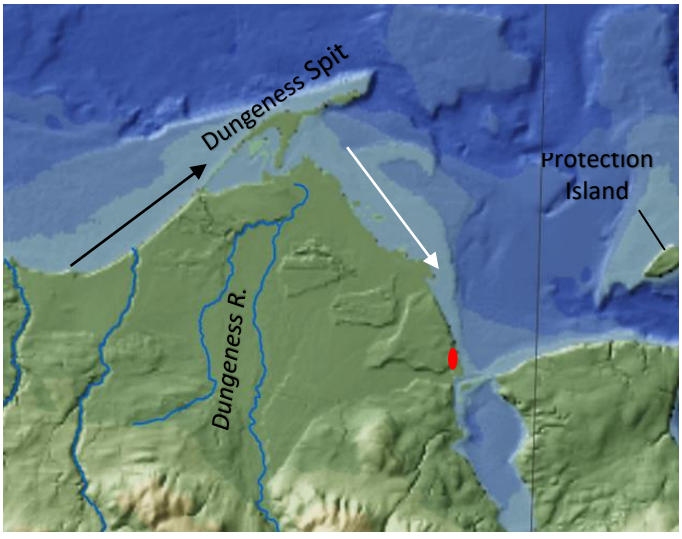
GEOLOGY OF THE BLUFF NORTH OF THE COUNTY PARK AT PORT WILLIAMS, CLALLAM COUNTY, WASHINGTON

Introduction

In the Puget Lowland of Washington there is evidence of at least six Pleistocene continental glaciations. During each glaciation, the Cordilleran ice mass likely followed roughly the same route from the Coast Mountains region of British Columbia. After splitting into two lobes just north of Port Townsend, Puget lobe ice passed south into the Puget Lowland, and the Juan de Fuca lobe flowed west out the strait for which it is named. Deposits of only three glaciations, all late Pleistocene—the Double Bluff, Possession, and Vashon—are exposed on the northeastern part of the Olympic Peninsula. The table in the 'preamble' lays out the characteristics and chronology of the glaciations and deposits at Port Williams.



Mountain and valley glaciers in the Olympic Mountains moved slightly out of sync with the arrival and departure of ice masses from Canada. Their drift did not reach this far north near Sequim. Instead, Vashon drift covers the foothills between older rock outcrops to about 2000 feet.

The black and white arrows on this map of the topography and bathymetry of the area north of Sequim indicate longshore current directions. The Dungeness River is an old river and probably scrolled widely east and west across the peninsula during the late Pleistocene. In the not-so-distant past it flowed east between the hills near the shore. The park from which we start this northward walk is marked by the red oval.

In western Washington, most Pleistocene nonglacial sediment was carried by rivers from the Cascades to the Pacific on shallow stream gradients. The Whidbey Formation records that environment, but no river edges are exposed here (or anywhere else that we know of). On a local scale, nonglacial alluvium is from nearby sources, the sediment that the streams(s) crossed. In contrast, most glacial sediment here is from Canada, brought along by the Juan de Fuca lobe. There is no local granite, so granite clasts are Canadian.

During the peak of any glaciation, sea level was lower, and more land was exposed. During the latest, Vashon glaciation, the Pacific coastline where the strait met the ocean was about 50 miles west of where it is today. We'd expect something like this in earlier glaciations.

The Port Williams bluff runs nearly north-south and cuts *across* the presumed east-west stream and ice paths, across both the Possession deposits and the prominent Olympia-age alluvium of an ancient Dungeness River (see Fig. 1).

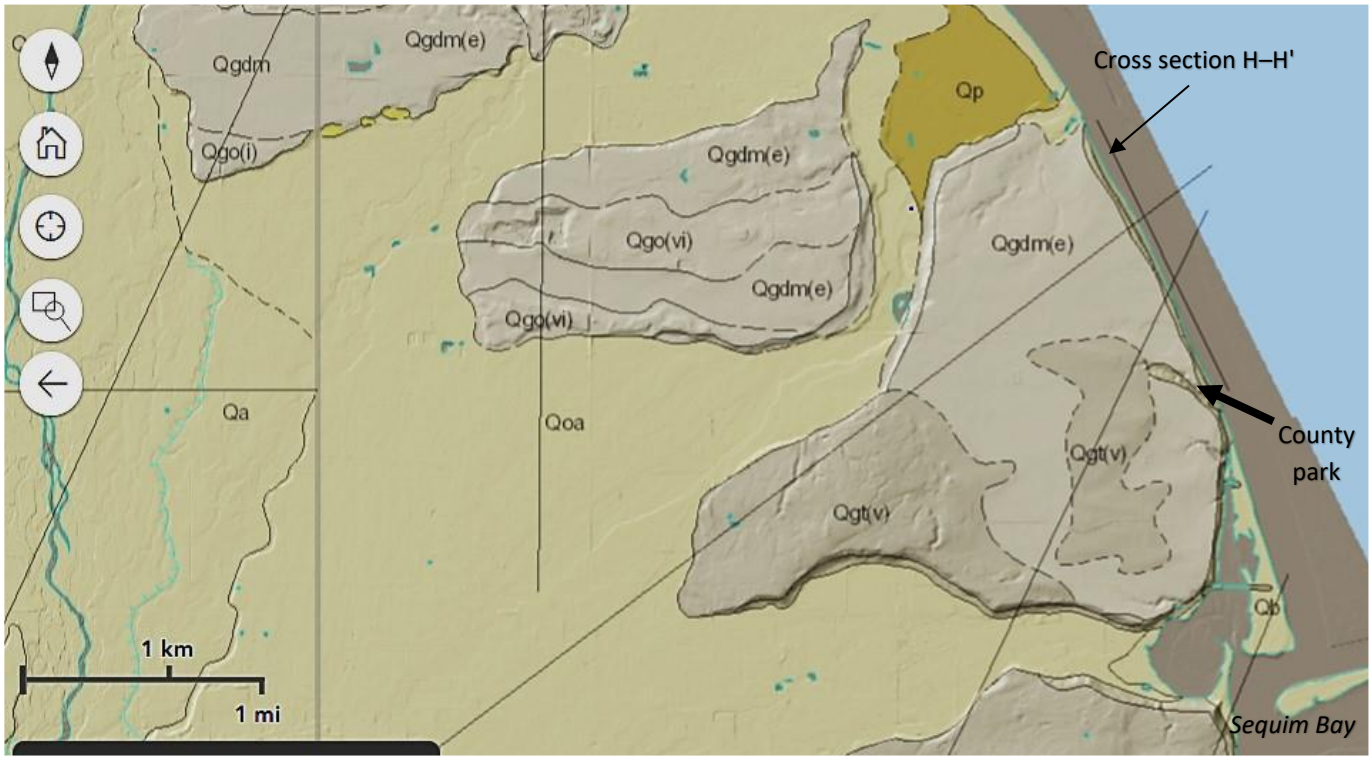
All pre-Vashon units were overridden and compacted by older ice lobes. At Port Townsend, Vashon ice was at least 4000 feet thick at about 14,500 (uncalibrated) years ago, when the Puget lobe terminus stood at its maximum extent south of Olympia. As noted elsewhere in the trip guides, that's at least 140 tons of rock-containing ice (confining pressure) per square foot of land surface or seafloor, enough to cause the under-ice surface to sink. The Possession-age lobe in the Puget lowland stopped near Tacoma and may have been thinner at its core; its record along the south coast of the strait is spotty and poorly dated. The difference in ice area and thickness likely caused different amounts of compaction, sea-level change, surface depression, and rebound for each glacial cycle.

In this bluff there is a preponderance of glacial sediment, much of it called drift. Here's the American Geologic Institute's 2005 definition: "A general term applied to all rock material (clay, silt, sand, gravel, boulders) transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier. Drift includes unstratified material (*till*) that forms moraines, and stratified deposits that form *outwash plains, eskers, kames, varves, fluvioglacial* sediments, etc. The term is generally applied to Pleistocene glacial deposits in areas (as large parts of North America and Europe) that no longer contain glaciers." The definition implies complex environments. Along this bluff we have drift that is glacial and drift that is glaciomarine.

From the table in the 'preamble' for Day 2, note that in this guide **g**lacio**m**arine **d**rift is referred to as **gmd** and the Olympia-age alluvium as **OB**. There is no formal name for the latter unit. **Gmd** saves a lot of typing and is faster to say and makes us sound more professional.

Figure 2, on page 4, is 23-year-old *sketch* cross section, so stop locations are approximate. We'll use this figure's labels for the geologic units on this walk. As we might expect, there is an unconformity (a gap in time) at contacts between all the units. There is probably no place along the shore of the Strait of Juan de Fuca where the true top or bottom of a unit is exposed, a situation common in glaciated terrain.

A few caveats: This is an active beach. Thanks to tides and storms undercutting the base of the bluff, large chunks fall off the bluff face from time to time. Many details in this guide's photos will look different on any walk. Bluff failures change details but bring what is high in the section to beach level for us to examine. The tide moves or removes material that falls. Fresh surfaces dry and crumble or are wetted by rain and look different in just days. Walking close to the bluff face is a bit dangerous. We can see the units higher on the bluff better by walking closer to the water. There is mud at water's edge near the spit…



Explanation of Map Units

Qa – alluvium of the modern Dungeness River (the blue sinuous line along the west edge of the map)

Qb – beach deposits

Qp – peat

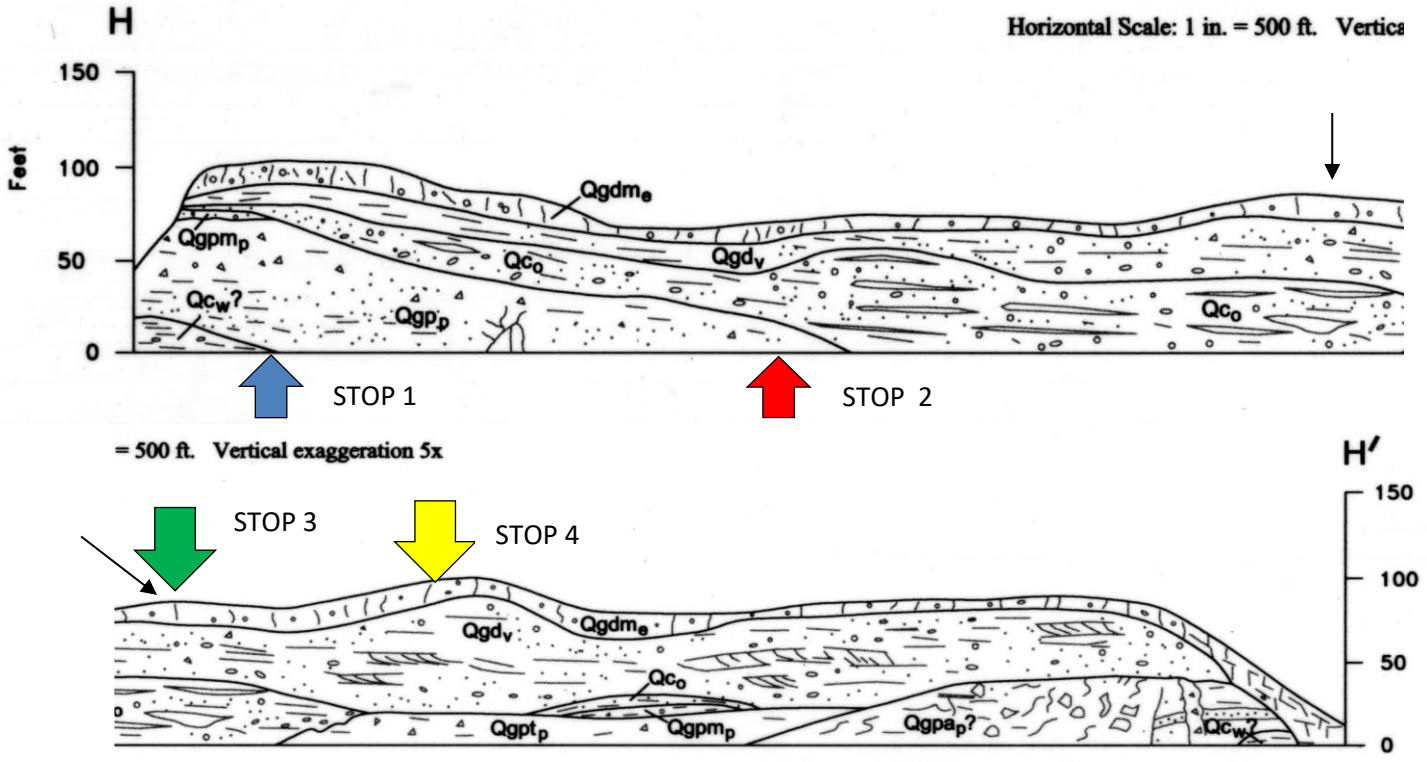
Qoa – post-Everson alluvium of ancestral Dungeness River, whose eastward course is suggested by the distribution of this unit

Qgdm(e) and Qgdm – Everson glaciomarine drift (or gmd)

Qgt(v) – Vashon till

Qgo(vi) and Qgo(i) – Vashon-age slumped ice-contact deposits

Figure 1. **Surficial geology at and west of the Port Williams bluff.** This guide covers about a mile of the southern part of cross section H–H' (see also Fig. 2). Older units exposed in the bluff cannot be shown at this map scale. Straight black lines crossing this image are other cross-section locations on the geologic map (H. Schasse and R. Logan, 1998, Geologic map of the Sequim 7.5-minute quadrangle, Clallam County, Washington: Washington Division of Geology and Earth Resources Open File Report 98-7, 22 p, 2 pl.). The darkest gray-brown shade is coastal water. The dual unit labels are because this map covers parts of three quadrangles (mapped at different times by various people); these quadrangles are joined at the pale gray vertical and horizontal lines in the west quarter of the map.



Explanation of unit labels

(The difference in unit names between Figs. 1 and 2 is due to different mapping protocols.)

Qgdm$_e$ – Everson glaciomarine drift
Qgd$_v$ – Vashon Stade undivided drift and advance outwash
Qc$_o$ – Non-glacial sediment of Olympia age (OB herein)
Qgpm$_p$ – Possession glaciomarine drift
Qgp$_p$ – Possession glacial drift
Qgpt$_p$ – Possession till
Qgpa$_p$? – Possession advance outwash
Qc$_w$? – Whidbey Formation

Figure 2. **The Port Williams bluff cross section H–H'** (Schasse and Logan, 1998, pl. 2). The overlap in the parts of the section is between the black arrows. From H (south end) to H' is about 1.2 miles. (Disregard the horizontal scale in this figure.) In the unit labels, the subscripts signal unit names. The question marks indicate that the units are identified on the basis of their stratigraphic position. There are no precise dates for units on this walk.

The Walk Begins

There are four stops on this walk. At each we'll look at the geologic features of the bluff nearby. The photos for each geologic unit are not in order along the walk. Lat/longs of significant or helpful features are provided.

All of the beach north of the park is private land. Please do not climb on the slopes. Please take no samples.

Just north of the county park is a small outcrop of Whidbey Formation continental/nonglacial, light brown and gray, alluvial, sandy silty and silty sand (unit Qc$_w$?; Fig. 3; see the table in the 'preamble'). In

Whidbey time, this area was a broad floodplain stretching west out the strait. The wide, braided river had a very low gradient, hence the fine sediment. The Whidbey is unconformably overlain by Possession drift (Fig. 4).

Figure 3 (above). The Whidbey Formation outcrop at 48˚05'52"N, 123˚02'49"W.

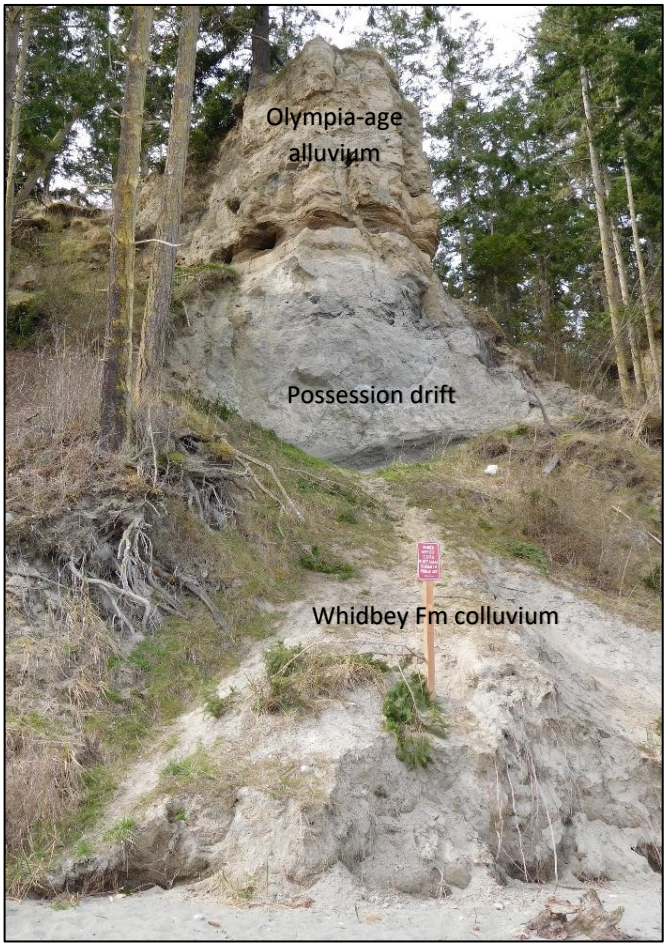


Figure 4 (right). A few yards north of the location of Fig. 3, the material above and below the sign is disturbed Whidbey colluvium. The Whidbey may crop out below the Possession drift (unit $Qgp_{p)}$ about 50 feet to the north, where it is gray and horizontally bedded. Here, the Whidbey/Possession contact is covered. The light brown sediment at the top of the outcrop is alluvium of Olympia age, unit Qc_o, OB herein.

Stop 1 includes the area on either side of the section shown in Figure 5. Possession till/drift (units $Qgpt_p$ and Qgp_p) dips gently to the north (cover photo and Fig. 2), cutting into the Whidbey Formation. The texture and apparent structure of this unit vary along the bluff. This unit may locally be lodgment till or watery sub-ice sediment dragged, compressed, internally sheared, or stretched as the ice moved west.

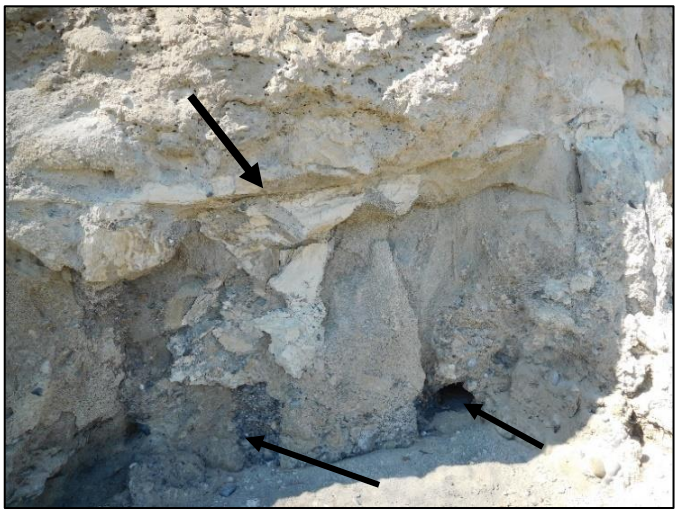
In places, the Possession drift's upper part is massive, finer sediment of the gmd (unit $Qgpm_p$). Gmd drapes on older material and hints at seafloor topography. D.J. Blunt and others collected marine clams from the gmd for their study of amino-acid racemization as a means to arrive at age estimations. In 1987, they reported 80 ±22 kyr, within the currently accepted age range for the Possession unit, but hardly precise. (This technique seems to be applied to teeth, not so much to other fossils.)

Figure 5. The section at Stop 1. Possession glacial drift, unit Qgp_p is above the grassy top of the sediment that has slipped off the bluff face. Above that is the brown Olympia-age alluvial gravel (OB; unit Qc_o); the straight arrow points to the Possession/OB contact (no or little gmd here). The angled arrow points to a small boulder on this contact. The contact between the OB alluvium and younger Everson gmd, unit $Qgdm_e$, is at the curved black arrow. The table in the preamble shows that the Vashon glaciation occurred between the deposition of these last two units. Is there any Vashon material here? **(**48˚05'53"N, 123˚02'56"W)

A little north of Stop 1 Possession gmd (unit $Qgpm_p$) lies on the drift. Wherever it crops out, the gmd is silt, indicating quiet water deposition. There ought to be dropstones (rocks that fall off floating ice and commonly dent the silty seafloor) in it, but there are very few here, it seems. Why? The large and small rocks on the gmd/OB contact are part of a lag deposit clasts that the river current could not move (Fig.6).

Figure 6. Examples of lag clasts at the Possession/OB contact. The cobble (left), at 48˚05'49"N, 123˚03'07"W, has glacial striations on the exposed face; it has been tilted 90 degrees from wherever it was originally. Note the crude OB bedding. The ruler is 6 inches long. The scattered pebbles (above) go with the sandy-er OB.

Above the Possession drift is non-glacial OB alluvium. Fossils (esp. pollen) show that this area and SW Canada was not as warm then as it is today. The brown gravel was laid down by an ancient Dungeness River. Many pebbles/cobbles came from foothills to the south, from the Eocene Makah Formation (sandstone, ca. 33 million years old [my]) and from basalt and minor sedimentary interbeds of

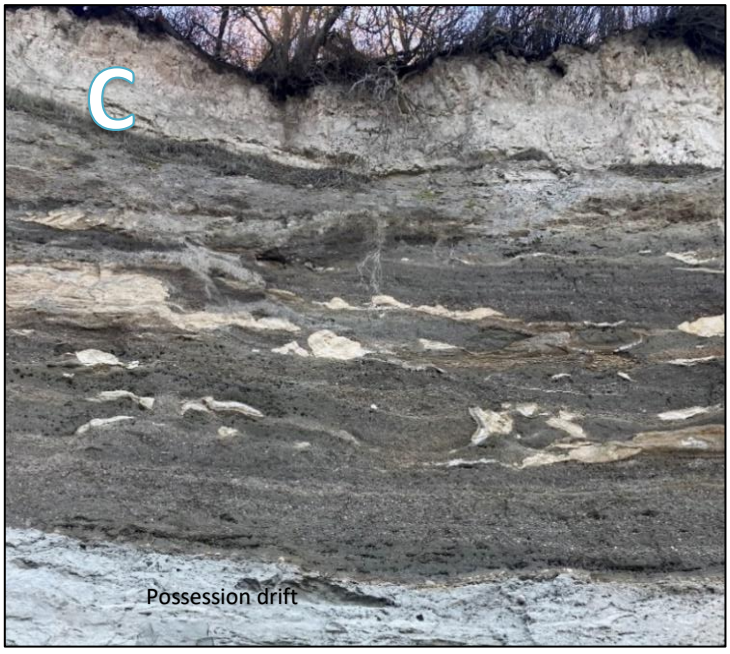


the Crescent Formation (53–49 my). Some OB sediment is from the underlying Possession drift: pebbles of granite and metamorphic rock from Canada.

Figure 7. Some of the complex structures in the Possession drift. Heavy arrow, a horizontal shear. Lighter arrows, injection structures.

Which way did the OB river flow? It's hard to tell without seeing a third dimension. Look for cross-bedding and imbrication or overlapping clasts. The various channels of the river left a complex pattern.

The sloping top of the Possession (cover photo) is not a result of folding; bedding in the OB matches the dip of the gmd or drift surface. Everywhere, the contact is sharp. (Why?) What varies is the presence or absence of the Possession gmd.



At **Stop 2** (48˚06'02"N, 123˚02'57"W; see Fig. 2), the focus is on details in the Possession drift and the OB—textures and structures created as the en-trained sediment crossed the pre-Possession topo-graphy (Fig. 7) and more of the light brown streaks and chunks in the OB (Fig. 8). Some of the chunks may be rip-ups, but most seem too thick to be rip-ups. Maybe they are overbank material.

Almost all bedding in the light brown chunks is folded (Fig. 8A, B); that occurred before the event that distributed the chunks at odd angles in the OB (Figs. 8, 9). Could all this contortion result from liquefaction of saturated alluvium? During liquefaction, grain-to-grain contact is disrupted, and sediment literally becomes a fluid. Liquified sediment and water are forced to a free face (here, river-bed surface?) and create sand volcanoes and injection structures that require opening of cracks into which sediment can rise. The light brown chunks settled oddly when the OB 'recovered'.

What caused the shaking???

Along the way near here we may see some tightly folded brown silt/fine sand below and intermixed with the drift. Possession advance outwash? Whidbey Formation sediment?

Figure 8, A, B. These light brown beds in the OB were folded before being dismembered. **A**. A 10-in.-thick fragment at beach level; **B**, this chunk, at 48˚06'09"N, 123˚03'02"W, is about 8 in. thick. **C,** the chunks 'float' in the OB bedding after the shaking.

Figure 9. Blocks of OB tossed together in a channel cut into the OB, beach level at 48˚06'08"N, 123˚03'00"W (late March 2021 photo). OB fragments were cut from their original arrangement (at a channel edge?) and redeposited during some (seismic?) shaking event. The white layer at the arrow seems to have been rammed from the left (south), split, bent down, stretched, and broken during this event. Folds in the layer give it the looped appearance.

In addition to disrupted and re-arranged beds, there's a lot of folding that suggests compression but that can also be caused by de-watering (Fig. 10).

Figure 10. Soft-sediment deformation in the OB. **Left,** fold amplitude is about 5 inches **(**48˚06'13"N, 123˚03'04"W). **Right**, the amplitude of the biggest fold is about 10 inches (48˚06'07"N, 123˚03'01"W).

At a minus tide, this short spit emerges at 48˚06'06"N, 123˚03'02"W. The shape of the spit hints at an old, large bluff collapse, but it might simply be related to the longshore drift (see the small map on p. 1). In the center-left background on the horizon is the east tip of the Dungeness Spit. Stop 3 is at the arrow.

Stop 3 (48˚06'13"N, 123˚03'03"W) is at a bluff collapse that occurred early in spring 2021. On the south edge and east of the debris pile are (were…) examples of iron cementation and incipient concretions(?), photos below. (The ruler is 6 inches long.) The section above the collapse has good examples of younger units.

The **STOP 4** area takes us from the reappearance of the Possession drift (Fig. 11) to the end of the walk. Now we give the Vashon outwash/drift and Everson gmd our attention. At the beginning of the walk, the Vashon unit was either very thin or not present; in this part of the bluff, there is an almost continuous outcrop of Vashon material and a well-developed bench below it.

Figure 11. South of Stop 4, Possession drift re-emerges from below the beach (at arrow). A veneer of sediment is starting to cover a fresh surface on the right. In this March 2021 photo, the top of the Possession on the right is about 2 feet above the beach.

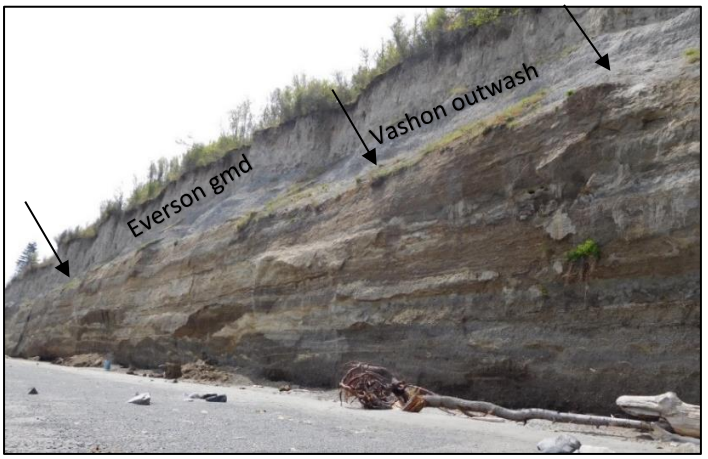
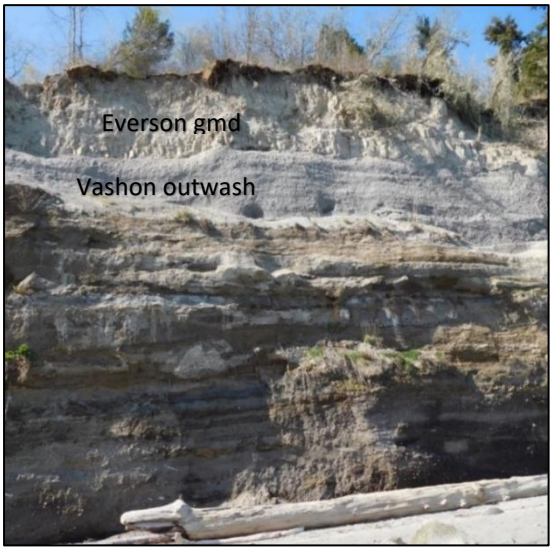


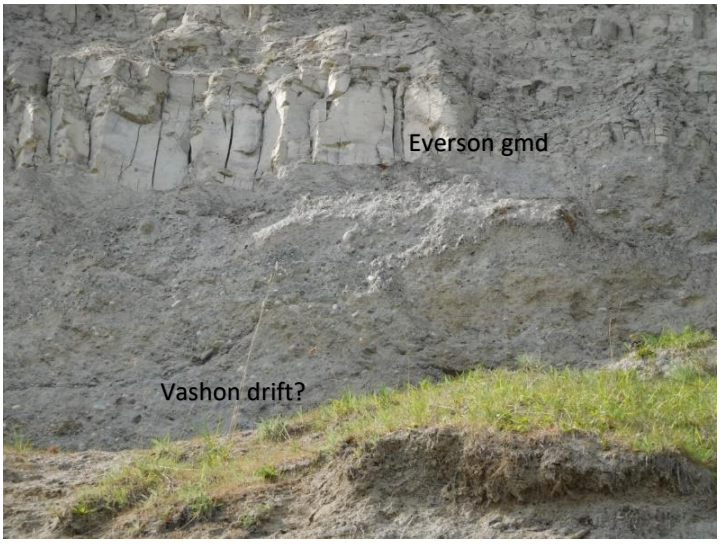
Figure 12. North of Stop 3, a bench (at the arrows) below the Vashon is increasingly obvious.

Lying on the OB, above a bench (Fig. 12), is Vashon advance outwash, unit Qgd_v (undivided outwash and drift in Fig. 2) and drift. The base of the outwash is about 20 kyr old. Expect to see well-bedded, coarse, gray sand.

In this part of Washington, Vashon till is sandy and contains well-rounded pebbles and cobbles. Like the Possession drift, it also has vague bedding—it was a water-rich deposit. It overlies the outwash in places.

On the next page are photos of some examples of outwash and drift.





Above left is bedded Vashon outwash; to the right is what looks like drift above the grassy bench. Note the columnar Everson above it. Neither Vashon unit is continuous.

Everson diamicton (unsorted gmd, unit $Qgdm_e$) is draped over the whole bluff and drops to beach level at the north end (Fig. 2). Bluff-top shape is that of the local seabed topography as the ice lobe melted away. The elevation of the bluff top approximates the amount of regional post-ice rebound, here, 100 feet, more or less.

Digression: On a QGS walk in July 2021, we saw remnants of two large sub-fossil bones, probably mammoth, low in the OB north of Stop 3. Collecting any fossil on private land requires permission of the owner, so we left them for others to find. Consensus for this bone: a vertebra. The other find was part of a long bone, just a white streak of friable cancellous material. Note the chaotic bedding and broken light brown clast above this bone. Seems amazing that bone could survive the rearrangement of gravel. Clearly there had been some bluff retreat since April to reveal these. Bone is not all that rare but falls and is carried off by tides or walkers. There are no known dates on Sequim mammoths. (Photo by Steve Mader)

Figure 13. The bluff at the end of the walk. There is no Possession gmd or Whidbey here, but all other bluff units are present.

More of the Possession drift is gradually exposed north of where it rises above the beach. At the end of the walk (Fig. 13), the drift is about 4 feet thick. Note the shears in it. (Is there evidence of motion?) The shears dip 42˚–50˚S and strike 273˚–280˚; others to the south strike ±200˚. And here are more of the dramatically contorted and rearranged light brown fragments in the OB.

The walk ends at 48˚06'21"N, 123˚03'60"W, at a sign on a tree (if it is still there…) on the beach announcing that the beach to the north is private property. Even though we have been on private property to this point, please do not trespass on Jamestown S'Klallam tribal land by going beyond here.

Take time to re-examine features during the walk back to the park.

References cited:

Blunt, D.J., Easterbrook, D.J., Rutter, N.W., 1987, Chronology of Pleistocene sediments in the Puget Lowland, Washington: Washington Division of Geology and Earth Resources Bulletin 77, p. 321-353.

Schasse, H.W., Logan, R.L., 1998, Geologic map of the Sequim 7.5-minute quadrangle, Clallam County, Washington: Washington Division of Geology and Earth Resources Open File Report 98-7, 22 p, 2 pl.

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