WASHINGTON STATE DEPARTMENT OF Natural Resources
Peter Goldmark - Commissioner of Public Lands
Division of Geology and Earth Resources
David K. Norman - State Geologist

Geologic Map of the Holly 7.5-minute Quadrangle, Jefferson, Kitsap, and Mason Counties, Washington

by Trevor A. Contreras, Sarah A. Weeks, Kelsay M. D. Stanton, Benjamin W. Stanton, Benjamin B. Perry, Timothy J. Walsh, Robert J. Carson, Kenneth P. Clark, and Shannon A. Mahan

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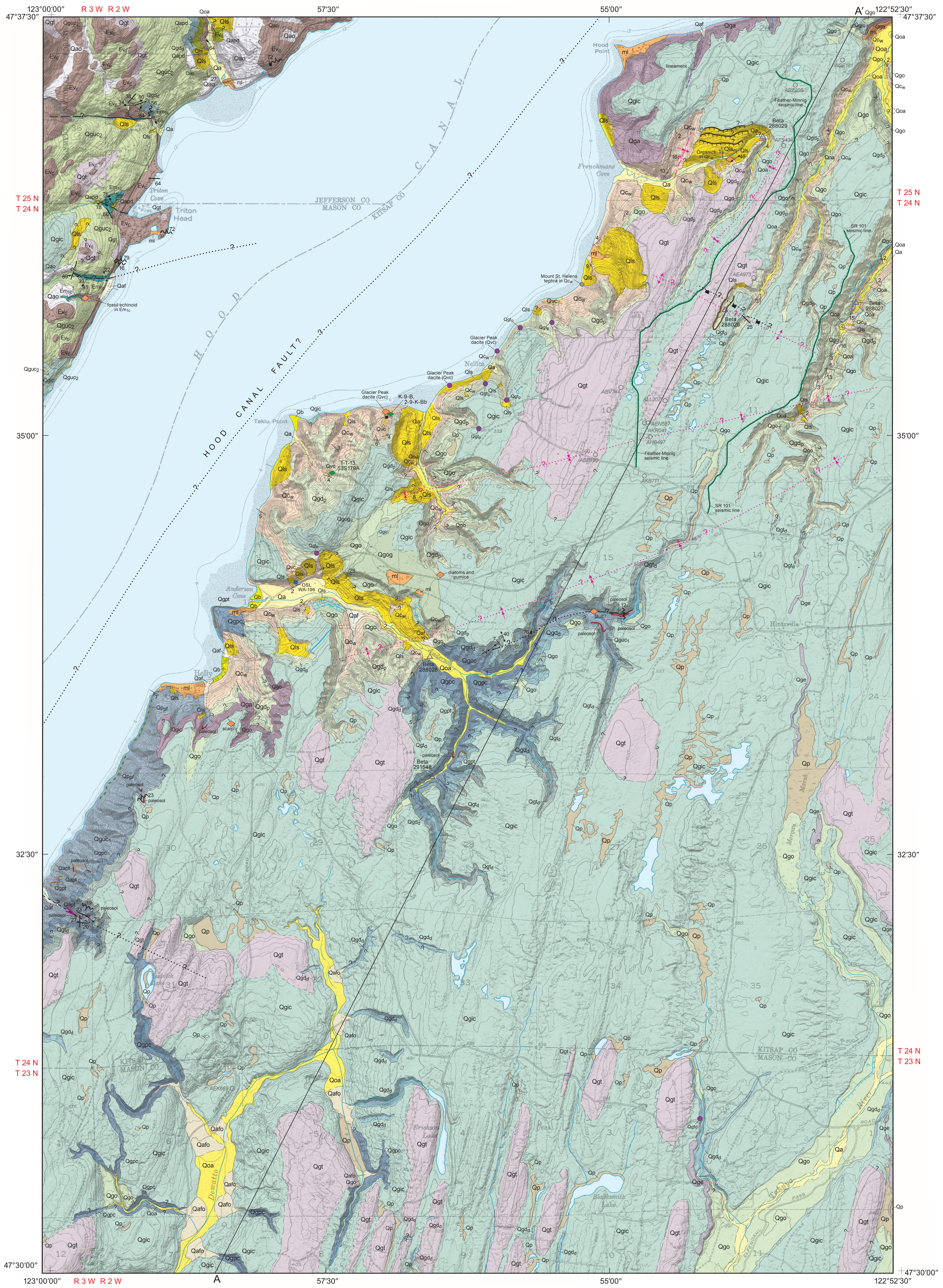
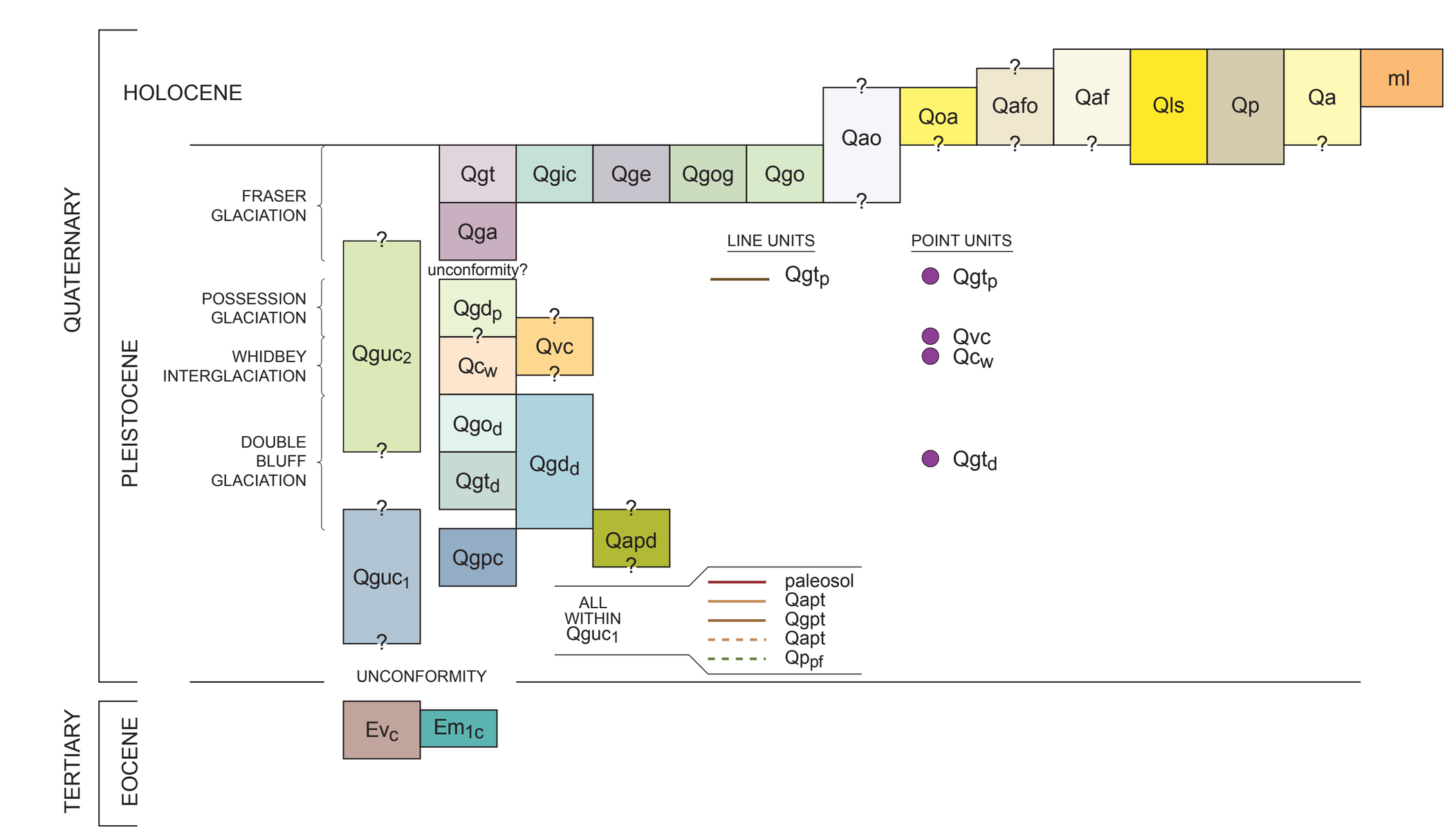


MAJOR FINDINGS

- Stratigraphic evidence suggests that the Seattle fault extends southwest from Green and Gold Mountains to Hood Canal and is represented by deformed Quaternary deposits.
- Dacite from Glacier Peak, found as dropstones and in a diamict, may represent a transition between Marine Isotope Stages (MIS) 4 and 5 (Whidbey- and Possesion-age) and suggests that drainages from the North Cascades provided sediment at that time.
- Vashon-age glacial till included in unit Qgic appears to be a subglacial melt-out till enriched in coarse sand and silt. This till is permeable to surface water infiltration in most of the map area.
- New age-control and limited exposures of till suggest that MIS 4 (Possession age) glacial ice advanced at least as far south as the map area.
- Large landslides north of Anderson Creek appear to be lateral spreads and may have been triggered by earthquakes.
- Radiocarbon ages from terraces in drainages on the Kitsap Peninsula suggest that most drainages were formed as Vashon-age glaciers melted and have been largely stable since. The terraces (unit Qoa) may provide evidence for deformation on the Seattle fault.

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

(See pamphlet for complete descriptions of map units.)

Quaternary Unconsolidated Deposits

HOLOCENE NONGLACIAL DEPOSITS

ml — **Modified land**—Locally derived sediment ranging from clay to gravel and diamicton; mixed and reworked by excavation and redistributed to modify topography.

Qa — **Alluvium**—Sand to cobble gravel; gray and generally unweathered; clasts subrounded to rounded; loose; moderately to well-sorted; deposited in stream valleys and estuaries.

Qb — **Beach deposits**—Transient sand to boulder gravel with shells; gray to brown-gray; clasts moderately to well-rounded; loose; may be well-sorted; derived locally.

HOLOCENE TO LATEST PLEISTOCENE NONGLACIAL DEPOSITS

Qp — **Peat**—Organic-rich sediment, including peat, muck, silt, and clay; dark brown to black; very soft to medium soft; typically in closed depressions.

Qls — **Landslide and mass-wasting deposits**—Clay, silt, sand, and gravel (diamicton); clasts angular to rounded; loose or soft; unsorted to poorly sorted and nonstratified. Not all landslides are shown; absence of mapped slide does not imply absence of hazard.

Qaf — **Alluvial fan**—Debris-flow diamicton and alluvial sand and gravel; gray; clasts subrounded to rounded; loose; forms concentric lobes where streams emerge from confining valleys.

Qafo — **Older alluvial fan**—Alluvial sand and gravel; gray to brown-gray; clasts subrounded to rounded; loose; forms concentric lobes where streams emerge from confining valleys. Some older fans may be active during large rain or snow storms.

Qoa — **Older alluvium**—Alluvial sand and gravel; gray to brown-gray; clasts subrounded to rounded; loose; age estimates indicate that these deposits filled outwash channels at various times during the Holocene.

PLEISTOCENE GLACIAL AND NONGLACIAL DEPOSITS

Recessional Deposits of the Fraser Glaciation (northern and Olympic sources)

Qao — **Vashon recessional Olympic-sourced outwash (late Pleistocene and Holocene)**—Fluvial cobble gravel to fine sand; orange-brown; clasts rounded to subangular; loose; moderately to well-sorted.

Qgo — **Vashon recessional outwash (late Pleistocene)**—Fluvial cobble and pebble gravel to fine sand; gray; clasts rounded to subangular; loose; moderately to well-sorted. Locally divided into:

Qgog — **Vashon recessional outwash gravels (late Pleistocene)**—Fluvial cobble to pebble gravel; gray; clasts rounded to subangular; loose; moderately to well-sorted; locally used as aggregate source.

Qgic — **Vashon ice-contact deposits**—Diamicton, cobbly pebble gravel and melt-out till; yellow-tan to gray; clasts subangular to subrounded; loose to dense; variously sorted; massive to well-stratified; till is friable and permeable. Locally divided into:

Qge — **Vashon eskers**—Gravel and sand; tan to brown; clasts moderately to well-rounded; loose; well-sorted; forms low, elongate, sinuous hills.

Proglacial and Subglacial Deposits of the Vashon Stade of the Fraser Glaciation

Qgt — **Vashon lodgment till**—Sand, pebbles, cobbles, silt, and clay (diamicton); gray; clasts subangular to rounded; compact; unsorted and unstratified; includes northern- and Olympic-sourced material.

Qga — **Vashon advance outwash**—Sandy (pebble) gravel and sand; gray to tan; mainly subrounded northern-sourced clasts; dense; stratified; thinly to thickly bedded; may inadvertently include deposits of Olympia or Possession age.

Pre-Fraser Glacial and Nonglacial Deposits

Pre-Fraser glacial deposits tentatively correlated with Marine Isotope Stage (MIS) 4 (Possession age)

Qgd_p — **Glacial drift of MIS 4 (Possession age), undivided**—Outwash and diamict; brown to gray; weathering varied; compact; well- to poorly sorted; may inadvertently include sand of MIS 3 and (or) 5 (Whidbey to Olympia age); found only north of Anderson Creek; where too small to show at map scale, shown as a point or line unit.

Qgt_p — **Glacial till of MIS 4 (Possession age)(line unit)**—Diamict; light brown to gray; mostly fresh; compact; poorly sorted; mapped north of Anderson Creek under Vashon age deposits; too thin to show at map scale—identity and existence certain, location accurate.

$Qguc_2$ — **Pre-Fraser glacial and nonglacial deposits, undivided**—Predominantly oxidized glacial deposits (outwash gravels and diamicts) of both Olympic and northern sources with minor nonglacial deposits; tentatively mapped as younger than MIS 6, but no age control available.

Pre-Fraser nonglacial deposits of MIS 5 (Whidbey age)

Qc_w — **Nonglacial prodelta deposits**—Sand, silt and clay; light brown to gray; clasts subrounded to well-rounded; very well-sorted; well-stratified; thinly laminated to thickly bedded; scattered layers of detrital wood, dacite sand, and tephra; luminescence age estimate of 82.5 ±3.89 ka. Locally divided into:

Qvc — **Volcaniclastic deposit from Glacier Peak**—Diamict and layers of dacite clasts (sand to small cobble boulder) in laminated sand, silt, and clay; tan to light gray; clasts subangular to moderately rounded; very stiff; poorly sorted, with lenses of dacite sand to cobble gravel; may represent transition to MIS 4.

Pre-Fraser glacial deposits tentatively correlated with MIS 6 (Double Bluff age)

Qgo_d — **Northern-sourced drift (cross section only)**—Outwash gravels below nonglacial unit Qc_w; found in water wells and interpreted from seismic data; likely MIS 6 recessional outwash, but could be older.

Qgt_d — **Northern-sourced lodgment till**—Sand, pebbles, cobbles, silt, and clay (diamicton); brown-gray; very dense; clasts subangular to rounded; unsorted and unstratified; includes northern- and Olympic-sourced material; unconformable beneath Vashon-age glacial deposits at and south of Anderson Creek; likely MIS 6, but could be older.

Qgd_d — **Glacial drift of MIS 6 (Double Bluff age), undivided**—Sand, sandy pebble gravel, and diamicton; brown to gray; compact; likely MIS 6 (Double Bluff age), but could be older.

Pre-Fraser glacial and nonglacial deposits older than MIS 6 (Double Bluff age)

$Qguc_1$ — **Pre-Fraser glacial and nonglacial deposits, undivided**—Predominantly glacial deposits (outwash gravels and diamicts) of both Olympic and northern sources; minor nonglacial deposits; includes at least three paleosols (most prominent shown as a line unit); lower sediments likely magnetically reversed. Locally divided into:

Qgpc — **Pre-Fraser northern-sourced glacial drift, undivided**—Predominantly glacial outwash sands and gravels with diamicts below unit Qgt_d; includes minor nonglacial silt and peat and at least one paleosol, suggesting multiple glacial advances; found at Anderson Creek and south.

paleosol — **Pre-Fraser paleosol (line unit)**—Buried soil horizon and (or) deeply weathered surface indicating prolonged subaerial exposure; identity and existence certain, location accurate.

Qgpt — **Pre-Fraser northern-sourced glacial till (line unit)**—Lodgment till or diamict; brown-gray; very dense; clasts subangular to rounded; unsorted and unstratified; found within unit $Qguc_1$ along Hood Canal near Holly; oldest tills possibly magnetically reversed; too thin to show at map scale; identity and existence certain, location accurate.

Qapt — **Pre-Fraser Olympic-sourced glacial till (line unit)**—Alpine till; brown-gray; very dense; clasts typically subangular; unsorted and unstratified; found within unit $Qguc_1$ along Hood Canal south of Holly; oldest tills possibly magnetically reversed; too thin to show at map scale; identity and existence certain, location accurate; where dashed, identity and existence certain, location inferred.

Qp_{pf} — **Pre-Fraser peat (line unit)**—Organic-rich sediment up to 0.8 ft thick and found within unit $Qguc_1$ along the eastern shore of Hood Canal near Holly; possibly magnetically reversed; too thin to show at map scale; identity and existence certain, location inferred.

Qapd — **Pre-Fraser Olympic-sourced glacial drift, undivided**—Outwash and diamict; orange-brown to gray; weathering varied; compact; clasts subangular to rounded; moderately to poorly sorted.

Tertiary Sedimentary and Volcanic Rocks

Em_{1c} — **Siltstone and sandstone (early to middle Eocene)**—Marine siltstone and feldspathic sandstone; dark gray to green-gray; fine- to coarse-grained; moderately to well-sorted; massive; locally fossiliferous or deformed; interpreted as sedimentary interbeds in the Crescent Formation.

Ev_c — **Crescent Formation basalt (early to middle Eocene)**—Basalt submarine flows; black to olive-green; fine- to coarse-grained; includes zeolite- and chlorite-group alteration minerals.

GEOLOGIC SYMBOLS

- Contact—Identity and existence certain, location accurate
- Contact—Identity or existence questionable, location accurate
- Contact—Identity and existence certain, location approximate
- Contact—Identity or existence questionable, location approximate
- Contact—Identity and existence certain, location inferred
- Contact—Identity or existence questionable, location inferred
- Contact—Identity or existence questionable, location concealed
- Fault, unknown offset—Identity and existence certain, location accurate
- Fault, unknown offset—Identity and existence certain, location approximate
- Fault, unknown offset—Identity or existence questionable, location approximate
- Fault, unknown offset—Identity or existence questionable, location inferred
- Fault, unknown offset—Identity or existence questionable, location concealed
- Reverse fault—Identity or existence questionable, location inferred; rectangles on upthrown block
- Reverse fault—Identity or existence questionable, location concealed; rectangles on upthrown block
- Anticline—Identity or existence questionable, location concealed
- Syncline—idenity or existence questionable, location concealed
- Monocline, anticlinal bend—Identity or existence questionable, location concealed
- Scarp—Identity and existence certain, location accurate, hachures point downscarp
- Fluvial terrace scarp—Location accurate, hachures point downscarp; question mark indicates identity questionable (could be landslide scarp)
- Landslide scarp—Location accurate, hachures point downscarp; question mark indicates identity questionable (could be fluvial terrace)
- A A′ Line of cross section
- Strand line (former shoreline)—Identity and existence questionable, location accurate
- Seismic data collection line—Location accurate
- Lineament—Identity or existence questionable, location inferred
- Beta 291548 — Age site, carbon-14 (^{14}C)
- OSL WA-196 — Age site, optically stimulated luminescence
- ABV744 — Water well
- fossil echinoid in Em_{1c} — Significant site (see data supplement for additional information)
- Mount St. Helens tephra in Qc_w — Electron microprobe site
- K-9-B — Geochemistry sample location
- Qgt_p — Geologic unit too small to show at scale—Includes units Qc_w, Qgt_p, Qgt_d, and Qvc
- 54 — Bedding—Showing strike and dip
- Horizontal bedding
- 26 — Joint—Showing strike and dip
- Vertical or near-vertical joint—Showing strike
- 41 — Minor fault—Showing strike and dip
- 80 — Slip lineation or slickensides on a fault or shear surface—Showing bearing and plunge of offset
- 52 — Slickensided surface—Showing strike and dip
- 13 — Bedding in unconsolidated sedimentary deposits—Showing strike and dip
- 27 — Foreset bedding in unconsolidated sedimentary deposits—Showing strike and dip
- Glacial striae—Showing bearing
- 23 — Shear—Showing strike and dip
- Shear—Showing strike

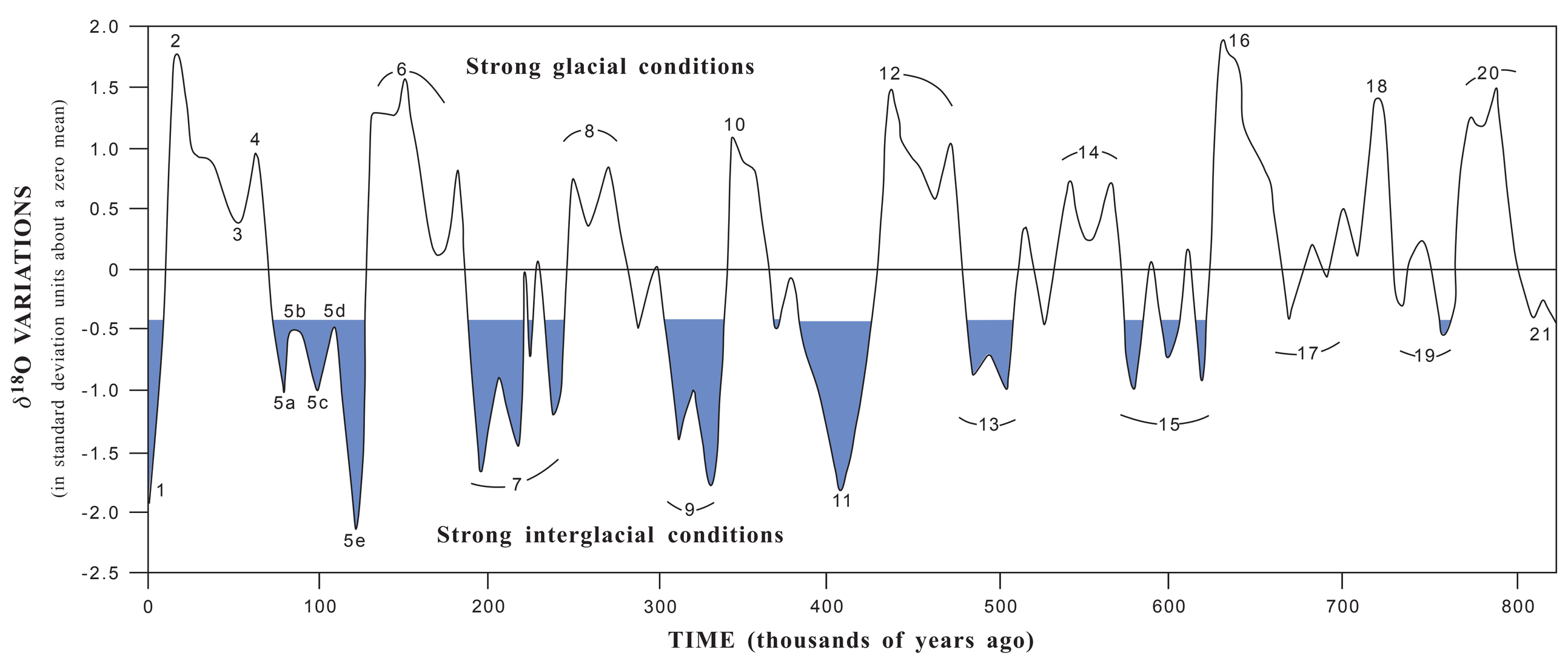
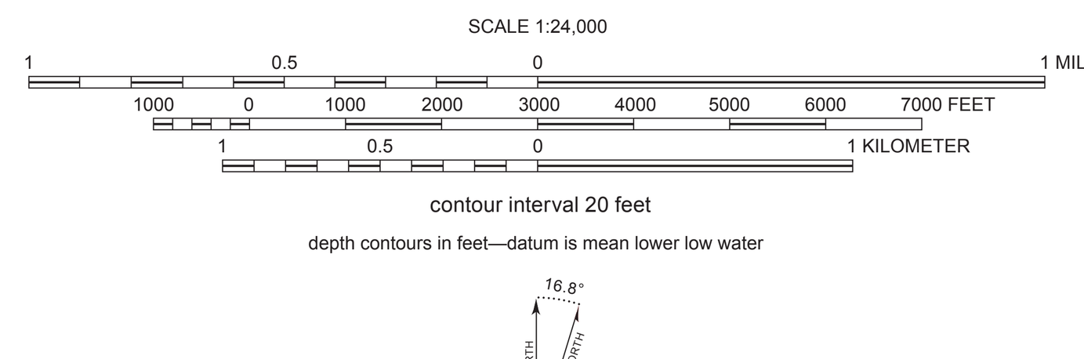


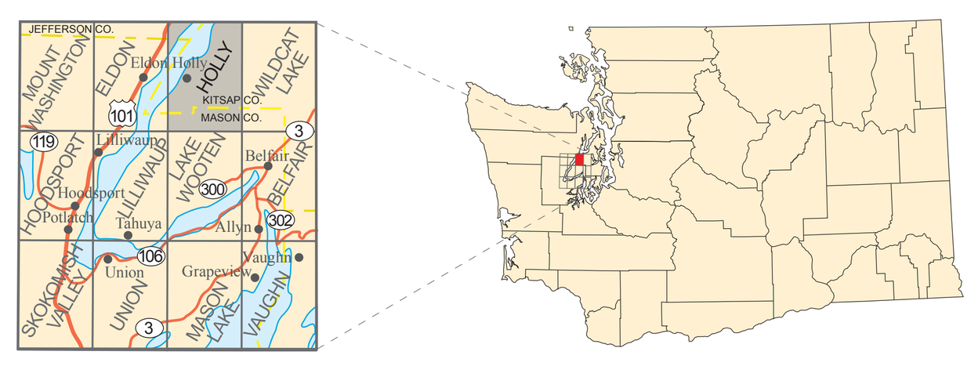
Figure 1. Marine oxygen-isotope stages for the past 800,000 years (redrawn from Morrison, 1991). The graph shows variations in the ratio of $^{18}O/^{16}O$ over time. The numbers within the graph are stage numbers; the even-numbered peaks (at top) are glacial maxima, and the odd-numbered troughs (at bottom) are interglacial minima. The blue areas indicate interglacial episodes defined by a cutoff at –0.5 $\delta^{18}O$ oxygen-isotope values (equivalent to Holocene interglacial values—the milder climate of the past 10 ka). Note that this last 800 ka of the Quaternary Period is dominated by times of glaciation.

Lambert conformal conic projection
North American Datum of 1927; to place on North American Datum of 1983, move the projection lines approximately 31 meters north and 93 meters east as shown by crosshair corner ticks
Base map from scanned and rectified U.S. Geological Survey Holly 7.5-minute quadrangle, 1953, photorevised 1985
Shaded relief generated from a lidar bare-earth digital elevation model (available from Puget Sound Lidar Consortium, http://pugetsoundlidar.ess.washington.edu/); sun azimuth 345°; sun angle 60°; vertical exaggeration 2x
Digital cartography and GIS by Trevor A. Contreras, J. Eric Schuster, and Anne C. Olson
Editing and production by Jaretta M. Roloff, Jessica L. Czajkowski, Katherine M. Reed, Karen D. Meyers, and Meredith C. Payne



contour interval 20 feet

depth contours in feet—datum is mean lower low water



In crowded areas, inferred and approximately located contacts are shown as solid lines to make the map more readable. In the GIS data for this map, the contacts are properly coded.

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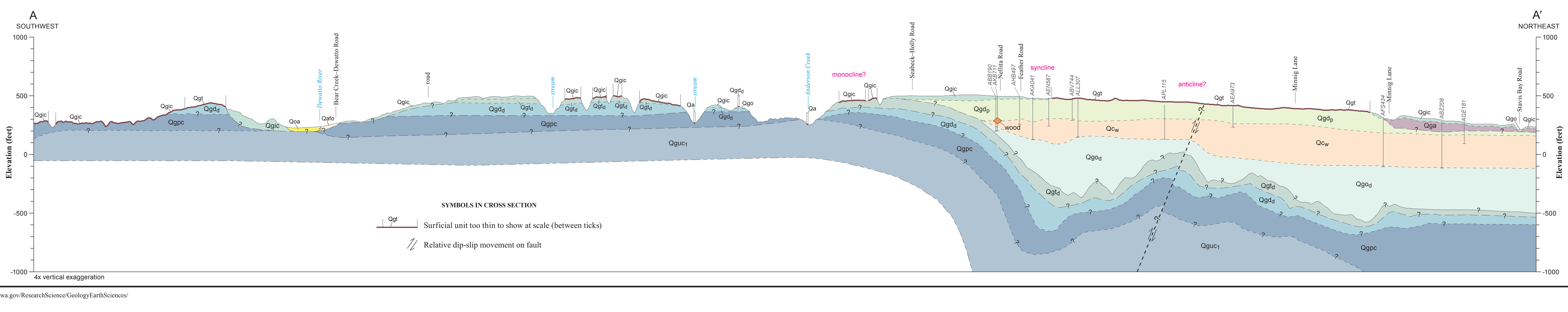

Table 1. Age-control data. Analytical methods used are ^{14}C, radiocarbon analysis; AMS, radiocarbon analysis by atomic mass spectrometry; OSL, optically stimulated luminescence analysis. All radiocarbon age estimates are presented as 'conventional radiocarbon age' with quoted errors representing one relative standard deviation (68% probability). Radiocarbon age estimates in parentheses followed by ka are calibrated results reported in calendar years before 1950 and within two standard deviations (95% probability). Radiocarbon 'greater than' age statements (for example, >43,500 B.P.) include a 2-sigma variance against background radiation. Uncertainty statements reflect random and lab errors; errors from unrecognized sample characteristics or flawed methodological assumptions (for example, ^{14}C sample contamination from younger carbon flux or incomplete pre-depositional re-setting of luminescence samples) are not known. Elevations are in feet (estimated using Puget Sound Lidar Consortium lidar grid elevations projected to State Plane South, NAD 83 HARN, supplemented by visual elevation estimates on bluffs).

Age site	Site name	Analytical method	Age estimate (^{14}C yr B.P. or ka)	$^{13}C/^{12}C$ (o/oo)	Material dated	Geologic unit	Lab no.	Elev. (ft)	Notes
1	Boyce Creek	^{14}C[1]	600 ±40 yr B.P. (0.660–0.530 ka)	-21.8	charred material	Qoa	Beta 288029	~128	Material under landslide deposit
2	Anderson Creek	AMS[1]	1400 ±40 yr B.P. (1.360–1.280 ka)	-26.7	charred material	Qoa	Beta 288028	~106	Incised terrace deposit
3	Stavis Creek	^{14}C[1]	3020 ±50 yr B.P. (3.360-3.070 ka)	-26.1	wood	Qoa	Beta 288027	~195	Incised terrace deposit
4	near waterfall	AMS[1]	5680 ±40 yr B.P. (6.550–6.400 ka)	-24.4	carbonized wood	Qoa (too small to map)	Beta 288026	~376	Incised terrace deposit
5	South Fork Anderson Cr	AMS[1]	>43,500 yr B.P.	-29.3	organic sediment	Qgpc	Beta 291548	~263	Considered radiocarbon infinite; found under older advance silts
6	Seabeck-Holly Rd	OSL[2]	82.5 ±3.89 ka	---	fine sand	Qc_w	WA-196	~57	Approximately 150 ft below unit Qvc deposit

[1] Analysis by Beta Analytic
[2] Analysis by Shannon Mahan (U.S. Geological Survey)