GEOLOGIC MAP OF WASHINGTON - SOUTHEAST QUADRANT

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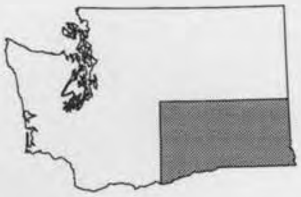
J. ERIC SCHUSTER, CHARLES W. GULICK, STEPHEN P. REIDEL,
KARL R. FECHT, AND STEPHANIE ZURENKO

WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
GEOLOGIC MAP GM-45
1997



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WASHINGTON DIVISION OF GEOLOGY AND EARTH RESOURCES
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Photograph on envelope: Oblique aerial view of the Palouse Falls area on the lower Palouse River in Whitman and Franklin Counties. View is toward the southeast, and, at river distance, the view is about one mile wide. Palouse Falls (185 ft high) is in the lower center of the photograph, the dark linear feature in the foreground is a railroad cut, and the grove of trees is the parking area for Palouse Falls State Park. Several Columbia River basalt flows covered this area about 15 million years ago. In the Palouse River canyon the lowest flows are two flows of the Sentinel Bluffs unit in the upper part of the Grande Ronde Basalt; the lip of the falls is in the Palouse Falls flow, and the flow under the parking lot is the Ginkgo flow, both part of the Frenchman Springs Member of the Wanapum Basalt. Upland areas farther from the river expose the Roza and Priest Rapids Members of the Wanapum (Carson and Pogue, 1996, p. 19). After basalt eruptions ceased streams began to establish valleys on the basalt surface, and windblown loess began to accumulate, in some places to depths of more than 200 feet. The paleo-Palouse River flowed westward down what is now Washtucna Coulee. Several times between about 19,000 and 11,000 years ago glacial outburst flood waters from glacial Lake Missoula flowed down the Cheney-Palouse scabland tract, entered the area of the photograph by way of Washtucna Coulee, and overtopped the drainage divide between the paleo-Palouse River and the Snake River. The floods stripped away the covering of loess, selectively eroded fractured areas of the basalt to form canyons, and changed the course of the Palouse River so that the post-flood river joins the Snake River to the south instead of continuing down Washtucna Coulee. At the latitude of Palouse Falls the area stripped by the floods is more than seven miles wide. The fracture systems that control this part of the course of the Palouse River trend N. 50° E., N. 20° W., and N. 55° W. (Carson and Pogue, 1996, p. 19). The short canyons trending away from the viewer are developed along the N. 55° W. fracture system, and the stretch of canyon just above the falls is on a N. 20° W. fracture. Since the end of the glacial floods talus slopes have softened the profiles of the cliffs, winds have deposited a thin veneer of loess, and soil-forming processes have allowed grasses and sagebrush to take root, but the landscape, in essence, dates from the ice age. Photograph courtesy of R. E. Peterson, Richland, WA.

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GEOLOGIC MAP OF WASHINGTON — SOUTHEAST QUADRANT

by

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INTRODUCTION

The Geologic Map of Washington—Southeast Quadrant is the third in a series of four 1:250,000-scale geologic maps that together will make up the third geologic map of Washington published by the Washington Division of Geology and Earth Resources and its predecessors. (The first is Stose, 1936, accompanied by Culver, 1936, and the second is Huntting and others, 1961.) 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 second, Geologic Map of Washington—Northeast Quadrant, is available as GM-39 (Stoffel and others, 1991). The last map of the series, Geologic Map of Washington—Northwest Quadrant, is currently in preparation (April, 1997).

In addition to the 1:250,000-scale geologic map, this report includes a **key to geologic units**, **descriptions of map units**, a **list of named units**, a **correlation diagram**, information on the **ages of geologic units**, a table showing the **distribution of map units** and **sources of unit description information**, a 1:625,000-scale **bedrock geologic and tectonic map**, **source-of-data maps**, and a list of **references cited**. A topographic base map, Washington Division of Geology and Earth Resources Topographic Map TM-3, is available separately.

MAP COMPILATION

The Moses Lake, Ritzville, and Rosalia 1:100,000-scale quadrangle geologic maps (Gulick, 1990a, 1990b; Waggoner, 1990) were compiled as part of the effort to generate the 1:250,000-scale geologic map of the northeast quadrant of Washington (Stoffel and others, 1991). Preliminary compilation of the Geologic Map of Washington—Southeast Quadrant began in 1990 and 1991 when all available published and unpublished geologic information was compiled for the remaining 1:100,000-scale quadrangles in southeastern Washington. These quadrangle maps and supporting texts were finished in 1993 and 1994 and released as Division of Geology and Earth Resources (DGER) open-file reports (Table 1). No report was prepared for the Wenatchee quadrangle because a geologic map of that quadrangle has been published by the U.S. Geological Survey (Tabor and others, 1982).

Authors Reidel and Fecht, assisted by M. A. Chamness, performed new field mapping in the Richland and Priest Rapids 1:100,000 quadrangles, and author Zurenko mapped a small area near the head of Rock Lake in the Rosalia 1:100,000 quadrangle. New mapping was also acquired through a DGER geologic mapping support program, which funded two mapping projects in the southeast quadrant of Washington. (See Acknowledgments.)

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

Compiler	Quadrangle	Open File Report Number
Gulick, C. W.	Connell	94-14
Gulick, C. W.	Moses Lake	90-1
Gulick, C. W.	Pullman	94-6
Gulick, C. W.	Ritzville	90-2
Reidel, S. P., Fecht, K. R.	Priest Rapids	94-13
Reidel, S. P., Fecht, K. R.	Richland	94-8
Schuster, J. E.	Clarkston	93-4
Schuster, J. E.	Goldendale	94-9
Schuster, J. E.	Hermiston	94-9
Schuster, J. E.	Orofino	93-4
Schuster, J. E.	Toppenish	94-10
Schuster, J. E.	Walla Walla	94-3
----	Wenatchee (Tabor and others, 1982)	None
Schuster, J. E.	Yakima	94-12
Waggoner, S. Z.	Rosalia	90-7

The 1:100,000-scale geologic maps and supporting data were then synthesized to prepare the 1:250,000-scale geologic map and other components of this publication.

ACKNOWLEDGMENTS

A publication such as this would not be possible were it not for the efforts of many geologists over a period of many years. The contributions of those who have produced maps and reports we used as sources of information are acknowledged by citation. (See **References Cited**.) Others have contributed in other ways to the success of the state geologic map project and the publication of this report. We gratefully acknowledge the contributions of those who are named below.

Cartographic and Editorial Support (DGER staff)

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Donald A. Swanson, U.S. Geological Survey
Gary D. Webster, Washington State University

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

Donald A. Swanson, U.S. Geological Survey
Ann Tallman, Kaiser Engineers Hanford Co.
Terry L. Tolan, Consulting Geologist, Kennewick, WA
Gary D. Webster, Washington State University

MAP DESIGN

Base Map

No appropriate topographic base map of Washington existed when this state geologic map project was initiated. Therefore, DGER chose to construct new 1:250,000-scale base maps by simplifying U.S. Geological Survey (USGS) 1:100,000-scale, metric-contour topographic maps of Washington. The 1:250,000-scale base maps were manually scribed from scale-stable reductions of 1:100,000-scale map separates. The control framework was a computer-generated latitude-longitude grid in a Universal Transverse Mercator Projection plotted by the USGS. The 1:250,000-scale base map for the southeast quadrant of Washington is available as a separate publication (Washington Division of Geology and Earth Resources Topographic Map TM-3).

Geologic Map

The Geologic Map of Washington—Southeast Quadrant displays geologic units chiefly by age and lithology, not by geologic formations. Formations are shown only for Miocene volcanic rocks; without this subdivision much of the 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, expressed by broad color ranges, distinguishes six general lithologic subdivisions: unconsolidated sedimentary deposits, sedimentary rocks and deposits, volcanic rocks, intrusive rocks, metasedimentary and metavolcanic rocks, and metamorphic rocks. The second level of detail, expressed by variations of color within each broad color range, indicates age. The third level of detail, represented by patterns, distinguishes lithologic units or small groups of lithologic units. The fourth level of detail, represented by the map symbols, identifies individual geologic map units.

Standard USGS age symbols are used for some 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 subscripted letter to distinguish it from other units of similar age and lithology. For example, the symbol for the Miocene Saddle Mountains Basalt is Mv_s. Subscripted numerals represent map units of similar lithologies, but of slightly different ages.

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

DESCRIPTIONS OF MAP UNITS

A lithologic description of each unit on the 1:250,000-scale geologic map is given in the **Descriptions of Map Units** (Sheet 1). Quaternary sediments are described first, followed by sedimentary rocks and deposits, volcanic rocks, intrusive rocks, metasedimentary and metavolcanic rocks, and metamorphic rocks. Within each lithologic group, map units are addressed in order of increasing age. Information concerning the ages and stratigraphic relations of the map units is given in the **Correlation Diagram** (Sheet 2). A tabulation in the section of this pamphlet titled Correlation Diagram presents additional information on the ages of geologic units. Table 2 shows the **Distribution of Map Units and Sources of Unit Description Information** in the southeast quadrant of Washington.

At the end of each unit description is a list of named units, if any, that make up the geologic map unit. Formally named formations that are included in lexicons published by the USGS are listed with the word "Formation" or the lithologic term capitalized. For informally named units the word "formation" or the 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 include sub-greenschist facies low-grade or unmetamorphosed deposits only. Metasedimentary and metavolcanic rocks are composed of sedimentary and volcanic rocks that have been metamorphosed to the greenschist facies. Metamorphic rocks are those that have been metamorphosed to the amphibolite facies or higher.

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 or widely recognized. Some of the named geologic units are represented on the 1:250,000-scale geologic map (Sheet 1) by a single symbol (age-lithologic unit), whereas other named units are represented by two or more symbols. References cited for each named unit consist of the citation(s) in which the unit was defined, redefined, or extensively reviewed. Locations given for each named unit are intended to guide the map user to the 1:100,000-scale quadrangle(s) in which the named geologic unit occurs.

SOURCES OF MAP DATA

Figures 1 through 4 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 figure captions. Complete citations are given in the **References Cited**. Patterned areas on Figure 1 indicate areas where authors Reidel and Fecht, assisted by M. A. Chamness, performed original geologic mapping for the state geologic map project. Author Zurenko performed original geologic mapping in a small area of Precambrian rock outcrop (unit p€sc) near the head of Rock Lake in the Rosalia 1:100,000-scale quadrangle, but this area is too small to show on Figure 1. Plate or sheet numbers are specified only for reports that contain more than one map plate or sheet. Some unpublished maps, cited as unpublished maps in the References Cited, were used to compile the 1:250,000-scale geologic map. They are available for inspection at the Division's Olympia office.

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 2. 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** (Sheet 1) and the **List of Named Units** (Sheet 2). Additional information about the ages of geologic units is given in the tabulation below. Stratigraphic relationships within the Columbia River Basalt Group are shown in more detail in Figure 5.

Queries at the top and/or bottom of a box on the diagram indicate that the upper or lower age limits are uncertain.

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 Sedimentary Deposits

Qd	Age inferred from geomorphology, ages of parent materials, and presence of interbedded Mazama tephra (about 7 ka, Kittleman, 1973, p. 2958; about 6.85 ka, Bacon, 1983).
Qla	Age inferred from geomorphology and stratigraphic position.

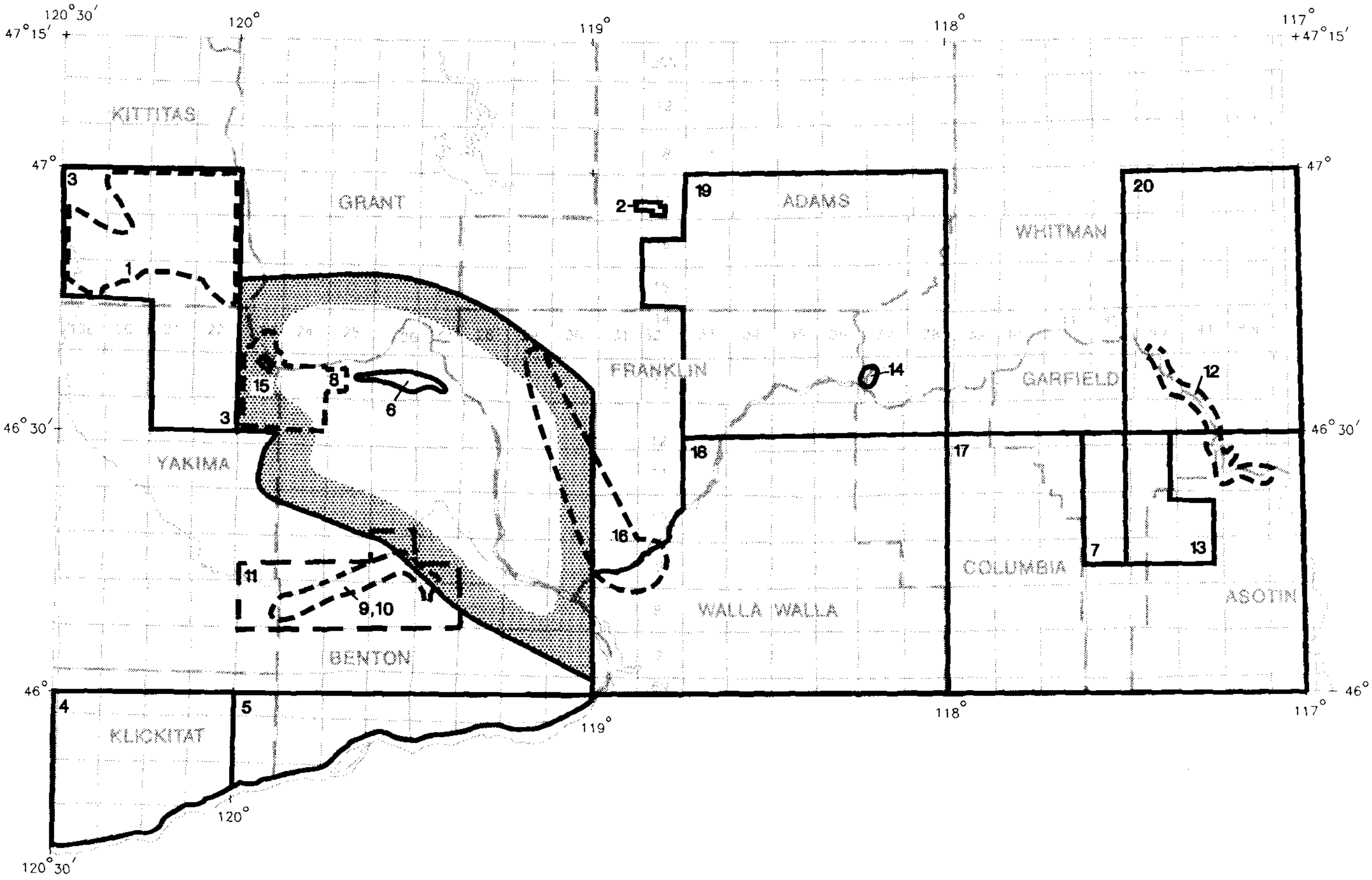

Figure 1. Index to sources of map data, scales 1:5,300 through 1:24,000.

EXPLANATION

1. Bentley, R. D.; Powell, J. E., Cent. Wash. Univ., unpub. mapping, 1984 (10 sheets, scale 1:12,000)
2. Burlington Environmental, Inc., 1990 (figure 3-1, scale 1:18,000)
3. Campbell, N. P., Yakima Valley Coll., unpub. mapping, 1978a (12 sheets, scale 1:24,000)
4. Campbell, N. P., Yakima Valley Coll., unpub. mapping, 1978b (11 sheets, scale 1:24,000)
5. Campbell, N. P., Yakima Valley Coll., unpub. mapping, 1978c (11 sheets, scale 1:24,000)
6. Fecht, 1978 (plate 1, scale 1:24,000)
7. Gillespie, B. A.; Hooper, P. R., Wash. State Univ., unpub. mapping, 1991 (2 sheets, scale 1:24,000)
8. Goff, 1981 (plate 1, scale 1:24,000)
9. Hagood, 1985 (scale 1:24,000)
10. Hagood, 1986a (scale 1:24,000)
11. Hagood, M. C., Westinghouse Hanford Co., unpub. mapping, 1986b (6 sheets, scale 1:24,000)
12. Hammatt and Blinman, 1977 (scale 1:24,000)
13. Hooper, P. R., Wash. State Univ., unpub. mapping, 1991 (scale 1:24,000)
14. Marshall, 1971 (scale 1:6,600)
15. Price, 1982 (plate 4, scale 1:5,300)
16. Swanson and Helz, 1979 (sheets 4-8, scale 1:24,000)
17. Webster, G. D., Wash. State Univ., unpub. mapping, 1978a (32 sheets, scale 1:24,000)
18. Webster, G. D., Wash. State Univ., unpub. mapping, 1978b (29 sheets, scale 1:24,000)
19. Webster, G. D., Wash. State Univ., unpub. mapping, 1978c (13 sheets, scale 1:24,000)
20. Webster, G. D., Wash. State Univ., unpub. mapping, 1978d (16 sheets, scale 1:24,000)

Patterned area is unpublished mapping for this report by S. P. Reidel and K. R. Fecht, assisted by M. A. Chamness.

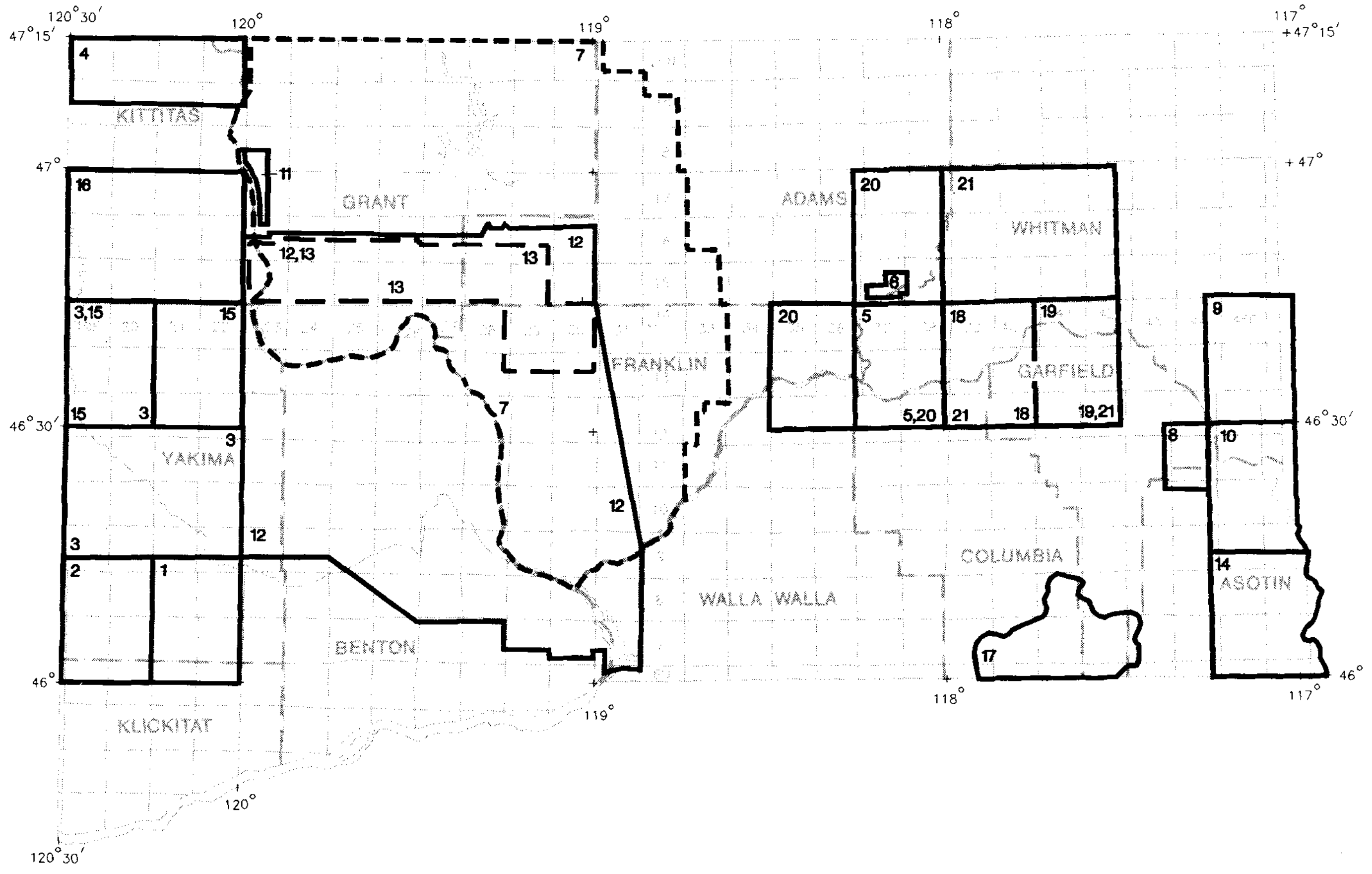

Figure 2. Index to sources of map data, scales 1:24,370 through 1:62,500.

EXPLANATION

1. Bentley and others, 1988a (scale 1:48,000)
2. Bentley and others, 1988b (scale 1:48,000)
3. Bentley and others, 1993 (sheets 1, 3 and 4, scale 1:31,680)
4. Campbell, 1988 (plate 5, scale 1:62,500)
5. Gard and Waldron, 1954 (scale 1:62,500)
6. Golder Associates, Inc., 1992 (figure 4-2, scale about 1:24,370)
7. Grolier and Bingham, 1971 (scale 1:62,500)
8. Hooper, P. R., Wash. State Univ., unpub. mapping, 1986 (scale 1:48,000)
9. Hooper and Webster, 1982 (scale 1:62,500)
10. Hooper and others, 1985 (scale 1:48,000)
11. Myers, 1973 (figure 4, scale 1:31,680)
12. Myers, Price, and others, 1979 (plate III-1, scale 1:62,500)
13. Reidel, 1988 (plates 1, 2, and 3, scale 1:48,000)
14. Reidel and others, 1992 (scale 1:48,000)
15. Shannon & Wilson, Inc., 1977 (figure 2R H.7-3, scale 1:62,500)
16. Shannon & Wilson, Inc., 1977 (figure 2R H.8-2, scale 1:62,500)
17. Swanson and Wright, 1983 (scale 1:48,000)
18. Waldron and Gard, 1954 (scale 1:62,500)
19. Waldron and Gard, 1955 (scale 1:62,500)
20. Webster, G. D., Wash. State Univ., unpub. mapping, 1978c (3 sheets, scale 1:62,500)
21. Webster, G. D., Wash. State Univ., unpub. mapping, 1978d (4 sheets, scale 1:62,500)

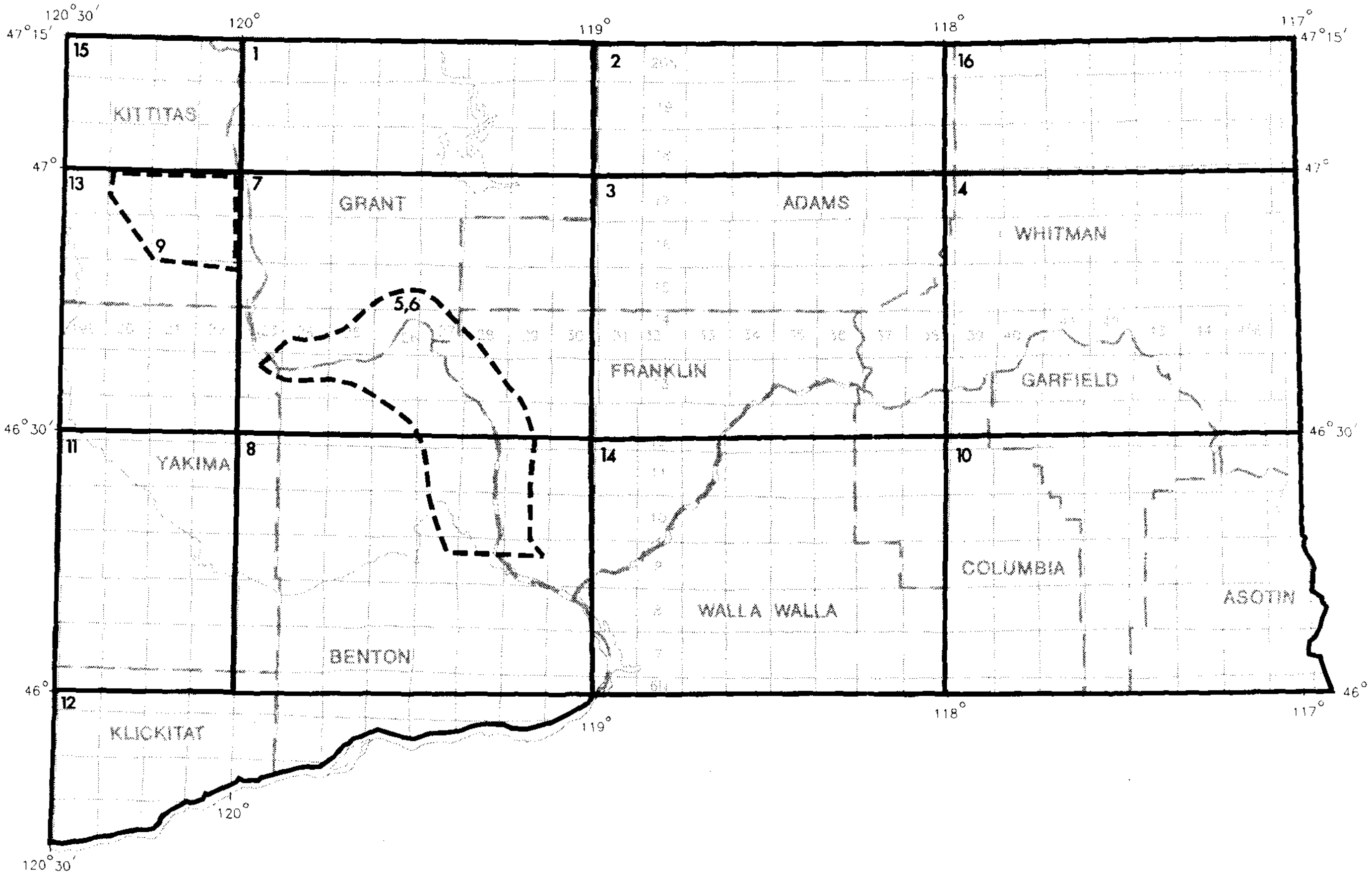

Figure 3. Index to sources of map data, scale 1:100,000.

EXPLANATION

1. Gulick, 1990a (scale 1:100,000)
2. Gulick, 1990b (scale 1:100,000)
3. Gulick, 1994a (scale 1:100,000)
4. Gulick, 1994b (scale 1:100,000)
5. Hays and Schuster, 1983 (scale 1:100,000)
6. Hays and Schuster, 1987 (scale 1:100,000)
7. Reidel and Fecht, 1994a (scale 1:100,000)
8. Reidel and Fecht, 1994b (scale 1:100,000)
9. Reidel, S. P., Wash. State Univ.; Tolan, T. L., consulting geologist, Kennewick, WA, unpub. mapping, 1991 (scale 1:100,000)
10. Schuster, 1993 (scale 1:100,000)
11. Schuster, 1994a (scale 1:100,000)
12. Schuster, 1994b (scale 1:100,000)
13. Schuster, 1994c (scale 1:100,000)
14. Schuster, 1994d (scale 1:100,000)
15. Tabor and others, 1982 (scale 1:100,000)
16. Waggoner, 1990 (scale 1:100,000)

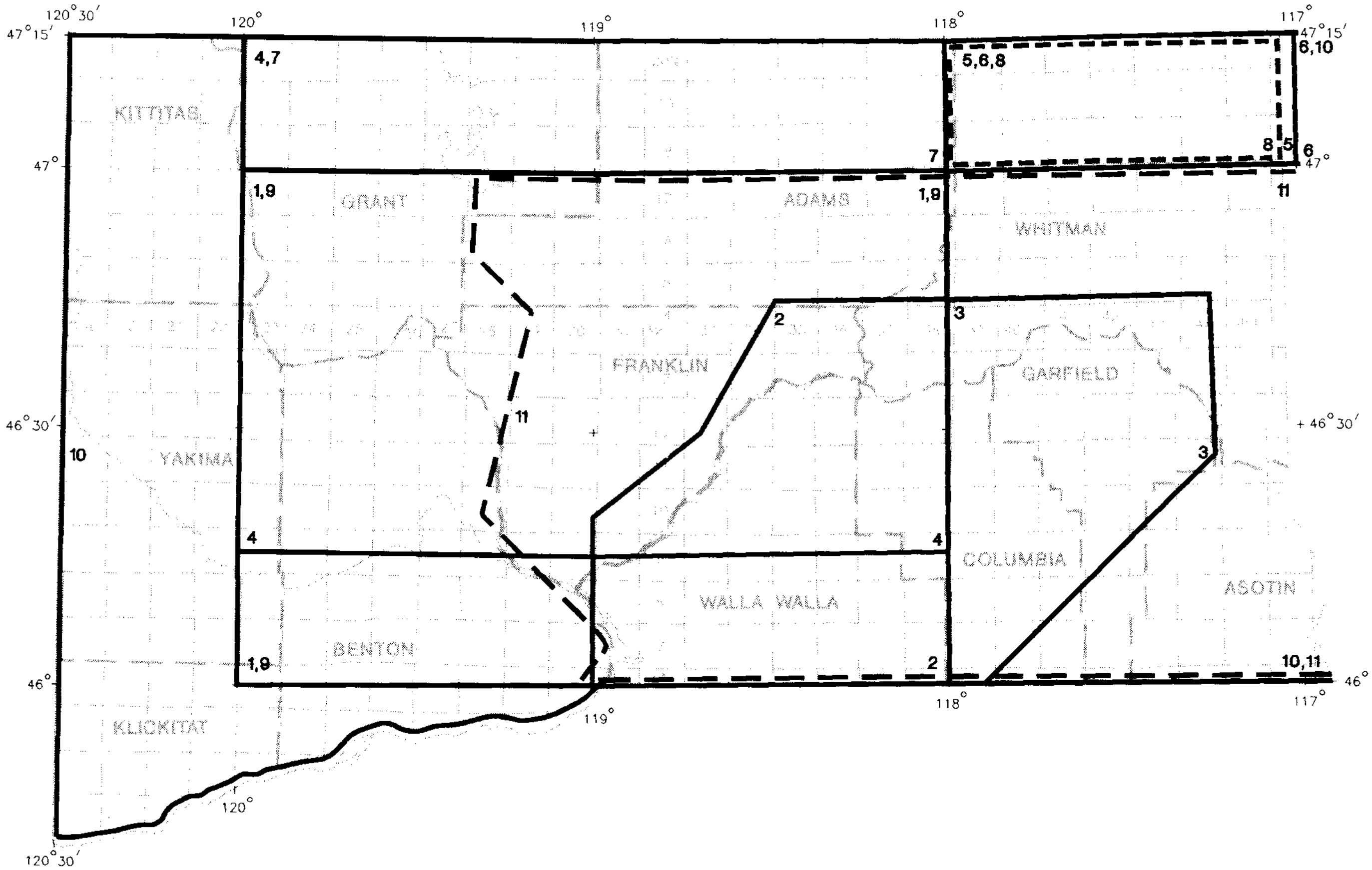

Figure 4. Index to sources of map data, scales 1:125,000 through 1:250,000.

EXPLANATION

1. Campbell and others, 1979 (scale 1:250,000)
2. Foundation Sciences, Inc., 1980 (plate 2, scale 1:170,000)
3. Foundation Sciences, Inc., 1980 (plate 3, scale 1:125,000)
4. Geomatrix Consultants, Inc., 1990 (figure 2, scale 1:250,000)
5. Griggs, 1966 (scale 1:125,000)
6. Griggs, 1973 (scale 1:250,000)
7. Hanson and others, 1979 (scale 1:250,000)
8. Kiver and others, 1979 (scale 1:250,000)
9. Rigby and others, 1979 (plate 7, scale 1:250,000)
10. Swanson and others, 1979a (scale 1:250,000)
11. Swanson and others, 1980 (scale 1:250,000)

SERIES		GROUP	SUB-GROUP	FORMATION	MEMBER	ISOTOPIC AGE(Ma)	MAGNETIC POLARITY
MIOCENE	upper	COLUMBIA RIVER BASALT GROUP	YAKIMA BASALT SUBGROUP	SADDLE MOUNTAINS BASALT	LOWER MONUMENTAL MEMBER	6	N
					ICE HARBOR MEMBER	8.5	
					basalt of Goose Island		N
					basalt of Martindale		R
					basalt of Basin City		N
					BUFORD MEMBER		
					ELEPHANT MOUNTAIN MEMBER	10.5	N,T
					basalt of Ward Gap		N,T
					basalt of Elephant Mountain		N,T
	middle				POMONA MEMBER	12	R
					ESQUATZEL MEMBER		N
					WEISSENFELS RIDGE MEMBER		
					basalt of Slippery Creek		N
					basalt of Tenmile Creek		N
					basalt of Lewiston Orchards		N
					basalt of Cloverland		N
					ASOTIN MEMBER	13	N
					basalt of Huntzinger		
					WILBUR CREEK MEMBER		N
					basalt of Lapwai		
					basalt of Wahluke		N
					UMATILLA MEMBER		
					basalt of Sillusi		N
					basalt of Umatilla		N
				WANAPUM BASALT	PRIEST RAPIDS MEMBER		
					basalt of Lolo	14.5	R
					basalt of Rosalia		R
					ROZA MEMBER		T,R
					FRENCHMAN SPRINGS MEMBER		
					basalt of Lyons Ferry		N
					basalt of Sentinel Gap		N
					basalt of Sand Hollow	15.3	N
					basalt of Silver Falls		N,E
					basalt of Ginkgo		E
					basalt of Palouse Falls		E
					ECKLER MOUNTAIN MEMBER		
					basalt of Shumaker Creek		N
					basalt of Dodge		N
					basalt of Robinette Mountain		N
				GRANDE RONDE BASALT	Sentinel Bluffs unit	15.6	N_2
					Slack Canyon unit		
					Fields Spring unit		
					Winter Water unit		
					Umtanum unit		
					Ortley unit		
					Armstrong Canyon unit		
					Meyer Ridge unit		R_2
					Grouse Creek unit		
					Wapshilla Ridge unit		
					Mt. Horrible unit		
					China Creek unit		N_1
					Downey Gulch unit		
					Center Creek unit		R_1
					Rogersburg unit		
					TEEPEE BUTTE MEMBER		
					Buckhorn Springs unit	16.9	
	lower			IMNAHA BASALT	See Hooper and others (1984) for Imnaha units	17.0	R_1
							T
							N_0
						17.3	R_0

Figure 5. Generalized nomenclature and stratigraphic relations of Columbia River basalt units. Modified from Reidel and others (1989).

Qa Age of streambed deposits inferred from paleomagnetics, geomorphology, ages of parent materials, and the presence of Mazama tephra (about 7 ka, Kittleman, 1973; about 6.85 ka, Bacon, 1983), Mount St. Helens set S tephra (about 13 ka; Mullineaux and others, 1978, p. 178) and Glacier Peak tephras G and B (about 11.25 ka; Mack and others 1983; Mehringer and others, 1984). Age of alluvial fans inferred from geomorphology, absence of caliche, and ages of parent materials; fans located below maximum elevation of glacial Lake Missoula outburst flooding are younger than the outburst flood deposits and are, therefore, Holocene; fans located above the maximum elevation of Pleistocene outburst flooding are Holocene or older; includes older alluvial fans (shown elsewhere as unit Qoa) in the Priest Rapids and Richland 1:100,000 quadrangles.

Qls Age inferred from geomorphology, stratigraphic position, pedogenic carbonate development, and ages of parent materials.

Qoa Age inferred from geomorphology, degree of cementing, and caliche development.

Qt Age inferred from geomorphology.

Qf$_b$ Swanson (1984, p. 49-52) suggests an age of 15 ka based on ^{14}C age estimates, sedimentology, and biostratigraphy in the Lake Bonneville area and stratigraphic position of deposits beneath glacial Lake Missoula outburst flood deposits in the Lewiston area; radiocarbon dates from wood collected in Lake Bonneville paleodeltas are 14–15 ka (Scott and others, 1982); Scott and Shroba (1980) estimate an age of 10–15 ka for soils buried by Bonneville deposits.

Ql Paleomagnetic measurements show that the second oldest loess unit in the Priest Rapids and Richland 1:100,000 quadrangles was deposited during the Matuyama Reversed-Polarity Chron (at least 790 ka), and the oldest loess unit is commonly capped by silcrete and is early Pleistocene or perhaps late Pliocene in age (Reidel and Fecht, 1994a, 1994b); uppermost loess locally contains Mazama tephra (Foley, 1982, p. 90), about 6.85–7 ka (Kittleman, 1973; Bacon, 1983); locally contains Glacier Peak G and B tephras (about 11.25 ka), Mount St. Helens S (13 ka; Mullineaux and others, 1978) and M (about 20 ka; Smith, 1980) tephras.

Qfs Youngest deposits are from floods that originated from ice dams along the Columbia River and are no older than the age of retreat of the ice from the Columbia River valley; most of the unit is associated with the last advance of the continental ice sheet and is thought to be younger than about 19 ka and older than about 11 ka on the basis of ^{14}C determinations that constrain the ages of advance and retreat of the Columbia ice lobe in southernmost British Columbia (Waitt, 1980); Mount St. Helens set S tephra, with an isotopic age estimate of 13 ka (Mullineaux and others, 1978), occurs below the top of the unit (Waitt, 1980); in the Priest Rapids and Richland 1:100,000 quadrangles the unit has been divided into four time-stratigraphic subunits on the basis of magnetic polarity, presence of tephra beds, pedogenic carbonate and other soil development, and stratigraphic position; the second oldest of these subunits is capped by pedogenic carbonate (stage III or IV of Machette, 1985), and the oldest has reversed magnetic polarity and is at least 790 ka (Reidel and Fecht 1994a, 1994b).

Qfg In the Priest Rapids and Richland 1:100,000 quadrangles the unit has been divided into four subunits on the basis of magnetic polarity, presence of tephra beds, pedogenic carbonate development, and stratigraphic position; the oldest and second oldest subunits are capped by pedogenic carbonate and cambic soil horizons; contains Mount St. Helens set S tephra (13 ka); same age as outburst flood deposits, silt and sand (unit Qfs).

Sedimentary Rocks and Deposits

QPls Age poorly constrained; younger than members of middle and upper Miocene Saddle Mountains Basalt that are involved in the landslides; here assumed to be post-Miocene.

QPcg Overbank facies has reversed magnetic polarity (Van Alstine, 1982); underlies oldest Pleistocene outburst flood deposits (top scoured by Pleistocene outburst floods); overlies Ringold Formation and Ice Harbor Member of Saddle Mountains Basalt; age is greater than about 1 Ma and less than 3 Ma.

QMcg Older than glacial Lake Missoula outburst flood and/or Bonneville flood deposits and younger than the Lower Monumental Member and/or Pomona Member (older than about 19 ka and younger than 12 Ma; most gravels probably younger than 6 Ma) (Hooper and others, 1985; Reidel and others, 1992).

Pcg The gravels have yielded fission-track ages of 3.64 ± 0.74 and 3.70 ± 0.2 Ma and are thought to lie wholly within the Pliocene (Waitt, 1979, p. 11).

PMc Overlain by unconsolidated Pliocene and Pleistocene deposits and underlain by the Ice Harbor Member of the Saddle Mountains Basalt (Fecht and others, 1985; Lindsey, 1991), which was dated at 8.5 Ma by McKee and others (1977). At the White Bluffs, the lower 20 m of the Ringold has normal magnetic polarity, and the upper 100 m has reversed polarity (Packer and Johnston, 1979; Rigby and others, 1979). Vertebrate fossils (Gustafson, 1978; Strand and Hough, 1952) and magnetic polarity data indicate that the unit is older than 3.4 Ma (Fecht and others, 1985, p. 37).

PMcg Age is the same as unit PMc.

PMa Age inferred from geomorphology, variable induration with pedogenic carbonate, and ages of parent materials.

Mc Older than the overlying Thorp Gravel (unit Pcg, see discussion of age above); younger than the underlying unit of the Columbia River Basalt Group (units Mv$_s$, Mv$_w$, or Mv$_g$, see discussions of age below); Campbell and Reidel (1991) place the age range of the Ellensburg Formation between 16.5 million and about 5 million years.

Mcg Interfingers with other fluvial and laharic deposits of the Ellensburg Formation, overlies the Priest Rapids Member of the Wanapum Basalt or one of the members of the Saddle Mountains Basalt, underlies the Pliocene Thorp Gravel (unit Pcg), and is upper or middle Miocene in age. In the Orofino 1:100,000 quadrangle underlies the lower Miocene Imnaha Basalt and is assumed to be early Miocene in age.

Ec$_1$ Northwest of the map area, in the Wenatchee 1:100,000-scale quadrangle, contains tuffs that yielded ages of 49-50 Ma (Tabor and others, 1982).

Jm Callovian to Oxfordian age on the basis of ammonites (Vallier, 1977, p. 51).

Volcanic Rocks

Columbia River Basalt Group

Mv$_s$	Saddle Mountains Basalt. Lower Monumental Member has yielded a K-Ar age of approximately 6 Ma (McKee and others, 1977). Ice Harbor Member is about 8.5 Ma, based on K-Ar age estimates (McKee and others, 1977). Elephant Mountain Member has produced K-Ar age estimates of 10.5 Ma (McKee and others, 1977) and 9.4 ± 0.7 Ma and 10.7 ± 0.8 Ma (Stoffel, 1984). The Pomona Member has been isotopically dated at 12 Ma (K-Ar method) by McKee and others (1977) and 12 Ma (^{40}Ar-^{39}Ar method) (S. P. Reidel, Wash. State Univ., unpub. data, 1991). Asotin Member was K-Ar dated at 13 Ma by Reidel and Fecht (1987, p. 666). Overlies the Priest Rapids Member of the Wanapum Basalt, which has been K-Ar dated at 14.5 Ma (Tolan and others, 1989).
Mv$_w$	Wanapum Basalt. Priest Rapids Member K-Ar dated at 14.5 Ma (Tolan and others, 1989). The basalt of Sand Hollow, a flow in the Frenchman Springs Member, yielded an isotopic age estimate of 15.3 Ma (Tolan and others, 1989). Overlies the Grande Ronde Basalt, which is as young as 15.6 Ma.
Mv$_g$	Grande Ronde Basalt. Isotopically (K-Ar; ^{40}Ar-^{39}Ar) dated at about 15.6 to 16.9 Ma (Baksi, 1989, p. 109; age information summarized by Reidel and others, 1989).
Mvi$_g$	Same age as non-invasive Grande Ronde Basalt (Mv$_g$).
Mv$_i$	Imnaha Basalt. K-Ar age 17.3–17.0 Ma (Baksi, 1989, p. 109).

Intrusive Rocks

Kia	At Viola, Idaho (northwest end of Moscow Mountain), unit yielded a K-Ar age estimate of 67.8 ± 2.5 Ma (Geochron No. B-4991)(Webster and Nuñez, 1982).
Kigd	Underlies magnetostratigraphic unit N1 of the Grande Ronde Basalt. Occurrence is the westernmost of several Cretaceous igneous stocks that include the monzodiorite on Paradise Ridge (in Idaho), the tonalite (unit Kit) of Bald Butte, and the granodiorite (unit Kia) at and near Viola, Idaho, 11 miles (18 km) northeast of Pullman. Owing to similarity to these Cretaceous silicic igneous stocks to the east, a Cretaceous age is likely.
Kit	A sample from the Chambers Road-U.S. Highway 195 junction (in Idaho) yielded a K-Ar age of 69.8 ± 2.6 Ma (Geochron No. B-4992) (Hooper and Webster, 1982).
KJi	A Cretaceous or Jurassic age was assigned because the unit is slightly metamorphosed and intrudes Triassic and Jurassic rocks.

Metasedimentary and Metavolcanic Rocks

pTmt	Age unknown. Unconformably overlain by Grande Ronde Basalt. Assigned a pre-Tertiary age because the unit is metamorphosed (greenschist facies).
pKq	Intruded by Cretaceous intrusive rocks. Savage (1973) assigned rocks of Kamiak Butte and other quartzite steptoes to the Precambrian Belt Supergroup (Ravalli Group, Revett Formation). Griggs (1973) assigned similar rocks in the Spokane 1:250,000-scale quadrangle to the Revett and Burke Formations. Savage suggested that Kamiak Butte and similar steptoes are block-faulted remnants isolated from the main mass of the northern Rocky Mountains and that the sediments originally formed in a shallow, shoreline-intertidal environment, but others believe that these pure quartzites are unlike the relatively impure, laminated, micaceous quartzites typical of the Belt Supergroup and have instead tentatively correlated "orthoquartzites of Kamiak Butte type" with similar Upper Proterozoic to Lower Cambrian quartzites (Addy and Gypsy Quartzites) of northeastern Washington (Hooper and Webster, 1982). We show the Belt Supergroup correlation as far south as the southern boundary of the Rosalia 1:100,000 quadrangle (units Yms$_4$ and Yms$_2$), following the usage of Waggoner (1990). Farther south, we show the rocks as pKq, following neither the Belt nor the Addy/Gypsy correlation because of the distance from known Belt or Addy/Gypsy rocks.
TRcb	Norian age on the basis of ammonites (Vallier, 1977, p. 50).
TRmt	Doyle Creek Formation is Karnian and possibly early Norian age on the basis of Karnian fossils in the underlying Wild Sheep Creek Formation and Norian fossils in the overlying Martin Bridge Limestone (Vallier, 1977, p. 44-45). Wild Sheep Creek Formation is Ladinian to Karnian age on the basis of ammonites and pelecypods (Vallier, 1977, p. 36).
Yms$_4$	Considered Precambrian Y on the basis of a possible lithologic correlation with the Striped Peak Formation, Missoula Group, Belt Supergroup (Waggoner, 1990).
Yms$_2$	Considered Precambrian Y on the basis of a correlation with the undivided Revett and Burke Formations, Ravalli Group, Belt Supergroup, made by Griggs (1973). (See further discussion above under pKq.)

Metamorphic Rocks

pꞒsc	Overlain by the Grande Ronde Basalt. Considered Precambrian on the basis of a possible correlation with the Precambrian Y Prichard Formation, the lowest formation of the Belt Supergroup (Waggoner, 1990).

DISTRIBUTION OF MAP UNITS AND SOURCES OF UNIT DESCRIPTION INFORMATION

Table 2 on the following pages shows the distribution of each geologic unit in southeastern Washington. Distribution is shown by indicating the 1:100,000-scale quadrangle(s) in which each geologic unit occurs. Because this information was compiled from 1:100,000-scale quadrangle reports (listed in Table 1), the 1:250,000-scale geologic map on Sheet 1 does not show precisely the same distribution, owing to the elimination of some small occurrences during the compilation process. Table 2 also lists the sources of information from which the unit descriptions were compiled. Full references to these sources can be found in **References Cited**.

EDGE MATCHES WITH OTHER STATE GEOLOGIC QUADRANT MAPS

Geologic units on the north and west edges of the southeast-quadrant 1:250,000-scale geologic map match well with the geologic units shown on the south edge of the geologic map of the northeast quadrant of Washington (Stoffel and others, 1991) and with the units along the east edge of the geologic map of the southwest quadrant (Walsh and others, 1987).

Table 2. Distribution of map units and sources of unit description information. 1:100,000 quadrangle abbreviations: CL, Clarkston; CO, Connell; GO, Goldendale; HE, Hermiston; ML, Moses Lake; OR, Orofino; PR, Priest Rapids; PU, Pullman; RI, Richland; RT, Ritzville; RO, Rosalia; TO, Toppenish; WW, Walla Walla; WE, Wenatchee; YA, Yakima. Although the members of the Columbia River Basalt Group formations are not divided out on the geologic map (Sheet 1), their distribution is included here. See Figure 5 for the stratigraphic position of the members

Map unit	1:100,000-scale quadrangle(s)	Sources of unit description information
Qd	CO, GO, HE, ML, PR, PU, RI, WW, WE	Grolier and Bingham, 1971; Myers, Price, and others, 1979; Reidel and Fecht, 1994a, 1994b; Rigby and others, 1979
Qla	CO, PU	Rigby and others, 1979
Qa	All	Baker and others, 1991; Bentley and others, 1988a, 1988b, 1993; Hooper and others, 1985; Hooper and Webster, 1982; Myers, Price, and others, 1979; Reidel and Fecht, 1994a, 1994b; Reidel and others, 1992; Rigby and others, 1979; Swanson and others, 1980; Swanson and Wright, 1983
Qls	All	Bentley and others, 1988a, 1988b, 1993; Fecht, 1978; Grolier and Bingham, 1971; Hanson and others, 1979; Hooper and others, 1985; Myers, Price, and others, 1979; Reidel, 1988; Reidel and Fecht, 1994a, 1994b; Rigby and others, 1979; Swanson and others, 1979a; Swanson and Wright, 1983
Qoa	TO, YA	Bentley and others, 1988a, 1988b, 1993
Qt	GO, HE, PU, TO, WE, YA	Bentley and others, 1993; Rigby and others, 1979
Qf$_b$	CL, CO, OR, PU	Hooper and others, 1985; Hooper and Webster, 1982; Reidel and others, 1992
Ql	All	Baker and others, 1991; Bentley and others, 1988a, 1988b, 1993; Grolier and Bingham, 1971; Hooper and others, 1985; Hooper and Webster, 1982; P. R. Hooper, Wash. State Univ., unpub. mapping, 1986; McDonald and Busacca, 1989; Myers, Price, and others, 1979; Reidel and Fecht, 1994a, 1994b; Reidel and others, 1992; Rigby and others, 1979
Qfs	All except RO	Baker and others, 1991; Bentley and others, 1988a, 1988b, 1993; Grolier and Bingham, 1971; Hanson and others, 1979; Hooper and others, 1985; Hooper and Webster. 1982; Myers, Price, and others, 1979; Reidel and Fecht, 1994a, 1994b; Reidel and others, 1992; Rigby and others, 1979; Van Alstine, 1982
Qfg	All except CL, OR, TO	Baker and others, 1991; Grolier and Bingham, 1965, 1971; Myers, Price, and others, 1979; Reidel and Fecht 1994a, 1994b; Rigby and others, 1979
QꝐls	CL, OR	Hooper and others, 1985; Reidel and others, 1992
QꝐcg	PR, RI	Reidel, 1988; Reidel and Fecht, 1994a, 1994b
QMcg	CL, CO, OR, PU, WW	Hooper and others, 1985; Reidel and others, 1992; Rigby and others, 1979
Ꝑcg	WE, YA	Bentley and others, 1993; Rigby and others, 1979; Waitt, 1979
ꝐMc	CO, ML, PR, RI, RT, WW, YA	Grolier and Bingham, 1971, 1978; Lindsey, 1991; Myers, Price, and others, 1979; Newcomb and others, 1972; Rigby and others, 1979
ꝐMcg	ML, PR, RI, WW, YA	Grolier and Bingham, 1978; Lindsey, 1991; Myers, Price, and others, 1979; Newcomb and others, 1972; Rigby and others, 1979
ꝐMa	PR	Myers, Price, and others, 1979; Reidel, 1988; Rigby and others, 1979
Mc	GO, HE, PR, PU, RI, TO, WE, YA	Bentley and others, 1988a, 1988b, 1993; Hooper and others, 1985; Reidel and Fecht, 1981, 1994a, 1994b; Reidel and others, 1992; Smith, 1988; Swanson and others, 1979a; Swanson and Wright, 1983
Mcg	GO, HE, PR, TO, YA	Bentley and others, 1988a, 1988b, 1993; Reidel, 1988; Reidel and others, 1992; Smith, 1988; Swanson and others, 1979a
Ec$_1$	WE	Tabor and others, 1982
Jm	OR	Morrison, 1964; Reidel and others, 1992; Vallier and Hooper, 1976; Vallier, 1977
Mv$_s$ (Saddle Mountains Basalt)		
Lower Monumental Member		
	CL, CO, PU	Swanson and others, 1980; Hooper and others, 1985
Ice Harbor Member		
	PR, RI, WW	Myers, Price, and others, 1979; Swanson and Helz, 1979; Swanson and others, 1980
Buford Member		
	CL	Hooper and others, 1985; Reidel and others, 1992; Swanson and others, 1980

Table 2. Distribution of map units and sources of unit description information *(continued)*

Map unit	1:100,000-scale quadrangle(s)	Sources of unit description information
Elephant Mountain Member		
	CL, CO, GO, HE, OR, PR, RI, TO, WW, YA	Bentley and others, 1988a, 1988b, 1983; P. R. Hooper, Wash. State Univ., unpub. mapping, 1986; Hooper and others, 1985; Myers, Price, and others, 1979; Reidel and others, 1992; Swanson and others, 1979a, 1980; Swanson and Wright, 1983
Pomona Member		
	CL, CO, GO, HE, PR, PU, RI, TO, WW, YA	Bentley and others, 1988a, 1988b, 1993; Hooper and others, 1985; Swanson and others, 1979a, 1980
Esquatzel Member		
	CO, PR, PU, RI, YA	Bentley and others, 1993; Myers, Price, and others, 1979; Reidel and Fecht, 1981; Swanson and others, 1979a, 1979b, 1980
Weissenfels Ridge Member		
	CL, OR, PU, RO	Hooper and others, 1985; Hooper and Webster, 1982; Reidel and others, 1992; Swanson and others, 1979a, 1980
Asotin Member		
	CL, CO, OR, PR, PU, YA	Bentley and others, 1993; P. R. Hooper, Wash. State Univ., unpub. mapping, 1986; Hooper and others, 1985; Hooper and Webster, 1982; Myers, Price, and others, 1979; Reidel and Fecht, 1981, 1987; Reidel and others, 1992; Swanson and others, 1979a, 1979b, 1980
Wilbur Creek Member		
	CL, CO, OR, PR, PU, YA	Bentley and others, 1993; Hooper and others, 1985; Hooper and Webster, 1982; Myers, Price, and others, 1979; Reidel and Fecht, 1981, 1987; Reidel and others, 1992; Swanson and others, 1979a, 1979b, 1980
Umatilla Member		
	CL, GO, HE, OR, PR, PU, RI, TO, WW, YA	Bentley and others, 1988a, 1988b, 1993; P. R. Hooper, Wash. State Univ., unpub. mapping, 1986; Hooper and others, 1985; Hooper and Webster, 1982; Reidel and Fecht, 1981; Myers, Price, and others, 1979; Reidel and others, 1992; Swanson and others, 1979a, 1980
Mv_w (Wanapum Basalt)		
Priest Rapids Member		
	All	Bentley and others, 1988a, 1988b, 1993; P. R. Hooper, Wash. State Univ., unpub. mapping, 1986; Hooper and others, 1985; Hooper and Webster, 1982; Myers, Price, and others, 1979; Reidel and Fecht, 1981; Reidel and others, 1992; Swanson and others, 1979a, 1980
Roza Member		
	All except HE	Bentley and others, 1988a, 1988b, 1993; Grolier and Bingham, 1978; P. R. Hooper, Wash. State Univ., unpub. mapping, 1986; Hooper and others, 1985; Hooper and Webster, 1982; Martin, 1989; Myers, Price, and others, 1979; Reidel and Fecht, 1981; Reidel and others, 1992; Swanson and others, 1979a, 1979b, 1980
Frenchman Springs Member		
	All except OR, RO	Beeson and others, 1985; Bentley and others, 1988a, 1988b, 1993; Grolier and Bingham, 1978; Myers, Price, and others, 1979; Reidel and Fecht, 1981; Swanson and others, 1979a, 1979b, 1980; Swanson and Wright, 1983
Eckler Mountain Member		
	CL, OR, PU, WW	Hooper and others, 1985; Reidel and others, 1992; Swanson and others, 1980; Swanson and Wright, 1983
Mv_g (Grande Ronde Basalt)		
N_2	All except HE, OR, RT, TO	Camp and others, 1978; P. R. Hooper, Wash. State Univ., unpub. mapping, 1986; Hooper and others, 1985; Reidel, 1983; Reidel and others, 1989, 1992; Swanson and others, 1979a, 1979b, 1980; Swanson and Wright 1983
R_2	CL, ML, OR, PR, PU, WW, WE, YA	Same as N_2
N_1	CL, OR, PU, WW, WE	Same as N_2
R_1	CL, OR, PU, WW, WE	Same as N_2
Mvi_g	WE	Tabor and others, 1982
Mv_i	CL, OR	Hooper and others, 1985; Reidel and others, 1992; Swanson and others, 1980
Kia	PU	Rigby and others, 1979
Kigd	PU	Hammatt and Blinman, 1976; Hooper and Rosenberg, 1970; Shedd, 1903; Treasher, 1925
Kit	PU	Hoffman, 1932; Hooper and Webster, 1982
KJi	OR	Reidel and others, 1992; Vallier and Hooper, 1976)
pTmt	CL	Swanson and others, 1980

Table 2. Distribution of map units and sources of unit description information (*continued*)

Map unit	1:100,000-scale quadrangle(s)	Sources of unit description information
pKq	PU	Hooper and Webster, 1982; Webster and Nuñez, 1982; Savage, 1973; Treasher, 1925
TRcb	OR	Reidel and others, 1992; Vallier, 1977; Vallier and Hooper, 1976
TRmt	OR	Reidel and others, 1992; Vallier, 1977; Vallier and Hooper, 1976
Yms_4	RO	Waggoner, 1990
Yms_2	RO	Waggoner, 1990
pЄsc	RO	Waggoner, 1990

Faults match well between the southeast- and northeast-quadrant maps. Fault locations match relatively well between the southeast and southwest quadrants, but there are some apparent changes in the type of fault. These changes are not compilation errors, but reflections of differences in interpretation between different source-map authors or between the same authors' maps published at different times. Many of these apparent fault-type changes are also present on the structure map of the Columbia Basin by Tolan and Reidel (1989). There is, as yet, no new mapping available to resolve these differences.

Folds match well between the northeast and southeast 1:250,000-scale quadrant maps, except for a syncline located just west of the Columbia River that is shown on the southeast quadrant map, but, for unknown reasons, not on the northeast quadrant map. The syncline is clearly shown extending into the northeast quadrant on the source map used for both quadrant maps (Tabor and others, 1982). An anticline on Ahtanum Ridge, south of Yakima, is shown on the southwest quadrant geologic map, but not on the southeast quadrant map. The fold apparently ends at the boundary between the two maps, because the geologic map by Bentley and others (1993) does not show the fold extending east of 120°30′W. Differences in folds between the southeast and southwest quadrant maps south of 46°N are, like the differences between faults, due to differences between interpretations by different source-map authors at different times, and newer mapping is not yet available to resolve the differences.

Although it is not an edge-match problem, the reader should be aware that the age of the Ringold Formation has been reinterpreted since the northeast-quadrant 1:250,000-scale geologic map was published. On the northeast-quadrant map (Stoffel and others, 1991) the Ringold was represented as Pleistocene-Pliocene in age (unit symbol QRcg). The Ringold is now interpreted as Pliocene-Miocene in age (Lindsey, 1991), and is shown as units RMc and RMcg.

The 1:625,000-scale geologic maps for the northeast and southeast quadrants differ in that the southeast quadrant shows several folds that do not appear on the northeast quadrant map. In some instances, it appears that the northeast quadrant map does not show the folds because they extend only a short distance into the northeast quadrant. In other instances the reasons why the folds were not shown on the northeast quadrant are not apparent.

BEDROCK GEOLOGIC AND TECTONIC MAP OF THE SOUTHEAST QUADRANT

The 1:625,000-scale **Bedrock Geologic and Tectonic Map** on Sheet 2 is a simplified version of the 1:250,000-scale geologic map (Sheet 1). This map omits unconsolidated sedimentary deposits and combines similar bedrock geologic units for simplicity. The simplified design of geologic units allows other elements of the geology, such as folds, faults, and dikes to show more clearly. Because the bedrock geologic units have been combined, the colors used on this map differ from those on Sheet 1.

ADDITIONAL INFORMATION ABOUT MEMBERS OF THE COLUMBIA RIVER BASALT GROUP

The members of the formations in the Columbia River Basalt Group are not shown on the geologic map (Sheet 1). The following descriptive information supplements that given in the **Descriptions of Map Units** on Sheet 1. See Figure 5 for the stratigraphic positions of these units.

Saddle Mountains Basalt

Lower Monumental Member—Single flow; nearly aphyric; microphenocrysts of olivine in opaque glass; rare plagioclase phenocrysts as long as 10 mm; normal magnetic polarity (Choiniere and Swanson, 1979); occurs as an intracanyon flow along the Snake River.

Ice Harbor Member—Flows, vents, northwest-trending feeder dikes, and minor tephra; plagioclase phenocrysts commonly more tabular (needlelike in cross section) than in other Saddle Mountains Basalt flows; consists of three informal units, from top to bottom, basalt of Goose Island with low-latitude normal magnetic polarity (Choiniere and Swanson, 1979), basalt of Martindale with reversed magnetic polarity (Choiniere and Swanson, 1979), and basalt of Basin City with normal magnetic polarity (Choiniere and Swanson, 1979); feeder dikes occur near Ice Harbor Dam in the Walla Walla 1:100,000 quadrangle and near Basin City in the Priest Rapids 1:100,000 quadrangle.

Buford Member—Medium-grained aphyric flow; contains sparse, small plagioclase phenocrysts in some places; reversed magnetic polarity (Swanson and others, 1979a, 1979b).

Elephant Mountain Member—Two aphyric to sparsely plagioclase-phyric flows, informally called the Ward Gap flow (upper) and the Elephant Mountain flow (lower); abundant plagioclase microphenocrysts; fine- to coarse-grained to glassy; locally diktytaxitic; normal to transitional magnetic polarity (Rietman, 1966; Choiniere and Swanson, 1979; Reidel and Fecht, 1981).

Pomona Member—One or two fine- to medium-grained flows; sparsely to slightly phyric with small phenocrysts of plagioclase (generally less than 5 mm long and commonly wedge shaped), clinopyroxene, and olivine; locally contains large clots (as much as 100 mm or more across) of plagioclase, pyroxene (including rare hypersthene), and olivine thought by Swanson and others (1980) to have formed during crystallization after eruption; reversed magnetic polarity (Choiniere and Swanson, 1979; Reidel and others, 1984); invasive contacts with Ellensburg Formation (unit Mc) common.

Esquatzel Member—One to two or more flows or flow units; sparsely phyric with irregularly distributed phenocrysts of plagioclase and clinopyroxene less than 5 mm in diameter; locally contains hyaloclastite; fine-grained; locally diktytaxitic; normal magnetic polarity (Choiniere and Swanson, 1979; Reidel and Fecht, 1981); no known feeder dikes.

Weissenfels Ridge Member—As many as four flows, not co-extensive, distinguished from each other in the field by size, character, and relative abundance of plagioclase and/or olivine phenocrysts; fine- to medium-grained; normal magnetic polarity; in the Clarkston and Orofino 1:100,000 quadrangles includes the basalts of Slippery Creek, Tenmile Creek, Lewiston Orchards, and Cloverland (Fig. 5); in the Pullman 1:100,000 quadrangle represented by the basalt of Lewiston Orchards; in the Rosalia 1:100,000 quadrangle represented by the basalt of Sprague Lake, which is probably correlative with the basalt of Lewiston Orchards; feeder dikes occur in the eastern part of the Clarkston 1:100,000 quadrangle and in the Orofino 1:100,000 quadrangle.

Asotin Member—Dense, sparsely olivine- and plagioclase-phyric flow; plagioclase phenocrysts less than 3 mm long, olivine phenocrysts less than 2 mm long; subophitic augite in coarser grained zones; includes associated sediments; commonly invasive into sediments; glassy, fine- to coarse-grained; locally ophitic and diktytaxitic; normal magnetic polarity (Camp, 1976; Choiniere and Swanson, 1979; Reidel and Fecht, 1981; Swanson and others, 1977, 1979a, 1980); no known feeder dike; locally mixed with Wilbur Creek Member to form Huntzinger flow, indicating nearly simultaneous eruption of the two members (Reidel and Fecht, 1987).

Wilbur Creek Member—Two or more flows; aphyric to sparsely plagioclase-phyric; sparse, large, locally skeletal plagioclase phenocrysts and scarce olivine microphenocrysts; fine- to coarse-grained to glassy; normal magnetic polarity (Choiniere and Swanson, 1979; Reidel and Fecht, 1981; Swanson and others, 1979a, 1980); no known feeder dike; locally mixed with Asotin Member to form Huntzinger flow, indicating nearly simultaneous eruption of the two members (Reidel and Fecht, 1987); consists of an upper subunit called the basalt of Lapwai, which occurs only in Idaho, and a lower subunit called the basalt of Wahluke (Reidel and Fecht, 1987).

Umatilla Member—Two or more flows; aphyric to sparse plagioclase phenocrysts as much as 0.7 cm across; glassy to very fine grained to fine grained, locally medium-grained; normal magnetic polarity (Rietman, 1966; Swanson and others, 1977, 1979a); consists of an upper subunit called the basalt of Sillusi and a lower subunit called the basalt of Umatilla; flows of the two subunits are known to physically mix in the Priest Rapids and Richland 1:100,000 quadrangles, forming one cooling unit (Reidel and Fecht, 1987); feeder dike for Sillusi flow occurs in the Grande Ronde River canyon, Clarkston 1:100,000 quadrangle; also includes the Bear Creek flow of Ross (1978, 1989) in the Clarkston 1:100,000 quadrangle.

Wanapum Basalt

Priest Rapids Member—Two or more flows in most places; aphyric, with rare but prominent plagioclase phenocrysts generally less than 5 mm long but rarely as much as 10 mm long; matrix of intergranular pyroxene, ilmenite blades, and some devitrified glass; local diabasic texture and pegmatoids in top flow; in the Walla Walla 1:100,000 quadrangle olivine phenocrysts 0.5–1 mm in diameter; fine- to coarse-grained, lower flows generally coarser grained than upper flow; locally finely diktytaxitic; reversed magnetic polarity (Rietman, 1966); major feeder dikes to the east in the Clearwater embayment (Camp, 1981); upper flow is informally named the basalt of Lolo and the lower flows the basalt of Rosalia.

Roza Member—One or two flows over wide areas; as many as six or seven flows, especially near vents; 0.5- to 1-cm plagioclase phenocrysts and glomerocrysts, commonly several hundred phenocrysts per square meter of flow surface; microphenocrysts of olivine and augite; fine- to coarse-grained; locally diktytaxitic; transitional to reversed magnetic polarity (Rietman, 1966; Choiniere and Swanson, 1979); feeder dikes in the Grande Ronde River and Asotin Creek canyons in the Clarkston 1:100,000 quadrangle, and extending through the Snake River canyon to the northwest as far as Winona in the northwest part of the Pullman 1:100,000 quadrangle; Big Butte and Little Butte in the Clarkston 1:100,000 quadrangle are two of the more southerly of many Roza vents; because of its large and nearly ubiquitous plagioclase phenocrysts and wide distribution, the member is a key marker unit across much of the Columbia Basin.

Frenchman Springs Member—Six or more flows; lower flow(s) generally more phyric than middle and upper flows; aphyric flows are fine grained, phyric flow(s) are fine to medium grained and sparsely to abundantly plagioclase phyric; many flows contain plagioclase glomerocrysts as much as 50 mm across; aphyric or nearly aphyric flows resemble the Grande Ronde Basalt; includes saprolite in places; subarkosic sedimentary rocks commonly occur at the base of the member; excursional to normal magnetic polarity (Rietman, 1966; Swanson and others, 1980; Swanson and Wright, 1983); feeder dikes occur in the Connell, Pullman, and Walla Walla 1:100,000 quadrangles.

Includes six informal units defined by Beeson and others (1985): basalt of Lyons Ferry; basalt of Sentinel Gap (Sentinel Gap flows and Union Gap flows of Bentley and others, 1988a, 1988b, 1993); basalt of Sand Hollow (Kelley Hollow flow and Sand Hollow flow of Bentley and others, 1988a, 1988b, 1993); basalt of Silver Falls; basalt of Ginkgo (Ginkgo flows of Bentley and others, 1988a, 1988b, 1993); and basalt of Palouse Falls.

Eckler Mountain Member—Three flow sequences: upper flow or flows (basalt of Shumaker Creek) fine-grained and aphyric; middle one to three flows (basalt of Dodge) very coarse grained, olivine-bearing, plagioclase-phyric, spheroidal- and yellow-weathering, commonly weathers to grus, much olivine altered to clay; lower flow (basalt of

Robinette Mountain) olivine-phyric, coarse-grained, diktytaxitic, distinguished from middle flows by lack of large plagioclase phenocrysts, diktytaxitic texture, and lack of grusy weathering; normal magnetic polarity (Choiniere and Swanson, 1979; Swanson and others, 1980); feeder dikes in the southern part of the Clarkston 1:100,000 quadrangle and in Oregon; saprolites and, in places, sedimentary interbeds above and below; coarse grain size, plagioclase phenocrysts, and spheroidal and yellow weathering make the basalt of Dodge an especially useful marker unit.

Reidel and others (1992, p. 5) suggest that the basalt of Shumaker Creek may actually lie above the basalt of Sentinel Gap, Frenchman Springs Member, and below the Roza Member.

Grande Ronde Basalt

N_2 Magnetostratigraphic unit—Upper flows of normal magnetic polarity. Includes the informal Sentinel Bluffs, Slack Canyon, Fields Spring, Winter Water, Umtanum, Ortley, and Armstrong Canyon units of Reidel and others (1989).

R_2 Magnetostratigraphic unit—Upper flows of reversed magnetic polarity. Includes the informal Meyer Ridge, Grouse Creek, Wapshilla Ridge, and Mt. Horrible units of Reidel and others (1989).

N_1 Magnetostratigraphic unit—Lower flows of normal magnetic polarity. Includes the informal China Creek and Downey Gulch units of Reidel and others (1989).

R_1 Magnetostratigraphic unit—Lower flows of reversed magnetic polarity. Includes the informal Center Creek, Rogersburg, and Buckhorn Springs units of Reidel and others (1989) and Teepee Butte Member (Reidel and Tolan, 1992).

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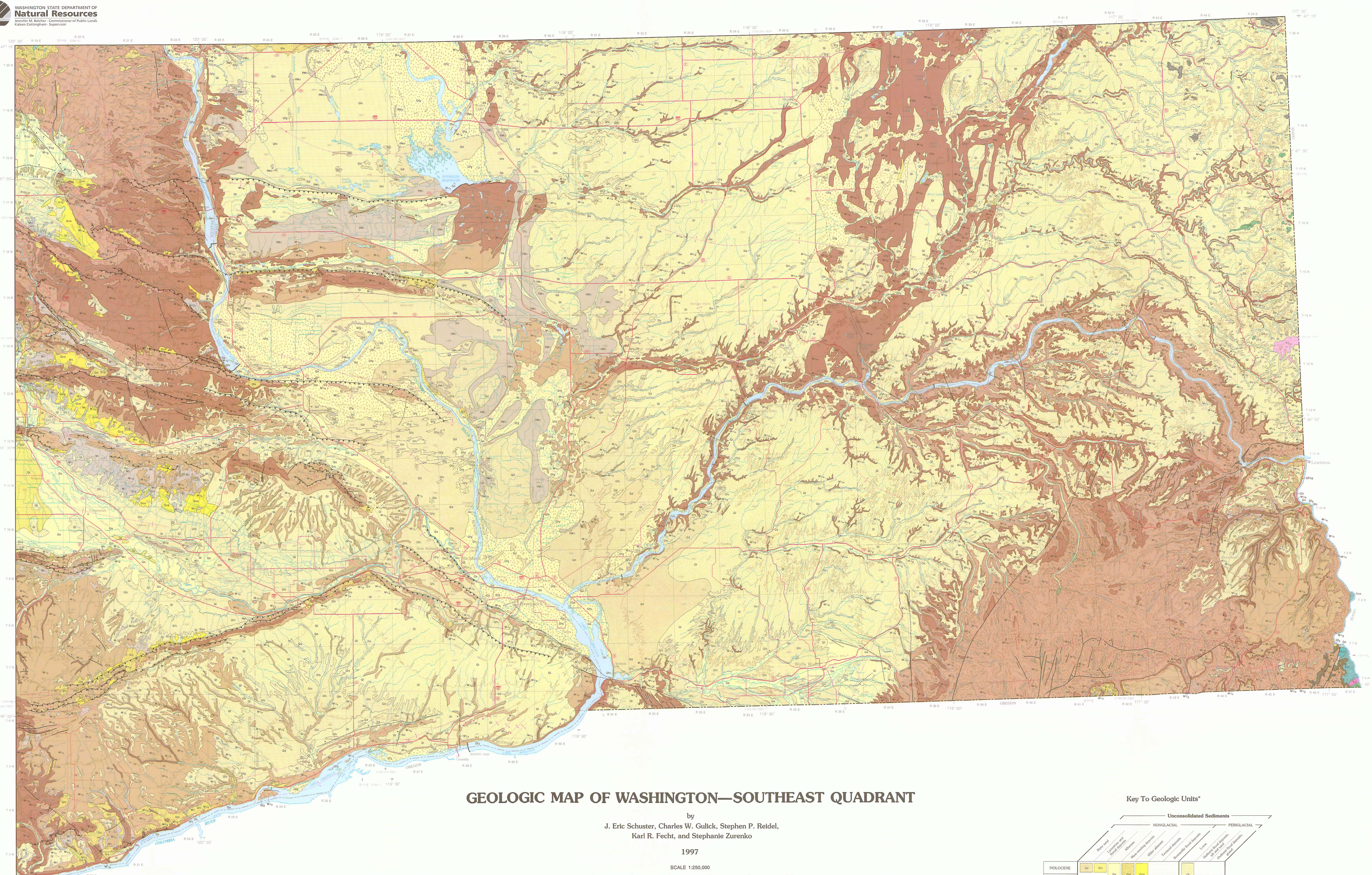
WASHINGTON STATE DEPARTMENT OF
Natural Resources
Jennifer M. Belcher - Commissioner of Public Lands
Kaleen Cottingham - Supervisor

Geologic Map of Washington—Southeast Quadrant
Washington Division of Geology and Earth Resources
Geologic Map GM-45
Sheet 1



Base compiled from U.S. Geological Survey 1:100,000-scale topographic quadrangles dated 1975-1984
Projection and 10,000 meter grid, zone 11, Universal Transverse Mercator
250,000-foot grid ticks based on Washington coordinate system, south zone
1927 North American Datum

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

Geologic Map GM-45
Washington Division of Geology and Earth Resources
Raymond Lasmanis, State Geologist

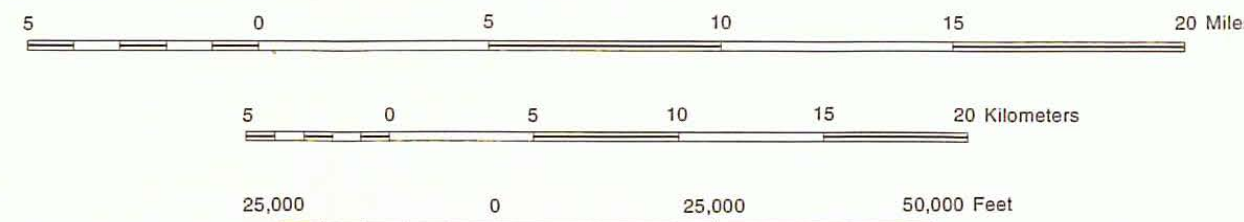
J. Eric Schuster, Assistant State Geologist and State Geologic Map Project Manager

GEOLOGIC MAP OF WASHINGTON—SOUTHEAST QUADRANT

by
J. Eric Schuster, Charles W. Gulick, Stephen P. Reidel,
Karl R. Fecht, and Stephanie Zurenko

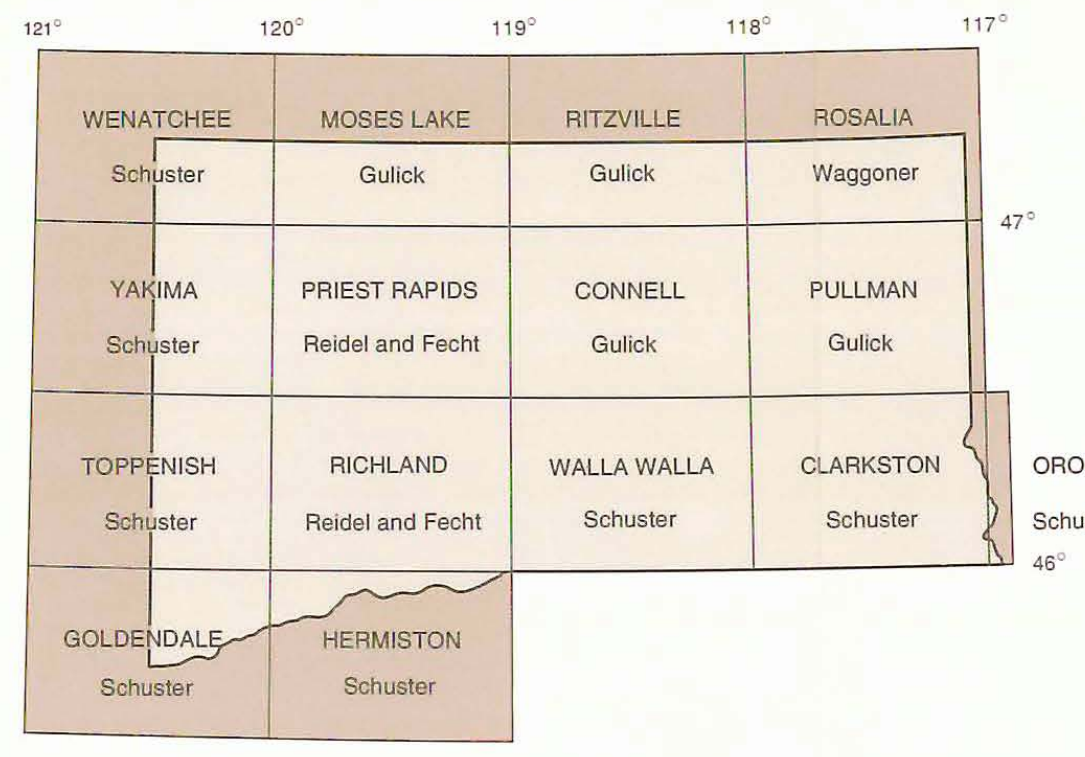
1997

SCALE 1:250,000

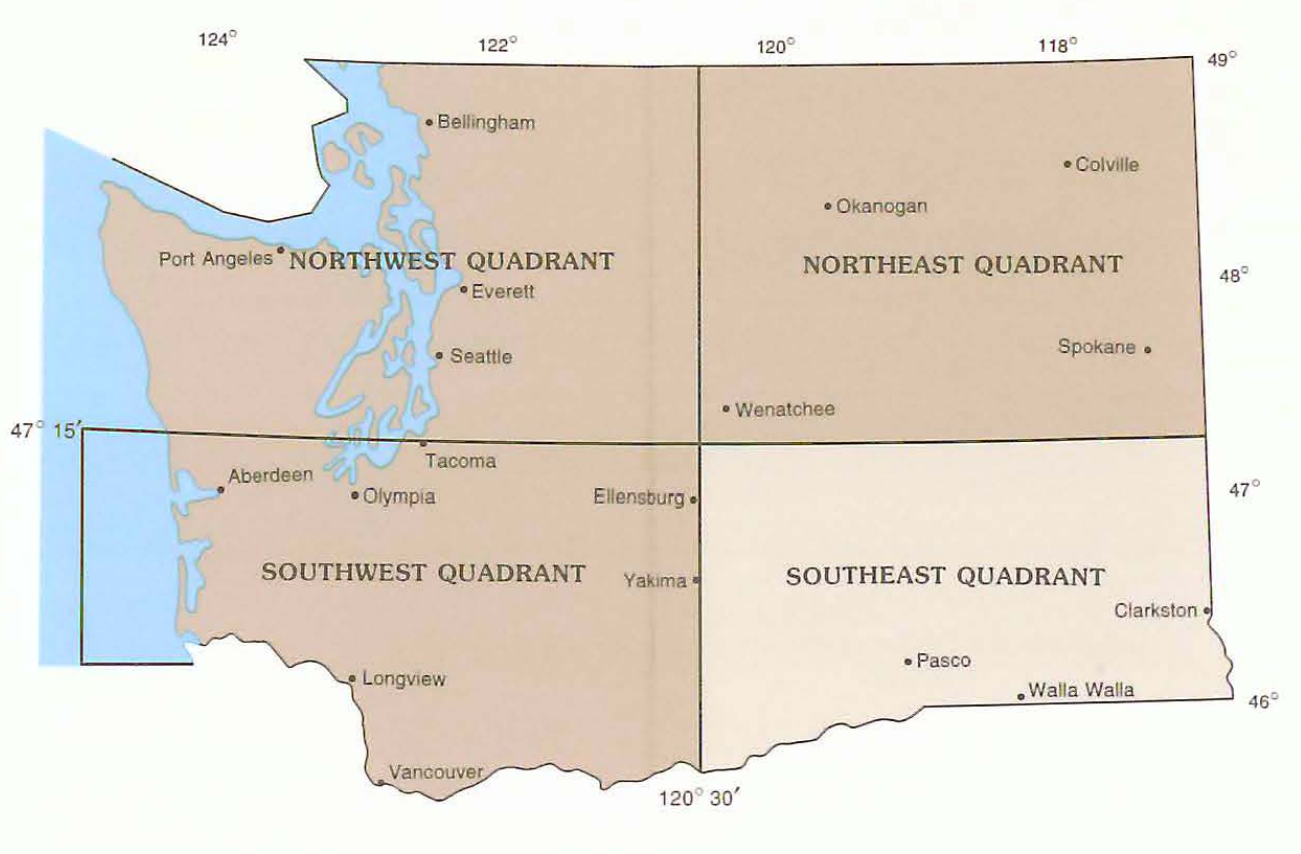


Contour Interval 200 Meters
National Geodetic Vertical Datum of 1929

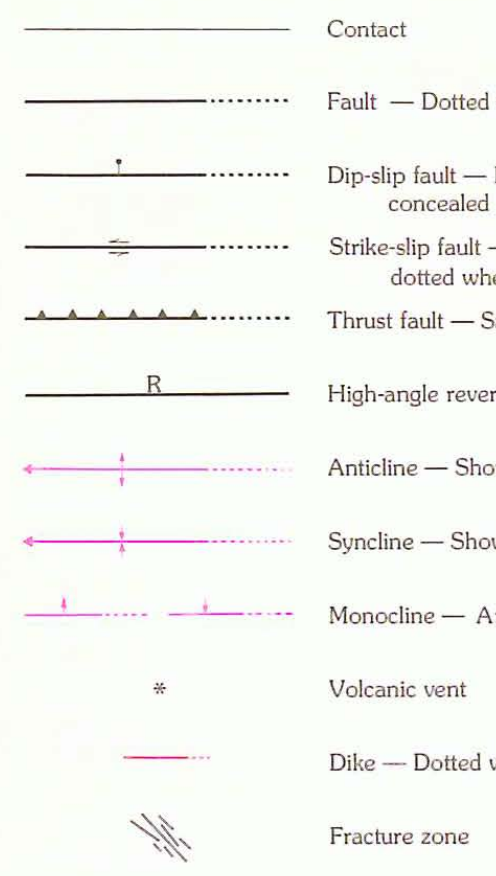
Compilation Responsibility by 1:100,000-scale Quadrangle



Quadrant Location

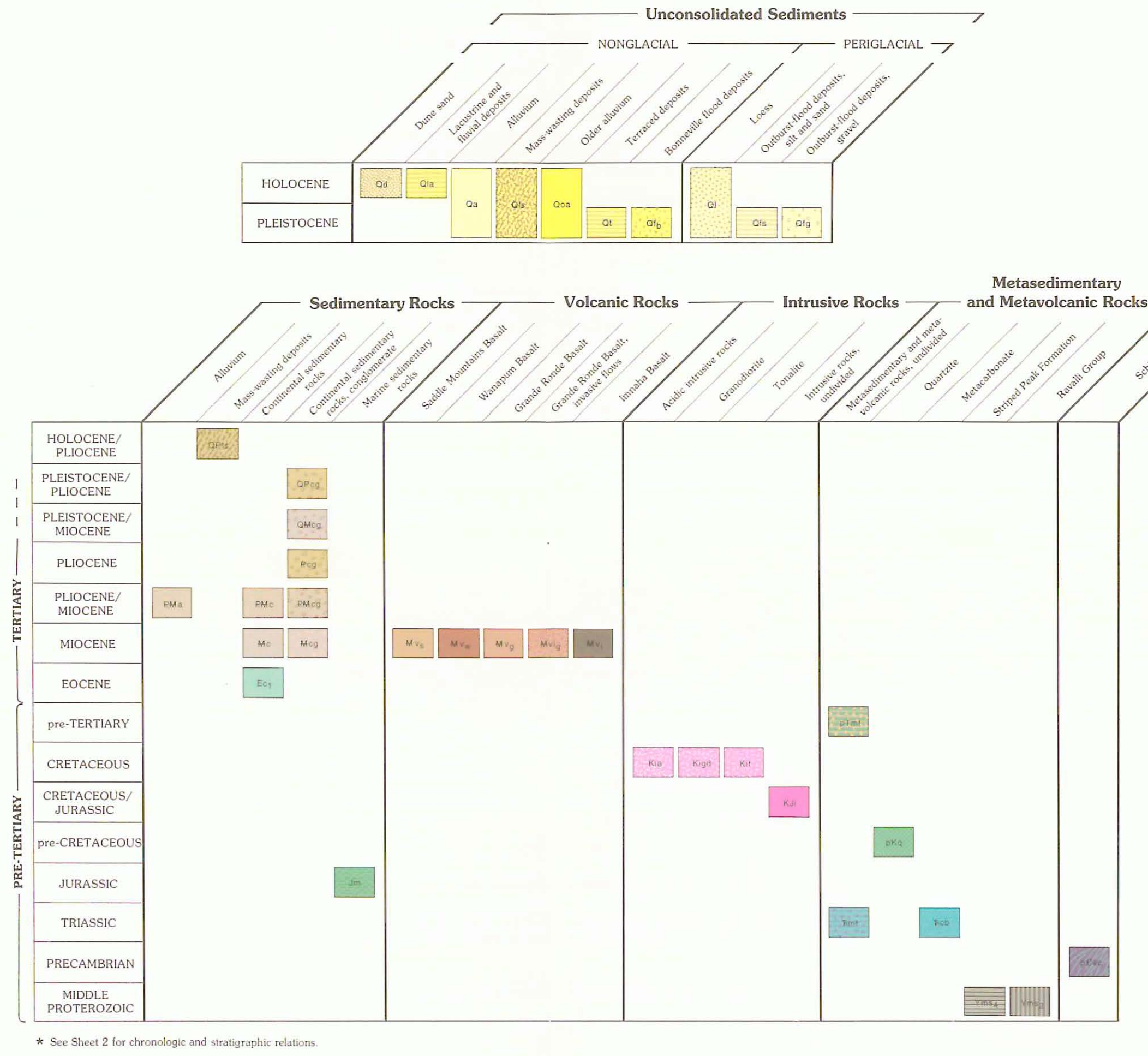


Geologic Symbols



Contact
Fault — Dotted where concealed
Dip-slip fault — Bar and ball on downthrown side; dotted where concealed
Strike-slip fault — Arrows show relative horizontal movement; dotted where concealed
Thrust fault — Sawteeth on upper plate; dotted where concealed
High-angle reverse fault — R on upthrown block
Anticline — Showing direction of plunge; dotted where concealed
Syncline — Showing direction of plunge; dotted where concealed
Monocline — Arrow on steeper limb; dotted where concealed
Volcanic vent
Dike — Dotted where concealed
Fracture zone

Key To Geologic Units*



* See Sheet 2 for chronologic and stratigraphic relations.

DESCRIPTIONS OF MAP UNITS

UNCONSOLIDATED SEDIMENTS

Quaternary Sediments

Nonglacial Deposits

Qd **Dune sand**—Eolian medium to fine sand and silt; composed of quartz, basalt, and/or feldspar grains; volcanic ash, commonly Mazama tephra, present locally; includes both active and stabilized dunes.

Qla **Lacustrine and fluvial deposits**—Clay, silt, and sand in interior drainage basins.

Qa **Alluvium**—Clay, silt, sand, and gravel deposited in streambeds and fans; varied thickness and sorting; includes terrace and organic deposits in places; commonly includes reworked loess, outburst flood deposits (units Qfs, Qfg), Mazama tephra, Ellensburg Formation (units Mc,Mcg) and Ringold Formation (units ₽Mc, ₽Mcg) sediments, and rounded to angular basalt clasts; older streambed deposits capped by pedogenic carbonates (stages I to IV of Machette, 1985) or silcrete; fan deposits in places overlain by and interstratified with loess and slopewash, little or no caliche development in fan deposits, fans generally cone-shaped with surface only moderately dissected; streambed deposits along rivers whose courses extend beyond the area covered by the Columbia River Basalt Group include pebbles and cobbles of quartzitic, granitic, metamorphic, and volcaniclastic rocks; normal to reversed magnetic polarity (Baker and others, 1991, p. 233).

Qls **Mass-wasting deposits**—Landslide and talus deposits composed of clay, silt, sand, and rounded to angular gravel- to boulder-size clasts; landslide surfaces commonly hummocky and, in some areas, blanketed with loess; landslide deposits chaotic, unstratified, and poorly sorted; clasts in talus primarily basaltic in composition; talus deposits on older, inactive slopes commonly cemented with pedogenic carbonates; includes colluvium in places.

Qoa **Older alluvium**—Semiconsolidated sand and gravel deposited in fans; clasts primarily basalt cemented by iron-stained clay; surface commonly dissected and capped by a well-developed caliche layer.

Qt **Terraced deposits**—Alluvial deposits of silt, sand, and gravel; locally includes lacustrine, paludal, and eolian deposits; clasts of diverse compositions and slightly to moderately weathered; poorly indurated; occurs above modern flood plains.

Qf_b **Bonneville flood deposits**—Gravel and sandy gravel; basalt clasts more abundant than clasts of granitic rocks and greenschist-facies volcaniclastic rocks; contains tephra clasts of pebble and cobble size and interbedded silt lenses; poorly sorted; moderately bedded; deposited as a result of rapid draining of Lake Bonneville; forms benches along the main stem of the Snake River, commonly in the mouths of tributary canyons; underlies Missoula flood deposits (unit Qfs).

Periglacial Deposits

Ql **Loess**—Eolian silt and fine sand; locally includes clay, multiple caliche (pedogenic carbonate, petrocalcic) horizons (stages I to IV of Machette, 1985), paleosols, tephra beds, silcrete, and cambic horizons; predominantly composed of angular quartz grains with lesser amounts of feldspar, mica, and hornblende; in its upper parts the loess displays weakly developed soil profiles and lacks petrocalcic horizons; pale orange, gray-tan, light-brown, tan, yellowish brown, brown, buff, or reddish yellow; massive; typical geomorphic expression is a complex of dunes; dune formation by southwesterly winds is indicated by long, gentle southwest sides and steep northeast sides, by strong northeast alignment of dune long axes, and by uniformly decreasing grain size to the northeast; thickness as much as 75 m near St. John (Rosalia 1:100,000 quadrangle) and Wilcox (Pullman 1:100,000 quadrangle) (Ringe, 1970); Ql/Qfs contact placed arbitrarily at about 900 ft (274 m) elevation in the central and south-central parts of the Walla Walla 1:100,000 quadrangle.

Includes the Palouse Formation.

Qfs **Outburst flood deposits, silt and sand**—Lacustrine silt and fine sand and fluvial fine to coarse sand; predominantly quartz and feldspar, with basalt grains in coarser sections; discrete tephra layers common; locally contains clastic dikes; stringers of coarse sand and gravel, small-scale cross-bedding, ice-rafted diamicton, and ice-melt structures present locally; locally contains interbedded alluvium, colluvium, and pedogenic horizons; rhythmically bedded; sand-dominated facies typically planar laminated and includes sporadic channel fill sequences; silt-dominated facies planar laminated and ripple cross-laminated, commonly displaying normal graded rhythmites; deposited by relatively low energy slack waters of outburst floods from glacial Lake Missoula and other ice-margin lakes; maximum thickness is more than 20 m in the south-central part of the Priest Rapids 1:100,000 quadrangle on a glacial outburst flood bar; unit is widely distributed in the western part of the map area, particularly in coulees and major river courses at elevations below 1,200 ft (366 m); generally not extensive above about 900 ft (274 m); Ql/Qfs contact placed arbitrarily at about 900 ft (274 m) elevation in the central and south-central parts of the Walla Walla 1:100,000 quadrangle.

Includes flood deposits of glacial Lake Missoula (Bretz and others, 1956; Baker and Bunker, 1985), Touchet Beds, and part of the Hanford formation (Carson and others, 1987).

Qfg **Outburst flood deposits, gravel**—Fluvial gravel; in sidestream facies clasts dominantly basalt with subordinate Ringold Formation sediments and caliche (Grolier and Bingham, 1971); in mainstream facies also contains clasts of granite, quartzite, diorite, volcanic porphyries, and metamorphic rocks; mainstream facies mostly distributed along the present and (or) former courses of the Columbia, Snake, and Yakima Rivers; locally includes poorly laminated and massive silt and sand and tephra layers; deposited by outburst floods from glacial Lake Missoula and other ice-margin lakes; grain size ranges from sand to boulders, size generally decreasing away from major scabland outburst flood channels; clasts rounded to angular; poorly sorted; generally matrix-poor, and matrix, where present, composed of basalt, quartz, and feldspar sand to granule grains; displays numerous bedding forms including massive, foreset, large-scale cross-bedded and plane-bedded channel and bar deposits; generally less than 15 m thick; unit is widespread along coulees and major river courses; locally overlain by loess.

Includes Pasco gravels (Carson and others, 1987; Myers, Price, and others, 1979) and part of the Hanford formation (Carson and others, 1987).

SEDIMENTARY ROCKS AND DEPOSITS

Quaternary–Pliocene Sedimentary Deposits

Q₽ls **Mass-wasting deposits**—Blocks of Columbia River Basalt Group rocks and younger sediments that have slid on sedimentary interbeds; occurs in canyons south of Clarkston.

Q₽cg **Continental sedimentary rocks, conglomerate**—Fluvial deposits; rounded clasts include quartzite, diorite, volcanic porphyries, and basalt; micaceous quartzo-feldspathic sand matrix; includes quartzo-feldspathic sand facies and silty overbank facies; lithologies indicate deposition by the Columbia and Yakima Rivers; unconsolidated to compact to weakly cemented; as much as 25 m thick.

Quaternary–Miocene Sedimentary Deposits

QMcg **Continental sedimentary rocks, conglomerate**—Pebble, cobble, and boulder gravel composed of approximately 30 percent basalt and 70 percent red and green metavolcaniclastic, porphyritic, and metamorphic (dominantly quartzite) rocks, and lesser granitic rocks in a fine to coarse sand matrix that is, in places, rich in basalt grains; unconsolidated; includes some sand beds and lenses; differentiated from Missoula flood deposits (units Qfs and Qfg) and Bonneville flood deposits (unit Qf_b) by composition of clasts, which are overwhelmingly basaltic (95+%) in gravels of the Missoula flood deposits and predominantly basaltic (50%) in the Bonneville flood deposits; may be derived from a flooding event(s) associated with the ancestral Salmon River (Webster and others, 1982); clasts angular to well-rounded; some deeply weathered basaltic and granitic clasts; as much as 60 m thick; forms terraces, lateral bars, and point bars in the present Snake River canyon and terraces and point bars in the Grande Ronde River valley and fills abandoned Snake River channels; in most places overlain by thin to thick veneers of slackwater Missoula flood sediments (unit Qfs); referred to as older Snake River gravels by Rigby and others (1979).

Includes unnamed gravel 3, unnamed gravel 2, unnamed gravel 1, Clarkston gravel, Clearwater gravel, Clarkston Heights gravel, and Asotin Creek gravel of Hooper and others (1985) and the undifferentiated unnamed gravels and Grande Ronde River gravel of Reidel and others (1992).

Pliocene Sedimentary Deposits

₽cg **Continental sedimentary rocks, conglomerate**—Coarse sand and gravel; moderately to highly weathered and poorly indurated stream terrace deposits; includes a mainstream facies that is associated with the main stem of the Yakima River, contains rounded to subrounded clasts of durable silicic to intermediate volcanic rocks, and occurs as high fluvial terraces, now incised as deeply as 100 m by small creek valleys, and a sidestream facies that is related to tributary streams of the Yakima River and that contains mostly subangular Grande Ronde Basalt clasts and occurs as high fluvial terraces (Waitt, 1979, p. 9-10); contact with underlying Ellensburg Formation units (Mcg, Mc) commonly unconformable near ridges, conformable in basins.

Consists of the Thorp Gravel.

Pliocene–Miocene Sedimentary Rocks and Deposits

Ringold Formation

The Ringold Formation consists of fine and coarse, semi-indurated, fluvial and lacustrine deposits in and near the Pasco Basin (Newcomb and others, 1972; Fecht and others, 1987; Lindsey, 1991). Lithologies indicate deposition by ancestral Columbia and Snake Rivers. The formation is as thick as 185 m in the deepest part of the Cold Creek syncline at the Hanford Site in the Priest Rapids and Richland 1:100,000 quadrangles (Lindsey, 1991). The Ringold Formation was named by Merriam and Buwalda (1917) for strata in the White Bluffs on the Priest Rapids 1:100,000 quadrangle. Two facies are shown on the map: finer deposits (unit ₽Mc) and coarser sediments, chiefly conglomerate (unit ₽Mcg).

₽Mc **Continental sedimentary rocks**—Interbedded fluvial and lacustrine sand, silt, and clay beds with local pebble lenses and stringers; sand chiefly quartz and feldspar, locally micaceous; contains diatomite beds, tephra beds, and fossils; commonly capped by pedogenic carbonate or silcrete; white, gray, green, reddish-brown, red, or tan; silty clay units horizontally laminated and generally lacking current-generated sedimentary structures; silt and sand units display horizontal and ripple bedding and cross-bedding.

Consists of the finer facies of the Ringold Formation.

₽Mcg **Continental sedimentary rocks, conglomerate**—Varicolored pebble to cobble conglomerate with sand matrix; clasts well-rounded and chiefly composed of quartzite, granite, basalt, metamorphic rocks, and porphyritic volcanic rocks; includes lenses of coarse to medium quartzo-feldspathic sand that are cross-bedded or foreset bedded in places; generally well sorted, massively bedded; locally imbricated; commonly uncemented, but in places moderately to poorly indurated with silica, iron oxide, and calcite.

Consists of the conglomeratic facies of the Ringold Formation.

₽Ma **Alluvium**—Pebble to cobble fanglomerate; subangular to angular fragments of basalt and Ellensburg sediments (units Mc, Mcg) ranging in size from cobble to medium sand; includes fluvial, mass-wasting, and landslide deposits; variously indurated with pedogenic carbonate; generally poorly bedded; exposed along the northern flank of the Saddle Mountains in the Smyrna Bench area of the Priest Rapids 1:100,000 quadrangle.

Miocene Sedimentary Rocks

Mc **Continental sedimentary rocks**—Fluvial clay, silt, sand, and pebble beds; local gravel and cobble lenses; local diatomite beds and lahars; includes lacustrine deposits; includes lignite beds in Clarkston and Richland 1:100,000 quadrangles; silts and sands locally tuffaceous and clays locally bentonitic; sands generally composed of quartz and feldspar with minor mica and, in the Clarkston 1:100,000 quadrangle, hornblende; some sands rich in basalt grains; paleosols common in fine-grained units; clasts composed of basalt, quartzite, diorite, and volcanic porphyries (Priest Rapids and Richland 1:100,000 quadrangles), basalt, red and green volcaniclastic rocks, quartzite, silicic igneous rocks, and metamorphic rocks (Clarkston and Orofino 1:100,000 quadrangles), basalt, andesite, and pumiceous rocks (Goldendale, Hermiston, Toppenish, and Yakima 1:100,000 quadrangles); fragmentary plant fossils common; in the Priest Rapids and Richland 1:100,000 quadrangles gravels form trains and represent ancestral courses of Columbia and Clearwater–Salmon Rivers (Fecht and others, 1987); white, off-white, gray, cream, light-yellow, reddish-brown; orange oxide staining in places; weakly to moderately indurated; overlies the Saddle Mountains Basalt and also occurs as interbeds between various flows of the Columbia River Basalt Group; poorly exposed except in roadcuts; generally erodes to gentler slopes than the basalts, prone to landslides (units Qls and Q₽ls) that involve both interbeds and basalt flows; in the Saddle Mountains Basalt interbeds are present between more flows and are thicker than in the Wanapum or Grande Ronde Basalts; individual interbeds as much as 50 m thick in the Pasco Basin (Priest Rapids and Richland 1:100,000 quadrangles) and Troy Basin (Clarkston 1:100,000 quadrangle); interbeds record subsidence and formation of structural basins (Lewiston, Troy, and Pasco basins); contacts conformable except where lava flows are invasive into unit.

Includes at least part of the Latah Formation (Griggs, 1976, p. 29-32) and the finer grained facies of the Ellensburg Formation. Smith (1988) includes, from youngest to oldest, the Rattlesnake Ridge Member, Selah Member, Mabton member (informal), Squaw Creek Member, and Vantage Member in the Ellensburg Formation; Campbell and Reidel (1991) add the informal Levey interbed (above the Rattlesnake Ridge Member), Cold Creek interbed (below the Selah Member), Quincy interbed (above the Squaw Creek Member), and other, unnamed, interbeds; Bingham and Grolier (1966) included the Beverly Member, defined as sedimentary deposits below the top of the uppermost Saddle Mountains flow and above the Priest Rapids Member.

Mcg **Continental sedimentary rocks, conglomerate**—Fluvial gravel, cobbles, silt, and sand; dominated by well-rounded quartzite clasts, with significant numbers of granitic, gneissic, metavolcanic, basaltic, and andesitic clasts; light yellow-tan to reddish orange; weakly to strongly indurated; deposited by the ancestral Columbia and Salmon–Clearwater Rivers.

Includes the coarser grained facies of the Ellensburg Formation (including the conglomerate of Snipes Mountain of Swanson and others, 1979a) and the sediments of Lime Hill of Reidel and others (1992).

Eocene Sedimentary Rocks

Ec_1 **Continental sedimentary rocks**—Micaceous feldspathic to lithofeldspathic sandstone; includes lesser amounts of carbonaceous siltstone and shale, pebbly sandstone, light-colored micaceous sandstone, and conglomerate; dark-gray, weathering to tan; poorly sorted; thin to very thick bedded; locally cross-bedded; exposed in the northwest corner of the map area.

Consists of the Swauk Formation.

Jurassic Sedimentary Rocks

Jm **Marine sedimentary rocks**—Black shale and argillite, brown sandstone, pebble conglomerate, and rare, thin limestone beds; thickness estimated at about 600 m; exposure area less than 1 mi^2 in the southeastern corner of the map area; bounded by angular unconformities.

Consists of Coon Hollow Formation (Morrison, 1964).

VOLCANIC ROCKS

Miocene Volcanic Rocks

Columbia River Basalt Group

Extensive tholeiitic basalt flows of the Columbia River Basalt Group underlie almost the entire map area. In Washington the Columbia River Basalt Group is composed of four formations. From youngest to oldest they are the Saddle Mountains Basalt, the Wanapum Basalt, the Grande Ronde Basalt, and the Imnaha Basalt. All four formations crop out in the map area. Formal and informal stratigraphic units that are currently recognized in the Columbia River Basalt Group are shown in Figure 5 of the pamphlet.

Each formation consists of numerous flows. These flows erupted from north-northwest-trending fissure systems in southeastern Washington and adjacent Idaho and Oregon during the early, middle, and late Miocene, from about 17.3 Ma to about 6 Ma (Baksi, 1989; Tolan and others, 1989; McKee and others, 1977; Reidel and Fecht, 1987).

Individual flow thickness is quite varied and generally ranges from a few meters to more than 100 m. Thickness of the Columbia River Basalt Group reaches more than 3.2 km in the Pasco Basin (Reidel and others, 1989). Average thickness, calculated from the volume (174,300 km^3) and original surface area (163,700 km^2) given by Tolan and others (1989), may be about 1.06 km (3,500 ft).

In the following descriptions details of cooling joints and other intraflow structures, interbed materials, fresh and weathered colors, weathering characteristics, thickness, and chemistry are omitted because they are quite similar from unit to unit. The flows are jointed, and the joints are typically blocky or columnar, so that most flows have colonnades and some have entablatures; most are black or gray on fresh surfaces, most weather from gray to some shade of red or brown; rubbly or pillowed bases are common, as are vesicular, scoriaceous, and rubbly flow tops. Chemistry, on the other hand, is extremely important in distinguishing one unit from others, but a satisfactory treatment of the subject is beyond the scope of this report.

Field mappers use a combination of stratigraphic relations, megascopic physical characteristics, magnetic polarity, and geochemistry to assign a flow to its formation and member. Usually a preliminary assignment is made in the field and later confirmed (or called into question) by chemical analyses.

Mv_s **Saddle Mountains Basalt**—Basalt flows; predominantly fine- to medium-grained, with some coarse-grained and glassy parts; most phenocrysts consisting of plagioclase, and lesser amounts of olivine phenocrysts and microphenocrysts; lower members and uppermost member normally magnetized, with two of the upper units reversely magnetized; feeder dikes, where known, in west-central Walla Walla and southeastern Priest Rapids 1:100,000 quadrangles (an upper member) or in eastern and (or) southeastern Clarkston 1:100,000 quadrangle (two of the lower members); commonly includes undivided sedimentary interbeds of the Ellensburg Formation (unit Mc) and undivided flows invasive into sedimentary interbeds. See the pamphlet for additional descriptive information.

Consists of the Lower Monumental, Buford, Elephant Mountain, Pomona, Esquatzel, Weissenfels Ridge, Asotin, Wilbur Creek, and Umatilla Members.

Mv_w **Wanapum Basalt**—Basalt flows; fine- to coarse-grained; microphenocrysts, phenocrysts, and glomerocrysts consisting variously of plagioclase, olivine, or, rarely, augite; lower flows of normal magnetic polarity, upper flows reversely magnetized, and middle flows excursional or transitional; feeder dikes in the Clarkston, Connell, Pullman, and Walla Walla 1:100,000 quadrangles and in western Idaho and northeastern Oregon; commonly includes undivided sedimentary interbeds of the Ellensburg Formation (unit Mc) and undivided flows invasive into sedimentary interbeds. See the pamphlet for additional descriptive information.

Consists of the Priest Rapids, Roza, Frenchman Springs, and Eckler Mountain Members.

Mv_g **Grande Ronde Basalt**—At least 120 flows; makes up 87 percent of the volume of the Columbia River Basalt Group; groundmass contains plagioclase, augite, and pigeonite; plagioclase phenocrysts are sparse, microphenocrysts of orthopyroxene, pigeonite, and olivine are rare; altered glass locally constitutes as much as 75 percent of a flow but is typically less than 50 percent; generally aphyric and fine-grained; divided into 17 informal units on the basis of magnetic polarity, stratigraphic position, physical characteristics, and geochemistry (Reidel and others, 1989); feeder dikes in the Clarkston and Pullman 1:100,000 quadrangles; saprolite or sedimentary interbed commonly occurs at the top; type locality in the canyon of the Grande Ronde River north of the mouth of Joseph Creek (secs. 21-23, T. 7 N., R. 46 E.) in the Clarkston 1:100,000 quadrangle (Camp and others, 1978; Reidel, 1983; Reidel and others, 1992); divided into four magnetostratigraphic units, from oldest to youngest, R_1, N_1, R_2, N_2 (where R is reversed and N is normal polarity).

Mvi_g **Grande Ronde Basalt, invasive**—Flows invasive into sedimentary interbeds of the Ellensburg Formation and Latah Formation (unit Mc) or unnamed units; occurs fairly commonly, especially toward the edges of the Grande Ronde Basalt, but shown only in the Wenatchee 1:100,000 quadrangle.

Mv_i **Imnaha Basalt**—Multiple flows; coarsely plagioclase-phyric (phenocrysts 5–25 mm long); medium- to coarse-grained; weathers to grus; less resistant to weathering than overlying Grande Ronde flows so outcrops are more subdued; normal magnetic polarity in the map area except for the top few flows, which are of transitional polarity (Hooper and others, 1979; Reidel and others, 1992; Swanson and others, 1980).

INTRUSIVE ROCKS

Cretaceous Intrusive Rocks

Kia **Acidic intrusive rocks**—Granodiorite and tonalite plutons; light-gray and yellow-gray; typically foliated or gneissose; crops out near the eastern edge of the map area as isolated steptoes that may represent stocks of the Idaho batholith.

Kigd **Granodiorite**—Biotite granodiorite or quartz monzonite; zoned potassium feldspar crystals reminiscent of Rapakivi texture and minor hornblende; indistinct biotite bands, elongate feldspar crystals, and sheet-like, sharply bounded, concordant, hornblende-bearing, mafic segregations that define a foliation and impart a gneissic appearance to the rock; cut by dikes of pegmatite; contains feldspathic segregations immediately adjacent to dark-green slickensided surfaces; light-gray; coarse-grained; foliated; exposed on both sides of the Snake River at Granite Point (secs. 13, 14, 23, and 24, T. 13 N., R. 43 E.) in the Pullman 1:100,000 quadrangle; the contact of the Granite Point bedrock with overlying basalt generally obscured by talus (Hooper and Rosenberg, 1970), but newer railroad cuts expose an unconformity at which basalt overlies a thin paleosol on the granodiorite (G. D. Webster, Wash. State Univ., written commun., 1994).

Consists of the granodiorite of Granite Point (Hooper and Rosenberg, 1970).

Kit **Tonalite**—Biotite tonalite that consists of quartz, unzoned andesine, muscovite, and biotite (partially altered to chlorite) with accessory apatite, zircon, and carbonate; inequigranular texture; subordinate hornblende-biotite-tonalite schlieren; cut by dikes of various compositions; at Bald Butte, in the southeastern part of the Pullman 1:100,000 quadrangle, this unit has a crystallization order of hornblende-biotite-tonalite (first), biotite-tonalite, aplite dikes, quartz-gabbro dikes, pegmatite dikes, and quartz veins (last) (Hoffman, 1932); weak foliation dips steeply and trends approximately east or parallel to the ridge of Bald Butte.

Cretaceous–Jurassic Intrusive Rocks

KJi **Intrusive rocks, undivided**—Granodiorite, quartz diorite, and gabbro; unmetamorphosed or slightly metamorphosed; exposed in a small area in the extreme southeast corner of the map area.

METASEDIMENTARY AND METAVOLCANIC ROCKS

Pre-Tertiary Metasedimentary and Metavolcanic Rocks

pTmt **Metasedimentary and metavolcanic rocks, undivided**—Argillite, greenstone, quartzite, quartzitic metasedimentary rocks, amphibolitic schist, phyllite, metagabbro, and plagiogranite; sheared, faulted, and locally mineralized; crops out in four small areas in the Tucannon River drainage (T. 8 and 9 N., R. 41 E.) and in one area in the headwaters of Menatchee Creek (T. 7 N., R. 43 E.) in the Clarkston 1:100,000 quadrangle; base not exposed.

Pre-Cretaceous Metasedimentary Rocks

pKq **Quartzite**—Orthoquartzite; nearly pure quartz with magnetite-cored goethite grains, sparse small crystals of feldspar, muscovite, biotite, zircon, and rutile and rare tourmaline grains; locally includes minor schist; white to creamy white, light-gray to bluish- and purplish-gray, pink and reddish-brown; recrystallized to coarse granoblastic texture; relict cross-lamination; massive bedding, inconspicuous bedding planes; dense and fresh to friable; occurs in the higher hills (steptoes) in the northeastern part of the Pullman 1:100,000 quadrangle, where, at Kamiak Butte, a 261-m-thick section consists of arenaceous orthoquartzite (Webster and Nuñez, 1982, p. 53), as well as intercalated metaconglomeratic quartzite chiefly composed of half-inch-diameter, reddish-brown to white, subangular to well-rounded quartzite pebbles that, excepting grain size, resemble the matrix; orthoquartzite on Kamiak Butte dips south or southeast, and beds appear truncated on the steeper north side by faulting and well developed, commonly iron-stained joints, and at least five, smaller, northwest-trending faults offset the main ridge slightly; Savage (1973) reported cataclastic textures in the orthoquartzite that include undulatory extinction, deformed twin lamellae, and differentially sheared quartz with sutured boundaries.

Triassic Metasedimentary and Metavolcanic Rocks

Ŧcb **Metacarbonate**—Massive limestone and dolomite, some carbonaceous beds; includes coarse reef debris; exposed in the southeast corner of the map area; overlies the Doyle Creek Formation (unit Ŧmt), probably unconformably; overlain with angular unconformity by Coon Hollow Formation (unit Jm).

Consists of the Martin Bridge Limestone (Hamilton, 1963).

Ŧmt **Metasedimentary and metavolcanic rocks, undivided**—Two formations of the Seven Devils Group (Vallier, 1977):

Doyle Creek Formation—Maroon and green volcanic breccia, metabasalt, keratophyre, and volcanic sandstone interbedded with shale, tuff, conglomerate, and thin limestone beds; exposed in the southeast corner of the map area; probably conformable with underlying Wild Sheep Creek Formation; probably unconformable with overlying Martin Bridge Limestone (unit Ŧcb); the uppermost formation of the Seven Devils Group.

Wild Sheep Creek Formation—Metabasalt, pillow basalt, and pillow breccia with coarse volcanic breccia and volcanic sandstone overlain by argillite, volcaniclastic rocks, limestone, and metabasalt; metabasalt abundant in the map area; exposed in an approximately 3-mi^2 area in the southeast corner of the map area and in a 1-mi^2 area a few miles to the north along the Snake River; unconformably overlies the Early Permian Hunsaker Creek Formation outside the map area; conformably overlain by the Doyle Creek Formation.

Consists of the Doyle Creek and the Wild Sheep Creek Formations (Vallier, 1977).

Precambrian Metasedimentary Rocks

Missoula Group, Striped Peak Formation—Predominantly gray, green, and red siltite with subordinate light-colored quartzite and minor pink dolomite lenses and (or) beds; dark argillite partings common; 150-m-thick zone of gray to reddish-gray, medium- to coarse-grained feldspathic quartzite commonly present about 300 m below the top of the formation; most outcrops characterized by a micaceous sheen on bedding surfaces; mud cracks, ripple marks, and mud-chip breccia common in red and green rocks; locally punky and bleached; occurs in the northeast corner of the map area.

Ravalli Group, Revett and Burke Formations, undivided—Mostly light-gray to greenish-gray, commonly micaceous siltite and white, commonly feldspathic quartzite; quartzite generally vitreous, locally containing rounded grains of opaque, bluish quartz; occurs in the northeast corner of the map area; Webster and Nuñez (1982, p. 49) described rocks on Steptoe Butte (T. 18 N., R. 44 E.) as reddish-brown, tan, and white, muscovite-bearing quartzite of the Revett Formation, the exposure south of Rosalia as "Quartzite, schist and gneiss of the Prichard Formation", and the exposures in sec. 6, T. 19 N., R. 44 E., as part of the Prichard Formation or the Striped Peak Formation; however, in this report, the rocks are shown as Revett-Burke, undivided, after Griggs (1973).

METAMORPHIC ROCKS

Precambrian Metamorphic Rocks

Schist—Chiefly fine- to medium-grained garnet-biotite-muscovite-quartz schist and coarse-grained phyllite with subordinate medium- to fine-grained micaceous quartzite and micaceous siltite; schist is shades of gray or brown on fresh surfaces; disseminated iron sulfide common throughout the unit; weathering surfaces generally rusty brown; quartzite and siltite commonly banded; banding appears to parallel relict bedding; schist contains garnet porphyroblasts (<1 mm), not typically visible in hand specimen, but on cut surfaces pale pink garnet porphyroblasts are visible; thin sections show that the rock lacks plagioclase; garnets are late-growth (post-mica), have no apparent rotation, and are colorless with abundant inclusions (quartz?); although foliation in the quartzite beds is not well developed, complete metamorphic recrystallization has occurred; in the schist and phyllite, foliation appears to parallel relict bedding; bedding appears to have been regular and continuous; the rock has two distinct cleavages; occurs in the west half of sec. 14, T. 20 N., R. 41 E. near the north end of Rock Lake in the Rosalia 1:100,000 quadrangle.

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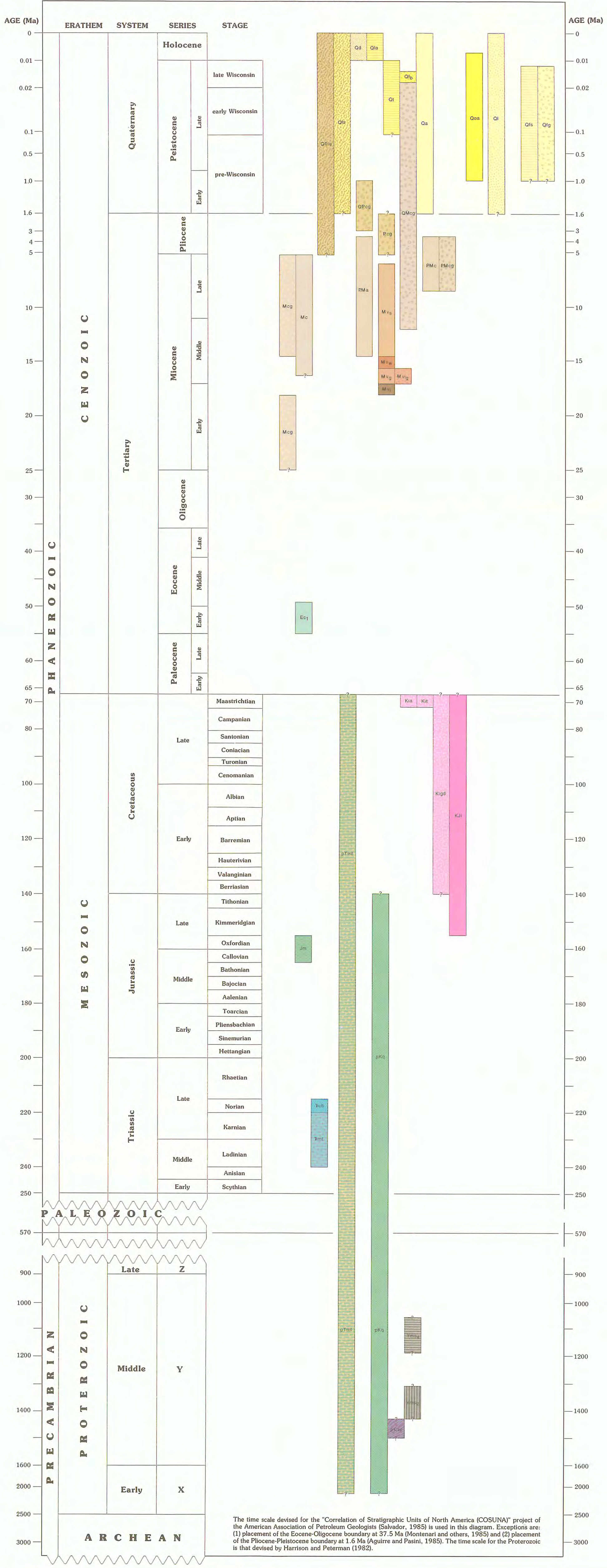
Sheet 1

Geologic Map of Washington—Southeast Quadrant
Washington Division of Geology and Earth Resources
Geologic Map GM-45
Sheet 2

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 (Montenari and others, 1985) and (2) placement of the Pliocene-Pleistocene boundary at 1.6 Ma (Aguirre and Pasini, 1985). The time scale for the Proterozoic is that devised by Harrison and Peterman (1982).

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

GEOLOGIC UNITS

VOLCANIC AND SEDIMENTARY ROCKS

Subgreenschist-Grade Metamorphism

Mv	Miocene basalt flows, including subjacent and intercalated sedimentary rocks
Evs	Eocene sedimentary and volcanic rocks
Js	Jurassic sedimentary rocks

METASEDIMENTARY AND METAVOLCANIC ROCKS

Greenschist-Grade Metamorphism

pTvs	Pre-Tertiary metasedimentary and metavolcanic rocks
pKs	Pre-Cretaceous metasedimentary rocks
Trvs	Triassic metasedimentary and metavolcanic rocks
Ys	Middle Proterozoic metasedimentary rocks

METAMORPHIC ROCKS

Amphibolite-Grade Metamorphism

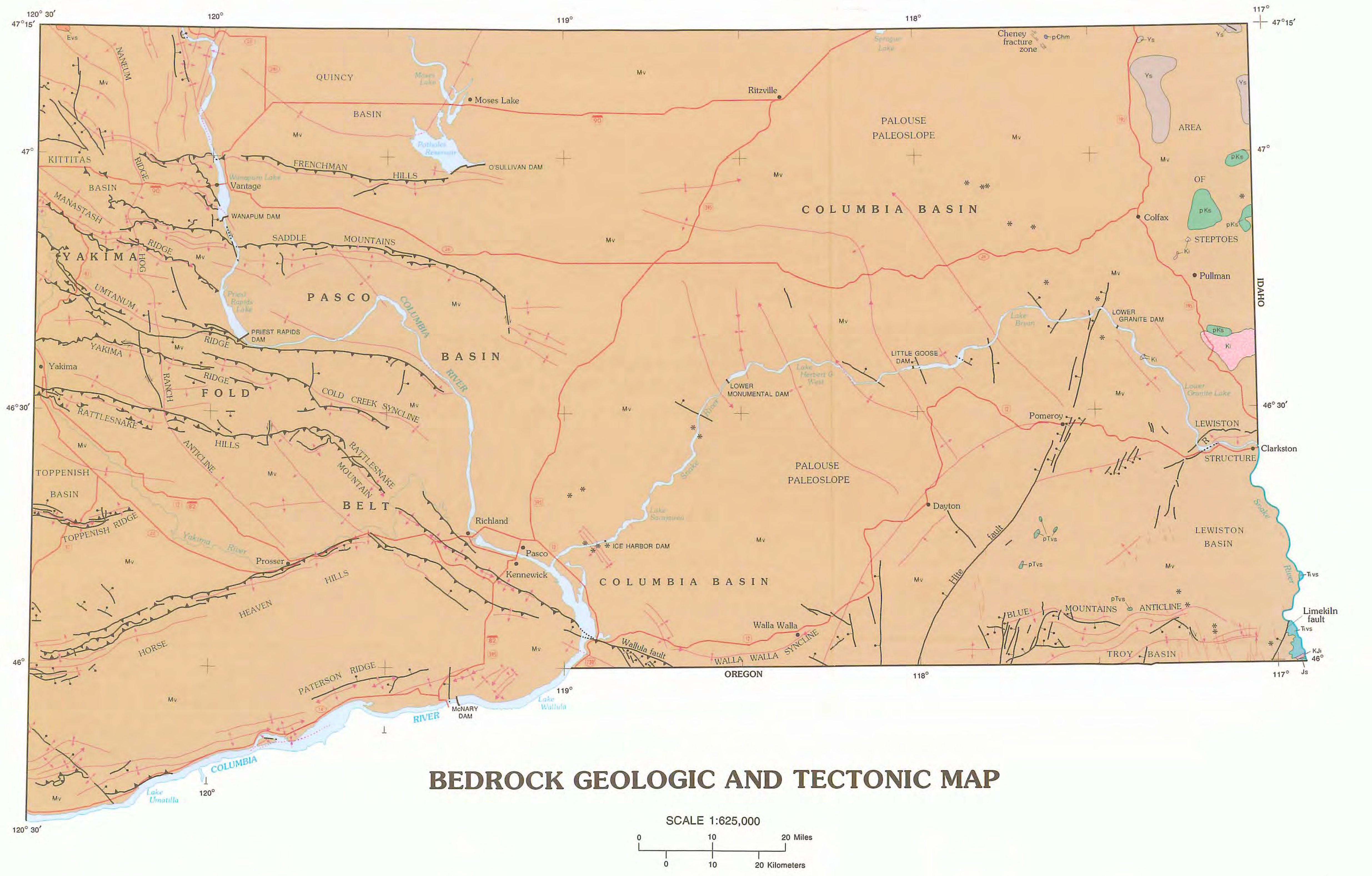
pChm	Precambrian heterogeneous metamorphic rocks

INTRUSIVE ROCKS

Ki	Cretaceous rocks
KJi	Cretaceous and Jurassic rocks

GEOLOGIC SYMBOLS

———	Contact
———– – –	Fault — dotted where concealed
——•—– – –	Dip-slip fault — Bar and ball on downthrown side; dotted where concealed
——⇄—– – –	Strike-slip fault — Showing relative horizontal movement; dotted where concealed
▲—▲—▲—▲– – –	Thrust fault — Sawteeth on upper plate; dotted where concealed
——R——	High angle reverse fault — R on upthrown block
←——↕—– – –	Anticline — Showing direction of plunge; dotted where concealed
←——↕—– – –	Syncline — Showing direction of plunge; dotted where concealed
—↓— —↑—	Monocline — arrow on steeper limb
*	Volcanic vent
——	Dike — Dotted where concealed
▨	Fracture zone



BEDROCK GEOLOGIC AND TECTONIC MAP

SCALE 1:625,000

0 10 20 Miles

0 10 20 Kilometers

LIST OF NAMED UNITS

(To accompany geologic map, sheet 1)

Lower-case designations of unit type (member, formation) indicates informal name. 1:100,000 quadrangle abbreviations: CL, Clarkston; CO, Connell; GO, Goldendale; HE, Hermiston; ML, Moses Lake; OR, Orofino; PR, Priest Rapids; PU, Pullman; RI, Richland; RT, Ritzville; RO, Rosalia; TO, Toppenish; WW, Walla Walla; WE, Wenatchee; YA, Yakima. Distributions of all units of the Grande Ronde Basalt of the Columbia River Basalt Group are from Reidel and others (1989) and include surface and subsurface extent. For all other units only the surface extent is listed.

GEOLOGIC UNIT	SYMBOL	DEFINING AND/OR REPRESENTATIVE REFERENCE	1:100,000 QUADRANGLE(S)
Armstrong Canyon, unit, N_2 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	GO HE
Asotin Member, Saddle Mountains Basalt	Mv_s	Swanson and others, 1979b	CL CO OR PR PU YA
Asotin Creek gravel	QMcg	Hooper and others, 1985	CL
Basin City, basalt of, Ice Harbor Member	Mv_s	Swanson and others, 1979b	PR RI WW
Bear Creek flow, Umatilla Member	Mv_s	Ross, 1978, 1989	CL
Belt Supergroup	Yms_4, Yms_2	Harrison and Campbell, 1963; Griggs, 1973	RO
Beverly Member, Ellensburg Formation	Mc	Bingham and Grolier, 1966	PR
Bonneville flood deposits	Qf_b	Malde, 1968	CO CL OR PU
Buckhorn Springs unit, R_1 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	CL CO GO HE ML OR PU PR RI RO RT TO WW YA
Buford Member, Saddle Mountains Basalt	Mv_s	Swanson and others, 1979b	CL
Burke Formation, Ravalli Group	Yms_2	Harrison and Campbell, 1963; Griggs, 1973	RO
Center Creek unit, R_1 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	All
China Creek unit, N_1 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	All
Clarkston gravel	Mcg	Webster and others, 1982	CL
Clarkston Heights gravel	QMcg	Webster and others, 1982	CL
Clearwater gravel	QMcg	Webster and others, 1982	CL
Cloverland, basalt of, Weissenfels Ridge Member	Mv_s	Hooper and others, 1985	CL OR
Cold Creek interbed, Ellensburg Formation	Mc	Campbell and Reidel, 1991	western part of map
Columbia River Basalt Group	Mv_s, Mv_w, Mv_g, Mvi_g, Mv_i	Swanson and others, 1979b; Tolan and others, 1989	All
Coon Hollow Formation	Jm	Morrison, 1964	OR
Dodge, basalt of, Eckler Mountain Member	Mv_w	Swanson and others, 1979b	CL OR PU WW
Downey Gulch unit, N_1 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	CL GO HE OR PU RI WW
Doyle Creek Formation	Trmt	Vallier, 1977	OR
Eckler Mountain Member, Wanapum Basalt	Mv_w	Swanson and others, 1979b	CL OR PU WW
Elephant Mountain Member, Saddle Mountains Basalt	Mv_s	Swanson and others, 1979b	CL CO GO HE OR PR RI TO WW YA
Elephant Mountain flow, Elephant Mountain Member	Mv_s	Swanson and others, 1979b	CL CO GO HE OR PR RI TO WW YA
Ellensburg Formation	Mc, Mcg	Schmincke, 1967; Swanson and others, 1979b; Smith, 1988	GO HE PR PU RI TO WE YA
Esquatzel Member, Saddle Mountains Basalt	Mv_s	Swanson and others, 1979b	CO PR PU RI YA
Fields Spring unit, N_2 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	CL PU
Frenchman Springs Member, Wanapum Basalt	Mv_w	Swanson and others, 1979b; Beeson and others, 1985	CL CO GO HE ML PR PU RI RT TO WW WE YA
Ginkgo, basalt of, Frenchman Springs Member	Mv_w	Beeson and others, 1985	CO GO HE ML PR RI TO WW YA
Goose Island, basalt of, Ice Harbor Member	Mv_s	Swanson and others, 1979b	PR RI WW
Grande Ronde Basalt, Columbia River Basalt Group	Mv_g, Mvi_g	Swanson and others, 1979b; Reidel and others, 1989	All
Grande Ronde River gravel	QMcg	Reidel and others, 1992	CL OR
Granite Point, granodiorite of	Kigd	Hooper and Rosenberg, 1970	PU
Grouse Creek unit, R_2 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	All
Hanford formation	Qfs, Qfg	Carson and others, 1987; Myers, Price, and others, 1979	PR RI
Huntzinger, basalt of, Asotin Member	Mv_s	Reidel and Fecht, 1987	PR
Ice Harbor Member, Saddle Mountains Basalt	Mv_s	Swanson and others, 1979b	PR RI WW
Imnaha Basalt, Columbia River Basalt Group	Mv_i	Swanson and others, 1979b	CL OR
Lapwai, basalt of, Wilbur Creek Member	—	Reidel and Fecht, 1987	occurs in Idaho
Latah Formation	Mc	Griggs, 1976	NE part of map, none shown
Levey interbed, Ellensburg Formation	Mc	Campbell and Reidel, 1991	western part of map
Lewiston Orchards, basalt of, Weissenfels Ridge Member	Mv_s	Swanson and others, 1979b	CL OR PU
Lime Hill, sediments of	Mcg	Reidel and others, 1992	OR
Lolo, basalt of, Priest Rapids Member	Mv_w	Swanson and others, 1979b	southern part of map
Lower Monumental Member, Saddle Mountains Basalt	Mv_s	Swanson and others, 1979b	CL CO PU
Lyons Ferry, basalt of, Frenchman Springs Member	Mv_w	Beeson and others, 1985	CL CO HE PU RI WW
Mabton member, Ellensburg Formation	Mc	Smith, 1988	western part of map
Martin Bridge Limestone	Trcb	Hamilton, 1963	OR
Martindale, basalt of, Ice Harbor Member	Mv_s	Swanson and others, 1979b	PR RI WW
Meyer Ridge unit, R_2 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	CL CO OR PU
Missoula Group, Belt Supergroup	Yms_4	Harrison and Campbell, 1963; Griggs, 1973	RO
Missoula, glacial lake, deposits	Qfs, Qfg	Bretz and others, 1956; Baker and Bunker, 1985	All
Mt. Horrible unit, R_2 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	All except OR RO
N_1 magnetostratigraphic unit, Grande Ronde Basalt	Mv_g	Swanson and others, 1979b	All
N_2 magnetostratigraphic unit, Grande Ronde Basalt	Mv_g	Swanson and others, 1979b	All except OR
Ortley unit, N_2 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	All except OR RO
Pasco gravels	Qfg	Carson and others, 1987; Myers, Price, and others, 1979	PR RI
Palouse Falls, basalt of, Frenchman Springs Member	Mv_w	Beeson and others, 1985	CO PR RI TO WW
Palouse Formation	Ql	Busacca, 1991	All
Pomona Member, Saddle Mountains Basalt	Mv_s	Swanson and others, 1979b	CL CO GO HE PR PU RI TO WW YA
Priest Rapids Member, Wanapum Basalt	Mv_w	Swanson and others, 1979b	All
Quincy interbed, Ellensburg Formation	Mc	Campbell and Reidel, 1991	western part of map
R_1 magnetostratigraphic unit, Grande Ronde Basalt	Mv_g	Swanson and others, 1979b	All
R_2 magnetostratigraphic unit, Grande Ronde Basalt	Mv_g	Swanson and others, 1979b	All
Rattlesnake Ridge Member, Ellensburg Formation	Mc	Schmincke, 1967	western part of map
Ravalli Group, Belt Supergroup	Yms_2	Harrison and Campbell, 1963; Griggs, 1973	RO
Revett Formation, Ravalli Group	Yms_2	Harrison and Campbell, 1963; Griggs, 1973	RO
Ringold Formation	RMc, RMcg	Lindsey, 1991	CO ML PR RI RT WW YA
Robinette Mountain, basalt of, Eckler Mountain Member	Mv_w	Swanson and others, 1979b	CL
Rogersburg unit, R_1 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	CL CO GO HE OR PR PU RI TO WW YA
Rosalia, basalt of, Priest Rapids Member	Mv_w	Swanson and others, 1979b	northern part of map
Roza Member, Wanapum Basalt	Mv_w	Swanson and others, 1979b	CL CO GO ML OR PR PU RI RT RO TO WW WE YA
Saddle Mountains Basalt, Columbia River Basalt Group	Mv_s	Swanson and others, 1979b	southern part of map
Sand Hollow, basalt of, Frenchman Springs Member	Mv_w	Beeson and others, 1985	CL CO GO HE ML PR PU RI RT TO WE WW YA
Selah Member, Ellensburg Formation	Mc	Schmincke, 1967	western part of map
Sentinel Bluffs unit, N_2 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	All except OR
Sentinel Gap, basalt of, Frenchman Springs Member	Mv_w	Beeson and others, 1985	CL CO GO HE ML PR PU RI RT TO WW YA
Seven Devils Group	Trmt	Vallier, 1977	OR
Shumaker Creek, basalt of, Eckler Mountain Member	Mv_w	Swanson and others, 1979b	CL
Sillusi, basalt of, Umatilla Member	Mv_s	Reidel and Fecht, 1981	CL GO HE OR PR PU RI TO WW YA
Silver Falls, basalt of, Frenchman Springs Member	Mv_w	Beeson and others, 1985	CO GO HE PR RI TO WW YA
Slack Canyon unit, N_2 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	All except OR
Slippery Creek, basalt of, Weissenfels Ridge Member	Mv_s	Swanson and others, 1979b	CL OR
Snipes Mountain, conglomerate of, Ellensburg Formation	Mcg	Swanson and others, 1979a	GO HE PR TO YA
Sprague Lake, basalt of, (equivalent to basalt of Lewiston Orchards?)	Mv_s	Swanson and others, 1979a	RO
Squaw Creek Member, Ellensburg Formation	Mc	Swanson and others, 1979b	western part of map
Striped Peak Formation, Missoula Group	Yms_4	Harrison and Campbell, 1963; Griggs, 1973	RO
Swauk Formation	Ec_1	Russell, 1900; Tabor and others, 1982	WE
Teepee Butte Member, R_1 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	All except RO
Tenmile Creek, basalt of, Weissenfels Ridge Member	Mv_s	Hooper and others, 1985	Cl OR
Thorp Gravel	RMcg	Waitt, 1979	WE YA
Touchet Beds	Qfs	Flint, 1938	CO PR RI TO WW YA
Umatilla, basalt of, Umatilla Member	Mv_s	Reidel and Fecht, 1981	CL GO HE OR PR PU RI TO WW YA
Umatilla Member, Saddle Mountains Basalt	Mv_s	Swanson and others, 1979b	CL GO HE OR PR PU RI TO WW YA
Umtanum unit, N_2 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	All except OR
Vantage Member, Ellensburg Formation	Mc	Swanson and others, 1979b	western part of map
Wahluke, basalt of, Wilbur Creek Member	Mv_s	Reidel and Fecht, 1987	CL CO OR PR PU YA
Wanapum Basalt, Columbia River Basalt Group	Mv_w	Swanson and others, 1979b	All
Wapshilla Ridge unit, R_2 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	All
Ward Gap flow, Elephant Mountain Member	Mv_s	Swanson and others, 1979b	CL CO GO HE OR PR RI TO WW YA
Weissenfels Ridge Member, Saddle Mountains Basalt	Mv_s	Swanson and others, 1979b	CL OR PU RO
Wilbur Creek Member, Saddle Mountains Basalt	Mv_s	Swanson and others, 1979b	CL CO OR PR PU YA
Wild Sheep Creek Formation	Trmt	Vallier, 1977	OR
Winter Water unit, N_2 Grande Ronde Basalt	Mv_g	Reidel and others, 1989	GO HE RI TO
Yakima Basalt Subgroup, Columbia River Basalt Group	Mv_s, Mv_w, Mv_g, Mvi_g	Swanson and others, 1979b	All

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