 34, pl. 12, fig. 3.
Cibicides wuellerstorfi (Schwager); Church, 1928, p. 266; Bandy and Rodolfo, 1964, p. 827, fig. 5A; Ingle, 1973, p. 536, 542, 545, 553, 556, 562.
Planulina wuellerstorfi (Schwager); Cushman, 1929c, p. 102-105, pl. 15, figs. 1-2; Phleger, Parker and Peirson, 1953, p. 49, pl. 11, figs. 1-2; Barker, 1960, p. 192, pl. 93, fig. 9; Haller, 1980, p. 265-266, pl. 18, fig. 2.

Ecology

Green, 1960, R, central Arctic Basin.
This was one of four good indicator species defined by Green for the abyssal biofacies in this region. The abyssal region was defined by the following parameters:

depth between 2250 and 2760 meters, temperature from -0.40 to -0.42°C, and salinity unknown, but probably 35°/oo. Green noted that "Cibicides wuellerstorfi is a deep, cold-water species of both the Atlantic and Pacific Oceans, and is thus in its normal habitat in the Arctic."

Lagoe, 1977, R, central Arctic Ocean.
The species was found to range between the depths of 1181 and 3242 meters, making up less than 1% of the benthonic foraminiferal assemblages in these two end members. Planulina wuellerstorfi comprised a maximum of 11% of the fauna at a depth of 2049 meters.

Lagoe, 1979a, R, deep, Arctic Ocean.
In a study of arctic sediments from the depths of 17 to 3709 meters in the Amerasian Basin, this species was found to be a dominant member of the Stetsonia horvathi biofacies, defined between 900 and 3709 meters. Associated with Planulina wuellerstorfi was Eponides tener, Chilostomella spp. and Quinqueloculina spp.

Bergen & O'Neil, 1979, R, Gulf of Alaska.
This species was found in middle and lower bathyal deposits from the Gulf of Alaska. The taxon was recovered between the depths of 1174 and 2281 meters, comprising 1% of the middle bathyal assemblage at a depth of 1174 meters and <1% of the lower bathyal faunas at 2205 and 2281 meters.

Douglas, 1973, Mio-R, DSDP, central North Pacific.
"By late Miocene time, mid-Pacific, deep-sea assemblages assume a fairly modern aspect, and species such as Cibicidoides [Planulina] wuellerstorfi...and Uvigerina peregrina are well established."

Bandy & Arnal, 1960, Mio-R, San Joaquin Valley, CA.
Bandy and Arnal suggest that this species is indicative of the abyssal biofacies in many of today's modern oceans. They state that it is commonly associated with varieties of Gyroidina soldanii, Anomalina californiensis and Bulimina corrugata in their study.

Crouch, 1952, R, 11 deep basins off southern CA.
Species is abundant in water temperatures below 3.0°C.

Bandy, 1963a, R, so. CA. continental borderland.
Specimens of Planulina wuellerstorfi larger than 1 mm were found between the depths of 1200 and 1979 meters in the basins off southern California. This taxon and Cyclammina cancellata were the only two "larger foraminiferal" taxa which Bandy determined comprised his "Fauna C". These species dominated the Santa Cruz and San Nicolas basins, in which the temperature ranged between 3.71 and 4.15°C, the salinity hovered near 34.52°/oo and the oxygen content fell between 0.5 and 0.8 ml/l. In these basins, Planulina wuellerstorfi's maximum size for its shallowest occurrence averaged 1.5 mm. "It attain[ed] a maximum of 2 mm. in [the] West Cortes basin..." but did not display a size gradient with depth.

Bandy & Chierici, 1966, R, California & Mediterranean.
This species occurs in bathyal deposits in the Mediterranean and off California, but was not included in Bandy and Chierici's generalized bathyal zonations schemes for these regions. They consider it an isobathyal species because its upper depth limit is between 1000 and 1100 meters in both areas. The authors note, however, that "...in the Gulf of Mexico (Parker, 1954) and elsewhere, it is a rare species between 500 and ca. 3,000 m and it is abundant below 3,000 m (Bandy and Echols, 1964). The rare occurrences recorded in the Mediterranean and off California are probably incomplete records...it is more characteristic of depths below 2,400 m."

Bagg, 1912, Plio-Pleis (?), so. CA., Timms Point+.
This early work found the species present in late Tertiary deposits of southern California and stated that it is a common constituent of recent deep-sea oozes. Bagg considered it to represent a bathymetric environment between 366 and 3658 meters.

Church, 1928, lower Plio, Los Angeles Basin, CA.
One of twenty-one species described in this early work from a late Tertiary well sample taken from a depth of 860 meters in South Huntington Beach.

Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a dominant member of the upper middle bathyal biofacies between the depths of 1219 and 1524 meters, with water temperatures ranging from 2.5 to 3.5°C.

Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.
The species was common in the trawls and not the cores. Bandy and Rodolfo determined that Planulina wuellerstorfi was a dominant member of their bathymetric group 2A. The group most likely had an upper depth limit of nearly 500 meters and continued down to a depth of nearly 5250 meters. The authors also found that the assemblage was abundant from 878 to approximately 2000 meters and peaked in abundance again near 3500 and 4500 meters.

Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
This species was recovered in recent sediments from the Peru-Chile Trench area. No depths or abundances of its occurrence was given.

Resig, 1976, Eocene-R, DSDP, Nazca Plate, Peru.
Utilizing only the sand size fraction (>0.062 mm) of the cored material, Resig recovered the taxon in Pleistocene/Holocene deposits from the Nazca Plate, where it comprised 3, 4, 12 and 17% of the faunal assemblage. The author noted that Streeter (1973) defined a deep-water (2500 to 4000 meters) assemblage in the Atlantic based upon the abundant presence of Cibicides [Planulina] wuellerstorfi and Epistominella exigua. Resig also presented its modern depth range for the area and considered it a bathymetric index

species, utilizing abundance presence, displaying these parameters: comprising approximately 5% of the fauna between nearly 250 to 2500 meters and 20% of the assemblage between 2500 and 4250 meters. She concluded by suggesting that Planulina wuellerstorfi and Epistominella exigua represent deposition at depths "...in excess of 2500 meters..."

Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.

In the Atlantic, this species was found at depths greater than 630 meters. In the equatorial Atlantic, it was found widespread in the study's bathymetric range from a depth of nearly 2000 to 7500 meters.

Phleger, 1951b, R, Northwest Gulf of Mexico.

The species was found at depths not less than 700 meters and recovered in abundances of 20% between 2700 and 2800 meters. Planulina wuellerstorfi also occurred at a frequency of greater than 20% between the depths of 2800 and 3400 meters.

Phleger & Parker, 1951, R, NW Gulf of Mex. & Atlantic.

In the Atlantic Ocean, this species was found between the depths of 630 and 4450 meters.

Lohmann, 1978, R, western South Atlantic.

Douglas & Woodruff, 1981, deep-sea benthonic forams.

Cushman, 1915, R, Pacific Ocean, Rotaliidae.

Cushman concluded that this is one of the most common species in the North Pacific. Brady collected the taxon in this region between the depths of 631 and 3749 meters and near the Hawaiian Islands from 503 to 2824 meters. Flint discovered Cibicides wuellerstorfi in the Panama Bay at a depth of 93 meters and Göes recovered it in the western Pacific in waters 1207 to 2196 meters deep. The taxon has also been found off the coast of Washington at a depth of 1437 meters, near the Galapagos Islands at 2522 meters, and from Guam to Yokahama and the Midway to Hawaiian Islands between the depths of 1216 and 4373 meters.

Distribution

Planulina wuellerstorfi was recovered in samples spanning nearly the entire length of the core, being obtained from a depth of 20 to 469.5 cm. However, the taxon is not present in some of the sand and sandy mud intervals and comprises only a low percentage of the fauna in several others. In the mud layers, Planulina wuellerstorfi accounts for less than 1 to 6.6% of the assemblage, with the highest values coming from 120 to 170 and 270 to 372.5 cm downcore. In the sand and sandy mud layers, the taxon reaches a maximum of only 1.0% of the fauna.

Pullenia bulloides (d'Orbigny)

Plate 22, figures 3, 4

Nonionina bulloides d'Orbigny; d'Orbigny, 1826, p. 293.
Pullenia bulloides (d'Orbigny); Cushman and Todd, 1943, p. 13-15, pl. 2, figs. 15-18; Barker, 1960, p. 174, pl. 84, figs. 12-13; Bandy, 1961, p. 26, pl. 5, fig. 13; Phleger, 1964, pl. 2, fig. 33; Ingle, 1973, p. 536, 542, 545, 553, 557, 562, 563; Boltovskoy and others, 1980, p. 43, pl. 25, figs. 9-11; Matoba and Yamaguchi, 1982, p. 1045.
Pullenia miocenica (?) Kleinpell; Haller, 1980, p. 262, pl. 14, fig. 3.

Ecology

Green, 1960, R, central Arctic Basin.

One of the species found to be present in this study.

Smith, 1963b, Pleis & R, Gulf of Alaska.

Dead individuals of this species were collected from a single bathyal sample obtained at the depth of 1950 meters. The taxon comprised 4% of the faunal assemblage at this depth.

Bergen & O'Neil, 1979, R, Gulf of Alaska.

This species was found in lower bathyal deposits from the Gulf of Alaska between the depths of 1662 and the study's limit of 2623 meters. It comprised a maximum of 3% of the faunal assemblage at 1662 and 1723 meters. Bergen and O'Neil noted that its shallowest appearance occurred in lower bathyal sediments, where it was associated with the first appearance of Oridorsalis umbonatus, Gyroidina altiformis and several other species. The authors also concluded that the taxon is a eurythermal species, exhibiting the same bathymetric distribution in the Gulf of Alaska and off California.

Lagoe, 1983, Oligocene-Plio, Gulf of Alaska.

Deposits of the PC unit of the Yakataga Reef section in the Gulf of Alaska studied by Lagoe contain Pullenia bulloides and appear to be representative of the Zemorrian (approximately Oligocene) stage. Considered a member of the Gyroidina orbicularis planata biofacies, this taxon was found associated with Melonis pompilioides, Bulimina inflata and Sphaeroidina variabilis. These taxa are considered to represent deposition in the bathyal zone by many authors (Bandy and Arnal, 1969; Ingle, 1980). Pullenia bulloides still lives at bathyal depths in this region today (Smith, 1963).

Cushman, 1927a, R, W. coast, Oregon to Central Amer.

The species was found near Monterey Bay at the depths of 2050 and 2816 meters, near the United States-Mexico border in 2542 meters of water, and off Ensenada at a depth of 2505 meters. Pullenia bulloides was also recovered in the vicinity of southern Baja, Mexico at the depths of 1677, 2890 and 3127 meters, and near Panama at 1289 and 1481 meters.

Morin, 1971, late Q, San Francisco, L.A., Baja CA.

Bandy & Arnal, 1960, Mio-R, San Joaquin Valley, CA.

This taxon occurs in abundance in the lower bathyal region of the tropical Pacific and is found associated with Gyroidina soldanii and Siphogenerina raphanus. "Typical forms being found between depths 3,624 [1105 meters] and 16,368 [4989 meters] feet (Chapman, 1910)."

Crouch, 1952, R, 11 deep basins off southern CA.

Species is abundant in the offshore basins and is associated with Zone T6. It prefers water temperatures around 3.0°C and less and is found at the depths of approximately 1219 to 2286 meters.

Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.

Natland reported that Pullenia bulloides was not recovered in the San Pedro Channel, between San Pedro and Santa Catalina Island, but that it was obtained in his land-based "Zone 4" region of the Hall Canyon section near Ventura, California. The taxon was also found at a depth of 2505 meters off Ensenada at Guide station 2 and at 2542 meters near the United States-Mexico border at Guide station 3.

Ingle, 1980, Tertiary, so. CA. continental borderland.

This species exhibits a "...transitional distribution from upper middle [500 to 1500 meters] to lower middle [1500 to 2000 meters] bathyal depths."

Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.

This species was found to be a dominant member of the lower bathyal biofacies between the depths of 2438 and 2743 meters, in waters with a temperature of 2.0°C.

Phleger, 1964, living, Gulf of California.

This species was found at 1234 meters and between the depths of 2368 and 3045 meters in the Gulf of California. The taxon's shallow limit, as well as those for three other species, was used to define a faunal boundary at a depth of 2377 meters.

Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.

Bandy & Arnal, 1957, R, W. coast of Central America.

In a study from Acapulco to the Gulf of Panama, this taxon was recovered between the depths of 1025 and 1911 meters. It was found to comprise 47% of the fauna at a depth of 1911 meters, 24% at 1600 meters and 13% of the fauna at the depths of 1246 and 1353 meters. Bandy and Arnal determined this taxon to be a less abundant member of the Uvigerina proboscidea fauna which inhabited the waters between the depths of 122 and 610 meters, where the temperature ranged between 2.6 and 3.8°C and the salinity was approximately 34.7 °/oo. Other typical species in this biofacies included Valvulineria araucana, V. glabra and Virgulina [Fursenkoina] nodosa.

Smith, 1964, R, El Salvador & Nicaragua.

The species was found between the depths of 1600 and 3100 meters.

Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.

The species was common in the cores and not in the trawls. Bandy and Rodolfo assigned Pullenia bulloides to their bathymetric group 4C which had an upper depth limit of 1932 meters. This assemblage was present between 1932 and 6000 meters, occurring in large percentages from 1932 to nearly 3000 meters and from approximately 4000 to 5900 meters. "This middle bathyal group contains a number of good depth indices, most of which are not known to live in water depths much less than that recorded for the Peru-Chile Trench area."

Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.

This species was obtained between the depths of 274 and 3550 meters in the Peru-Chile Trench area. The taxon comprised a maximum of 1.9% of the faunal assemblage at a depth of 3550 meters, but was also present in the shallow oxygen-minimum zone, exhibiting an oxygen content of <1 ml/l, between the depths of 150 and 400 meters in this region.

Resig, 1976, Eocene-R, DSDP, Nazca Plate, Peru.

Utilizing the sand size (>0.062 mm) fraction of DSDP core material collected on the Nazca Plate, Resig found the taxon comprising <1 and 3% of the Oligocene faunas, <1 , 2 and 3% of the Miocene biotas and 1, 3, 4 and 11% of the Pleistocene/Holocene assemblages. Based primarily upon previous works in this area, she determined that Pullenia bulloides, when present in recent deposits, commonly constitutes approximately 5% of the fauna between about 250 and 1000 meters, as well as from 3000 to 4250 meters water depth. Resig also found that the species may comprise up to 20% of the assemblage between the depths of 1000 and 3000 meters.

Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.

This species is widely reported in the North Atlantic foraminiferal literature. It was found to be widespread in the core and surface samples taken in this study in the equatorial and low-latitude North Atlantic between the depths of approximately 2000 and 7500 meters.

Phleger, 1951b, R, Northwest Gulf of Mexico.

Species found between the depths of 65 and 1000 meters

Phleger & Parker, 1951, R, NW Gulf of Mex. & Atlantic.

In the Atlantic Ocean, this species is widely distributed and reported from all depths. Brady (1884) noted that the taxon is rare in waters less than 550 meters.

Lohmann, 1978, R, western South Atlantic.

Boltovskoy and others, 1980, R, shelf, SW Atantic.

Boltovskoy and others, investigating recent shelfal foraminifers of the southwestern Atlantic, described Pullenia bulloides as a euhaline species in this region. It was found associated with Trifarina angulosa, Buliminella elegantissima, Bolivina seminuda, Cassidulina minuta, Elphidium magellanicum, E. gunteri, Cibicides lobatulus and Pullenia quinqueloba, among others.

Cushman & Todd, 1945, Mio, Buff Bay, Jamaica.
The species was reported in Miocene sediments from Buff Bay, Jamaica which were deposited at "...medium depths and not close to shore..." Cushman and Todd concluded that this is a very widely distributed taxon, having been recorded in the Miocene and Pliocene of Europe, the Miocene of Ecuador, the Oligocene of Trinidad and the Holocene of the Atlantic and Pacific Oceans.

Douglas & Woodruff, 1981, deep-sea benthonic forams.

Cushman, 1914, R, Pacific Ocean, Pullenia and others.
Brady, aboard the Challenger, collected this taxon in the North Pacific between the depths of 631 and 5029 meters. Off the Hawaiian Islands, it has been recovered in waters 905 to 2557 meters deep. Between Guam and Yokohama, Pullenia bulloides has been obtained between the depths of 717 and 3036 meters, with the average depth being 2743 meters.

Cushman & Todd, 1943, Cretaceous to R, Pullenia.
Reported from Miocene, Pliocene and Quarternary deposits, today this species is widely distributed in both the Pacific and Atlantic Oceans.

Sliter & Baker, 1972, Cret, benthic foram paleoecology.
Recent specimens are associated with waters deeper than the shelf.

Distribution

Pullenia bulloides was recovered from 27 of the 33 samples investigated in this study. Obtained between the depths of 46 and 469.5 cm downcore, this taxon displays its lowest abundances in the sand and sandy mud intervals and exhibits a general increase in abundance in the lower half of the core. In the mud intervals, Pullenia bulloides ranges from less than 1 to 5.3% of the fauna, reaching its maximum abundance in the sample located from 369.5 to 372.5 cm. In contrast, the taxon is either not present, or accounts for less than 1% of the assemblage, in the sand and sandy mud layers.

Pullenia quinqueloba (Reuss)
Plate 21, figure 7

Nonionina quinqueloba Reuss; Reuss, 1851, p. 71, pl. 5, fig. 31.

Pullenia quinqueloba (Reuss); Cushman and Todd, 1943, p. 10-11, pl. 2, fig. 5, pl. 3, fig. 8; Ingle, 1973, p. 525, 536, 553, 556, 557, 562, 563; Ingle, Keller and Kolpack, 1980, p. 142, pl. 5, fig. 8; Matoba and Yamaguchi, 1982, p. 1045.

Pullenia subcarinata (d'Orbigny); Barker, 1960, p. 174, pl. 84, figs. 14-15; Haller, 1980, p. 262, pl. 14, fig. 5.

Ecology

Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Ingle, 1973, N, DSDP Site 172, between CA. & Hawaii.
Crouch, 1952, R, 11 deep basins off southern CA.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Cushman & Valentine, 1930, R, Channel Ids., so. CA.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Brenner, 1962, R, shallow, Gulf of California.
Phleger, 1964, living, Gulf of California.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Resig, 1976, Eocene-R, DSDP, Nazca Plate, Peru.
Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
Phleger, 1951b, R, Northwest Gulf of Mexico.
Phleger & Parker, 1951, R, NW Gulf of Mex. & Atlantic.
Boltovskoy and others, 1980, R, shelf, SW Atantic.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman, 1914, R, Pacific Ocean, Pullenia and others.
Cushman & Todd, 1943, Cretaceous to R, Pullenia.
Found questionably in Cretaceous exposures, this species has certainly been recorded in Miocene to recent deposits.
Sliter & Baker, 1972, Cret, benthic foram paleoecology.
Recent specimens are found associated with waters of shelfal depth.

Distribution

Specimens of this taxon were recovered generally from the upper half of the core, between the depths of 80 and 272 cm downcore. Obtained in only five samples, Pullenia quinqueloba most often is represented by a single specimen in each locality. Present in both mud and sandy mud layers, the species always comprises less than 1% of the faunal assemblage.

Pullenia salisburyi Stewart and Stewart

Plate 21, figures 6, 8

Pullenia salisburyi R.E. and K.C. Stewart; R.E. and K.C. Stewart, 1930, p. 72, pl. 8, fig. 2; Cushman and Todd, 1943, p. 20-21, pl. 3, figs. 10-11; Uchio, 1960, pl. 10, fig. 22; Smith, 1964, p. B41, pl. 3, fig. 10; Ingle, 1973, p. 545, 549; Lankford and Phleger, 1973, p. 125, pl. 6, fig. 10; Haller, 1980, p. 262, pl. 14, fig. 6.

Ecology

Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Cushman & Todd, 1947b, Plio? Pleis?, Amchitka Is., AK.
Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.
  This species was found between the depths of 30 and 206 meters.
Cushman & Todd, 1947a, R, shallow water, coast of WA.
Lankford & Phleger, 1973, R, W. coastal N. America.
Resig, 1958, R, Santa Cruz Basin, CA.
Crouch, 1952, R, 11 deep basins off southern CA.
Cushman & Moyer, 1930, R, San Pedro, CA.
  The species was found at a depth of 33 meters.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Douglas & Heitman, 1979, R, so. California borderland.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Butcher, 1951, R, Coronado Bank, San Diego, CA.
  This species was found occurring in low relative frequency between the depths of 110 and 900 meters.
Uchio, 1960, R, living & dead, San Diego, CA.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
  This species was found to be a non-dominant member of the inner shelf biofacies between the depths of 18 and 37 meters, with water temperatures ranging from 14.0 to 18.0°C.
Smith, 1964, R, El Salvador & Nicaragua.
Cushman & Todd, 1943, Cretaceous to R, Pullenia.
  This species has been reported in Miocene to recent deposits.

Distribution

Pullenia salisburyi was obtained in low quantities from mud, sand and sandy mud layers between the depths of 120 and 469.5 cm downcore. The taxon accounts for between less than 1 and 1.5% of the assemblage in the mud intervals. And as with the mud layers, Pullenia salisburyi most often comprises less than 1% of the fauna in the sand and sandy mud deposits, but peaks at 1.1% in the sample taken from 133.5 to 136.5 cm downcore.

Pullenia spp.

Plate 22, figures 1, 2, 5

Pullenia sp. A. Plate 22, figure 1. The single specimen is characterized by a planispiral involute test composed of eight non-inflated chambers. The aperture is a very thin, elongate, interiomarginal slit running nearly from umbilicus to umbilicus. The sutures are barely, if at all, depressed.

Pullenia sp. B. Plate 22, figure 5. The four specimens are characterized by a planispiral involute test made up of six inflated chambers, resulting in a lobate periphery. The aperture is a rather wide crescentic arch, interiomarginally located, running nearly from umbilicus to umbilicus. The sutures are distinctly depressed.

Pullenia sp. C. Plate 22, figure 2. Three large individuals, characterized by planispiral involute tests composed of five inflated chambers, are assigned to this species. Each test has a lobate periphery and an inflated apertural face. The aperture is a thin interiomarginal arch running nearly from umbilicus to umbilicus and the sutures are depressed.

Ecology

Bandy, 1960b, general trends.
Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

A single specimen of Pullenia sp. A was recovered in the mud interval lying from 80 to 82 cm downcore. Two examples of Pullenia sp. B were obtained from the mud intervals located from 120 to 122 and 270 to 272 cm, while two other specimens, accounting for less than 1% of the faunal assemblage, were recovered from the sandy mud layer from 180 to 182 cm. In addition, singular specimens of Pullenia sp. C were obtained from three samples in this study. Two of the individuals were recovered from the mud intervals lying from

270 to 272 and 310 to 312 cm downcore. The third was extracted from the sand deposit between 412 and 414.5 cm.

Pyrgo depressa (d'Orbigny)
Plate 5, figure 3

Biloculina depressa d'Orbigny; d'Orbigny, 1826, p. 298, modeles no. 91; Cushman, 1917, p. 74-75, pl. 28, figs. 1-2; Cushman, 1927a, p. 140, pl. 2, fig. 2.
Pyrgo depressa (d'Orbigny); Drooger, 1953, p. 121, pl. 19, fig. 11; Barker, 1960, p. 4, pl. 2, figs. 12, 16, 17; Bandy and Rodolfo, 1964, p. 828, fig. 5B; Ingle, 1973, p. 563; Matoba and Yamaguchi, 1982, p. 1045.

Ecology

Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Resig, 1958, R, Santa Cruz Basin, CA.
Crouch, 1952, R, 11 deep basins off southern CA.
Bagg, 1912, Plio-Pleis (?), so. CA., Timms Point+.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman, 1917, R, Pacific Ocean, Miliolidae.

Distribution

With the exception of a single specimen of *Pyrgo depressa* recovered from the sand interval at 133.5 to 136.5 cm downcore, the taxon was obtained exclusively from mud intervals in the upper half of the core. Recovered in a total of six samples between the depths of 120 and 192 cm, *Pyrgo depressa* nearly always comprises less than 1% of the assemblage. Only in the mud layer from 120 to 122 cm does the species account for a maximum of 1.8% of the fauna.

Pyrgo murrhina (Schwager)
Plate 5, figures 1, 2

Biloculina murrhyna Schwager; Schwager, 1866, p. 203, pl. 4, fig. 15; Cushman, 1917, p. 75, pl. 28, fig. 3; pl. 29, fig. 1.
Pyrgo murrhina (Schwager); Cushman (in part), 1932, p. 64-65, pl. 15, figs. 1-2; Phleger and Parker, 1951, p. 7, pl. 3, fig. 11; Uchio, 1960, pl. 2, fig. 25; Bandy, 1961, p. 16, pl. 5, fig. 5; Ingle, 1973, p. 536, 545, 553, 556, 563; Matoba and Yamaguchi, 1982, p. 1048.
Pyrgo murrhyna (Schwager); Barker, 1960, p. 4, pl. 2, figs. 10, 11, 15.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Crouch, 1952, R, 11 deep basins off southern CA.
Bandy, 1963a, R, so. CA. continental borderland.
Bandy & Chierici, 1966, R, California & Mediterranean.
Bagg, 1912, Plio-Pleis (?), so. CA., Timms Point+.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a non-dominant member of the upper middle bathyal biofacies between the depths of 1219 and 1524 meters, with water temperatures ranging from 2.5 to 3.5°C.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Resig, 1976, Eocene-R, DSDP, Nazca Plate, Peru.
Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
Phleger, 1951b, R, Northwest Gulf of Mexico.
Phleger & Parker, 1951, R, NW Gulf of Mex. & Atlantic.
Cushman & Todd, 1945, Mio, Buff Bay, Jamaica.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman, 1932, R, tropical Pacific, Astrohiz.-Trocham.
Cushman, 1917, R, Pacific Ocean, Miliolidae.

Distribution

Examples of *Pyrgo murrhina* were obtained in mud, sand and sandy mud deposits between the depths of 80 and 272 cm downcore and in the lowermost sample from 467.5 to 469.5 cm. Associated primarily with the mud layers, the species generally comprises less than 1% of the fauna, but peaks at 1.3 and 3.0% in the mud intervals from 167.5 to 170 and 120 to 122 cm, respectively. In the one sand and two sandy mud layers where it was obtained, *Pyrgo murrhina* accounts for less than 1% of the faunal assemblage.

Quinqueloculina akneriana d'Orbigny
Plate 3, figure 6

Quinqueloculina akneriana d'Orbigny; d'Orbigny, 1846, p. 290, pl. 18, figs. 16-21; Galloway and Wissler, 1927, p. 38-39, pl. 7, fig. 3; Cushman, Stewart, and Stewart, 1930, p. 52, pl. 2, fig. 1; Ingle, 1973, p. 549; Haller, 1980, p. 231, pl. 2, fig. 4.

Ecology

Green, 1960, R, central Arctic Basin.

One of the four good indicator species defined by Green for the abyssal biofacies in central Arctic Basin. The abyssal region here is defined by these parameters: depth between 2250 and 2760 meters, temperature ranging between -0.40 and -0.42°C, and salinity unknown but probably 35°/oo. "Curtis (1955) pointed out that *Quinqueloculina* is typically found in shallow water but is not excluded from a deeper habitat."

Lagoe, 1977, R, central Arctic Ocean.
Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Cooper, 1961, R, intertidal, CA. & Oregon coast.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Bandy, 1963b, R, paralic, so. CA. & Gulf of CA.
Galloway & Wissler, 1927, Pleis, Palos Verdes, CA.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Bandy, 1956, general trends.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Curtis, 1955, Eocene, Texas, *Quinqueloculina*.

Distribution

Four mud intervals and one sand layer between the depths of 369.5 and 447.5 cm downcore yielded specimens of *Quinqueloculina akneriana*. The taxon always accounts for less than 1% of the faunal assemblage.

Quinqueloculina elongata Natland
Plate 4, figure 2

Quinqueloculina elongata Natland; Natland, 1938, p. 141-142, pl. 4, fig. 5; Lankford and Phleger, 1973, p. 126, pl. 1, fig. 19; Haller, 1980, p. 231, pl. 2, fig. 6; Matoba and Yamaguchi, 1982, p. 1048.

Ecology

Cushman & Todd, 1947a, R, shallow water, coast of WA.
Lankford, 1962, R, turbulent zone, W. coastal N. America.
Lankford & Phleger, 1973, R, W. coastal N. America.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy, 1956, general trends.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Curtis, 1955, Eocene, Texas, *Quinqueloculina*.

Distribution

Two poorly preserved specimens of *Quinqueloculina elongata*, accounting for less than 1% of the faunal assemblage, were recovered from the mud interval located 346.5 to 349.5 cm downcore.

Quinqueloculina spp.
Plate 4, figures 1, 7

Quniqueloculina sp. A. Plate 4, figure 1. Single specimen. Robust test, slightly elongate in side view, approximately two times as long as broad. Surface smooth, aperture obscured so no tooth could be seen. Very large apertural opening.

Quinqueloculina sp. B. Plate 4, figure 7. Single specimen. Normal size test, approximately two times as long as broad. Aperture a small opening, obscured so no tooth could be seen. Smooth surface texture.

Quinqueloculina spp. Other specimens were recovered but could not be identified due to their poor preservational state.

Ecology

Ingle, 1980, Tertiary, so. CA. continental borderland.
Bandy, 1956, general trends.
Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Douglas & Woodruff, 1981, deep-sea benthonic forams.
Curtis, 1955, Eocene, Texas, *Quinqueloculina*.

Distribution

A single specimen of *Quinqueloculina* sp. A was recovered from the sandy mud sample located from 369.5 to 372.5 cm downcore, while the representative of *Quinqueloculina* sp. B was obtained from the mud interval lying between 167.5 and 170 cm. In addition, singular unidentified specimens of *Quinqueloculina* were acquired from two mud intervals sampled from 330 to 332 and 445 to 447.5 cm downcore.

Recurvoides spp.
Plate 1, figure 9

Recurvoides spp. Three specimens, one of which is figured, are assigned to this genus. Their tests are primarily finely arenaceous, but occasional coarse grains are seen. The chambers are initially planispirally arranged, but begin to coil in a slightly different direction in the adult test. The aperture is usually not apparent, but in the figured specimen, is an interiomarginal oval surrounded by a lip. Time did not permit identification to the specific level.

Ecology

Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.
Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

Three specimens of *Recurvoides*, accounting for 1.2% of the faunal assemblage, were recovered from the mud interval located from 20 to 23.5 cm downcore.

Reophax communis Lacroix
Plate 1, figure 4

Reophax communis Lacroix; Lacroix, 1930, p. 4-5, tfs. 5-7; Uchio, 1960, pl. 1, fig. 3.

Ecology

Morin, 1971, late Q, San Francisco, L.A., Baja CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Uchio, 1960, R, living & dead, San Diego, CA.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman & McCulloch, 1939, R, Hancock Exp., Arenaceous.

Distribution

Fragmented examples of *Reophax communis* were acquired from the mud interval located from 20 to 23.5 cm downcore.

Reophax dentaliniformis Brady
Plate 1, figure 7

Reophax dentaliniformis Brady; Brady, 1881, p. 49; Hanna and Church, 1927, p. 200; Barker, 1960, p. 62, pl. 30, figs. 21-22; Uchio, 1960, pl. 1, fig. 4; Phleger, 1964, pl. 1, fig. 1; Smith, 1964, p. B27, pl. 1, fig. 2; Haynes, 1981, p. 109, key fig. 6.9, fig. 15.

Ecology

Smith, 1973, Pleis? & Holocene, North Pacific Ocean.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Hanna & Church, 1927, R, San Francisco Bay, CA.
Morin, 1971, late Q, San Francisco, L.A., Baja CA.
Cushman & Moyer, 1930, R, San Pedro, CA.
This species was found only at a depth of 338 meters.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Phleger, 1964, living, Gulf of California.
Smith, 1964, R, El Salvador & Nicaragua.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Phleger & Parker, 1951, R, NW Gulf of Mex. & Atlantic.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman, 1910, R, Pacific Ocean, Arenaceous.
Cushman & McCulloch, 1939, R, Hancock Exp., Arenaceous.

Distribution

Three specimens of *Reophax dentaliniformis*, comprising 1.2% of the faunal assemblage, were recovered from the mud interval lying between 20 and 23.5 cm downcore.

Reophax distans gracilis Earland
Plate 1, figure 8

Reophax distans Brady var. *gracilis* Earland; Earland, 1933, p. 76, pl. 2, fig. 21.

Ecology

Morin, 1971, late Q, San Francisco, L.A., Baja CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Uchio, 1960, R, living & dead, San Diego, CA.
Walton, 1955, R, Todos Santos Bay, Baja CA., Mexico.
Phleger, 1964, living, Gulf of California.
Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

Fragmented examples of *Reophax distans gracilis* were acquired from the mud layer located from 20 to 23.5 cm downcore.

Reophax (?) sp.
Plate 1, figure 5

Reophax (?) sp. The single specimen is characterized by two uniserial, non-overlapping, spherical chambers. The wall is finely arenaceous and no aperture is apparent.

Ecology

Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

A single specimen, questionably assigned to the genus *Reophax*, was obtained in the mud interval lying between 60 and 63 cm downcore.

Robertina bradyi Cushman and Parker
Plate 12, figure 8

Robertina bradyi Cushman and Parker; Cushman and Parker, 1936, p. 99, pl. 16, fig. 9

Ecology

Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
Cushman & Parker, 1936, R, species of *Robertina*
    Cushman and Parker noted that the holotype was collected in the Caribbean Sea and that other specimens were obtained at *Albatross* Station D2150 in 699 meters of water.
Cushman & Parker, 1947, Mio-R, *Bulimina*.

Distribution

A single specimen of *Robertina bradyi* was recovered from the mud interval located from 210 to 212 cm downcore.

Rosalina columbiensis (Cushman)
Plate 23, figures 3, 5; Plate 24, figure 1

Discorbis columbiensis Cushman; Cushman, 1925b, p. 43, pl. 6, fig. 13.
Rosalina columbiensis (Cushman); Uchio, 1960, p. 66, pl. 8, figs. 1-2; Smith, 1964, p. B44, pl. 5, fig. 2; Lankford and Phleger, 1973, p. 127-128, pl. 5, figs. 10-12; Wagner, 1978, p. 201-203, pl. 3, fig. 10, pl. 4, figs. 1-2; Haller, 1980, p. 255, pl. 10, figs. 2, 4; Ingle, Keller, and Kolpack, 1980, p. 144.

Ecology

Cockbain, 1963, R, Juan de Fuca & Georgia Sts., B.C.
    This species was found between the depths of 30 and 115 meters.
Cushman & Todd, 1947a, R, shallow water, coast of WA.
Lankford, 1962, R, turbulent zone, W. coastal N. America.
Lankford & Phleger, 1973, R, W. coastal N. America.
Haller, 1980, Plio, Humboldt Basin, California.
Douglas & Heitman, 1979, R, so. California borderland.
Uchio, 1960, R, living & dead, San Diego, CA.

Phleger & Ewing, 1962, R, lagoons, Baja CA., Mexico.
Smith, 1964, R, El Salvador & Nicaragua.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Phleger, Parker and Peirson (?), 1953, R, eq.-N. Atlantic.
Bradshaw, 1961, lab experiments on shallow forams.

Distribution

Present in mud, sand and sandy mud layers, Rosalina columbiensis was recovered between the depths of 20 and 469.5 cm downcore. In the mud intervals, the taxon comprises between less than 1 and 5.3% of the assemblage. In the sand and sandy mud layers, the species accounts for less than 1 to 1.5% of the fauna.

Saccammina spherica M. Sars
Plate 1, figure 6

Saccammina sphaerica M. Sars; M. Sars, 1869, p. 248; Cushman and Stainforth, 1945, p. 13, pl. 1, fig. 5.
Saccammina sphaerica G.O. Sars; Cushman, 1910, p. 39-40, figs. 33-36.

Ecology

Saccammina spherica M. Sars has been found as far north as the Amerasian Basin of the Arctic Ocean, where it was a constituent of the Trochammina nana biofacies between 17 and 350 meters (Lagoe, 1979a). In the North Pacific, this species is well distributed in the colder waters (Cushman, 1910). It was found to comprise 6% of the total faunal assemblage at 7230 meters in the Aleutian Trench and slightly less than 4% of the population at a depth of 4650 meters west of that region (Smith, 1973). In the Gulf of Alaska from the Kodiak Shelf to Cape Fairweather, the species also constituted a large portion of the middle to lower bathyal assemblage. It comprised a maximum of 4 and 6% of the population at 2281 and 1244 meters of water, respectively (Bergen and O'Neil, 1979).

The taxon has also been reported from lower latitude waters of the North Pacific. Off Monterey Bay, California at 36°36.5' N, 122°53' W, Saccammina spherica was collected in a bottom sample obtained at a depth of 2939 meters by the U.S. Coast and Geodetic Survey ship Discoverer (Cushman, 1927). It was also recovered near the turn of the century from the middle of the North Pacific at a tremendous depth of 3749 meters (Cushman, 1910). Considerably later, Smith (1973) obtained the species in a dredging of recent sediments northeast of the Hawaiian Islands in 5830 meters of water located approximately at 30°N, 160°W. Three of the 10 individuals of the depauperate assemblage encountered here were Saccamminia spherica. the species was also recovered in recent deposits obtained midway between San Francisco and the Hawaiian Islands at a depth of 3813 meters and from the colder waters south of Japan between 254 and 2836 meters water depth (Cushman, 1910). In addition, it is interesting to note that spherical benthonic foraminifers, such as Saccammina, have been positively correlated with subsurface deposit feeders in the abyssal central North Pacific (Bernstein and others, 1978).

Further south, this species has been reported off the Coast of Mexico as well. It was recovered in water depths between 1207 and 1820 meters in this region by the cruises of the Albatross (Cushman, 1910) and at 457 meters near Guadalupe Island by the Allan Hancock Pacific Expeditions (Cushman and McCulloch, 1939). In addition, Oligocene representatives of the taxon have been found associated with the Cipero Marl Formation outcrops exposed on Trinidad (Cushman and Stainforth, 1945).

Saccammina spherica is a constituent of recent benthonic foraminiferal assemblages in the Arctic and North Pacific Oceans. Its distribution has been positively correlated with the presence of colder water temperatures and subsurface deposit feeders in the abyssal regions of the North Pacific Ocean. Bathymetrically, the taxon appears to be highly variable, ranging from 17 to 1730 meters water depth. Yet, in the North Pacific just south, east and north of the area being investigated in this study, Saccammina spherica is associated with recent deposits recovered at great depths: often between 2000 and >4000 meters.

Distribution

Singular specimens of Saccammina spherica were recovered from three mud intervals in the upper portion of the core: in the core-top from 0 to 4 cm, and from 60 to 63 and 96.5 to 100 cm downcore.

Saracenaria sp.
Plate 5, figure 9

Saracenaria sp. The four specimens assigned to this genus are all megalospheric forms. The tests are characterized by a low number of chambers, usually three, with the later chambers uncoiling. The apertural face is greatly broadened and roughly triangular, with a radiate aperture present at the peripheral margin. Time did not permit identification to the specific level.

Ecology

Ingle, 1980, Tertiary, so. CA. continental borderland.
Bandy & Arnal (?), 1957, R, W. coast of Central America.
Smith (?), 1964, R, El Salvador & Nicaragua.

Distribution

Three representatives of the genus *Saracenaria*, accounting for less than 1% of the assemblage, were obtained from the mud interval lying between 139 and 143 cm downcore. An additional specimen was recovered from the mud layer located from 346.5 to 349.5 cm.

Sigmoilina cf. *S. tenuis* (Czjzek)
Plate 4, figure 6

Quinqueloculina tenuis Czjzek; Czjzek 1848, p. 149, pl. 13, figs. 31-34.
Sigmoilina tenuis (Czjzek); Cushman and Stainforth, 1945, p. 21, pl. 2, fig. 21; Cushman, 1946, p. 32-33, pl. 5, figs. 13-15; Matoba and Yamaguchi, 1982, p. 1048, pl. 1, fig. 1.
"*Sigmoilina*" *tenuis* (Czjzek); Barker, 1960, p. 20, pl. 10, figs. 7, 8, 11; Haller, 1980, p. 232, pl. 2, fig. 9.

Ecology

Green, 1960, R, central Arctic Basin.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Resig, 1958, R, Santa Cruz Basin, CA.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Bandy & Chierici, 1966, R, California & Mediterranean.
Bagg, 1912, Plio-Pleis (?), so. CA., Timms Point+.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Butcher, 1951, R, Coronado Bank, San Diego, CA.
This species was found occurring in low relative frequency between the depths of 100 and 1025 meters. Butcher noted that the taxon may occur in greater abundance below 1000 meters.
Uchio, 1960, R, living & dead, San Diego, CA.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a non-dominant member of the outer shelf biofacies between the depths of 37 and 73 meters, with water temperatures ranging from 12.5 to 18.0°C.
Natland, 1950, Plio-Pleis, Gulf of CA., outcrops.
"Rare in Pliocene beds of this report." Off southern California, the species was found in recent deposits between the depths of 20 and 1100 meters. *Sigmoilina tenuis* was also obtained in recent sediments at a depth of 38 to 2100 meters off Central America.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Cushman, 1929b, Late Tertiary, Venezuela & Ecuador.
Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
Phleger & Parker, 1951, R, NW Gulf of Mex. & Atlantic.
Bock, 1976 & 1982, R, shallow, Gulf of Mexico.
Cushman & Stainforth, 1945, Oligocene, Trinidad.
Cushman & Todd, 1945, Mio, Buff Bay, Jamaica.
Cushman, 1946, Tertiary-R, *Sigmoilina*.
McCulloch, 1977, more Allan Hancock Exped. forams.

Distribution

Two representatives of the taxon, accounting for less than 1% of the assemblage, were obtained from the mud interval lying from 270 to 272 cm downcore. Singular specimens of *Sigmoilina* cf. *S. tenuis* were also recovered from the successive mud and sand samples located between 330 and 338 cm.

Sigmoilina sp.
Plate 4, figure 5

Sigmoilina sp. Specimens assigned to this genus are characterized by an imperforate test and a terminal, rounded aperture. Four chambers are exposed on one side, five on the other. Chambers are added in such a way as to form a somewhat sigmoid appearance in apertural view. Time did not permit identification to the specific level.

Ecology

Blanc-Vernet, 1969, R, Mediterranean.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

Two specimens of Sigmoilina sp., comprising less than 1% of the faunal assemblage, were recovered from the sand interval located between 133.5 and 136.5 cm downcore.

Siphotextularia catenata (Cushman)

Textularia catenata Cushman; Cushman, 1911, p. 23, figs. 39-40.
Siphotextularia catenata (Cushman); McDougall, 1985, p. 385, 398.

Ecology

Cushman, 1911, R, Pacific Ocean, Textularids.
Murray, 1973, R, general ecology & distribution.

Distribution

Representatives of Siphotextularia catenata were recovered from 20 to 23.5, 167.5 to 170, and 230 to 447.5 cm downcore. Although acquired from sand and sandy mud intervals as well as the mud layers, the taxon is most abundant in the finer-grained deposits. In the muds, Siphotextularia catenata comprises between less than 1 and 1.3% of the fauna. In contrast, only singular specimens of the taxon were obtained from the sand and sandy mud intervals.

Stainforthia complanta (Egger)
Plate 15, figure 1

Virgulina schreibersiana Czjzek var. complanta Egger; Egger, 1895, p. 292, pl. 8, figs. 91-92.
Virgulina complanta Egger; Phleger and Parker, 1951, p. 19, pl. 9, figs. 1-3; Uchio, 1960, pl. 6, fig. 13; Smith, 1964, p. B33, pl. 2, fig. 11.
Cassidella complanata; Bandy and Rodolfo, 1964, p. 829, fig. 5C.
Fursenkoina complanata (Egger); Ingle, 1973, p. 542, 545, 553.
Stainforthia complanta (Egger); Ingle, Keller, and Kolpack, 1980, p. 144, pl. 5, figs. 10-11; Matoba and Yamaguchi, 1982, p. 1049.

Ecology

Lagoe, 1977, R, central Arctic Ocean.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Bandy & Chierici, 1966, R, California & Mediterranean.
Uchio, 1960, R, living & dead, San Diego, CA.
Brenner, 1962, R, shallow, Gulf of California.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Smith, 1964, R, El Salvador & Nicaragua.
Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Resig, 1976, Eocene-R, DSDP, Nazca Plate, Peru.
Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
Phleger, 1951b, R, Northwest Gulf of Mexico.
Phleger & Parker, 1951, R, NW Gulf of Mex. & Atlantic.
Bock, 1976 & 1982, R, shallow, Gulf of Mexico.
Cushman & Todd, 1945, Mio, Buff Bay, Jamaica.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman, 1942, R, tropical Pacific, Hetero.-Bulimin.

Distribution

Six samples, including both mud and sand layers between the depths of 171 and 414.5 cm downcore, contain low abundances of Stainforthia complanta. With the exception of three specimens which were recovered from the mud interval from 410 to 412.5 cm, only singular representatives of the taxon were present in each of the samples. In all cases, Stainforthia complanata comprises less than 1% of the faunal assemblage.

Stainforthia nodosa (Stewart and Stewart)
Plate 15, figure 2

Virgulina nodosa Stewart and Stewart; Stewart and Stewart, 1930, p. 64, pl. 8, fig. 4; White, 1956, p. 254, pl. 30, fig. 11; Smith, 1964, p. B33.
Stainforthia nodosa (R.E. and K.C. Stewart); Ingle, 1976, p. 536, 556.

Ecology

Green, 1960, R, central Arctic Basin.
Resig, 1958, R, Santa Cruz Basin, CA.
Crouch, 1952, R, 11 deep basins off southern CA.
Martin, 1952, Plio, Los Angeles Basin, CA.
This species was found present in the Repetto and Pico Formations.
White, 1956, Mio-Plio, Capistrano Fm., Orange Co., CA.
This species was reported to occur rarely in Pliocene deposits of the Upper Capistrano Formation.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a non-dominant member of the upper middle bathyal biofacies between the depths of 610 and 914 meters, with water temperatures ranging from 3.5 to 4.5°C.
Bandy & Arnal, 1957, R, W. coast of Central America.

Distribution

Low abundances of *Stainforthia nodosa* were obtained from mud, sand and sandy mud intervals between the depths of 230 and 469.5 cm downcore. The taxon comprises less than 1% of the assemblage in six of the seven samples they were recovered from, while peaking at 1.2% in the mud sample from 430 to 432.5 cm.

Stilostomella cf. *S. lepidula* (Schwager)
Plate 7, figure 3

Nodosaria lepidula Schwager; Schwager, 1866, p. 210, pl. 5, figs. 27-28.
Nodogenerina lepidula (Schwager); Cushman, Stewart, and Stewart, 1930, p. 63-64, pl. 4, fig. 5.
Siphonodosaria lepidula (Schwager); Walton, 1952, p. 139, pl. 25, fig. 12.
Stilostomella lepidula (Schwager); Ingle, 1973, p. 536; Haller, 1980, p. 252, pl. 8, fig. 7.

Ecology

Ingle, 1973, N, DSDP Site 172, between CA. & Hawaii.
Natland (?), 1933, R and Pico Fm., San Pedro & Ventura, CA.
White, 1956, Mio-Plio, Capistrano Fm., Orange Co., CA.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Natland, 1950, Plio-Pleis, Gulf of CA., outcrops.

Distribution

One fragmented specimen of *Stilostomella* cf. *S. lepidula* was recovered from the sand interval located from 133.5 to 136.5 cm downcore.

Stilostomella sp.
Plate 7, figure 2

Stilostomella sp. The single fragmented specimen is characterized by two slightly embracing, uniserial chambers separated by a depressed suture at right angles to the axis of the test. The aperture is terminal and round and the test wall finely perforate. The lower half of each chamber is adorned with eight costae of low relief, which fall in a direct line with those of the preceeding chamber.

Ecology

Ingle, 1980, Tertiary, so. CA. continental borderland.
Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

One fragmented specimen of *Stilostomella* sp. was recovered from the sand interval located from 133.5 to 136.5 cm downcore.

Suggrunda eckisi Natland
Plate 16, figure 8

Suggrunda eckisi Natland; Natland, 1950, p. 23, pl. 9, fig. 12; Smith, 1963a, p. A24-A25, pl. 31, figs. 13-14; Matoba and Yamaguchi, 1982, p. 1049, pl. 3, fig. 10.
Suggrunda (?) *eckisi* Natland; Uchio, 1960, pl. 7, figs. 5-6.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.
Harman, 1964, R, Santa Barbara Basin, CA.

Crouch, 1952, R, 11 deep basins off southern CA.
Marks and others, 1980, R, Santa Barbara Channel, CA.
Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.
Douglas & Heitman, 1979, R, so. California borderland.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Uchio, 1960, R, living & dead, San Diego, CA.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
    This species was found to be a dominant member of the upper bathyal biofacies between the depths of 366 and 610 meters, with water temperatures ranging from 4.5 to 6.0°C.
Natland, 1950, Plio-Pleis, Gulf of CA., outcrops.
    This species was recovered off southern California in recent deposits between the depths of 260 and 600 meters. In recent sediments off the west coast of Central America, *Suggrunda eckisi* was obtained between 81 and 1760 meters.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Smith, 1963a, R, Bolivinidae, El Salvador & Nicaragua.
Smith, 1964, R, El Salvador & Nicaragua.

Distribution

With the exception of two specimens recovered from the mud interval located from 270 to 272 cm downcore, *Suggrunda eckisi* is associated exclusively with sand and sandy mud deposits between the depths of 133.5 and 232 cm in this core. The taxon accounts for less than 1% of the assemblage in the samples, except for the sand interval from 133.5 to 136.5 cm where it peaks at 3.2%.

Trifarina angulosa (Williamson)

Plate 17, figure 7

Uvigerina angulosa Williamson; Williamson, 1858, p. 67, pl. 5, fig. 140; Hanna and Church, 1927, p. 202.
Angulogerina angulosa (Williamson); Cushman, Stewart and Stewart, 1930, p. 71, pl. 5, fig. 14; Cushman, 1948, key pl. 28, figs. 13, 14; Cushman and McCulloch, 1948a, p. 279-280, pl. 35, fig. 6; Marks, 1951, p. 63, pl. 7, fig. 16; Bandy, 1953a, p. 176, pl. 25, fig. 13; Boltovskoy, 1959, p. 475, pl. 2; Barker, 1960, p. 154, pl. 74, figs. 15, 16; Uchio, 1960, pl. 7, fig. 18; Boltovoskoy and others, 1980, p. 16, pl. 1, figs. 13-16; Haller, 1980, p. 253, pl. 7, fig. 10; Todd and Low, 1981, p. 32, 43, fig. 93; Matoba and Yamaguchi, 1982, p. 1036.
Trifarina angulosa (Williamson); Lankford and Phleger (in part), 1973, p. 129, pl. 3, fig. 29; Ingle, Keller, and Kolpack, 1980, p. 144, pl. 3, figs. 1, 4; Ingle, 1973, pp. 542, 549, 560, 562, 563.

Ecology

Trifarina angulosa (Williamson) is a cosmopolitan species (Bagg, 1912) which prefers to live in shallow waters. In boreal environments it inhabits shallower depths than in the warmer tropical water masses (Brenner, 1962). Recent offshore sediments of Baffin Bay contained specimens which usually make up 5% or less of the fauna and primarily represent water depths of less than approximately 250 meters (Phleger, 1952). Cushman and McCulloch (1948) have also recorded this species in waters as shoal as four meters off Alaska. Recent specimens have been recovered off British Columbia and in the Juan de Fuca and Georgia Straits, in 34 to 206 meters water depth (Cockbain, 1963).

In a review of the benthonic foraminifers of the western North American nearshore turbulent zone from Oregon to Panama, some difficulty was encountered discerning several species of *Trifarina* (Lankford, 1962; Lankford and Phleger, 1973). These authors found it necessary to coalesce the gradational forms between *Trifarina angulosa*, *T. baggi* (Galloway and Wissler), *T. hughesi* (Galloway and Wissler) and *T. fluens* (Todd) into a single clade. This "*Trifarina angulosa*" group existed throughout the geographical region examined, occurring at all depths to the study's maximum of 40 meters and on all of the substrates encountered.

Recent representatives of *Trifarina angulosa* have also been reported from the San Francisco Bay area. In an early work, Hanna and Church (1927) discovered rare individuals in the finer material dredged near the Farallon Islands in 219 meters or less water depth. Later, Bandy (1953a) detected the presence of this species from 122 to 213 meters on a transect off the Bay itself.

Farther south along the California coast, numerous citings of *Trifarina angulosa* have been reported. A single transect off Point Arguello found it present at 187 to 366 meters (Bandy, 1953a). Cushman and Moyer (1930) reported rare individuals from recent sediments obtained from 64 to 91 meters water depth off San Pedro, California, noting that the species was widely distributed in cool waters. The Allan Hancock Pacific Expedition identified the species at numerous localities off the Channel Islands in 13 to 229 meters of water while Ingle (1980) reported its presence along the Southern California continental borderland. In the latter work, the taxon's distribution appeared to be transitional between the outer shelf and upper bathyal waters, located approximately at 150 meters in this region. Farther south along California, *Trifarina angulosa* was found at 61 to 244 meters water depth on a transect off San Diego (Bandy, 1953a) and at 100 to 880 meters, with a maximum abundance between 100 and 550 meters, in the Coronado Bank region (Butcher, 1951).

Walton (1955) studied living and dead foraminifers of Todos Santos Bay, Baja California, Mexico and assigned *Trifarina angulosa* to his marginal bay facies which was confined to the relatively shallow waters between the islands and the mainland. The species was found most abundantly at approximately 91 to 183 meters. Farther offshore, Cushman and McCulloch (1948) recorded the taxon near Guadalupe Island at 366 meters. Nearby in the Gulf of California, Bandy (1961) found *Trifarina angulosa* to be a dominant species in his outer shelf fauna, ranging from 73 to 152 meters water depth. Brenner (1962) discovered it in both the northern and southern halves of the Gulf, where it seemed to prefer inhabiting the shallow waters greater than 50 meters. The species is also considered an outer shelf (50 to 150 meters) to upper bathyal (150 to 600 meters) inhabitant in the Gulf by Matoba and Yamaguchi (1982).

Trifarina angulosa is also widely distributed across the Pacific Ocean, having been found by Brady (1884) in the North Pacific from 91 to 914 meters and near the Hawaiian Islands from 190 to 2454 meters (Cushman, 1913a). In addition, Cushman (1913a) notes its presence near Japan at 366 to 593 meters and in the Panama Bay at 93 meters.

In the Atlantic Ocean, *Trifarina angulosa* is quite widespread (Phleger, 1952). Off the northeastern coast of the United States, the taxon appears abundantly. It has been found on the continental shelf from the Gulf of Maine-Maryland (Parker, 1948), peaking in offshore transects from 90 to 300 meters and 300 to 680 meters. Yet, according to Parker (1948), it has no facies significance (Phleger, 1952). In the British Isles, the species has also been recorded in shelf waters (Murray, 1971): in the Celtic Sea at 128 to 138 meters; in the Bristol Channel at 66 to 91 meters; along the shelf edge from 420 to 1002 meters; in the English Channel from 84 to 95 meters; near Plymouth in 10 to 60 meters water; and along the south coast of Cornwall from 14 to 42 meters. Based on the works of Parker (1958) and Chierichi and others (1962), the taxon is considered representative of bathyal waters from approximately 150 to 250 meters in the Mediterranean Sea (Bandy and Chierichi, 1966). In the Southwestern Atlantic, Boltovskoy and others (1980) consider *Trifarina angulosa* a euhaline species which is associated with the shelf. The taxon has also been found abundantly around the Falkland Islands and rarely in the Antarctic (Phleger, 1952).

In conclusion, *Trifarina angulosa* is a geographically widely distributed species which appears to be associated with shallow continental shelf waters, often occupying depths down to approximately 250 meters.

Distribution

With the exception of one rare occurrence, *Trifarina angulosa* was recovered exclusively from the sand lenses sampled in this study. The taxon comprises less than 1% of the faunal assemblage of the sand intervals sampled between 46 and 338 cm downcore.

Trifarina hughesi (Galloway and Wissler)

Plate 17, figure 8

Uvigerina hughesi Galloway and Wissler; Galloway and Wissler, 1927, p. 76, pl. 12, fig. 5.

Angulogerina hughesi (Galloway and Wissler); Cushman, Stewart and Stewart, 1930, p. 70-71, pl. 5, fig. 16; Cushman and McCulloch, 1948, pl. 36, fig. 2.

Trifarina angulosa (Galloway and Wissler); Lankford and Phleger (in part), 1973, p. 129, pl. 3, fig. 30.

Ecology

Cushman and Todd (1947) reported collecting *Trifarina hughesi* from the shallow waters surrounding the islands and directly off the coast of Washington. Prior to this time, fossil specimens from Pliocene and Pleistocene deposits had exclusively been reported in the California region. Although occuring only rarely in the Washington area, these specimens were recovered in 18 and 27 meters water depth.

More numerous citings of this taxon have since been reported from the Washington-Oregon border southward. Lankford (1962) and Lankford and Phleger (1973) combined *Trifarina hughesi* and three other species into a clade and traced its presence in the nearshore turbulent zone of western North America (see *Trifarina angulosa*). They found the "group" present between the intertidal zone and 40 meters from Oregon to Panama on all of the substrates encountered. Cooper (1961) also reviewed recent species occupying the intertidal zone from Oregon to San Diego and included *Trifarina hughesi* in his faunal list. Bandy (1953a) reported this species in his taxonomy as well, but did not specify in which of his three transects, off San Francisco, Point Arguello, and San Diego, it was recovered. Similarly, no depth ranges were recorded for *Trifarina hughesi* in his work.

In Southern California this taxon has been retrieved commonly to rarely in the Pliocene deposits of the Capistrano Formation in Orange County (White, 1956). It was also a member of the Pleistocene fauna recovered from the Lomita

Quarry of Palos Verdes (Galloway and Wissler, 1927). In addition, Ingle (1980) has stated that the genera generally inhabits the vicinity of the shelf-edge in Neogene sediments of the Califorina continental borderland. Recent offshore deposits in the Santa Cruz Basin off Santa Barbara have also yielded *Trifarina hughesi* in the waters from 137 to 183 meters deep (Resig, 1958). Resig (1958) reported it as a member of a typical shallow-water fauna recovered from the vicinity of Santa Barbara Island in 18 meters of water, where it comprised five percent of the assemblage.

In Northern Mexico, *Trifarina hughesi* has been reported from the San Pedro, San Benito and Guadalupe Islands, as well as from the Gulf of California, in waters 31 to 896 meters deep (Cushman and McCulloch, 1948). Brenner (1962) also found this taxon in the shallow waters less than 80 meters deep in the northern and southern halves of the Gulf of California.

In conclusion, *Trifarina hughesi* appears to be a rare, but persistent member of the shallow water fauna along the western North American coastline.

Distribution

Only three individuals of this species were recovered in the Monterey Fan levee deposits of this study. All were associated with a single sand lens located 171 to 173 cm downcore and together they comprise less than 1% of the faunal assemblage of that interval. fauna.

Trifarina (?) sp.

Trifarina (?) sp. A single, very fragile and partly broken specimen was recovered. The test is slightly pyritized, and as a result, the inner chambers are obscured. The aperture is also broken, but appears to have a neck instead of a slit as is found in *Reussella* (i.e., an elongate opening from the base of the chamber in the apertural face). The test is triangular in transverse section, with each side appearing slightly concave.

Ecology

Murray, 1973, R, general ecology & distribution.
Boltovskoy & Wright, 1976, Recent Foraminifera.

Distribution

The single specimen of *Trifarina* (?) sp. was recovered from the sand interval located from 133.5 to 136.5 cm downcore.

Triloculina tricarinata d'Orbigny

Plate 4, figure 8

Triloculina tricarinata d'Orbigny; d'Orbigny, 1826, p. 299, modeles no. 94; Cushman, 1917, p. 66-67, pl. 25, figs. 1-2; Keijzer, 1935, p. 29, fig. 6; Phleger, Parker and Peirson, 1953, p. 28, pl. 5, fig. 21; Barker, 1960, p. 6, pl. 3, fig. 17.
Miliolina tricarinata Heron-Allen and Earland; Heron-Allen and Earland, 1915, p. 562.

Ecology

Green, 1960, R, central Arctic Basin.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Bagg, 1912, Plio-Pleis (?), so. CA., Timms Point+.
Smith, 1964, R, El Salvador & Nicaragua.
Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
Bandy, 1956, general trends.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Heron-Allen & Earland, 1915, foram var., Port. E. Afr.
Keitzer, 1935, R, foram variability, Bali, Java+.
Cushman, 1932, R, tropical Pacific, Astrohiz.-Trocham.
Cushman, 1917, R, Pacific Ocean, Miliolidae.

Distribution

Representatives of *Triloculina tricarinata* were obtained in samples throughout the length of the core. Recovered from mud, sand and sandy mud intervals between the depths of 20 and 469.5 cm downcore, the taxon most often accounts for less than 1% of the assemblage. However, in the mud layer from 410 to 412.5 cm, *Triloculina tricarinata* peaks at 1.0%. In addition, in the successive sand and sandy mud samples taken between 171 and 182 cm, the species rises to 1.4 and 1.0% of the fauna, respectively.

Triloculina trigonula (Lamarck)
Plate 4, figure 9

Miliolites trigonula Lamarck; Lamarck, 1804, p. 351, pl. 17, fig. 4.
Triloculina trigonula (Lamarck); Cushman, 1917, p. 65-66, pl. 25, fig. 3; Keijzer, 1935, p. 29-30, fig. 7; Barker, 1960, p. 6, pl. 3, figs. 15-16; Ingle, Keller and Kolpack, 1980, p. 146; Haynes, 1981, p. 176, key fig. 8.12, fig. 7; Todd and Low, 1981, p. 23, 45, fig. 66; Matoba and Yamaguchi, 1982, p. 1049.

Ecology

Cushman & Todd, 1947a, R, shallow water, coast of WA.
Lankford, 1962, R, turbulent zone, W. coastal N. America.
Lankford & Phleger, 1973, R, W. coastal N. America.
Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
McGlasson, 1959, R, living & dead, S. Catalina Is., CA.
Cushman & Valentine, 1930, R, Channel Ids., so. CA.
Bagg, 1912, Plio-Pleis (?), so. CA., Timms Point+.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a non-dominant member of the inner shelf biofacies between the depths of 0 and 18 meters, with water temperatures ranging from 11.0 to 33.0°C.
Brenner, 1962, R, shallow, Gulf of California.
Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Bandy, 1956, general trends.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Heron-Allen & Earland, 1915, foram var., Port. E. Afr.
Keitzer, 1935, R, foram variability, Bali, Java+.
Cushman, 1932, R, tropical Pacific, Astrohiz.-Trocham.
Cushman, 1917, R, Pacific Ocean, Miliolidae.

Distribution

One specimen of Triloculina trigonula was recovered from the mud interval located 20 to 23.5 cm downcore.

Trochammina globigeriniformis (Parker and Jones)
Plate 3, figure 4

Lituola nautiloidea Lamarck var. globigeriniformis Parker and Jones; Parker and Jones, 1865, p. 407.
Trochammina globigeriniformis (Parker and Jones); Cushman, 1910, p. 124-125, figs. 193-195; Phleger, 1964, p. 383, pl. 1, fig. 21; Ingle, Keller and Kolpack, 1980, p. 146, pl. 5, figs. 12-13.
Ammoglobigerina globigeriniformis (Parker and Jones); Barker, 1960, p. 72, pl. 35, fig. 10.

Ecology

Green, 1960, R, central Arctic Basin.
Bergen & O'Neil, 1979, R, Gulf of Alaska.
Smith, 1973, Pleis? & Holocene, North Pacific Ocean.
Cushman, 1927a, R, W. coast, Oregon to Central Amer.
Cushman & Moyer, 1930, R, San Pedro, CA.
This species was found only at a depth of 33 meters.
Douglas & Heitman, 1979, R, so. California borderland.
Uchio, 1960, R, living & dead, San Diego, CA.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a non-dominant member of the outer shelf biofacies between the depths of 73 and 152 meters, with water temperatures ranging from 10.0 to 12.5°C.
Phleger, 1964, living, Gulf of California.
Bandy & Rodolfo (?), 1964, R, so. Ecuador to central Chile.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Parker, 1948, R, cont. shelf, Gulf of Maine-Maryland.
Cushman, 1910, R, Pacific Ocean, Arenaceous.

Distribution

Nine representatives of Trochammina globigeriniformis, constituting 3.6% of the faunal assemblage, were recovered from the mud interval located between 20 and 23.5 cm downcore.

Trochammina pacifica simplissima
Cushman and McCulloch
Plate 3, figure 3

Trochammina pacifica Cushman var. simplex Cushman and McCulloch; Cushman and McCulloch, 1939, p. 104, pl. 11, fig. 4.

Trochammina pacifica Cushman var. *simplissima* Cushman and McCulloch; Cushman and McCulloch, 1948b, p. 76; Bandy and Arnal, 1957, p. 2053.

Ecology

Cushman & Todd, 1947a, R, shallow water, coast of WA.
Uchio, 1960, R, living & dead, San Diego, CA.
Bandy & Arnal, 1957, R, W. coast of Central America.
Bandy & Rodolfo (?), 1964, R, so. Ecuador to central Chile.
Cushman & McCulloch, 1939, R, Hancock Exp., Arenaceous.

Distribution

One specimen of *Trochammina pacifica simplissima* was obtained from the mud interval located 20 to 23.5 cm downcore.

Uvigerina hispida Schwager
Plate 17, figure 3

Uvigerina hispida Schwager; Schwager, 1866, p. 249, pl. 7, fig. 95; Martin, 1952, p. 136, pl. 25, fig. 1; Ingle, 1973, p. 536, 545, 553, 563; Haller, 1980, p. 249, pl. 8, fig. 1; Matoba and Yamaguchi, 1982, p. 1049.

Ecology

Bandy, 1953a, R, San Francisco to San Diego, CA.

Bandy found this species to be a dominant member of the upper abyssal zones off San Francisco and Point Arguello and was commonly associated with high frequency occurrences of *Uvigerina proboscidea*, *Globobulimina barbata*, *Bulimina rostrata*, "...and the shallowest occurrence of *Gyroidina gemma* and *Gyroidina soldanii*." Off San Francisco, the upper abyssal zone lies between the depths of 1829 and 2103 meters and is characterized by salinity of from 34.6 to 34.7°/oo, temperature between 1.9 and 2.2°C, and an oxygen content from 1.6 to 1.9 ml/1. Bandy found the upper abyssal zone off Point Arguello, lying between 1829 and 2377 meters, exhibiting the following oceanographic parameters: temperature ranging between 1.8 and 2.2°C, salinity from 34.6 to 34.7°/oo, and an oxygen content from 1.8 to 2.2 ml/1.

Haller, 1980, Plio, Humboldt Basin, California.

Kheradpir, 1970, R, Tanner Basin, so CA.

This species was one of twelve obtained in recent material from a depth of 1200 meters in three cores from the Tanner Basin off southern California. Kheradpir noted that the benthonic foraminiferal species usually accounted for only <20% of the total foraminiferal population in these cores.

Bandy & Chierici, 1966, R, California & Mediterranean.

Based upon previous works, Bandy and Chierici determined that the upper depth limit of this taxon off California was found to be in the bathyal zone at a depth of 1000 meters, plus or minus 200 meters. The species was not reported present in the bathyal deposits of the Mediterranean.

Martin, 1952, Plio, Los Angeles Basin, CA.

This species was present in the Repetto and Pico Formations.

White, 1956, Mio-Plio, Capistrano Fm., Orange Co., CA.

This species was reported to occur rarely in Pliocene deposits of the Upper Capistrano Formation.

Ingle, 1980, Tertiary, so. CA. continental borderland.

This species was found to be a dominant member of the lower middle bathyal biofacies between the depths of 1500 and 2000 meters.

Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.

Uvigerina hispida was found to be a dominant member of the lower middle bathyal biofacies, found between the depths of 1524 and 1829 meters and in waters 2.0 to 2.5°C.

Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.

Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.

The species was common in the cores and not in the trawls. Bandy and Rodolfo assigned *Uvigerina hispida* to their bathymetric group 4C which had an upper depth limit of 1932 meters and continued down to 6000 meters. The assemblage occurred in large percentages from 1932 to nearly 3000 meters and from approximately 4000 to 5900 meters. "This middle bathyal group contains a number of good depth indices, most of which are not known to live in water depths much less than than recorded for the Peru-Chile Trench area...Uvigerinids of this middle bathyal depth interval include large (1.0 mm) spinose forms such as *Uvigerina hispida* as opposed to the costate forms occurring at shallower depths...Deep water species such as *Uvigerina senticosa*, *U. proboscidea* and *U. hispida* (all about 0.8-1.0 mm long) are identical with forms occurring in deep-water deposits of the middle and late Tertiary; these species are middle and deep bathyal types, most characteristic of depths more than 2000 m."

Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.

This species was found between the depths of 800 and 3550 meters in the Peru-Chile Trench area. The taxon comprised 6.9% of the fauna at a depth of 1242 meters and a maximum of 7.9% of the assemblage in 2634 meters of water. The authors considered it a non-dominant member of the upper middle bathyal biofacies between the depths of 500 and 1500 meters.

Cushman, 1929b, Late Tertiary, Venezuela & Ecuador.

This species is commonly found in the Late Tertiary deposits of Ecuador, Venezuela and Trinidad.

Bandy, 1956, general trends.

Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

With the exception of singular specimens of Uvigerina hispida recovered from the sandy mud and mud layers lying from 230 to 232 and 270 to 272 cm downcore, this taxon was obtained exclusively from the sand interval located from 46 to 48 cm. This sample yielded fifteen individuals of Uvigerina hispida, accounting for 4.1% of the faunal assemblage.

Uvigerina juncea Cushman and Todd

Plate 17, figure 1

Uvigerina juncea Cushman and Todd; Cushman and Todd, 1941, p. 78, pl. 20, figs. 4-11; Zalesny, 1959, p. 125; Bandy, 1964, p. 141; Bergen and O'Neil, 1979, p. 1292, pl. 3, fig. 4; Douglas and Heitman, 1979, p. 246; Ingle, 1980, p. 171; Keller, 1980, p. 839-840, 845, 849, 853.

Uvigerina hollicki Thalmann; Bandy, 1953a, p. 177, p. 25, fig. 8.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.

Bandy, 1953a, R, San Francisco to San Diego, CA.

Douglas & Heitman, 1979, R, so. California borderland.

Bandy, 1956, general trends.

Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

Specimens of Uvigerina juncea were recovered exclusively from the sand and sandy mud intervals of this study. Obtained in five sand samples between the depths of 46 and 414.5 cm downcore, the taxon comprises between less than 1 and 2.7% of the assemblage. In addition, in the sandy mud sample from 230 to 232 cm, Uvigerina juncea accounts for less than 1% of the fauna.

Uvigerina peregrina Cushman

Plate 17, figure 5

Uvigerina peregrina Cushman; Cushman, 1923, p. 166, pl. 42, figs. 7-10; Church, 1928, p. 268; Bandy, 1953a, p. 177, pl. 25, fig. 10; Smith (in part), 1964, p. B34-B35, pl. 2, fig. 16; Ingle, 1973, p. 542, 545, 549, 553, 560, 562, 563; Haller, 1980, p. 250.

Uvigerina curticosta Cushman; Uchio, 1960, p. 65, pl. 7, fig. 12.

Uvigerina peregrina curticosta (Cushman); Matoba and Yamaguchi, 1982, p. 1049, pl. 2, figs. 10-12.

Ecology

Smith, 1963b, Pleis & R, Gulf of Alaska.

This species was recovered in bathyal deposits obtained between the depths of 810 and 2070 meters. Live individuals, comprising 15% of the fauna, were collected at a depth of 810 meters; dead specimens accounted for 3.5, 4, and 14% of the assemblages at the depths of 2070, 1950 and 810 meters, respectively. Smith considered this taxon to be characteristic of the bathyal deposits in the Gulf of Alaska, noting that it occurs at similar depths off Washington, Oregon, California and the coast of Central America.

Todd & Low, 1967, R, Gulf of Alaska & SE Alaska.

Todd and Low found Uvigerina peregrina to be a common constituent of their Pamplona Searidge samples taken from the depths of 155, 174 and between 243 and 271 meters. It was also abundant in this region at the depth of 183 meters as well as in the Clarence Strait in southeastern Alaska in 393 meters of water. In addition, the authors reported the taxon to be a common member of the Kasaan Bay fauna between the depths of 86 and 104 meters, as well as a rare constituent in the Taku Harbor assembage obtained at a depth of 21 meters.

Bergen & O'Neil, 1979, R, Gulf of Alaska.

This species was found in outer neritic to lower bathyal deposits in the Gulf of Alaska. The taxon comprised <1% of the outer neritic assemblage at the depths of 99, 110, 119 and 183 meters. It also constituted a maximum of 14% of the upper bathyal fauna at a depth of 503 meters, 25% of the middle bathyal assemblage at 726 meters and 6% of the lower bathyal fauna in 1885 and 1976 meters of water. Uvigerina peregrina was found to reach its highest frequency abundance between 503 and 930 meters, corresponding to the deeper region of the upper bathyal zone and the shallower portion of the middle bathyal zone in the Gulf of Alaska. Bergen and O'Neil noted that this taxon appeared to be stenothermal because its distribution was shallower in the Gulf of Alaska than off California.

Smith, 1973, Pleis? & Holocene, North Pacific Ocean.

Several specimens of Uvigerina peregrina were collected in the core-top and downcore samples of a single locality on the Aleutian Terrace. Obtained at a depth of 2410 meters, this taxon comprised 6% of a depauperate assemblage, totaling 55 individuals, in the core-top. In addition, one individual was recovered from the downcore sample at a depth of 10 cm, 2 at the depths of 20 and 50 cm, 3 at the depth of 60 cm and 5 at 30 cm. The maximum abundance of any of these downcore assemblages totaled 10 individuals.

Rau, 1963, Mio, Poul Creek Formation, SE Alaska.

Uvigerina peregrina was found in the Miocene deposits of this study, the paleoecology of which were determined by the distributions of similar morphotypes existing today. The recent distribution of Uvigerina peregrina is "...known from a wide range of depths and temperatures. It is recorded from depths of 50 to 11,000 feet [15 to 3353 meters], but is found most commonly between depths of 1,000 and 4,000 feet [305 to 1219 meters] where temperatures are between 53 and 35F."

Cooper, 1961, R, intertidal, CA. & Oregon coast.

Cooper found this species to be a member of the intertidal faunal assemblage he recovered off the California and Oregon coasts.

Cushman, 1927a, R, W. coast, Oregon to Central Amer.

"...in general a cold-water species found at many stations in western north Atlantic off the coast of New England northward. Similar form in this collection at numerous stations, mostly in cold water."

Douglas, 1973, Mio-R, DSDP, central North Pacific.

"By late Miocene time, mid-Pacific, deep-sea assemblages assume a fairly modern aspect, and species such as Cibicidoides [Planulina] wuellerstorfi...and Uvigerina peregrina are well established."

Bandy, 1953a, R, San Francisco to San Diego, CA.

In both the northern transects off San Francisco and Point Arguello, Bandy found Uvigerina peregrina dominating the faunas in the bathyal zone to such an extent that he referred to them as the Uvigerina peregrina assemblages. The author then subdivided these faunas further off Point Arguello based upon the varying percentages of the other dominanting taxa. Off San Francisco, the bathyal zone at 518 meters was represented by the presence of the taxon and Epistominella evax and was characterized by the following oceanographic parameters: temperature of from 5.2 to 5.5C, salinity of 34.3°/oo and an oxygen content of 0.4 ml/l. Uvigerina peregrina comprised a maximum of nearly 15% of the faunal assemblage in this region. Off Point Arguello, the species dominated all three subzones of the bathyal zone, constituting a maximum of approximately 30, 45 and 65% of the assemblages at roughly 549, 732, and 853 meters, respectively. Along the Atlantic coast, Parker (1948) found the taxon to be a dominant species of the upper bathyal zone and Phleger and Parker (1951) associated it with the bathyal zone in the Gulf of Mexico. Bandy noted that the water temperatures of the bathyal zones of these studies corresponded with part of the range found off California. In the Point Arguello region, Uvigerina peregrina was found to dominate the faunas between the depths of 366 and 853 meters, with the temperature ranging from 3.8 to 6.6C, salinity of 34.1 to 34.4°/oo and an oxygen content from 0.4 to 1.8 ml/l. It is interesting to note that the bathyal faunal members fluctuated in abundance partly in response to the oxygen minimum existing at approximately 610 meters, but that Uvigerina peregrina crossed this minimum with very little change in frequency abundance. It appears from Bandy's data that the taxon is capable of living freely in low oxygen environments.

Morin, 1971, late Q, San Francisco, L.A., Baja CA.

Haller, 1980, Plio, Humboldt Basin, California.

The dominant taxa in the lower and middle Rio Dell Formation sediments were Uvigerina peregrina and Epistominella pacifica, both of which today are indicative of central shelf to upper-bathyal (50 to 610 meters) depths.

Bandy & Arnal, 1960, Mio-R, San Joaquin Valley, CA.

Living representatives of the middle bathyal environment, lying at 610 plus or minus 304 meters, include "...a preponderance of species of costate Uvigerina [U. peregrina], together with more coarsely ornamented species of Bolivina...", Epistominella pacifica and Cyclammina.

Harman, 1964, R, Santa Barbara Basin, CA.

This species was present in both slope and basin deposits between the depths of 372 and 531 meters, but was considered by Harman to be a member of the slope fauna because of its consistently high abundance there. The taxon comprised between <1 and 42% of the fauna on the slope and between <1 and 2% of the assemblage in the basin. The maximum abundances of 22, 28, and 42% of the assemblage occurred at 472, 372, and 410 meters, respectively. Uvigerina peregrina was recovered in higher percentages in the homogeneous, rather than the laminated, layers. "The living depth ranges of Uvigerina peregrina are reported by Resig (1958) as 730-1650 meters and by Uchio (1960) as 330-1190 meters. The frequency distribution of this species off Point Conception is greater than 10 per cent between depths of 366 and 730 meters (Bandy, 1953a). Since it is rarely found below a depth of 550 meters within the Santa Barbara Basin, the oxygen content may be a controlling factor in its distribution."

Resig, 1958, R, Santa Cruz Basin, CA.

Both living and dead individuals were recovered in this study. The live specimens of Uvigerina peregrina were recovered between the depths of 914 and 1646 meters, with the greatest abundance of live individuals occurring at 1463 meters. "The living distributions of...Uvigerina peregrina...are at the upper limits of the test distributions, indicating displacement of tests down-slope after death." The taxon lives below the sill depth of 1083 meters and is typically found within approximately 366 meters of the sill. The species is also one of only three to live on the sill as well as on both the east and west sides of the basin. Dead individuals were found between the depths of 549 and 1865 meters.

Crouch, 1952, R, 11 deep basins off southern CA.

Crouch found this species abundant in water temperatures between 3.0 and 8.5°C and comparatively rare in waters below this range. He considered Uvigerina peregrina a member of his Zone T4, which occurs between the depths of 274 and 610 meters in the open ocean.

Marks and others, 1980, R, Santa Barbara Channel, CA.

The upper depth limit of a moderate number of individuals of this species was found to be the lower upper bathyal zone between the depths of 325 and 457 meters in the Santa Barbara Channel. The taxon was reported to be associated with Loxostomum pseudobeyrichi, Cassidulinoides cornuta, Suggrunda eckisi, Epistominella smithi, Cassidulina delicata, C. translucens, Globobulimina affinis and Buliminella tenuata.

Bandy, 1953b, Mio-Plio-Pleis, Ventura Basin, CA.

This species was found in the Ventura Basin deposits and is now indicative of water depths of approximately 610 meters.

Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.

Natland recovered this species from the depths of 305 and the study's limit of 884 meters in the San Pedro Channel between San Pedro and Santa Catalina Island. He also noted that it was obtained at Guide station 17 at a depth of 1011 meters off San Diego, in the Trask samples from 1097 to 1999 meters and in his land-based "Zone 4" region of the Hall Canyon section near Ventura, California. Natland concluded that Uvigerina peregrina is a dominant member of his Zone IV biofacies, found at a depth of 274 to approximately 1981 meters, off California. This zone is characterized by a bottom temperature range from 4.0 to 8.5°C and commonly includes Bolivina spissa, Cassidulina cushmani, Globobulimina pacifica and Epistominella pacifica.

Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.

Zalesny found this species occurring between the depths of 40 and 841 meters in the Santa Monica Bay. The taxon comprised 6% of the fauna at a depth of 777 meters, 9% at 576 meters, 10% at 430 meters and a maximum of 15% of the assemblage at a depth of 119 meters.

Kheradpir, 1970, R, Tanner Basin, so CA.

This species was one of twelve obtained in recent material from three cores taken from a depth of 1200 meters in the Tanner Basin off southern California. Kheradpir noted that the taxon comprised between 30 and 40% of the benthonic foraminiferal assemblage below the Pleistocene-Holocene boundary, but constituted a much lower percentage of the recent biota. Based upon previous works (Bandy and Chierici, 1966; others, unspecified), he concluded that Uvigerina peregrina's upper depth limit in most areas is 100 meters, plus or minus 50 meters, its lower limit is variable, and off California, it occurs in the upper and middle bathyal regions but usually peaks in abundance above 1000 meters. Kheradpir speculated that the low percentages of this taxon obtained in his three cores from a depth of 1200 meters might be due to "...the high stand of sea level which eliminated the depths of greatest abundance of this species in the local area at this time." He also noted that the benthonic foraminiferal fauna in these cores usually comprised only <20% of the total foraminiferal population.

Douglas & Heitman, 1979, R, so. California borderland.

Bandy & Chierici, 1966, R, California & Mediterranean.

Based upon previous works, Bandy and Chierici determined that the upper depth limit of this taxon off California was found to be 100 meters, plus or minus 50 meters. A similar upper depth limit was recorded for the species in the Mediterranean, enabling the authors to conclude that Uvigerina peregrina is an isobathyal species. Other studies have shown a similar upper depth limit for the taxon in the Gulf of Mexico, the Gulf of California, and the Adriatic seas. Bandy and Chierici note that nearly 50% of the California specimens are found between 100 and 300 meters, with a similar percentage found between 100 and 800 meters in the Gulf of Mexico.

Church, 1928, lower Plio, Los Angeles Basin, CA.

One of twenty-one species described in this early work from a late Tertiary well sample taken from a depth of 860 meters in South Huntington Beach.

Martin, 1952, Plio, Los Angeles Basin, CA.

This species was present in the Repetto and Pico Formations.

Galloway & Wissler, 1927, Pleis, Palos Verdes, CA.

Galloway and Wissler found the species present in Pleistocene-aged quarry deposits in southern California. The authors noted that the assemblage recovered was similar to that obtained in Pleistocene sediments near Santa Barbara and included *Bolivina spissa*, *Quinqueloculina akneriana*, *Cibicides mckannai*, *Globobulimina pacifica*, *Trifarina hughesi* and *Cassidulina translucens*.

White, 1956, Mio-Plio, Capistrano Fm., Orange Co., CA.

This species was reported to occur rarely to abundantly in Pliocene deposits of the Upper Capistrano Formation.

Ingle, 1980, Tertiary, so. CA. continental borderland.

Ingle determined that the species was a characteristic member of the upper bathyal biofacies between the depths of 150 and 500 meters.

Butcher, 1951, R, Coronado Bank, San Diego, CA.

This species was found between the depths of 175 and 1025 meters off San Diego. It occurred in great abundance from 175 to 490 meters and in greatest abundance between the depths of 490 and 1025 meters.

Walton, 1955 (?), R, Todos Santos Bay, Baja CA., Mexico.

Walton found *Uvigerina peregrina* Cushman vars. (in part), as well as *Reophax gracilis*, *Bolivina pacifica*, *Globobulimina* spp., *Trifarina angulosa* and *Buccella frigida*, occurring most abundantly between the depths of approximately 91 and 183 meters. He also considered it a member of his outer bay facies, which occupied the deep channel and deeper part of Todos Santos Bay.

Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.

This species was found to be a dominant member of the upper bathyal biofacies, occurring between the depths of 244 and 366 meters, with the temperature ranging from 6.0 to 8.0°C.

Brenner, 1962, R, shallow, Gulf of California.

The samples in this study were collected to a maximum depth of 79.4 meters in the Gulf of California, and *Uvigerina peregrina* was recovered from both halves of the Gulf. Brenner noted that this taxon is usually found at depths greater than 600 meters on the Atlantic continental shelf.

Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.

Bandy & Arnal, 1957, R, W. coast of Central America.

In a study from Acapulco to the Gulf of Panama, this taxon was found at a depth of 55 meters and between the depths of 640 and 1911 meters. The species constituted 4% of the fauna at a depth of 55 meters, 8% at 1600 meters, 9% at 1353 meters, 13% at 1025 meters and a maximum of 27% of the faunal assemblage at a depth of 1911 meters. Bandy and Arnal noted that the prominent members of the middle bathyal fauna between the depths of 610 and 1219 meters included costate *Uvigerinas*, as well as *Bolivina spissa*, *Buliminella tenuata*, *Cassidulina delicata* and *Epistominella smithi*.

Smith, 1964, R, El Salvador & Nicaragua.

Smith synonymized both *Uvigerina peregrina* and *U. peregrina dirupta*, noting that a complete gradation existed between the two forms. She believed they could not be separated morphologically or geographically and that they ranged in depth between 800 and 1700 meters in her study. Smith found that *Uvigerina peregrina* was more abundant in the deeper samples, lying at 1600 and 1700 meters. In contrast, *Uvigerina peregrina dirupta* was more abundant in the shallower samples, found at 800 and 885 meters.

Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.

Two varieties of this taxon were described from the Peru-Chile Trench area. Variety A was found at the depths of 142, 274 and 1242 meters, comprising 22.5, 17.8 and 19.1% of the assemblages, respectively. These particularly high abundances correlate with the outer shelf (135 to 150 meters), upper bathyal (150 to 500 meters) and upper middle bathyal (500 to 1500 meters) biofacies as defined by the authors in this area. Variety B was obtained between 274 and 1800 meters, with a rare occurrence in the uncounted aliquot at the depth of 2568 meters. The form comprised mostly <1% of the faunal assemblages, but peaked at 1.2% of the faunas in 428 and 962 meters of water and at 1.4% at a depth of 800 meters. It is important to note that both forms were recovered from the shallow (150 to 400 meters) and deep (900 to 1700 meters) oxygen minimum zones defined for this region.

Parker, 1948, R, cont. shelf, Gulf of Maine-Maryland.

On the continental slope from Cape Cod to Maryland, *Uvigerina peregrina* was found associated with Parker's Zone 4, lying between 300 and at least 680 meters. The taxon was only found at a depth of 610 and 680 meters, which Parker noted were the two deepest stations in the study. When present, *Uvigerina peregrina* was reported to greatly dominate the faunal assemblage.

Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.

This species is reported as occurring on the western continental slope in the literature regarding foraminiferal distributions in the North Atlantic.

Phleger, 1951b, R, Northwest Gulf of Mexico.

Phleger found the species to be widespread in its distribution. He noted that *Uvigerina peregrina* was characteristic of depths between 100 and 1850 meters, and was not found to occur at depths less than 50 meters. It occurred in large numbers at depths of greater than 500 meters, and was recovered at one locality below 1850 meters.

Phleger & Parker, 1951, R, NW Gulf of Mex. & Atlantic.

The species was noted as present in the recent deposits of the northwest portion of the Gulf of Mexico. In the Atlantic Ocean, it is reported from 30 to 4300 meters, but is most commonly associated with deposits greater than 600 meters deep. Parker (1948) noted that it was a member of the deepest facies of the continental shelf and slope she studied between offshore Maine and Maryland, found between the depths of 300 and 680 meters. Phleger (1942) stated that the taxon occurs at its greatest abundance on the Atlantic Ocean slope at depths greater than 700 meters.

Bock, 1976 & 1982, R, shallow, Gulf of Mexico.
Lohmann, 1978, R, western South Atlantic.
Murray, 1971, R, British forams.

Murray concluded that this species was characteristic of the "...outer shelf and the top of the continental slope (100-1000 m)." He found living representatives in the Celtic Sea between 128 and 138 meters and on the shelf edge by the western approaches to the English Channel from a depth of 420 to 1002 meters. Dead specimens were recovered in the same localities as the living cited above, as well as in the Barents Sea, along the Norwegian coast, in the Bay of Biscay, off Galicia, and in the Skagerak, Kattegat and Gullmar Fjords.

Bandy, 1956, general trends.
Douglas & Woodruff, 1981, deep-sea benthonic forams.

Distribution

Mud, sand and sandy mud samples between the depths of 46 and 414.5 cm downcore yielded specimens of *Uvigerina peregrina*. However, with the exception of three singular specimens of the taxon occurring in an equal number of mud intervals located from 270 to 312 cm, all of the examples of this species were obtained from sand and sandy mud layers. *Uvigerina peregrina* comprises from less than 1 to 7.2% of the faunal assemblage in these coarser-grained deposits.

Uvigerina peregrina dirupta Todd
Plate 17, figure 6

Uvigerina peregrina Cushman var. *dirupta* Todd; Todd, *in* Cushman and McCulloch, 1948a, p. 267, pl. 34, fig. 3; Haller, 1980, p. 250, pl. 7, fig. 14.
Uvigerina bradyana Fornasini; Barker (in part), 1960, p. 156, pl. 74, fig. 26.
Uvigerina curticosta Cushman; Uchio, 1960, p. 65, pl. 7, fig. 13.
Uvigerina peregrina dirupta Todd; Bandy and Rodolfo, 1964, p. 828, fig. 5B; Ingle, 1973, p. 536.
Uvigerina peregrina Cushman; Smith (in part), 1964, p. B34-35, pl. 2, fig. 15.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.
Haller, 1980, Plio, Humboldt Basin, California.
Crouch, 1952, R, 11 deep basins off southern CA.
Ingle, 1980, Tertiary, so. CA. continental borderland.
Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.

This species was found to be a dominant member of the lower middle bathyal biofacies between the depths of 1524 and 1829 meters, with water temperatures ranging from 2.0 to 2.5°C.

Smith, 1964, R, El Salvador & Nicaragua.
Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.
Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman & McCulloch, 1948a, R, Hancock Exp. Buliminidae.

Specimens were collected near Santa Catalina Island at the depths of 549, 894 and 896 meters, as well as off Redondo Beach, California in 439 meters of water.

Distribution

Uvigerina peregrina dirupta, represented by just one or two specimens in each of five samples, was recovered between 230 and 414.5 cm downcore. These individuals, always comprising less than 1% of the faunal assemblage, were obtained from mud, sand and sandy mud layers.

Uvigerina proboscidea Schwager
Plate 17, figure 2

Uvigerina proboscidea Schwager; Schwager, 1866, p. 250, pl. 7, fig. 96; Cushman and McCulloch, 1948a, p. 267-268, pl. 34, fig. 4; Martin, 1952, p. 138, pl. 25, fig. 9; Bandy, 1953a, p. 177, pl. 25, fig. 11; Ingle, 1973, p. 536.
Uvigerina proboscidea Schwager var. *vadescens* Cushman; Cushman and McCulloch, 1948, p. 268, pl. 34, fig. 5; Matoba and Yamaguchi, 1982, p. 1049.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.

This species was found in middle and lower bathyal deposits in the Gulf of Alaska. The taxon was recovered between the depths of 1052 and 2037 meters, comprising <1% of the faunal assemblage at 1052, 1305 and 2037 meters. It also constituted 1% and 2% of the fauna at 1403 and 1790 meters, respectively. Bergen and O'Neil noted that the "...finely spinose forms (*U. proboscidea*...and *U. senticosa*) become more prevalent in the deepest samples."

Cooper, 1961, R, intertidal, CA. & Oregon coast.

Cooper found this species to be a member of the intertidal faunal assemblage he recovered off the California and Oregon coasts.

Douglas, 1973, Mio-R, DSDP, central North Pacific.

Uvigerina proboscidea, as well as *Melonis affinis* and *M. pompilioides*, first appears in the Pliocene deep-sea assemblage recovered by the Deep Sea Drilling Project in the mid-Pacific.

Bandy, 1953a, R, San Francisco to San Diego, CA.

Bandy found this species to be a dominant member of the upper abyssal zones off San Francisco and Point Arguello. The taxon was commonly associated with *Uvigerina hispida*, *Globobulimina barbata* and *Bulimina rostrata*, as well as the "...shallowest occurrence of *Gyroidina gemma* and *Gyroidina soldanii*." Off San Francisco, the upper abyssal zone is characterized by the following oceanographic parameters: depth between 1829 and 2103 meters, temperature from 1.9 to 2.2°C, salinity of 34.6 to 34.7 °/oo and and oxygen content of between 1.6 and 1.9 ml/l. The upper abyssal zone off Point Arguello ranges between 1829 and 2377 meters, and ranges in temperature from 1.8 to 2.2°C, salinity of 34.6 to 34.7 °/oo and an oxygen content from 1.8 to 2.2 ml/l.

Morin, 1971, late Q, San Francisco, L.A., Baja CA.

Crouch, 1952, R, 11 deep basins off southern CA.

Crouch found *Uvigerina proboscidea* commonly in water temperatures below 3.0°C, but he also recovered a few forms in warmer waters.

Zalesny, 1959, R, living & dead, Santa Monica Bay, CA.

Zalesny found this species occurring in only one sample in the Santa Monica Bay. At a depth of 331 meters, it comprised 3% of the faunal assemblage.

Martin, 1952, Plio, Los Angeles Basin, CA.

This species was found present in the Repetto and Pico Formations.

Ingle, 1980, Tertiary, so. CA. continental borderland.

Ingle concluded that this species is a characteristic member of the lower middle bathyal biofacies, found between the depths of 1500 and 2000 meters.

Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.

This species was found to be a dominant member of the lower middle bathyal biofacies, found between the depths of 1524 and 1829 meters, with water temperatures ranging from 2.0 to 2.5°C.

Matoba & Yamaguchi (?), 1982, Plio-Holocene, Gulf of CA.

Bandy & Arnal, 1957, R, W. coast of Central America.

In a study from Acapulco to the Gulf of Panama, this taxon was found between the depths of 777 and 1600 meters. The species was found to comprise 10% of the fauna at a depth of 1400 meters and 2% of the assemblage at 777, 1025 and 1600 meters. Due to its great abundance, Bandy and Arnal labeled the lower bathyal biofacies between the depths of 1219 and 1911 meters as the *Uvigerina proboscidea* fauna. Associated with the taxon was *Valvulineria araucana*, *V. glabra* [*laevigata*], *Virgulina* [*Fursenkoina*] *nodosa*, *Hoeglundina elegans* and *Pullenia bulloides*. This biozone was characterized by a temperature ranging from 2.6 to 3.8°C and a salinity of approximately 34.7 °/oo.

Smith, 1964, R, El Salvador & Nicaragua.

Species found between the depths of 885 and 3200 meters

Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.

"Deep water species such as *Uvigerina senticosa*, *U. proboscidea*, and *U. hispida* (all about 0.8-1.0 mm long) are identical with forms occurring in deep-water deposits of the middle and late Tertiary, these species are middle and deep bathyal types, most characteristic of depths more than 2000 m."

Cushman & Todd, 1945, Mio, Buff Bay, Jamaica.

The species was present in Miocene sediments from Buff Bay, Jamaica which were assumed to be deposited at "...medium depths and not close to shore..."

Bandy, 1956, general trends.

Douglas & Woodruff, 1981, deep-sea benthonic forams.

Cushman, 1913a, R, Pacific Ocean, Lagenidae.

Although slightly more robust than typical specimens, Cushman determined that this taxon was *Uvigerina proboscidea* and that it had been recovered at a depth of 1629 meters off Guam.

Cushman & McCulloch, 1948a, R, Hancock Exp, Buliminidae.

Specimens were collected near Seal Beach of Santa Catalina Island, between the depths of 86 and 411 meters, as well as off the coast of Columbia at a depth of 86 meters.

Cushman, 1942, R, tropical Pacific, Hetero.-Bulimin.

This species was collected by the U.S.S. *Albatross* in recent samples from the tropical Pacific between the depths of 1105 and 3542 meters.

Distribution

With the exception of a singular specimen of this taxon obtained from the mud layer located from 152.5 to 154.5 cm downcore, *Uvigerina proboscidea* was recovered exclusively from sand and sandy mud deposits in the upper half of the core. Found between the depths of 46 and 232 cm, the taxon comprises between less than 1 and 3.8% of the faunal assemblage.

Uvigerina senticosa Cushman
Plate 17, figure 4

Uvigerina senticosa Cushman; Cushman, 1927, p. 159, pl. 3, fig. 14; Cushman and McCulloch, 1948, p. 269, pl. 34, fig. 7; Bandy, 1953a, p. 177, pl. 25, fig. 12; Phleger, Parker, and Peirson, 1953, p. 38, pl. 8, figs. 4-5; Bandy and Rodolfo, 1964, p. 831, fig. 5D; Ingle, 1973, p. 536, 542, 545, 553, 562; Matoba and Yamaguchi, 1982, p. 1049.

Ecology

Bergen & O'Neil, 1979, R, Gulf of Alaska.
This species was found in the two lowest deposits collected in this study in the Gulf of Alaska. The two samples were obtained at the lower bathyal depths of 2516 and 2623 meters, where the taxon comprised <1% of the faunal assemblage. Bergen and O'Neil noted that the "...finely spinose forms (*U. proboscidea*...and *U. senticosa*) become more prevalent in the deepest samples."

Cushman, 1927a, R, W. coast, Oregon to Central Amer.
The holotype was obtained near the United States-Mexico border at a depth of 2542 meters. The species was also found at a number of other locations in this study.

Bandy, 1953a, R, San Francisco to San Diego, CA.
Bandy found this species to be a dominant member of the lower abyssal zone off Point Arguello at a depth of 3584 meters. Extremely high abundances of *Uvigerina senticosa*, comprising nearly 55% of the faunal assemblage, were found associated with lesser abundances of *Melonis pompilioides*, *M. barleeanus* and *Hoeglundina elegans* in this region. At a depth of 3584 meters, this zone is characterized by a temperature of 1.53°C, salinity of 34.66 to 34.68°/oo and an oxygen content of 2.9 to 3.0 ml/l.

Morin, 1971, late Q, San Francisco, L.A., Baja CA.

Crouch, 1952, R, 11 deep basins off southern CA.
This species was only found in waters approximating 3.0C.

Cushman & Moyer, 1930, R, San Pedro, CA.
This species was found only at a depth of 338 meters.

Natland, 1933, R and Pico Fm., San Pedro & Ventura, CA.
Natland reported that *Uvigerina senticosa* was not recovered in samples obtained in the San Pedro Channel or Hall Canyon section near Ventura, California, but that it was found at a depth of 2505 meters at Guide station 2 near Ensenada and at 2542 meters near the United States-Mexico border at Guide station 3.

Bandy & Chierici, 1966, R, California & Mediterranean.
Based upon previous works, Bandy and Chierici determined that the upper depth limit of this taxon off California was found to be 2400 meters, plus or minus 600 meters. This taxon was not reported from recent deposits in the Mediterranean.

Ingle, 1980, Tertiary, so. CA. continental borderland.
Ingle concluded that this species was a characteristic member of the lower bathyal biofacies, found at a depth of 2000+ meters.

Butcher, 1951, R, Coronado Bank, San Diego, CA.
This species was found occurring in low relative frequency between the depths of 100 and 950 meters.

Bandy, 1961, R, Gulf of CA., intertidal-1000+ fathoms.
This species was found to be a dominant member of the lower bathyal biofacies between the depths of 2438 and 2743 meters, with the water temperature lying at 2.0°C.

Matoba & Yamaguchi, 1982, Plio-Holocene, Gulf of CA.

Bandy & Arnal, 1957, R, W. coast of Central America.
In a study from Acapulco to the Gulf of Panama, this taxon was found to constitute 9% of the faunal assemblage in the deepest sample of this study, obtained at a depth of 1911 meters. The first occurrence of this papillate *Uvigerina* species "...together with a marked increase in the percentage of *U. proboscidea*, defines the lower part of the range for the Lower Bathyal fauna."

Bandy & Rodolfo, 1964, R, so. Ecuador to central Chile.
The species was common in the cores and not the trawls. Bandy and Rodolfo assigned *Uvigerina senticosa* to their bathymetric group 5. The group had an upper depth limit of 2489 meters and occurred in fairly low percentages throughout its range down to approximately 6000 meters. The assemblage also occurred deepest in the vicinity of the Peru-Chile Trench and shoaler near Panama. Bandy and Rodolfo noted that "...they do appear to be quite restricted to these greater depths...*Uvigerina senticosa*, a long (1.0 mm) calcium carbonate foraminifera, is papillate and represents the deepest member of the Uvigerinids (Bandy, 1960a)...Deeper water species such as *Uvigerina senticosa*, *U. proboscidea*, and *U. hispida* (all about 0.8-1.0 mm long) are identical with forms occurring in the deep-water deposits of the middle and late Tertiary; these species are middle and deep bathyal types, most characteristic of depths more than 2000 m."

Ingle, Keller & Kolpack, 1980, R, Peru-Chile Trench.
This species was only found at a depth of 3550 meters in the Peru-Chile Trench area, where it comprised 3.8% of the faunal assemblage. The taxon's presence, along with the dominant occurrence of *Melonis pompilioides*, characterized the lower bathyal biofacies between the depths of 2000 and 4000 meters, according to the authors.

Phleger, Parker and Peirson, 1953, R, eq.-N. Atlantic.
The authors state that this species is not reported in

the literature regarding foraminiferal distributions in the Atlantic Ocean. They also suggest that the taxon occurs at depths less than 500 meters off the coast of California, but this questionable statement is not supported by a reference. On the basis of this tenuis information, they report that the species was found displaced to a depth of 4940 meters in their samples from the equatorial and low-latitude North Atlantic.

Bandy, 1956, general trends.
Douglas & Woodruff, 1981, deep-sea benthonic forams.
Cushman & McCulloch, 1948a, R, Hancock Exp, Buliminidae.

The type specimen was collected off southern California in 2542 meters of water. Other specimens of Uvigerina senticosa were obtained off Ketchikan, Alaska at a depth of 15 meters, between the depths of 4 and 549 meters near the Channel Islands and at 293 meters off Los Frailes, Mexico.

Distribution

Specimens of Uvigerina senticosa were recovered from every sample investigated in this study with the exception of the core-top. Although occurring in very high quantities throughout the length of the core, the taxon displays a general increase in abundance with depth in core. In the mud layers, Uvigerina senticosa comprises from 12.7 to 61.9% of the assemblage. In contrast, the taxon accounts for only 1.4 to 5.9% of the fauna in the sand intervals.

Valvulineria araucana (d'Orbigny)
Plate 18, figure 7

Rosalina araucana d'Orbigny; d'Orbigny, 1839a, p. 44, pl. 6, figs. 16-18.
Valvulineria araucana (d'Orbigny); Cushman, 1927a, p. 160, pl. 4, figs. 7-8; Haller, 1980, p. 255-256, pl. 9, figs. 5-6; Ingle, 1973, p. 536, 542, 545, 553, 563; Ingle, Keller and Kolpack, 1980, p. 146, pl. 8, figs. 9-11.
"Valvulineria araucana (d'Orbigny)"; Matoba and Yamaguchi, 1982, p. 1049-1050, pl. 2, fig. 13.

Ecology

Valvulineria araucana (d'Orbigny) is a constituent of benthonic foraminiferal assemblages throughout the eastern Pacific Ocean. From the Kodiak shelf to Cape Fairweather in the Gulf of Alaska, Bergen and O'Neil (1979) found the taxon associated with their middle to lower bathyal deposits. Commonly comprising less than 1% of the total assemblage in its presence between 564 and 1976 meters, its abundance peaked at 3 and 4% at depths of 833 and 622 meters, respectively. The Deep Sea Drilling Project (Ingle, 1973), procuring core material at Site 182 from a depth of 1419 and 1434 meters on the upper continental slope southeast of Kodiak Island, also noted the presence of Valvulineria araucana in its faunal assemblage. Ingle (1973) concluded that its presence marked the deposition of upper and middle bathyal deposits at this location, as well as at the Deep Sea Drilling Project sites off Vancouver Island (Site 177), the Columbia River (Site 174), central Oregon (Site 175) and on the Delgada Fan, south of Cape Mendocino in northern California (Site 173). Haller (1980) also collected the taxon in northern California, in Pliocene deposits of the Humboldt Basin. Based upon the works of Bandy (1960b) and Lankford (1962), Haller concluded that Valvulineria araucana is characteristic of recent bathyal and abyssal depths between approximately 150 and >4000 meters.

Considerably farther south, offshore of Santa Barbara, several studies noted the presence of the taxon. In a review of recent benthonic foraminifers on the sill and basin proper of the Santa Cruz Basin, Resig (1958) determined that Valvulineria araucana was a common species along the west slope and sill. It was found to range between 732 and 1865 meters, with the sill depth lying at approximately 1083 meters. Harman (1964), investigating recent foraminifers of the Santa Barbara Basin, associated the species with both his slope and basin plain faunal provinces. Always comprising less than 1% of the assemblage, Valvulineria araucana was detected at depths of 430, 472 and 531 meters. A considerably shallower habitat for the taxon was reported by Marks, and others (1980) in the Santa Barbara Channel. Associated with Epistominella pacifica (Cushman) and E. exigua (Brady), the upper depth limit of a moderate number of specimens of Valvulineria araucana was in the lower neritic biofacies at a depth of 92 to 183 meters. Crouch (1952), investigating eleven deep basins off southern California from Santa Barbara to San Diego, also determined that Valvulineria araucana is most commonly associated with water temperatures between 4.0 and 5.0C.

Numerous studies in the Los Angeles region have noted the presence of the species. Cushman and Moyer (1930) found Valvulineria araucana at a depth of 732 meters off San Pedro and Natland (1933) found it between 280 and 884 meters in the San Pedro Channel. The species was also dredged up at a depth of 597 meters near Santa Catalina Island and discovered in the Pliocene-aged Pico Formation deposits exposed in the Hall Canyon section in Ventura (Natland, 1933). Samples collected by Dr. Parker Trask at depths ranging from 1097 to 1999 meters between Santa Catalina and Santa Cruz Islands yielded Valvulineria araucana as well (Natland, 1933). Zalesny (1959), investigating shallow portions of Santa Monica Bay, found the taxon from the depth of 408 to the study's limit of 841 meters. The species was reported to comprise 7% of the fauna at a depth of 549 meters, 8% in 576 meters of water and a maximum of 12% of the assemblage at a depth of 777 meters. Zalesny found that a substantial change in the foraminiferal biota occurred between the depths of 549 and 841 meters in the lower end of the Redondo Submarine Canyon, where Valvulineria araucana, as well as several other species, became the dominant species. These other taxa included: Cassidulina delicata, Epistominella smithi, E. pacifica, Buliminella tenuata and Bolivinita minuta. The waters between the depths of 549 and 841 meters were characterized by a temperature ranging from 4.9 to 5.6°C and a salinity ranging from 34.38 to 34.42^{o}/oo. Valvulineria araucana has also been regarded as a significant species in the Tanner Basin benthonic foraminiferal assemblage (Kheradpir, 1970; Morin, 1971). Kheradpir (1970) found that the species was one of twelve obtained in recent material from three cores taken from a depth of 1200 meters in the basin. He also discovered that the benthonic foraminiferal faunas usually comprised <20% of the total foraminiferal population. And lastly, White (1956), finding rare specimens of the taxon in the Pliocene-aged Upper Capistrano Formation deposits in Orange County, concluded that Valvulineria araucana prefers water depths of 610 to 853 meters based upon the work of Natland (1933).

Geographically less restricted foraminiferal studies in the southern Californian region have also been undertaken. Combining the results of several studies mentioned above, Bandy and Chierici (1966) deduced that the upper depth limit of Valvulineria araucana is 400 meters, plus or minus 100 meters, off California. Douglas and Heitman (1979) associated the taxon with the lower slope assemblages of both the nearshore and offshore basins of the California borderland, noting its isobathyal character in the less distant basins. In the inner basins, Valvulineria araucana is a non-dominant species, yet becomes more abundant between 450 and 900 meters. Here, it is associated with the East Pacific Intermediate Water, characterized by a temperature of 4.8 to 7.0°C, salinity of 34.2 to 34.4^{o}/oo and an oxygen content of 0.1 to 0.8 ml/l. The conditions under which this non-dominant species exists in the outer basins are quite similar except for depth: temperature ranges from 4.1 to 8.0°C, salinity from 34.3 to 34.4^{o}/oo, oxygen content of 0.3 to 1.1 ml/l, and depth from approximately 900 to 1800 meters. Ingle (1980), investigating the Cenozoic paleobathymetry of the southern California continental borderland, assigned Valvulineria araucana to his upper middle bathyal biofacies, lying between 500 and 1500 meters.

Studies near San Diego and the United States-Mexican border have included the taxon as well. In the early part of the century, the U.S. Coast and Geodetic Survey ship Guide dredged up Valvulineria araucana in 463, 468, 724, 785 and 1011 meters of water (Cushman, 1927a). In the vicinity of Coronado Bank, Butcher (1951) reported finding the species in high relative frequency throughout its bathymetric range of 300 to 990 meters. Similar depth ranges were recorded by Uchio (1960) for both living and dead Valvulineria araucana from San Diego to the Coronados Islands. He found living specimens inhabiting the waters between 293 and 1170 meters, peaking at 8 and 9% of the faunal assemblage at 1070 and 704 meters, respectively. Similarly, dead individuals were recovered between 219 and 1169 meters, comprising a maximum of 3% of the population at a depth of 640 meters.

Southward, Valvulineria araucana has been reported off both the western and eastern coasts of Baja California. Walton (1955), investigating both living and dead benthonic foraminifers of Todos Santos Bay, found the species occurring most abundantly between 183 and 640 to 732 meters. He concluded that it was a constituent of his offshore biofacies, which generally occupied the area outside the bay and to a depth of at least 1097 meters. To the east, in the Gulf of California, the taxon was a dominant member of the upper middle bathyal fauna, residing at a depth of 1219 to 1524 meters where water temperatures ranged between 2.5 and 3.5°C (Bandy, 1961). In Pleistocene deposits recovered by the Deep Sea Drilling Project from the Guaymas Basin of this region, Valvulineria araucana generally comprised 1 to 2% of the faunal assemblage, but increased to a surprising 16, 18 and 27% in a few instances (Matoba and Yamaguchi, 1982). Based upon the works of Bandy (1961) and Phleger (1964, 1965), the authors concluded that this taxon is commonly associated with the lower middle bathyal biofacies in this region.

Valvulineria araucana appears in recent deposits off Central and South America as well. From Acapulco to the Gulf of Panama, Bandy and Arnal (1957) found the taxon occurring between the depths of 777 and 1600 meters. It comprised <1% of the fauna at a depth of 823 meters, 1% at 777 and 1353 meters and a maximum of 6% of the faunal assemblage at the depths of 1143 and 1600 meters. Bandy and Arnal noted that it was a typical species of the lower bathyal fauna and that, in contrast to Walton's (1955) findings, it was of little significance shallower than 1143 meters. Other taxa found associated with Valvulineria araucana in this biozone were Pullenia bulloides, Pyrgo murrhina, Valvulineria glabra and Virgulina [Fursenkoina] nodosa. In their study region, the authors (1957) characterized the lower bathyal region by these parameters: depth from 1219 to 1911 meters, temperature of 2.6 to 3.8°C and salinity of approximately 34.7^{o}/oo. In the Peru-Chile Trench off the coast of Chile, Valvulineria araucana was found comprising <1 and 1.2% of the faunal assemblage at depths of 800 and 1800 meters, respectively, and was associated with the upper middle bathyal biofacies (Ingle, Keller, and Kolpack, 1980). The type specimen was obtained by d'Orbigny off Chile as well (Cushman, 1927a).

Valvulineria araucana was found as a displaced species in the low and middle latitudes of the North Atlantic by the Swedish Deep-Sea Expedition and primarily between the depths of 80 and 160 meters in the Gulf of Mexico (Phleger, Parker, and Peirson, 1953).

Obviously this taxon is ubiquitous in recent offshore deposits of the eastern Pacific Ocean. The upper depth limit of Valvulineria araucana appears to lie at approximately 100 meters off California (Marks and others, 1980). In addition, it appears that the taxon is most commonly associated with the upper middle bathyal biofacies, ranging between approximately 500 and 1500 meters (Ingle, 1980) in this region.

Distribution

Valvulineria araucana occurs in rather high abundance in the middle third of the core. Recovered from mud, sandy mud and sand intervals between the depths of 167.5 and 432.5 cm downcore, the taxon displays its highest abundances in the mud and sandy mud layers. In the mud deposits, Valvulineria araucana accounts for between less than 1 and 8.9% of the assemblage, while in the sandy muds it peaks at 8.7%. In contrast, the species accounts for less than 1 to only 1.1% of the fauna in the sand layers.

Valvulineria laevigata Phleger and Parker, 1951
Plate 18, figure 6

Eponides exigua Cushman (not Pulvinulina exigua H.B. Brady); Cushman, 1931, p. 44, pl. 10, figs. 1-2.
Valvulineria sp.; Parker, 1948, p. 240, pl. 4, figs. 13a-b.
Valvulineria laevigata Phleger and Parker; Phleger and Parker, 1951, p. 25, pl. 13, figs. 11-12; Ingle, 1973, p. 545; Ingle, Keller and Kolpack, 1980, p. 146, pl. 8, figs. 5-7.
Rotamorphina laevigata (Phleger and Parker); Phleger, Parker and Peirson, 1951, p. 47, pl. 10, figs. 17, 23.
Quadrimorphina laevigata (Phleger and Parker); Matoba and Yamaguchi, 1982, p. 1048, pl. 4, fig. 2.

Ecology

Valvulineria laevigata Phleger and Parker has been found to inhabit both the eastern Pacific and Atlantic Oceans. The species has been recorded as far north as central Oregon, where it was obtained in cored samples acquired by the Deep Sea Drilling Project at Site 175 (Ingle, 1973). The deposits were recovered offshore on the lower continental slope at a depth of 1999 meters. Unfortunately, information regarding the abundance of this taxon and the position of its recovery downcore was not presented in the study.

To the south, in an investigation of benthonic foraminifers of the slope and basins of the California borderland, Douglas and Heitman (1979) discovered that Valvulineria glabra Cushman (=V. laevigata) was a minor constituent of their lower slope biofacies in the outer offshore basins near Los Angeles. The assemblage was found to have a depth range of between 300 and 1900 meters, with a mean upper depth limit of 400 meters. The authors noted that the East Pacific Intermediate Water inhabits these same depths and is characterized by a temperature ranging from 4.1 to 8.0°C, a dissolved oxygen content of between 0.3 and 1.1 ml/l and a salinity value fluctuating between 34.3 and 34.4 °/oo.

The taxon, identified as Valvulineria glabra Cushman, was also obtained by Uchio (1960) from the Coronado Bank and surrounding vicinity off San Diego. The author discovered living specimens residing between the depths of 391 and 1170 meters, with the taxon comprising 7% of the assemblage at depths of 823 and 832 meters and 9 and 11% at 841 and 924 meters, respectively. Uchio also noted that living plus dead specimens were obtained between 567 and 1189 meters, constituting a maximum of 3 and 4% of the total assemblage at 896 and 704 meters.

Valvulineria laevigata has been reported in two studies of benthonic foraminifers of the Gulf of California as well (Brenner, 1962; Matoba and Yamaguchi, 1981). In contrast to the deep water occurrences reported elsewhere, Brenner (1962) found the taxon at a depth of only 21.2 meters in his study of the upper 91 meters of water in this region. Pleistocene occurrences of the species were also reported in cored material collected at two of the five Deep Sea Drilling Project sites in the Guaymas Basin (Matoba and Yamaguchi, 1981). Appearing in only three samples, Valvulineria laevigata comprised 1, 7 and 17% of the total faunal assemblage.

Off Central and South America, the taxon has been obtained at bathyal depths in two additional studies (Bandy and Arnal, 1957; Ingle, and others, 1980). Identified as Valvulineria glabra Cushman in recent sediments between Acapulco and the Gulf of Panama, Bandy and Arnal (1957) found the taxon comprising 2% of the assemblage at a depth of 1143 meters and present as a rare component of the fauna at 1600 meters. They considered it to be one of the most typical species of the lower bathyal Uvigerina proboscidea fauna, a fauna commonly residing between 1219 and 1911 meters in this region, with the temperature ranging between 2.6 and 3.8°C and a salinity of approximately 34.7 °/oo. The other species found to be typical of this biozone included Valvulineria araucana, Virgulina [Fursenkoina] nodosa, Pullenia bulloides, Hoeglundina elegans and Pyrgo murrhina. Ingle, Keller, and Kolpack (1980), also recovered Valvulineria laevigata to the south in the Peru-Chile Trench area between the depths of 800 and 2568 meters. They found it comprising 1.2% of the fauna at a depth of 1864 meters, 1.3% at 1800 meters, 2.6% at 800 meters and a maximum of 2.7% of the assemblage at a depth of 1242 meters.

In the Atlantic Ocean, Parker (1948) collected the taxon on the continental slope from Maine to Maryland between the depths of 300 and 680 meters. Elsewhere in the Atlantic, Phleger and Parker (1951) report that it has been obtained in waters 846 to 2137 meters deep.

Valvulineria laevigata appears to be representative of the upper middle bathyal biofacies in the eastern Pacific, defined by Ingle (1980) to lie between 500 and 1500 meters. The taxon has been reported in lower abundances from lower middle bathyal waters (1500 to 2000 meters) as well.

Distribution

Specimens of Valvulineria laevigata occur in low abundance between the depths of 20 and 372.5 cm downcore. Recovered from mud, sandy mud and sand deposits, the taxon displays its highest abundances in the sand layers. In all of the seven mud intervals in which it is present, Valvulineria laevigata comprises less than 1% of the faunal assemblage. The species also accounts for less than 1 to 1.9% of the fauna in its three sand layer appearances, and less than 1 to 1.4% of the sandy mud faunas.

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