AN ABSTRACT OF THE THESIS OF

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Abstract approved: Redacted for Privacy
(Dr. David A. Bostwick)

Fossil foraminifers from the Coaledo and Bastendorff Formations near Coos Bay in southwestern Oregon were studied in an attempt to determine the age and environment of deposition. Fresh unweathered samples were collected from sea cliffs between Cape Arago and Charleston, Oregon.

A large late Eocene delta is preserved in the rocks near Coos Bay, Oregon. The interpretations of previous workers, that the sandstones of the Coaledo Formation represent regressive offlap and the mudstones of the middle Coaledo and Bastendorff are the result of transgressive onlap of late Eocene seas, remain unchanged.

The number of known species of fossil foraminifers from the Coaledo and Bastendorff Formations has been increased as a result

of this study from 46 species to 148 species. The number of known planktonic species reported from the rocks of the region has been increased from 13 species to 28 species.

The Coaledo Formation is middle late Eocene in age and is correlated in part with the Uvigerina garzaensis Subzone of the Bulimina corrugata Zone and in part with the Amphimorphina jenkinsi Zone of the standard West Coast Narizian Stage. The Bastendorff Formation has been considered in previous studies to be partly Eocene and partly Oligocene in age. Study of benthic foraminifers indicates that the Bastendorff contains a Uvigerina cocoaensis fauna, which can be correlated with the lower part of the Refugian Stage of the Tertiary of California and with the late Eocene Cocoa sandstone of the Gulf Coast. Planktonic foraminifers from the Bastendorff are entirely late Eocene in age and are correlated with confidence with the Runangan Stage of New Zealand and tentatively with the P17 (=Globigerina gortani-Globorotalia (T.) centralis) partial range zone of tropical regions. The lower part of the Refugian Stage of the West Coast is considered here to be late Eocene rather than early Oligocene in age. The entire Bastendorff Formation is considered to be late Eocene in age.

The mudstones and siltstones of the middle Coaledo and Bastendorff have been previously interpreted as having been deposited in a shallow marine bay or upon the continental shelf. The present study of the fossil foraminifers of these formations has indicated that deposition of the middle Coaledo probably occurred at upper bathyal to lower neritic depths and that the Bastendorff Formation was deposited at lower bathyal to upper abyssal depths. High numbers of fossil radiolarians and planktonic foraminifers found in samples from the Bastendorff Formation suggest that deposition occurred in a region influenced by an open-ocean, mid-latitude water-mass, rather than on the continental shelf or in a restricted embayment.

The presence of a normal marine, deep-water microfauna in mudstone units, located stratigraphically between non-marine deltaic sandstones, implies that strong vertical movements occurred during and immediately following the deposition of the Coaledo delta. The idea of a simple lateral shifting of a prograding deltaic complex is not supported by the study of benthic foraminiferal faunas. Vertical movements in southwest Oregon in late Eocene time may have been the result of underthrusting of an oceanic plate beneath the North American plate.

The stratigraphic position, the sequence of sedimentary facies, and the occurrence of unique sandstone-filled channels with mudstone breccias all indicate that the beds at North and South Coves of Cape Arago should be correlated with similar strata of the Elkton Formation five miles south at Sacchi Beach rather than being considered a part of the Coaledo Formation.

Biostratigraphy and Paleoecology of the Coaledo and Bastendorff Formations, Southwestern Oregon

by

Guy Harlan Rooth

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TABLE OF CONTENTS

	Page
INTRODUCTION	1
Purpose	1
Location and Geologic Setting	1
History of Previous Investigations	2
Stratigraphic and Economic Studies	4
Paleontologic Investigations	8
Methods of Investigation	10
Field Procedures	10
Laboratory Procedures	11
PHYSICAL STRATIGRAPHY	13
Regional Geologic Setting	13
Elkton Formation at Sacchi Beach	15
Elkton Formation at North Cove	18
Description of Lithofacies at North Cove	18
Facies A, Dark Mudstones	18
Facies B, Interbedded silty mudstones and fine sandstones	24
Facies C, Mudstone-sandstone channels	28
Facies D, Sandstone channels with mudstone breccias	31
Elkton Formation at South Cove	38
Environmental Interpretation of beds at North Cove	38
Facies A	38
Facies B	39
Facies C and D	41
Regional Synthesis and Depositional History of the Elkton Formation	44
Coaledo Formation	50
General Statement	50
Lower Sandstone Member	50
Sedimentary Structures	51
Mollusks	56
Conditions of Deposition	57
Middle Mudstone Member	57
Upper Sandstone Member	59
Bastendorff Formation	64
Younger Formations	65

TABLE OF CONTENTS (CONTINUED)

	Page
STRUCTURAL GEOLOGY	66
Regional Setting	66
Folding and Faulting	67
Summary of Structural History	71
BIOSTRATIGRAPHY	73
Historical Development of Pacific Coast Biostratigraphic Zonation	73
Standard West Coast Zonation (mollusks)	75
Correlation Based Upon Benthic Foraminifers	77
Age of the Elkton Formation	77
Age of the Coaledo Formation	78
Age of the Bastendorff Formation	81
World-wide Planktonic Foraminiferal Zonation	86
General Statement	86
Planktonic Foraminifers from the Coaledo and Bastendorff Formations	90
Age Based Upon Planktonic Foraminifers	92
Correlation with Other Rock Units	95
PALEOECOLOGY	98
General Statement	98
Microfossils: Paleobathymetric and Paleoecologic Interpretations	99
Scope and Methods	99
Gross Population Trends	100
Foraminiferal Number	100
Planktonic-benthic Ratio	102
Species Diversity	104
Radiolarian Trends	106
Ostracod Trends	108
Composition of Tests	108
Benthic Faunal Groups	108
Species Comparison	109
Morphology of Tests	111
Dominant Benthic Faunal Groups	116
Geographic Distribution of Benthic Foraminifers	118
Mollusks: Paleobathymetric Interpretations and Geographic Variations	119
Paleobathymetry	119
Geographic Distribution	123
Paleooceanography	124

TABLE OF CONTENTS (CONTINUED)

	Page
PALEOGEOGRAPHY AND GEOLOGIC HISTORY	128
SUMMARY AND CONCLUSIONS	135
SYSTEMATIC PALEONTOLOGY	138
BIBLIOGRAPHY	220
APPENDICES	
Appendix A. Fossil Localities.	238
Appendix B. Stratigraphic Distribution of Mollusks in Coaledo and Bastendorff Formations.	245
PLATES	247

LIST OF FIGURES

Figure		Page
1.	Location of area studied.	3
2.	Generalized stratigraphic column of Tertiary rocks in the Cape Arago-Charleston region.	5
3.	Geologic map of the South Slough-Cape Arago area.	7
4.	Explanation of symbols used in Figures 5, 7, 8, 25.	16
5.	Stratigraphic section and north end of Sacchi Beach.	17
6.	Location of measured sections in Elkton-Coaledo transition at Sacchi Beach, South Cove and North Cove.	19
7.	Stratigraphic section along the south side of North Cove.	20
8.	Stratigraphic section along the northeast side of North Cove.	21
9.	Facies A. Laminated mudstones. Elkton Formation.	22
10.	Facies A. Laminated mudstones (dark) with interbedded muddy siltstones. Elkton Formation.	23
11.	Siltstone "roll-up" within Facies A. Elkton Formation.	23
12.	Facies B. Interbedded mudstones and siltstones. Elkton Formation.	25
13.	Facies B. Parallel lamination of carbonaceous siltstones within a sandstone unit. Elkton Formation.	26
14.	Facies B. Ripple-drift cross-lamination. Elkton Formation.	26
15.	Facies B. Contorted bedding in interbedded siltstones and mudstones. Elkton Formation.	27

LIST OF FIGURES (CONTINUED)

Figure		Page
16.	Facies B. Deformation of mudstone below laminated sandstone. Elkton Formation.	27
17.	Facies C. Contemporaneous multiple channels filled with alternating mudstones and siltstones. Elkton Formation.	30
18.	Facies D. Rounded mudstone clasts in sandstone matrix. Elkton Formation.	32
19.	Facies D. Mudstone breccia at base of large channel. Elkton Formation.	32
20.	Facies D. Mudstone breccia. Elkton Formation.	33
21.	Facies D. Elkton Formation.	33
22.	Facies D. Large mudstone block in sandstone-filled channel.	34
23.	Enlarged view of a part of Figure 21 showing flame structure.	34
24.	Enlarged view of a part of Figure 21 showing small scale faulting within channel sand.	34
25.	Stratigraphic sections. Elkton Formation, South Cove.	36
26.	Channels in cliffs at South Cove.	37
27.	Relationship of internal structures to flow regime within a turbidite.	40
28.	Sketch of channels in the photograph in Figure 17.	43
29.	Hypothetical origin of distal (Facies B, C) and proximal (Facies D) turbidites of the Elkton Formation.	44
30.	Location and correlation of stratigraphic sections in Elkton-Coaledo transition zone.	48

LIST OF FIGURES (CONTINUED)

Figure		Page
31.	Cross-laminated concretionary sandstone at Shore Acres State Park.	53
32.	Close-up of cross-lamination in Figure 31.	53
33.	Thinner units at Shore Acres State Park.	53
34.	Lower Coaledo concretionary beds at Shore Acres State Park.	54
35.	Close up of concretions. Lower Coaledo. Shore Acres State Park.	54
36.	Sandstone "roll-up". Lower Coaledo. Lighthouse Point.	55
37.	Interbedded muddy siltstones (dark) and carbonaceous cross-laminated sandstones (light). Lower Coaledo. Lighthouse Point.	55
38.	Close-up of ripple-drift, cross-laminated sandstone. Same location as Figure 37.	55
39.	Upper Coaledo at Yokam Point.	60
40.	Diagrammatic sketch of lithofacies exposed in sea cliffs near the coal seam at Yokam Point (Mussel Reef).	61
41.	Beaver Hill coal seam. Upper Coaledo. Yokam Point (Mussel Reef).	62
42.	Concretionary sandstone filling scour channel. Upper Coaledo. Yokam Point (Mussel Reef).	62
43.	Structural patterns in the Coos Synclinorium and adjacent offshore region.	68
44.	Faults in the coastal section.	69
45.	Evolution and stratigraphic range of selected Cibicides species.	82

LIST OF FIGURES (CONTINUED)

Figure		Page
46.	Occurrence of planktonic foraminifers in the Coaledo and Bastendorff Formations.	94
47.	Ranges of selected species of planktonic foraminifers across the Eocene-Oligocene boundary.	96
48.	Microfaunal trends: Foraminiferal number (foraminifers/gram); Radiolarian number (radiolarians/gram); Ostracod number (ostracods/200 grams).	103
49.	Foraminiferal trends: Composition of test; percent planktonic and benthic species; and number of benthic species.	105
50.	Morphology and bathymetry of fossil and recent uvigerinids.	113
51.	Summary of environmental trends based upon morphology of tests.	115
52.	Inferred maximum depth of molluskan assemblages.	122
53.	Reconstruction of late Eocene topography and paleoflora. Adapted from Hopkins (1967).	130
54.	Late Eocene paleography of southwestern Oregon.	132

LIST OF PLATES

Plate		Page
1	Figured specimens.	248
2	Figured specimens.	250
3	Figured specimens.	252
4	Figured specimens.	254
5	Figured specimens.	256
6	Figured specimens.	258
7	Figured specimens.	260
8	Figured specimens.	262
9	Figured specimens.	264
10	Figured specimens.	266
11	Figured specimens.	268
12	Percent and distribution of foraminifers in the Coaledo and Bastendorff Formations.	in pocket

LIST OF TABLES

Table		Page
1.	Historical review of Tertiary stratigraphy of the Coos Bay area.	9
2.	Correlation of late Eocene and Oligocene with standard Pacific Coast stages and faunal zones.	74
3.	Species distribution of mollusks in the Coaledo Formation.	76
4.	Range of stratigraphically significant benthic foraminifers in the Coaledo and Bastendorff Formations.	80
5.	Planktonic foraminifers reported from the Coaledo and Bastendorff Formations.	88
6.	Relationship of Cenozoic planktonic foraminiferal zones to other biostratigraphic zones. (After: Berggren, 1972).	91
7.	Bathymetric zones.	101
8.	Inferred optimum bathymetric ranges of modern counterparts of some Eocene foraminifers (modified from Bird, 1967).	110
9.	Porcellaneous foraminiferal morphology and bathymetry.	112
10.	Uvigerinid morphology and bathymetry.	114
11.	Dominant benthic faunal groups (N-Narizian, R-Refugian).	117
12.	Depth ranges of recent mollusks (after: Keen, 1963).	121
13.	Planktonic foraminiferal species diversity (modified from McKeel, 1972).	125

BIOSTRATIGRAPHY AND PALEOECOLOGY OF THE COALEDO AND BASTENDORFF FORMATIONS, SOUTHWESTERN OREGON

INTRODUCTION

Purpose

The purposes of this investigation are: 1) to describe the fossil foraminifers from the Coaledo and Bastendorff Formations in the Coos Bay region; 2) to establish the age of the rocks by correlation with standard West Coast and world-wide planktonic foraminiferal zonations; 3) to determine the position of the Eocene-Oligocene boundary in rocks near Coos Bay; 4) to determine the environment of deposition of the Eocene and Oligocene sedimentary rocks of the region.

Location and Geologic Setting

The area studied is located near Cape Arago on the southwest Oregon coast within Coos County, about ten miles west of Coos Bay, Oregon. It includes forty-three square miles, most of which lie within T. 26 S., R. 14 W. (Figure 1). The best exposures occur in the coastal section from Charleston to Cape Arago. Inland, exposures of bedrock are obscured by a covering series of uplifted terrace deposits and by a dense growth of brush and conifers that include salal, salmonberry, rhododendron, fir, cedar, hemlock and spruce. Fresh, unweathered rock may occasionally be found in the beds of streams. Access to the area is provided by paved roads from Charleston and numerous abandoned logging roads.

The Cape Arago area is part of a structural basin that lies near the junction of the north-trending Coast Range, composed of rocks of Tertiary age, and the older Mesozoic rocks of the Klamath Mountains. The rocks of the region consist of marine and non-marine sedimentary strata, with minor volcanics, that range in age from Eocene to Pliocene. The dominant structural feature is the north-trending South Slough syncline (Figure 3). Folded rocks of Eocene through Miocene age are contained within this structure. The Empire Formation of Pliocene age lies unconformably on the older strata. Quaternary dunes, terrace deposits and alluvium are widespread in the region.

The sequence studied includes marine strata of the middle member of the Elkton Formation, the Coaledo Formation and the Bastendorff Formation, as well as predominantly non-marine sandstones of the lower and upper members of the Coaledo Formation.

History of Previous Investigations

Since the pioneering efforts of Thomas Condon in the summer of 1885 (McCornack, 1928), many geologists have studied the rocks of the Coos Bay region. Interest in the geology of the area was

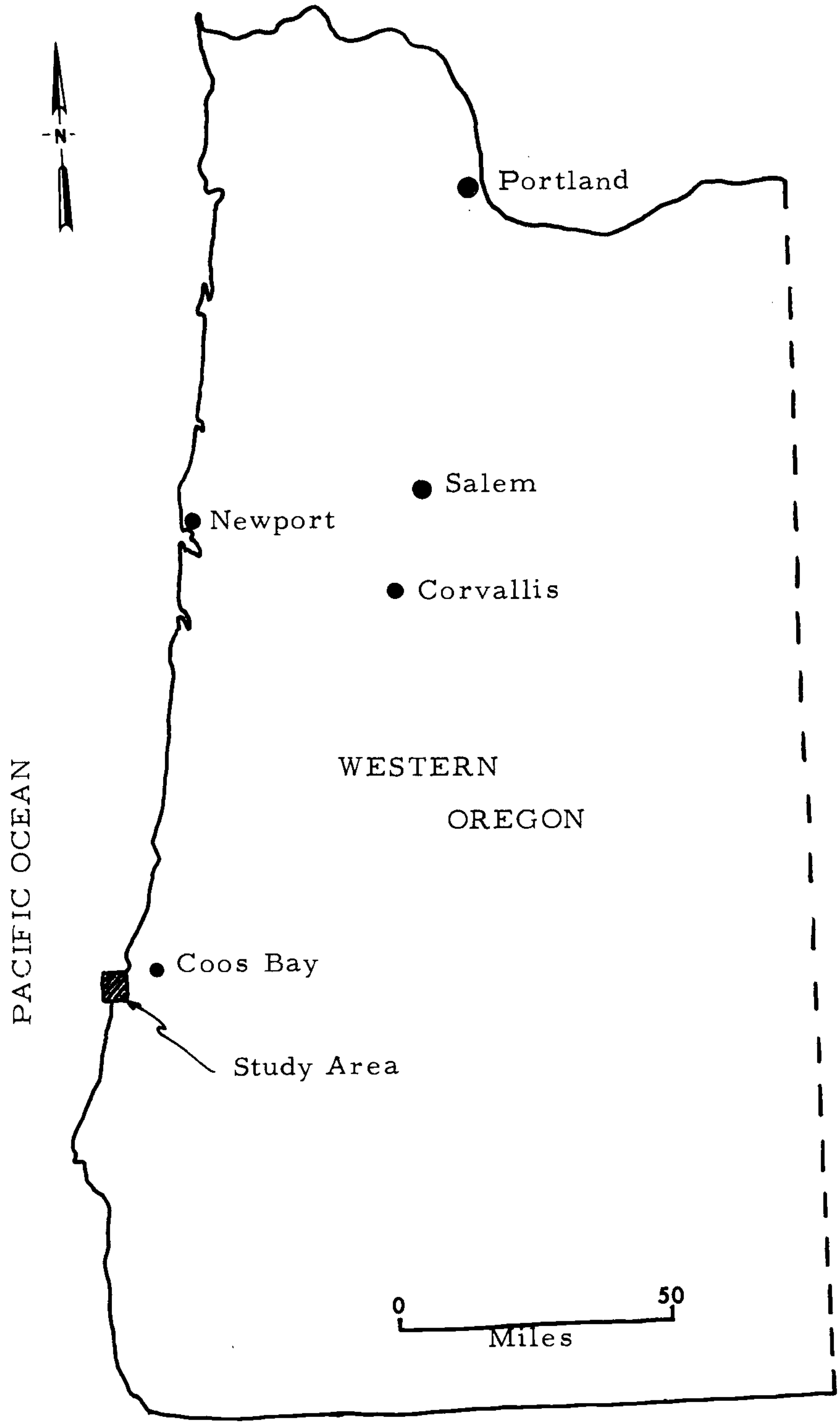


Figure 1. Location of area studied.

prompted by the presence of economic deposits of coal and abundant, well preserved fossils.

Stratigraphic and Economic Studies

The first geologic map of the region was published by Diller (1896), who was interested primarily in the coal deposits. He published additional reports on the Coos Bay area in 1899 and 1901 and coauthored a paper with Pishel in 1911. In 1896 Diller proposed the term "Arago beds," named after Cape Arago, for a series of sandstones, mudstones and siltstones lying above pre-Tertiary rocks and below the "Empire beds" of Pliocene age. Three years later he subdivided the "Arago beds" into coal-bearing strata which he designated the Coaledo Formation and non-coal-bearing strata which he called the Pulaski Formation.

The rocks originally included in the "Arago beds" by Diller have subsequently been designated as three separate formations as indicated below. Dall (1909) proposed the term "Tunnel Point beds" (Tunnel Point Formation of later authors) for sandstone cropping out in a promontory at the east end of Bastendorff Beach. Schenck (1927) proposed the name "Bassendorf shale" for a series of sedimentary rocks exposed at Bastendorff Beach. Youngquist (1961) has indicated that the correct spelling of the family name and geographic locality of the type section is Bastendorff. Wilmarth (1938) abandoned the term

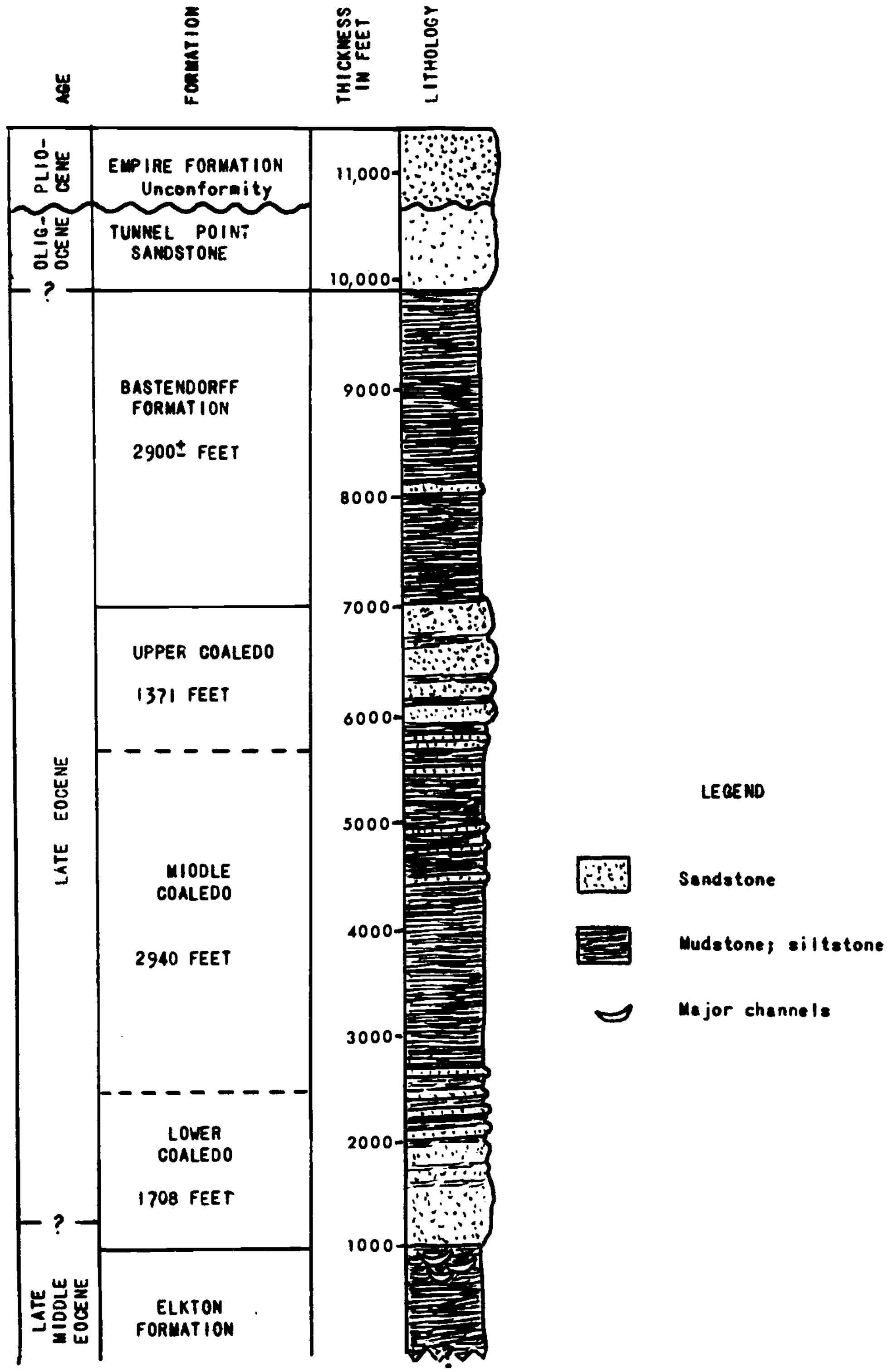
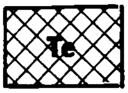


Figure 2. Generalized stratigraphic column of Tertiary rocks in the Cape Arago-Charleston region.

Explanation of the symbols used in the geologic map of the South Slough-Cape Arago area (Figure 3 on page 7).

Quaternary Beach Deposits

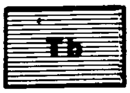
Unconformity



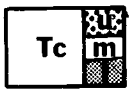
Empire Formation (Pliocene)

Unconformity

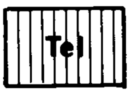
Tunnel Point Sandstone (Oligocene)



Bastendorff Formation (Late Eocene)

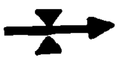


Coaledo Formation (Late Eocene)



Elkton Formation (Late middle Eocene)

Fault: solid where known; dashed where inferred


Plunging syncline


Anticline

Strike and dip of beds

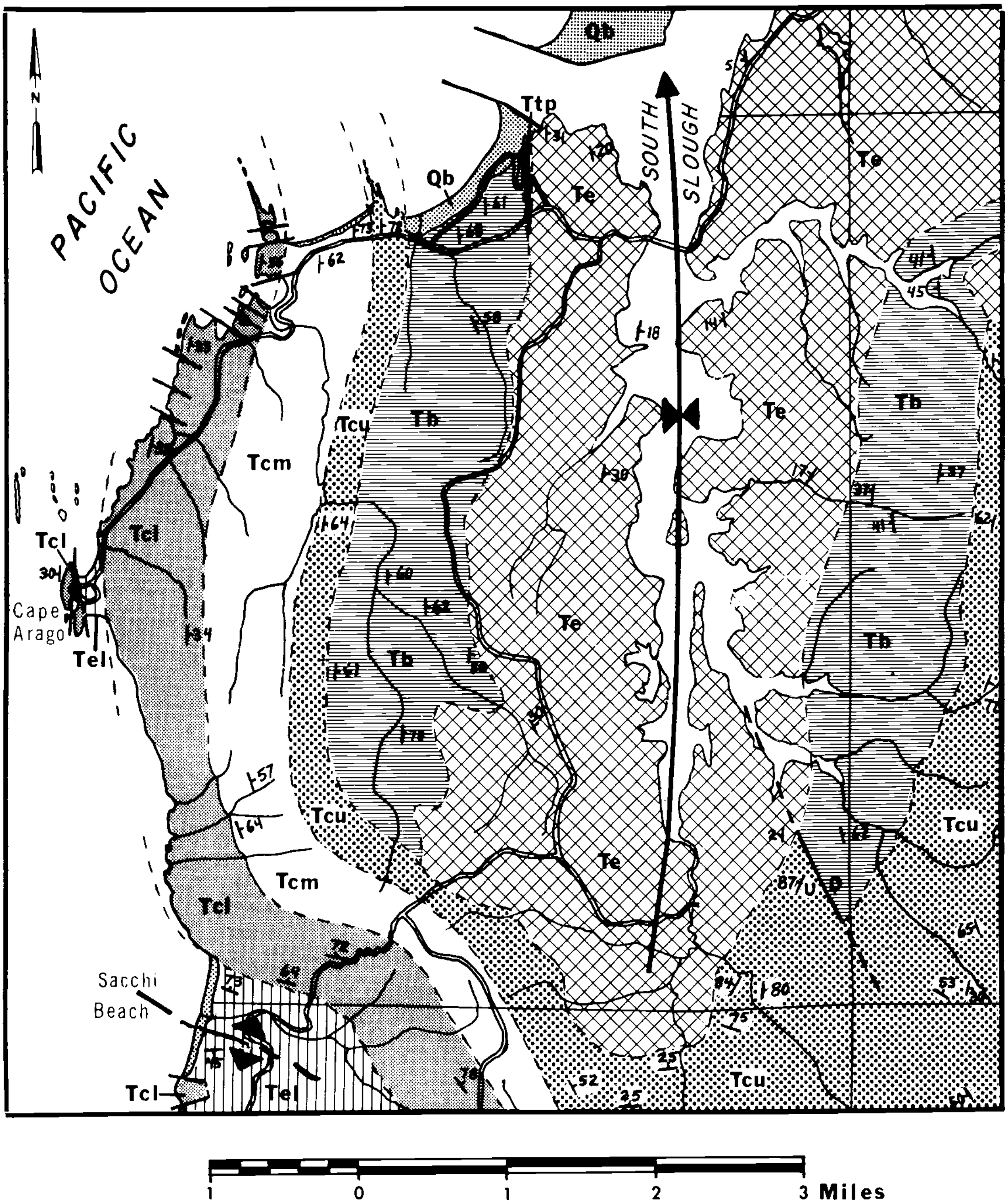


Figure 3. Geologic map of the South Slough—Cape Arago area.

"Pulaski" of Diller because it was preempted.

Turner (1938) proposed a subdivision of the Coaledo Formation into upper, middle and lower members on the basis of lithology and fossils exposed in the coastal section between Charleston and Cape Arago. This subdivision was accepted by Allen and Baldwin (1944) in their study of the geology and coal resources of the region and is used in this study with only minor modifications. C. E. Weaver (1944), however, recognized the Tunnel Point and Bastendorff Formations but resurrected the Arago Formation of Diller in place of the Coaledo Formation (Table 1).

In recent years Dott (1955, 1966) has dealt with environmental interpretations of the rocks based upon physical stratigraphy, sedimentary structures and petrography. Duncan (1953) restudied a part of the coal deposits of the region.

Paleontologic Investigations

The first known collections of fossils from this area were made by Thomas Condon in the summer of 1885 (McCornack, 1928). He sent these fossils to Charles A. White who subsequently described them in a U. S. Geological Survey bulletin four years later.

In his early publications on the geology of the region, Diller mentions fossils from several localities (Diller, 1896, 1899, 1901). Dall (1909) included fossils from the Empire Formation in his

Table 1. Historical review of Tertiary stratigraphy of the Coos Bay area.

Pacific Coast Molluscan Stages		Foraminiferal Time-Stratigraphic Units	Previous Authors								
Weaver et al., 1944		Mallory 1959	Diller 1896	Diller 1899	Dall 1909	Schenck 1927	Turner 1938	Weaver 1944	Allen & Baldwin 1944	Baldwin 1964	This Report
Oligocene	"Lincoln"	Refugian		Arago Formation: Coaledo Fm.	Tunnel Point Sandstone	Tunnel Pt. SS.	Tunnel Point Sandstone	Tunnel Point Sandstone	Tunnel Point Sandstone	Tunnel Point SS.	Tunnel Point SS.
Eocene	Keasey	Refugian	Arago Beds	Arago Formation: Coaledo Fm.	Arago Fm.: Transition	Bassendorf Sh.	Bassendorf Sh.	Bassendorf Sh.	Bastendorf Sh.	Bastendorf Fm.	Bastendorff Fm.
Eocene	"Tejon"	Narizian	Arago Beds	Arago Formation	Arago Fm.: Coaledo Fm.	Coaledo Fm.	U M L Coaledo Fm.	Arago Fm. = (Coaledo & Pulaski Fms.)	U M L Coaledo Fm.	U M L Coaledo Fm.	U M L Coaledo Fm.
Eocene	"Transition beds"	Narizian / Ulatisian	Arago Beds	Arago Formation: Pulaski Fm.	Arago Fm.: Pulaski Fm.	Pulaski Fm.	Pulaski Fm.		Tyee SS.	Sacchi Beach Memb. of Tyee Fm.	Elkton Fm.
Eocene	"Domengine"	Ulatisian	Arago Beds	Arago Formation: Pulaski Fm.	Arago Fm.: Pulaski Fm.	Pulaski Fm.	Pulaski Fm.		Tyee SS.	Sacchi Beach Memb. of Tyee Fm.	Elkton Fm.

publication on the Miocene fossils of the Astoria Formation. Additional megafossils were mentioned in papers by Arnold and Hannibal (1891) and Howe (1922), but the first comprehensive study of fossils of early Tertiary age was by Turner in 1938. C. E. Weaver published two additional reports on the megafossils in 1942 and 1945.

The presence of foraminifers in the Bastendorff Formation was first noted by Dall (1909), and early studies of the fauna were made by Cushman and Schenck (1928) and Detling (1946). The most comprehensive study was that of Detling in which she reported the presence of forty-six species of foraminifers. Additional short papers on foraminifers from the region were published by Cushman, R. E. Stewart, and K. E. Stewart (1947, 1949) and R. E. Stewart (1957). No comprehensive study of the foraminifers of the Tertiary rocks of the Coos Bay region has been made.

Hopkins (1967) has published a short paper on the Tertiary pollen present in these rocks, and more recently McKeel (1972) has described planktonic foraminifers from four samples collected in the area.

Methods of Investigation

Field Procedures

Field work was undertaken in the summer of 1964 and was completed in the summer of 1965. During this time the coastal section and several inland sections were measured by tape and compass, and samples were collected. In the parts of the coastal section where exposures of mudstone and siltstone are continuous, small grab samples were collected to form a larger, composite sample representing all of the rocks within a fifty foot stratigraphic interval. Along a county road cut at Bastendorff Beach the sample interval was reduced to twenty-five feet. Elsewhere, samples were collected from isolated outcrops and from thin siltstones interbeds within sandstone units. Locally, samples of small lithologic units such as graded beds and glauconite-rich layers were collected for specific paleoecologic purposes described in a later section. A total of 231 samples, each weighing eight to ten pounds, was collected of which only 86 were fresh and contained well-preserved faunas. All samples with a fresh appearance were processed to extract any foraminifers present. All weathered samples were examined with a binocular microscope for recognizable molds.

Laboratory Procedures

In the laboratory the entire sample was crushed to pieces smaller than one-half inch and then allowed to dry at room temperature for several days. The sample was then passed through a sample splitter until a portion weighing between 200-300 grams was obtained. The sample was weighed and then immersed in a jar of kerosene for several days. The kerosene-saturated rock was then plunged into boiling water containing baking soda to disaggregate the sample. It was usually necessary to repeat this process several times to break down the rock completely.

The sample was then washed on a sieve with openings of 62 microns, and the portion retained on the sieve was kept for microscopic examination.

A microsplitter was used to obtain a fraction of the washed sample that would contain an estimated 300 to 500 foraminifers. The microfossils in this fraction were then identified and counted. If microfossils were rare, the entire 200-300 gram sample was examined.

PHYSICAL STRATIGRAPHY

Regional Geologic Setting

The Cape Arago-Charleston region is a structural basin, containing Eocene to Pliocene sedimentary and minor volcanic rocks, which lies near the boundary of the Coast Range and Klamath Mountains structural provinces.

Eocene marine sedimentation in western Oregon is believed to have taken place in an embayment nearly four hundred miles long that occupied the western one-quarter of Washington and Oregon. Extensive submarine volcanism of the middle Eocene Siletz River and Tillamook Volcanics was followed by widespread deposition of marine sediments, in part by turbidity currents, that make up the Tyee Formation. The eastern margin of this marine embayment lies concealed beneath the rocks of the present day Cascade Range. The western margin of the Eocene embayment has been variously interpreted as restricted by a peninsula (Weaver, 1945), semi-restricted by shallow sills and islands (Snavely and Wagner, 1963) or almost completely open to the sea (Dott, 1966).

In Oregon the bulk of the rocks of the Coast Range are these Eocene rocks, which may have a thickness in excess of 30,000 feet (Weaver, 1945a). According to Snavely and Wagner (1963), late

Eocene time marked the beginning of a marine regression that culminated in the uplift of the Coast Range in late Oligocene and Miocene time.

During late Eocene time a deltaic complex developed in the Cape Arago region which resulted in the deposition of approximately 6,000 feet of interfingering marine and non-marine sedimentary rocks of the upper and lower members of the Coaledo Formation, while isolated Eocene volcanism was occurring a few miles to the east.

Marine transgressions occurred in the Cape Arago region during this time, resulting in the deposition of the middle member of the Coaledo Formation and the Bastendorff and Tunnel Point Formations. Isolated areas of marine sandstones of Miocene and Pliocene age are also known from the region.

It is evident that the area was strongly folded after the deposition of the Oligocene sedimentary rocks but prior to the deposition of the Empire Formation of Pliocene Age, because the Pliocene rocks lie with low angular unconformity upon the older, steeply dipping strata. Marine sandstones of Miocene age were dredged from the channel of the Coos River near the axis of the South Slough synclinorium (Figure 3) and the fossils contained were described by Moore (1963). Miocene rocks have not been located with certainty along the sea cliffs, but Armentrout (1967) has located beds in the wave-cut platform east of Fossil Point that he considers to be Miocene by reason of the presence of the pelecypod, Dosinia, known to be abundant in Miocene sandstones of the Astoria Formation.

Elkton Formation at Sacchi Beach

The Elkton Formation at Sacchi Beach is exposed in the core of an anticline, the axis of which strikes east-west and lies south of the mouth of Fivemile Creek. The base of the formation is not exposed. A stratigraphic section was measured along the north limb of the anticline and samples collected for examination of microfossils. A partial stratigraphic column is presented (Figure 5).

The Elkton Formation near the center of the anticline is predominantly a dark gray, thinly stratified mudstone with local thin, light gray siltstones and fine sandstones. The mudstones are several times thicker than the siltstones and are homogeneous to thinly laminated. Typically, the mudstones are silty, contain abundant carbonaceous material and isolated muscovite flakes and foraminifers. Fossil mollusks are rare and the sediments show almost no evidence of reworking by burrowing animals. Higher in the section along the north flank of the anticline thinly stratified, light-gray siltstones and sandstones are more common. The sandstones are micaceous and contain dark carbonaceous laminae which are usually parallel but infrequently show cross-laminations. The lower contacts of the sandstones are usually sharp with little or no scour of the underlying

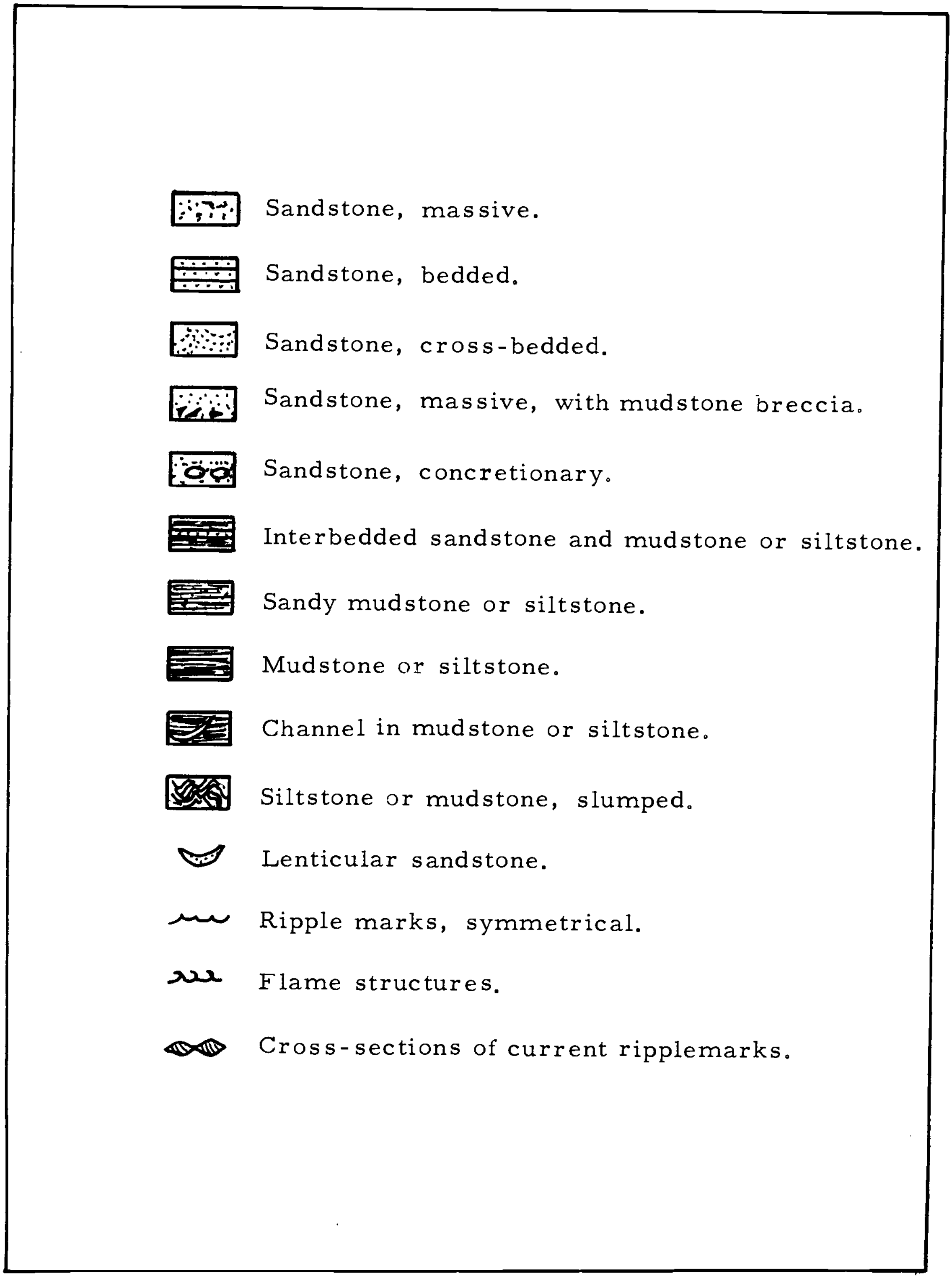


Figure 4. Explanation of symbols used in Figures 5, 7, 8, 25.

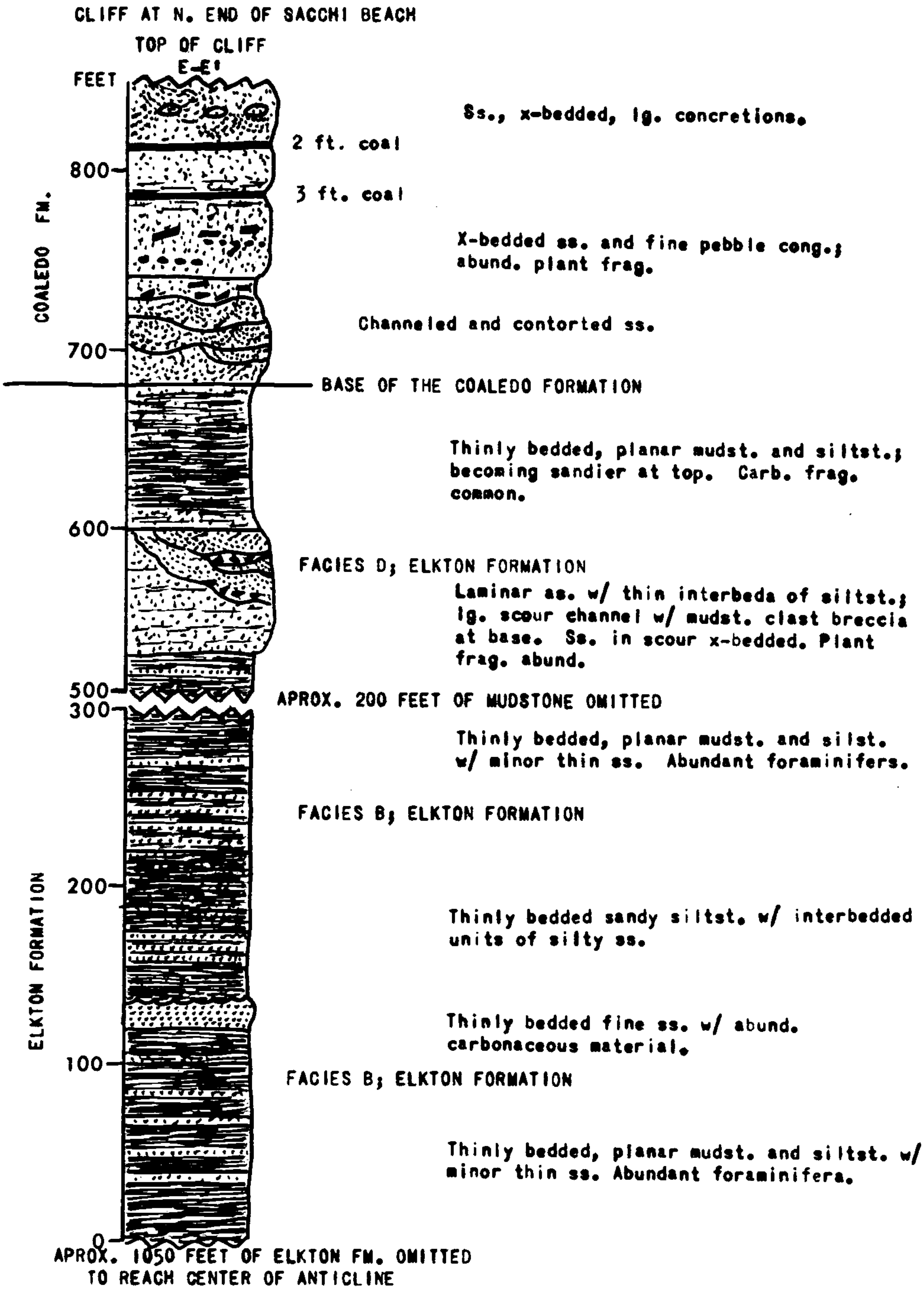


Figure 5. Stratigraphic section at north end of Sacchi Beach.

mudstones. Spectacular sandstone channels with thick mudstone breccias can be found which are similar to those in North and South Coves of Cape Arago. The formation becomes increasingly sandy upward until it grades into thick-bedded, cross-bedded carbonaceous sandstones of the lower member of the Coaledo Formation.

Elkton Formation at North Cove

The Elkton Formation in North Cove of Cape Arago was studied in detail because of the excellent exposures of sedimentary structures that facilitate environmental reconstruction. It is possible to subdivide the strata into four lithofacies on the basis of the nature of the rock type and the associated sedimentary structures.

Description of lithofacies at North Cove

Facies A, Dark mudstones. This facies is made up primarily of dark, gray carbonaceous mudstone which is homogeneous or banded on a scale that ranges from 0.5 to 10cm. Mudstones constitute greater than ninety percent of the rock, but thin layers of lighter-gray, laminated, muddy siltstones with diffuse borders are present. The bands are parallel giving the rock a marked striped appearance. Little evidence of burrowing by a benthic infauna was found. Cross-bedding, scour, or ripplemarks indicating bottom currents are very rare. The beds, in contrast to those higher in the section, show little

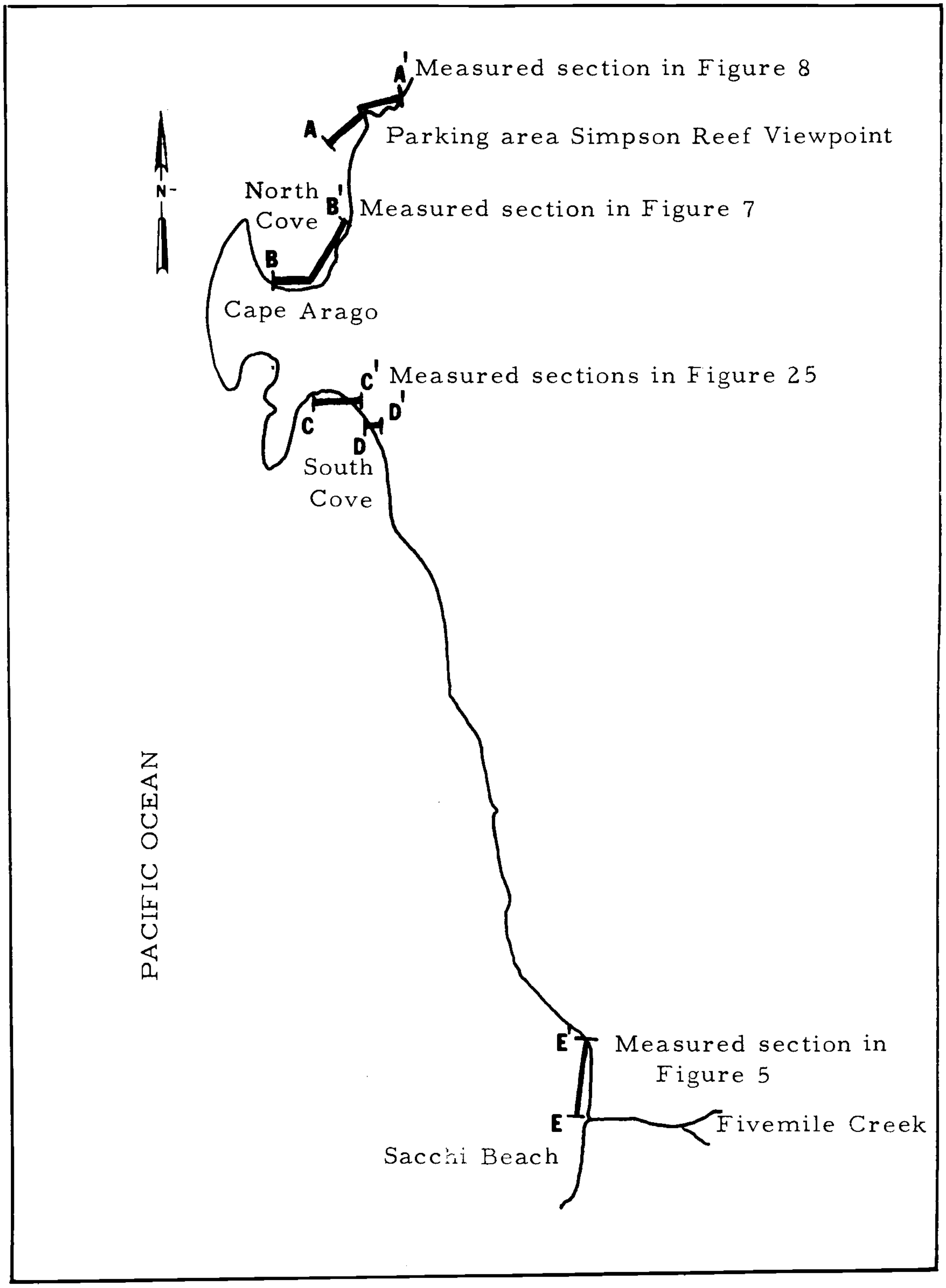


Figure 6. Location of measured sections in Elkton-Coaledo transition at Sacchi Beach, South Cove and North Cove.

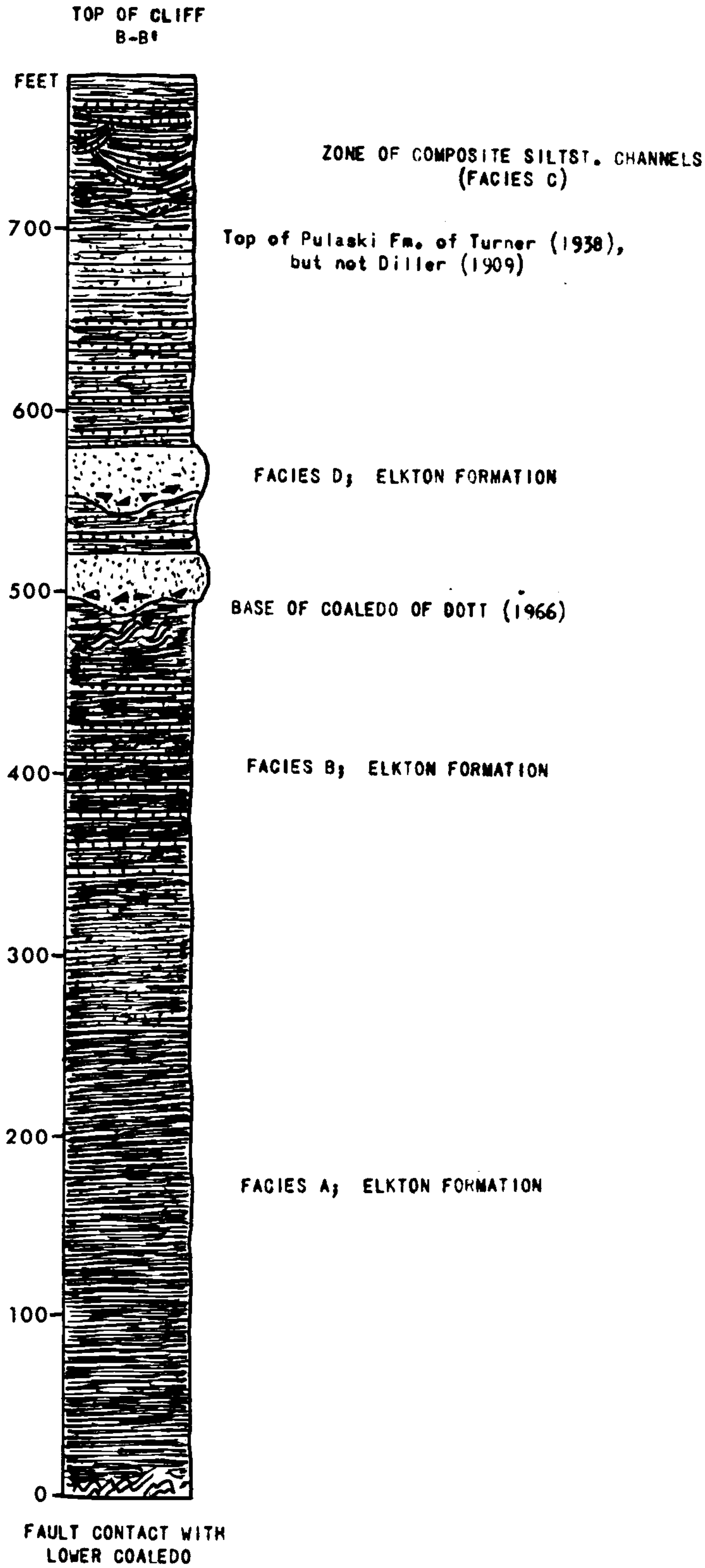


Figure 7. Stratigraphic section along the south side of North Cove (for location see Figure 6). Symbols explained in Figure 4.

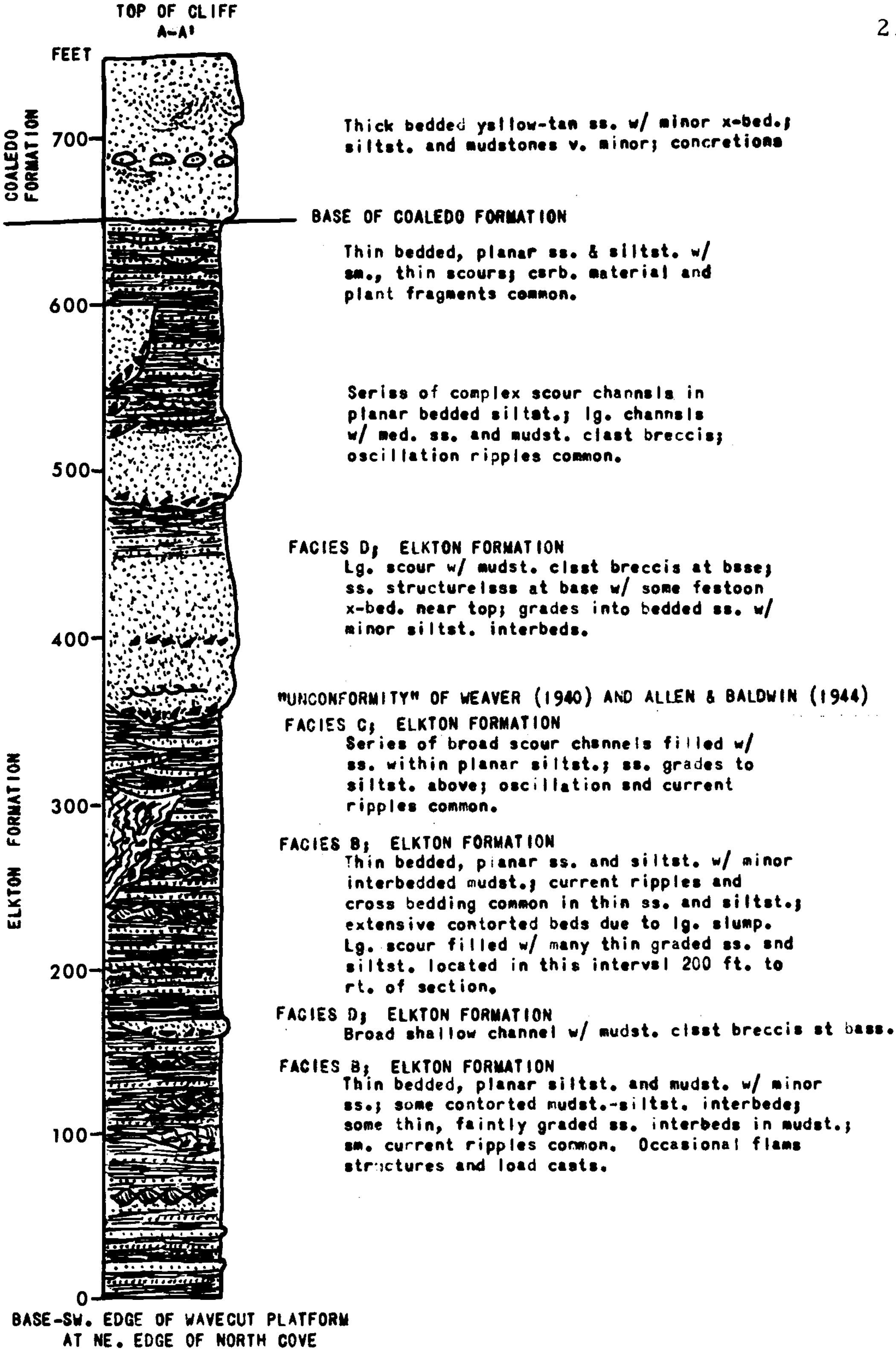


Figure 8. Stratigraphic section along the northeast side of North Cove (for location see Figure 6). Explanation of symbols is given in Figure 4.

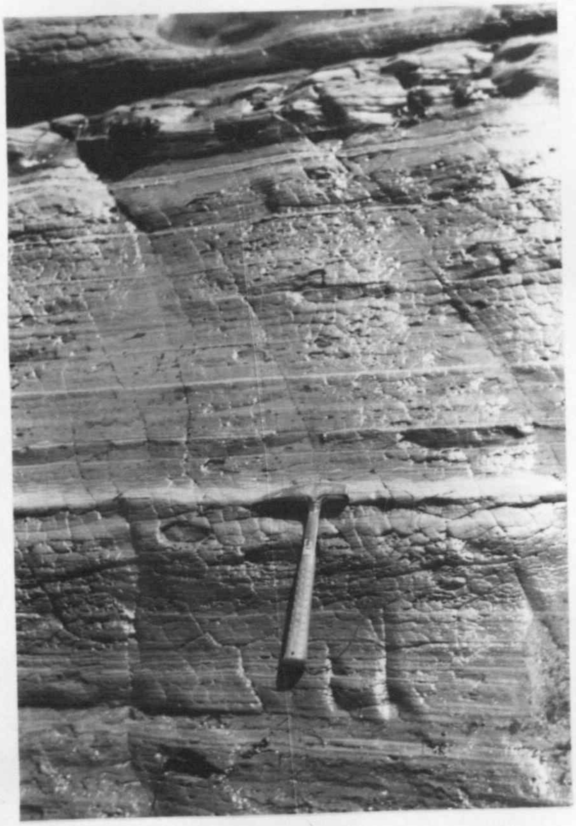


Figure 9. Facies A. Laminated mudstones. Elkton Formation, North Cove.

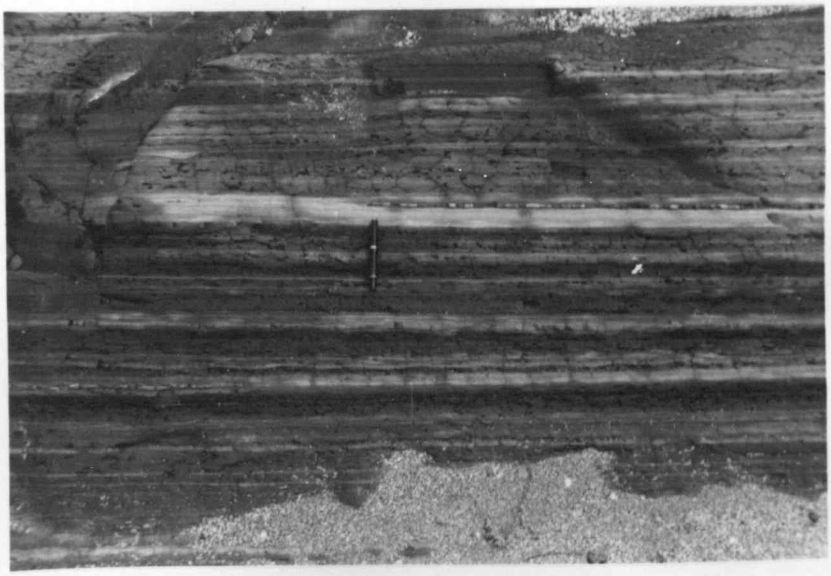


Figure 10. Facies A. Laminated Mudstones (dark) with interbedded muddy siltstones. Elkton Formation, North Cove.

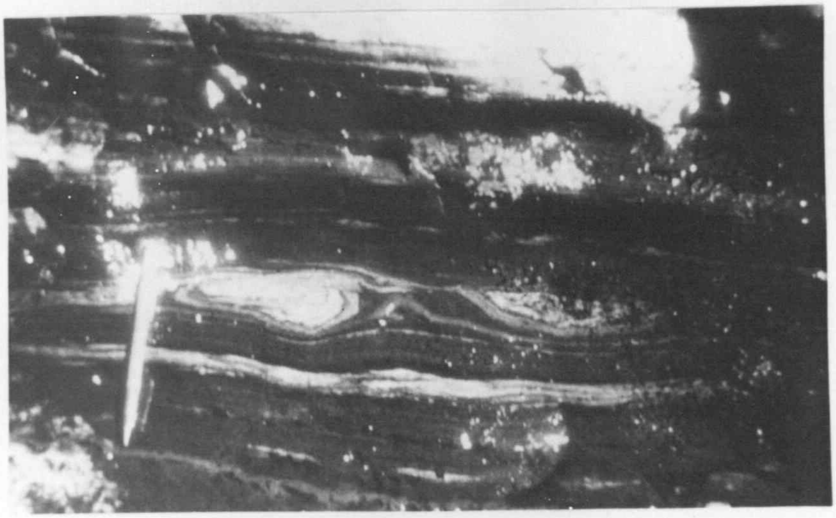


Figure 11. Siltstone "roll-up" within Facies A. Elkton Formation, North Cove.

evidence of slump or large scale gravity movements. Sedimentary structures consist of flame structures and rare laminated siltstone "roll-ups" (Figure 11) which are attributed, respectively, to compaction and liquefaction of the sediments before lithification.

Rocks belonging to this facies are exposed in the wave-cut platform and cliff at the westernmost edge of North Cove near the fault that marks the base of the section (Figure 7).

Facies B. Interbedded silty mudstones and fine sandstones. Facies B is characterized by an increase in sharp-based, sandy siltstones and fine sandstones interbedded with mudstones and by a marked increase in current structures. The transition between Facies A and the overlying Facies B is gradational, over a distance of several hundred feet, with the latter making up the bulk of the rocks exposed in North Cove.

In Facies B, the layers of dark silty mudstone and lighter sandstones are parallel as in Facies A, but the sandstones are thicker and more numerous. The sandstones are sharp-based and frequently exhibit normal graded bedding, from medium to coarse sand at the base to mud or clay at the top, so that the upper contact with the overlying mudstones is diffuse. The bases of the sandstones occasionally show sole markings and very commonly exhibit flame structures. Internally, many of the sandstones show a marked parallel lamination. Mica flakes and carbonaceous material are common (Figure 13).

Figure 12. Facies B. Interbedded mudstones and siltstones. Elkton Formation, North Cove. Slumping evident.

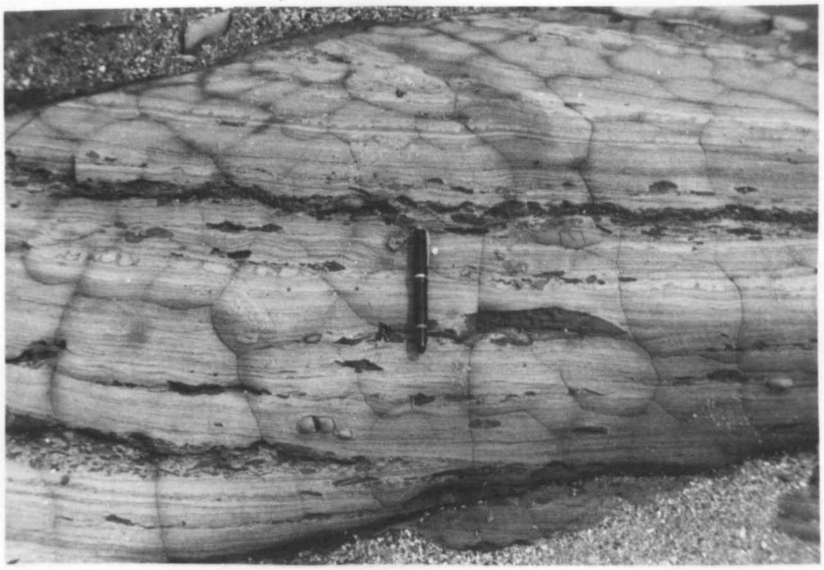


Figure 13. Facies B. Parallel lamination of carbonaceous siltstones within a sandstone unit. Note flame structures and angular mudstone clasts. Elkton Formation, North Cove.

Figure 14. Facies B. Ripple drift cross-lamination. Elkton Formation, North Cove.

Figure 15. Facies B. Contorted bedding in interbedded siltstones and mudstones. Elkton Formation, North Cove.

Figure 16. Facies B. Deformation of mudstone below laminated sandstone. Elkton Formation, North Cove.

Cross-bedding, other than ripple cross-lamination, is rare, wedge-planar and never of the trough or festoon type. Many of the sandstones show a vertical sequence of sedimentary structures from normally graded beds at the base, parallel lamination in the mid-part and ripple cross-lamination at the top. The sandstones frequently contain angular particles of mudstone, ranging from 0.5 to 10cm in size, that were undoubtedly derived from nearby interbedded mudstones (Figure 13). Nevertheless, evidence of bottom scour or erosion at the bases of sandstones is rare. Evidence of gravity deformation on a paleo-slope can be found in few contorted sandstones (Figure 15).

Mudstones in Facies B contain more silt than in Facies A and constitute about fifty percent of the rock. Near the top of Facies B the mudstones increasingly show evidence of small slumps and gravity movements and sometimes show deformation features that might be associated with liquefaction or current drag (Figure 16). Ripple cross-lamination attributed to bottom currents is very common within the siltstone units. Some ripples show lighter bands of gray silt alternating with darker bands of gray mud or carbonaceous material (Figure 14). Current directions indicated are extremely variable. There is little evidence of burrowing organisms disrupting the layering of the rocks.

Facies C, Mudstone-sandstone channels. Facies C consists of a series of channels filled with alternating mudstones and sandstones.

The channels are remarkable in that the channel fill consists of alternating layers of mudstones and sandstones that are identical to the surrounding sediments of Facies B. Both single (simple) channels and multiple (superimposed or imbricate) channels are exposed in the cliff at North Cove. No coarse sands or large brecciated zones occur at the base of the channels. A few sands near the base show a slight lenticular shape, but the texture of the sands is similar to those higher in the channel. The channels are broadly U-shaped, ranging in size from three feet to more than forty feet in height and ten to more than one hundred feet in width. All channels observed show a cross-sectional view that appears to be transverse to the axis of the channel. The width-height ratio is frequently greater than 4:1. No festoon or trough cross-bedding occurs in the sandstones within the channels. Wedge-planar cross-bedding was found in a few sands. The sands exhibit little or no scour of the underlying mudstone and commonly grade upward into the mudstone above. Load casts are present on the bottoms of some sandstones. The sediments are in all aspects identical to the surrounding mudstone-sandstone of Facies B except that the bedding is curved in conformity with the shape of the channel.

A prominent, multiple channel is located in the cliff at the northeast side of North Cove. The larger channel was truncated by a smaller channel; however, slightly higher in the sequence, sediments were deposited in layers that are continuous within both channels and

Figure 17. Facies C. Contemporaneous multiple channels filled with alternating mudstones and siltstones. Elkton Formation, North Cove.

in the region outside of the channels (Figures 17 and 28). This relationship indicates that the cutting of the channels (Facies C) and the deposition of the surrounding sediments (Facies B) were contemporaneous. Evidence to support the erosion of the channels and the deposition of Facies C within the channels by turbidites is presented in a later section.

Large channels of this type are present at both North and South Coves. Most of the large channels are concentrated in a zone a few hundred feet below the thick-bedded sandstones of the lower member of the Coaledo Formation. Complex multiple channels are visible in the wave-cut platform immediately below the parking lot and observation point for Simpson's Reef.

Facies D, Sandstone channels with mudstone breccias. The most striking sedimentary features to be found at North Cove are a series of sandstone-filled channels with angular penecontemporaneous breccias at their bases (Figures 18, 19, 20, 21 and 22). Clasts in the breccias are laminated mudstones of Facies A and B. The mudstone fragments are mostly angular, range in size from about 1/2 inch to more than 10 feet in length, and show little or no imbrication. Only the mudstone clasts in the lowest channels stratigraphically along the south side of North Cove show a high degree of rounding (Figure 18).

The sandstones within the channels weather to a distinctive tan but are light gray in fresh samples. A single mudstone breccia unit

Figure 18. Facies D. Rounded mudstone clasts in sandstone matrix. Base of lowest channel. Elkton Formation, North Cove.

Figure 19. Facies D. Mudstone breccia at base of large channel. Located in cliff at the base of viewpoint overlooking Simpson's Reef. Elkton Formation, North Cove.

Figure 20. Facies D. Mudstone Breccia. Same locality as Figure 18.

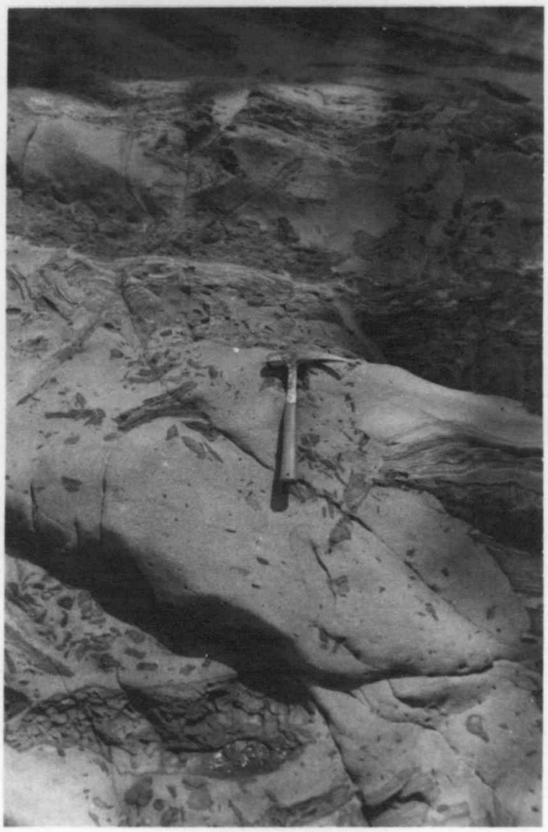


Figure 21. Facies D. Detailed view of a part of Figure 19.

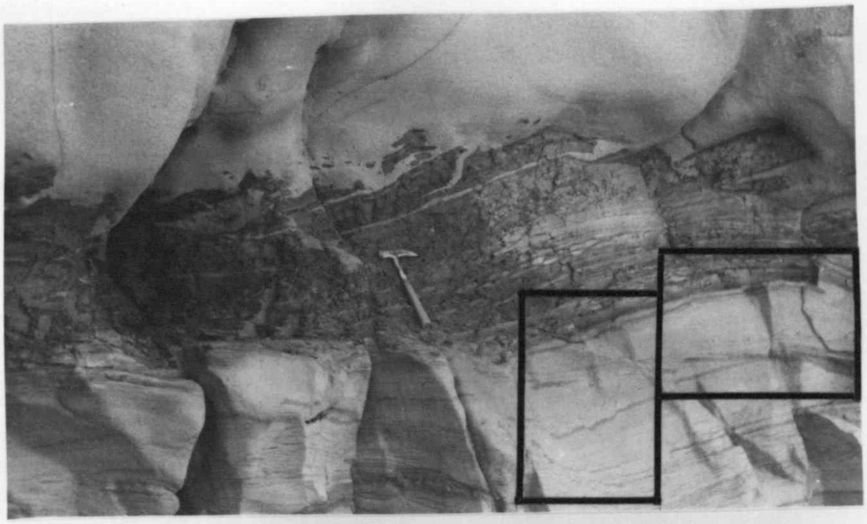


Figure 22. Facies D. Large mudstone block in sandstone-filled channel. Same locality as Figures 18, 19, 20.

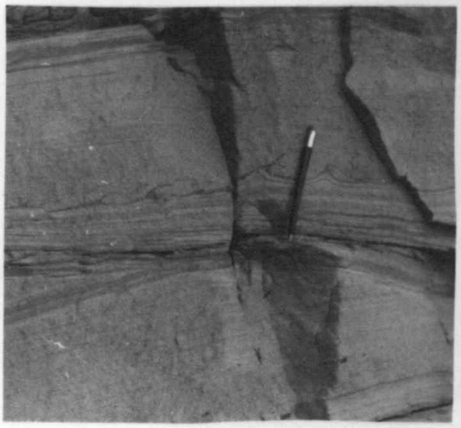


Figure 23. Enlarged view of a part of Figure 21 showing flame structure.

Figure 24. Enlarged view of a part of Figure 21 showing small scale faulting within channel sand.

is generally present at the base of the channel, but rarely a channel with more than one bed of breccia can be found. The sandstone matrix of the breccias is always massive and contains no evidence of cross-bedding or other fluvial characteristics. Rarely a mudstone clast can be seen standing on end perpendicular to the bottom of the channel completely surrounded by massive sandstone (Figure 19). The channel sandstones are composed of medium to coarse, texturally immature sands that have less mica flakes, carbonaceous matter and clay matrix than the sands of Facies B or C. Texturally they closely resemble the sands of the lower member of the Coaledo Formation. The bulk of the sandstones in the channels are structureless, but small localized zones can be found that show parallel thin-bedded units rich in carbonaceous matter. Wedge-planar cross-bedding sometimes occurs in these units. Flame structures and small normal faults with displacements of an inch or less can be seen within the channel exposed in the sea cliff below the lookout overlooking Simpson's Reef (Figures 23 and 24).

The sandstone channels range in thickness from a few feet to more than forty feet. The sides of the channels cut sharply across the surrounding mudstones and sandstones and in a few places are almost vertical. Channels of this type are not restricted to any single horizon or zone but are present throughout North Cove where at least six can be found. They are located stratigraphically above or below

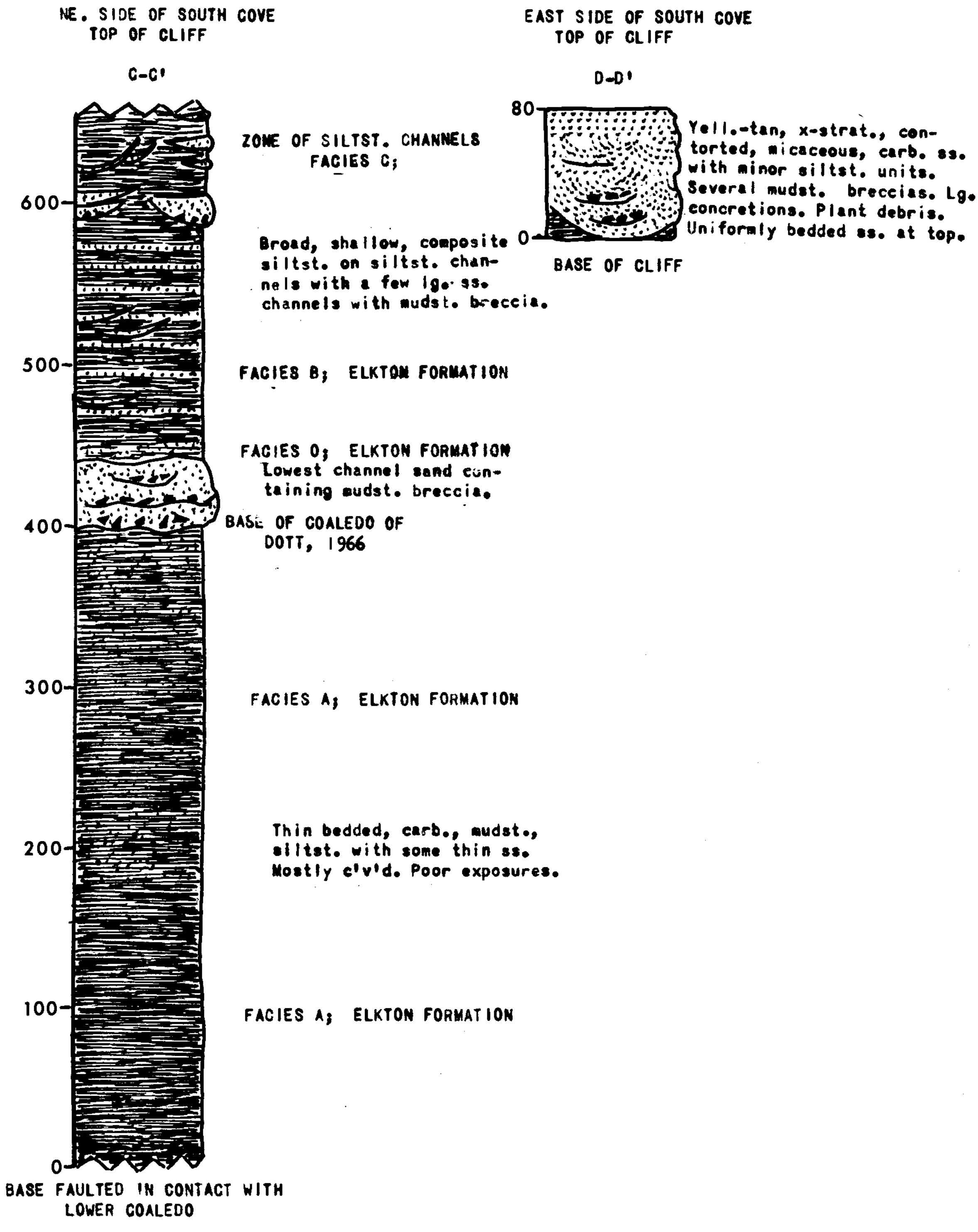


Figure 25. Stratigraphic sections. Elkton Formation, South Cove. (For location of sections see Figure 5).

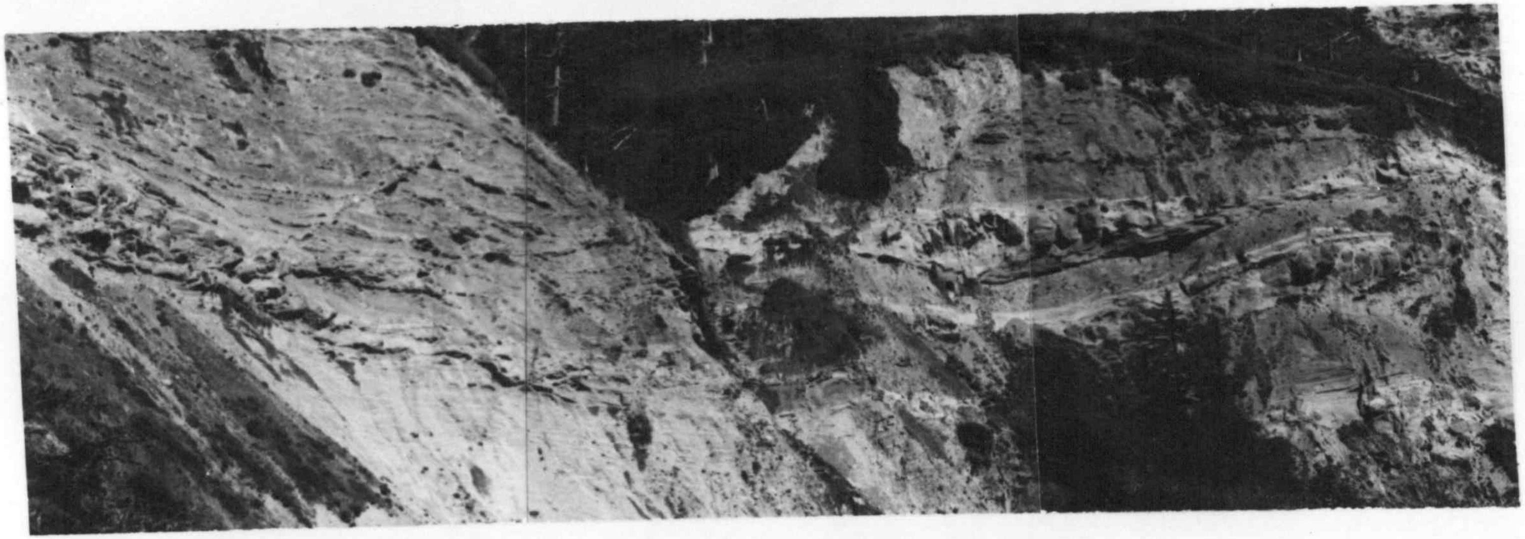


Figure 26. Channels in cliffs at South Cove. Elkton Formation.

the interbedded mudstone-sandstone channels of Facies C.

Several similar channels are present at South Cove and at Sacchi Beach. Bird (1967) has reported channels of the same type from a similar stratigraphic position more than forty miles to the northeast near Elkton.

Elkton Formation at South Cove

The Elkton Formation at South Cove of Cape Arago exhibits the same vertical succession of sedimentary facies as at North Cove (Figure 25). The dark mudstones of Facies A are present in the wave-cut platform at the west end of the cove. Facies A grades upward into interbedded silty mudstones and sandstones of Facies B. Near the top of the cliff along the east side of the cove Facies B is cut by channels similar to the mudstone-sandstone channels (Facies C) and sandstone channels (Facies D) that are found at North Cove (Figure 26).

Environmental Interpretation of Beds at North Cove

Facies A

The dark, thinly laminated mudstones of Facies A represent prolonged deposition of very fine mud in quiet water. The sequence is notable for its absence of evidence of a burrowing molluskan infauna. In spite of detailed sampling only a few species of fossil foraminifers were found. These included sparse specimens of *Bulimina* *schencki* and *Gyroidina girardana planata* which, suggesting deposition under upper bathyal or outer continental shelf conditions, occur in such small numbers as to be environmentally inconclusive. Other indicators of deeper or open oceanic water, such as planktonic foraminifers or radiolarians, are absent. No paleontologic evidence of a basin with restricted circulation, such as thin diatomites or gigantism in benthic foraminifers, was found.

Facies A was apparently deposited in quiet water in a locale lacking a burrowing infauna, but the depth cannot be accurately determined by either paleontologic or sedimentologic evidence (Figure 9). The presence of *Gyroidina girardana planata* suggests deeper water but is inconclusive. The problem of using *Gyroidina* as a paleodepth indicator is discussed in a later section.

Facies B

The first sign of an approaching coarser clastic supply is the appearance of normally-graded sandstones interbedded with mudstones in the overlying Facies B. The transition from Facies A to Facies B is gradational with a gradual increase in number and thickness of the siltstone units. The sandstones are sharp based, occasionally with flute and groove casts, and often exhibit vertical changes in internal sedimentary structures from a graded part at the base, to parallel lamination, to ripple-drift cross-lamination, to fine muds, a sequence that Bouma (1959, 1962) attributes to deposition by turbidity currents (Figure 27). The pattern of graded and cross-laminated sandstones interbedded with nonlaminated massive mudstones (or muddy siltstones) is repeated dozens of times in the beds of North Cove, South Cove and Sacchi Beach. Nowhere in the sequence can beds of sandstone be found that resemble cross-bedded cut-and-fill structures associated with fluvial deposits. The graded and parallel laminated parts of the sandstones are attributed to deposition by turbidity currents within the upper flow regime. The ripple-drift cross-lamination and overlying pelitic unit are attributed to the lower flow regime of the same turbidity current (Harms and Farnestock, 1965; Dzulynski et al., 1959; Dott, 1966; Reading and Walker, 1966; Walker, 1967 and 1969).

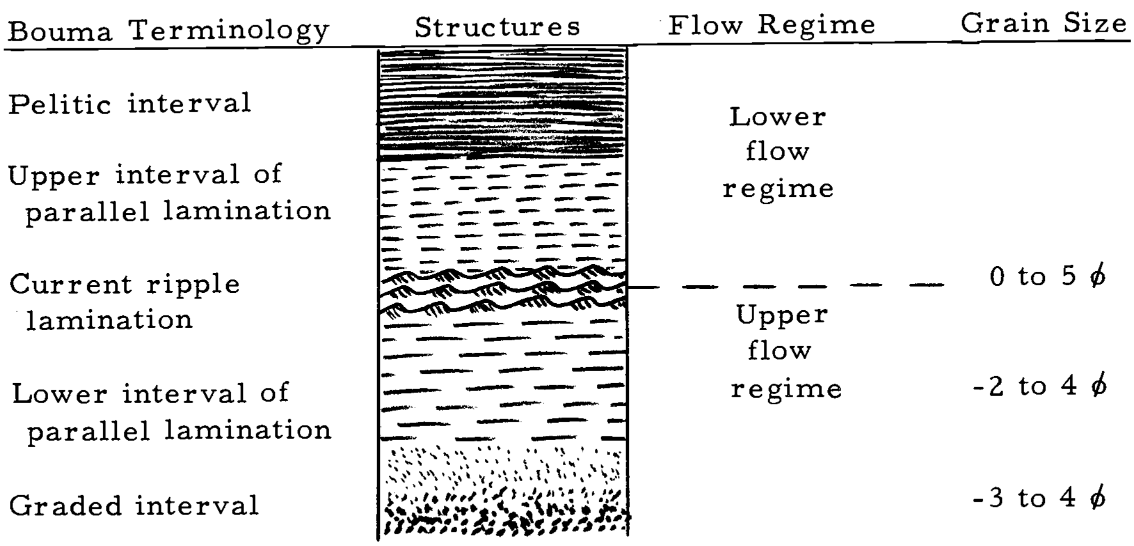


Figure 27. Relationship of internal structures to flow regime within a turbidite (After: Bouma, 1962; Harms and Fahnestock, 1965; and Pett and Walker, 1970).

Detailed sampling of the mudstones produced a foraminiferal assemblage low in species diversity (3 species) and in total abundance. Species recognized included Bulimina schencki and Gyroidina girardana planata, which were also present in Facies A, as well as Lenticulina inornatus. No firm conclusion regarding depth of water could be made. It is of interest to note that rounded, pyrite-filled specimens of the shallow water genus Quinqueloculina were found in this facies at South Cove. The edges of the tests were eroded in such a way as to indicate that the specimens were filled with pyrite before abrasion. Thus the specimens indicate the erosion and redeposition of an older fauna into the Elkton beds at South Cove. Open water indicators, such as planktonic foraminifers or radiolarians, were not found at North Cove, South Cove or Sacchi Beach by the author nor were they reported from Sacchi Beach by Bird (1967).

Facies C and D

The most striking sedimentary features in the Elkton Formation are the composite or multiple channels filled with alternating mudstones and sandstones (Facies C) and the sandstone-filled channels possessing basal mudstone breccias (Facies D). Neither of these types of channels show any evidence of fluvial processes such as festoon cross-bedding, multiple scour-and-fill, multiple lenses of gravel throughout the sand filling of the channel, or imbrication of mudstone boulders at the base of the channel.

Close examination of the breccias at the channel bases shows little if any rounding of the angular clasts in most channels. The sandstone matrix enclosing the clasts and the lack of rounding or imbrication of the clasts suggest a sliding motion in which the sand and angular mudstone blocks moved together rather than the large blocks being deposited in a fluvial channel as the current waned.

Dzulynski et al., (1959), Sanders (1965), Dzulynski and Walton (1965), Reading and Walker (1966) and Walker (1967) have described and illustrated brecciated, sand-filled channels that lack festoon or trough cross-bedding. These they have attributed to scour and deposition by bed load parts of turbidity currents (=fluxoturbidites of Dzulynski). Their published figures closely resemble the deposits herein called Facies D. Sanders (1965, p. 215) states "the bed load deposits of rivers almost invariably are cross-bedded on a larger scale, whereas such large scale cross-beds have never been reported from the 'bed load' parts of resedimented (turbidity) deposits." Shephard and Dill (1966) have attributed similar features to "sliding sand" or "turbulent sand-laden currents."

The composite or multiple channels filled with alternating, roughly parallel mudstones and sandstones (Facies C) are very similar to the rocks of Facies B that occur outside of the channels. It is significant that the fill at the top of a large multiple channel at the east end of North Cove is continuous with the sediments lying beyond the channel (Figures 17 and 28). The composite lack of fluvial characteristics within and outside the channel, coupled with the features described previously that suggest deposition by turbidity currents, strongly suggest that the deposition of both Facies B and C and the carving of the channel itself was by the suspended load of turbidity currents within the lower flow regime (see Figure 27). The carving of the channel would require only slightly higher flow regime than the surrounding deposits.

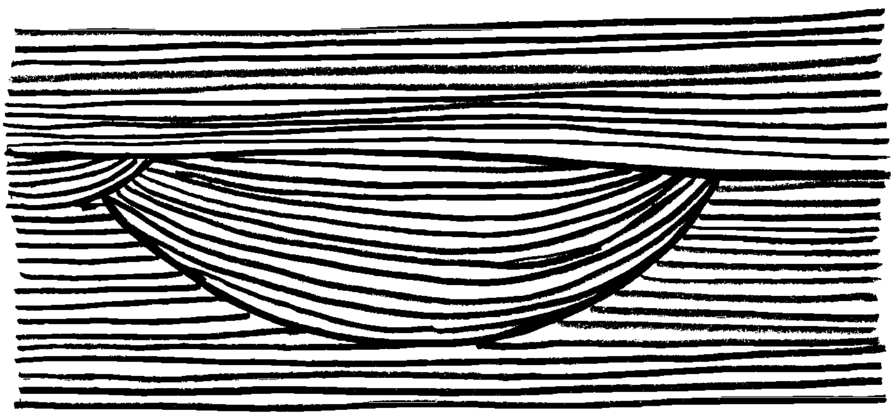


Figure 28. Sketch of channels in the photograph in Figure 17.

The carving of the channels and the deposition of Facies C and D can best be explained by the action of subaqueous gravity flows (turbidity currents). The following diagram adapted from Sanders (1965) and Reading and Walker (1966) illustrates the probable origin of both types of channels and their fills.

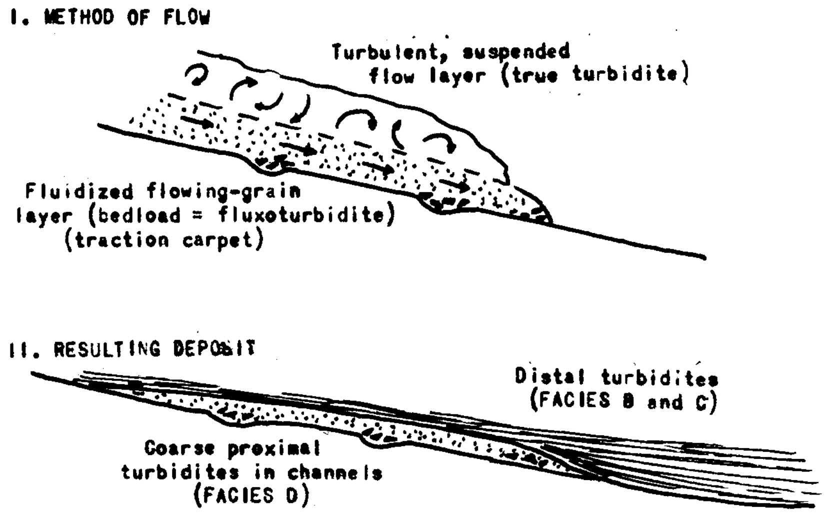


Figure 29. Hypothetical origin of distal (Facies B, C) and proximal (Facies D) turbidites of the Elkton Formation.

Regional Synthesis and Depositional History of the Elkton Formation

The beds exposed at North and South Coves of Cape Arago have been the subject of controversy inasmuch as they have been correlated with six formations of differing ages. In addition, it has been postulated that a major late Eocene unconformity of regional significance is contained within these strata. Diller (1901) and Weaver (1945a) did not mention the presence of an unconformity and included the strata at North and South Coves in the Pulaski and Arago Formations respectively (Table I). Turner (1938) considered the "shale conglomerate" (channel sand with an angular mudstone breccia at the base) below the viewpoint overlooking Simpson's Reef to represent an angular unconformity between the overlying Coaledo Formation and the underlying Pulaski Formation. Allen and Baldwin (1944) accepted the unconformity and base of the Coaledo Formation as suggested by Turner, but correlated the beds below the "unconformity" (beds at North and South Cove) with the Umpqua Formation. Allen and Baldwin (p. 23, 1944) stated:

> "Field relations in other parts of the quadrangle indicate that the unconformity beneath the shale conglomerate is of major importance, for the Tyee sandstone is missing and the sediments beneath the unconformity correspond to similar sediments containing an upper Umpqua fauna."

The beds at Sacchi Beach were also considered by these workers to be part of the Umpqua Formation. Stewart (1957) on the basis of foraminifers showed that the beds at Sacchi Beach were too young to be considered equivalent to the Umpqua Formation and correlated the Sacchi Beach beds with mudstones at Lorane and Elkton which were considered to be the upper part of the Tyee Formation. Hence, the name Elkton Siltstone Member of the Tyee Formation came into use for the beds at North and South Coves and Sacchi Beach (Baldwin, 1959, 1964).

Wheeler and Mallory (1962) and McWilliams (1968) have proposed a widespread late Eocene unconformity in the rocks of Oregon and Washington. They extend this unconformity to the Coos Bay Region, using evidence based upon the published literature rather than field relations. Dott (1966) studied the sedimentary structures and stratigraphy of the Cape Arago-Charleston region in detail and stated that a major unconformity is not present at Cape Arago. Baldwin (p. 191, 1966) accepted Dott's contention that an unconformity of major significance is not present at Cape Arago but reports that it can be found a short distance away.

> "Yet one need not leave the Coos Bay area to prove the unconformable relationship, because the Coaledo Formation rests on eroded Tyee and in proximity with lower Umpqua basalt at the forks of the Coos River and on a much thicker section of Tyee a few miles to the south or north. No trace of the Sacchi Beach or Elkton siltstone members is present at the base of the Coaledo other than at Sacchi Beach."

Baldwin (1973) has reassigned the part of the Tyee mentioned above to the Flournoy (=upper part of the Umpqua) Formation. Because Baldwin is convinced that an angular unconformity exists at the base of the Coaledo Formation and he accepts that it is not present at Cape Arago, he now includes the rocks at Cape Arago within the Coaledo Formation. He suggests that the base of the Coaledo Formation is not exposed at Cape Arago. However, he considers the beds in the same stratigraphic position at Sacchi Beach to be included in the Elkton Formation. Hence beds a few miles apart with similar channels, similar lithology and stratigraphic position are assigned by Baldwin (1966) to two different formations.

The author believes that both Baldwin and Dott are partially correct in their conclusions. Baldwin is correct in stating that a major unconformity exists beneath the Coaledo Formation in the regions south and east of Cape Arago. However, Dott is correct in concluding that the "shale conglomerate" of Turner (1938) is a localized erosional channel. Furthermore, at least a dozen similar channels exist in the Cape Arago-Sacchi Beach area at different stratigraphic positions. The author suggests that the beds at North and South Coves and at Sacchi Beach are equivalent and should be referred to the Elkton Formation of Bird (1967) and that no major unconformity is present in this sequence. Deposition of the Elkton Formation in the Cape Arago-Sacchi Beach region occurred during a part of the time interval represented inland by the unconformity. Deposition at Cape Arago was continuous from the time of the Elkton Formation to the deposition of the lower member of the Coaledo Formation.

The author believes that the beds at North and South Coves and at Sacchi Beach are equivalent because:

1) The four lithofacies present at North Cove are recognized and occur in the same sequence at North and South Coves and at Sacchi Beach (see Figure 30);

2) A total of 18 sandstone channels with mudstone breccias identical to those of Facies D at North and South Coves and Sacchi Beach occur over a distance of 50 miles along a SW-NE line from Sacchi Beach to Elkton. These channels are invariably near the top of

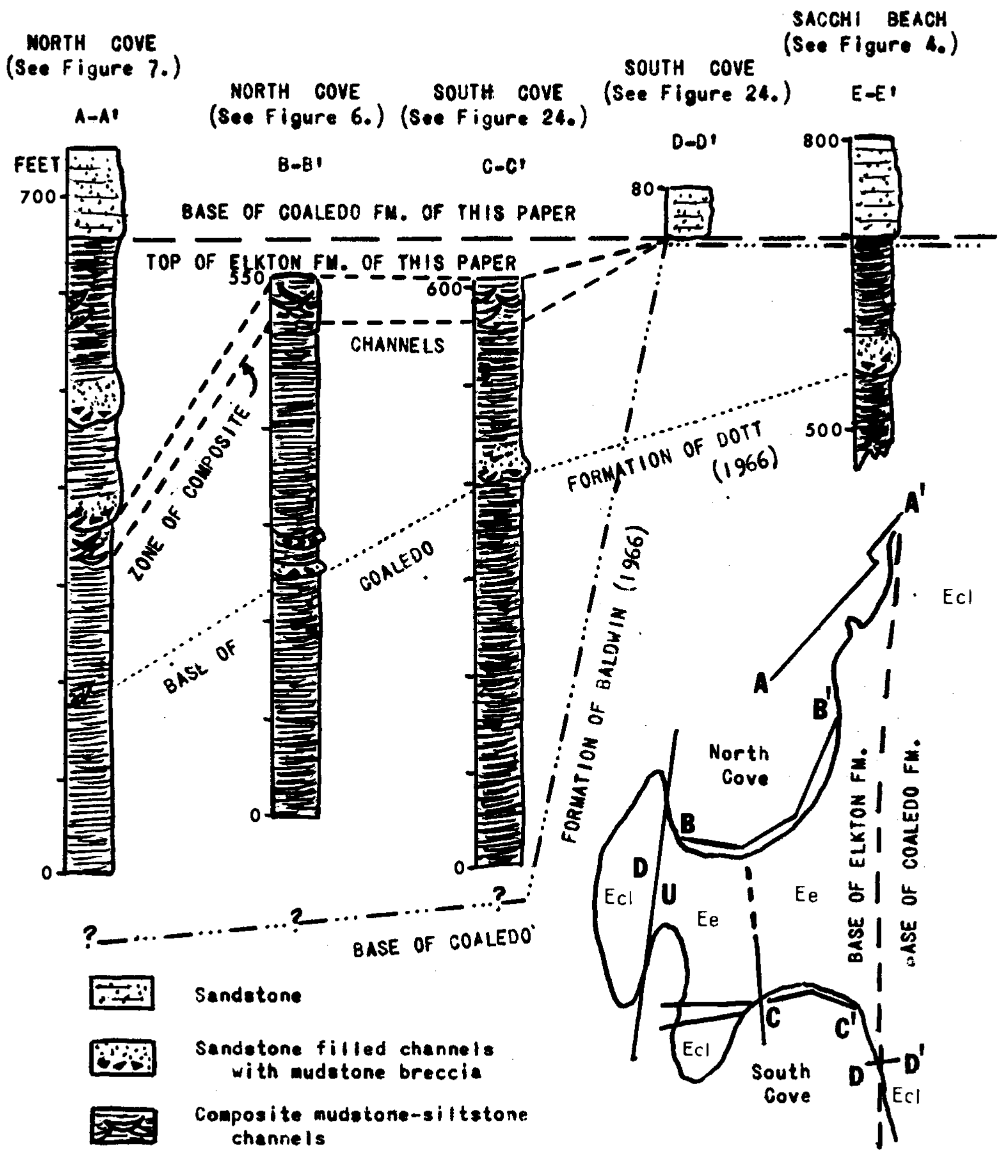


Figure 30. Location and correlation of stratigraphic sections in Elkton-Coaledo transition zone.

the Elkton Formation and below the Coaledo Formation, or the Coaledo Formation(?) of Baldwin according to Bird (1966);

3) Bird (1966) also notes that composite channels of alternating mudstone and sandstone similar to Facies C also occur inland near the top of the Elkton Formation;

4) The Elkton Formation appears to shallow progressively from upper bathyal depths in the upper Tyee, to neritic (300-600 feet) in the lower Elkton inland, to middle or inner neritic (less than 300 feet) for the uppermost Elkton inland and the entire exposure of the Elkton at Sacchi Beach (Bird, 1966). This shallowing trend is indicated at North and South Coves, as it is at Sacchi Beach, by the vertical progression from quiet water mudstones of Facies A to distal turbidite deposits and channels of Facies B and C to increasing numbers of proximal turbidite channels of Facies D near the base of the Coaledo Formation. The turbidite deposits represent the offshore indications of the tectonic uplift inland that furnished the clastic material for the overlying, prograding lower Coaledo delta;

5) Finally, the strata at all three localities (North Cove, South Cove and Sacchi Beach) are only a few miles apart and all lie in similar stratigraphic position directly below the basal sands of the Coaledo Formation.

Coaledo Formation

General Statement

Diller (1899) named the Coaledo Formation for a series of predominantly non-marine, coal-bearing, late Eocene strata exposed near the town of Coaledo located a few miles south of Coos Bay, Oregon. Turner (1938), while studying the fossil mollusks of the coastal section between Cape Arago and Charleston, proposed a three fold subdivision of the Coaledo into lower and upper sandstone members separated by a middle "shale" (mudstone) unit. This subdivision was accepted by Allen and Baldwin (1944) and is used in this study with only minor modifications (see Table 1).

Lower Sandstone Member

The lower sandstone member of the Coaledo Formation is typically a carbonaceous, micaceous, medium- to coarse-grained sandstone with medium- to large-scale cross-stratification. Subbituminous and lignite coals are found southeast of Cape Arago and inland from Sacchi Beach. Allen and Baldwin (1944) report as many as seven coal seams in this "lower group" of coals a few miles inland to the southeast of the coastal section.

The lower contact is so gradational with the underlying Elkton

Formation that no unequivocal base can be chosen. Dott (1966) placed the contact at the base of the lowermost of the channel sands with large brecciated zones (see Figure 30). If the lowest, coarse channel sand is accepted as the base of the Coaledo, then more than 600 feet of beds of typical Elkton lithology lie above that channel. In fact, the channel sands make up a very small percentage of the total lithology at that stratigraphic interval. The author recognizes that the base of the Coaledo is gradational, but he places the boundary much higher, where the lithology becomes predominantly thick-bedded, medium- to coarse-grained sandstone with only minor interbedded siltstones or mudstones (see Figure 30). This boundary more nearly coincides with the original definition of the Coaledo Formation and can more easily be traced inland. The upper boundary is placed at the top of the sandstone beds exposed at Lighthouse Point, which coincides with the subdivision of Turner (1938) and Allen and Baldwin (1944). The thickness of the lower Coaledo in the coastal section is approximately 1700 feet, but according to Allen and Baldwin (1944), it appears to thicken to the southeast to at least 1900 feet near Lampa Creek.

Sedimentary Structures

The sandstone units increase in thickness upward in the section and become more numerous until they are the dominant lithology in the middle part of the lower Coaledo. The sandstones commonly reach thicknesses of thirty feet or more and are separated by thinner bedded, siltier, more carbonaceous units (Figure 31). The sandstones frequently show abundant contorted strata, attributed to gravity deformation on a paleoslope. Large scale, wedge-planar cross-stratification truncated by regularly spaced parallel boundaries suggests aqueous deposition. Trough or festoon cross-stratification, curved scour channels, and pebbly zones suggestive of fluvial deposition are not common in this sequence. At Shore Acres State Park abundant calcareous concretions can be observed on several bedding surfaces now exposed in the sea cliffs (Figures 34 and 35). Toward the top of the lower Coaledo the sandstones thin, and the interbedded units thicken and decrease in grain size from siltstones to mudstones. Evidence of gravity deformation such as contorted strata and small scale slumps and liquefaction features such as roll-ups are common (Figure 36). At the lighthouse the sandstones usually are tabular units with sharp, clear, parallel upper and lower boundaries. Small scale scour, cross-lamination and ripple-drift laminae are very common within the sandstones and are highly visible owing to the abundance of carbonaceous debris on some bedding surfaces. The sandstones clearly indicate deposition from sediment-laden currents without scour of the underlying siltstones (Figures 37 and 28). The interbedded mudstones and siltstones appear to be homogeneous and structureless. Similar sedimentary features have been reported in estuaries and shallow marine deposits.

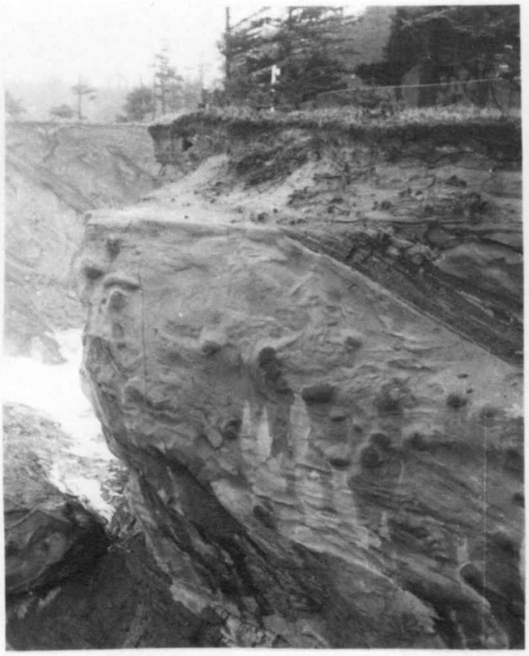


Figure 31. Cross-laminated concretionary sandstone at Shore Acres State Park.

Figure 32. Close up of cross-lamination in Figure 31.

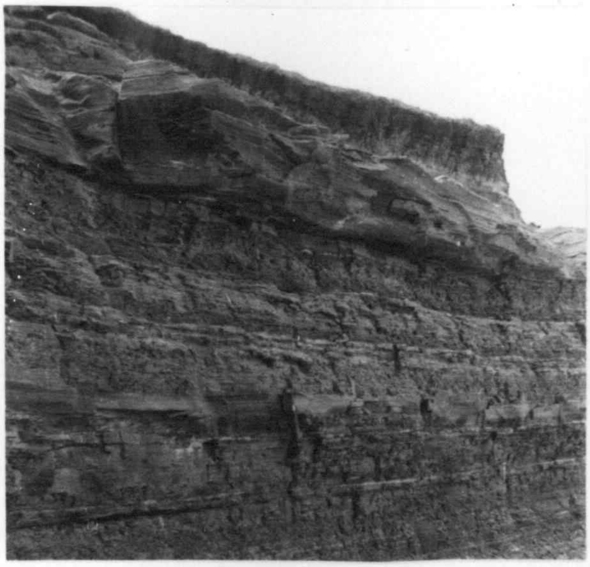


Figure 33. Thinner units at Shore Acres State Park are carbonaceous, micaceous siltstones and sandstones containing shark teeth and brittle stars.

Figure 34. Lower Coaledo concretionary beds at Shore Acres State Park.

Figure 35. Close up of concretions. Lower Coaledo. Shore Acres State Park.

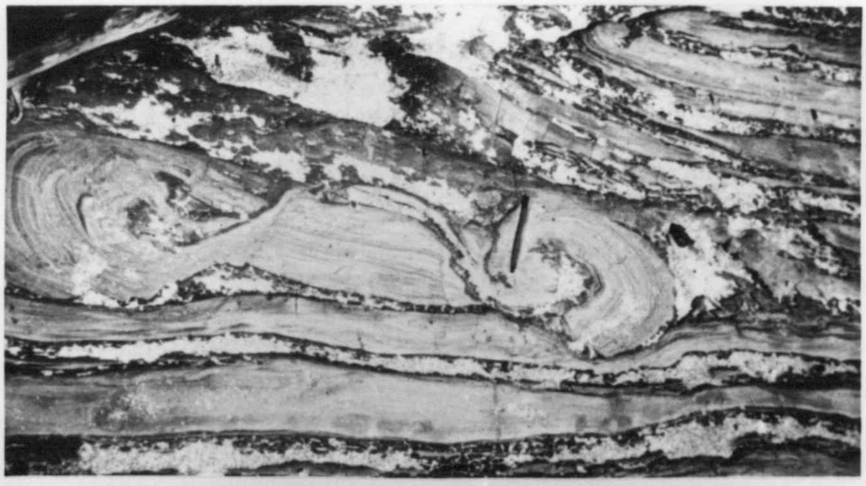


Figure 36. Sandstone "roll-up". Lower Coaledo. Lighthouse Point.

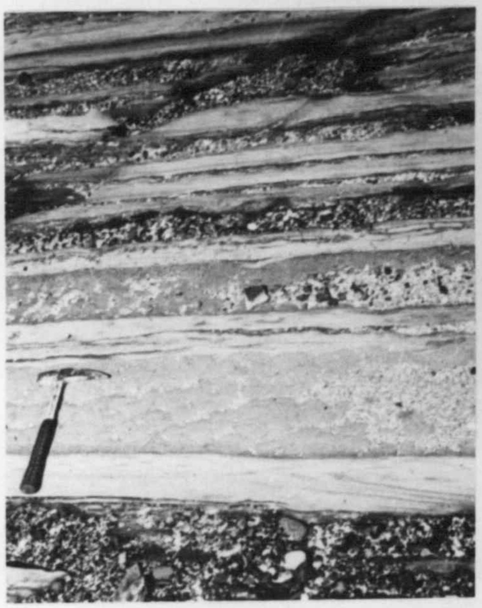


Figure 37. Interbedded muddy silt-stones (dark) and carbon-aceous cross-laminated sandstones (light). Lower Coaledo. Lighthouse Point.

Figure 38. Close-up of ripple-drift, cross-laminated sand-stone. Same location as Figure 37.

Mollusks

Fossil mollusks occur at several locations in the lower and upper part of the lower Coaledo but are rare in the middle part. Two localities within the down-dropped block of sandstone making up Cape Arago have yielded nine species of pelecypods and nineteen species of gastropods according to Weaver (1944). Of particular importance are the abundant razor clams Solena (Eosolen) columbia (Weaver and Palmer) and the sand dollar Eoscutella coosensis (Kew) found at Middle Cove, for both species are indicators of sandy substrates in a sublittoral environment.

Mollusks are rare in the middle part of the lower Coaledo but sometimes are present as thin lenses of small, thin-shelled pelecypods such as Nuculana sp. within the siltier units. Sharks' teeth and the brittle star, Ophiocrossota baconi Blake and Allison, are known from the beds near Shore Acres State Park.

The uppermost beds of the lower Coaledo contain several mollusk localities along the north side of Sunset Bay and in sandstone beds exposed at the south end of Lighthouse Beach. These localities are dominated by two faunas. One is rich in specimens of Turritella uvasana Conrad subsp. stewarti Merriam, and the other contains many specimens of Venericardia hornii clarki (Weaver and Palmer). Coarse-ribbed species of the genus Venericardia are indicative of sandy substrates in shallow bays where the coarse ribs aided in burrowing in the sand (Stanley, 1970).

Conditions of Deposition

The combination of shallow marine fossils coupled with the abundance of thick, cross-stratified sandstones that lack fluvial characteristics suggest that the lower and middle parts of the lower member of the Coaledo Formation were deposited in a predominantly shallow marine environment with strong current action. The sedimentation of the upper part of the lower Coaledo suggests deposition in a quieter environment, but one in which currents were still active. Detailed paleoecologic inferences based upon foraminifers and mollusks are presented in a later section.

Middle Mudstone Member

The middle member of the Coaledo Formation is best exposed in the coastal region between Lighthouse Point and Yokam Point (Mussel Reef). The lower part of the middle member also crops out at the easternmost end of the north side of Sunset Bay. The dominant rock types are tuffaceous, dark gray, mudstones and siltstones with three prominent sandstone units and numerous thin ash layers.

The lower contact of the middle member is at the top of the uppermost, thick-bedded sandstones of Lighthouse Point. About 260 feet above the base a resistant sandstone unit containing ten species of mollusks (Turner, 1938) crops out in the seacliff and the nearby beach. This same sandstone unit, rich in mollusks, crops out in the wavecut platform and in the cliff along the north side of Sunset Bay, where it is offset by three faults with lateral displacements of 10 to 20 feet. The upper contact of the middle Coaledo is gradational, and the boundary indicated by Turner (1938) and Allen and Baldwin (1944) is followed in this report (Figure 44).

The middle member is 2,940 feet thick and is rich in foraminifers and radiolarians in the lower and middle parts, but microfossils become less abundant higher in the section as the amount of sandstone increases. Mollusks and other macroscopic fossils are rare. Evidence of burrowing animals or extensive current action is also rare. Three prominent tuffaceous, nonfossiliferous sandstones, containing thin shale partings, crop out near the top of the unit.

Inland exposures are obscured by vegetation, terrace deposits and deep weathering; however, the middle member of the Coaledo Formation appears to thin and to grade by facies change into the upper and lower sandstone members toward the east and southeast.

Allen and Baldwin (1944) have suggested that the middle member might have been deposited in a shallow marine basin. Evidence, based upon foraminifers and radiolarians, of an open ocean, shelf environment is presented in a later section on paleoecology.

Upper Sandstone Member

The upper member of the Coaledo Formation is exposed in the coastal region at Yokam Point (also known locally as Mussel Reef). The most common rock type in the upper Coaledo is medium- to coarse-grained, light gray, micaceous sandstone that contains several lenses of conglomerate (Figure 39). Most of the sandstones are texturally submature to immature, feldspathic, micaceous, lithic (volcanic) wackes and arenites. Festoon or trough cross-stratification, erosion channels, and lenses of conglomerate are common in some sandstone units. Evidence of slump or gravity deformation on a paleoslope is less evident than in the lower Coaledo. Within a 50 foot stratigraphic interval at Yokam Point one can find marine sandstones containing abundant mollusks, a six foot bed of subbituminous coal (the Beaver Hill coal seam), a pebbly sandstone exhibiting festoon cross-stratification and coarse sandstones containing the estuarine Ostrea (Figure 41).

At Yokam Point the upper Coaledo is 1,371 feet thick and is apparently conformably overlain by the Bastendorff Formation. The upper contact is placed at the top of the prominent sandstone at the southwest end of Bastendorff Beach. The lower contact was described in a previous section. The upper Coaledo thickens to the east and south, and the number of distinct coal seams increases from one in the coastal section to six or seven inland (Allen and Baldwin, 1944).

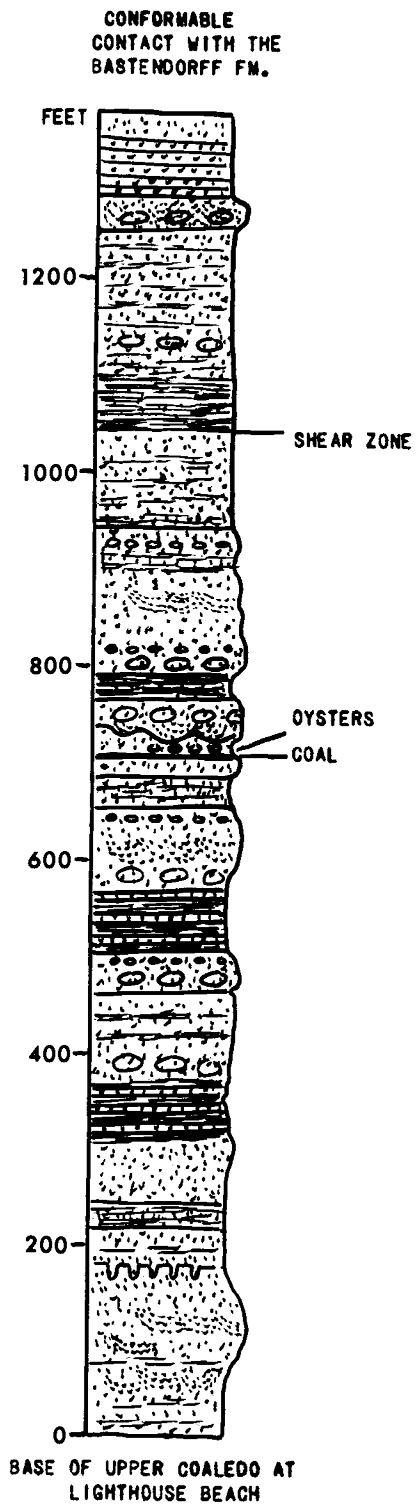


Figure 39. Upper Coaledo at Yokam Point. (See Figure 4 for explanation of symbols).

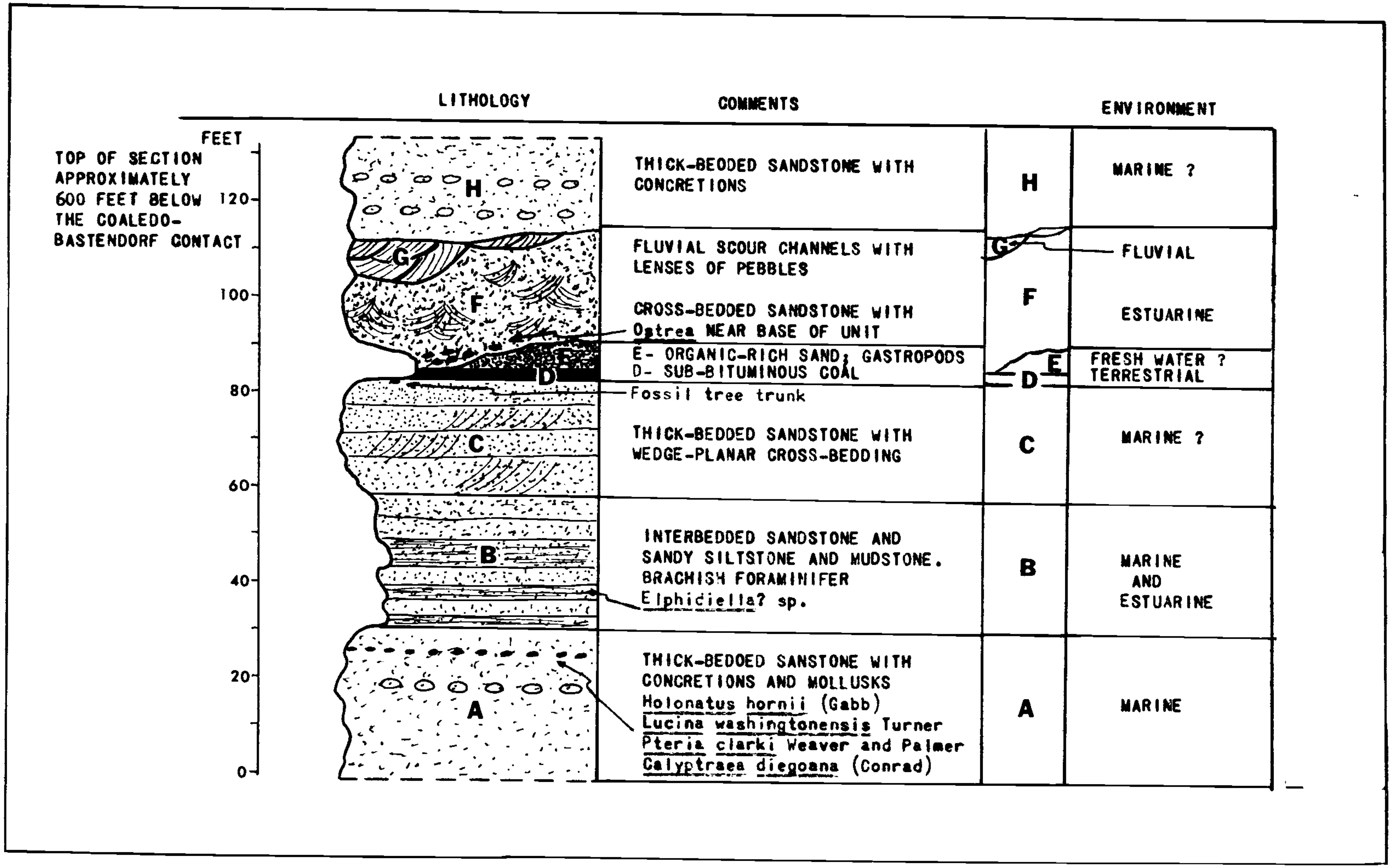


Figure 40. Diagrammatic sketch of lithofacies exposed in sea cliffs near the coal seam at Yokam Point (Mussel Reef). Upper Member of the Coaledo Formation.

Figure 41. Beaver Hill Coal Seam. Upper Coaledo. Yokam Point (Mussel Reef).

Figure 42. Concretionary sandstone filling scour channel. Looking seaward (northwest) from the location shown in Figure 41. Upper Coaledo. Yokam Point (Mussel Reef).

Allen and Baldwin (1944) have estimated the upper Coaledo, five miles to the south of Yokam Point, to be about 2,800 feet thick.

Marine, non-marine, and estuarine environments existed during upper Coaledo deposition. This is particularly well documented by the beds exposed near the Beaver Hill coal at Yokam Point (Figure 40). A massive sandstone (Unit A) containing the marine mollusks *Holonatus hornii* (Gabb), *Lucina washingtonensis* Turner, *Pteria clarki* Weaver and Palmer and *Calypteraea diegoana* (Conrad) is overlain by alternating beds of sandstone and siltstone (Unit B), which contain poorly preserved specimens of the brackish or intertidal foraminifer, *Elphidiella*. The Beaver Hill coal (Unit D) is overlain by a semi-consolidated, very organic-rich sandstone that contains many broken thin-shelled gastropods (Unit E). The coal and the overlying gastropod-rich layer are probably terrestrial in origin (Turner, 1938). A pebbly sandstone (Unit F) containing abundant oysters of the genus *Ostrea*, an occasional ectoproct (bryozoan), sharks' teeth, and platform teeth of a skate or ray, overlies the gastropod-rich layer. The oyster-rich layer occupies erosional channels cut in the underlying units. The estuarine, oyster-rich unit, in turn, is cut by fluvial scour channels containing trough or festoon cross-bedding (Unit G). The sedimentary structures and the fossils strongly suggest that deposition of the upper Coaledo beds occurred in marine, terrestrial, and estuarine environments. A fluctuation of the late Eocene strand line and the resulting changes in environment of deposition could have been brought about by vertical crustal movements or a lateral shifting of a prograding deltaic complex. Additional inferences concerning the environment of deposition, based upon fossil mollusks, are given in a later section.

Bastendorff Formation

The Bastendorff Formation is best exposed at the type section along Bastendorff Beach between Yokam Point (Mussel Reef) and Tunnel Point (Figures 3, 44). The Bastendorff Formation consists of approximately 2,900 feet of thinly laminated, dark-gray siltstones and mudstones that weather a light tan. Thin layers of white volcanic ash, usually less than one-fourth of an inch thick, are scattered throughout the unit. Several glauconite- and foraminifer-rich layers were found. The lower one-third of the formation at Bastendorff Beach is covered by alluvium from Miner Creek. A prominent tuffaceous sandstone, about 60 feet thick, crops out just east of the valley of Miner Creek. No fossils were found within the sandstone. The middle and upper parts of the formation are deeply weathered and obscured by thick brush. Exposures of rock are poor except along a new county roadcut (Figure 44).

Contacts of the Bastendorff with the underlying Coaledo Formation and the overlying Tunnel Point Formation appear to be conformable, but exposures are poor.

Mollusks are rare in the Bastendorff, but foraminifers and radiolarians are locally very abundant. Some samples were found to contain as many as 379 foraminifers and 1,751 radiolarians per gram of rock. A few small sharks' teeth, echinoid spines and diatoms are present.

The Bastendorff Formation is exposed inland at various localities within the Coos Synclinorium (Figure 43). Samples collected inland are deeply weathered and contain molds and casts of foraminifers and radiolarians that are, in most cases, very difficult to identify.

Schenck (1928) suggested, based upon a textural analysis, that the Bastendorff Formation was deposited in a "harbor," but evidence is presented in a later section that indicates a deeper, marine environment of normal salinity.

Younger Formations

The Tunnel Point sandstone (Oligocene), an unnamed Miocene sandstone, and the Empire Formation (Pliocene) crop out in the vicinity of South Slough (Figure 3). Younger (Pleistocene) terrace deposits are present near the coastal section. The biostratigraphy of these units is not included in this study.

STRUCTURAL GEOLOGY

Regional Setting

The major emphasis in this study has been the stratigraphy and micropaleontology of rocks exposed in the coastal regions from Charleston to Cape Arago, and at Sacchi Beach. Inland, in the vicinity of South Slough, the geologic map of Allen and Baldwin (1944) was field checked, stratigraphic units were traced, and microfossil samples were collected from the mudstone and siltstone units. The dominant structural feature in the area is the north-plunging South Slough syncline (Figure 3). South Slough occupies a structural and topographic low along the axis of the fold.

The South Slough syncline is, in turn, a part of the larger, north-plunging Coos synclinorium (Figure 43). The Coos synclinorium lies on the northwest edge of the older (Mesozoic) Klamath Mountain structural province. On the east, it is bounded by folded, early Tertiary (predominantly Eocene) sedimentary and volcanic rocks of the Coast Range. Trends of folds within the continental shelf to the west of the Coos synclinorium suggest the presence of a major, north-plunging anticlimorium (Figure 43). L. D. Kulm (personal communication, 1974) has mentioned the presence of a large structural basin lying offshore to the north-northwest of the Coos synclinorium. It is possible that the Coos synclinorium and the structures immediately to the west are, in reality, the southernmost extensions of a larger offshore basin.

Folding and Faulting

Inland from the coastal section, the Coaledo Formation lies unconformably upon the Umpqua Formation (early Eocene) and the Tyee Formation (middle Eocene). Allen and Baldwin (1944) have stated that the Umpqua and Tyee Formations were affected by a period of deformation, which occurred, prior to the deposition of the Coaledo Formation. Folding in the Umpqua and Tyee was not studied and is not included in the regional map (Figure 43). At the time of the study of the Coos synclinorium by Allen and Baldwin (1944), active coal mines facilitated the tracing of the sandstone units. Only the South Slough syncline, the Cape Arago anticline (of Allen and Baldwin, 1944), and the Sacchi Beach anticline were examined in this study.

Nearly 10,000 feet of sedimentary rocks of Eocene, Oligocene and Pliocene age are contained in the South Slough syncline. Along the western limb, the Coaledo (Eocene), Bastendorff (Eocene) and Tunnel Point (Oligocene) Formations all dip steeply eastward (Figure 44). All three formations are unconformably overlain by the Empire Formation of Pliocene age (Figures 3, 43). Moore (1963) has described fossil mollusks of Miocene age dredged from the bed of the Coos River near

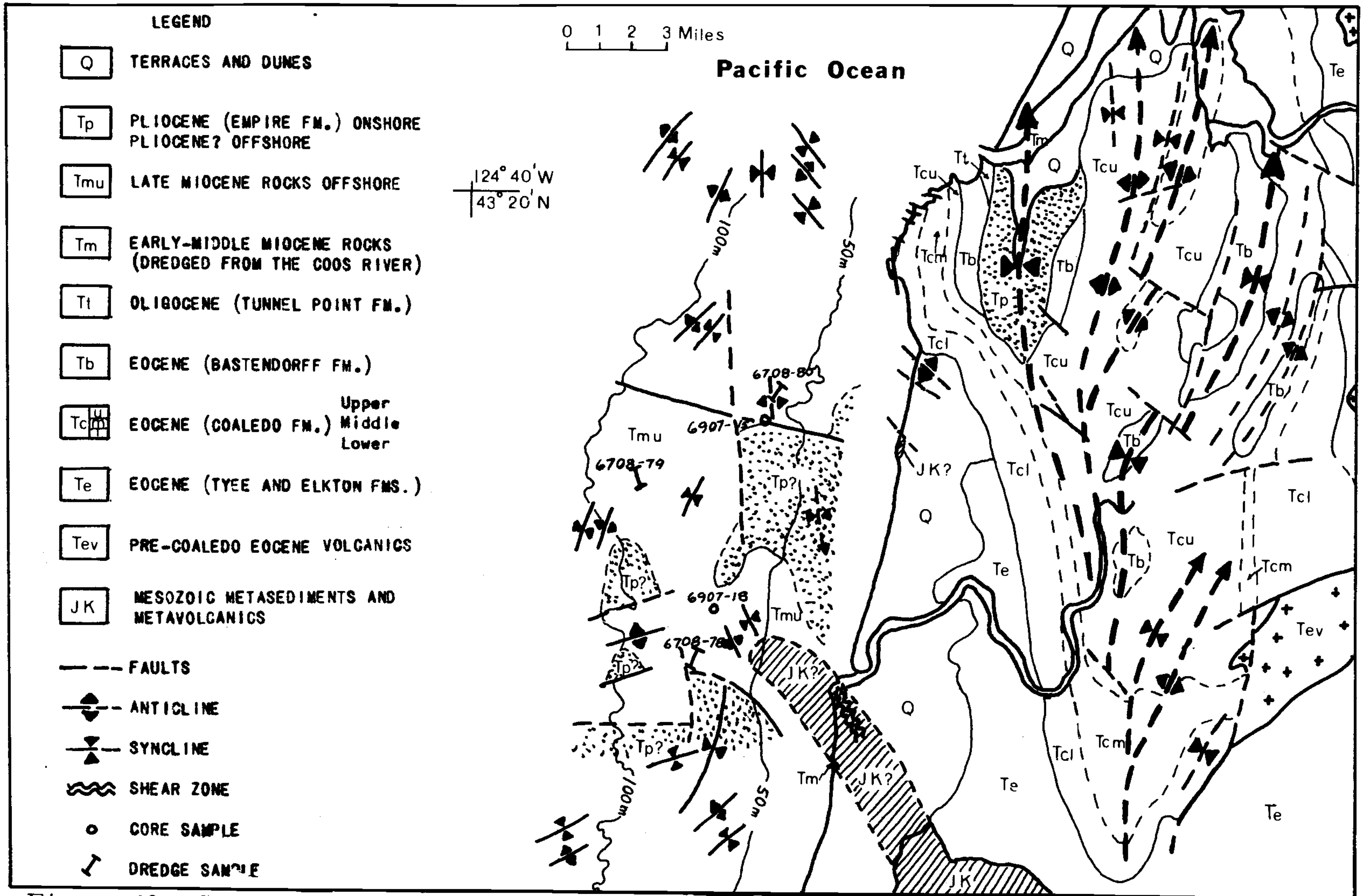


Figure 43. Structural patterns in the Coos Synclinorium and adjacent offshore region. After: Allen and Baldwin (1944), Baldwin (1964a), Dott (1966), Mackay (1969), and Fowler et al. (1971).

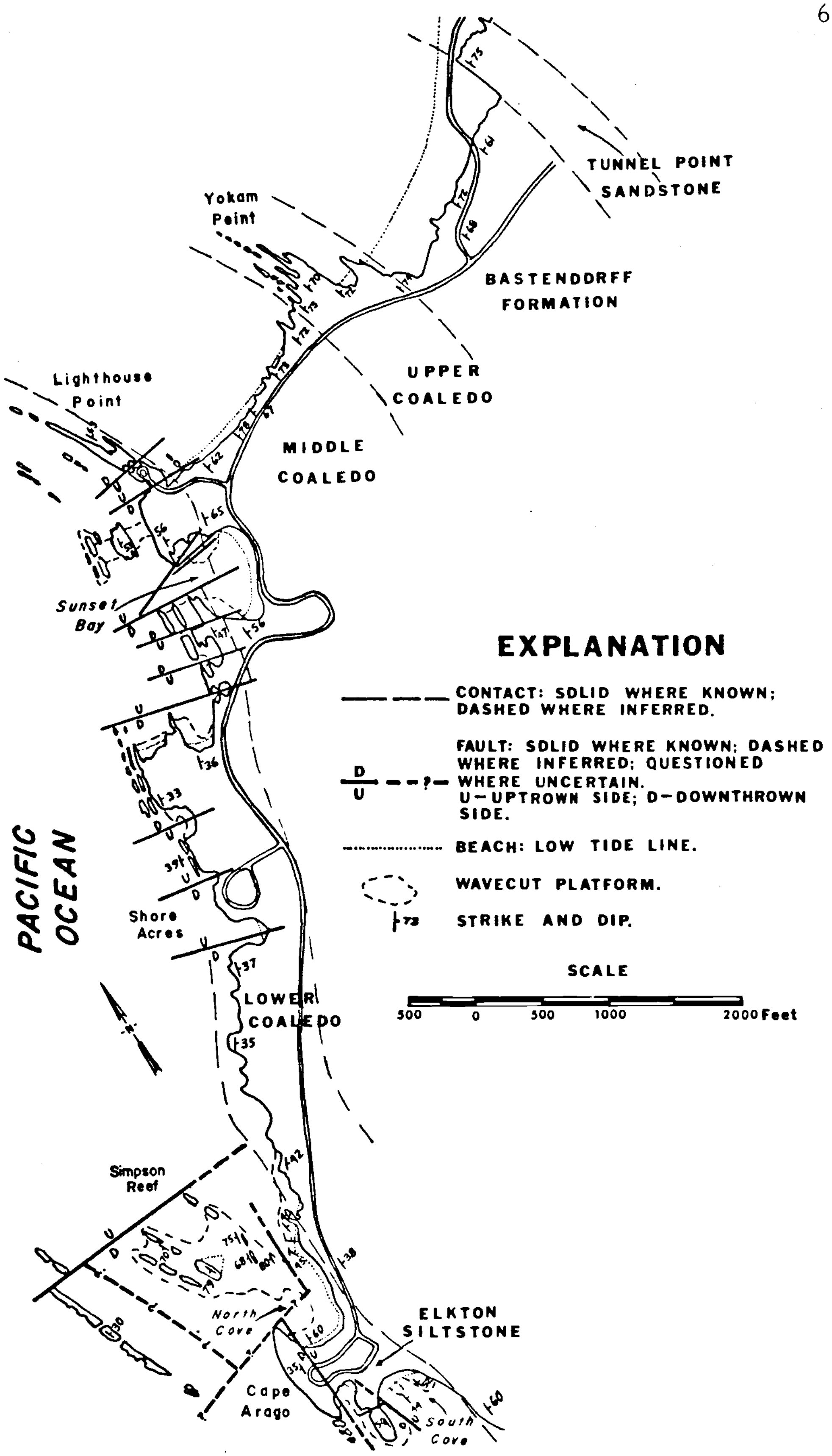


Figure 44. Faults in the coastal section.

the axis of the South Slough syncline. Armentrout (1967) reported the presence of the Miocene clam Diosinia in rocks of the wavecut platform east of Fossil Point. The folding of the South Slough syncline is apparently post-Oligocene and pre-Pliocene. According to Fowler et al. (1971), folding in the offshore region, to the west of Cape Arago, apparently occurred after the deposition of late Miocene sedimentary rocks and prior to the deposition of Pliocene sedimentary rocks (Figure 43). This may coincide with the time of major folding inland. Tilted Pleistocene terraces and small normal faults indicate that some deformation of the South Slough syncline has continued into post-Pleistocene time (Baldwin, 1966).

The axis of the "Cape Arago anticline" of Allen and Baldwin (1944) coincides with the "Cape Arago Fault" of the same authors. Overturned beds of the Elkton Formation, adjacent to the Cape Arago fault in North Cove, are considered, in this study, to be drag folds produced by faulting, rather than the overturned limb of an anticline.

The presence of an unnamed anticline at Sacchi Beach, as mentioned by Allen and Baldwin (1944) and Bird (1967), is accepted in this study. It should be noted, however, that exposures are discontinuous as a result of deep weathering, soil cover, and slumping. Moreover, the change in dip mapped as an anticline could be the result of slumping or faulting.

Most of the faults in the coastal region appear to be normal faults with small displacements that tend to be at right angles to the strike of sandstone beds. Much of the erosion of cliffs between Sunset Bay and Cape Arago is localized along the faults. Allen and Baldwin (1944) mention that a few faults in the inland region are parallel to the strike of the beds, but these faults are discernable only by anomalous dips and dislocation of coal seams. Duncan (1953) postulated that major faulting parallel to the strike of the beds might have occurred in the coastal section. He speculated that upper and lower sandstone members of the Coaledo Formation were, in reality, one unit and that the middle Coaledo and Bastendorff were equivalents. Regional mapping by Allen and Baldwin (1944), comparison of sedimentary structures of the Coaledo by Dott (1957), and the stratigraphic distribution of foraminifers of this study contradict Duncan's hypothesis.

Summary of Structural History

The major deformation that resulted in the folding and faulting of the Coos synclinorium and adjacent rocks of the continental shelf probably occurred in late Miocene time. That lesser episodes of diastrophism may have preceded the late Miocene folding is indicated by the presence of borings of the intertidal pelecypod, *Pholas*, at the top of the Tunnel Point Formation (Schenck, 1927). Minor faulting and warping has continued into recent time (Baldwin, 1966).

An angular unconformity occurs between the Empire

Formation of Pliocene age and the Tunnel Point Sandstone. This unconformity may extend offshore for, according to Baldwin (1966), Pliocene fossils wash ashore on the beach north of Bandon (Figure 43).

The north-plunging Coos synclinorium and adjacent structures to the west may be related to a larger sedimentary basin located to the north on the continental shelf.

BIOSTRATIGRAPHY

Historical Development of Pacific Coast Biostratigraphic Zonation

Biostratigraphic correlation of Pacific Coast Eocene marine sediments is based upon a single megafossil and two microfossil (foraminiferal) zonations (Table 2).

The earliest foraminiferal zonation was proposed by Laiming (1940) and was based mainly upon the stratigraphic range of one or two key species, plus a characteristic assemblage. The information upon which Laiming erected his zones was mainly oil company well data from central and southern California. As more has become known of the species distribution of foraminifers on the Pacific Coast, the stratigraphic ranges of Laiming's key species have been modified and the zonation has become less useful. In addition, Rau (1958) considers some of his assemblages to be facies equivalents of the same time intervals. A more recent, widely used zonation proposed by Mallory (1959) is based upon overlapping ranges of foraminiferal species. This zonation is a concurrent-range zone as defined by the American Commission on Stratigraphic Nomenclature (1961). Current attempts to develop a world-wide zonation based upon planktonic foraminifers are promising but are currently hindered by taxonomic problems and a lack of studies at higher latitudes. The objections of Steineck and

Table 2. Correlation of late Eocene and Oligocene formations with standard Pacific Coast stages and faunal zones.

SOUTHERN CALIFORNIA 1,2,3	SOUTHWESTERN OREGON	PACIFIC COAST CENOZOIC CORRELATION				SOUTHWESTERN WASHINGTON
ZONES	FORMATIONS	STAGES	AGE	ZONES 6	STAGE (MOLLUSKAN) 7	ZONES 8,9
Uvigerina vicksburgensis	TUNNEL POINT FORMATION	REFUGIAN 5	OLIG-OCENE — ? —		KEASEY	Eponides kleinpelli = Cassidulina galvinensis
Uvigerina cocoaensis	BASTENDORFF FORMATION	REFUGIAN 5	EOCENE		KEASEY	Sigmomorphina schencki
Amphimorphina jenkinsi	BASTENDORFF FORMATION	NARIZIAN 4	EOCENE	A-1 ?	TEJON AND TRANSITION	Bulimina schencki - Plectofrondicularia cf. P. jenkinsi
Amphimorphina jenkinsi	U — COALEDO FORMATION	NARIZIAN 4	EOCENE	A-1 / A-3	TEJON AND TRANSITION	Uvigerina cf. U. yazooensis
Bulimina corrugata zone: Uvigerina garzaensis Subzone; Uvigerina churchi Subzone	M, L — COALEDO FORMATION	NARIZIAN 4 — ? —	EOCENE	A-2 ?	TEJON AND TRANSITION	Bulimina cf. B. jacksonensis
Amphimorphina californica	ELKTON FORMATION	UPPER ULATISIAN 4	EOCENE	B-1A	DOMENGENE	Vaginulinopsis vacavillensis

1. Schenck and Kleinpell, 1936.
2. Kleinpell and Weaver, 1963.
3. Fairchild, Wesendunk and Weaver, 1969.
4. Mallory, 1959.
5. Kleinpell, 1938.
6. Laiming, 1940 (After Rau, 1964).
7. Weaver et al., 1944; Lowry and Baldwin, 1952.
8. Rau, 1964.
9. Rau, 1967.

Gibson (1971 and 1972) to zonations based upon benthic foraminifers will be discussed in more detail in a later section.

A megafossil (primarily molluskan) zonation proposed by Weaver et al. (1944) and modified by Lowry and Baldwin (1952) is widely used but lacks the precision of the zonations based upon foraminifers.

Standard West Coast Zonation (Mollusks)

Fossil mollusks were collected wherever they were encountered during fieldwork. The species distribution of the mollusks is presented in Table 3. Collection localities of this study are compared, in Appendix B, with those of Turner (1938) and Weaver (1944).

The mollusks of both the lower and upper sandstone members of of the Coaledo Formation resemble the fauna of the Tejon beds in California and the Cowlitz Formation in Washington. Both the Cowlitz Formation and the Tejon beds are thought to be of late Eocene age and are assigned to the "Tejon" stage of Weaver et al. (1944). The following table taken from Turner (1938) indicates the degree of similarity of the fauna of Coaledo Formation with that of the Tejon and Cowlitz Formations.

Table 3. Species Distribution of Mollusks in the Coaledo Formation.

	Upper Coaledo	Lower Coaledo
Total number of species	28	44
Species in common with the other sandstone member of the Coaledo	22	22
Species in common with the Tejon of California	11	9
Species in common with the Cowlitz of Washington	21	23
Species in common with either Cowlitz or Tejon or both	25	29
Species limited to Cowlitz or Tejon		21
Species in Cowlitz and Tejon but not limited to these formations	8	8
Absent in Cowlitz and Tejon but found in other formations	3	1

The data above imply a closer association with the Cowlitz Formation than with the Tejon beds. Comparisons based upon like faunal assemblages may be misleading, for the apparent similarity of Cowlitz and Coaledo faunas may be due to environmental factors (depth, substrate, etc.) rather than strict equivalence in time. Turner (1938) states, however, that the statistical evidence for correlation of the Coaledo Formation with the Cowlitz Formation and the Tejon beds is supported by species and subspecies that have been used as index fossils.

Weaver (1945) agrees with Turner with respect to the age of the Coaledo fauna and states that, of the 76 species that he identified from the Coaledo Formation, 82 percent occur in the Cowlitz Formation and 43 percent in the Tejon strata of Tejon Pass in southern California.

Correlation Based Upon Benthic Foraminifers

The stratigraphic distribution of benthic foraminifers from the Coos Bay region was compared with biostratigraphic zones currently in use in California and Washington (Table 2). Correlations with these zones were made by considering the published stratigraphic ranges of key (index) species, overlapping stratigraphic ranges of individuals and assemblages, and evolutionary sequences of a few selected species. Environmental factors believed to limit the distribution of some species were considered. It is important to note that the stratigraphic ranges of species presented in Table 4, Figure 45 and Plate 12 refer only to their distribution in rocks of the Coos Bay region. As additional detailed studies are made in Western Oregon, more precise information about the stratigraphic range of each species will be available.

Age of the Elkton Formation

Bird (1967), in concordance with Stewart (1957), considers the Elkton Formation to be late Ulatisian in age. This conclusion is based primarily upon the assumption that *Amphimorphina californica* is restricted to the upper part of the Ulatisian Stage in Oregon as it is in southern California. Rau (1964) states that *Amphimorphina californica* may range upward into the *Bulimina corrugata* Subzone of the superjacent Narizian Stage. The author has sampled Sacchi Beach beds, examined the microfauna, and concurs with the age as assigned by Bird. Extensive sampling of the Elkton Formation in North and South Coves at Cape Arago yielded only a few, poorly-preserved, non-diagnostic specimens of Bulimina schencki, Gyroidina girdana Quinqueloculina spp. and Lenticulina inornatus. The scarcity of foraminifers near the contact of the Elkton with the overlying Coaledo Formation was noted by Bird (1967) and is attributed by him to a shallowing of the seas during the deposition of the upper part of the Elkton Formation. Amphimorphina californica is believed to be a deep water species (probably upper bathyal) and is not found in the upper part of the Elkton Formation.

Thus, a diagnostic Ulatisian fauna was not found at North and South Coves, and the sedimentary rocks exposed there are correlated with the Elkton Formation at Sacchi Beach because of lithologic similarity and stratigraphic position (see previous section describing the Elkton-Coaledo contact). If this correlation is correct, a late Ulatisian age is indicated for the beds at North and South Cove.

Age of the Coaledo Formation

The lowest beds of the Coaledo that contain foraminifers are found near the top of the lower sandstone member in Sunset Bay and in the cliffs between Sunset Bay and Shore Acres State Park. None of the species listed by Mallory (1959) as restricted to, or typical of, the

Uvigerina churchi Subzone of the Bulimina corrugata Zone of the Narizian Stage are present in these beds (see Tables 2, 4).

The beds exposed in Sunset Bay, and in the lowermost 200-300 feet of the middle Coaledo at Lighthouse Beach, contain a fauna that is tentatively assigned to the Uvigerina garzaensis Subzone of the Bulimina corrugata Zone of early Narizian age. Although no species were found that are restricted to the subzone, the following species that are present have, according to Mallory (1959), their lowest stratigraphic occurrence in this subzone.

Bolivina basisenta
Bulimina microcostata
Eggerella subconica
Plectofrondicularia vokesi

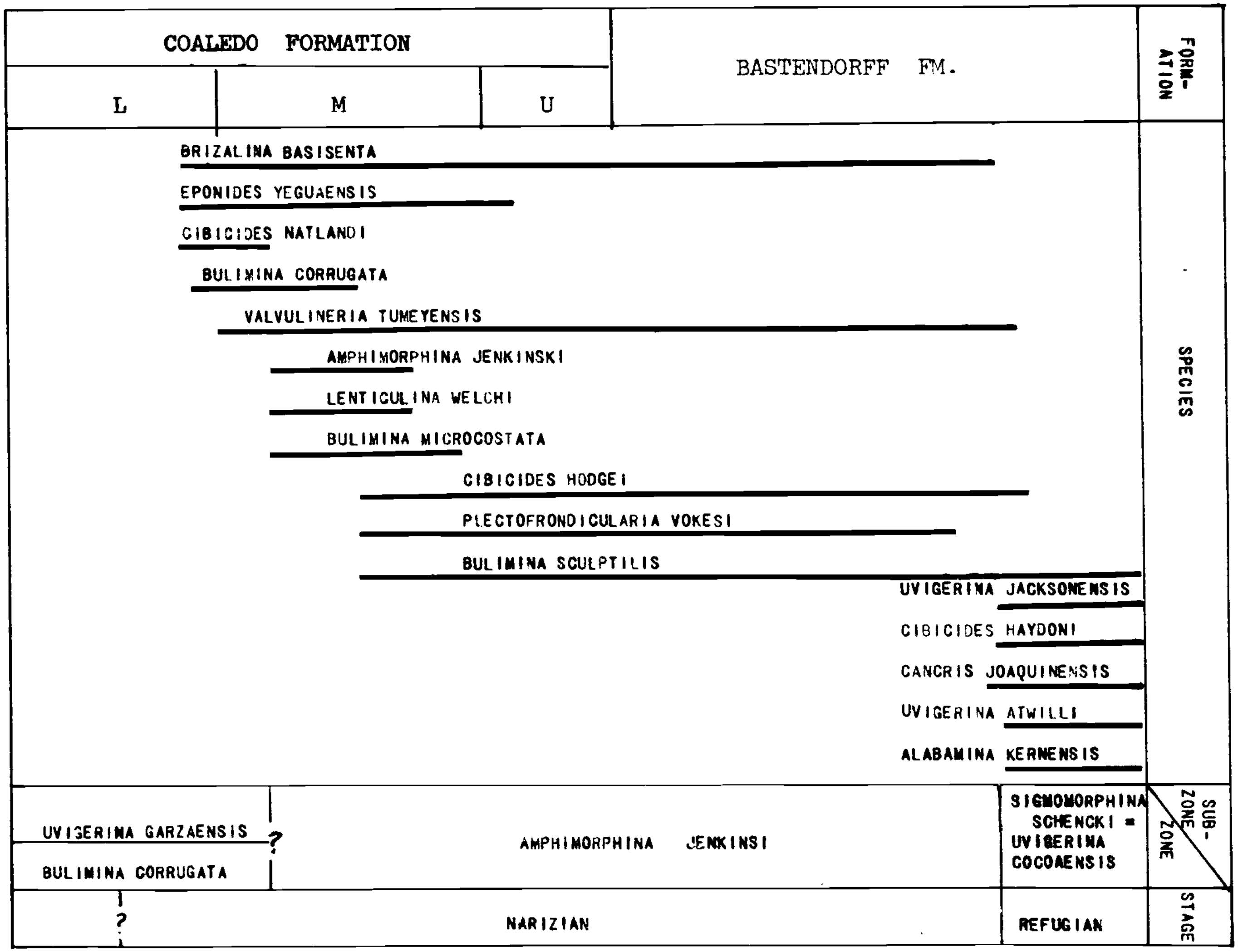
In addition, no species restricted by Mallory (1959) to the overlying Uvigerina garzaensis Subzone were found within this sequence of strata.

The remainder of the middle and all of the upper Coaledo beds contain a fauna that is typical of the Amphimorphina jenkinsi Zone of the Narizian Stage (see Table 4). Typical species include:

*Amphimorphina jenkinsi
*Lenticulina welchi
*Bulimina microcostata
*Cibicides hodgei
*Plectofrondicularia vokesi
Valvulineria tumeyensis
Quinqueloculina minuta
Spiroplectammina mississippiensis

* Lowest stratigraphic occurrence is within this zone according to Mallory (1959).

Table 4. Range of stratigraphically significant benthic foraminifers in the Coaledo and Bastendorff Formations.



The absence of the key species Amphimorphina jenkinsi, a bathyal form, in the upper part of the middle Coaledo, may be due to a gradual shallowing of the water, reflecting tectonism associated with the growth of the upper Coaledo deltaic sandstone. The stratigraphic ranges of selected species useful in correlation with other regions are given in Table 4.

Kleinpell and Weaver (1963) have discussed the stratigraphic ranges and possible evolutionary sequence of selected Cibicides spp. from within the Santa Barbara (California) embayment. It is of interest to note that the data collected on species of Cibicides in the Coaledo and Bastendorff Formations agrees very closely with the stratigraphic ranges established by Kleinpell and Weaver (Figure 45).

In summary, it appears possible to assign the beds near Sunset Bay and the lowermost 200-300 feet of the middle Coaledo to the Uvigerina garzaensis Subzone of the Bulimina corrugata Zone and to correlate the remainder of the Coaledo Formation with the Amphimorphina jenkinsi Zone of the Narizian Stage of the Eocene.

Age of the Bastendorff Formation

The Bastendorff Formation has been considered by various authors to be either Oligocene or partly Eocene and partly Oligocene in age.

Dall (1909) and Cushman and Schenck (1928) considered the

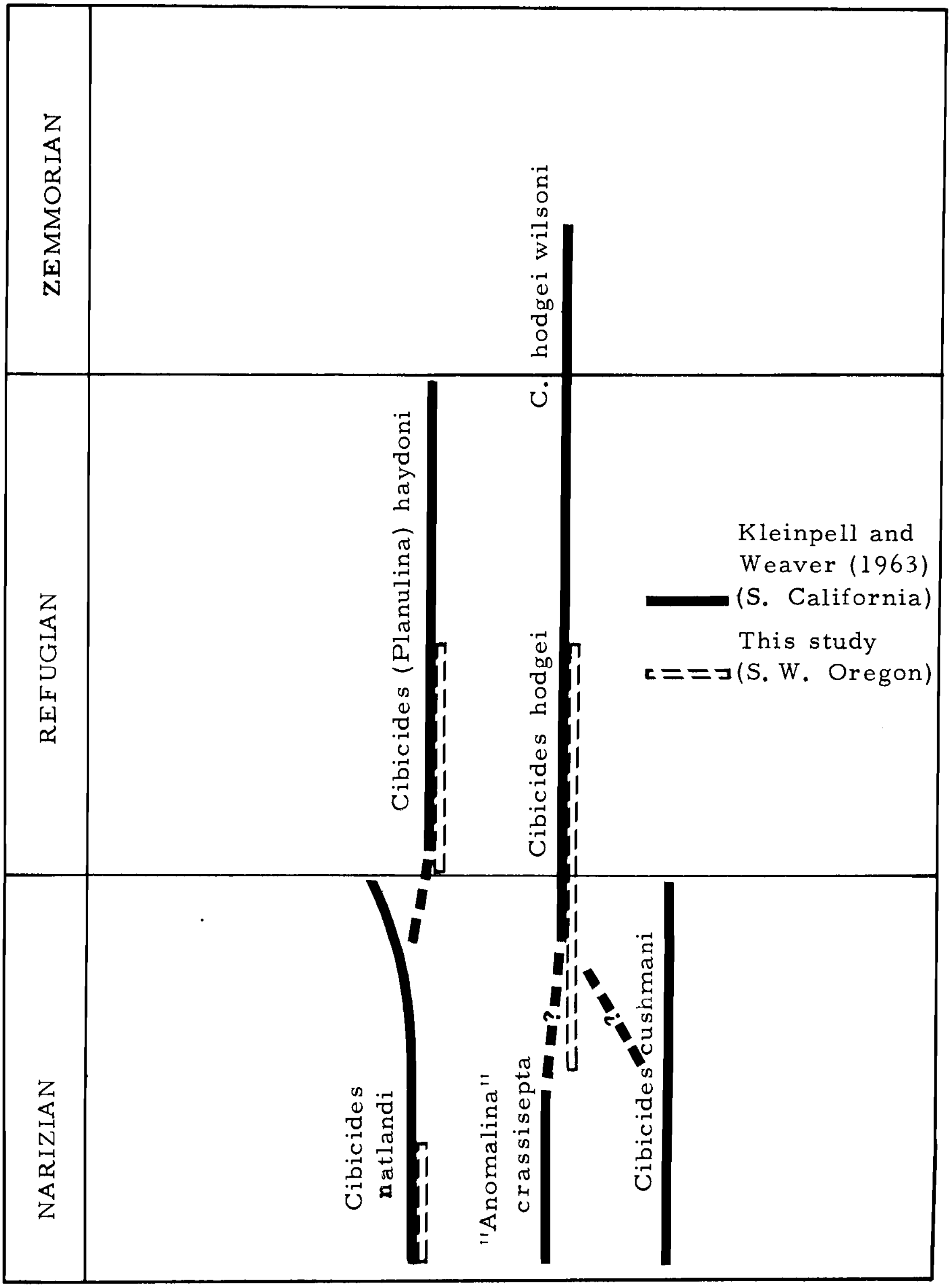


Figure 45. Evolution and stratigraphic range of selected <u>Cibicides</u> species. Adapted from Kleinpell and Weaver (1963).

Bastendorff to be Oligocene in age, basing their opinion upon fossil mollusks correlated with beds in California that are underlain by a Tejon (Eocene) fauna and overlain by a Vaqueros (Miocene) fauna. Cushman and Schenck (1928) decided that the Bastendorff is Oligocene in age, a conclusion based upon fossil mollusks; however, they noted that a few species of the foraminifers of the Bastendorff range downward into uppermost Eocene beds. Detling (1946), in a more comprehensive study of fossil foraminifers, did not clearly indicate an age for the Bastendorff.

Schenck and Kleinpell (1936) stated that the type Refugian Stage in California is characterized by Bulimina sculptilis, Plectofrondicularia packardi and Uvigerina cocoaensis. Laiming (1940, p. 194) in designating his early Oligocene "R" (Refugian)zone, states:

> "The uppermost zone here described and designated zone 'R' is characterized by the group of foraminifera figured by Cushman and Schenck (1928) from the Bassendorf shale of Oregon, typical of the Refugian stage of the California Tertiary."

> "Most characteristic for this zone are the occurrences of Uvigerina cocoaensis, 'Planulina' haydoni, Plectofrondicularia packardi and Bulimina sculptilis, the first two being confined to this zone."

Stewart (1956) stated that the upper 700± feet of the Bastendorff Formation contain the fauna used by Laiming to characterize his early Oligocene "R" zone (=Refugian Stage). Baldwin (1959, 1964 and 1966), Youngquist (1961), Beaulieu (1971) and other workers have subsequently considered the Bastendorff to be part Eocene and part Oligocene in age.

A problem exists, however, concerning the exact position of the Eocene-Oligocene boundary within the Bastendorff Formation. Beaulieu (1971, p. 5) states:

> "Youngquist (1961), referring to Baldwin (1959); and Baldwin (1964), referring to Stewart (1956), both specifically state that the upper two-thirds of the unit is Oligocene, whereas the lower third is late Eocene. Stewart (1956), however, in the cited article states that the upper 700 feet of the unit is early Oligocene, whereas the remainder (the lower 1,600 feet) is late Eocene. It would appear then, that the lower two-thirds of the Bastendorff is late Eocene and only the upper third is early Oligocene."

For reasons explained below, the author believes that the benthic and planktonic foraminiferal assemblages in the Bastendorff do not contain recognizable Oligocene species and that the entire formation should be considered to be late Eocene in age.

In the type area of the Refugian Stage Kleinpell and Weaver (1963) recognized a two-fold division of the stage. The lower of the two divisions is characterized by the presence of _Uvigerina cocoaensis_ (=_Uvigerina jacksonensis_ of this paper), _Uvigerina atwilli_ and _Alabamina kernensis_. Kleinpell (1938) noted the similarity of the _Uvigerina cocoaensis_ fauna to the late Eocene Cocoa Sand of the Gulf Coast. In a more recent article Kleinpell and Weaver (1963) correlated the _Uvigerina cocoaensis_ zone of the early Refugian of California with the

Cocoa Sand and stated that the lower part of the Refugian Stage of the West Coast is late Eocene in age. The fauna of the upper one-third of the Bastendorff Formation contains _Uvigerina cocoaensis_, _Cibicides (Planulina) haydoni_, _Plectofrondicularia packardi_ and _Bulimina sculptilis_, species important in identifying the "R" (=Refugian) Zone of Laiming. In addition to the species mentioned, the fauna contains _Alabamina kernensis_, a species that makes its first appearance in rocks of early Refugian Age (Kleinpell and Weaver, 1963).

In Washington, Rau (1964, 1966 and 1967) subdivided the Refugian Stage into a lower _Sigmomorphina schencki_ Zone and an upper _Cassidulina galvinensis_ Zone. The following species, considered by Rau (1966) to be restricted to, or typical of, the _Sigmomorphina schencki_ Zone, were found in the upper one-third of the Bastendorff Formation:

Ceratobulimina washburnei
Cancris joaquinensis
Uvigerina cocoaensis

Many additional species occurring in the Bastendorff Formation and in rocks of the _Sigmomorphina schencki_ Zone of southwest Washington were noted, but they were not restricted, by Rau, to this Zone. It is also significant to note that none of the species considered by Rau (1966) to be indicative of the superjacent _Cassidulina galvinensis_ Zone were found in the Bastendorff Formation (Table 4, Plate 12).

On the basis of benthic foraminifers the upper one-third of the

Bastendorff Formation is confidently correlated with the Sigmomorphina schencki Zone of Southwest Washington and with the Uvigerina cocoaensis Zone of the lower Refugian Stage of California. Since the lower Refugian of California is correlated with the late Eocene, Cocoa Sand of the Gulf States by Kleinpell and Weaver (1963), the Bastendorff Formation is considered to be of late Eocene age in its entirety. Evidence based upon planktonic foraminifers also suggests a late Eocene age and is presented in a subsequent section of this paper.

Moore (personal communication, 1969) has briefly examined some of the fossils radiolarians from the Coaledo and Bastendorff Formations and has found no species clearly indicative of an Oligocene age.

Stewart (1956) placed the Narizian Refugian boundary about 700 feet below the top of the Bastendorff Formation. Data gathered in this study suggests that the boundary is not sharp but is transitional over a stratigraphic interval of 200-300 feet. The author would place the boundary at Bastendorff Beach a little lower in the section than Stewart, at a distance of about 900 feet below the top of the Bastendorff Formation.

World-Wide Planktonic Foraminiferal Zonation

General Statement

Subbotina (1953) and Bolli (1957a, b) were the first to describe extensive Eocene planktonic foraminiferal faunas: one from the Caucasus and the other from Trinidad. Since the publication of the papers of Subbotina and Bolli, a number of papers have been written describing planktonic foraminifers of many regions. Blow (1969) and Blow and Banner (in Eames et al., 1962) have proposed a series of zones, based upon the stratigraphic ranges of planktonic species in the Lindi area of Tanganyika, Africa, that have gained wide acceptance. Jenkins (1971) has provided a summary of stratigraphic ranges in New Zealand and has compared the stratigraphic ranges of key species in Trinidad, Africa and New Zealand (Figure 47). Berggren (1972) has compared the planktonic zones of Blow and Banner (1962) to marine and nonmarine stages of North America and to marine stages in New Zealand and Europe (Table 6).

Interest in the use of planktonic foraminifers to date marine deposits has resulted in several papers describing species from rocks of Oligocene, Miocene and Pliocene age in California. No comprehensive studies of planktonic foraminifers from late Eocene and early Oligocene rocks in California, Oregon and Washington have been published. Lipps (1966, 1967) and Steineck and Gibson (1971) have discussed six species from a few samples in the Arroyo el Bulito area, Santa Barbara County, California. McKeel (1972) and McKeel and Lipps (1972) have described planktonic foraminifers, ranging in age from Eocene to Miocene, from the Coast Range of Oregon. The species

Table 5. Planktonic foraminifers reported from the Coaledo and Bastendorff Formations.

MIDDLE COALEDO	L. MIDDLE BASTENDORFF	UPPER BASTENDORFF
McKeel (1972) (6 species)	McKeel (1972) (5 species)	McKeel (1972) (2 species)
Globigerina prasaepsis	Chilogumbelina cubensis	Globigerina praebulloides
Globigerina senilis	Globorotaloides wilsoni	Globigerina sp.
Globigerina aff. G. ciperoensis	Globigerapsis index	
Pseudohastigerina lillisi	Globorotaloides aff. G. pseudokugleri	
Subbotina triloculinoides	Subbotina triloculinoides	
Clavigerinella columbiana		
Rooth (1974) (13 species)	Rooth (1974) (4 species)	Rooth (1974) (8 species)
Globigerina prasaepsis	Globigerapsis index?	Chilogumbelina cubensis
Globigerina senilis	Globigerina senilis	Globigerina tripartita tripartita
Globigerina aff. G. ciperoensis	Subbotina linaperta	Globorotalia increbescens
Pseudohastigerina migra	Globigerina prasaepsis ?	Globorotalia gemma
Pseudohastigerina aff. P. micra		Globorotalia opima nana
Catapsydrax echinatus		Globorotalia cf. G. gemma
Globigerina eocaena		Globigeria prasaepsis ?
Globigerina angiporoides		Globorotalia sp.
Globigerapsis index		
Subbotina linaperta		
Globigerina praebulloides occlusa		
Globigerina sp.		
Subbotina sp.		
Subtotal 16 species	Subtotal 8 species	Subtotal 10 species
	TOTAL SPECIES (both formations)	28 species

reported by McKeel (1972) from the Coaledo Formation (one sample) and the Bastendorff Formation (three samples) are compared with those found in the current study (Table 5).

Several problems occur in trying to correlate the species of southwest Oregon with the proposed world-wide planktonic zones. The planktonic species of higher latitudes differ significantly from those first described from the low latitude regions by Bolli (1957a, b) and Blow and Banner (1962). Jenkins (1971) has noted that key species used in low latitude regions to designate zones are sometimes absent in New Zealand; this is a situation that is also true in southwest Oregon.

Some workers have tended to subdivide local faunas into many subspecies and varietal forms to which they attributed great stratigraphic significance; these forms cannot always be recognized in other areas. Sudden extinctions in local regions have been presumed by some authors to be world-wide events. The taxonomy of planktonic foraminifers is difficult and is limited by the quality of published figures. . Few publications that describe planktonic forms mention the associated benthic foraminiferal fauna, thereby making correlation with benthic zones (or stages) difficult. Moreover, planktonic faunas from the rocks of reference sections for various ages or stages have not been studied adequately.

In spite of all the problems involved, the use of planktonic foraminifers to date marine deposits on a world-wide basis holds great promise. The identification of planktonic foraminifers, in this study, was limited by poor preservation, low abundances in some samples, and a lack of opportunity to examine actual specimens from other regions. As a result many of the identifications are considered tentative.

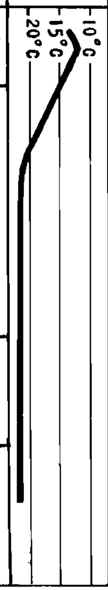
Planktonic Foraminifers from the Coaledo and Bastendorff Formations

A total of 28 species, assigned to 9 genera, have been reported from the Coaledo and Bastendorff Formations (Table 5). Most samples exhibit low species diversity and abundance, with the exception of samples in the upper one-third of the Bastendorff Formation (Figure 49, Plate 12). The stratigraphic distribution of planktonic species in the Coaledo and Bastendorff Formations is given in Figure 46 and Plate 12.

The planktonic foraminifers from the Coaledo and Bastendorff Formations strongly resemble the late Eocene faunas described by Srinivasan (1968) and Jenkins (1971) from New Zealand and faunas of a similar age from India described by Hortono (1969) and Samanta (1969, 1970a and 1970b). Of the species found in southwest Oregon, the following have been reported by Blow (1969) from late Eocene-early Oligocene rocks of low latitudes.

Globigerina angiporoides
Globigerina senilis (=*Globigerina ouachitaensis*)
Globigerina praebulloides occlusa
Globigerapsis index

Table 6. Relationship of Cenozoic planktonic foraminiferal zones to other biostratigraphic zones (After: Berggren, 1972).

CENOZOIC RADIOMETRIC TIME SCALE in my	AGE	NORTH AMERICA MAMMAL STAGES	WEST COAST (California) MARINE STAGES	NEW ZEALAND MARINE STAGES	PALEOTEMPERATURE CURVE	EUROPEAN STAGES	CENOZOIC PLANKTONIC FORAMINIFERAL ZONES (Banner and Blow, 1965; Blow, 1969; Berggren, 1972)	
	Early Oligocene	CHADRONIAN	ZEMORRIAN	WHAINGAROAN			P19	
35				RUNANGAN		LATTORFIAN	P18	G. tapuriensis Conc.-R-Z
	Late Eocene	DUCHESNIAN	REFUGIAN			BARTONIAN / PRIABONIAN	P17	G. gortanii/G. centralis P-R-Z
							P16	C. inflata T-R-Z
40		UINTAN		KAIATAN			P15	G. mexicana P-R-Z
			NARIZIAN	BORTONIAN		LUTETIAN	P14	T. rohri-B. havei P-R-Z
45							P13	O. beckmanni T-R-Z

Globorotalia (Turborotalia) gemma
Globorotalia (T.) opima nana
Pseudohastigerina micra
Chiloguembelina cubensis

The following species listed by Srinivasan (1969) from the late Eocene of New Zealand occur in the Coaledo and Bastendorff Formations.

Chiloguembelina cubensis
Pseudohastigerina micra
Globorotalia (T.) increbescens
Globorotalia (T.) opima nana
Globorotalia (T.) gemma
Globigerina angiporoides
Globigerina senilis (=G. ouachitaensis)
Subbotina linaperta
Globigerapsis index
Catapsydrax echinatus

Age Based Upon Planktonic Foraminifers

The fauna from southwest Oregon is very similar to late Eocene faunas of high latitude regions and is considered, on that basis, to be of late Eocene age. Correlation with low latitude regions cannot be made with certainty. None of the index species listed by Blow (1969), as restricted to the late Eocene P15, P16 and P17 zones of tropical regions, are present in the rocks of southwest Oregon (Table 6).

Bolli et al. (1957) consider the extinction of the genus Globigerapsis to coincide with the Eocene-Oligocene boundary. The genus is definitely present in both the Coaledo and Bastendorff Formations.

The following species, of Oligocene age, widely reported from rocks of both low and high latitudes, were not found in the Coaledo and Bastendorff formations:

Globigerina ampliapertura Bolli
Globigerina euapertura Jenkins
Globigerina labicrassa Jenkins
Globigerina opima opima Bolli

Globigerina angustiumbilicata Bolli may be present in the sample closest to the top of the Bastendorff Formation, but the specimens were poorly preserved and a positive identification could not be made. The ranges of selected species, considered by Jenkins (1971) to occur above or below the Eocene-Oligocene boundary, are given in Figure 47. While typical Oligocene foraminifers were not found in the Coaledo or Bastendorff Formations, it is important to note that McKeel (1972) does report the presence of the following Oligocene species in the Nye Formation at Yaquina Bay, Oregon:

Globigerina ampliapertura Bolli
Globigerina euapertura Jenkins
Globigerina angustiumbilicata Bolli

In conclusion, the Coaledo and Bastendorff Formations are considered to be late Eocene in age. They can be correlated with confidence with the Runangan Stage of New Zealand and tentatively correlated with the P17 (=Globigerina gortani-Globorotalia (T.) centralis) partial range zone of Banner and Blow (1965), Blow (1969) and Berggren (1972), as indicated in Table 6. The P16 and P17 Zones of

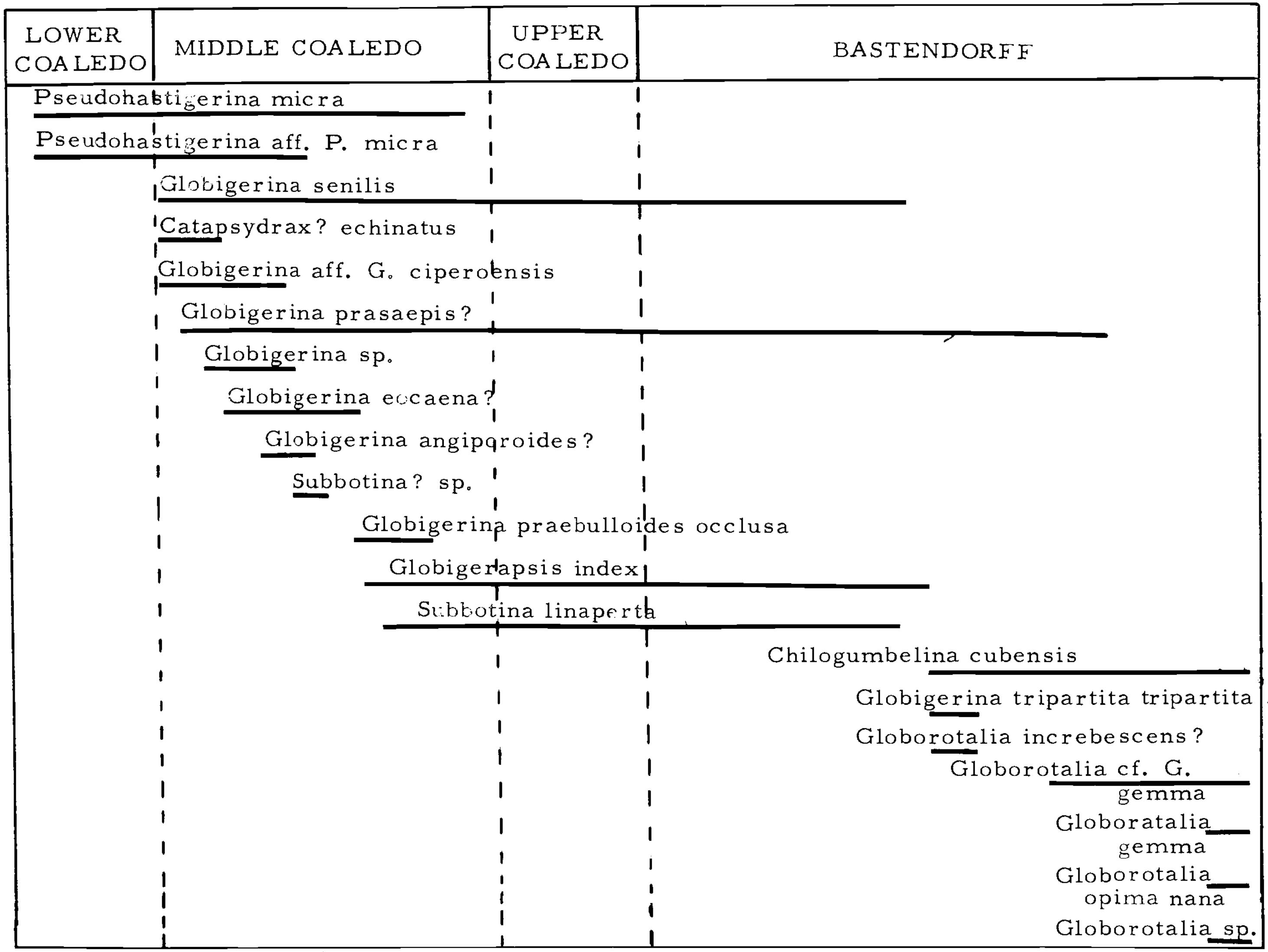


Figure 46. Occurrence of planktonic foraminifers in the Coaledo and Bastendorff Formations.

the world-wide planktonic zonation cannot be recognized at present in the Coaledo and Bastendorff Formations (Table 6). The age assigned to the Bastendorff Formation that is based upon the study of planktonic foraminifers agrees with the late Eocene (early Refugian) age determined by benthic forms in the same rocks. Early Oligocene planktonic foraminifers and late Refugian (early Oligocene) benthic foraminifers were not found in the Bastendorff Formation. Thus, the lower part of the Refugian Stage of California should be considered to be late Eocene in age. This conclusion has been supported by the work of Lipps (1966, 1967) and Steineck and Gibson (1971) who conclude that the upper part of the Gaviota Formation (Refugian) at Arroyo el Bulito in Santa Barbara County, California, is late Eocene in age. A difference of opinion concerning the age and possible time-transgressive nature of the Narizian and Refugian Stages has been recently discussed by Steineck and Gibson (1971, 1972), McWilliams (1972 and Phillips (1972).

Correlation With Other Rock Units

Based upon the biostratigraphic ranges of foraminifers in southwest Oregon and the published reports of other workers, an attempt is made to correlate the Coaledo and Bastendorff Formations with other West Coast rock units. Few detailed biostratigraphic studies have been completed in Oregon and much work is needed to

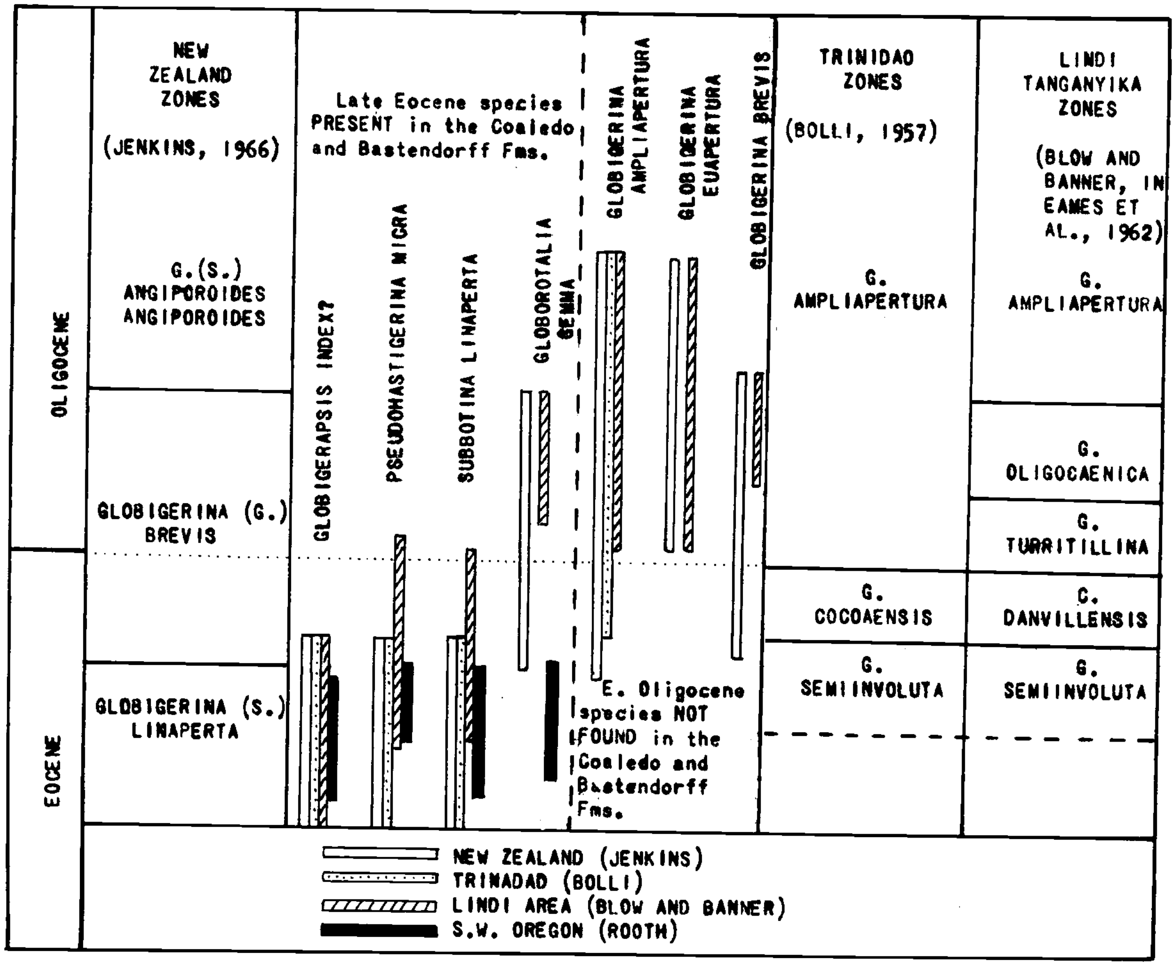


Figure 47. Ranges of selected species of planktonic foraminifers across the Eocene-Oligocene boundary. After: Jenkins (1971).

determine the exact relationships of formation boundaries to biostratigraphic zones.

The foraminiferal assemblages of the Coaledo Formation and the lower part of the Bastendorff Formation (Narizian Stage) are comparable to those of the Kreyenhagen Shale (Cushman and Seigfus, 1942) and the Alhambra Formation (Smith, 1957) of California; the Nestucca Formation (Stewart, 1957) and the "lower Toledo Formation" (Cushman, Stewart and Stewart, 1949) of Oregon; and the Skookumchuck Formation (Rau, 1964), the Cowlitz Formation (Beck, 1943), the McIntosh Formation (Rau, 1956) and the lower part of the Twin River Formation (Rau, 1964) of Washington.

The microfauna of the upper part of the Bastendorff Formation (early Refugian Stage) is similar to that of the Tumey Formation (Cushman and Simonson, 1944), the upper part of the Gaviota Formation (Wilson, 1954 and Kleinpell and Weaver, 1963), and the Wagonwheel Formation (Smith, 1956) of California; the Keasey Formation (Cushman and Schenck, 1928) and the "upper Toledo Formation" or "Alsea" beds (Cushman, Stewart and Stewart, 1949) of Oregon; and the lower Lincoln Creek and Twin River Formations (Rau, 1964) of Washington.

PALEOECOLOGY

General Statement

Analysis of the textures, internal structures and other physical properties of sedimentary rocks often yield clues as to the agent of transportation, energy level of the site of deposition and provenance. Paleobathymetry, however, can rarely be determined by sedimentary properties alone.

Fossils represent the remains of animals and plants adapted to living in a particular environment. An attempt is made to reconstruct the paleobathymetry of late Eocene time in southwestern Oregon utilizing the microfossils and megafossils found in the Coaledo and Bastendorff Formations. Speculations are presented concerning paleooceanography and geographic distribution of faunas.

Most of the interpretations made here are based upon a comparison of fossil and recent foraminifers. Although more is known about the correlation of recent foraminifers with bathymetry and environment than any other widespread group of marine organisms (Phleger, 1964), most of this knowledge is empirically based upon actual distributions, and very little is known about the factors that control the distributions (Bradshaw, 1961).

Many foraminiferal trends are discussed here, and while no single trend can be considered as proof of deposition at a particular depth or within a specific environment, taken collectively, a group of trends allows delineation of the environment with a reasonable degree of confidence.

Microfossils: Paleobathymetric and Paleoecologic Interpretations

Scope and Methods

Paleoecologic interpretation of fossil foraminifers based upon the bathymetric distribution of modern species originated with the work of Bagg (1912). Natland (1933) described the apparent bathymetric control of recent benthic faunal groups and made inferences concerning fossil assemblages in southern California. Quantitative analysis of modern faunas and various ecologic parameters has allowed further refinement of paleoecologic techniques (Walton, 1955; Bandy and Arnal, 1957; Resig, 1958; Zalesny, 1959; Uchio, 1960; Bandy, 1960; Bandy and Rodulfo, 1964; Phleger, 1964; and Ingle, 1967).

Two general approaches to paleoecologic interpretations have been utilized in this study. The first is a consideration of general quantitative aspects of the fauna, such as the number of species or the planktonic-benthic ratio. The second approach is through a comparison of modern species with fossil species, or groups of fossil species, assumed to have lived under similar environmental conditions.

Gross Population Trends

The studies of Bandy and Arnal (1960) and Bandy (1960, 1964) have provided a number of useful quantitative relationships that can readily be applied to fossil assemblages. These quantitative relationships are explained in the sections that follow.

Foraminiferal number

The foraminiferal number is the number of tests per gram of dry sediment. It is particularly useful in that direct comparisons can be made between fossil and modern assemblages. Data from modern assemblages, expressed as specimens per cm^2 of surface area, are not as useful as specimens per gram, because expressions based upon surface area cannot be readily compared to assemblages obtained from the disaggregation of a volume of rock.

In modern assemblages the foraminiferal number increases offshore, with maximum values occurring at the shelf edge (lower neritic zone) or within upper bathyal depths (Table 7). Foraminiferal numbers generally decrease into the lower bathyal zone but can be affected by influx of sediment by turbidites (resulting in a lower foraminiferal number) and by location in a region receiving unusually low amounts of terrigenous sediment (resulting in an abnormally high foraminiferal number).

Table 7. Bathymetric zones (after: Bandy, 1953).

Inner neritic zone	Littoral zone=high tide-low tide
Middle neritic zone	Low tide-150 feet 0-50 meters
Lower neritic zone	150-600 feet 50-200 meters
Bathyal zone	600-6000 feet 200-2000 meters
Upper abyssal zone	6000-8000 feet 2000-2660 meters

The foraminiferal numbers in the samples studied range from less than 1 to a high of 379 (Figure 49, Plate 12). In general, high foraminiferal numbers (20-100 forams./gram) were found in the lower two-thirds of the middle Coaledo and throughout the Bastendorff Formation although many individual samples contained only a few foraminifers per gram of sediment. Low foraminiferal numbers are present within the middle Coaledo near three prominent sandstones exposed along Lighthouse Beach (Figure 44). The highest foraminiferal number (379) occurs in thin-bedded, glauconitic sediments of the Bastendorff Formation that are exposed at the northeasternmost end of the cut in the county road at Bastendorff Beach. The glauconite-rich layers are usually about one-fourth to one-half an inch thick and are composed almost entirely of grains of glauconite and benthic foraminifers.

The thin glauconite-rich layers are intercalated between mudstones averaging 1.5 feet in thickness. The sequence shows no signs of slumping, graded bedding (of any type) or burrowing by a bottom infauna. A few fossils of the thin-shelled, free-swimming scallop, Delectopectin, are present. The foraminiferal numbers cited represent specimens from a sample containing all lithologies within a 50 foot stratigraphic interval and undoubtedly would be much higher if samples were taken only from the thin glauconite-rich layers.

In general, the foraminiferal numbers of the middle Coaledo suggest that deposition took place at lower neritic or upper bathyal depths. The high foraminiferal numbers and glauconite-rich sediment in the upper Bastendorff suggest deposition at bathyal depths in areas receiving a low influx of terrigenous sediments.

Planktonic-benthic Ratio

The ratio of planktonic to benthic foraminifers increases across the continental shelf to the shelf-slope break where it increases 100 fold (Ingle, 1967). This increase in the abundance of planktonic specimens is attributed to (1) variable and unfavorable ecologic conditions for planktonic forms over shallow shelf areas, (2) upwelling of nutrient-rich water at the shelf edge resulting in an increase in plankton productivity and (3) a longer water column allowing the tests of species living in deeper water as well as those at shallower depths to

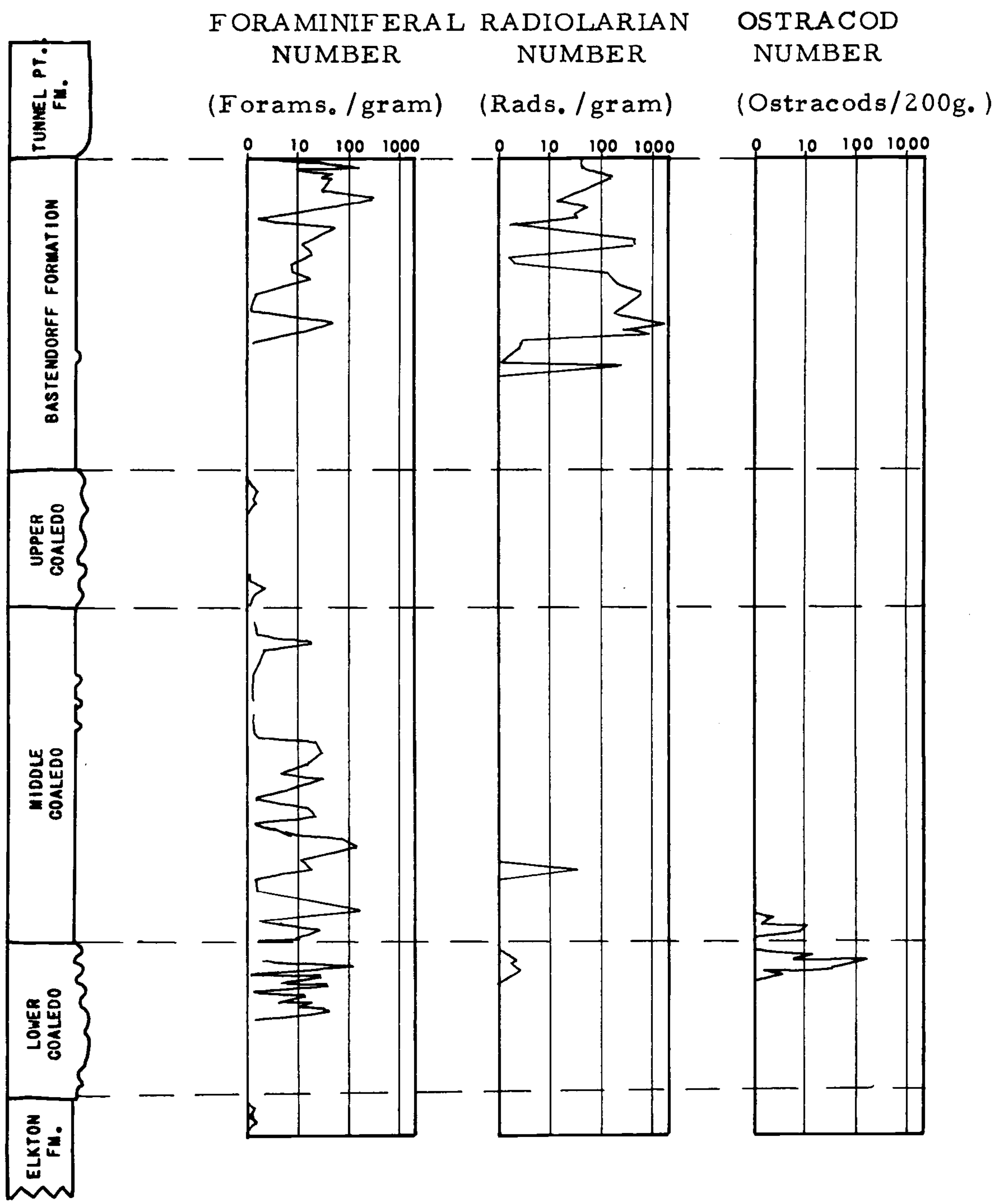


Figure 48. Microfaunal trends: Foraminiferal number (foraminifers/gram); Radiolarian number (radiolarians/gram); Ostracod number (ostracods/200 grams).

accumulate in bottom sediments (Bandy and Arnal, 1960; Bandy, Ingle and Resig, 1964; and Ingle, 1967).

Planktonic foraminifers are found in the middle Coaledo and the Bastendorff Formations. The percent of planktonic forms in the samples ranges from 0 percent to 29 percent in the uppermost one-half of the Bastendorff and from 0 percent to 35 percent in the lower one-third of the middle Coaledo (Figure 49, Plate 12). In general, the species diversity of planktonic foraminifers in the Coaledo (13 species) is similar to the Bastendorff (12 species), but the total number of planktonic specimens per sample is much higher in the Bastendorff. The percent of planktonics is dependent, in part, upon the abundance of the benthic fauna. A better measure of abundance of planktonic forms, perhaps, would be the number of planktonic specimens per gram of sediment, rather than the planktonic-benthic ratio.

The planktonic-benthic ratios from the Coaledo and Bastendorff Formations suggests deposition in water of lower neritic or bathyal depths.

Species Diversity

Studies of recent faunas have shown that the number of benthic species per sample increases offshore to a maximum in lower neritic to middle bathyal depths and then decreases in deeper environments (Bandy and Arnal, 1960). This trend may be presumably related to

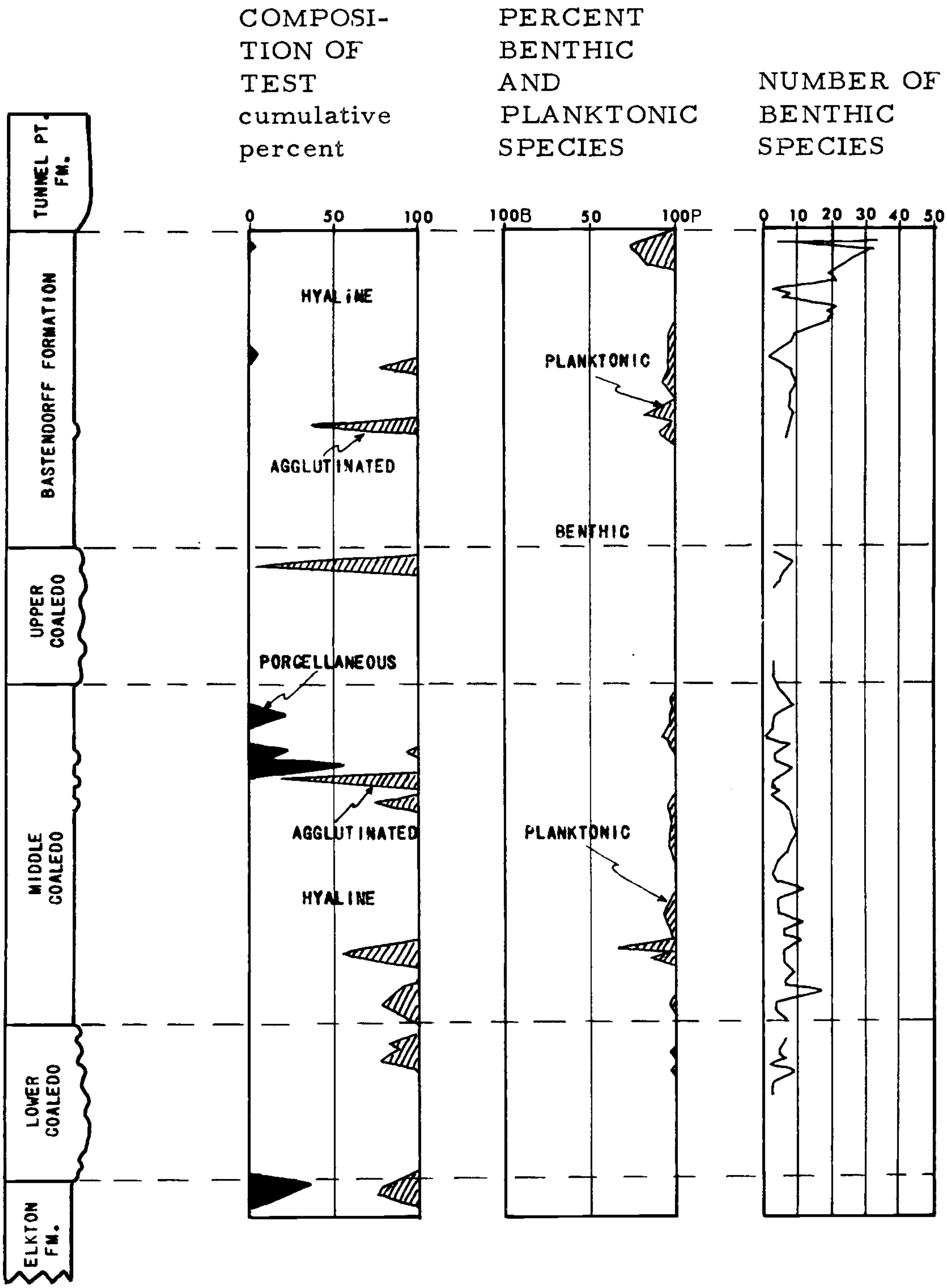


Figure 49. Foraminiferal trends: Composition of test; percent planktonic and benthic species; and number of benthic species.

optimum conditions for productivity, but it is abnormally affected by downslope displacement of shallow water forms (causing a higher diversity) or restricted circulation in closed basins (resulting in a lower diversity).

In the samples studied the species diversity ranges from a low of 1 to a high of 36. In general, the species diversity is greater in the Bastendorff Formation than in the Coaledo Formation (Figure 49). The samples exhibiting the highest species diversity, in general, also contain abundant planktonic forms. The species diversity trends suggest lower neritic or bathyal depths for the lower two-thirds of the middle Coaledo and the entire Bastendorff.

Radiolarian Trends

Radiolarians occur in the water column of oceanic waters from the surface down to depths of more than 8,000 meters (Orlov, 1959). The number of species and abundance of tests in bottom sediments increase with increasing length of the water column. Thus, the radiolarian number (number of tests per gram of dry sediment) increases with depth. The maximum numbers, according to Bandy (1953), Bandy and Arnal (1957, 1960), and Bandy and Rodolfo (1964), are found in sediments deposited at depths exceeding 2,000 meters. Only rarely are radiolarian tests found in deposits upon the continental shelves. The relative abundance of radiolarian tests with respect to foraminiferal tests is believed to indicate deposition at middle bathyal to abyssal depths. The radiolarian number may be lowered by influx of sediments by turbidity currents or raised by very low rates of sedimentation.

Heavy, thick-walled, spherical members of the suborder Spumellaria are, according to Orlov (1959), restricted to depths between 1,000 and 8,000 meters. Most of the specimens found in the Bastendorff and Coaledo are of this type.

Radiolarians were particularly abundant throughout the Bastendorff Formation. One sample, collected from the mid-part of the formation, yielded 1,751 specimens per gram of sediment (Figure 48, Plate 12). Molds and casts, as well as actual tests, were obtained from weathered deposits of the Bastendorff, whereas foraminifers were not preserved. In the Bastendorff samples containing the highest foraminiferal numbers, and only in those samples, up to 10 percent nasselline forms were found. Almost all of the Bastendorff samples contain radiolarians.

The high number of radiolarians, accompanied by abundant planktonic foraminifers and deep-water benthic foraminifers (described in a later section), suggest deposition of the Bastendorff Formation in lower bathyal to abyssal depths. A few samples from the lower part of the middle Coaledo contain abundant radiolaria, planktonic foraminifers, and spinose specimens of Uvigerina garzaensis, suggesting deposition at lower bathyal to abyssal depths.

Ostracod Trends

Ostracod values of 8 percent or more relative to foraminifers, according to Bandy (1963) and Fowler et al. (1966), are indicative of nearshore and lagoonal environments. In the samples studied, ostracods never exceeded one percent of the microfauna. It is worthwhile to note, however, that they were found in samples containing *Quinqueloculina* spp. (a bay or inner shelf species) or in samples adjacent to sandstones believed to be of fresh water or shallow marine origin (Figure 51, Plate 12).

Composition of Tests

The composition of foraminiferal tests from the Coaledo and Bastendorff Formations is given in Figure 49. The porcellaneous tests (of *Quinqueloculina* spp.) are indicative of deposition in bays or on the inner continental shelf (Table 9). No conclusions could be reached concerning the distribution of hyaline and agglutinated forms.

Benthic Faunal Groups

Recent benthic foraminifers are found living within definite depth zones (Bandy, 1953, 1961; Bandy and Arnal, 1957; and Bandy and Chierici, 1964). The upper bathymetric limits of some species may vary from area to area, but many other species have identical upper depth limits regardless of the geographic location (Bandy and Echols, 1964; Bandy and Chierici, 1964). The exact parameters causing specific species, or groups of species, to live exclusively within restricted depth zones have not been fully identified (Phleger, 1964).

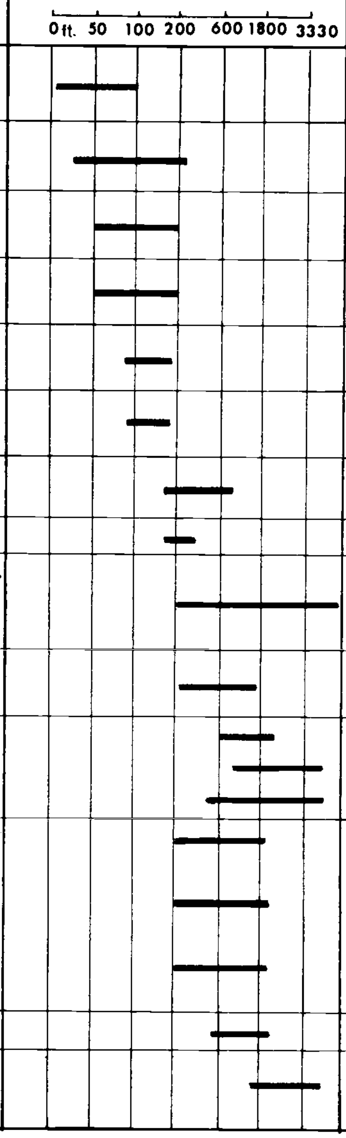
Two methods of investigation were utilized in this study. Although few species living today were present in the Eocene, Bandy and Arnal (1960) have demonstrated that fossil species having homeomorphic and isomorphic relationships with living species can be used as bathymetric indicators. In the first approach to the problem, extinct species were compared to living homeomorphs or isomorphs in an attempt to determine the paleobathymetry of the extinct species. In the second approach, an attempt was made to correlate the test morphology with environment following the concepts of Bandy (1960, 1964) and Bandy and Arnal (1960). Species that represent a particular depth range are described.

Species Comparison

Following the technique of Bird (1967), bathymetric data are summarized (Table 8) for commonly occurring homeomorphs or isomorphs of fossil species. The depth range of living specimens of the species was utilized wherever possible. The interpretations are necessarily subjective.

A comparison of the suggested depth ranges of Table 8 with

Table 8. Inferred optimum bathymetric ranges of modern counterparts of some Eocene foraminifers (modified from Bird, 1967).



FOSSIL	HOMEOMORPH OR ISOMORPH	OPTIMUM DEPTH	REFERENCE
Quinqueloculina imperialis	Q. lamarkiana		2, 6, 7, 8
Cibicides warreni	C. lobatulus		5, 6, 7, 8
Gaudryina laevigata	G. arenaria		2, 3, 5, 11
Globocassidulina globosa	Cassidulina globosa		7, 8, 11, 12
Nonion florinense	N. labradorium		6, 8
Brizalina basisenta	B. acuminata B. barbata		2, 3, 10 8, 12
Chilostomella hadleyi	C. ovoidea		4, 10, 11
Uvigerina? sp.	U. hollicki		3
Allomorphina trigona macrostoma	Allomorphina spp.		4
Cyclammina sammanica	C. cancellata		1, 7
Gyroidina girardana planata	G. altiformis G. orbicularis G. soldani		3, 7, 10 3, 8 2, 6, 8
Uvigerina atwilli	U. peregrina		2, 3
Uvigerina gardnerae	U. peregrina		2, 3
Uvigerina jacksonensis	U. peregrina		2, 3
Bulimina? sp.	B. affinis		2, 3, 7, 9
Uvigerina garzaensis	U. hispida		2

References:

1. Akers, 1954	5. Cockbain, 1963	9. Smith, 1964
2. Bandy, 1953	6. Jarman, 1962	10. Uchio, 1960
3. Bandy, 1961	7. Natland, 1933	11. Walton, 1955
4. Bandy, 1964	8. Phleger, 1960	12. Walton, 1964

Figure 51 indicates that the paleobathymetric inferences are in agreement with environmental interpretations based entirely on the sedimentary evidence.

Environmental interpretations based upon the current bathymetric ranges of two genera are not consistent with sedimentary evidence. The modern counterparts of Gyroidina girardana planata and Cyclammina pacifica have their upper limits in the upper bathyal zone. Both Gyroidina and Cyclammina are found in the silty sediments interbedded with fluvial and shallow marine sandstones of the lower member of the Coaledo Formation. The specimens are fresh and not abraded and, thus, do not appear to have been eroded from earlier formed deposits. The shallow water mollusks in nearby lower Coaledo sandstones are associated with sedimentary structures not attributed to deposition by turbidity currents or slumping into deeper water. It is suggested that perhaps the bathymetric range of Gyroidina and Cyclammina was not as restricted in the Eocene as it is today. A similar observation was made by Bird (1967) in studying the middle Eocene Elkton Formation of southwest Oregon and by Curtis (1955) in studying the Eocene Weches fauna of the Gulf Coast.

Morphology of Tests

Bandy (1960, 1964) and Bandy and Arnal (1957) have described a striking similarity between the shapes, sizes and ornamentations of species within a given genus and the environment in which the genera live. Two examples of the use of morphology to delineate environment are described below.

The relationship between the morphology of porcellaneous foraminifers and their bathymetric distribution is given in Table 9 (Bandy, 1960).

Table 9. Porcellaneous foraminiferal morphology and bathymetry.

	Bays	Shelf			Bathyal Zone		
		Inner	Central	Outer	Upper	Middle	Lower
Miliolids							
Quinqueloculines	——	- - -	- - -	- - -	- - -	- - -	- - -
Triloculines	——	- - -	- - -	- - -	- - -	- - -	- - -

From the table above one can expect that relatively abundant specimens of Quinqueloculina might indicate a bay or inner shelf environment of deposition. The distribution of Quinqueloculina spp. in the Coaledo and Bastendorff Formations (Figure 51 and Plate 12) is limited to samples collected near or within the shallow water sandstones of the lower and upper Coaledo and the Tunnel Point Formation. Thus, the stratigraphic occurrence supports the environmental interpretation suggested by the type of coiling of the quinqueloculinids.

A second example of bathymetric interpretation based upon morphology is that of the ornamentation of uvigerinids. The following table was also taken from Bandy (1964).

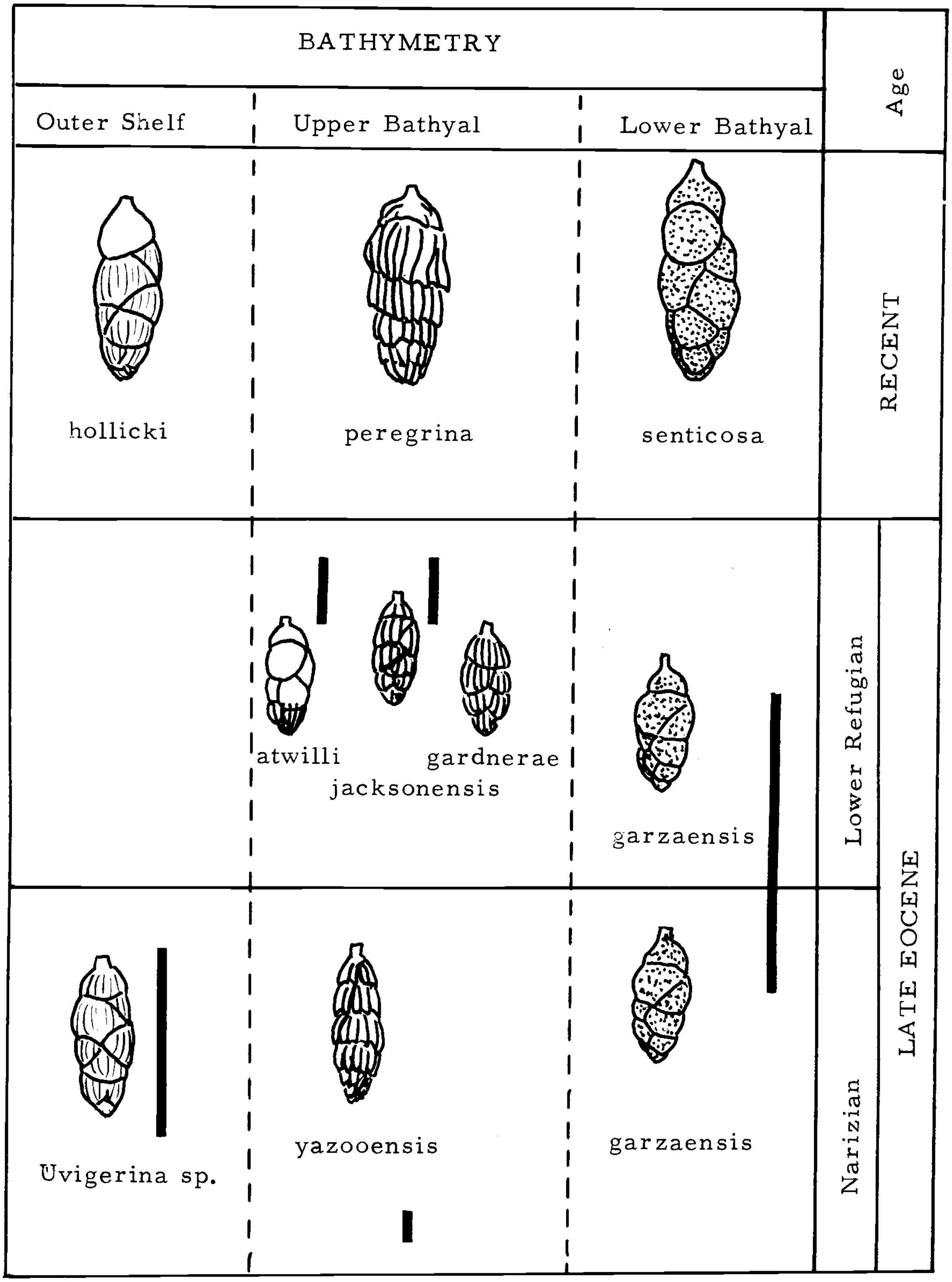


Figure 50. Morphology and bathymetry of fossil and recent uvigerinids.

Table 10. Uvigerinid morphology and bathymetry.

	Bays	Shelf			Bathyal Zone		
		Inner	Central	Outer	Upper	Middle	Lower
Uvigerina							
Striate species		tenuistriata					
Costate species					peregrina		
Costate-spinose species						dirupta	
Spinose species						probosidea	
Papillate species						senticosa	

In modern seas the uvigerinids living on the continental shelf are finely striate; whereas costate forms occur throughout the entire bathyal range and spinose forms are restricted to lower bathyal and abyssal depths.

In Figure 50 the ornamentation and stratigraphic range of Eocene uvigerinids collected in this study are compared to recent forms. An examination of the figure suggests that the presence of Uvigerina garzaensis in some samples from the middle Coaledo and Bastendorff Formations indicates an environment of deposition within the lower bathyal to upper abyssal zones. This assumption is strengthened by the presence of other bathyal benthic foraminifers and abundant radiolarians in the same samples.

The above examples are but two of many morphologic trends used by Bandy and his co-workers to determine paleobathymetry. The reader is referred to Bandy (1967) for a more complete discussion.

The morphologic parameters used in this study and the inferred

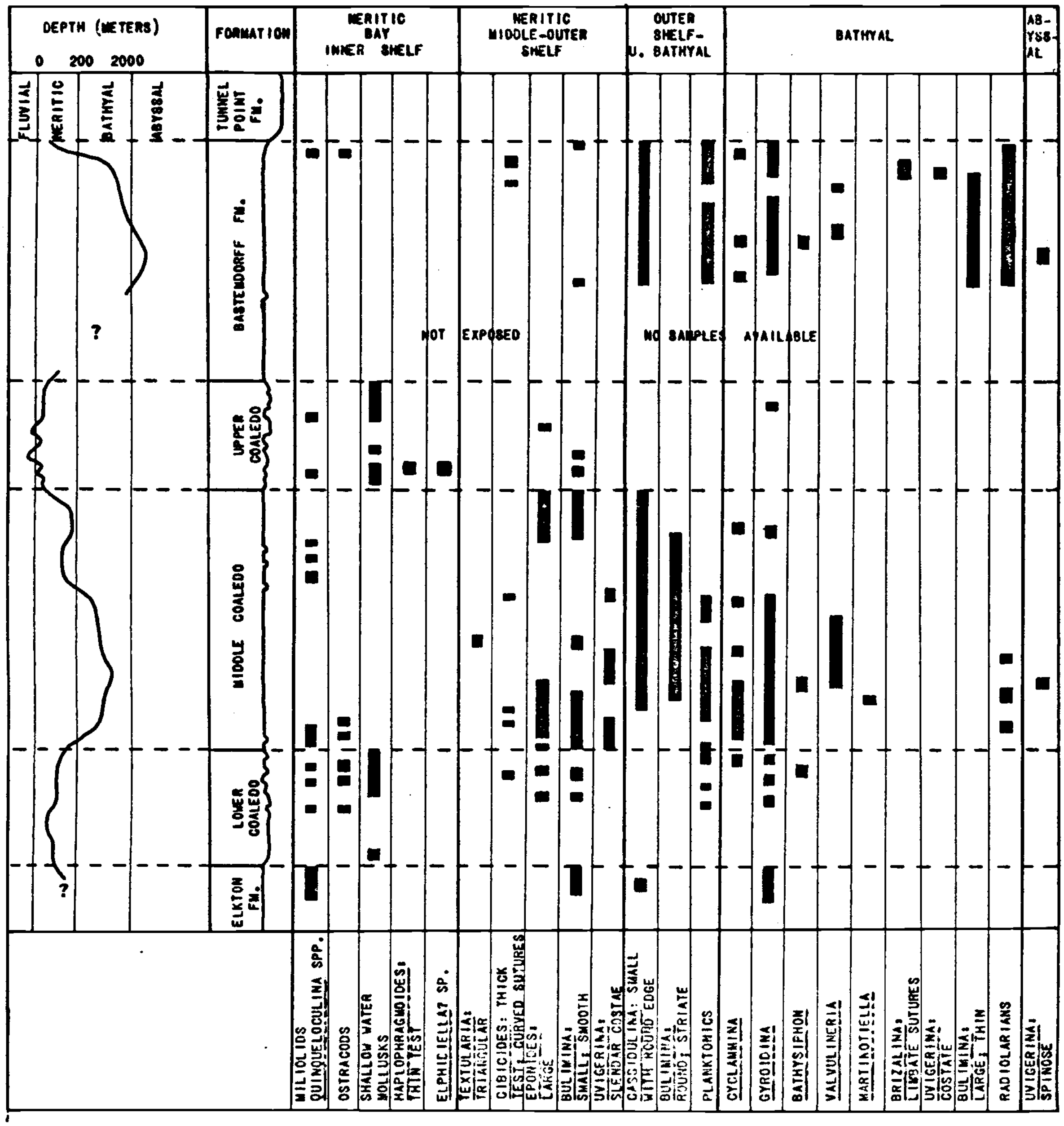


Figure 51. Summary of environmental trends based upon morphology of tests.

paleobathymetric distribution of foraminifers resulting from their use are summarized in Figure 51. The following trends are suggested by the morphology of benthic foraminifers:

1) Forms typical of bays or an inner shelf environment occur in close stratigraphic proximity to sandstones considered to be of deltaic or shallow marine origin;

2) Foraminifers assumed to have lived at middle to outer shelf depths are found in siltstones and mudstones in stratigraphic positions adjacent to bay and inner shelf faunas;

3) Forms thought to represent depths ranging from upper bathyal to upper abyssal are found in mudstones and siltstones of the middle Coaledo and Bastendorff Formations. The Bastendorff contains higher numbers and more species of foraminifers considered to represent bathyal depths than does the middle Coaledo.

A paleobathymetric curve, derived from a consideration of all of the paleoecologic factors studied, is presented in Figure 51.

Dominant Benthic Faunal Groups

Based upon all of the environmental factors considered above, the following species are considered to be characteristic of specific bathymetric ranges.

Table 11. Dominant Benthic Faunal Groups (N-Narizian; R-Refugian).

Group N-1.	BAY-INNER SHELF SPECIES	0-50 meters
	Elphidiella? sp.	
	Quinqueloculina imperialis	
	Quinqueloculina minuta	
	Quinqueloculina spp.	
	Trochammina spp.	
Group N-2.	OUTER SHELF SPECIES	50-200 meters
	Brizalina basisenta	
	Bulimina schencki	
	Buliminella bassendorfensis	
	Cibicides hodgei	
	Cibicides natlandi	
	Eponides yeguaensis	
	Guadyrina laevigata	
	Globocassidulina globosa	
	Nonion florinense	
	Textularia aff. T. lalickeri	
	Uvigerina sp. (striate)	
Group N-3.	BATHYAL SPECIES	200-2000 meters
	Allomorphina trigona macrostoma	
	Amphimorphina jenkinsi	
	Bathysiphon eocenica	
	Bulimina microcostata	
	Bulimina? sp. (lg. ovate, thin test)	
	Cyclammina pacifica	
	Cyclammina samanica	
	Globobulimina pacifica	
	Gyroidina girardana planata	
	Martinotiella sp.	
	Planularia crepidula	
	Plectofrondicularia packardi packardi	
	Plectofrondicularia packardi multilineata	
	Uvigerina yazooensis	
Group N-4.	ABYSSAL SPECIES	2000+ meters
	Uvigerina garzaensis	
	Cibicides warreni	

Table 11. (continued)

Group R-1.	BAY-INNER SHELF SPECIES	0-50 meters
	Quinqueloculina imperialis	
	Cibicides warreni	
Group R-2.	OUTER SHELF SPECIES	50-200 meters
	Brizalina basisenta	
	Bulimina schencki	
	Cibicides haydoni	
	Globocassidulina globosa	
Group R-3.	BATHYAL SPECIES	200-2000 meters
	Alabamina kernensis	
	Bathysipon eocenica	
	Brizalina huneri	
	Bulimina sculptilis	
	Bulimina? sp. (lg. ovate, thin test)	
	Cancris joaquinensis	
	Cyclammina pacifica	
	Globobulimina pacifica	
	Gyroidina girardana planata	
	Marginulina cf. M. subbulata	
	Planularia crepidula	
	Planularia tolmani	
	Plectofrondicularia packardi packardi	
	Uvigerina atwilli	
	Uvigerina gardnerae	
	Uvigerina jacksonensis	
Group R-4.	ABYSSAL SPECIES	2000+ meters
	Uvigerina garzaensis	

Geographic Distribution of Benthic Foraminifers

Late Eocene benthic foraminifers from the Coaledo and Bastendorff Formations were compared with published faunal lists from California and Washington in an attempt to identify species that had limited geographic distribution in late Eocene time.

Almost all of the fossil species from the Coaledo and Bastendorff Formations have been reported from both California and Washington. Two exceptions are _Brizalina_ _huneri_ and _Bulimina_ _microcostata_, which are not known from late Eocene rocks of Washington. Recent foraminiferal faunas of bathyal and abyssal depths are remarkably similar in both low and middle latitudes. However, Lankford and Phleger (1973) have shown that modern sublittoral and inner shelf faunas exhibit a greater degree of provinciality.

Variations between benthic foraminiferal faunas of the Coaledo and Bastendorff and faunas from Washington and California could not clearly be recognized. As is the case with modern faunas, the late Eocene, deep-water, benthic faunas (bathyal and abyssal depths) may have exhibited less variation with respect to latitude than shallow-water faunas. The late Eocene paleobathymetry played a more important role in determining the distribution of benthic foraminifers than latitudinal variations.

Mollusks: Paleobathymetric Interpretations and Geographic Variations

Paleobathymetry

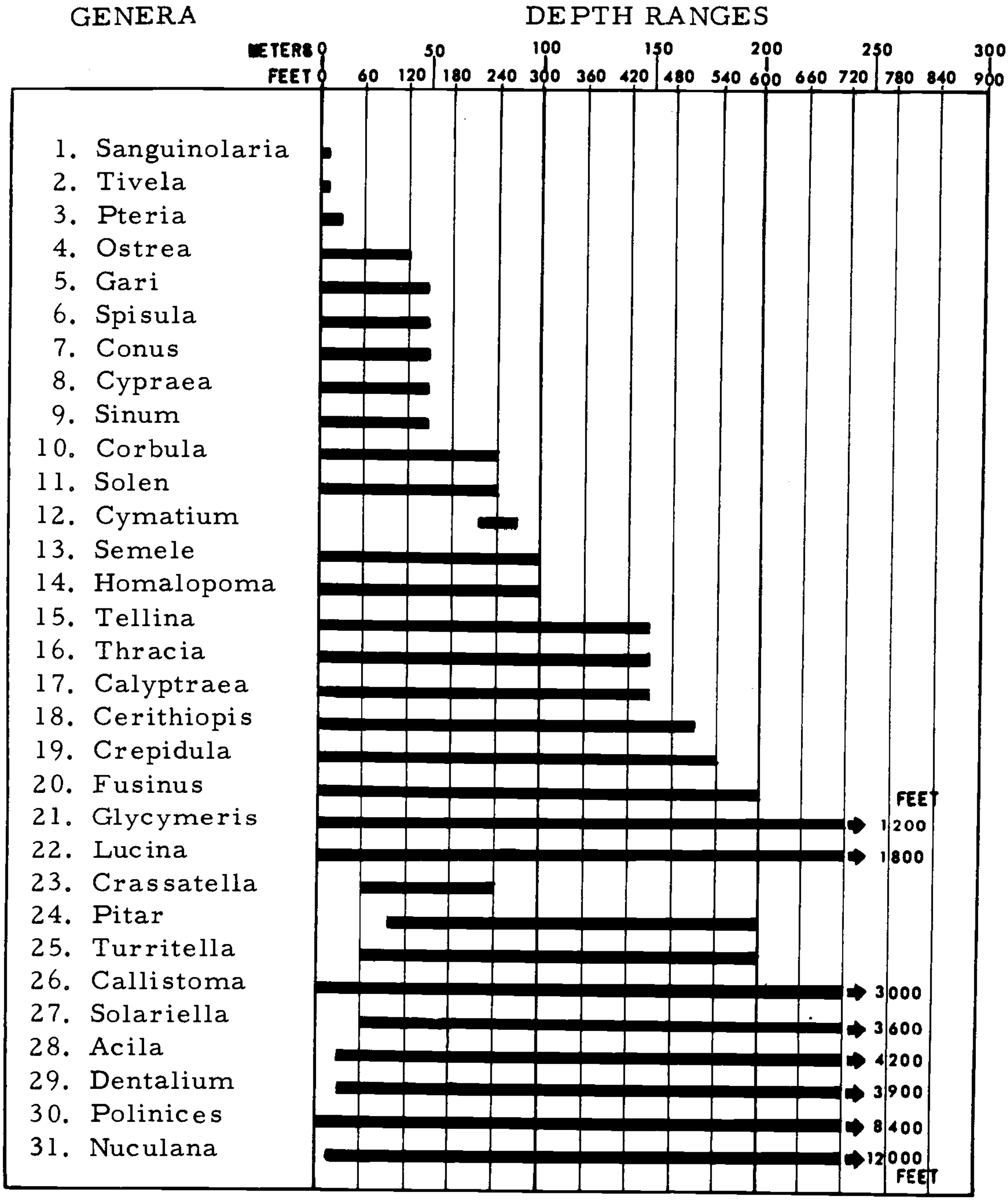
Mollusks were collected from as many of the known fossil localities of Turner (1938) and Weaver (1945a) as possible. The stratigraphic distributions in the Coaledo and Bastendorff Formations of modern genera, or of genera with living homeomorphs or isomorphs, is given in Appendix B. Since fossil foraminifers are very rare in the sandstones of the lower and upper Coaledo an attempt was made to determine the paleobathymetry of those units utilizing fossil mollusks.

The present-day depth ranges of selected genera are given in Table 12 (Keen, 1963). The fossil mollusks are compared to Table 12 and the genus with the most restricted depth range was selected as an indicator of the maximum depth of water at the time of deposition. The inferred maximum depth of the molluskan assemblages is indicated in Figure 52.

Most of the mollusks from the lower Coaledo suggest a maximum depth of water of between 20 and 40 fathoms. Mollusks from the upper Coaledo are indicative of maximum depths ranging from 0 to 10 fathoms. Estimates of the paleobathymetry based upon the assemblages of mollusks from four samples (064, 070, 711 and 757) are inconclusive because no genera with restricted bathymetric ranges were obtained. Moreover, genera present in the samples with maximum depth ranges of 70-100 fathoms, plotted in Figure 52, also lived in much shallower waters. It is possible that the assemblages could have been moved into deeper water by gravity processes.

A comparison of the fossil mollusks collected from the coastal section of the lower and upper Coaledo suggests that the lower Coaledo was deposited in deeper water (20-40 fathoms) than the upper Coaledo

Table 12. Depth ranges of recent mollusks (After: Keen, 1963).



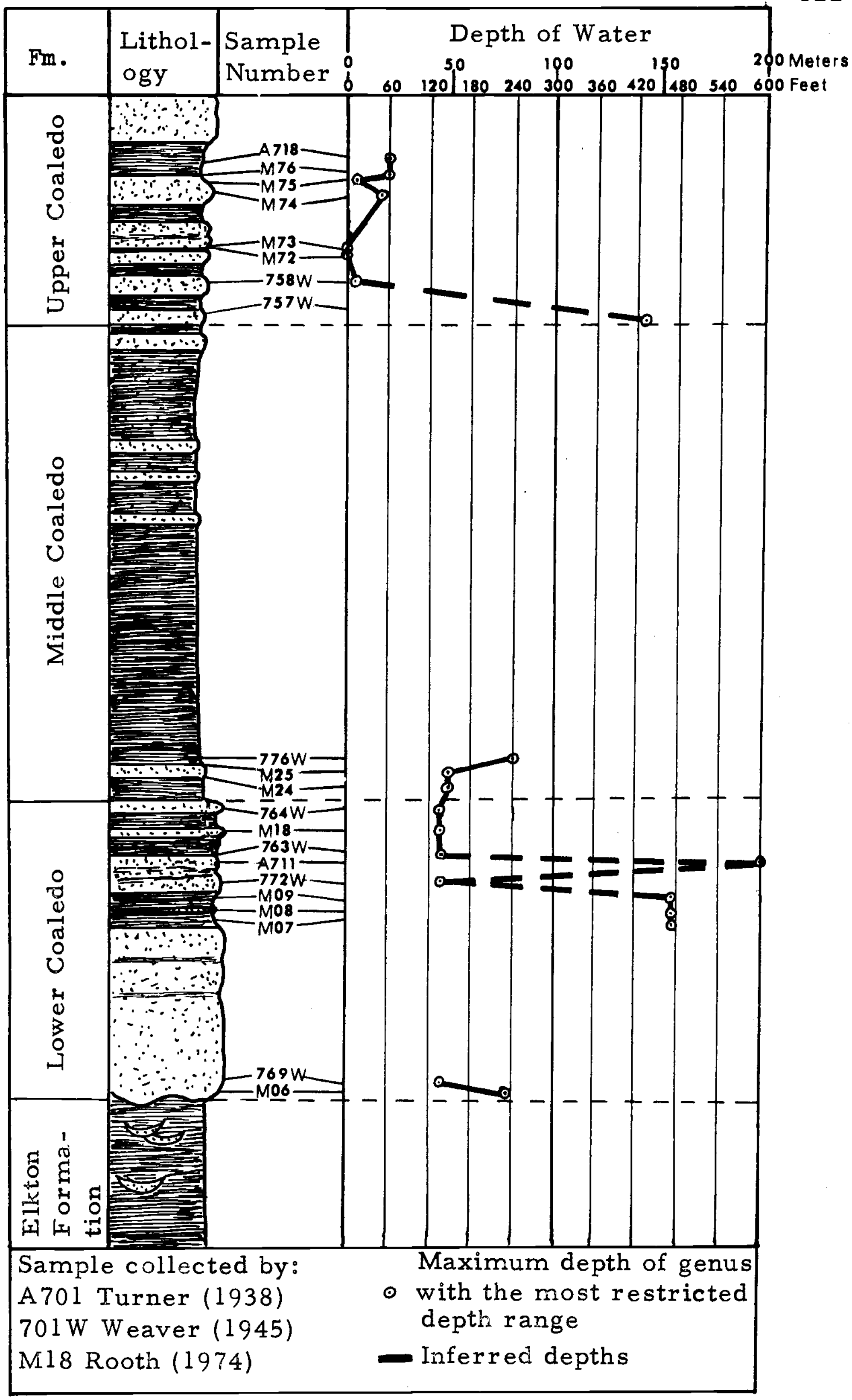


Figure 52. Inferred maximum depth of molluskan assemblages.

(0-10 fathoms). This conclusion is supported by the greater abundance of fluvial sandstones and the presence of terrestrial and estuarine facies in the upper Coaledo and the more common occurrence of sedimentary structures suggesting gravity deformation on a paleoslope (contorted strata, sandstone "roll-ups") in the lower Coaledo.

Geographic Distribution

Many authors have discussed the similarity between the genera of late Eocene mollusks on faunas of southwestern Oregon and those presently living in tropical (low latitude) regions (Turner, 1938; Weaver, 1945; Schenck and Keen, 1936; and Durham, 1950). Smith (1919), in describing the Tejon of California, stated that the following genera from the late Eocene of Oregon are similar or related to modern tropical forms.

Macrocallista
Venericardia
Crassatellites
Conus
Ficus
Fusus
Turritella

Addicott (1970) has more recently stated that a tropical marine climate existed in the middle latitudes of the eastern North Pacific during Eocene time that was characterized by widespread faunal units with high levels of taxonomic diversity. He indicates that the tropical Eocene fauna can be recognized from southern California (latitude

33°N) to the Gulf of Alaska (latitude 60°N). Addicott also notes that the high percentage of extinct Eocene genera (45%) limits accurate paleoecologic comparisons with recent molluskan faunas. He also points out the less diverse faunas of the Oligocene suggest cooler waters.

Paleooceanography

In modern cool water-masses, planktonic foraminifers are usually abundant in offshore waters but decrease or are absent nearshore (Lipps and Warme, 1966). The reasons for the decline of planktonic forms in nearshore waters is not clearly understood although Phleger (1954) has attributed it to the influence of terrestrial runoff. High rates of sedimentation and large populations of benthic foraminifers found in nearshore regions (continental shelves) tend to reduce the percentage of planktonic specimens per sample.

According to McKeel and Lipps (1972) high-latitude water-masses usually contain fewer species than lower-latitude tropical water-masses. The species of high-latitudes occur in greater numbers, have a simpler morphology and exhibit a greater degree of variation in morphology within a given species than species from lower-latitudes (McKeel and Lipps, 1972).

McKeel (1972) found that lower and middle Eocene rocks from Oregon contain 33 to 85 percent planktonic foraminifers, and in late

Eocene rocks the amount ranges from 7 to 12 percent. Variations in planktonic species diversity is presented in Table 13.

Table 13. Planktonic Foraminiferal Species Diversity (Modified from McKeel, 1972).

EPOCH	FORAMINIFERA		
	Oregon (McKeel, 1972)	Oregon (Rooth, 1974)	Trinidad (Bolli, 1957)
Early Oligocene	7	--	12
Late Eocene	11	28	19
Middle Eocene	16	--	34

Although the percentage of planktonic foraminifers was low in the samples studied (0-35%), the species diversity (28) was considerably higher than that reported by McKeel.

It is important to note that planktonic foraminifers of the Bastendorff Formation are found in samples containing high radiolarian numbers and benthic foraminifers believed to have lived at bathyal or upper abyssal depths. The planktonic foraminifers in the middle Coaledo, for the most part, make up less than 10 percent of the fauna and occur in samples lacking radiolaria and containing a lower neritic to upper bathyal benthic foraminiferal fauna.

The similarity of planktonic species from the Coaledo and Bastendorff Formations to those of high-latitudes regions such as New Zealand, as well as the apparent absence of many characteristic tropical species, has been discussed in an earlier section.

Based upon the particular species of planktonic foraminifers present, the percentage of planktonic forms, the presence or absence of radiolarians and the assumed paleobathymetry of associated benthic foraminifers, the following speculations concerning paleooceanography are made:

1) The number of species reported from high-latitudes coupled with the scarcity of forms restricted to the tropics suggests that a cool water-mass, analogous to the present day Transition water-mass, lay off the Oregon coast during the late Eocene. A similar conclusion was reached by McKeel and Lipps (1972);

2) The absence of radiolaria, the assumed paleobathymetry of benthic foraminifers and the low percentage of planktonic foraminifers indicate that the lower one-third of the middle Coaledo was deposited at middle to lower bathyal depths and that a gradual shoaling occurred during the deposition of the remainder of the middle Coaledo. The middle Coaledo only briefly came under the influence of an open ocean water-mass containing abundant radiolarians;

3) The higher percentage (usually 10-35 percent) of planktonic foraminifers and the presence of abundant radiolarians and bathyal to abyssal benthic foraminifers in Bastendorff Formation suggests that deposition occurred in waters of bathyal to upper abyssal depths under the influence of an open-ocean water-mass;

4) If, as postulated, a cool water-mass, analogous to the

modern Transition water-mass, lay off the Oregon coast during the late Eocene, and oceanic circulation was similar to that of today, then a southward-flowing current like the modern California Current may also have been present. McKeel and Lipps (1972) state that this current was clearly in existence by the Eocene and was probably established at least by the Cretaceous. Samples from the Coaledo and Bastendorff Formations neither confirm, nor deny, the existence of the current.

PALEOGEOGRAPHY AND GEOLOGIC HISTORY

Late Eocene marine deposition in southwestern Oregon took place in an embayment bordered by a swampy coastal-plain and nearby highlands. Two contrasting, hypothetical configurations of the southern part of the embayment have been proposed (Weaver, 1945b; Dott, 1966).

Weaver (1945b) envisioned a partially enclosed marine embayment, similar to the present day Puget Sound, as having occupied western Oregon in the late Eocene (Figure 54). In his report on the geology of the Coos Bay Region, Weaver (1945b) mentioned that there is evidence of a landmass to the west, but he did not describe the evidence. Dott (1966) found that the major direction of sediment transport in late Eocene non-marine rocks was from the southeast toward the northwest. The author could find no field evidence to substantiate Weaver's hypothesis of a source of sediments to the west of the Coos Bay Region. Snavely and Wagner (1963) have postulated a more open embayment in Oregon during late Eocene time but retain the idea that the late Eocene deposition near Coos Bay was bounded by a substantial landmass to the west (Figure 54).

Dott (1966), on the other hand, has postulated a northeasterly-trending coastline without any major landmasses to the west of the present day Coos Bay Region. Evidence, which is based upon an analysis of fossil foraminifers and favors the interpretation of Dott, is presented in a later part of this section.

Hopkins (1967) has described fossil pollen and spores from the region. A reconstruction of the late Eocene topography, paleoflora and paleoclimate based upon Hopkin's data suggests that the embayment was bordered by a warm, humid coastal plain, beyond which uplands and a mountainous area stretched farther to the south and east (Figure 53). Dott's (1966) petrologic study of the provenance of the Coaledo Formation indicates the presence of nearby basaltic volcanism in late Eocene time.

The earliest geologic event that occurred in the region studied was the deposition of the Elkton Formation. Bird (1967) has clearly shown, both at Sacchi Beach and inland near Elkton, that deposition of the Elkton Formation occurred in a sea becoming progressively shallower with time. The sequence of sedimentary facies in North and South Coves of Cape Arago agrees with Bird's (1967) interpretation. An uplifting of the region during the late Ulatizian and early Narizian Stages of Eocene time resulted in the deposition of the Elkton Formation in shoaling water and the deposition of the lower sandstone member of the Coaledo Formation. It has long been understood (Turner, 1938; Allen and Baldwin, 1944; Weaver, 1945b; and Dott, 1966) that the subsequent deposition of the marine mudstones of the middle Coaledo, the predominantly non-marine sandstones of the upper Coaledo

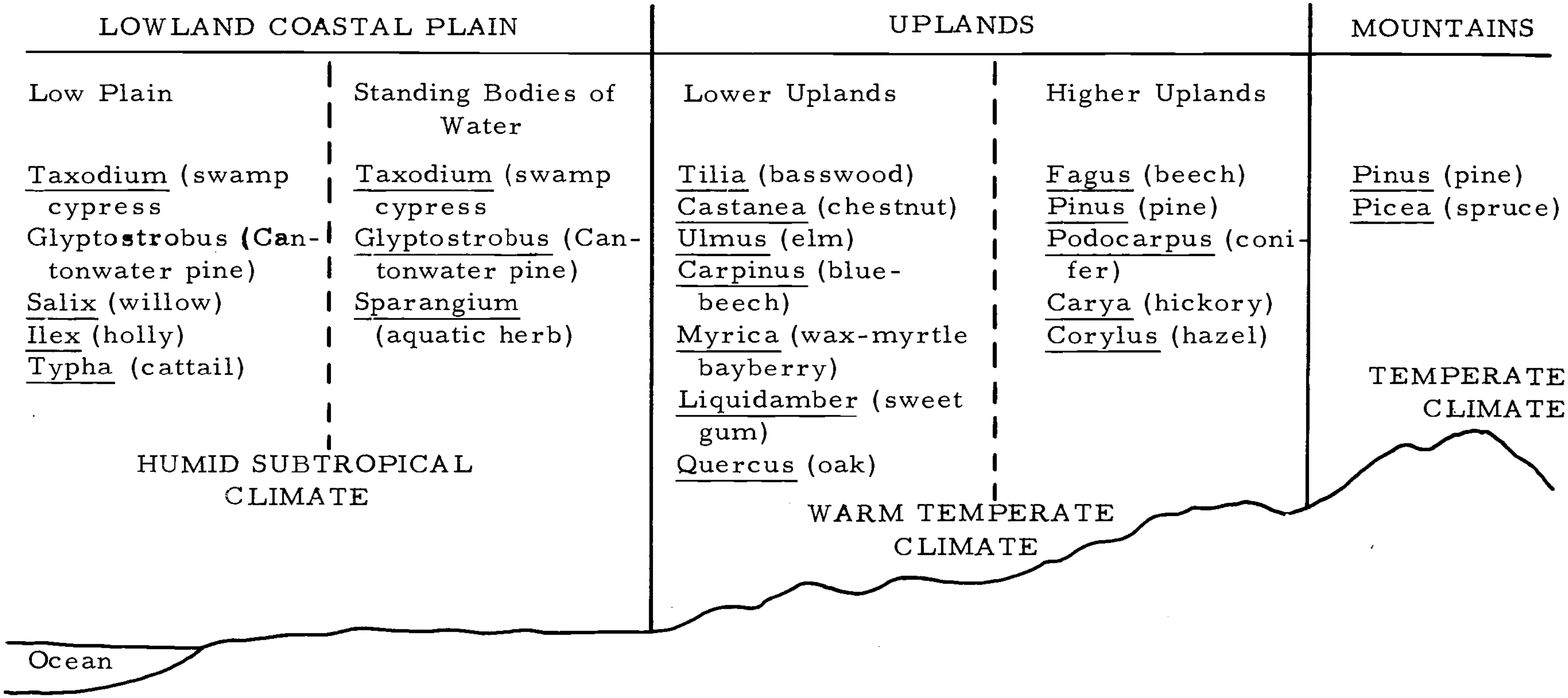
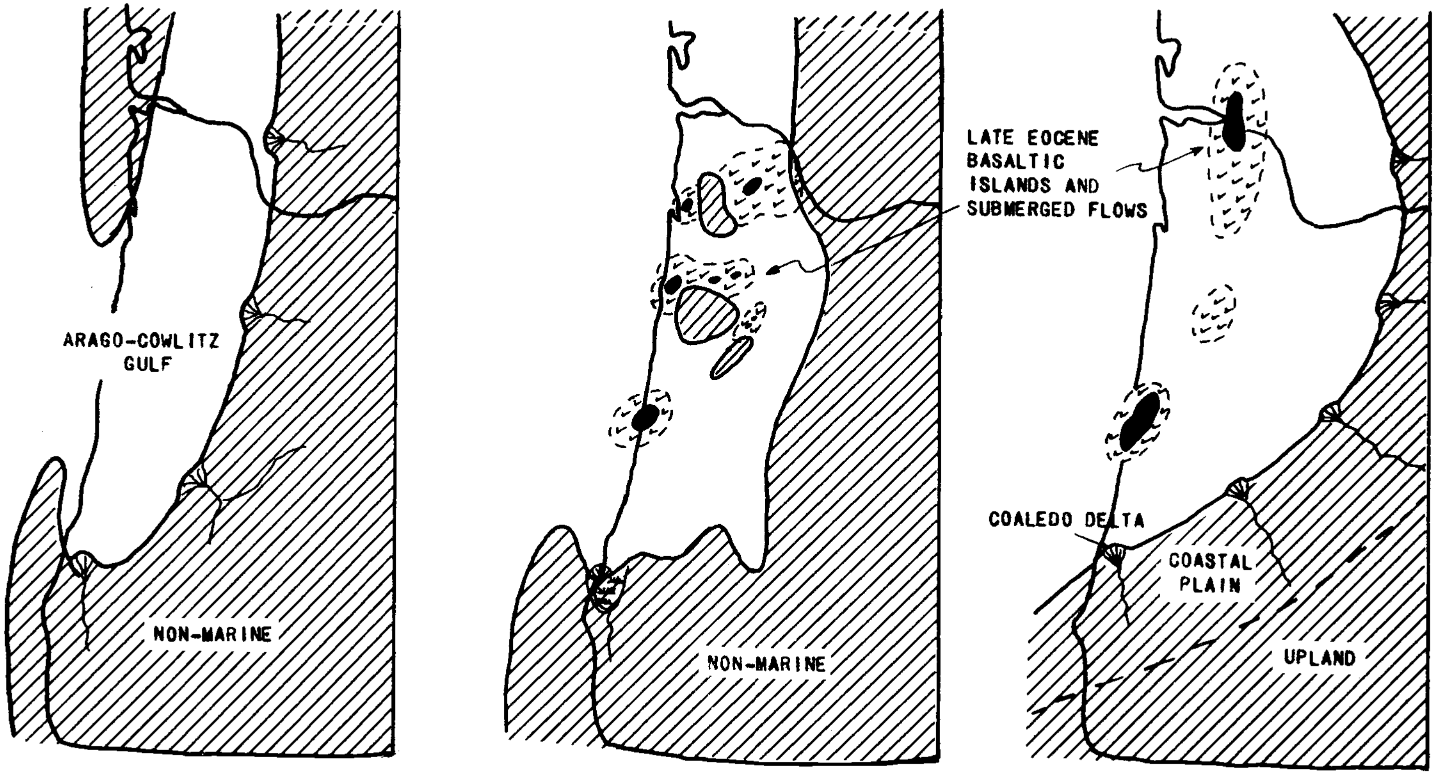


Figure 53. Reconstruction of late Eocene topography and paleoflora. Adapted from Hopkins (1967).

and the marine mudstones of the Bastendorff Formation represent transgressive and regressive phases of the late Eocene seas.

Earlier studies have suggested that the mudstones of the middle Coaledo and Bastendorff were deposited in a shallow marine environment (Schenck, 1928; Allen and Baldwin, 1944; Detline, 1946; and Dott, 1966). Dott (1966) has suggested that the marine transgressions, represented by the deposition of the middle Coaledo and Bastendorff, probably reflect a shifting of distributary outlets rather than a sudden absolute change of land and sea level. However, the inferred paleobathymetry based upon the study of fossil foraminifers (as presented in Figure 51 and described below) contradicts the interpretation of Dott and strongly suggests that extensive vertical movements occurred during late Eocene time.

Bathyal foraminifers occur in the middle Coaledo at a position about 900 feet above the contact with the underlying shallow marine sandstones of the lower Coaledo. Based upon fossil mollusks, the lower Coaledo is thought to have been deposited at depths of 120 to 240 feet (Figure 52). The microfossils in the samples from the middle Coaledo, mentioned above, suggest that deposition occurred at upper to middle bathyal depths of 1000 to 3000 feet (Figure 51). If these assumptions are correct, then subsidence of between 1000 to 2700 feet occurred during the deposition of the lower one-third of the middle member of the Coaledo Formation. Fossil foraminifers within the



(After: Weaver, 1945b)

(After: Snavely and Wagner, 1963)

(After: Dott, 1966)

Figure 54. Late Eocene paleogeography of southwestern Oregon.

upper two-thirds of the middle Coaledo suggest deposition in a progressively shallowing sea (Figure 51). Since the thickness of the sediments of the upper two-thirds of the middle Coaledo (2000 feet) is approximately equal to the depth of water at the start of deposition of the sequence, the shallowing trend of the middle Coaledo may be the result of filling of the basin accompanied by only minor uplift of the region.

The fluvial and shallow marine sandstones of the upper Coaledo indicate deposition at depths of 0 to 60 feet (Figure 52). Fossil foraminifers and radiolarians suggest that the Bastendorff Formation was deposited in lower bathyal to abyssal waters at depths of between 3000 to 6000 feet. Planktonic foraminifers and radiolarians, believed to be indicative of open oceanic waters in areas of low runoff, are very abundant in samples throughout the upper two-thirds of the Bastendorff Formation (Figures 48 and 49, and Plate 12). After deposition of the upper Coaledo deltaic, fluvial, and shallow marine sandstones, strong subsidence occurred in the region during the deposition of the Bastendorff Formation. The fossil foraminifers from the upper part of the Bastendorff do not indicate a progressive shallowing similar to that indicated by the upper part of the middle Coaledo. Samples, collected in the Bastendorff a few hundred feet below the contact with the overlying shallow marine Tunnel Point Sandstone, contain bathyal benthic foraminifers and high numbers of planktonic foraminifers and radiolarians. If the interpretations based upon fossil foraminifers are correct, strong uplift of the region occurred before the deposition of the Tunnel Point Sandstone.

The strong vertical movements postulated here for southwest Oregon may have been the result of underthrusting of an oceanic plate beneath the North American plate during late Eocene time. Macleod (1971) believes that an underthrusting of the oceanic plate beneath the continental plate, west of the present coastline of Oregon, started in mid-late Eocene time and continued into Oligocene time.

It is concluded in this study, based upon occurrences of fossil foraminifers and radiolarians, that the regression of the late Eocene seas associated with the upper and lower members of the Coaledo Formation and the transgressions associated with the deposition of the middle Coaledo and Bastendorff were influenced strongly by vertical movements of the region, rather than by lateral shifting of a deltaic complex along a stable coast.

The presence of oceanic and deep-water fossils in the Bastendorff Formation favors the open-ocean, paleogeographic interpretation of Dott (1966) for southwest Oregon in late Eocene time (Figure 54).

SUMMARY AND CONCLUSIONS

A large late Eocene delta is preserved in the rocks near Coos Bay, Oregon. The interpretations of previous workers, that the sandstones of the Coaledo Formation represent regressive offlap and the mudstones of the middle Coaledo and Bastendorff are the result of transgressive onlap of late Eocene seas, remain unchanged.

Fossil foraminifers collected from the mudstone units were studied in an attempt to determine the age of the formations and the conditions at the time of deposition.

The number of known species of fossil foraminifers from the Coaledo and Bastendorff Formations has been increased as a result of this study from 46 species to 148 species. The number of known planktonic species reported from the rocks of the region has been increased from 13 species to 28 species.

The Coaledo Formation is middle late Eocene in age and is correlated in part with the Uvigerina garzaensis Subzone of the Bulimina corrugata Zone and in part with the Amphimorphina jenkinsi Zone of the standard West Coast Narizian Stage. The Bastendorff Formation has been considered in previous studies to be partly Eocene and partly Oligocene in age. Study of benthic foraminifers indicates that the Bastendorff contains a Uvigerina cocoaensis fauna, which can be correlated with the lower part of the Refugian Stage of the Tertiary of California and with the late Eocene Cocoa sandstone of the Gulf Coast. Planktonic foraminifers from the Bastendorff are entirely late Eocene in age and are correlated with confidence with the Runangan Stage of New Zealand and tentatively with the P17 (=Globigerina gortani-Globorotalia (T.) centralis) partial range zone of tropical regions. The lower part of the Refugian Stage of the West Coast is considered here to be late Eocene rather than early Oligocene in age.

The mudstones and siltstones of the middle Coaledo and Bastendorff have been previously interpreted as having been deposited in a shallow marine bay or upon the continental shelf. The present study of the fossil foraminifers of these formations has indicated that deposition of the middle Coaledo probably occurred at upper bathyal to lower neritic depths and that the Bastendorff Formation was deposited at lower bathyal to upper abyssal depths. High numbers of fossil radiolarians and planktonic foraminifers found in samples from the Bastendorff Formation suggest that deposition occurred in a region influenced by an open-ocean, mid-latitude water-mass, rather than on the continental shelf or in a restricted embayment.

The presence of a normal marine, deep-water microfauna in mudstone units, located stratigraphically between non-marine deltaic sandstones, implies that strong vertical movements occurred during and immediately following the deposition of the Coaledo delta. The idea of a simple lateral shifting of a prograding deltaic complex is not supported by the study of benthic foraminiferal faunas. Vertical movements in southwest Oregon in late Eocene time may have been the result of underthrusting of an oceanic plate beneath the North American plate.

The stratigraphic position, the sequence of sedimentary facies, and the occurrence of unique sandstone-filled channels with mudstone breccias all indicate that the beds at North and South Coves of Cape Arago should be correlated with similar strata of the Elkton Formation five miles south at Sacchi Beach rather than being considered a part of the Coaledo Formation.

SYSTEMATIC PALEONTOLOGY

Synonomies given in the following section include reference to the original description and to several other papers in which extensive synonomies can be found.

In this study, genera are arranged according to the classification of Loeblich and Tappan (1964) with the exception of planktonic foraminifers which follow the classifications of Lipps (1966) and Parker (1967).

Identifications were made by comparison with published literature, hence many are uncertain. Species which are thought to be synonyms are listed in the discussion, but they are not formally placed in synonomy because type specimens were not available for study.

The stratigraphic ranges of each species are given for the Coaledo and Bastendorff Formations only. Figured specimens are deposited in the Paleontology Collection of the Department of Geology, Oregon State University, Corvallis, Oregon.

Phylum PROTISTA

Class SARCODINA Butschli, 1882

Order FORAMINIFERA d'Orbigny, 1826

Family ASTRORHIZIDAE

Genus RHADBAMMINA M. Sars, 1869

Rhabdammina cf. *R. eocenica* Cushman and G. D. Hanna
Pl. 1, fig. 1

Rhabdammina eocenica Cushman and G. D. Hanna, 1927, p. 209, pl. 13, fig. 23; Mallory, 1959, p. 104, pl. 1, figs. 1, 2.

Remarks: Several coarsely granular fragments are tentatively referred to this species.

Occurrence: Middle Coaledo and Bastendorff.

Genus BATHYSIPHON SARS, 1872

Bathysiphon eocenica Cushman and G. D. Hanna
Pl. 1, fig. 2

Bathysiphon eocenica Cushman and G. D. Hanna, 1927, p. 210, pl. 13, figs. 2, 3; Sullivan, 1962, p. 249, pl. 1, figs. 2, 3.

Remarks: Numerous specimens compare well with the published literature. They are typically flattened and composed of fine sand grains with much cement, imparting a finely granular surface to the test. A few specimens included here differ from the typical *B. eocenica* in that they are longer, have a thinner test and more shiny surface. Generally they resemble Bathysiphon cf. B. alexanderi of Bird (1967, pl. 6, fig. 5) and B. sanctaecrucis of Kleinpell and Weaver (1963, pl. 2, fig. 2) and, Sullivan (1962, pl. 1, fig. 4).

Occurrence: Lower and middle Coaledo; Bastendorff.

Bathysiphon sp.
Pl. 1, fig. 3

Description: Test a large, wide, elongate tube with pronounced constrictions producing a somewhat scalloped periphery. Wall aggulutinated, white in color, with abundant grains of fine sand. Aperture terminal at end of tube. Length 1.0-1.5mm (incomplete specimens); width 0.78-0.80mm; thickness 0.48-0.50mm.

Remarks: The specimens assigned to this genus are wider, have a thicker test with pronounced constrictions, and a more uneven margin than B. eocenica. The form is figured here for future reference.

Occurrence: Middle Coaledo.

Family HORMOSINIDAE

Genus REOPHAX Montfort, 1808

Reophax? sp.
Pl. 1, fig. 4

Remarks: A few poorly preserved specimens are referred to this genus.

Occurrence: Middle Coaledo.

Family LITUOLIDAE

Genus HAPLOPHRAGMOIDES Cushman, 1910

Haplophragmoides _deflata_ Sullivan
Pl. 1, fig. 9

Haplophragmoides _deflata_ Sullivan, 1962, p. 251, pl. 1, figs. 11, 12.

Remarks: The specimens compare favorably with illustrations of Sullivan's holotype.

Occurrence: Middle Coaledo.

Haplophragmoides _obliquecameratus_ Marks
Pl. 1, fig. 7

Haplophragmoides _obliquecameratus_ Marks, 1951, p. 35, pl. 1, fig. 1; Sullivan, 1967, p. 251, pl. 1, figs. 9, 10; Kleinpell and Weaver, 1963, p. 166, pl. 2, fig. 7.

Occurrence: Lower and middle Coaledo; Bastendorff.

Haplophragmoides sp.
Pl. 1, fig. 5

Remarks: This small species somewhat resembles _H._ _kirki_ Wickenden, but it is a more infated form possessing six chambers rather than four.

Occurrence: Middle Coaledo.

Haplophragmoides spp.

Remarks: Broken specimens and specimens too poorly preserved for specific identification are included here for statistical purposes.

Genus CYCLAMMINA Brady, 1879

Cyclammina clarki (G. D. Hanna)
Pl. 1, fig. 6

Nonionia clarki G. D. Hanna, 1923, p. 324, pl. 59, fig. 2.

Cyclammina clarki? (G. D. Hanna). Cushman and Schener, 1928, p. 303, pl. 42, fig. 1.

Cyclammina clarki (G. D. Hanna) Kleinpell and Weaver, 1963, p. 167, pl. 2, fig. 9.

Occurrence: Lower and middle Coaledo.

Cyclammina pacifica Beck
Pl. 1, fig. 8

Cyclammina pacifica Beck, 1943, p. 591, pl. 98, figs. 2, 3; Hornaday, 1961, p. 180, pl. 1, figs. 11a-c; Kleinpell and Weaver, 1963, p. 167, pl. 3, fig. 1.

Occurrence: Lower, middle, and upper Coaledo; Bastendorff.

Cyclammina samanica Berry
Pl. 1, fig. 11

Cyclammina samanica Berry, 1928, vol. 21, p. 393, Text-fig. 9; Kleinpell and Weaver, 1963, p. 167, pl. 3, fig. 2; Fairchild, Wesenduck and Weaver, 1969, p. 31, pl. 1, figs. 9a, b.

Remarks: The original figure of Cyclammina samanica by Berry (1928) was a line drawing, which failed to clearly show the characteristics of the species. The form was originally described as having a relatively thin test with a keel-like, distinctly compressed peripherial margin, a deep umbilicus, and straight, slightly depressed, almost invisible sutures. Specimens studied resemble the original description and figure and resemble the figures of Kleinpell and Weaver (1963) and Fairchild, Wesenduck and Weaver (1969). No mention was made, in the original description, of the form being partially evolute. Forms considered to be C. samanica by Sullivan (1962) and Weaver and Weaver (1962) are distinctly evolute and are placed in Cyclammina sp. below.

Occurrence: Middle Coaledo and Bastendorff.

Cyclammina sp.
Pl. 1, fig. 10

Remarks: This form is similar to Cyclammina samanica as figured by Sullivan (1962) and Weaver and Weaver (1962). This form differs from the description and figure of C. samanica Berry (1928) in that it is partially evolute, has readily discernable sutures, and lacks a peripheral keel. The author does not believe this form should be included in C. samanica. It is figured for future reference.

Occurrence: Middle Coaledo.

Cyclammina? sp.
Pl. 1, fig. 12

Remarks: Only a single specimen of this large, thick, coarse textured form was found. It is figured for future reference.

Occurrence: Lower Coaledo.

Genus AMMOBACULITES Cushman, 1910

Ammobaculites sp.
Pl. 2, fig. 1

Remarks: A single specimen is too poorly preserved for specific identification.

Occurrence: Middle Coaledo.

Family TEXTULARIIDAE

Genus SPIROPLECTAMMINA Cushman, 1927

Spiroplectammina mississippiensis (Cushman)
Pl. 2, fig. 2

Textularia mississippiensis Cushman. Cushman and Applin, 1926, p. 166, pl. 6, figs. 10, 11.

Spiroplectammina mississippiensis (Cushman) Mallory, 1959, p. 118, pl. 39, figs. 1a, b; Kleinpell and Weaver, 1963, p. 167, pl. 3, figs. 7a, b.

Remarks: Specimens studied possess a very small coiled portion and agree well with figures of Cushman and Applin (1926) and

Kleinpell and Weaver (1963). Two forms that appear to be identical in published figures are *Textularia warreni* (Cushman and Ellisor, 1931, p. 51, pl. 7, figs. 2a, b) and *T. mexicana* (Cushman and Barbat, 1932, p. 33, pl. 5, figs. 3a, b). Cushman, however, did not consider these forms to be conspecific.

Occurrence: Middle Coaledo.

Spiroplectammina sp.
Pl. 2, fig. 3

Remarks: A single specimen is referred to the genus *Spiroplectammina* and is figured here for future reference.

Occurrence: Middle Coaledo and Bastendorff.

Genus TEXTULARIA Defrance, 1824

Textularia aff. *T. lalickeri* Cushman and Renz
Pl. 2, fig. 4

Textularia lalickeri Cushman and Renz, 1941, pl. 1, fig. 4, 5.

Remarks: A single specimen characterized by a rapid increase in size of the last chambers is tentatively referred to *T. lalickeri*.

Occurrence: Middle Coaledo.

Family TROCHAMMINIDAE

Genus TROCHAMMINA Parker and Jones, 1859

Trochammina? sp.
Pl. 2, fig. 5

Description: Test large, flattened, with trochoid coiling. Chambers with prominent raised outer margins arranged in 3 1/2 to 4 1/2 whorls in the adult form. Four and one-half chambers on umbilical side. Periphery nearly circular and slightly lobulate. Sutures hidden, peripheral to raised rims of chambers. Aperture a low interiomarginal, extraumbilical arch. Surface moderately granular. Diameter 0.60-0.63mm; thickness 0.28-0.30mm.

Remarks: Although this form is fairly common in a few samples, preservation is such that it is difficult to determine the characteristics of the form. No specimens resembling this form were found in the literature.

Occurrence: Middle Coaledo.

Family ATAXOPHRAGMIIDAE

Genus GAUDRYINA d'Orbigny, 1839

Gaudryina alazanensis Cushman
Pl. 2, fig. 6

Gaudryina alazanensis Cushman, 1936, p. 14, pl. 2, fig. 17; Rau, 1948, p. 158, pl. 27, figs. 3, 4.

Remarks: Specimens from the Coos Bay material compare favorably with forms referred to this species by Rau. (1968, personal communication.)

Occurrence: Middle Coaledo.

Gaudryina laevigata Franke
Pl. 2, fig. 7

Gaudryina laevigata Franke. Cushman, 1937, p. 24, pl. 6, figs. 10-17; Sullivan, 1962, p. 253, pl. 2, figs. 12a-c.

Occurrence: Middle Coaledo.

Gaudryina sp.
Pl. 2, figs. 8, 9

Remarks: A few specimens of this form were found. The early portion of the test is triserial and the later portion is biserial. The aperture is interiomarginal and without a lip.

Occurrence: Lower Coaledo.

Gaudryina? sp.
Pl. 2, fig. 13

Remarks: Several specimens of this form were found that show a reduction in chambers from triserial to biserial in the later portions of the test.

Occurrence: Bastendorff.

Genus DOROTHIA Plummer, 1931

Dorothia oxycona? (Reuss)
Pl. 2, fig. 10

Gaudryina oxycona Reuss, 1860, p. 229, pl. 12, fig. 3.

Marssonella oxycona Mallory, 1959, p. 134, pl. 4, fig. 8.

Dorothia oxycona (Reuss) Bird, 1967, p. 103, pl. 7, figs. 9, 10; Loeblich and Tappan, 1964, p. 275, fig. 184 (5a-c).

Remarks: A single specimen is questionably referred to this species.

Occurrence: Middle Coaledo.

Genus EGGERELLA Cushman, 1933

Eggerella subconica Parr
Pl. 2, fig. 14

Eggerella subconica Parr, 1950. Sullivan, 1962, p. 254, pl. 3, fig. 7.

Occurrence: Lower Coaledo.

Eggerella? cf. *E. trochoides* (Reuss)
Pl. 2, figs. 15, 16

Eggerella? cf. *E. trochoides* (Reuss). Sullivan, 1962, p. 254, pl. 3, figs. 2a-b.

Remarks: A few specimens of a small form appear to be the same as *Egerella*? cf. *E. trochoides* as figured by Sullivan (1962). Sullivan compares his forms to *Eggerella*? *trochoides* Reuss of Cushman (1937, p. 46, pl. 5, fig. 1).

Occurrence: Lower and middle Coaledo.

Eggerella? sp.
Pl. 2, fig. 12

Remarks: Several specimens were found of a species that is tentatively placed in the genus *Eggerella*.

Occurrence: Middle Coaledo.

Genus MARTINOTTIELLA Cushman, 1933

Martinottiella sp.
Pl. 2, fig. 11

Remarks: A single specimen of the genus *Martinottiella* is figured here for future reference.

Occurrence: Middle Coaledo.

Family FISCHERINIDAE

Genus CYCLOGYRA Wood, 1842

Cyclogyra byramensis (Cushman)

Cornuspira byramensis Cushman, 1935, p. 27, pl. 4, figs. 4a-b; Cushman and Frizzell, 1943, p. 83, pl. 14, fig. 4; Rau, 1948, p. 160-161, pl. 28, figs. 10, 11.

Cornuspira lewisensis Beck, 1943, p. 594, pl. 101, figs, 4, 5.

Remarks: Beck (1943) states that the only difference between *Cyclogyra* (*Cornuspira*) *lewisensis* and *C. byramensis* is that *C. byramensis* is one-half the size of the former. The author considers the two forms to be conspecific.

Occurrence: Lower Coaledo.

Family MILIOLIDAE

Genus SPIROLOCULINA d'Orbigny, 1826

Spiroloculina wilcoxensis Cushman and Garrett
Pl. 3, fig. 1

Spiroloculina wilcoxensis Cushman and Garrett, 1939, pp. 78, 79, pl. 13, figs. 5, 6; Cushman and Simonson, 1944, p. 194, pl. 30, figs. 4-6; Hornaday, 1961, p. 181, pl. 2, fig. 3; Sullivan, 1962, p. 257, pl. 4, fig. 9; Weaver and Molander, 1964, p. 180, pl. 3, fig. 3.

Occurrence: Middle Coaledo and Bastendorff.

Genus QUINQUELOCULINA d'Orbigny, 1826

Quinqueloculina imperialis Hanna and Hanna
Pl. 3, figs. 2, 3

Quinqueloculina imperialis Hanna and Hanna, 1924, p. 58, pl. 13, figs. 7, 8, 10; Beck, 1943, p. 592, pl. 98, figs. 9, 10; Rau, 1948, p. 159, pl. 27, figs. 12, 13, 14; Rau, 1951, p. 429, pl. 63, fig. 13.

Remarks: Specimens have been compared with topotype material from the Cowlitz River in the collections of the Burke Museum of the University of Washington, Seattle and the topotype material in the personal collection of Dr. W. W. Rau. The dimensions of specimens from the Coaledo formation (length 1.22-1.28mm;

breadth, 1.20-1.25mm; thickness 0.48-0.54mm) compare well with the size of those reported by Beck (1943). Rau (1948) reported a bimodal size distribution of specimens from the Porter scale. Specimens from the Coos Bay region are the more numerous, smaller, megalospheric forms. No specimens with markedly larger tests were found in the material studied. Topotype material of *Quinqueloculina imperialis porterensis* Rau (1948, p. 159), pl. 27, figs. 9, 10, 11) was also examined and is identical to the smaller forms of *Q. imperialis* except that the aperture of the varietal form lacks dentation.

Occurrence: Lower, middle and upper Coaledo; Bastendorff.

Quinqueloculina minuta Beck
Pl. 3, figs. 4, 5, 6

Quinqueloculina minuta Beck, 1943, p. 593, pl. 99, figs. 5-7; Detling, 1946, p. 352, pl. 46, fig. 4 l-c; Sullivan, 1962, p. 256, pl. 4, fig. 11a-c.

Remarks: Specimens are few and are commonly somewhat eroded. They differ slightly from the figured types of Beck (1943) in that they are less pointed at the ends, giving the specimens a somewhat oval to rectangular outline that resembles very closely the figured specimens of Detling (1946) and Sullivan (1962).

Occurrence: Lower Coaledo.

Quinqueloculina sp.
Pl. 3, figs. 7, 8, 9

Remarks: A few specimens of a distinct form of _Quinqueloculina_ were found. The most distinctive feature found in all specimens is a marked compression of the penultimate chamber in the adult form, causing the chamber to be distinctly V-shaped. Only a few specimens were found, and all were fragmentary and poorly preserved, so no new species was erected.

Occurrence: Middle Coaledo.

Quinqueloculina spp.

Remarks: Broken or poorly preserved specimens, probably representing several species, are included here.

Occurrence: Elkton; Lower, middle and upper Coaledo; Bastendorff.

Family NODOSARIIDAE

Genus NODOSARIA Lamark, 1812

Nodosaria _consobrina_ (d'Obrigny)
Pl. 3, fig. 10

Dentalina _consobrina_ d'Orbigny, 1946, p. 46, pl. 2, figs. 1-3; Mallory, 1959, p. 163, pl. 12, fig. 12; pl. 41, fig. 5; Sullivan, 1962, p. 263, pl. 9, figs. 2, 3.

Nodosaria _consobrina_ (d'Orbigny) Smith, 1957, p. 166, pl. 22, figs. 16, 17. Bird, 1967, p. 106, pl. 8, fig. 24.

Remarks: This species appears to be quite variable in the degree of inflation of the initial chamber and in the presence or absence of a basal spine. Specimens included here are thin walled, have a bulbous proloculus, may or may not have a basal spine, and have a third chamber that is one and one-half times as long as the second chamber. They are identical to the published figures of Mallory (1959) and Sullivan (1962). They do not appear to be the same as the published figures of Wilson (1954, pl. 14, fig. 7), Hornaday (1961, pl. 4, fig. 9) or Kleinpell and Weaver (1963, pl. 6, figs. 3, 4). The specimens have been placed in the genus Nodosaria following Smith (1957) and Bird (1967) because the specimens show no sign of being asymmetrical.

Occurrence: Middle Coaledo and Bastendorff.

Nodosaria longiscata d'Orbigny
Pl. 3, fig. 12

Nodosaria longiscata d'Orbigny. Plummer, 1926, p. 82, pl. 4, fig. 17a, b; Hornaday, 1961, p. 185, pl. 4, fig. 4; Sullivan, 1962, p. 265, pl. 10, fig. 1; Weaver and Weaver, 1962, p. 28, pl. 7, fig. 17; Weaver and Molander, 1964, p. 184, pl. 6, fig. 15.

Nodosaria cf. N. longiscata d'Orbigny. Cushman, Stewart and Stewart, 1947, p. 98, pl. 13, fig. 1.

Remarks: Broken specimens consist of thin walled, elongated single chambers. Similar forms have been referred to Nodosaria arundinea Schwafer by Bird (1967, pl. 8, fig. 22), Weaver (1962, pl. 2, fig. 14) and Kleinpell and Weaver (1963, pl. 7, fig. 4). Mallory (1959) considered Nodosaria longiscata and N. arundinea to be separate form forms. He stated (personal communication, 1969) that he considers specimens with a smaller diameter and thinner test to be N. longiscata.

Occurrence: Middle Coaledo and Bastendorff.

Nodosaria cf. N. pyrula d'Orbigny
Pl. 3, fig. 11

Nodosaria pyrula d'Orbigny, 1826, p. 253, no. 13; Kleinpell and Weaver, 1963, p. 171, pl. 7, fig. 5; Weaver and Molander, 1964, p. 185, pl. 6, fig. 17.

Nodosaria cf. N. pyrula d'Orbigny, Beck, 1943, p. 599, pl. 105, figs. 19, 21; Detling, 1946, p. 354, pl. 48, fig. 7.

Remarks: All of the specimens included here consist of single chambers similar to the published figures.

Occurrence: Middle Coaledo.

Genus DENTALINA d'Orbigny, 1826

Dentalina colei Cushman and Dusenbury
Pl. 3, fig. 13

Dentalina colei Cushman and Dusenbury, 1934, p. 54, pl. 7, figs. 10-12; Beck, 1943, p. 598, pl. 103, fig. 18; Mallory, 1959, p. 162, pl. 12, fig. 9, pl. 41, fig. 3; Sullivan, 1962, p. 263, pl. 9, fig. 6a, b.

Occurrence: Middle Coaledo and Bastendorff.

Dentalina communis (d'Orbigny)
Pl. 3, fig. 14

Nodosaria (Dentalina) communis (d'Orbigny) Beck, 1943, p. 598, pl. 105, fig. 22; Detling, 1946, p. 353, pl. 48, fig. 3, 4; Cushman, Stewart and Stewart, 1947, p. 76, pl. 9, figs. 9a, b; Mallory, 1959, p. 162, pl. 12, fig. 9; Weaver and Weaver, 1962, p. 26, pl. 7, fig. 6.

Remarks: This form is quite common in the Coaledo formation. It differs from Nodosarella (Dentalina) cocoaensis in having more oblique sutures and an apical spine. It is very similar to Dentalina cooperensis but apparently differs in having thinner and more oblique sutures.

Occurrence: Lower, middle and upper Coaledo.

Dentalina cooperensis Cushman
Pl. 3, fig. 15

Dentalina cooperensis Cushman, 1935, p. 20, pl. 8, figs. 3, 4; Sullivan, 1962, pl. 9, figs. 4a, b, 5a, b.

Occurrence: Middle Coaledo.

Dentalina jacksonensis (Cushman and Applin)
Pl. 3, figs. 16, 17

Nodosaria jacksonensis Cushman and Applin, 1926, p. 170, pl. 7, figs. 14-16.

Dentalina jacksonensis (Cushman and Applin) Cushman, 1935, p. 20, pl. 8, figs. 7-9; Cushman and McMasters, 1936, p. 511, pl. 75, figs. 3-5; Rau, 1956, p. 74, pl. 14, figs. 8, 9; Mallory, 1959, p. 165, pl. 12, fig. 18.

Occurrence: Lower and middle Coaledo; Bastendorff.

Dentalina cf. D. pauperata d'Orbigny
Pl. 3, fig. 18

Nodosaria pauperata d'Orbigny. Hanna, 1923, p. 322, pl. 58, figs. 3, 5.

Dentalina pauperata (d'Orbigny). Cushman and Laiming, 1931, p. 99, pl. 10, figs. 11, 12; Smith, 1956, p. 29, pl. 13, fig. 6; Sullivan, 1962, p. 264, pl. 9, fig. 7; Kleinpell and Weaver, 1963, p. 170, pl. 6, fig. 5.

Remarks: A few specimens were found that resemble Dentalina pauperata as figured by Smith (1956) and Cushman and Laiming (1931) except that they have less inflated chambers.

Occurrence: Middle Coaledo and Bastendorff.

Dentalina? sp.
Pl. 3, fig. 20

Remarks: A single specimen of a form questionably referred to the genus Dentalina was found. It is figured here for future reference.

Occurrence: Bastendorff.

Genus LAGENA Walker and Jacob in Kanmacher, 1798

Lagena acuticostata Reuss
Pl. 3, fig. 22

Lagena acuticostata Reuss, Cushman, 1935, p. 23, pl. 9, figs. 5, 6; Mallory, 1959, pl. 14, figs. 1a, b; pl. 28, figs. 10a, b; pl. 41, figs. 8a, b.

Remarks: A single specimen compares well with the published figures.

Occurrence: Middle Coaledo.

Lagena cf. *L. conscripta* Cushman and Barksdale
Pl. 3, fig. 21

Lagena isabella (d'Orbigny) var. conscripta Cushman and Barksdale, 1930, p. 66, pl. 12, fig. 4.

Lagena conscripta Cushman and Barksdale, Beck, 1943, p. 601, pl. 107, fig. 38; Mallory, 1959, p. 175, pl. 14, fig. 4a, b; Sullivan, 1962, p. 266, pl. 10, fig. 10.

Remarks: A single specimen closely resembles *Lagena conscripta* of Sullivan (1962) except that it has nine costae rather than eleven as figured. It does not appear to be conspecific with *L. conscripta* of Hornaday (1961, pl. 4, fig. 11), which has smaller and more numerous costae.

Occurrence: Bastendorff.

<u>Lagena</u> <u>hexagona</u> (Williamson)
Pl. 3, fig. 23

<u>Entosolenia</u> <u>squamosa</u> <u>hexagona</u> Williamson, 1858, p. 20, pl. 2, fig. 23.

<u>Lagena</u> <u>hexagona</u> Cushman, 1935, p. 23, pl. 9, fig. 10; Beck, 1943, p. 602, pl. 107, fig. 23; Bird, 1967, p. 110, pl. 8, fig. 3; Mallory, 1959, p. 175, pl. 14, fig. 7, Weaver and Molander, 1964, p. 187, pl. 7, fig. 13.

<u>Occurrence</u>: Bastendorff.

<u>Lagena</u> <u>cf.</u> <u>L.</u> <u>substriata</u> Williamson
Pl. 3, fig. 24

<u>Lagena</u> <u>cf.</u> <u>L.</u> <u>substriata</u> Williamson, Beck, 1943, p. 602, pl. 107, fig. 30; Mallory, 1959, p. 176, pl. 14, fig. 8a, b; Sullivan, 1962, p. 267, pl. 10, fig. 11a, b.

<u>Remarks</u>: A single specimen appears to be similar in shape, size and surface ornamentation to figures of Beck (1943) and Sullivan (1962), but differs in that it has a more elongate neck. <u>Lagena</u> <u>cf.</u> <u>L.</u> <u>substriata</u> as figured by Mallory (1959, pl. 14, fig. 8a, b) is a much more sperical form lacking a distinct neck.

<u>Occurrence</u>: Lower Coaledo.

Genus LENTICULINA Lamark, 1804

<u>Lenticulina</u> <u>articulatus</u> (Cushman and Applin)
Pl. 4, fig. 12

Cristellaria articulata texana Cushman and Applin, 1926, p. 170, pl. 8, figs. 1, 2.

Robulus texanus (Cushman and Applin) Beck, 1943, p. 595, pl. 103, figs. 1, 2, 4, 5.

Robulus articulatus texanus (Cushman and Applin) Kleinpell and Weaver, 1963, p. 169, pl. 4, figs. 5a, b.

Occurrence: Middle Coaledo.

Lenticulina chehalisensis (Rau)
Pl. 4, fig. 10

Robulus chehalisensis Rau, 1948, p. 162-163, pl. 29, figs. 14, 15.

Remarks: Rau (1968, personal communication) examined specimens from the Coos Bay region and stated that they are referable to this species.

Occurrence: Middle Coaledo.

Lenticulina inornatus (d'Orbigny)
Pl. 4, figs. 4, 5

Robulina inornata d'Orbigny, 1846, p. 102, pl. 4, figs. 25, 26.

Robulus inornatus (d'Orbigny) Beck, 1943, p. 595, pl. 104, figs. 1-4, 10, 14; Detling, 1946, pl. 47, figs. 4, 5; Kleinpell and Weaver, 1963, p. 169, pl. 4, figs. 7a, b, 8; Bird, 1967, p. 111, pl. 8, figs. 8, 9.

Remarks: This species is very common in rocks from the Coos Bay region. The species is highly variable in size, curvature of the sutures and size of the umbo.

Occurrence: Elkton; Lower, middle and upper Coaledo; Bastendorff.

Lenticulina cf. L. mayi (Cushman and Parker)
Pl. 4, fig. 13

Robulus mayi Cushman and Parker, 1931, p. 2, pl. 1, figs. 3-5, Sullivan, 1962, p. 259, pl. 7, fig. 5a, b; Weaver and Weaver, 1962, p. 23, pl. 4, figs. 6a, b; Bird, 1967, p. 111, pl. 8, figs. 16, 17.

Lenticulina sp. Kleinpell and Weaver, 1963, pl. 5, fig. 3.

Lenticulina cf. L. mayi (Cushman and Parker) Fairchild, Wesenduck, and Weaver, 1969, p. 42, pl. 6, figs. 7, 8.

Remarks: Specimens differ from the figured types of Robulus mayi Cushman and Parker in that they are less elongate. They are identical to Robulus mayi of Sullivan (1962), Lenticulina sp. of Kleinpell and Weaver (1963) and Lenticulina cf. L. mayi of Fairchild, Wesenduck and Weaver (1969). Lenticulina propinqua cowlitzensis Beck is a similar form with fewer, more inflated chambers. The differences between these two forms may be of less than specific importance.

Occurrence: Middle Coaledo.

Lenticulina pseudovortex (Cole)
Pl. 4, fig. 11

Robulus pseudovortex Cole, 1927, p. 17, pl. 1, fig. 12; Cushman and

McMasters, 1936, p. 510, pl. 17, figs. 12a, b; Smith, 1957, p. 158, pl. 20, figs. 12a, b, 13a, b.

Lenticulina pseudovortex (Cole) Fairchild, Wesenduck and Weaver, 1969, p. 42, pl. 7, figs. 6a, b, 11a, b.

Occurrence: Bastendorff.

Lenticulina welchi (Church)
Pl. 4, figs. 7, 8, 9

Robulus welchi Church, 1931, Mallory, 1959, p. 143, pl. 7, fig. 8a, b; Rau, 1964, p. 15, pl. 5, figs. 6a, b.

Lenticulina welchi (Church) Bird, 1967, p. 112, pl. 8, fig. 20, 21.

Remarks: Robulus chiranus Cushman and Stone is considered by Bandy and Kolpack (1963, p. 160) to be a junior synonym or variety of this species and Hornaday (1961, p. 183).

Occurrence: Middle Coaledo.

Lenticulina sp. A
Pl. 4, figs. 1, 2

Remarks: This form is very similar to Lenticulina inornatus but differs in having a less distinct umbo and radial, peripheral apertures of earlier chambers, which are clearly visible.

Occurrence: Middle Coaledo.

Lenticulina sp. B
Pl. 4, fig. 3

Remarks: A few specimens were found of this form, which is figured here for future reference.

Occurrence: Bastendorff.

Lenticulina sp. C
Pl. 4, fig. 6

Remarks: This form, found in low numbers in a few samples, lacks an umbilical plug and has a periphery that is distinctly straightened in the last few chambers, producing an angular outline to the test.

Occurrence: Lower and middle Coaledo.

Lenticulina sp. D
Pl. 4, fig. 5

Remarks: A single specimen of this small form was found, and it is figured here for future reference.

Occurrence: Lower Coaledo.

Lenticulina? sp.
Pl. 4, fig. 14

Remarks: A single, asymmetrical specimen was found, which would have been referred to the genus Darybella by earlier workers. Loeblich and Tappan (1964, p. 520) consider Darybella to be merely an asymmetrical form of Lenticulina and state that large assemblages of any species of Lenticulina contain asymmetrical forms.

Occurrence: Lower Coaledo.

Lencitulina spp.

Remarks: Specimens too poorly preserved for specific identification are placed here.

Genus MARGINULINA d'Orbigny, 1926

Marginulina cf. M. adunca (Costa)
Pl. 5, fig. 1

Marginulina cf. M. adunca (Costa), Sullivan, 1962, p. 261, pl. 8, figs. 10a, b, 11.

Marginulina adunca (Costa), Weaver and Weaver, 1962, p. 25, pl. 6, fig. 9a, b; Weaver and Molander, 1964, p. 183, pl. 6, fig. 4.

Remarks: A single specimen appears to be identical to the specimen figured by Weaver and Molander (1964) and to resemble figures of Sullivan, (1962). This form apparently differs from *Marginulina inconspica* Hussey in being larger, having fewer chambers, and having a pronounced inflation of the last chamber.

Occurrence: Middle Coaledo and Bastendorff.

Marginulina exima Neugeboren
Pl. 5, fig. 5

Marginulina exima Neugeboren, Cushman and Ponton, 1932, p. 54, pl. 7, figs. 8a, b; Beck, 1943, p. 597, pl. 104, figs. 15, 16; Mallory, 1959, p. 149, pl. 10, fig. 1a, b, c; Sullivan, 1962, p. 262, pl. 8, fig. 9a, b; Weaver and Molander, 1964, p. 183, pl. 6, fig. 5.

Occurrence: Lower Coaledo.

Margulina cf. M. subbulata Hantren
Pl. 5, fig. 4

Marginulina subbulata Hantren, Cushman, 1925, p. 62, pl. 10, fig. 3a, b; Mallory, 1959, p. 151, pl. 9, figs. 13a, b, 14a, b, 15a, b; Weaver and Molander, 1964, p. 183, pl. 6, fig. 7.

Marginulina cf. M. subbulata Hantren, Beck, 1943, p. 597, pl. 104, fig. 7.

Occurrence: Bastendorff.

Marginulina sp. A
Pl. 5, fig. 3

Description: Test large, wide, gently tapering from greatest width formed by last chamber to a subacute initial end. Test one-half as wide as long with the last chamber making up one-third of the length of the test. Five chambers gradually increasing in size. Early portion slightly coiled, later rectilinear. Sutures slightly depressed, nonlimbate and inclined. Aperture somewhat produced, radiate and angled to the opposite side of test as the initial chambers. Wall thin, smooth. Length 0.90mm, width 0.57mm, thickness 0.38mm.

Remarks: A single, slightly crushed specimen appears to be distinct from other specimens of Marginulina. The last chamber is less inflated and not as large as in Marginulina adunca (Costa) or M. inconspicua Hussey. It resembles "Marginulina sp." of Kleinpell

(1963, pl. 6, fig. 2a, b) except that the initial end is more pointed than the one in Kleinpell's figure. It is figured here for future reference.

Occurrence: Lower Coaledo.

Marginulina sp. B
Pl. 5, fig. 2

Description: Test small, twice as long as wide. Three chambers, of which the last two are slightly inflated and make up most of the test. Sutures slightly depressed, first suture inclined, later suture perpendicular to length of test. Aperture produced, terminal. Wall smooth, fairly thick.

Remarks: A single specimen is figured here for future reference.

Occurrence: Middle Coaledo.

Genus PLANULARIA Defrance in deBlainville, 1826

Planularia crepidula (Fichtel and Moll)
Pl. 4, figs. 18-21

Lenticulina cf. L. crepidula Fichtel and Moll. Church, 1931, pl. 6, figs. 8-11.

Planularia crepidula (Fichtel and Moll) var. Hornaday, 1965, p. 35, pl. 3, fig. 7.

Remarks: Specimens appear to be identical to the specimen figured by Hornaday (1965, pl. 3, fig. 7).

Occurrence: Middle Coaledo and Bastendorff.

Planularia tolmani Cushman and Simonson
Pl. 4, figs. 16, 17

Planularia tolmani Cushman and Simonson, 1944, p. 195, pl. 30, figs. 13, 14; Cushman and Stone, 1947, p. 5, pl. 1, fig. 12; Cushman, Stewart and Stewart, 1949, p. 130, pl. 14, fig. 9; Weaver and Molander, 1964, p. 183, pl. 6, fig. 3a, b.

Occurrence: Bastendorff.

Genus PSEUDONODOSARIA Buomgart, 1949

Pseudonodosaria conica (Neugeboren)
Pl. 9, fig. 2

Glandulina conica Neugeboren, 1850, p. 51, pl. 1, figs. 5a, b.

Pseudoglandulina conica Cushman and Barksdale, 1930, p. 65, pl. 12, figs. 1-3; Weaver and Molander, 1964, p. 185, pl. 6, fig. 18, pl. 7, fig. 1; Bird, 1967, p. 114, pl. 8, fig. 23.

Occurrence: Lower Coaledo.

Pseudonodosaria ovata (Cushman and Applin)
Pl. 9, fig. 1

Nodosaria (Glandulina) laevigata d'Orbigny var. ovata Cushman and Applin, 1926, p. 169, pl. 17, figs. 12, 13.

Pseudoglandulina ovata (Cushman and Applin) Mallory, 1959, p. 174, Sullivan, 1962, p. 266, pl. 11, figs. 2a, 1b, 3, 4; Weaver and Molander, 1964, p. 185, pl. 7, fig. 2.

Occurrence: Lower and middle Coaledo.

Genus PLECTOFRONDICULARIA Liebus, 1902

Plectofrondicularia garzaensis Cushman and Siegfus
Pl. 5, fig. 6

Plectofrondicularia garzaensis Cushman and Siegfus, 1939, p. 26, pl. 6, fig. 9; Cushman and Simonson, 1944, p. 197, pl. 31, fig. 19; Wilson, 1954, p. 138, pl. 15, fig. 7; Mallory, 1959, p. 212, pl. 18, fig. 1; Kleinpell and Weaver, 1963, p. 173, pl. 8, figs. 4, 9.

Remarks: Specimens compare well with illustrations in the publications listed above. Sullivan, 1962, (p. 271) considered *Plectofrondicularia garzaensis* to be a junior synonym of *Plectofrondicularia vaughani*. The only apparent difference between the two species that is discernable in published figures is that *P. vaughani* retains the alternating nature of the initial chambers in the adult form by an offset of the apertures of successive chambers. This feature may be of less than specific importance, and *P. garzaensis* may be a junior synonym of *P. vaughani*, but the author would wish to examine type material before officially placing the two in synonomy.

Occurrence: Lower Coaledo.

Plectofrondicularia packardi multilineata Cushman and Simonson
Pl. 5, fig. 14

Plectofrondicularia packardi Cushman and Schenck var. *multilineata*

Cushman and Simonson, 1944, p. 195, pl. 32, figs. 2-4; Detling, 1946, p. 355, pl. 49, figs. 3, 5; Rau, 1948, p. 171, pl. 30, fig. 19, (not. fig. 15); Smith, 1956, p. 94, pl. 12, fig. 6; Sullivan, 1962, p. 270, pl. 12, fig. 10; Rau, 1964, p. 16, pl. 5, fig. 13.

Plectofrondicularia gracilis Smith, 1956, p. 94, pl. 12, figs. 2-5.

Remarks: The genus _Plectofrondicularia_ displays considerable variation in form in rocks of Tertiary age in Washington, Oregon and California. _P. packardi multilineata_ Cushman and Simonson (1944) is a widely distributed variant that occurs throughout rocks of late Eocene, Oligocene and possibly early Miocene age, according to Rau (1964, p. 12). The author restricts the use of _P. packardi multinineata_ in this study to those forms possessing several long, straight costae. _P. gracilis_ Smith is placed in synonomy as it falls within the range of continuous variations observed in the specimens studied. Smith (1956, p. 93) in the original description stated that _P. gracilis_ is gradational with _P. packardi multilineata_. For additional comments see the remarks under _Plectofrondicularia packardi packardi_.

Occurrence: Lower and middle Coaledo.

Plectofrondicularia packardi packardi Cushman and Schenck
Pl. 5, fig. 7

Plectofrondicularia packardi Cushman and Schenck, 1928, p. 311, pl. 43, figs. 14-15; Cushman and Simonson, 1944, p. 197, pl. 31, figs. 17, 18, pl. 32, fig. 1; Detling, 1946, p. 355, pl. 49, fig. 1; Rau, 1951, p. 438, pl. 65, fig. 12; Wilson, 1954, p. 138, pl. 15, fig. 8.

Plectofrondicularia packardi Cushman and Schenck var. packardi Smith, 1956, p. 94, pl. 12, figs. 1, 7; Sullivan, 1962, p. 270, pl. 12, figs. 11, 12; Kleinpell and Weaver, 1963, p. 174, pl. 8, figs. 5-7, 10, 14; Rau, 1964, p. 17, pl. 5, figs. 15 (not fig. 13).

Remarks: Plectofrondicularia packardi packardi differs from P. packardi multilineata in having a few short costae rather than numerous long costae. The costae are sometimes curved on the initial chamber. Cushman, Stewart, and Stewart erected several new species from the Eocene rocks of western Oregon including P. searsi from the Coaledo Formation at Sunset Bay (1947, p. 78, pl. 10, fig. 5; pl. 11, fig. 8) and P. oregonensis from Helmick Hill (1947, p. 100, pl. 13, figs. 8, 9). The published figures of the holotypes vary considerably, and unfortunately paratypes were not deposited in the Oregon State Department of Geology and Mineral Industries as stated in the publications listed above. Topotype material from Sunset Bay and Helmick Hill have been examined and the specimens show a continuous gradation in size, thickness of test, and number and length of costae. The author has included forms similar to P. searsi and P. oregonensis within P. packardi packardi. More material should be studied before placing those forms in synonomy, however. Rau, (1969, personal communication) has investigated the stratigraphic significance of variations in ornamentation of P. packardi packardi but could find no clear trend. The variations in size, thickness of test and surface ornamentation observed in this genus may be environmentally controlled and merits further investigation.

Occurrence: Lower and middle Coaledo; Bastendorff.

Plectofrondicularia vokesi Cushman, Stewart and Stewart
Pl. 5, fig. 10

Plectofrondicularia vokesi Cushman, Stewart and Stewart 1949, p. 132, pl. 15, fig. 4; Mallory, 1959, p. 214, pl. 17, fig. 18; Sullivan, 1962, p. 271, pl. 13, fig. 10; Kleinpell and Weaver, 1963, p. 174, pl. 9, fig. 2; Bird, 1967, p. 117, pl. 9, fig. 25; McWilliams, 1968, p. 76, Hypotype 28409 examined.

Occurrence: Middle Coaledo and Bastendorff.

Plectofrondicularia sp. A
Pl. 5, fig. 8

Remarks: This form is characterized by the numerous large, very highly arched chambers. It resembles Plectofrondicularia gracilis as figured by Smith (1956), Kleinpell and Weaver (1963), and Fairchild, Wesenduck and Weaver (1969) in size and shape of chambers but is totally lacking in external costae. It is figured here for future reference.

Occurrence: Middle Coaledo and Bastendorff.

Plectofrondicularia sp. B
Pl. 5, fig. 9

Remarks: This form may be related to Plectofrondicularia sp. A above, but it is much smaller and has thicker sutures that are markedly depressed. Only a few specimens were found.

Occurrence: Bastendorff.

Plectofrondicularia sp. C
Pl. 5, fig. 11

Remarks: Only a single specimen of this large form was found. It has a thin wall with depressed, arched sutures. The wall is too thin to permit assignment of this specimen to P. robusta of Kleinpell and Weaver (1963).

Occurrence: Lower Coaledo.

Genus AMPHIMORPHINA Neugeboren, 1850

Amphimorphina californica Cushman and McMasters
Pl. 5, fig. 12

Amphimorphina californica Cushman and McMasters, 1936, p. 513, pl. 15, figs. 31-35; Mallory, 1959, p. 84, pl. 18, fig. 6; Bird, 1967, p. 118, pl. 9, figs. 21, 22.

Remarks: Mallory (1959) states that this form is restricted to the upper Ulatisian stage. Rau (1964) has found A. californica in Oregon and Washington in rocks that he considers may be early Narizian in age. It is common in samples from Sacchi Beach, but is not present in the Elkton Formation at Cape Arago or in the Coaledo Formation.

Occurrence: Elkton Formation at Sacchi Beach.

Amphimorphina jenkinsi (Church)
Pl. 5, fig. 13

Plectofrondicularia jenkinsi Church, 1931, p. 208, pl. A, figs, 4, 5, 7-9; Detling, 1946, p. 355, pl. 49, figs. 2, 8.

Amphimorphina jenkinsi (Church) Mallory, 1959, p. 216, pl. 18, fig. 5; Sullivan, 1962, p. 272, pl. 13, fig. 15; Kleinpell and Weaver, 1963, p. 174, pl. 9, fig. 13.

Remarks: This species is common in samples from the middle member of the Coaledo Formation. Immature or broken specimens of less than six chambers do not show the typical four-sided end view. Specimens called Plectofrondicularia jenkinsi Church by Detling (1946) are included here.

Occurrence: Middle Coaledo.

Family POLYMORPHINIDAE

Genus GLOBULINA d'Orbigny, 1839

Globulina sp.
Pl. 6, fig. 2

Remarks: A single specimen of Globulina was found. It is similar to Globulina gibba globosa (Von Munster) as figured by Cushman (1935) and Mallory (1959). More material is needed for positive identification.

Occurrence: Bastendorff.

Genus GUTTULINA d'Orbigny, 1839

Guttulina problema d'Orbigny
Pl. 6, fig. 1

Guttulina problema d'Orbigny, 1826, p. 226, no. 14; Cushman and Schenck, 1928, p. 310, pl. 43, figs. 9-11; Detling, 1946, p. 354, pl. 48, fig. 11; Kleinpell and Weaver, 1963, p. 172, pl. 7, fig. 15.

Globulina irregularis d'Orbigny, 1846, p. 226, pl. 13, figs. 9, 10.

Guttulina irregularis (d'Orbigny) Beck, 1943, p. 602, pl. 106, figs. 3, 15; Cushman and Simonson, 1944, p. 196, pl. 31, figs. 10-12, Sullivan, 1962, p. 267, pl. 11, fig. 8a-c; Bird, 1967, p. 120, pl. 9, figs. 14-16.

Remarks: This is a highly variable species. Cushman and Simonson (1944) indicated that the Bastendorff and Tumey forms were probably the same. Wilson (1954, p. 137) thought that at least some of the specimens from the Keasey, Tumey and Gaviota Formations were identical. Smith (1956, p. 92) and Kleinpell and Weaver (1963, p. 172) have indicated that Guttulina problema and G. irregularis are conspecific.

Occurrence: Middle Coaledo and Bastendorff.

Family TURRILINIDAE

Genus BULIMINELLA, 1911

Buliminella bassendorfensis? Cushman and Parker
Pl. 6, fig. 13

Buliminella bassendorfensis Cushman and Parker, 1937, pp. 40, 53, pl. 4, fig. 13; Cushman and Parker, 1947, p. 66, pl. 17, fig. 6; Cushman and Stewart, R. E. and Stewart, K. E., 1947, p. 46, pl. 5, fig. 8.

Remarks: Poorly preserved, crushed specimens may be referrable to this species. *Buliminella bassendorfensis* was described by Cushman and Parker (1937, pp. 40, 53) from beds called the "Bassendorf shale", which crop out along the south side of Alsea Bay, Lincoln County, Oregon. Cushman, Stewart, R. E. and K. E. Stewart have reported that the form is identical with specimens from the Astoria Formation at Agate Beach, Lincoln County, Oregon (1947, p. 46). Rau, (1964, p. 17) reports *Buliminella subfusiformis* Cushman from rocks of Zemorrian and Saucesian ages including the upper portion of the Twin River Formation in Washington and the Astoria Formation and Nye Mudstone in Oregon. Mallory (personal communication, 1969) indicated that R. E. and K. E. Stewart had examined specimens of *Buliminella subfusiformis* and *B. bassendorfensis* and considered them to be conspecific. Sullivan, (1962, p. 273, text fig. 5) reports *B. subfusiformis* from the Butano Formation of Narizian age but does not place *B. bassendorfensis* in synonomy. The author has not examined specimens of *B. subfusiformis* and hence has not placed it in synonomy with *B. bassendorfensis*. The two forms should be studied, however, for if they are identical it would indicate that *B. subfusiformis* is not restricted to rocks of Zemorrian and Sauresian ages but occurs in older rocks in Oregon.

Occurrence: Lower and middle Coaledo; Bastendorff.

Buliminella? sp.
Pl. 6, fig. 4

Remarks: A single, poorly preserved, small specimen is tentatively placed in the genus *Buliminella*. Additional material is needed for positive identification.

Occurrence: Middle Coaledo.

Family BOLIVINITIDAE

Genus BRIZALINA Costa, 1856

Brizalina basisenta (Cushman and Stone)
Pl. 6, fig. 5

Bolivina basisenta Cushman and Stone, 1947, p. 15, pl. 2, fig. 20; Cushman, Stewart and Stewart, 1947, p. 61, pl. 8, fig. 7; p. 102, pl. 13, fig. 6; Cushman, Stewart and Stewart, 1949,

p. 133, pl. 15, fig. 8; Bird, 1967, p. 122, pl. 9, figs. 9, 10.

Bolivina basisenta Cushman and Stone var. oregonensis Cushman, R. E. Stewart and K. E. Stewart, 1947, p. 133, pl. 15, fig. 7.

Occurrence: Lower and middle Coaledo; Bastendorff.

Brizalina huneri (Howe)
Pl. 6, fig. 6

Bolivina huneri Howe, 1939, p. 66, pl. 9, fig. 3, 4; Beck, 1943, p. 606, pl. 107, fig. 21; Weaver and Molander, 1964, p. 191, pl. 9, fig. 8.

Remarks: Cushman topotype materials of Brizalina jacksonensis (Cushman and Applin) B. jacksonensis tumeyensis (Cushman and Applin), B. jacksonensis striatella (Cushman and Applin), and B. huneria (Howe) were examined in collections of the Burke Memorial Museum at the University of Washington. All of the forms are very similar and appear to vary only in degree of inflation of the test, limbosity of sutures and the presence or absence of striae. Bolivina huneri possesses distinct striae covering all but the last two chambers, whereas, B. jacksonensis striatella has striae covering about one-half of the test. Brizalina huneri is common in some samples from the Coos Bay region but forms similar to B. jacksonensis striatella were very rare. A discussion of B. jacksonensis and B. jacksonensis tumeyensis appears below.

Occurrence: Bastendorff.

Brizalina jacksonensis (Cushman and Applin)

Bolivina jacksonensis Cushman and Applin, 1926, p. 167, pl. 7, figs. 3, 4; Wilson, 1954, p. 140, pl. 15, fig. 15a, b; Weaver and Molander, 1964, p. 191, pl. 9, fig. 9.

Bolivina jacksonensis Cushman and Applin var. tumeyensis Cushman and Simonson, 1944, pl. 199, pl. 32, fig. 16; Kleinpell and Weaver, 1963, pl. 176, pl. 9, fig. 7a, b.

Bolivina cf. B. jacksonensis Cushman and Applin. Detling, 1946, p. 357, pl. 50, fig. 4; Bird, 1967, p. 122, pl. 9, figs. 17, 18.

Remarks: Comparisons were made with Cushman topotype material in the collections of the Burke Memorial Museum of the University of Washington. Within the same sample individual specimens could be found that were identical to Brizalina jacksonensis and B. jacksonensis tumeyensis. The varietal form is within the range of variation for the species and does not appear to be a distinct form.

Occurrence: Lower and middle Coaledo.

Brizalina sp.
Pl. 6, fig. 7

Remarks: A single, small specimen is figured here for future reference.

Occurrence: Lower Coaledo.

Family EOUVIGERINIDAE

Genus STILOSTOMELLA Guppy, 1894

Stilostomella cf. S. adolphina (d'Orbigny)
Pl. 9, fig. 8

Dentalina adolphina d'Orbigny, 1846, p. 51, pl. 2, figs. 18-20; Cushman and Schenck, 1928, p. 308, pl. 42, fig. 6; Rau, 1948, p. 166, pl. 29, fig. 6.

Nodosaria adolphina (d'Orbigny) Cushman and G. D. Hanna, 1927, p. 213, pl. 13, figs. 8. 9.

Nodogenerina adolphina (d'Orbigny) Mallory, 1959, p. 216, pl. 18, fig. 8a, b; pl. 41, fig. 10; Weaver and Molander, 1964, p. 188, pl. 8, fig. 8.

Remarks: This is a highly variable form. It appears to be distinct from Nodogenerina lepidula (Schwager) in having more elongate spines and less oppressed sutures, resulting in a straighter outline of the test.

Occurrence: Bastendorff.

Stilostomella cooperensis (Cushman)
Pl. 9, fig. 6

Nodogenerina cooperensis Cushman, 1933, p. 11, pl. 1, fig. 27; Mallory, 1959, p. 177, pl. 18, fig. 13; Weaver and Weaver, 1962, p. 29, pl. 8, fig. 8; Weaver and Molander, 1964, p. 188, pl. 8, fig. 10.

Ellipsonodosaria sp. B Cushman, Stewart and Stewart, 1949, p. 134, pl. 15, fig. 11.

Stilostomella cooperensis (Cushman) Bird, 1967, p. 125, pl. 10, fig. 4.

Occurrence: Lower and middle Coaledo; Bastendorff.

Stilostomella lepidula (Schwager)
Pl. 9, fig. 7

Nodosaria lepidula Schwager, Galloway and Morrey, 1931, p. 337, pl. 38, fig. 1.

Nodogenerina lepidula (Schwager) Cushman, 1948, p. 531, p. 26, fig. 36; Mallory, 1959, p. 217, pl. 18, fig. 10; Weaver and Weaver, 1962, p. 29, pl. 8, fig. 9; Weaver and Molander, 1964, p. 189, pl. 8, fig. 11.

Ellipsonodosaria sp. Cushman, Stewart and Stewart, 1947, p. 102, pl. 12, figs. 9, 9a, b.

Remarks: This species is a distinctive form that is common in late Eocene rocks of Western Oregon.

Occurrence: Lower and middle Coaledo; Bastendorff.

Stilostomella sp.
Pl. 9, fig. 10

Remarks: A single specimen was found that resembles Stilostomella lepidula except that the spines are more elongate and located all over each chamber rather than in a row.

Occurrence: Bastendorff.

Family BULIMINIDAE

Genus BULIMINA d'Orbigny, 1826

Bulimina _cf._ _B._ _alsatica_ Cushman and Parker
Pl. 6, fig. 8

Bulimina _alsatica_ Cushman and Parker, 1937, p. 39, pl. 4, figs. 6, 7; Cushman and Parker, 1947, p. 102, pl. 24, figs. 10, 11; Rau, 1964, p. 18, pl. 5, fig. 16.

Remarks: A single specimen was found that is considered by W. W. Rau to belong to this species (personal communication, 1969).

Occurrence: Middle Coaledo.

Bulimina _corrugata_ Cushman and Siegfus
Pl. 6, fig. 9

Bulimina _corrugata_ Cushman and Siegfus, 1936, p. 92, pl. 14, fig. 7; Mallory, 1959, p. 189, pl. 28, fig. 13; Weaver and Weaver, 1962, p. 31, pl. 9, fig. 3; Kleinpell and Weaver, 1963, p. 175, pl. 9, fig. 12; Rau, 1964, p. 17, pl. 5, fig. 11; Bird, 1967, p. 126, pl. 10, figs. 7, 8.

Remarks: Rau, (1964, p. 17, 18) considers that the highest occurrence of _Bulimina_ _corrugata_ in rocks from Oregon and Washington is of early late Eocene age. According to Mallory (1959, p. 57-59) it occurs in California in rocks of Ulatisian and Narizian stages.

Occurrence: Lower and middle Coaledo.

Bulimina microcostata Cushman and Parker
Pl. 6, figs. 10, 11

Bulimina microcostata Cushman and Parker, 1937, p. 47, pl. 6, figs. 4, 5; Kleinpell and Weaver, 1963, p. 175, pl. 9, fig. 13; Mallory, 1956, p. 194, pl. 16, fig. 9; Sullivan, 1962, p. 274, pl. 14, fig. 6a, b; Weaver and Molander, 1964, p. 189, pl. 8, fig. 18.

Remarks: This species is common in rocks of Narizian age in California but has not been reported from Washington or Oregon. It is abundant in some samples from the middle member of the Coaledo Formation. The portion of the test covered by striae is variable. Some specimens have striae on all chambers except the last, as illustrated by Kleinpell and Weaver (1963), but others have striae on only one-half of the test as illustrated by Weaver and Molander (1964).

Occurrence: Middle Coaledo.

Bulimina schencki Beck
Pl. 6, fig. 12

Bulimina schencki Beck, 1943, p. 605, pl. 107, figs. 28, 33; Mallory, 1959, p. 196, pl. 16, fig. 15; Rau, 1964, p. 18, pl. 5, fig. 10; Bird, 1967, p. 129, pl. 10, fig. 3.

Occurrence: Elkton; Lower, middle and upper Coaledo; Bastendorff.

Bulimina sculptilis Cushman and Schenck
Pl. 6, fig. 13

Bulimina sculptilis Cushman and Schenck, 1928, p. 311, pl. 43, fig. 16; Wilson, 1954, p. 193, pl. 15, fig. 12a, b; Smith, 1956, pp. 95-96, pl. 12, fig. 9, pl. 13, fig. 4a, b; Sullivan, 1962, p. 274, pl. 14, fig. 8a, b; Kleinpell and Weaver, 1963, p. 175, pl. 9, figs. 9, 10, 14; Weaver and Molander, 1964, p. 190, pl. 9, figs. 3a, b; 4a, b.

Bulimina sculptilis Cushman and Schenck var. lacinata Cushman and Parker, 1937, p. 38, pl. 4, figs. 4a-c; Cushman and Parker, 1947, p. 103, pl. 24, fig. 13a, b; Rau, 1951, p. 441, pl. 65, fig. 22; Rau, 1964, p. 18, pl. 6, fig. 1.

Bulimina cuneata (Cushman) Detling, 1946, p. 356, pl. 49, figs. 13, 15, 16.

Remarks: This form was first described from the Bastendorff Formation and has since been reported from many localities in California and Washington. Bulimina sculptilis lacinata does not appear to be a distinct form. A Narizian species, Bulimina lirata, appears to be a juvenile form of B. sculptilis and probably should be placed in synonomy.

Occurrence: Middle Coaledo and Bastendorff.

Bulimina? sp.
Pl. 9, fig. 5

Pseudopolymorphina? sp. Detling, 1946, p. 354, pl. 49, figs. 11, 12, 14.

Remarks: This species is common in some samples from both the Coaledo and Bastendorff Formations. The specimens are all very large and have extremely thin tests so that, although scores of specimens were examined, all of them were crushed and no complete specimens were found. The aperture was not observed and the exact shapes and arrangement of chambers could not be determined.

Occurrence: Middle Coaledo and Bastendorff.

Bulimina spp.

Remarks: Unidentifiable fragments of Bulimina other than those assigned to Bulimina? sp. above are placed here.

Genus GLOBOBULIMINA Cushman, 1927

Globobulimina pacifica Cushman
Pl. 9, figs. 3, 4

Globobulimina pacifica Cushman, 1927, p. 67, pl. 14, fig. 12; Beck, 1943, p. 606. pl. 107, fig. 16; Rau, 1948, p. 171, pl. 30, fig. 5; Weaver and Weaver, 1962, p. 32, pl. 9, fig. 15; Kleinpell and Weaver, 1963, p. 176, pl. 9, fig. 11; Fairchild, Wesenduck and Weaver, 1969, p. 55, pl. 11, figs. 16a, b.

Globobulimina pacifica oregonensis Cushman, Stewart and Stewart, 1947, p. 101, pl. 12, figs. 13a, b.

Remarks: *Globobulimina pacifica* is a common form in rocks from the West Coast of Tertiary age. There is considerable variation in the shape of specimens assigned to this species. Two specimens are figured to show the range in degree of inflation of the test found in rocks from Coos Bay. Included here are large rounded specimens assigned to *G. pacifica oregonensis* by Cushman, Stewart and Stewart (1947). Bandy and Kolpack (1963) considered *G. pacifica oregonensis* to be a junior synonym of *Globobulimina pyrula*, but the author considers the two forms to be distinct.

Occurrence: Lower, middle and upper Coaledo; Bastendorff.

Genus PRAEGLOBOBULIMINA Hofker, 1951

Praeglobobulimina? ovata (d'Orbigny)
Pl. 6, fig. 15

Bulimina ovata d'Orbigny, Cushman, 1921, p. 164, text fig. 4; Kleinpell and Weaver 1963, p. 175, pl. 9, fig. 8; Sullivan, 1962, p. 274, pl. 14, fig. 7a, b; Weaver and Molander, 1964, p. 189, pl. 8, fig. 19.

Bulimina ovata d'Orbigny var. *cowlitzensis* Beck, 1943, p. 605, pl. 107, fig. 22; Weaver and Weaver, 1962, p. 32, pl. 9, figs. 10, 11,

Praeglobobulimina ovata (d'Orbigny) Fairchild, Wesendunk and Weaver, 1969, p. 55, pl. 11, fig. 19.

Remarks: A series of gradational forms between *Bulimina ovata* and *B. ovata cowlitzensis* was observed in the samples studied. According to Loeblich and Tappan (1964, p. 559) *Praeglobobulimina* differs from *Bulimina* in lacking well developed borders of the tooth plate. They describe the tooth plate of *Praeglobobulimina* as having a simple fold and fixed shank joined to the anterior wall below the aperture. Preservation of the specimens was such that the nature of the tooth plate could not be determined. The specimens are questionably placed in the Genus *Praeglobobulimina* following the work of Fairchild, Wesenduck and Weaver (1969).

Occurrence: Lower and middle Coaledo; Bastendorff.

Praeglobobulimina? aff. *P. pyrula* (d'Orbigny)
Pl. 6, fig. 14

Bulimina aff. *B. pyrula* d'Orbigny, Mallory, 1959, p. 196, pl. 28, fig. 17a-c; Weaver and Molander, 1964, p. 190, pl. 9, fig. 1a-c.

Praeglobobulimina cf. *P. pyrula* (d'Orbigny) Fairchild, Wesendunk and Weaver, 1969, p. 55, pl. 11, fig. 13; pl. 12, fig. 1.

Remarks: Specimens resembling *Bulimina ovata* d'Orbigny but possessing a pronounced tapered appearance due to the small initial chambers are here. See comments above concerning the genus *Praeglobobulimina*.

Occurrence: Middle Coaledo.

Family UVIGERINIDAE

Genus UVIGERINA d'Orbigny, 1826

Uvigerina atwilli Cushman and Simonson
Pl. 6, fig. 16

Uvigerina atwilli Cushman and Simonson, 1944, p. 200, pl. 33, figs. 2-4; Detling, 1946, p. 357, pl. 50, figs. 5, 6; Rau, 1951, p. 444, pl. 65, fig. 21; Wilson, 1954, p. 140, pl. 16, fig. 1a, b; Smith, 1956, p. 96, pl. 12, fig. 10; Sullivan, 1962, p. 277, pl. 16, figs. 5, 6a, b, 7; Kleinpell and Weaver, 1963, p. 177, pl. 10, figs. 2a, b, 3.

Occurrence: Bastendorff.

Uvigerina jacksonensis Cushman
Pl. 6, fig. 17

Uvigerina jacksonensis Cushman, 1925, p. 67, pl. 10, fig. 13; Lamb, 1964, p. 462, pl. 1, figs. 5-9.

Uvigerina cocoaensis Cushman, 1925, p. 68, pl. 10. fig. 12; Cushman and Schenck, 1928, p. 312, pl. 43, figs. 17-19; Cushman and Simonson, 1944, p. 199, pl. 33, fig. 1; Rau, 1951, p. 444, pl. 65, fig. 28; Wilson, 1954, p. 140, pl. 16, fig. 2; Smith, 1956, p. 96, pl. 12, fig. 11; Kleinpell and Weaver, 1963, p. 177, pl. 10, fig. 5; Rau, 1964, p. 20, pl. 6, fig. 5.

Remarks: This species was originally described from the Gulf

Coast and is widespread in rocks from California, Oregon and Washington. Rau, (1964, p. 20) considers that it is restricted to rocks of Refugian age on the West Coast. Uvigerina cocoaensis Cushman and U. jacksonensis Cushman are two similar species that were described from the same locality near the old Cocoa Post Office, Alabama. Lamb, (1964, p. 463) studied the type locality and found that specimens of U. jacksonensis greatly outnumber those assigned to U. cocoaensis and that the two forms are gradational and hence conspecific. Of the two, Uvigerina jacksonensis has priority. Uvigerina atwilli is very closely related to U. jacksonensis but is probably not conspecific. In the Bastendorff Formation it is locally much more abundant than U. jacksonensis. The same relationship exists in the Tumey Formation of California according to Lamb (1964, p. 463). Forms called U. curta may be juveniles of U. jacksonensis.

Occurrence: Bastendorff.

Uvigerina gardnerae Cushman
Pl. 6, fig. 18

Uvigerina gardnerae Cushman (in Cushman and Applin), 1926, p. 175, pl. 8, figs. 16, 17; Smith, 1957, p. 177, pl. 26, fig. 7a-c; Kleinpell and Weaver, 1963, p. 177, pl. 10, fig. 6; Weaver and Molander, 1964, p. 191, pl. 9, figs. 12, 13a-c.

Occurrence: Bastendorff.

Uvigerina garzaensis Cushman and Siegfus
Pl. 6, fig. 19

Uvigerina garzaensis Cushman and Siegfus, 1939, p. 28, pl. 6, fig. 15; Cushman and Simonson, 1944, p. 199, pl. 32, figs. 20, 21; Detling, 1946, p. 357, pl. 50, fig. 8; Rau, 1951, p. 445, pl. 65, fig. 19; Smith, 1956, p. 97, pl. 13, fig. 2a, b; Mallory, 1959, p. 208, pl. 37, fig. 2a, b; Sullivan, 1962, p. 277, pl. 16, figs. 2, 3a, b; Weaver and Weaver, 1962, p. 34, pl. 10, fig. 11; Kleinpell and Weaver, 1963, p. 177, pl. 10, fig. 7; Rau, 1964, p. 20, 21, pl. 6, fig. 6; Weaver and Molander, 1964, p. 191, pl. 10. fig. 1.

Remarks: This widespread species occurs in rocks of Narizian and Refugian age on the West Coast and is indicative of lower bathyal depths.

Occurrence: Middle Coaledo and Bastendorff.

Uvigerina yazooensis Cushman
Pl. 6, fig. 20

Uvigerina yazooensis Cushman, 1933, p. 13, pl. 1, fig. 29; Mallory, 1959, p. 210, pl. 37, fig. 4a, b; Weaver and Weaver, 1962, p. 35, pl. 10, fig. 12.

Remarks: Specimens compare well with Cushman's type figures but are thinner, possess more chambers and have larger, more irregular costae than the figures of Mallory or Weaver and Weaver. A few specimens resemble _U. churchi_ Cushman and Siegfus as figured by Weaver and Weaver (1962, pl. 10, fig. 10) except that they possess larger and more irregular costae. _Siphogenerina mayi_ as figured by Fairchild, Wesenduck and Weaver (1969, pl. 13, fig. 3) appears to be quite similar, but the authors state that _S. mayi_ first appears in the upper Zemorrian stage in California.

Occurrence: Lower Coaledo.

Uvigerina? sp.
Pl. 6, figs. 21, 22

Remarks: This small, distinctive form may be a new species. It is characterized by its small size, compressed test and fine striations on all of the chambers. More material is needed before a new species can be erected, however.

Occurrence: Middle Coaledo.

Uvigerina spp.

Remarks: Steinkerns and unidentified, broken fragments are placed here.

Genus TRIFARINA Cushman, 1923

Trifarina hannai (Beck)
Pl. 9, fig. 9

Angulogerina hannai Beck, 1943, p. 607, pl. 108, fig. 26, 28; Cushman, Stewart and Stewart, 1947, p. 102, pl. 12, fig. 16.

Occurrence: Lower and middle Coaledo.

Family HETEROHELICIDAE

Genus CHILOGUEMBELINA Loeblich and Tappan, 1956

Chiloguembelina cubensis (Palmer)
Pl. 7, fig. 1

Gumbelina cubensis Palmer, 1934, p. 74, text-figs. 1-6.

Chiloguembelina cubensis (Palmer) Srinivasan, 1968, p. 142, pl. 13, fig. 1.

Occurrence: Bastendorff.

Family HANTKENINIDAE

Genus PSEUDOHASTIGERINA Blow and Banner, 1959

Pseudohastigerina micra (Cole)
Pl. 7, figs. 2, 3

Nonion micrus Cole, 1927, p. 22, pl. 5, fig. 12; Cushman, 1939, p. 5, pl. 1, fig. 20-22; Mallory, 1959, p. 181, pl. 15, fig. 3a-c; pl. 28, fig. 12a, b.

Hastigerina micra (Cole), Bolli, 1957, p. 161, pl. 35, figs. 1a-2b; Hartono, 1969, p. 158, pl. 20, figs. 6, 7.

Pseudohastigerina micra (Cole), Banner and Blow, 1959, pp. 19-20, text-figs. 4g-i; Berggren, Olsson and Reyment, 1967, p. 280, text-fig. 9; Samanta, 1969, p. 342, pl. 1, fig. 6a, b; Samanta, 1970, p. 210, pl. 3, fig. 5, 6; Cordey, Berggren and Olsson, 1970, p. 239, text-fig. 5, figs. 27-32.

Globanomalina micra (Cole), Loeblich and Tappan, 1964, fig. 531 (6-8); Bird, 1967, p. 138, pl. 12, figs. 4, 5; Srinivasan, 1968, p. 145, pl. 13, figs. 3, 4.

Remarks: This species is common, widespread and easily recognized in rocks of middle and late Eocene age. It has been assigned to various genera, however. Loeblich and Tappan (1964, p. 665) considered the genus Pseudohastigerina to be a junior synonym of Globanomalina. They redefined the genus Globanomalina to include planispiral and slightly assymmetrical forms and placed forms that were distinctly trochospiral in the genus Globorotaloides. Berggren and and Olsson (1967) have disagreed with the redefinition of Globanomalina proposed by Loeblich and Tappan (1964). They consider that Globanomalina should be used as originally defined by Haque (1956, p. 147) to include forms whose chambers were arranged in a trochoid spiral, usually very low. In their studies of the evolution of the members of genus Pseudohastigerina they have found forms transitional between trochospiral and planispiral coiling. Berggren and Olsson (1967, p. 28) emended Pseudohastigerina Blow and Banner to include planispiral and slightly asymmetric forms and to exclude the low-spired trochospiral forms which were originally included in the definition of the genus Globanomalina Haque. The concepts of Berggren and Olsson

(1967) that Pseudohastigerina wilcoxensis (Cushman and Ponton) is the earliest member of the genus and that it evolved from Globorotalia chapmani Parr. Cordley, Berggren and Olsson (1970) believe that P. micra (Cole) arose from P. wilcoxensis in late middle Eocene time.

Occurrence: Lower and middle Coaledo.

Pseudohastigerina aff. P. micra (Cole)
Pl. 8, figs. 18, 19

Remarks: A few specimens which are included here show a definite tendency towards a compression of the periphery of the last two chambers of the test producing a "keel-like" appearance. They resemble forms figured by Hartono (1969, pl. 20, fig. 7b) and Samanta (1969, pl. 1, fig. 7b). Cordey, Berggren and Olsson (1970, text-fig. 5, figs. 18-20) show a form intermediate between P. wilcoxensis and P. micra which resembles P. aff. P. micra except for greater inflation of the last chambers in their figured specimens.

Occurrence: Lower and middle Coaledo.

Family GLOBOROTALIIDAE

Genus GLOBOROTALIA Cushman, 1927

Globorotalia gemma Jenkins
Pl. 8, figs. 13, 14, 15

Globorotalia gemma Jenkins, 1965a, p. 1115, fig. 11, nos. 97-103; Samanta, 1969, p. 334, pl. 2, figs. 3a-c; Samanta, 1970, p. 36, pl. 6, figs. 4, 5.

<u>Turborotalia gemma</u> (Jenkins) Srinivasan, 1968, p. 146, pl. 14, figs. 3, 4, 11-13.

<u>Remarks</u>: A few specimens are identical to published figures of <u>Globorotalia gemma</u>. Many specimens are similar to <u>G. gemma</u> except that they have four chambers in the last whorl rather than four and one-half to six chambers as described by Jenkins (1965). They are referred to <u>G.</u> cf. <u>G. gemma</u> described below. Loeblich and Tappan (1964, p. 668) restricted the genus <u>Globorotalia</u> to forms possessing a non-preforate peripheral band or keel and <u>Turborotalia</u> to forms with ovate or rounded chambers lacking a keel. The author believes that the presence or absence of a keel may not be of generic significance and has followed the practice of Jenkins (1965), Hortono (1969), Samanta (1969, 1970a, 1970b), and Berggren (1969) by including both keeled forms and forms assigned to <u>Turborotalia</u> by Loeblich and Tappan within the genus <u>Globorotalia</u>.

<u>Occurrence</u>: Bastendorff.

<u>Globorotalia</u> cf. <u>G. gemma</u> Jenkins
Pl. 7, figs. 29, 30, 31

<u>Remarks</u>: Specimens placed here are very closely related to <u>Globorotalia gemma</u> Jenkins. They differ in that they possess four chambers in the final whorl, rather than four and one-half to six as described by Jenkins (1965), and the last chamber is inflated and hides the umbilicus. These specimens are much more numerous in

samples from the upper portion of the Bastendorff Formation than forms that can definitely be assigned to *G. gemma*.

Occurrence: Bastendorff.

Globorotalia increbescens? (Bandy)
Pl. 7, figs. 20, 21, 22

Globigerina increbescens Bandy, 1949a, p. 120, pl. 23, figs. 3a-c.

Globorotalia (*Turborotalia*) *increbescens* (Bandy) Blow and Banner, 1962, p. 118, pl. XIII T-V, IVII D, K.

Turborotalia increbescens (Bandy) Srinivasan, 1968, p. 146, pl. 14, figs. 5-7.

Globorotalia increbescens (Bandy) Samanta, 1970a, p. 36, pl. 6, figs. 26, 27.

Remarks: Several authors have described the close relationship between *Globorotalia increbescens* and *G. opima nana*. *G. increbescens* is a larger form with a more arched aperture and a more coarsely perforate wall. Identification of specimens is tentative because of poor preservation and few specimens. Specimens studied are less trochoid and have lower apertures than figured specimens of Bandy (1949) and Blow and Banner (1962). They compare well with figures of Srinivasan (1968) and are clearly not *G. gemma* or *G. opima nana*.

Occurrence: Bastendorff.

Globorotalia opima nana Bolli
Pl. 8, figs. 16, 17

Globorotalia opima nana Bolli, 1957, p. 118, pl. 28, fig. 3a-c; Samanta, 1969, p. 334, pl. 3, figs. 4a-c (synonomy); Samanta, 1970a, p. 37, pl. 6, figs. 11, 12.

Globigerina opima nana (Bolli) Todd, 1966, p. 133, pl. 9, figs. 3-4.

Turborotalia opima nana (Bolli) Srinivasan, 1968, p. 146, pl. 14, figs. 1, 2.

Occurrence: Bastendorff.

Globorotalia sp.
Pl. 7, figs. 14, 15, 16

Description: Shape of test very low trochospiral; equatorial periphery lobate; axial periphery rounded with no trace of a keel. Wall calcareous, thin, finely perforate with distinct clear spots (may have fewer perforations). Chambers inflated; 5 in last whorl; about two and one-half whorls; chambers of the last whorl increasing fairly rapidly in size. Sutures slightly curved; depressed. Umbilicus small; partially hidden by last chamber. Aperture a thin slit with a distinct border of thickened test material only slightly raised; interio-marginal at umbilical end becoming interio-areal at distal end, not visible in view of ventral side. Dimensions: diameter 0.25-0.27mm; thickness 0.10-0.12mm.

Remarks: Only two specimens of this form were found. They are very similar to Globorotalia gemma except for dark spots in the test, which may indicate areas that are non-perforate, and the nature of the aperture, which is a very thin slit located in the terminal face of the last chamber rather than being interio-marginal. It is found in the same stratigraphic range as specimens described above as G. gemma and G. cf. G. gemma.

Occurrence: Bastendorff.

Family GLOBIGERINIDAE

Subfamily GLOBIGERININAE

Genus GLOBIGERINA d'Orbigny, 1826

Globigerina angiporoides? Hornibrook
Pl. 8, fig. 26

Globigerina angiporoides Hornibrook, 1965, p. 835, figs. 1a-i, 2; Srinivasan, 1968, p. 147, pl. 15, fig. 9; Samanta, 1969, p. 330, pl. 3, figs. 1a-c.

Remarks: A single specimen is similar to published figures of Globigerina angiporoides Hornibrook. More material is needed for positive identification.

Occurrence: Middle Coaledo.

Globigerina anguistiumbilicata Bolli
Pl. 7, figs. 17-19

Globigerina ciperoensis angustimbilicata Bolli, 1957, p. 109, pl. 22, figs. 12a-13c.

Globigerina angustiumbilicata Bolli, Blow, 1959, p. 172, pl. 7, figs. 22a-c, 34; Samanta, 1969a, p. 31, pl. 6, fig. 3; Samanta, 1969b, p. 330, pl. 1, figs. 1a-c; Samanta, 1970, p. 189, pl. 1, fig. 1.

Occurrence: Middle Coaledo.

Globigerina eocaena? Gumbel
Pl. 7, figs. 8, 9, 10

Globigerina eocenica Gumbel, 1868, p. 662, pl. 2, figs. 109a, b; Samanta, 1969, pp. 330-331, text-figs. 1a-c.

Globigerina (Subbotina) eocaena Gumbel. Hagn and Lindenberg, 1966, pp. 349-355, pl. 1, figs. 1-6, text-figs. 3-4a.

Remarks: Because the original description was not adequate, it was restudied in detail by Hagn and Lindenberg (1966). The author has not been able to study the paper by Hagn and Lindenberg and has relied upon the discussion and illustrations of Samanta (1969, pp. 330-331) for identification of the species. Specimens studied resemble those figured by Samanta (text-fig. 1a-c). The shape and position of the aperture and chambers of Globigerina eocaena is similar to G. officinalis, but the former differs in having a definite apertural lip and a more triangular shape of the dorsal side of the test. Subbotina (Globigerina) yeguaensis is a less compact form having a larger final chamber and a larger, more irregular apertural lip than *G. eocaena*. This form is definitely not *G. eocaenica* Terquem as figured by Subbotina (1953).

Occurrence: Middle Coaledo.

Globigerina prasaepis? Blow
Pl. 8, figs. 1-3

Globigerina prasaepis? Blow, 1969, p. 382, pl. 10, fig. 13; McKeel, 1972, p. 62, pl. V, fig. 1.

Remarks: A few specimens resemble those figured by Blow (1969) and McKeel (1972) although positive identification could not be made.

Occurrence: Middle Coaledo and Bastendorff.

Globigerina praebulloides occlusa Blow and Banner
Pl. 8, figs. 20, 21, 22

Globigerina praebulloides occlusa Blow and Banner, 1962, pp. 93-94, pl. 9, figs. U-W; Samanta, 1969, p. 331, pl. 1, figs. 5a-c; Samanta, 1970, p. 33, pl. 6, figs. 6-8; Samanta, 1970b, p. 191, pl. 1, figs. 5-6.

Occurrence: Middle Coaledo.

Globigerina senilis Bandy
Pl. 8, figs. 4, 5, 6, 10, 11, 12

Globigerina ouachitaensis Howe and Wallace, var. *senilis* Bandy, 1949a, p. 121, pl. 22, fig. 5a-c.

Globigerina senilis Bandy. Blow and Banner, 1962, pp. 95-96, pl. 11, figs. R-U; Samanta, 1970a, p. 34, pl. 7, figs. 3-5; Samanta, 1970b, p. 192, pl. 1, fig. 4.

Remarks: *Globigerina senilis* was originally described by Bandy (1949) as a variety of *G. ouachitaensis* Howe and Wallace. Blow and Banner (1962), based upon examination of specimens from Tanganyika, East Africa, considered the form to be specifically distinct from *G. ouachitaensis*. This form is common in the Coos Bay material where specimens fit the description of *G. senilis* in having a small test, lobate periphery, four chambers in the last whorl with a final chamber smaller than the penultimate and a low, umbilical aperture. Individuals similar to *G. ouachitaensis*, with the final chamber larger than the penultimate were not observed.

Occurrence: Middle Coaledo and Bastendorff.

Globigerina tripartita tripartita Koch
Pl. 8, figs. 7, 8, 9

Globigerina bulloides d'Orbigny car. *tripartita* Koch, 1926, p. 746, text-fig. 21a, b.

Globigerina tripartita tripartita Koch. Blow and Banner, 1962, pp. 96-97, pl. 10, figs. A-F, text-fig. 18; Samanata, 1969, p. 332, pl. 3, figs. 6a-c.

Remarks: Specimens compare closely with the description and illustrations of *G. tripartita tripartita* Koch of Banner and Blow (1962) and Samanta (1969). The low arched aperture located in a small deep umbilicus seems diagnostic. In most specimens from Coos Bay the last chamber is flattened and has a tendency to cover the umbilicus.

Occurrence: Bastendorff.

Globigerina spp.

Broken specimens and specimens too poorly preserved for specific identification are included here.

Genus SUBBOTINA Brotzen and Pozaryska, 1961

Subbotina linaperta (Findlay)
Pl. 7, figs. 23, 24, 25

Globigerina linaperta Findlay, 1939, p. 125, pl. 13, figs. 54-57; Hornibrook, 1958, p. 26, 29, 33, pl. 1, figs. 19, 21; Samanta, 1969, p. 331, pl. 3, figs. 5a-o; Samanta, 1970a, p. 33, pl. 6, figs. 19-20; Samanta, 1970b, p. 190, pl. 1, fig. 7.

Subbotina linaperta (Findlay) Srinivasan, 1968, p. 149, pl. 16, figs. 7, 10, 11.

Remarks: This is a distinctive form with three chambers in the last whorl and a laterally directed, low, elongate aperture bordered by a distinct lip. Opinion differs as to the validity of the genus Subbotina Brotzen and Pozaryska. Loeblich and Tappan (1964, p. 673) consider Subbotina to be a valid genus and make the following comments.

> "Originally defined solely on the basis of wall surface, the present genus apparently includes species which are similar in form and apertural character. The coarsely pitted surface is found in species with a low and slightly extra-umbilical aperture and a distinctive lip, none of which are found in typical Globigerina."

Srinivasan (1968) considered Subbotina to be valid while Hortono (1969) and Samanta (1969, 1970a, 1970b) retained the use of Globigerina for forms with characteristics described above. The author has not had enough experience with planktonic foraminifera to resolve the question and has followed the classification of Loeblich and Tappan (1964).

Occurrence: Middle Coaledo and Bastendorff.

Subbotina? sp.
Pl. 7, figs. 4, 5, 6, 7

Description: Test fairly small with low trochospire. Equatorial periphery strongly lobulate. Axial periphery broadly rounded. Last whorl consists of four rounded inflated chambers with a definite enlargement of the last chamber. Two and one-half to three whorls in the adult form. Surface of test coarsely and distinctly pitted. All sutures depressed. Very, deep open umbilicus. Aperture extraumbilical to umbilical, interio-marginal; bordered by a narrow but distinct lip; usually not visible in umbilical view. Dimensions: diameter, 0.24-0.27mm; thickness, 0.12-0.15mm.

Remarks: Specimens are fairly abundant in some samples and appear to be distinct from published forms. The nature of the aperture clearly indicates that the specimens are not referrable to Globigerina officinalis or G. quadrilobata. Subbotina (Globigerina) yeguaensis has a more umbilical aperture with a larger lip and has three large chambers visible on the ventral side. This form may be new, but more material is needed before a new species can be described.

Occurrence: Middle Coaledo.

Subfamily ORBULININAE

Genus GLOBIGERAPSIS Bolli, Loeblich and Tappan, 1957

Globigerapsis index? (Finlay)
Pl. 8, figs. 23, 24, 25

Globigerinoides index Finlay, 1939, p. 125, pl. 14, figs. 85-88.

Globigerapsis index (Finlay) Bolli, Loeblich and Tappan, 1957, p. 165, pl. 36, figs. 14-17, Srinivasan, 1968, p. 149, pl. 16, figs. 8, 9, 12; Samanta, 1970b, p. 197, pl. 2, figs. 16, 17.

Remarks: Specimens strongly resembling Globigerapsis index are placed here. Preservation is such that the diagnostic multiple apertural openings (situated in the basal suture of the last chamber at its junctions with the intercamerial sutures of the earlier chambers) are partially obscured, making the identification tentative.

Occurrence: Middle Coaledo and Bastendorff.

Subfamily CATAPSYDRACINAE

Genus CATAPSYDRAX Bolli, Loeblich and Tappan, 1957

Catapsydrax? echinatus Bolli
Pl. 7, figs. 11, 12, 13

Catapsydrax echinatus Bolli, 1957, p. 165, pl. 37, figs. 2-5; Srinivasan, 1968, pl. 17, figs. 10-12.

Remarks: The genus Catapsydrax was erected for Globigerina-like forms possessing an umbilical bulla and one or more accessory infralaminal apertures in the adult form. Several people, including Hofker (1961), have questioned the taxonomic significance of the bulla as it may be a closed cyst of a reproductive stage that can develop in several different genera. The size, shape of chambers, position of the aperture and surface texture of the specimens studied seem identical to the holotype of Catapsydrax echinatus figured by Bolli (1957, pl. 37, figs. 2a-c).

Occurrence: Middle Coaledo.

Family DISCORBIDAE

Genus CANCRIS deMontfort, 1808

Cancris joaquinensis Smith
Pl. 9, figs. 13-15

Cancris joaquinensis Smith, 1956, p. 98, pl. 15, figs. 5, 6; Rau, 1964, p. 22, pl. 6, fig. 13.

Occurrence: Bastendorff.

Cancris sp.
Pl. 9, fig. 12

Remarks: A single specimen was found of a form that differs significantly from *Cancris joaquinensis* in the larger, more inflated last chamber. It is figured here for future reference.

Occurrence: Bastendorff.

Genus VALVULINERIA Cushman, 1926

Valvulineria menloensis Rau
Pl. 9, figs. 16, 17, 18

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

Remarks: Specimens from Coos Bay were compared with type material in the collections of W. W. Rau and found to be identical. Rau (personal communication, 1969) has considered *Valvulineria menloensis* to be a Miocene form, but its range must now be extended downward to the late Eocene.

Occurrence:

Valvulineria tumeyensis Cushman and Simonson
Pl. 8, figs. 19, 20, 21

Valvulineria tumeyensis Cushman and Simonson, 1944, p. 201, pl. 33, figs. 13, 14; Sullivan, 1962, p. 280, pl. 17, figs. 3a-c; 4a, b; 5a, b; 6a-c; Weaver and Weaver, 1962, p. 36, pl. 12, fig. 1a-c; Kleinpell and Weaver, 1963, p. 178, pl. 11, fig. 2a-c; Weaver and Molander, 1964, p. 193, pl. 11, figs. 1a-c, 2a-c, 3a-c.

Remarks: This is a highly variable species. Kleinpell and Weaver (1963, p. 179) and Weaver and Molander (1964, p. 193) consider *Valvulineria chirana* Cushman and Stone to be very similar to *V. tumeyensis* if not conspecific. *Eponides* cf. *E. pygmaea* Hantken as figured by Church (1931, pl. A, figs. 1-3) is considered by Kleinpell and Weaver (1963, p. 179) and Sullivan (1962, p. 280) to be a junior synonym of *V. tumeyensis*.

Occurrence: Middle Coaledo.

Family ELPHIDIIDAE

Genus ELPHIDIELLA Cushman, 1936

Elphidiella? sp.
Pl. 8, fig. 11

Remarks: A few pyritized internal molds were found that probably belong in the genus *Elphidiella*. A specimen is figured here for future reference.

Occurrence: Middle and upper Coaledo.

Family EPONIDIDAE

Genus EPONIDES deMontfort, 1808

<u>Eponides</u> <u>yeguaensis</u> (Weinzierl and Applin)
Pl. 9, figs. 1, 2, 3

<u>Eponides</u> <u>guayabalensis</u> Cole var. <u>yeguaensis</u> Weinzierl and Applin, 1929, p. 406, pl. 42, figs. 2a-c.

<u>Eponides</u> <u>yeguaensis</u> Cushman and McMasters, 1936, p. 514, pl. 76, figs. 1a-c.

<u>Eponides</u> <u>ellisorae</u> Garrett, 1939, p. 579, pl. 66, figs. 6-8; Cushman, Stewart and Stewart, 1957, p. 79, pl. 10, fig. 7.

<u>Remarks</u>: Specimens studied agree with the published description and figures of <u>Eponides</u> <u>ellisorae</u> by Garrett (1939). The degree of convexity of both the dorsal and ventral sides ranges from almost planiconvex to very definitely convex. In the majority of specimens studied, the dorsal side is usually moderately convex while the ventral side is almost flat. Most specimens have depressed non-limbate sutures on the ventral side, but some have raised limbate sutures. The specimens appear to be identical to <u>E.</u> <u>ellisorae</u> of Garrett (1939) and Cushman, Stewart and Stewart (1957). However, the specimens are also identical to topotype material from the Cowlitz Formation of Washington that Beck (1943) has called <u>Eponides</u> <u>yeguaensis.</u> Beck compared his Cowlitz material with topotypes of <u>E.</u> <u>yeguaensis</u> Cushman and McMasters from the Llajas Formation of California that appear to be very similar but are not formally placed in synonomy because type material could not be studied are <u>E.</u> <u>gaviotaensis</u> and <u>E.</u> <u>mexicanus</u>.

Occurrence: Lower, middle and upper Coaledo.

Family CIBICIDIDAE

Genus CIBICIDES deMontfort, 1808

Cibicides haydoni (Cushman and Schenck)
Pl. 10, fig. 13, 14, 15

Planulina haydoni Cushman and Schenck, 1928, p. 316, pl. 45, fig. 7a-c; Cushman and Simonson, 1944, p. 202, pl. 34, figs. 11, 12; Detling, 1946, p. 358, pl. 51, fig. 1; Wilson, 1954, p. 144, pl. 17, fig. 3a-c; Smith, 1956, p. 100, pl. 16, fig. 5a-c.

Cibicides haydoni (Cushman and Schenck) Kleinpell and Weaver, 1963, p. 181, pl. 14, fig. 3a-c.

Occurrence: Bastendorff.

Cibicides hodgei Cushman and Schenck
Pl. 10, fig. 7, 8, 9

Cibicides hodgei Cushman and Schenck, 1928, p. 315, pl. 45, figs. 3-5; Beck, 1943, p. 611, pl. 109, figs. 24-38; Cushman and Simonson, 1944, p. 359, pl. 51, figs. 6, 8; Rau, 1951, p. 451, pl. 67, figs. 28-30; Smith, 1956, p. 101, pl. 16, fig. 1a-c; Mallory, 1959, pp. 265-266, pl. 24, fig. 6a-c; Sullivan, 1962, p. 287, pl. 23, fig. 8a-c; Kleinpell and Weaver, 1963, p. 182, pl. 15, fig. 2a-c; Weaver and Molander, 1964, p. 199, pl. 17, fig. 16a-c.

Occurrence: Middle Coaledo and Bastendorff.

Cibicides mcmastersi? Beck
Pl. 10, figs. 10, 11, 12

Cibicides mcmastersi Beck, 1943, p. 612, pl. 109, figs. 2, 4, 15; McWilliams, 1968, p. 95.

Remarks: Specimens from Coos Bay are identical to topotype material from the Cowlitz Formation and hypotypes of McWilliams (1968) in the collections of the Burke Museum of the University of Washington. Detling (1946, pp. 359-360, pl. 51, figs. 9, 10) referred this species to Cibicides pseudowuellersdorfi Cole. The forms from Coos Bay are very similar to specimens of Cibicides pseudoungerianus (Cushman) var. evolutus Cushman and Hoisson as figured by Sullivan (1962, pl. 23, fig. 10a-c) and Kleinpell and Weaver (1964, pl. 15, fig. 3a-c; pl. 16, fig. 3a-c). C. mcmastersi may be a junior synonym of C. pseudoungerianus evolutus but it is not placed in synonomy because published figured showed considerable variation, and no type material could be examined.

Occurrence: Lower and middle Coaledo; Bastendorff.

Cibicides natlandi Beck
Pl. 10, figs. 16, 17, 18

Cibicides natlandi Beck, 1943, p. 612, pl. 16, fig. 2a, b; Rau, 1951, p. 452, pl. 67, figs. 26, 27; Hornaday, 1961, p. 195, pl. 13, figs. 2a-c, 3a-c, 4a-c; Kleinpell and Weaver, 1963, p. 182, pl. 16, fig. 2a, b; Weaver and Molander, 1964, p. 200, pl. 18, fig. 4a-c.

Remarks: Beck (1943, p. 612), Kleinpell and Weaver (1963, p. 25) and Weaver and Molander (1964, p. 199) have stated that Planulina haydoni is probably a Cibicides that evolved from Cibicides natlandi.

Occurrence: Lower and middle Coaledo.

Cibicides warreni Cushman, Stewart and Stewart
Pl. 10, figs. 4, 5, 6

Cibicides warreni Cushman, R. E. Stewart, and K. C. Stewart, 1947, p. 104, pl. 13, fig. 11; Cushman, R. E. Stewart and K. C. Stewart, 1949, p. 135, pl. 16, fig. 5; Bird, 1967, p. 149, pl. 13, figs. 4-6; McWilliams, 1969, p. 97.

Remarks: A few poorly preserved specimens were found that resemble figures of Cibicides warreni. Cibicides warreni is similar to C. hodgei in size, shape and arrangement of chambers, but is has thinner test and thin, slightly depressed sutures rather than thick, strongly limbate sutures as in C. hodgei. Hornaday (1961, p. 194, 195) states that C. warreni falls with range of variation of C. hodgei. In the Coos Bay material C. warreni appears in the middle member of the Coaledo Formation, and C. hodgei appears high in the Bastendorff Formation. No specimens intermediate in form or in stratigraphic position were observed, and the author prefers to consider C. warreni as a distinct form until more material from western Oregon can be studied.

Occurrence: Bastendorff.

Cibicides spp.

Remarks: Steinkerns and specimens too poorly preserved for specific identification are placed here.

Family CAUCASINIDAE

Genus CASSIDELLA Hofker, 1951

Cassidella hobsoni? Beck
Pl. 11, fig. 1

Virgulina hobsoni Beck, 1943, p. 606, pl. 197, figs. 6, 10; Weaver and Molander, 1964, p. 191, pl. 9, fig. 7.

Remarks: Several poorly preserved specimens are tentatively placed here.

Occurrence: Lower and middle Coaledo.

Family PLEUROSTOMELLIDAE

Genus NODOSARELLA Rzehak, 1895

Nodosarella? cf. N. cocoaensis (Cushman)
Pl. 3, fig. 19

Nodosaria cocoaensis Cushman, 1925, pl. 10, figs. 5, 6; Cushman, 1927, pl. 24, fig. 1.

Dentalina cocoaensis (Cushman), Ellisor, 1933, pl. 2, fig. 3.

Ellipsonodosaria cocoaensis (Cushman) Cushman, 1939, pl. 11, figs. 27-33.

Nodosarella cocoaensis (Cushman) Bird, 1967, p. 150, pl. 14, fig. 5.

Remarks: Numerous fragments consist of several chambers that are only slightly inflated, separated by clear sutures that are slightly depressed. The specimens compare well with topotype material of *N. cocoaensis* from the southern United States figured by Cushman (1935). The chambers are more elongate and less inflated than those of Dentalina jacksonensis. Cushman (1939), upon studying topotype material, placed this species in the genus *Ellipsonodosaria*. Loeblich and Tappan (1964) placed all uniserial forms of Ellipsonodosaria in synonomy with *Nodosarella*.

Occurrence: Middle Coaledo and Bastendorff.

Family CASSIDULINIDAE

Genus GLOBOCASSIDULINA Voloshinova, 1960

Globocassidulina globosa (Hantken)
Pl. 11, figs. 2, 3

Cassidulina globosa Hantken, 1875, p. 54, pl. 16, fig. 2; Cushman, 1935, p. 49, pl. 20, fig. 12; Cushman and Siegfus, 1942, p. 421, pl. 18, fig. 3a, b; Wilson, 1954, p. 143, pl. 17, fig. 1a, b; Mallory, 1959, p. 226, pl. 33, fig. 11a, b; Weaver and Weaver, 1962, p. 38, fig. 3a-c; Rau, 1964, p. 23, pl. 7, fig. 4; Weaver and Molander, 1964, p. 195, pl. 13, fig. 4a, b.

Globocassidulina globosa (Hantken) Loeblich and Tappan, 1964, p. 738, fig. 604 (6a, b); Bird, 1967, p. 152, pl. 14, figs. 1, 2.

Remarks: This is a small but distinctive species that is very common in portions of the Coaledo Formation. Loeblich and Tappan (1964, p. 738) have placed this species within the genus Globocassidulina.

Occurrence: Lower and middle Coaledo; Bastendorff.

Family NONIONIDAE

Genus CHILOSTOMELLA Reuss in Czjzek, 1849

Chilostomella hadleyi Keijzer
Pl. 11, fig. 5

Chilostomella hadleyi Keijzer, 1945, p. 205, pl. 4, fig. 55; Cushman and Todd, 1949, p. 88, pl. 15, figs. 12-14; Weaver, 1962, p. 386, pl. 7, fig. 3a-c; Bird, 1967, p. 152, pl. 14, figs. 9-11.

Chilostomella cf. C. hadleyi Keijzer, Weaver and Molander, 1964, p. 196, pl. 14, fig. 1a, b.

Occurrence: Bastendorff.

Chilostomella sp.
Pl. 11, fig. 6

Remarks: A single specimen of this form was found and is figured here for future reference.

Occurrence: Middle Coaledo.

Genus ALLOMORPHINA Reuss in Czjzek, 1849

Allomorphina trigona macrostoma Karrer
Pl. 11, fig. 4

Allomorphina macrostoma Karrer, 1961, p. 448, pl. 2, fig. 4; Rau, 1948, p. 173, pl. 31, figs. 4, 5; Hornaday, 1961, p. 193, pl. 11, fig. 5a-c; Weaver and Molander, 1964, p. 195, pl. 13, figs, 6a, b, 7a, b.

Allomorphina trigona macrostoma Karrer, Bandy and Kolpack, 1963, p. 159, Bird, 1967, p. 153, pl. 14, fig. 3.

Occurrence: Middle Coaledo.

Genus NONION deMontfort, 1808

Nonion florinense Cole
Pl. 11, figs. 7, 8

Nonion florinensis Cole, 1927, p. 22, pl. 4, fig. 4; Cushman, 1939, p. 5, pl. 1, figs. 17, 18; Fairchild, Wesenduck, and Weaver, 1969, p. 71, pl. 22, figs, 1a, b.

Nonion applini Howe and Wallace, 1932, p. 51, pl. 9, fig. 4; Cushman, Stewart and Stewart, 1947, p. 77, pl. 9, fig. 6.

Remarks: This form is common in the material from Coos

Bay where it was called Nonion applini by Cushman, Stewart and Stewart (1947). The author has examined topotype material of Cushman in the collections of V. Standish Mallory at the University of Washington and could find no significant differences between N. applini and N. florinense. Other forms that appear to be very similar, for which topotype material was not available, are N. mexicanum and N. alabamense. Forms called N. inflatum by Beck (1943) and Detling (1946) do not compare well with figures of holotypes of that species and are identical to N. florinense of this paper.

Occurrence: Lower, middle and upper Coaledo.

Nonion sp.
Pl. 11, fig. 9, 10

Remarks: A single specimen of a small form of Nonion was found and is figured here.

Occurrence: Lower Coaledo.

Genus NONIONELLA Cushman, 1926

Nonionella cf. N. insecta? (Schwager)
Pl. 11, figs. 17, 18

Nionella insecta (Schwager) Cushman and Ponton, 1932, p. 65, pl. 8, figs. 13, 14; Cushman, 1939, p. 29, pl. 8, fig. 1.

Remarks: A single specimen compares well with the forms figured by Cushman and Ponton (1932) and of Cushman (1939).

According to Cushman (1939) this species was originally described from the middle Eocene of North Africa. The original figures have not been examined, and the identification is based upon a specimen figured by Cushman (1939) from the Eocene of Alabama which he considered conspecific with the African form.

Occurrence: Lower Coaledo.

Nonionella? sp.
Pl. 11, figs. 15, 16

Remarks: A single specimen of distinct form is tentatively placed in the genus Nonionella. This form is characterized by strongly curved and distinctly raised sutures and a large, flaring last chamber. Preservation is poor, but the coiling differs slightly on the two sides of the test. The aperture was not observed clearly and there does not appear to be an extension of the last chamber into the umbilical region. More material is needed for identification and description of the form.

Occurrence: Middle Coaledo.

Genus PULLENIA Parker and Jones in Carpenter
Parker and Jones, 1862

Pullenia quinqueloba (Reuss)
Pl. 11, figs. 14, 15

Nonionina quinqueloba Reuss, 1851, p. 71, pl. 5, fig. 31.

Pullenia quinqueloba (Reuss) Cushman and Todd, 1943, p. 10, pl. 2, fig. 5; pl. 3, fig. 8; Mallory, 1959, p. 246, pl. 34, fig. 1a, b; Bird, 1967, p. 155, pl. 14, figs. 14, 15.

Occurrence: Middle Coaledo.

Family ALABAMINIDAE

Genus ALABAMINA Toulmin, 1941

Alabamina kernensis Smith
Pl. 11, figs. 19. 20, 21

Alabamina kernensis Smith, 1956, p. 99, pl. 15, figs. 3, 4; Rau, 1964, p. 22, pl. 7, fig. 1.

Remarks: Smith (1956) described this species from the Wagonwheel Formation of California and noted its presence in the Bastendorff Formation. Rau (1964) reports it from rocks of Refugian and pre-Refugian age in Washington. *Alabamina wilcoxensis* from lower Eocene rocks of Alabama, as figured by Loeblich and Tappan (1964), appears to be very similar to *A. kernensis*. *Alabamina kernensis* may be a junior synonym of *A. wilcoxensis*. Only a single specimen was found in the material studied.

Occurrence: Bastendorff.

Genus GYROIDINA d'Orbigny, 1826

Gyroidina condoni (Cushman and Schenck)
Pl. 11, figs. 22-27

Eponides condoni Cushman and Schenck, 1928, p. 313, pl. 44, figs. 6, 7a-c; Beck, 1943, p. 608, pl. 108, figs. 27, 29, 31.

Gyroidina condoni rotundiformis Cushman and Simonson, 1944, p. 201, pl. 33, figs. 17, 18, 19; DeLise, 1967, p. 38, pl. 4, figs. 3a-c.

Gyroidina condoni (Cushman and Schenck) Wilson, 1954, p. 142, pl. 16, fig. 10a-c; Smith, 1956, p. 97, pl. 14, figs. 6a-c, 7a-c; Hornaday, 1961, p. 192, pl. 9, fig. 5a-c; Sullivan, 1962, p. 280, pl. 18, fig. 2a-c; Kleinpell and Weaver, 1963, p. 179, pl. 11, fig. 3a-c; Weaver and Molander, 1964, p. 193, pl. 11, fig. 4a-c; Bird, 1967, p. 156, 157, pl. 14, figs. 21-23; De-Lise, 1967, p. 38, pl. 4, fig. 2a-c.

Remarks: There is considerable variation in figured specimens of Gyroidina condoni by different authors. The specimens studied include forms that compare favorably with the type description and show the diagnostic unequally biconvex test. Other specimens from the same samples vary in the degree of roundness of the periphery and the convexity of the doral side (from nearly flat to strongly convex). These include specimens sometimes assigned to G. condoni rotundiformis.

Occurrence: Lower and middle Coaledo; Bastendorff.

Gyroidina girardana planata Cushman
Pl. 11, figs. 28-30

Gyroidina orbicularis d'Orbigny var. planata Cushman, 1935, p. 45, pl. 18, fig. 3a-c; Mallory, 1959, p. 235, pl. 29, fig. 16a-c; Sullivan, 1962, p. 280, pl. 18, fig. 1a-c; Weaver and Weaver, 1962, p. 36, pl. 13, figs. 1a-c, 2a-c; DeLise, 1964, p. 38, pl. 4, fig. 4a-c; Rau, 1964, p. 21, pl. 6, fig. 10a-c.

Gyroidina girardana planata Bandy and Kolpack, 1963, p. 160; Bird, 1967, p. 157, pl. 14, figs. 16-18.

Occurrence: Elkton; Lower and middle Coaledo; Bastendorff.

Family ANOMALINIDAE

Genus ANOMALINA, d'Orbigny, 1826

Anomalina californiensis Cushman and Hobson
Pl. 11, figs. 11, 12

Anomalina californiensis Cushman and Hobson, 1935, p. 64, pl. 9, fig. 8; Smith, 1956, p. 100, pl. 16, fig. 3; Sullivan, 1962, p. 286, pl. 23, fig. 6a-c; Kleinpell and Weaver, 1963, p. 181, pl. 14, fig. 4a, b; Rau, 1964, p. 24, pl. 7, fig. 8a, b.

Remarks: Considerable variation in form occurs in the specimens observed. Some are nearly bisymmetrical and resemble published figures of Nonion pompiloides, but others are decidedly asymmetric. Rau (1964) states that the test of Anomalina californiensis is thinner than that of N. pompiloides. In Washington, A. californiensis is recorded from rocks of Refugian and Zemmorian age (Rau, 1964), but it has been reported from the Refugian stage in California (Smith, 1956).

Occurrence: Middle Coaledo.

Anomalina? sp.
Pl. 11, fig. 31, 32

Remarks: A single, small specimen, possibly a juvenile, resembles *Anomalina*? sp. of Hornaday (1961).

Occurrence: Bastendorff.

Family CERATOBULIMINIDAE

Genus CERATOBULIMINA Toula, 1915

Ceratobulimina washburni Toula, 1915
Pl. 11, figs. 33-35

Ceratobulimina washburni Cushman and Schenck, 1928, p. 314, pl. 45, fig. 1a-c; Beck, 1943, p. 609, pl. 108, figs. 20, 24; Rau, 1948, p. 172, pl. 31, figs. 15, 16, 17.

Occurrence: Middle Coaledo.

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APPENDICES

APPENDIX A.

FOSSIL LOCALITIES

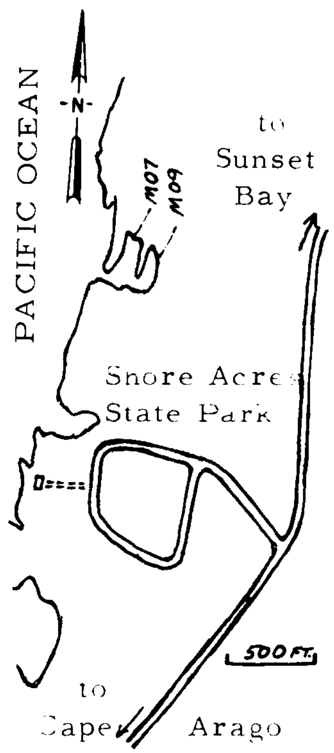
I. MOLLUSKS. The stratigraphic distribution of mollusks is given in Figures 39 and 52, Plate 12 and Appendix B. Published descriptions of molluskan sample localities within the Coaledo and Bastendorff Formations are presented in Turner (1938) and Weaver (1945a). Two new molluskan sample localities are described below. Other molluskan localities are mentioned in the sequential discussion of microfossil sample localities.

Locality M07 (Lower Coaledo)

Fine-grained sandstone and siltstone: northwest side of cove located 1500 feet north of Shore Acres State Park; SW1/4 SE1/4, Sec. 8, T. 26S., R. 14W.; Empire 15-minute quadrangle.

Locality M09 (Lower Coaledo)

Medium-grained carbonaceous sandstone: northeast side of cove located 1500 feet north of Shore Acres State Park; stratigraphically 220 feet higher than sample M07; SW1/4 SE1/4, Sec. 8, T. 26S., R. 14W; Empire 15-minute quadrangle.



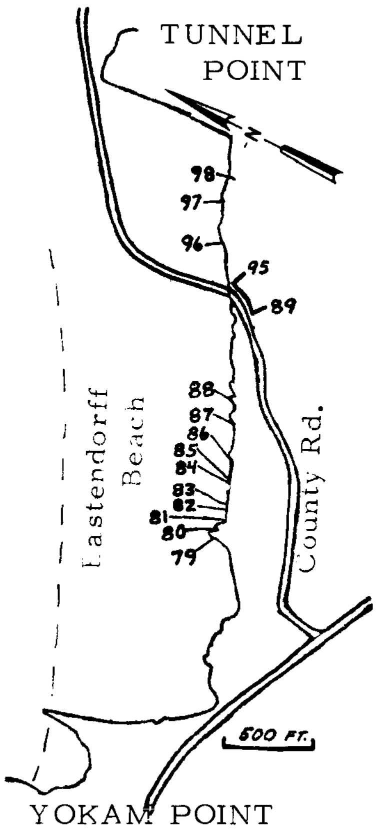
II. MICROFOSSILS. All of the microfossil localities described below are in the rocks of the coastal region of the Empire 15-minute quadrangle, from Tunnel Point on the northeast (NE1/4 NE1/4, Sec. 3, T.26S., R14W.) to South Cove of Cape Arago on the southwest (SE1/4 NE1/4, Sec. 19, T.26S., R.14W.). The sample localities are listed in descending stratigraphic sequence. The stratigraphic distribution of the samples is given in Plate 12.

Bastendorff Formation. All samples collected in cliffs along Bastendorff Beach. See accompanying sketch.

98-Siltstone: West bank of small stream at east end of Bastendorff Beach; 70 feet stratigraphically below the top of the Bastendorff.

97-Siltstone: Exposed at top of cliff below Pleistocene terrace sands; 150 feet stratigraphically below sample 98.

96-Very thin-bedded, almost fissile mudstone: 190 feet stratigraphically below sample 97.



Samples 89 through 95 are located in the cut along the county road from Bastendorff Beach to the county campground at the top of the terrace. Each sample is a composite of all lithologies within a 50 foot stratigraphic interval. Sample 95 is highest stratigraphically (but at the lowest elevation along the roadcut), and sample 89 is lowest stratigraphically (but at the highest elevation along the roadcut).

95-89-Thin-bedded siltstone and mudstone with a few glaconite-rich beds.

Samples 80 through 88 were collected from the cliffs along Bastendorff Beach between the cut along the county road and a prominent sandstone that crops out about 1000 feet stratigraphically above the lower contact of the Bastendorff Formation.

88-Dark gray siltstone with thin ash layers: in sea cliff below the cut along the county road; about 1200 feet stratigraphically below the top of the Bastendorff Formation.

87-Dark gray mudstone: 185 feet below sample 88; sample collected along ridge crest.

86-Dark gray mudstone: exposed throughout a 10 foot stratigraphic interval; 150 feet stratigraphically below sample 87.

85-84-Dark gray mudstone: exposed throughout a 50 foot stratigraphic interval at the top of sea cliff; 75 feet stratigraphically below sample 86.

83-Dark gray mudstone: from small pit excavated in sea cliff by previous collectors; about 150 feet stratigraphically above prominent sandstone that crops out 1000 feet stratigraphically above the base of the Bastendorff Formation.

82-Dark gray mudstone: 50 feet stratigraphically below sample 83.

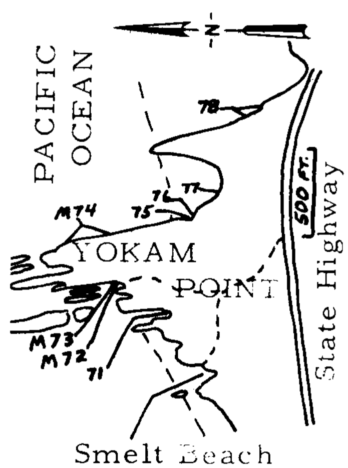
81-Intercalated siltstones and fine-grained sandstones: immediately east of the prominent sandstone containing locality 80.

80-Carbonaceous siltstone beds within gray sandstone: sandstone promontory resistant to erosion; 1000 feet above the lower contact of the Bastendorff Formation.

79-Fine-grained, carbonaceous siltstone: 6 feet west of the lower contact of the sandstone unit containing sample locality 80.

The lower one-third (approximately 1000 stratigraphic feet) of the Bastendorff Formation at Bastendorff Beach is covered by recent alluvium from a small stream and beach deposits. No samples could be obtained from the interval.

Upper Sandstone Member of the Coaledo Formation. Five samples containing microfossils and three collections of mollusks were made in rocks of the Upper Coaledo. The locations of samples are given in the accompanying diagram.



78-Dark gray, carbonaceous siltstone and very-fine sandstone: east side of resistant sandstone at the west end of Bastendorff Beach.

77-Grayish-green siltstone: in first cove west of Bastendorff Beach; approximately 500 feet stratigraphically below the Bastendorff-upper Coaledo contact.

76-Carbonaceous, sandy siltstone: beds 6 inches to 1 foot thick; 3 feet stratigraphically higher than sample 75.

75-Fine sandstone and 1 to 3 inch intercalated siltstones: same stratigraphic position as fossilferous (mollusks) sandstone of sample locality M74.

M74-Mollusks in fine sandstone: east side of major promontory of Yokam Point (Mussel Reef); two sample localities about 500 feet and 750 feet north of sample locality 75.

M73-Fossiliferous (mollusks), carbonaceous, poorly cemented, lithic sandstone (arenite): unit E of Figure 40; contains numerous Ostrea, and an occasional shark's tooth, platform tooth of a skate or ray, and byrozoan (ectoproct).

M72-Fossiliferous (mollusks), very organic-rich, semi-consolidated, brown sandy peat: numerous broken gastropods (possibly fresh water); in contact with the top of the Beaver Hill coal seam at Yokam Point (Figure 40).

71-Very fine-grained carbonaceous sandstone: second cove west and about 250 feet stratigraphically below the Beaver Hill coal seam.

Middle Mudstone Member of the Coaledo Formation. Samples 32 through 70 were collected from the middle Coaledo along the sea cliffs at Lighthouse Beach. The locations of samples are indicated in the accompanying diagram. All samples are composites of all rock types within a 50 foot stratigraphic interval.

70-65-Dark olive gray siltstones with intercalated thin tuffaceous sandstones: sequential, 50 foot stratigraphic samples from a point 450 feet below the upper Coaledo-middle Coaledo contact to the top (east side) of the easternmost of three prominent sandstones that crop out along Lighthouse Beach.

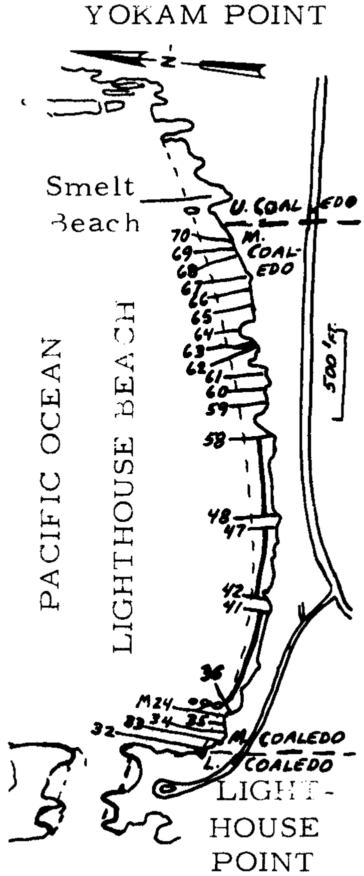
64-Fine-grained, 4-6 inch thick sandstone beds with 1 inch intercalated siltstones: forms easternmost of three promontories in the sea cliff along Lighthouse Beach; unit 131 feet thick.

63-62-Dark gray siltstone: collected in cove between sandstone unit mentioned above (containing sample locality 64) and a 17 foot thick promontory composed of light gray, tuffaceous sandstone.

61-59-Gray tuffaceous siltstone: samples collected east of the westernmost of three prominent sandstones that crop out along Lighthouse Beach.

58-36 and 35-32-Dark gray mudstones and siltstone: continuous samples, of all rock types within a 50 foot stratigraphic interval, from the lower contact of the westernmost of three sandstone promontories, to the middle Coaledo-upper Coaledo boundary at Yokam Point.

M24 - Medium-grained, gray sandstone: fossiliferous (mollusks) unit exposed in the sea cliff and as a discontinuous ridge protruding above the level of the beach sand.



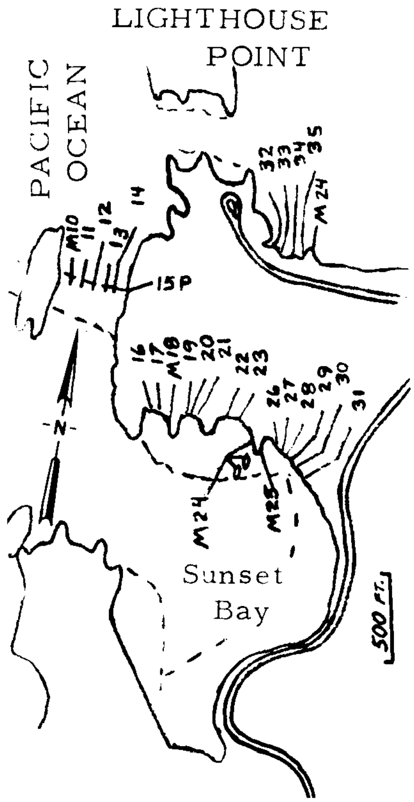
Lower Sandstone Member of the Coaledo Formation. Most of the sample localities within the lower Coaledo are located in and around Sunset Bay. A few mollusk samples were collected near Shore Acres State Park and at Cape Arago.

M25, M24 and M10-Dark gray sandstone: fossil mollusks collected from three localities indicated on the accompanying diagram.

31-26, 23, 22, 21-19 and 17-16-Dark gray mudstone and siltstone: samples collected in the cliffs along the north side of Sunset Bay at the localities indicated in the accompanying diagram; samples a composite of all rock types within a 50 foot stratigraphic interval.

15P-Carbonaceous sandstone: unidentified plant remains.

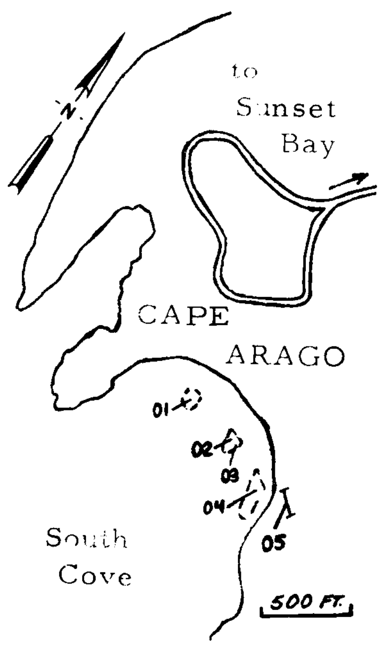
M09 and M07-New mollusk sample localities near Shore Acres State Park described in detail earlier in this section.



Elkton Siltstone. Microfossil samples 01 through 05 were collected from the Elkton Formation at South Cove of Cape Arago.

05-Interbedded sandstones and siltstones: Facies B; collected from cliffs at the east side of South Cove.

04-01-Dark black mudstone with minor thin intercalated siltstone: Facies A; collected from wave-cut platform at low tide at the locations shown in accompanying diagram.



APPENDIX B. STRATIGRAPHIC DISTRIBUTION OF MOLLUSKS IN COALEDO AND BASTENDORFF FORMATIONS

FORMATION	LOWER COALEDO									MIDDLE COALEDO				UPPER COALEDO							
SAMPLE NUMBERS	M06 776W	769W	M07	M08 773W	M09	772W A706	A711	763W A712	M018 A713 771W?	764W	M024 A714 765W	M025 762W	776W 761W	757W	758W A716	M073 A716?	M072	M074 A717	M075 A722 759W	M076 A722 760W	A718
PELECYPODA																					
Acila			x	x				x			x	x	x								
Corbula						x			x		x								x	x	
Crassatella		x						x	x										x	x	
Gari								x	x										x	x	
Glycymeris		x						x													x
Lucina (Lucinoma?)		x									x				x			x	x	x	x
Nuculana	x		x	x	x	x		x	x		?	x	x								
Ostrea																x					
Pitar	x		x	x	x	x		x	x	x	x		x					x			x
Pteria															x				x		
Sanguinolaria (Nuttallia)																			x		
Semele													?								
Spisula						x		x	x	x		x						x	x	x	x
Solen	x												x					x	x	x	
Sellina		x	x	x	x			?	x	x					x	x		x	x	x	x
Thracia								x					x								

SAMPLE NUMBERS: M073 Rooth (1974); 769W Weaver (1945); A711 Turner (1938)

x Present ? Questionably identified

Note: For descriptions of localities see Appendix A and Turner (1938) and Weaver (1945a).

APPENDIX B. (CONTINUED)

FORMATION	LOWER COALEDO										MIDDLE COALEDO			UPPER COALEDO							
SAMPLE NUMBERS M073 Rooth (1974) 769W Weaver (1945) A711 Turner (1938)	M06 776W	769W	M07	M08 773W	M09	772W A706	A711	763W A712	M018 A713 771W?	764W	M024 A714 765W	M025 762W	776W 761W	757W	758W A716	M073 A716?	M072	M074 A717	M075 A722 759W	M076 A722 760W	A718
GASTROPODA																					
Callistoma																x			x		
Calyptraea						x								x	x				x	x	
Cerithiopsis		x																			
Conus						x															
Crepidula		x						x							x	x					
Cymatium						x					x	x									
Cypraea (Zonaria)																					
Fusinus																					
Homalopoma		x																		x	
Polinices	x	x	x	x	x	x			x	x	x							x			x
Scaphander						x															
Sinum		x																			
Solariella		x																			
Turrietella	x			x			x		x	x	x										x

x Present ? Questionably identified

Note: For description of localities see Appendix A and Turner (1938) and Weaver (1945a).

PLATES

PLATE 1

Figures

1. Rhabdammina cf. R. eocenica Cushman and G. D. Hanna. X 34.
2. Bathysiphon eocenica Cushman and G. D. Hanna. X 48.
3. Bathysiphon sp. X 48.
4. Reophax? sp. X 60.
5. Haplophragmoides sp. X 48.
6. Cyclammina clarki (G. D. Hanna). X 48.
7. Haplophragmoides obliquecameratus Marks. X 48.
8. Cyclammina pacifica Beck. X 17.
9. Haplophragmoides deflata Sullivan. X 50.
10. Cyclammina sp. X 48.
11. Cyclammina samanica. Berry. X 48.
12. Cyclammina? sp. X 34.

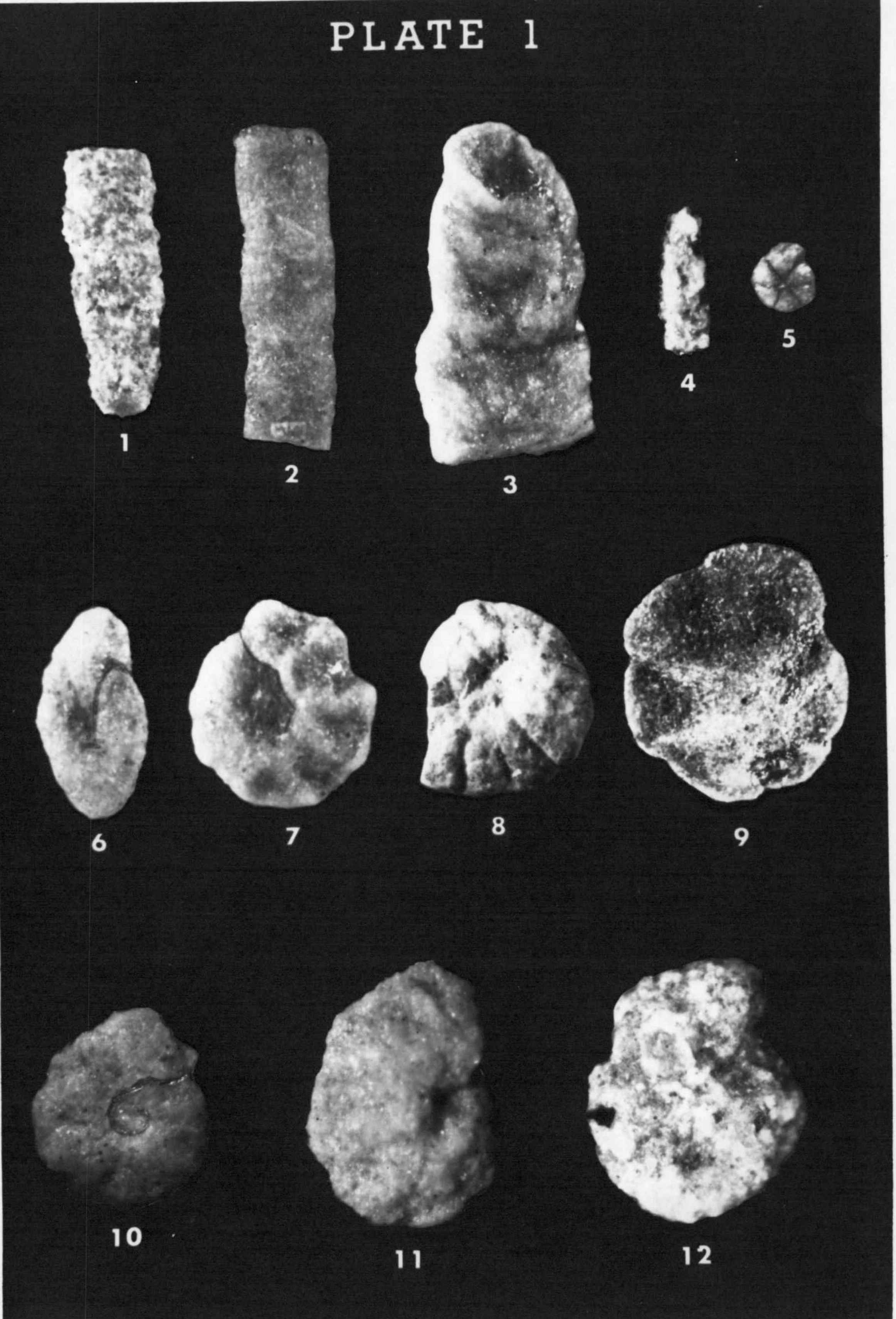


PLATE 1

PLATE 2

Figures 1. Ammobaculites sp. X 33.

2. Spiroplectammina mississippiensis (Cushman). X 45.

3. Spiroplectammina sp. X 45.

4. Textularia aff. T. lalickeri Cushman and Renz. X 58.

5. Trochammina? sp. X 45. dorsal view.

6. Gaudryina alazanensis Cushman. X 45.

7. Gaudryina laevigata Franke. X 45.

8, 9. Gaudryina sp. X 45. 8, peripheral view; 9, side view.

10. Dorothia oxycona? (Reuss). X 40.

11. Martinottiella sp. X 45.

12. Eggerella? sp. X 45.

13. Gaudryina? sp. X 45.

14. Eggerella subconica Parr. X 58.

15, 16. Eggerella? cf. E. trochoides (Reuss). X 58. 15, spiral view; 16, side view.

17. Cyclogyra byramensis (Cushman). X 33.

PLATE 2

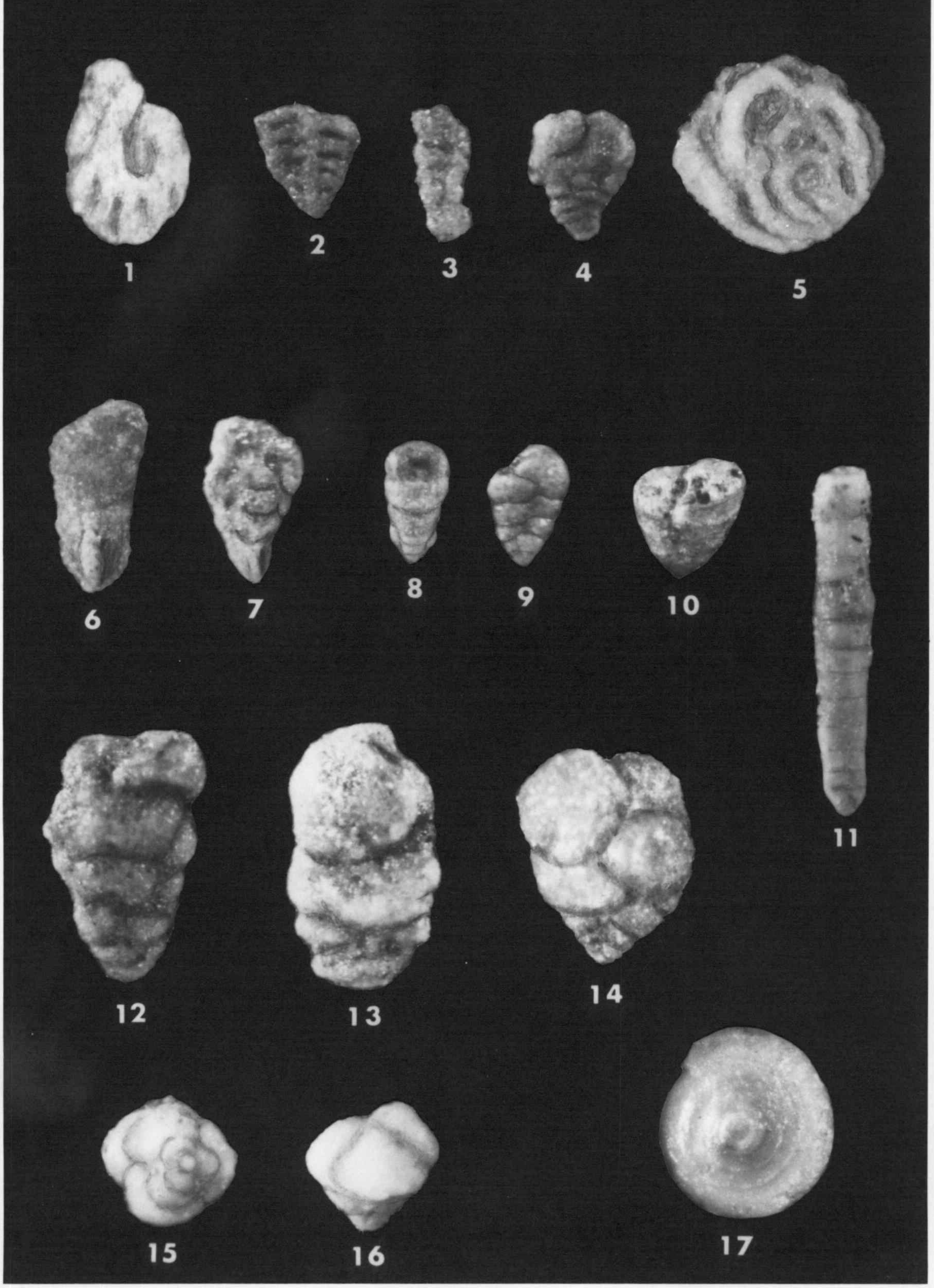


PLATE 3

Figures 1. Spiroloculina wilcoxensis Cushman and Garrett. X 144.

2, 3. Quinqueloculina imperialis Hanna and Hanna. X 45. 2, 3 opposite sides.

4, 5, 6. Quinqueloculina minuta Beck. X 70. 4, 6 opposite sides; 5, apertural view.

7, 8, 9. Quinqueloculina sp. X 33. 7, 9 opposite sides; 8 apertural view.

10. Nodosaria consobrina (d'Orbigny). X 45.

11. Nodosaria cf. N. pyrula d'Orbigny. X 45.

12. Nodosaria longiscata d'Orbigny. X 60.

13. Dentalina colei Cushman and Dusenbury. X 45.

14. Dentalina communis (d'Orbigny). X 60.

15. Dentalina cooperensis Cushman. X 33.

16, 17. Dentalina jacksonensis (Cushman and Applin). X 56.

18. Dentalina cf. D. pauperata d'Orbigny. X 45.

19. Nodosarella? cf. N. cocoaensis (Cushman). X 33.

20. Dentalina? sp. X 45.

21. Lagena cf. L. conscripta Cushman and Barksdale. X 65.

22. Lagena acuticostata Reuss. X 65.

23. Lagena hexagona (Williamson). X 50.

24. Lagena cf. L. substriata Williamson. X 65.

PLATE 3

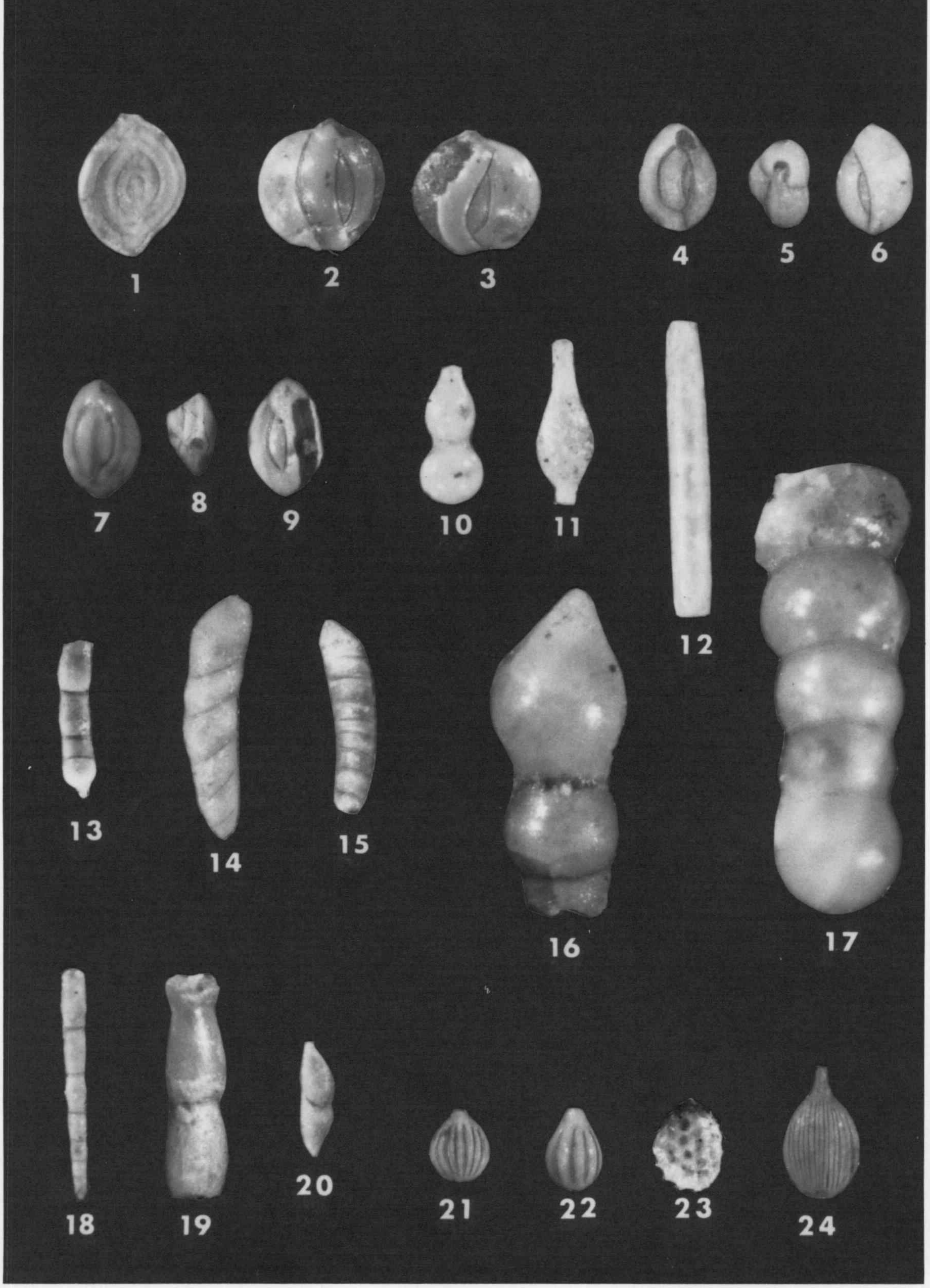


PLATE 4

Figures 1, 2. Lenticulina sp. A. X 45. 1, side view; 2, apertural view.

3. Lenticulina sp. B. X 45.

4, 5. Lenticulina inornatus (d'Orbigny). X 45. 4, side view; 5, apertural view.

6. Lenticulina sp. C. X 45.

7, 8, 9. Lenticulina welchi (Church). X 45. 7, side view; 8, apertural view; 9, side view.

10. Lenticulina chehalisensis (Rau). X 45.

11. Lenticulina pseudovortex (Cole). X 45.

12. Lenticulina articulatus (Cushman and Applin). X 45.

13. Lenticulina cf. L. mayi (Cushman and Parker). X 45.

14. Lenticulina sp. D. X 40.

15. Lenticulina? sp. X 45.

16, 17. Planularia tolmani Cushman and Simonson. X 45.

18-21. Planularia crepidula (Fichtel and Moll). X 45. 18, side view; 19, peripheral view; 20, side view; 21, peripheral view.

PLATE 4

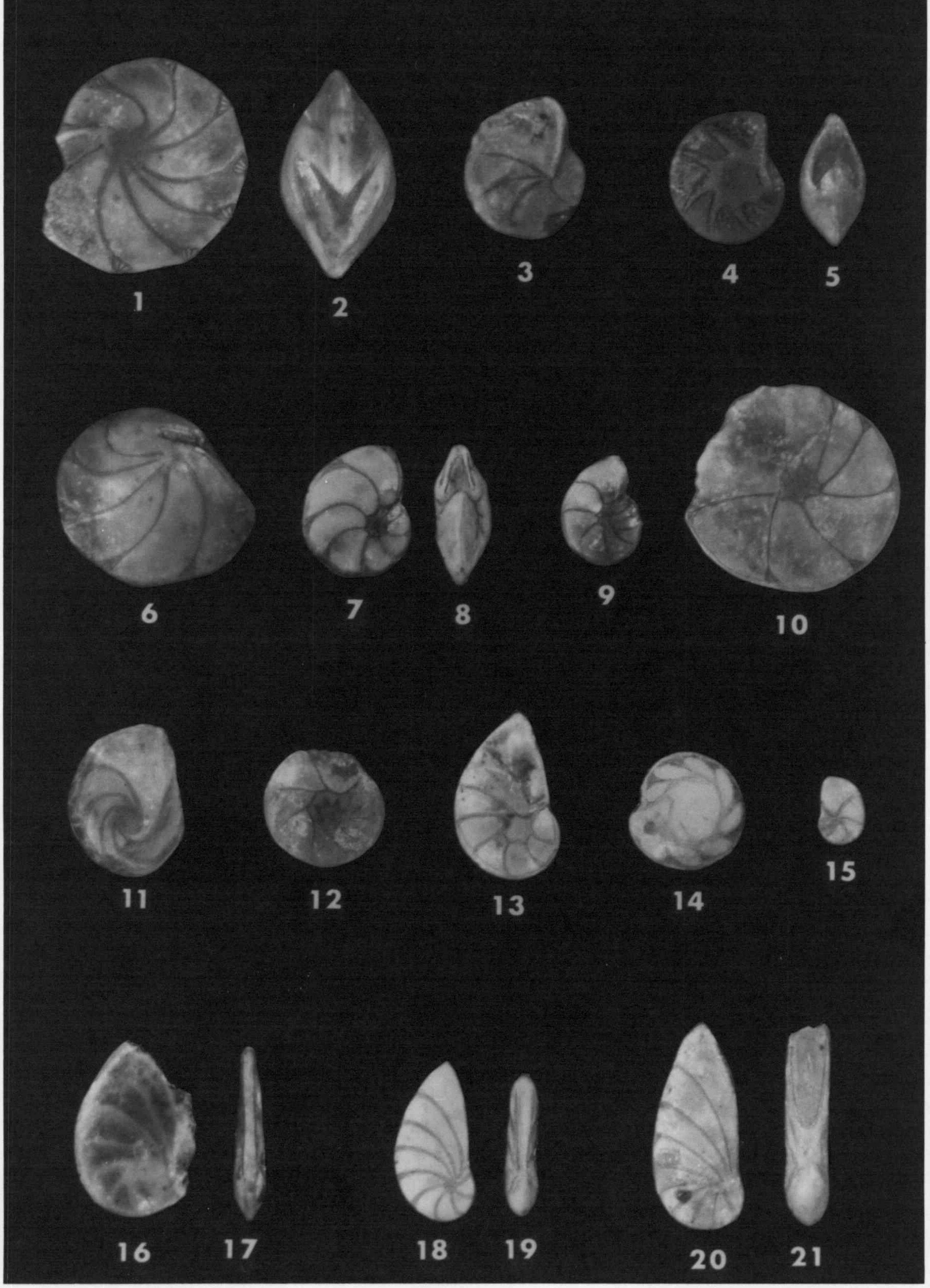


PLATE 5

Figures

1. Marginulina cf. M. adunca (Costa). X 45.
2. Marginulina sp. B. X 45.
3. Marginulina sp. A. X 45.
4. Marginulina cf. M. subbulata Hantken. X 45.
5. Marginulina exima Neugeboren. X 45.
6. Plectofrondicularia garzaensis Cushman and Siegfus. X 45.
7. Plectofrondicularia packardi packardi Cushman and Schenck. X 45.
8. Plectofrondicularia sp. A. X 45.
9. Plectofrondicularia sp. B. X 45.
10. Plectofrondicularia vokesi Cushman, Stewart and Stewart. X 45.
11. Plectofrondicularia sp. C. X 45.
12. Amphimorphina californica Cushman and McMasters. X 45.
13. Amphimorphina jenkinsi (Church). X 45.
14. Plectofrondicularia packardi multilineata Cushman and Simonson. X 72.

PLATE 5

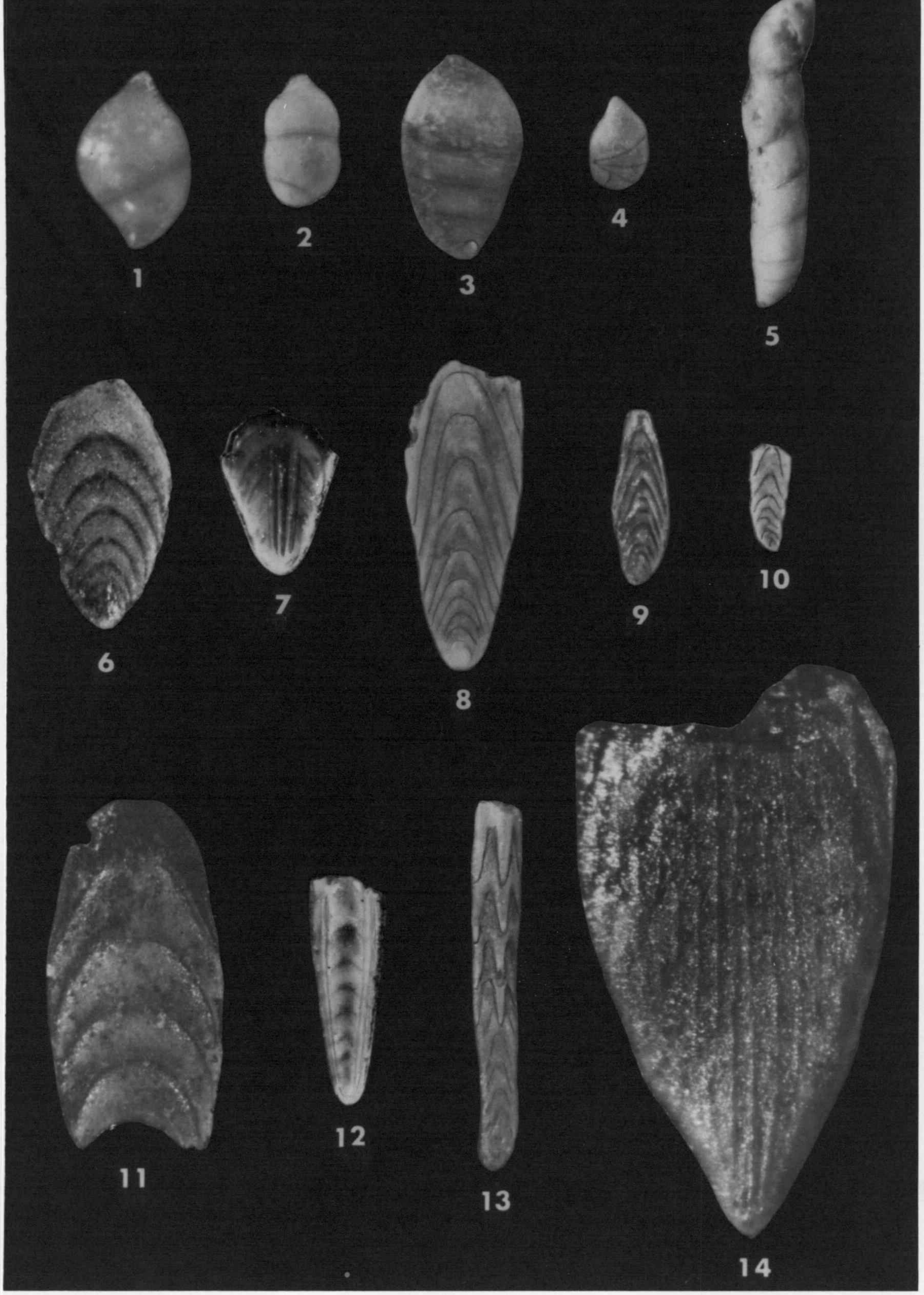


PLATE 6

Figures 1. Guttulina problema d'Orbigny. X 45.

2. Globulina sp. X 45.

3. Buliminella bassendorfensis? Cushman and Parker. X 60.

4. Buliminella? sp. X 75.

5. Brizalina basisenta (Cushman and Stone). X 70.

6. Brizalina huneri (Howe). X 50.

7. Brizalina sp. X 50.

8. Bulimina cf. B. alsatica Cushman and Parker. X 45.

9. Bulimina corrugata Cushman and Siegfus. X 45.

10. Bulimina microcostata Cushman and Parker. X 45.

11. Bulimina microcostata Cushman and Parker. X 48.

12. Bulimina schencki Beck. X 63.

13. Bulimina sculptilis Cushman and Schenck. X 45.

14. Praeglobobulimina? aff. P. pyrula (d'Orbigny). X 45.

15. Praeglobobulimina? ovata (d'Orbigny). X 45.

16. Uvigerina atwilli Cushman and Simonson. X 50.

17. Uvigerina cocoaensis Cushman. X 45.

18. Uvigerina gardnerae Cushman. X 45.

19. Uvigerina garzaensis Cushman and Siegfus. X 45.

20. Uvigerina yazooensis Cushman. X 45.

21, 22. Uvigerina? sp. 21, side view X 45; 22, side view X 75.

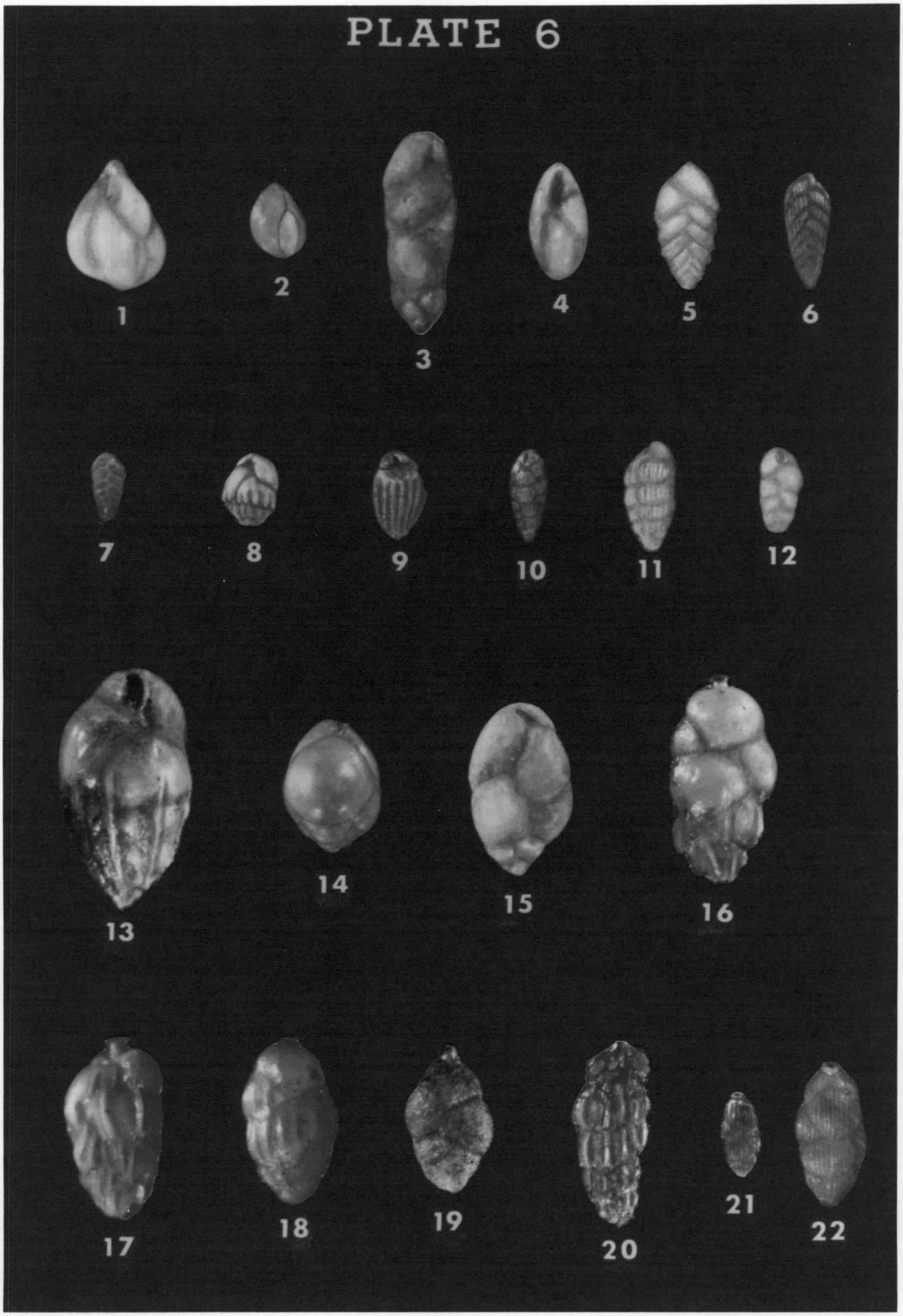

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PLATE 7

Figures 1. Chiloguembelina cubensis (Palmer). X 70.

2, 3. Pseudohastigerina micra (Cole). X 75. 2, side view; 3, side view.

4-7. Subbotina? sp. 4, ventral view X 133; 5, ventral view X 70; 6, peripheral view X 70; 7, dorsal view X 70.

8-10. Globigerina eocaena Gumbel. X 75. 8, ventral view; 9, peripheral view; 10, dorsal view.

11-13. Catapsydrax? echinatus Bolli. X 75. 11, dorsal view; 12, peripheral view; 13, ventral view.

14-16. Globorotalia sp. X 75.

17-19. Globigerina angustimbilicata Bolli. X 70. 17, ventral view; 18, peripheral view; 19, dorsal view.

20-22. Globorotalia increbescens? (Bandy). X 70. 20, ventral view; 21, peripheral view; 22, dorsal view.

23-25. Subbotina linaperta (Findlay). X 70. 23, ventral view; 24, peripheral view; 25, dorsal view.

26-28. Globigerina sp. X 70. 26, ventral view; 27, peripheral view; 28, dorsal view.

29-31. Globorotalia cf. G. gemma Jenkins. X 70. 29, ventral view; 30, peripheral view; 31, dorsal view.

PLATE 7

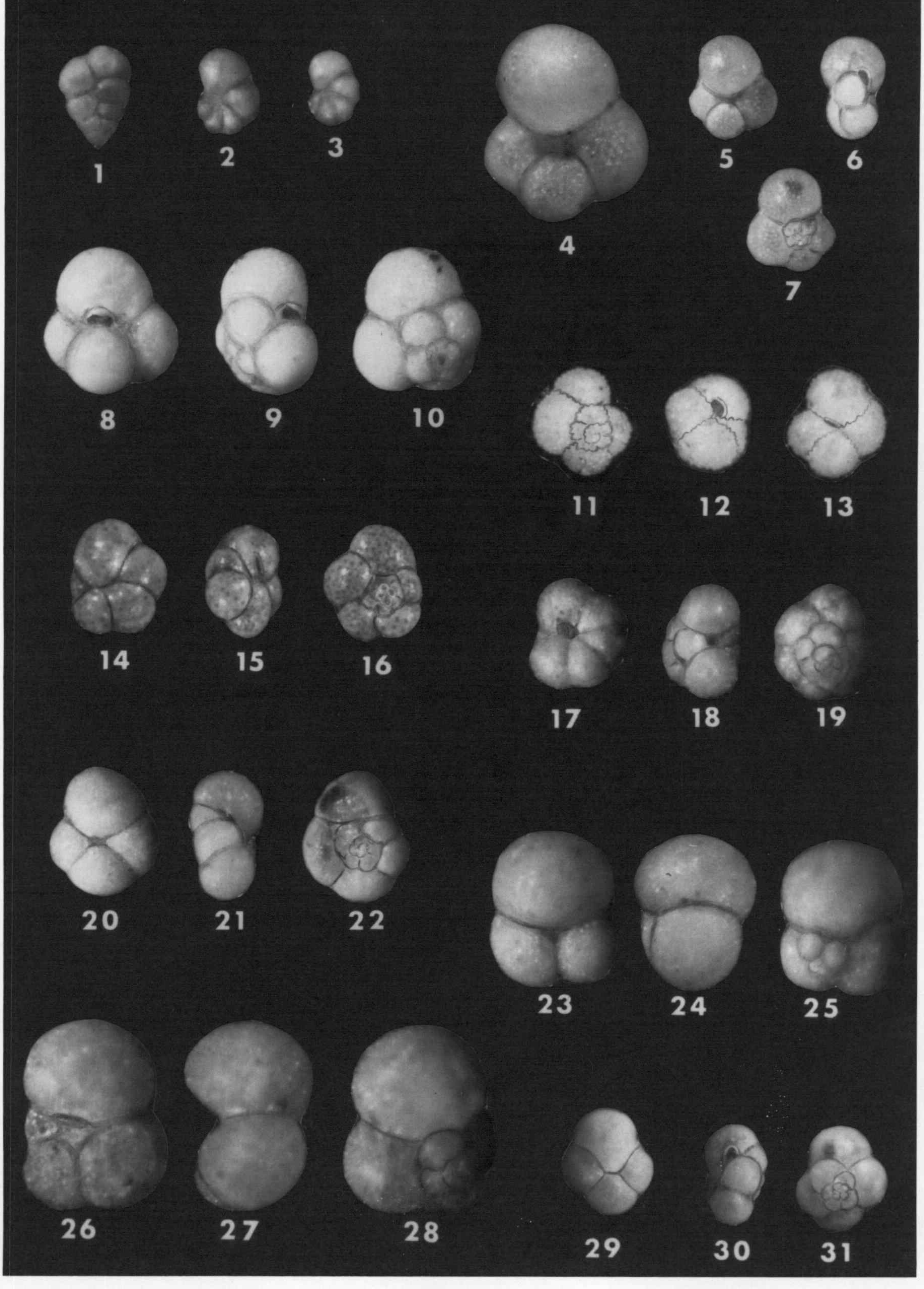
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PLATE 8

Figures

1-3. Globigerina prasaepis? Blow. X 65. 1, ventral view; 2, peripheral view; 3, dorsal view.

4-6. Globigerina senilis Bandy. X 65. 4, ventral view; 5, peripheral view; 6, dorsal view.

7-9. Globigerina tripartita tripartita Koch. X 60. 7, ventral view; 8, peripheral view; 9, dorsal view.

10-12. Globigerina senilis Bandy. X 65. 10, ventral view; 11, peripheral view; 12, dorsal view.

13-15. Globorotalia gemma Jenkins. X 65. 13, ventral view; 14, peripheral view; 15, dorsal view.

16, 17. Globorotalia opima nana Bolli. X 65. 16, ventral view; 17, dorsal view.

18, 19. Pseudohastigerina aff. P. micra (Cole). X 65. 18, side view; 19, peripheral view.

20-22. Globigerina praebulloides occlusa Blow and Banner. X 62. 20, ventral view; 21, peripheral view; 22, dorsal view.

23-25. Globigerapsis index? Findley. X 62. 23, ventral view; 24, peripheral view; 25, dorsal view.

26. Globigerina angiporoides? Hornibrook. X 62.

PLATE 8

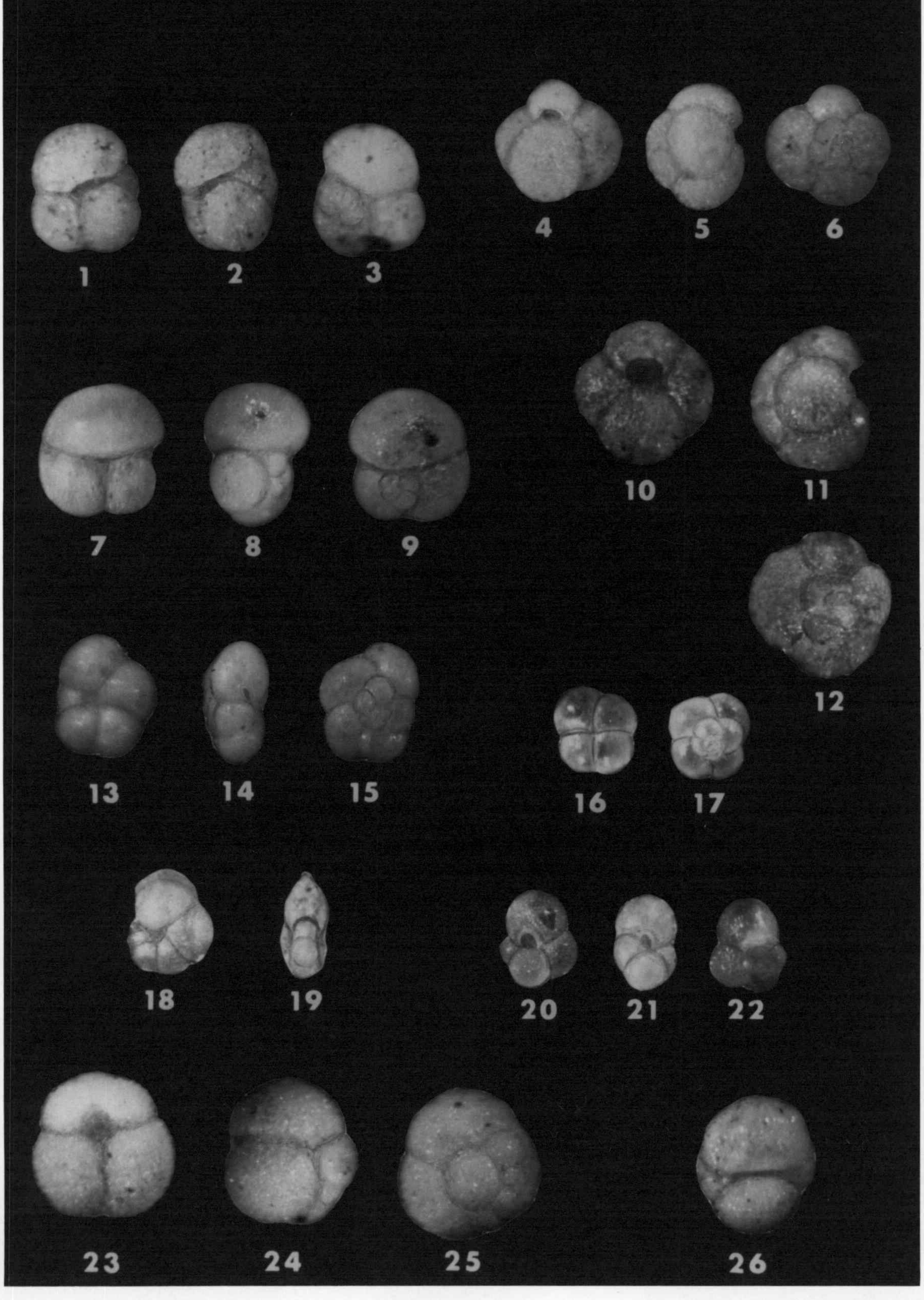

PLATE 9

Figures 1. Pseudonodosaria ovata (Cushman and Applin). X 45.

2. Pseudonodosaria conica (Neugeboren). X 45.

3, 4. Globobulimina pacifica Cushman. X 45.

5. Bulimina? sp. X 45.

6. Stilostomella cooperensis (Cushman). X 57.

7. Stilostomella lepidula (Schwager). X 75.

8. Stilostomella cf. S. adolphina (d'Orbigny). X 75.

9. Trifarina hannai (Beck). X 75.

10. Stilostomella sp. X 75.

11. Elphidiella? sp. X 75.

12. Cancris sp. X 45.

13-15. Cancris joaquinensis Smith. X 45. 13, dorsal view; 14, peripheral view; 15, ventral view.

16-18. Valvulineria menloensis Rau. X 45. 16, 18, opposite sides; 17, peripheral view.

19-21. Valvulineria tumeyensis Cushman and Simonson. X 35. 19, dorsal view; 20, peripheral view; 21, ventral view.

PLATE 9

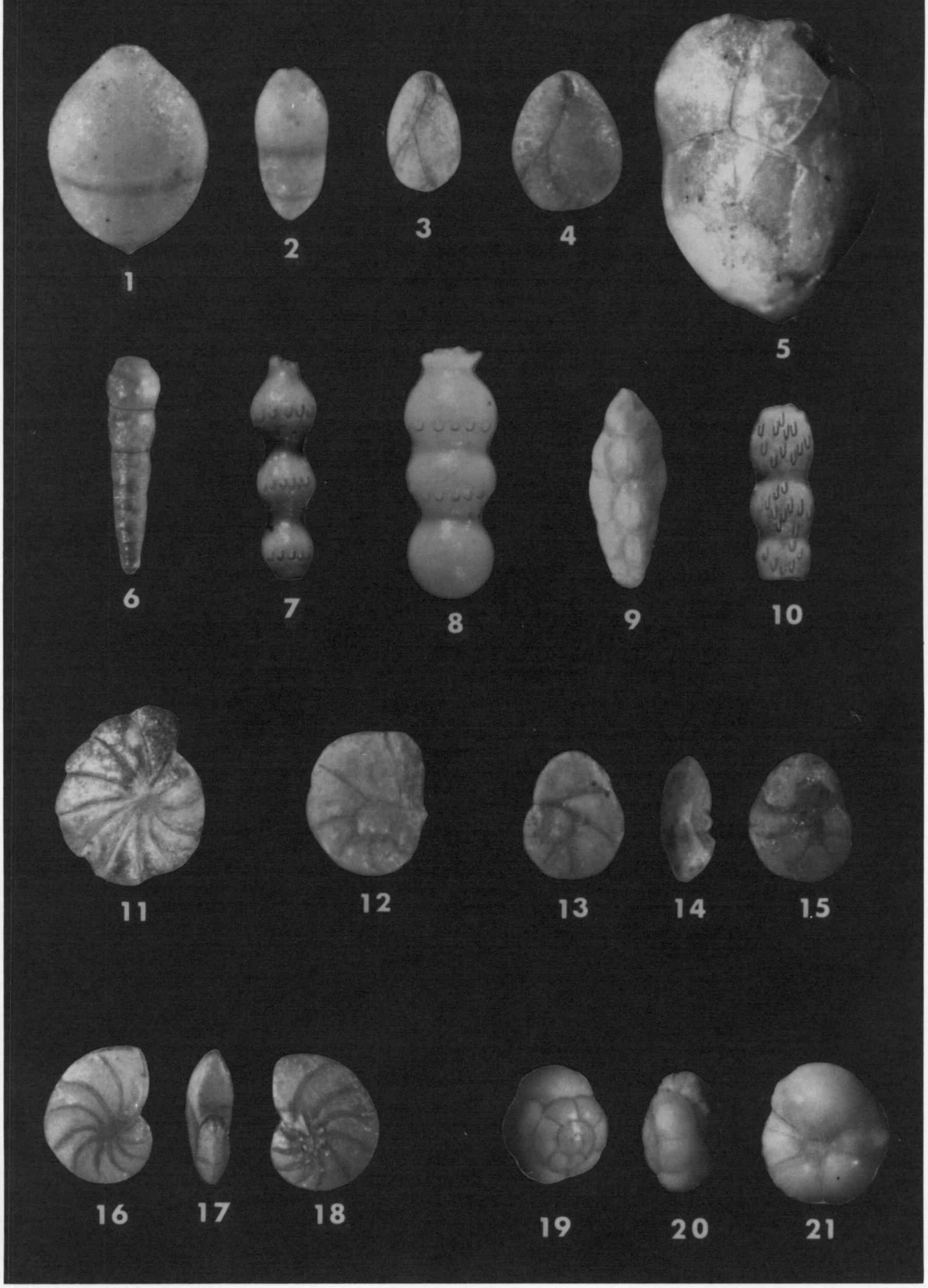

PLATE 10

Figures

1-3. Eponides yeguaensis (Weinzierl and Applin). X 45. 1, dorsal view; 2, peripheral view; 3, ventral view.

4-6. Cibicides warreni Cushman, Stewart, and Stewart. X 45. 4, dorsal view; 5, peripheral view; 6, ventral view.

7-9. Cibicides hodgei Cushman and Schenck. X 45. 7, ventral view; 8, peripheral view; 9, dorsal view.

10-12. Cibicides mcmastersi? Beck. X 45. 10, dorsal view; 11, peripheral view; 12, ventral view.

13-15. Cibicides haydoni (Cushman and Schenck). X 45. 13, dorsal view; 14, peripheral view; 15, ventral view.

16-18. Cibicides natlandi Beck. X 45. 16, dorsal view; 17, peripheral view; 18, ventral view.

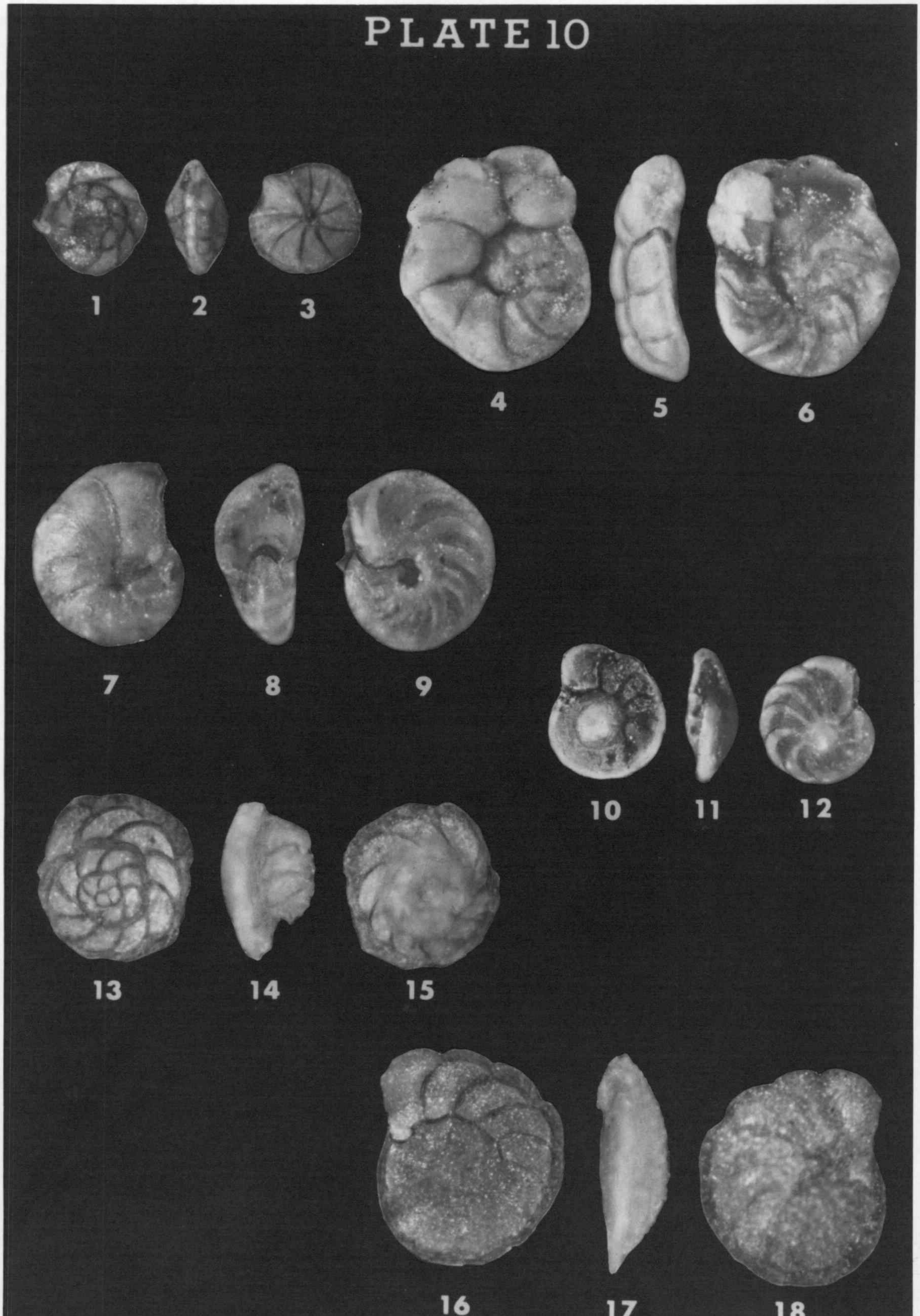
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PLATE 11

Figures 1. Cassidella hobsoni? Beck. X 45.

2, 3. Globocassidulina globosa (Hantken). X 63. 2, side view; 3, apertural view.

4. Allomorphina trigona macrostoma Karrer. X 45.

5. Chilostomella hadleyi Keijzer. X 33.

6. Chilostomella sp. X 45.

7, 8. Nonion florinense Cole. X 45. 7, side view; 8, peripheral view.

9, 10. Nonion sp. X 45.

11, 12. Anomalina californiensis Cushman and Hobson. X 45. 11, side view; 12, peripheral view.

13, 14. Pullenia quinqueloba (Reuss). X 73. 13, side view; 14, peripheral view.

15, 16. Nonionella? sp. X 45. 15, side view; 16, peripheral view.

17, 18. Nonionella cf. N. insecta? (Schwager). X 45. 17, 18, opposite sides.

19-21. Alabamina kernensis Smith. X 50. 19, dorsal view; 20, peripheral view; 21, ventral view.

22-24. Gyroidina condoni (Cushman and Schenck). X 45. 22, dorsal view; 23, peripheral view; 24, ventral view.

25-27. Gyroidina condoni (Cushman and Schenck). X 45. 25, dorsal view; 26, peripheral view; 27, ventral view.

28-30. Gyroidina girardana planata Cushman. X 45. 28, dorsal view; 29, peripheral view; 30, ventral view.

Plate 11 (continued)

Figures 31, 32. *Anomalina*? sp. X 45. 31, 32, opposite sides.

33-35. *Ceratobulimina washburni* Toula. X 33. 33, dorsal view; 34, peripheral view; 35, ventral view.