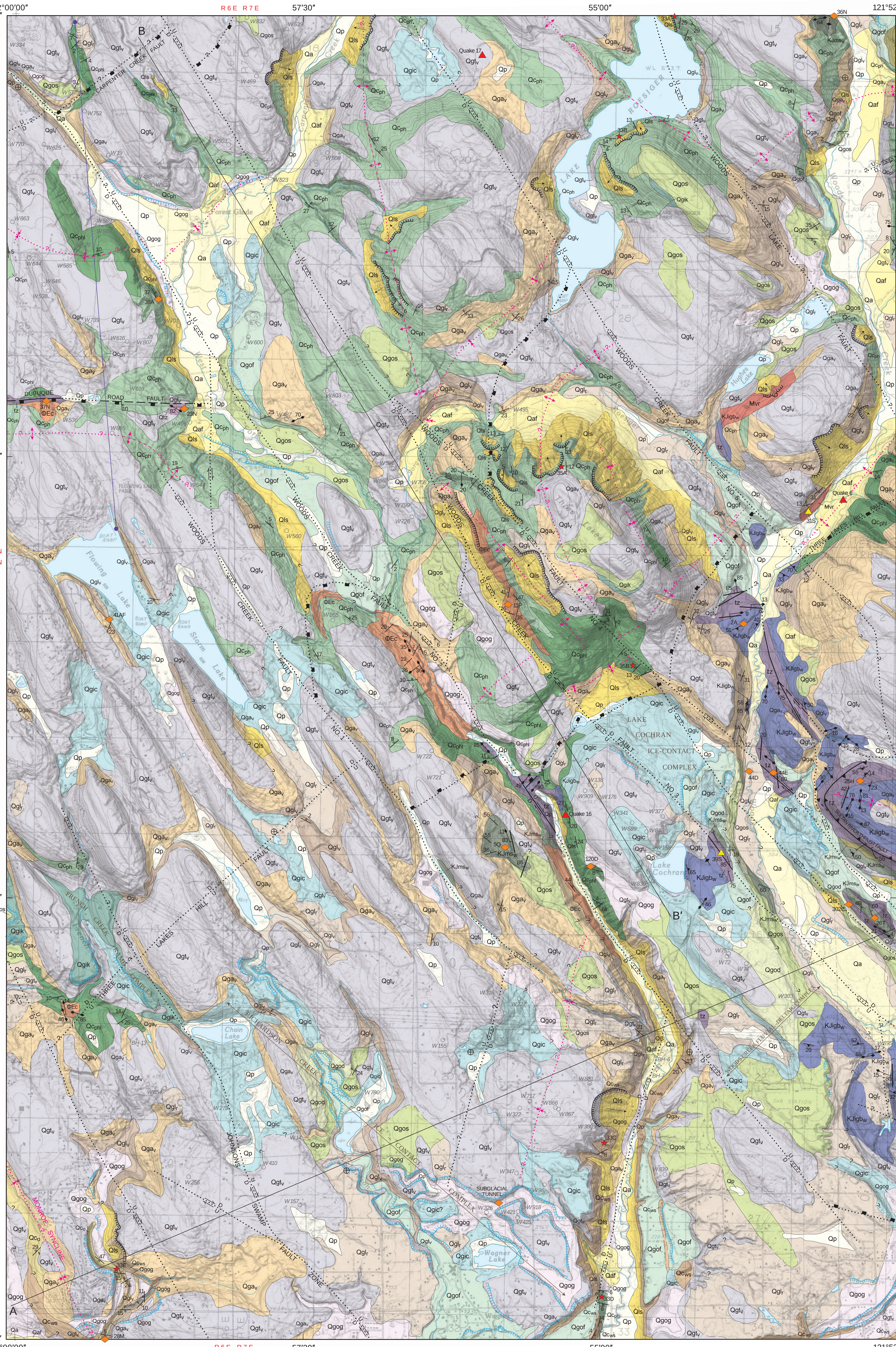
WASHINGTON STATE DEPARTMENT OF Natural Resources
Peter Goldmark - Commissioner of Public Lands
Division of Geology and Earth Resources
David K. Norman - State Geologist

WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
MAP SERIES 2015-01
Lake Roesiger 7.5-minute Quadrangle
Pamphlet accompanies map

Geologic Map of the Lake Roesiger 7.5-minute Quadrangle, Snohomish County, Washington

Joe D. Dragovich, Shannon A. Mahan, Megan L. Anderson, James H. MacDonald Jr., Joseph F. Schilter, Christina L. Frattali, Curtis J. Koger, Daniel T. Smith, Bruce A. Stoker, S. Andrew DuFrane, Michael P. Eddy, Recep Cakir, and Kirsten B. Sauer

October 2015



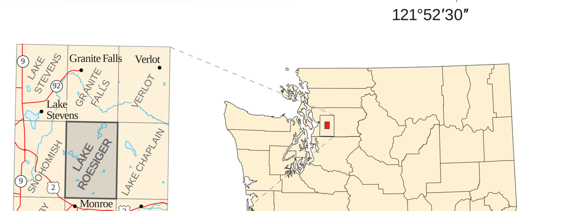
Lambert conformal conic projection
North American Datum of 1927; to place on North American Datum of 1983, move the projection lines approximately 17 meters north and 92 meters east as shown by crosshair corner ticks
Base map from scanned and rectified U.S. Geological Survey Lake Roesiger 7.5-minute quadrangle, 1997
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 45°; vertical exaggeration 0.03
GIS by Joseph F. Schilter and Christina L. Frattali
Digital cartography by by Anne C. Olson, J. Eric Schuster, and Ian J. Hubert
Editing and production by Alexander N. Steely

SCALE 1:24,000

contour interval 20 feet

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

Research supported by the U.S. Geological Survey, National Cooperative Geologic Mapping Program, under USGS award number G14AC00212. The views and conclusions contained in this document are those of the authors and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. Government.



MAJOR FINDINGS

- Deposits of the Olympia nonglacial interval and Whidbey Formation contain a record of the ancient Skykomish River in the southern half of the map area. These deposits are generally tilted south toward the broad axis of the Monroe syncline, a fold which is part of a family of neotectonic structures that control the lower Skykomish River valley.
- The Monroe synclinal basin continues from the Skykomish Valley across the southwest corner of the map area. Geophysical data, mapping, and geochronology indicate that this fold is cored by latest Pleistocene deposits of the Olympia nonglacial interval.
- The Explorer Falls basin preserves a thick sequence of weathered Pleistocene Pilchuck River alluvium. These deposits originally formed in a small graben which has been locally inverted.
- The northwest-trending Woods Creek fault zone is right-lateral to oblique and forms the eastern edge of the Everett basin.

DESCRIPTION OF MAP UNITS

(See the pamphlet for detailed map unit descriptions and Table 1 for a summary of sediment provenance)

Quaternary Sedimentary Deposits

HOLOCENE NONGLACIAL DEPOSITS

Qp **Peat**—Peat, muck, and organic silt and clay, locally with diatomite and thin beds of Mazama ash; loose or soft.

Qa **Alluvium**—Sand, silt, gravelly sand, and sandy pebble gravel; unit locally includes peat and organic sediments and (or) cobble gravel; clasts subrounded to rounded; some subangular to angular clasts in alluvium near Woods Creek; loose; well stratified and sorted; sand is planar bedded. LP, SP, or PP provenance, depending on nearest major river system.

Qls **Landslide deposits (Holocene to latest Pleistocene)**—Unsorted mixture of clay, silt, sand, gravel, and wood debris (diamicton) or boulder gravel, and local minor sand or gravel; loose. The absence of a mapped landslide does not imply the absence of hazard.

Qaf **Alluvial fan deposits (Holocene to latest Pleistocene)**—Diamicton, alluvial gravel, boulder gravel, and sand; loose, poorly to moderately sorted; moderately stratified to massive; locally contains significant amounts of debris flow deposits.

PLEISTOCENE GLACIAL AND NONGLACIAL DEPOSITS

Deposits of the Vashon Stade of the Fraser Glaciation

Recessional Deposits

Qgl_r **Recessional glaciolacustrine (glacial lake) deposits**—Silt and clayey or sandy silt to silty sand, typically with scattered dropstones; local lenses of sand or gravel; soft; deposited in proglacial lakes.

Qgos **Outwash sand deposits**—Sand and pebbly sand with some interbeds of silty sand, silt, or gravel; loose or soft; unstratified, weakly stratified, planar bedded, laminated, or rarely crossbedded.

Qgod **Deltaic outwash and kame-delta deposits**—Sandy cobble gravel, gravel, pebbly sand; loose; moderately to well sorted; thin to very thickly bedded; well stratified with conspicuous high-amplitude foreset beds.

Qgof **Fluvial outwash deposits**—Cobble and boulder gravel, gravel, pebbly sand, and interbeds of sand and rare silt; loose; moderately to well stratified; beds subhorizontal; locally crossbedded with many rip-up clasts.

Qgic **Ice-contact deposits**—Cobble to boulder gravel and gravel, locally containing diamicton, silty pebbly gravel, sand, pebbly sand, or silt; loose; moderately stratified and medium to very thickly bedded; abrupt grain-size changes common. Locally divided into:

Qgik **Ice-contact kames**—Cobble and boulder gravel, gravel, sand, and pebbly sand, with rare lenses of diamicton; loose; crossbedded, with localized oversteepened or slumped strata; cut-and-fill structures and common rip-up clasts of till or silt.

Qgog **Outwash gravel deposits, undivided**—Poorly exposed boulder–pebble gravel to pebbly sand; loose; massive to crudely bedded; largely ice-contact deposits; may include any of the gravelly Vashon recessional facies.

Advance Proglacial and Subglacial Deposits

Qgt_v **Lodgment till**—Diamicton (unsorted mixture of clay, silt, sand, and gravel); dense; matrix-supported; accreted at the base of the Vashon-age ice; typically has a friable shear fabric.

Qga_v **Advance outwash deposits**—Sand and pebble gravel, sand and cobble gravel, and local silt; dense; well sorted and stratified; thinly to thickly bedded; deltaic and channel bar foresets, cut-and-fill structures, and common silt rip-up clasts.

Qgl_v **Advance glaciolacustrine deposits**—Silt, clayey silt, pebbly silt, and diamicton; locally contains very thin to thick beds of sand, scattered dropstones, and iceberg melt-out or flow till; stiff or dense; stratification and sorting vary; massive to thinly bedded, laminated, or varved.

Pre-Fraser Glacial and Nonglacial Deposits

Qc_o **Deposits of the Olympia nonglacial interval**—Sand, sandy silt, silty sand, and silt, with some clay and (or) organic silty clay in the southwest corner of the map area; minor peat, charcoal, disseminated detrital organic matter, and gravel beds; sand typically yellow, gray-brown, or brown-gray with distinctive dark gray-orange oxidation; dense; well stratified; laminated to very thickly bedded; liquefaction features common; SP provenance.

Qc_{ws} **Whidbey Formation**—Sand, silt, and silty sand with lesser pebbly sand, clay, gravel, organic sediment including peat; lenses of (cobble) gravel observed regionally; sand is a light yellowish brown and weathers to a distinctive orange-gray; dense or hard; well sorted and stratified; SP provenance.

Qgt_d **Double Bluff till (cross section only)**—Diamicton; very dense and massive bedded; laterally extensive in the subsurface beneath the Whidbey Formation in the southern part of the map area.

Qc_{ph} **Pre-Hamm Creek nonglacial deposits**—Pebble gravel, gravelly sand, pebbly sand, sand, silty sand, silt with local cobble gravel and clay; sand is typically yellowish brown to pale brown, weathers orange; oxidized and strongly weathered with conspicuous mica; thin to very thickly bedded; well stratified; cross bedding, graded beds, charcoal, logs, or disseminated organic matter are common. PP provenance in the northern parts of the quadrangle, and SP provenance at one site (33D) along the south-central border of the map area.

Qc_{phl} **Pre-Hamm Creek nonglacial deposits, locally derived**—Sand, pebbly sand, sandy pebble gravel, with less gravel, cobble–boulder gravel, or rare silt; locally contains peat, logs, or organic sediments; distinct local Western mélange belt (LP) provenance.

Qgn_{pf} **Pre-Fraser glacial and nonglacial deposits, undivided (Pleistocene to Pliocene?)(cross section only)**—Dense to very dense gravel, boulder gravel, sand, silt, clay, and diamicton; may locally contain peat or organic sediments.

Tertiary Volcanic, Intrusive, and Sedimentary Rocks

Mvr **Rhyolite of Hughes Lake (Miocene)**—Poorly exposed, high-K, calc-alkaline rhyolite flow and crystal-vitric to vitric-crystal (lapilli) tuff; white to pinkish white, weathers light yellowish brown; U-Pb zircon age of 23.300 ±0.032 Ma at site 31S.

ΦEc **Rocks of Bulson Creek (Oligocene to Eocene)**—Lithic to lithofeldspathic sandstone with less conglomerate, pebbly sandstone, siltstone, or coal with minor claystone; mostly preserved in the Explorer Falls and (or) Everett basins.

Mesozoic Low- to Medium-Grade Metamorphic Rocks

KJm_w **Western mélange belt of Tabor and others (1993), undivided (Cretaceous to Jurassic)(cross section only)**—Meta-argillite, metasandstone, greenstone, metachert, with less metadiabase, metatonalite, slate, amphibolite, hornblendite, phyllite, minor marble with meta-quartz-diorite; ultramafic rocks rare regionally.

$KJmv_w$ **Metavolcanic rocks**—Low-grade greenstone derived from metamorphosed basaltic to andesitic tuff and volcanic flows of basaltic andesite to dacite.

$KJms_w$ **Metasedimentary rocks**—Low-grade marine feldspathic to feldspatholithic subquartzose metasandstone, silty metasandstone, meta-argillite, metatuff, and chert-pebble metaconglomerate; minor metachert and rare marble; well to moderately sorted.

$KJigb_w$ **Metagabbro**—Medium-grade metagabbro, quartz metagabbro, feldspathic hornblendite and amphibolite; less metatrondhjemite or metatonalite; metadiabase and rare meta-quartz-diorite are reported regionally; medium to coarse grained; generally slightly foliated to schistose or gneissose.

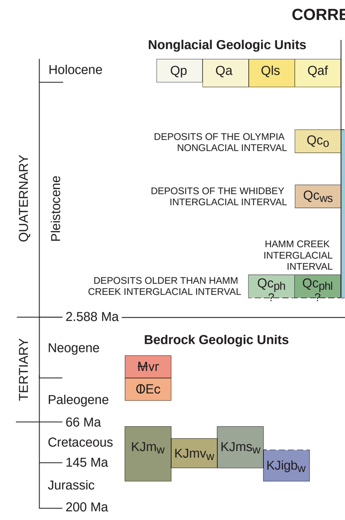
Holocene to Tertiary Tectonic Zones

tz / Qtz **Tectonic zone**—Cataclasite, fault breccia, clay-rich fault gouge, protomylonite, and (or) moderately to strongly slickenlined, fractured, and veined rocks in and near fault zones; variously colored and mottled; commonly altered. Unit Qtz is mapped where deformation is demonstrably Quaternary in age, such as along the Dubuque Road fault in the western part of the quadrangle.

GEOLOGIC SYMBOLS

- Contact—Solid where location accurate; long-dashed where approximately located; queried where identity or existence questionable
- Fault, unknown offset—Solid where location accurate; short-dashed where inferred; dotted where concealed; queried where identity or existence questionable
- Thrust fault—Solid where location accurate; dotted where concealed; triangles on upper (structurally higher) plate
- Reverse fault—Solid where location accurate; long-dashed where approximately located; dotted where concealed; queried where identity or existence questionable; rectangles on upthrown block.
- High-angle dip-slip fault—Dotted where concealed; queried where identity or existence questionable; U, upthrown block; D, downthrown block
- Right-lateral strike-slip fault—Solid where location accurate; long-dashed where approximately located; dotted where concealed; queried where identity or existence questionable; arrows show relative motion
- High-angle right-lateral, oblique-slip fault—Solid where location accurate; short-dashed where inferred; dotted where concealed; queried where identity or existence questionable; arrows show relative horizontal motion; U, upthrown block; D, downthrown block
- High-angle left-lateral, oblique-slip fault—Short-dashed where inferred; dotted where concealed; queried where identity or existence questionable; arrows show relative horizontal motion; U, upthrown block; D, downthrown block
- Anticline—Short-dashed where inferred; dotted where concealed; queried where identity or existence questionable
- Syncline—Short dashed where inferred; dotted where concealed; queried where identity or existence questionable
- Fluvial terrace scarp—Identity and existence certain; location accurate; hachures point downslope
- Landslide scarp—Identity and existence certain; location accurate; hachures point downslope
- A —— A′ Cross section line
- Location of Figure 4 cross section in accompanying pamphlet
- Direction of downslope movement of landslide
- 48 Inclined bedding—showing strike and dip
- Horizontal bedding
- 5 Inclined bedding in unconsolidated sedimentary deposits—showing strike and dip
- 32 Inclined foreset bedding in unconsolidated sedimentary deposits—showing strike and dip
- 60 Inclined cleavage—showing strike and dip
- Vertical cleavage—showing strike
- 67 Inclined metamorphic or tectonic foliation—showing strike and dip
- Vertical metamorphic or tectonic foliation—showing strike
- 86 Small, minor inclined fault—showing strike and dip
- Small, minor vertical or near-vertical fault—showing strike
- 36 Inclined slickenline, groove, or striation on fault surface—showing bearing and plunge
- 30 Slickenside—showing strike and dip
- 55 Inclined mylonitic foliation—showing strike and dip
- 31S Geochronology sample location, uranium-lead (U-Pb)
- 33A Geochronology sample location, infrared stimulated luminescence (IRSL)
- 23N Significant site
- Quake 6 Earthquake hypocenter; number corresponds to focal mechanisms in Appendix B
- W487 Water well
- BH-13 Drill hole for hydrocarbon exploration
- BH-6 Drill hole or test pit

CORRELATION OF MAP UNITS



The pamphlet provides direct or indirect age constraints for many of the geologic units, including new IRSL ages for glacial and nonglacial deposits (Appendix A). See Morrison (1991) for Pleistocene age constraints on the glacial and nonglacial intervals. Tabor and others (1993) indicate that the Western mélange belt meta-intrusive rocks (unit $KJigb_w$) are ~150–170 Ma and are about the same age or older than the Kimmeridgian to Valanginian (157–134 Ma) metasedimentary rocks of the belt. However, detrital zircon U-Pb ages for unit $KJms_w$ (Dragovich and others, 2014) indicate that the metasandstone in this unit is locally as young as 74 Ma.

CROSS SECTION EXPLANATION

- Qls Surficial geologic units too thin to show as polygons at the scale of the cross sections. Black ticks mark separate units.
- Arrows show relative fault movement in the plane of the cross section.
- Arrow point shows fault movement toward the viewer; arrow feathers show fault movement away from the viewer.
- W146 BH6 Water well or boring; water well labels begin with W; boring labels begin with B.

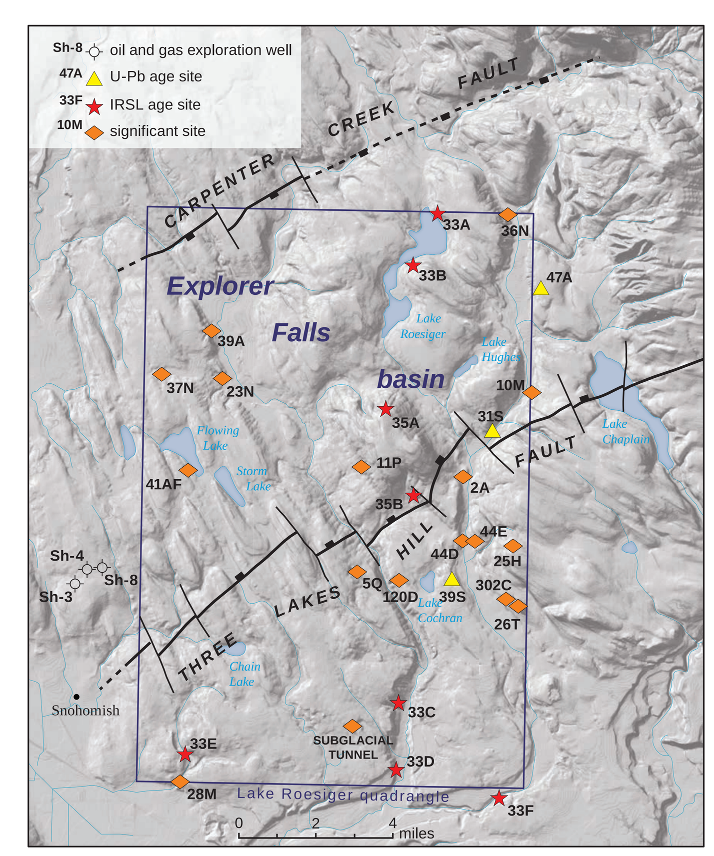


Figure M3. Map of oil and gas exploration wells, age sites, and significant sites in and near the Lake Roesiger quadrangle. The Three Lakes Hill and Carpenter Creek faults are shown schematically.

Lithologic Cross Sections A and B. For analyses of subsurface conditions, 931 wells, 54 geotechnical borings, and 214 test-pit stratigraphic logs were obtained from various public and private institutions. We show only the highest quality well and boring data near the cross sections. 234 wells were incorporated into the subsurface analyses for the diagrammatic cross section (Fig. 4, *in pamphlet*) and Cross Sections A and B. We show composite information where wells and borings are closely spaced and (or) where subsurface geologic conditions are stratigraphically consistent over a short distance. Figures M1 and M2 provide geophysical models of these lithologic cross sections. Appendix B provides information on earthquake hypocenters near the cross sections. The relationship between the Sultan River thrust, shown at depth on both cross sections, and the Lake Chaplain nappe is illustrated on Figure 6 in the pamphlet.

GEOPHYSICAL DATA AND INTERPRETATIONS

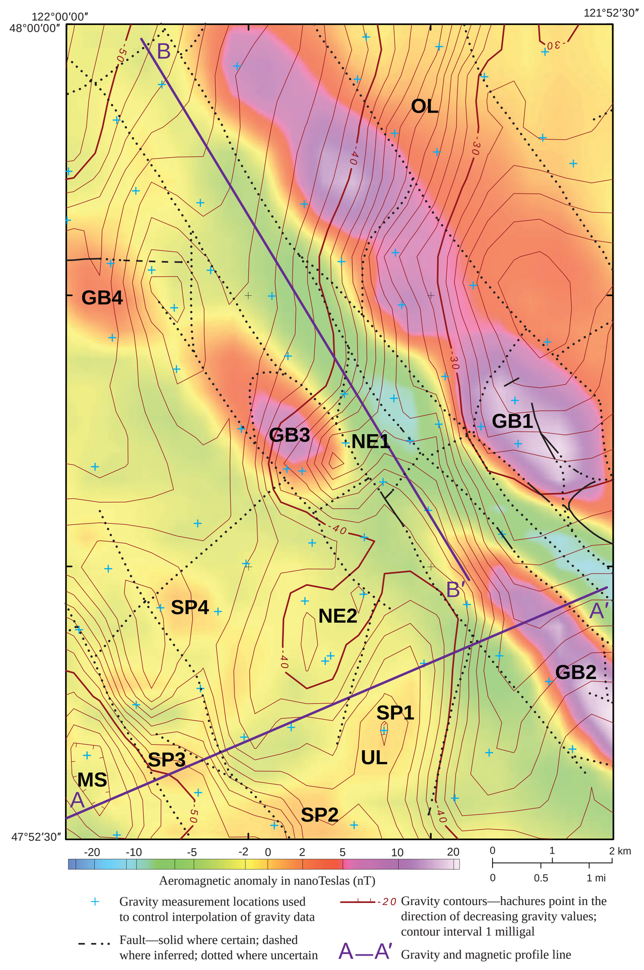
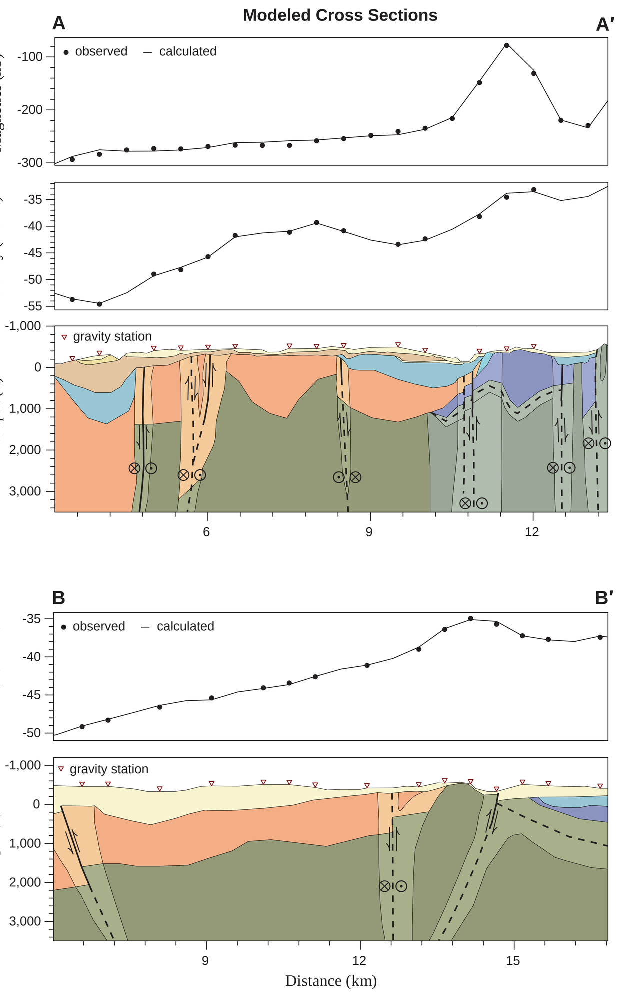


Figure M1. Aeromagnetic anomaly and isostatic gravity map of the Lake Roesiger quadrangle. Base map is reduced-to-pole aeromagnetic anomaly, filtered (upward continued and differenced with original grid) to bring out magnetic anomalies originating from near-surface sources. GB1 through GB4 are four distinct magnetic highs associated with Western mélange belt metagabbro (unit $KJigb_W$). The anomaly at GB1 starts at the label and continues northwest; this whole trend is considered the same anomaly. MS is a gravity low associated with Monroe syncline; NE1 and NE2 are northeast-trending gravity highs; OL is a strong gravity gradient associated with the eastern edge of a thick deposit of Oligocene sediment; SP1 to SP4 are weak aeromagnetic highs that correlate with areas of moderately magnetically susceptible Skykomish River provenance Pleistocene sediment along the northern limb of the Monroe syncline; UL is a small gravity low associated with a small unnamed basin.

Modeled Cross Sections



Density contrast (kg/m^3)	Susceptibility	Geologic units
Quaternary deposits		
$\Delta\rho = -650$	$\chi = 2$	undifferentiated Quaternary deposits
$\Delta\rho = -650$	$\chi = 4$	unit Qc_O
$\Delta\rho = -650$	$\chi = 4$	unit Qc_{WS}
$\Delta\rho = -650$	$\chi = 2$ to 5	unit Qgn_{pf}
Tertiary rocks		
$\Delta\rho = -400$	$\chi = 0.4$	unit ΦEc
Western mélange belt		
$\Delta\rho = 170$	$\chi = 50$	metagabbro, unit $KJigb_W$
$\Delta\rho = 10$	$\chi = 2$	metasedimentary, unit $KJms_W$
$\Delta\rho = 30$ to 50	$\chi = 1$ to 2	unit KJm_W, excluding metagabbro
Tectonic zones		
$\Delta\rho = -490$ to -470	$\chi = 0$	cataclasite of unit ΦEc
$\Delta\rho = 80$ to 110	$\chi = 40$ to 50	cataclasite of unit $KJigb_W$
$\Delta\rho = -70$ to 0	$\chi = 0$	cataclasite of unit $KJms_W$
$\Delta\rho = 10$ to 30	$\chi = 0$	cataclasite of unit KJm_W

Figure M2. Geophysical models A and B correspond to lithologic Cross Sections A–A′ and B–B′ (both at 2.5x vertical exaggeration) and show the match between modeled density and magnetic susceptibility from the cross sections and the observed gravity and aeromagnetic values. Here we use the total field magnetic anomaly to interpret both the shallow and deep-seated structures that contribute to the magnetic anomalies of the region, unlike in Figure M1, which focuses on near-surface structures.

Although we modeled the gravity data, we did not model the aeromagnetic data for B–B′ because most or all of the aeromagnetic anomalies along this transect are either to the east or west of the cross section line (see Fig. M1) and do not reflect the subsurface structure along the transect. Aeromagnetic data sampling distance along A–A′ is approximately twice the flightline spacing. Gravity data points are shown where good data control exists within 1.5 km of the line. The models extend to infinity in both directions perpendicular to the profiles, and data is tied to the model off to the right of both models, coinciding with locations where the model lines project across models developed in previous studies (Lake Chaplain quadrangle for A–A′ and Sultan quadrangle for B–B′). Δρ is the density contrast relative to normal crust (2,670 kg/m^3) used for the model; χ is magnetic susceptibility in SI units x 1,000. Note that the higher susceptibilities for deformed units correspond to deformed metagabbro and lower densities correspond to deformed metasedimentary rocks. Though a wide range of densities for cataclasite of unit $KJms_W$ are included in the model, most of these rocks have Δρ of -10 kg/m^3. Solid lines show fault locations that are well constrained by the geophysical data; dashed lines are faults constrained by surficial geologic mapping, but are less certain at depth.