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Quaternary Fault and Fold Database of the United States

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Tacoma fault (Class A) No. 581

Last Review Date: 2016-11-25

citation for this record: Brocher, T.M., Sherrod, B.L., Barnett, E.A., Haller, K.M., Johnson, S.Y., Blakely, R.J., and Lidke, D.J., compilers, 2016, Fault number 581, Tacoma fault, in Quaternary fault and fold database of the United States: U.S. Geological Survey website, https://earthquakes.usgs.gov/hazards/qfaults, accessed 12/14/2020 03:04 PM.

Synopsis	Prominent geophysical anomalies extend west-northwest across the south-central Puget Lowland from the Tacoma region to Hood Canal (Danes and nine others, 1965 #4723; Gower and others, 1985 #4725; Brocher and others, 2001 #4718). Brocher and others (2001 #4718) and Johnson and others (2004 #6235) suggest that the Tacoma fault is a backthrust to the south-dipping Seattle fault [570], and suggest that structural relief increases westward along the Tacoma fault. Coastal marsh uplift north of the Tacoma fault at Lynch Cove and Burley (Bucknam and others, 1992 #602), and coastal marsh subsidence south of the Tacoma fault at Wollochet Bay (Sherrod and others, 2002 #6240), are consistent with a minimum of 2–3 m of north –side-up slip on the western part of the Tacoma fault about 1,000 yr ago.
Name comments	Danes and others (1965 #4723) first noted the presence of prominent gravity anomalies in the south-central Puget Sound region. Gower and

	others (1985 #4725) noted these as well as prominent magnetic anomalies (their structure "K"), which they inferred to be caused by a fault or monoclinal fold. Based on seismic-reflection data, Pratt and others (1997 #4737) proposed that the gravity anomaly is caused by a monoclinal fold that formed above a bend in a thrust fault underlying the Seattle uplift. In contrast, Brocher and others (2001 #4718) proposed on the basis of seismic tomography that the boundary between the Seattle uplift and the Tacoma basin (to the south) is a steep, north-dipping reverse fault, which they refer to as the Tacoma fault. Seismic-reflection data reported by Johnson and others (2001 #6234; 2004 #6235),and paleoseismology data reported by Sherrod and others (2002 #6240; 2004 #6231, 2003 #6241). Nelson and others (2008 #7616) confirm the presence of the Tacoma fault over at least the western portion of the longer subsurface geophysical anomaly. Although this structure is also informally referred to as the "Tacoma fault zone," the name "Tacoma fault," as proposed by Brocher and others (2001 #4718), is retained herein for this mostly buried structure that in some areas is characterized by a zone of faults and (or) folds.
County(s) and State(s)	KING COUNTY, WASHINGTON KITSUP COUNTY, WASHINGTON
Physiographic province(s)	PACIFIC BORDER
Reliability of location	Good Compiled at 1:24,000 to 1:250,000 scale. *Comments:* Location of fault from GER_Seismogenic_WGS84 (http://www.dnr.wa.gov/publications/ger_portal_seismogenic_features.zip, downloaded 05/23/2016) attributed to Johnson and others (2004 #6235), Gower and others (1985 #4725), Logan and Walsh (2007 #7621), and Nelson and others (2008 #7616). Location of the western portion of the Tacoma fault in the south-central Puget Lowland is based on ALSM (Airborne Laser Swath Mapping) data and exploratory trenching (Sherrod and others, 2004 #6231).
Geologic setting	The east-striking, western Tacoma fault forms the northwestern boundary of the Tacoma basin and the southwestern boundary of the Seattle uplift. Seismic tomography reveals that the inferred structural relief on Eocene basement along the fault increases westward along strike, reaching a maximum near Lynch Cove (Brocher and others, 2001 #4718). Geodetic studies (*e.g.*, Khazaradze and others, 1999 #4734; Miller and others, 2001 #4732) indicate about 4–6 mm/yr of north-south crustal shortening in western Washington, some of which is likely accommodated by slip on the Tacoma fault. Long-term contraction rates across the Seattle uplift

	determined through analysis of fold geometry suggest between 0.25 and 1.0 mm/yr for the past few hundreds of thousands of yeas, which accounts for about 10 percent of the total shortening of the western Washington crust (Booth and others, 2004 #7635).
Length (km)	24 km.
Average strike	N89°E
Sense of movement	Thrust *Comments:* North-side up movement on the western Tacoma fault is clearly indicated by gravity and magnetic anomalies (Blakely and others, 1999 #4747), seismic tomography (Brocher and others, 2001 #4718), seismic-reflection data (Johnson and others, 2001 #6234, 2004 #6235), and paleoseismology (Bucknam and others, 1992 #602; Sherrod and others, 2002 #6240; 2004 #6231; 2003 #6241). The "Tacoma reverse fault is interpreted as a back thrust on the trailing edge of the belt, making the belt doubly vergent. Floor thrusts in the Seattle and Tacoma fault zones, imaged as discontinuous reflections, are interpreted as blind faults that flatten updip into bedding plane thrusts" (Brocher and others, 2004 #7631).
Dip	60–80° N *Comments:* On the basis of seismic tomography and microseismicity, Brocher and others (2001 #4718) suggested that the western part of the Tacoma fault dips steeply northward. Johnson and others (2004 #6235) similarly suggest a steep dip (about 70°) in the upper 1 km based on analysis of growth strata imaged on seismic-reflection data in Case Inlet. The north-dipping reverse faults of the Tacoma fault zone might sole into a south-dipping Seattle fault at a depth of greater than 10 km (Brocher and others, 2001 #4718, 2004 #7631; Johnson and others, 2004 #6235, Clement and others, 2010 #7612).
Paleoseismology studies	Paleoseismologic investigations of shoreline deposits and trenching studies have been conducted along and near the Tacoma fault. Detailed investigations of shoreline deposits at numerous sites imply late Holocene land-level changes that are interpreted to be results of uplift or subsidence associated with large earthquakes in the Puget Lowland. Some other coastal study sites nearby in the Puget Lowland, such as the Dumas Bay site, have been reported to show evidence that indicates an absence of late Holocene land-level changes, tsunami deposits, and other earthquake-related features. These other sites may still provide information that limits

the extent of late Holocene earthquake-related uplift, subsidence, and tsunamis. However, these other sites apparently do not record direct evidence of earthquake and faulting events and they are not included herein.

Lynch Cove (581-1) and Burley (581-2) sites. Bucknam and others (1992 #602) reported evidence for uplift of marsh sediments about 1,000 years ago at Lynch Cove and Burley, which are located several and a few kilometers north of the Tacoma fault, respectively. They reported that uplift at Lynch Cove was greater than 2 m. Liquefaction features at Burley indicate strong ground shaking at the time of uplift and a radiocarbon age from Lynch Cove implies that uplift occurred 1170–960 cal yr BP (Nelson and others, 2014 #7616), or shortly before A.D. 880–990 (Sherrod and others, 2004 #6231).

Oakland Bay site (581-3). Bucknam and others (1992 #602) reported that Oakland Bay was one of three sites in the southern Puget Sound where tidal flat sediments show evidence for uplift between about 1,000 and 1,500 years ago; based on radiocarbon ages from peat deposits, they reported that uplift at this site predates about 1,190±60 yr BP.

Little Skookum Inlet site (581-4). Sherrod (1998 #6239) and Sherrod and others (2001 #4740) reported that buried forest and high marsh soils record submergence at this site, which is located about 16 km south of the Tacoma fault. Sherrod and others (2001 #4740) further report that Douglas Fir stumps in growth position are buried by salt-marsh peat and that changes in seed and diatom assemblages at this site and at the Nisqually Delta (site 581-5), indicate rapid submergence. Radiocarbon ages, which include high-precision ages, imply submergence between 1,150 and 1,010 cal yr BP. They concluded that this rapid subsidence probably was a result of land-level changes related to a large earthquake during that time period. Subsidence at Little Skookum Inlet was at least 1 m and possibly greater than 3 m (Sherrod, 2001 #4740). The site is near the Olympia structure, and even though numerous geophysical studies have acquired data near the projected surface location of the Olympia structure as defined by potential field anomalies, the structure's tectonic character remains enigmatic (Odum and others, 2016 #7684), Thus, until the causative fault is identified, this site is documented here.

Nisqually delta sites (581-5). Includes three relatively close-spaced, coastal sites about 19 km south of the Tacoma fault along the Nisqually delta (Sherrod, 1998 #6239; Sherrod and others, 2001 #4740). From west to east, these three Nisqually delta sites are McAllister Creek, Nisqually River, and Red Salmon Creek. For the Red Salmon Creek site, Sherrod and others (2001 #4740) reported relations of submergence and burial of forest and high marsh soils similar to those noted at Little Skookum Inlet (581-4). For the McAllister Creek and Nisqually River sites, they reported that high marsh soils are buried by tidal flat mud and reported that at McAllister Creek, localized liquefaction coincided with submergence. Seed and diatom assemblages indicate rapid submergence at these sites and at Little Skookum Inlet, and radiocarbon ages imply rapid submergence between 1,150 and 1,010 cal yr BP. Sherrod and others (2001 #4740) concluded that this rapid subsidence reflects coseismic land-level changes related to a large earthquake during that time period. Relations at the Nisqually delta sites imply about 1 m of subsidence (Sherrod, 2001 #4740). Similarly these sites are near the Olympia structure, and even though numerous geophysical studies have acquired data near the projected surface location of the Olympia structure as defined by potential field anomalies, the structure's tectonic character remains enigmatic (Odum and others, 2016 #7684), Thus, until the causative fault is identified, this site is documented here.

Wollochet Bay site (581-6). Sherrod and others (2002 #6240; 2004 #6231) reported evidence for subsidence of marsh sediments between A.D. 980 and 1190 based on a radiocarbon age from the outermost rings of a Douglas Fir tree stump found partly exposed in growth position in a modern tidal flat of the bay. The Wollochet Bay site is located south of Burley and more than 10 km south of the Tacoma fault.

Catfish Lake scarp, site 581-7 (Blueberry trench of Sherrod and others, 2003 #6241, 2004 #6231). The trench exposed Vashon till and overlying post-glacial deposits. Imbricated and stratified pebbles in glacial deposits suggest folding. Low-angle faults cut through the base of post-glacial deposits and a Holocene soil horizon and disrupt clast orientation (Sherrod and others, 2003 #6241). No radiocarbon material was collected. Consequently, Sherrod and others (2003 #6241) concluded that folding could have occurred under the Vashon ice sheet or after, but faulting was post-glacial. The study also included airborne laser swath mapping (ALSM) of the Catfish Lake scarp a few kilometers west of Case Inlet. Although no organic material suitable for dating was found in the trench, a fault is inferred to cut a soil horizon of probable Holocene age. In addition, the pattern and distribution of clast fabric in the glacial till suggests up-to-the-north folding. Johnson and others (2004 #6235) reported folding of shallow Quaternary strata in a marine seismic-reflection line acquired in Case Inlet that lies on strike with and is a few kilometers east of the Catfish Lake scarp. They argued that this fold formed above a blind, north-dipping thrust fault.

	Case Inlet sites (581-8). Includes two relatively close-spaced, coastal sites along the north end of Case Inlet, directly north of the Tacoma fault. These two Case Inlet sites are the North Bay and Catfish Lake sites as shown and briefly described in Sherrod and others (2004 #6231). They reported that a raised tidal flat at these two sites suggests late Holocene uplift and that profiles of LiDAR (ALSM) data imply about 4 m of uplift. Nelson and others (2008 #7616) excavated three trenches. One did not expose evidence of post-glacial deformation (Owl trench); the remaining two exposed evidence of one surface-deforming event. Radiocarbon ages suggest the maximum age of most recent deformation of folded glacial deposit in the Cedars trench (site 581-9) across the Catfish Lake scarp is 4.3 ka and an offset Holocene soil in the Micah trench (site 581-10) across the Stansberry Lake scarp provides limiting ages for a single oblique-slip event occurring A.D. 410–990. In addition, the study by Nelson and others (2008 #7616) documents trenches excavated across the Sunset Beach scarps near Hood Canal, which define opposing walls of a graben. Bees' Nest trench (site 581-11) and Snake trench (site 581-12) exposed glacial and post-glacial sediments faulted into a graben along a set of normal faults. Radiocarbon ages in the two trenches yield a close maximum age of 1,290–1,080 cal yr BP for graben formation
Geomorphic expression	Washington’s Puget Lowland was occupied at least five times during the Pleistocene (10–130 ka) by lobes of the continental ice sheet, with the most recent ice retreat occurring about 16 ka (Porter and Swanson, 1998 #6237). Most of the present landscape reflects this glacial history (Booth, 1994 #4719) and, as a result, tectonic landforms are generally buried, eroded, or otherwise obscured. However, ALSM data revealed the presence of the east-trending Catfish Lake scarp, which has as much as 3 m of north-side-up vertical offset on the surface of glacial moraines along the western end of the Tacoma fault, west of Case Inlet (Sherrod and others, 2003 #6241, 2004 #6231). Marine seismic reflection investigation in Case Inlet suggest that displacement on the Tacoma fault zone is xpressed is expressed as folds rather than surface ruptures (Clement 2010 #7612).
Age of faulted surficial deposits	Glacial deposits, deposited about 16 ka (*e.g.*, Porter and Swanson, 1998 #6237), are folded along the Catfish Lake scarp (west of Case Inlet) on the western end of the Tacoma fault. Quaternary strata imaged in seismic-reflection data in Case Inlet are folded, but are not obviously faulted (Johnson and others, 2004 #6235).

Historic earthquake	
Most recent prehistoric deformation	latest Quaternary (<15 ka) *Comments:* Coastal marsh deposits a few kilometers north of the Tacoma fault at Lynch Cove and Burley were rapidly uplifted about 1,000 years ago (Bucknam and others, 1992 #602). In-situ tree stumps in coastal marsh deposits located several kilometers to the south of the fault subsided about 1000–800 years ago (Sherrod and others, 2002 #6240). Late Holocene deformation also is documented by Nelson and others (2008 #7616). The stratigraphic correlation of estuarine sites across Puget Sound are consistent with correlations based on paleomagnetic directions (Hagstrum and others, 2004 #7687).
Recurrence interval	 *Comments:* Trenches have exposed evidence of the most recent surface deformation; there is no information on recurrence intervals.
Slip-rate category	Between 0.2 and 1.0 mm/yr *Comments:* Analysis of Quaternary growth strata in the fold that formed above the apparently blind Tacoma fault in Case Inlet suggests a minimum vertical slip rate of about 0.2 mm/yr (Johnson and others, 2004 #6235). This estimate is considered a minimum because it assumes that the age of the base of the Quaternary section is about 2 ka. This slip rate estimate of 0.2 mm/yr agrees well with that inferred from the 3 m of vertical offset of the 16,000 year old glacial surface found along the Catfish Lake scarp (Sherrod and others, 2004 #6231; 2003 #6241). Similarly, marine seismic reflection data profiles acquired in Carr Inlet, 10 km to the east of Case Inlet, showed late Pleistocene or Holocene faulting at one location with about 3–4 m of vertical displacement (Clement and others, 2010 #7612).
Date and Compiler(s)	2016 Thomas M. Brocher, U.S. Geological Survey Brian L. Sherrod, U.S. Geological Survey Elizabeth A. Barnett, Shannon & Wilson, Inc. Kathleen M. Haller, U.S. Geological Survey Samuel Y. Johnson, U.S. Geological Survey Richard J. Blakely, U.S. Geological Survey, Emeritus David J. Lidke, U.S. Geological Survey
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