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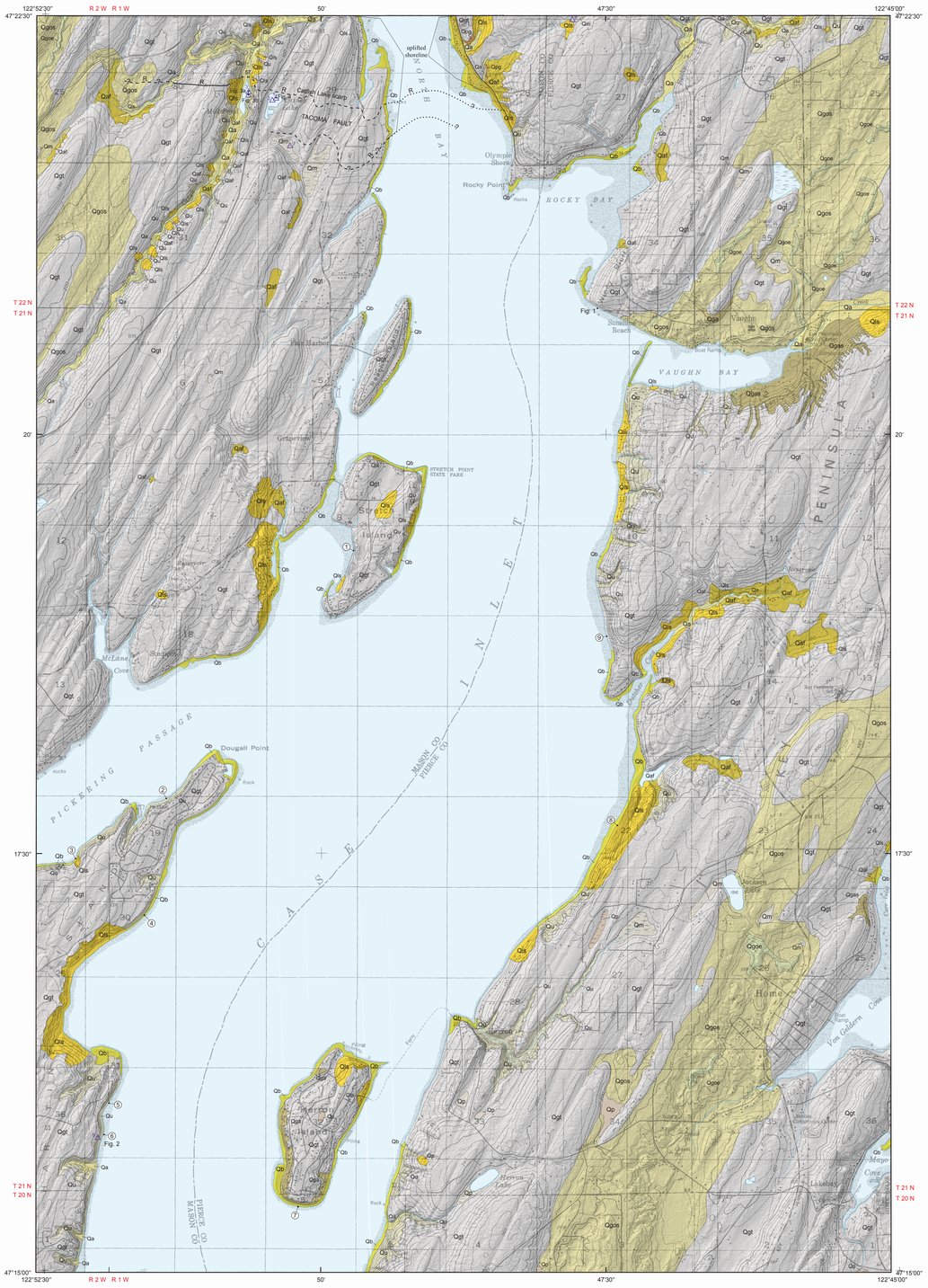

Lambert conformal conic projection
North American Datum of 1927; to place on North American Datum of 1983, move the projection lines approximately 17.3 meters north and 94.8 meters east as shown by crosshair corner ticks
Base map from scanned and rectified U.S. Geological Survey Vaughn 7.5-minute quadrangle, 1990
Shaded relief generated from a lidar bare-earth digital elevation model (available from Puget Sound Lidar Consortium, http://pugetsoundlidar.ess.washington.edu/); sun azimuth 315°; sun angle 45°; vertical exaggeration 4x
Digital cartography by Anne C. Heinitz and J. Eric Schuster
Editing and production by Jaretta M. Roloff

SCALE 1:24,000

1 0.5 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 0.5 0 1 KILOMETER

contour interval 20 feet

17°22'
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2007

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Geologic Map of the Vaughn 7.5-minute Quadrangle, Pierce and Mason Counties, Washington

by Robert L. Logan and Timothy J. Walsh

December 2007

MAJOR FINDINGS

In addition to lidar-based geologic mapping, this project provides new information about:

- The geometry, location, and age of last movement on the Tacoma fault;
- The relative antiquity of the Quaternary stratigraphy in this part of the central Puget Lowland; and
- The extent of late- and post-glacial outwash trains in the map area.

GEOLOGY

The Vaughn quadrangle lies in the center of the Puget Lowland, a region that was repeatedly shaped by glacial and nonglacial sedimentation and erosion during the Pleistocene epoch. There are no known outcrops of bedrock in the map area; in fact, Buchanan-Banks and Collins (1994) show the bedrock surface at a depth of about 900 ft below mean sea level (msl) at the southern end of the quadrangle and approximately 600 ft below msl at the quadrangle's northern end. The thick fill that covers the quadrangle consists of pre-Vashon glacial and nonglacial sediments capped by a relatively thin veneer of Vashon Drift. Unlike quadrangles in the eastern part of the Puget Lowland, the Vaughn quadrangle lacks sediment that is rich in pumice and volcanic glass from the stratovolcanoes of the Cascade Range—the sediments deposited by glaciers and proglacial streams consist almost entirely of rock fragments and grains from the granites and metamorphic rocks of the Coast Range of British Columbia. When the Puget Lowland was ice free between glacial advances in the Pleistocene, the glacial sediments were reworked by streams. Streams emanating from the Cascade Range never made it as far west as the Vaughn quadrangle. Therefore, the pre-Vashon nonglacial deposits in the Vaughn quadrangle are virtually indistinguishable from glacially derived sediments. To further complicate stratigraphic interpretations, glacial advances, especially during the Vashon Stade, were both depositional and erosional. This resulted in truncation of relatively flat-lying pre-Vashon sediments by Vashon ice erosion, and deposition of Vashon till on top of both Vashon-age advance outwash and much older glacial or nonglacial sediments (Fig. 1). Stratigraphic interpretations are somewhat tentative for much of the map area because of limited exposure, lateral discontinuity of most sediments, and sparse and inadequately descriptive well logs. Fortuitously, a pre-Vashon till (unit Qpt; Col. secs. 2–6; Figs. 1 and 2) that is clearly separated from the Vashon till (unit Qgt)—in many places by several tens of feet of silts, sands, gravels, and at least two radiocarbon-infinite peats—helps establish a framework for interpreting the stratigraphy by virtue of the till's continuity throughout much of the map area.

Pre-Vashon glacial and nonglacial sediments are exposed in shoreline bluffs and ravines. Unlike in the Fox Island quadrangle immediately to the east (Logan and others, 2006), no Olympia-age sediments (Armstrong and others, 1965) have been found in the Vaughn quadrangle. Instead, sediments subjacent to the Vashon till where well exposed, such as at Windy Bluff (Fig. 1), tend to be compact, oxide-stained sands resting on an older till, or as on Harstine Island, radiocarbon-infinite (^{14}C site 5, Table 1) silts or gravels. The entire sequence of pre-Vashon sediments dips gently to the south, possibly due to tectonic deformation. At Windy Bluff (Fig. 1), the top of a pre-Vashon till is exposed at about 50 ft above msl. What is presumed to be the same till disappears below msl (Fig. 2) near the south end of the quadrangle on the east shore of Harstine Island, about 7.5 mi southwest of Windy Bluff.

Vashon till (unit Qgt) is exposed at the top of many bluffs (Col. secs. 4, 5, 7, 8, and 9) because it covers most of the upland surface where it is molded into drumlins—elongate hills that were deposited at the base of the advancing Vashon glacier. Vashon till covers advance outwash (Col. sec. 1) or pre-Vashon sediment (Fig. 1), but where thick, forms nearly vertical shoreline bluffs many tens of feet high. The till-cored or -veneered drumlins were constantly streamlined by the moving ice during deposition. As a result, the long axes of these drumlins indicate the direction of ice movement. The drumlin-covered uplands are modified in places by syn- and postglacial water-laid sandy sediment deposited in broad, poorly defined outwash channels that commonly contain eskers. Groups of drumlins form a crudely fluted terrain over most of the quadrangle. This fluted terrain controls postglacial drainage patterns throughout much of the quadrangle. In the uplands, postglacial rill erosion exposes the sediments that underlie the till along the steep sides of some drumlins. Alluvial fans, recessional outwash, or post-glacial peat deposits cover the floor of troughs between some drumlins, but otherwise, the majority of the uplands is underlain by thick lodgment till. Lidar imagery was used to interpret and map these landforms during field mapping. Water-well logs were used to confirm inferred underlying geologic materials.

The eastern half of the Vaughn quadrangle encompasses part of the Key Peninsula, which is separated from the southwest portion of the Kitsap Peninsula and northern Harstine Island by Case Inlet, a former subglacial trough (Booth, 1994). Pickering Passage, also a former subglacial trough, separates Harstine Island, the largest of several islands in the quadrangle, from the southwestern Kitsap Peninsula.

Although the Puget Lowland hosted lakes that inundated the subglacial troughs both before and after the Vashon glaciation, as well as during previous glaciations, there is only limited evidence for late-glacial lacustrine deposits in the Vaughn quadrangle. The sand-draped terraces that are so common in the Fox Island quadrangle to the east (Logan and others, 2006) are absent. Instead, post-Vashon till sediments are limited to the sands and gravels in two recessional outwash trains. One of these trains crosses the Key Peninsula from the quadrangle's northeast corner to end at Vaughn Bay. The other crosses the quadrangle's southeast corner at Home and continues southwestward into the Longbranch quadrangle (Logan and others, 2003). Both trains contain several gravel pits—the late-glacial sands and gravels are fresh, clean, poorly compacted, and have little to no overburden, all of which makes them attractive as aggregate resources.

There are several geomorphic features visible in the lidar imagery (sec. 36, T22N R2W) that partially surround drumlins and appear to be strand lines, but instead of being cut by wave action along lake shorelines, the strand lines were probably eroded by subglacial streams. The subglacial-stream deposits (unit Qgos) are located at about the same elevation as glacial Lake Russell (Bretz, 1913) in the Fox Island quadrangle (that is, 220–250 ft above present msl) and were probably deposited beneath stagnant ice that bounded the western edge of the glacial lakes. Both lake and sub-ice outwash deposits were emplaced during the waning stages of the ice occupation at about 13,500 yr B.P. (Walsh and others, 2003) and are locally difficult to distinguish from one another, as they are both rich in sand (thus the contacts on the east-central edge of the map do not match those on the adjoining Fox Island quadrangle).

Several large deep-seated landslides affect long stretches of waterfront, as do numerous shallow landslides. Lidar imagery was used to map the extent of the landslides that could be shown at map scale; many other landslides are too small to be shown.

STRUCTURE

Sherrod and others (2003, 2004) used lidar imagery to locate the Tacoma fault, which they call the Catfish Lake scarp where it passes through the northern part of the quadrangle. During the Vaughn study, we used the same lidar imagery to determine that Mill Pond and Catfish Lake were formed by uplift along the Tacoma fault. The fault scarp dammed Sherwood Creek to form Mill Pond at the same time that it dammed a depression between drumlins to form Catfish Lake. Trees growing near the dammed streams were inundated and drowned by rising waters after movement on the fault. Eroded stumps of these trees (Figs. 3 and 4) still remain submerged or partially submerged beneath the surface, protected from complete decomposition by the cold, fresh waters of the lakes. Samples of wood taken from these stumps during the fall of 2006 yielded radiocarbon ages of 1240 ±60 and 1260 ±60 yr B.P. for Mill Pond (Figs. 3A and B; ^{14}C sites 3 and 4, Table 1) and 1140 ±50 and 1290 ±60 for Catfish Lake (Fig. 4; ^{14}C sites 1 and 2, Table 1). The stumps in Mill Pond appear to be less eroded than those from Catfish Lake, possibly because Mill Pond is stream fed and maintains a relatively constant level. Catfish Lake, on the other hand, is spring fed with a greater amount of water level fluctuation, leading to more exposure of the stumps to the air, causing greater erosion. Despite the apparent greater amount of erosion on the Catfish Lake stumps, the dates from both lakes are virtually indistinguishable. The amount of erosion of outer growth rings could not be determined, because no bark could be found on stumps from either lake, but erosion clearly occurred, as annual growth rings are truncated by the outer surfaces of the stumps. This means that the radiocarbon dates are older, possibly by as much as 100 years or more, than the last movement on the Catfish Lake scarp. Thus, the stump dates roughly correspond with the Sherrod and others (2003) radiocarbon age of 1170 ±90 yr B.P. acquired from *Triglochin sp.*, a marsh grass found in an uplifted shoreline terrace (north end of map), the origin of which they attributed to movement on the Tacoma fault.

Based on the observable trace and elevation recorded on the lidar of the Catfish Lake scarp and the location and elevation of the outlets of Mill Pond and Catfish Lake, the dip of the Tacoma fault at two locations appears to be about 57 degrees to the north. Using the general trend, dip, and location of uplifted shoreline terraces, the Tacoma fault trace was projected eastward as shown on the map. However, the projected trace does not account for other geomorphic features, such as the possible damming of two marshes southeast of Catfish Lake, an apparent uplifted shoreline in sec. 29, T22N R1W, and possible uplift in Rocky Bay on the Key Peninsula. Either a splay, a zigzag fault trace that would indicate significant dip-slip movement, or a right-stepping en-echelon strand of the Tacoma fault could lie south of and subparallel to the Catfish Lake scarp as shown on the map. The trace roughly corresponds to a fault shown in Clement and others (in press).

A stump in growth position from one of the marshes southeast of Catfish Lake (^{14}C site 7, Table 1) yielded a modern radiocarbon age. However, the marshes are so shallow that they dry up periodically, which means that any older stumps may have completely decomposed or there may not have been trees growing in the marsh areas at the time the marshes formed.

An eroded stump from a landslide- and subsequently beaver-dammed unnamed lake about a mile north-northeast of Rocky Point was also dated and yielded a modern age (^{14}C site 6, Table 1). Frequent breaching of the beaver and landslide dams may have caused any ancient stumps to have rotted away. Lacking any ancient dates from the lake, it is impossible to know if the impounding landslide was seismically induced.

DESCRIPTIONS OF MAP UNITS

Quaternary Unconsolidated Deposits

HOLOCENE NONGLACIAL DEPOSITS

Qa — **Alluvium**—Silt, sand, and gravel deposited in streams; may include some lacustrine deposits and organic materials, such as peat.

Qb — **Beach deposits**—Mud, sand, and gravel deposited in the intertidal zone, or residual pebble-cobble gravel and isolated boulders on a wave-cut platform.

Qls — **Landslide deposits**—Generally loose, jumbled, tan to gray, silty sandy gravel with few to no discernible sedimentary structures; surfaces of landslides are generally undulatory; some landslides in the quadrangle occur as large deep-seated slides and others as shallow surface failures or block falls.

Qm — **Marsh**—Shallow or seasonal lakes, commonly containing abundant tree snags, stumps, and other woody debris and commonly clogged with aquatic plants during periods of warm weather.

Qp — **Peat**—Organic-matter-rich sediments deposited in closed depressions; may include peat, muck, silt, and clay in and adjacent to wetlands.

Qaf — **Alluvial fan**—Silt, sand, and gravel deposited where upland streams meet valley floors; generally overlies till (unit Qgt) or late-stage outwash (unit Qgos).

PLEISTOCENE GLACIAL AND NONGLACIAL DEPOSITS

Vashon Drift

Qgos — **Vashon recessional outwash sand and silt**—Loose sand, silt, and gravel; gray, tan, or brown; clasts moderately to well rounded; generally well sorted; clasts and grains consist of northern-source plutonic, volcanic, and metamorphic rocks and rock fragments and poly-crystalline quartz carried by Vashon meltwater; drains well due to good porosity and permeability; generally forms thin to thick (25 ft or more) beds, deposited in poorly defined ice-contact channels; commonly associated with eskers; stratigraphically overlies Vashon till.

Qgoe — **Vashon recessional outwash, ice-contact deposits (eskers)**—Loose sand and gravel; tan to gray; moderately to well sorted and rounded; consists of sediment rich in plutonic, volcanic, and metamorphic clasts and polycrystalline quartz; good porosity and permeability; deposited by Vashon meltwater in areas occupied by stagnant ice; forms low, elongate sinuous hills in recessional outwash channels; stratigraphically overlies Vashon till.

Qgt — **Vashon till**—Unstratified to moderately stratified, compact, unsorted mixture of clay, silt, sand, and gravel deposited directly by glacial ice; gray to tan; nearly everywhere in sharp contact with underlying units; does not drain well as permeability and porosity are low; sand and finer grains in matrix are very angular; pebble- to boulder-size clasts are commonly striated and faceted, having angular and (or) rounded edges; boulders are generally disseminated and relatively rare; may contain interbeds of sand and gravel. The surface of this unit is characterized by streamlined drumlins, striations, and flutes that are generally hundreds to thousands of feet long. Angular to subrounded glacial erratic boulders, consisting mostly of plutonic or metamorphic rock, are common but disseminated on the surface of this unit. Unit may be capped by a few feet of unsorted and stained ablation sand and gravel or by unit Qgos. Vashon till locally crosscuts older sediments, forming angular unconformities. Drag folding and horizontal shearing may occur at the base of the till or internally between layers of till, especially in thick deposits. Unit Qgt ranges in thickness from 0 to at least 50 ft.

Qga — **Vashon advance outwash**—Sand and gravel with lacustrine clay, silt, and sand; gray to light brown; compact; well rounded and most commonly well sorted, so porosity and permeability are good; mostly polycrystalline quartz, plutonic, volcanic, and minor metamorphic grains; deposited during Vashon glacial advance; generally more compact than recessional outwash; most easily distinguished from recessional outwash if covered directly by Vashon till; may also contain pre-Vashon sediment at its base.

Qgas — **Vashon advance sand**—Sand with minor gravel; gray to light brown; loose, well rounded, and well sorted with good porosity and permeability; mostly polycrystalline quartz, plutonic, volcanic, and minor metamorphic grains; deposited during Vashon glacial advance; most easily distinguished from recessional sandy outwash if covered directly by Vashon till, but difficult to distinguish from pre-Vashon sand based on petrography alone; may cover silts and clays, thus forming prime conditions for large, deep-seated landslides.

Pre-Vashon Glacial Sediments

Qggl — **Pre-Vashon lacustrine silt (columnar sections only)**—Mostly silt with some clay; light to medium blue gray to yellowish-tan where weathered; compact; parallel-bedded, locally with a thin (½ in.) layer of organic material at its base; lies stratigraphically above and in sharp contact with unit Qpt.

Pre-Vashon Nonglacial Deposits

Qpo — **Pre-Vashon peat (columnar sections only)**—Peat found in bluff exposures; 1 to 5 ft thick; blocky; ranges from organic hash to compact, tough, matted woody material; dark brown to nearly black; yielded a radiometrically infinite age (^{14}C site 5; Table 1) or is located stratigraphically below sediments known to be of pre-Vashon age.

Undifferentiated Pleistocene Deposits

Qu — **Undifferentiated Pleistocene deposits**—Vashon and pre-Vashon sedimentary deposits in near-vertical bluff exposures not depictable at map scale or not distinguishable into glacial or nonglacial sediments; may contain any of the above units; see breakdown of units where illustrated as schematic columnar sections at points along shorelines.

Qps — **Pre-Vashon deposits of unknown age, fine-grained (columnar sections only)**—Silty sand and sandy silt with minor clay and some gravel interbeds; contains granitic, volcanic, and metamorphic grains with abundant polycrystalline quartz; moderately rounded; laminated to poorly bedded to cross-bedded; generally compact, but may be loose; locally to completely iron-oxide stained, with iron-oxide cemented layers.

Qpg — **Pre-Vashon deposits of unknown age, coarse-grained**—Sand and gravel with some sand and silt layers, otherwise poorly to moderately bedded; moderately to well rounded; contains granitic, volcanic, and metamorphic clasts; lightly to moderately oxidized; compact; contains localized iron-oxide cemented layers and channels.

Qpt — **Pre-Vashon till (columnar sections only)**—Gray to tan, unstratified, compact unsorted mixture of clay, silt, sand, and gravel deposited directly by glacial ice; in moderately sharp contact with underlying unit (Fig. 1) and overlying unit (Fig. 2); contains granitic, volcanic, and metamorphic grains with abundant polycrystalline quartz; petrographically indistinguishable from unit Qgt; permeability and porosity are low; sand and finer grains in matrix are very angular; pebble- to cobble-size clasts are commonly striated and faceted, having either or both angular or rounded edges; boulders are conspicuously lacking in this unit, at least none were observed in outcrop or as lag on adjacent beaches. The top and bottom contacts of this unit are planar, as opposed to the Vashon till's commonly wildly irregular contacts. On the east shore of Harstine Island, the till is overlain by a thin (generally ½ in. or less) layer of radiocarbon-infinite woody debris that lies at the base of a blue-gray laminated silt (unit Qggl)(Fig. 2). The woody debris was not dated directly, but a peat about 50 ft stratigraphically above the unit yielded a radiocarbon infinite date (^{14}C site 5; Table 1).

GEOLOGIC SYMBOLS

Contact

Reverse fault—Dashed where approximately located, dotted where concealed, queried where uncertain; R on upthrown side

^{14}C sample location

Columnar section

Fig. 2 Photo location

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Figure 1. Windy Bluff. The oldest sediments shown here (unit Qpg), which start at beach level, are gravels with sand lens interbeds that predate the oldest till found in the quadrangle (unit Qpt) and appear to have an incipient paleosol formed at their contact with unit Qpt. This old till may have been deposited by either the Double Bluff (OIS-6; Fig. 5) or Possession (OIS-4, Fig. 5) glaciers. Because of the old till's thickness and the fact that it continues to the southern end of the quadrangle, it is most likely that it was deposited during the Double Bluff glaciation, which was much more widespread than the Possession glaciation. A compact iron-stained sand (unit Qps) overlies the old till (unit Qpt). This sand appears to be more compact and stained than Vashon Stade advance sand (unit Qgas). A similar sand was mapped below Vashon advance sand in the Longbranch quadrangle (Logan and others, 2003) south of the Vaughn quadrangle. Vashon till (unit Qgt) caps and truncates the entire sequence.

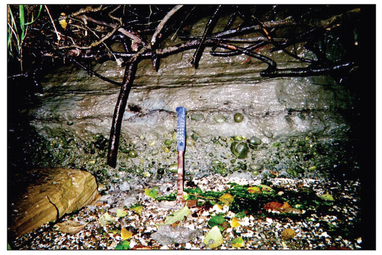

Figure 2. Unit Qpt (older till) at beach level just north of where it plunges below beach level. Photo was taken on the east shore of Harstine Island about 40 ft south of Columnar Section 6. The bottom of the hammer handle rests on a thin (½-in. thick) layer, mostly composed of small branches and organic hash, that marks the bottom of the overlying blue-gray silt (unit Qps). A radiocarbon-infinite peat is about 50 ft stratigraphically above this till.

Figure 3. Stumps in growth position in fault-dammed Mill Pond. Wood samples were taken from the outermost rings available to determine when the trees were killed by inundation. Note the lack of bark and considerable erosion.

Figure 4. A stump typical of those in Catfish Lake that appear to be more deeply eroded than those in Mill Pond. Despite deep erosion, the wood from these stumps is hard, tough, and very fresh appearing, as can be seen in the sample cut visible in the photograph.

COLUMNAR SECTIONS

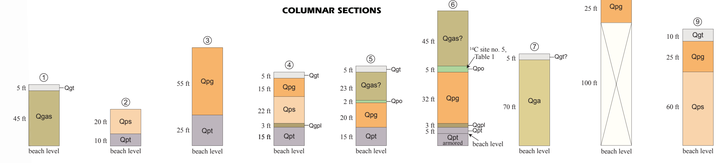

Table 1. Radiocarbon date table. Site numbers appear on the map and can be found by using the location. The first number in the location entry is the township followed by a slash, then the range (for example, 1W) and section number. The first number following the decimal point is the distance (in tenths of a section) east of the southwest corner of the section and the next number is the distance (in tenths of a section) north of the southern boundary of the section. The number following the hyphen (-) in the first four rows identifies the stump or snag that was sampled. The letter F in the fifth row designates sample F taken at that particular location. GPS coordinates were taken on each of the tree remnants sampled and are shown in the comments column. Samples were analyzed by Beta Analytic, Inc., of Miami, Florida. N/A, not applicable.

Site no.	Location	Sample no.	Measured radiocarbon date	$^{13}C/^{12}C$ ratio (‰)	Conventional radiocarbon date	Comments
1	21/1W29.14-3	Beta 221634	1170 ±50 yr B.P.	-26.6	1140 ±50 yr B.P.	wood from stump in Catfish Lake; GPS coordinates N47°22.004 W122°50.506
2	21/1W29.14-7	Beta 221635	1320 ±60 yr B.P.	-26.8	1290 ±60 yr B.P.	wood from stump in Catfish Lake; GPS coordinates N47°21.966 W122°50.496
3	21/1W30.84-1	Beta 221636	1260 ±60 yr B.P.	-26.2	1240 ±60 yr B.P.	wood from stump in Mill Pond (Fig. 3A); GPS coordinates N47.36491 W122.84524
4	21/1W30.84-2	Beta 221637	1300 ±60 yr B.P.	-27.2	1260 ±60 yr B.P.	wood from stump in Mill Pond (Fig. 3B); 60 ft south of site 3
5	21/2W36.94F	Beta 221638	N/A	-27.2	>44,240 yr B.P.	peat layer in bluff about 50 ft above beach, directly above unit Qpg and 35 ft above unit Qpt
6	22/1W22.30	Beta 228029	100 ±40 yr B.P.	-26.6	70 ±40 yr B.P.	wood from stump in landslide-dammed lake
7	22/1W29.31	Beta 228030	70 ±50 yr B.P.	-23.3	100 ±50 yr B.P.	wood from stump in shallow marsh

VARIATIONS $^{18}O/^{16}O$

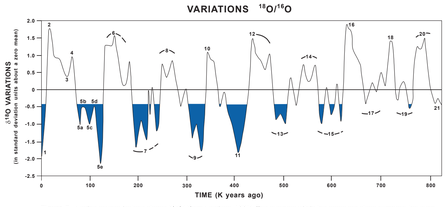

Figure 5. Marine oxygen-isotope stages (OIS) (from Morrison, 1991). The numbers within the graph are stage numbers; the even-numbered peaks (at top) are glacial maxima and the odd-numbered troughs (at bottom) are interglacial minima. The blue areas indicate interglacial episodes, based on a cutoff at -0.5 $\delta^{18}O$ oxygen-isotope values (equivalent to Holocene interglacial values).

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