NATURAL RESOURCES

# Geologic Map of the East Half of the Yakima 1:100,000 Quadrangle, Washington

compiled by
J. Eric Schuster

WASHINGTON
DIVISION OF GEOLOGY
AND EARTH RESOURCES

Open File Report 94-12
July 1994

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

CONTENTS



ILLUSTRATIONS



**PLATE** (accompanies text)

# GEOLOGIC MAP OF THE EAST HALF OF THE YAKIMA 1:100,000 QUADRANGLE, WASHINGTON

compiled by
J. Eric Schuster

## INTRODUCTION

This map of the east half of the Yakima 1:100,000-scale quadrangle, Washington, shows the geology of one of 15 complete or partial 1:100,000-scale quadrangles that cover the southeast quadrant of Washington (Fig. 1). Geologic maps of these quadrangles have been compiled by Washington Division of Geology and Earth Resources (DGER), Westinghouse Hanford Co., and Washington State University geologists and are the principal data sources for a new 1:250,000-scale geologic map of the southeast quadrant of Washington, which is in preparation. Eleven of these quadrangles are being released as DGER open-file reports (listed below). The map of the Wenatchee quadrangle has been published by the U.S. Geological Survey (Tabor and others, 1982), and the Moses Lake (Gulick, 1990a), Ritzville (Gulick, 1990b), and Rosalia (Waggoner, 1990) quadrangles were released in 1990.

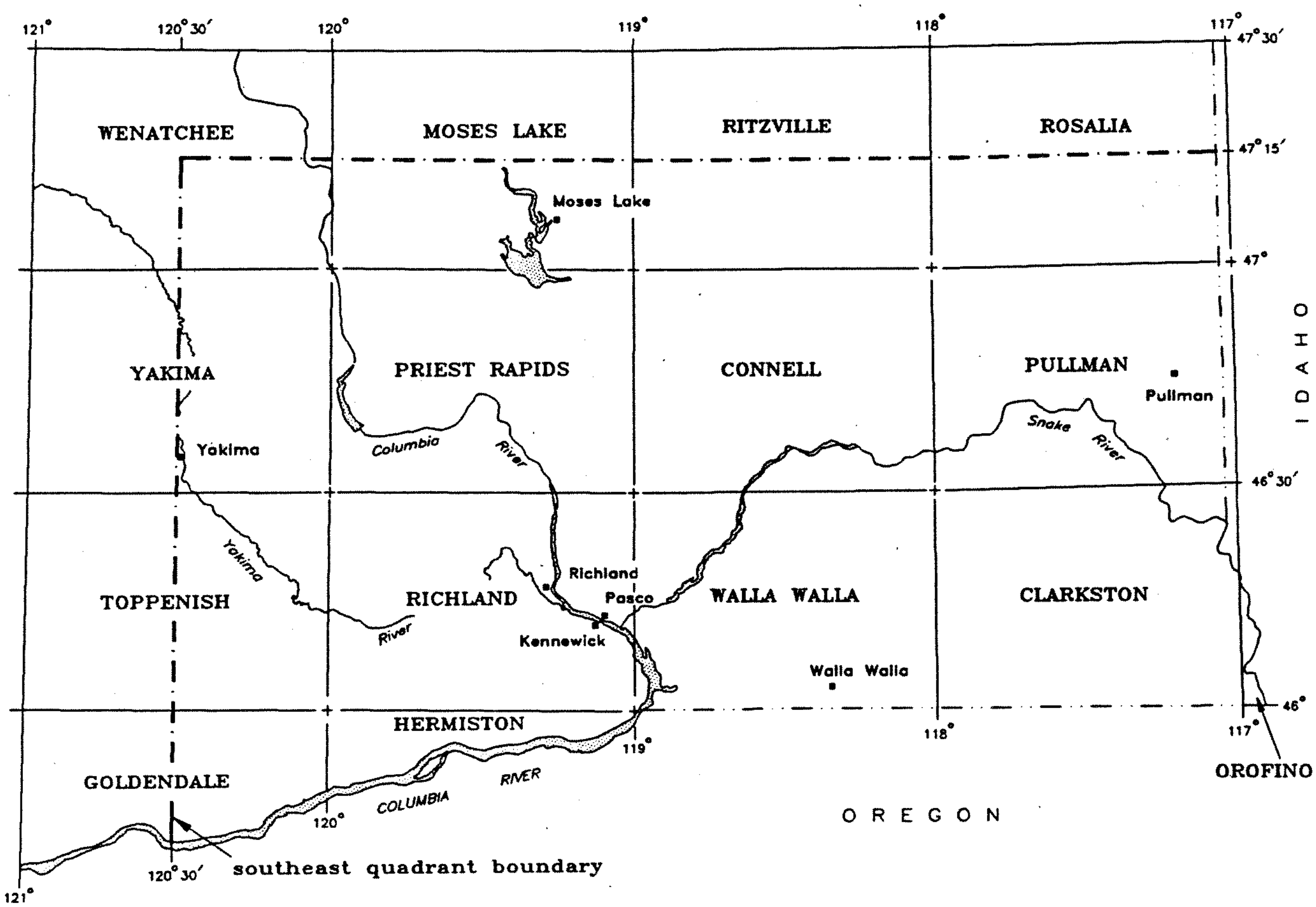



**Figure 1.** 1:100,000-scale quadrangles in the southeast quadrant of Washington.

Figure 2 shows geographic features referred to in this text and the locations of 7.5- and 15-minute quadrangles in the east half of the Yakima 1:100,000-scale quadrangle.

The geology of the east half of the Yakima quadrangle has not previously been compiled at 1:100,000 scale. Furthermore, this is the first 1:100,000 or smaller-scale geologic map of the area to incorporate both bedrock and surficial geology.

This map was compiled in 1993, using published and unpublished geologic maps as sources of data. The areas covered by these sources are shown on Figure 3. Except for Swanson and others (1979a) source maps with scales smaller than 1:100,000 were not used. Maps produced before 1979 were not used as sources of data for the Columbia River Basalt Group because prior to that year mappers generally did not use geochemistry or magnetic polarity to confirm assignment of basalt flows to stratigraphic units, nor did they employ the stratigraphy that was proposed by Swanson and others (1979b) and, with subsequent modifications, is universally used today. The lack of consistent, reliable identification procedures and standardized nomenclature makes it difficult to use the older maps unless one is personally familiar with the geology.

Figure 3 identifies some of the sources of data as primary. These are discussed further below. Some maps that were not used in compiling the geology of this report are shown on Figure 3 in an attempt to make the sources-of-data listing exhaustive and to inform the reader that these sources were not overlooked.

Three unpublished sources of geologic data were used:

- Ten 1984 1:12,000-scale geologic maps in the northern part of the east half of the Yakima 1:100,000 quadrangle by R. D. Bentley and J. E. Powell of Central Washington University (Bentley and Powell, 1984);
- N. P. Campbell's 1978 1:24,000-scale maps for the entire east half of the Yakima 1:100,000-scale quadrangle except for the Yakima East 15-minute quadrangle (Campbell, 1978); and
- S. P. Reidel's and T. L. Tolan's 1:100,000-scale geologic map of the northeast part of the east half of the Yakima 1:100,000-scale quadrangle (Reidel and Tolan, 1991).

As noted above, Figure 3 identifies some of the sources of data as primary. These sources were used in the following ways. Bentley and others (1993) was the source for both bedrock and surficial geology for the Yakima East 15-minute quadrangle. In the Badger Pocket, Boylston, and Black Rock Spring 15-minute quadrangles N. P. Campbell's unpublished reconnaissance 7.5-minute surficial geologic maps (Campbell, 1978) were the sources for the surficial geology and for the outlines of areas of exposure of the bedrock units, mostly Columbia River basalt. In bedrock areas of the Badger Pocket 15-minute quadrangle, details were taken from Figure 2R H.8-2 of Shannon & Wilson, Inc. (1977) and from Bentley and Powell (1984). In bedrock areas of the Boylston 15-minute quadrangle details were taken from Reidel (1991), and from Bentley and Powell (1984). In bedrock areas of the Black Rock Spring 15-minute quadrangle details were taken from Figure 2R H.7-3 of Shannon & Wilson, Inc. (1977) and from Swanson and others (1979a).

In a review of late Cenozoic structure and stratigraphy of south-central Washington Reidel and others (1994, Table 4) report Pleistocene(?) movement along the Union Gap fault (called the Ahtanum Creek fault in Geomatrix Consultants, Inc., 1988) along the north side of Ahtanum Ridge at Union Gap, probably in sec. 8, T. 12 N., R. 19 E. For further information refer to Geomatrix Consultants, Inc. (1988, p. 47-54).

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) is used in this report, with slight modifications: the Oligocene-Eocene boundary is set at 35.7 Ma (Montanari and others, 1985), and the Pleistocene-Pliocene boundary is set at 1.6 Ma (Aguirre and Pasini, 1985).

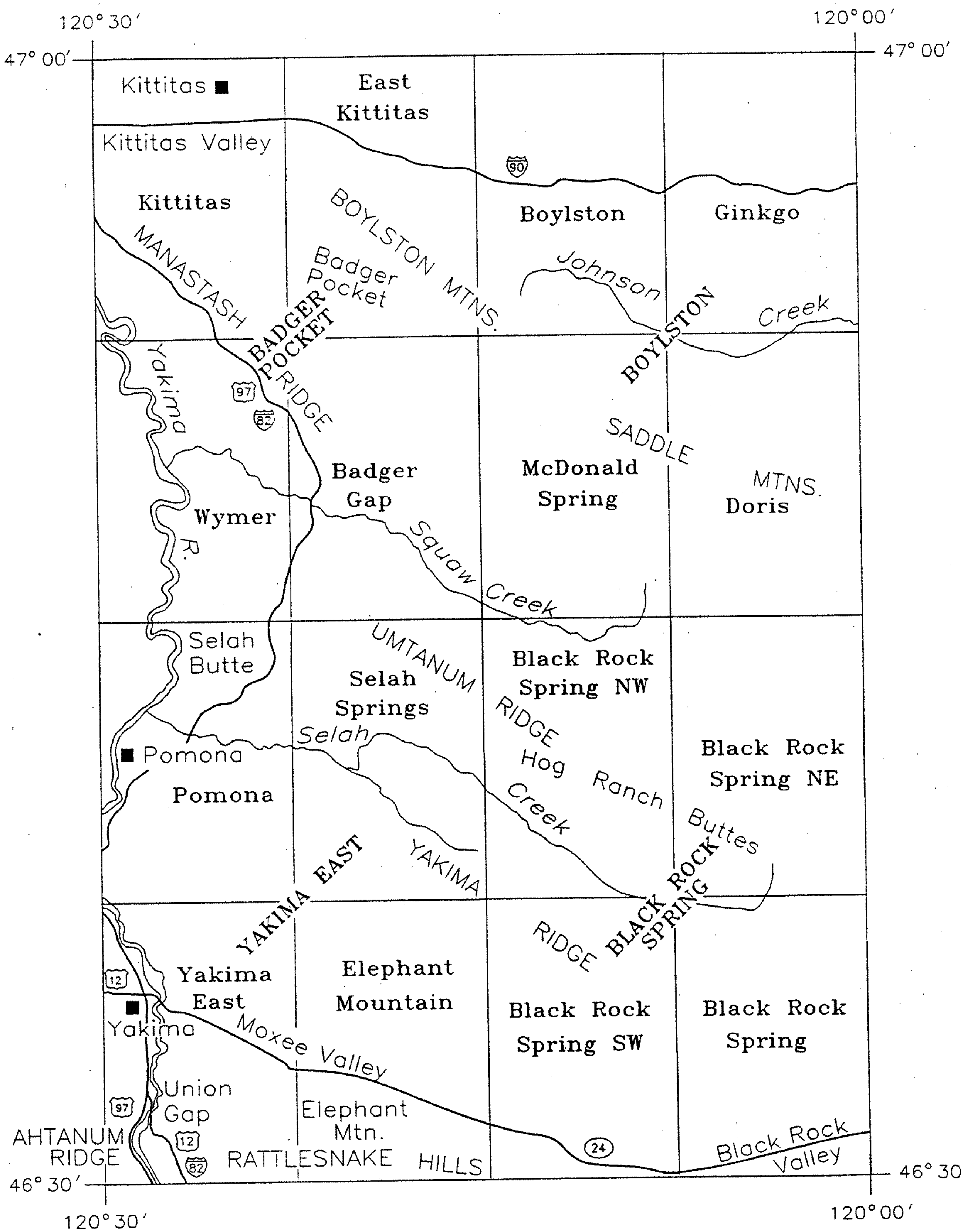
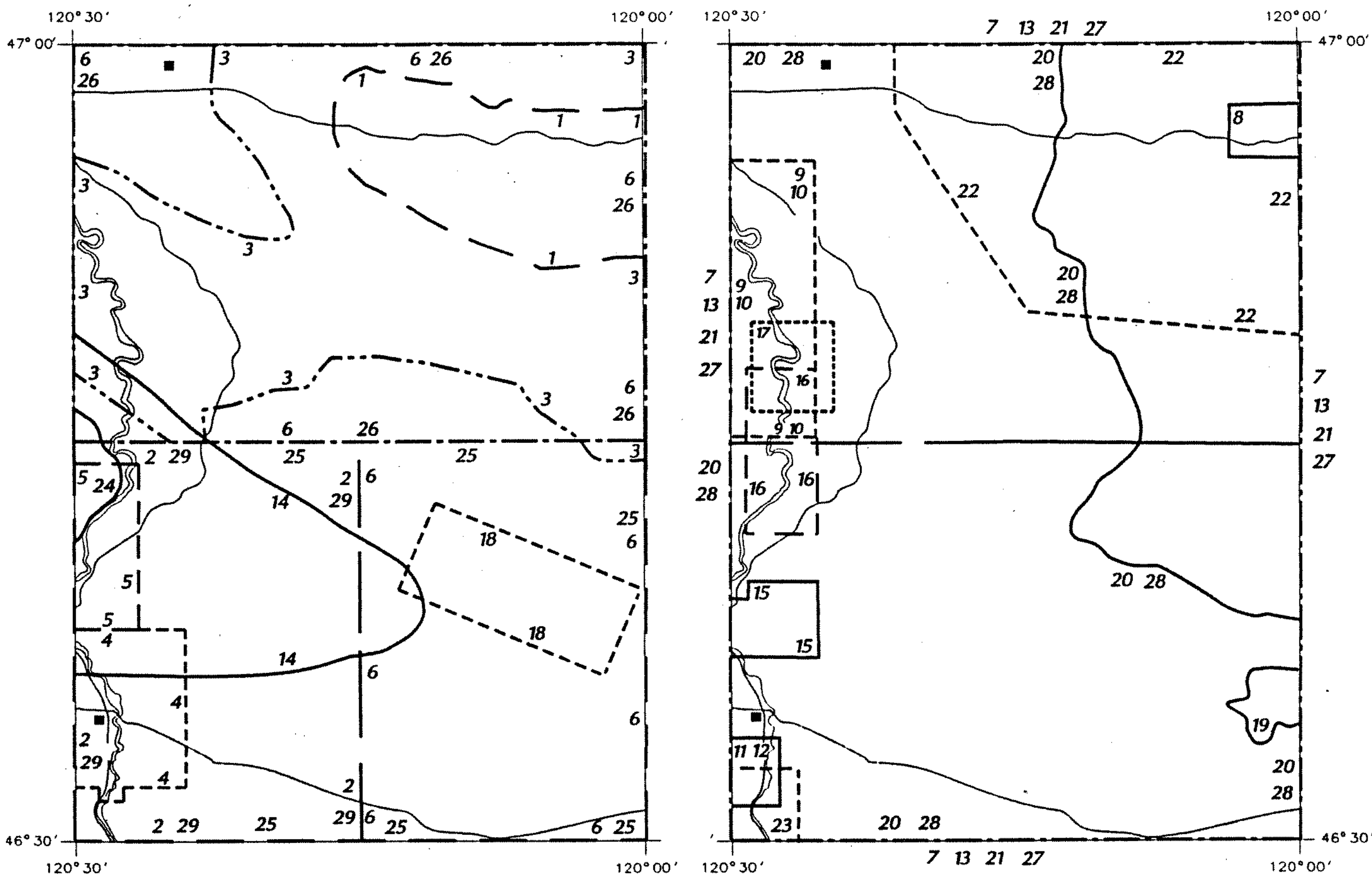



**Figure 2.** Index map showing geographic names and 7.5- and 15-minute [diagonal lettering] quadrangle locations, east half of the Yakima 1:100,000 quadrangle, Washington.




A

B

**Figure 3.** Sketch maps showing sources of geologic mapping for the east half of the Yakima 1:100,000 quadrangle. The primary sources of geologic data used in this compilation are marked with asterisks. The letter indicates which of the two maps displays the area covered by the source map.

| | | |
|---|---|---|
| 1. | a | Alto, 1955 (plate 5, scale 1:44,352) |
| 2.* | a | Bentley and others, 1993 (sheet 1, scale 1:31,680) |
| 3.* | a | Bentley, R. D.; Powell, J. E., 1984 (unpub. mapping, scale 1:12,000) |
| 4. | a | Campbell, 1976 (scale 1:24,000) |
| 5. | a | Campbell, 1977 (scale 1:24,000) |
| 6.* | a | Campbell, N. P., 1978 (unpub. mapping, scale 1:24,000) |
| 7. | b | Campbell, 1979 (scale 1:250,000) |
| 8. | b | Carson and others, 1987 (figure 3, scale 1:71,000) |
| 9. | b | Diery, 1967 (scale 1:24,000) |
| 10. | b | Diery and McKee, 1969 (figure 3, scale 1:125,000) |
| 11. | b | Foxworthy, 1957 (scale 1:62,500) |
| 12. | b | Foxworthy, 1962 (scale 1:62,500) |
| 13. | b | Geomatrix Consultants, Inc., 1988 (plate 2, scale 1:250,000) |
| 14. | a | Holmgren, 1967 (plate 1, scale 1:141,000) |
| 15. | b | Holmgren, 1967 (plate 2, scale 1:42,290) |
| 16. | b | Holmgren, 1969 (plate 1, scale 1:31,680) |
| 17. | b | Kienle and others, 1977 (figure A-2, scale 1:24,000) |
| 18. | a | Kienle and others, 1977 (figure A-4, scale 1:24,000) |
| 19. | b | Kienle and others, 1977 (figure A-5, scale 1:24,000) |
| 20. | b | Kinnison and Sceva, 1963 (scale 1:250,000) |
| 21. | b | Myers, Price, and others, 1979 (plates II-6 and II-15, scale 1:250,000) |
| 22.* | b | Reidel, S. P.; Tolan, T. L., 1991 (unpub. mapping, scale 1:100,000) |
| 23. | b | Robinson, 1966 (scale 1:153,000) |
| 24. | a | Sceva and others, 1949 (plate 2, scale 1:63,360) |
| 25.* | a | Shannon & Wilson, Inc., 1977 (figure 2R H.7-3, scale 1:62,500) |
| 26.* | a | Shannon & Wilson, Inc., 1977 (figure 2R H.8-2, scale 1:62,500) |
| 27.* | b | Swanson and others, 1979a (sheet 6, scale 1:250,000) |
| 28. | b | U.S. Army Corps of Engineers, 1978 (plates 7, 14, 18, scale 1:250,000) |
| 29. | a | Waters, 1955 (scale 1:62,500) |

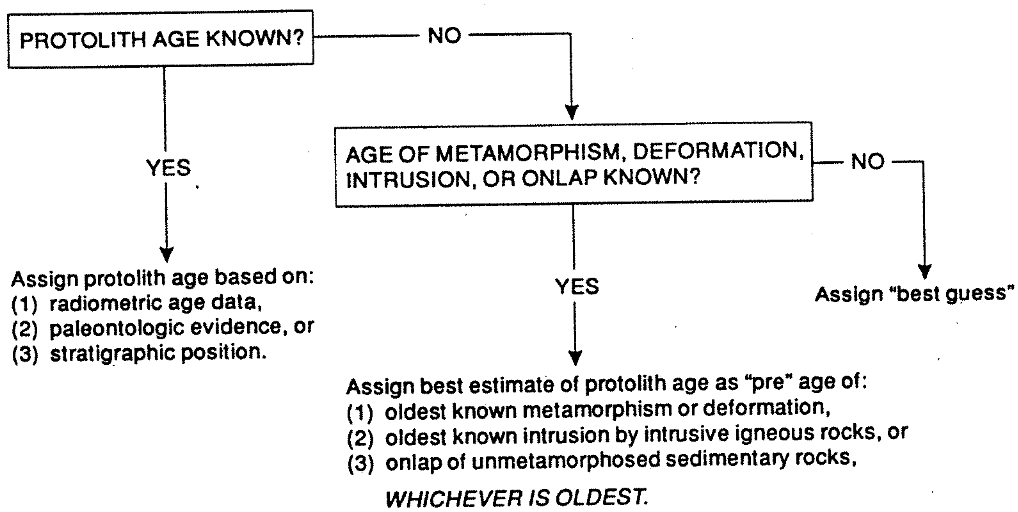



**Figure 4.** Flow chart for age assignment of geologic units. Protolith age or estimated protolith age may be assigned by correlation with other geologic units. The unit description includes information on how the age of the unit was determined.

Age assignments of geologic units were made following the flow chart in Figure 4. Because all potassium-argon (K-Ar) ages cited herein (Baksi, 1989; Tolan and others, 1989; McKee and others, 1977; Reidel and Fecht, 1987) were published after 1976, they are assumed to have been calculated using the decay and abundance constants adopted by the International Union of Geological Sciences in 1976 (Dalrymple, 1979). The actual constants used were not reported.

The current nomenclature and stratigraphic relations of the Columbia River Basalt Group are shown in Figure 5.

## DGER Southeast Quadrant Open-File Reports

Gulick, C. W., compiler, 1990a, Geologic map of the Moses Lake 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-1, 9 p., 1 plate.

Gulick, C. W., compiler, 1990b, Geologic map of the Ritzville 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-2, 7 p., 1 plate.

Gulick, C. W., compiler, 1994, Geologic map of the Connell 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 94-14, 18 p., 1 plate.

Gulick, C. W., compiler, 1994, Geologic map of the Pullman 1:100,000 quadrangle, Washington-Idaho: Washington Division of Geology and Earth Resources Open File Report 94-6, 23 p. 1 plate.

Reidel, S. P.; Fecht, K. R., compilers, in press, Geologic map of the Priest Rapids 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 94-13, 22 p., 1 plate.

Reidel, S. P.; Fecht, K. R., compilers, 1994, Geologic map of the Richland 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 94-8, 21 p. 1 pl.

| SERIES | | GROUP | FORMATION | MEMBER | ISOTOPIC AGE (Ma) | MAGNETIC POLARITY |
|---|---|---|---|---|---|---|
| MIOCENE | upper | COLUMBIA RIVER BASALT GROUP | 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 | | |
| | middle | | | ELEPHANT MOUNTAIN MEMBER | 10.5 | N,T |
| | | | | 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 | |
| | | | | basalt of Huntzinger | | N |
| | | | | WILBUR CREEK MEMBER | | |
| | | | | basalt of Lapwai | | N |
| | | | | basalt of Wahluke | | N |
| | | | | UMATILLA MEMBER | | |
| | | | | basalt of Sillusi | | N |
| | | | | basalt of Umatilla | | N |
| | | | WANAPUM BASALT | PRIEST RAPIDS MEMBER | 14.5 | |
| | | | | basalt of Lolo | | 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 (PRINEVILLE 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 | | |
| | | | GRANDE RONDE BASALT (PICTURE GORGE BASALT) | China Creek unit | | $N_1$ |
| | | | | Downey Gulch unit | | |
| | | | | Center Creek unit | | $R_1$ |
| | | | | Rogersburg unit | | |
| | | | | Teepee Butte unit | | |
| | | | | 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.** Chart showing generalized nomenclature and stratigraphic relations of the Columbia River Basalt Group. This figure includes units that do not appear in the east half of the Yakima 1:100,000 quadrangle. Modified from Reidel and others (1989).

Schuster, J. E., compiler, 1993, Geologic map of the Clarkston 1:100,000 quadrangle, Washington-Idaho, and the Washington portion of the Orofino 1:100,000 quadrangle: Washington Division of Geology and Earth Resources Open File Report 93-4, 43 p., 1 plate.

Schuster, J. E., compiler, 1994, Geologic map of the east half of the Toppenish 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 94-10, 15 p., 1 plate.

Schuster, J. E., compiler, 1994, Geologic map of the east half of the Washington portion of the Goldendale 1:100,000 quadrangle, and the Washington portion of the Hermiston 1:100,000 quadrangle: Washington Division of Geology and Earth Resources Open File Report 94-9, 17 p., 1 plate.

Schuster, J. E., compiler, 1994, Geologic map of the east half of the Yakima 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 94-12, 22 p., 1 plate.

Schuster, J. E., compiler, 1993, Geologic map of the Walla Walla 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 94-3, 18 p., 1 plate.

Waggoner, S. Z., compiler, 1990, Geologic map of the Rosalia 1:100,000 quadrangle, Washington-Idaho: Washington Division of Geology and Earth Resources Open File Report 90-7, 20 p., 1 plate.

## Acknowledgments

R. D. Bentley of Central Washington University, J. E. Powell of the Department of Natural Resources, Ellensburg, N. P. Campbell of Yakima Valley Community College, S. P. Reidel of Washington State University, and T. L. Tolan, consulting geologist, Kennewick, WA, provided unpublished geologic maps. R. D. Bentley, N. P. Campbell, J. E. Powell, S. P. Reidel, and D. A. Swanson of the U.S. Geological Survey reviewed the map and text and provided many helpful suggestions. C. F. T. Harris and K. G. Ikerd of the DGER cartographic staff and K. M. Reed of the DGER editorial staff prepared final copy and provided editorial support.

# DESCRIPTIONS OF MAP UNITS

## Sedimentary Deposits and Rocks

### Quaternary Sedimentary Deposits

Qa

Alluvium (Holocene)—Silt, sand, and gravel deposits of diverse composition, locally includes lacustrine, paludal, and eolian deposits in depressions; occurs in valley bottoms throughout the map area, but the most significant deposits are along the Yakima River; includes a mainstream facies (mainstream facies of Waitt, 1979) deposited directly by the Yakima River in which clasts are of mixed lithologies, and a sidestream facies (sidestream facies of Waitt, 1979) of dominantly basaltic composition deposited by tributaries of the Yakima River; age inferred from geomorphology and ages of parent materials. Description from Bentley and others (1993).

Qls

Mass-wasting deposits (Holocene to Pleistocene)—Landslide deposits; clay, silt, sand, and gravel, unstratified and poorly sorted; surface commonly hummocky; deposited by rotational-translational slides and debris flows; includes talus; found at the base of slopes and on lower slopes; age inferred from stratigraphic position, age of parent materials, and geomorphology. Description from Bentley and others (1993).

Ql

Loess (Holocene to Pleistocene)—Eolian silt and fine sand; locally includes multiple caliche layers and tephra beds; pale orange to brown; occurs in patches throughout the map area, but the most significant deposits are in Kittitas Valley, in the upper part of the valley of Selah Creek, in Moxee Valley, and in Black Rock Valley; uppermost loess locally contains Mazama tephra (Foley, 1982, p. 90), about 7 ka (Kittleman, 1973, p. 2958; Bacon, 1983, p. 105); paleomagnetic measurements show that the oldest loess was deposited during the Matuyama reversed polarity epoch and is at least 790 ka and probably 1 Ma or older (McDonald and Busacca, 1989, p. 338). Includes Palouse Formation. Description from Bentley and others (1993).

Qaf

Alluvial fans (Holocene to Pleistocene)—Sand and gravel of diverse composition; large clasts dominantly basalt; cone shaped; surface only moderately dissected; little or no caliche development; most extensively developed along the south side of Umtanum Ridge, along the north and south sides of Yakima Ridge, and along the north side of the Rattlesnake Hills; age inferred from geomorphology, lack of caliche development, and ages of parent materials. Description from Bentley and others (1993).

Qafo

Older alluvial fans (Holocene to Pleistocene)—Sand and gravel; semiconsolidated fanglomerate of primarily basalt clasts cemented by iron-stained clay; surface commonly dissected and capped by a well-developed caliche layer; occurs most extensively in the Badger Pocket area, along the south side of Johnson Creek, along the southwest side of Manastash Ridge in the vicinity of Interstate Highway 82, along the north side of Yakima Ridge, and along the north side of Moxee Valley; age inferred from geomorphology, cementing, and caliche development. Description from Bentley and others (1993).

Qfs

Outburst flood deposits, silt and sand (Pleistocene)—Silt, minor sand and gravel; rhythmically bedded and graded; locally contains clastic dikes and ice-rafted clasts; occurs in small patches along the east edge of the north part of the map area and in the Yakima River valley in the southwest part of the map area; 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, p. 675); additionally, Mount St. Helens S tephra, with an isotopic age estimate of 13 ka (Mullineaux and others, 1978, p. 178), occurs below the top of the Touchet Beds (Waitt, 1980, p. 667). Deposited by outburst floods from glacial Lake Missoula. Consists of the Touchet Beds. Description from Bentley and others (993).

Qfg

Outburst flood deposits, gravel (Pleistocene)—Gravels; clasts range from sand to boulders, size generally decreasing away from major Missoula flood channels; clasts chiefly basaltic, but include granitic, quartzitic, dioritic, and porphyritic rocks; deposited by outburst floods from glacial Lake Missoula, display numerous bedding forms, and present as large flood bars; found along the Columbia River at the eastern edge of the north part of the map area; same age as outburst flood deposits, silt and sand (unit Qfs above) and correlative with Touchet Beds. Description compiled from Grolier and Bingham (1965, 1971), Myers, Price, and others (1979), and Rigby and others (1979).

Qt

Terrace deposits (Pleistocene)—Alluvial deposits of silt, sand, and gravel; clasts of diverse compositions; locally includes lacustrine, paludal, and eolian deposits; poorly indurated; slightly to moderately weathered clasts; deposited by the main stem of the Yakima River and largely confined to its valley; includes deposits about 5 m above the modern Yakima River flood plain (lower terrace of Campbell, 1983) and about 10 m above the modern Yakima River flood plain (middle terrace of Campbell, 1983); age inferred from geomorphology. Description from Bentley and others (1993).

## Tertiary Sedimentary Rocks

$P_Lg$

Gravels (Pliocene)—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 commonly unconformable near ridges, conformable in basins; 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). Consists of the Thorp Gravel. Description compiled from Bentley and others (1993), Rigby and others (1979, p. 91), and Waitt (1979).

Ringold Formation

The Ringold Formation consists of fine and coarse, semi-indurated, fluvial and lacustrine deposits in and near the Pasco Basin (Lindsey, 1991). In the east half of the Yakima 1:100,000 quadrangle this unit crops out south of Johnson Creek near the east edge of the map area. The formation is as thick as 185 m in the deepest part of the Cold Creek syncline at the Hanford site, which is southeast of the map area (Lindsey, 1991). The unit is 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 north of Pasco, the lower 20 m of the Ringold has normal magnetic polarity, and the upper 100 m has reversed polarity (Rigby and others, 1979, p. 16). Microtine (rodent) fossils and magnetic polarity data indicate that the unit is older than 3.4 Ma (Fecht and others, 1985, p. 37).

$P_L$Mc

Continental sand, silt, and clay beds (Pliocene to Miocene)—Interbedded fluvial and lacustrine facies, local pebble lenses and stringers; silty clay units horizontally laminated and generally lacking current-generated sedimentary structures; silt and sand units display horizontal, ripple, and cross bedding; sand chiefly quartz and feldspar, locally micaceous; commonly capped by pedogenic carbonate or silcrete; contains diatomite beds, ash beds, and fossils; white, gray, green, red, and tan. Exposed north of the Saddle Mountains at the east edge of the quadrangle. Consists of the finer facies of the Ringold Formation. Description compiled from Newcomb and others (1972), Myers, Price, and others (1979), and Lindsey (1991).

$P_L$Mcg

Conglomerate (Pliocene to upper Miocene)—Varicolored pebble to cobble conglomerate with sand matrix; clasts well rounded and chiefly composed of quartzite, granite, basalt, metamorphic rocks, and porphyritic volcanic rocks; generally massively bedded with some imbrication; includes lenses of coarse to medium quartz and feldspar sand that are cross bedded or foreset bedded in places; commonly uncemented, but in places moderately to poorly indurated with silica, iron oxide, and calcite. Consists of the conglomeratic facies of the Ringold Formation. Description compiled from Myers, Price, and others (1979) and Rigby and others (1979).

Mc

Continental sedimentary deposits (upper and middle Miocene)—Fluvial sand, silt, and clay; local gravel lenses, diatomite, and lahars; white to reddish brown; derived from basaltic, andesitic, and pumiceous source rocks; weakly to moderately indurated; occurs stratigraphically above the Columbia River Basalt Group and as interbeds between units of the Columbia River Basalt Group; age determined by radiometric age estimates of interbedded basalt flows; overlies the Grande Ronde Basalt (15.6 Ma, Baksi, 1989, p. 109) and underlies the Pliocene Thorp Gravel (see discussion of age above under $P_L$g). Consists of the finer grained facies of the Ellensburg Formation. Description from Bentley and others (1993).

Mcg

Continental sedimentary deposits, conglomerate (upper Miocene)—Fluvial gravel, silt, and sand; light yellow-tan to reddish orange; weakly to strongly indurated; dominated by well-rounded quartzite pebbles, with significant numbers of granitic, gneissic, and andesitic clasts; deposited by the ancestral Columbia River; interfingers with other fluvial and laharic deposits of the Ellensburg Formation; underlain by the Priest Rapids Member of the Wanapum Basalt in the map area. Consists of the coarser grained facies of the Ellensburg Formation. Description from Bentley and others (1993).

## Tertiary Volcanic Rocks

### Columbia River Basalt Group

The Columbia River Basalt Group in Washington is composed of four formations. From top to bottom they are the Saddle Mountains Basalt, the Wanapum Basalt, the Grande Ronde Basalt, and the Imnaha Basalt. The upper three formations crop out in the east half of the Yakima 1:100,000-scale quadrangle. Generalized formal and informal stratigraphic units currently recognized in the Columbia River Basalt Group are shown on Figure 5.

The volcanic units of the Columbia River Basalt Group are described as fine, medium, or coarse grained. These terms are rarely quantified in the literature, but it is possible to do so on the basis of average length of plagioclase laths in the matrix. These categories generally correspond with the following plagioclase lengths: fine, ≤0.25 mm; medium, 0.25-0.5 mm; coarse, ≥0.5 mm (V. E. Camp, San Diego State Univ., written commun., 1992).

Saddle Mountains Basalt

$Mv_{s}$

Saddle Mountains Basalt, undivided (upper and/or middle Miocene)—Intracanyon-flow complex; locally includes some or all of the following: Pomona Member, Esquatzel Member, Asotin Member, and Wilbur Creek Member; occurs along Yakima Ridge. Also used where lack of information precludes showing members. Description from Bentley and others (1993).

$Mv_{sem}$

Elephant Mountain Member (upper Miocene)—Basalt flow; black to blue-black, gray-weathering; fine-grained; aphyric to sparsely plagioclase-phyric; normal to transitional magnetic polarity (Rietman, 1966; Choiniere and Swanson, 1979); occurs southeast of Elephant Mountain near the south edge of the map area; isotopically dated at 10.5 Ma by McKee and others (1977) and at 9.4 ± 0.7 Ma and 10.7 ± 0.8 Ma by Stoffel (1984). Description from Bentley and others (1993).

$Mv_{sp}$

Pomona Member (middle Miocene)—Basalt flow; gray to blue-black, gray-weathering; fine-grained; sparsely to slightly phyric, with abundant white to colorless plagioclase microphenocrysts, sparse plagioclase glomerocrysts, and sparse olivine phenocrysts; invasive contacts with Ellensburg Formation units common; well-developed entablature and fanning columns; where more than 50 m thick, well-developed 0.5-1-m-diameter columns dominant; reversed magnetic polarity (Choiniere and Swanson, 1979); widely distributed in the Selah Butte-Selah Creek, Yakima Ridge, and Ahtanum Ridge-Rattlesnake Hills areas; isotopically dated at 12 Ma (K-Ar method) by McKee and others (1977) and 12 Ma ($^{40}$Ar-$^{39}$Ar method) by S. P. Reidel (Wash. State Univ., unpub. data, 1991). Description from Bentley and others (1993).

$Mv_{se}$

Esquatzel Member (middle Miocene)—Basalt flow; blue-black, gray weathering; fine-grained; sparsely phyric, with plagioclase and clinopyroxene phenocrysts and glomerocrysts less than 5 mm across irregularly distributed in flow; normal magnetic polarity (Choiniere and Swanson, 1979); occurs as a valley-filling flow along Yakima Ridge in the southeast part of the map area. Description compiled from Bentley and others (1993) and Swanson and others (1979a, p. 5).

$Mv_{sa}$

Asotin Member (middle Miocene)—Basalt flow; blue-black on fresh exposures; weathers gray; fine-grained; sparsely olivine- and plagioclase-phyric; ophitic texture common; normal magnetic polarity (Swanson and others, 1979a,b); occurs in two small exposures in the Badger Gap quadrangle, and as a single intracanyon flow following an ancient river channel along Yakima Ridge; isotopically dated at 13 Ma by Reidel and Fecht (1987, p. 666). Description compiled from Bentley and others (1993) and Swanson and others (1979a).

$Mv_{swc}$

Wilbur Creek Member (middle Miocene)—Basalt flow; black to blue-black on fresh exposures; weathers gray-black; fine-grained; aphyric to sparsely plagioclase-phyric; normal magnetic polarity (Swanson and others, 1979a); occurs as a single intracanyon flow following an ancient river channel along Yakima Ridge in the southeast part of the map area; same age as the Asotin Member (Reidel and Fecht, 1987, showed that the lavas of the Asotin Member and the Lapwai flow of the Wilbur Creek Member mixed in the Pasco Basin), which is isotopically dated at 13 Ma (Reidel and Fecht, 1987, p. 666). Description from Bentley and others (1993).

$Mv_{su}$

Umatilla Member (middle Miocene)—Basalt flow; black to blue-black on fresh surfaces; weathers gray to red-orange; fine-grained; aphyric to very sparsely plagioclase-phyric; normal magnetic polarity (Rietman, 1966); occurs along Ahtanum Ridge-Rattlesnake Hills and as an intracanyon flow along Yakima Ridge. Description compiled from Bentley and others (1993) and Swanson and others (1979a).

Wanapum Basalt

$Mv_w$

Wanapum Basalt, undivided (middle Miocene)—Used where map scale and line weight or lack of information do not permit showing individual members.

$Mv_{wpr}$

Priest Rapids Member (middle Miocene)—Two basalt flows; gray-black, rusty brown-weathering; medium- to coarse-grained; diktytaxitic; aphyric, with rare plagioclase phenocrysts; well-developed colonnade with 0.5- to 1.5-m-diameter columns; reversed magnetic polarity (Rietman, 1966); occurs near Union Gap, in the Selah Butte-Selah Creek-Yakima Ridge area, near the east edge of the northern part of the map area, and in the north-central part of the map area; isotopic age 14.5 Ma (Tolan and others, 1989); upper flow is basalt of Lolo and the lower flow the basalt of Rosalia; the Lolo has higher MgO and lower $TiO_2$ contents than the Rosalia (Swanson and others, 1979b, p. G11, G37). Description from Bentley and others (1993).

$Mv_{wr}$

Roza Member (middle Miocene)—One or two basalt flows; gray-black, reddish brown-weathering; fine- to medium-grained; locally diktytaxitic; 0.5- to 1-cm plagioclase phenocrysts and glomerocrysts, commonly several hundred phenocrysts per square meter of flow surface; well-developed colonnade with columns as much as 1 m in diameter; transitional to reversed magnetic polarity (Choiniere and Swanson, 1979), Bentley and others (1993, p. 6) report normal magnetic polarity as measured in the field with a fluxgate magnetometer, and Swanson and others (1979a, p. 8) report that magnetic polarity is an unreliable criterion for field identification because of common overprint of present magnetic field; widely exposed throughout map area; older than Priest Rapids Member (14.5 Ma, Tolan and others, 1989) and younger than Frenchman Springs Member (15.3 Ma, Tolan and others, 1989). The Roza Member, because of its large and persistent plagioclase phenocrysts and wide distribution, is a key marker unit across much of the Columbia Basin. Description from Bentley and others (1993).

$Mv_{wfs}$

Frenchman Springs Member (middle Miocene)—Multiple flows; generally dark-gray to black; fine- to medium-grained; difficult to distinguish from flows of the Grande Ronde Basalt except that they are commonly plagioclase-phyric, especially the lower flows (Swanson and others, 1979a, 1979b); normal to excursional magnetic polarity (Fig. 5); outside the map area rests on Grande Ronde Basalt, commonly with an intervening sedimentary interbed; occurs widely throughout the map area, especially on Yakima Ridge and to the north of Yakima Ridge; isotopic age 15.3 Ma for basalt of Sand Hollow, a flow in the middle of the member (Tolan and others, 1989); Beeson and others (1985) defined the informal Frenchman Springs subunits shown on Figure 5. Includes the Sentinel Gap flows of Bentley and others (1993) (basalt of Sentinel Gap of Beeson and others, 1985), Kelley Hollow flow and Sand Hollow flow of Bentley and others (1993) (both included in the basalt of Sand Hollow of Beeson and others, 1985), and Ginkgo flows of Bentley and others (1993) (basalt of Ginkgo of Beeson and others, 1985):

Basalt of Sentinel Gap—Basalt flows; gray-black, weather gray to reddish gray; fine- to medium-grained; generally aphyric; an average of about three plagioclase glomerocrysts up to 2 cm in diameter per 10 $m^2$ of flow surface; colonnade of 1.5- to 2-m-diameter columns; locally pillowed base in lowermost flow; some hackly entablatures; one flow present in most of the map area, but locally two or more crop out on Yakima and Ahtanum Ridges.

Basalt of Sand Hollow—Two basalt flows; gray-black, weather gray to reddish gray; fine- to medium-grained; the upper flow (Kelley Hollow flow of Bentley and others, 1993) is phyric, with scattered (1-100 per $m^2$) plagioclase phenocrysts and glomerocrysts as large as 2 cm in diameter, and has thin entablature and well-developed colonnade with columns 0.5 to 1.5 m in diameter; the lower flow (Sand Hollow flow of Bentley and others, 1993) is generally aphyric, with rare phenocrysts as much as 2 cm in diameter and an average of three glomerocrysts per 10 $m^2$ of flow surface, and has locally hackly entablature, colonnade of 1.5- to 2-m-diameter columns, and locally pillowed base.

Basalt of Ginkgo—One to two basalt flows; gray-black, weather reddish gray; fine- to medium-grained; phyric, with 100 to 200 plagioclase glomerocrysts that reach 2 cm in diameter per square meter of flow surface; thin entablature and well-developed colonnade of columns 0.5 to 1.5 m in diameter; pillowed base.

Description from Bentley and others (1993).

## Grande Ronde Basalt

Grande Ronde Basalt (middle Miocene)—Twelve or more flows; generally aphyric; black to gray-black; reddish brown, gray, reddish gray, to grayish black weathering; fine- to medium-grained; widely exposed on and to the north of Yakima Ridge; base not exposed in map area; overlain by members of Wanapum Basalt, commonly with an intervening sedimentary interbed; isotopically dated at about 16.9 Ma to 15.6 Ma (Baksi, 1989, p. 109; age information summarized by Reidel and others, 1989, p. 24-25). Divided into four magnetostratigraphic units, the upper two of which are present in the map area:

$Mv_{gN2}$ Upper flows of normal magnetic polarity—Upper four or five flows are a high-Mg Grande Ronde chemical type (Swanson and others, 1979b); commonly microphyric with 1- to 3-mm-long equant plagioclase phenocrysts; lower flows (as many as five flows) are low-Mg Grande Ronde chemical type (Swanson and others, 1979b); fine-grained; aphyric; thick, massive, hackly entablatures over colonnades; discontinuous, invaded sedimentary interbeds common near top and bottom of this sequence of flows.

$Mv_{gR2}$ Upper flows of reversed magnetic polarity—Fine- to medium-grained; mostly aphyric, but contain local scattered plagioclase phenocrysts as much as 1 cm in diameter in some flows; poorly developed colonnade with columns as much as 0.5 m in diameter; poorly developed entablature with hackly and brick-bat jointing; some flows with multiple lobes; zeolites commonly present in vesicles; low-Mg Grande Ronde chemical type (Swanson and others, 1979b).

Description from Bentley and others (1993).

## REFERENCES CITED


Aguirre, Emiliano; Pasini, Giancarlo, 1985, The Pliocene-Pleistocene boundary: Episodes, v. 8, no. 2, p. 116-120.

Alto, B. R., 1955, Geology of a part of the Boylston quadrangle and adjacent areas in central Washington: University of Washington Master of Science thesis, 38 p., 2 plates, scale 1:44,352.

Bacon, C. R., 1983, Eruptive history of Mount Mazama and Crater Lake caldera, Cascade Range, U.S.A.: Journal of Volcanology and Geothermal Research, v. 18, p. 57-115.

Baksi, A. K., 1989, Reevaluation of the timing and duration of extrusion of the Imnaha, Picture Gorge, and Grande Ronde Basalts, Columbia River Basalt Group. In Reidel, S. P.; Hooper, P. R., editors, Volcanism and tectonism in the Columbia River flood-basalt province: Geological Society of America Special Paper 239, p. 105-111.

Beeson, M. H.; Fecht, K. R.; Reidel, S. P.; Tolan, T. L., 1985, Regional correlations within the Frenchman Springs Member of the Columbia River Basalt Group—New insights into the middle Miocene tectonics of northwestern Oregon: Oregon Geology, v. 47, no. 8, p. 87-96.

Bentley, R. D.; Campbell, N. P.; Powell, J. E., 1993, Geologic maps of part of the Yakima fold belt, northeastern Yakima County, Washington: Washington Division of Geology and Earth Resources Open File Report 93-3, 5 sheets, scale 1:31,680, with 13 p. text.

Campbell, N. P., 1976, Preliminary geologic map of the Yakima area: Washington Division of Geology and Earth Resources Open File Report 76-11, 1 sheet, scale 1:24,000.

Campbell, N. P., 1977, Geology of the Selah area, Yakima County, Washington: Washington Division of Geology and Earth Resources Open File Report 77-7, 3 sheets, scale 1:24,000.

Campbell, N. P., 1979, Surficial geologic map of the Yakima quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 79-15, 1 sheet, scale 1:250,000.

Campbell, N. P., 1983, Correlation of late Cenozoic gravel deposits along the Yakima River drainage from Ellensburg to Richland, Washington: Northwest Science, v. 57, no. 3, p. 179-193.

Carson, R. J.; Tolan, T. L.; Reidel, S. P., 1987, Geology of the Vantage area, south-central Washington—An introduction to the Miocene flood basalts, Yakima Fold Belt, and the Channeled Scabland. *In* Hill, M. L., editor, 1987, Cordilleran section of the Geological Society of America:Z Geological Society of America DNAG Centennial Field Guide 1, p. 357-362.

Choiniere, S. R.; Swanson, D. A., 1979, Magnetostratigraphy and correlation of Miocene basalts of the northern Oregon coast and Columbia Plateau, southeast Washington: American Journal of Science, v. 279, no. 7, p. 755-777.

Dalrymple, G. B., 1979, Critical tables for conversion of K-Ar ages from old to new constants: Geology, v. 7, no. 11, p. 558-560.

Diery, H. D., 1967, Stratigraphy and structure of Yakima Canyon between Roza Gap and Kittitas Valley, central Washington: University of Washington Doctor of Philosophy thesis, 117 p., 1 plate, scale 1:24,000.

Diery, H. D.; McKee, Bates, 1969, Stratigraphy of the Yakima Basalt in the type area: Northwest Science, v. 43, no. 2, p. 47-64.

Fecht, K. R.; Reidel, S. P.; Tallman, A. M., 1985, Paleodrainage of the Columbia River on the Columbia Plateau of Washington State—A summary: Rockwell Hanford Operations RHO-BW-SA-318 P, 55 p.

Foley, L. L., 1982, Quaternary chronology of the Palouse loess near Washtucna, eastern Washington: Western Washington University Master of Science thesis, 137 p.

Foxworthy, B. L., 1957, Geologic map of Ahtanum Valley, Yakima County, Washington: U.S. Geological Survey Open-File Report 57-44, 1 plate, scale 1:62,500.

Foxworthy, B. L., 1962, Geology and ground-water resources of the Ahtanum Valley, Yakima County, Washington: U.S. Geological Survey Water-Supply Paper 1598, 100 p.

Geomatrix Consultants, Inc., 1988, Seismotectonic evaluation of the northern Cascade mountains geomorphic province for Bumping Lake, Tieton, Keechelus, Kachess, Cle Elum, and Clear Lake dams: Geomatrix Consultants, Inc. [San Francisco, CA, under contract to] U.S. Bureau of Reclamation, 154 p., 12 plates.

Grolier, M. J.; Bingham, J. W., 1965, Geologic map of parts of Grant, Adams, and Franklin Counties, Washington: U.S. Geological Survey Open-File Report, 7 sheets, scale 1:62,500.

Grolier, M. J.; Bingham, J. W., 1971, Geologic map and sections of parts of Grant, Adams, and Franklin Counties, Washington: U.S. Geological Survey Miscellaneous Geologic Investigations Map I-589, 6 sheets, scale 1:62,500.

Gulick, C. W., compiler, 1990a, Geologic map of the Moses Lake 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-1, 9 p., 1 plate.

Gulick, C. W., compiler, 1990b, Geologic map of the Ritzville 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 90-2, 7 p., 1 plate.

Holmgren, D. A., 1967, The Yakima-Ellensburg unconformity, central Washington: University of Washington Master of Science thesis, 69 p., 3 plates.

Holmgren, D. A., 1969, Columbia River basalt patterns from central Washington to northern Oregon: University of Washington Doctor of Philosophy thesis, 56 p., 2 plates.

Hooper, P. R.; Kleck, W. D.; Knowles, C. R.; Reidel, S. P.; Thiessen, R. L., 1984, Imnaha Basalt, Columbia River Basalt Group: Journal of Petrology, v. 25, part 2, p. 473-500.

Kienle, C. F., Jr.; Bentley, R. D.; Anderson, James Lee, 1977, Geologic reconnaissance of the Cle Elum-Wallula lineament and related structures: Shannon & Wilson, Inc., 75 p.

Kinnison, H. B.; Sceva, J. E., 1963, Effects of hydraulic and geologic factors on streamflow of the Yakima River basin, Washington: U.S. Geological Survey Water-Supply Paper 1595, 134 p., 3 plates.

Kittleman, L. R., 1973, Mineralogy, correlation, and grain-size distributions of Mazama tephra and other postglacial pyroclastic layers, Pacific Northwest: Geological Society of America Bulletin, v. 84, no. 9, p. 2957-2980.

Lindsey, K. A., 1991, Revised stratigraphy for the Ringold Formation, Hanford site, south-central Washington: Westinghouse Hanford Co. WHC-SD-EN-EE-004, 12 p.

McDonald, E. V.; Busacca, A. J., 1989, Record of pre-late Wisconsin floods and of late Wisconsin flood features in the Cheney-Palouse scabland—Trip C. *In* Joseph, N. L.; and others, editors, Geologic guidebook for Washington and adjacent areas: Washington Division of Geology and Earth Resources Information Circular 86, p. 337-346.

McKee, E. H.; Swanson, D. A.; Wright, T. L., 1977, Duration and volume of Columbia River basalt volcanism, Washington, Oregon, and Idaho [abstract]: Geological Society of America Abstracts with Programs, v. 9, no. 4, p. 463-464.

Montanari, Alessandro; Drake, Robert; Bice, D. M.; Alvarez, Walter; Curtis, G. H.; Turrin, B. D.; DePaolo, D. J., 1985, Radiometric time scale for the upper Eocene and Oligocene based on K/Ar and Rb/Sr dating of volcanic biotites from the pelagic sequence of Gubbio, Italy: Geology, v. 13, no. 9, p. 596-599.

Mullineaux, D. R.; Wilcox, R. E.; Ebaugh, W. F.; Fryxell, Roald; Rubin, Meyer, 1978, Age of the last major scabland flood of the Columbia Plateau in eastern Washington: Quaternary Research, v. 10, no. 2, p. 171-180.

Myers, C. W.; Price, S. M.; and others, 1979, Geologic studies of the Columbia Plateau—A status report: Rockwell Hanford Operations RHO-BWI-ST-4, 541 p., 53 plates, scales 1:62,500 and 1:250,000.

Newcomb, R. C.; Strand, J. R.; Frank, F. J., 1972, Geology and ground-water characteristics of the Hanford Reservation of the U.S. Atomic Energy Commission, Washington: U.S. Geological Survey Professional Paper 717, 78 p., 3 pl.

Reidel, S. P.; Tolan, T. L.; Hooper, P. R.; Beeson, M. H.; Fecht. K. R.; Bentley, R. D.; Anderson, James Lee, 1989, The Grande Ronde Basalt, Columbia River Basalt Group; Stratigraphic descriptions and correlations in Washington, Oregon, and Idaho. *In* Reidel, S. P.; Hooper, P. R., editors, Volcanism and tectonism in the Columbia River flood-basalt province: Geological Society of America Special Paper 239, p. 21-53.

Reidel, S. P.; Campbell, N. P.; Fecht, K. R.; Lindsey, K. A., 1994, Late Cenozoic structure and stratigraphy of south-central Washington. *In* Lasmanis, Raymond; Cheney, E. S., coordinators, in press, Regional geology of Washington State: Washington Division of Geology and Earth Resources Bulletin 80, p. 159-180.

Reidel, S. P.; Fecht, K. R., 1987, The Huntzinger flow—Evidence of surface mixing of the Columbia River Basalt and its petrogenetic implications: Geological Society of America Bulletin, v. 98, no. 6, p. 664-677.

Rietman, J. D., 1966, Remanent magnetization of the late Yakima Basalt, Washington State: Stanford University Doctor of Philosophy thesis, 87 p.

Rigby, J. G.; Othberg, K. L.; Campbell, N. P.; Hanson, L. G.; Kiver, E. P.; Stradling, D. F.; Webster, G. D., 1979, Reconnaissance surficial geologic mapping of the late Cenozoic sediments of the Columbia Basin, Washington: Washington Division of Geology and Earth Resources Open File Report 79-3, 94 p., 7 plates.

Robinson, C. F., 1966, Stratigraphy and structural geology of Ahtanum Ridge, Yakima, Washington: University of Washington Master of Science thesis, 35 p., 1 plate, scale 1:153,000.

Salvador, Amos, 1985, Chronostratigraphic and geochronometric scales in COSUNA stratigraphic correlation charts of the United States: American Association of Petroleum Geologists Bulletin, v. 69, no. 2, p. 181-189.

Sceva, J. E.; Watkins, F. A., Jr.; Schlax, W. N., Jr., 1949, Geology and ground-water resources of the Wenas Creek Valley, Yakima County, Washington: U.S. Geological Survey Open-File Report, 80 p., 2 plates.

Shannon and Wilson, Inc., 1977, Geologic evaluations of structures in the Columbia Plateau. Subappendix 2R H of Washington Public Power Supply System, WPPSS nuclear project no. 1—Preliminary safety analysis report: Washington Public Power Supply System Docket no. 50-460, Preliminary safety analysis report, Amendment 23, v. 2B, Appendix 2R, Subappendix 2R H.

Stoffel, K. L, 1984, Geology of the Grande Ronde lignite field, Asotin County, Washington: Washington Division of Geology and Earth Resources Report of Investigations 27, 79 p., 1 plate, scale 1:48,000.

Swanson, D. A.; Anderson, James Lee; Bentley, R. D.; Byerly, G. R.; Camp, V. E; Gardner, J. N.; Wright, T. L., 1979a, Reconnaissance geologic map of the Columbia River Basalt Group in eastern Washington and northern Idaho: U.S. Geological Survey Open-File Report 79-1363, 26 p., 12 plates, scale 1:250,000.

Swanson, D. A.; Wright, T. L.; Hooper, P. R.; Bentley, R. D., 1979b, Revisions in stratigraphic nomenclature of the Columbia River Basalt Group: U.S. Geological Survey Bulletin 1457-G, 59 p., 1 plate.

Tabor, R. W.; Waitt, R. B.; Frizzell, V. A., Jr.; Swanson, D. A.; Byerly, G. R.; Bentley, R. D., 1982, Geologic map of the Wenatchee 1:100,000 quadrangle, central Washington: U.S. Geological Survey Miscellaneous Investigations Series Map I-1311, 26 p., 1 plate, scale 1:100,000.

Tolan, T. L.; Reidel, S. P.; Beeson, M. H.; Anderson, James Lee; Fecht, K. R.; Swanson, D. A., 1989, Revisions to the estimates of the areal extent and volume of the Columbia River Basalt Group. *In* Reidel, S. P.; Hooper, P. R., editors, Volcanism and tectonism in the Columbia River flood-basalt province: Geological Society of America Special Paper 239, p. 1-20.

U.S. Army Corps of Engineers, 1978, Yakima Valley regional water management study—Volume I, Summary; Volume II, Water quality; Volume III, Water budget; Volume IV, Geology and ground water: U.S. Army Corps of Engineers [Seattle], 4 v.

Waggoner, S. Z., compiler, 1990, Geologic map of the Rosalia 1:100,000 quadrangle, Washington-Idaho: Washington Division of Geology and Earth Resources Open File Report 90-7, 20 p., 1 plate.

Waitt, R. B., 1979, Late Cenozoic deposits, landforms, stratigraphy, and tectonism in Kittitas Valley, Washington: U.S. Geological Survey Professional Paper 1127, 18 p.

Waitt, R. B., 1980, About forty last-glacial Lake Missoula jökulhlaups through southern Washington: Journal of Geology, v. 88, no. 6, p. 653-679.

Waters, A. C., 1955, Geomorphology of south-central Washington, illustrated by the Yakima East quadrangle: Geological Society of America Bulletin, v. 66, no. 6, p. 663-684.

## Unpublished Mapping

Bentley, R. D.; Powell, J. E., 1984, Central Washington University: Maps covering most of the northeast quarter of the Yakima 1:100,000 quadrangle, 10 sheets, scale 1:12,000.

Campbell, N. P., 1978, Yakima Valley Community College: Reconnaissance surficial geologic maps of all the 7.5-minute quadrangles in the Badger Gap, Boylston, and Black Rock Springs 15-minute quadrangles, Kittitas and Yakima Counties, Washington, 12 sheets, scale 1:24,000.

Reidel, S. P. (Washington State University); Tolan, T. L. (consulting geologist, Kennewick, WA): Geologic map of the western Saddle Mountains area, Kittitas County, Washington, 1 sheet, scale 1:100,000.