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U.S. Geological Survey

Prepared in cooperation with
Washington State Division of Geology and Earth Resources, U.S. National Park Service, and U.S. Forest Service

Scientific Investigations Map 2940
Sheet 2 of 2
Pamphlet and CD-ROM accompany map

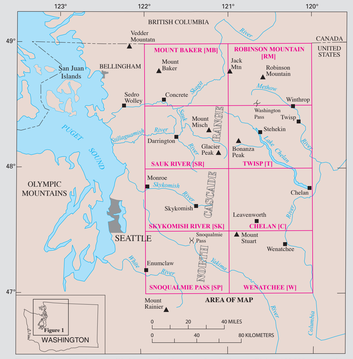


Figure 1. Map of northwestern Washington showing area of geologic map. Eight 1:100,000 topographic quadrangles that form geologic map are outlined and labeled. Quadrangle abbreviations and compass quadrants are used in the text as location codes to find places on the map, for example [MBse] is the southeastern part of the Mount Baker quadrangle. Abbreviations for all quadrangles are shown here and along the edge of the geologic map.

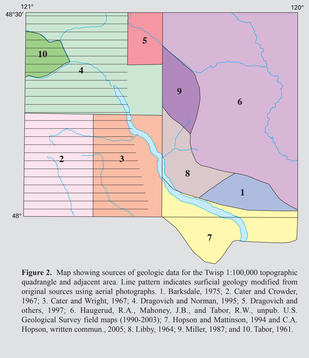


Figure 2. Map showing sources of geologic data for the Twisp 1:100,000 topographic quadrangle and adjacent area. Line pattern indicates surficial geology modified from original sources using aerial photographs. 1. Barksdale, 1975; 2. Cater and Crowder, 1967; 3. Cater and Wright, 1967; 4. Dragovich and Norman, 1995; 5. Dragovich and others, 1997; 6. Haugerud, R.A., Mahoney, J.B., and Tabor, R.W., unpub. U.S. Geological Survey field maps (1990-2003); 7. Hopson and Mattinson, 1994 and C.A. Hopson, written commun., 2005; 8. Libby, 1964; 9. Miller, 1987; and 10. Tabor, 1961.

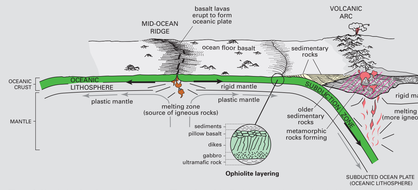


Figure 3. Sketch showing plate tectonic processes. The surface of the Earth is covered by many interlocking plates (lithosphere or crust). New crust forms at the mid-ocean ridge where oceanic plates move apart, allowing molten rock (magma) to reach the surface and erupt as basalt lavas. An oceanic plate descends below a continental plate at a subduction zone where plates converge; rocks of both plates melt at depth to produce magma that rises toward the surface. Much of the magma collects in large masses (magma chambers) in the continental crust. Some magma reaches the surface to build a line of volcanoes (volcanic arc). Eventually the magma in the chambers cools and crystallizes to become plutonic intrusive igneous rock. Sedimentary rocks on the ocean floor and some of the oceanic crust scrapes off at depth to become metamorphic rocks. Blow-up shows idealized layering of oceanic lithosphere (ophiolite).

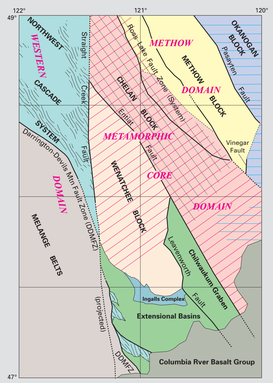


Figure 4. Map showing major geologic structures and major metamorphic episodes in the North Cascades, Washington. Areas of multiple regional metamorphism are sketched from field and laboratory data and descriptions in the literature. Boundaries are approximate. Domains shown are described in Tabor and Haugerud (1999).

early Tertiary and Late Cretaceous metamorphism

early Late Cretaceous metamorphism

early Late Cretaceous and Early Cretaceous metamorphism

Early Cretaceous blueschist metamorphism of Easton terrane

Early Cretaceous and local Jurassic metamorphism

Contact—Dotted where uncertain

Fault—Dashed where uncertain; dotted where projected under cover or intruded by younger rocks

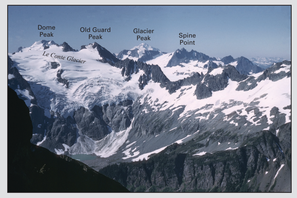


Figure 7. Looking south from east ridge of Mount Formidable [SRne]. Uplift and erosion, especially glacial erosion, exposed rocks that formed deep in the Earth's crust. Rocks of the Chelan Mountains terrane, including Cascade River Schist, form foreground cliffs. Underlying metamorphosed Marblemount pluton in Old Guard Peak [SRne] extends along jagged ridge into middle foreground. The Cloudy Pass batholith, a Miocene Cascade Arc pluton, supports Dome Peak [SRne] and Spire Point [SRne] in middle background. Glacier Peak volcano in the Cascade Magmatic Arc erupted on top of these eroded older rocks.

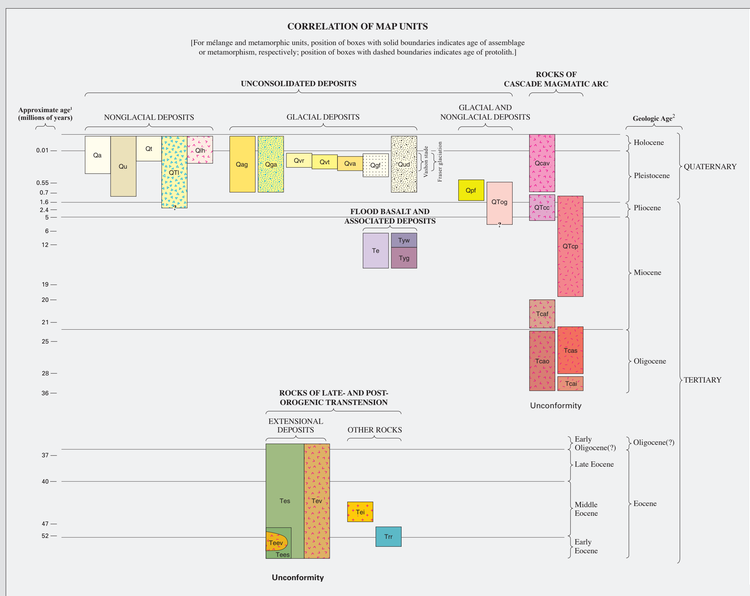
Figure 8. View northwest from Bacon Peak [MBsw]. Rocks of Easton Terrane (Shuksan Greenschist) form Anderson Butte [MBsw]. A huge block of ultramafic rock (dunite) in Bell Pass Mélange underlies Twin Sisters [MBsw]. Mount Baker volcano dominates skyline.

NOTE: See Nontechnical Pamphlet for figures that are not on this map sheet

Figure 9. Digital relief map showing maximum extent of Cordilleran Ice Sheet (white with blue contours; interval 200 m) in the North Cascades during the Vashon stade; probable alpine glaciers on high peaks and beyond the margins of the main ice sheet are not shown (Waitt, 1972; Booth, 1990; Jon Riedel, written commun., 2005). Mount Baker, Rattlesnake Mountain [SPrw], Jack Mountain [RMnw], and many lesser peaks extended above the ice-sheet surface as nunataks.

CORRELATION OF MAP UNITS

[For mélange and metamorphic units, position of boxes with solid boundaries indicates age of assemblage or metamorphism, respectively; position of boxes with dashed boundaries indicates age of protolith.]



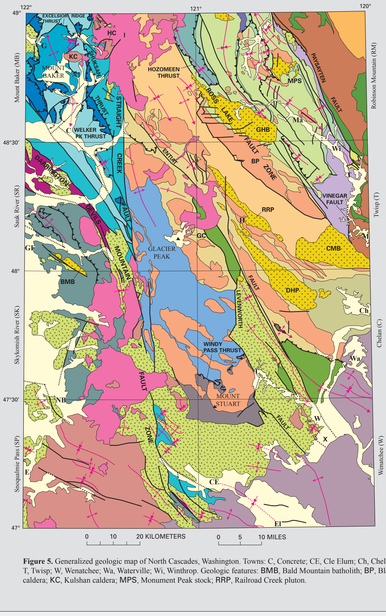


Figure 5. Generalized geologic map of North Cascades, Washington. Towns: C, Concrete; CE, Cle Elum; Ch, Chelan; E, Enumclaw; El, Ellensburg; GF, Granite Falls; G, Glacier; H, Holden; L, Leavenworth; M, Methow; Ma, Mazama; NB, North Bend; S, Skykomish; T, Twisp; W, Wenatchee; Wa, Waterville; Wi, Winthrop. Geologic features: BMB, Bald Mountain batholith; BP, Black Peak batholith; CMB, Cooper Mountain batholith; DHP, Duncan Hill pluton; GC, Gamma Ridge caldera; GHB, Golden Horn batholith; HC, Hannegan caldera; KC, Kulshan caldera; MPS, Monument Peak stock; RRP, Railroad Creek pluton.

FIGURE SYMBOLS

Contact—Dotted where concealed

High-angle fault—Dotted where concealed

Thrust fault—Dotted where concealed

Low-angle normal fault—Dotted where concealed

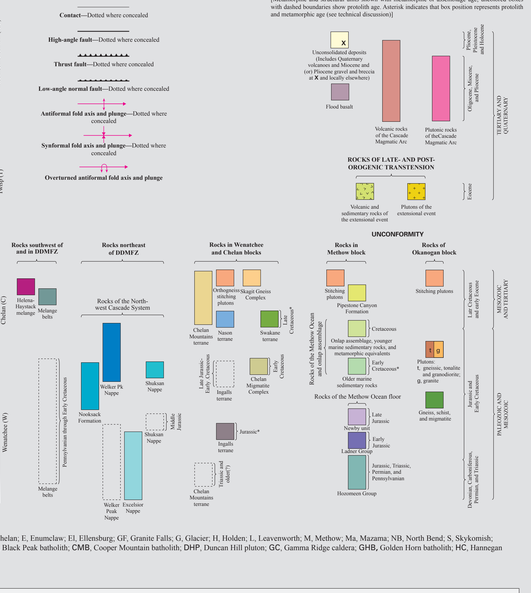
Antiformal fold axis and plunge—Dotted where concealed

Synformal fold axis and plunge—Dotted where concealed

Overturned antiformal fold axis and plunge

FIGURE CORRELATION

[Metamorphic and structural units shown with metamorphic or assemblage age; uncolored boxes with dashed boundaries show protolith age. Asterisk indicates that box position represents protolith and metamorphic age (see technical discussion)]



LIST OF MAP UNITS

[See technical or nontechnical pamphlets for unit descriptions. Note colors on the map vary as the underlying shaded-relief base varies. Unit age in parentheses after the unit name is the age of assemblage or metamorphism for mélange and metamorphic units. Location codes, such as "[MBsw]," following a place name, unit name, or geologic feature name indicates a location in the northwest quadrant of the Mount Baker quadrangle. The eight 1:100,000-scale quadrangles are outlined on the map, and quadrangle names and their abbreviations are labeled along the edges of the map, as well as on figures 1 and 5. The location code may consist of a quadrangle abbreviation or a combination of quadrangle and quadrant abbreviations. A location code at the end of the rock descripton gives the unit location on the map]

UNCONSOLIDATED DEPOSITS

NONGLACIAL DEPOSITS

Qa — **Alluvium of valley bottoms (Holocene and Pleistocene)**

Qu — **Alluvium (Holocene and Pleistocene)**

Qt — **Talus deposits (Holocene and Pleistocene)**

QTl — **Landslide deposits (Holocene, Pleistocene, and Pliocene?)**

Qh — **Lahars (Holocene and Pleistocene)**

GLACIAL DEPOSITS

Qag — **Alpine glacial deposits (Holocene and Pleistocene)**

Qga — **Deposits of alpine glaciers and Cordilleran Ice Sheet (Holocene and Pleistocene)**

Qvr — **Deposits of Vashon stade of Fraser glaciation of Armstrong and others (1965) (Pleistocene)**
Recessional outwash deposits

Qvt — **Till**

Qva — **Advance outwash deposits**

Qud — **Upland deposits (Holocene and Pleistocene)**

Qgf — **Deposits of glacial outburst floods (Pleistocene)**

GLACIAL AND NONGLACIAL DEPOSITS

Qpf — **Nonglacial and glacial sedimentary deposits older than Fraser glaciation (Pleistocene)**

QTog — **Older gravel (Pleistocene, Pliocene, and Miocene?)**

ROCKS OF CASCADE MAGMATIC ARC

Qcav — **Rocks of young Cascade volcanoes (Holocene and Pleistocene)**

QTcc — **Caldera deposits (Pleistocene, Pliocene, and Miocene)**

QTcp — **Intrusive rocks of Cascade Pass family (Pleistocene, Pliocene, and Miocene)**

Tcaf — **Volcanic rocks of Fifes Peak episode (Miocene)**

Tcas — **Intrusive rocks of Snoqualmie family (Miocene and Oligocene)**

Tcao — **Volcanic and sedimentary rocks of Ohanapecosh episode (Oligocene)**

Tcai — **Intrusive rocks of Index family (Oligocene)**

FLOOD BASALT AND ASSOCIATED DEPOSITS

Te — **Ellensburg Formation (Miocene)**

Yakima Basalt Subgroup of Columbia River Basalt Group (Miocene)

Tyw — **Wanapum Basalt**

Tyg — **Grand Ronde Basalt**

ROCKS OF LATE- AND POST-OROGENIC TRANSTENSION

EXTENSIONAL DEPOSITS

Tes — **Extensional sedimentary rocks (early Oligocene and Eocene)**

Tees — **Early extensional sedimentary rocks (middle and early Eocene)**

Teev — **Silver Pass Volcanic Member of Swauk Formation**

Tev — **Volcanic rocks (early Oligocene and Eocene)**

OTHER ROCKS

Te — **Intrusive rocks (middle Eocene)**

Trr — **Raging River Formation (middle and early? Eocene)**

OROGENIC AND PRE-OROGENIC ROCKS MOSTLY WEST OF STRAIGHT CREEK FAULT

ROCKS SOUTHWEST OF DARRINGTON-DEVILS MOUNTAIN FAULT ZONE

TKwb — **Rocks of western mélange belt (middle Eocene to Late Cretaceous)**

TKwg — **Quartz Mountain stock (Middle Jurassic)**

TKeb — **Rocks of eastern mélange belt (middle Eocene to Late Cretaceous)**

TKmg — **Migmatitic gneiss**

ROCKS IN DARRINGTON-DEVILS MOUNTAIN FAULT ZONE

TKhm — **Helena-Haystack mélange (middle Eocene and (or) Late Cretaceous)**
Serpentinite

TKhg — **Blocks of resistant rock**

ROCKS NORTHEAST OF DARRINGTON-DEVILS MOUNTAIN FAULT ZONE

Northwest Cascade System

Rocks of Autochthon

KJn — **Nooksack Formation (Early Cretaceous to Middle Jurassic)**

Jnw — **Wells Creek Volcanic Member**

Welker Peak and Excelsior Nappes

KJb — **Bell Pass mélange (Cretaceous to Late Jurassic)**

KJyn — **Yellow Aster Complex of Misch (1966) (Paleozoic or older protolith age)**

KJtn — **Twin Sisters Dunite of Ragan (1961, 1963)**

KJv — **Vedder Complex of Armstrong and others (1983) (pre-Permian protolith age)**

Chilliwack River terrane

J'Pc — **Cultus Formation of Brown and others (1987) (Early Jurassic and Late Triassic)**

PDc — **Chilliwack Group of Cairnes (1944) (Permian, Carboniferous, and Devonian)**

Shuksan Nappe

Easton terrane

Ket — **Tonalite gneiss of Hicks Butte (Early Cretaceous)**

Easton Metamorphic Suite

Ked — **Darrington Phyllite (Early Cretaceous)**

Kes — **Shuksan Greenschist (Early Cretaceous)**

OROGENIC AND PRE-OROGENIC ROCKS EAST OF STRAIGHT CREEK FAULT

ROCKS UNIQUE TO WENATCHEE BLOCK

Ingalls terrane

Jis — **Ingalls terrane (Jurassic)**

JPr — **Resistant blocks of igneous and meta-igneous rocks**

Jss — **Resistant blocks of sedimentary rocks**

Nason Terrane

Knyng — **Nason Ridge Migmatitic Gneiss (Late Cretaceous)**

Kncs — **Chiwaukum Schist (Late Cretaceous)**

ROCKS IN WENATCHEE AND CHELAN BLOCKS

Terrane overlap units and stitching plutons

TKsg — **Skagit Gneiss Complex (middle Eocene to Late Cretaceous)**

TKso — **Orthogneiss**

TKsn — **Orthogneiss of The Needle**

TKto — **Tonalitic orthogneiss (middle Eocene to Late Cretaceous)**

TKgo — **Granodioritic orthogneiss (middle Eocene to Late Cretaceous)**

Kt — **Tonalitic plutons (Late Cretaceous)**

Kg — **Granodioritic plutons (Late Cretaceous)**

Chelan Mountains terrane

TKns, Kns — **Napeequa Schist (middle Eocene to Late Cretaceous)**

TKnu, Knu — **Ultramafic rock**

TKcs, Kcs — **Cascade River Schist (middle Eocene to Late Cretaceous)**

TKmd, Kmd — **Marblemount plutons (middle Eocene to Late Cretaceous)**

TKmm — **Magic Mountain Gneiss (middle Eocene to Late Cretaceous)**

Swakane terrane

Kswg — **Swakane Biotite Gneiss (Late Cretaceous)**

Terrane uncertain

Kcxm — **Chelan Migmatite Complex of Hopson and Mattinson (1994) (Cretaceous)**

ROCKS UNIQUE TO ROSS LAKE FAULT ZONE

TKrb — **Ruby Creek heterogeneous plutonic belt of Misch (1966) (middle Eocene to Late Cretaceous)**

TKsx — **Skymo Complex of Wallace (1976) (middle Eocene to Late Cretaceous)**

TKm, Km — **Metamorphosed rocks of Methow Ocean (middle Eocene to Late Cretaceous)**

TKno — **Tonalitic orthogneiss (middle Eocene to Late Cretaceous)**

ROCKS IN METHOW BLOCK

Kpc — **Pipestone Canyon Formation (Late Cretaceous)**

Kpm — **Tonalite plutons in Methow block (Late Cretaceous)**

Kpy — **Pasayten Group of Kiessling and Mahoney (1997) (Late Cretaceous)**
Volcanic rocks

Kps — **Sedimentary rocks**

Rocks of Methow Ocean and onlap assemblages

Ktf — **Three Fools sequence of Haugerud and others (2002) (Cretaceous)**

KJos — **Older sedimentary rocks (Early Cretaceous and Late Jurassic)**

Rocks of Methow Ocean floor

KJt — **Tonalite intrusions (Early Cretaceous and Late Jurassic)**

JPzb — **Newby Group of Mahoney and others (2002) (Late Jurassic)**

JPzm — **Metamorphic rocks of McClure Mountain**

JPzl — **Ladner Group of Mahoney (1993) (Middle Jurassic)**

Hozomeen terrane

MzPzh — **Hozomeen Group (Mesozoic and Paleozoic)**

ROCKS IN OKANOGAN BLOCK

Okanogan terrane

Kld — **Tonalite and diorite (Late Cretaceous)**

Kgg — **Granite and granodiorite (Early Cretaceous)**

Kor — **Remmel batholith (Early Cretaceous)**

Kot — **Older tonalite (Early Cretaceous)**

Kh — **Hornblendic metamorphic rocks (Early Cretaceous and Jurassic)**

Kjog — **Mylonitic granodiorite, gneissic trondhjemite, and banded gneiss (Early Cretaceous and Jurassic)**

EXPLANATION OF MAP SYMBOLS

GEOLOGIC SYMBOLS

Contact—No contact where approximately located or gradational (mostly unit Qud)

Fault—Dotted where concealed

High-angle fault

Thrust fault

Low-angle fault—Extensional fault

GEOGRAPHIC SYMBOLS

Town

Major highway

Road

Trail

River

Water boundary—Blue boundary shown at edge of lake, or large river

Glacier or snow

Mountain or peak

Park, wilderness, recreation area, or scenic highway boundary

Topographic map (1:100,000 scale) boundary—Name [abbreviation] of topographic map labeled along east and west edges of map

Figure 12. Granite of Cascade Pass family on the west wall of Nooksack cirque in foreground. Ruth Mountain [MBrw] to northeast is carved from volcanic breccia of Pliocene Hannegan Caldera. Both rocks formed in the Cascade Magmatic Arc. Extensive glacial moraine covers valley floor.

Figure 13. Beds of sandstone (Eocene Swauk Formation) in older extensional deposits on south side of the east ridge of Summit Chief Mountain [SKse].

Figure 14. Disrupted sandstone, greenstone, and light-colored dikes in argillite matrix of western mélange belt unit TKwb, South Fork Stillaguamish River [SRsw].

Figure 15. View east from Mount Index [SKnw] across Skykomish River valley to Gunn and Baring peaks [SKne], underlain by large erosion-resistant tectonic slices of migmatitic gneiss in less-resistant sedimentary rocks of eastern mélange belt. Grotto Mountain is composed of granodiorite of Miocene Grotto batholith, the eroded root of a Cascade Magmatic Arc volcano. Mountains on skyline beyond are carved from rocks of Nason terrane (in Wenatchee block), predominantly Late Cretaceous Chiwaukum Schist and Mount Stuart batholith. Foreground rock is Jurassic metagabbro, another tectonic slice mixed into eastern mélange belt in latest Cretaceous or early Tertiary.

Figure 16. Large lumps of erosion-resistant rock dotting serpentinite matrix of Helena-Haystack mélange (units TKrm, TKrg). Most lumps are greenstone or Shuksan Greenschist. View northwest from ridge southwest of Day Lake [SRnw].

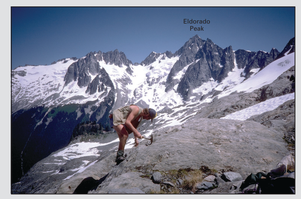


Figure 17. View of Eldorado Peak [MBse], looking northeast from divide between Sibley and Marble Creeks. In foreground, metaconglomerate of late Cretaceous Cascade River Schist contains cobbles (deposited in Triassic) stretched to form streaks. Orthogneiss of Eldorado pluton visible in background. Small glaciers and moraine deposits in valley are visible behind geologist.

Figure 19. View from Mount Winthrop [RMnw] south along Cascade Crest. Well-bedded sandstone of Cretaceous Three Fools Sequence (rocks of Methow Ocean) form crest. Divide at right was rounded by overriding Cordilleran Ice Sheet. Mixed glacial deposits (drift) from ice sheet and local alpine glaciers are visible in valley bottom.

Figure 20. Hozomeen greenstone in Methow block north of Little Beaver Creek [MBne], where it is probably Triassic, and on Hozomeen Mountain [MBne], where it is Late Paleozoic. View northeast from ridge south of Little Beaver Creek.

Geologic Map of the North Cascade Range, Washington

By
Ralph A. Haugerud and Rowland W. Tabor

2009

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