WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
GEOLOGIC MAP GM-58

WASHINGTON STATE DEPARTMENT OF
Natural Resources
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Geologic Map of the Coupeville and Part of the Port Townsend North 7.5-minute Quadrangles, Island County, Washington

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Figure 1. Lidar-based hillshade image of central Whidbey Island. Vertical exaggeration is 6 times. Simulated sun angle is 45 degrees; sun azimuth, 315 degrees. The image illustrates the systematic distribution of landforms in the area. Strong north-south drumlinization in the southeast reflects south-directed Vashon ice movement; weak north-south drumlinization and an overprint of southwest-trending drumlinization in the north reflect south-directed ice movement followed by southwest-directed ice movement. The Coupeville moraine in the center marks a one-time ice margin; east and west of the moraine, elevated outwash terraces with braided relict channels and kettles reflect ice-proximal, marine-influenced deposition of Pamlico Sound outwash. Smooth lowlands north and south of the moraine represent paleo-sea floor.

Lambert conformal conic projection
North American Datum of 1927; to place on North American Datum of 1983, move the projection lines 70 feet north and 500 feet east as shown by colored ticks
Base map from scanned and rectified U.S. Geological Survey 7.5-minute Coupeville and Port Townsend North quadrangles, 1973
Shaded relief generated from lidar; sun azimuth 315 degrees; sun angle 45 degrees; vertical exaggeration 5x
Digital cartography by Anne C. Heinitz
Editing and production by Karen D. Meyers

SCALE 1:24,000
1 MILE
1 KILOMETER
contour interval 20 feet

GEOLOGIC SETTING AND DEVELOPMENT

Like most of the Puget Lowland, the map area is dominated by glacial sediment and lacks bedrock exposures. Jones (1999) inferred between 1800 ft (west of Point Partridge) and 3300 ft (east of Penn Cove) of unconsolidated deposits in the area; Mosher and others (2000) and Johnson and others (2001) used geophysical data to suggest that the top of Miocene(?) (Johnson and others, 1996) bedrock in the map area is about 1150 to 2600 ft below the surface (depending on location). The oldest sediment exposed in the map area is thought to be Double Bluff Drift, which is found at beach level south of Ebeys Landing (shoreline section B; Easterbrook, 1968; Thorsen, 2001). Based on stratigraphic position, Double Bluff Drift would likely date to marine oxygen-isotope stage (hereinafter "stage") 6, or about 185 to 125 ka (thousands of calendar years before 1950) (references to oxygen-isotope stages in this report are as defined in fig. 4 of Morrison, 1991), although direct age estimates suggest that some exposures may be older (Berger and Easterbrook, 1993; Blunt and others, 1987; Easterbrook, 1994a,b).

The oldest widely exposed unit is the interglacial Whidbey Formation, which forms the base of the section along West Beach and Blowers Bluff, where it is as much as about 120 ft thick (cobluenar section 5). We believe the formation to be correlative in the map area with stage 5, or about 125 to 80 ka, based on stratigraphic position and dates from within or near the map area (Table 1). Pollen within the Whidbey Formation suggests an initially cool climate that warmed later during Whidbey time (Hansen and Mackin, 1949; Easterbrook and others, 1967; Heusser and Heusser, 1981). Petrography and sedimentology suggest that a south- to west-flowing(?) ancestral Skagit (or Stillaguamish?) River extended into the map area and deposited the Whidbey Formation sediments (Polenz and others, 2005, and petrographic data from the project) in a low-energy setting similar to the modern lower Skagit River, flood plain, and delta, which are located about 5 to 20 mi northeast of the map area. Exposures of Whidbey deposits above sea level are rare or absent in the map area south of Penn Cove, inviting the interpretation that erosion has largely obliterated Whidbey sediments there, or that the ancestral Skagit River may have reached a lake or the sea in the vicinity of Penn Cove, so that Whidbey deposits never were deposited south of Ebey's Landing.

The Whidbey Formation is overlain by Possession Drift of stage 4 or about 80 to 60 ka. Age statements by Easterbrook (1994 a,b), Blunt and others (1987), and Easterbrook and Rutter (1981, 1982) range between 50 to 80 ka and 80 ±22 ka. However, all appear to refer to the same amino acid-based analyses, some of which were reportedly derived from samples from Blowers Bluff. Possession Drift in many locations provides the only means of distinguishing Whidbey sediment from very similar, younger "deposits of the Olympia nonglacial interval" (Polenz and others, 1989).

We believe deposits of the Olympia nonglacial interval in the map area to be correlative with stage 3 (roughly 60 to 20 ka (Martinson, 1991; Table 1)). No direct juxtaposition of the Whidbey Formation and deposits of the Olympia nonglacial interval has been recognized in the map area, but the lower parts of some bluffs (for example, columnar section 4 and 7) may include Whidbey Formation beneath an unrecognized disconformity. A deposit east of Long Point contains Glacier Peak volcanic pebbles (Table 2, samples 136-1 and 136-2) and strongly resembles Whidbey Formation deposits elsewhere, but was assigned to the Olympia nonglacial interval based on a 34,610 ±510 ^{14}C/ yr B.P. date from a soil speucion and the lack of a recognized unconformity between soil and Whidbey Head. Wagner and Wiley (1980) used geophysical data to extend it to west of Point Partridge as a Holocene fault and added multiple subsidiary(?) faults and folds, some of which are truncated by the Southern Whidbey Island fault. They also showed a buried Holocene fault with the Ebeys Landing and Fort Casey. The unit consists of sea-floor sediment, and its variegated character appears to reflect initial proximity of the ice front (Domack, 1983). For detailed characterization, see Domack (1983, 1984, 1982), Domack and Lawson (1985), and Dethier and others (1995). The age of the unit spans the entire Everson Interstade (see Geologic Setting and Development). Locally divided into:

Landslides—Apparent landslides that lack evidence for recent activity. Slide surfaces are dominated by glaciomarine drift material that may be slightly looser than glaciomarine drift outside the slump area. We infer the submarit to be Everson Interstade(?) submarine(?) slumps that do not necessarily pose a slide hazard.

Ice-marginal moraine—Cobbly to bouldery, angular to rounded gravel with loose, powdery matrix, plenty of void spaces, and abundant erratics on the surface; forms a gentle, 500 to 800 ft wide ridge across Coupeville (Fig. 1); marks the ice margin during the early part of the Everson Interstade, likely before deposition of a shell in glaciomarine drift (unit $Qgdm_g$) dated at 13,650 ^{14}C/ yr B.P. (Table 1, sample no. Beta 1319; see Geologic Setting and Development).

Partridge Gravel — Sand, gravel, and sand-gravel mixtures with minor interlayered silt and silty sand; at least 210 ft thick above sea level southeast of its type section at Partridge Point, with well records locally suggesting an additional 135 ft below sea level (Carlstad, 1992); forms angle-of-repose slopes, such as at Partridge Point. The unit includes three outwash facies that compose a coarsening-upward, marine, kame-delta–turbidite complex (Carlstad, 1992; cross section A): a mostly horizontally bedded, sand-dominated, bottom-set sea floor facies with common low-energy gravity flow cross-bedding, flame structures, and other soft sediment deformation features, but apparently lacking (?) dropstones; an overlying foreset-bedded sand and gravel facies and a capping, top-set, channelized gravel and sand facies that lack locally coarses to a bouldery gravel and reflects a shallow-water deltaic to subaerial, braided stream environment (outwash channels in Fig. 1) with abundant cut-and-fill cross-bedding. Many exposures of the bottom-set sand facies include sparse, randomly distributed inclusions and apparently gravity-sorted trains of sand- to fine gravel-sized, detrital fragments of peat, charred wood, charcoal, coal, pumice, and dacite. Carlstad (1992) suggested that tephra found in this unit is the Lake Tapps tephra. However, we agree with Franklin Foit (Washington State University, written commun., Feb. 2005), Dragovich and others (2005), and Joe Dragovich (Wash. Div. of Geology and Earth Resources, written commun., Feb. 2005; oral commun., Mar. 2005) that the tephra chemistry and field relations instead favor a Glacier Peak origin and suspect that the deposits are re-worked from nearby units, mostly units Qc_o and Qm_o. The age of the unit is unknown, but the Everson Interstade, sometime after initial incursion of marine water into the Puget Lowland but before deposition of a marine shell dated at 13,650 ±350 ^{14}C/ yr B.P. (Table 1; see Geologic Setting and Development for field relations). Assuming an average thickness of 100 to 250 ft, we estimate that the unit holds approximately 0.2 to 0.6 mi^3 of sand and gravel.

High-energy outwash gravel—Variegated deposit of gravel with lenses of sand, silt, and clay and with inclusions of boulder-sized, subangular to well-rounded silt and clay rip-up clasts and channel lag gravel derived from massive to well-bedded, compact, pre-Fraser deposits of fines (columnar sections 3 and 5; Easterbrook, 1994b); crudely to well bedded, locally imbedded, and commonly including steep bedding, gravelly inclusions (intrusions?) into underlying units, and other indicators of a high-energy flow regime; typically supports vertical bluff faces but locally forms angle-of-repose slopes; widely exposed beneath glaciomarine drift (unit $Qgdm_g$) along the Penn Cove shoreline between Coupeville and Blowers Bluff, where it steeply truncates at least 40 ft of pre-Fraser section (columnar section 5). The unit is interpreted herein as deposited in a subglacial fire outwash, except in upland areas between State Route 20 and Penn Cove near the northern map boundary, where the depositional and post-stratigraphic setting is unclear. Like the Partridge Gravel (unit $Qgom_p$), this unit is clearly overlain by glaciomarine drift (unit $Qgdm_g$). Based on exposures in a gravel pit southwest of Penn Cove, we believe that the unit locally grades into and thus is a lateral facies equivalent of the Partridge Gravel. For that reason and because the unit is apparently nowhere overlain by convincing exposures of Vashon till (unit Qg_v), we assign it to the Everson Interstade. We separate the unit from Partridge Gravel because Partridge Gravel is marine-deltaic and lacks the characteristics of high-energy flow that mark this unit.

VASHON STADE

Till—Mix of clay, silt, sand, and gravel deposited as diamicton directly by Vashon Stade glacier ice; gray where fresh, light yellowish brown where oxidized; unsorted and lacks internal stratification; massive to very thick where lodgment till is well developed; most commonly matrix supported, but locally clast supported; matrix more angular than water-worked sediments, resulting in a gritter feel than the matrix of unit $Qgdm_g$; cobbles and boulders commonly faceted and (or) striated; forms a patchy cover varying from less than 0.5 to more(?) than 50 ft thick, with thicknesses of 10 to 30 ft most common; may include outwash and ablation till that are too thin to substantially mask the underlying, rolling till plain; locally capped with 0.5 to 4 ft of sandy silt that is equivalent to but too thin to be separately mapped as unit Qs; up to house-sized erratic boulders commonly signal that till is underfoot, but such boulders may also occur as obvious, isolated, lag boulders; some of the underlying deposits have been modified by meltwater; medium sized typically caps loose surface sediment, but the underlying till is unwarthered; may include flow banding; typically forms vertical faces in coastal bluffs. The unit locally resembles unit $Qgdm_g$ (Domack, 1982, 1984; Domack and Lawson, 1985). Until Qg_v lies stratigraphically between overlying recessional glaciomarine drift (unit $Qgdm_g$) and underlying advance outwash (units Qga_v and Qga_{vg}). Its stratigraphic position relative to unit $Qgog_p$ remains unresolved. Local and nearby age controls constrain the age of the unit to between about 18 ka (=15,000 ^{14}C/ yr B.P.; Swanson, 1994; Porter and Swanson, 1998; Booth, 1991) and sometime before deposition of a shell that yielded an age estimate of 13,650 ±350 ^{14}C/ yr B.P. (see Geologic Setting and Development and Table 1). This unit may include local exposures of older till that are similar in stratigraphic position, lithology, and appearance. Locally divided into:

Ablation till—Unsorted, unstratified melt-out deposit of loose gravel, sand, silt, and clay.

Advance outwash—Sand and pebble to cobble gravel with some bouldery facies; local silt and clay; may contain till fragments; gray to grayish brown and grayish orange; clasts well rounded; typically well sorted and clean except in some ice-proximal deposits near the top of the unit; compact, but in many exposures only minimally cohesive; parallel-bedded, locally cross-bedded; less than 20 ft thick in most exposures; commonly overlain by unit Qg_v along a sharp contact and stratigraphically unit Qc_o, commonly forms angle-of-repose benches within coastal bluffs. The age of this unit is bracketed to between about 18 and 20 ka by local and nearby age controls that place the Pleistocene/Holocene boundary at 11.7 ka (Table 1; columnar section 4) and an estimate of Vashon ice arrival by Porter and Swanson (1998) (see Geologic Setting and Development). Locally divided into:

Sand-dominated advance outwash

Vashon and Everson drift, undivided—Glaciomarine drift (unit $Qgdm_g$), till (unit Qgd_v), and advance outwash (units Qga_v and Qga_{vg}) undifferentiated; combined into single unit where map scale or exposure do not permit separate presentation.

Deposits of the Olympia Nonglacial Interval (Pleistocene)

Armstrong and others (1965) defined as "Olympia Interglaciation" the "climatic episode immediately preceding the last major glaciation" and associated it with "nonglacial strata lying beneath Vashon Drift". We avoid the label "Olympia Interglaciation" because stage 3 (60-20 ka) is not a true interglacial period (as defined in fig. 4 of Morrison, 1991).

Nonglacial deposits—Silt, clay, sand, and local lenses and interbeds of fine gravel; includes the widespread "West Beach silt" facies interpreted as loess by Thorsen (1983a,b, 2001); compact; typically horizontally bedded to massive; commonly forms vertical bluffs; silt facies locally contain sparse gastropod fossils (columnar section 4 and shoreline section B; Table 1). Petrographic study (Dragovich and others, 2005, and this study) indicates that alluvial facies reflect ancestral Skagit River provenance. Sparse, local Glacier Peak dacite and pumice pebbles, such as those found to the east of Long Point (columnar section 7; Table 2, samples 136-1 and 136-2), are chemically indistinguishable from lahar runout deposits within the Whidbey Formation (unit Qma_o), but no lahar runout deposits were recognized in this unit. The age of the West Beach silt is constrained in the map area to between about 37,000 and 27,000 ^{14}C/ yr B.P. by dates from overlying and underlying units (Table 1, sample nos. Beta 154508 and Beta 169086). The age of the entire unit may be limited to between about 37,000 and 16,800 ^{14}C/ yr B.P. by six radiocarbon dates from the field area and the above-mentioned 37,000 ^{14}C/ yr B.P. date from West Beach just north of the field area (Table 1). Alternatively, undated strata within the unit may include significantly older deposits of the Olympia nonglacial interval. This unit may include fine-grained early Vashon advance deposits ("Transitional beds" of Pessl and others (1989)), such as at North Penn Cove (columnar section 4), where the upper radiocarbon date and sedimentary characteristics of overlying silty sediment may be compatible with early Vashon association.

Deposits of the Possession Glaciation (Pleistocene)

Possession Drift—Glaciomarine drift and underlying till and advance outwash sand; distinguished from equivalent Fraser Glaciation units by stratigraphic position. Glaciomarine drift facies highly variegated; typically clayey silt, silty clay, clay, and clay-rich diamicton; buff, ranging to ash gray or white; compact and commonly with vertical desiccation cracks; commonly contains shells; more compact than Everson Interstade equivalent; locally indistinguishable from till. Till facies typically sandy diamicton; ash gray to white; compact. Outwash sand gray; medium to fine grained; classified as advance based on field relations along West Beach north of map area (Dragovich and others, 2005). The unit is mostly glaciomarine drift along Blowers Bluff; it is dominantly sand at West Beach and within 1.5 mi southeast of Ebeys Landing, but glaciomarine drift overlying till farther south along the same bluff. Sand at West Beach is very similar to and was distinguished from underlying channel sand of unit Qc_o based on mineralogic content determined from petrography. We believe the unit age to be about 80 to 60 ky (see Geologic Setting and Development).

Interglacial Deposits of the Whidbey Formation (Pleistocene)

Whidbey Formation—Sand, silt, clay, peat layers, occasional fine gravel, and rare medium gravel; where exposed, most commonly weathered to a subtly multicolored to light-yellowish appearance; forms base of section along shoreline bluffs of West Beach and Blowers Bluff and most commonly consists of a basal flood-plain facies overlain by a channel sand facies. The flood-plain facies is typically 10 to 20 ft thick, well stratified (subhorizontally), and commonly slightly oxidized, forms prominent vertical bluffs, and contains discontinuous peat beds. Along West Beach, the flood-plain facies is at least 30 ft thick at columnar section 1, but descends below sea level 3000 ft to the south (see Structure). The flood-plain facies is overlain by a roughly 30 ft thick, clean, gray, cross-bedded to massive channel sand facies (columnar section 1) that typically forms an angle-of-repose cliff and so resembles the overlying Possession glacial sand (unit Qgs_p) that petrographic analysis may be needed for separation of these two units. At Blowers Bluff, the flood-plain facies reaches a maximum thickness of 25 ft and is overlain by a gravelly, cross-bedded channel sand facies that is lavender to light yellowish gray, 15 to 80 ft thick, and somewhat prone to forming angle-of-repose benches; this facies is continuous with similar deposits in the Blowers Bluff portion of the Oak Harbor 7.5-minute quadrangle north of the field area, where Dragovich and others (2005) informally named it the lahar runout of Oak Harbor and used mineralogic composition to demonstrate an ancestral Skagit River basin provenance. We agree with Dragovich and others (2005) that local concentrations of dacite and pumice pebble trains (see columnar section 5 and Easterbrook, 1994b) come from Glacier Peak lahar runout deposits (Table 2; Dragovich and others, 2005). We believe the unit age to be about 125 to 80 ka (see Geologic Setting and Development).

Deposits of the Double Bluff Glaciation (Pleistocene)

Double Bluff Drift—Glaciomarine drift (silt, clay, and diamicton) and locally underlying till; resembles equivalent Vashon Drift units but is assigned to the Double Bluff Glaciation based on stratigraphic position; recognized in the map area only along about 1500 ft of shoreline southeast of Ebeys Landing (shoreline section B); lithology reflects British Columbian provenance (Easterbrook and others, 1967). The age of the unit appears to be 185 to 125 ky or older (see Geologic Setting and Development).

Undivided Pre-Fraser Nonglacial Deposits (Pleistocene)

Pre-Fraser nonglacial deposits, undivided—Sand, silt, clay, peat, some fine gravel, and rare medium gravel; well stratified to massive; resembles units Qc_o and Qc_{og} and is thought to be nonglacial but may locally include glacial material; mapped in a single exposure about 3000 ft west of columnar section 4; stratigraphically situated below Fraser glacial deposits but otherwise of unknown age and association; likely of Olympia or Whidbey age, but an older origin has not been ruled out.

Undivided Pleistocene Deposits

Pleistocene deposits, undivided—Sediment of unknown age and association; may include both glacial and interglacial deposits. In an exposure west of Long Point (columnar section 6), the unit consists of a 73 ft thick section of gray, medium- to fine-grained, subangular to subrounded, poorly sorted, compact to mildly compact, plane- to gently cross-bedded, lithologically diverse sand with sparsely disseminated, thin (< 1 in. thick) organic pockets of granule-sized pumice and coal; soft-sediment deformation structures and (or) liquefaction features are exposed in the basal 20 ft of section; sand is interlayered with at least three compact, discontinuous diamictons up to 6 ft thick, with sparse to rare, subrounded to angular granule to pebble clasts; diamictons greenish to olive and dark gray; grains angular to subangular; lithologic composition mixed and not indicative of specific source area or glacial or interglacial conditions; angularity of particles in diamicton suggests till. In a separate exposure 0.3 mi southwest of the Coupeville dock, the unit consists of compact, quartz-rich sand. The unit also includes an exposure of somewhat compact cobble gravel near the top of a hill 4000 ft southeast of Lovejoy Point. This exposure is in the sideslope of a hill that rises about 10 ft above the surrounding glaciomarine drift and recreational outwash gravel, suggesting that the hill is cored with older sediment.

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