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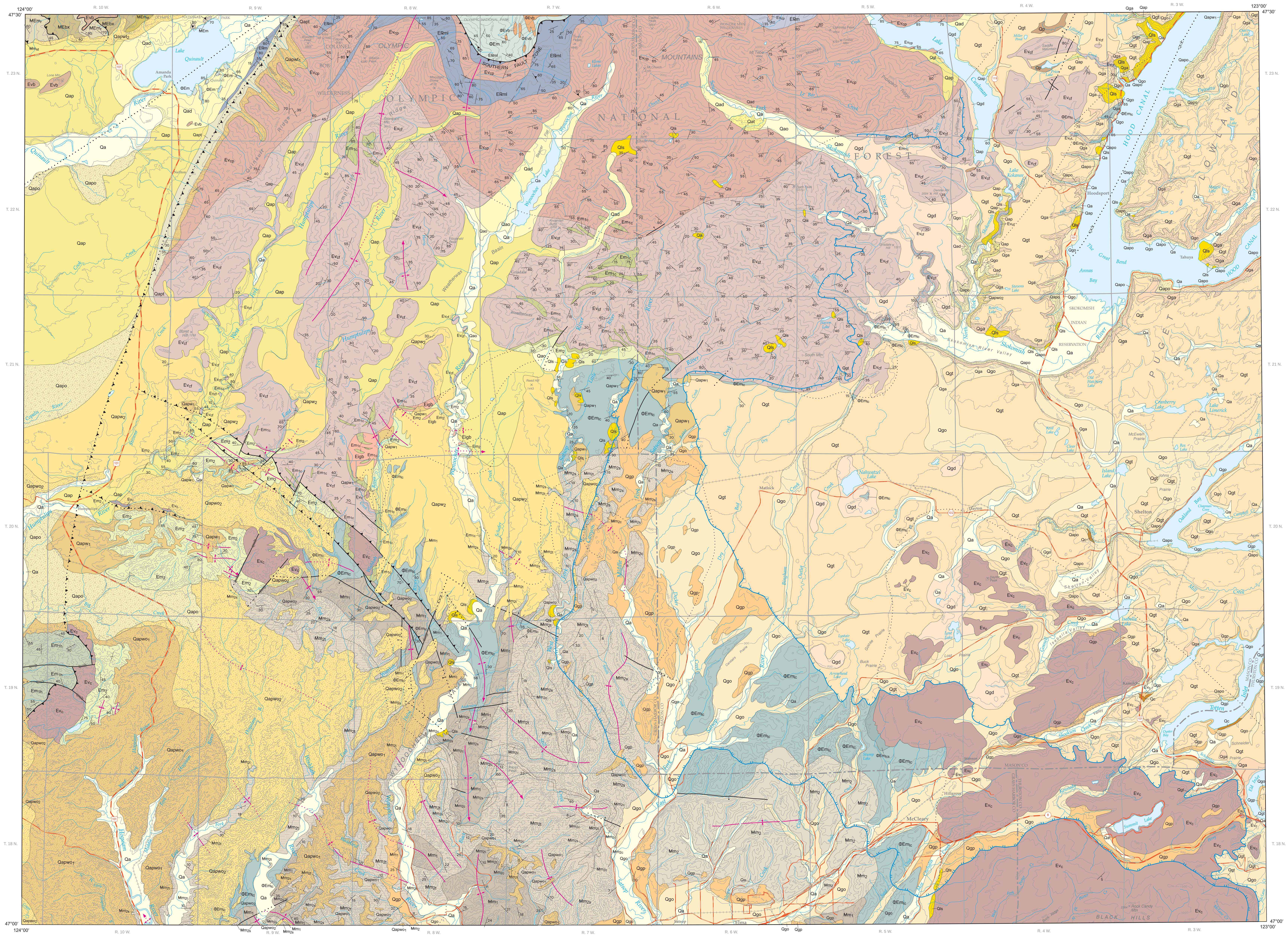


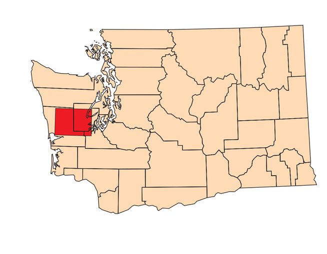
Lambert conformal conic projection
North American Datum of 1927
Base map information from the Washington Department of Natural Resources Geographic Information System
Digital cartography by Anne C. Heinitz, Charles G. Caruthers, and J. Eric Schuster.
Editing and production by Karen D. Meyers and Jaretta M. Roloff

SCALE 1:100 000

1 0 1 2 3 4 5 6 7 8 MILES

1 0 1 2 3 4 5 6 7 8 9 10 KILOMETERS

contour interval 100 feet (500 feet above 500 feet elevation)



Geologic Map of the Shelton 1:100,000 Quadrangle, Washington

by Robert L. Logan

2003

INTRODUCTION

Methods and Nomenclature

This map was compiled from previously published geologic maps and unpublished thesis maps, and supplemented by reconnaissance field mapping and remote sensing studies using aerial photos, digital elevation models, and Side-Looking Airborne Radar (SLAR) images. Although Quaternary and some bedrock unit boundaries are commonly diffuse or obscured by heavy vegetation or weathering, they are depicted by solid lines on this map.

Geologic unit symbols indicate the age and general rock type of the unit they symbolize and may have a subscript that identifies a formation or a finer age break. Unit symbols for Olympic Mountains–derived alpine glacial deposits were chosen to show relative time of deposition rather than symbolize the unit names assigned by the original mappers. This reduces the need for arbitrary scratch boundaries between indistinguishable units in areas where ice from different drainages merged beyond the Olympic Mountains front.

Geology

Paleocene to Eocene marine sedimentary rocks of the Blue Mountain unit (Tabor and Cady, 1978) are the oldest rocks in the quadrangle. However, Eocene marine volcanic rocks of the Crescent Formation, which overlie and interfinger with the Blue Mountain unit at their base, form the basement throughout most of this quadrangle. In the northwest part of the quadrangle, these two units are separated from Miocene to Eocene marine sedimentary rocks of the Olympic Peninsula core by the Southern fault zone (Tabor and Cady, 1978). The Eocene to Oligocene Lincoln Creek Formation was deposited on the Crescent Formation basaltic basement rocks. In the Miocene, the Astoria Formation was deposited on the Lincoln Creek Formation, followed by the Montesano Formation in the late Miocene. These units are located in the south-central part of the quadrangle in the northern part of the Grays Harbor sedimentary basin (Snavely and Wagner, 1963; Fowler, 1965). All of the bedrock units have been folded and faulted as a result of continued transpression along the western edge of the North America plate.

Olympic Mountains–derived alpine glacial deposits cover much of the northern and western parts of the map area. The eastern part of the map area is capped by sediments deposited by ice that originated in the northwestern part of the North American continent along the Canadian part of the Cordillera. These glacial deposits are referred to as continental or Cordilleran deposits.

Geologic mapping of alpine glacial deposits has historically been either of a regional reconnaissance nature or restricted to discrete drainage basins. As a result of the basin-mapping approach, local names were given to many glacial deposits throughout the southern Olympic Mountains. In this map, an attempt has been made to make approximate age correlations between these locally named units. Previous studies are outlined below and are followed by an explanation of the approach used in this map to depict alpine glacial units.

Crandell (1964) completed a reconnaissance report in which he described four major alpine glacial advances in the southwest Olympic Mountains. He maintained that three of these advances occurred during Wisconsinan time and one during pre-Wisconsinan time, and that “the only surficial deposit of probable glacial origin beyond the outermost till of Wisconsin age is fluvial gravel”, referring to extensive iron-oxide-stained gravels north of Grays Harbor. He based his age determinations on weathering and physiographic characteristics of the deposits, but his conclusions about the timing of the four alpine glacial advances do not agree with those of later workers.

Moore (1965) mapped and named three alpine glacial advances in the Quinault River drainage basin. He named his glacial units, from oldest to youngest, the Donkey Creek drift, the Humptulips drift, and the Chow Chow drift. However, he assigned the extensive gravel deposits north of Grays Harbor a pre-Pleistocene age and suggested that these gravels are of nonglacial origin.

Carson (1970) mapped and named alpine glacial units in the vicinity of the Wynoochee River based on relative terrace levels, weathering characteristics, and degree of stream dissection. His units from oldest to youngest are the Wedekind Creek formation, the Mobray drift, and the Grisdale I to VI drifts. He also described a primarily continental glacial drift he named the Helm Creek drift (not shown on this map). He suggested that the Helm Creek drift was deposited sometime after the Wedekind Creek Formation but before a continental glacial drift that he thought was the Salmon Springs Drift. However, his “Salmon Springs” drift was later shown to be the Double Bluff Drift by Easterbrook and others (1981). He also described the Weatherwax formation, which he interpreted as outwash that was deposited between lobes of the Mobray drift and his “Salmon Springs” drift.

Thackray (1996) studied moraines in the Hoh and Queets River drainage basins to the northwest of the Shelton quadrangle, where he also proposed the existence of four alpine ice advances. He provides evidence that the oldest of the drifts, the Wolf Creek, is reversely magnetized, indicating an age of at least 780,000 yr, corresponding to the end of the last magnetic reversal. His next youngest unit, the Whale Creek drift, he assigns to oxygen isotope stage 6, which corresponds to the glaciation immediately preceding the last major interglacial period. This roughly corresponds to the Double Bluff Drift of the Puget Lowland at more than 125,000 yr (Thackray, 1996). His Lyman Rapids drift forms outwash terraces that parallel the modern and last interglacial shorelines and are indistinguishable from the older portions of Moore’s Chow Chow outwash on the basis of rock materials, stratigraphy, geomorphology, and weathering characteristics. Thackray assigned late Wisconsinan ages to his youngest alpine drift units, the Twin Creeks and Hoh Oxbow drifts.

On this map, units Qapw$_1$ (drift), Qapwo$_1$ (outwash), and Qapwt$_1$ (till) are the oldest pre-Wisconsinan units and include the Wedekind Creek formation and possibly part of the Weatherwax formation of Carson (1970) and the Donkey Creek drift and “moderately to intensely deformed sand and gravel” (north of Grays Harbor) of Moore (1965), and are probably age equivalent to the Wolf Creek drift (Thackray, 1996).

Units Qapw$_2$, Qapwo$_2$, and Qapwt$_2$ are the younger pre-Wisconsinan units and include unnamed drifts in the East Fork and West Fork Humptulips Rivers, the Mobray drift (Carson, 1970), and the Humptulips drift and “flat lying and slightly deformed sand and gravel” (north of Grays Harbor) of Moore (1965), and are probably age-equivalent to the Whale Creek drift of Thackray (1996).

Units Qap, Qapo, and Qapt are pre–late Wisconsinan and include the Grisdale I and II drifts of Carson (1970), unnamed drifts in the Humptulips River valley, and the older part of Moore’s (1965) Chow Chow drift (southwest of Lake Quinault), and are probably age equivalent to Thackray’s Lyman Rapids drift. The Skokomish Gravel, considered by Molenaar and Noble (1970) to be nonglacial alpine fluvial gravel but interpreted here and by Carson (1979) as alpine outwash, is included in unit Qapo because it is probably much older than the Olympia nonglacial interval (Carson, 1979); all or parts of this unit could be pre-Wisconsinan.

The youngest Pleistocene alpine units are Qad, Qao, and Qat and are interpreted here to include the younger part of the Chow Chow drift of Moore (1965) in the Quinault basin (which constitutes the moraine impounding Lake Quinault), the Grisdale III and VI drifts of Carson (1970), a glacial outburst flood deposit in the West Fork Satsop River, and an unnamed drift in the upper reaches of the Skokomish River basin. These units were likely deposited at the same time as the Twin Creeks and Hoh Oxbow drifts (Thackray, 1996) in the Queets and Hoh River basins.

Alpine glacial deposits in this quadrangle are derived almost exclusively from the marine sedimentary and volcanic bedrock of the interior of the Olympic Peninsula. Beyond the mountain front, other rock types have been, to a very small degree, incorporated into the alpine deposits. In contrast, continental glacial deposits characteristically contain granitic and metamorphic rock and abundant polycrystalline quartz.

Molenaar and Noble (1970) described the continental glacial deposits and provided an overview of the glacial history of southeastern Mason County in the southern Puget Lowland. Their units included deposits of Vashon Stade of the Fraser Glaciation and pre–Vashon Stade glacial and nonglacial units. Carson (1970) mapped the extent of two continental ice advances adjacent to the southern Olympic Mountains and suggested that the oldest and most extensive of these deposits correlates with the Salmon Springs Drift near Puyallup. Not until Easterbrook and others (1981) obtained radiometric ages on the Lake Tapps tephra in the Puget Lowland was it recognized that the Salmon Springs deposits were older than previously thought and that at least two glacial advances, the Possession and Double Bluff, were not represented in the stratigraphy of the Puyallup site. Easterbrook and others (1981) maintained that because the Possession Drift advanced only as far south as Tacoma, Carson’s “Salmon Springs” drift is more likely the Double Bluff Drift.

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REFERENCES

Brandon, M. T.; Vance, J. A., 1992, Tectonic evolution of the Cenozoic Olympic subduction complex, Washington State, as deduced from fission track ages for detrital zircons: American Journal of Science, v. 292, no. 8, p. 565-636.

Carson, R. J., 1970, Quaternary geology of the south-central Olympic Peninsula, Washington: University of Washington Doctor of Philosophy thesis, 67 p., 4 plates.

Carson, R. J., 1976, Geologic map of north-central Mason County, Washington: Washington Division of Geology and Earth Resources Open File Report 76-2, 1 sheet, scale 1:62,500.

Carson, R. J., 1979, Reinterpretation of the Skokomish gravel, southwestern Puget Lowland, Washington [abstract]: Northwest Scientific Association, Annual Meeting, 52nd, Program and Abstracts, p. 31.

Crandell, D. R., 1964, Pleistocene glaciations of the southwestern Olympic Peninsula, Washington: U.S. Geological Survey Professional Paper 501-B, p. B135-B139.

Easterbrook, D. J., 1985, Correlation of Pleistocene deposits in the northwestern U.S. [abstract]: Geological Society of America Abstracts with Programs, v. 17, no. 7, p. 571.

Easterbrook, D. J.; Briggs, N. D.; Westgate, J. A.; Gorton, M. P., 1981, Age of the Salmon Springs glaciation in Washington: Geology, v. 9, no. 2, p. 87-93.

Fowler, G. A., 1965, The stratigraphy, foraminifera and paleoecology of the Montesano Formation, Grays Harbor County, Washington: University of Southern California Doctor of Philosophy thesis, 355 p.

Molenaar, Dee; Noble, J. B., 1970, Geology and related ground-water occurrence, southeastern Mason County, Washington: Washington Department of Water Resources Water-Supply Bulletin 29, 145 p., 2 plates.

Moore, J. L., 1965, Surficial geology of the southwestern Olympic Peninsula: University of Washington Master of Science thesis, 63 p., 1 plate.

Porter, S. C., 1970, Glacier recession in the southern and central Puget Lowland, Washington, between 14,000 and 13,000 years B.P. [abstract]: American Quaternary Association, Meeting, 1st, p. 107.

Rau, W. W., 1966, Stratigraphy and foraminifera of the Satsop River area, southern Olympic Peninsula, Washington: Washington Division of Mines and Geology Bulletin 53, 66 p., 8 plates.

Rau, W. W., 1967, Geology of the Wynoochee Valley quadrangle, Grays Harbor County, Washington: Washington Division of Mines and Geology Bulletin 56, 51 p., 1 plate.

Rau, W. W., 1973, Geology of the Washington coast between Point Grenville and the Hoh River: Washington Division of Geology and Earth Resources Bulletin 66, 58 p.

Rau, W. W., 1981, Pacific Northwest Tertiary benthic foraminiferal biostratigraphic framework—An overview. *In* Armentrout, J. M., editor, Pacific Northwest Cenozoic biostratigraphy: Geological Society of America Special Paper 184, p. 67-84.

Rau, W. W., 1984, The Humptulips Formation—A new Eocene formation of southwest Washington: Washington Geologic Newsletter, v. 12, no. 4, p. 1-5.

Rau, W. W., 1986, Geologic map of the Humptulips quadrangle and adjacent areas, Grays Harbor County, Washington: Washington Division of Geology and Earth Resources Geologic Map GM-33, 1 sheet, scale 62,500.

Rigg, G. B., 1958, Peat resources of Washington: Washington Division of Mines and Geology Bulletin 44, 272 p.

Schuster, R. L.; Logan, R. L.; Pringle, P. T., 1992, Prehistoric rock avalanches in the Olympic Mountains, Washington: Science, v. 258, no. 5088, p. 1620-1621.

Snavely, P. D., Jr.; Brown, R. D., Jr.; Roberts, A. E.; Rau, W. W., 1958, Geology and coal resources of the Centralia–Chehalis district, Washington, with a section on Microscopical character of Centralia–Chehalis coal, by J. M. Schopf: U.S. Geological Survey Bulletin 1053, 159 p., 6 plates.

Snavely, P. D., Jr.; Wagner, H. C., 1963, Tertiary geologic history of western Oregon and Washington: Washington Division of Mines and Geology Report of Investigations 22, 25 p.

Tabor, R. W.; Cady, W. M., 1978, Geologic map of the Olympic Peninsula, Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-994, 2 sheets, scale 1:125,000.

Thackray, G. D., 1996, Glaciation and neotectonic deformation on the western Olympic Peninsula, Washington: University of Washington Doctor of Philosophy thesis, 139 p., 2 plates.

DESCRIPTION OF MAP UNITS

Quaternary Sediments

NONGLACIAL DEPOSITS

Qa — **Alluvium (Holocene)**—Sorted combinations of silt, sand, and gravel deposited in streambeds and alluvial fans; clasts are generally rounded and composed of sandstone, derived either from local bedrock sources or from reworked Olympic Peninsula (alpine) and Puget Lowland (continental) glacial deposits; locally may include alpine drift, peat, lacustrine, or landslide deposits; surface is undissected by streams relative to pre-Holocene terrace surfaces.

Qls — **Landslide deposits (Holocene)**—Poorly sorted mixtures of locally derived rock and (or) soil emplaced by mass-wasting processes; deposits vary widely in size, composition, and mode of emplacement; only the largest landslides are shown; includes rock falls (Schuster and others, 1992) in the southeast Olympic Peninsula that are probably seismically induced, and large deep-seated landslides along Hood Canal (Carson, 1976) and along steep-sided inner gorges of river valleys in the southern Olympics; smaller shallow deposits such as debris flows in steep mountain drainages and rock topples along coastal bluffs, although numerous and dangerous, are too small to show at the map scale.

Qp — **Peat (Holocene)**—Fibrous peat, woody peat, muck, lake mud, and sphagnum; fibrous peat is light to dark brown to reddish brown, muck is black, and lake mud and woody peat are steel gray (Rigg, 1958).

Qc — **Undifferentiated sedimentary deposits (Pleistocene)**—Silt and fine sand with interbedded, radiocarbon-infinite peat and organic hash layers; generally tens of feet thick; nonindurated; olive-brown where oxidized to blue-gray where fresh; locally interbedded with or underlying the Skokomish Gravel and locally contains dropstones; may contain both glacial and nonglacial components.

ALPINE GLACIAL DEPOSITS

Qad — **Alpine drift, late Wisconsinan (Pleistocene)**—Undifferentiated medium-gray till and outwash sand and gravel with little to no weathering apparent; clasts consist mostly of local sandstone and basalt; may contain alluvium, colluvium, landslide debris, and peat; generally restricted to upper reaches of valleys in the Olympic Mountains.

Qat — **Alpine till, late Wisconsinan (Pleistocene)**—Compact, poorly sorted mixture of silt, sand, gravel, and rare boulders; light gray; clasts larger than pebble size are commonly faceted and striated; sand fraction is generally very angular; composed mostly of Crescent Formation basalt but may also contain sedimentary and low-grade metasedimentary rocks from the interior of the Olympic Mountains; most commonly occurs as 1 to 2 ft thick layers of lodgment till on bedrock, but also occurs in apparently much thicker pockets; many outcrops are not extensive enough to show at map scale.

Qao — **Alpine outwash, late Wisconsinan (Pleistocene)**—Stratified sand and gravel derived from Crescent Formation basalt or sandstone of the Olympic Mountains; may contain other local rock types in lower reaches of Olympic streams; locally contains silt and clay; generally not deeply weathered; composes lower stream terraces; stream dissection of terrace surfaces is poorly developed.

Qap — **Alpine drift, pre–late Wisconsinan (Pleistocene)**—Undifferentiated till and outwash sand and gravel; gray with local orange weathering; locally covered with cream-colored weathered loess; consists of mostly ground and end moraine.

Qapo — **Alpine outwash, pre–late Wisconsinan (Pleistocene)**—Stratified sand, gravel, and cobbles; in the Quinault basin, clasts consist of sandstone and less-abundant basalt from the Olympic Mountains core and peripheral rocks; in streams draining the southern and southeastern Olympics, clasts consist primarily of Crescent Formation basalt with less-abundant Olympic-core sandstone; may include peat, silt, and clay, and may be capped by weathered loess; clasts are generally more rounded than those in till and lack facets and striations; poorly to moderately sorted; gray to subtle yellow with wispy orange weathering.

Qapt — **Alpine till, pre–late Wisconsinan (Pleistocene)**—Compact, gray to brown, poorly sorted mixture of silt, sand, gravel, and boulders of local provenance found at lower elevations along the north side of Quinault Ridge; occurs as lodgment till covering bedrock; small-size fraction is very angular; larger-size fraction is commonly faceted and striated; may also contain older till.

Qapw$_2$ — **Alpine drift, younger pre-Wisconsinan (Pleistocene)**—Undifferentiated till, outwash sand and gravel, lacustrine silt and clay, and loess; clasts are composed primarily of basalt and sandstone from peripheral and core rocks of the Olympic Peninsula; weathered to depths exceeding 12 ft; red-orange weathering rinds on clasts; ancient surfaces are moderately dissected by streams; locally covered with a well-developed soil and strongly incised by streams, indicating possibly greater age.

Qapwt$_2$ — **Alpine till, younger pre-Wisconsinan (Pleistocene)**—Compact mixture of silt, sand, and gravel; may contain some faceted and striated boulders; may also contain outwash or loess; deeply weathered to brownish red; located along the north side of the Quinault River valley; true age unknown; mapped by Moore (1965) as Humptulips till and drift.

Qapwo$_2$ — **Alpine outwash, younger pre-Wisconsinan (Pleistocene)**—Sand and gravel composed of sandstone and basalt derived from the core of the Olympic Mountains; clasts are generally moderately to well rounded with characteristic red-orange weathering rinds; poorly to moderately sorted; weathered to depths exceeding 12 ft.

Qapw$_1$ — **Alpine drift, older pre-Wisconsinan (Pleistocene)**—Undifferentiated till, outwash sand and gravel, and lacustrine silt and clay; deep red-orange; weathered to depths exceeding 60 ft with clasts thoroughly weathered; ancient moraine surfaces are highly dissected by streams.

Qapwt$_1$ — **Alpine till, older pre-Wisconsinan (Pleistocene)**—Compact, nonsorted mixture of clay, silt, sand, and gravel with boulders; larger clasts are faceted and striated, and are locally angular due to short transport distances; sand-size fraction is very angular; clasts consist of locally derived basalt; shown schematically on map in upper reaches of hanging valleys on north side of Quinault Ridge, where pockets of locally derived till are present in ravine bottoms and side channels and locally covered with colluvium.

Qapwo$_1$ — **Alpine outwash, older pre-Wisconsinan (Pleistocene)**—Sand and pebble gravel with local beds of coarse gravel and silt; so deeply weathered that clasts can be cut by a knife; iron oxide imparts reddish-brown color and a moderate degree of cementation to the gravels; extensive deposits scattered along the southern and western flanks of the Olympic Mountains suggest a glacial origin.

CONTINENTAL GLACIAL DEPOSITS

Fraser Glaciation, Vashon Stade

Qgo — **Proglacial and recessional outwash, late Wisconsinan (Pleistocene)**—Typically poorly to moderately sorted, rounded gravel and sand with localized coarser- and finer-grained constituents; lithologically varied mixture of mostly northern-provenance clasts, especially containing granitic and metamorphic rocks that identify the unit as being deposited by the Puget lobe of the Cordilleran glacier; also contains varying amounts of locally derived Crescent Formation basalt, and in the Mox Chehalis Creek valley, central Cascade Range–derived andesitic clasts; typically shades of gray where fresh or brown where stained especially in proglacial and morainal areas; buff staining near the ground surface; fine sand, silt, and clay constitute local overbank sediments having relatively poor permeability or deltaic foreset bedding along north sides of valleys with higher permeability; porous and permeable enough to yield small to moderate quantities of groundwater; very poorly consolidated to loose; moderately to well-rounded clasts; mostly unweathered with rare weathered reworked clasts; thickness varies and is not well known; most commonly occupies outwash channels scoured into or through till.

Qgd — **Drift, late Wisconsinan (Pleistocene)**—Undifferentiated till and outwash sand and gravel of mostly northern provenance; contains granitic and metamorphic clasts and abundant polycrystalline quartz characteristic of sediments deposited by the Puget lobe of the Cordilleran glacier; minor locally derived Crescent Formation basalt may also be present; may contain clay, silt, sand, gravel, or rare boulders; light gray where fresh with rare reworked weathered clasts and local yellow to brown mineral staining; may be stratified or nonstratified; compact to loose; may occur as morainal ridges; contains mixtures of till and outwash not separately mappable; clasts in till are rounded, faceted, and (or) striated; clasts in outwash are sub- to well-rounded; finer-grained fraction is angular in till versus sub- to well-rounded in outwash; age of maximum ice advance in map area has been estimated to be 14,000 yr (Porter, 1970) to 12,600 yr (Carson, 1970).

Qgt — **Till, late Wisconsinan (Pleistocene)**—Unsorted, unstratified, highly compacted mixture of clay, silt, sand, gravel, and boulders deposited by glacial ice of the Puget lobe; gray; may contain interbedded stratified sand, silt, and gravel; sand-size fraction is very angular and contains abundant polycrystalline quartz, which distinguishes this unit from alpine till; cobbles and boulders are commonly striated and (or) faceted; although unweathered almost everywhere, may contain cobbles or small boulders of deeply weathered granitic rock.

Qga — **Advance outwash, late Wisconsinan (Pleistocene)**—Glaciofluvial sand and gravel and lacustrine clay, silt, and sand deposited during the advance of glaciers; sandy units commonly thick, well sorted, and fine grained, with interlayered coarser sand, gravel, and cobbles and silt rip-up lag deposits at their base; may contain nonglacial sediments; generally overlain by till.

Pre–Fraser Glaciation

Qgp — **Drift, (Pleistocene)**—Undifferentiated till and outwash sand and gravel of northern provenance, containing characteristic granitic and metamorphic clasts; commonly oxidized or stained orange; likely of Double Bluff age (Easterbrook, 1985); also includes the Helm Creek deposits of Carson (1970).

Tertiary Sedimentary Rocks

Mm$_2$, Mm$_{2s}$, Mm$_{2t}$, Mm$_{2c}$ — **Marine sedimentary rocks (middle to upper Miocene)**—Coarse- to fine-grained, silty, friable, lithofeldspathic and feldspatholithic sandstone; also contains local to widespread conglomerate, siltstone, and mudstone; blue-gray where fresh, orange-brown where weathered; locally tuffaceous; most commonly massive, but bedding locally enhanced by conglomerate lenses and beds; contains carbonized wood, mica flakes, and concretionary beds; contains foraminiferal faunas referable to the Mohnian and Delmontian Stages (Rau, 1966, 1967); undifferentiated unit (unit Mm$_2$) locally divided into a sandstone-dominated unit (unit Mm$_{2s}$), a siltstone unit (unit Mm$_{2t}$), and a conglomerate unit (unit Mm$_{2c}$); consists of the Montesano Formation.

Mm$_1$ — **Marine sedimentary rocks (lower to middle Miocene)**—Silty, feldspathic sandstone; fine grained; friable; micaceous; gray where fresh, weathers to olive-brown or creamy orange; massive to thin bedded; contains tuffaceous beds; abundant siltstone and silty sandstone containing macerated carbonaceous material; local basaltic sandstone, pebble conglomerate, and poorly sorted basal conglomerate; contains foraminiferal faunas referable to the Saucesian, Relizian, and Luisian(?) Stages (Rau, 1967); consists of the Astoria(?) Formation.

Mm$_{st}$ — **Marine thick-bedded sedimentary rocks (Miocene)**—Thick, laterally discontinuous, medium- to very coarse-grained, micaceous, feldspatholithic to lithofeldspathic sandstones separated by thin-bedded (1–12 in.) sandstone, siltstone, claystone, and shale; minor siltstone-, shale-, and slate-clast breccia, granule conglomerate, and pebble conglomerate; bedding of thick sandstones generally thicker than 3 ft; common platy shale, slate, or siltstone clasts; consists of part of the Hoh rock assemblage (Rau, 1973).

MEm — **Marine sedimentary rocks (Miocene–Eocene)**—Undifferentiated lithofeldspathic to feldspatholithic micaceous sandstone, siltstone, and slate; minor granule and pebble conglomerate.

MEm$_r$ — **Marine rhythmites and other thin-bedded sedimentary rocks (Miocene–Eocene)**—Laminated and (or) thin-bedded (1–8 in.), lithofeldspathic and feldspatholithic, micaceous sandstone, siltstone, and slate; thin-bedded units commonly rhythmically bedded; phacoidal structures common.

MEm$_{st}$ — **Marine thick-bedded sedimentary rocks (Miocene–Eocene)**—Thick-bedded (generally >3 ft) feldspatholithic to lithofeldspathic micaceous sandstones separated by much thinner beds of laminated sandstone and siltstone; minor granule and pebble conglomerate.

MEbx — **Breccia (Miocene–Eocene)**—Lenses and angular blocks of sandstone, siltstone, shale, conglomerate, and volcanogenic rocks in a matrix of either black shale with scaly cleavage or intensely sheared sandstone and siltstone; includes diapiric muds, fault breccias, and submarine landslide deposits; includes part of the Hoh rock assemblage (Rau, 1973).

ΦEm — **Marine sedimentary rocks (Oligocene–Eocene)**—Sandstone, siltstone, and slate; sandstone is fine- to very coarse-grained, moderately to poorly sorted, subangular, and lithofeldspathic or feldspatholithic; minor granule conglomerate; contains detrital mica; locally sheared; platy slate clasts locally abundant; probably contiguous with rocks to the northeast in the Olympic core (Tabor and Cady, 1978) that yielded unreset zircon fission-track ages of 32 and 48 Ma (Brandon and Vance, 1992).

ΦEm$_{lc}$ — **Marine sedimentary rocks (Oligocene–Eocene)**—Light-gray tuffaceous siltstone and fine-grained tuffaceous sandstone; outcrops commonly have hackly joint structure; indistinctly bedded to massive, commonly concretionary; lower strata contain discontinuous beds of basaltic and glauconitic sandstone; deposited in an offshore marine environment; contains foraminiferal faunas referable to the Refugian and Zemorrian Stages (Rau, 1966, 1967); consists of the Lincoln Creek Formation.

ΦEm$_{lcs}$ — **Marine sedimentary rocks (Oligocene–Eocene)**—Basaltic lithic sandstone; massive; fine grained; light greenish gray to medium olive-brown; clasts are mostly basalt and andesite with minor amounts of feldspar, quartz, and mica; local water-laid pumiceous lapilli tuff; contains silicified wood fragments; contains marine fossils and local calcareous concretions (Snavely and others, 1958); contains foraminifera of the Refugian Stage (Rau, 1966, 1967); consists of the basal sandstone of the Lincoln Creek Formation.

Em$_2$ — **Marine sedimentary rocks (middle to upper Eocene)**—Micaceous siltstone and mudstone, numerous beds of massive sandy siltstone, and sparse sandstone beds; locally contains thin lamellae of macerated carbonaceous material; scattered calcareous concretions and concretionary layers; light-gray tuffaceous strata prevalent in lower parts of unit; contains foraminiferal faunas referable to the Narizian Stage; consists of the Humptulips Formation (Rau, 1984).

Em$_{1c}$ — **Crescent Formation sedimentary rocks (lower to middle Eocene)**—Generally parallel- and thin-bedded basaltic siltstone and sandstone interbeds found within the Crescent Formation that contain foraminiferal assemblages referable to the Ulatisian and possibly Penutian Stages (Rau, 1986).

Em$_{1h}$ — **Marine sedimentary rocks (Eocene)**—Medium- to coarse-grained, indurated ‘greywacke’ sandstone with minor siltstone interbeds; mostly chaotically faulted and deeply weathered; interpreted to be of pre-Narizian age based on fossil and structural data (Rau, 1986); consists of part of the Hoh rock assemblage (Rau, 1973).

ERm — **Marine sedimentary rocks (Eocene to Paleocene)**—Basaltic lithic sandstone with as much as 15 percent rounded clinopyroxene clasts and 5 percent potassium feldspar; thick beds of black, mica-rich lithic sandstone common locally; conspicuous thick to very thick bedding; black weathering to red; medium grained; consists of the basaltic sandstone facies of the Blue Mountain unit (Tabor and Cady, 1978).

ERml — **Marine sedimentary rocks (Eocene to Paleocene)**—Volcanic lithic sandstone; black; micaceous; thick to very thick to massive; consists of the thick-bedded facies of the Blue Mountain unit (Tabor and Cady, 1978).

Tertiary Igneous Rocks

ΦEvb — **Basalt (Oligocene–Eocene)**—Undifferentiated dark greenish gray basaltic rocks within the Olympic core; includes basaltic breccia with minor massive basalt, pillow basalt, and tuff; may be altered to greenstone; may include red or green argillite; assigned an Oligocene to Eocene age because these rocks are interbedded with unit OEm.

Evb — **Basalt (Eocene)**—Altered basalt and (or) basaltic breccia mixed with reddish, green, or gray clasts of argillite; basalt is green or dark gray and contains abundant calcite, chlorite, and other very fine-grained secondary minerals; altered plagioclase phenocrysts persist in some basalt; occurs as isolated blocks that are commonly fault-bounded and surrounded by sedimentary rocks.

Eigb — **Gabbro (middle to upper Eocene)**—Uralitized plagioclase-pyroxene gabbro or diabase; porphyritic; subophitic; alteration minerals include zeolite, fibrous amphibole, and chlorite; formed as sills and dikes at the top of the Crescent Formation basalt and intruded the overlying early Narizian Humptulips Formation (Rau, 1986).

Ev$_c$ — **Crescent Formation basalt, undifferentiated (lower to middle Eocene)**—Submarine, plagioclase-pyroxene basalt with local diabase and gabbro; pervasive zeolite and chlorite alteration in the matrix; commonly amygdaloidal with zeolite and (or) chlorite amygdules; dark gray with greenish tint, brown where weathered, reddish and variegated along altered contact zones; contains flows, pillow basalt, and breccias; refilled lava tubes common in breccias; columnar joint orientation is commonly highly variable; highly vesiculated and (or) pillowed units are commonly highly altered and contain abundant clay minerals, whereas thick units with strong columnar joint formation tend to be less altered; commonly sheared and faulted; contains rare interbeds of laminar basaltic siltstone or fine sandstone with foraminiferal faunas referable to the Ulatisian Stage (Rau, 1981). Locally divided into:

Ev$_{cf}$ — **Crescent Formation basalt, flow dominated**

Ev$_{cp}$ — **Crescent Formation basalt, pillow dominated**

GEOLOGIC SYMBOLS

Contact—dotted where concealed

Fault, unknown offset—dotted where concealed

Normal fault—bar and ball on downthrown side; dotted where concealed

Thrust fault—sawteeth on upper plate; dotted where concealed

Right-lateral strike-slip fault—dotted where concealed

Left-lateral strike-slip fault—dotted where concealed

Anticline—dotted where concealed; large arrowhead shows direction of plunge

Syncline—dotted where concealed; large arrowhead shows direction of plunge

Maximum extent of late Wisconsinan Cordilleran ice sheet; barbs point toward ice front

Maximum extent of pre–late Wisconsinan Cordilleran Ice sheet

Inclined bedding—showing strike and dip

Vertical bedding—showing strike

Overturned bedding—showing strike and dip

Inclined bedding in phacoids in shear zone—showing strike and dip

Inclined crenulated or warped bedding—showing approximate strike and dip

Inclined foliation—showing strike and dip

Inclined foliation and bedding—showing strike and dip