Field Observations and Logs from the Rose Hip Trench Exposure Across a North-facing Scarp Within the Seattle Fault Zone, Southern Bainbridge Island, Washington

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Pamphlet to accompany

Scientific Investigations Map 3520

2024

U.S. Department of the Interior
U.S. Geological Survey

U.S. Geological Survey, Reston, Virginia: 2024

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Suggested citation:
Angster, S.J., Sherrod, B.L., Johns, W., and Pearl J., 2024, Field observations and logs from the Rose Hip trench exposure across a north-facing scarp within the Seattle Fault Zone, southern Bainbridge Island, Washington: U.S. Geological Survey Scientific Investigations Map 3520, pamphlet 6 p., https://doi.org/10.3133/sim3520.

Associated data:
Angster, S.J., Sherrod, B.L., Staisch, L.M., and Pearl, J.K., 2024, Radiocarbon, field measurements, and ground-based magnetic transect data supporting the study of north-facing scarps along the Seattle fault zone in Washington: U.S. Geological Survey data release, https://doi.org/10.5066/P132XQOW.

ISSN 2329-132X (online)

Cover. Photograph looking southwest at the Rose Hip trench across a fold scarp on southern Bainbridge Island, Washington. Photograph by Stephen Angster, U.S. Geological Survey, August 20, 2020.

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Field Observations and Logs from the Rose Hip Trench Exposure Across a North-facing Scarp Within the Seattle Fault Zone, Southern Bainbridge Island, Washington

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Introduction

The Seattle Fault Zone is an approximately 70-km-long, east-west-trending zone of south-dipping blind reverse faults within the Puget lowland region in Washington (fig. 1; Johnson and others, 1999; Blakely and others, 2002; ten Brink and others, 2002). It is one of many active Quaternary fault zones within the Puget lowland that accommodate contemporary intraplate north-south contractional strain (Wells and others, 1998; McCaffery and others, 2000). Because of their proximity to the densely populated Puget lowland region (fig. 1), these active fault zones potentially pose a greater earthquake hazard than do larger, but more distant, plate boundary earthquakes. A comprehensive understanding of rupture history and kinematics of these local fault zones can support quantifying the hazard they pose to the region.

An uplifted marine terrace and 1,050–1,020 years before present (yr B.P.; relative to A.D. 1950) tsunami deposits within the Puget Sound record a large (magnitude 7+) Seattle Fault earthquake (fig. 2; Atwater and Moore, 1992; Bucknam and others, 1992; Atwater, 1999). The marine terrace was uplifted 5–7 meters (m), resulting from north-vergent folding of the hanging wall above a blind master-ramp thrust of the Seattle Fault Zone (Bucknam and others, 1992; ten Brink and others, 2006) (fig. 2). Paleoseismic trench studies across Holocene fault scarps within the hanging wall provide additional evidence for multiple late Holocene ruptures on secondary faults of the Seattle Fault Zone (for example, Nelson and others 2003a, b, c). These secondary faults possibly pose independent sources of seismic hazard (Kelsey and others, 2008), and study of such fault scarps provides opportunities to better understand the history, geometry, and kinematics of rupture within the larger Seattle Fault Zone.

We present preliminary mapping and trench-site information from a paleoseismic investigation across a newly identified active fold scarp located within the hanging wall of the Seattle Fault Zone on southern Bainbridge Island, Washington (red circle in fig. 2). This pamphlet provides a brief introduction to the geologic setting for context, describes our methods and main observations from the investigation. The map sheet presents a large-scale lidar map and trench photomosaics, logs, unit descriptions, and locations of radiocarbon samples from the trench. Structural measurements (strike and dip) and radiocarbon sample data (table 1) are provided in Angster and others (2024). These field observations and laboratory data are being used to develop a history of latest Pleistocene and Holocene surface rupture on this newly identified fault strand within the Seattle Fault Zone.

Geologic Framework

Bainbridge Island lies within the Puget lowland, a glacially sculpted low-lying area between the Cascade Range to the east and the Olympic Mountains to the west (fig. 1). The Puget Lobe of the Cordilleran ice sheet most recently occupied the Puget lowland during the Vashon Stage and covered Bainbridge Island under ~1 kilometer (km) of ice from 17,600–16,600 calibrated yr B.P. (Porter and Swanson, 1998) and mantled the landscape with Vashon Drift. During the relatively rapid retreat of the Vashon ice sheet, pro-glacial lake water reached elevations as high as 110 m around Bainbridge Island, and the following post-ice marine limit reached an elevation of 20–30 m (Thorson, 1989; Haugerud, 2005).

East-west-trending topographic bedrock highs coincide with the trace of the Seattle Fault Zone across the Puget lowland (fig. 2). Uplifted Tertiary strata of the Blakely Harbor and Blakeley Formations are well exposed along this structural high across and within the modern wave-cut shorelines of southern Bainbridge Island (fig. 3; Fulmer, 1975). The steeply north-dipping beds of these units form discontinuous north- and south-facing scarps within the landscape (fig. 3; Haugerud, 2005). The general attitude of the bedding here defines the north-dipping forelimb of the hanging-wall monoclinal fold above the blind master fault(s) of the Seattle Fault Zone.

The south-facing scarps of the Toe Jam Hill and IslandWood Faults on southern Bainbridge Island record multiple Holocene surface-rupturing earthquakes along north-dipping reverse faults that slip along bedding-plane surfaces of the Blakely Harbor Formation (fig. 3; Nelson and others, 2003a, c; Haugerud, 2005;

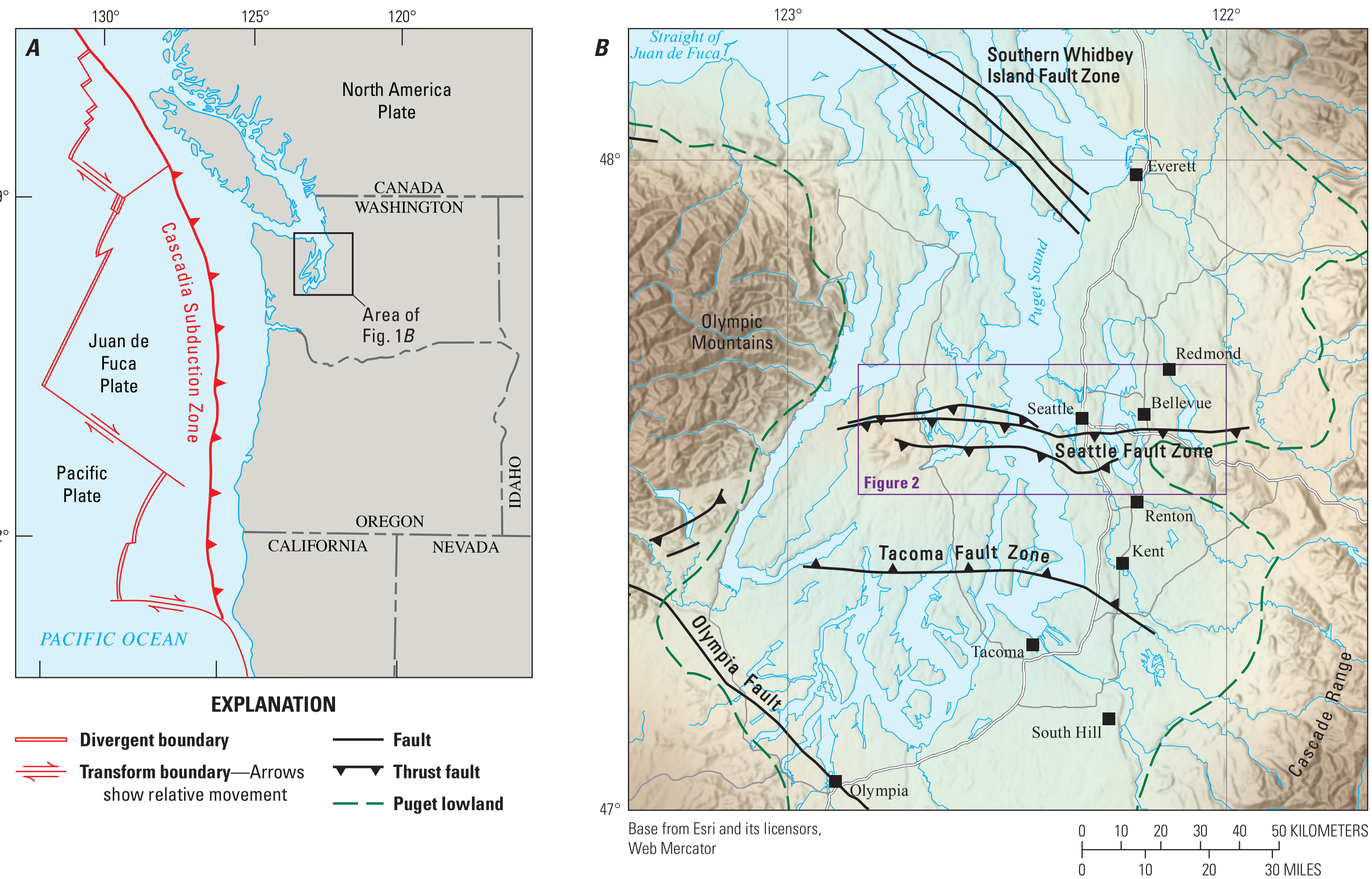


Figure 1. *A*, Regional tectonic map of the Pacific Northwest. *B*, Shaded-relief map showing active fault zones of the Puget lowland, Washington.

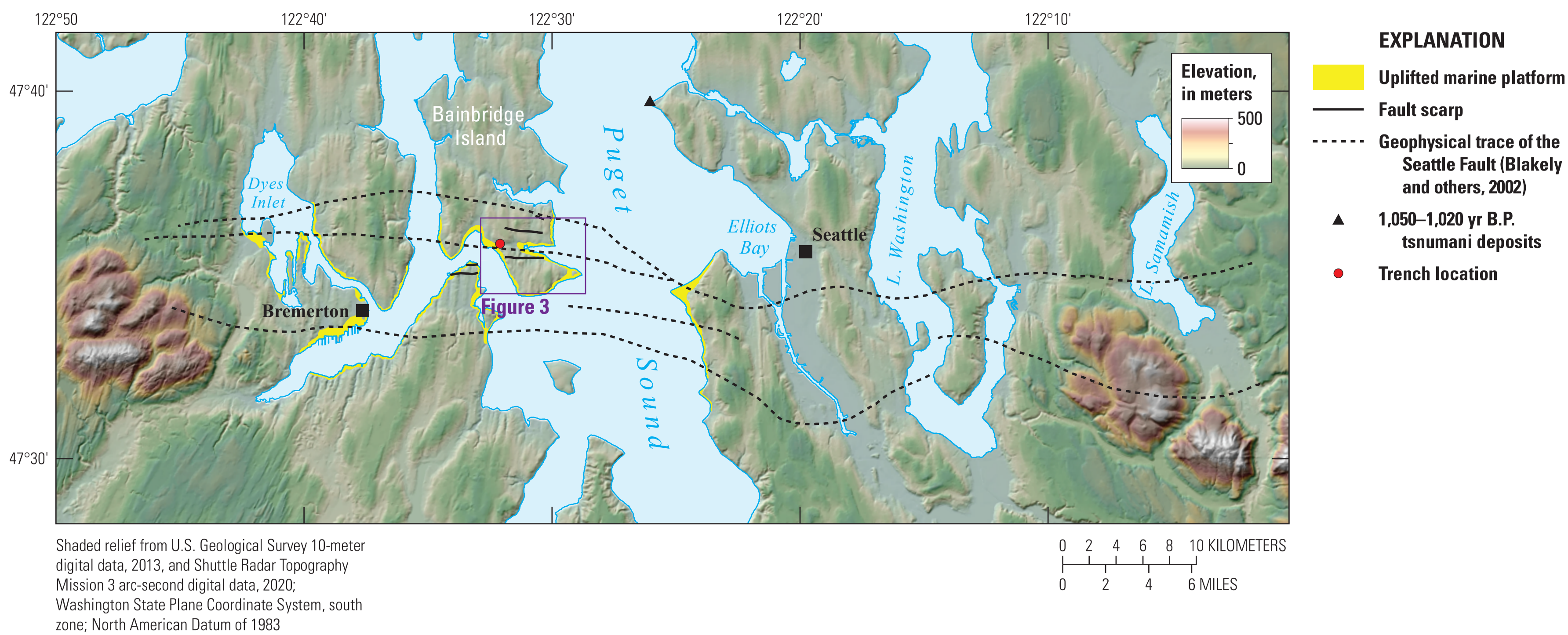


Figure 2. Colored shaded-relief map showing main geophysical lineaments of the Seattle Fault Zone (Blakely and others, 2002), mapped fault scarps, and uplifted marine platform (Bucknam and others, 1992).

Table 1. Results of radiocarbon age dating of detrital charcoal from the Rose Hip trench, southern Bainbridge Island, Washington.

[Data from Angster and others (2024). yr B.P., years before present; cal. yr B.P., calibrated years before present]

Sample number[1]	^{14}C age (yr B.P.)[2]	Calibrated age (cal. yr B.P.)[3]
1	9,210±40	10,497–10,249
2	105±25	264–23
3	150±25	283–0
4	495±15	538–509
5	210±20	303–0
6	165±15	285–0
7	155±15	281–0
8	160±20	284–0
9	105±15	257–33
10	4,740±25	5,581–5,329
11	195±15	290–0
12	200±20	296–0
13	9,260±40	10,568–10,286
14	185±15	287–0
15	130±20	270–10
16	145±15	278–6
17	105±15	257–33
18	920±20	911–752
19	700±15	675–573
20	145±25	281–0

[1] Laboratory sample identification number from National Ocean Sciences Accelerator Mass Spectrometry, Woods Hole Oceanographic Institution.

[2] Reported in radiocarbon years before present (A.D. 1950) using the Libby half-life of 5,568 years following conventions of Stuiver and Polach (1977) and Stuiver (1980).

[3] Calibrated to 95-percent Highest Density Interval age range from Oxcal 4.4 (Bronk Ramsey (2009) using IntCal 20 calibration curve (Reimer and others, 2020).

Kelsey and others, 2008). As many as four late Quaternary earthquakes are recorded along the scarp of the Toe Jam Hill Fault, three that occurred in the past 2,500 years; the most recent fault rupture likely corresponded to the 1,050–1,020 yr B.P. regional earthquake on the master ramp thrust (Nelson and others, 2003a). Evidence of independent rupture of the Toe Jam Hill Fault is preserved by a second localized uplifted marine platform on the west coast of Bainbridge Island north of the Toe Jam Hill Fault (Kelsey and others, 2008).

Recently updated lidar coverage across southern Bainbridge Island (Quantum Spatial, 2018) reveals a continuous bedrock lineament associated with a north-facing scarp within an east-west trending topographic trough between the Toe Jam Hill and IslandWood Faults (fig. 4, map sheet). As part of an effort to assess and characterize the seismic hazard associated with the Seattle Fault Zone, we excavated and studied a trench exposure across the scarp to understand the scarp's origin.

Methods

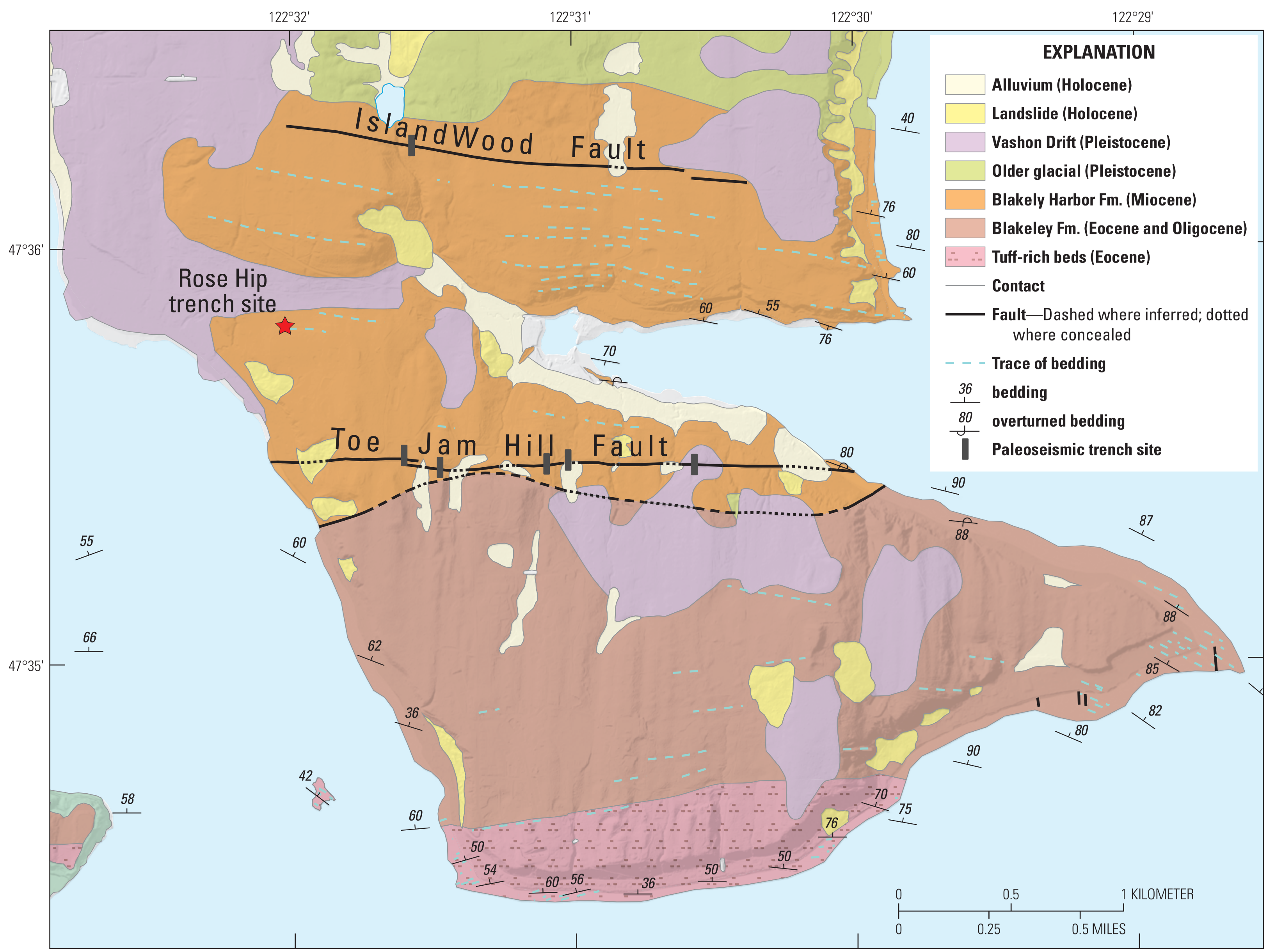
We hand-excavated a 6×2×1.2 m (length × width × depth) slot trench perpendicular to the scarp in August 2020. The vertical east and west walls of the trench were gridded at 1-m spacing and then photographed. Structural and stratigraphic relations were then marked with flags and the walls photographed again. Photomosaics of the trench walls were developed with structure-from-motion modeling using Agisoft Metashape Pro software (for example, Reitman and others, 2015). Unit descriptions were generated for each mapped unit. Soil nomenclature and descriptions follow techniques and terminology described by Birkeland (1984) and the U.S. Department of Agriculture Natural Resources Conservation Service (Schoeneberger and others, 1998), and soil color was determined using Munsell soil color charts (Munsell Color, 2010). Detrital charcoal fragments (1–5 cm) were collected for radiocarbon dating and then analyzed at Woods Hole Oceanographic Institute. Locations of collected detrital charcoal samples are shown on the logs (map sheet) and the data are presented in table 1 and Angster and others (2024).

Rose Hip Trench Site

The Rose Hip trench site is located in an open field on private land near the western end of an ~1.5-km-long, east-west-trending lineament marked by steeply truncated bedrock ridges and a <1.5-m-high, broad, north-facing scarp within Vashon Drift and younger alluvial deposits (fig. 4, map sheet). At the trench site, the <1.5-meter-high scarp abuts against a perennial wetland developed on a glaciated surface (see lower right photos on map sheet). We measured ~1.2 m of south-side-up vertical displacement of the ground surface across the scarp (fig. 4, map sheet).

The trench exposed monoclinally folded bedrock (unit 1), fractured and faulted glacial-related deposits (units 2 and 3), and laminated lacustrine deposits (unit 4) that contain a dark soil (unit 5Ab) developed within the top ~25 cm. In the lower, northern end of the trench, a minor low-angle fault offsets units 2, 3, and 4 by ~40 cm. These structurally deformed units (units 2–5) are truncated at the southern end of the trench, forming an angular unconformity, and appear conformable at the northern end of the trench with the overlying, gently northward sloping, continuous beds of slope-derived colluvium (units 6–10). A second buried soil (unit 7Ab) caps unit 6 at the northern end of the trench within the structural low of the monocline (fig. 3).

The observations from this investigation record late Pleistocene to Holocene north-vergent folding and faulting; thus, it is likely that the scarp, and the continuous lineament it partly defines, is the surface manifestation of late Pleistocene to Holocene-age earthquake(s) on a shallow south-dipping fault within the Seattle Fault Zone.



Shaded relief from Shuttle Radar Topography Mission 3 arc-second digital data, 2020;
Universal Transverse Mercator, zone 10 north; World Geodetic System of 1984

Figure 3. Map showing the geology, bedding orientation, and bedding plane traces of Blakely Harbor and Blakeley Formations (Haugerud, 2005), and paleoseismic trench sites (Nelson and others 2003a, c), southern Bainbridge Island, Washington.

Acknowledgments

This work was funded by the U.S. Geological Survey (USGS). We are very grateful to Jennifer and Mark Donahue for allowing us to excavate the trench on their land. We thank Kelsay Stanton from the Earth Space and Science Department at the University of Washington, Mark Molinari from GeoEngineers, and Ralph Haugerud of the USGS for providing assistance and helpful feedback during a review of the trench. Lydia Staisch and Charles Trexler of the USGS provided technical reviews of this publication. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

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