STATE OF WASHINGTON

DEPARTMENT OF NATURAL RESOURCES

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Bulletin No. 62

FORAMINIFERA, STRATIGRAPHY, AND PALEOECOLOGY OF THE QUINAULT FORMATION, POINT GRENVILLE-RAFT RIVER COASTAL AREA, WASHINGTON

By
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1889

STATE PRINTING PLANT OLYMPIA, WASHINGTON

1970

For sale by Department of Natural Resources, Olympia, Washington.
Price $3.00

FOREWORD

In recent years increasing interest has been shown in oil and gas exploration along the Washington coast, both onshore and offshore. To provide basic geologic data that can be used in evaluating the petroleum resource potential, the Division of Mines and Geology of the Department of Natural Resources is now engaged in detailed geologic studies along the coast of Washington. Bulletin No. 62 is the first technical report on this project.

Foraminifera (microfossils) contained in the Quinault Formation are described and illustrated, and from them interpretations are made of the paleoecology and stratigraphy of the formation. Such technical data from the limited onshore outcrops of the formation are particularly significant, because the formation or its stratigraphic equivalent is believed to be far more widespread on the adjacent Continental Shelf, where it is much less accessible for examination. These strata hold perhaps the greatest favor as a potential petroleum reservoir, both on and offshore.

Our coastal geologic studies are being conducted by Dr. Weldon W. Rau, a geologist on the Division of Mines and Geology staff for the past 10 years, and who was with the U.S. Geological Survey for 10 years prior to joining the Division. During this time he has directed essentially all his research to biostratigraphy of the Tertiary rocks of western Washington and Oregon and therefore is well qualified to make the current studies.

Although data and conclusions presented in this report are of interest primarily for petroleum exploration, the basic geologic information may well be useful in other fields of geologic exploration and of some general educational value also.

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November 12, 1970

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FORAMINIFERA, STRATIGRAPHY, AND PALEOECOLOGY OF THE QUINAULT FORMATION, POINT GRENVILLE-RAFT RIVER COASTAL AREA, WASHINGTON

BY WELDON W. RAU

ABSTRACT

One new species and fifty-six additional species of Foraminifera from the Quinault Formation are illustrated and their significance discussed. Assemblages were collected from 101 localities in 4 measured sections and in isolated outcrops exposed along the Washington coast between Point Grenville and the vicinity of the Raft River.

The total stratigraphic thickness of the beds included may be as much as 6,200 feet, although relations between sections are not known precisely. The Duck Creek-Pratt Cliff section alone, composed of siltstone and fine-grained sandstone, is some 4,600 feet thick. Sandstone and conglomerate of the Cape Elizabeth section are believed to lie stratigraphically above, and they constitute some 1,600 feet of thickness. The siltstone section south of Taholah and the sandstone section north of Point Grenville both may correlate with some part of the Duck Creek-Pratt Cliff section.

The Quinault Formation rests unconformably on highly contorted older rocks of the Hoh Formation that are largely of early to middle Miocene age (Saucesian and Relizian stages). In places where these formations are in fault contact, a tectonic melange of the older (Hoh) rocks appears to have been injected in a diapiric manner into the Quinault Formation.

Locally, the Quinault Formation represents an upper part of the upper Tertiary-lower Quaternary sequence, most of which is stratigraphically higher than the upper Miocene Montesano Formation of southwest Washington. The stratigraphic distribution of Foraminifera in the Quinault Formation compares broadly with that of the standard west coast Pliocene section of the Repetto-Pico sequence (Repettian stage to possibly lower Hallian stage of Natland) of the Los Angeles basin and vicinity. Furthermore, in other basins along the coast, the Foxen Mudstone of the Santa Maria area, the Purisima and Merced Formations of the San Francisco area, the Rio Del Formation and Scotia Bluffs Sandstone of northern California, and the Port Orford and Elk River Formations exposed near Cape Blanco, Oregon, all either contain foraminiferal assemblages that, in a general way, compare with those of parts of the Quinault Formation, or the stratigraphic sequence of occurrence of the contained Foraminifera is similar to that of the Quinault Formation. Therefore, the Quinault Formation may represent an interval in the development or filling of its basin of deposition similar to the intervals represented by other formations in a number of young basins of deposition along the west coast, including that of the standard west coast Pliocene section in the Los Angeles area.

Environmental conditions of deposition in the four measured sections of the Quinault Formation are noticeably varied, as revealed by the foraminiferal assemblages. The section north of Point Grenville was deposited largely in neritic conditions, probably at no greater depth than 200 feet in temperate-to-cool water (13° to 8° C). Minor foraminiferal evidence also suggests that some of the sediments may have been redeposited at greater depths, but not necessarily deeper than 1,500 feet. In the section south of Taholah, faunas indicate more than one condition of deposition. Final deposition was likely at upper bathyal depths (900 to 2,000 feet) in cool-to-cold water (9° to 4° C). However, much of the material was derived, possibly by turbidity currents, from sediments originally deposited in a neritic environment (0 to 600 feet) under temperate water conditions. In the Cape Elizabeth section, the very few Foraminifera known suggest shallow-water conditions of deposition and therefore support lithologic evidence for upper neritic conditions in the lower siltstone-sandstone part and for littoral deposition of carbonaceous coarse-grained sandstone and conglomerate in the upper part. The Duck Creek-Pratt Cliff section contains Foraminifera indicating that deposition of these beds took place largely on the outer edge of the Continental Shelf in lower neritic to uppermost bathyal depths (400 to 1,000 feet) in cool-to-cold water (12° to 7° C).

Quinault Foraminifera, therefore, reflect varied depositional environments. Stratigraphic distribution suggests a sequence of ecological events comparable to that in other young west coast basins of deposition, most of which are considered Pliocene in age.

INTRODUCTION

LOCATION AND ACCESS

Outcrops of the Quinault Formation occur largely in sea cliffs and on the beaches of the Washington coast between Point Grenville and a point about 1 mile north of the mouth of the Raft River within the Quinault Indian Reservation (Fig. 1). Also, a few small isolated outcrops occur to the south between Point Grenville and Moclips, Washington. With the latter exception, practically all outcrops of the formation are in the Taholah 15-minute quadrangle and lie within Tps. 21, 22, and 23 N., R. 13 W.; and between latitudes 47°15′ and 47°30′ N., and longitudes 124°15′ and 124°25′ W. Eastward from the coast, thick deposits of sand and gravel almost completely cover the area, and nowhere in the Taholah quadrangle are outcrops of the Quinault Formation known more than 3 miles from the coast. Most inland outcrops of the formation are in secs. 2, 3, 9, 10, 11, 15, and 22, T. 22 N., R. 13 W.

Access to the reservation, with the permission of the Quinault Tribal Council, is largely by logging roads; the partly constructed State Highway 9-C; and usable parts of the "Cape Elizabeth" road, which parallels much of the coast in this area. The beaches can be approached at only a few places, because of the high, nearly vertical sea cliffs in much of the area. All beaches are accessible at low tide with the exception of a stretch of beach about a quarter of a mile long at Pratt Cliff, where most of the cliffs plunge directly into the sea. A continuous section of the Quinault Formation is exposed in these cliffs, but, unfortunately, during the investigation for this report it could be viewed only by helicopter, so measurements of this section were estimated from attitudes available at the north and south ends of this inaccessible area.

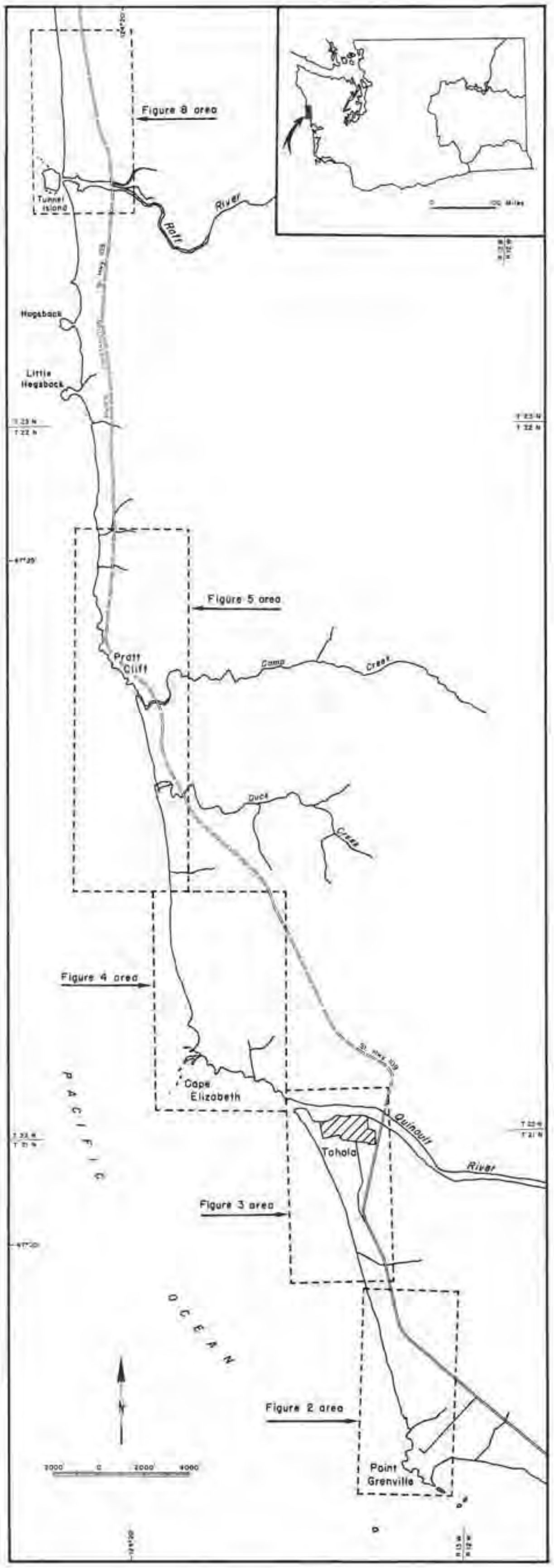


FIGURE 1.—Index map of the five outcrop areas of the Quinault Formation discussed in this report.

FIELD WORK AND ACKNOWLEDGMENTS

Geologic field studies in the area of the Taholah quadrangle began in the summer of 1967, during which time most of the sections discussed in the report were sampled and measured. Additional data were gathered for the study during the summer months of 1968 and 1969, while primarily investigating the general geology of this and surrounding areas.

The cooperation of the Quinault Tribal Council in granting access to the reservation and the guide services and general assistance of many of the local residents are greatly appreciated. The Aloha Logging Company and the Washington State Highway Department were most helpful in supplying road maps and access to locked areas. Several oil companies aided greatly in many ways. Particular thanks are due D. B. Braislin, of the Union Oil Company of California, for making available comparative foraminiferal materials and for offering helpful comments. The general assistance and constructive discussions of J. R. Sprague, A. D. Horn, and R. S. Boettcher, of the Mobil Oil Company, are greatly appreciated. All staff members of the Washington Division of Mines and Geology have aided in various ways in the preparation of this report. Particular thanks are due to M. T. Huntting, Supervisor, for his editorial comments and for administrative assistance connected with the publishing of this report. The capable assistance throughout the summer months of J. P. Braislin in 1967 and of G. D. Cloud during 1968 and 1969 is gratefully acknowledged. All photographs of Foraminifera accompanying the report were retouched by D. A. Winsor.

PURPOSE, METHOD OF STUDY, AND SCOPE

Comprehensive geologic investigations are being undertaken by the Division of Mines and Geology of the Washington State Department of Natural Resources in a major segment of the westernmost part of the Olympic Peninsula to provide a basis for evaluation of oil and gas possibilities of the area, as well as other mineral resources. These more extensive geologic investigations are being conducted between Point Grenville and the Hoh River and extend eastward into the foothills of the Olympic Mountains.

Detailed information on the stratigraphy and foraminiferal distribution of the Quinault Formation exposed in this area is of particular importance, because known onshore outcrops of the formation are confined almost entirely to this area. However, equivalent strata are widespread to the west on the Continental Shelf, where investigations are limited largely to drilling and geophysical operations. Furthermore, in the subsurface of both onshore and offshore areas, these rocks are potentially favorable as a reservoir for oil and gas.

The Quinault Formation is exposed in four major and separate sections along the Washington coast. Each of these sections was sampled thoroughly for Foraminifera, and its thickness was computed from a Brunton compass and tape traverse. The 57 foraminiferal species illustrated and discussed in this report are from 101 localities within these 4 sections and nearby isolated outcrops. Based on faunal composition of the formation and the distribution of the various species of Foraminifera within each section, a general history of deposition is constructed for the containing sediments. Broad correlations of the Quinault Formation are made with similar beds of other areas on the Pacific coast, and suggestions are presented regarding its relative geologic age. Furthermore, ecological conditions under which the sediments in the various sections were most likely deposited are determined by an evaluation of the composition of the containing foraminiferal faunas.

PREVIOUS WORK

Arnold (1906) first applied the name Quinault (Quinaielt) Formation to the strata exposed between Cape Elizabeth and Point Grenville, which he described as more than 2,200 feet in thickness and composed of conglomerates, shales, and some sandstone. As an equivalent, he also included concretionary sandstone at the mouth of the Raft River. On the basis of megafossils from the formation, he referred the Quinault Formation to the Pliocene and correlated it with the Purisima Formation of central California.

Reagan (1909) followed Arnold's concepts of the Quinault Formation, but regarded beds in the vicinity of the mouth of the Raft River as the Raft River Formation.

Arnold and Hannibal (1913, p. 589, 592) referred at least some of the strata formerly called Quinault Formation to the Empire Formation (Miocene). They stated: "Small Empire areas occur . . . between Cape Grenville and the mouth of the Quinault River, between Cape Elizabeth and Raft River, and at the mouth of Raft River." They also referred broadly to some of the beds near Taholah as the Merced Formation (Mio-Pliocene) for which they estimated a thickness of some 500 feet.

Lupton (1914), in his reconnaissance study of the Olympic coastal area for oil and gas, described the rocks in the outcrop area of the Quinault Formation in considerable detail. He suggested that these rocks exposed along the coast in this area represent the east limb of a large anticline, whose north-south axis lies offshore. He further stated that several small anticlines cross this major structure nearly at right angles.

Weaver, in both "Tertiary Faunal Horizons of Western Washington" (1916b) and "The Tertiary Formations of Western Washington" (1916a), referred all beds formerly and presently regarded as the Quinault Formation to his Montesano Formation, which he regarded as upper Miocene in age, based on megafossils. He further used the term *Yoldia strigata* zone to apply to the fauna of the Grays Harbor region occurring in beds he regarded as "upper Miocene." His major section of study for these rocks in the coastal region apparently was that of the Cape Elizabeth area, as he presented detailed descriptions of these beds.

Weaver (1932), in his report on the geology and structure of the region north of the Quinault River, referred some of those beds under consideration in the current report to "the middle Miocene," and others to "the upper Miocene." At that time he definitely referred to the Cape Elizabeth sandstone and conglomerate section as "upper Miocene." Apparently, he regarded all other moderately deformed beds along the coast in this vicinity as "middle Miocene," with the possible exception of at least some of the Duck Creek-Pratt Cliff section. In one part of his report he refers to at least the southern part of that section as "upper Miocene," whereas in another part he calls these beds "middle Miocene."

Weaver (1937) adopted the formation designation of "Quinault" as originally used by Arnold (1906) for beds occurring in a small area immediately north and south of the mouth of the Quinault River between Point Grenville and Cape Elizabeth, and apparently he no longer included in his Montesano Formation any of the rocks exposed along the coast. He referred generally to Point Grenville as the southern extent of outcrops of the Quinault Formation, and stated that the contact with older rocks might be either a fault or an unconformity. However, in his 1937 report he did not specifically point out what he regarded as the northern limit of the Quinault Formation along the coast, and therefore it is not known whether he regarded the beds of the Duck Creek-Pratt Cliff section of the current report as part of the Quinault Formation. In 1916 he did include these beds in his Montesano Formation. Based largely on studies of the Merced Formation of California, he no longer regarded any of these rocks as late Miocene in age and suggested a late-middle to early-late Pliocene age for these beds.

In 1942, Weaver apparently again revised his opinion slightly and suggested, in his correlation chart, a late-early to middle Pliocene age for the Quinault Formation, a conclusion similar to the early Pliocene age suggested by Arnold (1906) in his original description of the formation.

Cushman, Stewart, and Stewart (1949) were the first to illustrate and discuss Foraminifera from the Quinault Formation. Their assemblage came from a single locality in the Quinault Formation exposed along the coast in an area between the Point Grenville and Taholah sections of the current report. Their assemblage is surprisingly large for having come from one locality within this formation. Many of the forms were encountered also in the present study. Cushman, Stewart, and Stewart noted a close affinity of their foraminiferal assemblage with that of a part of the Wildcat Formation of northern California, which they related to the lower Pliocene.

Snavely and Wagner (1963), in their report on the Tertiary history of western Oregon and Washington, included the sediments of the Quinault Formation as typical of those deposited in a basin during Pliocene time from older uplifted Tertiary formations. Most of this basin is west of the present coastline.

Weissenborn and Snavely (1968), in their summary of the geology and mineral resources of the coastal area, briefly mention the rocks of the Cape Elizabeth area and refer them to a late Miocene to Pliocene age.

Other than the brief references in the two reports cited immediately above, very little has actually been published specifically on the Quinault Formation since 1949. In addition to the above-mentioned published reports, several unpublished studies have been conducted on various phases of the formation. Significant among these is the unpublished work of Sheldon L. Glover (1945) on the geology of the west coast of the Olympic Peninsula. His maps are available for inspection at the office of the Division of Mines and Geology in Olympia, Washington. He described the coastal outcrops of the Quinault Formation in considerable detail, including those in the Pratt Cliff area and in the vicinity of the mouth of the Raft River. Other isolated areas of outcrops are also discussed, such as those of the Wreck Creek area; Copalis area; and that which Reagan (1909) originally designated as the Quillayute Formation, near the confluence of the Bogachiel and Soleduck Rivers.

Fowler (1965), in a Ph.D. dissertation dealing with the Montesano Formation in a nearby area, listed foraminiferal species found in 12 samples from the Point Grenville and Taholah sections of the Quinault Formation and stated that the fauna of the Quinault Formation is definitely younger than that of the Montesano Formation. Based on Fowler's 1965 findings, Ingle (1967) concluded that the planktonic Foraminifera from a part of the Quinault Formation indicate significantly higher surface temperatures than occur at this latitude today.

The most recent work dealing with the Quinault Formation is a master's thesis by Horn (1969) on the sedimentary history of the formation. His studies were based on observations in the same sections as those of the present report. Included in his report are detailed observations on the various lithologic units, a study of the petrology and petrography of the sediments, descriptions of the various sedimentary structures, and an analysis of paleocurrent directional features. He postulated that the sediments of the Quinault Formation were deposited from the east and southeast, forming a coastal deltaic plain. He concluded, as have others in the past, that the uplift of the Olympic Mountains and surrounding highlands supplied most of the sediments of the at least 7,000-foot thickness of the Quinault Formation.

GENERAL GEOLOGY

AREAL EXTENT OF THE QUINAULT FORMATION

The Quinault Formation, as recognized in this report, consists of moderately folded siltstone, sandstone, and conglomerate beds exposed mainly along the coast between Point Grenville and a point about one mile north of the mouth of the Raft River (Fig. 1, p. 2). Within this stretch of coastline four essentially continuous sections are exposed and are referred to in this report as follows: The section north of Point Grenville (exposed for some three-quarters of a mile north of Point Grenville) (Fig. 2, p. 6); the section south of Taholah (exposed for about one-half mile along the coast in an area about three-quarters of a mile south of the town of Taholah) (Fig. 3, p. 7); the Cape Elizabeth section (extending from the mouth of the Quinault River on the north to a point about one and one-quarter miles north of the Cape) (Fig. 4, p. 8); and the Duck Creek-Pratt Cliff section (extending from the mouth of Duck Creek to a point about three-quarters of a mile north of the north end of Pratt Cliff) (Fig. 5, p. 9).

The area along the coast occupied by these sections is regarded here as the type area of the Quinault Formation. A few small additional outcrops are also included several miles south of Point Grenville, and also in the vicinity of the mouth of the Raft River (Fig. 8, p. 13), but they are so small and so isolated that they represent no appreciable section. The eastern extent of the formation is not known in detail because thick Pleistocene(?) deposits cover much of the area, but nowhere are outcrops of the formation known more than 3 miles inland from the present coastline. To the west, the formation may well be far more extensive. Recent offshore geophysical investigations conducted by petroleum companies, as well as by Federal and university oceanographic research groups, suggest that strata both structurally and stratigraphically comparable to the Quinault Formation may underlie much of the Continental Shelf off the Washington coast. A number of wells have been drilled on or near the coast, and a few were situated offshore. Approximately 20 miles to the north of the Quinault River and nearly 20 miles offshore west of Destruction Island, a well drilled by Pan American Petroleum Corporation to a depth of 10,368 feet penetrated some 2,000 feet of strata that, based on foraminiferal studies by the writer, paleontologically can be correlated with at least parts of the onshore beds of the Quinault Formation. Southward along the coast, particularly in the Ocean City area some 20 miles south of the Quinault River, at least thirteen wells for which records are available have been drilled onshore and one approximately 2 miles offshore. All have penetrated some strata believed to be similar to the Quinault Formation. In some places these beds are at least 2,500 feet thick. Paleontologic evidence from a few of these wells verifies a correlation of these beds with the Quinault Formation of the type area. Several additional wells have been drilled offshore beyond 3 miles, but no information has been made available from them. Therefore, although exposures of the formation are largely confined to a narrow strip along the coast between Point Grenville and the Raft River, this evidence suggests that it is actually a rather widespread unit, mainly on the Continental Shelf and extending at least 20 miles to sea and for at least 40 miles along the coast.

ASSOCIATED ROCKS

OLDER ROCKS

The Quinault Formation rests unconformably on older rocks, commonly called the Hoh Formation. However, in many places within the type area, faulting has also played an important part in bringing older rocks into juxtaposition with the Quinault Formation. Continuous seismic profile records from off the Washington coast (Snavely, P. D., Jr., U.S. Geological Survey, oral communication, 1970) substantiate such an extensive unconformity on the Continental Shelf. The actual contact can be seen in several places within the type area. It is probably best exposed in an outcrop along the coast in the NE¼ sec. 9, T. 22 N., R. 13 W., at the end of a foot trail leading to the beach (Fig. 5, p. 9). At this point the Quinault Formation dips some 25° SE. and rests on a somewhat irregular surface that also dips gently southward. The contact is well defined by color contrast between the relatively light-colored sandy siltstone of the Quinault

Formation and the very dark gray older rocks beneath. Although a certain amount of differential movement may have taken place on this surface, the undulating and low-angle nature of this contact suggests that in this area it may well be essentially unfaulted. Older rocks are exposed in the sea cliffs for a distance of about 2½ miles from this point northward to within about ½ mile of the mouth of the Raft River. Koch (1968), in an unpublished research paper, described and discussed the rocks exposed in this area. Here, and in nearly all other places along the coast where the Quinault Formation is in association, the older rocks consist of a completely chaotic mass of nearly structureless melange. This disturbed rock unit has been referred to the Hoh Formation by Weaver (1916a). Locally, it has become known unofficially as the "Hoh Breccia" because of its completely chaotic nature. For the most part, this rock is an incompetent siltstone that appears to have undergone intensive squeezing. Almost all clasts of siltstone display slickensided surfaces. Within the general matrix of the squeezed siltstone, more resistant clasts of many different rock types occur, some boulders of which are several tens of feet in diameter. Rock types commonly included are altered andesitic volcanic rock, indurated sandstone or graywacke, indurated siltstone, conglomerate, greenstone, and other metamorphic rocks. The volcanic headlands known as "The Hogsback" and "Little Hogsback" are within this outcrop of melange and may well be large resistant blocks within a matrix, which is generally of siltstone. Although the structure within these older rocks is largely chaotic, faint pseudobedding or perhaps shearing-planes are apparent locally. Within the major area of outcrop immediately south of the mouth of the Raft River this bedding(?) strikes dominantly northeast and dips southeast some 35° to 40°.

Foraminiferal assemblages from the Hoh Formation from 15 coastal localities between Cape Elizabeth and the Raft River indicate various ages ranging from late Oligocene (Zemorrian stage) to middle Miocene (Relizian stage), but most of them are early Miocene (Saucesian stage) in age.

Although Glover (1945) suggested that faulting probably had some effect on the nature of these rocks, he also implied that slumping might have been the main force that caused their chaotic condition. Weissenborn and Snavely (1968) referred to these rocks as a tectonic melange and suggested that they are similar to the so-called "Argille Scagliose" of the foothills of the northern Apennines in Italy (Sitter, 1956). As postulated for the "Argille Scagliose," Weissenborn and Snavely suggested that the chaotic condition of some of the rocks along the Washington coast may also be a result of a combination of gravity thrust and intraformational gravity sliding.

Current investigations by the writer and by Stewart (1970) in areas immediately east and north of the area of this report show that much of the lowlands and westernmost foothills of the Olympic Mountains are underlain by intensely folded and broken massive to thick-bedded graywackes, thin-bedded sandstones and siltstones, and massive siltstones that also range in age largely from late Oligocene to middle Miocene (Zemorrian stage to Relizian stage). These rocks are distinct both faunally and lithologically, as well as structurally, from rocks of the same general age, both to the north along the northern border of the Olympic Peninsula and to the south in the Grays Harbor basin and southward into Oregon, and therefore appear foreign to the general surrounding province. Melange similar to that of the Taholah-Raft River area is also present in local areas of the west-central part of the Olympic Peninsula.

Speculations on the tectonics of the Olympic Mountains are beginning to emerge, and popular among these ideas are those employing plate tectonics, for which the basic mechanism is relative eastward movement of the sea-floor materials (Stewart, 1970). Briefly, it is postulated that these materials, largely turbidite sedimentary rocks at least as young as middle Miocene age, have moved eastward against the North American continent and have been restricted possibly by the upturned buttress of the Crescent Volcanics, as well as by pre-Cenozoic rocks farther to the east. This restriction of eastward-moving oceanic materials has caused intense folding, together with successive underthrusting of these beds (Tabor and Cady, 1965; Tabor and others, 1970; Stewart, 1970), the most recent breaks and downward thrusting having taken place farthest to the west. Those disturbed rocks present along the coast in the Taholah-Raft River area may well be part of a zone, or zones, of thrusting. However, because of the apparent mobility of these rocks, it is further suggested that at least in some instances they may have been placed in juxtaposition with the Quinault Formation by piercement or diapiric methods, which in turn may have added even further to their chaotic condition. Diapiric structures are known to occur on the Continental Shelf off Washington and Vancouver Island, where they have been identified in continuous seismic profiles obtained by various petroleum companies and research groups such as the U.S. Geological Survey (P. D. Snavely, Jr., written communication, 1970); University of Washington (Bennett and Grim, 1968); and by the Department of Energy, Mines, and Resources of Canada (D. L. Tiffin, oral communication, 1970). A possible onshore example can be seen along the coast between the mouth of Duck Creek and Cape Elizabeth, where a melange of older rocks is exposed for a distance of some 1,400 feet. In this area the Quinault Formation appears to be in fault contact with both the north and south ends of the outcrop of the melange. The older rocks are completely broken and structureless near both contacts, showing only faint shearing planes nearly parallel to the contacts. Large blocks of graywacke, volcanic rocks, and well-bedded sandstone and siltstone are present in a matrix of finely broken siltstone and gougelike clayey material. Structural relations and the nature and composition of the older rocks, therefore, suggest that in this area, at least, the Quinault Formation may well have been penetrated by the underlying, relatively mobile rocks of the Hoh Formation.

YOUNGER BEDS

The Quinault Formation is overlain by nearly horizontal Pleistocene(?) deposits of silt, sand, and gravel. These overlying deposits have been measured in several places and are as much as 100 feet thick. Particularly well exposed and thick beds of these deposits can be seen in the cliff a mile or so south of the town of Taholah. Inland from the coast, Pleistocene(?) deposits are extensive, and with the exception of a few outcrops of older rocks in streambeds and roadcuts, these deposits almost completely cover the Quinault Formation and older rocks. In places in secs. 10, 15, and 22, T. 22 N., R. 13 W., the Pleistocene(?) cover is relatively thin and a number of outcrops of the Quinault Formation can be seen.

MEASURED SECTIONS

Generally, the section north of Point Grenville consists of sandstone and is characterized by numerous and large sedimentary structures. To the north, the section south of Taholah is largely siltstone and is quite fossiliferous. North of the Quinault River the Cape Elizabeth section consists largely of sandstone and some siltstone in the lower part, grading up to much conglomerate and some sandstone in the upper part. In the northernmost part of the outcrop area, the Duck Creek-Pratt Cliff section consists mainly of fine sandstone and sandy siltstone.

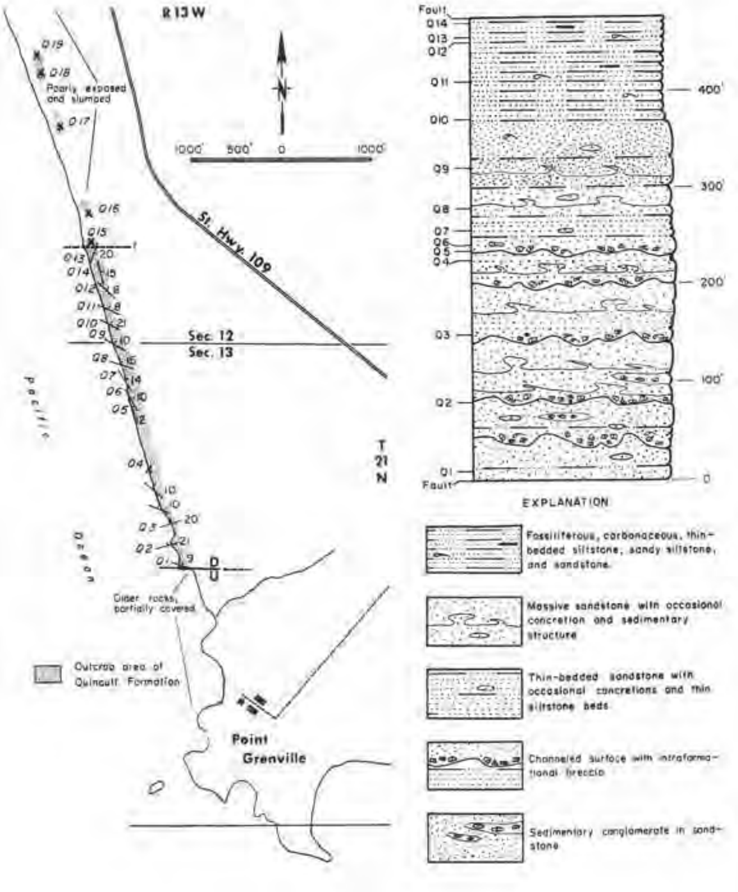


FIGURE 2.—Section north of Point Grenville; columnar section and traverse.

SECTION NORTH OF POINT GRENVILLE

Beds of the section north of Point Grenville dip generally north-northeast between 10° and 25° (Fig. 2). This section is bounded on the south (base) almost certainly by an eastward-trending fault where it is in contact with badly distorted older rocks, which are nearly covered by deposits of slumped Pleistocene(?) sand and gravel. The north end (top) of the Point Grenville section also appears to be bounded by an eastward-trending fault. Thin-bedded strata exposed immediately south of this point swing from a northeast dip to an east dip, and at the contact the beds on the south side of the fault dip southeast, suggesting a downward drag on the south side of the fault. Although immediately north of this point the rocks are also part of the Quinault Formation, they are distinct from those of the Point Grenville section, in that they are largely a massive sandy siltstone and some fine-grained sandstone. Some of the change in the attitude of the beds south of the fault may be due in part to slumping, but because of the major lithologic change at this point, it appears to be a fault contact that has been modified by slumping. Farther north from this contact, rocks are generally more massive and finer grained than those of the Point Grenville section and are more nearly like the beds of the Taholah section to the north.

Lithologically, the beds of the section north of Point Grenville are basically sandstone, as shown in the columnar section of Figure 2. They are characterized by numerous and large sedimentary structures, particularly in the lower part of the section. At least five irregularly channeled surfaces are present at various levels in the section. Immediately above each surface, large angular clasts, mostly of siltstone and other sedimentary rocks, usually fill these channels, together with numerous broken fossils. Thick-bedded to massive sandstone is common above and below these channels, and in places thin-bedded sandstone is also present. Excellent and large sedimentary structures are common. Some of these are: flame structures; scour-and-fill; and broken or "pulled apart" beds of thin, as well as thick, bedded sandstone. Horn (1969) discusses these features in detail. Approximately the lower 250 feet of section displays pronounced channeling and disruption of beds. The next 100 feet of section is rather massive sandstone, having only vague bedding and a few sedimentary structures. The uppermost 100 feet is very well bedded carbonaceous, fossiliferous sandstone and siltstone. These uppermost beds show only minor slump features.

Between the north end (top) of the Point Grenville section and the south end (base) of the section south of Taholah, an interval of about three-quarters of a mile, the Quinault Formation is poorly exposed, slumped, and in one area is completely covered by Pleistocene(?) deposits.

SECTION SOUTH OF TAHOLAH

Immediately south of the mouth of the first major stream south of Taholah, the Quinault Formation reappears and represents the base of the Taholah section (Fig. 3). Here the beds dip northeast, and northward from this point they gradually swing to a northwest dip at the north

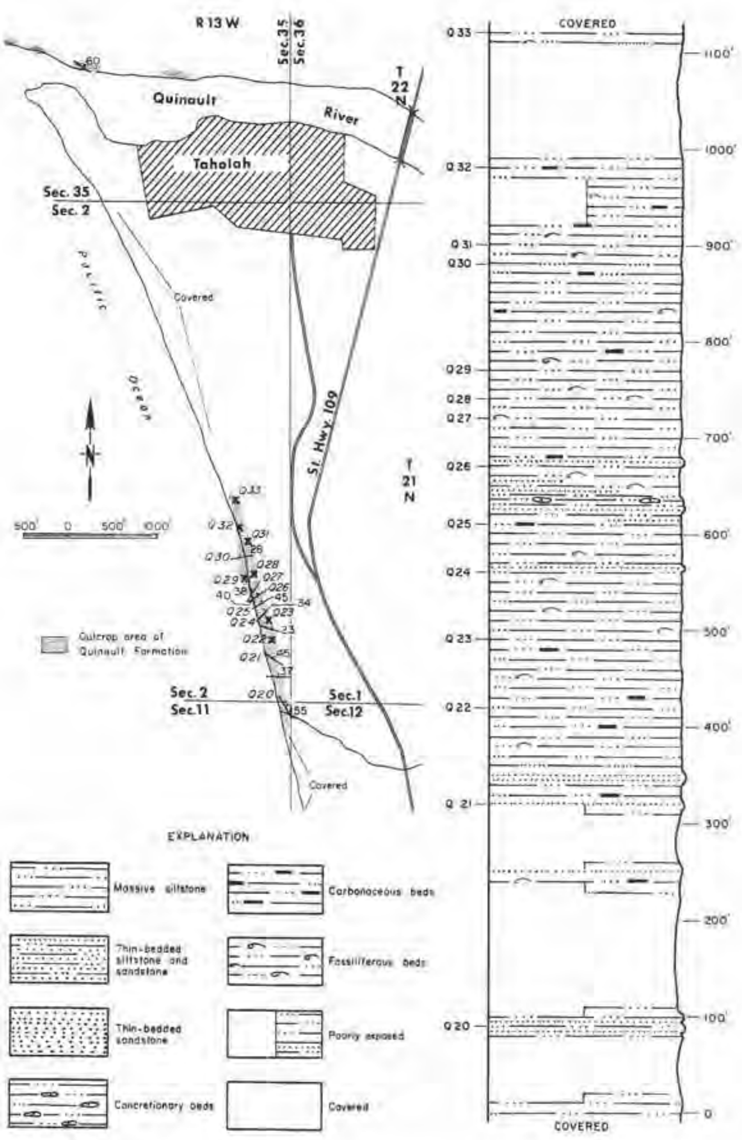


FIGURE 3.—Section south of Taholah; columnar section and traverse.

end of the section. Lithologically, this section is composed of uniformly massive siltstone, as shown in the columnar section of Figure 3. Bedding can usually be determined, but it is seldom obvious. A few thin beds of fine-grained sandstone are present; some of these are calcareous, and therefore more resistant than the siltstone. Fossils and macerated carbonaceous material are common throughout the section. Concretions are rare, but a few do occur near the middle of the section. The Quinault Formation is concealed from the north end of the Taholah section to the Quinault River, a distance of about 1 mile.

Immediately north of the mouth of the Quinault River, massive siltstone similar to that of the Taholah section reappears. It is poorly exposed at the base of landslides from this point westward for about a quarter of a mile, to a point where it appears to rest uncomformably on badly disturbed and contorted older rocks (Fig. 4). This outcrop of slumped older rocks extends westward a few hundred feet, where it ends sharply against gently southeast-dipping conglomerate beds of the Cape Elizabeth section of the Quinault Formation. This sharp contact almost certainly represents a fault, which probably trends in a north-northeast direction and has the east side up. It appears that a major displacement has taken place at this point, as an upper part of the Cape Elizabeth section is in juxtaposition with the older rocks. Within this small distance of a few hundred feet it is possible, therefore, to see an upper and a lower part of the Quinault Formation separated by a small outcrop of older rocks.

CAPE ELIZABETH SECTION

From the fault contact described above, the Cape Elizabeth section is exposed westward and northward up the coast to a point about 1¼ miles north of Cape Elizabeth, where the Quinault Formation is in fault contact with the older, highly disturbed rocks. In this interval the Quinault Formation is almost continuously exposed in high cliffs and, at low tide, on the beach. As shown in the columnar section of Figure 4, the rocks consist largely of conglomerate, sandstone, and some sandy siltstone. The lower 300 feet of section is largely bedded fine-grained sandstone and sandy siltstone; also a considerable amount of carbonaceous material, some fossils, and a few concretions. Thin conglomerate beds first appear about 300 feet above the base of the section. They are overlain by about 150 feet of fine-grained sandstone and carbonaceous, fossiliferous siltstone. Some 500 feet above the base of the section, thick conglomerate beds occur as the dominant lithology and continue from this horizon to the top of the section. These conglomerate beds are interbedded with carbonaceous siltstone and sandstone beds, some of which are concretionary. Many of the surfaces between the conglomerates and other sedimentary beds are channeled. Much carbonaceous material is present throughout the section, some in the form of carbonized logs and branches. Marine invertebrate megafossils occur at several horizons in the lower part of the section, but none were found in the upper, conglomerate, part of the section. Foraminifera are extremely rare, and none were found in the upper 400 feet of the section. The beds dip variously from 10° to 20° consistently to the southeast and east, with the exception of the northernmost few hundred feet of exposure. There, a reversal can be seen, the dip being to the northeast, thus the beds dip in a direction opposite to the plane of the contact with the older rocks. This contact strikes northwest and dips moderately to the southwest. Within some 10 feet of the contact the beds are sharply dragged upward and actually dip steeply southward, thus indicating a downward drag on the south side of the fault contact. This contact has been variously interpreted as either a fault or a depositional contact. Weaver (1916a), among others, considered it to be a fault contact, whereas Glover (1945) believed it to be depositional. Winter storms of the 1968-69 season exposed much of the bedrock in the contact area; it could then be seen that the regional bedding in the Quinault Formation is at a distinct angle to the plane of the contact, thus indicating a fault that cuts across the bedding of the Quinault Formation.

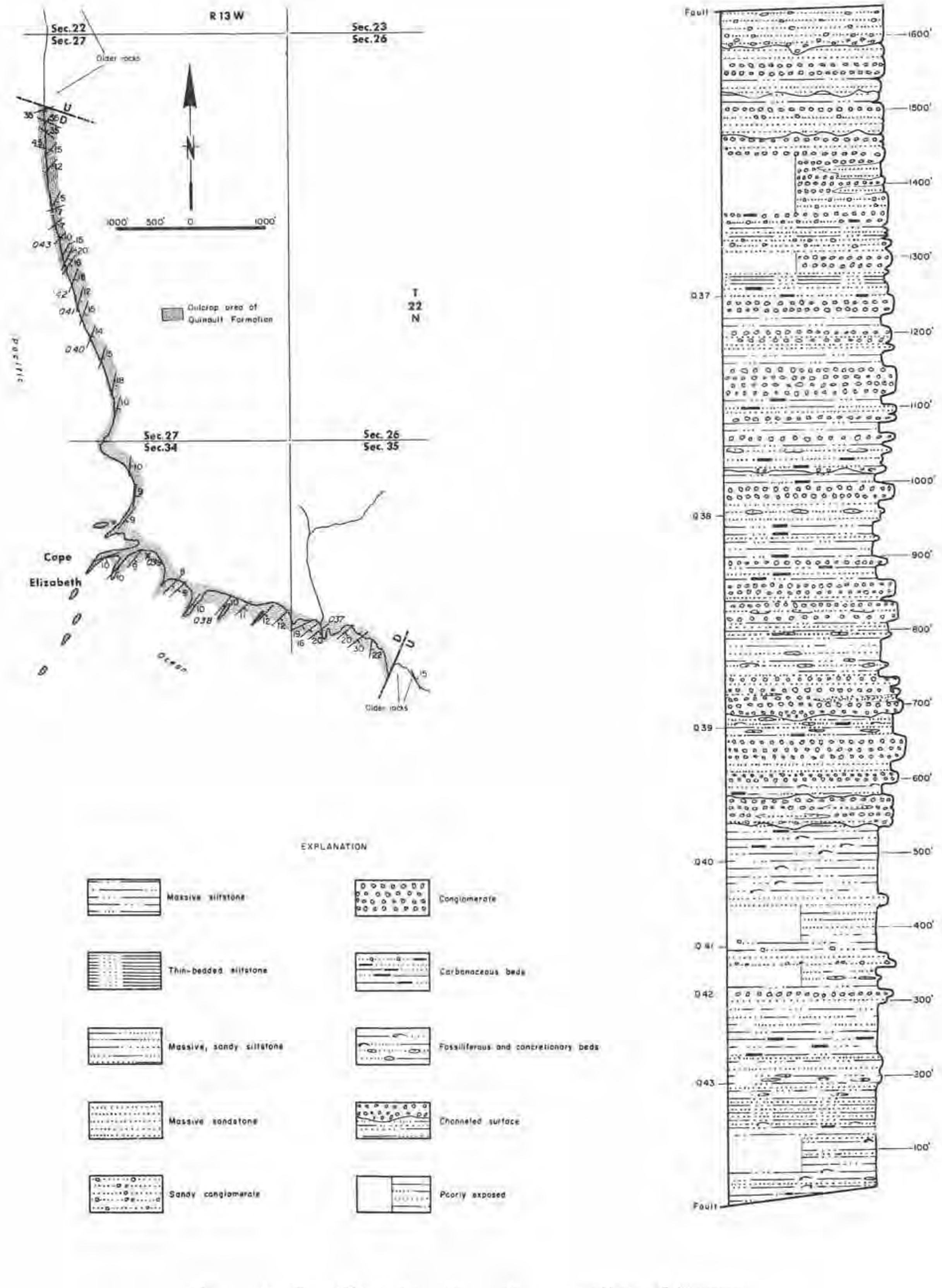


FIGURE 4.—Cape Elizabeth section; columnar section and traverse.

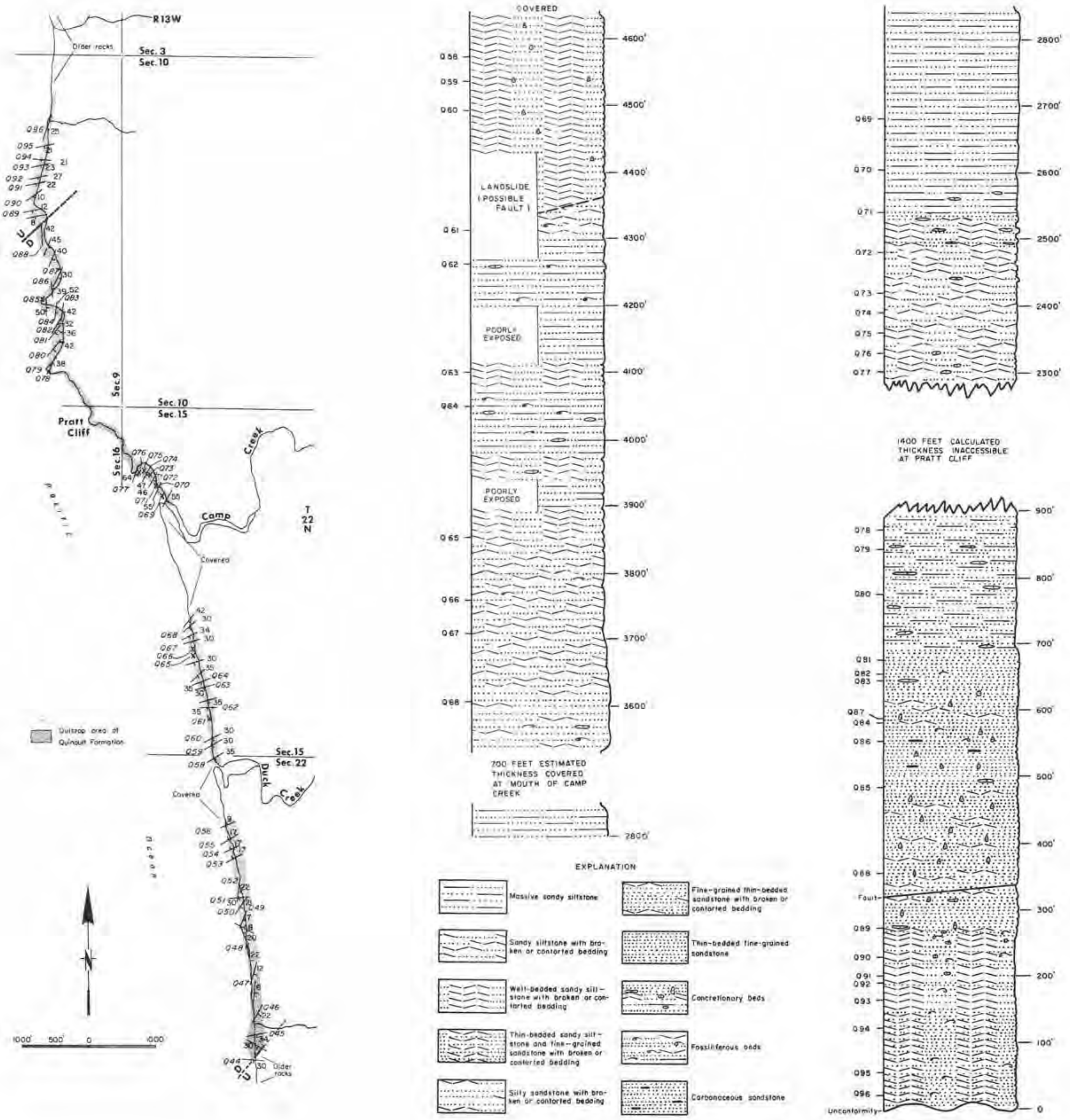


FIGURE 5.—Duck Creek-Pratt Cliff section; columnar section and traverse.

Older, badly disturbed rocks are exposed along the beach northward from this fault for some 1,400 feet. At the northern end of this outcrop the Quinault Formation is once again in fault contact with these older rocks. The plane of this fault strikes to the northeast and appears to dip moderately to the southeast (Fig. 5, on p. 9). The Quinault Formation is almost continuously exposed from this point northward nearly to the mouth of Duck Creek. However, in much of this area the strike of the beds is nearly parallel to the coast and the dips are to the east and southeast; therefore, very little section is exposed. Toward the northern part of this series of outcrops, the dip of the beds is reversed to a northerly direction, thus repeating the small section to the south. This series of outcrops is not described as a measured section of the Quinault Formation in this report, but they are regarded as isolated beds of the formation. These rocks are very fossiliferous, and therefore several localities in this area of outcrop are referred to in the present report. The beds are mostly siltstone with vague bedding, and they display much evidence of having been penecontemporaneously disturbed, perhaps by animal boring and also by bedding plane slump. They are similar to those beds exposed immediately north of Duck Creek that are in the upper part of the measured Duck Creek-Pratt Cliff section.

DUCK CREEK-PRATT CLIFF SECTION

In the northernmost part of the outcrop area of the Quinault Formation, the Duck Creek-Pratt Cliff section extends continuously along the coast from the north side of Duck Creek to a point about 1,800 feet south of Camp Creek (Fig. 5). An estimated 700 feet of section is concealed north of this point, but the section appears again on the north side of Camp Creek and is continuously exposed north to Pratt Cliff, where, although also continuously exposed, it is not accessible. However, from offshore the beds appear to dip consistently southeast and to be uninterrupted throughout this area. On the basis of attitudes at the south and north ends of Pratt Cliff, it is estimated that some 1,400 feet of section is represented in this inaccessible area. The section is continuously exposed north of Pratt Cliff for a distance of about three-quarters of a mile. At this northernmost point the Quinault Formation rests uncomformably on the badly disturbed older rocks. As shown on the columnar section of Figure 5, the basal 300 feet of this section is mostly bedded sandy siltstone showing frequent evidence of penecontemporaneously disturbed bedding, possibly the result of animal boring and bedding plane slump. Fossils are common, and small concretions are scattered throughout. The overlying 400 feet or so of section is mostly fine-grained, thin-bedded sandstone. Some of these beds also show evidence of having been disturbed shortly after deposition, and some beds are carbonaceous. This interval of section is particularly characterized by numerous 4- to 8-inch-long concretion-like pear-shaped structures, the long axes of which are perpendicular to the bedding plane. They appear to have been cavities that were formed in the sediments, possibly by mollusks or some other boring type of animal, and were subsequently filled with additional sediments. No shell material was found in these structures. The uppermost 200 feet of section north of Pratt Cliff is a vaguely bedded silty sandstone containing scattered concretions. Some 500 feet of section exposed between the south end of Pratt Cliff and Camp Creek is largely a massive sandy siltstone. Penecontemporaneously disturbed beds and a few concretions are present in the lower 300 feet of this part of the section. Some 200 feet of section exposed immediately south of the mouth of Camp Creek is mostly silty fine sandstone and contains a few fossils and scattered concretions. The remaining nearly 1,000 feet of section exposed immediately north of the mouth of Duck Creek is largely sandy siltstone containing scattered fossils and concretions. Many of the individual beds in this interval show slump and churned-appearing sedimentary structures. The upper 300 feet or so is rather well bedded.

Attitudes throughout this section, as shown in the traverse in Figure 5, indicate a rather gently undulating structure that dips mostly southeast, generally between 20° and 40°. At and near the basal contact to the north they dip to the southeast, then swing to a south dip a few hundred yards south of the contact, where the beds may be interrupted by possible faulting. South of this possible faulting the beds dip nearly due east, then a few hundred yards farther south they swing to a southeast dip once again and continue to dip southeast to the north end of Pratt Cliff. From offshore it appears as though rather steep southeast dips continue throughout Pratt Cliff. Fairly steep (30° to 40°) dips in a southeast direction continue to the top of the section at the mouth of Duck Creek.

REGIONAL CONSIDERATIONS, STRUCTURAL AND STRATIGRAPHIC

Arnold (1906) described the outcrop area of the Quinault Formation as a great syncline between Cape Elizabeth and Point Grenville. Weaver (1916a), in the same area, also mapped a syncline, the axis of which extends northeastward about one-half mile south of Taholah. In 1937 he stated that the Quinault Formation lies within a shallow syncline complicated by numerous small fractures and normal faults. The gross structural configuration implied by the attitudes within the coastal outcrops of the Quinault Formation is that of a syncline, the axis of which lies somewhere in the vicinity of Taholah. However, it would appear that this gross feature may be modified by faulting somewhat more than some of the earlier workers suggest.

The Duck Creek-Pratt Cliff section, a part of the north limb of this apparent synclinal feature, based on continuity and uniformity of direction of dip, most likely constitutes a reliable, essentially continuous section (Fig. 5). Furthermore, its base most likely represents one of the lowest known horizons in the outcrop area of the Quinault Formation, because it rests with apparent unconformity on older rocks (Hoh Formation). The only other possible place along the coast that may represent a basal horizon in the formation is immediately north of the mouth of the Quinault River. However, at this point there is no appreciable section above. The Duck Creek-Pratt Cliff section, therefore, most likely represents some

4,600 feet of essentially continuous section. Those beds exposed in the vicinity of both sides of the mouth of Duck Creek constitute the upper part of the section.

The Cape Elizabeth section (Fig. 4, p. 8), on the basis of continuity and uniformity of structure, also represents an essentially continuous section, which also is a part of the north limb of this synclinal structure. However, because this section is bounded at both the bottom and top by faults, its stratigraphic relation to the Duck Creek-Pratt Cliff section is uncertain. Both lithologically and faunally there appears to be no correlation between the two sections, in that the Duck Creek-Pratt Cliff section generally suggests an offshore marine environment, whereas the Cape Elizabeth section appears to represent a nearshore, possibly estuarine, and, in some places, even nonmarine environment. Most of the very few foraminiferal species found in the Cape Elizabeth section are either rare or absent in the Duck Creek-Pratt Cliff section. Aside from displacement that may have taken place on the faulting at the base of the Cape Elizabeth section, regionally the apparent updip position of the Cape Elizabeth section with respect to the Duck Creek-Pratt Cliff section suggests that the Cape Elizabeth section is the younger of the two. This relation is substantiated lithologically, and to some extent faunally, by subsurface records from onshore and offshore wells drilled mainly to the south in the Ocean City area. Coarse clastic rocks, such as are present in the Cape Elizabeth section, are encountered in these wells above finer grained sedimentary rocks that contain Foraminifera similar to those of the Duck Creek-Pratt Cliff section. The available evidence, therefore, although not conclusive, suggests that the Cape Elizabeth section constitutes an upper part of the Quinault Formation and is stratigraphically above the entire Duck Creek-Pratt Cliff section (Fig. 6).

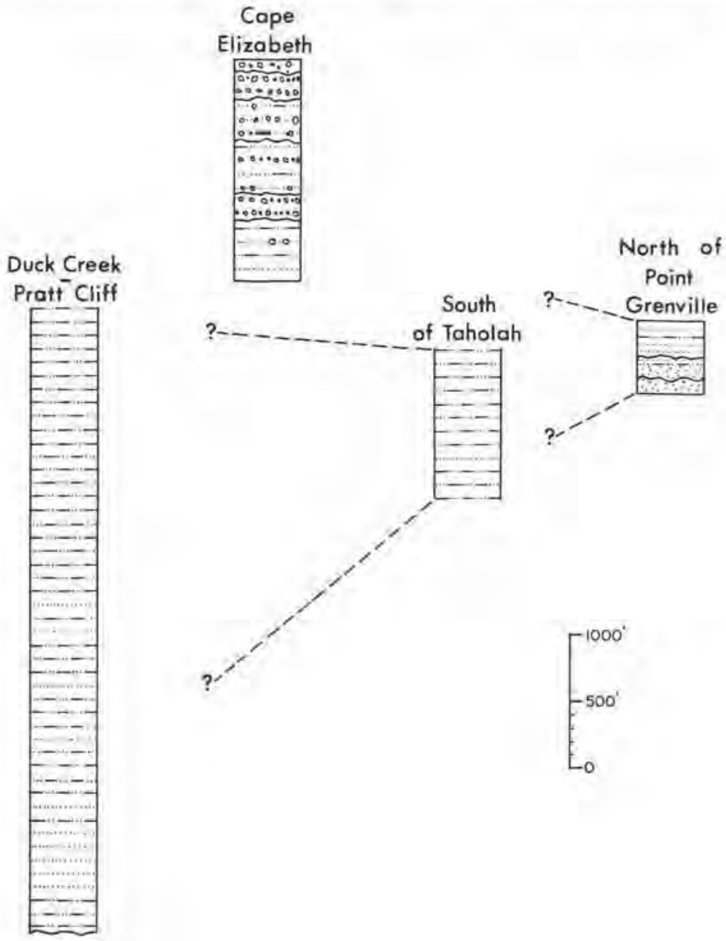


FIGURE 6.—Suggested correlations of the four measured sections of the Quinault Formation.

The section south of Taholah dips generally north and northeast, therefore suggesting that it represents a part of the south limb of the supposed regional downwarp. Disregarding possible structural complications, it would therefore be expected that this section could be correlated with some part of the north limb, particularly the Cape Elizabeth section. However, there appears to be no correlation, either lithologically or faunally. The section south of Taholah is basically rather massive, fossiliferous siltstone. It contains Foraminifera that suggest substantial water depths during deposition, and therefore is totally unlike the conglomerate and sandstone and meager shallow-water fauna of the Cape Elizabeth section. The beds on the north side of the Quinault River immediately north of Taholah and the mouth of the river (Fig. 3, p. 7), although mostly slumped, are essentially identical both faunally and lithologically to the section south of Taholah. Therefore, it is suggested that the massive siltstone section south of Taholah may continue northward beneath alluvial cover to this point north of the river, where it rests on older rocks but is separated from the Cape Elizabeth section by a fault with major displacement a few hundred feet to the west (Fig. 4, p. 8). Parts of the Duck Creek-Pratt Cliff section are reasonably similar to the section south of Taholah. Generally the rocks of the latter section are more massive and finer grained, and some differences are present also in the faunas. However, a thickness estimated to be greater than the total section south of Taholah is inaccessible at Pratt Cliff for sampling and examination. It is possible, therefore, that the section south of Taholah represents a stratigraphic position similar to some part of the Duck Creek-Pratt Cliff section, but conclusive evidence is lacking at this time.

The section north of Point Grenville, as shown in Figure 2, p. 6, also dips generally northeast, and therefore would appear to lie below the section south of Taholah. However, for a distance of about three-quarters of a mile between the two sections, the Quinault Formation is either covered with Pleistocene(?) gravel or is badly slumped, and therefore the relation between the two sections cannot be definitely determined. As pointed out previously, both the north end (top) and the south end (base) of the Point Grenville section are probably terminated by eastward-trending faults, older rocks being in juxtaposition on the south end and some other part of the Quinault Formation on the north. From this evidence it appears that the Point Grenville section is isolated and probably is not continuous with and therefore not necessarily stratigraphically below the section south of Taholah.

Lithologically, the Point Grenville section is unique mainly because of the numerous large sedimentary structures. It does not particularly compare either faunally or lithologically with the Cape Elizabeth section, although both have elements of shallow-water deposition. Any probable correlation of these sections would most likely be confined to a lower sandstone part of the Cape Elizabeth section and all or part of the Point Grenville section (Fig. 6). None of the Duck Creek-Pratt Cliff section is particularly similar, either lithologically or faunally, to the Point Grenville section. Furthermore, the siltstone section south of Taholah is also lithologically unlike the sandstone of the Point Grenville section, but faunally they are similar.

Because the Point Grenville section is isolated and lithologically distinct from all other sections, it is not possible to make a definite correlation of these beds with the other sections. However, faunal similarities suggest that deposition of the section north of Point Grenville could have been penecontemporaneous, in part, and (or) possibly later than that of the section south of Taholah.

AGE AND CORRELATION

GENERAL STATEMENT

A number of relatively young basins of deposition along the Oregon and particularly the California coast have been receiving sediments almost continuously since late Miocene time. Deposition in these basins, at least in part, probably took place penecontemporaneously with the deposition along the Washington coast of the upper Tertiary-lower Quaternary sequence, of which the Quinault Formation is a part. However, detailed correlations of the major outcrops of the Quinault Formation with certain segments of the depositional sequence in each basin are made with some reservations. The length of geologic time during which upper Tertiary-lower Quaternary strata were deposited is relatively short, and therefore evolutionary changes are minor among the foraminiferal species involved. However, ecological differences, such as water depth and temperature, had a pronounced effect on the composition of faunas in these young basins of deposition. Therefore, correlations from basin to basin based on evolutionary changes may be largely masked by the greater effects of variations or similarities of environments of deposition. Ecological conditions are considerably varied, not only throughout time, but obviously at any given moment in various parts of all basins, as well as within each basin. Even so, the overall ecological evolution or the sequence of ecological events in each of these basins is broadly comparable; that is, the similarity is essentially that of progressive basin filling. Relatively deep-water conditions are indicated in the lower part of each sequence, followed by shoaling conditions, succeeded by shallow-water to nonmarine conditions that dominate at the top. Therefore, rather than to attempt conventional correlations based largely on evolution of species, it is perhaps more realistic to compare the dominating ecological conditions reflected by the Foraminifera in each of these basins with those of the Quinault Formation. To this extent the foraminiferal assemblages of the various sections of the Quinault Formation are compared with those of other late Tertiary-early Quaternary basins of the west coast.

LOCAL CORRELATIONS—SOUTHWEST WASHINGTON

OCEAN CITY AREA

Until recently, essentially no local framework of biostratigraphic correlation had developed in the rocks of late Tertiary-early Quaternary age in western Washington. With increased interest in possible petroleum production from these relatively young rocks, some generalizations have developed during the past 15 years. Most of this information has been obtained from the subsurface, penetrated in a few wells drilled in the Ocean City area, some 20 to 25 miles south of the area of outcrop of the Quinault Formation. The faunal succession known in these wells suggests that the Quinault Formation represents an upper part of the local upper Tertiary-lower Quaternary sequence. It is perhaps best exemplified in the Union Oil Company of California-State No. 3 well, where some 3,600 feet of upper Tertiary-lower Quaternary strata were penetrated above older rocks of the Hoh Formation. Foraminifera from the upper 2,500 feet of strata in this well are typical of those of the Quinault Formation. Shallow-water forms found largely in the upper part of the Quinault Formation are dominant in the uppermost part of the well, and deeper water forms gradually become more abundant downward to a depth in the well of about 2,500 feet. At this horizon a substantial number of forms make their first appearance and continue to occur to the top of the Hoh Formation at a depth of about 3,600 feet. Many of these species represent substantial water depth, and most of them are either not known in the Quinault Formation, or occur only rarely in the basal part of the formation. A few of these species are:

Bolivina sinuata Galloway and Wissler
Bulimina rostrata Brady
Bulimina subacuminata Cushman and Todd
Rotalia garveyensis Natland
Valvulineria malagaensis Kleinpell

The fauna from this part of the well can best be compared with those assemblages generally regarded as late Miocene or earliest Pliocene in age in other basins of deposition along the coast, particularly in the southern California region.

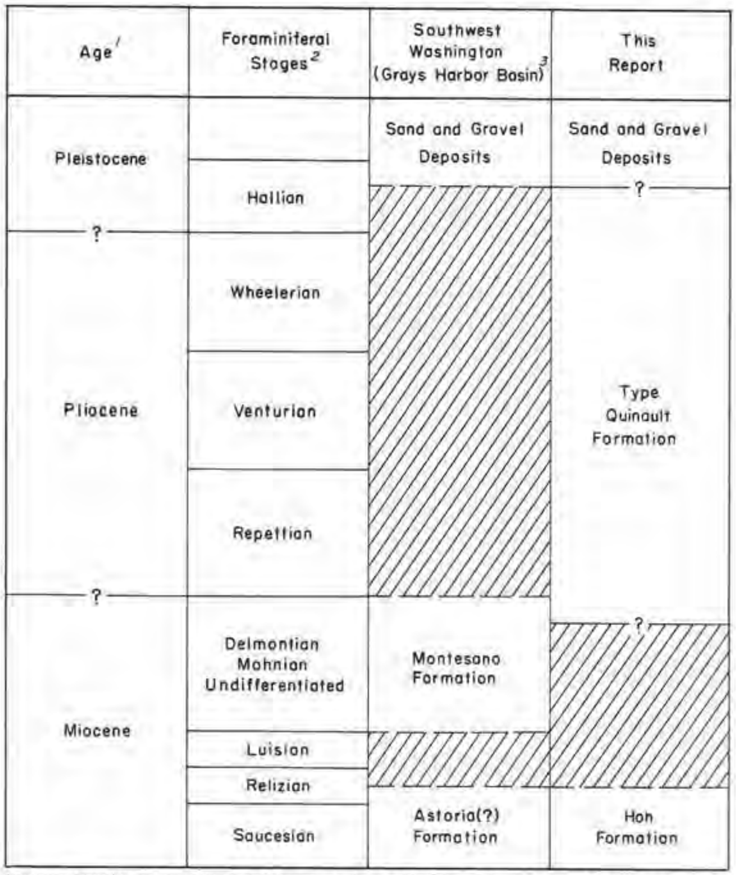
From biostratigraphic relations known in the Ocean City area, it therefore is suggested that an uppermost part of the Tertiary sequence of that area correlates broadly with the Quinault Formation in its area of outcrop. However, a lower part of this sequence (from a depth of 2,500 feet to 3,600 feet in the Union Oil Company of California-State No. 3 well) may be stratigraphically below most, if not all, outcrops of the Quinault Formation.

MONTESANO AREA

The stratigraphic relation between the Quinault Formation and the Montesano Formation, exposed a few miles to the east, has long been pondered. Outcrops of the two units are separated by a covered area only a few miles wide, yet suggested correlations have been somewhat varied in the past. Weaver (1916a) at one time included all the Quinault Formation of this report in his Montesano Formation, and regarded it as late Miocene in age, but later (1942) he removed from the Montesano Formation at least the Cape Elizabeth section and regarded it as the Quinault Formation of Pliocene age. Still later (Weaver and others, 1944), it was suggested that perhaps the lower part of the Quinault Formation might be contemporaneous with a part of the Montesano Formation. Conclusions of Weaver and of other writers until that time were based largely on mollusks.

In recent years, studies of the Foraminifera of the Montesano Formation (Fowler, 1965; Rau, 1967) support a late Miocene age for the formation, or in part, extend its age into the early Pliocene, depending upon individual interpretations on where the Mohnian and Delmontian stages of Kleinpell should be placed with respect to the boundary between the Miocene and Pliocene epochs (Fig. 7). Even though assemblages of the Quinault and Montesano Formations have many species in common, particularly the assemblages of the Duck Creek-Pratt Cliff section of the Quinault Formation, and of the Montesano Formation in general, few if any elements in the faunas particularly indicate a precise correlation. Substantially represented forms of the Quinault Formation that are either conspecific or very similar to those common to the Montesano Formation, are listed below:

Buccella inusitata [*B. frigida* in Montesano Formation]
Buliminella curta
Cibicides mckannai
Epistominella pacifica
Florilus basispinatum
Globigerina bulloides
Nonionella miocenica
Pullenia salisburyi
Uvigerina, finely costate
Uvigerina subperegrina
Virgulina californica ticensis



[1] Berggren (1969), based on radiometric data, suggests that the Mio-Pliocene boundary may fall somewhere within the Wheelerian stage. Various workers place the Plio-Pleistocene boundary either in or at the base of the Hallian stage.

[2] Miocene stages of Kleinpell (1938); Plio-Pleistocene stages of Natland (1952).

[3] After Rau (1967)

FIGURE 7.—Generalized correlation chart showing suggested relations between the stratigraphy of the Quinault Formation and that of the Montesano Formation of southwest Washington.

On the Pacific coast several of these species, particularly *B. curta* and *V. californica ticensis*, typically occur in rocks of late Miocene age. *Rotalia garveyensis*, although not found by the writer in any of the measured sections of the Quinault Formation, has been reported from somewhere in the vicinity of the lower part of the Duck Creek-Pratt Cliff section by others (Boettcher, R. S., Mobil Oil Company, written communication, 1969). Furthermore, specimens tentatively referred to this species were collected by the writer from an isolated locality (Q-97) near the mouth of the Raft River (Fig. 8), together with species typical of the lower part of the Duck Creek-Pratt Cliff section. The presence of this species may well be significant, inasmuch as its highest occurrence is regarded by many workers as generally marking

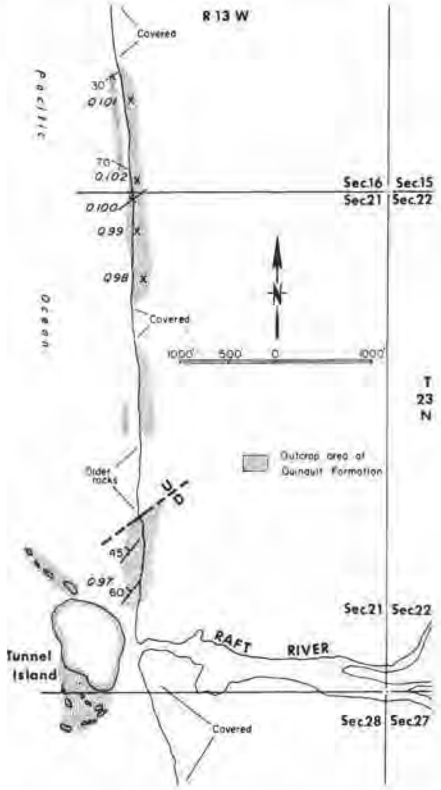


FIGURE 8.—Sketch map showing miscellaneous collecting localities along the coast north of the Raft River.

the top of the Miocene, particularly in the Los Angeles basin. Furthermore, in the Montesano Formation it was found only in the upper part (Fowler, 1965; Rau, 1967). Because this species occurs in the basal part of the Quinault Formation and the top of the Montesano Formation, and because in general the foraminiferal faunas in these parts of the respective formations are similar, foraminiferal evidence supports previous conclusions for a correlation of the lowermost part of the Quinault Formation (basal part of the Duck Creek-Pratt Cliff section) and the uppermost part of the Montesano Formation Fig. 7).

Essentially no foraminiferal evidence is available for a correlation of the Cape Elizabeth section with any part of the Montesano Formation. Although a number of identical or conspecific foraminiferal species are present in both the section south of Taholah and the Montesano Formation, none of these is particularly significant with respect to a correlation. Furthermore, species not recorded in the Montesano Formation but present in the section south of Taholah, such as *Cassidulina limbata* and *Elphidium hughesi*, suggest that this Quinault section may be of slightly different age, possibly younger than any part of the Montesano Formation. The section north of Point Grenville contains even fewer forms known in the Montesano Formation, and therefore a correlation of these units also is not particularly supported by Foraminifera.

SOUTHERN CALIFORNIA, A WEST COAST STANDARD

The upper Tertiary-lower Quaternary sequence is particularly well developed in the coastal region of southern California, especially in the Ventura and Los Angeles basins, as well as in the Santa Barbara Channel area. Much of the petroleum from that region has been produced from these rocks. Largely because of this economic significance, a detailed biostratigraphic framework has been developed for these strata. It has become generally accepted as the west coast standard with which most correlations are made of upper Tertiary-lower Quaternary beds of the west coast area. Many workers have contributed to this biostratigraphic standard, but, because of its commercial aspect, much of the knowledge acquired has not been made readily available in published form. The work of Natland (1933, 1938, 1950, 1952, and 1957) and that of Wissler (1943) are among the major studies dealing with the actual biostratigraphic framework of these rocks. Ingle (1967) presented a major contribution dealing with the planktonic Foraminifera of upper Tertiary beds in southern California. Additional works, primarily concerned with taxonomy of the Foraminifera, were presented by Galloway and Wissler (1927a and 1927b), Stewart and Stewart (1930), Cushman and Gray (1946a and 1946b), Martin (1952), and White (1956). Many others have contributed to the refinement of the biostratigraphy of these rocks, although perhaps not all in published form. Numerous variations are in use among individual workers and commercial organizations with respect to precisely where boundaries are placed, but most authorities are in general agreement with a basic framework. For the purpose of comparing what is known concerning the biostratigraphy of the Quinault Formation, only a broad view of this standard framework is needed, and therefore the following summary is presented.

Pliocene beds in the Los Angeles and Ventura basins and vicinity are divided essentially into the Repetto Formation at the base and the Pico Formation at the top. Rocks assigned to the upper Miocene, such as the Puente Formation and Santa Margarita Formation, underlie the Repetto Formation; whereas the Pico Formation is overlain by beds usually assigned to the Pleistocene, such as the Santa Barbara, Saugus, and Las Posas Formations, and the Timms Point Silt and Lomita Marl. Natland (1952), in his dissertation on "Pleistocene and Pliocene stratigraphy of southern California," developed foraminiferal stages for this sequence, using the term "Repettian" to constitute the lowest stage of the Pliocene, which is essentially represented in beds of the Repetto Formation (Fig. 7, p. 13). His Venturian stage constitutes a middle part of the Pliocene and in the Los Angeles basin is represented in a lower part of the Pico Formation. His Wheelerian stage constitutes an upper part of the Pliocene and is largely represented in the upper part of the Pico Formation. The Hallian stage of Natland generally constitutes the Pleistocene, although the boundary between the Hallian and the Wheelerian stages is now placed variously in or between the Pico and overlying beds.

It has been demonstrated, particularly by the work of Natland, that the Pliocene-Pleistocene sequence in the Los Angeles basin, as well as in other basins in the vicinity, reflects a history of basin filling, both faunally and lithologically. To a large extent, faunas of the Repettian stage are those typical of substantial water depths. Succeeding faunas of the Venturian, Wheelerian, and Hallian stages largely represent progressive shoaling from bathyal to littoral depths. Basically, then, correlation of the stages of Natland and, for that matter, essentially all faunal subdivisions observed in the southern California region, are based on the similarity of the succession of ecological conditions reflected by the faunas of each basin. Local correlations, therefore, are based largely on the premise that similar successions of ecological events took place within each basin of deposition during Pliocene and Pleistocene time. However, major exceptions are most certainly to be expected because of the varieties of ecological conditions present in any basin at a given time. Natland, as early as 1933, and a number of other workers since that time have made this observation, and recently it was particularly well stated by Ingle (1967, p. 218, 219), "There is neither a ubiquitous lithology or biota characteristic of all areas at any moment; . . . ." Nevertheless, for the purpose of broadly relating stratigraphy from basin to basin, the succession of ecological events recorded in the upper Tertiary-lower Quaternary sequence along the Washington coast, as partly represented in the Quinault Formation, could be expected to be somewhat comparable to that in other west coast upper Tertiary-lower Quaternary basins of deposition. The following suggested correlations are based on this concept and are therefore somewhat generalized.

The Duck Creek-Pratt Cliff section, together with nearby isolated outcrops, may well represent the lowest part of the Quinault Formation exposed along the coast. Its fauna (checklist, p. 20) probably best compares with that of the lower part of the upper Tertiary-lower Quaternary sequence of the Los Angeles area occurring in the Repetto Formation and possibly part of the Pico Formation. Foraminifera suggesting a correlation with beds in a relatively low position in the sequence are a few forms commonly associated with subjacent beds of the upper Miocene, such as *Rotalia garveyensis*, *Uvigerina hootsi*, and *Virgulina californiensis ticensis*. However, a greater number of forms from the Duck Creek-Pratt Cliff area are common to the Repetto and Pico Formations, such as *Bulimina elegantissima*, *Cassidulina reflexa*, *Florilus basispinatum*, *Nonion miocenica*, *Pullenia salisburyi*, *Uvigerina juncea, and Uvigerina subperegrina*. The few pre-Repetto forms, particularly *R. garveyensis*, tend to suggest that the lower part of the section may correlate with an uppermost part of the Miocene (Mohnian and Delmontian stages, undifferentiated, of Kleinpell, 1938) of the southern California sequence. However, the major part of the foraminiferal fauna probably best compares with those of the Pliocene Repetto and Pico Formations of the southern California sequence and therefore equates with the Repettian and Venturian stages and possibly even a part of the Wheelerian stage of Natland (1952).

The meager foraminiferal fauna of the Cape Elizabeth section, by itself, is hardly sufficient from which to even suggest a correlation. But, since all those Foraminifera that are present and the nature of the lithology both indicate shallow-water deposition, it is speculated that this section represents a latter stage of deposition and therefore is an upper part of the local sequence. On that basis, this section may well equate broadly with the uppermost part of the Pico Formation (late Pliocene) and possibly some of the overlying lower Quaternary deposits such as the Santa Barbara Formation, the Timms Point Silt, Lomita Marl, and Las Posas Formation of the southern California area.

Foraminifera of the section south of Taholah compare broadly with those of much of the Los Angeles sequence, including most of the Repetto Formation and the Pico Formation, and possibly even some of the overlying beds of Pleistocene(?) age. However, of those foraminiferal species present in both the Taholah section and some part of the Los Angeles sequence, noticeably more are known to be present in the Pico Formation. Of these, the following are probably most significant because they are well represented in the Taholah section:

Cassidulina limbata
Cibicides mckannai
Elphidium hughesi foraminosum
Uvigerina subperegrina

Even though the evidence is not at all strong, Foraminifera from the Taholah section best compare with those of the middle part of the Los Angeles sequence of late Tertiary-early Quaternary deposition, and therefore probably best relate to the Venturian and Wheelerian stages of Natland (1952).

The section north of Point Grenville also contains a number of forms common in the southern California upper Tertiary-lower Quaternary sequence. Some of these are particularly common to the Pico Formation, a few of which are known to extend into the overlying rocks of probable Pleistocene age, and others down into the underlying Repetto Formation. Possibly most significant because of their abundance in the Point Grenville section are the following forms:

Cassidulina limbata
Cassidulina reflexa
Elphidium microgranulosum
Florilus basispinatum

Although the evidence is not all conclusive, Foraminifera of this section of the Quinault Formation also best compare with those of the Pico Formation of southern California, and perhaps relate to the Wheelerian, and possibly lower part of the Hallian stage of Natland (1952).

In general summary, the foraminiferal sequence of the four measured sections of the Quinault Formation compare in a broad way with that known in the Repetto-Pico sequence of the Los Angeles area and vicinity. Although the evidence is not at all conclusive, the lowermost part of the Quinault Formation of this report may equate to rocks of late Miocene age, and the uppermost part of the formation to beds thought to be as young as early Pleistocene in age in the Los Angeles area (Fig. 7, p. 13).

OTHER WEST COAST AREAS

OREGON

Several small basins of late Tertiary deposition are known along the Oregon coast, notably in the Coos Bay area and in the vicinity of Cape Blanco. At Coos Bay a sequence including the Empire Formation and possibly the Port Orford Formation may well correlate in some way with at least a part of the Quinault Formation. Arnold and Hannibal (1913) first suggested such a correlation, basing their conclusions largely on mollusks. At that time these beds were regarded as Miocene in age, but in recent years they have been considered Pliocene in age (Allen and Baldwin, 1944; Weaver and others, 1944). Unfortunately, no foraminiferal information is available from these rocks, and therefore it is not possible in this report to contribute knowledge of the stratigraphic relation between these Oregon beds and those of the Quinault Formation.

In the vicinity of Cape Blanco, Bandy (1950) described and discussed Foraminifera from what he referred to as the Port Orford and Elk River Formations, which he regarded as middle or late Pliocene and Pleistocene in age, respectively. Most of the species listed from the Port Orford Formation are conspecific with those in some part of the Quinault Formation of this report. Possibly the greatest faunal similarity is in the Duck Creek-Pratt Cliff section, where *Florilus basispinatum* is a major element in the fauna, as is the case in the Port Orford section of the Cape Blanco area. A significant variation, however, is the great abundance of *Elphidiella hannai* in the Port Orford Formation, in contrast to only rare occurrences of the form in any part of the Quinault Formation. An appreciable number of species listed from the Elk River Formation are also present in some part of the Quinault Formation, particularly those listed from the Elk River *Elphidiella hannai* zone, even though *E. hannai* is the dominant species in the Elk River assemblage also.

These foraminiferal comparisons suggest, in a general way, that similar ecological conditions may have existed during the deposition of the beds near Cape Blanco and those in at least parts of the Quinault Formation, and that, although the evidence is not conclusive, deposition of these two sequences of beds could have been, in part, contemporaneous.

NORTHERN CALIFORNIA

Along the coastal area of northern California in the vicinity of the Eel River, late Tertiary deposits known as the Wildcat group have been mapped in detail (Ogle, 1953) and Foraminifera contained therein studied rather extensively (Cushman, Stewart, and Stewart, 1930; Stewart and Stewart, 1949; Crawford, Hughes, *In* Ogle, 1953, p. 46). It is likely that some of these northern California beds may have been deposited penecontemporaneously with those of the Quinault Formation of the Washington coast. Cushman, Stewart, and Stewart (1949) were the first to point out the similarity in the foraminiferal fauna of part of the Quinault Formation and that of part of the Wildcat Group. At that time, they tentatively correlated these beds with a middle part of the Repetto Formation of southern California, of early Pliocene age. In the following discussion, comparisons of the foraminiferal faunas of the Wildcat Group are made with those of the four sections of the Quinault Formation of this report.

None of the assemblages of the Wildcat Group are particularly similar to those of the Duck Creek-Pratt Cliff section. However, those from a lower-middle part (lower part of the Rio Del Formation and possibly the Eel River Formation) best compare with the Foraminifera of this section.

The extremely limited assemblage of the Cape Elizabeth section is best compared with that of an upper part of the Wildcat Group (upper part of the Rio Del Formation, and the Scotia Bluffs Sandstone). In assemblages from both areas, *Elphidium,* such as *E. hughesi,* are consistently present, but mostly are not found in lower parts of the Wildcat Group. *Elphidiella hannai* seems to be confined to the upper part of the northern California sequence, and it is also found in the Cape Elizabeth section. Although these similarities do not necessarily indicate contemporaneity of deposition, they do suggest similar environments of deposition; namely, shallow, possibly brackish, water conditions. Such faunal assemblages dominate in the upper part of the Wildcat Group, a stratigraphic position similar to that suggested for the Cape Elizabeth section with respect to the entire outcrop area of the Quinault Formation. Furthermore, the sequence of the lithologies seen in the Scotia Bluffs Sandstone and the Carlotta Formation of the upper part of the Wildcat Group is generally similar to that of the Cape Elizabeth section of the Quinault Formation; that is, sandstone in the lower part grading up to conglomerate at the top. Ogle (1953) suggests tentative correlations of the upper part of the Scotia Bluffs Sandstone and the Carlotta Formation with "deposits at the mouth of Elk River, Oregon," and also of the lower part of the Scotia Bluffs Sandstone with a part of the Empire Formation at Coos Bay, Oregon.

Foraminifera from the section south of Taholah can best be compared with those of a middle to upper part of the Wildcat Group (mainly the Rio Del Formation). Salient faunal similarities are: the common occurrence of such forms as *Cassidulina limbata, Cibicides mckannai,* and low, finely costate *Uvigerina*; and the less common occurrence of *Elphidiella hannai, Elphidium hughesi, Polymorphina charlottensis,* and coarsely costate *Uvigerina.*

The fauna of the section north of Point Grenville probably is more like that of the Wildcat Group than are any of those from other sections in the Quinault Formation. Some of the more significant forms present in both are:

Cassidulina limbata
Cassidulina translucens
Elphidiella hannai
Elphidium hughesi
Elphidium microgranulosum
Polymorphina charlottensis
costate *Uvigerina*

According to available information, these forms are all largely confined to a middle and upper part of the Wildcat Group (Rio Del Formation and possibly Scotia Bluffs Sandstone).

In general summary, the foraminiferal faunas of the middle and upper parts of the Wildcat Group of northern California (Rio Del Formation and Scotia Bluffs Sandstone) best compare with those of the Quinault Formation of the Washington coast. Although these similarities do indicate comparable depositional environments, they do not necessarily indicate contemporaneous deposition. However, assuming that the Cape Elizabeth section does represent the upper parts of the Quinault Formation, the faunal sequence, as well as the general lithologic sequence of the entire Quinault Formation, is broadly comparable to that of the middle and upper part of the Wildcat Group, which Ogle (1953) regards as ranging from middle to upper Pliocene in age. Others suggest that the upper part of the sequence may be Pleistocene in age (Stewart and Stewart, 1949).

SAN FRANCISCO PENINSULA

Along the coast in the San Francisco Peninsula area, a sequence of upper Tertiary-lower Quaternary deposits known as the Purisima and Merced Formations may well have been deposited during a time similar to that of the Quinault Formation. Arnold (1906), in his original discussion of the Quinault Formation, mentioned that the megafossils suggest a possible correlation of the formation to the Purisima Formation. Later, Weaver (1937) stated that megafossils from the Quinault Formation between Point Grenville and the mouth of the Quinault River [sections north of Point Grenville and south of Taholah] are closely allied with those of the Merced Formation. The Merced Formation is generally regarded as middle Pliocene through early Pleistocene in age, whereas the Purisima Formation is considered middle Pliocene in age and is possibly, in part, equivalent to a lower part of the Merced Formation (Glen, 1959).

The available information on Foraminifera from this California sequence is limited to reports on two small assemblages, one from the type Merced Formation at Seven Mile Beach (Stewart and Stewart, 1933), and the other from the Purisima Formation of the Halfmoon Bay area

(Goodwin and Thomson, 1954). The best comparisons of these faunal assemblages and those of the Quinault Formation are with those of the Purisima Formation and of the Duck Creek-Pratt Cliff section. Substantially represented in both are *Buliminella elegantissima, Cibicides fletcheri, Florilus basispinatum (Pseudononionella cushmani), Uvigerina juncea,* smooth *Globobulimina,* and *Nonionella miocenica.* Other forms are also present in lesser numbers in both formations.

Foraminiferal assemblages of the other sections of the Quinault Formation are not noticeably similar to those of the known faunas of the Purisima-Merced sequence. Generally then, based on limited foraminiferal information from this California sequence, the Foraminifera of the Quinault Formation are not greatly similar and therefore do not strongly support evidence for a correlation. However, the best comparison is with the Foraminifera of the Duck Creek-Pratt Cliff section and those of the Purisima Formation.

SANTA MARIA DISTRICT

Comprehensive studies of Woodring and Bramlette (1950) on the Santa Maria District of California serve as a particularly detailed source of data on the biostratigraphy of that region. It is therefore possible to make at least broad comparisons of the Foraminifera of that area with those of the Quinault Formation. Such comparisons show that noticeably more Foraminifera of the Quinault Formation are listed from the Foxen Mudstone of middle-to-late Pliocene age (Woodring and Bramlette, 1950) than from any of the other units of that area. Species well represented in both the Quinault Formation and the Foxen Mudstone, and therefore the most significant with respect to a suggested correlation, are *Cassidulina limbata, Elphidium hughesi, Nonionella miocenica,* costate *Uvigerina,* and varieties of *Virgulina californica.* Faunas of the two sections between Point Grenville and Taholah compare somewhat more favorably with those of the Foxen Mudstone than do those of the Duck Creek-Pratt Cliff section. Notable are the presence of both *E. hughesi* and *C. limbata* in the Taholah-Point Grenville sections, and the absence of these species in the Duck Creek-Pratt Cliff section.

Similarities in faunal assemblages here again suggest that conditions of deposition may have been reasonably similar in the two areas, but only in a broad sense is it likely that the Quinault Formation, particularly the beds of the Taholah-Point Grenville sequence, correlates with the Foxen Mudstone of the Santa Maria District. It is probably more realistic to consider that these Quinault beds may represent a position in the development of the depositional sequence within the local basin similar to that represented by the Foxen Mudstone in its basin of deposition.

PALEOECOLOGY

GENERAL STATEMENT

The environment in which various parts of the Quinault Formation were deposited is fairly well indicated by the contained Foraminifera. Fortunately, many of the species are living, or are represented by morphologically similar forms in the seas today, particularly along the eastern Pacific. Therefore, by examining the known distribution of these species, it is possible to infer, at least in a broad way, the thermal conditions and particularly water depths under which groups of species or assemblages of the Quinault Formation most likely lived. Considerable data have been assembled on the occurrence and distribution of living Foraminifera off the west coast. Probably the first records of such information extend back to those of Brady (1884), in which he reported on Foraminifera dredged during the voyage of the Challenger in 1873-1876. Since that time many other contributions have been made. Outstanding among early reports is that of Cushman (1910-1916), in his monograph on the Foraminifera of the North Pacific. During the past 20 years or so a number of additional studies have been made on the occurrence and distribution of living Foraminifera in the eastern Pacific. Reports on many of these are organized in such a manner as to be particularly helpful in determining the representative paleoecology of faunas contained in Tertiary strata of the west coast. Among these, reports by the following are especially useful, and therefore they have been relied upon extensively in the present study: Bandy (1953), Cooper (1961), Crouch (1952), Cushman and Todd (1947), Enbysk (1960), and Natland (1957).

Although some species are found widespread throughout much of the Quinault Formation, the faunal composition of each section is varied. However, within each section the composition is relatively uniform, at least to the extent that the fauna of each section most likely represents a reasonably similar environment of deposition throughout. Therefore, in the following discussion, the ecological significance of various species is discussed separately for each section. Those species found consistently throughout a section obviously were best adapted to the prevailing environment of deposition, and therefore their known present-day distribution is of greatest interest. However, some species occurring in a limited number of samples may also be of importance, particularly if their present-day distribution varies from that of the more commonly occurring forms. These species may support evidence for redeposition of sediments before complete consolidation, as is indicated by the sedimentary features of some in the strata of the Quinault Formation.

SECTION NORTH OF POINT GRENVILLE

Foraminifera from this section (checklist, p. 20) almost certainly indicate a neritic environment of initial deposition. This conclusion is borne out by the present-day distribution of the five most commonly occurring species of this section:

Buccella inusitata
Cassidulina limbata
Cibicides fletcheri
Elphidium hughesi
Globigerina bulloides

The first of these, *B. inusitata,* is known in Puget Sound and off the Washington coast today, where it is recorded almost entirely from neritic depths (0 to 600 feet). Furthermore, it, together with *B. frigida* (Cushman), a similar form, is largely confined to northern latitudes, where water temperatures are cool to cold. *Cassidulina limbata* is a widely known species along the eastern Pacific today, where it occurs largely in lower neritic depths (125 to 600 feet), but is also known down to a depth of at least 900 feet in southern latitudes. This species is particularly common in neritic assemblages from California northward to Alaska. According to Natland (1957), it is common within temperature ranges of 13° to 8.5° C. Records of *C. fletcheri* are mostly from off southern California, extending northward to Cape Blanco, Oregon, at littoral and neritic depths down to at least 100 feet in temperatures ranging from 17.5° to 13° C. *Elphidium hughesi,* although not known in today's seas, is similar to several Recent species well-known off the west coast. One of these, *E. articulatum* (d'Orbigny), is a common and widespread element along the coast in upper neritic depths (0 to 125 feet) at temperatures between 21° and 13° C. (Natland, 1957). According to Enbysk (1960), *E. tumidum* Natland and *E. translucens* Natland are recorded from depths between 0 and 125 feet along the coast from Alaska to Oregon, where temperatures are at least as low as 7° C. at times. *Ephidium translucens,* therefore, apparently indicates wide tolerance for temperatures, as Cooper (1961) records *E. translucens* from beach and tide-pool deposits throughout the coastal area from San Diego to the Columbia River, where temperatures average considerably higher than in Alaskan waters. The frequent occurrence of *G. bulloides,* a planktonic form, does not infer a great deal about water depths. However, it does suggest open-sea conditions. Its presence may also generally suggest temperate to cool water conditions.

A second group of species listed below, although not found as frequently as those listed above, do represent a substantial part of the total foraminiferal fauna of this section:

Elphidiella hannai
Elphidium microgranulosum
Epistominella pacifica
Florilus basispinatum
Oolina borealis
Quinqueloculina cf. *Q. akneriana*

With the exception of *E. pacifica,* records of all these species are nearly confined to neritic depths along the eastern Pacific. Most are widespread along the coast and suggest a wide tolerance for temperature. However, records of both *O. borealis* and *Q. akneriana* suggest that they favor temperate to cool water temperatures. *Polymorphina charlottensis,* a less commonly occurring form, further substantiates temperate water conditions. The distribution of *E. pacifica* in the eastern Pacific is in noticeable contrast to that of all other frequently occurring forms of the section, in that it is known largely from middle and upper bathyal depths (600 to 3,000 feet) in temperatures ranging from 8.5° to 5.5° C. It is also known from depths approaching 7,000 feet in temperatures down to 1.9° C. Although this relatively common form is the only one that suggests substantial depths, several other, less common species, such as *Uvigerina senticosa* and *U. subperegrina,* occur rarely in a few localities of the section.

In view of this relatively minor evidence, the possibility of redeposition of at least some of the sediments to a deeper environment should not be overlooked. It is perhaps significant that all deeper water elements are confined to the lower half of the section.

In summary, therefore, the preponderance of foraminiferal evidence suggests that the section of Quinault Formation exposed north of Point Grenville was originally deposited in neritic depths (0 to 600 feet), and most likely was confined to depths of not more than 200 feet. Water temperatures were probably temperate to cool (13° to 8° C.), much like, or possibly slightly warmer than, those along the present-day Washington coast. In addition, lesser evidence suggests that redeposition of at least some of these sediments may have been to bathyal depths, not necessarily deeper than 1,500 feet in cold water.

SECTION SOUTH OF TAHOLA

The foraminiferal fauna of this section, shown in the checklist, page 20, is in some respects similar to that of the section north of Point Grenville, but differs in that it contains noticeably more species with affinities for deeper water conditions. Those species occurring in a large majority of the samples from this section are listed below:

Buccella inusitata
Cassidulina limbata
Cibicides mckannai
Globigerina bulloides
Globigerina pachyderma
Uvigerina juncea

Buccella inusitata and *C. limbata,* as mentioned previously, are distinctly representative of a neritic environment and together tend to favor temperate to cool water conditions. According to the records, *C. mckannai* or morphologically similar forms are somewhat rare from the Recent seas off the west coast, but a few are known only from deep water (bathyal) environments. *Globigerina bulloides,* as stated previously, suggests temperate to cool water in open-sea conditions. Similar conditions are also suggested by *G. pachyderma.* Ingle (1967) reports, and his conclusion is supported in the collection of the present study, that sinistral coiling of this form is dominant in the section south of Taholah. According to Ingle, such coiling suggests temperate water conditions. In addition, records of Enbysk (1960) substantiate this conclusion in that the species is reported as common from numerous localities in the northeast Pacific. Probably the most noticeable difference between the fauna of this section and that of section north of Point Grenville is the presence of a substantial number of *Uvigerina.* Although *U. juncea* is the most commonly occurring species of this genus; in general, all other species can be considered together with this form, as all those present indicate essentially the same conditions—mainly deep, cold water. *Uvigerina juncea* is common today off the coast of Washington and Oregon in lower neritic to upper bathyal depths (Enbysk 1960). Bandy (1953) reports *U. hollicki* Thalmann, a similar low-costate form, from depths ranging from 400 to 700 feet in water temperatures between 13° and 7.4° C. off southern and central California. *Uvigerina subperegrina,* a coarsely costate form, although not among the most commonly occurring species of this section, is present in a number of the collections. This species is similar to today's commonly occurring *U. peregrina* Cushman, which distinctly prefers bathyal depths. In the northeast Pacific it is typically common from depths between 600 and 6,000 feet. Off California, Bandy (1953) records it from 1,200 to 2,400 feet in water temperatures ranging from 6.6° to 4° C. Natland (1957) lists this species as characteristic of his biofacies IV, which prevails at depths between 900 and 2,000 feet at temperatures between 8.5° and 5° C. in eastern Pacific waters. He also states that the upper boundary of this biofacies apparently is controlled somewhat by temperature, because off southern California the 8.5° isotherm is at 900 feet, while off Panama it is at 1,500 feet. However, he further points out that other factors must enter in, because northward the 8.5° isotherm is at sea level in Alaskan waters, but the form is not known there in shallow water. It would, therefore, seem that the presence of coarsely costate *Uvigerina* such as *U. peregrina* and *U. subperegrina* is somewhat indicative of bathyal depths in waters not exceeding 8.5° C. Other species occurring less frequently in this section but still found in a substantial number of samples are listed below:

Elphidium hughesi
Nonionella miocenica
Pullenia miocenica
Quinqueloculina akneriana

Forms such as *E. hughesi*, as previously mentioned, distinctly prefer shallow neritic depths. The records of *Nonionella* such as *N. miocenica* are largely from neritic environments, favoring warm to temperate water conditions. *Pullenia bulloides*, similar to *P. miocenica*, is, according to Natland (1957), one of a group of species found typically at substantial depths (4,000 to 7,500 feet) in cold water (3.2° C.) in many deeper parts of today's seas. As previously mentioned, *Q. akneriana* apparently favors neritic conditions in temperate to cool water.

In view of the known present-day distribution of the most commonly occurring Foraminifera of the section south of Taholah, it appears most likely that more than one condition of deposition is represented by the fauna—basically, a shallow water or neritic depth in perhaps temperate water conditions, and bathyal depths in cold water. From the known distribution of Foraminifera in the eastern Pacific of today, it would be difficult to find a single condition satisfactory for the entire foraminiferal fauna of this section. Faunal evidence is, therefore, strong for redeposition of at least part of the section. More overall evidence exists, perhaps, for deposition at neritic depths, but the bathyal element is strongly significant also. Therefore, the beds as we see them today were most likely deposited at upper bathyal depths, perhaps 900 to 2,000 feet in cool to cold water (9° to 4° C.), but much of the material was derived, possibly in part as the result of turbidity currents or even by normal current action, from materials originally deposited in a neritic environment of perhaps 0 to 600-foot depths in temperate water conditions. The comparatively fine-grained nature of the sediments suggests deposition in an area well removed from the source of material, and therefore supports the faunal evidence for deposition well offshore.

CAPE ELIZABETH SECTION

Based on the few Foraminifera found (checklist, p. 20), the strata in this section almost certainly were deposited in shallow water. Although numerous samples were taken from localities well distributed throughout the entire section, unfortunately, Foraminifera were found in limited numbers of species, as well as of individuals, from only seven widely spaced localities. Furthermore, no specimens were found in the uppermost conglomerate part of the section. Therefore, the Foraminifera are not greatly useful for determining details about the ecological conditions under which the beds of this section were deposited. However, the available evidence is consistent in that the eight species all definitely occur, or have some similar living form, in the present-day littoral to upper neritic environments along the west coast. Most frequently occurring, and therefore of greatest significance, is *Elphidium hughesi*. As previously mentioned, similar forms are found today typifying littoral and upper neritic conditions rather widespread along the west coast in temperatures varying widely from perhaps 21° to 7° C. Other species from scattered localities throughout the section are:

Buccella inusitata
Cassidulina limbata
Cibicides conoideus
Discorbis(?) *columbiensis*
Globigerina bulloides
Nonion depressulum matagordanum

Because all these species were found in very limited numbers, they alone are not greatly significant with respect to the probable ecologic conditions under which the strata of this section were deposited. However, it is noteworthy that the known distribution in the seas today of all these or similar species, except the planktonic *G. bulloides*, is essentially confined to upper neritic or littoral conditions. Because no deep-water Foraminifera were found in this section, foraminiferal evidence is lacking for secondary transport of these sediments from shallow to deep water. The lack of Foraminifera in much of the section, particularly the upper part, suggests brackish, or possibly even partly nonmarine, conditions. Based on lithology, together with the distribution of Foraminifera, as well as a few scattered molluscan fossils in the lower part, water depths may have been greater (possibly upper neritic) during the deposition of the lower sandstone and siltstone part of the section, whereas littoral or beach deposits are most likely represented by the carbonaceous conglomerate and coarse sandstone of the upper part of the section.

DUCK CREEK-PRATT CLIFF SECTION

The Foraminifera from this section (checklist, p. 20), as a group, firmly indicate a neritic environment of deposition. Some sixteen species, or groups of species, constitute most of the Foraminifera collected from this section. Of these, at least half are largely confined to, or at least show a decided preference for, a neritic environment in the eastern Pacific of today; these species are listed below:

Angulogerina semitrigona
Buccella inusitata
Buliminella elegantissima
Cibicides conoideus
Cibicides fletcheri
Florilus basispinatum
Oolina borealis
Nonionella miocenica
Pullenia salisburyi

The present-day distribution of *B. inusitata*, *C. fletcheri*, *F. basispinatum*, *O. borealis*, and *N. miocenica*, as already discussed, indicates a preference for neritic depths, particularly a lower part of this zone. Furthermore, most of them suggest rather wide-ranging temperature conditions. However, *B. inusitata* and *O. borealis* indicate a preference for cool water. Records of *C. fletcheri* are rare in the northeast Pacific, and are largely confined to coastal waters off California and southward in relatively warm temperatures, possibly between 17.5° and 13° C. This species, together with *C. conoideus*, a similar form not known, or at least rare in Recent deposits, constitutes a very persistent-occurring element in the Duck Creek-Pratt Cliff section. *Angulogerina semitrigona* is present today in Puget Sound and off the coast from Alaska to Oregon (Cushman and Todd, 1947; Enbysk, 1960), where it is found largely at lower neritic depths in temperatures ranging from 13° to 5° C. Records show that *B. elegantissma* is confined mostly to neritic depths in the northeast Pacific, but is also found deeper in southern latitudes. This distribution suggests that it may not have a tolerance for warm water. However, Natland (1957) lists it as characteristic of his biofacies I, which he indicates represents a depth of 0 to 20 feet, having a wide temperature range of 24° to 5° C. He further states that it is known down to 580 meters. *Pullenia salisburyi* is common in the northeast Pacific largely at lower neritic depths, but is also known from the upper bathyal zone (1,200 feet). The available records, therefore, suggest that this form may well have a preference for cool water. Most of the remaining commonly occurring forms of the Duck Creek-Pratt Cliff section show a preference in today's seas for lower neritic to upper bathyal depths; they are listed below:

Cassidulina islandica
Cassidulina reflexa
Epistominella pacifica
Globobulimina auriculata
Uvigerina (all forms)

Records of *C. islandica* are largely from neritic depths in cold water. *Cassidulina reflexa* is recorded rarely, and then at neritic depths off Washington (Enbysk, 1960). A similar form, *Cassidulina tortuosa* Cushman and Hughes, is frequently recorded in the eastern Pacific from the Gulf of Alaska to California in neritic to lower bathyal depths (Todd and Low, 1967; Enbysk, 1960; Bandy, 1953). Natland (1957) regards this form as one of the characteristic species of his biofacies III (125 to 900 feet; 13° to 8.5° C.). Although detailed records of the distribution of *G. auriculata* are not completely clear, this general form is widespread in the seas today. Furthermore, it appears to have affinities for cold water. It is common in the arctic or cold-water regions at neritic depths, but is also found today at abyssal depths off the coast of Washington and Oregon (Enbysk, 1960). *Epistominella pacifica* is recorded largely from depths mostly below 600 feet, in cold water, possibly not much above 8.5° C. Temperature may be a factor in allowing this form to live in shallow depths if the water is relatively cold. Species of *Uvigerina* present in this section, as previously discussed, also show a distinct preference for depths no less than lower neritic (600 feet). Some are most frequently found at greater depths in the bathyal and abyssal zones. Furthermore, although low-costate forms such as *U. juncea* and related species probably tolerate temperatures up to 13° C., others, such as the coarsely costate *U. subperegrina* and the hispid *U. senticosa*, much prefer cold water, possibly not greatly above 8.5° C.

In summary, with respect to depth of deposition, the preponderance of the evidence suggests that the frequently occurring species of the Duck Creek-Pratt Cliff section could have existed together at lower neritic, or possibly no deeper than uppermost bathyal depths, possibly at depths between 400 and 1,000 feet. Furthermore, it is significant to note an almost complete lack of forms known to be restricted to littoral and upper neritic depths, particularly representatives of *Elphidium*. This is a major difference between the assemblages of this section and other sections of the Quinault Formation. Indications of the probable water temperature during deposition are noticeably in favor of cool, rather than warm, conditions. Although a number of forms have tolerance for a rather wide variation in temperature, in the eastern Pacific few, if any, are restricted to warm water. Representatives of *Cibicides* might be the exception, as there are only a few records of *C. fletcheri* in the cool waters of the northeast Pacific. Recent records of a far larger number of other species of this section indicate a preference for cool to cold water, and a few are essentially confined to such conditions. Those forms somewhat indicative of relatively deep water, such as *Epistominella pacifica* and various representatives of *Uvigerina*, are essentially restricted to relatively cool conditions. Therefore, it is possible that some of these forms may have existed in somewhat more shallow conditions than normal, provided that water temperatures were cool or cold. Because of the absence of shallow-water forms restricted to relatively warm water, faunal evidence clearly indicates that water temperatures were cool to cold, possibly between 12° and 7° C., during the deposition of the Duck Creek-Pratt Cliff section of the Quinault Formation.

Redeposition of some of the sediments by turbidity currents or conventional low-speed movements no doubt did take place during the deposition of this section, as is evident by the physical appearance of the sedimentary beds (Horn, 1969). However, the change of environment of the sediments probably was less severe than is evident in some of the other sections of the Quinault Formation. Probably all deposition took place in the vicinity of the outer edge of the Continental Shelf in lower neritic to upper bathyal depths.

FORAMINIFERA

GENERAL STATEMENT

Previous studies in connection with Foraminifera of the Quinault Formation are largely confined to the work of Cushman, Stewart, and Stewart (1949), in which they systematically discussed and illustrated 23 species from two samples. Their material came from a location described as the S½ sec. 12, T. 21 N., R. 13 W. This location is in an area of isolated outcrops between the sections north of Point Grenville and south of Taholah (see Fig. 2, p. 6) of the present report. The only other reference to Foraminifera of the Quinault Formation was made by Ingle in 1967. Using data on planktonic Foraminifera that was re-

CHECKLIST

Foraminifera from the four measured sections and from miscellaneous localities of the Quinault Formation.
C = common; F = few; R = rare; ? = questionably identified.

Species	Sections: North of Point Grenville														South of Taholah														Cape Elizabeth						
Localities:	Q-14	Q-13	Q-12	Q-11	Q-10	Q-9	Q-8	Q-7	Q-6	Q-5	Q-4	Q-3	Q-2	Q-1	Q-33	Q-32	Q-31	Q-30	Q-29	Q-28	Q-27	Q-26	Q-25	Q-24	Q-23	Q-22	Q-21	Q-20	Q-37	Q-38	Q-39	Q-40	Q-41	Q-42	Q-43
Angulogerina semitrigona (Galloway and Wissler)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Anomalinoides quinaultensis Rau n. sp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Bolivina acuminata Natland	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
advena Cushman	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Buccella inusitata Andersen	F	F	F	R	F	R	C	F	C	F	F	F	R	...	F	R	?	R	R	?	R	R	...	?	?	?	...	?	...	...	...	...	?	F	...
Bulimina subacuminata Cushman and Todd	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Buliminella curta Cushman	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	F	...	...	...	...	...	...	...	...	...	...
elegantissima (d'Orbigny)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Cassidulina californica Cushman and Hughes	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
islandica Nörvang	R	?	F	...	...	R	...	R	...	...	...	...	...	...	...	...	...	...	...	F	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...
limbata Cushman and Hughes	?	R	...	...	R	...	F	R	F	F	R	R	R	...	C	F	C	F	C	F	C	C	R	F	...	R	...	...	...	...	...	...	?	?	...
reflexa Galloway and Wissler	...	...	...	...	...	...	...	F	...	F	F	R	...	...	...	...	...	...	F	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
translucens Cushman and Hughes	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C	...	...	...	...	...	...	...	...	...	...
Chilostomella cf. *C. czizeki* Reuss	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Cibicides conoideus Galloway and Wissler	F	R	...	...	R	...	F	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...
fletcheri Galloway and Wissler	R	R	F	?	C	R	F	?	F	F	R	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
mckannai Galloway and Wissler	R	F	?	...	...	...	...	...	...	...	...	...	...	...	?	C	C	C	F	F	F	F	...	?	...	...	...	...	...	...	...	...	...	...	...
Dentalina cf. *D. baggi* Galloway and Wissler	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
cf. *D. decepta* (Bagg)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Dentalina? sp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...
Discorbis? columbiensis Cushman	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Elphidiella hannai (Cushman and Grant)	...	...	...	...	...	...	...	...	R	R	R	...	...	R	...	...	...	F	...	...	...	...	...	...	...	...	...	...	...	...	F	...	?	...	...
Elphidium hughesi foraminosum Cushman	R	C	C	C	F	R	C	F	F	C	F	F	R	R	F	R	R	...	...	R	...	...	...	...	?	...	?	...	F	...	R	C	R	C	C
hughesi hughesi Cushman and Grant	...	F	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C	...	...	...	R	F
microgranulosum (Galloway and Wissler)	...	R	R	...	F	...	R	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Epistominella pacifica (Cushman)	C	?	C	R	R	...	...	F	...	...	...	...	...	...	F.	R	...	...	...	...	...	...	...	...	...	F	...	...	...	...	...	...	...	...	...
Eponides healdi R. E. and K. C. Stewart	...	...	R	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Florilus basispinatum (Cushman and Moyer)	R	...	C	F	F	...	...	...	?	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Gaudryina pliocenica Cushman and R. E. and K. C. Stewart	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	R	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Glandulina laevigata d'Orbigny	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Globigerina bulloides d'Orbigny	C	R	...	R	F	F	...	R	F	R	R	...	...	...	R	R	...	...	F.	F	R	?	...	F	...	...	...	R	...	...	...	...	R	R	...
pachyderma (Ehrenberg)	R	...	C	...	...	...	...	...	...	...	...	...	...	...	R	R	...	F	R	F	F	...	R	F	R	R	R	...	...	...	...	...	...	...	...
Globobulimina auriculata (Bailey)	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	F	R	...	...	...	...	...	...	...
Globorotalia crassiformis (Galloway and Wissler)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...
Lagena dentaliniformis Bagg	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
pliocenica timmsana Cushman and Gray	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
substriata Williamson	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...
Nonion depressulum matagordanum Kornfeld	R	...	R	...	R	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	F	...
cf. *N. goudkoffi* Kleinpell	...	R	R	...	R	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Nonionella miocenica Cushman	...	...	...	...	...	...	...	...	...	...	...	...	R	...	R	R	...	R	...	R	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...
Oolina borealis Loeblich and Tappan	...	R	R	...	R	...	R	...	R	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
melo d'Orbigny	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Plectofrondicularia? sp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Polymorphina charlottensis Cushman	...	R	...	...	...	...	F	...	R	...	...	...	...	...	...	R	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Pullenia miocenica Kleinpell	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	F	R	...	F	...	F	F	...	?	...	...	...	...	...	...	...	...	...	...	...
cf. *P. salisburyi* R. E. and K. C. Stewart	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Pyrgo spp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	R	...	...	...	...	...	...	...
Quinqueloculina cf. *Q. akneriana* d'Orbigny	R	R	F	...	...	...	F	...	...	...	...	R	...	...	C	...	...	F	F	...	...	R	...	F	...	...	R	...	...	...	...	...	...	...	...
Rotalia cf. *R. garveyensis* Natland	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Sphaeroidina bulloides d'Orbigny	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Uvigerina juncea Cushman and Todd	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	F	F	...	F	F	C	C	...	...	?	...	...	R	...	...	...	...	...	...	...
cf. *U. hootsi* Rankin	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...	F	...	...	...	...	...	...	...	...	...	...	...
senticosa Cushman	...	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...
subperegrina Cushman and Kleinpell	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	?	...	R	...	R	R	...	R	...	...	...	...	...	...	...	...
Valvulineria malagaensis Kleinpell	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
washingtonensis (Cushman and R. E. and K. C. Stewart)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Virgulina californiensis ticensis Cushman and Kleinpell	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Species	Duck Creek-Pratt Cliff																																						
Localities:	Q-58	Q-59	Q-60	Q-61	Q-62	Q-63	Q-64	Q-65	Q-66	Q-67	Q-68	Q-69	Q-70	Q-71	Q-72	Q-73	Q-74	Q-75	Q-76	Q-77	Q-78	Q-79	Q-80	Q-81	Q-82	Q-83	Q-87	Q-84	Q-86	Q-85	Q-88	Q-89	Q-90	Q-91	Q-92	Q-93	Q-94	Q-95	Q-96
Angulogerina semitrigona (Galloway and Wissler)	...	R	...	R	F	...	R	...	R	...	...	...	...	R	R	...	...	F	R	R	R	F	...	R	R	R	...	F	R	...	?	R	...	F	F	F	R	R	F
Anomalinoides quinaultensis Rau n. sp.	R	R	R	R	F	...	R	...	R	...	...	...	...	R	...	...	...	...	...	...	R	F	R	R	F	...	R	?	R	R	...	R	R	C	C	C	?	R	R
Bolivina acuminata Natland	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
advena Cushman	R	R	R	...	R	...	...	R	R	...	...	...	R	...	...	...	R	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...
Buccella inusitata Andersen	F	F	F	R	R	...	R	R	F	...	...	R	F	F	R	R	F	C	F	F	F	F	...	R	R	R	...	...	?	...	R	R	R	F	R	R	...	...	R
Bulimina subacuminata Cushman and Todd	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Buliminella curta Cushman	...	...	R	...	?	...	...	...	?	...	...	?	...	...	?	...	...	R	R	...	...	R	...	...	...	...	...	...	...	...	...	...	...	?	...	...	...	...	...
elegantissima (d'Orbigny)	F	...	F	R	F	...	F	...	R	...	F	...	...	R	...	...	R	...	...	R	F	R	R	...	R	R	...	...	...	...	...	R	R	R	F	R	...	R	R
Cassidulina californica Cushman and Hughes	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
islandica Nörvang	F	F	R	R	R	...	R	R	...	...	...	...	R	...	...	R	R	...	...	...	R	R	...	R	R	...	...	...	...	...	R	...	?	F	R	R	...	...	...
limbata Cushman and Hughes	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
reflexa Galloway and Wissler	R	F	R	R	F	...	...	...	...	...	...	...	...	...	...	...	R	R	...	R	R	R	R	C	F	C	F	C	F	C	C	F	C	C	C	C	C	C	C
translucens Cushman and Hughes	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Chilostomella cf. *C. czizeki* Reuss	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Cibicides conoideus Galloway and Wissler	F	F	F	F	F	...	R	?	?	...	?	...	...	R	...	R	R	F	...	?	F	F	R	F	R	R	F	F	F	F	F	F	F	F	F	R	R	R	R
fletcheri Galloway and Wissler	...	R	...	C	F	?	R	...	...	...	...	...	...	...	...	R	R	R	...	...	?	...	...	F	R	R	R	R	R	R	F	...	R	F	F	F	C	F	C
mckannai Galloway and Wissler	...	?	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	?	...	...
Dentalina cf. *D. baggi* Galloway and Wissler	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
cf. *D. decepta* (Bagg)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Dentalina? sp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Discorbis? columbiensis Cushman	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Elphidiella hannai (Cushman and Grant)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Elphidium hughesi foraminosum Cushman	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
hughesi hughesi Cushman and Grant	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
microgranulosum (Galloway and Wissler)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Epistominella pacifica (Cushman)	...	...	...	...	R	...	...	R	R	F	...	...	...	...	...	?	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...
Eponides healdi R. E. and K. C. Stewart	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Florilus basispinatum (Cushman and Moyer)	...	?	?	R	F	R	C	R	C	C	C	F	F	R	R	...	F	F	F	C	R	...	R	R	...	?	...	F	R	...	...	...	...	F	R	R	...	...	F
Gaudryina pliocenica Cushman and R. E. and K. C. Stewart	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Glandulina laevigata d'Orbigny	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Globigerina bulloides d'Orbigny	...	R	...	...	?	...	...	...	F	...	...	...	R	F	...	F	F	F	R	R	...	...	...	F	F	?	...	R	?	...	R	...	...	...	R	F	?	...	F
pachyderma (Ehrenberg)	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	R	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R
Globobulimina auriculata (Bailey)	...	...	...	C	C	C	F	?	C	C	C	C	C	F	C	C	C	C	C	C	C	R	?	R	F	...	...	...	...	...	...	...	...	F	C	...	...	F	F
Globorotalia crassiformis (Galloway and Wissler)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Lagena dentaliniformis Bagg	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	?	...
pliocenica timmsana Cushman and Gray	...	...	...	R	R	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	?	...	...	...	...	...	...	...	...	...	...	?	...	...	...	?
substriata Williamson	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...	...	R	...	...	...	...	...
Nonion depressulum matagordanum Kornfeld	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
cf. *N. goudkoffi* Kleinpell	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Nonionella miocenica Cushman	...	...	...	F	F	...	...	...	R	...	...	...	R	...	...	R	F	R	...	?	...	...	...	F	F	...	...	...	...	...	...	...	...	F	F	F	...	...	...
Oolina borealis Loeblich and Tappan	R	...	...	F	R	...	...	...	R	...	...	...	...	R	R	R	R	R	...	...	R	R	R	F	...	...	R	F	...	F	R	R	...	R	R	R	F	R	F
melo d'Orbigny	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	?	...	R	...	...	...	...	...	...	...	...	...	...	...	...	R	...	R	...	...	...
Plectofrondicularia? sp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Polymorphina charlottensis Cushman	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Pullenia miocenica Kleinpell	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
cf. *P. salisburyi* R. E. and K. C. Stewart	...	?	R	...	...	...	?	?	R	...	...	...	...	?	F	R	R	F	R	F	...	...	R	R	...	R	...	...	...	...	R	...	R	...	R	...	...	?	...
Pyrgo spp.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Quinqueloculina cf. *Q. akneriana* d'Orbigny	...	...	...	...	...	R	...	C	...	?	...	...	...	...	...	R	...	R	...	...	...	...	...	R	R	R	...	...	...	...	...	...	...	...	?	R	...	...	...
Rotalia cf. *R. garveyensis* Natland	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Sphaeroidina bulloides d'Orbigny	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Uvigerina juncea Cushman and Todd	?	...	R	?	...	...	R	...	R	...	...	...	?	...	?	R	F	F	F	R	...	...	...	?	...	...	...	...	...	...	...	...	...	R	R	R	...	...	R
cf. *U. hootsi* Rankin	...	...	...	...	R	...	R	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	?	?	...	...	...	...
senticosa Cushman	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	R	...	R	...	...	...	...	...	R	...	...	...	...	...
subperegrina Cushman and Kleinpell	...	...	...	...	F	...	?	...	...	...	...	?	...	...	...	R	...	...	...	...	...	?	...	F	...	R	...	...	?	...	...	...	R	...	...	?	R	...	R
Valvulineria malagaensis Kleinpell	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
washingtonensis (Cushman and R. E. and K. C. Stewart)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Virgulina californiensis ticensis Cushman and Kleinpell	...	...	...	...	...	...	...	...	...	...	...	...	F	C	...	C	F	C	R	R	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...

Species	Miscellaneous Localities																										
Localities:	Q-15	Q-16	Q-17	Q-18	Q-19	Q-34	Q-35	Q-36	Q-44	Q-45	Q-46	Q-47	Q-49	Q-48	Q-50	Q-51	Q-52	Q-56	Q-55	Q-54	Q-53	Q-97	Q-98	Q-99	Q-100	Q-102	Q-101
Angulogerina semitrigona (Galloway and Wissler)	...	...	...	?	...	...	...	?	F	R	R	F	R	R	R	F	F	F	...	...	F	...	...	...	...	F	...
Anomalinoides quinaultensis Rau n. sp.	...	...	...	...	...	...	...	...	...	...	R	R	R	R	R	R	R	...	...	...	R	...	...	...	...	...	...
Bolivina acuminata Natland	...	...	F	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
advena Cushman	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	R	...
Buccella inusitata Andersen	...	...	...	R	...	?	R	R	...	R	...	...	...	...	...	R	R	...	...	...	...	?	...	...	R	...	...
Bulimina subacuminata Cushman and Todd	...	...	F	...	R	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...	F	...
Buliminella curta Cushman	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	R	...	R	...
elegantissima (d'Orbigny)	...	...	...	...	...	...	...	...	...	...	F	F	R	...	R	...	R	F	R	...	R	...	...	...	R	...	R
Cassidulina californica Cushman and Hughes	C	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
islandica Nörvang	...	...	...	F	F	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	R	...	R	...	...	...
limbata Cushman and Hughes	C	...	R	...	...	F	R	C	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	C
reflexa Galloway and Wissler	...	...	F	...	...	...	...	...	C	R	R	F	R	F	F	F	F	R	F	F	F	...	...	...	...	...	...
translucens Cushman and Hughes	...	...	F	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	C	F	F	...	...
Chilostomella cf. *C. czizeki* Reuss	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Cibicides conoideus Galloway and Wissler	...	...	...	...	R	...	?	...	R	F	...	R	R	R	...	R	...	...	R	R	R	R	...	...	...	R	R
fletcheri Galloway and Wissler	...	...	...	F	F	F	...	...	F	...	R	F	R	F	F	F	F	...	F	R	R	F	...	...	...	...	...
mckannai Galloway and Wissler	R	...	...	R	...	...	...	F	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	?	R
Dentalina cf. *D. baggi* Galloway and Wissler	F	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
cf. *D. decepta* (Bagg)	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Dentalina? sp.	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Discorbis? columbiensis Cushman	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Elphidiella hannai (Cushman and Grant)	R	...	R	...	...	...	...	...	...	...	...	...	...	...	...	?	...	...	...	R	...	...	...	...	...	...	...
Elphidium hughesi foraminosum Cushman	...	...	...	...	...	...	F	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
hughesi hughesi Cushman and Grant	...	...	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
microgranulosum (Galloway and Wissler)	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Epistominella pacifica (Cushman)	...	...	R	F	...	C	F	...	...	R	...	...	R	...	...	...	...	...	...	...	...	F	R	R	...	R	R
Eponides healdi R. E. and K. C. Stewart	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...
Florilus basispinatum (Cushman and Moyer)	...	...	...	?	...	...	...	...	C	...	...	R	...	F	...	R	...	...	F	C	F	R	...	...	...	?	...
Gaudryina pliocenica Cushman and R. E. and K. C. Stewart	F	...	...	...	...	...	...	F	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Glandulina laevigata d'Orbigny	...	...	F	...	R	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...	F	...
Globigerina bulloides d'Orbigny	...	...	...	F	R	F	C	...	...	R	F	R	F	...	R	F	F	F	R	...	...	F	C	F	R	...	R
pachyderma (Ehrenberg)	R	...	...	...	...	F	R	...	...	R	...	...	...	...	?	R	...	?	...	...	...	F	R	R	...	...	...
Globobulimina auriculata (Bailey)	...	...	C	...	...	...	...	C	...	R	F	...	C	C	F	C	...	C	C	C	F	R	...	...	...	C	...
Globorotalia crassiformis (Galloway and Wissler)	...	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Lagena dentaliniformis Bagg	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	R	R	R	...	...	...	...	...	...	...	...	...
pliocenica timmsana Cushman and Gray	...	...	...	...	...	...	...	...	R	...	...	R	...	...	?	...	...	F	?	R	R	R	...	...	...	...	R
substriata Williamson	...	...	...	R	?	...	...	...	...	...	...	R	...	...	...	...	...	...	...	...	...	?	...	...	...	R	...
Nonion depressulum matagordanum Kornfeld	...	...	...	?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
cf. *N. goudkoffi* Kleinpell	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Nonionella miocenica Cushman	...	...	R	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...	R	...	...	...	...	...
Oolina borealis Loeblich and Tappan	...	...	...	...	...	...	R	...	F	?	F	F	F	F	F	F	F	F	F	R	R	R	...	...	...	R	R
melo d'Orbigny	...	...	...	...	...	...	...	...	R	...	R	R	R	...	...	...	...	R	...	...	R	R	...	...	...	R	...
Plectofrondicularia? sp.	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Polymorphina charlottensis Cushman	R	...	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...
Pullenia miocenica Kleinpell	...	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
cf. *P. salisburyi* R. E. and K. C. Stewart	...	...	...	...	...	...	...	F	...	...	R	...	R	R	...	R	...	R	R	...	R	F	R	...	...	F	F
Pyrgo spp.	...	...	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
Quinqueloculina cf. *Q. akneriana* d'Orbigny	R	...	...	R	R	...	F	...	...	...	...	...	...	...	R	...	...	R	...	...	R	R	...	...	...	R	...
Rotalia cf. *R. garveyensis* Natland	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	F	...	...	...	...	...
Sphaeroidina bulloides d'Orbigny	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	?	R	...	...	...	...	...	R	...
Uvigerina juncea Cushman and Todd	...	...	F	...	R	...	...	F	R	...	?	?	F	...	R	C	F	R	...	...	?	C	C	F	F	...	C
cf. *U. hootsi* Rankin	...	...	F	...	...	...	...	...	...	...	...	...	...	...	R	...	...	...	...	...	...	R	...	...	...	...	R
senticosa Cushman	...	...	F	C	C	...	...	R	...	...	...	R	R	?	...	...	R	...	...	R	...	...	R	R	R	...	...
subperegrina Cushman and Kleinpell	R	...	F	R	R	...	...	R	R	...	F	R	R	R	R	F	R	F	R	...	F	?	R	R	C	...	R
Valvulineria malagaensis Kleinpell	...	...	F	...	R	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	R	...	F	...	...
washingtonensis (Cushman and R. E. and K. C. Stewart)	C	C	...	...	...	...	...	R	...	...	...	...	...	R	R	R	...	...	...	...	...	...	...	...	...	...	...
Virgulina californiensis ticensis Cushman and Kleinpell	...	...	...	...	...	...	...	...	...	?	...	?	...	R	...	R	...	R	R	R	...	F	...	?	...	...	...

corded in a Ph. D. dissertation by Fowler (1965) on the Montesano Formation, Ingle presented evidence that he believes suggests a noticeable temperature change during the deposition of the Quinault Formation.

In the present report, 57 species are illustrated and discussed from 101 localities in four measured sections, and in nearby isolated outcrops exposed along the coast from Point Grenville to approximately 1 mile north of the mouth of the Raft River (Fig. 1, p. 2). Generally, Foraminifera were found distributed rather uniformly, in numbers of individuals as well as numbers of species, throughout the beds, excepting those of the Cape Elizabeth section (checklist). Only eight species were found in samples from seven localities of the latter section, although collections were made from many more localities in this well-defined and continuous section. The largest assemblages, in terms of individuals, probably came most consistently from the Duck Creek-Pratt Cliff section and nearby isolated outcrops. Furthermore, samples from these beds were consistently fossiliferous.

Variations are present in each of the 101 assemblages of this report, in the species they contain, the abundance of each species, or a combination of the two. These variations are shown in the checklist, where comparisons can be made of each assemblage. Further discussion of faunal composition is made under sections on Age and Correlation and on Paleoecology.

SYSTEMATIC DISCUSSION

Synonymies are not necessarily complete, but usually the original reference is cited together with either a complete synonymy or a citation to a reference in which the synonymy is more nearly complete.

The classification followed is of Cushman (1950), with minor modifications. Identifications are based largely on descriptions and illustrations from the literature, but many comparisons have been made with various type materials. Although identifications are conclusions of the author, it has been the attempt to also incorporate the thinking and opinions of other micropaleontologists in both academic and commercial fields.

Family VERNEUILINIDAE

Genus **Gaudryina** d'Orbigny, 1839

Gaudryina pliocenica Cushman and R. E. and K. C. Stewart

Plate 1, figure 1

Gaudryina pliocenica CUSHMAN and R. E. and K. C. STEWART, 1949, p. 150, pl. 17, fig. 2.

This species is rare in the present collection and is confined to a few samples from the section south of Taholah and nearby isolated outcrops.

Gaudryina pliocenica was originally described from the Quinault Formation by Cushman, Stewart, and Stewart (1949) from a locality between the sections south of Taholah and north of Point Grenville.

Length of figured specimen, 1.15 mm; width, 0.48 mm; breadth, 0.46 mm.

Figured specimen (WSMG 1001), from locality Q-15.

Family MILIOLIDAE

Genus **Quinqueloculina** d'Orbigny, 1826

Quinqueloculina cf. **Q. akneriana** d'Orbigny

Plate 1, figure 2

Quinqueloculina akneriana D'ORBIGNY, 1846, p. 290, pl. 18, figs. 16-21; GALLOWAY and WISSLER, 1927a, p. 38, pl. 7, fig. 3; CUSHMAN and GRAY, 1946b, p. 3, pl. 1, fig. 7.

Specimens tentatively referred to this species are found in small numbers throughout most of the sections. They display considerable variation in form, particularly in their breadth-length ratio and the amount of chamber inflation.

Q. akneriana d'Orbigny is recorded from a number of late Tertiary and Recent deposits on the west coast, mainly in California and Oregon.

Length of figured specimen, 0.75 mm; breadth, 0.56 mm; thickness, 0.40 mm.

Figured specimen (WSMG 1002), from locality Q-65.

Genus **Pyrgo**, Defrance, 1824

Pyrgo spp.

Plate 1, figure 3

More than one species of *Pyrgo* may be represented by a few poorly preserved specimens from several localities. The best preserved specimen is figured here.

Length of figured specimen, 0.35 mm; breadth, 0.27 mm; thickness, 0.25 mm.

Figured specimen (WSMG 1003), from locality Q-20.

Family LAGENIDAE

Genus **Dentalina** d'Orbigny, 1826

Dentalina cf. **D. baggi** Galloway and Wissler

Plate 1, figure 5

?*Dentalina baggi* GALLOWAY and WISSLER, 1927a, p. 49, pl. 8, figs. 14, 15.

Dentalina are extremely rare in the present collections and are limited to a few isolated localities in the landslide area between the section south of Taholah and the section north of Point Grenville. One form seems similar to *D. baggi* Galloway and Wissler, known from the Pliocene of California, the late Tertiary of Oregon, and the Recent of the Gulf of Alaska and the Arctic. Locally it is tentatively recorded from the Montesano Formation of Washington.

The present specimen differs from those of Galloway and Wissler in that the chambers are less inflated. Some of the sutures are nearly flush with the surface of the test.

Length of figured specimen (fragmentary), 1.50 mm; diameter, 0.38 mm.

Figured specimen (WSMG 1004), from locality Q-15.

Dentalina cf. **D. decepta** (Bagg)

Plate 1, figure 6

?*Nodosaria decepta* BAGG, 1912, p. 55, pl. 16, fig. 1.
?*Dentalina decepta* (Bagg), GALLOWAY and WISSLER, 1927a, p. 49, pl. 8, figs. 14, 15.

Rare in only one sample are specimens similar in shape to Bagg's form. However, no costae are present on the early part of the test.

Dentalina decepta is known from the Plio-Pleistocene of California and from the Pliocene to Recent of Japan and the Recent of the Gulf of Alaska.

Length of figured specimen (fragmentary), 1.18 mm; diameter, 0.19 mm.

Figured specimen (WSMG 1005), from locality Q-18.

Dentalina? sp.

Plate 1, figure 4

A very few fragmented specimens from two localities may be *Dentalina*. The chambers are inflated and globular, and the sutures are strongly depressed. They appear similar to those of Bagg (1912) and others figured as *Dentalina soluta* Reuss. All specimens are without the final or apertural chamber, and therefore it is not possible to be certain of their generic placement.

Length of figured specimen (fragmentary), 0.78 mm; breadth, 0.32 mm.

Figured specimen (WSMG 1006), from locality Q-18.

Genus **Lagena** Walker and Jacob, 1798

Lagena dentaliniformis Bagg

Plate 1, figure 8

Lagena dentaliniformis BAGG, 1912, p. 45, pl. 13, figs. 1, 2; CUSHMAN and GRAY, 1946b, p. 21, pl. 4, figs. 10, 11.

This extremely rare form is typically curved. Some have a noticeable indentation in the central part of the test, as shown on one specimen figured by Bagg.

The only known record of this form is from Plio-Pleistocene deposits at Timms Point, California.

Length of figured specimen, 0.96 mm; diameter, 0.16 mm.

Figured specimen (WSMG 1007), from locality Q-47.

Lagena pliocenica timmsana Cushman and Gray

Plate 1, figure 7

Lagena pliocenica timmsana CUSHMAN and GRAY, 1946a, p. 68, pl. 12, figs. 15-17; CUSHMAN and GRAY, 1946b, p. 19, pl. 3, figs. 43, 44.

A few specimens from scattered localities seem identical to those figured by Cushman and Gray as *Lagena pliocenica timmsana*. They differ from the typical form of *Lagena pliocenica* in that the test is more globular and the base is rounded. A few specimens display slightly twisted costae, as shown by Cushman and Gray (1946a) in their Figure 15.

The original reference from the Timms Point material of California is the only other known record of the subspecies, although specimens from the Gulf of Alaska (Todd and Low, 1967) are similar to this form.

Lagena pliocenica [*sensu lato*] is recorded from Puget Sound and is also known from the Pliocene and Recent along the west coast of North America and in Japan (Todd and Low, 1967).

Diameter of figured specimen, 0.27 mm; length, 0.42 mm.

Figured specimen (WSMG 1008), from locality Q-56.

Lagena substriata Williamson

Plate 1, figure 9

Lagena substriata WILLIAMSON, 1848, p. 15, pl. 1, fig. 12, CUSHMAN, 1929, p. 68, pl. 11, fig. 4; CUSHMAN, STEWART, and STEWART, 1930, p. 57, pl. 3, fig. 9; CUSHMAN and LAIMING, 1931, p. 100, pl. 11, fig. 1; CUSHMAN, 1944, p. 21, pl. 3, fig. 8.

Lagena striata (d'Orbigny) CUSHMAN and GRAY, 1946b, p. 20, pl. 3, figs. 51-54.

(For additional references see Ellis and Messina, 1940-70.)

This species is very rare, occurring in only a few samples. It was originally recorded from off the British Isles. Numerous additional records are from both the Tertiary and Recent, occurring in the Miocene of Florida and California, the Plio-Pleistocene of California, and the Recent off California.

Diameter of figured specimen, 0.26 mm; length, 0.40 mm.

Figured specimen (WSMG 1009), from locality Q-26.

Family POLYMORPHINIDAE

Genus **Glandulina** d'Orbigny, 1826

Glandulina laevigata d'Orbigny

Plate 1, figure 10

Nodosaria (Glandulina) laevigata D'ORBIGNY, 1826, p. 252, pl. 10, figs. 1-3.

Glandulina laevigata d'Orbigny, MARTIN, 1952, p. 118, pl. 17, fig. 3; WHITE, 1956, p. 246, pl. 27, figs. 4, 5.

Pseudoglandulina laevigata (d'Orbigny), CUSHMAN, STEWART, and STEWART, 1949, p. 151, pl. 17, fig. 4.

(For additional references see Martin, 1952.)

This widely recorded form is rare in a few isolated localities. Its occurrence in the Quinault Formation was first noted by Cushman, Stewart, and Stewart (1949). It is well known in the upper Tertiary of the west coast and the Recent of the Pacific, Arctic, and the Atlantic Oceans.

Length of figured specimen, 0.58 mm; thickness, 0.34 mm.

Figured specimen (WSMG 1010), from locality Q-19.

Genus **Polymorphina** d'Orbigny, 1826

Polymorphina charlottensis Cushman

Plate 1, figure 12

Polymorphina charlottensis CUSHMAN, 1925a, p. 41, pl. 6, fig. 9; CUSHMAN, STEWART, and STEWART, 1930, p. 59, pl. 4, fig. 6; CUSHMAN and GRAY, 1946b, p. 25, pl. 4, figs. 30, 31; CUSHMAN and TODD, 1947, p. 12, pl. 2, fig. 11; TODD and LOW, 1967, p. A25, pl. 3, fig. 13.

(For additional references see Cushman and Gray, 1946b.)

This form occurs in only a very few samples, mostly from the section north of Point Grenville. It was originally described from dredgings from 25 fathoms in Queen Charlotte Sound off British Columbia and has since been recorded from numerous localities, largely from the Recent of the northern Pacific Ocean and upper Tertiary of the west coast.

Because Recent records of this form are largely from shallow depths at northern latitudes, shallow, cool-water conditions of deposition are suggested.

Length of figured specimen, 1.34 mm; breadth, 0.46 mm; thickness, 0.27 mm.

Figured specimen (WSMG 1011), from locality Q-8.

Family NONIONIDAE

Genus **Nonion** Montfort, 1808

Nonion depressulum matagordanum Kornfeld

Plate 1, figure 13

Nonion depressulum matagordanum KORNFELD, 1931, p. 87, pl. 13, fig. 2; CUSHMAN, 1939, p. 21, pl. 5, fig. 26; CUSHMAN and MCCULLOCH, 1940, p. 145, pl. 17, fig. 1.

Nonionina depressula BAGG, 1912, (not Walker and Jacob), p. 88, pl. 26, fig. 16, pl. 28, figs. 7, 8.

Nonion depressulum CUSHMAN and GRAY, 1946b, (not Walker and Jacob), p. 25, pl. 4, fig. 32.

A limited number of specimens from a few localities, probably representing shallow depths of deposition, appear very close to the figure and description by Kornfeld (1931). The nearly circular side view and fewer chambers (eight to ten) in the last whorl make it distinct from *Nonion depressulum* (Walker and Jacob) [*sensu stricto*] as originally described (see *Nautilus depressulus* Walker and Jacob, 1798, *In* Ellis and Messina). A great many records are given for *N. depressulum*, many of which are unlike the original illustration and some of those are here placed in the subspecies *N. depressulum matagordanum* Kornfeld. Records of this form in Recent deposits indicate that it is confined generally to shallow waters, probably not more than 600 feet in depth.

The types are from Recent sediments off Texas in the Gulf of Mexico. This form has also been recorded from rocks of Miocene and younger age of Texas. In addition, it is known from the Plio-Pleistocene of California and in Recent deposits off California.

Diameter of figured specimen, 0.38 mm; thickness, 0.10 mm.

Figured specimen (WSMG 1012), from locality Q-42.

Nonion cf. **N. goudkoffi** Kleinpell

Plate 1, figure 15

?*Nonion goudkoffi* KLEINPELL, 1938, p. 231, pl. 20, figs. 2, 5; PIERCE, 1956, p. 1301, pl. 137, fig. 8.

Rare in several samples from the Point Grenville section are specimens that appear very close to *Nonion goudkoffi* Kleinpell except that they are noticeably larger than those described by Kleinpell. Bagg's illustration (1912, pl. 27, figs. 4, 5) of *Nonionina umbilicatula* (Montague), which he records from the Pleistocene of California, is similar to the present specimen, but the illustrations of the types of *N. umbilicatula* (Montague) are quite dissimilar.

Nonion goudkoffi is recorded from rocks of late Miocene age (upper Mohnian and lower Delmontian) of California (Kleinpell, 1938; Pierce, 1956).

Diameter of figured specimen, 0.50 mm; thickness, 0.24 mm.

Figured specimen (WSMG 1013), from locality Q-12.

Genus **Florilus** Montfort, 1808

Florilus [Nonionella] basispinatum (Cushman and Moyer)

Plate 1, figure 16

Nonion pizarrensis basispinata CUSHMAN and MOYER, 1930, p. 54, pl. 7, fig. 18.

Nonion pizarrense basispinatum Cushman and Moyer, CUSHMAN, 1939, p. 25, pl. 6, fig. 28; CUSHMAN and MCCULLOCH, 1940, p. 158, pl. 17, figs. 8, 9, pl. 18, figs. 4, 5; CUSHMAN and GRAY, 1946b, p. 25, pl. 4, figs. 33-35; CUSHMAN and TODD, 1947, p. 12, pl. 2, fig. 12; BANDY, 1950, p. 275, pl. 41, fig. 7.

The presence of a granular surface in the umbilical region and, on some specimens, along the sutures, together with a definite offset of the final chamber from the plane of coiling, suggests that this form best be referred to the genus *Florilus* de Montfort, 1808, as presented by Loeblich and Tappan (1964).

This species occurs at a number of localities in all sections except south of Taholah. It is known previously from rocks of Plio-Pleistocene age in California and Oregon and has been recorded from the Recent in shallow water off the west coast of America from Alaska to Ecuador.

Length of figured specimen, 0.62 mm; breadth, 0.43 mm; thickness, 0.30 mm.

Figured specimen (WSMG 1014), from locality Q-12.

Genus **Nonionella** Cushman, 1926

Nonionella miocenica Cushman

Plate 1, figure 14

Nonionina auris CUSHMAN, 1926a, (not d'Orbigny), p. 91, pl. 13, fig. 4.

Nonionella miocenica CUSHMAN, 1926b, p. 64; CUSHMAN, 1939, p. 31, pl. 8, fig. 9; RAU, 1951, p. 437, pl. 64, figs. 26-28; GOODWIN and THOMSON, 1954, p. 173, pl. 32, figs. 7-9; WHITE, 1956, p. 247, pl. 27, fig. 10.

This well-known species was found at a number of localities throughout much of the Quinault Formation.

Numerous records of this species are known from rocks of Miocene and Pliocene age in California, Oregon, and Washington. It is also known from Recent deposits from Alaska to Costa Rica (Cushman and McCulloch, 1940, p. 161, 162).

Length of figured specimen, 0.37 mm; breadth, 0.28 mm; thickness, 0.22 mm.

Figured specimen (WSMG 1015), from locality Q-75.

Genus **Elphidium** Montfort, 1808

Elphidium hughesi foraminosum Cushman

Plate 1, figure 19

Elphidium hughesi CUSHMAN and GRANT, 1927, p. 76, pl. 7, fig. 5.

Elphidium hughesi foraminosum CUSHMAN, 1939, p. 49, pl. 13, fig. 8; CUSHMAN and GRAY, 1946b, p. 26, pl. 4, fig. 42.

Most specimens of this species are referred to the subspecies *E. hughesi foraminosum* Cushman. They differ from the typical form in that the thickness is less, the chambers are less inflated, sutures are nearly flush with the surface, the umbilicus has a heavier and more prominent boss, and the retral processes tend to be more conspicuous. In a few specimens, particularly some of those listed from the Cape Elizabeth traverse, a moderate umbonal knob is developed, the peripheral edge is sharply rounded, and the retral processes are quite coarse. Specimens with these latter features resemble *E. oregonensis* Cushman and Grant, but differ in being smaller and having fewer chambers.

Records of *E. hughesi foraminosum* Cushman are mainly from rocks of Pliocene and Pleistocene(?) age of California.

Diameter of figured specimen, 0.50 mm; thickness, 0.22 mm.

Figured specimen (WSMG 1016), from locality Q-8.

Elphidium hughesi hughesi Cushman and Grant

Plate 1, figure 11

Elphidium hughesi CUSHMAN and GRANT, 1927, p. 75, pl. 7, fig. 1; CUSHMAN, STEWART, and STEWART, 1930, p. 61, pl. 3, fig. 15; CUSHMAN, 1939, p. 49, pl. 13, fig. 7; BANDY, 1950, p. 276, pl. 41, fig. 11.

This species shows much variation in form. Only those from a few localities, particularly Q-38, in the Cape Elizabeth traverse, are referred to *E. hughesi* [*sensu stricto*].

The restricted form is known from rocks reportedly of the late Miocene, Pliocene, and Pleistocene of California and Oregon.

Diameter of figured specimen, 0.34 mm; thickness, 0.14 mm.

Figured specimen (WSMG 1017), from locality Q-38.

Elphidium microgranulosum (Galloway and Wissler)

Plate 1, figure 22

Themeon decipiens GALLOWAY and WISSLER, 1927a, p. 83, pl. 12, figs. 15, 16 (given as *Themeon granulosa* on plate explanation).

Themeon granulosus GALLOWAY and WISSLER, 1927b, p. 193.

Elphidium granulosus (Galloway and Wissler) BANDY, 1950, p. 275, pl. 41, fig. 8.

Elphidium microgranulosum (Galloway and Wissler) *In* THALMANN, 1951, p. 222. [New name presented by authors for the homonym *E. granulosus* (Galloway and Wissler)].

The surface of the test is typically granular, and the sutural pores are small, nearly obscure. This species is rare in the present collection. Forms figured as *E. frigidum* Cushman (1948) are similar to the present Quinault specimens. However, holotype figures of *E. frigidum* show that the retral processes are more distinct and elongate, and the test is narrower with respect to its length than is the case with the Quinault specimens.

Elphidium microgranulosum was originally recorded from the Plio-Pleistocene of California and is also recorded from the Pliocene and Pleistocene of Oregon. The similar *Elphidium frigidum* is recorded largely from the Recent in the Arctic, but is known along the west coast and is recorded from nearby Puget Sound.

Length of figured specimen, 0.48 mm; thickness, 0.21 mm.

Figured specimen (WSMG 1018), from locality Q-10.

Genus **Elphidiella** Cushman, 1936

Elphidiella hannai (Cushman and Grant)

Plate 1, figure 20

Elphidium hannai CUSHMAN and GRANT, 1927, p. 77, pl. 8, fig. 1; CUSHMAN, STEWART, and STEWART, 1930, p. 62, pl. 3, figs. 16, 17.

Elphidiella hannai CUSHMAN, 1939, p. 66, pl. 19, figs. 1, 2; CUSHMAN and MCCULLOCH, 1940, p. 177, pl. 20, fig. 11; CUSHMAN and TODD, 1947, p. 15, pl. 2, fig. 22; BANDY, 1950, p. 276, pl. 41, fig. 10; GOODWIN and THOMSON, 1954, p. 174, pl. 32, figs. 27, 28.

This species is restricted to a few scattered localities in several of the measured sections and nearby outcrops. Sutural pores are extremely fine and are visible on only the best preserved specimens.

Previous records of *E. hannai* are from rocks reportedly of Pliocene and Pleistocene age in California and Oregon. It is also known from Recent deposits at shallow depths along the west coast from Alaska to Mexico (Cushman and McCulloch, 1940, p. 178).

Diameter of figured specimen, 0.56 mm; thickness, 0.28 mm.

Figured specimen (WSMG 1019), from Q-39.

Family HETEROHELICIDAE

Genus **Plectofrondicularia** Liebus, 1903

Plectofrondicularia? sp.

Plate 1, figure 21

A few specimens from a single isolated locality between Taholah and Point Grenville may belong to the genus *Plectofrondicularia*.

A form illustrated from a number of upper Tertiary localities of the west coast has been referred to as *Frondicularia advena* Cushman (White, 1956, p. 252). The present Quinault form may belong there; however, it is wider than most that are referred to this species.

Length of figured specimen (fragmentary), 0.92 mm; breadth, 0.46 mm; thickness, 0.08 mm.

Figured specimen (WSMG 1020), from Q-18.

Family BULIMINIDAE

Genus **Buliminella** Cushman, 1911

Buliminella curta Cushman

Plate 1, figure 18

Buliminella curta CUSHMAN, 1925b, p. 33, pl. 5, fig. 13; KLEINPELL, 1938, p. 248, pl. 7, fig. 3; pl. 15, fig. 4; CUSHMAN and PARKER, 1947, p. 64, pl. 16, fig. 22; WHITE, 1956, p. 254, pl. 30, fig. 12.

(For additional references see Cushman and Parker, 1947, and White, 1956.)

Rare specimens from a very few localities are best referred to *B. curta* Cushman. Numerous records of this species are from all parts of the California Miocene. It is also known from the Pliocene of Italy and California and the Recent of the Pacific. Locally it is recorded from the Montesano Formation (upper Miocene?) of Washington.

Length of figured specimen, 0.53 mm; diameter, 0.19 mm.

Figured specimen (WSMG 1021), from locality Q-23.

Buliminella elegantissima (d'Orbigny)

Plate 1, figure 17

Bulimina elegantissima D'ORBIGNY, 1839, p. 51, pl. 7, figs. 13, 14.

Buliminella elegantissima (d'Orbigny), CUSHMAN, 1919, p. 606; CUSHMAN and PARKER, 1947, p. 67, pl. 17, figs. 10-12; BANDY, 1953, p. 176, pl. 24, fig. 14.

(For additional references see Cushman and Parker, 1947.)

This species occurs somewhat persistently, although never in large numbers, throughout many of the samples from the Duck Creek-Pratt Cliff section. It is a widely distributed species, both geographically and stratigraphically, but was originally described from the Recent off the west coast of South America. It has since been recorded from the Recent in many parts of the world, including nearby British Columbia, is known from rocks as old as the Eocene of the gulf coast, and is also recorded throughout much of the Tertiary and Quaternary from the east coast, and west coast. Locally it occurs in the Montesano Formation (upper Miocene?) of Washington. Its occurrence in Recent deposits is largely from near-shore, shallow-water environments.

Length of figured specimen, 0.42 mm; diameter, 0.15 mm.

Figured specimen (WSMG 1022), from locality Q-68.

Genus **Bulimina** d'Orbigny, 1826

Bulimina subacuminata Cushman and R. E. Stewart

Plate 2, figure 1

Bulimina subacuminata CUSHMAN and R. E. STEWART, 1930, p. 65, pl. 5, figs. 2, 3; CUSHMAN and PARKER, 1938, p. 56, pl. 9, fig. 9; CUSHMAN and PARKER, 1947, p. 116, pl. 27, fig. 8; CROUCH, 1952, pl. 2, fig. 7; MARTIN, 1952, p. 132, pl. 22, fig. 12; WHITE, 1956, p. 254, pl. 30, fig. 8.

This rare species is found in only a few isolated localities. It was originally described by Cushman and Stewart from the Bear River area of Humboldt County, California and has since become a well-known form in the Pliocene of the Los Angeles basin of California, where it is confined largely to a lower part of that sequence of deposition.

Length of figured specimen 0.37 mm; breadth, 0.26 mm.

Figured specimen (WSMG 1023), from locality Q-17.

Genus **Globobulimina** Cushman, 1927

Globobulimina auriculata (Bailey)

Plate 2, figure 2

Bulimina auriculata BAILEY, 1851, p. 12, pl. 1, figs. 25-27; CUSHMAN and GRAY, 1946b, p. 29; CUSHMAN and PARKER, 1947, p. 129, pl. 29, figs. 22-24; CUSHMAN and TODD, 1947, p. 18, pl. 3, fig. 3; CUSHMAN, STEWART, and STEWART, 1949, p. 152, pl. 17, fig. 6.

Globobulimina auriculata (Bailey) PARKER, 1952, p. 416, pl. 5, fig. 29; TODD and LOW, 1967, p. 26, pl. 3, fig. 38.

(For additional references see Cushman, Stewart, and Stewart, 1949.)

Thin-walled Buliminidae are particularly common in the Duck Creek-Pratt Cliff section. Although most specimens are distorted, they seem to be best referred to *Globobulimina auriculata* (Bailey).

This species was first recorded from the Quinault Formation by Cushman, Stewart, and Stewart (1949). Elsewhere it is common in the western Atlantic and is recorded in the eastern Pacific, including the Gulf of Alaska and locally in Puget Sound. It is also known from Plio-Pleistocene rocks of Timms Point, California.

Length of figured specimen, 0.56 mm; thickness, 0.37 mm.

Figured specimen (WSMG 1024), from locality Q-73.

Genus **Virgulina** d'Orbigny, 1826

Virgulina californiensis ticensis Cushman and Kleinpell

Plate 2, figure 4

Virgulina californiensis ticensis CUSHMAN and KLEINPELL, 1934, p. 10, pl. 1, fig. 17; CUSHMAN, 1937, p. 21, pl. 3, figs. 16, 17; RAU, 1967, p. 35, text fig. 8.

This form is well represented in many of the samples from the Duck Creek-Pratt Cliff area. However, it is absent in all samples from the Cape Elizabeth, Taholah, and Point Grenville areas.

Virgulina californiensis ticensis Cushman and Kleinpell was first recorded from the upper Miocene (Mohnian Stage) of California. Recently it has been recorded locally from the Montesano Formation (upper Miocene?) of Washington. Specimens from the Montesano Formation have been compared with those of the Quinault Formation and appear essentially identical.

Length of figured specimen, 0.66 mm; breadth, 0.19 mm; thickness, 0.18 mm.

Figured specimen (WSMG 1025), from locality Q-73.

Genus **Bolivina** d'Orbigny, 1839

Bolivina advena Cushman

Plate 2, figure 5

Bolivina advena CUSHMAN, 1925b, p. 29, pl. 5, fig. 1; CUSHMAN, 1937, p. 95, pl. 10, fig. 16; KLEINPELL, 1938, p. 264, pl. 7, fig. 6; CUSHMAN, STEWART, and STEWART, 1947, pt. 1, p. 18, pl. 2, fig. 12; RAU, 1951, p. 442, pl. 65, fig. 9.

A few specimens from scattered localities in the Duck Creek-Pratt Cliff area display all the characteristics of *B. advena* Cushman. They are particularly characterized by the slight but apparent lobate nature of each suture near the central part, as shown particularly well on Cushman's 1937 illustration.

This species was originally described from the upper Miocene of California, but has since been recorded from other parts of the California Miocene. It is known from the lower and middle Miocene of Oregon and is recorded locally from the lower and middle Miocene of Washington.

Length of figured specimen, 0.34 mm; breadth, 0.13 mm; thickness, 0.10 mm.

Figured specimen (WSMG 1026), from locality Q-59.

Bolivina acuminata Natland

Plate 2, figure 6

Bolivina subadvena serrata NATLAND, 1938, p. 145, pl. 5, figs. 8, 9.

Bolivina subadvena acuminata Natland *In* CUSHMAN and GRAY, 1946b, p. 34, pl. 5, fig. 46; CUSHMAN, STEWART, and STEWART, 1949, p. 153, pl. 17, fig. 10.

Bolivina acuminata NATLAND, 1950, p. 22, pl. 5, fig. 21; BANDY, 1953, p. 176, pl. 24, fig. 6; WHITE, 1956 p. 250, pl. 29, fig. 3.

(For more complete synonymy see White, 1956.)

A few specimens from a single isolated outcrop between Taholah and Point Grenville display all the characteristics of *B. acuminata* Natland.

The first and a number of subsequent records of this form are from the Recent of the Pacific. It has since been recorded from the Plio-Pleistocene of California and the Pliocene of the Gulf of California. Cushman, Stewart, and Stewart (1949) were the first to record this species from the Quinault Formation of Washington.

Length of figured specimen, 0.57 mm; breadth, 0.26 mm; thickness, 0.10 mm.

Figured specimen (WSMG 1027), from locality Q-17.

Genus **Oolina** d'Orbigny, 1839

Oolina borealis Loeblich and Tappan

Plate 2, figure 12

Oolina borealis LOEBLICH and TAPPAN, 1954, p. 384; TODD and Low, 1967, p. 28, pl. 3, fig. 34.

Lagena costata (Williamson) CUSHMAN, 1944, p. 21, pl. 3, fig. 4; CUSHMAN and TODD, 1947, p. 10, pl. 2, fig. 1.

(For more complete synonymy see Todd and Low, 1967, p. 28.)

This species is found in small numbers from numerous localities in all sections except the section south of Taholah. It was originally described from the Recent off the British Isles and is known worldwide, usually from cold water (Todd and Low, 1967).

In addition, this and similar species have been recorded in California from rocks of Pliocene age.

Diameter of figured specimen, 0.32 mm; length, 0.45 mm.

Figured specimen (WSMG 1028), from locality Q-61.

Oolina melo d'Orbigny

Plate 2, figure 3

Oolina melo D'ORBIGNY, 1839, p. 20, pl. 5, fig. 9; LOEBLICH and TAPPAN, 1953, p. 71, pl. 12, figs. 8-15; TODD and Low, 1967, p. 29, pl. 3, fig. 27.

Lagena melo (d'Orbigny) BAGG, 1912, p. 49, pl. 14, figs. 16, 17.

(For a more complete synonymy see Todd and Low, 1967, p. 29.)

This form is rare in the present collection. Broken specimens characteristically show an entosolenian tube. Surface ornamentation consists of distinct costae parallel to the long axis of the test and numerous faint striations extending at right angles between the costae.

Similar forms have been recorded from the upper Miocene and the Pliocene of California and are referred to either the species *Lagena scalariformis* (Williamson) (Martin, 1952; Pierce, 1956) or *L. foveolata* Reuss (Cushman, Stewart, and Stewart, 1930).

Oolina melo was originally described from off the Falkland Islands and has been widely recorded both from the Arctic and the Antarctic, as well as from lower latitudes (Todd and Low, 1967).

Diameter of figured specimen, 0.19 mm; length, 0.24 mm.

Figured specimen (WSMG 1029), from locality Q-33.

Uvigerina d'Orbigny, 1826

Uvigerina cf. **U. hootsi** Rankin

Plate 2, figure 7

Uvigerina hootsi Rankin *In* CUSHMAN and KLEINPELL, 1934, p. 22, pl. 3, figs. 8, 9; KLEINPELL, 1938, p. 295, pl. 22, fig. 6; CUSHMAN and TODD, 1941a, p. 46, pl. 13, figs. 16, 17; CUSHMAN and GRAY, 1946b, p. 36, pl. 6, fig. 13; CUSHMAN and MCCULLOCH, 1948, p. 259, pl. 33, fig. 3; MARTIN, 1952, p. 137, pl. 25, fig. 3; WHITE, 1956, p. 258, pl. 32, fig. 5; PIERCE, 1956, p. 1301, pl. 138, fig. 15.

A few specimens from scattered locations are similar to *U. hootsi*. They differ, however, in that their chambers are less inflated than the typical form. They also resemble *U. juncea* Cushman and Todd, but are without costae and are proportionately shorter. Possibly they represent an immature or impoverished form of *U. juncea*.

Uvigerina hootsi was originally recorded from the upper Miocene of California and has since become a well-known form in much of the upper Miocene of the west coast Tertiary. It is also recorded from the Plio-Pleistocene of California, and is recorded from the Recent(?) off the Pacific coast. Locally it is known from the Montesano Formation of late Miocene(?) age of Washington.

Length of figured specimen, 0.50 mm; breadth, 0.27 mm.

Figured specimen (WSMG 1030), from locality Q-32.

Uvigerina juncea Cushman and Todd

Plate 2, figure 8

Uvigerina juncea CUSHMAN and TODD, 1941b, p. 78, pl. 20, figs. 4-11; CUSHMAN and GRAY, 1946b, p. 36, pl. 6, figs. 10-12; CUSHMAN and TODD, 1947, p. 19, pl. 3, fig. 9; MARTIN, 1952, p. 137, pl. 25, fig. 4.

This *Uvigerina* varies considerably in both shape and ornamentation and therefore might well be referred to as any one of several species. Considering particularly variations in ornamentation, the present forms are best referred to *U. juncea* Cushman and Todd. Some have fine, low costae, on others costae grade to rows of fine spines, and still others are nearly without ornamentation. Many of the Quinault specimens, however, are broader than most forms previously described. Generally, they display an approximate 2:1 ratio of length to breadth, whereas the ratio of most of those originally described by Cushman and Todd show more nearly 3:1.

Previous records of *U. juncea* are confined largely to the Pliocene and Pleistocene of California. It is also known from the Recent off the west coast.

Length of figured specimen 0.70 mm, breadth 0.32 mm.

Figured specimen (WSMG 1031), from locality Q-27.

Uvigerina senticosa Cushman

Plate 2, figure 9

Uvigerina senticosa CUSHMAN, 1927, p. 159, pl. 3, fig. 14; CUSHMAN, STEWART, and STEWART, 1930, p. 68, pl. 5, fig. 9; CUSHMAN, STEWART, and STEWART, 1949, p. 153, pl. 17, fig. 13; BANDY, 1953, p. 177, pl. 25, fig. 12; PIERCE, 1956, p. 1301, pl. 139, fig. 2.

Uvigerina senticosa adiposa WHITE, 1956, p. 259, pl. 32, fig. 9.

Uvigerina with hispid ornamentation are relatively rare in the Quinault Formation and are all referred to *U. senticosa* Cushman. This species was originally recorded from the formation by Cushman, Stewart, and Stewart (1949).

The first record of this species is from the Recent of the eastern Pacific. It has since been recorded from the upper

Miocene, and the Pliocene, and Pleistocene of California, as well as from the Recent off the west coast.

Length of figured specimen, 0.48 mm; breadth, 0.27 mm.
Figured specimen (WSMG 1032), from locality Q-81.

Uvigerina subperegrina Cushman and Kleinpell
Plate 2, figure 10

Uvigerina subperegrina Cushman and Kleinpell, 1934, p. 12, pl. 2, figs. 9-11; Kleinpell, 1938, p. 298; Cushman and Todd, 1941a, p. 52, pl. 14, figs. 19-23; Cushman and Gray, 1946b, p. 36, pl. 6, fig. 14; Cushman, Stewart, and Stewart, 1949, p. 153, pl. 17, fig, 8; Pierce, 1956, p. 1301, pl. 139, fig. 3.

This costate species occurs in many of the samples from the section south of Taholah and the Duck Creek-Pratt Cliff section, but seldom is it found in large numbers from any one locality. Cushman, Stewart, and Stewart (1949) first recorded this species from the Quinault Formation.

The species was originally recorded from the upper Miocene of California and has since become a well-known species of that part of the west coast Tertiary sequence. It is recorded also from the Plio-Pleistocene of Palos Verdes Hills, California, and the Miocene of Florida and Virginia. Locally it is also known from the Montesano Formation.

In addition there are several references to *Uvigerina peregrina* Cushman in the upper Miocene, the Plio-Pleistocene, and Recent of the west coast. Illustrations of some of these seem similar to the present Quinault form (Martin, 1952; White, 1956; Bandy, 1953; Galloway and Wissler, 1927a; Cushman, Stewart, and Stewart, 1930).

Length of figured specimen, 0.43 mm; breadth, 0.24 mm.
Figured specimen (WSMG 1033), from locality Q-26.

Genus **Angulogerina** Cushman, 1927
Angulogerina semitrigona (Galloway and Wissler)
Plate 2, figure 11

Uvigerina semitrigona Galloway and Wissler, 1927a, p. 77, pl. 11, fig. 21.

Angulogerina semitrigona (Galloway and Wissler), Campbell, 1935, p. 46, text fig. 9; Cushman and Todd, 1941b, p. 76, pl. 18, fig. 6; pl. 19, fig. 18; Cushman and Gray, 1946b, p. 37, pl. 6, fig. 16; Cushman and Todd, 1947, p. 19, pl. 3, fig. 7.

This species, although never in large numbers, occurs in many of the samples from the Duck Creek-Pratt Cliff section and nearby isolated outcrops, but is practically absent in samples from the other sections.

Angulogerina semitrigona was originally described from the Plio-Pleistocene of Palos Verdes Hills, California, and has since been recorded from the Recent off the coast of California and in nearby Puget Sound.

Length of figured specimen, 0.38 mm; breadth, 0.22 mm.
Figured specimen (WSMG 1034), from locality Q-91.

Family DISCORBIDAE
Genus **Discorbis** Lamarck, 1804
Discorbis? columbiensis Cushman
Plate 2, figure 13

Discorbis columbiensis Cushman, 1925a, p. 43, pl. 6, fig. 13; Cushman and Todd, 1947, p. 20, pl. 3, figs. 14-16.

Fragmented specimens from one locality in the section north of Point Grenville are best referred to *D. columbiensis* Cushman. Also they seem to be similar to a form figured as *D. rosaceus* (d'Orbigny) by Cushman and Gray (1946b, pl. 6, fig. 21) from the Timms Point material of California. However, the present Quinault specimens differ from d'Orbigny's type illustrations of this species in having more chambers in the last formed whorl and a thicker test.

Some question exists as to the proper generic placement of at least the present specimens, but, because materials are limited, it is not possible in this report to resolve this doubt.

Discorbis columbiensis Cushman was originally described from a depth of 20 fathoms in Queen Charlotte Sound, British Columbia, and has since been recorded from Puget Sound, Washington.

Diameter of figured specimen, 0.30 mm; thickness, 0.14 mm.

Figured specimen (WSMG 1035), from locality Q-5.

Genus **Valvulineria** Cushman, 1926
Valvulineria malagaensis Kleinpell
Plate 2, figure 14

Valvulineria araucana malagaensis Kleinpell, 1938, p. 308, pl. 22, figs. 10-12; Pierce, 1956, p. 1301, pl. 141, fig. 8.

Valvulineria araucana (d'Orbigny) Cushman, Stewart, and Stewart, 1949, p. 154, pl. 17, fig. 14.

A few specimens from several isolated localities north of the mouth of the Raft River and between Taholah and Point Grenville are best referred to *Valvulineria malagaensis* Kleinpell. This form is known from the upper Miocene of California. The present specimens differ from *V. araucana* (d'Orbigny) in that they are small, and the last chamber does not overlap the earlier coils of the ventral side. Forms figured by Cushman, Stewart, and Stewart (1949) from the Quinault Formation seem to be the same as the present specimens.

Diameter of figured specimen, 0.38 mm; thickness, 0.24 mm.

Figured specimen (WSMG 1036), from locality Q-17.

Valvulineria washingtonensis (Cushman and R. E. and K. C. Stewart)
Plate 2, figure 15

Cibicides concentricus washingtonensis Cushman and R. E. and K. C. Stewart, 1949, p. 157, pl. 18, fig. 8.

The present specimens seem identical to forms originally illustrated by Cushman and R. E. and K. C. Stewart from the Quinault Formation. The present specimens display all the features of *Valvulineria*, particularly the characteristic platelike cover over much of the umbilical area. *Valvulineria menloensis* Rau, from the early Miocene of Washington (Rau, 1951), is very similar to *V. washingtonensis* and may well be synonymous with it.

This form occurs in samples of the present material from only a few isolated localities. The only other record of *Valvulineria washingtonensis* is from the Quinault Formation.

Diameter of figured specimen (immature specimen), 0.66 mm; thickness, 0.26 mm.

Figured specimen (WSMG 1037), from locality Q-15.

Family ROTALIIDAE

Genus **Eponides** Montfort, 1808

Eponides healdi R. E. and K. C. Stewart

Plate 2, figure 16

Eponides healdi R. E. and K. C. STEWART, 1930, p. 70, pl. 8, fig. 8; KLEINPELL, 1938, p. 319; PIERCE, 1956, p. 1301, pl. 140, fig. 5.

This species is rare in a few samples from isolated localities. It was originally described from the lower Pliocene of California and has since been recorded from the upper Miocene of California.

Diameter of figured specimen, 0.40 mm; thickness, 0.24 mm.

Figured specimen (WSMG 1038), from locality Q-17.

Genus **Buccella** Andersen, 1952

Buccella inusitata Andersen

Plate 2, figure 17

Buccella inusitata ANDERSEN, 1952, p. 147, 148, figs. 10, 11.
Eponides peruvianus (d'Orbigny) CUSHMAN and KELLETT, 1929, p. 10, pl. 4, fig. 5.
Eponides frigidus (Cushman) CUSHMAN and TODD, 1947, p. 21; CUSHMAN, 1948, p. 71, pl. 8, fig. 7.

One of the more commonly occurring forms throughout the sections compares well with illustrations and the description of the types *Buccella inusitata* Andersen. Because much variation in both size and form is shown among individuals in the present collection, it might be thought that more than one species is represented. However, a complete gradation of form and size occurs among specimens within individual samples, and therefore they are all referred to one species. Diameter varies from 0.25 mm to 0.60 mm. The most noticeable variation in form is the amount of convexity of the ventral surface, which varies from nearly flat to an amount of convexity equal to that of the dorsal side. The angle of the periphery also varies from acute, nearly keeled, to subround.

Some specimens, particularly the smaller ones, are similar to the type of *B. frigida* (Cushman), but differ in having a greater number of chambers. *Buccella tenerrima* (Bandy) [*Rotalia tenerrima* Bandy] is similar to some of the specimens but differs in having umbilical bosses.

The types of *B. inusitata* are from the Recent of Puget Sound, Washington. In his synonymy, Anderson (1952) includes forms from the Recent of both the west coast of South America and the Arctic. Although records of the species are limited, its known occurrence suggests that it probably favors cool temperatures similar to those in which the closely related *B. frigida* (Cushman) occurs.

Diameter of figured specimen, 0.55 mm; thickness, 0.17 mm.

Figured specimen (WSMG 1039), from locality Q-8.

Genus **Rotalia** Lamarck, 1804

Rotalia cf. **R. garveyensis** Natland

Plate 2, figure 18

?*Rotalia garveyensis* NATLAND, 1938, p. 147, pl. 6, fig. 6; PIERCE, 1956, p. 1301, pl. 140, fig. 4.

A few specimens from a locality near the mouth of the Raft River (Q-97) are tentatively referred to *R. garveyensis*. In addition, R. S. Boettcher, of Mobil Oil Co. (oral communication, 1969) reported this species from the vicinity of the lower part of the Duck Creek-Pratt Cliff section. Those from locality Q-97 vary slightly from the typical form known in the upper Miocene of California in that the umbonal plug is not as well developed; the sutures are not quite radiate; and there are fewer chambers, usually seven, in the last whorl.

Rotalia garveyensis Natland was originally described from the lower part of the Repetto Formation of the Los Angeles basin in California, and has since been recorded from upper Miocene beds of the same region. Its highest occurrence, at least in that area, has become known as an excellent point of correlation and is generally used to mark a horizon at or near the Miocene-Pliocene boundary.

Diameter of figured specimen, 0.22 mm; thickness, 0.10 mm.

Figured specimen (WSMG 1040), from locality Q-97.

Genus **Epistominella** Husezima and Maruhasi, 1944

Epistominella pacifica (Cushman)

Plate 2, figure 20

Pulvinulinella pacifica CUSHMAN, 1927 p. 165, pl. 5, figs. 14, 15; CUSHMAN, STEWART, and STEWART, 1930 p. 73, pl. 6, fig. 5.
Epistominella pacifica (Cushman), MARTIN, 1952, p. 136, pl. 24, fig. 8.
Epistominella cf. *E. pacifica* (Cushman), GOODWIN and THOMPSON, 1954, p. 176, pl. 32, figs. 10, 11.
Pseudoparrella subperuviana (Cushman), CUSHMAN, STEWART, and STEWART, 1949, p. 154, pl. 18, fig. 1.

This species occurs in a number of samples from several of the sections. Nearly all specimens are strongly convex ventrally, and moderately to nearly flat on the dorsal side. The periphery is acute to nearly keeled. Six to seven chambers make up the last formed coil, the final one or two being only slightly inflated; sutures are distinct, flush with surface, except that they are depressed slightly between the last one or two chambers. Aperture is an elongate narrow slit parallel with the periphery.

The present specimens compare most closely with the description and illustrations of the type *Epistominella pacifica* (Cushman). The only possible difference may be in more convexity of the dorsal surface in most of the Quinault specimens. In this respect they closely resemble *Epistominella pulchella* Husezima and Maruhasi, 1944.

Epistominella pacifica (Cushman) was first described from the Recent off the west coast of America. It is known also from rocks of middle and late Miocene and Pliocene age in California. It has been recorded from the Montesano Formation of Washington of probable late Miocene age (Rau, 1967) and was previously recorded from the Quinault Formation as *Pseudoparrella subperuviana* (Cushman) (Cushman, Stewart, and Stewart, 1949).

Diameter of figured specimen, 0.32 mm; thickness, 0.18 mm.

Figured specimen (WSMG 1041), from locality Q-12.

Family CASSIDULINIDAE

Genus **Cassidulina** d'Orbigny, 1826

Cassidulina californica Cushman and Hughes

Plate 2, figure 19

Cassidulina californica CUSHMAN and HUGHES, 1925, p. 12, pl. 2, fig. 1; WHITE, 1956, p. 255, pl. 31, fig. 1; TODD and LOW, 1967, p. 37, pl. 5, fig. 13.

(For additional references see White, 1956, p. 255.)

This species was found at a single isolated outcrop (Q-15) between Point Grenville and Taholah.

It was originally described from the Palos Verdes Hills of California, and has since been recorded from the Plio-Pleistocene sequence in other areas of California. Records of this species are also from the Pliocene of Panama and the Recent off the Pacific coast from the Gulf of Alaska to San Diego, California.

Diameter of figured specimen, 0.75 mm; thickness, 0.45 mm.

Figured specimen (WSMG 1042), from locality Q-15.

Cassidulina islandica Nörvang

Plate 3, figure 1

Cassidulina islandica NÖRVANG, 1945, p. 41, figs. 7, 8d-f; CUSHMAN, 1948, p. 75, pl. 8, fig. 13; LOEBLICH and TAPPAN, 1953, p. 118-120, pl. 24, fig. 1.

Cassidulina islandica forma *minuta* NÖRVANG, 1945, p. 43, figs. 8a-c; CUSHMAN, 1948, p. 75, pl. 8, fig. 11; PARKER, 1952, p. 421, pl. 6, figs. 22a, 23; PHLEGER, 1952, p. 83, pl. 14, fig. 30.

Cassidulina islandica nörvangi THALMANN, 1952, *In* Phleger, p. 83 (footnote).

Cassidulina californica Cushman and Hughes, CUSHMAN, STEWART, and STEWART, 1949, p. 154, pl. 18, fig. 3.

Following the usage of Loeblich and Tappan (1953), all Quinault specimens of this form are placed under the species *C. islandica*, although most fall within the size range Nörvang designated for his forma *C. islandica minuta*, which later was changed by Thalmann, because it is a homonym of *C. minuta* Cushman, to *C. islandica nörvangi*. The present specimens are particularly similar to that figured by Phleger (1952) from the Recent of the Arctic.

This form was originally recorded from the Quinault Formation as *C. californica* Cushman, Stewart, and Stewart (1949). It occurs throughout much of the Quinault Formation, and particularly in the Duck Creek-Pratt Cliff section. Previous records of it are largely from the Arctic, but it is also recorded off the New Hampshire coast. Loeblich and Tappan observed that many earlier references to *C. crassa* d'Orbigny probably should be referred to *C. islandica*, and therefore the geographic and possibly stratigraphic distribution of this form may well be considerably greater than is presently recorded.

Diameter of figured specimen, 0.30 mm; thickness, 0.18 mm.

Figured specimen (WSMG 1043), from locality Q-28.

Cassidulina limbata Cushman and Hughes

Plate 3, figure 2

Cassidulina limbata CUSHMAN and HUGHES, 1925, p. 12, pl. 2, fig. 2; GALLOWAY and WISSLER, 1927a, p. 78, pl. 12, fig 12; CUSHMAN, STEWART, and STEWART, 1930, p. 74, pl. 6, fig. 7; KLEINPELL, 1938, p. 333, pl. 9, fig. 21; CUSHMAN and GRAY, 1946b, p. 42, pl. 7, figs. 14-16; CUSHMAN and TODD, 1947, p. 22, pl. 4, fig. 4; CUSHMAN, STEWART, and STEWART, 1949, p. 155, pl. 18, fig. 2; BANDY, 1950, p. 280, pl. 42, fig. 4; MARTIN, 1952, p. 135, pl. 24, fig. 6; BANDY, 1953, p. 176, pl. 25, fig. 2.

(For additional references see Cushman, Stewart, and Stewart, 1949, p. 155.)

Cassidulina limbata Cushman and Hughes is one of two commonly occurring forms of the genus in the collection and constitutes one of the more prominent elements in the fauna. A gradation of form is present from that typified by *C. limbata*, having only a moderate narrowing of the central part of the chambers, to that having a decided constriction of the central part of the chambers, as shown by *C. reflexa* Galloway and Wissler. In the original description of *C. limbata*, Cushman and Hughes may well have considered those forms here placed in *C. reflexa* as a variety within *C. limbata*.

Apparently a third variation has been recognized in the group known as *C. tortuosa* Cushman and Hughes, but it does not appear to be present in the Quinault material. In this form, according to the original description and illustrations, the chambers are more contorted and sutures more angular than are shown on any of the specimens of the present collection. However, some authors have placed forms in *C. tortuosa* that appear to be very close to *C. reflexa*.

Cassidulina limbata occurs most extensively in the sections south of Taholah and north of Point Grenville, whereas *C. reflexa* is dominant in the Duck Creek-Pratt Cliff area. *Cassidulina limbata* was first recorded from the Quinault Formation by Cushman, Stewart, and Stewart (1949) from along the coast between Taholah and Point Grenville.

It was originally described from the Plio-Pleistocene of Palos Verdes Hills, California, and has since been recorded from the Pliocene of northern California as well as the Miocene of other parts of California. It is known from the Pleistocene of Oregon and lives today off the California coast and in Puget Sound, Washington.

Diameter of figured specimen, 0.56 mm; thickness, 0.24 mm.

Figured specimen (WSMG 1044), from locality Q-37.

Cassidulina reflexa Galloway and Wissler

Plate 3, figure 5

Cassidulina reflexa GALLOWAY and WISSLER, 1927a, p. 80, pl. 12, fig. 3.

Cassidulina tortuosa CUSHMAN and GRAY, 1946b, [not Cushman and Hughes], p. 42, pl. 7, fig. 17.

This species is common, particularly in the Duck Creek-Pratt Cliff section. It was originally recorded from the Plio-Pleistocene at Palos Verdes Hills, California. (Discussion under *Cassidulina limbata* gives additional information on this species.)

Diameter of figured specimen, 0.59 mm; thickness, 0.29 mm.

Figured specimen (WSMG 1045), from locality Q-94.

Cassidulina translucens Cushman and Hughes

Plate 3, figure 3

Cassidulina translucens CUSHMAN and HUGHES, 1925, p. 15, pl. 2, fig. 5; CROUCH, 1952, p. 838, pl. 6, fig. 13; MARTIN, 1952, p. 136, pl. 24, fig. 4; BANDY, 1953, p. 176, pl. 25, fig. 6; WHITE, 1956, p. 256, pl. 31, fig. 5.

(For additional references see Martin, 1952, p. 136.)

Specimens from several localities display all the characteristics of *Cassidulina translucens* Cushman and Hughes.

This species is known previously from the Plio-Pleistocene of Palos Verdes Hills, California, and is recorded in today's sea off the California coast.

Diameter of figured specimen, 0.38 mm; thickness, 0.19 mm.

Figured specimen (WSMG 1046), from locality Q-23.

Family CHILOSTOMELLIDAE
Genus **Chilostomella** Reuss, 1850
Chilostomella cf. **C. czizeki** Reuss
Plate 3, figure 4

Chilostomella cf. *C. czizeki* Reuss, CUSHMAN, STEWART, and STEWART, 1949, p. 156, pl. 18, fig. 5.

Specimens seemingly identical to those figured by Cushman, Stewart, and Stewart (1949) from the Quinault Formation occur in the present material from an isolated locality.

Length of figured specimen, 0.59 mm; diameter, 0.33 mm.

Figured specimen (WSMG 1047), from locality Q-17.

Genus **Pullenia** Parker and Jones, 1862
Pullenia miocenica Kleinpell
Plate 3, figure 6

Pullenia miocenica KLEINPELL, 1938, p. 338, pl. 14, fig. 6; CUSHMAN and TODD, 1943, p. 17, pl. 3, figs. 3, 4.

Pullenia cf. *P. miocenica* Kleinpell, PIERCE, 1956, p. 1301, pl. 137, fig. 12.

(For additional references see Cushman and Todd, 1943.)

This form is characterized particularly by six to seven chambers in the last whorl and by its slightly lobate periphery.

Cushman, Stewart, and Stewart (1949) record a form as *Pullenia* cf. *P. bulloides* (d'Orbigny) from the Quinault Formation that may well belong here. However, their form has fewer chambers, as does the type *P. bulloides.*

Specimens of the present collection are confined to samples from a few localities in the section south of Taholah. Previous records of *P. miocenica* are from the Miocene in California.

Length of figured specimen, 0.40 mm; breadth, 0.38 mm; thickness, 0.37 mm.

Figured specimen (WSMG 1048), from locality Q-26.

Pullenia cf. **P. salisburyi** R. E. and K. C. Stewart
Plate 3, figure 7

The present specimens differ from the types and other illustrations of *P. salisburyi* in that they have seven to eight chambers in the last whorl instead of the usual six. In all other respects the Quinault forms are comparable. Their occurrence is confined to samples from the Duck Creek-Pratt Cliff area.

Pullenia salisburyi has a wide geographic as well as stratigraphic distribution. It was originally recorded from the Pliocene of California and has since been recorded from numerous localities of the California Miocene, Pliocene, and Recent. Locally, it is known from rocks of Eocene, Oligocene, and Miocene age and is recorded from the Recent of nearby Puget Sound.

Length of figured specimen, 0.45 mm; breadth, 0.38 mm; thickness, 0.21 mm.

Figured specimen (WSMG 1049), from locality Q-77.

Genus **Sphaeroidina** d'Orbigny, 1826
Sphaeroidina bulloides d'Orbigny
Plate 3, figure 9

Sphaeroidina bulloides D'ORBIGNY, 1826, p. 26, modeles, no. 65; CUSHMAN, STEWART, and STEWART, 1930, p. 76, pl. 7, fig. 2; CUSHMAN, STEWART, and STEWART, 1949, p. 156, pl. 18, fig. 7; PIERCE, 1956, p. 1301, pl. 137, fig. 13.

(For additional references, see Ellis and Messina, 1940-70.)

This species is rare from a few isolated localities. It was originally recorded from the Quinault Formation by Cushman, Stewart, and Stewart (1949) and is common in the Tertiary and Recent of the west coast, as well as numerous other Tertiary and Recent localities throughout the world.

Diameter of figured specimen, 0.37 mm.

Figured specimen (WSMG 1050), from locality Q-19.

Family GLOBIGERINIDAE
Genus **Globigerina** d'Orbigny, 1826
Globigerina bulloides d'Orbigny
Plate 3, figure 10

Globigerina bulloides d'Orbigny, PARKER, 1962, p. 221, pl. 1, figs. 1-8; INGLE, 1967, p. 356, pl. 33, figs. 1-3.

(For additional references see Parker, 1962.)

This widely recorded species occurs at many localities throughout all sections. Although rarely found in large numbers, it is the most frequently occurring *Globigerina* in the collection. Some might well be considered *G. bulloides quadrilatera* Galloway and Wissler, but have not been differentiated in this report. (See Ingle, 1967, p. 356, pl. 33, fig. 4.)

Length of figured specimen, 0.29 mm; thickness, 0.19 mm.

Figured specimen (WSMG 1051), from locality Q-14.

Globigerina pachyderma (Ehrenberg)
Plate 3, figure 8

Globigerina pachyderma (Ehrenberg), PARKER, 1962, p. 224, pl. 1, figs. 26-35; pl. 2, figs. 1-6; INGLE, 1967, p. 356, pl. 33, figs. 6, 7; pl. 34, figs. 1-4.

(For additional references and discussion see Parker, 1962).

This well-known species occurs, although never in large numbers, at a number of localities, particularly in the section south of Taholah. It was first recorded from the Quinault Formation by Fowler (*In* Ingle, 1967). They note a change from dextrally coiled specimens in the Point Grenville section to dominantly sinistrally coiled forms in the supposedly higher part of the section south of Taholah, thus suggesting a change from warm to cooler surface conditions. Although *G. pachyderma* is extremely rare in samples of the present study from the Point Grenville section, it was found in substantial numbers in the section south of Taholah. These specimens are dominantly sinistrally coiled, as pointed out by Ingle.

As discussed in a previous section, there is some reason to consider the deposition of the Point Grenville section as contemporaneous or possibly post that of the section south of Taholah rather than representing a sequence of deposition younger than that of the section south of Taholah as inferred by Fowler (*In* Ingle, 1967). Therefore, there may be some question about the significance of the direction of coiling of *G. pachyderma* in the Quinault Formation.

Diameter of figured specimen, 0.35 mm; thickness, 0.26 mm.

Figured specimen (WSMG 1052), from locality Q-30.

Family GLOBOROTALIIDAE

Genus **Globorotalia** Cushman, 1927

Globorotalia crassaformis (Galloway and Wissler)

Plate 3, figure 11

Globigerina crassaformis GALLOWAY and WISSLER, 1927a, p. 41, pl. 7, fig. 12.

Globorotalia punctulata (Fornasini), PHLEGER, PARKER, and PEIRSON, 1953, p. 20, pl. 4, figs. 8-12.

Globorotalia crassaformis (Galloway and Wissler) PARKER, 1962, p. 235, pl. 4, figs. 17, 18, 20, 21; INGLE, 1967, p. 357, pl. 38, figs. 3-5.

(For additional synonymy and discussion see Phleger, Parker, and Peirson, 1953, and Parker, 1962.)

This species was first recorded from the Quinault Formation by Fowler (*In* Ingle, 1967). Its presence is believed by Ingle to suggest higher surface temperature during at least part of Quinault time than exists today in the nearby offshore. It is very rare in the present collection, occurring at only two localities in the section south of Taholah. It is recorded from the Plio-Pleistocene of California and is common today in warm, temperate, and tropical seas.

Diameter of figured specimen, 0.29 mm; height, 0.19 mm.

Figured specimen (WSMG 1053), from locality Q-33.

Family ANOMALINIDAE

Genus **Anomalinoides** Brotzen, 1942

Anomalinoides quinaultensis Rau, n. sp.

Plate 3, figure 12

Test somewhat compressed, variably biconvex to nearly planoconvex, involute, mature specimens slightly evolute on one side, typically with umbonal plug on both sides, but on some poorly developed on one side, periphery rounded; chambers usually nine in last formed whorl, gradually increasing in height, last few chambers slightly inflated, particularly on mature specimens; sutures distinct, slightly depressed between last few chambers, slightly curved, somewhat limbate; walls very coarsely perforate with irregularly shaped and arranged pores forming an overall roughness to the surface; aperture a low interiomarginal, very slightly lipped slit extending completely across the base of the apertural chamber and also along the base of at least two additional chambers on one side.

Diameter of holotype, 0.27 mm; thickness, 0.13 mm.

This umbonate form is unique within the present material of the Quinault Formation and appears unlike any other described species. It is characterized by its coarsely punctate surface, small size, and umbonal plugs. Within the present material it is confined to samples from the Duck Creek-Pratt Cliff section and vicinity. Because of this restricted occurrence locally, possible stratigraphic significance within a part of the Quinault Formation may be suggested for this species.

The species is named after the Quinault Formation in which it is found and the Quinault Indian Reservation, on which most of the onshore outcrops of the formation occur.

Holotype (WSMG 1054), from locality Q-93

Genus **Cibicides** Montfort, 1808

Cibicides conoideus Galloway and Wissler

Plate 3, figure 13

Cibicides conoideus GALLOWAY and WISSLER, 1927a, p. 63, pl. 10, fig. 7.

This conically shaped, planoconvex species seldom occurs in large numbers but is present from many localities, particularly those of the Duck Creek-Pratt Cliff section. Its umbonate umbilical region is also a conspicuous characteristic. This species was originally described from the Plio-Pleistocene of the Palos Verdes Hills, California.

Diameter of figured specimen, 0.34 mm; thickness, 0.18 mm.

Figured specimen (WSMG 1055), from locality Q-86.

Cibicides fletcheri Galloway and Wissler

Plate 3, figure 14

Cibicides fletcheri GALLOWAY and WISSLER, 1927a, p. 64, pl. 10, figs. 8, 9; MARTIN, 1952, p. 125, pl. 20, fig. 2; BANDY, 1953, p. 176, pl. 24, fig. 2; PIERCE, 1956, p. 1300, pl. 140, fig. 2.

The planoconvex shape of the test and the rapid increase in size of the chambers are among the prominent features characterizing this species. It occurs in numerous samples from both the section north of Point Grenville and the Duck Creek-Pratt Cliff section but is essentially absent in samples from the section south of Taholah.

Cibicides fletcheri was originally described from the Plio-Pleistocene of the Palos Verdes Hills, California, and has since been recorded from rocks of late Miocene and of Pliocene age of California. It is also known to be living today off the California coast.

Diameter of figured specimen, 0.46 mm; thickness, 0.21 mm.

Figured specimen (WSMG 1056), from locality Q-12.

Cibicides mckannai Galloway and Wissler [**sensu lato**]

Plate 3, figure 15

Cibicides mckannai GALLOWAY and WISSLER, 1927a, p. 65, pl. 10, figs. 5, 6; CROUCH, 1952, p. 842, pl. 7, figs. 11, 12; WHITE, 1956, p. 249, pl. 28, fig. 6.

Cibicides mckannai suppressus MARTIN, 1952, p. 126, pl. 20, fig. 3.

This species occurs in most of the sections and is particularly common in the rocks exposed south of Taholah. It displays considerable variation, and some of the specimens, such as that figured, are probably closest to *C. mckannai suppressus* Martin.

Original records of this species are from the Plio-Pleistocene of the Palos Verdes Hills of southern California. It has since been recorded from the Pliocene in other parts of California and the Recent off the California coast. Locally it is recorded from the Montesano Formation of Washington.

Diameter of figured specimen, 0.46 mm; thickness, 0.19 mm.

Figured specimen (WSMG 1057), from locality Q-31.

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PLATES 1 - 3

EXPLANATION OF PLATE 1

All specimens are from the Quinault Formation exposed along the Washington coast between Point Grenville and the mouth of the Raft River. All figures × 50 except figures 1, 4, 5, 6, and 12, which are × 25.

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FORAMINIFERA, QUINAULT FORMATION, WASHINGTON

EXPLANATION OF PLATE 2

All specimens are from the Quinault Formation exposed along the Washington coast between Point Grenville and the mouth of the Raft River. All figures × 50.

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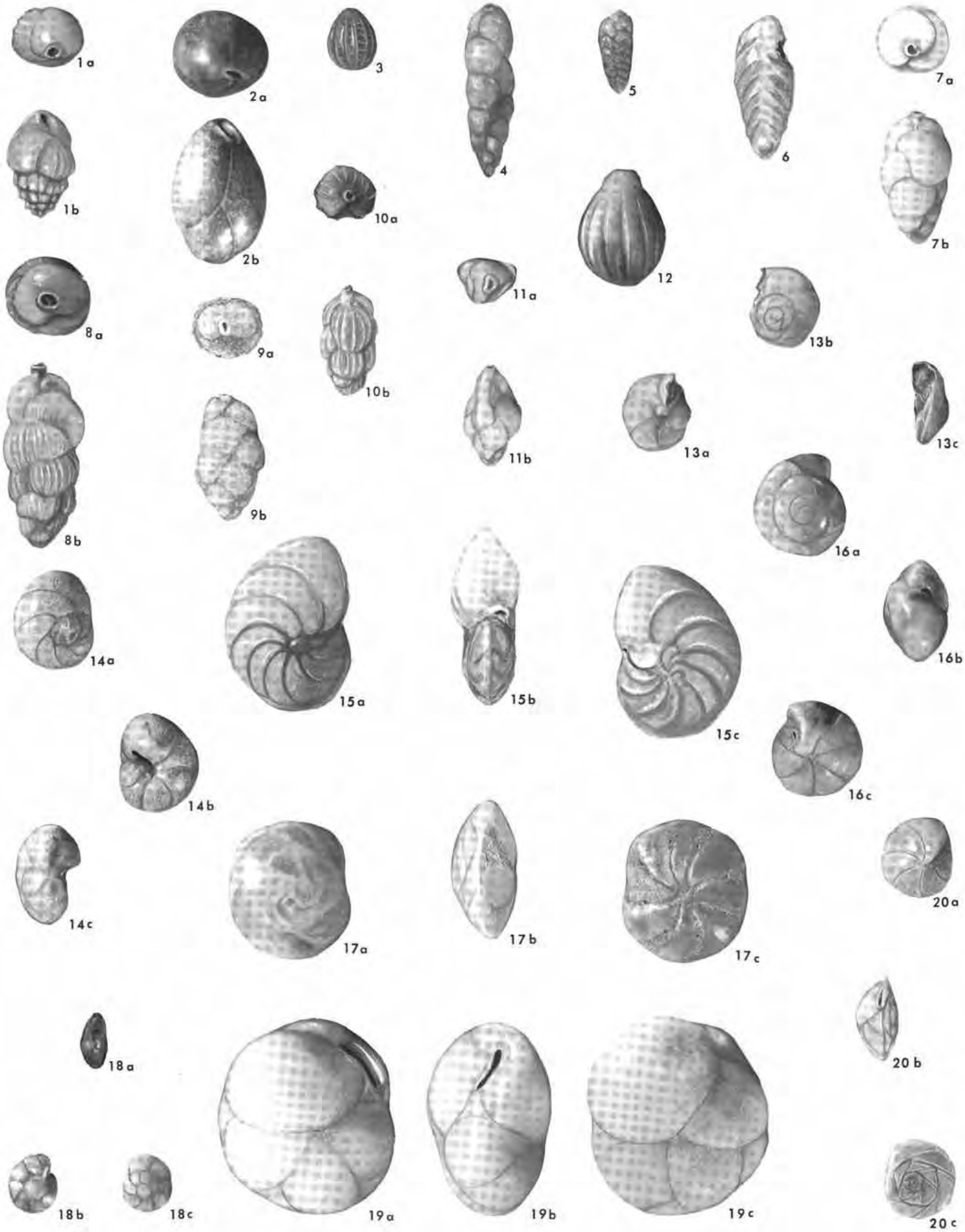
5.	*Bolivina advena* Cushman	25
6.	*Bolivina acuminata* Natland	25
7.	*Uvigerina* cf. *U. hootsi* Rankin	26
8.	*Uvigerina juncea* Cushman and Todd	26
9.	*Uvigerina senticosa* Cushman	26
10.	*Uvigerina subperegrina* Cushman and Kleinpell	27
11.	*Angulogerina semitrigona* (Galloway and Wissler)	27
12.	*Oolina borealis* Loeblich and Tappan	26
13.	*Discorbis? columbiensis* Cushman	27
14.	*Valvulineria malagaensis* Kleinpell	27
15.	*Valvulineria washingtonensis* (Cushman and R. E. and K. C. Stewart)	27
16.	*Eponides healdi* R. E. and K. C. Stewart	28
17.	*Buccella inusitata* Andersen	28
18.	*Rotalia* cf. *R. garveyensis* Natland	28
19.	*Cassidulina californica* Cushman and Hughes	28
20.	*Epistominella pacifica* (Cushman)	28

DEPARTMENT OF NATURAL RESOURCES
DIVISION OF MINES AND GEOLOGY

BULLETIN 62
PLATE 2



FORAMINIFERA, QUINAULT FORMATION, WASHINGTON

EXPLANATION OF PLATE 3

All specimens are from the Quinault Formation exposed along the Washington coast between Point Grenville and the mouth of the Raft River. All figures × 50.

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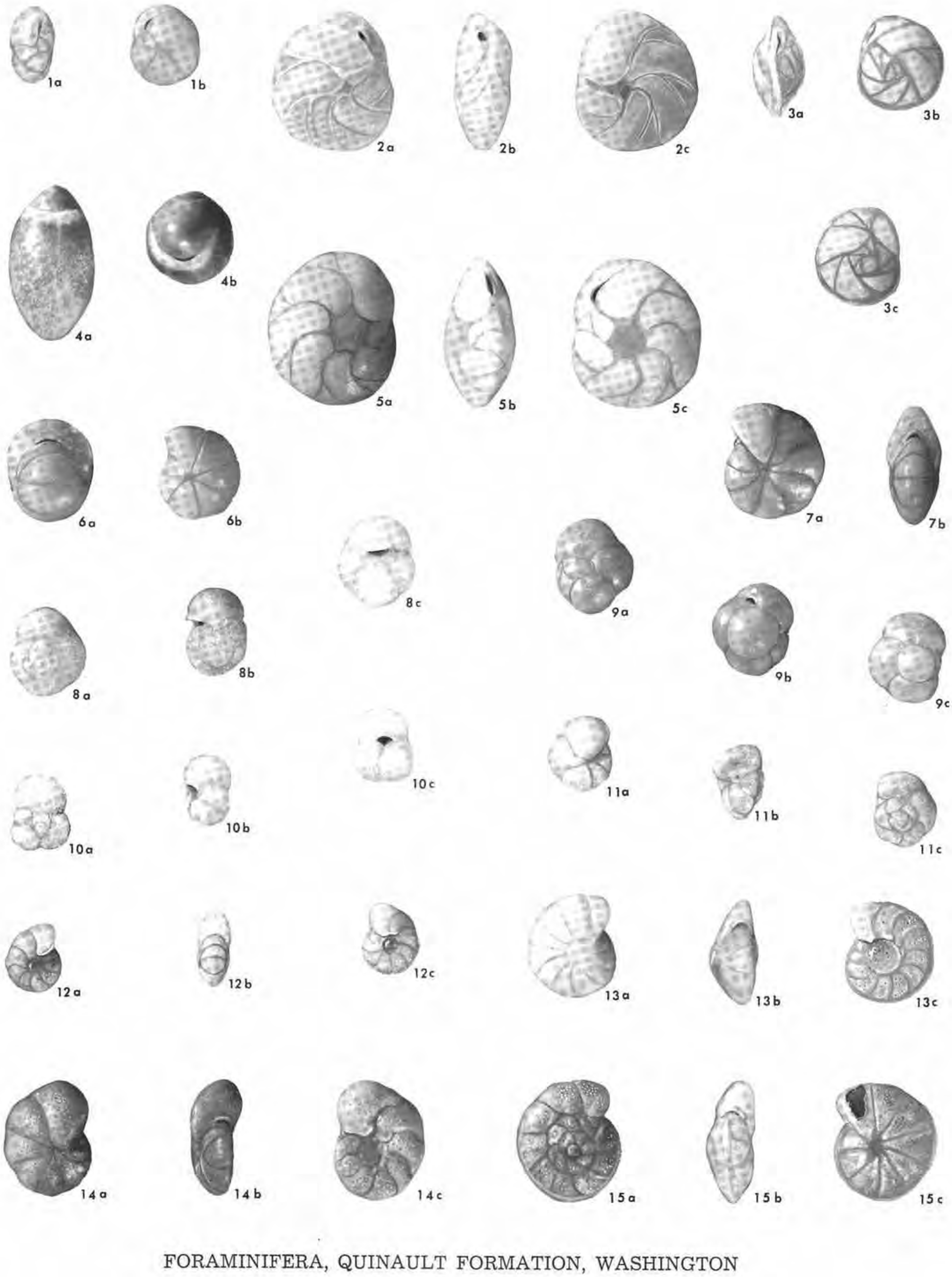
FIGURE 1. *Cassidulina islandica* Nörvang	29
2. *Cassidulina limbata* Cushman and Hughes	29
3. *Cassidulina translucens* Cushman and Hughes	29
4. *Chilostomella* cf. *C. czizeki* Reuss	30
5. *Cassidulina reflexa* Galloway and Wissler	29
6. *Pullenia miocenica* Kleinpell	30
7. *Pullenia* cf. *P. salisburyi* R. E. and K. C. Stewart	30
8. *Globigerina pachyderma* (Ehrenberg)	30
9. *Sphaeroidina bulloides* d'Orbigny	30
10. *Globigerina bulloides* d'Orbigny	30
11. *Globorotalia crassaformis* (Galloway and Wissler)	31
12. *Anomalinoides quinaultensis* Rau n. sp., Holotype	31
13. *Cibicides conoideus* Galloway and Wissler	31
14. *Cibicides fletcheri* Galloway and Wissler	31
15. *Cibicides mckannai* Galloway and Wissler	31



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