

# Geologic Map of the McMurray 7.5-minute Quadrangle, Skagit and Snohomish Counties, Washington, with a Discussion of the Evidence for Holocene Activity on the Darrington–Deville Mountain Fault Zone

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DESCRIPTION OF MAP UNITS (see pamphlet for more detailed unit descriptions)

## Quaternary Sedimentary Deposits

### HOLOCENE NONGLACIAL DEPOSITS

- Qa Alluvium of Pilchuck Creek (Holocene)**—(Boulder) gravel and sand; gray; subrounded to rounded clasts; loose, well stratified, and well sorted, plane-bedded sands common.
- Qp Peat (Holocene)**—Peat, muck, and organic silt and clay, locally with thin beds of Mount Mazama tephra (~6,900 yr B.P.).
- Qoa Older alluvium of Pilchuck Creek (Holocene to latest Pleistocene)**—Cobble gravel, gravel, and sand and minor silt.
- Qls Landslide deposits (Holocene to latest Pleistocene)**—Diamictum with lesser (boulder) gravel; contains minor sand or gravel beds where locally modified by stream processes.

### PLEISTOCENE GLACIAL AND NONGLACIAL DEPOSITS

#### Deposits of the Fraser Glaciation

#### EVERSON INTERSTADE RECESSIONAL DEPOSITS

- Ogdm Glaciomarine drift (Pleistocene)**—Silt, clay, and dropstone-bearing diamictum, locally with lenses of sand or gravel.
- Ogds Outwash gravel (Pleistocene)**—Gravelly sand and sandy (cobble) gravel, locally with lenses or beds of sand and silt and rare beds of poorly sorted gravels and diamictum.
- Ogls Ice-contact kame deposits (Pleistocene)**—Sandy gravel, sand, and pebbly sand.
- Ogds Deltaic outwash (Pleistocene)**—Sandy cobble gravel, gravel, pebbly sand, and sand.
- Ogds Outwash sand (Pleistocene)**—Sand and pebbly sand, locally with interbeds of silty fine sand or silt.
- Ogls Glaciolacustrine deposits (Pleistocene)**—Clay, silt, sandy silt, silty sand, sand, and diamict with scattered dropstones.

#### VASHON STADE DEPOSITS

- Ogvl Lodgment till (Pleistocene)**—Nonstratified, unsorted mixture of clay, silt, sand, and gravel (diamictum) with disseminated cobbles and boulders.
- Ogvs Advance outwash deposits (Pleistocene)**—Sand, pebbly sand, and sandy gravel with scattered beds of cobble gravel with local silt and clay interbeds.
- Ogvs Advance glaciolacustrine deposits (Pleistocene)**—Clay and silt with local scattered dropstones.

#### Deposits of the Olympia Nonglacial Interval

- Olc Olympia beds (Pleistocene)**—Boulder gravel, cobbly gravel, gravel, sand, and silt, with minor clay, peat, and diamictum.

#### Deposits of the Possession Glaciation

- ot Older till (Pleistocene)**—Diamictum.
- oo Older outwash (Pleistocene)(Cross Section B only)**—Silty sand, locally with scattered gravel and occasional gravel interbeds.

## Tertiary Volcanic, Intrusive, and Sedimentary Rocks

### VOLCANIC AND HYPABYSSAL INTRUSIVE ROCKS

- Eib Diabase (Eocene)**—Homogeneous, medium-grained, subophitic basaltic diabase dikes and sills.
- Evr Rhyolite (Eocene)**—Rhyolite, andesite, and minor volcanolithic sandstone, conglomerate, and breccia.

### SEDIMENTARY ROCKS

#### Rocks of Bulson Creek

- OEcbg Rocks of Bulson Creek, conglomerate facies (Oligocene to Eocene)**—Conglomerate with local interbeds and lenses of sandstone, lesser coal and siltstone, and rare pelocolls and diamictic.
- OEcsa Rocks of Bulson Creek, sandstone facies (Oligocene to Eocene)**—Sandstone with interbeds of siltstone, pebbly sandstone, coal, shale, and rare lenses of conglomerate.

#### Chuckanut Formation

- Eoc Coal Mountain unit (Eocene)**—Feldspathic sandstone, locally with pebbly sandstone, siltstone, mudstone, and coal.

### Mesozoic to Paleozoic Low-Grade Metamorphic and Intrusive Rocks

#### HELENA-HAYSTACK MÉLANGE (Northwest Cascades System)

- Jmvs Greenstone (Jurassic)**—Metabasaltic greenstone with minor metagabbro, metadiacite, metarhyolite, and minor slate, phyllite, and metasandstone.
- Jhs Ultramafic (Jurassic)**—Serpentinite with minor partially serpentinized dunite, peridotite, and pyroxenite.

#### TRAFTON SEQUENCE (Eastern Mélangé Belt)

- ITmcs Metachert (Jurassic to Triassic)**—Metamorphosed chert and cherty argillite; locally includes minor argillite, siltstone, feldspatholithic sandstone or wacke, greenstone, tuff, and limestone.
- ITmcs Greenstone (Jurassic to Triassic)**—Metabasalt and green metatuff with minor thin interbeds of metachert locally.
- Ri Meta-intrusive (Paleozoic)**—Medium to coarse-grained hornblende metadiorite, metadiorite with minor pyroxene-metagabbro, and rare hornblende.

#### Tertiary to Recent Tectonic Zones

- tz Tectonic zones (Tertiary to Recent)**—Protomylonite, mylonite, cataclastic, fault breccia, and slickensided and fractured rocks in fault zones.

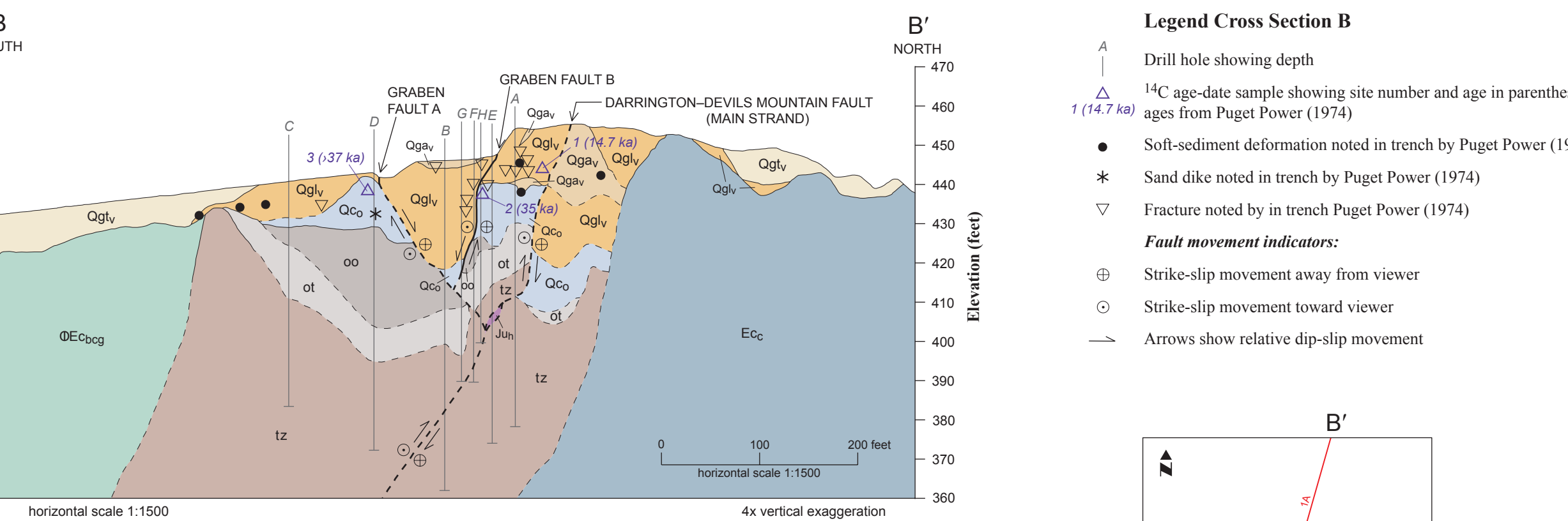
## GEOLOGIC SYMBOLS

- Age-date sample site, fossil
- Age-date sample site, zircon fission-track
- Age-date sample site, U-Th-Pb
- Age-date sample site, radiocarbon
- Geochemistry sample site
- Critical site
- Water well
- Terrace—hachures on downslope side
- Landslide scarp—hachures on downslope side
- Bedding—showing strike and dip
- Overturned bedding—showing strike and dip
- Vertical bedding—showing strike
- Bedding in Quaternary sedimentary deposits—showing strike and dip
- Forest bedding in Quaternary sedimentary deposits—showing strike and dip
- Foliation in low-grade metamorphic rock—showing strike and dip
- Vertical or near-vertical foliation in metamorphic rock—showing strike
- Mylonitic foliation—showing strike and dip
- Slickensided surface—showing strike and dip
- Vertical slickensided surface—showing strike
- Minor fault—showing strike and dip
- Minor fold—showing bearing and plunge
- Slip lineation or slickensides on a fault or shear surface—showing bearing and plunge of offset
- Contact—dashed where inferred
- Fault, unknown offset—dashed where inferred; dotted where concealed; queried where uncertain
- Normal fault, bar and ball on downthrown side—dashed where inferred; dotted where concealed
- Thrust fault, sawtooth on upper plate—dotted where concealed; queried where uncertain
- Reverse fault, R on upthrown side—dashed where inferred; dotted where concealed; queried where uncertain
- Right-lateral strike-slip fault—dashed where inferred; dotted where concealed
- Left-lateral strike-slip fault—dashed where inferred
- Normal right-lateral strike-slip fault, bar and ball on downthrown side—dotted where concealed; queried where uncertain
- Normal left-lateral strike-slip fault, bar and ball on downthrown side—dashed where inferred; dotted where concealed
- Reverse right-lateral strike-slip fault, R on upthrown side—dotted where concealed
- Reverse left-lateral strike-slip fault, R on upthrown side—dotted where concealed
- Anticline—dashed where inferred; dotted where concealed; queried where uncertain
- Overturned anticline—dashed where inferred; dotted where concealed; queried where uncertain
- Syncline—dashed where inferred; dotted where concealed; queried where uncertain
- Overturned syncline—dashed where inferred; dotted where concealed; queried where uncertain

## THE DARRINGTON-DEVILE MOUNTAIN FAULT ZONE

The Darrington-Deville Mountain fault zone (DDMFZ) is a major regional fault zone that has likely been locally active in the Holocene. (See "Darrington-Deville Mountain Fault Zone" in pamphlet for more detailed information.) The fault zone divides rocks of the Northwest Cascades System on the north from the Eastern and Western mélanges on the south and has a complex displacement history beginning in the mid-Eocene (or perhaps the mid-Cretaceous) and continuing to the Recent. Tertiary left-lateral strike-slip offset is well demonstrated for the DDMFZ by this section and outcrop scale structures and by the geometry of antithetic and synthetic faults and an echelon fold axes. The Eocene and Oligocene stratigraphic record indicates that the broad DDMFZ has a complex Tertiary transpressional and transtensional strike-slip history. The Mount Washington and McMurray fault zones in the McMurray quadrangle are subparallel to the generally northwest-trending echelon fold axes; they are major antithetic right-lateral faults within the DDMFZ.

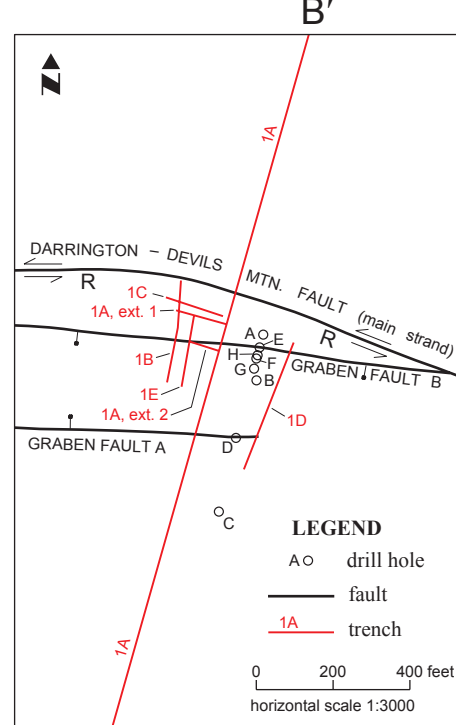
Recent activity along the DDMFZ has been concentrated along the main strand of the fault, with perhaps some additional offsets along nearby antithetic and synthetic segments. Available stratigraphic and geophysical evidence is most consistent with reverse-slip offset of the main strand, with perhaps some transpressional left-lateral strike-slip and oblique movement. Lower Quaternary strata, such as the Olympia beds, have apparently been uplifted along and south of the main strand, implying episodic, south-side-up DDMFZ faulting in the Quaternary. Holocene offset is also suggested by uplifted older alluvium, subtle truncations of glacial fluting, an anomalously steep river gradient where Pilchuck Creek crosses the DDMFZ main strand, and spatial correspondence of earthquake hypocenters with the main strand. Reinterpretation of trench data acquired by Puget Power (1974) at two locations (Cross Section B and site 29) provides direct evidence for Holocene offset of the main strand. We reinterpreted the more easterly trench stratum (site 29) as tectonically mixed fault gouge, glacial till, organic-rich fault colluvium or paleosol of Olympia nonglacial age, and Tertiary sedimentary-rock fault gouge. Puget Power (1974) also dug several trenches and bored eight exploratory drill holes across the DDMFZ main strand in the north-central part of the study area (red box on geologic map). Cross Section B is our interpretation of this information. Recent lidar images of the area show two east-west-trending scarps subparallel to the main strand that we interpret as fault scarps. The trench logs show a prominent offset of the glacial and nonglacial deposits where the most prominent scarp meets the trenches. We interpret these features as Holocene fault (graben) scarps formed in the hanging wall of the DDMFZ active main strand.



**Cross Section B.** Puget Sound Power and Light Company (1974) dug seven tightly spaced, north-south and east-west trenches and bored eight exploratory drill holes (A-H; 55–89 ft depth) across the main strand of the Darrington-Deville Mountain fault zone (DDMFZ)(see index map right). Cross Section B-B' was constructed using this trench and drill hole log information, as well as our local geologic mapping and observations. This information was projected onto the plane of the cross section, which follows Puget Power's trench 1A (index map). The profile for the section was constructed using a combination of trench and current topographic and lidar elevation data. Because these trenches were dug on a pipeline egress, some of the land surfaces were noted as "graded and disturbed" by Puget Power (1974). Stratigraphic relations suggest a combination of Holocene reverse main-strand faulting with an uncertain amount of strike-slip displacement. Fractures and sand dikes were noted in the trench logs. Graben fault B occurs along a lidar-defined scarp (Fig. 5, pamphlet). This scarp is associated with distinct stratigraphic displacement noted by Puget Power in their trench logs. They previously attributed the displacement to "slumping" (see "Darrington-Deville Mountain Fault Zone" in the pamphlet). Graben fault A occurs along the easternmost end of a lidar-defined scarp. Areas of fracturing, shown schematically with point symbols on the cross section, were commonly noted as having little or no stratigraphic displacement by Puget Power. This may be suggestive of a component of Holocene strike-slip displacement perpendicular to the plane of the main north-south trenches. Note the "uplift" of older Quaternary deposits along the main strand, particularly the apparent uplift and erosion of advance outwash (unit Qoa) south of the main strand reverse fault. We have generalized the contact relations between units Qglv, Qoa, Ec, and OEcbg on the map plane from the more detailed geologic contact relations on Cross Section B-B'. Unit tz in the cross section is a broad zone of fault gouge and highly fractured rocks formed along the main strand here. The top of unit tz defines a paleosurface that was buried during the last glaciation. The tectonic lens of serpentinite noted in drill hole E is likely inherited Helena-Haystack mélangé basement. The broad zone of gouge, occurrence of the exotic pre-Tertiary serpentinite, and tectonic juxtaposition of units Ec and OEcbg are some of the characteristics that contain this gouge zone to be the DDMFZ main strand. See "Darrington-Deville Mountain Fault Zone" and information provided in unit descriptions (units Qglv, Qoa, Ec) in the pamphlet for further information, particularly concerning the radiocarbon ages (ages 1, 2, and 3).

## Legend Cross Section B

- Drill hole showing depth
- <sup>14</sup>C age-date sample showing site number and age in parentheses; ages from Puget Power (1974)
- Soft-sediment deformation noted in trench by Puget Power (1974)
- Sand dike noted in trench by Puget Power (1974)
- Fracture noted by in trench Puget Power (1974)
- Fault movement indicators:**
- Strike-slip movement away from viewer
- Strike-slip movement toward viewer
- Arrows show relative dip-slip movement



## B-B' Index Map.

Data presented in Cross Section B-B' were projected into the line of the cross section from nearby trenches and drill holes, located as shown in this map. This map represents a small area (outlined in red) in the north-central part of the quadrangle. See Figure 5 in the pamphlet for a lidar image of the fault scarps in and around the index map area.

## Legend Cross Section A

- Bedding, dashed where inferred
- Well or composite well showing depth
- Fault movement indicators:**
- Strike-slip movement away from viewer
- Strike-slip movement toward viewer
- Arrows show relative dip-slip movement

