NATURAL RESOURCES

GEOLOGIC MAP OF THE TACOMA 1:100,000-SCALE QUADRANGLE, WASHINGTON

Compiled by J. Eric Schuster, Ashley A. Cabibbo,
Joseph H. Schilter, and Ian J. Hubert

WASHINGTON
DIVISION OF GEOLOGY
AND EARTH RESOURCES
Map Series 2015-03
November 2015

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INDEMNIFICATION

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Contents

FIGURES

TABLES

MAP SHEET

Geologic Map of the Tacoma 1:100,000-scale Quadrangle, Washington

Compiled by J. Eric Schuster, Ashley A. Cabibbo, Joseph F. Schilter, and Ian J. Hubert

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INTRODUCTION AND PURPOSE

The Tacoma 1:100,000-scale quadrangle is located in western Washington (Fig. 1). It extends from the southern edge of Seattle in the north to Olympia in the southwest and from the foothills of the Cascade Range on the east to within a few miles of the Olympic Mountains to the west and northwest. The largest city in the quadrangle is Tacoma, with a population of 200,000. The quadrangle includes parts of Pierce, King, Thurston, Kitsap, and Mason Counties. Most of the southern Puget Sound is within the quadrangle; other major landscape features are river valleys with headwaters in the Cascade Range, including, from north to south, the Cedar, Green, White, Carbon, Puyallup, and Nisqually Rivers. Interstate Highway 5 traverses the quadrangle from southwest to northeast, passing through Olympia, Tacoma, and Seattle. Smaller communities are scattered throughout the quadrangle; most are served by state highways. Elevations range from sea level at Puget Sound to high elevations of 800 ft near Olympia, 2,300 ft at Gleason Hill in the southeast corner of the quadrangle, and 2,000 ft east of Squak Mountain in the northeast corner of the quadrangle. The gross topographic setting of the area is the low-elevation, generally north–south-trending Puget Lowland trough, flanked by the foothills of the Cascade Range to the east, the Black Hills near Olympia, and the Olympic Mountains to the west and northwest of the quadrangle. The climate is relatively mild, with precipitation totaling about 35 to 55 inches per year, mostly in the form of rain, with more to the east in the Cascade foothills. Temperatures in the Puget Lowland usually range from about 20° to 90° F. Much of the quadrangle has urban and suburban development, and in these areas the forest cover has been greatly thinned. Most undeveloped areas are forested with second-growth coniferous and deciduous forests.

The purpose of this compilation is to make the geology of the Tacoma quadrangle available for use in regional spatial analyses and other digital applications, for providing a framework for planning and land management, and for evaluating geologic hazards and resources. It was prepared in cooperation with the U.S. Geological Survey (USGS) National Geologic Mapping Program.

General Geology

Bedrock is exposed in the eastern part of the quadrangle in the form of Miocene to Eocene continental sedimentary rocks, Oligocene and Eocene volcaniclastic rocks, Miocene lahars, and Miocene to Eocene dikes, sills, and small stocks. Bedrock in the southwest corner of the quadrangle consists of Eocene basalt.

Quaternary unconsolidated deposits are the dominant rock type within the quadrangle. These unconsolidated deposits reach depths of more than 2,400 ft below sea level in the Tacoma basin, centered near McNeil Island, and more than 3,400 ft below sea level in the West Tacoma basin, centered near the northwest corner of the quadrangle (Eungard, 2014). They include deposits of six continental glacial episodes, two alpine glaciations, and six interglacial intervals (see correlation diagram on Map Sheet).

Deposits of the Vashon Stade of the Fraser Glaciation in the quadrangle cover a total land area several times larger than all of the other geologic units combined. Across the quadrangle, landforms of glacial till were created by generally south- to southwest-moving continental ice sheets. The resulting topographic fluting is readily visible on the hillshade basemap. Best developed along the east and southeast margins of the Vashon ice sheet, landforms constructed of mostly recessional outwash occupy valleys created by large-volume ice-marginal meltwater streams. These landforms are still present except for areas covered by more recent alluvium, lahars from Mount Rainier, and, increasingly, urban development.

The correlation diagram on the Map Sheet shows a gap from about 330,000 to 800,000 years ago that is not represented by any deposits, except possibly the Wingate Hill Drift. Deposits in this age range very likely exist because marine oxygen-isotope stages (Morrison, 1991) show that several additional glacial and nonglacial episodes likely occurred during this time interval. Such deposits have not been confirmed because: (1) there are few dating techniques that adequately cover this time period and few suitable candidate lithologies; (2) stratigraphic relations among the older glacial and nonglacial deposits are known only in limited areas, and correlation of unknown units to these areas is difficult because exposures along valley walls are intermittent; (3) except for weathering, the various glacial deposits greatly resemble each other, as do the nonglacial deposits; and (4) such deposits may have been removed in many areas by erosion and glacial excavation. Stratigraphic relationships among many of the older glacial and nonglacial units are well known in and near the Sumner 7.5-minute quadrangle. However, outside of this area, the identity of these older units is inferred from their position below Vashon deposits, finite versus infinite radiocarbon dates, glacial or nonglacial lithologic character, and stratigraphic succession. Luminescence age estimates are beginning to solidify some of these inferences.

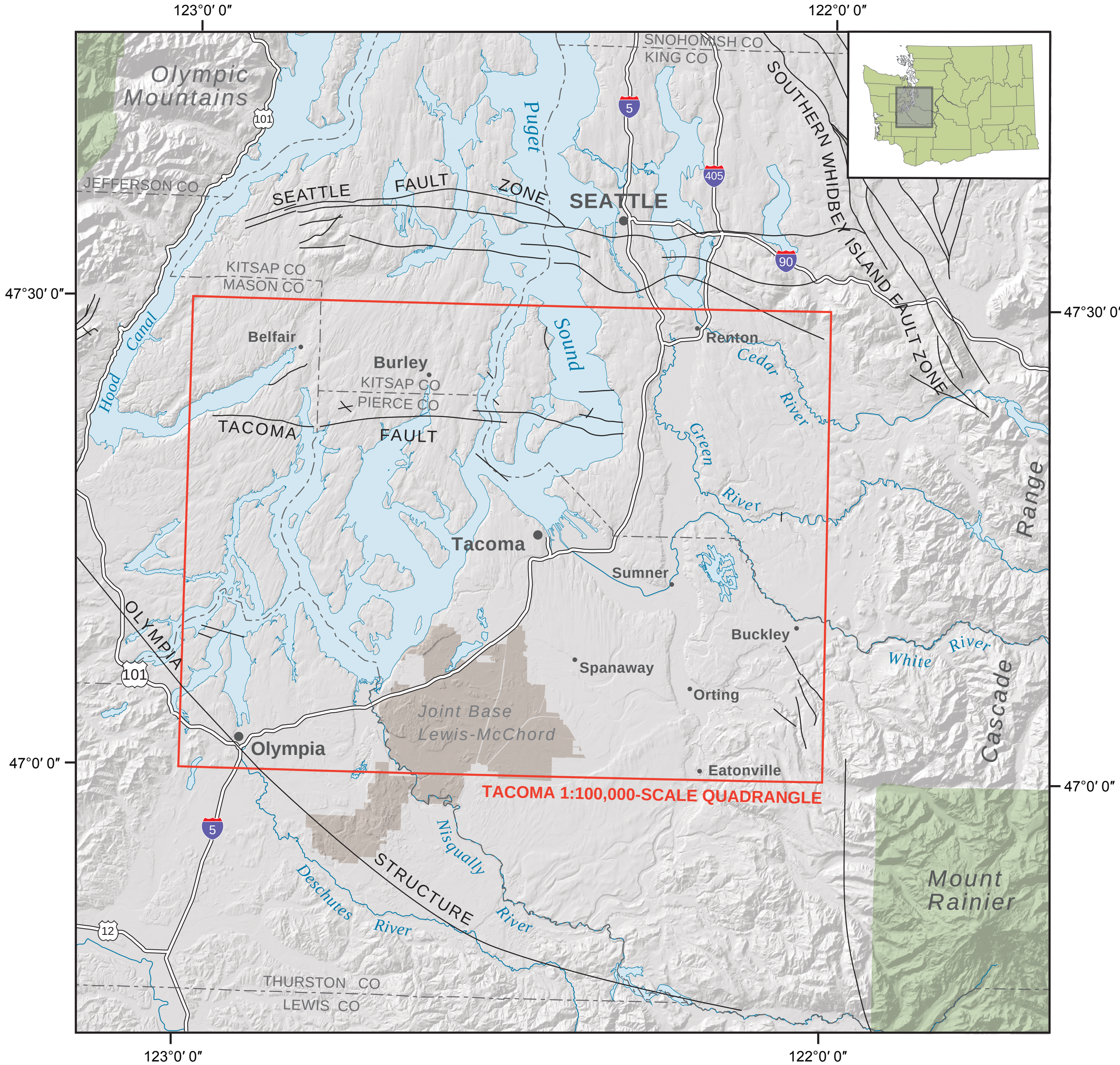

Figure 1. Regional figure showing the Tacoma 1:100,000-scale quadrangle and its relationship to regional structures..

METHODS

Source Maps

The maps that served as sources of data were selected on the basis of these criteria: (1) the map had a scale of 1:24,000 (7.5-minute quadrangle), (2) the map was in digital (geographic information system [GIS]) form, and (3) if more than one 1:24,000-scale map was available for the same 7.5-minute quadrangle, the latest map with geologic units defined in terms of age and lithology was preferred. The selected published maps already in digital form were the Belfair, Burley, Des Moines, Fox Island, Lacey, Lake Wooten, Longbranch, Maple Valley, Mason Lake, McNeil Island, Nisqually, Olalla, Poverty Bay, Squaxin Island, Tumwater, and Vaughn 1:24,000-scale quadrangles. Unpublished digital 1:24,000-scale maps provided by Kathy Goetz Troost include the Gig Harbor, Puyallup, Steilacoom, Tacoma North, and Tacoma South quadrangles. In addition, we selected several published maps that were not yet in digital format, including the Auburn, Black Diamond, Buckley, Orting, Renton, Sumner, Vashon, and Wilkeson 7.5-minute quadrangles. The Frederickson, Fort Lewis, and Spanaway 1:50,000-scale published maps were also incorporated. See *Sources of Map Data* figure on the Map Sheet for locations of 7.5-minute quadrangles and source-map citations.

Faults and folds were compiled from several regional sources in addition to the geologic maps identified on the sources of map data figure (Map Sheet). Parts of the Tacoma fault are from the fault compilation of Czajkowski and Bowman (2014) and Johnson and others (2004); faults in the southern part of the Squaxin Island 7.5-minute quadrangle are from Clement and others (2010); the Seattle fault is from Liberty and Pratt (2008); some faults in the Vashon 7.5-minute quadrangle are from Booth and others (2015). The Olympia structure is from Jack Odem (U.S. Geological Survey, written commun., 2015). Folds are from Johnson and others (2012).

Other sources of information were geochemical data from a rock geochemistry database by Bowman and others (2014), and geochronologic data from a database by Czajkowski (2014). Digital geology and geochronologic contributions from Kathy Goetz Troost and Shannon A. Mahan are noted in Acknowledgments.

Compilation Strategy

The paper geologic maps for the Auburn, Black Diamond, Buckley, Fort Lewis, Frederickson, Orting, Renton, Spanaway, Sumner, Vashon, and Wilkeson quadrangles were scanned, georeferenced, and digitized. The digital geologic data for the 32 individual 7.5-minute source-map quadrangles were copied into a geodatabase for the Tacoma 1:100,000-scale quadrangle. We simplified the geology to achieve 1:100,000-scale legibility while retaining as much geologic information as possible. This process involved smoothing contacts, assigning age-lithology unit labels in accordance with Division standards, resolving edge-match problems, merging small geologic unit polygons into larger ones with generalized labels, converting small geologic unit polygons or merged polygons into line or point geologic units, and occasionally deleting small polygons. This process necessitated introducing positional changes of lines and polygons of up to 1,000 ft or more. The geochronology, geochemistry, and paleomagnetic polarity data points were left in their original reported positions. For this reason, samples may appear to be located in geologic unit polygons other than those from which the data were collected.

Older line and point geologic units commonly appear to lie within younger polygon geologic units. This is because the older units are located within erosional windows in the younger units. The map often depicts faults in Quaternary geologic units without showing map-scale offset. In these cases, the offset has been documented by larger-scale studies, including mapping, topical investigations, and paleoseismic trenching.

We used 14 adjacent 1:24,000-scale quadrangle maps, all completed since 2003, to help define contacts, units, and structures near the Tacoma quadrangle boundary. We also checked the 8 surrounding 1:100,000-scale quadrangles to ensure relatively consistent geology amongst the maps. There are some mismatches in geology along the quadrangle boundary that are intentional. These mismatches are mostly because more detailed and newer mapping exists in this compilation than in adjacent quadrangles.

UNIT DESCRIPTIONS[1]

Quaternary Unconsolidated Deposits

HOLOCENE TO LATE PLEISTOCENE NONGLACIAL DEPOSITS

Qf **Artificial fill (Holocene)**—Gravel, sand, silt, concrete, garbage, slag, and other materials used as fill, as well as natural deposits mixed and reworked by excavation and (or) redistribution that obscures or substantially alters the original geologic deposit. Thin areas of fill are present elsewhere in the map area, but are too small to show at map scale. Unit Qf is located in the more heavily populated parts of the Tacoma quadrangle; the largest area of fill and modified land is associated with the Port of Tacoma at Commencement Bay. Description compiled from Booth (1991, 1995), Booth and Waldron (2004), and Troost and others (2005).

Qa **Alluvium (Holocene to late Pleistocene)**—Loose, stratified to massively bedded, fluvial silt, sand, and gravel; locally includes sandy and silty estuarine deposits; typically well rounded and moderately to well sorted. Alluvium in the quadrangle has five main sources: (1) sedimentary rocks of the Puget Group, (2) basaltic and andesitic volcanic rocks of the Ohanapecosh and Fifes Peak Formations, (3) hypersthene and hornblende andesite lava flows and pyroclastic rocks of Mount Rainier, (4) Snoqualmie Granodiorite and related intrusive rocks, and (5) Vashon Drift. Exposures locally resemble the unit's sediment sources. Alluvium is deposited on floodplains and in swamps, streams, adjacent banks, and estuaries. This unit is gradational with, and may locally include, peat (unit Qp) or alluvial fan (unit Qaf) deposits. Alluvium is generally Holocene in age but may locally include some unrecognized recessional outwash terraces (unit Qgo) and other late Pleistocene deposits. Thickness ranges from a few feet to as much as 600 ft. Unit Qa is exposed in the valleys of rivers and creeks; the largest areas of alluvium are in the valleys of large rivers that enter the Tacoma quadrangle from the Cascade Range. Description compiled from Crandell (1963), Walters and Kimmel (1968), Walsh and others (2003a,b,c), Booth and Troost (2005), Haugerud (2009), and Tabor and others (2000).

Qp **Peat (Holocene to late Pleistocene)**—Loose, locally very soft and wet, organic and organic-rich sediment, including muck, silt, and clay; may contain thin widespread layers of volcanic ash. Peat may readily flow laterally under load or, if confined, compress to as little as 10 percent of its original undisturbed volume. Thickness ranges from less than 1 ft to as much as 23 ft. Peat is found in closed depressions, tidal flats, and coastal wetlands. It tends to grade into alluvium (unit Qa) peripherally away from Puget Sound. Peat post-dates Vashon ice and is predominantly Holocene, but locally includes some late Pleistocene deposits. Description compiled from Crandell

[1] See Appendix Tables 1–4 for geochronology and geochemistry

(1963), Mullineaux (1965a), Booth (2004), and Polenz and others (2009a,b).

Qls **Landslide deposits (Holocene to late Pleistocene)**—Loose, unsorted, and unstratified clay, silt, soil, and (or) organic matter and angular to rounded sand, gravel, and boulders; may locally retain primary bedding; commonly include liquefaction features. Slow-moving slumps commonly transform into slump-earthflows, which are often recognized by bowed or randomly tilted trees. Slumps typically occur at the interface between poorly compacted, poorly cohesive, permeable sands that overlies relatively impermeable silt or clay. More rapid shallow debris flows commonly initiate at the interface between an impermeable substrate, such as till (unit Qgt), and shallow, loose, permeable soils rich in organic matter. Small landslides are common in steep bluffs and slopes and consist of slumps and earth flows caused by surf erosion or by sapping springs. Deep-seated landslides are indicated by uphill scarps, bulbous toes, position in hillslope hollows, and hummocky surfaces in lower reaches; deposits may appear as imbricated forward- or back-tilted blocks in headward areas. Deep-seated slides tend to be relatively large. Rock topples and (or) falls occur wherever near-vertical bluffs are present, typically because silt- or clay-rich layers fail along bluffs; most are too small to be shown at map scale. Some landslides, particularly those in glaciated uplands, may be inactive and stable in current conditions. Absence of a mapped slide does not imply absence of sliding or hazard, as some slides are too small to show at map scale. Only the largest landslides can be shown at 1:100,000 scale; they are located on Puget Sound, Hood Canal, and major river valley bluffs. Description compiled from Walsh and others (2003b), Haugerud (2005, 2009), Polenz and others (2009a,b), and Waldron (1962).

Qaf **Alluvial fan deposits (Holocene to late Pleistocene)**—Stratified and typically poorly sorted silt, sand, gravel, and boulders forming concentric lobes where streams emerge from confining valleys and reduced gradients cause sediment loads to be deposited. Alluvial fan deposits are gradational with alluvium (unit Qa) and generally overlie till (unit Qgt), recessional outwash (unit Qgo), or landslide deposits (unit Qls). Description compiled from Derkey and others (2009a,b), Haugerud (2009), Polenz and others (2009a,b), and Booth and others (2013).

Qvl_e **Electron Mudflow (Holocene)**—Unsorted mixture of subangular andesitic rock fragments in a purplish-gray, clayey sand matrix. Components of the mudflow are derived from Mount Rainier and the Ohanapecosh and Fifes Peak Formations. The most distinctive rocks in the mudflow are boulders of a black scoriaceous hypersthene andesite as much as 5 ft in diameter (Table 3, map nos. 29–30 and 47). The largest boulders in the deposit, however, are reddish-brown breccia of Mount Rainier provenance. Grain size decreases from boulders near the southeastern boundary of the Tacoma quadrangle to clayey sand north of Alderton and south of the Puyallup River. Unit thickness ranges from a few millimeters to at least 26 ft. The deposit rests on the surface of a former flood plain of the Puyallup River, suggesting that thickness depends on the relief of the buried flood plain surface. The Electron Mudflow underlies at least 13 mi^2 of the floor of the Puyallup Valley and crops out within the Orting and Sumner 7.5-minute quadrangles. Several radiocarbon analyses within the study area constrain the age of lahar deposition to between <200 and 840 ±190 years BP (Table 1, map nos. 211–214). However, more recent analyses from outside of the Tacoma quadrangle (Pringle, 2008) suggest that the flow was deposited between A.D. 1502–1503. Description compiled from Crandell (1963).

Qvl **Lahar deposits (Holocene to late Pleistocene)**—Lahar runout and overbank deposits of three lahars from the Mount Rainier Summerland eruptive period; unsorted mixtures of andesitic rock fragments in a clayey sand matrix; post-glacial. Unit Qvl is represented on the map by two radiocarbon ages from charcoal sampled within and directly above the lowermost lahar. The samples yield a maximum age between 2480 ±40 and 2540 ±60 years BP (Table 1, nos. 178–179). Description compiled from Zehfuss (2005).

Qvl_o **Osceola Mudflow (Holocene)**—Unstratified mixture of subrounded to subangular andesitic rock fragments in a plastic clayey sand matrix. The lower part of the deposit contains abundant cobbles and boulders; the upper part contains progressively fewer stones ranging from pebbles to small cobbles. The mudflow varies in color from grayish purple to medium or light gray with a faint purplish cast; it oxidizes to mottled yellowish brown. Thickness is as much as 75 ft, depending on irregularities in the surface of the Vashon Drift below. Dragovich and others (1994) report a maximum thickness of 100 feet in the subsurface near Sumner. This unit originated as a volcanic mudflow, and lateral tracing up the valley of the White River has established its source as the northeast side of Mount Rainier, although a few clasts are derived from the Snoqualmie Granodiorite. Widespread in the eastern part of the quadrangle, the mudflow is best seen in the valley walls of the White River where the valley is crossed by U.S. Highway 410 north of Buckley. Wood fragments are a characteristic component and range in size from 10-ft-long logs several feet in diameter to a thin layer of plant material. Most logs are fresh, although a few are decayed or partly carbonized. The deposit drains poorly, owing to its fine-grained, nearly impermeable matrix and its nearly flat upper surface. Several charcoal and wood fragments sampled from this unit (Table 1, nos. 112, 173, and 180–181) indicate the mudflow occurred between 4,700 ±250 and 5,050 ±90 years BP. Description compiled from Crandell (1963).

Qt **Terrace deposits (Holocene to late Pleistocene)**—In the Black Diamond 7.5-minute quadrangle well-sorted, sandy pebble-cobble gravel; locally contains boulders; 10 to 30 ft thick; deposited by the Green River in late Pleistocene and early Holocene time. Farther south, along the White River, unpaired terrace deposits 15 to 30 ft thick generally consist of 5 to 15 ft of medium to very coarse sand underlain by 10 to 15 ft of pebble to boulder gravel; rock types in the terrace alluvium closely resemble that of the Osceola Mudflow from which the alluvium was largely derived; mid-Holocene in age (post Osceola Mudflow). Description compiled from Crandell (1963) and Mullineaux (1965b).

PLEISTOCENE GLACIAL DEPOSITS

Deposits of the Vashon Stade of the Fraser Glaciation

Qgd **Vashon Drift**—Includes all deposits of the Vashon Stade of the Fraser Glaciation where they have not been subdivided on source maps or where outcrops of Vashon Stade subunits are too small to be shown at map scale. Stratified and unstratified sand, silt, clay, gravel, and diamicton deposited during glacial advance and retreat; includes advance outwash, recessional outwash, ice-dammed-lake sediment, and ice-contact features. Vashon Drift was deposited in the quadrangle between about 15,000 and 13,500 yrs BP. Unit Qgd is widespread throughout the quadrangle. Description compiled from Polenz and others (2009a,b), Walters and Kimmel (1968), and Booth and others (2004).

Qgo **Recessional outwash**—Silt, clay, sand, and gravel deposited by meltwater from a receding glacier; sand and gravel deposited by streams; sand and silt deposited in proglacial lakes; rich in northern-source plutonic and metamorphic clasts; variably sorted; loose to compact; massive to well stratified; horizontal to steeply dipping beds; forms drumlins, eskers, kettles, kames, and deltas; stratigraphically overlies Vashon Till. Unit Qgo is widespread in the quadrangle, especially in upland areas. Description compiled from Walters and Kimmel (1968) and Logan and others (2006). Divided into:

Qgl **Recessional glaciolacustrine deposits**—In the central part of the quadrangle generally very fine-grained sand, silt, and clay or stratified sand with scattered pebbles and cobbles and occasional lenses of till or silt. In the western part of the quadrangle generally clayey and (or) fine sandy silt with sparse, disseminated dropstones; laminated and commonly vertically jointed to structureless; gray to brown on fresh surfaces, pale yellow when dry and oxidized; dark horizontal banding may represent varve sequences; thickness generally 10 ft or less. Deposited in ice-enclosed, ice-marginal, and ice-dammed lakes. Description compiled from Booth and Waldron (2004), Walters and Kimmel (1968), Logan and others (2003a), and Polenz and others (2009b).

Qgo_i **Recessional outwash ice-contact deposits**—Sand, gravel, silt, and clay; tan to gray; loose; moderately to well sorted and rounded; good porosity and permeability; contains a mixture of dynamic-ice and stagnant-ice features and hummocky topography. Eskers form low, elongate, sinuous hills in subglacial recessional outwash channels. Kames composed of pebble gravel and sand deposited in irregular mounds against a glacier and characterized by local abrupt vertical and horizontal changes in grain size and inclusion of till. Kettles are ice-contact depressions of irregular shape that are typically found in gravel. Many kettles in the quadrangle are occupied by groundwater lakes. Unit Qgo_i is widely distributed, especially in upland areas. Description compiled from Derkey and others (2009a), Polenz and others (2009a,b), Logan and others (2003c), Mullineaux (1965a), and Walters and Kimmel (1968).

Qgod **Recessional outwash delta deposits**—Sand and pebble to cobble gravel, minimal silty sand, and rare boulders; well sorted; predominantly unweathered; deposited where meltwater streams encountered standing water; deposits characterized by bottomset, foreset, and topset beds. Unit Qgod is distributed widely throughout the quadrangle. Description compiled from Mullineaux (1965b) and Crandell (1963).

Qgo_{sg} **Steilacoom Gravel**—Pebbles to boulders as much as 1.5 ft in diameter; consistently coarse over large areas; local crossbedding; commonly less than 20 ft thick, maximum thickness 60 ft; kettles and other ice-contact depressions range in width from 50 ft to 2 mi; deposited and reworked by several rivers that originated from proglacial Lake Puyallup during glacial retreat. Unit Qgo_{sg} is widespread in the south-central part of the quadrangle. At an aggregate mine near Sequalitchew Creek north of Dupont, a deltaic deposit of the Steilacoom Gravel has an exposed thickness of 185 ft and a probable total thickness of about 400 ft (Washington Division of Geology and Earth Resources, Surface Mine Reclamation Permit no. 12668). Description compiled from Walters and Kimmel (1968).

Qgos **Recessional outwash sand**—Moderately to well sorted sand; locally includes lenses and beds of pebble gravel and some silt; gray to brown; matrix free; loose; moderate to well rounded; as much as 100 ft thick; deposited in ice-contact channels, in and around margins of glacial lakes; commonly associated with eskers and kettles. Unit Qgos is mapped in the west and southeast parts of the quadrangle. Description compiled from Derkey and others

(2009a), Polenz and others (2009a,b), and Logan and others (2003c).

Qgt **Vashon Till**—Clay, silt, sand, and gravel; deposited directly by glacial ice and characterized by the presence of northern-provenance clasts; gray to brown, yellowish brown where oxidized; unstratified and highly compact; finer sand grains within matrix are angular; rare angular to subrounded glacial erratic boulders; surface features include moraines, drumlins, striations, and flutes; commonly 2 to 10 ft thick, however, thicknesses of 30 ft have been mapped; sharp contact with underlying units; low permeability and porosity causes poor drainage. Unit Qgt is widespread throughout the quadrangle. Description compiled from Logan and others (2003c) and Derkey and others (2009a).

Qga **Advance outwash**—Sand and pebble to cobble gravel; almost completely devoid of silt or clay, except near base of unit; typically light gray to light brown; generally unoxidized; poorly to well sorted; very compact; locally as much as 300 ft thick; deposited by streams flowing from the advancing ice sheet. Unit Qga is fairly widespread. Detrital wood sampled from this unit on the east side of Nisqually Reach (Table 1, map no. 203) produced a radiocarbon age of 13,410 ±80 years BP. Description compiled from Booth and others (2004). Unit Qga is divided into:

Qgas **Advance outwash sand**—Fine- to medium-grained sand; fluvial and lacustrine facies; lenses of silt or gravel; typically well rounded and well sorted; prone to deep-seated landslides because the unit has high porosity and permeability and overlies impermeable clay. Unit Qgas is mapped extensively in the western half of the quadrangle, and where exposed in the Tacoma area (shown as part of Qga due to map scale), is locally called the Colvos or Esperance Sand. Description compiled from Logan and others (2003b, 2006) and Polenz and others (2009a,b).

Qga_{lc} **Lawton Clay**—Laminated to massive silt, clayey silt, and silty clay interbedded with layers of sand that are locally crossbedded; light gray to dark blue-gray; local ripple marks; as much as 80 ft thick; deposited in proglacial or lowland lakes. Unit Qga_{lc} is mapped as line and point units in the Olalla and Tacoma North 7.5-minute quadrangles. Description compiled from Mullineaux and others (1965) and Tabor and others (2013).

Qad_e **Evans Creek Drift (Fraser Glaciation, Evans Creek Stade)**—Till, poorly sorted sand and gravel, and boulders as large as 5 ft in diameter; locally at least 50 ft thick; forms moraines and terraces; deposited by an alpine glacier along the Carbon River. During this time, the Puget Lowland remained free of ice, while alpine glaciers were prominent. Pebbles in the drift are of central Cascade Range provenance, except for two percent of clasts that are from Mount Rainier. Unit Qad_e is mapped in the southeast corner of the Wilkeson 7.5-minute quadrangle. Description compiled from Crandell (1963) and Borden and Troost (2001).

Qu **Fraser-age continental glacial and nonglacial deposits**—Undifferentiated continental glacial deposits of the Fraser Glaciation, Vashon Stade, and pre-Vashon nonglacial deposits. Unit Qu is mapped along the bluffs of Case Inlet.

Pre-Vashon Glacial and Nonglacial Deposits

Qc_o **Sediments of the Olympia nonglacial interval**—Discontinuous nonglacial sediment of variable thickness generally represented by thin to thick interbedded fluvial sand and silt, abundant organic material, localized gravel, some fine-grained laminated lacustrine sequences, tephras, and lahars. Like today, Mount Rainier, the Cascade Range north of Mount Rainier, and the Olympic Mountains were the sources of sediment; deposited in Puget Sound, river valleys, and lake basins. Maximum known thickness is 150 ft; commonly known as Olympia beds; mapped in bluff exposures near Puget Sound and found in wells in the south-central part of the quadrangle. Many radiocarbon samples have been analyzed for this unit (Table 1); they commonly yielded “infinite” ages because the Olympia beds are, in part, older than the upper limit of reliable radiocarbon dating. Luminescence sample site (map no. 92) produced an age between 34 ±4 ka and 36 ±2 ka (Table 1). Borden and Troost (2001, p. 2) consider the Olympia beds to have been deposited between 15 and 60 ka. See Table 2, map nos. 5–9, for geochemical analyses of tephra samples from Devil’s Head. Description compiled from Borden and Troost, 2001, Minard and Booth (1988), Logan and others (2003a), and Walters and Kimmel (1968).

Qcp **Pre-Fraser continental sedimentary deposits, nonglacial**—Composite geologic unit that includes any combination of units Qc_o (Olympia beds), Qc_w (Whidbey Formation), Qc_p (Puyallup Formation), and Qc_a (Alderton Formation). Unit Qcp is widely exposed in bluffs throughout the Tacoma quadrangle.

Qapc **Pre-Vashon alpine glacial drift and nonglacial deposits**—Undifferentiated alpine glacial and nonglacial deposits older than the Fraser Glaciation, Vashon Stade. Unit Qapc is mapped as a linear geologic unit within the bluffs of the Nisqually River valley.

Qgpc **Pre-Vashon continental glacial drift and nonglacial deposits**—Composite geologic unit that includes combinations of all of the continental glacial and nonglacial deposits older than the Vashon Stade of the Fraser Glaciation. Unit Qgpc is widespread in bluffs near Puget Sound and Hood Canal and in valley walls of major rivers.

$Qgpc_{po}$ **Pre-Olympia continental glacial and nonglacial deposits**—Composite geologic unit that includes combinations from among all of the continental glacial and nonglacial geologic units that are older than deposits of the Olympia nonglacial interval (Olympia beds, unit Qc_o). Unit $Qgpc_{po}$ is shown along bluffs adjacent to Puget Sound south of the city of Gig Harbor and south of Point Evans, both in the Gig Harbor 7.5-minute quadrangle.

Qgp_p **Possession Drift**—Sand, gravel, compact sandy till, and glaciomarine drift, with lenses of sand and gravel; gray and oxidized near top of unit; locally contains shells and shell fragments; laterally discontinuous but visible in cliffs and bluffs; mapped in bluff exposures in the Vashon 7.5-minute quadrangle on northern and southern Vashon Island and Maury Island, and in the Gig Harbor 7.5-minute quadrangle to the north and south of Point Evans. Description compiled from Easterbrook and others (1967).

Qgp **Pre-Fraser continental glacial drift**—Composite geologic unit that includes any combination of pre-Fraser continental glacial deposits. Unit Qgp is widely exposed in bluffs near Hood Canal and Puget Sound.

Qc_w **Whidbey Formation**— Nonglacial sedimentary deposits; fluvial sands and gravels and massive to laminated marine and lacustrine silt and clay; wide range of oxidation levels; exposures commonly poor. Like the other nonglacial Pleistocene units, the Whidbey is discontinuous, not northern sourced, variable in thickness, primarily fluvial, contains organic material, and includes localized gravel, lacustrine deposits, tephras, and lahars. Whidbey Formation has been mapped in bluffs on Maury Island and from Gig Harbor south to Point Fosdick. The unit is represented on the map by luminescence sample sites (map nos. 84–86, 91, and 96–97), and geochemistry sample sites of interlayered tephras (map nos. 10–18 and 34–47). Probable subsurface Whidbey Formation deposits have been identified in boreholes in the south-central part of the Tacoma 1:100,000-scale quadrangle by Borden and Troost (2001, p. 17). These deposits are 10–40 ft thick at elevations between 120 and 170 ft above mean sea level. Description compiled from Booth (1991) and Borden and Troost (2001).

Qc_{po} **Pre-Olympia continental sedimentary deposits, nonglacial**—Composite geologic unit that includes any combination of units Qc_w (Whidbey Formation), Qc_p (Puyallup Formation), and Qc_a (Alderton Formation). Unit Qc_{po} is shown as several geochronology sample sites (map nos. 21, 27–29, 81, and 100) in the bluffs along Puget Sound (Table 1).

Qap_h **Hayden Creek Drift**—Alpine glacial till and outwash sand and gravel; at the type area about 6 mi southeast of the Tacoma quadrangle, the unit consists of about 23 ft of till overlying bedrock; stones of the Cascade Range near the top of the unit have weathering rinds 0.02 to 0.1 in. thick and average 0.04 in.; oxidized yellowish brown to dark brown to a depth of about 6.5 ft; uppermost 5 ft slightly to moderately plastic but structureless; thin clay coatings were not recognized in the soil profile; the till veneers the walls of the Carbon River and Voight Creek; more than 16 ft of oxidized outwash sand and gravel were mapped near Upper Fairfax at the southeast corner of the Tacoma quadrangle, and also recognized beneath till of the Evans Creek Drift a short distance away in the valley wall of Evans Creek; constructional topography of the unit has been considerably modified by stream erosion and mass-wasting process, but many large moraines and a few closed depressions can still be recognized. The unit underlies the Evans Creek Drift and is older the the Wingate Hill Drift. Description compiled from Crandell and Miller (1974).

Qap_w **Wingate Hill Drift**—Alpine glacial till and outwash gravel; till is compact and dark brown; oxidized brown or yellowish brown to a depth of up to 12 ft.; andesite stones in the upper 1 ft have weathering rinds 0.1 to 0.25 in. thick and average about 0.2 in.; at Wingate Hill, 1 mi southwest of Carbonado, the till is 11 ft thick and overlies deeply weathered Lily Creek Formation; the weathering profile usually includes a clayey B horizon 20 to 39 in. thick and has joint surfaces with thin clay coatings; outwash deposits are oxidized to depths of as much as 33 ft; moraines are recognized in only a few places and their original constructional topography has been extensively modified by mass-wasting and stream erosion; this unit is mapped in the southeast corner of the Tacoma quadrangle in interfluves above elevations reached by deposits of the Vashon Drift; age poorly constrained, but younger than Lily Creek Formation and older than Hayden Creek Drift. Description compiled from Crandell (1963) and Crandell and Miller (1974).

Qgp_d **Double Bluff Drift**—Till, glaciomarine drift, glaciofluvial sand and gravel, and glaciolacustrine silt; abundant wood and shells; moderately weathered. Double Bluff Drift stratigraphically underlies the Whidbey Formation and crops out in cliff exposures at or near sea level. Unit Qgp_d is represented on the geologic map solely by numerous luminescence sample sites that have questionable unit identification in the Gig Harbor, Poverty Bay, and Vashon 7.5-minute quadrangles. The Tacoma 1:100,000-scale quadrangle is the southernmost known extent of the unit. Description compiled from Easterbrook (1969, 1986).

Qgp_s **Salmon Springs Drift**—Medium to coarse sand, pebble to cobble gravel, and till, with thin beds and some lenses of silt and clay; locally contains peat and volcanic ash; clasts usually covered with iron-oxide stain; well sorted; locally contains tight silt and clay matrix; small zones of openwork gravel show dark-brown manganese-oxide stain and have a clay matrix; granite clasts frequently disintegrated; some volcanic rocks deeply weathered and decomposed; continental glacial drift, chiefly fluvial, derived from British Columbia and the northern and central Cascade Range. Sand is crossbedded and frequently has incised channels filled with gravel. Till is gray to oxidized orange and very compact. Silt is light gray to brown and often contain a large amount of volcanic ash. Maximum known thickness along Duwamish Valley is about 200 ft, but generally 50 ft or less elsewhere. Salmon Springs Drift is best exposed in the vicinity and north of Sumner; south of Sumner, the drift is thin. The drift rests unconformably on the eroded and weathered surface of the Puyallup Formation (unit Qc_p) and is overlain unconformably by Vashon Drift (unit Qgd). The base of the drift decreases in altitude to the north along the erosional unconformity with the underlying Puyallup Formation.

In exposures near Sumner, the presence of nonglacial sediment between two deposits of drift in this stratigraphic interval indicates two advances of a single major glaciation. Reversely magnetized Lake Tapps tephra exposed within this unit yields fission track ages of 0.87 ±0.27 to 1.1 Ma (Table 1; Westgate and others, 1987). Pollen from a peat bed between the two drifts is dominated by pine and fir, suggesting a cool, moist climate. Unit Qgp_s is exposed along the bluffs of the Green River in the Auburn, Black Diamond, Renton, and Sumner 7.5-minute quadrangles. Description compiled from Crandell (1963), Walsh (1987), and Smith (1976).

Qvl_{lc} **Lily Creek Formation**—Unconsolidated lahar deposits; sand, gravel, ash, and white pumice interbedded with compact mudflows; wholly or partly altered to clay to depths of 10 to 50 ft; medium to poorly sorted; lenticular fills rest in channels cut into older units of the formation; mudflows and coarse fluvial sand deposits contain abundant angular andesite fragments; maximum known thickness is 273 ft, but may be as much as 800 or 900 ft; mostly derived from lavas and pyroclastic rocks of Mount Rainier, although some gravel units contain an equal percentage of rocks from the central Cascade Range. Lily Creek Formation is limited to drainages of the Cascade Range foothills between Wingate Hill and Spar Pole Hill and is confined to the south and east by bedrock of the Northcraft Formation (unit Evc_n). Crandell (1963, p. A22) proposed equivalence of the older part of the Lily Creek Formation with the Alderton Formation in the lowland, and the younger part with the Puyallup Formation. This also seems to imply equivalence of the middle part of the Lily Creek with the Stuck Drift in the lowland. Description compiled from Crandell (1963).

$Qgpc_{pd}$ **Pre–Double Bluff continental glacial and nonglacial deposits**—Composite geologic unit that includes combinations from among all of the continental glacial and nonglacial geologic units older than the Double Bluff (unit Qgp_d), including glacial deposits from the Salmon Springs (unit Qgp_s), Stuck, and Orting Glaciations (unit Qgp_o). Unit $Qgpc_{pd}$ is widely distributed at or near the base of bluffs along the White and Puyallup River valleys and in the vicinity of Sumner and the northern end of Vashon Island. Stuck Drift (shown only as part of composite units) includes very compact till and outwash sand and gravel, locally includes laminated sand, silt, and volcanic ash; up to 73 ft thick; reversely magnetized; typically oxidized but otherwise unweathered except for disintegrating granitic clasts; deposited by the Puget lobe; maximum extent unknown. Description compiled from Crandell (1963) and Walters and Kimmel (1968).

$Qgpc_{ps}$ **Pre–Salmon Springs continental glacial and nonglacial deposits**—Composite geologic unit that includes some combination of Puyallup Formation (unit Qc_p), Alderton Formation (unit Qc_a), Stuck Drift (shown only as part of composite units—see unit $Qgpc_{pd}$ for description), and Orting Drift (unit Qgp_o); mapped along Fennel Creek south of Bonney Lake.

Qc_p **Puyallup Formation**—Alluvial and lacustrine silt, sand, and gravel from Mount Rainier and the central Cascade Range; compact peat beds and mudflows common; average unit thickness about 135 ft; exposures weathered to clay to a depth of about 10 in. Laminated pinkish-gray silt and fine gray sand grade to light-gray, medium to coarse sand as much as 70 ft thick. Lenses of light-gray andesite pebbles and gravel, as well as coarse sand-sized yellowish-gray pumice, are common. Mudflows are as much as 21 ft thick. The Puyallup Formation closely resembles the older Alderton Formation (unit Qc_a) in lithology, types of deposits, and distribution. The Lily Creek Formation (unit Qvl_{lc}) is the partial(?) upstream equivalent of the Puyallup Formation. $^{40}Ar/^{39}Ar$ age determinations of 1.69 ±0.11 and 1.64 ±0.13 Ma (Table 1, map nos. 167–168) were obtained from a pumice layer within this unit on the south side of the Puyallup River near Sumner. Unit Qc_p is mapped in the northeast part of the quadrangle, within the Auburn, Black Diamond, and Puyallup 7.5-minute quadrangles. Description from Crandell (1963) and Crandell and others (1958).

Qc_a **Alderton Formation**—Alluvial sand, pebble to boulder gravel, mudflows, and peat. Sediments are at least 100 ft thick and primarily derived from Mount Rainier. Peat and silty peat layers contain various species of fossil pollen. A notable pumiceous tuff is exposed near the top of the unit and consists of a pinkish-gray ash of fine sand-sized matrix with phenocrysts of hypersthene and hornblende. Tuff also contains angular rock fragments and carbonized wood fragments. This unit was deposited during the interval after the Orting Glaciation and partially(?) correlates with the Lily Creek Formation (unit Qvl_{lc}). Outcrops are limited to the walls of the Puyallup Valley near the town of Alderton in the Sumner 7.5-minute quadrangle; the unit is only represented on the map by a $^{40}Ar/^{39}Ar$ age sample (map no. 177), which yielded a maximum ash deposition age of 1.6 Ma. The Alderton Formation is separated from the overlying Stuck Drift by an erosional unconformity. Description compiled from Crandell (1963) and Crandell and others (1958).

Qgp$_o$ **Orting Drift**—Deeply oxidized sand and gravel with minor amounts of sand and compact till; reversely magnetized, suggesting an age greater than 690,000 yr (Easterbrook and others, 1985). The till is yellowish gray, yellowish brown where oxidized, and is discontinuous over broad areas at any one horizon. It is a very compact, unsorted, and unstratified mixture of subangular pebbles, cobbles, and boulders in a sandy silt matrix. Stratified sediments consist principally of pebble and cobble gravel and sand. At many places, the gravel is poorly sorted and closely resembles till except for a lack of fine sediment and large boulders. The gravel is commonly closely packed in a matrix of yellowish-brown, fine to medium sand, but locally there are beds and lenses of openwork gravel several feet thick. Much of the stratified sediment is of central Cascade Range provenance. Bedding is generally not well defined, although there are outcrops with cut-and-fill stratification, deltaic foreset beds, and crossbedding. The Orting Drift is vertically offset as much as 50 ft in places by normal faults. In one place, the beds are jumbled blocks of gravel, sand, and till, suggesting that they were deposited on or against ice whose subsequent melting caused collapse, faulting, and jumbling of the deposits. The greatest known thickness of Orting Drift is about 260 ft, most of it gravel. Orting Drift crops out in a belt about 3 mi wide along the foothills of the Cascade Range. North of Orting and South Prairie, the drift disappears beneath a cover of younger formations. The most extensive outcrops are along the valley walls of the Carbon River and South Prairie Creek where the drift seems to be a single widespread sheet of gravel resting upon an eroded bedrock surface. Without exception, till of this age is of northern provenance; most of the gravel not closely adjacent to a till sheet, however, is from the central Cascade Range. This suggests that the gravel was deposited by streams originating in the Cascade Range. Because of its stratigraphic position and lithology, the drift probably represents the earliest glaciation of the southeastern Puget Lowland. Orting Drift is inferred to be at least partly older than the Lily Creek Formation (unit Qvl$_{lc}$). Unit Qgp$_o$ is exposed in the Black Diamond, Buckley, Orting, Sumner, and Wilkeson 7.5-minute quadrangles. Description compiled from Crandell (1963) and Walsh (1987).

Tertiary Intrusive, Volcanic, and Sedimentary Rocks

Ɱc$_h$ **Hammer Bluff Formation (late Miocene)**—Continental sedimentary rocks consisting of an upper member of clayey fluvial sand and gravel derived from volcanic rock, with thin silt and clay lenses and wood fragments, and a lower member of lacustrine and fluvial quartzose sand and kaolinitic clay. The formation is cohesive and compact. Maximum known thickness is about 100 ft; the upper member is about 75 ft thick and the lower member about 28 ft thick. The lower member includes volcanic ash beds and woody lignite. Hammer Bluff Formation crops out along the north channel wall of the Green River southwest of Black Diamond and is bounded by angular unconformities both above and below. It is overlain by Orting Drift (unit Qpg$_o$) and underlain by rocks of the Puget Group (unit Ec$_{2pg}$). An assemblage of fossil plants near the bottom of the upper member is late Miocene (Mullineaux, 1965b). The upper member is strongly iron stained, includes many stones and sand grains partly weathered to clay, and is relatively clay-rich and impermeable, causing slope failure. Unit Ɱc$_h$ is mapped along the northern bluff of the Green River at the east edge of the quadrangle. Description compiled from Mullineaux (1965b) and Phillips (1984).

Ɱvl **Lahars (middle to late Miocene)**—Hornblende-bearing pumice gravel, several ash layers, and three lahars containing carbonized wood. Alluvial sand and gravel and semiconsolidated lacustrine sand, silt, and clay derived from the Ohanapecosh Formation (unit Φvc$_{oh}$) east of this quadrangle both underlie and overlie the lahars. Although the maximum thickness of the lahars may be 125 ft, exposures are generally small and of limited extent. Outcrops of the fluvial and lacustrine deposits along the valley walls of Voight Creek cannot be correlated with any other formation, although distinctive hornblende-rich volcanic debris (Table 3, map nos. 23 and 24) in South Prairie Creek and Wilkeson Creek channels has been correlated with the Ellensburg Formation of central Washington. Structural and topographic relations of the Miocene lahars and the Puget Group near Burnett indicate that the contact between them is an angular unconformity. Fossil leaves found in lacustrine deposits are middle or late Miocene in age. Unit Ɱvl is mapped along Wilkeson and Voight Creeks east of Orting. Description compiled from Gard (1968).

ⱮΦi **Intrusive latite (Miocene to Oligocene)**—Three latite masses intrude the Northcraft Formation (unit Evc$_n$) within the Orting 7.5 minute quadrangle. Only the largest is distinguishable on the Tacoma quadrangle—it is an oval mass of light gray to creamy tan latite, 800 ft wide and 3,000 ft long, cropping out southeast of Orting in and along Fox Creek (Table 3, map no. 41). The rock consists of oligoclase and pyroxene phenocrysts in a cryptocrystalline groundmass; original phenocrysts of pyroxene have been replaced by magnetite. The long axis of the intrusion trends eastward almost parallel to the channel. The latite is well jointed and breaks into platy fragments. It has contorted flow bands, local drag folds, and contains many xenoliths of gray and tan igneous rock unlike other rocks in the area. In some places, the latite is so crowded with angular inclusions of recrystallized glass that even in thin sections it is easily mistaken for a breccia. Description compiled from Gard (1968).

ⱮΦid **Quartz diabase (Miocene to Oligocene)**—Sill of dark-gray quartz diabase (diorite) (Table 3, map nos. 42 and 43), weathered to a light greenish gray in places; appears chalky where feldspars have been strongly weathered; holocrystalline and medium grained; at least 950 ft thick.

The sill is porphyritic near its margins, with phenocrysts of white feldspar and pyroxene in a fine-grained, dark-greenish-gray groundmass. The sill coarsens inward to a hypidiomorphic-granular texture, suggesting marginal chilling. Unit MΦid is found within the Carbon River valley south of Carbonado and is traceable for nearly 3 mi between west-dipping beds of the Carbonado Formation. Description compiled from Gard (1968).

MΦiad **Intrusive andesite and dacite (Miocene to Oligocene)**—Light-gray massive hornblende dacite porphyry (Table 3, map no. 40), deeply weathered in places to feldspar, amphibole, and clay grus. Irregularly shaped cavities are common; small cavities enclose zeolites and green montmorillonite, and large cavities may be entirely empty or thinly lined with montmorillonite. Massive porphyry surrounded by columnar-jointed porphyry implies emplacement at shallow depth—possibly as a laccolith. Xenoliths commonly include rounded to angular andesite as much as 14 in. across and, less commonly, black tuff resembling the hydrothermally altered tuff of the Northcraft Formation (unit Evc$_{n}$). Unit MΦiad is mapped in a quarry south of Orting. Unit also includes gray, black, and greenish-gray, fine- to medium-grained, porphyritic pyroxene andesite sills and dikes with prominent feldspar and pyroxene phenocrysts (Table 3, map no. 25). The sills and dikes intrude the Eocene and Oligocene rocks (Puget Group and Ohanapecosh Formation) in the southeast corner of the quadrangle; only the largest are shown. Description compiled from Gard (1968).

ΦEc **Continental sedimentary rocks (Oligocene to Eocene)**—Tuffaceous sandstone and conglomerate, mudstone, and shale; exposed thickness is about 1,600 ft. Generally poorly indurated; may be locally cemented by calcite and zeolites; strongly iron-stained and partly weathered to clay. Outcrops along the Cedar River near Renton form an angular unconformity with overlying Salmon Springs Drift (unit Qgp$_{s}$) and lie disconformably above the Renton Formation (part of the Puget Group, unit Ec$_{2pg}$). Description compiled from Mullineaux (1965c) and Waldron (1962).

Φvc$_{oh}$ **Ohanapecosh Formation (Oligocene)**—Conglomerate, sandstone, siltstone, and shale composed of clay minerals, subangular feldspar, small rock fragments, scattered pyroxene fragments, magnetite grains, calcite, and zeolites. Typically greenish gray, though may locally be black, brown, red, or white. Volcanic sandstone low in the formation is poorly sorted. Conglomerate commonly contains well-rounded andesite pebbles 0.5-in. across. Several andesite sills have intruded the volcanic sedimentary rocks. Some of the siltstone beds are platy and contain well-preserved leaf impressions and scattered organic material. The Ohanapecosh Formation crops out along the southeast edge of the Tacoma quadrangle. It is best exposed in the steep valley walls of South Prairie Creek and in the south valley wall of Page Creek east of Wilkeson. This unit overlies the Spiketon Formation (part of the Puget Group). Exposures of these strata in roadcuts northeast of Burnett imply a conformable contact. Similarity of composition, stratigraphic position, and age suggest that at least part of the Ohanapecosh is equivalent to the basaltic sandstone member of the Lincoln Creek Formation in the Centralia 1:100,000-scale quadrangle to the south and similar rocks near Renton. Assemblages of fossil plants from the Ohanapecosh Formation are variously regarded as Eocene or Oligocene; Gard (1968, p. B17–18) considers the Ohanapecosh Formation in the southeast corner of the Tacoma quadrangle to be Oligocene. Description compiled from Gard (1968).

Φida **Intrusive dacite (upper Oligocene)**—Basaltic, andesitic, or dacitic rocks; medium dark gray to dark greenish gray; porphyritic in texture. Phenocrysts of plagioclase feldspar and augite locally make up 10 to 20 percent of the rock in a groundmass of fine to very fine laths of plagioclase feldspar, pyroxene, chlorite, clay minerals, and magnetite. This unit intrudes the Puget Group at several locations in the Maple Valley 7.5-minute quadrangle. Most intrusions are less than 40 ft thick, though one on Fifteenmile Creek is about 400 ft thick. Differences among exposures of this unit further south, such as just east of Lake Desire near Cedar Mountain, include finer-grained crystals and more chloritic alteration. K-Ar geochronology east of the quadrangle near Black Diamond indicates that the intrusive rocks are upper Oligocene and perhaps cogenetic with volcanic rocks overlying the Puget Group (Turner and others, 1983). Rocks of this unit form massive outcrops or steep slopes because they are more resistant to weathering and erosion than the enclosing sedimentary rocks. Description compiled from Phillips (1984) and Vine (1969).

ΦEian **Intrusive porphyritic andesite (Oligocene to Eocene)**—Irregularly shaped intrusive rocks and a sill of porphyritic andesite, probably emplaced at shallow depth. Unit ΦEian is intersected by numerous minor faults and joints and by veins of montmorillonite, calcite, quartz, and other minerals. These rocks are younger than the Tukwila Formation of the Puget Group. Unit ΦEian is mapped as a geologic point unit along the Black River where it meets the Duwamish River near Tukwila. Description compiled from Mullineaux (1965a).

Ec$_{2pg}$ **Continental sedimentary rocks of the Puget Group (early Eocene to early Oligocene)**—Sandstone, tuffaceous sandstone, siltstone, shale, carbonaceous shale, claystone, tuff, and coal. Sandstone is feldspathic and micaceous; tabular sandstone beds are massive to crossbedded and occasionally have channel cut-and-fill structures. Light to dark siltstone forms poor outcrops, is often thinly laminated, and contains organic matter; coal beds are as thick as 16 ft. The Puget Group includes the Spiketon, Northcraft, Carbonado, Renton, Tukwila, and Tiger Mountain Formations, and additional arkosic sandstone and marine and nonmarine sedimentary rocks. Puget Group rocks crop out along the northeastern and eastern borders of the quadrangle. Fossil leaves indicate an early Eocene to early Oligocene age for the Puget Group in the Green River area (Table 1, map no. 51). However, radiometric dating of ash partings sampled near Black Diamond east of the quadrangle suggests a much shorter age range (41.2 ±1.8 to 45.0 ±2.1 Ma) (Turner and others, 1983). Geochemistry of numerous interlayered tuff beds sampled from three boreholes at the southeast corner of the map area are shown in Table 3 (map nos. 44–58). Description compiled from Gard (1968), Mullineaux (1965a,c), Phillips (1984), Troost and others (2005), and Vine (1969). Locally divided into:

Evc$_n$ **Northcraft Formation (Eocene)**—Andesite breccia; generally brownish or yellowish black, but may be brick red, dark gray, greenish gray, or black on fresh surfaces; includes tuff that may be hydrothermally altered and lesser amounts of volcanic conglomerate and volcanic sandstone, both of which are interbedded with mudflow breccia. The breccia, which may be many tens of feet thick, forms massive beds of angular andesite rock fragments. The conglomerate consists of subrounded porphyritic andesite pebbles 1 to 4 in. across in a matrix of subangular silt- and sand-sized volcanic rock fragments and minor quantities of feldspar and pyroxenes. The Northcraft Formation lies at or near the surface in the southeast corner of the quadrangle. To the east, the unit is thin and overlain by the Spiketon Formation (also of the Puget Group), but is up to 2,000 ft thick. Fossil leaves collected east and south of the Tacoma quadrangle indicate an Eocene age. Weathered or uncemented breccia erodes readily, and large resistant fragments commonly protrude from outcrops. Most layers of breccia in the Northcraft Formation appear to have been emplaced as lahars, but some may be breccias of pyroclastic origin or flow breccias. Description compiled from Gard (1968).

Ei **Porphyritic intrusive igneous rocks (Eocene)**—Greenish-gray rocks composed of zoned and altered plagioclase and hornblende phenocrysts. Subhedral plagioclase phenocrysts constitute about 40 percent of the rock, euhedral hornblende phenocrysts about 5 percent, and the remainder is a fine-grained volcanic matrix. Unit Ei is exposed in the canyon walls of Issaquah Creek in the northeast corner of the Tacoma quadrangle along the lower east slope of Squak Mountain. Although the contact with adjacent Renton and Tukwila Formations (the Puget Group) is not exposed, this intrusive rock apparently cuts across beds of the Tukwila Formation. Elsewhere, it is lenticular in shape and may be a small stock. Unit Ei resembles fragments in conglomerate and tuff breccia in the upper part of the Tukwila Formation, but it may also be a volcanic vent that supplied extrusive material. Description compiled from Booth (1995) and Vine (1969).

Eib **Intrusive porphyritic basalt and andesite**—Irregular masses of igneous rock contain visible grains of plagioclase and very small mafic minerals; black to various shades of brown. Microscopically, rocks are porphyritic and commonly contain a matrix of interstitial glass; composed of 50 percent or more plagioclase and generally some pyroxene. Interstitial glass in some of the rocks is relatively fresh; in others, it is altered to palagonite or nontronite, or to a carbonate and clay-mineral mixture. Unit is exposed at several localities adjacent to the Duwamish valley near Tukwila. Rocks of this unit are generally massive, but locally have columnar structure and appear to have intruded the Puget Group. This unit is probably no older than late Eocene. Description compiled from Waldron (1962).

Ev$_c$ **Crescent Formation (Eocene)**—Plagioclase-pyroxene tholeiitic basalt (Tables 2 and 4, map nos. 26–33), with local diabase and gabbro; dark gray with a greenish tint, brown where weathered, and reddish and variegated along altered contact zones. Pervasive zeolite and chlorite or chloritoid alteration occurs in the matrix. Basalt is commonly amygdaloidal with zeolite and (or) chlorite amygdules; pillows are characteristic of the lower part of the Crescent Formation. This unit contains variously oriented columnar jointed flows or sills, as well as breccias; refilled lava tubes are common in breccias; commonly sheared and faulted. Highly vesicular units are commonly altered and contain abundant clay minerals; whereas thick units with strong columnar jointing tend to be less altered. Parts of the formation may be submarine in origin. Unit Ev$_c$ crops out in the southwest corner of the quadrangle. Description compiled from Walsh and others (2003a).

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Appendix. Compiled Geochronology and Geochemistry

Table 1. Age-control data compiled from previous studies in the Tacoma quadrangle. Map numbers tabulated by method correspond to sample locations shown on the map sheet, which are ordered sequentially starting with the northwest corner of the quadrangle. Geochron ID values are from the Analysis ID field within the Washington State Geochronology Database (Czajkowski, 2014); additional analytical data, sources, and error reporting are reported there in more detail. In general, the level of uncertainty reported here is that which was reported by the original authors; no attempt has been made to standardize these values. Most luminescence data were obtained from Shannon Mahan (U.S. Geological Survey, 2015, written commun.). IRSL, infrared stimulated luminescence; OSL, optically stimulated luminescence; TL, thermoluminescence.

Map no.	Age estimate	Analytical method	Material dated	Geologic unit	Lab no.	Geochron ID	Notes	Latitude Longitude
Radiocarbon (^{14}C years BP)								
1	>46,000	^{14}C: conventional	wood	Qcp	Beta 254696	10969	Sampled from Simson Creek area	47.428319 -122.917289
2	290 ±40	^{14}C: conventional	wood	Qa	Beta 253254	10981	Sampled from outer growth rings of horizontal log in river cut bank	47.490166 -122.813471
3	403 ±62	^{14}C: conventional	plant material	Qp	Geochron 17121	11248	Sampled from tidal flat in Lynch Cove	47.450863 -122.835213
4	356 ±51	^{14}C: conventional	plant material	Qp	Geochron 17120	11249	Sampled from tidal flat in Lynch Cove	47.450863 -122.835213
5	1,170 ±90	^{14}C: conventional	peat	Qp	Beta 29145	11250	Sampled from tidal flat in Lynch Cove; represents minimum age of abrupt uplift	47.450863 -122.835213
6	1,050 ±70	^{14}C: conventional	wood	Qp	Beta 36046	11251	Sampled from woody root in growth position in tidal flat in Lynch Cove; represents age of abrupt uplift	47.450863 -122.835213
7	1,420 ±70	^{14}C: conventional	wood	Qa	Beta 45382	11252	Sampled from detrital wood fragment beneath peat in tidal flat in Lynch Cove; represents maximum age of abrupt uplift	47.450863 -122.835213
8	2,700 ±85	^{14}C: conventional	marine shell	Qa	Geochron 16267	11253	Sampled from tidal flat in Lynch Cove	47.450863 -122.835213
9	540 ±40	^{14}C: conventional	organic material	Qp	Beta 229237	10967	Sampled by push core at 3 ft depth in sag pond	47.419274 -122.86005
10	1,040 ±40	^{14}C: conventional	wood	Qls	Beta 229238	10968	Sampled by push core at 4 to 5 ft depth; from clay in sag pond	47.419274 -122.86005
11	43,560 ±820	^{14}C: conventional	peat	Qc_o	Beta 253255	10976	Sampled from silt in stream cutbank	47.374849 -122.783819
12	>48,000	^{14}C: conventional	organic sediment	Qcp	Beta 218750	10092	Sampled at 320 ft depth from boring	47.493475 -122.665429
13	1,130 ±50	^{14}C: conventional	peat	Qp	– – –	11260	Sampled from basal peat in marsh near Burley; marks age of abrupt uplift	47.411952 -122.630286
14	>43,400	^{14}C: conventional	wood	Qc_p	Beta 253253	11009	Sampled from stiff clay at top of beach below sand	47.375672 -122.652514
15	40,660 ±970	^{14}C: conventional	peat	Qc_o	Beta 128806	10090	Sampled from outcrop in Fragaria	47.461634 -122.538313
16	39,050 ±940	^{14}C: conventional	peat	Qc_o	Beta 128805	10083	Sampled in Olalla Creek quarry (abandoned)	47.426428 -122.555456
17	>40,000	^{14}C: measured	peat	Qgp_p	– – –	10363	Sampled near Maplewood	47.408943 -122.5588
20	>42,000	^{14}C: measured	peat	Qgp_p	USGS 1982	10364	Kitsap Formation type section	47.396704 -122.55249
21	>41,420	^{14}C: conventional	peat	Qc_{po}	Beta 131069	10079	Sampled in bluff near Maplewood South	47.394123 -122.553406
22	38,790	^{14}C: conventional	organic sediment	Qc_o	Beta 131071	10078	Bluff at Haug’s	47.386934 -122.550131
23	>44,290	^{14}C: conventional	peat	Qc_o	Beta 131072	10253	Sampled from outcrop near Haug’s; contamination possible	47.386934 -122.550131
24	>38,000	^{14}C: conventional	peat	Qc_{po}	W 1515	10365	Sampled from bluff near Maplewood	47.387819 -122.551525

Map no.	Age estimate	Analytical method	Material dated	Geologic unit	Lab no.	Geochron ID	Notes	Latitude Longitude
Radiocarbon (^{14}C years BP), continued								
25	>42,000	^{14}C: measured	peaty silt	Qco	W 2028	10503	Bluff on west side of Colvos Passage 0.8 mi south of Maplewood	47.387819 -122.551525
27	38,360 ±780	^{14}C: conventional	wood	Qcpo	Beta 125674	10093	Sampled from bluff at Wingehaven Park	47.497732 -122.459066
28	>44,630	^{14}C: conventional	wood	Qcpo	Beta 125675	10095	Sampled from bluff at Wingehaven Park	47.497769 -122.45904
29	43,030 ±2,470	^{14}C: conventional	peat	Qcpo	Beta 125676	10094	Sampled from bluff at Wingehaven Park	47.497739 -122.45904
30	>42,000	^{14}C: measured	peat	Qcp	USGS 1622	10545	Sampled from ravine near Scola Beach	47.492766 -122.361132
31	>37,000	^{14}C: reported	peat	Qcp	Geochron 8933	11060	– – –	47.481305 -122.359073
32	>37,000	^{14}C: reported	peat	Qcp	Geochron 8934	11059	– – –	47.482038 -122.357883
33	12,300 ±200	^{14}C: measured	peat	Qp	University of Washington 1	10507	Sampled from base of Miller Creek Bog near SeaTac airport	47.471551 -122.305263
34	36,800 ±1,000	^{14}C: measured	peat	Qco	University of Washington 31	10089	Sampled from depth of 311 ft in borehole in SeaTac; corrected for tritium contamination	47.456516 -122.280238
35	>37,000	^{14}C: reported	peat	Qcp	Geochron 8935	11061	– – –	47.448452 -122.263438
36	5,950 ±400	^{14}C: measured	peat	Qp	USGS 779	10532	Sampled from peat above ash in Bow Lake; ash identified as either Glacier Peak or Mazama	47.439217 -122.294335
37	6,600 ±400	^{14}C: measured	peat	Qp	USGS 776	10531	Sampled from peat below ash in Arrow Lake; ash identified as either Glacier Peak or Mazama	47.424945 -122.28008
38	6,630 ±400	^{14}C: measured	peat	Qp	USGS 777	10530	Sampled from peat above ash in Arrow Lake; ash identified as either Glacier Peak or Mazama	47.424945 -122.28008
39	670 ±40	^{14}C: conventional	plant material	Qa	Beta 162209	10081	Sampled from test pit at SeaTac	47.419098 -122.302763
40	>37,000	^{14}C: measured	wood	Qcp	USGS 259	10308	Sampled from interglacial sediments in bluff at Zenith	47.392193 -122.325474
41	>38,000 ±0	^{14}C: measured	wood	Qgp?	USGS 671	10091	Sampled from sand directly above pre-Vashon till in excavation in Renton	47.49194 -122.233003
42	>38,000	^{14}C: measured	wood	Qcp	USGS 1029	10516	Sampled from peaty clay in clay pit on south side of Cedar River; attempt to date the onset of Vashon Glaciation	47.475537 -122.192637
43	450 ±200	^{14}C: measured	wood	Qa	USGS 2027	10505	Sampled at 26 ft depth in alluvial fill of Duwamish Valley	47.458203 -122.234758
44	290 ±30	^{14}C: conventional	wood	Qls	Beta 162220	10085	Excavation in Fairwood	47.446962 -122.130306
45	>46,600	^{14}C: measured	– – –	Qcp	– – –	10277	Sampled in boring on Cedar hill at 209 ft depth	47.458476 -122.050564
46	>46,880	^{14}C: measured	– – –	Qcp	– – –	10278	Sampled in boring on Cedar hill at 328 ft depth	47.458476 -122.050564
47	35,500 ±830	^{14}C: conventional	organic sediment	Qco	Beta 167899	10087	Sampled from boring on Cedar Hill	47.458476 -122.050564
48	>45,810	^{14}C: measured	– – –	Qcp	– – –	10276	Sampled in boring on Cedar hill at 76 ft depth	47.458476 -122.050564
49	28,980 ±340	^{14}C: conventional	peat	Qco	Beta 168685	10086	Sampled from boring on Cedar Hill	47.458291 -122.047475
50	14,740 ±70	^{14}C: conventional	peat	Qco	Beta 168684	10088	Sampled from boring on Cedar Hill	47.458707 -122.044201
52	>45,000	^{14}C: conventional	wood	Qcp	Beta 197908	10265	Sampled in boring at Francis Lake gravel pit	47.434581 -122.045417

Map no.	Age estimate	Analytical method	Material dated	Geologic unit	Lab no.	Geochron ID	Notes	Latitude Longitude
Radiocarbon (^{14}C years BP), continued								
53	>45,000	^{14}C: conventional	wood	Qcp?	Beta 197907	10084	Sampled in boring at Francis Lake gravel pit	47.434581 -122.045417
54	>45,000	^{14}C: conventional	wood	Qcp	Beta 197909	10266	Sampled in boring at Francis Lake gravel pit	47.434581 -122.045417
55	70 ±40	^{14}C: conventional	wood	– – –	Beta 228029	10975	Sampled from stump in landslide-dammed lake	47.374542 -122.797786
56	1,140 ±50	^{14}C: conventional	wood	– – –	Beta 221634	10970	Sampled from stump of tree drowned by earthquake-induced stream damming in Catfish Lake	47.366651 -122.841187
57	1,290 ±60	^{14}C: conventional	wood	– – –	Beta 221635	10971	Sampled from stump of tree drowned by earthquake-induced stream damming in Catfish Lake	47.366459 -122.841727
58	1,240 ±60	^{14}C: conventional	wood	– – –	Beta 221636	10972	Sampled from stump of tree drowned by earthquake-induced stream damming in Mill Pond	47.367305 -122.845193
59	1,260 ±60	^{14}C: conventional	wood	– – –	Beta 221637	10973	Sampled from stump of tree drowned by earthquake-induced stream damming in Mill Pond	47.366954 -122.845244
60	100 ±50	^{14}C: conventional	wood	Qp	Beta 228030	10974	Sampled from shallow marsh	47.361841 -122.839129
61	>44,240	^{14}C: conventional	peat	Qcp	Beta 221638	10977	Sampled from above pre-Vashon deposits in bluff above beach	47.263262 -122.867188
62	>44,620	^{14}C: conventional	peat	Qcp	– – –	11193	Sampled from sand, silt, and gravel below Vashon-age deposits	47.367509 -122.676977
63	19,040 ±130	^{14}C: conventional	wood	$\mathrm{Qc_o}$	Beta 213390	11194	Sampled from wispy silt layer within thick sand bed	47.320729 -122.688187
64	>44,250	^{14}C: conventional	peat	Qcp	– – –	11192	Sampled from sand, silt, and gravel below Vashon-age deposits	47.280091 -122.69113
65	41,940 ±2,550	^{14}C: conventional	peat	$\mathrm{Qc_o}$	Beta 162211	10075	Drummond Drive	47.353567 -122.568622
66	>45,070	^{14}C: conventional	peat	Qcp	Beta 142520	10264	Sampled from bluff at Point Dalco	47.334579 -122.520348
67	15,110 ±130	^{14}C: conventional	organic sediment	$\mathrm{Qc_o}$?	Beta 75435	10072	Sampled from hillside at Washington Correction Center for Women	47.339422 -122.609283
71	>38,220	^{14}C: conventional	plant material	Qcp	Beta 105922	10071	Sampled from bluff at Point Defiance	47.318323 -122.539663
72	>50,080	^{14}C: conventional	plant material	Qgp	Beta 105921	10070	Sampled from bluff at Point Defiance	47.317905 -122.537607
74	26,610 ±410	^{14}C: conventional	organic sediment	$\mathrm{Qc_o}$	Beta 105924	10069	Sampled from bluff at Point Defiance	47.317133 -122.534943
75	>43,200	^{14}C: conventional	wood	Qcp	Beta 128803	10259	Sampled from bluff at Point Defiance	47.316935 -122.548232
79	>46,750	^{14}C: conventional	peat	Qcp	Beta 80938	10262	Sampled from bluff at Tacoma Boathouse	47.307488 -122.518127
80	>44,530	^{14}C: conventional	wood	Qgp	Beta 128802	10258	Sampled from bluff on Salmon Beach	47.301917 -122.534701
81	>47,360	^{14}C: conventional	peat	$\mathrm{Qc_{po}}$	Beta 105923	10255	Sampled from bluff on Salmon Beach	47.298416 -122.532607
82	>47,340	^{14}C: conventional	plant material	Qcp	Beta 105918	10254	Sampled from outcrop on Salmon Beach	47.292335 -122.528655
87	>44,740	^{14}C: conventional	peat	Qcp	Beta 168206	10064	Sampled from beach bluff near Point Evans	47.289924 -122.5511
88	13,340 ±40	^{14}C: conventional	pine cone	$\mathrm{Qc_o}$?	Beta 145431	10065	Sampled from bluff near Point Evans	47.289924 -122.551095
89	13,430 ±60	^{14}C: conventional	plant material	$\mathrm{Qc_o}$?	Beta 136969	10066	Sampled from bluff near Point Evans	47.289925 -122.551094

Map no.	Age estimate	Analytical method	Material dated	Geologic unit	Lab no.	Geochron ID	Notes	Latitude Longitude
Radiocarbon (^{14}C years BP), continued								
93	42,950 ±2,430	^{14}C: conventional	peat	Qco	Beta 168205	10063	Sampled from beach bluff near Point Evans Light	47.284635 -122.548579
94	>42,720	^{14}C: conventional	peat	Qcp	Beta 141203	10062	Sampled from bluff near Wollachet North	47.277541 -122.59049
95	>45,240	^{14}C: conventional	organic sediment	Qcp	Beta 140644	10061	Sample from bluff near Bayview	47.275301 -122.598913
98	22,570 ±310	^{14}C: conventional	organic sediment	Qco	Beta 145430	10050	Sampled from beach bluff in Magnolia Heights	47.267058 -122.596394
99	>40,620	^{14}C: conventional	peat	Qcp	Beta 137975	10049	Sampled from ditch in Magnolia Heights	47.266512 -122.597013
102	44,880 ±3,050	^{14}C: conventional	peat	Qco	Beta 120061	10045	Sampled from gully near Tacoma Narrows	47.260638 -122.543478
103	3,410 ±50	^{14}C: conventional	organic sediment	Qp	Beta 128801	10067	Sampled from bluff near Brown's Point	47.297614 -122.419753
104	34,860 ±350	^{14}C: conventional	organic sediment	Qco	Beta 131070	10059	Sampled from gully in Garfield Park	47.274002 -122.460019
105	27,180 ±110	^{14}C: conventional	peat	Qco	Beta 136970	10060	Sampled from bluff in Garfield Park	47.274012 -122.460036
106	44,390 ±2,970	^{14}C: conventional	peat	Qco	Beta 120059	10256	Sampled from outcrop at Garfield Park	47.273231 -122.4591
107	32,740 ±410	^{14}C: conventional	peat	Qco	Beta 122230	10057	Sampled from gully in Garfield Park	47.273231 -122.4591
109	39,190 ±870	^{14}C: conventional	organic sediment	Qco	Beta 122231	10055	Sampled from gully in Garfield Park	47.272231 -122.454809
110	41,310 ±2,020	^{14}C: conventional	peat	Qco	Beta 120060	10048	Sampled from gully in Garfield Park	47.268622 -122.458021
111	42,210 ±2,310	^{14}C: conventional	peat	Qco	Beta 128804	10047	Sampled from bluff on Shuster Parkway	47.266802 -122.446567
112	5,050 ±90	^{14}C: measured	wood	Qvlo	University of Washington 62	10074	Age of Osceola Mudflow from sample at 320 ft depth in borehole near Kent	47.352105 -122.256527
116	>53,480	^{14}C: conventional	wood	Qga	Beta 95340	10058	Reworked charcoal sampled from sand in Woodworth quarry	47.275459 -122.369999
117	36,690 ±650	^{14}C: measured	sediment	Qco	Beta 57731	10056	Sampled from Woodworth quarry	47.274198 -122.375151
118	32,040 ±690	^{14}C: conventional	organic sediment	Qco	Beta 80937	10054	Sampled from thin paleosol from Woodworth quarry	47.273516 -122.374428
119	>41,710	^{14}C: conventional	organic sediment	Qco	Beta 86482	10052	Sampled from paleosol in bluff in Woodworth quarry	47.273516 -122.374428
120	27,530 ±390	^{14}C: conventional	organic-rich sediment	Qco	ISGS 3301	10053	Sampled from thin paleosol from bluff in Woodworth quarry	47.273516 -122.374428
121	>37,000 ±0	^{14}C: measured	wood	Qcp	USGS 258	10051	Sampled from bog deposit beneath Vashon Drift in gravel pit in east Tacoma	47.273 -122.373756
124	36,650 ±720	^{14}C: conventional	peat	Qco	Beta 87981	10046	Sampled from base of nonglacial sequence in Manke gravel pit	47.265804 -122.357919
125	>46,450	^{14}C: conventional	peat	Qco	Beta 89875	10044	Sampled from Foran quarry	47.262058 -122.353982
128	>45,440	^{14}C: conventional	wood	Qcp	Beta 207133	10076	Lakeside Industries gravel pit	47.372099 -122.079435
129	6,500 ±200	^{14}C: measured	peat	Qp	Lamont (Columbia University) 269C	10073	Maximum age of Mazama tephra sampled at 13.75 ft depth in boring in Grass Lake	47.353701 -122.072209

Map no.	Age estimate	Analytical method	Material dated	Geologic unit	Lab no.	Geochron ID	Notes	Latitude Longitude
Radiocarbon (^{14}C years BP), continued								
130	10,200 ±500	^{14}C: measured	peat	Qp	Lamont (Columbia University) 269D	10286	Sampled at 365 ft depth in boring in Grass Lake; age likely represents Vashon ice recession	47.353701 -122.072209
131	>44,010	^{14}C: conventional	peat	Qcp	Beta 156817	10988	Sampled on northeast shore of Squaxin Island	47.218584 -122.919517
132	>38,950	^{14}C: conventional	peat	Qcp	Beta 156818	10987	Sampled on west shore of Squaxin Island	47.20221 -122.921762
133	>45,000	^{14}C: measured	wood	Qcp	University of Washington 49	10032	Sampled from beach bluff on south shore of Hammersley Inlet	47.200325 -122.95399
134	>45,280	^{14}C: conventional	wood	Qcp	Beta 167217	10983	Sampled from southern shore of Hammersley Inlet, east of Mill Creek	47.197648 -122.990043
135	>43,550	^{14}C: conventional	peat	Qcp	Beta 148521	10985	Sampled on east shore of Totten Inlet	47.167733 -122.945413
136	44,170 ±2,900	^{14}C: conventional	peat	Qc_o?	Beta 150759	10986	Sampled on east shore of Totten Inlet	47.158886 -122.957616
137	38,060 ±620	^{14}C: conventional	peat	Qc_o	Beta 167211	10984	Sampled on Eld Inlet, northeast of Sanderson Harbor	47.152919 -122.931301
138	33,220 ±300	^{14}C: conventional	peat	Qc_o	Beta 129456	10996	Sampled from peat in water well at 137 ft depth near Boston Harbor	47.134198 -122.882028
139	>44,840	^{14}C: conventional	peat	Qcp	Beta 154172	10978	Sampled west of Joemma Beach on Key Peninsula	47.240565 -122.827331
140	>46,730	^{14}C: conventional	peat	Qcp	Beta 143714	10979	Sampled near Wilson Point on east side of Hartstene Island	47.225327 -122.854623
141	>50,000	^{14}C: measured	peat	Qcp	University of Washington 74	10303	Re-analysis of tritium-contaminated sample UW-7 in bluff east of Johnson Point	47.176743 -122.815023
142	30,120 ±250	^{14}C: conventional	charcoal	Qc_o	Beta 151930	11052	Sampled from fining-upward sequence at Devil's Head on southern Key Peninsula	47.167265 -122.769149
143	>44,270	^{14}C: conventional	peat	Qcp	Beta 154051	11053	Sampled from Devil's Head on southern Key Peninsula	47.167265 -122.769149
144	50,500 ±1,200	^{14}C: reported	peat	Qc_o	University of Washington Stuiver	10003	Devil's Head on Key Peninsula	47.167265 -122.769149
146	>47,750	^{14}C: conventional	peat	Qcp	Beta 105920	10043	Sampled from beach bluff on Fox Island	47.238997 -122.630812
147	>60,000	^{14}C: reported	peat	Qcp	University of Washington Stuvier	10002	McNeil Island shoreline	47.195666 -122.658134
148	>46,440	^{14}C: conventional	peat	Qcp	Beta 143715	11008	Sampled from roadcut below fine sand on east side of Key Peninsula by Filucy Bay	47.191472 -122.749733
149	>44,730	^{14}C: conventional	detrital wood	Qcp	Beta 151280	11002	Sampled from northeast shore of Ketron Island	47.162042 -122.630507
150	>45,580	^{14}C: conventional	detrital wood	Qcp	Beta 142628	11005	Sampled from sandy gravel in upper part of canyon at Sandy Point on Anderson Island	47.150931 -122.678627
151	>41,110	^{14}C: conventional	detrital wood	Qcp	Beta 142629	11006	Sampled from sandy gravel in upper part of canyon at Sandy Point on Anderson Island	47.150931 -122.678627
152	>44,010	^{14}C: conventional	peat	Qcp	Beta 143712	11003	Sampled from sand at beach level on southern tip of Ketron Island	47.147446 -122.639262
154	>45,180	^{14}C: conventional	detrital wood	Qgp	Beta 138641	11004	Sampled from Cole Point on Anderson Island	47.142168 -122.682938
155	>44,000	^{14}C: measured	peat	Qcp	University of Washington 67	10302	Re-analysis of tritium-contaminated sample UW-19 in bluff along Cormorant Passage	47.138882 -122.629937
156	41,380 ±1,940	^{14}C: conventional	peat	Qc_o	Beta 120064	10025	Sampled in normally magnetized nonglacial sequence at Solo Point	47.136841 -122.63327

Map no.	Age estimate	Analytical method	Material dated	Geologic unit	Lab no.	Geochron ID	Notes	Latitude Longitude
Radiocarbon (^{14}C years BP), continued								
157	40,720 ±1,910	^{14}C: conventional	peat	Qc_o	Beta 143102	11007	Sampled from south end of ^{134}Th Ave on Anderson Island	47.133739 -122.717108
158	12,960 ±180	^{14}C: conventional	wood	Qgd	ISGS 3343	10041	Sampled from silty sand beneath base of Vashon Drift in bluff at Sunset Beach	47.222888 -122.565031
159	13,620 ±80	^{14}C: conventional	wood	Qgd	Beta 89876	10040	Sampled from silty sand beneath base of Vashon Drift in bluff at Sunset Beach	47.222887 -122.565033
160	13,340 ±110	^{14}C: conventional	wood	Qgd	Beta 105919	10042	Sampled from outcrop on Sunset Beach	47.222889 -122.565035
161	>43,090	^{14}C: conventional	peat	Qc_o	Beta 120063	10028	Bluff at Gordon Point	47.17001 -122.609688
162	41,190 ±570	^{14}C: conventional	peat	Qc_o	Beta 128799	10257	Sampled from bluff at Gordon Point	47.17001 -122.609688
163	13,510 ±80	^{14}C: conventional	wood	Qgl	Beta 79885	10022	Sampled at 92 ft depth in boring near base of Vashon at Carter Lake School	47.127114 -122.520403
164	>41,300	^{14}C: conventional	wood	Qgp	Beta 81801	10261	Sampled from boring at Carter Lake School	47.127114 -122.520403
165	17,110 ±290	^{14}C: conventional	organic sediment	Qc_o	Beta 89256	10039	Sampled from Route 7 canyon	47.224203 -122.413785
166	44,160 ±3,100	^{14}C: conventional	peat	Qc_o	Beta 120062	10037	Sampled from outcrop in Swan Creek	47.220739 -122.394461
169	>51,000	^{14}C: measured	peat	Qgp_s	Groningen 4074	10033	Re-analysis of USGS-672 sampled from east valley wall of Stuck River	47.217128 -122.218679
170	>49,000	^{14}C: measured	peat	Qgp_s	Groningen 4094	10034	Re-analysis of USGS-672 sampled from east valley wall of Stuck River	47.217128 -122.218679
171	>50,100 ±400	^{14}C: measured	peat	Qgp_s	Groningen 4116	10035	Enriched re-analysis of USGS-672; considered minimum age in valley wall west of Lake Tapps	47.217128 -122.218679
173	4,700 ±250	^{14}C: measured	wood	Qvl_o?	USGS 564	10030	Sample of Osceola Mudflow in Puyallup River bank	47.188858 -122.239124
175	>45,000	^{14}C: measured	peat	Qcp	USGS 3011	10565	Sampled from peat layers in reversed magnetic polarity silt in Auburn borrow pit	47.166813 -122.250177
176	>45,000	^{14}C: measured	peat	Qcp	USGS 3012	10566	Sampled from peat layers in reversed magnetic polarity silt in Auburn borrow pit	47.166813 -122.250177
178	2,480 ±40	^{14}C: conventional	charcoal	Qvl?	Beta 196058	11386	Sampled from overbank deposit between two lahar deposits overlain by C-pumice-bearing lahar deposits in the White River Gorge, Golden Valley area; age marks the Summerland episode; maximum age of C pumice	47.198565 -122.107985
179	2,540 ±60	^{14}C: conventional	charcoal	Qvl	Beta 196058	11387	Sampled from lowermost of three lahar deposits (top lahar contains C pumice) in White River Gorge in Golden Valley area; age marks the Summerland episode; is the maximum age of C pumice	47.197833 -122.107209
180	4,980 ±60	^{14}C: measured	charcoal	Qvl_o?	University of Washington 283	10638	Sample from Jokumsen site dating the age of mudflow	47.191807 -122.042096
181	4,950 ±450	^{14}C: measured	wood	Qvl_o	Lamont (Columbia University) 223B	10029	Approximate age of Osceola Mudflow	47.179641 -122.012508
182	>46,290	^{14}C: conventional	wood	Qcp	Beta 167214	10990	Sampled at Gull Harbor in Budd Inlet	47.113603 -122.892269
183	>44,760	^{14}C: conventional	peat	Qcp	Beta 167215	10993	Sampled at Big Tykle Cove in Budd Inlet	47.0975 -122.931118
184	>44,370	^{14}C: conventional	peaty silt	Qcp	Beta 167213	10992	Sampled at Little Tykle Cove in Budd Inlet	47.089829 -122.933508

Map no.	Age estimate	Analytical method	Material dated	Geologic unit	Lab no.	Geochron ID	Notes	Latitude Longitude
Radiocarbon (^{14}C years BP), continued								
185	>47,470	^{14}C: conventional	wood	Qcp	Beta 113497	10989	Sampled in Mission Creek drainage; age uncertain	47.064569 -122.88921
186	>45,420	^{14}C: conventional	peaty silt	Qcp	Beta 167210	10991	Sampled at Tugboat Annie's restaurant along Budd Inlet	47.062427 -122.916393
187	10,710 ±100	^{14}C: conventional	wood	Qp	Beta 39190	10994	Sampled at the Natural Resources Building, Olympia	47.037201 -122.898418
188	540 ±50	^{14}C: conventional	wood	Qp	Beta 39191	10995	Sampled at the Natural Resources Building, Olympia	47.037201 -122.898418
189	>45,700	^{14}C: conventional	wood	Qcp	Beta 143971	11519	Sampled from pre-Fraser silt in Butterball Cove	47.118198 -122.76216
190	>46,970	^{14}C: conventional	wood	Qcp	Beta 143031	11520	Sample from peat layer above tephritic sand in Butterball Cove	47.118198 -122.76216
191	42,640 ±2,750	^{14}C: conventional	wood	Qc_o	Beta 143972	11044	Sampled from suspected debris flow at Beachcrest on west shore of Nisqually Reach	47.109287 -122.75112
192	>43,350	^{14}C: conventional	wood	Qcp	Beta 152236	11045	Re-analysis of Beta-143972 at Beachcrest on west shore of Nisqually Reach	47.109287 -122.75112
193	28,110 ±310	^{14}C: measured	– – –	Qc_o	Beta 5175	10020	Bluff near Sequalitchew	47.117046 -122.665066
194	38,710 ±780	^{14}C: conventional	wood cellulose	Qc_o	Beta 133322	10019	Dupont gravel pit	47.116645 -122.65898
195	>31,960	^{14}C: conventional	wood cellulose	Qc_o	Beta 133323	10018	Dupont gravel pit	47.11664 -122.65898
196	38,640 ±950	^{14}C: conventional	wood cellulose	Qc_o	Beta 136968	10260	Sampled from outcrop at Dupont gravel pit	47.11664 -122.65898
197	>45,060	^{14}C: conventional	peat	Qcp	Beta 162218	10017	Boring in Dupont gravel pit	47.110691 -122.642883
198	130 ±60	^{14}C: conventional	plant material	Qp	Beta 109230	11687	Sampled from mud along bank of Red Salmon Creek	47.083041 -122.694753
199	1,010 ±50	^{14}C: conventional	wood	Qp	Beta 110746	11686	Sampled from outer rings of stump in growth position along bank of Red Salmon Creek	47.083041 -122.694753
200	1,030 ±70	^{14}C: conventional	plant material	Qp	Beta 110150	11688	Sampled from laminated silt and clay along east bank of the Nisqually River and represents the age of burial	47.082988 -122.705119
201	1,140 ±80	^{14}C: conventional	plant material	Qp	Beta 102336	11689	Sampled from mud in tidal meander in cut bank of the Nisqually Delta at McAllister Creek and represents the age of burial	47.074395 -122.731468
202	35,960 ±1,160	^{14}C: conventional	peat	Qc_o	Beta 173747	10997	Sampled on west side of Nisqually Reach	47.07422 -122.73382
203	13,410 ±80	^{14}C: conventional	detrital wood	Qga	Beta 173043	10998	Sampled from east side of Nisqually Reach	47.073937 -122.692518
204	>43,060	^{14}C: conventional	detrital wood	Qcp	Beta 173748	10999	Sampled from east side of Nisqually Reach at Cosgrave Hill near Fort Lewis	47.058306 -122.690579
205	>44,950	^{14}C: conventional	organic sediment	Qcp	Beta 177610	11000	Sampled near Cosgrave Hill on east side of Nisqually Reach	47.050195 -122.682124
206	>46,120	^{14}C: conventional	organic sediment	Qcp	Beta 177609	11001	Sampled from silt southeast of Cosgrave Hill on east side of Nisqually Reach	47.0414 -122.675312
207	13,630 ±90	^{14}C: conventional	peaty silt	Qgl	Beta 52222	10021	Sampled at 60 ft depth in boring near top of Vashon glaciolacustrine sediments in gravel pit	47.119484 -122.59891
208	25,100 ±600	^{14}C: conventional	wood	Qc_o	Isotopes Inc (Teledyne) 15437	10795	Sampled in borehole at 60 ft depth on McChord Air Force Base	47.105458 -122.556257
209	>45,140	^{14}C: conventional	peat	Qcp	Beta 162216	10016	Fort Lewis area	47.104818 -122.523782
210	>40,000	^{14}C: conventional	wood	Qgp	Isotopes Inc (Teledyne) 15705	10794	Sampled in borehole at 96 ft depth on McChord Air Force Base	47.124077 -122.375923

Map no.	Age estimate	Analytical method	Material dated	Geologic unit	Lab no.	Geochron ID	Notes	Latitude Longitude
Radiocarbon (^{14}C years BP), continued								
211	<200 ±0	^{14}C: measured	wood	Qvl$_e$?	USGS 407	10015	Age of mudflow deposits sampled in field near Orting	47.076087 -122.182694
212	<200 ±0	^{14}C: measured	wood	Qvl$_e$?	USGS 424	10309	Sampled in field at Orting; age of mudflow	47.076087 -122.182694
213	840 ±190	^{14}C: conventional	plant material	Qvl$_e$	– – –	11548	Sampled from Puyallup River; age of the Electron Mudflow	47.038281 -122.202008
214	550 ±190	^{14}C: conventional	– – –	Qvl$_e$	– – –	11547	Sampled from Puyallup River; age of the Electron Mudflow	47.025692 -122.205235
216	1,950 ±200	^{14}C: measured	wood	Qa?	USGS 706	10528	Sampled from Voight Creek; date contradicts interpretation of glacial deposits	47.034232 -122.095349
Fission Track								
114	1.06 ±0.11 Ma	fission track	glass	Qgp$_s$	– – –	40309	Sampled near Algona; age corrected for partial track fading	47.299863 -122.259482
115	0.65 ±0.08 Ma	fission track	glass	Qgp$_s$	– – –	40310	Sampled near Algona	47.299863 -122.259482
123	1.1 Ma	fission track	zircon	Qgp$_s$	– – –	40317	Sampled from four tephra layers in reversely magnetized deposits	47.268755 -122.366812
126	0.87 ±0.27 Ma	fission track	zircon	Qgp$_s$?	USGS Denver	40213	Sampled near Auburn; represents the age of volcanism	47.308721 -122.203625
127	0.66 ±0.04 Ma	fission track	glass	Qgp$_s$?	USGS Denver	40212	Sample from near Auburn; age is anomalously young	47.308721 -122.203625
172	0.84 ±0.42 Ma	fission track	zircon	Qgp$_s$	USGS Denver	40216	Sampled along east valley wall of Stuck River, Salmon Springs vicinity; represents the age of volcanism	47.216492 -122.222059
174	0.84 ±0.21 Ma	fission track	zircon	Qgp$_s$	USGS Denver	40211	Sample of dacite ash collected near Sumner and represents the age of volcanism	47.210936 -122.213726
^{40}Ar/^{39}Ar								
167	1.69 ±0.11 Ma	^{40}Ar/^{39}Ar	plagioclase	Qc$_p$	– – –	31421	Age of pumice deposition; Puyallup Formation type section; south side of Puyallup River near Sumner; gravel pit exposure	47.184236 -122.251309
168	1.64 ±0.13 Ma	^{40}Ar/^{39}Ar	hornblende	Qc$_p$	– – –	31422	Age of pumice deposition; Puyallup Formation type section; south side of Puyallup River near Sumner; gravel pit exposure	47.184236 -122.251309
177	1.6 Ma	^{40}Ar/^{39}Ar	plagioclase	Qc$_a$	– – –	31420	Maximum age of Stuck glaciation and age of ash deposition; Alderton type section; west bank of Puyallup River near Alderton	47.162142 -122.237689
Luminescence								
18	133 ±6 ka	IRSL	fine sand	Qgpc$_{po}$?	USGS WA 25	– – –	Minimum feldspar age; Raymond Beach at Sandford Point; collected by S. Mahan (USGS)	47.399522 -122.525403
18	138 ±6 ka	IRSL	fine sand	Qgpc$_{po}$?	USGS WA 25	– – –	Maximum feldspar age; Raymond Beach at Sandford Point; collected by S. Mahan (USGS)	47.399522 -122.525403
18	98 ±13 ka	TL	fine sand	Qgpc$_{po}$?	USGS WA 25	– – –	Vashon Island; Raymond Beach at Sandford Point; collected by S. Mahan (USGS)	47.399522 -122.525403
19	142 ±6 ka	IRSL	silt	Qgpc$_{po}$?	USGS WA 26	– – –	Minimum feldspar age; Vashon Island; Raymond Beach at Sandford Point; collected by S. Mahan (USGS)	47.399597 -122.524834
19	162 ±9 ka	IRSL	silt	Qgpc$_{po}$?	USGS WA 26	– – –	Maximum feldspar age; Vashon Island; Raymond Beach at Sandford Point; collected by S. Mahan (USGS)	47.399597 -122.524834
26	130 ±7 ka	IRSL	silt	Qgp$_d$?	USGS WA 29	– – –	Minimum feldspar age; Wingehaven Park; collected by S. Mahan (USGS)	47.497832 -122.457708

Map no.	Age estimate	Analytical method	Material dated	Geologic unit	Lab no.	Geochron ID	Notes	Latitude Longitude
Luminescence, continued								
26	194 ±83 ka	TL	silt	Qgp$_d$?	USGS WA 29	– – –	Maximum age of sediment; Wingehaven Park, collected by S. Mahan (USGS)	47.497832 -122.457708
68	219 ±15 ka	IRSL	silt	Qgp$_d$?	USGS WA 14	– – –	Minimum feldspar age; Gig Harbor area; 1.5 m above beach; collected by S. Mahan (USGS)	47.326231 -122.575257
68	312 ±29 ka	IRSL	silt	Qgp$_d$?	USGS WA 14	– – –	Maximum feldspar age; Gig Harbor area; 1.5 m above beach; collected by S. Mahan (USGS)	47.326231 -122.575257
68	196 ±35 ka	TL	silt	Qgp$_d$?	USGS WA 14	– – –	TL provides maximum age of sediment; Gig Harbor area; 1.5 m above beach; collected by S. Mahan (USGS)	47.326231 -122.575257
69	243 ±21 ka	IRSL	sand	Qgp$_d$?	USGS WA 15	– – –	Minimum feldspar age; Gig Harbor area; collected by S. Mahan (USGS)	47.322274 -122.575334
69	325 ±29 ka	IRSL	sand	Qgp$_d$?	USGS WA 15	– – –	Maximum feldspar age; Gig Harbor area; collected by S. Mahan (USGS)	47.322274 -122.575334
69	158 ±24 ka	TL	sand	Qgp$_d$?	USGS WA 15	– – –	TL generally provides maximum age of sediment, in this case provides a minimum age; Gig Harbor area; collected by S. Mahan (USGS)	47.322274 -122.575334
69	120 ±9 ka	OSL: quartz	sand	Qgp$_d$?	USGS WA 15	– – –	Gig Harbor area; collected by S. Mahan (USGS)	47.322274 -122.575334
70	204 ±18 ka	IRSL	– – –	Qgp$_d$?	USGS WA 13	– – –	Minimum feldspar age; Point Defiance; collected by S. Mahan (USGS)	47.318728 -122.541227
70	224 ±21 ka	IRSL	– – –	Qgp$_d$?	USGS WA 13	– – –	Maximum feldspar age; Point Defiance; collected by S. Mahan (USGS)	47.318728 -122.541227
73	217 ±17 ka	IRSL	– – –	Qgpc$_{po}$	USGS WA 11	– – –	Minimum feldspar age; Point Defiance; collected by S. Mahan (USGS)	47.317779 -122.536131
73	236 ±17 ka	IRSL	– – –	Qgpc$_{po}$	USGS WA 11	– – –	Maximum feldspar age; Point Defiance; collected by S. Mahan (USGS)	47.317779 -122.536131
73	142 ±9 ka	IRSL	– – –	Qgpc$_{po}$	USGS WA 12	– – –	Minimum feldspar age; near trail at Point Defiance; collected by S. Mahan (USGS)	47.317779 -122.536131
73	182 ±11 ka	IRSL	– – –	Qgpc$_{po}$	USGS WA 12	– – –	Maximum feldspar age; near trail at Point Defiance; collected by S. Mahan (USGS)	47.317779 -122.536131
76	146 ±11 ka	IRSL	sand	Qgp$_d$?	USGS WA 44	– – –	Minimum and maximum feldspar age; Point Defiance; collected by S. Mahan (USGS)	47.316797 -122.534838
76	150 ±17 ka	TL	sand	Qgp$_d$?	USGS WA 44	50208	Maximum age of sediment; Point Defiance; collected by S. Mahan (USGS)	47.316797 -122.534838
76	>99 ka	OSL: blue light	sand	Qgp$_d$?	USGS WA 44	50209	Point Defiance; collected by S. Mahan (USGS)	47.316797 -122.534838
77	73 ±4 ka	IRSL	sand	Qgp$_p$?	USGS WA 45	50210	Minimum feldspar age; Point Defiance; collected by S. Mahan (USGS)	47.316797 -122.534838
77	76 ±5 ka	IRSL	sand	Qgp$_p$?	USGS WA 45	50211	Maximum feldspar age; Point Defiance; collected by S. Mahan (USGS)	47.316797 -122.534838
77	69 ±6 ka	OSL: blue light	sand	Qgp$_p$?	USGS WA 45	50212	Point Defiance; collected by S. Mahan (USGS)	47.316797 -122.534838
78	265 ±12 ka	IRSL	– – –	Qgp$_d$?	USGS WA 10	– – –	Minimum feldspar age; Point Defiance; collected by S. Mahan (USGS)	47.316835 -122.533358
78	286 ±14 ka	IRSL	– – –	Qgp$_d$?	USGS WA 10	– – –	Maximum feldspar age; Point Defiance; collected by S. Mahan (USGS)	47.316835 -122.533358
78	223 ±22 ka	TL	– – –	Qgp$_d$?	USGS WA 10	– – –	TL generally provides maximum age of sediment, in this case provides a minimum age; Point Defiance; collected by S. Mahan (USGS)	47.316835 -122.533358
83	128 ±8 ka	IRSL	sand	Qgp$_d$?	USGS WA 16	– – –	Cemented sand below WA-17; minimum feldspar age; Gig Harbor area; collected by S. Mahan (USGS)	47.29005 -122.54988

Map no.	Age estimate	Analytical method	Material dated	Geologic unit	Lab no.	Geochron ID	Notes	Latitude Longitude
Luminescence, continued								
83	137 ±9 ka	IRSL	sand	Qgpd?	USGS WA 16	– – –	Cemented sand below WA-17; maximum feldspar age; Gig Harbor area; collected by S. Mahan (USGS)	47.29005 -122.54988
83	35 ±3 ka	OSL: Quartz	sand	Qgpd?	USGS WA 16	– – –	Gig Harbor area; collected by S. Mahan (USGS)	47.29005 -122.54988
84	98 ±5 ka	IRSL	– – –	Qcw?	USGS WA 17	– – –	Minimum feldspar age; sampled above peat layer; Gig Harbor area; collected by S. Mahan (USGS)	47.29005 -122.54988
84	103 ±5 ka	IRSL	– – –	Qcw?	USGS WA 17	– – –	Maximum feldspar age; sampled above peat layer; Gig Harbor area; collected by S. Mahan (USGS)	47.29005 -122.54988
84	46 ±2 ka	OSL: blue light	– – –	Qcw?	USGS WA 17	– – –	Sampled above peat layer; Gig Harbor area; collected by S. Mahan (USGS)	47.29005 -122.54988
85	119 ±6 ka	IRSL	sand	Qcw?	USGS WA 18	– – –	Minimum feldspar age; sand from peat layer; Gig Harbor area; collected by S. Mahan (USGS)	47.29005 -122.54988
85	126 ±5 ka	IRSL	sand	Qcw?	USGS WA 18	– – –	Maximum feldspar age; sand from peat layer; Gig Harbor area; collected by S. Mahan (USGS)	47.29005 -122.54988
85	83 ±8 ka	TL	sand	Qcw?	USGS WA 18	– – –	TL generally provides maximum age of sediment, in this case provides a minimum age; sand from peat layer; Gig Harbor area; collected by S. Mahan (USGS)	47.29005 -122.54988
86	145 ±12 ka	IRSL	silt	Qcw?	USGS WA 19	– – –	Minimum feldspar age; bottom of sequence; Gig Harbor area; collected by S. Mahan (USGS)	47.29005 -122.54988
86	167 ±9 ka	IRSL	silt	Qcw?	USGS WA 19	– – –	Maximum feldspar age; bottom of sequence; Gig Harbor area; collected by S. Mahan (USGS)	47.29005 -122.54988
86	91 ±10 ka	TL	silt	Qcw?	USGS WA 19	– – –	TL generally provides maximum age of sediment, in this case provides a minimum age; bottom of sequence; Gig Harbor area; collected by S. Mahan (USGS)	47.29005 -122.54988
90	126 ±10 ka	IRSL	silt	Qgpd?	USGS WA 43	50221	Minimum feldspar age; Gig Harbor area; collected by S. Mahan (USGS)	47.289428 -122.549494
90	139 ±12 ka	IRSL	silt	Qgpd?	USGS WA 43	50222	Maximum feldspar age; Gig Harbor area; collected by S. Mahan (USGS)	47.289428 -122.549494
91	74 ±7 ka	IRSL	sand	Qcw?	USGS WA 41	– – –	Minimum feldspar age; Point Evans section; collected by S. Mahan (USGS)	47.286181 -122.548537
91	103 ±9 ka	IRSL	sand	Qcw?	USGS WA 41	– – –	Maximum feldspar age; Point Evans section; collected by S. Mahan (USGS)	47.286181 -122.548537
91	122 ±10 ka	TL	sand	Qcw?	USGS WA 41	– – –	Maximum age of sediment; Point Evans section; collected by S. Mahan (USGS)	47.286181 -122.548537
91	>101 ka	OSL: Quartz	sand	Qcw?	USGS WA 41	– – –	Point Evans section; collected by S. Mahan (USGS)	47.286181 -122.548537
92	34 ±4 ka	IRSL	silt	Qco?	USGS WA 42	50219	Minimum feldspar age; Gig Harbor area; collected by S. Mahan (USGS)	47.286221 -122.548337
92	36 ±2 ka	IRSL	silt	Qco?	USGS WA 42	50220	Maximum feldspar age; Gig Harbor area; collected by S. Mahan (USGS)	47.286221 -122.548337
96	36 ±3 ka	IRSL	silt	Qcw?	USGS WA 20	– – –	Minimum feldspar age; Sam Folly Gulch; collected by S. Mahan (USGS)	47.275856 -122.554874
96	44 ±3 ka	IRSL	silt	Qcw?	USGS WA 20	– – –	Maximum feldspar age; Sam Folly Gulch; collected by S. Mahan (USGS)	47.275856 -122.554874
96	21 ±7 ka	TL	silt	Qcw?	USGS WA 20	– – –	TL generally provides maximum age of sediment, in this case provides a minimum age; Sam Folly Gulch; collected by S. Mahan (USGS)	47.275856 -122.554874
97	106 ±7 ka	IRSL	sand	Qcw?	USGS WA 21	– – –	Minimum feldspar age; Tacoma Narrows Bridge; collected by S. Mahan (USGS)	47.273479 -122.556623

Map no.	Age estimate	Analytical method	Material dated	Geologic unit	Lab no.	Geochron ID	Notes	Latitude Longitude
Luminescence, continued								
97	126 ±6 ka	IRSL	sand	Qc_w?	USGS WA 21	– – –	Maximum feldspar age; Tacoma Narrows Bridge; collected by S. Mahan (USGS)	47.273479 -122.556623
97	120 ±12 ka	TL	sand	Qc_w?	USGS WA 21	– – –	Maximum age of sediment; Tacoma Narrows Bridge; collected by S. Mahan (USGS)	47.273479 -122.556623
97	40 ±2 ka	OSL: Quartz	sand	Qc_w?	USGS WA 21	– – –	Tacoma Narrows Bridge; collected by S. Mahan (USGS)	47.273479 -122.556623
100	118 ±6 ka	IRSL	silt	Qc_{po}?	USGS WA 22	– – –	Minimum feldspar age; Tacoma Narrows Bridge; collected by S. Mahan (USGS)	47.265159 -122.543223
100	139 ±6 ka	IRSL	silt	Qc_{po}?	USGS WA 22	– – –	Maximum feldspar age; Tacoma Narrows Bridge; collected by S. Mahan (USGS)	47.265159 -122.543223
100	76 ±8 ka	TL	silt	Qc_{po}?	USGS WA 22	– – –	Minimum age; Tacoma Narrows Bridge; collected by S. Mahan (USGS)	47.265159 -122.543223
101	97 ±10 ka	IRSL	silt	$Qgpc_{po}$?	USGS WA 23	– – –	Minimum feldspar age; Tacoma Narrows Bridge; collected by S. Mahan (USGS)	47.262891 -122.544497
101	130 ±9 ka	IRSL	silt	$Qgpc_{po}$?	USGS WA 23	– – –	Maximum feldspar age; Tacoma Narrows Bridge; collected by S. Mahan (USGS)	47.262891 -122.544497
101	97 ±9 ka	TL	silt	$Qgpc_{po}$?	USGS WA 23	– – –	Maximum age of sediment; Tacoma Narrows Bridge; collected by S. Mahan (USGS)	47.262891 -122.544497
108	79 ±6 ka	IRSL	– – –	Qc_w?	USGS R	– – –	Minimum feldspar age; Ruston Way/Garfield Park area; collected by S. Mahan (USGS)	47.273069 -122.458343
108	104 ±8 ka	IRSL	– – –	Qc_w?	USGS R	– – –	Maximum feldspar age; Ruston Way/Garfield Park area; collected by S. Mahan (USGS)	47.273069 -122.458343
108	65 ±7 ka	TL	– – –	Qc_w?	USGS R	– – –	TL generally provides maximum age of sediment, in this case provides a minimum age; Ruston Way/Garfield Park area; collected by S. Mahan (USGS)	47.273069 -122.458343
113	193 ±9 ka	IRSL	sand	Qgp_d?	USGS WA 7	– – –	Minimum feldspar age; Redondo near Dash Park; collected by S. Mahan (USGS)	47.344932 -122.318247
113	234 ±12 ka	IRSL	sand	Qgp_d?	USGS WA 7	– – –	Maximum feldspar age; Redondo near Dash Park; collected by S. Mahan (USGS)	47.344932 -122.318247
122	225 ±17 ka	IRSL	– – –	Qgp_d?	USGS WA 6	– – –	Minimum feldspar age; Jones quarry; collected by S. Mahan (USGS)	47.270852 -122.367177
122	251 ±16 ka	IRSL	– – –	Qgp_d?	USGS WA 6	– – –	Maximum feldspar age; Jones quarry; collected by S. Mahan (USGS)	47.270852 -122.367177
145	70 ±9 ka	OSL: blue light	sand	Qgp_p	USGS	50290	Collected by K. Troost (University of Washington) and analyzed by S. Mahan (USGS)	47.167212 -122.767924
U-Pb								
215	2.9 Ma	$^{206}Pb/^{238}U$	zircon	Qvl_{lc}	Geophysics Lab, CIW	20296	A maximum age for the Lily Creek Formation; some contamination from older zircon likely occurred	47.083333 -122.116667
Fossil								
51	late Eocene	fossil	plant fossils	Ec_{2pg}	– – –	70386	Leaf fossils	47.454458 -122.077562

Table 2. Normalized major element rock geochemistry for the Tacoma 1:100,000 quadrangle in weight percent. WSU, Washington State University; USGS, U.S. Geological Survey; EMP, electron microprobe; XRF, x-ray fluorescence; – – –, no data. Gray shading indicates corresponding trace element analyses in Table 3. Database ID number corresponds to Geochemistry ID number in the Rock Geochemistry Database (Bowman and others, 2014), which contains additional analytical information for most samples. Superscript numbers in the Unit column correspond to sources of data: [1] Logan and others (2009); [2] Walsh and others (2003c), [3] Walsh and others (2003d); [4] Gard (1968); [5] U.S. Geological Survey (2008); [6] Bowman and others (2014).

Map no.	Unit	Sample no. Laboratory	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cl	SO_3	Total (%)	Method	Comments	Latitude Longitude	Database ID
5	Qc_o tephra[3,6]	19-1W-2.68 WSU	75.4	13.69	1.55	– – –	0.31	1.53	3.62	3.48	0.24	– – –	– – –	0.15	– – –	– – –	EMP	Sand below peat layer containing bimodal reworked tephra (Sunset Amphitheater tephra from Mount Rainier and another strongly resembling Mount St. Helens set Cy); bulk sample; 20 shards analyzed	47.16729 -122.7667	35
6	Qc_o tephra[3,6]	19-1W-2.68 WSU	76.5	13.98	1.1	– – –	0.33	1.8	3.74	2.33	0.11	– – –	– – –	0.08	– – –	– – –	EMP	Sand below peat layer containing bimodal reworked tephra (Sunset Amphitheater tephra from Mount Rainier and another strongly resembling Mount St. Helens set Cy); Glass 1; 5 shards analyzed	47.16728 122.76678	36
7	Qc_o tephra[3,6]	19-1W-2.68 WSU	75.04	13.59	1.7	– – –	0.31	1.43	3.58	3.86	0.29	– – –	– – –	0.17	– – –	– – –	EMP	Sand below peat layer containing bimodal reworked tephra (Sunset Amphitheater tephra from Mount Rainier and another strongly resembling Mount St. Helens set Cy); Glass 2; 15 shards analyzed	47.16728 -122.76678	37
8	Qc_o tephra[3,6]	PLW8/11/ 01P2ASH T487N-3 USGS	75.23	13.81	1.63	– – –	0.29	1.38	3.82	3.54	0.3	– – –	0.02	– – –	– – –	92.63	EMP	Sand below peat layer containing bimodal reworked tephra (Sunset Amphitheater tephra from Mount Rainier and another strongly resembling Mount St. Helens set Cy); Mode 1; 8 shards analyzed	47.16728 -122.76678	38
9	Qc_o tephra[3,6]	PLW8/11/ 01P2ASH T487N-3 USGS	74.43	14.01	1.86	– – –	0.46	1.59	3.97	3.35	0.32	– – –	0.03	– – –	– – –	95.42	EMP	Sand below peat layer containing bimodal reworked tephra (Sunset Amphitheater tephra from Mount Rainier and another strongly resembling Mount St. Helens set Cy); Mode 2; 4 shards analyzed	47.16728 -122.76678	39
10	Qc_w? tephra[3,6]	19-1E-17.41A WSU	76.43	14.17	1.11	– – –	0.35	1.84	3.65	2.21	0.12	– – –	– – –	0.09	– – –	– – –	EMP	Tephra interbedded with gravel; correlated with unspecified tephra from Mount Rainier; 15 shards analyzed	47.127745 -122.70835	33
11	Qc_w? tephra[3,6]	PLW8/11/ 01_P3 T487N-4 USGS	76.55	14.19	1.02	– – –	0.34	1.79	3.9	2.07	0.09	– – –	0.04	– – –	– – –	91.37	EMP	Tephra interbedded with gravel; correlated with unspecified tephra from Mount Rainier; 10 shards analyzed	47.12774 -122.70835	34
12	Qc_w? tephra[3,6]	19-1E-11- 73E-1 USGS	74.13	13.76	– – –	1.79	0.32	1.5	4.14	3.82	0.32	0.05	0.05	0.15	0.01	96.18	EMP	Richly pumiceous sand with large-amplitude crossbeds that imply transport toward the west and northwest; correlates to Sunset Amphitheater pumice; 26 shards analyzed	47.14711 -122.63882	18
13	Qc_w? tephra[3,6]	19-1E-11- 73E-2 USGS	74.82	13.54	– – –	1.5	0.27	1.38	4.02	3.95	0.3	0.04	0.06	0.14	0.01	94.73	EMP	Richly pumiceous sand with large-amplitude crossbeds that imply transport toward the west and northwest; correlates to Sunset Amphitheater pumice; 21 shards analyzed	47.14711 -122.63882	19
14	Qc_w? tephra[3,6]	19-1E-11- 73E-3 USGS	74.59	13.56	– – –	1.55	0.33	1.43	4.03	3.94	0.39	0.03	0.01	0.15	0.01	94.27	EMP	Richly pumiceous sand with large-amplitude crossbeds that imply transport toward the west and northwest; correlates to Sunset Amphitheater pumice; 15 shards analyzed	47.14711 -122.63882	20

Map no.	Unit	Sample no. Laboratory	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cl	SO_3	Total (%)	Method	Comments	Latitude Longitude	Database ID
15	Qcw? tephra[3,6]	19-1E-11.73C WSU	75.04	13.42	1.68	– – –	0.3	1.41	3.71	3.91	0.29	– – –	– – –	0.17	– – –	– – –	EMP	Richly pumiceous sand with large-amplitude crossbeds that imply transport toward the west and northwest; correlates to Sunset Amphitheater pumice; 16 shards analyzed	47.14711 -122.63882	21
16	Qcw? tephra[3,6]	19-1E-11.73D WSU	75.05	13.56	1.71	– – –	0.3	1.43	3.63	3.84	0.29	– – –	– – –	0.16	– – –	– – –	EMP	Richly pumiceous sand with large-amplitude crossbeds that imply transport toward the west and northwest; correlates to Sunset Amphitheater pumice; 17 shards analyzed	47.14711 -122.63882	22
17	Qcw? tephra[3,6]	19-1E-11.73E WSU	74.85	13.65	1.74	– – –	0.31	1.42	3.69	3.83	0.31	– – –	– – –	0.17	– – –	– – –	EMP	Richly pumiceous sand with large-amplitude crossbeds that imply transport toward the west and northwest; correlates to Sunset Amphitheater pumice; 16 shards analyzed	47.14711 -122.63882	23
18	Qcw? tephra[3,6]	PLW8-11-01P4 T483N-7 USGS	75.27	13.54	1.66	– – –	0.27	1.28	3.79	3.87	0.28	– – –	0.04	– – –	– – –	90.34	EMP	Richly pumiceous sand with large-amplitude crossbeds that imply transport toward the west and northwest; correlates to Sunset Amphitheater pumice; 16 shards analyzed	47.14711 -122.63881	24
26	Evc basalt[2,6]	SCH1017011 WSU	48.78	14.18	– – –	12.76	6	12.17	2.56	0.17	2.872	0.298	0.197	– – –	– – –	98.27	XRF	Total Fe expressed as FeO; normalized on a volatile-free basis	47.01591 -122.96430	16
27	Evc basalt[2,6]	SCH1016011 WSU	49.36	14.69	– – –	11.7	6	12.23	2.59	0.33	2.621	0.281	0.195	– – –	– – –	98.57	XRF	Total Fe expressed as FeO; Normalized on a volatile-free basis	47.00996 -122.94375	12
28	Evc basalt[2,6]	SCH1016012 WSU	49.07	14.79	– – –	12.15	6.47	11.85	2.53	0.38	2.296	0.251	0.201	– – –	– – –	98.29	XRF	Total Fe expressed as FeO; Normalized on a volatile-free basis	47.00566 -122.94510	13
29	Evc basalt[2,6]	SCH1016013 WSU	48.75	15.56	– – –	11.6	6.04	13.09	2.4	0.22	1.947	0.19	0.195	– – –	– – –	98.39	XRF	Total Fe expressed as FeO; Normalized on a volatile-free basis	47.00999 -122.93291	14
30	Evc basalt[2,6]	SCH1016014 WSU	48.35	15.49	– – –	11.91	7.17	11.23	3.34	0.21	1.911	0.186	0.191	– – –	– – –	97.2	XRF	Total Fe expressed as FeO; Normalized on a volatile-free basis	47.01108 -122.92595	15
31	Evc basalt[1,6]	18/2W 65.59 WSU	49.41	15.88	– – –	11.44	6.49	11.29	2.83	0.27	2.01	0.22	0.16	– – –	– – –	– – –	XRF	– – –	47.01297 -122.91639	11
32	Evc basalt[1,6]	18/2W 60.06 WSU	49.64	15.47	– – –	9.91	7.12	12.56	2.55	0.32	2.07	0.2	0.17	– – –	– – –	– – –	XRF	– – –	47.01149 -122.90652	10
33	Evc basalt[1,6]	18/2W 60.05 WSU	49.39	15.52	– – –	11	7.03	11.81	2.49	0.29	2.13	0.2	0.14	– – –	– – –	– – –	XRF	– – –	47.01082 -122.90656	9
34	Qcw? tephra[3,6]	19N-1W-23.85A WSU	76.59	14.27	1.07	– – –	0.33	1.8	3.45	2.26	0.11	– – –	– – –	0.09	– – –	– – –	EMP	Lower 5 to 10 ft of fluvial sediments containing highly concentrated tephra; closely resembles Mount St. Helens set Cy or proto-C tephra (Walsh and others, 2003); 16 shards analyzed	47.11909 -122.76237	25
35	Qcw? tephra[3,6]	19N-1W-23.85A USGS	76.1	14.13	– – –	1.07	0.35	1.77	3.93	2.29	0.14	0.05	0.05	0.08	0.02	94.32	EMP	Lower 5 to 10 ft of fluvial sediments containing highly concentrated tephra; closely resembles Mount St. Helens set Cy or proto-C tephra (Walsh and others, 2003); 25 shards analyzed	47.11909 -122.76237	26
36	Qcw? tephra[3,6]	PLW8/ 11/01P1 T483N-8 USGS	76.14	14.37	1.07	– – –	0.35	1.82	4.03	2.1	0.09	– – –	0.02	– – –	– – –	86.54	EMP	Lower 5 to 10 ft of fluvial sediments containing highly concentrated tephra; closely resembles Mount St. Helens set Cy or proto-C tephra (Walsh and others, 2003); 9 shards analyzed; Mode 1	47.11909 -122.76237	27
37	Qcw? tephra[3,6]	PLW8/ 11/01P1 T483N-8 USGS	73.47	15	1.75	– – –	0.36	1.48	4.63	3.07	0.19	– – –	0.05	– – –	– – –	94.77	EMP	Lower 5 to 10 ft of fluvial sediments containing highly concentrated tephra; closely resembles Mount St. Helens set Cy or proto-C tephra (Walsh and others, 2003); 9 shards analyzed; Mode 2	47.11909 -122.76237	28

Table 3. Unnormalized major element rock geochemistry for the Tacoma 1:100,000 quadrangle in weight percent. WSU, Washington State University; USGS, U.S. Geological Survey; EMP, electron microprobe; XRF, x-ray fluorescence; – – –, no data. Gray shading indicates corresponding trace element analyses in Table 4. Database ID number corresponds to Geochemistry ID number in the Rock Geochemistry Database (Bowman and others, 2014), which contains additional analytical information for most samples. Superscript numbers in the Unit column correspond to sources of data: [1] Logan and others (2009); [2] Walsh and others (2003c), [3] Walsh and others (2003d); [4] Gard (1968); [5] U.S. Geological Survey (2008); [6] Bowman and others (2014).

Map no.	Unit	Sample no.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cl	SO_3	Total (%)	LOI	Method	Comments	Latitude Longitude	Database ID
1	Qa? dacite[5]	C199783	57.9	20.6	3.59	– – –	1.52	3.96	2.99	1.3	0.52	0.29	0.06	– – –	– – –	100.41	7.68	XRF	Hylebos pumice	47.27288 -122.37400	– – –
2	Qgt? andesite[5]	W166438	56.2	17.2	0	3.6	3.5	3.4	3.4	0.62	0.17	0.19	0.1	– – –	– – –	88.38	– – –	– – –	CO2 = 0.95%; H_2O = 1.3%	47.37482 -122.12623	– – –
4	Qgo? rhyolite[5]	W201402	81.4	9.5	0	0.44	0.26	1.9	1.9	3.2	0.23	0.06	0.01	– – –	– – –	98.9	– – –	– – –	Ash flow tuff; CO2 = 0.01%, H_2O = 1.3%	47.32483 -122.03622	– – –
19	Qgpc$_{pd}$? dacite[5]	C199768	63.5	17.5	4.45	– – –	1.84	4.86	4.03	1.58	0.59	0.2	0.08	– – –	– – –	100.15	1.52	XRF	Sumner pumice lump	47.22343 -122.22733	– – –
20	Qgpc$_{pd}$? dacite5	C199769	63.5	17.2	4.52	– – –	2.09	4.97	3.69	2	0.61	0.19	0.08	– – –	– – –	100.14	1.1	XRF	Sumner pumice lump	47.22343 -122.22733	– – –
21	Qvl$_e$ andesite[5]	C198431	60.2	17.4	6.15	– – –	3.12	6.04	4.07	1.57	0.94	0.3	0.1	– – –	– – –	100.26	0.37	XRF	breadcrust bomb	47.13982 -122.23400	– – –
22	Qvl$_e$ andesite5	C198432	60.1	17.3	6.18	– – –	3.12	6.06	4.06	1.55	0.94	0.29	0.1	– – –	– – –	100.1	0.4	XRF	breadcrust bomb	47.13982 -122.23400	– – –
23	₥vl hornblende-bearing pumice[4,6]	154659	60	18.6	2.6	– – –	2.6	5.6	4.2	1.1	0.76	– – –	0.09	– – –	– – –	99.5	– – –	XRF	H_2O = 1.3%	47.13003 -122.06503	8295
24	₥vl hornblende dacite[4,6]	154660	66.4	16.1	1.1	– – –	1.4	4.3	4	2	0.45	– – –	0.06	– – –	– – –	99.68	– – –	XRF	H_2O = 2.2%	47.13003 -122.06503	8296
25	₥Φiad pyroxene andesite[4,6]	154655	61.6	16.9	3.2	– – –	2.6	5.4	4.5	1.1	0.71	0.18	0.06	– – –	– – –	100.1	– – –	XRF	H_2O = 1.4%	47.13315 -122.01568	8291
39	Qvl$_e$ andesite[5]	C198433	59.8	17.4	6.1	– – –	3.13	6.04	4.04	1.54	0.91	0.28	0.1	– – –	– – –	99.8	0.46	XRF	breadcrust bomb	47.10510 -122.21789	– – –
40	₥Φiad hornblende dacite porphyry[4,6]	154654	67.4	16.3	1.6	– – –	1.4	4.1	4.2	1.9	0.42	0.16	0.06	– – –	– – –	99.69	– – –	XRF	H_2O = 0.40%	47.06803 -122.21031	8290
41	₥Φi latite[4,6]	154658	71.4	15.1	1.8	– – –	0.28	0.52	5.8	2.9	0.34	– – –	0.03	– – –	– – –	99.85	– – –	XRF	H_2O = 1.2%	47.02648 -122.14971	8294
42	₥Φid quartz diabase[4,6]	154657	60.4	17.5	2.3	– – –	3.2	5.4	4	1.7	0.82		0.09	– – –	– – –	100.16	– – –	XRF	H_2O = 1.4%	47.00015 -122.20660	8293
43	₥Φid quartz diabase[4,6]	154656	59.9	16.2	2	– – –	3.4	5.8	3.2	1.8	0.63	0.13	0.08	– – –	– – –	99.74	– – –	XRF	H_2O = 2.8%	47.04733 -122.04254	8292
44	Ec$_{2pg}$ tuff[5]	D501234	40.4	17.1	9.02	– – –	3.39	7.18	0.36	0.31	2.21	0.22	0.11	– – –	– – –	99.09	18.8	XRF	Drillhole sample of tuff at 364 ft depth	47.04622 -122.02872	– – –
45	Ec$_{2pg}$ tuff[5]	D501230	53.6	23	3.54	– – –	2.2	0.88	0.16	4.88	0.39	0.06	0.08	– – –	– – –	99.39	10.6	XRF	Drillhole sample of tuff at 268 ft depth	47.04288 -122.03039	– – –

Map no.	Unit	Sample no.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	Cl	SO_3	Total (%)	LOI	Method	Comments	Latitude Longitude	Database ID
46	Ec2pg tuff[5]	D501231	50.3	15.2	8.82	– – –	2.88	2.93	3.85	1.28	1.88	0.21	0.11	– – –	– – –	99.06	11.6	XRF	Drillhole sample of tuff at 424 ft depth	47.04289 -122.03039	– – –
47	Ec2pg tuff[5]	D501232	52.1	15.5	8.46	– – –	2.53	2.43	3.71	1.08	1.99	0.21	0.13	– – –	– – –	98.94	10.8	XRF	Drillhole sample of tuff at 449 ft depth	47.04289 -122.03039	– – –
48	Ec2pg tuff[5]	D501233	52.1	23.3	5.22	– – –	3.24	0.44	3.37	3.03	1.64	0.25	0.02	– – –	– – –	98.92	6.31	XRF	Drillhole sample of tuff at 1242 ft depth	47.04289 -122.03039	– – –
53	Ec2pg tuff[5]	D501235	54.1	16.5	8.73	– – –	3.27	6.35	4.52	0.6	2.05	0.24	0.11	– – –	– – –	99.34	2.87	XRF	Drillhole sample of tuff at 240 ft depth	47.04149 -122.02539	– – –
54	Ec2pg tuff[5]	D501236	56.3	22.2	3.05	– – –	1.55	1.42	0.9	4.07	0.83	0.17	0.06	– – –	– – –	99.08	8.53	XRF	Drillhole sample of tuff at 758 ft depth	47.04149 -122.02539	– – –
55	Ec2pg tuff5	D501237	47	24.4	3.04	– – –	1.39	4.41	0.67	4.51	1.03	0.22	0.11	– – –	– – –	98.48	11.7	XRF	Drillhole sample of tuff at 770 ft depth	47.04149 -122.02539	– – –

Table 4. Unnormalized trace element rock geochemistry for the Tacoma 1:100,000 quadrangle in weight percent. Superscript letters after the sample number denote the analytical method: [a] x-ray fluorescence; [b] instrumental neutron activation analysis; [c] inductively coupled plasma mass spectrometry; [d] not indicated. All samples analyzed at Washington State University, except for those from USGS (2008), for which no laboratory was reported. Database ID number corresponds to Geochemistry ID number found in the Rock Geochemistry Database (Bowman and others, 2014), which contains additional analytical information for most samples. Superscript numbers in the Unit column correspond to sources of data: [1] Logan and others (2009); [2] Walsh and others (2003c), [3] Walsh and others (2003d); [4] Gard (1968); [5] U.S. Geological Survey (2008); [6] Bowman and others (2014).

Map no. Sample no.	Unit	Ba	Ce	Co	Cr	Cs	Cu	Dy	Rb	Er	Eu	Ga	Gd	Hf	Ho	La	Lu	Mo	Nb	Nd	Ni	Pb	Pr	Sc	Sm	Sr	Ta	Tb	Th	Tm	U	V	Y	Yb	Zn	Zr	Latitude Longitude
1 C199783[a]	Qa? dacite[5]	541	34	--	18	3	20	--	32	--	--	20	--	--	--	20	--	--	--	21	16	12	--	--	--	425	--	--	8	--	2	54	15		58	185	47.27288 -122.37400
2 W166438[d]	Qgt? andesite[5]	150	--	30	70	--	70	--		--	--	15	--	--	--	--	--	--	--	--	70	500	--	20	--	500	--	--	--	--	--	100	--	2	--	100	47.37482 -122.12622
3 D226465[b]	Qgp$_{s}$? tuff[5]	996	33.7	0.54	0	1.99	--	1.42	68	--	0.315	--	1.8	2.67	--	18.9	0.209	--	--	14.1	0	--	--	1.21	1.72	115	0.886	0.28	8.13	0	3.71	--	--	1.31	0	105	47.36649 -122.03455
19 C199768[a]	Qgpc$_{pd}$? andesite[5]	463	32	--	12	3	9	--	43	--	--	21	--	--	--	19	--	--	--	12	6	10	--	--	--	443	--	--	3	--	2	43	14	--	60	141	47.22343 -122.22733
20 C199769[a]	Qgpc$_{pd}$? andesite[5]	461	38	--	33	3	12	--	46	--	--	21	--	--	--	17	--	--	--	16	7	11	--	--	--	435	--	--	3	--	4	57	14	--	60	138	47.22343 -122.22733
21 C198431[a]	Qvl$_{e}$ andesite[5]	444	43	--	26	3	18	--	41	--	--	22	--	--	--	23	--	--	--	30	13	10	--	--	--	554	--	--	4	--	2	110	17	--	78	173	47.13982 -122.23400
22 C198432[a]	Qvl$_{e}$ andesite[5]	445	49	--	23	4	21	--	39	--	--	21	--	--	--	23	--	--	--	26	12	10	--	--	--	563	--	--	5	--	2	116	17	--	74	174	47.13982 -122.23400
26 11SCH1017011[a]	Ev$_{c}$ basalt[2,6]	50	50	--	241	--	227	--	0	--	--	22	--	--	--	29	--	--	17.5	--	93	4	--	46	--	247	--	--	1	--	--	379	37	--	112	182	47.01591 -122.96430
27 SCH1016011[a]	Ev$_{c}$ basalt[2,6]	76	30	--	234	--	198	--	2	--	--	22	--	--	--	17	--	--	16.5	--	84	0	--	36	--	245	--	--	0	--	--	368	36	--	103	165	47.00996 -122.94375
28 SCH1016012[a]	Ev$_{c}$ basalt[2,6]	86	21	--	142	--	152	--	5	--	--	18	--	--	--	18	--	--	15.2	--	62	3	--	40	--	254	--	--	4	--	--	337	30	--	96	153	47.00566 -122.94510
29 SCH1016013[a]	Ev$_{c}$ basalt[2,6]	60	22	--	186	--	168	--	2	--	--	22	--	--	--	9	--	--	11.4	--	57	0	--	45	--	233	--	--	0	--	--	320	30	--	89	117	47.00999 -122.9329
30 SCH1016014[a]	Ev$_{c}$ basalt[2,6]	54	24	--	228	--	154	--	1	--	--	20	--	--	--	12	--	--	11.6	--	62	0	--	43	--	306	--	--	1	--	--	313	27	--	88	116	47.01108 -122.92594
31 18/2W 65.59[c]	Ev$_{c}$ basalt[1,6]	80	25	--	124	0.05	157	5.75	2.3	3.07	1.73	18	5.37	3.38	1.14	10.34	0.38	--	10.92	17.07	51	0.67	3.62	40	4.75	234	0.7	0.93	0.93	0.43	0.28	299	28.05	2.53	88	123	47.01295 -122.91639
32 18/2W 60.06[c]	Ev$_{c}$ basalt[1,6]	63	24.2	--	96	0.02	162	5.79	3.3	3.04	1.7	16	5.35	3.1	1.15	10.04	0.39	--	10.13	16.2	63	3.21	3.44	45.4	4.63	246	0.64	0.92	0.87	0.43	0.26	308	27.85	2.56	90	111	47.01148 -122.90651
33 18/2W 60.05[c]	Ev$_{c}$ basalt[1,6]	55	23.3	--	76	0.02	168	5.65	2.5	3	1.67	16	5.21	3.13	1.12	9.69	0.38	--	10.39	15.9	57	2.91	3.38	45	4.57	243	0.67	0.91	0.9	0.42	0.27	316	27.34	2.49	99	112	47.01081 -122.90655
38 C222065[c]	Qvl$_{e}$ andesite[5]	429	--	15.2	50	2.32	32	--	44.5	--	--	19.5	--	--	--	22	--	1.1	10.3	--	30.8	--	--	14.6	--	455	--	--	--	0.3	2.3	119	15.1	--	69	--	47.11016 -122.22010
39 C198433[a]	Qvl$_{e}$ andesite[5]	441	37	--	26	3	16	--	39	--	--	22	--	--	--	20	--	--	--	13	15	9	--	--	--	555	--	--	2	--	4	113	18	--	77	171	47.10510 -122.21789

Map no. Sample no.	Unit	Ba	Ce	Co	Cr	Cs	Cu	Dy	Rb	Er	Eu	Ga	Gd	Hf	Ho	La	Lu	Mo	Nb	Nd	Ni	Pb	Pr	Sc	Sm	Sr	Ta	Tb	Th	Tm	U	V	Y	Yb	Zn	Zr	Latitude Longitude
44 D501234[a]	Ec2pg tuff[5]	220	30	--	49	--	174	--	13	--	--	--	--	--	--	30	--	--	--	--	55	--	--	--	--	250	--	--	--	--	--	--	23	--	100	168	47.04621 -122.02872
45 D501230[a]	Ec2pg tuff[5]	960	170	--	20	--	26	--	176	--	--	--	--	--	--	75	--	--	--	--	17	--	--	--	--	215	--	--	--	--	--	--	61	--	98	325	47.04288 -122.03039
46 D501231[a]	Ec2pg tuff[5]	400	34	--	62	--	128	--	41	--	--	--	--	--	--	30	--	--	--	--	48	--	--	--	--	250	--	--	--	--	--	--	21	--	86	160	47.04288 -122.03039
47 D501232[a]	Ec2pg tuff[5]	435	30	--	65	--	128	--	33	--	--	--	--	--	--	30	--	--	--	--	46	--	--	--	--	280	--	--	--	--	--	--	19	--	83	162	47.04288 -122.03039
48 D501233[a]	Ec2pg tuff[5]	2100	280	--	20	--	31	--	82	--	--	--	--	--	--	122	--	--	--	--	28	--	--	--	--	300	--	--	--	--	--	--	108	--	210	750	47.04289 -122.03039
49 D501795[b]	Ec2pg tuff[5]	1030	137	6.24	13.7	18	--	--	205	--	1.29	--	10.1	11.2	--	68.9	0.91	--	--	58.8	9.7	--	--	6.32	12.7	231	6.2	1.66	29.1	1.02	9.46	--	--	6.6	92.1	357	47.04289 -122.03039
50 D501796[b]	Ec2pg tuff[5]	432	26.5	29	65.5	0.93	--	--	32.7	--	1.35	--	5.04	3.84	--	10.7	0.189	--	--	18.3	49	--	--	15.2	4.9	315	0.918	0.603	0.862	0.23	0.343	--	--	1.35	85.5	154	47.04289 -122.03039
51 D501797[b]	Ec2pg tuff[5]	385	29.6	23.8	68.1	1.04	--	--	39.3	--	1.25	--	4.68	4.04	--	12.3	0.192	--	--	20.1	55	--	--	14.9	5.13	266	0.929	0.645	1.27	0.24	0.538	--	--	1.41	86.5	168	47.04289 -122.03039
52 D501798[b]	Ec2pg tuff[5]	2130	294	7.69	1.2	3.89	--	--	91.2	--	4.84	--	20.1	23.5	--	145	1.34	--	--	130	38	--	--	13.1	25.5	328	10.7	3.04	19.1	1.52	6.29	--	--	9.59	186	713	47.04289 -122.03039
53 D501235[a]	Ec2pg tuff[5]	205	30	--	50	--	166	--	15	--	--	--	--	--	--	30	--	--	--	--	58	--	--	--	--	540	--	--	--	--	--	--	24	--	97	180	47.04150 -122.02539
54 D501236[a]	Ec2pg tuff[5]	1100	134	--	20	--	63	--	132	--	--	--	--	--	--	74	--	--	--	--	17	--	--	--	--	350	--	--	--	--	--	--	58	--	114	425	47.041450 -122.02539
55 D501237[a]	Ec2pg tuff[5]	1200	174	--	20	--	52	--	144	--	--	--	--	--	--	91	--	--	--	--	14	--	--	--	--	495	--	--	--	--	--	--	63	--	120	550	47.04149 -122.02539
56 D501799[b]	Ec2pg tuff[5]	214	29.8	28.9	76.3	0.329	--	--	15.8	--	1.68	--	5.1	4.42	--	11.7	0.218	--	--	22.5	87.9	--	--	16.2	5.65	588	1.02	0.696	0.729	0.259	0.351	--	--	1.56	94.2	163	47.04149 -122.02539
57 D501800[b]	Ec2pg tuff[5]	1160	134	7.87	33.8	7.14	--	--	145	--	1.61	--	10.6	13.2	--	59.9	0.775	--	--	64	18	--	--	13.8	13	387	4	1.46	20.6	0.928	6.6	--	--	5.47	109	421	47.04149 -122.02539
58 D501801[b]	Ec2pg tuff[5]	1220	132	24.4	14.4	7.29	--	--	165	--	1.83	--	11.2	16	--	59.3	0.881	--	--	65	27.3	--	--	12.7	14.2	552	4.53	1.8	21.9	1.05	6.93	--	--	6.31	109	565	47.04149 -122.02539