GEOLOGIC MAP GM 24

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DEPARTMENT OF NATURAL RESOURCES
BERT L. COLE, Commissioner of Public Lands
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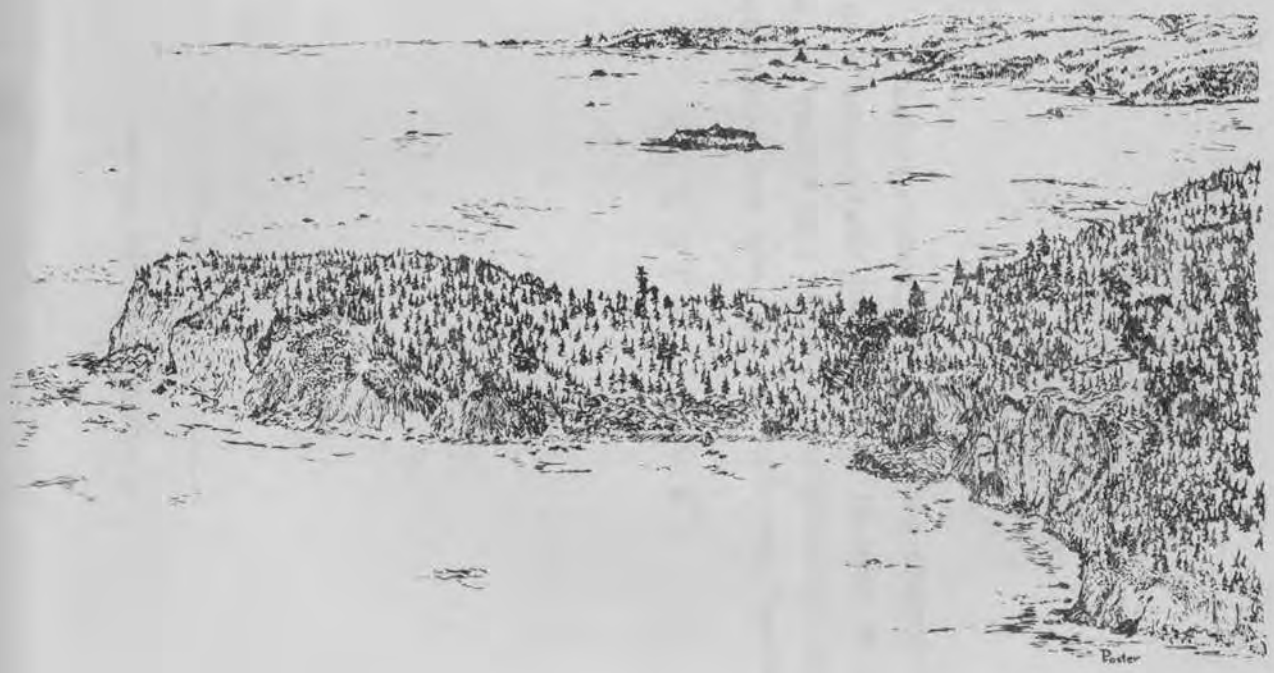
DIVISION OF GEOLOGY AND EARTH RESOURCES
VAUGHN E. LIVINGSTON, JR., State Geologist

GEOLOGIC MAP IN THE VICINITY OF THE LOWER BOGACHIEL AND HOH RIVER VALLEYS, AND THE WASHINGTON COAST

By
WELDON W. RAU



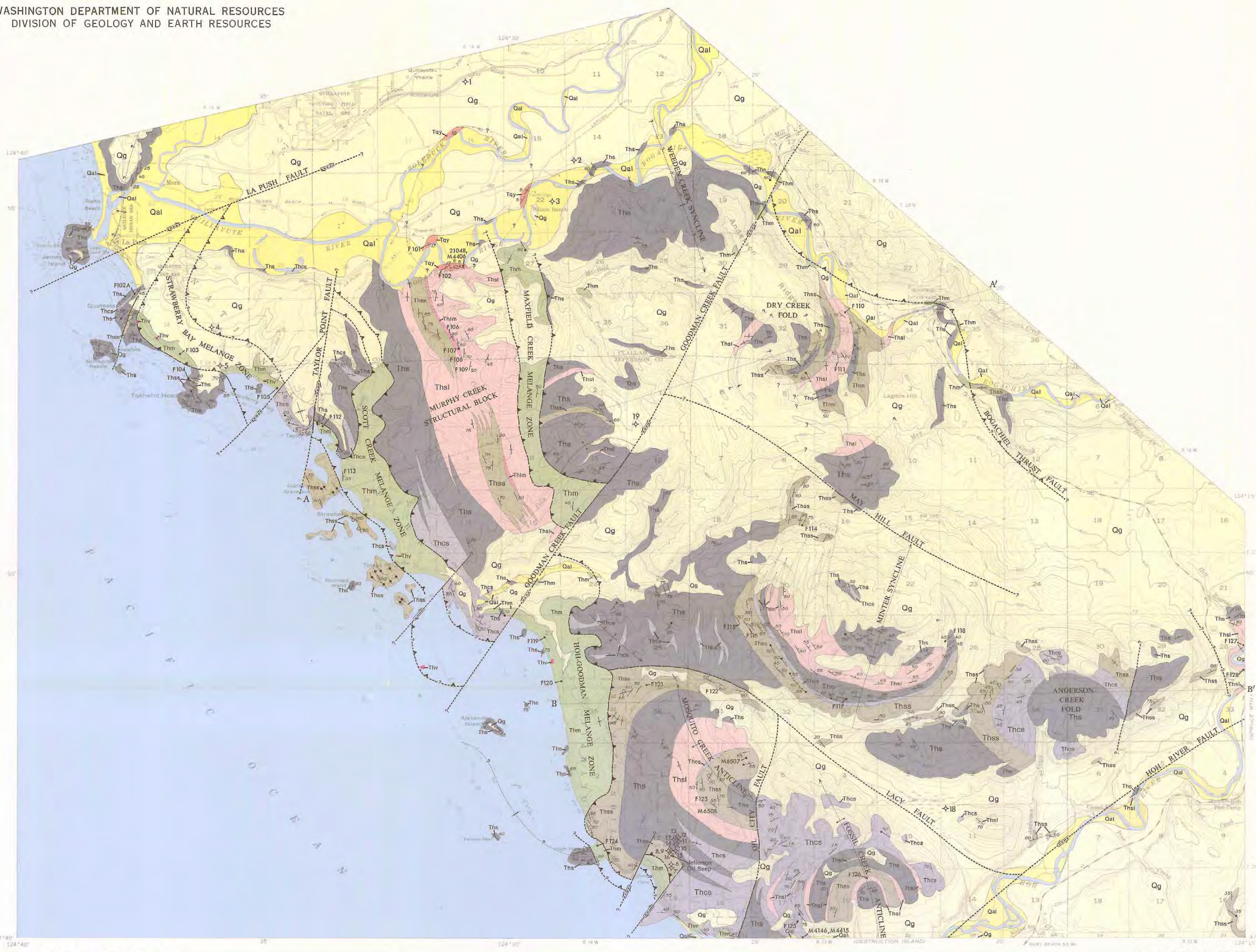
GEOLOGIC MAP GM 24

1979

For sale by Department of Natural Resources, Olympia, Washington
Price $4.50

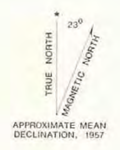
WASHINGTON DEPARTMENT OF NATURAL RESOURCES
DIVISION OF GEOLOGY AND EARTH RESOURCES

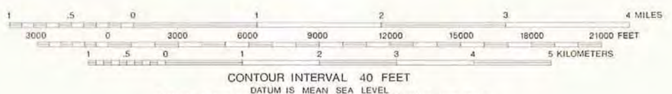
GEOLOGIC MAP
GM—24



Base map by U.S. Geological Survey, 1956 and 1957

Geology by Weldon W. Rau, 1974–1978





CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL
Shoreline Shown Represents the Approximate Line of Mean High Water
The Mean Range of Tide is Approximately 6 Feet

EXPLANATION

QUATERNARY

Holocene — Qal — **Alluvium**
Unconsolidated silt, sand, and gravel

Pleistocene — Qg — **Alpine glacial drift**
Outwash, silt, sand, gravel, and till(?)

UNCONFORMITY

TERTIARY

Late Miocene or Pliocene — Tqy — **Quillayute Formation**
Massive to well-bedded siltstone and sandstone, and conglomerate

UNCONFORMITY

Eocene, Oligocene, and Miocene — Thsl, Thlm, Thss, Ths, Thcs, Thm, Thv — **Hoh rock assemblage**

Thsl, massive to thin-bedded siltstone
Thlm, calcareous siltstone and concretionary lenses
Thss, thin- to medium-bedded siltstone and sandstone of about equal amounts
Ths, massive to thick-bedded graywacke sandstone
Thcs, coarse- to very coarse-grained graywacke sandstone, grit, and conglomerate
Thm, melange rocks of intensely sheared claystone and siltstone, containing blocks of indurated siltstone, graywacke sandstone, and altered volcanic rocks
Thv, volcanic rocks undifferentiated, including very large blocks within melange rocks

Contact, approximately located
Dashed where gradational; dotted where concealed; queried where unknown or probable

Fault
Dashed where inferred; dotted where concealed; queried where questionable; arrows indicate apparent direction of motion

Thrust fault
Dashed where approximately located; dotted where concealed; queried where uncertain. Sawteeth on upper plate

Anticline
Showing trace of axial plane and direction of plunge; dotted where concealed; dashed and queried where uncertain

Syncline
Showing trace of axial plane and direction of plunge; dotted where concealed; dashed and queried where uncertain

Fold
Undifferentiated synclinal or anticlinal structures are referred to as folds

50 Inclined — 90 Vertical — 35 Overturned — Horizontal

Strike and dip of beds
Ball on inclined symbol indicates top direction known; 90 on vertical symbol indicates top direction

Strike of beds from aerial photographs

F101
Microfossil collecting locality

M4415 , 21048
U.S. Geological Survey, macrofossil collecting locality

Petroleum test wells

INTRODUCTION

Early contributions to geology of the mapped area by Arnold (1906), Reagan (1909), Arnold and Hannibal (1913), Lupton (1914), and Weaver (1916) are primarily of a reconnaissance nature and confined to the coast and major river valleys. Glover (1945) collected much detailed geologic data along the coast and assembled a series of unpublished coastal geologic maps. In 1937, Weaver revised some of his original work. Recent contributions include a summary of the geology and mineral resources along the coast by Weissenborn and Snavely (1968); and several studies by Stewart (1970, 1971, 1974) on petrology, metamorphism, and structural relations, including a regional geologic map of the west-central part of the Olympic Peninsula. Other related studies in adjacent areas that are important to concepts employed in the present report and map are by the following: Tabor (1975) on the geology of the Olympic National Park; Cady (1975) dealing with the tectonic setting of the Olympic Peninsula; Snavely, Pearl, and Lander (1977) who summarize offshore geology and oil and gas potential; MacLeod, Tiffin, Snavely, and Currie (1977) on geologic interpretations of geophysical anomalies in the Strait of Juan de Fuca; and Tabor and Cady (1978a and 1978b) who present a compilation of known geology of the Olympic Peninsula and an interpretation of structure in the Olympic Mountains. The present map is the result of a continuation of geologic mapping and related studies already completed in the adjacent area to the south (Rau, 1970, 1973, 1975; Rau and Grocock, 1974).

The cooperation and courtesies extended to the author during the course of field investigations by members of the National Park Service, Olympic National Park, and the Olympic area office of the Washington State Department of Natural Resources are gratefully acknowledged. Thanks are also extended to many individuals of the various communities of the area for their generous assistance. Technical discussions with Parke D. Snavely, Jr., have been most helpful. The able field assistance of John B. Hall, Jon W. Lindberg, and Jack J. Jansons is gratefully acknowledged.

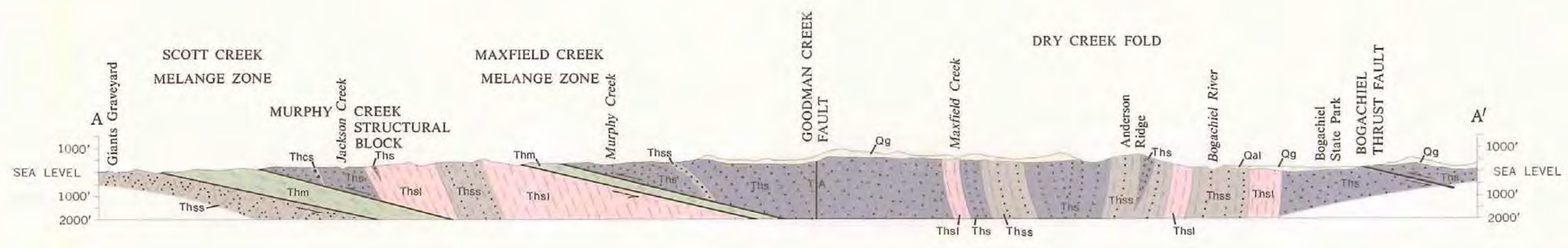
GENERAL STATEMENT

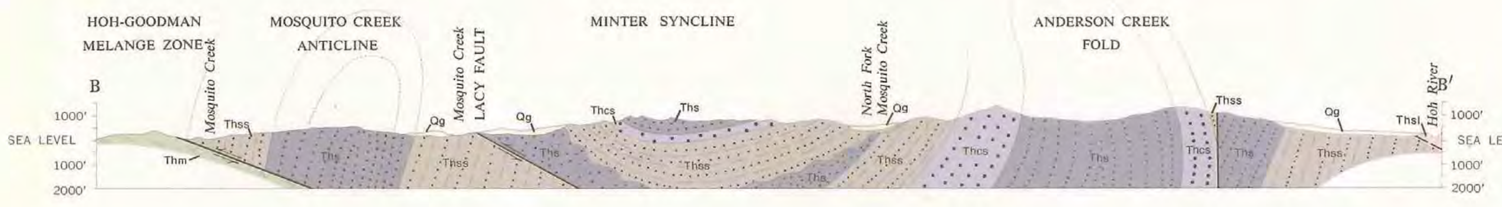
The primary purpose of this report and map is to show the distribution of Tertiary rock units in as much detail as possible, as well as to locate the major structures and faults within these rocks. Interpretations of these onshore data are further intended to contribute toward a better understanding of the overall tectonic framework of Tertiary rocks of the Washington coast and the adjacent continental shelf. Most faults shown are conceptual and either separate abruptly differing structural trends or are necessary to explain rock type distribution or structural patterns. Intense shearing has provided a criterion for the precise placement of some faults.

Because bedrock in many large areas is masked by thick deposits of drift, Tertiary rocks are shown only where they actually crop out or are known to be only thinly covered. Structural interpretations are necessarily limited and the extent of each Tertiary unit has not been fully determined in drift-covered areas. All areas are soil covered and heavily vegetated. Outcrops are primarily confined to the seacoast, major river valleys and their tributaries, roadcuts, and some ridge tops.

Tertiary rocks are represented by two major units—the intensely folded and faulted pre-late Miocene Hoh rock assemblage, and limited outcrops of the moderately deformed overlying late Miocene-Pliocene Quillayute Formation. The latter unit rests with decided angular unconformity on Hoh rocks. Its known extent is confined to four outcrops within a few square miles along the Bogachiel and Soleduck Rivers.

Mapping of Quaternary deposits is generalized to show either alluvium or alpine glacial drift. Although in places further subdivisions are apparent, particularly in the alpine glacial drift, in view of the scope of this map, these subdivisions are not shown.





Cross section A–A′ Movement on Goodman Creek Fault (T – toward, A – away)

DESCRIPTION OF THE MAP UNITS

SURFICIAL DEPOSITS

ALLUVIUM

Qal: silt, sand, and gravel—major deposits of unconsolidated sediments, largely confined to river bottoms and spits at the mouth of major streams and along nearby coastal areas.

ALPINE GLACIAL DRIFT (Qg)

Thick deposits of alpine drift of both outwash sand and gravel and till completely mask bedrock in large parts of the mapped area. The area north of the Quillayute and Bogachiel Rivers, including the Quillayute Prairie and lower Soleduck River valley, is almost entirely blanketed by drift. Thick and extensive deposits are present in the areas of Anderson Ridge-Lagitos Hills and tributaries of Maxfield Creek and Goodman Creek. The entire area northeast of the Bogachiel Valley and much of the area to the south between the Hoh and Bogachiel Valleys is also thickly blanketed with drift. Another major area of drift extends from the headwaters of Mosquito Creek southward to and including the Hoh Valley. In most of these areas, drift generally extends up to an elevation of at least 600 feet; but ridges and areas of higher elevation are usually free of drift, particularly in the areas drained by Minter Creek and Weeden Creek. Other major areas essentially free of drift are the coastal areas including the Murphy Creek drainage between the Bogachiel River valley and Goodman Creek valley, and south of Goodman Creek along the coast to the Hoh River including much of the Mosquito Creek drainage. In many of these drift-free areas the bedrock is generally deeply weathered, suggesting an extensive period of subaerial exposure. Therefore, these areas may never have been drift covered. In a few isolated areas, small deposits of gravel are present somewhat higher than 600 feet elevation. Such deposits are particularly prevalent on the north side of the Hoh Valley near the coast. The highest peak in that area, Hoh Mountain at 1,214 feet, and other nearby areas are gravel covered. These deposits are perhaps remnants of older more extensive deposits that may have filled the Hoh Valley to this level.

Outwash sand and gravel and till constitute the major drift deposits of the region. About 85 percent of all stones contained in these deposits are graywacke sandstone, many of which contain numerous dark-colored siltstone clasts. Other pebbles consist of volcanic rock, red argillite, phyllite, and light-colored chert. All of these materials represent an "Olympic" origin. Granitic and other "non-Olympic" stones have been found extensively only in the area north of the Quillayute River, largely in the Quillayute Prairie-Soleduck River valley area. These materials thus suggest a continental glacial origin for at least part of the drift in the Quillayute Prairie-Soleduck River valley areas as opposed to an alpine glacial origin for the drift located farther to the south. Lacustrine deposits are also present, particularly in upland areas. Carbonized wood, varying from macerated plant material to logs and stumps, is associated with lacustrine deposits and is also dispersed throughout some of the outwash sand and gravel as well as till deposits.

Extensive deposits of buff-colored clay, silt, and sand blanket much of the coastal area, including offshore sea stacks, to a depth varying from 5 feet to 15 feet. These materials are present inland also but are thinner away from the coastal area. They are thought to be eolian deposits that were laid down during a low stand of sea level at the close of the Pleistocene when a wide expanse of coastal plain lay bare of vegetation and served as a source area of sediment for transport by the prevailing westerly winds.

Although the ages of various drift deposits are not fully known, a few dates have been established for some of the coastal deposits. Heusser (1972, 1974) has recorded a radiocarbon date of 16,700 ±160 B.P. for some of the peat materials from the uppermost part of the sea cliff near Kalaloch to the south of the mapped area and of 18,800±800 B.P. for peat overlying Alpine drift in the Hoh River valley to the east. Florer (1972; personal communication, 1978), based on a pollen correlation, has estimated an age of about 8,000 years B.P. for materials from the deposits of supposed eolian origin exposed near La Push. The oldest Pleistocene date thus far established in the coastal region is also from the Kalaloch section. There, a pollen correlation has been made of materials from well down in the section with materials from Salmon Springs Drift of the Puget Sound region that are radiocarbon dated by enrichment techniques at $71{,}500\pm^{1700}_{1400}$ years (Stuiver and others, 1978). Also, a radiocarbon age of 59,600±700 years has been established for peat overlain by till in the Bogachiel River valley at an elevation of some 400 feet in the eastern part of the presently mapped area (Stuiver and others, 1978; Heusser, 1978). In addition, Heusser (1974, 1978) has recorded a radiocarbon age of 30,000±800 years B.P. for materials from a peat bog near the Hoh-Bogachiel drainage divide on Highway 101 at an elevation of some 600 feet. Both of these deposits, however, rest stratigraphically above still older drift of unknown age. Furthermore, in the Kalaloch section a thickness of some 25 feet of sediments lies beneath those dated at 71,400± years and above an elevated wave-cut terrace carved in Tertiary rocks. The trace of this terrace is exposed in many of the sea cliffs and sea stacks from Point Grenville to the Quillayute River (Rau, 1973) and because the terrace is gently warped, it is seen at various levels ranging from present-day sea level to some 150 feet above sea level. The age of the terrace is unknown but Heusser (1977) has speculated that it may have been formed about 125,000 years ago at the time of high eustatic sea level during the last interglaciation. South of the Hoh River, in places, the elevated terrace has been cut into and formed on still older unconsolidated deposits rather than Tertiary rocks. These deposits are also thought to be drift but are more widespread and much thicker than the deposits resting on the elevated terrace (Rau, 1973; Heusser, 1974). Locally in the Kalaloch-Point Grenville area, the unconsolidated material extends up to an elevation of about 400 feet. Deposits with similar stratigraphic relations are also widespread between the Bogachiel and Hoh River valleys where, in many places, they extend up to an elevation of at least 800 feet. It, therefore, appears that the most extensive and thickest drift deposits in coastal areas pre-date the capability of the recently developed enrichment techniques for radiocarbon dating (Stuiver and others, 1978).

THE QUILLAYUTE FORMATION (Tqy)

The name Quillayute Formation was first used by Reagan (1909), and although his description of the areal extent of the formation is generalized to include the Quillayute River valley and much of the area of its tributaries, he apparently believed that it covered a much larger area than subsequent studies show. He regarded molluscan fossils from the Maxfield Creek locality (sec. 28, T. 28 N., R. 14 W.) to be of Pliocene age. Arnold and Hannibal (1913, p. 604) referred to the formation as "typical Empire sandstone." In 1916, Weaver considered the Quillayute Formation to be late Miocene in age and Hertlein and Crickmay (1925) and Palmer (1927a) concurred with this conclusion. In 1937, Weaver inferred a Pliocene age for faunas from these beds suggesting they may be slightly older than those in the Quinault Formation and younger than those of the Montesano Formation of southwest Washington.

In recent years, W. O. Addicott of the U.S. Geological Survey has made additional collections of macrofossils from the Quillayute Formation exposed at the mouth of Maxfield Creek on the south bank of the Bogachiel River. His collections, together with others from this locality (USGS localities M4406 and 21048), number some 60 species, (Addicott, written communication, 1978). Listed below are some of the more commonly occurring taxa.

Gastropods:
Antiplanes perversa (Gabb)
Calicantharus n. sp.
Calliostoma sp.
Crepidula praerupta Conrad
Cryptonatica clausa (Broderip and Sowerby)
Mediargo mediocris (Dall)
Mitrella cf. *M. tuberosa* (Carpenter)
Molopophorus bogachieli (Reagan)
Nassarius cf. *N. andersoni* (Weaver)
Neptunea lyrata altispira (Gabb)
Neptunea tabulata (Baird)
Nucella imperialis (Dall)
Nucella lamellosa (Gmelin)
Nucella praecursor (Dall)
Nucella cf. *N. trancosana* (Arnold)
Olivella sp.
Semicassis aequisulcatum (Dall)

Bivalves:
Acila blancoensis Howe
Clinocardium cf. *C. meekianum* (Gabb)
Nuttallia montesanoensis (Weaver)
Protothaca cf. *P. staleyi hanniballi* Howe
Securella securis (Shumard)
Semele montesanoensis (Weaver)
Siliqua sp.
Spisula albaria arnoldi (Dall)
Spisula n. sp. Addicott
Tellinella merriami (Weaver)

Echinoid:
Kewia cf. *K. blancoensis* (Howe)

According to Addicott (written communication, 1978), "This fauna is late Miocene in age and represents the Wishkahan Stage of Addicott (1976). It correlates with the fauna of the lower part of the Montesano Formation of the northern margin of the Grays Harbor basin near Aberdeen and Montesano, southwest Washington. Many species are also common with the fauna of the Empire Formation at Coos Bay, southwest Oregon."

Addicott further states, "Principal elements of the Quillayute macrofauna—*Spisula, Securella, Protothaca, Nucella,* and *Cryptonatica*—suggest a very shallow water environment in the higher reaches of the inner sublittoral zone."

Foraminifera from two localities (F101 and 102; see checklist) are not indicative of a precise age. Most are known from both the late Miocene Montesano Formation as well as the Pliocene Quinault Formation.

Present mapping limits the known areal extent of the Quillayute Formation to four areas of outcrop, three of which are on the Bogachiel River (secs. 22, 28, and 29, T. 28 N., R. 14 W.) and one on the Soleduck River (sec. 16, T. 28 N., R. 14 W.), all within a radius of about 1 mile.

The beds are largely medium- to coarse-grained, olive- to buff-colored friable sandstone with lenses of fossiliferous pebble conglomerate. Sandy siltstone is exposed in the western part of the Maxfield Creek outcrop in section 28, and the entire outcrop of section 29 is massive fossiliferous siltstone. Although nowhere during the course of the present investigation has the base of the formation been observed, the unit, with moderate dips no greater than 17 degrees, obviously rests with decided unconformity on underlying, steeply dipping older Hoh rocks, some of which crop out nearby.

HOH ROCK ASSEMBLAGE

Weaver (1916) first applied the term "Hoh Formation" to many of the rocks exposed in the northwestern part of the Olympic Peninsula. Later, the extent of the formation was restricted somewhat and recognized as Oligocene and Miocene in age (Palmer, 1927b; Weaver, 1937). The type section was designated by Weaver as ". . . the shales and overlying massive brown sandstones, which are exposed between the mouth of Hoh River and the northern portion of Hoh Head." This locality is within the extreme southwest part of the presently mapped area. Current mapping, together with recently completed studies and mapping in the adjoining area to the south, the Destruction Island and Taholah quadrangles (Rau, 1973, 1975), as well as studies of others (Glover, 1940; Weissenborn and Snavely, 1968; Stewart, 1970; and Snavely and MacLeod, written communication, 1974), has shown that rocks included in Weaver's 1937 description not only are varied lithologically but also vary greatly in age. Also, they have undergone differing amounts of tectonism from moderate folding and faulting to intense shearing and disarrangement of strata. In view of these findings, and because it has been demonstrated that these strata are not a distinct mappable unit with a definable top and base, they are now informally referred to as the Hoh rock assemblage (Rau, 1973, 1975). Recent studies (Snavely, and others, 1979) suggest that at least some of the Hoh rocks are a part of a deep marginal basin facies with outcrops known, in places, from the central western coast of Vancouver Island to northwestern Oregon.

As recognized in the adjoining area south of the Hoh River, two major groups of rocks make up the Hoh rock assemblage: (1) those strata believed to be largely turbidite in origin, consisting of tightly folded, steeply dipping but coherent sequences of siltstone, graywacke sandstone, and conglomerate; and (2) melange rocks with completely disarranged, chaotically mixed blocks of siltstone, graywacke sandstone, conglomerate, and volcanic material in a matrix of intensely sheared siltstone and claystone.

Fossils are rare in Hoh rocks, not only in the presently mapped area but throughout the known areal extent of these rocks. Foraminifers are recorded here (see checklist) from 27 localities within the mapped area and provide information on the geologic age of strata of some of the major structural blocks. Assemblages from 5 localities in the Minter structure (F114-118) and three in the Mosquito Creek structure (F121-123) suggest a late Oligocene or early Miocene age (Zemorrian or Saucesian Stage). Two assemblages (F125 and 126) from the Fossil Creek structure may be of the same age as those of the Mosquito Creek structure but more precisely they suggest an early Miocene Saucesian age. Foraminifers suggesting a similar age are also recorded from both the Strawberry Bay melange zone (F103 and 105) and Scott Creek melange zone (F112 and 113). Although no fossil data were found in rocks of the Anderson Creek structure, diagnostic early Miocene Saucesian foraminifers were collected from two localities (F127 and 128) immediately to the east. However, faults may extend between these localities and the main body of the Anderson Creek structure. Diagnostic late Eocene Narizian or Refugian foraminifers were collected from four localities in the Murphy Creek structural block (F106-109) that lies between the Scott Creek melange zone to the west and the Maxfield Creek melange zone to the east. In addition, foraminifers of probable late Eocene age were found in a siltstone clast from conglomerate exposed at Quateata headland (F102A), as well as from a siltstone bed exposed at Teahwit Head (F104). Furthermore, three small collections (F119, 120, and 124) from the Hoh-Goodman melange zone may also be late Eocene in age. These Eocene fossils are the southernmost on record in the Olympic coastal area except those recorded at Point Grenville (Rau, 1975), some 40 miles to the south. All fossils known between these two areas indicate younger ages of early Miocene to Pliocene. Diagnostic fossils have not been found in several major structural blocks, namely the Weeden Creek and Dry Creek structures, the sandstones unconformably beneath the Minter structure, and the contorted coastal rocks of headlands, and offshore sea stacks south of Teahwit Head.

A large majority of the foraminiferal assemblages from Hoh rocks suggests that water depths were substantial during deposition, probably no less than bathyal (150 to 2,500 meters). The persistent occurrence of planktonic globigerinids suggest that open-sea conditions prevailed. Late Eocene assemblages with very few, if any, shallow water taxa and substantial numbers of deep water foraminifers, such as *Gyroidina soldanii*, costate and hispid uvigerinids, *Cibicides*, and a few *Melonis pompilioides*, collectively suggest cold water temperatures at upper bathyal to, and more likely, middle or lower bathyal depths. Deep water taxa also predominate in Oligocene and early Miocene assemblages. Substantial numbers of costate buliminids and uvigerinids, hispid uvigerinids, *Gyroidina soldanii*, substantiate cold water at bathyal depths. However, in association with these deep water taxa, some assemblages also contain shallower water species, such as *Elphidium minutum, Buccella mansfieldi oregonensis*, and *Florilus incisum*. The local occurrence of these and other shallow water taxa suggest that either more moderate depths prevailed at times or shallow water foraminifers were transported and redeposited at greater depths where they could have been mixed with deep water taxa. Such an action could have taken place by turbid transport of sediments, a process thought to be common to the origin of many Hoh rocks (Rau, 1973).

Major collections of macrofossils are from the "Fletcher's Ranch" locality (M4146, and M4415) in the Fossil Creek structure (see map). Taxa listed below have been identified by W. O. Addicott of the U.S. Geological Survey.

Gastropods:
Bruclarkia oregonensis (Conrad)
Cancellaria cf. *C. alaskensis* Clark
Crepidula cf. *C. praerupta* Conrad
Natica cf. *N. clarki* Etherington
Trochita n. sp. Moore

Scaphopod:
Dentalium sp.

Bivalves:
Anadara sp.
Acila cf. *A. conradi* (Meek)
Clinocardium cf. *C. praeblandum* Keen
Diplodonta parilis (Conrad)
Glycymeris cf. *G. vancouverensis* Clark and Arnold
Katherinella sp.
Lucinoma?
Nuculana sp.
Panopea cf. *P. snohomishensis* (Clark)
Securella sp.
Solamen snavelyi Addicott
Solen conradi Dall
Solen aff. *S. clallamensis* Clark and Arnold
Spisula albaria (Conrad)
Spisula cf. *S. albaria coosensis* Howe
Tellina emacerata Conrad
Thracia schencki Tegland
Vertipecten fucanus (Dall)

Addicott (written communication, 1978) refers this assemblage to his Pillarian Stage (Addicott, 1976) of early Miocene age. He further states that the assemblage has many species in common with the fauna of the Clallam Formation of the Clallam Bay area, including the stratigraphically restricted species, *Vertipecten fucanus*.

Environmental conditions suggested by the Fletcher's Ranch fauna are, according to Addicott, subtidal to perhaps 30 meters depth. He further observed that all of the bivalves are disarticulated so it is possible that post-morten transport has occurred. Foraminifers from a nearby locality (F125) are a mixture of deep and shallow water taxa and support the conclusion of at least local redeposition of some materials.

Smaller collections of macrofossils (M6507 and M6508) have been identified by Addicott (listed below) from the Mosquito Creek structure (see map). He concludes that they suggest a Miocene age similar to the Fletcher's Ranch assemblage, and that assemblage from M6507 suggests inner shelf depths but the two taxa from M6508, although inconclusive, suggest deeper water, perhaps outer shelf to uppermost bathyal depths. The foraminiferal assemblage from the same locality (F123) supports macrofossil data for substantial water depths.

	USGS localities M6507	M6508
Gastropods:		
Bruclarkia cf. *B. oregonensis* (Conrad)	X	
Musashia indurata (Conrad)		X
Bivalves:		
Anadara sp.	X	
Lucinoma acutilineata (Conrad)		X
Panopea abrupta (Conrad)	X	
Securella ensifera (Dall)?	X	
Spisula albaria (Conrad)	X	
Tellina emacerata Conrad	X	
Vertipecten fucanus (Dall)	X	

The following seven lithologic types in the Hoh rock assemblage have been recognized and their distribution shown on the map:

Thsl: siltstone—massive to rhythmically bedded with thin laminae of fine-grained sandstone.

Thlm: calcareous siltstone—bedded, indurated siltstone with concretionary lenses.

Thss: siltstone and sandstone—about equal amounts of light-gray to blue-gray rhythmically bedded siltstone and fine-grained sandstone; beds range in thickness from 3 to 40 cm.

Ths: sandstone—light-gray, blue-gray when freshly broken, olive-gray when weathered; fine- to medium-grained, massive to thick-bedded with thin to thick laminae of siltstone; contains abundant lithic fragments. In places, includes undifferentiated conglomerate, grit, and coarse-grained sandstone.

Thcs: conglomerate, grit, and coarse- to very coarse-grained sandstone—conglomerate clasts are largely volcanic with lesser amounts of chert, argillite, siltstone, graywacke sandstone, and granitic rocks; sandstone is massive, blue-gray when freshly broken, olive-gray when weathered and contains abundant lithic fragments commonly including dark-gray shale chips.

Thm: melange rocks—chaotically mixed blocks, varying greatly in size, of massive sandstone, laminated siltstone and sandstone, massive siltstone, and altered volcanic rocks set in a dark-gray, intensely sheared matrix of clays and siltstone fragments.

Thv: volcanic rocks—undifferentiated, including large blocks within melange rocks of altered volcanic breccia, tuffs, and massive basalt.

STRUCTURAL (TECTONIC) INTERPRETATIONS

Structural interpretations of Hoh coastal rocks have varied considerably during the past 70 years or so of geologic exploration. Early interpretations were necessarily limited largely to data from coastal outcrops (Reagan, 1909; Lupton, 1914; Weaver, 1916, 1937; Glover, 1945). With increased logging activities during the past 10 or 15 years, accessibility to inland areas, as well as many new roadcut outcrops, has made much additional data available. Although structural patterns are readily apparent in some of these areas, in others they are not. The Minter syncline, for example, is manifested well on topographic maps and aerial photographs, whereas the Mosquito Creek anticline and other structures are discernible only after an examination of the structural data. Thus, varying amounts of interpretation have necessarily been employed to develop what is believed to be a realistic explanation of rock type distribution and structural information. Mapping previously completed immediately to the south (Rau, 1975) also made use of new inland data. However, efforts were concentrated largely on showing rock type distribution and structural data with limited interpretations of these findings. Current mapping, north of the Hoh River, has added much information to the regional structure of Hoh coastal rocks. A better understanding of the tectonic setting has therefore developed from the combined structural information of both coastal areas. In addition, the currently developing regional tectonic framework for the Olympic Peninsula (Stewart, 1971; Rau, 1973; Tabor, 1975; Cady, 1975; Snavely, personal communication, 1978; Tabor and Cady, 1978b) has served as a model for structural interpretations applied here to coastal Hoh rocks.

Coastal mapping south of the Hoh River demonstrated that major faults bound large blocks of strongly folded sedimentary sequences and that, in places, melange zones are also bound by significant faults (Rau, 1975). It was further suggested that some of the major faults south of the Hoh River might be thrusts, but due to the lack of confirming data they were not interpreted as such on the map. In the area of the present map, however, structural data, together with the distribution of melange zones as well as intervening sedimentary sequences, further strengthen a tectonic model of thrusting. Therefore, major north-trending melange zones are interpreted as major zones of thrusting. Subsequent northeast-trending strike-slip faults are shown to have segmented and offset the major thrust zones, as well as intervening sedimentary sequences. Thus, large blocks of strongly folded sedimentary Hoh rocks are basically bound by a combination of thrust and strike-slip faults. Thrusting is shown as underthrusting to the east, in keeping with the generally employed tectonic framework of the Olympic Mountains (Stewart, 1971; Tabor, 1975; Cady, 1975; Tabor and Cady, 1978b). Because very few data are available to indicate direction and type of thrusting within the present area, it is entirely possible that, in places, overthrusting could have developed instead, as is known to have occurred in areas to the north (Snavely, personal communication, 1978).

The coastal headlands and offshore rocks north of the Goodman Creek Fault are interpreted as the easternmost outcrops of an eastward underthrust plate that has been thrust beneath the Murphy Creek block along the Strawberry Bay and Scott Creek melange zones. The age of these headlands and offshore rocks is not fully confirmed. However, a small foraminiferal fauna from a siltstone clast of a conglomerate exposed on the north side of Quateata headland (F102A) suggests a late Eocene age, an age similar to that confirmed in the Murphy Creek structural block to the east. Inasmuch as the actual formation of this conglomerate took place at a later date, possibly post-Eocene time, the evidence, although not conclusive, suggests that these coastal rocks may be younger than those to the east of the melange zone as would be expected if underthrusting to the east has taken place.

South of the Goodman Creek Fault, large outcrops of resistant rock, such as Alexander Island, Perkins Reef, and Hoh Head, may also represent parts of a thrust plate with similar structural relations to the rocks to the east as is suggested for rocks north of the Goodman Creek Fault. However, alternatively, these blocks could represent resistant remnants of the overlying Mosquito Creek plate resting on melange rocks; or they may be resistant blocks that were once incorporated in the Hoh-Goodman melange.

In addition to an interpretation of thrusting as an explanation for major melange zones, diapirism may have played an important role in modifying both the composition of melange rock assemblages and their distribution, as well as structural patterns both within melange rocks and in adjacent rocks. Continuous seismic profiling in nearby offshore areas has produced evidence of diapirism (Snavely and MacLeod, 1971; Tiffin, Cameron, and Murray, 1972), and onshore outcrops of features believed to be similar are recorded in an area a few miles south of the Hoh River (Rau and Grocock, 1974). The exact effect of diapirism on structural relations and the distribution of rocks may not always be clearly shown. However, due to the incompetence of melange materials, the actual contacts between melange rocks and the more competent rock of each thrust plate most likely have been somewhat modified by diapirism and associated minor faulting. Such local modifications of the regional structure are apparent in a number of places within the mapped area. For example, the regional northwest strike in the Hoh Head-Hoh River area is locally modified to a northeast strike in the Jefferson Cove area near the fault contacts between melange rocks and the adjacent resistant sandstones and conglomerates. Also, near the south end of the Scott Creek melange zone the regional northwest trend in the conglomerates and sandstones to the south is modified to a northeast strike near the fault contact.

Several periods of deformation are evidenced by the combined structural relations in Hoh rocks and the relative ages of rocks in various structural blocks. Attitudes anomalous to regional structures and conflicting local data on the top direction of strata based on sedimentary features are among significant evidence for more than one period of folding. For example, top direction indications in the Dry Creek fold are rare but those recorded are somewhat conflicting and suggest that tight, perhaps isoclinal, folding of the strata took place prior to the deformation that formed the broad regional fold now apparent in the Dry Creek area. The age of the rocks that lie unconformably beneath the Oligocene-Miocene (Zemorrian-Saucesian) rocks of the Minter syncline has not been determined. However, the degree of alteration, induration, and shearing of the massive sandstone to the west of the Minter syncline, as well as all the rocks of the Anderson Creek structure to the southeast, is noticeably greater than it is in the overlying Oligocene-Miocene strata of the Minter syncline. No fossil data and very little structural data are available in the massive sandstones of the Weeden Creek block, but these rocks also appear to have undergone more deformation than others in nearby areas. Offshore rock outcrops, the rocks that make up most of the coastal headlands, and possibly the late Eocene rocks of the Murphy Creek block to the east appear to have been intensely folded with axes of folding generally in a north-south direction. This structural pattern was subsequently modified into the present-day configuration by broad regional folding.

In other areas evidence suggests only one period of major folding. Of these, the Oligocene-Miocene rocks of the Minter syncline are most apparent. In these rocks the attitudes are relatively uniform with moderate dips and top indications are completely consistent. The rocks of both the Mosquito Creek and Fossil Creek blocks are of a similar age and also most likely have undergone only one major period of folding. However, attitudes are not as consistent and dips are greater but top indications are consistent. Thus, these rocks, although probably limited to one major period of folding, appear to have undergone more severe deformation during that period than rocks of similar age in the Minter syncline.

TERTIARY GEOLOGIC HISTORY

A number of major geologic events can be reconstructed from an examination of the distribution of lithologies, fossils, and structural relations of Tertiary rocks. Sedimentation, largely as turbidite deposition prior to Oligocene time, took place at bathyal depths as reflected by late Eocene fossils and rocks of the Murphy Creek block, and possibly the rocks of the Anderson Creek fold and associated massive sandstones to the west, the rocks of the Weeden Creek syncline, Dry Creek fold, and perhaps some of the rocks of coastal headlands and offshore outcrops. Subsequent deformation and emergence, at least in places, also took place prior to Oligocene time for many of these rocks. Folding was severe, possibly isoclinal in places, as recorded especially well in some of the rocks of coastal headlands and offshore outcrops. Emergence and erosion are recorded particularly well in the Minter syncline where moderately folded Oligocene-Miocene strata are believed to rest with decided unconformity on strongly deformed sandstones to the west and the rocks of the Anderson Creek structure to the south and east. This contact could alternatively be interpreted as a folded fault in which case, without fossils or other age control in the more deformed rocks, they would not necessarily have to be older than the adjacent Oligocene-Miocene strata of the Minter syncline. If, however, emergence and subaerial erosion did take place, then submergence followed prior to the deposition of the Oligocene-Miocene strata as represented in the Minter syncline and Mosquito Creek and Fossil Creek anticlines. Oligocene-Miocene sedimentation, for the most part, also took place as turbidite deposition in a bathyal environment. A second period of deformation of Hoh rocks is recorded by the folding of the Oligocene-Miocene rocks, as well as older rocks, into broad structures much as is seen today particularly in the Minter syncline, and in the Mosquito Creek and Fossil Creek anticlines. Subsequent to this folding, faulting took place as is represented especially well by the Oil City Fault. Following sometime in the middle or possibly late Miocene, major diastrophism took place as reflected largely by extensive thrust faulting. The earliest faulting during this period appears to be represented by the northwest-trending Lacy Fault because it is intersected by the Hoh-Goodman melange zone. The May Hill and Bogachiel Faults may also be of a similar age. The latest and possibly the most severe faulting during the middle or late Miocene time is expressed by the north-northwest trending thrust faults bounding the major melange zones—Hoh-Goodman, Strawberry Bay, Scott Creek, and Maxfield Creek. Not only do structural relations indicate that this major faulting occurred sometime after early and possibly middle Miocene time, but early Miocene fossils contained in blocks in some of the melange zones also indicate that faulting occurred during post early Miocene time. Subsequent to this period of major thrusting and prior to latest Miocene or Pliocene time the rocks were again broken by extensive faults, but this time by northeast-trending strike-slip faults, especially the La Push, Goodman Creek, and Hoh River Faults. Both left and right lateral movements are expressed by this faulting. Minor folding accompanied faulting as a result of drag on the major strike-slip faults, such folding is expressed well, for example, in the coastal rocks adjacent to the La Push Fault. Emergence, subaerial erosion, and submergence once again took place prior to the deposition of the late Miocene or Pliocene shallow-water Quillayute Formation. Gentle folding as expressed by low dips in the Quillayute strata probably represents the last deformation to take place during the Tertiary period.

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Petroleum test wells

1. Mordello L. Vincent *et al* Olympic No. 1.
NW¼SW¼ sec. 9, T. 28 N., R. 14 W.; 1932; T.D. 2,940 (2,898?) ft.
2. Eastern Petroleum Co. Soleduck No. 1
660 ft. from S. line, 660 ft. from W. line, sec. 14, T. 28 N., R. 14 W.; 1973; T.D. 1,050 ft.
3. Sol Duc Oil Co. Bogachiel
1,320 ft. from N. line, 132 ft. from E. line, sec. 22, T. 28 N., R. 14 W.; 1924; T.D. 2,225 ft.
4. St. Helens Oil Co. Godfredson No. 1
SE¼NW¼ sec. 35, T. 28 N., R. 15 W.; 1955; T.D. 1,005 ft.
*5. La Push Oil Co. La Push
Approx. N¼ corner sec. 2, T. 27 N., R. 15 W.; 1899 or 1902; T.D. approx. 600 ft.
6. Jefferson Oil Co. Hoh Head No. 1
SE¼SW¼SE¼ sec. 12, T. 26 N., R. 14 W.; 1913, 1914; T.D. 901 ft.
7. Jefferson Oil Co.; Swastika Oil Co. Hoh Head No. 2
SE¼SW¼SE¼ sec. 12, T. 26 N., R. 14 W.; 1914, 1919; T.D. 986 ft; 1,120 ft.
8. Leslie Petroleum Co.; Hoh River Oil and Gas Development Co. with General Petroleum Co. Sims No. 1; Gilkey No. 1
Center SE¼NW¼SE¼ sec. 12, T. 26 N., R. 14 W.; 1931; T.D. 2,069 ft.; 2,155 ft.
9. Hoh River Oil and Gas Development Co. Gilkey No. 2
Center SE¼NW¼SE¼ sec. 12, T. 26 N., R. 14 W.; 1933; T.D. 866 ft.
10. Hoh River Oil Co. or Mutual Exploration Co. Core Hole No. 1
750 ft. NE. of Gilkey wells; 1934; T.D. 325 ft.
11. Hoh River Oil Co. or Mutual Exploration Co. Core Hole No. 2
Approx. 150 ft. NE. of Core Hole No. 1; 1934; T.D. 250 ft.
12. Hoh River Oil Co. or Mutual Exploration Co. Core Hole No. 3
10 ft. N., 800 ft. W. of E¼ cor. sec. 12, T. 26 N., R. 14 W.; 1934; T.D. 520 ft.
13. Hoh River Oil Co. or Mutual Exploration Co. Milwaukee No. 1
2,750 ft. N., 950 ft. W. of SE. cor. sec. 12, T. 26 N., R. 14 W.; 1934; T.D. 977 ft.
14. Washington Oil Co., Ltd.; Consolidated Oil Co. of Washington, Inc. Kipling No. 1; Gilkey No. 3
NW¼SE¼, sec. 12, T. 26 N., R. 14 W; 1937; T.D. 316 ft., 808 ft.
15. Washington Oil Co. Ltd. Kipling No. 2
200 to 300 ft. E. of Kipling No. 1; 1936; T.D. 656 ft.
16. Consolidated Oil Co. of Washington, Inc. Consolidated No. 2 (Gilkey No. 5)
SE¼NW¼SE¼ sec. 12, T. 26 N., R. 14 W., 150 ft. S. of Kipling No. 1; 1937; T.D. 1,070 ft.
17. Hoh River Oil Co. or Mutual Exploration Co. Churchill No. 1
NW. cor. NE¼SE¼ sec. 12, T. 26 N., R. 14 W.; 1937; T.D. 1,600 ft.
18. Hoh River Oil Co. or Mutual Exploration Co. Lacy No. 1
NW¼ sec. 11, T. 26 N., R. 13 W. at Lacy Seep; 1934; T.D. 803 ft.
19. Belco Petroleum Corp. Milwaukee Land 1-1
109 ft. from S. line, 693 ft. from W. line, sec. 1, T. 27 N., R. 14 W.; 1966; T.D. 6,880 ft.

*Several published and unpublished records locate this well in the NW¼ sec. 1, T. 27 N., R. 15 W., but no evidence of a well was found at this location during the course of investigations. However, the remains of an old drilling operation is located at approximately the N¼ corner, sec. 2, T. 27 N., R. 15 W. An abandoned trail, originally used to reach the beach from the main highway (old beach trail No. 3), passes immediately by the remains of this well.

The drilling dates are also uncertain. An account of a drilling operation that compares with the general description of the LaPush No. 1 was given in a book entitled "Barth Ar-Kell" by S. E. Lofgren (Publications Press, Seattle, 1949). It mentions 1899 as the drilling date. However, several other published and unpublished records list 1902 as the drilling date.

CHECKLIST OF FORAMINIFERA

(C – common; F – few; R – rare; ? – questionably identified)

SPECIES	F101	F102	F102A	F103	F104	F105	F106	F107	F108	F109	F110	F111	F112	F113	F114	F115	F116	F117	F118	F119	F120	F121	F122	F123	F124	F125	F126	F127	F128
Angulogerina hannai Beck								R		?										C	R								
Anomalina californiensis Cushman and Hobson								R		?																?			
Anomalina garzaensis Cushman and Siegfus									C	?																			
Anomalina sp.			F																										
Bolivina sp.																									R				
Buccella frigida (Cushman)		R																											
Buccella mansfieldi oregonensis (Cushman, R. E. and Stewart, K. C.)															R												C		?
Buccella sp.			R																										
Bulimina cf. B. curtissima Cushman and Siegfus			R			R							C												?				
Bulimina inflata alligata Cushman and Laiming				R											C				F				?	C		R			
Bulimina sculptilis Cushman								C																					
Buliminella curta Cushman		R																											
Cassidulina crassipunctata Cushman and Hobson															C								C	C		C	C	F	F
Cassidulina cf. C. kernensis Smith									R	R															?				
Cassidulina laevigata carinata Silvestri	C	?																											
Cassidulinoides sp.															R											R			
Chilostomella cf. C. cylindroides Reuss									?			?	R																
Cibicides mckannai Galloway and Wissler	R	?																											
Cibicides cf. C. mcmastersi Beck			?							C	R									C	?								
Cibicides cf. C. pseudoungerianus evolutus Cushman and Hobson				R		F	F		F	C			F	R	R		R		R		?			F		R			
Cibicides cf. C. spiropunctatus Galloway and Morrey			?				F																						
Dentalina consobrina d'Orbigny								R	F																				
Dentalina dusenburyi Beck					R	R																							
Dentalina quadrulata Cushman and Laiming				R															F										
Dentalina pauperata (d'Orbigny)								?	R																	?			
Dentalina spp.											R					R				R		R			?				
Eggerella bradyi (Cushman)										?																			
Elphidium cf. E. minutum Cushman													?		C								C	R		?	C		C
Eponides cf. E. duprei Cushman and Schenck									R																				
Eponides keenani Cushman and Kleinpell						F					?			?			?								?	R			
Eponides umbonatus (Reuss)							F				F	R		R															
Fissurina spp.				R		R					R		R				R												
Florilus cf. F. belridgensis (Barbat and Johnson)	R																												
Florilus costiferum (Cushman)																												F	?
Florilus incisum kernensis (Kleinpell)															C		?		?							F			
Fursenkoina spp.										R														?	R		R		
Glandulina laevigata d'Orbigny	R																												
Globigerina spp.	R	R	C	R		F	R	C	C	F	F	R	R	R		R	F	C	C	R		R			R	F			R
Globobulimina cf. G. auriculata (Bailey)		R																											
Globobulimina cf. G. guayabalensis (Cole)									R																				
Globobulimina ovata d'Orbigny			?															C							R				
Globocassidulina globosa (Hantken)																				C					R				
Guttulina irregularis d'Orbigny													?																
Gyroidina cf. G. condoni Cushman and Schenck								R												?	?				?				
Gyroidina soldanii d'Orbigny				?		?	R	F		F			R	?	F				F			?	F	C	R	C		R	C
Gyroidina soldanii octocamerata Cushman and G. D. Hanna							R	F	C											R	R								
Involutina sp.				R							R																		
Karreriella cf. K. chilostoma (Reuss)								R	F				?																
Karreriella washingtonensis Rau																		R											
Lagena cf. L. conscripta (Cushman and Barksdale)										R										R									
Lagena sp.	R																												
Lenticulina sp.							R		R		R				F	F							R			R			
Marginulina sp.																							R						
Martinottiella cf. M. nodulosa Cushman				R		R					F						R	R				R							
Melonis halkyardi (Cushman)								R	R	F																			
Melonis cf. M. pompilioides (Fichtel and Moll)								F		R					F				?	?			F	C			R		
?Nodosarella cf. N. alexanderi (Cushman)								R	R	R											?								
Nodosarella sp.								R																					
Nodosaria anomala Reuss							C		R		?	?																	
Nodosaria longiscata d'Orbigny				R	R				?			?					F				R								
Nonionella cf. N. florinense (Cole)			F																										
Nonionella miocenica Cushman	R	C												F				F									F		
Oolina sp.				R					R										R					R			R		
Plectofrondicularia cf. P. miocenica directa Cushman and Laiming				R														R	?					?		?			
Plectofrondicularia packardi multilineata Cushman and Simonson								F							R						?								
Plectofrondicularia packardi packardi Cushman and Schenck								R																					
Plectofrondicularia vaughani Cushman			?	R																									
Plectofrondicularia cf. P. vokesi Cushman and R. E. and K. C. Stewart			R			R												R	?										
Praeglobobulimina pupoides (d'Orbigny)							R		R					?		R													
Pseudoglandulina inflata (Bornemann)				F				C	R	R					C	F	R	R								F	?		
Pseudoglandulina aff. P. inflata (Bornemann)																								C		?			
Pullenia bulloides (d'Orbigny)				R					F	?			F																
Pullenia cf. P. malkinae Coryell and Mossman	C																												
Pullenia salisburyi R. E. and K. C. Stewart																				?					?				
Quinqueloculina akneriana d'Orbigny	R																												
Sigmoilina sp.				R		F										R	F								R				
Sphaeroidina variabilis Reuss				R		?																							
Stilostomella frizzelli (Rau)																										F			
Stilostomella cf. S. sanctaecrucis (Kleinpell)				F		R	?	R	F	F			F	?			?	?								?			
Stilostomella? cf. S. wegemanni (Cole)															R														
Uvigerina auberiana d'Orbigny				F		F							C	C	?	F	F	F	C					R		F	C		
Uvigerina cocoaensis Cushman								F																					
Uvigerina gallowayi Cushman													?																
Uvigerina garzaensis Cushman and Siegfus							F			R																			
Uvigerina cf. U. hootsi Rankin		F																											
Uvigerina juncea Cushman and Todd	C																												
Uvigerina subperegrina Cushman and Kleinpell	F	?																											
Uvigerina cf. U. vicksburgensis Cushman and Ellisor													F																
Uvigerinella cf. U. californica Cushman				C					F																			?	
Uvigerinella obesa impolita Cushman and Laiming						?																					R	C	C
Valvulineria jacksonensis welcomensis Mallory								C		C							?												
Valvulineria menloensis Rau															R														
Valvulineria tumeyensis Cushman and Simonson			R						R																				
Valvulineria willapaensis Rau								F																					

GEOLOGIC MAP IN THE VICINITY OF THE LOWER BOGACHIEL AND HOH RIVER VALLEYS, AND THE WASHINGTON COAST

By

WELDON W. RAU

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