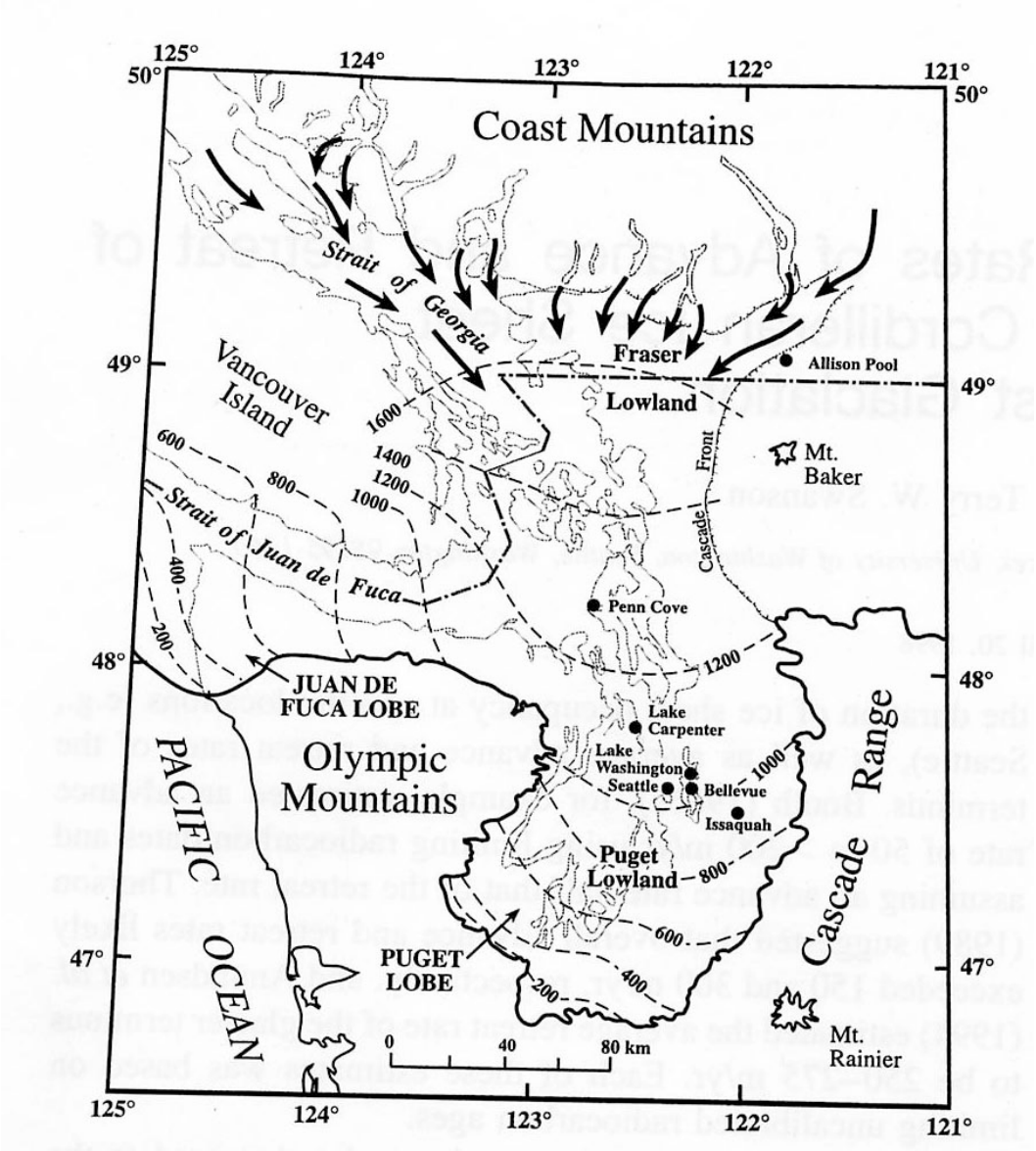
Whidbey Island Glaciation

During the last glaciation, the margin of the Cordilleran Ice Sheet (CIS) expanded from the Coast Mountains and Fraser Lowland of southwestern British Columbia into northwestern Washington. As the CIS reached the Olympic Mountains, it divided into two lobes: one flowed west through the Strait of Juan de Fuca out onto the now-submerged continental shelf (the Juan de Fuca Lobe), while the second (Puget Lobe) flowed south into the Puget Lowland between the Olympic Mountains and the Cascade Range. Similar to much of the landscape of the Puget Lowland, Whidbey Island's topography and underlying stratigraphy is strongly imprinted by the advance and retreat history of the Puget Lobe during the last glaciation.



As the Puget Lobe advanced southward, it dammed the predominantly northward flowing drainage system which had developed before glaciation. This created a set of proglacial lakes which deposited fine-grained sediments (clays) now known as the Lawton Formation. Next, when the ice was closer, the sediments from glacial runoff, mostly well-sorted sands, were deposited as the Esperance Formation. On top of this is the poorly-sorted Vashon till, deposited directly by the glacier. All of these units were further carved and shaped during the subsequent retreat of the ice, so that both depositional and erosional features are present on the island.

Travel north on I-5 to Exit 189 (Mukilteo Whidbey Island exit) and take Highway 526 west Follow 526 until reaching an intersection. Keep to the right and follow the traffic signs directing traffic towards the Mukilteo Ferry and 525 (Mukilteo Speedway). Follow 526 to the bottom of a steep hill. Keep to the right and turn right (north) onto 525 (Mukilteo Speedway). Signs will point to the Mukilteo Ferry. Merge right into the ferry lane at the appropriate location along the Mukilteo Speedway.

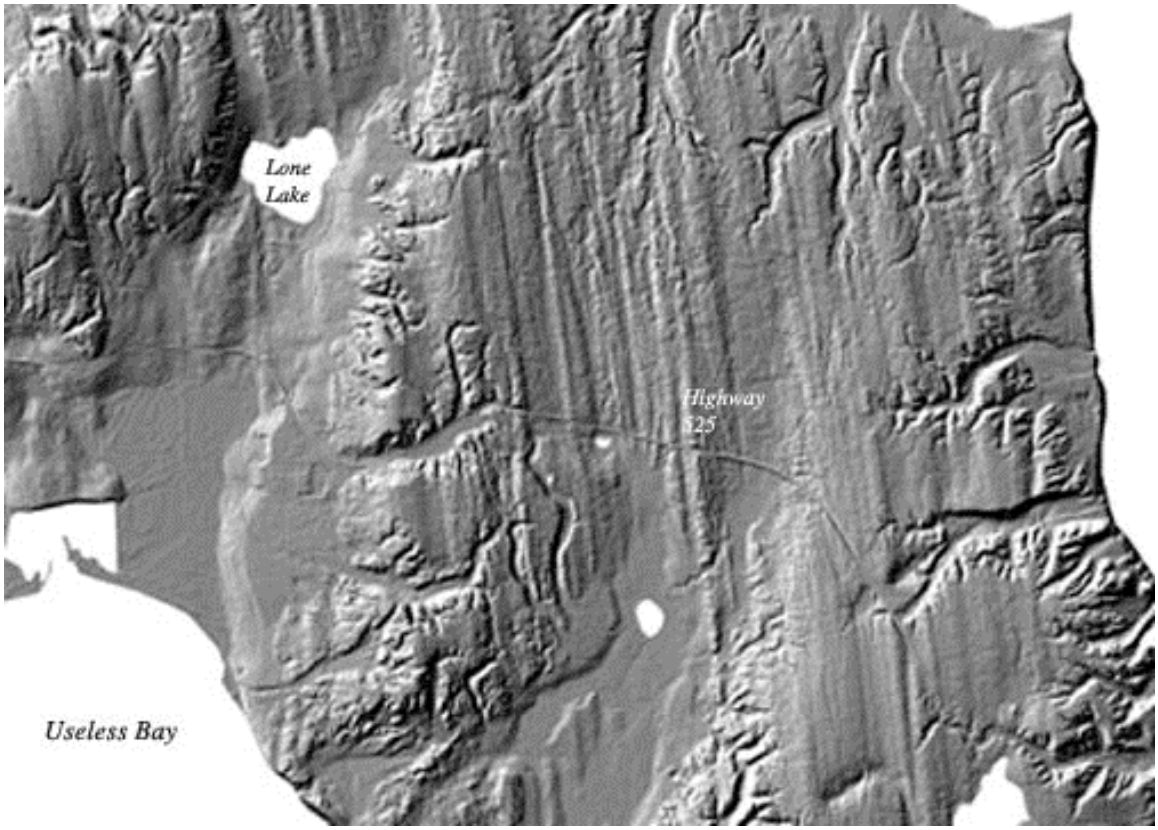
Set odometer to 0.0 miles on the ferry. Exit the ferry terminal at Clinton, merge to the left lane and go north on 525. At 0.2 miles, turn left onto Humphrey Road, at 0.4 miles left onto Berg Road, at 0.5 miles right onto Conrad Street. Park on the left-hand side of the road near the intersection.

Stop 1. Clinton Erratic

This is a greenstone, which is what, exactly?

Note the compass orientation of the long axis of the exposed part of the rock, and examine the surface for grooves or striations. What does this suggest about the timing of deposition for this erratic?

Return to 525 north. Upon leaving Clinton, the road crosses a post-glacial outwash plain, with many individual channels which are shown on the LIDAR image below. At 1.8 miles, turn right onto Forgotten Lane and park at the wooden water tower.



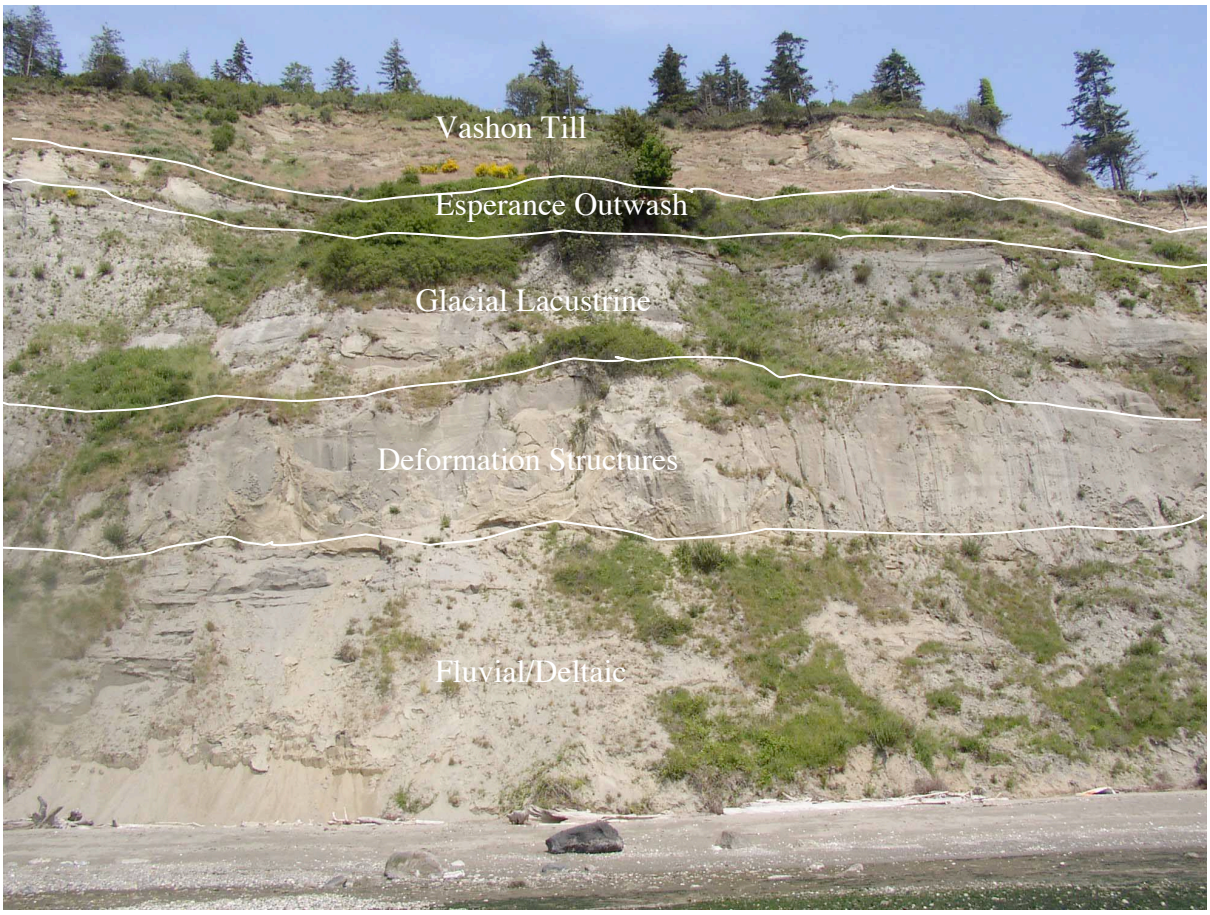
Stop 2. Clinton Water Tower

The bluff to the southeast of the tower consists of two units; the lower is outwash and the upper is till. Describe their different textures and comment upon the shape of the contact between the two.

Return to 525 north. At approximately 7.0 miles, note Useless Bay to the left, named for its shallow depth. Multiple shorelines are visible between Useless Bay and Lone Lake on the LIDAR image above. At 9.3 miles, turn left onto Double Bluff Road and proceed to the county park at the end.

Stop 3. Double Bluff

At this stop we will have an opportunity to observe the complete advance glacial stratigraphy and older non-glacial units defined here as the Whidbey Formation. It is possible to observe glacial till, glacial marine drift, and outwash from a previous episode of glaciation dating from around 180,000 to 250,000 years ago, as well as deposits from the last glaciation.



Deformation structures are exposed in the non-glacial units about 20 m above the beach. The Vashon glacial stratigraphy is represented in the upper 20 m of the bluff.

Describe the composition, texture, and thickness of each layer. Note in particular the deformation structures, which have been attributed to liquefaction, during which the sediment loses its cohesion and stiffness, flowing like a liquid. Such deformation may arise from gravitational loading of the sediment or from disturbing it during earthquakes. What do we know about the history of this area that might make it difficult to decide between the two?

Return to 525 north. At 26.0, highway 525 becomes highway 20. Note that the topography is flatter here-- we are on the upper surface of a moraine delta. At 31 miles, enter Coupeville and turn left onto S. Main Street. Drive past the school and park at Big Rock Apts.

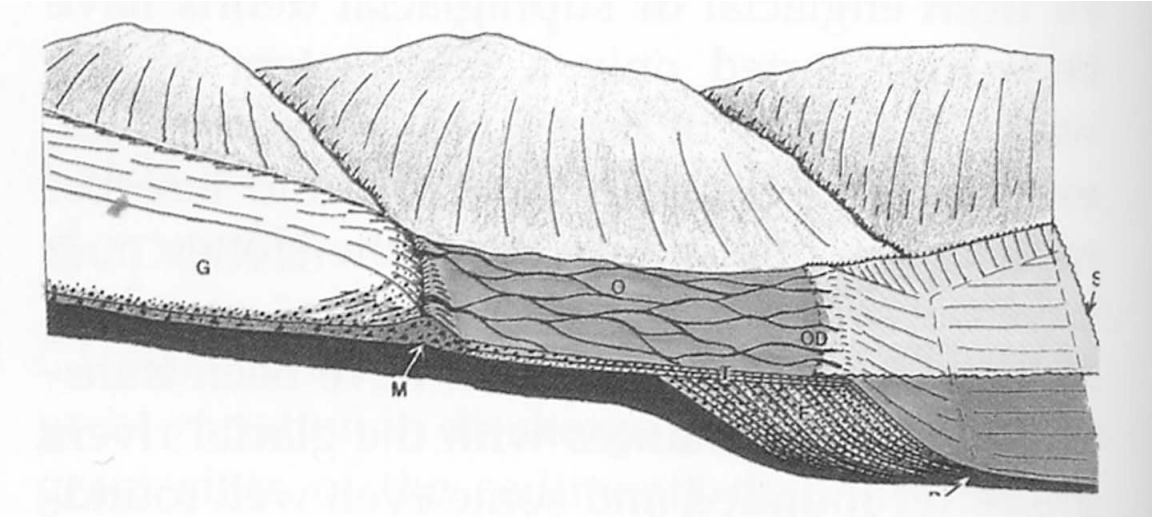
Stop 4. Coupeville Erratic

This is another greenstone erratic carried from the vicinity of Mt. Erie on Fidalgo Island. (Mt. Erie will be visible towards the end of the trip.) Estimate its exposed dimensions.

Return to 20 north. At 33.5 miles pull into the slow-moving vehicle turnout and park at the entrance to the gravel pit.

Stop 5. Central Whidbey Gravel Pit

We have been driving across a delta that developed in front of the terminus of the glacier. This exposure reveals part of the internal structure of such a marine delta, shown schematically below:



What is the composition of these beds? Hint: This is a gravel pit. Which way are they dipping? How does this compare with the diagram above?

Continue on 20 north. Look for kettles (depressions) around Penn Cove. The cove itself was occupied by a body of stagnant ice which was subsequently buried in outwash during an episode of readvancing ice. At mile 35, turn left onto Libbey Road. At mile 36, turn left onto Hill Valley Drive and enter Fort Ebey State Park. Park in the Lake Pondilla parking lot.

Stop 6. Fort Ebey Kettle

Walk down to the beach and identify the kettle, which has been partially dissected by wave action. Note the collapse features. Look for pumice clasts. What are two possible explanations for how the pumice arrived here?

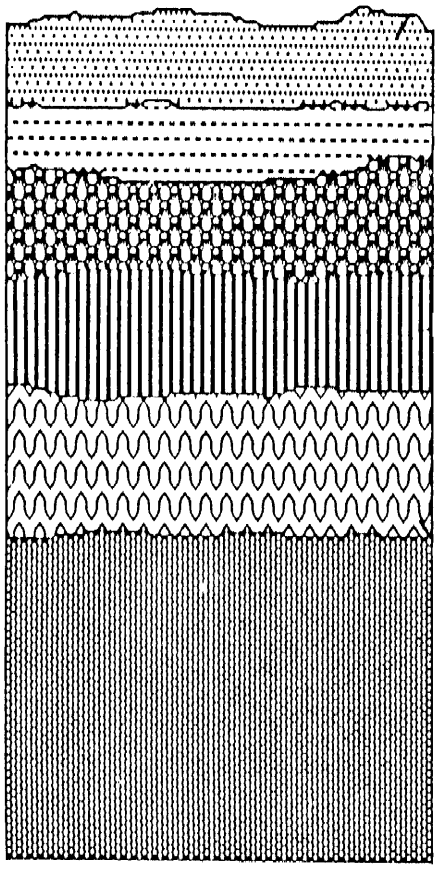
Describe the different textures of sediment exposed along the beach.

Return to 20 north and drive across Deception Pass to Fidalgo Island. Time permitting, stop at Mt. Erie. Return to Seattle.

Fidalgo Island Field Trip

INTRODUCTION

Fidalgo Island is one of the San Juan Islands, which are composed of a series of **terranes** sandwiched between the North Cascades and Vancouver Island. These terranes are interpreted as having originated as small oceanic islands that became accreted to the continent. One way to demonstrate that a terrane is of oceanic origin is to locate and identify the remains of oceanic plate material at the **suture zone** where the collision took place. Such material typically occurs as a distinct suite of rocks known as an **ophiolite sequence**. The structure of an ophiolite sequence is illustrated below:



TURBIDITES: Poorly-sorted sandstones derived from sediments that sweep down off the adjacent continent onto the deep ocean floor.

PELAGIC SEDIMENTS: Deep marine sediments deposited onto the ocean floor, primarily by biological precipitation. Commonly contains **chert**, a massive chemical sedimentary rock composed of silica (quartz).

PILLOW BASALTS: Mafic lava which was extruded onto the ocean floor, forming a mass of small, rounded shapes called **pillows**.

SHEETED DIKES: Beneath the lava flows, magma was continuously injected along cracks in the rift zone, creating linear sheets of **basalt** dikes.

LAYERED CUMULATES: Layers of **gabbro** that were added to the base of the crust from the magma chamber beneath the rift zone.

ULTRAMAFICS: Olivine-rich rocks from the mantle, commonly **peridotite**. This layer typically has been hydrothermally altered into a metamorphic rock called **serpentinite**.

During collision and subduction, these layers usually become faulted and folded so extensively that identifying an intact ophiolite sequence is nearly impossible. Nonetheless, if Fidalgo Island represents the collision boundary for an oceanic terrane, then one should be able to find most of the components of the above sequence.

TIPS FOR FIELD OBSERVATIONS

When stopped at each of the outcrops, try to identify portions of the ophiolite sequence. Make a note of the location of each layer alongside the above diagram.

Record the kind of rock encountered at each locality on the attached map. While driving between stops, see whether the same rock can be identified in roadcuts or other exposures. Try to fill in the blank portions of the map by extrapolating out to the edges of a particular kind of rock. For example, it is reasonable to assume that all of Mt. Erie is composed of the same rock type.

At each stop, consider and briefly answer the questions listed below. Observe the outcrop, then make your best interpretation of what is revealed there.

ITINERARY

STOP #1: Little Mountain Viewpoint

Take **Exit 225** from **Interstate 5 North**. Turn **right** at the end of the offramp, then immediately **left** onto **Cedardale Street**. Turn **right** onto **Blackburn Road**, and follow this to a **gravel road** on the **right** that is marked as the entrance to **Little Mountain Park**. The viewpoint is at the top of this gravel road.

Weather permitting, we will stop here to look across the bay to the hills that comprise the San Juan Islands. We are standing on the foothills of the North Cascades looking westward. Note that much of the bay has been filled in with delta sediments carried out of the North Cascades by the Skagit River.

We will pass over the Skagit River delta on the way to Fidalgo Island. From **I-5**, take **Exit 230**. Follow **Route 20 West** into Anacortes, then follow the signs to the **San Juan ferries**. Instead of turning into the ferry lot, continue straight into **Washington State Park**.

STOP #2: Green Point

Take the **first turnout** on the Washington State Park **Loop Road**, and park near the boat ramp.

Look at the rocks exposed along the shoreline. Because the exteriors have been so heavily weathered here, you will need to break open a fresh surface for examination.

What is the dominant mineral in this rock?

Why is this type of rock rarely encountered at the Earth's surface? Describe one way this rock could have ended up at this location.

Note the pattern of distribution for vegetation. Why might plants have difficulties growing on the types of soils that form here?

Mark this location on the ophiolite sequence diagram and the map, then try to fill in its extent as we drive to the next stop. Note that wherever this rock type is exposed along the coastline, it appears as a dark band.

STOP #3: Mt. Erie

Return to the ferry turnoff. Immediately **before** the turnoff, turn **right** onto **Anacortes Beach Road**. Follow this to its end, then turn **right** onto **Havekost Road**, then take a **left** onto **Rosario**. At the **Lake Erie Store**, turn **left** onto **Heart Lake Road**. Next, turn **right** onto **Mt. Erie Road** and follow it to the top of Mt. Erie.

Describe the rock exposed at the top of Mt. Erie.

Do you consider this rock to be a part of the ophiolite sequence?

Why is this kind of rock located here?

This rock is very resistant to erosion and forms most of the highlands in the San Juan Islands. Note the stratigraphic relationship of this pluton with that of the other outcrops. This will place constraints on the ages and timing of geologic events.

STOP #4: Rosario Beach

Return to the Lake Erie Store. Continue past Campbell Lake, then turn **right** onto **Route 20 West**, then **right** onto **Rosario Road**. Next, turn **left** onto **Rosario Beach**, keep **left at the fork**, and park at the beach.

Follow the trail beyond the picnic shelter to the large outcrop looking over the water of Rosario Bay. A number of different rocks are exposed here at different levels. Walk around the area, identifying different kinds of rocks. Keep track of the layers you have encountered, starting at the water's edge and leading up to the top of the hill. Also note the orientation of the layers.

The sedimentary layers exposed here were originally deposited horizontally. What is their orientation today?

Note this location on the map and place it within the ophiolite sequence.

STOP #5: Deception Pass

Return to **Route 20 West**, turn **right** onto it, and continue south to Deception Pass. Park alongside the road on the north side of the bridges and proceed carefully to the outcrops. **Watch for traffic**.

What kind of rock is exposed here?

Have you seen similar rocks at any other stop? Which one?

Note this location on the map and find its position in the ophiolite sequence.

INTERPRETATION AND CONCLUSION

You have now assembled enough petrologic and stratigraphic data to make your own interpretation of the nature of the tectonic events that led to the formation of the island. Are you convinced that the rocks at these outcrops represent an ophiolite suite? What other strata would you like to find to strengthen this conclusion? Where would you go on the island to look for additional evidence?