WASHINGTON STATE DEPARTMENT OF
Natural Resources
Peter Goldmark - Commissioner of Public Lands
Division of Geology and Earth Resources
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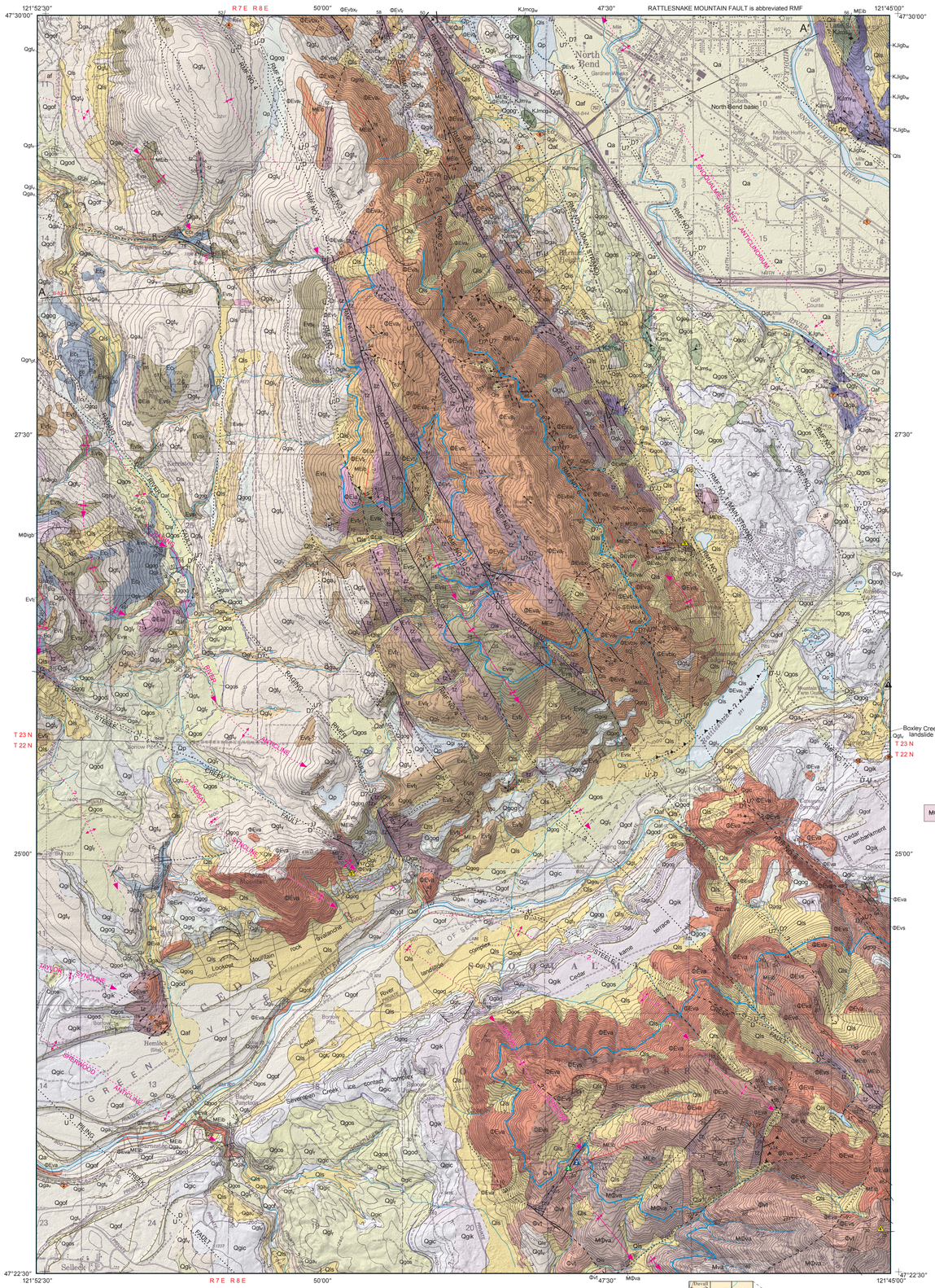
WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
GEOLOGIC MAP GM-73
North Bend 7.5-minute Quadrangle
February 2009
Pamphlet accompanies map

Geologic Map of the North Bend 7.5-minute Quadrangle, King County, Washington, with a discussion of Major Faults, Folds, and Basins in the Map Area

by Joe D. Dragovich, Timothy J. Walsh, Megan L. Anderson, Renate Hartog, S. Andrew DuFrane, Jeff Vervoot, Stephanie A. Williams, Recep Cakir, Kelsay Davis Stanton, Fritz E. Wolff, David K. Norman, and Jessica L. Czajkowski

February 2009



Lambert conformal conic projection
North American Datum of 1927; to place on North American Datum of 1983, move the projection lines approximately 20 meters north and 91 meters east as shown by crosshair corner ticks
Base map from scanned and rectified U.S. Geological Survey North Bend 7.5-minute quadrangle, 1993
Shaded relief generated from a lidar bare-earth digital elevation model (available from Puget Sound Lidar Consortium, http://pugetsoundlidar.ess.washington.edu/); sun azimuth 315°; sun angle 60°; vertical exaggeration 2X
Digital cartography and GIS by J. Eric Schuster, Charles G. Caruthers, Anne C. Heinitz, Jessica L. Czajkowski, and Robert H. Berwick
Editing by Katherine M. Reed, Jaretta M. Roloff, and Jessica L. Czajkowski
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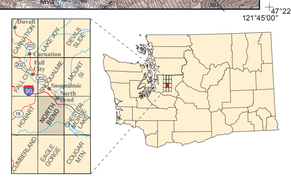
SCALE 1:24,000
1 0.5 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 0.5 0 1 KILOMETER
contour interval 40 feet
supplementary contour interval 20 feet

This geologic map was funded in part by the U.S. Geological Survey National Cooperative Geologic Mapping Program

16°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 2008



MAJOR FINDINGS

- Snoqualmie River sediments are compositionally similar to the older fluvial sediments we map as Olympia beds of Armstrong and others (1965). The distribution of Olympia sediments between strands of the eastern Rattlesnake Mountain fault zone suggests they have been uplifted by post mid-Pleistocene(?) faulting.
- The volcanic rocks of Rattlesnake Mountain occur as a complexly faulted imbricate body within the broad Rattlesnake Mountain fault zone.
- The younger(?) proximal volcanic rocks of Rattlesnake Mountain are fault-imbricated with Puget Group volcanic and sedimentary rocks in both the eastern and western parts of Rattlesnake Mountain fault zone.
- Local seismicity, tectonically deformed glacial deposits, and uplifted Olympia beds suggest the eastern Rattlesnake Mountain fault zone is active in some places.
- The dextral Rattlesnake Mountain fault zone probably joins the active Southern Whidbey Island fault zone about 20 mi north-northwest of the study area.
- The Steele Creek fault (named herein) aligns with the Olympic–Wallowa lineament and may be seismically active in the mid-crust.
- Landslide-susceptible Vashon Stade recessional ice kames and kame deltas are perched along mountainsides and were deposited near the edge of the receding Puget lobe.
- Recessional glaciolacustrine sands and silts were mapped in the Cedar and Raging River valleys. A still-stand of glacial Lake Snoqualmie at ~800 ft above present sea level elevation is evidenced by lake strandlines and lake sediment distribution in the northeast part of the map area during glacial ice recession.
- The distribution of advance glaciolacustrine deposits (Lawton Clay) indicates development of large ice-dammed proglacial lake basins during the Puget lobe's advance (unit Qgl_a) and retreat (unit Qgl_r).

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STRUCTURAL GEOLOGY AND NEOTECTONICS SUMMARY

Strike-slip offset is indicated for the Rattlesnake Mountain fault zone (RMFZ) by the fault strand linearity, along-strike variation in structural features, the steep bedding in Tertiary and pre-Tertiary rocks near faults, dominance of subhorizontal slickenlines within fault zones, and shallow focal mechanisms. Much of the Snoqualmie River valley may be structurally controlled by fault strands, strike-slip basins, and en-echelon fold axes of the RMFZ. The RMFZ is projected north of the map area and appears to be colinear with the active Southern Whidbey Island fault zone (Dragovich and others, 2007; Sherrod and others, 2008). Rattlesnake Mountain fault no. 1 (RMF-1) is the main strand of the RMFZ. Activity along this fault is suggested by deformed Quaternary sediments both southwest of North Bend (plate, critical site 6) and southeast of Rattlesnake Lake (plate, critical site 9). We interpret the ancient Snoqualmie River sediments (unit Qc_o) as having been uplifted along the RMF-1 and (or) nearby faults during the Quaternary. Rattlesnake Mountain faults nos. 7 and 8 are east of the main strand and appear to bound the North Bend basin (cross section). Recent activity along RMF-11 or RMF-1 is suggested by the relatively shallow hypocenters below these faults as shown on Figure 4A in the pamphlet. Fractured Vashon advance lake deposits (unit Qgl_a) occur near RMF-11 below critical site 10 (plate) at depth and directly north of the map area. RMF-6 is a subvertical fault that separates the volcanic rocks of Rattlesnake Mountain (unit ΦEvt_r) from the pre-Tertiary basement (Western mélange belt rocks). On April 29, 1945, a moderate earthquake (M5.5–5.7) occurred near our projection of RMF-6 or RMF-11 near Chester Morse Lake, 1 mi east of the study area. RMF-3 and RMF-4 were mapped by Dragovich and others (2007) on the basis of stratigraphic and geophysical anomalies across these structures in the Fall City area. The anomalies imply Pleistocene fault offset. These major faults are steep in the northern part of the map area but splay southwestward into several northeast-dipping faults that separate the imbricate bodies of volcanic rocks of Rattlesnake Mountain from the Tukwila Formation (unit Evt_t). Fault trace geometries and geophysical anomaly patterns indicate a northeasterly dip for some of the faults in the southwestern RMFZ. The Steele Creek fault is a north-side-up fault that follows a west-northwest-trending lineament northeast of Williams Creek and deformed rocks along both Steele and Williams Creeks. This fault aligns with the Olympic–Wallowa lineament and is inferred to be an active north-northeast–dipping reverse fault that may interact in a complex way with the western RMFZ. The Southeast Rattlesnake Mountain earthquake cluster may occur on the Steele Creek fault, or it may be at the intersection of the RMF-4 and the Steele Creek fault (Fig. 4 in pamphlet). The best alignment of the cluster's hypocenters suggests that a northeast-dipping fault exists below the southeastern RMFZ. We tentatively correlate the cluster with offset along the Steele Creek fault at depth. Although controversial, a regional décollement may be indirectly deduced by the relatively high density of ~17- to 28-km-deep hypocenters that cannot easily be correlated with surface faults (Fig. 4 in pamphlet). The Seattle fault zone and the RMFZ intersect northwest of the map area where the RMFZ forms the eastern tectonic boundary of the Seattle uplift. In this model, dextral strike-slip offset along the RMFZ accommodates northerly vergence on the Seattle fault zone within the mid-crust.

DESCRIPTION OF MAP UNITS

QUATERNARY SEDIMENTARY DEPOSITS

Holocene Nonglacial Deposits

- af — Artificial fill and modified land
- Qa — Alluvium
- Qp — Peat
- Qls — Landslide deposits (Holocene to latest Pleistocene)
- Qaf — Alluvial fan deposits (Holocene to latest Pleistocene)

Pleistocene Glacial and Nonglacial Deposits

DEPOSITS OF THE FRASER GLACIATION

Vashon Stade Recessional Deposits

- Qgos — Outwash sand
- Qgr — Recessional glaciolacustrine (glacial lake) deposits
- Qgof — Fluvial outwash deposits
- Qgic — Ice-contact deposits, undivided
  - *Locally divided into:*
  - Qgi — Ice-contact deposits, till
  - Qgik — Ice-contact deposits, kames
- Qgod — Deltaic outwash and kame deltas
- Qgog — Outwash gravel deposits, undivided

Vashon Stade Advance Proglacial and Subglacial Deposits

- Qgl_v — Vashon lodgment till
- Qgo_a — Advance outwash deposits
- Qgl_a — Advance glaciolacustrine deposits
- Qgo_a + Qgl_a — Advance deposits, undivided (cross section only)

Pre-Fraser Glacial and Nonglacial Deposits

DEPOSITS OF THE OLYMPIA NONGLACIAL INTERVAL

- Qgn_{pf} — Glacial and nonglacial deposits, undivided (Pleistocene to Pliocene?)
  - *Locally divided into:*
  - Qc_o — Olympia beds of Armstrong and others (1965)

TERTIARY VOLCANIC, SEDIMENTARY, AND INTRUSIVE ROCKS

Tertiary Intrusive Rocks

- MΦigb / MΦigd — Snoqualmie batholith granodiorite and gabbro (Miocene to Oligocene) (unit MΦigd cross section only)
- MEib — Basaltic andesite to basalt dikes (Miocene to Eocene)
- ΦEia — Andesite porphyry (Oligocene to Eocene?)

Tertiary Volcanic and Sedimentary Rocks

- Mva — Fifes Peak Formation (Miocene)
- MΦva — Volcanic rocks of Eagle Gorge (Miocene and Oligocene)
- Φvt — Tuff of Stampede Pass of Hammond (1963)

Ohanapecosh Formation of Tabor and others (2000)

- ΦEva — Proximal volcanic facies – andesite (Oligocene to Eocene)
- ΦEvs — Distal facies – volcanic sedimentary rocks (Oligocene to Eocene)

Volcanic Rocks of Rattlesnake Mountain of Walsh (1984)

- $ΦEva_r$ — Volcanic rocks of Rattlesnake Mountain, andesite (Oligocene to Eocene)
  - *Locally divided into:*
  - $ΦEvbx_r$ — Volcanic rocks of Rattlesnake Mountain, tuff breccia (Oligocene to Eocene)
  - $ΦEvt_r$ — Volcanic rocks of Rattlesnake Mountain, tuff (Oligocene to Eocene)

Puget Group and Raging River Formation

- Ec_r — Renton Formation (late to middle? Eocene)
- Evt_t — Tukwila Formation, sedimentary and volcanic rocks (middle Eocene)
- Evt_t — Tukwila Formation, tuff (middle Eocene)
- Ec_t — Tiger Mountain Formation (middle Eocene)
- Em_r — Raging River Formation (middle to early? Eocene) (cross section only)

TERTIARY TO RECENT TECTONIC ZONES

- tz — Tectonic zone

MESOZOIC LOW- TO MEDIUM-GRADE METAMORPHIC ROCKS OF THE WESTERN MÉLANGE BELT

- $KJms_w$ — Western mélange belt metasedimentary rocks (Cretaceous to Jurassic)
- $KJmcg_w$ — Western mélange belt metaconglomerate (Cretaceous to Jurassic)
- $KJmv_w$ — Western mélange belt metavolcanic rocks (Cretaceous to Jurassic)
- $KJigb_w$ / KJu_w — Western mélange belt metagabbro (unit $KJigb_w$) and ultramafite (unit KJu_w) (Cretaceous to Jurassic)
- $KJgn_w$ — Western mélange belt gneiss (Cretaceous to Jurassic)
- basement(?) — Geophysically defined basement? (cross section only); see pamphlet and cross section caption (below)

GEOLOGIC SYMBOLS

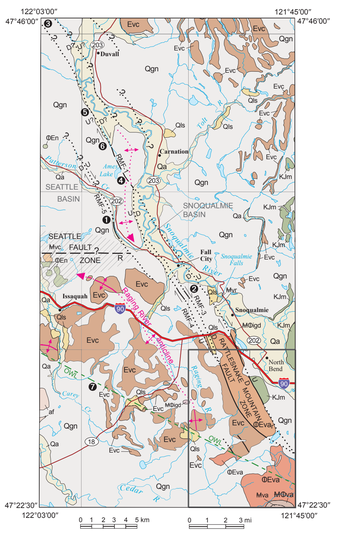
- W277 — Water well
- B-83-4 — Hydrocarbon exploration drill hole
- Age-date sample site, fossil
- Age-date sample site, zircon fission-track ("age site" in pamphlet)
- Age-date sample site, U-Pb ("age site" in pamphlet)
- Age-date sample site, ^{14}C ("age site" in pamphlet)
- Age-date sample site, Ar-Ar ("age site" in pamphlet)
- Critical site (see pamphlet)
- KJu_w — Geologic unit too small to show as a polygon at map scale
- 24 — Bedding—showing strike and dip
- Bedding—showing strike and direction of dip
- Vertical bedding—showing strike
- Horizontal bedding
- 34 — Bedding in unconsolidated sediments or volcanic fragmental deposits—showing strike and dip
- F 44 — Foreset bedding in unconsolidated sediments or volcanic fragmental deposits—showing strike and dip
- 40 — Foliation in metamorphic rock—showing strike and dip
- Vertical or near-vertical foliation in metamorphic rock—showing strike
- 60 — Mylonitic foliation—showing strike and dip
- 55 — Slickensided surface—showing strike and dip
- Vertical slickensided surface—showing strike
- 35 — Slip lineation or slickensides on a fault or shear surface—showing bearing and plunge of offset
- 70 — Minor fault—showing strike and dip
- Minor vertical or near-vertical fault—showing strike
- 28 — Minor fold—showing bearing and plunge
- Continental ice limit, late Wisconsinan
- Landslide scarp—hachures point downslope
- Arrow showing direction of landslide movement
- Late Pleistocene strandline (former shoreline)
- MEib — Dike (unit MEib) (Miocene–Eocene?)—aphanitic basalt to basaltic andesite
- Terrace—dotted where concealed; hachures point downslope
- Contact—dashed where inferred; queried where uncertain
- ? — Fault, unknown offset—dashed where inferred; dotted where concealed; queried where uncertain
- R R ? — Thrust fault, sawteeth on upper plate—dashed where inferred; dotted where concealed; queried where uncertain
- R R ? — Reverse fault, R on upthrown side—dashed where inferred; dotted where concealed; queried where uncertain
- U D ? — Right-lateral strike-slip fault—dashed where inferred; dotted where concealed; queried where uncertain; relative vertical movement shown by U and D
- ? — Left-lateral strike-slip fault—dashed where inferred; dotted where concealed; relative vertical movement shown by U and D
- U D — High angle dip-slip fault—dotted where concealed; relative vertical movement shown by U and D
- ? — Anticline—long dashed where approximately located; dotted where concealed; queried where uncertain; large arrowhead shows direction of plunge
- ? — Syncline—long dashed where approximately located; dotted where concealed; queried where uncertain; large arrowhead shows direction of plunge

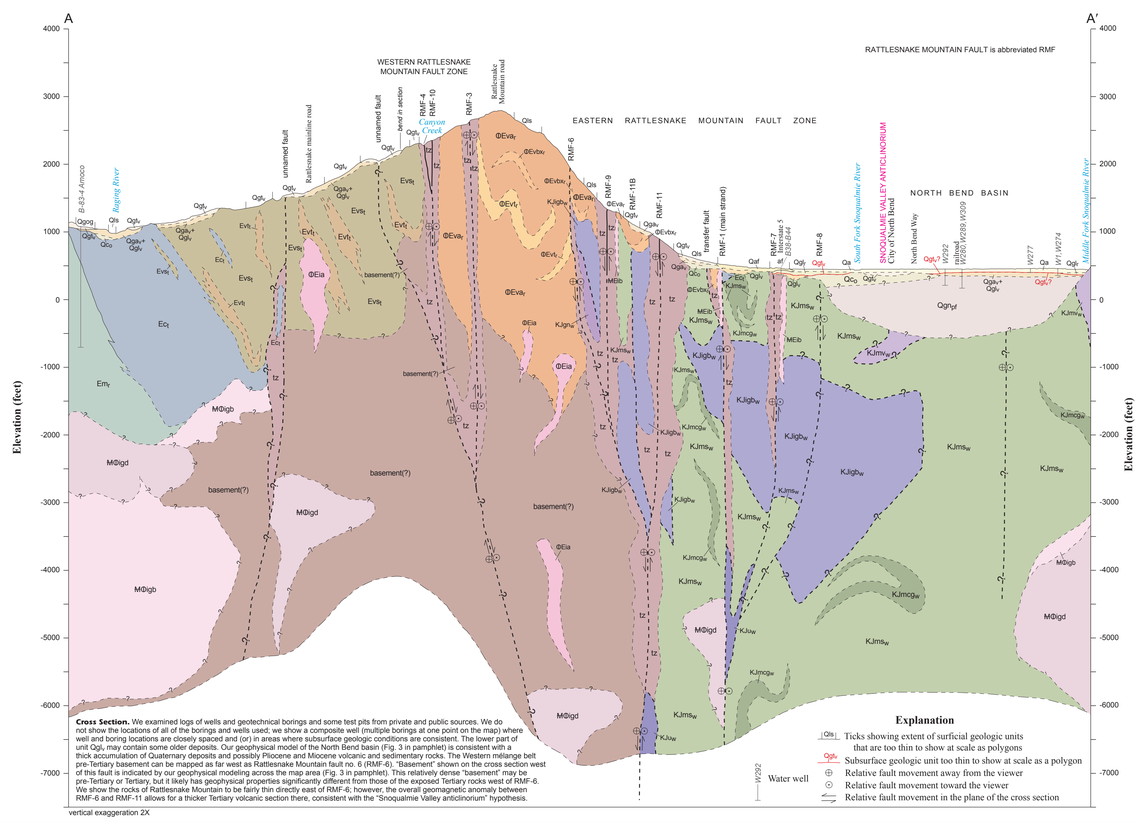
Figure 2. Simplified geologic map of the region (modified from Dragovich and others, 2002). Mapping shown for the North Bend 7.5-minute quadrangle is generalized. Gray rectangles are 7.5-minute quadrangle boundaries; the bold outline surrounds the North Bend quadrangle. The Fall City quadrangle is directly northwest of the North Bend quadrangle. *Site 1*: Deformed Olympia beds along Rattlesnake Mountain fault no. 5 (RMF-5) documented by Dragovich and others (2007); this fault is inferred to form the westernmost boundary of the Rattlesnake Mountain fault zone northwest of the North Bend quadrangle and may be the main bounding fault to the Seattle fault zone in the Fall City quadrangle. Dragovich and others (2007) did not find evidence for post-Olympia nonglacial interval motion along fault RMF-5. *Site 2*: Uplifted ancient Snoqualmie River alluvium (Olympia beds) of Dragovich and others (2007). We obtained a Miocene U-Pb zircon age (22 Ma) from rhyolite directly east of here. (Note unit Mvr at Snoqualmie Falls). *Site 3*: Inferred active faults and lineaments defining the currently recognized southeastern limit of the active Southern Whidbey Island fault zone; the zone occupies a wide band a few miles northwest of this site. *Site 4*: Tolt Hill anticline. *Site 5*: This linear slope break along the edge of the Snoqualmie River valley aligns with lineaments along Ames Lake and forms the inferred northward extension of RMF-1. See Dragovich and others (2007) for discussion of uplifted(?) old glacial and nonglacial deposits directly west of the inferred main strand (RMF-1) near here. *Site 6*: Deformed recessional outwash near the Rattlesnake Mountain fault zone main strand in the Carnation 7.5-minute quadrangle. See figure 4 of Dragovich and others (2007). *Site 7*: Olympic–Wallowa lineament (OWL) as originally defined by Raisz (1945) in and west of the study area. The Steele Creek fault is coincident with this early definition of this lineament.

Description of Map Units (Figure 2)

- af — Artificial fill and modified land (Holocene)
- Qa — Alluvium (Holocene)
- Qls — Landslide deposits (Holocene)
- Qgn — Glacial and nonglacial deposits, undivided (Pleistocene)
- Mva — Fifes Peak Formation (Miocene)
- Mvr — Rhyolite at Snoqualmie Falls (Miocene)
- Mvc — Volcanic and sedimentary rocks (Miocene)
- MΦigd — Granodiorite and gabbro of the Snoqualmie batholith (Miocene–Oligocene)
- MΦva — Rocks of Eagle Gorge (Miocene–Oligocene)
- ΦEva — Ohanapecosh Formation (Oligocene–Eocene)
- $ΦEva_r$ — Volcanic rocks of Rattlesnake Mountain (Oligocene–Eocene?)
- ΦEn — Nearshore sedimentary rocks of the Blakeley Formation (Oligocene–Eocene)
- Evc — Volcanic and sedimentary rocks; includes the Puget Group, Raging River Formation, and volcanic rocks of Mount Persis (Eocene)
- KJm — Low-grade metamorphic rocks of the Western mélange belt (Cretaceous–Jurassic)
- 7 — Sites discussed in caption and text
- OWL — Olympic–Wallowa lineament (see "Steele Creek Fault and the Olympic–Wallowa Lineament" in the pamphlet and on the geologic map)

See 'Geologic Symbols' for fault and fold symbology





Cross Section. We examined logs of wells and geotechnical borings and some test pits from private and public sources. We do not show the locations of all of the borings and wells used; we show a composite well (multiple borings at one point on the map) where well and boring locations are closely spaced and (or) in areas where subsurface geologic conditions are consistent. The lower part of unit Qgl_v may contain some older deposits. Our geophysical model of the North Bend basin (Fig. 3 in pamphlet) is consistent with a thick accumulation of Quaternary deposits and possibly Pliocene and Miocene volcanic and sedimentary rocks. The Western mélange belt pre-Tertiary basement can be mapped as far west as Rattlesnake Mountain fault no. 6 (RMF-6). "Basement" shown on the cross section west of this fault is indicated by our geophysical modeling across the map area (Fig. 3 in pamphlet). This relatively dense "basement" may be pre-Tertiary or Tertiary, but it likely has geophysical properties significantly different from those of the exposed Tertiary rocks west of RMF-6. We show the rocks of Rattlesnake Mountain to be fairly thin directly east of RMF-6; however, the overall geomagnetic anomaly between RMF-6 and RMF-11 allows for a thicker Tertiary volcanic section there, consistent with the "Snoqualmie Valley anticlinorium" hypothesis.

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