U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

SCIENTIFIC INVESTIGATIONS MAP 3060
SHEET 3 OF 3

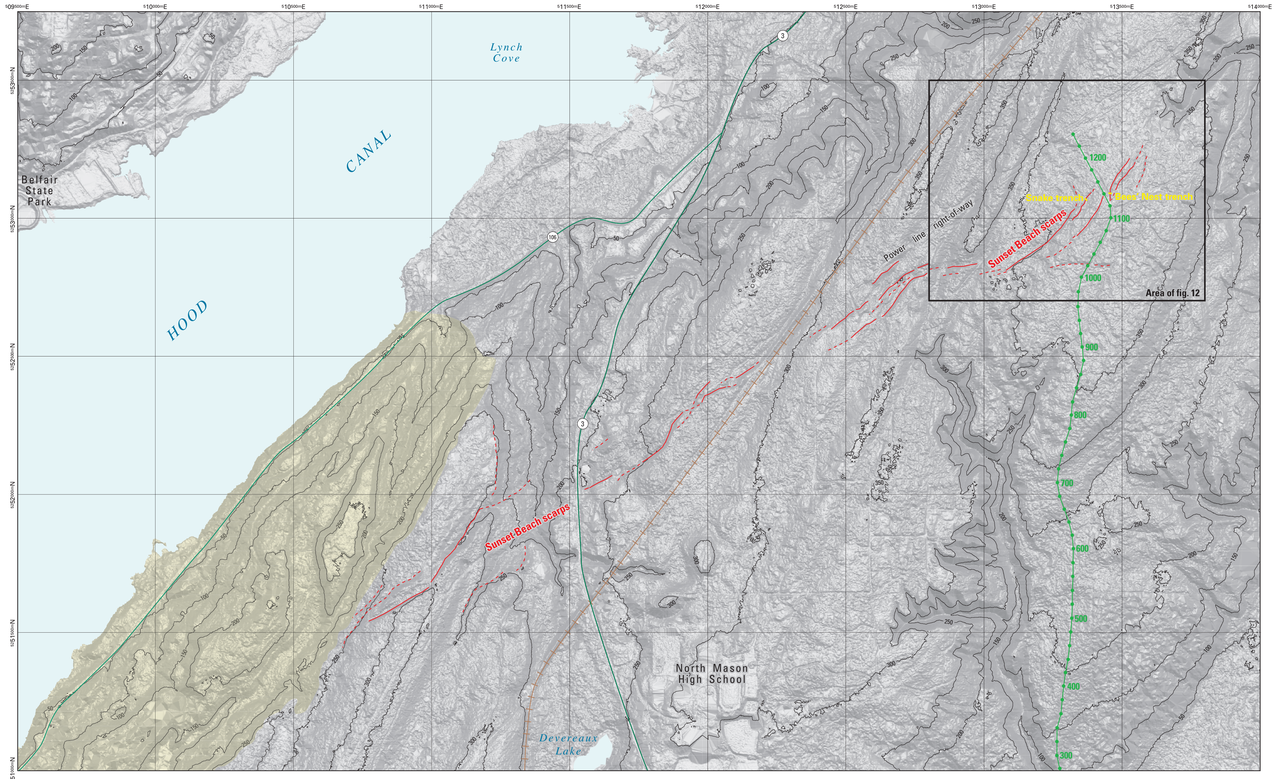


Figure 11. Detailed ALSM (airborne laser swath mapping; also known as LiDAR) image showing Sunset Beach scarps and sites of the Snake and Bees' Nest trenches. Red line marks approximate base of scarp, dashed where origin or location of the scarps are less certain. Contours generated from ALSM data have errors of less than ±30 cm. Base contour is mean sea level. The DEM (digital elevation model) consists of two ALSM hillshade layers: top layer azimuth 80°, height above horizon 60°, 5x vertical component, 75% transparent; bottom layer azimuth 310°, height above horizon 60°, 5x vertical component, 70% transparent.

EXPLANATION OF SYMBOLS ON ALSM IMAGES (Figures 11 and 12)

- Base of scarp, dashed where uncertain
- Highway
- Railroad
- Area shaded yellow marks Holocene landslides northeast of Sunset Beach
- 700 — Common depth points (CDP) for seismic profile

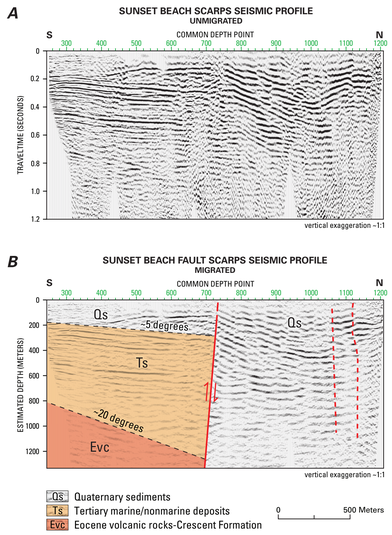


Figure 13. High-resolution north-south unmigrated travel time (A) and migrated depth (B) sections east of Hood Canal (fig. 11). The north end of the profile crosses the Sunset Beach scarps between the Snake and Bees' Nest trench sites (fig. 12). Displaced reflectors suggest steeply dipping reverse faults beneath and to the south of the scarps; a general trend of north-dipping reflectors suggests the profile is located on the north limb of a fold related to the Tacoma fault. Common depth point (CDP) spacing is 2.5 m. Data were recorded using an accelerated 200 kg hammer and a 120-channel seismic recording system (Liberty, 2007).

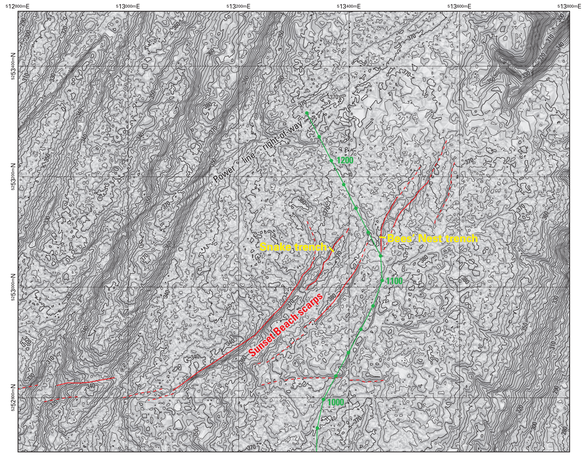
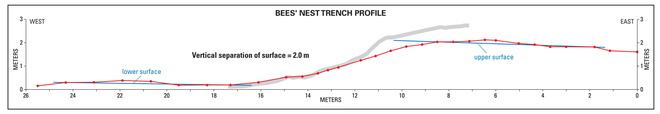


Figure 12. Detailed ALSM image showing Sunset Beach scarps and sites of the Snake and Bees' Nest trenches. Red lines mark approximate base of scarps, dashed where origin or location of the scarps are less certain. Contours generated from ALSM data have errors of less than ±30 cm. Base contour is mean sea level. The DEM consists of two ALSM hillshade layers: top layer azimuth 80°, height above horizon 60°, 5x vertical component, 80% transparent; bottom layer azimuth 310°, height above horizon 60°, 5x vertical component, 75% transparent.

TABLE 2. RADIOCARBON DATA FOR CHARCOAL SAMPLES FROM THE SNAKE AND BEES' NEST TRENCHES

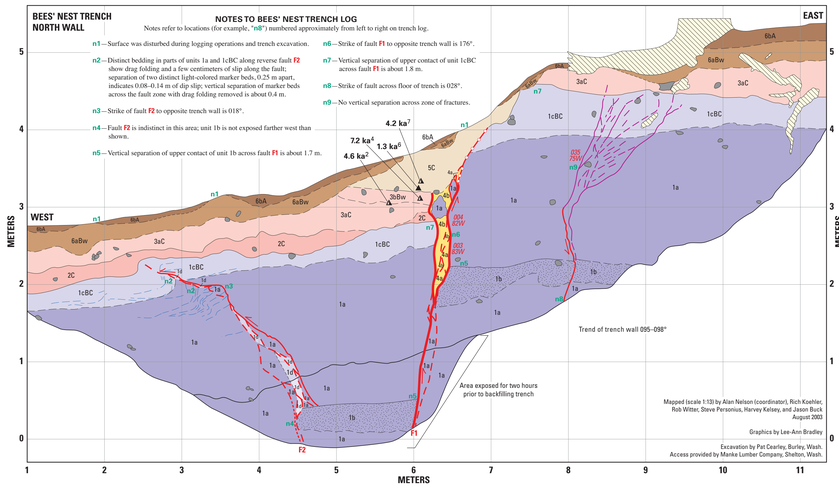
Field number	Unit number	Station[1] h,v (m)	Radiocarbon lab number[2]	Lab-reported age (^{14}C yr BP at 1σ)[3]	Calibrated age (cal yr BP at 2σ)[4]	Sample weight (mg)[5]	^{13}C (‰)	Description of dated material[6]
Snake trench								
SK-25	5bBw	5.35, 2.50	OS-43390	1,600±65	1,690-1,340	11.4	-25.5	10x3x5-mm fragment burned wood
SK-28	5bBw	6.21, 1.60	CAMS-101667	1,455±35	1,410-1,290	10.6s	-24.2	4 delicate 2x1x1-mm fragments
SK-29	5bBw	6.55, 2.42	OS-43060	1,280±45	1,300-1,070	11.7	-26.7	5x5x4-mm fragile fragment
SK-31	5bBw	6.36, 1.50	CAMS-101668	2,120±40	2,310-1,990	18.7s	-24.9	8x4x4-mm dense fragment
SK-6	5bBw	5.64, 2.19	OS-43059	5,750±40	6,660-6,440	23.7	-26.0	10x6x2 bark-like fragment
Bees' Nest trench								
BN-2	3bBw	5.85, 3.04	CAMS-101664	3,980±40	4,570-4,330	10.5	-26.4	9x5x4-mm fragment
BN-4	3bBw	6.10, 3.11	CAMS-101665	6,175±40	7,230-6,940	51.6	-25.1	9x8x7-mm dense fragment
BN-6	5C	6.06, 3.21	CAMS-101666	1,280±40	1,290-1,080	8.1	-25.1	6x2x1-mm fragment
BN-7	5C	6.10, 3.30	OS-43058	3,680±40	4,150-3,890	17.9	-24.0	6x14x4-mm fragment

[1]Location (horizontal, vertical) on reference grid used to map north wall of Bees' Nest trench and southwest wall of Snake trench. Superscripts on sample ages shown on trench logs are the digits of field sample numbers (first columns).
[2]Laboratories: OS, National Ocean Sciences AMS Facility (NOSAMS), Woods Hole Oceanographic Institution, Massachusetts; CAMS, Lawrence Livermore National Laboratories, California.
[3]AMS (accelerator mass spectrometer) ages (methods described in Gagnon and others, 2000). Quoted error for each AMS analysis is the larger of counting error or target reproducibility error.
[4]Ages in solar years calculated using OxCal (version 3.10; Bronk Ramsey, 2001; probability method) with the INTCAL04 atmospheric dataset (Reimer and others, 2004). NOSAMS' (OS), and Lawrence Livermore's (CAMS) results from the Third International Radiocarbon Comparison show minimal offset from comparison means suggesting that no additional interlaboratory variance is required for calibration. Calibrated ages show time intervals of >95% probability distribution at 2σ. Calibrated ages shown on trench logs are weighted averages of age probability distribution functions (Telford and others, 2004) rounded to nearest 100 years.
[5]"s" indicates samples with adhering sediment when submitted to ^{14}C laboratory; weight is a maximum for organic material in the sample.
[6]Unless indicated otherwise, ages are on angular, unabraded fragments of charcoal with distinct wood cellular structure. In each sample, the largest, most angular, least decayed fragments of charcoal were selected to minimize the chance of analyzing carbon much older than the host sediment. Most sediment adhering to fragments was removed with brushes or dental tools in distilled water at 6–25X. Charcoal was picked directly from sediment collected from the trench wall.



EXPLANATION OF PROFILE SYMBOLS

- Segment of profile measured from northeast and southwest ends of trench wall with a rod and digital level (method of Machette, 1989); red dots show end points of profile segments
- Surface from which heights and offsets were calculated (method of Machette, 1989)
- Approximate location of upper surface of logged trench



NOTES TO BEES' NEST TRENCH LOG

Notes refer to locations (for example, "n8") numbered approximately from left to right on trench log.

- n1—Surface was disturbed during logging operations and trench excavation.
- n2—Distinct bedding in parts of units 1a and 1cBC along reverse fault F2 show drag folding and a few centimeters of slip along the fault; separation of two distinct light-colored marker beds, 0.25 m apart, indicates 0.08–0.14 m of dip slip; vertical separation of marker beds across the fault zone with drag folding removed is about 0.4 m.
- n3—Strike of fault F2 to opposite trench wall is 018°.
- n4—Fault F2 is indistinct in this area; unit 1b is not exposed farther west than shown.
- n5—Vertical separation of upper contact of unit 1b across fault F1 is about 1.7 m.
- n6—Strike of fault F1 to opposite trench wall is 176°.
- n7—Vertical separation of upper contact of unit 1cBC across fault F1 is about 1.8 m.
- n8—Strike of fault across floor of trench is 028°.
- n9—No vertical separation across zone of fractures.

EXPLANATION OF UNITS IN BEES' NEST TRENCH

Unit 6—Pebbly silty sand to silty sand (horizons of modern surface soil developed on root stirred sediment; late Holocene)
- 6bA — **6bA**—Organic-rich, silty sand with abundant roots and much coarse woody debris (A, AB, and O horizons, eroded or overthickened in places by shallow surface disturbance from logging operations)
- 6aBw — **6aBw**—Pebbly silty sand, massive to very weak subangular blocky structure (discontinuous, weak Bw horizon, broken by root stirring)

Unit 5C—Pebbly silty sand (slope colluvium eroded from fault scarp and deposited in wedge near base of scarp following faulting; Cox horizon; late Holocene)

Unit 4—Friable diamict to pebbly silty sand (sediment filling fault zone fissures; late Holocene)
- 4b — **4b**—Pebbly silty sand mostly derived from unit 3
- 4a — **4a**—Pebbly diamict breccia mostly derived from unit 1

Unit 3—Massive sandy gravel to pebbly silty sand (root stirred sediment with late Holocene soil, probably derived from proglacial or immediately postglacial fluvial deposit; buried by slope colluvium near base of scarp; late Holocene)
- 3bBw — **3bBw**—Pebbly silty sand with very weak crumb soil structure and slightly redder hue or chroma than unit 3aC (weak Bw horizon)
- 3aC — **3aC**—Sandy gravel (Cox horizon)

Unit 2C—Crossbedded compact pebbly silty sand (subglacial or proglacial fluvial deposit; Cox horizon; late Pleistocene)

Unit 1—Sandy pebbly diamict (ice-contact deposits, probably subglacial; late Pleistocene)
- 1d — **1d**—Shattered but intact pieces of unit 1 near fissures and fractures
- 1cBC — **1cBC**—Massive diamict with strong platy structure (B and (or) Cox horizon in weathered upper part of unit 1)
- 1b — **1b**—Pebbly sand
- 1a — **1a**—Dense massive pebbly diamict

EXPLANATION OF SYMBOLS IN TRENCHES

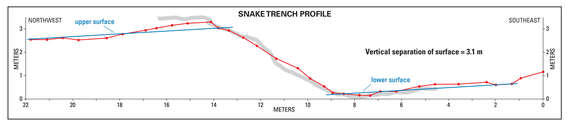
Faults and fractures
- Primary fault
- Secondary fault
- Indistinct secondary fault
- Indistinct secondary fault with small uncertain displacement
- Eroded free face
- 106 / 05N — Strike (*θ–360*) and dip (*05N*) of fault
- Distinct fracture
- Indistinct fracture

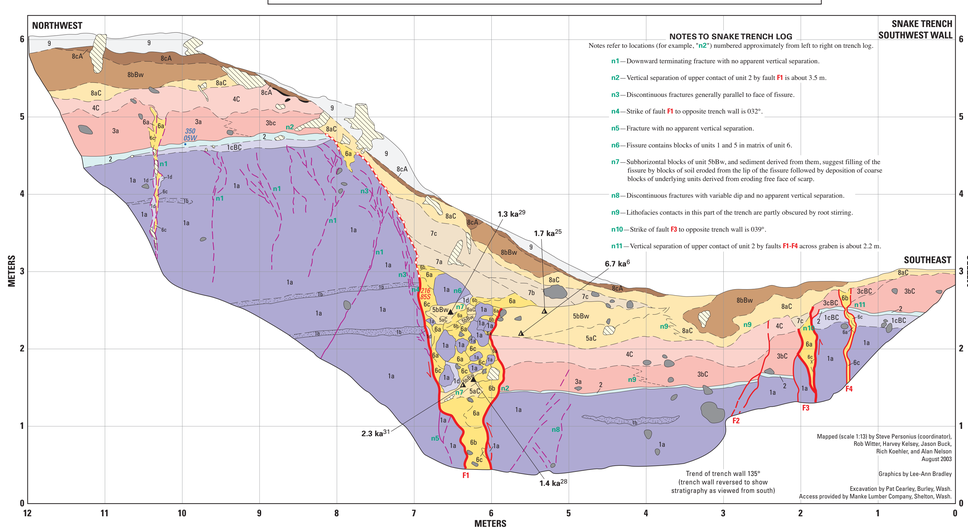
Contacts
- Sharp or distinct
- Gradual and (or) indistinct
- Inferred

Intra-unit bedding, lamination, or structures
- Sharp or distinct
- 095 / 85N — Strike (*θ–360*) and dip (*85N*) of bedding or lamination

Symbols
- Large roots or pieces of wood, and areas disturbed by modern roots
- Selected cobbles and boulders
- 1.9 ka[11] — Calibrated radiocarbon ages, rounded to nearest 100 yr (ka is 1,000 cal yr B.P.; dated material is charcoal; superscript is field sample number on table 1)
- ▲ Close maximum age for host sediment (probably less than a few hundred years older than sediment)
- ▲ Maximum age for host sediment
- △ Minimum age for host sediment

EXPLANATION OF COLORS USED TO SHOW GENESIS OF TRENCH LOG UNITS
(colors do not imply correlations from trench to trench)
- Subglacial and/or proglacial ice-contact and/or fluvial deposit (stippled where sandy)
- Weathered or root-stirred subglacial or proglacial ice-contact deposit (stippled where particularly sandy)
- Proglacial or postglacial fluvial deposit
- Root-stirred slope colluvium
- Sediment filling fault-related fissures
- Youngest fault-scarp related slope colluvium
- Forest A and O horizons
- Forest B horizons





NOTES TO SNAKE TRENCH LOG

Notes refer to locations (for example, "n2") numbered approximately from left to right on trench log.

- n1—Downward terminating fracture with no apparent vertical separation.
- n2—Vertical separation of upper contact of unit 2 by fault F1 is about 3.5 m.
- n3—Discontinuous fractures generally parallel to face of fissure.
- n4—Strike of fault F1 to opposite trench wall is 032°.
- n5—Fracture with no apparent vertical separation.
- n6—Fissure contains blocks of units 1 and 5 in matrix of unit 6.
- n7—Subhorizontal blocks of unit 5bBw, and sediment derived from them, suggest filling of the fissure by blocks of soil eroded from the lip of the fissure followed by deposition of coarse blocks of underlying units derived from eroding free face of scarp.
- n8—Discontinuous fractures with variable dip and no apparent vertical separation.
- n9—Lithofacies contacts in this part of the trench are partly obscured by root stirring.
- n10—Strike of fault F3 to opposite trench wall is 039°.
- n11—Vertical separation of upper contact of unit 2 by faults F1-F4 across graben is about 2.2 m.

EXPLANATION OF UNITS IN SNAKE TRENCH

Unit 9—Massive pebbly cobbly silty sand (surface sediment disturbed by recent logging operations and trenching excavation)

Unit 8—Pebbly silty sand to silty sand (horizons of modern surface soil developed on root stirred sediment; late Holocene)
- 8cA — **8cA**—Organic-rich, silty sand with abundant roots and much coarse woody debris (A, AB, and O horizons, eroded or overthickened in places by shallow surface disturbance from logging)
- 8bBw — **8bBw**—Pebbly silty sand, massive to very weak subangular blocky structure (discontinuous, weak Bw horizon, broken by root stirring)
- 8aC — **8aC**—Massive pebbly silty sand (Cox horizon)

Unit 7—Pebbly silty sand to pebble gravel (slope colluvium eroded from fault scarp and deposited near base of scarp following faulting; late Holocene)
- 7c — **7c**—Pebbly silty sand (weakly stratified fault-scarp debris wedge)
- 7b — **7b**—Pebble gravel (sorted-clast debris wedge; distal toe of wedge is root stirred)
- 7a — **7a**—Pebbly silty sand (upper part of debris/wash wedge, partly root stirred)

Unit 6—Friable diamict to pebbly silty sand (sediment mostly filling fault zone fissures; late Holocene)
- 6c — **6c**—Pebbly diamict breccia mostly derived from unit 1
- 6b — **6b**—Pebbly silty sand mostly derived from unit 5
- 6a — **6a**—Diamict to pebbly silty sand derived from units 1, 2, 3, 4, and 5

Unit 5—Massive pebbly silty sand (root-stirred sediment with late Holocene soil; buried by slope colluvium near base of scarp; late Holocene)
- 5bBw — **5bBw**—Pebbly silty sand with very weak subangular blocky soil structure and slightly redder hue or chroma than unit 5aC (weak Bw horizon)
- 5aC — **5aC**—Massive pebbly silty sand (Cox horizon)

Unit 4C—Friable fine pebbly sand to pebbly diamict (ice-contact, proglacial, or immediately postglacial fluvial deposit, possibly braided stream deposit; upper part root stirred; Cox horizon developed in unit; late Pleistocene to Holocene)

Unit 3—Moderately compact pebbly diamict (subglacial or proglacial ice-contact fluvial deposit; late Pleistocene)
- 3cBC — **3cBC**—Cemented, iron-stained, pebbly sand (discontinuous Bs and Cox horizon)
- 3bC — **3bC**—Silty sandy gravel (Cox horizon)
- 3a — **3a**—Silty sandy gravel

Unit 2—Light gray to white sandy silt to silty sand (subglacial or proglacial still-water deposit; late Pleistocene)

Unit 1—Sandy pebbly diamict (ice-contact deposits, probably subglacial; late Pleistocene)
- 1d — **1d**—Shattered but intact pieces of unit 1 in fissures along faults
- 1cBC — **1cBC**—Massive diamict with strong platy structure (B and (or) Cox horizon in weathered upper part of unit 1)
- 1b — **1b**—Pebbly sand
- 1a — **1a**—Dense massive pebbly diamict

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FIELD AND LABORATORY DATA FROM AN EARTHQUAKE HISTORY STUDY OF SCARPS IN THE HANGING WALL OF THE TACOMA FAULT, MASON AND PIERCE COUNTIES, WASHINGTON

By

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