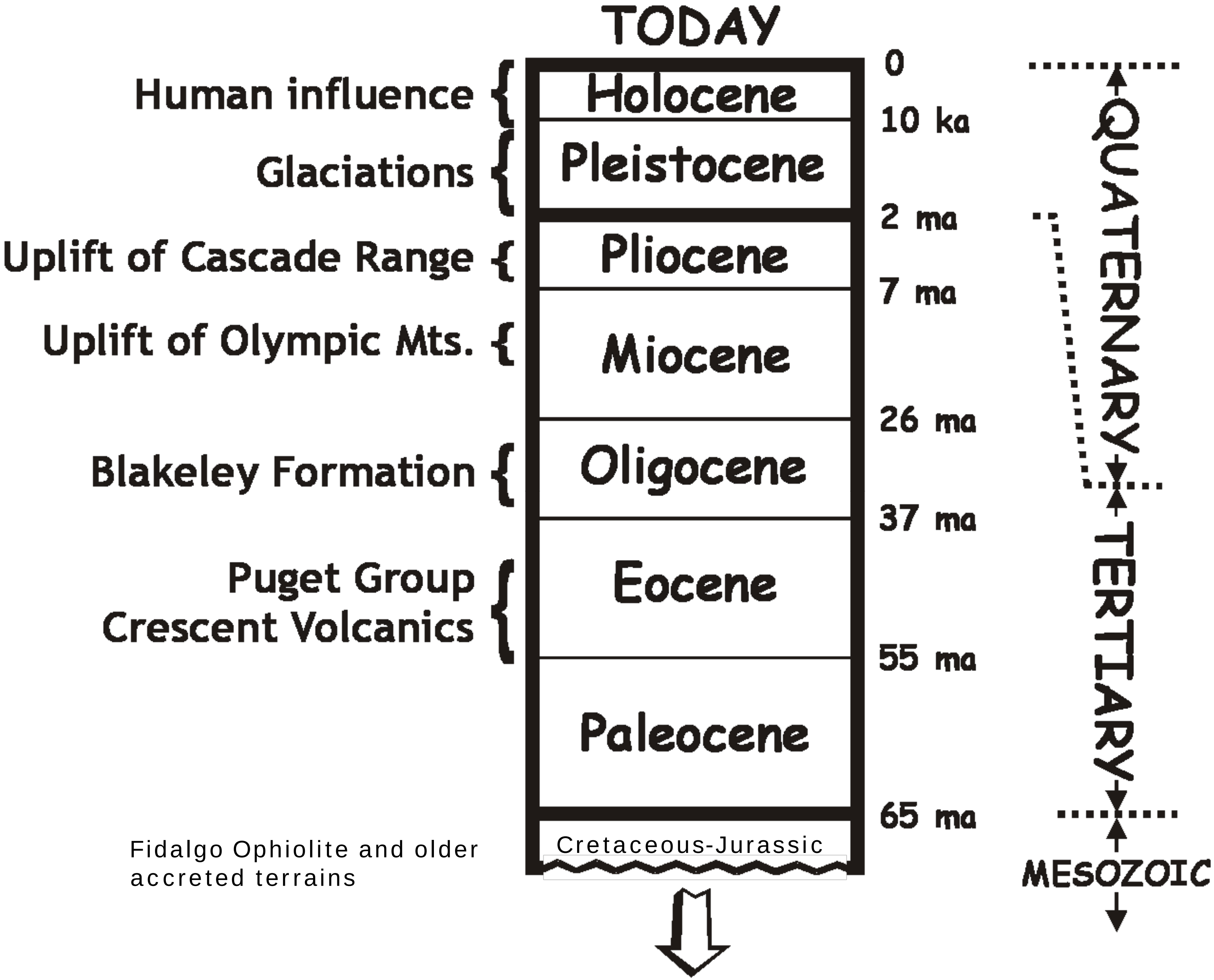
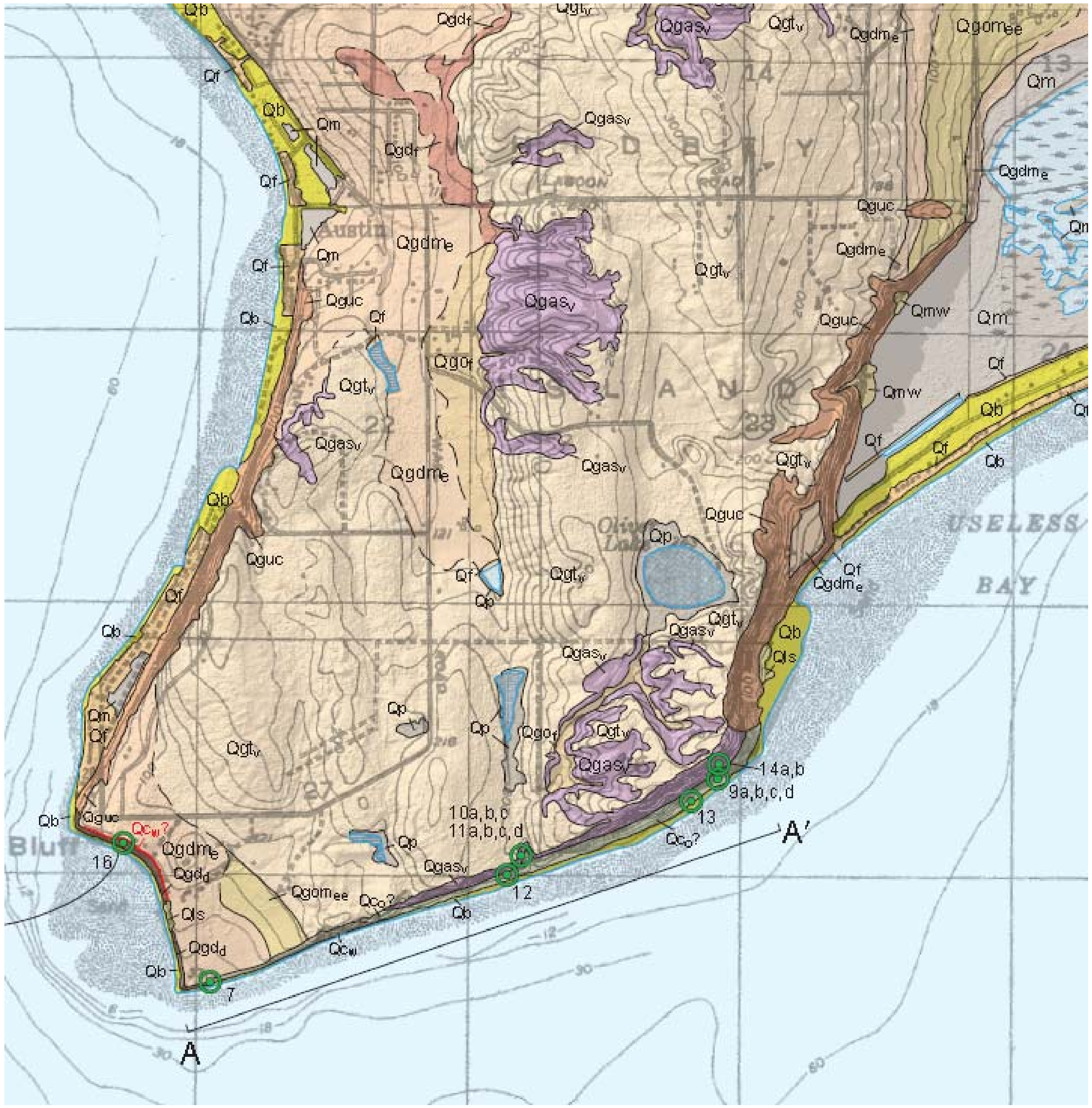

TODAY
Human influence
Glaciations
Uplift of Cascade Range
Uplift of Olympic Mts.
Blakeley Formation
Puget Group
Crescent Volcanics
Fidalgo Ophiolite and older accreted terrains
Holocene
Pleistocene
Pliocene
Miocene
Oligocene
Eocene
Paleocene
Cretaceous-Jurassic
0
10 ka
2 ma
7 ma
26 ma
37 ma
55 ma
65 ma
QUATERNARY
TERTIARY
MESOZOIC

Double Bluff



Vashon Stade

Qgt$_v$ **Till**—Typically unweathered, unsorted mix of clay- through boulder-size material (diamicton) deposited directly by ice; includes extensive areas of compact (advance outwash?) sand; compact, well-developed facies resemble concrete; locally loose in ablation till (also separately mapped as unit Qgta$_v$) and well-sorted in some sand-dominated areas; commonly has erratic boulders on the surface; gray where fresh, oxidizes to yellowish brown; very low permeability in compact diamicton but locally highly permeable in sandy or loose facies; most commonly matrix supported; cobbles and boulders commonly faceted and (or) striated; surface mostly fluted by overriding ice; generally forms a patchy and seemingly randomly distributed cover up to at least 70 ft thick, with 2 to 30 ft most common; in the center of some well-formed drumlins, exposed as well-developed lodgment till more than 30 ft thick that pinches out in less than 300 ft, giving way to well-bedded, compact (advance outwash?) sand; may include flow banding; typically forms vertical faces in coastal bluffs; locally resembles unit Qgdm$_e$; lies stratigraphically between overlying unit Qgdm$_e$ and underlying units Qga$_v$ and Qgas$_v$; may include unrecognized exposures of older till. Regional age data appear to constrain the age of the unit to between about 18 ka and the onset of the Everson Interstade.

Qga$_v$ **Advance outwash**—Locally bouldery pebble to cobble gravel, sand, and some layers and lenses of silt and clay; may contain till fragments; gray to grayish brown and grayish orange; clasts typically well rounded, well sorted, and clean, except in ice-proximal deposits which are less sorted and more angular; compact; mostly well stratified; very thinly to very thickly bedded; contains planar and graded beds, cut-and-fill structures, trough and ripple cross-beds, and foresets; maximum observed thickness estimated at about 85 ft; deposited as proglacial fluvial (and deltaic) sediment; tends to coarsen upward in complete sections; may include Evans Creek alpine outwash; commonly overlain by unit Qgt$_v$ along a sharp contact, and lies stratigraphically above units Qc and Qc$_o$. The estimated age is about 18 to 20 ka or older. Locally divided into:

Qgas$_v$ **Advance outwash sand**—Mostly lacustrine sand with layers of silt; locally grades upward into gravel; thick and extensive, with maximum observed thickness of greater than 170 ft; commonly forms angle-of-repose slopes along drainages and coastal bluffs; includes Lawton Clay and Esperance Sand (bluff section A). Widespread, relict valleys in southern Whidbey Island are deeply incised into unit Qgas$_v$ and typically lack modern streams, due to high permeability in the unit.

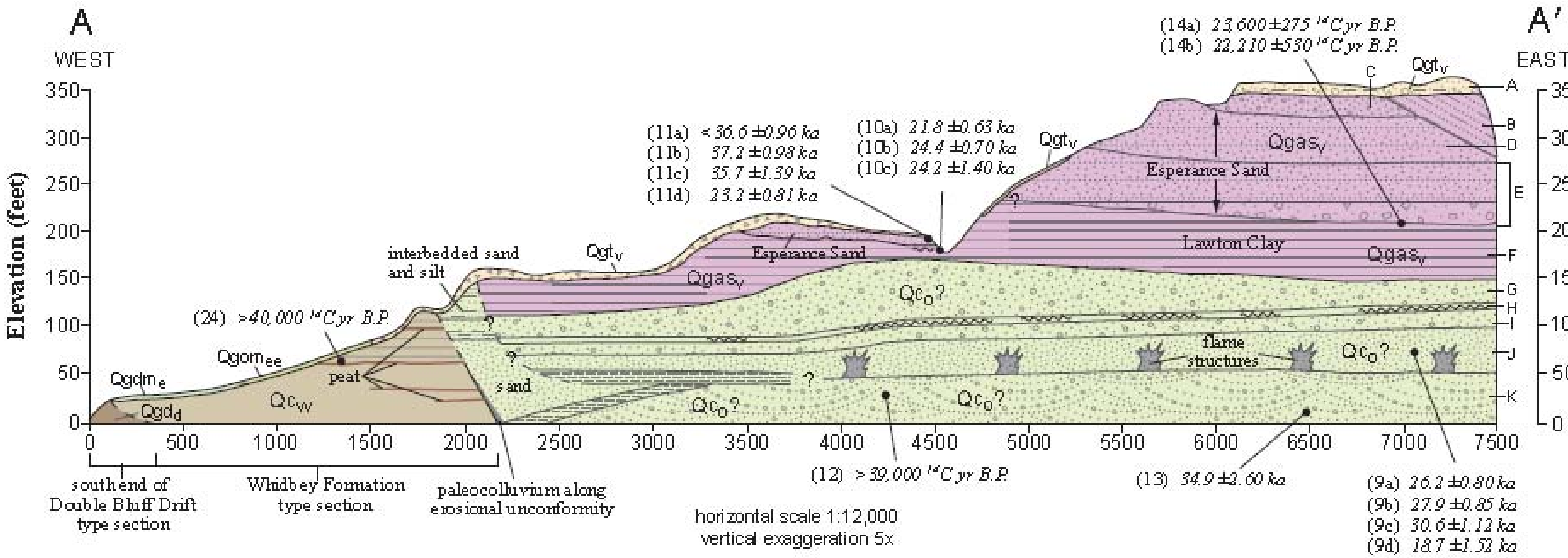
DEPOSITS OF THE OLYMPIA NONGLACIAL INTERVAL (PLEISTOCENE)

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

Qc$_o$ **Nonglacial deposits**—Sand, silt, clay, peat, and minor fine gravel; where shown in our map area, includes exclusively detrital peat, although nonglacial deposits are typically distinguished by the presence of in-place peat; compact; includes horizontally bedded, massive, and cross-bedded facies; commonly forms vertical bluffs; like units Qc$_w$ and Qc, probably deposited in a paleo-floodplain or channel setting.

INTERGLACIAL DEPOSITS OF THE WHIDBEY FORMATION (PLEISTOCENE)

Qc$_w$ **Whidbey Formation**—Sand, silt, clay, peat, and minor fine gravel; compact; mostly weathered to subtly variegated light-yellowish in exposed faces; includes floodplain and channel-sand facies. The floodplain facies typically is well stratified (subhorizontally) and slightly oxidized, forms prominent vertical bluffs, and contains discontinuous peat beds. The channel-sand facies typically is clean, gray, and cross-bedded to massive, and tends to form angle-of-repose slopes. Pollen indicates that climate at the time of Whidbey deposition was initially cool but then warmed (Hansen and Mackin, 1949; Easterbrook and others, 1967; Heusser and Heusser, 1981). The formation's type section (Easterbrook and others, 1967) is located east of Double Bluff at the south end of the map area (bluff section A). Based on a new radiocarbon date (27,980 ±530 ^{14}C yr B.P.) from about 2000 ft northwest of that type section (columnar section 6; Table 1, loc. 16), we queried inclusion with the Whidbey Formation of some deposits previously so mapped (Easterbrook and others, 1967). We also follow Stoffel's (1980) lead in reassigning sediment east of the Whidbey Formation type section from Whidbey Formation (Easterbrook and others, 1967) to units Qc$_o$ and Qgas$_v$ (bluff section A). We could not locate some exposures previously mapped as Whidbey Formation (Table 1, locs. 19–22) and may have locally included Whidbey deposits with unit Qc$_o$, Qc, Qguc, or Qmw. We believe the unit age to be about 125 to 80 ka, or stage 5.



Schematic bluff section, modified from Stoffel (1980). Subunit descriptions A–K condensed from Stoffel (1980): **A**, Vashon till and gravel; **B**, Vashon advance outwash silt and sand (beds dip 30-40° into bluff); **C**, Vashon advance outwash sand and gravel; **D**, Esperance Sand—cross bedded, fine; **E**, Esperance Sand—very fine sand and silt, with (ice-rafted?) large sandstone blocks; **F**, Lawton Clay—glaciolacustrine silt and clay; **G**, nonglacial, horizontally laminated sand with reworked silt fragments; **H**, nonglacial, horizontally laminated fine sand and massive clay and silt, deformed into diapiric structures; **I**, nonglacial, horizontally laminated sand with scattered trains and clusters of sand and silt pebbles; **J**, nonglacial silty sand with large flame structures of silt and sand (a prominent cliff former); **K**, nonglacial planar-bedded sand with scattered pebbles and rounded detrital peat fragments, rare cobbles, and abundant cut and fill structures. Alphanumeric symbols locate dates shown in Table 1.

South Whidbey Island Fault Zone

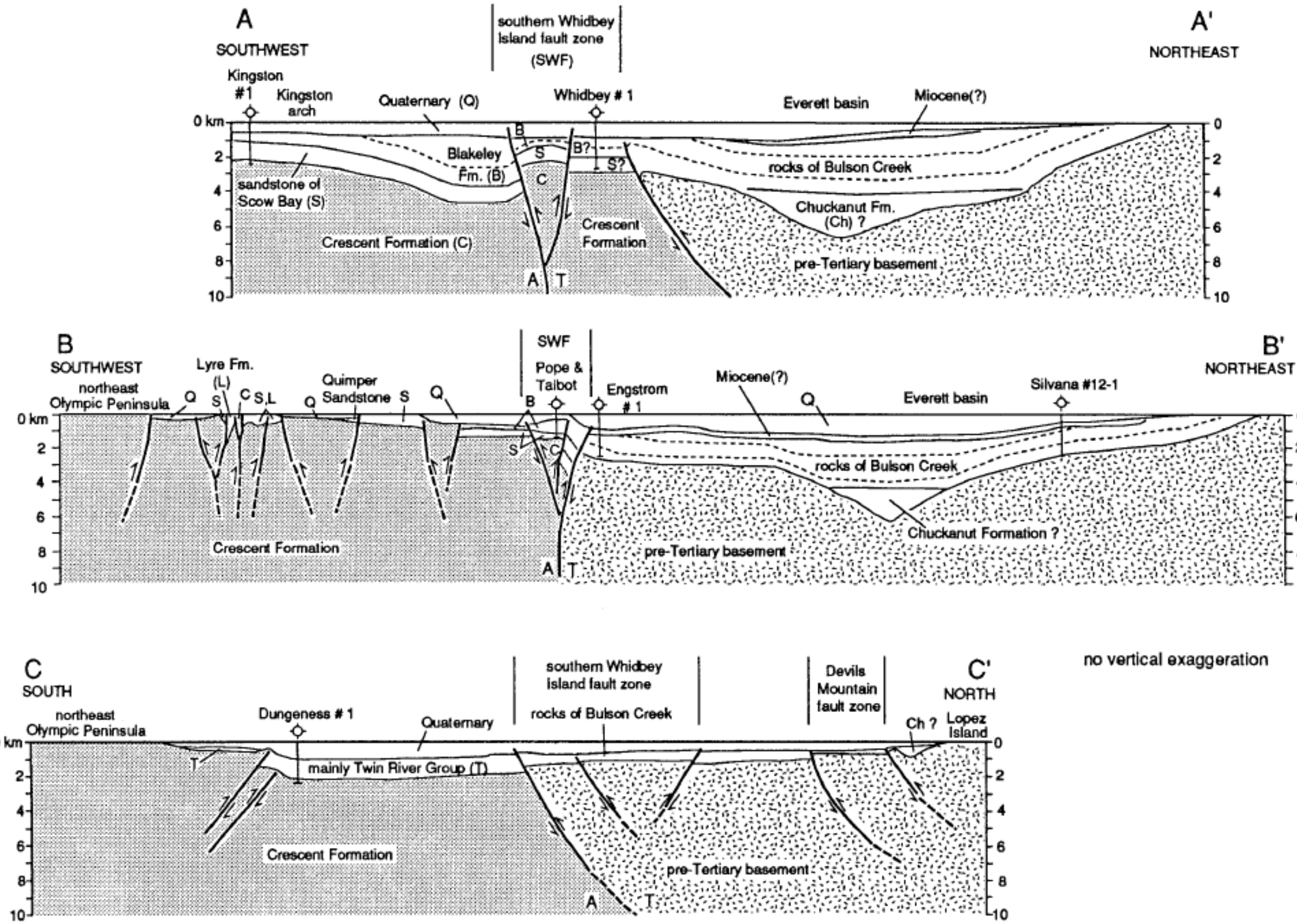
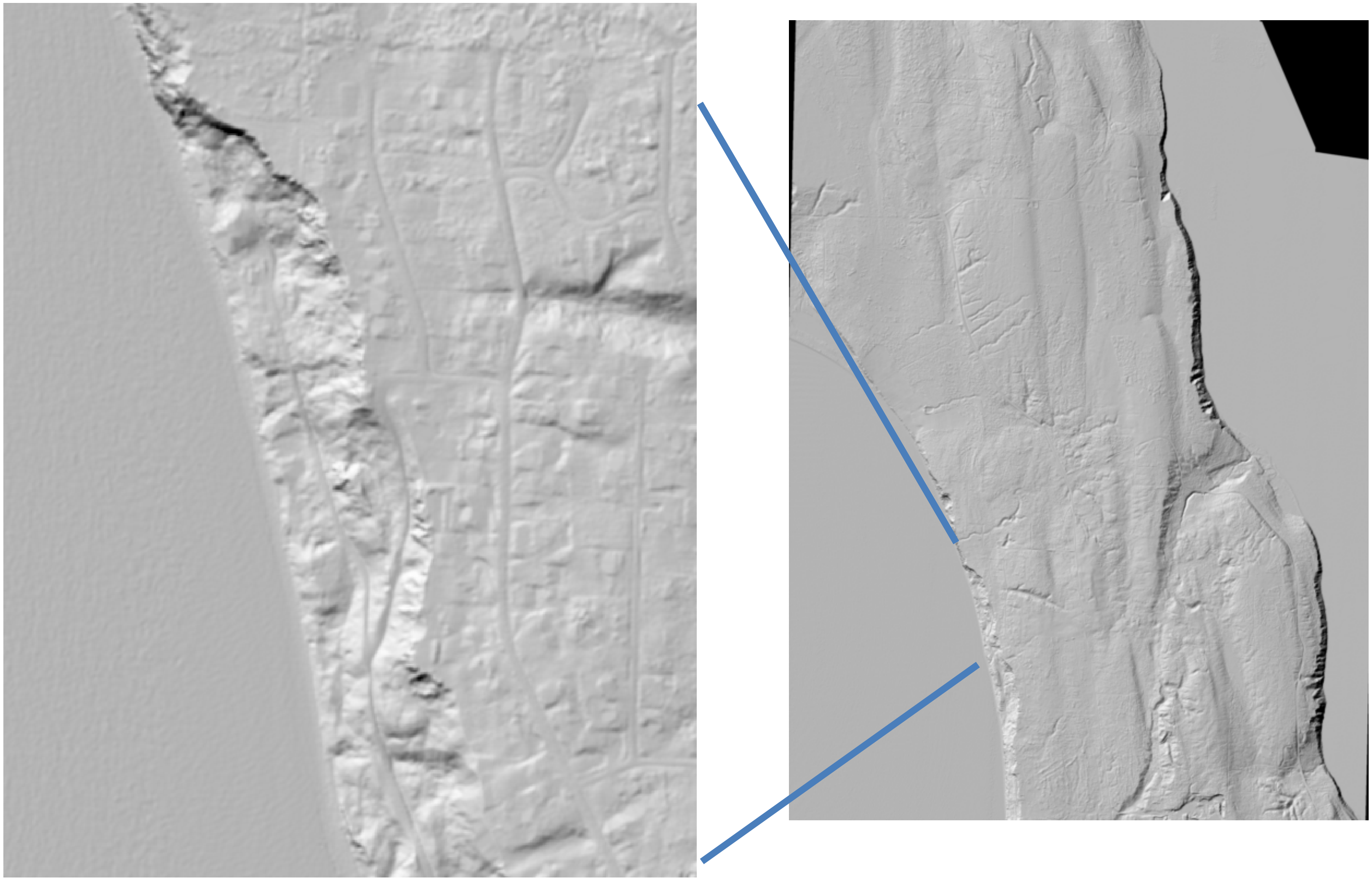


Figure 10. Geologic cross sections across the south Whidbey Island area. Section lines shown in Figure 2. Many faults (heavy solid lines) are inferred to have undergone both vertical offset (indicated by arrows) and lateral offset. T = lateral offset toward viewer; A = lateral offset away from viewer. Boreholes projected onto cross sections from various distances, as shown in Figure 2.

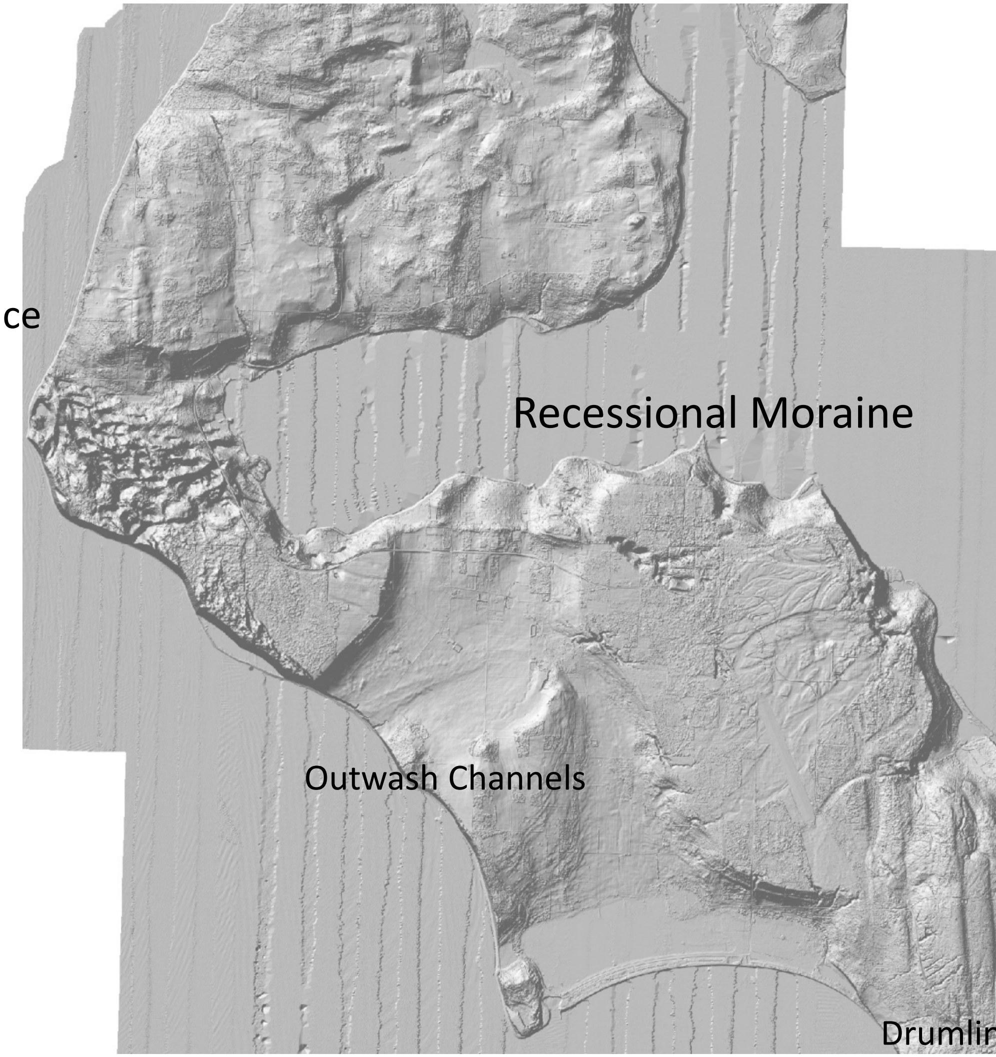
Samuel Y. Johnson, Christopher J. Potter, John J. Miller, John M. Armentrout, Carol Finn and Craig S Weaver
The southern Whidbey Island fault: An active structure in the Puget Lowland Washington, *Geological Society of America Bulletin 1996;108;334-354*

Ledgewood Beach



Ledgewood Beach

Central Whidbey Island Lidar



Rocky Point

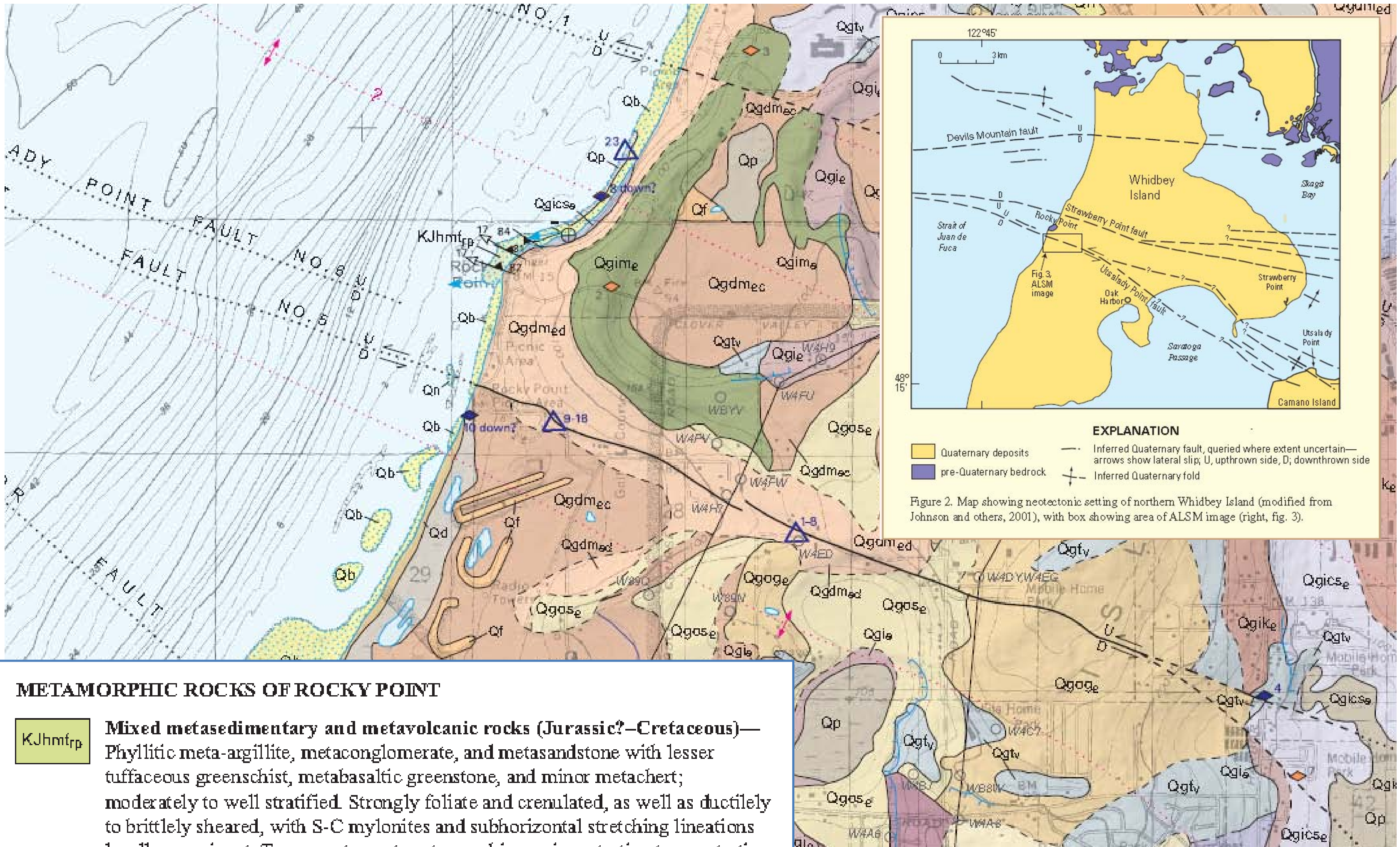


Figure 2. Map showing neotectonic setting of northern Whidbey Island (modified from Johnson and others, 2001), with box showing area of ALSM image (right, fig. 3).

METAMORPHIC ROCKS OF ROCKY POINT

KJhmf_rp	**Mixed metasedimentary and metavolcanic rocks (Jurassic?–Cretaceous)**—Phyllitic meta-argillite, metaconglomerate, and metasandstone with lesser tuffaceous greenschist, metabasaltic greenstone, and minor metachert; moderately to well stratified. Strongly foliate and crenulated, as well as ductilely to brittlely sheared, with S-C mylonites and subhorizontal stretching lineations locally prominent. Two syn- to post-metamorphic semipenetrative to penetrative deformations are evident. The deformational style of these rocks is likely due to Tertiary and (or) pre-Tertiary deformation near a major strike-slip fault zone.

Scarp of Utsalady Fault – Whidbey Island

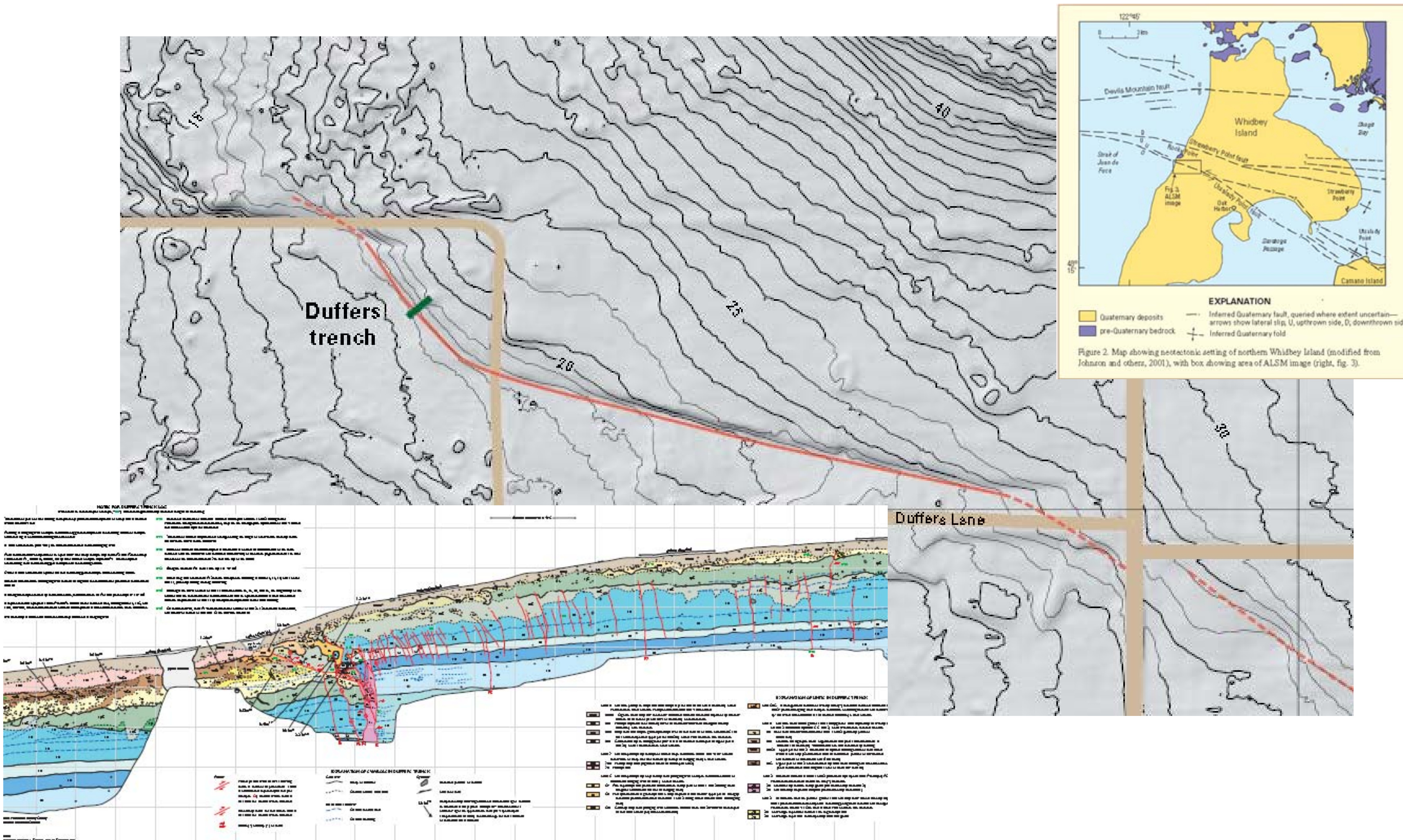
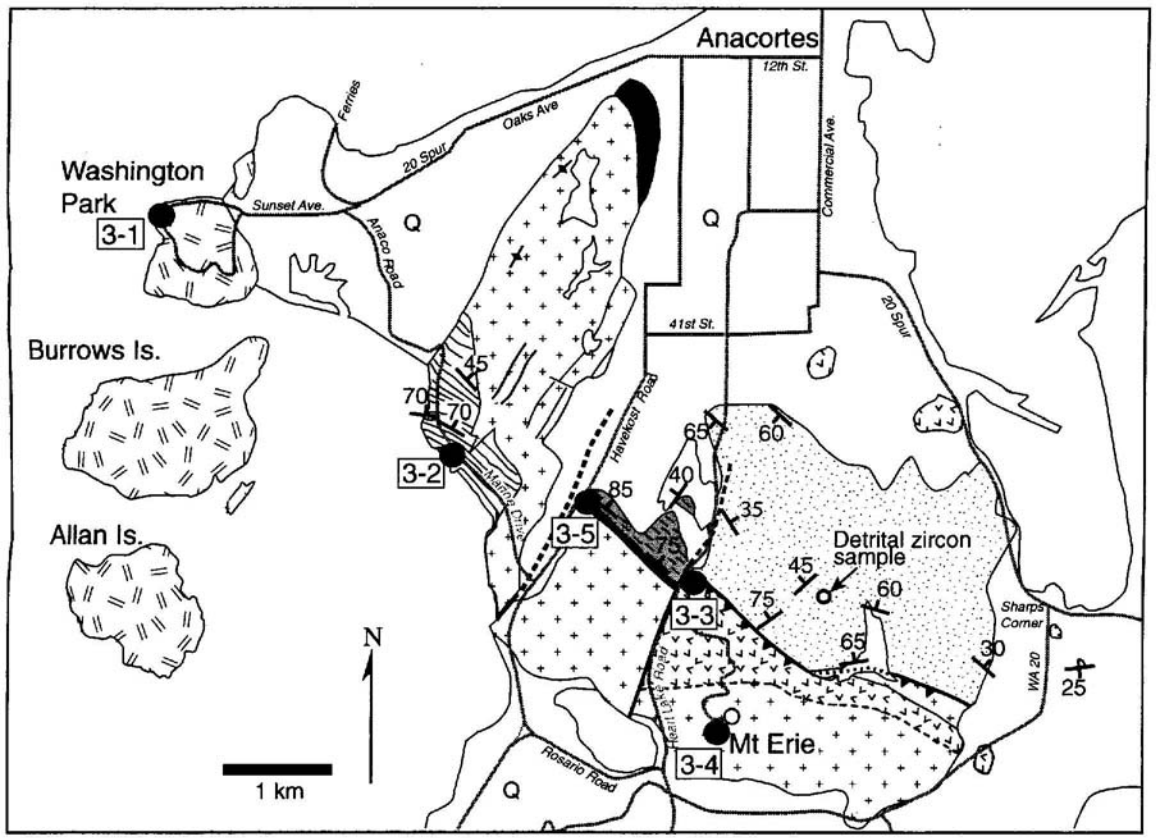
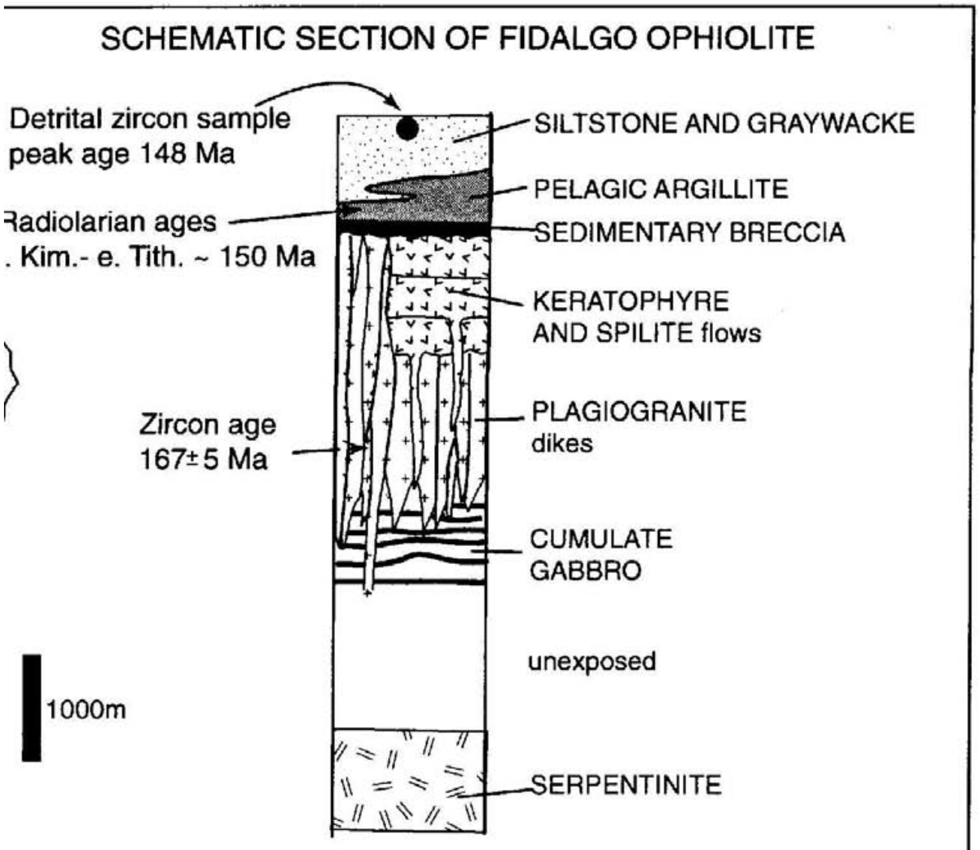


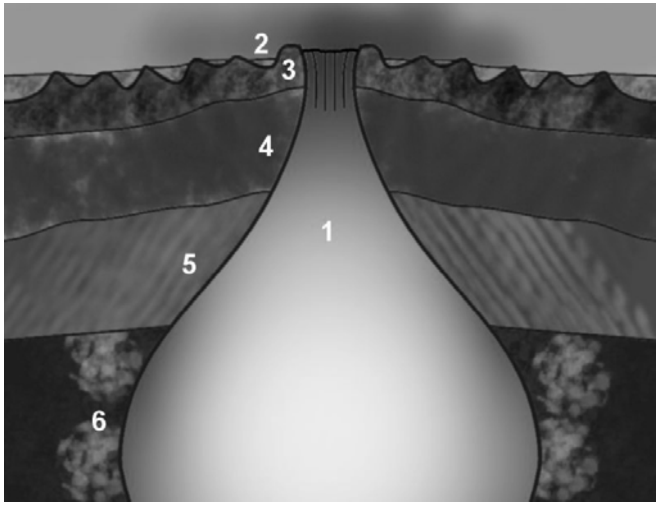
Figure 2. Map showing neotectonic setting of northern Whidbey Island (modified from Johnson and others, 2001), with box showing area of ALSM image (right, fig. 3).

Geologic Map of Anacortes



Map Units and Idealized Ophiolite (oceanic spreading center)





A simplified structure of an ophiolite suite:

1. axial magma chamber
2. sediments
3. pillow basalts
4. sheeted basaltic dykes
5. layered gabbro
6. dunite/peridotite cumulates

CEE 437 Field Trip

February 8 and 12, 2009

Health and Safety

Health and safety is our number 1 priority. There will be a sign in form to acknowledge health and safety training and the attendance at a "tailgate" meeting. The main health and safety issues are:

(1) Drive safely – observe speed limits and all other laws and regulations. Remember you are in University vehicles. ***This is especially important on the Loop Drive at Washington Park – the speed limit is 10 mph, the road is very narrow and shared with pedestrians and cyclists. Slow down and give a wide berth to foot traffic***

(2) Avoid climbing on slopes unless directed to do so.

(3) If on a slope watch for those below and avoid knocking down loose debris

(4) Watch for cars and traffic in parking lots when getting into and out of cars

(5) Dress warmly and with gear appropriate for rain. If chilled take a break in a vehicle

(6) Be aware of tides schedules when working beaches to avoid being stranded (Figure 1)

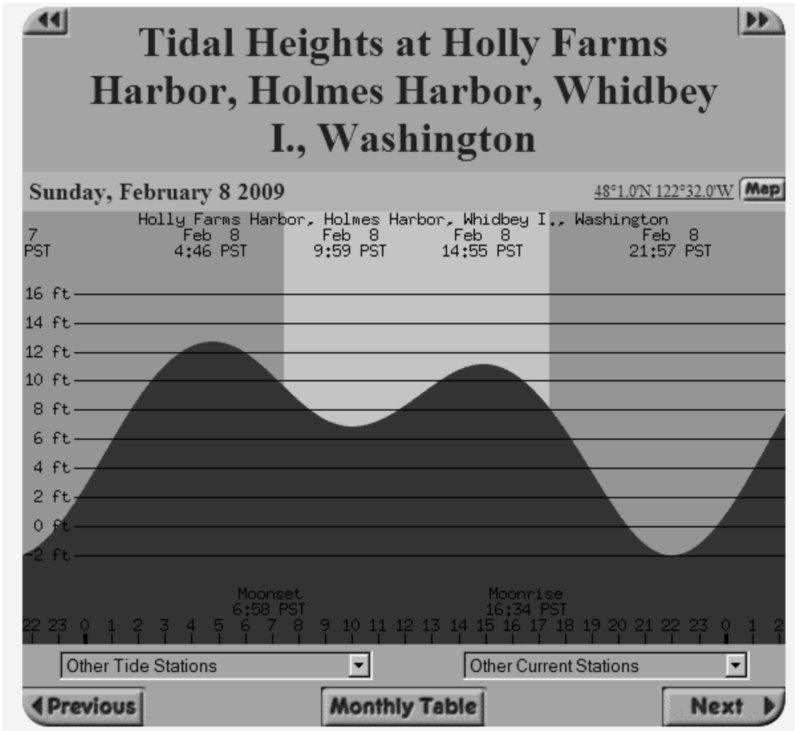
(7) If on a beach and there is an earthquake, head for high ground

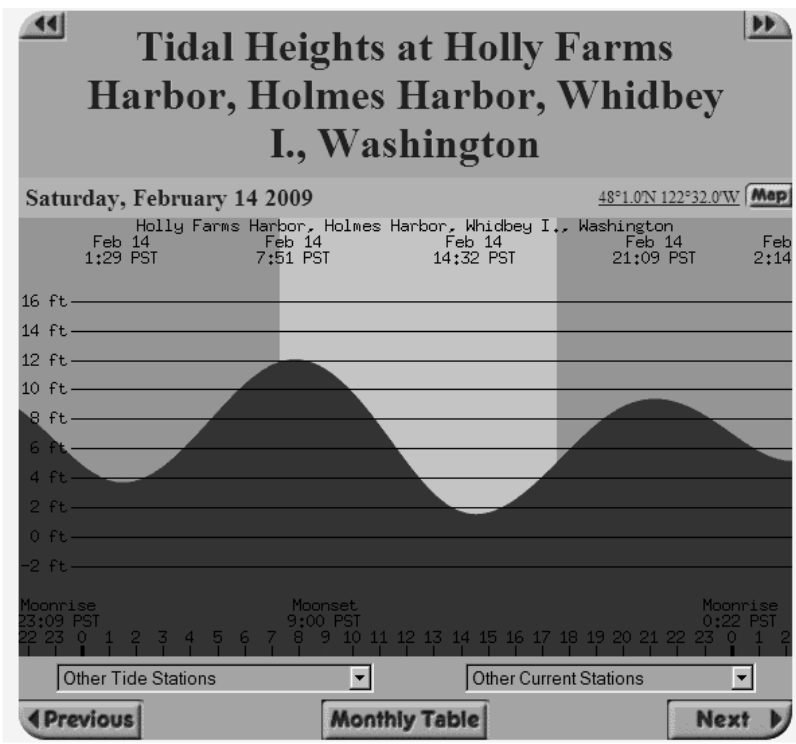
(8) Drivers have information on the nearest emergency rooms should accidents happen.

(9) Other:

Practical Matters:

There will be toilets (or at least Port-a-Potties) at Stop 1, lunch, and Stop 4. We will not have time for other stops before we start our return unless desperation sets in.


Tidal Heights at Holly Farms Harbor, Holmes Harbor, Whidbey I., Washington
Sunday, February 8 2009
48°1.0'N 122°32.0'W
Map
Holly Farms Harbor, Holmes Harbor, Whidbey I., Washington
7 PST
Feb 8 4:46 PST
Feb 8 9:59 PST
Feb 8 14:55 PST
Feb 8 21:57 PST
16 ft
14 ft
12 ft
10 ft
8 ft
6 ft
4 ft
2 ft
0 ft
-2 ft
Moonset 6:58 PST
Moonrise 16:34 PST
22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2
Other Tide Stations
Other Current Stations
Previous
Monthly Table
Next


Tidal Heights at Holly Farms Harbor, Holmes Harbor, Whidbey I., Washington
Saturday, February 14 2009
48°1.0'N 122°32.0'W
Map
Holly Farms Harbor, Holmes Harbor, Whidbey I., Washington
Feb 14 1:29 PST
Feb 14 7:51 PST
Feb 14 14:32 PST
Feb 14 21:09 PST
Feb 2:14
16 ft
14 ft
12 ft
10 ft
8 ft
6 ft
4 ft
2 ft
0 ft
-2 ft
Moonrise 23:09 PST
Moonset 9:00 PST
Moonrise 0:22 PST
22 23 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 0 1 2
Other Tide Stations
Other Current Stations
Previous
Monthly Table
Next

Stop 1: Double Bluff

Goal: Observe and understand glacial stratigraphic sequence. Note we are also effectively in the South Whidbey Island Fault Zone. There is a paper on this in each vehicle with interesting seismic reflection profiles.

Exercises:

(1) While walking on beach note and collect/identify the following rocks/sediments
  a. Granite
  b. Basalt
  c. Peat
  d. Sandstone
  e. Schist or gneiss
  f. Other?

(2) Using the stratigraphic column from the Freeport quadrangle map, confirm that you can recognize
  a. Vachon till
  b. Esperance sand
  c. Lawton Clay
  d. Sub-Vachon interglacial sands

(3) Observe and sketch
  a. Clastic dikes and flame (Consider liquefaction and whether these are seismically generated or not)

  b. Unconformity (features with appearance of being eroded off in the sedimentary column, hint: look, at the clastic dikes in the interglacial sands)

  c. Channels with coarse fill

  d. Crossbedding

  e. Slumped blocks of Lawton Clay (note position on the bluff -- If you can't get to it, it comes to you!)

Stop 2. Ledgewood Park

This stop complements Stop 1, by illustrating the consequences of slope instability. Note the LIDAR images that show classic "scallop" forms of moderately to deeply seated landslides. The LIDAR image also shows nice examples of the drumlinization, which typifies most of the sub-glacial surface of the Puget Sound area. We will discuss remediation measures to limit slide growth.

Note also in the complementary packer a photo of structure damage. This stop is mainly for looking, but keep an eye for the following:

(1) Head Scarp

(2) Landslide Toe

(3) Rotated blocks, "Drunken" trees

Non-Stop 2a. Moraines, Kettle, and Kame Country

Note the Lidar image of the Coupeville area. This is a classic recessional moraine where the glacial paused during its retreat. The kettles are the result of ice blocks that melted in the moraine and left a collapse behind. The topographic map shows many closed depressions.

We won't make a stop here (the LIDAR image tells the story better, and most of this area is forested). But as we travel along the highway, note an abundance of gravelly material alone the roadside of Route 20, and compare that with the till. The moraine material (like most supra glacial stuff) is well washed of its sand fraction and finer by outwash, but till, which deposits directly beneath the glacier has a wide range of grain sizes from clay to boulders. It can be quite competent and even fracture. In /Scandinavia and the Midwest, tills were assumed to be impervious and groundwater aquifers in underlying sands were thought to be isolated from agricultural contamination. Due to till fractures, this sadly appears to not be the case.

Stop 3. Rocky Point – Jurassic metamorphic rocks raised along fault, and surface traces of active faulting

The Rocky Point stop will look at active traces of the Ustalady Fault zone which runs east-west from the Cascades across Whidbey Island. We will look at the scarp, which was trenched and documented in a US Geological Survey poster, which we will discuss at the site.

Rocky Point is the first bedrock we see on this trip. What does its appearance tell us about relative motions of the two sides of the Fault zone? If we have time and tides are low enough to get to outcrops, we will take strikes and dips on the foliations of these metamorphic rocks.

Exercise – carefully look at the outcrops. What types of rocks were the original sources prior to metamorphism? Note foliation direction and obtain its orientation. Compare these to foliation directions in the plates of the Anacortes-Laconner geologic map.

Stop 4a. Marine Way, Anacortes.

This stop is a recent set of cuts in bedrock for planned residential construction. The main rock types are layered gabbro with granitic-composition dikes, overprinted by more recent fractures, both tensile and shear. With instructor guidance, note which are which, and note clay fillings (gouge) on some of the more prominent shear zones. Note the figure in the complementary handout showing an ophiolite sequences (rocks which are emplaced along oceanic mid ocean ridges). Our last stop in Washington Park will look at ultramafic peridotites, where we will do fracture mapping. Nearby is Mount Erie which is a small diorite pluton. Consider how this sequence of rocks – peridotite, gabbro, diorite, and granitic dikes evolves from mafic/basic to felsic/acidic.

Stop 4. Washington Park, Anacortes

Our last stop is mainly for fracture mapping. Besides the gorgeous view, the rock is a relatively rare type – a metamorphosed peridotite, which is thought to reflect the composition of the mantle. This is a rock rich in ferro-magnesian minerals, especially olivine, which is a mineral with isolated tetrahedra (no bond between the tetrahedral corners). How might this explain a relative vulnerability of this mineral to weathering compared with quartz? Also note the scarcity of vegetation and red-clay soils. What might the red source be? Anyone bought a red-dyed "red dirt" tshirt in Hawaii?

For fracture mapping we will lay out several scan lines – tapes along pavements. Form groups, lay out tapes on the rock pavements. Prepare a sheet of "Write-in-rain notebook paper and record along the tape the following:

(1) Distance along tape (col 1)
(2) Strike and dip (col 2) – dip may be hard , if not possible assume vertical.
(3) Pole trend and plunge (col 3) and plot on the stereonet provided
(4) JRC (joint roughness coefficient) col 4
(5) Approximate trace length (col 5)
(6) Termination type (I for terminating in rock, T for terminating against another fracture, and O for obscured. Col 6
(7) When done with the data (possibly back in Seattle), compute P10 frequency and correct for orientation bias (Terzaghi correction)
(8) On a spreadsheet compute the spacing between each fracture and prepare a histogram. Is this normal distribution or something else?

When finished take a look at vertical rock faces down below to compare the view you get from the rock pavements.

Not-a-Stop 5 - Lahars

We will pull out and briefly discuss the Anacortes-Laconner geologic map, especially the lahar maps These show deposits that are measured from geotechnical as thick as 20 feet on the Skagit delta. These are catastrophic mud flows from failing glaciers on Glacier Peak – similar events have happened on all of Washington's volcanoes and they are not necessarily triggered by eruptions. There are also lahar materials embedded in Whidbey Formation south of Rocky Point from before the glacial era.

Polar projection

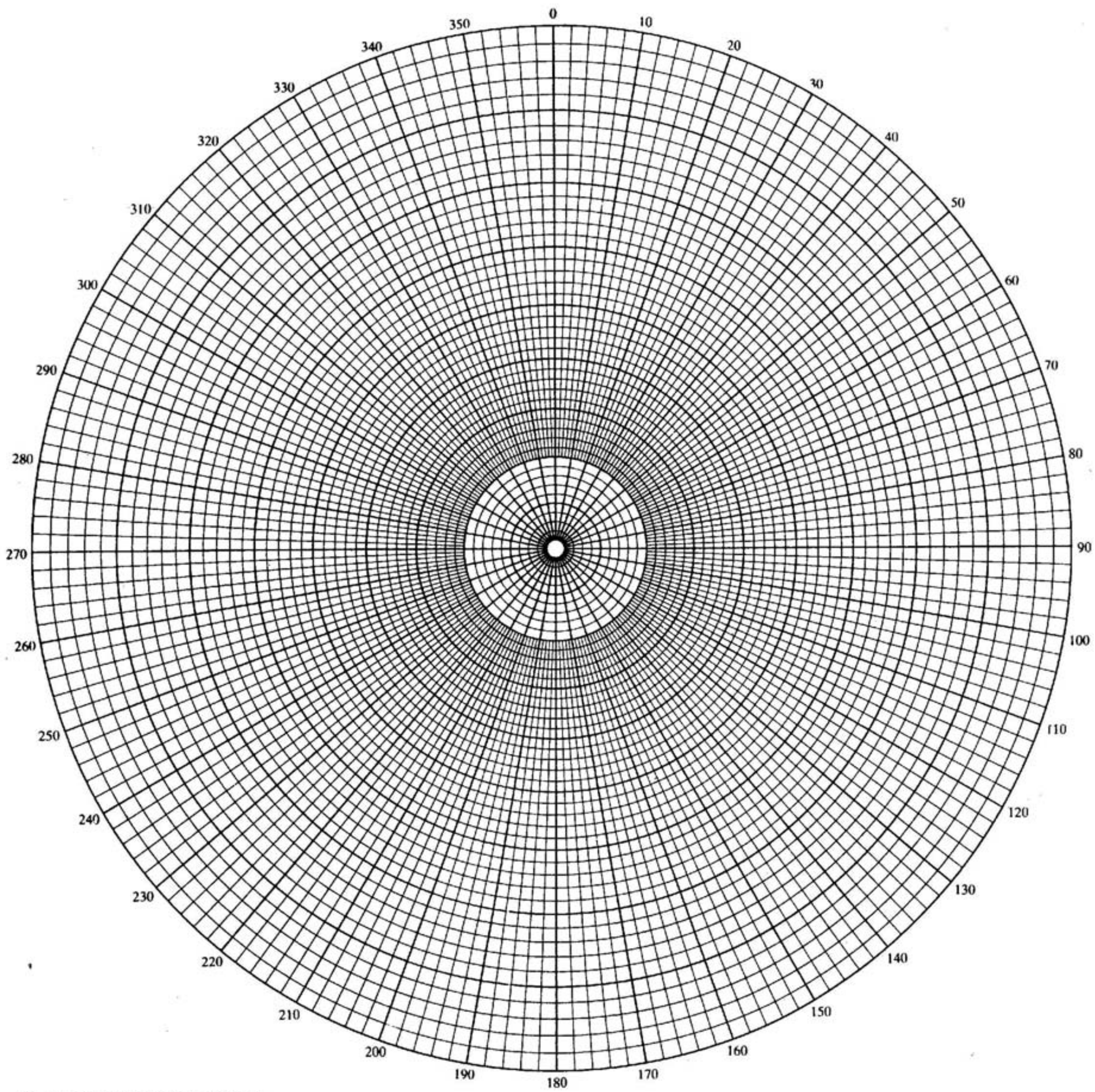
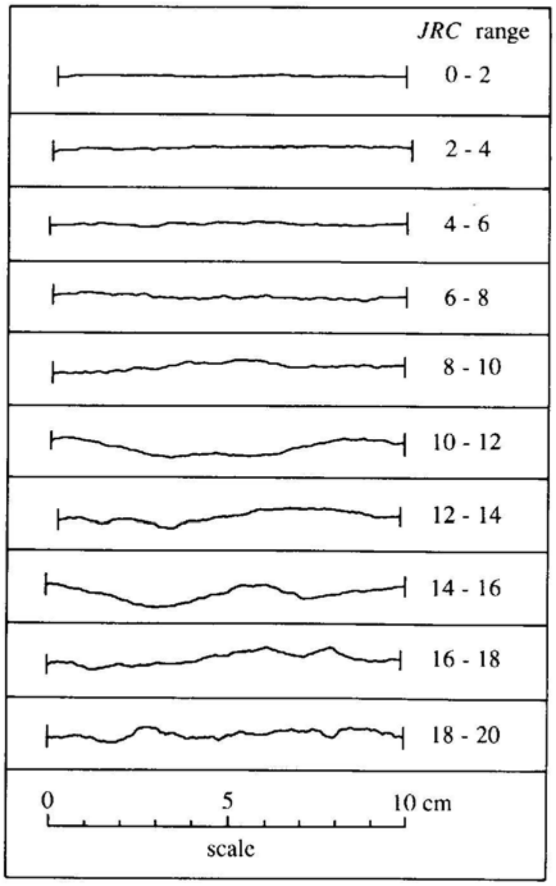


Figure 2.4 Polar equal-angle net.



4 Typical discontinuity roughness profiles and associated *JRC* values (after
ıd Choubey, 1977).

Barton, N, and V. Choubey, 1979, The shear strength of joints in theory and practice, Rock Mechanics, **10**, 1-54