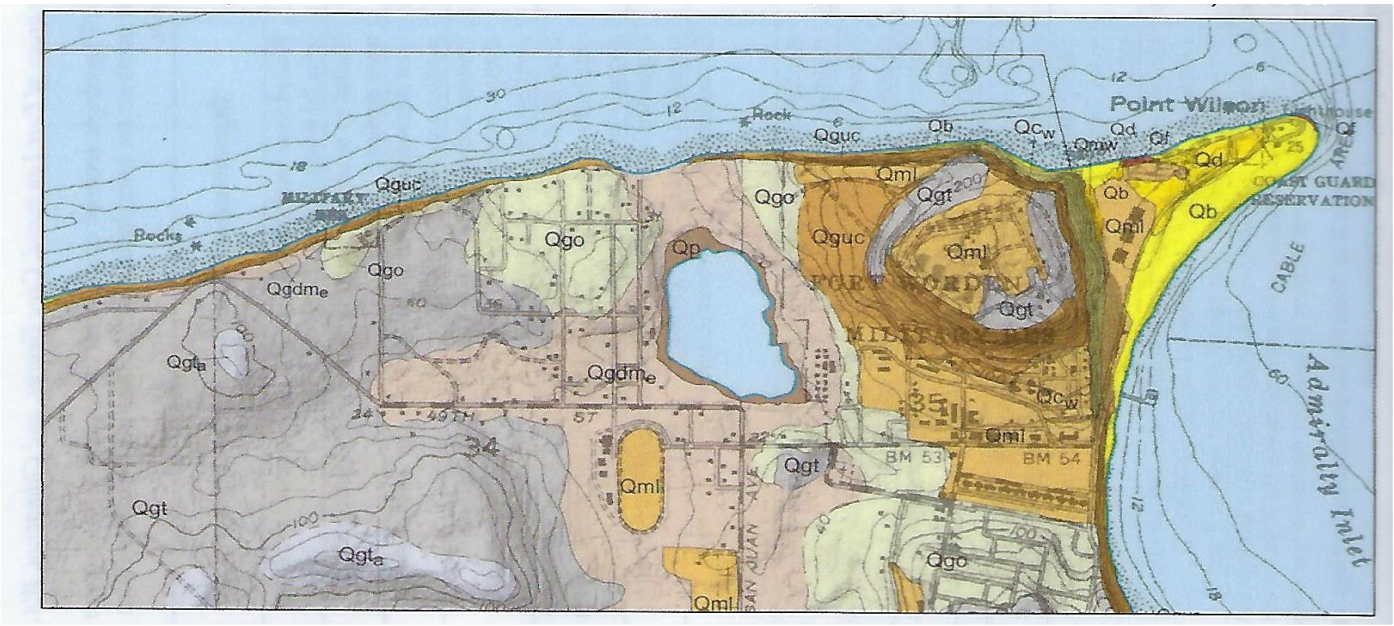
GEOLOGY OF THE NORTH BEACH BLUFF AT FORT WORDEN, JEFFERSON COUNTY, WASHINGTON

Location	Latitude/Longitude	Description
A	48.1428/-122.7619 (48°08'33.9"/122°45'43.0")	Trail to the beach is to the left (west) of Battery Kinzie. This walk (a-j) is about a mile long.
B	48.1428/-122.7637 (48°08'34.0"/122°45'49.3")	"Drowned forest": sunken logs, branches, and roots exposed at minus tide. Battery Ash (arrow) is closest to the landslide scarp in the 'alcove'.
C	48.1434/-122.7673 (48°08'36.3"/122°46'02.2")	West side of alcove, which has a landslide and unstable slope features
D	48.1435/-122.7683 (48°08'36.5"/122°46'05.9")	West edge of peat layer in the Whidbey Formation
E	48.1433/-122.7697 (48°08'36.0"/122°46'11.0")	Large erratic on beach with brass USGS marker; Battery Tolles on the upland between here and Location F
F	48.1433/-122.7718 (48°08'35.9"/122°46'18.4")	Beach near west end of Battery Tolles; coarser alluvium high in the bluff. Battery Walker is in the small clearing east of Location G.
G	48.1431/-122.7771 (48°08'35.1"/122°46'37.7")	Everson-age delta-like diamicton deposit (the "jumble") at beach level. It is overlain by glaciomarine drift (gmd) with an irregular top surface.
H	48.1431/-122.7790 (48°08'35.0"/122°46'44.3")	Large clast of the Vashon till in the bluff face
I	48.1427/-122.7806 (48°08'33.8"/122°46'50.2")	The "wandering rock". The bluff face is gmd and diamicton overlain by thin layer of dark loess below vegetation.
J	48.1427/-122.7822 (48°08'33.8"/122°46'55.8")	End of concrete boat ramp at low tide. The county park is directly south.
a)	48.1363/-122.7628 (48°08'10.6"/122°45'46.1")	Marine Science Center parking lot; Whidbey Formation is exposed by 2016 debris slides at star.
parking	48.1415/-122.7611 (48°08'29.4"/122°45'39.9")	The concrete pad south of Battery Kinzie, a good place to leave a car for this walk. It requires a Discovery Pass. Red arrow. ***We meet here.***
parking	48.1423/-122.7822 (48°08'32.2"/122°46'55.8")	The star near the west edge of this map is at the North Beach County Park day-use parking lot. No pass is needed.

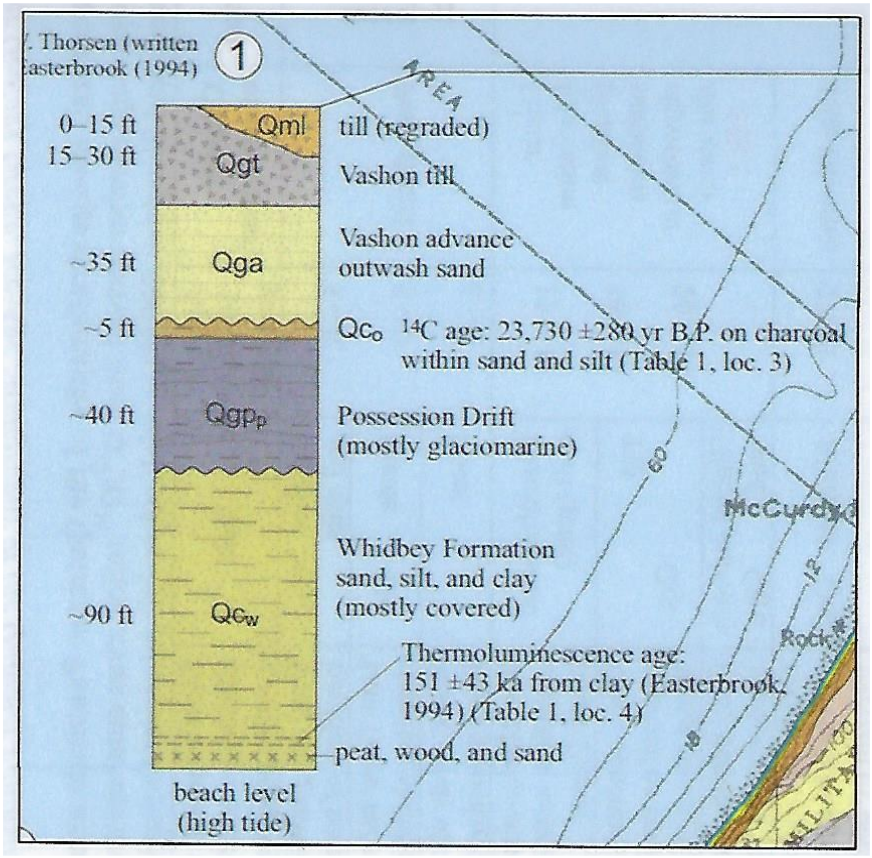


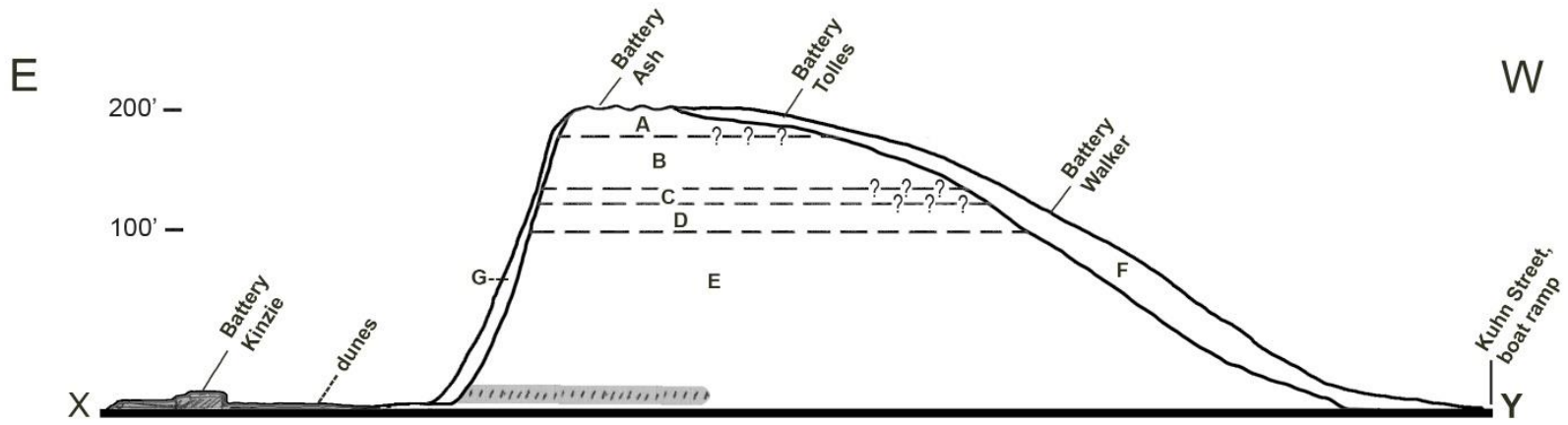
This **geologic map of the northwest part of the Quimper Peninsula, including the Fort Worden area** (mostly in brown tones), is taken from Schasse, H.W., and Slaughter, S.L., 2005, Geologic map of the Port Townsend South and part of the Port Townsend North 7.5-minute quadrangles, Jefferson County, Washington, published by the Washington Geological Survey. The section below is in the alcove. Possession Drift and Olympia sediments are rarely visible.

Explanation of unit labels on geologic map and section. By Washington Geological Survey (and, with some exceptions, U.S. Geological Survey) convention: Q, Quaternary (Pleistocene and Holocene; Pleistocene units have a g in them); g, deposits of glacial origin; c, nonmarine (continental) deposits; subscripts indicate unit's name. (Unit chronology is in Table 1 in the 'preamble'.)

From youngest to oldest (mostly):

- Qml – land disturbed by the military, county, or city
- Qmw – mass wasting, landslide or colluvial deposits
- Qd – dunes
- Qb – beach deposits
- Qp – peat
- Ql – loess
- Qgdm$_e$ – glacial-marine (or glacio-marine) drift, Everson age (incl. the diamicton or "jumble)
- Qgt$_a$ – Vashon ablation till
- Qgt – Vashon lodgment till
- Qgo and Qga – Vashon advance outwash
- Qguc – glacial deposits, undifferentiated, nonmarine sediment
- Qgp$_p$ – Possession Drift
- Qc$_o$ – Olympia beds
- Qc$_w$ – Whidbey Formation



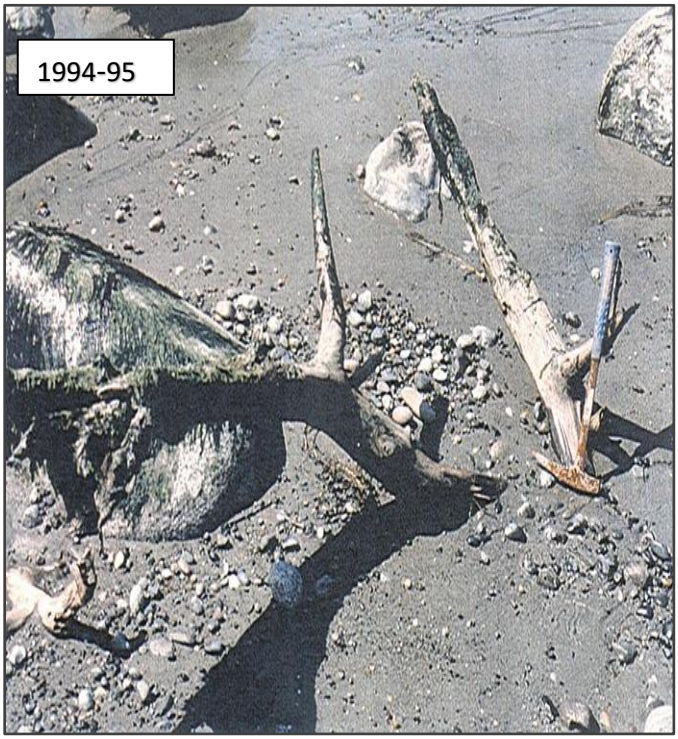


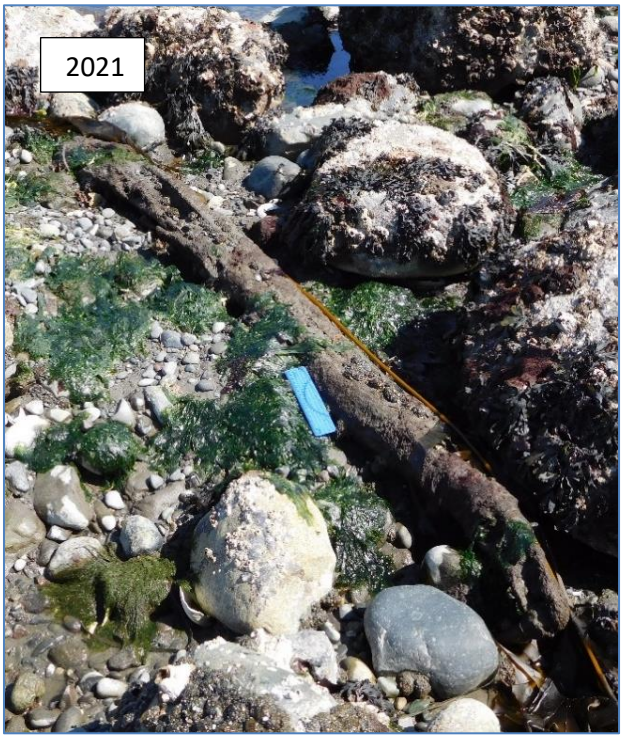
A - Vashon till
B - Vashon advance outwash
C - Olympia-age sediment
D - Possession drift
E - Whidbey Formation
F - Everson recessional outwash: gmd + diamicton
G - modern colluvium
- peat

X to Y = approx. 1 mile. Note vertical exaggeration.

Diagrammatic cross section of the geology of North Beach between Battery Kinzie and the county park on Kuhn Street. Vertical exaggeration means that each geologic unit drawn here is thicker than it would be if this were drawn to scale. The dashed lines indicate that the contacts are approximately located. The till has been rearranged by the U.S. Army; bluff erosion is greatest north of each battery. The east limit of unit F is conjectured. (Prepared by Varn Brooks)

LOCATION A, development of Point Wilson. The relative strength of the longshore drift currents is indicated by the length of the black arrows; double-ended arrow is tidal current. Riprap (stars) at the Coast Guard facilities and Battery Kinzie fails to stop gradual southward movement of the spit. Simple white arrow indicates Location B, the "drowned forest". Mystery features are at the curved arrow. (2006 Washington Dept. of Ecology aerial oblique photo)





LOCATION B, the "drowned forest". ***Left***: Barkless branches protrude from the beach; the hammer on the right is about 3 feet long (photo by R. Forbes, copied by V. Brooks). ***Right***: A tree remnant 25 or 26 years later is rotting fast. Blue ruler is 6 inches long. *Continued on the next page.*

LOCATION B (cont'd). Tree remains, at arrows, are amid the boulders, shown here at a minus tide.

Southwest of Location B is the **North Beach bluff "corner"**. The fat black arrow points to the contact between colluvium, on the left, and the gently west-dipping Whidbey Formation. The Whidbey extends to the longer black arrow near the top of the bluff in the alcove a bit to the west. For about 7 feet from beach level is a sandy clay, over which is silvery gray 'peat' (tips of white arrows). The peat is compressed riparian vegetation. On the right edge of this April 2021 photo, the peat base is at 5 feet above the beach. Sub-peat clay supports the bluff in the alcove and underlies the area offshore.

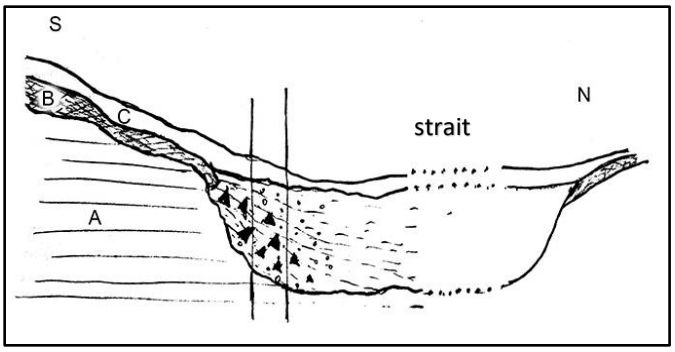
LOCATION C is at the west end of the alcove, site of an active landslide.'

1935 U.S. Army archive vertical aerial photo of Fort Worden. What's the stuff at the fat white arrow? Compare the alcove and the ledges near bluff top here and on the cover page. The ledges may be contacts, but for which geologic units? (See Table 1 in the guide's 'preamble'.) The curved arrow points to Location D. Battery Ash is at the circle. Battery Walker, at the star, has a looped road on the beach side; it is no longer there, thanks to active southward bluff retreat.

Just east of **Location C** at the west edge of the alcove, this window of Whidbey Formation peeks out of the unstable slope. Shed debris usually covers the top edge of the beach. The peat base is below beach level here but emerges a few tens of feet west of here and rises above the beach at the dogleg in the shoreline (between locations B and D), as shown in the photo immediately below. The peat extends west to Location D. (March 2021 photo)

Below: Shiny sub-peat clay supports the dogleg to the west of the alcove, just beyond Location C. The arrow points to the compressed peat, which is easily eroded by storm waves.

Above. About 60 feet beyond Location C in the base of the bluff, these dark pieces of subfossil wood are in the sub-peat Whidbey sandy clay that supports the sharp curve in the shoreline (above right). The wood is visible only when the outcrop is clean. The ruler is 6 inches long.



Between Locations C and D is a bluff-top layer of Everson sand/gravel and light brown clasts, the "jumble" herein, that is more obvious and lower to the west. This **hypothetical section across the strait** shows how geologic units may contribute to the appearance of the bluff face. Sea level may have been as high as letter B, but the water was shallow. We walk between the vertical lines, across the sediment input, into the sketch. A, Whidbey Formation alluvium; B, Vashon till; C, Everson diamicton and gmd; triangles, "jumble" of clasts of Whidbey and layers and till. (See Location G.) *No vertical or horizontal scale implied.* (2016 sketch by J. Dragovich; digital version by V. Brooks.)

East of Location D were indications of seismic activity. ***Upper left***: An injection structure, now gone, where liquefied sub-peat sandy clay spurted up through the Whidbey peat. ***Upper right***: Just beyond the last outcrop of the peat were convoluted sandy beds (also now gone), *below* the clay that is above the peat. ***Lower left***: Remains of a paired injection (at arrows) and its dividing 'wall' (star) were east of the single injection above left and had the same strike. (May 2021 photo) ***Lower right***: A thin injection up through the peat in one of many tension cracks. (June 2021 photo)

LOCATION D, **the west end of the peat** (at white arrow in photo ***above***). The red lines show the dip of bedding above and west of the end of the peat. The beds just above the peat on the right contain scattered pebbles and coarse sand where the peat is cut out; there is no faulting here. Bedding to either side of the coarse material is uniform sandy clay. The clay above the peat drops to beach level and continues west for about 150 yards, supporting the bluff. In the photo ***below***, the deformation is at the *top* of the clay above the peat. The plastic tent peg is set in sand that has cascaded down the bluff and partially covered the deformed sandy clay. About 4 inches of the 8-inch peg shows here.

LOCATION E. This ∽8-foot-high boulder**, an erratic,** is greenstone, a metamorphosed gabbro; there is a suitable source directly north in Canada. A bronze USGS benchmark medal lies on the top (at arrow tip). Turn around and note the distinct upper-slope ledge, with grass on it, above which is grayer bedded sand. This ledge may be a contact hinted at in the 1935 military air photo.

At the top of the bluff south across from Location E is the Everson "jumble" of light brown blocks in gravel. It includes this ∽10-foot **clast of Vashon till** (black line parallel to vague bedding). Follow the "jumble" layer containing the large (and small) light brown clasts to the west.

Soft-sediment deformation in the Whidbey Formation.

LOCATION F is the bluff between Locations E and G, where various sedimentary structures in Whidbey alluvium are exposed. Watch for the contact between Whidbey and Vashon and younger units.

At **LOCATION G**, in the upper bluff 150 feet west of Battery Walker is **the "jumble"**, of Everson age; it is just barely younger than Vashon till, which it also cut into and transported. Here, the "jumble" abuts/cuts into the Whidbey Formation clast source. The gray sediment east (left) of the fallen blocks is massive Whidbey sand. The force of the gravel-laden water (possibly beneath ice) carving into the Whidbey on the left was enough to dislodge (frozen?) clasts. Note the gravel between the blocks and at the upper right. Included among the Whidbey clasts are chunks of Vashon till that may be the source of much of the gravel. This "jumble" extends offshore for at least 70 feet and west beyond the end of this walk.

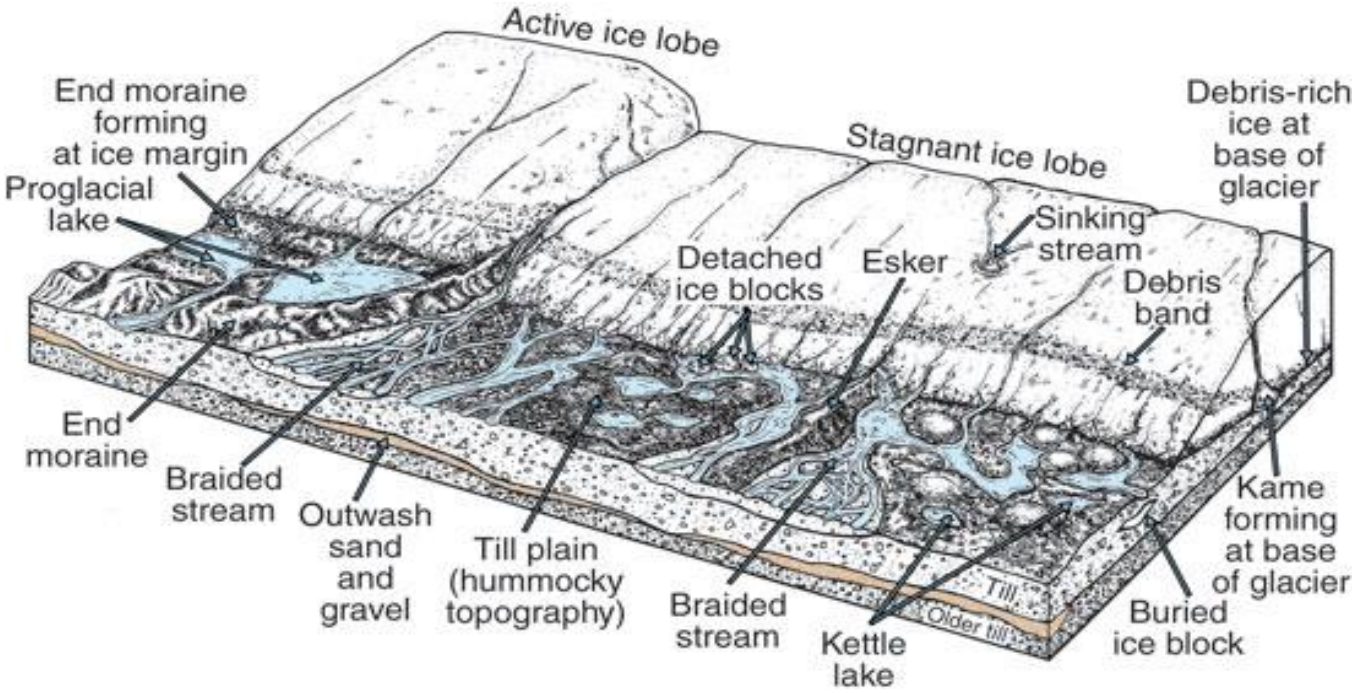
Is this debris of an outburst flood? Please argue for or against!

LOCATION H. A clast (∽4 ft wide) of **Vashon till in the "jumble"** about 300 feet east of the boat ramp in 2018. It is surrounded by smaller Whidbey and till fragments in gravel. The arrow indicates current direction. The local overall dip of the "jumble" is northwestward; note the imbrication (overlap) of elongate clasts.

Bluff-top vegetation rests on dark brown Holocene **loess** (eolian silt) that is part of the thin soil in this area.

Between here and the boat ramp (Location J), the Everson gmd and diamicton and underlying Vashon till are well exposed and intermixed—raising the question: how old is the "jumble"?

This sketch is at the Kansas Geological Survey's website (http://www.kgs.ku.edu, accessed in 2017). Even though it's for a mid-continent location, it shows what the **Everson depositional environments** must have been like here: shallow marine water beyond the ice edge, daily shifts in deposition. (Think: Glacier Bay, Alaska, today.)



LOCATION I. The >1-ton **"wandering rock"** in 2016, earlier chosen as a point from which to record bluff retreat at the point at the arrow. That distance varied from 40+ feet to ∽9 feet. In June 2019 its highest part was ∽45 feet from the point indicated. How far is it today?

Small, white, subfossil *Hiatella* (a cold-water clam), mussel shells, and rare foraminiferans have been found in the gmd/diamicton, proving the gmd is marine. The sole known outcrop in the park that contained these shells eroded away early in 2021.

At LOCATION J, at the county park's boat ramp was this view (to the east) of the gmd surface at low tide after an April 2013 mid-tide storm removed beach sand and gravel. The low row of rocks crossing the beach has since washed away. At the boat ramp, note the arrangement of beach sand. (Photo by V. Brooks)

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Fort Worden's History

This fort was one of three authorized in 1896 (Spanish American War) to protect Puget Sound, but it was not until 1903 that it was established as an Army post. In that year more than 20 buildings were erected, including a power house; communications by cable among the three forts were set up then. The fort expanded during WWI. That year saw construction of barracks and officers' quarters. The balloon hanger was built in 1921.

After 51 years of operation, the fort was closed in 1953, and soon after, it became the Fort Worden Diagnostic and Treatment Center (a juvenile detention center). The Army retained control of the fortified facilities. The fort was set up as an emergency site in 1962, a command center in case of an atomic war.

In 1973 the fort was acquired by the Washington State Parks and Recreation Commission; it became a park, and the first campground was opened. Three years later, the Artillery Museum opened, and in 1982, the Commanding Officer's house became a museum.

Today, part of the fort area is run by the Port Townsend Public Development Authority. The park is home to the Port Townsend School of Woodworking, Copper Canyon Press, a campus of Goddard College, and the Port Townsend Marine Science Center. The State operates the campgrounds and maintains the lighthouse and the trails. Using park property requires a Discovery Pass, available at several places within the park.

A longer version of this guide, with a reference list, is on the Quimper Geological Society website; see (https://quimpergeology.org/wp-content/uploads/2019/11/GEOLOGIC-GUIDE-TO-BLUFF-ALONG-NORTH-BEACH-FORT-WORDEN-Oct2019.pdf); it contains photos of outcrops before the winter storms of 2020-21.