

EOCENE AND OLIGOCENE PLANKTONIC FORAMINIFERA FROM THE CENTRAL AND SOUTHERN OREGON COAST RANGE

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ABSTRACT

Tertiary sediments exposed in the central and southern Oregon Coast Range were examined for planktonic foraminifera. Forty-two samples were obtained from the Siletz River Volcanics, the Tyee, Yamhill, and Nestucca Formations, an unnamed siltstone at Alsea Bay, the Yaquina Formation, the Nye Mudstone, and the Astoria Formation in the central Coast Range, and from the Elkton Siltstone and the Umpqua, Coaledo, and Bastendorff Formations in the southern Coast Range. These formations previously have been correlated with the Penutian through Relizian microfaunal stages recognized in California. Thirty species of planktonic foraminifera were recovered from six of the twelve rock units sampled.

Planktonic foraminifera from the "lower" Umpqua are dominated by *Globorotalia aequa* and other species

indicative of the early Eocene. Upper Tyee and north Agate Beach (Elkton Siltstone) samples contain the middle Eocene species *Acarinina bullbrooki*, *Globigerinatheka mexicana*, and *Guembelitra columbiana*. In the Coaledo, Nestucca, and lower Bastendorff Formations, specimens of *Globigerina senilis*, *Globigerinatheka index*, or *Chiloguembelina cubensis* are dominant. These and other species present are typical of late Eocene or basal Oligocene age. Planktonic foraminifera of the upper Bastendorff Formation are almost entirely *Globigerina praebulloides*, possibly indicating an Oligocene age.

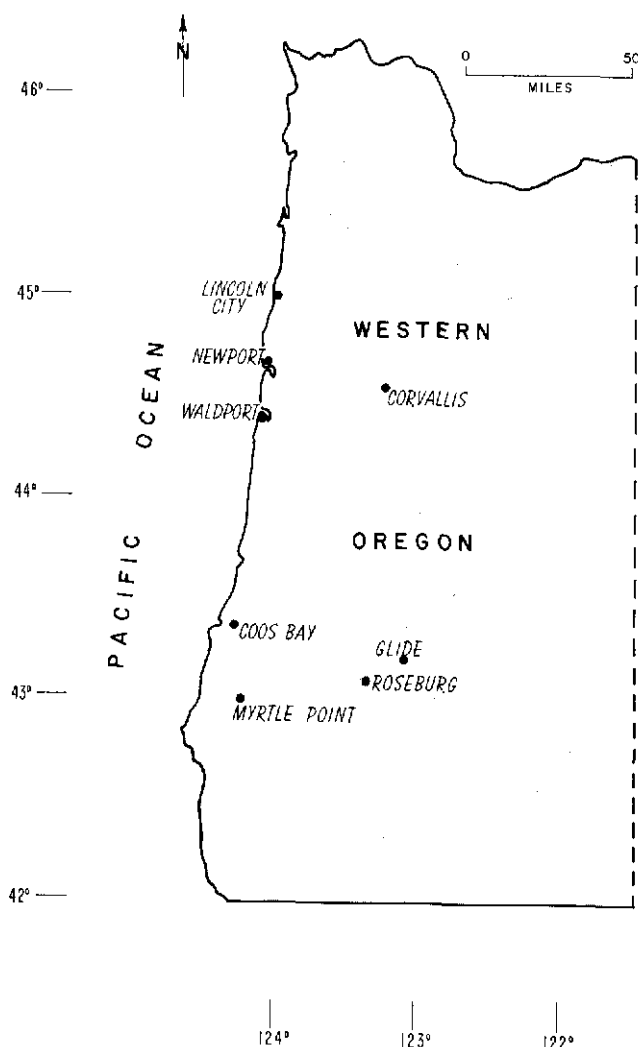
Ratios of western Oregon planktonic to benthonic foraminifera suggest deposition beneath offshore water masses in early and middle Eocene times, followed by deposition near shore in post-middle Eocene.

INTRODUCTION

Until recently, detailed studies of Tertiary planktonic foraminifera from the state of Oregon had not been made. Occurrences had been recorded only incidentally in studies of other problems (Bandy, 1944; Allen and Baldwin, 1944; Detling, 1946; Stewart, 1956; Snively, MacLeod, and Rau, 1969a; Fowler, Orr, and Kulm, 1971). Recently, we recorded 26 species of planktonic foraminifera and calcareous nannoplankton from the Coast Range of Oregon (McKeel and Lipps, 1972).

Our purpose here is to present additional descriptions and interpretations of planktonic foraminiferal occurrences in Tertiary rocks of the central and southern Oregon Coast Range. Thirty-seven rock samples from isolated outcrops of Tertiary strata near Corvallis, Lincoln City, Newport, Myrtle Point, Roseburg, and Glide, Oregon (text fig. 1) were collected, processed and examined for planktonic foraminifera. Five samples (previously collected and known to contain planktonic foraminifera) from more continuous exposures along the beach near Coos Bay were obtained from the University of California Museum of Paleontology, Berkeley, California.

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TEXT FIGURE 1

Cities in the Oregon Coast Range near localities sampled for this study.

BIOSTRATIGRAPHY

A composite section of over 25,000 feet (7,625 m) of Tertiary marine sedimentary and volcanic rocks are exposed near and to the east of both Newport and

Coos Bay in the Oregon Coast Range. These rocks were deposited in an elongate trough extending from the Klamath Mountains in southern Oregon north to Vancouver Island, Canada. The rocks have been divided into several recognizable units in the Newport and Coos Bay areas (table 1). Summary descriptions of the units and geology were given by Snavely and Wagner (1963), Baldwin (1964), and Snavely, MacLeod, and Rau (1969a).

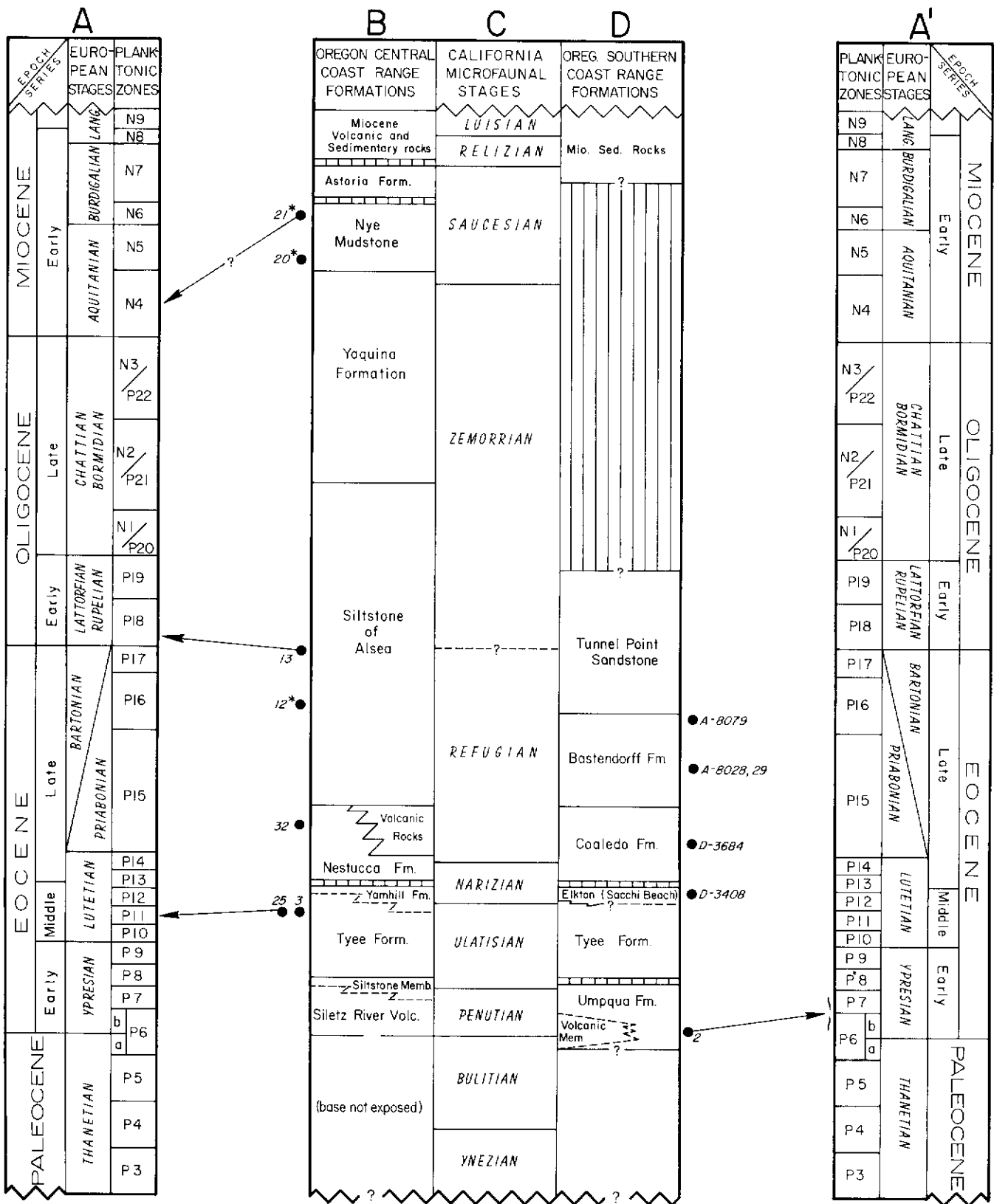
Samples for the present study were obtained from twelve formations and formational units primarily in the Newport and Coos Bay areas. In the central Coast Range near Newport, the Tyce, Yamhill, and Nestucca Formations, the unnamed "Siltstone of Alsea," the Yaquina Formation, the Nye Mudstone, and the Astoria Formation were sampled (text figs. 2a,c). A beach cliff exposure of the Nestucca Formation near Lincoln City (text fig. 2a) and interbeds of the Siletz River Volcanics at Coffin Butte near Corvallis also were sampled. In the southern Coast Range, samples were collected from the Umpqua Formation near Glide (text fig. 3a), Roseburg, and Myrtle Point. Other samples also were obtained from beach exposures of the Elkton Siltstone and the Coaledo and Bastendorff Formations near Coos Bay (text fig. 3b).

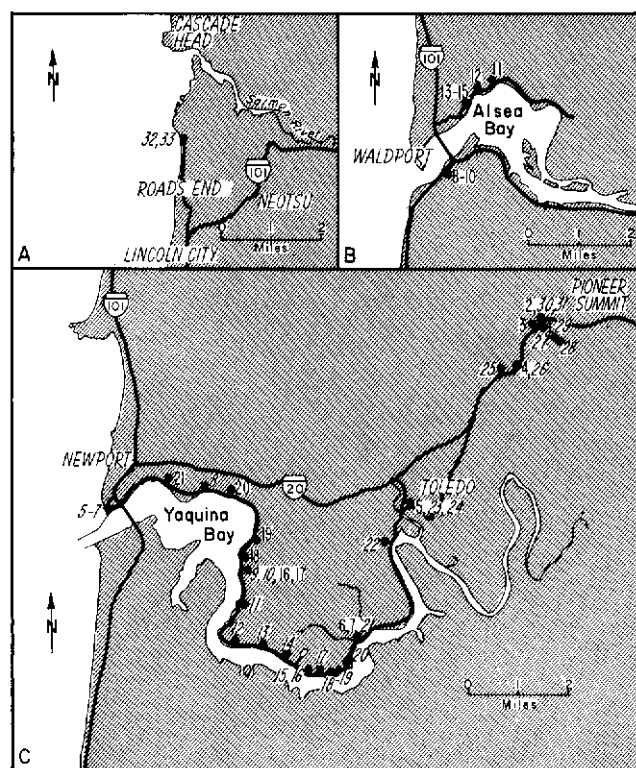
Benthonic foraminifera occur abundantly in all formations sampled. On the basis of benthonic species, Snavely, MacLeod, and Rau (1969a) assigned the central Coast Range formations to the west coast microfaunal stages of Kleinpell (1938) and Mallory (1959). Formations of the southern Coast Range have been correlated with those in the central Coast Range (Baldwin, 1964; Braislin, Hastings, and Snavely, 1971).

Generally, rock exposures are rare and discontinuous, and planktonic foraminiferal occurrences are intermittent within the exposures. However, eight samples yielded thirty species of planktonic foraminifera (table 2). Although many species are stratigraphically long-ranging, some have restricted stratigraphic ranges in low-latitude tropical regions. These species permit partial correlation of the benthonic California Stages as

TABLE 1

Chart correlating formations of central and southern Oregon Coast Range with California benthonic foraminiferal stages of Kleinpell (1938) and Mallory (1959), the standard tropical planktonic foraminiferal zones and the European stages. Correlation of columns A and A' with C after Berggren and Van Couvering (1973); B with C after Snavely, MacLeod, and Rau (1969a); B with D after Braislin, Hastings, and Snavely (1971). Also shown are approximate stratigraphic positions and regional correlation of Oregon planktonic foraminiferal assemblages of this study. Samples indicated by an asterisk are from McKeel and Lipps (1972) and are shown here for comparison with new data.





TEXT FIGURE 2

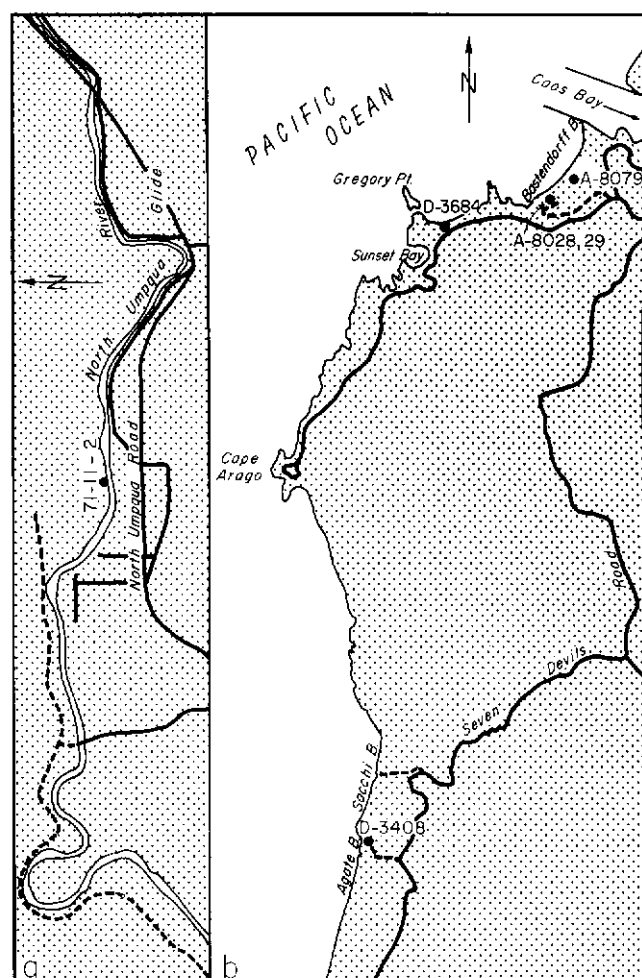
Maps of central Oregon Coast Range collecting localities. A. Roads End north of Lincoln City. B. Alsea Bay near Waldport. C. Yaquina Bay near Newport. Sample localities of McKee and Lipps (1972) represented by roman numbers, shown here for comparative purposes. Sample localities of this study represented by italicized numbers.

recognized in Oregon with the widely recognized planktonic foraminiferal biostratigraphic zones of the tropics.

CENTRAL COAST RANGE

Siletz River Volcanics

The oldest rocks exposed in the central Coast Range are referred to as the Siletz River Volcanics (Snively and Baldwin, 1948), which are composed of basaltic lava and breccia largely of marine origin (Snively, MacLeod, and Wagner, 1968) with interbedded siltstone and sandstone. These sedimentary interbeds are considered equivalent in age to the widespread Umpqua



TEXT FIGURE 3

Maps of southern Oregon Coast Range sample localities. A. North Umpqua River near Glide. B. Beach exposures near Coos Bay.

Formation of the southern Coast Range (table 1). Benthonic foraminifera from the interbeds indicate that the volcanics are referable to Mallory's (1959) Ulatian and possibly Penutian Stages (Snively, MacLeod, and Rau, 1969a). Rocks in California assigned to these stages have recently been correlated with the middle and early Eocene (Lutetian and Ypresian) by Steineck and Gibson (1971).

TABLE 2

Occurrences of planktonic foraminifera in samples from Tertiary formations in the central and southern Oregon Coast Range. Sample localities indicated with an asterisk with accompanying species (not figured) are from McKee and Lipps (1972) and are listed here for comparative purposes.

A Abundant C Common F Few R Rare ? Quest. Identified	EPOCH	E O C E N E										OLIGOCENE	MIO.
	SERIES	Early	Middle			Late							
	FORMATION	UMPQUA	TYEE	ELKTON	COALEDON	NESTUGCA	ALSEA		BASTENDORFF		NYE		
		Lower	Upper	?	Middle	Upper	Lower	Middle	Middle	Upper	Lower	Upper	
	SAMPLE NO.	71-11-2	67-12-3*	71-06-25	D-3408	D-3684	71-06-32	67-12-12	67-12-13*	A-8028, 29	A-8079	67-12-20	67-12-21*
<i>ACARININA ESNAENSIS</i>	F												
<i>GLOBOROTALIA AEQUA</i>	A												
<i>GLOBOROTALOIDES</i> cf. <i>G. IMITATA</i>	R												
<i>PSEUDOHASTIGERINA WILCOXENSIS</i>	F												
<i>SUBBOTINA</i> cf. <i>S. TRILOCULARIS</i>	R												
<i>GLOBOROTALIA</i> sp.	R			R									
<i>SUBBOTINA BOLIVARIANA</i>			C										
<i>GLOBOROTALOIDES TURGIDA</i>	R		R										
<i>PSEUDOHASTIGERINA SHARRIVERENSIS</i>	R		R										
<i>PSEUDOHASTIGERINA</i> cf. <i>P. MICRA</i>	C		R										
<i>TRUNCOROTALOIDES COLLECTEA</i>	A		F										
<i>SUBBOTINA LINAPERTA</i>	R		R		R								
<i>CLAVIGERINELLA COLOMBIANA</i>	R		R		?R	?R							
<i>ACARININA BULLBROOKI</i>				F									
<i>CATAPSYDRAX PRIMITIVA</i>				F									
<i>GLOBIGERINATHEKA MEXICANA</i>				R									
<i>GLOBIGERINA</i> cf. <i>G. YEGUAENSIS</i>	A												
<i>ACARININA</i> cf. <i>A. ANGULOSA</i>					R								
<i>GLOBOROTALOIDES</i> sp.				R									
<i>GUMBELITRIA COLOMBIANA</i>				R									
<i>PSEUDOHASTIGERINA LILLISI</i>				F		F							
<i>GLOBIGERINA</i> aff. <i>G. CIPEROENSIS</i>						C							
<i>GLOBIGERINA PRASAEPIS</i>						C							
<i>GLOBIGERINA SENILIS</i>						C		C					
<i>SUBBOTINA OREGONENSIS</i> , n. sp.						R							
<i>GLOBIGERINATHEKA INDEX</i>						F			F				
<i>CHILOGUEMBELINA VICTORIANA</i>							R	R		F			
<i>CHILOGUEMBELINA CUBENSIS</i>							F	C		C			
<i>? GLOBIGERINA</i> sp.							?F	?F				?R	
<i>GLOBIGERINA MINIMA</i>								C					
<i>GLOBIGERINA PRAETURRITILINA</i>								R					
<i>GLOBOROTALOIDES</i> aff. <i>G. PSEUDOKUGLERI</i>								C					
<i>SUBBOTINA WILSONI</i>								F		R			
<i>GLOBIGERINA</i> sp.										(1)			
<i>GLOBIGERINA PRAEBULLOIDES</i>										F		F	C
<i>GLOBIGERINA ?AMPLIAPERTURA</i>												?F	
<i>CATAPSYDRAX</i> sp.												R	
<i>GLOBIGERINA ANGUSTIUMBILICATA</i>													R
<i>GLOBIGERINA EUAPERTURA</i>													R
<i>GLOBIGERINA JUVENILIS</i>													A
<i>GLOBIGERINOIDES PRIMORDIUS</i>													F
													(1)

Although planktonic foraminifera from the Siletz River Volcanics were not found during this study, the species *Pseudohastigerina micra* (Cole) (as *Globanomalina*) and *Globorotalia aragonensis* Nutall have been recorded from this formation (Snively, MacLeod, and Rau, 1969a). These species occur in early and middle Eocene sediments elsewhere.

Tyee Formation

The Tyee Formation disconformably overlies the Siletz River Volcanics and consists of over 6,000 feet (1,830 m) of turbidite sandstone and siltstone in the central Coast Range (Snively, MacLeod, and Rau, 1969a). Benthonic foraminifera are common in the top siltstones of graded beds, and in siltstone interbeds. Throughout the formation, these foraminifera are indicative of Mallory's (1959) Ulatisian Stage (Snively, MacLeod, and Rau, 1969a). One sample of this study (no. 25) from the upper part of the tyee Formation (text fig. 2; table 2) yielded abundant planktonic foraminifera. Of the species found (table 2), *Truncorotaloides collactea* is a long ranging form (Jenkins, 1965), but *Acarinina bullbrookii* is restricted to the tropical Eocene zones P9 to P11 (Berggren, 1968). *Globigerinatheka mexicana* ranges from middle and late Eocene zones P11 to lower P15, in the tropics (Blow, 1969). The co-occurrence of the latter two species indicates that the upper Tyee Formation at locality 25 west of Pioneer Summit (text fig. 2C) is middle Eocene (Lutetian) in age (table 1).

Yamhill Formation

A dark-grey siltstone known as the Yamhill Formation (Baldwin, and others, 1955) conformably overlies the Tyee and contains abundant benthonic foraminifera that suggest correlation with Mallory's (1959) late Ulatisian and early Narizian stages (Snively, MacLeod, and Rau, 1969a). The only planktonic foraminifera found upon reexamination of sample number 5 of McKee and Lipps (1972) were extremely rare specimens of *Pseudohastigerina* cf. *P. micra* (Cole).

Nestucca Formation

The Nestucca Formation consists of tuffaceous siltstones and volcanic rocks, variable in thickness, which unconformably overlie the Yamhill Formation (Snively, MacLeod, and Rau, 1969a). Bathyal benthonic foraminifera have been recovered that are indicative of the late Narizian and early Refugian Stages, considered late Eocene in age (see table 1).

Planktonic microfossils previously have not been re-

ported from the Nestucca. To account for this absence of plankton, McKee and Lipps (1972) suggested that conditions extant during the deposition of the upper Yamhill Formation may have persisted in the late Eocene, or that perhaps the Nestucca Formation was deposited in isolated marine embayments (Snively, MacLeod, and Rau, 1969a), possibly separated by islands from the open sea.

In this study, a few specimens of the planktonic foraminiferal species *Globigerinatheka index* were recovered from the Nestucca Formation (sample no. 32) near Lincoln City, at Roads End (text fig. 2a). This species apparently was restricted to temperate waters and rarely invaded tropical water (Blow, 1969, p. 330). Detailed field studies are not yet completed in this area, but the Roads End sample is from high in the section (N. S. MacLeod, written commun., 1972). *Globigerinatheka index* ranges from late middle Eocene to basal Oligocene in New Zealand and elsewhere (Jenkins, 1965; Blow, 1969). Floods of this species occur in faunas from California considered to be late middle Eocene in age (Steineck, 1971).

Alsea Siltstone, Yaquina Formation, Nye Mudstone, and Astoria Formation

Overlying the Nestucca Formation in ascending order are the Siltstone of Alsea, Yaquina Formation, Nye Mudstone, and Astoria Formation. Thirteen samples collected from these formations near Newport were found to be barren of planktonic foraminifera. Plankton from the Siltstone of Alsea and Nye Mudstone were discussed by McKee and Lipps (1972) and are listed in table 2.

SOUTHERN COAST RANGE

Umpqua Formation

The oldest Tertiary rocks exposed in the southern Coast Range are assigned to the Umpqua Formation. This formation is over 12,000 feet (3,660 m) thick in the type area (Diller, 1898), and consists of thin, rhythmically bedded sandstones and shales, with conglomerate, tuff, coal, and limestone interbeds. It overlies folded and sheared metamorphosed sedimentary and volcanic rocks of Jurassic to Cretaceous age. The nature of its contact with these pre-Tertiary units has been related to crustal shortening and sea-floor spreading (Anonymous, 1969, p. A46). Volcanic rocks which conformably underlie or interfinger with the Umpqua are correlative with the Siletz River Volcanics of the central Coast Range.

The Umpqua Formation is considered lower and middle Eocene in age based on foraminifera (Stewart, 1956). Stewart found that the foraminiferal fauna of the "lower" Umpqua of Baldwin (1963), where it is exposed along the North Umpqua River near Glide, is similar to Laiming's (1940) Capay C zone of California, which is considered equivalent to the Penutian Stage of Mallory (1959).

One "lower" Umpqua sample (no. 2) of this study from near Glide (text fig. 3a) yielded six species of planktonic foraminifera (table 2), including *Globorotalia aequa*, *Globorotalia* sp., *Acarinina esnaensis*, and *Pseudohastigerina wilcoxensis*. *G. aequa* and *A. esnaensis* range from late Paleocene (Thanetian) to earliest Eocene (Ypresian) in the Gulf Coastal Plain and in Trinidad (Bolli, 1957b; Loeblich and Tappan, 1957). The genus *Pseudohastigerina* appears for the first time in the early Eocene (Berggren, Olsson, and Reymont, 1967); its oldest representative is *P. wilcoxensis*, known from the early lower Eocene in New Zealand (Jenkins, 1965) and from the early Eocene of Northern Europe (Berggren, 1969). It also occurs commonly in rocks of the late Ynezian, and more rarely into the late Penutian Stage in California (Mallory, 1959). Regional correlation of the planktonic foraminifera in sample no. 2 of the "lower" Umpqua Formation suggests an early Eocene (early Ypresian) age (table 1).

Stewart (1956) listed three species of planktonic foraminifera, also considered to be from the "lower" Umpqua near Glide. They are "*Globorotalia*" cf. "*G.*" *crassata* (Cushman), "*G.*" *crassata* (Cushman) var. *densa* (Cushman), and *Guembelitra* cf. *G. columbiana* Howe, none of which were found in the lower Umpqua sample of this study.

Tyee Formation

In the southern Coast Range, the Tyee Formation lies conformably and disconformably upon the Umpqua. It is composed principally of massive micaceous sandstone, occasionally crossbedded, with lesser amounts of shale (Turner, 1938). The Tyee here is variable in thickness (Diller, 1898), and has a greater proportion of sand to silt and shale than its central Coast Range counterpart. It is of shallow-water, shelf origin, and near the source of the bathyal turbidites in the Tyee exposed to the north (Snively, Wagner, and MacLeod, 1964; Lovell, 1969).

Benthonic foraminifera are rare and planktonic foraminifera are absent in the southern Coast Range Tyee Formation (see Stewart, 1956). The apparent absence of planktonic foraminifera may be attributed to the shal-

low, nearshore origin of the Tyee Formation in southwestern Oregon, where stream runoff may have restricted the plankton (Snively, Wagner, and MacLeod, 1964, p. 461). No samples from the southern Tyee were collected or examined in this study.

Elkton Siltstone

Baldwin (1961) designated 2,000–3,000 feet (610–915 m) of argillaceous siltstone and thinly bedded sandstone the "Elkton siltstone member of the Tyee Formation." It rests conformably in most places on sandstone characteristic of the Tyee. In this study the Elkton Siltstone is discussed separately, although it is still considered to be a member of the Tyee Formation (Beaulieu, 1971). Benthonic foraminifera are abundant in the Elkton Siltstone (Stewart, 1956).

A sample (no. D-3408) rich in planktonic foraminifera was recovered at north Agate Beach near Coos Bay (text fig. 3b), from a slump block which is situated stratigraphically beneath the Coaledo Formation along the beach. This isolated exposure is lithologically similar to, and probably is representative of, the Elkton Siltstone. The benthonic foraminifera of this sample have been assigned to Mallory's (1959) late Ulatisian Stage (J. G. Marr, written commun., 1972).

Five species of planktonic foraminifera were recovered from the north Agate Beach sample (table 2). *Pseudohastigerina lillisi* was described originally (as *Pullenia*) by Church (1931, 1943) from the Narizian Kreyenhagen Shale. Planktonic microfossils indicate that at least in some typical sections, the Narizian Stage (Kreyenhagen Shale) is middle Eocene, spanning part of the range for the tropical planktonic P10–P14 Zones (Bandy, 1972). *Guembelitra columbiana* ranges from the *Hantkenina aragonensis* Zone (P10) through the *Orbulinoides beckmanni* Zone (P13) in Trinidad (Beckmann, 1957). It also has been reported from the Sacate Formation (latest Narizian) in southern California which is considered late middle Eocene in age based on planktonic foraminifera (Steineck and Gibson, 1971). Therefore regional correlation of the north Agate Beach planktonic foraminifera suggests a middle Eocene (Lutetian) age (table 1).

Coaledo Formation

The Coaledo Formation lies with angular unconformity upon the underlying Umpqua Formation and upon shaly sandstones of uncertain assignment. The unconformity is of major importance in the Coos Bay area, for beneath the Coaledo, the Tyee Formation is missing (Allen and Baldwin, 1944). The Coaledo is

about 6,000 feet (1,830 m) thick where it is exposed along the coast (Allen and Baldwin, 1944). Turner (1938, p. 27–29) described the formation and divided it into three members. The lower and upper members are very similar, consisting predominantly of tuffaceous sandstone with some intercalated sandy shale beds, grit and coal beds, indicating shallow-water to nonmarine conditions at the time of deposition (Allen and Baldwin, 1944). The middle Coaledo is largely a tuffaceous shale with some lenses of sand.

Abundant benthonic foraminifera occur in the lower and middle members of the Coaledo Formation, but are restricted in occurrence in the upper member (Detling, 1946; Cushman, Stewart, and Stewart, 1948; Stewart, 1956). Samples from coastal exposures of the Coaledo have been assigned by J. G. Marr (written commun., 1972) to the latest Ulatisian and Narizian benthonic foraminiferal stages of Mallory (1959). Specifically, Marr considers the middle member of the Coaledo Formation to be late Narizian in age.

In this study, six species of planktonic foraminifera (table 2) were recovered from a middle Coaledo sample (no. D-3684; text fig. 3b). *Globigerina prasaepis* ranges in the tropics from latest Eocene (Zone P17) through the middle Oligocene (Blow, 1969). *Globigerina senilis* is known from late Eocene through middle Oligocene rocks in the tropics and Alabama (Bandy, 1949; Blow, 1969). The genus *Clavigerinella* is restricted to the middle and late Eocene in low latitudes (Bolli, Loeblich, and Tappan, 1957). Therefore, regional correlation of the middle Coaledo planktonic foraminifera indicates a late Eocene (Priabonian/ Bartonian) age (table 1). Also found in the middle Coaledo sample (no. D-3684) is a distinctive new species of *Subbotina*, described herein as *S. oregonensis*.

Bastendorff Formation

The Bastendorff Formation apparently conformably overlies the predominantly sandy member of the upper Coaledo (Allen and Baldwin, 1944). It is a thinly laminated shale with some thin strata of carbonaceous sandy shale and feldspathic sandstone. The Bastendorff has a total thickness of about 2,100 feet (640 m) along the beach, but the lower 1,000 feet (305 m) of this is not exposed (Allen and Baldwin, 1944).

Benthonic foraminifera are abundant in the Bastendorff Formation (Cushman and Schenk, 1928). Samples from the Bastendorff have been assigned to the California late Narizian and Refugian stages of Mallory (1959) and Kleinpell (1938) by J. G. Marr (written commun., 1972).

An assemblage (two samples, three feet apart) from the lower middle Bastendorff Formation (nos. A-8028,29; text fig. 3b) yielded five species of planktonic foraminifera (table 2). *Chiloguembelina cubensis* is long ranging, but *Subbotina wilsoni* is restricted to the late Eocene in Peru, and *Globigerinatheka index* is not in rocks younger than basal Oligocene in age (Bolli, 1972). The occurrence of the latter two species indicates an age no younger than basal Oligocene, and probably latest Eocene (Zone P17 of Blow, 1969) or older, for the lower middle Bastendorff assemblage (table 1).

A sample (no. A-8079; text fig. 3b) from the top of the Bastendorff Formation yielded a few well-preserved specimens (two species) of planktonic foraminifera (table 2), *Globigerina praebulloides* being the dominant species. This species also commonly occurs in the Nye Mudstone (table 2).

SUMMARY

The standard tropical plankton zonation is not equally applicable to all the Oregon planktonic assemblages of this study. The "lower" Umpqua sample, for example, can be placed within the Paleogene Zones P6b or P7. The upper Tyee sample (no. 25) is probably P11 in age. Higher in the section, the biostratigraphic usefulness of the zonation (as applied to Oregon rocks) decreases, especially in post-middle Eocene sediments. Samples from the Nestucca, Coaledo, and Bastendorff Formations, for example, are not closely assigned to the zonation based on planktonic foraminifera alone. This difficulty is perhaps due to a change in Oregon depositional sites in late middle Eocene time (see next section).

PALEOOCEANOGRAPHY

Planktonic foraminifera are sparse in mid-Tertiary (late Eocene to early Miocene) rocks of western Oregon, constituting from 1 percent to 15 percent of the total foraminifera recovered (table 3). The intermittent and sparse occurrence of planktonic foraminifera in these Oregonian rocks are not indicative of truly oceanic water masses. In modern cool-water masses, planktonic foraminifera are usually abundant in offshore waters, but decrease or are absent in near-shore areas (Lipps and Warme, 1966). The reasons for this decrease are not now clear although it appears to be related to runoff of terrestrial waters (Phleger, 1954). On these bases it has been inferred that off Oregon during the late Eocene and Oligocene, there

TABLE 3

Percent planktonic foraminifera of total foraminifera in samples from the Oregon Coast Range.

Formation or Formational unit	Sample No.	Percent Planktonic Foraminifera	Age (Series/Epoch)
Upper Nye	21*	1	early Miocene
Lower Nye	20*	1	?late Oligocene
Upper Bastendorff	A-8079	7	?Oligocene
Middle Bastendorff	A-8029	9	late Eocene
Middle Bastendorff	A-8028	12	late Eocene
Middle Alsea	13*	14	late Eocene
Lower Alsea	12*	3	late Eocene
Upper Nestucca	32	8	?late Eocene
Middle Coaledo	D-3684	12	late Eocene
?Elkton	D-3408	85	middle Eocene
Upper Tyee	25	71	middle Eocene
Upper Tyee	3*	33	middle Eocene
Lower Umpqua	2	55	early Eocene

* Sample number from McKeel and Lipps (1972).

was significant runoff from land to restrict oceanic plankton from nearshore basins (McKeel and Lipps, 1972).

However, in the early Tertiary (early and middle Eocene) assemblages reported here, planktonic foraminifera constitute greater than 30 percent and as high as 85 percent of the total foraminifera (table 3). This may indicate an offshore, more oceanic environment during deposition of these rocks, in contrast to the near-shore post-middle Eocene conditions off Oregon.

The apparently abrupt decrease in the relative abundance of planktonic foraminifera in post-middle Eocene Oregonian rocks perhaps best can be explained by the tectonic history proposed by MacLeod (1971). During the early and middle Eocene, deepwater siltstones and turbidites were deposited upon an oceanic basalt basement west of the North American plate margin as it existed then. In mid-late Eocene time widespread tectonism occurred and resulted in a major regional unconformity, which is interpreted by MacLeod as the beginning of an oceanic plate underthrusting beneath the North American plate west of Oregon and Washington. The tectonism, change of sedimentary environment to shallower water nearshore deposition, and subaerial volcanism indicate that at this time western Oregon and Washington may have become part of the North American plate, probably due to underthrusting of the oceanic plate west of the present coast (MacLeod 1971).

Species diversity of Oregon planktonic foraminifera is low compared to other areas, usually with one or two overwhelmingly dominant species per sample

(table 2). Correlative localities in tropical regions have yielded many more species than those from Oregon (McKeel and Lipps, 1972).

The early Eocene Umpqua planktonic foraminifera (from sample no. 2) of this study are dominated by a single species of *Globorotalia* (*G. aequa*); most species of this genus are normally indicative of low latitudes in modern environments (Bradshaw, 1959). However, the species diversity of the Umpqua sample is low, as are the other Oregon samples. Therefore we suggest that *Globorotalia aequa* was a more temperate species of the genus, as is *G. truncatulinoides* of modern faunas in the Pacific Ocean (Bradshaw, 1959). *Globorotalia aequa* also is a typical species of early Eocene low-diversity assemblages from northern Europe (Berggren, 1969).

SYSTEMATIC PALEONTOLOGY

Identifications and descriptions of planktonic foraminifera are based largely on comparisons of Oregon specimens with published figures. Abundance categories (see table 2) designate the following number of picked specimens per species: abundant (>100), common (41–100), few (11–40), rare (2–10).

Planktonic foraminiferal specimens from the Elkton, Coaledo, and Bastendorff Formations were returned to the University of California Museum of Paleontology, Berkeley, California. The remaining specimens have been deposited in the collections of the United States National Museum (USNM), Washington, D.C. In addition, all specimens illustrated in our previous paper (McKeel and Lipps, 1972) have also been deposited in the U.S. National Museum under numbers USNM 209207–209228.

Superfamily GLOBIGERINACEA

Carpenter, Parker, and Jones, 1862

Family GLOBOROTALIIDAE

Cushman, 1927

Subfamily GLOBOROTALIINAE

Cushman, 1927

Genus *Globorotalia* Cushman, 1927

Globorotalia aequa Cushman and Renz

Plate 1, figures 2a–c

Globorotalia crassata (Cushman) var. *aequa* CUSHMAN and RENZ, 1942, p. 12, pl. 3, figs. 3a–c.

Remarks. This species is 98 percent dextrally coiled in over 100 observed specimens from the lower Umpqua assemblage. Typical specimens are relatively small, one of which is figured in plate 1, figures 2a–c. Rare large

specimens possess a higher umbilical shoulder, and are more typical of *G. aequa*.

Globorotalia sp.

Plate 1, figures 1a–c, and Plate 2, figures 4a–c

Test a large trochospire, spiral side slightly convex, umbilical side strongly convex, outline slightly lobate, periphery sharply angled with a thick spinose keel. Wall covered with thick, stubby spines, otherwise smooth, final reduced chamber, when present, smooth. Chambers lunate on spiral side, angular on umbilical side, inflated, increasing rapidly in size, 4 in the final whorl. Sutures on dorsal side strongly curved; on umbilical side depressed, radial. Umbilicus and aperture obscured by matrix.

Remarks. This species is more robust than *Globorotalia aequa*, and has a distinct peripheral keel.

Genus **Acarinina** Subbotina, 1953

Acarinina cf. *A. angulosa* (Bolli)

Plate 3, figures 3a–c

Globigerina soldadoensis angulosa BOLLI, 1957, p. 71–72, pl. 16, figs. 4–6.

Remarks. This species differs from *G. soldadoensis angulosa* in having fewer chambers per whorl and an aperture that tends to be umbilical-extraumbilical rather than umbilical. However, it also is very similar to *A. interposita* Subbotina (Subbotina, 1953, Plate XXIII in *Acarinina* section, figs. 7a–c), and perhaps should be referred to Subbotina's taxon.

Acarinina bullbrookii (Bolli)

Plate 2, figures 3a–c

Globorotalia bullbrookii BOLLI, 1957, p. 167, pl. 38, figs. 4a–5c.

Remarks. This species differs from *A. esnaensis* in having a larger test, chambers which increase slowly in size, and an extraumbilical aperture.

Acarinina esnaensis (LeRoy)

Plate 1, figures 5a–d

Globigerina esnaensis LEROY, 1953, p. 31, pl. 6, figs. 8–10.

Remarks. Larger specimens than the ones figured were found, but all were damaged due to the fragile wall.

Genus **Truncorotaloides** Brönnimann
and Bermúdez, 1953

Truncorotaloides collactea (Finlay)

Plate 2, figures 6a–c

Globorotalia collactea FINLAY, 1939, p. 37, pl. 29, figs. 164–165.

Remarks. The specimen here illustrated has a subrounded periphery in contrast to a previously illustrated Tyee specimen by McKeel and Lipps (1972) with a subangular periphery. Due to the extreme rareness of supplementary apertures, plus the presence of a coarsely spinose wall, the genus *Acarinina* may prove to be a more suitable assignment for this common species.

Family **HANTKENINIDAE** Cushman, 1927

Subfamily **HANTKENININAE** Cushman, 1927

Genus **Clavigerinella** Bolli, Loeblich,
and Tappan, 1957

Clavigerinella colombiana (Petters)

Plate 3, figures 8a–c, and Plate 4,
figures 6a,b

Hastigerinella colombiana PETTERS, 1954, p. 40, pl. 8, figs. 10a,b.

Remarks. The rare small specimens of *Clavigerinella* found at north Agate Beach (Elkton Siltstone) and in the Coaledo Formation are typical only of immature specimens from the upper Tyee (see McKeel and Lipps, 1972), and perhaps represent a separate, higher ranging species. These immature specimens have a slightly asymmetrical, equatorial to extra-umbilical, highly arched aperture.

PLATE 1

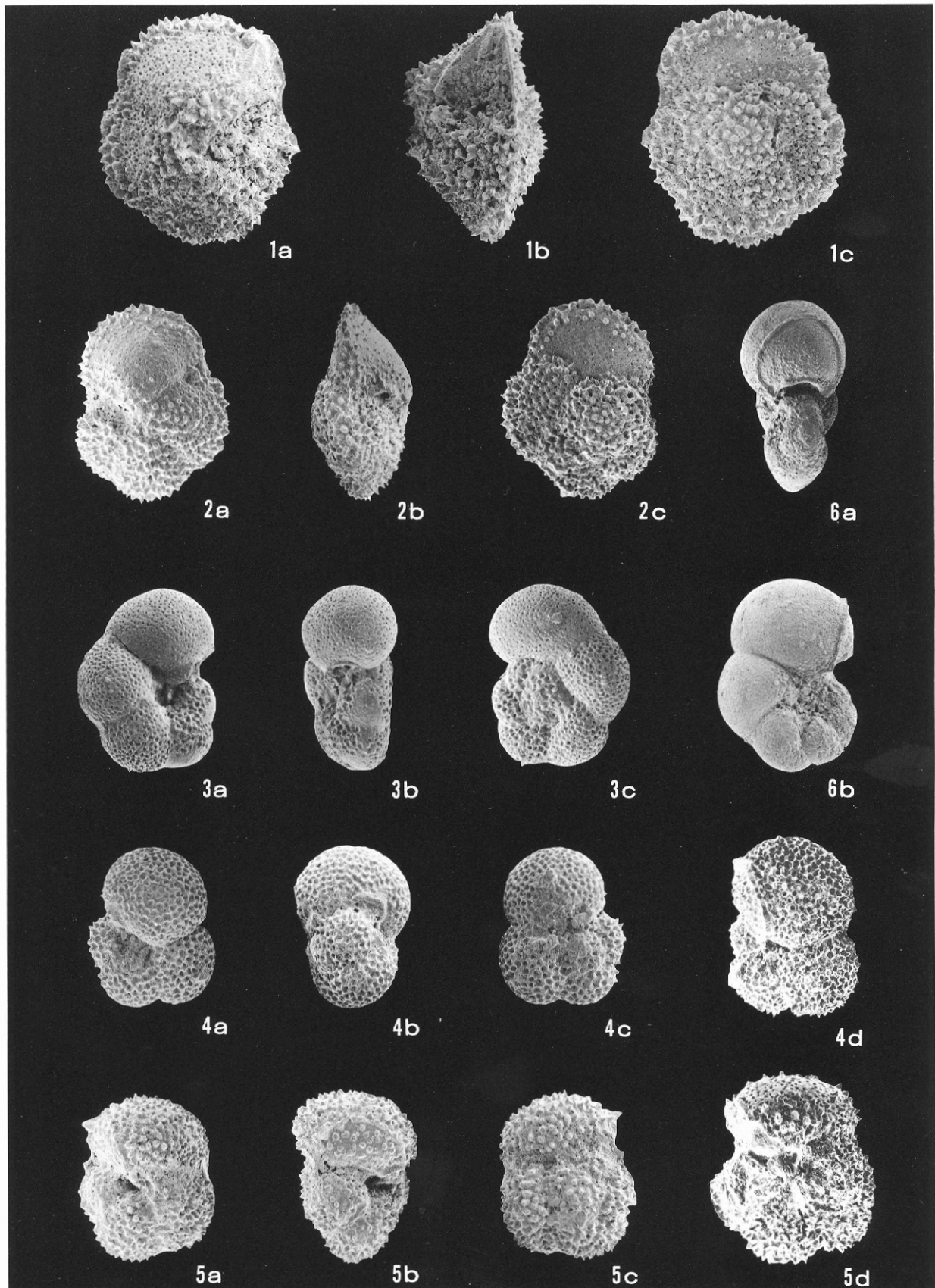
Planktonic foraminifera from the "lower" Umpqua Formation (sample no. 2 of this study). a. umbilical view, b. edge

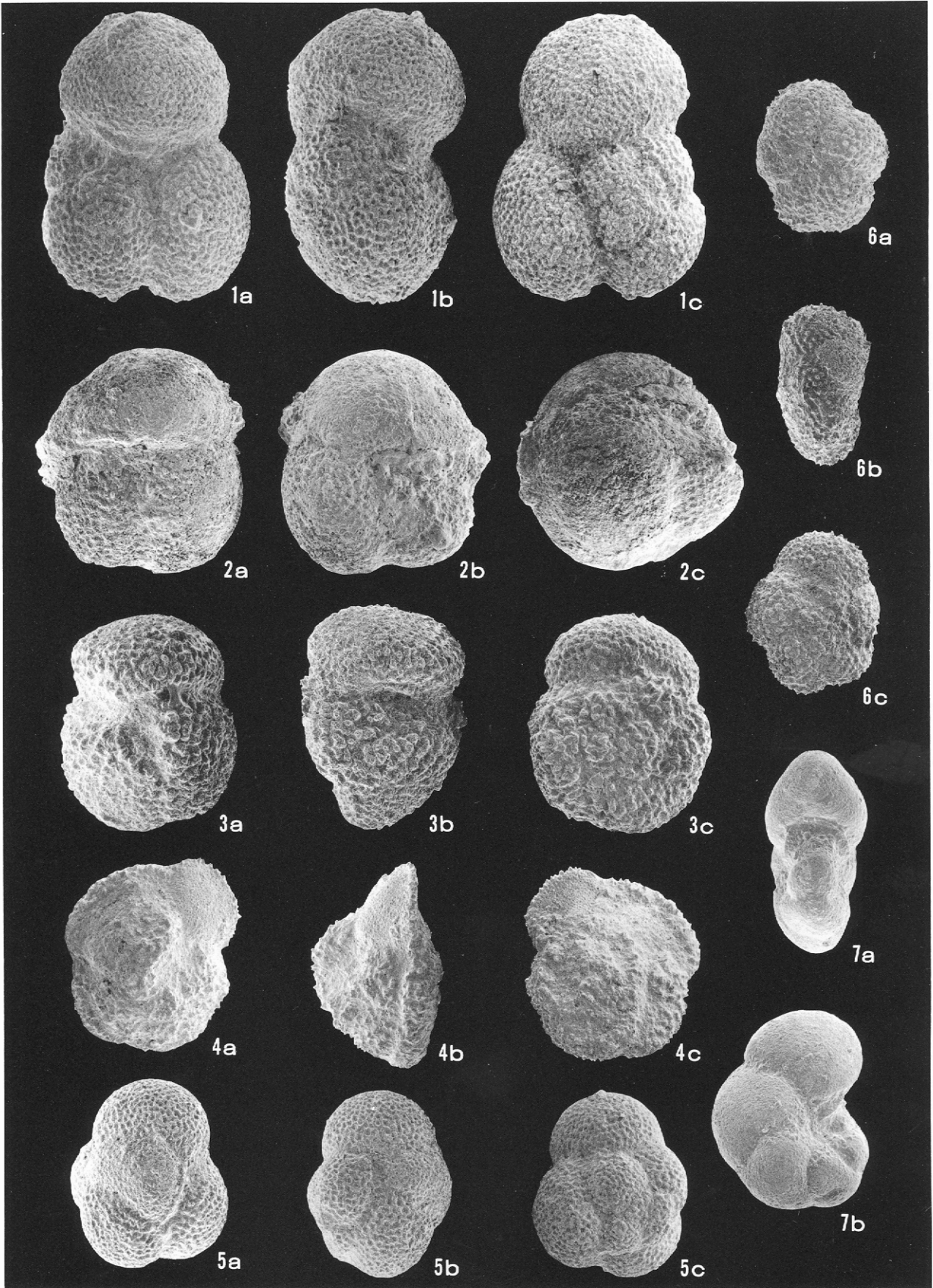
Figures

1. *Globorotalia* sp.
Typical specimen. USNM 209229.
2. *Globorotalia aequa* Cushman and Renz
Typical specimen (immature). USNM 209230.
3. *Globorotaloides* cf. *G. imitata* (Subbotina)
Large specimen. USNM 209231.
4. *Subbotina* cf. *S. trilocularis* (d'Orbigny)

view, c. spiral view, unless otherwise noted. All figures scanning electron micrographs, $\times 100$.

- a–c. Typical specimen. d. Large specimen, umbilical view. USNM 209232.
5. *Acarinina esnaensis* (LeRoy)
a–c. Typical specimen. d. Large specimen, umbilical view. USNM 209233, 209234.
6. *Pseudohastigerina wilcoxensis* (Cushman and Ponton)
Typical specimen. a. Edge view. b. Side view. USNM 209235.





Genus *Pseudohastigerina* Banner and Blow, 1959

Pseudohastigerina lillisi (Church)

Plate 3, figures 7a,b, and Plate 4, figures 5a–c

Pullenia lillisi CHURCH, 1931, p. 209, pl. A, fig. 10. *Ibid.*, 1943, p. 182, (description).

Remarks. Topotypes of “*Pullenia*” *lillisi* Church from the Kreyenhagen Shale of California were examined, and found to be *Pseudohastigerina*. Mature specimens from the Coaledo sample (sample D-3684) were compared with and found to be very similar to the topotypes. The north Agate Beach (Elkton) specimens all are small, and appear to be identical with immature specimens from the Coaledo sample. This species of *Pseudohastigerina* differs from others found during this study by the loose coiling in the late stages of ontogeny, accompanied by a highly arched aperture.

Pseudohastigerina cf. *P. micra* (Cole)

Plate 2, figures 7a,b

Nonion micrus COLE, 1927, p. 22, pl. 5, fig. 12.

Remarks. These specimens are considered intermediate between *Pseudohastigerina wilcoxensis* and *P. micra* in that the tests are ovoid in outline as in the former, but compressed in edge view as in the latter.

Pseudohastigerina wilcoxensis

(Cushman and Ponton)

Plate 1, figures 6a,b

Nonion wilcoxensis CUSHMAN and PONTON, 1932, p. 64, pl. 8, figs. 11a,b.

Remarks. This species differs from *Pseudohastigerina* cf. *P. micra* by having a broadly rounded periphery and less curved sutures (Berggren, Olsson, and Reymont, 1967, p. 271).

Family CATAPSYDRACIDAE Bolli, Loeblich and Tappan, 1957

Genus *Catapsydrax* Bolli, Loeblich, and Tappan, 1957

Catapsydrax primitiva Blow and Banner

Plate 2, figures 5a–c

Catapsydrax unicava primitiva BLOW and BANNER, 1962, p. 114, pl. XIV, p. 166, pl. 37, figs. 7a,b.

Remarks. These bullate specimens possibly are ecologic or reproductive variants of *Globigerina* cf. *G. yeguaensis* (pl. 2, fig. 1)

Genus *Globorotaloides* Bolli, 1957a

Globorotaloides cf. *G. imitata* (Subbotina)

Plate 1, figures 3a–c

Globorotalia imitata SUBBOTINA, 1953, v. 76, p. 206, pl. 16, figs. 14–16.

Remarks. This species possesses a combination of characteristics displayed by *G. pseudobulloidis* and *G. imitata* (see Loeblich & Tappan, 1957, p. 190, 192), but most closely resembles the latter. It differs from typical *G. imitata* by having more chambers per whorl, which increase fairly rapidly rather than gradually in size, and by having a distinctly perforate wall.

Globorotaloides aff. *G. pseudokugleri* (Blow)

Plate 5, figures 4a–c

Globorotalia pseudokugleri BLOW, 1969, in Brönnimann, P., and Renz, H. H., eds., p. 391, pl. 10, figs. 4–6.

Remarks. Our specimens differ from typical *G. pseudokugleri* in being smaller, having 6 rather than 7 chambers in the last whorl, and in appearing to have distinct pore-pits, which *G. pseudokugleri* lacks.

PLATE 2

Planktonic foraminifera from the upper Tyee Formation (sample no. 25). a. umbilical view, b. edge view, c. spiral

Figures

1. *Globigerina* cf. *G. yeguaensis* Weinzierl and Applin
Large specimen. USNM 209236.
2. *Globigerinatheka mexicana* (Cushman)
Typical specimen. a,b. Apertural views. c. View showing base and great inflation of final chamber. USNM 209237.
3. *Acarinina bullbrookii* (Bolli)
Typical specimen. USNM 209238.
4. *Globorotalia* sp.

view, unless otherwise noted. All figures scanning electron micrographs, $\times 100$ unless otherwise noted.

- Large specimen with reduced final chamber. $\times 50$. USNM 209239.
5. *Catapsydrax primitiva* Blow and Banner
Typical specimen. USNM 209240.
6. *Truncorotaloides collactea* (Finlay)
Specimen with reduced final chamber. USNM 209241.
7. *Pseudohastigerina* cf. *P. micra* (Cole)
Typical specimen. a. Edge view. b. Side view. USNM 209242.

Globorotaloides sp.

Plate 3, figures 1a–c, 2a–c

Description. Test a low trochospire, biconvex, outline lobate, periphery rounded. Wall of large specimens covered with prominent, thick, closely spaced pustular spines, smaller and less prominent on smaller specimens, giving pitted appearance. Chambers subglobular to spherical, increasing rapidly in size, 4 to 5 in the last whorl. Sutures depressed, curved in early stages, radial in late stages. Aperture a low, umbilical-extraumbilical arch, bordered by a distinct lip.

Remarks. This species is similar to *Globorotaloides suteri* Bolli (1957a, p. 117), but lacks highly inflated chambers and a finely cancellate wall. Reduced final chambers are often present, which partly, but never completely, cover the umbilicus.

Genus *Subbotina* Brotzen and Pozaryska, 1961

Subbotina linaperta (Finlay)

Plate 3, figures 4a–c

Globigerina linaperta FINLAY, 1939, p. 125, pl. 13, figs. 54–57.

Remarks. This species differs from *Subbotina oregonensis* n. sp., by having a less coarsely pitted wall and a much more rapidly increasing chamber size.

Subbotina oregonensis McKeel

and Lipps sp. nov.

Plate 4, figures 3a–c

Description. Test a low trochospire, biconvex, outline lobate, periphery rounded. Wall very coarsely pitted, reticulate. Chambers inflated, increasing regularly in size, 3 to 3½ in ultimate whorl, almost spherical. Sutures moderately depressed, radial. Aperture a low, umbilical-extraumbilical slitlike opening bordered by a rimlike lip.

Remarks. This species is easily differentiated from other species in the Coaledo sample by its relative small size and coarsely pitted wall. It differs from the Umpqua specimens of *Subbotina* cf. *S. trilocularis* by having a more coarsely pitted wall, and fewer chambers per whorl, which increase less rapidly in size. The type locality is in the middle Coaledo Formation (locality D-3684) exposed along the beach just southeast of Gregory Point (text fig. 3b).

Globigerina senilis Bandy

Plate 4, figures 2a–c

Globigerina ouachitaensis senilis BANDY, 1949, p. 121, pl. 22, figs. 5a–c.

Remarks. The Coaledo specimens closely resemble Bandy's (1949) figured holotype. *Globigerina senilis* differs from *G. prasaepis* in the open, more highly arched, but laterally more restricted aperture and the reduced (but not bullalike) final chamber.

Globigerina cf. *G. yeguaensis* Weinzierl and Applin

Plate 2, figures 1a–c

Globigerina yeguaensis WEINZIERL and APPLIN, 1929, p. 408, pl. 43, figs. 1a,b.

Remarks. This variable species differs from *S. linaperta* by its much larger size, pustulate wall, slower increase in chamber size through the penultimate chamber, and more highly arched aperture. It differs from typical *Globigerina yeguaensis* in having less inflated chambers.

Globigerina sp.

Plate 5, figures 7a–c

Test a small trochospire, outline lobate, periphery rounded. Wall evenly covered with closely spaced,

PLATE 3

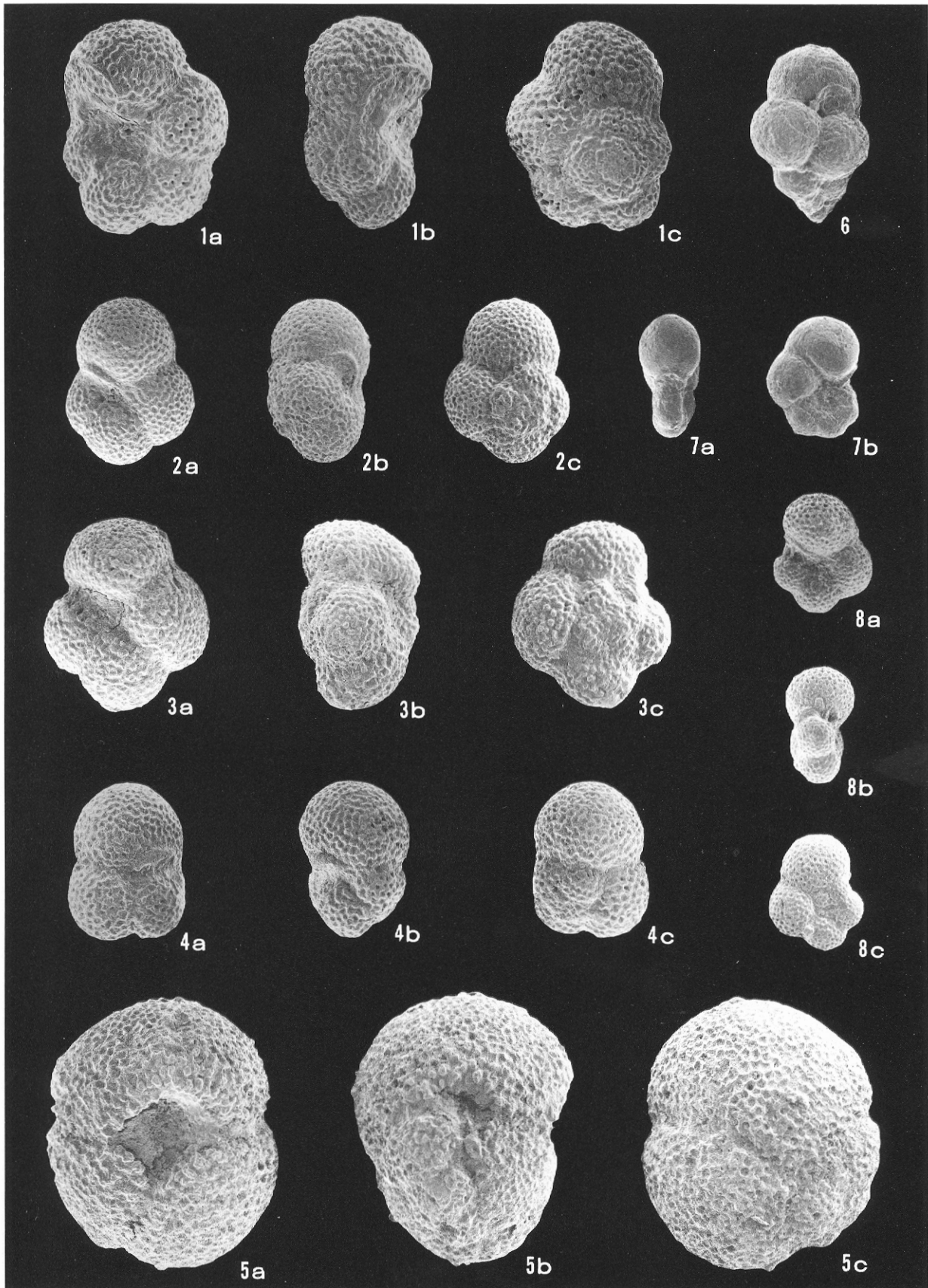
Planktonic foraminifera from the Elkton Siltstone (sample no. D-3408), and the Nestucca Formation (sample no. 32). a. umbilical view, b. edge view, c. spiral view, unless otherwise

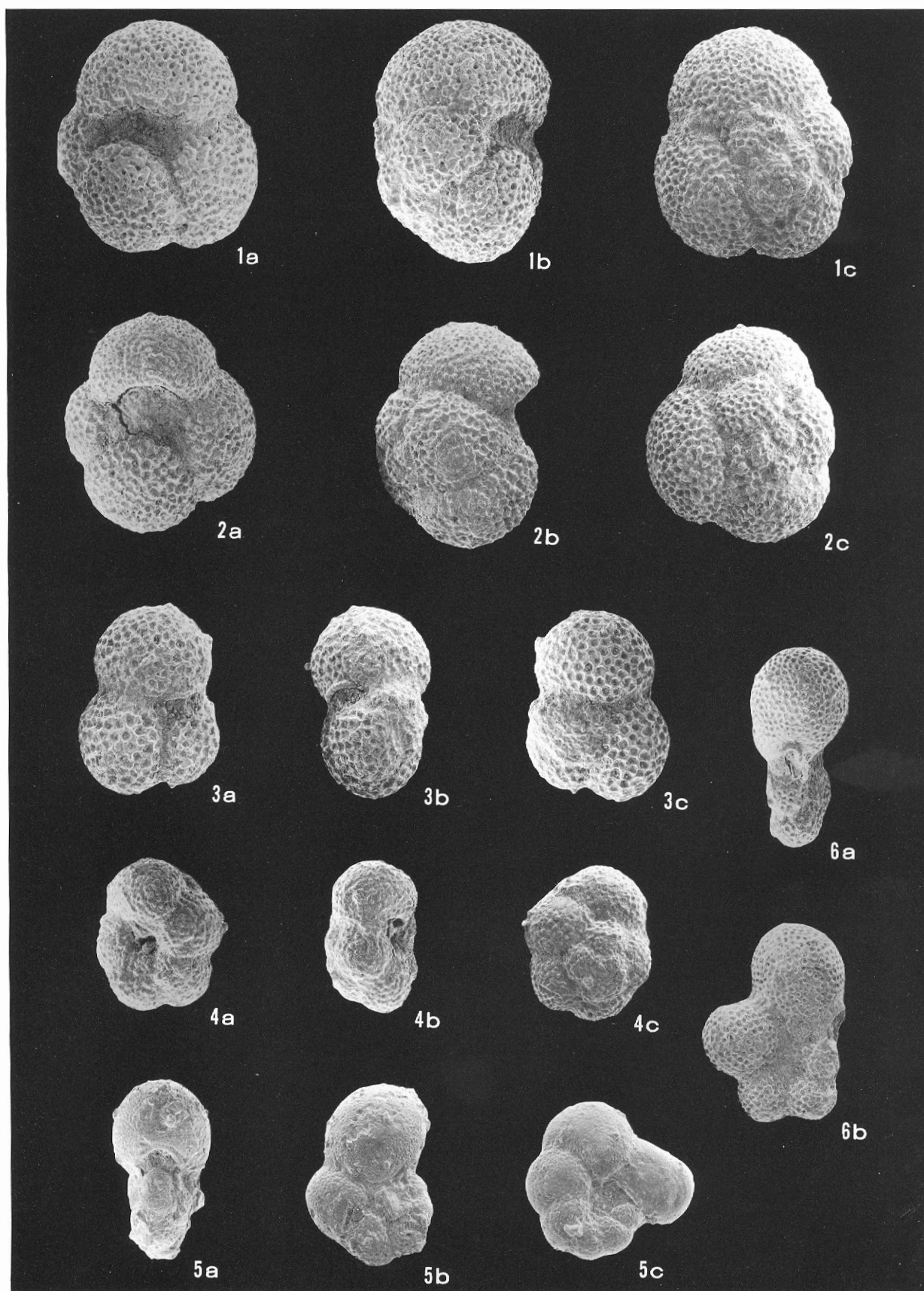
Figures

1. *Globorotaloides* sp.
Large specimen with secondarily deposited stubby spines. Sample no. D-3408.
2. *Globorotaloides* sp.
Typical specimen. Sample no. D-3408.
3. *Acarinina* cf. *A. angulosa* (Bolli)
Typical specimen. Sample no. D-3408.
4. *Subbotina linaperta* (Finlay)
Typical specimen. Sample no. D-3408.

noted. All figures scanning electron micrographs, × 100 unless otherwise noted.

5. *Globigerinatheka index* (Finlay)
Typical specimen. Sample no. 32. USNM 209243.
6. *Guembelitra columbiana* Howe
Typical specimen; apertural view. Sample no. D-3408. × 200.
7. *Pseudohastigerina lillisi* (Church)
Typical small specimen. a. Edge view. b. Side view. Sample no. D-3408.
8. *Clavigerinella ?columbiana* (Petters)
Juvenile specimen with asymmetrical aperture. Sample no. D-3408.





short pustular spines, joined by ridges, giving a pitted appearance. Chambers subspherical, increasing moderately and evenly in size, 4 in the last whorl. Sutures depressed, radial. Aperture a low, umbilical slitlike opening, bordered by a distinct lip.

Remarks. A single specimen was found. It may be an immature representative of a known species.

Family GLOBIGERINIDAE Carpenter,
Parker and Jones, 1862

Genus *Globigerina* d'Orbigny 1826

Globigerina aff. *G. ciperoensis* Bolli

Plate 4, figures 4a–c

Globigerina ciperoensis BOLLI, 1954, p. 1, figs. 3–6.

Remarks. This species closely resembles *G. ouachitaensis ciperoensis* forma *atypica* of Blow (1969, pl. 17, figs. 10–11), but has a pustulate rather than spinose wall.

Globigerina praebuloides Blow

Plate 5, figures 5a–c, 6a–c

Globigerina praebuloides BLOW, 1959, p. 180, pl. 9, fig. 48.

Remarks. Specimens from the top of the Bastendorff Formation appear to be identical to those found in the upper Nye Mudstone (see McKeel and Lipps, 1972, pl. 2, fig. 6).

Globigerina prasaepis Blow

Plate 4, figures 1a–c

Globigerina prasaepis BLOW, 1969, in Brönnimann, P., and Renz, H. H., eds., p. 382, pl. 10, fig. 13.

Remarks. Future functional morphologic studies of the variable final chamber in recent planktonic foraminifera may indicate that *G. prasaepis* and *G. senilis* of the Coaledo assemblage are conspecific (see Hofker, 1959, p. 2). In like manner, *G. senilis* and specimens referred to as *G. minima* from the Alsea siltstone may

be conspecific (see McKeel and Lipps, 1972, pl. 3, figs. 2,3).

Subbotina cf. *S. trilocularis* (d'Orbigny)

Plate 1, figures 4a–d

Globigerina trilocularis D'ORBIGNY, 1826, p. 277, no. 2.

Remarks. This species is distinguished from other species in the Umpqua assemblage by the pitted wall and nearly spherical chambers. *Subbotina* cf. *S. trilocularis* differs from *S. linaperta* and *S. oregonensis* n. sp. by having 4 rather than 3 to 3½ chambers in the ultimate whorl. It differs from typical *Globigerina trilocularis* d'Orbigny by the presence of a distinct apertural lip.

Subbotina wilsoni (Cole)

Plate 5, figures 2a–c

Globigerina wilsoni COLE, 1927, Am. Paleontology Bull., v. 14, no. 51, p. 34, pl. 4, figs. 8–9.

Remarks. This species resembles *Subbotina bolivariana* but is smaller and in general less involute on the spiral side (Weiss, 1955, p. 309). Previously illustrated specimens (as *Globigerina*) from the Siltstone of Alsea (see McKeel and Lipps, 1972, pl. 3, fig. 5) are pyritized, thus displaying a smooth wall. Bastendorff specimens are not pyritized, and have an evenly pitted wall.

Genus *Globigerinatheka* Brönnimann, 1952,
emended Proto Decima and Bolli, 1970.

Globigerinatheka index (Finlay)

Plate 3, figures 5a–c, and Plate 5, figures 1a–c

Globigerinoides index FINLAY, 1939, p. 125, pl. 14, figs. 85–88.

Remarks. Immature specimens are easily recognizable as *G. index* by the distinctive wall texture, but usually lack a supplementary aperture.

PLATE 4

Planktonic foraminifera from the middle Coaledo Formation (sample no. D-3684). a. umbilical view, b. edge view, c. spiral

Figures

1. *Globigerina prasaepis* Blow
Typical specimen.

2. *Globigerina senilis* Bandy
Typical specimen.

3. *Subbotina oregonensis* McKeel and Lipps sp. nov.
Holotype, UC Berkeley collection.

view, unless otherwise noted. All figures scanning electron micrographs, × 100.

4. *Globigerina* aff. *G. ciperoensis* Bolli
Typical specimen.

5. *Pseudohastigerina lillisi* (Church)
a, b. Typical specimen. a. Edge view. b. Side view.
c. Side view of specimen with aberrant final chamber.

6. *Clavigerinella ?colombiana* (Petters)
Typical small specimen. a. Edge view. b. Side view.

Globigerinatheka mexicana (Cushman)

Plate 2, figures 2a-c

Globigerina mexicana CUSHMAN, 1925, p. 4-9, pl. 1, figs. 8a,b.

Remarks. Tyee specimens appear to be identical to the holotype figured by Blow and Saito (1968, p. 358), except that some have four apertures rather than three.

Family HETEROHELICIDAE Cushman, 1927

Subfamily HETEROHELICINAE Cushman, 1927

Genus *Chiloguembelina* Loeblich and Tappan, 1956

Chiloguembelina cubensis (Palmer)

Plate 5, figures 3a,b

Gumbelina cubensis PALMER, 1934, p. 74, figs. 1-6.

Remarks. The Bastendorff specimens are very similar to those from the Siltstone of Alsea (see McKeel and Lipps, 1972, pl. 3, fig. 6).

Genus *Guembelitria* Cushman, 1933

Guembelitria columbiana Howe

Plate 3, figure 6

Guembelitria columbiana HOWE, 1939, p. 62, pl. 8, figs. 12-13.

Remarks. Three specimens of this tiny species were found in the north Agate Beach (Elkton) sample.

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REFERENCES

- ALLEN, J. E., and BALDWIN, E. M., 1944, Geology and coal resources of the Coos Bay quadrangle, Oregon: Oregon Dept. Geology and Mineral Industries Bull. 27, p. 1-153.
- ANONYMOUS, 1969, Geological, geophysical, and mineral-resource studies, Pacific coast region: U.S. Geol. Survey Prof. Paper 650-A, p. A45-A48.
- BALDWIN, E. M., 1961, Geologic map of the lower Umpqua

- River area, Oregon: U.S. Geol. Survey Oil and Gas Inv. Map OM-204.
- , 1963, Lower and middle Eocene formations of southwestern Oregon [abs.]: Geol. Soc. America Spec. Paper 76, p. 188-189.
- , 1964, Geology of Oregon: Oregon Univ., Eugene Oregon, Cooperative Book Store, p. 1-165.
- BALDWIN, E. M., BROWN, R. D., JR., GAIR, J. E., and PEASE, H. M., JR., 1955, Geology of the Sheridan and McMinnville quadrangles, Oregon: U.S. Geol. Survey Oil and Gas Inv. Map OM-155.
- BANDY, O. L., 1944, Eocene foraminifera from Cape Blanco, Oregon: Jour. Paleontology 18, p. 366-377.
- , 1949, Eocene and Oligocene foraminifera from Little Stave Creek, Clarke County, Alabama: Am. Paleontology Bull. 32, 210 p.
- , 1972, Late Paleogene-Neogene planktonic biostratigraphy and its geologic implications, California: Program of Abstracts, Pacific Sec. Soc. Econ. Paleontologists and Mineralogists, Bakersfield, California, p. 18.
- BANNER, F. T., and BLOW, W. H., 1959, The classification and stratigraphical distribution of the Globigerinaceae: Palaeontology, v. 2, pt. 1, p. 1-27.
- BEAULIEU, J. D., 1971, Geologic formations of western Oregon: Oregon Dept. Geology and Mineral Industries Bull. 70, 72 p.
- BECKMANN, J. P., 1957, *Chiloguembelina* Loeblich and Tappan and related foraminifera from the lower Tertiary of Trinidad, B.W.I.: U.S. Natl. Mus. Bull. 215, p. 83-93.
- BERGGREN, W. A., 1968, Phylogenetic and taxonomic problems of some Tertiary planktonic foraminiferal lineages: Tulane Studies Geol. 6, p. 1-22.
- , 1969, Paleogene biostratigraphy and planktonic foraminifera of Northern Europe: Internat. Conf. Planktonic Microfossils, 1st, Geneva (1967), Proc., v. 1, p. 121-160.
- BERGGREN, W. A., and VAN COUVERING, J., 1973, Late Neogene chronostratigraphy, biostratigraphy, biochronology and paleoclimatology: Woods Hole Oceanog. Inst. Tech. Rept. 73-40, 275 p.
- BERGGREN, W. A., OLSSON, R. K., and REYMENT, R. A., 1967, Origin and development of the foraminiferal genus *Pseudohastigerina* Banner and Blow, 1959: Micropaleontology, v. 13, p. 265-288.
- BLOW, W. H., 1959, Age, correlation and biostratigraphy of the Upper Tocuyo (San Lorenzo) and Pozon Formations, eastern Falcon, Venezuela: Am. Paleontology Bull. v. 39, no. 178, p. 67-252.
- , 1969, Late Middle Eocene to Recent planktonic foraminiferal biostratigraphy: Internat. Conf. Planktonic Microfossils, 1st, Geneva (1967), Proc., v. 1, p. 199-422.
- BLOW, W. H., and BANNER, F. T., 1962, The mid-Tertiary (Upper Eocene-Aquitania) Globigerinaceae, in Eames, F. E., Banner, F. T., Blow, W. H., and Clarke, W. J., Fundamentals of Mid-Tertiary Stratigraphical Correlation: Cambridge Univ. Press, p. 61-151.
- BLOW, W. H., and SAITO, T., 1968, The morphology and taxonomy of *Globigerina mexicana* Cushman, 1925: Micropaleontology, v. 14, p. 357-360.
- BOLLI, H. M., 1954, Note on *Globigerina concinna* Reuss 1850: Cushman Found. Foraminiferal Research Contr., v. 5, pt. 1, p. 1-3.

- , 1957a, Planktonic foraminifera from the Oligocene-Miocene Cipero and Lengua Formations of Trinidad, B.W.I.: U.S. Natl. Mus. Bull. 215, p. 97–124.
- , 1957b, The genera *Globigerina* and *Globorotalia* in the Paleocene-Lower Eocene Lizard Springs Formation of Trinidad, B.W.I.: U.S. Natl. Mus. Bull. 215, p. 61–82.
- , 1957c, Planktonic foraminifera from the Eocene Navet and San Fernando formations of Trinidad, B.W.I.: U.S. Natl. Mus. Bull. 215, p. 155–172.
- , 1972, The genus *Globigerinatheka* Brönnimann: Jour. Foram. Research, v. 2, no. 3, p. 109–136.
- BOLLI, H., LOEBLICH, A. R., JR., and TAPPAN, HELEN, 1957, Planktonic foraminiferal families Hankeniniidae, Orbulinidae, Globorotalidae and Globotruncanidae: U.S. Natl. Mus. Bull. 215, p. 3–50.
- BRADSHAW, J. S., 1959, Ecology of living planktonic foraminifera in the North and Equatorial Pacific: Cushman Found. Foram. Research Contr., v. 10, p. 25–64.
- BRAISLIN, D. B., HASTINGS, D. D., and SNAVELY, P. D., JR., 1971, Petroleum potential of Western Oregon and Washington and adjacent continental margin: Am. Assoc. Petroleum Geologists Mem. 15, p. 229–238.
- BRÖNNIMANN, P., 1952, *Globigerinoida* and *Globigerinatheka*, new genera from the Tertiary of Trinidad, B.W.I.: Cushman Found. Foram. Research, Contr., v. 3, pt. 1, p. 25–28.
- BRÖNNIMANN, P., and BERMÚDEZ, P. J., 1953, *Truncorotaloides*, a new foraminiferal genus from the Eocene of Trinidad, B.W.I.: Jour. Paleontology, v. 27, p. 817–820.
- BROTZEN, F., and POZARYSKA, K., 1961, Foraminifères du Paléocène et de l'Eocène inférieur en Pologne septentrionale remarques paléogéographiques: Rev. Micro-paléontologie, v. 4, no. 3, p. 155–166.
- CARPENTER, W. B., PARKER, W. K., and JONES, T. R., 1862, Introduction to the study of the foraminifera: Ray Soc. Publs., p. 1–319.
- CHURCH, C. C., 1931, Foraminifera of the Kreyenhagen shale: Calif. Div. Mines State Mineralogists Rept., v. 27, p. 202–213.
- , 1943, Descriptions of foraminifera: Calif. Div. Mines Bull. 118, p. 182.
- COLE, W. S., 1927, A foraminiferal fauna from the Guayabal Formation in Mexico: Am. Paleontology Bull. v. 14, no. 51, p. 1–46.
- CUSHMAN, J. A., 1925, New Foraminifera from the Upper Eocene of Mexico: Cushman Lab. Foram. Research Contr., v. 1, no. 1, p. 4–10.
- , 1927, An outline of a re-classification of the foraminifera: Cushman Lab. Foram. Research Contr., v. 3, pt. 1, p. 1–105.
- , 1933, Post-Cretaceous occurrence of *Gumbelina* with a description of a new species: Cushman Lab. Foram. Research Contr., v. 9, p. 64–69.
- CUSHMAN, J. A., and PONTON, G., 1932, An Eocene foraminiferal fauna of Wilcox age from Alabama: Cushman Lab. Foram. Research Contr., v. 8, pt. 3, p. 51–72.
- CUSHMAN, J. A., and RENZ, H. H., 1942, Eocene, Midway, foraminifera from Soldado Rock, Trinidad: Cushman Lab. Foram. Research Contr., v. 18, pt. 1, p. 1–14.
- CUSHMAN, J. A., and SCHENCK, H. G., 1928, Two foraminiferal faunules from the Oregon Tertiary: California Univ., Dept. Geol. Sci. Bull., v. 17, p. 305–324.
- CUSHMAN, J. A., STEWART, R. E., and STEWART, K. C., 1948, Five papers on foraminifera from the Tertiary of western Oregon: Oregon Dept. Geology and Mineral Industries Bull. 36, p. 1–111.
- DETLING, M. R., 1946, Foraminifera of the Coos Bay lower Tertiary, Coos County, Oregon: Jour. Paleontology, v. 20, p. 348–361.
- DILLER, J. S., 1898, Description of the Roseburg Quadrangle: U.S. Geol. Survey Geol. Atlas, Roseburg Folio (no. 49), p. 1–4, maps.
- FINLAY, H. J., 1939a, New Zealand Foraminifera: Key species in stratigraphy—No. 2: Royal Soc. New Zealand Trans. Proc., Wellington, New Zealand, v. 69, pt. 1, p. 89–128.
- , 1939b, New Zealand Foraminifera: Key species in stratigraphy—No. 3: Royal Soc. New Zealand Trans. Proc., Wellington, New Zealand, v. 69, pt. 3, p. 309–329.
- FOWLER, G. A., ORR, W. N., and KULM, L. D., 1971, An upper Miocene diatomaceous rock unit on the Oregon continental shelf: Jour. Geology, v. 79, p. 603–608.
- HOFKER, J., 1959, On the splitting of *Globigerina*: Cushman Found. Foram. Research Contr., v. 10, p. 1–9.
- HOWE, H. V., 1939, Louisiana Cook Mountain foraminifera: Louisiana Geol. Surv. Bull. 14, p. 1–122.
- JENKINS, D. G., 1965, [(1966)] Planktonic foraminiferal zones and new taxa from the Danian to Lower Miocene of New Zealand. New Zealand Jour. Geology and Geophysics v. 8, p. 1088–1126.
- KLEINPELL, R. M., 1938, Miocene stratigraphy of California: Am. Assoc. Petroleum Geologists, Tulsa, Oklahoma, 450 p.
- LAISING, B. G., 1940, Some foraminiferal correlations in the Eocene of the San Joaquin Valley, California. Pacific Sci. Cong., 6th, 1939, Proc., v. 2, p. 535–568.
- LEROY, L. W., 1953, Biostratigraphy of the Maqfi section, Egypt: Geol. Soc. America Mem., New York, no. 54, p. 1–73.
- LIPPS, J. H., and WARME, J. E., 1966, Planktonic foraminiferal biofacies in the Okhotsk Sea: Cushman Found. Foram. Research Contr., v. 17, p. 125–134.
- LOEBLICH, A. R., JR., and TAPPAN, H., 1956, *Chiloguembelina*, a new Tertiary genus of the Heterohelidae (Foraminifera): Washington Acad. Sci. Jour., v. 46, no. 11, p. 340.
- , 1957, Planktonic foraminifera of Paleocene and Early Eocene age from the Gulf and Atlantic Coastal Plains: U.S. Natl. Mus. Bull. 215, p. 173–198.
- LOVELL, J. P. B., 1969, Tyee Formation: Undeformed turbidites and their lateral equivalents: mineralogy and paleogeography: Geol. Soc. America Bull. 80, p. 9–22.
- MACLEOD, N. S., 1971, Plate tectonics and the Tertiary geology of western Oregon and Washington, in Moen, A. D., ed., Symposium on tectonism of the Pacific Northwest: Am. Geophysics Union Trans., v. 52, p. 640–641.
- MALLORY, V. S., 1959, Lower Tertiary biostratigraphy of the California Coast Ranges: Am. Assoc. Petroleum Geologists, Tulsa, Oklahoma, 416 p.
- MCKEEL, D. R., and LIPPS, J. H., 1972, Calcareous plankton from the Tertiary of Oregon: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 12, p. 75–93.
- ORBIGNY, A. D', 1826, Tableau méthodique de la classe des Céphalopodes: Ann. Sci. Nat., Paris, sér. 1, tome 7, p. 96–314.
- PALMER, D. K., 1934, The Foraminiferal Genus *Gumbelina*

- in the Tertiary of Cuba: Soc. Cubana Hist. Nat. Filipe Poey Mem., v. 8, p. 73-76.
- PETERS, V., 1954, Tertiary and Upper Cretaceous Foraminifera from Colombia, S. A.: Cushman Found. Foram. Research Contr., v. 5, p. 37-41.
- PHLEGER, F. B., 1954, Foraminifera and deep-sea research: Deep-Sea Research, v. 2, p. 1-23.
- PROTO DECIMA, FRANCA, and BOLLI, H. M., 1970, Evolution and variability of *Orbulinoides beckmanni* (Saito): Eclogae Geol. Helv., v. 63, no. 3, p. 883-905.
- SNAVELY, P. D., JR., and BALDWIN, E. M., 1948, Siletz River volcanic series, northwestern Oregon: Am. Assoc. Petroleum Geologists, v. 32, p. 805-812.
- SNAVELY, P. D., JR., and WAGNER, H. C., 1963, Tertiary geologic history of western Oregon and Washington: Washington Div. Mines and Geology Rept. Inv. 22, p. 1-25.
- SNAVELY, P. D., JR., WAGNER, H. C., and MACLEOD, N. S., 1964, Rhythmic bedded eugeosynclinal deposits of the Tyee Formation, Oregon Coast Range: Kansas Geol. Survey Bull. 169, p. 461-480.
- SNAVELY, P. D., JR., MACLEOD, N. S., and WAGNER, H. C., 1968, Tholeiitic and alkalic basalts of the Eocene Siletz River Volcanics, Oregon Coast Range: Am. Jour. Sci., v. 266, p. 454-481.
- SNAVELY, P. D., JR., MACLEOD, N. S., and RAU, W. W., 1969a, Geology of the Newport area, Oregon, Part 1: The Ore Bin, v. 31, p. 25-48.
- , 1969b, Geology of the Newport area, Oregon, Part 2: The Ore Bin, v. 31, p. 49-71.
- STEINECK, P. L., 1971, Middle Eocene refrigeration—New evidence from California planktonic foraminiferal assemblages: Lethaia, v. 4, p. 125-129.
- STEINECK, P. L., and GIBSON, J. M., 1971, Age and correlation of the Eocene Ulatian and Narizian stages, California: Geol. Soc. America Bull., v. 82, p. 477-480.
- STEWART, R. E., 1956, Stratigraphic implications of some Cenozoic foraminifera from western Oregon: The Ore Bin, v. 18, 19, no. 2, 3 text-figures.
- SUBBOTINA, N. N., 1953, Globigerinidy, Khantkennidy i Globorotaliidy. Vses. Neft. Nauchno-Issled. Geol.-Razved. Inst. Trudy, n. ser., v. 76, p. 1-294.
- TURNER, F. E., 1938, Stratigraphy and Mollusca of the Eocene of western Oregon: Geol. Soc. America Spec. Paper 10, p. 1-130.
- WEINZIERL, L. L., and APPLIN, E. R., 1929, The Claiborne Formation on the Coastal Domes: Jour. Paleontology, v. 3, no. 4, p. 384-410.
- WEISS, L., 1955, Planktonic index foraminifera of northwestern Peru: Micropaleontology, v. 1, p. 301-319.

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PLATE 5

Planktonic foraminifera from the Bastendorff Formation.
a. umbilical view, b. edge view, c. spiral view, unless otherwise

Figures

1. *Globigerinatheka index* (Finlay)
Typical specimen. Sample no. A-8028.
2. *Subbotina wilsoni* (Cole)
Typical specimen. Sample no. A-8029.
3. *Chiloguembelina cubensis* (Palmer)
Typical specimen. a. Edge view. b. Side view. Sample no. A-8028.

noted. All figures scanning electron micrographs, $\times 100$.

4. *Globorotaloides* aff. *G. pseudokugleri* (Blow)
Typical specimen. Sample no. A-8028.
5. *Globigerina praebulloides* Blow
Typical specimen. Sample no. A-8079.
6. *Globigerina praebulloides* Blow
Four-chambered specimen. Sample no. A-8079.
7. *Globigerina* sp.
This single specimen was found. Sample no. A-8079.

