GEOLOGIC MAP OF WASHINGTON - NORTHEAST QUADRANT

by

KEITH L. STOFFEL, NANCY L. JOSEPH, STEPHANIE ZURENKO WAGGONER,
CHARLES W. GULICK, MICHAEL A. KOROSEC, and BONNIE B. BUNNING

WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
GEOLOGIC MAP GM-39
1991

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Brian Boyle - Commissioner of Public Lands
Art Stearns - Supervisor
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Raymond Lasmanis, State Geologist

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Photograph on envelope: Northwest-dipping cuesta formed on resistant layers of gneiss in the Okanogan metamorphic core complex near Riverside, Washington; Okanogan River in the foreground. Aerial view to the northeast. Photograph courtesy of K. F. Fox, Jr., U.S. Geological Survey.

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PREFACE

State geologic maps are valuable tools that can be used for exploration for mineral resources, evaluation of geologic hazards, land-use planning, and education. Previous geologic maps of the state of Washington were published by our predecessors, the Washington Division of Geology (Culver, 1936) and the Washington Division of Mines and Geology (Huntting and others, 1961). Both of these maps are now out of print. The scale of the first two state geologic maps was 1:500,000. However, 74 percent of all published and thesis geologic maps of areas in Washington postdate the 1961 state geologic map. We therefore decided to publish the new state geologic map in four quadrants at a scale of 1:250,000 to better display this accumulated information.

As in the first map of this quadrant series (Walsh and others, 1987), we have attempted to make this geologic map useful at several levels of detail and to a variety of users by (1) employing time-lithologic units on the map rather than formations; (2) portraying unconsolidated deposits in as much detail (where available) as bedrock units; (3) using a multiple-level scheme of colors, patterns, and map symbols to represent the geologic units; and (4) providing a wider range of supporting materials than is commonly found on state geologic maps. Full explanation of these characteristics is given in the text that follows.

The state geologic map program has entailed an exhaustive effort to obtain all existing published and unpublished geologic map data, and to synthesize the information into a series of 1:100,000- and 1:250,000-scale geologic maps and reports. This project has enhanced working contacts, data exchange, and mutual support among geologists at the Division of Geology and Earth Resources and at universities, in federal agencies, and in the private sector.

We are proud of this map and look forward to the continuing challenge of compiling the remaining two quadrant maps. We hope that you will realize as many benefits in the use of this map as we have in its preparation.

J. Eric Schuster, Project Manager

Bonnie B. Bunning, Assistant Project Manager

William M. Phillips, Assistant Project Manager

May 22, 1991

GEOLOGIC MAP OF WASHINGTON – NORTHEAST QUADRANT

by

Keith L. Stoffel, Nancy L. Joseph, Stephanie Zurenko Waggoner,
Charles W. Gulick, Michael A. Korosec, and Bonnie B. Bunning

INTRODUCTION

The Geologic Map of Washington – Northeast Quadrant is the second in a series of four 1:250,000-scale geologic maps, which together will make up the third geologic map of Washington published by the Washington Division of Geology and Earth Resources and its predecessors. The Geologic Map of Washington – Southwest Quadrant, the first map in the series, is available as Washington Division of Geology and Earth Resources Geologic Map GM-34 (Walsh and others, 1987). The remaining two maps in the series, the Geologic Map of Washington – Southeast Quadrant and the Geologic Map of Washington – Northwest Quadrant, are currently in preparation (May 1991).

In addition to the geologic map, the northeast quadrant publication includes a **key to geologic units**, **descriptions of map units**, a **list of named units**, a **correlation diagram**, a 1:625,000-scale **bedrock geologic and tectonic map**, a **summary of the geologic history of northeastern Washington**, **source-of-data maps**, and a list of **references cited**. A topographic base map is available separately.

MAP COMPILATION

Preliminary compilation of the Geologic Map of Washington – Northeast Quadrant began in 1984, when all available published and unpublished geologic information was compiled on sixteen 1:100,000-scale quadrangles. (See Sheet 1.) Between 1984 and 1988, Division of Geology and Earth Resources (DGER) geologists mapped (at reconnaissance and detailed levels) areas where previous geologic mapping was either inadequate or lacking. New geologic mapping was also acquired during that time through a DGER geologic mapping support program, which funded 23 university graduate student and faculty member mapping projects. (See Acknowledgments.) The new geologic mapping has been augmented by 23 new potassium-argon (K-Ar) ages, 2 new radiocarbon (^{14}C) ages, and 230 new whole-rock geochemical analyses, which are provided in the reports listed in Table 1.

In 1990, following extensive reviews by geologists outside the DGER, fourteen of the sixteen 1:100,000-scale geologic maps were released as Washington Division of Geology and Earth Resources open-file reports (Table 1). Reports were not prepared for the Chelan and Wenatchee quadrangles because geologic maps of those quadrangles have been published by the U.S. Geological Survey (USGS) (Tabor and others, 1982, 1987). The sixteen 1:100,000-scale geologic maps and accompanying source-of-data maps, descriptions of map units, isotopic and fossil age data, and whole-rock geochemistry data were then synthesized to prepare the 1:250,000-scale geologic map of Washington and the other components of this publication.

ACKNOWLEDGMENTS

The Geologic Map of Washington – Northeast Quadrant is the culmination of the efforts of hundreds of geologists over the better part of a century. The contributions of many of the geologists are acknowledged by citation. (See **References Cited**.) Regrettably, many other significant works are not cited. We gratefully acknowledge all those geologists who have made vital contributions toward deciphering the complex geology of northeastern Washington.

Numerous individuals have contributed greatly to the success of the state geologic map project and the publication of this report. We offer warm thanks to the people named on the following pages for their invaluable contributions.

Table 1. Compiler, 1:100,000-scale quadrangle, and DGER open-file report number for geologic maps in the northeast quadrant of Washington

Compilers	Quadrangle	Open File Report Number
Bunning, B. B.	Twisp	90-9
Gulick, C. W.	Moses Lake	90-1
Gulick, C. W.	Ritzville	90-2
Gulick, C. W.; Korosec, M. A.	Banks Lake	90-6
Gulick, C. W.; Korosec, M. A.	Omak	90-12
Joseph, N. L.	Colville	90-13
Joseph, N. L.	Nespelem	90-16
Joseph, N. L.	Spokane	90-17
Korosec, M. A.	Chelan	—
Stoffel, K. L.	Republic	90-10
Stoffel, K. L.	Oroville	90-11
Stoffel, K. L.; McGroder, M. F.	Robinson Mtn.	90-5
Waggoner, S. Z.	Rosalia	90-7
Waggoner, S. Z.	Chewelah	90-14
Waggoner, S. Z.	Coulee Dam	90-15
Walsh, T. J.	Wenatchee	—

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Edward E. Geary (San Jose State University)
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Charles W. Gulick (Eastern Washington University)
Willard N. Hopkins (San Jose State University)
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Moira T. Smith (University of Arizona)
Dale F. Stradling (Eastern Washington University)
W. Michael Wade (San Jose State University)
Laureen Wagoner (Washington State University)
Patricia J. White (University of Washington)
Glenn R. Wiedenhoeft (Washington State University)

Unpublished Geologic Mapping

Brian F. Atwater (USGS)
Eric R. Braun (consulting geologist)
Eric S. Cheney (University of Washington)
Edward D. Fields (Boise Cascade Corp.)
Kenneth F. Fox, Jr. (USGS)
John W. Goodge (formerly University of Montana)
Vicki L. Hansen (formerly University of Montana)
Larry G. Hanson (formerly University of Washington)
Eugene P. Kiver (Eastern Washington University)
Michael F. McGroder (Exxon Production Research Co.)
Fred K. Miller (USGS)
C. Dean Rinehart (USGS)
J. Eric Schuster (DGER)
James R. Snook (Eastern Washington University)
Dale F. Stradling (Eastern Washington University)
Gerald W. Thorsen (DGER, retired)
Victoria R. Todd (USGS)
Joseph R. Wilson (Law Environmental Services; formerly USGS)
Robert G. Yates (USGS, retired)

Unpublished Isotopic Age Data

Brian F. Atwater (USGS)
Robert J. Fleck (USGS)
Eugene P. Kiver (Eastern Washington University)
Fred K. Miller (USGS)
Robert B. Miller (San Jose State University)
C. Dean Rinehart (USGS)
Robert C. Roback (University of Texas at Austin)
Victoria R. Todd (USGS)

Fossil Identification and/or Data

Claire Carter (USGS)
J. Thomas Dutro, Jr. (USGS)
Anita G. Harris (USGS)
Philip R. Jackson (Teck Resources Inc.)
Kirk R. Johnson (Yale University)
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Whole-rock Geochemical Analyses

Peter R. Hooper (Washington State University)

Field Trip and Mine Tour Leaders

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Richard Tschauder (Hecla Mining Co.)
Paul L. Weis (USGS, retired)
James W. Whipple (USGS)

Discussions of Regional Geology

Kathryn Andrew (British Columbia Ministry of Energy, Mines and Petroleum Resources)
Brian F. Atwater (USGS)
Herb E. Bradshaw (consulting geologist)
Eric S. Cheney (University of Washington)
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Robert B. Miller (San Jose State University)
Jack A. Morton (Resource Finance Inc.)
C. Dean Rinehart (USGS)
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Review of 1:100,000-scale Open-File Reports

Brian F. Atwater (USGS)
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Paul L. Weis (USGS, retired)

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

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Fred K. Miller (USGS)
Donald A. Swanson (USGS)
Rowland W. Tabor (USGS)

MAP DESIGN

Base Map

No appropriate topographic base map of northeastern Washington existed when the state geologic map project was initiated. Therefore, the Division chose to construct a new 1:250,000-scale base map by simplifying 1:100,000-scale, metric-contour topographic maps of northeastern Washington, which were published recently by the USGS or are in preparation by that agency. The 1:250,000-scale base map was manually scribed from scale-stable reductions of 1:100,000-scale map separates. The control framework was a computer-generated latitude-longitude grid plotted on a Universal Transverse Mercator Projection by the USGS. The 1:250,000-scale base map is available as a separate publication (Washington Division of Geology and Earth Resources Topographic Map TM-2).

Geologic Map

The Geologic Map of Washington – Northeast Quadrant is chiefly an age-lithology map, not a geological formation map. Formations are shown only for Miocene volcanic rocks and for Precambrian metasedimentary and metavolcanic rocks. These exceptions have been made because without this subdivision into formations, the geologic map would be too simplistic to be of much benefit to the map user.

A multiple-level scheme of colors, patterns, and map symbols has been used to portray age and lithology of geologic units on the 1:250,000-scale geologic map. (See **Key to Geologic Units** on Sheet 1.) The first level of detail, which is expressed by broad color ranges, distinguishes six general lithologic subdivisions: unconsolidated sediments, sedimentary and volcanic rocks, metasedimentary and metavolcanic rocks, metamorphic rocks, intrusive rocks, and mixed metamorphic and intrusive rocks. The second level of detail, which is 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 the map symbols, identifies individual geologic map units.

Standard USGS age symbols are used for most map units, but because of the prevalence of Tertiary rocks in Washington, each Tertiary epoch has been assigned a separate age symbol. The Tertiary symbols were chosen with the help of the editorial staff of the USGS (Denver), but the USGS has not formally adopted these symbols. Lithologic symbols used here were devised specifically for the DGER state geologic map project, and are not standard USGS symbols. Where formations are shown on the 1:250,000-scale geologic map, the map symbol includes a subscript letter or number to distinguish it from other units of similar age and lithology — for example, the symbol for the Miocene Saddle Mountains Basalt is **Mv_s**.

Because the 1:250,000-scale map units are age-lithologic units, formations consisting of diverse rock types are separated into their component lithologies and consequently are included in more than one map unit. To determine all map units by which a named unit (formation or group) is shown, consult the **List of Named Units** (Sheet 2).

DESCRIPTIONS OF MAP UNITS

A lithologic description of each map unit on the 1:250,000-scale geologic map is given in the **Descriptions of Map Units** (Sheet 2). Quaternary sediments are described first, followed by sedimentary and volcanic rocks, metasedimentary and metavolcanic rocks, intrusive rocks, mixed metamorphic and igneous rocks, and metamorphic rocks. Within each lithologic group, map units are addressed in order of increasing age. Information concerning the age and stratigraphic relations of the map units is given in the **Correlation Diagram** (Sheet 3).

At the end of each unit description is a list of named units that make up the geologic map unit. Formally named formations that are included in lexicons published by the USGS are listed without citation and with the word "Formation" or lithologic term capitalized. Informally named units are followed by the citation to the work that defines the unit; for these units, the word "formation" or lithologic term is not capitalized. Some map units consist of a single formation or part of a formation; others are a combination of named and unnamed units; still others consist only of unnamed age-lithologic units. 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.

Sedimentary and Volcanic Rocks

Sedimentary and volcanic rocks include sub-greenschist-facies low-grade deposits only. Classification of sandstones follows the terminology of Dickinson (1970). Assignment of volcanic rock names was made on the basis of whole-rock geochemistry and the total alkali-silica (TAS) diagram (LeMaitre, 1984; Zanettin, 1984).

Metasedimentary and Metavolcanic Rocks

Metasedimentary and metavolcanic rocks include sedimentary and volcanic rocks that have been metamorphosed to the greenschist facies. Sedimentary and volcanic names are preceded by the prefix "meta" in order to readily distinguish greenschist-facies metasedimentary and metavolcanic rocks from sub-greenschist-facies sedimentary and volcanic rocks and from amphibolite-facies high-grade metamorphic rocks derived from sedimentary and volcanic rock protoliths. For example, the term "metalimestone" is applied to recrystallized greenschist-facies limestone to distinguish it from recrystallized amphibolite-facies marble and from limestone that is not recrystallized.

Intrusive Rocks

Intrusive rock names in the Descriptions of Map Units follow the International Union of Geological Sciences (IUGS) modal classification (Streckeisen, 1973). Geologic map units that consist of 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) *acidic intrusive rocks*, which include the IUGS alkali feldspar granite, granodiorite, tonalite, and quartz monzonite fields; (2) *intermediate intrusive rocks*, which include the IUGS monzonite, quartz monzodiorite, monzodiorite, quartz diorite, and diorite fields; (3) *basic intrusive rocks*, which include the IUGS gabbro, quartz gabbro, monzogabbro, and quartz monzogabbro fields; (4) *syenitic intrusive rocks*, which include the IUGS syenite, quartz syenite, alkali-feldspar syenite, and alkali-feldspar quartz syenite fields; and (5) *alkalic intrusive rocks*, which include the IUGS foid-bearing alkali-feldspar syenite, foid-bearing syenite, foid-bearing monzonite, foid syenite, and foid monzosyenite fields. Alkalic intrusive rock names (shonkinite, malignite, and foyaite) were assigned using the modal classification of Miller (1972).

Mixed Metamorphic and Igneous Rocks

Mixed metamorphic and igneous rocks are heterogeneous, migmatitic rocks that formed by deep burial, ultrametamorphism, and partial fusion (anatexis) of layered sedimentary and volcanic rocks and/or by injection of magma into layered sedimentary and volcanic rocks. This category of rock types includes migmatite and agmatite, which are migmatitic at an outcrop scale, and mixed metamorphic and igneous rocks, which are migmatitic at a 1:24,000 quadrangle scale.

Metamorphic Rocks

Metamorphic rocks include sedimentary and volcanic rocks that have been metamorphosed to the amphibolite facies or higher (layered metamorphic rocks), and moderately to strongly foliated intrusive rocks (orthogneiss) that have been thermally or dynamically metamorphosed.

LIST OF NAMED UNITS

The **List of Named Units** (Sheet 2) is a summary of named geologic units that appear in published literature. The list includes *all* formal and *selected* informal unit names that are currently in use, as well as a few names that were once widely used, but are now considered archaic.

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 are intended to guide the map user to the general area on the 1:250,000-scale map in which the named geologic unit occurs.

SOURCES OF MAP DATA

Figures 1 through 6 constitute a series of index maps that illustrate 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 explanations. Complete citations are given in the **References Cited**. Patterned areas on Figure 1 indicate areas where DGER geologists performed original geologic mapping for the state geologic map project. References that supplied other geologic data (such as isotopic and fossil ages or geochemistry) are not indicated on these figures, but are listed in the References Cited. Plate or sheet numbers are specified only for reports that contain more than one of these elements.

Some unpublished maps and data, cited as written or oral communications in this report, were used to compile the 1:250,000-scale geologic map. They are available for inspection at the Division's Olympia office.

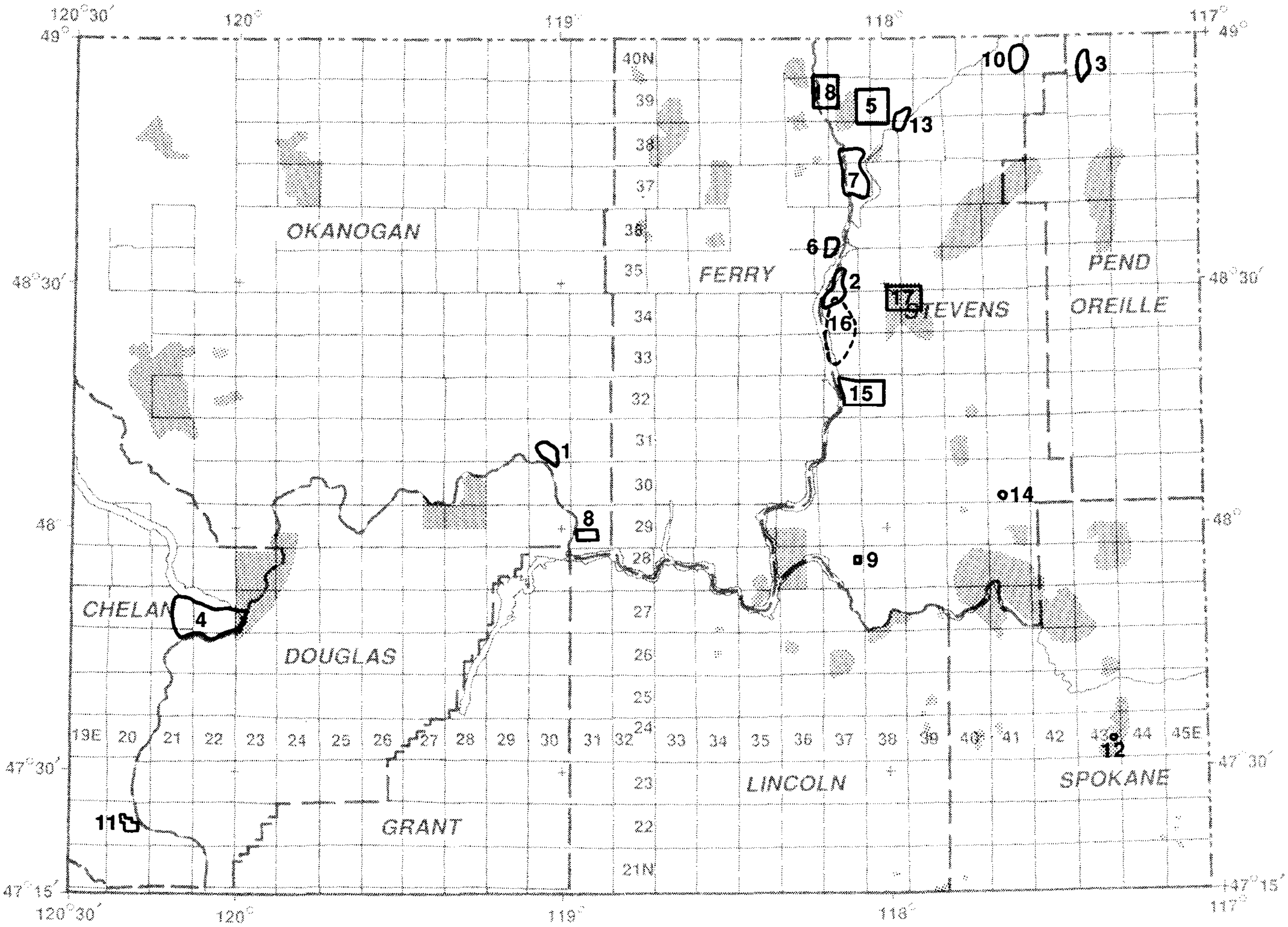

Figure 1. Index to sources of map data, scales 1:1,200 through 1:21,600. Shaded areas, original mapping by DGER geologists.

EXPLANATION

1. Broch, 1979; plate 3.1, scale 1:12,000
2. Cole, 1960; plate 1, scale 1:21,480
3. Greenman, 1976; plate 1, scale 1:12,000; plate 2, scale 1:2,570
4. Hopson, 1955; plate 2, scale 1:19,500
5. Hyde, 1985; geologic map, scale 1:12,000
6. Jones and others, 1961; plate 1, scale 1:9,600
7. Kuenzi, 1961; plate 1, scale 1:16,800
8. Milliken, 1981; figure 4, scale 1:12,000
9. Nash, 1978; sheet 2, scale 1:1,200
10. O'Keefe, 1980; plate 1, scale 1:5,700
11. Ott, 1988; plate 1, scale 1:12,000
12. Page, 1942; plate 32, scale 1:2,400
13. Phillips, 1979; plate, 1:6,000
14. Rigg, 1958; figure 224, scale 1:21,600
15. Smith, 1982; plate 1, scale 1:14,900
16. Smith, M. T., DGER unpub. mapping, 1990; scale 1:12,000
17. Snook, 1981; plate 1, scale 1:6,000
18. West, J. R., 1976; figure 1, scale 1:12,000

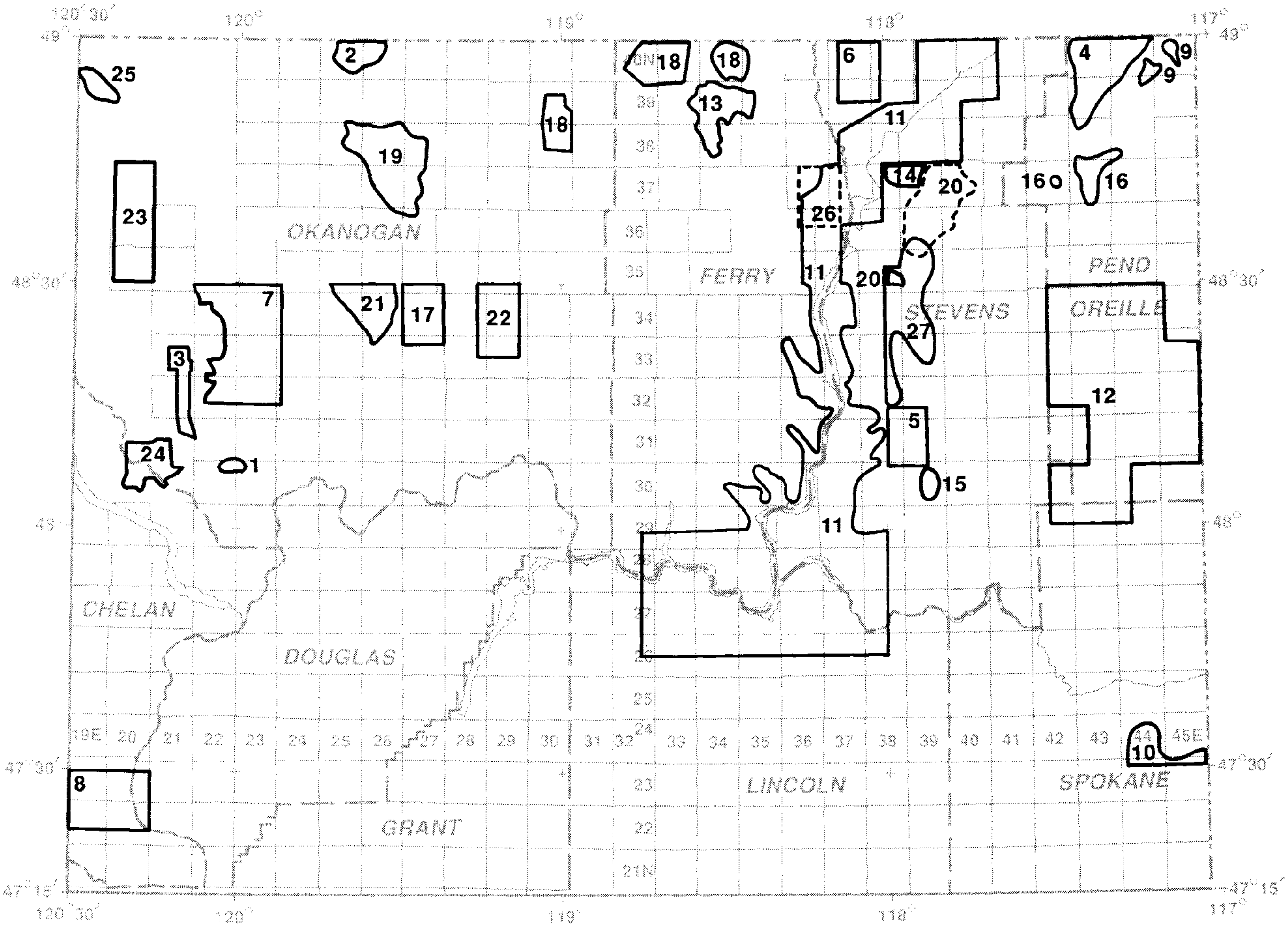

Figure 2a. Index to sources of map data, scale 1:24,000.

EXPLANATION

1. Buddington, 1986; plate
2. Buddington, A. M., Western Washington Univ., written commun., 1987
3. DiLeonardo, 1987; plate 1
4. Dings and Whitebread, 1965; plate 1
5. Evans, 1987; plate 1
6. Fox, 1981; sheet 1
7. Frey, A. M., DGER unpub. mapping, 1988
8. Gresens, 1983; plates 1 and 2
9. Groffman, 1986; plate
10. Hosterman, 1969; plate
11. Kiver, E. P.; Stradling, D. F., Eastern Washington Univ., written commun., 1987
12. Kiver, E. P.; Stradling, D. F., DGER unpub. mapping, 1988
13. Knaack, C. M., DGER unpub. mapping, 1987
14. Laskowski, 1982; figure 2A
15. Miller, F. K., USGS, written commun., 1988
16. Miller, F. K., USGS, written commun., 1988
17. Minard, 1985; sheet
18. Orr, 1985; maps A, B, and C
19. Pine, 1985; plate 1
20. Schuster, J. E., DGER, written commun., 1988
21. Sims, 1984; plate
22. Singer, 1984; plate 1
23. Todd, V. R., USGS, written commun., 1989
24. Wade, 1988; plate
25. White, 1986; figure 3
26. Wilson, 1980; sheet 1
27. Yates, R. G., USGS retired, written commun., 1986

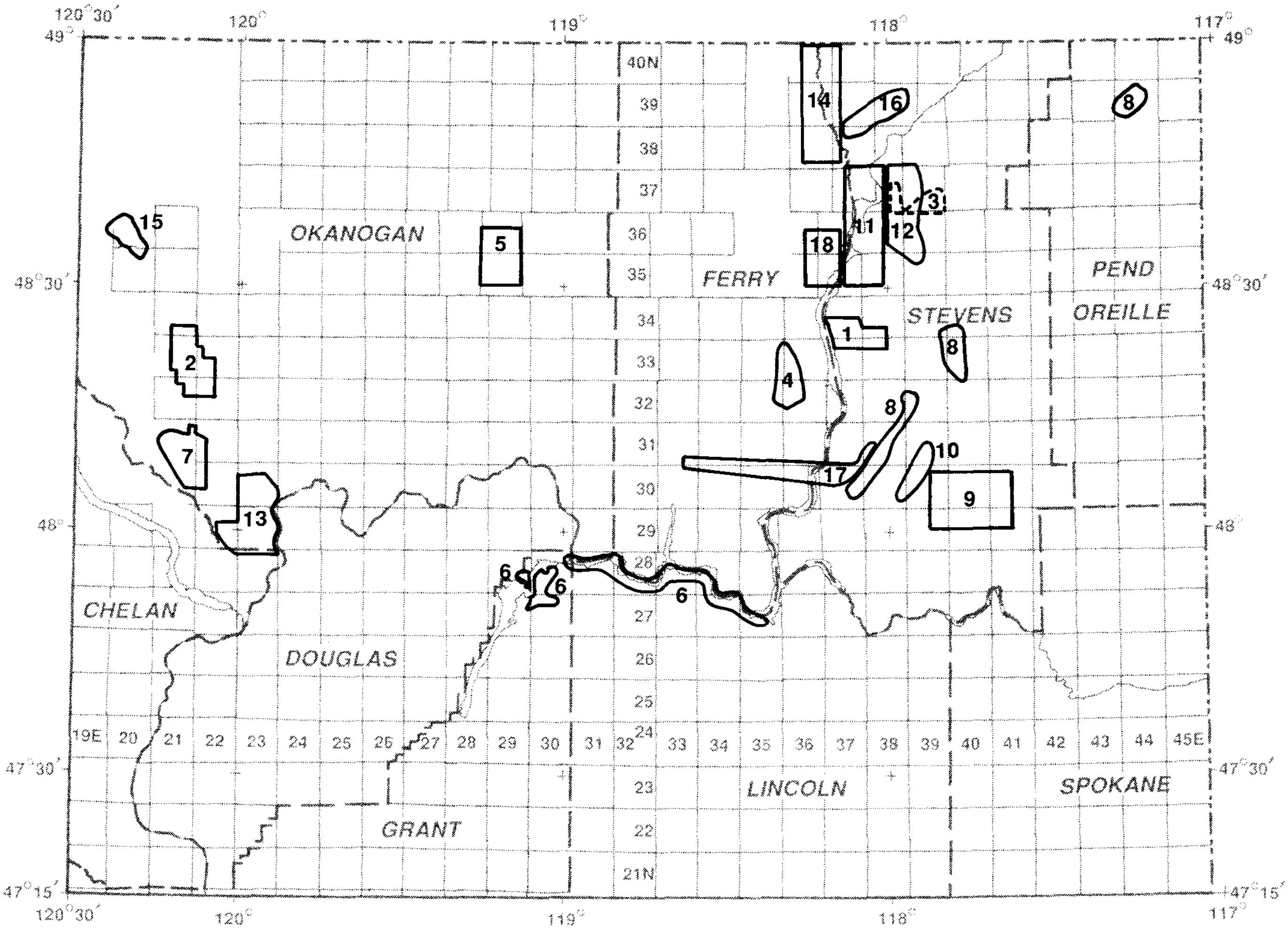

Figure 2b. Index to sources of map data, scale 1:24,000 (continued).

EXPLANATION

1. Abrams, 1980; plate 1
2. Burnet, 1976; figure 21.
3. Duncan, 1982; plates 1 and 24.
4. Fullmer, 1986; plate7.
5. Gulick, 1987; plate 1
6. Holder, R. W.; Holder, G. A. M., DGER unpub. mapping, 1987
7. Hopkins, 1987; plate 111.
8. Lindsey, 1988; plates 1, 2, 4, and 5
9. McLucas, 1980; plates 1 and 2
10. Miller, F. K., USGS, written commun., 1989
11. Mills, 1985; plates 1 and 2
12. Mills and others, 1985; sheets 1 and 2
13. Raviola, 1988; plate
14. Rhodes, 1980; plates 1 and 2
15. Riedell, 1979a; plate 1
16. Roback, R. C., Univ. of Texas at Austin, written commun., 1990
17. Smith, M. T., DGER unpub. mapping, 1989
18. Wilson, 1981a; sheet 1

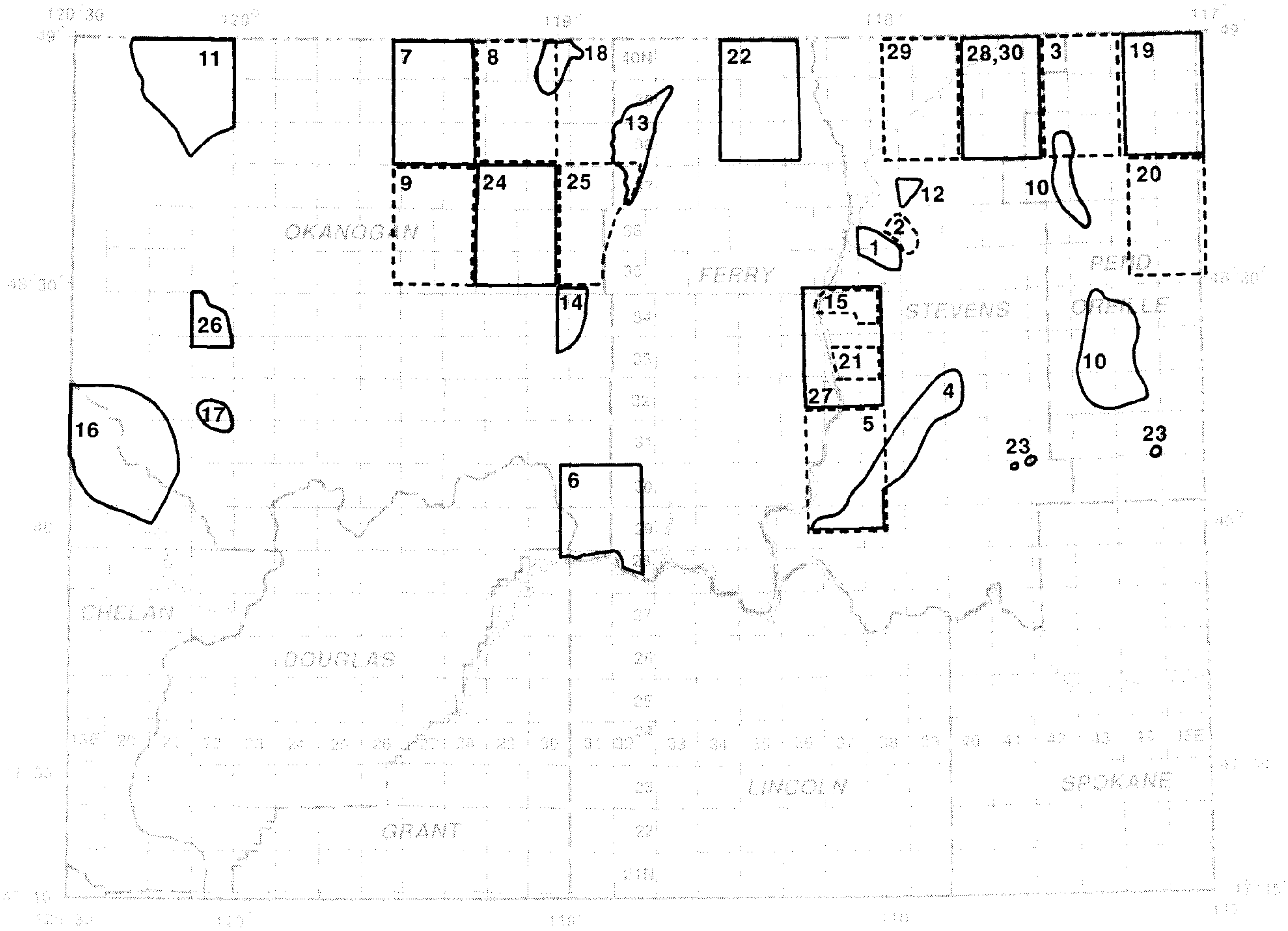

Figure 3. Index to sources of map data, scales 1:25,000 through 1:50,688.

EXPLANATION

1. Bradshaw, 1964; plate 25, scale 1:27,500
2. Brainard, 1982; figure 2, scale 1:39,600
3. Burmester and Miller, 1983; plate, scale 1:48,000
4. Campbell and Loofbourow, 1962; plate 1, scale 1:36,000
5. Campbell and Raup, 1964; sheet, 1:48,000
6. Carlson, 1984; plate, scale 1:48,000
7. Fox, 1970; sheet, scale 1:48,000
8. Fox, 1978; sheet, scale 1:48,000
9. Fox, K. F., Jr.; Rinehart, C. D., USGS, written commun., 1988, scale 1:48,000
10. Gager, 1982; maps B and C, scale 1:33,790
11. Hawkins, 1963; plate 1, scale 1:31,680
12. Hogge, 1982; figure 2, scale 1:36,000
13. Holder, 1990; plates 1A and 1B, scale 1:50,690
14. Holder, R. W.; Holder, G. A. M., Georgia Southern College, written commun., 1989, scale 1:48,270
15. Janzen, 1981; plate, scale 1:25,000
16. Libby, 1964; plate 27, scale 1:31,680
17. McKee, Bates, Univ. of Washington, written commun., 1968, scale 1:32,000
18. McMillen, 1979; figure 7, scale 1:31,680
19. Miller, 1983; plate, scale 1:48,000
20. Miller, F. K., USGS, written commun., 1988, scale 1:48,000
21. Orlean, 1981; plate [geology], scale 1:25,000
22. Pearson, 1977; sheet, scale 1:48,000
23. Rigg, 1958; figures 125 and 221, scale 1:42,670
24. Rinehart, C. D.; Fox, K. F., Jr., USGS, written commun., 1988, scale 1:48,000
25. Rinehart and Greene, 1988; plate, scale 1:48,000
26. Ryason, 1959; fig. 11, scale 1:29,370
27. Snook and others, 1990; sheet, scale 1:48,000
28. Yates, 1964; sheet, scale 1:31,680
29. Yates, 1971; sheet, scale 1:31,680
30. Yates, 1976; plate 1, scale 1:31,680

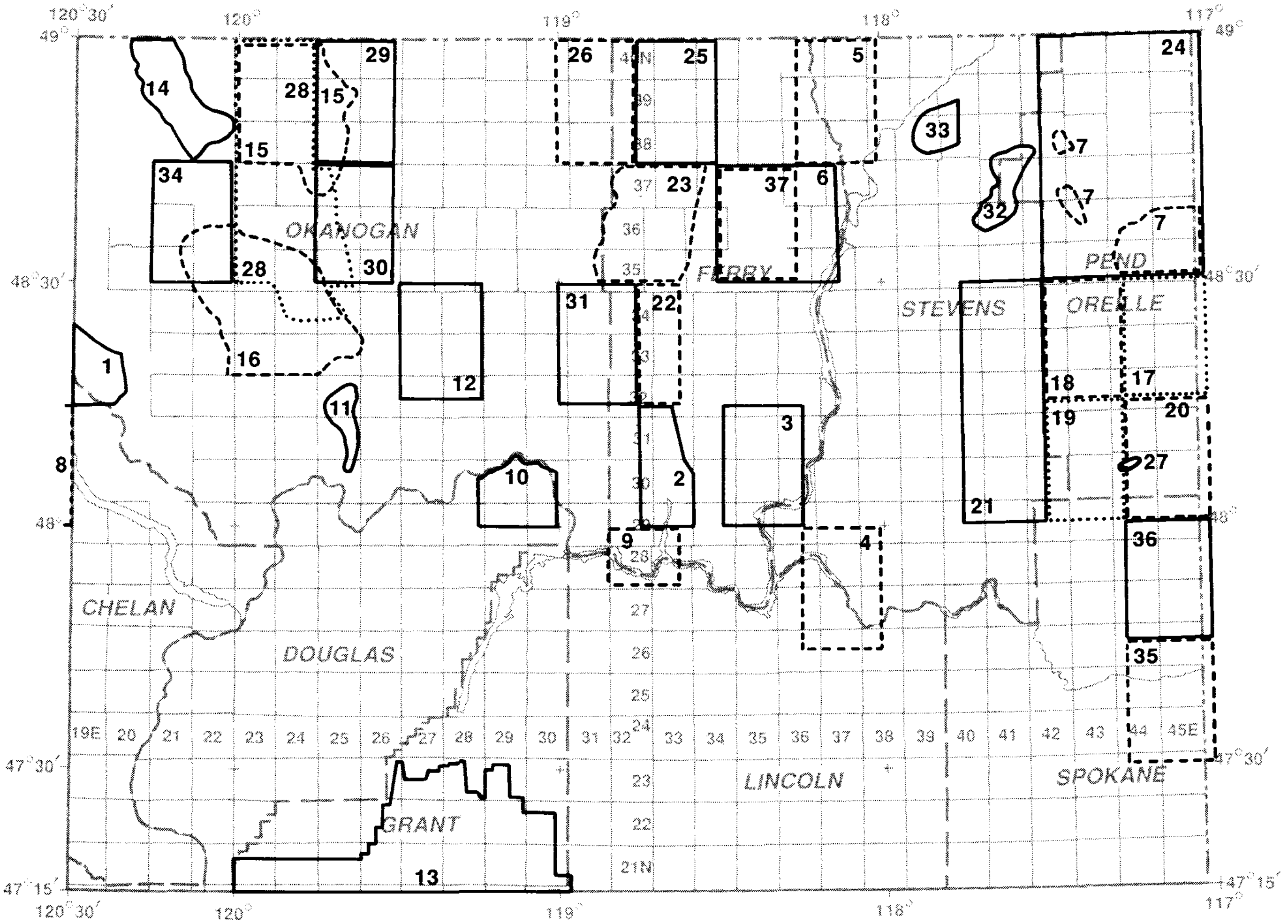

Figure 4. Index to sources of map data, scales 1:62,500 through 1:96,000.

EXPLANATION

1. Adams, 1961; plate 2, scale 1:63,360
2. Atwater, 1986; plate 2, scale 1:62,500
3. Becraft, 1966; sheet, scale 1:62,500
4. Becraft and Weis, 1963; plate 1, scale 1:62,500
5. Bowman, 1950; plate 1, scale 1:63,360
6. Campbell and Thorsen, 1975; sheet, scale 1:62,500
7. Castor and others, 1982; plate 22, scale 1:62,500
8. Cater and Wright, 1967; sheet, scale 1:62,500
9. Fleshman and Dodd, 1982; plate 9, scale 1:67,580
10. Fox, K. F., Jr., USGS, written commun., 1988, scale 1:62,500
11. Fritz, 1978; plate, scale 1:62,500
12. Goodge, J. W.; Hansen, V. L., formerly USGS, written commun., 1988, scale 1:62,500
13. Grolier and Bingham, 1971; sheets 1 and 2, scale 1:62,500
14. Hawkins, 1968; plate 1, scale 1:63,360
15. Hibbard, 1971; figure 3, scale 1:62,500
16. Menzer, 1982; plate 1, scale 1:63,360
17. Miller, 1974a; sheet, scale 1:62,500
18. Miller, 1974b; sheet, scale 1:62,500
19. Miller, 1974c; sheet, scale 1:62,500
20. Miller, 1974d; sheet, scale 1:62,500
21. Miller and Clark, 1975; plates 1 and 2, scale 1:62,500
22. Moye, 1984; plate 1, scale 1:62,500
23. Muessig, 1967; plate 1, 1:62,500
24. Park and Cannon, 1943; plate 1, scale 1:96,000
25. Parker and Calkins, 1964; plate 1, scale 1:62,500
26. Pearson, 1967; sheet, scale 1:62,500
27. Rigg, 1958; figure 124, scale 1:78,000
28. Rinehart, 1981; plate 1, scale 1:96,000
29. Rinehart and Fox, 1972; plate 1, scale 1:62,500
30. Rinehart and Fox, 1976; plate 1, scale 1:62,500
31. Staatz, 1964; plate 1, scale 1:62,500
32. Thorsen, 1966; figure 11, scale 1:63,360
33. Todd, 1973; figure 2, scale 1:84,480
34. Todd, V. R., USGS, written commun., 1988, scale 1:62,500
35. Weis, 1968; sheet, scale 1:62,500
36. Weissenborn and Weis, 1976; sheet, scale 1:62,500
37. Wilson, J. R.; formerly USGS, written commun., 1987, scale 1:62,500

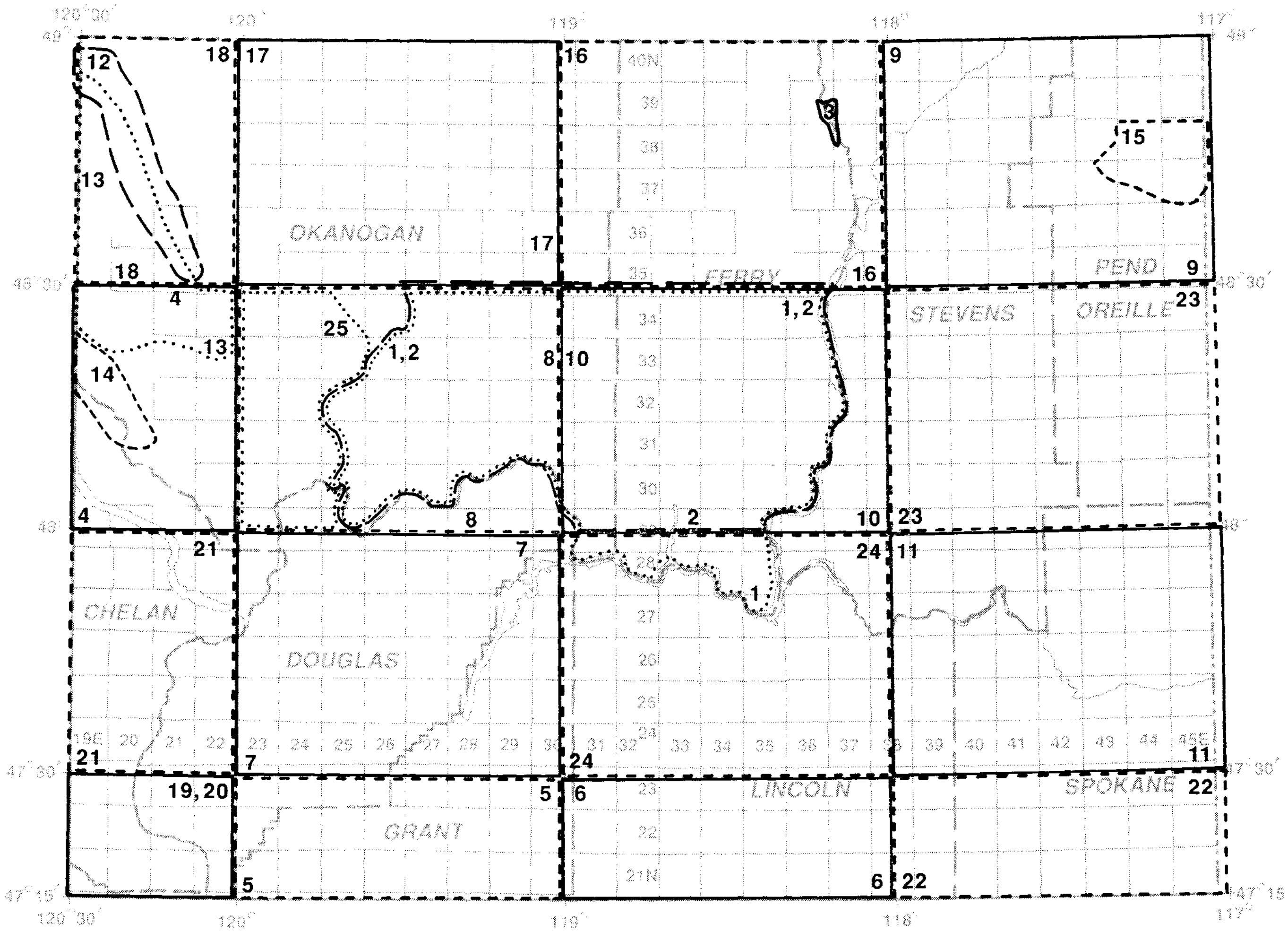

Figure 5. Index to sources of map data, scales 1:100,000 through 1:101,400.

EXPLANATION

1. Atwater and Rinehart, 1984; plates 1, 2, and 3, scale 1:100,000
2. Atwater, B. F.; Rinehart, C. D., USGS, written commun., 1987, scale 1:100,000
3. Braun, E. R., consultant; Fields, E. D., Boise Cascade Corp., written commun., 1989, scale 1:100,000
4. Bunning, 1990; plate, scale 1:100,000
5. Gulick, 1990a; plate, scale 1:100,000
6. Gulick, 1990b; plate, scale 1:100,000
7. Gulick and Korosec, 1990a; plate, scale 1:100,000
8. Gulick and Korosec, 1990b; plate, scale 1:100,000
9. Joseph, 1990a; plate, scale 1:100,000
10. Joseph, 1990b; plate, scale 1:100,000
11. Joseph, 1990c; plate, scale 1:100,000
12. Lawrence, 1968; plate 1, scale 1:101,380
13. McGroder and others, 3 plates, 1990
14. Miller, 1987; plate 1, scale 1:100,000
15. Miller and Frisken, 1984; figure 2, scale 1:101,380
16. Stoffel, 1990a; plate, scale 1:100,000
17. Stoffel, 1990b; plate, scale 1:100,000
18. Stoffel and McGroder, 1990; plate, scale 1:100,000
19. Tabor and others, 1977; sheet, scale 1:100,000
20. Tabor and others, 1982; plate, scale 1:100,000
21. Tabor and others, 1987; plate, scale 1:100,000
22. Waggoner, 1990a; plate, scale 1:100,000
23. Waggoner, 1990b; plate, scale 1:100,000
24. Waggoner, 1990c; plate, scale 1:100,000
25. Wilson, J. R., formerly USGS, written commun., 1987, scale 1:100,000

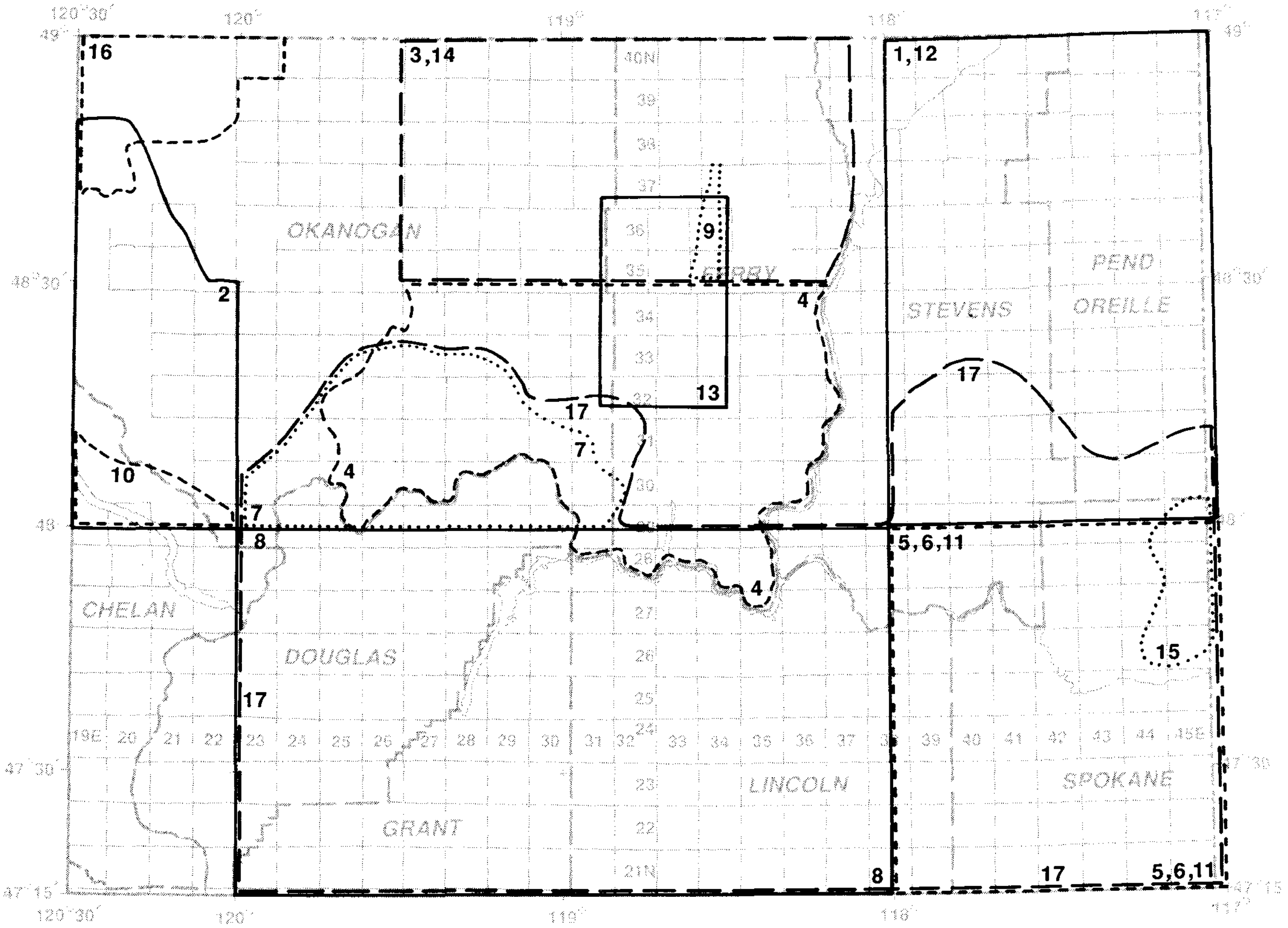

Figure 6. Index to sources of map data, scales 1:125,000 through 1:475,200.

EXPLANATION

1. Aadland and others, 1979; sheet, scale 1:250,000
2. Barksdale, 1975; plate 1, scale 1:125,000
3. Cheney and others, 1982; figure 2, scale 1:289,650
4. Colville Confederated Tribes Geology Department, 1984; plate 1, scale 1:250,000
5. Griggs, 1966; sheet, scale 1:125,000
6. Griggs, 1973; sheet, scale 1:250,000
7. Hanson, 1979; sheet, scale 1:250,000
8. Hanson and others, 1979; sheet, scale 1:250,000
9. Holder, 1985; figure 4, scale 1:185,000
10. Hopson, 1955; plate 1, scale 1:389,900
11. Kiver and others, 1979; sheet, scale 1:250,000
12. Miller and Yates, 1976; sheet 1, scale 1:125,000
13. Moye, 1987; figure 2, scale 1:405,530
14. Orr and Cheney, 1987; figure 2, scale 1:475,200
15. Rhodes and others, 1989; figure 2, scale 1:233,950
16. Staatz and others, 1971; plate 1, scale 1:200,000
17. Swanson and others, 1979a; sheets 1, 2, 4, and 5, scale 1:250,000

CORRELATION DIAGRAM

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 **Correlation Diagram** on Sheet 3. The color, pattern, and unit symbol in each box are the same as those for the unit's polygons on the map. Unit symbols on the diagram can be cross-referenced with the **Descriptions of Map Units** and the **List of Named Units**.

Solid lines on the borders of the boxes indicate that the age range of the unit is well constrained. Dashed lines along the border of the boxes indicate that the age is poorly constrained. Queries at the top and/or bottom of a box indicate that the upper or lower age limits of the unit are uncertain. Dashed lines connecting boxes indicate that the map unit includes rocks of more than one age.

Information about the age of geologic units on the diagram is summarized in the text below. More detailed information is given in the series of DGER open-file reports for this quadrant (Table 1). Formal and informal unit names are printed in bold lettering in order to facilitate cross-referencing of the **Descriptions of Map Units** with the **List of Named Units**.

We have used the geologic time scale devised for the "Correlation of Stratigraphic Units of North America (COSUNA)" project of the American Association of Petroleum Geologists (Salvador, 1985) as the basis for this Correlation Diagram. Exceptions are (1) the Eocene-Oligocene boundary is placed at 35.7 Ma (Montanari and others, 1985), (2) the Pliocene-Pleistocene boundary is assigned a 1.6 Ma age (Aguirre and Pasini, 1985), and (3) the Proterozoic time scale is from Harrison and Peterman (1982).

Quaternary Sediments

Qs	Holocene alluvium and peat and late(?) Wisconsin[1] glacial deposits, undivided. The age is assumed from stratigraphic position.
Qls	Holocene and late(?) Wisconsin[1] landslide deposits. The age is assumed from stratigraphic position.
Qd	These active and stabilized dunes generally overlie late Wisconsin[1] glacial and outburst flood deposits and are assumed to be of Holocene age.
Qp	This unit consists of Holocene organic debris deposited in depressions formed on the surfaces of late Wisconsin[1] glacial and outburst flood deposits.
Qla	Holocene lake deposits. Beach(?) gravel that interfingers with lacustrine silt contains charcoal that has yielded a ^{14}C age of 5,870 ± 140 years B.P. (Waggoner, 1990b).
Qa	Holocene alluvium on modern floodplains and alluvial fans.
Qoa	Age uncertain. Alluvial deposits in terraces along the Wenatchee River "record aggradation of the Wenatchee valley, probably caused by damming of the Columbia and Wenatchee River by flood bars, perhaps during several [glacial outburst] flood events in Columbia River valley" (Tabor and others, 1982, p. 21). Alluvial fans west of Lake Lenore are dissected and locally capped by caliche.
Ql	The youngest loess blankets late Wisconsin[1] outburst flood deposits and locally contains Mazama tephra (7 ka) (Patton and Baker, 1978). Older loess commonly exhibits well-developed soil profiles and caliche layers and is intercalated with pre-late Wisconsin outburst flood deposits. The oldest loess is characterized by reversed magnetic polarity, indicating it was deposited prior to 790 ka (McDonald and Busacca, 1989).
Qfs	This unit is of the same age as unit Qfg.
Qfg	The youngest outburst flood deposits, which are intercalated with Mount St. Helens set S tephra (13 ka) (Mullineaux and others, 1978), were deposited between 15,300 and 12,700 years ago (Waitt, 1985). Older outburst flood deposits exhibit well-developed soil profiles and locally contain ash identified as Mount St. Helens set C tephra (36 ka) (Moody, 1987). The oldest outburst flood deposits are intercalated with loess that is characterized by reversed magnetic polarity, indicating it was deposited prior to 790 ka (McDonald and Busacca, 1989).
Qgt	Late Wisconsin[1].
Qgo	Late Wisconsin[1].
Qgl	Late Wisconsin[1]. South of Tiger (T36N, R43E), charcoal yielded a ^{14}C age of 15,000 ± 170 years B.P. (Joseph, 1990a).
Qgp	These pre-late Wisconsin[1] deposits are characterized by well-developed soil profiles, caliche horizons, and intensely weathered rock clasts.
Qgd	In areas covered by late Wisconsin[1] ice, deposits are chiefly of late Wisconsin age. Topographically above and beyond the limit of late Wisconsin ice, this unit includes pre-late Wisconsin till and outwash as well as late Wisconsin outwash and glaciolacustrine deposits.
Qglf	Along the Columbia and Sanpoil River valleys, the unit is chiefly of late Wisconsin[1] age (Atwater, 1986). Along the Spokane River and its tributaries, the unit includes both late Wisconsin and pre-late Wisconsin deposits (Rigby, 1982; Kiver and Stradling, 1982a, 1982b).
Qad	On Calispell Peak (T34N, R42E), poorly developed soils indicate a late Wisconsin[1] age (E. P. Kiver and D. F. Stradling, Eastern Washington Univ., oral commun., 1990). In the Wenatchee River valley (T23N, R19E)

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[1] The ages of Quaternary sediments in the northeast quadrant of Washington are uncertain because the deposits have yielded few isotopic ages. Therefore, age assignment is based on correlation with relatively well dated deposits of the Cordilleran ice sheet in the Puget Lowland of western Washington (Blunt and others, 1987) and with deposits of the Laurentide ice sheet in the North American midcontinent (Willman and Frye, 1970). The latest glaciation, which is correlative with the Fraser glaciation in western Washington and the late Wisconsin glaciation in the midcontinent, began approximately 20 ka and ended approximately 10 ka. Older glaciations, which are correlative with pre-Fraser glaciations in western Washington and with early Wisconsin and/or older glaciations in the midcontinent, occurred before 38 ka; some are at least as old as 800-900 ka (Blunt and others, 1987).

and in the Chelan Mountains (T28N, R19-20E), poorly developed soils indicate that most deposits are late Wisconsin in age, but well-developed soils and weathered clasts in deposits topographically above and beyond the late Wisconsin ice limit indicate a pre-late Wisconsin age (Tabor and others, 1987). Deposition of the pre-late Wisconsin alpine drift apparently occurred between 130 and 150 ka (Tabor and others, 1987).

Sedimentary and Volcanic Rocks

QRcg The unit contains Pleistocene mammalian fossils and Pliocene-late Pleistocene freshwater molluscs and ostracods (Grolier and Bingham, 1978).

RMls The unit is composed of clasts of Wanapum Basalt (14.5-15 Ma). The deeply dissected nature of the topography suggests a pre-Pleistocene age (Tabor and others, 1982).

RMcg West of Springdale (T29-30N, R38-39E), the unit apparently overlies Grande Ronde Basalt (15.5-16.5 Ma). South of Lake Chelan (T24N, R20E and T26N, R21E), the unit includes Grande Ronde Basalt clasts. The weakly to moderately indurated nature of the conglomerates suggests a pre-Pleistocene age (Tabor and others, 1987).

Mc This unit is intercalated with Grande Ronde and Wanapum Basalts, which have yielded numerous K-Ar ages between 14.5 and 16.5 Ma outside of the map area. The unit contains Miocene fossil floras (Knowlton, 1926).

Columbia River Basalt Group

Mv$_s$ This unit is correlative with the Weissenfels Ridge Member of the Saddle Mountains Basalt, which has yielded K-Ar ages between 12 and 13 Ma outside the map area (Swanson and others, 1979b; Beeson and others, 1985; Reidel and Fecht, 1987).

Mv$_w$ Numerous K-Ar ages between 14.5 and 15.5 Ma have been reported from this unit outside the map area (Swanson and others, 1979b; Beeson and others, 1985; Reidel and Fecht, 1987).

Mv$_g$ Numerous K-Ar ages between 15.5 and 16.5 Ma have been reported from this unit outside the map area (Swanson and others, 1979b; Beeson and others, 1985; Reidel and Fecht, 1987).

Mvi$_g$ K-Ar ages between 15.5 and 16.5 Ma have been reported from this unit outside the map area (Swanson and others, 1979b; Beeson and others, 1985; Reidel and Fecht, 1987).

Φc Silicic tuff beds have yielded two fission-track zircon ages of approximately 34 Ma (Tabor and others, 1982). These sedimentary rocks contain Oligocene palynomorphs and fossil leaves.

Evd$_2$ Rocks of this unit have yielded several K-Ar hornblende ages between 41 and 48 Ma (Pearson and Obradovich, 1977).

Ev$_2$ K-Ar biotite and whole-rock ages of approximately 48 Ma have been reported for this unit (Pearson and Obradovich, 1977; Stoffel, 1990a).

Evt$_2$ Age assignment is based on stratigraphic position. The unit overlies Sanpoil Volcanics (48-52 Ma) (unit Evd$_1$) and underlies flows of the Klondike Mountain Formation (41-48 Ma) (unit Evd$_2$).

Evc$_2$ Shale beds at several locations contain early middle Eocene floras (Wolfe and Wehr, 1987) and Eocene fossil fish (Pearson, 1967). The unit stratigraphically overlies dacite flows of Sanpoil Volcanics (48-52 Ma) (unit Evd$_1$) and locally underlies dacite and andesite flows of the Klondike Mountain Formation (41-48 Ma) (unit Evd$_2$).

Ec$_2$ Silicic tuff beds from outside the map area yield fission-track zircon ages between 42 and 49 Ma (Gresens and others, 1981). The rocks contain Eocene palynomorphs and fossil leaves (Newman, 1971, 1975).

Ecg$_2$ In the Pend Oreille River valley, the unit contains early to middle Eocene palynomorphs (Harms, 1982). Near Cusick (T33N, R44E), the unit contains clasts of Sanpoil Volcanics (48-52 Ma) (unit Evd$_1$). Near Wenatchee, age assignment is based on the gradational nature of the contact with unit Ec$_2$, which has yielded several fission-track zircon ages between 42 and 49 Ma (Gresens and others, 1981).

Evd$_1$ Numerous K-Ar hornblende and biotite ages range from 43 to 52 Ma, with the majority between 48 and 52 Ma (Pearson and Obradovich, 1977; Rinehart and Fox, 1972, 1976; Yates and Engels, 1968; Atwater and Rinehart, 1984). Near Island Mountain (T39N, R19E), the unit is cut by an andesite plug (unit Eian), the age of which is 47 Ma (White, 1986).

Evt$_1$ Northeast of Cusick (T33N, R44E), the unit has a K-Ar biotite age of approximately 53 Ma (Pearson and Obradovich, 1977). Southeast of Republic, the unit has yielded a K-Ar biotite age of 50 Ma (Atwater and Rinehart, 1984). North of Conconully (T37N, R24E), this unit is cut by a diorite plug (50 Ma) (unit Eid). Elsewhere, the unit's age assignment is based on its stratigraphic position between or beneath flows that have yielded ages of 48-52 Ma (unit Evd$_1$).

Ev$_1$ Northeast of Nespelem, rocks of this unit have yielded a K-Ar biotite age of 49 Ma (B. F. Atwater, USGS, written commun., 1989). Near Island Mountain (T39N, R19E), the unit is stratigraphically overlain by unit Evd$_1$ and intruded by an andesite plug (47 Ma) (unit Eian). Northwest of Omak (T36N, R25E), age assignment is based on correlation with units Evd$_1$, Evt$_1$, and Eida.

Evc$_1$ Near Oroville, this unit is cut by a dacite plug (52 Ma) (unit Eida). Elsewhere, age assignment based on stratigraphic position beneath dacite flows, ages of which are between 45 and 48 Ma (unit Evd$_1$).

Ec$_1$ The **Swauk Formation** outside the map area (T21N, R19E) contains tuff that yielded ages of 49-50 Ma (Tabor and others, 1982). Unnamed rocks near Oroville (T40N, R26-27E) were intruded by dacite plugs (51-52 Ma). Sedimentary rocks in the **volcanics of Island**

Mountain (T39N, R19E) are stratigraphically overlain by volcanic rocks (unit Ev$_1$) that are cut by an andesite plug that yielded an age of 47 Ma (unit Eian). Unnamed rocks near Tonasket (T38N, R27E) are stratigraphically overlain by tuff (unit Evt$_1$) that underlies dacite flows that yielded radiometric ages of 48-52 Ma (unit Evd$_1$).

Ecg$_1$ Near Oroville, the unit is cut by dacite plugs that have been radiometrically dated at 51-52 Ma (unit Eida). Northeast of Kettle Falls, the unit is stratigraphically overlain by volcaniclastic rocks (unit Evc$_1$) that are overlain by dacite flows that range in age from 48 to 52 Ma (unit Evd$_1$). North of Conconully (T37N, R24E), the unit is stratigraphically overlain by tuff (unit Evt$_1$) that is, in turn, overlain by dacite flows that range in age from 48 to 52 Ma (unit Evd$_1$) and is cut by a diorite plug that yielded a radiometric age of 50 Ma (unit Eid).

TKc The **Pipestone Canyon Formation** contains minor silicic tuff beds that have yielded a fission-track zircon age of 70 ± 5 Ma (J. A. Vance, Univ. of Washington, written commun., 1990) and a fossil flora that suggests a Paleocene age (K. R. Johnson, Yale Univ., written commun., 1988).

Kv$_2$ The early Late Cretaceous (Coniacian) age of this unit is based on the gradational contact with, and similar composition to the Fawn Peak stock (88 Ma) (unit Kid). A maximum age is defined by the stratigraphic position above the late Early Cretaceous to early Late Cretaceous (middle Albian to Turonian) Winthrop Sandstone (unit Kc$_2$) and Virginian Ridge Formation (units Km$_2$ and Kcg$_2$).

Kvs$_2$ Age assignment is based on the interfingering relation with the middle Albian to Turonian Winthrop Sandstone (units Kc$_2$ and Kcg$_2$).

Kc$_2$ The **Winthrop Sandstone** contains an Albian(?) flora. Age assignment of the unit is based on the interfingering relation with the middle Albian to Turonian Virginian Ridge Formation (unit Km$_2$).

Km$_2$ Rocks of this unit contain late Early and early Late Cretaceous pelecypods and belemnites (Albian and Cenomanian) (Barksdale, 1975; Trexler, 1984) and gastropods (Turonian) (V. R. Todd, USGS, written commun., 1989).

Kcg$_2$ The **Sophie Mountain Formation** contains a Cenomanian-Campanian(?) flora (Daly, 1912; Little, 1982). The age of **Virginian Ridge Formation** conglomerate is assigned on basis of the interfingering relation with other Virginian Ridge Formation sedimentary rocks (unit Km$_2$).

Kcg$_1$ The unit contains middle to late Albian gastropods, brachiopods, and pelecypods (Maurer, 1958; McGroder and others, 1990).

Km$_1$ The **Harts Pass Formation** contains late Early Cretaceous (late Aptian to middle Albian) pelecypods, ammonites, and gastropods (Barksdale, 1975; V. R. Todd, USGS, written commun., 1989). The **Panther Creek Formation** contains early Early to late Early Cretaceous (late Hauterivian to early Albian) pelecypods (Barksdale, 1975) and Aptian-Albian gastropods, cephalopods, and pelecypods (V. R. Todd, USGS, written commun., 1989). The **Goat Creek Formation** contains no fossils in the study area, but Barremian-early Albian fossils have been found in the formation in southern British Columbia (Coates, 1974)

KJv Age assignment is based on probable correlation with unit KJvs.

KJvs Age uncertain. Northeast of Buck Mountain (T36N, R21E), the unit contains middle Early Cretaceous (Hauterivian to middle Barremian) pelecypods, ammonites, and belemnites (Maurer, 1958; Barksdale, 1975), early to middle Early Cretaceous (Berriasian to Barremian) belemnites, and Late Jurassic to Early Cretaceous (Oxfordian to Valanginian(?)) pelecypods (McGroder and others, 1990). Near Twisp (T33N, R21-22E), the unit is intruded by plutons (unit KJiq) that yield K-Ar hornblende ages of 139 Ma (Bunning, 1990; V. R. Todd, USGS, written commun., 1988), indicating that at least part of the unit is Jurassic.

KJvt Age assignment is based on interfingering relation with unit KJvs (Bunning, 1990).

KJm Age assignment is based on interfingering relation with unit KJvs (Bunning, 1990).

Jm In the map area, the unit contains cycad fragments and belemnite molds that are not age diagnostic. Age assignment is based on correlation with the Early to Middle Jurassic (Sinemurian to Bajocian) Ladner Group in southern British Columbia (Tennyson and Cole, 1987).

Metasedimentary and Metavolcanic Rocks

KJmv Age uncertain. The unit is intruded by the Black Peak batholith (90 Ma) (unit Kog). Age assignment is based on possible correlation with the volcanic member of the Midnight Peak Formation (units Kv$_2$ and Kvc$_2$) or the Buck Mountain Formation and Newby Group, undivided (units KJvs, KJvt, KJm, and Jm).

KJmt Age uncertain. The unit is intruded by the Carlton stocks (unit KJiq), which have yielded a K-Ar hornblende age of 130 Ma (Hopkins, 1987). Age assignment is based on tentative correlation with the Newby Group, undivided (units KJvs, KJvt, KJm, and Jm).

Jmv The **Rossland Group** in the map area is overlain(?) by volcanic rocks that have yielded radiometric ages of 165 Ma and overlies metaconglomerate composed of granitic rocks reported to be 196 Ma (Roback and Walker, 1989). The Rossland Group in southern British Columbia contains Early Jurassic (Sinemurian-Toarcian) marine macrofossils (Höy and Andrew, 1988). The Ellemeham Formation unconformably overlies the Anarchist Group (unit Pmm) and Kobau Formation (unit Ŧmt), and is intruded by the Shankers Bend alkalic complex (unit Jik), which is thought to be correlative with part of the Similkameen composite pluton (170 Ma) (Rinehart and Fox, 1972).

Jcg The **Ellemeham Formation** metaconglomerate contains clasts of Ellemeham Formation metavolcanic rocks (unit Jmv) (Rinehart and Fox, 1972). Age assignment of the **Rossland Group** metaconglomerate is based on its interfingering relation with Rossland Group metavolcanic rocks (unit Jmv) (Fox, 1981).

TRmv **Cave Mountain Formation** metavolcanic rocks stratigraphically overlie Cave Mountain Formation metasedimentary rocks (unit TRmm) that contain Late(?) Triassic ammonites and pelecypods (Misch, 1966; Rinehart and Fox, 1976). The **Palmer Mountain Greenstone** grades into and locally intrudes the Upper Triassic(?) Kobau Formation (unit TRmt) (Rinehart and Fox, 1972). Age assignment of metavolcanic rocks at Buckhorn Mountain (T40N, R31E) is based on the compositional similarity to metavolcanic rocks in the Kobau Formation (unit TRmt).

TRmm **Cave Mountain Formation** metasedimentary rocks contain Late(?) Triassic ammonites and pelecypods (Misch, 1966; Rinehart and Fox, 1976). Age assignment of **metamorphic complex of Conconully** metasedimentary rocks is based on their interfingering relation with the Cave Mountain Formation (Rinehart and Fox, 1976). Age assignment of unnamed rocks near Buckhorn Mountain (T40N, R31E) is based on their tentative correlation with the Cave Mountain Formation. The upper part of the **Flagstaff Mountain sequence** (T39-40N, R38-39E) has yielded Late Triassic (Karnian to Norian) conodonts (R. C. Roback, Univ. of Texas at Austin, written commun., 1989; Joseph, 1990a).

TRcb **Cave Mountain Formation** metacarbonate rocks interfinger with Upper(?) Triassic Cave Mountain Formation metasedimentary rocks (unit TRmm). The upper part of the **Flagstaff Mountain sequence** (T39N, R38E) contains Late Triassic (Karnian to Norian) conodonts (R. C. Roback, Univ. of Texas at Austin, written commun., 1989; Joseph, 1990a). Unnamed rocks northeast of Curlew (T40N, R34E) have yielded Late Triassic ammonites, brachiopods, pelecypods, and crinoid columnals (Parker and Calkins, 1964).

TRmt The unit is intruded by the Similkameen composite pluton (170 Ma) (units Jia and Jik) and the Upper Triassic(?) Loomis pluton (unit TRigd), indicating a minimum age of Late Triassic (Rinehart and Fox, 1972). The relation with older rock units is uncertain.

TRPmm This unit locally contains discontinuous layers and pods of metalimestone that have yielded Early Triassic (Scythian) pelecypods, cephalopods, and gastropods and Early to Late Permian fusulinids, crinoids, bryozoans, brachiopods, and corals (Kuenzi, 1961, 1965; Skinner and Wilde, 1966).

TRPmv Near Curlew, age assignment is based on the interfingering relation with unit TRPmt (Parker and Calkins, 1964). Northwest of Kettle Falls, age assignment is based on spatial relation with unit TRPmm (Mills, 1985) and on compositional similarity to unit TRPmv near Curlew.

TRPmt Locally, this unit contains layers and pods of metalimestone (units TRcb and Pcb) that have yielded Late Triassic ammonites, brachiopods, pelecypods, and crinoid columnals and Early Permian (Wolfcampian to Leonardian) fusulinids, bryozoans, brachiopods, and corals (Parker and Calkins, 1964; Muessig, 1967).

Pzmm Age uncertain. Age assignment is based on possible correlation with either the Anarchist Group (units Pmm and Pcb) or the Covada Group (units Omm, Ocb, and Omv) (K. F. Fox, Jr., USGS, written commun., 1988; M. T. Smith and G. E. Gehrels, Univ. of Arizona, written commun., 1990; Joseph, 1990b; Stoffel, 1990b).

Pmm **Spectacle Formation** (Anarchist Group) metasedimentary rocks in the Okanogan River valley contain Permian brachiopods, pelecypods, and gastropod molds (Rinehart and Fox, 1972). **Anarchist Group** phyllite on Buckhorn Mountain (T40N, R30E) has yielded sheared and fragmented Permian(?) corals (McMillen, 1979). Unnamed metasedimentary rocks north of Kettle Falls contain Permian brachiopods, pelecypods, gastropods, scaphopods, crinoid stems, and plant fragments (Mills and Davis, 1962; B. J. West, 1976; Mills, 1985). Unnamed metasedimentary rocks east of Barstow (T38-39N, R37E) have yielded abundant late Early Permian (Leonardian) macrofossils and conodonts (R. C. Roback, Univ. of Texas at Austin, written commun., 1988; Stoffel, 1990a). Age assignment of rocks west of Northport (T40N, R37-39E) is based on correlation with the Permian Mount Roberts Formation in southern British Columbia (Little, 1982). Age assignment of the rocks northeast of Curlew and along the West Fork Sanpoil River (T35N, R30-32E) is based on tentative correlation with the Anarchist Group (Rinehart and Greene, 1988).

Pcb North of Kettle Falls, the unit contains Early to Late Permian (Leonardian to Guadalupian) fusulinids, tetracorals, bryozoans, ostracods, crinoids, and foraminifers (Mills and Davis, 1962; B. J. West, 1976; Mills, 1985); near Curlew Lake (T37N, R33-34E), it contains Early Permian (Wolfcampian to Leonardian) fusulinids, bryozoans, brachiopods, and corals (Muessig, 1967). Age assignment of metalimestone in the Okanogan River valley and on Buckhorn Mountain is based on its interfingering relation with unit Pmm (Rinehart and Fox, 1972; McMillen, 1979). Age assignment of metalimestone near Barstow (T38N, R37E) is based on its proximity and similarity to metalimestone bodies in Lower Permian metasedimentary rocks (unit Pmm) near Toulou Creek. Age assignment of rocks near Swan Lake (T35N, R32E) is based on their tentative correlation with the Anarchist Group (Rinehart and Greene, 1988).

CDmm The **Flagstaff Mountain sequence** contains late Middle to Late Devonian (Givetian to Famennian) conodonts (Beka, 1980; Adekoya, 1983). The **Pend Oreille sequence** has yielded Late Devonian conodonts (Beka, 1980). Age assignment of the **Grass Mountain sequence** is based on its correlation with the Flagstaff Mountain and Pend Oreille sequences. Correlative rocks in southern British Columbia contain brachiopods that are no older than Devonian, no younger than Permian, and may be Carboniferous (Little, 1982).

CDcb Unnamed rocks near Springdale (T30N, R40E) contain Late Mississippian (Meramecian to Chesterian) conodonts (Waggoner, 1990b). Unnamed rocks east of Valley (T31N, R41E) have yielded Famennian conodonts and macrofossils (Miller and Clark, 1975; Waggoner, 1990b). Age assignment of metacarbonate rocks in the **Grass Mountain sequence** is based on their interfingering relation with metasedimentary rocks in the Grass Mountain sequence (unit CDmm).

CDmv Age uncertain. The unit is interbedded with metasedimentary rocks of the Flagstaff Mountain sequence (unit CDmm) (Yates, 1971).

CDmt Age uncertain. The unit is interbedded with metasedimentary rocks of the Flagstaff Mountain and Pend Oreille sequences (unit CDmm) (Yates, 1971).

COmm Age uncertain. Near the Columbia River north of Hunters (T30-35N, R36-38E), the unit conformably overlies the Covada Group (units Omm, Ocb, and Omv), suggesting a maximum age of Ordovician (M. T. Smith and G. E. Gehrels, Univ. of Arizona, written commun., 1990; Joseph, 1990b). East of Hunters (T30N, R37E), the unit contains Middle Cambrian to Early Ordovician conodonts, but their occurrence in turbidite sequences suggests that the conodonts may have been reworked from older rocks (Joseph, 1990b). East of Kettle Falls (T36-38N, R38E), these rocks contain late Famennian conodonts (Laskowski, 1982; Sandberg and others, 1988), suggesting that at least part of the unit is Late Devonian. Fossil data and lithologic compositions suggest that this unit may be correlative with unit CDmm.

COcg The unit is interbedded with unit COmm.

COmv The unit is interbedded with unit COmm.

Dcg Metaconglomerate clasts contain reworked Lower to Middle Devonian (Lochkovian to Eifelian) conodonts; Middle Devonian (Givetian) conodonts in the conglomerate matrix apparently represent the age of deposition (Greenman, 1976; Greenman and others, 1977).

Dcb North of Metaline Falls (T40N, R43E), the unit contains Late Devonian (Frasnian) corals and conodonts (Greenman and others, 1977). East of Hunters (T30N, R37E), the unit contains Famennian conodonts (Joseph, 1990b) and brachiopods (Dutro and Gilmour, 1989).

Smm The unit contains Early Silurian (Llandoverian to Ludlovian) conodonts (Greenman and others, 1977).

Omm The unit contains middle to late Early Ordovician conodonts, trilobites, and brachiopods (Snook and others, 1981; R. J. Ross, Jr., Colorado School of Mines, written commun., 1988).

Ocb This unit is interbedded with unit Omm.

Omv This unit is interbedded with unit Omm.

Oar The unit contains Early to Late Ordovician graptolites, conodonts, trilobites, and a crustacean and sponge (Park and Cannon, 1943; Schuster, 1976; Greenman and others, 1977; Snook and others, 1981; Carter, 1989a, 1989b; Schuster and others, 1989).

OЄcb The **Metaline Formation** contains Early Cambrian[1] to Middle Ordovician trilobites, brachiopods, conodonts, and fish (Bennett, 1941; Park and Cannon, 1943; Dings and Whitebread, 1965; Miller and Clark, 1975; Yates, 1976; Repetski, 1978; Repetski and others, 1989; Carter, 1989a, 1989b; Schuster and others, 1989). Age assignment of unnamed rocks north of Cusick (T35N, R43E) is based on correlation with the Metaline Formation.

OYmm Age uncertain. Lithologic compositions suggest possible correlation with parts of the Metaline Formation (unit OЄcb) and Addy Quartzite (unit ЄZq) (Becraft and Weis, 1963) and/or with part of the Deer Trail Group (units Ymm, Ycb2, Yar2, Ycb1, and Yar1) (Waggoner, 1990c)

Єmm The unit is interbedded with unit Єcb.

Єcb The unit contains Early Cambrian archeocyathids, trilobites, brachiopods, and bryozoans (Dings and Whitebread, 1965; Hampton, 1978).

ЄZq The **Addy** and **Gypsy Quartzites** contain Early Cambrian trilobites, brachiopods, and molluscs (Park and Cannon, 1943; Okulitch, 1951; Miller and Clark, 1975; Lindsey and others, 1990). Fossils are restricted to the upper parts of these formations; the lower parts of the formations are barren of fossils. Lindsey (1987, p. 70) believes that the sudden appearance of fossils in the upper parts of the formations represents "a true 'evolutionary' first appearance, and not a facies controlled first appearance", and that the Precambrian-Cambrian boundary is in the lower parts of the formations.

Windermere Group

The minimum age of the **Windermere Group** is broadly constrained by stratigraphic position beneath the Lower Cambrian and Upper Proterozoic Addy and Gypsy Quartzites (unit ЄZq). The maximum age is based on the inception of rifting, which probably began shortly before extrusion of the Upper Proterozoic (meta)volcanic rocks of the Huckleberry Formation (unit Zmv) approximately 750 Ma (Devlin and others, 1988).

Zq Age is constrained only by stratigraphic position within the Windermere Group.

Zmm Age is constrained only by stratigraphic position within the Windermere Group.

Zmv K-Ar ages from metavolcanic rocks of the **Huckleberry Formation** range from 238 to 928 Ma and cluster between 613 and 862 Ma (Miller and others, 1973), but because the Rb-Sr isotopic systems of the dated metavolcanic rocks have been severely disturbed, the K-Ar ages probably do not represent the age of extrusion (Devlin and others, 1985). Sm-Nd isochron ages of 674 ± 212 Ma, 762 ± 44 Ma, and 795 ± 115 Ma are also reported from the Huckleberry Formation (Devlin

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[1] Early Cambrian fossils have been recovered only from rocks near Addy, which were originally assigned to the Old Dominion Limestone; elsewhere, the oldest fossils in this unit are Middle Cambrian.

and others, 1988); the 762 Ma age is apparently the most reliable of the ages and is thought to broadly represent the extrusive age of the metavolcanic rocks (Devlin and others, 1988).

Zcg Age is constrained only by stratigraphic position within the Windermere Group.

Deer Trail Group

Ymm, Ycb$_2$, Yar$_2$, Ycb$_1$, Yar$_1$

Age assignment of the Deer Trail Group is based on correlation of the entire group with units Yms$_3$ and Yms$_4$ of the Belt Supergroup (Miller and Whipple, 1989).

Priest River Group

Yar, Yq, Ycb

Age assignment of the **Priest River Group** is based on correlation with the Deer Trail Group (units Ymm, Ycb$_2$, Yar$_2$, Ycb$_1$, and Yar$_1$), which is thought to be correlative with units Yms$_3$ and Yms$_4$ of the Belt Supergroup (Miller and Whipple, 1989).

Belt Supergroup

The **Belt Supergroup** in the northern Rocky Mountains is unconformably overlain by Windermere Group metavolcanic rocks (unit Zmv) (762 Ma) (Miller and others, 1973) and unconformably overlies crystalline basement rocks that have yielded isotopic ages of approximately 1,700 Ma in Canada (Burwash and others, 1962). The age range of the Belt Supergroup shown on the correlation diagram (Sheet 3) follows the interpretative geochronology of Obradovich and others (1984) and Harrison (1984).

Yms$_4$ Age uncertain. Correlative rocks in western Montana have yielded Rb-Sr isochron ages of approximately 1,100 Ma (Obradovich and others, 1984).

Yms$_3$ Age is constrained only by stratigraphic position within the Belt Supergroup.

Yms$_2$ Age is constrained only by stratigraphic position within the Belt Supergroup.

Yms$_1$ Age uncertain. The unit is intruded by abundant metadiorite sills, one of which (near Bonners Ferry, Idaho) has yielded a U-Pb zircon age of 1,433 ± 13 Ma (Zartman and others, 1982).

Intrusive Rocks

Mian The **andesite and dacite of Burch Mountain** has yielded K-Ar hornblende ages of 10-11 Ma (Engels and others, 1976; Tabor and others, 1987).

Φian The **hornblende andesite porphyry complex of Horse Lake Mountain** has yielded K-Ar hornblende ages of 25-30 Ma (Tabor and others, 1982).

Eian The **volcanics of Island Mountain** have yielded a K-Ar whole-rock age of 47 Ma (White, 1986).

Unnamed andesite near Oroville (T40N, R27E) intrudes Eocene conglomerate (unit Ecg$_1$).

Eir Unnamed rhyolite near Lake Chelan (T26-28N, R20-21E) intrudes the Duncan Hill pluton (48 Ma) (unit Eig) (Tabor and others, 1987).

Unnamed rhyolite dikes near Eightmile Creek (T39N, R20E) probably emanate from the Monument Peak stock (49 Ma) (Tabor and others, 1968).

The **intrusive rhyolite near West Fork** has yielded a K-Ar biotite age of 50 Ma (Atwater and Rinehart, 1984).

Eitr Unnamed trachyte east of Chesaw (T40N, R31E) intrudes the Sanpoil Volcanics (48-52 Ma) (unit Eida) (Pearson, 1967).

Eida Numerous radiometric ages (K-Ar biotite and hornblende, fission-track zircon and apatite) range from 45 to 54 Ma and cluster between 48 and 52 Ma (Joseph, 1990b; Stoffel, 1990a, 1990b; Waggoner, 1990b, 1990c).

Ei The **intrusive complex north of Grant Lake** is a heterogeneous mixture of units TKig, Eimd, Eida, and Eig. Formation of the complex probably occurred approximately 50 Ma (Gulick and Korosec, 1990b).

Eik Unnamed alkalic rocks northeast of Kettle Falls (T38N, R38E) have yielded a K-Ar biotite age of 51 Ma (Yates and Engels, 1968).

Unnamed alkalic rocks near Chesaw (T38N, R31E and T39N, R29E) intrude the O'Brien Creek Formation (unit Evc$_1$) (Pearson, 1967; Fox, 1973).

Unnamed alkalic rocks near Oroville intrude Eocene conglomerate (unit Ecg$_1$) (Fox, 1973).

Eis **Coryell intrusive rocks** have yielded K-Ar biotite ages of 51-52 Ma (Yates and Engels, 1968).

Eiat Preliminary U-Pb geochronology and Sr isotopic data (from outside the map area) suggest that the **Mount Rathdrum granite** is approximately 52 Ma (Bickford and others, 1985; Armstrong and others, 1987).

Eia The **Silver Point Quartz Monzonite** has yielded K-Ar biotite and hornblende ages of 48-52 Ma (Miller and Engels, 1975; J. C. Engels *in* Miller and Clark, 1975).

Eig The **Duncan Hill pluton** has yielded a K-Ar biotite age of 46 Ma (Cater and Crowder, 1967; Tabor and others, 1987).

The **Monument Peak stock** has yielded a K-Ar biotite age of 48 Ma (Tabor and others, 1968).

The **granite of Deadhorse Creek** has yielded a K-Ar biotite age of 50 Ma (Atwater and Rinehart, 1984).

The **Fire Mountain pluton** granite intrudes Fire Mountain pluton quartz monzonite (50-53 Ma) (Holder, 1985; Pearson and Obradovich, 1977).

The **Sheppard Granite** intrudes the Upper Cretaceous Sophie Mountain Formation (unit Kcg$_2$), is cut by lamprophyre dikes (53 Ma) (Yates and Engels, 1968), and is thought to be a phase of the Coryell intrusive rocks, which have yielded radiometric ages of 51-52 Ma (Little, 1982).

The **Long Alec Creek pluton** has yielded a K-Ar biotite age of 53 Ma (Stoffel, 1990a).

The **granite of upper Stepstone Creek** intrudes the Moses Mountain pluton (unit TKia) and unit Eida (Joseph, 1990b).

Unnamed granite near Orient (T40N, R37E) intrudes the O'Brien Creek Formation (unit Evc$_1$) and Sanpoil Volcanics (unit Evd$_1$) (J. R. West, 1976).

Eiqm The granodiorite phase of the **Cooper Mountain batholith** (unit Eigd) has yielded a radiometric age of 48 Ma (Tabor and others, 1987; V. R. Todd, USGS, written commun., 1990).

The **Empire Lakes pluton** has yielded a K-Ar biotite age of 50 Ma (Stoffel, 1990a).

The **Fire Mountain pluton** has yielded a K-Ar biotite age of 51 Ma (Pearson and Obradovich, 1977).

Unnamed quartz monzonite near Loon Lake (T30N, R41E) has yielded a K-Ar biotite age of 51-52 Ma (J. C. Engels *in* Miller and Clark, 1975).

The **Long Alec Creek pluton** has yielded a K-Ar biotite age of 52-53 Ma (Pearson and Obradovich, 1977; Stoffel, 1990b).

Monzonite east of Storm King Mountain intrudes unit Eimd (Holder, 1990).

Eigd The **Duncan Hill pluton** has yielded a U-Pb zircon age of 48 Ma (Tabor and others, 1987) and K-Ar hornblende and biotite ages of 43-48 Ma (Cater and Crowder, 1967; Tabor and others, 1987).

The **Cooper Mountain batholith** has yielded a K-Ar biotite age of 48 Ma (Tabor and others, 1987; V. R. Todd, USGS, written commun., 1990; Bunning, 1990).

The **granodiorite of Joe Moses Creek** has yielded a K-Ar biotite age of 48 Ma (B. F. Atwater, USGS, written commun., 1989; Joseph, 1990b).

The **Lost Peak stock** has yielded K-Ar biotite and fission-track zircon ages of 48-52 Ma (White, 1986).

The **Noname stock** has yielded fission-track titanite and zircon ages of 54-56 Ma (Buddington, 1986).

Eimd The **Kettle Crest pluton** has yielded K-Ar biotite and hornblende ages of 45-48 Ma (Atwater and Rinehart, 1984).

The **Friedlander Meadows pluton** has yielded K-Ar biotite and hornblende ages of 47-48 Ma (B. F. Atwater, USGS, written commun., 1987; Waggoner, 1990c).

The **Swimptkin Creek pluton** has yielded K-Ar biotite and hornblende ages of 45-50 Ma (Fox and others, 1976; Atwater and Rinehart, 1984; B. F. Atwater, USGS, written commun., 1987; Gulick and Korosec, 1990b).

The **Devils Elbow pluton** has yielded a K-Ar biotite age of 50 Ma (Atwater and Rinehart, 1984).

Unnamed monzodiorite near Springdale (T29N, R40E) has yielded a K-Ar biotite age of 50 Ma (J. C. Engels *in* Miller and Clark, 1975).

The **Henry Creek diorite** has yielded K-Ar biotite and hornblende ages of 51-54 Ma (Pearson and Obradovich, 1977; Stoffel, 1990a).

Eiq The **Hungry Mountain stock** has yielded a K-Ar hornblende age of 45 Ma (Hopkins, 1987).

Eid Unnamed rocks near Sinlahekin Creek (T37N, R24E) intrude middle Eocene tuff (unit Evt$_1$) (Stoffel, 1990b).

The **diorite of Little Moses Mountain** (T33N, R30E) intrudes the Moses Mountain pluton (unit TKia) and is cut by dikes of the granite of upper Stepstone Creek (unit Eig) (Atwater and Rinehart, 1984).

Eib Unnamed gabbro west of Toroda (T40N, R32E) intrudes middle Eocene volcaniclastic rocks (unit Evc$_2$) (Pearson, 1967).

Unnamed gabbro near Wenatchee (T22N, R20E) intrudes the Chumstick Formation (unit Ec$_2$) and is cut by Oligocene andesite plugs (unit Φian) (Gresens, 1983).

Unnamed gabbro and diorite near Kettle Falls intrude Triassic-Permian metasedimentary rocks (unit TRPmm); because they have not been metamorphosed, the intrusions are thought to be post-Middle Jurassic in age.

Ɍit The **Oval Peak batholith** has yielded U-Pb zircon and titanite ages of 61-65 Ma (Miller and Walker, 1987; Miller and others, 1989).

TKiat The **granite of Swawilla basin** has yielded K-Ar biotite ages of 54 and 59 Ma from the border phase (unit TKia) (Atwater and Rinehart, 1984; B. F. Atwater, USGS, written commun., 1987; Waggoner, 1990c); these are minimum crystallization ages[1].

TKiaa The **garnet-bearing granite of McGinnis Lake** (T30N, R31E) intrudes the quartz porphyry of Mount Tolman and the porphyritic granite of Keller Butte (unit TKig), which have yielded minimum crystallization ages[1] of 56-61 Ma (K-Ar biotite, muscovite, and sericite) (Atwater and Rinehart, 1984).

Age assignment of alaskitic rocks in the **Coyote Creek, Moses Mountain,** and **Mount Bonaparte plutons** is based on K-Ar (biotite and muscovite) and fission-track (allanite and apatite) ages of 49-59 Ma from the main phases of the plutons (unit TKia), which are thought to represent minimum crystallization ages[1] (Fox and others, 1976; Naeser and others, 1970; Atwater and Rinehart, 1984).

The alaskite-aplite-pegmatite phase of the **Mount Spokane granite** cuts the granitic phase (unit Kiat), the age of which is thought to be approximately 90 Ma. The alaskite-aplite-pegmatite has yielded Rb-Sr whole-rock + muscovite ages of 40 and 47 Ma and Rb-Sr whole-rock ages of 84 and 113 Ma (Armstrong and others, 1987); some of the latter ages came from samples from the

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[1] Numerous K-Ar and fission-track ages between 47 and 61 Ma have been reported from Tertiary-Cretaceous intrusive rocks (units TKiat, TKiaa, TKia, TKig, and TKigd) in the Kettle, Okanogan, Lincoln, and Priest River metamorphic core complexes. These ages are thought to represent the age of uplift and cooling of the core complexes and not the magmatic crystallization ages of the intrusions, which are unknown.

granitic phase of the pluton. These data suggest a Late Cretaceous magmatic age and an Eocene metamorphic age.

Unnamed alaskite-aplite-pegmatite south of Spokane (T24N, R42-44E) intrudes Precambrian high-grade metamorphic rocks (unit pЄhm); age assignment is based on compositional similarity to unit TKiaa northeast of Spokane (Joseph, 1990c).

TKia The **porphyritic granodiorite of Manila Creek** has yielded K-Ar biotite and hornblende ages of 41-47 Ma (B. F. Atwater, USGS, written commun., 1989; Joseph, 1990b); these are minimum crystallization ages[1].

The **Moses Mountain pluton** has yielded K-Ar biotite ages of 48-49 Ma (Atwater and Rinehart, 1984; B. F. Atwater, USGS, written commun., 1987; Gulick and Korosec, 1990b); these are minimum crystallization ages[1].

The **plutonic complex of Johnny George** has yielded K-Ar biotite and hornblende ages of 49-50 Ma (B. F. Atwater, USGS, written commun., 1987; Waggoner, 1990c); these are minimum crystallization ages[1].

The **Mount Bonaparte pluton** has yielded K-Ar (biotite and muscovite) and fission-track (allanite and apatite) ages of 49-59 Ma (Fox and others, 1976; Naeser and others, 1970); these are minimum crystallization ages[1].

The **granite of Swawilla Basin** has yielded K-Ar biotite ages of 54-59 Ma (Atwater and Rinehart, 1984; B. F. Atwater, USGS, written commun., 1987; Waggoner, 1990c); these are minimum crystallization ages[1].

Age assignment of the **Fifteenmile Creek pluton** is based solely on compositional similarity to other unit TKia plutons.

Age of unnamed acidic intrusive rocks elsewhere in the map area is unknown, but mineralogic compositions and spatial associations suggest that they are either Late Cretaceous or early Tertiary.

TKig The **Coyote Creek pluton** has yielded K-Ar biotite ages of 49-51 Ma (Fox and others, 1976; Atwater and Rinehart, 1984); these are minimum crystallization ages[1].

The **granite of Daisy Trail** has yielded a K-Ar biotite age of 50 Ma (Atwater and Rinehart, 1984); this is a minimum crystallization age[1].

The **granite west of Armstrong Mountain** has yielded a K-Ar biotite age of 53 Ma (Atwater and Rinehart, 1984); this is a minimum crystallization age[3].

The **quartz porphyry of Mount Tolman** has yielded K-Ar (sericite and muscovite) ages of 56-58 Ma (Atwater and Rinehart, 1984); these ages were determined from secondary minerals in hydrothermally altered rocks and are therefore minimum crystallization ages[1].

Unnamed granitic rocks east of Nespelem (T31N, R29E) have yielded K-Ar biotite and muscovite and Rb-Sr isochron ages of 50-59 Ma (B. F. Atwater, USGS, written commun., 1987; R. J. Fleck, USGS, written commun., 1989; Gulick and Korosec, 1990b); these are minimum crystallization ages[1].

The **porphyritic granite of Keller Butte** has yielded K-Ar biotite ages of 53-61 Ma (Atwater and Rinehart, 1984; B. F. Atwater, USGS, written commun., 1987; Waggoner, 1990c); these are minimum crystallization ages[1].

TKigd The **porphyritic granodiorite southwest of Omak Lake** has yielded a K-Ar biotite age of 53 Ma (Atwater and Rinehart, 1984); this is a minimum crystallization age[3].

TKit The **Arbuckle Mountain pluton** has yielded a K-Ar biotite age of 81.2 ± 3.0 Ma (Gulick and Korosec, 1990a), but because it intrudes rocks of the Chelan complex that yield K-Ar biotite and hornblende ages between 56 and 60 Ma, the accuracy of the 81 Ma age is questionable; a Late Cretaceous or early Tertiary crystallization age is suspected.

TKid Age assignment is based on interpretation of the unit as a border phase of the Tertiary-Cretaceous Mount Bonaparte pluton (unit TKia) (Cheney and others, 1982; Orr and Cheney, 1987).

Mzigb Age uncertain. The unit intrudes the Salmon Creek schists and gneisses (units pJhm and pJmb).

Kida Unnamed dacite and andesite dikes and sills yielded K-Ar hornblende ages of 82-93 Ma (V. R. Todd, USGS, written commun., 1988; Stoffel and McGroder, 1990).

Kiat Unnamed two-mica granite northwest of Spokane (T27N, R42E) has yielded K-Ar biotite and muscovite ages of 48-53 Ma (Miller and Engels, 1975), but these ages are probably reset; the magmatic crystallization age is interpreted as approximately 100 Ma (Joseph, 1990c).

The **granodiorite of Hall Mountain** has yielded K-Ar muscovite and biotite ages of 87-99 Ma (Miller and Engels, 1975).

The **monzogranite of Hungry Mountain** has yielded K-Ar biotite and muscovite ages of 92-97 Ma (Miller and Engels, 1975).

The **monzogranite of Granite Pass** has yielded a K-Ar muscovite age of 98 Ma (Miller and Engels, 1975).

The **Phillips Lake Granodiorite** has yielded K-Ar biotite and muscovite ages that range from 50 to 86 Ma (Miller and Engels, 1975; J. C. Engels *in* Miller and Clark, 1975); these ages reflect cooling during Late Cretaceous and early Tertiary uplift and/or deformation. The apparent magmatic crystallization age is approximately 100 Ma (J. C. Engels *in* Miller and Clark, 1975).

Unnamed two-mica granite south and west of Ione (northern extension of the **Phillips Lake Granodio-**

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[1] Numerous K-Ar and fission-track ages between 47 and 61 Ma have been reported from Tertiary-Cretaceous intrusive rocks (units TKiat, TKiaa, TKia, TKig, and TKigd) in the Kettle, Okanogan, Lincoln, and Priest River metamorphic core complexes. These ages are thought to represent the age of uplift and cooling of the core complexes and not the magmatic crystallization ages of the intrusions, which are unknown.

rite, in T35-38N, R41-43E) has yielded K-Ar biotite and muscovite ages of 49-102 Ma (Yates and Engels, 1968; Miller and Engels, 1975); these ages reflect cooling during Late Cretaceous and early Tertiary uplift and/or deformation. The apparent magmatic crystallization age is approximately 100 Ma (J. C. Engels *in* Miller and Clark, 1975).

The **granodiorite of Dubious Creek** has yielded K-Ar biotite and muscovite ages of 96-102 Ma (Miller and Engels, 1975); these ages are from outside of the map area.

The **Blickensderfer Quartz Monzonite** has yielded K-Ar biotite and muscovite ages of 101-102 Ma (Miller and Engels, 1975).

Unnamed two-mica granite south of Sullivan Lake (T37N, R43-44E) has yielded K-Ar biotite and muscovite ages of 103 Ma (Miller and Engels, 1975).

The **Mount Spokane granite** has yielded K-Ar biotite and muscovite ages between 47 and 49 Ma (Miller and Engels, 1975), a Rb-Sr (whole rock + biotite) age of 51 Ma (Armstrong and others, 1987), Rb-Sr whole-rock ages of 84 and 159 Ma (some of these samples coming from the pegmatite phase) (Armstrong and others, 1987), and U-Pb zircon ages between 94 and 143 Ma (Armstrong and others, 1987). These data suggest a Late Cretaceous (≅ 90 Ma) magmatic age (with older inherited zircon) and an Eocene metamorphic age (Armstong and others, 1987).

Kiaa Aplite east of Malott (T32N, R25E) is a phase of the **equigranular granite of Virginia Lake**, which has yielded K-Ar biotite ages of 65 and 75 Ma (B. F. Atwater, USGS, written commun., 1987; Gulick and Korosec, 1990b); these are minimum crystallization ages.

Unnamed alaskite east of Deer Lake (T30N, R42E) has yielded a K-Ar muscovite age of 80 Ma (J. C. Engels *in* Miller and Clark, 1975).

Alaskite northeast of Colville (T38N, R41E) is a phase of the **Spirit pluton**, which has yielded radiometric ages of 93-102 Ma (Yates and Engels, 1968).

Unnamed alaskite-aplite-pegmatite east of Ruby (T35N, R44E) intrudes the Galena Point Granodiorite (101 Ma) (Miller and Engels, 1975).

Unnamed alaskite-aplite-pegmatite north of Fort Spokane (T28-29N, R35-36E) intrudes and/or grades into granite and granodiorite plutons, the ages of which are probably 100 Ma (Waggoner, 1990c).

Kia The **Bottle Spring pluton** has yielded a K-Ar biotite age of 89 Ma (V. R. Todd, USGS, written commun., 1988; Stoffel, 1990b).

The **Evans Lake pluton** has yielded a K-Ar biotite age of 89 Ma (from ductilely deformed rocks along the southern border of the pluton) (Rinehart and Fox, 1976); this is a minimum crystallization age.

Unnamed monzogranite southwest of Springdale (T28-29N, R37-39E) has yielded ages ranging from 63 to 105 Ma (U-Pb zircon and monazite, Pb-Th zircon and monazite, Pb-α, Rb-Sr isochron, and fission-track apatite and titanite) (Becraft and Weis, 1963; Ludwig and others, 1981; Asmerom and others, 1988); the age data suggest that the pluton is either a composite of intrusions (older on the east) (Asmerom and others, 1988) or an Upper Cretaceous intrusion that was locally metamorphosed (western part) during middle Eocene plutonism (Ludwig and others, 1981).

The **Aeneas Creek pluton** has yielded K-Ar hornblende and biotite ages of 92-98 Ma (Rinehart and Fox, 1976; Stoffel, 1990b).

The **Cathedral batholith** has yielded K-Ar biotite ages of 94-98 Ma (Hawkins, 1968; Berry and others, 1976).

The **Fan Lake Granodiorite** has yielded K-Ar biotite and hornblende ages of 96-98 Ma (Miller and Engels, 1975).

The **Starvation Flat Quartz Monzonite** has yielded K-Ar biotite and hornblende and Pb-α zircon ages of 99-100 Ma (Larsen and others, 1958; Miller and Engels, 1975; J. C. Engels *in* Miller and Clark, 1975).

Unnamed granite east of Colville (T35N, R40-41E) has yielded a K-Ar biotite age of 100 Ma (Miller and Engels, 1975).

The **Galena Point Granodiorite** has yielded a K-Ar biotite age of 101 Ma (Miller and Engels, 1975).

Kig The **equigranular granite of Virginia Lake** has yielded K-Ar biotite ages of 65-75 Ma (B. F. Atwater, USGS, written commun., 1988; Gulick and Korosec, 1990b); these are minimum crystallization ages.

The **monzogranite of Sand Creek** has yielded a K-Ar biotite age of 99 Ma (Miller and Engels, 1975).

The **Spirit pluton** has yielded K-Ar muscovite, biotite, and hornblende ages of 93-102 Ma (Yates and Engels, 1968).

Kiqm The **Leader Lake quartz monzonite** has yielded a Rb-Sr mineral isochron age (combined with a sample of the Conconully pluton) of 82 Ma and a fission-track (apatite) age of 94 Ma (Menzer, 1970).

The **Horseshoe Mountain pluton** has yielded K-Ar hornblende and biotite ages of 95-103 Ma (Stoffel, 1990b).

Kigd The **granodiorite of Soap Lake Mountain** has yielded a K-Ar biotite age of 55 Ma (B. F. Atwater, USGS, written commun., 1987); this is a minimum crystallization age.

The **Texas Creek stock** has yielded K-Ar hornblende ages of 84-87 Ma (V. R. Todd, USGS, written commun., 1990; Bunning, 1990); these reported ages from the dioritic phase of the stock are minimum crystallization ages.

The **Pasayten stock** has yielded K-Ar biotite and hornblende ages of 85-88 Ma (Tabor and others, 1968).

The **Conconully pluton** has yielded Rb-Sr mineral isochron, fission-track (titanite and apatite), and Pb-α zircon ages of 82-90 Ma (Menzer, 1970). Discordant K-Ar ages between 62 and 81 Ma (Rinehart and Fox, 1976; Berry and others, 1976) "suggest that a younger thermal event, centered east of the pluton, may have reduced the apparent mineral ages in the eastern part of the pluton" (Rinehart and Fox, 1976, p. 38).

Unnamed granodiorite southwest of Springdale (T27N, R37-39E) has yielded Pb-α (whole rock) ages of 95-105 Ma (Becraft and Weis, 1963).

Unnamed granodiorite southeast of Ione (T36N, R44E) has yielded K-Ar biotite and hornblende ages of 99-100 Ma (Miller and Engels, 1975).

Unnamed granodiorite southeast of Ruby (T35N, R44E) has yielded K-Ar biotite and hornblende ages of 100-104 Ma (R. J. Fleck, USGS, written commun., 1989; Joseph, 1990a)

Age assignment of unnamed granodiorite in the **Okanogan batholithic complex** is based on ages reported from the tonalitic phase of the complex (unit Kit).

Kit The **Cardinal Peak pluton** has yielded a U-Pb zircon age of 75 Ma (Miller and others, 1989).

The **Entiat pluton** has yielded concordant U-Th-Pb zircon ages of 75-85 Ma, K-Ar biotite and hornblende ages of 56-73 Ma, and fission-track (apatite and zircon) ages of 48-58 Ma (Tabor and others, 1987); the ages indicate Late Cretaceous magmatic crystallization and early Tertiary uplift and cooling.

Unnamed tonalite in the **Okanogan batholithic complex** has yielded a preliminary U-Pb zircon age of approximately 112 Ma (Hugh Hurlow, Univ. of Washington, oral commun., 1990) that apparently represents a magmatic crystallization age; numerous fission-track (apatite and titanite), K-Ar (biotite and muscovite), and Rb-Sr isochron ages between 76 and 108 Ma represent the ages of uplift and cooling of the complex (Stoffel, 1990b; Stoffel and McGroder, 1990; Gulick and Korosec, 1990b).

Kiq The **Lone Frank pluton** has yielded K-Ar hornblende and biotite ages of 93-97 Ma (Stoffel, 1990b).

Kid Diorite in the **Texas Creek stock** has yielded K-Ar hornblende ages of 84-87 Ma (V. R. Todd, USGS, written commun., 1990; Bunning, 1990); these are minimum crystallization ages.

The **Fawn Peak stock** has yielded K-Ar biotite ages of 87-88 Ma (Riedell, 1979a, 1979b; V. R. Todd, USGS, written commun., 1989).

The **Aeneas Creek pluton** has yielded K-Ar hornblende and biotite ages of 92-98 Ma (Rinehart and Fox, 1976; Stoffel, 1990b); these reported ages are from the central phase of the pluton (unit Kia).

The **McFarland Creek stock** is intruded by the Cooper Mountain batholith (48 Ma) (units Eigd and Eiqm) and the Hungry Mountain stock (45 Ma) (unit Eiq) (Bunning, 1990); the magmatic crystallization age is uncertain.

Kigb Age assignment of gabbro in the **Entiat pluton** is based on concordant U-Th-Pb ages of 75-85 Ma reported from the tonalitic phase (unit Kit) of the pluton (Tabor and others, 1987).

KJia The **granite and granodiorite near Meteor** has yielded K-Ar biotite ages of 55 and 61 Ma and a K-Ar hornblende age of 110 Ma (Atwater and Rinehart, 1984; B. F. Atwater, USGS, written commun., 1989; Joseph, 1990b); the hornblende age is a minimum crystallization age.

Other unit KJia intrusions cut Paleozoic and/or lower Mesozoic metasedimentary rocks and are locally intruded by lower Tertiary-Upper Cretaceous plutons (units TKia and TKig).

KJigd The **granodiorite of Rogers Bar** has yielded a K-Ar hornblende age of 71 Ma (Atwater and Rinehart, 1984); this is a minimum crystallization age.

The **Anderson Creek pluton** has yielded discordant K-Ar biotite and hornblende ages of 100 and 116 Ma, respectively (Engels and others, 1976); the hornblende age is a minimum crystallization age.

The **Whiskey Mountain pluton** has yielded a K-Ar hornblende age of 119 Ma (Stoffel, 1990b); this is a minimum crystallization age.

Other unit KJigd intrusions cut Paleozoic and/or lower Mesozoic metasedimentary rocks; the **Wauconda pluton** (T37N, R30-31E) is intruded by the lower Tertiary-Upper Cretaceous Mount Bonaparte pluton (unit TKia).

KJiq Granodiorite in the **Whiskey Mountain pluton** has yielded a K-Ar hornblende age of 119 Ma (Stoffel, 1990b), which is a minimum age of crystallization.

The **Carlton stocks** have yielded K-Ar hornblende ages of 130 Ma (Hopkins, 1987); because the stocks are locally deformed and metamorphosed, this age is a minimum age of crystallization (Bunning, 1990).

The **Alder Creek stock** has yielded K-Ar hornblende ages of 137-139 Ma (V. R. Todd, USGS, written commun., 1990; Bunning, 1990); because the stock is locally deformed and metamorphosed, these ages are minimum ages of crystallization (Bunning, 1990).

Quartz diorite in the **Frazer Creek complex (Wolf Canyon quartz diorite)** has yielded K-Ar biotite ages of 104-109 Ma and K-Ar hornblende ages of 130-139 Ma (V. R. Todd, USGS, written commun., 1990; Bunning, 1990); the strong discordance between biotite and hornblende ages indicates that the hornblende ages are minimum ages of crystallization.

The **Bowers quartz diorite** (part of the **Toats Coulee pluton**) intrudes the Upper Triassic(?) Loomis pluton (unit Ŧigd).

KJid Age and contact relations uncertain.

KJigb Age assignment of gabbro in the **Frazer Creek complex (Red Shirt gabbro)** is based on K-Ar hornblende ages of 130-139 Ma reported from quartz diorite in the complex (unit KJiq); these are minimum ages of crystallization.

Age and contact relations of **gabbro near Stranger Creek** (T32N, R36E) are uncertain.

Jik Age assignment of alkalic rocks in the **Similkameen composite pluton** is based on several ages of approximately 171 Ma reported from the central phase of the pluton (unit Jigd) (Engels, 1971; Buddington and Burmester, 1990).

Age assignment of **Shankers Bend alkalic complex** is based on its compositional similarity to the alkalic rocks in the Similkameen composite pluton, which suggests "that they were probably emplaced during the same episode of plutonism and are derived from the same magmatic source" (Rinehart and Fox, 1972, p. 59).

Age of the **intrusive rocks of Shasket Creek** is uncertain; they intrude Triassic-Permian metasedimentary and metavolcanic rocks (unit T̄RPmt) and are cut by Eocene dacite dikes (unit Eida) (Parker and Calkins, 1964).

Jia The **Similkameen composite pluton** has yielded Rb-Sr isochron and K-Ar (hastingsite) ages of 171 Ma (Engels, 1971; Buddington and Burmester, 1990); a concordant U-Pb zircon age of 170 ± 2 Ma is reported from the northern border of the pluton near Keremeos, British Columbia (Parkinson, 1985).

The **Lane Mountain pluton** has yielded K-Ar biotite and hornblende ages of 156-172 Ma (Miller and Engels, 1975; J. C. Engels *in* Miller and Clark, 1975; F. K. Miller, USGS, oral commun., 1988; Waggoner, 1990b).

Jiqm The unnamed pluton west of Palmer Lake (T39N, R24E) has yielded discordant K-Ar biotite and hornblende ages of 131 and 162 Ma, respectively (Stoffel, 1990b); the hornblende age is a minimum crystallization age.

Jigd The **Blue Goat pluton** has yielded discordant K-Ar biotite and hornblende ages of 99 and 142 Ma, respectively (Rinehart and Fox, 1976); the hornblende age is a minimum crystallization age.

Jit The **Button Creek stock** has yielded K-Ar hornblende ages of 150-153 Ma (V. R. Todd, USGS, written commun., 1990; Stoffel and McGroder, 1990).

Jiq Unnamed quartz diorite west of Northport (T40N, R37E) grades into basic intrusive rocks (unit Jib) that are compositionally similar to, and locally grade into metavolcanic rocks in the Jurassic Rossland Group (unit Jmv) (Rhodes, 1980).

Jib Unnamed basic intrusive rocks west of Northport (T39-40N, R37-38E) intrude Permian metasedimentary rocks (unit Pmm) and the Jurassic Rossland Group (unit Jmv); "similarities in composition between the Rossland Group and the related mafic intrusive rocks along with the gradational nature of at least some of the contacts between the two suggests [sic] that the gabbros may be the coarse-grained equivalent of the basalts" (Rhodes, 1980, p. 33).

T̄Rigd The **Loomis pluton** has yielded weakly discordant K-Ar biotite and hornblende ages of 179 and 194 Ma, respectively (Rinehart and Fox, 1972); the hornblende age is a minimum crystallization age.

The **Flowery Trail Granodiorite** has yielded K-Ar biotite ages of 66-100 Ma and K-Ar hornblende ages of 146-198 Ma (J. C. Engels *in* Miller and Clark, 1975); hornblende ages are minimum crystallization ages.

T̄Rib Because the **Chopaka intrusive complex** was metamorphosed in the Early Jurassic (K-Ar actinolitic hornblende age of the gabbro = 190 ± 15.6 Ma [Hibbard, 1971]) and was intruded by the Loomis pluton (unit T̄Rigd) in the Late Triassic(?), the magmatic crystallization age of the complex must be Triassic or older.

Other unit T̄Rib intrusions in the map area (T36-40N, R26-30E) intrude the Anarchist Group (units Pmm and Pcb) and Kobau Formation (unit T̄Rmt). The composition of the basic intrusive rocks is similar to that of basic igneous rocks in the Chopaka intrusive complex (unit T̄Rib), the Palmer Mountain Greenstone (unit T̄Rmv), and the Kobau Formation (unit T̄Rmt) (Hibbard, 1971; Rinehart and Fox, 1972); stratigraphic and cross-cutting relations suggest that all are roughly coeval.

Ꝑib Age uncertain. The unit intrudes Paleozoic metasedimentary rocks (unit Ꝑmm).

Oigb Age uncertain. The unit intrudes metasedimentary rocks of the Ordovician Covada Group (units Omm and Ocb) and may be the intrusive equivalent of metavolcanic rocks in the group (unit Omv).

Zib This unit intrudes Proterozoic Y Deer Trail Group (units Ymm, Ycb$_2$, Yar$_2$, Ycb$_1$, and Yar$_1$) and Priest River Group (units Yar, Yq, and Ycb). The composition of unit Zib is similar to that of the Proterozoic Z metavolcanic rocks (unit Zmv), which suggests that unit Zib is the intrusive equivalent of the metavolcanic rocks (Campbell and Loofbourow, 1962; Miller and Clark, 1975) that were extruded approximately 760 Ma (Devlin and others, 1988).

Yib This unit intrudes the Proterozoic Y Prichard Formation (unit Yms$_1$). No isotopic ages are known from unit Yib in the map area, but a U-Pb zircon age of 1,433 Ma is reported from correlative rocks (Crossport C sill of Bishop, 1973) near Bonners Ferry, Idaho (Zartman and others, 1982).

u Because the "mineralogical gradation between the gabbroic [unit T̄Rib] and ultramafic portions of the [Chopaka intrusive] complex and the lack of small-scale crosscutting relationships supports [sic] the idea that they were emplaced at essentially the same time" (Hibbard, 1971, p. 3028), ultrabasic rocks in the **Chopaka intrusive complex** must be Triassic or older.

Because ultrabasic rocks elsewhere in the map area are thought to be fault-bounded, their ages are uncertain.

Mixed Metamorphic and Igneous Rocks

TKmi **Skagit Gneiss** is a heterogeneous unit composed of rocks of at least three ages: Eocene (approximately 45 Ma) lineated granitic plugs and dikes; Late Cretaceous and Paleocene (60-75 Ma) directionless to strongly foliated leucocratic tonalite and tonalitic gneiss (correlative with units Ꝑit, Ꝑog, Kit, and Kog); and Triassic, Permian, and older(?) schist, quartzite, amphibolite, and calc-silicate rocks (correlative with units T̄RPhmc and T̄RPmb).

The **plutonic complex of Johnny George** mixed metamorphic and igneous rocks (T27-28N, R34-35E) consist of biotite gneiss of uncertain age and affinity, and leucocratic granite, aplite, and pegmatite that are probably equivalent to Upper Cretaceous and lower Tertiary intrusive rocks (unit TKia). Monzodiorite intrusions that are probably correlative with the Friedlander Meadows pluton (50 Ma) (unit Eimd) cut the mixed rocks. Formation of the complex probably occurred during intrusion of the leucocratic granite, aplite, and pegmatite in the Late Cretaceous and/or early Tertiary.

Kmg Migmatitic banded gneiss in the **Chelan complex** has yielded a weakly discordant U-Pb zircon age of 185 Ma (Mattinson, 1972); zircons probably represent a mixture of older inherited zircons and new magmatic zircons. The migmatitic gneiss probably formed "in the Late Cretaceous from melts that were derived by mobilization or anatexis of older rocks...The gradation of the more massive plutons into migmatitic terrane and the spectrum of U-Pb zircon ages representing mixtures of inherited and new components of this refractory mineral strongly support such an interpretation" (Tabor and others, 1987, p. 8).

KJmi, KJmg

These heterogeneous units are composed of rocks of at least two ages: weakly to strongly foliated, leucocratic tonalite and granodiorite that strongly resemble Upper Jurassic and Lower Cretaceous orthogneiss (unit KJog), and hornblende-biotite schist and gneiss, amphibolite, and minor calc-silicate rocks that are probably correlative with pre-Jurassic layered metamorphic rocks (units pJhm and pJam). The heterogeneous rocks are cut by Early Cretaceous plutons (unit Kit). They probably formed in the Late Jurassic or Early Cretaceous by anatexis of pre-Jurassic layered metamorphic rocks (units pJhm and pJam) or by injection of Upper Jurassic to Lower Cretaceous intrusive rocks (unit KJog) into the layered rocks (Hawkins, 1968; Menzer, 1983; Raviola, 1988; V. R. Todd, USGS, written commun., 1988).

Metamorphic Rocks

Rog The **Lake Juanita leucogneiss** has yielded a U-Pb zircon age of 59 Ma (Miller and others, 1989).

Orthogneiss in the **Oval Peak batholith** has yielded U-Pb zircon ages of 61-62 Ma (Miller and others, 1989); directionless rocks of the batholith (unit Rit) have yielded U-Pb (zircon and titanite) ages of 61 and 65 Ma, respectively (Miller and Walker, 1987; Miller and others, 1989).

The **War Creek gneiss** intrudes the Black Peak batholith (90 Ma) and is deformed along the Gabriel Peak tectonic zone, which was active between 45 and 65 Ma (Miller, 1987; Miller and others, 1989). The magmatic crystallization age is Late Cretaceous or early Tertiary.

Kog Leucocratic orthogneiss in the **Chelan complex** "is thought to have formed in the Late Cretaceous from melts that were derived by mobilization or anatexis of older rocks...The gradation of the more massive plutons into migmatitic terrane and the spectrum of U-Pb zircon ages representing mixtures of inherited and new components of this refractory mineral strongly support such an interpretation...Metamorphic overprinting of the plutons must have occurred contemporaneously with or immediately after their emplacement if we accept the 70 to 86 m.y. U-Pb sphene ages...and the K-Ar hornblende and biotite ages as old as 84 m.y." (Tabor and others, 1987, p. 8).

Light-colored gneiss in the **heterogeneous schist and gneiss unit of the Mad River terrane** (reassigned to **rocks of the Napeequa River area** of the Chelan Mountains terrane by Tabor and others, 1989) has yielded concordant to moderately discordant U-Th-Pb zircon ages between 71 and 127 Ma (Tabor and others, 1987); "the light colored granodioritic gneiss appears to contain a mixture of newly crystallized Late Cretaceous and inherited and probable Paleozoic or older zircon" (Tabor and others, 1987, p. 11).

The **Black Peak batholith** has yielded U-Pb (zircon and titanite) ages of 89-91 Ma (Hoppe, 1984).

One of the **Bearcat Ridge plutons** has yielded a U-Pb zircon age of approximately 90 Ma (R. B. Miller, San Jose State Univ., oral commun., 1990).

The **Newman Lake Gneiss** has yielded discordant U-Pb zircon ages of 97 and 139 Ma and a Rb-Sr (whole rock + biotite) age of 45 Ma (Armstrong and others, 1987). Because the U-Pb ages and initial Sr isotopic ratios are similar to those of the Mount Spokane granite (unit Kiat), magmatic crystallization of the Newman Lake Gneiss is thought to have occurred during the Late Cretaceous (Armstrong and others, 1987).

Unnamed orthogneiss northeast of Spokane (T27-30N, R35E) grades into the Mount Spokane granite (unit Kiat) and the Newman Lake Gneiss (unit Kog); age assignment is based on interpretation of the unit as mylonitically deformed Mount Spokane granite (Weissenborn and Weis, 1976).

Kogm Mesocratic orthogneiss in the **Chelan complex** is intimately associated with, and is probably the same age as leucocratic orthogneiss (unit Kog) in the complex.

KJog Age uncertain. K-Ar biotite and hornblende and fission-track (titanite and apatite) ages between 76 and 106 Ma (Menzer, 1970; Berry and others, 1976; V. R. Todd, USGS, written commun., 1990; Bunning, 1990; Stoffel and McGroder, 1990) represent the age of uplift and cooling or age of latest ductile deformation of the plutons. A Rb-Sr isochron age of 129 Ma from the **Leader Mountain granodioritic gneiss** (Menzer, 1970) and a U-Pb zircon age of 120 Ma from the **Methow gneiss** (R. B. Miller, San Jose State Univ., oral commun., 1990) may represent magmatic crystallization ages. U-Pb zircon ages of 140-150 Ma are reported from compositionally and texturally similar intrusions in the Eagle plutonic complex in southern British Columbia (Greig, 1988).

Jog This unit intrudes the Upper Triassic(?) Loomis pluton (unit Ŧigd) and Tillman Mountain tonalitic gneiss (unit Ŧog); the minimum age is constrained by discordant K-Ar biotite and hornblende ages of 151 and 170 Ma (Rinehart and Fox, 1972).

Ŧog The **Tillman Mountain tonalitic gneiss** has yielded discordant K-Ar biotite and hornblende ages of 97 and 173 Ma (Stoffel, 1990b); because it is intruded by the Similkameen composite pluton (170 Ma) (unit Jia) and grades into the Upper Triassic(?) Loomis pluton (unit Ŧigd), a Late Triassic magmatic crystallization age is suspected.

The **Osoyoos batholith** (in southern British Columbia) has yielded a U-Pb zircon age of 202 Ma (Parkinson, 1985); a K-Ar biotite age of 49 Ma from the map area (Fox and others, 1976) indicates that post-crystallization deformation and thermal metamorphism occurred during the middle Eocene.

Mzog Unnamed rocks west of Tonasket (T37N, R26E) intrude the Permian Anarchist Group and Triassic(?) metamorphic complex of Conconully (Rinehart and Fox, 1976).

The **Reed Creek quartz dioritic orthogneiss** has yielded K-Ar biotite and hornblende ages of 57 and 75 Ma, respectively (Atwater and Rinehart, 1984) and Rb-Sr isochron and Pb-α zircon ages of 83 and 170 Ma, respectively (Menzer, 1983).

Unnamed rocks of this unit elsewhere intrude the Leecher Metamorphics and Salmon Creek schists and gneisses (units pJhm and pJmb) and amphibolite and schist of Twentyfive Mile Creek (units ŦPhmc and ŦPmb); they are locally cut by Upper Cretaceous or Eocene plutons.

ŦPhmc Granofels in the **younger gneissic rocks of the Holden area** (Cater and Crowder, 1967), which are correlative with the amphibolite and schist of Twentyfive Mile Creek (Tabor and others, 1987), has yielded a discordant U-Pb (zircon) age from biotite-quartz-oligoclase granofels that "gives on older concordia intercept of 265 +/- 15 m.y. if the younger intercept is assumed to be 60-90 m.y., the age bracket for the Late Cretaceous metamorphism (Mattinson, 1972, p. 3773). The granofels has been interpreted to be a metamorphosed keratophyre...and thus the 265 m.y. (Permian) age is believed to represent the depositional age" (Tabor and others, 1987, p. 5).

ŦPmb This unit is interbedded with unit ŦPhmc.

pJam The age of both the **Basic complex** and **Ashnola Gabbro** is uncertain; metamorphic textures and compositional layering perpendicular to the regional structural trend suggest a pre-Late Cretaceous age (Daly, 1912). Age assignment is based on compositional similarity to amphibolite layers in pre-Jurassic heterogeneous rocks (unit pJhm).

pJmb This unit has the same age as unit pJhm.

pJhm, pJmb

Age uncertain. The metamorphic rocks yield K-Ar ages (biotite, muscovite, and hornblende) of approximately 100 Ma (V. R. Todd, USGS, written commun., 1989; Bunning, 1990; Gulick and Korosec, 1990b). Most are intruded by Cretaceous plutons, but the **Salmon Creek schists and gneisses** and unnamed rocks north of Conconully (T37-40N, R24-25E) are intruded by the Upper Triassic(?) Loomis pluton (unit Ŧigd), suggesting a pre-Jurassic age.

pЄam This unit is interlayered with unit pЄhm; age assignment is based on interpretation of the unit as a metamorphosed equivalent of unit Yib (Miller, 1974c, 1974d; Miller and Clark, 1975).

pЄqz Age and contact relations are uncertain. Age assignment is based on its compositional similarity to known Precambrian rocks in the region. The unit is probably correlative with part of the **Belt Supergroup** (units Yms$_4$, Yms$_3$, Yms$_2$, and Yms$_1$) and with pre-Beltian rocks.

pЄhm Age and contact relations of **gneiss near Chester Creek** and **gneiss near Round Mountain** (T24-25N, R43-45E) are uncertain. Age assignment is based on their compositional similarity to known Precambrian rocks in the region. Rb-Sr isotopic data suggest that the protolith age of the rocks is Proterozoic Y or older (Armstrong and others, 1987), which suggests that the rocks are correlative with the Belt Supergroup (units Yms$_4$, Yms$_3$, Yms$_2$, and Yms$_1$) and with pre-Beltian rocks.

Metamorphic rocks near Priest Lake, Idaho, which are laterally continuous with the unnamed metamorphic rocks west of Newport (T30-33N, R42-44E), have yielded a Rb-Sr whole-rock age of 1,440 Ma (Armstrong and others, 1987). Because unit pЄhm locally grades into the Prichard Formation (unit Yms$_1$), at least part of unit pЄhm probably represents thermally metamorphosed Proterozoic Y metasedimentary rocks (Miller and Clark, 1975). On the basis of Rb-Sr isotopic data, Armstrong and others (1987) suggest that the unit also includes rocks older than the Prichard Formation (pre-Belt Supergroup basement rocks).

Age assignment of unnamed rocks south of Newport (T30N, R44-45E) is based on tentative correlation of this unit with the unnamed metamorphic rocks west of Newport (unit pЄhm).

pЄgn Highly discordant U-Pb zircon ages suggest that zircon in the **Swakane Biotite Gneiss** originally crystallized at least 1,600 Ma (Mattinson, 1972). However, because the protolith of the unit is uncertain, interpretation of the age data is difficult. "If the original rock was volcanic, a Middle Proterozoic or earlier age should represent its time of formation. Many of the zircons appear rounded, however, suggesting a detrital origin. Hence, the protolith could be sedimentary, and the Precambrian age of the zircons would represent a maximum age" (Tabor and others, 1987, p. 9).

pЄbg The **Hauser Lake Gneiss** has yielded a Rb-Sr isochron age of 2,053 Ma and a discordant U-Pb zircon age of 1,668 Ma (Armstrong and others, 1987). Near Priest River, Idaho, rocks correlative with the Hauser Lake Gneiss are intruded by augen gneiss that has yielded a Rb-Sr isochron age of 1,440 Ma (Clark, 1973). The unit is probably correlative with the Prichard Formation (unit Yms$_1$) and/or pre-Beltian rocks.

Age and contact relations of the **gneiss of Mica Peak** (T24-25N, R45E) are uncertain; age assignment is based on compositional similarity of this unit to known Precambrian rocks in the region. The unit is probably correlative with part of the Belt Supergroup and with pre-Beltian rocks.

pTog, pTam, pTsc, pTqz, pTmb, pThm, pTbg

Protolith ages of the metamorphic rocks in the Kettle and Okanogan metamorphic core complexes (gneiss domes) are unknown. "Specific correlation of the...rocks with sequences elsewhere in the Cordillera is difficult because the rocks in the domes are highly metamorphosed and deformed and cannot be traced out of the core into lower grade equivalents" (Orr and Cheney, 1987, p. 61). The quartzofeldspathic composition of the layered metamorphic rocks in the complexes suggests that they may be correlative with Precambrian metasedimentary rocks in the region (Cheney, 1980; Orr and Cheney, 1987). Upper Cretaceous(?) to middle Eocene plutons (units TKia, TKig, Eimd, Eiqm, and Eig) cut the metamorphic rocks in the complexes, establishing a minimum age for the metamorphic rocks (Holder and Holder, 1988; Holder and others, 1989). K-Ar biotite and hornblende ages reported from the metamorphic rocks in the core complexes range from 46 to 67 Ma (Fox and others, 1976; Engels and others, 1976; Atwater and Rinehart, 1984), indicating that uplift and cooling of the complexes occurred during the latest Cretaceous and early Tertiary. U-Pb zircon ages of 87-100 Ma from a single sample of the **Tonasket Gneiss** are the only U-Pb ages reported from the metamorphic rocks in the complexes (Fox and others, 1976); it is not clear whether these ages represent protolith or metamorphic ages.

pTgn Unnamed monzonitic and syenitic gneiss near Oroville (T39-40N, R28-29E) has yielded K-Ar biotite and hornblende ages between 50 and 58 Ma (Fox and others, 1976) and fission-track (epidote and titanite) ages of 63 and 66 Ma, respectively (Naeser and others, 1970). This unit grades into and interfingers with the Permian Anarchist Group (units Pmm and Pmcb), the Upper Triassic Osoyoos batholith (unit Ŧog), and the Wauconda pluton (unit KJigd) and is cut by the Mount Bonaparte pluton (unit TKia). Gradational contacts and absence of magmatic features such as satellitic dikes and xenoliths led Fox (1973) to suggest that the gneiss formed by the alkali metasomatism of pre-existing rock units before intrusion of the Mount Bonaparte pluton.

Tectonic Rocks

tz Along the Twisp River–Foggy Dew fault (T31-34N, R19-21E), the unit consists of the mylonitically deformed Oval Peak batholith (61-65 Ma) (units Ᵽit and Ᵽog), Battle Mountain and Tuckaway Lake gneisses (unit Ᵽog), and Twisp Valley schist (unit ŦPhmc) (Miller, 1987; Miller and others, 1989). Northwest of the map area, the unit includes Gabriel Peak orthogneiss (65 Ma metamorphic age), which is the deformed equivalent of the Black Peak batholith (unit Kog) (90 Ma) (Miller, 1987). The unit is cut by the Cooper Mountain batholith (48 Ma) (unit Eigd); these relations indicate that ductile deformation occurred between 65 and 48 Ma (Miller, 1987; Miller and others, 1989).

Along the Newport fault (T31-35N, R43-45E), this unit is dominantly chloritic microbreccia; locally, it includes chloritic breccia composed of clasts of mylonitically deformed Precambrian metamorphic rocks (unit pЄhm), Phillips Lake Granodiorite (100 Ma) (unit Kiat), and Silver Point Quartz Monzonite (50 Ma) (unit Eia). In the upper plate of the fault south of Tiger (T34-35N, R43E), the unit includes brecciated Addy Quartzite (unit ЄZq) and Metaline Formation (unit OЄcb). The middle Eocene Tiger Formation (unit Ecg$_2$) locally overlies the chloritic breccia and locally contains breccia clasts; these relations indicate deformation occurred during the middle Eocene.

Along the Omak Lake fault (T32-33N, R27-28E) this unit consists of breccia composed of clasts of the plutonic complex of Boot Mountain (unit KJmi) and Coyote Creek pluton (units TKig and TKiaa); the deformation probably occurred during the Late Cretaceous and early Tertiary.

Along the Jumpoff Joe fault (T34N, R41E), this unit consists of mylonitically and brittlely deformed Proterozoic Y metasedimentary rocks (unit Yms$_3$), Proterozoic Z metavolcanic rocks (unit Zmv), Precambrian metamorphic rocks (unit pЄhm), and Phillips Lake Granodiorite (100 Ma) (unit Kiat) (Miller and Clark, 1975). It is overlain by middle Eocene Tiger Formation (Ecg$_2$); these relations indicate deformation occurred between 100 and 48 Ma.

Along the Eagle Mountain fault (T33N, R41E), this unit is composed of sheared Precambrian metasedimentary rocks (unit Yms$_3$) and Cretaceous intrusive rocks (100 Ma) (unit Kiat); the age of deformation is Late Cretaceous or younger.

Along the Pasayten fault (T34-36N, R21-22E), the unit consists of mylonitically deformed Upper Jurassic and Lower Cretaceous orthogneiss (unit KJog) and chloritic breccia composed of clasts of the mylonitic gneiss (Lawrence, 1968; V. R. Todd, USGS, written commun., 1988). Near Island Mountain (T39N, R19E), the fault is overlain or intruded by middle Eocene volcanic rocks of Island Mountain (units Ec$_1$, Ev$_1$, Evd$_1$, Eian, and Eida) (White, 1986); therefore, deformation along the Pasayten fault must have occurred between the Late Jurassic and middle Eocene.

BEDROCK GEOLOGIC AND TECTONIC MAP AND TABLE SUMMARIZING THE GEOLOGIC HISTORY OF THE NORTHEAST QUADRANT

The 1:625,000-scale **bedrock geologic and tectonic map** on Sheet 3 is a simplified version of the 1:250,000-scale geologic map (Sheet 1). It graphically portrays the sedimentary, volcanic, intrusive, metamorphic, and deformational history of northeastern Washington, which is summarized in a table on Sheet 3. The colors used on this map differ from those on Sheet 1 because map units have been combined for simplicity.

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WASHINGTON STATE DEPARTMENT OF
Natural Resources
Brian Boyle - Commissioner of Public Lands
Art Stearns - Supervisor

GEOLOGIC MAP OF WASHINGTON—NORTHEAST QUADRANT

by

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J. Eric Schuster, Assistant State Geologist and State Geologic Map Project Manager
Bonnie B. Bunning and William M. Phillips, Assistant State Geologic Map Project Managers

1991

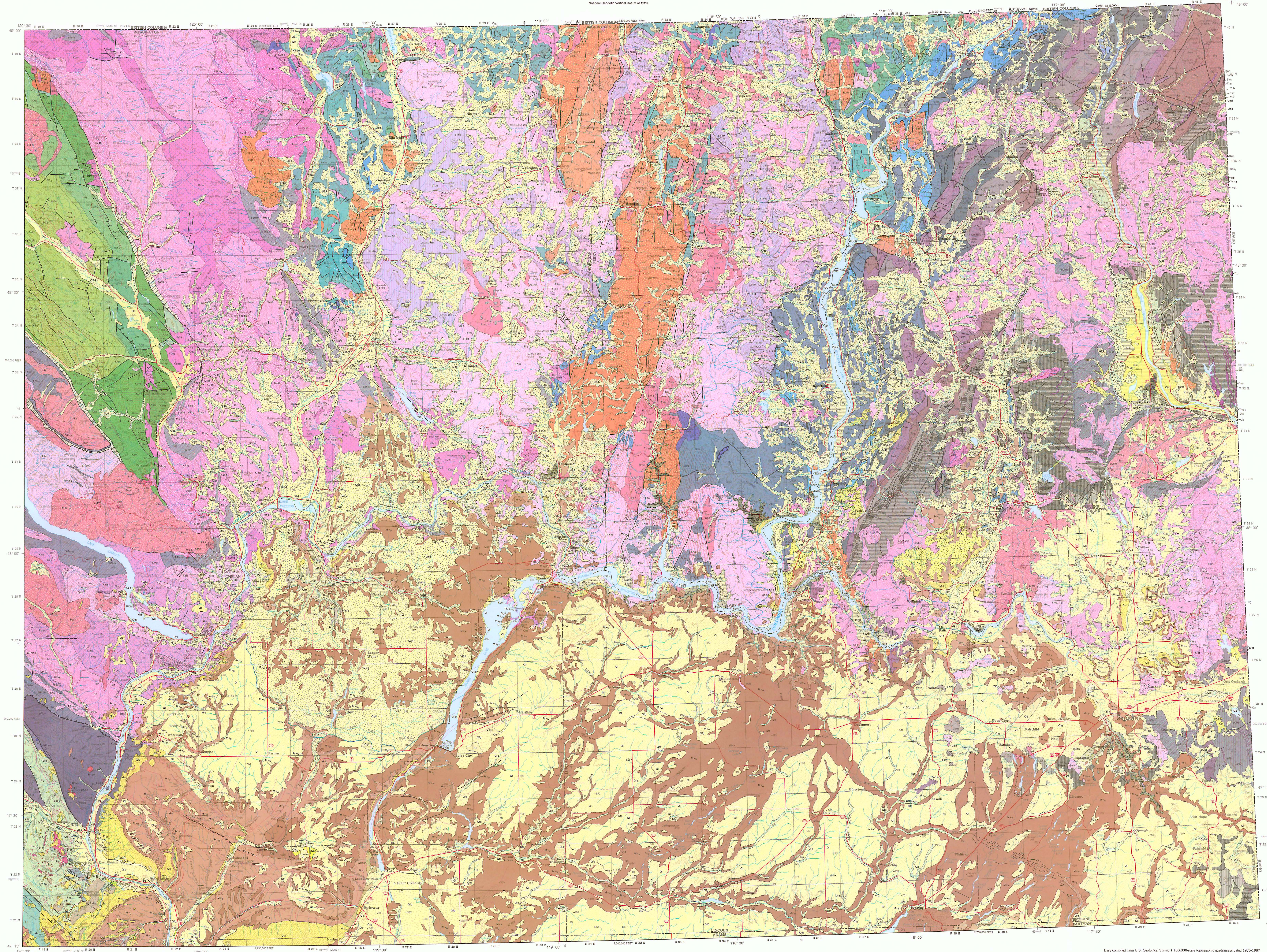
SCALE 1:250,000

5 0 5 10 15 20 Miles

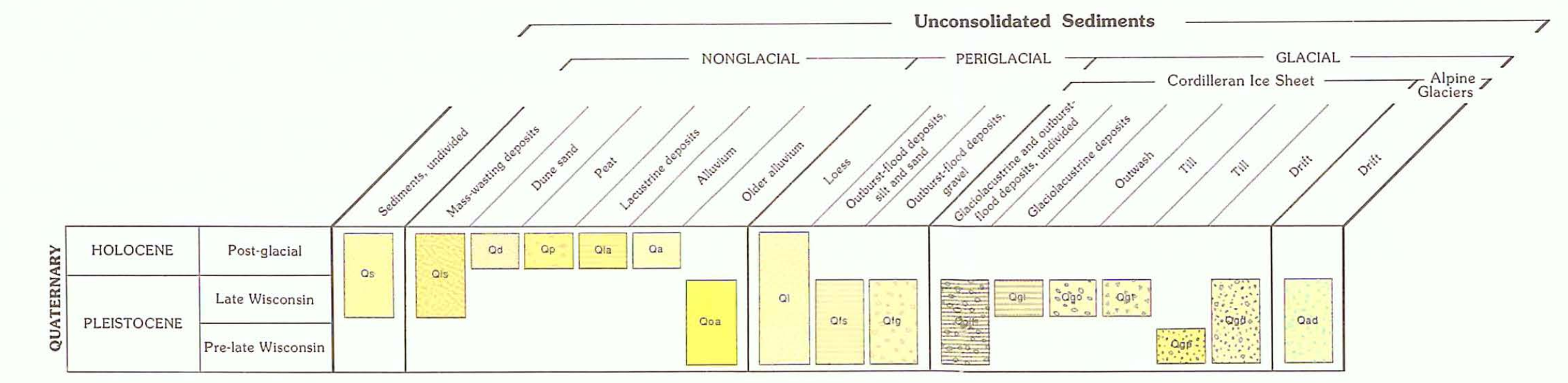
5 0 5 10 15 20 Kilometers

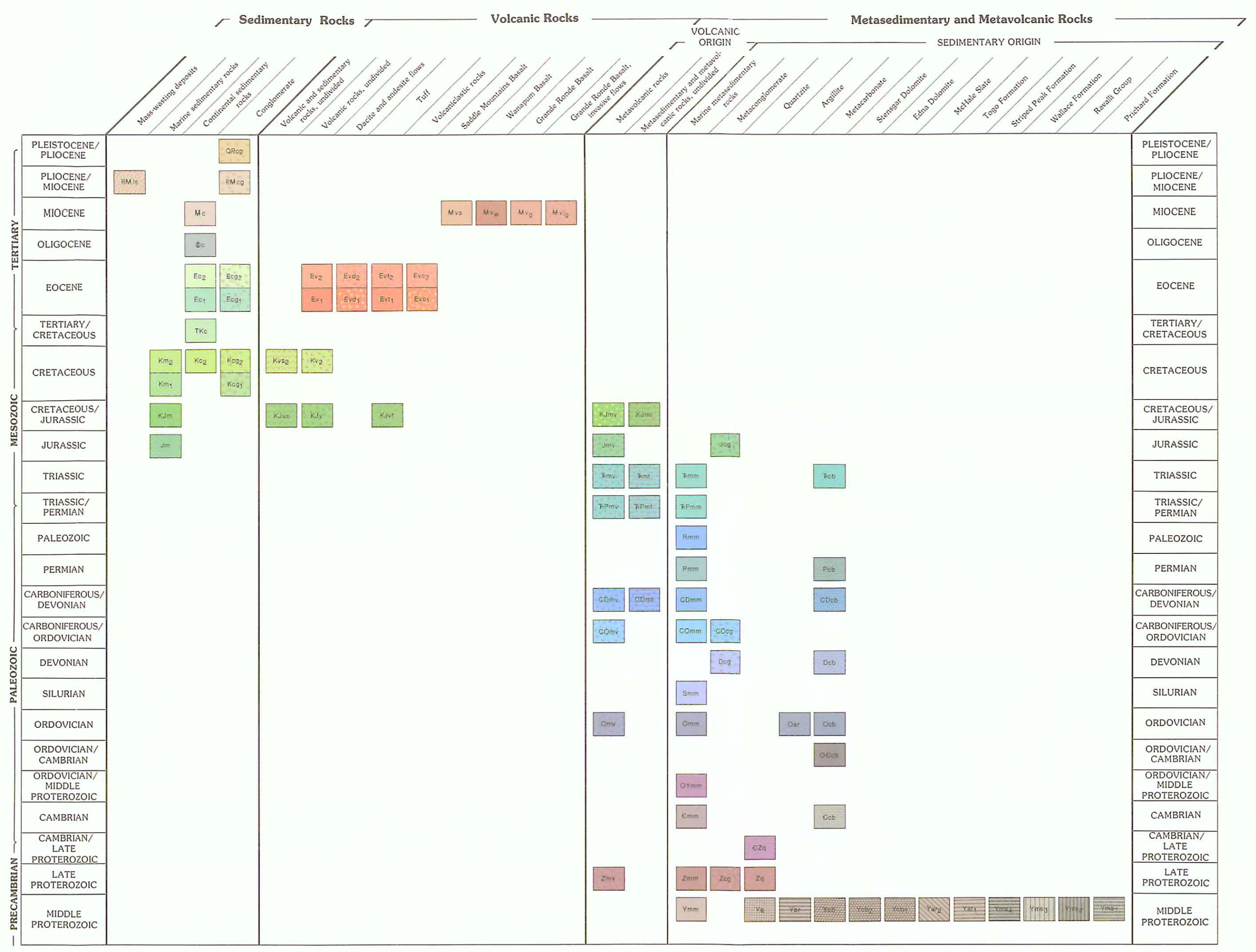
25,000 0 25,000 50,000 Feet

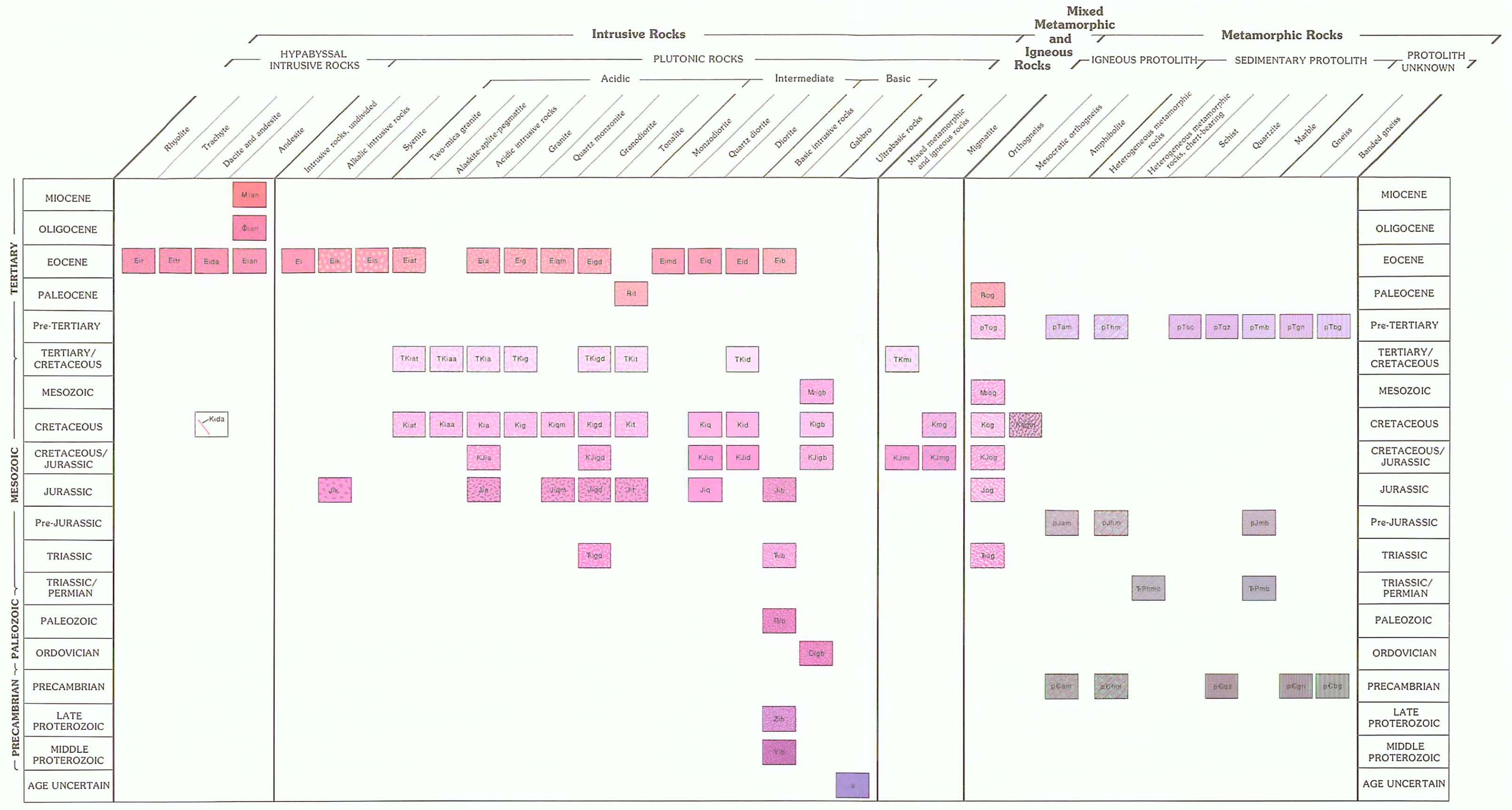
Contour Interval 200 Meters
National Geodetic Vertical Datum of 1929



Key To Geologic Units*







* See Sheets 2 and 3 for detailed unit descriptions and chronologic and stratigraphic relations.

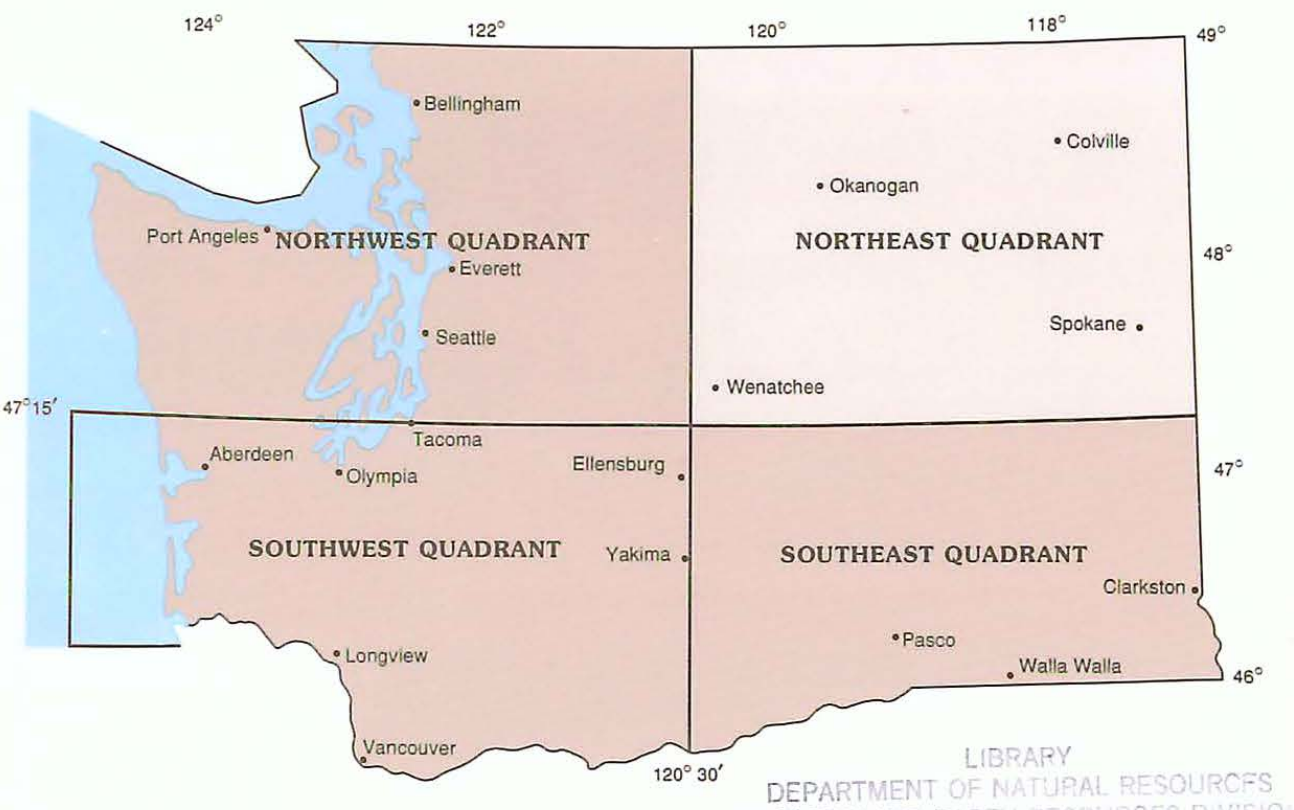
Geologic Symbols

- Contact
- Scratch boundary — Boundary between areas of reconnaissance and detailed mapping
- Gradational contact
- Fault — Dashed where approximately located: dotted where concealed
- Dip-slip fault — Bar and ball on downthrown side: dashed where approximately located: dotted where concealed: queried where presence or character uncertain
- Strike-slip fault — Arrows indicate direction of movement
- Low-angle normal fault — Blocks on upper plate: dotted where concealed: queried where presence or character uncertain
- Thrust fault — Sawteeth on upper plate: dashed where approximately located: dotted where concealed: queried where presence or character uncertain
- Anticline — Direction of plunge shown where known: dashed where approximately located: dotted where concealed
- Syncline — Direction of plunge shown where known: dashed where approximately located: dotted where concealed
- Overturned anticline
- Overturned syncline — Direction of plunge shown where known: dotted where concealed
- Monocline — Dashed where approximately located: dotted where concealed
- Approximate maximum extent of pre-late Wisconsin Cordilleran Ice Sheet
- Maximum extent of the late Wisconsin Cordilleran Ice Sheet
- Dike
- Dike swarm — Used for dike swarms of unit Eida only
- ▨ Tectonic zone
- Fracture zone

Compilation Responsibility by 1:100,000-scale Quadrangle

121°	120°	119°	118°	117°
ROBINSON MTN Stoffel	OROVILLE Stoffel	REPUBLIC Stoffel	COLVILLE Joseph	49°
TWISP Bunning	OMAK Gulick	NESPELEM Joseph	CHEWELAH Waggoner	48°
CHELAN Korosec	BANKS LAKE Gulick	COULEE DAM Waggoner	SPOKANE Joseph	
WENATCHEE Walsh	MOSES LAKE Gulick	RITZVILLE Gulick	ROSALIA Waggoner	47°

Quadrant Location



Geologic Map GM-39
Washington Division of Geology and Earth Resources
Raymond Lasmanis, State Geologist

Base compiled from U.S. Geological Survey 1:100,000-scale topographic quadrangles dated 1975-1987
Projection: zone 11, Universal Transverse Mercator
250,000-foot grid ticks based on Washington coordinate system, north zone
1927 North American Datum
Cartographic design and production by Nancy A. Eberle, Carl F. T. Harris, Donald W. Hiller, and Keith G. Ikerd

DESCRIPTIONS OF MAP UNITS

UNCONSOLIDATED SEDIMENTS

Quaternary Sediments

Nonglacial Deposits

Periglacial Deposits

Glacial Deposits

Late Wisconsin Deposits of the Cordilleran Ice Sheet

Pre-Late Wisconsin Deposits of the Cordilleran Ice Sheet

Late Wisconsin and pre-Late Wisconsin Deposits of the Cordilleran Ice Sheet

Deposits of Alpine Glaciers

SEDIMENTARY AND VOLCANIC ROCKS

Pleistocene and Pliocene Sedimentary Rocks

Pliocene and Miocene Sedimentary Rocks

Miocene Sedimentary and Volcanic Rocks

Columbia River Basalt Group

Oligocene Sedimentary Rocks

Middle and Upper Eocene Sedimentary and Volcanic Rocks

Lower and Middle Eocene Sedimentary and Volcanic Rocks

Tertiary and Cretaceous Sedimentary and Volcanic Rocks

Upper Cretaceous Sedimentary and Volcanic Rocks

Lower Cretaceous Sedimentary and Volcanic Rocks

Cretaceous and Jurassic Sedimentary and Volcanic Rocks

Jurassic Sedimentary Rocks

METASEDIMENTARY AND METAVOLCANIC ROCKS

Cretaceous and Jurassic Metasedimentary and Metavolcanic Rocks

Jurassic Metasedimentary and Metavolcanic Rocks

Triassic Metasedimentary and Metavolcanic Rocks

Triassic and Permian Metasedimentary and Metavolcanic Rocks

Paleozoic Metasedimentary Rocks

Permian Metasedimentary Rocks

Carboniferous and Devonian Metasedimentary and Metavolcanic Rocks

Carboniferous to Ordovician Metasedimentary and Metavolcanic Rocks

Devonian Metasedimentary Rocks

Silurian Metasedimentary Rocks

Ordovician Metasedimentary and Metavolcanic Rocks

Ordovician and Cambrian Metasedimentary Rocks

Ordovician to Proterozoic Y Metasedimentary Rocks

Cambrian Metasedimentary Rocks

Cambrian and Proterozoic Z Metasedimentary Rocks

Proterozoic Z Metasedimentary and Metavolcanic Rocks

Windermere Group

Proterozoic Y Metasedimentary Rocks

Deer Trail Group

Priest River Group

Belt Supergroup

INTRUSIVE ROCKS

Miocene Intrusive Rocks

Oligocene Intrusive Rocks

INTRUSIVE ROCKS (continued)

Eocene Intrusive Rocks

Hypabyssal Intrusive Rocks

Plutonic Rocks

Paleocene Intrusive Rocks

Tertiary and Cretaceous Intrusive Rocks

Cretaceous Intrusive Rocks

Hypabyssal Intrusive Rocks

Plutonic Rocks

Cretaceous and Jurassic Intrusive Rocks

Jurassic Intrusive Rocks

Triassic Intrusive Rocks

INTRUSIVE ROCKS (continued)

Paleozoic Intrusive Rocks

Ordovician Intrusive Rocks

Proterozoic Z Intrusive Rocks

Proterozoic Y Intrusive Rocks

Intrusive Rocks of Uncertain Age

MIXED METAMORPHIC AND IGNEOUS ROCKS

Tertiary and Cretaceous Mixed Metamorphic and Igneous Rocks

Cretaceous Mixed Metamorphic and Igneous Rocks

Cretaceous and Jurassic Mixed Metamorphic and Igneous Rocks

METAMORPHIC ROCKS

Paleocene Metamorphic Rocks

Igneous Protolith

Cretaceous Metamorphic Rocks

Igneous Protolith

Cretaceous and Jurassic Metamorphic Rocks

Igneous Protolith

Jurassic Metamorphic Rocks

Igneous Protolith

Triassic Metamorphic Rocks

Igneous Protolith

Mesozoic Metamorphic Rocks

Igneous Protolith

Triassic and Permian Metamorphic Rocks

Sedimentary Protolith

Pre-Jurassic Metamorphic Rocks

Igneous Protolith

Sedimentary Protolith

Precambrian Metamorphic Rocks

Igneous Protolith

Sedimentary Protolith

Protolith Unknown

Pre-Tertiary Metamorphic Rocks

Igneous Protolith

Sedimentary Protolith

Protolith Unknown

TECTONIC ROCKS

Geologic Map of Washington—Northeast Quadrant
Washington Division of Geology and Earth Resources
Geologic Map GM-39
Sheet 2

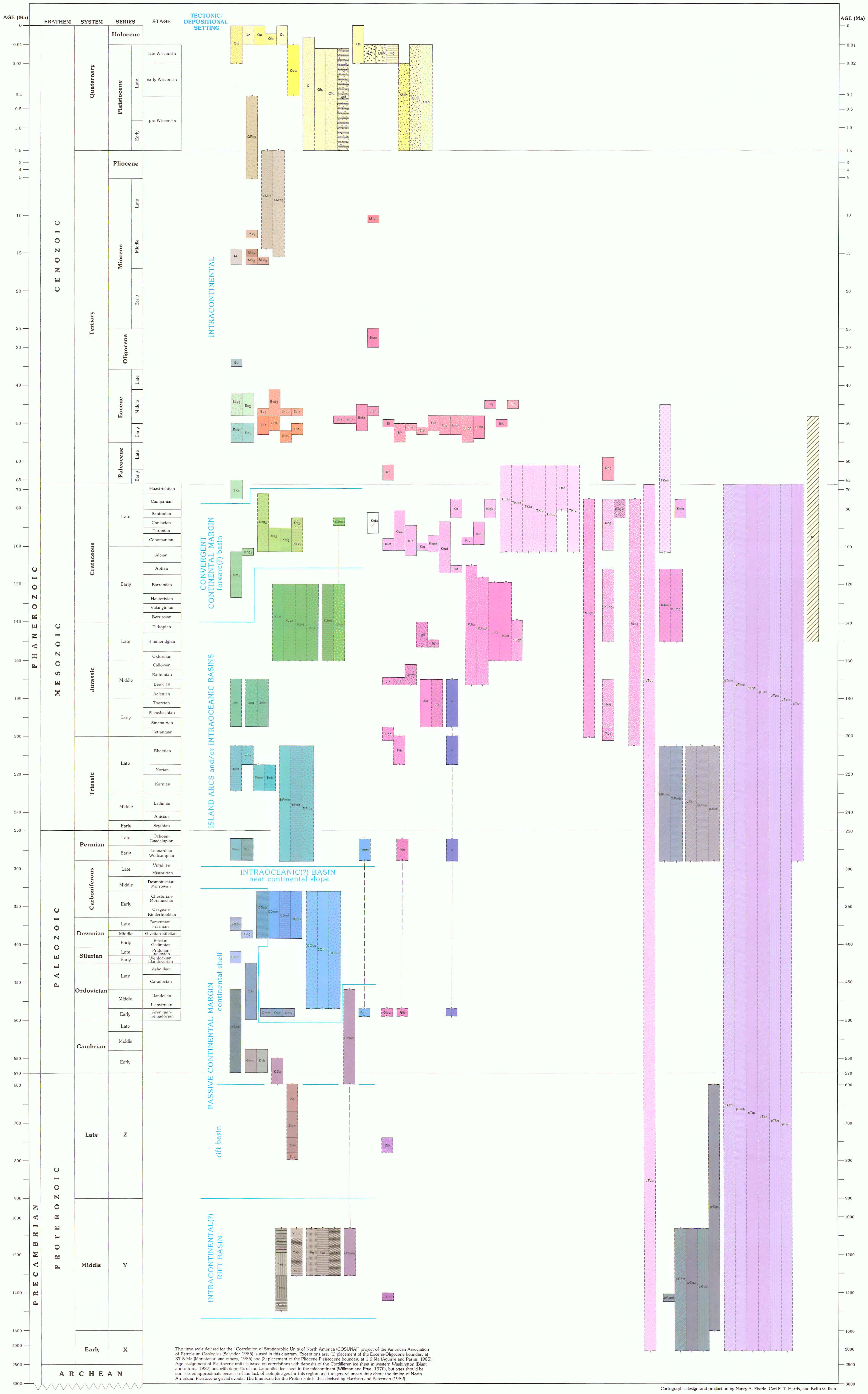
LIST OF NAMED UNITS

CD, Coulee Dam; NE, Nespelem; CH, Chewelah; CO, Colville; RM, Robinson Mtn.; BL, Banks Lake; CL, Chelan; ML, Moses Lake; OM, Omak; RI, Ritzville; RO, Rosalia; SP, Spokane; WE, Wenatchee; TW, Twisp; RE, Republic; OR, Oroville. Unit names given in italics are names that were once widely used but that are now abandoned.

GEOLOGIC UNIT	SYMBOL	DEFINING AND/OR REPRESENTATIVE REFERENCE	100,000-SCALE QUADRANGLE	AREA
Addy Quartzite	ꞒZq	Weaver, 1920; Campbell and Loofbourow, 1962; Lindsey and others, 1990	CD CH CO NE RE	central part of the NE ¼ of the map area
Aeneas Creek pluton	Kia, Kid	Rinehart and Fox, 1976	OR	T37N, R26E
Alder Creek stock	KJiq	Barksdale, 1975	TW	T33N, R21-22E
Alta Lake, amphibolite, schist, and gneiss of	pJhm, KJmg	Raviola, 1988	BL OM	T29N, R23E
Anarchist Group	Pmm, Pcb, Ᵽmm	Daly, 1912; Rinehart and Fox, 1972	OR RE	NW ¼ of the map area
Anderson Creek pluton	KJigd	Hibbard, 1971; Rinehart and Fox, 1972	OR	T39-40N, R25E
Anglin, orthogneiss of	pTog	Fox and Rinehart, 1988	OR	T36-37N, R27-30E
Antoine Creek, hornblende tonalite gneiss of	Mzog	Tabor and others, 1987	CL TW	T29N, R22E
Arbuckle Mountain pluton	TKit	Raviola, 1988	BL	T28-29N, R23E
Armstrong Mountain, granite west of	TKig	Atwater and Rinehart, 1984; Holder and Holder, 1988	OM	T32N, R29E
Ashnola Gabbro	pJam	Daly, 1912; Staatz and others, 1971	RM	T40N, R21E
Barnaby Creek, granodiorite of	KJia	Atwater and Rinehart, 1984	NE	T35N, R36E
Barstow granodiorite	Eigd	Bowman, 1950	RE	T38N, R37E
Basic complex	pJam	Daly, 1912	RM	T40N, R19-20E
Battle Mountain gneiss	tz	Miller, 1987	TW	T31-32N, R19-21E
Bearcat Ridge plutons	Kog	Cater and Wright, 1967	TW	T30N, R19E
Beaver Creek, basalt of	Mv_g	Tabor and others, 1982	WE CL	T24N, R22E
Belt Supergroup	Yms_4, Yms_3, Yms_2, Yms_1	Walcott, 1899; Willis, 1902; Smith and Barnes, 1966; Clapp and Deiss, 1931; Ransome and Calkins, 1908	CH CO RO SP	E ¼ of the map area
Billy Goat Mountain, volcanics of	KJv	Staatz and others, 1971	RM	T36-40N, R19-21E
Black Peak batholith	Kog	Misch, 1952, 1966; Miller, 1987	TW	T33N, R19E
Blickensderfer Quartz Monzonite	Kiat	Miller, 1974a	CH	T33-34N, R45E
Blue Goat pluton	Jigd	Rinehart and Fox, 1976	OR	T36-37N, R25E
Boot Mountain, plutonic complex of	KJmi, pJhm	Atwater and Rinehart, 1984	OM	T31-33N, R26-28E
Bottle Spring pluton	Kia	Rinehart, 1981	OR	T37-38N, R23E
Bowers quartz diorite	KJiq, KJigd	Hibbard, 1971	OR	T38-39N, R24-25E
Brays Landing, conglomerate of	ᵽMcg	Tabor and others, 1987	CL	T26N, R21E
Bridge Creek intrusions	Eig, Eiqm	Holder and Holder, 1988	NE	T32N, R34E
Bridge Creek, ultramafic and mafic rocks near	u	Atwater and Rinehart, 1984	NE	T31-32N, R33-34E
Buck Mountain Formation	KJv, KJvs, KJvt	Barksdale, 1975	RM TW	T32-37N, R20-22E
Buckhorn Mountain pluton	KJigd	Little, 1957; Fox, 1978; McMillen, 1979	OR RE	T40N, R30E
Buffalo Hump Formation	Ymm	Campbell and Loofbourow, 1962; Miller and Whipple, 1989	CH NE	T29-32N, R37-40E and T24-26N, R39-40E
Bullfrog Mountain Formation	Pmm	Rinehart and Fox, 1972	OR	NW ¼ of the map area
Burch Mountain, andesite and dacite of	Mian	Tabor and others, 1987	CL	T24N, R20E
Burke Formation	Yms_2	Ransome, 1905; Hobbs and others, 1965; Miller and Clark, 1975	CH CO RO SP	E ¼ of the map area
Button Creek stock	Jit	Barksdale, 1975	RM	T37N, R20-21E
Cardinal Peak pluton	Kit	Cater and Wright, 1967	TW	T29-30N, R19E
Carlton stocks	KJiq	Barksdale, 1975	TW	T31-32N, R21-22E
Carter Mountain, dacite of	Evd_1, Evt_1, Ec_1	Rinehart and Fox, 1976	OR	T36-37N, R26E
Cathedral batholith	Kia	Daly, 1912; Hawkins, 1963	OR RM	T37-40N, R21-23E
Cave Mountain Formation, basaltic metavolcanic member of the	Ŧmv	Rinehart and Fox, 1976	OM OR	T34-36N, R25-26E
Cave Mountain Formation, dark gray metalimestone member of the	Ŧcb	Rinehart and Fox, 1976	OR	T34-36N, R25-26E
Cave Mountain Formation, metadolomite and metalimestone member of the	Ŧcb	Rinehart and Fox, 1976	OM OR	T34-35N, R25-26E
Cave Mountain Formation, metasiltstone member of the	Ŧmm	Rinehart and Fox, 1976	OR	T34-36N, R25-26E
Cave Mountain Formation, slate and metalimestone member of the	Ŧmm	Rinehart and Fox, 1976	OR	T34-36N, R25-26E
Chelan complex	Kmg, Kog, Kogm, Kigb, ŦPhmc, ŦPmb	Hopson, 1955; Hopson and Mattinson, 1971; Tabor and others, 1987	TW BL CL	Lake Chelan vicinity
Chester Creek, gneiss near	pꞒhm	Weis, 1968	SP	T24N, R44E
Chewack River gneiss complex	Kit, KJmi	Hawkins, 1968	RM	T38-40N, R21-22E
Chopaka intrusive complex	Ŧib, u	Hibbard, 1971	OR	T40N, R24-25E
Chumstick Formation	Ec_2, Ecg_2	Gresens and others, 1981; Tabor and others, 1982, 1987	CL WE	T20-25N, R19-20E
Cody Lake, hypabyssal intrusive suite of	Eida	Atwater and Rinehart, 1984	CD NE OM	central part of the map area
Columbia River Basalt Group	Mv_s, Mv_w, Mv_g, Mvi_g	Waters, 1961; Griggs, 1976; Swanson and others, 1979b	BL CD CH CL ML NE OM RI RO SP WE	S ½ of the map area
Colville batholith	TKia, TKig, TKiat, TKiaa, TKid, TKigd, Eiqm, Eimd, Eid, Eigd, Eig	Pardee, 1918; Waters and Krauskopf, 1941; Holder and Holder, 1988	CD NE OM OR RE	N-central part of the map area
Conconully pluton	Kigd	Rinehart, 1981; Menzer, 1983	OM OR	T34-36N, R23-25E
Conconully, metamorphic complex of	Ŧmm, pJhm, pJmb	Rinehart and Fox, 1976	OM OR	T35-37N, R24-26E
Cook Lake, porphyritic granite and granodiorite of	Kia	Atwater and Rinehart, 1984	OM	T32N, R26E
Cooper Mountain batholith	Eigd, Eiqm	Barksdale, 1975	BL OM TW	T29N, R20-22E
Coryell intrusive rocks	Eis	Daly, 1912; Yates, 1971	CO	T40N, R38-39E
Covada Group	Omm, Ocb, Omv	Pardee, 1918; Smith and Gehrels, 1989; Joseph, 1990b	CD NE RE	T28-34N, R32-37E
Coyote Creek pluton	TKig, TKiaa	Atwater and Rinehart, 1984; Holder and Holder, 1988	OM	T31-32N, R29E
Coyote Ridge quartz dioritic gneiss	KJog	Menzer, 1983	OM TW	T33-34N, R22-23E
Crawfish Lake tonalite gneiss	pTog	Singer, 1984	OM OR	T34-35N, R29E
Daisy Trail, granite of	TKig	Atwater and Rinehart, 1984; Holder and Holder, 1988	NE	T31-34N, R33-35E
Darling Lake gabbro	Mzigb	Menzer, 1964, 1983	OM	T33N, R25E
Deadhorse Creek, granite of	Eig	Atwater and Rinehart, 1984; Holder and Holder, 1988	NE	T30N, R32E and T32N, R34E and T35N, R33E
Deer Trail Group	Ymm, Ycb_2, Yar_2, Ycb_1, Yar_1	Weaver, 1920; Bennett, 1941; Campbell and Loofbourow, 1962; Miller and Whipple, 1989	CH NE SP	T29-32N, R37-40E and T24-26N, R39-40E
Deerhorn Creek, schist near	pTog	Atwater and Rinehart, 1984	NE	T34N, R31E
Devils Elbow pluton	Eimd, Eid	Atwater and Rinehart, 1984; Holder and Holder, 1988	NE	T30-33N, R32-33E
Devils Elbow suite	Eimd	Holder and Holder, 1988	CD NE OM OR RE	N-central part of the map area
Dubious Creek, granodiorite of	Kiat	Miller, 1982b	CH	T32N, R46E
Duffy Creek, invasive flow of	Mvi_g	Tabor and others, 1982	WE	T23N, R22E
Duncan Hill pluton	Eigd, Eig	Cater and Wright, 1967; Tabor and others, 1987	CL TW	T27-29N, R19-20E
Dunn Mountain pluton	KJigd	Rinehart and Fox, 1976	OR	T35N, R25E
Edna Dolomite	Ycb_1	Campbell and Loofbourow, 1962; Miller and Whipple, 1989	CD CH NE	T29-32N, R37-40E
Edwards Slough diorite	KJigd	Hibbard, 1971	OR	T39-40N, R25E
Ellemeham Formation	Jmv, Jcg	Rinehart and Fox, 1972	OR	T38-40N, R26-27E
Ellensburg Formation	Mc	Smith, 1901; Mackin, 1961; Swanson and others, 1979b	BL CL OM WE	T20N, R21E and T26N, R22E and T26-27N, R25E
Empire Lakes pluton	Eiqm	Holder and Holder, 1988; Holder, 1990	RE	T38-39N, R32E
Entiat pluton	Kit, Kigb	Hopson, 1955; Tabor and others, 1987	CL	T25-27N, R19-21E
Evans Lake pluton	Kia	Grose, 1949; Rinehart and Fox, 1976	OM OR	T35N, R26E
Fan Lake Granodiorite	Kia	Miller, 1974c	CH SP	T29-30N, R43-44E
Fancher Field, gravel of	Qfg	Tabor and others, 1982	WE	T23N, R20E
Fawn Peak stock	Kid	Barksdale, 1975	RM	T36N, R20E
Felix Creek, granite of	Kig	Atwater and Rinehart, 1984	OM	T32N, R26E
Fifteenmile Creek pluton	TKia	Bowman, 1950; Fox, 1981	RE	T39N, R37E
Fire Mountain pluton	Eiqm, Eig	Holder, 1985; Holder and Holder, 1988	NE RE	T35-37N, R34E
Flagstaff Mountain sequence	CDmm, CDmv, CDmt, Ŧmm, Ŧcb	Yates, 1971; Beka, 1980; Joseph, 1990a	CO	T39-40N, R38-39E
Flowery Trail Granodiorite	Ŧigd	Clark and Miller, 1968	CH	T32-33N, R41E
Frazer Creek complex	KJiq, KJigb	Barksdale, 1975	OM TW	T33-34N, R22-23E
Freeman, quartzite near	pꞒqz	Weis, 1968	SP	T24N, R45E
French Valley, gneissic granodiorite of	pTog	Goodge and Hansen, 1983; Atwater and Rinehart, 1984	OM	T33-34N, R27-28E
Frenchman Springs Member of the Wanapum Basalt	Mv_w	Mackin, 1961; Bingham and Grolier, 1966; Swanson and others, 1979b	BL CD ML RI RO WE	S ½ of the map area
Friedlander Meadows pluton	Eimd	Atwater and Rinehart, 1984; Holder and Holder, 1988	CD NE	T29-30N, R34E
Galena Point Granodiorite	Kia	Miller, 1974a	CH CO	T33-35N, R45E
George Creek, granite of	TKia	Atwater and Rinehart, 1984	CD	SE ¼ of T28N, R35E
Gerome andesite	Evd_1, Evt_1	Weaver, 1920; Becraft and Weis, 1963; Pearson and Obradovich, 1977	CD NE	T27-30N, R36-38E
Gleason Mountain, monzogranite of	Kiat	Miller, 1982c	CO	T35N, R45E
Goat Creek Formation	Km_1	Barksdale, 1975	RM	T36-39N, R19-21E
Goat Mountain porphyry	Eida	Raviola, 1988	OM	T29N, R23E
Grande Ronde Basalt	Mv_g, Mvi_g	Taubeneck, 1970; Swanson and others, 1979b	BL CD CH CL ML NE OM RI RO SP WE	S ½ of the map area
Granite Pass, monzogranite of	Kiat	Miller, 1983	CO	T38N, R45E
Grant Lake, intrusive complex north of	Ei	Atwater and Rinehart, 1984	OM	T32N, R29E
Grass Mountain sequence	CDmm, CDcb	Yates, 1971	CO	T39-40N, R40-41E
Gypsy Quartzite	ꞒZq	Park and Cannon, 1943; Lindsey and others, 1990; Miller, 1982a	CO	NE corner of the map area
Hall Creek, paragneiss and orthogneiss of	pTog, pThm	Atwater and Rinehart, 1984	NE	T33-34N, R34-35E
Hall Mountain, granodiorite of	Kiat	Miller and Theodore, 1982	CO	T35-37N, R44-45E
Hammond, invasive flow of	Mvi_g	Hoyt, 1961; Tabor and others, 1982	WE CL	T21-23N, R23E
Harts Pass Formation	Km_1	Barksdale, 1975	RM	T36-39N, R19-21E
Hauser Lake Gneiss	pꞒbg	Weis, 1968; Armstrong and others, 1987	SP	E of Spokane
Henry Creek diorite	Eimd	Holder and Holder, 1988; Holder, 1990	RE	T37N, R 32-33E
Herron Creek intrusion	Eiqm	Muessig, 1967; Holder and Holder, 1988	RE	T37N, R33-34E
Herron Creek suite	Eiqm, Eig	Holder and Holder, 1988	NE RE	N-central part of the map area
Hodgson Creek monzonite	Eiqm	Bowman, 1950	RE	T38N, R37E
Horse Lake Mountain, hornblende andesite porphyry complex of	Φian	Tabor and others, 1982	WE	T22-23N, R19-20E
Horseshoe Mountain pluton	Kiqm	Hibbard, 1971	OR	T39-40N, R23-24E
Howard Creek, invasive flow of	Mvi_g	Rosenmeier, 1968; Tabor and others, 1982	WE	T21N, R19E
Huckleberry Formation	Zmv, Zcg	Bennett, 1941; Campbell and Loofbourow, 1962; Miller and others, 1973	CH NE	T30-34N, R38-40E
Huckleberry Formation, conglomerate member of the	Zcg	Bennett, 1941; Campbell and Loofbourow, 1962; Miller and others, 1973	CH NE	T30-34N, R38-40E
Huckleberry Formation, greenstone member of the	Zmv	Bennett, 1941; Campbell and Loofbourow, 1962; Miller and others, 1973	CH NE	T30-34N, R38-40E
Hungry Mountain, monzogranite of	Kiat	Miller, 1982c	CO	T35N, R45E
Hungry Mountain stock	Eiq	Hopkins, 1987	TW	T30-31N, R21E
Isabella Ridge, andesite of	KJv	Dixon, 1959; Stoffel and McGroder, 1990	RM	T38-40N, R19-20E
Island Mountain, volcanics of	Evd_1, Ev_1, Ec_1, Eida, Eian	Staatz and others, 1971; White, 1986	RM	T39-40N, R19E
Joe Moses Creek, granodiorite of	Eigd	Atwater and Rinehart, 1984; Holder and Holder, 1988	NE	T30N, R32E
Johnny George, plutonic complex of	TKia, TKmi	Atwater and Rinehart, 1984; Holder and Holder, 1988	CD NE	T27-29N, R34-35E
Kaniksu batholith	Kia, Kig, Kigd, Kiat, Kiaa	Park and Cannon, 1943; Yates and others, 1966	CH CO	NE ¼ of the map area E of the Columbia River and N of Chewelah
Keane Ranch, basalt of	Mv_g	Tabor and others, 1982	WE	T23N, R22E
Keller Butte, porphyritic granite of	TKig	Atwater and Rinehart, 1984	CD NE	T29-30N, R31-32E
Keller Butte suite	TKia, TKig, TKigd, TKiat, TKiaa, TKid	Holder and Holder, 1988	BL CD NE OM OR RE	N-central part of the map area
Kelly Hill phyllite	CDmm	Bowman, 1950	RE	T38-39N, R37-38E
Kettle Crest pluton	Eimd	Cheney and others, 1982; Holder, 1985; Holder and Holder, 1988	NE RE	T34-37N, R34E
Klondike Mountain Formation	Evd_2, Ev_2, Evt_2, Evc_2	Muessig, 1962, 1967; Pearson and Obradovich, 1977	OR RE	Republic area
Klondike Mountain Formation, basalt member of the	Evd_2	Muessig, 1962, 1967	RE	Republic area
Klondike Mountain Formation, middle member of the	Evc_2	Muessig, 1962, 1967	RE	Republic area
Klondike Mountain Formation, Tom Thumb Tuff member of the	Evc_2	Muessig, 1962, 1967	RE	Republic area
Kobau Formation	Ŧmt	Bostock, 1940; Rinehart and Fox, 1972	OR	T39-40N, R25-30E
Kruger alkaline body	Jik	Daly, 1912; Rinehart and Fox, 1972	OR	T40N, R26E
Lake Juanita leucogneiss	Ᵽog	Miller, 1987; Miller and others, 1989	TW	T31-32N, R19-20E
Lane Mountain pluton	Jia	Aadland and others, 1979; Waggoner, 1990b	CH	T31N, R39E
Latah Formation	Mc	Pardee and Bryan, 1926; Griggs, 1976	SP	Spokane area
Leader Lake quartz monzonite	Kiqm	Menzer, 1983	OM	T33N, R25E
Leader Mountain granodioritic gneiss	KJog, Mzog	Menzer, 1964, 1983	OM OR	T33-34N, R24E and T35-36N, R23E
Ledbetter Slate	Oar	Park and Cannon, 1943	CH CO NE RE	central part of the NE ¼ of the map area
Leecher Metamorphics	pJhm, Mzog	Barksdale, 1948	TW OM	T31-33N, R22E
Leola Volcanics	Zmv	Park and Cannon, 1943	CO	NE corner of the map area
Little Roundtop pluton	Kig	Miller, 1974c	CH	T30-31N, R41-42E
Little Moses Mountain, diorite of	Eid	Atwater and Rinehart, 1984	OM	T33N, R30E
Lone Frank pluton	Kiq	Rinehart, 1981	OR	T37N, R23E
Long Alec Creek pluton	Eiqm, Eig	Parker and Calkins, 1964; Holder and Holder, 1988	RE	T39-40N, R34-35E
Loomis pluton	Ŧigd	Pelton, 1957; Hibbard, 1971; Rinehart and Fox, 1972	OR	T38-40N, R24-25E
Loon Lake granite	Kia, Kig, Kigd, Kiat, Kiaa, Kog, TKia, TKiaa, Eia, Eiqm, Eimd, Jia	Weaver, 1920; Campbell and Loofbourow, 1962	CD CH NE SP	E-central part of the map area E of the Columbia River and S of Chewelah
Lost Peak stock	Eigd	Tabor and others, 1968	RM	T38-39N, R19E
Mad River terrane, heterogeneous schist and gneiss of the	ŦPhmc, ŦPmb, Kog	Tabor and others, 1987	CL	T25-26N, R19-21E
Maitlen Phyllite	Ꞓmm, Ꞓcb	Park and Cannon, 1943	CH CO NE RE	NE corner of the map area
Manila Creek, porphyritic granodiorite of	TKia	Atwater and Rinehart, 1984	CD NE OM	T29-30N, R29-34E
McClure Mountain unit	KJmt	DiLeonardo, 1987	TW	T31-32N, R21-22E
McFarland Creek stock	Kid	Hopkins, 1987	TW	T30-31N, R21-22E
McGinnis Lake, garnet-bearing granite of	TKiaa	Atwater and Rinehart, 1984	NE	T29-30N, R31E
McHale Slate	Yar_2	Campbell and Loofbourow, 1962; Miller and Whipple, 1989	CD CH NE SP	T29-32N, R37-40E and T24N, R39E
Metaline Formation	OꞒcb	Park and Cannon, 1943; Repetski, 1978; Repetski and others, 1989	CH CO NE RE	NE ¼ of the map area
Meteor, granite and granodiorite near	KJia	Atwater and Rinehart, 1984	NE	T32N, R35-36E
Methow gneiss	KJog	Barksdale, 1948, 1975	OM TW	T30-31N, R22-23E
Mica Peak, gneiss of	pꞒbg, pꞒqz	Weis, 1968	SP	T24N, R45E
Midnight Peak Formation	Kc_2, Kv_2, Kvs_2	Barksdale, 1948, 1975	RM TW	T33-37N, R19-20E
Mission argillite	metasedimentary and volcanic rock units pꞒ to Ŧ	Weaver, 1920; Mills, 1985	CO	NE ¼ of the map area
Mission Creek, gneissic porphyritic granodiorite of	pTog	Atwater and Rinehart, 1984	OM OR	T33-34N, R27-28E
Missoula Group	Yms_4	Clapp and Deiss, 1931; Nelson and Dobell, 1961	CH CO RO	E ½ of the map area
Monk Formation	Zmm	Daly, 1912; Park and Cannon, 1943; Miller, 1983	CH CO RE	NE ¼ of the map area
Monument Peak stock	Eig	Tabor and others, 1968	RM	T38N, R19E
Moses Mountain pluton	TKia, TKiaa	Atwater and Rinehart, 1984; Holder and Holder, 1988	NE OM OR RE	T34-35N, R30-31E
Mount Bonaparte pluton	TKia, TKiaa, TKid	Fox, 1978; Cheney and others, 1982; Holder and Holder, 1988	OR RE	N-central part of the map area
Mount Rathdrum granite	Eiat	Rhodes and Hyndman, 1984	SP	Newman Lake vicinity
Mount Roberts Formation	Pmm	Little, 1960; Yates, 1971	CO RE	T40N, R37-38E
Mount Spokane granite	Kiat, TKiaa	Bickford and others, 1985; Armstrong and others, 1987	CH SP	T26-30N, R44-45E
Mount Tolman, quartz porphyry of	TKig	Atwater and Rinehart, 1984	CD NE	T29N, R32-33E
N_2 magnetostratigraphic unit of the Grande Ronde Basalt	Mv_g, Mvi_g	Swanson and others, 1979b	BL CD CH CL ML NE OM RI RO SP WE	S ½ of the map area
Nahahum Canyon Member of the Chumstick Formation	Ec_2	Gresens and others, 1981; Tabor and others, 1987	CL WE	T23-25N, R19E
Napeequa River area, rocks of the	ŦPhmc, ŦPmb, Kog	Crowder and others, 1966; Tabor and others, 1987, 1989	CL	T25N, R19E
Nespelem Silt	Qgl, Qglf	Pardee, 1918; Atwater, 1986	CD OM NE	Columbia, Nespelem, and Sanpoil River drainages
Newby Group	KJvs, KJvt, KJm, KJv, Jm	Barksdale, 1948, 1975	TW RM	T30-37N, R20-22E
Newman Lake Gneiss	Kog	Weis, 1968; Armstrong and others, 1987	CH SP	T26-30N, R45E
Noname stock	Eigd	Barksdale, 1975	OM TW	T30-31N, R22-23E
North Creek Volcanics	KJmv	Misch, 1966	TW	T34N, R19E
North Fork Camp hybrid gneiss	Jog	Hibbard, 1971	OR	T39N, R24-25E
North Star Creek, metadiorite near	Ᵽib	Atwater and Rinehart, 1984	NE	T33N, R30E
O'Brien Creek Formation	Evt_1, Evc_1, Ecg_1	Muessig, 1962, 1967; Pearson and Obradovich, 1977	CH CO NE OR RE	N-central part of the map area
Okanogan batholithic complex	Kit, Kigd, KJog, KJmi	Barksdale, 1948, 1975	OM OR RM TW	NW corner of the map area
Old Baldy pluton	KJog	Rinehart, 1981	OM OR	T35-36N, R23E
Old Dominion Limestone	OꞒcb	Weaver, 1920; Bennett, 1944; Mills, 1977; Waggoner, 1990b	CD CH CO RE	central part of the NE ¼ of the map area
Omak Lake, porphyritic granodiorite southwest of	TKigd	Atwater and Rinehart, 1984	OM	T32N, R27E
Osoyoos batholith	Ŧog	Daly, 1912; Krauskopf, 1938	OR	T40N, R28E
Oval Peak batholith	Ᵽit, Ᵽog	Adams, 1961; Barksdale, 1975	TW	T32-33N, R19-20E
Palmer Mountain Greenstone	Ŧmv	Rinehart and Fox, 1972	OR	T39-40N, R26E
Palmer volcanics	Evd_1, Evc_1, Evc_2	Weaver, 1920; Pearson and Obradovich, 1977	CO RE	T35-36N, R38E
Palouse Formation	Ql	Treasher, 1925; Patton and Baker, 1978; McDonald and Busacca, 1988	BL CD ML RI RO SP	S ½ of the map area
Panther Creek Formation	Km_1	Barksdale, 1975	RM	T36-39N, R19-21E
Park granite stock	Kig	Daly, 1912	RM	T40N, R20E
Parmenter Creek, serpentine near	u	Atwater and Rinehart, 1984	NE	T32N, R31E
Pasayten stock	Kigd	Tabor and others, 1968	RM	T37N, R19E
Patterson Lake conglomerate	Kcg_1	Maurer, 1958	TW	T34N, R21E
Pend Oreille Andesite	Evd_1	Schroeder, 1952; Miller, 1974a; Pearson and Obradovich, 1977	CH	T32-33N, R44E
Pend Oreille sequence	CDmm, CDmt	Yates, 1964, 1971	CO	T40N, R39-42E
Phillips Lake Granodiorite	Kiat	Miller and Clark, 1975	CH CO	T31-34N, R41-43E
Pipestone Canyon Formation	TKc	Barksdale, 1948, 1975	TW	T34N, R22E
Pogue Mountain quartz monzonite	Kiqm	Menzer, 1964, 1983	OM	T34N, R26E
Prichard Formation	Yms_1	Ransome, 1905; Harrison and Jobin, 1963; Miller and Clark, 1975	CH CO	NE ¼ of the map area
Priest Lake, granodiorite of	Kigd	Miller, 1982c	CO	T36N, R46E
Priest Rapids Member of the Wanapum Basalt	Mv_w	Mackin, 1961; Bingham and Grolier, 1966; Swanson and others, 1979b	BL CD CH CL ML NE OM RI RO SP	S ½ of the map area
Priest River Group	Yar, Yq, Ycb	Daly, 1912; Park and Cannon, 1943; Miller, 1983	CO	NE corner of the map area
Quartz Mountain area, granodiorite gneiss complex of the	KJmi	Staatz and others, 1971	RM	T40N, R19-21E
R_2 magnetostratigraphic unit of the Grande Ronde Basalt	Mv_g, Mvi_g	Swanson and others, 1979b	BL CD CL ML OM WE	S ½ of the map area
Ravalli Group	Yms_2	Emmons and Calkins, 1913; Gibson, 1948	CH CO RO SP	E ¼ of the map area
Red Shirt gabbro	KJigb	Menzer, 1983	OM TW	T33-34N, R22-23E
Reed Creek quartz dioritic orthogneiss	Mzog	Menzer, 1964, 1983	OM	T33-34N, R25E
Reeves Limestone Member of the Maitlen Phyllite	Ꞓcb	Fyles and Hewlett, 1959; Yates, 1964	CO	NE corner of the map area
Revett Formation	Yms_2	Ransome, 1905; Harrison and Campbell, 1963; Hobbs and others, 1965	CH CO RO	E ¼ of the map area
Ringold Formation	QRcg	Merriam and Buwalda, 1917; Grolier and Bingham, 1978	BL ML	T21-22N, R26E
Roaring Creek, greenstone near	pTam	Atwater and Rinehart, 1984	NE	T35N, R31E
Rogers Bar, granodiorite of	KJigd	Atwater and Rinehart, 1984	NE	T30N, R36E
Rossland Group	Jmv, Jcg	Daly, 1912; Weaver, 1920	RE CO	NE ¼ of the map area between the Kettle and Columbia Rivers
Round Mountain, gneiss near	pꞒhm	Weis, 1968	SP	T24N, R46E
Roza Member of the Wanapum Basalt	Mv_w	Mackin, 1961; Bingham and Grolier, 1966; Swanson and others, 1979b	BL CD ML OM RI RO	S ½ of the map area
Saddle Mountains Basalt	Mv_s	Bingham and Grolier, 1966; Swanson and others, 1979b	RI RO	T20-21N, R39-40E
Salmon Creek schists and gneisses	pJhm, pJmb	Goldsmith, 1952; Menzer, 1983	OM	NW ¼ of the map area near Omak
Sand Creek, monzogranite of	Kig	Burmester and Miller, 1983	CO	T38N, R43E
Sanpoil Volcanics	Evd_1, Evt_1, Ev_1	Muessig, 1962, 1967; Pearson and Obradovich, 1977	CD CH CO NE OR RE	NE ¼ of the map area
Scatter Creek Rhyodacite	Eida	Muessig, 1962, 1967	RE	Republic area
Seventeenmile Mountain, quartz monzonite of	Eiqm	Atwater and Rinehart, 1984	NE	T35N, R33-34E
Shankers Bend alkalic complex	Jik	Rinehart and Fox, 1972; Fox, 1973	OR	T40N, R26E
Shasket Creek, intrusive rocks of	Jik	Parker and Calkins, 1964	RE	T40N, R33-34E
Shedroof Conglomerate	Zcg	Park and Cannon, 1943	CO	NE corner of the map area
Sheep Mountain area, hornblende gneisses of the	pJam	Staatz and others, 1971	RM	T40N, R19-20E
Shellrock Point volcanics	Evd_1	Menzer, 1983	OM	T34-35N, R26E
Sheppard Granite	Eig	Daly, 1912; Yates, 1964	CO	T40N, R39-42E
Silver Point Quartz Monzonite	Eia	Miller, 1969; Miller and Clark, 1975	CH SP	T30-31N, R43-45E and T28-29N, R40-41E
Similkameen composite pluton	Jia, Jik	Daly, 1912; Rinehart and Fox, 1972	OR	T40N, R23-26E
Skagit Gneiss	TKmi	Libby, 1964; Misch, 1966; Tabor and others, 1989	TW	T30-32N, R19-21E
Soap Lake Mountain, granodiorite of	Kigd	Atwater and Rinehart, 1984	OM	T32N, R25E
Sophie Mountain Formation	Kcg_2	Bruce, 1917; Little, 1960; Yates, 1964	CO	T40N, R38E
Spanish Camp gneiss complex	KJmi, Kit	Hawkins, 1968	RM	T40N, R19-21E
Spectacle Formation	Pcb, Pmm	Rinehart and Fox, 1972	OR	T37-40N, R25-30E
Spirit pluton	Kig, Kiaa	Yates, 1964, 1971	CO	T38N, R38-41E
Sprague Lake, basalt of	Mv_s	Swanson and others, 1979a; Hooper and Swanson, 1987; Wright and others, 1989	RI RO	T20-21N, R39-40E
Squaw Mountain, plutonic and metamorphic complex of	KJmi	Atwater and Rinehart, 1984	OM	T31N, R30E
St. Peters Creek, metamorphic rocks of	pThm, pTmb, pTsc	Parker and Calkins, 1964	RE	T36-38N, R34E
St. Regis Formation	Yms_2	Ransome, 1905; Harrison and Jobin, 1963	CH CO RO	E ¼ of the map area
Starvation Flat Quartz Monzonite	Kia	Clark and Miller, 1968; Miller and Clark, 1975	CH CO	T34-35N, R39-41E
Stensgar Dolomite	Ycb_2	Weaver, 1920; Bennett, 1941; Campbell and Loofbourow, 1962; Miller and Whipple, 1989	CD CH NE	T29-32N, R37-40E
Stepstone Creek, granite of upper	Eig	Atwater and Rinehart, 1984; Holder and Holder, 1988	NE OM	T33N, R30-31E
Stevens Lake, plutonic complex west of	KJmi	Atwater and Rinehart, 1984	OM	T31-32N, R25-26E
Storm King Mountain, monzonite east of	Eiqm	Holder and Holder, 1988	RE	T37N, R32E
Storm King pluton	TKia	Cheney and others, 1982; Holder and Holder, 1988	RE	T37-38N, R32E
Stranger Creek, gabbro near	KJigb	Atwater and Rinehart, 1984	NE	T32N, R36E
Striped Peak Formation	Yms_4	Ransome, 1905; Harrison and Jobin, 1963; Miller and Whipple, 1989	CH CO RO	E ¼ of map area
Summit-Frazer trondhjemitic gneiss	Kit, KJog, KJmi	Menzer, 1983	OM OR RM	NW ¼ of the map area
Summit Creek pluton	Kit, KJog	Barksdale, 1975	OM TW	T32N, R22-23E
Swakane Biotite Gneiss	pꞒgn	Waters, 1932; Crowder and others, 1966; Tabor and others, 1987	CL WE	T23-25N, R19-21E
Swauk Formation	Ec_1	Russell, 1900; Tabor and others, 1982	WE	T21-24N, R19-20E
Swawilla Basin, granite of	TKia, TKiat	Atwater and Rinehart, 1984	BL CD NE	T28-30N, R29-33E
Swimptkin Creek pluton	Eimd	Fox and others, 1976; Holder and Holder, 1988	OM OR	T34-35N, R29E
Tenas Mary Creek, metamorphic rocks of	pThm, pTam, pTsc, pTmb, pTqz, pTbg, pTog	Parker and Calkins, 1964; Cheney and others, 1982	NE OR RE	N-central part of the map area
Texas Creek stock	Kigd, Kid	Barksdale, 1975	TW	T31-32N, R22E
Three Sisters Formation	Zq	Walker, 1934; Miller, 1982a Lindsey and others, 1990	CO	NE corner of the map area
Tiffany complex	KJmi	Goldsmith, 1952	OR	T36-37N, R23-24E
Tiffany Mountain, gneissic trondhjemite of	KJmi	Rinehart, 1981	OM OR RM TW	NW ¼ of the map area
Tiger Formation	Ecg_2	Park and Cannon, 1943; Gager, 1983	CH CO	T32-34N, R43-44E and T36-38N, R42-43E and N of Chewelah
Tillman Mountain tonalitic gneiss	Ŧog	Hibbard, 1962, 1971; Rinehart, 1981	OR	T37-40N, R23-24E
Toats Coulee pluton	Jog, KJiq	Rinehart and Fox, 1972	OR	T39N, R24-25E
Togo Formation	Yar_1	Campbell and Loofbourow, 1962; Miller and Whipple, 1989	CD CH NE	T28-31N, R37-39E
Tonasket Gneiss	pTbg	Snook, 1962, 1965; Fox and others, 1976	OM OR	NW ¼ of the map area
Tuckaway Lake gneiss	tz	Miller, 1987	TW	T31-32N, R19-20E
Twentyfive Mile Creek, amphibolite and schist of	ŦPhmc	Tabor and others, 1987	BL CL TW	T29-30N, R19-23E
Twin Lakes, mafic intrusive rocks near	Oigb	Atwater and Rinehart, 1984	NE	T34N, R36E
Twin Peaks, andesite of	Evd_1, Evt_1	Rinehart and Fox, 1976	OR	T37N, R24-25E
Twisp Formation	Jm	Barksdale, 1975	TW RM	T34-35N, R21E
Twisp Valley schist	ŦPhmc	Adams, 1961; Miller, 1987	TW	T31-34N, R19-21E
Ventura member of the Midnight Peak Formation	Kc_2	Barksdale, 1975	RM TW	T33-37N, R19-21E
Virginia Lake, equigranular granite of	Kig, Kiaa	Atwater and Rinehart, 1984	OM	T32N, R25E
Virginian Ridge Formation	Km_2, Kcg_2	Barksdale, 1948, 1975	RM TW	T33-37N, R19-21E
Volcanic member of the Midnight Peak Formation	Kv_2, Kvs_2	Barksdale, 1975	RM TW	T33-36N, R19-20E
Wakefield, orthogneiss near	Kit, KJmi	Atwater and Rinehart, 1984	OM	T31-32N, R25-26E
Wallace Formation	Yms_3	Ransome, 1905; Hobbs and others, 1965; Miller and Whipple, 1989	CH CO RO SP	E ¼ of the map area
Wanapum Basalt	Mv_w	Swanson and others, 1979b	BL CD CH CL ML NE OM RI RO SP WE	S ½ of the map area
War Creek gneiss	Ᵽog	Adams, 1961; Miller, 1987	TW	T32-33N, R19E
Wauconda pluton	KJigd	Fox, 1978; Rinehart and Greene, 1988	OR RE	T37-38N, R30-31E
Weissenfels Ridge Member of the Saddle Mountains Basalt	Mv_s	Swanson and others, 1979b	RI RO	T20-21N, R39-40E
Wenatchee Formation	Φc	Gresens and others, 1981; Tabor and others, 1987	CL WE	T21-24N, R20E
West Fork, intrusive rhyolite near	Eir	Atwater and Rinehart, 1984	NE	T34N, R31E
Whiskey Mountain pluton	KJigd, KJiq	Krauskopf, 1938; Waters and Krauskopf, 1941; Rinehart and Fox, 1972	OR	T39N, R26-27E
Windermere Group	Zmv, Zcg, Zmm, Zq	Walker, 1926; Little, 1960; Miller and others, 1973	CH CO NE RE	NE ¼ of the map area
Windy Hill quartz dioritic orthogneiss	Mzog	Menzer, 1983	OM	T34N, T25E
Winthrop Sandstone	Kc_2	Russell, 1900; Barksdale, 1975	RM TW	T33-37N, R19-20E
Winthrop Sandstone, volcanic member of the	Kvs_2	Bunning, 1990	TW	T33-34N, R19-20E
Wolf Canyon quartz diorite	KJiq	Menzer, 1983	TW	T33-34N, R22E
Yakima Basalt Subgroup	Mv_s, Mv_w, Mv_g, Mvi_g	Waters, 1961; Wright and others, 1973; Swanson and others, 1979b	BL CD CH CL ML NE OM RI RO SP WE	S ½ of the map area

CORRELATION DIAGRAM

(To accompany geologic map, sheet 1)

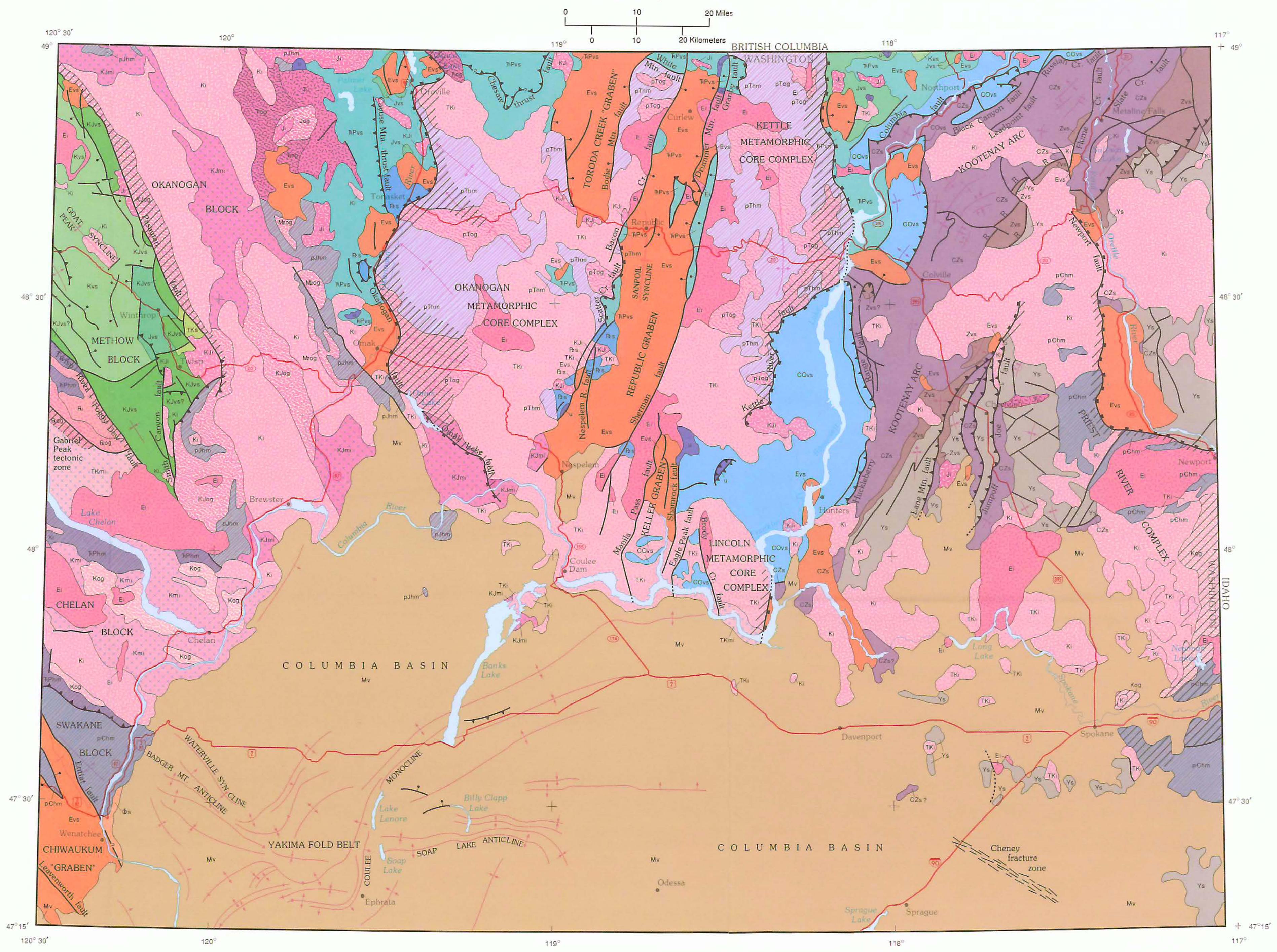


The time scale devised for the "Correlation of Stratigraphic Units of North America (COSUNA)" project of the American Association of Petroleum Geologists (Salvador 1985) is used in this diagram. Exceptions are: (1) placement of the Eocene-Oligocene boundary at 37.5 Ma (Monatanari and others, 1985) and (2) placement of the Pliocene-Pleistocene boundary at 1.6 Ma (Aguirre and Pasini, 1985). Age assignment of Pleistocene units is based on correlations with deposits of the Cordilleran ice sheet in western Washington (Blunt and others, 1987) and with deposits of the Laurentide ice sheet in the midcontinent (Willman and Frye, 1970), but ages should be considered approximate because of the lack of isotopic ages for this region and the general uncertainty about the timing of North American Pleistocene glacial events. The time scale for the Proterozoic is that devised by Harrison and Peterman (1982).

Cartographic design and production by Nancy A. Eberle, Carl F. T. Harris, and Keith G. Ikerd

BEDROCK GEOLOGIC AND TECTONIC MAP

SCALE 1:625,000



GEOLOGIC SYMBOLS

Contact — Dashed where approximately located

Fault — Dotted where concealed; R indicates reverse fault; queried where presence and character uncertain

Dip-slip fault — Ball and bar on downthrown side

Thrust fault — Sawteeth on upper plate; dotted where concealed; queried where presence and character uncertain

Low-angle normal fault — Blocks on upper plate; dotted where concealed

Anticline — Direction of plunge indicated by arrow

Syncline — Direction of plunge indicated by arrow

Overturned anticline

Overturned syncline

Monocline

▨ Zone of pervasive ductile deformation, approximately located

Zone of brittlely fractured rocks

GEOLOGIC UNITS

VOLCANIC AND SEDIMENTARY ROCKS

Subgreenschist-Grade Metamorphism

- Mv Miocene volcanic rocks
- Φs Oligocene sedimentary rocks
- Evs Eocene volcanic and sedimentary rocks
- TKs Tertiary to Cretaceous sedimentary rocks
- Kvs Cretaceous volcanic and sedimentary rocks
- KJvs Cretaceous and Jurassic volcanic and sedimentary rocks

METAVOLCANIC AND METASEDIMENTARY ROCKS

Subgreenschist- (West) and Greenschist- (East) Grade Metamorphism

- Jvs Jurassic rocks

Greenschist-Grade Metamorphism

- ŦPvs Triassic and Permian rocks
- ₽s Paleozoic metasedimentary rocks
- COvs Carboniferous to Ordovician rocks
- CZs Carboniferous to Late Proterozoic Z metasedimentary rocks
- Zvs Proterozoic Z rocks
- Ys Proterozoic Y metasedimentary rocks

METAMORPHIC ROCKS

Amphibolite-Grade (Thermal) Metamorphism

Layered Metamorphic Rocks

- pThm pre-Tertiary rocks
- pJhm pre-Jurassic rocks
- ŦPhm Triassic and Permian rocks
- pЄhm Precambrian rocks

Mixed Metamorphic and Igneous Rocks

- TKmi Tertiary and Cretaceous rocks
- Kmi Cretaceous rocks
- KJmi Cretaceous and Jurassic rocks

Thermal and/or Dynamic Metamorphism

- ₽og Paleocene orthogneiss
- pTog pre-Tertiary orthogneiss
- Mzog Mesozoic orthogneiss
- Kog Cretaceous orthogneiss
- KJog Cretaceous and Jurassic orthogneiss
- Jog Jurassic orthogneiss
- Ŧog Triassic orthogneiss

INTRUSIVE ROCKS

Not Metamorphosed

- Ei Eocene rocks
- ₽i Paleocene rocks
- TKi Tertiary and Cretaceous rocks
- Ki Cretaceous rocks
- KJi Cretaceous and Jurassic rocks
- Ji Jurassic rocks
- Ŧi Triassic rocks
- u Ultrabasic rocks (age uncertain)

SUMMARY OF GEOLOGIC HISTORY

AGE	VOLCANIC AND SEDIMENTARY ROCKS	INTRUSIVE ROCKS	METAMORPHISM AND DEFORMATION	TECTONIC/ DEPOSITIONAL SETTING
middle Miocene	Mv Continental flood basalt; minor continental clastic sedimentary rocks	Basaltic dikes (not shown on map)	Initial development of the Columbia Basin, Yakima fold belt, and north-northwest-trending fissures (vents for basalt flows) during regional subsidence and north-northwest(?) compression; deformation continued into the late Miocene and Pliocene	Uncertain; possible North American intracontinental back-arc extensional basin; possible crustal hot spot; possible incipient North American continental rift
early Oligocene	Φs Continental clastic sedimentary rocks; minor silicic volcanic rocks	Andesitic plugs and dikes (not shown on map)	?	North American intracontinental basin
early and middle Eocene	Evs Andesitic to rhyolitic volcanic and volcaniclastic rocks; continental clastic sedimentary rocks	Ei Epizonal calc-alkalic and alkalic intrusive rocks	Regional east-west extension; rapid uplift of the Swakane block and Okanogan, Kettle, Lincoln, and Priest River metamorphic core complexes accompanied by low-angle, normal ("detachment") faulting (both ductile and brittle deformation) and broad folding; formation of volcano-tectonic depressions ("grabens") by high- and low(?)-angle, normal faulting, strike-slip faulting, and broad folding(?)	Transition from compressional magmatic arc to North American intracontinental, back-arc extensional basin
Paleocene and Late Cretaceous	TKs, Kvs Andesitic to rhyolitic volcanic and volcaniclastic rocks; continental and shallow- to deep-water, marine clastic sedimentary rocks (both continental and arc sources)	₽i, TKi, Ki Mesozonal and epizonal calc-alkalic intrusive rocks	Continued development of the Methow block accompanied by strike-slip and dip-slip ductile deformation along the Twisp River–Foggy Dew fault and dip-slip and strike-slip movement on the Pasayten fault; amphibolite-grade metamorphism, migmatization, and ductile deformation of older rocks in the Chelan block (units ŦPhm, TKmi, and Kmi) and Okanogan, Kettle, Lincoln, and Priest River metamorphic core complexes (units pThm and pTog) accompanied by intrusion of syntectonic plutons (₽og, Kog, and TKi)	Convergent continental margin; forearc(?) basin and magmatic arc along margin of North American continent
Early Cretaceous	Kvs, KJvs? Andesitic to rhyolitic volcanic and volcaniclastic rocks; shallow- to deep-water, marine clastic sedimentary rocks (continental source)	Ki (in Okanogan block only) Mesozonal calc-alkalic intrusive rocks	Initial development of the Methow block by folding, thrust faulting, and dip-slip faulting; formation of the Okanogan block during amphibolite-grade metamorphism, migmatization, and ductile deformation of older rock (units pJhm and KJmi) and intrusion of syntectonic plutons (KJog)	Convergent continental margin; forearc(?) basin along margin of North American continent
Jurassic	Jvs, KJvs? Basaltic to rhyolitic volcanic and volcaniclastic rocks; shallow- to deep-water, marine clastic sedimentary rocks (arc source)	Ji Gabbroic plugs and dikes (west of Northport) and calc-alkalic and alkalic intrusive rocks	Continued(?) development of the "Kootenay arc" during Early Jurassic folding and thrust faulting that accompanied accretion of Jurassic, Triassic(?), and Permian(?) allochthonous terranes to the North American continent	Island and magmatic arcs
Triassic and Permian	ŦPvs Basaltic to dacitic volcanic and volcaniclastic rocks; shallow- to deep-water, marine clastic sedimentary rocks (arc source) and carbonate rocks	Ŧi Gabbroic plugs and dikes (not shown on map); Late Triassic calc-alkalic intrusive rocks	Initial development of the "Kootenay arc" during Late Triassic folding and thrust faulting that accompanied accretion of Triassic and Permian allochthonous terranes to the North American continent; probably regional amphibolite-grade metamorphism and migmatization of older rocks (units pThm and pЄhm)	Island arcs and/or intra-oceanic basin; location relative to North American continent during time of deposition uncertain
Carboniferous to Ordovician	COvs Shallow- to deep-water, marine clastic sedimentary rocks (both continental and arc sources) and carbonate rocks; basaltic volcanic rocks	Gabbroic plugs and sills (not shown on map)	Regional subsidence and extension	Intra-oceanic extensional basin near continental slope; location relative to North American continent during time of deposition uncertain
Carboniferous to Late Proterozoic Z	CZs Shallow- to deep-water, marine clastic sedimentary rocks (continental source) and carbonate rocks	None	Regional subsidence	North American passive continental margin, shelf
Proterozoic Z	Zvs Marine (possibly some glaciomarine) sedimentary rocks (continental source) and carbonate rocks; basaltic volcanic rocks	Gabbroic sills (not shown on map)	Regional extension and subsidence; high-angle dip-slip and possible strike-slip faults; possible Late Proterozoic(?) metamorphism of Proterozoic X and/or Archean rocks	North America continental margin rift basin
Proterozoic Y	Ys and part of pЄhm in the Priest River Complex Marine and/or continental clastic sedimentary rocks (continental source), carbonate rocks, evaporites	Gabbroic sills (not shown on map)	Regional extension and subsidence; possible strike-slip faults	North American intracontinental(?) rift basin
Proterozoic Z or Y	pЄhm in the Swakane block Dacitic volcanic rocks(?) or clastic sedimentary rocks(?) (subsequently metamorphosed to amphibolite grade)	?	?	Uncertain; location relative to North American continent during time of deposition uncertain
Proterozoic X and/or Archean	Part of pЄhm in the Priest River Complex Clastic sedimentary rocks (subsequently metamorphosed to amphibolite grade)	?	?	?