GEOLOGIC MAP OF WASHINGTON – NORTHWEST QUADRANT

by
JOE D. DRAGOVICH, ROBERT L. LOGAN, HENRY W. SCHASSE, TIMOTHY J. WALSH, WILLIAM S. LINGLEY, JR., DAVID K. NORMAN, WENDY J. GERSTEL, THOMAS J. LAPEN, J. ERIC SCHUSTER, AND KAREN D. MEYERS

WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
GEOLOGIC MAP GM-50
2002

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This publication is dedicated to Rowland W. Tabor, U.S. Geological Survey, retired, in recognition and appreciation of his fundamental contributions to geologic mapping and geologic understanding in the Cascade Range and Olympic Mountains.

WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES

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Envelope photo: View to the northeast from Hurricane Ridge in the Olympic Mountains across the eastern Strait of Juan de Fuca to the northern Cascade Range. The Dungeness River lowland, capped by late Pleistocene glacial sediments, is in the center foreground. Holocene Dungeness Spit is in the lower left foreground. Fidalgo Island and Mount Erie, composed of Jurassic intrusive and Jurassic to Cretaceous sedimentary rocks of the Fidalgo Complex, are visible as the first high point of land directly across the strait from Dungeness Spit. The lowland to the right of Mount Erie is Whidbey Island, consisting predominantly of late Pleistocene glacial and nonglacial sediments. The highest visible peak, Mount Baker (10,778 ft), consists primarily of late Quaternary andesitic lava flows. The lower peaks in the foreground of Mount Baker compose Twin Sisters Mountain, which consists of the Permian to Triassic Twin Sisters Dunite. Mount Shuksan (9,127 ft) is visible to the right and behind Mount Baker. The Mount Shuksan massif is composed of Jurassic Shuksan Greenschist of the Easton Metamorphic Suite. Peaks to the left of Mount Baker along the skyline consist of Permian to Devonian metasedimentary and metavolcanic rocks of the Chilliwack Group. *Photograph by Karl W. Wegmann.*

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CONTENTS

ILLUSTRATIONS

TABLES

PLATES

GEOLOGIC MAP OF WASHINGTON—NORTHWEST QUADRANT

by

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INTRODUCTION

The Geologic Map of Washington—Northwest Quadrant is the last in a series of four 1:250,000-scale geologic maps that together make up the third complete geologic map of Washington at a scale of 1:500,000 or larger published by the Washington Division of Geology and Earth Resources (DGER) and its predecessors. (The first two, Culver and Stose, 1936, accompanied by Culver, 1936, and Huntting and others, 1961, are out-of-print.) The first three quadrants of the third geologic map of Washington are available as: Geologic Map of Washington—Southwest Quadrant, DGER Geologic Map GM-34 (Walsh and others, 1987); Geologic Map of Washington—Northeast Quadrant, DGER Geologic Map GM-39 (Stoffel and others, 1991); and Geologic Map of Washington—Southeast Quadrant, DGER Geologic Map GM-45 (Schuster and others, 1997).

Separate topographic base maps (DGER Topographic Maps TM-1, TM-2, and TM-3) are available for the first three quadrants (southwest, northeast, and southeast), but because the northwest quadrant was prepared digitally, a separate topographic map was not printed.

MAP COMPILATION

The 1:250,000-scale Geologic Map of Washington—Northwest Quadrant was compiled chiefly from 1:100,000-scale geologic maps that were prepared by staff of the U.S. Geological Survey (USGS) and DGER, as noted in Table 1. Other geologic studies were used to locally refine the geologic map. Many of these studies are shown in the Sources of Map Data section.

ACKNOWLEDGMENTS

The USGS STATEMAP component of the National Cooperative Geologic Mapping Program supported 1:24,000-scale geologic mapping and the compilation and (or) conversion to digital format of several 1:100,000 quadrangles under the following contracts: 1434-93-A-1176, 1434-94-A-1258, 1434-95-A-01384, 1434-HQ-96-AG-01524, 1434-HQ-97-AG-01809, 98HQAG2062, 99HQAG0136, 00HQAG0107, and 01HQAG0105. Mapping on the Olympic Peninsula was funded with grants from the Minerals Management Service, Continental Margins Program (subagreement nos. 14-12-0001-30387, 14-35-0001-30497, and 14-35-0001-30643), and the Olympic Natural Resources Center (University of Washington contract nos. 234153 and DNR FY96-165).

The Geologic Map of Washington—Northwest Quadrant is a result of the efforts of scores of geologists over many decades. The contributions of many of these geologists are acknowledged by citation (see References Cited, p. 30) and Sources of Map Data (p. 65). We gratefully acknowledge all of those geologists who have made vital contributions toward deciphering the complex geology of northwestern Washington.

Rowland W. Tabor (USGS, retired) to whom this publication is dedicated, is the principal author of mapping

Table 1. 1:100,000-scale quadrangle, compiler(s), and chief source report for geologic maps in the northwest quadrant of Washington. For the Chelan, Mount Baker, Robinson Mountain, Sauk River, Skykomish River, Snoqualmie Pass, and Wenatchee 1:100,000-scale quadrangles, the compilers listed below modified the referenced map by converting the map-unit symbology to the system used by DGER and simplifying the geology for presentation at 1:250,000 scale. R. W. Tabor (USGS, retired) supplied digital geology for the Mount Baker, Sauk River, Skykomish River, and Snoqualmie Pass 1:100,000 quadrangles. Where the report is given as 'digital' there has been no conventional geologic map released; instead, the 1:100,000-scale geology for these quadrangles is available as digital (Arc/Info) coverages (Washington DGER, 2001) at the address listed inside the front cover of this pamphlet

Quadrangle	Compiler(s) (1:250,000)	Report (1:100,000)
Bellingham	J. D. Dragovich	Lapen (2000)
Cape Flattery	H. W. Schasse	digital
Chelan	J. D. Dragovich	Tabor and others (1987a)
Copalis Beach	R. L. Logan	digital
Forks	W. J. Gerstel and W. S. Lingley, Jr.	Gerstel and Lingley (2000)
Mount Baker	D. K. Norman and J. D. Dragovich	Tabor and others (in press b)
Mount Olympus	W. J. Gerstel and W. S. Lingley, Jr.	digital
Port Angeles	H. W. Schasse	digital
Port Townsend	H. W. Schasse	digital
Robinson Mountain	J. D. Dragovich	R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)
Roche Harbor	R. L. Logan	digital
Sauk River	H. W. Schasse	Tabor and others (in press a)
Seattle	T. J. Walsh	digital
Shelton	R. L. Logan	digital
Skykomish River	J. D. Dragovich	Tabor and others (1993)
Snoqualmie Pass	T. J. Walsh and J. D. Dragovich	Tabor and others (2000)
Tacoma	T. J. Walsh	digital
Twisp	J. D. Dragovich and D. K. Norman	Dragovich and Norman (1995)
Wenatchee	T. J. Walsh and J. D. Dragovich	Tabor and others (1982b)

that covers approximately three quarters of the northwest quadrant. Over the last 40 years, he has published 28 peer-reviewed technical books and articles and made dozens of presentations at professional conferences. Without this work, large parts of the Cascades and Olympics would still be poorly understood. In addition, Rowland has made a remarkable effort to communicate geology to the general public. He has written nine field guides and ten books for general audiences. He has also provided several detailed reviews of this map.

Although many individuals are acknowledged below, we wish to express our appreciation to two persons who have been especially helpful. Edwin H. (Ned) Brown, Western Washington University, retired, has shared his regional overview of the geology of northwestern Washington and helped prepare the lithotectonic domain map, major batholiths and plutons map, P-T diagram, and metamorphic facies map associated with this pamphlet (see Figs. 4, 5, and 6 on Sheet 3). Weldon W. Rau, DGER, retired, in addition to mapping much of the southwestern Olympic Peninsula, has supported numerous scientists working in the Puget Lowland and Olympic Peninsula with reliable foraminiferal age determinations and lithostratigraphic correlations.

Many others have contributed to the success of the state geologic map project and the publication of this report. We gratefully acknowledge their contributions below.

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Review of 1:250,000-scale Geologic Map and Report

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Rowland W. Tabor, USGS, retired

MAP DESIGN AND STANDARDS

Base Map

The base map for Sheet 1 was derived from digital information held in the Washington State Department of Natural Resources Geographic Information System database. Much of this information was prepared by the USGS from USGS 1:24,000- and 1:62,500-scale topographic maps. Contours were generated from 10-m digital elevation model data and manually adjusted to fit streams. Public land survey and transportation features may have been updated using other government records, maps, digital data, and (or) aerial imagery, particularly from the Washington State Department of Transportation and the USGS. Hydrography is from the Washington State Department of Fish and Wildlife. Most names of cultural and natural features are from the USGS Geographic Names Information System (GNIS) data files at http://geonames.usgs.gov/. Road names and numbers are taken from county or municipal maps and DNR, U.S. Forest Service, and other government maps where appropriate. The base map was not field checked.

The map projection is Universal Transverse Mercator, Zone 10. Horizontal control is derived from the Washington State Plane Coordinate System, south zone, 1927 North American Datum. Vertical control is based on the National Geodetic Vertical Datum of 1929.

Geologic Map

The Geologic Map of Washington—Northwest Quadrant displays geologic units chiefly by age and lithology, not by geologic formations or terranes. Formations are shown only for the Grande Ronde Basalt of the Columbia River Basalt Group, the Sumas Drift, and the Crescent Formation in order to make these important and widespread units distinguishable from nearby rocks of similar age and lithology. The age of each unit is assigned according to the flow chart in Figure 1. The age of metamorphosed units is the protolith age, not the age of metamorphism.

A multiple-level scheme of colors, patterns, and map symbols has been used to portray the age and lithology of geologic units on the 1:250,000-scale geologic map (see the key to geologic units on Sheet 1). The first level of detail, expressed by broad color ranges, distinguishes six general lithologic subdivisions: unconsolidated sedimentary deposits, sedimentary deposits and rocks, volcanic deposits and rocks, intrusive rocks, low-grade metamorphic rocks, and high-grade metamorphic rocks. The second level of detail, expressed by variations of color within each broad color range, indicates age. The third level of detail, represented by patterns, distinguishes lithologic units or small groups of lithologic units. The fourth level of detail, represented by symbols, identifies individual geologic map units.

Unit symbols consist of uppercase letters denoting age, with youngest first, followed by lowercase letters, showing first the general lithologic subdivision, then detailed lithologic information. For example, KJigb is the symbol for Cretaceous to Jurassic intrusive gabbro. Where formations are shown on the map, the symbol includes a subscripted letter. For example, the symbol for the Miocene Grande Ronde Basalt is Mv_g. Detailed age discriminations are denoted by a subscripted number, with the larger number indicating the younger age. In the symbols for Tertiary rocks, numeric subscripts denote that a unit is either below (subscript 1) or above (subscript 2) a regional unconformity.

Most of the age symbols are based on standard USGS age symbols, but because of the prevalence of Tertiary rocks in Washington, each Tertiary series has been assigned a separate age symbol. These Tertiary symbols differ somewhat from draft symbols recently released for review by the USGS (U.S. Geological Survey, 2000).

Because the 1:250,000-scale map units are age-lithologic units, formations consisting of diverse types or ages of rocks are separated into their component lithologies and (or) ages and included in more than one map unit. To determine all map units (symbols) in which a named unit is included, consult the List of Named Units in this pamphlet (Table 2, p. 47).

Positional accuracy of the 1:250,000-scale geologic information is variable. All of the geologic information on

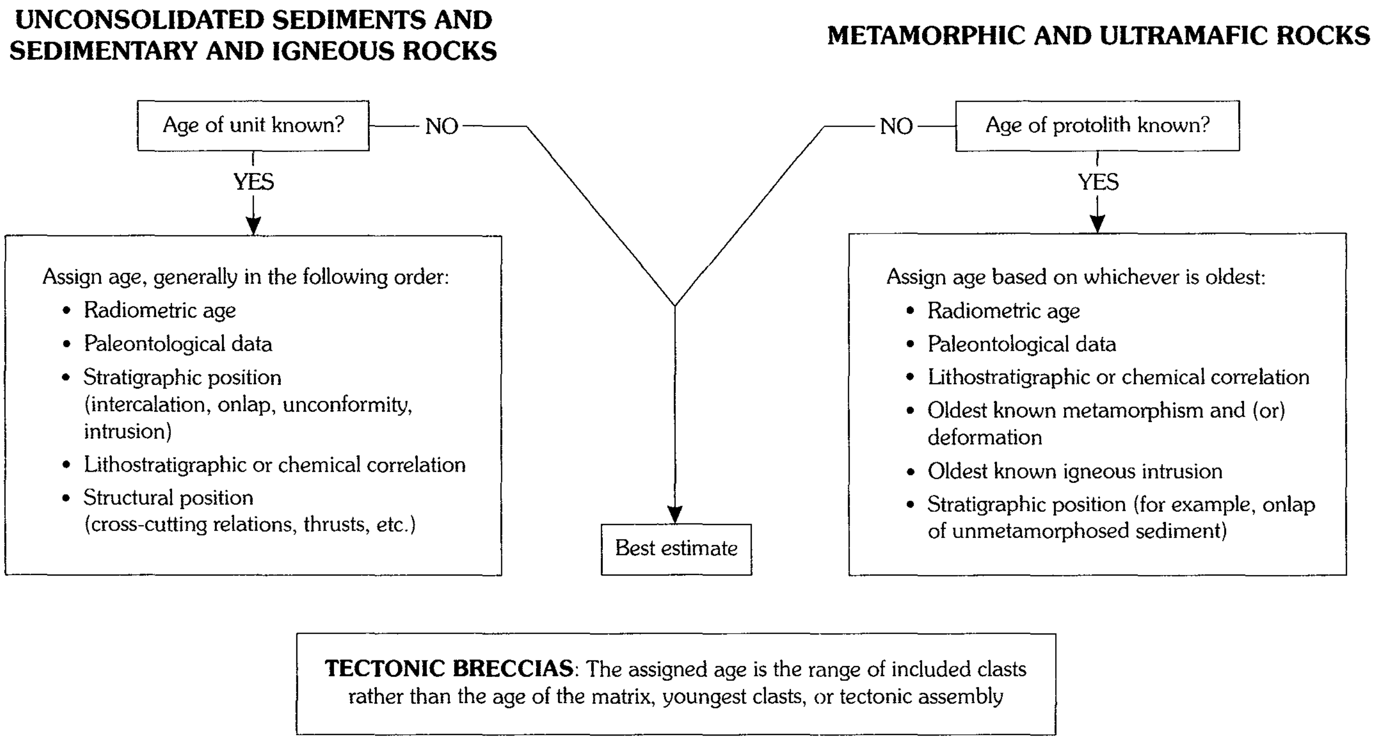

Figure 1. Flow chart for age assignment of geologic units. The entire age range of any given faunal assemblage is used unless the age of the unit is otherwise constrained.

Sheet 1 was derived directly from or modified from digital sources at 1:100,000 or larger scales, but in many areas these data were generalized to improve readability at 1:250,000 scale.

GEOLOGIC PROVINCES AND TERRANES

The northwest quadrant includes three of the state's physiographic provinces—the North Cascades, Puget Lowland, and Olympic Mountains (Fig. 2). The North Cascades comprises a series of pre-Tertiary accreted terranes, Cretaceous to mid-Tertiary metamorphic and plutonic complexes, and Cretaceous to Holocene thrusts and high-angle faults. The Olympic Mountains are a mostly Tertiary subduction complex comprising underplated deep-marine siliciclastic rocks and the overlying marine basalt and autochthonous marginal marine basin fill. Between these two provinces lies the Puget Lowland, which was invaded repeatedly in Pleistocene time by ice of the Cordilleran ice sheet (Fig. 3) that covered the contact between the North Cascades and Olympic Mountains provinces with unconsolidated sediments as much as 1000 m thick.

Most pre-Tertiary rocks in the map area were accreted to North America during the Mesozoic and early Tertiary and record a long period of terrane amalgamation in the Pacific Northwest, the details of which are poorly understood. Several of these terranes are far-traveled and demonstrate the mobile nature of the lithosphere in the circum-Pacific basin. Major Tertiary and pre-Tertiary geologic provinces of northwestern Washington State are shown on Figure 4 on Sheet 3.

Because the nomenclature of tectonostratigraphic terranes and lithic assemblages is informal and tends to undergo frequent revisions, we avoided these designations for most units. For information on terranes and lithic assemblages in the map area, see Tabor and Cady (1978a), Whetten and others (1978), Coney and others (1980), Monger and others (1982), Engebretson and others (1984), Brown (1986, 1987), Brown and others (1987), Silberling and others (1987), Tabor (1987, 1994), Tabor and others (1987b, 1989, in press a,b), Brandon and others (1988), Brandon and Vance (1992), Snavely and others (1993), Babcock and others (1994), and Tabor and Haugerud (1999).

FAULTS AND FOLDS

Major faults in the northwest quadrant of Washington are shown on Figure 4 on Sheet 3.

The Cascade Range and San Juan Islands consist of Mesozoic to possibly early Tertiary folded thrust belts cut by and (or) rejuvenated as high-angle faults. The Cretaceous to Eocene Straight Creek fault divides the area into eastern domains dominated by high-grade metamorphic rocks and western domains composed of unmetamorphosed and low-grade rocks.

The Olympic Peninsula consists of a westward-younging accretionary thrust belt ranging from early Tertiary to Pliocene or younger (Tabor and Cady, 1978b; Palmer and Lingley, 1989). The eastern part of this thrust belt was folded into a regional, east-plunging antiform during the Miocene (Tabor, 1975). All of these structures are cut by Miocene to Holocene northeast-trending strike-slip faults (Rau, 1979; Gerstel and Lingley, 2000).

The Puget Lowland is cut by a series of west- and northwest-trending faults, many of which are suspected to be Quaternary in age (Daneš and others, 1965; Gower and others, 1985; Rogers and others, 1996a,b; Bucknam and others, 1992; Johnson and others, 2001). On Sheet 1, we show the Seattle fault, the southern Whidbey Island fault, the Darrington–Devils Mountain fault, the northern Whidbey Island fault (renamed Utsalady Point fault by Johnson and others, 2001), the Hood Canal fault, and other suspected Quaternary faults as dotted (that is, covered by Quaternary sediments) because their identification is based on geophysical techniques rather than mapping of fault offsets in Quaternary sediments. One of the strands of the Seattle fault on Bainbridge Island is shown as a solid line, however, because its scarp has recently been identified on LIDAR (Light Detection and Ranging) imagery and trenched (Nelson and others, 2002). The Saddle Mountain East and Saddle Mountain West faults near Lake Cushman are also shown as solid because trenching studies have demonstrated them to have Quaternary displacement (Wilson and others, 1979). Quaternary fault offset has been demonstrated at Rocky Point on Camano Island (Johnson and others, 2001) and at Vasa Park along the southwest shore of Lake Sammamish, but these locations are too small to distinguish at this scale. Paleoseismologic studies on many of these geophysical lineaments are currently in progress. It is premature to show active faults on this map and we defer to the studies in progress.

Several faults that separate bedrock from unconsolidated sediments are shown as unconcealed (solid lines) on Sheet 1. This usage merely indicates that the fault plane is exposed in outcrop and does not necessarily imply offset of Quaternary sediments.

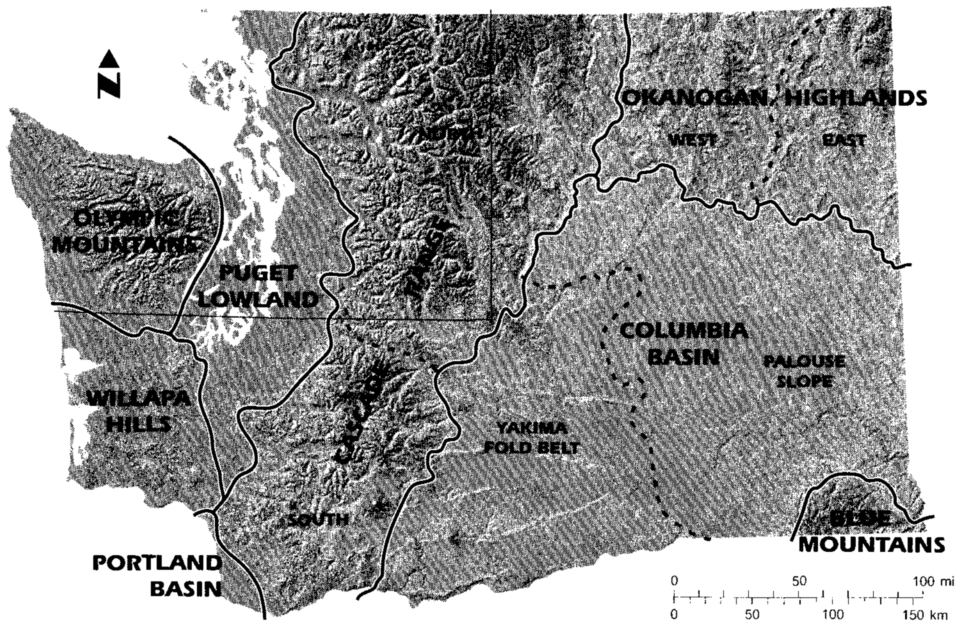

Figure 2. Major physiographic provinces of Washington (modified from Lasmanis, 1991). Fainter outline of the Northwest Quadrant is shown for reference.

DESCRIPTIONS OF MAP UNITS

Descriptions of Map Units on Sheet 2 gives a lithologic description of each unit on the 1:250,000-scale geologic map. Units are grouped by major lithologic category. Within each lithologic group, map units are addressed in order of increasing age. Within each unit description, lithologies are generally presented in order of decreasing abundance. Information concerning the ages and stratigraphic relations of the map units is given in the Ages of Map Units (Sheet 3) and this pamphlet (p. 7).

At the end of each unit description is a list of formally or informally named units, if any, that make up the geologic map unit. Formally named units included in lexicons published by the USGS or in the Geolex database (http://ngmdb.usgs.gov/Geolex/geolex_home.html) are listed without citation and with the word 'Formation' or the lithologic term capitalized (for example, Vashon Drift). Informally named units are followed by the citation to the work that defines the unit; for these units, the word 'formation' or the lithologic term is not capitalized (for example, rocks of Bulson Creek [Lovseth, 1975]). (Major batholith names are considered informal but are not listed with references.) If the map unit consists entirely of named units, the words 'consists of' are applied to the list of names given. If the map unit contains both named and unnamed units, the word 'includes' is used.

Unconsolidated Sediments and Sedimentary and Volcanic Rocks

Unconsolidated sediments are classified according to the Udden-Wentworth scale (see Pettijohn, 1957). Classification of sandstones follows the terminology of Dickinson (1970). Assignment of volcanic rock names was made on the basis of quartz–alkali feldspar–plagioclase–feldspathoid (QAPF) modes or by whole-rock geochemistry and the total alkali-silica (TAS) diagram (Le Maitre and others, 1989).

Intrusive Rocks

Intrusive rock names follow the International Union of Geological Sciences (IUGS) modal classification (Le

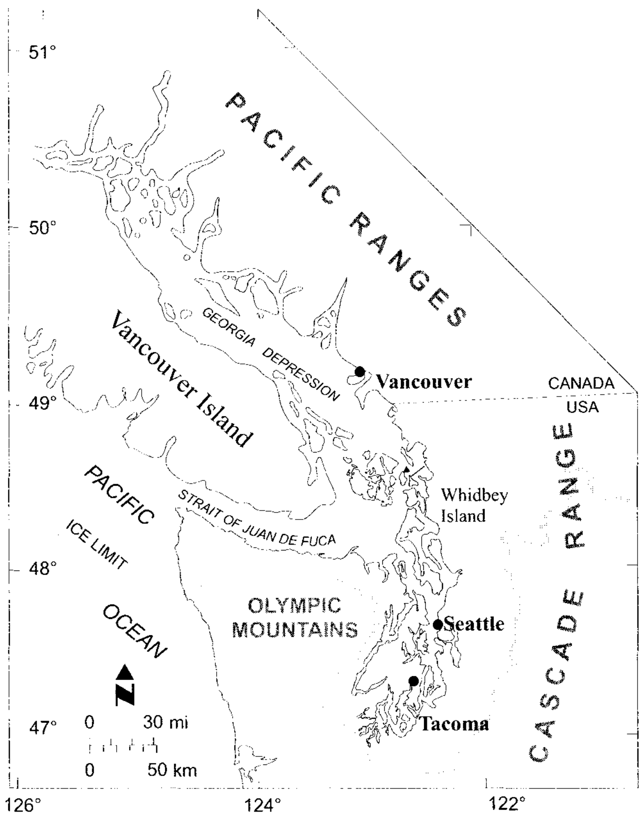

Figure 3. A substantial part of the Northwest Quadrant was repeatedly covered by ice of the Cordilleran ice sheet during Pleistocene time, leaving deposits as thick as about 1000 m. The approximate southwestern limit of latest Pleistocene ice (Vashon Stade of the Fraser Glaciation, about 15,000 years ago) is shown here by the thick gray line and in more detail on Sheet 1 (modified from Booth, 1994).

Maitre and others, 1989). Geologic map units that contain a single rock type or are dominated by one rock type are given lithologic names such as 'granite' or 'diorite'. Geologic map units that contain a mixture of rock types are assigned to one of the following generic categories: (1) intermediate intrusive rocks, which include the IUGS monzonite, quartz monzodiorite, monzodiorite, quartz diorite, and diorite fields (for example, unit ⅅii); (2) basic (mafic) intrusive rocks, which include the IUGS gabbro, quartz gabbro, monzogabbro, and quartz monzogabbro fields and their fine-grained equivalents (for example, unit Jib). Major plutons and batholiths in the map area are shown on Figure 5 on Sheet 3.

Metamorphic Rocks

Metamorphic rocks are divided into low and high grades based on metamorphic facies. Low-grade rocks are metamorphosed to the greenschist or blueschist facies, and high-grade rocks are metamorphosed to the amphibolite facies or higher (Fig. 6 on Sheet 3). Rare eclogite and granulite facies rocks occur among the high-grade metamorphic rocks in the northern Cascade Range (Brown and others, 1982; Misch, 1966).

Rocks metamorphosed to below the greenschist and blueschist facies, such as those metamorphosed to the zeolite or prehnite-pumpellyite facies, are categorized as non-metamorphic. However, the division between non-metamorphic rocks and low-grade metamorphic rocks in the map area is locally problematic, particularly between the prehnite-pumpellyite facies and the low-temperature blueschist facies. We generally assigned to the blueschist facies rocks that contain the blueschist metamorphic index minerals (Na-amphibole, lawsonite, and (or) aragonite). However, many geologic units contain only minor or rare occurrences of these minerals, making the distinction between low-grade and non-metamorphosed rocks unclear. For example, the Eastern mélange belt, which we included in the low-grade metamorphic rocks, probably does not contain lawsonite but probably does contain aragonite (Tabor and others, in press a). Conversely, the Fidalgo Igneous Complex may contain metamorphic aragonite in places, but we followed previous work (Brown and others, 1981) and assigned it to the non-metamorphic category.

Low-grade rocks are subdivided into metasedimentary and metavolcanic rocks, which generally are described using sedimentary and volcanic names preceded by the prefix 'meta'. However, some rocks in the low-grade metamorphic category have undergone extensive recrystallization and are assigned metamorphic rock names. For example, the rocks of unit Jsh have been recrystallized to a well-foliated schist and are thus called greenschist.

In some cases, a map unit includes both low-grade and high-grade rocks. For example, most of the metamorphic rocks of the North Cascades Crystalline Core have undergone amphibolite-facies metamorphism, but, in some areas, metamorphic grade reached only the greenschist facies. We include these rocks in the high-grade metamorphic category but acknowledge that low-grade rocks prevail in some areas (for example, in areas where the Ingalls Tectonic Complex and Cascade River Schist are mapped).

Many rocks in the map area are polymetamorphic. In such cases, we assign the grade designation on the basis of the last regional metamorphism, which is mostly Cretaceous and locally early Tertiary in the map area. For example, the rocks of the Vedder complex (Armstrong and others, 1983), which we assigned to the low-grade metamorphic category (unit pPsh), were subjected to a Permian amphibolite-facies metamorphism as well as a Cretaceous blueschist-facies metamorphism.

LIST OF NAMED UNITS

The List of Named Units (Table 2, p. 47) is a summary of named geologic units that appear in the geologic literature. The list includes all formal and many informal unit names that are currently in use or widely recognized. Some of the named geologic units are represented on the 1:250,000-scale geologic map (Sheet 1) by a single symbol (age-lithologic unit), whereas other named units are represented by two or more symbols. References cited for each named unit consist of the citation(s) in which the unit was defined, redefined, or extensively reviewed. Locations given for each named unit guide the map user to the 1:100,000-scale quadrangle(s) and township(s) and range(s) in which the named geologic unit occurs.

SOURCES OF MAP DATA

Figures 7 through 14 (p. 65–70) are index maps showing the areas covered by the sources of geologic mapping data used to compile the 1:250,000-scale geologic map. On each of these index maps, numbered areas correspond to abbreviated citations in the figure captions. Complete citations are given in the References Cited. Shaded areas on Figure 7 show where DGER compilers performed original geologic mapping for the state geologic map project. Plate or sheet numbers are specified only for reports that contain more than one map plate or sheet. Some unpublished maps and contract reports were used to compile the 1:250,000-scale geologic map and are listed in the References Cited (p. 30). They are available for inspection at the Division's Olympia office.

We used an unpublished map by R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000) as the major source for the geology we show in the Robinson Mountain 1:100,000-scale quadrangle. With this map, Haugerud and Tabor significantly modify the stratigraphy of the Methow block (Fig. 4 on Sheet 3), present several new informal stratigraphic names, redefine some formal geologic units, and recommend abandoning some geologic unit names. Information related to emerging Methow stratigraphy can be found in Mahoney (1993), Miller and others (1994), Haugerud and others (1996, 2002), Mahoney and others (1996), Dragovich and others (1997a), Kiessling and Mahoney (1997), Kiessling (1998), and Kiessling and others (1999).

AGES OF MAP UNITS

The age range for each age-lithologic unit on the 1:250,000-scale geologic map (Sheet 1) is represented by a colored box on the Ages of Map Units on Sheet 3. The color, pattern, and unit symbol in each box are the same as those used for the unit's map polygons on Sheet 1. Unit symbols can be cross-referenced with the Descriptions of Map Units (Sheet 2) and the List of Named Units (Table 2, p. 47).

Solid lines on the borders of a box indicate that the age range of the unit is well constrained. Dashed lines on the borders of a box indicate that the age is poorly constrained. Queries at the top and (or) bottom of a box indicate that the upper and (or) lower age limits are uncertain.

We have used the geologic time scale of Palmer and Geissman (1999) as the basis for this diagram. Provincial biostratigraphic stage correlations are from the "Correlation of Stratigraphic Units of North America" project of the American Association of Petroleum Geologists (Salvador, 1985) and were slightly modified to match parts of the time scale of Palmer and Geissman. The age scale on this diagram is not linear; scale changes are noted along the left side of the diagram.

For consistency among the four quadrangles of the 1:250,000-scale geologic map of Washington, several age-lithology symbols from previous quadrangles are retained for the northwest 1:250,000 quadrangle, even if the symbols are in slight conflict with present usage or new data. The absolute age boundaries in Palmer and Geissman (1999) vary significantly from those used on the other 1:250,000 quadrangles of the state geologic map. However, the diagram of Ages of Map Units (Sheet 3) depicts the best available information.

Additional information about the ages of map units is given below. Formal and informal unit names are printed in bold lettering to facilitate cross-referencing with the Descriptions of Map Units and List of Named Units. Radiocarbon dates are uncalibrated.

Unconsolidated Sediments

NONGLACIAL

Qml — Modified land and fill. Age known to be historic.

Qd — Holocene dune sand. Age inferred from geomorphology.

Qb — Beach deposits. Age inferred from geomorphology.

Qls — Landslide deposits. Age inferred from geomorphology, stratigraphic position, and ages of parent materials. Landslides in the Puget Lowland vary from presently active to having initiated late in Fraser glacial time.

Qp — Peat deposits. Age inferred from geomorphology, nature of parent materials, and, commonly, stratigraphic position above Fraser-age glacial deposits.

Qa — Alluvium. Age inferred from geomorphology. Alluvial deposition may have begun in the late Pleistocene, immediately following the latest ice retreat.

Qoa — Older alluvium. Age inferred from geomorphology, stratigraphic position overlying latest-glacial deposits, and Mazama ash (6730 ka) in an older alluvial terrace of the Dungeness River (Schasse and Wegmann, 2000).

Qc — Pleistocene continental sediments (includes part of the Whidbey and Puyallup Formations and part of the Olympia beds). Younger age limit inferred from stratigraphic position beneath glacial deposits. Base assumed to be no older than Quaternary, although possibly correlative with pre-Quaternary sediments in the Puyallup Valley (Easterbrook, 1994). **Olympia beds** have been radiocarbon-dated at about 15 to 28 ka in the Seattle and Whidbey Island areas (Armstrong and others, 1965; Whetten and others, 1980a) and at 17 ka to less than 46 ka in the Tacoma area (Borden and Troost, 2001). The **Whidbey Formation** has been dated at 100 to 150 ka by amino-acid racemization and thermoluminescense (Easterbrook and others, 1982; Berger and Easterbrook, 1993). Deposits previously mapped as the **Puyallup Formation** near Seattle are reversely magnetized (Hagstrum and others, 2002) and inferred to have been deposited during the Matuyama Reversed-Polarity Chron (~0.8 to 1.7 m.y.a.).

Ql Loess. No age information on this map but to the southeast probably ranges from early Pleistocene to early Holocene based on reversed magnetic polarities of the lowermost units, tephrochronology, and radiocarbon chronology (Reidel and Fecht, 1994; Busacca and McDonald, 1994).

GLACIAL

Continental

Qgd_s Undifferentiated glacial drift, Sumas Stade of the Fraser Glaciation (consists of the Sumas Drift). **Sumas Drift** is radiocarbon dated at about 11.3 ka (Easterbrook, 1962, 1969, 1976; Blunt and others, 1987) and overlies units Qgo and Qgdm.

Qgdm Glaciomarine drift (consists of the Deming Sand and part of the Everson Glaciomarine Drift). **Everson Glaciomarine Drift** overlies and is locally interbedded with the top of Vashon Drift (see unit Qgo), underlies Sumas Drift (see unit Qgd_s), and is radiocarbon dated at about 11.5 to 13.6 ka (Easterbrook, 1969; Dethier and others, 1995).

Qgl Glaciolacustrine deposits (includes part of the Vashon Drift undivided). Deposited during the Vashon ice occupation; generally overlies till (see unit Qgt) and outwash (see unit Qgo) deposits.

Qgd Undifferentiated glacial drift (consists of part of the Vashon Drift undivided and part of the Everson Glaciomarine Drift). **Vashon Drift**, undivided, has the same age span as units Qgo, Qgt, Qga, Qgo, and Qgdm (~11.3–18.3 ka).

Qgo Undifferentiated outwash (includes part of the Partridge Gravel, part of the Everson Glaciomarine Drift, and part of the Vashon Drift undivided). Recessional outwash at various locations has been radiocarbon dated at about 11.3 to 14.5 ka (Dethier and others, 1995, 1996; Dragovich and others, 1998; Easterbrook, 1968; Heusser, 1973; Pessl and others, 1989; Petersen and others, 1983). This age span includes deposits of the Everson Interstade.

Qgog Outwash gravel (includes the Arlington Gravel Member of the Vashon Drift and part of the Vashon Drift undivided). Not directly dated but inferred to be generally the proximal part of unit Qgo (~11.3–14.5 ka).

Qgos Outwash sand (includes the Stillaguamish and Marysville Sand Members of the Vashon Drift, part of the Vashon Drift undivided, and part of the Partridge Gravel). Not directly dated but inferred to be the distal, younger part of unit Qgo (~11.3–14.5 ka).

Qgt Till (includes part of the Vashon Drift undivided). Based on radiocarbon dates, inferred to be older than about 13 ka (Blunt and others, 1987) and younger than about 16 ka (Porter and Swanson, 1998). Unit Qgt has a wider age span in the northern than in the southern Puget Lowland.

Qga Advance outwash (includes the Colvos and Esperance Sand Members of the Vashon Drift and part of the Vashon Drift undivided). Underlies unit Qgt. Reported radiocarbon ages range from about 13.6 ka (Borden and Troost, 2001) to about 18.3 ka (Blunt and others, 1987).

Qgp Undifferentiated drift of pre-Fraser age (includes part of the Salmon Springs Drift). Underlies and thus predates Vashon Drift (see units Qga, Qgt, Qgd, and Qgo), so is older than about 18.3 ka.

Alpine

Qad, Qao Late Wisconsinan alpine drift and outwash (includes part of the Hoh Oxbow and Twin Creeks drifts, part of the Chow Chow drift, part of the Grisdale drifts, and part of the Lakedale and Evans Creek Drifts). In the Hoh and Clearwater basins, age ranges from about 19.5 to 39 ka based on radiocarbon dating (Thackray, 1996; Gerstel and Lingley, 2000). Correlations in other parts of the Olympic Peninsula are based on geomorphology and weathering characteristics (Washington DGER, 2001). In the Cascade Range, age is estimated at 19 to 23 ka by Armstrong (1981), at 15 to 25 ka by Armstrong and others (1965), and at less than 15 ka by Porter (1976), and some deposits are capped by Glacier Peak tephra (see unit Qvp), dated at about 11 ka (Tabor and others, 1993). May include some Holocene alpine glacial deposits. Locally overlain by unit Qga.

Qap Early Wisconsinan alpine drift (includes part of the Chow Chow drift, the Lyman Rapids drift, part of the Grisdale drifts, the drift of Mount Stickney, and part of the Kittitas Drift). Age estimated at 55 to 110 ka in the western Olympic Mountains on the basis of geomorphology (Thackray, 1996). Other parts of unit Qap in the Olympics are correlated to the above ages based on geomorphology and weathering characteristics (Washington DGER, 2001). In the Cascade Mountains, unit Qap is more generally interpreted as pre-late Wisconsinan based on weathering and geomorphology (Walsh and others, 1987).

Qapo Early Wisconsinan alpine outwash (includes part of the Chow Chow drift, the Lyman Rapids outwash, the Skokomish Gravel, and part of the Kittitas Drift). Age estimated at 55 to 110 ka in the western Olympic Mountains on the basis of geomorphology (Thackray, 1996). Other parts of unit Qapo in the Olympics are correlated to the above ages based on geomorphology and weathering characteristics (Washington DGER, 2001). Porter (1976) estimated the Kittitas Drift to be less than 120 ka on the basis of weathering-rind thicknesses on basalt cobbles. Colman and Pierce (1981) suggested ages of either 65 ka or 140 ka for the Hayden Creek Drift and less than 250 ka for the Wingate Hill Drift on the basis of weathering-rind thicknesses. These units are not shown on this map, but are probably correlative to our unit Qapo.

Qapw$_2$ Younger pre-Wisconsinan alpine drift (includes the Whale Creek drift, the Humptulips drift, the Mobray drift, and part of the Weatherwax formation). Inferred to be latest pre-Wisconsinan, based on geomorphology, weathering characteristics, and stratigraphic position, and correlated (DGER, 2001) with the **Whale Creek drift** at about 140 to 190 ka (marine oxygen isotope stage 6)(Thackray, 1996).

Qapw$_1$ Older pre-Wisconsinan alpine drift (includes the Donkey Creek drift, the Wedekind Creek formation, the Wolf Creek drift, and part of the Weatherwax formation). Inferred to be pre-Wisconsinan, based on geomorphology, weathering characteristics, and stratigraphic position, and correlated (DGER, 2001) with **Wolf Creek drift**, which is possibly reversely magnetized and, therefore, older than 780 ka (Thackray, 1996). Colman and Pierce (1981) estimated the **Wedekind Creek formation** to be older than 800 ka based on weathering-rind thicknesses on basalt cobbles.

GLACIAL AND NONGLACIAL

Qguc Undifferentiated surficial deposits (includes part of the Double Bluff, Possession, and Everson Glaciomarine Drifts, part of the Vashon Drift undivided, part of the Whidbey Formation, and part of the Olympia beds). These undifferentiated deposits include poorly exposed sediments of probable Quaternary age.

Qgpc Deposits of pre-Fraser age, undifferentiated (includes part of the Whidbey and Puyallup Formations, part of the Possession, Salmon Springs, and Double Bluff Drifts, and part of the Olympia beds). Underlies and thus predates Fraser-age deposits (see units Qga, Qgo, Qgt, Qgd, Qgdm, and Qgl), so is older than about 18.3 ka.

Sedimentary Rocks and Deposits

TERTIARY

Pliocene–Miocene

PMn Nearshore sedimentary rocks (consists of the Quinault and Quillayute Formations). Contains Pliocene and latest Miocene foraminiferal and macrofossil faunas (Rau, 1975, 1979).

Miocene

Mm Marine sedimentary rocks (consists of part of the Hoh rock assemblage). Contains foraminiferal faunas referable to the Saucesian and Relizian Stages (Rau, 1973, 1975, 1979), early to middle Miocene macrofossils (Addicott, 1976b), and middle Miocene zircon fission-track ages (R. J. Stewart, Univ. of Wash., written commun., 1999).

Mm$_2$ Middle–upper Miocene marine sedimentary rocks (consists of the Montesano Formation). The **Montesano Formation** contains middle and late Miocene foraminiferal faunas referable to the Mohnian and Delmontian Stages (Rau, 1967).

Mm$_1$ Lower–middle Miocene marine sedimentary rocks (consists of the Astoria Formation). The **Astoria Formation** contains foraminiferal faunas referable to the Saucesian through Relizian Stages (Rau, 1986).

Mmst Marine thick-bedded sedimentary rocks (includes part of the Hoh rock assemblage). Has yielded fission-track ages ranging from 13.7 Ma (R. J. Stewart, Univ. of Wash., written commun., 1999) to 25.8 Ma (Gerstel and Lingley, 2000) and is interbedded with units containing foraminiferal faunas referable to the Saucesian and Relizian Stages (Rau, 1975, 1979).

Mn Lower Miocene nearshore sedimentary rocks (consists of the Clallam Formation). Contains foraminiferal faunas referable to the Saucesian Stage (Rau, 1964, 1981) and molluscan fauna referable to the Pillarian Stage (Addicott, 1976a,b, 1981).

Mc Continental sedimentary rocks (consists of the Ellensburg and Hammer Bluff Formations). The age of the **Ellensburg Formation** in general is bracketed by the overlying 3.6 to 3.7 Ma Thorp Gravel and the underlying Columbia River Basalt Group (see units Mv$_g$ and Mvi$_g$)(Schuster and others, 1997). Campbell and Reidel (1991) place the age range of the Ellensburg between about 5 and 16.5 Ma based on K-Ar ages of interbedded Columbia River basalts. On this map, all of the Ellensburg is interbedded with Grande Ronde Basalt (see unit Mv$_g$). The **Hammer Bluff Formation** in the eastern Puget Lowland is assigned a Miocene age on the basis of fossil leaves and lithologic correlation with the Ellensburg (Mullineaux and others, 1959).

Mc_2 Continental sedimentary rocks (consists of the Blakely Harbor Formation). The **Blakely Harbor Formation** overlies Oligocene rocks of the Blakeley Formation (see units ΦEm and ΦEn) and contains late Miocene pollen (T. J. Walsh, DGER, unpub. data).

Miocene–Oligocene

MΦm Marine sedimentary rocks (consists of the Pysht Formation). Contains foraminiferal faunas referable to Zemorrian and Saucesian Stages (Rau, 1964, 1981; Snavely and others, 1980) and molluscan fauna referable to the Juanian Stage (Addicott, 1976b, 1981).

Miocene–Eocene

MEm Marine sedimentary rocks (includes part of the Hoh rock assemblage and part of the Western Olympic and Grand Valley lithic assemblages). In the western Olympic Peninsula, contains foraminiferal faunas referable to the Narizian (Lingley, 1995) to Saucesian Stages (R. J. Stewart, Univ. of Wash., written commun., 1999) and has produced zircon fission-track ages ranging from 18.3 Ma (R. J. Stewart, Univ. of Wash., written commun., 1999) to 47.2 Ma (Gerstel and Lingley, 2000). In the east-central Olympic Mountains, fission-track ages range from 23.9 to 32.6 Ma (R. J. Stewart, Univ. of Wash., written commun., 1999) and the unit is interbedded with unit MEmst.

MEmst Marine thick-bedded sedimentary rocks (includes part of the Hoh rock assemblage and part of the Grand Valley and Western Olympic lithic assemblages). In the western Olympic Peninsula, contains foraminiferal faunas referable to the Narizian or Refugian (Rau, 1979) to Saucesian Stages (R. J. Stewart, Univ. of Wash., written commun., 1999) and has produced zircon fission-track ages ranging from 22.1 to 37.5 Ma (Gerstel and Lingley, 2000). In the central Olympic Mountains, has produced fission-track ages ranging from 18.8 Ma (Brandon and Vance, 1992) to 38.8 Ma (R. J. Stewart, Univ. of Wash., oral commun., 2002).

MEbx Breccia (includes part of the Hoh rock assemblage and part of the sandstone of the Sooes River area). In the western Olympic Peninsula, contains foraminiferal faunas referable to the Ulatisian to Relizian Stages (Rau, 1987; Snavely and others, 1993) and has produced fission-track ages ranging from 17.7 Ma (R. J. Stewart, Univ. of Wash., written commun., 1999) to 48.2 Ma (Brandon and Vance, 1992). In the western Olympic Peninsula, the matrix is dominantly Miocene, based on foraminiferal assemblages (Rau, 1975, 1979). In the southeastern Olympic Mountains, structural and stratigraphic relations suggest a probable Oligocene to Eocene age.

Oligocene–Eocene

ΦEm Marine sedimentary rocks (includes the Makah and Lincoln Creek Formations, the Marrowstone Shale, the Quimper Sandstone, part of the Western Olympic, Elwha, and Needles–Gray Wolf lithic assemblages, part of the sandstone of the Sooes River area, part of the Hoh rock assemblage, and part of the Blakeley Formation). In the Olympic Peninsula, characterized by foraminiferal faunas referable to the Narizian to Zemorrian Stages (Snavely and others, 1980, 1993; Tabor and Cady, 1978a; Gerstel and Lingley, 2000; Schasse and Logan, 1998; Schasse and Wegmann, 2000; H. W. Schasse and Michael Polenz, DGER, written commun., 2002) and megafossils ranging from Paleocene to late Eocene (Cady and others, 1972b; Squires and Goedert, 1997). Has produced fission-track ages typically ranging from 25.6 Ma (R. J. Stewart, Univ. of Wash., written commun., 1999) to 44.6 Ma (Gerstel and Lingley, 2000). In the Puget Lowland, the **Quimper Sandstone** contains foraminiferal faunas referable to the Narizian to Zemorrian Stages (Armentrout and Berta, 1977), and the **Blakeley Formation** contains foraminiferal faunas referable to the Refugian to Zemorrian Stages (Fulmer, 1975).

ΦEmst Marine thick-bedded sedimentary rocks (includes part of the Western Olympic, Elwha, and Needles–Gray Wolf lithic assemblages and part of the Hoh rock assemblage). Has yielded fission-track ages ranging from 29.0 to 47 Ma (R. J. Stewart, Univ. of Wash., written commun., 2001) and is interbedded with the older part of unit ΦEm, which contains foraminiferal faunas referable to the Narizian.

ΦEn Oligocene–upper Eocene nearshore sedimentary rocks (consists of part of the rocks of Bulson Creek and part of the Blakeley Formation). The **rocks of Bulson Creek** contain a molluscan fauna referable to the late Eocene or early Oligocene (Marcus, 1981). Zircons from an ashflow tuff yielded a fission-track age of about 41 to 43 Ma (Lovseth, 1975; Marcus, 1981). The **Blakeley Formation** near Issaquah contains foraminiferal faunas referable to the Zemorrian Stage (Walsh, 1984).

ΦEc Continental sedimentary rocks (consists of the Huntingdon Formation and part of the rocks of Bulson Creek). The **Huntingdon Formation** is upper Eocene to possibly lower Oligocene, based on a single pollen analysis (Mustard and Rouse, 1994). Mustard and Rouse (1994) conclude that the Huntingdon is correlative with the Chuckanut Formation (see unit Ec), but others (Miller and Misch, 1963; Dragovich and others, 1997b) suggest that the Huntingdon overlies the Chuckanut with angular discordance. For the **rocks of Bulson Creek**, see unit ΦEn.

Eocene

Em Marine sedimentary rocks (includes part of the sandstone of the Sooes River area and part of the Lyre Formation). Contains early Eocene coccoliths and foraminiferal assemblages referable to the Refugian to Ulatisian Stages or older (Snavely and others, 1993). At Point of the Arches, may include rocks as old as Cretaceous (Snavely and others, 1993).

Em_2 Middle–upper Eocene marine sedimentary rocks (includes the Raging River, Hoko River, and Humptulips Formations, the sandstone of Bahobohosh, the siltstone of Waatch Point, the siltstone and sandstone of Waatch quarry, part of the Lyre and Aldwell Formations, and part of the sandstone of the Sooes River area). East of Point of the Arches, Snavely and others (1993) report early Narizian to Refugian foraminiferal faunas. The **Aldwell Formation** contains foraminiferal faunas referable to the late and early Narizian Stage (Rau, 1964, 1981; Snavely, 1983). Sparse foraminifera in the **sandstone of Bahobohosh** are assigned to the Narizian Stage (Snavely and others, 1993). The **Hoko River Formation** has yielded late Narizian Stage foraminifera (Snavely and others, 1980). Foraminifera from the **Lyre Formation** have been referred to the late Narizian Stage (Snavely, 1983). Benthic foraminifera from the upper part of the **Raging River Formation** are early Narizian Stage (Johnson and O'Connor, 1994; Vine, 1969; Rau, 1981). Foraminifera from the **siltstone and sandstone of Waatch quarry** (probably a facies of the Aldwell Formation) are early Narizian Stage (Snavely and others, 1993).

Em_1 Lower–middle Eocene marine sedimentary rocks (includes the sandstone of Scow Bay, the siltstone of Brownes Creek, the basaltic sandstone and conglomerate of Lizard Lake, the siltstone and sandstone of Bear Creek, part of the Crescent Formation, and part of the sandstone of the Sooes River area). Mollusks in mudflow deposits of the **siltstone and sandstone of Bear Creek** are assigned an early late Eocene to late middle Eocene age by W. O. Addicott, foraminifera considered reworked from the Crescent Formation are assigned to the early Eocene Penutian Stage by W. W. Rau, and foraminifera from siltstone beds are assigned to the early Narizian and (or) late Ulatisian Stage by W. W. Rau (Snavely, 1983; Snavely and others, 1993). Sedimentary rocks of the **Crescent Formation** contain foraminifera referable to the Ulatisian Stage (Rau, 1964). **Basaltic sandstone and conglomerate of Lizard Lake** contain foraminifera assigned to the late Ulatisian Stage (Snavely and others, 1993). **Sandstone of Scow Bay** contains foraminifera assigned to the Ulatisian and possibly Penutian Stages (Thoms, 1959; Armentrout and Berta, 1977). Foraminifera from rocks east of Point of the Arches are assigned to early Narizian and late Ulatisian Stages (Snavely and others, 1993).

Ec Continental sedimentary rocks (includes the Chuckanut Formation). A dacite tuff near the top of the lowermost member of the **Chuckanut Formation**, the Bellingham Bay Member, produced a zircon fission-track age of 49.9 Ma (Johnson, 1982, 1984), and the youngest detrital zircons from the base of the Chuckanut produced zircon fission-track ages of 55 to 58 Ma (Johnson, 1982, 1984). The upper members of the Chuckanut Formation yielded palynomorphs interpreted as middle to late Eocene (Reiswig, 1982).

Ec_2 Middle–upper Eocene continental sedimentary rocks (includes the Roslyn, Tiger Mountain, and Renton Formations, Puget Group undivided, part of the Chumstick Formation, part of the Barlow Pass Volcanics, and part of the Naches Formation undivided). The **Barlow Pass Volcanics** have produced zircon fission-track ages between 42 and 46 Ma (Tabor and others, 1984, in press a) and a sparse Eocene fossil leaf collection (Spurr, 1901). Zircons in tuffs in the **Chumstick Formation** yielded fission-track ages ranging from about 42 to 49 Ma and detrital zircons yielded ages ranging from about 45 to 66 Ma (Tabor and others, 1987a; Gresens and others, 1981). Palynomorphs indicate a late Eocene age (Newman, 1971, 1975). The **Tiger Mountain Formation** overlies the Raging River Formation (see unit Em_2), which has Narizian foraminifera, and the Tiger Mountain Formation is interbedded with the base of the Tukwila Formation (see unit Evc), which is about 41 Ma. The **Renton Formation** conformably overlies the Tukwila Formation and contains fossil leaves referable to the Kummerian Stage (Vine, 1969; Wolfe, 1968). Ash beds in coal in the **Puget Group** yielded plagioclase K-Ar and apatite fission-track ages ranging from about 41 to 45 Ma (Turner and others, 1983; Frizzell and others, 1984). Fossil leaves and sparse vertebrate remains indicate a middle and (or) late Eocene age for the **Roslyn Formation** (Foster, 1960), and palynomorph assemblages placed the Roslyn in the middle and late Eocene (Newman, 1981). The Roslyn Formation conformably overlies the Teanaway Formation (see unit Evb), which is about 47 Ma. Fossil leaves from the **Naches Formation** indicate an Eocene age, and zircon fission-track ages from a rhyolite ash-flow tuff and whole-rock K-Ar ages on basalt, both low in the Naches section, indicate a 40 to 44 Ma age.

Ec_1 Lower–middle Eocene continental sedimentary rocks (includes part of the Swauk Formation undivided). Palynomorph assemblages from the

Swauk Formation indicate an early to middle Eocene age (Newman, 1975), and zircon fission-track ages from the medial Silver Pass Volcanic Member (see unit Evd) mostly indicate 50 to 52 Ma ages (Vance and Naeser, 1977; Tabor and others, 1984). The Swauk Formation is overlain by the Teanaway Formation (see unit Evb), which is about 47 Ma.

Ecg_2 Middle–upper Eocene conglomerate and sandstone (consists of part of the Chumstick Formation). Interbedded with other rocks of the **Chumstick Formation** (see unit Ec_2).

Ecg_1 Lower–middle Eocene conglomerate and sandstone (consists of part of the Swauk Formation undivided). Interbedded with other rocks of the **Swauk Formation** (see unit Ec_1).

Eocene–Paleocene

ERm Marine sedimentary rocks (consists of the Blue Mountain unit). The **Blue Mountain unit** contains foraminiferal faunas referable to the Penutian to Ulatisian Stages (Tabor and Cady, 1978a).

CRETACEOUS

Km_1 Marine sedimentary rocks (includes the conglomeratic strata of Two Buttes Creek, the strata of Freezeout Creek of the Harts Pass Formation, Harts Pass Formation undivided, the Panther Creek Formation, Jackita Ridge unit undivided, and the strata of Majestic Mountain). The **Panther Creek Formation** contains macrofossils of Hauterivian to Albian age (Stoffel and McGroder, 1990). The **Harts Pass Formation**, now part of the Three Fools Creek sequence (R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000), conformably overlies the Panther Creek Formation, is unconformably overlain by the Virginian Ridge Formation and the Winthrop Formation (both Cretaceous), and contains a diverse assemblage of macrofossils of late Aptian to middle Albian age (Stoffel and McGroder, 1990).

Kn Nearshore sedimentary rocks (includes the Cedar District, Protection, Extension, Haslam, and Comox Formations and Nanaimo Group undivided). The **Nanaimo Group** contains late Campanian and late Santonian fossils (Ward, 1978; Whetten and others, 1978; Pacht, 1984; Mustard and Rouse, 1994).

Kc_2 Continental sedimentary rocks (consists of Goat Wall unit undivided, the Ventura Member of the Midnight Peak Formation, Winthrop Formation undivided, the Slate Peak Member of the Virginian Ridge Formation, the strata of Cow Creek of the Virginian Ridge Formation, part of the volcanic rocks of Three A M Mountain of the Winthrop Formation, and part of the Midnight Peak Formation undivided). The **Winthrop Formation** is Cenomanian to Turonian and possibly extends into the late Albian because it lies above the Harts Pass Formation (see unit Km_1), contains latest Albian or earliest Cenomanian volcanic detritus, and interfingers with and overlies the Virginian Ridge Formation (R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000). Dragovich and others (1997a) reported U-Pb zircon ages of about 97.5 Ma for a sill that intrudes Winthrop Formation and about 100 Ma for a tuffaceous sandstone in the lower part of the Winthrop Formation. Marine pelecypods, gastropods, and belemnites indicate a Cenomanian age for the **Virginian Ridge Formation** (Barksdale, 1975; Trexler, 1985; R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000).

Kcg_2 Conglomerate (consists of the Devils Pass Member of the Virginian Ridge Formation). Same age as unit Kc_2.

Kcg_1 Conglomerate (consists of the conglomerate of the Harts Pass Formation). Same age as **Harts Pass Formation**; see under unit Km_1.

KJm Marine sedimentary rocks (includes part of the Fidalgo Complex). The **Fidalgo Complex** contains radiolarians ranging from Callovian to Tithonian (Gusey, 1978; Brandon and others, 1988). Correlative sandstones on James Island have yielded latest Jurassic fossils (Garver, 1988), and clastic sediments overlying the predominately igneous portion of the complex have produced a single clam of latest Jurassic or earliest Cretaceous age (Mulcahey, 1975). Unnamed rocks east of Ross Lake contain fossils ranging in age from Oxfordian to Valanginian (Early Jurassic–Early Cretaceous)(R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000).

KJn Nearshore sedimentary rocks (consists of the Spieden Group). The **Spieden Group** contains Late Jurassic and Early Cretaceous fossils (Johnson, 1981).

JURASSIC

Jm Marine sedimentary rocks (consists of the Dewdney Creek Formation). The **Dewdney Creek Formation** contains Middle Jurassic fossils in the Manning Park area north of the map area.

TRIASSIC

Ŧn Nearshore sedimentary rocks (consists of the Haro Formation). The **Haro Formation** contains late Triassic fossils (McLellan, 1927).

Mixed Volcanic and Sedimentary Rocks

PALEOCENE—CRETACEOUS

RKvs Sedimentary and volcanic rocks, undivided. Rocks of the Portage Head–Point of the Arches area contain radiolarians indicative of an Early Cretaceous age, and sedimentary rocks in this sequence are intruded by a Paleocene dacite sill (Snavely and others, 1993).

CRETACEOUS–JURASSIC

KJvs Volcanic and sedimentary rocks, undivided (consists of part of the Fidalgo Complex). See the **Fidalgo Complex** under unit KJm.

JURASSIC–PERMIAN

JPvs Volcanic and sedimentary rocks, undivided (consists of the Hozomeen Group). The **Hozomeen Group** contains Early Permian (Tennyson and others, 1982), Triassic, and Jurassic radiolarians (Haugerud, 1985). See Tabor and others (in press b) for a probable Pennsylvanian age for part of the Hozameen Group.

Volcanic Deposits and Rocks

QUATERNARY

Qvr Rhyodacite to dacite (includes part of the rocks of Kulshan caldera undivided). One of the eruptions at Kulshan caldera is K-Ar dated at 1.15 Ma (Tabor and others, in press b; Hildreth, 1996).

Qvd Dacite flows (consists of volcanic rocks and deposits of Glacier Peak undivided and the dacite of Disappointment Peak). High-precision K-Ar dates suggest that the present cone of Glacier Peak began to form about 600,000 yr B.P. (Tom Sisson and Marvin Lanphere *in* Tabor and others, in press a).

Qvp Pyroclastic deposits (includes Glacier Peak tephra, part of the andesite of Black Buttes, and part of the White Chuck assemblage). Beget (1981, 1982) recognized at least seven tephra eruptions at Glacier Peak, ranging in age from 316 to 12,500 years.

Qvt Tuff (includes the White Chuck tuff, the ignimbrite of Swift Creek, part of the rocks of Kulshan caldera undivided, part of the White Chuck fill, and part of the White Chuck assemblage). The major caldera-forming eruption at Kulshan caldera is dated at 1.46 Ma (Hildreth, 1996), and the **White Chuck tuff** of Glacier Peak occurs in the upper part of the **White Chuck assemblage** and is latest Pleistocene in age (11–12 ka)(Beget, 1981, 1982).

Qva Andesite flows (consists of the andesites of Bastile Ridge, Coleman Pinnacle, Cougar Divide, Lasiocarpa Ridge, Lava Divide, The Portals, Pinus Lake, and Table Mountain, the andesite of Swift Creek, andesite of Mount Baker undivided, and part of the andesite of Black Buttes). K-Ar ages range from about 9 to 900 ka (Hildreth and Lanphere, 2000; Tabor and others, in press b).

Qvb Basalt flows (consists of the White Chuck cinder cone and the basalts of Lake Shannon, Park Butte, and Sulphur Creek). Age is based on the degree of erosion, stratigraphic relations with tephras and 11.5 to 19.0 ka glacial deposits (Tabor and others, 1993, in press a), and K-Ar dates of 94 and 716 ka (Tabor and others, in press b).

Qvl Lahars (includes the Suiattle fill, the White Chuck, Kennedy Creek, Dusty Creek, Chocolate Creek, and Baekos Creek assemblages, the Lyman lahar, the lahar of the Middle Fork Nooksack River, the Osceola Mudflow, and part of the White Chuck fill). Lahars, pyroclastic deposits, and volcanic sediments associated with Glacier Peak consist mostly of the late Pleistocene **White Chuck assemblage** (11.2–11.8 ka), the mid-Holocene **Dusty Creek**, **Kennedy Creek**, and **Baekos Creek assemblages** (5.1–5.5 ka), and the late Holocene **Chocolate Creek assemblage** (1.7–1.8 ka) of Beget (1981, 1982; Dragovich and others, 1999, 2000a; J. D. Dragovich, DGER, unpub. data). **Lahars in the Middle Fork Nooksack River**, associated with Mount Baker, have yielded radiocarbon ages of 5.7 and 6.0 ka (Kovanen, 1996; Hyde and Crandell, 1978). Radiocarbon ages for the **Osceola Mudflow** range from 5.5 ka to 5.8 ka (Crandell, 1971).

TERTIARY

Pliocene

Rv Volcanic rocks (consists of the volcanic rocks of Gamma Ridge and part of the Hannegan Volcanics). The **volcanic rocks of Gamma Ridge** at Glacier Peak produced zircon fission-track ages of between 1.6 and 2.0 Ma (Tabor and others, in press a). The **Hannegan Volcanics** produced hornblende K-Ar ages of 3.3 and 3.6 Ma and a zircon fission-track age of 4.4 Ma (Tabor and others, in press b).

Rvx Volcanic breccia (consists of part of the Hannegan Volcanics). Same as unit Rv.

Miocene

Mvt Tuff (consists of part of the Fifes Peak Formation). Interbedded with other rocks of the **Fifes Peak Formation** (see unit Mva).

Mva Andesite (includes the Howson andesite, the andesite of Sugarloaf Peak, and part of the Fifes Peak Formation). The **Howson andesite** produced a hornblende K-Ar age of 6.2 Ma (Frizzell and others, 1984). Radiometric ages from the **Fifes Peak For-**

mation range from 16.9 to 24.2 Ma (Frizzell and others, 1984).

Mv_g Middle Miocene Grande Ronde Basalt (consists of Grande Ronde Basalt undivided). **Grande Ronde Basalt** produced K-Ar and ^{40}Ar-^{39}Ar ages of about 15.6 to 16.9 Ma (Baksi, 1989; Reidel and others, 1989).

Mvi_g Middle Miocene Grande Ronde Basalt invasive flows (consists of the invasive flow of Howard Creek of the Grande Ronde Basalt). Same age range as unit Mv_g.

Mvc Volcaniclastic rocks (includes the breccia of Kyes Peak and the volcaniclastic rocks of Cooper Pass). The **volcaniclastic rocks of Cooper Pass** unconformably overlie the lower and middle Eocene Swauk Formation (see units Evd and Ec_1), and several discordant zircon fission-track dates and a hornblende K-Ar date suggest a middle and late Miocene age (Tabor and others, 2000). The **breccia of Kyes Peak** unconformably overlies the Eocene Barlow Pass Volcanics (see units Ec_2 and Evr)(Tabor and others, 1993).

Mvc_2 Volcaniclastic rocks. Have produced laser fusion ^{40}Ar-^{39}Ar ages on pumice of 11.4 m.y. (T. J. Walsh, DGER, unpub. data) and K-Ar ages of 9.3 and 14.7 m.y. (Yount and Gower, 1991); correlated with unit Mc_2 on Bainbridge Island.

Miocene–Oligocene

MΦvt Tuff (consists of the Eagle tuff). The **Eagle tuff** of Yeats (1977) unconformably overlies the Barlow Pass Volcanics (see unit Evr)(Yeats, 1958a; Tabor and others, 1993) and yields zircon fission-track ages of 22 to 24 Ma (Vance and Naeser, 1977).

MΦva Andesite flows (consists of the volcanic rocks of Eagle Gorge). An included rhyodacite tuff produced a zircon fission-track age of 21 Ma (Frizzell and others, 1984).

Oligocene

Φvr Rhyolite (includes part of the volcanic rocks of Chikamin Creek and part of the volcanic rocks of Mount Daniel). The **volcanic rocks of Chikamin Creek** have produced apatite and zircon fission-track ages of 23 to 28 Ma (Tabor and others, 1987a). For the **volcanic rocks of Mount Daniel**, see unit Φvd.

Φvd Dacite (includes the volcanic rocks on Garfield Mountain, part of the volcanic rocks of Mount Daniel, and part of the volcanic rocks of Pioneer Ridge). The **volcanic rocks of Mount Daniel** have produced apatite and zircon fission-track ages between 25 and 34 Ma; the younger ages may be reset (Tabor and others, 1993, 2000). The **volcanic rocks of Pioneer Ridge** overlie granodiorite of Mount Despair (30–35 Ma)(see unit Φigd) and are intruded by tonalite of the Perry Creek phase of the Chilliwack composite batholith (23–25 Ma)(see unit MΦit)(Tabor and others, 1993).

Φvt Tuff (includes the Lake Keechelus tuff member of the Ohanapecosh Formation, the tuff of Boundary Creek, part of the volcanic rocks of Big Bosom Buttes, part of the volcanic rocks of Chikamin Creek, and part of the volcanic rocks of Mount Daniel). Tabor and others (1993) tentatively assigned an Oligocene age to the **volcanic rocks of Big Bosom Buttes**, which unconformably overlie the 30 Ma Pocket Peak phase of the Chilliwack composite batholith (see unit Φig) but appear to be intruded by tonalite of the Baker River phase of the Chilliwack composite batholith (see unit Φigd), which is probably older than 31 Ma (Tabor and others, 1993). For the **volcanic rocks of Chikamin Creek**, see unit Φvr. For the **volcanic rocks of Mount Daniel**, see unit Φvd. For the **Ohanapecosh Formation**, see unit Φvc. A zircon fission-track age for an unnamed part of unit Φvt near Swauk Pass of about 33 Ma was reported by Tabor and others (1982b).

Φvc Volcaniclastic rocks (includes Ohanapecosh Formation undivided and the volcanic rocks of Rattlesnake Mountain). The **Ohanapecosh Formation** has produced plant fossils assigned to the Kummerian Stage (Wolfe, 1968, 1981; Vine 1969) and K-Ar and zircon fission-track ages ranging from 25 to 36 Ma (Tabor and others, 1984, 2000; Vance and others, 1987; Turner and others, 1983).

Φvx Volcanic breccia (includes the breccia of Round Lake, the volcanic rocks of Mount Rahm, part of the volcanic rocks of Big Bosom Buttes, and part of the volcanic rocks of Pioneer Ridge). The **breccia of Round Lake** is thermally metamorphosed by the Oligocene Dead Duck pluton (about 26 Ma)(see unit MΦigd)(Tabor and others, 1988, in press a). The **volcanic rocks of Mount Rahm** are intruded by the 22 to 25 Ma Perry Creek phase of the Chilliwack composite batholith (see unit MΦit)(Tabor and others, in press b). For the **volcanic rocks of Big Bosom Buttes**, see unit Φvt. For the **volcanic rocks of Pioneer Ridge**, see unit Φvd.

Oligocene–Eocene

ΦEva Andesite (includes rocks previously called Keechelus Andesitic Series). Interbedded with and overlies the Renton Formation (see unit Ec_2) southeast of Taylor; interbedded with the base of unit ΦEn near Issaquah.

ΦEvb Basalt (includes part of the Needles–Gray Wolf, Western Olympic, and Elwha lithic assemblages).

Includes faunal assemblages referable to the Narizian Stage and is interbedded with and extruded on rocks of Oligocene to Eocene age (Tabor and Cady, 1978a).

Eocene

Ev Volcanic rocks (includes part of the volcanic rocks of Mount Persis, part of the Barlow Pass Volcanics, and part of the Naches Formation undivided). The **volcanic rocks of Mount Persis** are intruded and metamorphosed by the 34 Ma Index batholith and have produced a hornblende K-Ar age of 38.1 Ma (considered a minimum age; Tabor and others, 1993) and an apatite fission-track age of 47.4 Ma, which appears to be too old (Tabor and others, 1993). The **Naches Formation** has produced K-Ar and fission-track ages of about 40 to 44 Ma (Tabor and others, 1984). For **Barlow Pass Volcanics**, see unit Evr.

Evr Rhyolite (includes the rhyolite of Hanson Lake, part of the Barlow Pass Volcanics, part of the Teanaway Formation, part of the Naches Formation undivided, and part of the Crescent Formation). The **Naches Formation** yielded zircon fission-track ages of about 40 to 45 Ma (Tabor and others, 2000). The **Barlow Pass Volcanics** have yielded zircon fission-track ages of 35 to 46 Ma from rhyolite tuff (Tabor and others, in press a).

Evd Dacite (includes the Silver Pass Volcanic Member of the Swauk Formation). Zircon fission-track ages from the **Silver Pass Volcanic Member of the Swauk Formation** are mostly 50 to 52 Ma (Vance and Naeser, 1977; Tabor and others, 1984).

Evt Tuff (includes the Mount Catherine Rhyolite Member of the Naches Formation, part of the Crescent Formation, and part of the Lyre Formation). The **Mount Catherine Rhyolite Member of the Naches Formation** is interbedded with sedimentary rocks of the Naches Formation (see unit Ec$_2$).

Eva Andesite (includes part of the Lyre Formation and part of the volcanic rocks of Mount Persis). Andesite near Anderson Lake is interbedded with sedimentary rocks of the upper Eocene **Lyre Formation** (see unit Em$_2$). For **volcanic rocks of Mount Persis**, see unit Ev.

Evb Basalt (includes part of the Teanaway and Aldwell Formations, part of the Chumstick Formation, part of the Naches Formation undivided, and part of the sedimentary and basaltic rocks of Hobuck Lake). In the central and eastern Olympic Mountains, these rocks are interbedded and tectonically intercalated with Miocene to Eocene rocks (see units MEm and MEmst). In the western Olympic Mountains, they are tectonically intercalated with unit MEbx. May, in part, be chemically correlative with lower to middle Eocene Crescent Formation (see unit Ev$_c$) and upper Eocene Grays River basalt (south of the map area)(Lingley and others, 1996). Coccoliths from the Portage Head–Point of the Arches area have been assigned to the early Eocene (Snavely and others, 1993). K-Ar determinations from the **Teanaway Formation** indicate an age of about 47 Ma (Tabor and others, 1984).

Ev$_c$ Lower–middle Eocene Crescent Formation (consists of part of the Crescent Formation). The **Crescent Formation** contains foraminiferal assemblages referable to the Penutian to Ulatisian Stages (Rau, 1964) and has produced ^{40}Ar-^{39}Ar radiometric ages of 56.0 to 45.6 Ma (Duncan, 1982).

Evc Volcaniclastic rocks (includes the Tukwila Formation, part of the sedimentary and basaltic rocks of Hobuck Lake, and part of the sandstone of the Sooes River area). The **Tukwila Formation** yielded a zircon fission-track age of about 41 Ma and a hornblende K-Ar age of about 42 Ma (Turner and others, 1983). Foraminifera in the **sedimentary and basaltic rocks of Hobuck Lake** are assigned to the late Ulatisian Stage, and coccoliths from these beds are assigned to the late middle Eocene (Snavely and others, 1993). Foraminifera from the area east of Point of the Arches are assigned to the early Narizian Stage (Snavely and others, 1993).

CRETACEOUS

Kv$_2$ Volcanic rocks (consists of the volcanic breccia of Mount Ballard of the Virginian Ridge Formation, volcanic rocks of the Goat Wall unit, part of the Midnight Peak Formation undivided, and part of the volcanic rocks of Three A M Mountain of the Winthrop Formation). R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000) consider the **volcanic breccia of Mount Ballard** time-equivalent to part of the Virginian Ridge Formation (see unit Kc$_2$) and the **volcanic rocks of Three A M Mountain** time-equivalent to part of the Winthrop Formation (see unit Kc$_2$).

JURASSIC

Jv Volcanic rocks (consists of part of the Fidalgo Complex). Volcanic rocks of the **Fidalgo Complex** are intruded by or unconformably overlie intrusive rocks of the complex. Field relations with other parts of the complex indicate a Jurassic age for most of the complex. See the Fidalgo Complex under units Ji and KJm.

Intrusive Rocks

TERTIARY

Pliocene

Rida Dacite. Similar volcanic rocks at Cady Ridge (see unit RMida) have a hornblende K-Ar age of about 5 Ma (Tabor and others, 1993).

Rig Granite (includes the granite of Ruth Mountain and the granite porphyry of Egg Lake of the Chilliwack composite batholith). The **granite porphyry of Egg Lake** underlies the Hannegan Volcanics (see unit Rv), but also appears to intrude the northern fault bounding the Hannegan Volcanics, suggesting that the granite porphyry is about the same age as the Hannegan Volcanics (about 3.6 Ma). The **granite of Ruth Mountain** is estimated to be older than 4.4 Ma based on a nested pluton pattern with the quartz monzonite and granite of Nooksack Cirque (Tabor and others, in press b) (see unit Riqm).

Riqm Quartz monzonite (consists of the quartz monzonite and granite of Nooksack Cirque of the Chilliwack composite batholith). The **quartz monzonite and granite of Nooksack Cirque**, quartz diorite and quartz monzodiorite of Icy Peak (see unit Riq), and granite porphyry of Egg Lake (see unit Rig) may all be younger than 4.4 Ma and may be in part resurgent into the caldera filled with the Hannegan Volcanics (Tabor and others, in press b) (see unit Rv).

Rigd Granodiorite (includes the Lake Ann stock of the Chilliwack composite batholith and the Cool Glacier stock). The **Cool Glacier stock** produced concordant hornblende and biotite K-Ar ages of about 4 Ma (Tabor and others, in press a). Biotite K-Ar ages from **Lake Ann stock** and from nearby hornfels yielded ages of 2.7 and 2.5 Ma, respectively (Tabor and others, in press b).

Riq Quartz diorite (consists of the quartz diorite and quartz monzodiorite of Icy Peak of the Chilliwack composite batholith). The **quartz diorite and quartz monzodiorite of Icy Peak** intrude the Hannegan Volcanics (see unit Rv) and are faulted against the granite of Ruth Mountain (see unit Rig) but are intruded by the quartz monzonite and granite of Nooksack Cirque (see unit Riqm)(Tabor and others, in press b).

Pliocene–Miocene

RMida Dacite (consists of the volcanic rocks of Cady Ridge). Hornblende from a dacite dike that is probably cogenetic with the **volcanic rocks of Cady Ridge** yielded a K-Ar age of about 5 Ma (Tabor and others, 1993).

Miocene

Mida Dacite (includes part of the Cloudy Pass batholith). See the **Cloudy Pass batholith** under unit Mit.

Mian Andesite (includes part of the Cloudy Pass batholith). See the **Cloudy Pass batholith** under unit Mit.

Mig Granite (consists of the granites of western Bear Mountain and Depot Creek of the Chilliwack composite batholith, the Mineral Mountain pluton of the Chilliwack composite batholith, part of the Cloudy Pass batholith, part of the Snoqualmie batholith undivided, and part of the Chilliwack composite batholith undivided). The **Mineral Mountain pluton** yielded zircon U-Pb ages of about 6.5 and 7 Ma (Tabor and others, in press b).

Miqm Quartz monzonite (consists of the quartz monzodiorite of Redoubt Creek and part of the Chilliwack composite batholith undivided). The **quartz monzodiorite of Redoubt Creek** yielded a hornblende K-Ar age of 10.8 Ma. Mathews and others (1981) reported a 12 Ma age for a stock at the head of McNaught Creek in Canada, which is interpreted to be part of the Redoubt Creek pluton (Tabor and others, in press b).

Migd Granodiorite (includes the Ruth Creek pluton of the Chilliwack composite batholith, the stock on Sitkum Creek, part of the Cloudy Pass batholith, and part of the Snoqualmie batholith undivided). Biotite and whole-rock Rb-Sr analyses of the **Ruth Creek pluton** define an age of 8.7 Ma (Tabor and others, in press b). Early K-Ar ages substantiated the Miocene age of the **Snoqualmie batholith**; new K-Ar ages indicate the age of the northern part of the batholith is about 25 Ma, the central part is a minimum of about 20 Ma, and the southern part is about 18 Ma (Tabor and others, 1993). For the **Cloudy Pass batholith**, see unit Mit.

Mit Tonalite (includes the Downey Mountain stock, the tonalite of Silver Creek, part of the Cloudy Pass batholith, part of the Cascade Pass dike, part of the Mount Buckindy pluton, and part of the Snoqualmie batholith undivided). Hornblende and biotite K-Ar ages on the **Cloudy Pass batholith** and associated rocks range from 20 to 23 Ma, with slight discordance (Tabor and others, in press a). Hornblende and biotite from the **Cascade Pass dike** yielded K-Ar ages of 16 to 19 Ma; concordant pairs suggest that the age is about 18 Ma (Tabor and others, in press a). K-Ar ages from hornblende and biotite pairs of the **Mount Buckindy pluton** are concordant at 16 and 15 Ma, respectively (Tabor and others, in press a). The **tonalite of Silver Creek** yielded a concordant K-Ar age of 20 Ma from hornblende and biotite (Tabor and others, 1993).

Migb Gabbro (consists of the Mount Sefrit gabbronorite of the Chilliwack composite batholith). The **Mount Sefrit gabbronorite of the Chilliwack composite batholith** yielded a Rb-Sr age of 23 Ma (Tepper and others, 1993).

Mix Intrusive breccia (includes the intrusive breccia of Conglomerate Point, the porphyries and breccias of Lyall Ridge, part of the Mount Buckindy pluton, part of the Cascade Pass dike, and part of the Cloudy Pass batholith). See the **Cloudy Pass batholith** and **Mount Buckindy pluton** under unit Mit.

Miocene–Oligocene

MΦian Andesite. Intrudes the Ohanapecosh Formation (see unit Φvc) and probably predates the Snoqualmie batholith (Tabor and others, 2000).

MΦig Granite (includes the granite of Mount Hinman of the Snoqualmie batholith, the granite of San Juan Creek of the Grotto batholith, part of the Snoqualmie batholith undivided, and part of the Grotto batholith undivided). See the **Snoqualmie batholith** under unit Migd.

MΦigd Granodiorite (includes the Monte Cristo stock and Dead Duck pluton of the Grotto batholith and part of the Snoqualmie batholith undivided). Hornblende and biotite K-Ar ages from the **Monte Cristo stock** are concordant at about 24 Ma (Tabor and others, in press a). The **Dead Duck pluton** yielded concordant K-Ar ages of about 25 and 27 Ma from two hornblende-biotite pairs and a zircon fission-track age of 26 Ma (Tabor and others, in press a). For the **Snoqualmie batholith**, see unit Migd.

MΦit Tonalite (includes the Perry Creek phase of the Chilliwack composite batholith, the Hozomeen stock, and part of the Grotto batholith undivided). K-Ar ages on hornblende and biotite from the **Perry Creek phase of the Chilliwack composite batholith** range from about 22 to 25 Ma (Tabor and others, in press b). For the **Grotto batholith**, see unit MΦigb. The **Hozomeen stock** has produced K-Ar ages of 18 and 24 Ma (Tabor and others, in press b).

MΦigb Gabbro (includes part of the Snoqualmie batholith undivided and part of the Grotto batholith undivided). Hornblende and biotite K-Ar ages from the **Grotto batholith** range from 23 to 27 Ma (Tabor and others, 1993). For **Snoqualmie batholith**, see unit Migd.

MΦix Breccia (includes part of the Snoqualmie batholith undivided). See the **Snoqualmie batholith** under unit Migd.

Oligocene

Φian Andesite (consists of the metaporphyry on Troublesome Mountain and part of the volcanic rocks of Mount Daniel). **Volcanic rocks of Mount Daniel** have produced an apatite fission-track age of 33.5 Ma (Tabor and others, 2000) and zircon fission-track ages of 24.6 to 26.7 Ma (Tabor and others, 1993); the younger ages may be reset by the intrusion of the Snoqualmie batholith (Tabor and others, 1993). The **metaporphyry on Troublesome Mountain** is intruded by the Miocene–Oligocene Grotto batholith (Tabor and others, 1993).

Φir Rhyolite (consists of part of the volcanic rocks of Mount Daniel). See **volcanic rocks of Mount Daniel** under unit Φian.

Φig Granite (consists of the biotite alaskite of Mount Blum and the Pocket Peak phase of the Chilliwack composite batholith). K-Ar ages of muscovite and biotite from the **Pocket Peak phase of the Chilliwack composite batholith** are concordant at 29.5 and 30.9 Ma, respectively; hornblende from a dike cutting the Pocket Peak phase yielded a K-Ar age of about 32.5 Ma; the Pocket Peak phase is intruded by tonalite dikes of the Chilliwack Valley phase of the Chilliwack composite batholith (see unit Φit); this pluton continues north of U.S.–Canada border as the Mount Rexford quartz monzonite, where Richards and McTaggart (1976) reported a K-Ar age from biotite of 26 Ma (Tabor and others, in press b). The **biotite alaskite of Mount Blum** sharply intrudes the granodiorite of Mount Despair (see unit Φigd) and has yielded two biotite K-Ar ages of 29.4 and 30.8 Ma; biotite and whole-rock Rb-Sr analyses give ages of about 30 Ma, and zircon fission-track ages from adjacent hornfels are about 20 Ma (Tabor and others, in press b).

Φigd Granodiorite (consists of the Baker River and Indian Mountain phases of the Chilliwack composite batholith, the biotite granodiorite of Little Beaver Creek of the Chilliwack composite batholith, part of the granodiorite of Mount Despair of the Chilliwack composite batholith, the Goblin Peak and Sunday Creek stocks of the Index batholith, and Index batholith undivided). The **Indian Mountain phase of the Chilliwack composite batholith** has produced discordant hornblende and biotite K-Ar ages of about 26 and 23 Ma, possibly reset by the nearby Chilliwack Valley phase of the Chilliwack composite batholith (see unit Φit). Some of the Indian Mountain could be as old as 30 Ma (Tabor and others, in press b). The **granodiorite of Mount Despair of the Chilliwack composite batholith** has produced isotope ages ranging from about 30 to 35 Ma, a Rb-Sr age of

33.5 Ma, and a zircon fission-track age of about 20 Ma; it is sharply intruded by the 30 Ma biotite alaskite of Mount Blum (see unit Φig)(Tabor and others, in press b). **Biotite granodiorite of Little Beaver Creek of the Chilliwack composite batholith** has produced hornblende and biotite K-Ar ages of about 25 and 23 Ma, respectively, and the pluton is intruded by the Perry Creek phase of the Chilliwack composite batholith (see unit MΦit)(Tabor and others, in press b). The **Sunday Creek stock of the Index batholith** yielded a hornblende K-Ar age of about 33 Ma (Tabor and others, 1993. The Index batholith has produced roughly concordant hornblende and biotite K-Ar ages of about 34 Ma, zircon U-Pb ages of about 34 Ma, and a zircon fission-track age of 33 Ma (Tabor and others, 1993). See the **Index batholith** under unit Φig.

Φit Tonalite (consists of the Chilliwack Valley phase of the Chilliwack composite batholith, the tonalite of Maiden Lake of the Chilliwack composite batholith, the heterogeneous tonalite and granodiorite of Middle Peak of the Chilliwack composite batholith, the Silesia Creek pluton of the Chilliwack composite batholith, the Shake Creek stock, and part of the Squire Creek stock undivided). The **Chilliwack Valley phase of the Chilliwack composite batholith** yielded two K-Ar hornblende ages of about 24 and 27 Ma and a biotite age of 26 Ma; the Chilliwack Valley phase intrudes the 30 Ma Pocket Peak phase (see unit Φig) and the 34 Ma gabbro of Copper Lake (see unit Φib) (Tabor and others, in press b). The **Silesia Creek pluton of the Chilliwack composite batholith** has produced concordant hornblende and biotite K-Ar ages of about 30 Ma (Tabor and others, in press b). The **tonalite of Maiden Lake of the Chilliwack composite batholith** has produced a concordant zircon age of 29 Ma; Tabor and others (in press b) tentatively include it in the Chilliwack composite batholith. The **Squire Creek stock** on Vesper Peak has produced a whole-rock K-Ar age of 32.7 Ma (Tabor and others, in press a). The main body of the Squire Creek stock yielded a concordant K-Ar age of about 35 Ma and a zircon U-Pb age of about 35 Ma (Tabor and others, in press a).

Φiq Quartz diorite (consists of the Price Glacier pluton of the Chilliwack composite batholith and part of the Squire Creek stock undivided). The **Squire Creek stock** at Granite Lake yielded poorly reproducible K-Ar hornblende ages of about 37 Ma and a zircon fission-track age of about 30 Ma (Tabor and others, in press a).

Φii Intermediate intrusive rocks (consists of part of the granodiorite of Mount Despair of the Chilliwack composite batholith). Agmatite is associated with the **granodiorite of Mount Despair** (see unit Φigd).

Φib Basic (mafic) intrusive rocks (consists of the gabbro of Copper Lake of the Chilliwack composite batholith, the diorite of Ensawkwatch Creek of the Chilliwack composite batholith, and part of the Chilliwack composite batholith undivided). A three-point Rb-Sr isochron for the **gabbro of Copper Lake** gives an age of 34 Ma (Tepper, 1991), which is supported by intrusion of the gabbro of Copper Lake by tonalite of the 26 Ma Chilliwack Valley phase of the Chilliwack composite batholith (see unit Φit)(Tabor and others, in press b).

Oligocene–Eocene

ΦEida Dacite (consists of the Sauk ring dike). The **Sauk ring dike** yielded a poorly reproducible K-Ar hornblende age of 37 Ma, another K-Ar hornblende age of about 40 Ma, and a zircon fission-track age of 32 Ma (Tabor and others, in press a).

ΦEian Pyroxene andesite (consists of rocks formerly called the intrusives of the Keechelus Andesitic Series). This unit intrudes the top of the Renton Formation (see unit Ec_2) and is inferred to correlate with lava flows that intrude the Renton Formation (Walsh, 1984).

Eocene

Ei Dikes, undivided. Dikes crosscut Eocene rocks, are younger than earliest Tertiary metamorphism, are related to Eocene faulting and nearby Eocene intrusive bodies, and few cut the Miocene Cloudy Pass batholith (Cater, 1982).

Eir Rhyolite (includes the porphyritic dacite of Basalt Peak and the dacite of the Old Gib volcanic neck). By correlation with similar rhyolite flows interbedded with lower Roslyn Formation (see unit Ec_2), rhyolite intrusions into the base of the Roslyn Formation are presumed slightly younger than Teanaway Formation (see unit Evb), which is older than about 47 Ma. The **dacite of the Old Gib volcanic neck** produced K-Ar ages of 44 Ma (Dragovich and Norman, 1995) and 45 Ma (Cater and Crowder, 1967; Engels and others, 1976). The **porphyritic dacite of Basalt Peak** is considered by Cater (1982) to be identical to the dacite of the Old Gib volcanic neck.

Eian Andesite. Unnamed intrusions southwest of Issaquah are inferred to be subvolcanic intrusions feeding the Tukwila Formation (42 Ma)(see unit Evc)(Turner and others, 1983).

Eib Basic (mafic) intrusive rocks (includes basaltic plugs and dikes of Chiwawa River, part of the Crescent Formation, and part of the Teanaway dike swarm). Silicified basic intrusive rocks are mapped within the **Crescent Formation** (see unit Ev_c) by Snavely and others (1993). The age of **basaltic plugs and dikes of Chiwawa River** is uncertain, but the dikes probably intrude Eocene Chumstick Formation (see unit Ec_2)(Cater and Crowder, 1967) and appear to be related to other hypabyssal intrusive rocks assigned to the Eocene and Miocene (Dragovich and Norman, 1995).

Eig Granite (consists of the Golden Horn batholith, the Monument Peak stock, the Mount Pilchuck stock, and the Rampart Mountain pluton). Hornblende and biotite K-Ar ages and U-Pb zircon ages for the **Golden Horn batholith** range from 46 to 48 Ma (Misch, 1964; Hoppe, 1984; Miller and others, 1989). Tabor and others (1968) reported a biotite K-Ar age for the **Monument Peak stock** of 47.9 Ma. The **Mount Pilchuck stock** has concordant biotite and muscovite K-Ar ages of 49 Ma, a zircon fission-track age of about 45 Ma, and a three-point strontium isochron indicating a crystallization age of 44.3 Ma (Tabor and others, in press a). The **Rampart Mountain pluton** intrudes the Eocene Larch Lakes pluton (see unit Eigd) and the Late Cretaceous Entiat pluton (see units Kid and Kit) and is intruded by probable Miocene to Eocene dikes (Dragovich and Norman, 1995).

Eigd Granodiorite (includes the Fuller Mountain plug, the Granite Falls stock and associated plutons, the Railroad Creek pluton, the Larch Lakes pluton, the Castle Peak stock, and the biotite granodiorite and granite near Holden). Concordant hornblende and biotite K-Ar ages place the **Castle Peak stock** at about 50 Ma (Tabor and others, 1968). A hornblende K-Ar age for the **Fuller Mountain plug** was about 47 Ma (Tabor and others, 1993). The **Granite Falls stock** has produced a minimum hornblende K-Ar age of about 44 Ma (Tabor and others, in press a). The **Railroad Creek pluton** yielded hornblende and biotite K-Ar ages of 42.6 and 43.7 Ma, respectively (Engels and others, 1976). The **Larch Lakes pluton** intrudes the Cretaceous Entiat pluton (see unit Kit), is cut by Eocene dikes, and is probably Eocene (Cater, 1982). Preliminary U-Pb monazite age data support Cater's interpretation (R. B. Miller, San Jose State Univ., written commun., 2002).

Eit Tonalite (includes the hornblende biotite tonalite near Holden and part of the Copper Peak and Holden Lake plutons). **Copper Peak** and **Holden Lake plutons** are intruded by the late Eocene Duncan Hill pluton (see unit Eiq)(Dragovich and Norman, 1995). The **hornblende biotite tonalite near Holden** intrudes the Late Cretaceous Cardinal Peak pluton (see unit Kit), is crosscut by dikes associated with the Eocene Railroad Creek pluton (see unit Eigd), and is overprinted by a metamorphic fabric that Haugerud and others (1991) attribute to middle Eocene deformation (Dragovich and Norman, 1995).

Eiq Quartz diorite (includes the Duncan Hill pluton). Hornblende and biotite K-Ar ages for the **Duncan Hill pluton** range from 45 to 48 Ma; zircons yield roughly concordant U-Th-Pb ages of about 48 Ma (Tabor and others, 1987a).

Eigb Gabbro (includes the diabase of Camas Land, part of the Crescent Formation, part of the Barlow Pass Volcanics, and part of the Teanaway dike swarm). See the **Barlow Pass Volcanics** under unit Ec_2.

Paleocene

Ꞓit Tonalite (consists of the Oval Peak pluton). The **Oval Peak pluton** produced zircon U-Pb ages of about 65 Ma (Miller and Bowring, 1990) and a titanite U-Pb age of 65.3 Ma (Miller and Walker, 1987).

PRE-TERTIARY

pTigd Granodiorite and granite (consists of the Bald Mountain pluton). Zircon U-Th-Pb ages from the **Bald Mountain pluton** suggest crystallization or recrystallization at about 50 to 55 Ma, nearly equivalent to the nearby compositionally similar Mount Pilchuck stock (see unit Eig), but much older $^{207}Pb/^{206}Pb$ ages of about 120 Ma indicate either a Pb component from xenocrystic zircons or that the Bald Mountain pluton is older and has been intruded by the Mount Pilchuck stock. Textures and field relations indicate that the Bald Mountain pluton is older than the Mount Pilchuck stock (Tabor and others, in press a; Tabor and others, 1993) and probably pre-Tertiary.

pTigb Gabbro (consists of the Money Creek gabbro and part of the Western mélange belt). Tabor and others (1993) conclude that the **Money Creek gabbro** is older than the Snoqualmie batholith. Ages are uncertain, but most are altered by the Snoqualmie batholith.

TERTIARY–CRETACEOUS

TKig Granite pegmatite (consists of the Sisters Creek pluton and part of the Skagit Gneiss Complex undivided). The well-defined metamorphic fabric of the **Sisters Creek pluton** and granite gneiss of the **Skagit Gneiss Complex** indicates that they are probably pre- to syn-metamorphic plutons of mid- to Late Cretaceous or earliest Tertiary age (Tabor and others, 1994; Dragovich and Norman, 1995).

TKi Intrusive rocks (consists of the Ruby Creek heterogeneous plutonic belt). Zircons from the **Ruby Creek heterogeneous plutonic belt** yielded a U-Pb age of 48 Ma (Miller and others, 1989). R. A.

Haugerud and R. W. Tabor (USGS, written commun., 2000) indicate that much of the plutonic belt is Tertiary to Cretaceous (Misch, 1966) and consists mostly of intrusive rocks from the Golden Horn batholith (see unit Eig) and Black Peak batholith (see unit Kit).

CRETACEOUS

Kiaa Alaskite pegmatite (consists of part of the Entiat pluton). See the **Entiat pluton** under unit Kit.

Kigd Granodiorite (consists of the Buck Creek and High Pass plutons, the Foam Creek stock, the Cyclone Lake, Downey Creek, and Jordan Lakes plutons, the Beckler Peak stocks of the Mount Stuart batholith, the Hidden Lake stock, the stock near Tamarack Peak, the stock south of Early Winters Creek, the Lost Peak and Pasayten stocks, the Rock Creek stock, part of the Sulphur Mountain pluton, and part of the Mount Stuart batholith undivided). The **Jordan Lakes pluton** yielded zircon U-Pb and Pb-Pb ages of about 74 and 90 Ma, respectively; hornblende yielded a 74 Ma K-Ar age, but biotite K-Ar ages ranged from about 58 to 61 Ma (Tabor and others, in press a). Walker and Brown (1991) favor an intrusive age of about 73 to 74 Ma. The **Cyclone Lake pluton** yielded a muscovite K-Ar age of about 57 Ma and biotite K-Ar ages of 27 to 28 Ma, considerably younger than the hornblende and biotite ages from the contemporaneous Jordan Lakes pluton. These younger cooling ages reflect the greater depth of intrusion for the exposed part of the Cyclone Lake pluton (Tabor and others, in press a). The **Foam Creek stock** produced K-Ar ages of 29 to 78 Ma; the oldest age, a muscovite age, apparently represents the minimum age of metamorphism (Tabor and others, in press a). The **High Pass pluton** intrudes the 93 to 94 Ma Sulphur Mountain pluton (see below), and uplift produced K-Ar cooling ages of biotite of 54 to 59 Ma and of hornblende of 59 to 72 Ma (Tabor and others, in press a). Hurlow (1992) obtained concordant U-Pb ages of about 85 Ma for the High Pass pluton. The **Beckler Peak stocks** of the Mount Stuart batholith intrude the Mesozoic Tonga Formation (see unit Mzsc) and produced biotite K-Ar ages of about 89 and 92 Ma, a hornblende K-Ar age of about 86 Ma, an apatite fission-track age of 42 Ma, allanite fission-track ages of 84 and 98 Ma, and an epidote fission-track age of 83 Ma (Engels and Crowder, 1971). Zircons from the **Sulphur Mountain pluton** produced U-Pb ages of about 96 Ma (Walker and Brown, 1991) and K-Ar ages of biotite and hornblende from about 55 to 72 Ma; hornblende is consistently older than biotite and the ages probably reflect cooling (Walker and Brown, 1991; Tabor and others, in press a). See the **Mount Stuart batholith** under unit Kit.

Kit Tonalite (includes Black Peak batholith undivided, the Reynolds Peak phase of the Black Peak batholith, the stock near Fortune Creek, the Grassy Point stock, the Seven Fingered Jack pluton, the Clark Mountain pluton, the Dirtyface pluton, the Tenpeak pluton, the tonalite of Harding Mountain of the Mount Stuart batholith, part of the Cardinal Peak and Entiat plutons, and part of the Mount Stuart batholith undivided). The Paleocene gneiss of War Creek (see unit Rog) intrudes and contains inclusions and screens of the **Reynolds Peak phase of the Black Peak batholith**, which is about the same age as the main phase. The main phase of the **Black Peak batholith** produced a 90-Ma zircon U-Pb age (Hoppe, 1984) and a 90-Ma hornblende K-Ar age (Misch, 1964). The **Cardinal Peak pluton** produced biotite K-Ar ages of about 57 Ma, muscovite K-Ar ages of about 59 Ma (Dawes, 1991), a zircon U-Pb age of about 75 Ma (Miller and others, 1989), and mildly discordant U-Pb zircon ages of 72 to 79 Ma (Haugerud and others, 1991). A biotite K-Ar age was about 77 Ma (Engels and others, 1976) and hornblende K-Ar, Ar-Ar, and zircon U-Pb ages were about 91 to 93 Ma for the **Tenpeak pluton** (Walker and Brown, 1991). The **Entiat pluton** produced K-Ar and U-Pb ages that indicate uplift in the Eocene and a crystallization age of about 75 to 85 Ma (Tabor and others, 1987a). The **Seven Fingered Jack pluton**, a continuation of the Entiat pluton, intrudes the Triassic Dumbell Mountain pluton (see unit Ŧog) and is intruded by probable Eocene dikes (Dragovich and Norman, 1995). The **Mount Stuart batholith** has isotopic ages, which indicate that the age of the eastern pluton is about 93 Ma (Walker and Brown, 1991) and the western pluton about 85 Ma (Tabor and others, 1993). The **tonalite of Harding Mountain of the Mount Stuart batholith** has produced concordant hornblende and biotite K-Ar ages of about 88 Ma (Tabor and others, 1993).

Kiq Quartz diorite (includes part of the Cardinal Peak pluton and part of the Chaval pluton). See the **Cardinal Peak pluton** under unit Kit. Zircon U-Pb ages from the **Chaval pluton** and its dikes are about 92 to 94 Ma (Walker and Brown, 1991).

Kid Diorite (includes the Lightning Creek stocks, part of the Entiat pluton, and part of the Mount Stuart batholith undivided). The **Entiat pluton** intrudes the Triassic Dumbell Mountain pluton (see unit Ŧog) and is intruded by probable Eocene dikes; K-Ar and U-Pb ages are variable but generally indicate uplift in the Eocene and a crystallization age of about 75 to 85 Ma (Hurlow, 1992; Mattinson, 1972; Tabor and others, 1987a). See the **Mount Stuart batholith** under unit Kit.

Kigb Gabbro (consists of the Riddle Peaks pluton and part of the Mount Stuart batholith undivided). The **Riddle Peaks pluton** is probably the same age as the Late Cretaceous Cardinal Peak pluton (see unit Kit)(Dragovich and Norman, 1995; Cater, 1982). A gabbro of the **Mount Stuart batholith** has produced concordant zircon U-Th-Pb ages of about 96 Ma (Tabor and others, 1987a).

CRETACEOUS–JURASSIC

KJigb Gabbro (includes the Skymo complex). The Portage Head–Point of the Arches area has produced a hornblende K-Ar age of about 144 Ma (Snavely and others, 1971) and zircon fission-track ages of about 90 and 93 Ma (R. J. Stewart, Univ. of Wash., written commun., 1999). The **Skymo complex** is metamorphosed and locally includes leucosomes typical of the Skagit Gneiss Complex. Its age is possibly Eocene (Baldwin and others, 1997). However, a tentative Sm-Nd mineral/whole rock isochron for one sample suggests that the Skymo complex may be Tertiary (Baldwin and others, 1997).

JURASSIC

Ji Intrusive rocks, undivided (consists of part of the Fidalgo Complex). Three U-Pb zircon ages from the **Fidalgo Complex** range from 160 to 170 Ma, and the oldest radiolarian ages in overlying sedimentary rocks are Callovian (Middle Jurassic) (Lapen, 2000). Brown and others (1979) reported a 155 Ma K-Ar age (whole rock) and Whetten and others (1978) obtained a U-Pb age (zircon) of 167 Ma, both on trondhjemites. See also unit KJm.

Jit Tonalite (consists of part of the Eastern mélange belt undivided, part of the Western mélange belt, and part of the Helena–Haystack mélange). Tonalite of the **Eastern mélange belt** produced zircon $^{207}Pb/^{206}Pb$ ages of 62 to 77 Ma (Tabor and others, 1993), which may be partially reset; the tonalite component of the Eastern mélange belt is considered to have an Early Jurassic protolith age (Tabor and others, 1993). See the metagabbros of the Eastern mélange belt under unit Jigb. U-Th-Pb zircon ages range from 150 to 170 Ma for four metatonalite-metagabbro masses in the **Western mélange belt** (Tabor and others, 1993, in press a). Tonalite in the **Helena–Haystack mélange** produced concordant zircon U-Pb ages of about 150 Ma, and a conventional K-Ar hornblende age from amphibolite is 141 Ma, which is probably a minimum age (Tabor, 1994; Tabor and others, in press a). See Helena–Haystack mélange amphibolites and metagabbros under units Jam and Jigb, respectively.

Jib Basic (mafic) intrusive rocks (consists of the Esmeralda Peaks diabase of the Ingalls Tectonic Complex, the Fourth Creek gabbro, the Hawkins Formation, part of the Eastern mélange belt undivided, part of the Western mélange belt, and part of the Ingalls Tectonic Complex undivided). On the basis of isotopic ages of gabbro and radiolarians in chert, components of the **Ingalls Tectonic Complex** are inferred to be Late Jurassic in (protolith) age (Miller and others, 1993b). Gabbro in the Ingalls Tectonic Complex has produced a Late Jurassic zircon U-Pb 155 Ma age (Southwick, 1974; Tabor and others, 1987a; Miller and others, 1993b). U-Pb age is discordant, and probable crystallization is between 154 and 162 Ma, with the older age more likely based on radiolarian ages in overlying cherts (Miller and others, 1993b; R. B. Miller, San Jose State Univ., written commun., 2002). Vance and others (1980) suggest a Middle and Late Jurassic age for original igneous crystallization of mafic and ultramafic rocks of the **Eastern mélange belt** (Tabor and others, 1993, in press a).

Jigb Gabbro (consists of part of the Fidalgo Complex, part of the Helena–Haystack mélange, part of the Easton Metamorphic Suite, and part of the Eastern mélange belt undivided). See **Eastern mélange belt** under units Jit and Jib. See **Fidalgo Complex** under units Ji and KJm. Three nearly concordant Jurassic U-Pb ages of 160 to 170 ma were obtained from **Helena–Haystack mélange** (Whetten and others, 1980a,b, 1988; Dragovich and others, 1998). See Helena–Haystack mélange under units Jam, Jit, and Jmv.

TRIASSIC

T̵iq Quartz diorite (consists of the Magic Mountain Gneiss and part of the Marblemount pluton). A muscovite K-Ar age of about 94 Ma from the **Marblemount pluton** (formerly Marblemount Meta-Quartz Diorite) probably represents the age of metamorphism (Tabor and others, in press b). Concordant zircon U-Pb ages indicate a Late Triassic crystallization age of 220 Ma (Mattinson, 1972; Tabor and others, in press a).

MESOZOIC–PALEOZOIC

MzPzi Intrusive rocks. Several mappable metagabbros and metatonalites intruded rocks of the Chilliwack Group and Cultus Formation (Tabor and others, in press b). Zircon from one of the hornblende tonalites yielded slightly discordant U-Th-Pb ages of about 370 to 400 Ma (Early Devonian), and hornblende had a K-Ar age of about 406 Ma (Tabor and others, in press a).

PENNSYLVANIAN

ℙi Intrusive rocks (includes part of the Trafton sequence). Metatonalite blocks in the **Trafton sequence** are at least as old as Pennsylvanian (320

Ma) based on U-Th-Pb ages (Tabor and others, in press a). Quartz diorite of the Trafton sequence yielded a concordant U-Pb protolith age of 315 to 320 Ma (Whetten and others, 1988).

PRE-DEVONIAN

pDi Intrusive rocks (includes the Turtleback Complex and part of the Yellow Aster Complex). The **Turtleback Complex** has yielded ages of 554 Ma for hornblende K-Ar in metagabbro (Whetten and others, 1978) and 507 Ma for zircon U-Pb in tonalite (Brandon and others, 1988). Mattinson (1972) suggests an intrusive age of 460 Ma, and Whetten and others (1978) suggest an intrusive age of 471 Ma. $^{207}Pb/^{206}Pb$ in zircon indicates a minimum age of Early Devonian (Whetten and others, 1978; Brandon and others, 1988). For the **Yellow Aster Complex**, zircon from hornblende tonalite yielded slightly discordant U-Th-Pb ages of about 370 to 400 Ma, and hornblende had a K-Ar age of about 406 Ma (Tabor and others, in press a. Zircons from a metatonalite yielded discordant U-Pb ages of about 330 to 390 Ma (Tabor and others, in press b). Also see Yellow Aster Complex under unit pDgn.

Mixed Metamorphic and Igneous Rocks

CRETACEOUS–JURASSIC

KJmi Mixed metamorphic and igneous rocks (consists of the tonalite of Doe Mountain of the Remmel batholith and the tonalite of Bob Creek). Biotite K-Ar dates for the **tonalite of Bob Creek** are about 100 Ma (R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000). The **tonalite of Doe Mountain** yielded both concordant and discordant K-Ar biotite and muscovite ages, and a probably genetically related dike yielded concordant biotite and muscovite K-Ar ages that indicate an uplift and cooling age of about 95 Ma. Hurlow and Nelson (1993) report Cretaceous to Late Jurassic U-Pb and Pb-Pb ages. Late Jurassic and Early Cretaceous U-Pb zircon ages have also been reported from compositionally similar intrusions in the Eagle plutonic complex of southern British Columbia (Stoffel and McGroder, 1990).

Ultramafic Rocks

PRE-TERTIARY

pTu Ultramafic rocks (consists of the Twin Sisters Dunite, part of the Bell Pass mélange undivided, part of the Jack Mountain Phyllite, and part of the Little Jack unit). Ultramafic rocks in the **Bell Pass mélange**, including the **Twin Sisters Dunite**, participated in mid-Cretaceous thrusting (about 85–100 Ma) and are thus assigned a pre-Tertiary age (Tabor and others, in press b). Rocks of the **Jack Mountain Phyllite** were probably metamorphosed in Late Cretaceous to middle Eocene time and have been thermally metamorphosed by middle Eocene and older plutons of the Ruby Creek heterogeneous plutonic belt (see unit TKi) (Tabor and others, in press b; R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000).

JURASSIC

Ju Ultramafic rocks (consists of part of the Fidalgo Complex, part of the Helena–Haystack mélange, part of the Easton Metamorphic Suite, part of the Ingalls Tectonic Complex undivided, and part of the Western mélange belt). Jurassic ultramafic rocks are probably similar in age to the age dated portions of the ophiolite complexes. See **Fidalgo Complex** under unit Ji; **Helena–Haystack mélange** under units Jigb, Jit, and Jmv; **Ingalls Tectonic Complex** under units KJhmc and Jib; and **Western mélange belt** under units Jit, KJmm, and KJmc.

Metamorphic Rocks

Greenschist and Blueschist Facies (Low-Grade Rocks)

PRE-TERTIARY

pTms Metasedimentary rocks (consists of the conglomerate of Bald Mountain and the metaconglomerate of Sumas Mountain). Pollen suggests a Late Cretaceous to early Tertiary age for the **conglomerate of Bald Mountain**. The penetrative deformation and metamorphism recorded in this unit make a pre-Tertiary age likely. Two chert clasts yielded possible Triassic radiolarians; a fission-track age from detrital zircon from a possibly correlative rock is between 60 and 73 Ma. Tabor and others (in press b) consider the rock to be Late Cretaceous. The **metaconglomerate of Sumas Mountain** of Dragovich and others (1997b) is probably a tectonic block within the Bell Pass mélange. The conglomerate is metamorphosed and therefore pre-Tertiary.

pTmt Metasedimentary and metavolcanic rocks, undivided (consists of part of the Bell Pass mélange undivided, part of the Vedder complex, part of the Elbow Lake Formation, and part of the Yellow Aster Complex). The **Bell Pass mélange** undivided contains tectonic inclusions of the **Elbow Lake Formation** (see unit JPmt), **Yellow Aster Complex** (see unit pDi), **Vedder complex** (see unit pPsh), blueschist of Baker Lake (see unit JPmt), and Twin Sisters Dunite (see unit pTu). The Bell Pass mélange is older than the mid-Cretaceous thrusting and metamorphism of the Northwest Cascades System.

MESOZOIC

Mzsh Low-grade schist (consists of the schist of Crook Mountain, part of the Jack Mountain Phyllite, part of the Tonga Formation, part of the Little Jack unit, and part of the Elijah Ridge Schist). For the **schist of Crook Mountain**, see the Chiwaukum Schist (see unit Mzsc). The **Jack Mountain Phyllite** predates Late Cretaceous metamorphism of the northeastern portion of the North Cascades Crystalline Core. R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000) speculate that the Jack Mountain Phyllite may be Cretaceous and correlative with unmetamorphosed Mesozoic clastic strata of the Methow block to the east (Tabor and others, in press b). For the **Tonga Formation**, see unit Mzsc.

CRETACEOUS

Kmcg Metaconglomerate (consists of the metaconglomerate of South Creek, Virginian Ridge Formation undivided, and part of the rocks of Easy Pass). The **metaconglomerate of South Creek** probably correlates lithologically with the Devils Pass Member of the Virginian Ridge Formation (see unit Kcg$_2$), unconformably overlies the Twisp Valley Schist (see Napeequa Schist under unit JPhmc), is intruded by ca. 98 Ma porphyry dikes, probably underlies a 100 Ma tuff east of the Twisp River, and is contact-metamorphosed by the 90 Ma Black Peak batholith (see unit Kit)(Dragovich and others, 1997a). **Rocks of Easy Pass** of Miller and others (1994; R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000) are lithologically correlative with the metaconglomerate of South Creek and are older than the 90 to 60 Ma metamorphism that affects the northeastern portion of the North Cascades Crystalline Core. These metamorphosed equivalents of the Methow block are probably mostly Albian (Early Cretaceous)(Miller and others, 1994; Dragovich and others, 1997a).

Kmt Metasedimentary and metavolcanic rocks, undivided (consists of the North Creek Volcanics, part of the rocks of Easy Pass, part of the Winthrop Formation undivided, part of the Elijah Ridge Schist, and the plagioclase porphyry of the Twisp River valley). The **North Creek Volcanics** are intruded by the 90 Ma Black Peak batholith (see unit Kit) and the ca. 98 Ma **plagioclase porphyry of the Twisp River valley** (Dragovich and others, 1997a). A tuff bed in the lower part of the unit has a zircon U-Pb age of about 100 Ma (Dragovich and others, 1997a). Dragovich and others (1997a) correlate the North Creek Volcanics with the **Winthrop Formation** and volcanic rocks of Three A M Mountain (see units Kv$_2$ and Kc$_2$). See **rocks of Easy Pass** under unit Kmcg.

CRETACEOUS–JURASSIC

KJms Metasedimentary rocks (consists of part of the Goat Island terrane). Rocks of the **Goat Island terrane** are lithologically similar to Jurassic and Cretaceous parts of the Lopez structural complex (see unit KJmm) of Brandon and others (1988) (Whetten and others, 1988; Dragovich and others, 2000c).

KJmm Marine metasedimentary rocks (consists of the Constitution Formation, part of the Lopez structural complex, Nooksack Formation undivided, part of the Lummi Formation, and part of the Western mélange belt). The **Nooksack**, **Lummi**, and **Constitution Formations** pre-date mid-Cretaceous (100–85 Ma) thrusting in the Northwest Cascades System. Clasts in the Constitution Formation are probably derived from the underlying Orcas Formation (Jurassic–Triassic, unit JTmc), Turtleback Complex (pre-Devonian, unit pDi), and Garrison Schist (pre-Permian, unit pPsh) (Vance, 1975, 1977), and radiolarians from chert are of Late Jurassic or Early Cretaceous age (Brandon and others, 1988). Radiolarians from near the base of the Lummi Formation are Late Jurassic to Early Cretaceous (Carroll, 1980). Blake and others (2000) report Toarcian to Tithonian radiolarian ages from chert. White mica Ar-Ar ages suggest a metamorphic event of possible latest Jurassic and (or) Early Cretaceous age (Lamb, 2000; Lapen, 2000), although the white mica may be detrital. The Nooksack Formation contains Late Jurassic to Early Cretaceous belemnites and buchia and concretions with Mesozoic radiolaria (Misch, 1966; Tabor and others, in press b). Metamorphosed components of the **Western mélange belt** contain Late Jurassic to Early Cretaceous macrofossils; radiolarians in cherts are Early Jurassic (Tabor and others, 1993, 2000, in press a). Macro- and microfossils, including radiolarians from cherts interbedded with pillow basalts, indicate that the **Lopez structural complex** is Jurassic to Cretaceous (Whetten and others, 1978, 1988; Brandon and others 1988).

KJmc Metachert (consists of part of the Western mélange belt). Most **Western mélange belt** components contain Late Jurassic to earliest Cretaceous radiolarian chert and megafossil-bearing argillite. The limestone blocks are Permian and may have originally been emplaced as olistostromes (Tabor and others, 1993, in press a).

KJmv Metavolcanic rocks (includes part of the Western mélange belt, part of the Goat Island terrane, and part of the Lopez structural complex). The metavolcanic rocks of the **Western mélange belt** have not been dated. See the Western mélange belt under units Jit and KJmc. See the **Goat Island**

terrane under unit KJms. See the **Lopez structural complex** under unit KJmm.

JURASSIC

Jmm Marine metasedimentary rocks (consists of part of the Helena-Haystack mélange). See the **Helena-Haystack mélange** under units Jigb, Jmv, Jam, and Jit.

Jar Meta-argillite (includes the De Roux unit, the Peshastin Formation, part of the Ingalls Tectonic Complex undivided, and part of the Eastern mélange belt undivided). See the **Ingalls Tectonic Complex** under units KJhmc and Jib. Radiolarians in the **Eastern mélange belt** are Middle to Late Jurassic (Tabor and others, in press a). Although its age is poorly known, Miller and others (1993b) suggest that the **De Roux unit** may be correlative with the Western mélange belt and thus probably has a Mesozoic to latest Paleozoic age. We assign a Jurassic age to this unit but recognize that it may be significantly older.

Jph Phyllite (consists of the Darrington Phyllite, the semischist and phyllite of Mount Josephine of the Easton Metamorphic Suite, and the slate of Rinker Ridge). The **Darrington Phyllite** is part of the Easton Metamorphic Suite, for which K-Ar and Sr-Rb ages indicate metamorphism at about 110 to 130 Ma and a protolith age not much older, probably Middle or Late Jurassic (Brown and others, 1982; Armstrong and Misch, 1987; Tabor and others, 1993, in press a,b). The **semischist and phyllite of Mount Josephine** are correlated with the Darrington Phyllite (Dragovich and others, 1998; Tabor and others, in press b), and Pb-U zircon ages from a related metadiorite on Bowman Mountain are 163 Ma (Gallagher and others, 1988). Metagabbro north of the Skagit River has produced U-Pb ages of about 160 Ma (Dragovich and others, 1998, 1999). These metagabbros may be Easton Metamorphic Suite (Gallagher and others, 1988) or Helena–Haystack mélange (Dragovich and others, 1998). There is no age control on the **slate of Rinker Ridge**; Tabor and others (in press a,b) propose a correlation with the mostly pre-Jurassic Chilliwack Group, but lithology suggests correlation with the Darrington Phyllite.

Jsh Greenschist (consists of the Shuksan Greenschist). The **Shuksan Greenschist** is part of the Easton Metamorphic Suite, for which K-Ar and Sr-Rb ages indicate metamorphism at about 110 to 130 Ma and a protolith age not much older, probably Middle or Late Jurassic (Brown and others, 1982; Armstrong and Misch, 1987; Tabor and others, 1993, in press a,b).

Jmt Metasedimentary and metavolcanic rocks, undivided (consists of part of the Lummi Formation and part of the Helena–Haystack mélange). The **Lummi Formation** contains Early to Late Jurassic radiolarians in chert (Whetten and others, 1978; Carroll, 1980; Blake and others, 2000; Lapen, 2000). See the **Helena–Haystack mélange** under units Jit and Jmv.

Jmv Volcanic and metavolcanic rocks, undivided (includes the metavolcanic unit of Deer Peak, the Lookout Mountain unit of the Newby Group, part of the Helena-Haystack mélange, part of the Easton Metamorphic Suite undivided, and part of the Ingalls Tectonic Complex undivided). The **Helena–Haystack mélange** yielded a U-Pb zircon age of 168 Ma and a muscovite K-Ar metamorphic (exhumation) age of about 90 Ma, which was confirmed by a two-point, whole rock and muscovite Rb-Sr isochron age of about 94 Ma (Tabor and others, in press a). See Helena–Haystack mélange under units Jigb, Jit, and Jam. Gabbro in the **Ingalls Tectonic Complex** has produced a Late Jurassic zircon U-Pb date (Tabor and others, 1987a), and a K-Ar hornblende age of statically recrystallized diabase of about 85 Ma, but this is probably a minimum age of recrystallization, produced by the heat of the 93 Ma Mount Stuart batholith (Tabor and others, 1982b). See also the Ingalls Tectonic Complex under units KJhmc and Jib. A tuff from strata correlative to the **Lookout Mountain unit of the Newby Group** yielded a U-Pb zircon age of 151 Ma (Late Jurassic) (Mahoney and others, 1996). The Newby Group of Mahoney and others (1996) is intruded by 141 to 150 Ma plutons, suggesting that the top of the Newby Group is Late Jurassic.

Jmvd Metavolcanic rocks, dacite (consists of the Wells Creek volcanic member of the Nooksack Formation). A tuff in the **Wells Creek volcanic member of the Nooksack Formation** has produced zircon U-Pb ages of 173 to 187 Ma, which are interpreted by J. M. Mattinson to indicate crystallization at about 175 to 180 Ma (Franklin, 1985).

JURASSIC–TRIASSIC

JŦmm Marine metasedimentary rocks (includes part of the Cultus Formation). The **Cultus Formation** contains radiolarians ranging in age from Triassic to Late Jurassic (Tabor and others, in press b; Blackwell, 1983; Monger, 1970).

JŦmc Metachert (consists of the Orcas Formation and part of the Eastern mélange belt undivided). The **Orcas Formation** contains Triassic to Early Jurassic radiolarians and Late Triassic conodonts (Brandon and others, 1988). The **Eastern mélange belt** contains Late Triassic and Jurassic radiolarians (Tabor and others, 1993, in press a) and locally contains Permian fusilinids in limestone and marble beds (Danner, 1966; Tabor and others, 1993).

JŦmt Metasedimentary and metavolcanic rocks (consists of the volcanic rocks of Whitehorse Mountain and part of the Eastern mélange belt undivided). The **Eastern mélange belt** contains Late Triassic conodonts and Late Triassic and Jurassic radiolarians and yielded a hornblende K-Ar age of about 121 Ma, which is probably a minimum age for metamorphism (Tabor and others, in press a). Some of the rocks of the Eastern mélange belt have been lithologically correlated with the Jurassic to Mississippian Trafton sequence (see unit JMmt)(Tabor and others, 2000).

JŦmv Metavolcanic rocks (includes part of the Cultus Formation). The metavolcanic rocks of the **Cultus Formation** have not been dated, but the marine metasedimentary rocks (see under unit JŦmm) of the formation contain Late Triassic to Late Jurassic fossils.

JURASSIC–PERMIAN

JPmt Metasedimentary and metavolcanic rocks, undivided (consists of the blueschist of Baker Lake and part of the Elbow Lake Formation). Poorly preserved radiolarians from the **Elbow Lake Formation** are probably Jurassic to Permian (Tabor and others, 1994; Dragovich and others, 1997b; Brown and others, 1987); the age of the meta-igneous rocks is unknown. The **blueschist of Baker Lake** is possibly derived from the Elbow Lake Formation (Tabor and others, in press b).

JURASSIC–MISSISSIPPIAN

JMmt Metasedimentary and metavolcanic rocks, undivided (consists of part of the Trafton sequence). The **Trafton sequence** contains Mississippian to Middle Jurassic radiolarians, Permian fusulinids, and metatonalite blocks as old as Pennsylvanian (Tabor and others, in press a).

JURASSIC–DEVONIAN

JDmt Metasedimentary and metavolcanic rocks, undivided (consists of undivided Chilliwack Group and Cultus Formation). Unit JDmt is the **undivided Chilliwack Group and Cultus Formation** of Tabor and others (1994, in press b). Marble in the Chilliwack Group contains Devonian to Permian fossils, though most are Mississippian (Danner, 1966; Tabor and others, in press a,b). See also the Chilliwack Group under unit PDmb. The Cultus Formation contains Late Triassic to Late Jurassic fossils (Brown and others, 1987; Blackwell, 1983; Monger, 1966; Tabor and others, 1994).

TRIASSIC–PERMIAN

ŦPmv Metavolcanic rocks (consists of the Deadman Bay Volcanics). The **Deadman Bay Volcanics** contain fusulinids and radiolarians that range from Late Triassic to Early Permian (Danner, 1966; Brandon and others, 1988).

PERMIAN–DEVONIAN

PDms Metasedimentary rocks (consists of the sedimentary rocks of Mount Herman of the Chilliwack Group and part of the Chilliwack Group undivided). The **Chilliwack Group** contains Devonian to Permian fossils (Danner, 1966) and Late Devonian U-Pb ages from detrital zircons (McClelland and Mattinson, 1993). See the Chilliwack Group under units PDmb and PDmt.

PDmb Limestone and marble (consists of part of the Chilliwack Group undivided). **Chilliwack Group** limestone and marbles range from Silurian to Devonian to Permian and contain Mississippian crinoids (Danner, 1966; Liszak, 1982). Single crystal U-Pb ages of detrital zircons from Chilliwack rocks yielded Late Devonian ages (McClelland and Mattinson, 1993). See also the Chilliwack Group under unit PDmt.

PDmt Metasedimentary and metavolcanic rocks, undivided (consists of the East Sound Group and part of the Chilliwack Group undivided). The **Chilliwack Group** contains Devonian to Permian fossils (Danner, 1966) and Late Devonian U-Pb zircon ages (McClelland and Mattinson, 1993). The **East Sound Group** contains Permian to Devonian fossils (Danner, 1966, 1977). Preliminary U-Pb ages of detrital zircons near the base of the unit yielded ages that range from 342 to 426 Ma (Lapen, 2000).

PDmv Metavolcanic rocks (consists of part of the Chilliwack Group undivided, the volcanic rocks of Mount Herman of the Chilliwack Group, and the metavolcanic rocks of North Peak). See the **Chilliwack Group** under units PDms, PDmt, and JDmt.

PRE-PERMIAN

pPsh Schist (consists of the Garrison Schist and part of the Vedder complex). The protolith age of the **Vedder Complex** and **Garrison Schist** is pre-Permian based on K-Ar and Rb-Sr mineral and whole-rock analyses that indicate Permian to earliest Triassic metamorphism (Armstrong and others, 1983; Brandon and others, 1988).

Amphibolite Facies and Higher (High-Grade Rocks)

TERTIARY

Paleocene

Rog — Orthogneiss (consists of the gneiss of War Creek). The **gneiss of War Creek** intrudes and contains large inclusions and screens of the 90 Ma Black Peak batholith (see unit Kit), and it underwent ductile deformation in the Ross Lake fault zone sometime between 65 and 48 Ma; a preliminary U-Pb titanite age of 85 to 87 Ma suggests that the pluton may be Cretaceous (Miller, 1987).

TERTIARY–CRETACEOUS

RKog — Paleocene–Cretaceous orthogneiss (consists of the orthogneiss of Mount Benzarino and the orthogneiss of Gabriel Peak). The **orthogneiss of Gabriel Peak** yielded a zircon and titanite U-Pb age and poorly defined Rb-Sr isochron age of about 68 Ma; calculated $^{206}Pb/^{238}U$ ages are 68.2 Ma for zircon and 64.6 and 61.0 Ma for titanite (Hoppe, 1984; Miller, 1987). Unit includes the **orthogneiss of Mount Benzarino** due to confusion pertaining to the extent and nature of the orthogneiss of Gabriel Peak (R. W. Tabor, USGS, written commun. to J. D. Dragovich, 1993).

TKog — Orthogneiss (includes the leucogneiss of Lake Juanita, the orthogneiss of Mount Triumph, the orthogneiss of Stehekin, the orthogneisses of Boulder Creek, Purple Creek, and Rainbow Mountain, the migmatitic orthogneiss of McGregor Mountain, and part of the Skagit Gneiss Complex undivided). Concordant to mildly discordant U-Pb age of zircons from orthogneiss in the **Skagit Gneiss Complex** indicate syn-metamorphic igneous crystallization between 90 and 49 Ma (Haugerud and others, 1991; Hoppe, 1984; Miller and Bowring, 1990; Dragovich and Norman, 1995). Wernicke and Getty (1997) interpreted Sm-Nd data and U-Pb zircon ages to represent igneous crystallization at 68 Ma and Ar-Ar ages of 47 and 45 Ma of hornblende and biotite to represent cooling. This is in agreement with K-Ar data from other parts of the Skagit Gneiss Complex. Orthogneiss locally includes minor remnant lenses or layers of older schist, amphibolite, and ultramafite correlative with the Cascade River Schist or Napeequa Schist (see units Ŧhm or JPhmc, respectively). The Skagit Gneiss Complex also contains bodies of orthogneiss (see unit Ŧog) with Triassic intrusive ages that are probably correlative with the Marblemount pluton (see unit Ŧiq)(Haugerud an others, 1991). See also Skagit Gneiss Complex under unit TKbg.

TKbg — Banded gneiss (consists of part of the Skagit Gneiss Complex undivided, part of the Napeequa Schist, part of the Cascade River Schist of Misch (1966), and part of the Cascade River Schist of Tabor and others (in press a)). Undivided orthogneiss, metavolcanic and metasedimentary rocks, and paragneiss of the **Skagit Gneiss Complex**. See age information on the orthogneiss under unit TKog. Paragneiss and amphibolite are lithologically similar to both the **Napeequa Schist** (Jurassic–Permian, unit JPhmc) and volcanic arc **Cascade River Schist** (Triassic, unit Ŧhm) and are probably migmatized and heavily intruded equivalents of those units (Tabor and others, in press b; Dragovich and Norman, 1995). These non-intrusive components of the Skagit Gneiss Complex have yielded zircon U-Pb ages of 140 Ma and 136 Ma and Sm-Nd depleted mantle model ages of 450 Ma, 390 Ma, and 1.09 Ga (Rasbury and Walker, 1992). The age of this map unit is left at Tertiary to Cretaceous to agree with the orthogneiss components of the Skagit Gneiss Complex (see unit TKog). See the Napeequa Schist under unit JPhmc and the Cascade River Schist under unit Ŧhm for the age of the schistose country rock of the banded gneiss units (Tabor and others, 1994, in press b). See Haugerud and others (1991) for a more complete discussion of the intrusive history of the Skagit Gneiss Complex.

PRE-TERTIARY

pTog — Orthogneiss (consists of part of the Napeequa Schist). Gneiss in the heterogeneous schist and gneiss unit of the **Napeequa Schist** (Tabor and others, 1989, in press a) has yielded concordant to moderately discordant U-Th-Pb zircon ages between 71 and 127 Ma (Tabor and others, 1987a). The gneiss contains Late Cretaceous and inherited and probable Paleozoic or older zircon (Tabor and others, 1987a).

pTgn — Gneiss (consists of the Swakane Biotite Gneiss). The **Swakane Biotite Gneiss** contains rounded zircons more than 1,650 m.y. old (Mattinson, 1972). Its protolith age is at least pre-Tertiary. Recent U-Pb and Sm-Nd analyses of zircon (Rasbury and Walker, 1992; Troy Rasbury, University of Texas at Austin, written commun. to R. W. Tabor, 1993) indicate that the gneiss may have been derived from sedimentary rocks as young as Cretaceous (Tabor and others, in press a). The only definitive age constraint is that it is older than 68 Ma pegmatite dikes (Mattinson, 1972). Rasbury and Walker (1992) report zircon data and conclude that if the Swakane has a sedimentary protolith, it can only be constrained to Cretaceous or older.

MESOZOIC

Mzsc Schist and amphibolite (includes part of the Tonga Formation and part of the Chiwaukum Schist). The protolith age of **Chiwaukum Schist** predates the Late Cretaceous metamorphism of the Nason terrane and intrusion of the Mount Stuart batholith (~90–95 Ma)(Duggan and Brown, 1994). Tabor and others (1993) correlate the Chiwaukum Schist (see also under unit Mzsc) with the Tonga Formation. The **Tonga Formation** may be correlative with the Lookout Mountain Formation of Miller and others (1993b) south of the map area, which, in turn, is intruded by a pluton that yielded a zircon U-Pb age of about 155 Ma, making both formations pre-Late Jurassic (Tabor and others, 1993). Rb-Sr data may indicate that the Chiwaukum Schist is early Jurassic to latest Triassic (Gabites, 1985; Evans and Berti, 1986; Magloughlin, 1986). Conversely, if some of the ultramafic rock in the Chiwaukum Schist was originally emplaced as submarine serpentinite-rich debris flows from the Late Jurassic Ingalls Tectonic Complex, then the Chiwaukum sediments were deposited between the Late Jurassic and the Late Cretaceous (Tabor and others, 1987).

CRETACEOUS

Khm Heterogeneous metamorphic rocks (consists of part of the Chaval pluton). See the **Chaval pluton** under unit Kiq.

Kog Orthogneiss (includes the Marble Creek Orthogneiss, the Eldorado Orthogneiss, the Bearcat Ridge plutons, the Sloan Creek plutons, the Leroy Creek pluton, the orthogneisses of Haystack Creek and Alma Creek, the gneissic tonalites of Pear Lake and Excelsior Mountain, the light-colored gneiss of Wenatchee Ridge, part of the tonalitic gneiss of Bench Lake, part of the Sulphur Mountain pluton, and part of the Nason Ridge Migmatitic Gneiss). The **Bearcat Ridge plutons** produced a U-Pb age of 89 Ma (Miller and others, 1993a). The **Eldorado Orthogneiss** produced several concordant zircon U-Pb ages of about 88 and 92 Ma (Mattinson, 1972; Haugerud and others, 1991) and a hornblende K-Ar cooling age of 43 Ma (Engels and others, 1976; Babcock and others, 1985. Hornblende and biotite from the **Sloan Creek plutons** yielded K-Ar ages of about 75 to 78 Ma; U-Th-Pb and U-Pb ages from the same samples and others are concordant at about 90 Ma, which is interpreted to be the crystallization age (Hoppe, 1984; Walker and Brown, 1991; Tabor and others, in press a). U-Th-Pb analyses of zircon from the **gneissic tonalite of Excelsior Mountain** suggest Late Cretaceous recrystallization, but $^{207}Pb/^{206}Pb$ ages as old as 120 Ma in the finer-grained fraction may reflect pre-Cretaceous crystallization of the original pluton (Tabor and others, 1993). A Cretaceous age may be likely for this metamorphosed intrusive body on the basis of its resemblance to the Sloan Creek plutons (Hoppe, 1984; Walker and Brown, 1991; Tabor and others, 1993). K-Ar ages of muscovite and biotite are about 48 and 44 Ma, respectively, for the **orthogneiss of Haystack Creek**, and reflect Eocene metamorphism and (or) unroofing. Cretaceous age is based upon the lithologic similarity to orthogneiss bodies within the Skagit Gneiss Complex that yielded U-Pb zircon ages of 60 to 70 Ma (Mattinson, 1972; Wernicke and Getty, 1977; Tabor and others, in press b). The **Leroy Creek pluton** intrudes the Triassic Dumbell Mountain pluton (see unit TRog) and is intruded by the 75 Ma Seven Fingered Jack pluton (see unit Kit), hence the ages of 45 and 54 Ma determined on mica (Engels and others, 1976) are much too young and indicate heating by later intrusions (Cater, 1982) or are cooling ages. A Late Cretaceous age is assigned based on similarities with other nearby Cretaceous plutonic bodies (Dragovich and Norman, 1995). U-Pb ages of zircon from the **Marble Creek Orthogneiss** are slightly discordant at about 75 Ma and probably represent the age of intrusion; K-Ar ages of muscovite and biotite, about 50 and 44 ma, respectively, reflect Eocene metamorphism and (or) unroofing (Tabor and others, in press b). Muscovite and biotite K-Ar ages of about 49 and 39 Ma, respectively, for the **orthogneiss of Alma Creek** probably reflect Eocene unroofing (Tabor and others, in press b). A Late Cretaceous intrusive age is assigned based upon similarities with other nearby Cretaceous plutonic bodies. The **light-colored gneiss of Wenatchee Ridge** yielded concordant biotite and muscovite K-Ar ages of 81 and 83 Ma, respectively (Tabor and others, 1993), which fall within the range of 90 to 60 Ma for the last episode of regional metamorphism for the North Cascades (Mattinson, 1972). A latest Cretaceous intrusive age is indicated by a U-Pb sphene age of 93 Ma (Miller and others, 2000). See **Entiat pluton** under unit Kid, **Nason Ridge Migmatitic Gneiss** under unit Kbg, and **Sulphur Mountain pluton** under unit Kigd. The **gneissic tonalite of Pear Lake** is assigned a latest Cretaceous age based on similarities with other nearby Cretaceous plutonic bodies. The **tonalitic gneiss of Bench Lake** has not been dated, but probably formed during the Late Cretaceous metamorphic event (94 to 85 Ma) in the North Cascades (Tabor and others, in press a).

Kbg Banded gneiss (consists of part of the Nason Ridge Migmatitic Gneiss, the banded gneiss of Wenatchee Ridge, part of the Chiwaukum Schist, and part of the tonalitic gneiss of Bench Lake). See the **Chiwaukum Schist** under unit Mzsc for the age of the schist and amphibolite bands of the banded gneiss units. The banded gneiss in the southern North Cascades Crystalline Core (Fig. 4 on Sheet 3) is Chiwaukum Schist that has been transformed into migmatite by repeated intrusion along the bedding and (or) foliation. This transformation occurred in the Late Cretaceous (after about 90 Ma). Discordant ages from zircon of the **Nason Ridge Migmatitic Gneiss** indicate crystallization at 89 Ma; Rb-Sr isochrons suggest ages of about 79.5 and 86 Ma, which probably represent cooling ages (Tabor and others, in press a). For **banded gneiss of Wenatchee Ridge**, see light-colored gneiss of Wenatchee Ridge under unit Kog. Walker and Brown (1991) interpret discordant ages of zircon to indicate primary crystallization at 89 Ma. Magloughlin (1993) reports Rb-Sr analyses with isochrons yielded cooling ages of 79.5 Ma and 86.2 Ma.

CRETACEOUS–JURASSIC

KJhmc Heterogeneous chert-bearing metamorphic rocks (consists of part of the Ingalls Tectonic Complex undivided). Gabbro of the **Ingalls Tectonic Complex** yielded a U-Pb age on zircon of 155 Ma (Late Jurassic), and the chert contains Late Jurassic radiolarians; the unit was thermally metamorphosed by the intrusion of the Late Cretaceous Mount Stuart batholith (Tabor and others, 1987a, 1993; Miller and others, 1993b). The Ingalls Tectonic Complex locally contains slivers of Cretaceous orthogneiss with a 9.4 U-Pb age (R. B. Miller, San Jose State Univ., written Commun., 2001). See also Ingalls Tectonic Complex under unit Jib.

KJog Orthogneiss (consists of the trondhjemite of Lamb Butte and Remmel batholith undivided). The **trondhjemite of Lamb Butte** grades into both the Cretaceous to Jurassic tonalite of Doe Mountain (see under unit KJmi) and the Cretaceous to Jurassic trondhjemite of Eightmile Creek, east of the map area (Stoffel and McGroder, 1990). Trondhjemite of Lamb Butte is the deformed western margin of the **Remmel batholith**. East of the map area, K-Ar biotite ages of about 107 and 99.8 Ma probably represent the age of latest ductile deformation (Stoffel and McGroder, 1990). U-Pb zircon ages of 140 to 150 Ma are reported from compositionally and texturally similar intrusions in the Eagle plutonic complex in southern British Columbia (Greig, 1988). Hurlow and Nelson (1993) obtained discordant U-Pb ages of at least 111 Ma from the trondhjemite of Lamb Butte.

JURASSIC

Jam Amphibolite (consists of part of the Helena–Haystack mélange and part of the Easton Metamorphic Suite undivided). Concordant U-Pb zircon ages from tonalite of the **Helena–Haystack mélange** are about 150 Ma, and a conventional K-Ar age analysis of hornblende from the amphibolite yielded an age of 141 Ma (Tabor and others, in press a). We assign a Jurassic age to the amphibolite due to the similarity of the amphibolite age with other age-dated components of the Helena–Haystack mélange. Also see Helena–Haystack mélange under units Jit, Jigb, and Jmv. In the Gee Point–Iron Mountain area, rocks yielded K-Ar and Rb-Sr ages of 144 to 160 Ma, older than the 130 Ma age for the regional blueschist metamorphism of the **Easton Metamorphic Suite** (Brown and others, 1982). See further age information for parts of the Easton Metamorphic Suite under unit Jph.

Jgn Migmatitic gneiss (consists of the Baring Migmatites and part of the Eastern mélange belt undivided). A Late Cretaceous to Eocene age of formation of the **Eastern mélange belt** was suggested by Tabor (1994). Whetten and others (1980b) obtained U-Th-Pb zircon ages of about 190 Ma from a tonalite phase of the migmatitic gneiss.

JURASSIC–PERMIAN

JPhmc Heterogeneous chert-bearing metamorphic rocks (includes part of the Napeequa Schist, which includes: the Twisp Valley Schist, the Rainbow Lake Schist, the rocks of the Napeequa River area, and part of the Cascade River Schist of Misch (1966)). The protolith age of the **Napeequa Schist** is not known, but the age may be Permian to Jurassic, based on correlation with other oceanic assemblages in the Pacific Northwest such as the Hozomeen Group (see unit JPvs)(Tabor and others, in press b).

TRIASSIC

Ŧhm Heterogeneous metamorphic rocks (includes the younger gneissic rocks of the Holden area, the Spider Mountain Schist, part of the Cascade River Schist of Misch (1966), and part of the Cascade River Schist of Tabor and others (in press a)). Zircon U-Pb ages from a metatuff of the **Cascade River Schist** are about 220 Ma (Cary, 1990; Tabor and others, in press b), and possible detrital zircons give an upper concordia-intercept age of 265 Ma (Permian)(Tabor and others, in press a).

Ŧog Orthogneiss (consists of the Dumbell Mountain pluton, the orthogneiss of The Needle of the Skagit Gneiss Complex, part of the Skagit Gneiss Complex undivided, and part of the Marblemount pluton). The **Dumbell Mountain pluton** is Triassic (about 220 Ma) based upon several roughly concordant results of U-Pb analyses (Mattinson, 1970, 1972). Hurlow (1991) also obtained a slightly discordant age of about 218 Ma for the Dumbell

Mountain pluton. Wall rocks similar to those of the Late Triassic (~220 Ma) Marblemount pluton, discordant U-Pb zircon ages, and the absence of other late Paleozoic or early Mesozoic plutonic suites in the North Cascades suggest that the **orthogneiss of The Needle** is a metamorphosed Late Triassic pluton of the Marblemount plutonic belt (Haugerud and others, 1991). See the **Marblemount pluton** under unit Ŧiq.

PRE-DEVONIAN

pDgn Gneiss (consists of part of the Yellow Aster Complex). Protolith ages for the **Yellow Aster Complex** are difficult to deduce, given discordant U-Pb ages in meta-igneous rocks and questions concerning an igneous versus detrital origin of zircons in quartzose gneiss. Mattinson (1972) reported a Pb-Pb age for zircon in quartzose gneiss of 1,452 to 2,000 Ma, the former being interpreted as the minimum protolith age. A metamorphic age of 415 Ma from a U-Pb analysis of metamorphic sphene is the basis for the pre-Devonian protolith age (Lapen, 2000; Mattinson, 1972). See also the Yellow Aster Complex under unit pDi.

EDGE MATCHES WITH OTHER QUADRANTS

Southwest Quadrant

Discrepancies along the boundary between the northwest and southwest (Walsh and others, 1987) quadrants in the southwestern Olympic Peninsula are primarily due to the availability of new mapping and reinterpretation of geologic units in the northwest quadrant. The new mapping was enhanced by the use of side-looking airborne radar (SLAR), digital elevation models (DEM), and airphoto analysis to identify areas of progressive dissection of terrain and glacially influenced landforms that were subsequently field checked and delineated at 1:24,000-scale. Most discrepancies have been resolved as much as possible and are illustrated on 1:100,000-scale digital maps of the Shelton and Copalis Beach quadrangles (Washington DGER, 2001), which are available upon request from DGER at the address shown inside the cover of this pamphlet.

Because glacial deposits dominate the geology of most of the Puget Lowland, we have chosen to retain more detail in the Quaternary glacial units on the northwest quadrant than was retained on the map of the southwest quadrant (Walsh and others, 1987). This accounts for many discrepancies between the glacial units on the southwest and northwest quadrants.

Northeast Quadrant

Differences in geologic units and structure between the northwest and northeast (Stoffel and others, 1991) quadrant maps are primarily the result of new geologic mapping and radiometric age dating during the last decade. These differences are described below, roughly from south to north.

In the Chelan and Twisp 1:100,000-scale quadrangles, recent U-Pb age dating indicates that the Swakane Gneiss may contain Paleozoic detrital zircons (Rasbury and Walker, 1992), so we have assigned a pre-Tertiary age (unit pTgn) instead of the Precambrian age that was assigned in the northeast quadrant (unit pCgn)(Stoffel and others, 1991).

In the Chiwawa River area of the Chelan 1:100,000-scale quadrangle, orthogneiss bodies in the Napeequa Schist are assigned a pre-Tertiary age in the northwest quadrant (unit pTog), whereas they were assigned a Cretaceous age in the northeast quadrant (unit Kog). This change acknowledges that the age of some of these bodies is poorly known and that some may be pre-Tertiary.

In the Chelan, Twisp, and Robinson Mountain 1:100,000-scale quadrangles, a Jurassic to Permian age is assigned to the Napeequa Schist of the Chelan Mountains terrane (Tabor and others, in press a) in the northwest quadrant (unit JPhmc), which differs from the Triassic to Permian age assigned to this unit in the northeast quadrant (unit ŦPhmc). This difference is based on the correlation of the Napeequa Schist with the Hozomeen Group (Haugerud, 1985), which extends into the Jurassic. The distribution of the Napeequa Schist of the Chelan Mountains terrane also differs between the northwest and northeast quadrants. Recent mapping (Miller and others, 1994) suggests that many of the supracrustal metamorphic rocks southeast of Holden (T31N R17E) belong to the Cascade River unit of the Chelan Mountains terrane (unit Ŧhm on northwest quadrant)(Tabor and others, 1989), not the Napeequa Schist as shown in the northeast quadrant.

In the northwest quadrant, we do not use the lithologic term migmatite (unit Kmg in the northeast quadrant), partially because of the difficulty in determining the boundaries of migmatization, which are commonly diffuse and gradational. Instead, we use mostly intrusive lithologic symbols (for example, unit Kit) or metamorphic terms (banded gneiss, unit TKbg) for migmatitic rocks.

In the Chelan and Twisp 1:100,000-scale quadrangles, the Duncan Hill pluton is compositionally heterogeneous along the length of the body from mostly granite and granodiorite to the southeast to mostly quartz diorite to the northwest. Thus, the Duncan Hill pluton was included in units Eig and Eigd in the northeast quadrant, but is included in unit Eiq in the northwest quadrant.

In the Twisp 1:100,000-scale quadrangle near Lake Chelan, the northeast quadrant map shows the Skagit Gneiss Complex as unit TKmi, emphasizing both the intrusive igneous material and the metamorphic selvages of schist and amphibolite. In the Stehekin (T33N R18E) region in the northwest quadrant, the Skagit Gneiss Complex is mostly orthogneiss (Dragovich and Norman, 1995) and contains only minor or rare supracrustal metamorphic rocks; we emphasize the predominance of orthogneiss by assigning these rocks to unit TKog. Also in the Lake Chelan area, the leucogneiss of Lake Juanita (Miller,

1987) was included in unit Rog in the northeast quadrant, but is included in the Skagit Gneiss Complex in the northwest quadrant (unit TKog).

In the Twisp River valley of the Twisp 1:100,000-scale quadrangle, recent mapping (Dragovich and others, 1997a) has delineated the metaconglomerate of South Creek (unit Kmcg in the northwest quadrant), which unconformably overlies the Twisp Valley Schist (unit JPhmc). This recent mapping also suggests that the Twisp River fault either does not exist or is a minor brittle structure, and that the tectonic zone shown along the Twisp River valley in the northeast quadrant (unit tz) is actually contiguous with the North Creek fault just north of the Twisp River valley (Dragovich and others, 1997a). Dragovich and others (1997a) correlate the North Creek Volcanics (Misch, 1966) with the Cretaceous Winthrop Formation, whereas these rocks were correlated with the Cretaceous to Jurassic Newby Group (Barksdale, 1975) in the northeast quadrant; thus, rocks shown as unit KJmv on the northeast quadrant are included in unit Kmt on the northwest quadrant.

New geologic mapping in the Robinson Mountain 1:100,000-scale quadrangle (R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000) substantially changes the geologic mapping, structural interpretations, stratigraphy, and geologic understanding of the Methow basin as compared to previous studies (Tennyson, 1974; Barksdale, 1975; McGroder and others, 1990; Stoffel and McGroder, 1990), resulting in many differences between the maps of the northeast and northwest quadrants in this area. (See discussion under Sources of Map Data.) This new mapping recognizes that much of the Virginian Ridge Formation contains fluvial (continental) sedimentary rocks; thus, rocks that were shown as marine sedimentary rocks on the northeast quadrant (unit Km_2) are assigned to the continental sedimentary rock category on the northwest quadrant (unit Kc_2).

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Table 2. List of named units. BEL, Bellingham; CFL, Cape Flattery; CHL, Chelan; CPB, Copalis Beach; FRK, Forks; MBK, Mount Baker; MOL, Mount Olympus; PAN, Port Angeles; PTW, Port Townsend; RBM, Robinson Mountain; RCH, Roche Harbor; SAU, Sauk River; SEA, Seattle; SHL, Shelton; SKY, Skykomish River; SNO, Snoqualmie Pass; TAC, Tacoma; TWS, Twisp; WEN, Wenatchee

Geologic unit	Symbol	Defining and (or) representative references	1:100,000 quadrangle(s)	Area (township and range)
Aldwell Formation	Em$_2$ Evb	Brown and others (1960), Snavely and others (1993)	CFL, MOL PAN, SEA	T27N R2W; T28N R2W; T29N R3-6W; T30N R6-12W; T31N R12-14W; T32N R14-15W
Alma Creek, orthogneiss of	Kog	Misch (1977, 1979), Tabor and others (in press b)	MBK	T36N R11E
Arlington Gravel Member, Vashon Drift	Qgog	Newcomb (1952)	PTW	T31N R5-6E; T32N R5-6E
Astoria Formation	Mm$_1$	Howe (1926)	SHL	T21N R7W
Baada Point Member, Makah Formation, see Makah Formation				
Baekos Creek assemblage, volcanic rocks and deposits of Glacier Peak	Qvl	Beget (1981, 1982)	SAU	see Kennedy Creek assemblage
Bahobohosh, sandstone of	Em$_2$	Snavely and others (1993)	CFL	T32N R14-15W; T33N R15-16W
Baker Lake, blueschist of, Bell Pass mélange	JPmt	Brown and others (1987), Tabor and others (in press b)	MBK	T37N R8-9E; T38N R9E
Baker River phase, Chilliwack composite batholith, Index family	Φigd	Tabor and others (in press b)	MBK	T37N R10E; T38N R10-11E; T39N R9-10E; T40N R9-10E; T41N R9E
Bald Mountain, conglomerate of	pTms	Misch (1966), Johnson (1982), Tabor and others (in press b)	BEL MBK	T39N R4E; T40N R4-7E
Bald Mountain pluton	pTigd	Dungan (1974), Tabor and others (1993, in press a)	SAU SKY	T29N R8-9E; T30N R7-8E
Baring Migmatites	Jgn	Yeats (1958a, 1964)	SKY	T26N R11E; T27N R10-11E
Barlow Pass Volcanics	Ec$_2$ Eigb, Ev Evr	Vance (1957), Ristow (1992), Evans and Ristow (1994), Tabor and others (in press a)	SAU	T27N R11E; T28N R10-12E; T29N R10-12E; T30N R10-12E; T31N R9-11E
Basalt Peak, porphyritic dacite of	Eir	Cater (1982), Tabor and others (1987a)	CHL	T28N R17E; T29N R17E
Bastile Ridge, andesite of, andesite of Mount Baker	Qva	Tabor and others (in press b)	MBK	T38N R7-8E
Bear Creek, siltstone and sandstone of	Em$_1$	Snavely and others (1993)	CFL	T30N R12-13W; T31N R13-14W
Bear Mountain, granite of western, Chilliwack composite batholith, Cascade Pass family	Mig	Tabor and others (in press b)	MBK	T40N R11E
Bearcat Ridge plutons	Kog	Cater and Wright (1967), Cater (1982)	TWS	T30N R18-19E; T31N R17-18E
Beckler Peak stocks, Mount Stuart batholith	Kigd	(Yeats, 1958a, 1977)	SKY	T25N R12-13E; T26N R12-13E; T27N R1E
Bell Pass mélange, undivided	pTmt pTu	Brown and others (1987), Tabor and others (1994, in press a,b)	BEL MBK SAU	T31N R10-11E; T32N R11E; T32N R10-11E; T33N R10E; T34N R9-10E; T35N R8-10E; T36N R6-10E; T37N R6-9E; T38N R6-7,9E; T39N R4-7,9E; T40N R4-7,9E; T41N R6-7,9E
Bell Pass mélange. Includes and listed under: Elbow Lake Formation, Yellow Aster Complex, Vedder complex, blueschist of Baker Lake, Twin Sisters Dunite, and metaconglomerate of Sumas Mountain.				
Bellingham Bay Member, Chuckanut Formation, see Chuckanut Formation				
Bench Lake, tonalitic gneiss of	Kog Kbg	Tabor (1961), Fluke (1992), Tabor and others (in press a)	SAU TWS	T32N R14-15E; T33N R13-14E; T34N R13E
Big Bosom Buttes, volcanic rocks of	Φvx Φvt	Vance (1957), Tabor and others (in press b)	MBK	T40N R9-10E; T41N R10E
Black Buttes, andesite of, andesite of Mount Baker	Qva Qvp	Tabor and others (in press b)	MBK	T37N R7-8E; T38N R7E
Black Peak batholith, undivided (also includes Reynolds Peak phase, listed separately)	Kit	Misch (1952, 1966), Miller (1987)	RBM TWS	T33N R18-19E; T34N R17-18E; T35N R16-18E; T36N R14,16E

Geologic unit	Symbol	Defining and (or) representative references	1:100,000 quadrangle(s)	Area (township and range)
Blakeley Formation	ΦEm ΦEn	Weaver (1912b), Warren and others (1945), Fulmer (1975), Walsh (1984)	SEA	T24N R1-2,4-6E
Blakely Harbor Formation	Mc2	Fulmer (1975), Yount and Gower (1991)	SEA	T24N R2E
Blue Mountain unit	ERm	Tabor and Cady (1978a), Einarsen (1987)	CFL, MOL PAN, SHL	T23N R5-8W; T24N R4-5W; T25N R4W; T26N R4W; T27N R3-4W; T28N R3-5W; T29N R3-10W; T30N R9-12W
Bob Creek, tonalite of	KJmi	R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T40N R19E
Boulder Creek, orthogneiss of, Skagit Gneiss Complex	TKog	Nicholson (1991)	TWS	T33N R17-18E
Boundary Creek, tuff of	Φvt	R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T41N R19E
Brownes Creek, siltstone of	Em1	Snavely and others (1993)	CFL	T30N R12W; T31N R12-14W; T32N R14-15W
Buck Creek pluton	Kigd	Cater and Crowder (1967), Cater (1982), Ford and others (1988)	TWS	T30N R15-16E; T31N R15E
Bulson Creek, rocks of	ΦEc ΦEn	Lovseth (1975), Marcus (1981), Whetten and others (1988)	PTW	T27N R5-6E; T28N R5-7E; T29N R6-7E; T30N R6E; T31N R6E; T32N R5-6E; T33N R2-6E
Cady Ridge, volcanic rocks of	RMida	Crowder and others (1966)	SKY	T28N R12-13 E; T29N R14E
Camas Land, diabase of	Eigb	Russell (1900), Smith (1904), Southwick (1966)	WEN	T23N R18E
Cardinal Peak pluton	Kiq Kit	Cater and Crowder (1967), Cater and Wright (1967), Cater (1982), Miller and Paterson (2001)	SAU TWS	T29N R18-19E; T30N R17-18E; T31N R17E; T32N R16-17E; T33N R11-12E; T34N R11E
Carpenters Creek Tuff Member, Makah Formation, see Makah Formation				
Cascade Pass dike, Cascade Pass family	Mix Mit	Yeats (1958b), Tabor (1963), Tabor and others (in press a,b)	MBK, RBM SAU	T33N R12E; T34N R12-13E; T35N R13-14E
Cascade Pass family. Includes and listed under: granite of western Bear Mountain, Cascade Pass dike, Chilliwack composite batholith undivided, Cloudy Pass batholith, Cool Glacier stock, granite of Depot Creek, Downey Mountain stock, granite porphyry of Egg Lake, quartz diorite and quartz monzodiorite of Icy Peak, Lake Ann stock, Mineral Mountain pluton, Mount Buckindy pluton, quartz monzonite and granite of Nooksack Cirque, quartz monzodiorite of Redoubt Creek, Ruth Creek pluton, granite of Ruth Mountain, tonalite of Silver Creek, and stock on Sitkum Creek.				
Cascade River Schist of Misch (1966)(see also Napeequa Schist)	JPhmc TKbg Ŧhm	Misch (1966)	MBK SAU TWS	T33N R14,16E; T34N R11-14E; T35N R11-13E; T36N R11-12E; T37N R11E
Cascade River Schist of Tabor and others (in press a) (redefined), undivided (see also Napeequa Schist)	TKbg Ŧhm	Cater and Crowder (1967), Cater and Wright (1967), Tabor and others (in press a,b)	CHL MBK SAU TWS	T28N R18E; T29N R17-19E; T30N R17-19E; T31N R16-17E; T32N R16E; T33N R14,16E; T34N R12-14E; T35N R11-13E; T36N R11E
Cascade River Schist of Tabor and others (in press a)(redefined). Includes: Spider Mountain Schist, listed separately.				
Castle Peak stock	Eigd	Daly (1912), Lawrence (1967)	RBM	T40N R16-17E
Cedar District Formation, Nanaimo Group	Kn	Dawson (1886, 1890), Muller and Jeletzky (1970), Ward (1978)	BEL	T38N R2W
Chaval pluton	Khm Kiq	Bryant (1955), Tabor and others (in press a)	SAU	T33N R11-12E; T34N R11E
Chelan Complex, see Entiat Pluton				
Chikamin Creek, volcanic rocks of	Φvr Φvt	Tabor and others (1987a)	CHL	T29N R17E
Chilliwack composite batholith, undivided, Cascade Pass family	Mig Miqm	Tabor and others (1993, 2000, in press b)	MBK SAU SKY SNO	T23N R10-11E; T24N R9-11E; T30N R13-14E; T31N R14-15E; T32N R14,16E; T39N R10-11E; T40N R11-12E; T41N R12E
Chilliwack composite batholith of the Cascade Pass family. Includes and listed under: granite of western Bear Mountain, granite of Depot Creek, granite porphyry of Egg Lake, quartz diorite and quartz monzodiorite of Icy Peak, Lake Ann stock, Mineral Mountain pluton, quartz monzonite and granite of Nooksack Cirque, quartz monzodiorite of Redoubt Creek, Ruth Creek pluton, and granite of Ruth Mountain.				
Chilliwack composite batholith, undivided, Index family	Φib	Tabor and others (in press b)	MBK	T38N R10-11E; T39N R10-11E; T40N R10-12E

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Chilliwack composite batholith of the Index family. Includes and listed under: Baker River phase, gabbro of Copper Lake, diorite of Ensawkwatch Creek, tonalite of Maiden Lake, biotite alaskite of Mount Blum, granodiorite of Mount Despair, Pocket Peak phase, Price Glacier pluton, and Silesia Creek pluton.				
Chilliwack composite batholith of the Snoqualmie family. Includes and listed under: Chilliwack valley phase, Indian Mountain phase, biotite granodiorite of Little Beaver Creek, Mount Sefrit gabbronorite, and Perry Creek phase.				
Chilliwack Group, undivided	PDmt PDmb PDms PDmv	Cairnes (1944), Tabor and others (in press a,b)	BEL MBK SAU	T30N R11E; T31N R10-11E; T32N R10-11E; T33N R10-11E; T34N R9-10E; T35N R8-10E; T36N R7-10E; T37N R6-8E; T38N R6,8-9E; T39N R4,7-9E; T40N R5-9E; T41N R5-9E
Chilliwack Group. Includes and listed under: sedimentary rocks of Mount Herman and volcanic rocks of Mount Herman.				
Chilliwack Group and Cultus Formation, undivided	JDmt	Tabor and others (1994, in press b)	MBK	T36N R9E; T37N R9E; T40N R9E
Chilliwack valley phase, Chilliwack composite batholith, Snoqualmie family	Φit	Tabor and others (in press b)	MBK	T39N R10-11E; T40N R10-11E; T41N R10-11E
Chiwaukum Schist	Mzsc Kbg	Page (1939), Tabor (1961), Grant (1966), Plummer (1969), Tabor and others (1987a, 1988, 1993, in press a), Ford and others (1988)	CHL SAU SKY	T24N R15-16E; T25N R12-17E; T26N R12-17E; T27N R12-15E; T28N R11-16E; T29N R11-15E; T30N R11-14E; T31N R12-14E; T32N R11-13E; T33N R11-12E
Chiwawa River, basaltic plugs and dikes of	Eib	Cater and Crowder (1967), Cater and Wright (1967)	TWS	T30N R16E; T31N R17E
Chocolate Creek assemblage, volcanic rocks and deposits of Glacier Peak	Qvl	Beget (1981, 1982)	SAU	T30N R13-14E; T31N R11-14E; T32N R11-12E; T33N R10-11E; T35N R4E
Chow Chow drift	Qad, Qao Qap, Qapo	Moore (1965)	CPB SHL	T21N R10-12W; T22N R10-12W; T23N R9-10W
Chuckanut Formation	Ec	McLellan (1927), Johnson (1982, 1984, 1991), Evans and Ristow (1994), Mustoe and Gannaway (1997)	BEL MBK PTW SAU	T33N R3-5,7-8E; T34N R4-8E; T35N R6-8E; T36N R3-4E; T37N R1-4E; T38N R1-2W,1-6E; T39N R3-7E; T40N R5-7E
Chuckanut Formation. Includes: Bellingham Bay Member, Coal Mountain unit, Governor's Point Member, Maple Falls Member, Padden Member, Slide Member, and Warnick Member.				
Chumstick Formation (includes the Nahahum Canyon Member, not listed separately)	Ec_2 Ecg_2 Evb	Gresens and others (1981)	CHL WEN	T22N R18-19E; T23N R17-19E; T24N R17-19E; T25N R17-19E; T26N R16-18E; T27N R17-18E; T28N R16-17E; T29N R17E
Clallam Formation	Mn	Arnold (1906), Gower (1960), Addicott (1976a,b)	CFL	T31N R11-12W; T32N R11-12W
Clark Mountain pluton	Kit	Cater and Crowder (1967)	TWS	T29N R15E; T30N R15E
Cloudy Pass batholith, Cascade Pass family	Mian, Mida Mig, Migd Mit, Mix	Youngberg and Wilson (1952), Cater and Crowder (1967)	SAU TWS	T30N R12-14,16E; T31N R14-16E; T32N R14-16E; T33N R14-16E
Coal Mountain unit, Chuckanut Formation, see Chuckanut Formation				
Coleman Pinnacle, andesite of, andesite of Mount Baker	Qva	Tabor and others (in press b)	MBK	T39N R8-9E
Colvos Sand Member, Vashon Drift	Qga	Garling and others (1965)	SEA TAC	see Vashon Drift
Comox Formation, Nanaimo Group	Kn	Dawson (1886, 1890), Muller and Jeletzky (1970), Ward (1978)	BEL	T37N R1-2W
Conglomerate Point, intrusive breccia of	Mix	Yeats (1958a)	SKY	T29N R11E
Constitution Formation	KJmm	Vance (1975), Brandon and others (1988)	BEL, PAN PTW, RCH	T34N R2-3W; T35N R2-4W; T36N R1-4W; T37N R1W
Cool stock, Cascade Pass family, see Cool Glacier stock				
Cool Glacier stock, Cascade Pass family	Rigd	Tabor and Crowder (1969), Tabor and others (1993, in press a)	SAU	T30N R14E
Cooper Pass, volcaniclastic rocks of	Mvc	Ashleman (1979), Tabor and others (2000)	SNO	T22N R13E

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Copper Lake, gabbro of, Chilliwack composite batholith, Index family	Φib	Tepper (1991), Tabor and others (in press b)	MBK	T39N R10E; T40N R10E
Copper Peak pluton	Eit	Cater and Crowder (1967), Cater (1982), Ford and others (1988), Dragovich and Norman (1995)	TWS	T31N R16-17E
Cougar Divide, andesite of, andesite of Mount Baker	Qva	Tabor and others (1994, in press b)	MBK	T39N R8E
Cow Creek, strata of, Virginian Ridge Formation, Pasayten Group	Kc_2	R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T38N R19E
Crescent Formation	Ev_c Em_1 Eib Eigb Evr Evt	Arnold (1906), Weaver (1937), Tabor and Cady (1978a), Rau (1986), Snavely and others (1993), Babcock and others (1994)	CFL MOL PAN PTW SEA SHL	T20N R8-9W; T21N R5-10W; T22N R4-10W; T23N R3-9W; T24N R1E,1,3-5W; T25N R2-4W; T26N R1-4W; T27N R2-4W; T28N R1E,2-5W; T29N R1E,1-9W; T30N R3-4,6-13W; T31N R8,12-14W; T32N R14-15W
Crook Mountain, schist of	Mzsh	Tabor and others (1987a)	CHL	T28N R15-16E
Cultus Formation	J₮mm J₮mv	Daly (1912), Blackwell (1983), Brown and others (1987)	MBK	T36N R7,9E; T37N R7-9E; T41N R7E
Cultus Formation and Chilliwack Group, undivided	JDmt	Tabor and others (1994, in press b)	MBK	T36N R9E; T37N R9E; T40N R9E
Cyclone Lake pluton	Kigd	Bryant (1955), Ford and others (1988), Fluke (1992), Tabor and others (in press a)	SAU	T34N R11-12E
Darrington Phyllite, Easton Metamorphic Suite	Jph	Misch (1966)	BEL MBK PTW SAU SKY SNO	T21N R13-14E; T22N R13E; T23N R12-13E; T24N R12-13E; T25N R12E; T26N R12E; T29N R11E; T30N R11E; T31N R10-11E; T32N R9-11E; T33N R6-10E; T34N R5-10E; T35N R4-6,8,10-11E; T36N R2-7,10-11E; T37N R3-6,9-10E; T38N R5-6,9-10E; T39N R4,6-7,9-10E; T40N R8-9E
Dead Duck pluton, Grotto batholith, Snoqualmie family	M̶Φigd	Tabo and others (in press a)	SAU	T31N R11E
Deadman Bay Volcanics	₮Pmv	Brandon and others (1988)	BEL, RCH	T35N R4W; T37N R2W
Deer Peak, metavolcanic unit of	Jmv	Brown and others (1987)	SAU	T33N R7E; T34N R7E
Deming Sand	Qgdm	Easterbrook (1962)	BEL	T38N R5E; T39N R4-5E
Depot Creek, granite of, Chilliwack composite batholith, Cascade Pass family	M̶ig	Tabor and others (in press b)	MBK	T40N R12E
De Roux unit	Jar	Miller (1975, 1980, 1985), Miller and others (1993b)	WEN	T22N R15E
Devils Pass Member, Virginian Ridge Formation, Pasayten Group	Kcg_2	Trexler (1985), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	MBK TWS	T34N R19E; T35N R19E; T36N R18E; T37N R17E; T38N R16E
Dewdney Creek Formation	Jm	Mahoney (1993), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T40N R17-18E
Dirtyface pluton	Kit	Russell (1900), Ford (1959), Cater and Crowder (1967), Miller and others (2000)	CHL	T27N R16E; T28N R16E
Disappointment Peak, dacite of, volcanic rocks and deposits of Glacier Peak	Qvd	Tabor and Crowder (1969), Beget (1981, 1982), Tabor and others (in press a)	SAU	T30N R14E
Doe Mountain, tonalite of, Remmel batholith	KJmi	Daly (1912), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T40N R19E
Donkey Creek drift	$Qapw_1$	Moore (1965)	SHL	T21N R9W
Double Bluff Drift	Qgpc Qguc	Easterbrook (1965), Easterbrook and others (1967), Easterbrook (1994)	BEL, PAN PTW, SEA	north Puget Sound, eastern Strait of Juan de Fuca
Downey Creek, sill complex of, see Downey Creek pluton				

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Downey Creek pluton	Kigd	Ford and others (1988), Tabor and others (in press a)	SAU	T31N R14E; T32N R14-15E; T33N R12-13E
Downey Mountain stock, Cascade Pass family	Mit	Grant (1966), Tabor and others (in press a)	SAU	T32N R12-14E
Dtokoah Point Member, Makah Formation, see Makah Formation				
Dumbell Mountain pluton	Ŧog	Cater and Crowder (1967), Cater and Wright (1967), Cater (1982), Tabor and others (1989)	TWS	T29N R17-18E; T30N R16-17E; T31N R16-17E; T32N R16E
Duncan Hill pluton	Eiq	Libby (1964), Cater and Crowder (1967), Cater (1982), Ford and others (1988)	CHL TWS	T28N R18-19E; T29N R17-19E; T30N R17-18E; T31N R17E
Dusty Creek assemblage, volcanic rocks and deposits of Glacier Peak	Qvl	Beget (1981, 1982)	SAU	see Kennedy Creek assemblage
Eagle Gorge, volcanic rocks of	MΦva	Hammond (1963), Tabor and others (2000)	SNO	T20N R8E; T21N R8-10E; T22N R8-10E
Eagle tuff	MΦvt	Yeats (1977), Tabor and others (1993)	SKY	T26N R11E; T27N R11-12E
Early Winters Creek, stock south of	Kigd	Tabor and others (1968), Tennyson (1974), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T36N R18-19E
East Sound Group	PDmt	McLellan (1927), Brandon and others (1988)	BEL RCH	T36N R2-3W; T37N R1E,1-3W
Eastern mélange belt, undivided (includes volcanic rocks of Whitehorse Mountain, listed separately)	Jar, Jgn Jib, Jigb Jit, JŦmc JŦmt	Yeats (1958a), Tabor and others (1982a, 1989, 1993, 2000, in press a)	PTW SAU SKY SNO	T22N R11E; T23N R10-11E; T24N R10E; T25N R10-11E; T26N R10-11E; T27N R10-11E; T29N R9-11E; T30N R9-10E; T31N R8-11E; T32N R6-10E; T33N R5-7E
Easton Metamorphic Suite, undivided	Jam Jmv Jigb Ju	Haugerud and others (1981), Brown (1986), Gallagher and others (1988), Tabor and others (1993, in press a,b)	BEL, MBK SAU, SKY SNO	T33N R8-11E; T34N R7-8,10E
Easton Metamorphic Suite. Includes and listed under: Darrington Phyllite, semischist and phyllite of Mount Josephine, and Shuksan Greenschist. Greenstones (units Jmv and Jigb) and ultramafic rocks (unit Ju) north of the Skagit River (T36N R3-5E) are correlated with the Easton Metamorphic Suite by Gallagher and others (1988) and Lapen (2000) and with the Helena–Haystack mélange by Whetten and others (1980b) and Dragovich and others (1998, 1999, 2000b).				
Easy Pass, rocks of	Kmcg Kmt	Miller and others (1994), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T35N R16-17E; T36N R14,16E; T37N R14E
Egg Lake, granite porphyry of, Chilliwack composite batholith, Cascade Pass family	Rig	Tabor and others (in press b)	MBK	T39N R10E
Elbow Lake Formation, Bell Pass mélange	JPmt pTmt	Blackwell (1983), Brown and others (1987), Sevigny and Brown (1989)	BEL MBK SAU	T37N R6E; T38N R6E; T39N R4E; T40N R4-5E; also, some of the distribution shown under Bell Pass mélange, undivided, is Elbow Lake Formation
Eldorado Orthogneiss	Kog	Misch (1966), Ford and others (1988), McShane (1992), Tabor and others (in press a,b)	MBK, RBM SAU, TWS	T32N R16-17E; T33N R14,16E; T34N R14E; T35N R12-14E; T36N R12-13E
Elijah Ridge Schist	Kmt Mzsh	Misch (1966), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T36N R14E; T37N R14E
Ellensburg Formation	Mc	Schmincke (1967), Swanson and others (1979)	WEN	T20N R18E; T21N R18-19E
Elwha lithic assemblage	ΦEm ΦEmst ΦEvb	Tabor and Cady (1978a)	MOL PAN	T24N R5-6W; T25N R5-6W; T26N R5-7W; T27N R5-7W; T28N R7W; T29N R7-9W
Ensawkwatch Creek, diorite of, Chilliwack composite batholith, Index family	Φib	Tabor and others (in press b)	MBK	T40N R10E

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Entiat pluton, Chelan Complex	Kiaa Kit Kid	Waters (1932), Cater and Crowder (1967), Cater and Wright (1967), Hopson and Mattinson (1971), Mattinson (1972), Tabor and others (1987a), Miller and Paterson (2001)	CHL TWS	T27N R18-19E; T28N R17-19E; T29N R17-18E; T30N R16-17E; T31N R16E
Esmeralda Peaks diabase, Ingalls Tectonic Complex	Jib	Miller (1975, 1985)	SNO WEN	T22N R15-17E; T23N R14-15E
Esperance Sand Member, Vashon Drift	Qga	Newcomb (1952), Mullineaux and others (1965)	SEA	see Vashon Drift
Evans Creek Drift	Qad Qao	Armstrong and others (1965)		widespread in the Cascade Range and eastern Olympic Mountains
Everson Glaciomarine Drift	Qgd, Qgdm Qgo Qguc	Easterbrook (1968, 1976), Dethier and others (1995, 1996), Dragovich and others (1997b, 1998, 1999, 2000b,c)	BEL PAN PTW RCH	moderately widespread north of T30N between R3W and R5E
Excelsior Mountain, gneissic tonalite of	Kog	Tabor and others (1993)	SKY	T28N R12E
Extension Formation, Nanaimo Group	Kn	Dawson (1886, 1890), Muller and Jeletzky (1970), Ward (1978)	BEL	T37N R1-2W
Falls Creek unit, Makah Formation, see Makah Formation				
Fidalgo Complex	Ji, Jigb Ju, Jv KJm KJvs	Whetten and others (1978, 1988), Brown and others (1979), Brandon and others (1988), Blake and others (2000), Burmester and others (2000)	BEL PTW	T34N R1-2W; T35N R1-2W; T34N R1-2E; T35N R1-2E
Fidalgo Ophiolite, see Fidalgo Complex				T34N 1-2E; T35N 1-2E
Fifes Peak Formation	Mva Mvt	Warren (1941), Vance and others (1987), Tabor and others (2000)	SNO	T20N R9-10E; T21N R8-10E; T22N R8-9E
Foam Creek stock	Kigd	Ford (1959), Crowder and others (1966), Tabor and others (in press a)	SAU	T29N R14E; T30N R14E
Fortune Creek, stock near	Kit	Laursen and Hammond (1974), Tabor and others (2000)	SNO	T23N R14E
Fourth Creek gabbro, Ingalls Tectonic Complex	Jib	Miller (1975)	WEN	T22N R15-16E; T23N R14-16E
Freezeout Creek, strata of, Harts Pass Formation, Three Fools Creek sequence	Km_1	R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T36N R17E; T37N R16-17E; T40N R14,16E; T41N R14E
Fuller Mountain plug	Eigd	Tabor and others (1993)	SKY	T24N R8E
Gabriel Peak, orthogneiss of	RKog	Misch (1977), Hoppe (1984), Miller (1987)	RBM TWS	T35N R14,16E; T36N R14,16E
Gamma Ridge, volcanic rocks of	Rv	Crowder and others (1966), Tabor and Crowder (1969), Tabor and others (in press a)	SAU	T30N R14E; T31N R14-15E
Garfield Mountain, volcanic rocks on	Φvd	Tabor and others (1993)	SKY	T24N R10-11E
Garrison Schist	pPsh	Danner (1966), Vance (1975, 1977), Brandon and others (1988)	RCH	T35N R4W; T36N R4W
Glacier Peak, volcanic rocks and deposits of, undivided	Qvd	Culver (1936), Tabor and Crowder (1969), Beget (1981, 1982)	SAU	T30N R14-15E; T31N R14-15E
Glacier Peak, volcanic rocks and deposits of. Includes and listed under: Baekos Creek assemblage, Chocolate Creek assemblage, dacite of Disappointment Peak, Dusty Creek assemblage, Glacier Peak tephra, Kennedy Creek assemblage, Suiattle fill, White Chuck assemblage, White Chuck cinder cone, White Chuck fill, and White Chuck tuff.				
Glacier Peak tephra, volcanic rocks and deposits of Glacier Peak	Qvp	Porter (1976), Beget (1981, 1982), Tabor and others (in press a)	SAU	T30N R13-16E; T31N R14-15E
Goat Island terrane	KJms KJmv	Whetten and others (1988), Dragovich and others (2000c)	PTW	T33N R2-3E
Goat Wall unit, undivided, Pasayten Group	Kc_2	R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T37N R18-19E
Goat Wall unit. Includes and listed under: volcanic rocks of Goat Wall unit and Ventura Member of the Midnight Peak Formation.				

Geologic unit	Symbol	Defining and (or) representative references	1:100,000 quadrangle(s)	Area (township and range)
Goat Wall unit, volcanic rocks of, Pasayten Group	Kv_2	R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T37N R18-19E
Goblin Peak stock, Index batholith, Index family	Φigd	Weaver (1912a), Tabor and others (1993)	SKY	T28N R12E; T29N R11-12E
Golden Horn batholith	Eig	Misch (1952), Stull (1969)	RBM TWS	T35N R16-19E; T36N R14,16-18E; T37N R14,16-17E
Governor's Point Member, Chuckanut Formation, see Chuckanut Formation				
Grand Valley lithic assemblage	MEm MEmst	Tabor and Cady (1978a)	MOL	T25N R5W; T26N R5W; T27N R5-7W; T28N R5-7W
Grande Ronde Basalt, undivided	Mv_g	Swanson and others (1979)	WEN	T20N R18-19E; T21N R18-19E
Grande Ronde Basalt. Includes and listed under: invasive flow of Howard Creek.				
Granite Falls stock and associated plutons	Eigd	Yeats and Engels (1971), Whetten and others (1988), Tabor and others (in press a)	PTW SAU	T30N R7E; T31N R6E
Grassy Point stock	Kit	Crowder and others (1966), Tabor and others (in press a)	SAU	T31N R14E
Grisdale drifts	Qad, Qao Qap	Carson (1970)	SHL	T21N R7-8W; T22N R7-8W; T23N R7-8W
Grotto batholith, undivided, Snoqualmie family	MΦig MΦigb MΦit	Yeats (1958a), Erikson (1969), Tabor and others (1993)	SKY	T25N R12E; T26N R10-11E; T27N R11E; T28N R11E; T29N R11E; T30N R11E
Grotto batholith, Snoqualmie family. Includes and listed under: Dead Duck pluton, Monte Cristo stock, and granite of San Juan Creek.				
Hammer Bluff Formation	Mc	Glover (1936), Mullineaux and others (1959), Vine (1969)	TAC	T21N R6E
Hannegan Volcanics	Rv Rvx	Misch (1952), Tabor and others (in press b)	MBK	T38N R10E; T39N R10E
Hanson Lake, rhyolite of	Evr	Danner (1957), Tabor and others (in press a)	SAU	T29N R7E; T30N R6-8E
Harding Mountain, tonalite of, Mount Stuart batholith	Kit	Tabor and others (1987a, 1993)	CHL SKY	T23N R15E; T24N R14-15E
Haro Formation	T̄n	McLellan (1927), Vance (1975)	RCH	T36N R4W
Harts Pass Formation, undivided, Three Fools Creek sequence	Km_1	Barksdale (1975), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T35N R18-19E; T36N R17-19E; T37N R16-18E; T38N R14,16-18E; T39N R14,16-19E; T40N R14,16-18E; T41N R14E
Harts Pass Formation, Three Fools Creek sequence. Includes and listed under: strata of Freezeout Creek and conglomerate of Harts Pass Formation.				
Harts Pass Formation, conglomerate of, Three Fools Creek sequence	Kcg_1	R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T38N R14E; T39N R14E
Haslam Formation, Nanaimo Group	Kn	Dawson (1886, 1890), Muller and Jeletzky (1970), Ward (1978)	BEL	T37N R1-2W
Hawkins Formation, Ingalls Tectonic Complex	Jib	Smith (1904), Southwick (1962), Miller (1975, 1985)	WEN	T22N R16-18E; T23N R15,17-18E
Haystack Creek, orthogneiss of	Kog	Misch (1979), Tabor and others (in press b)	MBK	T35N R12E; T36N R12E
Haystack Creek leucotrondhjemitic orthogneiss, see Haystack Creek, orthogneiss of				
Haystack terrane, see Helena–Haystack mélange. Greenstones (units Jmv and Jigb) and ultramafic rocks (unit Ju) north of the Skagit River (T36N R3-5E) are correlated with the Easton Metamorphic Suite by Gallagher and others (1988) and Lapen (2000) and with the Helena–Haystack mélange by Whetten and others (1980b) and Dragovich and others (1998, 1999, 2000b).				
Helena–Haystack mélange	Jam, Jmt Jigb, Jit Jmm, Jmv Ju	Whetten and others (1980b, 1988), Tabor (1994), Dragovich and others (1998, 1999, 2000b)	BEL PTW SAU	T30N R10E; T31N R9-10E; T32N R9,10E; T33N R4-9E; T34N R4-8E; T35N R4-5; T36N R3-6E
Hidden Lake stock	Kigd	Misch (1966)	MBK SAU	T35N R12-13E
High Pass pluton	Kigd	Cater and Crowder (1967), Cater (1982), Ford and others (1988), Hurlow (1992)	TWS	T29N R16E; T30N R15-16E

Geologic unit	Symbol	Defining and (or) representative references	1:100,000 quadrangle(s)	Area (township and range)
Hobuck Lake, sedimentary and basaltic rocks of	Evb Evc	Snavely and others (1993)	CFL	T31N R13-14W; T32N R14-15W; T33N R15W
Hoh lithic assemblage, see Hoh rock assemblage				
Hoh rock assemblage	M̶Em M̶Emst M̶Ebx, M̶m M̶mst, ΦEm ΦEmst	Rau (1973), Tabor and Cady (1978a)	CPB FRK	T25N R10-12W; T26N R10-12W; T27N R13-14W; T28N R13-15W
Hoh Oxbow drift	Qad, Qao	Thackray (1996)	FRK, MOL	T26N R11-12W; T27N R11-12W
Hoko River Formation, lower Twin River Group	Em_2	Snavely and others (1978), Tabor and Cady (1978a), Snavely and others (1993)	CFL PAN	T29N R4-5W; T30N R5-12W; T31N R8,10,12-14W; T32N R13-15W; T33N R14-15W
Holden, biotite granodiorite and granite near	Eigd	Cater and Wright (1967), Cater (1982)	TWS	T31N R17E
Holden, hornblende biotite tonalite near	Eit	Cater and Wright (1967), Cater (1982)	TWS	T30N R17E; T31N R17E
Holden area, younger gneissic rocks of the	Ŧhm	Cater and Crowder (1967), Cater and Wright (1967), Miller and others (1994)	TWS	T29N R18-19E; T30N R17-19E; T31N R16-18E; T32N R16-17E
Holden Lake pluton	Eit	Cater and Crowder (1967), Cater (1982), Ford and others (1988), Dragovich and Norman (1995)	TWS	T32N R16E
Howard Creek, invasive flow of, Grande Ronde Basalt	$M̶vi_g$	Rosenmeier (1968)	WEN	T20N R18-19E; T21N R18-19E
Howson andesite	M̶va	Smith and Calkins (1906), Tabor and others (2000)	SNO	T22N R14E
Hozomeen Group	JPvs	Daly (1912), McTaggart and Thompson (1967), Haugerud (1985), Tabor and others (in press b)	MBK RBM	T37N R14,16E; T38N R14,16E; T39N R13-14E; T40N R13-14E; T41N R13-14E
Hozomeen stock	M̶Φit	Tabor and others (1968), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	MBK RBM	T40N R14E
Humptulips drift	$Qapw_2$	Moore (1965)	CPB SHL	T20N R9-13W; T21N R9-13W; T22N R9,12-13W; T23N R9-13W
Humptulips Formation	Em_2	Rau (1984)	SHL	T20N R9W; T21N R9W
Huntingdon Formation	ΦEc	Miller and Misch (1963), Dragovich and others (1997b)	BEL	T39N R4-5E; T40N R4-5E
Icy Peak, quartz diorite and quartz monzodiorite of, Chilliwack composite batholith, Cascade Pass family	Riq	Tabor and others (in press b)	MBK	T39N R10E
Index batholith, undivided, Index family	Φigd	Weaver (1912a), Tabor and others (1993)	SKY	T25N R9E; T26N R9-10E; T27N R8-11E; T28N R9-12E; T29N R10-12E
Index batholith. Includes and listed under: Goblin Peak stock, Sunday Creek stock, and metaporphyry on Troublesome Mountain.				
Index family. Includes and listed under: Baker River phase, biotite alaskite of Mount Blum, Chilliwack composite batholith undivided, gabbro of Copper Lake, diorite of Ensawkwatch Creek, Goblin Peak stock, Index batholith undivided, tonalite of Maiden Lake, granodiorite of Mount Despair, Pocket Peak phase, Price Glacier pluton, Sauk ring dike, Shake Creek stock, Silesia Creek pluton, Squire Creek stock, Sunday Creek stock, and metaporphyry on Troublesome Mountain.				
Indian Mountain phase, Chilliwack composite batholith, Snoqualmie family	Φigd	Tabor and others (in press b)	MBK	T39N R10-11E; T40N R11E
Ingalls Tectonic Complex, undivided	Jar KJhmc Jib Jmv Ju	Hopson and Mattinson (1973), Southwick (1974), Miller (1975, 1977, 1980, 1985), Cowan and Miller (1981), Miller and others (1993b)	CHL SKY SNO WEN	T22N R14-18E; T23N R14-18E; T24N R14-17E; T25N R16-17E
Ingalls Tectonic Complex. Includes and listed under: Esmeralda Peaks diabase, Fourth Creek gabbro, Hawkins Formation, and Peshastin Formation.				
Isabella Ridge, andesite of, see Lookout Mountain unit of the Newby Group				
Jack Mountain Phyllite	Mzsh pTu	Misch (1966)	MBK RBM	T37N R14,16E; T38N R13-14E; T39N R13-14E; T40N R13E

Geologic unit	Symbol	Defining and (or) representative references	1:100,000 quadrangle(s)	Area (township and range)
Jackita Ridge unit, undivided, Three Fools Creek sequence	Km_1	R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T36N R17E; T37N R16E; T38N R16E; T39N R14,16-17E; T40N R14,16-17E
Jackita Ridge unit, Three Fools Creek sequence. Includes and listed under: strata of Majestic Mountain and conglomeratic strata of Two Buttes Creek.				
Jansen Creek Member, Makah Formation, see Makah Formation				
Jordan Lakes pluton	Kigd	Bryant (1955), Ford and others (1988), Fluke (1992), Tabor and others (in press a)	SAU	T34N R11-12E; T35N R11-12E
Keechelus Andesitic Series	ΦEva ΦEian	Warren and others (1945), Walsh (1984)	SNO	west-central Cascade Range
Kennedy Creek assemblage, volcanic rocks and deposits of Glacier Peak (includes Dusty Creek and Baekos Creek assemblages, also listed separately)	Qvl	Dethier and Whetten (1981), Beget (1981, 1982), Dragovich and others (1998, 1999, 2000a,b,c)	BEL PTW SAU	T30N R13-15E; T31N R10-15E; T32N R8-13E; T33N R10-11E; T34N R3-4,10E; T35N R4-6E
Kittitas Drift	Qap Qapo	Porter (1975, 1976), Waitt (1979)	WEN	T20N R16E; T21N R15-16E; T23N R17-18E
Klachopis Point Member, Makah Formation, see Makah Formation				
Kulshan caldera, rocks of, undivided (includes ignimbrite of Swift Creek, listed separately)	Qvr Qvt	Hildreth and Lanphere (1994), Hildreth (1994, 1996), Tabor and others (in press b)	MBK	T38N R8E; T39N R8E
Kyes Peak, breccia of	Mvc	Tabor and others (1982a, 1993)	SKY	T28N R11-12E; T29N R11-12E
Ladner Group, see Dewdney Creek Formation				
Lake Ann stock, Chilliwack composite batholith, Cascade Pass family	Rigd	James (1980), Tabor and others (in press b)	MBK	T38N R9E; T39N R9E
Lake Juanita, leucogneiss of, Skagit Gneiss Complex	TKog	Miller (1987), Miller and Bowring (1990)	TWS	T33N R18E
Lake Keechelus tuff member, Ohanapecosh Formation	Φvt	Fiske and others (1963), Tabor and others (2000)	SNO	T21N R11E; T22N R11E
Lake Shannon, basalt of	Qvb	Tabor and others (in press b)	MBK	T36N R8E
Lakedale Drift	Qao, Qad	Porter (1975, 1976), Waitt (1979)	WEN	T21N R18E; T23N R17-18E
Lamb Butte, trondhjemite of	KJog	Hurlow and Nelson (1993), Todd (1995a,b)	RBM	T40N R18-19E
Larch Lakes pluton	Eigd	Cater (1982)	TWS	T30N R17E
Lasiocarpa Ridge, andesite of, andesite of Mount Baker	Qva	Tabor and others (in press b)	MBK	T39N R8E
Lava Divide, andesite of, andesite of Mount Baker	Qva	Cater and Wright (1967), Tabor and others (in press b)	MBK	T38N R8E
Leroy Creek pluton	Kog	Cater (1982)	TWS	T30N R16E; T31N R16E
Lightning Creek stocks	Kid	Daly (1912), Staatz and others (1971), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T40N R14E; T41N R14E
Lincoln Creek Formation	ΦEm	Weaver (1912b), Arnold and Hannibal (1913), Beikman and others (1967)	SHL	T20N R7-8W; T21N R6-7W; T22N R4W; T23N R3-4W
Little Beaver Creek, biotite granodiorite of, Chilliwack composite batholith, Snoqualmie family	Φigd	Tabor and others (in press b)	MBK	T39N R12E; T40N R12-13E
Little Jack unit	Mzsh pTu	Tabor and others (1989, in press b), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	MBK RBM	T37N R14,16E; T38N R14E; T39N R13E; T40N R13E
Lizard Lake, basaltic sandstone and conglomerate of	Em_1	Snavely and others (1993)	CFL	T31N R12-13W; T32N R14W

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Lookout Mountain unit, Newby Group	Jmv	Barksdale (1948, 1975), Dixon (1959), Stoffel and McGroder (1990), Mahoney and others (1996), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T40N R18-19E
Lopez structural complex	KJmm KJmv	Brandon (1980), Cowan and Miller (1981), Brandon and others (1988), Blake and others (2000), Burmester and others (2000)	PTW	T34N R1-2W
Lost Peak stock	Kigd	Tabor and others (1968)	RBM	T38N R18-19E; T39N R18-19E
Lummi Formation	Jmt KJmm	Vance (1975), Blake and others (2000)	BEL PTW	T34N R1W; T35N R2E,1-2W; T36N R1W,1-2E; T37N R1-2E; T38N R1E
Lyall Ridge, porphyries and breccias of	M̶ix	Cater (1960), Grant (1966, 1969)	TWS	T32N R16E; T33N R16E
Lyman lahar	Qvl	Dragovich and others (1999, 2000a,b)	BEL PTW	T34N R3-4E; T35N R4-6E
Lyman Rapids drift	Qap	Thackray (1996)	FRK, MOL	T24N R11-12W; T25N R11W
Lyman Rapids outwash	Qapo	Thackray (1996)	FRK	T24N R11-13W; T25N R11-12W
Lyre Formation	Em_2 Em Eva Evt	Weaver (1937), Brown and others (1956, 1960), Ansfield (1972), Tabor and Cady (1978a), Snavely and others (1993)	CFL PAN PTW SEA	T28N R2-3W; T29N R1-2W; T30N R7-12W; T31N R12-14W; T32N R14-15W; T33N R15-16W
Magic Mountain Gneiss	Ŧiq	Tabor (1961)	SAU TWS	T33N R14E; T34N R13-14E
Maiden Lake, tonalite of, Chilliwack composite batholith, Index family	Φit	Tabor and others (in press b)	MBK	T38N R9E; T39N R9E
Majestic Mountain, strata of, Jackita Ridge unit, Three Fools Creek sequence	Km_1	R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T36N R17E; T37N R16-17E
Makah Formation, undivided, middle Twin River Group	ΦEm	Snavely and others (1978, 1980, 1993)	CFL PAN	T29N R3W; T30N R3-11W; T31N R7-12W; T32N R12-14W; T33N R14-15W
Makah Formation, middle Twin River Group. Includes: Baada Point Member, Carpenters Creek Tuff Member, Dtokoah Point Member, Falls Creek unit, Jansen Creek Member, Klachopis Point Member, and Third Beach Member.				
Maple Falls Member, Chuckanut Formation, see Chuckanut Formation				
Marble Creek Orthogneiss, Skagit Gneiss Complex	Kog	Misch (1966, 1979), Tabor and others (in press b)	MBK	T35N R12E; T36N R11-12E
Marblemount pluton (includes the Marblemount Meta-Quartz Diorite, not listed separately)	Ŧiq Ŧog	Misch (1952, 1966), Tabor and others (1989, in press a,b)	MBK SAU TWS	T29N R17-18E; T30N R16-17E; T31N R16-17E; T32N R16E; T33N R13-14E; T34N R12-14E; T35N R11-12E; T36N R11E; T37N R11E
Marrowstone Shale	ΦEm	Durham (1944)	PTW	T30N R1E,1-2W
Marysville Sand Member, Vashon Drift	Qgos	Newcomb (1952), Minard (1985g)	PTW	T29N R5E; T30N R5E; T31N R5E
McGregor Mountain, migmatitic orthogneiss of, Skagit Gneiss Complex	TKog	Adams (1962), Nicholson (1991)	TWS	T33N R17E
Middle Fork Nooksack River, lahar of the	Qvl	Hyde and Crandell (1978)	BEL	T38N R5E; T39N R5E
Middle Peak, heterogeneous tonalite and granodiorite of, Chilliwack Composite batholith, Index family	Φit	Tabor and others (in press b)	MBK	T40N R10E; T41N R10E
Midnight Peak Formation, undivided (includes Ventura Member of the Midnight Peak Formation, listed separately)	Kc_2 Kv_2	Barksdale (1948, 1975), Staatz and others (1971), Stoffel and McGroder (1990)	RBM	T34N R19E; T35N R19E; T37N R17-19E; T38N R17-18E
Mineral Mountain pluton, Chilliwack composite batholith, Cascade Pass family	M̶ig	Tabor and others (in press b)	MBK	T39N R10-11E
Mobray drift	$Qapw_2$	Carson (1970)	SHL	T20N R7-8W; T21N R7-8W

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Money Creek gabbro	pTigb	Plummer (1964), Tabor and others (1993)	SKY	T26N R10E
Monte Cristo stock, Grotto batholith, Snoqualmie family	MΦigd	Yeats (1958a), Erikson (1969), Tabor and others (1993), Tabor and others (in press a)	SAU SKY	T29N R11E; T30N R11E
Montesano Formation	Mm2	Weaver (1912b)	SHL	T20N R6-7W; T21N R6-7W
Monument Peak stock	Eig	Tabor and others (1968), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T37N R19E; T38N R18-19E; T39N R19E
Mount Baker, andesite of, undivided	Qva	Tabor and others (1994, in press b), Hildreth and Lanphere (2000)	MBK	T37N R7-8E; T38N R7-8E
Mount Baker, andesite of. Includes and listed under: andesite of Bastile Ridge, andesite of Black Buttes, andesite of Coleman Pinnacle, andesite of Cougar Divide, andesite of Lasiocarpa Ridge, andesite of Lava Divide, andesite of Pinus Lake, andesite of The Portals, andesite of Swift Creek, and andesite of Table Mountain.				
Mount Ballard, volcanic breccia of, Virginian Ridge Formation, Pasayten Group	Kv2	R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T37N R17E
Mount Benzarino, orthogneiss of	RKog	Misch (1977), Hoppe (1984), Miller (1987), Dragovich and Norman (1995)	TWS	T33N R17-18E; T34N R16-17E; T35N R16-17E
Mount Blum, biotite alaskite of, Chilliwack composite batholith, Index family	Φig	Tabor and others (in press b)	MBK	T37N R10E; T38N R10-11E
Mount Buckindy pluton, Cascade Pass family	Mit Mix	Bryant (1955), Tabor and others (2000)	SAU	T33N R12E; T34N R12-13E
Mount Catherine Rhyolite Member, Naches Formation	Evt	Foster (1957), Tabor and others (1984)	SNO	T22N R11E; T23N R11E
Mount Daniel, volcanic rocks of	Φvd, Φvr Φvt, Φian Φir	Ellis (1959), Simonson (1981), Tabor and others (1993, 2000)	SKY SNO	T22N R14E; T23N R13-14E; T24N R13-14E
Mount Despair, granodiorite of, Chilliwack composite batholith, Index family	Φigd Φii	Tabor and others (in press b)	MBK	T36N R11E; T37N R10-12E; T38N R10-11E; T39N R10-11E
Mount Herman, sedimentary rocks of, Chilliwack Group	PDms	Tabor and others (in press b)	MBK	T38N R9E; T39N R9E
Mount Herman, volcanic rocks of, Chilliwack Group	PDmv	Tabor and others (in press b)	MBK	T38N R8-9E; T39N R8-9E
Mount Hinman, granite of, Snoqualmie batholith, Snoqualmie family	MΦig	Erikson (1969), Tabor and others (1993)	SKY	T24N R13E
Mount Josephine, semischist and phyllite of, Easton Metamorphic Suite	Jph	Tabor and others (1994, in press a,b), Dragovich and others (1998, 1999)	BEL MBK SAU	semischist occurs as relict semischistose metasandstone and metaconglomerate beds in Darrington Phyllite in the Sauk and Skagit River valley areas
Mount Persis, volcanic rocks of	Ev Eva	Tabor and others (1982a)	SEA, SKY SNO	T23N R7-8E; T24N R8E; T25N R8-9E; T26N R6-10E; T27N R7-9E
Mount Pilchuck stock	Eig	Yeats and Engels (1971)	SAU	T30N R8E
Mount Rahm, volcanic rocks of	Φvx	Mathews and others (1981), Haugerud and others (1991), Tabor and others (in press b)	MBK	T40N R12-13E; T41N R12-13E
Mount Sefrit gabbronorite, Chilliwack composite batholith, Snoqualmie family	Migb	Tepper and others (1993), Tabor and others (in press b)	MBK	T39N R9-10E; T40N R9E
Mount Stickney, drift of	Qap	Booth (1990)	SKY	T29N R8E
Mount Stuart batholith, undivided	Kid Kigb Kigd Kit	Russell (1900), Smith (1904), Erikson (1977), Tabor and others (1982a,b, 1987a, 1993), Paterson and others (1994)	CHL SKY WEN	T23N R15-17E; T24N R14-17E; T25N R13-17E; T26N R12-16E; T27N R12-15E
Mount Stuart batholith. Includes and listed under: Beckler Peak stocks and tonalite of Harding Mountain.				
Mount Triumph, orthogneiss of	TKog	Tabor and others (1994, in press b)	MBK	T37N R11E; T38N R11E

Geologic unit	Symbol	Defining and (or) representative references	1:100,000 quadrangle(s)	Area (township and range)
Naches Formation, undivided (includes Guye Sedimentary Member, not listed separately)	Ec_2, Ev Evb, Evr	Smith and Calkins (1906), Foster (1967), Tabor and others (1978, 2000)	SKY SNO	T20N R12-13E; T21N R11-13E; T22N R10-13E; T23N R11-13E; T24N R12E
Naches Formation. Includes and listed under: Mount Catherine Rhyolite Member.				
Nanaimo Group, undivided	Kn	Dawson (1886, 1890), Muller and Jeletzky (1970), Ward (1978), Pacht (1984), Mustard and Rouse (1994)	RCH	T36N R3-4W; T37N R2-4W
Nanaimo Group. Locally divided into and listed under: Cedar District Formation, Comox Formation, Extension Formation, Haslam Formation, and Protection Formation.				
Napeequa River area, rocks of the (see also Napeequa Schist)	JPhmc	Cater and Crowder (1967), Tabor and others (1994, in press b)	CHL	T28N R15-16E; T29N R15-16E; T30N R15-16; T31N R15E
Napeequa Schist	JPhmc pTog TKbg	Tabor and others (1987a, 1989, in press a,b)	CHL MBK SAU TWS	T25N R19E; T26N R18-19E; T27N R17-19E; T28N R15-18E; T29N R15-17E; T30N R15-17E; T31N R14-16E; T32N R12-15E; T33N R11-13E; T34N R11-13,16-19E; T35N R11-14,16E; T36N R11-12,14E; T37N R11-14E; T38N R11E
Napeequa Schist. Defined by Tabor and others (in press a) to include: rocks of the Napeequa River area, Rainbow Lake Schist, Twisp Valley Schist, and part of Cascade River Schist of Misch (1966).				
Napeequa unit, see Napeequa Schist				
Nason Ridge Migmatitic Gneiss	Kbg Kog	Vance (1957), Tabor and others (1988, 1993, in press a)	CHL SAU SKY	T27N R12-15E; T28N R12-15E; T29N R12-14E; T30N R11-14E; T31N R11-12E; T32N R11-12E; T33N R12E
Needle, The, orthogneiss of, Skagit Gneiss Complex	Ŧog	Haugerud and others (1991), Tabor and others (in press b)	MBK	T36N R13E; T37N R12-13E
Needles–Gray Wolf lithic assemblage	ΦEm ΦEmst ΦEvb	Tabor and Cady (1978a)	CFL MOL PAN	T24N R4-5W; T25N R4-5W; T26N R4-5W; T27N R4-5W; T28N R4-7W; T29N R5-12W; T30N R10-12W
Newby Group. Includes and listed under: Lookout Mountain unit.				
Nooksack Cirque, quartz monzonite and granite of, Chilliwack composite batholith, Cascade Pass family	Riqm	Tabor and others (in press b)	MBK	T39N R9-10E
Nooksack Formation, undivided	KJmm	McKee and others (1956), Misch (1966, 1977), Sondergaard (1979), Tabor and others (in press b)	MBK	T36N R8-9E; T37N R8-9E; T38N R7-9E; T39N R7-8E; T40N R7-8E
Nooksack Formation. Includes and listed under: Wells Creek volcanic member.				
North Creek Volcanics	Kmt	Misch (1966), Miller and others (1994)	TWS	T34N R18-19E; T35N R18E
North Peak, metavolcanic rocks of	PDmv	Smith and Calkins (1906), Ashleman (1979), Tabor and others (2000)	SNO	T21N R13E; T22N R13E
Ohanapecosh Formation, undivided	Φvc	Fiske and others (1963)	SNO	T20N R7-12E; T21N R7-12E; T22N R7-11E; T23N R8-9E
Ohanapecosh Formation. Includes and listed under: Lake Keechelus tuff member.				
Old Gib volcanic neck, dacite of	Eir	Cater and Crowder (1967), Cater (1982)	TWS	T30N R16E
Olympia beds	Qc Qgpc Qguc	Armstrong and others (1965), Mullineaux and others (1965), Borden and Troost (2001)	PAN, PTW SEA, TAC	widespread in bluffs along Puget Sound
Orcas Chert, see Orcas Formation				
Orcas Formation	JŦmc	McLellan (1927), Vance (1975), Brandon and others (1988)	BEL, PAN RCH	T34N R3W; T35N R2-4W; T36N R1-4W; T37N R1-2W
Osceola Mudflow	Qvl	Crandell and Waldron (1956), Vallance and Scott (1997)	TAC	T20N R5-6E; T21N R5-6E
Oval Peak pluton	Rit	Adams (1961), Libby (1964), Miller (1987), Miller and Bowring (1990), Miller and others (1993c)	TWS	T33N R19E
Padden Member, Chuckanut Formation, see Chuckanut Formation				

Geologic unit	Symbol	Defining and (or) representative references	1:100,000 quadrangle(s)	Area (township and range)
Panther Creek Formation	Km$_1$	Barksdale (1975), Stoffel and McGroder (1990)	RBM	T37N R17E; T38N R14,17E; T39N R14,17,19E; T40N R14,17,19E
Park Butte, basalt of	Qvb	Tabor and others (in press b)	MBK	T37N R7E
Partridge Gravel, Vashon Drift	Qgo, Qgos	Easterbrook (1968)	PTW	T31N R1-2E; T32N R1W,1-2E
Pasayten Group (Daly, 1912; Coates, 1974; R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000). Includes and listed under: strata of Cow Creek, Devils Pass Member of the Virginian Ridge Formation, Goat Wall unit undivided, volcanic rocks of the Goat Wall unit, volcanic breccia of Mount Ballard, Slate Peak Member of the Virginian Ridge Formation, volcanic rocks of Three A M Mountain, Ventura Member of the Midnight Peak Formation, Virginian Ridge Formation undivided, and Winthrop Formation undivided.				
Pasayten stock	Kigd	Tabor and others (1968), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T37N R18-19E; T38N R17-19E
Pear Lake, gneissic tonalite of	Kog	Tabor and others (1993)	SKY	T28N R13E
Perry Creek phase, Chilliwack composite batholith, Snoqualmie family	MΦit	Tabor and others (in press b)	MBK	T38N R11-13E; T39N R11-12E; T40N R12-13E; T41N R13E
Peshastin Formation, Ingalls Tectonic Complex	Jar	Smith (1904), Southwick (1962), Miller (1975), Miller and Frost (1977)	WEN	T22N R15-18E; T23N R17-18E
Pinus Lake, andesite of, andesite of Mount Baker	Qva	Tabor and others (in press b)	MBK	T39N R8E; T40N R8E
Pioneer Ridge, volcanic rocks of	Φvd, Φvx	Tabor and others (in press b)	MBK	T38N R11E
Pocket Peak phase, Chilliwack composite batholith, Index family	Φig	Tabor and others (in press b)	MBK	T39N R10E; T40N R9-10E; T41N R10E
Portals, The, andesite of, andesite of Mount Baker	Qva	Tabor and others (in press b)	MBK	T38N R8E; T39N R8E
Possession Drift	Qgpc Qguc	Easterbrook and others (1967)	BEL, PAN PTW, SEA	widespread in bluff exposures in the northern Puget Sound and eastern Strait of Juan de Fuca
Price Glacier pluton, Chilliwack composite batholith, Index family	Φiq	Tabor and others (in press b)	MBK	T39N R9-10E
Protection Formation, Nanaimo Group	Kn	Dawson (1886), Muller and Jeletzky (1970), Ward (1978)	BEL	T38N R2W
Puget Group, undivided	Ec$_2$	White (1888), Willis and Smith (1899), Vine (1969)	SNO TAC	T20N R7E; T21N R6-7E; T22N R6-7E
Puget Group. Locally subdivided into and listed under: Renton Formation, Tiger Mountain Formation, and Tukwila Formation.				
Purple Creek, orthogneiss of, Skagit Gneiss Complex	TKog	Haugerud and others (1991), Nicholson (1991)	TWS	T32N R18E; T33N R17-18E
Puyallup Formation	Qc, Qgpc	Crandell and others (1958)	TAC	bluff exposures in Puyallup Valley
Pysht Formation, upper Twin River Group	MΦm	Snavely and others (1978, 1993)	CFL PAN	T30N R4-8W; T31N R8-12W; T32N R11-13W
Quillayute Formation	RMn	Reagan (1909), Rector (1958), Rau (1979)	FRK	T28N R14W
Quimper Sandstone	ΦEm	Durham (1944), Whetten and others (1988)	PTW SEA	T29N R1-2W,1E; T30N R1W,1E
Quinault Formation	RMn	Arnold (1906), Rau (1970), Palmer and Lingley (1989)	CPB	T21N R13W; T22N R13W; T23N R13W
Raging River Formation	Em$_2$	Vine (1962, 1969), Wolfe (1968), Johnson and O'Connor (1994)	SEA, SKY SNO	T23N R4,7E; T24N R7E
Railroad Creek pluton	Eigd	Libby (1964), Cater and Crowder (1967), Cater (1982), Ford and others (1988)	TWS	T30N R18-19E; T31N R17-18E; T32N R16-17E; T33N R16-17E; T34N R16E
Rainbow Lake Schist (see also Napeequa Schist)	JPhmc	Adams (1962), Miller and others (1994)	TWS	T34N R16-17E
Rainbow Mountain, orthogneiss of, Skagit Gneiss Complex	TKog	Haugerud and others (1991), Nicholson (1991)	TWS	T33N R17E
Rampart Mountain pluton	Eig	Cater (1982), Dragovich and Norman (1995)	TWS	T29N R17E; T30N R17E
Rattlesnake Mountain, volcanic rocks of	Φvc	Walsh (1984)	SKY SNO	T23N R7-8E; T24N R8E

Geologic unit	Symbol	Defining and (or) representative references	1:100,000 quadrangle(s)	Area (township and range)
Redoubt Creek, quartz monzodiorite of, Chilliwack composite batholith, Cascade Pass family	Miqm	Tabor and others (in press b)	MBK	T40N R11-12E; T41N R12E
Remmel batholith, undivided	KJog	Daly (1912), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T40N R18-19E
Remmel batholith. Includes and listed under: tonalite of Doe Mountain.				
Renton Formation, Puget Group	Ec$_2$	Waldron (1962), Wolfe (1968), Vine (1969)	SEA, SNO TAC	T22N R7E; T23N R4-7E; T24N R5-7E
Reynolds Peak phase, Black Peak batholith	Kit	Miller (1987)	TWS	T33N R18-19E; T34N R18E
Riddle Peaks pluton	Kigb	Cater and Crowder (1967), Cater and Wright (1967), Cater (1982)	TWS	T31N R17E; T32N R16-17E
Rinker Ridge, slate of	Jph	Tabor and others (in press a,b)	MBK SAU	T32N R10E; T33N R9-10E; T34N R8-9E; T35N R7-8E
Rock Creek stock	Kigd	Staatz and others (1971), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T39N R17E; T40N R17E
Roslyn Formation	Ec$_2$	Russell (1900), Smith (1903a,b), Bressler (1951), Wolfe (1968)	SNO WEN	T20N R14-16E; T21N R14-16E
Round Lake, breccia of	Φvx	Vance (1957), Tabor and others (in press a)	SAU	T30N R11-12E; T31N R11-12E
Ruby Creek heterogeneous plutonic belt	TKi	Misch (1966, 1977), Tabor and others (1994, in press b), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	MBK RBM	T37N R14,16E; T38N R14E
Ruth Creek pluton, Chilliwack composite batholith, Cascade Pass family	Migd	Tepper (1991), Tabor and others (in press b)	MBK	T39N R9-10E; T40N R9E
Ruth Mountain, granite of, Chilliwack composite batholith, Cascade Pass family	Rig	Tabor and others (in press b)	MBK	T39N R9-10E
Salmon Springs Drift	Qgp Qgpc	Crandell and others (1958), Easterbrook and others (1981)	TAC	T20N R5E; T21N R5E; T22N R5E
San Juan Creek, granite of, Grotto batholith, Snoqualmie family	MΦig	Tabor and others (1993)	SKY	T27N R11E; T28N R11E
Sauk ring dike, Index family	ΦEida	Tabor and others (in press a)	SAU	T29N R11E; T30N R11E; T31N R11E
Scow Bay, sandstone of	Em$_1$	Allison (1959), Armentrout and Berta (1977), Gower (1980)	PTW	T29N R1W,1E; T30N R1E
Seven Fingered Jack pluton	Kit	Cater and Crowder (1967), Cater and Wright (1967), Cater (1982), Ford and others (1988)	TWS	T30N R16-17E; T31N R16E
Shake Creek stock of Squire Creek stock, Index family	Φit	Vance (1957), Tabor and others (in press a)	SAU	T30N R10E
Shuksan Greenschist, Easton Metamorphic Suite	Jsh	Weaver (1945), Misch (1966), Haugerud and others (1981), Brown (1986)	BEL MBK PTW SAU SKY SNO	T21N R13E; T22N R13E; T23N R13E; T26N R11-12E; T27N R11-12E; T30N R11E; T31N R10-11E; T32N R10-11E; T33N R10-11E; T34N R5-6,10-11E; T35N R5-8,10-11E; T36N R5-11E; T37N R5,7-11E; T38N R9-10E; T39N R9-10E; T40N R9E
Shuksan Metamorphic Suite, see Easton Metamorphic Suite				
Silesia Creek pluton, Chilliwack composite batholith, Index family	Φit	Tabor and others (in press b)	MBK	T40N R9-10E; T41N R9E
Silver Creek, tonalite of, Cascade Pass family	Mit	Tabor and others (1993)	SKY	T28N R11E; T29N R11E
Silver Pass Volcanic Member, Swauk Formation	Evd	Foster (1960), Tabor and others (2000)	SKY, SNO WEN	T20N R13E; T21N R13-14,17-18E; T24N R13E
Sisters Creek pluton	TKig	Tabor (1961)	TWS	T33N R14E

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Sitkum Creek, stock on, Cascade Pass family	₥igd	Tabor and others (in press a)	SAU	T30N R14E
Skagit Gneiss Complex, undivided	TKbg TKig TKog Ŧog	Misch (1966), Babcock and Misch (1989), Haugerud and others (1991), Tabor and others (in press b)	MBK RBM TWS	T31N R18-19E; T32N R17-19E; T33N R16-18E; T34N R14,16-17E; T35N R14,16E; T36N R12-14E; T37N R11-14E; T38N R11-14E; T39N R11-13E; T40N R11-12E; T41N R11-12E
Skagit Gneiss Complex. Includes and listed under: orthogneiss of Boulder Creek, leucogneiss of Lake Juanita, Marble Creek Orthogneiss, migmatitic orthogneiss of McGregor Mountain, orthogneiss of The Needle, orthogneiss of Purple Creek, orthogneiss of Rainbow Mountain, and orthogneiss of Stehekin.				
Skagit Volcanics, see volcanic rocks of Mount Rahm				
Skokomish Gravel	Qapo	Molenaar and Noble (1970)	SHL, TAC	T21N R3-5W; T22N R2-5W; T23N R3W
Skymo complex	KJigb	Wallace (1976), Hyatt and others (1996), Baldwin and others (1997), Tabor and others (in press b)	MBK	T38N R13E; T39N R13E
Slate Peak Member, Virginian Ridge Formation, Pasayten Group	Kc_2	Trexler (1985)	RBM	T34N R18-19E; T35N R18-19E; T36N R18-19E; T37N R17-18E; T38N R17E
Slide Member, Chuckanut Formation, see Chuckanut Formation				
Sloan Creek plutons	Kog	Vance (1957), Crowder and others (1966), Heath (1971), Longtine (1991), Tabor and others (1993, in press a)	SAU SKY	T28N R12E; T29N R12E; T30N R11-12E; T31N R11-12E; T32N R11E
Snoqualmie batholith, undivided, Snoqualmie family	₥ig, ₥igd ₥it, ₥Φig ₥Φigb ₥Φigd ₥Φix	Foster (1960), Tepper and others (1993), Tabor and others (2000), Tabor and others (in press b)	SKY SNO	T21N R10E; T22N R9-11E; T23N R9-13E; T24N R9-13E; T25N R9-11E; T26N R10E
Snoqualmie batholith. Includes and listed under: granite of Mount Hinman.				
Snoqualmie family. Includes and listed under: Chilliwack valley phase of the Chilliwack composite batholith, Dead Duck pluton, Grotto batholith undivided, Indian Mountain phase of the Chilliwack composite batholith, biotite granodiorite of Little Beaver Creek, Monte Cristo stock, granite of Mount Hinman, Mount Sefrit gabbronorite, Perry Creek phase of the Chilliwack composite batholith, granite of San Juan Creek, and Snoqualmie batholith undivided.				
Sooes River area, sandstone of	₥Ebx ΦEm, Em_2 Em_1, Em Evc	Tabor and Cady (1978a)	CFL	T31N R14-15W; T32N R14-15W
South Creek, metaconglomerate of	Kmcg	Dragovich and others (1997a)	TWS	T34N R18-19E
Spider Mountain Schist (see also Cascade River Schist)	Ŧhm	Tabor (1961)	SAU TWS	T33N R14E; T34N R13-14E
Spieden Group	KJn	Johnson (1981), Brandon and others (1988)	RCH	T36N R3-4W; T37N R3-4W
Squire Creek stock, undivided, Index family (includes Shake Creek Stock, listed separately)	Φiq Φit	Vance (1957), Baum (1968), Tabor and others (in press a)	SAU	T29N R10E; T30N R9-10E; T31N R9E; T33N R7-8E
Stehekin, orthogneiss of, Skagit Gneiss Complex	TKog	Adams (1961), Miller and others (1994), Dragovich and Norman (1995)	TWS	T32N R18E; T33N R17-18E
Stillaguamish Sand Member, Vashon Drift	Qgos	Newcomb (1952), Minard (1985a,b)	PTW SAU	T30N R6-7E; T31N R6-7E; T32N R5-7E
Sugarloaf Peak, andesite of	₥va	Page (1939), Tabor and others (1987a)	CHL	T26N R18E
Suiattle fill, volcanic rocks and deposits of Glacier Peak	Qvl	Ford (1959), Tabor and Crowder (1969), Beget (1981, 1982)	SAU	T30N R14-15E; T31N R14-15E
Sulphur Creek, basalt of	Qvb	Tabor and others (in press b)	MBK	T37N R7-9E
Sulphur Mountain pluton	Kigd Kog	Ford (1957, 1959), Crowder and others (1966), Cater (1982), Tabor and others (in press a)	SAU TWS	T30N R15E; T31N R14-15E; T32N R13-15E

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Sumas Drift	Qgd_s	Armstrong and others (1965), Easterbrook (1976)	BEL	T35N R3-4E; T36N R4-5E; T38N R1-5E; T39N R1W,1-5E; T40N R1W,1-6E; T41N R1W,1-6E
Sumas Mountain, metaconglomerate of, Bell Pass mélange	pTms	Dragovich and others (1997b)	BEL	T39N R4E; T40N R4-5E
Sunday Creek stock, Index batholith, Index family	Φigd	Weaver (1912a), Bethel (1951), Tabor and others (1993)	SKY	T25N R9E
Swakane Biotite Gneiss	pTgn	Waters (1932), Crowder and others (1966), Tabor and others (1987a), Rasbury and Walker (1992)	CHL SAU TWS	T24N R18-19E; T25N R18-19E; T26N R18-19E; T27N R18E; T29N R16-17E; T30N R15-16E; T31N R15-16E; T32N R15E
Swauk Formation, undivided (includes Silver Pass Volcanic Member, listed separately)	Ec_1 Ecg_1	Smith (1904), Foster (1960), Tabor and others (2000)	SKY SNO WEN	T20N R17-18E; T21N R13-14,16-19E; T22N R13-19E; T23N R13-14,18E; T24N R13-14E; T25N R12-13E; T26N R12E
Swift Creek, andesite of, andesite of Mount Baker	Qva	Hildreth (1996), Tabor and others (in press b)	MBK	T38N R8-9E
Swift Creek, ignimbrite of, rocks of Kulshan caldera	Qvt	Hildreth and Lanphere (1994), Hildreth (1994, 1996), Tabor and others (in press b)	MBK	T38N R8-9E; T39N R8-9E
Table Mountain, andesite of, andesite of Mount Baker	Qva	Tabor and others (in press b)	MBK	T39N R8-9E
Tamarack Peak, stock near	Kigd	Tennyson (1974)	RBM	T38N R16-17E
Teanaway dike swarm	Eib Eigb	Smith (1904), Smith and Calkins (1906), Southwick (1966)	SNO WEN	T20N R17E; T21N R13-14,17-18E; T22N R13-18E
Teanaway Formation	Evb Evr	Smith and Willis (1901), Smith (1904), Frizzell and others (1984), Tabor and others (1984), Tabor and others (2000)	SNO WEN	T20N R13-14,16-18,E; T21N R13-18E; T22N R15-16E
Tenpeak pluton	Kit	Russell (1900), Cater and Crowder (1956), Ford (1959), Van Diver (1964), Crowder and others (1966), Tabor and others (in press a)	CHL SAU SKY TWS	T28N R15-16E; T29N R14-16E; T30N R14-15E; T31N R14-15E
Third Beach Member, Makah Formation, see Makah Formation				
Three A M Mountain, volcanic rocks of, Winthrop Formation, Pasayten Group	Kv_2 Kc_2	R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T37N R17-18E
Three Fools Creek sequence (R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000). Includes and listed under: strata of Freezeout Creek, Harts Pass Formation undivided, conglomerate of the Harts Pass Formation, strata of Majestic Mountain, conglomeratic strata of Two Buttes Creek, and Jackita Ridge unit undivided.				
Tiger Mountain Formation, Puget Group	Ec_2	Vine (1962, 1969), Wolfe (1968)	SKY, SNO TAC	T23N R5,7E
Tonga Formation	M̶sc M̶sh	Yeats (1958a), Tabor and others (1993), Duggan and Brown (1994)	SKY	T25N R12E; T26N R12E; T27N R12E; T28N R12E
Trafton sequence	JMmt ℙi	Danner (1966), Dethier and others (1980), Whetten and others (1988), Tabor and others (in press a)	PTW SAU	T30N R8E; T31N R6-8E; T32N R5-8E; T33N R5E
Trafton terrane, see Trafton sequence				
Troublesome Mountain, metaporphyry on, Index batholith, Index family	Φian	Weaver (1912a), Tabor and others (1993)	SKY	T28N R11E
Tukwila Formation, Puget Group	Evc	Waldron (1962), Wolfe (1968), Vine (1969)	SEA, SKY SNO, TAC	T22N R7-8E; T23N R4-8E; T24N R5-7E
Turtleback Complex	pDi	McLellan (1927), Whetten and others (1978), Brown and Vance (1987), Brandon and others (1988)	BEL RCH	T36N R1-4W; T37N R1E,1-2W
Twin Creeks drift	Qad, Qao	Thackray (1996)	MOL	T26N R9-10W
Twin River Group, lower, see Hoko River Formation				
Twin River Group, middle, see Makah Formation				
Twin River Group, upper, see Pysht Formation				

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Twin Sisters Dunite, Bell Pass mélange	pTu	Misch (1952), Ragan (1961)	BEL MBK	T36N R7-8E; T37N R6-7E; T38N R6E
Twisp River valley, plagioclase porphyry of	Kmt	Dragovich and others (1997a)	TWS	T34N R18-19E
Twisp Valley Schist (see also Napeequa Schist)	JPhmc	Adams (1962), Miller and others (1993c)	TWS	T33N R18-19E; T34N R18-19E
Two Buttes Creek, conglomeratic strata of, Jackita Ridge unit, Three Fools Creek sequence	Km_1	R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T37N R16-17E; T38N R16-17E; T39N R16E; T40N R16E
Vashon Drift, undivided (includes Lawton Clay Member and Pilchuck Clay Member, not listed separately)	Qga, Qgd Qgl, Qgo Qgog Qgos, Qgt Qguc	Willis (1898), Newcomb (1952), Armstrong and others (1965), Mullineaux and others (1965), Booth and Goldstein (1994)	BEL, MOL PAN, PTW RCH, SEA SHL, TAC	widespread in lowland areas
Vashon Drift. Includes and listed under: Arlington Gravel Member, Colvos Sand Member, Esperance Sand Member, Marysville Sand Member, Partridge Gravel, and Stillaguamish Sand Member.				
Vedder complex, Bell Pass mélange	pPsh pTmt	Daly (1912), Armstrong and others (1983), Brown and others (1987), Tabor and others (in press b)	MBK	T38N R6-7E; also, some of the distribution shown under Bell Pass mélange, undivided, is Vedder complex
Ventura Member, Midnight Peak Formation, Goat Wall unit, Pasayten Group	Kc_2	Barksdale (1975), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T37N R18-19E
Virginian Ridge Formation, undivided, Pasayten Group	Kmcg	Barksdale (1948, 1975), Tennyson and Cole (1978), Trexler and Bourgeois (1985), McGroder and others (1990), Miller and others (1994), Dragovich and others (1997a), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM TWS	T34N R18-19E; T35N R16-19E; T36N R14,16,18-19E; T37N R14,17-19E; T38N R16-19E; T39N R17-19E; T40N R17-19E
Virginian Ridge Formation. Includes and listed under: strata of Cow Creek, Devils Pass Member, volcanic breccia of Mount Ballard, and Slate Peak Member.				
Waatch Point, siltstone of	Em_2	Snavely and others (1993)	CFL	T32N R14-15W; T33N R15-16W
Waatch Quarry, siltstone and sandstone of	Em_2	Snavely and others (1993)	CFL	T33N R15W
War Creek, gneiss of	Rog	Adams (1961), Miller (1987), Miller and Bowring (1990)	TWS	T32N R18-19E; T33N R18-19E
Warnick Member, Chuckanut Formation, see Chuckanut Formation				
Weatherwax formation	$Qapw_1$ $Qapw_2$	Carson (1970)	SHL	T21N R6W
Wedekind Creek formation	$Qapw_1$	Carson (1970)	SHL	T21N R7-8W; T20N R7W
Wells Creek volcanic member, Nooksack Formation	Jmvd	Misch (1966), Tabor and others (in press b)	MBK	T37N R8-9E; T39N R7-8E; T40N R7-8E
Wenatchee Ridge, banded gneiss of	Kbg	Rosenberg (1961), Van Diver (1964), Tabor and others (1987a, 1993), Magloughlin (1993), Miller and others (2000)	CHL	T26N R16E; T27N R15-16E; T28N R15-16E
Wenatchee Ridge, light-colored gneiss of	Kog	Van Diver (1964), Tabor and others (1987a)	CHL	T27N R15-16E; T28N R16-17E
Western mélange belt	Jib, Jit, Ju KJmc KJmm KJmv pTigb	Frizzell and others (1984), Tabor and others (1982a, 1993, 2000, in press a)	PTW SAU SKY SNO	T22N R9E; T23N R8-10E; T24N R8-10E; T25N R8-10E; T26N R8-10E; T27N R8-10E; T28N R7-9E; T29N R7-9E; T30N R6-9E; T31N R6-8E; T32N R6-8E
Western Olympic lithic assemblage	MEm MEmst ΦEm ΦEmst ΦEvb	Tabor and Cady (1978a)	CFL FRK MOL PAN	T26N R8-11W; T27N R8½-12W; T28N R9-10W
Whale Creek drift	$Qapw_2$	Thackray (1996)	FRK	T24N R11-12W; T25N R11W

Geologic unit	Symbol	Defining and (or) representative references	1:100,000 quadrangle(s)	Area (township and range)
Whidbey Formation	Qc Qgpc Qguc	Easterbrook (1965)	BEL PAN PTW SEA	T23N R2E; T24N R1-2E; T25N R2E; T26N R3E; T27N R2-4E; T28N R1W,3-4E; T29N R2-4E; T30N R3W; T32N R1E; T34N R2E; T35N R1E; T36N R1-2E
White Chuck cinder cone, volcanic rocks and deposits of Glacier Peak	Qvb	Rosenberg (1961), Tabor and Crowder (1969), Beget (1981), Tabor and others (1993)	SAU SKY	T29N R12-14E; T30N R13-14E
White Chuck fill, volcanic rocks and deposits of Glacier Peak	Qvl Qvt	Ford (1959), Tabor and Crowder (1969), Beget (1981, 1982)	SAU	T30N R12-14E; T31N R11-12E
White Chuck tuff, volcanic rocks and deposits of Glacier Peak	Qvt	Ford (1959), Tabor and Crowder (1969), Beget (1981, 1982)	SAU	T31N R11-12E
White Chuck assemblage, volcanic rocks and deposits of Glacier Peak	Qvl Qvt Qvp	Beget (1981, 1982)	SAU	T30N R13-15E; T31N R10-15E; T32N R8-13E; T33N R10-11E
Whitehorse Mountain, volcanic rocks of, Eastern mélange belt	JTmt	Tabor and others (1989, in press a)	SAU	T32N R8-9E
Winthrop Formation, undivided, Pasayten Group (also includes volcanic rocks of Three A M Mountain, listed separately)	Kc_2 Kmt	Russell (1900), Barksdale (1975), Dragovich and others (1997a), Kiessling and Mahoney (1997), Kiessling (1998), Kiessling and others (1999), R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)	RBM	T36N R18-19E; T37N R18-19E; T38N R17-19E; T39N R17-19E; T40N R18-19E
Winthrop Sandstone, see Winthrop Formation				
Wolf Creek drift	$Qapw_1$	Thackray (1996)	FRK	T24N R11-12W; T25N R11W
Yellow Aster Complex, Bell Pass mélange	pDgn pDi pTmt	Misch (1966), Brown and others (1987), Sevigny and Brown (1989), Tabor and others (in press a,b)	BEL MBK SAU	T33N R10E; T34N R9-10E; T35N R8-10E; T36N R6-10E; T37N R6-8E; T38N R6-7E; T39N R5-6E; T40N R4-5,7-9E; T41N R5E; also, some of the distribution shown under Bell Pass mélange, undivided, is Yellow Aster Complex

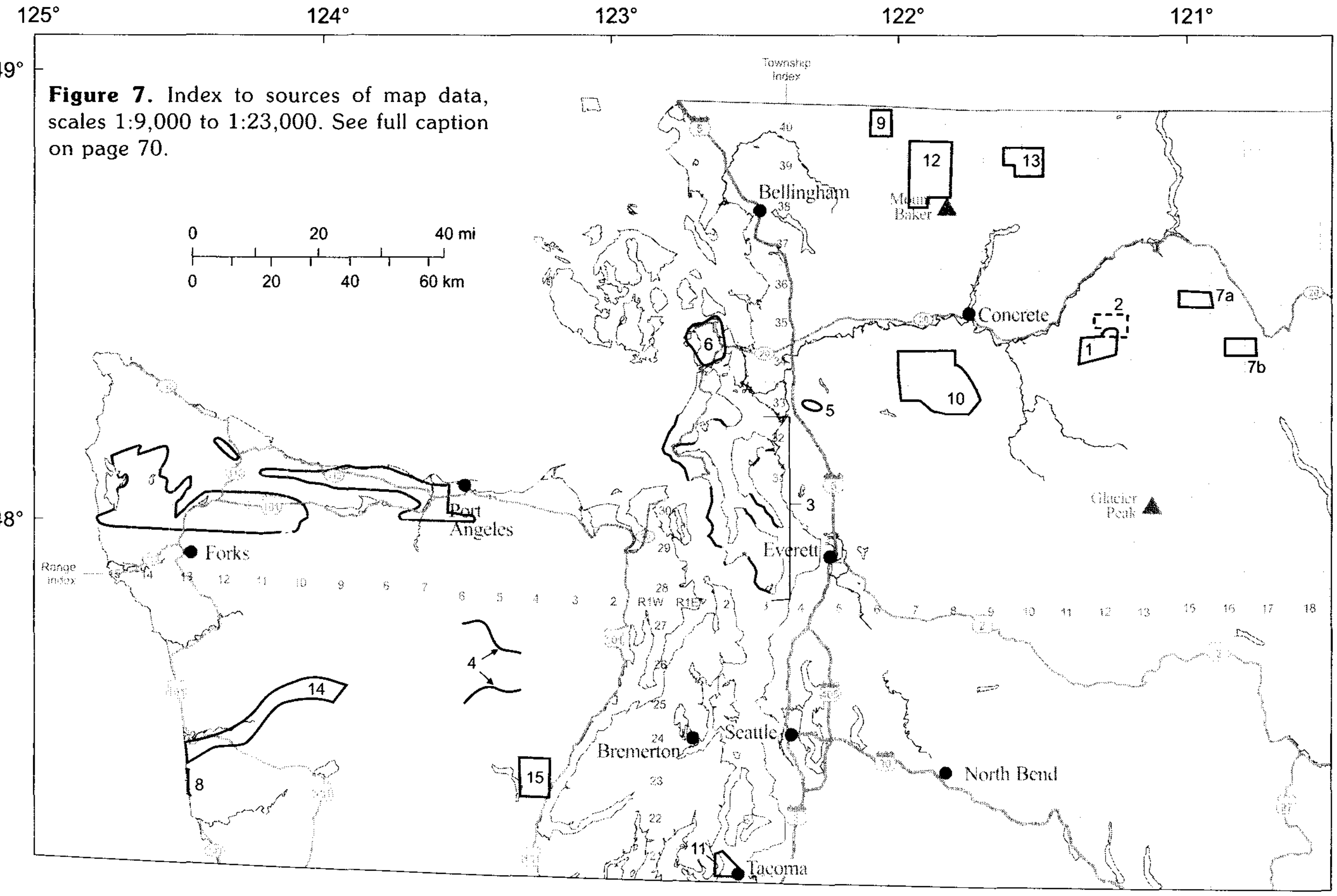


Figure 7. Index to sources of map data, scales 1:9,000 to 1:23,000. See full caption on page 70.

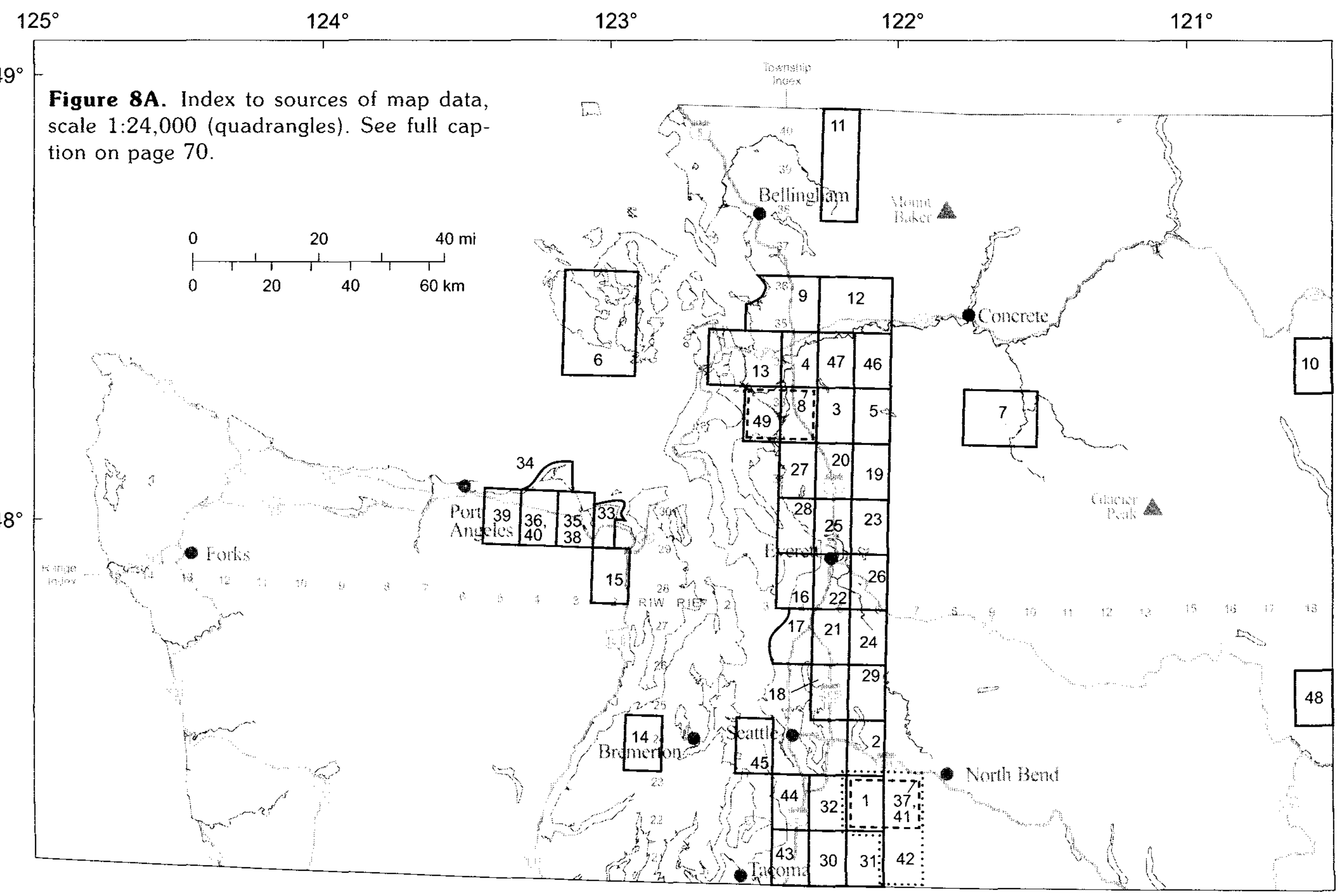


Figure 8A. Index to sources of map data, scale 1:24,000 (quadrangles). See full caption on page 70.

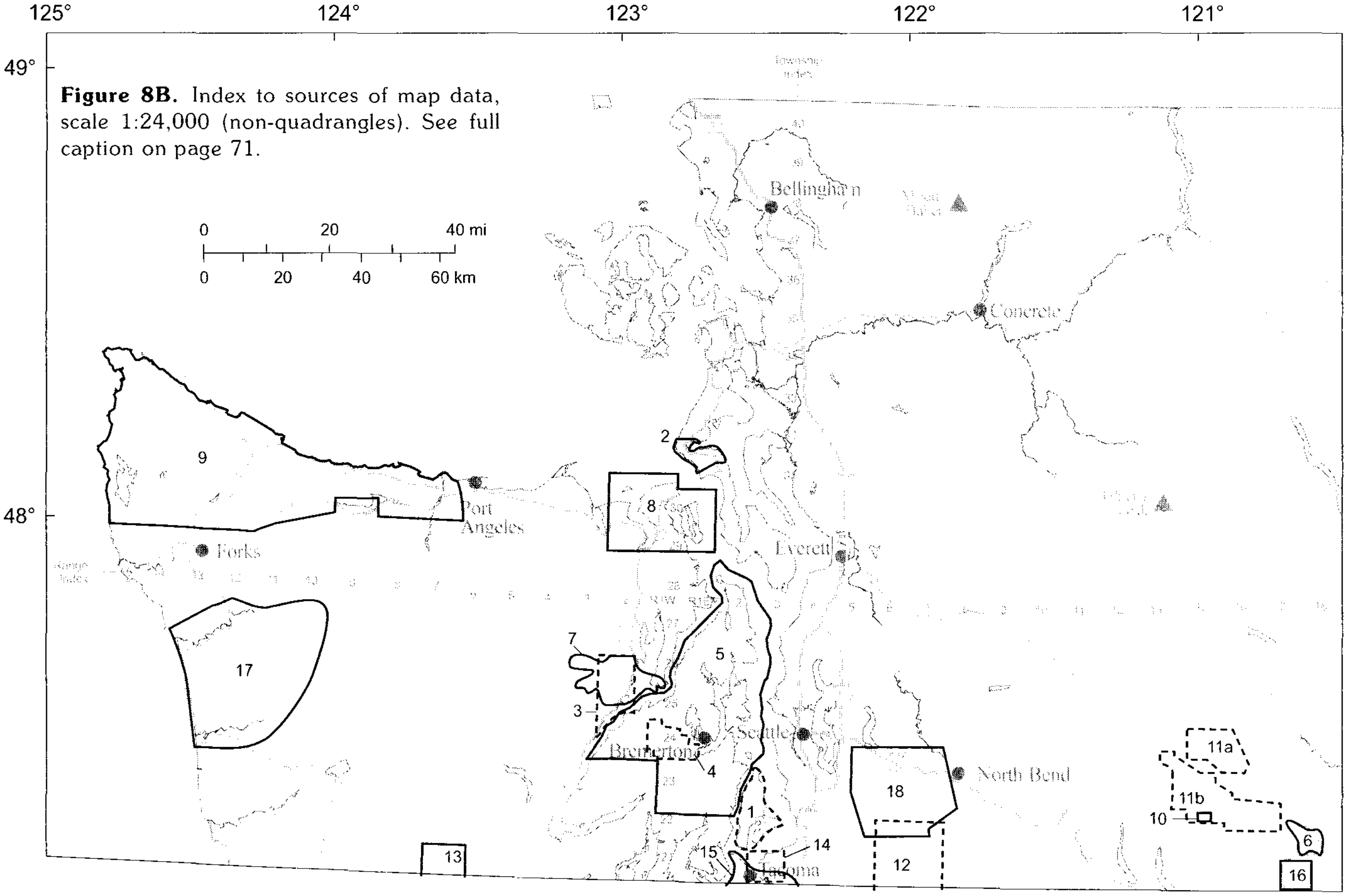


Figure 8B. Index to sources of map data, scale 1:24,000 (non-quadrangles). See full caption on page 71.

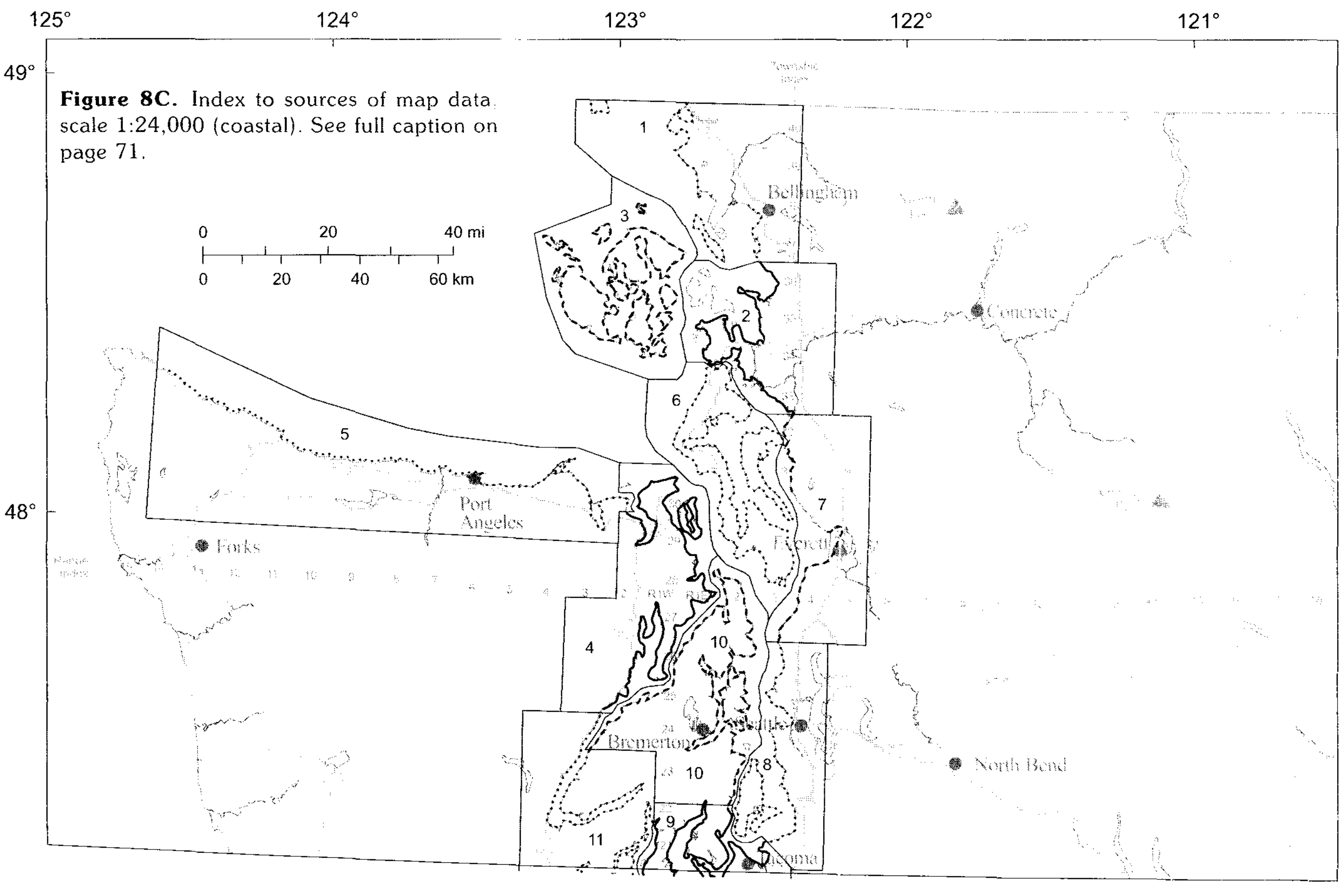


Figure 8C. Index to sources of map data, scale 1:24,000 (coastal). See full caption on page 71.

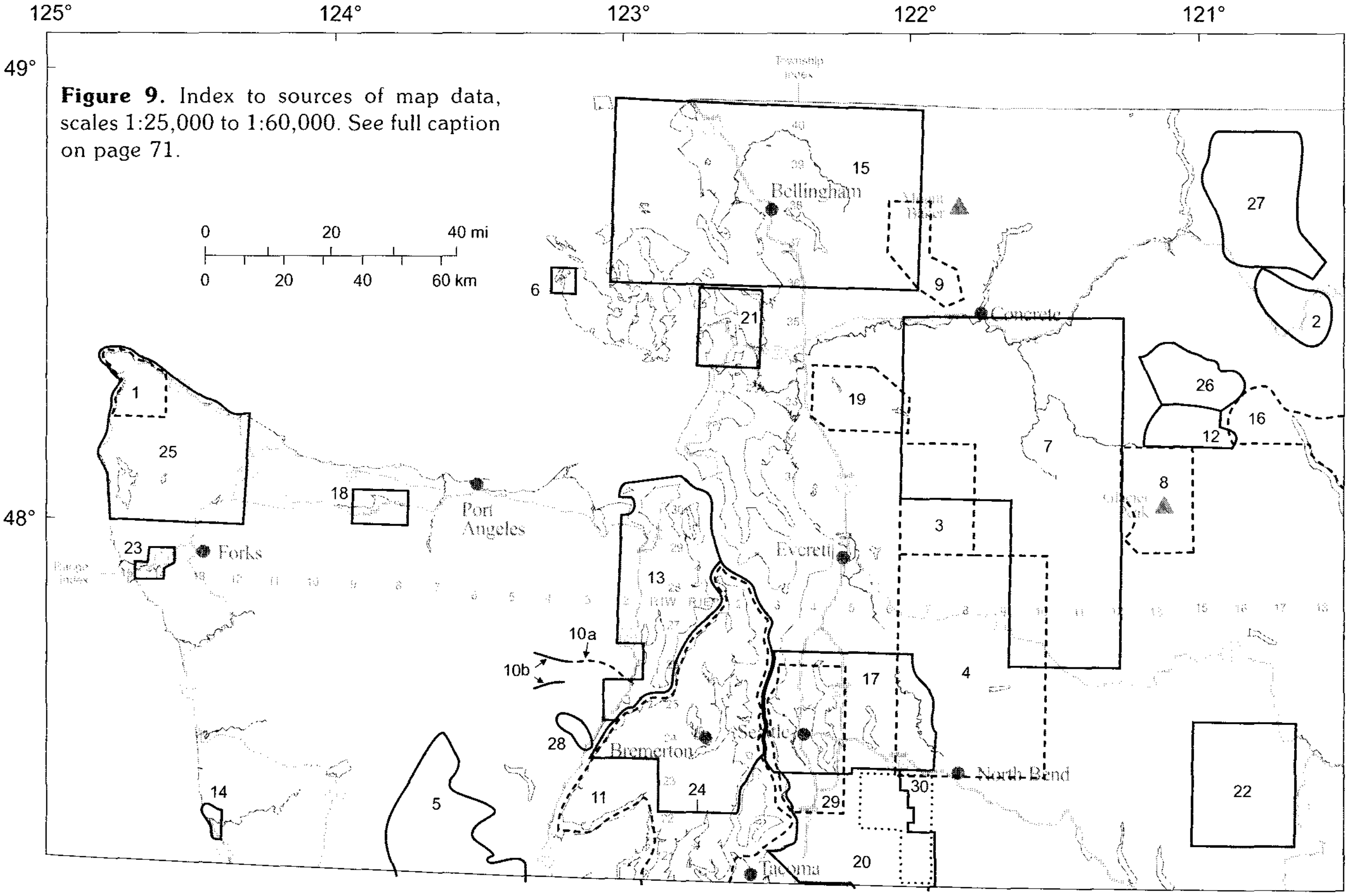


Figure 9. Index to sources of map data, scales 1:25,000 to 1:60,000. See full caption on page 71.

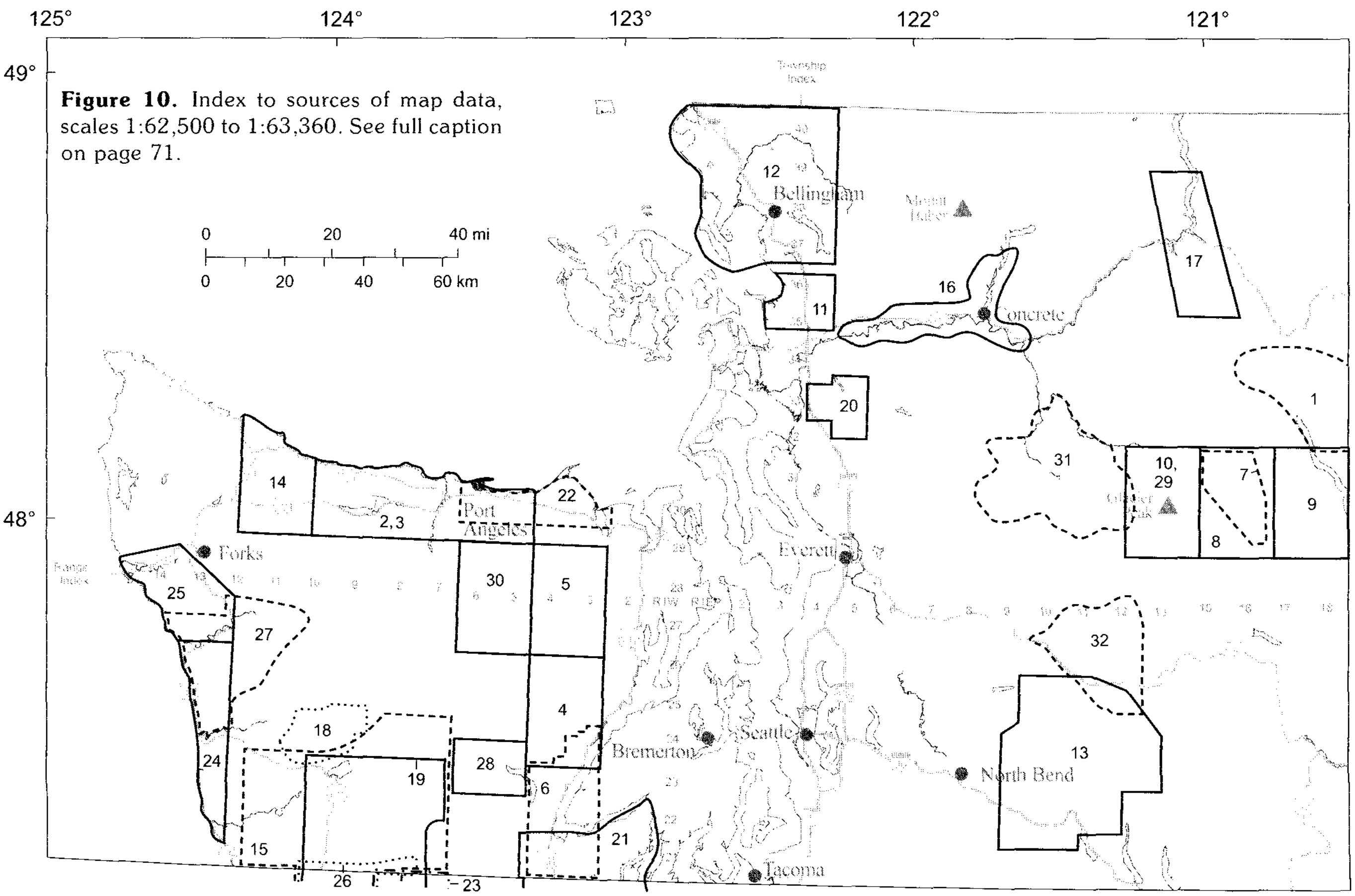


Figure 10. Index to sources of map data, scales 1:62,500 to 1:63,360. See full caption on page 71.

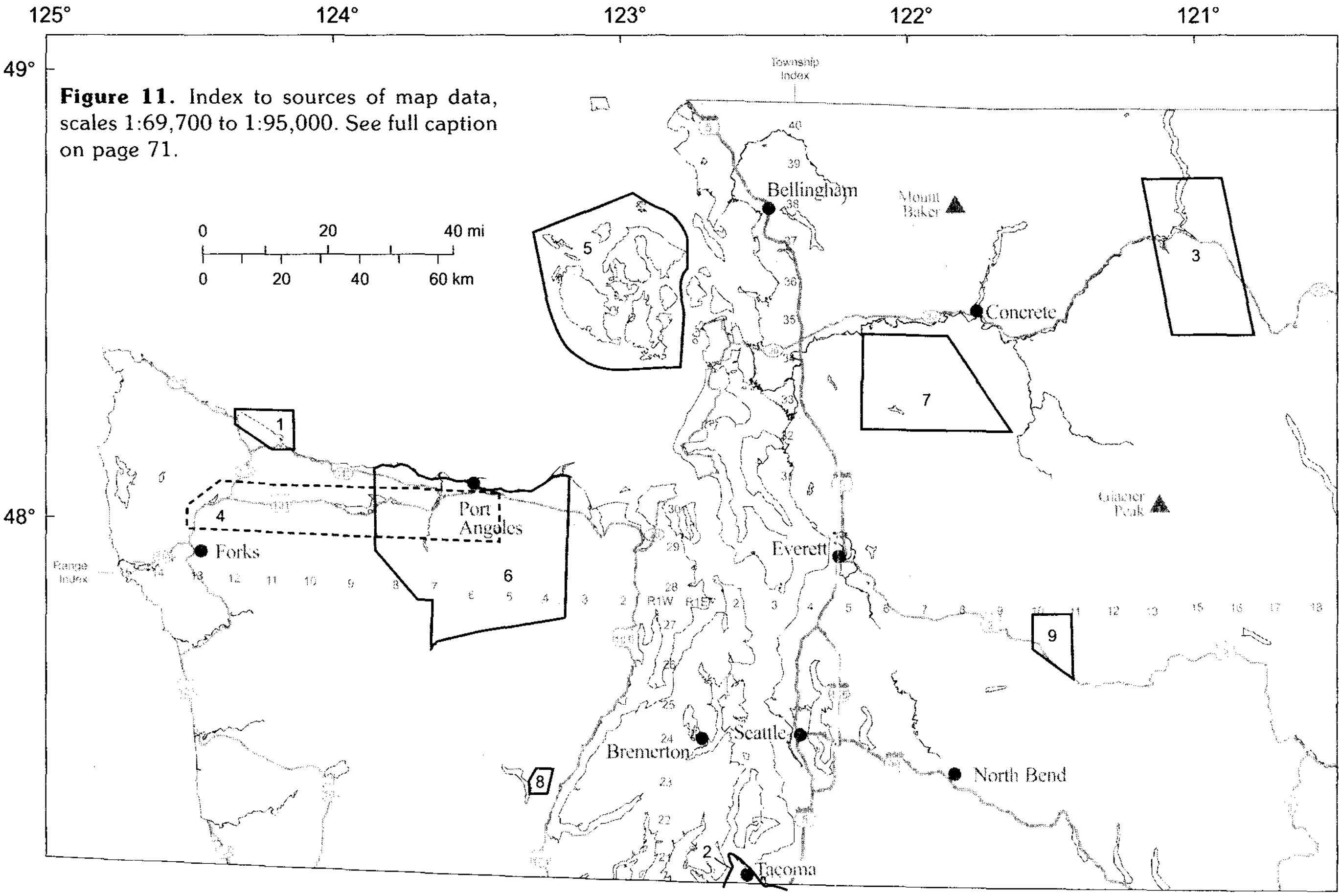


Figure 11. Index to sources of map data, scales 1:69,700 to 1:95,000. See full caption on page 71.

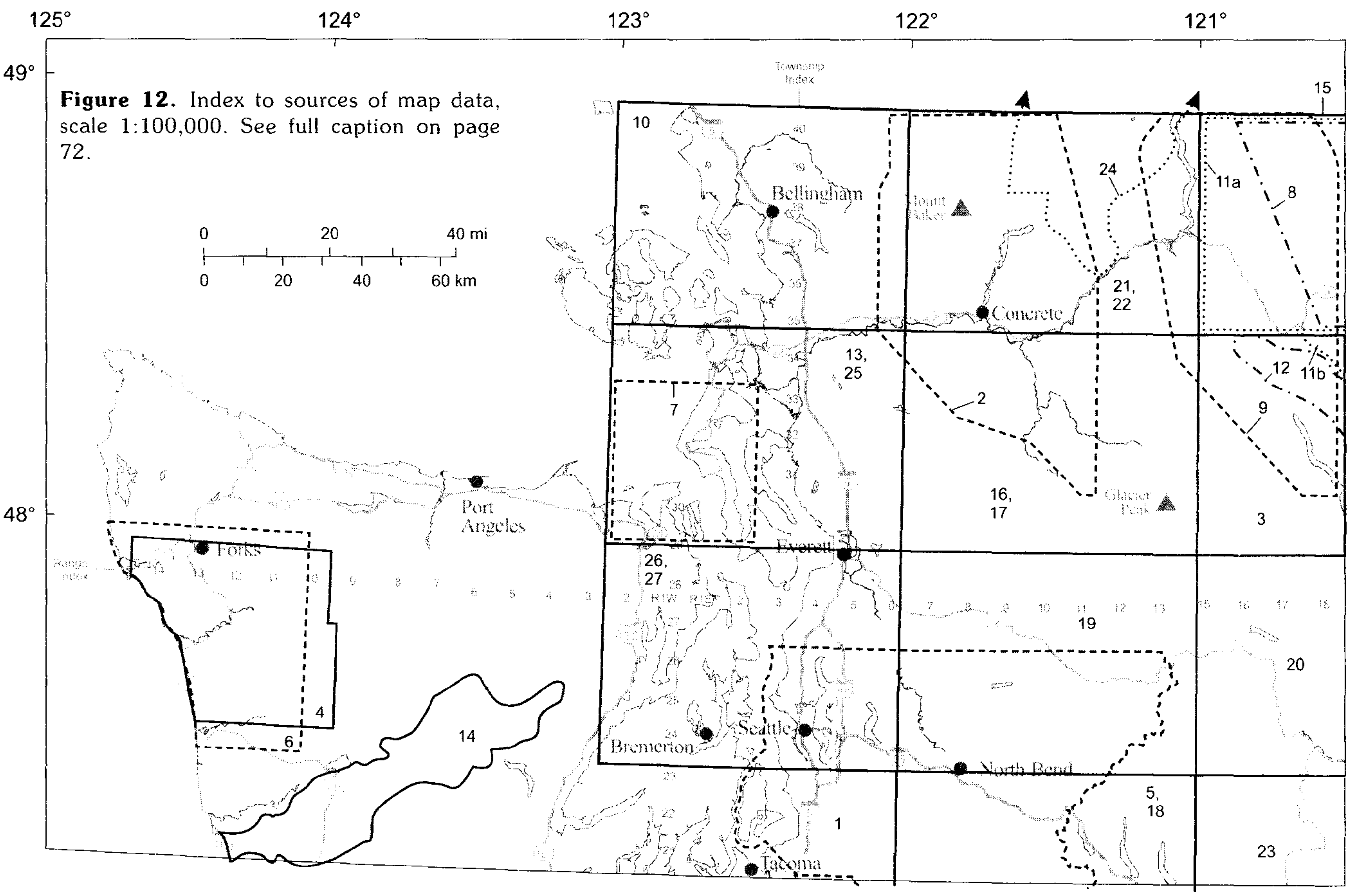


Figure 12. Index to sources of map data, scale 1:100,000. See full caption on page 72.

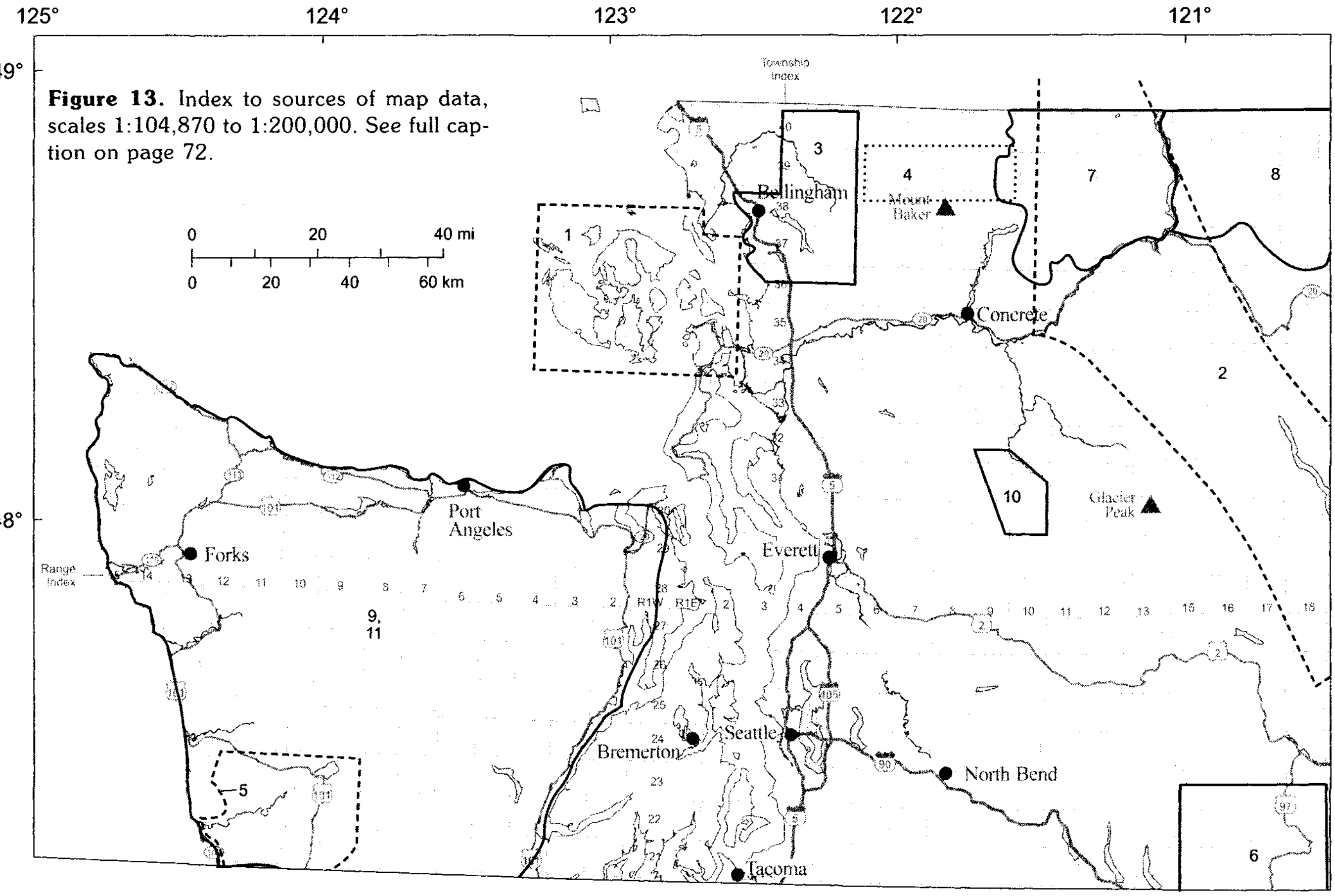


Figure 13. Index to sources of map data, scales 1:104,870 to 1:200,000. See full caption on page 72.

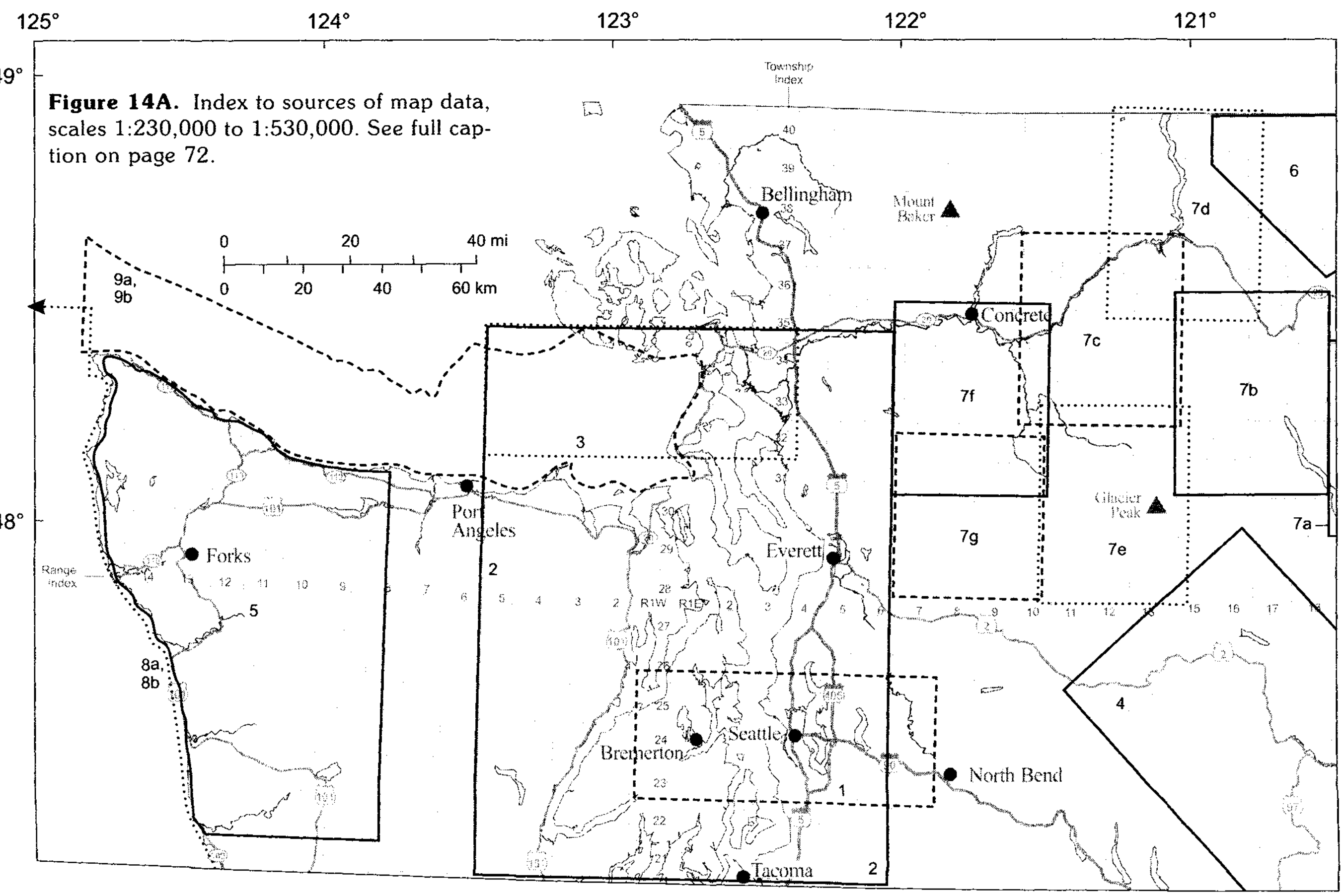


Figure 14A. Index to sources of map data, scales 1:230,000 to 1:530,000. See full caption on page 72.

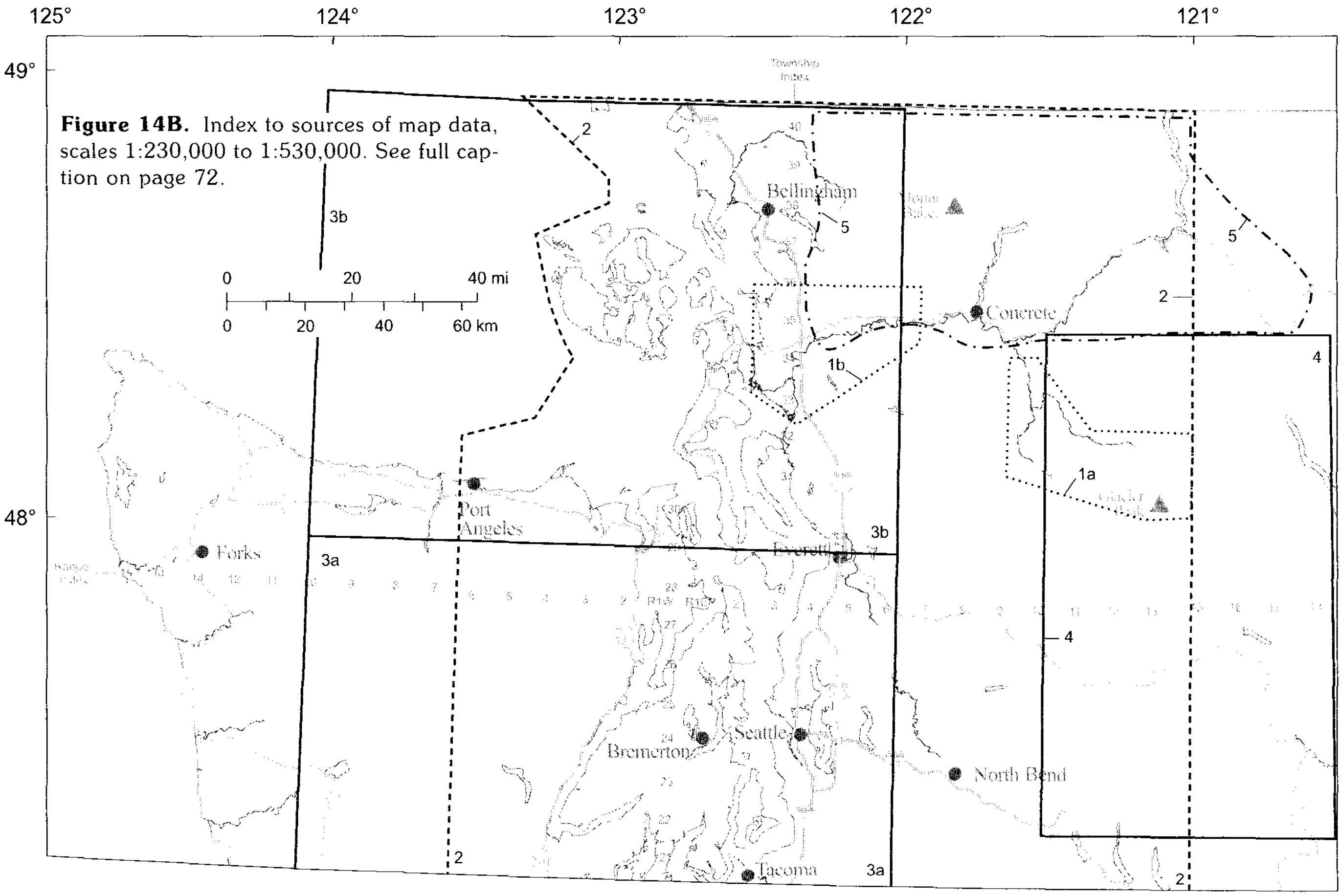


Figure 14B. Index to sources of map data, scales 1:230,000 to 1:530,000. See full caption on page 72.

CAPTIONS FOR SOURCE OF DATA MAPS

Figure 7. Index to sources of map data, scales 1:9,000 to 1:23,000.

1. Cary (1990); plate I, scale 1:15,840
2. Dragovich (1989); scale 1:10,560
3. Easterbrook (1968); scale 1:18,000
4. García (1996); plate 3, scale 1:19,000
5. Graham (1988); fig. 6, scale 1:9,000
6. Gusey (1978); scale 1:12,000
7. Hoppe (1984)
   7a plate 1, scale 1:12,000
   7b plate 2, scale 1:12,000
8. Koch (1968); scale 1:13,000
9. Liszak (1982); scale 1:15,000
10. Reller (1986); plate I, scale 1:15,840
11. Smith (1972); scale 1:23,000
12. Sondergaard (1979); plate 1, scale 1:15,840
13. Tepper (1985); scale 1:12,000
14. Wegmann (1999); plates 1, 2, 3, and 4, scale 1:12,000
15. Wilson (1975); plate 1, scale 1:10,000

Figure 8A. Index to sources of map data, scale 1:24,000 (quadrangles).

1. Booth (1995)
2. Booth and Minard (1992)
3. Dethier and Whetten (1980); plates 1 and 2
4. Dethier and Whetten (1981); plate 1
5. Dethier and others (1980); 2 plates
6. Dethier and others (1996); plate 1
7. J. D. Dragovich, L. A. Gilbert son, W. S. Lingley, Jr., and Michael Polenz (DGER, written commun., 2002)
8. J. D. Dragovich, L. A. Gilbert son, D. K. Norman, Garth Anderson, and G. T. Petro (DGER, written commun., 2002)
9. Dragovich and others (1998); plate 1
10. Dragovich and others (1997a); plate 1
11. Dragovich and others (1997b); plates 1 and 2
12. Dragovich and others (1999); plate 1
13. Dragovich and others (2000c); plate 1
14. Haeussler and Clark (2000)
15. Haeussler and others (1999)
16. Minard (1982)
17. Minard (1983a)
18. Minard (1983b)
19. Minard (1985a)
20. Minard (1985b)
21. Minard (1985c)
22. Minard (1985d)
23. Minard (1985e)
24. Minard (1985f)
25. Minard (1985g)
26. Minard (1985h)
27. Minard (1985i)
28. Minard (1985j)
29. Minard and Booth (1988)
30. Mullineaux (1965a)
31. Mullineaux (1965b)
32. Mullineaux (1965c)
33. Othberg and Palmer (1979a); plate 1
34. Othberg and Palmer (1979b); plate 1
35. Othberg and Palmer (1979c); plate 1
36. Othberg and Palmer (1982); plate 1
37. Rosengreen (1965); plate I
38. Schasse and Logan (1998)
39. H. W. Schasse and Michael Polenz (DGER, written commun., 2002)
40. Schasse and Wegmann (2000)
41. Vine (1962)
42. Vine (1969); plate 1
43. Waldron (1961)
44. Waldron (1962)
45. Waldron (1967)
46. Whetten and others (1979); plates 1 and 2
47. Whetten and others (1980a); plate 1
48. Whetten and Laravie (1976)
49. Wunder (1976)

Figure 8B. Index to sources of map data, scale 1:24,000 (non-quadrangles).

1. Booth (1991)
2. Carlstad (1992)
3. Carson (1976b)
4. Clark (1989); plate 1
5. Deeter (1979); plate 7
6. Fraser (1985); plate 2
7. Frisken (1965); plate II
8. Gayer (1976)
9. Halloin (1987); plates 1–22, 24–31, 36–43, 49–53, and 58–61; inset sheets 41, 48, and 57
10. Miller (1975); plate 1
11. Miller (1980)
    11a plate I
    11b plate II
12. Phillips (1984); plate 1
13. Rau (1966); plate 2
14. Smith (1976)
15. Smith (1977)
16. Taylor (1985); plate 2
17. Thackray (1996); plate 1
18. Walsh (1984); plate 1

Figure 8C. Index to sources of map data, scale 1:24,000 (coastal). Thin lines encompass maps within each county.

1. Washington Department of Ecology (1977)
2. Washington Department of Ecology (1978a)
3. Washington Department of Ecology (1978b)
4. Washington Department of Ecology (1978c)
5. Washington Department of Ecology (1978d)
6. Washington Department of Ecology (1979a)
7. Washington Department of Ecology (1979b)
8. Washington Department of Ecology (1979c)
9. Washington Department of Ecology (1979d)
10. Washington Department of Ecology (1979e)
11. Washington Department of Ecology (1980)

Figure 9. Index to sources of map data, scales 1:25,000 to 1:60,000.

1. Ansfield (1972); plate 1, scale 1:47,520
2. Boggs (1984); fig. 38, scale 1:36,200
3. Booth (1989); scale 1:50,000
4. Booth (1990); plate 1, scale 1:50,000
5. Carson (1970); plate I, scale 1:48,000
6. Danner (1966); fig. 23, scale 1:28,400
7. Evans and Ristow (1994); fig. 3, scale 1:31,660
8. Ford (1959); plate 5, scale 1:39,600
9. Frasse (1981); plate 1, scale 1:31,680
10. García (1996)
    10a plate 1, scale 1:25,000
    10b plate 2, scale 1:38,000
11. Garling and others (1965); plate 1, scale 1:60,000
12. Grant (1966); plate 2, scale 1:31,680
13. Grimstad and Carson (1981); plate I, scale 1:48,000
14. Horn (1969); fig. 6, scale 1:50,000
15. Johnson (1982); plate 1, scale 1:50,000
16. Libby (1964); plate 27, scale 1:31,680
17. Liesch and others (1963); plate 1, scale 1:48,000
18. Logan and Schuster (1991); fig. 2, scale 1:55,440
19. Lovseth (1975); fig. 2, scale 1:50,600
20. Luzier (1969); plate 1, scale 1:48,000
21. Mulcahey (1975); plate, scale 1:42,000
22. Plummer (1969); plate III, scale 1:60,000
23. Rector (1958); plate 3, scale 1:31,250
24. Sceva (1957); plate 1, scale 1:48,000
25. Snavely and others (1993); scale 1:48,000
26. Tabor (1961); plate 24, scale 1:31,680
27. Tennyson (1974); fig. 2, scale 1:48,000
28. Todd (1939); fig. 10, scale 1:31,680
29. Waldron and others (1962); scale 1:31,680
30. Warren and others (1945); scale 1:32,500

Figure 10. Index to sources of map data, scales 1:62,500 to 1:63,360.

1. Adams (1961); plate 2
2. Brown (1970)
3. Brown and others (1960)
4. Cady and others (1972a)
5. Cady and others (1972b)
6. Carson (1976b)
7. Cater (1969); plate 1
8. Cater and Crowder (1967)
9. Cater and Wright (1967)
10. Crowder and others (1966)
11. Dragovich and Grisamer (1998); fig. 3
12. Easterbrook (1976)
13. Erikson (1968); plate 1
14. Gower (1960)
15. Harvey (1978); plate
16. Heller (1978); plate B
17. Kriens (1988); plate 5
18. Lingley and others (1966); plate 1
19. Long (1975b); plate 1
20. Marcus (1981); plate
21. Molenaar and Noble (1970); plate 1
22. Othberg and Logan (1977); DGER unpub. map
23. Rau (1967); fig. 2
24. Rau (1975)
25. Rau (1979)
26. Rau (1986)
27. Stewart (1970); plate 1
28. Tabor (1982)
29. Tabor and Crowder (1969); plate 1
30. Tabor and others (1972)
31. Vance (1957); plate 1
32. Yeats (1958a); plate 1

Figure 11. Index to sources of map data, scales 1:69,700 to 1:95,000.

1. Addicott (1976); fig. 2, scale 1:84,480
2. Brown and Caldwell and others (1985); fig. 15-8, scale 1:75,000
3. Kriens and Wernicke (1990); plate 1, scale 1:94,000
4. Long (1975); figs. 11, 12, 14, and 16, scale 1:95,000; fig. 19, scale 1:72,000
5. Russell (1975); plate 1, scale 1:70,000
6. Tabor (1983); fig. 15, scale: 1:69,700
7. Tabor (1994); fig. 4, scale 1:86,900
8. Wilson (1983); fig. 1, scale 1:93,000
9. Yeats (1964); plate 1, scale 1:81,000

Figure 12. Index to sources of map data, scale 1:100,000.

1. D. B. Booth, R. A. Haugerud, and J. B. Sackett (Univ. of Wash. USGS, written commun., 2000)
2. Brown and others (1987)
3. Dragovich and Norman (1995); plate 1
4. Friends of the Pleistocene (1996); plate 1
5. Frizzell and others (1984); plate
6. Gerstel and Lingley (2000); plate 1
7. Gower (1980)
8. R. A. Haugerud and R. W. Tabor (USGS, written commun., 2000)
9. Kriens (1988); plate 6
10. Lapen (2000); plate 1
11. McGroder and others (1990)
    11a plate 2
    11b plate 3
12. Miller (1987); sheet 1
13. Pessl and others (1989)
14. Quinault Indian Nation and others (1999); plates 2.3A, 2.3B, 2.3C, and 2.3D
15. Stoffel and McGroder (1990); plate
16. Tabor and others (in press a)
17. Tabor and others (1988); plate
18. Tabor and others (2000)
19. Tabor and others (1993)
20. Tabor and others (1987a)
21. Tabor and others (1994); plate 1
22. Tabor and others (in press b)
23. Tabor and others (1982b)
24. Tepper (1991); map 1
25. Whetten and others (1988)
26. Yount and Gower (1991); plate 1
27. Yount and others (1993); sheet 1

Figure 13. Index to sources of map data, scale 1:104,870 to 1:200,000.

1. Brandon and others (1988); fig. 3, scale 1:137,000
2. Haugerud and others (1991); fig. 2, scale 1:164,075
3. Miller and Misch (1963); fig. 2, scale 1:169,000
4. Misch (1977); fig. 4, scale 1:126,700
5. Moore (1965); plate 1, scale 1:125,000
6. Smith (1904); plate, scale 1:125,000
7. Staatz and others (1972); plate 1, scale 1:200,000
8. Staatz and others (1971); plate 1, scale 1:200,000
9. R. J. Stewart (Univ. of Wash, written commun., 1999); scale 1:125,000
10. Tabor (1994); fig. 5, scale 1:104,870
11. Tabor and Cady (1978a); scale 1:125,000

Figure 14A. Index to sources of map data, scale 1:230,000 to 1:530,000.

1. Blakely and others (2002); figs. 3 and 4, scale 1:476,190
2. S. Y. Johnson (USGS, written commun. 2001); scale 1:250,000
3. Johnson and others (2001); fig. 2, scale 1:312,500
4. Miller and others (2000); fig. 2b, scale1:392,160
5. Snavely and Kvenvolden (1989); plate 1, scale 1:250,000
6. Tabor and others (1968); fig. 2, scale 1:250,000
7. Tabor and others (1989); scale 1:230,000
    7a map 1, scale 1:230,000
    7b map 2, scale 1:230,000
    7c map 3, scale 1:230,000
    7d map 4, scale 1:230,000
    7e map 5, scale 1:230,000
    7f map 6, scale 1:230,000
    7g map 7, scale 1:230,000
8. Wagner and others (1986); scale 1:250,000
    8a plate 5, scale 1:250,000
    8b plate 4, scale 1:250,000
9. Wagner and Tomson (1987); scale 1:250,000
    9a plate 3, scale 1:250,000
    9b plate 6, scale 1:250,000

Figure 14B. Index to sources of map data, scale 1:230,000 to 1:530,000.

1. Dragovich and others (2000a); fig, 2, scale 1:338,980
    1a fig. 2, map A
    1b fig. 2, map B
2. Gower and others (1985); scale 1:250,000
3. High Life Helicopters (1981); scale 1:500,000
    3a volume IIB, appendix B, scale 1:500,000
    3b volume IIC, appendix B, scale 1:500,000
4. Miller and others (2000); fig. 5a, scale 1:500,000
5. Misch (1966); plate 7.1, scale 1:530,000

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands

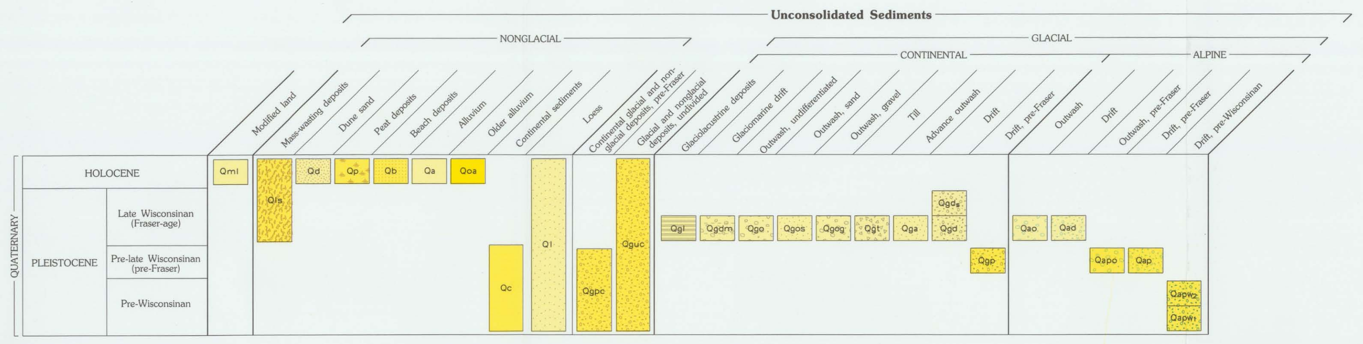
GEOLOGIC MAP OF WASHINGTON—NORTHWEST QUADRANT

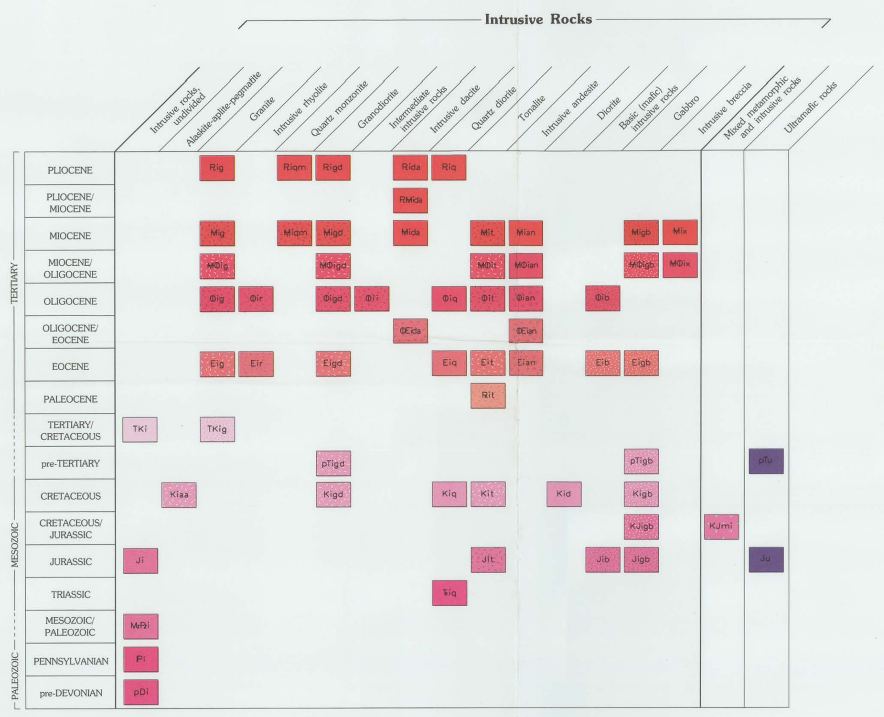
by

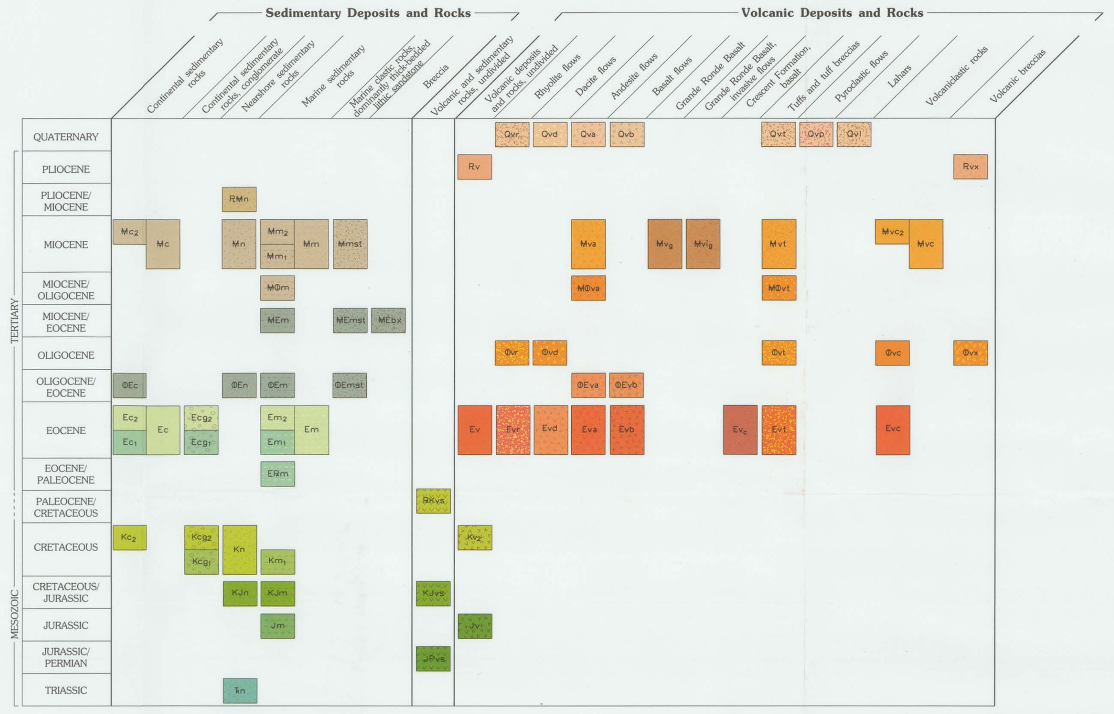
Joe D. Dragovich, Robert L. Logan, Henry W. Schasse, Timothy J. Walsh, William S. Lingley, Jr., David K. Norman, Wendy J. Gerstel, Thomas J. Lapen, J. Eric Schuster, and Karen D. Meyers

David K. Norman, Assistant State Geologist and State Geologic Map Manager
J. Eric Schuster, former Assistant State Geologist and State Geologic Map Manager

2002







SCALE 1:250,000

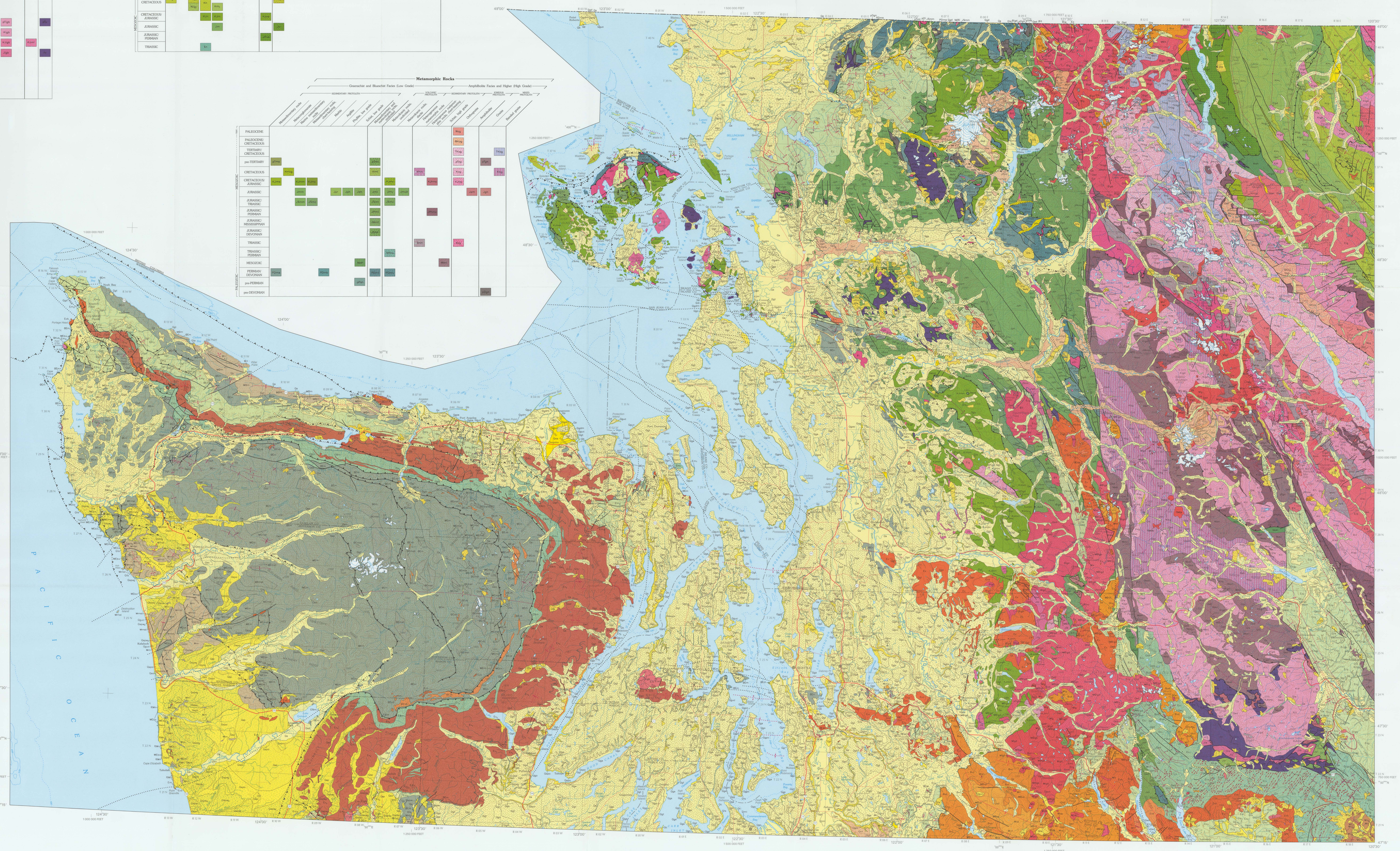
Contour Interval 200 Meters
Supplementary contours at 100 meters above sea level
and 100 meters below sea level
National Geodetic Vertical Datum of 1929

This publication is dedicated to Rowland W. Tabor, U.S. Geological Survey, retired, in recognition and appreciation of his fundamental contributions to geologic mapping and geologic understanding in the Cascade Range and Olympic Mountains

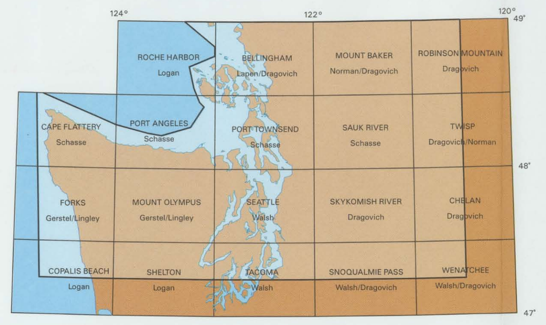
Prepared in cooperation with the U.S. Geological Survey

Geologic Symbols

- Contact
- Scratch boundary -- Indicates unreconciled differences at source map boundaries
- Fault -- Dotted where concealed
- Reverse fault -- Dotted where concealed; R on upthrown block
- Dip-slip fault -- Bar and ball on downthrown side; dotted where concealed
- Strike-slip fault -- Arrows show relative horizontal movement; dotted where concealed
- Low-angle normal fault -- Blocks on upper plate; dotted where concealed
- Thrust fault -- Sawteeth on upper plate; dotted where concealed
- Oblique-slip fault -- Arrows show relative horizontal movement, bar and ball on downthrown side; dotted where concealed
- Anticline -- Showing direction of plunge; dotted where concealed
- Syncline -- Showing direction of plunge; dotted where concealed
- Overturned anticline -- Showing direction of plunge; dotted where concealed
- Overturned syncline -- Dotted where concealed
- Monocline -- Arrow on steeper limb
- Approximate maximum extent of pre-late Wisconsinan Cordilleran Ice Sheet
- Maximum extent of the late Wisconsinan Cordilleran Ice Sheet
- Ei dike
- Eib dike
- Eigb dike



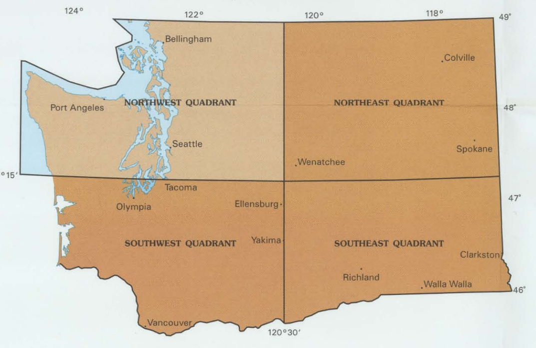
Compilation Responsibility by 1:100,000-scale Quadrangle



Base derived from Washington Department of Natural Resources and Washington Department of Transportation databases.
Projection and 150,000-meter grid tics, Zone 10, Universal Transverse Mercator.
250,000-foot grid tics based on Washington Coordinate System, South Zone.
1927 North American Datum.

Cartographic design and production by Charles Caruthers, Anne Heinitz, and Keith Ikerd.
Washington Division of Geology and Earth Resources, 2002.

Quadrant Location



DESCRIPTIONS OF MAP UNITS

UNCONSOLIDATED SEDIMENTS

QUATERNARY

NONGLACIAL

relatively undissected; locally includes alpine drift, peat, lacustrine, landslide, lahar, and rare loess deposits.

Qoa **Older alluvium** — Stratified gravel, cobbles, sand, and silt in terraces above modern flood plains; commonly iron stained; includes alluvial-fan, landslide, and colluvial deposits graded to terrace surface; locally includes volcaniclastic or lahar deposits.

Qc **Pleistocene continental sediments** — Stratified clay, silt, sand, gravel, and peat of fluvial, deltaic, lacustrine, and (or) estuarine origin; locally contains lahars and tephras. *Includes part of the Whidbey and Puyallup Formations and part of the Olympia beds (Armstrong and others, 1965).*

Ql **Loess** — Pale orange to brown eolian silt and fine sand; locally contains caliche and tephra.

GLACIAL

Continental

Qgd_s **Undifferentiated glacial drift, Sumas Stade of the Fraser Glaciation** — Loose, stratified cobbles, gravel, sand, and minor silt beds of glaciofluvial and glaciodeltaic origin; locally contains till and unconsolidated glaciolacustrine sediments. *Consists of the Sumas Drift.*

Qgdm **Glaciomarine drift** — Diamicton and poorly stratified gravelly silt with dropstones; poorly compacted and locally fossiliferous; contains lenses to thick layers of fluvial, deltaic, and glaciomarine gravel, sand, silt, and clay; locally capped by shallow-water clay or silt. *Consists of the Deming Sand and part of the Everson Glaciomarine Drift.*

Qgl **Glaciolacustrine deposits** — Sand, silt, and clay deposited in proglacial lakes; laminated with disseminated dropstones. *Includes part of the Vashon Drift undivided.*

Qgd **Undifferentiated glacial drift** — Till, sand, gravel, silt, and clay; mostly Vashon till and outwash not separately mappable at the map scale. *Consists of part of the Vashon Drift undivided and part of the Everson Glaciomarine Drift.*

Qgo **Undifferentiated outwash** — Recessional and proglacial stratified sand, gravel, and cobbles with minor silt and clay interbeds deposited in delta, ice-contact, beach, and meltwater stream environments; may include advance outwash. *Includes part of the Partridge Gravel, part of the Everson Glaciomarine Drift, and part of the Vashon Drift undivided.*

Qgog **Outwash gravel** — Recessional and proglacial stratified pebble, cobble, and boulder gravel deposited in meltwater streambeds and deltas. *Includes the Arlington Gravel Member of the Vashon Drift and part of the Vashon Drift undivided.*

Qgos **Outwash sand** — Recessional and proglacial sand with minor gravel or silt; well sorted and stratified. *Includes the Stillaguamish and Marysville Sand Members of the Vashon Drift, part of the Vashon Drift undivided, and part of the Partridge Gravel.*

(Moore, 1965), part of the Grisdale drifts (Carson, 1970), and part of the Lakedale and Evans Creek Drifts.

Qap **Early Wisconsinan alpine drift** — Till and outwash sand and gravel; gray with local orange weathering; locally covered with weathered loess. *Includes part of the Chow Chow drift (Moore, 1965), the Lyman Rapids drift (Thackray, 1996), part of the Grisdale drifts (Carson, 1970), the drift of Mount Stickney (Booth, 1990), and part of the Kittitas Drift.*

Qapo **Early Wisconsinan alpine outwash** — Stratified sand, gravel, and cobbles; locally includes peat, silt, clay, and weathered loess; gray to subtle yellow weathering. *Includes part of the Chow Chow drift (Moore, 1965), the Lyman Rapids outwash (Thackray, 1996), the Skokomish Gravel, and part of the Kittitas Drift.*

$Qapw_2$ **Younger pre-Wisconsinan alpine drift** — Outwash sand and gravel, lacustrine silt and clay, till, and loess; red-orange; weathered to depths exceeding 4 m; weathering rinds on clasts; ancient surfaces are moderately dissected by streams. *Includes the Whale Creek drift (Thackray, 1996), the Humptulips drift (Moore, 1965), the Mobray drift (Carson, 1970), and part of the Weatherwax formation (Carson, 1970).*

$Qapw_1$ **Older pre-Wisconsinan alpine drift** — Outwash sand and gravel, till, and lacustrine silt and clay; deep red-orange; weathered to depths exceeding 20 m with clasts thoroughly weathered; ancient surfaces are highly dissected by streams. *Includes the Donkey Creek drift (Moore, 1965), the Wedekind Creek formation (Carson, 1970), the Wolf Creek drift (Thackray, 1996), and part of the Weatherwax formation (Carson, 1970).*

GLACIAL AND NONGLACIAL

Qguc **Undifferentiated surficial deposits** — Clay, silt, sand, gravel, till, diamicton, and peat; unit shown where steep slopes preclude more detailed delineation at map scale; includes pre-Holocene deposits and Holocene alluvium or landslide deposits found along steep slopes of narrow stream valleys on the northern Olympic Peninsula; also includes poorly exposed sediments at the base of the Vashon Drift whose stratigraphic assignment is undetermined. *Includes part of the Double Bluff, Possession, and Everson Glaciomarine Drifts, part of the Vashon Drift undivided, part of the Whidbey Formation, and part of the Olympia beds (Armstrong and others, 1965).*

Qgpc **Deposits of pre-Fraser age, undifferentiated** — Clay, silt, sand, gravel, till, and peat, generally moderately to deeply weathered and compact; unit shown where field data are insufficient for more precise differentiation or where steep slopes preclude more detailed delineation at map scale; also includes deposits in the Cascade Range not specifically correlative to named units in the Puget Lowland; locally may include some early Fraser-age lacustrine sediments. *Includes part of the Whidbey and Puyallup Formations, part of the Possession, Salmon Springs, and Double Bluff Drifts, and part of the Olympia beds (Armstrong and others, 1965).*

SEDIMENTARY DEPOSITS AND ROCKS

TERTIARY

Pliocene–Miocene

RMn **Nearshore sedimentary rocks** — Siltstone, sandstone, and conglomerate; fossiliferous; concretionary and carbonaceous; contains flame and ball-and-pillow structures. *Consists of the Quinault and Quillayute Formations.*

Miocene

Mm **Marine sedimentary rocks** — Thin-bedded (1–20 cm) and (or) laminated, lithofeldspathic sandstone and siltstone with less abundant claystone, shale, and thick-bedded (>60 cm) sandstone; minor conglomerate and shale-clast breccia; commonly weathers orange; rhythmically bedded and carbonaceous in part. *Consists of part of the Hoh rock assemblage (Rau, 1973).*

Mm_2 **Middle–upper Miocene marine sedimentary rocks** — Coarse- to fine-grained, silty, friable, lithofeldspathic or feldspatholithic sandstone; local conglomerate, siltstone, and (or) claystone; blue-gray, weathers orange-brown; locally tuffaceous; local conglomerate lenses and beds; contains carbonized wood, mica, and concretions. *Consists of the Montesano Formation.*

Mm_1 **Lower–middle Miocene marine sedimentary rocks** — Fine-grained, silty, feldspathic sandstone; thick to thin bedded; friable and micaceous; gray, weathers to olive-brown or orange; contains abundant siltstone with fragments of carbonaceous material; locally tuffaceous; contains minor basaltic sandstone and pebble conglomerate, especially at the base. *Consists of the Astoria Formation.*

Mmst **Marine thick-bedded sedimentary rocks** — Thick sequences of laterally discontinuous, medium- to very coarse-grained, micaceous, feldspatholithic to lithofeldspathic sandstone; minor siltstone-, shale-, and slate-clast breccia, granule conglomerate, and pebble conglomerate; bedding generally thicker than 1 m; common platy shale, slate, or siltstone clasts; sequences separated by thin-bedded (1–30 cm) sandstone, siltstone, claystone, and shale. *Includes part of the Hoh rock assemblage (Rau, 1973).*

Mn **Lower Miocene nearshore sedimentary rocks** — Micaceous feldspathic sandstone and conglomerate with minor siltstone; typically thick bedded; locally pebbly, bioturbated, and (or) cross-bedded with syndepositional deformation; commonly mollusk-bearing and carbonaceous. *Consists of the Clallam Formation.*

Mc **Continental sedimentary rocks** — Poorly consolidated sandstone, siltstone, and conglomerate; commonly tuffaceous; includes tuff breccias, lahars, volcanic sandstone, and lignite. *Consists of the Ellensburg and Hammer Bluff Formations.*

Mc_2 **Continental sedimentary rocks** — Pebble to cobble conglomerate, siltstone, carbonaceous shale, and minor lignite stringers; clasts dominantly basaltic, but also include andesite, dacite, metamorphic rocks, and lithic sandstone. *Consists of the Blakely Harbor Formation.*

Miocene–Oligocene

MΦm **Marine sedimentary rocks** — Poorly indurated mudstone to sandy siltstone with calcareous concretions; conglomerate near the base; locally contains medium- and coarse-grained, micaceous, lithic and quartzofeldspathic sandstone. *Consists of the Pysht Formation.*

Miocene–Eocene

MEm **Marine sedimentary rocks** — Laminated and (or) thin-bedded (1–20 cm), lithofeldspathic and feldspatholithic, micaceous sandstone, siltstone, and slate in the western Olympic Peninsula and semischist, slate, and (or) phyllite in the Olympic Mountains; minor thick-bedded sandstone, granule conglomerate, and thick-layered (>60 cm) semischist, all with platy shale, siltstone, tuff, or slate clasts grading to platy-clast breccia; thin-bedded units commonly rhythmic; mostly metamorphosed to zeolite facies; phacoidal structures common. *Includes part of the Hoh rock assemblage (Rau, 1973) and part of the Western Olympic and Grand Valley lithic assemblages (Tabor and Cady, 1978a).*

MEmst **Marine thick-bedded sedimentary rocks** — Thick sequences of laterally discontinuous, medium- to very coarse-grained, micaceous, feldspatholithic to lithofeldspathic sandstone or semischist with siltstone or slate clasts grading to platy siltstone- or slate-clast breccia; generally bedded thicker than 1 m; minor granule conglomerate and pebble conglomerate; phacoidal structures common; mostly metamorphosed to zeolite facies; sequences separated by thin-bedded (1–60 cm) sandstone, semischist, siltstone, slate, and (or) phyllite. *Includes part of the Hoh rock assemblage (Rau, 1973) and part of the Grand Valley and Western Olympic lithic assemblages (Tabor and Cady, 1978a).*

MEbx **Breccia** — Lenses and angular blocks of sandstone, siltstone, shale, conglomerate, and volcanogenic rocks in a matrix of black shale or slate with scaly cleavage or intensely sheared sandstone and siltstone; in the eastern Olympic Mountains, contains semischist and volcanic fragments in a matrix of phyllite; includes diapiric muds, fault breccias, and submarine landslide deposits. *Includes part of the Hoh rock assemblage (Rau, 1973) and part of the sandstone of the Sooes River area (Tabor and Cady, 1978a).*

Oligocene–Eocene

ΦEm **Marine sedimentary rocks** — Consists of laminated and (or) thin-bedded (1–20 cm), lithofeldspathic and feldspatholithic micaceous sandstone, siltstone, and slate in the northern and northwestern Olympic Peninsula, and semischist and slate or phyllite in the central Olympic Mountains; minor thick-bedded (>60 cm) sandstone, granule conglomerate, platy-clast breccia, and semischist; common platy shale, siltstone, or slate clasts; mostly metamorphosed to zeolite facies; common rhythmic bedding and phacoids. In the Puget Lowland and southern Olympic Peninsula, consists of thick-bedded, light gray tuffaceous siltstone and fine-grained tuffaceous sandstone, locally rhythmically interbedded; discontinuous basaltic and glauconitic sandstone beds in lower part; grades to unit ΦEn near Issaquah. *Includes the Makah and Lincoln Creek Formations, the Marrowstone Shale, the Quimper Sandstone, part of the Western Olympic, Elwha, and Needles–Gray Wolf lithic assemblages (Tabor and Cady, 1978a), part of the sandstone of the Sooes River area (Tabor and Cady, 1978a), part of the Hoh rock assemblage (Rau, 1973), and part of the Blakeley Formation.*

ΦEmst **Marine thick-bedded sedimentary rocks** — Thick sequences of laterally discontinuous, medium- to very coarse-grained, micaceous, feldspatholithic to lithofeldspathic sandstone or semischist, generally bedded thicker than 1 m; common siltstone, shale, or slate clasts grading to breccia; common phyllite and granule conglomerate; minor pebble conglomerate; metamorphosed to zeolite facies in part with local Al-pumpellyite; sequences separated by medium- to thin-bedded sandstone, siltstone, or slate. *Includes part of the Western Olympic, Elwha, and Needles–Gray Wolf lithic assemblages (Tabor and Cady, 1978a) and part of the Hoh rock assemblage (Rau, 1973).*

ΦEn **Oligocene–upper Eocene nearshore sedimentary rocks** — Basaltic sandstone, siltstone, and sandy pebble conglomerate, commonly with shallow-marine megafossils and coal; near Mount Vernon, also contains mica and quartz pebbles. *Consists of part of the rocks of Bulson Creek (Lovseth, 1975) and part of the Blakeley Formation.*

ΦEc **Continental sedimentary rocks** — Lithic to feldspathic sandstone, pebble and cobble conglomerate, siltstone, shale, claystone, and coal; locally planar-bedded or cross-stratified; conglomerate is poorly bedded and includes clasts of igneous rocks, gneiss, chert, argillite, serpentinite, and quartz; matrix is coarse sand or, less commonly, silt and clay. *Consists of the Huntingdon Formation and part of the rocks of Bulson Creek (Lovseth, 1975).*

Eocene

Em **Marine sedimentary rocks** — Very thick- to medium-bedded conglomerate, sandstone, and pillow basalt; also thin-bedded to laminated siltstone and very fine-grained sandstone with minor gray and red limestone; minor tuffaceous basaltic siltstone and mudflow breccia; locally graded and carbonaceous with rare coal stringers. *Includes part of the sandstone of the Sooes River area (Tabor and Cady, 1978a) and part of the Lyre Formation.*

Em_2 **Middle–upper Eocene marine sedimentary rocks** — Sandstone, siltstone, conglomerate, breccia, mudstone, argillite, and minor pillow basalt and sills of diabase or gabbro; graded, micaceous, carbonaceous, lithic to quartzose, concretionary, calcareous, and fossiliferous with minor chert pebbles. *Includes the Raging River, Hoko River, and Humptulips Formations, the sandstone of Bahobohosh (Snavely and others, 1993), the siltstone of Waatch Point (Snavely and others, 1993), the siltstone and sandstone of Waatch quarry (Snavely and others, 1993), part of the Lyre and Aldwell Formations, and part of the sandstone of the Sooes River area (Tabor and Cady, 1978a).*

Em_1 **Lower–middle Eocene marine sedimentary rocks** — Sandstone, siltstone, mudstone, argillite, conglomerate, and breccia; minor volcaniclastic and mafic igneous rocks; micaceous, carbonaceous, and lithofeldspathic with minor chert pebbles; siltstone and claystone are calcareous and fossiliferous. *Includes the sandstone of Scow Bay (Allison, 1959), the siltstone of Brownes Creek (Snavely and others, 1993), the basaltic sandstone and conglomerate of Lizard Lake (Snavely and others, 1993), the siltstone and sandstone of Bear Creek (Snavely and others, 1993), part of the Crescent Formation, and part of the sandstone of the Sooes River area (Tabor and Cady, 1978a).*

Ec **Continental sedimentary rocks** — Fluvial sandstone, conglomerate, and mudstone with coal seams up to several meters thick; sandstone is generally feldspathic and biotite-rich with minor muscovite; medium- to thick-bedded and cross-bedded; basal conglomerate common. *Includes the Chuckanut Formation.*

Ec_2 **Middle–upper Eocene continental sedimentary rocks** — Lithofeldspathic to feldspathic sandstone, conglomerate, siltstone, shale, and coal; interbeds of basaltic to rhyolitic tuffaceous and pumiceous sandstone and tuff; conglomerate includes chert and quartz pebbles and cobbles; weakly metamorphosed in part; abundant muscovite and leaf fossils and minor biotite. *Includes the Roslyn, Tiger Mountain, and Renton Formations, Puget Group undivided, part of the Chumstick Formation, part of the Barlow Pass Volcanics, and part of the Naches Formation undivided.*

Ec_1 **Lower–middle Eocene continental sedimentary rocks** — Micaceous-feldspathic and lithofeldspathic sandstone and pebbly sandstone, with carbonaceous siltstone, shale, conglomerate, and coal; locally interbedded with tuff and volcanic breccia. *Includes part of the Swauk Formation undivided.*

Ecg_2 **Middle–upper Eocene conglomerate and sandstone** — Pebbles, cobbles, and boulders of gneiss, vein quartz, and volcanic rock in a weakly cemented matrix of feldspathic sandstone, and angular to subrounded clasts of biotite gneiss and vein quartz in a matrix of reddish sandstone; locally dominated by clasts of tonalite, granodiorite, schist, and serpentinite. *Consists of part of the Chumstick Formation.*

Ecg_1 **Lower–middle Eocene conglomerate and sandstone** — Pebble-cobble conglomerate interbedded with feldspathic and lithofeldspathic sandstone and minor siltstone and shale, and monolithologic fanglomerates with serpentinized peridotite in a serpentinite sand matrix. *Consists of part of the Swauk Formation undivided.*

Eocene–Paleocene

ERm **Marine sedimentary rocks** — Lithic sandstone, semischist, siltstone, slate, granule or pebble conglomerate, and siltstone- or slate-clast breccia; very dark gray; commonly laminated and rhythmically bedded with abundant muscovite and basalt detritus; weakly metamorphosed. *Consists of the Blue Mountain unit (Tabor and Cady, 1978a).*

CRETACEOUS

Km_1 **Marine sedimentary rocks** — Feldspathic sandstone, shale, and minor conglomerate composed of pebbles, cobbles, and boulders of plutonic, metamorphic, volcanic, and sedimentary rocks in a feldspathic sandstone matrix. *Includes the conglomeratic strata of Two Buttes Creek (R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000), the strata of Freezeout Creek (R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000) of the Harts Pass Formation, Harts Pass Formation undivided, the Panther Creek Formation, Jackita Ridge unit undivided (R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000), and the strata of Majestic Mountain (R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000).*

Kn **Nearshore sedimentary rocks** — Sandstone, conglomerate, shale, and minor coal deposited during several deep-marine to terrestrial cycles. *Includes the Cedar District, Protection, Extension, Haslam, and Comox Formations and Nanaimo Group undivided.*

Kc_2 **Continental sedimentary rocks** — Well-stratified, thin- to thick-bedded biotite-bearing lithofeldspathic sandstone to chert-lithic sandstone, siltstone, and conglomerate; locally contains mudstone and andesitic volcanic rocks; conglomerates are rich in either chert clasts or sandstone, siltstone, and granite clasts; locally contains fluvial redbeds, paleosols, wood, leaf and fern fossils, scoured surfaces, load casts, and in-situ stumps. *Consists of Goat Wall unit undivided (R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000), the Ventura Member of the Midnight Peak Formation, Winthrop Formation undivided, the Slate Peak Member of the Virginian Ridge Formation, the strata of Cow Creek (R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000) of the Virginian Ridge Formation, part of the volcanic rocks of Three A M Mountain (R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000) of the Winthrop Formation, and part of the Midnight Peak Formation undivided.*

Kcg_2 **Conglomerate** — Chert-pebble conglomerate with minor sandstone and siltstone; locally planar-bedded with low-angle cross-beds; includes dikes and sills of mafic pyroxene and (or) hornblende porphyry. *Consists of the Devils Pass Member of the Virginian Ridge Formation.*

Kcg_1 **Conglomerate** — Cobble conglomerate; clasts dominantly hornblende tonalite, with granodiorite, aplite, felsic volcanics, and rare limestone. *Consists of the conglomerate of the Harts Pass Formation (R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000).*

CRETACEOUS–JURASSIC

KJm **Marine sedimentary rocks** — Sandstone, siltstone, and minor tuff; sandstones commonly volcanolithic; west of the Straight Creek fault, also contains argillite, tuffaceous chert, pebble to boulder conglomerate and breccia, radiolarian chert, marl, and rare coal; conglomerate typically rich in volcanic and plutonic clasts; siltstone and sandstone are thin- to thick-bedded; contains rip-up clasts; locally faulted and (or) metamorphosed. *Includes part of the Fidalgo Complex.*

KJn **Nearshore sedimentary rocks** — Volcanic-lithic pebble conglomerate and breccia with siltstone and sandstone interbeds. *Consists of the Spieden Group.*

JURASSIC

Jm **Marine sedimentary rocks** — Thin-bedded volcanic-lithic sandstone and pelite. *Consists of the Dewdney Creek Formation.*

TRIASSIC

Tn **Nearshore sedimentary rocks** — Volcanic-lithic siltstone, sandstone, tuff, conglomerate, breccia, and limestone. *Consists of the Haro Formation.*

MIXED VOLCANIC AND SEDIMENTARY ROCKS

PALEOCENE–CRETACEOUS

RKvs **Sedimentary and volcanic rocks, undivided** — At Point of the Arches (T32N R16W), consists of silicified, compositionally heterogeneous, micaceous subquartzose and quartzose sandstone interbedded with argillite, chert, metabasalt, pillow basalt, basalt breccia, mudflow breccia, conglomerate, and mélange of Paleocene and (or) Cretaceous rocks; mélange consists of silicified feldspathic quartzose sandstone, metadacite, metatuff, basalt, phyllite. Unit also includes minor Oligocene–Eocene marine turbidites and Paleocene intrusive hornblende dacite.

CRETACEOUS–JURASSIC

KJvs **Volcanic and sedimentary rocks, undivided** — Basalt to dacite tuff, lapilli tuff, and flows interlayered with thin- to very thick-bedded volcaniclastic or tuffaceous siltstone, sandstone, and conglomerate; locally includes chert and siliceous argillite; contains pumpellyite, chlorite, epidote, prehnite, albite, and possibly aragonite. *Consists of part of the Fidalgo Complex.*

JURASSIC–PERMIAN

JPvs **Volcanic and sedimentary rocks, undivided** — Greenstone with local pillows and minor tuff and breccia, volcanic-lithic sandstone, argillite, limestone, ribbon chert, and rare uralitic pyroxene gabbro; sandstones include marine fossils; mostly recrystallized to prehnite-pumpellyite facies. *Consists of the Hozomeen Group.*

VOLCANIC DEPOSITS AND ROCKS

QUATERNARY

Qvr **Rhyodacite to dacite** — Biotite-hypersthene-hornblende-plagioclase rhyodacite, hornblende-pyroxene dacite, and olivine-pyroxene and hornblende-pyroxene andesite; intrudes and overlies unit Qvt near Mount Baker. *Includes part of the rocks of Kulshan caldera undivided (Hildreth, 1994, 1996; Hildreth and Lanphere, 1994).*

Qvd **Dacite flows** — Porphyritic clinopyroxene-hypersthene dacite flows and rubble; mostly unconformable on pre–Glacier Peak rocks; includes oxyhornblende-hypersthene dacite on Disappointment Peak. *Consists of volcanic rocks and deposits of Glacier Peak undivided (Culver, 1936) and the dacite of Disappointment Peak (Tabor and Crowder, 1969).*

Qvp **Pyroclastic deposits** — Dacite ash and pumice deposits east of Glacier Peak and near-vent fragmental deposits of Mount Baker. *Includes Glacier Peak tephra (Porter, 1976; Beget, 1981, 1982), part of the andesite of Black Buttes (Tabor and others, in press b), and part of the White Chuck assemblage (Beget, 1981, 1982).*

Qvt **Tuff** — Intracaldera rhyodacite ash-flow tuff filling Kulshan caldera locally includes caldera-lake sedimentary deposits, intercalated sheets of rockfall breccia, caldera-collapse megablocks, cross-cutting andesite dikes, welded dacite vitric tuff, and irregular intrusions; White Chuck tuff consists of vitric tuff, locally with scattered pumiceous concentrations. *Includes the White Chuck tuff (Ford, 1959; Tabor and Crowder, 1969), the ignimbrite of Swift Creek (Hildreth, 1994, 1996; Hildreth and Lanphere, 1994), part of the rocks of Kulshan caldera undivided (Hildreth, 1994, 1996; Hildreth and Lanphere, 1994), part of the White Chuck fill (Ford, 1959; Tabor and Crowder, 1969), and part of the White Chuck assemblage (Beget, 1981, 1982).*

Qva **Andesite flows** — Pyroxene andesite and minor hornblende andesite flows, flow breccias, dikes, and hypabyssal intrusives on and near Mount Baker; also contains agglutinate, scoria, pyroclastic-flow deposits, and olivine basalt. *Consists of the andesites of Bastile Ridge, Coleman Pinnacle, Cougar Divide, Lasiocarpa Ridge, Lava Divide, The Portals, Pinus Lake, and Table Mountain (Tabor and others, in press b), the andesite of Swift Creek (Hildreth, 1996), andesite of Mount Baker undivided (Tabor and others, in press b), and part of the andesite of Black Buttes (Tabor and others, in press b).*

Qvb **Basalt flows** — Olivine and pyroxene basalt flows, tuff, scoria, and breccia with less abundant hyaloclastite and basaltic andesite. *Consists of the White Chuck cinder cone (Rosenberg, 1961; Beget, 1981; Tabor and Crowder, 1969) and the basalts of Lake Shannon, Park Butte, and Sulphur Creek (Tabor and others, in press b).*

Qvl **Lahars** — Unsorted, generally unstratified mixtures of pebbles, cobbles, and boulders supported by a matrix of sandy mud originating from Mount Baker and Mount Rainier, and moderately to well-bedded assemblages of lahars, dacite pyroclastic flow and surge deposits, air-fall ash, minor lacustrine deposits and alluvium, and rare dacite flows originating from Glacier Peak; the Osceola Mudflow is clay-rich and cohesive, becoming better sorted downstream, and forms hummocks as high as 20 m. *Includes the Suiattle fill (Ford, 1959; Tabor and Crowder, 1969; Beget, 1981), the White Chuck, Kennedy Creek, Dusty Creek, Chocolate Creek, and Baekos Creek assemblages (Beget, 1981), the Lyman lahar (Dragovich and others, 1999, 2000a,b), the lahar of the Middle Fork Nooksack River (Hyde and Crandell, 1978), the Osceola Mudflow, and part of the White Chuck fill (Ford, 1959; Tabor and Crowder, 1969).*

TERTIARY

Pliocene

Rv **Volcanic rocks** — Rhyolitic, andesitic, and basaltic altered tuff, volcanic breccia, volcanic sandstone, welded tuff, and tuffaceous conglomerate; minor basalt flows. *Consists of the volcanic rocks of Gamma Ridge (Crowder and others, 1966; Tabor and Crowder, 1969) and part of the Hannegan Volcanics.*

Rvx **Volcanic breccia** — Volcanic breccia with clasts of andesite and older rocks in an andesite tuff matrix. *Consists of part of the Hannegan Volcanics.*

Miocene

Mvt **Tuff** — Rhyodacite crystal-lithic ash-flow tuff. *Consistsofpar toftheF ifesP eakF ormation.*

Mva **Andesite** — Andesite, basaltic andesite, and basalt flows and flow breccias; subordinate porphyritic hornblende and crystal-lithic tuff; some flows contain both clinopyroxene and orthopyroxene; minor mudflow breccia, dacite, volcanic sandstone, conglomerate, and siltstone with leaf fossils. *Includes the Howson andesite (Smith and Calkins, 1906), the andesite of Sugarloaf Peak (Page, 1939; Tabor and others, 1987a), and part of the Fifes Peak Formation.*

Mv_g **Middle Miocene Grande Ronde Basalt** — Fine-grained, aphyric to sparsely phyric basalt with basaltic andesite chemistry; interbeds of tuffaceous sandstone, siltstone, and conglomerate. *Consists of Grande Ronde Basalt undivided.*

Mvi_g **Middle Miocene Grande Ronde Basalt invasive flows** — Sills and dikes of basaltic andesite and peperites formed by the invasion of Grande Ronde Basalt lava into poorly consolidated sediments. *Consists of the invasive flow of Howard Creek (Rosenmeier, 1968) of the Grande Ronde Basalt.*

Mvc **Volcaniclastic rocks** — Rhyolite, andesite, and dacite volcaniclastic breccia, sandstone, siltstone, and conglomerate; tuff and tuff breccia; locally abundant schist and granitic clasts up to 200 m long and 50 m high; local chlorite, sericite, and epidote alteration or thermal metamorphism. *Includes the breccia of Kyes Peak (Tabor and others, 1982a) and the volcaniclastic rocks of Cooper Pass (Ashleman, 1979).*

Mvc_2 **Volcaniclastic rocks** — Tuffaceous, pumiceous, poorly sorted, indurated sandstone and conglomerate interbedded with numerous air-fall tuffs, located around the south shore of Lake Sammamish (T24N R6E).

Miocene–Oligocene

MΦvt **Tuff** — Rhyolite to dacite tuff, ash-flow tuff, and breccia. *ConsistsoftheEagletuff(Y eats,1977).*

MΦva **Andesite flows** — Predominantly dark-green to black andesite flows and flow breccia; also includes basaltic andesite and basalt flows, breccia, well-bedded tuff, and volcaniclastic rocks. *Consists of the volcanic rocks of Eagle Gorge (Hammond, 1963; Tabor and others, 2000).*

Oligocene

Φvr **Rhyolite** — Rhyolite tuff, breccia, flows, and local intrusions. *Includes part of the volcanic rocks of Chikamin Creek (Tabor and others, 1987a) and part of the volcanic rocks of Mount Daniel (Simonson, 1981; Tabor and others, 2000).*

Φvd **Dacite** — Dacite and minor andesite and rhyolite in flows, flow breccia, welded tuff, dikes, sills, domes, and plugs; local sandstone-block megabreccia; alteration common. *Includes the volcanic rocks on Garfield Mountain (Tabor and others, 1993), part of the volcanic rocks of Mount Daniel (Ellis, 1959; Tabor and others, 1993, 2000), and part of the volcanic rocks of Pioneer Ridge (Tabor and others, in press b).*

Φvt **Tuff** — Rhyolite to dacite, fine-grained to lapilli, crystal-lithic and ash-flow tuff; rhyolite to dacite breccia; locally interbedded with feldspathic sandstone. *Includes the Lake Keechelus tuff member (Tabor and others, 2000) of the Ohanapecosh Formation, the tuff of Boundary Creek (R. A. Haugerud and R. W. Tabor, USGS, written commun., 2000), part of the volcanic rocks of Big Bosom Buttes (Tabor and others, in press b), part of the volcanic rocks of Chikamin Creek (Tabor and others, 1987a), and part of the volcanic rocks of Mount Daniel (Tabor and others, 2000).*

Φvc **Volcaniclastic rocks** — Well-bedded, multicolored, lithic and crystal-lithic andesite or dacite tuff, breccia, basalt and andesite flows, and rhyolite tuff; locally abundant leaf fossils. *Includes Ohanapecosh Formation undivided and the volcanic rocks of Rattlesnake Mountain (Walsh, 1984).*

Φvx **Volcanic breccia** — Dacite and andesite breccia, mudflow breccia, and minor tuff beds, flows, feldspathic sandstone, and conglomerate. *Includes the breccia of Round Lake (Tabor and others, in press a), the volcanic rocks of Mount Rahm (Haugerud and others, 1991), part of the volcanic rocks of Big Bosom Buttes (Tabor and others, in press b), and part of the volcanic rocks of Pioneer Ridge (Tabor and others, in press b).*

Oligocene–Eocene

ΦEva **Andesite** — Porphyritic basaltic andesite flows and flow breccias with minor andesite, basalt, dacite, and volcaniclastic rock. *Includes rocks previously called Keechelus Andesitic Series (Warren and others, 1945).*

ΦEvb **Basalt** — Dark green-gray basalt and basaltic tuffs, basalt breccia, and basaltic sandstone with rare pillow or amygdaloidal basalt; includes gabbro, diabase, greenstone, and interbedded gray or brick-red limestone; metamorphosed to zeolite facies. *Includes part of the Needles–Gray Wolf, Western Olympic, and Elwha lithic assemblages (Tabor and Cady, 1978a).*

INTRUSIVE ROCKS

TERTIARY

Pliocene

Rida **Dacite** — Porphyritic biotite-hornblende-hypersthene dacite and dacite breccia forming plugs and dikes, locally with quartz phenocrysts and well-developed columnar jointing.

Rig **Granite** — Hornblende-biotite granite, granodiorite, and porphyritic granodiorite; compositionally heterogeneous; commonly altered. *Includes the granite of Ruth Mountain (Tabor and others, in press b) of the Chilliwack composite batholith and the granite porphyry of Egg Lake (Tabor and others, in press b) of the Chilliwack composite batholith.*

Riqm **Quartz monzonite** — Quartz monzonite and granite with minor granodiorite and quartz monzodiorite; uralitic with relict clinopyroxene. *Consists of the quartz monzonite and granite of Nooksack Cirque (Tabor and others, in press b) of the Chilliwack composite batholith.*

Rigd **Granodiorite** — Pyroxene-biotite-hornblende granodiorite and quartz monzodiorite. *Includes the Lake Ann stock (James, 1980) of the Chilliwack composite batholith and the Cool Glacier stock (Tabor and Crowder, 1969).*

Riq **Quartz diorite** — Biotite-clinopyroxene quartz diorite and quartz monzodiorite with minor hypersthene and uralite; locally plagioclase-phyric. *Consists of the quartz diorite and quartz monzodiorite of Icy Peak (Tabor and others, in press b) of the Chilliwack composite batholith.*

Pliocene–Miocene

RMida **Dacite** — Biotite-hornblende-hypersthene dacite plugs with columnar jointing and dikes; also includes altered breccia and flows. *Consists of the volcanic rocks of Cady Ridge (Crowder and others, 1966).*

Miocene

Φiq **Quartz diorite** — Biotite-hornblende quartz diorite and porphyritic hornblende-clinopyroxene quartz diorite. *Consists of the Price Glacier pluton (Tabor and others, in press b) of the Chilliwack composite batholith and part of the Squire Creek stock undivided (Tabor and others, in press a).*

Φii **Intermediate intrusive rocks** — Agmatite consisting of swarms of dark rounded inclusions of mafic biotite-hornblende quartz diorite and fine-grained tonalite in a granodiorite and tonalite matrix. *Consists of part of the granodiorite of Mount Despair (Tabor and others, in press b) of the Chilliwack composite batholith.*

Φib **Basic (mafic) intrusive rocks** — Pyroxene and (or) hornblende gabbro, diorite, and quartz diorite. *Consists of the gabbro of Copper Lake (Tabor and others, in press b) of the Chilliwack composite batholith, the diorite of Ensawkwatch Creek (Tabor and others, in press b) of the Chilliwack composite batholith, and part of the Chilliwack composite batholith undivided.*

Oligocene–Eocene

ΦEida **Dacite** — Porphyritic dacite, andesite, and hornblende tonalite; commonly altered to secondary epidote, chlorite, sericite, and albite. *Consists of the Sauk ring dike (Tabor and others, in press a).*

ΦEian **Pyroxene andesite** — Pyroxene andesite sills up to 120 m thick and less common dikes; commonly dark gray, except white to red where hydrothermally altered on Tiger Mountain and where they intrude coal seams. *Consists of rocks formerly called the intrusives of the Keechelus Andesitic Series (Warren and others, 1945).*

Eocene

Ei **Dikes, undivided** — Chiefly dark-colored aphanitic dacite, rhyodacite, spessartite, hornblende-quartz diabase, augite minette, and kersantite; also light-colored aphyric biotite-quartz granite, granodiorite, quartz diorite, and minor alaskite; occurs as dikes mostly less than 60 m thick.

Eir **Rhyolite** — In the Teanaway River basin, consists of dikes and plugs of friable white rhyolite; elsewhere, consists of porphyritic biotite hornblende dacite. *IncludestheporphyriticdaciteofBasaltP eak(Cater ,1982;T aborand*

METAMORPHIC ROCKS

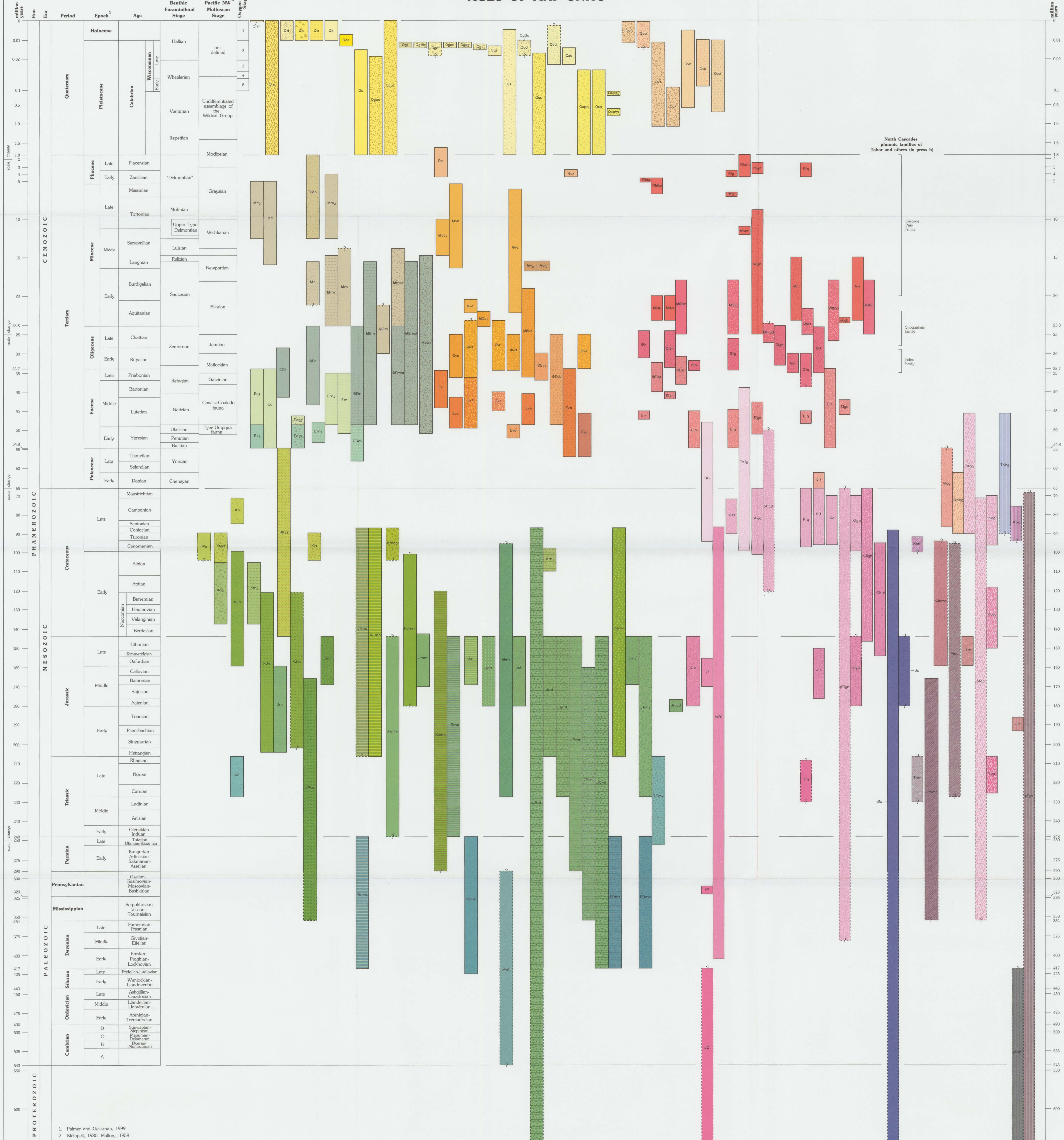
Greenschist and Blueschist Facies (Low-Grade Rocks)

Amphibolite Facies and Higher (High-Grade Rocks)

MIXED METAMORPHIC AND IGNEOUS ROCKS

ULTRAMAFIC ROCKS

AGES OF MAP UNITS



1. Palmer and Geissman, 1999
2. Kleinpell, 1980; Mallory, 1959
3. Addicott, 1979; Armentrout, 1981

FIGURES

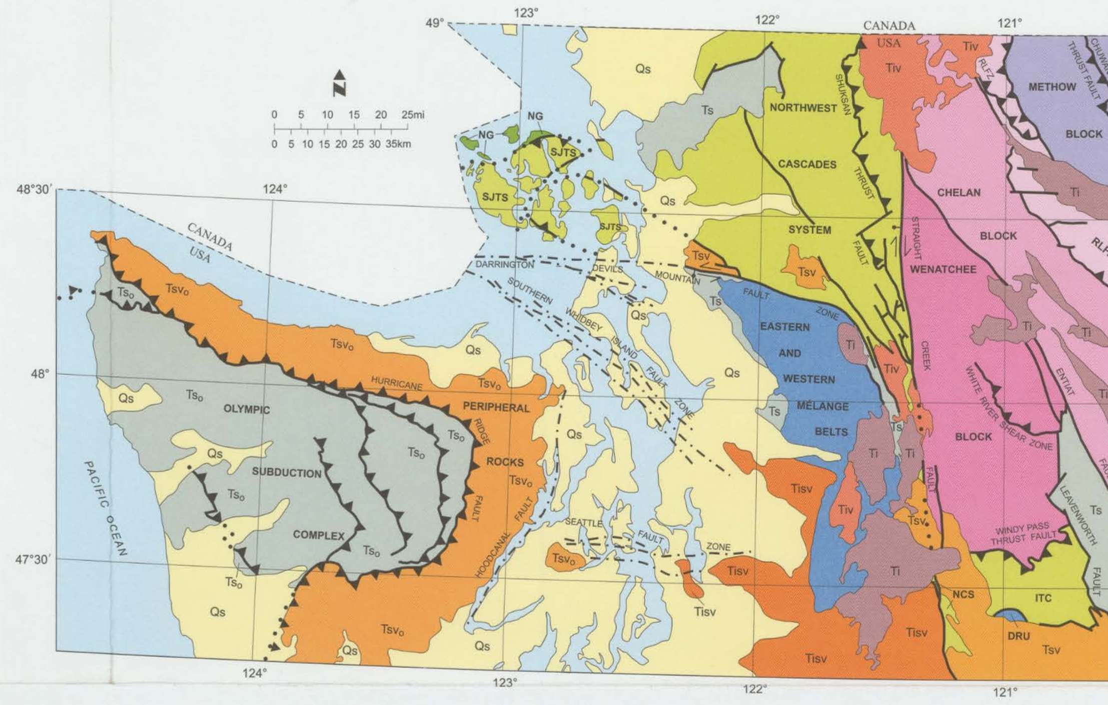
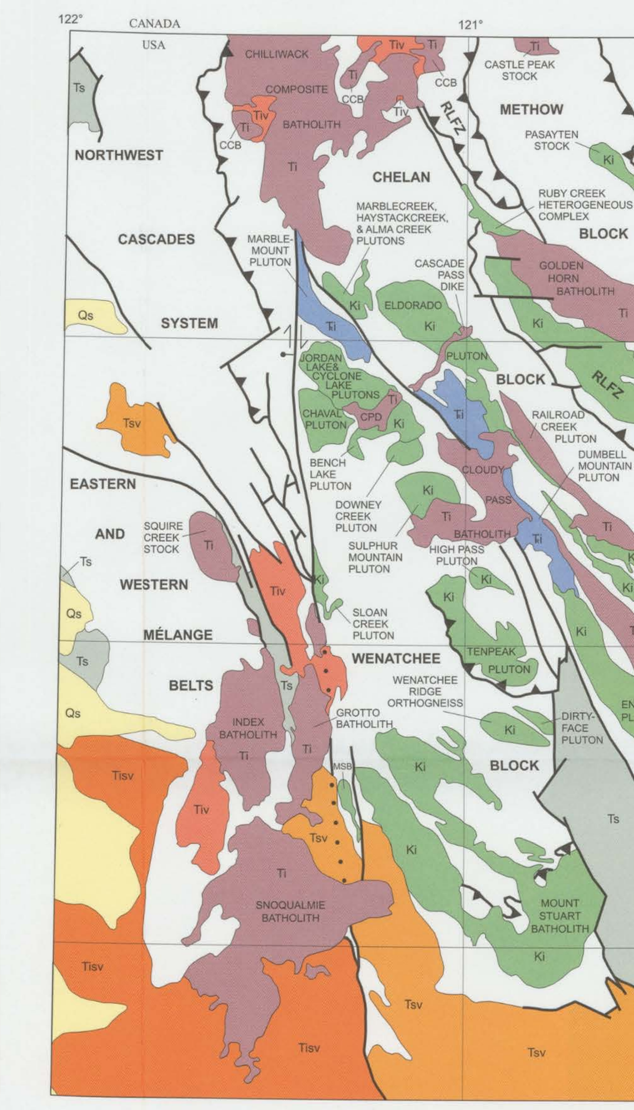


Figure 4. Simplified geologic map of northwestern Washington showing major lithotectonic domains. The Puget Lowland (Fig. 2) is transected by northwest-, northeast-, and west-trending faults bounding thick sequences of Paleocene to Miocene rocks. The Olympic subduction complex and peripheral rocks are exposed as a westward-verging accretionary thrust belt in the core of an east-plunging antiform (Tabor, 1975). Metamorphic rocks in the Ross Lake fault zone (RLFZ) have protoliths characteristic of both the Methow block and the North Cascades Crystalline Core; metamorphism is intermediate between the high-grade metamorphic rocks of the crystalline core and non-metamorphosed rocks of the Methow block. The Chelan block has mostly Tertiary uplift or exhumation ages, while the Wenatchee block has mostly Late Cretaceous uplift or exhumation ages. In the Northwest Cascades System (NCS) and the San Juan thrust system (SJTS), the Helena–Haystack mélange and Fidalgo Complex (see Sheet 1) probably occur as the structurally highest portion (Whetten and others, 1980b; Tabor, 1994). The Nanaimo Group (NG) forms an external unit to the NCS and SJTS (Brandon and others, 1988). The Nooksack Formation (see Sheet 1), including the Wells Creek Volcanics of Misch (1966)(Nooksack terrane of Tabor and others, 1994), forms the autochthon upon which the Northwest Cascades System was tectonically emplaced during the Cretaceous. The De Roux unit (formerly part of the Ingalls Tectonic Complex) is probably a tectonic sliver of the Western mélange belt imbricated onto the Ingalls Tectonic Complex (Miller and others, 1993b). The Eastern and Western mélange belts of Frizzell and others (1984), including the Trafton sequence of Danner (1966), may have been thrust over Northwest Cascades System in the Cretaceous to earliest Tertiary (Tabor, 1994).



Plutonic rocks (Fig. 5 only)

- Ti — Tertiary plutons
- Ti — Triassic metaplutons
- Ki — Cretaceous plutons and metaplutons
- pre-Tertiary bedrock (locally includes Tertiary orthogneiss in the Chelan Block)

EXPLANATION (Figs. 4 and 5)

- high-angle fault – dotted where concealed
- thrust fault – sawteeth on upper plate; dotted where concealed
- oblique-slip fault – arrows show relative horizontal movement; bar and ball on downthrown side; dotted where concealed
- major suspected active faults

GEOLOGIC UNITS

Quaternary Deposits

- Qs — surficial deposits, undivided

Tertiary Rocks

- Tisv — intrusive, volcanic, and sedimentary rocks, undivided
- Ts — sedimentary rocks; locally divided into:
  - Ts_o — Olympic subduction complex
- Tsv — sedimentary and volcanic rocks; locally divided into:
  - Tsv_o — peripheral rocks of the Olympic Mountains
- Tiv — intrusive and volcanic rocks
- Ti — intrusive rocks

Pre-Tertiary Rocks

- OB — Okanogan block
- Methow block

North Cascades Crystalline Core (Tabor and others, 1987b, 1989); divided into:

- RLFZ — rocks of the Ross Lake fault zone
- Chelan block (locally includes Tertiary orthogneiss)
- Wenatchee block
- NCS — Northwest Cascades System (Brown and others, 1987); locally divided into:
  - SJTS — San Juan thrust system (Brandon and others, 1988; Whetten and others, 1978)
  - ITC — Ingalls tectonic complex (Miller, 1980, 1985)
- NG — Nanaimo Group
- Eastern and Western mélange belts (Frizzell and others, 1984); locally divided into:
  - DRU — De Roux unit (Miller, 1985; Miller and others, 1993b)

Figure 5. Map showing the major batholiths and plutons of the North Cascades region. See Figure 4 for the names of the lithotectonic domains not shown here. CCB, Chilliwack composite batholith; CPD, Cascade Pass dike; MSB, Mount Stuart batholith.

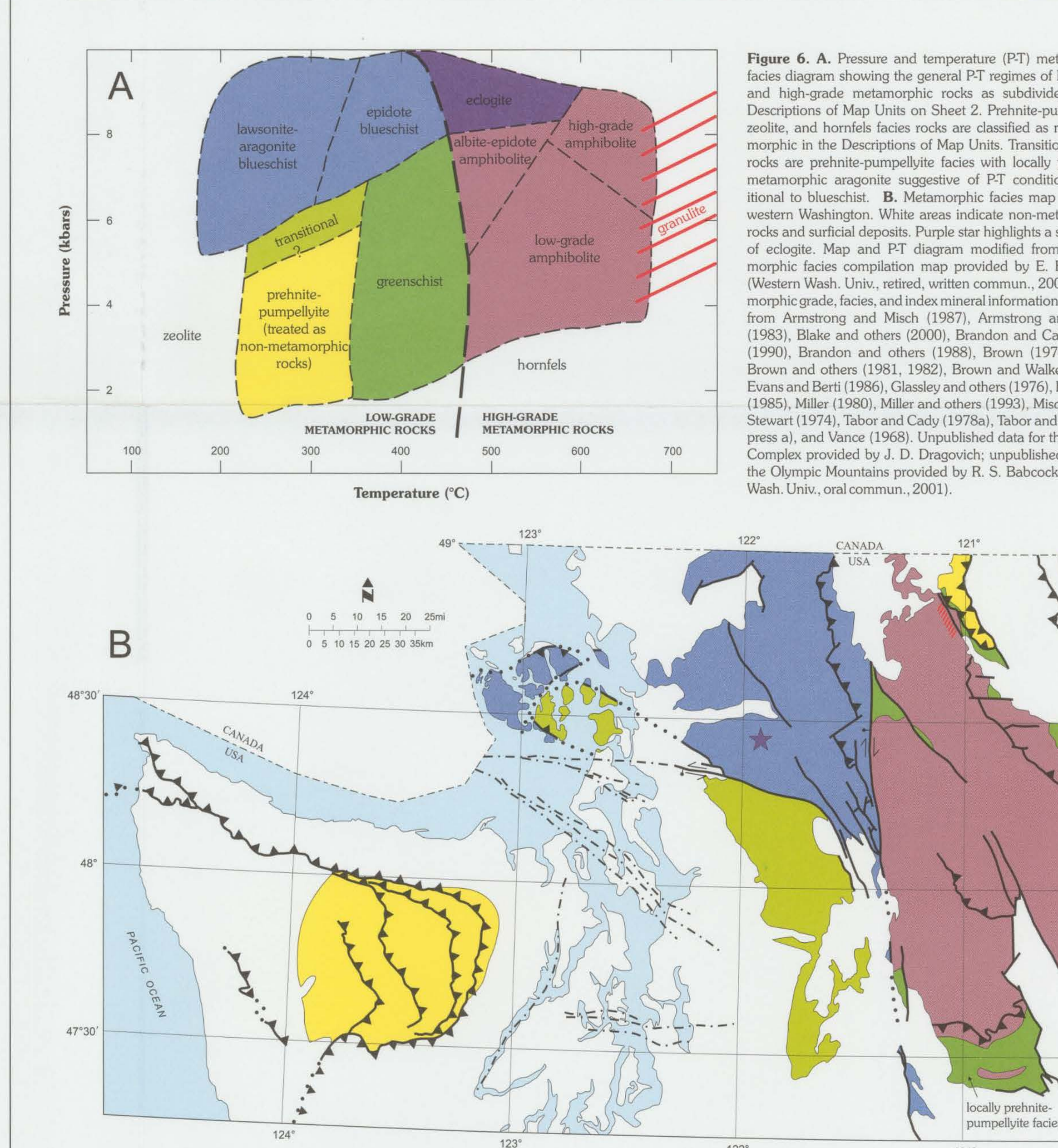


Figure 6. A. Pressure and temperature (P-T) metamorphic facies diagram showing the general P-T regimes of low-grade and high-grade metamorphic rocks as subdivided in the Descriptions of Map Units on Sheet 2. Prehnite-pumpellyite, zeolite, and hornfels facies rocks are classified as non-metamorphic in the Descriptions of Map Units. Transitional facies rocks are prehnite-pumpellyite facies with locally preserved metamorphic aragonite suggestive of P-T conditions transitional to blueschist. **B.** Metamorphic facies map of northwestern Washington. White areas indicate non-metamorphic rocks and surficial deposits. Purple star highlights a small area of eclogite. Map and P-T diagram modified from a metamorphic facies compilation map provided by E. H. Brown (Western Wash. Univ., retired, written commun., 2001). Metamorphic grade, facies, and index mineral information compiled from Armstrong and Misch (1987), Armstrong and others (1983), Blake and others (2000), Brandon and Calderwood (1990), Brandon and others (1988), Brown (1974, 1988), Brown and others (1981, 1982), Brown and Walker (1993), Evans and Berti (1986), Glassley and others (1976), Haugerud (1985), Miller (1980), Miller and others (1993), Misch (1966), Stewart (1974), Tabor and Cady (1978a), Tabor and others (in press a), and Vance (1968). Unpublished data for the Fidalgo Complex provided by J. D. Dragovich; unpublished data for the Olympic Mountains provided by R. S. Babcock (Western Wash. Univ., oral commun., 2001).