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

MISCELLANEOUS FIELD STUDIES MAP MF-2420
Version 1.0

Maps and Data from a Trench Investigation of the Utsalady Point Fault, Whidbey Island, Washington

By

Samuel Y. Johnson,[1] Alan R. Nelson,[1] Stephen F. Personius,[1] Ray E. Wells,[2] Harvey M. Kelsey,[3] Brian L. Sherrod,[4] Koji Okumura,[5] Rich Koehler,[6] Robert Witter,[6] Lee-Ann Bradley,[1] and David J. Harding[7]

2003

[1]U.S. Geological Survey, Box 25046, MS 966, Denver Federal Center, Denver, CO 80225
[2]U.S. Geological Survey, 345 Middlefield Road, Menlo Park, CA 94025
[3]Department of Geology, Humboldt State University, Arcata, CA 95521
[4]U.S. Geological Survey at Department of Earth and Space Sciences, University of Washington, Seattle, WA 98195
[5]Department of Geography, Hiroshima University, 1-2-3 Hagamiyama, Higashi-Hiroshima, 739-8522 JAPAN
[6]William Lettis and Associates, Inc., Earth Science Consultants, San Rafael, CA 94901
[7]NASA, Goddard Space Flight Center, Mail Code 921, Greenbelt, MD 20771-0001

INTRODUCTION

The Utsalady Point fault is one of several faults that pose potential earthquake hazards to the densely populated Puget Lowland of Washington State (Gower and others, 1985; Johnson and others, 1994, 1996, 1999, 2001; Brocher and others, 2001; Mosher and Johnson, 2001; Blakely and others, 2002). The Utsalady Point fault was first recognized by Johnson and others (2001) who considered it part of a broad zone of crustal deformation that extends from the eastern Strait of Juan de Fuca across Whidbey Island and the Puget Lowland into the Cascade Range (figs. 1, 2). Other structures in this zone include the Devils Mountain fault and the Strawberry Point fault.

In the winters of 2000-2001 and 2001-2002, Airborne Laser Swath Mapping (ALSM) surveys were flown over Island County. Funding and support for acquisition of these data were provided by NASA, the U.S. Geological Survey, Island County, and the Puget Sound Lidar Consortium. ALSM data have proven to be extremely useful in identification of tectonic landforms in the Puget Lowland (for example, Harding and Berghoff, 2000). For this investigation, high-resolution "bald-earth" digital elevation models (DEMs) derived from the ALSM data led to the discovery of an approximately

1.4-km-long scarp along the Utsalady Point fault (fig. 3) west-northwest of Oak Harbor on northern Whidbey Island.

Trenching investigations are the most direct way of interpreting the history of large earthquakes on faults (McCalpin, 1998), which are critical in the assessment of regional earthquake hazards (for example, Frankel and others, 2002). In the summer of 2002, the U.S. Geological Survey excavated two trenches, informally named "Duffers" and "Teeka," across the Utsalady Point fault scarp recognized on the ALSM data (figs. 4, 5). Stratigraphic and structural relations in these trenches were mapped (figs. 6-8) on digital photo mosaics using paleoseismologic methods similar to those described in McCalpin (1998) and Nelson and others (2002).

This report presents primary field and laboratory data for the Duffers and Teeka trenches. Trench logs show the distribution of stratigraphic units as well as faults, shears, folds, and other features of possible earthquake origin. Adjacent to each log is a summary explanation of stratigraphic units, briefly describing lithology, texture, stratification, structure, and inferred age and origin. Note that neither the colors nor the numbers used to label stratigraphic units indicate direct correlation between the two trenches. Units are generally numbered from oldest to youngest, however many units overlap in age. Notes outlining important stratigraphic or structural relations are included on the logs. Radiocarbon ages and their inferred relationship to stratigraphic units are plotted on the trench logs and summarized in the table to the right.

This report does not attempt to construct an earthquake history for the Utsalady Point fault, nor does it attempt to show how surface faulting and folding events in each trench may correlate between trenches. These objectives, and how they impact earthquake hazard assessments in the Puget Lowland, will be the subject of a future report.

ACKNOWLEDGMENTS
This investigation was supported by the Earthquake Hazards Program of the U.S. Geological Survey. Land access was provided by Gail and Ray Priest (Teeka trench), and by the United States Navy, Whidbey Island Naval Air Station (Duffers trench). Collin McGinness expertly excavated the trenches. Our logistics and planning were greatly aided by Gail and Ray Priest, Ben Altz-Stamm, Matt Nash, Doug Kelly, Sherri Davis, and Steve Lombardo. Outstanding GIS and drafting support were provided by Susan Rhea and Margo Johnson, respectively.

REFERENCES
Blakely, R.J., Wells, R.E., Weaver, C.S., and Johnson, S.Y., 2002, Location, structure, and seismicity of the Seattle fault, Washington: Geological Society of America Bulletin, v. 114, p. 169-177.

Brocher, T.M., Parsons, T., Blakely, R.J., Christensen, N.I., Fisher, M.A., Wells, R.E., and the SHIPS Working Group, 2001, Upper crustal structure in Puget Lowland, Washington—Results from the 1998 seismic hazards investigation in Puget Sound: Journal of Geophysical Research, v. 106, p. 13,541-13,564.

Bronk-Ramsey, C., 1998, Probability and dating: Radiocarbon, v. 40, p. 461-474.
Frankel, A.D., Peterson, M.D., Mueller, C.S., Haller, K.M., Wheeler, R.L., Leyendecker, E.V., Wesson, R.L., Harmsen, S.C., Cramer, C.H., Perkins, D.M., and Rukstales, K.S., 2002, Documentation for the 2002 update of the National seismic hazard maps: U.S. Geological Survey Open-File Report 02-420.

Gower, H.D., Yount, J.C., and Crosson, R.S., 1985, Seismotectonic map of the Puget Sound region, Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-1613, scale 1:250,000.

Harding, D.J., and Berghoff, G.S., 2000, Fault scarp detection beneath dense vegetation cover—Airborne lidar mapping of the Seattle fault zone, Bainbridge Island, Washington State: Proceedings of the American Society of Photogrammetry and Remote Sensing Annual Conference, Washington, D.C., May 2000, 9 p.
http://duff.geology.washington.edu/data/raster/lidar/harding.pdf

Johnson, S.Y., Dadisman, S.V., Childs, J.R., and Stanley, W.D., 1999, Active tectonics of the Seattle fault and central Puget Lowland—Implications for earthquake hazards: Geological Society of America Bulletin, v. 111, p. 1042-1053, and oversize insert.

Johnson, S.Y., Dadisman, S.V., Mosher, D.C., Blakely, R.J., and Childs, J.R., 2001, Active tectonics of the Devils Mountain fault and related structures, northern Puget Lowland and eastern Strait of Juan de Fuca region, Pacific Northwest: U.S. Geological Survey Professional Paper 1643, 46 p., 2 plates.

Johnson, S.Y., Potter, C.J., and Armentrout, J.M., 1994, Origin and evolution of the Seattle basin and Seattle fault: Geology, v. 22, p. 71-74 and oversize insert.

Johnson, S.Y., Potter, C.J., Armentrout, J.M., Miller, J.J., Finn, C., and Weaver, C.S., 1996, The southern Whidbey Island fault, an active structure in the Puget Lowland, Washington: Geological Society of America Bulletin, v. 108, p. 334-354 and oversize insert.

McCalpin, J.P., 1998, Paleoseismology: Orlando, Florida, Academic Press, 608 p.

Mosher, D.C., and Johnson, S.Y. (eds.), Rathwell, G.J., Kung, R.B., and Rhea, S.B. (compilers), 2001, Neotectonics of the eastern Strait of Juan de Fuca; a digital geological and geophysical atlas: Geological Survey of Canada Open-File Report D3931 (CD digital product), 18 maps and accompanying text and figures.

Nelson, A.R., Johnson, S.Y., Wells, R.E., Pezzopane, S.K., Kelsey, H.M., Sherrod, B.L., Bradley, L-A., Koehler, R.D., III, Bucknam, R.C., Haugerud, R.A., and LaPrade, W.T., 2002, Field and laboratory data from an earthquake history study of the Toe Jam Hill fault, Bainbridge Island, Washington: U.S. Geological Survey Open-File Report 02-60; 37 p., 2 plates.

Stuiver, M., Reimer, P.J., Bard, E., Beck, J.W., Burr, G.S., Hughen, K.A., Kromer, B., McCormac, G., Plicht, J.V.D., and Spurk, M., 1998, INTCAL98 radiocarbon age calibration, 24,000-0 cal BP: Radiocarbon, v. 40, p. 1041-1084.

Taylor, R.E., Stuiver, M., and Reimer, P.J., 1996, Development and extension of the calibration of the radiocarbon time scale—Archeological applications: Quaternary Science Reviews, v. 15, p. 655-668.

EXPLANATION OF UNITS IN DUFFERS TRENCH

Unit 8—Massive, pebbly to silty sand and sandy silt (root-stirred AB and B horizons). Latest Pleistocene to late Holocene. Partly correlative with unit 4 in footwall.
8dAB—Organic-rich sandy silt; root casts; disturbed and overthickened in places by shallow surface disturbances (A and Bw soil horizons). Late Holocene.
8cB—Pebbly silty sand, root-stirred (Bw or Bt horizon with weak subangular blocky structure). Late Holocene.
8bB—Silty sand and silty to gravelly sand (Bw or Bt soil horizon or silica-cemented C soil horizon developed on upper part of unit 2b). Latest Pleistocene to late Holocene.
8aB—Gravel and silty to sandy gravel (Bw or Bt soil horizon developed on upper part of unit 2a). Latest Pleistocene to late Holocene.
Unit 7—Massive pebbly silty sand (root-stirred slope colluvium, buries unit 4 soil; on and below base of scarp that was formed by collapsed hanging wall). Late Holocene.
7bB—Pebbly silty sand (argillic Bt horizon developed on 6a).
7a—Pebbly sand.
Unit 6—Massive pebbly silty clay to silty sand (hanging-wall-collapse colluvium and fill of extensional hanging-wall fissures). Late Holocene.
6c—Fine to pebbly sand (sediment derived from sandy parts of units 1 and 2 filling small, irregular, extensional fissures in hanging wall).
6b—Poorly sorted mix of gravelly sand to silty clay clasts and matrix; upper part is strongly cemented (sediment derived from units 1 and 2 filling extensional fissures in hanging wall).
6aB—Gravelly silty sand (hanging-wall colluvium derived from unit 2 with well-developed Bt soil horizon and (or) silica cementation).
Unit 5BC—Heterogeneous mixture of weakly silica(?) cemented sediment derived from units 1 and 2; (faulted hanging-wall-collapse colluvium, occurring beneath and southwest of thrust tip; has weak, discontinuous B soil horizon structure). Late Holocene.
Unit 4—Massive, iron-stained gravel, sand, sandy gravel, and silty sand (soil weakly developed on unit 2 and buried by units 5, 6, and 7). Latest Pleistocene to late Holocene.
4d—Root casts filled with sediment of units 1 and 2 (probably predates unit 8 soil).
4cA—Massive, dark gray to black, organic-rich sand (root-stirred remnants of buried A soil horizons). Within fault zone and deformed by faulting.
4bCB—Upper part of unit 2, characterized by iron staining and root casts filled with silt and clay (Cox horizon with discontinuous patches of Bw horizon and remnants of bleached A and E horizons).
4aC—Upper part of unit 2, characterized by faint iron-staining and uncommon root casts (Cox soil horizon with irregular zones of weak Bw horizon).

Unit 3—Sheared sediment of units 1 and 2 (deformed by slip on faults F4 and (or) F5). Latest Pleistocene strata deformed in the late(?) Holocene.
3b—Massive silty sand to sandy gravel (derived mostly from unit 2).
3a—Massive silty clay and sandy silt (derived mostly from unit 1).
Unit 2—Stratified to massive pebbles, gravel, sand, and silty sand; unconformably deposited on unit 1 (beach and shoreface deposits, recording postglacial rebound and emergence). Latest Pleistocene, about 14-15 ka. Soil is latest Pleistocene to late Holocene.
2b—Low-angle to parallel-bedded, fine to gravelly sand.
2a—Low-angle to parallel-bedded pebbly sand and gravel.
Unit 1—Interbedded silty clay, silt, sand, and pebbly sand; common graded beds, softsediment deformation structures and dropstones (glacial marine drift, mainly deposited by turbidity currents). Latest Pleistocene, about 15 ka.
1hB—Clayey silt and silty clay with prismatic soil structure; weak Bt soil horizon developed on unit 1.
1gC—Massive upper part of unit 1g, characterized by prominent orange, iron-stained mottling and root casts.
1g—Laminated very fine sandy silty clay.
1f—Pebbly silt and clay diamicton (iceberg meltout or subaqueous debris flow deposit).
1eC—Massive upper part of unit 1e, characterized by loss of sedimentary structure, prominent orange iron-stained mottling, and root casts.
1e—Laminated silty clay with thin beds of fine to medium sand; scattered dropstones.
1d—Four to five distinct graded beds (medium-granular sand to silty clay), interbedded with silty clay; scattered dropstones.
1c—Weakly laminated silty clay with minor silt and fine sand.
1b—Interbedded and laminated silty clay to medium sand with common graded bedding, dropstones, and soft-sediment deformation structures.
1a—Interbedded and laminated silty clay to fine sand, with common graded bedding and soft-sediment deformation structures. 3b

EXPLANATION OF UNITS IN TEEKA TRENCH
Unit 9—Organic-rich, massive, poorly sorted mix of sandy clayey silt, organic debris, pebbles, cobbles, and boulders (rubble and fill deposited by human activity—land-clearing and modification). Early to mid-20th century.
Unit 8—Massive, poorly sorted mix of sand, pebbles, and soil clasts and organic debris, filling shallow concave-upward depressions (fill of tree-throw craters). Holocene.
Unit 7— Massive, variably organic-rich sandy clayey silt with scattered pebbles. (A, B, and BC soil horizons and fills of tree-throw craters). Latest Pleistocene to Holocene.
7cA—Mat of grass roots, mixed with sandy clayey silt; granular soil structure (AO soil horizon).
7bB—Sandy clayey silt with scattered pebbles; subangular blocky soil structure grades upward to granular structure; pervasive penetration by modern roots (Bw soil horizon).
7aBC—Silty to medium sand and sandy clayey silt with scattered pebbles; weakly cemented; weak, irregular subanglar blocky soil structure; irregular penetration by modern roots (BC soil horizon formed by weathering of unit 3).

Unit 6—Massive, fine to coarse sand with scattered pebbles and rare charcoal fragments (footwall slope colluvium, derived primarily from unit 3a and unit 5AB). Late Holocene.
Unit 5AB—Organic-rich sandy silt to silty fine sand with well-developed granular soil structure; scattered charcoal fragments (AB soil horizon developed on unit 3a, buried by unit 6 slope colluvium). Holocene.
Unit 4—Massive, sheared and (or) brecciated sediment of units 1 and 2. Within fault zone. Latest Pleistocene strata deformed in the latest Pleistocene to late(?) Holocene.
4b—Brecciated mix of silty clay and medium to coarse sand; common alignment of breccia clasts parallel to fault and shear planes; root casts; derived from units 1a, 2a, 2b, and 2c.
4a—Silty clay with prominent shear fabric and brecciation; pervasive root casts; derived from unit 1.
Unit 3— Sheet-like body of massive to horizontal- or low-angle bedded, moderately to well sorted, fine to coarse sand with scattered pebbles (beach and shoreface deposits, recording postglacial rebound and emergence). Latest Pleistocene, about 14-15 ka.
3c—Organic-stained, plane-bedded to internally massive, well sorted, medium to coarse sand; erosional base with very gentle relief locally overlain by thin pebble lag; minor orange mottling.
3b—Silty clay clasts derived from unit 1, dispersed in unit 3a.
3a— Massive to horizontal or low-angle bedded, moderately to well sorted, fine to coarse sand with scattered pebbles; variable cementation; common root casts.
Unit 2—Variably stratified sand, silt, and clay fill of channels cut into unit1 (glacial marine drift deposits of submarine channels). Latest Pleistocene, about 15 ka.
2c—Massive, poorly sorted silty clay and sand clasts, variably disaggregated; scattered pebbles; uncommon root casts (redeposited glacial marine drift, eroded from channel walls).
2b—Thin beds of silty clay; interbedded with unit 2a sand.
2a—Parallel-bedded and crossbedded, well-sorted, medium to coarse sand with uncommon scattered pebbles; upper part has uncommon root casts (redeposited shoreface sand).
Unit 1—Generally massive silty clay diamicton with uncommon scattered pebbles (glacial marine drift). Latest Pleistocene, about 15 ka.
1b—Poorly sorted, pebbly sandy silt and clay; pervasive root casts, irregular cementation.
1a—Silty clay diamicton with uncommon thin, discontinuous lenses and laminations of sandy silt and very fine to fine sand; uncommon dropstones and soft-sediment deformation structures; common root casts.

Figure 1. Map showing part of northwestern Washington and southwest British Columbia, including Whidbey Island (WI) and study area (below, fig. 2).

Figure 2. Map showing neotectonic setting of northern Whidbey Island (modified from Johnson and others, 2001), with box showing area of ALSM image (right, fig. 3).

Figure 3. Airborne Laser Swath Mapping (ALSM) image showing the location of the scarp of the Utsalady Point fault on northern Whidbey Island, Washington. ALSM survey

was conducted by Terrapoint LLC under contract to U.S. Geological Survey and NASA. DEM with contours based on ALSM data produced by Susan Rhea, U.S. Geological Survey. Projection is universal transverse Mercator (UTM), zone 10, NAD 83.

Figure 4. View to north-northeast of Teeka trench. Log of steep west trench wall (on left) is shown in Figure 7. Logs of terraced walls on east side of trench are shown in Figure 8.

Figure 5. View to northeast of Duffers trench. Log of steep northwest wall of trench is in

Figure 6. Map of Duffers trench.

Figure 7. Map of west wall of Teeka trench.

Figure 8. Map of the east, terraced wall of Teeka trench (see fig. 4).