

SOURCES OF DATA (Unpublished)

(7) Gower (1960) (8) Rau (1966) (9) Rau (1967) (10) Rau (1975) (13) R. J. Stewart (written commun., 1974). (14) R. W. Tabor, K. Pisciotto, R. J. Stewart,

(18) R. J. Carson, III (written commun., (3) W. M. Cady, N. S. MacLeod, J. W. Shervais, M. L. Sorensen, R. J. Stewart, and R. B. Tallyn (unpublished data). (4) W. M. Cady, R. W. Tabor, R. Koeppen, N. S. MacLeod, K. Pisciotto, M. L. Sorensen, R. J. Stewart, R. Tallyn, amd R. S. Yeats (unpublished data). (5) Cady, Tabor, MacLeod, and Sorensen (1972). (24) Moore (1965). (6) Cady, Sorensen, and MacLeod (1972). (11) P. D. Snavely, Jr., N. S. MacLeod, and J. E. Pearl (written commun., 1974). (12) P. D. Snavely, Jr., (written commun., 1970).

Note: This data list is divided into two separately

alphabetized sections. Below is material used more or less unmodified (solid lines)

(1) Brown, Gower, and Snavely (1960)

(2) Brown (1968)

lished data).

(15) Tabor, Yeats, and Sorensen (1972).

(19) Frisken (1965). (20) Hamlin (1962) (21) Hawkins (1967). (22) Harvey (1959). (23) Miller (1967). (25) C. F. Park, Jr., J. R. Balsley, Jr., W. M. Cady, F. M. Chace, R. H. Cowie, H. L. James, J. M. Nelson, R. J. Roberts, J. W. Robinson, J. A. Straczek, S. E. Watson, and R. G. Yates (unpublished (26) W. W. Rau(written commun., 1974). (27) Sherman (1960). (28) Stewart (1970). (29) Thoms (1959).

Material used with considerable modification and addition (Dashed lines-bedrock geology.

Hatchered lines-surficial deposits).

(16) Allison (1959).

(17) Carson (1970).

R. B. Tallyn, and R. S. Yeats (unpub-(30) Todd (1939). (31) Walter Warren (unpublished data).

Two metamorphic events are recorded in rocks of the east part of the core. A

general recrystallization associated with penetrative deformation occurred about 29 m.v.

zonation as depicted on the map is based on thin-section study. The laumontite-prehnite

ago (middle Oligocene) and a local recrystallization associated with faulting and quartz

veining took place about 17 m.y. ago (middle Miocene; Tabor, 1972). Metamorphic

and pumpellyite line and parts of the prehnite and pumpellyite-pumpellyite line are

from Stewart (1974; written commun., 1974). Pumpellyite is difficult to identify in

written commun., 1973), but their limits have not been mapped.

many areas, thus the boundaries are tentative. Laumontite and other zeolites also occur

in peripheral rocks of the northwestern peninsula (P. D. Snavely, Jr., and N. S. MacLeod,

Basaltic rocks

diabase and gabbro, tuffaceous argillite, and limestone. In some units the basaltic rocks

especially the larger ones, may be in place within their enclosing sedimentary unit (for

Basaltic rocks in the core include basalt, pillow basalt, basaltic breccia and tuff,

are metamorphosed to greenstone and greenschist. Although some masses of basaltic rocks.

instance, the Elwha lithologic assemblage), many of the small pods and lenses are surroun-

ded by sheared rock, indicating that they may be allochthonous. Some foraminifers found

in the eastern core rocks are in red limestone associated with basaltic rocks; although the

basalts appear to be Eocene, the age of the enclosing sedimentary unit could be different.

Elwha lithic assemblage

The Elwha lithic assemblage is a belt of strongly deformed predominantly fine

Most of the basaltic rocks are described with the units that enclose them.

grained rocks that extends across the core of the Olympic Mountains and underlies a

and minor (less than 30 percent) thin-bedded sandstone and semischist predominate.

Several areas mapped within the belt contain 30-50 percent thin- to medium-bedded

bedded lineated sandstone and granule and pebble conglomerate. Pods and lenses of

basaltic metavolcanic rocks range from layers or masses several hundred meters long

lithic assemblage from adjoining units are the abundance of volcanic lenses and pods

features are identifiable in individual outcrops, the assemblage is a broken formation.

Except for well-developed cleavage, large areas of pelitic rocks look relatively undisturbed,

but where sandstone beds were formerly present, the rock now consists of a mosaic of

boudins ranging in length from a few centimeters to several hundred meters and longer.

ages form pencil structures, and several generations of isoclinal folds are conspicuous

throughout much of the unit. Quartz veining is pronounced, and earlier generations of

on Mount Claywood is interbedded with sandstone that appears to be part of the strati-

graphic sequence. The foraminifers are of early or middle Eocene age (W. W. Rau, writ-

Although many of the basalt or greenstone pods in the core are surrounded by sheared rocks and thus are probably considerably displaced, red foraminiferal limestone

Grand Valley lithic assemblage

percent) and very rare basaltic volcanic rocks and associated red limestone. It is a broken

formation characterized by pervasive cleavage, divergent fold axes, and sandstone display-

ing prominent boudinage structure. Large folds are common. Deformation increases from

northeast to southwest, where cleavage has completely destroyed sedimentary features in

The rocks of the Grand Valley lithic assemblage, which lies between the Eocene

The Needles-Gray Wolf lithic assemblage

sedimentary rocks of the Blue Mountain unit rarely contain micaceous rocks. The three

The Needles-Gray Wolf lithic assemblage is characterized by conspicuous detrital mus-

covite flakes in sandstone and finer grained muscovite in siltstone and slate, whereas adjoining

fundamental divisions of the assemblage are (1) a lower section of thin-bedded slate, siltstone,

and sandstone with a few slivers and larger masses of pillow basalt, foliated greenstone, and

This assemblage has well-developed slaty cleavage. Locally bedding is rearranged

This assemblage contains few fossils, but near the middle of the upper section is a

tuffaceous slate, (2) a discontinuous zone in the middle studded with basalt and diabase,

roughly marking the contact between the lower and upper sections, and (3) an upper sec-

tion characterized by thick beds of mica sandstone and volcanic material near its base.

mechanically by the cleavage; pencil structure in slate is ubiquitous. Parts of the assemb-

lage are broken formations. Thin-bedded rocks are isoclinally folded. The sandstone lo-

thin zone of microbreccia with Paleocene and Eocene fossils in its matrix (Cady and

others, 1963); sandstone at the north end of The Needles contains a late(?) Eocene fauna

(Cady, Tabor, MacLeod, and Sorensen, 1972). Poorly preserved microfossils in limestone

associated with basaltic rock south of Grand Creek are identifiable only as Tertiary (W. W.

Sandstone of the Sooes River area

Ulatisian to lower Refugian (middle and late Eocene) in age (P. D. Snavely Jr. and others,

Western Olympic lithic assemblage

including Mount Olympus, and is continuous to the coast north of the Quillayute River. Except for the pelitic belts, the predominant rock is thick-bedded sandstone. The abun-

exposed in the western part of this assemblage from most of the other assemblages.

dance of K-feldspar (at least 1 percent and commonly 3-10 percent) distinguishes the rocks

Penetrative deformation and recrystallization are intense on the east side of the

assemblage but decrease westward and northwestward; sandstone phacoids in sheared ar-

throughout. Pencil cleavage is common on the east but disappears to the west. Rocks on the west contain considerable laumontite in contrast to prehnite and pumpellyite or pum-

pellyite alone on the east side. Hawkins (1967) described sandstone and semischist in the

Mount Olympus area with special reference to their metamorphic minerals and textures. Mapped fold traces and faults immediately south of the Soleduck River are gener-

alized from bedding attitudes and may be oversimplified. Locally, bedding attitudes change

The western Olympic lithic assemblage is distinguished from the adjoining Elwha

Fossils are scarce in the assemblage. Mollusks collected by Walter Warren west of

Mount Appleton have been assigned by Ralph Stewart to the Oligocene (see Harvey, 1959,

Hoh River identified by W. W. Rau are all late Eocene (Narizian or early Refugian; Gower,

commun., 1972). A small exposure of rhythmically bedded siltstone and sandstone at Point

Eocene foraminifers are found in red limestone and associated with sheared basalt adjacent

to the Calawah fault zone near Sore Thumb, in siltstone in the Middle Fork of the Dickey

Snavely, Jr. and N. S. MacLeod, written commun., 1974). These rocks, however, may be

Included in the western Olympic lithic assemblages are "undifferentiated rocks south

Some material in the descriptions on the map has been adapted from Stewart (1970,

In the southeastern part of the core, where the major northwest-trending assemblages

are cut off by or strongly bent along the southern shear zone (fig. 2), we could not distinguish

the major lithologic assemblages on the basis of silt-to-sand ratios. On the map wash contacts of this unit with other assemblages are designated by color where their gross distinguishing

The southeastern part of the core is composed predominantly of highly disrupted

slivers and pods from a few meters to kilometers long. Deformation and structures are much

No identifiable fossils have been found in the southeastern part of the core, but

like those of the Elwha lithic assemblage. Quartz veins are very conspicuous. Much of the

unit, especially in the North Fork of the Skokomish River area, is so thoroughly sheared

the unit probably includes parts of the other Eocene to Oligocene(?) assemblages of the

Hoh lithic assemblage

Sandstone, siltstone, and shale exposed along the coast and in the western foothills

of the core are here referred to as the Hoh lithic assemblage. The Hoh Formation of Weaver (1916, p. 67-77, 275; 1937, p. 185-187) embraced nearly all the rocks exposed on the

coast between Cape Flattery and Point Grenville and in outcrops in a landward belt about

24 km wide. It was considered Oligocene and Miocene in age (Weaver, 1937, p. 186). The

the informal name "Hoh rock assemblage" for mostly Miocene strata of the general area,

formed as the east part of the core and as the undifferentiated rocks on the southeast part

of the core. Slaty cleavage is rarely developed even where bedding is completely disrupted

by penetrative shear. Most rocks of this unit contain laumontite. Quartz veins occur only

basis of numerous but scattered foraminifers (Rau. 1973, p. 5; written commun., 1972)

mouth (Rau, 1973, p. 6; W. O. Addicott, written commun., 1972). Uppermost Oligocene

elsewhere on the peninsula. They are bounded by shears or are associated with large shear

be in fault contact with the western Olympic assemblage and in part with the undifferen-

p. 2022-2023; see also Youngquist, 1961, p. 12), the Elk Ridge block, Mosquito Creek

block, and most of the Central block of Stewart (1970). Descriptions of rocks in the

assemblage are adapted from Stewart (1970, p. 10-20, 23-31, and table 1) and W.W. Rau

Undifferentiated rocks

Two areas of rock are included in a map unit designated "undifferentiated rocks": (1) Thick- to very thick bedded black sandstone with considerable slate and argillite in

the south-central part of the core extends eastward in a bent tongue between slate belts

semblage. These strata have yielded no definitive fossils; they may well include rocks of

the Quillayute River is mostly highly sheared, and some outcrops yield microfossils of

(W. W. Rau, written commun., 1975), indicating a probable mixture of Hoh and western

Eocene, Oligocene, and Miocene age. (2) Sandstone exposed between Mosquito Creek and

late Eocene and Oligocene age, whereas others yield fossils of early and middle Miocene age

Slaty cleavage and pencil structures are common, and bedding is strongly disrupted

on the east, especially in the southern fault zone. Although the rocks are well recrystallized,

foliated sandstone and semischist are rare. To the west, recrystallization is less intense even

in highly disrupted rocks such as those in the belt stretching from Quinault Lake to the

Queets River, along the Clearwater River, and in beach outcrops north of Mosquito Creek.

part of the Mosquito Creek block of Stewart (1970, p. 10, 12, 32, and table 1), and some

Quinault Formation and Quillayute Formation of Reagan (1909)

Harbor County. Horn (1969) and Rau (1973) summarized considerable earlier work and

described the Quinault Formation in detail. Descriptions here, except where otherwise

noted, are from Horn (1969, p. 44-150) and Rau (1970, p. 6-12). Similar rocks exposed along the Bogachiel River (near the Quillayute River) were first described as the Quillayute

ate, siltstone, and sandstone exposed near the mouth of the (

Formation by Reagan (1909, p. 203) and later by Weaver (1937, p. 195).

1970), although the Quinault may extend into the upper Miocene.

the Sumas Stade about 10,000 years ago (Crandell, 1965, p. 344).

The undifferentiated rocks include the Manor Ridge part of the central block and

Arnold (1906, p. 465) proposed the name Quinault Formation for slightly deformed

Both formations appear unconformably to overlie the steeply dipping older rocks of

the Hoh lithic assemblage. The lower contact of the Quinault Formation is exposed on the

by unconsolidated deposits. The Quinault has an exposed thickness of 1,400 m but may be

The formations are Pliocene (Rau, 1973, p. 13 and W. O. Addicott, written commun.,

Much of the lowlands and foothills of the north and east side of the Olympic Penin-

thicker than 1,770 m. Only 5-10 m of the Quillayute is exposed, and the total thickness

Glacial deposits

sula is mantled with glacial debris derived from the cordilleran ice sheet. The west and

southwest sides of the peninsula are flooded with moraine and outwash gravels associated

have been generalized from aerial photographs, and some were supplied by R. J. Stewart

(written commun., 1974). The contact between the cordilleran and alpine deposits along

Glacial and interglacial deposits of the cordilleran ice sheet include pre- or early

Salmon Springs Drift of the maximum ice advance more than 50,000 years ago (Heusser,

the Vashon Stade, on the order of 15,000 years ago (Armstrong and others, 1965, p. 327).

Drift derived from rocks in the peninsula was deposited in at least four glacial ad-

1974, p. 1550) and drift of several younger advances, the most extensive being that of

Ice readvanced on the east side of the Olympic Peninsula, in the Puget Lowland, during

vances, the greatest occurring before Salmon Springs time, more than 70,000 years ago

(Heusser, 1972, p. 199). Deposits of this early glaciation occur in the Hoh Valley and pro-

bably on Donkey Creek and Helm Creek (Heusser, 1974, p. 1558; see also Moore, 1965,

Stade of the Fraser Glaciation. On the west, major Olympic valley glaciers such as the

Bogachiel and Hoh retreated more than 19,000 years ago (Heusser, 1974, p. 1558).

Only the largest accumulations of Holocene surficial deposits are shown.

and Carson, 1970). The last major advance of the Olympic glaciers was in the Evans Creek

Surficial deposits

the South Fork of the Skokomish River is from W. A. Long (written commun., 1974).

with the Olympic alpine glaciers. Some of the contacts of these deposits and moraine crests

coast north of Pratt Cliff, but the Quillayute Formation of Reagan (1909) is surrounded

of the western Olympic lithic assemblage and slate and phyllite in the Elwha lithic as-

Basalt masses in the Hoh lithic assemblage are similar to dated Eocene basalt masses

Between the Hoh and the Clearwater Rivers, the Hoh lithic assemblage appears to

The Hoh lithic assemblage includes the Browns Point Formation of Glover (1940,

and diversified assemblage of megafossils from the north side of the Hoh River near its

(Zemorrian) foraminifers occur in some areas (W. W. Rau, written commun., 1975).

The rocks of the assemblage are predominantly early and middle Miocene, on the

The Hoh lithic assemblage is folded and faulted, but only locally is it as strongly de-

great heterogeneity of rocks referred to the Hoh Formation led Rau (1973, p. 5) to use

sandstone and semischist in less than 50 percent slate and phyllite with scattered basalt

of the Calawah River fault zone" of Gower (1960), the Spruce Mountain and the northeastern

part of the central blocks of Stewart (1970), and the Burma Road sequence of Tallyn (1972).

Southeastern part of the core

1960; R. J. Stewart, written commun., 1970; P. D. Snavely Jr. and N. S. MacLeod, written

lithic assemblage by its abundant sandstone and scarce basaltic rocks. The assemblage is

lithologically indistinguishable from the unit designated "undifferentiated rocks."

p. 45-46). The mollusks could be Refugian (latest Eocene or early Oligocene; W. O.

Addicott, written commun., 1974). Microfossils from scattered locations north of the

Grenville also contains late Eocene microfossils (Rau, 1973, p. 3). Lower and middle

River, and near Swan Bay on Lake Ozette (W. W. Rau, written commun., 1970; P. D.

exotics in the melange of the Calawah and other fault zones (fig. 2).

gillite occur only in localized zones on the west. Folding and faulting are pronounced

The western Olympic lithic assemblage underlies much of the west part of the core,

of apparent different provenance. Scattered microfossils identified by W. W. Rau are

written commun., 1974). Locally the rocks are highly disrupted.

abruptly, and many beds are overturned.

p. 20-34) and Tallyn (1972, p. 4-16).

features could no longer be identified

and we follow his example.

(written commun., 1974).

Olympic lithic assemblages.

in basaltic rocks.

that it is considered part of the southern fault zone.

tiated rocks (R. J. Stewart, written commun., 1974).

Folding and faulting are common throughout the unit.

of Stewart's rock descriptions have been incorporated on the map.

A fault-bounded unit of thick-bedded sandstone crops out in the northwestern part

of the core, which is similar in age to that of adjoining units but includes sedimentary rocks

thin-bedded rocks. A second cleavage has developed along axial planes of folded first

cleavage. Pencil structures in slates are common, and quartz veins are locally abundant.

Elwha lithic assemblage and Needles-Gray Wolf lithic assemblage, probably are also Eo-

cene in age. Poorly preserved foraminifers from limestone west of Wellesley Peak are

identifiable only as Tertiary (W. W. Rau, written commun., 1968).

cally displays boudinage and well-developed foliation.

The Grand Valley lithic assemblage has abundant sandstone and semischist (30-60

Formerly thinly interbedded shale and sandstone are now foliated breccia. Several cleav-

The Elwha lithic assemblage is intensely deformed. Although primary depositional

to outcrop-sized masses 3 m or less across. Features that help distinguish the Elwha

and scattered quartz granule conglomerate beds.

quartz veins are ptygmatically folded.

ten commun., 1968).

sandstone and semischist, and a few others are characterized by abundant thick-

considerable part of the upper Elwha River drainage and its tributaries. Slate, phyllite,

GEOLOGIC MAP OF THE OLYMPIC PENINSULA, WASHINGTON By R. W. Tabor and W. M. Cady

are very similar, but where exposures are poor, its trace can be inferred by lithologies;

sandstone of the Needles-Gray Wolf lithic assemblage of the core contains conspicuous

mica and is generally lighter colored and coarser grained than dark volcanic sandstone of

In general, volcanic rocks of the Crescent Formation intertongue with sedimentary

rocks of the overlying Aldwell Formation, although along the Sekiu River to the northwest

River Formations. In the Dungeness forks-Texas Valley area, the Blue Mountain unit may

well include rocks assigned elsewhere to the Aldwell and the lower part of the Twin River

ain unit is indistinguishable from most of the Aldwell and parts of the Lyre and Twin

Formation. In this area the Blue Mountain unit does include rocks mapped as undiffer-

entiated Lyre and Twin River by Brown, Gower, and Snavely (1960). Conglomerates of

this same area are similar to Lyre conglomerate, and some could be correlative. In the

Wynoochee River area, Rau (1967, p. 11) reports an unconformity at the top of the Cres-

except for phyllosilicates and zeolites. Basalt of the Crescent contains considerable preh-

southwest, the Blue Mountain unit contains rare metamorphic pumpellyite and (or) epi-

Mountain unit contains deep-water early(?) and middle Eocene (Penutian and Ulatisian

Stage of Mallory, 1959) planktonic for aminifers (Rau, 1964, p. G3-G4, written commun.

1965, 1972). Coccoliths are common in the limestone (Garrison, 1967, 1973), and some

identified by J. D. Bukry from sediments interbedded with Crescent basalt near Stolzen-

berg Mountain on the north limb of the horseshoe are of early Eocene age (Snavely and

others, written commun., 1974). Megafossils, abundant in basaltic sandstone at Crescent

beneath the main volcanic pile in the West Branch of the Wynoochee River area are Eocene

(Arnold, 1906; W. O. Addicott, written commun., 1971, 1973). Sedimentary rocks from

include gray limestone and interbedded mudstone that contain benthonic shallow-water

foraminifers that are middle (Rau, 1964, p. G3-G4) or possibly late Eocene W. W. Rau,

Big Ouilcene River contain numerous rounded exotic boulders (as much as 3 m across)

of hornblende quartz diorite with a hornblende age of 53.4 m.y. (Cady and others, 1966;

from red limestone at the base of the Crescent or from the Blue Mountain unit along the

age has not been substantiated; all subsequent attempts to recollect fossils from this loca-

Wynoochee River, are of Late Cretaceous age (R. D. Brown, written commun., 1972). This

lity have been unsuccessful. No other definite pre-Tertiary fossils have been found in rocks

Aldwell Formation

is predominantly dark marine mudstone and siltstone with minor dark, fine-grained sand-

stone, conglomerate, and lenses of pillow basalt, basalt breccia, and lapilli tuff. It overlies

and locally intertongues with the Crescent Formation on the northern part of the peninsula

(Carroll, 1959, fig. 8; McWilliams, 1965, p. 20-22). In the Mount. Zion area locally along

the north side of the peninsula the Aldwell is missing entirely. The Aldwell Formation in-

cludes part if not all of the fine-grained clastic rocks referred to the Boundary Argillite or

Shale by earlier workers (Weaver, 1937, p. 124; Loney, 1951, p. 19; Drugg, 1958, p. 28-29;

Bagley, 1959, p. 21-22; Lindquist, 1961, p. 23-26; Hamlin, 1962, p. 24-26; Strain, 1964,

others, 1960) but may be thicker to the west. It is middle and early late Eocene (upper

The formation is about 900 m thick in its type area near Lake Aldwell (Brown and

Ulatisian and lower Narizian; Rau, 1964, p. G4). Descriptions on the map are adapted from

Lyre Formation

Brown, Snavely, and Gower (1956) and Brown, Gower, and Snavely (1960) and applied to

rocks of similar lithology and stratigraphic position. Included in the Lyre Formation is the

very coarse breccia at Cape Flattery, Portage Head, Point of the Arches, and Abbey Island.

Also included in the Lyre is fossiliferous sandstone with minor shale near Maynard and in

local scour (Ansfield, 1972, p. 13), but it is unconformable in the Cape Flattery area (P. D.

Snavely, written commun., 1974). On Mount Zion the conglomerate is rich in clasts derived

from the underlying basalts, indicating that at least there it is a transgressive deposit; north

deposit. Conglomerate rich in volcanic material and leaf-bearing sandstone included in the

The thickness of the Lyre ranges from less than 300 m to more than 1,000 m in the

Fossils are scarce in the Lyre and its age has been mostly determined by its stratigra-

Microfossils from the breccia and conglomerate at the Point of the Arches and south

phic position. The northwestern outcrop belt has been referred to the late Eocene (Narizian)

(Brown and others, 1956; P. D. Snavely, Jr., and N. S. MacLeod, written commun., 1973).

of Portage Head are late Eocene (late Narizian to Refugian) as determined by W. W. Rau

(P. D. Snavely, Jr., and N. S. MacLeod, written commun., 1973). Sandstones at Maynard

are also late Eocene (W. O. Addicott, written commun., 1964; W. W. Rau, written commun.,

Unnamed sedimentary rocks

out in the Humptulips Wynoochee-Satsop area and have been described by Rau (1966, p.

Thin-bedded siltstone and sandstone in thrust contact with basaltic rocks of the Crescent Formation crop out on the northwestern peninsula between Waatch Point and

12-13; 1967, p. 13-15). They unconformably overlie the Crescent Formation and, on the

Bear Creek. These rocks are similar to parts of the Lyre Formation and the lower mem-

ber of the Twin River Formation and are less intensely deformed than the sandstones of

the western Olympic lithic assemblage to the south. Limited exposures of highly sheared

rock suggest that the Calawah fault separates the Twin River-like rocks from the western

Dikes and sills

sill intrudes black argillite. A K-Ar age of hornblende from the quartz diorite is 59±3 m.y.

(Snavely and others, 1972), but pervasive alteration suggests that this is a minimum age.

intrude the basaltic sandstone facies of the Blue Mountain unit northwest of Lake Cush-

a K-Ar age of 42.6±0.7 m.y., or late Eocene (Tabor and others, 1972).

man. The country rock is baked at the contact. Hornblende from a quartz diorite dike has

Twin River Formation

northern Olympic Peninsula composes the Twin River Formation. It was first described by

Arnold and Hannibal (1913, p. 584-585) but is used here as it was redefined and described

by Brown and Gower (1958). It has been divided into a lower, middle, and upper member

by Gower (1960) and Brown, Gower, and Snavely (1960), and Snavely, MacLeod, and Pearl

with an angular unconformity on the east in the Snow Creek area. The formation is about

5,000 m thick west of the Lyre River where it is overlain by the Clallam Formation. Micro-

zian to lower Refugian, Rau, 1964, p. G6) to early Miocene (Addicott, in press) to the north-

Twin River on the east. Descriptions of the members of the Twin River are modified from

Lincoln Creek Formation

A thick sequence of tuffaceous mudstone, siltstone, and sandstone, the Lincoln

Creek Formation, unconformably overlies the Crescent Formation and unnamed sedimen-

tary rocks in the Wynoochee and Satsop River areas. A basaltic sandstone is present at its base. The Lincoln Creek Formation was named and described by Beikman, Rau, and

Wagner (1967) in the Grays Harbor area to replace Weaver's (1912) name Lincoln For-

mation which was preempted. Similar rocks crop out in isolated spots around the south-

eastern slopes of the mountains as far as Hood Canal. Descriptions used here are adapted

Foraminiferal assemblages, mollusks, and pollen (Rau, 1966, p. 16-17; written

commun., 1972; W. A. Addicott written commun., 1968; R. H. Tschudy written commun.

Highly weathered shale and sandstone lying west of the West Fork of the Wishkah

The Quimper Sandstone was named by Durham (1942, p. 86-87) for marine sand-

The Quimper contains late Eocene (Refugian) microfossils (Berta and Armentrout,

The Clallam Formation consists of thick-bedded marine and nonmarine sandstone

1973, p. 11) and Oligocene mollusks (Durham, 1944); it correlates with the middle part of

Clallam Formation

and conglomerate with local coal beds. It was named by Arnold (1906, p. 461) but is

used here as restricted by Weaver (1937, p. 14A) and Gower (1960). The formation is

estimated to be more than 760 m thick (Gower, 1960). Sandstone and conglomerate

originally mapped with the Clallam Formation near Last Creek (Gower, 1960) are now

considered to be part of the upper Twin River Formation (H. D. Gower, written commun.

foraminiferal fauna and correlates with the lower part of the Astoria Formation of south-

western Washington (Gower, 1960; Addicott, 1975, p. 289; written commun., 1970). Des-

Astoria(?) Formation

sibly Luisian) in the Wynoochee River area have been described by Rau (1966, p. 17-18;

1967, p. 21-22) and questionably referred by nim to the Astoria Formation of Ethering-

ton (1931). The Astoria(?) Formation conformably overlies the Lincoln Creek Formation

Montesano Formation of Weaver (1912)

cribed by Rau (1966, p. 19-20; 1967, p. 28-34) who mapped three members of the unit

on the basis of the relative abundance of sandstone, siltstone and fine-grained sandstone,

and conglomerate. The unit overlies older formations with a pronounced unconformity

by Weaver (1937, p. 191, but Rau (1967, p. 34) revised its age to late Miocene and par-

tially correlated it with the lower part of the Quinault Formation (Rau, 1970, p. 13-14.

CORE ROCKS

rocks had been referred (Danner, 1955, p. 26) to the Cretaceous(?) Soleduck Formation

of Reagan (1909, p. 160-161), which, as originally defined, included the Blue Mountain

unit as well as core rocks as used here. Weaver (1937, footnote p. 17) restricted the Sole-

complex, no definite pre-Tertiary rocks have been found on the Olympic Peninsula. Al-

though Weaver (1915, p. 244) originally designated as Hoh Formation most of the rocks

described by Reagan as Soleduck, he later restricted the Hoh Formation to Tertiary rocks

ly arenaceous or pelitic rocks with or without stringers and pods of basaltic volcanic and

intrusive rocks. Although sedimentary structures are well preserved over much of the area

and parts of each lithic assemblage are in normal stratigraphic succession, most of the units

are broken formations; they are penetratively mesoscopically sheared throughout and pro-

bably bounded by major thrust faults (fig. 2). We do not know if any units are true me-

langes, that is, if they include exotic blocks of other stratigraphic units, but many basalt

and greenstone phacoids may be exotic, especially those in Oligocene and Miocene units

in the west and southeast parts of the core. Isoclinal folds are common in the east part

of the core, but predominant top directions are north, east, and southeast, that is, outward

from the core. West of Mt. Olympus structural trends of beds and top directions are more

ricane Ridge Road-to 300 m wide, as along the Gray Wolf fault a little west of Gray Wolf

Pass. In these zones all beds, including folded ones, are broken into boudins. In some areas,

such as along the Gray Wolf fault east of Grand Valley, folds in thick beds of sandstone

are truncated by the fault. In many areas all the rocks are so pervasively sheared that to

boundaries of mappable lithologic units, such as where thin-bedded, mostly pelitic rocks

of the core, especially coreward from the zone of basalt lenses in the Needles-Gray Wolf

ruption of all beds and the lack of distinct lithologic units make it difficult to map other

bounding faults westward, although they probably merge with the Hurricane Ridge fault

(fig. 2). From the Mount Stone area southwest to west of the North Fork of Skokomish,

formed rocks, mostly basalt of the Needles-Gray Wolf lithic assemblage. This fault and the

Rocks of the western part of the core are much less penetratively sheared and

recrystallized than the rocks of the eastern part of the core, but where mapped in great-

The thickness of the rock units is difficult to estimate because of the extreme

er detail, they appear to be broken up by major faults into blocks with distinct litho-

deformation, but the individual sequences of rock, such as the western Olympic lithic

a narrow belt of slaty tectonic breccia separates the disrupted core rocks from less de-

distributed shearing in rocks to the west are designated the southern fault zone.

logic assemblages and structural styles (see Stewart, 1970).

assemblage, were probably thousands of meters thick.

limit a fault to one line is somewhat arbitrary. In general, we have placed faults at the

adjoin a terrane rich in massive or thick-bedded sandstone. Along the southeast margin

lithic assemblage, shearing and disruption are particularly intense. The persistent dis-

The faults that bound the mapped units are revealed locally by zones of intense tectonism 60-80 m wide-such as along the Hurricane Ridge fault where it crosses the Hur-

The eastern part of the core is composed of elongate arcuate belts of predominant-

Because of this naming confusion and because the Soleduck Formation was never des-

duck to the pre-Tertiary part of the core sequence, but except for the Point of the Arches

Rocks in the core of the Olympic Mountains are Eocene to middle Miocene. Core

and appears to be at least 760 m thick in the Wynoochee Valley area.

The Montesano Formation, named by Weaver (1912, p. 20), has been further des-

It contains a rich mollusk assemblage and was considered late Miocene and Pliocene

Marine siltstone and sandstone of early and middle Miocene age (Saucesian to pos-

The Clallam Formation is early Miocene on the basis of an abundant molluscan and

1962) indicate that the Lincoln Creek is late Eocene and Oligocene (Refugian and Zemor-

rian). It correlates with the middle part of the Twin River Formation on the northern

River, which we have mapped as the Lincoln Creek Formation, may be the Astoria For-

Quimper Sandstone of Durham (1942)

stone on the east side of the Quimper Peninsula. On the west side of the peninsula, less

than 30 m of sandstone is exposed, resting with slight angular unconformity on older

beds (Durham, 1944, p. 106). A small outcrop of similar sandstone is exposed on the

fossils and megafossils indicate that the Twin River ranges in age from late Eocene (Nari-

west, although rocks younger than Oligocene (Refugian) have not been identified in the

(written commun., 1974), but these members have not been mapped on the eastern peninsula.

The Twin River Formation is mostly conformable with older units but overlies them

The unnamed sandstone and siltstone of the northwestern peninsula yield microfossils of middle and late Eocene age (Ulatisian to Refugian) (P. D. Snavely Jr. and others,

On the south side of Point of the Arches a hornblende microquartz diorite dike or

Dikes of feldspathic peridotite and hornblende quartz diorite (less than 100 m thick)

A thick series of marine sandstone, shale, and minor conglomerate exposed along the

Unnamed marine siltstone and sandstone, with conglomerate beds near the base, crop

of the Sekiu River the conglomerate contains little volcanic material and is a deep-water

Lyre unconformably overlie andesite tuff also included in the Lyre near Lake Gibbs.

Cape Flattery area (Ansfield, 1972, fig. 6) and on Mount Zion. Much of its variation in

thickness is due to facies changes (see Brown and others, 1956), but the Lyre appears to

Salmon Creek (Allison, 1959, fig. 9; Thoms, 1959, p. 17-18, fig. 9).

be truncated by the Twin River Formation in the Snow Creek area.

basis of foraminifers, are late Eocene (Narizian) (Rau, 1967, p. 14)

Olympic lithic assemblage (fig. 2).

Brown, Gower, and Snavely (1960).

from Rau (1966, p. 13–17; 1967, p. 16–20).

mation or the unnamed sedimentary rocks of Rau (1967).

west side of Port Discovery, just south of Gibb Point.

the Twin River and the Lincoln Creek Formations.

cription of the unit is based on Gower (1960).

and is as much as 1,070 m thick (Rau, 1967, p. 21).

cribed as a mappable unit, we do not use it here.

part of the peninsula

written commun., 1974).

The Lyre Formation, named by Weaver (1937, p. 121), is used here as redefined by

Locally the Lyre appears to be conformable on the underlying Aldwell except for

The Aldwell Formation, named and described by Brown, Gower, and Snavely (1960),

Basalt flows and interbedded mud flow breccias in the lower Crescent north of the

Globotruncana Foraminifera, collected by Hollis Hedberg (written commun., 1958)

the upper part of the Crescent Formation exposed on the north side of the peninsula

Bay, and gastropods from the thick-bedded sandstone facies of the Blue Mountain unit

Pelagic red limestone in the lower part of the Crescent Formation and in the Blue

nite and pumpellyite. However, from the area of the Hamma Hamma River south and

Most of the peripheral sedimentary rocks contain no regional metamorphic minerals

the formations are unconformable (P. D. Snavely, written commun. 1974). The Blue Mount-

INTRODUCTION The Olympic Peninsula has long been a geologic puzzle because of its inaccessibility, and exploration of the rugged mountainous interior came late in the history of the United States. The *Press* Party crossed the range in the winter of 1889-90 and reported slate and sandstone in the core, but they lost all their geologic specimens when their raft capsized on the Quinault River (Wood, 1967, p. 108, 192). Serious geologic studies of the peninsula began with Arnold (1906). Reagan (1909), Weaver (1912, 1916), Lupton (1914), and Palmer (1927). Most of this early work was confined to the coast and flanks of the mountains on the northwestern peninsula. Weaver (1937, p. 26-34) established a general picture of Olympic Peninsula geology, but the first systematic mapping was begun in the late 1930's by the U.S. Geological Survey's manganese project under the leadership of C. F. Park, Jr. (1942, 1946) and by Walter Warren (1941). About this same time students from the University of Washington began mapping small areas (fig. 1) and one student, Wilbert Danner, prepared the first summary of Olympic geology (Danner, 1955). Our work stems in part from the early mapping of Park and Warren and the later quadrangle mapping of Gower (1960) and Brown, Gower, and Snavely (1960). In 1961

Figure 1. Maps showing sources of data

the Blue Mountain unit.

cent Formation.

written commun., 1965, 1968).

Brown, Gower, and Snavely (1960).

Engels and others 1976).

we began 1:62,500-scale mapping in the Tyler Peak and Brothers quadrangles (Cady, Tabor, MacLeod, and Sorensen 1972; Cady, Sorensen, and MacLeod 1972) and extended the work westward into the Mount Angeles quadrangle (Tabor and others, 1972). We began reconnaissance mapping of the entire peninsula in 1969 and concluded fieldwork in 1973. The data for this map have been drawn from all the aforementioned workers and many more (fig. 1, sources of data). Considerable help with the mapping was given by

Norman S. MacLeod (1961-62). Martin L. Sorensen (1964-68), Richard J. Stewart (1967-71), Robert B. Tallyn (1969-70), Robert S. Yeats (1968-69), Kenneth Pisciotto (1971), and Robert Koeppen (1972). Able field assistants were Steve MacAlpine (1967), Larry Wallace (1969), William Glassley (1970), Tjuke Suradi (1970), John Shervais (1971), Eduardo Rodriguez (1972), and Diana Porter (1972). National Park and National Forest personnel have been most helpful. We thank in particular George Bowen, Mike and Paula Doherty, Glen Gallison, Jack and Jane Hughes, David Huntzinger, David Karracker, Louis Kirk, Robert Kaune, and Bruce Morehead of Olympic National Park, and Bob L. Barstad, Terry Fieldhouse, Jack Grubb, Pat Hannah, Bryton Lausch, Harold Nyberg, and Marvin Smith of Olympic National Forest Dutch Quam of River Trails Ranch and Nick and Pearl Nikodym of Nob Hill Ranch packed most ably for us many times. John Olson provided campsites and Charlie Lewis, a helicopter pad. Crown-Zellerbach Corporation and Rayonier Corporation allowed study

on private lands on the northwestern peninsula. Helpful discussion and stimulation have been given by Warren Addicott, Val Ansfield, Robert Brown, Robert Carson, Dwight Crandell, Howard Gower, Arthur Grantz, Dan Horn, John Livingston, Allan Koch, Norman MacLeod, Stan Mallory, Mike Miller, Robert Orwig, Steve Porter, Weldon Rau, Parke Snavely, Jr., Sig Snelson, Dick Stewart, and Robert Yeats.

DEFINITIONS Bedding thickness Very thin bedded 1-5 cm (centimeters) Thin bedded 5-60 cm Thick bedded 60-120 cm Very thick bedded greater than 120 cm Broken formation A mappable rock unit characterized by strong tectonic disruption, mostly by shearing, but maintaining some lithologic character and continuity; does not contain exotic blocks (Hsu, 1968,p. 1066). Less than 1/16 mm (millimeter) Grain size Very fine sand 1/16-1/8 mm 1/8-1/4 mm Fine sand Medium sand 1/4 - 1/2 mmCoarse sand 1/2-1.0 mmVery coarse sand 1-2 mm 2-4 mm Granule Pebble 4-64 mm Cobble 64-256 mm Boulder greater than 256 mm

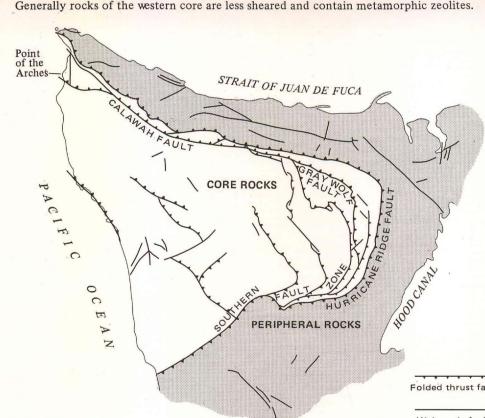
Melange A mappable body of rock characterized by extreme tectonic disruption, mostly by penetrative shear, and containing numerous blocks of exotic rock incorporated from other stratigraphic units (after Hsu, 1968). = 0.0394 inchMetric conversion millimeter = 0.394 inch= 3.28 feet1 kilometer = 0.62 mile Pencil structure Elongate slivers or rods of rock ranging in size from 1 x 5 cm to 0.2 x 1 m bounded by intersecting cleavages or bedding and cleavage. Mostly confined to pelitic rocks but crudely developed in some sand-Phacoid

An augen, lens, or pod of rock in a foliated matrix. As used here generally refers to tectonic inclusion of sandstone or semischist from a few centimetres to many kilometres in dimension enclosed in a matrix of sheared argillite, slate, or phyllite. Rhythmite sequence Evenly spaced, generally graded, sandstone beds alternating with finer grained sandstone or siltstone; commonly beds are several to 50 cm thick, and of relatively constant thickness in any one sequence. Sandstone classification after Crook (1960).

Note: Most Olympic sandstones fall in this field. For brevity, subquartzose is The sandstones of the Olympic Peninsula are varieties of graywacke. Placement of rocks in this classification scheme has been done mostly by estimating abundance

of grains in thin section. Sedimentary breccia Sandstone with abundant argillite or slate chips ranging from 2 to 20 cm across; slate chip breccia. Semischist Foliated sandstone with crudely alined minerals and MAJOR GEOLOGIC TERRANES Two major bedrock terranes make up the Olympic Peninsula: the peripheral rocks

and the core rocks (fig. 2). The oldest peripheral rocks are sandstone, argillite, and conglomerate, the Blue Mountain unit, that underlie and intertongue with lower(?) and middle Eocene basaltic volcanic rocks, the Crescent Formation. The outcrop belt of the Crescent Formation forms a large horseshoe pattern open on the west. The Crescent is overlain by fossiliferous Eocene through Miocene sedimentary rocks of mostly marine origin. All the peripheral rocks are folded and faulted, but they are in general stratigraphically continuous. In contrast, the rocks in the core are highly deformed, although they also range in age from early(?) and middle Eocene to middle Miocene. The rocks of the eastern core are penetratively sheared and metamorphosed in the pumpellyite and low greenschist facies. Generally rocks of the western core are less sheared and contain metamorphic zeolites.



High-angle fault Figure 2. Map showing major geologic terranes, faults, and speculative faults The oldest rocks of the peninsula are exposed only at Point of the Arches on the coast. On sea cliffs and sea stacks, metamorphosed and altered Jurassic or older pyroxene gabbro is overlain by probable pre-Tertiary pillow basalt and sedimentary rocks. The whole complex is overlain unconformably by Eocene sedimentary breccia and conglomerate of the Lyre Formation. The youngest rocks of the peninsula are relatively undeformed marine and brackish estuarian clastic sedimentary rocks, the Pliocene Quinault Formation and the Pliocene Quillayute Formation of Reagan (1909). They crop out only on the west side of the Glacial debris derived from a continental ice sheet surrounds the mountains on the

northwest, north, east, and southeast. Many mountain valleys and much of the lowland on the west are flooded with gravels derived from the Olympic alpine glaciers. Moraines of Olympic glaciers dot the higher slopes and valleys as well. GENERAL DESCRIPTION OF THE ROCK UNITS

Point of the Arches pluton and associated rocks The predominant rock is massive to gneissic, altered uralitic gabbro and diorite with minor irregular bodies of hornblendite and cataclastic plagioclase gneiss. Along the coast on the south, the gabbro is overlain by pillow basalt that in turn is in fault contact with highly faulted argillite and sandstone intruded by a microquartz diorite dike or sill. On the northern shore the gabbro is bordered by a wide argillaceous shear zone containing large phacoids (some larger than 3 m) of sandstone, greenstone, and hornblende quartz diorite. Some of the rocks in this zone resemble the probable pre-Tertiary sedimentary rocks on the south side of the pluton; others look like the Tertiary rocks of the Olympic Mountains. The entire complex is overlain unconformably by the upper Eocene Lyre Formation, here a breccia and conglomerate containing a variety of pre-Tertiary clasts including many of gabbro and diorite similar to rocks in the complex. Hornblende from the uralitic gabbro has a K-Ar age of 144±2.4 m.y. The sedimentary rocks on the south are intruded by a 59-m.y.-old dike or sill (Snavely and others, 1972; Engels and others, 1976). The pervasive metamorphism of all the rocks indicates that these are minimum ages; the plutonic rocks are thus assigned a Jurassic or older age, and the sedimentary rocks a probable pre-Tertiary age. The plutonic rocks resemble the

lower Paleozoic Turtleback Complex of the San Juan Islands described by McLellan (1927, p. 142-154) and Mattinson (1972, p. 3769-3777). PERIPHERAL ROCKS

Crescent Formation and the Blue Mountain unit The name Crescent Formation was first applied by Arnold (1906, p. 460) to volcanic and volcaniclastic rocks in the vicinity of Crescent Bay and is used here with modification as it was applied by Brown, Gower, and Snavely (1960) to the volcanic and volcaniclastic rocks, hypabyssal intrusive rocks, and sedimentary interbeds exposed between Lake Crescent and Morse Creek. Intertongued and interbedded with the Crescent Formation are dark sandstone, argillite, and minor conglomerate that, although predominantly older than the Crescent, are in part coeval and younger. We refer these rocks to the Blue Mountain unit but describe them with the Crescent Formation because of their intimate depositional relation to it. We also include in the Crescent Formation isolated masses of basaltic rocks cropping out in the Blue Mountain unit that are on strike with as well as stratigraphically below the main part of the Crescent Formation. The Crescent Formation consists of basaltic rocks that are predominantly oceanic tholeiite with some alkalic tholeiite. On the basis of TiO₂, P₂O₅, and K₂O content, the basalt appears to be like ridge, seamount, or intra-arc basin tholeiite. Glassly (1974) considers the lower unit to be of ocean ridge origin and the upper unit to be of oceanic island origin on the basis of differences in TiO2 and rare-earth element content. The lower unit is characterized by abundant pillows and planktonic foraminifers (Rau, 1964, p. G3, G13-G14). The upper unit has much more breccia, sedimentary interbeds with benthonic foraminifers (Rau, 1964, p. G14), and scattered columnar-jointed flows. These flows are

especially conspicuous along Hood Canal. Most of the manganese deposits occur in the lower part of the lower unit as demonstrated by the location of prospects on the map (partly compiled from Magill, 1960). The thickness of the Crescent Formation varies considerably. Maximum thickness is unknown owing to folding and perhaps faulting. In the Dosewallips region the formation may be more than 15 km thick (Cady, Tabor, MacLeod, and Sorensen, 1972; Cady, Sorensen, and MacLeod, 1972; compare with Glassley, 1974, p. 792). Northwest of Blue Mountain, marine sedimentary sandstone and shale of the Blue of black sandstone.

Mountain unit appear to fill a gap between two separate accumulations of basalt, although a possible angular unconformity near the Deer Park road (Tabor and others, 1972) indicates that the stratigraphic relation may be more complicated. Two coeval facies of the Blue Mountain unit are mapped on the south and southeast sides of the Olympic Mountains a facies with conspicuous, thick beds of basaltic sandstone and a facies rich in thick beds Most of the peripheral rocks are separated from the core rocks by faults, including the Calawah fault and the Hurricane Ridge fault and its continuation to the south. Shearing of rock along the faults is well exposed in only a few areas, such as along the Hurricane Ridge Road near Boulder Creek north of the Hamma Hamma River, and in Slate Creek above Staircase Ranger Station. The rocks on either side of the Hurricane Ridge fault

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